# Peipsi and IJsselmeer for mutual reference

Colophon

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# In the mirror of a lake

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# Foreword

Managing large territories is not an easy task, all the more so if the greater part of the territory consists of water, as is the case with large lakes. In the recent past, water management was directed merely at water quantity, water quality and the various users such as fishery, sand and drinking water extraction, transport and recreation. However, recent European legislation, such as the Water Framework Directive and Birds and Habitat Directive, aims to achieve an integrated management strategy, with a balanced position of the user functions while at the same time safeguarding the existing natural values. Applying a conceptual strategy with clear and relevant goals for the natural environment requires knowledge of different fields. For smaller water bodies such as streams and small lakes and fens, a lot of information is available on a national scale and the classification of these water bodies is not too difficult. Large lakes, however, do not have many reference points in Europe and thus one has to compare the present situation with a few relevant examples at a much larger distance.

For the IJsselmeer area we now can compare the situation with that of Lake Peipsi. We are glad we can look back at a series of five fruitful years of international collaboration with our Estonian and Russian colleagues. In our opinion the project was a success, in many aspects. Apart from the exchange of information, which has served the process of mutual learning very much, the teamwork resulted in many alliances and new projects have started from the partnership in this troika of nationalities.

Already during the course of the project the spin-off was clear; several projects in the IJsselmeer area benefited from the insights of the project. Moreover the stakeholder tours to Peipsi have increased the awareness of how important habitat scale and completeness is in relation to the natural functioning of the lake. We are convinced that the local authorities in Estonia and Russia will make good use of the findings presented here. It goes without saying that the learning benefits were mutual.
We want to congratulate the project team with the jointly achieved results and look forward to extended initiatives following the present collaboration.

Fred Delpeut
General Director
Rijkswaterstaat
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General Director
Rijkswaterstaat
Centre for Water Management


Waddenzee
Kornwerderzand
Makkum
Afsluitdijk
Breezanddijk
Workum
Hindeloopen
Den Oever
Molkwerum
Stavoren
Steile Bank
Lemmer
Medemblik
IJSSELMEER
Enkhuizen
Emmeloord
Urk
Hoorn
Zwarte meer
Markermeer
Ketelmeer
Kampen
Vossemeer
IJssel
Lelystad
Drontermeer
Volendam
Marken
Oostvaardersplassen
Veluwemeer
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Amsterdam
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ESTONIA
RUSSIA
Slantsy
Narva River
Smolnitsa
Gostitsy
Rannapungerja
Plyussa River
Lohusuu
Kozlov Bereg
Mustvee
Polichno
Omedu
Gdov
Ranna
Gdovka River
Plyussa River
Kodavere
Kallaste
PEIPSI
Lahepera
Lahepera lake
Klenno
Spitsyno
Plyussa River
Varnja
Zalakhtov'
Raskopel'
Koosa lake
Praaga
Yamm
Emajõgi River
Emajõgi River
Meerapalu
Kalli lake
Piirissaar Island
Zhelcha River
Tartu
Leegu lake
Podborov'e
Remda
Samolva
Mehikoorma
Chernaya River
Pnevo
Put'kovo
Lämmijärv
Baglitsy
Mtezh
Räpina
PIHKVA
Lüübnitsa
Tolba River
Drislivik
Põlva
Talabskije Islands
Lis'e
Kamenka Island
Molozhva
Piusa River
Velikaya River
Pechory
Pskov
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ESTONIA
RUSSIA
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30 km

# Introduction and background

Mennobart van Eerden

Lake Peipsi (Peipsi-Pihkva Järv in Estonian and Pskovskoe-Chudskoye Ozero in Russian language) is located on the Estonian-Russian border. With its 3,500 km$^2$ it is one of the largest shallow lakes in Europe. This lake, from now on called Lake Peipsi, bears many resemblances to a Dutch lake complex consisting of Lake IJsselmeer, Lake Markermeer and Borderlakes (2,000 km$^2$) and can therefore serve as a reference for the natural stage of a large lowland lake. The lake is known for the existence of large wetlands in the surroundings (Carp 1980, Commission of the European Communities 1995).

In October 1998, the basis for future co-operation was established during a reconnaissance mission to Lake Peipsi. Work for the Pan-European Wetland Inventory corroborated the parallels between Peipsi and IJsselmeer at a European scale (Nivet and Frazier2004). Further enhanced by the requirements set by the Water Framework Directive to define and elaborate management objectives for the so-called Good Ecological Potential (GEP), plans have been developed to start a comparative project with a focus on Lake Peipsi.

As a result, managers of Rijkswaterstaat Directorate IJsselmeergebied and specialists from Rijkswaterstaat RIZA familiar with the Dutch Lake IJsselmeer visited the area of Lake Peipsi in June 2001 and again in June 2002. They arranged meetings with both Estonian and Russian specialists (Van Eerden *et al.*, 2001). These visits resulted in a seminar in The Netherlands in December 2002, where Russian and Estonian managers and scientists exchanged information with their Dutch counterparts. The seminar also included visits to institutes and field locations. And most importantly, all three parties discussed ways for future co-operation.

In 2003 the project's structure and objectives were finalised and fieldwork and activities started. Between 2003 and 2006 the project was carried out according to year plans, which finally resulted in this publication.

**Lake Peipsi and Lake IJsselmeer as mutual mirrors**

The IJsselmeer area is highly developed, while the ecology and the landscape are under increasing pressure. Dikes make up its coastline and its water tables are maintained at fixed levels. Contrary, the natural values of Lake Peipsi are rather undisturbed, However, a tendency towards further economical development is visible. In the field of ecology the Dutch can learn from the Russian and Estonian situation, while, on the other hand, the Russians and Estonians may take advantage of the organisational and economical development in The Netherlands.

Both lakes are shallow, which sets them apart from other large European lakes, such as Lake Geneva in Switzerland and Lakes Vänern/Vättern in Sweden. Many of the groups of organisms living in the lakes are the same. Water birds use the same flyway and form a direct link between Peipsi and IJsselmeer. Also, both food webs show striking resemblances. Algae, macrophytes, plankton, benthos, fish, and insects are often represented by the same species. For instance, the finding that Smelt *Osmerus eperlanus* and Zebra Mussels *Dreissena polymorpha* play a crucial role in both systems was of such significance that a joint project was set up. Of course there are differences as well, but this makes the project only more interesting. Although comparison is the basis for the reference approach (with emphasis on aspects like habitat scale, naturalness and ecology), the differences also set the scene for in-depth understanding of the processes. By comparing the situation in both regions, one may arrive more easily at the required insights for each separate system. As monitoring datasets of both systems reach back more than 75 years, there was a need for synthesis rather than for completely new studies. More to the west of Lake Peipsi is Lake Võrtsjärv, which is smaller but lies in the same catchment area. The physical conditions of Lake Võrtsjärv, with much suspended matter in the water column, resemble those in Lake Markermeer, reason to compare these two lakes. Furthermore, the connecting river Emajõgi has extended floodplains where the hydrological conditions are still intact, which is why this area was chosen as a reference area for natural bog, fen and hayfield habitat.

**Project structure**

The project was initiated and financed by Rijkswaterstaat. Contracts were made with partners in Estonia and Russia in order to receive the required data in time. A master plan served as general outline for the project. Project clusters were defined and trilateral teams were formed to carry out the work. A general division was made between water- and land related subjects. Year-plans served as the annual basis for the work packages. These packages constituted the basis of the deliverables and are presented as separate chapters in this publication.

**Partner organisations**

Partner organisations were chosen on the basis of their type of activity in the region. For the scientific part in Estonia the Agricultural University of Tartu was a key player, whereas in Russia this was both the Pedagogical University and the Pskov department of GosNIORKH, the federal fisheries' institute, both located in Pskov. The Centre for Transboundary Co-operation in Tartu and NGO Chudskoye Project facilitated logistics and organisational affairs, including stakeholder meetings and awareness raising. In Table 1 the people are listed who bore a significant part in the project.

**Aims and goals: mutual reference for long-term management**

For IJsselmeer, reference to Peipsi directs the way for natural restoration (ranging from achieving an even better water quality and more natural water level fluctuations to spatial planning of new wetlands and a better coherence of habitats). Study of the situation at each system is facilitated by the existence, on both sides, of large databases concerning specific aspects. The wish to integrate these into detailed management concepts was the driving force behind the new project.

For Peipsi, where natural conditions still prevail, comparison with IJsselmeer is of help in formulating directives for integrated water management, based on knowledge developed in The Netherlands. The administrative organisation, the presence of water boards in the hinterland, the functioning of locks, shipways and high-tech water purification plants are aspects of interest for Lake Peipsi, although only superficially touched upon in this project during study tours. Moreover, the consequence of loss of natural values of the intensively used water system is an obvious point of interest.

Obvious goals for Peipsi would be the preservation of the high level of biodiversity, the establishment of the concept of sustainable use of natural resources such as fish, elimination of pollution and stimulation of eco-tourism.

**Table 1.** *Partner organisations and persons contributing to the implementation of the project*

| Person | Organisation |
|---|---|
| *Russia* | |
| Mr. Vladimir Borisov | Zoology Department, Teacher Training Institute, Pskov, Russia |
| Mrs. Marina Melnik | Pskov Dept. of State Inst. of Fish Resources GosNIORKH, Pskov Russia |
| Mr. Victor Musatov | Administration for Natural Resources and Ecology of Pskov Oblast, Russia |
| Mr. Sergey Timofeev | NGO 'Chudskoye Project' office, Pskov, Russia |
| Mrs. Olga Vassilenko | NGO 'Chudskoye Project' office, Pskov, Russia |
| Mrs. Olga Zhuravkova | Zoology Department, Teacher Training Institute, Pskov, Russia |
| *Estonia* | |
| Mrs. Külli Kangur | Agricultural University, Võrtsjärv Limnological Station, Estonia |
| Mrs. Kati Kangur | Agricultural University, Võrtsjärv Limnological Station, Estonia |
| Mr. Andres Kuresoo | Agricultural University, Institute of Zoology and Botany, Tartu, Estonia |
| Mr. Leho Luigujõe | Agricultural University, Institute of Zoology and Botany, Tartu, Estonia |
| Mrs. Lea Vedder | Center for Transboundary Co-operation (CTC), Tartu. Estonia |
| *The Netherlands* | |
| Mr. Gert Butijn | RWS/Regional Directorate IJsselmeer area, Lelystad, The Netherlands |
| Mr. Roel Doef | RWS/Regional Directorate IJsselmeer area, Lelystad, The Netherlands |
| Mr. Mennobart van Eerden | RWS/Centre for Water Management, Lelystad, The Netherlands |
| Mr. Hans den Hollander | RWS/AGI, Delft, The Netherlands |
| Mr. Luc Jans | RWS/Centre for Water Management, Lelystad, The Netherlands |
| Mr. Eddy Lammens | RWS/Centre for Water Management, Lelystad, The Netherlands |
| Mrs. Sophie Lauwaars | RWS/Regional Directorate IJsselmeer area, Lelystad, The Netherlands |
| Mrs. Gerda Lenselink | RWS/Centre for Water Management, Lelystad, The Netherlands |
| Mrs. Ute Menke | RWS/Centre for Water Management, Lelystad, The Netherlands |
| *Organisation* | |
| Mr. Henk Bos | RWS/Centre for Water Management, Lelystad, The Netherlands |
| Mrs. Marina de Vries | RWS/Centre for Water Management, Lelystad, The Netherlands |

More specifically, we formulated four questions in two major fields of attention that served as focal points throughout the study:

***Patterns and processes in the open water areas of Lake Peipsi and Lake IJsselmeer***

*Key question 1:* how does nutrient load via the incoming rivers affect the state of the system?
- Focus on algal production, benthos, fish and bird communities

*Key question 2:* how does the suspended silt load of Lake Markermeer and Lake Võrtsjärv affect the ecosystem and natural values?
- Focus on algal production, benthos, fish and bird communities

***Patterns and processes in adjacent floodplains in the hinterland of Peipsi and IJsselmeer***

*Key question 3:* how do natural fluctuations of the water table at the lake affect the functioning of shoreline vegetation?
- Focus on emergent macrophytes, spawning of fish, amphibians and birds

*Key question 4:* how does habitat scale and connectivity contribute to the occurrence of natural values and general ecological functioning?
- Focus on biodiversity issues, buffering and resilience effects.



### Outline of this book

Part one of this book describes the main activities carried out throughout the period of implementation of the project (2003-2006). The purpose of this part is to address the context of international regulations, point to the general issue of a reference study for mutual benefit and outline the main methods applied. The exchange of information was one of the major goals of this project. Joint missions served to get acquainted with each other's situation. Rather than based on literature data, the personal experience of people contributed very much to the understanding of the data. As such, this is a methodological aspect of the project, which is therefore dealt with in this part.

Part two compares the general features of Peipsi and IJsselmeer. The purpose of this chapter is to provide an overview of the general aspects in both lakes, in pictures, topography, scenery and population. Emphasis is put on the similarities but also on the differences, which are mainly caused by the level of human occupation.

Part three forms the backbone of the study; lakes are compared, both at the level of open water and on the level of adjacent floodplain and associated landscapes. The purpose of this part is to provide general information on the specific situation of both lake systems, concentrating per chapter on:
- Status of present situation, with a focus on 2000-2005 as most important years
- Spatial distribution of the present situation; north-south gradients, with reference to Võrtsjärv where relevant, emphasis on spatially distinct "hotspots", etc. Trends over time with respect to spatial distribution may illustrate important shifts in the system
- Trends; comparing the situation around 1980-1985 to that of 2000-2005 and pointing out main directions and possible causes.

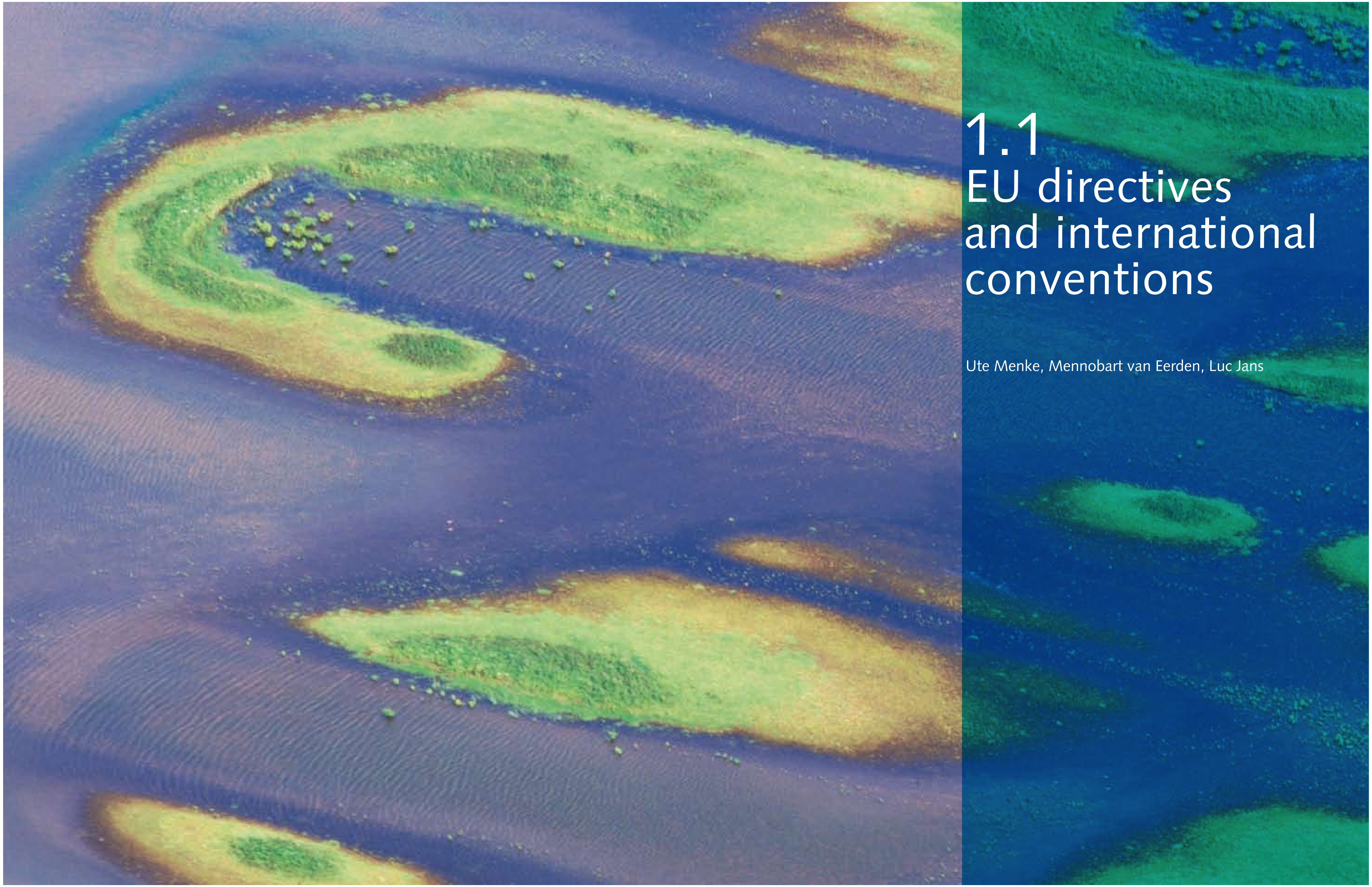
As time was limited, priority was given to 1) and 2), with focal years 1976, 1985, 1987, 1996, 1999 and 2002, (years refer to Landsat imagery for Lake Peipsi).

### Future plans

Methods for managing water quantity, the use of models in forecasting safety and water quality issues are examples of the direction of future work. For both lakes the use of models will become increasingly important in order to forecast the future situation. At the same time, great effort will have to be put in monitoring as well as unravelling some key questions. Climate change is another factor of mutual concern; both lake systems are affected, but probably not in identical ways, depending on geographical position and state of the system. At the edge of the distribution of a species a small change may cause big effects compared to a similar change for another species for which the lake has a more central position with regard to its distribution.
The effects of utilisation of a habitat are also of interest to managers of both lake systems. While Lake IJsselmeer is already used intensively, Lake Peipsi will also face an increasing demand for the use of natural resources. Formerly the demand was only on fish, while in future transport and recreational pressure will increase. It is quite likely that Lake Peipsi can benefit a great deal from comparing the developments in IJsselmeer that have been recorded over the past fifty years.

# 1

# Framework and methods



# 1.1 EU directives and international conventions

Ute Menke, Mennobart van Eerden, Luc Jans

A description of the current status and the recent ecological functioning of Lake Peipsi can support the management of Lake IJsselmeer in setting realistic as well as ambitious goals for the Water Framework Directive. On the other hand, the intensively managed IJsselmeer can be a source of inspiration and information for future management of Lake Peipsi.

**Protected areas**

There are two major frameworks concerning the opportunities and obstacles for further developments in Lake Peipsi and Lake IJsselmeer. The oldest, the Ramsar Convention, dates back to 1971 and has more recently been followed by a number of EU Directives. The most important EU directives for the management of these large wetlands are: the Birds Directive (79/409/EEC), the Habitat Directive (92/43/EEC) and the Water Framework Directive (2000/60/EEC). Apart form these EU Directives, protection is guaranteed by designation of areas in accordance with the Ramsar Convention and national laws (e.g. designation of national parks). Figures 1 and 2 show an overview of the protected and/or assigned areas in both lake areas. Some areas are protected by more than one directive and/or convention.

The EC Bird and Habitat Directives serve to safeguard natural values and biodiversity. Important bird species are covered by the Bird Directive, whereas other animal and plant species are covered by the Habitat Directive. Large areas in both Lake IJsselmeer and Lake Peipsi comply with the criteria of international importance.
The IJsselmeer area with the lakes IJsselmeer, Markermeer, IJmeer, the Borderlakes and other water bodies are specially protected areas with respect to the Bird and Habitat Directive and belong to the Natura 2000 network.
The qualifying bird species for the IJsselmeer area are both breeding birds and migratory birds. The areas of the Habitat Directive are not fully agreed yet. Areas that have been reported to the EU are the Frisian Lake IJsselmeer coast, the Gouwzee, the coastal zone of Muiden, Lake Veluwemeer, Lake Wolderwijd and Lake Zwarte Meer.
Lake Peipsi, Lake Pihkva and Lake Võrtsjärv are typical lowland lakes. On the Estonian side, Lake Võrtsjärv and the north-eastern part of Lake Peipsi and part of the western shore are protected under Natura 2000. A very important area is Alam-Pedja in the floodplain and marshes of the river Emajõgi between Lake Peipsi and Lake Võrtsjärv.

**WFD: a new dimension**

Since the approval of the European Water Framework Directive (WFD) in December 2000, water management in the EU countries has a new dimension. All EU member states are obliged to monitor, evaluate and, if necessary, make restoration plans for the national water bodies, in order to reach the good ecological potential by 2015.
An important part of the evaluation is establishing reference conditions for the different types of water bodies. The reference condition is necessary to compare the water body's actual state with the desired one, as demanded by the WFD. Most water bodies in The Netherlands are more or less modified in such a way that it is impossible to trace back the original situation.





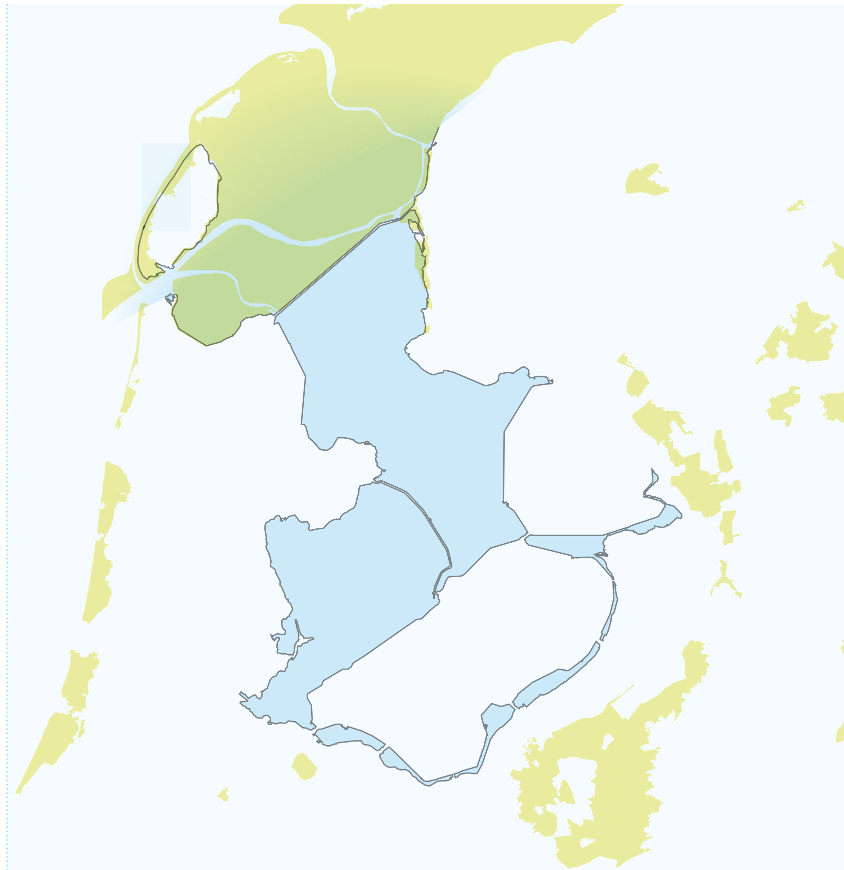


**Figure 1** *Protected areas IJsselmeer and surroundings (see text).*

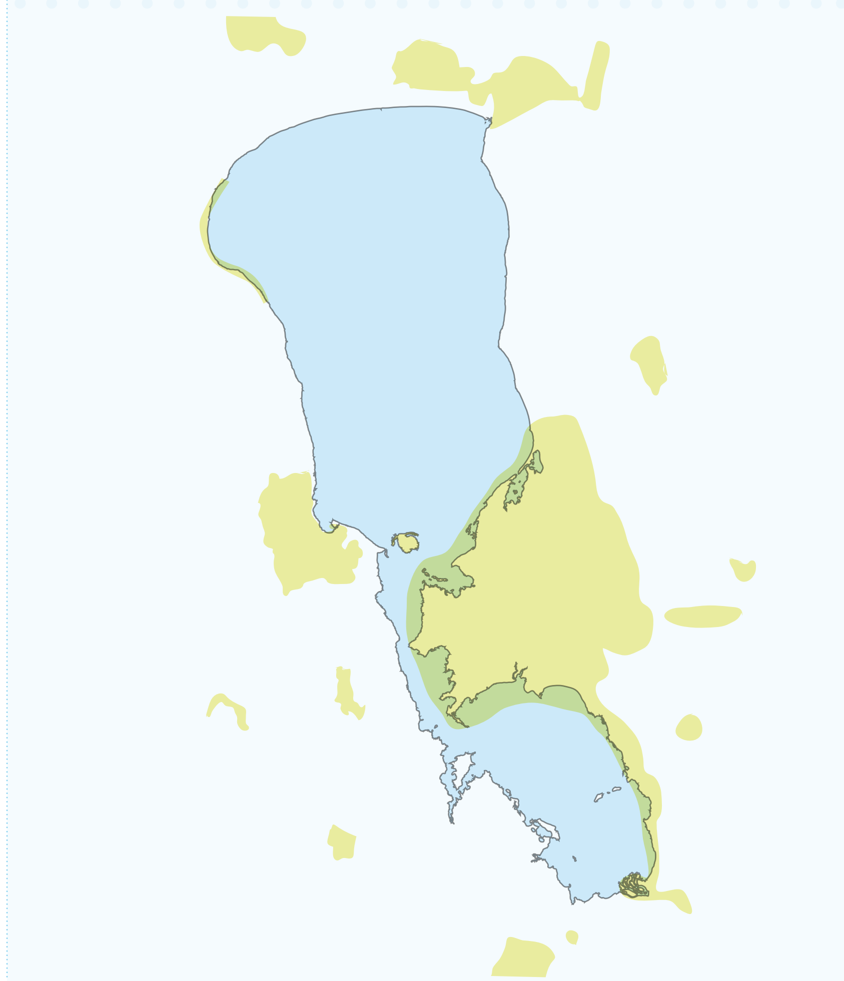


**Figure 2** *Protected areas Peipsi and surroundings (see text).*

Within the WFD obligation, every member state must define a catchment management plan (art. 13) including measures to reach a good ecological situation by 2015 or, in the case of heavily modified water bodies, to reach a good ecological potential (GEP). Besides, a good chemical condition must be achieved.
The hydro-morphological and physical-chemical conditions determine the possibilities of adapting a water body to the reference situation. Lake Peipsi, which lies on both sides of the boundary between Estonia and Russia, was identified as the most appropriate reference for Lake IJsselmeer. Although Lake Peipsi is not in its pristine state, it still has a natural water level fluctuation and a relatively low load of nutrients, while the connections with its natural hinterland are largely intact.
A description of the current status and the recent ecological functioning of Lake Peipsi can support the management of Lake IJsselmeer in setting realistic as well as ambitious goals for the Water Framework Directive. In the case of Lake IJsselmeer, the goals of the Maximum Ecological Potential/GEP will be based on the recent situation in order to define pragmatic goals. Co-operation with the Lake Peipsi partners and using this lake as a reference inspired the Dutch water managers. Focus was put on:

- The role of nutrients;
- The importance of more natural land-water transitions;
- The importance of more natural mouths of brooks and small rivers;
- The importance of connecting valuable habitats by creating corridors for fauna and flora;
- The role of habitat scale and level of disturbance.

Just like The Netherlands, Estonia is obliged to adapt its monitoring programme to the WFD standards and will have to evaluate the ecological, chemical and physical situation. If necessary it has to make a restoration plan. Russia has no legal obligation to the EU Directives, but shares with Estonia a common responsibility for the management of the lake.

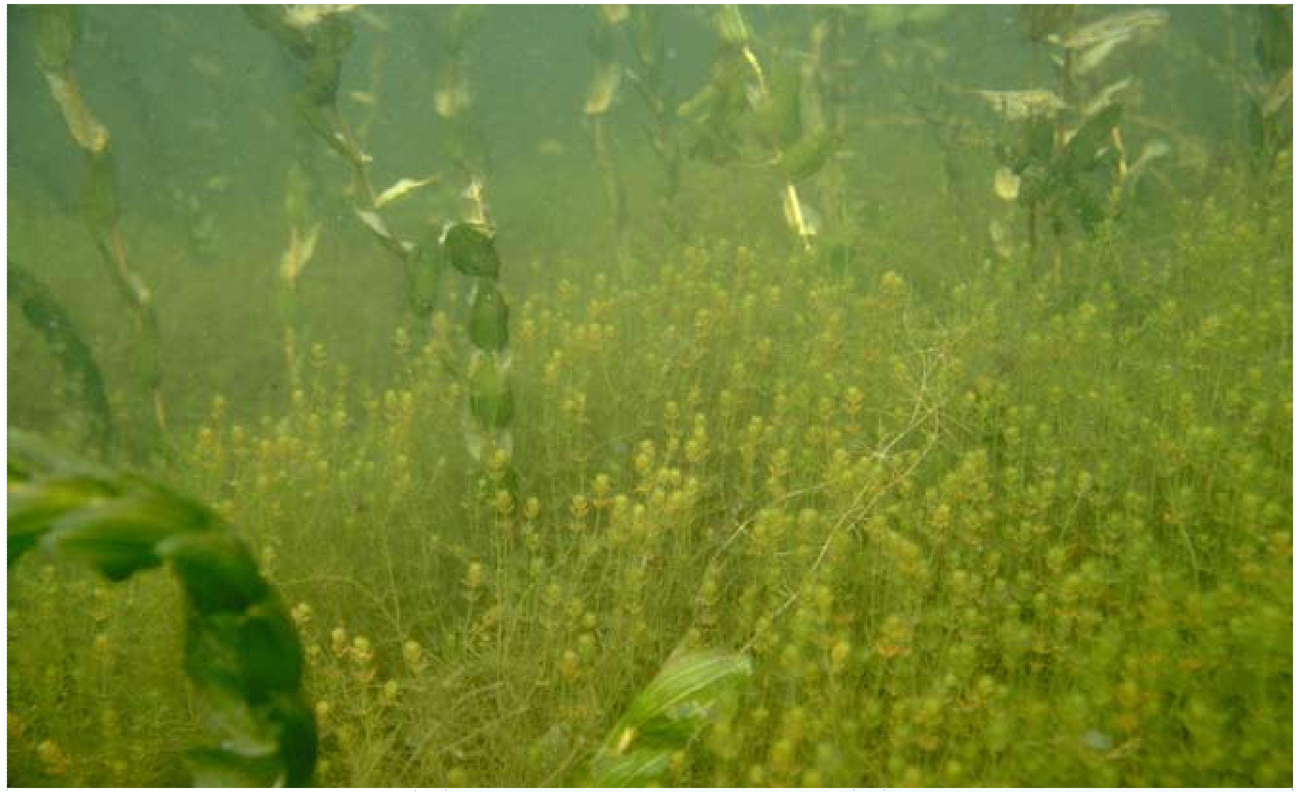
*Purification plants are indispensable to prevent water polution.*

**Table 1.** *Main characteristics of Lake IJsselmeer and Lake Peipsi*

| | IJsselmeer (& Markermeer) | Peipsi (& Võrtsjärv) |
|---|---|---|
| Water level | Fixed and managed (in winter 20 cm lower than in summer) | Almost natural with large seasonal variations, only one managed outlet |
| Hydro-morphological pressure | Very high; dikes, dams, developed infrastructure | Quite low; outlet work in the Lake Narva dam, in the north |
| Main pressures on ecosystem | Nutrient load (eutrophication) and fishery (although reduced considerably during the last 20 years); exotic species | Eutrophication and fishery, increasing grey market and poaching |
| Aquatic vegetation and emergent macrophytes | Limited occurrence due to artificial banks and shores and embankment of shallow zones | Dense fields of emergent vegetation; shores were grazed by cattle in the past |
| Ecological functioning | Stopover and wintering site for migratory birds; limited functions for plants, insects and large mammals; close to the sea | Well developed botanical values with extended role for various animal groups. Stop-over site during bird migration |

### Assessing the ecological condition of the lakes

To test the ecological condition of water bodies tools were developed in The Netherlands to compare the present ecological condition with the natural reference condition. During a workshop, these assessment tools ("M21=big shallow lakes") were applied in Lake IJsselmeer, Lake Markermeer, Lake Peipsi and Lake Võrtsjärv in order to get an idea of the relative ecological conditions of all four lakes and to test the applicability of these tools. They make use of specific characteristics of phytoplankton, macrophytes, macrofauna and fish. Applying the Dutch assessment tool (M21) proved unsuitable for the lakes Peipsi and Võrtsjärv. The observed bias is due to specific conditions in each lake system. It is therefore recommended to have the monitoring and the assessment method fine-tuned for each lake. Especially the requested data at the level of species cause bias and therefore lead to unrealistic results. Finally, it became clear that the warm 1990s caused a shift in the ecological conditions especially in these northern lakes and could be considered as a climatological constraint.



*Low nutient levels give room for clear water. Stoneworts and pondweed.*

In summary:

- Dutch assessment tool M21 is not applicable for Lake Peipsi and Lake Võrtsjärv
- Assessment tool should be adapted for each lake, taking into account area specific characteristics
- Variation in climate (water level and temperature) should be included in the assessment
- Main pressures are nutrients and fishery
- Weighted means should be used for assessment (open water plus littoral area)

  *It was highly recommended to come up with a site-based MEP and GEP for Lake IJsselmeer and Lake Markermeer but to use background information for these objectives from the present study.*

### Special position of The Netherlands

In The Netherlands almost 42% of all water bodies are classified as heavily modified water bodies (HMWB's) and another 43% as artificial water bodies (AWB's). Notice the special position of The Netherlands in Figure 3. The EU's emphasis concerning these Heavily Modified Water Bodies is on aiming to reach a good ecological potential in the longer term. The objectives are not described in a very detailed manner; a certain degree of freedom is given to the

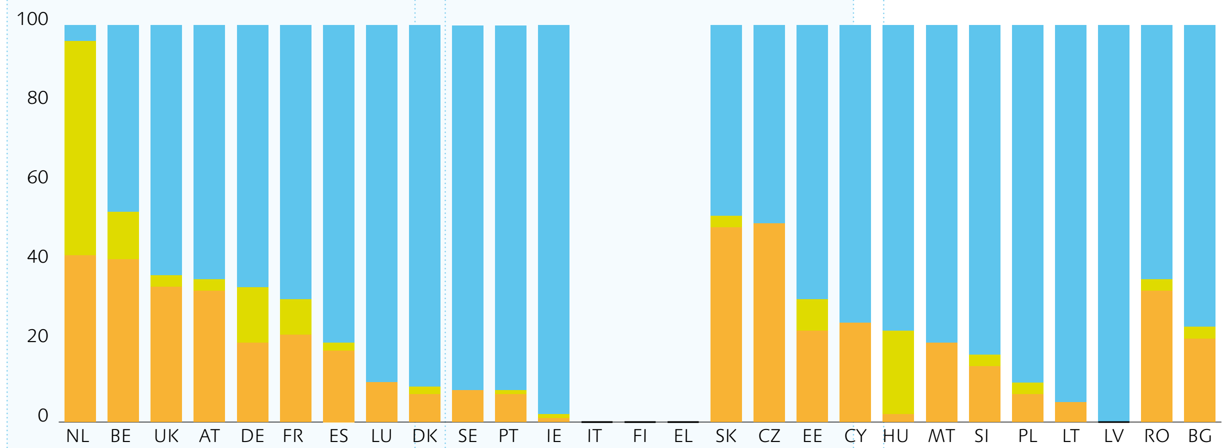



**Figure 3.** *Percentages of provisionally identified Heavily Modified Water Bodies for the EU-15, EU-25 and EU-27 countries. (orange = HMWB), Artificial Water Bodies (green = AWB) and Natural Surface Water Bodies (light blue = NSWB) per Member State (based on data reported by Member States). (NL=The Netherlands; EE=Estonia) Source: COM 2007.*

policy makers as well as the water managers. In case technical and/or financial conditions hamper timely implementation (restoration), the objectives may be changed.

In The Netherlands the Ministry of Transport, Public Works and Water Management (Ministerie van Verkeer en Waterstaat, 2007) is very much in favour of combining the improvement of the landscape or regional quality with implementing the WFD measures. Landscape quality is not a very clearly defined term; every region with its inhabitants and various stakeholders has its own objectives. In any case, the ministry will come up with one catchment plan for the IJsselmeer area that includes the development objectives of the WFD as well as the management plans of the Natura 2000 sites.

In Estonia, the situation is quite different from that in The Netherlands with only 25% of the water bodies designated as HMWB's. A small percentage of about 7% is AWB (Figure 3). Most water bodies are still natural. The Narva River/Lake Peipsi basin is not designated as a transboundary River Basin District (RBD) to the WFD yet, because of the uncertainties for Russia to meet the (anticipated) requirements (EWA, 2004).





**Peipsi, a part of IJsselmeer**
*Mennobart van Eerden*
*For the first time I discovered the area of Peipsi in 1996, while working on the Pan European Wetland Inventory together with Wetlands International. From that time on it was clear to me that Lake Peipsi could be a reference for IJsselmeer. I'm glad we had the opportunity to get a project running, with three nationalities which formed the basis of a series of good products and a series of new friendships.*

*Highlights were several, the visit of the bog islands in Emajõe Suursoo with a Golden Eagle sneaking away; the aerial waterbirds count with Antonov 2 over Russian territory and that evening in Velikaya delta or the moment in Dalfsen when we could hand over the Van Veen grab to our Estonian and Russian colleagues. Also the display of Great Snipes at the lek at midnight was superb, or that endless rainy-day bog with berries near Pnevo. Many times I considered Peipsi as being part of IJsselmeer, as if it were just around the corner!*

*Learning from differences is perhaps as useful than looking for similarities; both were present in our project, but the first was rather unexpected for me at the beginning.*

**Complete gradients and a striking diversity of vegetation**
*Ute Menke*
*Peipsi was a special project because of the co-operation with so many different partners from various backgrounds and because of the opportunity to compare two shallow lakes, one 'young and man-made' and the other 'old and natural'. Highlights were (of course) the fieldwork and the Peipsi seminars in Estonia, Russia and the Netherlands, the exchange of experiences and knowledge as well as the applied working methods. One major eye-opener was to see the Peipsi landscape with its complete gradients from the water up to the mires versus what is left in the 'wet heart of the Dutch IJsselmeer area'. Striking were the expanse and the diversity of vegetation along the natural shores with natural water level fluctuations, and the quietness in most areas. The IJsselmeer area is so densely populated and used so intensively for recreation, while around Peipsi there are only a 'few' inhabitants and the 'pressure' on land and water is very low. The Peipsi experience changed our ideas about nature development projects in the IJsselmeer area.*

**A wealth of information on various ecological levels**
*Sophie Lauwaars*
*The research in Peipsi and IJsselmeer provided a wealth of information which was not available in the Netherlands on this scale. The project was well organised, containing the different ecological levels, ranging from waterquality and reed to birds of prey and mammals. It led to a unique international transfer of knowledge between Dutch, Estonian and Russian organisations and it stimulated collaboration between Russian and Estonian organisations. For me personally, the visit to the Peipsi area in June 2005 certainly was rewarding, as were the visits of the Estonian and Russian colleagues to the Netherlands. The atmosphere in the project group was very pleasant. At the same time, we learnt that collaboration with Estonia and Russia works differently than collaboration in the Netherlands. In dealing with the Estonian and Russian colleagues, these cultural differences have to be taken into account.*

**Passion for Peipsi inspiring for IJsselmeer**
*Roel Doef*
*Dealing with nature development, I knew that we didn't have a well thought-out vision for Lake IJsselmeer. I felt paralysed by a lack of historical and geographical references. The study tour to Peipsi in 2001 was an absolute breakthrough in my thinking. It provided me with a tremendous amount of energy and my mission became to spread the "Peipsi-gospel" and a new vision for IJsselmeer. I learnt that water bodies which function well are not only connected with water between the dikes, but also with the hinterland. Think in gradients from the Veluwe to the Waddenzee. Such a vision gives physical planning, with respect to ecological and economic functions, a new challenge. The cooperation with the Russian and Estonian colleagues was inspiring and pleasant. During (field)visits we learnt to understand the functioning of the (eco)systems. But perhaps even more important was that we learnt to understand each other, since trust is the basis for cooperation.*

**Visiting Russia and skating in the Netherlands**
*Andres Kuresoo*
*The project was very special because it offered an opportunity to travel in Russia and to communicate with Russians again for the first time after a long break. In all, we made seven visits to Russia during the project. In the Netherlands, we learnt a lot about modern lake management. In Estonia, we were able to integrate the know-how of various Estonian lake ecologists. Professionally I learnt a lot about the general ecological functioning of lakes and in the narrower field of bird ecology. Emotionally, the project allowed us to make a lot of new friends. The most rewarding moments for me personally were when we went skating in the Netherlands with real skates, which I had not done for a long time, as well as the joint field work we did during ground trips, boat trips and aerial surveys in Russia. A special eye-opener was the fact that satellite images (IKONOS) for detailed analyses of ground data could be applied on biota as well.*

# 1.2 Mutual reference as a common goal: the international scope of coping with differences

Mennobart van Eerden

Working abroad widens the scope. This project was set up because of the expectation that an international comparative study might lead to mutual benefit. On the whole, the idea proved correct that a common interest, in our case the study of two large lakes, would allow each participant to benefit by personal achievement in various learning aspects, while the project itself benefited as well by achieving its scientific goals.

Mutual learning requires an open mind and an explorative attitude. A common subject, in our case the scientific baseline, is needed to set the agenda and to keep people interested. Moreover, both sides need to see the advantages of such an approach. Cultural differences will come up sooner or later, but in this project on the whole the differences were not so great that they influenced the results. By referring to each other's situation, parallels and differences both contributed to a better understanding.

**Scope, expectations and methods applied**

A multi-disciplinary approach was applied, based on existing datasets in both regions, combined with specifically obtained data. The aspects of habitat scale and biodiversity at landscape level were considered crucial with respect to the comparison of both areas. We considered the lakes in the wider sense, not just the water body with adjacent shore areas, but also the hinterland. As such we were to unravel the characteristics at water body level and on the level of entire landscapes. The transboundary position of Peipsi led us to investigate both the Estonian and the Russian side. For the team this meant new contacts on either border, which stimulated the co-operation between scientists in the Peipsi area. The transboundary nature also caused some difficulties in the organisation of the project; with respect to visa, border zone permissions and other administrative regulations we greatly benefited from the experience and skills our partners have in working in their respective systems.
International co-operation revealed differences as well as parallels. This was true for the data gathering as well as for the people involved. Individual differences determine the attitude and progress that can be made in such comparative studies. Both sides also need to see the advantages of such an approach. However, sooner or later one comes across cultural differences. Working methods prove different, interests differ and the social background of people partly determines their approach and behaviour and as such the outcome of the project. However, in most cases the differences between people we met were not such that they negatively influenced the results that were obtained. Sometimes it just took some time to explain to each other what each side meant.

**Capacity building and institutional co-operation**

Individual specialists in the fields of geomorphology, hydrology, plant ecology, animal ecology, limnology, fishery biology and landscape ecology share the working field when working in large lakes. However, their work is often directed at purely scientific questions just comprising their own discipline. Little emphasis is put on integrating results and/or interdisciplinary achievement.





We tried to get a little further through integrated research and questioning; although time was rather limited, we consider our approach useful.
Regarding the institutes involved, the project helped to train people to work for common goals. Our aim was to build partnership, at least between the scientists involved, hoping that the positive atmosphere which was present throughout the period of co-operation would extend to the level of institutes as well. As we have noticed, the Peipsi-IJsselmeer project has led to other Russian-Estonian collaboration projects and plans are being developed to continue in some way or another with IJsselmeer as well.

**Reference area abroad: a new approach?**

Large lakes are compound entities. Not only within the water body itself, but also in relation to the surrounding territory, the complex ecological relationships require a lot of data and many years of monitoring before one is to see changes happening. The next necessary step, understanding the causality behind the trends described, is even more difficult. In limnology it is therefore not uncommon to compare lakes with respect to separate aspects such as nutrient load, algal composition or fishery management, just to mention some. With respect to landscape ecological subjects this has been demonstrated less often.
In the case of Peipsi-IJsselmeer we used the reference concept in a multi-disciplinary way, taking the method across the land-water interface. Although it is often impossible to extract the correct information from an individual dataset, it often proves very well possible to do so in combination with other, independently obtained datasets. Therefore we believe that this reference concept is a workable way to achieve a better insight in the home situation. This is especially true if the aspect of time is involved; this is easily understood when comparing datasets covering many decades, which gives an enormous time advantage. Also, the slightly different conditions that are met at the site of reference may easily falsify or corroborate likely possibilities or hypotheses derived solely from at-the-site research.

# 1.3 Communication

Mennobart van Eerden & Luc Jans

Communication is crucial in any project, but it is of vital importance in an international setting. Understanding people is a prerequisite for any common achievement. Therefore we tried to communicate quite a lot in this project. Not only among participants in the project group, but also with managers in all three countries and with stakeholders interested in the outcome of the project.

People's skills contribute as much to the final result as does the emotional quality of their interactions. The latter is influenced very much by social background and political climate. These affect the way people judge their environment, whether from a scientific-technical or from an emotional point of view. This explains why differences occur in methods and approach, but it also determines the expectations people have concerning the outcome of their own research or of jointly gathered results. Also, a certain dataset can be interpreted differently, depending on the context in which different people view these data.

At the start of the project, a flyer was produced to promote and explain the context and the contents of the project during the years. The flyer proved useful as a handout at stakeholder meetings in The Netherlands and on various occasions in Estonia and Russia.
Project documents served as a constant backbone and were used to maintain the general direction of the project. Another way of propagating the project was through a website (http://www.peipsi.nl/). This website was also used for exchanging reports and presentations. The website proved especially useful for reference to relevant Peipsi aspects during work on other projects.

In the course of the project, presentations were given on several occasions for a varied audience. Presentations of project results and stakeholder meetings contributed to the sharing of information and to the dissemination of results. Through those meetings, there was interaction between the project partners and the regional water and nature managers. A number of articles and papers were written for local newspapers or magazines. Also some scientific articles were written, partly based on the data gathered in this project.





**Discovering the Russian side of Lake Peipsi**
*Leho Luigujõe*
*This project was special for me first of all because of the excellent co-operation between the partners. It also gave us the opportunity to see how colleagues work in Russia and in the Netherlands. The high quality of expertise from the Netherlands, from IKONOS to the feeding ecology of birds, made this co-operation very useful. For me, it also was the first opportunity to visit and work on the Russian side of the lake. The new contacts with Russian and Dutch colleagues will surely give the green light to future co-operation.*

*The most rewarding moment for me personally was the opportunity to participate in the aerial count held on the Russian side of Lake Peipsi. My impression was that this would not be possible, but it was, thanks to great organisation on the Russian side! Thanks to this project, we have improved our knowledge of migrating and staging waterbirds on the Russian side of the lake. Before this project, that knowledge was quite poor. Another great eye-opener was provided by working on the IKONOS pictures. It would be nice to continue this work in another project.*

**Understanding human influence on nature**
*Kulli Kangur*
*The project has expanded our and the world's scientific understanding of how the large lakes' ecosystems function. Lake IJsselmeer, which has no ice-cover period nor water level fluctuations, offered a great comparison to Lake Peipsi. I appreciate the contacts established with scientific experts and water managers.*
*I have a great respect for the Dutch experts' endeavours in re-establishing and protecting their natural environment and was impressed by the successes of nature development in the Netherlands.*
*I especially enjoyed the fruitful academic discussions during the final stages of reporting. For all of us it has led to good ideas for future co-operation and projects. The most rewarding aspect was that the project has broadened my understanding of the influence of human activities on a natural environment. Especially of how water level fluctuations facilitate evolving and sustaining biodiversity. This is a useful lesson for our Võrtsjärv case, where a dam was planned recently.*

**Ambition and perseverance as inspired by mutual learning**
*Gert Butijn*
Working at a regional water management service, it was a special experience to be involved in this ambitious international research project. The project started out from personal contacts between scientists and developed into a rather big research and mutual learning program involving various parties in three countries.
In spite of its size and complexity, the central focus always remained on adequate water management for both lakes. I was impressed by the perseverance people demonstrated in developing and executing the program, even though geo-political conditions were not always favourable.
The project was useful because it provided references for the development of an ecologically sound IJsselmeer area in compliance with the EU Water Framework Directive.
It also provided a foundation for the evaluation and selection of strategies for water management and for related issues in fishery and nature preservation. In addition, it generated cross-border publicity for our management area and organisations in the Peipsi area were provided with tools to facilitate communication in regional water development.

**Beautiful transitions in a fascinating landscape**
*Luc Jans*
*The project was special for me because it brought me to fascinating places where I met interesting people. It also had a positive impact on a number of controversies in the Netherlands. Because many people have seen and experienced the Peipsi area, different (and more appropriate) priorities are set in the IJsselmeer area. By expanding our scope of vision it became easier to determine whether the certain problems are actually caused on our local level. The most rewarding moment for me was the stakeholders' mission of 2006. It was interesting to organize that mission and even more so to share my knowlegde and my enthousiasm about natural lake systems with others.*
*The Peipsi area is fascinating simply because it is a landscape which demonstrates what the Netherlands looked like a thousand years ago, before we started building dikes everywhere.*
*I was particularly impressed by the beautiful transition from pine-forests to dry sandy soils, through peat-moor and peat-bog to the dales of rivers and rivulets, which in turn pass into the shores of the lake. In the large inundation areas, the lake and the rivers continually interact. Another eyeopener was the experience that there are gradients within Lake Peipsi. This made me realise that our lakes must surely contain gradients as well, or at least they must have done so in the past.*

# 1.4 Study tours and missions to Peipsi and IJsselmeer

Roel Doef

In the course of the IJsselmeer/Peipsi project, government officials and water managers of Estonia, Russia and The Netherlands paid regular visits to both lakes. The general aim of the study tours was to exchange knowledge; furthermore they were essential for improving communication and project coherence.

Seminars, symposia, lectures, discussions, exchanging (digital) reports, excursions and field-visits were methods used to exchange knowledge. Related to the project goals, specific data gathering and thematic workshops were organised. A chronological overview of the study tours and field activities is presented below.

**1998/1999**

The first step towards a joint Peipsi-IJsselmeer project was made. As part of a Dutch Wetland Restoration Course, representatives of RIZA paid their first visit to the Russian side of Lake Peipsi. The Dutch were struck by the unspoilt nature of the lake and its resemblance to Lake IJsselmeer. This field mission and a visit to a seminar in Estonia in the winter of 1999 were presented during a lunch-lecture in Lelystad. Two years later all this resulted in a report that compared "Peipsi" and "IJsselmeer" and which formed the basis for the current project.

***"Lake Peipsi resembles Lake IJsselmeer in many ways, but is not as heavily modified"***

**2001**

In June, two managers from Rijkswaterstaat IJsselmeergebied and two scientists from RIZA familiar with Lake IJsselmeer visited Lake Peipsi both on the Russian and the Estonian side (Van Eerden *et al.*, 2001). Contacts were established between Russian[1], Estonian[2] and Dutch civil servants, the landscape and ecology were explored, the information exchange started. Right from the beginning it was clear that these activities were likely to succeed in a joint project with mutual interests.

***"A fruitful co-operation is based upon trust"***

**2002**

A project meeting was organised in Estonia (where for the first time Dutch, Russian and Estonian participants met each other). The network was maintained and broadened; lectures and a field-excursion took place. A seminar in The Netherlands was prepared. In December 2002 this seminar with four Russian- and five Estonian participants took place (Doef *et al.*, 2003). Besides excursions to and workshops about the IJsselmeer area the focus was on setting up a project plan for the coming years and detailing the first work plan for 2003.

1 (Zoology Department, Teacher Training Institute - Pskov, NGO Chudskoye Project, Pskov Dept. of State Institute of Fish Resources, Gos NIORKH & Administration for Natural Resources and Ecology of Pskov Oblast).

2 (Centre for Transboundary Co-operation, Agricultural University, Võrtsjärv Limnological Station, Agricultural University, Institute of Zoology and Botany, Tartu)





***"Skating on natural ice is a catalyst for working on international water management!"***

**2003**

There were two "single-person-visits". One visit was made to Estonia/Russia and served to continue the project management and to do specific fieldwork on birds. The other trip was made to Estonia, to work out the data-exchange.
A special "ground truth" mission (Borisov *et al.*, 2003) on mapping landscape ecology was carried out. Based on false colour LANDSAT TM satellite images, field observations were conducted on the Russian and Estonian side to interpret the images. In this joint project, satellite images are used to determine the different landscape types. In future, changes in environmental conditions can be followed over the years.

***"The scale of landscapes is to a large extent responsible for their quality"***

**2004**

A kick-off meeting for the official project was held. The Dutch consulate in St. Petersburg and the Dutch Embassy in Tallinn were visited. During this year four other missions took place, each with another accent: bird counts and research, comparison of Lake Võrtsjärv and Lake Markermeer (van Dijk *et al.*, 2004). In relation to the Peipsi-project the Dutch WATC-course was attended. In December a project meeting was held in The Netherlands as well as a workshop focusing on the Water Framework Directive and the Birds and Habitats Directive (Lammens & Lenselink, 2004).

***"From inspiration to a vision on integrated water management"***

**2005**
In May a mission focused on an integrated bird count at Lake Peipsi in combination with a progress meeting and a discussion of the 2005 year plan. In June participants in the Peipsi projects attended the International Shallow Lake Conference in Dalfsen, The Netherlands. A special mission was organised to collect ideas and principles about brooks and brook restoration (Jans *et al.*, 2005). This mission also resulted in joint fieldwork for the projects 2.2 (biodiversity and hotspot inventory) and 3.2. (floodplain and wetland processes in relation to management). A study tour for nine Dutch stakeholders focused on ecological reconstruction projects. The mission (Doef *et al.*, 2005) was useful in creating a shared vision in relation to the management plans (BHD/WFD). At the end of the year during a working visit EE-RU-NL partners discussed progress as well as the preparation for the 2006 plan of action and the outline of the final conference and reporting (Jans, 2005).

***"Now I know what you mean by completeness of the ecosystem!"***

**2006**
In spring a mission to The Netherlands was organized to discuss the year plan 2006 and the contents of the final report. Two single-person visits took place, one to prepare the stakeholders' mission later that year, and one field mission to classify the IKONOS satellite images. A second stakeholder mission (Zwart & Jans, 2006) was organised for vision building and dissemination of common knowledge. Focus was on the common goals of management in the "Wet Heart of The Netherlands". The Large Lakes Symposium in Tartu, in September, was also attended by three Dutch participants in the Peipsi-project. At the end of the year the draft contributions to the final report were discussed in Tartu.

***"Rather similar but interestingly different as well!"***

**2007**
The final report was written. On December 12, a symposium was held in Lelystad. Discussion focused on how to direct the future co-operation and emphasis was laid upon dissemination of the results. The message from the project Peipsi-IJsselmeer has been put across in various expert and policy making meetings in The Netherlands.

***"As you sow, you shall reap."***





**Table 1** *Overview of the different missions, their main direction and scope.*

| Year | Lake | Participants | Direction and scope |
|---|---|---|---|
| **1998** | P | 2 | Landscape assessment |
| **1999** | P | 2 | Seminar Peipsi-IJsselmeer |
| **2001** | P | 4 | Project preparation |
| **2002** | P | 4 | Project management / fieldtrip birds |
| | IJM | 9 | Seminar and project start-up |
| **2003** | P | 1 | Project management / fieldtrip birds |
| | P | 1 | Data management |
| | P | 3 | Ground check of satellite images |
| **2004** | P | 3 | Project management |
| | P | 4 | Field trip Võrtsjärv-Markermeer |
| | IJM | 1 | Wetland Restoration Course |
| | P | 1 | Project meeting |
| | IJM | 8 | Workshop/field trip IJsselmeer management |
| **2005** | P | 1 | Integrated aerial bird count (Est, Ru) |
| | IJM | 6 | International Symposium Shallow Lakes, Dalfsen |
| | P | 4 | Brook mission |
| | P | 9 | Stakeholders mission |
| | IJM | 8 | Progress meeting |
| **2006** | IJM | 8 | Meeting year plan 2006 and final report |
| | P | 1 | Preparation stakeholders mission, bird inventory |
| | P | 2 | Fieldwork IKONOS satellite images |
| | P | 9 | Stakeholders mission |
| | P | 3 | International Large Lake Symposium, Tartu |
| | P | 4 | Meeting on concept final report |
| **2007** | IJM | 8 | Final symposium December |

P = Peipsi, IJM = IJsselmeer

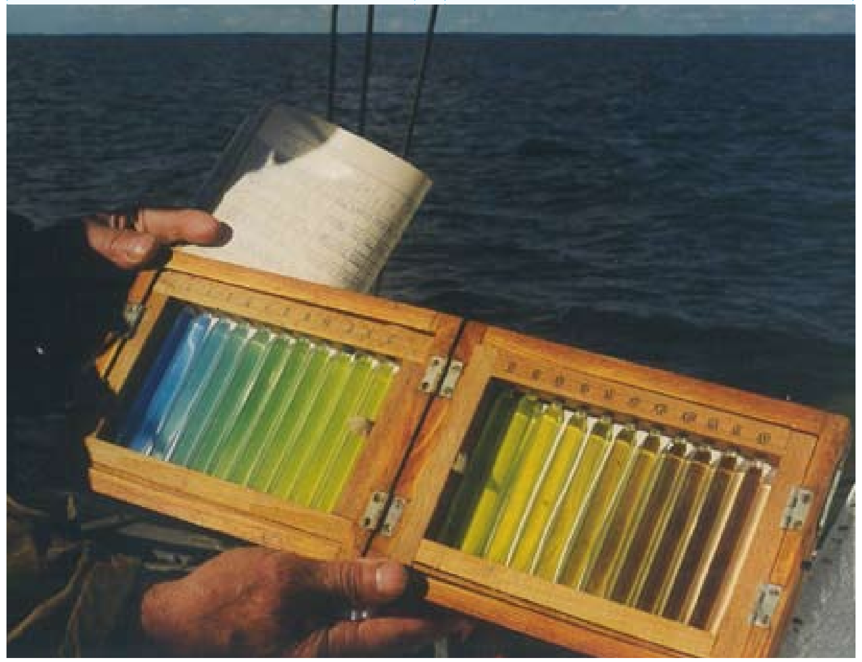
# 1.5 Joint fieldwork and stakeholder missions

Roel Doef

Joint fieldwork is practical teamwork on location, complementary to studies of literature. Fieldwork is mainly focused on collecting specific research data, but it also serves as a source of inspiration. The size, scale, proportion, shape and order of elements, of for instance the landscape, form a set of reference data that can be a powerful addition to theoretical knowledge.
Fieldwork can in one way inspire theoretical brainwork, and in another way serve as a check on brainwork. Several examples of joint fieldwork are presented below, to point out the different findings and atmospheres as well as the process of mutual learning.

**Building the network of Estonian and Russian workers and setting up joint missions to Lake IJsselmeer**

Although defining the project and preparing a working plan prevailed in 2002, joint field excursions were made in Estonia in June and in The Netherlands in December. Locations visited were: Houtribdijk, Enkhuizen harbour, cormorant-breeding area de Ven, water intake authority WRK near Andijk, and nature development/recreation project Vooroever near Andijk. Moreover, the Veluwe Borderlakes were visited (Doef *et al*, 2003). The mission's intention was for the foreign workers to get acquainted with the heavily modified Dutch situation. From 29 November till 6 December 2004 a progress meeting was held in The Netherlands (Lammens & Lenselink, 2004). A workshop demonstrated that the



**First impression**

"We witnessed the taking of samples to establish water quality, or the abundance of algae, zooplankton and benthos and had discussions about the monitoring programme. With respect to water quality the monitoring has the same frequency (monthly) as in The Netherlands, but monitoring algae, zooplankton and benthos is done much more frequently, as samples are taken on a monthly basis. Also fish is monitored more frequently, which gives a good seasonal picture of the development of the fish communities. The elaboration of sampling is much more laborious than we are used to. This is partly due to lack of auto-analysers, good microscopes and software for processing data. The excursions were instructive. They gave a good overview of how monitoring is done on both sides. They also helped getting an overall picture of the entire lake. For the elaboration of the project proposal this is essential."





**The landscape in a wider perspective**

"The presence, at scale, of these different landscape units with many transitional communities is of great importance to the biological diversity of the area. Large mammals like bear, wolf, lynx and elk are still present, as are beaver, otter, roe deer and red deer. Birds that have become extinct in The Netherlands or which are extremely endangered as breeding species such as Crane, Golden Plover and Black Grouse are still numerous in the mesotrophic and oligotrophic wetlands around Peipsi, as was observed in Remdovski zakaznik. These conditions are of interest if one is to restore nature (as intended in The Netherlands) but they are also extremely valuable to preserve for future generations (Estonian/Russian situation). Effect of the scale of the landscape, the level of disturbance, and the relation between groundwater and lake water are aspects for future study. Likewise, the lakeward extension of reed and bulrush stands is of great interest. In The Netherlands the situation is often the reverse, with areas of macrophytes retreating. During the excursion on 7, 9 and 10 June we had the opportunity to get across several of these gradients."

managers of both lake systems were in a different position with regard to the WFD. For both systems the ecological goals have to be defined, but for Peipsi that is the natural reference condition whereas for the heavily modified lakes in the IJsselmeer area this is the adapted reference condition. The discussions during this workshop were related to the problems of finding suitable reference conditions, detecting the main pressures on both systems and evaluating the current ecological condition while also taking the climate change into consideration. To offer the Estonian and Russian colleagues a good insight in the functioning of the Dutch great lake systems, excursions were organised to the Oostvaardersplassen, the shores of Lake IJsselmeer and the lock system Houtribsluizen. A boat trip offered the possibility to see the recently created nature island "Kreupel", which was designed to serve as breeding habitat for Terns and other waterbirds. On board, common sampling equipment and techniques for monitoring of macrofauna on large lakes were demonstrated and methods discussed. Then the more natural parts of the Frisian coastline and the fish auction in Urk were visited. The next day, an excursion to the (Veluwe) Borderlakes and its nature development projects showed another part of the IJsselmeer complex.

**Natural brook outlets**

The aim of the mission to the Peipsi area in June 2005 was to gather ideas and principles on naturally functioning brooks and brook restoration in order to evaluate the feasibility of brook restoration along the Veluwe Borderlakes. The information from Peipsi will help to focus on the right topics and set achievable targets.
To obtain information about dimensions of the brooks, rivers, floodplains, inundation zones, etc. satellite images were studied. For the classification of these images (IKONOS) field data are required. So during this field mission data about the vegetation composition were gathered as well. Approximately 50 locations were visited.
The inspiration we drew from seeing examples like the Abisza brook mouth, north of Molgova (see picture) was overwhelming. The scenery of these landscapes could well fit in the NW Veluwe border zone as it exists today. Restoring former functions could contribute significantly to the natural values in these areas. Special attention was paid to the role of moist and wet meadows and inundated parts of the floodplain. To share our ideas with the local representatives of management authorities, we made a special working document: "How can the brook outlets along Lake Peipsi/Pihkva inspire the Dutch water managers along the Lake IJsselmeer area?" (Menke *et al.*, 2004).

**Conclusions**

- The Emajõgi River is a special river between two lakes; The river's hydro-dynamics are very much influenced by the lakes; its water level is more stable than that of normal rivers. Wind-induced currents may occur.
- Partly connected water bodies are very important for the fish species (especially Pike). These can be old meanders but also areas inundated by the lake. They must be connected to the main stream or water body for (ideally) for at least 1 to 2 months.
- Vegetation zones were more closely related to inundation zones than expected; variation depended on how much influence the lake had, on the natural morphology (soil, elevation), as well as management practices.
- Decreasing agricultural use in many floodplains (haymaking has stopped in many cases) in Estonia as well as in Russia resulted in more and more bush and forest re-growth.
- Large water level fluctuations (in lakes > 1m) during the year as well as over the years are an important factor. The water levels during the field mission (at the end of June 2005) were still very high. The level of Lake Võrtsjärv was

*Macrofauna sampling, IJsselmeer*

only 25 cm lower than the highest level of 2005. The same was true for the rivers Chernaya and Zhelcha and some brooks where extended areas were still flooded or moist.

- In essence the Veluwe shorelands have much in common with those around Peipsi; high(er) sandy soils with extended forests; brooks and small rivers which flow into these lakes. A big difference is the absence of (large) inundation areas. Increasing the inundated areas between the higher Veluwe forests and Lake Veluwemeer would add greatly to a natural situation. However, this area is used intensively for agricultural purposes.
- In nearly all the brooks and rivers observed, black (peat) water was the rule. The river basins were formed by fen and peat areas, wet forests (and agricultural fields) and, further away, by the effluent of raised bogs.
- Some rivers (for example the Põltsamaa River) have high banks directly along the river. Others, like the Emajõgi, Chernaya and Zhelcha, have lower levees; the inundation period of these rivers was much longer than that of the Põltsamaa River. This is partly related to the degree of dependence upon the lakes. Rivers strongly influenced by the lake have far greater fluctuations than those further away or with a greater fall.

### Note on forest/trees in floodplain areas

Forest/trees are very important for a complete ecosystem; many animals migrate between the forests and the open floodplains. When the hydrology and/or the management of a floodplain changes, an open floodplain can be overgrown by forest in just a few years. The patchiness of open and closed parts in the floodplain determines the overall natural value. Anyhow bush encroachment will cause a tremendous change in biodiversity. Trees along the banks of the rivers will create their own microhabitat e.g. by depositing woody debris in





the water, which will alter the natural values of the aquatic system (depending on species and number the effect may be positive or negative. Beavers have a big influence on the forest development. They can really limit the amount of trees on the banks. In doing so they create new habitat and as such form an important factor in the local hydrological regime. Many animals and plant communities depend on such changes, therefore the Beaver is considered a keystone species.

### First integrated water bird counts

Twice during the project we conducted integrated bird counts on the Russian and Estonian side of Lake Peipsi and Lake Pihkva. In October 2004 an aerial count was performed on the Estonian side, followed a couple of days later by a systematic count by boat on the Russian side, all the way up from Pskov to the coast north of Raskopel Bay.
In May 2005 an integrated aerial bird count was carried out on the Estonian and Russian side, this time with an even larger coverage of the coastline (>90%). Waterfowl data are still scarce for the whole of Lake Peipsi, therefore this attempt to survey this vast territory almost simultaneously is valuable both from a methodological and from a scientific point of view. The flights and visits to the border zone could be undertaken with special permission by the boarder guards. The huge area was checked in 2.6 hours on the Estonian side (Cessna 172) and 4 hours on the Russian side (Antonov 2). From above, the image we had of the landscape was completed. The areas of Emajõe Suursoo, Remdovskiy Zakaznik and Pechorskiy Zakaznik were the wildest and most complex ecosystems. We had already studied these areas on the ground, so we were able to recognize the different habitats quickly. Preparatory desk work had provided us with a bird count grid and by simultaneous observation by two observers and one navigator we could efficiently perform this job.
The bird counts showed the importance of Lake Peipsi and Lake Pihkva for waterbirds. For example, the count in May resulted in 39 White-tailed Eagles, 2 Golden Eagles and 1 (early arrived) Osprey. Water birds were unevenly distributed, like in IJsselmeer, due to differences in foraging opportunities. The greater transparency of the water was again striking, although a gradient of increased visibility was noticeable from Lake Pihkva to the North. As other data have shown, this gradient is especially prominent during high summer when algal growth is at its peak.
A lot of pictures were taken of shoreline structures, floodplains, bogs, wet forests, river deltas and brook mouths. This material greatly adds to the ground surveys that were conducted.

### "Shallow lakes in a changing world", scientific symposium in Dalfsen, The Netherlands

Colleagues of the Peipsi-project were invited to the International Shallow Lakes Conference, 5-9 June 2005, where papers and posters were presented. A special workshop was organised to focus on the comparison between Peipsi and IJsselmeer. Three topics related to the Peipsi-IJsselmeer project were defined and discussed in parallel groups during the workshop (Menke *et al.*, 2005).

- Smelt and climate change (temperature): What is the role of temperature (especially warm summers) in Smelt population dynamics and to what extent does temperature overrule the effects of changes in zooplankton production?
  Smelt *Osmerus eperlanus* is the most important planktivorous fish and an important prey for piscivorous fish like Pike *Esox lucius*, Pikeperch *Stizostedion lucioperca* and Perch *Perca fluviatilis*, birds and fisheries in

IJsselmeer and Peipsi. Smelt populations vary strongly from year to year and in both lakes the populations are in decline this last decade. The future state of the piscivorous predators seems to depend on the development of the smelt population. Comparing the time series is useful for detecting any common cause for the fluctuations.

- The consequences of implementing the European Water Framework Directive and the European Bird and Habitat Directive in different countries. For Lake Peipsi and Lake Võrtsjärv and the lakes in the IJsselmeer area the EU Water Framework Directive demands the definition of ecological goals. Estonia and The Netherlands also have to define goals for the Bird- and Habitat Directives areas. In this group we explored the different ways the individual countries cope with the European Directives.

- Climate changes and water-level fluctuation.
  In this part of the workshop the influence of climate change on water-level fluctuation was discussed as well as the ecosystem's functioning as a result of this.

After the symposium two Van Veen grabs, used for instance for *Dreissena* sampling, were presented to the Estonian and Russian colleagues. By using the same equipment, comparison of data will be more straightforward.





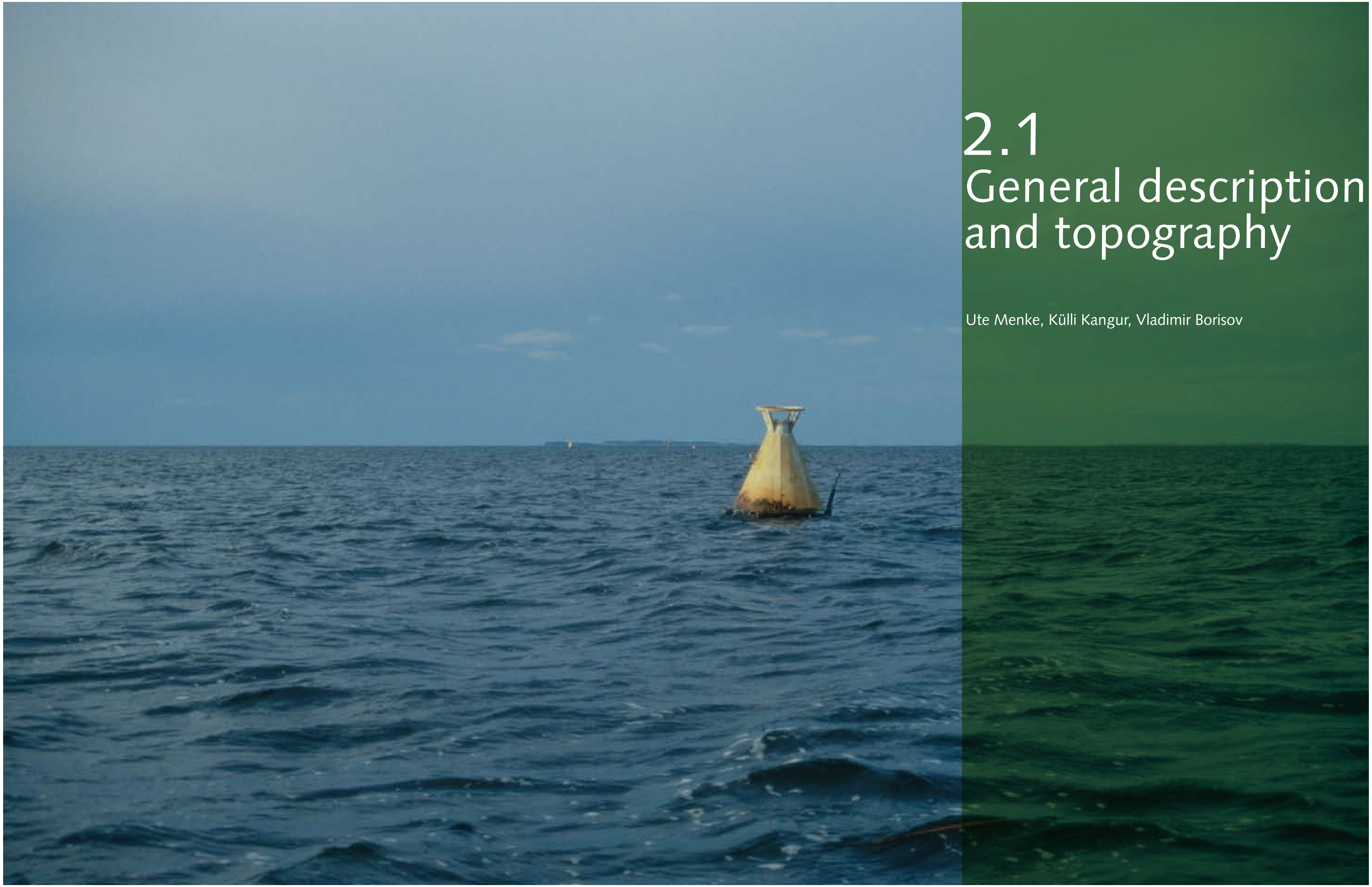

*Applying similar methods facilitates comparison (Dalfsen 2005, Van Veen Grab)*

**Stakeholder missions Peipsi**

In several Dutch co-operation programmes, the various IJsselmeer stakeholders expressed a keen interest in visiting reference sites. Therefore they were invited to visit Peipsi in 2005 and 2006. Stakeholders were connected to the municipality of Almere, the provinces of Flevoland and Gelderland and the Waterboard Zuiderzeeland. The currently very complex situation in the IJsselmeer area with respect to political, environmental and spatial planning agendas, requires both background knowledge and an overall picture of the wider context. Thus a lot of communication and sharing of ideas is necessary before a common opinion can be reached.
The study tour provided valuable input for future co-operation between the various governmental organizations based on shared experiences and discussions.

