Effects of climate change on water quality in the Ilperveld

Jiske van der Wiele
0564958
Master Biological Sciences
programme Limnology & Oceanography
University of Amsterdam, IBED
Master thesis, 50 ECTS

Supervisors: Wilko Verweij (RIVM), Esther van der Grinten (RIVM)
Examiner: Michiel Kraak (UvA)

September 2009 - May 2010

Contents **page**

Summary

In this study, the effects of climate change on the aquatic Natura 2000 goals of the Ilperveld were investigated. The Ilperveld is a brackish peat land area in the province of Noord-Holland. The Ilperveld is designated to preserve habitat type 3140, which is nutrient-poor water with *Chara spp.* vegetation. In addition, populations and habitats of the fish species European Bitterling (*Rhodeus amarus*), Spined Loach (*Cobitis taenia*) and Bullhead (*Cottus perifretum*) need to be preserved. In general, the effects of climate change on a local scale (Ilperveld) differ from the effects that are described on a national scale. On a national scale, big issues that can increase due to climate change are an increase in harmful cyanobacterial blooms and salinization of the surface waters. For the Ilperveld these issues seem no threat because the surface water already has a relatively high chloride concentration. In general, from this study it appears that dry periods in summer combined with an elevated temperature is the main threat for the Ilperveld, because this combination increases peat oxidation. For the water quality, an increase in eutrophication and water turbidity are the main threats. Eutrophication increases due to an increase in water inlet during dry periods, and increased nutrient run-off from the peat soils during wet periods. The predicted alternation between dry periods and intense rainfalls in summer, can lead to temporary peak concentrations of nutrients in the surface water. The turbidity of the water increases due to more recreation in summer, peat degradation, and an increase in benthivorous fish.

Oligo-mesotrophic water with Chara spp. vegetation

The water quality that is required for oligo-mesotrophic water with *Chara spp*. vegetation is currently not reached in most parts of the Ilperveld. However, the brackish variant (vegetations of *N. marina* and *R. maritima*) of this habitat type is able to survive at slightly higher nutrient and chloride concentrations, and from this study it became clear that these brackish macrophytes are neutral in response to temperature. A shift towards the brackish variant of this habitat type is favorable. The largest threats for this habitat type (both variants) are a decline in water transparancy and increased eutrophication.
At elevated eutrophication and salinization levels, the plant communities that belong to the habitat type oligo-mesotrophic water with *Chara spp.* vegetation (Nitellopsidetum obtusae and Charetum hispidae) shift to other communities. In bad case, it is likely that the water vegetation develops in vegetations of *Ceratophyllum demersum, Potamogeton pectinatus, Zannichellia palustris*, and *Azolla filiculoides*. However in the worst case, the vegetation disappears completely and the water is going to be dominated by algae.

European Bitterling

The European Bitterling *(Rhodeus amarus)* has a unique spawning relationship with freshwater mussels. A decline in freshwater mussel numbers, results also in a decline in European Bitterling numbers. An increase in muddy conditions and a decrease in the oxygen concentration of the water are disadvantageous for both mussel and fish. The fish is also sensitive for high chloride concentrations, low water levels and a decline in macrophyte abundance. An increase in water temperature seems no threat, because the European Bitterling is a thermophilic species.
This fish is currently abundant in the isolated compartments. But when due to climate change, the environmental conditions in the compartments become unfavorable; the fish are unable to migrate. Unfavorable conditions that can occur in the compartments for the European Bitterling are expected mainly in summer. The chloride concentration can

become too high, and the water level too low. So, many negative effects of climate change are expected for the European Bitterling.

Spined Loach

The influence of climate change on the Spined Loach (*Cobitis taenia*) is not totally clear; this is partly due to the unknown distribution of this species in the Ilperveld. An advantage for the Spined Loach is that the fish can survive at low oxygen concentrations and low water levels. An increase in water temperature seems no threat. The fish is just like the European Bitterling a freshwater fish, which means that an increase in the chloride concentration and especially fluctuations in choride levels could be negative. There is also not much known about predators and dispersal distances. From this small amount of information, it seems that climate change is not a threat for the Spined Loach in the Ilperveld.

Bullhead

The Bullhead (*Cottus perifretum*) is distributed in the open water of the Ilperveld. Here, chloride and sulphate concentrations are higher, and the pH is slighty higher than in the compartments. Bottlenecks for the Bullhead are decreasing oxygen concentrations and increasing water temperatures. However, warming of the open water occurs slower compared with the compartments. When alien crayfish are introduced in the Ilperveld, this is a risk for the Bullhead. The risk consists of direct predation or competition for habitat with the crayfish. In addition, other predators like fish-eating birds can also increase in the future. Migration is not hindered by obstacles, but the fish itself is unable to cross large distances. An increase in muddy conditions is disadvantageous for Bullhead. In contrast, salinization seems no threat. Probably, climate change has little influence on Bullhead in the Ilperveld.

Future

It can be concluded from this study that the effects of climate change make it more diffcult to achieve the aquatic Natura 2000 goals of the Ilperveld. In addition, there are many inconsistencies round the Natura 2000 goals and the different functions of the area. The species approach of Natura 2000 conflicts with the preservation of the unique brackish character of the Ilperveld.

Introduction

Climate change is nowadays a hot subject. Global climate scenarios predict an increase in air temperature, changing precipitation patterns and sea level rise. These changes will influence water systems (water quantity and quality), and subsequently agriculture, economy and the human population. Climate change will also affect nature via changes in abiotic conditions and (corresponding) changes in biotic conditions. In addition, for some nature areas in the Netherlands it is expected that climate change will form an extra problem for the achievement of the nature goals (van Rooij *et al.,* 2009).
The exact direction and extent of climate change is still uncertain. Specific predictions of the ecological consequences of climate change are also surrounded by uncertainties. In addition, little knowledge is present about effects of climate change on aquatic ecosystems. Nevertheless, it is nowadays possible to anticipate on negative effects of climate change by taking additional measures.

The Ilperveld is a unique nature area (Natura 2000) near Amsterdam. It is a (former) brackish peat land area which contains both terrestrial and aquatic nature.
In this study, the influence of climate change on the aquatic Natura 2000 goals of the Ilperveld is considered. It is tried to find out if climate change facilitates or hinders the achievement of the aquatic Natura 2000 goals.

1. The Ilperveld

- **The Ilperveld is a unique nature area, because of its brackish character**
- **The Ilperveld functions as a water transport system**
- **The surface water of the Ilperveld is very phosphate- and sulphur-rich**

In this chapter, an introduction of the nature area Ilperveld is presented. The location, history, water management, and water quality of the area are mentioned in the previous order.

1.1 Location

The Ilperveld is a large peat land area (900 ha) embedded between the cities Amsterdam, Purmerend and Zaandam. On a smaller scale, The Ilperveld lies between the villages Landsmeer, Den Ilp and Ilpendam (figure 1). The area is surrounded by roads, the Noord-Hollands kanaal, and drained lakes. Since 1950, the Ilperveld is managed by Landschap Noord-Holland (a nature conservation organisation), which purchased parcels from farmers. Currently, Landschap Noord-Holland manages 600 hectare in the Ilperveld. The remaining surface, which is approximately 350 hectare, is managed by farmers. Besides the function of a nature area, the area has also a recreational function and agricultural function. The agricultural land use consists mainly of dairy production. Around 15.000 people per year visit the Ilperveld (Beheerplan Ilperveld 2007- 2017). This high number is a combination of the large surface of the area, and the location (3 surrounding cities). The recreation consists of water recreation, because the Ilperveld is not crossed by roads, and only accessible via water. Such landscapes are nowadays rare in the western part of The Netherlands, because of urbanization.
A result of the enclosure of the Ilperveld by adjacent villages, cities, agriculture and roads is that the system receives a high nitrogen deposition from the surrounding (Huurnink *et al*, 2009).

The Ilperveld has a high regional, national and even international value (Beheerplan Ilperveld 2007- 2017). At all policy levels, the Ilperveld is indicated as a nature area. On an international scale, the area is, together with the Oostzanerveld, Varkensland and Twiske, part of a European network of nature areas (Natura 2000). The Ilperveld is designated as a Bird Directive area (2000) and Habitat Directive area (2005). On a national scale, the area is part of the EHS (Ecologische Hoofdstructuur) of The Netherlands. The EHS is a coherent network of nature areas in The Netherlands.

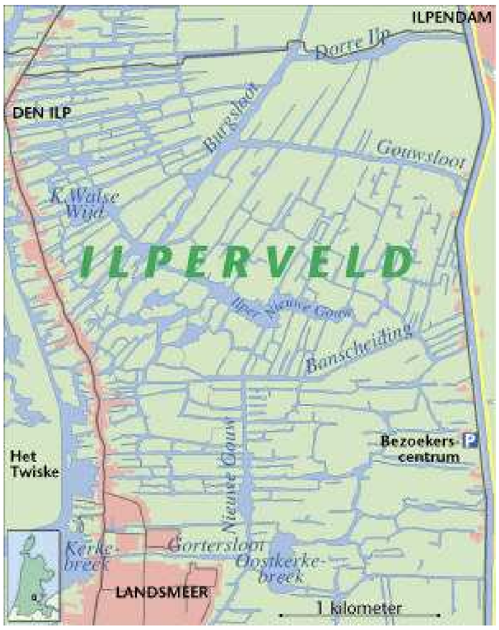


Figure 1. The Ilperveld. Beheerplan Ilperveld 2007-2017

Typical landscapes of the Ilperveld are an alternation between extensive grasslands (with many birds), reedbeds, open water, reed seams, moss reeds, quaking fens, and bog forests. Characteristic (and rare) plant species are the bog orchid, (*Hammarbya paludosa*), heath plants like *Empetrum nigrum* and *Erica tetralix*, peat mosses (*Sphagnum),* ragged robin (*Lychnis flos-cuculi),* common scurvygrass (*Cochlearia officinalis),* the grass *Agrostis stolonifera* and much reed (*Phragmites australis).* The aquatic vegetation is less developed. However, the vegetation consists of rare brackish water indicator species. Brackish water indicators are the holly-leaved naiad (*Najas marina)* and wigeongrass *(Ruppia maritima).* Characeae species like *Chara major* and *Chara connivens* occur sporadically in isolated waters of the Ilperveld. Furthermore, important animal species are the Dutch tundra vole (*Microtus oeconomus arenicola),* the duck *Anas strepera,* the bittern *Botaurus stellaris,* common snipe (*Gallinago gallinago*), harriers (*Circus aeruginosus* and *Circus cyaneus*), pond bat (*Myotis dasycneme*), and the fishes European Bitterling (*Rhodeus amarus*), Spined Loach (*Cobitis taenia*) and the Bullhead (*Cottus perifretum*) (Beheerplan Ilperveld 2007- 2017).

1.2 History

Nowadays, the Ilperveld is part of the largest peat land area at the north Amsterdam. The landscape is created by the medieval land reclamation and drainage of a raised bog area. The history of the Ilperveld can not be dissociated from human activities. The Ilperveld is affected for 1000 years by human activities. Drainage, manuring, peat excavation, grazing by cattle, and many other human activities (like duck farms) transformed the Ilperveld from a bog area to a large nature reserve in an agricultural area. Peat excavation created a characteristic irregular allotment pattern with small and large ditches, in between islands, and terrestrialization of turf ponds (figure 2). The duck farms that flourished in the early 20th century influenced the water quality and sediment quality (Beheerplan Ilperveld 2007- 2017).

Figure 2. Characteristic allotment pattern of the Ilperveld, with small and large ditches and in between islands and turf ponds. Source: Beheerplan Ilperveld 2007 – 2017.

Around 3300 BC the Ilperveld was part of a large brackish bog. This bog developed in a raised bog area. The raised bog phase was very stable and persisted for 2500 years. Around 850 AD the climate changed, and the raised bog area dried out. When a peat area desiccates, the water level drops, the peat oxidizes and land subsidence occurs. This development made it easier for humans near the area to drain water from the bog. They dug drainage ditches and transformed the raised bog area into an agricultural area. The drainage and dry periods resulted in a change of the raised bog area to a low lying peat area. However, due to this change, the area became prone to floods from the former Zuiderzee. The Ilperveld came permanently under the influence of brackish, nutrient rich water. Chloride concentrations could reach till 9000 mg/l. In 1932, the input of brackish water from the Zuiderzee declined, because the Afsluitdijk was constructed. The Zuiderzee changed into the freshwater lake IJselmeer. Nowadays the Ilperveld has still a slightly brackish character with characteristical brackish water vegetations, because brackish water from het Noordzeekanaal is supplied via the Noord-Hollands kanaal. Peat lands are common in the western part of The Netherlands; however the Ilperveld is unique because of the historical influence of brackish water from the former Zuiderzee (Beheerplan Ilperveld 2007- 2017).

1.3 Water management

The Ilperveld is an open water system and is part of the Waterlandse Boezem (water system; figure 3). The water surface of the Ilperveld covers about 11 % of the total water surface of the Waterlandse Boezem. A large part of the Waterlandse Boezem consists of drained lakes and areas where the water level is kept artificially low. The Ilperveld is not influenced by seepage into the system. Seepage out the system occurs; the water that seeps out of the Ilperveld per day is approximately 12 mm.

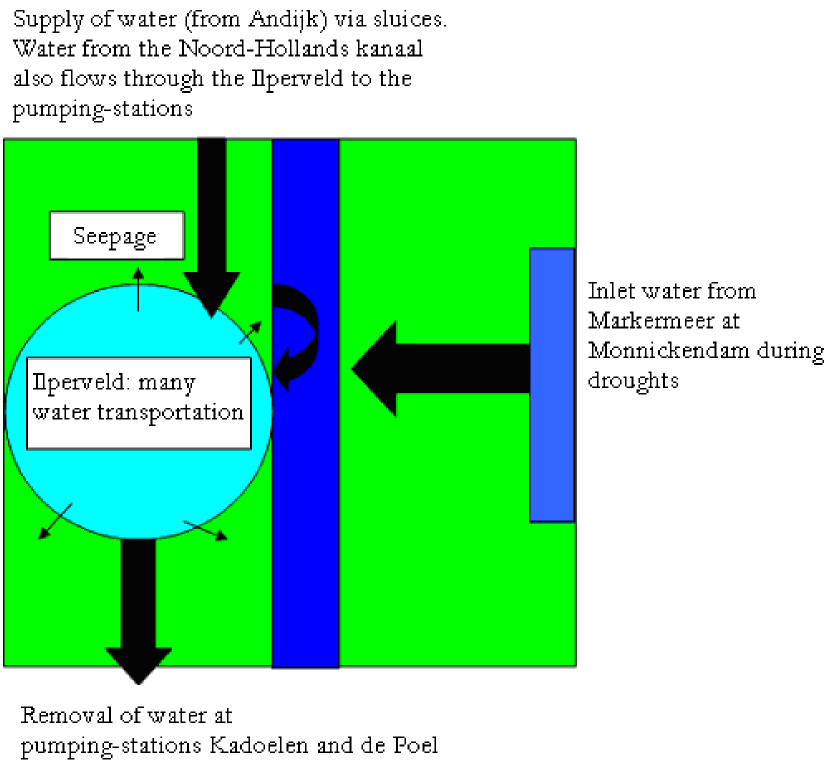


Figure 3. Water management of the Ilperveld. The Ilperveld is shown as part of the Waterlandse Boezem (green frame). The arrows represent the water flows that enter and leave the Ilperveld.

The water level in the Waterlandse Boezem is kept constant; the Ilperveld has a stable water level of -1.53 meter NAP. Variations of the water level occur through whipping up of the water (by wind and boats), and extreme precipitation events. These variations range from -10 cm to + 10 cm. During dry periods, the water level can drop till 20 cm below ground level (Niels Hogeweg, personal communication). A consequence of maintaining a stable water level is that water has to be supplied continuously. Therefore, water from Noord-Holland (via Noord-Hollands kanaal and sluices) is supplied continuously to the Ilperveld (figure 3). The Ilperveld functions as a transit system of water; during the whole year, water flows in and out. The excess of water flows to the pumping-station Kadoelen (figure 3). Van Kranenburg *et al.* (2000), made an estimation of the water volume that enters the Ilperveld from the Waterlandse Boezem in summer. This is approximately 180.000 m^3 per six months. This means that one third of the water stock in the Ilperveld is replaced during summer.

The goal to maintain a stable water level can also result in water shortage during summer. Therefore, water inlet from other systems (Markermeer) takes place during dry periods (figure 3). This could have consequences for the water quality. At the inlet point (Monnickendam) the water is clear and has a reasonably quality (table 1), but on the way to the Ilperveld the water becomes enriched with nitrogen and phosphate (table 1). The enrichment is caused by run-off from agriculture parcels and areas where the water level is kept artificially low. Other water quality parameters that increase on the way to the Ilperveld are pH, sulphate, chloride, and chlorophyll-a concentration, whereas the water transparency declines.
Furthermore, natural fluctuations in the water level (water level in winter higher than in summer) are absent. These fluctuations are needed for the development of reed beds, and temporary droughts can lower the nutrient levels in the water layer (van Kranenburg *et al.*, 2000).

Table 1. Water quality of the inlet water (from Markermeer), water of the Waterlandse Boezem before entering the Ilperveld, and water of the Ilperveld, all measured in 1997. Source: van Kranenburg et al., 2000.

	pH	P-tot (mg/l)	N-tot (mg/l)	Chlorophyll-a (mg/l)	Chloride (mg/l)	Sulphate (mg/l)	Transparancy (m)
Inlet water	8.29	0.18	1.326	0.036	189	130	0.508
Gouwsloot, before entering Ilperveld	8.12	0.348	3.052	0.185	680	190	0.29
Ilperveld, Oostkerkerbreek	8.7	0.402	3.88	0.174	666	197	0.28

1.4 Current water quality

When considering the water quality of the Ilperveld, a distinction has to be made between isolated water bodies and open water. In certain parts of the area, water bodies were isolated in order to improve the water quality. The improvement of the water quality was part of 'Plan Watersnip', a large restoration project that started in 1997. The water board Hoogheemraadschap Hollands Noorderkwartier measures the water quality in the open water. Landschap Noord-Holland measures and monitors the water quality in the isolated 'Watersnip' compartments.
To achieve nature goals, the management of the Ilperveld focuses on the isolated waters, because the remaining open water is of a very poor quality.

1.4.1 Chemical water quality

In general, the water of the Ilperveld is slightly brackish (500 – 1000 mg/l chloride), very turbid and contains high nutrient concentrations (Beheerplan Ilperveld, 2007 - 2017). The water quality of the open water is relatively poor compared to the water quality in the compartments (see table 2, page 16). The water quality in the compartments improved after the restoration measures of Plan Watersnip. Graphs of the chemical water quality during the period 1999-2006 of the compartments are shown in appendix 1. In the compartments, lower pH, chloride and sulphate levels are found compared to the open water. However, thick mud layers are present in these compartments. In November 2009, the mud layer in the compartments was on average 0.5 meter (van den Boogaard *et al.,* 2010).

Table 3. SEND standard values for the province of Noord - Holland for fresh polder water, and the Water Framework Directive indication 'good' on the ruler of physical-chemical quality elements for the types M30 and M10. In the last column the water quality of the measuring point Molensloot is shown (obtained from table 2) for comparison. Sources: Witteveldt et al., 2002; Evers et al., 2007; Altenburg et al., 2007.

	SEND	WFD type M30	WFD type M10	Molensloot (1991 – 2007)
pH	6.5 - 8.5	6 - 9	5.5 - 8	8.2
Chloride (mg/l)	< 150	300 - 3000	≤ 300	555.7
Sulphate (mg/l)	< 120			171.9
Total P (mg/l)	< 0.15	≤ 0.11	≤ 0.15	0.49
Total N (mg/l)		≤ 1.8	≤ 2.8	4.2
Ammonium (mg/l)	< 0.2			
Nitrate (mg/l)	< 0.15			
Transparancy (m)		≥ 0.9	≥ 0.65	0.33

When the measured values from table 2 (including the Molensloot from table 3) are compared with standard values for water in the province Noord-Holland (SEND; Stelsel van Ecologische Normdoelstellingen), and Water Framework Directive aims, it seems that especially the sulphate, phosphate and nitrate concentrations exceed the standards and aims (table 3). The SEND standard values are specifically developed for the province of Noord-Holland and are based on 19 different water types. The Ilperveld belongs to the water type that is characterized by gradual desalinization.
Total phosphorus concentrations in both open and isolated waters exceed SEND values, and WFD aims. Total nitrogen concentrations are also higher than the WFD aims (table 3). In the open water, the sulphate concentrations are high, exceeding the SEND

standard value (table 3). However in the isolated water, sulphate concentrations are lower (table 3). The high nutrient concentrations of the surface water in the Ilperveld are the result of external eutrophication and internal eutrophication (Van Kranenburg *et al.,* 2000). The earlier described supply of water during dry periods from other systems is a form of external eutrophication. The most common form of external eutrophication is manuring in the area and surrounding polders (Van Kranenburg *et al.,* 2000; Huurnink *et al.*, 2009).
Internal eutrophication refers to the mineralization of the organic peat sediment. In these sediments many nutrients are accumulated over time. Under influence of sulphate, and bicarbonate-rich water, these nutrients are released into the surface water. Via this way, nutrient enrichment takes place, without the external addition of nutrients. Bicarbonate (HCO_3) and sulphate play an important role. A high bicarbonate concentration in the surface water causes enhanced peat degradation, because the acid conditions under which the peat arised, disappears. As a result, the peat degrades and the nutrients that were captured in the peat are released. The presence of sulphate in the surface water and ground water stimulates internal eutrophication in two ways. First, by the reduction of sulphate to sulphide, bicarbonate is released, and the intern eutrophication is accelerated. Second, the reduction of sulphate to sulphide increases the release of phosphate, because by the reduction of sulphate, phosphate is mobilized that was bound to iron (Van Kranenburg *et al.,* 2000; Witteveldt, 2002; Huurnink *et al.*, 2009).
In addition, the sediments of the Ilperveld contain much sulphide, because the system is sulphate-rich and the iron-sulphur ratio in the sediments is low (Kiwa Water Research & EGG, 2007; Brouwer *et al.,* 2006; Leon Lamers, personal communication). Field experiments in the Ilperveld performed by the research institute B-Ware showed that the iron-sulphur ratio in the sediments of the open water and turf ponds is low, which means that much sulphide is formed and that phosphate mobilization is stimulated (Brouwer *et al.,* 2006).
The high sulphide concentration in the sediments could hinder the establishment of macrophytes, because the measured sulphide concentrations are toxic for some characteristic macrophytes (Brouwer *et al.,* 2006).

1.4.2 Ecological water quality

The open water of the Ilperveld has a low floristic diversity (Beheerplan Ilperveld 2007-2017). In the open water of the Ilperveld, a low submersed macrophyte biomass occurs. Vegetation samples in the Gouwsloot in 2003 and 2007 (data from Limnodata) showed many littoral macrophytes like reed (*Phragmites australis*), pond sedge (*Carex riparia*), water mint (*Mentha aquatica*), yellow iris *(Iris pseudacorus*), narrow leaf cattail (*Typha angustifolia*), great water dock (*Rumex hydrolapathum*) and the brackish water indicator sea club-rush *(Bolboschoenus maritimus).* The only submerged macrophyte in these samples was the pondweed *Potamogeton pectinatus.* Recently, the freshwater indicator *Stratiotes aloides* was observed in the Ilperveld (van den Boogaard *et al.,* 2010).

In 2003 and 2006, the fish stock of the Ilperveld was determined as part of Plan Roerdomp, another nature restoration project, started in 2002. The classification of the fish stock was performed according to the fish stock types composed by the OVB (Organistatie ter Verbetering van de Binnenvisserij). The fish stocks are related to the water quality (table 4). Each fish stock represents a different water quality condition.

Table 4. Fish stock types for shallow water (< 4 m) composed by OVB.

Fish stock type	**Macrophyte coverage (%)**	**Characterizing fish species**
Rudd - Pike	60 – 100	Pike, Rudd, Tench, Crucian Carp, European Bitterling
Pike - Roach	20 - 60	Roach, Perch, Silver Bream, Pike
Roach – Bream	10 – 20	Roach, Silver Bream, Bream, Pike Perch, Perch
Bream – Pike Perch	0 -10	Bream, Pike Perch, Roach

In general, the fish stock of the Ilperveld is characterized by freshwater fish (van den Boogaard *et al.,* 2010). The fish stock of the open water of the Ilperveld is composed of high numbers of Bream, Roach, and Perch. The fish stock of the open compartment 7 (not isolated, control) could be characterized as the Roach-Bream type (Van Straaten *et al*, 2006). This type is characterized by fish like Bream and Perch*,* low macrophyte coverage (10-20%), and turbid, eutrofied water (table 4; Vis & Water Magazine, 2001). Fish samples from the Gouwsloot and ditches near the Gouwsloot (open water) in 2003 and 2006 showed high percentages of Bream, Perch and Roach (Van Straaten *et al*, 2006). All these ditches were characterized as the Bream – Pike Perch type (figure 4). In general, a very high biomass of eurytope fish species (Perch, Bream, Roach) was observed in relation to the biomass of limnofilic species (Rudd, European Bitterling, Crucian Carp, Spined Loach). Eurytope fish species have broad ecological amplitude and can live in any biotope. On the contrary, limnofilic species are restricted to biotopes with a well developed macrophyte community. In the ditches near the Gouwsloot, eurytope biomass was 97-99 % and the limnofilic species biomass was 1 - 3 %. The proportion of the benthivorous fish biomass (fish feeding on bottom- dwelling organisms) is also very high in these ditches. Turbid water is characterized by a high biomass of benthivorous fishes.

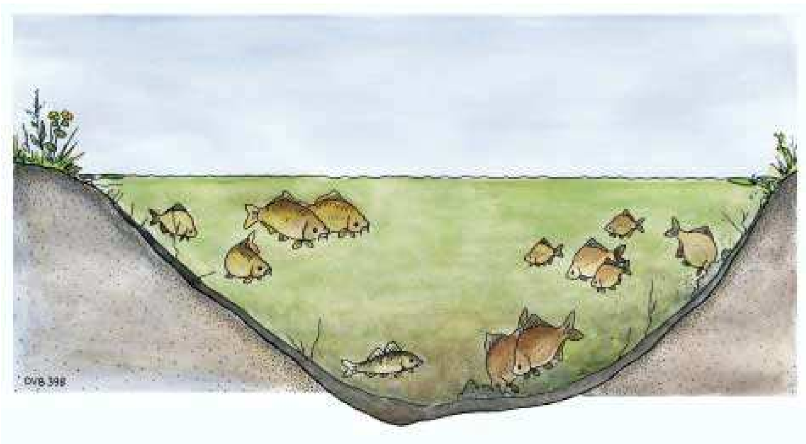


Figure 4. The Bream-Pike Perch type. Source: Vis & Water Magazine, 2001.

In the isolated waters, the ecological quality is better than in the open water.
Before the restoration measures of Plan Watersnip, the water had the same ecological quality as the above described open water.

After the measures (2000), the ecological quality was highest in compartment 9. The fish stock developed to a Pike-Roach type in this compartment (figure 5). This implies that the water had a good transparancy, and a high submerged macrophyte biomass. Syntaxonomically the plant community in this compartment belonged to the community Najadetum marinae, with the characterizing species *Najas marina*, *Potamogeton pectinatus, Zannichellia palustris*, *Ceratophyllum demersum*. Also, *Chara connivens* occurred in this compartment. In the other compartments, the transparancy improved, but the development of macrophytes was less than in compartment 9. Many floating macrophytes, like duckweeds, were recorded.
The fish stock in the compartments improved also, but to a lesser extent than in compartment 9, where Bream and Carp were removed (biomanipulation).
In all compartments, European Bitterling was found, and comprised 4 -15 % of the fish that was caught in 2000. Despite this positive development, the ecological quality declined slightly in the compartments in succeeding years. Samples from 2003 and 2006 showed that in compartment 9, water transparency decreased, and numbers of Perch and Roach increased (Van Straaten *et al*, 2006). No European Bitterling individuals were catched in this compartment in 2003 and 2006; in 2009 however, high numbers were caught again (see chapter 2). Nevertheless, the fish stock was characterized as the Pike-Roach type in 2006 (Van Straaten *et al*, 2006). The eurytope fish biomass was higher than the limnofilic fish biomass, but the benthivorous fish biomass was low. A positive change occurred in compartment 12/13, where the fish stock developed in a Pike-Roach type, and the macrophyte coverage was on average 60 % (Van Straaten *et al*, 2006). In compartment 12/13 eurytope biomass was lower than limnofilic fish biomass and the benthivorous fish biomass was lower than the piscivorous fish biomass. In this year, more compartments are isolated, so that 5.2 % of the total surface water becomes isolated from the Waterlandse Boezem (www.ilperveldintegraal.nl)

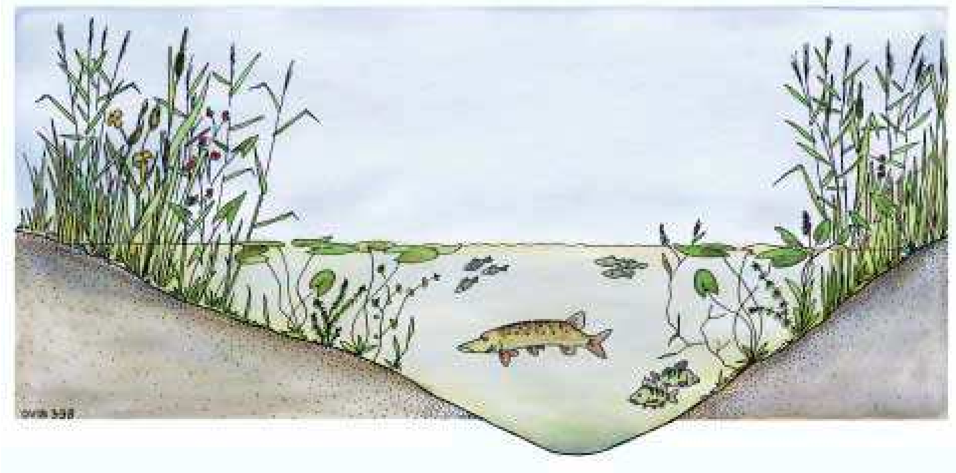


Figure 5. The Pike-Roach type. Source: Vis & Water Magazine, 2001.

Despite the high nutrient concentrations in the surface water of the Ilperveld, cyanobacterial biomass is very low (Lamers *et al.*, 2006). Chlorophyll-a measurements from 2003-2005 (Lamers *et al.*, 2006) in the Ilperveld showed that the phytoplankton community was not dominated by cyanobacteria, but that diatoms and green algae were the most abundant. Apparently, the eutrophic conditions did not result in cyanobacterial dominance. Lamers *et al.* (2006), suggested that the brackish conditions are an obstruction for certain cyanobacterial species such as *Microcystis*.
Furthermore, a correlation between temporary desiccation in summer and high algal biomass was observed. An increase in algal biomass was observed from 2003-2005 in

some turf ponds, which could be the result of temporary desiccation (Lamers *et al.*, 2006). In some compartments, massive growth of filamentous algae growth was observed in 2000, 2003, 2006, and 2010 (see figure 6). In compartment 9 for example, a massive growth of *Cladophora glomerata* developed in the fall of 2000. This algal accumulation was removed by the managers because an oxygen deficiency in the water column appeared (Witteveldt, 2002).

In conclusion, current bottlenecks concerning the water quality in the Ilperveld are high nutrient concentrations in the surface water, high sulphide concentrations in the sediments, and a low water transparency. In addition, the chloride concentration is too low for characteristic brackish water flora and fauna. Elevated sulphide concentrations in the sediments and a low water transparency prevent the establishment of submersed macrophytes. A low coverage of macrophytes and a low water transparency in the open water result in a fish stock dominated by eurytope fish species like Bream, Roach, and Perch. In the Watersnip compartments, the water quality improved after isolation from the open water, dredging, and biological measures. The compartments contain lower sulphate and chloride levels and a higher water transparency. This resulted in increased macrophyte coverage and improved fish stock.

Figure 6. Filamentous algae growth in compartment 9. Personal observation in April 2010.

*Table 2. Average of water quality data of open and isolated water of the Ilperveld. The water quality of the open water was measured in the period 1991 - 2007, by Hoogheemraadschap Hollands Noorderkwartier. The average water quality in Watersnip compartments was measured 26-1-2009 by Landschap Noord-Holland. * The average transparency of the period 1997-2000. Sources: Limnodata, M. Witteveldt (data compartments), and Witteveldt, 2002.*

Location	Temperature (ºC)	pH	Oxygen (mg/l)	Transparency (m)	Chloride (mg/l)	P-tot (mg/l)	N-tot (mg/l)	Chlorophyll-a (mg/l)	Sulphate (mg/l)
Batesloot (2001 – 2005)	17	8.1	9.5	0.18	501.1	0.4	3.3	0.06	121.9
Kees Walse Wijd (1997)	16	8.5	10	0.29	660	0.41	4.08	0.167	183.3
Molensloot (1991-2007)	13.2	8.2	8.9	0.33	555.7	0.49	4.2	0.143	171.9
Compartment 7 (open)		7.8		0.188 *	220.6	0.45	4.0		87.5
Compartment 13 (half isolated)		6.5		0.276 *	69	0.37	3.7		13.5
Compartment 9 (isolated)		7.2		0.441 *	110.2	0.42	3.1		32.46

2. Natura 2000 and Ilperveld

- **The Ilperveld is a Natura 2000 area and is designated to maintain habitat type 3140, European Bitterling, Spined Loach, and the Bullhead**
- **A rare brackish variant is present in the area of habitat type 3140**
- **The European Bitterling is very common in the Ilperveld; the Spined Loach and Bullhead are less common.**

This chapter describes the aquatic Natura 2000 goals for the Ilperveld. The specific habitat types and species are described, as well as their distribution in the Ilperveld and Noord-Holland. First, an introduction of Natura 2000 is presented.

2.1 Introduction Natura 2000

The nature in Europe is currently under pressure through pollution, climate change, tourism, agriculture, urbanization and other human activities. As a result, habitats are being destroyed or fragmented, and biodiversity declines. Natura 2000 is an initiative of the European Union, which aims to stop the decline of biodiversity in Europe. Within this framework, the 27 EU member states cooperate to protect the most vulnerable nature, species and habitats of Europe (European Commission, 2009). One of the main ways by which this objective is to be achieved is the site-specific implementation of the Birds and Habitats Directives. This means setting up a European network of nature areas, the Natura 2000 network, which contains all areas that are protected on the basis of the Bird directive (1979) and Habitat Directive (1992). Currently, about 25000 areas are recorded in the network, which makes this the largest network of protected nature areas of the world. Examples of Natura 2000 sites are the Wadden Sea in The Netherlands, Hainich forest in Germany, Castro Verde in Portugal, and the natural forests in Scandinavia (European Commission, 2009; Ministry of Agriculture, Nature and Food Quality, 2006).