# 2

# General features



# 2.1 General description and topography

Ute Menke, Külli Kangur, Vladimir Borisov

Lake Peipsi and Lake IJsselmeer have a lot in common, but they differ in many ways as well. Both lakes are shallow, which sets them apart from other big European lakes. They are both situated between 50° N and 60° N. Weather conditions, however, are very different. Both lakes are dammed, but differ greatly in water level regulation. Also, in Lake IJsselmeer fresh water sediments have been deposited for 75 years, whereas in Lake Peipsi this process has been going on for more than 8,000 years.

### Lake IJsselmeer

Lake IJsselmeer is the largest water body in The Netherlands. Including Lake Markermeer and the Borderlakes it extends over almost 2,000 $km^2$.
It originated in 1932 when the barrier dam, closing the former Southern Sea (in Dutch: Zuiderzee) was completed. The saline and brackish water of the Zuiderzee turned into fresh water because of the inflowing water of the River IJssel, a branch of the River Rhine, and rainfall. Natural banks – with a natural gradient – occur only along the Borderlakes and along the coast of the province of Friesland and some parts of the province of North-Holland.
Out of the original 365,000 ha of surface water, some 165,000 ha (45,2%) was successively reclaimed. Most polders were reclaimed in the freshwater period (North-East Polder in 1942, Eastern Flevoland in 1957, and Southern Flevoland in 1968). Only the Wieringermeer polder (1930) was reclaimed from the Zuiderzee. As a result of all reclamations the shoreline increased from 383 km (without islands) in 1932 to 773 km in 1968.
All other banks and shorelines consist of artificial dikes which have steep slopes. Pristine conditions cannot be found in the area anymore. Few rivers drain into Lake IJsselmeer, such as the IJssel, Overijsselse Vecht, Utrechtse Vecht, and Eem. Besides these larger rivers, only small streams and brooks coming from higher, sandy moraine deposits, like the Veluwe area drain into the lake. Furthermore, many pumping stations discharge polder water into the lake. The largest are Lemmer, Stavoren and the seven stations in the North-East Polder and Flevoland.

The average depth of the lake is about 4.5 metres. The shallowest places can be found close to the old Zuiderzee coast line; whereas the deepest parts are situated in the old tidal gullies and the artificial sand extraction pits. The recent topography of Lake IJsselmeer is the result of sedimentation in the old tidal gullies in the middle part by sediments brought in by the River IJssel, and of erosion of the lake bottom in the surrounding area (see Figure 1).

Lake Markermeer, created in 1975, is nowadays a disconnected water body with an average depth of about 4 metres. Some major changes in the water exchange in Lake IJsselmeer are due to the construction of a 26 km long dam between Enkhuizen and Lelystad, the Houtribdijk. This dam closed off the northern sandy part from the more clayey southern part. This resulted in a more turbid system with a mobile silt layer in Lake Markermeer.





**Table 1.** *IJsselmeer-characteristic facts and figures (water quality parameters in geometric means, spring to autumn)*

| Characteristic | IJsselmeer | Markermeer | Gooimeer | Eemmeer | Wolderwijd-Nuldernauw | Veluwemeer | Drontermeer | Vossemeer | Ketelmeer | Zwarte Meer |
|---|---|---|---|---|---|---|---|---|---|---|
| Surface area, $km^2$ | 1139 | 696 | 26 | 15.6 | 25.6 | 31.7 | 5.6 | 2.8 | 35.9 | 18.1 |
| Shoreline length in km | 229.5 | 221.4 | 40.2 | 38.5 | 58.5 | 51 | 29 | 13.4 | 56.5 | 35.2 |
| Maximum depth, m | 22.2 | 32.6 | 29.9 | 8.4 | 8.2 | 11.1 | 7.96 | 6.1 | 17.5 | 10.4 |
| Mean depth, m | 4.4 | 3.5 | 4.5 | 1.7 | 1.5 | 1.55 | 1.25 | 1.2 | 3.1 | 1 |
| Water volume, $km^3$ | 5.1 | 2.6 | 0.1 | 0.03 | 0.05 | 0.05 | 0.007 | 0.004 | 0.1 | 0.03 |
| Residence time (in years) | 5 [1] | 12 | ca. 2 | ca. 1 | 3.8 [2] | 1.9 | 0.6 | 0.1 | 0.1 | 0.03 [3] |
| TP, mg P $m^{-3}$ | 91 | 77 | 100 | 188 | 59 | 59 | 95 | 127 | 134 | 149 |
| PO4-P, mg P $m^{-3}$ | 7.8 | 7.1 | 38 | 55.5 | 6.2 | 7.1 | 8 | 13.6 | 54 | 25.5 |
| TN, mg N $m^{-3}$ | 2035 | 1297 | 1800 | 2494 | 1317 | 1494 | 1799 | 1834 | 2856 | 3093 |
| DIN, mg N $m^{-3}$ | 1995 | 1257 | 1698 | 2380 | 1259 | 1433 | 1740 | 1764 | 2734 | 2970 |
| Chlorophyll a content, mg $m^{-3}$ | 48.8 | 36.1 | 13.6 | 16.7 | 8.6 | 14.5 | 26.5 | 37.2 | 7.9 | 17.9 |
| Secchi depth, m | 0.53 | 0.28 | 0.92 | 0.49 | 0.88 | 0.7 | 0.61 | 0.46 | 0.8 | 0.66 |
| OECD (1982) classification | eutrophic | eutrophic | eutrophic | eutrophic | meso-trophic | meso-trophic | eutrophic | meso-trophic | eutrophic | eutrophic |

1 in summer; 3-4 in winter
2 Nuldernauw 1.4
3 Up to a few weeks

The fine sediments are suspended in the water column. This means transparency in this lake is less than in Lake IJsselmeer; the water is more turbid but contains more clay and peat particles.

Since 1942 the former islands of Schokland and Urk have been part of the North-East Polder.
Only one island still remains, Marken. It is situated in Lake Markermeer and was connected to the main land by a dam in 1957. On the other hand, Lake IJsselmeer is dotted with recent artificial islands, e.g. the storage depot "IJsseloog" in Lake Ketelmeer, which is used for storing contaminated soils, and a few nature development projects such as IJsselmonding, Kreupel, Dode Hond and a dozen of smaller projects along the Frisian coast and in the Borderlakes as well.

### Lake Peipsi

Lake Peipsi has a total surface area of 3,555 $km^2$, of which 1,570 $km^2$ (44%) belong to Estonia and 1985 km2 (56%) to Russia. It is a freshwater lake, as many rivers and streams (about 240 in total) drain into Lake Peipsi. The largest is the Velikaya River (with its basin of 25,200 $km^2$), followed by the River Emajõgi (with a basin of 9,745 $km^2$), and the River Zhelcha (1,220 $km^2$). Together these three rivers make up 80% of the total basin and the total inflow. The annual mean runoff of Lake Peipsi through the Narva River into the Narva reservoir is more than 12 $km^3$. Although the lake in hydrological sense is still in a natural state, 88% of the water courses flowing into Lake Peipsi are rivulets and ditches with a length of less than 10 km. The shoreline of 875 km is a natural one; there are no dikes or embankments along the shore.

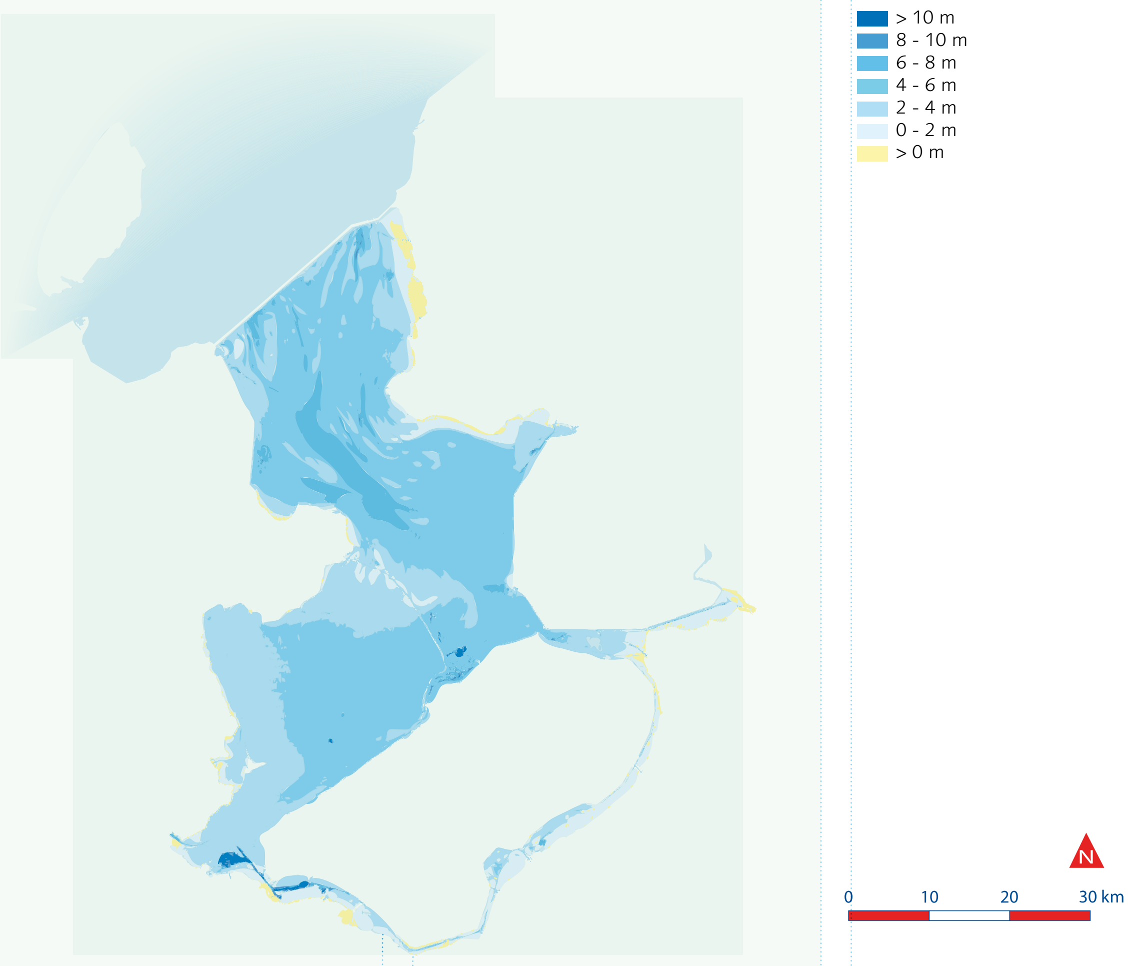



**Figure 1.** *Depth contours in IJsselmeer*

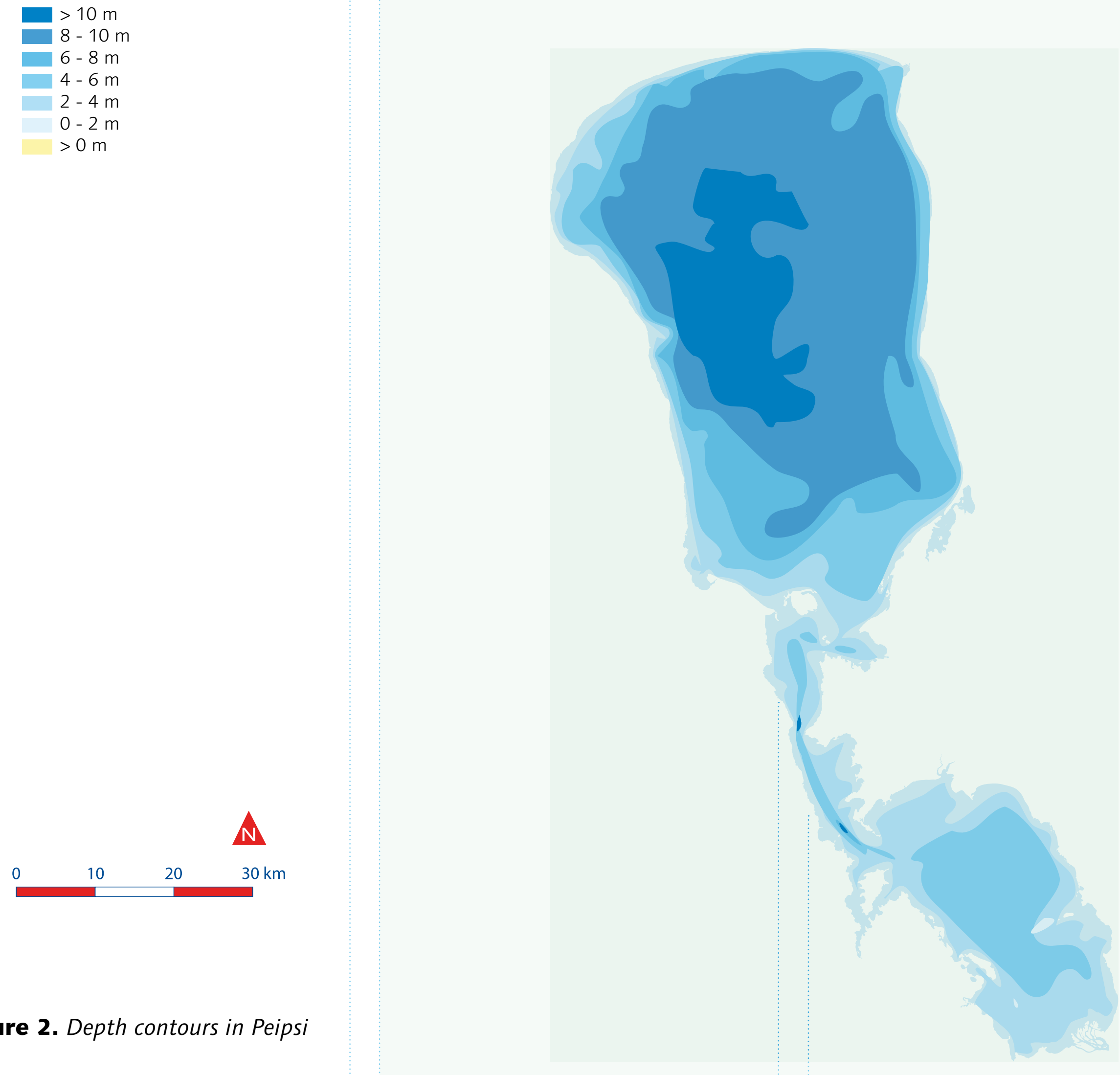



**Figure 2.** *Depth contours in Peipsi*

Forests cover large areas in the basin, In the northern area and eastern shores they make up to 60-70% of the surface area, while in the southern and western shores it is 30-40%. Mires and bogs cover up to 10% of the catchment area and another 15-20% are wetlands, such as wet meadows and forests. Large parts of arable land are to be found in the western and southern part of the basin. The biggest cities in the basin are Pskov (Russia) and Tartu (Estonia). In total some 1.1 million people live in this basin, mostly more than 50 km away from the lakeshores. So population pressure is low.

The lake is shallow. Its mean depth is 7.1 m, with a maximum of 15.3 m (Jaani, 2001a). Lake Peipsi consists of three limnologically different parts (Figure 2). The northern part, Lake Peipsi s.s. is the largest and deepest (Table 2).
The southern part, Lake Pihkva, is half as deep as Lake Peipsi s.s. The strait in-between is known as Lake Lämmijärv. This complex has 35 islands and islets, the biggest being Kolpino (11.1 km$^2$) in Russia, Piirissaar (7.5 km$^2$) in Estonia and Kamenka (4 km$^2$) in Russia near the western coast of Lake Pihkva (Jaani, 2001). Furthermore at the Russian side there are the islands of Talabskije.
The lake surface may increase by 780 km$^2$ in spring, when the water level is about 1m higher. In October the lowest water levels occur (see chapter 3.9).

According to the Estonian lake typology, Lake Peipsi is a unique water body which belongs to the separate type of large unstratified eutrophic lakes with light water of medium hardness (average 2.29 mEq $l^{-1}$ in 1985-2005) located on mineral land.
The outflowing Narva River (mean annual discharge 399 m$^3$/s) runs into the eastern part of the Baltic Sea. The residence time of water in the entire lake is about two years. The water level is not regulated. Natural water level fluctuations have shown an overall range of 3.04 metres over the last 80 years, with an average annual range of 1.15 m (Jaani, 2001b). Long-term variability of water level in Lake Peipsi has an expressive cyclic nature, see chapter 3.9.
Due to the large surface area and the relative shallowness of the lake, temperature stratification is unstable and can be disturbed even by moderate winds or gentle undulation. Therefore the lake's water is usually rich in oxygen during the open water period. The lake is, as a rule, covered with ice from December till April, during which period the near-bottom water frequently suffers from oxygen deficiency. Lake water is warmest (usually 21-22 °C maximum) in July-August (Figure 3).
According to OECD (1982) classification, Lake Peipsi s.s. now classifies as a eutrophic water body, while the trophic status of lake Lämmijärv is close to hypertrophic and Lake Pihkva really is a hypertrophic lake (Table 2).

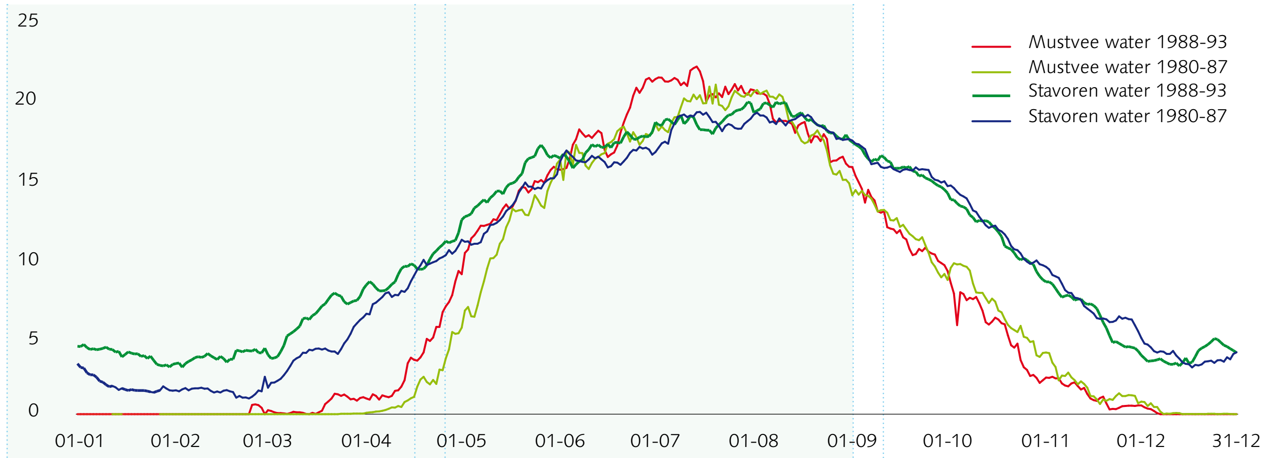



**Figure 3.** *Seasonal changes in temperature in Lake IJsselmeer (Noordhuis, 2007) and Lake Peipsi (Jaani, 2001c).*

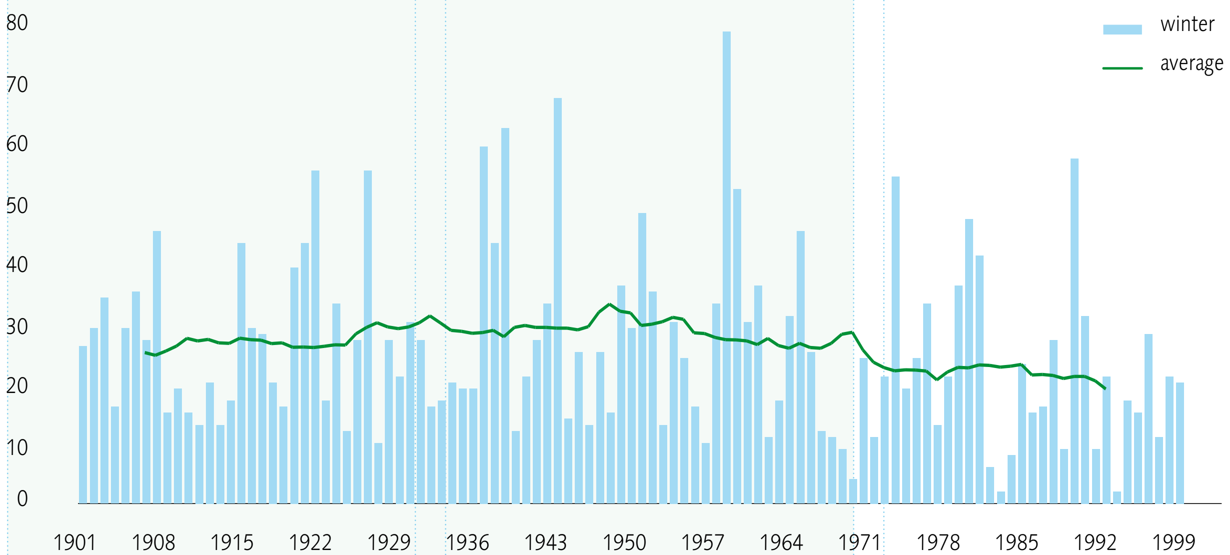



**Figure 4.** *Number of days below zero degrees Celsius in The Netherlands (De Bilt), starting in autumn of 1901 and a running mean over 25 years (KNMI); (Noordhuis, 2007).*

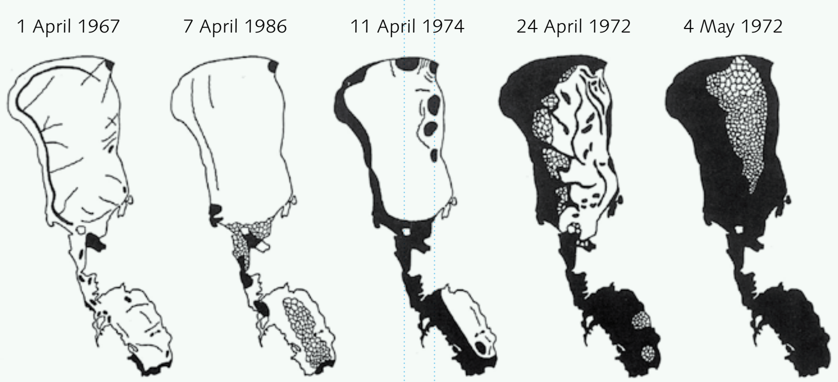



**Figure 5.** *Ice melting in Lake Peipsi in spring, illustrated by typical phases from different years;* ■*=water,* □*=ice (from: Jaani, A., 2001c)*



**Table 2.** *Peipsi – characteristic facts and figures*

| Characteristic | Lake Peipsi s.s./ Chudskoye | Lake Lämmijärv/ Teploye | Lake Pihkva/ Pskovskoye | All Lake Peipsi |
|---|---|---|---|---|
| Surface area, $km^2$ | 2611 | 236 | 708 | 3555 |
| Maximum depth, m | 12.9 | 15.3 | 5.3 | 15.3 |
| Mean depth, m | 8.3 | 2.5 | 3.8 | 7.1 |
| Water volume, $km^3$ | 21.79 | 0.60 | 2.68 | 25.07 |
| TP, mg P $m^{-3}$ | 39.8 | 77.4 | 143.2 | 50.2 |
| PO4-P, mg P $m^{-3}$ | 6.6 | 12.1 | 31.4 | 8.3 |
| TN, mg N $m^{-3}$ | 658 | 856 | 1006 | 718 |
| DIN, mg N $m^{-3}$ | 121 | 130 | 108 | 122 |
| Chlorophyll a mg $m^{-3}$ | 17.5 | 28.5 | 53.5 | 20.9 |
| Secchi depth, m | 1.7 | 0.9 | 0.7 | 1.4 |
| OECD (1982) classification | eutrophic | eutrophic/ hypertrophic | hypertrophic | eutrophic |

### Climate with temperatures and wind directions

Both lakes are situated in the northern hemisphere. The climate is temperate-humid. In The Netherlands, the annual average temperature is slightly higher; while the temperature differences in Peipsi are more extreme as this region is more continentally influenced. Temperatures below zero degrees Celsius occur in Peipsi from November until March.

The main difference between the lakes, even in times of climate change, is that the winters are more severe and last longer in Peipsi. Therefore, the lake normally is frozen for 4 to 5 months a year. This means that spring and the growth of vegetation around and on the lake as well as the biomass production starts relatively late compared to IJsselmeer (Figure 5). Lake IJsselmeer was hardly ever covered by ice during the last two decades. The last thick ice cover was in 1996 (see peak at the right part in Figure 4). An ice layer on Lake IJsselmeer and Lake Markermeer can only develop after a minimum period of 10-15 days with temperatures below zero °C. In the more shallow Borderlakes the situation is different. Here, ice appears within 5 days of temperatures lower than minus 5°C.

Summer temperatures can reach higher extremes in the Peipsi area. This means that the total biomass production equals the Dutch situation during summer and that similar events such as the massive development of blue green algae may occur. The massive algal production can sometimes (in shallow and smaller waters) lead to fish diseases and finally cause death of fish. In more open waters, layers of algae are floating on the surface, which are even visible on the Landsat images In Lake Markermeer, too, this effect is clearly visible.
The temperature increase between January and March was particularly high from the 1990s onwards. The world average temperature increase was only 0.37 °C, but in The Netherlands the increase was 1.61 °C. In the Estonian and Russian region of Lake Peipsi, the temperature increase was about 0 °C.

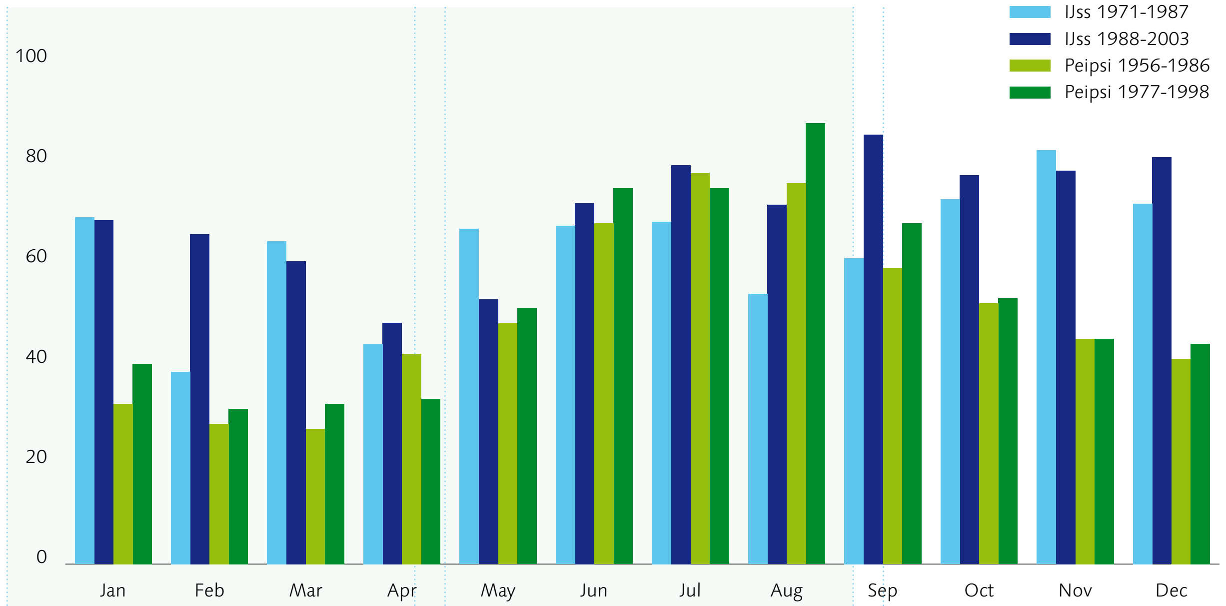



**Figure 7.** *Monthly average precipitation (two periods) in "De Bilt", The Netherlands (Noordhuis, 2007) and in Mehikoorma at Lake Peipsi (S. Keevallik et al., 2001).*

Global warming in Lake IJsselmeer is coupled with an increase of exotic species (crustaceans, molluscs and fish) such as the Caspian crustacean Dikerogammarus. So far this has not happened in Peipsi. The appearance of exotic species in Lake IJsselmeer is mainly due to the fact that its "hinterland" was widened by the opening of the Main-Donau Canal in 1992. Since then, the river basins of the Rhine and the Danube are connected, while shipping has intensified.

The average precipitation in Lake Peipsi at the station Mehikoorna varies between 595 mm (1956-86) and 635 mm (1977-1998), see Figure 7.
The average precipitation in The Netherlands varies between 780 mm and 835 mm, see Figure 7. In The Netherlands the precipitation is more equally distributed through the year, whereas in Lake Peipsi peaks occur during summer and autumn. January to April is a relatively dry period.

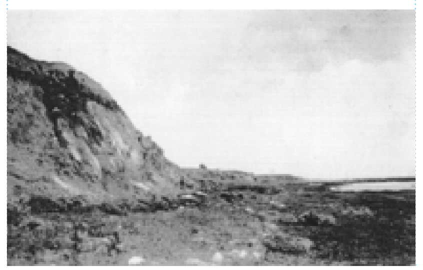
Winds in the IJsselmeer area are mainly coming from W and SW directions. Winds coming from the SW have increased since the second half of the 1990s compared to those coming from the NE. Winds from the SW bring the biggest amount of rain to the region. More winds from the south-west have an effect on the re-suspension of silt and organic particles in Lake IJsselmeer; the changing winds influence the spatial pattern of suspended matter, algae and floating layers.

In Lake Peipsi the situation is slightly different. In the western part, the most frequent winds come from the west and south-west direction as well. In the eastern part southerly winds are more frequent and there are less western winds. Moreover, the number of calm days is higher. A special feature is the so-called lake breeze. This implies a higher frequency of easterly winds at the western shore during the afternoon and the evening compared to the night and the morning. At the eastern shore it is the other way around. This effect is also noticeable at Lake IJsselmeer during warm summer days.

**Lake IJsselmeer – geology and geomorphology**

A big part of the Lake IJsselmeer area lies in a declining zone. This process has been going on for a very long time; therefore the thickness of the Quaternary sediments varies between 200 and 300 metres. Most sediments are sandy, but with intercalations of gravel, clay and peat layers depending on the climate.

*Mirnserklif Frisian coast, 1913*







The landscape was primarily shaped by glaciers during the Saalien cold period (130,000 years ago). During this last ice age (the Weichselian period which ended 12,000 years ago) the area was a sand-blown tundra but not covered in ice, although the glaciers at that time reached as far south as Northern Germany.
Remnants of the glaciers can be seen in the province of Friesland and the former island of Urk, for instance in the outcrops of boulder clay. This boulder clay makes up big parts of the lake bottom in the northern IJsselmeer and is only covered with a thin layer of Aeolian sands. The boulder clay or till material was, by the way, also used for building the Barrier dam to close of the Zuiderzee in 1932.
Furthermore, the glaciers pushed up the ridges and sandy plateaus of the Veluwe and Utrechtse Heuvelrug. These ridges are now the highest points in the Lake IJsselmeer area. Their peaks reach up to 60 metres above sea level.
Other visible – glacial formed – geomorphologic features in the Dutch landscape are drumlins and pingos (in Friesland). These features were created after the ice sheet withdrew. In The Netherlands, this happened 130,000 years ago after which the so-called fine cover sands covered the landscape.
Around Lake Peipsi, the geomorphologic features are relatively young and therefore more eye-catching. Eskers, drumlins and kames are still visible at many places.

Sea level changes during the Holocene led to flooding of the Pleistocene landscape. About 8000 BP the sea level in the Lake IJsselmeer area was about 20 metres below present day sea level.
The old Pleistocene landscape was completely covered by Holocene sediments. Old river systems were covered by thick clay and humic layers (gyttja).
These Holocene sediments can be up to 15 metres thick in the old channels. The thickness of these young sediments decreases towards the former coastline of the Zuiderzee, e.g. towards west and north.
From a freshwater lake point of view, lake IJsselmeer is a very young system, which just started about 6 years after the completion of the Barrier Dam.
Its Holocene history varies enormously from an ecosystem perspective.
It developed from a tidal area with extensive lakes, marshes and fens into a freshwater lake surrounded by dikes with scarce natural connections to the hinterland.

**Lake Peipsi – geology and geomorphology**

Geological times were different compared to The Netherlands. The so-called bedrocks emerge in some parts of the Peipsi basin at surface level, for example the outcrops of Upper Devonian sandstones (ca. 380 my) near Kallaste at the eastern shore of Lake Peipsi, along the north-western shore of Lake Võrtsjärv as well as along the River Emajõgi.

These bedrocks were eroded and reshaped by the glaciers in the (Late) Pleistocene. The thickness of the Quaternary deposits (ca. 2 million years old) in the Peipsi basin varies between 5 to 10 metres in the northern part and up to 40 metres in Lake Peipsi itself. In some parts, no Quaternary deposits are present or at the most just a thin layer of half a metre. During the Pleistocene ice ages, still, glaciofluvial and glaciolacustrine sediments were deposited. Also large ice-pushed erratic boulders are present on the shore. Fine Aeolian sands can be found all over the basin. In certain places, shifting sands and dunes still occur e.g. to the north of Pskov and the NE hinterland of Lake Pskov.

Lake Peipsi started about 13,000 years ago as a big ice-dammed water basin with complicated water level changes. Short-term erosion processes did not influence the glacial topography outside the lake's recent boundaries.

Natural cliff, east coast Lake Peipsi, 1998

Its greatest depth (15.3 metres) occurs between Mehikoorna (Estonia) and Pnevo (Russia) where the lake has its bottleneck.
The highest point in the basin reaches up to 318 m above sea level. It is to be found in the southern part of the basin. In general, however, the basin is flat with undulations of till and cover sand ridges and outcrops of bedrock.
The Peipsi basin owns its shape to tectonic movement. The northern part has been (and still is) rising faster than the southern part of the lake. Several studies were carried out to determine the exact rate of the uplifts. However, this is difficult because sediments and/or water cover all old shorelines. During the Holocene the lake level changed continuously since the last ice age (the Weichselian). During the last 8000 years, the lake level of Väike Emajõgi for instance has risen 7 metres and that of Emajõgi 6 metres.

Another difference is that the sedimentation process in the freshwater Peipsi basin has been going on for more than 10,000 years. The deepest parts in Lake Peipsi have been filled up with a thick layer of gyttja or sapropel. These layers may be as thick as 10 metres, for instance in an erosion gully in the glacial deposits south of Piirissaar Island. These humic and (at least on top of the lake bottom) soft sediments are not a very attractive substrate for the freshwater mussels like *Dreissena polymorpha* (see part 3) and the top layer of this sediment can easily get into suspension during strong winds.
In Lake IJsselmeer, the top layer substrate is mainly sandy. This is still a legacy of the former Zuiderzee when sands were deposited. As Lake IJsselmeer was part of the North Sea in those days, strong tidal currents determined the substrate in its northern part. Sandy soils also occur along the former coast of the northern and western Borderlakes. Lake Markermeer and the southern Borderlakes have a more clayey bottom. This considerably affects the transparency and also the attractiveness for freshwater mussels.
The Holocene sediments in the IJsselmeer area thus vary from marine to fresh environments; whereas in Lake Peipsi only freshwater sediments occur as deposits on the glacial lake floor.

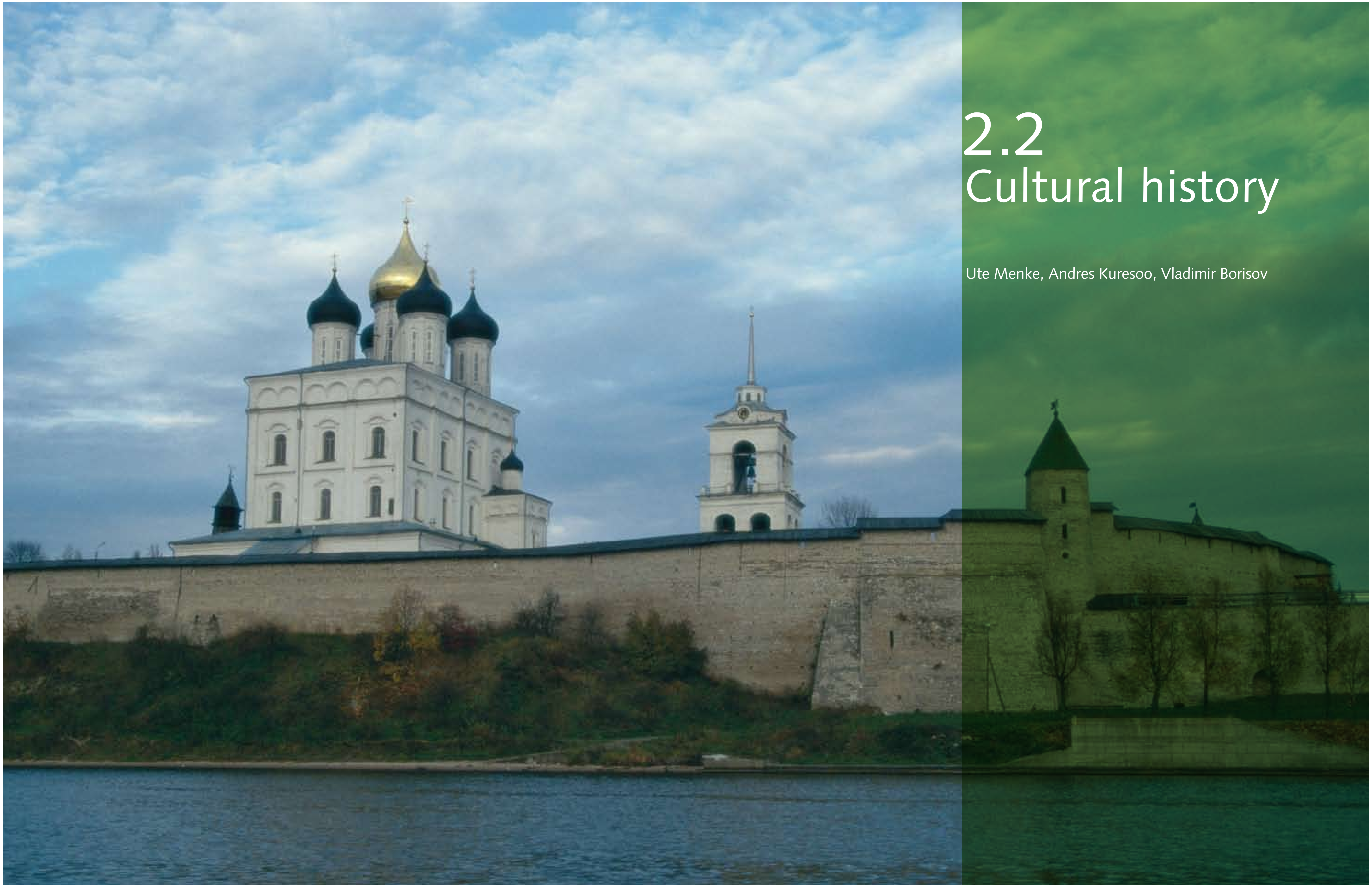




**The Afsluitdijk 75 years of safety**
*Sophie Lauwaars*

The Afsluitdijk, the causeway dyke that separates Lake IJsselmeer from the sea, is one of the main dams protecting a large area of The Netherlands from flooding. Construction of the Afsluitdijk began in 1927. Work commenced at either end and also on the Breezand sand flats in the middle, where an artificial island was constructed. On 28 May 2007, it was 75 years to the day since the final gap in the dyke was closed, turning the estuarine Zuiderzee into the freshwater Lake IJsselmeer.
Ever since, the new Lake IJsselmeer is only connected to the Wadden Sea by a system of sluices. Discharge sluices are necessary to release the water that builds up in Lake IJsselmeer. There are 25 of these sluices in the Afsluitdijk, each of them 12 metres wide. The discharge sluices are also of great importance to fish stocks. Various constructions allow fish like Eel, Salmon and Sea Trout to enter Lake IJsselmeer. Especially at the turn of the tide, when the speed of the current slows down, fish can enter the lake.
There also are three sets of locks that allow shipping in and out of Lake IJsselmeer. When ships are passing through, seawater from the Wadden Sea can enter along the bottom of the locks. This flow of salt water is inhibited as far as possible by means of a screen of air bubbles in the lock.
Only just to the south of the north-eastern end of the dyke, near Makkum, there are remnants of brackish water vegetation.
The Afsluitdijk is now a major part of the heritage of The Netherlands. It is still undergoing further development. Climate change and stricter safety regulations require it to be strengthened and the capacity of the discharge sluices is to be increased. The executive body of the Ministry of Transport, Public Works and Water Management (Rijkswaterstaat) is currently working on a project to increase the discharge capacity. A preliminary decision on this project includes a provision for the new discharge sluices to be equipped with a fish ladder at the north-eastern end, where the dyke heads to the west of Kornwerderzand. In time, possibilities for re-establishing a brackish water zone will be investigated. So far, the use of freshwater for drinking water and for agriculture has prevented this ecological direction.

*The Zuiderzee was closed off in 1932*



# 2.2 Cultural history

Ute Menke, Andres Kuresoo, Vladimir Borisov

The three countries that border the two lakes, Russia, Estonia and The Netherlands, have old ties related to the lakes. In medieval times, several cities in these countries were part of the Hansa trading organisation. In more recent times both lakes experienced similar developments in shipping and fishing.

In medieval times, cities such as Novgorod and Pskov in Russia, Tartu (old name "Dorpadt") and Narva in Estonia and Kampen) in The Netherlands were part of the Hansa trading organisation, an historic "European Trading Network" (Figure 1). Tartu and Pskov could be reached by seagoing vessels at that time, because in the Middle Ages the rivers Emajõgi and Pärnu still had an open connection to the Baltic Sea in the west (Figure 2). The uplift of the land changed the courses of these rivers and the recent construction of the dam in the Narva River meant the end of the open connection. The Dutch cities Deventer and Kampen still have access to the sea.

The Hanseatic League existed until the late 16th century. The league could not deal any longer with the economical, political and social changes of those days. A last meeting was held in 1669 with only a few members left. Today some old Hansa cities are organising annual meetings again. In 2005, a Hansa meeting was held, including medieval meals, goods, artists and musicians. Today, Tartu University has many ties with the Wageningen University and the city of Pskov has set up projects with the city of Nijmegen on economic and environmental issues – a renewal of the good old contacts with The Netherlands.

Well before Holland's "Golden Age", the 17th century, the Zuiderzee already was an important trade route. The population of Amsterdam, for instance, grew from 3,000 inhabitants in 1400 to 27,000 in 1560 (Van de Ven, 1993). Other cities like Hoorn and Enkhuizen were important harbours during the existence of the Dutch East India Company (the so-called VOC), which linked The Netherlands to the Far East, especially Indonesia.
The Hansa towns were thriving thanks to the good connection to the North Sea through the River IJssel. Also smaller cities along the IJsselmeer coast, such as Stavoren and Urk were important harbours at that time. Even villages like Makkum, Vollenhove, Elburg and Harderwijk were well-known fishing harbours and some of them even had "city rights". After closing off the Zuiderzee and the construction of the large polders, most of these cities and villages lost their "direct" connection to the North Sea and trade decreased. For the fishermen this meant a shift in fish species and in turn fishing techniques. In eight years' time the Zuiderzee changed into a freshwater lake.
To this day the fishermen of Urk (an island until 1942) mainly fish out on sea. They expanded their fishing grounds to greater parts of the North Sea, even to the Atlantic Ocean. In the old days there were 2,000 boats and 4,000 fishermen; nowadays (in 2005) there are just 68 companies left and only 40 boats are active on the lake at a day-to-day basis.
Eel fishing has always been famous. Table 1 gives an overview of catches in the Zuiderzee in 1931. A catch of 21.5 million kilograms of fish represented a value of 3.5 million Dutch guilders (today: 9.76 million euro). After the construction of the Barrier Dam, saline species such as Herring and Anchovy completely disappeared. Eel and Smelt, however, can still be found in Lake IJsselmeer today

**Figure 1.** *The extent of the Hansa trading organisation around 1400.*

**Figure 2.** *Fragment of the Petrus Kaerius Caelaviti map of Livonia ca. 1630, (Jaani, 2001a).*





*Enkhuizen*

although their number has decreased (see chapter 3.4). Pike and Perch became the main fishes of prey in the freshwater lake.
A Dutch newcomer was the Pikeperch, which came from Central and Eastern Europe and spread quite quickly through Lake IJsselmeer. In 1937 about 70,000 kg of Pikeperch were caught and as much as 2.5 million kg were caught in the last 4 months of 1939. The Pikeperch did very well in that young Lake IJsselmeer because it does not depend on vegetated shore zones as spawning areas, as do species like Perch, Bream, Roach and others. Another newcomer was Ruffe. In 1937 fishermen caught 1 million kg of this species. A description of the importance of fish species at present can be found in chapter 3.4.

**Table 1.** *Fish catches in the Zuiderzee in 1931 before construction of the Barrier Dam (Zinderen Bakker, 1940).*

| Fish species | Herring | Anchovy | Eel | Flounder | Smelt | Shrimp |
|---|---|---|---|---|---|---|
| Catches in million kg in 1931 | 12 | 3.5 | 0.94 | 2.3 | 1.35 | 1.6 |

In Lake Peipsi, developments in shipping and fishing were similar. Today there still are some fishing companies active at the lake.
Cities like Pskov and Tartu played an important role in the cultural history of their countries. Tartu still is a well-known university city with about 19,000 students. The university was founded in 1632. Its vicinity to Latvia and Russia offered potential for the development of transit and border trade. Nowadays, the Tallinn-Tartu highway contributes to the growth of the region's importance. In Pskov, the famous Kremlin was built in 1138. The city was founded close to the mouth of the River Velikaya, a strategic position on the (rail)way from Latvia to St. Petersburg. Furthermore, the lake provided a good income from fish. Along the River Velikaya many monasteries were founded. Today, the area together with the region of Pechory towards the north-west is of great importance in terms of cultural heritage.

## The Battle at Warns, Zuiderzee 1345

On September 26, 1345 a battle was fought on the shores of the Zuiderzee, at the Frisian south coast, known as the Battle of Warns. At that time, the Zuiderzee was a major barrier between the different settlements that emerged in The Netherlands. Quite a few attempts were made to conquer the Frisian tribes from the west. During the battle of Warns the nobility of Holland was defeated and many of the bravest warriors and eldest men were killed.
The battle was lost because of tactical mistakes, the landscape playing an important role in favour of the Frisians. Duke William IV had planned to attack the Frisians on the other shore of the Zuiderzee. The Hollanders, lead by William and his uncle Duke Jan van Beaumont, sailed with a fleet from Enkhuizen. At the Frisian shore William divided his men into two groups. One group went ashore north of Stavoren, the other near Laaxum. The Hollanders wore harnesses, but they did not bring horses, because in the boats all space was needed for soldiers, provision, building material and labour men. They planned to set up camp at the monastery of St Odulphus near Stavoren and to use this as a base to invade the Frisian territory.
At the approach of the Hollanders, the Frisians had left Laaxum and Warns and the troops of Duke William set the towns on fire. When the Hollanders moved on westward to Stavoren, however, the Frisians attacked them near the coast. The Hollanders with their heavy outfits could not move easily on the marshy grounds and they tried to escape back to the coast. Near Roode Klif, a steep gradient sloping down towards the sea, the Frisians, who knew the area very well, defeated them completely. All men died, including Duke William.
When the troops of Duke de Beaumont near Stavoren heard what had happened, they tried to escape. But before they could reach their ships they were overtaken and killed as well, except for a few men who managed to reach the ships and sail back to Amsterdam.
The battle was characterised by a series of tactical mistakes. Splitting up the troops proved a disaster. The Frisians initially retreated and chose to fight the Hollanders in the open, marshy landscape. This proved to be the right choice, perhaps helped by the fact that William started to move west before his main troops, including the archers, could follow. The sea prevented the retreat of the Hollanders. The Frisians were possibly helped further by the elevations in the landscape near Roode Klif, which gave them an overview and extra power as they were fighting downward.
Later on, in the battle against the western front lead by Jan van Beaumont, the Frisians won under similar conditions, again with the sea as their ally. They chased the Hollanders into the water, where they were killed.






## The battle on the ice, Lake Peipus 1242

The Battle on the Ice, also known as the Battle of Lake Peipus, was a battle between Novgorod and the Teutonic Knights which took place on April 5, 1242 on the ice of Lake Peipsi. The battle was one of the most significant defeats suffered by Roman Catholic crusaders during the Northern Crusades, which were directed against pagans and Eastern Orthodox Christians rather than against the Muslims in the Holy Land. The crusaders' defeat in the battle effectively marked the end of any significant campaigns against the Orthodox Novgorod Republic and other Russian territories in the aftermath of the conquest of Estonia.
Hoping to exploit the Russian weakness in the wake of the Mongol and Swedish invasions, the Teutonic Knights attacked the neighboring Novgorod Republic and occupied Pskov, Izborsk and Koporye in the autumn of 1240. When they approached Novgorod itself, the local citizens called 20-year-old Prince Alexander Yaroslavich, whom they had banished to Pereslavl earlier that year, back to the city. During the campaign of 1241, Alexander managed to recapture Pskov and Koporye from the crusaders.

### *The battle*

In the spring of 1242, the Teutonic Knights led by Prince-Bishop Hermann of Buxhoeveden of the Bishopric of Dorpat defeated a reconnaissance detachment of Novgorodians about 20 km south of the fortress of Dorpat (Tartu). The knights and their auxiliary troops of local Ugaunian Estonians then met with Alexander's forces at the narrow strait that connects the northern and southern parts of Lake Peipsi on April 5, 1242. Alexander, intending to fight in a place of his own choosing, retreated in order to draw the often over-confident Crusaders to the frozen lake.
The number of crusaders probably lay somewhere between 500 and 1000 men. Most of them were Germans, including knights of the Teutonic Order and their squires, although there also were large numbers of Danes and Swedish and Estonian mercenaries. The Russian force, on the other hand, consisted of about 5,000 soldiers: Alexander and his brother Andrew's bodyguards (druzhina), around 1,000 men, plus the militia of Novgorod (which was not at full force, because there was no direct threat to Novgorod).
According to contemporary Russian chronicles, after hours of hand-to-hand fighting Alexander ordered the left and right wings of his archers to enter the battle. By that time the knights were exhausted by the constant fighting and struggling with the slippery surface of the frozen lake. In disarray the Crusaders started to retreat further onto the ice, and the appearance of the fresh Russian cavalry made them run for their lives. When the knights attempted to rally themselves at the far side of the lake, the thin ice started to collapse under the weight of their heavy armour and many knights drowned.
This happened NW of the present village of Samolva. According to the First Novgorod Chronicle, Prince Alexander and all the men of Novgorod drew up their forces at the lake near Uzmen and they fought with them during the pursuit on the ice seven versts short of the (north-western) Subol shore.

The Battle on the Ice was described as an event of major significance, especially by Russian historians. The knights' defeat at the hands of Alexander's forces prevented the crusaders from recapturing Pskov, the linchpin of their eastern crusade. The Novgorodians succeeded in defending Russian territory and the German crusaders never mounted another serious challenge eastward.


# 2.3 Economy and population

Ute Menke, Andres Kuresoo, Vladimir Borisov

Differences in population density and in pressure on the land are the main reason why Lake IJsselmeer and Lake Peipsi are developing in different ways. In Russia and Estonia, many agricultural fields were abandoned during the last decade, while in The Netherlands, pressure on the land has become even greater than before. Lake IJsselmeer is intensively used for recreation and even housing, whereas Lake Peipsi is much more pristine.

For Estonia, recent economic changes are related to the shift from communism to a market oriented economy. In the Russian Federation, too, big changes took place after "perestroika" in the early 1990s. These economic changes had their effects on agriculture. Many agricultural fields were abandoned to nature and are no longer (or only scarcely) maintained. However, as the interpreted Landsat images show (Figure 1), there is a significant difference between the Estonian and the Russian part. The number of agricultural fields is much higher on the Estonian part. The origin lies in history, as German knights started to settle in the Baltic States as early as the 13$^{th}$ century. The pressure on the land was much higher than in the Russian region. In Russia, the most valuable agricultural soils are in the loess and schernosem (black soils) belt in the south of the country. There was no need to drain and cultivate the land in the Peipsi region, a mere boundary zone of the (even at that time) vast territory of the Russian Federation. Due to the relatively low population density, there was little need to increase production.

In The Netherlands, land use changed dramatically over the last 100 years. Comparing the maps of 1900 and 1990, for example, shows that large bog areas in the northern part of The Netherlands have vanished completely (Figure 2). Another significant development is evident in the coverage of forests. Large parts are reforested again by now. The recent picture shows how high the human pressure is in a densely populated country such as The Netherlands.

Differences in population density and (in turn) pressure on the land are the main reason why the two lakes have developed in different ways. Figure 3 and 4 show the two lakes and human population density from the major cities and villages around them. Lake IJsselmeer has major cities like Amsterdam, Almere and Lelystad in the area. About 1 million peope live in and around Amsterdam alone, while the the so-called Randstad has about 7 million inhabitants. The selected area of study, the IJsselmeer area, is home to 2.2 million people.

The most important reason to start reclaiming land form the Zuiderzee at the beginning of the 20th century was the need for more arable land (table 1), though infrastructure was a major reason, too. The IJsselmeer region and especially the polder cities saw rapid change during these last decades.
The city of Almere was founded in January 1970. At that time, Almere had 52 inhabitants. In January 2006 this number had grown to 178,458. Lelystad – the capital of the province – has about 70,000 inhabitants today. However, more

**Figure 1.** *IJsselmeer en Peipsi Landsat image in false colour (green biomass is depicted in red).*


**Figure 2.** *Land use changes in The Netherlands 1900 versus 1990 (Van Beusekom, 2007).*

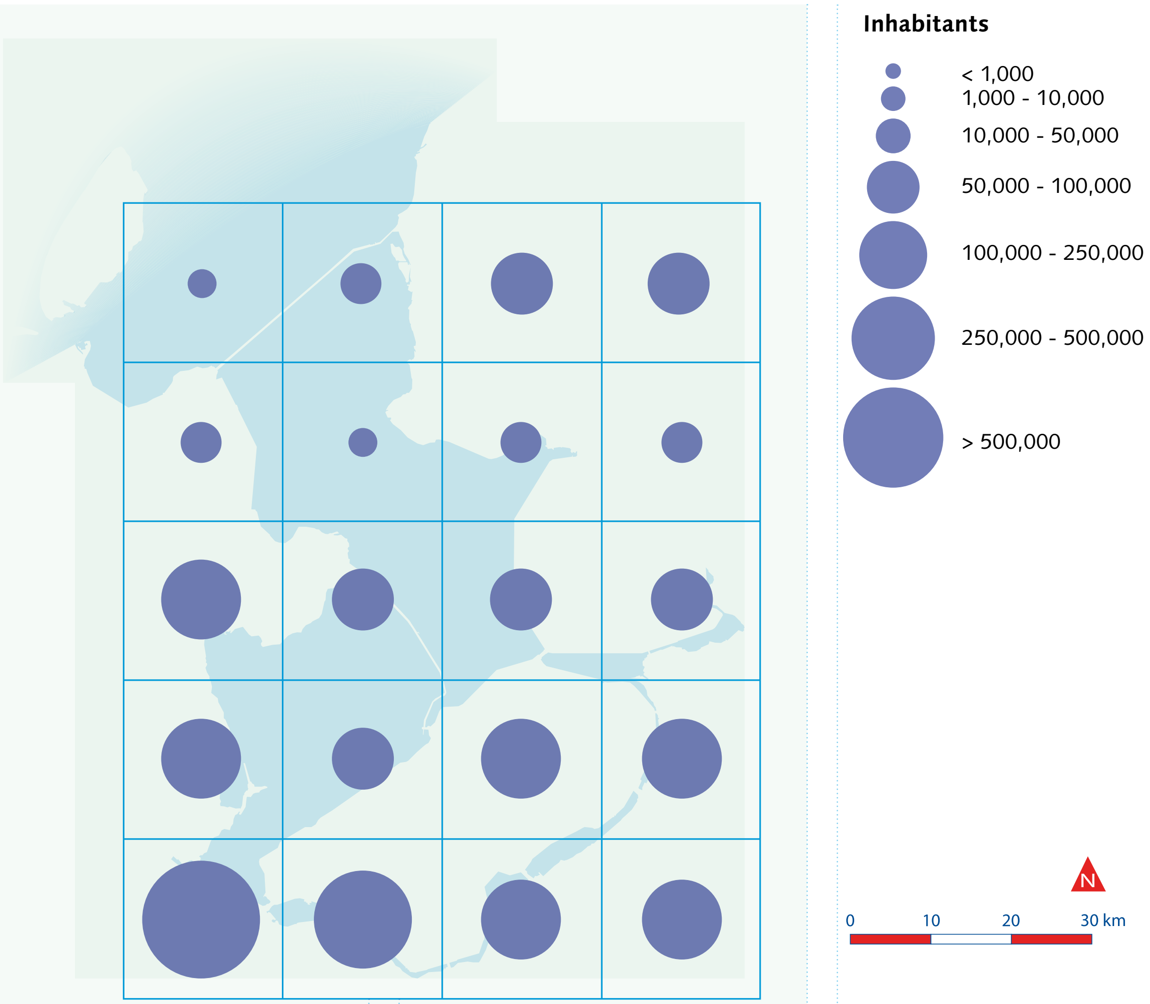



**Figure 3.** *Human population density IJsselmeer*

and more of the reclaimed land is redeveloped into nature areas in order to create recreational space for these fast growing cities.

**Table 1.** *Land use in the IJsselmeerpolders in percentage of surface area per polder (Van de Ven, 1993).*

| Land use | Wieringermeer (1930) | North-East polder (1942) | Eastern Flevoland (1957) | Southern Flevoland (1968) |
|---|---|---|---|---|
| Agriculture | 87 | 87 | 75 | 50 |
| Urban | 1 | 1 | 8 | 18 |
| Forest and nature | 3 | 5 | 11 | 25 |
| Roads and water channels | 9 | 7 | 6 | 7 |

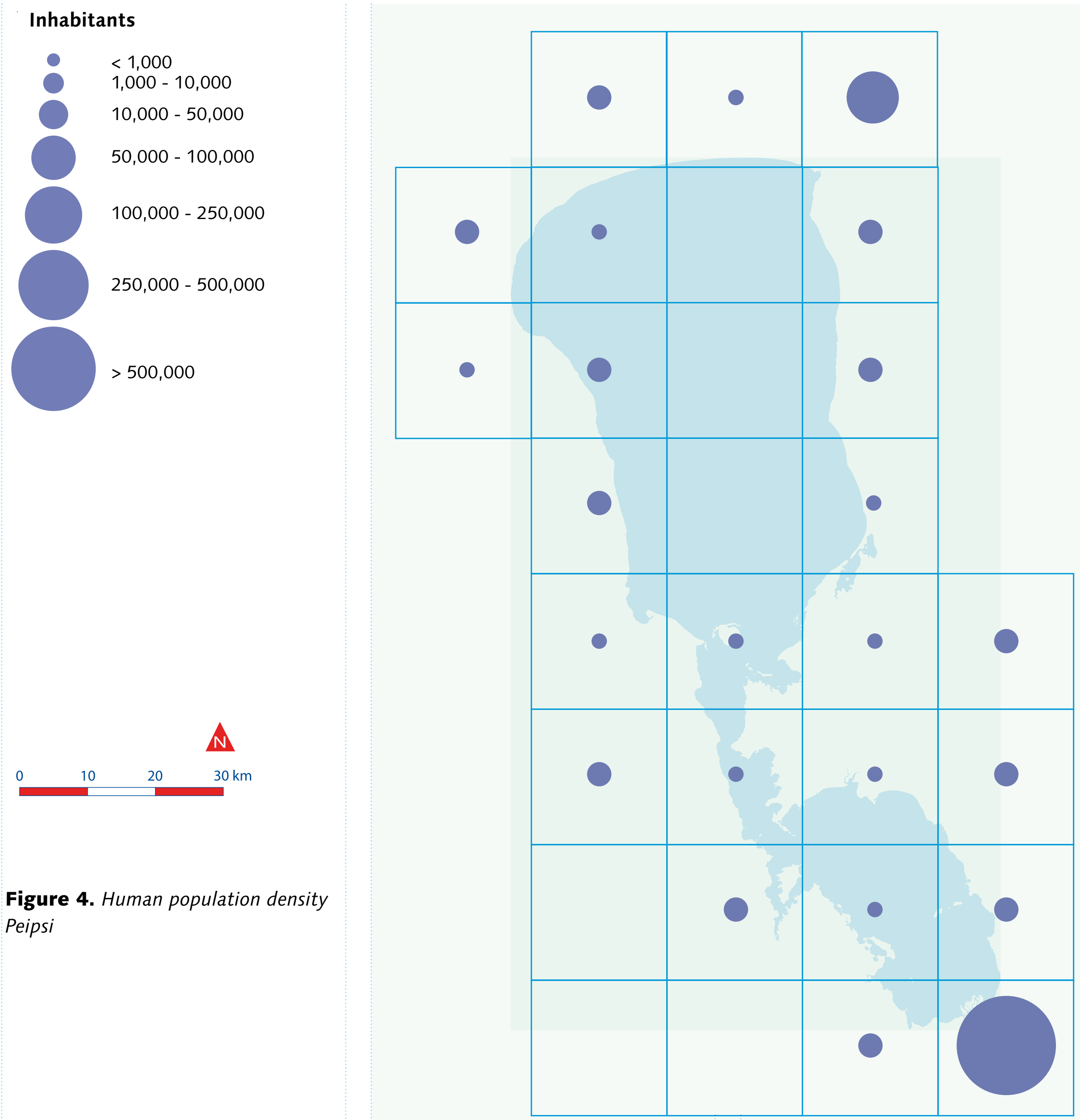



**Figure 4.** *Human population density Peipsi*

Before 1991, when Estonia was still part of the Soviet Union, Estonian agricultural production was limited to meat and milk. Grain to feed the cattle was imported from other areas within the Soviet Union (Kuresoo, 2006). The products were sold elsewhere in the Soviet Union and were highly subsidised. After its independence Estonia opened its markets and applied for the liberalised trade policy. However, Estonia was a newcomer on the EU markets, while the Russian market was largely lost to Estonia by the end of 1998. Due to increased competition in Europe, the amount of land cultivated, dropped by 50% (from about 1 million ha in 1980 down to 530,000 ha in 2006). The same is true for livestock of pigs, cattle and sheep. Nowadays Estonian farmers have to compete with their 'colleagues' in other EU countries. As a result, production levels increased again, facilitated by EU subsidies over the last 15 years.

Similar developments took place on the Russian side of Lake Peipsi. Reclamation works reached their climax in the 1980s, but in the 1990s the works were discontinued due to lack of funds. The arable land in the Pskov area was reduced from 875,000 ha in 1990 to 576,000 ha in 2000 (reduction of 50% between 1985 and the present day). Not surprisingly, crop yields declined as well as the use of fertiliser almost stopped.

The decrease in terrestrial biodiversity around Lake Peipsi cannot be explained by the recent shifts in agriculture alone. The area has always been a huge wetland with bogs and fens, which was not very suitable for farming. A change in landscape management took place after World War II, when the extensive, small-scale farming plots were abandoned, and once again between 1960 and 1980, when the wetlands were drained.
Fifteen years ago a new problem emerged. For instance, the big Räpina polder as well as the former big Soviet *kolkhozes* were abandoned. Meadows and wet grasslands were no longer used for grazing cattle nor for haymaking and rapid bush encroachment occurred. Now that they are no longer used for intensive farming, these areas are no longer attractive for certain bird species such as the Ruff, Black-tailed Godwit, Common and Great Snipe. In future, management measures need to be redirected in order to keep part of the area open.
In the Pskov region a new nature management was introduced by the Beaver, since its successful reintroduction in 1952. The Beaver occupied former shallow irrigation channels in bogs and peat areas and in doing so contributes to ecological restoration of those wetlands.

Eutrophication of the water as a result of the use of fertilizers in agriculture was reduced enormously in the last two decades; in Estonia just 1/5 of the mineral fertilizers used in 1985 was still in use in 2001. For Russia exact data are not available, but probably reduction was more than 90% over the same period.

In The Netherlands the impact of diffuse pollution on water bodies is well known. Since the approval of the Water Framework Directive, in 2000, all water managers take care to ensure a good water quality or at least a good potential by 2015. The farmers play an important role in this process. More and more they are seen as landscape or nature managers. Measures to reduce the impact of N- and P-nutrients for the water and soil system are expensive and sometimes the result is not measurable at all. The problem is that nutrients in the water system not just originate from recent fertilization but also from historic times. In order to stimulate farmers to change their fertilizing practices, the authorities must support good management with subsidies; the farmers will not accept a new policy if they are the only ones to bear the risk.
The farmers have various possibilities to reduce the input of nutrients in water systems. The development of "helophyte filters" can reduce the emission of N and P. The slurry dug up from agricultural ditches should be spread out more evenly over the fields and not just on the banks. In that case, the backlogging of P may be ten times lower. By cutting and removing the grass along water bodies the banks will become poorer and the amount of species will increase. The development of water vegetation will have positive results on the water quality, e.g. by reducing algal growth.
The Dutch government has earmarked a lot of money for the years until 2020 to improve the smaller elements in the rural landscape (see *Praktijkonderzoek Plant en Omgeving*, www.ppo.wur.nl).

As pressure on the land in The Netherlands will become even greater, it will be very difficult to find space for nature ("green") and water ("blue"). However, from an economic point of view great emphasis is put on further urban development in relation to a green environment worth living in.

*Abondoned fields*

In Estonia and Russia, this trend is not likely to occur in the near future. It would be good if people were to realise how valuable it is that gradients are still intact and that different types of landscapes still coexist. Wetlands and nature areas can also generate prosperity in a more sustainable way. In North-West Europe we have learned that certain habitats (e.g. raised bogs) cannot be restored anymore or only at extremely high costs. Needless to say, the preservation of these large marshes, fens and bogs is an important future goal, especially as space becomes even more valuable.

**Leisure**

In the IJsselmeer area, leisure activities are of great importance (50% of the direct added value of the economical activities, NEI, 2000). The lakes are used for recreational shipping, swimming, sailing and so on. Many tourists are also attracted by the large populations of birds in the area. They like to watch them. That is why nature organisations (that represent 3 million members) and other area managers organize trips and field visits to nature development sites and nature areas on a regular basis.

Along Lake Peipsi, recreational activities are on the increase as well, but so far they do not contribute much to the incomes of local people. Small private enterprises develop Bed & Breakfast facilities. However, compared to the Dutch situation with its millions of foreign tourists in the IJsselmeer area, tourism in the Peipsi area is still at a very low level. On the Russian side, this trend has not even started. Apart from some claims for new building sites by the "new rich", most of the territory remains untouched by economic developments as yet.

## Skating on natural ice

*Roel Doef & Theo Vulink*

Through the eyes of famous Dutch painters, we may get an impression of the way of life in Holland centuries ago. The paintings of Hendrick Avercamp (1585-1634), for example, show that skating on natural ice was already immense popular at that time. In the 14th century, the Dutch stopped skating on leg bones of animals and started to use wooden platform skates with flat iron bottom runners.

***Ice –fever***

***"I always thought the Dutch a sensible lot. Practical, bourgeois, steady. But in winter, when the canals freeze, the Dutch, like Brazilians at Carnival, are taken with a fever. Skating fever"***

***Kees de Jong, a Frisian skater and shopkeeper, has skated the Elfstedentocht several times "for the honour of reaching the finish." He also skates to feel free in nature and to socialise. "There are no ranks on the ice," de Jong says. "You can talk to everybody you wouldn't ordinarily talk to."***

Many Dutch, including skating champion Ria Visser, describe skating on natural ice as a visual and auditory high. "When you are on the ice, the whole world looks different," said Visser, who likes to skate in the lake country of Utrecht. "You hear the silence. It's beautiful."
Archive from The Boston Globe
The Dutch fascination with skating might have something to do with the Dutch 'love-hate relationship' with water. Water is essential for living, but in delta regions it also represents a permanent threat. Water is a serious enemy because of the potential risk of flooding. During an ice-period, however, the ice is conquered by skaters and generally beloved. Gliding over large surface areas of ice gives people a unique feeling of freedom and the oftentimes immense athletic exercise evokes an unequivocal sense of joy and sociability.

***"Elfstedentocht"***

The Eleven-city tour is a legendary skating tour of 200 km through eleven cities in the province of Friesland in The Netherlands. The tour passes through three cities bordering on Lake IJsselmeer, named Stavoren, Hindeloopen and Workum. Whenever the tour is organised, people in The Netherlands get skating fever. Almost everybody is directly or indirectly involved in one way or another. More than 16,000 recreational skaters and approximately 600 serious competitors participate. However, since 1963 the tour has taken place only three times, in 1985, 1986 and 1997. How long will it take before it will happen again?
Skating on Lake IJsselmeer is even rarer; not only is the quality of the ice often below the standards of the acceptable, also the freezing period needs to be even longer before ice on this lake can be trusted. 4 February 1996, a ca 50 km tour was organised from Enkhuizen to Stavoren v.v. During this horribly cold tour, skaters encountered ice ridges and some small open water areas right in the centre of the lake and were generally challenged by hard weather conditions. Nevertheless, some 40,000 sportsmen still cherish their memories of this tour.

***Climate change makes skaters travel far and wide***

As periods of severe frost occur less and less often in The Netherlands, the climate really seems to change. Despite the lack of natural ice during the last decennium, skating is still very popular in The Netherlands. Several large cities own a 400 meter indoor skating ring, but still the greatest thrill of course is skating on natural ice. Therefore Dutch skaters travel all over the world to skate in countries that feature colder winters.

***Skating tour Lake Peipsi, Mustvee, Jõgeva county, 2007 and 2008***

Estonian, Russian and Dutch people have a love for winter sports in common. Due to established contacts in the course of the Peipsi-IJsselmeer project a new initiative was started: co-operation on ice-skating. Currently, we have rallied support from several Dutch skating enthusiasts from various backgrounds, united in the Holland-Estonia foundation.

After the 2006 skating tour on Lake Peipsi, which was organised on Estonian initiative, in 2007 the Holland-Estonia foundation conducted an exploring mission to Mustvee at Lake Peipsi. This led to the co-operation of this foundation with the organizers from Jõgeva county for joint participation in the organisation of a 100 km skating-event on 1 March 2008. This tour will be widely advertised among professional and recreational skaters. It is expected that Estonian, Russian and Dutch skaters will establish a new tradition, moving from science into sport.

*Difficult ice conditions, IJsselmeer, February 4, 1996*

*Skating tour Lake Peipsi, Mustvee, March 2007*

# 3 Lakes compared

# 3.1 Comparison of phosphorus concentrations, chlorophyll-a and transparency between Lakes IJsselmeer, Peipsi and Pihkva

Eddy Lammens, Tõnu Möls, Külli Kangur & Marina Melnik

Nutrient load is one of the most important variables influencing the ecological status of a lake. Total P-concentration in Lake Peipsi has always been low but increased since the 1990s; transparency has decreased showing a delayed response. In Lake IJsselmeer total P used to be quite high, but nowadays it is lower than any level ever measured before in this lake, so the ecological situation seems to be better than ever at first sight. For the water manager of Lake IJsselmeer it is important to know what to expect if the nutrient load were to decrease even further, causing the food web to change and changing feeding conditions for birds as well.

Nutrient load is one of the most important variables influencing the ecological status of a lake. It is important to know what to expect if the nutrient load were to decrease to levels as requested by the Water Framework Directive. A high nutrient load implies a high organic production and therefore, potentially, a high carrying capacity for fish and birds, but it also leads to a high density of algae and therefore to low transparency and little opportunity for water plants to grow as is the case in the present situation.
In this comparative study we compare Lake IJsselmeer en Lake Peipsi with respect to nutrients, chlorophyll and transparency and consider the ecological state of Lake Peipsi as a good reference state for Lake IJsselmeer. We discuss the implications of lower nutrient levels in Lake IJsselmeer regarding the ecological state of Lake Peipsi.

### General methods

We used long time series of total P, dissolved Phosphorus, chlorophyll-a and Secchi-disc transparency measured monthly in lakes IJsselmeer, Peipsi and Pihkva. However, the values of these variables could not be used directly but were estimated by covariance analysis, using a large generalised linear model to correct for year, day within year, geographical position and sampling depth (Möls *et al.*, 2004; Möls 2005). For the analyses we used SAS System, Release 8.2 (SAS Institute Inc., 1999), especially the GLM procedure. For the time series we used 1st August as reference date and for the seasonal series we used 2005 as reference year.

### Nutrients at the base of the foodweb

A high concentration of nutrients may lead to a high density of algae and therefore to low transparency and little opportunity for water plants to grow. This is particularly the case in lakes with a long residence time, that is to say longer than one month. On the other hand, a high nutrient load also means high organic production and therefore, potentially, a high carrying capacity for fish and birds. This capacity, however, depends on the structure of the food web. Nowadays, the total P concentration in Lake IJsselmeer is already lower than any level ever measured before in this lake, so the ecological situation seems to be better than ever at first sight. If the nutrient load were to decrease even further, this might cause the food web to change and change feeding conditions for birds as well. There is a general fear that the carrying capacity

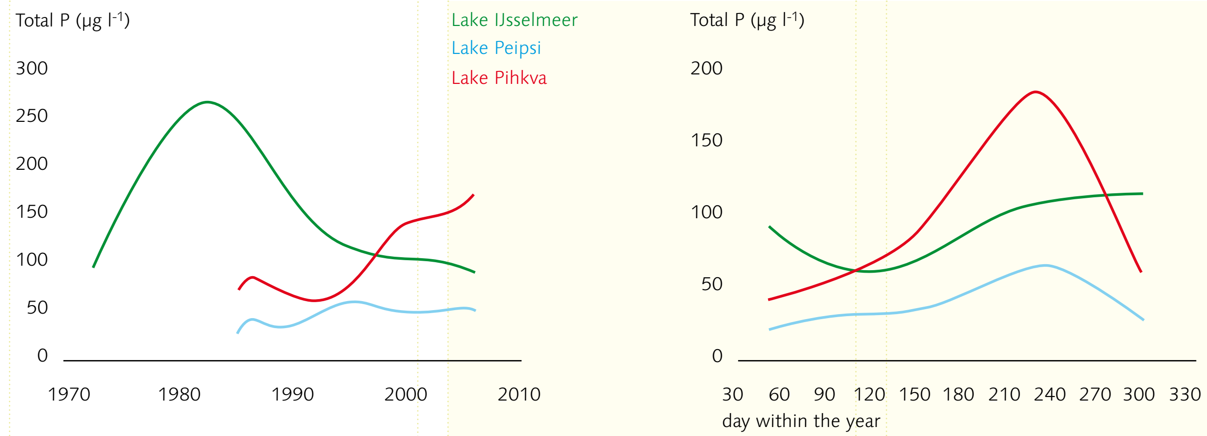



**Figure 1.** *Total Phosphorus concentration referenced to 1st August (left) during the period 1970-2006 and seasonal development referenced to 2005 (right).*

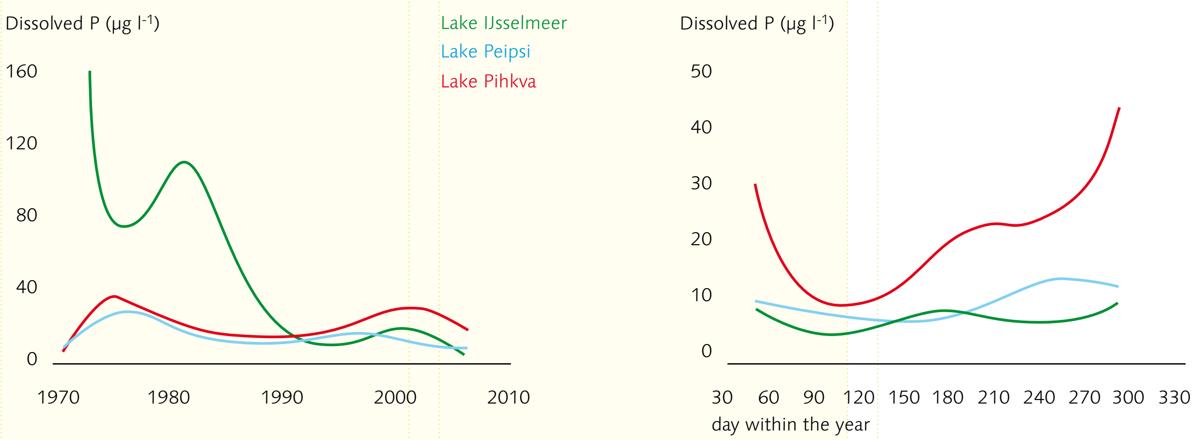
of the lake will decrease to such an extent that Natura 2000 goals cannot be achieved and have to be adapted, or else the water manager may risk penalties for the management applied.
The food for water birds consists of vegetation, benthic macro-invertebrates and fish (Van Eerden 1997). At high nutrient loads, algal blooms cause low transparency and prevent vegetation to develop. They also cause excessive (suffocating) sedimentation rates for Zebra Mussels and stimulate the dominance of Bream, which is hardly edible for piscivorous birds. So a food web dominated by blue-greens and Bream does not really contribute to a high biodiversity and to a good food base for water birds. Therefore, intermediate levels of P-load, which allow sufficient water transparency for water plants to develop and good conditions for Zebra Mussels, are preferable.
In Lake IJsselmeer, Lake Peipsi and Lake Pihkva, P-concentration is one of the most important variables determining the chlorophyll-a concentration and transparency. According to a paleolimnological study of Cremer & Bunnik (2006), the total P concentration in IJsselmeer has never been low. At its original size and well before the eutrophication started in the 1940s, the lake must have been mesotrophic with estimated total P concentrations of 40-80 $\mu g\ l^{-1}$.

### Total P concentration

In IJsselmeer the concentration of total P peaked at the beginning of the 1980s at about 250 $\mu g\ l^{-1}$. Due to measures limiting the emissions of P from households, agriculture and industry, the concentration of total P decreased to < 100 $\mu g\ l^{-1}$ in 2005 (Figure 1). In spring the concentration is minimal (ca. 60 $\mu g\ l^{-1}$) and in autumn maximal (about 120 $\mu g\ l^{-1}$). In Lake Peipsi and Lake Pihkva levels are generally lower but the trend is just the opposite: in the 1980s the total P concentration was minimal (40-60 $\mu g\ l^{-1}$) and the concentration increased up to 60 $\mu g\ l^{-1}$ in Lake Peipsi and even > 150 $\mu g\ l^{-1}$ in Lake Pihkva in 2005 (Figure 1). In Lake Peipsi it varies seasonally between 20 and 60, in Lake Pihkva between 40 and 180 $\mu g\ l^{-1}$ (Figure 1).

### Dissolved P

The amount of dissolved P ($PO_4$) indicates whether P is utilised by algae and therefore incorporated in the food web. A high concentration of dissolved P indicates a surplus of P and therefore algae are either limited by light at low transparency or by grazing at high transparency. In IJsselmeer until the beginning of the 1990s, the concentration of P was so high and the water transparency so low that algae were no longer P-limited, but light-limited due to self-shading caused by high algal density. In the beginning of the 1990s, the reduction of the P load was so effective that the surplus P disappeared and dissolved P dropped to levels of 5-15 $\mu g\ l^{-1}$ (Figure 2), comparable to values in Lake Peipsi and Lake Pihkva, where P was also limiting. In Lake Peipsi this low



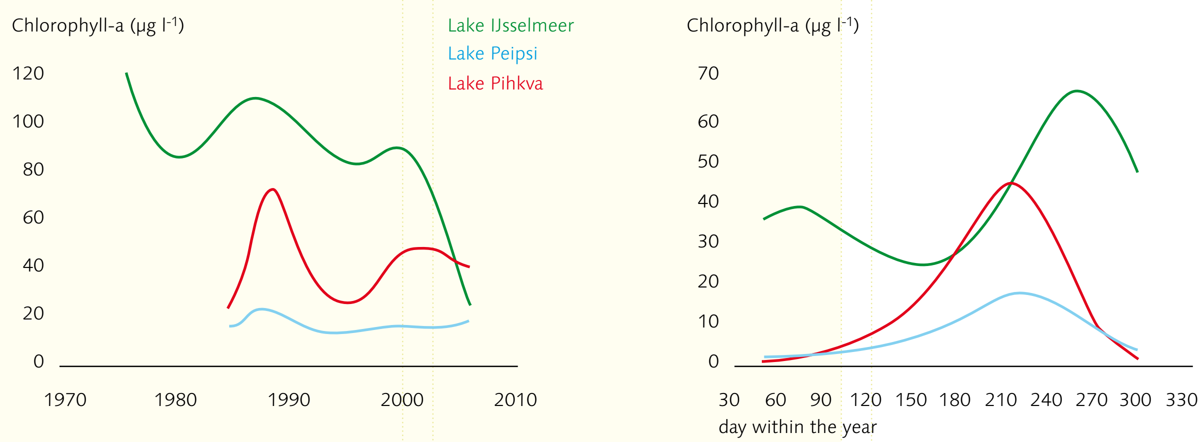

level could be maintained until 2005, but in Lake Pihkva the concentration increased up to 30 $\mu g\ l^{-1}$ (Figure 2), indicating a surplus of dissolved P. The fast increase of P concentration in Lake Pihkva is related to the inflow of nutrients from the river Velikaya. At the Russian side the sewage treatment plants are hardly effective and cause an increasing load of P. In Lake Pihkva dissolved P is only limiting in spring, whereas in Lake Peipsi and recently in Lake IJsselmeer P is limiting also during the rest of the year (Figure 2).

**Figure 2.** *Dissolved P concentration referenced to 1st August (left) during the period 1970-2006 and seasonal development referenced to 2005 (right).*

### Chlorophyll-a

In Lake IJsselmeer the chlorophyll-a concentration showed a delayed response to the total P concentration, as it took time for the surplus P to disappear. The chlorophyll-a concentration started to decrease in the 1990s when P became limiting and went down to 20 -60 $\mu g\ l^{-1}$ in the 2000s (Figure 3), maybe also because of extra top-down control by Zebra Mussels and zooplankton in spring. However, in Lake Peipsi and Lake Pihkva there was no significant increase in chlorophyll-a concentration as yet or at least a delay in the expected increase (Figure 3). Probably the increase in total P is compensated by some top-down effect, such as grazing by zooplankton or Zebra Mussels, which may be the reason for the relatively high concentration of dissolved P in Lake Pihkva. In spring the concentration of chlorophyll-a is always (relatively) low compared to July-August in Peipsi-Pihkva and August-September in IJsselmeer (Figure 3). The time needed for the blue-greens to develop explains this time lag. The difference in climate between The Netherlands and Estonia explains the relatively low chlorophyll-a concentration in spring and autumn, when temperature in Estonia is lower than in The Netherlands.

**Figure 3.** *Chlorophyll-a concentration referenced to 1st August (left) during the period 1970-2006 and seasonal development referenced to 2005 (right).*







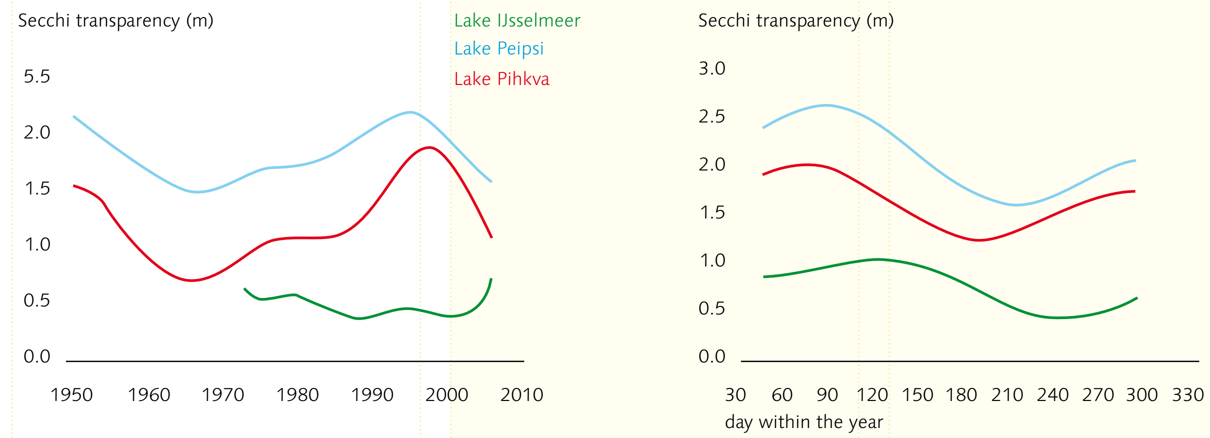




**Figure 4.** *Water transparency referenced to 1st August (left) during the period 1970-2006 and seasonal development referenced to 2005 (right).*

### Water transparency

Water transparency has always been quite low in Lake IJsselmeer, about 50 cm. Only after 2005 water transparency increased up to 75 cm Secchi-disc depth (Figure 4). Transparency in Lake Pihkva has always been lower than in Lake Peipsi. Since the 1980s transparency increased from 1 m to 1.5 m at the end of the 1990s in Lake Pihkva and from 1.5 to >2 m in Lake Peipsi. After 2000 there has been a decrease in transparency in both lakes (Figure 4). In all lakes transparency is highest in spring and early summer and decreases in the second half of the year (Figure 4).

*Bloom of bluegreen algae, result of high water temperature and too high nutrient level.*

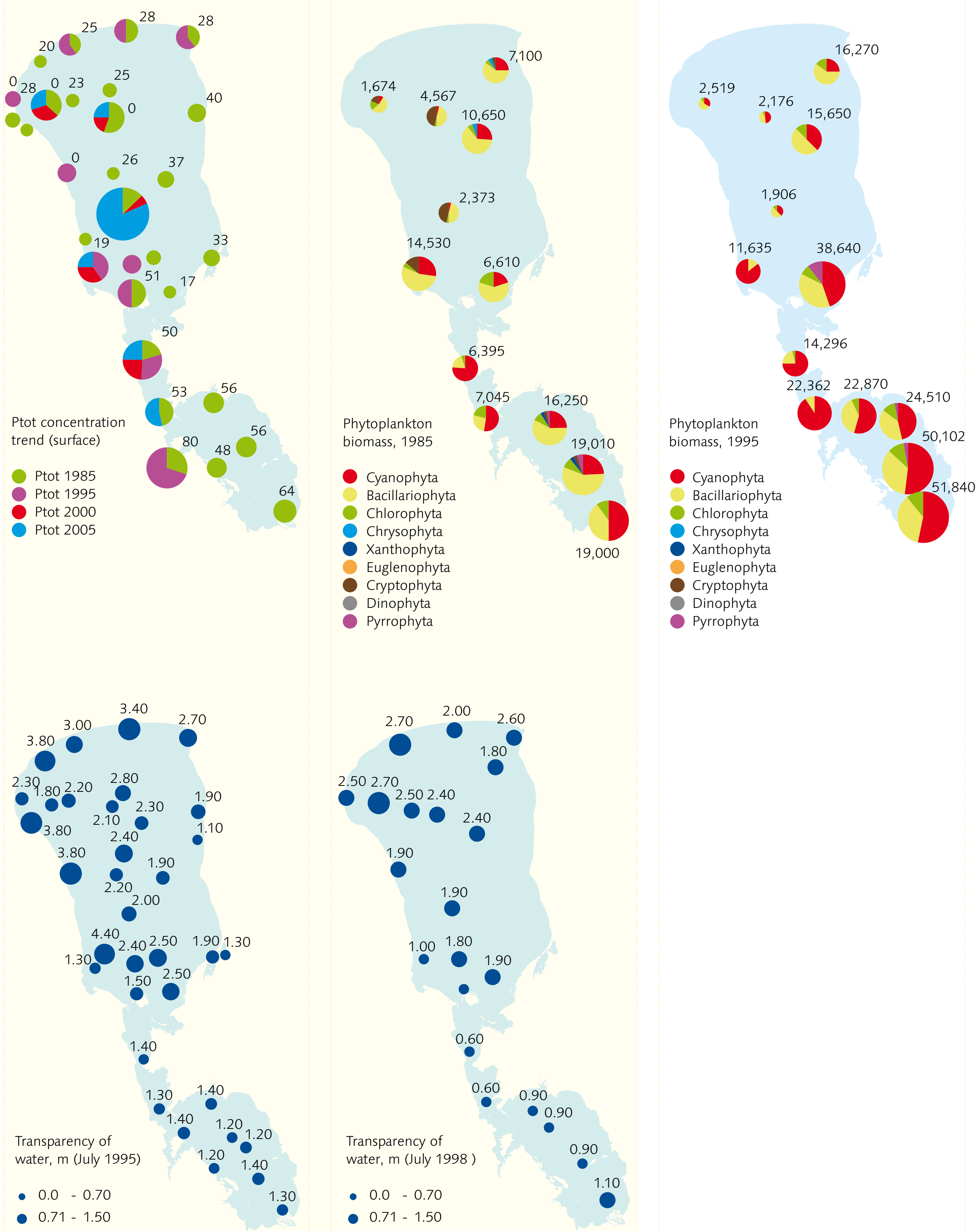



**Figure 5.** *Spatial distribution of total P concentration, phytoplankton biomass and transparency in Peipsi and Pihkva.*

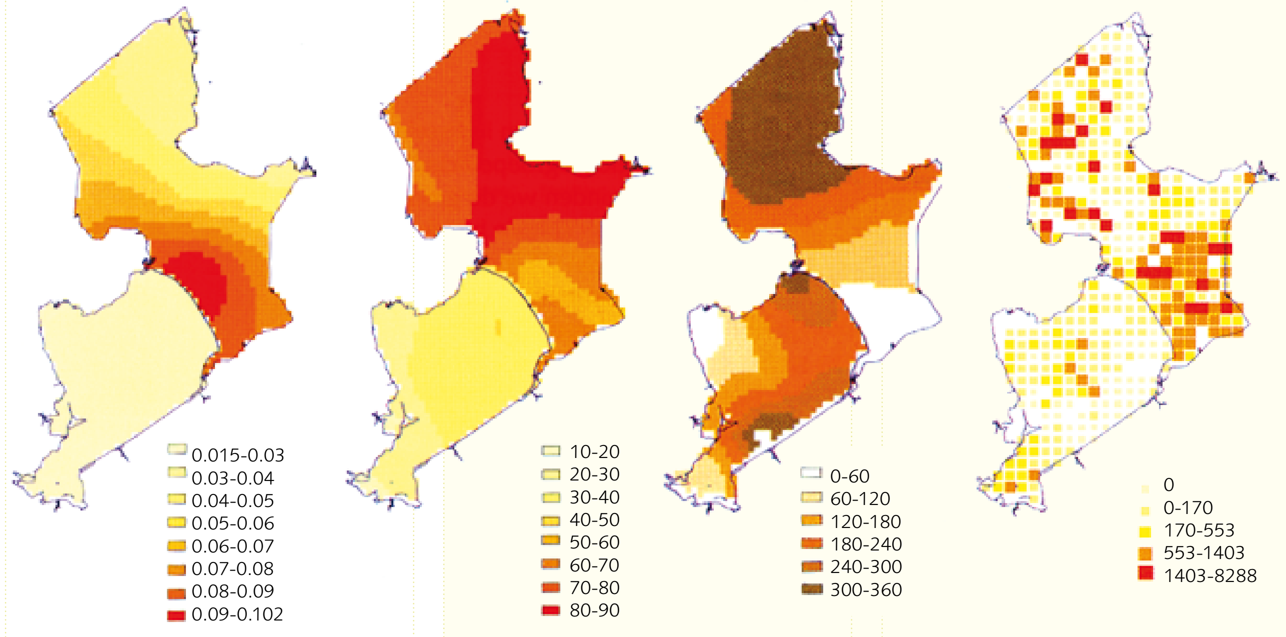



**Figure 6.** *The spatial distribution of the concentration of dissolved P, chlorophyll-a, bluegreens and the density of Zebra Mussels in IJsselmeer and Markermeer averaged over the period 1972-1995 during April-October (after Lammens 1999)*

### Spatial patterns

The main source of nutrients for Lake Peipsi comes from the river Velikaya and enters Lake Pihkva at the southern end. This is the reason for the decreasing gradient in total P concentration from the south to the north (Figure 5). As P is limiting the growth of algae, this gradient is also present for the biomass of phytoplankton (Figure 5) and related to the gradient of transparency in the lake (Figure 5).

In IJsselmeer a similar gradient is present from the point where the river IJssel enters the lake. However, the nutrient load in IJsselmeer used to be much higher than in Lake Peipsi and yet for many years the P concentration in the lake did not limit the biomass of algae, but light did. As a consequence the gradient in P concentration does not correspond with the gradient of algae (see Figure 6). In fact the gradient of algal concentration is just the opposite to that of total P. If there were only limitation by light there would be no gradient at all, but because there is a top-down effect of Zebra Mussels in the southern part of the lake, the density of algae is limited by grazing of algae by mussels, causing this opposite gradient (Figure 6). This effect of grazing by mussels is also apparent in Lake Markermeer. The western parts, as well as Lake IJmeer in the south, contain the highest mussel densities, the lowest algal densities and a relatively high transparency (see also text box Markermeer).

Considering the last decennium, the changes in total P, dissolved P, chlorophyll-a and transparency are very slow, but there is a steady decrease of total P and chlorophyll-a and an increase of transparency (Figure 7). At the inflow and in the southern part the concentration of dissolved P is still much higher than in the more northern parts, indicating that P is not fully utilised (Figure 7). Total P concentrations between south and north hardly differ (Figure 7), so the high dissolved P concentration is not an overload but it is not utilised because grazing prevents algae to develop fully. This is clear from the low chlorophyll-a concentration and high transparency in the southern part of the lake.

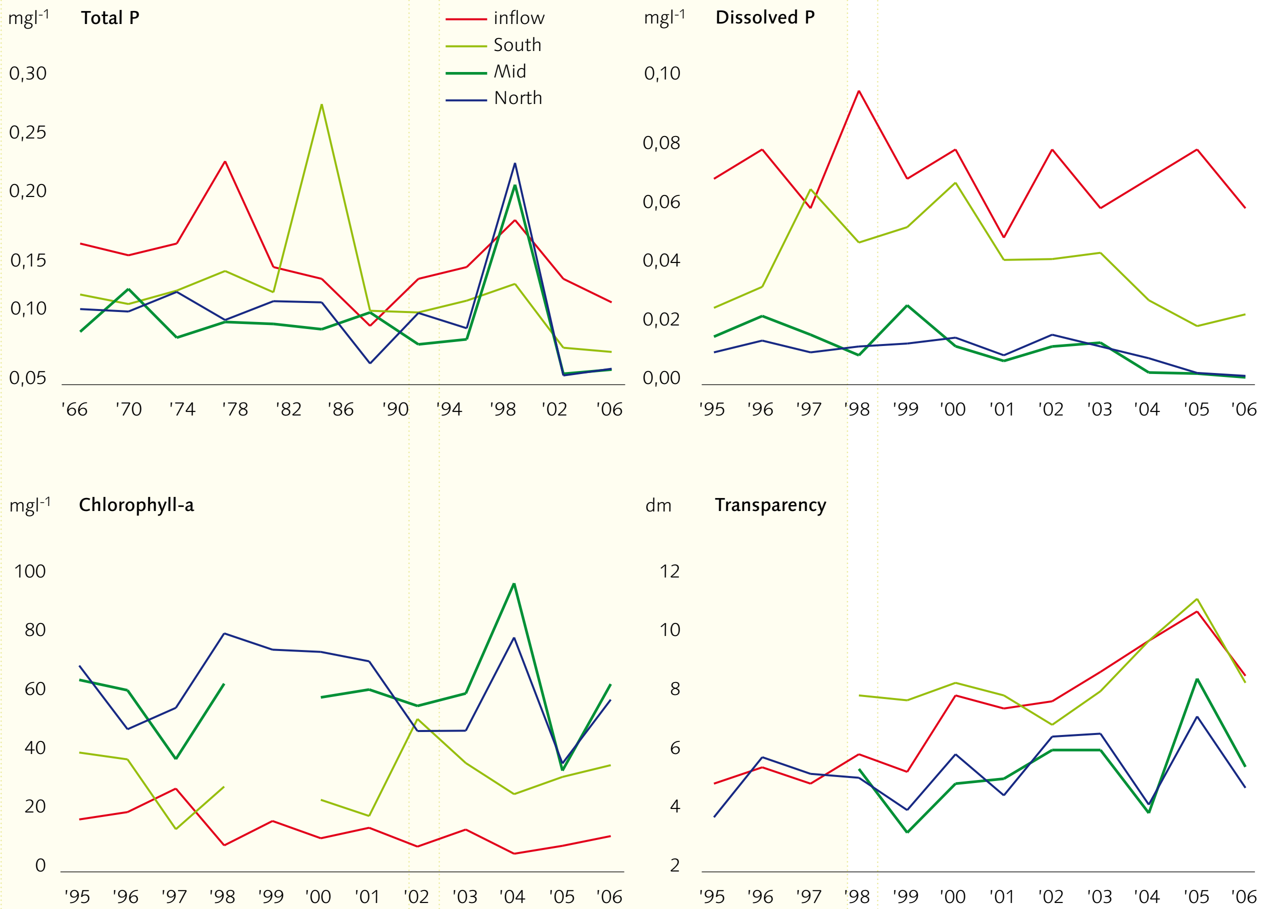



**Figure 7.** *Concentration of total P, dissolved P and chlorophyll-a, and Secchi-depth transparency (April-September) in IJsselmeer during the period 1995-2006.*

**Conclusions**

Since the beginning of the 1980s, total P decreased in Lake IJsselmeer, but chlorophyll-a did not begin to decrease until the 1990s and transparency only increased after 2000. In 2005 and 2006 the concentration of chlorophyll-a decreased even below 60 μg $l^{-1}$ and transparency increased from 50 to 75 cm. In Lake Peipsi and Lake Pihkva, the total P concentration has always been quite low (40-60 μg $l^{-1}$) but P-concentration increased since the 1990s causing in chlorophyll-a and transparency a (delayed) response. Transparency increased since the 1980s and decreased after 2000 but chlorophyll did not respond clearly. Both in Lake Peipsi and Lake IJsselmeer a spatial gradient in total P-concentration is present. In Lake Peipsi this gradient is directly translated into chlorophyll-a levels and transparency. In Lake IJsselmeer the opposite is true because of a strong top-down grazing effect of Zebra Mussels.

Since the 1990s there is no overload of P anymore in IJsselmeer. As a consequence, algae are no longer light-limited by self shading and P has become limiting for the biomass of algae in the northern part of the lake.
In the northern part the reduction in P-load indeed leads to a decrease in chlorophyll-a and increase in transparency.
In the southern part grazing by Zebra Mussels limits the biomass of algae and causes the high concentration of dissolved P. Despite a high total P concentration, transparency is relatively high due to grazing by Zebra Mussels.
In Lake Peipsi the opposite is true. Here, total P levels correspond well with chlorophyll-a levels and transparency.





The main question is how this limitation in production in IJsselmeer will affect the structure of the food web. The decrease in algal biomass approaches the level in Lake Pihkva, but it is still higher than in Lake Peipsi. Therefore the present structure of the food web in Lake Peipsi and Lake Pihkva may be a good prediction of what might be expected to happen in IJsselmeer in the years to come. The nutrient decrease in the Borderlakes has led to positive effects like greater transparency, more macrophytes and more waterbirds (Ibelings *et al.* 2007, Lammens *et al.* 2004, Noordhuis 2007, Portielje & Oostinga 2003). The main question is to what extent the developments in the Borderlakes may predict the developments in the large lakes in IJsselmeer. See also chapters 3.4, 4.1 and 4.3.

*Clear water, ideal habitat for Pike.*

## Peipsi and IJsselmeer as *Dreissena* lakes

*Ruurd Noordhuis, Külli Kangur & Marina Melnik*

Both Peipsi and IJsselmeer have populations of Zebra Mussels Dreissena polymorpha. They are important as filterfeeders of phytoplankton and as food for benthivorous waterbirds. Average densities are similar at several hundreds of individual per $m^2$, and, allthough they are not particularly high when compared to other lakes, average filtration rates in relation to lake volumes are high because both lakes are relatively shallow. A volume of water corresponding to the lake volume may be filtered within a week. This means that the mussels are one of the key factors in nutrient and silt dynamics and water quality, as well as in the food web.

However, the mussels are not evenly distributed over the lakes. Densities are highest in areas where movement of water results in low sedimentation rates and good food supply for filter feeders. In Lake Peipsi, the narrow transition area between Lake Pihkva and Lake Peipsi s.s. is such a place (Figure1), the central parts being empty. In Lake IJsselmeer the area where the water from the River IJssel enters in the southeast (Figure 2) . In Lake Peipsi, which is deeper than Lake IJsselmeer, this may also partly explain the increased densities in coastal areas. On the other hand, in both lakes densities are low where soft sediments offer little support. Good substrate is supplied by gravel and stones in Lake Peipsi and by shells of Sand Gapers Mya arenaria from the brackish past in Lake IJsselmeer. Wherever this substrate is exposed, densities of Zebra Mussels are relatively high.

But especially in the deeper parts of the lakes, soft sediment accumulates over the years. In Lake Peipsi this is the result of the local hydrogeology of a largely enclosed lake with only a narrow outlet to the Baltic Sea. In the deeper, central parts of the lake, the top layer of the sediment cannot support Zebra Mussels, and the population is more or less restricted to the coastal areas. Eutrophication may add on this by means of accumulation of dead organic matter and associated low oxygen levels at the bottom. The latter may be the case in Lake Pihkva, where mussel densities have decreased.

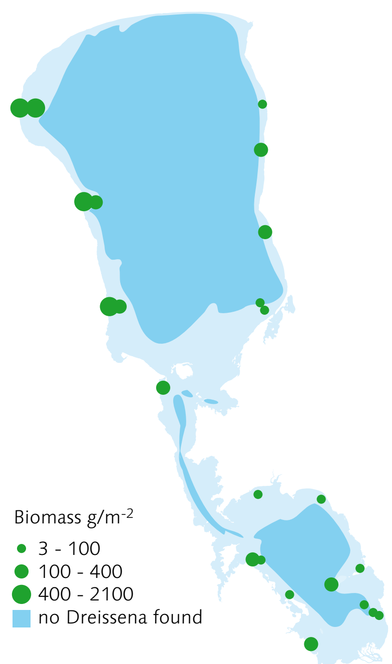



**Figure 1.** *Distribution of Zebra Mussels in Lake Peipsi.*

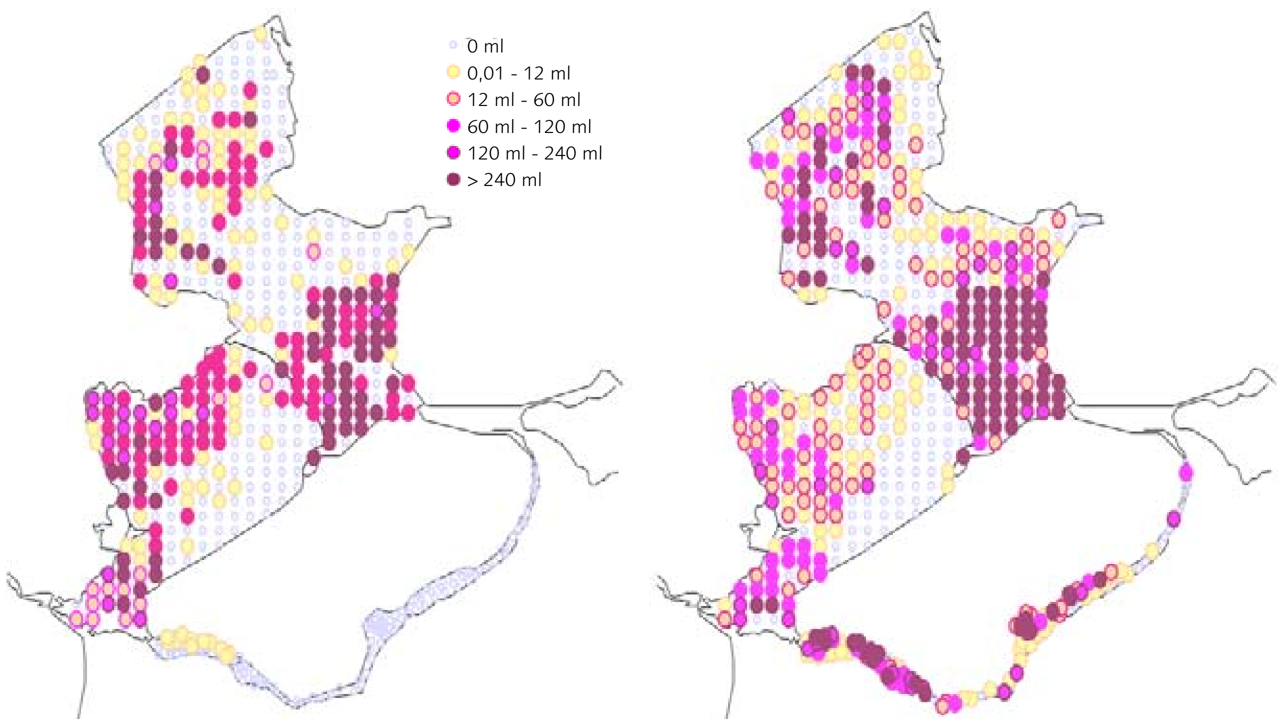
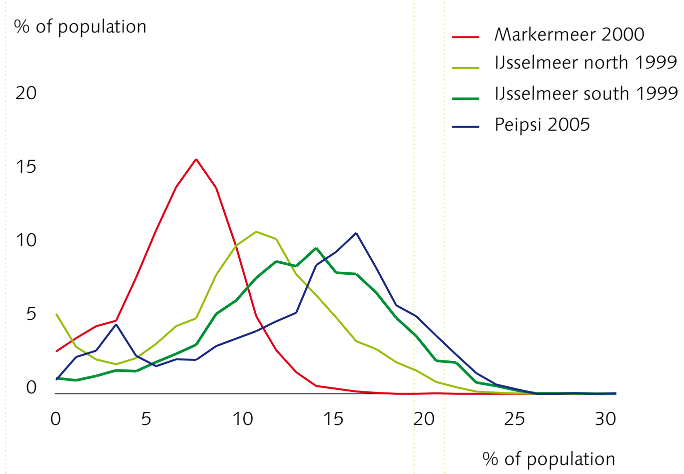



**Figure 2.** *Distribution of Zebra Mussels in IJsselmeer area in 1981 (left) and in 1999/2000 (right).*

In Lake IJsselmeer sedimentation and eutrophication play a similar part in ecosystem dynamics, especially after an equal degree of confinement resulted from closure of the lake from the Wadden Sea. Nowadays, like in Lake Peipsi, Zebra Mussels are absent from the deeper central parts of Lake IJsselmeer, where the former gullies that led the water from the River IJssel to the Wadden Sea are gradually filling up with silt. In Lake Markermeer in the south, the original silt layer on the bottom, which is easily stirred up by wind because of the small depth of the lake, started moving to the deeper parts. The consolidated clay underneath became exposed and started eroding, producing more silt that cannot leave the lake because of the endikements. During the early 1990s, mussel densities in Lake Markermeer dropped by two thirds and transparency decreased from 40 to 20 cm. The remaining mussels are very small in relation to those in Lake IJsselmeer (and Lake Peipsi) and have poor condition (Figure 3). In the nearby Borderlakes on the other hand, Zebra Mussels returned after two decades of absence, when severe problems resulting from eutrophication were dealt with, and water quality improved.

While the natural processes of sedimentation in Lake Peipsi and in the Zuiderzee that preceded lake IJsselmeer were slow and in balance with the natural geomorphology. The current problems only arose after human intervention took place, when the ecology of the lakes had to cope with deterioration of water quality and relocation of sediments after endikement and compartmentalization. This means that much of these problems can be overcome by reversing this intervention, or at least by understanding the mechanisms involved and making further adjustments in management or structure to counter the effects. In the Borderlakes this has already resulted in ecosystem recovery. For Lake Markermeer, proposals are in the making.

**Figure 3.** *Length distribution of Zebra Mussels in Lake Peipsi and in several parts of IJsselmeer.*
*The largest mussels occur in Peipsi and the smallest recently in Markermeer.*



# 3.2 Spatial diversity in IJsselmeer: limnological biodiversity in relation to compartmentalisation

Ruurd Noordhuis

Lake IJsselmeer was created in 1932 by shutting off a former inland sea called "Zuiderzee" (Southern Sea) by a dam. Even before that, land reclamations had altered the coastal areas especially in the west, resulting in relatively deep waters bordered by dikes. In the east, the coasts were largely natural, with local sand cliffs bordering glacial levees and dune-like sand ridges deposited during floods, and with extended shallows that were partially exposed during low tides and easterly winds. After closure of the Southern Sea, about half the area was reclaimed. The remaining water was divided into several larger and smaller compartments: Lake IJsselmeer, Lake Markermeer and a chain of about ten smaller, shallow "Borderlakes" around a cluster of polders. This compartmentalisation affected the developments in the different parts, with both positive and negative effects on the biodiversity of the water bodies concerned.

**Spatial diversity of the Zuiderzee**

The Zuiderzee was brackish, with a chloride concentration ranging from 15,000 mg/l in the north (continuous with the Wadden Sea) to 2000 mg/l in the south, and a gradient towards fresh water in the mouth of the River IJssel in the east. The northern part had an estuarine character with seasonal migration of several species of fish and crustaceans and a benthos of mainly salt-water species like the molluscs *Cerastoderma edule*, *Macoma balthica* and *Mya arenaria*. The composition of flora and sessile fauna was related to the distance from the river mouth, with freshwater species like pondweeds *Potamogeton* close to the river and species like *Ruppia* and seaweeds *Fucus* and eelgrass *Zostera* more towards the Wadden Sea (Brouwer & Tinbergen 1939). The southern part, away from the main channels that connected the river mouth to the Wadden Sea, had calm waters and clayey sediments, and a more lagoon-like brackish community of species, e.g. *Cerastoderma glauca* and *Balanus improvisus*, and a decapode once thought to be endemic to the area, the "Zuiderzee Crab" *Rythropanopeus harrissii* (Redeke 1922). It later turned out to be an early invader from eastern North-America, but it is typical of less dynamic, brackish waters nevertheless.

**Brackish and estuarine remnants in recent years**

After closure of the dam in 1932, the water turned fresh for the greater part within a few months and only most species intolerant of freshwater had already disappeared by 1935 (de Beaufort 1954). Only a few places in the south-west have up till present slightly elevated chloride concentrations, for instance where the lake connects to the brackish North Sea Canal and a few places where brackish polder water is pumped into the lake. In these places, a few brackish species have maintained limited populations (Figure 1), for example the amphipods *Gammarus duebeni* and *Corophium lacustre* and the isopod *Cyathura*

*carinata* that all used to range throughout much of the Zuiderzee (de Beaufort 1954). The relatively sheltered position of these locations towards prevailing winds and the corresponding relatively high water quality, as well as the long residence time and the local morphology that may prevent brackish water from immediate dilution have probably preserved adequate conditions for these species.

Lake IJsselmeer to the north is deeper and has a much shorter residence time. It shows a different kind of remnants of the past: it still offers a connection between the Wadden Sea and the River IJssel for fish that are able to swim into the current when the sluices are opened. Both in the north and in the south of Lake IJsselmeer, as well as in Lake Ketelmeer that connects it to the River IJssel, densities of migrating fish species are generally much higher than in Lake Markermeer and the Borderlakes (Figure 2). Especially Seatrout *Salmo trutta trutta* and River Lamprey *Lampetra fluviatilis* are still able to reach the River IJssel in fair numbers. A number of more estuarine species are found mainly in the northern parts of Lake IJsselmeer and are virtually absent elsewhere (Twaite Shad *Alosa fallax*, Common Whitefish *Coregonus lavaretus*, Houting *Coregonus oxyrynchus* and Flounder *Platichthys flesus*. In the north, even Brown Shrimps *Crangon crangon* are caught every now and then (yearly reports of Institute of Fishery Research RIVO, e.g. Patberg *et al.* 2006). However, for these small animals the strong current directed to the Wadden Sea during opening of the sluices prevents the original estuarine migration from taking place on a natural scale.

**Spatial diversity in freshwater species**

In other parts of the area, the dams and sluices that divide the remaining water into a number of compartments contributed to some spatial differences in species composition of flora and fauna. Some slow moving species like the gastropod *Theodoxus fluviatilis* were found in only a few isolated compartments of the lake complex. Most species, however, are found wherever favourable habitat conditions occur. Spatial differences in species compositions are largely connected to differences in depth, sediment type and water quality.

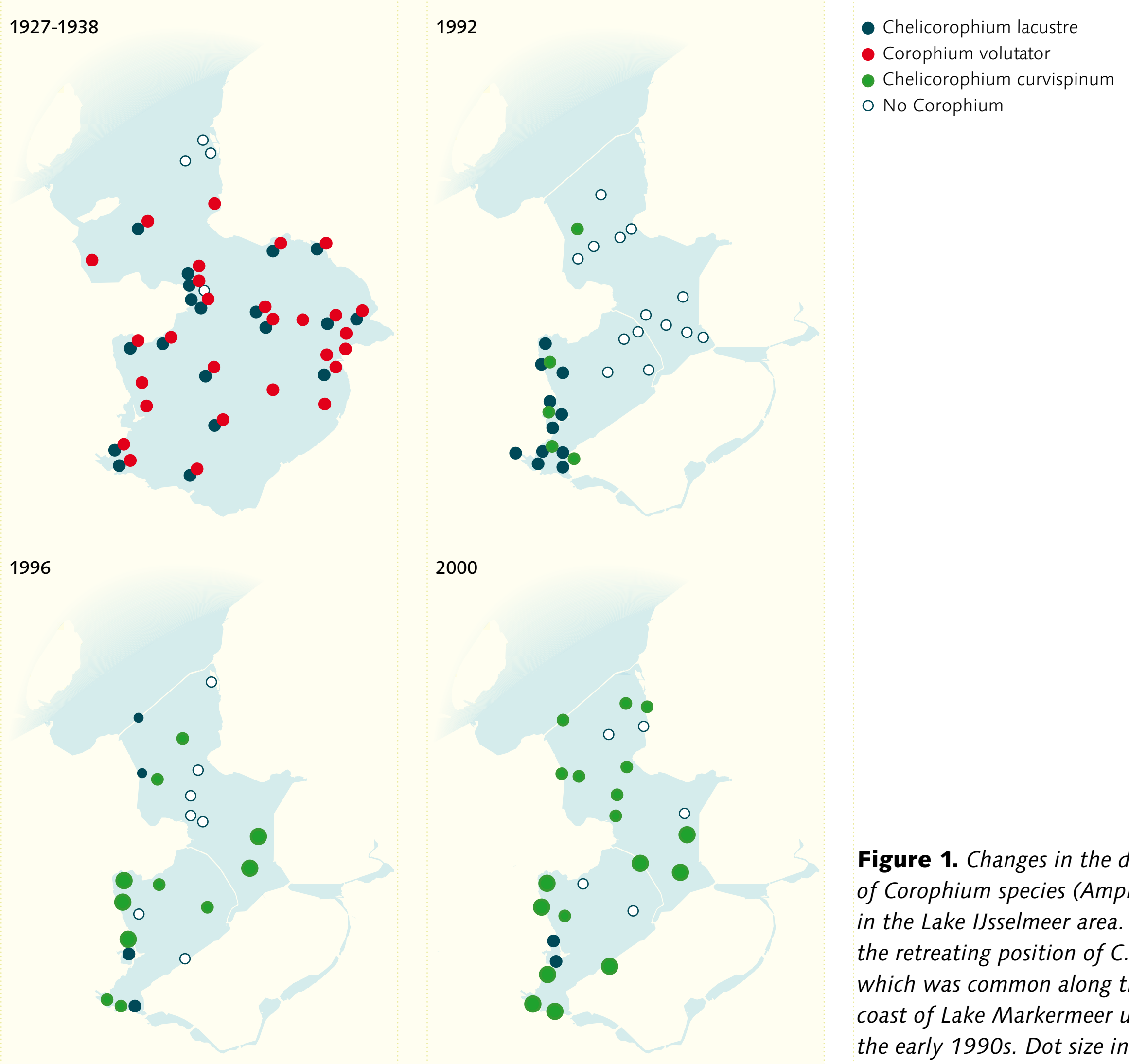



**Figure 1.** *Changes in the distribution of Corophium species (Amphipoda) in the Lake IJsselmeer area. Notice the retreating position of C. lacustre, which was common along the west coast of Lake Markermeer until the early 1990s. Dot size indicates abundance.*

Water quality deteriorated because of eutrophication during the 1950s, 1960s and 1970s, especially in the isolated compartments of the Borderlakes. The communities of submerged macrophytes and associated fauna that had developed after 1932 largely disappeared. A complex of measures, however, reduced the nutrient load of all compartments since the 1980s (Hosper 1997; Meijer 2000). As a result, the original ecosystem of fresh water with pondweeds and stoneworts, filtering Zebra Mussels and a fish community dominated by Perch and Roach returned to the Borderlakes (van den Berg 1999; Noordhuis 1997). Due to the small depth of these compartments, the vegetation is dense, covers large areas and is fed on by large numbers of waterbirds, like Mute and Bewick's Swan, Pintail and Red-crested Pochard (Noordhuis *et al.* 2002). Common Pochard, Tufted Duck and Coot feed on both plants and Zebra Mussels. In the central Borderlakes the submerged vegetation is largely made up of several stonewort species of the genus *Chara*, possibly in relation to local seepage of carbon-rich water from the Veluwe sands (Figure 3). The Borderlakes are unique with respect to the scale in which stoneworts occur at the shallows,






**Figure 2.** *Distribution of several species of migrating and estuarine fish, including the Brown Shrimp Crangon crangon. The Borderlakes and Lake Markermeer are isolated because of the compartments that were created.*

probably in one of the biggest stands in Western Europe (over 3000 ha), and also with respect to the numbers of non-diving as well as diving waterbirds that are able to feed on them (over 100,000 hervivorous and benthivorous birds during winter).

On the other side of the area the water is deeper, but in the south-west, due to relatively high transparency caused by its wind sheltered location, submerged macrophytes also increased. However, the moderate depth (2-3 m) resulted in a different species composition than in the Borderlakes, with dominance of the pondweed *Potamogeton perfoliatus* and the stonewort *Nitellopsis obtusa*. In combination with the occurrence of Zuiderzee relics like *Chelicorophium lacustre* and *Cyathura carinata*, this gives the south-western corner of the area a unique character within the system. In the north-west the water is generally too deep for macrophytes.

### Reduction of biodiversity by invading species

Unfortunately, some of the spatial diversity is threatened by invasive species, particularly the invertebrate fauna. Especially since the opening of the Main-Danube Canal in 1992, new species arrived from the Ponto-Caspian area almost every year (bij de Vaate *et al.* 2002). One of the invaders from this area, the amphipod *Chelicorophium curvispinum*, gradually colonised the IJsselmeer area during the 1990s, although it had reached The Netherlands even earlier (1987, via Mittellandkanal). Eventually it reached high densities and it seems to have

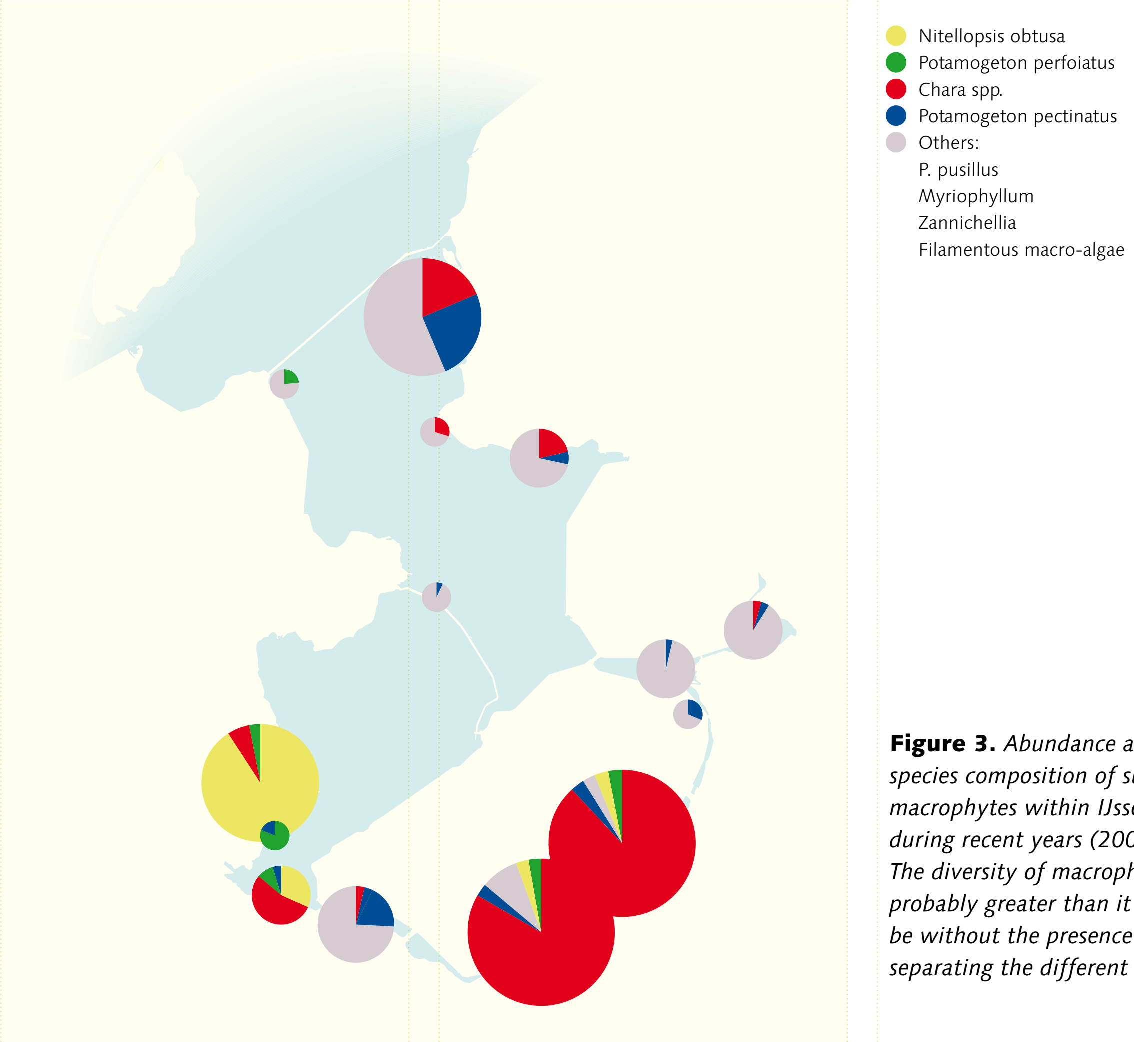



**Figure 3.** *Abundance and species composition of submerged macrophytes within IJsselmeer during recent years (2003-2006). The diversity of macrophytes is probably greater than it would be without the presence of dams separating the different lakes.*

reduced the *C. lacustre* population in the south-west to a marginal existence. One of the few species that used to be restricted to just a few of the smaller compartments of the Lake IJsselmeer area, the gastropod *Theodoxus fluviatilis*, disappeared altogether within two years after the amphipod *Dikerogammarus villosus* appeared (Tab. 1, 2). This invader colonised the entire area in 1997, apparently not hampered too much by the sluices and the direction of flow between the compartments. It seems to be rather voracious in The Netherlands (van Riel 2007) and may have consumed so many of the gastropod's eggs that it eventually died out. Densities of many other species greatly decreased in 1997.

Two larger crustacean invaders have increased strongly since the mid-1990s: the Chinese Mitten Crab *Eriocheir sinensis* (mainly in Lake IJsselmeer) and the North American Spiny-cheek Crayfish *Orconectes limosus* (high densities in the Borderlakes). Along with the increase of the first, the number of records of Brown Shrimps in fykenets in northern Lake IJsselmeer decreased and they have not been reported at all after 2001 (Figure 4). Part of this may be due to consumption of shrimps in the fykenets that are used for monitoring, but this cannot explain their total disappearance as not all fykenets contain crabs. Other factors may be involved as well and the case remains to be studied, but whatever the cause, yet another remnant of the original diversity of the area seems to have vanished.





**Table 1.** *Distribution and abundance of the gastropod Theodoxus fluviatilis in the Borderlakes. Numbers refer to animals counted at fixed sampling stations.*

| | Ketelmeer | Vossemeer | Drontermeer | Veluwemeer | Wolderwijd | Nuldernauw | Nijkerkernauw | Eemmeer | Gooimeer | IJmeer |
|---|---|---|---|---|---|---|---|---|---|---|
| **1994** | 0 | 0 | 0 | 0 | 70 | 59 | 0 | 0 | 0 | |
| **1995** | 0 | 0 | 0 | 0 | 250 | 90 | 0 | 0 | 0 | 743 |
| **1996** | 0 | 0 | 0 | 0 | 228 | 57 | 0 | 0 | 3 | 400 |
| **1997** | 0 | 0 | 0 | 0 | 159 | 17 | 0 | 0 | 0 | 240 |
| **1998** | 0 | 28 | 0 | 0 | 270 | 209 | 0 | 0 | 0 | 100 |
| **1999** | 0 | 157 | 23 | 0 | 472 | 0 | 0 | 0 | 0 | 0 |
| **2000** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **2001** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **2002** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **2003** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **2004** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **2006** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

**Table 2.** *Distribution and abundance of the invading amphipod Dikerogammarus villosus in the Borderlakes. Numbers refer to animals counted at fixed sampling stations.*

| | Ketelmeer | Vossemeer | Drontermeer | Veluwemeer | Wolderwijd | Nuldernauw | Nijkerkernauw | Eemmeer | Gooimeer | IJmeer |
|---|---|---|---|---|---|---|---|---|---|---|
| **1994** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| **1995** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **1996** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **1997** | 13 | 64 | 109 | 199 | 1 | 5 | 133 | 275 | 13 | 0 |
| **1998** | 47 | 65 | 27 | 85 | 200 | 46 | 81 | 1000 | 720 | 2000 |
| **1999** | 344 | 33 | 39 | 114 | 20 | 55 | 32 | 470 | 113 | 150 |
| **2000** | 55 | 66 | 290 | 69 | 105 | 225 | 179 | 110 | 90 | 19 |
| **2001** | 177 | 40 | 64 | 31 | 27 | 107 | 123 | 414 | 720 | 320 |
| **2002** | 736 | 56 | 93 | 220 | 236 | 226 | 200 | 170 | 213 | 500 |
| **2003** | 17 | 32 | 32 | 560 | 48 | 1230 | 1552 | 944 | 1440 | 992 |
| **2004** | 856 | 184 | 606 | 932 | 752 | 1296 | 738 | 1168 | 1024 | 544 |
| **2006** | 151 | 121 | 50 | 96 | 54 | 416 | 544 | 206 | 291 | 204 |

### Future developments

Some of these invaders (but not *Eriocheir*) might be slowed down with respect to their final population size or rate of increase by returning some of the estuarine dynamics into Lake IJsselmeer. That is to say, if this means that the northernmost waters become brackish again at a landscape scale. Studies on how to enhance fish migration from the Wadden Sea toward the River IJssel and vice versa are already being carried out. If the sluices in the north remain open until there is no difference in water level between Lake IJsselmeer and Wadden Sea, instead of closing them at the usual difference of 20 cm, this may already greatly improve chances for fish (and crustaceans) to get in. Allowing water from the Wadden Sea to get in will further restore some of the original gradients in flora and fauna composition. To a lesser extent this may also take place if other barriers are opened, as gradients replace the more

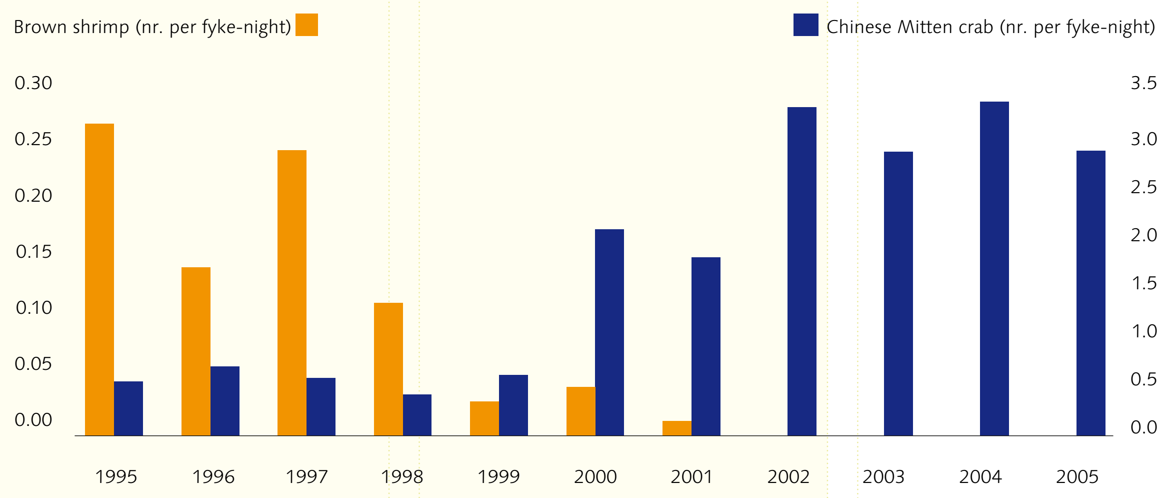



**Figure 4.** *Changes in the abundance of the marine Brown Shrimp Crangon crangon and the Chinese Mitten Crab Eriocheir sinensis in northern Lake IJsselmeer according to their presence in fykenets that are used for fish monitoring.*

abrupt differences in flora and fauna that are the result of creating artificial compartments. The recent removal of a sluice between two of the Borderlakes created an open connection, which already led to the range expansion of Water milfoil *Myriophyllum spicatum* and Narrow-leaf Water-plantain *Alisma gramineum*, two macrophytes that used to be restricted to the lakes to the north of this sluice. Hopefully in future, spatial diversity of the different biota will show more gradual differences in abundance, determined by water depth, sediment type and water quality, and less by barriers between compartments.

**Conclusion**

At present the spatial heterogeneity of the total complex of lakes is rather large and probably larger than it would be if water could move freely around the entire basin. Although in theory the situation without dams is better biologically, the present situation in Lake IJsselmeer provides clear examples that, given the present condition of water quality, the opposite may be true. Water quality in the Borderlakes improved after sanitizing the effluent of intensive farms at the Veluwe. Together with the seepage effects and the closing off part of the area for eutrophicated river water, this was the start of a tremendous development, giving room for the largest population of stonewort in Europe.
Whether the barrier dams slow down the immigration rate of the invading species is doubtful. However, for many fish they do form an impassable obstacle unless fish ladders are constructed. Only in the case of brackish water one may wish to see the area of this habitat become extended at landscape scale rather than the re-connection for fish migration alone. However, the latter is still a major contribution to the improvement of the present situation and the challenge will be to establish brackish water in such a way that the other functions (mainly use by man) will not be harmed. The effect of effluent of brackish polder water in Lake Markermeer and the possible benefits of a greater influence by the connection with the North Sea through the North Sea Canal need to be explored.





**Markermeer: leaving the last polder unfinished**
*Mennobart van Eerden*

In 1975 the Houtribdijk was closed. On this dike, a road was built connecting Enkhuizen on the west bank of Lake IJsselmeer and the new town of Lelystad. The road, however, was not the most important reason for creating the dike. The main reason was the embankment of what had to be the final polder of the Zuiderzee project as defined by ir Cornelis Lely. The clayey bottom was typical for the inner part of the estuary and led to plans for developing agriculture here. Only the Enkhuizerzand was sandy and in the original plans this part was designated to become a forestry area or to bear special crops like bulbs or potatoes.

The polder, however, was never created. Instead, the closure of the Houtribdijk separated part of IJsselmeer, Lake Markermeer. This part extends over some 70,000 ha, leaving 120,000 ha to the north to be called Lake IJsselmeer later on. The closing off implied separation from the influence of the river Rhine; no longer could eutrophicated river water flow directly into this part of the lake. Perhaps more important in the longer run was the redistribution of silt in the deeper parts along the Houtribdijk and along the Flevoland coast. Clay particles eroding from the western shores because of the wind were transported eastward and were deposited in the deeper parts, the former central part of the Zuiderzee. In 20 years time, this created the so called IJsselmeer deposits, a layer of sedimentation which is now more than one meter high. The formerly sandy bottom was replaced by soft mud and all the original benthic fauna (Zebra Mussels and crustaceans) were replaced by chironomids. The wind-induced waves cause the silt to become re-suspended easily and this in turn leads to an increase of turbidity. Fish and birds which need to see their prey (and each other) are greatly hampered because of the sediment storms and overall production is noticeably lower than in the remaining part of IJsselmeer. Not only is biomass of the fish stock smaller, also individual growth of fish is slower than in the northern part, primarily due to the effect of lower primary production.
Although the effect of the dam on fish populations was thus merely negative (lower stocks, smaller specimens and fewer possibilities for migratory movements), the effect of the silt load on the rate of depredation remains unclear. Possibly, because of the turbid conditions, the predatory fish can hardly manage to control the population, as they do when waters are more clear. The observation suggesting this hypothesis is that in Lake Markermeer the Smelt populations never reached such low values as they recently did in Lake IJsselmeer (1997, 2003, 2006).

The effect of extreme turbidity on fish availability for bird populations is even more pronounced. Cormorants are unable to exploit waters below Secchi depths of 40 cm (Van Eerden & Voslamber 1995). In recent years, Secchi depths in Lake Markermeer are below this level for the greater part of the season (see Van Eerden & van Rijn 2005). Rather than making extreme efforts to clear up the entire lake, restoring the original gradient in underwater visibility would seem an appropriate goal to achieve. In this way the ecological role of moderate levels of turbidity could become the common attribute of this part of the system, ideally in combination with a better connection to the northern part, Lake IJsselmeer.

*Houtribdijk*

# 3.3 Reproduction of main commercial fish species in Lake Peipsi-Pihkva

Marina Melnik

In the past decade (1997-2006), six fish species were of major commercial importance in Lake Peipsi-Pihkva: Smelt, Pikeperch, Bream, Pike, Perch and Roach. Spawning grounds for individual species show marked differences, as does the timing of spawning. Changes in climate affect the spawning and the success of larval recruitment; this negatively affects the salmonid species, especially Vendace and Peipsi Whitefish, but possibly also Smelt. Whitefish species have lost their commercial importance in the lake and can nowadays be found in by-catch only.

### Smelt *Osmerus eperlanus*

Smelt belongs to the group of early spawning fish species in Lake Peipsi-Pihkva. Smelt begins spawning shortly after ice melt, at a water temperature of 4-7 °C. In some years, spawning males of Smelt can be found at water temperature of 3.5-3.6 °C and females at 3.7-3.8 °C. The intensity of Smelt spawning in Lake Peipsi-Pihkva depends on a number of factors: time of the thaw, water level fluctuations, wind and temperature (Petrov, 1940, 1947; Tjurin, 1947, 1967; Meshkov & Sorokin, 1952; Efimova, 1958; Pikhu, 1966; Dorozhkina, 1975; Kuderskiy, Fedorova, 1977; Dorozhkina, 1985). In Lake Pihkva, spawning of Smelt usually starts in the second half of April, in Lake Peipsi several days later. The spawning lasts 10-15 days and sometimes up to a month, which is quite rare. The mass spawning period is short, 4-5 days, at a water temperature between 5-14 °C.

Major Smelt spawning grounds in Lake Pihkva are located around the outlet area of the Velikaya River in wind-protected areas, that is to say in the vicinity of small islands of the river delta, on sloping grounds and at depths of 1.6-3.2 m. Apart from these main Smelt spawning areas in the lake, Smelt eggs were found in the northern part of the lake (Razokov Cape), in the western part (Island of Kolpino) and in the central part (northern sides of the Islands of Zalita and Belov) in different years. In Lake Peipsi Smelt spawning grounds stretch out almost all along the eastern, northern and western coast of the lake. Smelt lays eggs mainly on shredded plant remains drawn by the current to the "depth change area": at 2-3 m in Lake Pihkva and at 4-6 m in Lake Peipsi. Shredded plant remains consist of sedge, cane, manna, duckweed and water moss, the latter being the favourite spawning substrate of Smelt in both lakes. Smelt can also lay eggs on mineral substrate like stones, pebbles and coarse sand.

According to long-term monitoring data, the beginning of the Smelt spawning period and its length is mainly determined by water temperature. The earliest Smelt spawning period in Lake Peipsi-Pihkva in 1989-2006 was recorded on March 29, the latest was recorded on May 10. The mean long-term Smelt spawning period starts on April 19. The mean long-term length of the Smelt spawning period comprises 12 days (see Table 1).

### Pikeperch *Stizostedion lucioperca*

Pikeperch spawning grounds in Lake Peipsi are located in the southern part (Pedasplya, Raskopelye Bay, Samolvinskaya Bay, around the villages of Podborovje, Ostrovitsi, Kunest and the Island of Piirisaar). In Lake Pihkva, Pikeperch spawning grounds were found in the Velikaya River fore delta, in the south-western and north-eastern parts of the lake. Pikeperch spawning grounds can be found in Lake Lämmijärv, too. Pikeperch lays eggs in depressions with bottoms consisting of sand and pebbles, preferably a solid bottom (Petrov, 1947; Shirkova, 1966; Negonovskaya, 1974; Kozlov, 1980). The mean long-term Pikeperch spawning period in Lake Peipsi is around mid May, which is 5-10 days later than in Lake Pihkva (see Table 1).

**Table 1.** *Spawning periods of the main commercial fish species in Lake Peipsi-Pihkva (average data of 1989-2006)*

| Fish species | Range in spawning period | Average date of start of spawning period | Average duration of spawning period (days) |
|---|---|---|---|
| **Smelt** *Osmerus eperlanus* | 29.03 - 10.05 | 19.04 | 12 |
| **Pike** *Esox lucius* | 10.04 - 20.05 | 20.04 | 21 |
| **Roach** *Rutilus rutilus* | 13.04 - 13.05 | 24.04 | 8 |
| **Perch** *Perca fluviatilis* | 17.04 - 20.05 | 26.04 | 7 |
| **Bream** *Abramis brama* | 05.05 - 17.06 | 13.05 | 21 |
| **Pikeperch** *Stizostedion lucioperca* | 10.05 - 10.06 | 15.05 | 15 |

### Bream *Abramis brama*

Bream spawning grounds are located in the south-western, south-eastern and southern parts of Lake Peipsi and in the northern, north-western and north-eastern delta areas of the Velikaya River flowing into Lake Pihkva. Moreover, spawning Bream get into rivers flowing into Lake Pihkva and in the fore delta into Lake Peipsi-Pihkva for spawning. Bream lay eggs at a depth of 30 to 80 cm on flooded meadows and on submersed macrophytes, on roots and stems of *Equisetum*, *Acorus*, *Ceratophyllum*, *Nuphar* and *Potamogeton*. Water Soldier *Stratiotes aloides* is the most preferred substrate for egg laying (Petrov, 1947; Shirkova, 1966, 1974; Karataev, 1974; Dgebuadze, Tryapitsina, Dorozhkina, 1976; Kontsevaya, 1983, 2005).

The start and duration of the Bream spawning period in Lake Peipsi-Pihkva is determined by water temperature. In years when the water is warmed up early and rapidly, spawning begins in the first decade of May. Bream spawning peak is recorded mostly in the late second to early third decade of May; it usually ends in the first decade of June or, very rarely, at the end of the second decade of June. The earliest Bream spawning period in Lake Peipsi-Pihkva in the past thirty years occurred in 1998, on May 5. Late spawning started on May 28 in 1980 and on May 24 in 2003. The latest spawning period for Bream was recorded in 2003, ending on June 17 (see Table 1).

### Pike *Esox lucius*

In Lake Peipsi-Pihkva, Pike spawning grounds are located in coastal areas, corresponding to the availability of submerged plants, and particularly in outlet areas of tributaries, bays and flood-plain lakes. Pike spawning grounds can be found all along the coast of Lake Pihkva. However, the main spawning grounds are bound to shallow waters of the Velikaya River fore delta. Pike gets into all the rivers flowing to Lake Pihkva for spawning. Good spawning grounds for Pike are available also in Lake Lämmijärv/Teploye. In Lake Peipsi, the main Pike spawning grounds are located in the southern part of the water body, corresponding with abundant aquatic vegetation (Petrov, 1947; Efimova, 1966; Meshkov, 1966; Sazonova, 1979, 1982. 1985). Pike spawning commences soon after ice melt at a water temperature of +3.0-3.8 °C. It may last up to a month and a half. The peak usually occurs between the early third decade of April and the first decade of May (see Table 1). Pike lays its eggs on soft aquatic plants or flooded meadow plants.

**Perch** ***Perca fluviatilis***

Perch spawning grounds are located over almost the entire length of the Lake Pihkva coast, but the southern part of the lake is considered to be the most favourable area. Perch will also spawn in the entire shallow water area of Lake Peipsi where aquatic vegetation is present, but again especially in the southern part of the lake. Perch can spawn on sand and pebbles as well as on plant substrate. In Lake Pihkva, Perch spawning grounds are located in the northern part at a depth of 3-4 m, in Lake Peipsi in the central and northern parts at a depth of 6 to 8 m, on sand and pebbles (Petrov, 1947; Shirkova, 1966; Pikhu A and Pikhu A, 1974; Frantova, 1975).

Perch can spawn in the sloping areas where fyke nets are installed during Smelt spawning period. Perch spawning usually commences in the second half of April at water temperatures of 8-11 °C. The Perch spawning period lasts 6 to 8 days (see Table 1).

**Roach** ***Rutilus rutilus***

Roach spawning grounds are located in shallow, sun exposed areas of the lake. In Lake Pihkva, the main spawning grounds are located in the Velikaya River delta, in Kuleiskiy and Vyarskiy bays in the northern and eastern parts of the lake. In Lake Peipsi, Roach spawning grounds are recorded mainly in Raskopelye and Samolva bays, in the area of Island of Pijrisaar and along the coast of Lake Teploye/Lämmijärv. Roach spawning grounds are located at a depth of 20 to 60 cm in different areas of the lake. In Lake Peipsi-Pihkva, Roach usually spawns between late April and the first half of May (Petrov, 1947; Mitrofanova, 1976; Antipova, Kontsevaya, 1983; Alexeeva, 2004). The eggs are deposited on aquatic plants and the remains of last year's vegetation.

Ice on Lake Pihkva thaws much earlier than on Lake Peipsi and Roach spawning usually begins somewhat earlier. The beginning and the end of the spawning period are determined by water temperature. Mass Roach spawning usually occurs at a water temperature of 7.0-12.4 °C, the average duration of the spawning period being 8 days. In some years the spawning period goes on for almost a month (see Table 1).

**Peipsi whitefish** ***Coregonus lavaretus***

In Lake Peipsi-Pihkva whitefish inhabit the deeper parts of Lake Peipsi. Only a few are recorded in Lake Pihkva. Long-term studies show that whitefish stocks in Lake Peipsi are also rather small. Occasionally whitefish stocks showed an upward trend that subsequently resulted in the increase of catches. Large whitefish catches in Lake Peipsi were recorded only twice: in 1933 (130 tonnes) and in 1989 (116 tonnes).

Factors affecting the development of whitefish population in Lake Peipsi were repeatedly covered in books (Sorokin, 1939; Petrov, 1947; Petrushevskiy & Kogteva, 1954; Shirkova, 1957; 1966; 1974; Tjurin, 1974; Kontsevaya & Antipova, 1986; Kriksunov & Kontsevaya, 1986; Kontsevaya, 1995; Kontsevaya, Krauze, Vaino, 2004). Based on these authors, analysing the range of factors which adversely affect the status of whitefish stocks in Lake Peipsi leads to the following picture.

Whitefish inhabiting Lake Peipsi, as well as Smelt and Vendace, are adapted to cold-water conditions. According to monitoring data, Lake Peipsi whitefish become disturbed at water temperatures of 19-20 °C. However, the past decade (1997-2006) contained a greater number of hot days with peak water temperatures of 20 °C and more, well above the long-term mean. Under conditions of abnormally hot summers, surface water temperature in Lake Peipsi may even amount to +25 °C, bottom water temperature being +22 °C.