The key objective of the Natura 2000 network is to protect biodiversity in Europe. The species and habitat types that fall under this obligation must therefore be protected at a national level. It has been agreed that the member states of the European Union will take all necessary measures to protect the Natura 2000 sites, species, and habitats in their country (Ministry of Agriculture, Nature and Food Quality, 2006).

The Netherlands proposed 162 areas, which can form the Dutch contribution to the Natura 2000 network. However, the sites are not definitively designated. The designation process is as follows: after the request to the EU, the concerning areas are noted by the EU on a list of areas that need to be protected. After this, the Dutch Ministry of Agriculture, Nature and Food Quality registers the site as a Natura 2000 area. In this registration, the nature values (which animals, plants, and their habitats) of the particular area are mentioned, and in which way these values have to be protected. In addition, a management plan has to be prepared. The management plans are prepared in close consultation with owners, users, municipalities, provinces and water boards.

If this process proceeds well, the areas obtain a definitive designation as a Natura 2000 area. A definitive management plan is valid for six years. This process is established in the Natuurbeschermingswet 1998. In this law, Natura 2000 is embedded in Dutch legislation. All 162 Dutch areas have to be definitively designated in December 2010. Within 3 years after the definitive designation of an area, the management plan has to be finished (European Commission, 2009).

One of the Natura 2000 areas (number 92) in The Netherlands is the Ilperveld, Varkensland, Oostzanerveld and Twiske. This area is not yet definitely designated. The area is registered and a draft management plan is composed.
The surface of this area is 2.584 ha, and contains lakes and marshes. The Ilperveld is a Habitat directive area and a Bird Directive area, as well as Oostzanerveld and Varkensland, which means that these areas are designated to maintain individual species and specific habitat types. The Twiske is only a Bird Directive area.

2.2 Aquatic Goals

Table 5 shows the aquatic Natura 2000 goals for the Ilperveld. The habitat types and species are discussed separately in the order of the table.

Table 5. Aquatic Natura 2000 goals for the Ilperveld. Source: Huurnink et al., 2009

		Preservation status	Preservation goal	
			Area	Quality
Habitat type	**Code**			
Oligo-mesotrophic water with *Chara spp.* vegetation	H3140	Very unfavorable	Expansion	Retention
Habitat species				
European Bitterling (*Rhodeus amarus*)	H1134	Moderate unfavorable	Retention	Retention
Spined Loach (*Cobitis taenia*)	H1149	Favorable	Retention	Retention
Bullhead (*Cottus perifretum*)	H1163	Moderate unfavorable	Retention	Retention

2.2.1 Oligo-mesotrophic water with Chara spp. vegetation

Habitat type 3140 encloses submersed macrophytes in nutrient poor (oligotrophic to mesotrophic), alkaline, and clear water. The vegetation consists of *Chara* species. Typical species are *Chara connivens, Nitellopsis obtuse, Chara major, Chara globularis, Nitella flexilis, Chara aspera.* Plants and macrophytes are classified into plant communities. These communities consist of several species that have the same abiotic preferences. Characteristic plant communities of this habitat type are Nitelletum translucentis, Nitellopsidetum obtusae, Charetum hispidae, Charetum asperae and Charetum canescentis.
This habitat type strongly declined since 1950 in the Netherlands by a deterioration of the water quality coupled with an increased turbidity of the water (Huurnink *et al.*, 2009). During the period 1994-2004 there was a slight increase in distribution area of the habitat type. However, the national trend is slightly negative in recent years. In this Natura 2000 area, a rare brackish variant of the habitat type is present. Typical macrophytes of this brackish variant are *Ruppia maritima* and *Najas marina.* Therefore, this Natura 2000 area contributes considerably to the national objective of this habitat type, which is preservation of the area and an improvement of the quality (Ministry of Agriculture, Nature and Food Quality, 2008). The habitat type is well developed in the northern part of the Oostzanerveld. But also in the isolated waters of the Ilperveld the surface area of the habitat type increased recently (Huurnink *et al.*, 2009).

2.2.2 European Bitterling

European Bitterling (*Rhodeus amarus*, Cyprinidae; figure 7) is a freshwater fish with a remarkable spawning relationship with freshwater mussels (further explanation in chapter 3.3). The European Bitterling is a carp, and belongs to the order of Cypriniformes. This fish is one of the smallest representatives of the Cypriniformes in our country and inhabits shallow waters with high macrophyte and helophyte abundance (de Lange & van Emmerik, 2006).

Figure 7. European Bitterling. Source: Sportvisserij Nederland, 2006.

Although this Natura 2000 area lies currently within the main distribution range of the European Bitterling, this fish can be considered as an invasive species (van Damme *et al*, 2007). From approximately 1980, *R. amarus* has rapidly expanded its range and has colonized various habitats including rivers, artificial canals and estuarine waters in many European countries (van Damme *et al*, 2007).

2.2.3 Spined Loach

The Spined Loach (*Cobitis taenia*; figure 8) belongs also to the Cypriniformes, but to another family than the European Bitterling, namely the Cobitididae. Of the three Loach species that occur in our country, the Spined Loach is the smallest (8 -10 cm).

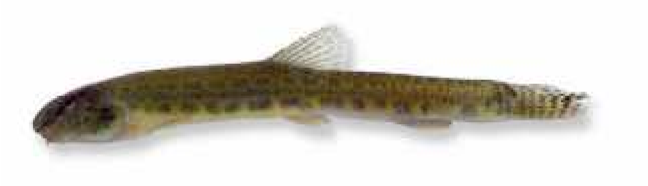


Figure 8. Spined Loach. Source: Sportvisserij Nederland, 2006.

Cobitis taenia is a bottom-dwelling fish. During the day the fish hides on the sediments that are covered by aquatic vegetation. At night, the Spined Loach moves over the sediment searching for food. *Cobitis taenia* has a large Eurasian geographical distribution that ranges from Europe to Siberia. The Spined Loach is a common species in The Netherlands, and has therefore a favorable preservation status (Ministry of Agriculture, Nature and Food Quality, 2008).

2.2.4 Bullhead

The genus *Cottus* belongs to the family Cottidae, order Scorpaeniformes. This genus is common in Europe, including in The Netherlands (Peters, 2009; Ministry of Agriculture, Nature and Food Quality, 2008). Bullheads in the Netherlands used to be indicated with the name *Cottus gobio* (figure 9). However, recent genetical research has showed that in The Netherlands two different species are present, namely *Cottus perifretum* and *Cottus* *rhenanus*. Most Bullheads that occur in The Netherlands belong to the species *Cottus perifretum* (Ministry of Agriculture, Nature and Food Quality, 2008).

Figure 9. Bullhead. Source: Sportvisserij Nederland, 2006.

Originally, the Bullhead occurs in shallow, unpolluted, oxygen-rich streams. In The Netherlands, the Bullhead is especially present outside these streams, in paved shore zones of lakes, canals and rivers. During the 19th century, the species settled in these paved habitats, such as some part of the Ilperveld. The Bullhead is a small fish (average length 12 cm) that prefers a hard substrate, and a good shelter place. Landfill sites are also preferred by this species (Niels Hogeweg, personal communication).

2.3 Current distribution

2.3.1 Oligo-mesotrophic water with Chara spp. vegetation

The poor water quality in the Natura 2000 area forms a continuous threat to this habitat type. Only in the northern part of the Oostzanerveld and isolated parts of the Ilperveld this habitat type is represented. So to reach the goals for this habitat type, an improvement of the water quality is essential. A positive note is that the water quality of the Ilperveld is improved nowadays over a surface of 150 hectare due to the earlier mentioned nature restoration projects Plan Watersnip and Plan Roerdomp.

Figure 10. Chara major between reed vegetation. Source: SynBioSys, 2008

In the Natura 2000 area the rare brackish variant of the habitat type is present, as well as the pointed habitat type (Oligo-mesotrophic water with *Chara spp.* vegetations*)*.
Both versions have the same ecological requirements, only the required chloride concentration differs (chloride range *Ruppia maritima:* 1000 – 10 000 mg/l). In the whole Natura 2000 area, the surface of the brackish variant is 80 hectare, and the surface of the pointed habitat type is 8 hectare (Huurnink *et al.,* 2009). Macrophytes that are observed are *Najas marina, Ruppia maritima*, *Zannichellia palustris, Potamogeton pectinatus, Potamogeton pusillus, Ceratophyllum demersum, Nitellopsis obtusa, Chara globularis, Chara major* (figure 10) *and Chara connivens.* These species indicate presence of the communities Najadetum marinae, Ruppietum maritimae (brackish variant), Nitellopsidetum obtusae, and Charetum hispidae (original variant) in the Natura 2000 area (Kiwa Water Research & EGG, 2007).

2.3.2 European Bitterling

The European Bitterling is widely distributed in the Ilperveld and Noord-Holland (figure 11). The fish can be found in the open water as well as in the isolated compartments. In 1998, the percentage of European Bitterling in the open water of the Ilperveld was 2.5 % of the total amount of fish that was caught (Hofman, 2000). After the recovery measures of Plan Watersnip, the percentage of European Bitterling in the isolated compartments was 4-15 % of the total amount of fish that was caught in 2000 (Hofman, 2000).
Table 6 and 7 show that the number of European Bitterling observed in 2006 is lower than in 2003. Both the open water and isolated compartments show a decline in European Bitterling numbers. In the isolated compartments the numbers are still higher than in the open water. Despite this decline, compartment 12/13 harbors a relative large population. Isolation of water seems favorable for this fish, because then a favorable habitat develops. This habitat is clear water with much macrophytes, and reed in the tidal zone. Eventually, adverse effects occur for the population due to low exchange with deeper waters, and predation by predatory fish. This adverse effects occurred in compartment 9 (van Straaten *et al*, 2006). In October 2009 however, more than 1000 European Bitterlings were caught in compartment 9 during a fish depletion by the managers (Niels Hogeweg, personal communication; Sluis *et al.,* 2009). A possible explanation for the absence of European Bitterlings in compartment 9 in 2003 and 2006 is predation by young individuals of Pike (Hogeweg, personal communication).

Table 6.Number of European Bitterling catched in open water of the Ilperveld

Location	2003	2006
Gouwsloot	4	
Compartment 7a	29	16
Snoek Dors	27	3

Table 7. Number of European Bitterling catched in isolated compartments of the Ilperveld

Location	2003	2006	2009
Compartment 6	6	7	
Compartment 10	35	2	
Compartment 12/13	1264	210	
Compartment 9	0	0	> 1000

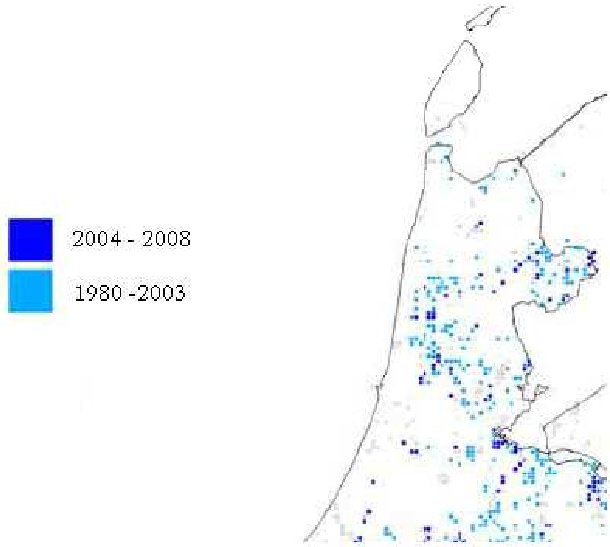


Figure 11. Distribution of European Bitterling (1x1 km grid). Modified after Kranenbarg et al., 2009.

2.3.3 Spined Loach

The distribution of this fish in the Ilperveld is largely unknown. The fish is probably present, as well as the preferred habitat. It is likely that the fish lives in small ditches with clear and shallow water, with vegetations of *Potamogeton pusillus* and *Elodea spp.* (Ron van 't Veer, personal communication). The distribution is probably underestimated because the species is hard to catch with the existing fish methods. The fish samples from 2003 and 2006 showed no Spined Loach individuals. Another explanation for this absence in the samples could be the inactivity of these fish in winter (van Straaten *et al*, 2006). In surrounding areas of the Ilperveld, the Spined Loach is actually present (figure 12).

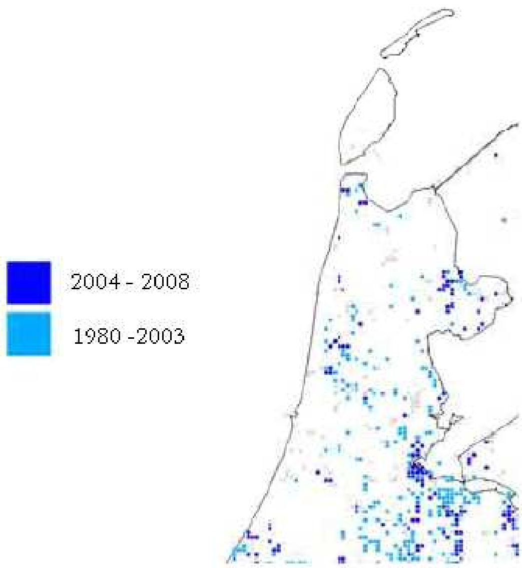


Figure 12. Distribution of Spined Loach (1x1 km grid) Modified after Kranenbarg et al., 2009.

2.3.4 Bullhead

Although the Bullhead was originally not present in the Ilperveld, the species can be found in low numbers in the area, especially along banks of the larger open waters. The species can be found on hard, sometimes artificial substrates like stones, rubbish, and dams.

In 2003 and 2006, three individuals were found in ditches near the Gouwsloot. The cause of the low abundance in the samples could probably also be attributed to the used fish method (seines). Additional sampling with another method showed that the distribution of the Bullhead in the Ilperveld is common at banks with rubbish (van Straaten *et al*, 2006). Also this fish seems to be present in surrounding areas of the Ilperveld (figure 13).

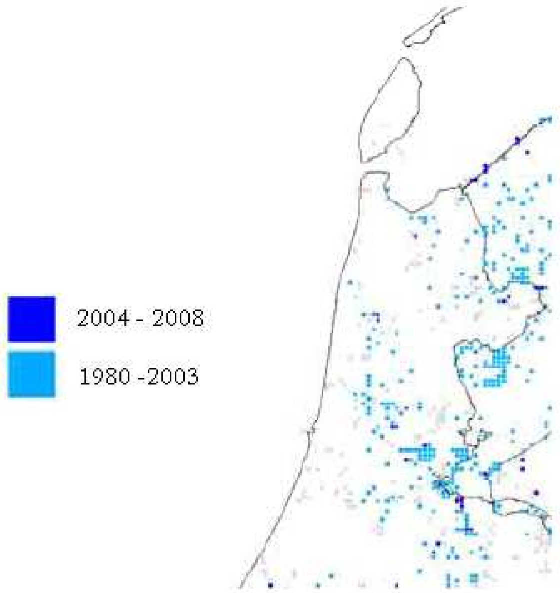


Figure 13. Distribution of the Bullhead (1x1 km grid).
Modified after Kranenbarg et al., 2009.

3. Environmental requirements for the Natura 2000 species

- **Habitat type 3140 has high water quality demands**
- **All fish and macrophytes prefer clear water**
- **The European Bitterling depends strongly on freshwater mussels**

This chapter decribes the abiotic and biotic conditions that are required for the Natura 2000 macrophytes and fish species.

3.1 Abiotic conditions macrophytes

The abiotic requirements for four macrophytes are shown as response curves from the program SynBioSys (version 1.20, 2008) in appendix 2. In this chapter, a summarizing table with the Ellenberg values is shown (table 8). The program SynBioSys provides ecological information about single plant species, plant communities, and landscapes. The basis of the program is formed by the Landelijke Vegetatie Databank (LVD), managed by Alterra. This file consists of approximately 350.000 samples from the period 1930-2000. Two *Chara* species and two brackish species (*Najas marina* and *Ruppia maritima*) were chosen, because *Chara spp.* vegetations are the Natura 2000 goal and the two brackish species are also a variant that is present in the Ilperveld. The response curves are based on 35.000 samples. From every sample, average indicator values (Ellenberg) were calculated by the program SynBioSys.
Additional information about abiotic conditions found in literature is added in table 9.

Table 8. Ranges of Ellenberg values for the four chosen plant species. Values are obtained from the response curves made in SynBioSys shown in appendix 2. The meaning of the values is described below.

	Temperature	Light preference	pH	Nitrogen richness	Salt tolerance
Najas marina	5 -7	5 -7	7 - 9	4 - 8	0 - 3
Ruppia maritima	5 -7	7 - 8	7 - 9	3 - 8	2 - 9
Chara major	5 - 6	5 - 8	5 - 8	3 - 7	0 - 2
Chara connivens	5 - 7	5 -9	6 - 8	3 - 6	1 - 5

Indication for temperature

1 = cold preferring plant
2 = cold preferring plant / cool areas
3 = plant of cool areas
4 = plant of cool areas / moderately warm areas

5 = plant of moderately warm areas
6 = plant of moderately warm areas / warm areas
7 = plant of warm areas
8 = plant of warm areas/ extreme warm areas
9 = plant of extreme warm areas

Indication for light preference

1 = very shadow preferring
2 = very shadow preferring / shadow preferring
3 = shadow preferring
4 = shadow preferring / half shadow preferring
5 = half shadow preferring
6 = half shadow preferring / half light preferring
7 = half light preferring
8 = light preferring
9 = very light preferring

Indication for pH

1 = strongly acid
2 = strongly acid / acid
3 = acid
4 = acid / weakly acid
5 = weakly acid
6 = weakly acid till weakly alkaline
7 = weakly acid till weakly alkaline
8 = alkaline
9 = strongly alkaline

Indication for nitrogen

1 = very nitrogen poor bottoms
2 = very nitrogen poor bottoms / nitrogen poor bottoms
3 = nitrogen poor bottoms
4 = nitrogen poor bottoms / moderately nitrogen rich bottoms
5 = moderately nitrogen rich bottoms
6 = moderately nitrogen rich bottoms / nitrogen rich bottoms
7 = nitrogen rich bottoms
8 = pronounced nitrogen rich bottoms
9 = very pronounced nitrogen rich bottoms

Indication for salt tolerance

0 = tolerates no salt
1 = tolerates salt
2 = oligohaline
3 = beta-mesohaline
4 = alpha/beta-mesohaline
5 = alpha-mesohaline
6 = alpha-mesohaline/polyhaline

7 = polyhaline
8 = euhaline
9 = euhaline/hyperhaline

3.1.1 Abiotic conditions plant communities

As said before, in the Natura 2000 area (and also in the Ilperveld) the communities Najadetum marinae, Ruppietum maritimae, Nitellopsidetum obtusae, and Charetum hispidae are likely to be present (Kiwa Water Research & EGG, 2007). Some abiotic information of these communities are noted in SynBioSys (version 1.20, 2008).

3.1.1.1 Najadetum marinae

The species *Najas marina* is characteristic for this community. The community is present in brackish ditches with peaty sediment. The water transparency is high, moderately nutrient rich, alkaline, carbonate and sulphate rich. The water depth is approximately one meter. The community is sensitive for increased water turbidity, but to a lesser extent than Nitellopsidetum obtusae. The distribution of this community is not well-known, but probably northern Middle-Europe.
In the Netherlands the community is rare and confined to low-lying peat lakes like the Nieuwkoopse plassen, Naardermeer, and Ankeveense plassen. Sporadically, the community is present north of Amsterdam, in the peat land area to which the Ilperveld belongs.

3.1.1.2 Ruppietum maritimae

The species *Ruppia maritima* is characteristic for this community. In addition, *Zannichellia palustris subsp. pedicellata* can be abundant in this community. The community is present in ditches with sediment that has a high percentage of organic material. The maximum water depth in our country at which this community occurs is 0.7 metres. The community is meso- to oligohaline and can withstand variations in chloride levels. Threats are reduced salinization and eutrophication. Within Europe, this community is most frequent at Scandinavian, Mediterrean, and Atlantic coasts. In the Netherlands, the community is rare, and mainly occurs in the province of Zeeland.

3.1.1.3 Nitellopsidetum obtusae

Nitellopsis obtusa en *Nitella hyalina* are characteristic species of this community. The community occurs in mesotrophic to eutrophic (peat) lakes. The maximum water depth in the Netherlands at which this community occurs is 3 metres; commonly the depth is not greater than 1.5 meter. The water can be fresh to slightly brackish. The community grows mainly on muddy, sandy sediments. The pH ranges from 7.5 – 9.2 in the Netherlands. The community is extremely sensitive for phosphate addition. When the phosphate concentration exceeds 0.02 mg/l, the coverage of this community declines. The distribution area ranges from Western to Eastern Europe. Around 1940, the community occurred in peat lakes of The Netherlands; however the community is nowadays rare. In the Botshol and Naardermeer well-developed communities are present. A large threat is the turbidization of waters.

3.1.1.4 Charetum hispidae

The species *Chara major* is characteristic for this community. The community has high demands concerning the water quality. The phospate concentration has to be low, and the water transparancy at maximum. Alkaline water with a low chloride concentration is preferred. The water depth is larger dan 50 cm and the sediment has to be sandy with no mud. The community occurs in central Europe, and the Atlantic parts. This community is rare in The Netherlands, and in peat lakes the vegetations occur sporadically. Recovery is not easy, because of the high water quality demands (even higher than Nitellopsidetum obtusae).

In conclusion, most species that are described previously can persist till approximately 1000 mg/l chloride. Some species like *R. maritima* can tolerate very high chloride concentrations. In freshwater however, phosphate is the limiting factor for a successful development of habitat type 3140. For a successful development, it is important that the phosphate concentration is very low (0.04 - 0.1 mg/l) (Huurnink *et al.,* 2009). Good light conditions (high water transparancy and high light intensity) are a critical factor for the establisment of *Chara spp.* (Simons *et al.,* 1994). The community Charetum hispidae has the highest water quality demands and seems most vulnerable.

3.2 Biotic conditions macrophytes

Consumers of macrophytes are the ducks *Anas strepera* and *Anas clypeata,* and the Coot *Fulica atra* (Huurnink *et al.,* 2009). *Anas strepera* eats seeds and roots of Characeae like *Chara spp.* and *Nitellopsis obtuse,* and also thread forming algae. Numbers of *Anas strepera* increased in the Natura 2000 area since the nineties. Numbers of the other duck, *Anas clypeata* reduced in recent years. A cause of this reduction is possibly the poor water quality, since this species is favored by a good water quality (Huurnink *et al.,* 2009). The three species mentioned here, are also Natura 2000 species.

3.3 Environmental conditions fishes

In table 10 and 11, the abiotic and biotic conditions of the fishes are noted. Important to mention is the unique spawning relationship of European Bitterling with freshwater mussels. This relationship is often considered as a mutualistic relationship; however there are also clues that the European Bitterlings parasitize the mussels (Smith *et al.,* 2004). During the spawning season, males develop coloration and seek a healthy mussel to make it his territory, and defend this territory around the mussel. When a sexually mature female comes by, he tries to attract her. The females can be recognized by the long ovipositors. When the efforts of the male Bitterling have effect, the females use their long ovipositors to place their eggs onto the gills of a mussel through the mussel's exhalant siphon. Subsequently, males fertilize the eggs by releasing sperm into the inhalant siphon of the mussel, so that water filtered by the mussel carries the sperm to the eggs. The Bitterling embryos inhabit the mussel for one month during which time they develop into actively swimming larvae (Smith *et al.,* 2004; Huurnink *et al.,* 2009).

Information about predators of the three fish species is scarce. It seems that predatory fish avoid predation on the European Bitterling because the fish tastes bitter. Pikeperch and Perch are mentioned as predators (De Lange & van Emmerik, 2006). De Lange &

van Emmerik (2006) noted that Bitterling embryos and eggs are protected against predation by their settlement in the mussel.
On the contrary, the Bullhead has many predators that vary from fish like Eel (strong preference for bullhead), Pike, and Perch to fish eating birds like the grey heron *(Ardea cinerea)* (Peters, 2009). Crayfish are also mentioned as predators of Bullheads (Tomlinson & Perrow, 2003). The Common Tern (*Sterna hirundo)* and Bittern (*Botaurus stellaris*) are also fish eating birds that occur in the Ilperveld. In addition, these are designated Natura 2000 species for the Ilperveld. The number of breeding couples of *Sterna hirundo* declines, and in 2006 there were only two breeding locations of the Common Tern in the Ilperveld (Huurnink *et al.,* 2009). The Bittern is common in the Ilperveld (Huurnink *et al.,* 2009). *Sterna hirundo* is a vision hunter and has a preference for small fish which is obtained during dives. The Bittern forages among the reed of shallow water (Huurnink *et al.,* 2009). It is likely that these two birds predate on European Bitterling, Spined Loach and Bullhead; exact information about prey species was not found. Further information about predators of the Spined Loach was not found. Van Beek (2003) mentions that another Loach, *Misgurnus fossilis,* is predated by the Purple Heron (*Ardea purpurea*).

Table 9. Additional information about abiotic conditions for the selected macrophytes found in literature.

	Water temperature (°C)	Germination (°C)	Phosphate (mg/l)	Chloride (mg/l)	pH	Transparancy (cm)	Sources
Najas marina			<1.2	<530			Limnodata *
Chara connivens					7.82	60 cm	Witteveldt *et al.,* 2002
Habitat type 3140	Optimum 20 - 25	20 -25	0.04 -0.1	60	> 6	Half of depth	Huurnink *et al.,* 2009; Simons *et al.,* 1994
Nitellopsidetum obtusae				150 – 1000	7 - >7.5		http://www.synbiosys.alterra.nl/natura2000/
Charetum hispidae				< 150	> 7.5		http://www.synbiosys.alterra.nl/natura2000/

* Limnodata, respons data. The response of species to environmental factors is determined based on the occurrence of the species in the entire database (all years and locations). The presented values in the above table (phosphate and chloride concentrations) are 90-percentiles. This means that 90 % of all the measured values lie below that value.

Table 10. Abiotic conditions of the European Bitterling, Spined Loach, and Bullhead.

	Maximum temperature (°C)	Spawning temperature (°C)	Chloride (mg/l)	Oxygen (mg/l)	Phosphate (mg/l)	Sulphate (mg/l)	pH	Water depth (m)
Rhodeus amarus	> 24 [4]	14 - 20 [4]	Max. 1000 [2]	No data	No data	No data	No data	> 0.5 [7]
Cobitis taena	29 [4]	18 - 26 [4]	< 195 [1] Max. 1000 [2]	< 11.8 [1] Min. < 2 [3]	< 0.53 [1]	< 96.2 [1]	< 8.3 [1]	< 1.37 [1]
Cottus perifretum	20 [3] or 30 [4] optimum 14 - 16[3]	7 - 14 [4]	Max. 3000 [2]	Optimum 8 - 11 Min. 8 [3]	No data	No data	5.8 - 9 [5]	0.1 - 20 [5]

[1] Limnodata, respons data. The response of species to environmental factors is determined based on the occurrence of the species in the entire database (all years and locations). The presented values in the above table are 90-percentiles. This means that 90 % of all the measured values lie below that value.

[2] Paulissen *et al.,* 2007

[3] Verdonschot *et al.*, 2007.

[4] van der Grinten *et al.,* 2007

[5] Peters, 2009

[7] De Lange & van Emmerik, 2006.

Table 11. Biotic conditions of the Natura 2000 fishes. Sources: Huurnink et al., 2009, Ministry of Agriculture, Nature and Food Quality, 2008*; Peters, 2009; de Lange & van Emmerik, 2006.*

	Food	Substrate	Macrophyte presence	Other biotic indicators
Rhodeus amarus	Mainly algae, sometimes insect larvae, amphipods, snails or worms.	Bottom that consists of sand, gravel, clay, peat, or a thin mud layer.	Very necessary	Symbiotic relationship with freshwater mussels of the genera *Unio* and *Anodonta*
Cobitis taena	Worms, insect larvae, snails, crustaceans, detritus	Fine substrates like a layer loose mud or sand are preferred	Necessary	
Cottus perifretum	Crustaceans (amphipods, waterlouse) snails and insect larvae	Preference for hard substrate like stones or gravel, also branches or roots for shelter.	Not necessary	

3.4 Effect indicator Natura 2000

At the Natura 2000 website of the Ministry of Agriculture, Nature and Food Quality, a so called effect indicator is presented for every Natura 2000 area. This indicator is a tool for managers, licensors, and suppliers that cope with operations in or around the Natura 2000 area. The indicator is a tool to explore potential negative effects of future plans, measures and activities. The indicator provides information about the sensitivity of species and habitat types for the most common disturbances. The information is indicative, which means that if one wants to determine if an activity is harmful in practice, further research is necessary. For the species and habitat type of this Natura 2000 area that are concerned in the present study, the effect indicator is shown in table 12. Both habitat type 3140 and fish are very sensitive to desiccation, surface loss and fragmentation. Habitat type 3140 is according to this effect indicator very sensitive to acidification and salinization. This supports the data of table 9. For eutrophication however, the habitat type can be considered sensitive, but not extremely sensitive as mentioned in table 9. In contrast with previous information (table 10), all three fish species are considered here as sensitive for salinization. However, table 10 shows more precise information about chloride ranges, and therefore it can be stated that the Bullhead is less sensitive for salinization compared with the other two fish. Substrates are also important for the fish, as earlier mentioned in table 11.

Table 12. Effect indicator of the Natura 2000 area 92 (Ilperveld, Oostzanveld, Varkensland en Twiske). Selected are the species and habitat types that are concerned in this study. Source: (http://www.synbiosys.alterra.nl/natura2000/gebiedendatabase.aspx?subj=n2k&groep=8&id=n2k92&topic=effectenmatrix).

	1	2	3	4	5	6	7	8	9	10
Habitat type 3140	sensitive	sensitive	very sensitive	sensitive	not sensitive	very sensitive	sensitive	very sensitive	not sensitive	n.v.t.
European Bitterling	very sensitive	very sensitive	not sensitive	sensitive	n.v.t.	sensitive	very sensitive	very sensitive	not sensitive	sensitive
Spined Loach	very sensitive	very sensitive	not sensitive	sensitive	n.v.t.	sensitive	very sensitive	very sensitive	not sensitive	very sensitive
Bullhead	very sensitive	very sensitive	not sensitive	sensitive	n.v.t.	sensitive	very sensitive	very sensitive	not sensitive	sensitive

- very sensitive
- sensitive
- not sensitive
- n.v.t.

Disturbance factors

1. Surface loss
2. Fragmentation
3. Acidification
4. Eutrophication
5. Desalinization
6. Salinization
7. Pollution
8. Desiccation
9. Raised water levels
10. Change in substrate dynamics

4. Climate change in Noord-Holland

- **Climate change in Noord-Holland involves warmer and drier summers, with many heavy rainfall events. The winters are expected to be warmer and wetter**
- **Climate change can result in both water shortages and surpluses**
- **Indirect effects of climate change are increased salinization, recreation and an increase in warmth preferring species**

4.1 Introduction

It is mentioned earlier in this study that climate change is nowadays a hot subject. That the climate is changing is currently observable (Box 1 and 2). However, the seriousness of the impact of climate change, and the cause of the observed climate change, are point of debate under authorities and scientists. The IPCC projected a disastrous scenario for the future. However, the IPCC has made some mistakes in their projections. But the main conclusions remain unchanged, and thus are the IPCC reports the basic assumption in this study, like in most climate scenarios and projections.
In this chapter, the direct effects of climate change (temperature and precipitation) are discussed, followed by the effects on water quantity and quality. Indirect effects of climate change that are relevant for Noord-Holland like salinization, and effects on nature and recreation are mentioned briefly at the end of the chapter.

4.2 Direct effects

In the past years, the average temperature in the Netherlands (and surrounding countries) increased twice as fast as the global temperature increased (KNMI, 2008, 2009). Surface water temperatures increase with increasing air temperatures (Livingstone, 2003). Particularly the temperature of shallow waters is tightly coupled to the air temperature (Mooij *et al.*, 2005). Indeed, average temperatures of lakes IJsselmeer, Zwemlust, Veluwemeer and Tjeukemeer increased from 1961 to 2001 (Mooij *et al.*, 2008). In the period 1977 – 2007, the water temperature in Noord-Holland increased with 1.65 °C (van Dam, 2009).

Box 1. The autumn and winter of 2006/2007

The autumn of 2006 en the subsequent winter were very warm. Around Amsterdam the average autumn temperature in 2006 was 13.8 °C. The normal average autumn temperature is 10.8 °C. The average winter temperature of the subsequent winter was 6.8 °C, whereas the normal average winter temperature is 3.5 °C. This difference is more than is expected in 2050 under the W+ scenario. So this (extreme) warm autumn and winter of 2006/2007 would be around 2050 still a warm autumn and winter.

Box 2. The summer of 2003

The summer of 2003 was extremely hot and dry for our current climate. People even died as a consequence of heat stress. The average temperature around Amsterdam was in the summer of 2003 18.5 °C; that is almost 2 °C higher than the normal average summer temperature of 16.6 °C. Under the W and W+ scenarios, the expected summer temperature in 2050 would be 1.7 till 2.8 °C higher than normal. This indicates that the summer of 2003 would be an average summer in 2050.

In 2006, the KNMI (Royal Netherlands Meteorological Institute) developed with the aid of global and regional climate models, four projected climate scenarios for the Netherlands. The scenarios are possible images of the climate in the Netherlands around 2050 (and 2100). They describe the most likely changes in climate in the Netherlands in 2050, compared to the situation in 1990 (KNMI, 2009). The W and W+ scenarios are the so called warm scenarios and use an increase of 2 °C of the average temperature in 2050 (table 13). The G and G+ scenarios are the more moderate scenarios and use an increase of 1 °C. In addition, the Netherlands could also be influenced by changes in atmospheric circulation, so therefore the G+ and W+ scenarios are developed and indicate a change in atmospheric circulation. The four scenarios and their characteristics are shown in table 13. In the scenarios with a change in atmospheric circulation (G+ and W+), the winters become milder and wetter due to prevailing western winds, and the summers become warmer and drier caused by prevailing eastern winds (KNMI, 2009).
Generally, the four scenarios indicate that the sea level continues to rise, that warming of the Netherlands continues, that winters become on average wetter, that there is little influence of climate change on the storm climate, and that more extreme precipitation events will occur in summer and winter (KNMI, 2009).

Table 13. The four climate scenarios for the Netherlands developed by the KNMI in 2006.