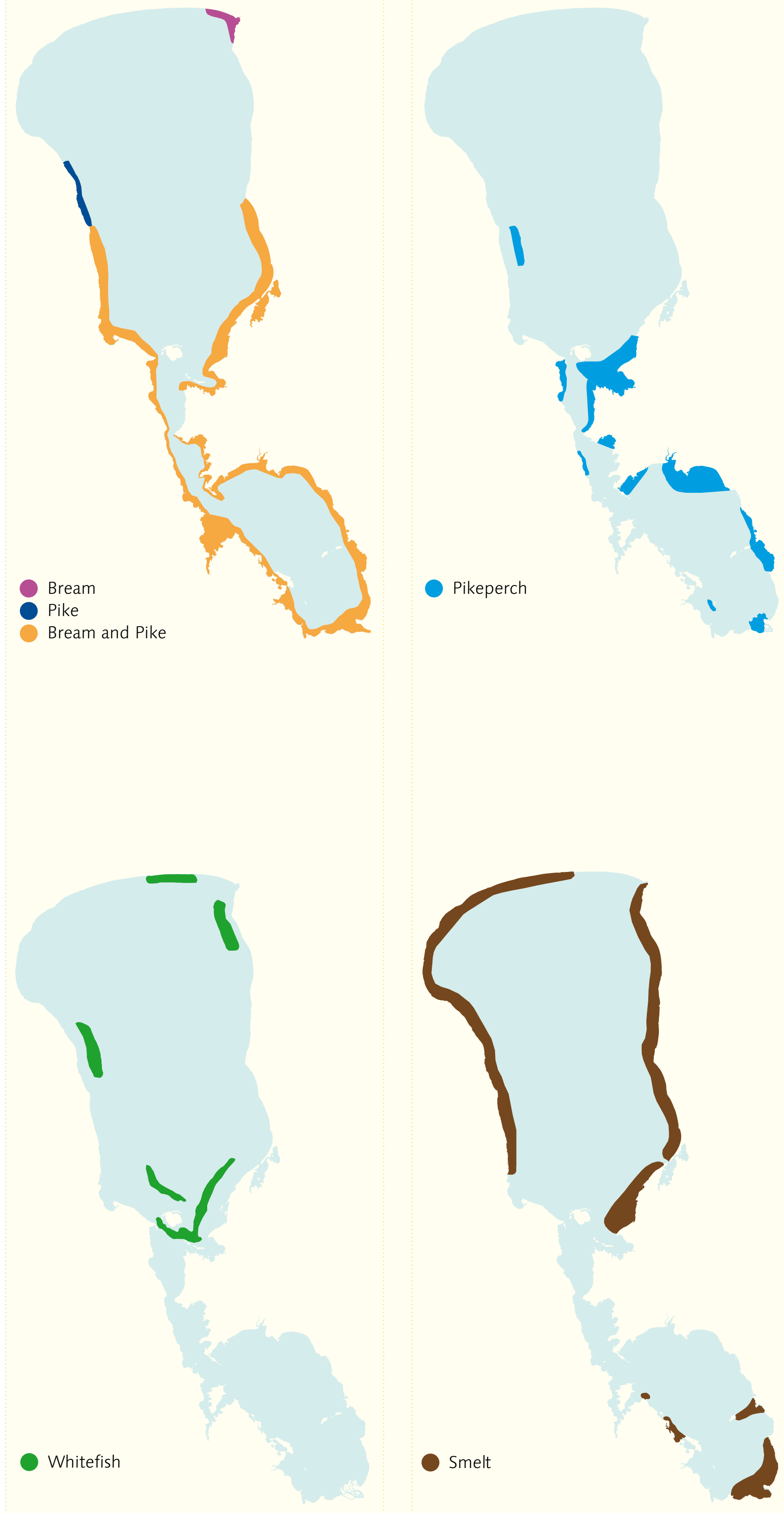



**Figure 1.** *Spawning grounds of the main commercial fish species in Lake Peipsi-Pihkva*

Lake Peipsi is shallow, its maximum depth being 12.9 m and the average depth 8.3 m. Therefore, despite its large surface area of 2611 km², the lake is warmed up rapidly in summer. In warm summers, the water column of the lake is heated up profoundly, creating oppression for cold-water fish species. Consequently, all three fish species show a retarded growth rate in hot summers.

Moreover, Lake Peipsi whitefish are strongly subject to parasites like *Tetracotylus* and other fish tapeworm diseases. Monitoring of whitefish infection in 1960s-1980s already proved a *Tetracotylus* infection rate of 30-60%. According to the data of Pskov Veterinary and Bacteriological Station, in the past decade whitefish of different age were contaminated with a *Tetracotylus* infection rate of 17-50%. They were also infected by *Diphyllobotrium dendriticum*, which amounted to 50-65%.
In our opinion, unfavourable weather conditions that regularly occurred in the autumn-winter periods in the late 1980s-1990s and even in the early 2000s contributed to the poor state of the stocks in 1990s – early 2000s. These conditions, late and unstable freezing of the lake and abnormally early thawing, were recorded in the autumn-winter periods of 1989-1992, 1995, 1997 and in 2001-2002, 2005-2006. They are unfavourable for whitefish reproduction and development of eggs.
The availability of spawning grounds is another important factor contributing to the development of fish populations. However, this factor hardly attributes to the development of whitefish populations in Lake Peipsi. Whitefish spawning grounds in Lake Peipsi cover a rather small surface area. They are located mainly in the southern part of Lake Peipsi, in the area of population centres like Ostrovtsi, Podoleshje, Podborovje, at the Islands of Ozolets, Gorodets, Sigovets and at the villages of Praaga and Pedasplja. Small Whitefish spawning grounds are located in the eastern part of the lake, around the villages of Vetvennik, Kunest and Raskopel, and in the northern part in the area the villages Alaye, Kozlov Bereg and Laptovitsi. Whitefish usually starts spawning in late October – November. The spawning period usually lasts two weeks to a month, subject to hydro-meteorological conditions like water temperature, wind and the onset of the freezing period. Whitefish spawns on sandy, mixed sand-and-pebbles and stony bottoms at water temperatures of +3.5 to 5.0 °C. Most often eggs are deposited at a depth of 2 to 5 m (Sorokin, Kovalev, 1962; Shirkova, 1966, 1974; Kontsevaya, 1985).

*Emajõgi river floodplain in early spring, spawning habitat for Pike.*

**Vendace *C. albula***

Vendace is another salmonid fish that mainly inhabits Lake Peipsi and is rarely recorded in Lake Pihkva. Vendace spawning grounds are located in the same areas of Lake Peipsi as are the main Whitefish spawning grounds. Differences between the two are only slight regarding the start of spawning, the length of the spawning period and the temperature thresholds. Vendace spawning usually begins between the second half of November and the first half of December at water temperature close to 0 °C (fluctuations: 0.5-2.0 °C). In some years Vendace females were found at spawning grounds in late December. Vendace lays eggs on hard bottoms consisting of sand-and-pebbles (Petrov, 1947; Kovalev, 1962; Efimova, 1966).
According to long-term monitoring, Vendace stocks are subject to considerable fluctuations depending fishery pressure and the growth rate of the different generations. In the second half of 1970-1980s, Lake Peipsi-Pihkva had favourable conditions for natural reproduction, fattening and increase in numbers of the majority of commercial fish species. Particularly for Pikeperch and Vendace (both carnivorous and piscivorous fish species), feeding conditions were exceptionally favourable because of the steady increase of the water level and the occurrence of warmer (but not too hot) summers.
The works by A.P. Shirkova (1966) and M.Z. Galtsova (1974) provide detailed analysis of factors affecting the development of Vendace generations in Lake Peipsi. According to the data of these authors, fluctuations in the numbers of Vendace juveniles were mostly due to hydrological and hydrometeorological changes, particularly to changes in water level and water temperature in the period of natural breeding. Reduced breeding success in autumn-winter and early spring periods in years with low water levels was caused by the reduction of available spawning grounds, strong predation of Vendace eggs by Ruffe *Gymnocephalus cernuus* and Burbot *Lota lota* in winter and deterioration of the food conditions for larvae in spring.
In the period 1950-1980, along with the water level, water temperature also played an important role, particularly in the early development stages of Vendace. Low spring temperatures hampered the development of zooplankton, which resulted in a lack of food for Vendace fries converting to exogenous feeding. This factor contributed to the increased death rate of Vendace fries.
In Lake Peipsi, Vendace fries usually come out of their eggs during several days after the lake is cleared of ice (in the second half of April, at a temperature of at least 4-5 °C). According to monitoring data, an increase in temperature taking place in the second half of April – May (over 10 °C) appears to be the most favourable for Vendace fries to come out of their eggs and for their development. According to Shirokova (1966), late and cold springs are unfavourable for Vendace juveniles, resulting in lower recruitment. Earlier and warmer springs provide better food conditions for Vendace juveniles, resulting in increased survival and larger recruitment.
Studies revealed that the last highly productive Vendace generation was born in 1985. Due to this generation and the previous two, Vendace stocks and catch in 1986-1988 were quite high. In 1986, 1988-1990 Vendace stocks declined

in the lake. From 1991 to 2006 catches of Vendace fingerlings (per one unit of effort undertaken by means of a research trawl) were already so low that it was impossible to estimate juvenile numbers.

In our opinion, the reduction of Vendace stocks in Lake Peipsi recorded in the 1990s was due to abiotic and biotic environmental factors and over-catches that took place in 1986-1989 (Efimova, 1966; Galtsova, 1974; Kontsevaya, 2005). Abiotic factors affecting the reproduction conditions for Vendace include the mild winters of the early 1990s and 2000s, which were characterised by late freezing of Lake Peipsi and an early clearing of the ice from the lake. According to Pokrovskiy (1961), this accounts for a high mortality rate of Vendace eggs. In the 1990s, strong and long-term freezing in Lake Peipsi was recorded in 1993-1994 and again in 1998-1999. In the past seven years, the longest freezing period of Lake Peipsi was recorded in 2000 and 2003. The freezing of 2003, which lasted 169 days, even was the longest in the period 1980-2004. However, it should be emphasized that despite the long freezing periods recorded in these years, Vendace stocks in Lake Peipsi were already very poor. However, this situation cannot be accounted for only by the small numbers of sexually mature individuals of Vendace. It is also caused by a series of other factors, such as the silting up of the spawning grounds which was recorded in the past decade, high temperatures during the summer fattening period, oxygen deficiency in benthic layers in some years during summer and predation of Vendace eggs by Ruffe, the number of which is quite high in Lake Peipsi. Another biotic factor restricting the increase of Vendace stocks in Lake Peipsi is the increased pressure by piscivorous fish species, particularly by the large Pikeperch stock.

*Some species may spawn under the ice, such as Whitefish.*





## Spawning areas of fishes in IJsselmeer

*Mennobart van Eerden*

Spatial and temporal patterns exist in spawning Smelt. In IJsselmeer and Markermeer spawning concentrates on onshore stretches of dikes. Smelt spawns also at sandy bottoms along the edges of gullies of the former Zuiderzee tidal system. In the Borderlakes no permanent population exists and no spawning occurs. Smelt spawns usually at water temperatures between 6-9 °C. Large concentrations usually occur at the spawning areas and these are intensively fished with the aid of fykenets.

*General pattern of spawning*

Spawning areas of fishes in IJsselmeer are either confined to firm substrate (sand, stones, shell remains) or to patches of macrophyte or macro algae. To the first category belong the salmonids like Houting *Coregonus oxyrhynchus* , Smelt *Osmerus eperlanus*, Lake Trout *Salmo trutta* and Bullhead *Cottus gobio*. They make ample use of vegetative material. The percids like Perch Perca fluviatilis, Pikeperch *Stizostedion lucioperca* and Ruffe *Gymnocephalus cernuus* spawn on hard bottom to, but very often some organic material is present as well (plant remains, pieces of wood, Zebra Mussels). Known spawning places of percids are Muiderzand, Enkhuizerzand (both sides), Spaanderbank, Lacon, Middelgronden, Wieringervlaak and the Steenplaten south of the Afsluitdijk. The cyprinids like Roach *Rutilus rutilus*, Bream *Abramis brama* and Carp *Cyprinus carpio* make preferably use of vegetated areas. In IJsselmeer these are confined to specific coastal areas like the south coast of Lake IJmeer, the Gouwzee near Marken, the bays along the Frisian coast between Lemmer and Laaxum, near Makkum but also on the opposite shore near Medemblik. Bream may also spawn among boulders of the dikes, especially when they are covered with sessile algae. Bream and Ide *Leuciscus idus* also perform spawning migration to the River IJssel and Vecht. In the Borderlakes all species except the salmonids spawn. The dense cover by stoneworts and pondweeds favours spawning conditions and provides shelter for the larvae and young fish. In the stoneworts considerable numbers of Spined Loach *Cobitis taenia* occur.

*Smelt*

This keystone species in the foodweb usually spawns in March at water temperatures 6-9 °C. In IJsselmeer the important spawning areas are the dike of Noordoostpolder, Oost Flevoland and parts of the Houtribdijk between Lelystad and Enkhuizen. In Lake Markermeer the dike of Zuid Flevoland forms the major spawning area. Most Smelt spawn at lengths of 7-9 cm in Lake IJsselmeer and 6-7 cm in Lake Markermeer. However, a small cohort of larger 2+ Smelt (>18 cm) and 1+ Smelt (> 12 cm) occur, noticeably in Lake IJsselmeer. These larger fishes arrive earlier at the spawning places and spawn earlier too. Near Rotterdamsche Hoek and at the mouth of the River IJssel traditionally larger Smelt occur. It is not clear as to what extent the larger Smelt belong to the migratory part of the population. Before the Zuiderzee was closed off, Smelt migrated as 0+ to the Wadden Sea and North Sea to winter. The majority returned for spawning as 2+ or 3+ in their third or fourth calendar year. At that age Smelt becomes piscivore. Figure 1 shows the spawning areas of Smelt. The chart is compiled from data provided by fishermen and it clearly shows the importance of the onshore, wave-exposed habitat for this species. This is probably connected to the fact that Smelt eggs need oxygen rich water.

Lake Smelt often dies after spawning. This usually happens in late spring and summer, mostly connected with periods of warm weather. When a mass die off occurs, floating Smelt are everywhere and are massively washed ashore. This led to the common sense idea that fishing on spawning Smelt has little or no effect on the population. In salmonids the number of eggs is not limiting the population recruitment, which further contributed to the habit of harvesting at the spawning places. The fishery became intensive after 1982 with peak landings of 1500 tonnes. The declining stocks, however, eventually led to the ban of fishery in several years, e.g. 2004 and 2005. In 2006 fishing of a cohort quotum of 1500 tonnes was permitted again, in combination with a restriction in time, a “fishing window” in relation to the actual spawning behaviour of females. Field assessment of the threshold of 50% spawning females led to 800 tonnes of Smelt commercially fished that year and many remained in the lake and survived until extremely hot summer weather killed the entire cohort in July. Still, this 0+ cohort played an important role in the provisioning of fish-eating birds, e.g. Great crested Grebes, Cormorants and Common Terns.

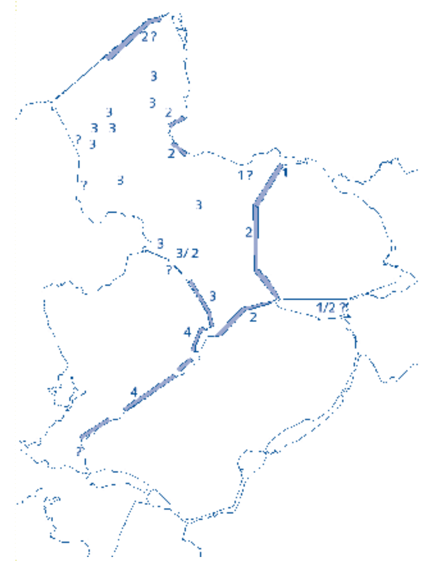


**Figure 1.** *Chart of Smelt spawning areas (late 1980s) in relation to period of year of mass spawning. Notice the position of the wind exposed dike sections that are most important to the species.*

*(1= late February, 2= mid March, 3= late March, 4= begin April)*

# 3.4 Fish stock and fishery

Eddy Lammens, Andu Kangur, Peeter Kangur, Marina Melnik

There is a large correspondence in the abundance of fish species in Peipsi and IJsselmeer. In both lakes the changes caused by climate effects lead to an increase of pikeperch and a decline of smelt.
The high fish yield in Peipsi suggests that the larger, but less eutrophic Peipsi has a more efficient energy transfer through the food web.
The very low number of Eel in Peipsi is compensated by high yields of Pikeperch, Perch and Pike. Also the yield of Smelt is higher in Peipsi than in IJsselmeer. The main difference between the fish communities in Peipsi and IJsselmeer is caused by the absence of a natural shore-line in IJsselmeer, preventing Pike and Burbot to develop.

Despite the increase in nutrient load in Peipsi, the catches went down because of climate change, sedimentation of spawning grounds, overexploitation and a top down effect by pikeperch, whereas the decline of catches in IJsselmeer was probably reinforced by the decline of the nutrient load. It is unlikely that the further decrease in nutrients in IJsselmeer to the level of that in Peipsi will lead to lower fish catches. It is more important to reduce the intensity of fishery in both lakes to a level that allows balanced fish populations to develop. Apart from that, climate change will probably have more pronounced effects than nutrient reduction.

### Species composition

The fish stocks in Peipsi and IJsselmeer show many similarities considering species composition and regarding changes in the population dynamics of these species during the past 20 years. Fish species that are abundant in both lakes are Smelt *Osmerus eperlanus*, Perch *Perca fluviatilis*, Pikeperch *Stizostedion lucioperca*, Ruffe *Gymnocephalus cernuus*, Bream *Abramis brama* and Roach *Rutilus rutilus*.
An important difference is the presence of Pike *Esox lucius*, Burbot *Lota lota* and Vendace *Coregonus albula* in Peipsi, whereas these species are almost absent in IJsselmeer. Pike and Burbot are absent in IJsselmeer because these species need floodplains as spawning places and therefore a natural water level fluctuation in combination with a shallow shore line. Pike and Burbot used to be very abundant in the Frisian lakes in the period when the meadows were flooded during winter, creating spawning places for these species. These areas have been lost since the water level was regulated after the closure of the Afsluitdijk. The absence of Vendace is most probably related to climate conditions preventing Vendace to have successful spawning in IJsselmeer (Kangur *et al.* 2007).
Eel *Anguilla anguilla* is abundant in IJsselmeer, but almost absent in Peipsi. Eel can enter the IJsselmeer relatively easily through the sluices in the Afsluitdijk. In March-April young Eel enters the lake coming from the Waddenzee (see chapter 3.2) and a large part grows up in the lake. Eel can only enter Peipsi coming from Lake Võrtsjärv, where eel was stocked in the past. For the same reason, other diadromous fish are also present in IJsselmeer and





**Table 1.** *Fish species in Peipsi and IJsselmeer*

| Fish species | Peipsi (36) | IJsselmeer (40) |
|---|---|---|
| Sea lamprey *Petromyzon marinus (L.)* | | x |
| River lamprey *Lampetra fluviatilis (L.)* | | x |
| Brook lamprey *Lampetra planeri (Bloch)* | x | x |
| Eel *Anguilla anguilla (L.)* | x | x |
| Twaite Shad *Alosa fallax (Lacépède)* | | x |
| Bream *Abramis brama (L.)* | x | x |
| Silver bream *Blicca bjoerkna (L.)* | x | x |
| Bleak *Alburnus alburnus (L.)* | x | x |
| Riffle minnow *Alburnoides bipunctatus (Bloch)* | x | |
| Vimba bream *Vimba vimba (L.)* | x | |
| Asp *Aspius aspius (L.)* | x | x |
| Crucian carp *Carassius carassius (L.)* | x | x |
| Gibel carp *Carassius auratus (L.)* | x | x |
| Nase *Chondrostoma nasus (L.)* | | x |
| Carp *Cyprinus carpio (L.)* | | x |
| Gudgeon *Gobio gobio (L.)* | x | x |
| Sunbleak *Leucaspius delineatus (Heckel)* | x | |
| Chub *Leuciscus cephalus (L.)* | x | x |
| Ide *Leuciscus idus (L.)* | x | x |
| Dace *Leuciscus leuciscus (L.)* | x | x |
| Minnow *Phoxinus phoxinus (L.)* | x | |
| Bitterling *Rhodeus sericeus (Pallas)* | | x |
| Roach *Rutilus rutilus (L.)* | x | x |
| Rudd *Scardinius erythrophthalmus (L.)* | x | x |
| Tench *Tinca tinca (L.)* | x | x |
| Spined loach *Cobitis taenia (L.)* | x | x |
| Mud loach *Misgurnus fossilis (L.)* | x | x |
| Stone loach *Barbatula barbatula (L.)* | x | |
| Wels *Siluris glanis (L.)* | x | x |
| Pike *Esox lucius (L.)* | x | x |
| Smelt *Osmerus eperlanus eperlanus (Pallas)* | x | x |
| Whitefish *Coregonus lavaretus maraenoides (Poljakow)* | x | x |
| Houting *Coregonus oxyrinchus (L.)* | | x |
| Vendace *Coregonus albula (L.)* | x | |
| Atlantic *Salmon Salmo salar (L.)* | | x |
| Brook trout *Salmo trutta fario (L.)* | x | x |
| Sea trout *Salmo trutta trutta(L.)* | | x |
| Grayling *Thymallus thymalus (L.)* | x | |
| Burbot *Lota lota (L.)* | x | x |
| Three-spined stickleback *Gasterosteus aculeatus (L.)* | x | x |
| Nine-spined stickleback *Pungitius pungitius (L.)* | x | x |
| Bullhead *Cottus gobio (L.)* | x | x |
| Ruffe *Gymnocephalus cernuus (L.)* | x | x |
| Perch *Perca fluviatilis (L.)* | x | x |
| Pikeperch *Stizostedion lucioperca (L.)* | x | x |
| Thick-lipped *Grey Mullet Chelon labrosus (Risso)* | | x |
| Flounder *Platichthys flesus (L.)* | | x |

absent in Peipsi, such as Lamprey, Flounder, salmonids and even some marine fishes such as Twaite Shad and Mullet (see Table 1).
Because of its connection with the River IJssel, riverine fishes are also found occasionally such as Dace *Leuciscus leuciscus*, Nase *Leuciscus cephalus* and others (see Table 1). The total number of species in IJsselmeer is at least 40, whereas in Peipsi at least 36 species (Kangur *et al.* 2007b in press) have been found. Because Peipsi is still a natural lake with a fully developed littoral zone some species related to that zone (limnophilic and oxygen-tolerant species) are present in larger number in Peipsi, but rare or absent in IJsselmeer (Table 1).

### Changes in the populations

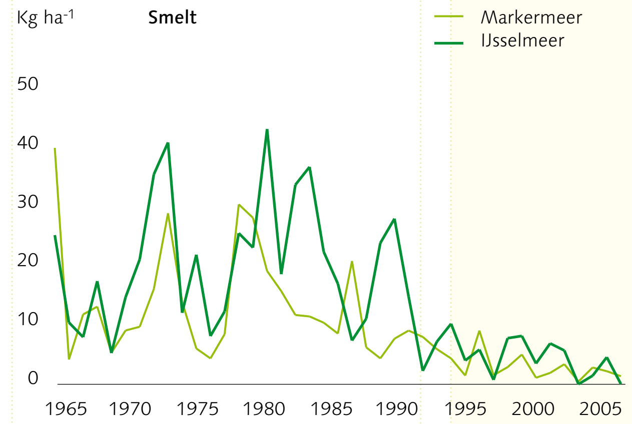
During the last 20 years both lakes experienced large changes which were set off by climate change. In both lakes there was a significant decrease of the Smelt population (Figure 1a), but in IJsselmeer it seems to be more dramatic than in Peipsi (Kangur *et al.* 2007, Noordhuis 2007). The most important predator of this fish, Pikeperch, increased significantly in both lakes since the beginning of the 1990s (Figure 2), but more dramatically in Peipsi than in IJsselmeer (Kangur *et al.* 2007, Noordhuis 2007). The increase of the Pikeperch populations is clearly related to the increase in temperature (Noordhuis 2007). The change in growth rate in relation to temperature is very high for Pikeperch and quite low for Smelt (Mooij & Lammens, 1992). High temperature causes the biomass of Pikeperch to increase more rapidly than that of Smelt and therefore the Smelt population will be limited by predation pressure. There appeared to be a significant negative effect of hot summers on the abundance of Smelt with a lag of 1 and 2 years (Kangur *et al.* 2007a). A warming of the aquatic environment, coupled with concurrent eutrophication and resulting cyanobacterial blooms, has decreased reproductive success and increased direct adult mortality (fish kills) of Smelt in Peipsi (Kangur *et al.* 2007a).
Apart from the negative effects of higher temperature there is probably also a negative effect of the decrease in nutrients which occurred concurrently in IJsselmeer and which may have limited the feeding conditions of this fish.
As all these effects occurred simultaneously, it is difficult to distinguish between these effects in IJsselmeer. In Peipsi there was no nutrient decrease at all and the less dramatic decrease of Smelt in this lake may be related to this difference. The collapse of Vendace and decrease of Burbot (Figure 3) and whitefish in Peipsi is partly related to the increase in water temperature in winter, which created unfavourable spawning conditions for these species, again in combination with an increased predation pressure of Pikeperch on Vendace (Kangur *et al.* 2007a in press).
Perch could not profit from the change in temperature and the commercial catches strongly decreased since 1990 (Figure 4a). The main reason for this decline is not overexploitation by commercial fishery, but the fact that Perch became an important prey-fish for Pikeperch. The strong increase of the Pikeperch populations caused the decline of the Perch populations in both lakes. In addition, about 100-150 tons of Perch is caught using hooks by recreational fishermen every winter from Peipsi.

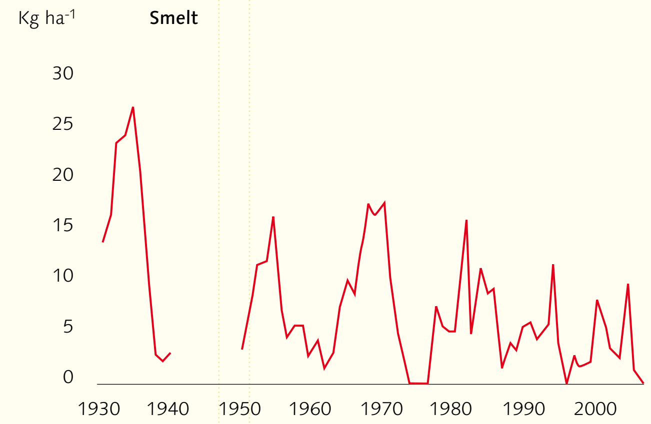
### Fish biomass and nutrient load

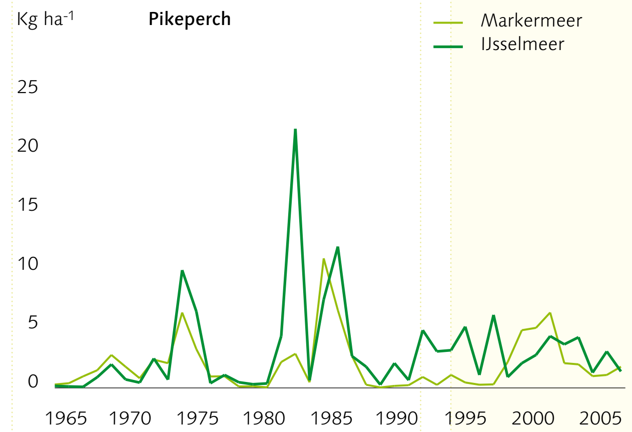
Although the nutrient load in Peipsi increased in the period 1995-2005, the total fish biomass decreased in lake Peipsi, whereas in lake IJsselmeer the fish biomass even increased, despite the decline of the nutrient load (Table 2, Figure 4d). In Peipsi the successful recruitment of Pikeperch caused a high predation pressure on the fish community and was the most probable reason for the decline of the populations of small fish (Figure 4). In IJsselmeer the opposite happened. The increase in the fish community was mainly caused by the increase of Ruffe, a species that benefits from the lower Pikeperch stock as well as the increase in temperature.

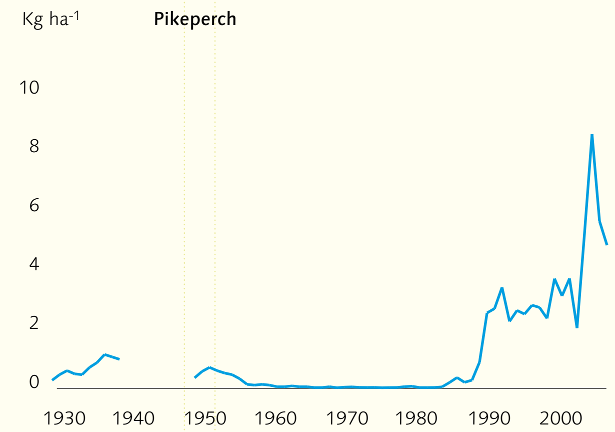


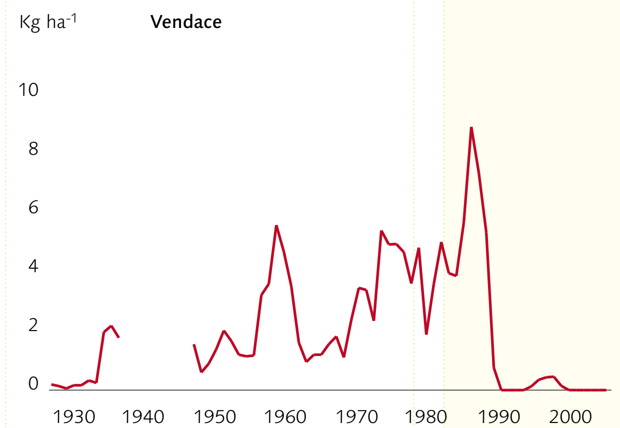




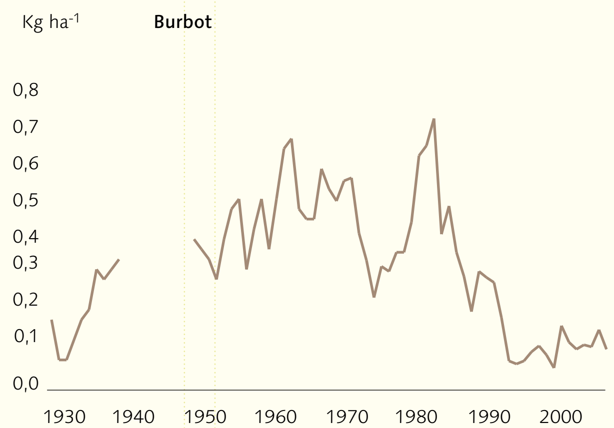




**Figure 1a.** *The density of the Smelt Osmerus eperlanus population from 1966 to 2006 in IJsselmeer.*

**Figure 1b.** *The density of the Smelt population from 1931 to 2005 in Peipsi.*

**Figure 2a.** *The CPUE of the Pikeperch Stizostedion lucioperca population from 1966 to 2005 in IJsselmeer.*

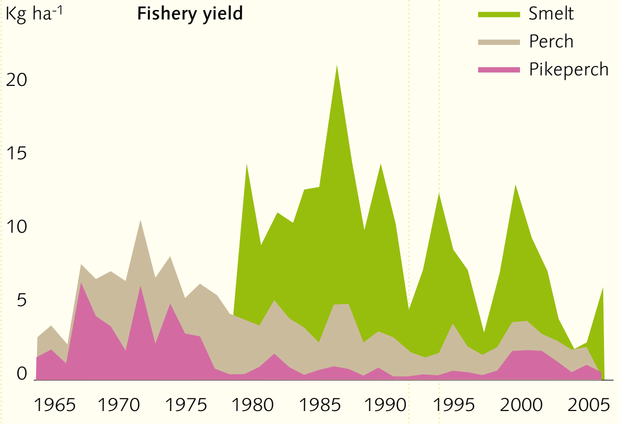
**Figure 2b.** *The catches of Pikeperch from 1931 to 2005 in Peipsi.*

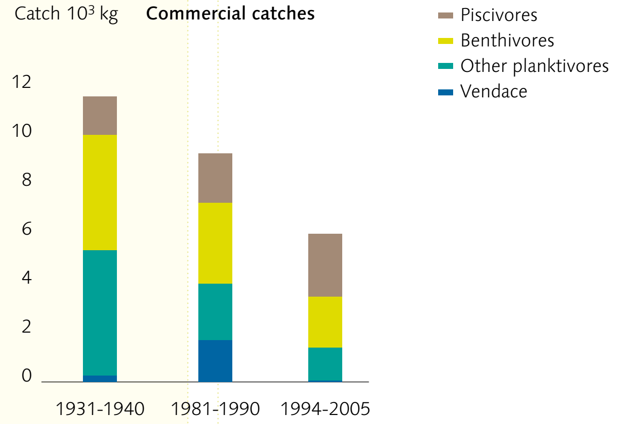
**Figure 3a.** *The catches of Vendace Coregonus albula from 1931 to 2005 in Peipsi.*

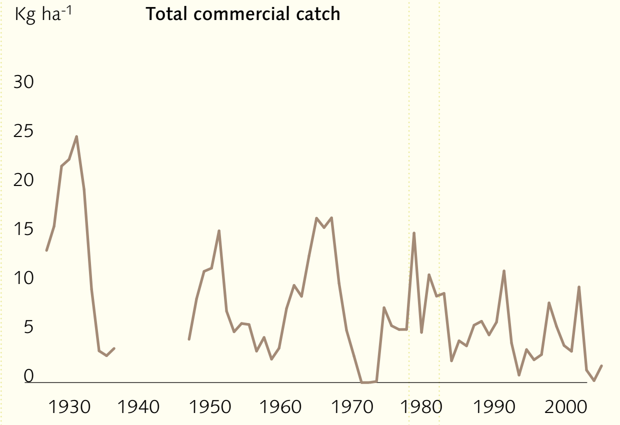
**Figure 3b.** *The catches of Burbot from 1931 to 2005 in Peipsi.*

**Table 2.** *CPUE (kg per hour trawling) (after Kangur et al. 2007b).*

| Species | 1986 | 1998-2002 |
|---|---|---|
| Smelt | 15.9 | 6.4 |
| Vendace | 26.9 | 0.03 |
| Whitefish | 1.11 | 0.04 |
| Pike | 6.3 | 12.6 |
| Roach | 40.5 | 30.3 |
| Bleak | 0.9 | 4.2 |
| Bream | 169.7 | 27.2 |
| Burbot | 1 | 0.8 |
| Perch | 92.1 | 18.6 |
| Pikeperch | 5.4 | 86.8 |
| Ruffe | 28.1 | 16.6 |
| Total | 387.8 | 203.7 |



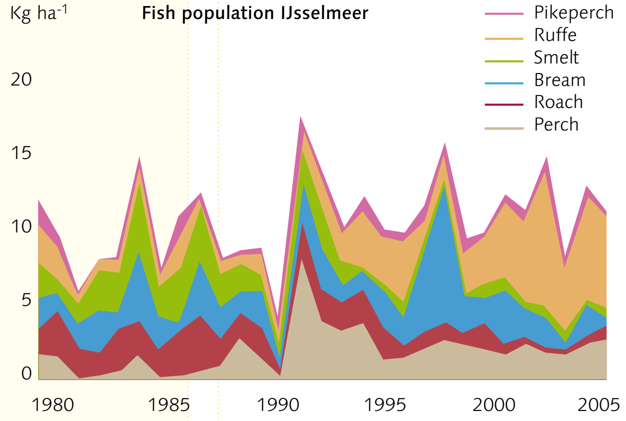




**Figure 4a.** *The composition of the commercial catches in IJsselmeer*

**Figure 4b.** *The composition of the commercial catches in three periods in Peipsi (redrawn from Kangur et al. 2007a in press).*

**Figure 4c.** *The total commercial catch from 1931 to 2005 in Peipsi.*

**Figure 4d.** *The density of the fish populations in IJsselmeer from 1976 to 2004.*





### The impact of fishery

Fishery is an important factor in the ecosystem of both IJsselmeer and Peipsi. In both lakes the fishery is very intensive and has a large impact on the size composition of the fish community. In both lakes the fishery is concentrated on Pikeperch, Perch, Bream and Smelt, whereas in IJsselmeer Eel is also very important whereas in Peipsi Pike and Burbot are. The Vendace fishery in Peipsi has stopped because of the collapse of the population. The most direct impact of fishery in both lakes is the negative impact on total biomass and size composition of the populations. Particularly the size composition of the Pikeperch population is affected because the specimens larger than the legal size (42 cm, in IJsselmeer and 35 cm in autumn 2007, but only 20 cm of standard length in autumn 2006 in Peipsi) are almost completely removed leaving an unbalanced population of only a few young year-classes.
Perch is caught with the same nets as Pikeperch and therefore the story is the same for Perch, but the fishery is less intensive because the fish grows slower than Pikeperch and therefore more year-classes are present. But also in this species size-classes larger than 25 cm are hardly present. The fishery on Smelt in spring when Smelt is concentrated in the spawning areas was forbidden during the last years in IJsselmeer, as the size of the stock was so small that the survival of the species is endangered. In both lakes the fishery causes the same problems of overexploitation, but the effects of climate change seem to have more effect on the total stock than fishery as such.
As most Eel >30 cm is caught in fykes, the Eel fishery in IJsselmeer does not only affect the size composition of the Eel population, also large amounts of young fish are caught as by-catch (ca. 20 kg ha$^{-1}$). Particularly large quantities of Perch and Pikeperch are removed by this fishery, causing a high mortality among the Perch and Pikeperch population (van Dam *et al.* 1995).

### Use of nets

Trawls were used in Lake Peipsi until the end of the 1950s and in IJsselmeer until the end of the 1960s. In IJsselmeer, Eel was the most valuable fish species with Perch and Pikeperch as by-catches. In Peipsi Smelt and Vendace were the main catch, with Perch, Bream, Pike, Burbot and Pikeperch as by-catches. As the trawl was considered quite destructive for the recruitment of young fish > 5 cm, this fishing gear was forbidden in IJsselmeer in 1970. The Eel fishery was continued with fykes, long lines and eel boxes, and the Pikeperch and Perch fishery with nylon gill-nets. In Peipsi the net size was changed from small meshes (catching fish > 5 cm) to large meshes catching fish >10 or > 20 cm, whereas the number of trawls was reduced by 75%. In both lakes most fish species recovered and catches increased. Eventually in both lakes the fishery intensity increased again and once more led to overexploitation.

*Bream*

In Lake Peipsi, fishing was markedly intensified after WW II due to high demand for food. Trawling was expanded drastically and severely damaged the stock of Pikeperch, as this species prefers open water areas, which are more suitable for trawling. Also the stock of Bream suffered from overexploitation. In the late 1950s, trawling was prohibited, but trawls were replaced by another fine-meshed active fishing gear, Danish (bottom) seines. Due to inappropriate fishery management the stocks and catches of Pikeperch and Bream declined to a very low level for three decades. From 1974, the number of Danish seines was gradually reduced from 137 in 1966 to 40 at present (20 in both states) while the mesh size (measured between adjacent knots) of the cod-end of the seine increased from 8-12 mm to 20-22 mm (Pihu & Kangur, 2000), lately to 24 mm. As a result of rearrangement of fishery, the stock and catches of pikeperch began to grow rapidly. By the turn of decade 1980/1990, two marked changes occurred in the fish community of Lake Peipsi: a major increase of Pikeperch stock preceded a sharp decline in Vendace population. Ongoing eutrophication, decrease of water transparency and increase of water temperature are unfavorable for Vendace but favourable for Pikeperch. Over the long term, the fish community of Lake Peipsi has shifted from clean- and cold-water species such as Vendace, Whitefish and Burbot to more Pikeperch, which prefers productive, warm and turbid waters (Kangur *et al.* 2007b). The next drastic increase in fishing pressure in Peipsi was caused by socio-political changes brought along with the collapse of Soviet Union. The possibility to export fish to the European market appeared. At the beginning of 1990s, fishing became a highly significant source of employment. Therefore, the number of fishermen doubled in comparison with the end of the Soviet period. During the last decade the fishery in the lake is regulated according to the Estonian-Russian Fisheries Agreement from 1994, whereas since 2000, quotas are established for all commercial species.

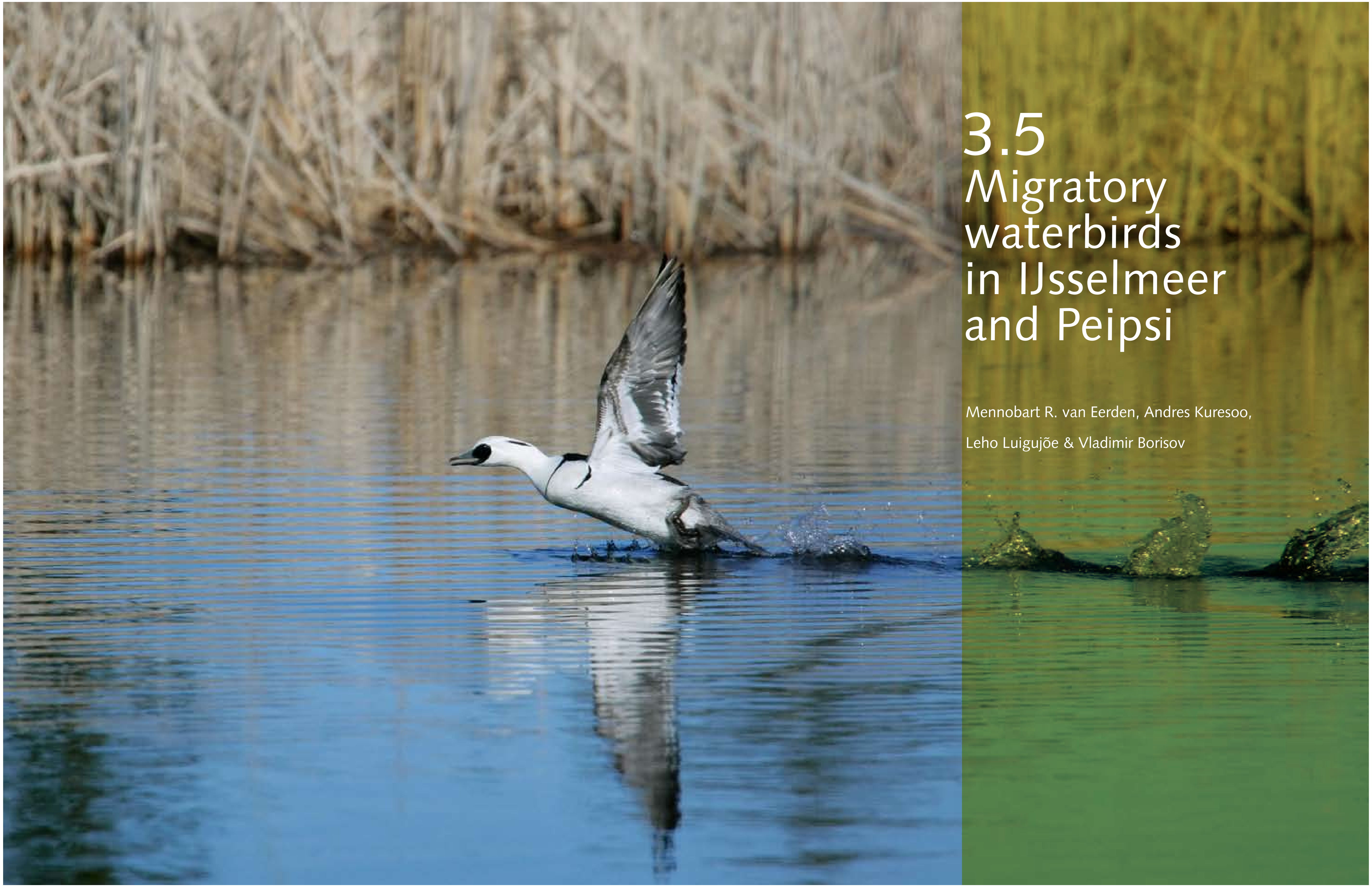
**Total catch**

The total catch in Peipsi amounted to ca. 40 kg $ha^{-1}$ in the 1930s and declined to ca. 20 kg $ha^{-1}$ in the 2000s (Figure 4b and 4c). Particularly planktivorous fish such as Smelt, Whitefish and Vendace (catch stopped) declined to less than 50% of the original catch and piscivorous fish (mainly Pikeperch and Pike) increased by almost 100%. In IJsselmeer the catch is about 50% of the catch in Peipsi. In IJsselmeer particularly Eel, Smelt, Pikeperch and Perch decreased by more than 50%, only the catch of Bream and Roach increased due to increased prices and declining catches of other commercial fish (Deerenberg & de Boois 2005). Although the nutrient load and nutrient concentration in Peipsi is lower than in IJsselmeer, the yield is higher than in IJsselmeer. It seems that the energy transfer in the Peipsi food web is more efficient than in IJsselmeer.

**Conclusions**

The differences between the fish communities in Peipsi and IJsselmeer and their exploitation show that the less eutrophic Peipsi has a higher yield than IJsselmeer. The lack of Eel in Peipsi is compensated by high yields of Pikeperch, Perch and Pike. Also the yield of Smelt is higher in Peipsi than in IJsselmeer. In both lakes the fish communities are overexploited and climate change has a dominant negative effect on Smelt and Vendace and a positive effect on Pikeperch. Despite the increase in nutrient load in Peipsi, the catches went down because of a strong top down effect of Pikeperch and negative climate impact on Smelt and Vendace. It is very unlikely that the further decrease in nutrients in IJsselmeer to the level of that in Peipsi will lead to lower fish catches. It is more important to reduce the intensity of fishery in both lakes to a level that allows balanced fish populations to develop. Apart from that, climate change will probably have more pronounced effects than nutrient reduction.

*Pikeperch catches have increased in Peipsi*



# 3.5 Migratory waterbirds in IJsselmeer and Peipsi

Mennobart R. van Eerden, Andres Kuresoo,
Leho Luigujõe & Vladimir Borisov

Waterbirds form a conspicuous part of the fauna of both Peipsi and IJsselmeer. The same species use both lakes as stop-over sites and IJsselmeer as a wintering site. However, food abundance and food availability differ considerably in both areas. Diving ducks, for instance, depend on Zebra Mussels in both lakes. These mussels form large beds on the former seabed in IJsselmeer, but they can not find firm substrate in the large parts of Peipsi which were covered by sedimentation of silt and detritus over thousands of years. Fish-eating waterbirds, which hunt on sight have to choose their foraging areas between the limits set by algal blooms and suspended silt in IJsselmeer, whereas in Peipsi water transparency is not limiting bird numbers. For herbivorous birds, the availability of macrophytes in Peipsi is strongly determined by water level fluctuation, while in IJsselmeer the fixed water table leads to partly over-used food stocks.


*Aerial bird count*
*Pskov, May 2005*





From 1980 onwards, aerial surveys of water birds were carried out each month at IJsselmeer, using a high-winged Cessna 172 aeroplane. During each count, which lasts about six hours, the entire shoreline including adjacent inland waters and polder areas is covered. The open water is sampled by flying regularly spaced-out loops at a fixed height of 150 m and a constant speed of 145 km $h^{-1}$. Along the shorelines all water birds are identified and counted by two observers, while during the loops only the birds within a fixed angle are noted. In this way an estimate is made of the total number of species with a regular but low-density distribution.
For Peipsi such long-term integrated monitoring is not available. However, sections of the coastline have been counted on both sides, the longest time series occurring on the Estonian side. During the project, existing data from these shore-based counts were used. Moreover, two integrated counts covering the entire lake were organised, in October 2004 and May 2005. These counts, applying both aerial and ship-based methods, resulted in a 90% coverage of the lake shores on both the Estonian and the Russian side. Additional information was obtained in 2006.

**Bird species and numbers**

The counts showed that the same species, belonging to virtually the same populations, occur at both lakes. Benthos-eating birds, fish-eating birds and herbivorous birds alike use both lakes as stop-over sites and IJsselmeer as a wintering site. IJsselmeer on average has more birds, irrespective their feeding guild, than Peipsi.

**Benthos-eating birds**

On a yearly basis, the IJsselmeer area is haunt for a larger number of benthos eaters than Peipsi (Tables 1 and 2). Both the maximum number as well as the longer staging period cause a large difference in annual use in terms of bird-days. Although monthly counts are lacking for Peipsi, it is estimated that the number of bird-days spent in IJsselmeer is ten to twenty times higher.
If bird species are compared, Peipsi and IJsselmeer share the majority of species, Tufted Duck and Scaup being the most numerous *Dreissena* eaters in both lake systems. Peipsi has a greater number of Long-tailed Duck *Clangula hyemalis*, Goldeneye *Bucephala clangula*, Common and Velvet Scoter *Melanitta nigra*, *M. fusca*, which reflects the greater depths of this lake compared to IJsselmeer. These species winter also in large open sea areas such as the Baltic, the Gulf of Bothnia and the coastal areas of the North Sea.
Contrary to IJsselmeer, the food choice of the community of avian benthos eaters at Peipsi is largely unknown. Only for Tufted Duck and Scaup feeding on *Dreissena* was actually recorded by direct observation. However, considering the absence of larger molluscs and given the distribution of the larger assemblies of ducks, it is unlikely that the benthos eaters in Peipsi rely on anything else than *Dreissena*. Only the River Snail *Viviparus viviparus* could provide an additional food source, but given its large size it can only serve as food for seaducks and possibly Scaup.

**Table 1.** *Annual average mean and maximum of waterbirds in IJsselmeer, Markermeer and Borderlakes. Data for Borderlakes compiled by R. Noordhuis.*

| Species | | Average maximum | | | | Absolute maximum | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | IJmeer | Markermeer | IJsselmeer | Borderlakes | IJmeer | Markermeer | IJsselmeer | Borderlakes |
| **Fish** | | | | | | | | | |
| **Grey Heron** | *Ardea cinerea* | 10 | 22 | 96 | 276 | 23 | 40 | 218 | 516 |
| **Great White Egret** | *Casmerodius albus* | 1 | 7 | 5 | 14 | 10 | 22 | 16 | 73 |
| **Spoonbill** | *Platalea leucorodia* | 10 | 78 | 126 | 42 | 20 | 164 | 214 | 120 |
| **Great crested Grebe** | *Podiceps cristatus* | 342 | 1,037 | 6,756 | 2,206 | 785 | 3,569 | 14,043 | 3,867 |
| **Cormorant** | *Phalacrocorax carbo* | 1,260 | 5,520 | 12,894 | 5,039 | 8,565 | 11,909 | 25,418 | 11,060 |
| **Smew** | *Mergus albellus* | 183 | 1,308 | 1,342 | 420 | 1,225 | 5,643 | 6,495 | 1,119 |
| **Goosander** | *Mergus merganser* | 240 | 1,046 | 10,496 | 703 | 1,380 | 4,945 | 29,756 | 1,578 |
| **Red-breasted Merganser** | *Mergus serrator* | 0 | 12 | 1,206 | 43 | 2 | 135 | 10,252 | 594 |
| **Caspian Tern** | *Sterna caspica* | 0 | 0 | 6 | 1 | 2 | 4 | 50 | 17 |
| **Common Tern** | *Sterna hirundo* | 145 | 520 | 1,425 | 1,462 | 1,895 | 1,957 | 6,507 | 2,297 |
| **Black Tern** | *Chlidonias niger* | 1072 | 30,159 | 60,707 | 233 | 2,300 | 36,027 | 107,858 | 656 |
| **Benthos** | | | | | | | | | |
| **Pochard** | *Aythya ferina* | 10,758 | 9,658 | 8,405 | 31,034 | 33,120 | 22,785 | 52,775 | 52,798 |
| **Tufted Duck** | *Aythya fuligula* | 28,050 | 41,473 | 33,850 | 33,563 | 59,200 | 76,497 | 105,753 | 45,550 |
| **Scaup** | *Aythya marila* | 2,090 | 9,623 | 111,473 | 8 | 12,310 | 77,305 | 224,180 | 31 |
| **Goldeneye** | *Bucephala clangula* | 491 | 1,159 | 3,062 | 755 | 2,222 | 4,560 | 17,120 | 1,670 |
| **Coot** | *Fulica atra* | 4,920 | 14,637 | 13,884 | 38,729 | 13,170 | 30,843 | 35,185 | 69.482 |
| **Plants** | | | | | | | | | |
| **Bewick's Swan** | *Cygnus bewickii* | 9 | 57 | 687 | 1,665 | 70 | 134 | 2,302 | 4,590 |
| **Pinkfeet** | *Anser brachyrhynchus* | 0 | 0 | 614 | 0 | 0 | 0 | 3,500 | 3 |
| **Bean Goose** | *Anser fabalis* | 0 | 229 | 1,036 | 1,607 | 0 | 1,500 | 3,150 | 3,603 |
| **White fronted Goose** | *Anser albifrons* | 1,186 | 3,053 | 13,094 | 5,195 | 3,515 | 9,475 | 43,145 | 8,760 |
| **Greylag Goose** | *Anser anser* | 633 | 2,019 | 2,154 | 3,959 | 2,600 | 3,525 | 4,920 | 6,112 |
| **Barnacle Goose** | *Branta leucopsis* | 752 | 694 | 6,121 | 160 | 5,150 | 2,025 | 15,150 | 1,138 |
| **Wigeon** | *Anas penelope* | 7,233 | 31,315 | 28,222 | 33,497 | 18,700 | 71,455 | 70,303 | 81,449 |
| **Gadwall** | *Anas strepera* | 197 | 868 | 887 | 1618 | 700 | 2,084 | 1,816 | 5,807 |
| **Red-crested Pochard** | *Netta rufina* | 5 | 4 | 0 | 60 | 18 | 14 | 0 | 181 |
| | **Total** | **59,587** | **154,498** | **318,548** | **162,289** | | | | |

**Table 2.** *Annual average mean and maximum of waterbirds in Peipsi and Võrtsjärv.*

| Species | | Average maximum | | Absolute maximum | |
|---|---|---|---|---|---|
| | | Peipsi | Võrtsjärv | Peipsi | Võrtsjärv |
| **Fish** | | | | | |
| **Grey Heron** | *Ardea cinerea* | 62 | 10 | 122 | 11 |
| **Great White Egret** | *Casmerodius albus* | 3 | 1 | 6 | 2 |
| **Great crested Grebe** | *Podiceps cristatus* | 3,021 | 935 | 5,835 | 1,7 |
| **Cormorant** | *Phalacrocorax carbo* | 425 | 97 | 1 | 276 |
| **Smew** | *Mergus albellus* | 1,137 | 1,663 | 1,872 | 3,300 |
| **Goosander** | *Mergus merganser* | 1,157 | 982 | 2,971 | 1,833 |
| **Red-breasted Merganser** | *Mergus serrator* | 60 | 45 | 80 | 78 |
| **Caspian Tern** | *Sterna caspica* | 1 | + | 3 | + |
| **Common Tern** | *Sterna hirundo* | 17 | + | 20 | + |
| **Black Tern** | *Chlidonias niger* | 121 | + | 184 | + |
| **Benthos** | | | | | |
| **Pochard** | *Aythya ferina* | 182 | 50 | 600 | 80 |
| **Tufted Duck** | *Aythya fuligula* | 6,363 | 217 | 10,033 | 305 |
| **Scaup** | *Aythya marila* | 12,865 | 10 | 31,042 | 32 |
| **Common Scoter** | *Melanitta nigra* | 561 | 1 | 997 | 2 |
| **Velvet Scoter** | *Melanitta fusca* | 224 | 1 | 409 | 2 |
| **Goldeneye** | *Bucephala clangula* | 3,458 | 548 | 7,862 | 2 |
| **Coot** | *Fulica atra* | 912 | 250 | 1,059 | 400 |
| **Plants** | | | | | |
| **Bewick's Swan** | *Cygnus bewickii* | 1,157 | 131 | 4,000 | 250 |
| **Whooper Swan** | *Cygnus cygnus* | 143 | 36 | 310 | 66 |
| **Mute Swan** | *Cygnus olor* | 170 | 20 | 208 | 48 |
| **Bean Goose** | *Anser fabalis* | 1,943 | 1,713 | 3,528 | 2,500 |
| **White-fronted Goose** | *Anser albifrons* | 4,902 | 12,043 | 8,500 | 14,130 |
| **Barnacle Goose** | *Branta leucopsis* | 532 | 235 | 1,662 | 320 |
| **Brent Goose** | *Branta bernicla* | 222 | 0 | 528 | 0 |
| **Wigeon** | *Anas penelope* | 3,736 | 1,005 | 9,155 | 1,100 |
| **Gadwall** | *Anas strepera* | 21 | 2 | 31 | 2 |
| **Pintail** | *Anas acuta* | 270 | 75 | 715 | 100 |
| **Shoveler** | *Anas clypeata* | 155 | 150 | 260 | 480 |
| **Mallard** | *Anas platyrhynchos* | 3,945 | 867 | 9,195 | 1,500 |
| **Teal** | *Anas crecca* | 1,348 | 34 | 2,733 | 70 |
| **Garganey** | *Anas querquedula* | 156 | 34 | 439 | 50 |
| | **Total** | **49,269** | **17,255** | | |

Note: in Peipsi considerable numbers (> 200) of Long-tailed Duck *Clangula hyemalis* and Black-throated Diver *Gavia arctica occur*; due to their offshore occurrence their actual number has to be assessed still.

**Fish-eating birds**

Also for the fish-eating waterbirds, both lakes share most of the species, although again IJsselmeer generally has higher numbers than Peipsi. Both lakes share the presence of large numbers of Goosander *Mergus merganser*, Great crested Grebe *Podiceps cristatus* and Smew *Mergus albellus*. IJsselmeer has more Red-breasted Mergansers *Mergus serrator*, whereas Peipsi has a greater number of divers, notably Black-throated Diver *Gavia arctica*. In IJsselmeer large numbers of Cormorants are present, a species which is just appearing in small number at Lake Peipsi. For gulls and terns the situation is comparable, IJsselmeer having a higher overall number, although the share of species is almost complete. For Black Tern *Chlidonias niger*, IJsselmeer takes a very special position with respect to numbers. Up to the early 1990s, in August numbers recorded were far over 100,000 birds, originating from a vast area in Eastern Europe. Such congregations are exceptional at a European scale.

**Herbivorous birds**

For the group of herbivores the tendency is similar. White-fronted Goose *Anser albifrons*, Greylag Goose *Anser anser* and Bean Goose *Anser fabalis* are the most important grey geese. Apart from Greylag and Bean, which can be found in large numbers on agricultural fields, all other species rely on pastureland. IJsselmeer has large numbers of Barnacle Geese *Branta leucopsis*, a species uncommon in Peipsi. Wigeon *Anas penelope* is the most common dabbling duck in both lakes, but again also for this species IJsselmeer greatly outnumbers Peipsi. The herbivorous waterbirds mainly depend upon high quality grasslands and not so much on natural vegetation. Due to fertilizer application, these fields remain attractive for the greater part of winter (see Van Eerden *et al.* 2006), thus positioning the Dutch polders at a number one European rank with respect to waterbird density. The hinterland of Friesland and Noord Holland serves these birds as important feeding ground in winter. In autumn the leftovers of sugarbeet, potato and stubblefields in the Noordoostpolder, Flevoland and Wieringermeer attract large numbers of geese, swans and Mallards.
Finally, the occurrence of Stonewort *Chara spp*. in the Borderlakes and locally also in Lake Markermeer and Lake IJsselmeer is worth mentioning. This development, which took place in the late 1990s and early 2000s after the improvement of the water quality, now gives home to tens of thousands of herbivorous water birds, notably Wigeon, Bewick's swan, Gadwall *Anas strepera* and Red-crested Pochard *Netta rufina* (cf table 1).

**Food abundance and availability for waterbirds**

That IJsselmeer on average has more birds than Peipsi, is probably related to the geographical position, which makes IJsselmeer more suitable as a wintering area. But is also related to the fact that IJsselmeer offers a greater food availability than Peipsi. However, this situation is not stable, which causes concern with respect to the future situation.

**Benthic prey**

The old remains of seashells still present in the bottom of the lakes in the IJsselmeer area form the basic substratum for *Dreissena*. The IJsselmeer area is a former estuary closed off from the sea in 1932. It currently consists of two large freshwater components: Lake IJsselmeer in the north (c. 125,000 ha) and Lake Markermeer/IJmeer in the south (ca. 70,000 ha). The water system is fed by the river IJssel, a branch of the river Rhine, and thus both lakes are eutrophic and relatively turbid. Average water depths are about 5 m in the north and some 3-4 m in the south, well within reach of diving ducks. In the north most of the soil consists of sand, while in the southern part mostly clayish sediments have been deposited. Clay soils in the north are restricted to the bottoms of some former tidal gullies and former sandpits, because of their greater depths.





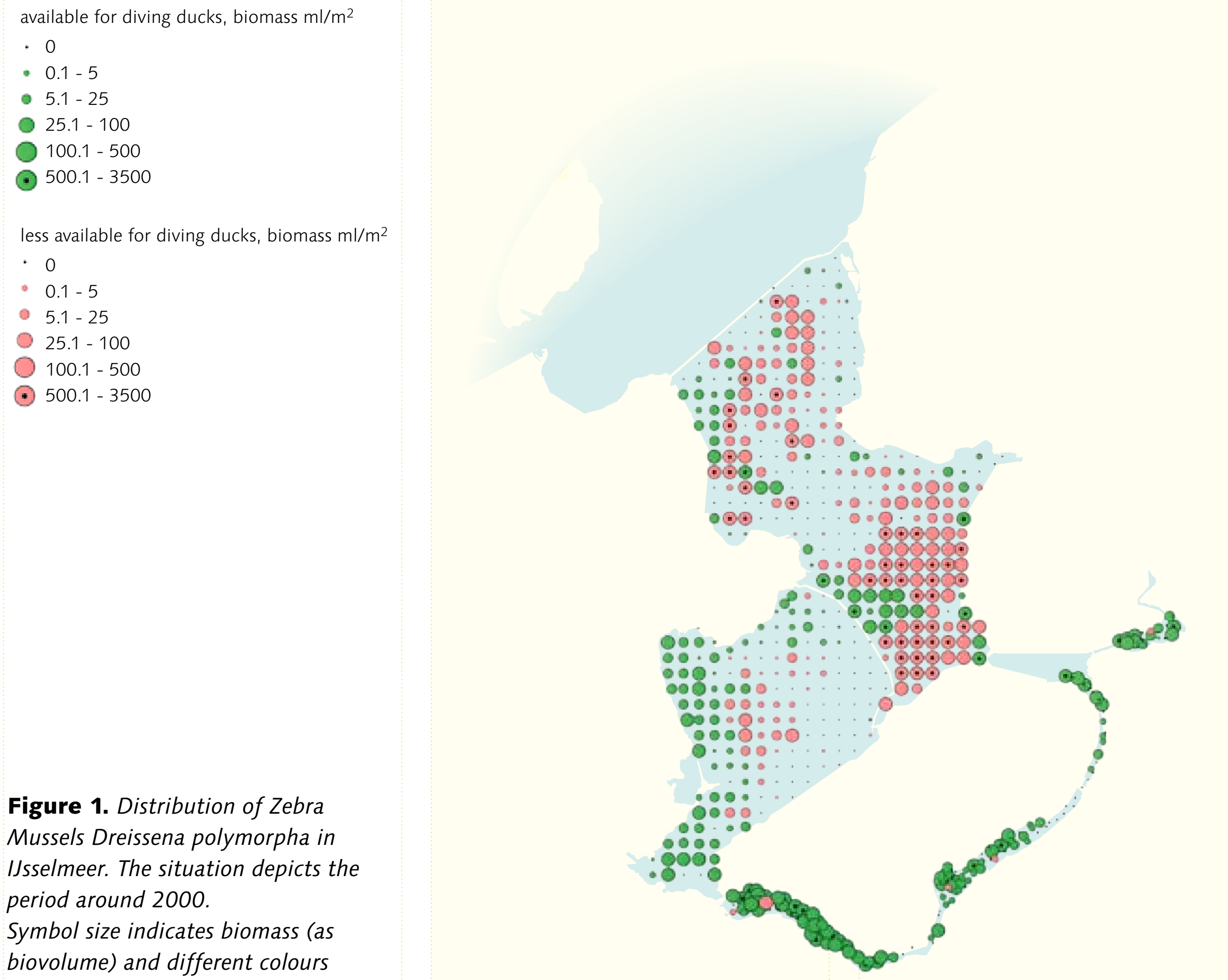



**Figure 1.** *Distribution of Zebra Mussels Dreissena polymorpha in IJsselmeer. The situation depicts the period around 2000. Symbol size indicates biomass (as biovolume) and different colours indicate mussels available to diving ducks.*

Figure 1 shows the presence of *Dreissena* in IJsselmeer. The largest stands occur in the northern part, whereas in Lake Markermeer over the past 15 years a strong decline has been noticed. In the Borderlakes *Dreissena* has become re-established in large numbers after water quality improved in the course of the 1990s. The available fraction for waterbirds is determined by flesh content of the mussel and water depth (De Leeuw 1997). As can be seen, in the larger lakes the highest available fraction of the mussel stocks for waterbirds occurs in Lake IJmeer, followed by Lake Markermeer and then Lake IJsselmeer. In absolute terms the opposite is true, as the largest overall stocks are present in the north. The narrow Borderlakes resemble Lake IJmeer with respect to the high fraction available (Figure 1). Diving ducks may harvest 20-60% of available mussel stocks, locally this may even be over 80% (Van Eerden 1997).
In Peipsi no information is available on the level of consumption of *Dreissena* by waterbirds. Here, *Dreissena* occurs between 1.5 and roughly 5 meters of water depth. In deeper water the bottom is covered with a soft layer of sapropelium, preventing the mussels to attach their byssus threads to firm objects. Below 5.5 meters water depth hardly any mussels occur. This difference with IJsselmeer is striking; it turns out that the natural sedimentation process over thousands of years has led to large areas without any possibilities for stands of larger bivalves, which need firm substrate.

**Fish prey**

Waterbirds like mergansers, grebes and cormorants feed on fish prey while performing the so-called pursuit diving method. Because they need to swallow their fish whole, only small fish form attractive prey. They need to see their prey under water and therefore these species are active during daylight hours only. Besides fish size and density, underwater vision is limiting the use of fish resources. Therefore turbidity by suspended matter and/or algal blooms is an important factor determining prey availability for fish-eating birds.
Gulls and terns also rely on fish for part of their diet; however, rather than by diving they use the habit of hunting by plunge diving from the air.
They rely therefore on the presence of prey in the uppermost top water layers (0-10 cm depth).
Both IJsselmeer and Peipsi share the presence of Smelt *Osmerus eperlanus* as important food item for fish-eating waterbirds. For IJsselmeer we possess a large dataset about prey choice of the group of fish-eating birds. For Peipsi this is not the case. However, given the resemblance of the composition of the fish community of both lake systems (chapter 3.4) it is very likely that the diet of the fish-eating waterbirds in Peipsi consists largely of this species, too.
In IJsselmeer Cormorants *Phalacrocorax carbo* show a markedly different diet, feeding on Ruffe *Gymnocephalus cernuus*, Perch *Perca fluviatilis* and Roach *Rutilus rutilus*. For Lake Peipsi this may be true for the group of divers as well. These large birds, with the size of a Cormorant, may also rely on other fish prey than Smelt. In Peipsi Cormorants are present in very low number as yet.
Besides Smelt, gulls and terns also feed on the bycatch of fishermen; this comprises Ruffe, 0+ and 1+ Perch, Pikeperch and Roach, all species which reproduce in large numbers in the lake.
In large lakes waterbirds may harvest some 10-15% of the available stock of smaller fish (Van Eerden 1997 & unpublished).

**Plant food**

For herbivorous birds plant food is important. Seeds of annual pioneer species such as Celery-leaved Buttercup *Ranunculus sceleratus* and various Chenopodiaceae provide food for Teal *Anas crecca*, Pintail *A. acuta* and partly Shellduck *Tadorna tadorna*. These species rely on shallow zones, forelands, wet grasslands and marshes. Especially when fluctuating water tables allow the plant species to germinate, grow and flower, enough seeds can be produced for these birds. In IJsselmeer the Oostvaardersplassen forms the major haunt for this group, due to the fact that natural shores are lacking over the greater part of the coastline. In Peipsi the centre point was Lake Pihkva, before the rapid deterioration of aquatic vegetation took place in the late 1980s and 1990s. Well before that, in the 1950s, this part of the lake held tens of thousands of Wigeon, Teal, Mallard, Coot and other species which depend on aquatic macrophytes (Leus 1961). Swans, geese and dabbling ducks like Mallard *Anas platyrhynchos* can feed on leaf material of Reed *Phragmites australis* or waterplants but may also grub the watery soil for subterraneous tubers, stolons and bulbs.
Water table is of prime importance again as this determines both growing conditions for plants as well as conditions during harvest by water birds. Seasonally changing water tables serve this purpose best, with rising water tables in autumn after a drier period during summer. Annual and especially perennial plant species develop better when marshes have a dry phase for several years in a run before they become flooded again. Experiments with an artificial drawdown in Oostvaardersplassen have shown this during the period 1987-1991. The newly emerged soils of the marsh led to a tremendous re-growth of marsh plants, eventually resulting in 600 ha newly formed reed in the fourth year (Vulink & Van Eerden 1998). During the pioneer stage the seed production was enormous; over 125,000 Teal were attracted in autumn 1988,

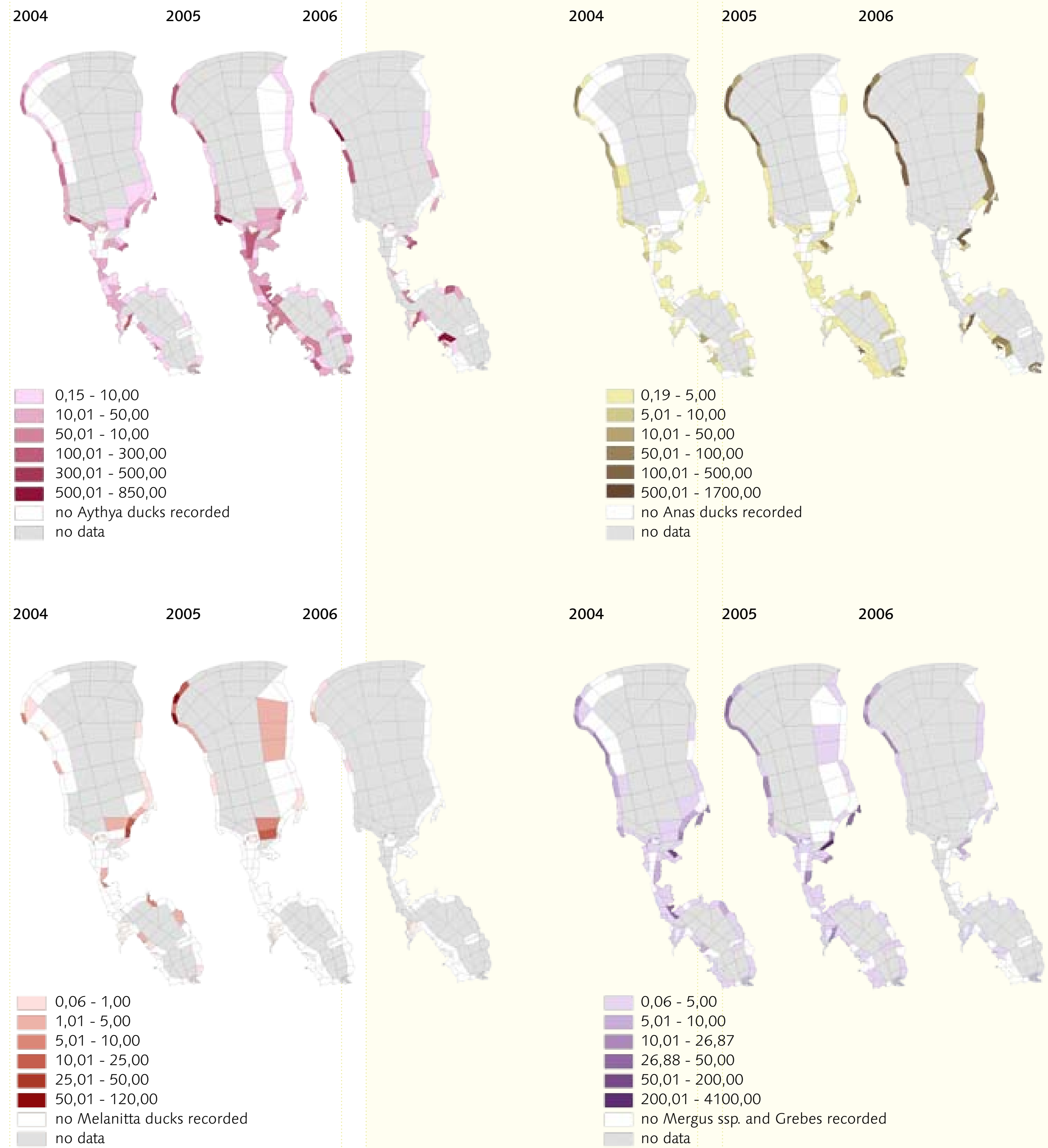



**Figure 2.** *Spatial distribution of diving ducks Aythya spp., dabbling ducks Anas spp., seaducks Melanitta spp. and mergansers and grebes in Peipsi, Pihkva and Lämmijärv in 2004, 2005 and 2006.*

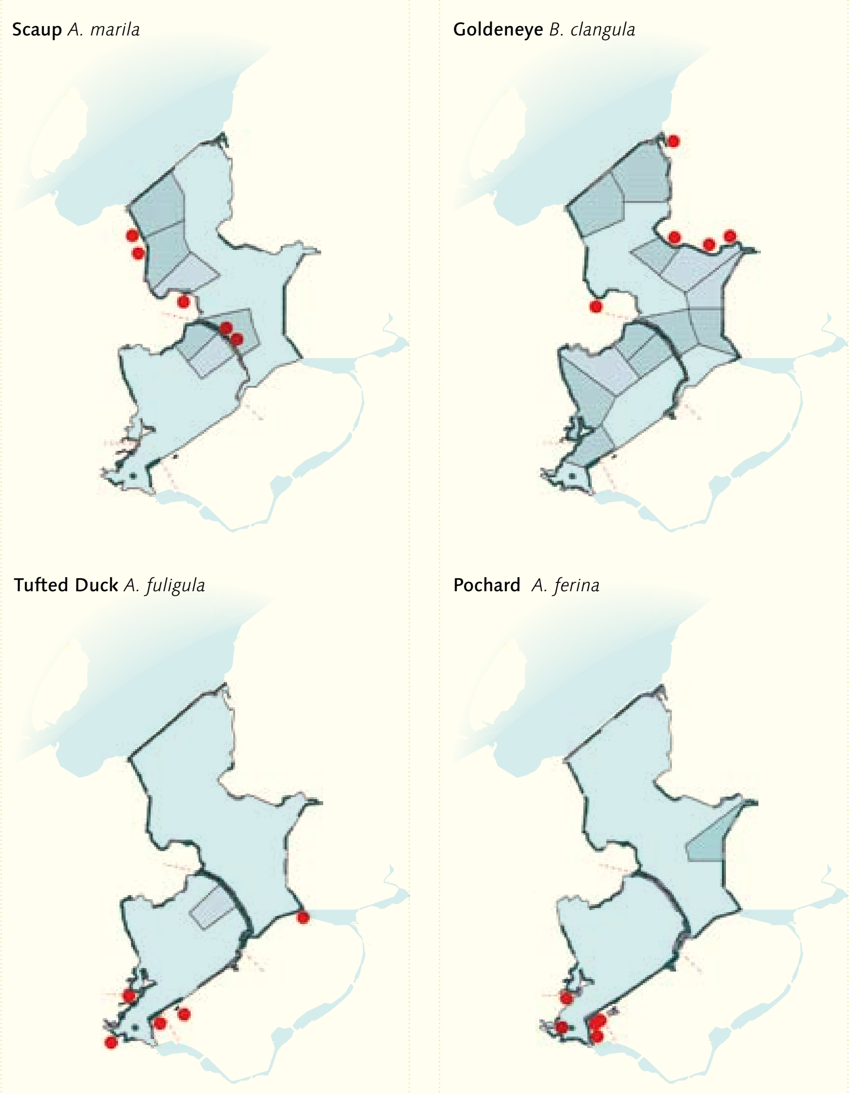



**Figure 3.** *Spatial occurrence of three species of Aythya diving ducks and Goldeneye in Lake IJsselmeer.*

*Red dots indicate the top five localities (1980-2005)*

demonstrating the immediate reaction of waterbirds to a sudden but massive change in food supply (480 tonnes of seed, Van Eerden 1993).
The fixed water tables in IJsselmeer do not allow such situations to happen again. In Peipsi, however, natural water table fluctuations do take place and this leads to tremendous variations in food availability for water birds from one year to another. During this study, for example, we could witness the difference between 2004/05-2005/06, when high waters prevailed, and 2006/07-2007/08, when water tables were about one meter (!) lower in autumn (see also text box Bewick's Swans).

### Spatial distribution of birds in relation to food stocks

Water birds in both systems are distributed in accordance with their main food source. The trophic gradient, which exists within Peipsi, causes more eutrophicated conditions in the southern part of the system. Water plants still occur, but much less than 40 years ago. Reed and bulrush are flourishing here and as long as algal blooms and disturbance permit, fish-eaters congregate for breeding in these areas. For mussel-eaters and fish-eaters outside the breeding season, the transient area between both lakes seems to provide optimal foraging conditions with respect to fish availability and water transparency.





The open water in the northern part of Peipsi is still *terra incognita* as far as the use by foraging waterbirds is concerned. For herbivores the situation of Lake Pihkva is far from ideal at the moment. Figure 2 shows the actual distribution of dabbling (*Anas spp*.) and diving ducks (*Aythya, Bucephala*, *Melanitta spp*.)

In IJsselmeer the major part of herbivorous water birds rely on agricultural food, except in the Borderlakes, Lake IJmeer, Lake Gouwzee and along the Frisian coast, where aquatic vegetation is still a prominent part of the shallows.
Finally the importance of habitat scale in relation to the presence of waterbirds needs to be mentioned. In IJsselmeer the northern part, which contains the vastest areas of open water, is used by physically larger species (e.g. Goosander and Scaup) compared to the southern part (Smew and Tufted Duck). For Peipsi this trend is also visible (divers, Scaup and scoters at the open parts of Lake Peipsi, grebes and Tufted Duck in inshore areas and Lake Pihkva). At present, the closed off southern part of IJsselmeer, Lake Markermeer, imposes a strong constraint on the feeding opportunities of fish-eaters (low underwater visibility) and benthos-eaters (low food stock because of sedimentation of silt).

### Benthos-eating birds

In benthos-eating diving ducks feeding on *Dreissena* mussels we could demonstrate a tight relationship between lake-wide sampling of benthos and duck numbers over the years (Van Eerden & De Leeuw 2007). Earlier, we found a relationship between mussel biomass, water depth and duck numbers by sampling of large (25-50 $km^2$) sub areas (Van Eerden 1997). This makes clear that scaling up of small patches to larger areas is valid and that carrying capacity of the lake is determined largely by the available benthos stocks. Regions where large numbers of diving ducks occur thus correspond in general with areas of abundant occurrence of mussels. In IJsselmeer these are the borderlakes, Lake IJmeer, western half of Lake Markermeer and the shallow zones in Lake IJsselmeer (Figure 3).

In Peipsi such analysis has not yet been carried out. However, the diving ducks concentrate in Lake Pihkva from Kolpino island in the NW to the bays of Chernaya River in the NE part, with isolated occurrence around the archipelago of Talabskiy and Kamenka Island. Few diving ducks are found along the eastern and southern shores of Lake Pihkva in autumn and spring. Here, few *Dreissena* occur. However, locally summer concentrations of Tufted Duck occur that may indicate wing moult. In IJsselmeer we found that moulting diving ducks do not feed on *Dreissena* but on micro-molluscs and benthic ostracods. In Lämmijärv diving ducks are numerous on both shores and in Lake Peipsi the area along the west coast, all the way from Piirisaar Island to Lohusuu north of Mustvee is important. At the Russian side important staging areas occur in Zhelcha River bay, Raskopel Bay and the adjacent offshore areas and, especially for *Melanitta* sea ducks and Scaup *Aythya marila*, coastal and offshore areas as far to the north as Gdov. The bottom in all these areas consists of sand, till and the presence of stones on the bottom is typical. These areas coincide with the areas where *Dreissena* occurs. In sandy areas also small prey like the bivalves *Pisidium*, *Sphaerium* and gastropods like *Bithynia*, *Potamopyrgus*, *Viviparus* and *Limnaea* occur. The highest densities occur in the area where the two parts of the lake are connected. Especially the outflow area of Lake Lämmijärv into Lake Peipsi is important. This area is rich in *Dreissena* (eutrophicated water from Pihkva) and the bottom is not covered by soft sediments probably because of the water movement between the two lakes.

In IJsselmeer the availability of mussels decreases from Lake IJmeer and the Borderlakes, via Lake Markermeer to Lake IJsselmeer. Average water depth increases and mussel quality decreases in this order. This is reflected

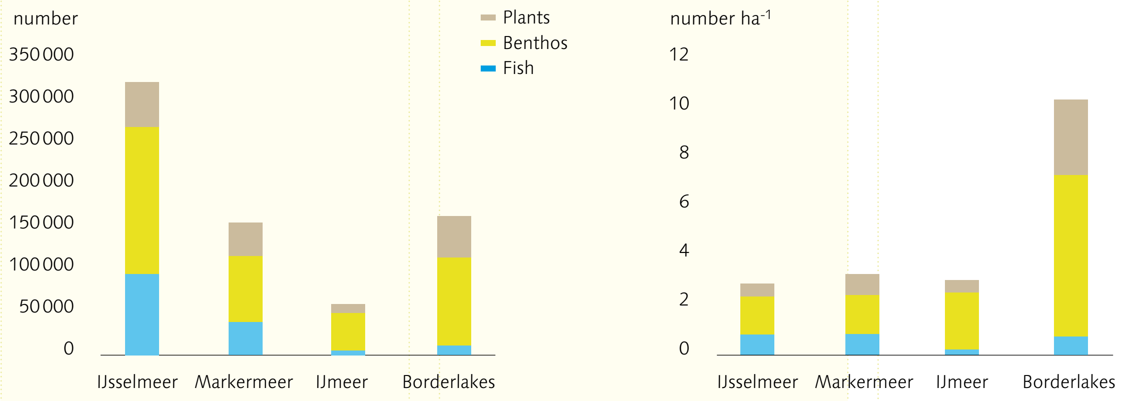



**Figure 4.** *Absolute (left) and relative (right) numbers of water birds in various lakes in the IJsselmeer system, based on average annual numbers.*

by the relative importance of the different parts of the lakes for water birds (Figure 4). In absolute terms most water birds are present in the largest lake, Lake IJsselmeer. In terms of density Lake IJmeer and the Borderlakes are more important, especially for benthos (both) and plant eaters (Borderlakes).

**Fish-eating birds**

In fish-eating water birds the situation is more obscure, due to the fact that the available fraction of the food supply is more difficult to quantify. Especially in this group Lake IJmeer stays behind in comparison with the other lakes. Recently most fish-eaters are to be found in the northern part of the system and to some extent in the area of the Borderlakes, where water transparency is greater than in the major part of Lake Markermeer. All moulting Great crested Grebes concentrate in the northern part as well. For the shallow IJsselmeer system, which because of its turbidity is still rather similar to an estuarine environment, we demonstrated the movement of colonially nesting Cormorants from the centre/south to the northern part, caused by the recent deterioration of the situation in Lake Markermeer (Van Rijn & Van Eerden 2002 and see below). Also, the major part of breeding gulls and terns is centred at Lake IJsselmeer.
In Peipsi both lake compartments serve as feeding areas for fish eaters. However, also in this case the south-eastern part of Lake Peipsi and the northern part of the entire west coast constitute the most important places where fish-eating birds can be found. Although detailed observations are lacking, these areas probably have intermediate levels of underwater transparency, especially in autumn. Moreover, they correspond to the areas where Smelt spawns (see chapter 3.3) and young fish tend to aggregate and are thus considered the most favourable areas for fish-eating birds.
It is interesting in this context to compare Peipsi with another lake in Estonia. In Lake Võrtsjärv, which is more turbid than Peipsi, the number of fish-eating birds is generally lower than at Lake Peipsi. However, frequent observations of large (2000-3300), socially fishing flocks of Smew in the southern part of the lake in autumn, show the peculiar position of this lake. The more turbid underwater visibility conditions compared to Peipsi makes it a suitable foraging area for this species. Interestingly, the abundance of Smelt (Järvalt *et al.* 2004) allows social foraging to occur, as could be observed in Lake Markermeer before the deterioration took place.

Like in IJsselmeer, island situations in Peipsi attract ground-breeding fish-eaters in spring. The Talabskiy islands, Kamenka and Kolpino Island, as well as Piirisaar and the islets off Samolva function as such. The colonies of gulls and terns also occur on floating packets of (ice-broken) reed stems and these occur most extensively around the north-eastern shores of Lake Pihkva (wind effects). Breeding fish-eaters therefore are distributed more to the southern part of the system, primarily in relation to the availability of breeding habitat. In spring algal blooms are absent and this may be the reason that Lake Pihkva is still functioning in this respect.

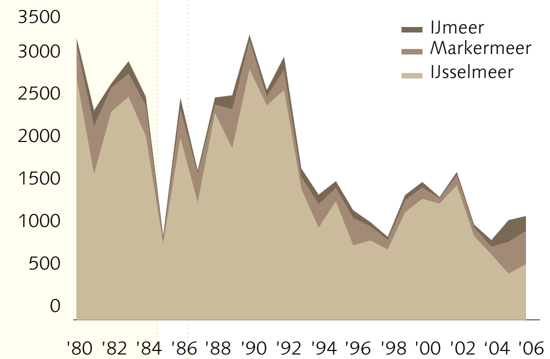
**Herbivorous birds**

In plant-eating birds the correlation with the availability of foraging areas is most easily seen. Both in IJsselmeer as in Peipsi the majority of geese occurs in areas where large-scale polder areas occur. Bean Geese and White-fronted Geese congregate in large numbers in the polders NE of Tartu, between Praaga and Lahepera and in the region of Räpina. On the Russian side smaller flocks occur, in accordance with the smaller surface areas of agricultural fields. With respect to natural food the situation is different. Tuber- and stolon-feeding Bewick's Swans are found along both the Estonian and Russian coast of Lake Peipsi, to a lesser extent also along the northern shores of Lake Pihkva, associated to the presence of pondweeds (see box text). Other macrophyte feeding water birds, such as Wigeon, Gadwall, Coot and Mallard have their centrepoint at Lake Pihkva. However, numbers have greatly fallen, in comparison to the situation some fifty years ago. Due to continuous eutrophication, this lake has lost most of its aquatic macrophytes and as such has greatly lost importance as staging site for herbivorous water birds. The situation bears reminiscence to that of the border lakes in IJsselmeer. The continuous eutrophication via the brooks entering the lake, caused macrophytes to disappear rapidly in the cause of the 1970s. Algal blooms took over and only major efforts could change this situation. Stopping contamination at the source and flushing in winter with clean polder water proved successful at last, although it was not before the second half of the 1990s when recovery was finally apparent.

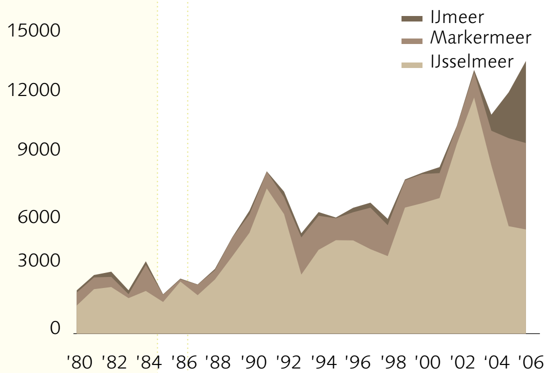
**Trends in bird numbers**

Generally speaking a downward trend in bird numbers is apparent in parts of both large lakes systems. In Lake Peipsi no clear trend is available but in Lake Pihkva the downward trend is obvious. In Lake IJmeer, Lake Markermeer and Lake IJsselmeer the negative trend is apparent in several species. Over a period of 25 years (1980-2004) 10 species are on the decline in Lake IJmeer, 8 species in Lake Markermeer and 5 species in Lake IJsselmeer (Table 3). The largest lake thus shows the least negative change and vice versa.
Some species show no trend at all, or even a positive one. This is the case for species which have a link with fertilised grasslands for feeding (geese, Mute Swans *Cygnus olor* and Wigeon). The trend is also up for Cormorant, which illustrates the over-fished state of the lake with a shift towards smaller fish (species and age classes, Van Rijn & Van Eerden 2002). The creation of new breeding habitats for colonially nesting terns and gulls has caused a positive trend in Common Tern in all three lakes.
A general upward trend for most species is occurring in the Borderlakes of IJsselmeer since 1990. Following the improved water quality and subsequent colonisation by *Dreissena* and *Chara*, these lakes have become revitalised as it were. This is a strong indication that local, food-based causes are reflected in these trends. What happened to the species at the other lakes? To answer that question it is necessary to have a closer look at the individual species.

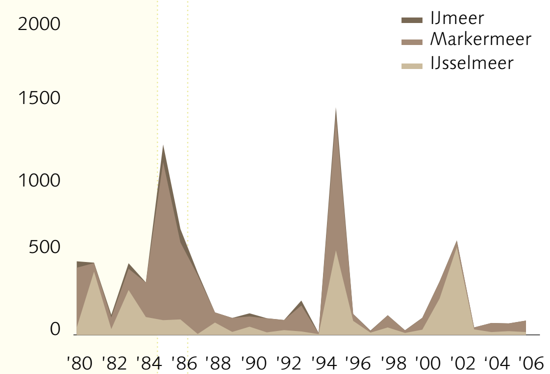
**Great crested Grebe** *Podiceps cristatus*
Great crested Grebes show a marked negative trend in Lake IJsselmeer and also, up to 2004, in Lake IJmeer and Lake Markermeer. Numbers were always higher in Lake IJsselmeer, but recently this difference almost vanished. The species has been increasing in the Borderlakes in recent years up to the level of Lake Markermeer. The strong downward trend in Lake IJsselmeer therefore was not compensated. In IJsselmeer traditionally the large moult concentrations occur in August and September. Great crested Grebes winter in deeper water, old gullies and sandpits.




**Cormorant**
*Phalacrocorax carbo*
Cormorants show an upward trend in all three lakes. In Lake IJsselmeer they have long been more numerous, and the increase started earlier and progressed at a higher rate than in the other two lakes. From 2004 on, a marked increase is visible in Lake Markermeer and Lake IJmeer, corresponding to a strong decrease in Lake IJsselmeer. This may be an internal shift in habitat use related to the fish situation, which was also visible to a lesser extent in 1993, 1997 and 1998 (Markermeer only).

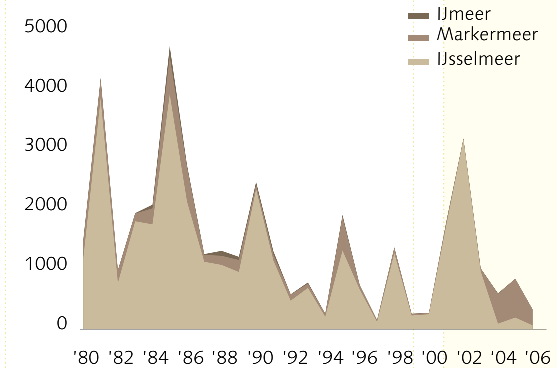



**Smew** *Mergus albellus*
The occurrence of Smew is irregular and coincides with periods of ice. Traditionally the highest numbers occur in Lake Markermeer, the winters 1985/86, 1986/87 and 1988/89 showing a clear pattern which was also recorded in the 1970s. In 1995/96 Smew peaked again in Lake Markermeer but this time also a marked peak in Lake IJsselmeer occurred. In 2002/03 and 2003/04 Smew peaked in Lake IJsselmeer only. Over the years, numbers decrease in Lake Markermeer and Lake IJmeer and show a slight increase in Lake IJsselmeer. Recently the species also increased in the Borderlakes but overall numbers have decreased strongly.

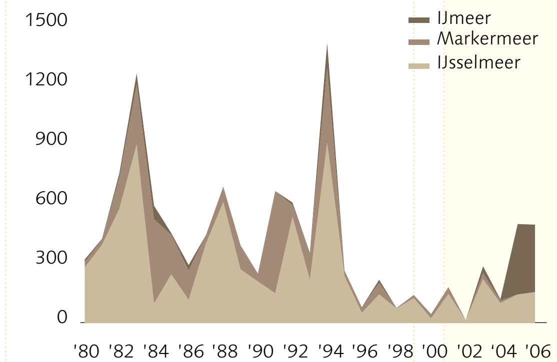




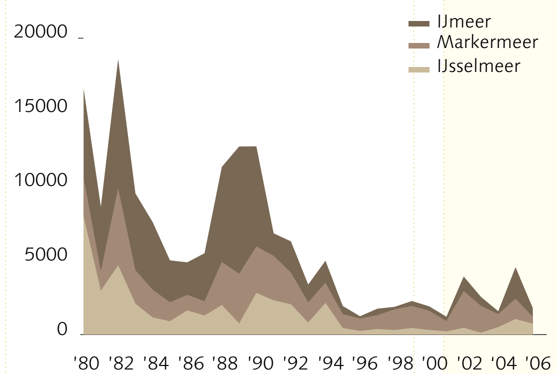


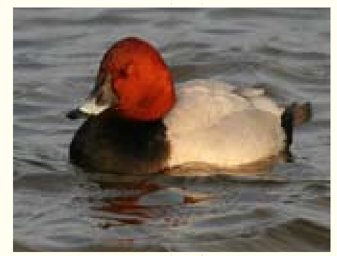




**Goosander** *Mergus merganser*
Goosander is more numerous in Lake IJsselmeer than in Lake Markermeer. Numbers fluctuate according to the winter situation; in ice winters more goosanders tend to winter than in mild winters. The species shows a general decline in numbers. Absolute lows were 1994/95, 1997/98, 2004/05 and 2006/07. Recently somewhat higher numbers were recorded at Lake Markermeer (since 2004/05), but this may well be an internal shift due to the low Smelt stocks in Lake IJsselmeer (see Cormorant and Great crested Grebe).



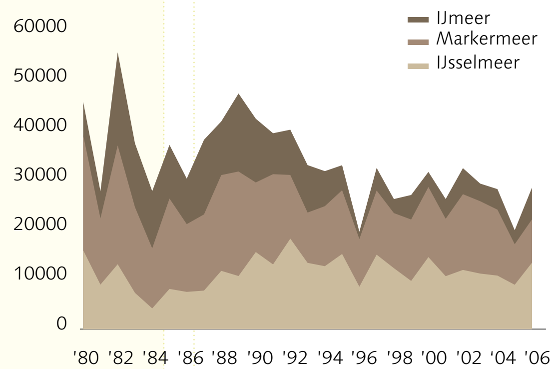

**Black Tern** *Chlidonias niger*
Black Tern is present for only a short period, from late July until early September with peak numbers in August. In the 1980s Lake IJsselmeer and Lake Markermeer both could harbour large numbers. In several years the peaks were out of phase, suggesting a shift between both lakes. In years of lower numbers in Lake IJsselmeer numbers increased in Lake Markermeer. After 1995 overall numbers have dropped dramatically, both in Lake IJsselmeer and Lake Markermeer. The relatively high numbers in Lake IJmeer are related to the realisation of the new nature area Hoekelingsdam, which serves as a resting place.

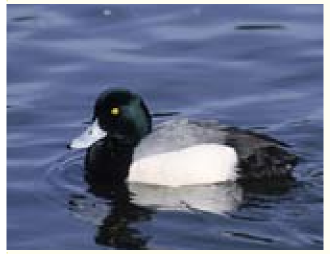


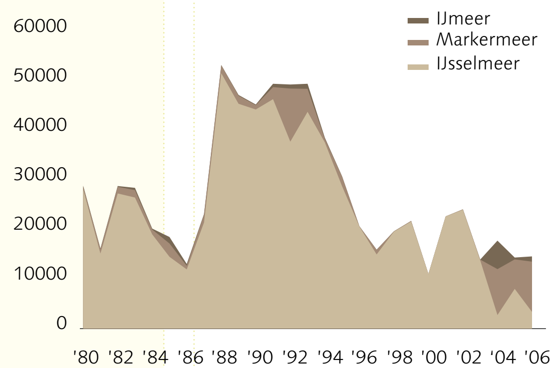
**Pochard** *Aythya ferina*
Pochard is one of the few species with a centrepoint in Lake IJmeer, due to shallow water and aquatic vegetation. In Lake IJsselmeer large numbers were recorded in the 1970s, the year 1980/81 being the last in this series. Peak numbers occurred in Lake IJmeer (and to a lesser extent Lake IJsselmeer and Lake Markermeer) in 1982/83 and 1989/90. Although all three lakes show an overall downward trend, 2002/03 (Markermeer) and 2005/06 (IJmeer) showed somewhat higher numbers. Part of the recorded decline was compensated by an increase in the Borderlakes.

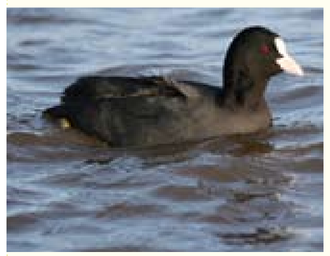
**Tufted Duck** *Aythya fuligula*
Tufted Duck is one of the most common benthos eating species. In Lake Markermeer and Lake IJmeer numbers are generally higher than in Lake IJsselmeer. However, Lake IJmeer and Lake Markermeer show an overall downward trend, while Lake IJsselmeer shows a gradual increase. Lake IJmeer shows the steepest decline. Especially after 1993/94 numbers have been permanently lower than before. A more gradual decline is apparent in Lake Markermeer. The Borderlakes have taken up the majority of Tufted Duck since 1995.



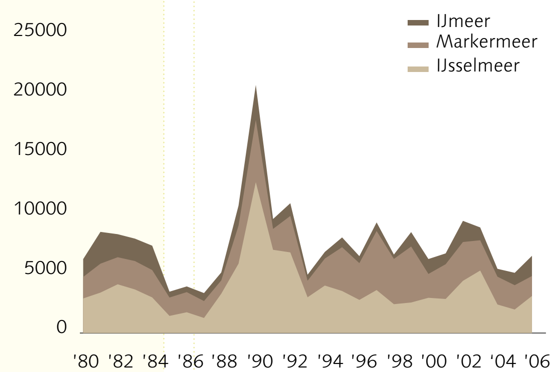



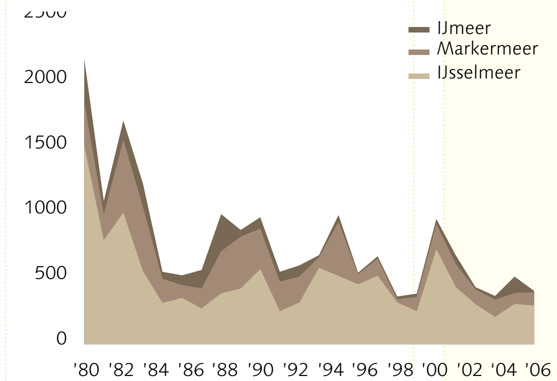
**Scaup** *Aythya marila*
Scaup is primarily confined to Lake IJsselmeer. Occasiaonally larger numbers occur in Lake Markermeer and rarely in Lake IJmeer. The same is true for the Borderlakes. Scaup is confined to large-scale water bodies and Lake IJsselmeer fits this requirement in wintering habitat. An overall decline is apparent, except for the period 1988/89-1995/96, when a significant but temporary influx was observed, probably due to the combined effect of a shift from the Waddensea (low stocks of Blue Mussels *Mytilis edulis*) and larger stocks of Dreissena (Van Eerden & De Leeuw 2007). As in other species, the low number in Lake IJsselmeer in recent years causes a shift to Lake Markermeer and even Lake IJmeer.

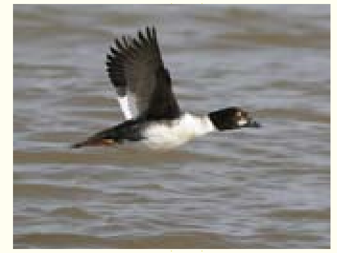


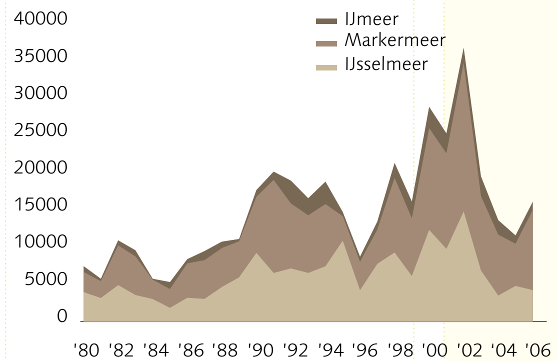
**Coot** *Fulica atra*
Coot is herbivore (aquatic vegetation) in summer, benthivore (*Dreissena*) in autumn and herbivore (grass) in late winter and spring. The large peak around 1990 is explained by a big spat fall of *Dreissena* in 1987, resulting in good mussel stocks the years after, an effect which lasted two years for Lake IJmeer and Lake Markermeer and five years for Lake IJsselmeer. There is no overall trend for Lake IJsselmeer, a slightly negative trend for Lake IJmeer and an increasing trend for Lake Markermeer. Coot numbers have greatly increased in the Borderlakes since the mid 1990s.

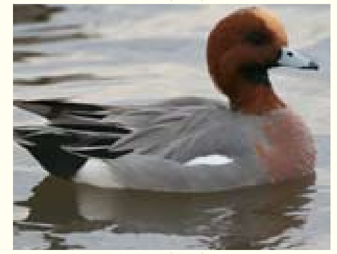


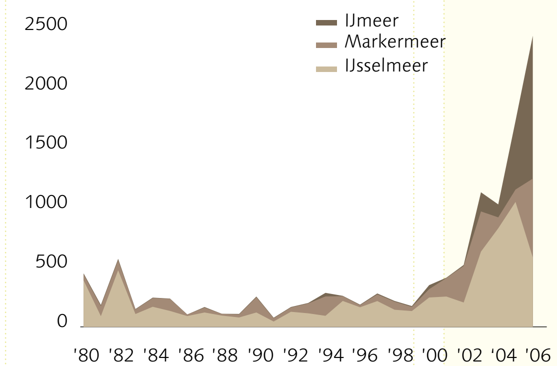



**Goldeneye** *Bucephala clangula*
Goldeneye are predominantly IJsselmeer birds in winter, but with fair numbers in Lake Markermeer and Lake IJmeer. In all three lakes a significant downward trend is apparent. For Lake IJsselmeer a strong decline occurred already between 1980/81 and 1983/84, followed by stabilising numbers. In Lake IJmeer a peak occurred in 1987/88, part of a wider peak in Lake Markermeer around 1988/89 and followed by a peak in Lake IJsselmeer one year later. More or less simultaneous peaks also occurred around 1982/83, 1993/94 and 1998/99.



**Wigeon** *Anas penelope*
Wigeon relies on wet grassland but may also forage on fertilised grasslands at night. Strongholds for the species exist along the Frisian coast and in Noord Holland between Hoorn and Marken. Contrary to most species, Wigeon show a continuous increase, the least so in Lake IJmeer. Winters with snow cause Wigeon to move, which happened in 1984/85, 1985/86 and 1996/97. A strong reversed trend started since 2003/04 in Lake IJsselmeer and to a lesser extent also in Lake Markermeer. This may be related to the recent marked increase in wintering geese, noticeably Barnacle Goose *Branta leucopsis* in the coastal areas of Friesland and Noord Holland.




**Common Tern** *Sterna hirundo*
Common Tern nests on sparsely vegetated soils. It used temporary breeding sites such as sanded areas which were cleared for building purposes. Besides, breeding on short grass and musselbanks along the Frisian coast occurred, thus making use of natural conditions. Newly created breeding areas like Naviduct near Enkhuizen (since 2001), Hoekelingsdam in Lake IJmeer (since 2003) and the island Kreupel (since 2003) provided new space. In a wide range of 15 km around these sites foraging terns can be found.

**Table 3** *Trend over 25 years in average number of birds per annum for three different lakes in IJsselmeer. Recently, the trend for Common Tern in Lake IJmeer has turned positive due to nature development projects creating breeding habitat.*

| Species | IJsselmeer 1980-2004 | Markermeer 1980-2004 | IJmeer 1980-2004 |
|---|---|---|---|
| **Fish** | | | |
| **Great crested Grebe** *Podiceps cristatus* | ■■■ (decrease) | ■■■ (decrease) | ■■■ (decrease) |
| **Cormorant** *Phalacrocorax carbo* | ■■ (increase) | ■■ (increase) | ■ (stable) |
| **Smew** *Mergus albellus* | ■ (increase) | ■■■ (decrease) | ■■■ (decrease) |
| **Goosander** *Mergus merganser* | ■■■ (decrease) | ■■■ (decrease) | ■■■ (decrease) |
| **Black Tern** *Chlidonias niger* | ■■■ (decrease) | ■■■ (decrease) | ■■■ (decrease) |
| **Benthos** | | | |
| **Pochard** *Aythya ferina* | ■■■ (decrease) | ■■ (decrease) | ■■■ (decrease) |
| **Tufted Duck** *Aythya fuligula* | ■ (increase) | ■■ (decrease) | ■■■ (decrease) |
| **Scaup** *Aythya marila* | ■ (stable) | ■■ (decrease) | ■■■ (decrease) |
| **Coot** *Fulica atra* | ■ (stable) | ■■ (increase) | ■■ (decrease) |
| **Goldeneye** *Bucephala clangula* | ■■■ (decrease) | ■■■ (decrease) | ■■■ (decrease) |
| **Plant** | | | |
| **Wigeon** *Anas penelope* | ■■ (increase) | ■■ (increase) | ■■ (increase) |
| **Bare soil** | | | |
| **Common Tern** *Sterna hirundo* | ■■ (increase) | ■■ (increase) | ■■■ (decrease) |

■■■ decrease
■■■ stable
■■■ increase

### Lakes in perspective

In conclusion: IJsselmeer has on average more birds, irrespective of their feeding guild, than Peipsi. Probably this is related to the geographical position (IJsselmeer is a wintering area), but also to the greater food availability than in Peipsi. However, this situation is not stable (see below) which causes concern with respect to the future situation. By contrast, the variety of species during migration is higher in Peipsi than IJsselmeer. This is probably due to the more diverse range of available habitat, both under water as well as along the coast and the inland areas (sea chapter 4.2). In the following sections the driving factors behind the waterbird numbers are discussed.

### Smelt and fish-eating birds

On a European scale the vulnerability of fish-eating waterbirds is apparent. Shallow open freshwaters constitute an unpredictable habitat. In IJsselmeer and Peipsi a downward trend is visible for stocks of Smelt. Lake IJsselmeer and Lake Markermeer are important because of their size and the abundance of a land-locked population of the small salmonid species of Smelt. They share this phenomenon with Peipsi and other large lakes in Russia, like Ilmen, Beloe, Seliger, Ribinsk, Ladoga and Onega a.o. (see Kuderskiy & Federova 1977). The warm summers of recent years show how fragile this situation is; effects on the availability of zooplankton, the role of depredation by Pikeperch and/or the occurrence of anoxia have been mentioned as possible reasons for the decline. However, as the decline in Smelt stocks in both Peipsi and IJsselmeer occurred over many years rather than just being of recent origin, it is unlikely that temperature is the only influencing factor. Whatever the mechanism, it is clear that from the perspective of bird conservation the low numbers of Smelt are not easily compensated for by any other small fish. Apparently, in winter the behaviour of 0+ of the larger species and of Ruffe is such that they are not

*Smelt*





*Zebra Mussels*

*Steile Bank*

easily available as prey for fish-eating waterbirds. The future status of species like Goosander, Smew and Red-breasted Merganser will therefore be under great pressure, especially if they are pushed westwards under harsh winter conditions. The same holds for Black Tern, which uses the IJsselmeer are for fattening up on its way to the African wintering grounds.
In smaller compartments Smelt does not occur permanently. Only in connected situations Smelt may move up from the open water bodies into smaller scaled waters, e.g. Lake Ketelmeer and Lake Gooimeer as well as the regions near the IJ in Amsterdam. Likewise, Lake Võrtsjärv still has a permanent Smelt population, probably thanks to its connection to Lake Peipsi (Järvalt *et al.* 2004).

### Zebra Mussel as keystone species

The crucial role of *Dreissena* as principal food for wintering benthos-eating water birds (cf Pedroli 1977) causes concern. Zebra Mussels are strongly depressed by sedimentation of silt in Lake Markermeer and are facing a gradual decline in Lake IJsselmeer, so the situation is far from ideal. However, comparison with Peipsi shows that in this natural lake there also is only a limited area available for larger mussels. Due to the much greater age of the water system (>8000 years), natural sedimentation has led to soft bottoms in the deepest parts in the north. Recently this also occurred in the southern Lake Pihkva due to eutrophication.
Soft bottoms do hold benthos organisms like larvae of Chironomid midges, but these are only available as prey for water birds if densities are high (> 30 g fwt $m^{-2}$ at 4 m water depth). As a rule, these densities occur neither in IJsselmeer nor in Peipsi. Occasonally they do occur in Peipsi at depths of 6-9 m (max 15 m) (cf. Timm *et al.* 2001), but this surely is out of reach of most diving ducks.
In the IJsselmeer area, the Borderlakes present an interesting case in this respect. Given the hard and sandy underwater bottoms, which are relics from the Zuiderzee times, and a low external phosphorus load, high densities of *Dreissena* could establish themselves here once the water quality had improved. Diving ducks responded eagerly to these developments (see Noordhuis 1997). Perhaps more promising is the availability of a variety of species of snails and micro bivalves in the Borderlakes, in combination with a dense cover of Stoneworts *Chara*. This shows that clear water with a low nutrient load can, if only after a period of ten years, lead to a highly productive situation which contributes significantly to the carrying capacity of the system. As shown by the waterbird density calculations, the Borderlakes have the best values for benthos and plant-eating water birds per unit of surface area.

### Land-water transitions as resting places for waterbirds

In winter, water birds use much of their energy for thermoregulation. Experiments with intact, plumage dry carcasses of water birds show a strong correlation between the degree of water contact and heat loss. If completely submerged (diving position), birds lost 4.8 times more heat per unit of time than while on land, while birds in swimming position lost 2.2 times more heat than on land. Body mass was the most important determinant of heat transfer (De Vries & Van Eerden 1995). In a semi-natural diving device, De Leeuw (1997) could verify increased energy expenditure during cold weather with live diving ducks, using the doubly labelled water technique.
Body mass, in relation to the degree of water contact, can be used as a gross predictor for the energy cost of thermoregulation, being largest for smaller birds during diving or swimming. Generally, higher conductance will lead to a tendency among the smaller species toward wintering further southward, although especially small birds (1 kg and less) may use the tactics of leaving the water whenever possible. Another way to save energy costs is to choose

sheltered resting areas in bays, along the lee shores or on smaller water bodies inland. Given this constraint by cold water, the availability of wetlands with sufficient resting areas where birds can spend part of the day out of the water is probably an important factor contributing to the carrying capacity of wetlands by reducing the costs of living of the water birds (cf van Eerden 1997). Likewise the presence of inundated meadows and forelands is of importance for geese. Such areas are found in Oostvaardersplassen, Lepelaarplassen, polder IJdoorn and along the Frisian coast and consequently they attract a great number of geese at night.
In Lake Peipsi and Lake Võrtsjärv geese sleep on the water of the large lakes in autumn, while in spring they sleep on the ice near open water or on inundated areas in the floodplains (cf Kuresoo *et al.* 2004). Natural, gently sloping shores with vegetation-free soils are especially suitable for this function, as are vegetation-free islets, mudflats or inundated meadows. On the other hand, some bird species such as mergansers and grebes preferably do not rest on land. For these birds ice edges function as resting places during periods of frost, while they feed in patches of open water, in ice holes and even under the ice nearby. A study on prey choice and prey mass ingested by Great crested Grebes confirmed that winter conditions with cold water impose extra costs for water birds. Due to low water temperatures, prey intake had almost doubled in comparison to the situation in late summer just after wing moult (Wiersma *et al.* 1995). This information is important for modelling energy flow through the food web (for Lake IJsselmeer see Buijse *et al.* 1993). In Peipsi birds on migration to and from the boreal breeding grounds may need extra prey because they need to replenish their fat reserves. In winter Peipsi is frozen over, so waterbirds have to move away further south. With respect to fish and benthos predation this limited use because of ice cover may lead to lower predation rates.

In both lakes waterbirds make extensive use of the shallows as described above; in IJsselmeer a lot of diving ducks that feed on the open water of the lake during the night, spend the daytime resting on smaller water bodies inland or behind dams (e.g. Lepelaarplassen, Gouwzee, PWN water storage basins). In Peipsi the curved shape of the shores provides enough shelter, especially since the shores are virtually inaccessible due to dense vegetation.





**Oostvaardersplassen: a wetland of inspiration**
*Mennobart van Eerden*

The making of new polders was originally inspired primarily by the need for new agricultural land. Post-war developments supported this policy of intensified production and man-made conditions for living below the sea. Later on, forestry, recreation and inhabitation by new citizens became an issue, first in Lelystad in eastern Flevoland (1957), later on to a much larger extent in the region of Almere in southern Flevoland (1968). In parallel to this multi-functional destination of the newly created soils, a very large wetland was established in this polder. Earlier on, biologists like Dingeman Bakker had developed the idea, based on experiences with natural colonisation in the Noordoostpolder (1942), to sow reed from aeroplanes at the time of pumping away the last of the water. In doing so, the natural reed vegetation helped to evaporate the remaining water in the clayey soils and to improve aeration conditions by its strong roots. The usual procedure was to burn the reeds in winter and, after ploughing, to sow the first agricultural crops such as colza.
Applying this technique, the new polders at first were temporal wetlands consisting of an enormous surface area of reeds. This extensive marshland bordering the large lake unintentionally contributed to the natural functioning of the system for more than 60 years. By the time the marsh was cleared up, the remaining parts of the polder were still being developed, followed by another polder where the same sequence of events took place. This led to the existence of 15,000 to 40,000 ha of wetlands which were home to species like Bearded Tit *Panurus biarmicus* and Marsh Harrier *Circus aeruginosus*.
On adjacent territories of newly cultivated soils, outbursts of voles occurred, attracting raptors like Rough-legged Buzzard *Buteo lagopus*. The populations of these species were able to expand tremendously and after the reclamation of a new polder a Europe-wide influx of Bearded Tits occurred, ranging from Great Britain to Poland and leading to a re-colonisation of many smaller wetlands.
This temporary richness was recognised in the early 1970s and led to the establishment of a permanent wetland reserve of 3600 ha, called Oostvaardersplassen. Drawing a straight line on the map to preserve a Spoonbill colony, the new territory was provided with a small dike, a pumping station and an outlet in 1974, thus preventing the wetland from drying up as a result of the drainage of the surrounding agricultural lands.
Since then, the area has developed and so have the ideas about managing the area. There was a recurring concern that the originally preserved wetland might be too small to serve all functions after cultivation of the surrounding areas. This eventually led to the extension of the reserve by another 2000 ha. This border zone acts as a buffer between the wet central part and the surrounding agricultural zone. Large-scale experiments with water table management, together with the introduction of semi-natural populations of Heck cattle, Konik horse and red deer have greatly altered the ideas about nature development. In combination with the scale of the area, large herbivores are a steering factor for vegetation development. Waders, geese and other grazing water birds depend on open areas, so a permanent high grazing pressure is needed to keep the area free of rough growth. Also, the corpses of large herbivores serve as food for carrion eaters like Raven *Corvus corax* and White-tailed Eagle *Haliaeetus albicilla*. These habitat factors clearly contributed to the first successful breeding attempts of the latter species since the middle ages.
The Oostvaardersplassen consist of a polder within a polder and therefore the water tables have to be managed artificially. Fish cannot enter the marsh from Lake Markermeer, but birds can easily fly across the dikes to feed in the lake whilst breeding in the reserve. This reserve, which now has a "history" of some forty years, hosts some of the stronghold populations of wetland birds. For instance, the largest inland colony of Spoonbills *Platalea leucorodia* (100-220 pairs in recent years), the only colony of Great White Egrets *Egretta alba* (143 pairs in 2006) and the largest population of Bittern *Botaurus stellaris* (30-50 pairs), to mention just a few. There are plans to connect Oostvaardersplassen to the Horsterwold forest and possibly the Veluwe region. This would lead to an extension of the migratory movements of large herbivores and would as such contribute to the seasonal functioning of the reserve. By extensive use of the grasslands and inundated areas in summer and partial withdrawal to the higher, drier grounds in winter, the role of the herbivores in the system could become more natural than it is at present.

*Habitat scale provides gradients*

# 3.6 Inventory of landscape units and vegetation classes using remote sensing and aerial photography

Ute Menke, Mennobart van Eerden, Andres Kuresoo,
Leho Luigujõe, Vladimir Borisov and Hans den Hollander

Landscape patterns in IJsselmeer and Peipsi strongly reflect the different degrees of human occupation. In IJsselmeer, the original situation was altered considerably in favour of agricultural use or urbanisation. By contrast in Peipsi, large gradients of the original landscapes are still present. Therefore, Peipsi can serve as a reference area for the natural situation in the IJsselmeer area. The coastal forms, the gradients and the connectivity among the landscapes demonstrate the origin from which the Dutch situation has evolved.

To identify and quantify the different landscapes around Lake Peipsi and Lake IJsselmeer, an image analysis was carried out. The landscape classification of the IJsselmeer area is based on an existing GIS based inventory on land use (LGN, dating from 2002). For Peipsi, Landsat images covering the area from August 1978 to August 2002 were bought. The image of the year 1996 was used for the landscape classification of Peipsi, because there are fewer disturbances by clouds in that picture than in the more recent ones.
Each image covers an area of 180x180 kilometres. The resolution of the multi-spectral images is 30x30 m (den Hollander, 2003). Besides the Landsat images, some IKONOS images were used in some selected areas in order to get a better and more detailed insight in the vegetation cover, for example in the Velikaya Delta and the floodplain of Alam-Pedja. The IKONOS images (den Hollander, 2005) cover a minimum surface area of 10x10 km and are very useful for getting more detailed information on vegetation types and structures (4x4 m).
The landscape classification is determined by the reflection of the vegetation. Time of year, geomorphology and soil type have an effect. Moreover, moisture differences are also important, which further complicates the accuracy that can be obtained. The great advantage, however, is the uniform assessment of large, continuous areas, which would never be possible by any other means.
Nevertheless, carrying out a landscape classification by an analysis of Landsat TM images is not possible without a ground survey. It appeared that different classes/legend units are quite similar in spectral reflection. Some classes were corrected on the basis of observations made during the field surveys and on the basis of expert judgement.
Some examples of the corrections:

- In the reed beds along the shoreline of the lake and along rivers (young) willow and birch woods occur which have similar reflections.
- Agricultural crops often have similar reflection values as some “natural” vegetation. The reflection of potatoes and reed for example is the same. Corrections were made, based on actual land use patterns, assessed by ground checks as well as structural characteristics.

**Landscape development**

The landscape characteristics in and around Lake IJsselmeer are comparable to the ones around Lake Peipsi. The geomorphology (the relief) is quite similar, although differences in geological development occur (see chapter 2.1). The Dutch landscape was shaped by the land ice cover during the Saalien and the tundra-period during the Weichselien. Along Lake IJsselmeer we find boulder clays (the cliffs of Gaasterland) and cover sands as well as the





ice-pushed ridges of the Veluwe. These are some of the higher areas in The Netherlands.
In the Peipsi area, we find the same undulating relief of boulder clays and cover sands from the last ice age, although in some parts of Lake Peipsi, and in Lake Võrtsjärv as well, old Devonian sandstones and limestones appear as outcrops, which form steep cliffs (see chapter 2.1). In the lower parts and the catchments of small rivers and brooks, thick layers of peat could grow extensively in the Peipsi catchment, a process that is still going on in large parts nowadays.

**Differences in landscapes**

The complete landscape gradient is more or less intact in the Peipsi catchment, from raised bogs via transitional bogs and peat to fens and large water bodies. In The Netherlands, on the other hand, the landscape was divided up consecutively into small segments by successive embankments, extensive agricultural use and the continuous process of urbanisation and infrastructure development. As a result, the natural connectivity of landscape elements does not exist here anymore, leaving only patches that serve as a reminder of the original. This becomes very obvious on the Landsat images (see chapter 2.3) of both lakes. IJsselmeer is characterised by many straight lines and lots of square or rectangle structures. Lake Peipsi shows a scattered overall pattern with gradual and natural contours. Almost the entire shoreline is natural, with the exception of the Räpina Polder at the western shore in Estonia, where a dike runs along the shore and some villages are built on high levees bordering the lake.

Figure 1 shows the distribution of main landscape units in Peipsi and IJsselmeer. The terrestrial part was set to 100% of the surface area. In the case of Peipsi this is 1.4 million hectares, in the case of IJsselmeer it is 800,000 hectares. For IJsselmeer two different periods, 1900 (after Van Beusekom, 2007) and 2002 are presented to show the developments in time. The period of 1900 bears a stronger resemblance to the present distribution in Peipsi, although human influence was already very strong by that time. Only 20% of the landscape was still semi-natural.

The IJsselmeer figures show that the amount of grassland was reduced in favour of agricultural and urban areas by 2002; this shift in percentage also has to do with the reclamation of the polders, which turned a water surface of 165,000 ha into land. The polders also affected the forest coverage. The (planted) forest area increased by more than 15,000 ha. Lake Peipsi area is still natural in large parts. Of course, the forests are managed there as well, but in a more extensive way.

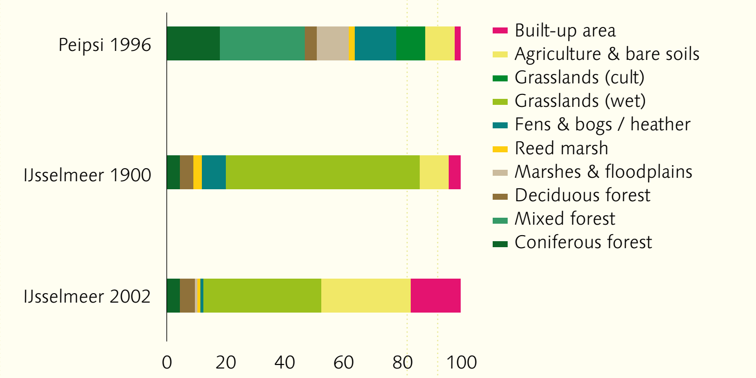
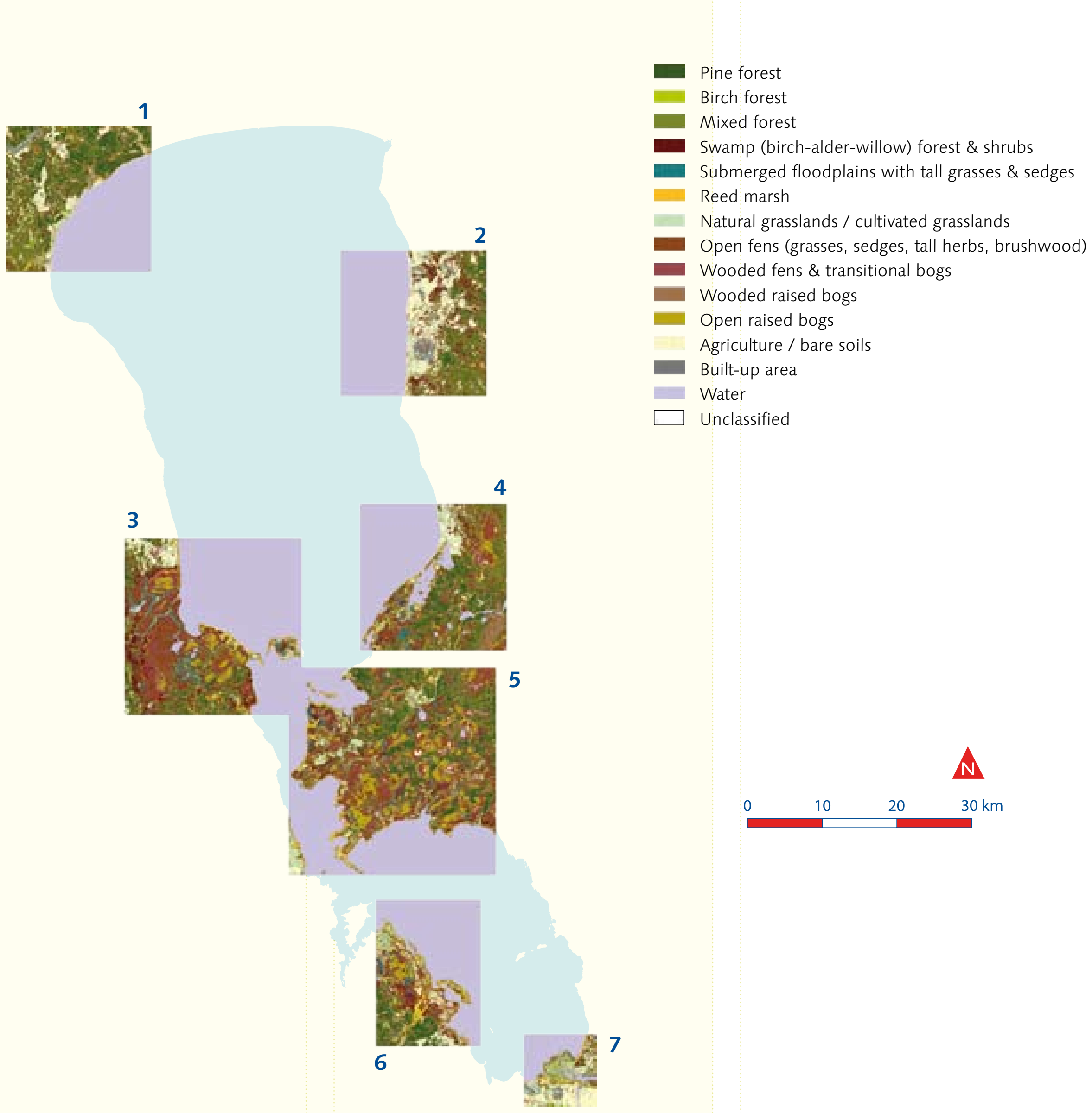



**Figure 1.** *Landscape units in Peipsi (1996) and IJsselmeer (1900 and 2002)*



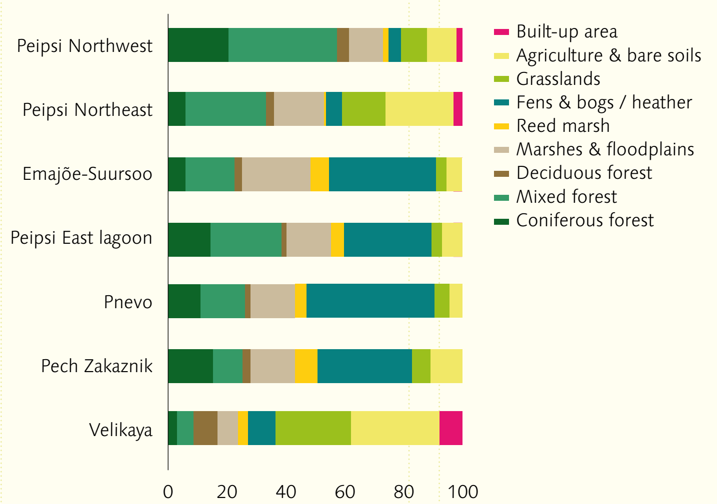
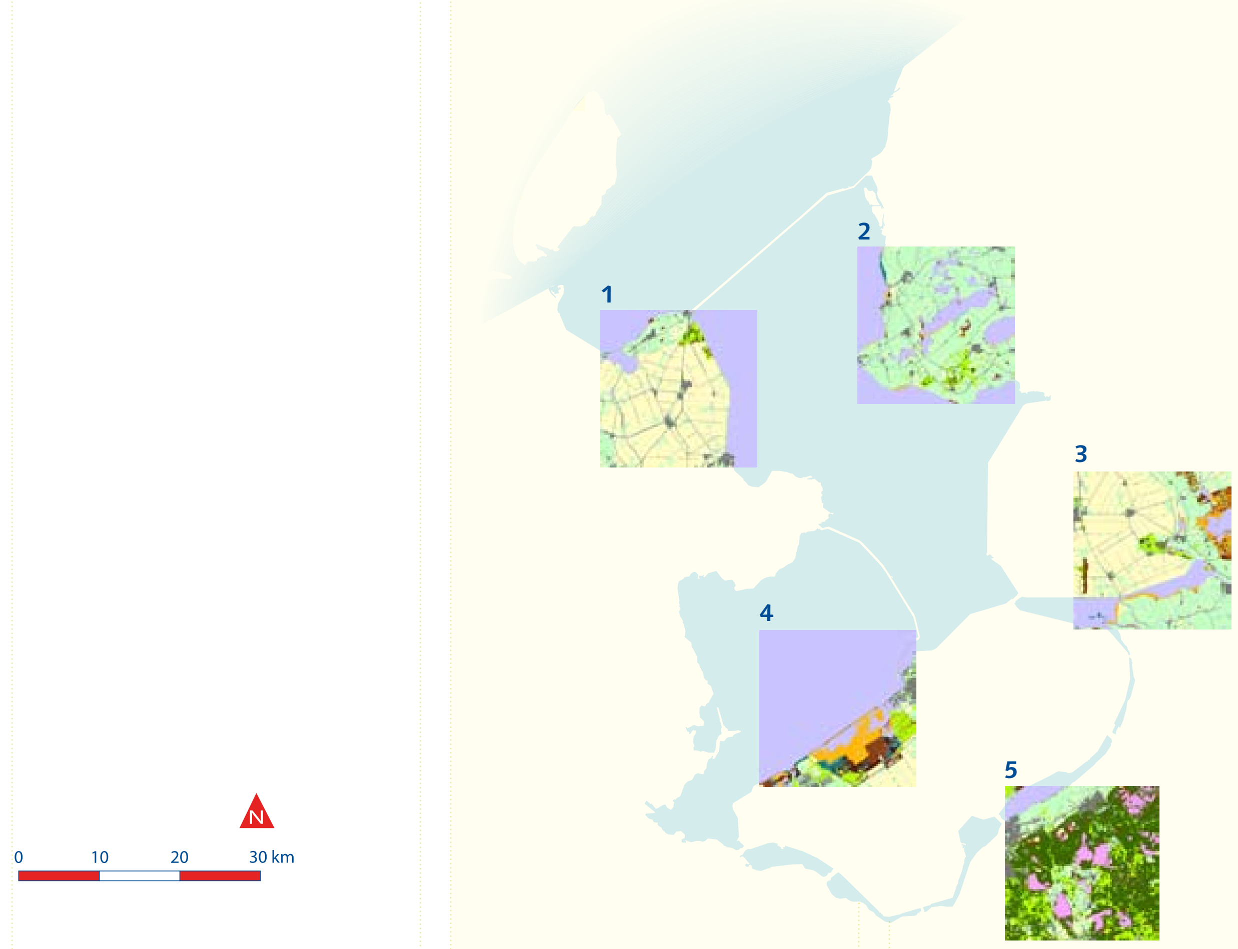




**Figure 2.** *Landscape units in the 7 selected areas of Peipsi in 1996 (terrestrial part was set to 100% of surface area)*



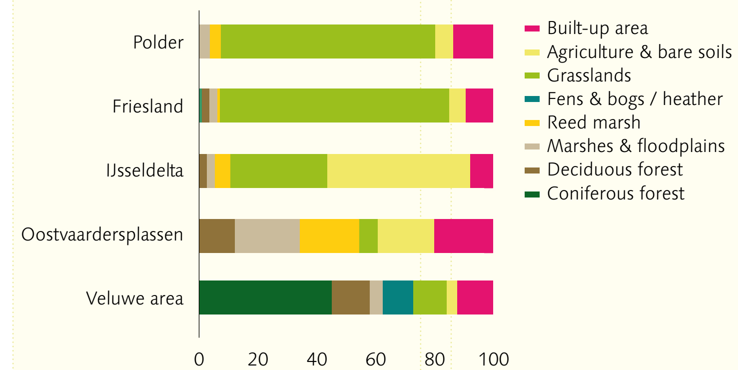




**Figure 3.** *Landscape units in the five selected areas of IJsselmeer in 2002.*

### Selected landscapes in both lake regions

Some specific areas were chosen in both lake regions to describe the patterns of vegetation cover in more detail, in relation to the connectivity of habitats and their importance for fauna elements (Figure 2 and 3).

### Lake Peipsi (7 areas selected, see figure 2)

#### Coastal zones in the north-west and north-east (1&2)

The landscape at the north-west coast of Lake Peipsi in Estonia is mainly characterised by forests and to a lesser extent by marshes and floodplain areas. Fens and bogs still occur but these are surrounded by agricultural activities. A surface area of 380 hectares is built-up.
The landscape at the north-east coast of Lake Peipsi in Russia is comparable to that in the north-west, but the forest cover is less dense. Instead, more grassland occurs. Much more land is used for agricultural purposes, close to cities such as Gdov; some 600 hectares are built-up areas. The most important crops are potatoes, winter wheat and rye.

#### The Emajõe-Suursoo fens and floodplains (3)

The Emajõgi River is visible on the true colour image as a blue meandering ribbon within a green floodplain with many small backwaters and oxbows. The lakes are partly covered by helophytes, consisting both of floating and of submerged vegetation. The vegetation association varies over short distances in some raised bog areas but in many cases vast plains of transitional bogs occur with little or no variation. The small lakes are attractive as fishing areas for Osprey and other species that need a large surface area for feeding as well as a save place for the nest.

The landscape is characterised by marshes and floodplains with Birch (*Betula* spp.) and Alder (*Alnus* spp.), some mixed forest (on the higher parts) and fens and bogs at some distance of the river. The shoreline is made up of organic soils and many young birch trees grow here. These trees cannot always withstand the strong winds and may fall over all along the shore, which leads to actively eroding stretches over a length of several kilometres. At the southern range of this very large complex, raised bogs occur with bog islands consisting of mineral soil. Here, mixed forests occur with a peculiarly high number of plant species, the trees being both deciduous and evergreens. These bog islands are winter homes for the Brown Bear, as appeared from the discovery of traces and several winter dens.

#### Coastal lagoon and lake spit area (4)

The eastern shore of Peipsi is indented by an interesting lagoon-like bay in the area of Raskopel. The bay is sheltered from the open water of the lake by an almost closed spit, consisting of sand. This structure was created by wind action and calls to mind the (much larger) lagoon coasts along the south coast of the Baltic. The sheltered bay has a sandy bottom and a vegetation of macrophytes. At the spit small dunes occur with vegetation patterns (a.o. *Juniperus*) caused by wind erosion and cyclic succession. South of Raskopel there is a shallow peninsula with sparse reed and sedge vegetation on the lee side and extensive beds of Pondweed *Potamogeton* further offshore. Inland the sands are covered by wooded heath land and Pine forests, which are mixed with Birch in the wetter parts.

#### Raised bogs and complex of floodplains and larger rivers (5)

The high mounds of the raised bogs of Pnevo are situated between various floodplains and surrounded by higher grounds, which consist of dunes and heath lands of shifting sand and are largely covered by lichens. Long gradients

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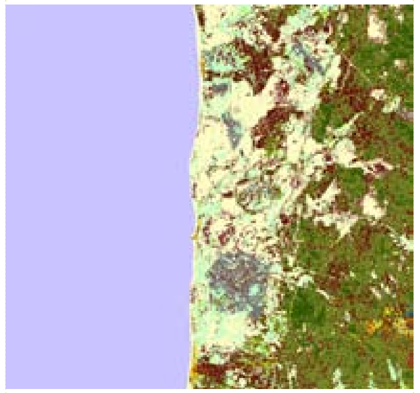

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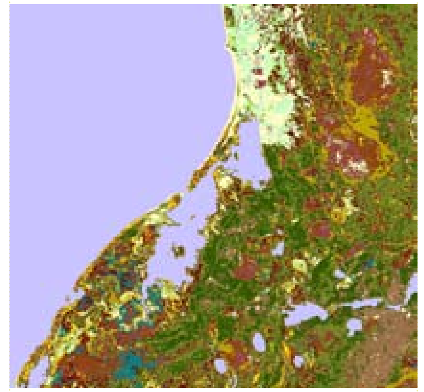
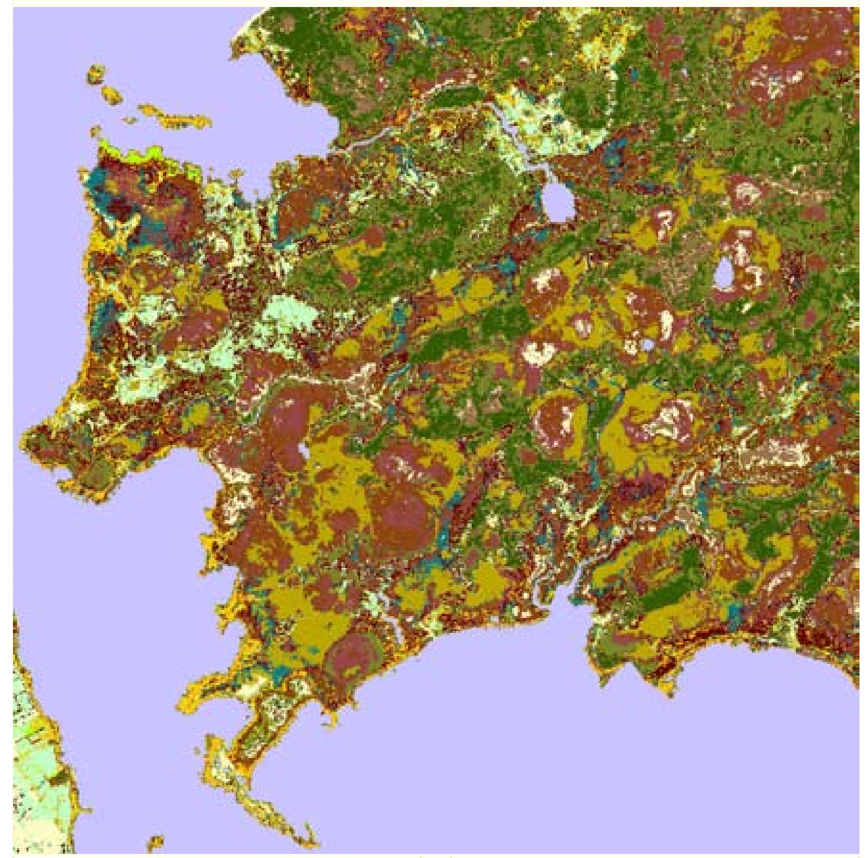






consisting of all stages of wetland types occur in the area, ranging from shallow waters, low fens with sedges, transitional fens and wooded raised bogs to open raised bogs. These big mires can be identified in false colour as large, irregular, rather circular light green spots, the largest containing a number of small peat lakes. They consist of a wealth of *Sphagnum* species ranging from the very wet light green *S. cuspidatum* to the hummocks covered by the reddish *S. magelanicum*. In this area a lot of species occur which are characteristic of oligotrophic and ombrotrophic conditions. Rare species like *Rhynchospora alba*, *Drosera intermedia* and *Oxycoccus palustris*, to mention a few. Only rainwater, poor in contaminants like sulphur and ammonium, enters these bogs.
The higher sands that run in between the bogs are covered with Pine forest, again at the edges consisting of Birch. Seepage causes de edges to be rather wet and this leads to the combination of reed growing in between Pine tree areas. The sandy wet forests consist of Alder and Birch, often with marsh vegetation ranging from eutrophic *Typha* and *Iris pseudacorus* stands to *Calla palustris* and *Menyanthes trifoliata* representing mesotrophic conditions. At the shore, wet eutrophic Alder forests occur. In some cases grazed areas occur where large boulders of the glacial deposits remain. The onshore reeds are coarse and tall and large patches of drifting vegetation occur (floating reeds, cut off by drift ice, wind-drifted peatland, woody debris etc), providing breeding habitat for colony breeders like Black Tern *Chlidonias niger*, Black-headed Gulls *Larus ridibundus* and Little Gulls *L. minutus*.
The larger rivers Zhelcha and Chernaya have extensive floodplains consisting of *Carex* meadows and swamps, edged by swamp forests. In spring, large areas become inundated as a result of melt water occurring farther upstream or because of raised water tables at the lake. This area is one of the largest examples of a landscape where the entire complex of lakes, fens and bogs is virtually intact on a very large scale. The area is home to Brown Bear, Wolf, Lynx and six species of eagles (see chapter 3.8).

5

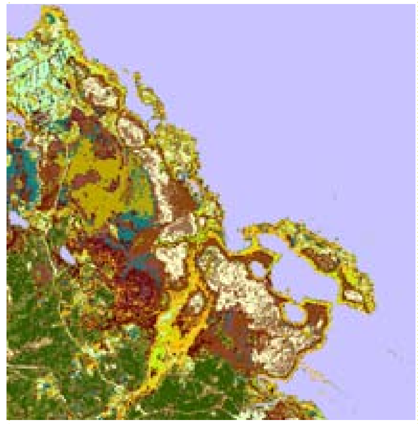


**The area of Pechorskiy Zakaznik (6)**

The region is characterised by an undulating relief of boulder clay and sandy ridges. In the depressions, low fens with sedges and grasses developed. Extensive agriculture and fishing are the main sources of income; the population density is very low in this region. The houses are very traditional and so are the roads. The way of farming is small-scale and only little mechanised. So, the negative impacts on soils and habitats are limited.

The reed zone can be more than 150 metres broad here and in front of this zone the *Schoenoplectus* stands can be found as circular clones or in the deeper water. The floodplains of the River Piusa form another very important landscape feature in this region with the large grasslands and *Carex* meadows with willows. This *Carex* meadow habitat is a famous home to the beaver. The beaver can easily dig its tunnels in the vegetation and can also build dams and homes in marshland without many trees. The floodplains are flooded almost every spring and act then as a nursery habitat for young fish. Especially, the Pikeperch uses these floodplains as spawning areas. In the mouth of the River Piusa floating and submerged vegetation is present, which attracts water birds like the Whooper and Bewick's Swan (see chapter 3.5).

6



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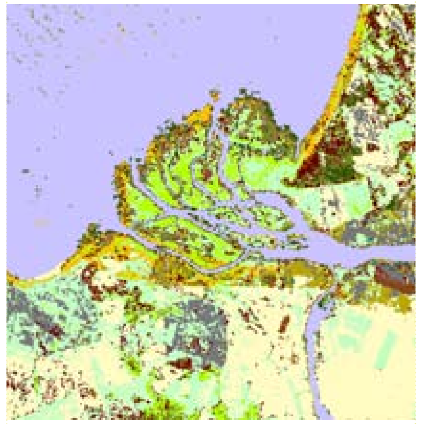

**The Velikaya Delta (7)**

This delta forms the most southern part in Lake Pihkva. Although the River Velikaya brings in a large freight of nutrients and even contaminants, the area is still natural from a vegetational point of view. The water is highly eutrophic and therefore only small patches of Water Soldier *Stratiotes aloides* are present in the more still backwaters. The delta consists of many small islands and some larger ones, where some willows grow on the edges. Most parts of the delta are not inhabited. Only little shipping-traffic is going on at the moment. This contributes to the significance of the area as, for example, a bird area.

Figure 4 shows the area as Ikonos image in greater detail.

The marked contrast between the natural delta, the city area of Pskov and the agricultural areas in this part of the lake is obvious. The classified picture as well as the false colour image show the effect of the filtering capacity of the delta. Very clear water flows out of the delta into the more turbid and/or algae-rich lake waters. However, in summer, blooms of filamentous blue green algae may develop extensively, as is visible, for example, in the image of August 1996 (see Figure 5, *Microcystis aeruginosa*).

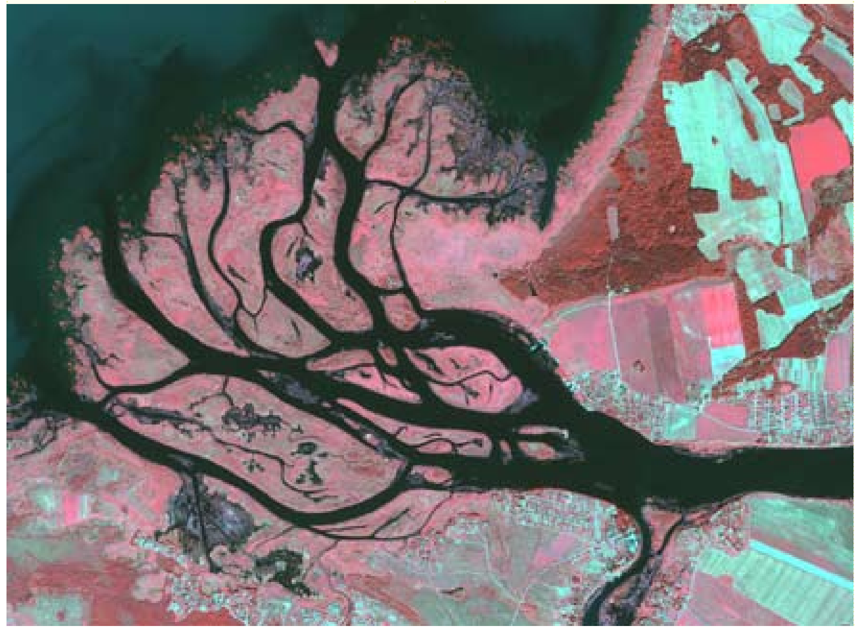

**Figure 4.** *Velikaya Delta in Lake Pihkva – part of IKONOS image of 11x11 km (from Sept. 7, 2005)*

**Figure 5.** *Algal bloom, August 1996*

The river islands are mainly covered by reed and brushwood vegetation consisting of Willow *Salix spp*. Rush vegetation (small tufts) occurs mainly at the outer edges of the delta and not so much in the riverine part.