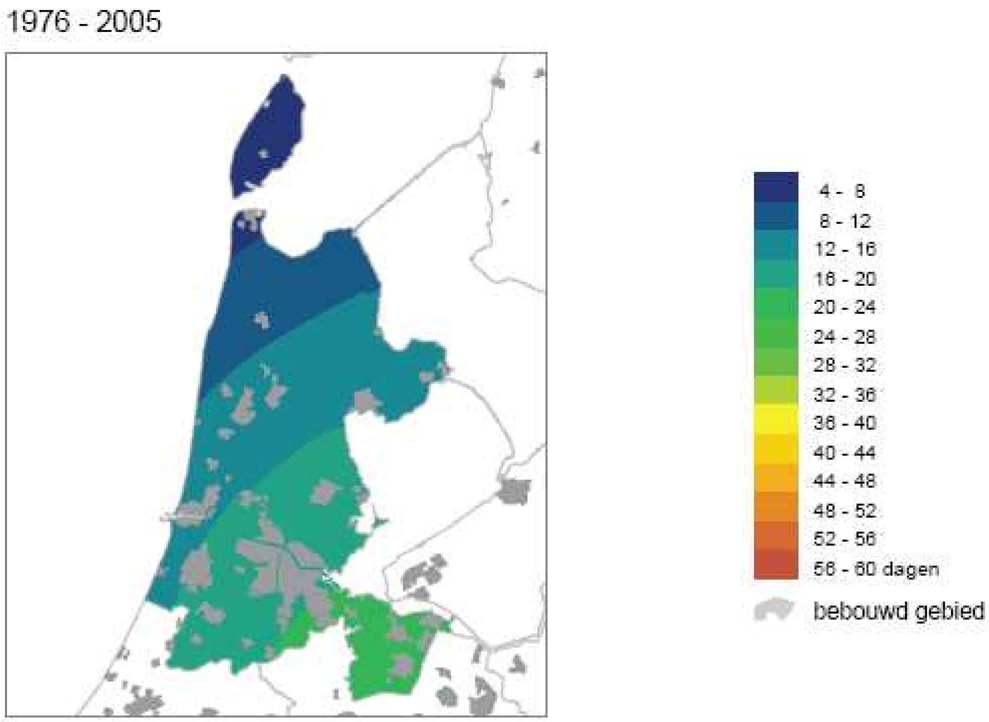
Scenario	Global temperature increase in 2050 compared to 1990	Atmospheric circulation	Average precipitation in winter	Average precipitation in summer	Sea level rise
G	+ 1 °C	no change in air circulation patterns	+ 4 %	+ 3 %	15-25 cm
G+	+ 1 °C	winter: more westernly winds; summer: more easternly winds	+ 7 %	- 10 %	15-25 cm
W	+ 2 °C	no change in air circulation patterns	+ 7 %	+ 6 %	20-35 cm
W+	+ 2 °C	winter: more westernly winds; summer: more easternly winds	+ 14 %	- 19 %	20-35 cm

The rapid warming of the Netherlands mentioned at the start of this chapter, leads to believe that the temperature changes of the W and W+ scenarios are likely to occur in the future (KNMI, 2009). However, with the current knowledge it can not be stated which scenario is most likely (Van Bakel *et al.,* 2008).

Beside differences between climate change in the Netherlands and global climate change, regional differences in climate within the Netherlands are also recognized (KNMI, 2009). For example it is likely that the coastal area of the Netherlands faces droughts from the G+ and W+ scenarios combined with short periods of extreme precipitation from the G and W scenarios. Overall, higher average precipitation in the provinces Noord-Holland en Zuid-Holland and Friesland is expected, compared to the other provinces (KNMI, 2009). For the province Noord – Holland in particular, different direct and indirect effects of climate change are recorded in the 'Klimaateffectschetsboek Noord- Holland' (van Bakel *et al.,* 2008). This document translates climate change to a regional level. Future trends for the climate variables temperature and precipitation are described here, with the support of maps. The maps show a rough pattern and the contour lines should not be interpreted as an exact separation between the different classes. In addition, the maps do not show where the impact of climate change is most considerable. For example, at the locations with the highest projected precipitation amounts, problems with flooding not necessary develop automatically.

4.2.1 Temperature

Under all KNMI'06 scenarios, warming continues. Compared to the climate in 1990 (= average period 1976 – 2005), the winter temperature increases from 0.9 (G) - 2.3 (W+) °C and the summer temperature increases from 0.9 (G) to 2.8 (W+) °C in 2050 (van Bakel *et al.,* 2008). Especially in the W+ and G+ scenarios extreme temperatures increase strongly. Under these scenarios easternly winds occur more frequently in summer. In combination with the temperature increase this results in an increase in the average number of warm days (> 25 °C; figure 14), compared with the scenarios G and W and the climate of the period 1976 – 2005 (Van Bakel *et al.,* 2008).



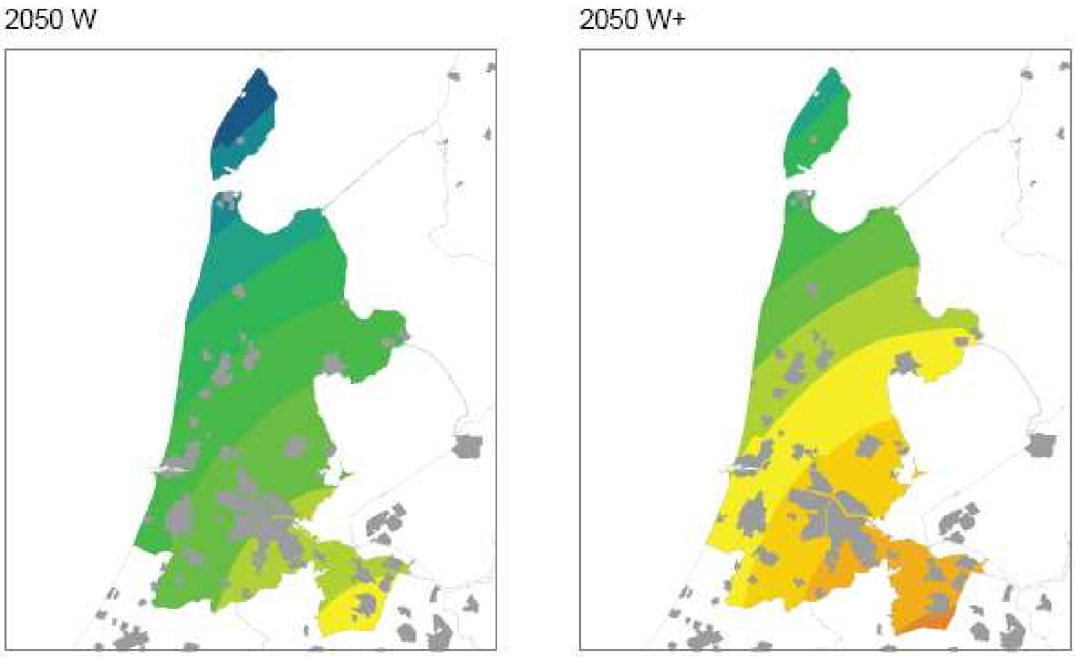
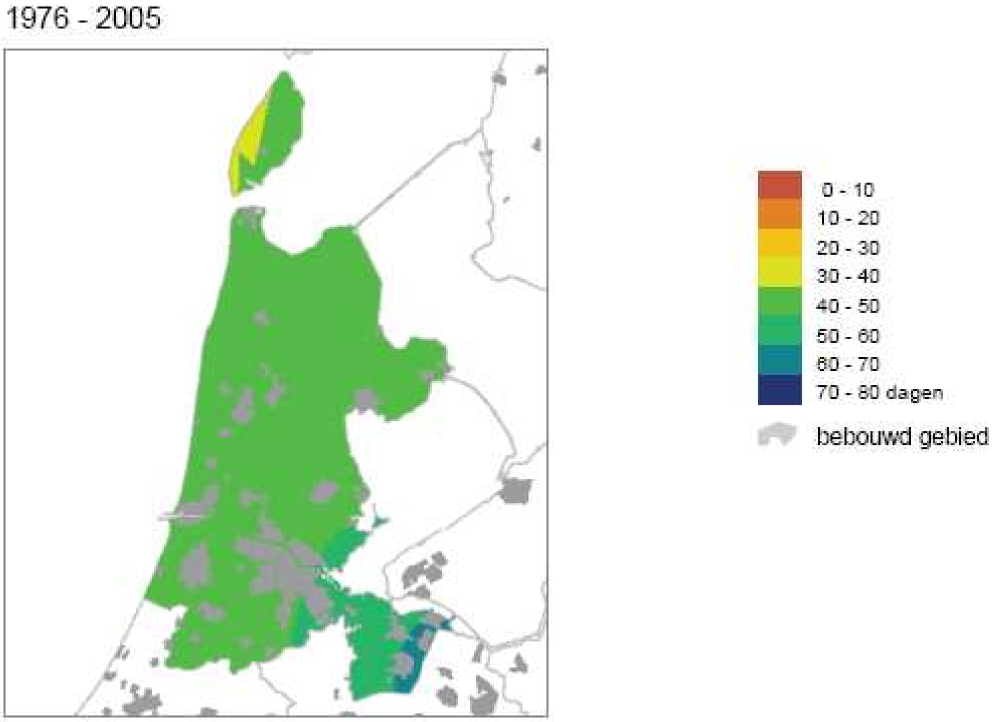


Figure 14. Average number of warm days (> 25 °C) per year for the period 1976 -2005, around 2050 for the W scenario, and around 2050 for the W+ scenario. The maps are based on an automatic interpolation of climate data from individual KNMI weather stations. Data generated with a transformation program. Displayed local variations can be partly determined by the used interpolation technique and the location of the KNMI stations. "dagen" means days and "bebouwd gebied" means built-up area.

On the contrary, westernly winds occur more frequently in winter under the '+' scenarios. In combination with the temperature increase, this results in a decline of the average number of frost days (minimum temperature < 0 °C; figure 15), compared with the G and W scenarios and the climate of the period 1976 – 2005 (van Bakel *et al.,* 2008).



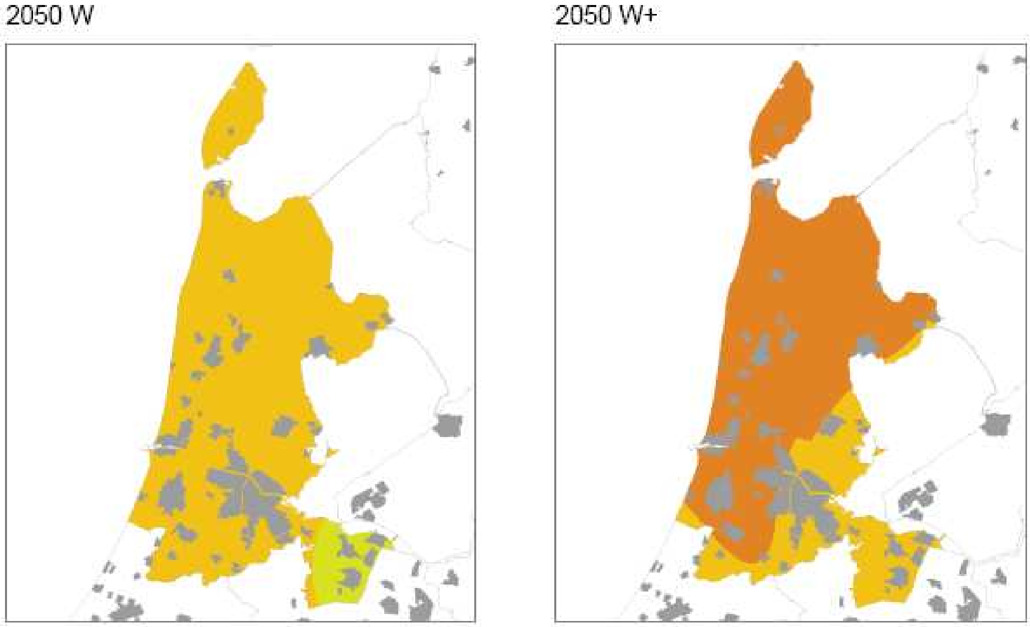


Figure 15. Average number of frost days (minimum temperature < 0 °C) per year for the period 1976 -2005, around 2050 for the W scenario, and around 2050 for the W+ scenario. The maps are based on an automatic interpolation of climate data from individual KNMI weather stations. Data is generated with a transformation program. Displayed local variations can be partly determined by the used interpolation technique and the location of the KNMI stations. "dagen" means days and "bebouwd gebied" means built-up area.

4.2.2 Precipitation

In all scenarios, the average winter precipitation increases around 2050. The strongest increase occurs in the W+ scenario (figure 16). An increase in average summer precipitation occurs in the G and W scenarios. But in the '+' scenarios (with a change in atmospheric circulation), the average summer precipitation decreases compared with the scenarios G and W and the climate of the period 1976 – 2005 (figure 17). This decline in precipitation is caused mainly by a decline the amount of rainy days. Especially the summer under the W+ scenario is expected to be very dry. To sum up, the G and W scenarios project an increase in precipitation in both summer and winter (wet scenarios) round 2050. The G+ and W+ scenarios project an increase in average winter precipitation, and a decline in average summer precipitation (van Bakel *et al.,* 2008).

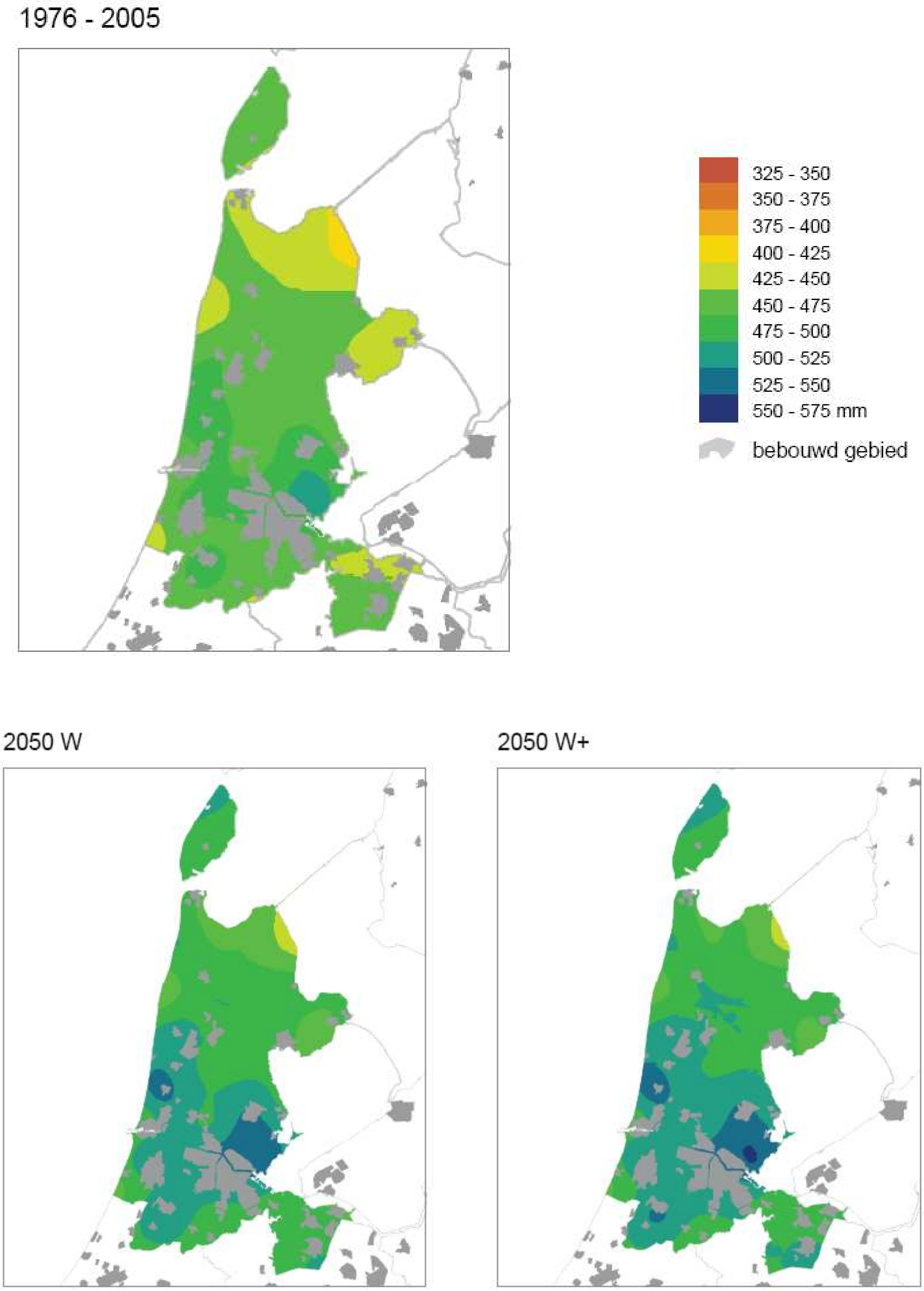


Figure 16. Average winter precipitation per year (October - March; in mm) for the period 1976 - 2005, around 2050 for the W scenario, and around 2050 for the W+ scenario. The maps are based on an automatic interpolation of precipitation data from individual KNMI weather stations. Data is generated with a transformation program. Displayed local variations can be partly determined by the used interpolation technique and the location of the KNMI stations. "bebouwd gebied" means built-up area.

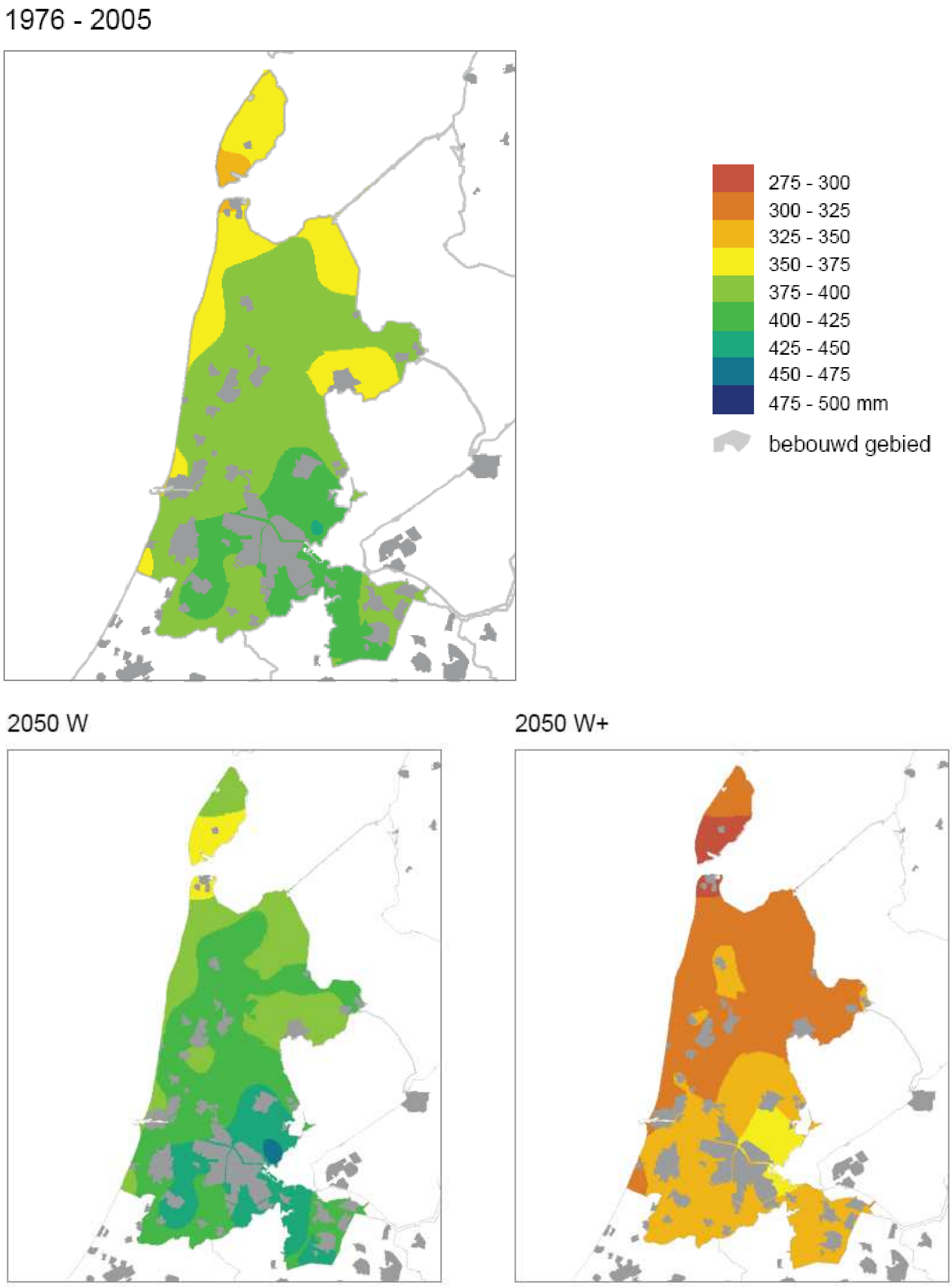


Figure 17. Average summer precipitation per year (April - September; in mm) for the period 1976 - 2005, around 2050 for the W scenario, and around 2050 for the W+ scenario. The maps are based on an automatic interpolation of precipitation data from individual KNMI weather stations. Data is generated with a transformation program. Displayed local variations can be partly determined by the used interpolation technique and the location of the KNMI stations. "bebouwd gebied" means built-up area.

4.2.3 Extreme precipitation

According to the IPCC and the four KNMI'06 scenarios, extreme precipitation events increase in the future. In the summer months this means an increase in heavy rainfall. In winter this means longer precipitation periods. The number of days with a precipitation amount of minimal 15 mm (extreme precipitation) increases in all KNMI'06 scenarios in 2050 compared with the period 1976 – 2005 (figure 18; van Bakel *et al.,* 2008). .

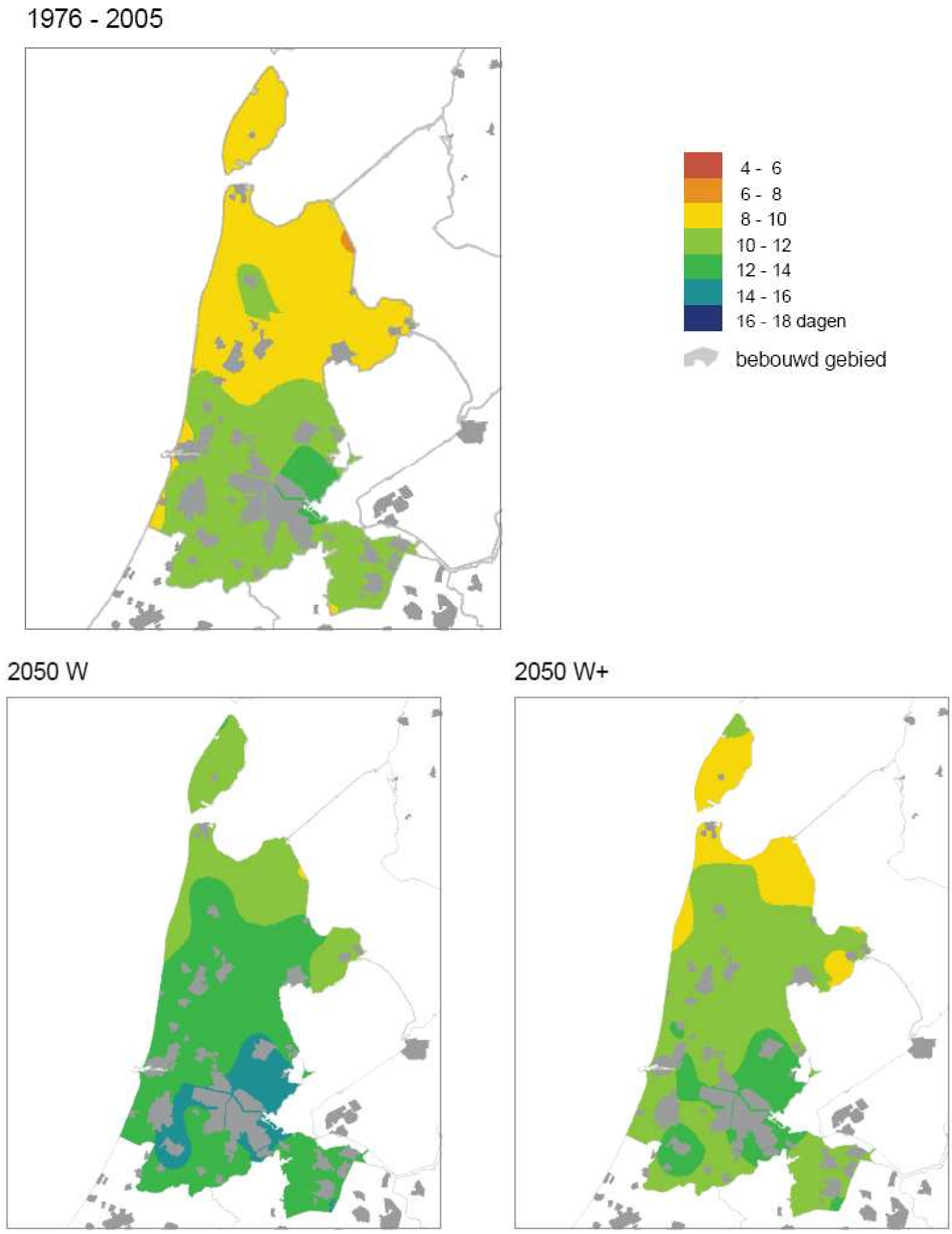


Figure 18. Average number of days per year with 15 mm or more precipitation for the period 1976 - 2005, around 2050 for the W scenario, and around 2050 for the W+ scenario. The maps are based on an automatic interpolation of precipitation data from individual KNMI weather stations. Data is generated with a transformation program. Displayed local variations can be partly determined by the used interpolation technique and the location of the KNMI stations. "dagen" means days and "bebouwd gebied" means built-up area.

Precipitation shortages, the other side of extreme precipitation, are also likely to occur especially in the W+ and G+ scenarios. As a result of the increased temperatures in summer, the potential evaporation increases also (8 % - 15 % in the G+ and W+

scenarios). At the same time, the precipitation declines strongly under these scenarios (see figure 17). This can result in an increase of droughts in summer. Around 2050, the average maximum precipitation shortage in The Netherlands ranges from 151 mm (G) to 220 mm (W+) (van Bakel *et al.,* 2008). The projected maximum precipitation shortage round 2050 under the W+ scenario (220 mm) resembles the maximum precipitation shortage of the summer of 2003 (van Bakel *et al.,* 2008).

4.2.4 Wind, sunshine and sea level rise

Changes in the wind climate are expected to be small compared to the natural year-to-year variation. According to the KNMI'06 scenarios, a slight increase in wind speed occurs in the '+' scenarios in winter.
The KNMI'06 scenarios deliver no information about changes in the intensity and duration of sunshine. However, van Bakel *et al.* (2008) expect an increase in hours of sunshine in the summer for the W+ and G+ scenarios. This would be the result of fewer rainy days. Finally, the absolute sea level rise around 2050 lies in the range of 15-35 cm (table 13). However, land subsidence is not taken into account here.

4.2.5 Increase atmospheric carbon dioxide concentration

It is difficult to assess the direct influence of higher atmospheric CO_2 concentrations on aquatic ecosystems. First of all, the concentration of carbonate and bicarbonate in the water does not change linearly with the atmospheric CO_2 concentrations, because of many processes taking place in the water, that influence the inorganic carbon pool. Secondly, higher inorganic carbon concentrations in the water only increase the primary production of algae or macrophytes in case of carbon limitation.
Many lakes are supersaturated with CO_2 because they receive organic matter from the catchment which decomposes in the lake (Van de Waal *et al.*, 2009). In these systems an increase of the productivity due to elevated CO_2 in the atmosphere is not expected. However, as a result of human activity the input of nitrogen and phosphorus to the global biochemical cycle exceeds that of the C-input by several orders of magnitude (Schippers *et al.*, 2004b). As a consequence nutrient-rich and C-limiting freshwater systems will be more common in the future. Schippers *et al.*, (2004b) suggested that in these systems increased atmospheric CO_2 may aggravate phytoplankton blooms, which already are causing major water quality problems. Although it is difficult to assess the effects of higher atmospheric CO_2 concentrations on aquatic ecosystems, changes in species composition can be expected (Schippers *et al.*, 2004b).

Summarizing, climate change in the province of Noord-Holland involves warmer and drier summers, with many heavy rainfall events. The winters are expected to be warmer and wetter. Under the worst case scenario W+, many warm days per year, a small number of frost days, high precipitation amounts in winter and low amounts in summer (but rainfall becomes more intense) are expected round 2050.
Elevated temperatures and changing precipitation regimes influence the water quantity and subsequently the water quality. Consequences for water quantity and water quality will be discussed next.

4.2.6 Water quantity

The changes in temperature and precipitation regimes have consequences for the water quantity. Since smaller amounts of rain in summer and increasing evaporation are predicted by the KNMI'06 scenarios, there is a risk of a long dry period in summer, especially under the W+ scenario. In summer, water levels will drop as well as the river discharges (Bates *et al.*, 2008; IPCC, 2007) Small pools and streams could dry out in summer. Due to the low water levels, a water shortage can arise. In the spring of 2007 a water shortage already occurred; farmers in the north of the province sprinkled their field with water from ditches, because there was a rain water deficiency. The low lying peat areas and even the Lake IJssel are sensitive to droughts (Blom *et al.,* 2008). Droughts can also have indirect effects, like salinization and a decreased contaminant dilution capacity (van Bakel *et al.,* 2008; Bates *et al.*, 2008). Faster oxidation of peat is expected in the peat lands of Noord-Holland due to high temperatures and low groundwater levels in summer. In addition, crop damage due to droughts is likely to occur under the W+ and G+ scenarios (van Bakel *et al.,* 2008). De Groot *et al* (2009) made an estimation of how climate proof the Netherlands are around 2050 for water shortages and water surpluses. This robustness analyses are a combination of different maps (shown at www.klimaateffectatlas.wur.nl) and calculations based on sensitivity for climate effects per land use type. The final score gives the degree of robustness that varies from very robust to very vulnerable, and is showed in maps (figures 19 and 20) White spots on the maps are areas where the effect (water shortage or surplus) does not occur. No data was available for the grey areas.

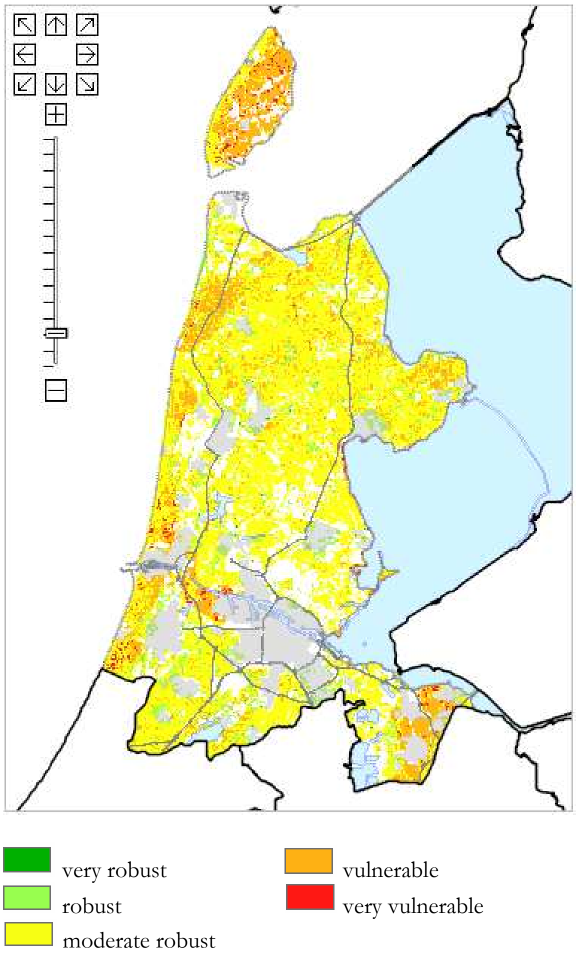


Figure 19. Degree of robustness for water shortages in Noord-Holland around 2050 under the W+ scenario. The map is the result of the combination of different indicators like water supply, moisture shortage, water quality requirements, and drought sensitivity with the land use map of The Netherlands. This map gives only an indication and is based on national data that is combined to one map view. Source: klimaateffectatlas 1.0

Figure 19 shows that the area in which the Ilperveld is located, is moderately robust to water shortages. Similar to water shortages, a surplus of water can also cause problems. On a national scale, the projected increase in winter precipitation will lead to higher river discharges (IPCC, 2007, Bates *et al.*, 2008, KNMI, 2009). Subsequently, high water levels and high river flow increase the probability of flooding. For the province of Noord-Holland, flooding risks could change due to climate change, however the size of this effect is unknown (van Bakel *et al.,* 2008). According to Blom *et al.* (2008), the peat areas in Noord-Holland are not sensitive to flooding from rivers. In contrast, heavy rainfall events can cause problems. In rural areas, heavy rainfall events can cause local flooding, and crop damage. Figure 20 shows the degree of robustness for water surpluses round 2050 under the wet W scenario. This figure shows that the area in which the Ilperveld is located, is not very vulnerable to water surpluses

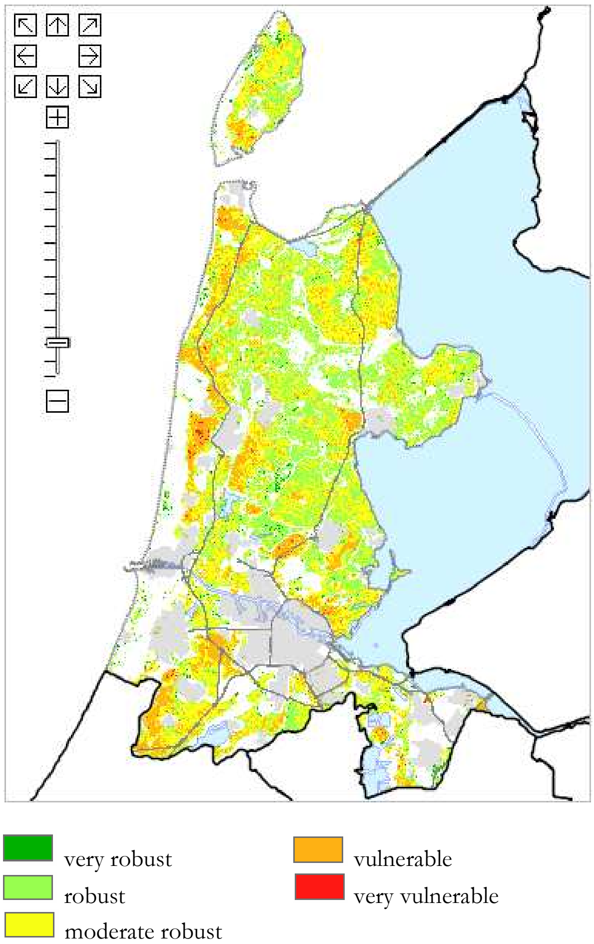


Figure 20. Degree of robustness for water surplus in Noord-Holland around 2050 under the W scenario. The map is the result of the combination of different indicators like inundation depth and exceeding chance, and the sensitivity based on the econimcal value of a land use function. This map gives only an indication and is based on national data that is combined to one map view. Source: klimaateffectatlas 1.0

4.2.7 Water quality

Climate change aggravates existing problems with surface water quality in the Netherlands, such as the occurrence of cyanobacteria, and eutrophication problems (Verweij *et al.,* 2010). This applies also to the water quality in Noord-Holland. When the chemical water quality is considered, it seems that higher temperatures lead to accelerated (bio) chemical reactions. For instance, nitrification and denitrification are biochemical processes directly related to temperature, and the rates of these processes are expected to increase due to warming (Verweij *et al.,* 2010). Denitrification causes a loss of nitrogen to the air, and thereby for reduced eutrophication. The expected heavy rainfall events in summer could lead to increased run-off of nutrients from agriculture, and a risk of sewage system overflows in urban areas (Bates *et al.*, 2008; Mooij *et al.*, 2005; van Bakel *et al.,* 2008). Acidification of freshwaters results mainly from acid precipitation. Acid precipitation is caused by the emissions from SO_2, NO_x and NH_3, mainly from traffic, agriculture and industry (Likens *et al.*, 2007). The KNMI '06 scenarios predict an increase in mean annual precipitation, which can lead to increased input of acidifying components into the surface water (Van Dijk *et al.*, 2009).
The temperature increase in summer, increased nutrient run-off, and a more stable water column results in dominance of cyanobacteria in surface waters (Pearl and Huisman, 2008; Mooij *et al.,* 2005; van Bakel *et al.,* 2008). A consequence of an increase in

cyanobacteria is that bathing locations, like ‘t Twiske, are being closed more frequently in summer. Surface scums of cyanobacteria and higher water temperatures cause a decline in oxygen concentration of the surface water. Dessications cause a decreased contaminant dilution capacity, resulting in higher contaminant concentrations in surface waters. Also, problems with drinking water supply are expected in Noord-Holland. The warming of the surface water, combined with higher contaminant concentrations, reduces the water quality. In addition, this increases the risk of microbial infections in drinking water (Verweij *et al.,* 2010). Finally, global warming affects the concentration of oxygen in water systems. The amount of oxygen that can dissolve in water decreases with increasing temperature (Kersting, 1983). This can be disadvantageous for many fish species.