The backwaters on the river islands are almost completely covered by aquatic plants, such as *Nuphar lutea*, *Nyphaea alba*, *Cladium mariscum*, *Potamogeton* species and others. In areas close to the main stream, a lot of filamentous green algae occur and water plants are heavily loaded by perifyton because of eutrophication.

**IJsselmeer (5 areas selected, see figure 3)**

**Shoreline and banks**

The length of the shoreline of the Lake IJsselmeer increased a lot after the large embankments took place starting in 1930. In the former Zuiderzee, the length of the shoreline was 383 km (and with islands 419 km). Even then, the banks were not completely natural by that time. Dikes were already built from 1000 AD on to protect the hinterland from flooding by the North Sea and Zuiderzee. Today the banks are formed for 55% by dikes and an increased shoreline length due to the reclamation of the big polders up to 774 km. A typical dike profile is quite steep and has a foot made of basalt stones. The older dikes were constructed of boulders of granite that initially came from the Pleistocene areas of Drenthe in The Netherlands. It is not easy or simply impossible for helophytes to grow here. The reed zones (if any) along the dike feet are quite small ranging from 1 to 5 m. The quality of the reed is generally moderate; quite slender stems in high density and an average height of ca. 2.5 m (see chapter 3.9).

Natural land-water transitions do occur along the so-called "buitendijkse gebieden" meaning forelands in the lake and not protected by the winter dikes along the Frisian coast and along the mainland coastline of the Border lakes. These shores are subject to wave action and certain water level differences because of wind effects. Some sediment deposition occurs at the onshore vegetation, mainly after storms from the West. The reed zones in these areas can be up to 25 metres wide and the quality of the reed is varying in relation to the wave dymanics, the coarsest stands occurring at the most dynamic places (see chapter 3.9).

Before the enclosure of the Lake IJsselmeer, some boulder clay cliffs also occurred in Gaasterland and close to Vollenhove. Due to the embankment and the construction of wooden piles in front of the cliffs, erosion could no longer continue. Nowadays, the cliffs are overgrown and therefore hard to distinguish.

Around 1900, the landscape in The Netherlands was so much more differentiated, consisting of grasslands, wet heath, fens, marshes and bare soils (shifting sands). Cover by forests was very low at that time, as were areas with infrastructure and built-up areas. In 1900, built-up areas covered just 920 hectares, whereas in 2002 this was more than 89,000 ha. The southwest region, in which the city of Amsterdam is situated, shows the highest value with 13,000 ha of paved area (that is almost 1/3 of the total sub-area).

Major changes took place in agriculture and therefore in the land used for agricultural production and grasslands. In 2002, these amounted to 141,000 ha and 218,000 ha respectively. Around 1900, there only were 244,000 ha of moist cultural grasslands for hay-making in a traditional, extensive way, which constituted a very suitable habitat for many meadow birds, insects and small mammals.

**The Wieringermeer Polder (1)**

The figure shows that the selected polder, Wieringermeer, contains a relatively large area of cultural grasslands compared to the other polders.

**The Frisian coast (2)**

The selected area in Friesland is covered for a large part (see Figure x) by grasslands and meadows. The relief is slightly undulating due to geomorphology; the higher mounds are formed of boulder clay, whereas the lower parts are sandy, clayey or even peaty. The coast along Lake IJsselmeer still has some hydrodynamics left and it is therefore still an important hotspot for flora and fauna. Facing the north-eastern shoreline some forelands occur, which were deposited by the tidal system in the former Zuiderzee. These forelands for a good part still have a natural shore zone where wind-driven dynamics occur, even though water levels are controlled. Along these shores, specific geomorphological elements like beach levees can be found (e.g. Makkumer Noordwaard). This phenomenon is favoured by the increase of the water level (seiches) at times of strong western winds, when brief but significant deviations from the managed water level occur.

**Nature areas of Wieden and Weerribben and IJssel delta (3)**

The low fen area of Wieden and Weerribben, designated as a Dutch national park, is situated north of the River IJssel delta. This is a region with a large variety of habitats. A gradient occurs from boulder clays and cover sand ridges with wooden hedges on higher levels down to the excavated peat areas. These former extraction areas were widened by storms and erosion of the peat shores. The lakes look similar to those of Lake Peipsi as far as vegetation is concerned, but of course the scale and the disturbance by man are different here. In high season, recreation pressure is considerable.
A special feature is the delta of the River IJssel, the northern branch of the River Rhine, which now has its apex in Lake Ketelmeer. The IJssel delta is almost completely dedicated to intensive agriculture, mainly dairy farms. The old farm buildings were built on small mounds to be protected from flooding. Recently, some artificial islands were built in the mouth of the River IJssel in order to create more diversity and to store the soil that was excavated to deepen the navigation route. Originally, however, this area bore a resemblance to the Velikaya delta in Lake Peipsi.
The man-made islands are protected against erosion in the west of the islands by boulder dams, but the eastern parts are open and U-shaped so that the water can fluctuate there. The development has just started and it will be years before the macrophyte zone equals the Peipsi situation. Although there is some concern about the effect of decreasing dynamics on the water-reed stands that occur here (Foppen & Deuzeman, 2007), this project already created an additional coastline which attracts enormous numbers of water birds.

**IJsselmeer Polders with Oostvaardersplassen (4)**

The polders are quite monotonous landscapes used for agriculture. Main crops are flower bulbs, potatoes and corn, but some parts are used for dairy faming and fruit farming as well. In some areas forests were planted. Little or no vegetation occurs in the water in front of the dikes. However, the dikes are in demand as spawning places for Smelt (*Osmerus eperlanus*, see chapter 3.3). Some areas in the polder are designated as nature areas. The largest, Oostvaardersplassen, is a legacy of the situation shortly after reclamation. It was the lowest area and thus an extremely wet and muddy place after the completion of the dikes in Southern Flevoland (see Box). Since then, the area has become a nature reserve of ca 6,000 hectares and home to many plant and animal species. Strong gradients of marsh vegetation occur because of the gentle slope of the former lake bottom.

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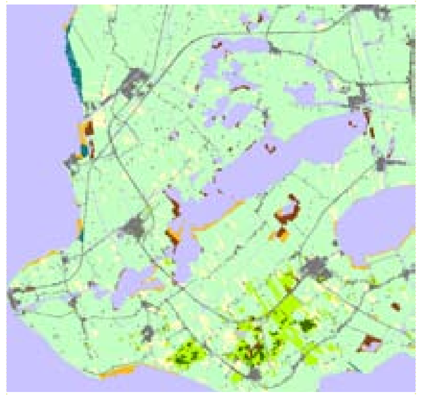

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The originally lower surface level of this wetland area now is elevated compared to the surrounding agricultural areas of Southern Flevoland. Intensive drainage of the agricultural fields led to considerable soil subsidence, much more so than was the case in the nature area, where the groundwater level remained higher. The nature area is characterised by large, extremely shallow (0-30 cm) water bodies with a natural shores and vegetation zonation. A lot of pioneer vegetation occurs on clayey soils (*Typha latifolia* and *T. angustifolia*, *Tephroseris palustris*, *Rorippa amphibia*) and strong wind effects result in regularly changing water tables. At the highest places during reclamation, natural Willow forests could develop. These are now home to breeding colonies of Cormorants and the trees serve as a post for large predators like White-tailed Eagle *Haliaeetus albicilla* and Osprey *Pandion haliaetus*.

5

**The Veluwe area (5)**

The Veluwe, a higher ground to the east of Lake IJsselmeer, is an ice-pushed area of ridges and sandy plateaus. The area is now partly covered with forests and heather dwarf shrubs (*Calluna, Erica*) interspersed with small fens. From their source in the higher parts of the Veluwe, brooks run into the Border lakes. These small brooks form a very special ecosystem and an important corridor for fish, amphibians and insects. But in the lower areas, these brooks were negatively affected by man, mainly to serve intensive farming practices. The small meandering streams were straightened and deepened, so that agricultural activities could take place right up to the edge of a stream. Almost no buffer zone was left for the growth of helophytes and the catch of nutrients, while flooding never happens any more.
The Eem valley is a flat area with meadows and quite some agricultural dairy production. Few farms were actually built in this area so that the landscape is still rather open. However, intensive agriculture led to an enormous effect of eutrophication in the Borderlake Eemmeer. Recently, plans are being made for creating a marsh vegetation zone at the mouth of the River Eem in order to reduce the input of nutrients and to fix the silt particles.

## Eagles at Lake Peipsi

*Vladimir Borisov, Leho Luigujõe, Andres Kuresoo & Mennobart van Eerden*

In the region of Lake Peipsi in total 6 species of breeding eagles occur. In relation to landscape characteristics the data of distribution show the importance of the absence of disturbances in combination with large-scale gradients in biotopes. Habitats span the full range from oligotrophic to eutrophic conditions, from wet to dry and from large scale open to small-scale mosaic.

Large predators at the top of the food chain reflect the underlying structure of ecological relationships. Often they are considered flagship species, their presence showing the healthy state of the environment (Bijleveld 1974). Larger eagles are relatively scarce in Europe and confined to areas with a certain amount of "wilderness". This habitat component is one aspect of their occurrence probably due to lack of disturbance by man. The other aspect is the signalling value they have because of their vulnerability to contaminants in the food chain. In the 1960s large numbers of eagles died in western Europe due to the use of pesticides such as DDT, Aldrin, Dieldrin and lateron PACs (Van Dijk *et al.* 1982). After the ban on DDT (e.g. in 1973 in The Netherlands) the populations recovered. By that time, however, the larger eagles were faced with another problem, the deterioration of the landscape they live in. Intensive drainage led to the lowering of groundwater tables, the improvement of agriculture caused the decline of smaller mammals and the increase of the human population led to more infrastructure and disturbance in the rural areas. Large predators are nowadays confined to forested areas, mostly mountainous, which provide a buffer against disturbance of any kind by humans. In lowland areas the role of man is physically more prominent and therefore the large predatory species are present in limited numbers only.

***Peipsi as eagle habitat***

The areas around Lake Peipsi still contain the complete array of biotopes belonging to the original landscape types. Only the absence of primary forest is different from the natural situation. Primary forests being absent, the presence of undisturbed woodlots at the so called "bog islands", i.e. sandy outcrops in extensive raised bogs, still constitutes an important biotope. These bog islands comprise a mixed set of tree and bush species, both deciduous and evergreens. Among the deciduous species rare species occur such as Oak *Quercus robur*, Ash *Acer* pseudoplatanum and Lime *Tilia cordata*.

***Species account***

Six species of eagles are regularly breeding in the area, two of which are rare: Short-toed Eagle *Circaetus gallicus*, a specialist on reptiles and Spotted Eagle *Aquila clanga*, confined to productive wetlands. These two species are at the edge of their European distribution, Short-toed having a more southern distribution and Spotted Eagles being mainly confined to the taiga belt in Russia. Osprey *Pandion haliaetus*, as a fish specialist, is related to smaller lakes, rivers and the coastal area of Peipsi. Of the more common species, Lesser Spotted Eagles *Aquila pomarina* frequent the edges of wetlands, the patchy, extensively used agricultural landscape consisting of a mosaic of grazed pastures, hayfields and arable lands. White-tailed Eagle *Haliaeetus albicilla* is one of the most prominent birds of prey to be encountered. It breeds widely spread around the lake and, unlike the other species, most individuals stay in the area all year.

***Osprey*** *Pandion haliaetus*

Osprey is a regular breeder around Lake Peipsi and Lake Võrtsjärv. Both on the Estonian and Russian side breeding couples have occupied nests for many decades. Osprey feeds on fish, which they catch mostly within 10 km from the nest. The distribution of the species is therefore associated with the boundaries of the large lakes, but also smaller interior lakes and fens and open floodplains with larger rivers. Most Osprey return late April, early May and leave soon after breeding in July-August. Osprey breeds in forests, most often in edge situations and frequently in isolated trees in bogs. The species is, less dependent on extensive bog complexes, probably because it feeds outside the bog, unlike the Golden Eagle, which depends on terrestrial prey and therefore needs large surface areas. Osprey were seen taking Roach *Rutilus rutilus* and Bream *Abramis* brama during spawning season in Lake Peipsi, and also Perch *Perca fluviatilis* in isolated lakes. The total population amounts to 35 to 40 pairs centred in the following areas: in the north Puhatu Bog (8-10 p.), in the west Emajõe Suursoo (4 p.), Meenikunno Bog (1-2 p.) Meelva Bog (1p.Kuus & Kalamees 2003), and Lisja bog complex (3 p.), in the east Remdovskiy Zakaznik (8-10 p.) and Raskopel complex (3 p.). Also along the floodplain area of Emajõgi River the species breeds further inland, at Lake Võrtsjärv (1 p) and Alam Pedja (1 p.,Kuus & Kalamees 2003).

***White-tailed Eagle*** *Haliaeetus albicilla*

One of the commonest of the large avian predators, the White-tailed Eagle, is present in the area around the year. In summer the large nests are occupied by breeding couples, while young of the previous year and immatures up to four years old can be seen as well. The non-breeders are often the most conspicuous and are assembled sometimes in small flocks sitting on islands, on big boulders along the lake, in dead trees etc. From the air alone during the May 2005 survey, 39 eagles were seen, 27 in Estonia and 12 in Russia Breeding White-tailed Eagles occupy large nests which they preferably build in old Pine trees *Pinus sylvestris*, sometimes also in broad-leaved trees like tall Oak *Quercus robur* and Poplar *Populus tremula*. The total population in the region of Peipsi consists of about 33 to 42 pairs, which, together with the immature birds, amounts to some 100 to 130 individuals. They occur in the north in Agusalu (1p.), in coastal Peipsi in the NW (3 p.), in the west in Emajõe Suursoo (8-10 p.), , in the east in Remdovskij Zakaznik (10-15 p.), Podborovye and Raskopel coasts (3 p.). In the flood plain area of Emajõgi River White-tailed Eagles breed around Lake Võrtsjärv (2 p.) and in Alam Pedja (4-5p., Kuus & Kalamees 2003). The west coast of Lake Pihkva and the area north of Raskopel has fewer eagles, possibly due to higher density of human population. In winter White-tailed Eagles concentrate at the ice of Lake Peipsi. Especially in areas which are not completely frozen over, the eagles try to catch fish. Also, they were seen scavenging fish from fishermen, who fish under the ice by making holes. Most often such specialists concentrate on Lake Lämmijärv.

***Golden Eagle*** *Aquila chrysaetos*

This large eagle is confined to large raised bog areas, both on the Estonian and the Russian side. It breeds in woodlots at bog islands but only in extensive raised bog areas. These areas are difficult to walk in so minimal disturbance occurs. Nests are built in Pine trees (*Pinus sylvestris*), especially old specimens with an open, flattened crown. Also Fir (*Picea abies*) and Oak (*Quercus robur*) may be used. Golden Eagles hunt locally on Willow Grouse *Lagopus lagopus*, Black Grouse *Lyrurus tetrix* and in some bogs possibly on waders (Muraka, Remdovskiy Zakaznik). Another boreal element present at the bogs is Blue Hare *Lepus timidus*, the young of which are also a likely target as prey. The importance of other food sources is barely known, but probably carrion will be important as well. Sometimes Golden Eagles wander at the forest edges and enter the extensively used agricultural fields. Here, young Badger *Melis melis* and Fox *Vulpes vulpes* are possible prey (Glutz von Blotzheim *et al.* 1971). Golden Eagles constitute a great natural value and indicate the presence of large-scale intact landscapes with a low level of disturbance. Some of the adults tend to winter in the area, showing a larger distribution at that time. In Peipsi the total population is estimated at 13 to 18 pairs, centrepoints being the complexes of Emajõe Suursoo (1 p.) to the west, Muraka (1-2 p.), Puhatu-Poruni and Agusalu to the north (2-3 p. Kuus & Kalamees 2003), the bogs on both sides of Piusa River near Budovich and Lisja in the SW (2 p.) and Remdovskiy Zakaznik and surroundings (4-6 p.). Some of the remote bog areas east of Gdov may also be home to this species but data are missing at present.

***Osprey*** *Pandion haliaetus*

***White-tailed Eagle*** *Haliaeetus albicilla*

***Golden Eagle*** *Aquila chrysaetos*

***Lesser Spotted** Eagle Aquila pomarina*
This species is a prominent bird of the patchy landscape consisting of riverine forests, floodplain areas, extensively managed hayfields, wet meadowland and small scaled arable lots (see Lõhmus & Väli 2001, 2005, Väli *et al.* 2004a). It frequents edge situations often perching on a tree or hovering over likely foraging areas.
It was observed preying on small mammals such as Water Vole *Arvicola terrestris* (2x) and Mole *Talpa europaea* (1x), whereas Common Vole *Microtes arvalis* and Field Vole *Microtes agrestis* are known to be important prey from literature (Glutz von Blotzheim *et al.* 1971). Regularly it was observed that Lesser Spotted Eagles take frogs (Common Frog *Rana temporaria*) in floodplain areas.
Lesser Spotted Eagle is a migratory species. The main departure is in late August, early September and returning birds are present again in late April, early May. The population in the region of Peipsi is estimated roughly at 60 to 75 pairs. Strongholds are the forests around Emajõe Suursoo (15-20 pairs), Alam Pedja (12-15 p.), Remdovskij Zakaznik (12-15 p.) and the Zhelcha River flood plain between Yamm and Podborovye (8-10 p.). Especially on the Russian side the species is probably more widely distributed, also outside the protected areas along the upstream parts of Chernaya River, Tolba River, Plyussa River and the region east of Torokhovo upstream of Kuna River.

***Spotted Eagle** Aquila clanga*
Being the larger of the two smaller Aquila eagles, this species is often mistaken for the more common, Lesser Spotted Eagle (Väli *et al.* 2005). A problem with identification is the fact that interbreeding with pomarina occurs at the western part of the range (Väli *et al.* 2004b, 2005) . During our project we observed one pure pair at a nesting locality only once, in Remdovskij Zakaznik. A probable hybrid was seen in Emajõe Suursoo (MRE) and was also described at Alam Pedja (Kuus & Kalamees 2003). Spotted Eagles forage in wetlands more frequently than Lesser Spotted do. They may hunt extensively on Water Vole Arvicola terrestris, dabbling ducks and Coot Fulica atra. On bogs also grouse constitute important prey (cf Väli *et al.* 2008).
The total population in the region is provisionally estimated at 5 to 10 pairs, according to Kuus (2003) and personal observations but this is one of the most difficult species to assess. Spotted Eagle concentrates in the largest wetland complexes: Emajõe Suursoo (1-2 p.) Alam Pedja (2-4 p., Kuus & Kalamees 2003) and on the Russian side in Remdovskij Zakaznik (2-4 p.).
No data exist about dates of arrival and departure. Most likely arrival will be in the second half of April. As the species is less peaked during autumn migration, individuals may tend to hang around till late autumn, later than pomarina, depending on weather conditions and food availability.

***Short-toed Eagle** Circaetus gallicus*
This raptor species is the other highlight of the area. Being specialised in reptile prey, the Short-toed Eagle arrives rather late in the season, not before the first decade of May. The birds already leave the area in the course of August to fly to their African winter quarters. Short-toed Eagle has its northernmost breeding in Estonia and adjacent latitudes in Russia. Therefore the species is extremely scarce. In some years only sub adults prospect the area, without making any breeding attempt. Such observations were described annually for Estonia (EOS archives). Short-toed Eagle feeds almost exclusively on snakes, the abundant Water Snake *Natrix natrix* being probably the most important prey. Whether the also abundant Viper Vipera berus is also taken in this region is not known. According to Glutz von Blotzheim *et al.* (1971), this species always comes far behind Natrix in areas where both reptiles are common. One breeding couple was assessed in 1999 between Remda and Rudnitsa in Remdovskij Zakaznik (MRE, VB). The floodplain area of Zhelcha River and tributaries, together with the adjacent raised bog areas constitute ideal foraging grounds for the species. The Estonian atlas project yielded another record of breeding in the NW part of Lake Peipsi in the area of Iisaku. The total population is tentatively estimated at 2 pairs. In some years when spring is late probably no breeding occurs at all.

***Peipsi eagles in Dutch perspective***
The observations and description of the pattern of distribution show the importance of large-scale areas, rich in gradients with a low level of disturbance. Outside of mountainous areas it is rare to find six species of eagles breeding in Europe. As such it is a clear indication of habitat completeness and corroborates the findings of chapter 3.2.2. In The Netherlands eagles are only present as non-breeders during migration. White-tailed Eagle is the only one with annual observation on up to ten localities, comprising 5 to 10 individuals, mostly immatures. The Oostvaardersplassen along the coast of Lake Markermeer is one of those areas where this species occurs annually. Since the embankment of the polder in 1968, 1-4 individual birds have been observed each year (Van Rijn *et al.* in prep.). Apparently the area has the strongest appeal to the species, although observations were also recorded in the region of the Borderlakes, the mouth of the River IJsel, the Frisian coast and the Wieden in Overijssel. After summering of a couple in 2004 and 2005, the first breeding attempt of White-tailed Eagle since recording began took place in 2006. The pair in Oostvaardersplassen, a strictly protected nature reserve of ca 6000 ha (see box), successfully raised a young in 2006 and again in 2007 (Bijlsma & De Rooder 2007). From these observations it is clear that landscape quality, combined with abundant food and little disturbance, are prime factors for the presence of these birds. For IJsselmeer this leads to a strong plea for the establishment of large-scale marshes, which possess the qualities outlined above. Besides White-tailed Eagle, also Osprey and, if climate continues to warm, Short-toed Eagle may profit from these developments.

***Lesser Spotted Eagle** Aquila pomarina*

***Spotted Eagle** Aquila clanga*

# 3.7 Bird banding and observations on daily migration at the territory of Pskov region (1959 - 2006)

Vladimir Borisov, Larissa S. Shcheblykina &
Liudmilla P. Uryadova

Massive bird concentrations occur at the eastern shores of Lake Peipsi in autumn. During more than 50 years, annual counts of visible migration have been performed. Catching and banding of migrants revealed additional information about population structure and migratory routes.
Great changes were recorded in the number of migrants, especially in the number of forest dwelling songbirds, which declined dramatically. On the other hand some species of water birds tend to increase, especially herbivorous geese and swans but also Jackdaw, all species which rely in winter on agricultural habitat to a large extent.

Bird banding work in Pskov region started in 1959 by teachers and students of Pskov State Pedagogical Institute (PSPI). Especially during autumn migration, large concentrations of birds occur on the eastern shores of Lake Peipsi. Counting, catching and ringing of birds reveals data on migratory routes and wintering places, both of local and migratory populations. Details about duration of migration and the choice of resting and feeding areas contribute to the preservation of species. Catching leads to identification of gender and age structure of migratory birds and provides extra information about the occurrence of rare species in the migratory flow. Bird captures are especially valuable in comparison with visual observations at observation points and at permanent routes. The eastern coast of Lake Peipsi was chosen, being the place of massive concentration of migratory flow. The most convenient location proved to be a sandy cape, covered by low bush jutting out to the west into Lake Lämmijärv/Teploye in the vicinity of Pnevo village (Gdov rayon). Birds have been marked using standard aluminium rings, which were obtained from the Bird Banding Centre in Moscow. Figure 1 shows the general movement of migratory birds.

Annually during autumn (September-October), migratory birds arriving at our area from the northern and north-eastern part of European Russia are banded. In the beginning of the 1960s this work was done near the village of Mtezh (Pskov rayon) at the northern coast of Lake Pihkva. Later on, it took place near the village of Pnevo (Gdov rayon) along the east coast of Lake Lämmijärv, the territory where currently the State zoological zakaznik and the Ramsar wetland site “Chudskoye/Pskovskoye Lakeside Lowland” are located. Additionally during some years, songbirds (Passeriformes) were banded as well during winter in the green areas surrounding Pskov city.
In spring-summer (May-July), nestlings were banded at the following observation stations: Yelizarovo (summer biological station of PSPI), some years in the Yamm settlement near Gdov, in the Alol settlement near Pustoshka and near the town Pechory, all with the help of students practicing field ornithology. Since 1990 the work has been done from the village of Pnevo (Gdov rayon), which is currently a biological station of PSPI.

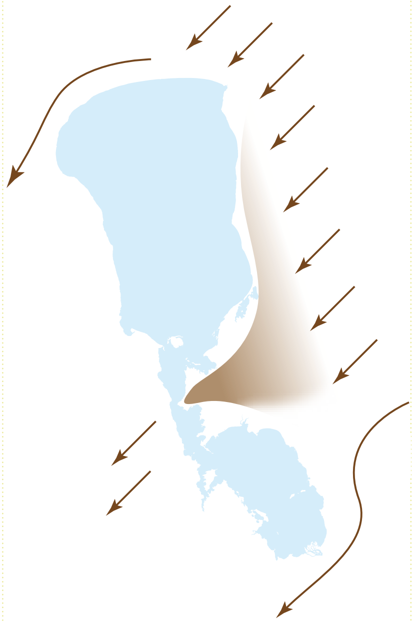


**Figure 1** *Schematised pattern of movement of migratory birds in autumn in relation to topography of Lake Peipsi.*

**Banding of migrants**

During 48 years some 33,000 individual birds were banded. They belonged to 99 families and 12 orders (Galliformes, Columbiformes, Charadriiformes, Anseriformes, Falconiformes, Strigiformes, Cuculiformes, Caprimulgiformes, Coraciiformes, Piciformes, Apodiformes, Passeriformes) out of the 18 orders registered in the territory of the Pskov region.
The largest number of birds was banded during autumn, along with standardised observations at the eastern coast of Lake Peipsi. Up to the 1990s, birds were caught with a large cotton net trap of the so called Rybachinsky or Helgoland type (Dolnik, Paevsky, 1976; Uryadova, 1976). The length of that trap is 80m, the height at entrance 12 m and the width 30 m. As the trap descends, the mesh size gets smaller. The trap is placed in an open area and oriented towards the birds’ flying direction. In the first corridors of the trap there always are some low bushes, which serve to attract birds and to guide them deeper into the funnel. As the bush was growing, the trap was moved to a more suitable place several times. Recently it became impossible to use traps of such a type, due to overgrowing of such open areas. Therefore we started to use mist nets instead. In Table 1 some general information about the distribution of banded birds by orders is listed, as well as a percentage of the trapped birds by orders to their total number.

**Table 1.** *Distribution of banded birds by orders (1959-2006)*

| Order | Number of individuals | % |
|---|---|---|
| Passeriformes, songbirds | 31,972 | 98.230 |
| Piciformes, woodpeckers | 359 | 1.103 |
| Strigiformes, owls | 65 | 0.200 |
| Charadriiformes, waders | 50 | 0.154 |
| Columbiformes, pigeons | 24 | 0.072 |
| Falconiformes, birds of prey | 18 | 0.055 |
| Galliformes, fowl | 17 | 0.052 |
| Anseriformes, water birds | 16 | 0.049 |
| Caprimulgiformes, nightjars | 14 | 0.043 |
| Coraciiformes, rollers | 7 | 0.021 |
| Cuculiformes, cuckoos | 5 | 0.015 |
| Apodiformes, swifts | 1 | 0.003 |
| Total | 32,548 | 100.00 |

The largest number of banded birds belong to the order of Passeriformes, songbirds. First of all this reflects their proportion in the natural biocoenosis, and secondly it relates to the construction of this type of traps, which ensures capturing this group. In some years there were invasions of special groups like woodpeckers (Piciformes) and owls (Strigiformes) (Meshkov & Uryadova, 1972), although their overall proportion is only one percent. Other orders are represented only occasionally.

**Species accounts**

Most commonly present were Siskin *Carduelis spinus* (5,913 individuals, corresponding to 21.9 % of the total number of trapped birds), Great Tit *Parus major* (3,034 birds, 11.1%) and Finch *Fringilla coelebs* (2,881 birds, 10.5 %).

The proportion of other species of that order: Blue Tit *Parus caeruleus*, Willow Tit *Parus montanus*, Coal Tit *Parus ater*, Firecrest *Regulus regulus*, Brambling *Fringilla montifringilla*, Bullfinch *Pyrrhula pyrrhula*, Starling *Sturnus vulgaris*, Long-tailed Tit *Aegithalos caudatus*, Pied Flycatcher *Muscicapa hypoleuca*, Fieldfare *Turdus pilaris* and Songthrush *Turdus iliacus* is near one percent.
For other species that index does not exceed one percent.
Siskin and Great Tit were exceptionally abundant during autumn invasions in some years (Uryadova, Shcheblykina, 1995). This and their habit of migrating in flocks explains the first position of these species among the trapped birds. Finch form the bulk of the migratory flow in almost every year (Meshkov, 1960; Meshkov & Uryadova, 1967; Uryadova & Shcheblykina, 1995), which explains its third rank among the birds captured. Different species of tits and Goldcrest *Regulus regulus* can also be remarkable for invasions and in such years during autumn migration their number among the trapped birds is high as well (Meshkov *et al.*, 1976). Individuals of Starling, Pied Flycatcher as well as thrush species were mostly banded as nestlings in their nests. *Turdus sp*. and Pied Flycatcher were attracted to nest in forest areas by means of nestling boxes and log houses.

The number of banded birds varied greatly over the years, from several hundreds to several thousands of birds. Most favourable for banding were the following years: 1969 (2,197 birds banded), 1966 (3,595) and especially 1975 (4,691). Precisely in these years we recorded a peak of ring returns. The largest number of returns was recorded for families of Passeriformes: finches, tits, starlings and thrushes. This can be explained by their high numbers in north-west Russia which has vast areas of suitable breeding habitat.

Banding of birds showed that small Passeriform birds passing over the observation stations along Lake Peipsi winter to the SW in Germany, France, the Czech Republic, Poland, Italy, Turkey, Belgium, Spain, England and Austria. Local breeding populations move mainly to France, Germany and Italy. Our data confirm the general findings from bird banding data at Kurshskaya spit in the region of Kaliningrad (Paevsky, 1971).

We also have returns of rings of birds which were trapped at other stations. During the period between 1959 and 2001 we received 337 ring returns for 52 bird species of different orders (Table 2).

Returns of rings of Passeriformes are dominating, corresponding to their rank among the birds ringed (see Table 1). Although not so numerous in absolute terms, the return rate of waterbirds, waders, birds of prey, pigeons and fowl, expressed as a percentage of the number of ringed birds, is much higher (5-25%) than in the group of song birds (1%).

*Bullfinch and Redpoll*



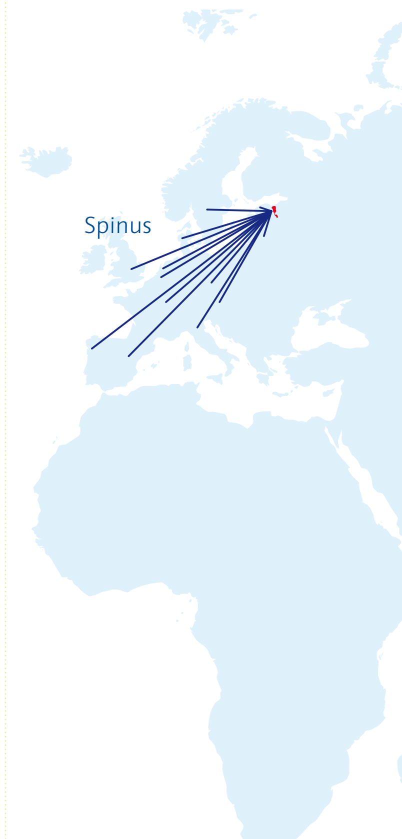



**Figure 2.** *Recovery of Siskin (Spinus) and Starling (Sturnus) ringed in Pskov and Gdov rayon.*

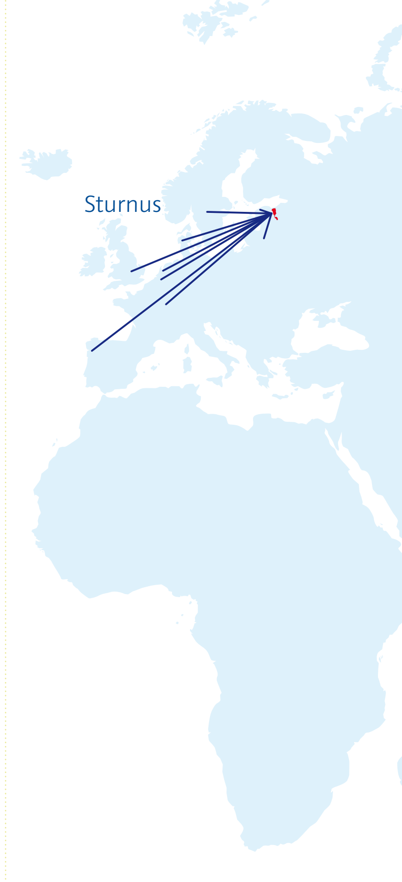



**Table 2.** *Distribution of recoveries of birds, trapped elsewhere, separate for different orders.*

| Order | Number of ring returns | % |
|---|---|---|
| Passeriformes, songbirds | 300 | 89.0 |
| Anseriformes, waterbirds | 20 | 6.0 |
| Charadriiformes, waders | 7 | 2.1 |
| Ciconiiformes, storks | 3 | 0.8 |
| Falconiformes, birds of prey | 3 | 0.8 |
| Strigiformes, owls | 2 | 0.6 |
| Galliformes, fowl | 1 | 0.3 |
| Columbiformes, pigeons | 1 | 0.3 |
| Total | 337 | 100.0 |

Environmental research in the territory of a natural protected area of any level of protection always foresees the study of rare and protected species of animals. That is why banding of such bird species is of great interest. During the period indicated, it was possible to band 13 rare or uncommon species: Ural Owl *Strix uralensis* (1), Hoopoe *Upupa epops* (4), Roller *Coracias garrulus* (3), Green Woodpecker *Picus viridis* (1), White-backed Woodpecker *Dendrocopos leucotos* (3), Bluethroat *Cyanosylvia svecica* (8), Little Flycatcher *Ficedula parva* (8), Nutcracker *Nucifraga caryocatactes* (6), Thrush Nightingale *Luscinia luscinia* (6), Hawfinch *Coccothraustes coccothraustes* (2), Rustic Bunting *Emberiza rustica* (2), Ortolan *Emberiza hortulana* (1), Greenish Warbler *Phylloscopus trochiloides* (1). We also had returns of rare species like Caspian Tern *Hydroprogne caspia* and Osprey *Pandion haliaetus*, which were banded at other stations in the territory of the Russian Federation and abroad.

### Visible migration

During daytime many migrants congregate in bushes and forests to continue their journey after sunset. In relation to wind direction, the visible passage may be extended over daytime hours, especially when headwinds cause the birds to fly low. Comparison between years reveals enormous fluctuations in total numbers observed. Figure 3 shows the annual sums per species for the most commonly observed birds. The pattern is illustrated by a short description of five forest dwelling species and six waterbird species (Figure 3):

**Chaffinch** *Fringilla coelebs*

Chaffinch is the most common migrant during autumn migration. Especially in the second half of the 1960s enormous numbers were counted, peaking in 1967 with a total of 4.26 million birds. Other top years were 1998 (4.72 million), 1968 (2.72 million), 1966 (2.39 million) and 1969 (1.88 million). Although 1998 ranks second over the total period, the general impression is that nowadays far less Chaffinches pass by during autumn migration. Still, numbers of 100,000 birds may be counted, which is considerable. In winter Chaffinch feeds at forest edges and bush lands where it takes mainly seeds, e.g. of Beech *Fagus sylvatica* and annual herbs.

**Siskin** *Carduelis spinus*

Siskin is the second most common migrant during autumn migration. This small seedeater, which can be seen in massive flocks in Alder (*Alnus glutinosa*) trees,

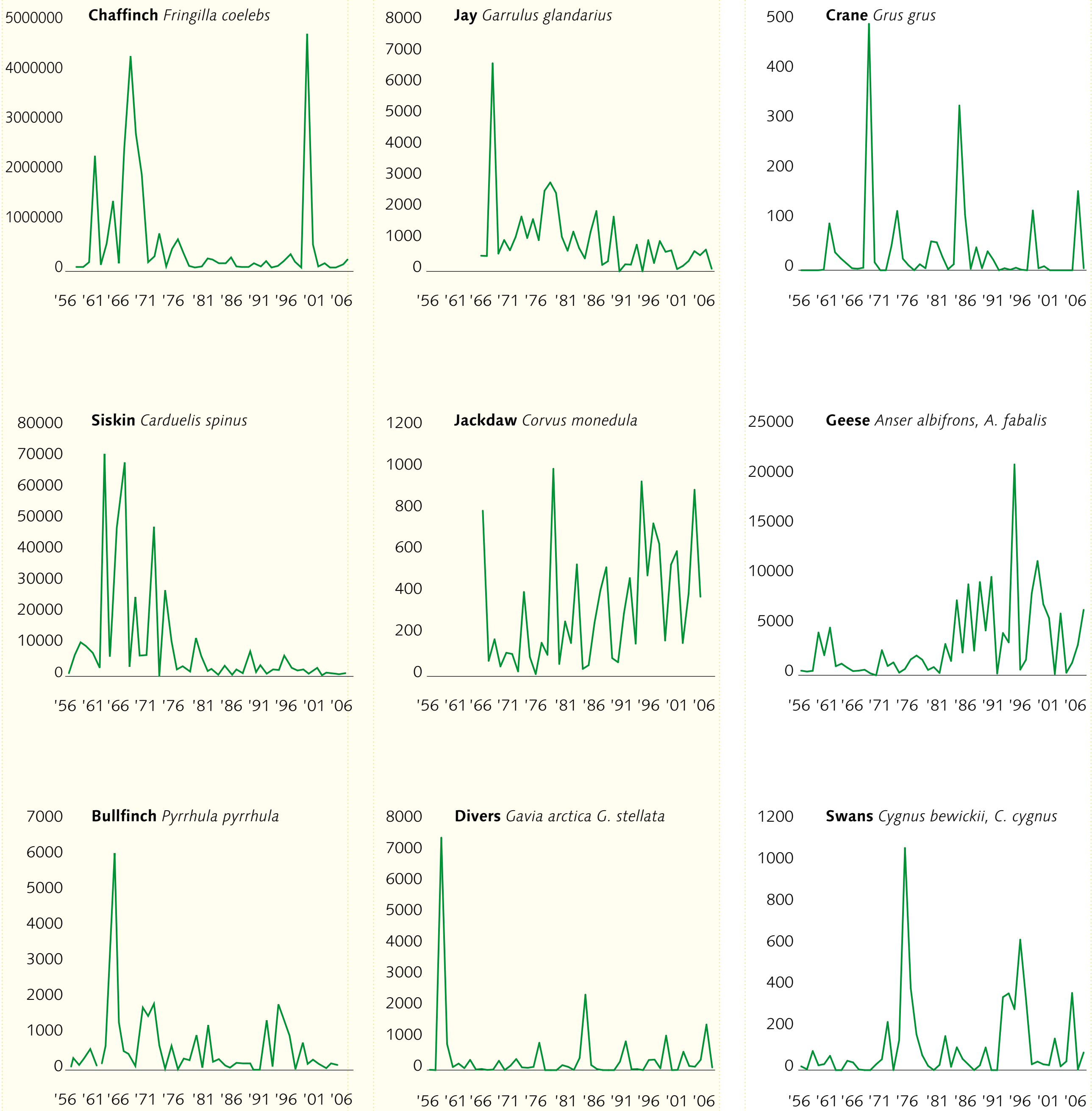



**Figure 3.** *Long-term patterns in total number of migrants during autumn migration (Sept-Oct), observed during systematic counts along the eastern shore of Lake Peipsi.*

shows a downward trend. Peak years all lay before 1976 and the top years are 1964 (69.6 thousand), 1967 (67.2 thousand), 1973 (46.8 thousand), 1966 (45.9 thousand) and 1975 (25.7 thousand). After 1980, annual totals comprise less than ten thousand birds. Siskin feeds in winter on seeds of trees (e.g. Alder) as well as on seeds of annual and perennial rough growth vegetation along forest edges.

**Bullfinch** *Pyrrhula pyrrhula*
In contrast to the previous species, Bullfinch migration shows no significant downward trend. Annual numbers fluctuate by a factor four, the highest totals recorded in 1966 (5900), 1975 (1750), 1995 (1700), 1972 (1600) and 1973 (1400). Bullfinch is a forest dwelling bird which relies on buds and berries for a large part of its winter diet.

**Jay** *Garrulus glandarius*
Jay numbers show a continuous decline over time. Especially after 1985, numbers observed are lower than before and numbers tend to fluctuate more. Jay is a forest inhabitant which in winter to a large extent relies on fruits of trees, e.g. acorns of Oak *Quercus robur* or Hazelnuts *Coryllus avellana*.

**Jackdaw** *Corvus monedula*
Jackdaw is one of the few passerine birds which are on the increase. From a mere 100 birds in the late 1950s, the annual total counted rose about tenfold. Jackdaw winters in agricultural habitat and this may have caused the upward trend. Jackdaw feeds on stubble fields and on meadows.

**Divers** *Gavia arctica, G. stellata*
Divers are large fish-eating waterbirds that winter in coastal habitat. In summer they breed on lakes, often in tundra and taiga habitat. Black-throated Diver *G. arctica* breed in small numbers in bog lakes and wetlands adjacent to Lake Peipsi. The majority of migrants passing to the west originates from a vast area further east. Most birds probably comprise *G. arctica*, as *G. stellata* follows a more coastal migration. Divers show an irregular pattern of passage but no clear overall trend. The best years were 1959 (7473), 1985 (2425), 2006 (1464), 1990 (1108) and 1992 (923).

**Crane** *Grus grus*
Cranes do not show up in large numbers during migration. In this region the species migrates mainly southward and may easily cross large water bodies, in turn causing no large congregations along the shores of Lake Peipsi. There is no clear trend in the highly fluctuating numbers observed, the largest totals being 1968 (495), 1984 (331), 2005 (159), 1997 (120) and 1973 (119).

**Geese** *Anser albifrons, A. fabalis*
Geese form a conspicuous part of the visible migration. Starting late September, migration continues for the greater part of October. In some years considerable migration also occurs in the second half of October and in November, after the period of systematic counts. Both species occur but the majority of migrants counted are White-fronted Goose *Anser albifrons*. The general trend is clearly upwards; especially after the mid 1980s high numbers were recorded. In the longer run an overall tenfold increase is visible, in recent years amounting to ca 10,000 birds counted. Wintering geese rely on fertilised grasslands, like for instance in The Netherlands.

**Swans** *Cygnus bewickii, C. cygnus*
Swans observed during autumn migration comprise two species, Bewick's Swan *Cygnus bewickii* and Whooper Swan *Cygnus Cygnus*. Both are breeding on tundra and taiga lakes respectively. They winter in wetlands and in western Europe they frequent agricultural habitats (sugar beet, potato and stubble fields besides grasslands). Although strongly fluctuating, swans, like the other water birds, show an upward trend in the long run. After 1997, however, this trend may be reversed (see also box text Bewick's Swans), due to the recent general decline in overall population size. Interestingly, swan numbers observed during migration show a correlation to the water table in the lake. The periods 1973-1977 and 1993-1997 both were characterised by lower than average water table, which corresponded to higher swan numbers than on average. This might be caused by local attraction to aquatic vegetation and subsequent movement within the area of Lake Peipsi, but also by swans arriving from other lakes in the region, e.g. Lake Ilmen near Novgorod.

## Bird migration affected by large water surface areas

*Mennobart van Eerden & Mervyn Roos*

Many birds migrate between summer breeding places and wintering areas. At the northern hemisphere and in Europe especially, the main direction is NE in spring and SW in autumn. There are, however, many exceptions, which depend on individual species, weather and landscape characteristics. Generally speaking, the land birds fly a broad front and concentrate along the seashores. The seabirds do the same but at sea, concentrating in near shore areas only at times of storm. In some places real bottlenecks occur, due to the peculiar shape of the landforms. The most famous of these are Falsterbo in south Sweden, Gibraltar in southern Spain and the Bosporus in Turkey.
At these places massive concentrations of birds pass by, originating from a vast hinterland. At a smaller scale large lakes may have an effect on migration routes as well. For a long time, birds have been counted near Pnevo, at the isthmus of lakes Peipsi and Pihkva. Along the Zuiderzee a lot of counts were taken at the southeastern shore near Harderwijk in the 1950s. The creation of polders and new dike connections altered the migration pathways.
The interest in bird migration routes is broader than just the scientific point of view. Bird migration routes play a role in discussions about planning routes for low flying aircraft, the establishment of windmill parks and construction of large bridges, tall buildings, high tension wires a.o.

### *Visible migration of birds in the area of the former Zuiderzee*

Along the coasts of the former Zuiderzee, in autumn most birds took the route along the eastern shore (Tinbergen 1941, 1962) and further SW. At the coast of the North Sea near Den Haag the largest congregations were recorded in the dune area (Van Dobben 1937). Between Harderwijk and Nunspeet the slightly curved coast also caused concentration effects, especially at SW winds (Figure 1). This route was particularly used by Starlings *Sturnus vulgaris*, finches, thrushes and pipits. Between Stavoren and Enkhuizen birds crossed the open area of the Zuiderzee, especially at easterly winds, both in spring and autumn. At that time, the Zuiderzee formed a vast inland sea, which was difficult to oversee, particularly at the southern and eastern part of the basin. When the Afsluitdijk was created birds could continue a SW heading in NW Friesland during autumn migration. Also in spring this new route was commonly taken during daytime, as it still is at present. Enkhuizen-Stavoren still is a passage that is taken during easterly winds in spring. The creation of the island Kreupel 5 km north of Andijk facilitated this crossing, because it is a visual landmark underway (since 2003). This route is taken by many geese and Wigeon Anas penelope, which find extensive feeding grounds in Friesland and Zeeland.

The reclamation of Noordoostpolder (NOP) in 1942, Oostelijk Flevoland (OF) in 1957 and Zuid Flevoland (ZF) in 1968 formed a major change in the position of the land-water borders in The Netherlands. The eastern part of the Zuiderzee basin became land and successively forests and fields arose where at first there only was open water. Instead of being guided by the coastline, many birds fly in broad front across the polders towards SW in autumn and NE in spring. Nowadays the eastern shore of Markermeer forms a leading edge and birds cross Lake Ketelmeer near Zwolse Hoek in OF where a bridge connects this polder with NOP. This point has been recently chosen as a counting post in order to record visible migration in a standardised way. (see http://www.ketelbrug.nl/). The visible migration is recorded by large numbers in many species, mainly consisting of finches, pipits, starlings and swallows, but also waterbirds and raptors. Again, E-NE winds cause the birds to fly lower in spring when considerable concentration may occur at this point. In autumn, moderate winds between SE and SW offer the best conditions to observe birds here. The western shores of NOP are further to the west than in Flevoland and together with the east-west directed Lake Ketelmeer this explains the concentration effect at the Ketelbrug. However, during some days the observers notice that birds refuse to fly across the bridge and instead migrate east along the northern shore of Lake Ketelmeer (see also Gallacher 1978). Table 1 lists the total number of birds observed during recent years. A lot of rare birds were spotted at this site recently (Table 2). Although the site is manned almost daily at times of favourable weather, the presence of rare species in the records is remarkable. Observed were:
Cattle Egret *Bubulcus ibis*,
Lesser White-fronted Goose *Anser erythropus*,
Pallid Harrier *Circus macrourus*,
Red-footed Falcon *Falco vespertinus*,
Marsh Sandpiper *Tringa stagnatilis*,
Gull-billed Tern *Gelochelidon nilotica*,
Bee-eater *Merops apiaster* and
Crested Lark *Galerida cristata*.

Compared to the Zuiderzee situation, the number of migrants that follow the coasts at the SE edge of the lake system has declined. However, the “Borderlake route” is still followed by a lot of waterbirds that migrate between the different water bodies and also a lot of passerines continue to fly this route. As was the case in Tinbergen’s time, finches, thrushes and pipits form the bulk of passerine migrants here.
A relatively narrow stretch of water that forms the Borderlakes continues to play a role in guiding the birds’ pathway, although numbers have greatly fallen compared to the times of the Zuiderzee. Nowadays, the presence of fully grown forests at the side of the polders facilitates the crossing of this water; birds can easily see the opposite shore and many times flocks of migrants are seen following the water rather than the land in this case. Raptors easily soar across the water at times of sufficient uplift.

*Ketelbrug*

**Figure 1** *Main routes of visible bird migration during spring (right) and autumn (left) before and after finalisation of land reclamation works in the Zuiderzee area.*

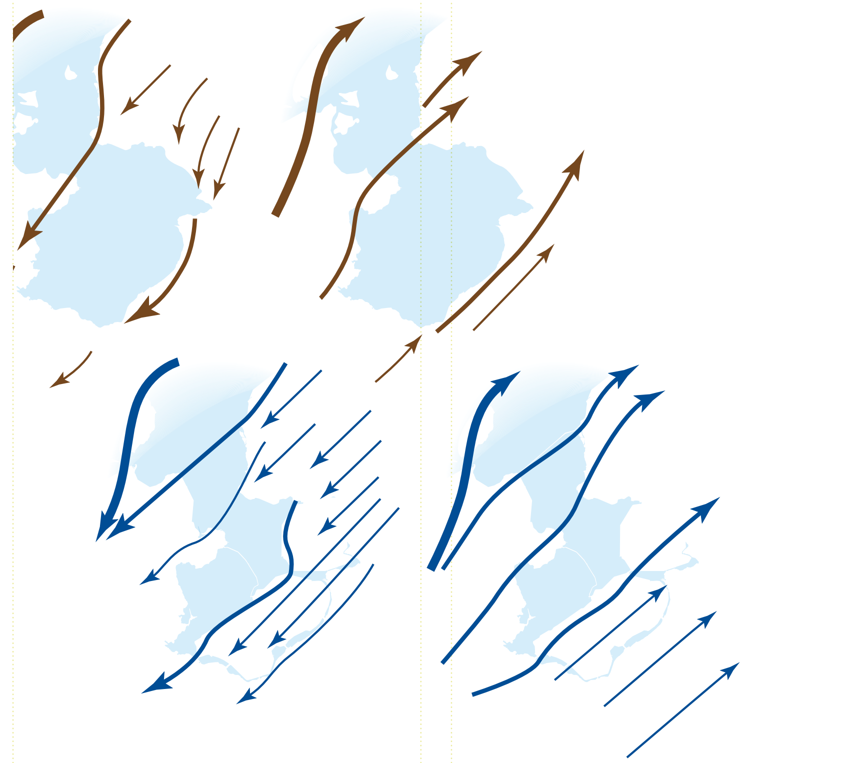


**Table 1** *Total number of migrants observed during counts at Ketelbrug; listed are total numbers per year for the 10 most abundant species during autumn (July-Nov) and spring migration (Feb-May)*

| Species | Latin name | Autumn | Spring | Year |
|---|---|---|---|---|
| Starling | *Sturnus vulgaris* | 417,682 | 57,080 | 2006 |
| Meadow Pipit | *Anthus pratensis* | 17,494 | 160,140 | 2005 |
| Chaffinch | *Fringilla coelebs* | 98,039 | 1,615 | 2005 |
| Lapwing | *Vanellus vanellus* | 54,459 | 8,588 | 2006 |
| Redwing | *Turdus iliacus* | 51,139 | 29 | 2005 |
| White-fronted Goose | *Anser albifrons* | 28,897 | 5,994 | 2005 |
| Black-headed Gull | *Larus ridibundus* | 16,474 | 17,329 | 2006 |
| Fieldfare | *Turdus pilaris* | 29,495 | 268 | 2005 |
| Barn Swallow | *Hirundo rustica* | 10,335 | 12,019 | 2006 |
| Skylark | *Alauda arvensis* | 19,811 | 1,969 | 2005 |

**Table 2** *Observations of rare birds during systematic counts at Ketelbrug*

| Species | Latin name | Date | Remarks |
|---|---|---|---|
| Black Stork | *Ciconia nigra* | 13 08 2006 | 6 in one flock |
| Long-legged Buzzard | *Buteo rufinus* | 29 09 2006 | juvenile, very few records for NL |
| Imperial Eagle | *Aquila heliaca* | 03 04 2005 | Immature, first record for NL |
| Lesser Kestrel | *Falco naumanni* | 04 05 2006 | Adult male |
| Great Snipe | *Gallinago media* | 31 08 2005 | 2, rarely seen during migration |
| White-winged Tern | *Chlidonias leucopterus* | 17 05 2007 | 172, incredibly huge number |
| Little Auk | *Alle alle* | 23 10 2005 | 62, extremely high number for inland |
| Red-rumped Swallow | *Hirundo daurica* | 29 11 2006 | 1, extremely late in the season as well |
| Fan-tailed Warbler | *Cisticola juncidis* | 11 10 2005 | 1, almost no records of migration except for the far south-west of the country where there is a small population |
| Two-barred Crossbill | *Loxia leucoptera* | 09 11 2005 | Female/juvenile, rarely seen during migration |

# 3.8 Floodplain and shoreline habitat for amphibians, reptiles and mammals: the role of landscape completeness and connections

Mennobart van Eerden, Luc Jans, Vladimir Borisov,
Andres Kuresoo and Leho Luigujõe

The way an area functions biologically relates to the underlying landscapes and habitat components. Comparing the occurrence of certain species may yield insight into the degree of habitat completeness. Especially if areas are compared at a large scale, conclusions can be drawn in this context. This chapter focuses on the distribution of three groups of animals which have a strong link to the quality of the landscape, i.e. on reptiles and amphibians and on mammals.

Amphibians are nearly all strongly related to water, at least during reproduction. Primary water quality, the absence of predators and the availability of sufficient food are important prerequisites which determine the occurrence of viable populations. In the case of reptiles, a strong link to water bodies is only present for some species such as Grass snake *Natrix natrix*. When focusing on these groups (see text boxes), it is clear that these species are very much related to the occurrence of microstructure elements in the landscape. They need specific habitats in different phases of their life span. As their home range is limited, they need to have those habitats close to each other and not separated by large barriers like roads, buildings, larger water bodies etc.. The presence of safe wintering areas which provide protection from frost and flooding is equally important, as are places to deposit the eggs, either in water (avoiding fish predators) or on land, for example in warm breeding heaps of decaying plant material. Also, the young need sheltered places to grow up in, with few predators and abundant food.

The most natural way is to preserve the habitat diversity set by environmental conditions and to allow natural processes to run their course. However, if significant degradation of the original array of biotopes has already occurred, specific management actions may restore such natural patterns and create appropriate habitats. This approach is especially effective if pressure from other functions is huge, as is the case in The Netherlands.

In the case of small mammals (mice, shrews, bats etc.), the microhabitat composition is also important. For these groups, winter and summer habitats may differ as well and some species (e.g. bats) may cover long migration routes between specific habitats. The larger mammals take up an exceptionally interesting position. Their home range requires a lot of space and the absence of disturbance is a more prominent requirement than for smaller species.

The fact that they were hunted for a long time (often down to extinction) contributes to this difference between larger and smaller species. Therefore, the occurrence of large mammals in the wild is an explicit sign of habitat completeness on the scale of entire landscapes.

### Amphibians and reptiles

In total, 18 species of amphibians and reptiles occur in the regions of both lakes, 16 of which are present in both regions (see Table 1). In IJsselmeer (and The Netherlands) two species are absent, Red-bellied toad *Bombina bombina* and Green toad *Bufo viridis*. Although uncommon or rare, Natterjack toad *Bufo calamita* and Smooth snake *Coronella austriaca* have larger populations in the areas around IJsselmeer than around Peipsi, which is related to the bio-geographical range these species occupy. The other 14 species are all (by far)

*Green Toad* *Bufo viridus*





**Table 1.** *Species of amphibians and reptiles occurring in the areas of IJsselmeer and Peipsi*

| Species | Latin name | IJsselmeer | Peipsi |
|---|---|---|---|
| **Warty newt** | *Triturus cristatus* | Locally at the Veluwe and Utrecht | Uncommon |
| **Smooth newt** | *Triturus vulgaris* | Common and widely distributed | Common and widely distributed |
| **Red-bellied toad** | *Bombina bombina* | Absent | Locally occurring, declining |
| **Common spadefoot** | *Pelobates fuscus* | Locally in the IJssel valley | Locally in the Velikaya valley |
| **Common toad** | *Bufo bufo* | Common and widely distributed | Common and widely distributed |
| **Natterjack toad** | *Bufo calamita* | Locally abundant in pioneer habitat | Rare, declining |
| **Green toad** | *Bufo viridis* | Absent | Locally occurring, declining |
| **Common frog** | *Rana temporaria* | Common and widely distributed | Common and widely distributed |
| **Moor frog** | *Rana arvalis* | Locally at the Veluwe, fens in SE Friesland and Overijssel | Common and widely distributed |
| **Lake frog** | *Rana ridibunda* | Locally common and widely distributed | Common and widely distributed |
| **Edible frog** | *Rana esculenta* | Common and widely distributed | Common and widely distributed |
| **Pool frog** | *Rana lessonae* | Locally abundant in pools | Locally abundant in pools |
| **Sand lizard** | *Lacerta agilis* | Locally at the Veluwe | Locally common at dune areas and heath land |
| **Viviparous lizard** | *Lacerta vivipara* | Common at Veluwe, Utrecht and Overijssel | Common and widely distributed |
| **Slow worm** | *Anguis fragilis* | Locally at the Veluwe | Common and widely distributed |
| **Grass snake** | *Natrix natrix* | Common and widely distributed | Common and widely distributed |
| **Smooth snake** | *Coronella austriaca* | Rare at the Veluwe | Locally in forests east of Pskov |
| **Adder** | *Vipera berus* | Locally at the Veluwe | Common and widely distributed |

more numerous in the area of Peipsi. Not only is local density higher, also the distribution over different habitats is wider than in the IJsselmeer region. For instance, in the Veluwe area Adder (*Vipera berus*) nowadays is confined to larger complexes of wet heath lands with scattered bush growth. In the area of Peipsi, Adders can be found over a wide range of habitats, from raised bogs to higher parts in fen areas and also along forest edges and in extensively cultivated agricultural areas. The same was true for the Dutch situation until the 1950s.

### Mammals

The Beaver *Castor fiber* is the largest rodent native to Europe, with adults weighing 18-20 kg, sometimes more. Wild Beavers occurred up to 1826 when the last Dutch specimen was killed in Zalk along the river IJssel. The Beaver has been reintroduced in The Netherlands since the year 1988 (Biesbosch and Gelderse Poort). The population of Beavers around Lake IJsselmeer is growing fast, starting from a series of escapes out of the semi-wild conditions in nature park Lelystad in the early 1990s. Already about 70 individuals have been recorded in the southern part of the IJsselmeer area, in and around Flevoland (2007). Up until now, the Beavers concentrate in the inland water bodies (canals, marshlands etc.). They are only occasionally recorded along the shorelines of the large lakes, probably because of a lack of marshes on the lakeside of the dikes. Considering the fast growing population of the Beavers, it is expected that within one or two decades the Beavers will have spread over all the suitable habitats around Lake IJsselmeer.

In the Peipsi area, the Beaver was also extinct and it was reintroduced as well, but earlier than in The Netherlands (± 1950). Nowadays the number of Beavers in the Peipsi area is enormous. Beavers really have a big impact on the vegetation structure on the banks, especially along the banks of rivers and brooks flowing into the lake. They may limit the growth of woody species and they locally influence the water level by making dams. Beavers are especially common in the areas of Emajõe Suursoo, Pechorskiy Zakaznik and Remdovskiy Zakaznik. The combination of small streams, vegetated lakes surrounded by wet forests and levees with a variety of deciduous trees constitutes an ideal habitat. Beaver burrows can be as dence as 53/200km$^2$ (Laanetu, 2001).

Muskrat *Ondatra zibethicus* is locally very common in The Netherlands. They are intensively controlled in most places because of the destructive impact they can have on the stability of dikes and banks. In 2006 we discovered a large population in the Oostvaardersplassen area (more than 1100 winter burrows in a density up to 1.3 burrow per ha marsh). The mammals create open spaces in the dense monotonous reed land of the Oostvaardersplassen, which results in suitable habitats for several bird species. In the marshes surrounding the Peipsi area, Muskrats are common. Unlike The Netherlands, no significant trapping occurs, although the species is huntable.

The Otter *Lutra lutra* has been reintroduced (since 2003) some 10 to 20 kilometres away from the large lakes of the IJsselmeer area. Due to the fragmented habitat and the number of barriers between their actual living habitat and the lakes, it will take considerable time to re-establish a sustainable population of Otters in the IJsselmeer area. Recently Otters were recorded in Zwartemeer and at the nature restoration area at the mouth of the river IJssel (2006, 2007). Large freshwater marshlands with abundant fish stocks form the main habitat of this species. Everywhere along the shores and marshes around Lake Peipsi, Otters are commonly present.

Large predators have been extinct in The Netherlands for a long time. Species like Lynx *Lynx lynx* (6th century), Brown Bear *Ursus arctos* (11th century), and Wolf *Canis lupus* (early 19th century) were always heavily persecuted, which eventually led to their disappearance. Although those species show some signs of recovery in Europe, it cannot be expected that they will return to The Netherlands on their own in the decades to come. These species still occur in the Lake Peipsi area, although density is generally low. They are clear indicators of the presence of a complete ecosystem and as such they have an enormous value. The large predators need to find enough food to survive, their habitats must not be too fragmented in order to guarantee genetic contact at meta population level and the level of disturbance by hunting pressure, recreation and built up areas needs to be low. The presence of large predators influences the behaviour and distribution of the other mammals. Species like Deer and Elk have to spread out more over the area and are 'controlled' in a natural way. As such, the large predators have a significant effect on the distribution of their prey animals, and thus they have an effect upon the development of the vegetation. Remdovskiy Zakaznik, Emajõe Suursoo and the forests north of Peipsi near and inside Muraka National Park are core areas for these species.

Associated to farms, large herbivore species like cattle and horses are widely present around the IJsselmeer area. Some species occur only in nature conservation areas and under fenced conditions, such as Red Deer *Cervus elaphus* in the Oostvaardersplassen and Wild Boar *Sus scrofa* on the Veluwe, whereas the smaller Roe Deer *Capreolus capreolus* also occurs as a wild animal in agricultural areas. Horses and cattle are re-introduced in nature conservation areas in order to create and maintain grasslands. By slowing down bush encroachment, these large herbivores create all kinds of open habitats suitable for other species (see Vulink, 2001 and references therein).
In Oostvaardersplassen, large herbivores have been introduced since 1982. Populations in the fenced area are now at maximum and there is a vivid

*Bear, Lynx and Elk are present in Peipsi*



discussion going on about the level to which numbers should grow and how the surplus of the population should be dealt with. The intensive grazing pressure in this nature reserve has led to the maintenance of the grassland areas and even to the extension of large open areas, which were previously covered by brushwood and rough herbs such as Reed *Phragmites australis*. For grazing geese, which prefer short swards, and for the hunting conditions of herons, bitterns, egrets, spoonbills and waders, this highly contributed to favourable circumstances. For bush-dwelling passerines, breeding raptors and other species which like patchy habitats with a lot of cover, the high grazing pressure is causing a decline in numbers.
Grazing intensity at common farmland is such that natural values associated with grassland are declining over the past decades. Meadow birds like Black-tailed Godwit *Limosa limosa* have seriously fallen in numbers, whereas species like Common Snipe *Gallinago gallinago* and Ruff *Philomachus pugnax* are explicitly rare as a breeding species. During migration, these species still inhabit the areas where formerly breeding occurred as well.

Agriculture in Peipsi is not be compared with agriculture in The Netherlands. Not only the intensity of farming, also the percentage of agricultural land differs a lot. Cattle and horse grazing are declining, especially around the lakeshores and on small-scale meadows inland. The Estonian side clearly still has more grazers than the Russian side. Extensive grasslands and hayfields form a specific habitat for a series of rare birds (see chapter 3.8). Due to the decreasing grazing pressure, rough growth and bush encroachment occur over large areas, which cause a serious threat to the entire community depending on a grassland habitat.

For smaller mammals, the situation is less well known. As these mammals are not hunted upon, their abundance can only be established by specific inventories. Night activity further complicates observations and therefore information is far less accurate than information on larger mammals. In the area of Lake Peipsi no specific research was carried out during our study. Occasional observations, information received from local inhabitants and data from literature form the basis for the description of numbers and distribution.

Table 2 presents a full list of species. In IJsselmeer 44 species occur, in Peipsi 57. For wild species this is 36 and 52 respectively, a considerable difference. This difference is especially prominent in the groups of large mammals. Both the large predators and the large herbivores are largely absent in the Dutch situation. For small mammals, the species numbers are more balanced with 33 species in IJsselmeer against 38 species in Peipsi.

**Table 2.** *Occurrence of mammals in the area of Peipsi and IJsselmeer*

| English name | Scientific name | IJM | Peipsi | Lake IJsselmeer area | Lake Peipsi area |
|---|---|---|---|---|---|
| **Larger herbivores** | | | | | |
| **Red deer** | *Cervus elaphus* | (o) | o | Present in large numbers in Oostvaardersplassen (fenced since ) | Rare in forests |
| **Roe deer** | *Capreolus capreolus* | ooo | oo | Common in the whole area | Common in the whole area |
| **Elk** | *Alces alces* | | oo | Absent since ca 1025 | Common in the whole area |
| **Beaver** | *Castor fiber* | (o) | (ooo) | In the wild extinct since 1826. Present in the Flevopolder after reintroduction early 1990s | Common in the whole area after reintroduction 1950s |
| **Wild boar** | *Sus scrofa* | (o) | oo | Absent, fenced population at Veluwe forests and heathlands | Small population, expanding from the South since mid 1990s |
| **Horse** | *Equus ferus* | (ooo) | (o) | Present in large numbers in nature conservation areas and locally on farm land | Very small and declining numbers on farmland |
| **Cattle** | *Bos taurus* | (ooo) | (o) | Present in large numbers in nature conservation areas and on farm land | Declining numbers on farmland |
| **Larger predators** | | | | | |
| **Bear** | *Ursus arctos* | | oo | Absent since ca 1025 | Present in small number in large forests and bogs |
| **Wolf** | *Canus lupus* | | o | Absent since ca 1850 | Present in small number in large bogs and forest |
| **Lynx** | *Lynx lynx* | | o | Absent since ca 500 | Present in small number in larger forests |
| **Wild cat** | *Felis sylvestris* | | oo | Absent since ca 1850 | Regularly in the forests |
| **Intermediate predators and omnivores** | | | | | |
| **Raccoon Dog** | *Nyctereutes procyonides* | | (oo) | Absent | Locally abundant immigrant |
| **European Mink** | *Mustela lutreola* | | o | Absent since 1885 | Present in small number |
| **American Mink** | *Mustela vison* | (o) | (o) | Locally but uncommon | Locally |
| **Stoat** | *Mustela putorius* | o | oo | Locally in marshes and farmland | Locally abundant |
| **Pine marten** | *Martes martes* | o | oo | Rare but increasing | Locally common |
| **Stone marten** | *Martes foina* | o | | Rare but increasing | Absent |
| **Fox** | *Vulpes vulpes* | ooo | oo | Common | Common in the whole area |
| **Otter** | *Lutra lutra* | o | ooo | Absent since 1988 Reintroduction in Weerribben close to the IJsselmeer area in 2002 | Common in the whole area |
| **Raccoon** | *Procyon lotor* | (o) | (o) | Rare immigrant | Rare immigrant |
| **Badger** | *Meles meles* | o | o | Local, Gaasterland and at Veluwe forests, locally and rare in Flevoland | Common in the whole area |
| **Small predators and herbivores** | | | | | |
| **Western Hedgehog** | *Erinaceus europaeus* | ooo | o | Common in the whole area | Rare in the area |
| **Pygmy shrew** | *Sorex minutus* | o | o | Locally in half-open habitat | Common |
| **Common shrew** | *Sorex araneus* | ooo | ooo | Common in moist areas | Common |
| **Water shrew** | *Neomys fodiens* | o | oo | Rare | Locally abundant |
| **Common mole** | *Talpa europaea* | ooo | o | Very common | Locally common |
| **Daubenton's bat** | *Myotis daubentoni* | oo | ? | Common | Unknown status |
| **Natterer's bat** | *Myotis nattereri* | | ? | Absent | Unknown status |
| **Brandt's bat** | *Myotis brandtii* | | ? | Absent | Unknown status |
| **Whiskered bat** | *Myotis mystacinus* | oo | oo | Common | Common |
| **Pond bat** | *Myotis dasycneme* | o | ? | Common but local, open water | Unknown status |
| **Brown long-eared bat** | *Plecotus auritus* | o | ? | Locally common in open areas | Unknown status |
| **Common pipistrelle** | *Pipistrellus pipistrellus* | ooo | oo | Very common and widespread | Common |
| **Nathusius' pipistrelle** | *Pipistrellus nathusii* | o | oo | Locally wintering and on passage | Common |
| **Parti-coloured bat** | *Vespertilio murinus* | o | o | Rare and only recently discovered | In forests, uncommon |
| **Serotine** | *Eptesicus serotinus* | o | | Locally but never common | Absent |
| **Northern bat** | *Eptesicus nilssoni* | | ? | Absent | Unknown status |
| **Noctule** | *Nyctalus noctula* | o | ? | Locally abundant | Unknown status |
| **Leisler's bat** | *Nyctalus leisleri* | | ? | Absent | Unknown status |
| **Rabbit** | *Oryctolagus cuniculus* | o | | Locally common on sandy soils, Gaasterland, Veluwe coast | Absent |
| **European hare** | *Lepus europeus* | oo | oo | Locally abundant, often declining in agricultural area | Common in the whole area |
| **Mountain hare** | *Lepus timidus* | | o | Absent | Rare, in bogs |
| **Flying squirrel** | *Pteromys volans* | | o | Absent | Rare, occasionally in dense oldgrown forests with Aspen |
| **Squirrel** | *Sciurus vulgaris* | oo | o | Locally common in forests | Locally in forests |
| **Garden dormouse** | *Eliomys quercinus* | | o | Absent | Locally in mixed forests |
| **Common dormouse** | *Muscardinus avellanarius* | | o | Absent | Rare in southern forests |
| **Bank vole** | *Clethrionomys glareolus* | oo | oo | Locally abundant in forests on sandy soils | Common in mixed forests |
| **Water vole** | *Arvicola terrestris* | ooo | ooo | Very common | Very common |
| **Common vole** | *Microtus arvalis* | oo | oo | Common | Common |
| **Field vole** | *Microtus agrestis* | o | o | Locally common | Locally common |
| **Root vole** | *Microtes oeconomus* | o | o | Local and isolated in moist areas | Widely distributed |
| **Muskrat** | *Ondatra zibethicus* | ooo | ooo | Present in large numbers, heavily trapped in agricultural areas | Present in large numbers |
| **Striped field mouse** | *Apodemus agrarius* | | oo | Absent | Locally common |
| **Wood mouse** | *Apodemus sylvaticus* | o | oo | Local | Common |
| **Yellow-necked mouse** | *Apodemus flavicollis* | | oo | Absent | Locally common |
| **Harvest mouse** | *Micromys minutus* | o | oo | Local, in pioneer situation | Locally common |
| **Black rat** | *Rattus rattus* | | o | Local, declining | Local, in kolkhoz areas |
| **Brown rat** | *Rattus norvegicus* | oo | oo | Locally abundant | Locally abundant |
| **House mouse** | *Mus musculus* | oo | | Locally abundant | Absent |
| **Northern birch mouse** | *Sicista betulina* | | o | Absent | Rare in Birch forests |
| **Coypu** | *Myocastor coypus* | (o) | | Very local, IJssel delta 2005 | Absent |
| **Ermine** | *Mustela erminea* | o | oo | Local, decreasing | Locally abundant |
| **Weasel** | *Mustela nivalis* | oo | oo | Locally and never abundant | Locally abundant |

( ) introduced, escaped or in fenced areas;
o small number or very local,
oo common, regularly distributed,
ooo in large number, widespread

**Amphibians, reptiles, mammals and landscape characteristics in Peipsi and IJsselmeer**

IJsselmeer and its hinterland differ greatly from that of Peipsi. With regard to species abundance the larger species are no longer present in the Dutch situation and for many species the period of extinction is accurately known. For the larger species this often was hundreds of years ago. That there is such a strong relation with the size of mammals is due to the large home range of individual animals. Bear and Wolf need 20-50,000 ha of continuous and varied landscape types and for a viable population these figures may rise up to a factor ten.

Figure 1 summarises species number for different groups in both Peipsi and IJsselmeer. As outlined above, the groups consisting of small predators as well as amphibians and reptiles show the greatest similarities between both areas. They comprise species of which the individuals need a habitat range between 1-500 ha. The large predators and, to a lesser extent, the large herbivores show the greatest difference when the two areas are compared.

Figure 1 shows that this difference parallels the difference in habitat space that these groups use. At present IJsselmeer is deprived of species that require the largest home range.

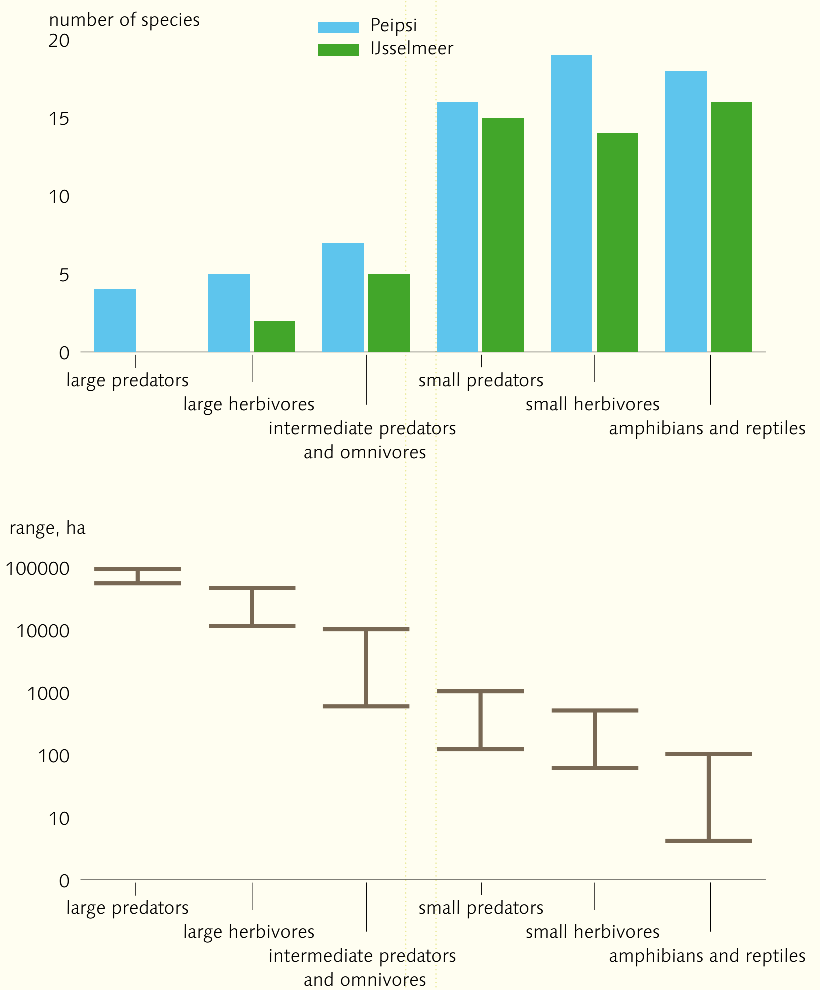



**Figure 1.** *Number of species for mammals (5 different ecological guilds), amphibians and reptiles in the regions of Peipsi and IJsselmeer.*

**Natterjack toad** ***Bufo calamita***

In The Netherlands the species often colonises new construction sites, because of the availability of open, sandy habitats. Interestingly, in the Noordoostpolder the species is still widely distributed, possibly as a combined effect of loamy to sandy soils and many ditches and small waterways which are regularly managed. Its tolerance for brackish conditions, which enables it to reproduce in waters with 500-1000 mg $Cl^- l^{-1}$, may give the Natterjack toad an extra competitive advantage over other amphibian species. In the areas outside of the dikes, the species is (almost) absent. Only near Lelystad (2005, 2007) and along the Houtribdijk between Lelystad and Enkhuizen (2006), the species was recently recorded.

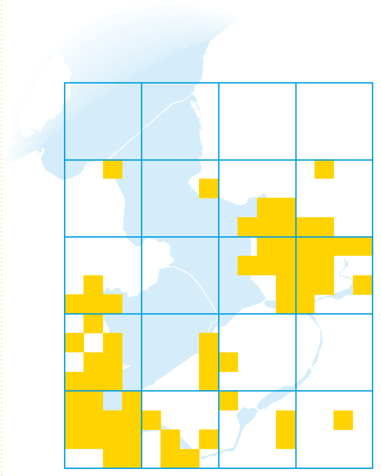
**Grass snake** ***Natrix natrix***

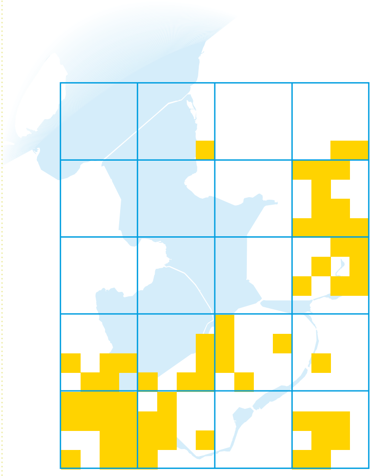
The Grass snake is a species which is strongly related to wetlands. The species finds its food (frogs, small fishes etc.) in water with vegetated banks. For their eggs they need hotbeds of leaves, compost and/or manure. During wintertime they need dry, not too cold places. In the IJsselmeer area they especially like to spend the winter in the open spaces between the basalt blocks and granite boulders which cover the dikes. So for their entire existence Grass snakes need the spatially close combination of wetlands and dry sunny places for wintering and warming-up. In the Netherlands there are three subpopulations, one in Utrecht/Noord Holland, one in the Veluwe/IJssel area and one in Friesland/Drenthe (see map). These areas are becoming more and more connected to each other through an expansion of the Flevo polders. The newly created wet habitats along the Borderlakes, Oostvaardersplassen and Lepelaarplassen, as well as forests in Noordoostpolder, Oost Flevoland and Zuid Flevoland contribute to this development.

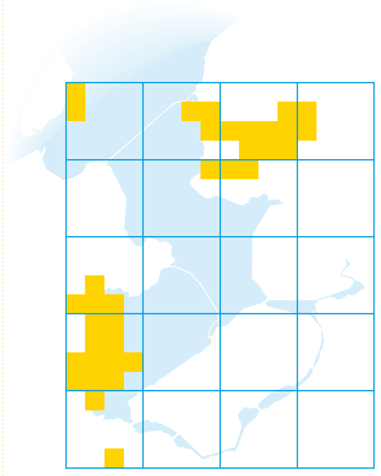
**Root vole** ***Microtus oeconomus***

The Dutch Root vole is an uncommon rodent, of which the subspecies arenicola is endemic to the Netherlands. The Root vole is especially related to dynamic reed banks and rough, wet grasslands. It can cope with fluctuating water levels. The species is threatened in the Netherlands (and protected by the European Habitats Directive) as the more hydrologically dynamic habitats have decreased very fast in the past decades; dikes were built and water levels were regulated more and more. The Root vole is a species which can colonise new areas very fast. This quality gives the species an advantage over the Common vole *Microtus arvalis* and the Field vole *Microtus agrestis*, which are much less mobile. Root voles need nutritious winter food, such as Licorice root *Hedysarum* or bulbills of Marsh Arrowgrass *Trichlogin palustre*, species which occur in dynamic rough grasslands. The species profits from dynamic wetland conditions under isolated conditions where other vole species are absent.

*Source: VOFF*

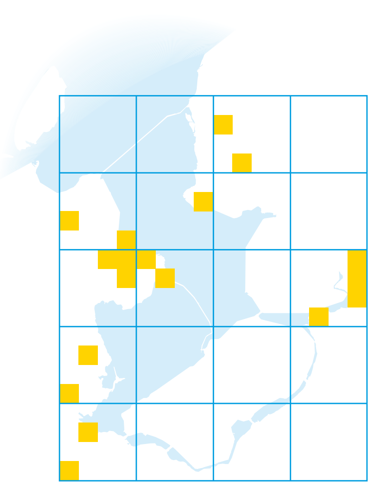






**Pond bat** ***Myotis dasycneme***

The four bat species, most of which are strictly related to wetlands and open water areas, are the Pond bat *Myotis dasycneme*, the Noctule *Nyctalus noctula*, Nathusius' Pipistrelle (*Pipistrellus nathusii* and, to a lesser extent, the Daubenton's bat (*Myotis daubentoni*. The first three species are quite common along the shores of Lake IJsselmeer and the Borderlakes. Especially the Pond bat forages above (large) open waters and uses waterways to migrate. The Daubenton's bat forages mainly above smaller water bodies, such as canals, ponds and ditches. The Noctule uses large open polders and wetlands in the IJsselmeer area from colonies in trees in Utrecht and Gaasterland.
All species need hollow trees or openings in houses or churches for their roost and colonies. Those places should not be too far away from their foraging habitats. For the Pond bat, most colonies are on the Eastern side of Lake IJsselmeer, e.g. in Urk, but there is no detailed inventory available.



## Great Snipe and microstructure of floodplain habitat

*Andres Kuresoo and Leho Luigujõe*

Microhabitat features of wet grassland determine the attractiveness of floodplain areas for Great Snipes Gallinago media, a globally threatened bird species. IKONOS satellite images of high resolution provided integrated vegetation charts. Foraging areas of snipes are determined by food-related features like soil moisture content and earthworm density as well as anti-predator related features such as the presence of tussocky vegetation providing cover. The lek is situated in areas with sufficient dry-wet gradients, so as to buffer inter- annual changes in nearby foraging areas.

Lowland populations of the Great Snipe *Gallinago media* are threatened throughout the breeding range, due to draining of floodplain grasslands and the rapid decline of traditional management practices like haymaking and traditional grazing of meadows.
The Estonian population is estimated roughly at 600 lekking males at least (Kuresoo & Luigujõe 2003), the bulk of which is concentrated in the Peipsi-Võrtsjärv floodplain area. At present the most vital population is known in Alam-Pedja Nature Reserve, where up to 800 ha of floodplain meadows are managed annually since 2000.
In Altnurga, a specific area in the north-eastern part of the nature reserve in the Pedja River floodplain, a complex study was performed in 2005-2006 to analyse distribution patterns of some rare meadow bird species in relation to microhabitat features. Altnurga floodplain is substantially altered by man-made structures. It features a network of ditches, created around 80 years ago, and the deep north-south directed Konsu ditch, dug about 30 years ago. The latter has been changed by spring floodwater, which destroyed a riverbank at the northern part of the ditch. Grasslands to the east of Konsu ditch (in an area dominated by) *Calamagrostis epigejos* have meanwhile been used as improved hayfields or for growing other crops.
We used an IKONOS image of the area, taken 5 May 2006, on which ground truthing was performed by Dutch experts within one month, starting May 15. A detailed vegetation map was the result of this investigation.
The vegetation in this area consists of wet meadow and hay land species, dominated by *Alopecurus* and *Poa* in the intermediate moist areas and *Calamagrostis* in the somewhat drier areas. The lowest parts, flooded each year, consist of *Carex cespitosa* and *Filipendula*; in May these areas still contain water on the surface. The levee vegetation consists of *Arrhenatherum elatius*. Some patches of low bush occur, mainly *Salix*.
A large Great Snipe arena (up to 35 males at the lek, Figure 1) was found already in 2005, on the left bank of the Pedja River. In the course of a systematic search in 2005 (400 m around the centre of the lek), 26 (2005) and 8 males (2006) were flushed from feeding sites.
The main feature of the floodplain meadow, which has attracted the Great Snipe over a series of years, is a large variety of soil moisture. As snipes are present in the area from late April to early August, they can only reproduce successfully in areas with a large range in soil wetness. They prey on soil vertebrates (mainly earthworms), which they locate on touch by penetrating the soil with their long bill. Comparing soil parameters in Altnurga samples (20 snipe feeding samples and 20 random samples, both from 2005) revealed that the range in moisture is broad (Figure 2, soil moisture measured on 16 and 17 June 2005). In such areas, snipes can cope with seasonal changes in soil moisture (due to differences in flooding or rain patterns) by selecting optimal feeding patches within a short range from the lek. Figure 1 shows that feeding sites in 2005 (a wet period) occurred in the drier part of the floodplain, whereas feeding sites from 1999 and 2006 (a dry/moderately wet period) occurred in low lying areas.
It is known from earlier studies that males of Great Snipe mainly hunt on earthworms (96,5 % of the total weight of invertebrates consumed, Kuresoo & Luigujõe 2003). The highest biomass of this prey is available in 8-10 cm upper level of soil. Feeding patterns of snipes in different years demonstrate the opportunistic patch use. Birds concentrate on areas where earthworms are available with high biomass but easily accessible as well, due to a good penetrability of the soil. In 2005 the snipes restricted their hunting to soil patches where soil penetrability was >6,0 cm (measured by penetrometer, Figure 3).

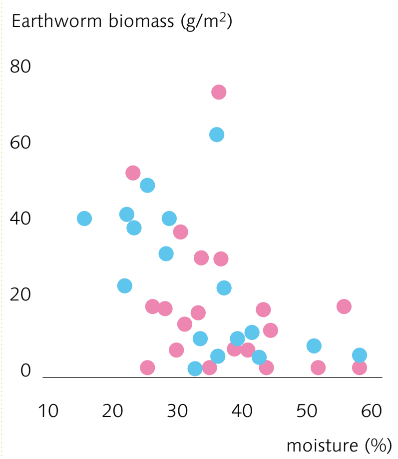



**Figure 2.** *Earthworm biomass plotted against soil moisture at Altnurga floodplain.*

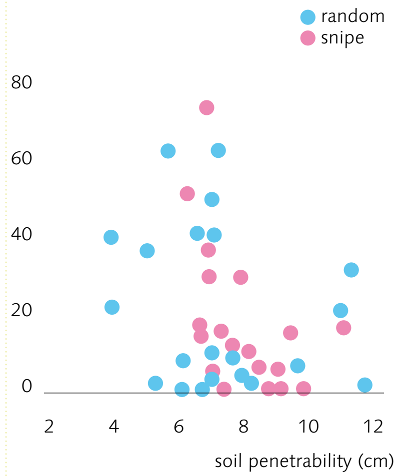
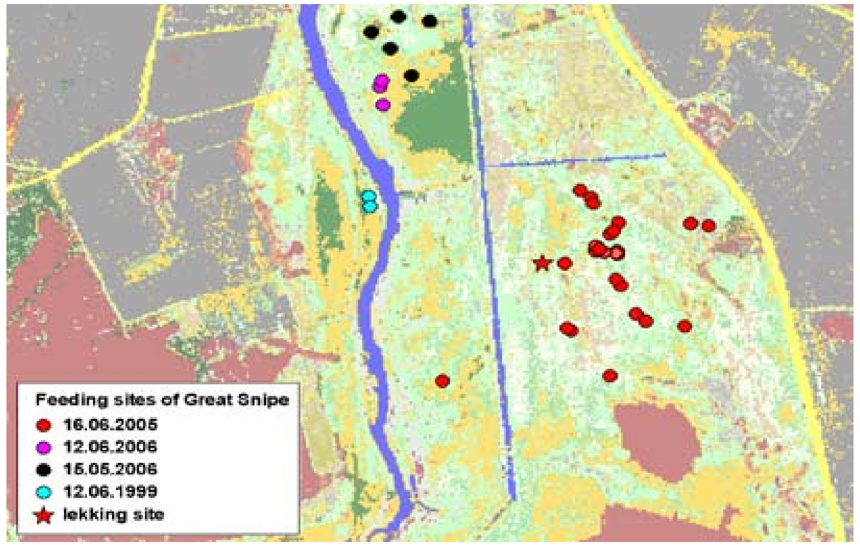



**Figure 3.** *Earthworm biomass plotted against soil penetrability at Altnurga floodplain, 2005*

Patch use by snipes is further restricted by other key microhabitat features, which are related to anti-predator behaviour of the birds. Feeding snipes cannot be localised easily by visual observation due to their extremely cryptic plumage as well as to their perfect ability to hide between tussocks and vegetation. This last point seems essential in the ultimate choice of micro habitat – birds tend to prefer specific plant species/vegetation types which provide the best possible protection against predators or the best chance of a safe escape when a predator is approaching. From previous work we know that snipes choose feeding areas with small tussocks and avoid thick, monotonous and high plant cover. All rough types of vegetation are definitely avoided by snipes at Altnurga, although some low willow bush growth is often present within short range of the lek (Figure 1).
Great Snipes are thus dependent upon patchy areas in floodplain areas of small rivers. The strong gradients ensure that natural fluctuations of water tables have little effect on the availability of good feeding sites within short range of the lek. As such the area of Altnurga shows the peculiar influence of agriculture on the occurrence of this rare bird; cultivation, dunging and superficial drainage have all contributed to the present situation. In other parts of Alam Pedja more natural sites also attract this species; in all cases, however, traditional management of meadows is an important element in the micro distribution.

**Figure 1.** *Distribution of the Great Snipe (lekking ground and feeding sites) in Altnurga floodplain (Alam-Pedja Nature Reserve) in comparison with vegetation classification (Klaas van Dort and Hans den Hollander).*



# 3.9 Water level fluctuation and developments in aquatic vegetation

Luc Jans, Külli Kangur, Marina Melnik & Vladimir Borisov

Natural water level fluctuations are beneficial for emergent macrophytes such as Reed and Bulrush vegetation. In Peipsi these plants are dominant along all shores. They occur at depths up to 1.5 m and show a lakeward expansion. In IJsselmeer, shores are often steep and artificial, which prevents the development of natural vegetation. Where more natural gradients still occur, vegetation patterns resemble those in Peipsi, although on a limited scale. Bulrush especially is scarce and is only present in Lake Zwartemeer and locally in the Borderlakes. This species is indicative of hydrodynamic fluctuations, which in the Dutch situation are mainly caused by wind effects.
The deteriorating water quality in Lake Pihkva leads to the decrease of pondweeds, as was the case in IJsselmeer and the Borderlakes in the 1970s. Some weeds have returned, though, thanks to purification plants and flushing with clean polder water. As a result, stoneworts *Characeae* reappeared in the 1990s.

Water level fluctuations are caused by differences in the amount of precipitation, by evaporation or both. Locally, changes may occur because water is transported over long distances of shallow open water, either by the river, the current or by the wind. Intense showers or the sudden melting of snow may cause rapid changes, especially in the downstream areas of the catchment area. In estuarine situations tidal effects may add to wind effects, which was the situation in the former Zuiderzee until 1932.
Keeping water tables at a fixed level is common practice now throughout Europe. Especially in The Netherlands, hydrological engineering has been a key activity for many decades. Its aim was to guarantee safety and to meet agricultural demands. The resulting decrease in shorelines with natural vegetation was considered as problematic in cases where the landscape or recreation became important. Recently, the cost/benefit analysis of natural versus artificially protected shores renewed the interest in rehabilitation of natural shorelines. The question was how environmental conditions influence the growth of reeds and submersed vegetation.

**Water level fluctuation**

In Peipsi there is no strict water level management. Only the Narva River dam disconnects the system from the Baltic Sea. The water level is merely dependent on regional differences in precipitation and evaporation within the catchment area, as well as on the occurence and amount of melting snow. Generally this leads to seasonal variations in water level, with higher levels in spring and lower levels in summer and autumn.
In IJsselmeer, by contrast, the water level has been strictly regulated since the lake was created in 1932. During winter, the water level is kept at 40 cm below





NAP (Dutch ordnance level) in the major part of the area. From April 1 to October 15, a higher level of 20 cm below NAP is maintained as far as possible to guarantee farmers a sufficient supply of water. Consequently, the Dutch situation is markedly different from that in Peipsi, with a reversed pattern in water level: higher in summer and lower in winter (see Figure 1).

**Seasonal variation**

The seasonal variation in water level is bigger in Peipsi than in the IJsselmeer area (Figure 1). Normally, the water level in Lake Peipsi is high in spring and declines during summer and autumn. However, this pattern is not always the same over the years. Depending on the specific annual weather conditions, the water level can follow completely different patterns in different years.
Of course, the water level fluctuation in the IJsselmeer area is also dependent on specific weather conditions. However, due to regulation and management, the fluctuation pattern mainly follows the agreed levels. At times, the River IJssel discharges so much water into the lake and/or the water level on the other side of the Barrier Dam is so high that the lake's water level may rise by some decimetres. However, this situation occured for several days, up to several weeks at the most.

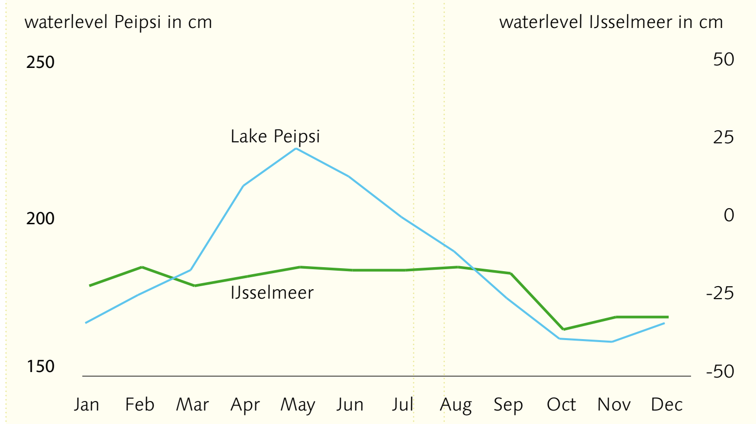



**Figure 1.** *Water level changes during the year in Peipsi and IJsselmeer (data 2000-2005).*

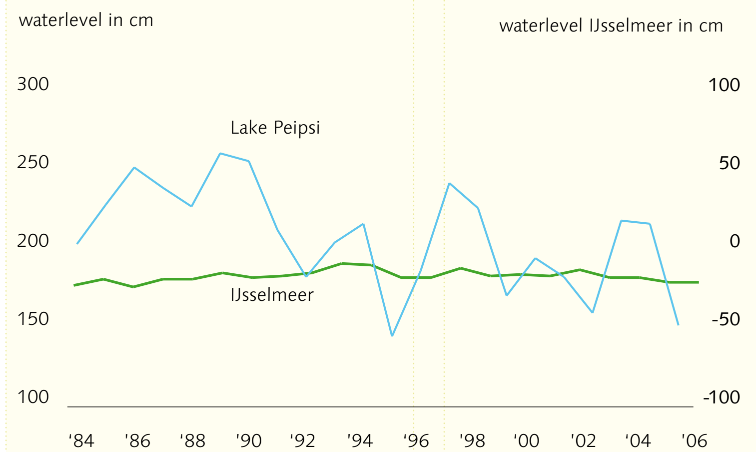



**Figure 2.** *Water level variation in Lake Peipsi and Lake IJsselmeer over the years.*

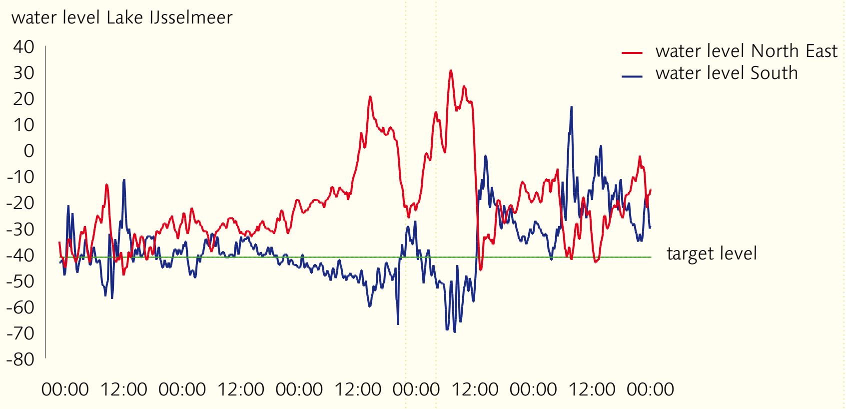



**Figure 3.** *Real time recording of wind-driven differences in water level on two locations in Lake IJsselmeer (1-5 March 1998) with partly strong winds (SW storms).*

#### Variation between years

The yearly average water level in Lake Peipsi may fluctuate more than 1 meter, whereas in Lake IJsselmeer the range is no more than 15 centimetres. The water level of Lake Peipsi is nearly completely dependent on precipitation and evaporation in the catchment area. There is hardly any influence by man. Even the Narva River dam, built 1955, is used to generate hydro-electric power rather than to regulate the lake's water levels.

#### Wind effects

The various lakes in the IJsselmeer area are quite shallow. The major part in the north is only 4 to 5 meters deep on average. The edges along the Frisian coast, Lake IJmeer near Amsterdam and the Borderlakes are locally less than 1.5 m deep. Under stormy conditions, which occur once or twice a year on average, this shallowness causes the water surface to slope strongly, resulting in a difference of up to 1 metre in the waterlevels on both sides of the lake (Figure 3). Less extreme wind conditions, causing fluctuations of 30 cm at either end, occur almost every day. These small scale fluctuations are the only dynamics the area experiences. In Peipsi, such daily variations were never investigated, but they probably occur to a lesser extent (< 0.5 m) as the lakes are deeper, the wind is less strong and the water is frozen during a large part of the stormy season.

#### Ice period

In the period 1985-2005, Peipsi was covered in ice during 130 days per year on average, compared to just 0-10 (max. 30) days per year in IJsselmeer (see also chapter 2.1). During a period of ice-cover there is hardly any physical influence of the water on the shore vegetation. However, during the melting period, depending on the actual wind circumstances, there can be a severe influence of drifting ice. The drifting ice can completely remove the natural vegetation from the shores. Moreover, the power of drifting ice may destroy everything in its course. Such events occur in the Peipsi region more often than in the IJsselmeer area.

#### Land-water interaction and general vegetation patterns

In the Peipsi area, the land-water interaction zone is quite broad due to the combination of large water level fluctuations and the natural gradients of the shores (no dikes). This results in wide Reed banks along the shores of almost the entire lake and extensive marshes near the mouths of rivers and brooks. As stated before, the surface area of the lake may vary up to 20%. Therefore, large areas surrounding the lake are partly inundated during the year. At certain locations, the 'shoreline' moves hundreds of metres within a year. In fact, it is more appropriate not to speak of a *shoreline* but of a shore zone due to the water level fluctuations along the wide banks of Lake Peipsi.

*Mixed stand of Schoenoplectus, Typha and Nuphar*

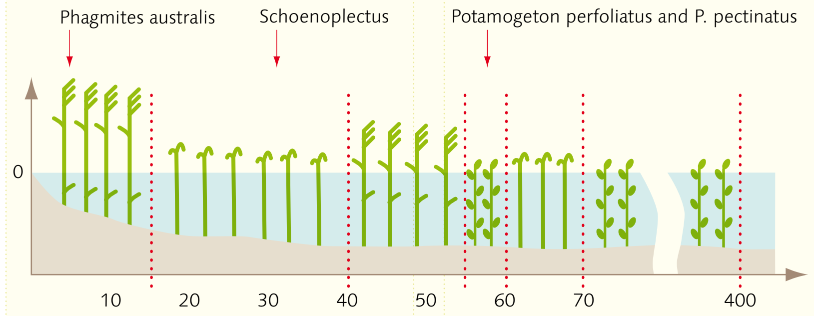


**Figure 4.** *Typical geobotanical cross-section of shores in Lake Pihkva showing alternating emergent and submersed vegetation along a gradual slope.*

*Potamogeton perfoliatus*

This shore zone shows a clear zonation in vegetation. In the most terrestrial part (landside) extensive Reed beds *Phragmites australis* occur. This is mainly the zone which is flooded every year, but not permanently. The next zone consists mainly of Bulrush *Schoenoplectus lacustris*. vegetation. These rushes have much more a pioneer character. The places where this Bulrush vegetation occurs are less uniform compared to the Reed stands. The rushes occur in deeper water and form distinct clones, which may be decades old. Further into the lake more and submersed aquatic plant species occur, such as pondweeds *Potamogeton spp*. (Figure 4).

In IJsselmeer such zonation is only rarely found. If natural vegetation occurs at all, then in most cases this is a rather narrow belt of closed reeds (5-15m) with no signs of lakeward expansion as in Peipsi.




#### Reed beds

The reed vegetation along the shoreline of Lake Peipsi has increased a lot during the last decades. This expansion of reed since the 1950s is related to the proceeding process of eutrophication in combination with the decrease in grazing pressure of cattle. In the first half of the twentieth century, Lake Peipsi was really poor in nutrients. At that time, nutrients in the system limited expansion of the reed beds. The expansion of reeds follows the gradient in nutrient flow, starting in the south and proceeding towards the north.
At present, only at the northernmost shores no reeds occur, which is also due to sandy bottoms and exposure to the prevailing winds. Contrastingly, the largest stands occur in the delta of the river Velikaya, at the southernmost fringe of the system (Figure 5).

In Lake IJsselmeer, the nutrient status was already much higher in the twentieth century. After the Zuiderzee was dammed in 1932, Lake IJsselmeer became a freshwater system. Vegetation started to grow on the former tidal flats.
It started with a pioneer vegetation of Bulrush, but later on reed was growing on large parts of the shore zone. However, due to the regulated water level the reed vegetation never expanded far into the water. Often, as for instance in the Borderlakes, retreating reed shores have been described. The permanent level of attack by waves partly explains this phenomenon (Coops, 1996).
The relation between reed and nutrient availability can also been seen in a different way. The structure of reed vegetation (height of shoots) in the southern part of Peipsi (e.g. Lake Pihkva and Velikaya delta) differs from that in the northern part. Reeds in the delta grow higher (up to 3-4 meters) than in the northern part (2-2.5 m) (Figure 6). This is strongly related to the nutrient gradient but also to the degree of the hydrodynamics. This relation between the reed vitality and the degree of hydrodynamics can also be observed in Lake IJsselmeer. The most dynamic parts in the area (Zwarte Meer and Makkumer Noordwaard) still have the most extensive and most vital reed vegetation.

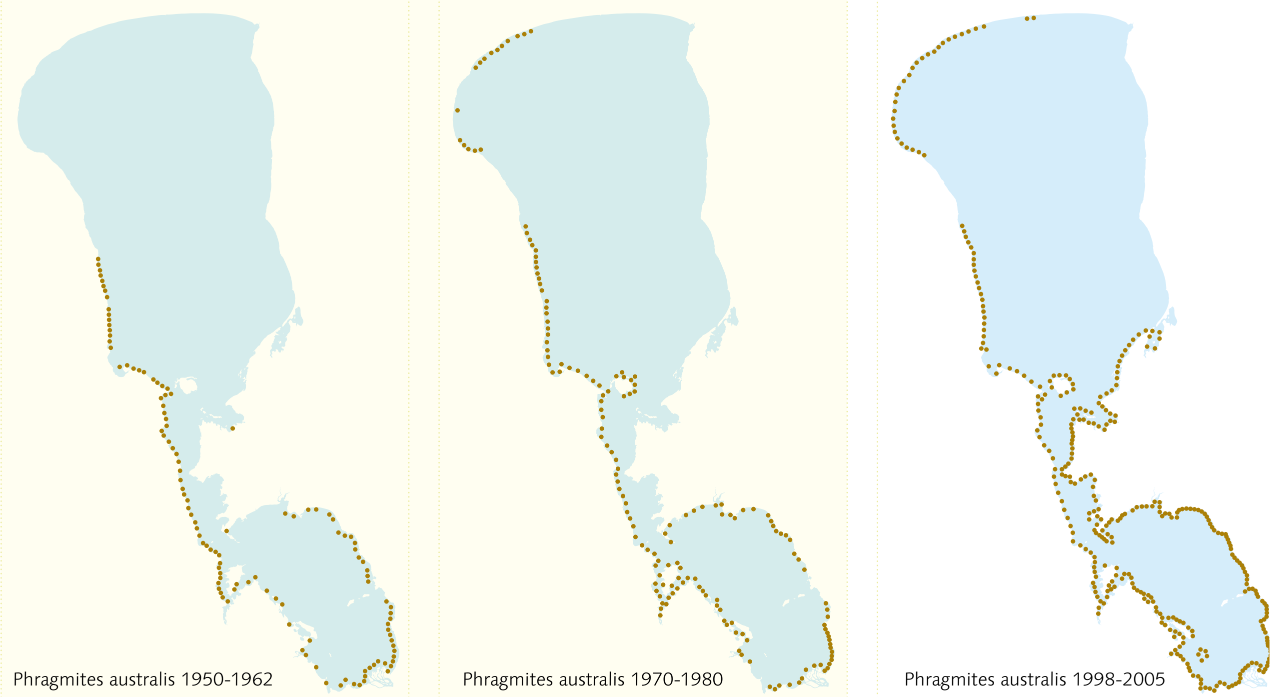



**Figure 5.** *Reed expansion in Lake Peipsi between 1950 and 2005 (based on Pihu & Haberman, 2001 and Sudnitsina et al.).*

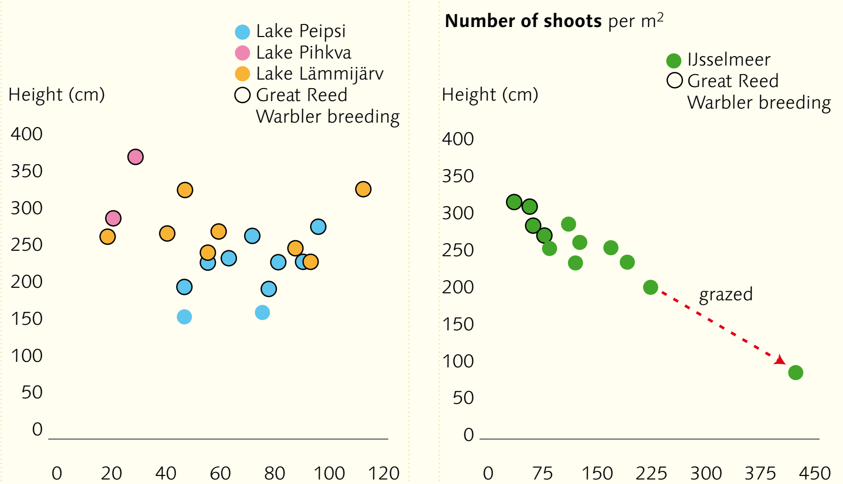



**Figure 6.** *Number of shoots versus the height of reed beds in Peipsi and IJsselmeer. Great Reed Warblers occur at the taller and open reedbeds, where stem density is <125/m².*

The height of the reed beds is strongly related to the density of the stems and the diameter of the stems. A low density of reed stems is related to a large diameter and a large height. A high density of stems is related to less height and a smaller diameter. If reed beds are managed (cut) or the hydrodynamics are small, the number of shoots per square meter increases but shoot diameter decreases. The same effect occurs when geese or cattle graze the shoots during spring or summer (Van Eerden *et al.* 1997). Figure 6 shows the relationships for different parts of Peipsi and IJsselmeer. Compared to Peispi, the IJsselmeer data generally show a higher number of shoots at a smaller diameter. Interestingly, places with the largest hydrodynamics (mainly because of wind) still show the coarsest types. These comprise the stands where Great Reed Warbler *Acrocephalus arundinaceus* breed, a species still very common in Peipsi.

### Bulrush vegetation

The bulrush *Schoenoplectus* vegetation mainly occurs in places where active sedimentation takes place. In Peipsi, extended bulrush vegetation occurs for example in the outer edges of the Velikaya delta. In the IJsselmeer area, large bulrush vegetations have formerly occurred in Lake Zwarte Meer. After the construction of the Afsluitdijk, the area became a freshwater lake and bulrush vegetation initially increased. But since 1940-1950 a strong decrease of the zone with bulrush vegetation has occured (Figure 7). The decrease was caused on the one hand by a strong reduction in water dynamics (due to reclaiming of the Noordoostpolder from Lake IJsselmeer in 1942) and on the other hand by disconnection from the River IJssel (channel "Ganzendiep"), which put an end to active sedimentation processes in the Zwarte Meer area.

### Aquatic vegetation

In the Borderlakes of IJsselmeer, submersed aquatic vegetation was almost completely absent in the period 1970-1980 due to very poor water quality. Only Fennel pondweed *Potamogeton pectinatus* was still present at the most shallow places in the Borderlakes. Since the mid 1980s, a larger spectrum of species has re-occupied the area. Extensive measures were taken to improve the water quality, which led to spectacular results. In the early 1990s, even the stonewort *Chara* species returned in the Borderlakes and other more sheltered places. Obviously, these sheltered places are preferred foraging areas for all kind of waterbirds. At present, herbivorous waterbirds concentrate in the Borderlakes and locally along the Frisian coast, Gouwzee and IJmeer, all closely related to the occurrence of submersed vegetation. Nevertheless, still only a limited part of the shoreline of Lake IJsselmeer is covered by submersed aquatic vegetation. The combination of steep shore lines, deep water and strong wave movements makes more than half of the shoreline of Lake IJsselmeer unfit for aquatic vegetation.

In Peipsi submersed aquatic vegetation is widely spread along the shores. With approximately 30 species of higher plants the community is better developed than in IJsselmeer, where only 13 species occur (Tjeertes 2007).

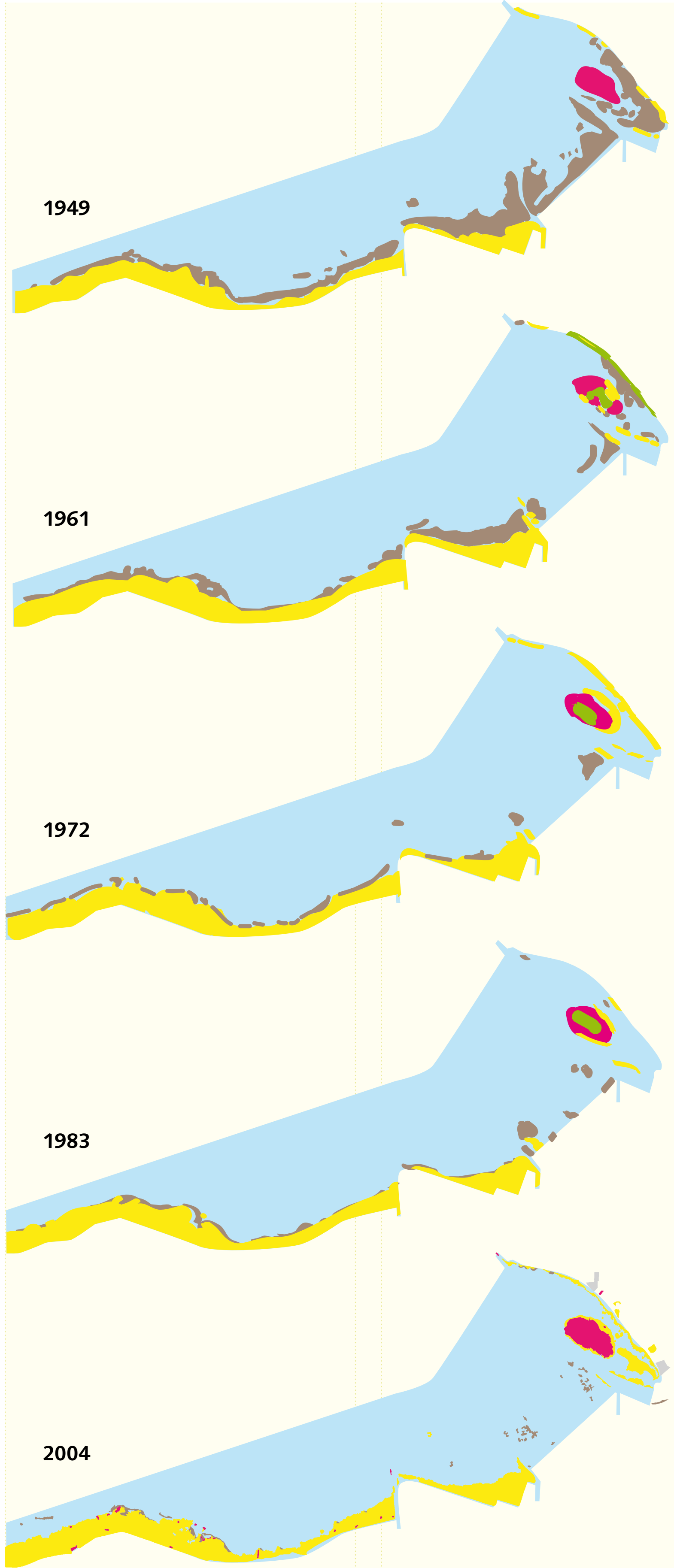
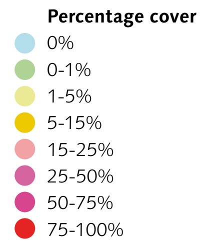
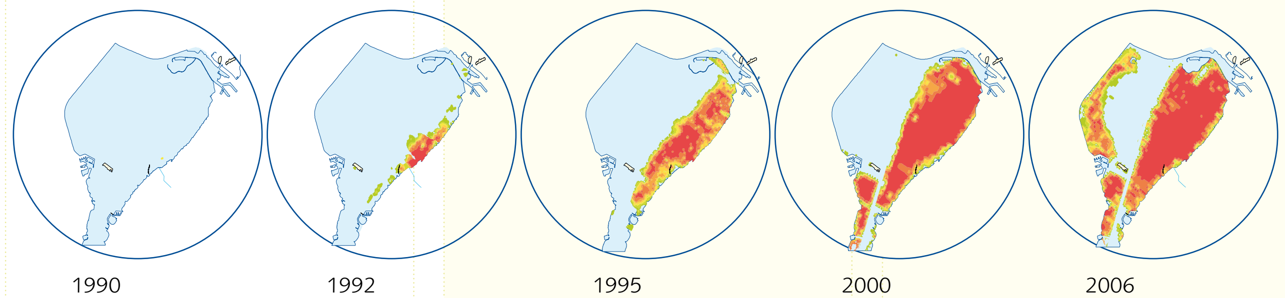



**Figure 7.** *The development of Bulrush vegetation in Lake Zwarte Meer since 1949 (partly based on Coops, 1992). Noordoostpolder was reclaimed in 1942.*




**Figure 8.** *Distribution of aquatic vegetation (mainly Potamogeton spp. and Chara spp.) in the IJsselmeer area (2004-2006). Expansion in Lake Wolderwijd shown in detail (1990-2006)*



## Bewick's Swans at Lake Peipsi

*Leho Luigujõe & Andres Kuresoo*

The NW-European population of the Bewick's Swan *Cygnus bewickii* is threatened. Population was at a maximum in the 1990s and decreased sharply from the late 1990s onwards. Present numbers are estimated roughly at 20 thousand individuals (Wetlands International 2006). Apart from periodical low reproduction periods in arctic breeding grounds, shortage of habitats and food in stopover sites may be reasons for decline. During migration and stopover in autumn, Lake Peipsi supports up to 25% of the flyway population of Bewick's Swans. The main cause of the fluctuations in fall staging numbers of swans at Lake Peipsi are the substantial fluctuations of the water level, which strongly affect the availability of macrophytes.

### *Numbers of staging Bewick's Swans at Lake Peipsi*

Regular ground counts between 1994-2006 were carried out at the Lohusuu-Mustvee-Varnja permanent survey area (Figure 2). The survey route covers 61 km of the coast from 31 observation points. According to other surveys performed in autumn (aerial count covering all Estonian coastline of the lake in 1994 and 1998, integrated counts of waterfowl in Russia and Estonia in 2004-2006), this permanent survey area is harbouring roughly half of the whole Peipsi population of the Bewick's Swan. The dynamics of the population are most adequately reflected by counts in October, when the numbers of Bewick's Swans are highest (Figure 1). The October maximum number does not reflect the actual number of all staging swans, as the average length of stop-over at Lake Peipsi was 14,7 days (SD=5,3), based on regular observations of 14 colour-marked swans in 1991-1994 in the permanent survey area (AK, LL).

Long-term water level fluctuations in the lake substantially affect the foraging patterns of Bewick's Swans as well as of other surface feeding waterfowl like ducks and geese. During periods of low water table, there is a broad zone of suitable shallows with water depth < 0,7 m, offering swans access to their key food, two species of pondweed: *Potamogeton perfoliatus* and *P. pectinatus*. These plant species are widely, but patchily distributed in Lake Peipsi. However, due to the changes of water level, food is not constantly available to swans during their autumn stopover.

*Low water near Mustvee in autumn of 2006*

In 1994-2006, the average water level in October was lower than the long-term average (1.64 m versus 1.79 m for the period 1930-2006), which implies that the shallows of the lake were more attractive to fall staging Bewick's Swans than is the case on average.

The peak and low numbers of Bewick's Swans in autumn correlate with low and high water levels respectively; years with high numbers i recent years were 1996 and 1997, 2001 and 2002 and 2006 and2007. In these years, the swans stayed for several weeks and peak numbers were between 2000-3500 ex. In other years birds rested for a shorter period and numbers fluctuated more strongly, maximum numbers staying markedly behind (0-750 ex.).

Apart from fluctuations due to changes in water table, there is an overall declining trend of Bewick's Swans (ca 4% per year, see linear trend in Figure 1), which corresponds well with estimations leading experts for the species (Wetlands International) made for the whole population. It remains to be shown whether the cyclic pattern of staging numbers, with an apparent bi-annual peak at a 5 years interval, is realistic and has a biological reason.

### *Staging patterns of Bewick's Swans at Lake Peipsi*

Figure 2 was compiled using all existing data on staging Bewick's Swans at the Estonian side of the lake between 1990-2004. The maximum numbers of swans counted in each counting unit gives an impression of the spatial functioning of the lake for this species. Fieldwork carried out in the course of this project (2004-2006) revealed all known and potential areas of Bewick's Swans, which were visited both on the Estonian and Russian side of the lake. Of the consecutive years, the first two, 2004 and 2005, were characterised by high water tables and the last, 2006, by an extremely low water table. In years of high water level, only a few of the more extensive shallows in the Estonian part were used by swans and always in low numbers. By contrast, in 2006 up to 3000 birds were observed on both sides of the lake (Figure 3, 4), corroborating the strong relationship with water tables. Perhaps not surprisingly, the number of swans along the coasts of Lake Pihkva was low in 2006. Despite the low water level this is probably due to the deteriorating stands of pondweed due to eutrophication.

Also interesting is the fact that fall staging swans never showed up in significant numbers on agricultural land, neither in the years of high numbers nor in the years of low numbers. Apparently at this time of year, they depend exclusively on pondweed or macrophytes in general.





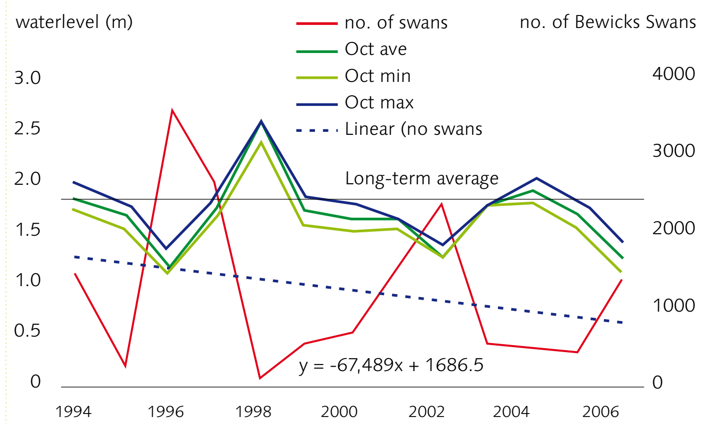



**Figure 1.** *Numbers of Bewick's Swan in October (1994-2006) in the permanent survey area plotted against October water level (0 = 28,0 m ASL) at Mustvee hydrological station at Lake Peipsi. The long-term average water level for the station in October is 1.79 m.*

**Figure 2.** *Distribution pattern of Bewick's Swan at Lake Peipsi (Estonian side) in autumn 1990-2004. Dark green dots are internationally important sites for the population (1% criteria =200 individuals).*

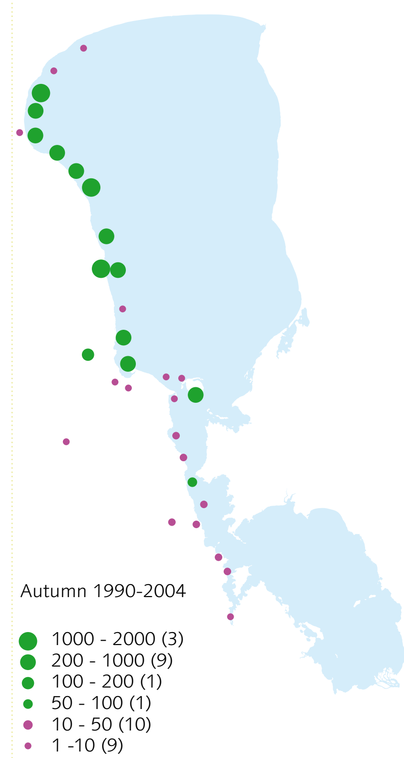



**Figure 3.** *Distribution pattern of Bewick's Swan in Lake Peipsi according to integrated counts in autumn 2005 (high water level situation).*

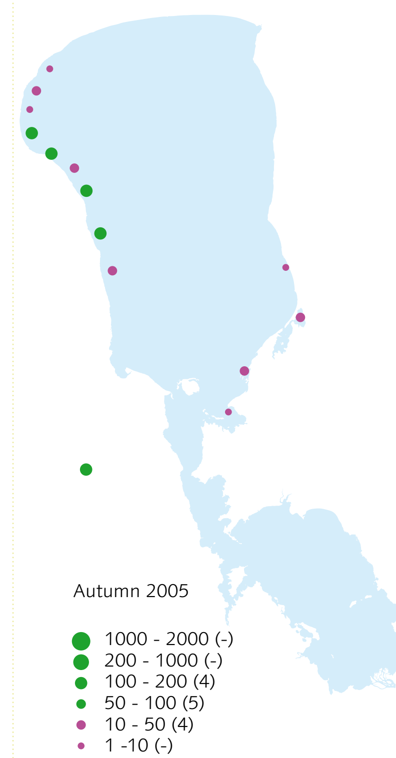
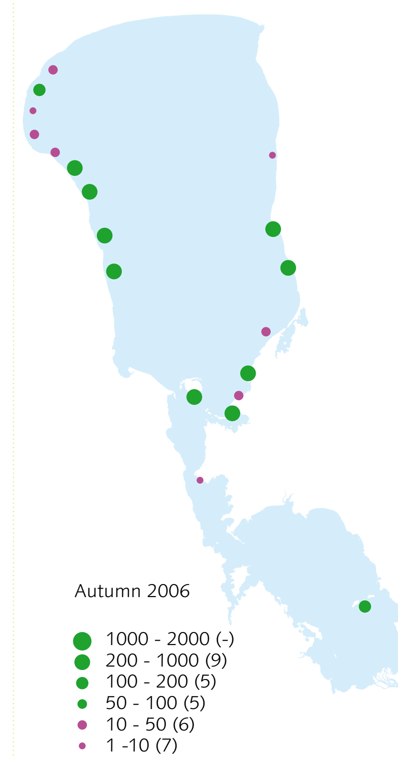



**Figure 4.** *Distribution pattern of Bewick's Swan in Lake Peipsi according to integrated counts in autumn 2006 (low water level situation).*



# 4
# Integration and scenarios

# 4.1 Spatial distribution of nutrients in Peipsi and Pihkva and the relation with higher trophic levels in the food web

Külli Kangur, Marina Melnik & Eddy Lammens

Between Lake Pihkva and Lake Peipsi significant spatial gradients have been described for total phosphorus and total nitrogen concentrations. These gradients relate to gradients in density of algae and transparency and partly also of zooplankton. For zoobenthos this gradient is not clear at all. For fish it is different per species, which is more easily explained by the spawning places of the different species and not at all by possible differences in food availability.

A recent increase in nutrient load, particularly phosphorus, increased the difference between Lake Pihkva and Lake Peipsi. Lake Pihkva has changed into a more eutrophic lake, more similar to IJsselmeer when considering total P, chlorophyll-a concentration and transparency. However, it is still a natural lake with a fluctuating water level and associated floodplains. Therefore the dynamics of the fish populations seem to be controlled more by water level fluctuations than by eutrophication. It is still unclear whether the changes in nutrient load are more important than the changes in climate.

**The distribution of P and N**

On average the total P concentration is significantly larger in Lake Pihkva (60-120 $\mu g\ l^{-1}$) than in Lake Peipsi (40 $\mu g\ l^{-1}$) with intermediate levels in Lake Lämmijärv (Kangur & Möls, 2007 in print). The main source of nutrients is the Velikaya River which ends in Lake Pihkva. Going from Lake Pihkva to Lake Peipsi, nutrients are retained in the sediments (P) or disappearing in the air by denitrification (Figure 1) and therefore this gradient of nutrients is quite natural. The gradient in P concentration, however, has become steeper since 1995, because of an increasing load of P arriving from the Velikaya River. Also for nitrogen there is a clear gradient form Lake Pihkva to Lake Peipsi (900 $\mu g\ l^{-1}$ to 650 $\mu g\ l^{-1}$), but in contrast to phosphorus there is no increase over the last 20 years (Figure 1).

As a consequence the algae are more limited by N than by P. This is clear from the amount of dissolved P and N. The concentration of dissolved N (DIN) is not significantly different (ca. 100 $\mu g\ l^{-1}$) between Lake Peipsi and Lake Pihkva (in contrast to total N) whereas the concentration of dissolved P is significantly higher in Lake Pihkva (ca. 20 vs. ca. 10 $\mu g\ l^{-1}$), demonstrating that N is almost completely assimilated, whereas there is a surplus of dissolved P in Lake Pihkva.

Apart from the difference between Lake Pihkva and Lake Peipsi, there is also a difference between the Russian part and the Estonian part of Lake Peipsi. In the Russian part (or rather the south-eastern part including a part on the Estonian side) the concentration of total P is higher, and again the concentration of total N hardly differs. This may be related to a larger run-off load of P from the Russian side and/or poorly functioning sewer treatment plants.

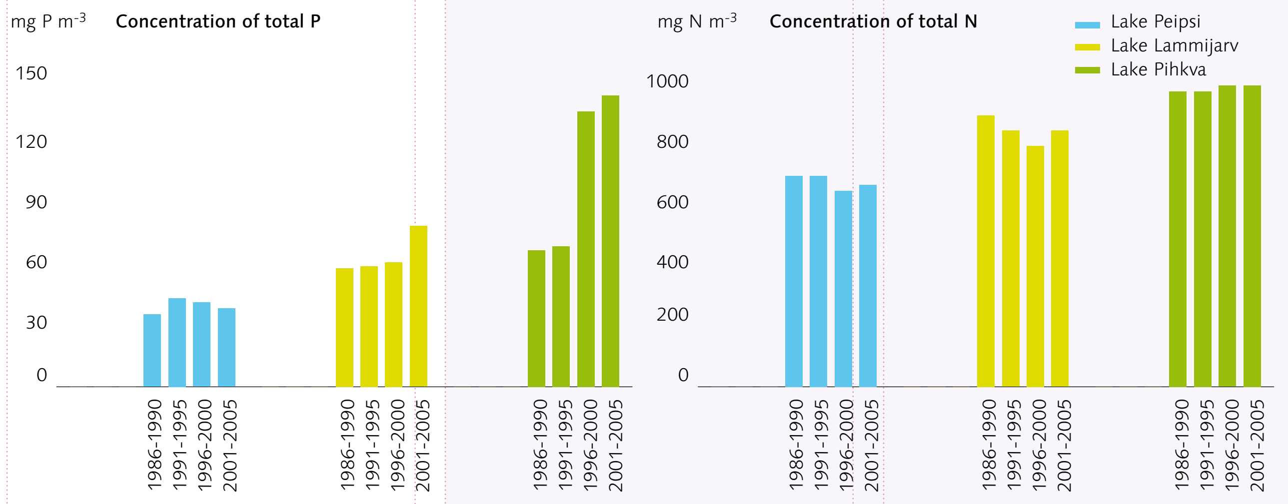



**Figure 1.** *Concentration of total P and total N in Peipsi, Lämmijärv and Pihkva from 1985 to 2005 (after Kangur & Möls, 2007 in print).*

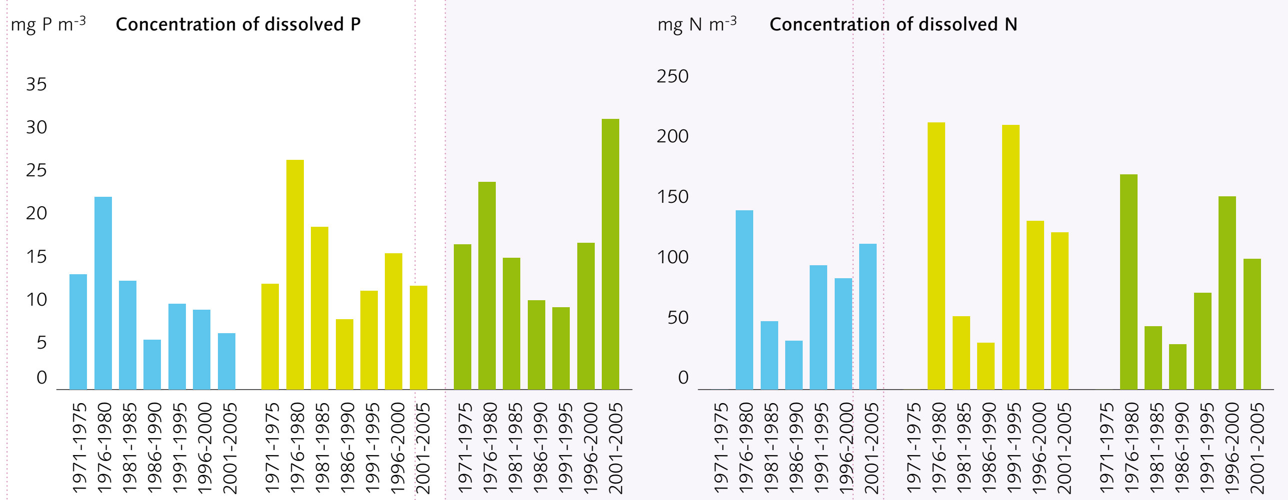
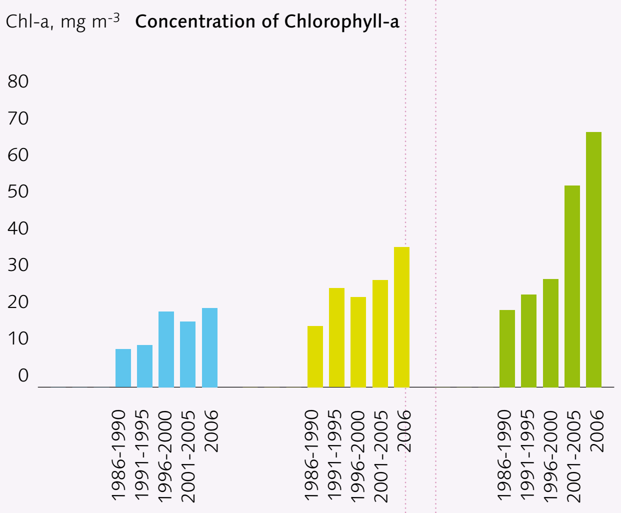



**Figure 2.** *Concentration of dissolved P and N in Peipsi, Lämmijärv and Pihkva from 1971 to 2005 (after Kangur & Möls, 2007 in print).*



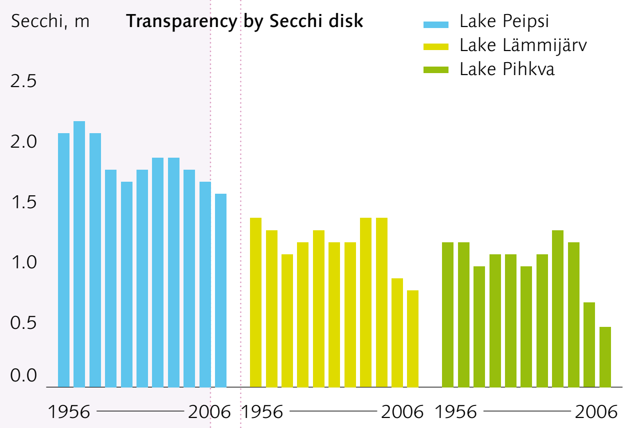




**Figure 3.** *(left) Concentration of chlorophyll-a during open water period in Peipsi, Lämmijärv and Pihva from 1985 to 2006*

**Figure 4.** *(right) Transparency by Secchi disk during open water period in Peipsi, Lämmijärv and Pihkva from 1956 to 2006.*

### Chlorophyll

In correspondence with the high total P and total N concentration in Lake Pihkva, the chlorophyll-a concentration is significantly higher in Lake Pihkva (20-50 μg l-1) than in Lake Peipsi (10-20 μg l-1), and also significantly higher in the Russian part of Lake Peipsi than in the Estonian part. In comparison to IJsselmeer the Lake Peipsi values are quite low, but in Lake Pihkva they are similar (see chapter 3.1 and Figure 3).

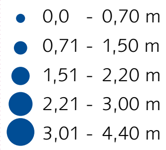
### Transparency

Because of the low chlorophyll-a levels, the transparency in Lake Peipsi is quite high (> 1.5 m) during the summer months and low in Lake Pihkva (0.5-1 m), the latter corresponding quite well to that in IJsselmeer (Figure 5). Particularly in Lake Pihkva and Lake Lämmijärv, transparency has decreased much more rapidly since 2000 than in Lake Peipsi, because of the more rapid increase in P concentration in these lakes. The gradient in transparency in IJsselmeer has a different cause than in Peipsi. In Lake Peipsi and Lake Pihkva the cause is limitation by nutrients, whereas in IJsselmeer there is even a negative correlation between nutrients and chlorophyll. Here, limitation by grazing of phytoplankton by Zebra Mussels *Dreissena polymorpha* is the most plausible explanation (see chapter 3.1).

In correspondence with the chlorophyll-a concentration, the transparency is not only significantly lower in Lake Pihkva than in Lake Peipsi, but also significantly lower in the Russian part of Lake Peipsi than in the Estonian part (Figure 5). In comparison to IJsselmeer the Lake Peipsi values are quite high, but in Lake Pihkva they are almost the same as in IJsselmeer (see chapter 3.1).

### Phytoplankton and zooplankton

In correspondence with the gradient of nutrients in both lakes, the phytoplankton shows a gradient of increasing density from south to north and from east to west, clearly limited by nutrients and in turn limiting the transparency (Figure 6). The dominant groups are bacillariophyta (diatoms), cyanophyta (blue-greens) and chlorophyta (green algae). The phytoplankton dominants alternate in different seasons, years and lake parts (Laugaste *et al.*, 2001). In the areas with high nutrient concentrations the share of cyanophyta is relatively high, but in general bacillariophyta dominate during most of the year (Figure 6). In Peipsi *Gloeotrichia echinulata* and in Pihkva *Aphanizomenon flos-aquae* were dominant among blue-greens in summer (Laugaste *et al.*, 2001).



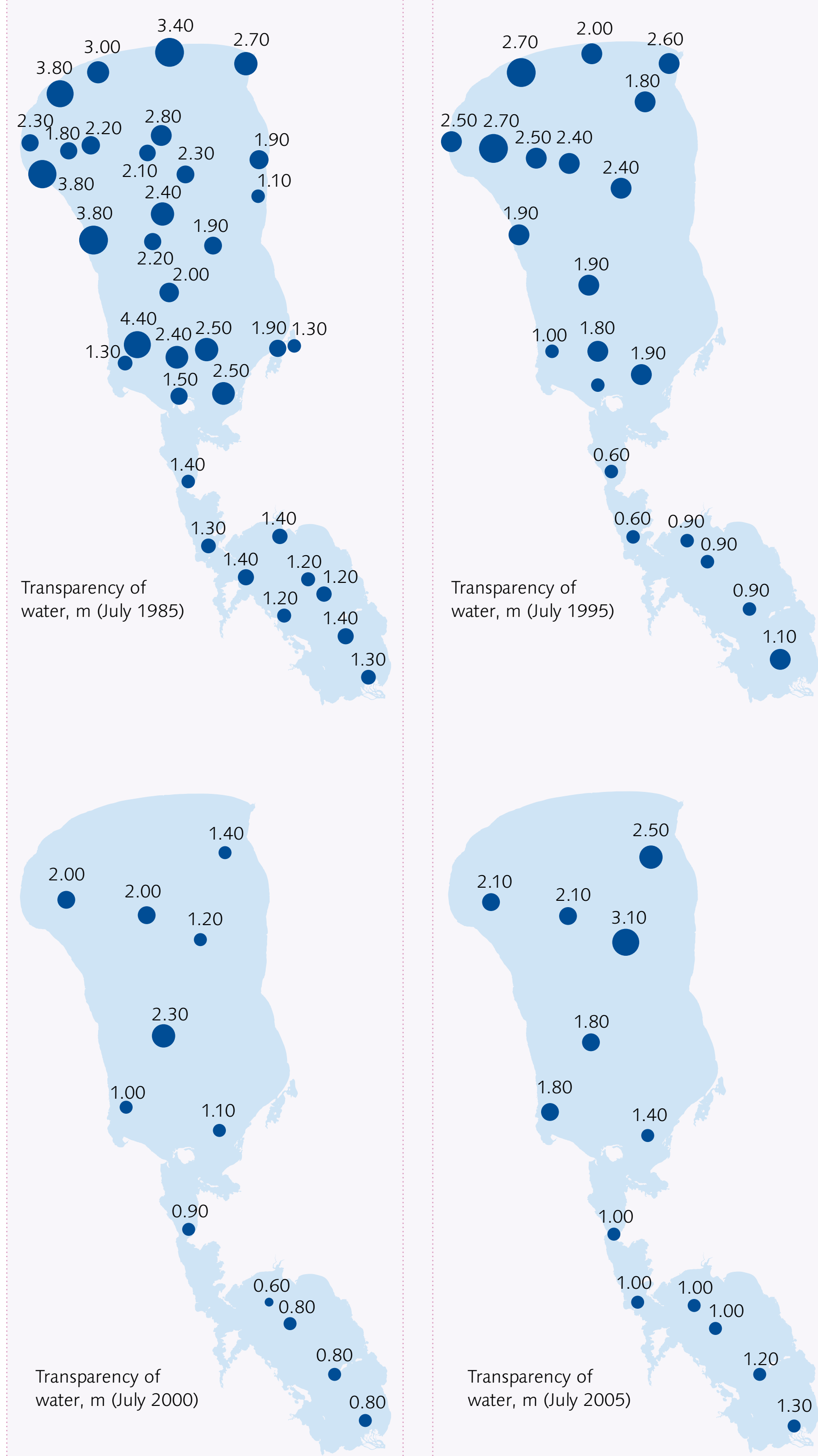




**Figure 5.** *Transparency in Peipsi, Lämmijärv and Pihkva in 1985-2005*

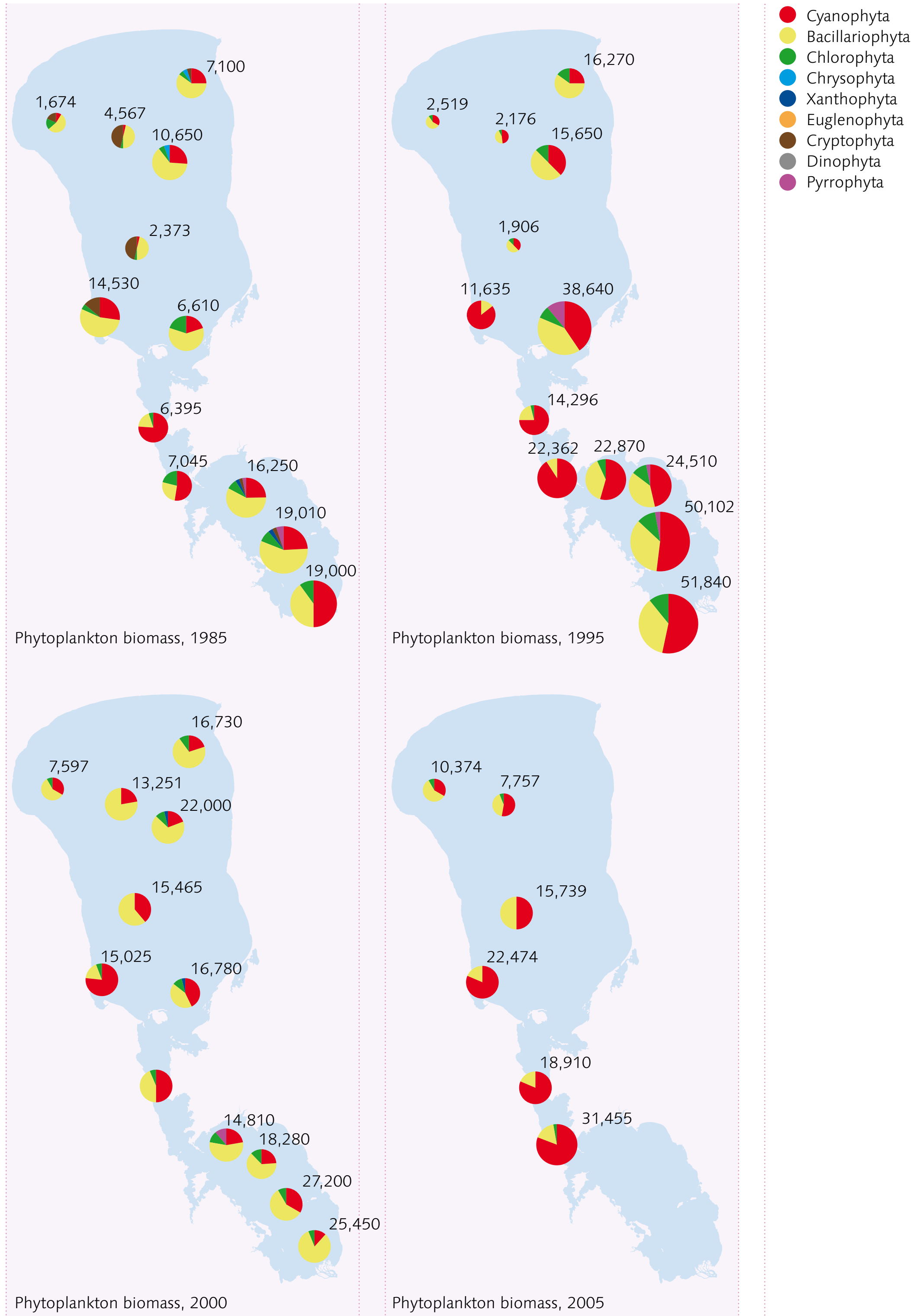



**Figure 6.** *The biomass (gm-3) and composition of phytoplankton in Peipsi, Lämmijärv and Pihkva in 1985-2005. In the group Pyrrophyceae the two groups Dinophyceae and Cryptophyceae are taken together.*



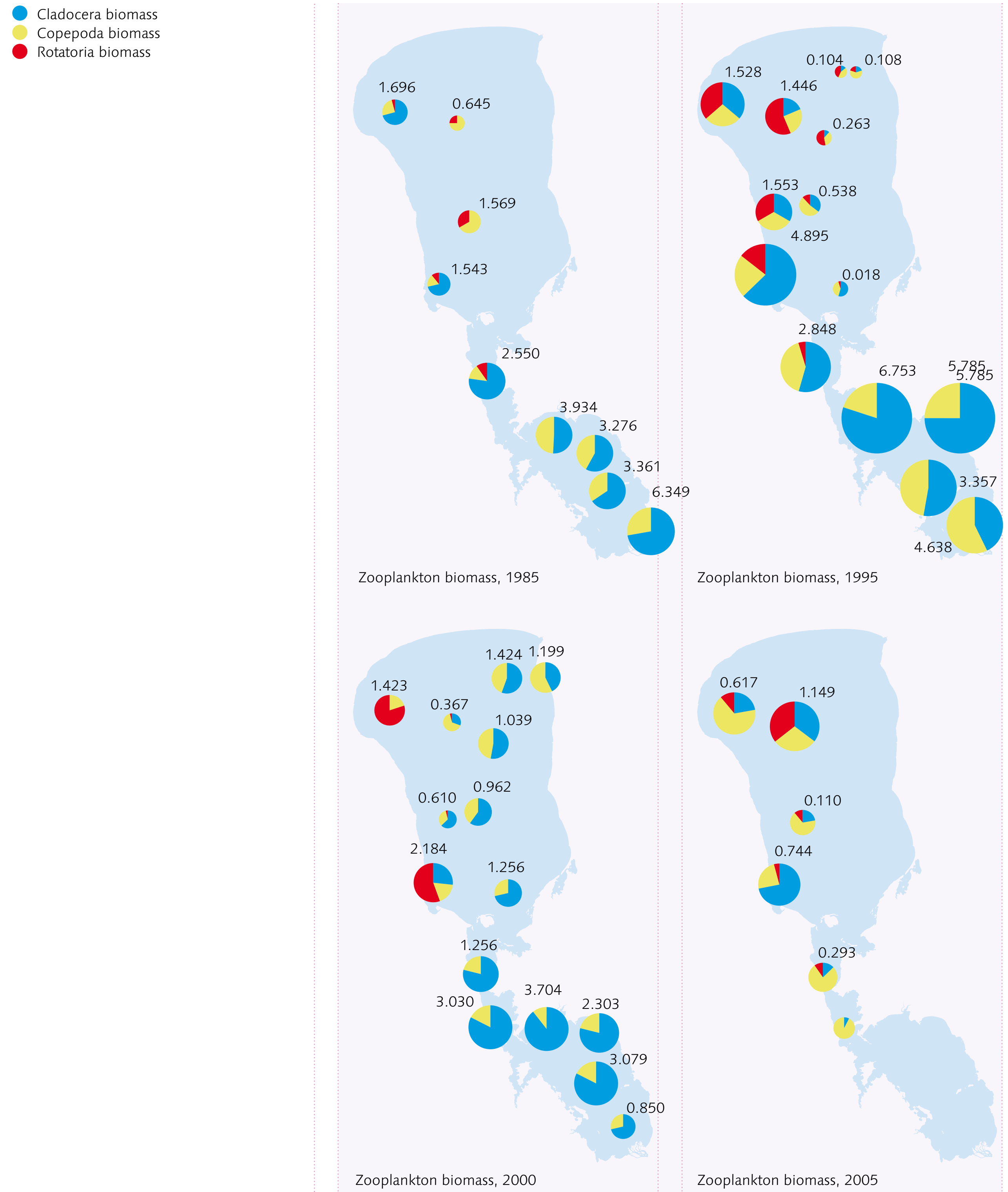



**Figure 7.** *The biomass (gm-3) and composition of zooplankton in Peipsi, Lämmijärv and Pihkva in 1985-2005*

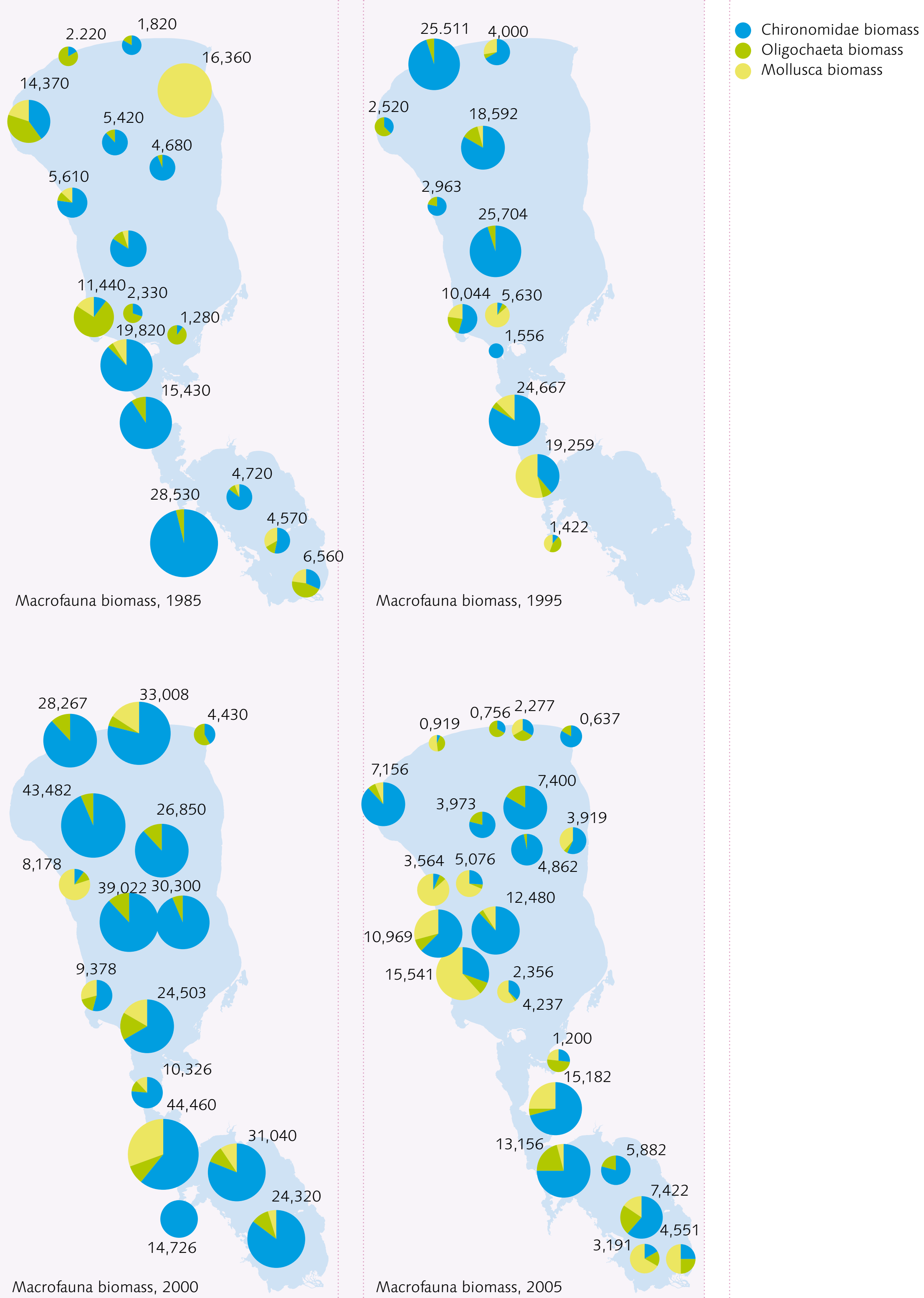



**Figure 8.** *The biomass ($gm^{-2}$) and composition of zoobenthos in Peipsi, Lämmijärv and Pihkva in 1985-2005*

Also zooplankton follows the general picture of high densities in Lake Pihkva and low densities in Lake Peipsi (Figure 7). The dominant groups are cladocera, copepoda and rotatoria, but the latter are only abundant in Lake Peipsi and do not play a significant role in Lake Pihkva. Within Lake Peipsi there is not a clear east-west gradient as was obvious for phytoplankton (Figure 7).