4.3 Indirect effects

4.3.1 Salinization

Low groundwater levels, sea level rise and land subsidence can increase brackish seepage in many polders in Noord-Holland (Schermer, Beemster, Purmer and Haarlemmermeerpolder) thereby increasing natural salinization on the long term (van Bakel *et al.,* 2008). Climate change can also lead to salinization by the increase of the frequency, period and intensity of salt loads. Especially in dry summers, when the dilution capacity declines and the chloride concentrations increases, problems are expected (van Bakel *et al.,* 2008). Salinization of surface waters can have negative consequences for some agricultural branches such as the horticulture. Positive effects are also known. For cattle, salinization of surface water causes a decline in liver fluke disease (Tauw, 2009), and according to RIZA (2005), salinization due to climate change can have a positive effect on the surface waters of brackish polders, like the Ilperveld.

4.3.2 Recreation

In all climate scenarios, the temperature will increase. This results in a high number of warm days in summer (figure 14). So more days become available for recreation. For the recreational sector, climate change seems to be positive (van Bakel *et al.,* 2008). Recreation numbers are connected with temperature and the hours of sunshine. In 2007 for example, less people visited recreation areas in Noord-Holland compared with 2006. This decline is probably caused by the unstable weather in the summer of 2007 (van Bakel *et al.,* 2008). Disadvantages of more recreation are more traffic-jams in the direction of the beaches, and crowded swimming places. An additional risk is that warming of surface waters will reduce the quality of swimming water, and increase potential health risks (Verweij *et al.,* 2010; van Bakel *et al.,* 2008).

4.3.3 Nature (aquatic ecosystems)

On the European level, climate change has a negative impact on the conservation status of 42 habitat types and 144 species of the EU Habitat Directive. Wetland habitats, such as bogs, mires and fens, are most affected by climate change (European Environment Agency, 2010). Fragmentation of nature areas and habitats enhances effects of climate change (Vos *et al.,* 2008).

Climate change influences aquatic ecosystems via changing abiotic conditions and changes in species compositions. Increased temperatures and carbon dioxide concentrations can affect processes such as photosynthesis, respiration and decomposition, generally accelerating them (European Environment Agency, 2010). Changes in ice cover periods, river discharge regimes, thermal stratification, nutrient availability and the extended growing season affect species composition and food web structures. For example, earlier spring activities can lead to food-mismatches between different components of the food web (Daufresne *et al.*, 2004; Vos *et al.,* 2008). In aquatic ecosystems, early phytoplankton blooms could lead to a food-mismatch with some zooplankton species (Verdonschot *et al.*, 2007). In addition, climate change causes a shift of geographical species distribution in a northern direction. As a result new species can invade the Netherlands. The number of invasive aquatic species is expected to increase (Verweij *et al.*, 2010; EEA, 2010; Vos *et al.,* 2008). Overall, a decline in biodiversity and an increase in opportunistic species is expected (Vos *et al.,* 2008).
In the Netherlands, warmth preferring species increased in recent years (figure 21). There are already examples of aquatic species (dragonflies, brown trout) that have shifted northward in response to climate warming. It is expected that thermophilic fish and invertebrates replace cold-water taxa (European Environment Agency, 2010).
Weather extremes such as floods and droughts lead to more fluctuations in population dynamics, which could lead to the extinction of some aquatic species (Vos *et al.,* 2008).

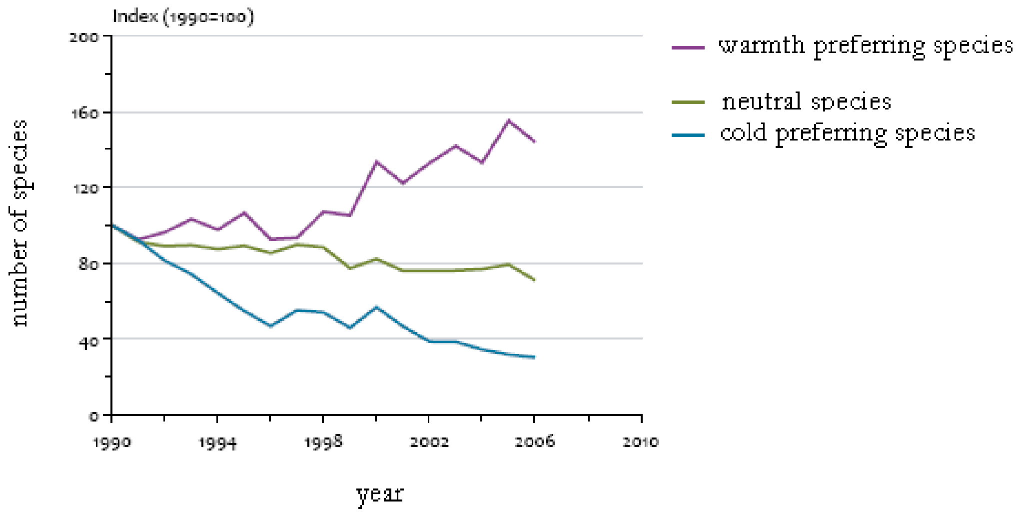


Figure 21. Graph of increases and decreases of warmth and cold preferring species in the Netherlands. Cold preferring species declined, warmth preferring species increased, and neutral species remained more or less stable in recent years. Modified from PBL, 2009.

5. Influence of climate change on ecosystems

- **Climate change enhances peat oxidation and eutrophication in the Ilperveld**
- **The water turbidity increases due to more recreation and mud movement**
- **An increase in salinization has little influence on the surface water of the Ilperveld**

5.1 Introduction

In the previous chapter direct and indirect effects of climate change were described. This was done for the entire province of Noord-Holland. In this chapter, it is tried to scale down the influence of climate change, from the regional level to specific habitats of the Ilperveld. First, the impact of climate change on the Western Peat District, including the Ilperveld is considered. Second, the influence of climate change on the Ilperveld is considered. Local impacts on the level of habitat types are very difficult to describe, because within nature areas many variation in abiotic conditions exists (van Rooij *et al.*, 2009). However, conclusions or projections were estimated for the habitat level, and eventually for the species level (next chapter), by the support of projected changes on larger scales (Western Peat District and Ilperveld).

The nature in the Netherlands is classified in nature (target) types by the Ministry of Agriculture, Nature and Food Quality. There are two typologies, one from 1995 and one from 2001. The typology of 2001 is more specific. In some reports that are used for this study, this classification of nature is used. Therefore, an overview of the aquatic nature types that occur in the Ilperveld is presented in table 14.

Table 14. aquatic nature types of Ilperveld according to the two typologies.

1995		**2001**	
3.1	Fresh stagnant water	3.13	Brackish stagnant water
3.2	Brackish stagnant water	3.14	Buffered pool
		3.15	Buffered ditch
		3.17	Isolated turf pond
		3.18	Buffered lake
		3.19	Canal

5.2 Western Peat District

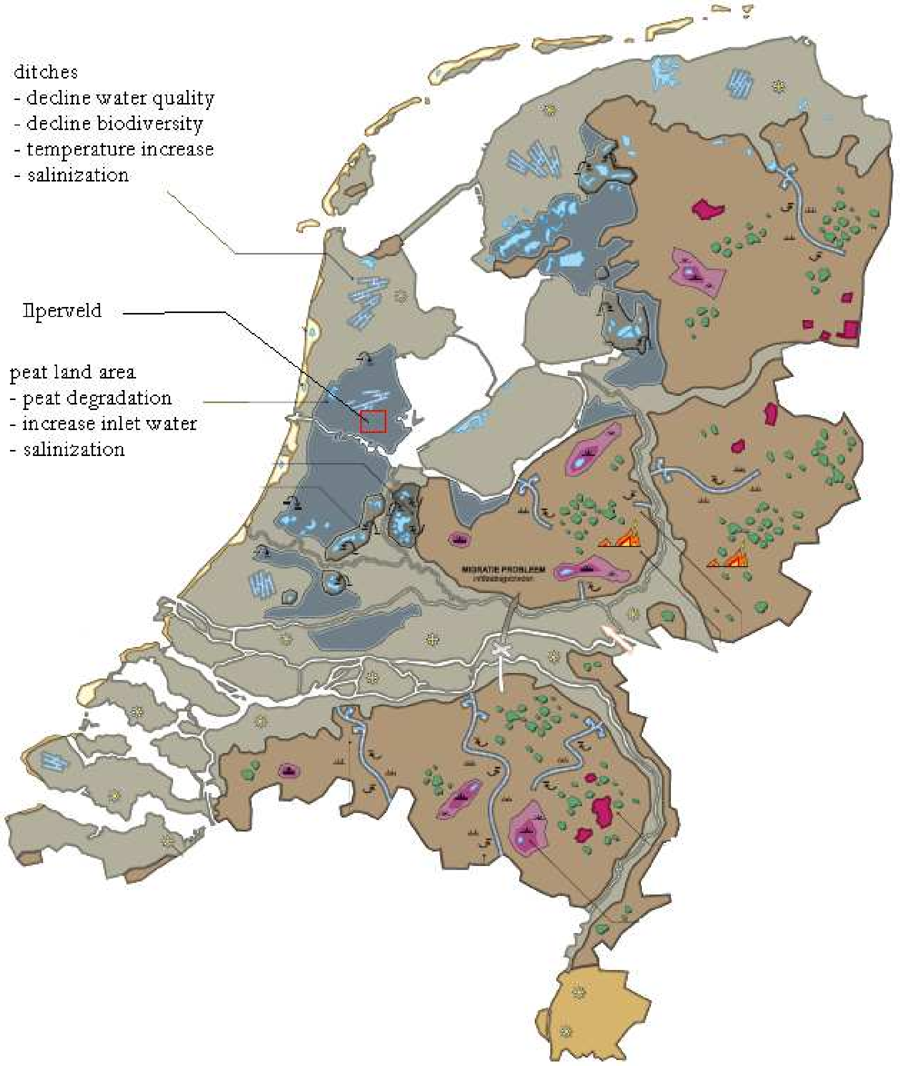


Figure 22. Eco-hydrological effect map modified from Witte et al., 2009. Shown is one map for scenarios W en W+. The map is established by simulations with PAWN (hydrological model), literature, knowledge of process, and the klimaatatlas project.

Climate change will affect via the increased dynamics in the water system, the nature of The Netherlands (Witte *et al*., 2009). Witte *et al.* (2009) explored the consequences for the nature of The Netherlands under scenario W (most wet scenario) and W+ (most dry scenario). They made an eco-hydrological effect map (figure 22) for the entire country. The Ilperveld lies in the Western Peat District, indicated in figure 22. In this area, especially negative effects of climate change are expected. Dry summers and elevated temperatures cause peat degradation. The dry summers cause a drop in ground water level, whereby the peat is degraded by oxidation. The temperature increase is responsible for a faster degradation rate (Van Bakel *et al.,* 2008). As a result of the low water level in summer, more water is needed to maintain the water level. As a third negative consequence for the peat area salinization is mentioned (Witte *et al*., 2009).
The peat land area contains not only peat soils, but also many ditches. In both wet conditions and dry conditions, the water quality of ditches declines. But, as said in the previous chapter, salinization can also have a positive effect on the surface water of

(former) brackish areas. Extreme wet conditions result in more nutrient run-off from land into the surface water (Witte *et al.*, 2009). Dry conditions result in elevated contaminant and nutrient concentrations in ditches, and in shallow ditches there is a high risk of a complete dry out. Because the water temperature of shallow waters follows the air temperature (Mooij *et al*, 2005), ditches warm quickly. Elevated water temperatures can cause oxygen deficiencies, algae blooms, and a decline in biodiversity (Witte *et al.*, 2009). These negative changes apply to the Western Peat District; they do not automatically apply to the Ilperveld.

5.3 Ilperveld

5.3.1 General

Blom *et al.* (2008) made a sensitivity analysis for nature areas within the EHS for climate change. This analysis was done according to the nature types typology. The Ilperveld contains nature types that are little to moderately sensitive to climate change (figure 23). These are both terrestrial and aquatic nature types. When individual effects are considered, it seems that nature types in The Ilperveld are especially sensitive to droughts, heat stress and salinization. The area is considered to be insensitive for flooding with surface water. However, sensitivity to flooding with rain water is not considered in this study. From the sensitivity analysis of Blom *et al.* (2008) it appeared that fresh stagnant water (3.1) can be considered more sensitive to droughts and heat stress than brackish stagnant water (3.2). An explanation is that brackish species are more tolerant to fluctuations in chloride concentrations and water level than freshwater species. In addition, more bottlenecks for fresh stagnant water due to climate change are expected than for brackish stagnant water (Blom *et al.*, 2008).

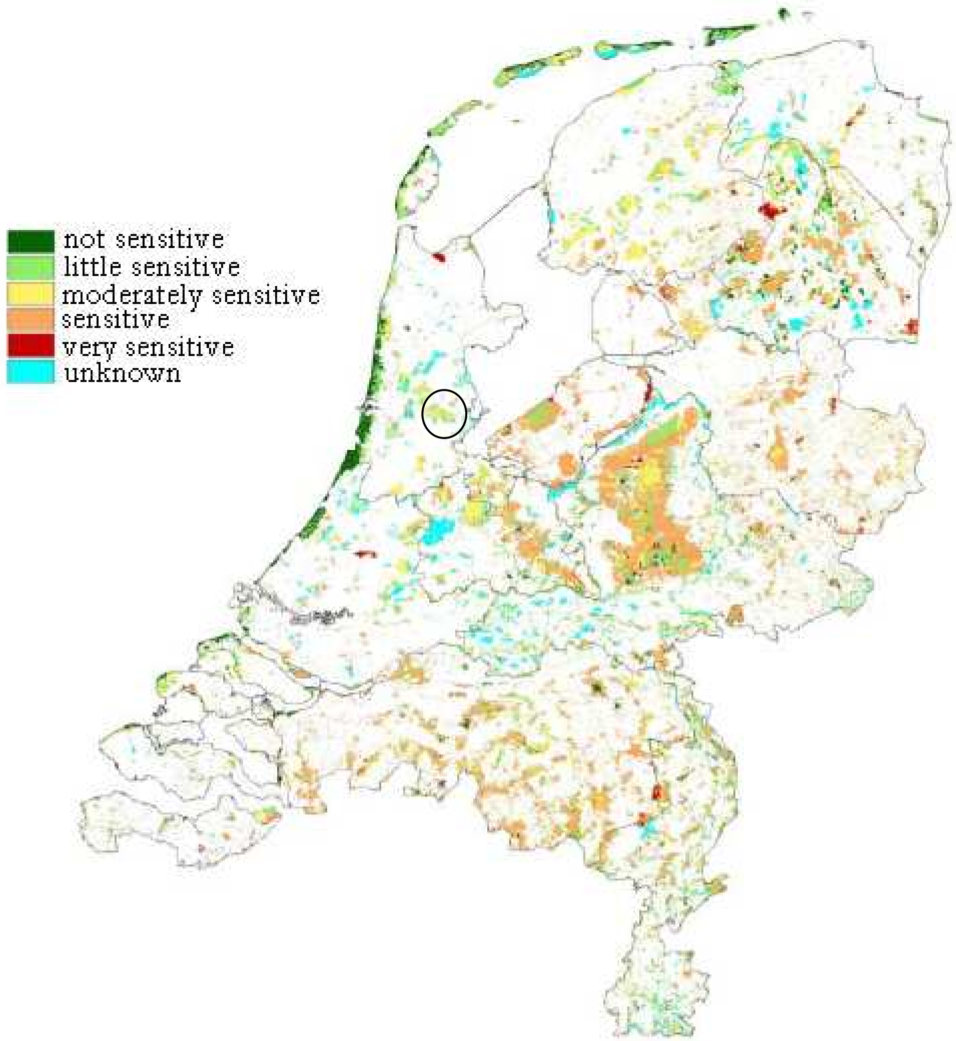


Figure 23. Sensitivity of nature areas within the EHS to climate change. The Ilperveld lies within the circle. Modified from Blom et al., 2008.

5.3.2 Floods

Dynamics in the water system increase in the future due to wetter winters, drier summers, and intense rainfall. This also applies for the Ilperveld. In the maps of the previous chapter, a local precipitation maximum is shown on Amsterdam. This is probably caused by the urban heat island effect (Van Bakel *et al.,* 2008). However, problems due to floods do not automatically develop.

5.3.3 Droughts

The largest bottleneck of peat land areas in The Netherlands is nowadays subsidence of the peat soils by peat oxidation (Woestenburg, 2009). This peat oxidation is caused by the drainage of the peat soil (by agriculture), and low (ground) water levels. When the peat soil is drained, oxygen can penetrate into the peat, and biological degradation of the peat (oxidation) is possible. By peat oxidation, the peat that lies above the ground water level is degraded and emitted as carbon dioxide to the atmosphere. As a result, the soil surface level subsides. The oxidation process occurs mainly in summer, when the ground water

levels are low and the temperatures are high. Low water levels in ditches have also a negative effect on the subsidence of the peat soils. Measurements in Friesland showed a peat subsidence rate of more than 2 cm per year at a water level of 120 cm below ground level (Woestenburg, 2009). But also at a drainage depth of 60 cm, which is more regular in the Western Peat District, subsidence rates still can be 1-1.5 cm per year (Bas van de Riet, personal communication). In addition, the profile of the peat soils is also important. In peat soils that are covered with a thick clay layer (20-40 cm), the subsidence is less compared with pure peat soils. Pure peat soils that are deeply drained are the most vulnerable to subsidence (Woestenburg, 2009).
Climate change forms a threat to the peat areas, because climate change will aggravate the current problem of peat subsidence. All four climate scenarios for the Netherlands predicted an increase in peat oxidation, and thus in subsidence. As a result of the projected higher temperatures and drier summers, the subsidence increases in 2050 with 50 % under the W+ scenario (Woestenburg, 2009). In peat areas without coverage of a clay layer, it is predicted that in 2100 the soil surface level will subside (by unchanged water management) 94 cm under the current climatic conditions, under the G scenario 107 cm and under the W+ scenario 144 cm (Woestenburg, 2009). Elevations of the water levels till 40 cm below ground levels are not enough to prevent the peat subsidence.
The subsidence of the peat soils is also a current problem for the Ilperveld, and the peat degradation is expected to increase due to climate change (Brouwer *et al.,* 2006; Leon Lamers, personal communication). The peat subsidence in the Natura 2000 area is currently 2-3 mm per year (Kiwa Water Research & EGG, 2007). The subsidence is caused by drainage and areas where the water level is kept artificially low (figure 24). According to Huurnink *et al.* (2009) the Natura 2000 area consists mainly of peat soils with a covering layer of clay. However the clay layer in the Ilperveld lies approximately 18 meter below surface, which means that the peat above this layer is not covered by clay and is vulnerable to oxidation.

Figure 24. Area in the Ilperveld where the water level is kept artificially low.

Another consequence of a dry period in summer for the Ilperveld, is that more water inlet from Monnickendam (Markermeer) is necessary to maintain the water level. Witte *et al.* (2009) calculated that under the W scenario an increase of 1 - 2 % compared with the current inlet in July is expected. Under the W+ scenario, the increase will be higher. Both brackish stagnant (nature type 3.2) and fresh stagnant water (nature type 3.1) in the Ilperveld are considered to be sensitive for this future increase in inlet water (Witte *et al.*, 2009). Furthermore, more general consequences of droughts are an increased risk of desiccation, increased nutrient and contaminant concentrations, increased algae growth and oxygen deficiencies. The isolated water compartments and turf ponds in the Ilperveld are vulnerable for desiccation in summer. In the summer of 2003, some turf ponds partly dried out, and the in the period 2003-2005 the composition of the sediment and water layer was monitored (Brouwer *et al.,* 2006). Due to oxidation processes, sulphate and iron concentrations increased in the sediments, and the phosphate concentration decreased because it was bound to the released iron (Brouwer *et al.,* 2006). In addition, considerable filamentous algae growth and oxygen defiecincies are already observed in the Ilperveld (see chapter 1; Lamers *et al*, 2006).

5.3.4 Eutrophication

The risk of an increase in inlet water in summer is mentioned by many authors (RIZA, 2005; van Bakel *et al.,* 2008; Witte *et al.,* 2009). This increase in especially sulphate-rich inlet water can enhance the internal eutrophication. According to Lamers *et al.* (2006) and Brouwer *et al.* (2006) this applies particularly to freshwater systems and not to brackish water systems, like the Ilperveld, because brackish systems originally contain much sulphate. This assumption is supported by a laboratory experiment performed by the research institute B-Ware (Brouwer *et al.*, 2006) and Lamers *et al.* (2006) with sediments from turf ponds of the Ilperveld. The influence of salinization on the sediments (biochemical processes) and water layer was tested in this experiment. Sulphate was also added in some treatments. In the experiment, addition of sulphate to the surface water did not lead to an increase in phosphate mobilization. From this experiment, it seems that there are no indications for increased phosphate mobilization due to sulphate enrichment in the Ilperveld. This is the result of the unfavorable iron – sulphur ratio in the sediments, which resulted in high phosphate availability already at the start of the experiment. Thus, phosphate mobilization due to sulphate enrichment (internal eutrophication) occurs originally in the Ilperveld because much sulphate is present. There are indications that this process is enhanced on the short term not by sulphate addition, but by desalinization (van Kranenburg *et al.,* 2000; Lamers *et al.,* 2006; Leon Lamers, personal communication).

Nutrients can also enter the surface water via run-off from (agricultural) land. The nutrient run-off from land to the surface water is expected to increase due to more heavy rainfall. The run-off of nutrients from peat soils to the surface water occurs via different routes. These routes include surface run-off (soil surface run-off plus the top 10 cm of the soil), shallow run-off (10-25 cm), and deep run-off (run-off below 25 cm) (STOWA, 2007). In the case of peat soils, most run-off occurs via shallow run-off (10-25 cm) (STOWA, 2007). This transport occurs relatively fast and is most apparent in winter at high ground water levels in combination with rainfall (STOWA, 2007). In addition, nutrients leach out from the peat to ditches via the transport of excess rainwater. The lower the water level of the ditch is, the more nutrients leach out to the surface water. Because at a low water level, the excess of rainwater flows deeply through the peat soil to the ditch (Woestenburg, 2009). Since climate change includes lower water levels and more (intense) precipitation, the nutrient run-off from peat soils is expected to increase. For the Ilperveld, this includes that especially phosphate, nitrate and sulphate will be transported to the surface water due to intense rainfall (Leon Lamers, personal communication). However, additional run-off of phosphate due to intense rainfall to surface water where the phosphate concentration already exceeds the standards (in both open and isolated waters, see table 3) makes little difference since the concentration is

already way too high (Leon Lamers, personal communication). Especially at places where the water quality is relatively good, the nutrient run-off will negatively affect the water quality (Leon Lamers, personal communication).
In October 2004, a high sulphate level was measured at two locations in the open water of the Ilperveld. It is possible that this elevation was the result of a dry period in summer followed by a day with extreme rainfall. The dry period caused sulphate mobilization (oxidation) on land, which was transported to the surface water after the rainfall, before sulphate reduction occurred again (Brouwer *et al.,* 2006).

5.3.5 Salinization

In general, the chloride concentration in surface waters is expected to increase in dry years (RIZA, 2005). In the current climate, the repeat time of a saline year is 11 years. With a temperature increase of 1 °C in 2050, this repeat time is reduced to 7 years (RIZA, 2005). Especially the chance on an extreme saline year (like 1976) increases in such years. Concentrations higher than the Maximal Allowable Risk level (MTR) for surface water (200 mg/l chloride; www.rivm/rvs/normen.nl) can be exceeded. However, the current chloride concentration of the surface water of the Ilperveld lies between 500 and 1000 mg/l, already exceeding the MTR. An elevated chloride concentration in dry summers is already observed in the open water of the Ilperveld. In the summer of 2003, the chloride concentration in the Molensloot was higher than other summers (figure 25). Many polders and drained lakes in Noord-Holland are influenced by brackish seepage water. It is expected that climate change enhances this 'natural' (or internal) salinization by brackish seepage water (van Bakel *et al.,* 2008). In the Ilperveld, no natural salinization by brackish seepage water occurs. However, the surrounding drained lakes face brackish seepage water (Niels Hogeweg, personal communication). It is possible however, that external salinization of the inlet water may occur. Salinization of the inlet water from the Markermeer may increase due to the breaking out of saline water from adjacent polders, and droughts (Loeve *et al.,* 2006). Because this water flows through the Ilperveld, a certain amount of external salinization can be expected. Very sensitive aquatic nature types to salinization are: 3.14, 3.15, 3.17 and 3.18 (table 14). The types 3.13 and 3.19 are classified less sensitive (Paulissen *et al.,* 2007). For the isolated compartments, more fluctuations in chloride concentrations are expected. In winter, chloride concentrations decrease due to increased input of freshwater in the form of precipitation. In summer, increased evaporation causes a higher chloride concentration. This trend is already visible. In appendix 1 it is shown that the average chloride concentration fluctuated in all compartments between 1999 and 2006, and that the highest chloride peaks occurred in July 1999 and August 2002.
In conclusion, it is expected that the Ilperveld is not influenced by an increase in natural salinization in the future. However, external salinization of the surface water that flows through the Ilperveld may occur. Because the current chloride concentration in the Ilperveld is already higher than the MTR of 200 mg/l, the expected higher chloride load of the surface water has little or no influence on the Ilperveld. However, the isolated compartments and turf ponds will face more fluctuations in chloride levels.

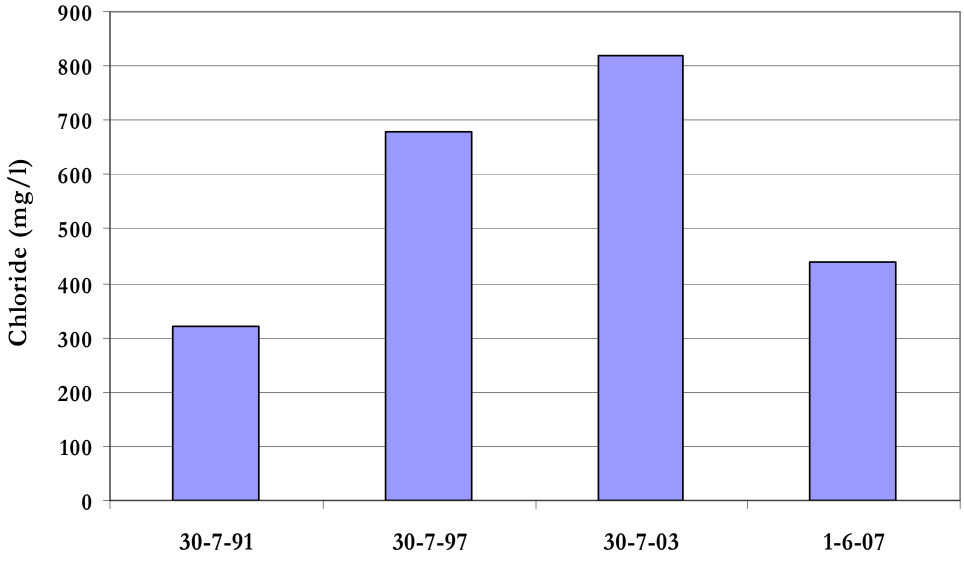


Figure 25. Chloride concentrations in subsequent summers at the Molensloot (open water). Measured in the period 1991 - 2007, by Hoogheemraadschap Hollands Noorderkwartier.

5.3.6 Recreation

The Ilperveld is currently a poplar recreation area; around 15000 people per year visit the Ilperveld (Beheerplan Ilperveld 2007- 2017). This number will increase as a result of the projected warmer summers and increased accessibility of the area (more activities like canoe trips, excursions, and group activities planned). The management of the Ilperveld (Landschap Noord-Holland) focuses on nature – oriented recreation (Beheerplan Ilperveld 2007- 2017). Examples of this kind of recreation are canoe trips, and sailing with electric boats and rowing boats. Sport fishery is restricted to the open water to protect the development of habitat type 3140 in isolated water. In addition, it is tried to spare the isolated waters from motorized boats.
The thick mud layers that are present in the Ilperveld cause an increased turbidity of the water column, when it is moved by wind, benthivorous fish or boats. Because climate change is likely to increase recreation, an increased turbidity in the water column is expected. Especially motorized boats in the open water cause movement of mud, thereby increasing turbidity of the water. If the speed of the boats is low (6 km/h; figure 26), nothing is wrong. But personal observations indicate a high speed of some boats, especially in the open water. When this continues, movement of mud continues and the turbidity increases. So, negative effects are expected due to an increase in motorized boats. In particular, the compartments contain a thick mud layer (see chapter 1), but motorized boats seem no threat here. However, the mud production in the sediments will increase due to elevated temperatures (Leon Lamers, personal communication). The current growth rate of the mud layer in the Ilperveld is estimated at 6 cm per year (van den Boogaard *et al.,* 2010). Especially in the shallow water of the isolated compartments it is expected that elevated temperatures cause an increase in the mud layer. This mud layer can cause increased turbidity when it is moved by benthivorous fish or wind.

The projected increase in problems with cyanobacterial dominance (Pearl and Huisman, 2008; Mooij *et al.,* 2005; van Bakel *et al.,* 2008) do not apply (or to a lesser extent) to the

Ilperveld. Since the Ilperveld is no swimming area (like the nearby Twiske), and the surface water contains few cyanobacteria, the well-known negative effects (reduced swimming, health problems, smell) due to cyanobacterial dominance are not expected. However this can not be excluded on the long term and maybe cyanobacteria become more dominant in the Ilperveld due to the temperature increase and increased eutrophication.

Figure 26. Sign in the Ilperveld, which says that the maximum speed for boats is 6km/h.

6. Influence of climate change on species

- **An increase in water temperature seems unfavorable only for the Bullhead**
- **A decrease in water transparency is disadvantageous for all species**
- **The three-spined stickbleback and alien crayfish species can alter biological interactions**

Climate change can directly influence species, by means of changing abiotic conditions. For instance, a temperature elevation can accelerate physiological processes such as photosynthesis and decomposition. Or as mentioned in chapter 4, it causes a shift in geographical species distribution in a northern direction. Climate change can also influence species indirectly. New species that invaded in an ecosystem can compete with native species for food or shelter. Relations between predators and their prey can also alter due to the introduction of new species, or fluctuations in predator and prey numbers can occur. In this chapter, it is tried to predict the influence of climate change on the Natura 2000 species of the Ilperveld. First the influence of changing abiotic conditions is described for macrophytes and fishes, followed by the influence of changing biotic conditions. No information was found of the influence of climate change on pH in the Ilperveld.

6.1 Changes in abiotic conditions

6.1.1 Increase in water temperature

Water temperature is one of the factors that determine the overall health of aquatic ecosystems. Most aquatic organisms have a specific range of temperatures that they can tolerate, which determines their spatial distribution across a region (European Environment Agency, 2010). Species respond differently to warming. Some benefit of warming and expand their range northwards; the so called warmth preferring species. Other species with a northernly distribution withdraw from The Netherlands and move northwards; the so called cold preferring species. For the so called neutral species, the future climate remains suitable.
Van der Veen *et al.* (2007) developed the Climate Response Database. This database gives information about the response of taxa to the predicted temperature increase. The taxa are classified in the above response groups: neutral, warmth preferring and cold preferring. For certain macrophytes that are present in the Ilperveld, this database was used (see table 15). According to Blom *et al.* (2008) the percentage of cold preferring species that occur within the Ilperveld is 11-20 %. In addition, van Bakel *et al.* (2008) noted that the Ilperveld is an intermediate location concerning cold preferring and warmth preferring species. This means that catastrophic species shifts will probably not occur.

6.1.1.1 Macrophytes

Temperature influences photosynthesis, reproduction, morphology and development of macrophytes (Verdonschot *et al.,* 2007). In many cases, a temperature increase has a positive effect on photosynthesis, unless the temperature optimum of the particular species is exceeded (Verdonschot *et al.,* 2007). Earlier flowering (thus extension of the growing season), higher growth rate, a larger amount of leaves and larger-sized leaves are effects of elevated temperatures on macrophytes (Kwadijk *et al.,* 2008). However, these

effects are species-specific. For certain pondweeds (*Potamogeton* and *Chara)* a temperature elevation results in a decline in plant cover. *Potamogeton* species even disappear when the water temperature is higher than 25 ºC (Kerkum *et al.,* 2004). Besides physiological effects, higher temperatures can also affect the composition of macrophyte communities. Macrophytes that have a temperature dependent dormant period (e.g. seeds or rhizomes) could emerge earlier due to warmer springs. This can result in a competitive advantage in comparison with macrophytes that have a day length dependent dormant period (Verdonschot *et al.*, 2007). Rhizomes of *Potamogeton pectinatus* for example react on temperature; they emerge when the water temperature is 8 ºC or higher (Verdonschot *et al.*, 2007). On the contrary, *Najas marina* has no dormant seeds or rhizomes during winter. This means that the germination takes place at high temperatures, and the species is fully developed late in the season (SynBioSys, 2008).
The response of some macrophytes that are recorded in the Ilperveld to warming (table 15) shows that for these macrophytes, the future climate remains suitable (neutral species) or gets even better (warmth preferring species). For *Chara spp.* no response was found in the database; however the abiotic conditions from chapter 3 and appendix 2 revealed that *C. major* and *C. connivens* can tolerate warm conditions.

Table 15. Results of Climate Response Database (V1.1), for certain macrophytes that occur in the Ilperveld

Cold preferring	Neutral	Warmth preferring
	Zannichellia palustris	*Ceratophyllum demersum*
	Potamogeton pectinatus	*Azolla filiculoides*
	Potamogeton pusillu	
	Najas marina	
	Ruppia maritima	
	Lemna minor	
	Lemna trisulca	
	Lemna gibba	

When plant communities are considered in stead of single species (figure 27), it appears that Charetum hispidae is observed less frequently at high temperatures than the other three communites. In addition, this community occurs at relatively lower temperatures than the other three communities, and could be negatively affected by elevated temperatures. Positive is that the temperature range of Charetum hispidae is broader than that of the other communites (figure 27).
An increase in the atmospheric carbon dioxide concentration has no influence on the water of the Ilperveld, because the water is already saturated with CO_2, so the system is not carbon limited (Leon Lamers, personal communication). In chapter 4 it was noted that in these kind of systems an increase of the primary productivity due to elevated CO_2 in the atmosphere is not expected.

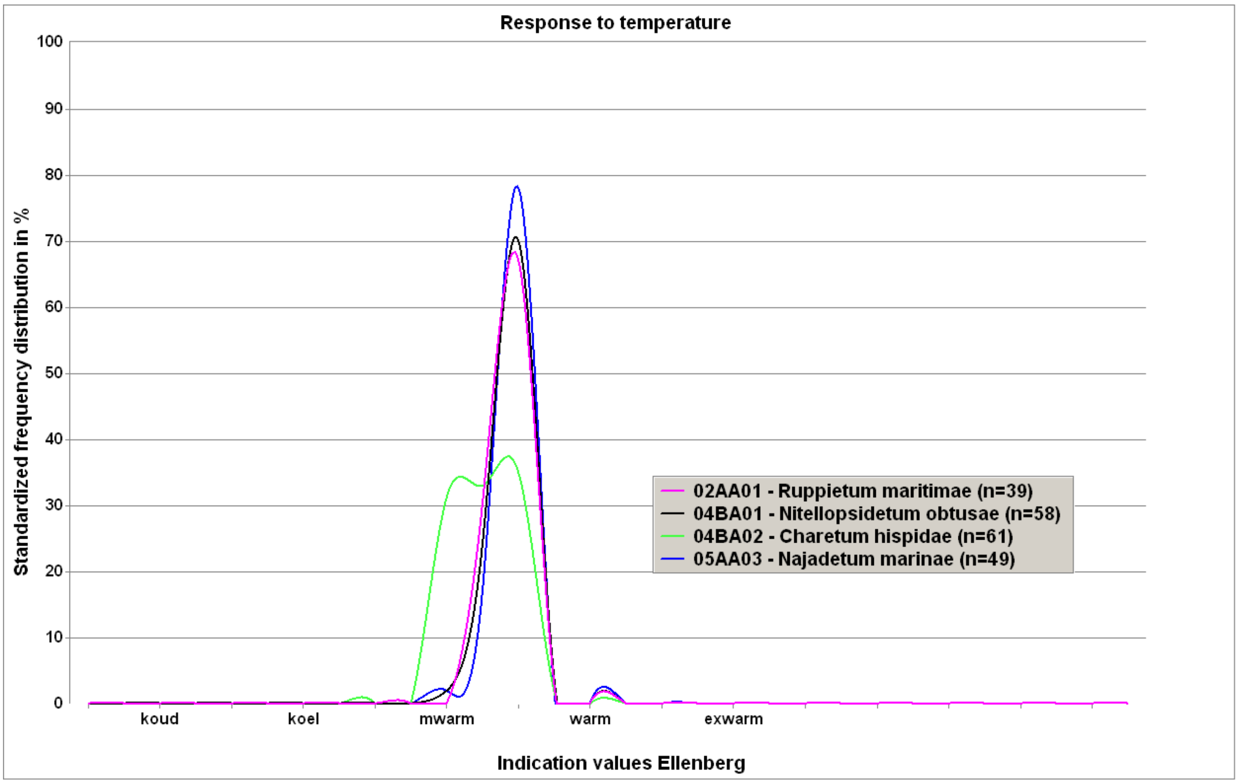


Figure 27. Comparison of plant communities for response to temperature. The abiotic conditions of the plant communities are based on the indicator values of Ellenberg. For every community, response curves are showed for the (abiotic) factor temperature. The presented response curve is determined by a standardized frequency distribution of average Ellenberg indication numbers of vegetation samples that belong to the community. Source: SynBioSys version 1.20

6.1.1.2 Fish

Fish are cold-blooded organisms, which means that their body temperature equals the temperature of the surrounding environment. Therefore, growth, reproduction and behavior depend on the water temperature (Van der Grinten *et al.*, 2007). Especially an elevated winter temperature can be beneficial for many fish, because this results in increased growth and activity (Verdonschot *et al.,* 2007). In general, elevated water temperatures are unfavorable for fish with a relative low temperature optimum, and favorable for fish with a relative high temperature optimum (Verdonschot *et al.,* 2007). An additional risk of elevated water temperatures are more infections (Verdonschot *et al.,* 2007). The water temperature of many waters in Noord-Holland increased during the past 30 years (van Dam, 2009). Due to climate change, a further warming of surface waters is to be expected. High temperatures of the surface waters of the Ilperveld occurred in the summers of 1984, 1997, 1999, 2001 and 2006. In June 1984 the water temperature in the open water of the Ilperveld was 25.9 ºC. In the summers of 1997, 2001 and 2006, temperatures of 24 ºC were measured (Limnodata). Unfortunately, there were no temperature data available of the hot summer of 2003. In addition, less data of the water temperature in the compartments was available (only measured in 1998 and 1999). The highest temperature was 21 ºC measured in July 1999 in compartments 9 and 13. Especially in the compartments, water temperatures can rise very fast due to the shallow, standing water. The previous mentioned water temperatures measured in the Ilperveld do not seem yet a threat to the European Bitterling and Spined Loach, because they have higher maximum temperatures. The Spined Loach has a wide temperature range (van der Grinten *et al.,* 2007). However, the Bullhead has a preference for a low

water temperature. There is however conflicting information found in literature about the maximum temperature (20 °C or 30 °C; see table 10). Still, the Bullhead seems most vulnerable to elevated water temperatures.
Due to the elevated temperatures, temperature dependent processes like spawning of fish will start earlier in the season (Kwadijk *et al.,* 2008). The spawning temperatures of the European Bitterling and Spined Loach are relatively high compared with the spawning temperature of the Bullhead. This means that the spawning of the Bullhead is expected to occur much earlier in the season. This can have negative effects, such as a mismatch with prey species and decreased larval survival. Spined Loach can be considered as a species adapted to reproduction in warm water (van der Grinten *et al.,* 2007).

6.1.2 Slight increase in chloride concentration

6.1.2.1 Macrophytes

When the surface water of the Ilperveld is influenced by external salinization, this is most favorable for *Ruppia maritima* because this species is observed in hyperhaline waters (chapter 3 and appendix 2). From the chapter 3 and appendix 2, it seems that *Chara major* and *Najas marina* have the lowest salt tolerance. When the communities are considered (figure 28), it seems that the Ruppietum maritimae is favored by high chloride concentrations. In addition, this community can tolerate fluctuations in chloride level (SynBioSys, 2008). The other three communities are less tolerant. According to the data in table 9 Charetum hispidae prefers the lowest chloride concentration (< 150 mg/l), and is therefore vulnerable to external salinization.

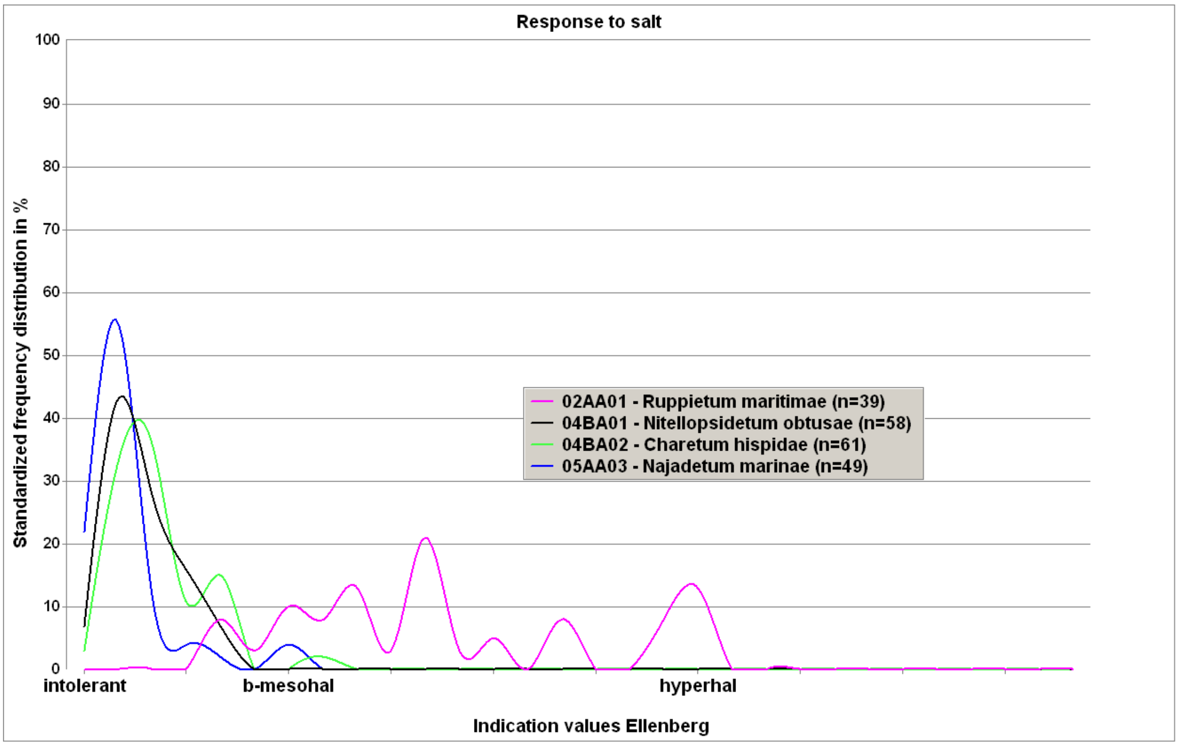


Figure 28. Comparison of plant communities for response to salt. The abiotic conditions of the plant communities are based on the indicator values of Ellenberg. For every community, response curves are showed for the (abiotic) factor salt. The presented response curve is determined by a standardized frequency distribution of average Ellenberg indication numbers of vegetation samples that belong to the community. Source: SynBioSys version 1.20

6.1.2.2 Fish

According to Paulissen *et al.* (2007), European Bitterling and Spined Loach are sensitive to salinization. The maximum chloride concentration at which these fish can survive is 1000 mg/l (table 10). Characteristic of the fish stock of slightly brackish waters (WFD type M30; Evers *et al.,* 2007) is that it consists mainly of freshwater fish. Till a chloride concentration of 1000 to 2000 mg/l all fish can be observed (Evers *et al.,* 2007). Higher chloride concentrations lead to a decline due to chloride toxicity or changes in the food web. The maximum concentration of 1000 mg/l chloride was already exceeded in the open water of Ilperveld, in September 1991 and 2003 and June 1997. In September 2003 the chloride concentration was even 1270 mg/l. Still, this is not so deplorable for European Bitterling and Spined Loach, because they are observed mainly in the isolated compartments. In these compartments, the limit of 1000 mg/l chloride has not yet been exceeded. Chloride concentrations in the compartments are lower than in the open water (table 2). Based on these data, it seems that the isolated compartments are good place for European Bitterling and Spined Loach. However, as said before, more fluctuations in chloride level will occur. Blom *et al.* (2008) note that brackish organisms are better adapted to these chloride fluctuations, and aditionally fluctuations in water level. In the future, the open water may become unsuitable for these two fish due to a too high chloride concentration. On the contrary, the Bullhead has a higher chloride maximum (3000 mg/l), is observed in the open water and can be considered less sensitive to salinization.

6.1.3 Eutrophication

6.1.3.1 Macrophytes

Especially the *Chara* species are negatively affected by an increase in phosphate concentration. Habitat type 3140 requires 0.04 – 0.1 mg/l phosphate (Huurnink *et al.,* 2009). The current phosphate concentration already exceeds this desired concentration. In general, brackish macrophytes can occur at a slightly higher phosphate concentration than freshwater macrophytes (Leon Lamers, personal communication). Indeed, from chapter 3 and appendix 2, it appeared that the brackish macrophytes *N. marina* and *R. maritima* are observed more at nutrient-rich conditions than the *Chara* species. Figure 29 shows that at increased eutrophication, the community Nitellopsidetum obtusae (fresh) develops into the Najadetum marinae (brackish). This community develops subsequently at increased eutrophication in vegetation types chacterized by *Potamogeton pectinatus*, *Zannichellia palustris,* and *Ceratophyllum demersum.* These species are already present in the Ilperveld. A similar scheme in SynBioSys showed that the community Charetum hispidae develops when eutrophication takes place in vegetation types of *Ceratophyllum demersum* and *Potamogeton pusillus.* Vegetation types chacterized by *Potamogeton pectinatus*, *Zannichellia palustris,* and *Ceratophyllum demersum* and *Potamogeton pusillus* are relatively species poor. Vegetation types with *Ceratophyllum demersum* and *Potamogeton pusillus* are common in peat areas and are observed often together with *Lemna* species in waters with high nutrient loads (SynBioSys, 2008). Vegetation types with *Potamogeton pectinatus* and *Zannichellia palustris* are observed in brackish waters with high phosphate levels. High chloride levels are tolerated (till 15000 mg/l), and the sediments are rich in sulphide (SynBioSys, 2008).

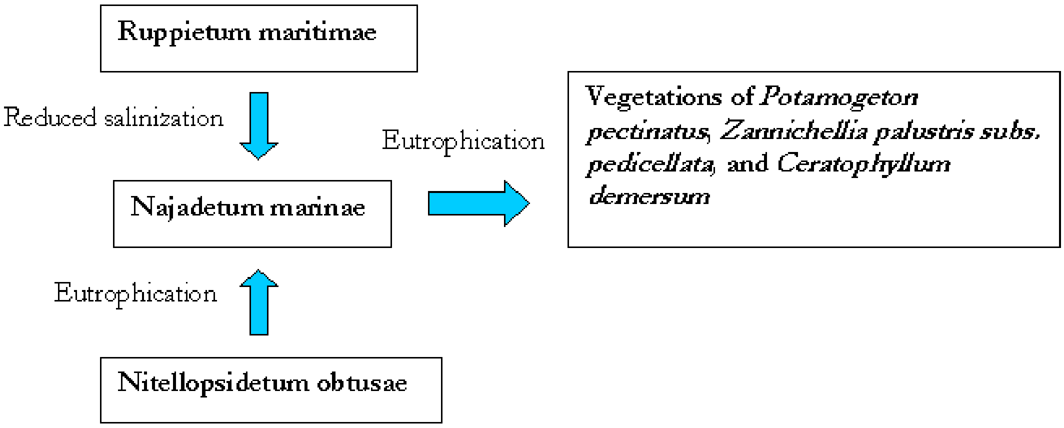


Figure 29. Succession scheme of three plant communities. Modified from SynBioSys version 1.20.

6.1.3.2 Fish

Eutrophication is a less important factor for fish than temperature or oxygen concentrations. Eutrophication can have indirect effects on fish by induced algae blooms, increased turbidity and decreased macrophyte coverage. A comparison of table 2 and 10 shows that the sulphate concentration in the open water is too high for the Spined Loach. Again, the isolated compartments show a lower concentration. In addition, the phosphate concentration in both isolated and open water is at the high side for the Spined Loach. Huurnik *et al.* (2009) noted that eutrophication can affect populations of Spined Loach, by the creation of an oxygen poor environment, which results in less food. According to Peters (2009), the Bullhead can occur in nutrient rich waters, and is the appearance of this species not limited by the current water quality. However, upper limits concerning nutrient concentrations are absent. This applies also to the European Bitterling, which is not considered to be sensitive to eutrophication, but data is lacking (de Lange & van Emmerik, 2006). It is thus expected that eutrophication indirectly affects the fishes, by for instance a decreased macrophyte coverage, which results in a loss of the habitat for the European Bitterling.

6.1.4 Decrease in water transparency

6.1.4.1 Macrophytes

In the previous chapter it was mentioned that the water transparency declines due to climate change. In general, all four macrophytes require a high water transparency and from chapter 3 it became clear that especially the *Chara* species require a high water transparency. In the open water this high water transparency is not reached. A water transparency of just 0.1 meter was measured in the spring of 2005 in the Batesloot. The required high water transparency was only reached in December 1991 and 1992 in the Kerkebreek. In the isolated compartments, the transparency is slightly higher. From table 8 it appears that *Chara connivens* has the highest light preference. It is therefore expected that the *Chara* species are most negatively affected by an increased turbidity.
When the communities are considered, the Nitellopsidetum obtusae and Charetum hispidae are considered to be more sensitive to turbid water than Najadetum marinae (Synbiosys, 2008). From figure 30 it appears that especially the Charetum hispidae is a light preferring plant community.

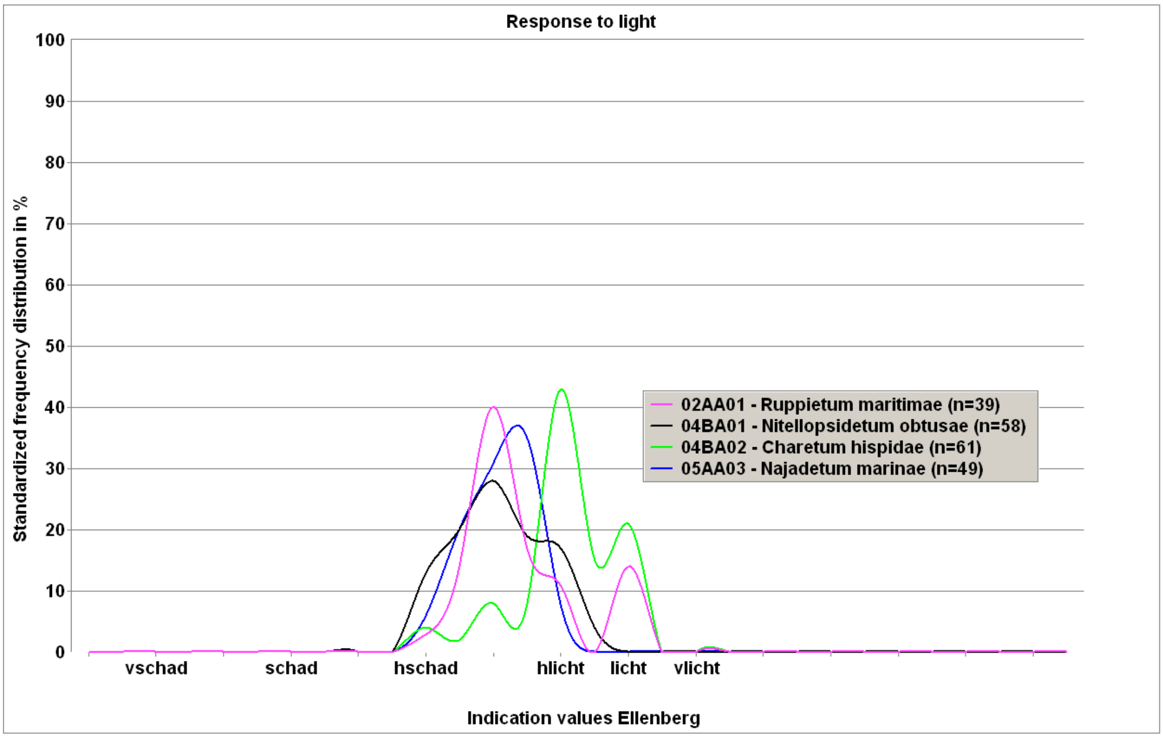


Figure 30. Comparison of plant communities for response to light. The abiotic conditions of the communites are based on the indicator values of Ellenberg. For every community, response curves are showed for the (abiotic) factor light. The presented response curve is determined by a standardized frequency distribution of average Ellenberg indication numbers of vegetation samples that belong to the community. Source: SynBioSys version 1.20

6.1.4.2 Fish

An increase in muddy conditions is disadvantageous for the Bullhead and freshwater mussels, because these species prefer a hard substrate. Increased water turbidity is also disadvantageous for the European Bitterling and Spined Loach, since these fish prefer clear water with macrophytes. On the contrary, eurytope and benthivorous fish like Bream can benefit from an increase in muddy conditions.

6.1.5 Low water level

6.1.5.1 Macrophytes

In 2009, the water depth of ditches in the compartments was measured (van den Boogaard *et al.,* 2010). The average depth in the middle of the ditches varied from 0.4 to 0.7 meter. In several compartments, the water was shallow (0.2 - 0.3 meter). The water levels can drop especially in summer in these isolated compartments, because of increased evaporation and decreased precipitation.

Low water levels in summer could be disadvantageous for the communities Nitellopsidetum obtusae, Charetum hispidae and Najadetum marinae because these communities are observed at a minimal depth of 0.5 meter. On the contrary, Ruppietum maritimae has a preference for lower water depths (max. 0.7 meter). Figure 31 shows that the water depth in a turf pond in compartment 9 is currently low due to the thick mud layer. This water depth is probably too low for the communities Nitellopsidetum obtusae, Charetum hispidae and Najadetum marinae. Yet, the water transparency is high.

Figure 31. Clear water and a thick mud layer in compartment 9. Observed in April 2010.

6.1.5.2 Fish

The Bullhead is probably not influenced by the low water levels in the compartments, because this fish is not observed here and the species can occur at a wide variety of depths. Spined Loach can spawn in shallow water (till 4 cm) and prefers shallow locations with macrophyte presence (Huurnink *et al.,* 2009; Sportvisserij Nederland, 2006). So no negative effects of a low water level for Bullhead and Spined Loach are expected. In contrast, the European Bitterling needs a water depth larger than 0.5 meter. In the compartments 7, 9 10, 11 and 12 there are some deep locations that are suitable for the European Bitterling (van den Boogaard *et al.,* 2010). However, these locations are limited. A further drop in water level during summer is a threat for the European Bitterling.

6.1.6 Decline in oxygen concentration

6.1.6.1 Fish

Fish are dependent on oxygen availability, which is expected to decrease due to warming. Most fish can maintain adequate levels of oxygen uptake in waters with dissolved oxygen concentrations above 5 mg/l. When concentrations drop below 5 mg/l, many species employ physiological and behavioral adaptations to maintain adequate rates of oxygen uptake, but as dissolved oxygen concentrations drop below 2-3 mg/l most species will die (Ficke *et al*., 2007). Oxygen concentrations below 5 mg/l occurred sporadically at some locations in the Ilperveld (Limnodata).
It is expected that the oxygen concentration declines anyhow due to warming of the surface water, due to a higher oxygen consumption and decreased solubility in warm water. In addition, increased filamentous algae growth can occur in the isolated compartments, which can lead to an oxygen deficiency in the water column. In general, a decline in oxygen concentration is disadvantageous for fish. In particular, the Bullhead requires relatively much oxygen (table 10), and therefore climate change forms a threat for this species. The Spined Loach has a low minimum oxygen concentration (table 10), because it has besides the gills an extra breathing possibility, namely via the intestines (Huurnink *et al.,* 2009). This fish species can thus be favored by oxygen deficiencies. For European Bitterling, no data were found.

6.2 Changes in biotic conditions

6.2.1 Macrophytes

Ceratophyllum demersum and *Azolla filiculoides* are warmth preferring species (table 15). These macrophytes are also already observed in the Ilperveld (chapter 1 and 2). These species can become more dominant in the surface water of the Ilperveld due to climate change. Both species are warmth preferring species, and can withstand high nutrient concentrations (table 15 and picture 19). Especially the floating species *Azolla filiculoides* can reach high abundances at high phosphate levels, because the plant can fix nitrogen from the air, which gives the plant access to this essential nutrient (Lamers *et al.,* 2008). In addition, the species can reach high growth rates (Lamers *et al.,* 2008). When ditches become covered with an *Azolla filiculoides* layer other macrophytes are unable to establish due to decreased water transparency and light, and an oxygen deficiency can occur beneath the layer. Increased abundance of *Ceratophyllum demersum* however, is less harmful because this submerged macrophyte prefers a high water transparency like the *Chara* species and *N. marina* and *R. maritima*. The difference is that this species can occur at higher nutrient concentrations. It is possible that species that forage on macrophytes also increase due to climate change. The duck *Anas strepera* for example is nowadays common in the Ilperveld, and has a preference for shallow, nutrient rich waters. In addition to plant material, the food can also consist of snails and insects (Huurnink *et al.,* 2009). It seems that this species is opportunistic, and can be favored by climate change. This also applies for the Coot *Fulica atra.* However, no data was found of the temperature ranges. The other duck species *Anas clypeata* is favored by a good water quality and therefore it is less likely that this species increases due to climate change.

6.2.2 European Bitterling

The European Bitterling can not reproduce when freshwater mussels of the family Unionidae are absent (Smith *et al.,* 2004). So this fish depends strongly on these freshwater mussels. The presence of freshwater mussels determines the distribution of the European Bitterling in an area (de Lange & van Emmerik, 2006; Smith *et al.,* 2004). Unfortunately, mussels are frequently removed during dredging activities. This means that the European Bitterling is not able to reproduce there anymore and as a result the population declines (de Lange & van Emmerik, 2006).
Pollution, eutrophication, and an increase in mud are unfavorable for freshwater mussels, and thus indirectly for the European Bitterling (Van Straaten et al, 2006; de Lange & van Emmerik, 2006). Also mussels are consumed by muskrat (*Ondatra zibethicus)* and the brown rat (*Rattus norvegicus)* (de Lange & van Emmerik, 2006; Niels Hogeweg, personal communication). In the Ilperveld, two species of the family Unionidae are present, namely *Unio pictorum* and *Anodonta cygnea.* From previous studies, it became clear that the fish have a stronger preference for the mussel *Unio pictorum* to deposit the eggs (Smith *et al.,* 2004). As a result, a higher reproduction success can be reached when *Unio pictorum is* present (Smith *et al.,* 2004). However, in the Ilperveld *Anodonta cygnea* is the most common mussel. This is not surprising since *A. cygnea* is observed at higher phosphate, nitrogen, pH, chloride and sulphate levels (table 16). In addition, *A. cygnea* can, compared with other freshwater mussels, better withstand muddy conditions (Van Straaten *et al.,* 2006). Climate change seems no positive development for the preferred mussel *Unio pictorum.* According to Geurts *et al.,* (2008) isolation of turf ponds is a problem for the migration opportunities of the mussels, which can have consequences for the European Bitterling.

More direct biotic effects on the European Bitterling are a decrease in macrophyte coverage, increase risk of parasites and an increase in food (de Lange & van Emmerik, 2006). The European Bitterling eats mainly algae; an increase in algal biomass is possible due to climate change, especially in the isolated compartments where the Bitterling is observed. De Lange & van Emmerik (2006) noted that the European Bitterling is affected by many parasites; it is possible that some of these parasites increase due to warming. Finally, a decrease in macrophyte coverage is unfavorable for the European Bitterling (de Lange & van Emmerik, 2006). If predation on the Bitterling increases due to climate change is hard to tell, because not much is known about predators. However, it is expected that warmth preferring fish species like Carps, Pikeperch and Bream (max. temperatures between 27 and 41 °C; van der Grinten *et al.,* 2007) increase due to climate change (Verdonschot *et al.,* 2007). For the fish eating birds *Sterna hirundo* and *Botaurus stellaris* that possibly hunt on the European Bitterling it is less clear whether they increase due to climate change. Numbers of the Common Tern are declining in the Ilperveld and the increased water turbidity causes a decline of the forage area (Huurnink *et al.,* 2009). So, certainly no increase is expected based on this information. The Bittern is recorded in the Climate Response Database and can be considered as a neutral species in response to temperature.

6.2.3 Spined Loach

The only biotic change due to climate change that can affect the Spined Loach that was found in this study is a decrease in food due to a low oxygen concentration in the water. As said before, the fish itself can withstand low oxygen concentrations. However, the food that consists mainly of invertebrates can not withstand a low oxygen concentration. In this situation, food is absent for Spined Loach (Huurnink *et al.,* 2009). As already said before, for the fish eating birds the Common Tern and Bittern it is not clear whether they increase due to climate change.

6.2.4 Bullhead

Some authors mentioned the risk of increased alien crayfish abundances for the Bullhead (Tomlinson & Perrow, 2003; van Straaten et al, 2006). This risk can consist of direct predation on the Bullhead or competition for the habitat.
Alien crayfish species are already observed in the Netherlands, but not yet in the Ilperveld. Currently, the most wide-spread species is *Orconectus limosus.* This species is already observed in Amsterdam and Volendam (Limnodata). *O. limosus* is an opportunistic feeder, and has been observed feeding on macrophytes and fish eggs (van der Meulen, 2009). Another species, *Procambarus clarkii,* can be considered as a warmth preferring species, is known to be very tolerant to changing environmental conditions, and is able to survive in water with extremely low oxygen levels (van der Meulen, 2009). *Procambarus clarkii* is increasingly found in the Netherlands; the first *P. clarkii* that was observed above the Noordzeekanaal was caught in 2008 in Durgerdam (Stichting EIS-Nederland, 2008). It is expected that the increase in water temperature, mainly in winter, results in a higher risk of invasions of alien crayfish species (Van der Meulen, 2009). Furthermore, an increase in temperature is linked with an increase in crayfish activity, and van der Meulen (2009) showed that the crayfish can have a negative influence on the Water Framework Directive aims (Van der Meulen, 2009). Another predator of the Bullhead is the Grey Heron (*Ardea cinerea).* This species is a warmth preferring species according to the Climate Respons Database and can be considered as a risk for the Bullhead when the temperature increases.

Another fish species that can possibly increase in the Ilperveld due to climate change is the three-spined stickleback (*Gasterosteus aculeatus*). This fish was already observed in the Ilperveld in 2006 near the Gouwsloot (3 individuals), in a ditch called Snoek Dors (5 indivuduals) in compartment 7 (15 individuals), compartment 6 (10 individuals), and compartment 12/13 (one individual) (Van Straaten *et al.,* 2006). This species has a high maximum temperature, a high salt tolerance (because it is a migratory fish), and has in general low environmental requirements (Sportvisserij Nederland, 2006; table 16). In addition, the presence of macrophytes is not necessary (Sportvisserij Nederland, 2006). This fish predates on water fleas (zooplanktivore) which can have consequences for the food web and water transparency (see figure 32).

A possible increase of the three-spined stickleback in the Ilperveld can have another consequence. Aaser *et al.* (1994) noted that sticklebacks are ineffcient predators of the shrimp *Neomysis integer*. This shrimp is typically occuring in brackish water environments (Mees *et al.,* 1994). In the open water of Ilperveld, the species was observed from 1984 to 2003, occasionally in high numbers (Limnodata). The shrimp can be considered as euryhaline (high salt tolerance) and eurythermic (high temperature tolerance) (Mees *et al.,* 1994). In addition, *Neomysis integer* is an omnivorous species; it is an predator of zooplankton and an detrivore. When a lot of sticklebacks are present, *Neomysis integer* numbers increase, and predation on zooplankton increases. This reduces the grazing pressure on the phytoplankton, and consequently algal biomass increases, and the water transparancy decreases (figure 32). Aaser *et al.* (1994) noted that predation pressure of *Neomysis integer* on zooplankton is particularly high in eutrophic brackish lakes. In experiments that Aaser *et al.* (1994) performed, a strong positive correlation between chlorophyll-a and *Neomysis integer* density was found. So, an increase in the number of the three-spined stickleback can increase the predation pressure on zooplankton, which can result in increased algal biomass and decreased water transparancy.

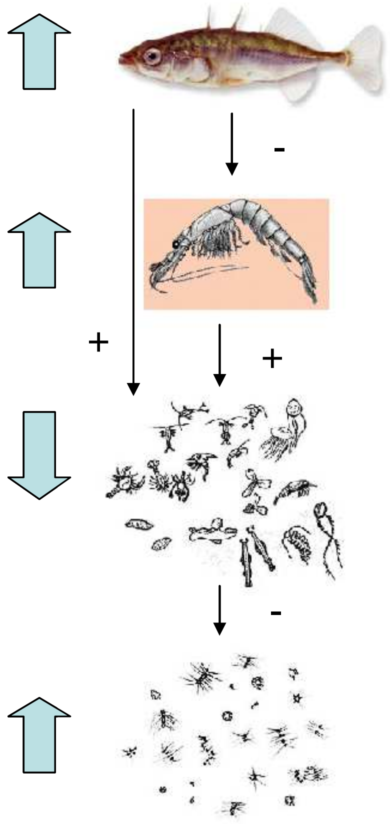


Figure 32. Increased numbers of Gasterosteus aculeatus (1st blue arrow) can result in increased numbers of Neomysis integer (2nd blue arrow) and a decline in zooplankton biomass and increase in phytoplankton biomass (last two blue arrows).

6.3 Migration

When the environmental conditions become unfavorable for fish, migration is an option. However, fishes differ in the ability to migrate, and migration routes can be absent or blocked. The dispersion distance is the distance that species can span between different habitat areas during their dispersion. The dispersion distance for the European Bitterling is 1-3 km (de Lange & van Emmerik, 2006). The Bullhead has a low ability to migrate, and moves maximum 15-20 meters (Huurnink *et al.,* 2009). So the dispersion capability of this species is low. For Spined Loach, no data was found. It is important that habitats are not located too far from each other, to allow dispersal of the species when the environmental conditions become unsuitable. The recently developed fish passage can help the fish to migrate between the compartments and the open water. However, completely isolated compartments like compartment 9 prevent migration. When the conditions become unsuitable here, fish are not able to leave the compartment (figure 33). When a larger scale is considered, the Waterlandse Boezem is a large area for fish with few migration obstructions (Hofman *et al.*, 2005). Migrating fish like the European eel *(Anguilla anguilla)* and sticklebacks can enter the area from the south via the Noordzeekanaal. Fish can migrate to the Noord-Hollands kanaal, and the other Natura 2000 areas (Varkensland, Twiske and Oostzanerveld), because the Ilperveld has many open water connections. Also, an upward movement to the direction of Purmerend is possible (Hofman *et al.,* 2005). Isolation of large parts of the Waterlandse Boezem (like Ilperveld) can be seen as a threat for fish migration (Hofman *et al.,* 2005).

Figure 33. Compartment 6: migration to the open water is prevented by the dividing wall.

Table 16. Abiotic conditions of the two freshwater mussels (fist two rows), two alien crayfish species, the three spined stickleback, and water fern (Azolla)

	Temperature (°C)	Spawning temperature (°C)	Chloride (mg/l)	Oxygen (mg/l)	Phosphate (mg/l)	Nitrogen (mg/l)	Sulphate (mg/l)	pH
Unio pictorum			< 231.75 [1]	< 12 [1]	< 0.83 [1]	< 7.73 [1]	< 146.67 [1]	< 8.35 [1]
Anondonta cygnea			< 288 [11]	< 12.02 [1]	< 1.04 [1]	< 9.09 [1]	< 174. 81 [1]	< 8.51 [1]
Orconectus limosus			< 139.05 [1]	< 11.27 [1]	< 0.44 [1]	< 6.35 [1]	< 78 [1]	<8.19 [1]
Procambarus clarkii	Optimum 22 – 30 [4]							
Gasterosteus aculeatus	26 – 27 [2] Optimum 16 [3]	5 - 20 [2]	< 1180 [1]	< 11.98 [1] Optimum 9 - 12 Min. 7 [3]	< 1.4 [1]	< 10.32 [1]	< 155.25 [1]	< 8.3 [1]
Azolla filiculoides	Warmth preferring, see table 15		< 285.63 [1]		< 2.04 [1]	< 14.76 [1]	< 173.88 [1]	< 8.85 [1]

[1] Limnodata, response data. The response of species to environmental factors is determined based on the occurrence of the species in the entire database (all years and locations). The presented values in the above table are 90-percentiles. This means that 90 % of all the measured values lie below that value.

[2] van der Grinten *et al.,* 2007

[3] Verdonschot *et al.*, 2007

[4] van der Meulen, 2009

7 Conclusions

7.1 Conclusions

From this study it appeared that climate change influences probably all aquatic Natura 2000 goals of the Ilperveld. Especially the habitat type oligo-mesotrophic water with *Chara spp.* vegetation and the European Bitterling are negatively affected by climate change. However, positive effects are also expected. For instance, the Spined Loach benefits from higher temperatures, lower oxygen levels, and low water levels. The effects of different factors of climate change (that probably will occur in the Ilperveld) on the aquatic Natura 2000 goals Ilperveld are presented in table 17 (page 73).
So what does climate change means for the achievement of the Natura 2000 goals? First, the water quality in the Ilperveld is currently poor, and needs to be improved to reach the aquatic Natura 2000 goals. Climate change aggravates the problem of the poor water quality and makes it therefore more difficult to reach the aquatic Natura 2000 goals on the long-term. Especially for the habitat type oligo-mesotrophic water with *Chara spp.* vegetation it is difficult to reach the aim (expand the surface area), because climate change causes probably more eutrophication and increasing water turbidity, and the current distribution of this habitat type is small in the Ilperveld.
The Natura 2000 goal for the fishes is retention of the surface area and quality of the habitat. For the Spined Loach and European Bitterling this is possible to achieve in the light of climate change. An essential condition is that proposed restoration measures (like dredging and the creation of more habitat variation) will be taken. Retention of the small Bullhead population is also achievable, even without large restoration measures. It is obvious however, that climate change does not facilitates the achievement of the aquatic Natura 2000 goals.

7.2 Measures

Because climate change does not facilitates the achievement of the aquatic Natura 2000 goals in the Ilperveld, additional measures to easen the effects of climate change are necessary in some cases. In the light of climate change, it is important that nature areas have enough resilience against weather extremes. This can be achieved by enlargement of the areas (and habitats). Also, connections with other areas are important, to facilitate movement of species. For the Ilperveld this is difficult to achieve, because it is build in between cities, villages and roads. At the southern border of the Ilperveld lies the Landsmeerderveld. This is also an open area that can function as a buffer zone. It is not sure if this area stays open, because several plans for houses and even a road for the people of Landsmeer to Amsterdam were discussed in the local politics. The current council is composed of the VVD and PvdA. In the newly developed council program (2010-2014), this extra road to Amsterdam is not constructed. Specific measures for the habitat type and fish are discussed next.

7.2.1 Oligo-mesotrophic water with Chara spp. vegetation

All measures that improve the water quality are necessary for permanent establishment of this habitat type. In particular for the *Chara* species, it is important that the water transparency is high. Measures for improvement of the water quality are proceeding from the Water Framework Directive and additional measures described in the Natura 2000 management plan (Huurnink *et al.,* 2009). Measures in the framework of the Water Framework Directive are described on a regional level (Waterland). The proposed measures mentioned in the Natura 2000 management plan (Huurnink *et al.*, 2009) are more focused on the Ilperveld. The proposed measures for improvement of the water quality are shown in table 18. In the turf ponds of the Ilperveld, only dredging is proposed. Some measures that are not mentioned in table 18 first need to be investigated. For instance, a softening of the inlet water, a covering layer of sand on the sediments (Huurnink *et al.,* 2009). Even a change in the water management is discussed. This change includes a stop of the water flow from the Noord-hollands kanaal into the Ilperveld (Niels Hogeweg, personal communication).

Table 18. Measures for improvement of the water quality, in the framework of the Water Framework Directive (Waterland) and Natura 2000 (isolated compartments). Source: Huurnink et al., 2009.

Measure	Waterland	Isolated compartments Ilperveld
Dredging	X	X
Reduction transit by boats		X
Natural water level		X
Natural fish management	X	X
Raise of water level		X
Reduce of manuring	X	X
Reduce mud	X	
Removal of duckweeds and floating algae	X	
Removal of obstacles for fish (dams)	X	
Tackle diffuse sources like recreation, traffic and shipping	X	

For the habitat type 3140 (oligo-mesotrophic water with *Chara spp*. vegetation), Huurnink *et al.* (2009) noted that temporal cleaning of the water together with the measures for turf ponds and isolated water shown in table 18 are sufficient to achieve the Natura 2000 goal, which is expansion of the area and retention of the quality. Another (rigorous) measure that is proposed for the improvement of the water quality is salinization of the surface water (Tauw, 2009). In the light of climate change, this could a favorable measure. By salinization, the quality of the habitat type is maintained. In addition, vegetations of *N. marina* and *R. maritima* are able to survive at slightly higher nutrient concentrations, which is easier for the management.
Salinization can also reduce the phosphate mobilization from the sediments.
In the earlier described laboratory experiments of Brouwer *et al.* (2006) and Lamers *et al.* (2006) high chloride concentrations (7090 mg/l) reduced phosphate concentrations in the sediment fluid. In addition, a very low salinization level (71 mg/l chloride) of the surface water of the Ilperveld seems to increase the phosphate mobilization. It is assumed that the increase of the chloride concentration influences different microbial processes. Microbes that are adapted to a certain chloride level are inhibited at higher chloride concentrations and become inactive. As a result, microbial processes like sulphate reduction decline and the phosphate mobilization is reduced.
The option of experimental salinization of the Ilperveld is going to be investigated by Landschap Noord-Holland, research institute B-Ware, and the water board Hoogheemraadschap Hollands Noorderkwartier (Niels Hogeweg, personal communication). It is expected however, that salinization is very expensive and requires a lot of effort (Tauw, 2009).

7.2.2 European Bitterling

For retention of the surface area and quality of the habitat (Natura 2000 goal) it is important that within the compartments, a lot of habitat variation is present. Measures that are mentioned in the recently appeared management plan for fish (van den Boogaard *et al.,* 2010) are focused on more habitat variation for the Natura 2000 fish in the isolated compartments (European Bitterling and Spined Loach). Examples are the construction of gentle banks, and winter places for fish. More habitat variation is favorable in the light of climate change, because this reduces the effects of weather extremes, such as droughts. In addition, the construction of the fish passage in compartment 7, is favorable for small fish like European Bitterling, because more migration is possible. So the fish can migrate from this compartment when the environmental conditions become unsuitable. Migration to other areas (Twiske or Varkensland) should also be facilitated. Maybe it is also an option to introduce more *U. pictorum* individuals in the area, since this mussel is endemic and a high reproductive success can be made with this mussel. Supportive measures that Huurnink *et al.* (2009) proposed are dredging (in phases) and after dredging, the replacement of mussels back in the water. Also the measures from table 18 for the improvement of the water quality are advantageous for the European Bitterling. Finally, the removal of benthivorous fish like Bream and Carp (fish stock management) is also a positive measure. Carefulness is needed with the introduction of new fish (such as young Pike). Experimental salinization (chloride level of 2200 mg/l; Tauw, 2009) is not disadvantageous for the European Bitterling if the fish stays in the compartments where the chloride levels become not higher than 1000 mg/l.

7.2.3 Spined Loach

For retention of the surface area and quality of the habitat (Natura 2000 goal) it is important that within the compartments, a lot of habitat variation is present, just like with the European Bitterling. In addition, the construction of the fish passage in compartment 7, is favorable for this fish, because more migration is possible. Dredging is also a positive measure. Experimental salinization is not disadvantageous for the Spined Loach if the fish stays in the compartments where the chloride levels do not become higher than 1000 mg/l.

7.2.4 Bullhead

For the Bullhead, it is important that large habitats are created, with sufficient hard substrates, like stones. According to Huurnink *et al.* (2009) and Niels Hogeweg, stones will be dropped across banks of the open water, which will improve the habitat. When crayfish are observed in the Ilperveld, it is important that these will be removed. Besides a risk for the Bullhead, crayfish also negatively influence the water quality aims. A reduction of the motorized boats is also positive, because this reduces the mud movement. Experimental salinization seems not disadvantageous for the Bullhead since the chloride level of 2200 mg/l lies in the range. However, in saline years, the chloride concentration in the open water may become too high.

7.3 Future perspectives

Currently, the Ilperveld is under pressure by urbanization, agriculture, municipalities, the province Noord-Holland and people living in the neighborhood. For example, the province of Noord-Holland wants to transform the Ilperveld into a freshwater area, which is against the opinion of the management. In addition, many people visit the area and recreate in the area. Important for this group is that the area stays open, remains quit with the sound of many whistling birds. Because the Ilperveld has this recreational function, it is difficult to achieve some measures like the prohibition of motorized boats. Even the interests in the Natura 2000 management plan are conflicting. Both bird habitats and aquatic habitats need to be preserved. An enrichment of the grasslands with nutrients is favorable for the birds, but leads to more nutrient run-off which is unfavorable for the aquatic goals. As time goes by, the pressure enhances, and the effects of climate change aggravate the current problems.
So for the future, it seems that choices have to be made for the Ilperveld. Achievement of the aquatic Natura 2000 goals remains difficult if nutrient enrichment (of grasslands and surface water) continues, and more recreation occurs due to warmer summers.

I think, as an aquatic ecologist, that it is important that the Ilperveld keeps the unique (historical) brackish character. When the Ilperveld will regain this historical brackish character, the nature function and recreational function can occur together. The unique brackish character attracts both rare brackish species and recreational people. As said before, salinization of the surface water is positive for habitat type 3140. Also, recreation and the preservation of the meadow birds are not affected by salinization. A disadvantage of salinization is that the achievement of the Natura 2000 goals for European Bitterling and Spined Loach are probably not made. But these two species have a wide distribution in Noord-Holland, so I think it is no disaster if they disappear from the Ilperveld. So, salinization is favorable for the ecosystem Ilperveld, and unfavorable for some Natura 2000 species. Here lies a serious discrepancy: Natura 2000 protects individual species, while the Ilperveld is an ecosystem, and my opinion is that the Ilperveld needs to be considered as an ecosystem.

- **The conclusions of this study are:**

1. **Effects of climate change make it more diffcult to achieve the aquatic Natura 2000 goals of the Ilperveld.**
2. **There are many inconsistencies round the Natura 2000 goals and the different functions of the area.**
3. **The species approach of Natura 2000 conflicts with the preservation of the unique brackish character of the Ilperveld.**

Table 17. Summary of effects of climate change on aquatic Natura 2000 goals Ilperveld. + means positive effect; - means negative effect; 0 means no clear effect; ? means effect unknown or uncertain; x means not discussed in this study.

	> water temperature	> chloride concentration	> eutrophication	< water transparancy	< oxygen concentration	Low water levels
Habitat type 3140	0	+	-	-	x	-
European Bitterling	+	-	0	-	?	-
Spined Loach	+	-	0	-	+	+
Bullhead	-	+	0	0	-	0

Acknowledgements

Of course I want to thank my supervisors from the RIVM: Wilko Verweij and Esther van der Grinten. I am very pleased about the supervision during this internship; it was more than sufficient. I enjoyed this internship at the RIVM (LER); everything was well organized and it was a pleasant stay. I am also grateful to Michiel Kraak, who was again my examiner from the UvA. I would also like to thank Niels Hogeweg (Landschap Noord-Holland), who provided much information about the Ilperveld. Thank to Niels, I am almost an expert on the Ilperveld. Other people who helped me with this project by providing information and helped thinking are: Leon Lamers (Radboud Universiteit Nijmegen), Bas van de Riet (Landschap Noord-Holland), Ron van ’t Veer (Van 't Veer & De Boer - Ecologisch Advies- en Onderzoeksbureau), Martin Witteveldt (Landschap Noord-Holland), Jan van der Wiele (father) and my UvA colleague Imke van Moorselaar.

References

Literature

Aaser HF, Jeppesen E, Søndergaard M 1995. Seasonal dynamics of the mysid *Neomysis integer* and its predation on the copepod *Eurytemora affinis* in a shallow hypertrophic brackish lake. Mar. Ecol. Prog. Ser. 127, p 47 -56.

Altenburg W, Arts G, Baretta-Bekker JG, van den Berg MS, van den Broek T, Buskens R, Bijkerk R, Coops HC, van Dam H, van Ee G, Evers CHM, Franken R, Higler B, Ietswaart T, Jaarsma N, de Jong DJ, Joosten AMT, Klinge M, Knoben RAE, Kranenbarg J, van Loon WMGM, Noordhuis R, Pot R, Twisk F, Verdonschot PFM, Vlek H, Wolfstein K, Backx JJGM, Beers M, van den Berg MS, van den Broek T, Buskens R, Buijse AD, Duursema G, Fagel M, de Leeuw J, van der Molen J, Nijboer RC, Vriese T, Duijts R, Hartholt JG, Jager Z, Stikvoort EC, 2007. Referenties en maatlatten voor natuurlijke watertypen voor de Kaderrichtlijn Water. STOWA, Utrecht.

Bates BC, Kundzewicz ZW, Wu S, Palutikof JP Eds. 2008. Climate Change and Water. Technical Paper of the Intergovernmental Panel on Climate Change, IPCC Secretariat, Geneva, 210 pp.

Blom G, Paulissen M, Vos C, Agricola H 2008. Effecten van klimaatverandering op landbouw en natuur. Nationale knelpuntenkaart en adaptatiestrategieën. Plant Research International B.V., Wageningen.

Brouwer E, Smolders AF, van Diggelen J, Geurts J, 2006. Begeleidend onderzoek bij de uitvoering van herstelmaatregelen in het Ilperveld. Tussenrapportage. B-WARE Research Centre, Nijmegen. Rapportnummer: 2006.06

Daufresne M, Roger MC, Capra H, Lamouroux N 2004. Long-term changes within the invertebrate and fish communities of the Upper Rhône River: effects of climatic factors. Global Change Biology 10, p: 124-140.

De Groot M, Stuyt L, Schuiling R 2009. Klimaatscan structuurvisie. Klimaateffect Atlas 1.0. Interprovinciaal Overleg, Klimaat voor Ruimte, Kennis voor Klimaat, Ruimte voor Geoinformatie, Waterdienst.

De Lange MC, van Emmerik WAM 2006. Kennisdocument bittervoorn. *Rhodeus amarus* (Bloch, 1782). Kennisdocument 15. Sportvisserij Nederland, Bilthoven.
European Environment Agency (EEA), 2010. 10 messages for 2010: Freshwater ecosystems. EEA, Copenhagen.

Europese Commissie 2009. Natura 2000 – de natuur van Europa: ook voor u. Luxemburg: Bureau voor officiële publicaties der Europese Gemeenschappen. ISBN 978-92-79-11575-2

Evers CHM, van den Broek AJM, Buskens R, van Leerdam A, Knoben RAE 2007. Omschrijving MEP en maatlattenvoor sloten en kanalen voor de Kaderrichtlijn Water. STOWA, Utrecht.

Ficke AD, Myrick CA, Hnasen LJ 2007. Potential impacts of global climate change on freshwater fisheries. Reviews in Fish Biology and Fisheries 17, p: 581-613.

Geurts J, Sarneel J, Pires MD, Milder-Mulderij G, Schouwenaars J, Klinge M, Verhoeven J, van der Wielen S, Jaarsma N, Verberk W, Esselink H, Ibelings B, van Donk E, Roelofs J, Lamers L, 2008. Onderzoek ten behoeve van het herstel en beheer van Nederlandse laagveenwateren. Tussentijdse OBN-rapportage, Fase 2, tweede onderzoeksjaar, April 2008.

Hofman C, 2000. Visstandonderzoek Ilperveld Plan Watersnip vak 6, 9 en 12. Urban van Aar, Bureau voor Water en Landschapsarchitectuur.

Hofman CC, Roodzand H, Schreijer M 2005. Nota Visbeleid. Basis voor integraal waterbeheer onder de Kaderrichtlijn Water. Afdeling Beleidsontwikkeling en Planvorming Hoogheemraadschap Hollands Noorderkwartier. Registratienummer04.30598

Huurnink M, van Hooff A, Oudejans P 2009. Concept beheerplan Natura 2000 gebied Ilperveld, Varkensland, Oostzanerveld en Twiske. Tauw 2009.

IPCC (Intergovernmental Panel on Climate Change) 2007. Climate change 2007: Synthesis report.

Kerkum LCM, Bij de Vaate A, Bijstra D, De Jong SP, Jenner HA 2004. Effecten van koelwater op het zoete aquatische milieu. RIZA rapport 2004.033, Lelystad, november 2004.

Kersting K 1983. Bimodal diel dissolved oxygen curves and thermal stratification in polder ditches. Hydrobiologia, 107 (2), p: 165 -168.

Kiwa Water Research & EEG 2007. Knelpunten- en kansenanalyse Natura 2000-gebied 92 – Ilperveld, Varkensland, Oostzanerveld en Twiske. Kiwa Water Research, Nieuwegein/ EGG, Groningen. Projectnummer 30.7047.050

KNMI (Royal Netherlands Meteorological Institute) 2008. De toestand van het klimaat in Nederland 2008. KNMI, De Bilt.

KNMI (Royal Netherlands Meteorological Institute) 2009. Klimaatverandering in Nederland. Aanvullingen op de KNMI'06 scenario's. KNMI, De Bilt.

Koese B, 2008. Rode Amerikaanse Rivierkreeft rukt op. Kreeften nieuwsbrief 2, Stichting EIS Nederland.

Kranenbarg J, Struijk R, de Bruin A, Kuijsten W, Spikmans F, Frigge P 2009. Verspreidingsonderzoek vissen 2008. Stichting RAVON, Nijmegen. Rapport 2009-06.

Kwadijk J, Jeuken A, van Waveren H 2008. De klimaatbestendigheid van Nederland Waterland. Verkenning van knikpunten in beheer en beleid voor het hoofdwatersysteem. Tussenrapportage technisch achtergrondrapport Klimaatbestendig Nl Waterland, Deltares rapport T2447, Delft.

Lamers L, Geurts J, Bontes B, Sarneel J, Pijnappel H, Boonstra H, Schouwenaars J, Klinge M, Verhoeven J, Ibelings B, van Donk E, Verberk W, Kuijper B, Esselink H, Roelofs J 2006. Onderzoek ten behoeve van het herstel en beheer van Nederlandse laagveenwateren. Eindrapportage 2003-2006. Directie Kennis, Ministerie van Landbouw, Natuur en Voedselkwaliteit, Ede. Rapport DK nr. 2006/057-O

Lamers L, Smolders A, van Diggelen J, Lucassen E, Kleijn D, Roelofs J, 2008. Pitrus, l'enfant terrible van het natte natuurbeheer? Lastige beheersvragen in de Nederlandse veenweiden. Tussen Duin en Dijk 7, p 30-36.

Landschap Noord-Holland. Beheerplan Ilperveld 2007 – 2017.

Likens G (Lead Author); Environmental Protection Agency (Content source); Wayne Davis, Lori Zaikowski and Stephen C. Nodvin (Topic Editors) 2007. "Acid rain." In: Encyclopedia of Earth. Eds. Cutler J. Cleveland (Washington, D.C.: Environmental Information Coalition, National Council for Science and the Environment).

Livingstone DM 2003. Impact of secular climatic change on the thermal structure of a large temperate central European lake. Climatic Change 57, p: 205-225.

Loeve R, Droogers P, Veraart J 2006. Klimaatverandering en waterkwaliteit. Wetterskyp Fryslân. FutureWater report 58.

Mees J, Abdulkerim Z, Hamerlynck O 1994. Life history, growth and production of *Neomysis integer* in the Westerschelde estuary (SW Netherlands). Mar. Ecol. Prog. Ser. 109, p 43 -57.

Ministerie van Landbouw, Natuur en Voedselkwaliteit 2008. Bittervoorn (*Rhodeus sericeus amarus*) (H1134). Profielen Habitatsoorten, versie 1 september 2008.

Ministerie van Landbouw, Natuur en Voedselkwaliteit 2008. Kalkhoudende oligo-mesotrofe wateren met benthische Chara spp. Vegetaties (H3140). Verkorte naam: kranswierwateren. H3140 versie 1 sept 2008, met erratum 24 maart 2009.

Ministerie van Landbouw, Natuur en Voedselkwaliteit 2008. Kleine modderkruiper (*Cobitis taenia*) H1149. Profielen Habitatsoorten, versie 1 september 2008.

Ministerie van Landbouw, Natuur en Voedselkwaliteit 2008. Rivierdonderpad (*Cottus gobio*) H1163. Profielen Habitatsoorten, versie 1 september 2008.

Ministry of Agriculture, Nature and Food Quality 2006. Natura 2000 targets document – Summary: setting conservation objectives for the Natura 2000 network in the Netherlands. Drukkerij Giethoorn ten Brink BV, Meppel.

Mooij WM, De Senerpont Domis LN, Hülsmann S 2008. The impact of climate warming on water temperature, timing of hatching and young-of-the-year growth of fish in shallow lakes in the Netherlands. Journal of Sea Research 60, p: 32-43.

Mooij WM, Hülsmann S, De Senerpont Domis LN, Nolet BA, Bodelier PLE, Boers CM, Pires LMD, Gons HJ, Ibelings BW, Noordhuis R, Portielje R, Wolfstein K, Lammens

EHRR 2005. The impact of climate change on lakes in the Netherlands: a review. Aquatic Ecology 39, p: 381– 400.

Paerl HW, Huisman J 2008. Blooms like it hot. Science 320, p: 57-58.
Paulissen MPCP, Schouwenberg EPAG, Wamelink GWW 2007. Zouttolerantie van zoetwatergevoede natuurdoeltypen. Verkenning en kennislacunes. Alterra-rapport 1545, Wageningen.

PBL 2009. Wegen naar een klimaatbestendig Nederland. Planbureau voor de Leefomgeving (PBL), Bilthoven, april 2009. PBL-publicatienummer 500078001.

Peters JS 2009. Kennisdocument donderpad het geslacht *Cottus*. Kennisdocument 09 (herziene versie) Sportvisserij Nederland, Bilthoven.

RIZA 2005. Droogtestudie Nederland. Aard, ernst en omvang van watertekorten in Nederland. Eindrapport. RIZA-rapport 2005.016; ISBN 9036957230.

Schippers P, Lurling M, Scheffer M 2004b. Increase of atmospheric CO2 promotes phytoplankton productivity. Ecology Letters 7, p: 446-451.

Simons J, Ohm M, Daalder R 1994. Restoration of Botshol (The Netherlands) by reduction of external nutrient load : recovery of a characean community, dominated by *Chara connivens*. Hydrobiologia 275/276, p 243 – 253.

Sluis D, van Straaten M, Nederpel V 2009. Uitdunningsvisserij vak 9 in het Ilperveld. Verslag van het wegvangen van bodemwoelende vis. Van der Goes & Groot, Kwintsheul/Alkmaar.

Smith C, Reichard M, Jurajda P, Przybylski M 2004. Review. The reproductive ecology of the European bitterling (*Rhodeus sericeus*). J. Zool., Lond. 262, p 107–124.

STOWA, 2007. Uitspoeling van meststoffen uit Grasland, Emissieroutes onder de loep. Rapportnummer 2007-14.

Tauw 2009. Uitwerking scenario’s Ilperveld, Varkensland en Oostzanerveld.

Tomlinson ML, Martin RP 2003. Ecology of the Bullhead. Conserving Natura 2000 Rivers Ecology Series No. 4. English Nature, Peterborough.

Van Bakel PJT, Bessembinder J, Blom-Zandstra M, Hermans CML, Idenburg A, Kooiman JW, Oude Essink GHP,. Paulissen MPCP, van Rooij S, Steingröver E, Stuyt LCPM, Verbout A, Vos CC, Walgreen M, Wever N 2008. Klimaateffectschetsboek Noord-Holland. Provincie Noord-Holland. Dossier: B1661.01-001

Van Beek GCW 2003. Kennisdocument Grote modderkruiper, *Misgurnus fossilis* (Linnaeus, 1758). Kennisdocument 1. Sportvisserij Nederland, Bilthoven.

Van Dam H, 2009. Evaluatie basismeetnet waterkwaliteit Hollands Noorderkwartier Trendanalyse hydrobiologie, temperatuur en waterchemie 1982-2007. Herman van Dam, Adviseur Water en Natuur, Amsterdam. Rapportnummer AWN 708.

Van Damme D, Bogutskaya N, Hoffmann RC, Smith C 2007. The introduction of the European bitterling (*Rhodeus amarus*) to west and central Europe. Fish and Fisheries 8, p 79 - 106

Van de Waal DB, Verschoor AM, Verspagen JMH, Donk E, Huisman J 2009. Climate-driven changes in the ecological stoichiometry of aquatic ecosystems. Frontiers in the Ecology and the Environment. Doi:10.1890/080178

Van den Boogaard B, van de Haterd RJW, Bodekke PHN, Bergsma JH 2010. Visstandbeheerplan Ilperveld. Met aandacht voor overige natuurwaarden. Bureau Waardenburg bv / Landschap Noord-Holland, Culemborg/Castricum. rapport nr. 10-049

Van der Grinten E, Herpen FCJ, van Wijnen HJ, Evers CHM, Wuijts S, Verweij W 2007. Afleiding maximumtemperatuurnorm goede ecologische toestand (GET) voor Nederlandse grote rivieren. RIVM rapport 607800004, Bilthoven.

Van der Meulen M 2009. Alien freshwater species and their influence on the goals set by the Water Framework Directive. Master thesis, Limnology & Oceanography. IBED, Universitiy of Amsterdam and RIVM.

Van Dijk J, Koenders M, Rebel K, Schaap M, Wassen M 2009. State of the art of the impact of climate change on environmental quality in the Netherlands. A framework for adaptation. Knowledge for climate. KfC report number KfC 006/09.

Van Kranenburg JP, Kollen J, de Graaf M 2000. Ilperveld Wonderschoon. Visie streefbeelden en watersysteem Ilperveld. Agens Raadgevend Bureau & Grontmij, Hoorn/Alkmaar.

Van Rooij S, Steingröver E, Witte F, Goosen H 2009. Klimaatscan Natura 2000 gebieden. Klimaateffect Atlas 1.0. Interprovinciaal Overleg, Klimaat voor Ruimte, Kennis voor Klimaat, Ruimte voor Geoinformatie, Waterdienst.

Van Straaten M, Sluis DJ, Nederpel V 2006. Visstandonderzoek in relatie tot Bittervoorn in het Ilperveld. Monitoring Plan Roerdomp Ilperveld 2003-2006. Eindrapport. Van der Goes en Groot, Kwintsheul/Alkmaar. G&G-rapport 2006-4.

Verdonschot RCM, de Lange HJ, Verdonschot PFM and Besse A 2007. Klimaatverandering en aquatische biodiversiteit. 1. Literatuurstudie naar temperatuur. Wageningen, Alterra, Alterrarapport 1451.

Verweij W, van der Wiele J, van Moorselaar I, van der Grinten E 2010. Impact of climate change on water quality in the Netherlands. RIVM Report 607800007/2009.

Vis & Water Magazine, 1e jaargang, nr 4, December 2001.

Vos CC, Kuipers H, Wegman RMA, van der Veen M 2008. Klimaatverandering en natuur: identificatie knelpunten als eerste stap naar adaptatie van de EHS. Alterra-rapport 1602, Wageningen.

Witte JPM, Runhaar J, Ek R 2009. Ecohydrologische effecten van klimaatverandering op de vegetatie van Nederland. KWR, Utrecht.

Witteveldt M 2002. Monitoring Plan Watersnip 1997 – 2000. Agens Raadgevend Bureau, Hoorn.

Woestenburg M 2009. Waarheen met het veen. Kennis voor keuzes in het westelijk veenweidegebied. Uitgeverij Landwerk. ISBN 9789077824108. Grafisch Service Centrum, Wageningen.

Internet

www.ilperveldintegraal.nl

www.klimaateffectatlas.wur.nl

www.limnodata.nl website developed by Royal Haskoning in order of STOWA and Sportvisserij Nederland

http://www.rivm.nl/rvs/normen/normsearchresult.jsp?stof=chloride&norm=milieukwaliteit&veld=substancename

www.sportvisserijnederland.nl Soortprofielen Bittervoorn, Kleine modderkruiper, Rivierdonderpad en Driedoornige stekelbaars.

http://www.synbiosys.alterra.nl/natura2000/ Ministry of Agriculture, Nature and Food Quality

http://www.synbiosys.alterra.nl/natura2000/gebiedendatabase.aspx?subj=n2k&groep=8&id=n2k92&topic=effectenmatrix Natura 2000 effect indicator.

Programs

SynBioSys version 1.20 © 2000-2008, Alterra.

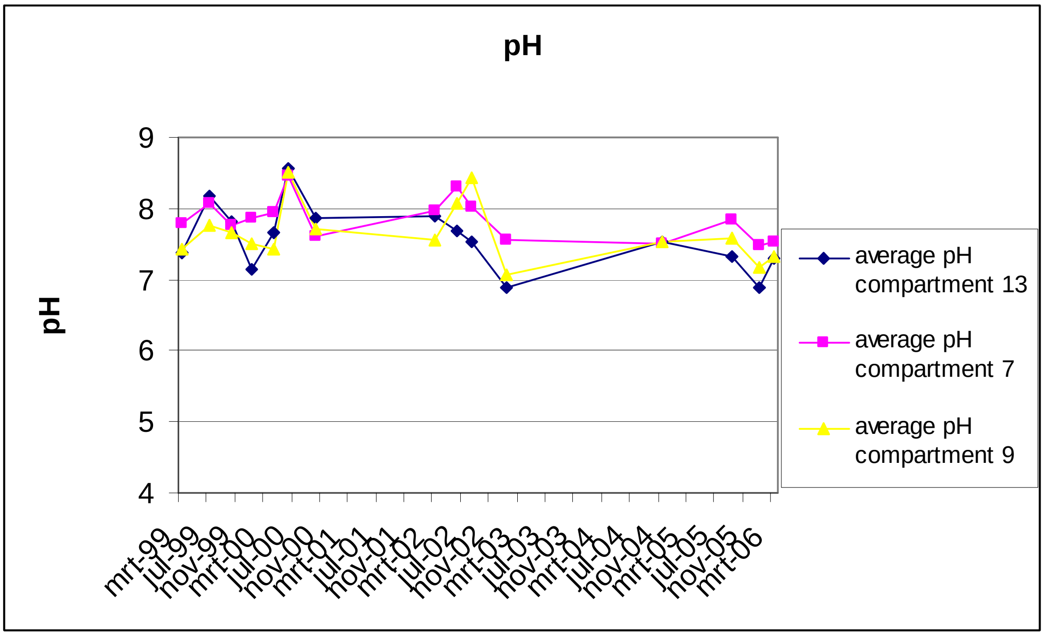
Van der Veen, M, Wiesenekker E, Nijhof BSJ, Vos CC, 2007. Klimaatrespons database V1.1. Ontwikkeld binnen BSIK- Programma Klimaat voor Ruimte, project "Adaptatie EHS". Alterra, Wageningen.

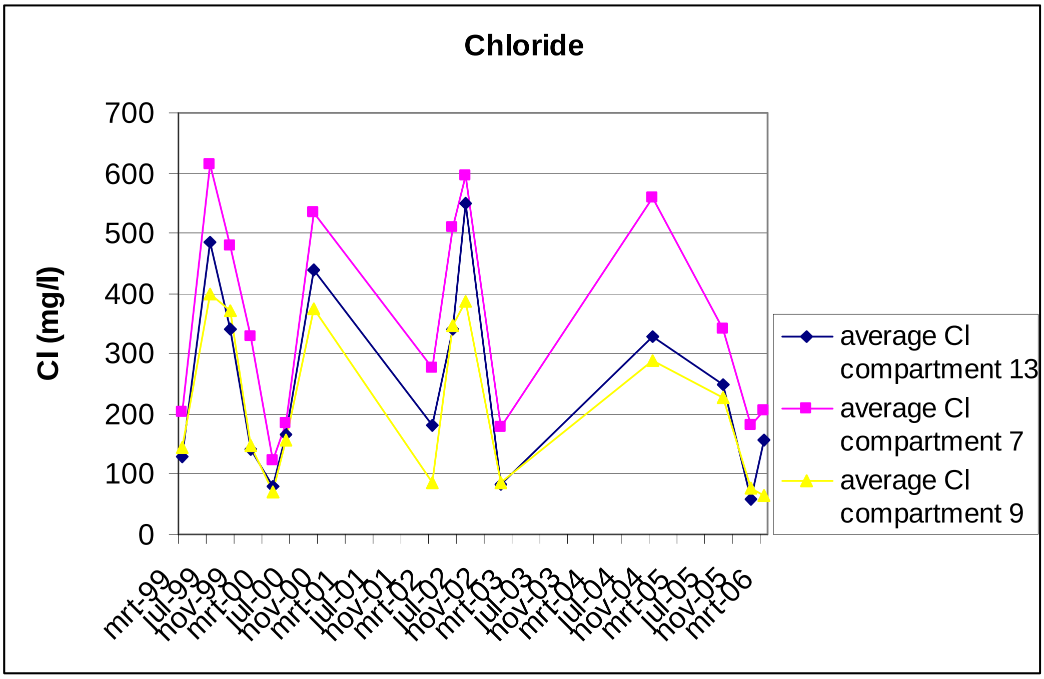
Personal communication

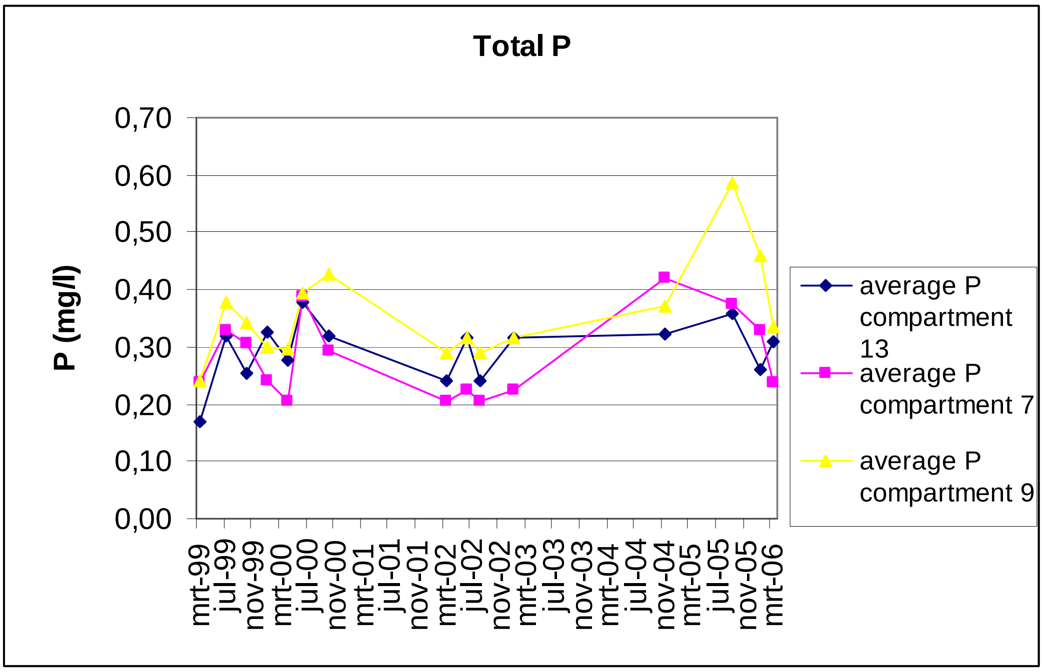
Communication by email with Bas van de Riet
Communication by email with Martin Witteveldt
Interview (by phone) Ron van 't Veer
Interview Leon Lamers
Interviews Niels Hogeweg

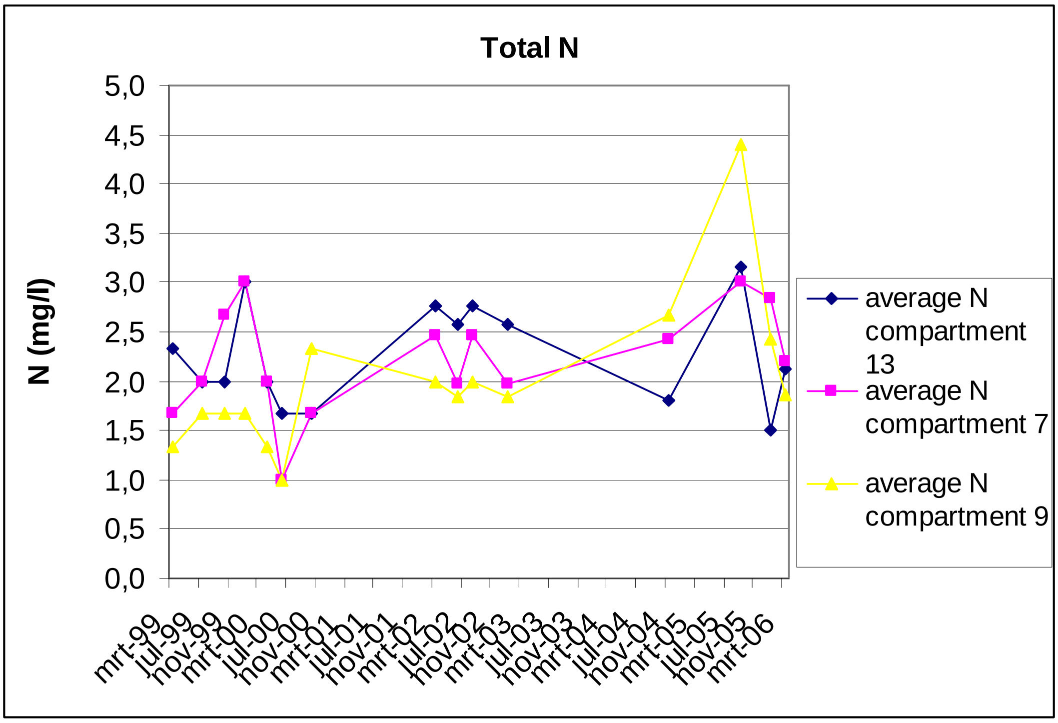
Appendix 1

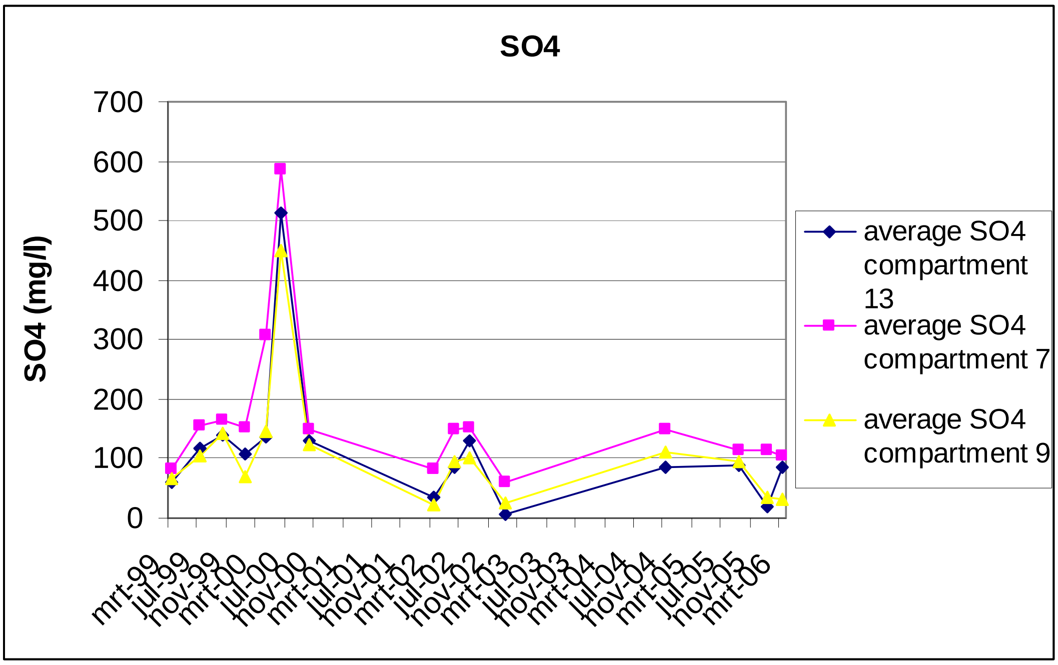
Development of certain water quality parameters in Watersnip compartments 7,9,13 1999-2006. Each compartment had three measuring locations; the average values are calculated from this three locations.
Compartment 7: control, no measures in this compartment were performed
Compartment 13: partly isolated, dredged.
Comparted 9: total isolation, dregded, and fish management





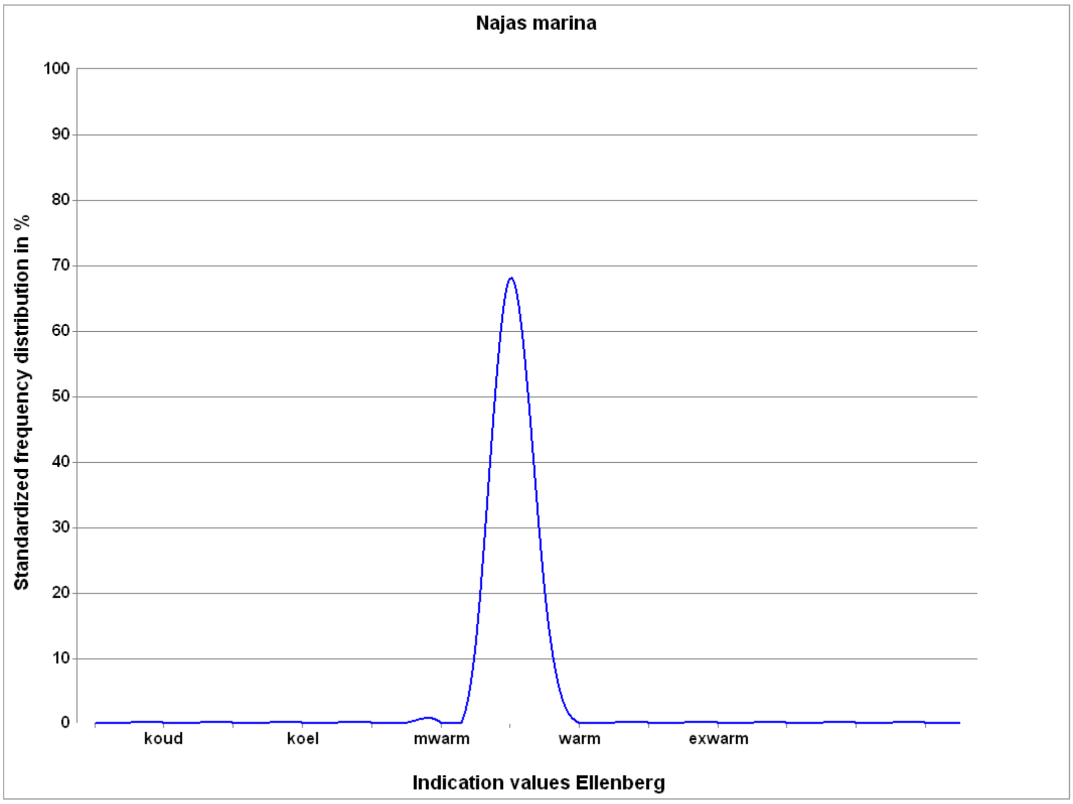

Total P
P (mg/l)
0,70
0,60
0,50
0,40
0,30
0,20
0,10
0,00
mrt-99
jul-99
nov-99
mrt-00
jul-00
nov-00
mrt-01
jul-01
nov-01
mrt-02
jul-02
nov-02
mrt-03
jul-03
nov-03
mrt-04
jul-04
nov-04
mrt-05
jul-05
nov-05
mrt-06
average P compartment 13
average P compartment 7
average P compartment 9

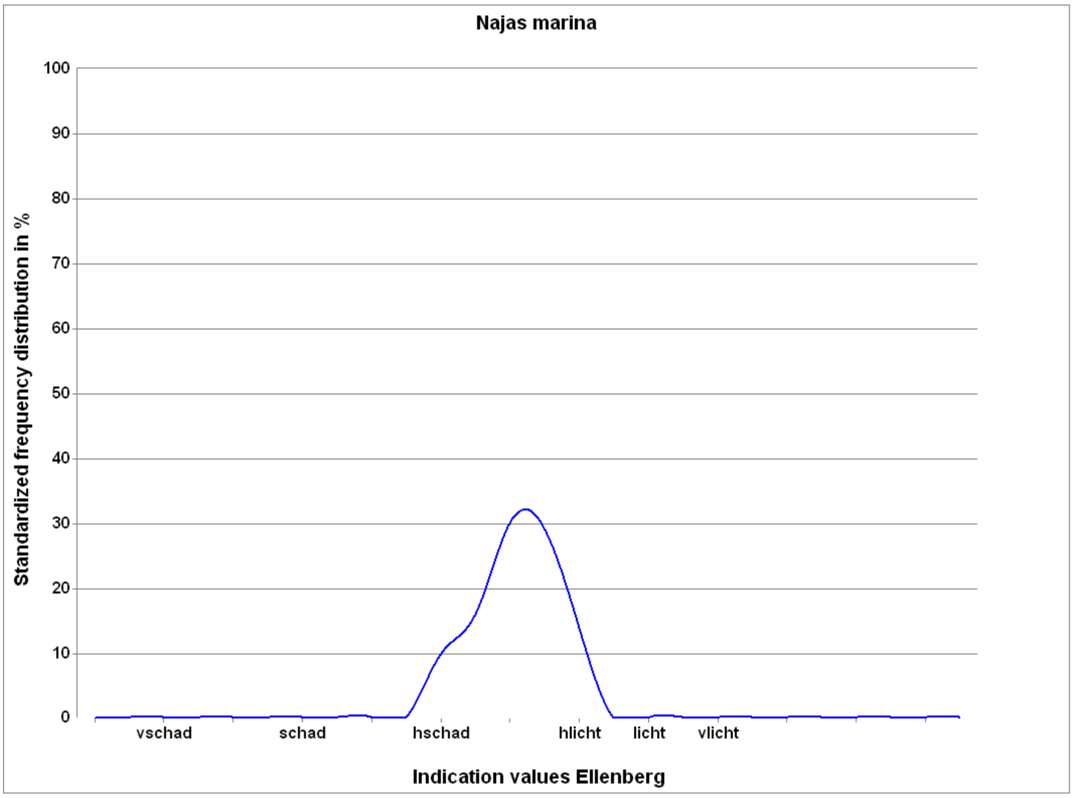

Total N
N (mg/l)
5,0
4,5
4,0
3,5
3,0
2,5
2,0
1,5
1,0
0,5
0,0
mrt-99
jul-99
nov-99
mrt-00
jul-00
nov-00
mrt-01
jul-01
nov-01
mrt-02
jul-02
nov-02
mrt-03
jul-03
nov-03
mrt-04
jul-04
nov-04
mrt-05
jul-05
nov-05
mrt-06
average N compartment 13
average N compartment 7
average N compartment 9

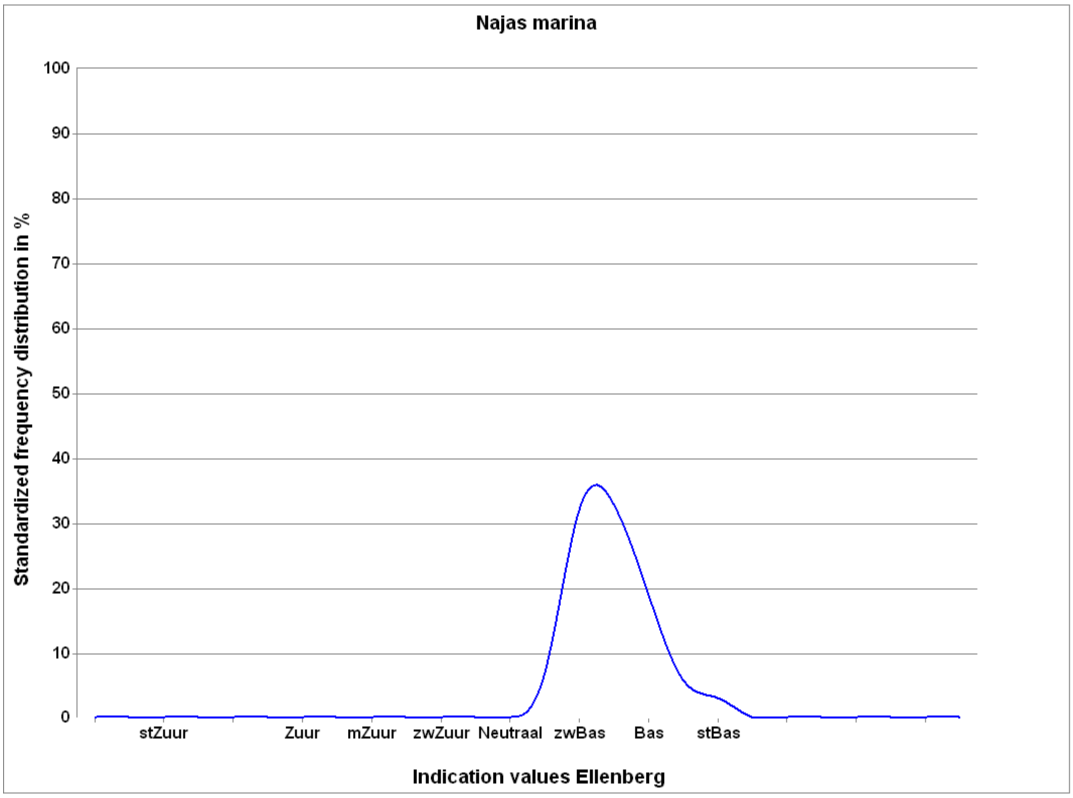

SO4
SO4 (mg/l)
700
600
500
400
300
200
100
0
mrt-99
jul-99
nov-99
mrt-00
jul-00
nov-00
mrt-01
jul-01
nov-01
mrt-02
jul-02
nov-02
mrt-03
jul-03
nov-03
mrt-04
jul-04
nov-04
mrt-05
jul-05
nov-05
mrt-06
average SO4 compartment 13
average SO4 compartment 7
average SO4 compartment 9

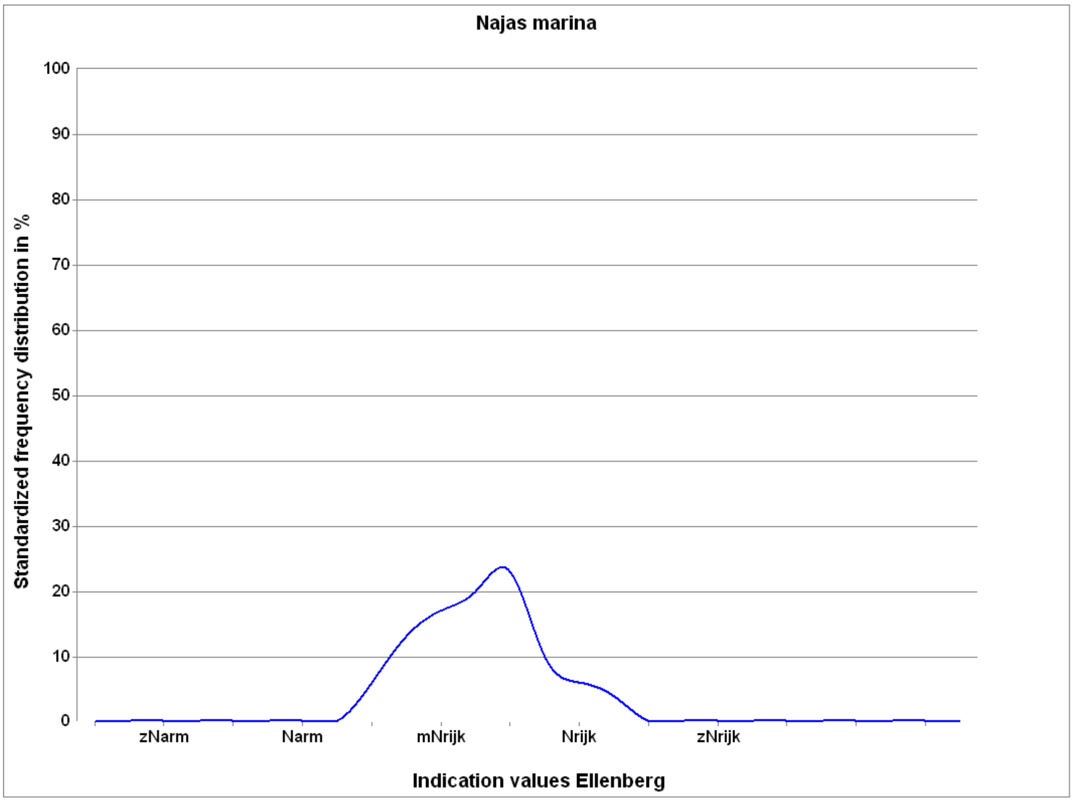
Appendix 2

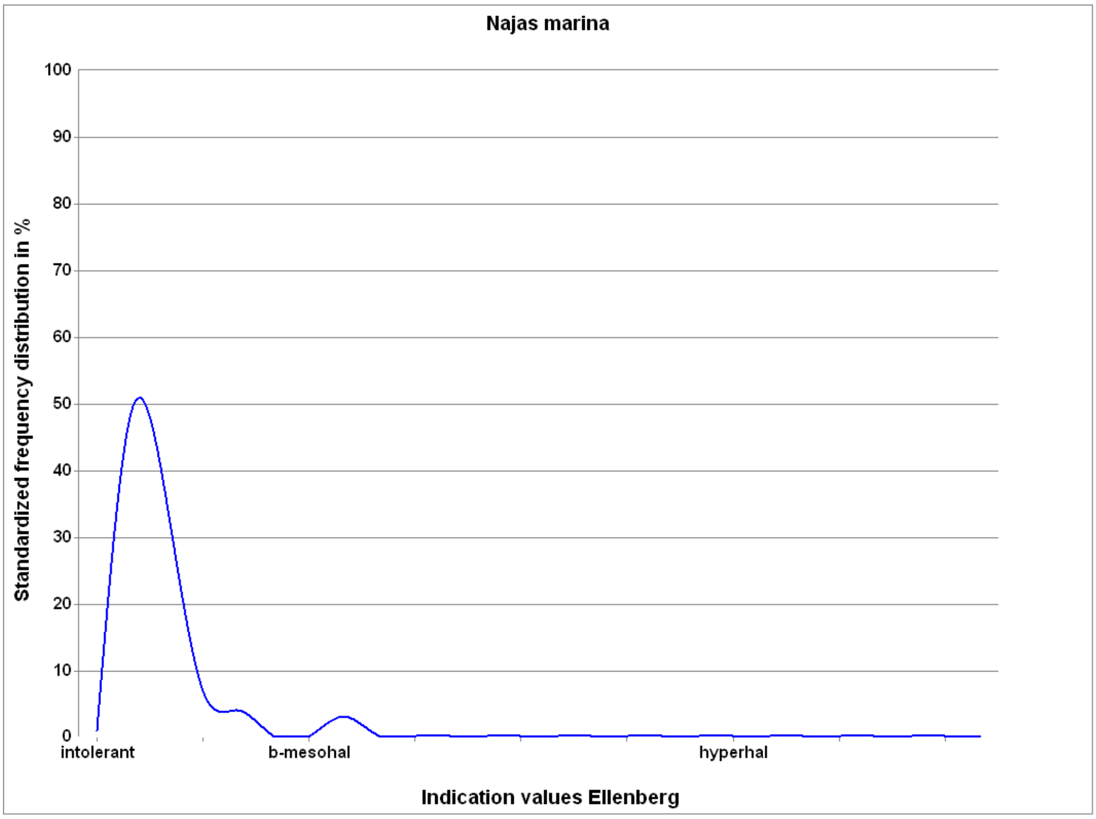
Response curves of the four macrophytes from the program SynBioSys (version 1.20, 2008). The response curves are based on the presence and absence of species. From the most observed species in the samples, a standardized frequency distribution of the average indication values per abiotic factor was made. Of each species, five graphs are shown; 1. indication for temperature; 2. indication for light preference; 3. indication for pH; 4. indication for nitrogen richness; 5. indication for salt tolerance.

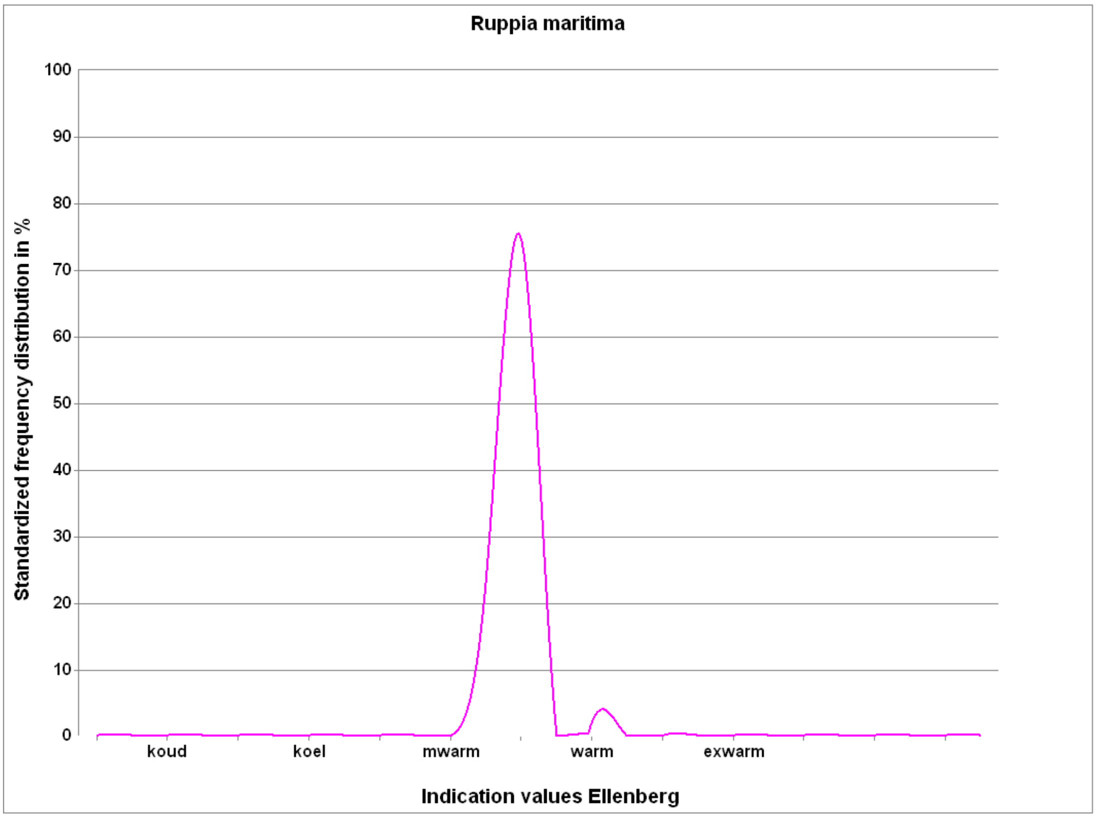


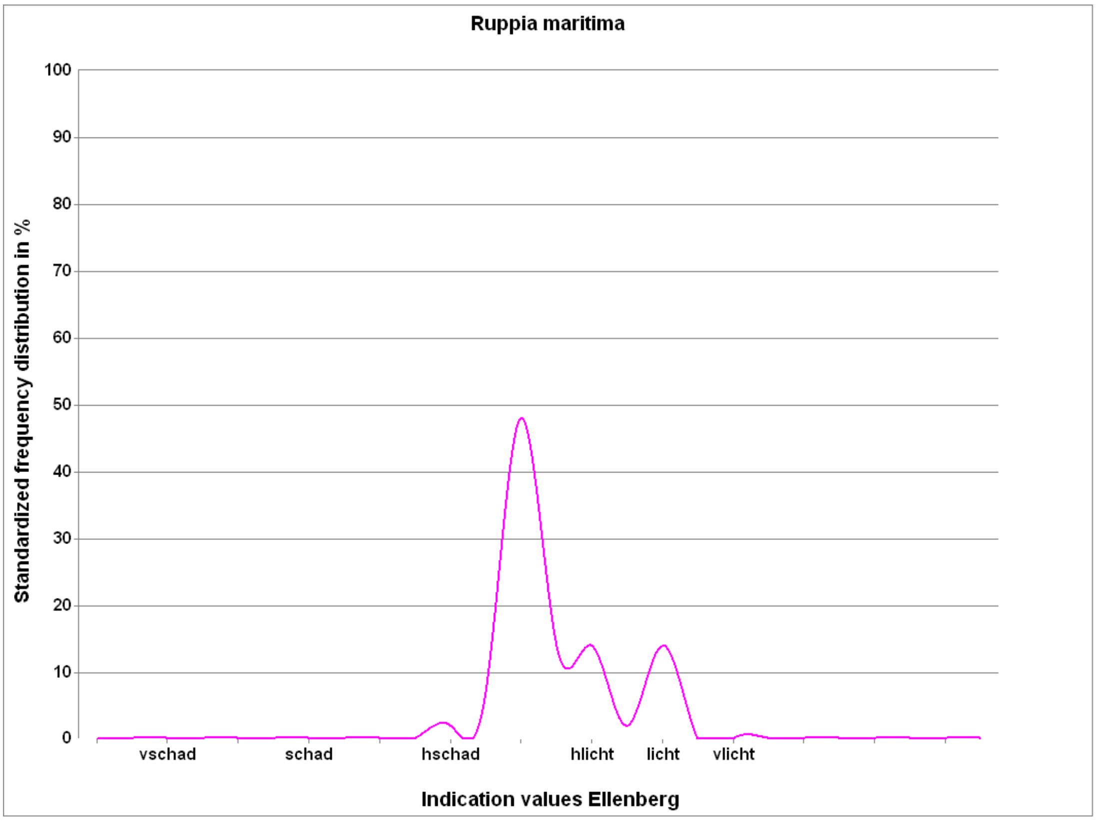

Najas marina
Standardized frequency distribution in %
100
90
80
70
60
50
40
30
20
10
0
vschad
schad
hschad
hlicht
licht
vlicht
Indication values Ellenberg

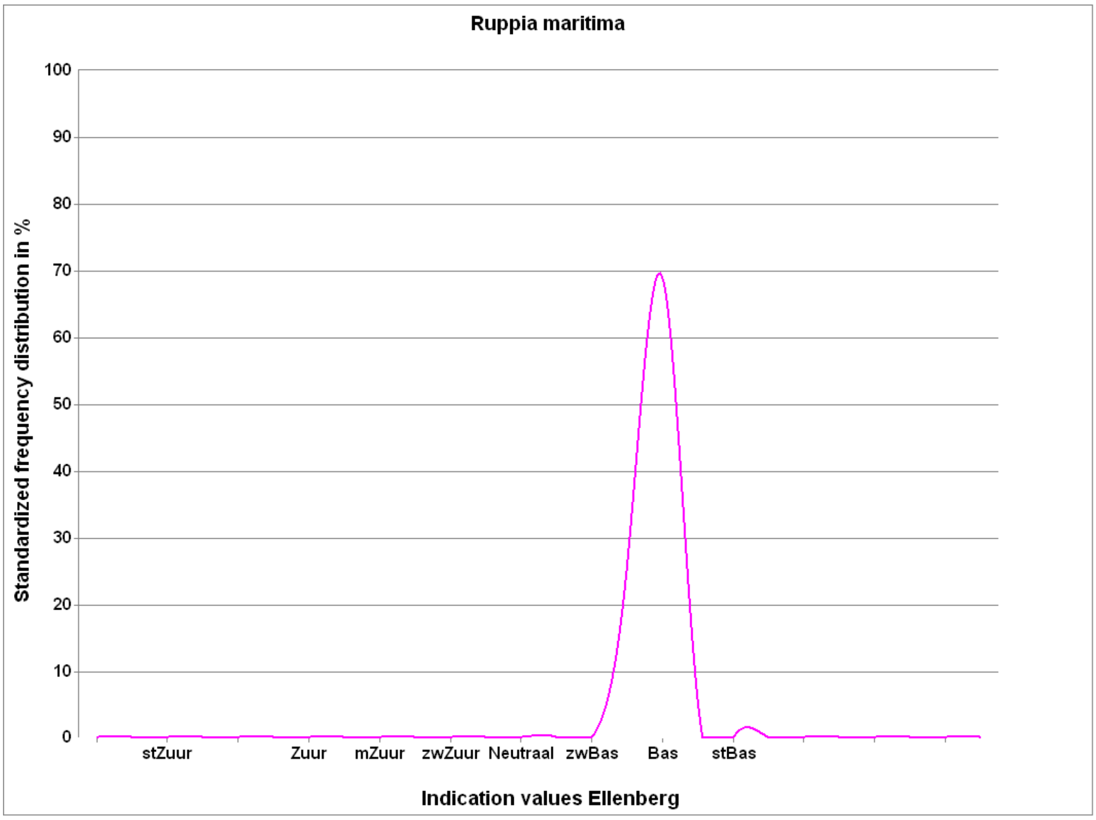

Najas marina
Standardized frequency distribution in %
100
90
80
70
60
50
40
30
20
10
0
stZuur
Zuur
mZuur
zwZuur
Neutraal
zwBas
Bas
stBas
Indication values Ellenberg

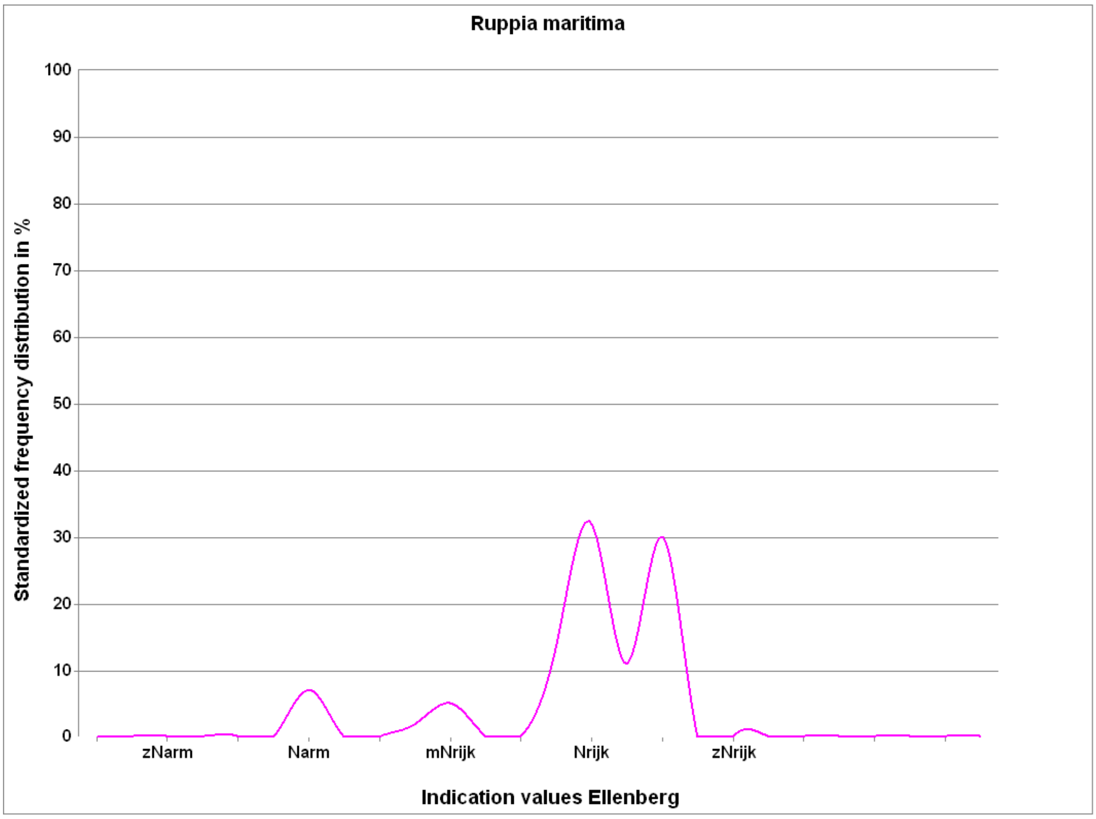

Najas marina
100
90
80
70
60
50
40
30
20
10
0
Standardized frequency distribution in %
zNarm
Narm
mNrijk
Nrijk
zNrijk
Indication values Ellenberg

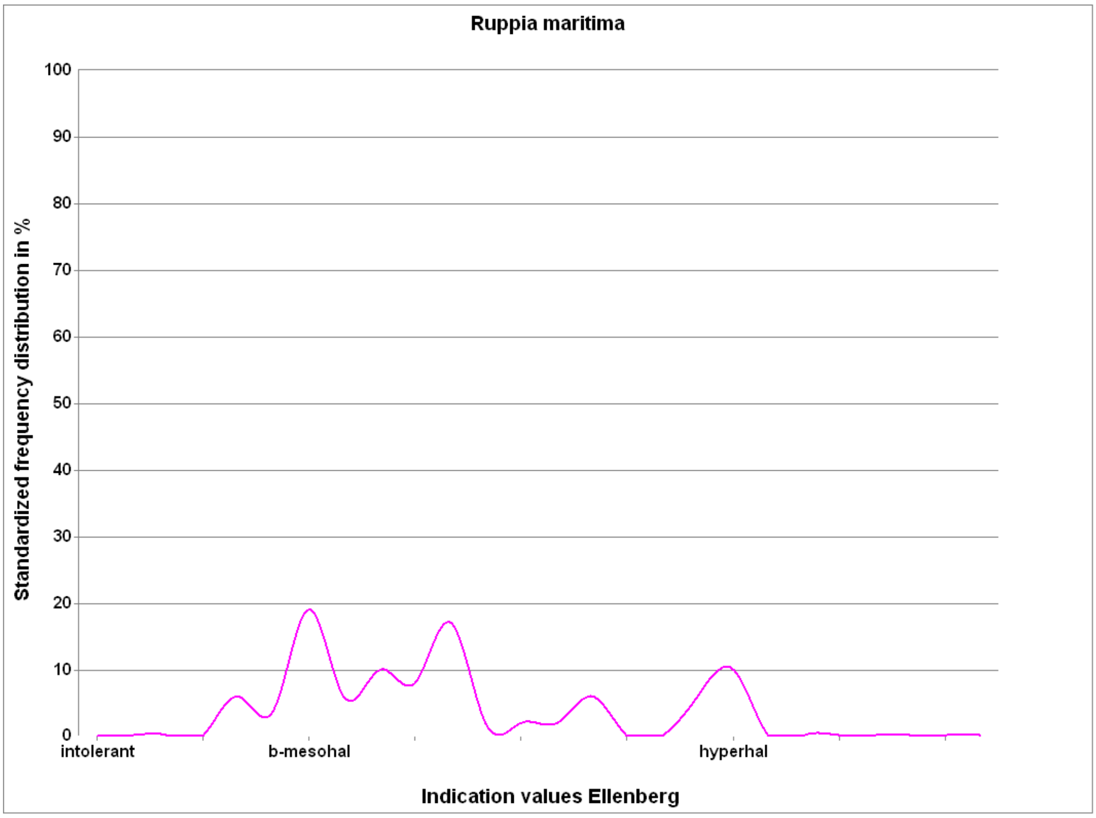

Najas marina
100
90
80
70
60
50
40
30
20
10
0
Standardized frequency distribution in %
intolerant
b-mesohal
hyperhal
Indication values Ellenberg

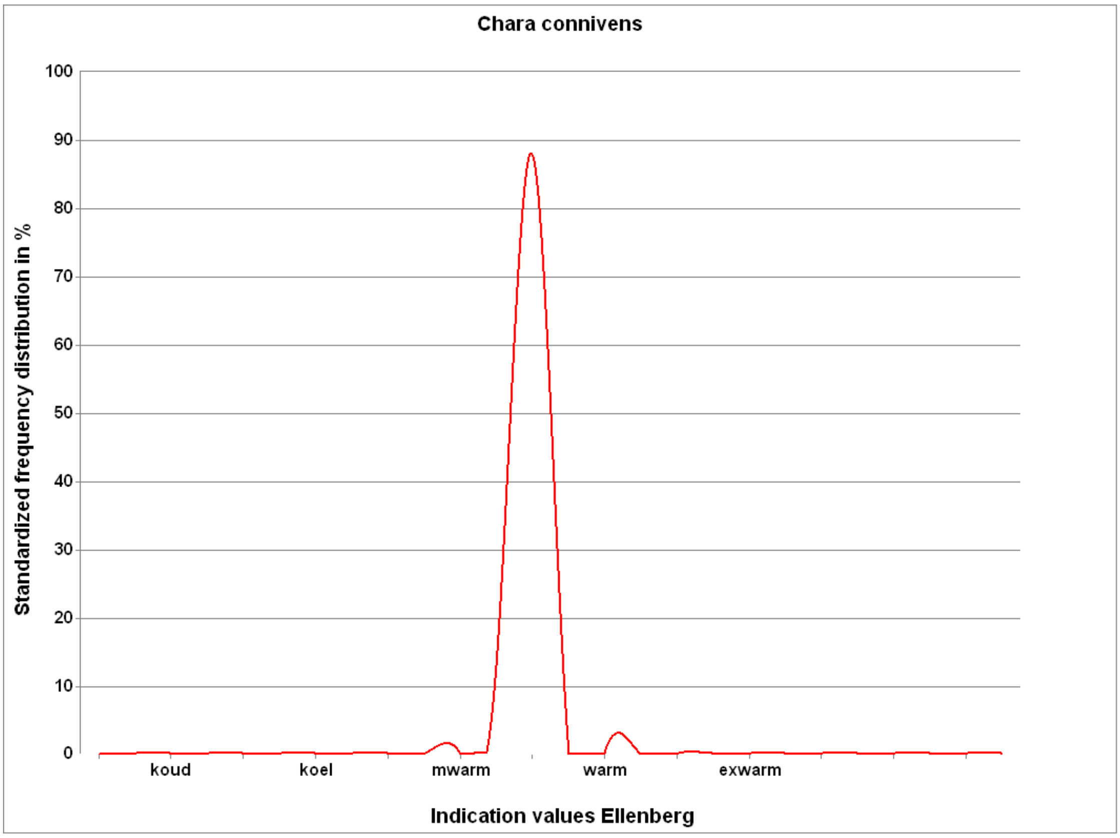

Ruppia maritima
Standardized frequency distribution in %
100
90
80
70
60
50
40
30
20
10
0
koud
koel
mwarm
warm
exwarm
Indication values Ellenberg

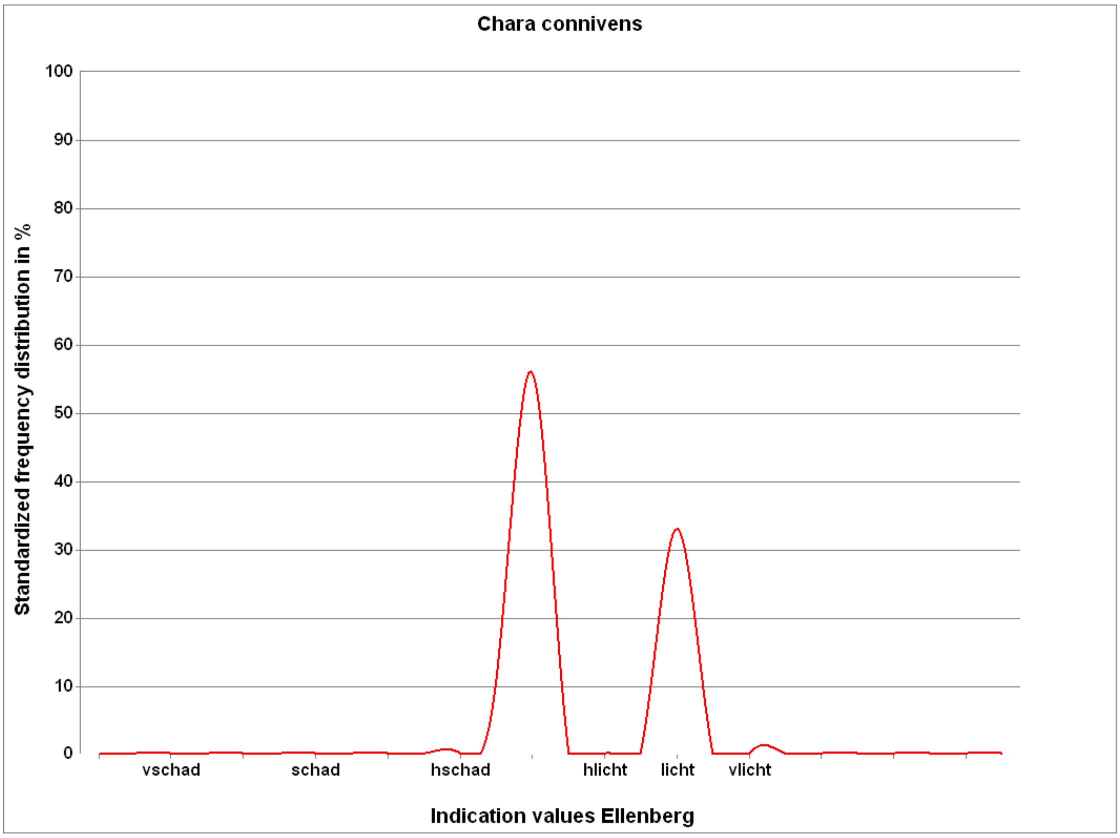

Ruppia maritima
Standardized frequency distribution in %
100
90
80
70
60
50
40
30
20
10
0
vschad
schad
hschad
hlicht
licht
vlicht
Indication values Ellenberg

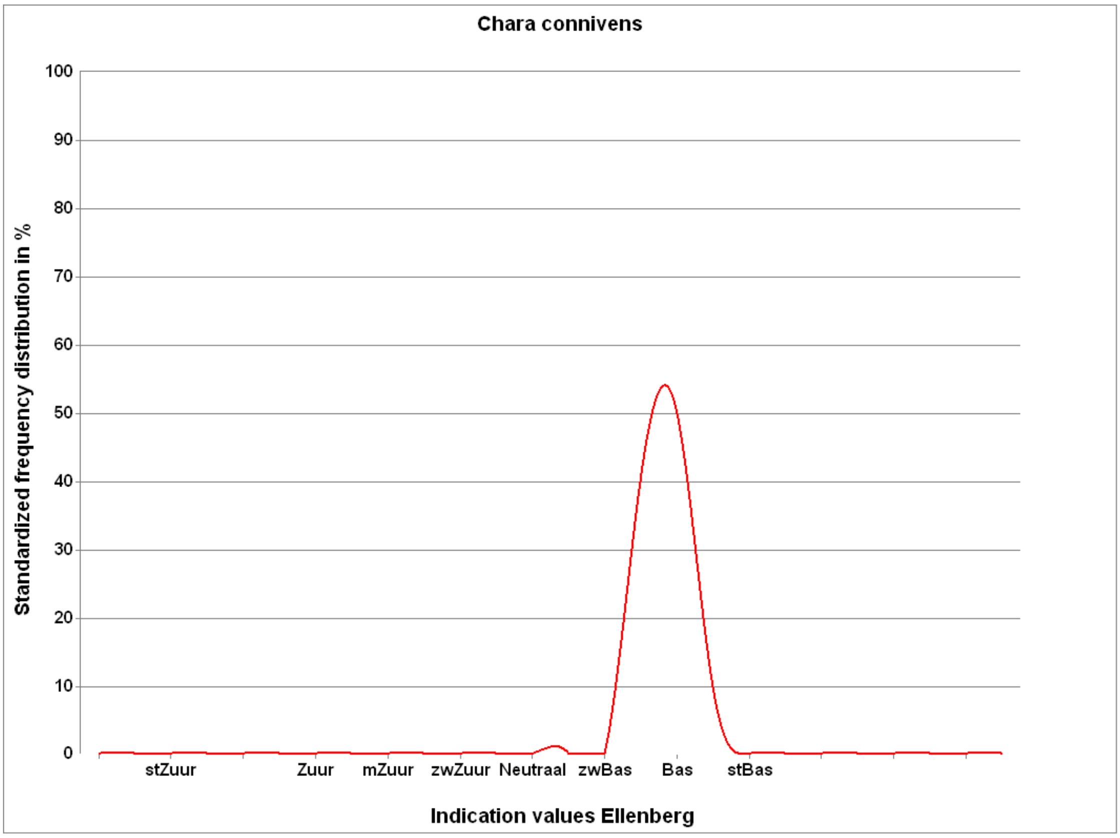

Ruppia maritima
Standardized frequency distribution in %
100
90
80
70
60
50
40
30
20
10
0
stZuur
Zuur
mZuur
zwZuur
Neutraal
zwBas
Bas
stBas
Indication values Ellenberg

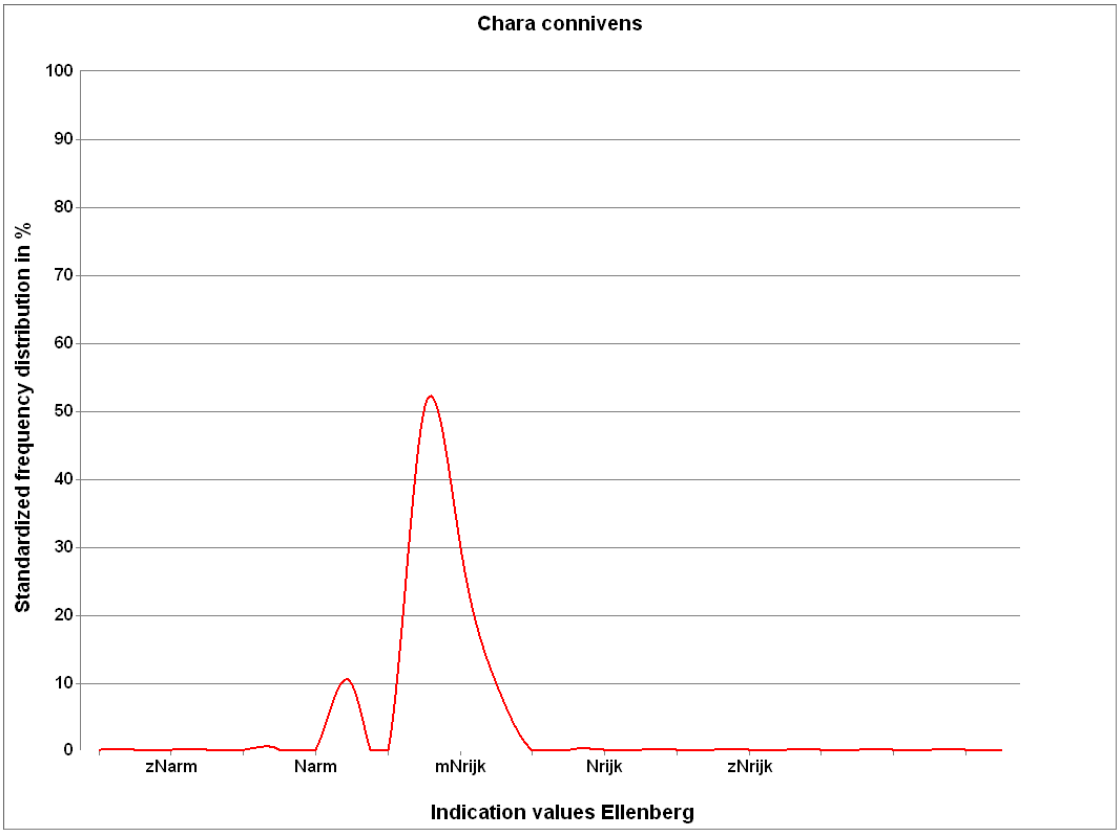

Ruppia maritima
Standardized frequency distribution in %
100
90
80
70
60
50
40
30
20
10
0
zNarm
Narm
mNrijk
Nrijk
zNrijk
Indication values Ellenberg

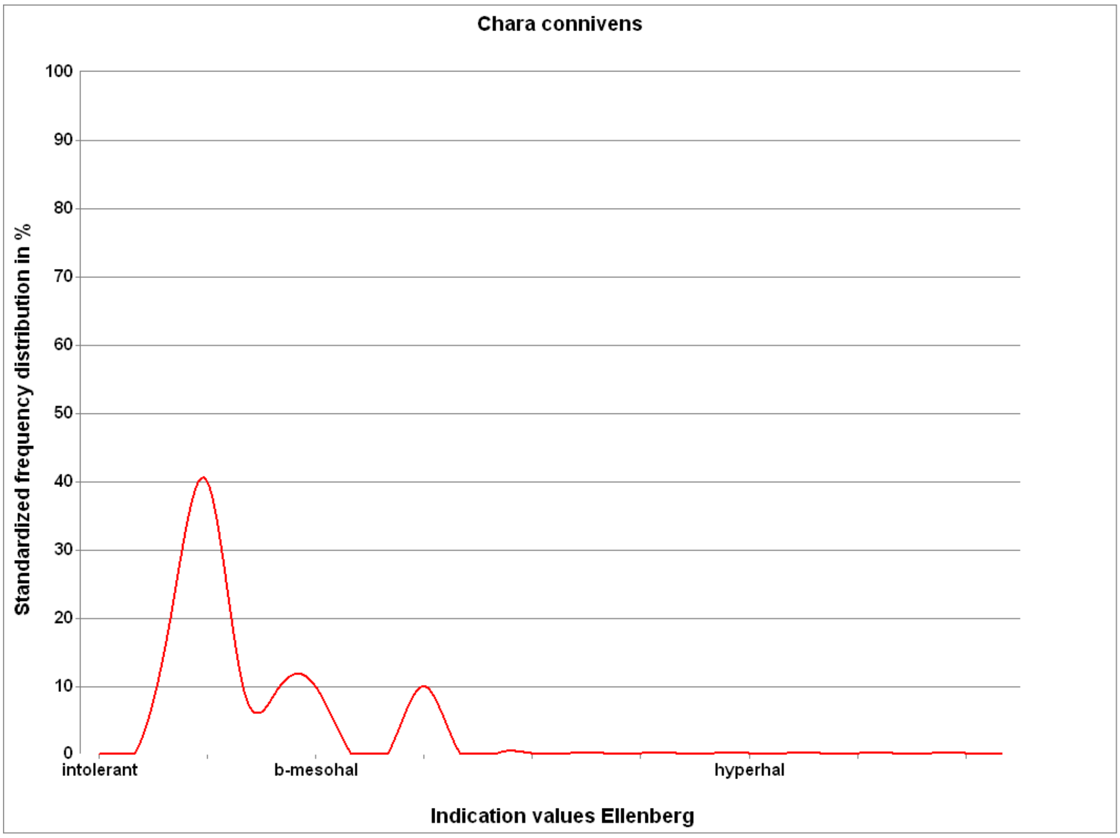

Ruppia maritima
Standardized frequency distribution in %
100
90
80
70
60
50
40
30
20
10
0
intolerant
b-mesohal
hyperhal
Indication values Ellenberg

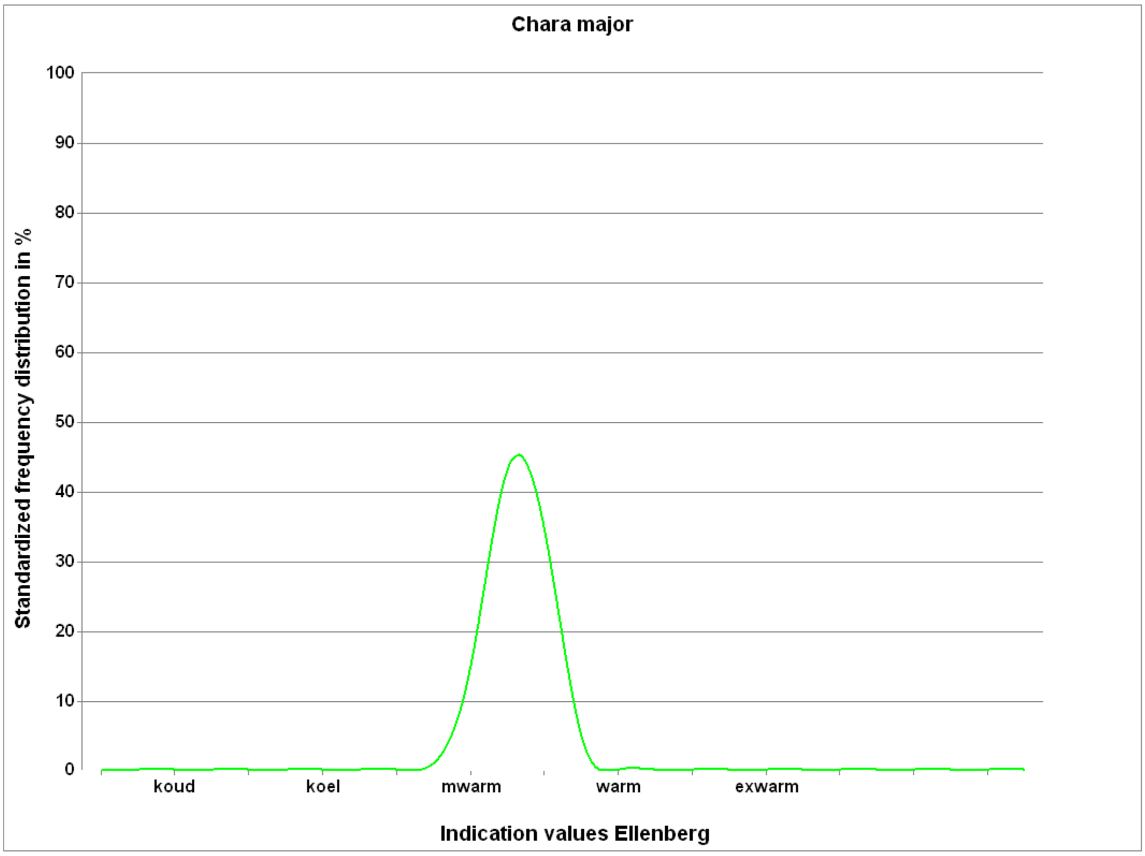

Chara connivens
Standardized frequency distribution in %
100
90
80
70
60
50
40
30
20
10
0
koud
koel
mwarm
warm
exwarm
Indication values Ellenberg

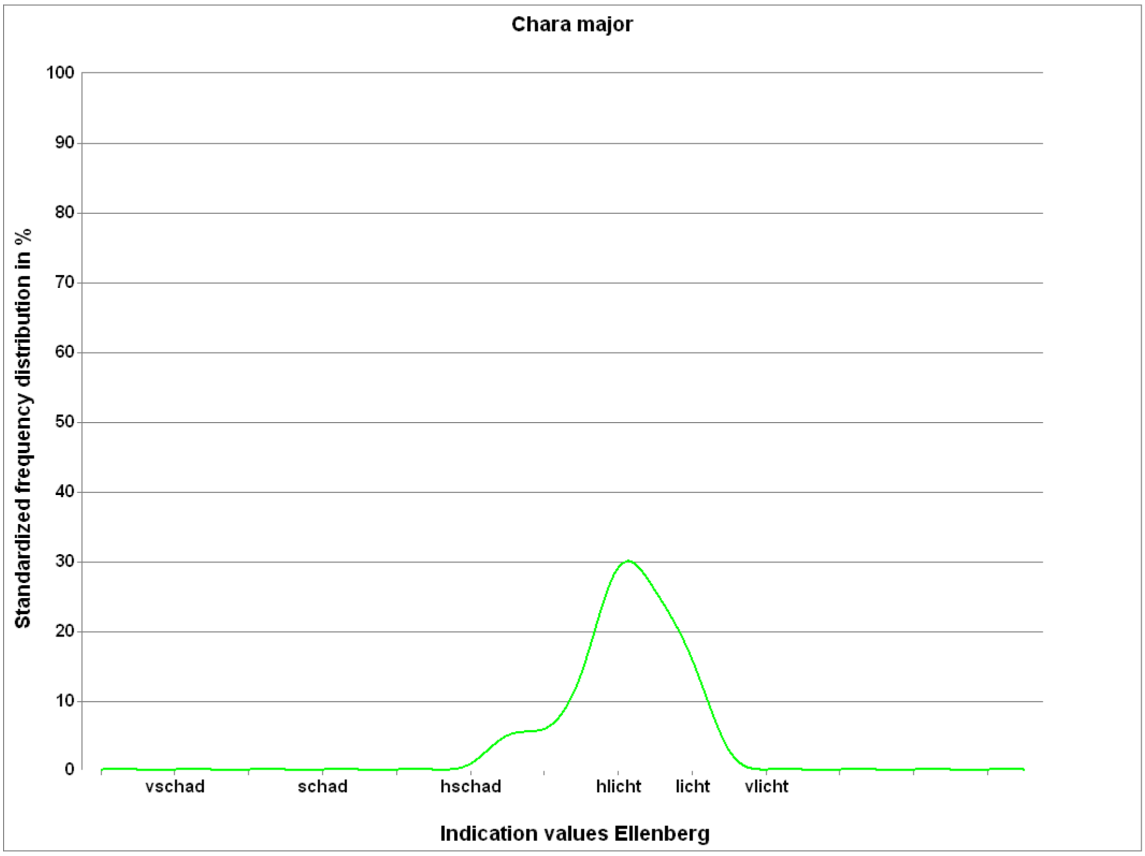

Chara connivens
Standardized frequency distribution in %
100
90
80
70
60
50
40
30
20
10
0
vschad
schad
hschad
hlicht
licht
vlicht
Indication values Ellenberg

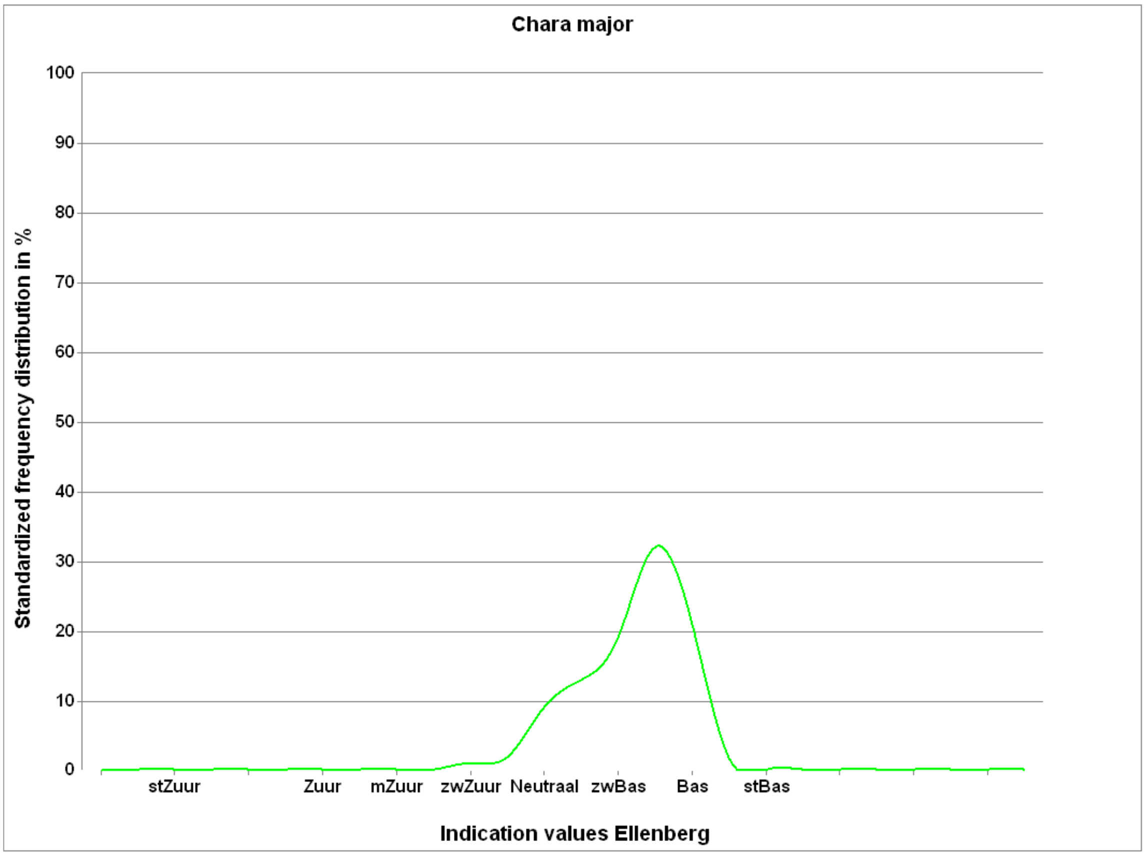

Chara connivens
Standardized frequency distribution in %
100
90
80
70
60
50
40
30
20
10
0
stZuur
Zuur
mZuur
zwZuur
Neutraal
zwBas
Bas
stBas
Indication values Ellenberg

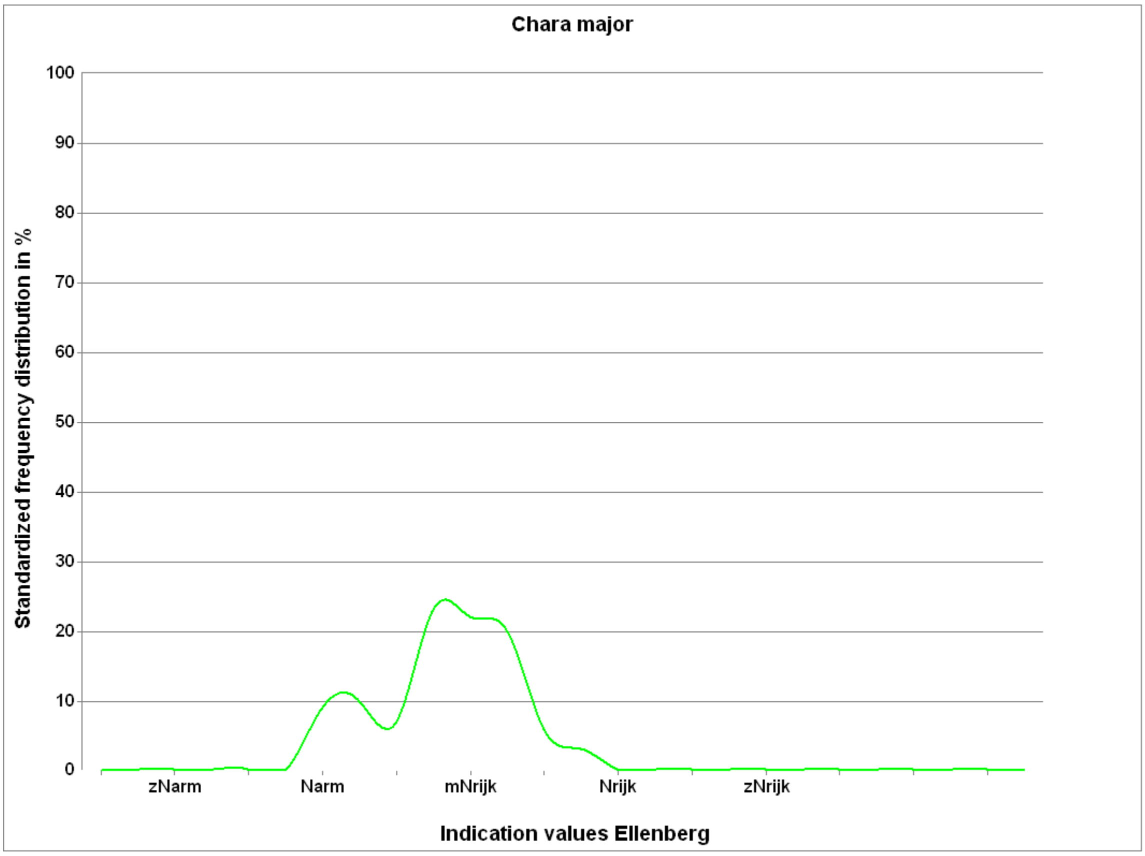

Chara connivens
Standardized frequency distribution in %
100
90
80
70
60
50
40
30
20
10
0
zNarm
Narm
mNrijk
Nrijk
zNrijk
Indication values Ellenberg

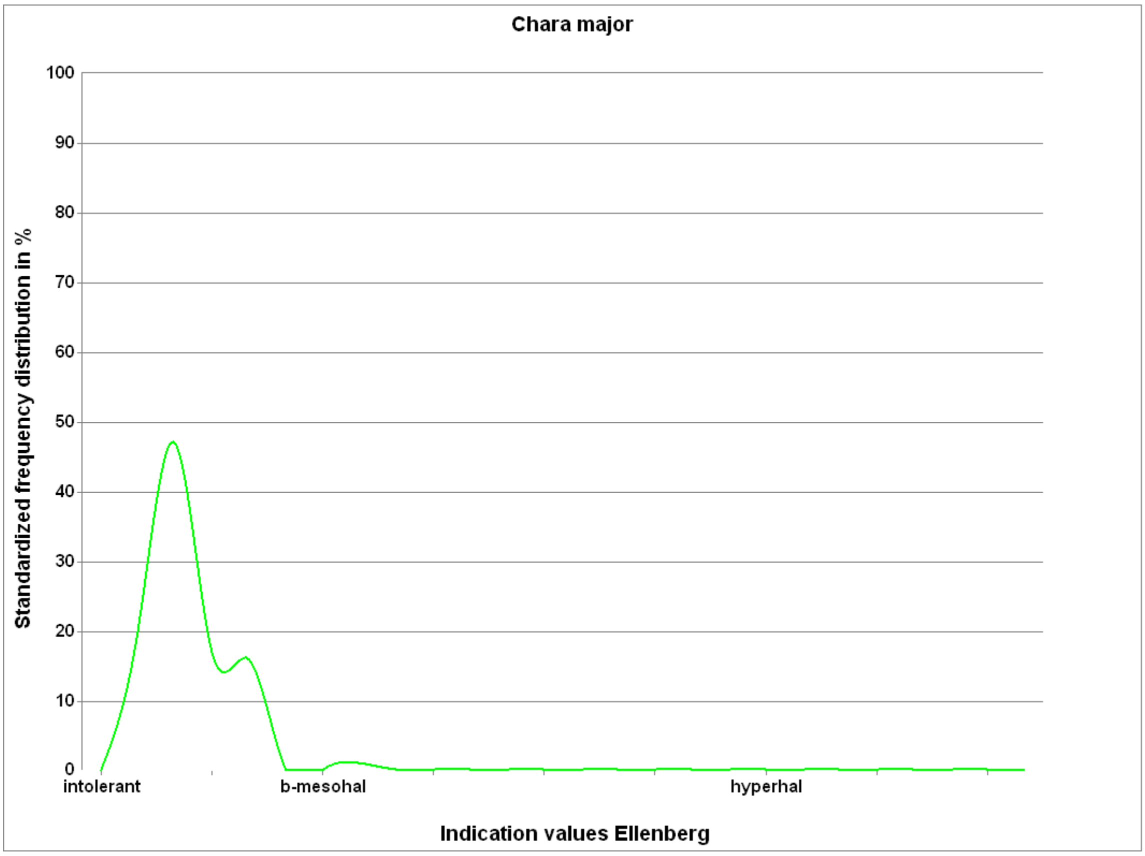

Chara connivens
Standardized frequency distribution in %
100
90
80
70
60
50
40
30
20
10
0
intolerant
b-mesohal
hyperhal
Indication values Ellenberg


Chara major
100
90
80
70
60
50
40
30
20
10
0
Standardized frequency distribution in %
koud
koel
mwarm
warm
exwarm
Indication values Ellenberg


Chara major
100
90
80
70
60
50
40
30
20
10
0
Standardized frequency distribution in %
vschad
schad
hschad
hlicht
licht
vlicht
Indication values Ellenberg


Chara major
100
90
80
70
60
50
40
30
20
10
0
Standardized frequency distribution in %
stZuur
Zuur
mZuur
zwZuur
Neutraal
zwBas
Bas
stBas
Indication values Ellenberg


Chara major
100
90
80
70
60
50
40
30
20
10
0
Standardized frequency distribution in %
zNarm
Narm
mNrijk
Nrijk
zNrijk
Indication values Ellenberg


Chara major
100
90
80
70
60
50
40
30
20
10
0
Standardized frequency distribution in %
intolerant
b-mesohal
hyperhal
Indication values Ellenberg