**Macrofauna**

For macrofauna there is no clear gradient from the south to the north or from the east to the west (Figure 8). Chironomidae, oligochaeta and mollusca dominate the macro-zoobenthos. In contrast to phytoplankton and zooplankton, macrofauna is not related to water volume but to surface area. The amount of organic matter accumulating on the bottom will compensate the differences in volume in Lake Peipsi and Lake Pihkva: the high density of phytoplankton in Lake Pihkva may lead to a similar amount of organic sediment as the lower density in Lake Peipsi, because the water column in Lake Peipsi is more than twice higher. Therefore the amount accumulating on the bottom may be almost the same and may lead to similar feeding conditions for chironomids, oligochaeta and mollusca. As far as Zebra Mussels are concerned, only the shallow shore line up to 4-7 meter is occupied. The deeper parts with a thick layer of organic matter do not seem suitable for this species (see box *Dreissena*).

**Fish**

Considering the two main predatory fish species, Pike *Esox lucius* and Pikeperch *Stizostedion lucioperca*, it is obvious that pike is more abundant in the shallow but more turbid Lake Pihkva, whereas for Pikeperch the opposite is true (Figure 9). For Bream *Abramis brama* and Roach *Rutilus rutilus* also Lake Pihkva seems more suitable than Lake Peipsi considering the density. Pike, Bream and Roach use the floodplains for spawning and in that respect Lake Pihkva is more suitable than Lake Peipsi, because the proportion floodplain-open water is more favourable in Lake Pihkva than in Lake Peipsi. Pikeperch is not dependent on floodplains as this species makes its own nest in the open water area and is therefore more abundant in the open water. Apparently, the high turbidity does not prevent Pike to grow even higher stocks in Lake Pihkva than in the clearer Lake Peipsi. Probably floodplains are more important than transparency.

**Discussion**

The gradients of nutrient concentrations in Lake Pihkva and Lake Peipsi are related to the inflow of nutrient-rich water coming from the Velikaya River. As a large part of the nutrients is retained on its way from the inlet of Lake Pihkva (Velikaya) to the outlet of Lake Peipsi, the concentration of nutrients decreases towards the outlet. This is true for total phosphorus as well as for total nitrogen. It also causes a gradient in density of algae and transparency, and therefore a gradient in organic production. This gradient runs from Lake Pihkva to Lake Peipsi and within Lake Peipsi there is a gradient from south-east to north-west. Higher in the food-chain, this gradient is also present for zooplankton, but only when comparing Lake Pihkva and Lake Peipsi, not within Lake Peipsi itself. For zoobenthos this south-north gradient is not clear at all and for fish it is different per species.

When considering the depth of Lake Pihkva and Lake Peipsi, the difference in concentration of nutrients is largely evened out and can therefore merely be explained as a dilution effect. Integrating the whole water column makes both lakes more equal and may explain the small differentiation in the zoobenthos distribution. For fish the differences between north and south are more easily explained by the spawning behaviour of the different species and not at all by a possible difference in primary production.

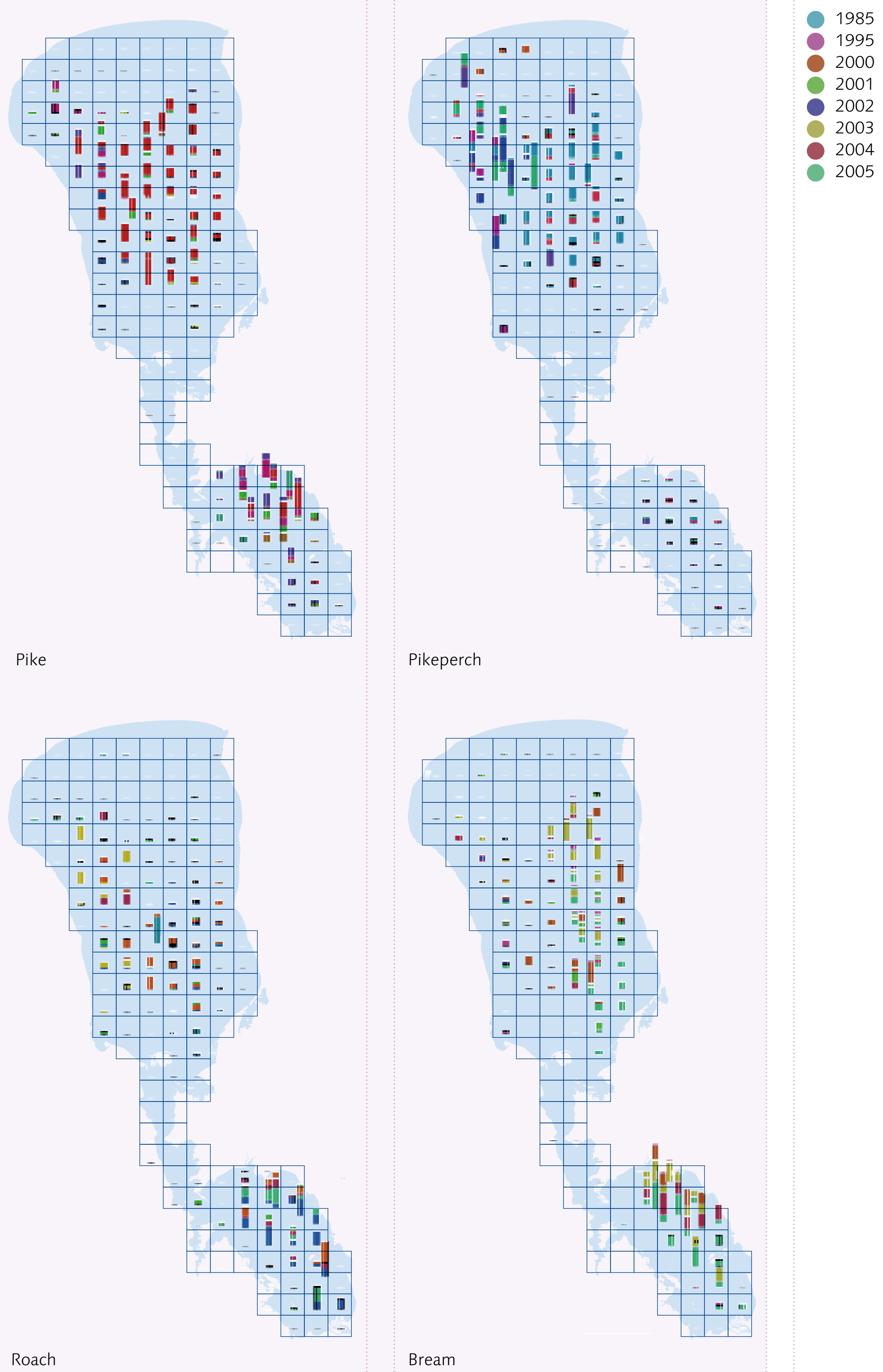


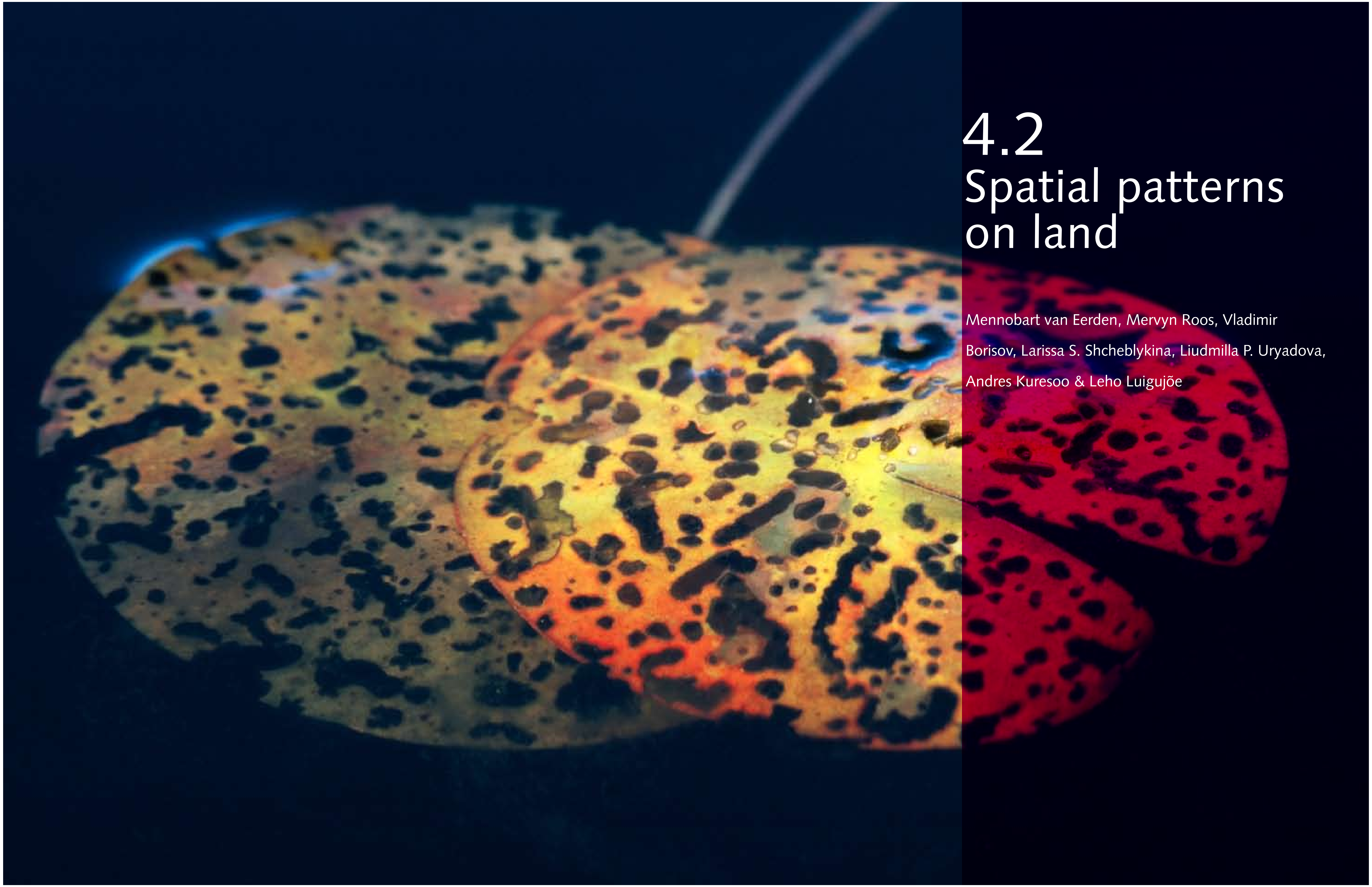

**Figure 9.** *The relative biomass of Pike, Pikeperch, Bream and Roach in Peipsi, Lämmijärv and Pihkva in 1995-2005*

Since 1995 there has been an increase in nutrient load, particularly of phosphorus. This has caused the difference between Lake Pihkva and Lake Peipsi to become greater than it was in the past. The share of cyanobacteria increased and problems with blooms of cyanobacteria occurred recently. It is still unclear whether this is related to a gradual change in climate and whether it is comparable to the changes in the fish populations. Because of these changes Lake Pihkva has changed into a more eutrophic lake, very similar to IJsselmeer when considering total P, chlorophyll-a concentration and transparency. However, Lake Pihkva still is a natural lake with a fluctuating water level and associated floodplains. Therefore the dynamics of the fish populations seem to be more controlled by water level fluctuations, temperature fluctuations and flood plains than by eutrophication per se.

**Acknowledgements**

In this chapter data obtained within framework of the Estonian target financed project SF 0362483s03 and the Estonian Science Foundation grant 6820 are used. We thank the following scientists for contributing with data: Juta Haberman, Andu Kangur, Peeter Kangur, Reet Laugaste, Anu Milius and Tõnu Möls.

*Salted Roach being air-dried.*



# 4.2 Spatial patterns on land

Mennobart van Eerden, Mervyn Roos, Vladimir Borisov, Larissa S. Shcheblykina, Liudmilla P. Uryadova, Andres Kuresoo & Leho Luigujõe

Biodiversity patterns on land were related to environmental characteristics of the landscape around the lake. For comparison we focus on breeding birds in a grid of 20x20 km. Peipsi has more species than IJsselmeer, reflecting the more complete ecosystem. Bird species in the individual grid cells relate to habitat type, especially the bog and fen series contributes to species richness.

A high biodiversity is often mentioned as a nature conservation goal. The term is often used in policy documents and rarely quantified. The different plant and animal groups that constitute an ecosystem are rarely investigated at a level that allows for integrated analysis. Our project in Peipsi and IJsselmeer is no exception. The group of plants and insects alone would already comprise over 5000 species, not to mention the other invertebrate groups. As landscape patterns were already mapped at a larger scale in both regions, we grasped the opportunity to describe the large-scale pattern of distribution of breeding birds in relation to habitat. Habitat is defined as the conglomerate of physical and biotic factors at a place where an animal lives (Partridge 1978).
Birds were reasonably well investigated. In The Netherlands and Estonia mapping of breeding birds was carried out by SOVON (2000) and Renno (1993), EOS (2000) respectively. For Russia fewer data were available and here we used mainly literature data and our own observations between 1999-2006. For reasons of comparison we used a grid of 20x20 km in both Peipsi and IJsselmeer, thus allowing large-scale comparison of different landscapes. As was already pointed out in chapter 3.6, both areas differ a lot, the main difference being that the percentage of cultivated land in IJsselmeer is much higher than in Peipsi. The method of large grid cells allows not only large-scale comparison, it is also the only way to compare such large territories without a lot of missing values. Moreover, for rare birds the advantage is that the exact positioning of breeding sites is not indicated to a level that threatens the conservation status.

**Methods**

In IJsselmeer 20 cells of 400 km$^2$ were analysed, in Peipsi 27. All cells were adjacent to water and up to one level or, in a few cases, two levels to the interior. That means that on average the coastal region is focused at in a range of up to 20 (35) km around the lake. In this way, the role of contrasting landscapes like polders, forests, heath lands, bogs and fens with respect to biodiversity could be described.
Breeding birds differ greatly regarding size and habitat use. For instance, different species of songbirds may be found in reed beds, wet meadows, open bare sand, bogs and fens as well as forests. Ducks and waders prefer open wet landscapes, whereas birds of prey use large hunting territories around breeding sites, which require a low level of disturbance. Therefore the presence of breeding birds is indicative of habitat quality. Bird species were categorised as "dry" (field & forest) or "wet" (wet meadows, fens, marshes and shores). Another division was the distinction between colonial and solitary species. We used three levels of occurrence with respect to observation level: surely, probably and possibly breeding. Here we present all scores combined, for reasons of simplicity. In order to focus on specific groups, we identified rare birds as breeding in less than 8 (IJsselmeer) and 12 (Peipsi) grid cells.





*Oostvaardersplassen, example of long gradients in marsh vegetation.*

The distribution of these rare species is analysed separately in order to focus on specific needs of these species with respect to habitat choice.
Analysis of landscape characteristics follows the procedure outlined in chapter 3.6. Water was left out for reasons of comparison of breeding habitat s.s.

**Overall number of species IJsselmeer**

In the area of study, 195 species were found breeding, the lowest number being 72 and the highest 155. Figure 1 shows that, generally speaking, per cell more breeding bird species occur towards the east and south. This is related to the fact that the percentage of water decreases in these directions. About half of the species consist of species of fields and forests, thus having a relationship with rather dry habitats. In the polders of Flevoland and especially at the Veluwe, this percentage was even higher, ca. 65 resp. 75%. Surprisingly, colonially breeding water birds were present in all grid cells, the highest percentage occurring in Flevoland (nr 14, with Oostvaardersplassen), Noord Holland (nr 17 with Naardermeer) and Friesland (nr 2 with Workumer- and Makkumerwaard). These areas share the presence of large nature reserves consisting of shallow water and a large transitional zone between water and land (wet grasslands, reed beds, wet forests and fen-peat).

**Rare and uncommon species IJsselmeer**

If we concentrate on the rare species, a shift towards the species of wet areas is visible (Figure 2). In the grid cells bordering the large lakes, often three quarters or more are water birds, with a large proportion of colonially nesting water birds. High-ranking are large complexes of wetland habitat like Oostvaardersplassen, IJmeer, Naardermeer and Vechtplassen, Zwarte Meer and Wieden as well as Weeribben, Lake Tjeukemeer, Linde- and Tjonger floodplains. In contrast with Figure 1, there is an obvious difference between the coastal and "inland" grid cells with respect to the proportion of "dry" and "wet" rare species. This is related to the fact that colonially breeding water birds need a larger scale of open water and wetland habitat. Vice versa, the rarer birds confined to drier soils hardly appear in the region of IJsselmeer and Markermeer/IJmeer. Apparently they are found mainly in afforested areas. The cells 12, 16, 18 and 19 comprise the Borderlakes. The percentage occurrence of rarer water birds is highest in Zwartemeer/Wieden and IJmeer/Naardermeer, intermediate in Veluwemeer/Drontermeer and Gooimeer, Eemmeer and lowest in Wolderwijd and Nuldernauw. The percentage of open water decreases in this order, as does the quality of reed beds.

**Relationship with habitat characteristics**

The landscape in the IJsselmeer area is not very diverse. Arable and grasslands, most of which highly artificial in terms of plant species and fertilisation, constitutes over 90% of the land surface area in 13 out of 20 cells of 400 km$^2$. Rare species occur predominantly in those areas where a larger surface area of wetlands or forests occurs. Interestingly though, the largest numbers of rare species do not occur in the areas where this percentage is highest (cells 20, 19 Veluwe, and 14 Oostvaardersplassen) but in cells 12 (Wieden/Zwartemeer), 16 (Veluwemeer/Veluwe) and 17 (Naardermeer/IJmeer). These areas share the combination of shallow freshwater, open fen and a considerable afforested area or heath land. Open fens share a great part of rare breeding species. Perhaps because these areas are so well protected and managed, the relationship with surface area does not show so clearly. Apparently the management of habitat is an important issue. Of course, our method does not account for the total number of breeding pairs present. This quantitative measure probably would emphasise the role of habitat scale more clearly than the methods applied here.

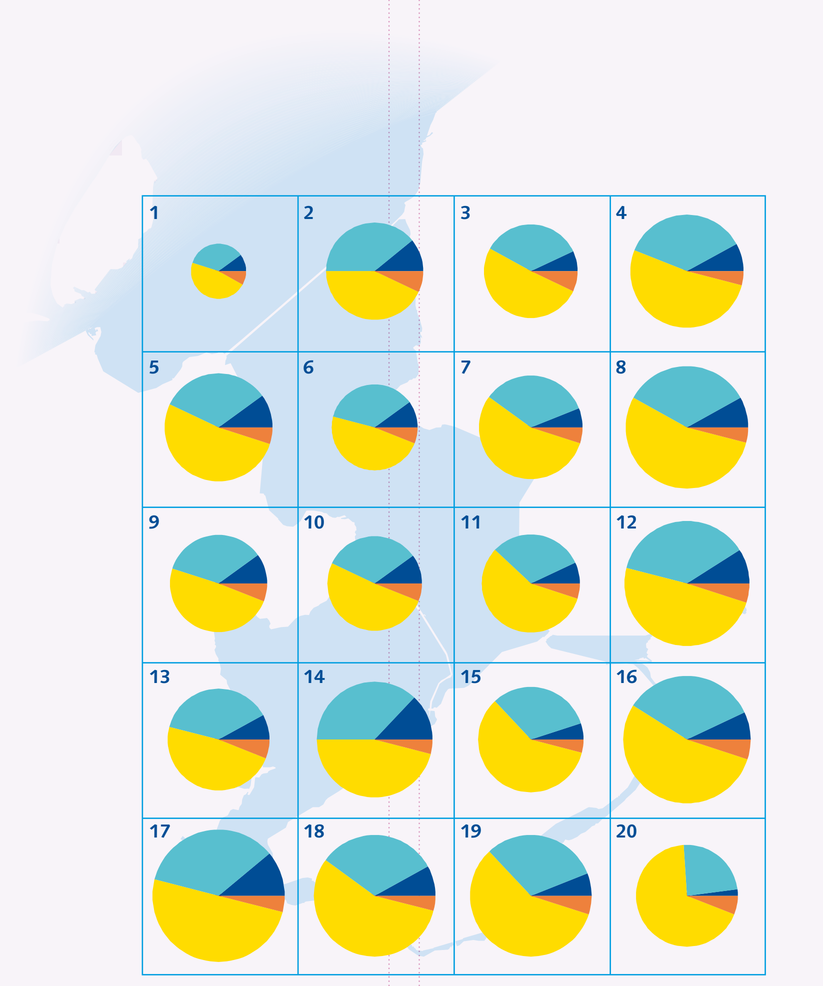



**Figure 1.** *Spatial distribution of total number of species of breeding birds in IJsselmeer. A division is made between land and water birds, the colonially nesting species indicated separately.*

**Overall number of species Peipsi**

In the area of study, 201 species were found breeding, the lowest number being 87 and the highest 171. The number of breeding species is thus 4% higher than in IJsselmeer. For individual grid cells this difference is larger, often 10-15% more species breeding in Peipsi. Figure 3 shows the distribution of the species. Most grid cells host 150 species or more and the distribution is rather even (Figure 4). The total number is mainly due to the occurrence of birds confined to drier landscapes. Water birds add to this and in these cells the highest number of species are found. This is the case in cells nr. 3 (Narva River and wetlands), 15 (Emajõe Suursoo), 16 (Kolpino Island, Samolva Bay, raised bogs of Emajõe Suursoo), 17 (Zhelcha River and bogs), 20 (Pnevo and Lämmijärv reedlands), 21 (Chernaya River and bog complex), 24 (Lisye bogs and forelands), 25 (Talabskiy islands and coast of Remdovskiy Zakaznik).

**Rare and uncommon species Peipsi**

Rare species distribution shows a clear pattern with larger differences over the grid cells (Figure 5). A main cluster is formed by the cells 15, 16, 17, 20, the area of the isthmus between Peipsi and Pihkva. The number of rare birds is relatively high also in cells 19, 21, 23-25 and 27, the coast around Lake Pihkva. These are significantly more important than the coasts of Lake Peipsi s.s. Interestingly, the northernmost three grid cells are important, too (1-3), covering the extensive forest areas with large inland raised bog and floodplain





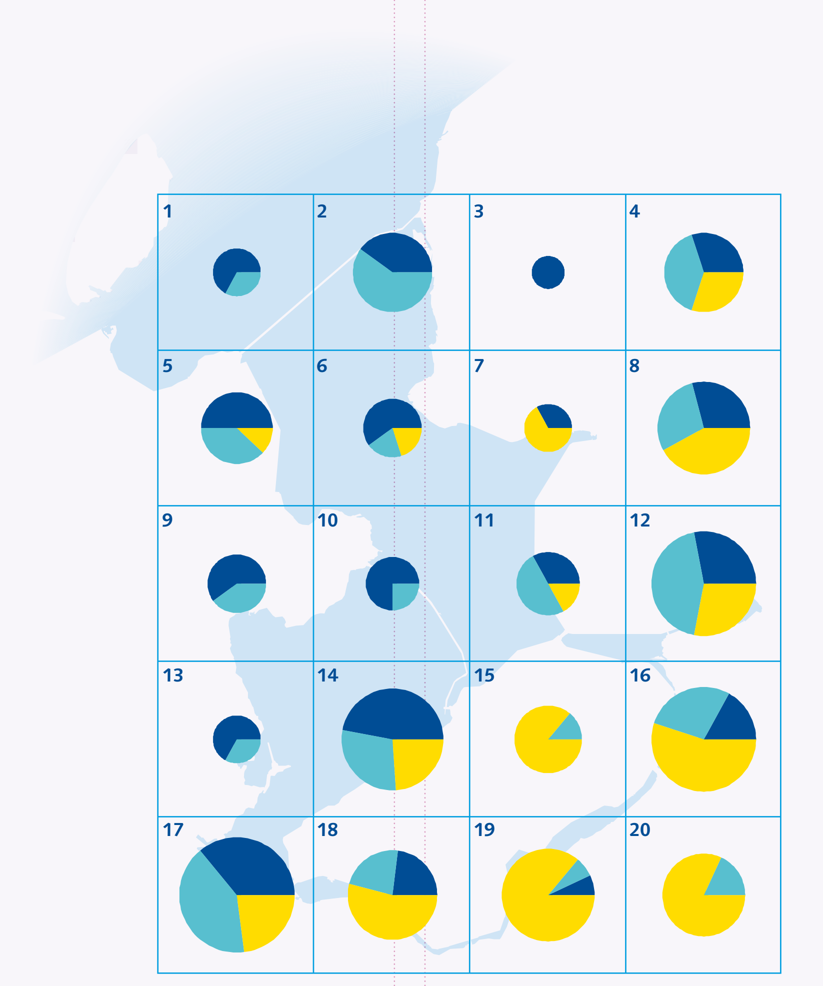
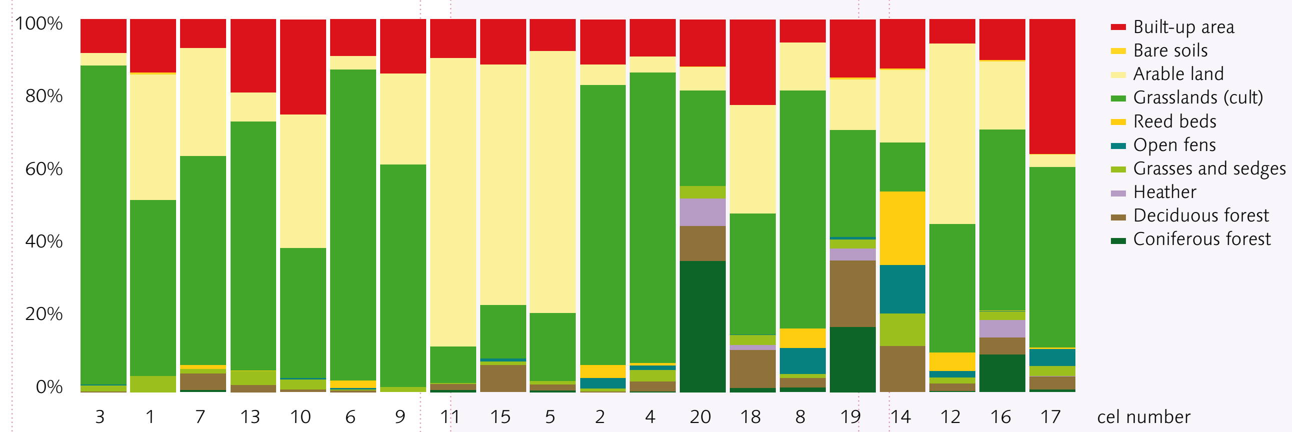



**Figure 2.** *Spatial distribution of number of species of rare breeding birds in IJsselmeer. A division is made between land and water birds, the colonially nesting species indicated separately*

**Figure 3** *Landscape characteristics for 27 grid cells in the region of IJsselmeer, arranged according to increasing number of rare species of birds breeding (cells 3 –>17)*



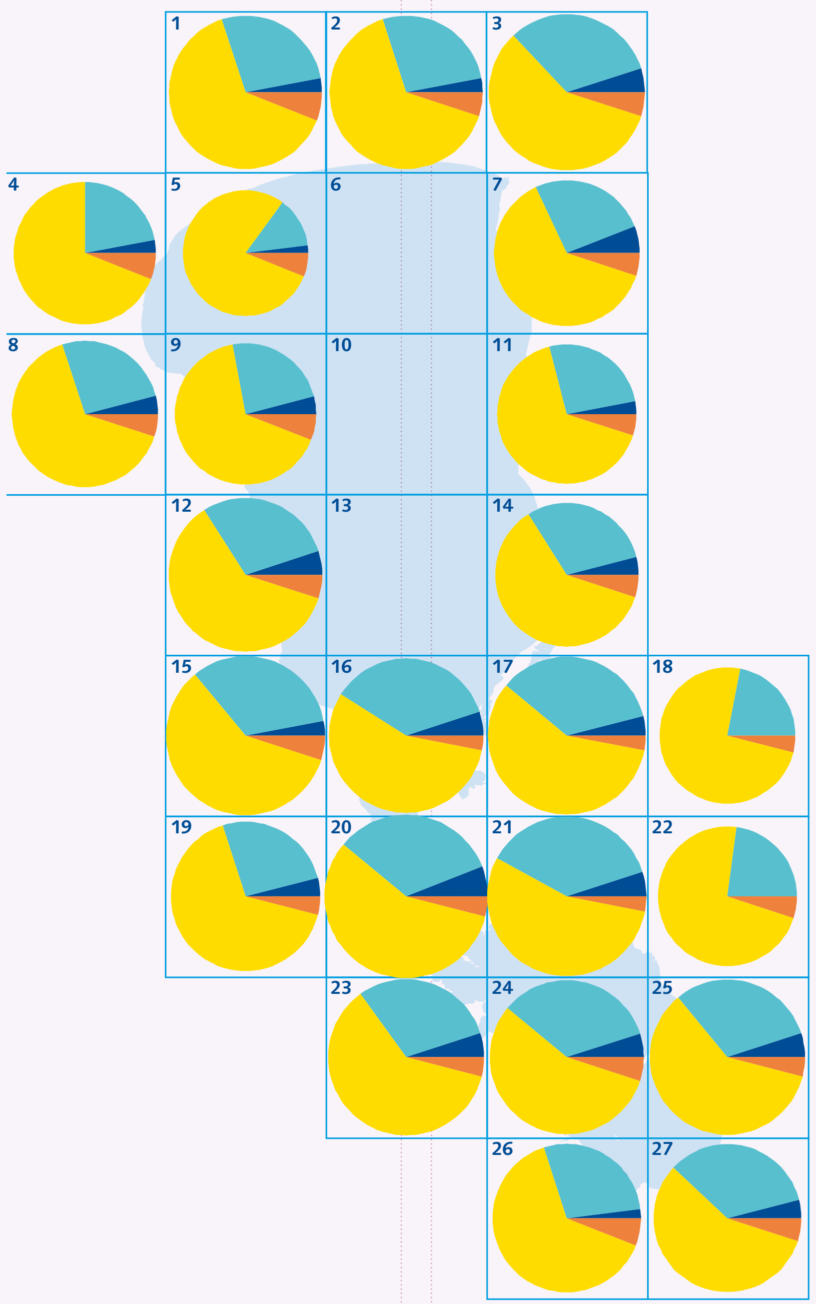



**Figure 4.** *Spatial distribution of total number of species of breeding birds in Peipsi. A division is made between land and water birds, colonially nesting species are indicated separately*

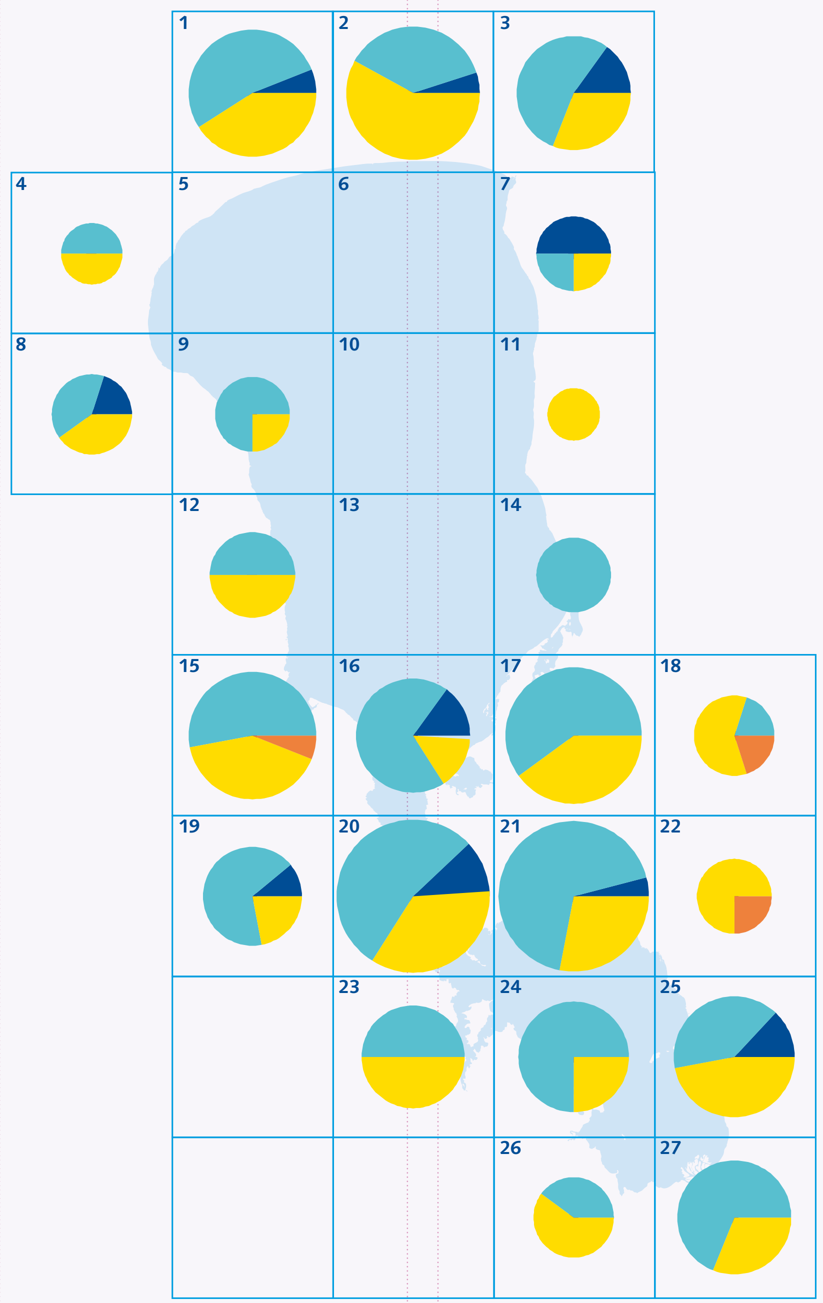



**Figure 5.** *Spatial distribution of number of rare species of breeding birds in Peipsi. A division is made between land and water birds, the colonially nesting species are indicated separately*

areas between Oonurme River in the west and Narva and Piyussa Rivers in the East.
In Peipsi, no strict spatial division between the proportion of "dry" and "wet" species occurs. Only in the area of Raskopel Bay (14) waterbirds form an exclusive group. The other cells comprise a fluctuating portion (25-60%) of "dry" species confined to forest and bog areas. In cells 18 and 22 land birds predominate. Colonial water birds are related to the area where islands occur, i.e. the area of Lämmijärv mentioned earlier, the Talabskiy Islands and, again, also the wet bog complexes in the north and Kozlov Bereg in the NE of Peipsi.

### Relationship with habitat characteristics

Figure 6 shows landscape characteristics for individual grid cells, according to the classification outlined in chapter 3.6. By arranging the grid cells in descending order with respect to the number of rare breeding birds, the following conclusions can be drawn. Firstly, the highest number of rare birds correspond to areas with relatively little forest (20-40%), combined to a high proportion of wetlands, consisting of a mix of fen-peat, open raised and ridge-hollow bogs, bog forests (30-40%), little agriculture (10%) and no or almost no built-up areas. Within this group the number of breeding species decreases from 20-26 rare species in the three best cells, to 15-17 in the next three cells, parallel to fewer fen-peat and bog forests and slightly more exploitation (hayfields, arable land).
In the next group this trend continues, ranging from 13 to 5 species. Wetland area further declines along this ranking, while arable and grasslands amount up to 30% and forests increase up to 40%.
A third group containing 4 species or less shows even more afforested area (40-50%) as well as the highest proportion of paludified forests (10%). Except for the forest, some cells in these groups are quite reminiscent to the best category, having a considerable (and varied) amount of wetlands (especially open ridge-hollow bogs) but apparently not too many rare breeding birds. Examples are the numbers 7 (Dobruchi), 14 (Klenno) and 2 (Agusalu), cells which contain fewer rare species than expected.
Another exception to this pattern is found in nr 16 (Lisye) on the west coast of Lake Pihkva, which holds 13 rare species; in comparable areas at the east coast this is 10-13 species more. We believe that the influence of man might be responsible to for this. The mentioned areas all lie within the neighbourhood of small villages, or, in the north, towns. The disturbance by people may be the factor limiting the rarest breeding species to occur here, but further research is required to verify this hypothesis.
A positive outlier is the Velikaya Delta (27). According to the landscape pattern with few fen peat and almost no raised bog areas, combined with a large proportion of arable lands and hayfields in the neighbourhood of a big town, far fewer species are to be expected. However, the reserve status of part of the delta, as well as the highly diversified riverine habitat of the flooded grasslands, reed beds and creeks may be responsible for the unexpectedly high number of species found.

### Biodiversity assessment complete?

Besides the overall number of species, the numerical factor would yield significant distinction in relation to habitat. Numbers of breeding pairs (if available) would be an extra level of distinction. For instance in colonial water birds, an area like Oostvaardersplassen hosts about 150-200 pairs of Spoonbills, 50-140 pairs of Great White Egret and >1500 pairs of Cormorants. Also Bittern *Botaurus stellaris* may breed with >40 pairs in this reserve due to the presence of large-scale marshes and wet meadows and pools. Nowhere else these species are so numerous. In the entire region (even at country-scale and beyond), the Oostvaardersplassen therefore acts as a real hotspot for colonially breeding





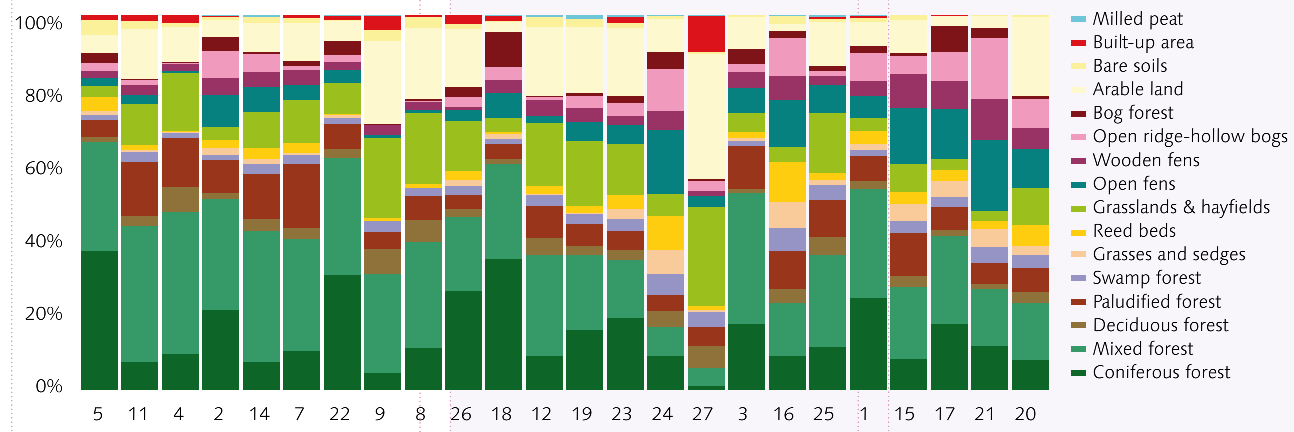



**Figure 6** *Landscape characteristics for 27 grid cells in the region of Peipsi, from left to right arranged according to increasing number of rare species of birds per breeding (cell 5 –>20)*

water birds, even more clearly so than is visible from Figure 2. Likewise, for ground-breeding terns, the island of Kreupel has a similar position for colonially breeding birds, by far outnumbering all other grid cells. Here, the presence of more than 4000 breeding pairs of Common Tern, accompanied by an array of other rare species, makes this island incomparable to all other areas.
Unfortunately, the quantitative data are insufficient to carry out such analysis in detail. It is interesting, however, to see that the rankings outlined above for the overall number of breeding species and the rare species describe the basic pattern quite well. For Peipsi this is even more so, as quantitative data are lacking over large areas, but also because Peipsi has less colonial breeding birds. Therefore we think that the patterns observed reflect the actual situation with reasonable accuracy.
Of course the large inland areas and extremely inaccessible bog complexes, especially on the Russian side, may contain species that have not yet been discovered. This may be true for some boreal species of forests like owls (Great Grey Owl *Strix nebulosa*), birds of prey like Merlin *Falco columbarius*, rare passerines like Rustic Bunting *Emberiza rustica*, Booted Warbler *Hippolais caligata* and Lanceolated Warbler *Locustella lanceolata*, all species which reach their westernmost distribution range in the area to the east of Lake Peipsi. The same holds in the northeast for some rare boreal waders such as Terek Sandpiper *Xenus cinereus* and Jacksnipe *Lymnocryptes minimus*. Although individual grid cells will yield several different new species after continued investigation, the overall pattern presented here is probably valid.

### Lakes compared

Peipsi hosts more breeding species than IJsselmeer. This is directly related to the presence of large-scale marshes and fens, peat bogs and floodplain areas. Furthermore, the undisturbed forests and countryside, combined with intact ground water profiles and, on average, mesotrophic instead of eutrophic conditions, are responsible for this. A 15% difference may not seem significant, but on this habitat scale it is.
A few examples may illustrate the different availability and quality of terrestrial habitat in both regions. In IJsselmeer we find four species of woodpeckers breeding, one being common (Great Spotted Woodpecker *Dendrocopus major*) and three less common (Black *Dryocopus martius*, Green *Picus viridis* and Little Woodpecker *Dendrocopus minor*). Peipsi forests share these species but also have White-backed *D. leucotos* , Grey-headed *P. canus*, Three-toed *Picoides tridatylus* and Middle Spotted woodpecker *D. medius*. A similar example can be given for owls: four species breed in the forests and marshes around IJsselmeer, eight in Peipsi.

On the aquatic side, species like Little Gull *Larus minutus* and Black Tern *Chlidonias niger* illustrate the mesotrophic conditions, providing a lot of insects and the presence of floating mats of macrophytes where the birds can breed. In the shoreline of Peipsi, the striking dominance of Great Reed Warbler *Acrocephalus arundinaceus* illustrates the dynamics of the water table, resulting in tall, coarse reeds. In IJsselmeer part of the rare breeding birds are related to the estuarine character of the area. Still species like Avocet *Recurvirostra avosetta*, Sandwich Tern *Sterna sandvicencis*, Arctic Tern *S. paradisaea* and Kentish Plover *Charadrius alexandrinus* are present as a breeding bird at places where bare mud or coarse sand with shells are available. This habitat is very much under pressure and needs dynamics like wind, water current or, even better, tides. Conditions of stand still lead to the deterioration of the (sub)-habitat involved and consequently the long-term loss of these species.

Another way of comparison is to look more specifically at the rare species. Table 1 lists the 10 most rare species in each region, according to their presence or absence established by the grid method. Rare in this way means with an extremely limited distribution, not referring to the total number of breeding birds. Of the 40 most rare species in Peipsi, 14 occur as breeding bird in IJsselmeer, the other way around, of the 40 rarest species of breeding birds in IJsselmeer, 22 occur in Peipsi. Again, this corroborates the greater biodiversity in Peipsi. It is interesting to see a species like Cormorant on the list for Peipsi, and White-tailed Eagle for IJsselmeer. This illustrates that the current expansion of these species is either NE for Cormorant or westward for White-tailed Eagle. The rarest species show relatively many "borderline" species, i.e. on the edge of their distribution. Often, these species show up at the regions most suitable to them, that is in the best habitat (Fretwell & Lucas 1970). Therefore we consider the focus on this group relevant.
Only two species occur in the top 20 of both regions: Little Bittern *Ixobrychus minutus* and Little Tern *Sterna albifrons*. Both are water birds and specialists. Little Bittern favours mesotrophic fen conditions and Little Tern bare sand with shells in the neighbourhood of rich fishing grounds. Both habitats are rare or unstable and can only be found enduringly in areas with large transitional zones of habitat and/or dynamic processes. Similar factors explain the occurrence of rare country birds like Hoopoe *Upupa epops* and Roller *Coracias garrulus* in Peipsi and Grey Shrike *Lanius excubitor* and Tawny Pipit *Anthus campestris* at the Veluwe, the latter two now probably extinct as breeding birds (SOVON).

### Conclusions

Birds show a strong relationship with landscape characteristics, habitat diversity and level of protection being both important. Peipsi is by far more diverse with respect to habitat and this completeness of the different landscape zones is reflected by higher species diversity than in IJsselmeer. In IJsselmeer the dominant role of agriculture determines the present situation. Due to the creation of strict reserves along with the establishment of "new nature", the situation is still not too bad. Especially by focusing further on the restoration of marsh and fen habitat, both in the lake as well as inland, the situation could be restored even more.

The fact that IJsselmeer has relatively more colonially breeding species is probably due to two factors. First, the existence of many island situations, many of which are man-made, and secondly, the fact that the feeding situation is different from Peipsi: a lot of small fish (mainly Smelt, but also larger species as prey for Cormorants) occur locally and are exploitable in the water column only locally. Breeding in colonies, combined with social foraging, may help birds to find these fish in unpredictable habitat.

*White-backed Woodpecker, Peipsi*

**Table 1.** *20 most rare breeding birds in Peipsi and IJsselmeer, according to distribution pattern. Species ranked according to systematic order*

| Peipsi | IJsselmeer |
|---|---|
| Little Grebe *Tachybaptus ruficollis* | Little Bittern *Ixobrychus minutus* |
| Red-necked Grebe *Podiceps ruficollis* | Night Heron *Nyctycorax nyctycorax* |
| Cormorant *Phalacrocorax carbo* | Little Egret *Egretta garzetta* |
| Little Bittern *Ixobrychus minutus* | Ferruginous Duck *Aythya nyroca* |
| Whooper Swan *Cygnus cygnus* | White-tailed eagle *Haliaeetus albicilla* |
| Short-toed Eagle *Circaetus gallicus* | Yellow-legged Gull *Larus cachinnans* |
| Peregrine Falcon *Falco peregrinus* | Great Black-backed Gull *Larus marinus* |
| Dunlin *Calidris alpina* | Little Gull *Larus minutus* |
| Great Snipe *Gallinago media* | Arctic Tern *Sterna paradisaea* |
| Lesser Black-backed Gull *Larus fuscus* | Little tern *Sterna albifrons* |
| Little Tern *Sterna albifrons* | Wryneck *Jynx torquilla* |
| White-winged Black tern *Chlidonias leucoptera* | Tawny Pipit *Anthus campestris* |
| Great Grey Owl *Strix nebulosa* | Grey Wagtail *Motacilla cinerea* |
| Hoopoe *Upupa epops* | Thrush Nightingale *Luscinia luscinia* |
| Roller *Coracias garrulus* | Melodious Warbler *Hippolais polyglotta* |
| Middle Spotted Woodpecker *Dendrocopus medius* | Zitting Cisticola *Cisticola juncidis* |
| Green Woodpecker *Picus viridus* | Short-toed Treecreeper *Certhia familiaris* |
| Citrine Wagtail *Motacilla citreola* | Grey Shrike *Lanius excubitor* |
| Dipper *Cinclus cinclus* | Two-barred Crossbill *Loxia leucoptera* |
| Booted warbler *Hippolais caligata* | Parrot Crossbill *Loxia pytyopsittacus* |

*Spoonbills, IJsselmeer*

# 4.3 Future trends in water

Eddy Lammens, Külli Kangur, Marina Melnik & Mennobart Van Eerden

It is clear that the food web in both lakes will change according to both global warming and management. A lower fishery pressure will lead to more predators and fewer fish-eating water birds. However, because of the complex interrelationships of the components, these trends are not easily outlined for specific groups or species. Modelling exercises may help to forecast future developments.

One of the most important differences between Peipsi and IJsselmeer is the degree of naturalness of both lakes. Although there is a significant eutrophication pressure on Peipsi, with increasing blooms of blue-greens and decreasing transparency (chapter 3.1), the lake is still natural with a highly developed shore-line vegetation and a large array of different habitats (chapter 3.6). In contrast to Peipsi, IJsselmeer is heavily modified and cannot be restored to a completely natural condition (Lammens *et al.* in press). The water level is fixed and the transition from water to land is very abrupt because of the presence of dikes and dams. So the interactions between water and land, mediated by flood plains, are absent in IJsselmeer in contrast to Peipsi (chapter 3.9). This is unlikely to change in the near future in IJsselmeer. Because of the minimal interaction with floodplain areas in IJsselmeer, it is unlikely that the fauna and flora communities in the water will become more similar to Peipsi, even if the nutrient load in IJsselmeer were to decrease to such a level that nutrient concentrations in both lakes are similar and transparency in IJsselmeer increases to > 1.5 m. The dams and the dikes have an important safety function and therefore complete restoration is not an option. However, mitigation is demanded by the WFD, as long as there is no damage to present functions. In that respect there are some options to improve the shore-line by creating marshes, which may act as spawning places and nurseries for young fish and constitute important areas for amphibians, water birds and mammals (Van Eerden *et al.* in press).

**Nutrients and climate**

In both lakes changes in the near future will be primarily related to changes in nutrient loads, climate and fishery. Also in Peipsi the nutrient load will eventually decrease again to levels comparable to 50 years ago with transparencies of about 2 meter (see chapter 3.1). However, the effects of climate change may hamper the 'restoration' process, as blue-greens have better chances to develop at high temperatures, even when nutrient levels are relatively low (see Table 1, chapter 3.1). In IJsselmeer the expected effects of changes in nutrient load cannot be related to former times when the load was low, because we have no data of this period. IJsselmeer was created in 1932 and only during the period up to 1950 the load of nutrients was relatively low. By paleolimnological research we were able to make an estimate of nutrient concentrations (40-80 µg $l^{-1}$ P), using diatoms as tracers (Cremer & Bunnik, 2006). Therefore, IJsselmeer does not really provide a natural reference by going back in time and it may be possible that nutrient levels will drop to a level of even 40 µg $l^{-1}$, which would be comparable to the concentration in Lake Veluwemeer since 1996. Less production of organic material (mainly algae) does not necessarily mean less food for fish and birds, but rather a shift in the food web. At such a low concentration of nutrients, transparency will be more than 1 m and also in the northern part of IJsselmeer Zebra Mussels will have more opportunity to develop, comparable to what happened in the Borderlakes since the second half of the 1990s (Waardenburg 2003). Roach and Perch will probably increase in abundance and Bream, Pikeperch and Smelt will decrease (Van den Berg *et al.* 2001). Both fish and birds respond to a change in transparency, as underwater visibility influences foraging behaviour (chapter 3.5).

**Climate change**

Climate change, however, may interfere in both lakes with decreasing levels of eutrophication and may have a delaying effect, as blue-greens will have more opportunity to develop, which will have a negative effect on transparency. Haldna *et al.* demonstrate that chlorophyll-a levels increased, transparency decreased and blue-greens bloomed in warm years with low water levels in Lake Peipsi and Lake Pihkva. There also are strong indications that Smelt and Vendace decrease in density and biomass because of direct and indirect effects of an increase in water temperature (see also chapters 3.3 and 3.4). The last 15 years have shown decreases of Smelt, (also of Vendace and Burbot in Peipsi) and increases of Pikeperch in both lakes (Kangur *et al.* in pres (1 and 2)). Particularly in Peipsi, the increase of Pikeperch is spectacular and causes indirect top-down effects on its prey-fish Smelt and Vendace (chapter 3.4). If climate change also has effects on the flooding regimes in the hinterland and shorebound marshes, this will also affect the recruitment of Pike, Bream and Roach in a negative way.

**Fishery**

In both lakes, fishery has a strong impact on the fish community. In IJsselmeer there is a need to reorganise the fishery because of the strong overexploitation of Pikeperch, Perch and Eel (Lammens *et al.* in press). The reduction of Eel fishery has already started, the reduction of gill-net fishery will follow. Due to overexploitation, these fish species have quite unbalanced populations consisting mainly of young individuals. The switch to a more extensive fishery will lead to a larger biomass of predatory fish, which in turn will cause a larger predation pressure on prey fish such as Smelt, Roach and Perch. In combination with climate change, the conditions for Pikeperch in particular will improve, but this will be counteracted by the decline of the Smelt population and a decrease of the nutrient concentration, favouring more clear water. The balance between a Pikeperch dominated ecosystem and a Perch (and Pike) dominated system may be influenced by a possible expansion of Zebra Mussels, causing a strong top down effect. In Peipsi this effect seems to be more limited and the lake is deep enough to give sufficient refuge to Pikeperch, even when transparency is high. Moreover, in Peipsi it will be more difficult to reorganise the fishery because its relative economic importance is higher than in IJsselmeer.

**Water birds**

Future trends in water birds very much depend on the availability of food. If the dominating effect of suspended silt in Lake Markermeer is reduced, the function for fish-eating birds may be restored. However, most water birds depend on Smelt outside the breeding season, and the future of this fish is uncertain. Therefore, the situation for fish-eating birds remains problematic. Attempts are made to unravel the ecology of Smelt and to see what could be done to preserve this species for IJsselmeer. Only if other small species become as abundant as Smelt was up to the early 1990s, the situation may improve. This can only happen if large-scale marshes produce more small cyprinids and sticklebacks.
For IJsselmeer the increasing transparency in winter favours Cormorants (Van Eerden, Van Rijn & Roos in press), but is generally negative for pursuit divers like mergansers, Smew and grebes and also for plunge divers like Black Tern

and Common Tern (chapter 3.5). These species all favour intermediate clear waters (chapter 3.5). Restoring the original gradient in transparency across the Houtribdijk, as it existed before 1975, would be of help in creating a dynamic zone where both fish and birds find suitable habitat.
In Peipsi, the current expansion of Cormorants will soon lead to the establishment of a population in summer. Cormorants already started to breed in the region, in the Gulf of Finland in big numbers and also closer by in Lake Võrtsjärv (Kuresoo & Luigujõe 2000). The future developments in this lake could be comparable to the situation in IJsselmeer, where Cormorants are an important part of the system since many decades.

**Macrophytes**

With respect to macrophytes, no expansion is to be expected in Reed, Bulrush and sedges at the current fixed water levels in IJsselmeer. Water level management is crucial with respect to future trends. If more natural water tables were established, emergent macrophytes would be favoured. Currently, plans are being developed to make better use of wind induced differences in water tables. This relationship is underlined by the occurrence of the most vital reed beds at places where wind-induced changes occur frequently (Th. Vulink, J. Daling unpublished data). Especially for a vulnerable species like Great Reed Warbler this would mean a positive change.
For Peipsi, no big changes are to be expected with respect to aquatic macrophytes and reed. If the water quality of Lake Pihkva were to improve, extension of pondweeds could be expected. Moreover, the delta of Velikaya River could profit from a better water quality, as less filamentous algae would develop and mesotrophic species like *Stratiotes* and *Menyanthes* would recover.

In conclusion, it is clear that the foodweb in both lakes will change according to both climate and management. However, because of the complex interrelationships of the components, these trends cannot easily be outlined for specific groups or species. Effects like resilience may mask shifts in the water system that could be expected on the basis of, for instance, nutrient concentrations (Scheffer 2004). Modelling exercises may help to forecast future developments.

*Cormorants hunt socially at semi-turbid waters, IJsselmeer, January 2007*

# 4.4 Future trends on land and effects of climate change

Mennobart van Eerden & Ruurd Noordhuis

The developments due to changes in climate and land use will greatly influence the ecological functioning of the region. For Peipsi and IJsselmeer an outline is presented of the main trends with their effect on flora, fauna and the ecological functions. First we examine the trends in relation to autonomous developments with a main focus on climate change. Next, the related effects due to expected changes in land use are discussed.

Climate change has strong indirect effects upon biodiversity of ecosystems. Production and consumption of energy contribute to rising temperatures and this causes large shifts in the boundaries of ecotones and clear but very different effects on the life forms which belong to them. Land use patterns have a strong influence on the ecological direction and determine, depending on the intensity of management, which natural values prevail. As agriculture plays a major role in the western world, emphasis is put on this sector, the more so because of the various roles it plays with respect to the state of the water systems. Waterbirds from the lakes feed in agricultural fields (grassland and arable) and nutrients from fertilised agricultural areas or intensive animal husbandry seep into water currents which flow into the lake and affect its trophic state.
Forestry is a derived form of agriculture *sensu stricto*. In the Nordic countries it is an important part of the ecosystem and plays an important role in overall biodiversity. Management of forestry greatly affects the environmental conditions.

**Climate change**

Generally speaking, global warming at any given location causes southerly species to flourish, whereas northerly species withdraw. Migratory birds may adapt their choice of winter quarters and numbers will change, corresponding to the amount of food available (see Van Eerden 1997 for review). Of course, this shift can only occur if geographical conditions provide sufficient equivalent habitats and if the management of natural values is comparable. It is beyond the scope of this publication to deal extensively with this topic. However, with respect to large lowland lakes the following effects can be noted:

- In IJsselmeer in winter, the use of agricultural fields by grazing ducks, geese and swans increases as higher temperatures keep the swards in better condition, permitting growth to continue in midwinter. Less ice in IJsselmeer causes important shifts in waterbirds attending. For fish-eaters, for instance, it means fewer mergansers and Smew, but more Cormorants in winter. Among diving ducks, fewer Scaup but more Pochard will occur.
- Irregular occurrence of snow melt during wintertime, followed by renewed freezing, causes problems for vegetation but also has negative effects on hibernating animals like bats, badger, bear, butterflies and beetles. This effect is more pronounced in areas which used to have permanent ice and snow cover, such as Peipsi.
- High winter temperatures cause problems in the timing of spawning of fishes. Winter spawners like Vendace *Coregonus albula* and Common Whitefish *C. lavaretus* which spawn under the ice have problems if winter conditions set in late or only partially (Peipsi); in IJsselmeer, higher winter temperatures may disturb the timing of springtime spawning for cold water species like Smelt *Osmerus eperlanus*, as the optimal spawning temperature is already reached in late winter and has no relation anymore to the seasonal sequence of events such as zooplankton development.
- Higher summer temperatures in IJsselmeer and Peipsi cause increasing problems with algal blooms, summer deaths of fish (e.g. Smelt, Ruffe *Gymnocephalus cernuus*) and anoxic conditions with increasing chance of destruction of benthos (e.g. Zebra Mussels *Dreissena polymorpha*).
- Higher summer temperatures cause better growing conditions in IJsselmeer and Peipsi for a predatory species like Pikeperch *Stizostedion lucioperca*, which has a strong effect on the remaining populations of smaller fish, thus negatively effecting the feeding conditions for birds.

Now that the issue of climate change is widely recognised, the discussion on how to counteract the effects has a prominent position on political and research agendas. Regardless of the measures taken, the process has already accelerated to such an extent that the effects of rising temperatures will be very prominently measurable and will lead to large shifts in ecosystems.

**Agriculture**

Agricultural policy determines to a large extent the development of a large surface area of land. This is no different in the vicinity of large lakes. Global change and the changing demands for dairy products on EU and world markets may lead to a decline in the surface area of grasslands. For wintering herbivorous waterbirds, these are the most important areas with respect to carrying capacity. Potato and sugarbeet fields, which play a role to catch up swans and geese in autumn and early winter, will be less subject to change in the near future. Finally, EU policy has yet another effect. The trend is to reduce the amounts of fertilisers and herbicides applied. In the case of fertilisers, this will have two effects, first, a decreasing content of crude protein in the leaves of grass blades in winter and second, a possible shortening of the season of growth during winter. These will lead to a lower carrying capacity of grasslands for herbivorous waterbirds (first the smaller species like Wigeon *Anas penelope*, but also geese and swans, cf Van Eerden *et al.* 2006).

As far as space for breeding meadow birds is concerned, The Netherlands once held the largest surface area of this habitat in Europe. The tendency was and still is towards larger farms and a further industrialisation of the sector. Only in set-aside areas and strict reserves nature conservation goals prevail and a suitable habitat is preserved. However, due to the general decline of the populations involved, the hotspots are no longer attracting so many birds. For example, Black-tailed Godwit *Limosa limosa* decreased by a factor 10 in The Netherlands in twenty years (SOVON).
In Peipsi this is not the case as yet. In Estonia and also on the Russian side, the abandonment of agricultural fields has been going on since 1990. Fewer cattle in grazed areas resulted in large-scale bush encroachment. In the early stages this is not entirely detrimental to the ecosystem, as many species profit from the decreased disturbance and the increase in herbs. Within 10 years, however, these areas develop into bush-land and their importance for waterbirds and waders is completely lost. Until recent this was largely true for the Estonian side; however, a renewed interest in agriculture is apparent here as economy grows. EU-policy provides possibilities for farmers to emigrate and already quite a few Dutch farmers moved to Estonia to start up a new company. The enlarged scale on which local management is carried out implies less room for critical species confined to wet meadows and hayfields (Kuresoo & Luigujõe 2003). Geese may profit from these developments.

### Forestry
Forestry products play an important role in the rural economy of Estonia and Russia. The increasing demand for timber in China currently lead to strongly increasing prices. This may affect the harvesting strategy in the Peipsi region as well. Although secondary for almost the entire surface area, the mixed forests of Fir and Birch are of considerable importance with respect to biodiversity. The relatively high groundwater tables lead to extensive undergrowth like haircap moss associations with dwarfshrubs (e.g. *Erica*, *Vaccinium*), grasses or ferns, depending on the type of soil. A various portion is taken up by Aspen *Populus tremula* and Pine *Pinus sylvestris*, under wet conditions leading to Willow *Salix* and Alder (*Alnus glutinosa*, *A. incana*) forests. Changing soil water levels in relation to forestry practices will alter the conditions for mushrooms, one of the important by-products in forests. For local people they constitute an important source of food. The same is true for berries, which are collected manually in autumn both in forests and in bogs.
Forest products for energy use may lead to different exploitation patterns in the future. Especially the flooded and wet alluvial forests, which now have little or no economic importance, may become exploited.
In The Netherlands, the use of forests for human recreation has been recognised for many decades, apart from their use for wood production and contribution to nature and environment. Forests have therefore been developed in a multi-purpose sense for a long period. The newly planted forests in the IJsselmeerpolders are no exception. On the sandy soils of the mainland, the use of forests as recreation areas maybe even more prominent. The Veluwe is a forest area with important heath and bare sand habitats and plays an important role with respect to biodiversity; however, especially in comparison to the Peipsi forests, the lowered groundwater tables lead to fewer species (*cf* chapter 4.2).

### Wind energy
The continuous struggle to find alternative sources of energy led to the creation of numerous windmill parks in The Netherlands. In Flevoland alone, more than 500 windmills were erected in the past decade. Sevaral projects were realised along the shores of the large lakes. Proposals to build windmills on the dikes separating Lake Markermeer and Lake IJsselmeer, as well as on the Afsluitdijk between Lake IJsselmeer and Waddenzee, were not carried out so far because the effect on Natura 2000 values remains uncertain. These dikes, which are surrounded entirely by open water, are frequently flown over by waterbirds. Especially the twice-daily movements at twilight are a matter of concern. In a recent study, Van Eerden & Van Rijn (2005) showed the effect of the placing of windmills on the daily roost of diving ducks like Tufted Duck *Aythya fuligula* and Coot *Fulica atra*. The waterbirds significantly avoided the dike stretch after the mills were raised just in front of the dike. Apart from the danger of collision during migration and daily foraging flights, windmills will greatly affect the openness of the water body. Already the line formation along the dike of Noordoostpolder strongly scaled down the central section of Lake IJsselmeer. The former free horizon at a distance of about 8 km at the water's surface is now reduced to a third, thus diminishing the perception of space. To what extent this also affects the use of the area by waterbirds requires further investigation.
In Peipsi, plans for windmill parks in the lake are under study. Unlike IJsselmeer, the major part of the open water in Peipsi is not designated as Natura 2000 area (Estonia) nor given special protection (Russian Federation). Therefore the open water habitat is still prone to large-scale developments.





### Future developments
Intensive agriculture is increasingly dependent upon the availability of exactly timed and larger amounts of water for the crops. In spring, early lowering of groundwater tables implies an early start of growth and farmers are eager to have the water pumped away as soon as possible. Recently, however, hot spells in April already lead to sprinkling with water from IJsselmeer. As summers become warmer, this will soon lead to an increased demand for sprinkling water. Not only in the immediate vicinity of the lakes, but also in the hinterland of Noord and Zuid Holland as well as Friesland, more water will be needed in summer. In those areas, not only the crops but also the grasslands on peat lands require sufficient water to counterbalance the subsidence of the soil. This, as well as the increased use of the lake as a reservoir for drinking water for the increasing population, has a large impact on the desired quantity of water in IJsselmeer.
In Peipsi, concern about the future state of the forests has led to several initiatives. One of them is the Pskov Model Forest of WWF. It is proposed to pay attention not only to the amount and quality of the trees but also to the stability and biodiversity of the ecosystem. The project works according to landscape maps which contain the basic parameters of ecosystems: fertility of soils, humidity, amount of species and persistence of the system. This serves as a groundplan to decide what to plant in this specific ecosystem in order to have optimum economic and ecological results, where and when to introduce some new species which do not ruin the ecosystem, where a clearance would affect the abundance of various animals etcetera. Both in Estonia and in Russia, the harvest procedure so far largely is by selective felling. If, however, for economic reasons a large-scale shift towards clear-cutting and monoculture forestry were to develop, this would lead to a dramatic decrease in biodiversity and possibly to hydrological effects as well (e.g. Kenk 1992, M. Schelhaas pers. comm.). Another advantage of landscape forestry is the possibility to plan the future development of the forest and to make forecasts for various situations, for example, to predict what kind of forest will grow in different landscapes after a fire or after clearance.

The Dutch policy is to keep water in the soil for a longer time. Whether this will result in higher groundwater tables in the sandy areas, remains questionable. The demand for drinking water will increase and this will be an important factor restricting the opportunities to restore a more natural situation, such as the one still present in Peipsi. By contrast, the situation in the low-lying polder areas is different. Here, a rising groundwater table is very well possible and at present experiments are carried out to study the effects of such changes on various parameters (Suzanne Stuifzand pers. comm.)

To summarise, the use of water and land by man will be intensified in the years to come. In order to maintain the identity of the large shallow lakes and their environment, considerable effort is needed to safeguard the natural values. The challenge is not to adopt a stand-still principle but to use the concept of sustainable development. Again, the use of zoning in spatial planning might offer opportunities to reconcile the contradictory aims of using natural resources and safeguarding natural values.

# 4.5 Developments in the use of natural resources and human pressure

Ute Menke & Mennobart van Eerden

A prospect of the major pressures by man on the environmental conditions is given. In IJsselmeer the increasing pressure by people requires a balanced management in the near future. By zoning the open water with respect to the different forms of use, the Natura 2000 values in the system could profit tremendously and existing values are better protected. In Peipsi the increasing pressure on the system is at present at the level of increased use of natural resources and deteriorating environmental conditions. Integrated planning would be a useful step towards sustainable development in the longrun.

**Future outlook – Peipsi**

The main feature of Peipsi is the naturalness of the system. Large habitats of bogs and fens are still connected to the lake by many brooks, streams and rivers. The hydrology of the water and soil system is largely intact. Around Lake Peipsi natural processes are allowed to take place, as human settlements are not immediately affected by erosion (coastal, fluvial or transport of sand by wind) or high ground water level. These natural processes create niches or habitats for animals like the Sand Martin *Riparia riparia* and Sand Lizard *Lacerta agilis*. Large-scale erosion of birch trees along the lake edge over a length of many kilometres does not lead to any special recognition or harassment in the region. However, as a process it creates a habitat for spawning fishes as well as protective structures for larvae and it helps to prevent over-predation by predatory fish and birds.
Population pressure is still low and apart from fishery there is little impact on the system. However, the increasing threat of pollution (mainly by nutrients from larger cities such as Pskov and Gdov) causes concern with respect to the future state of the water quality. Of course there also are some disturbances caused by agriculture, but so far this does not have such a great impact on landscapes and soils on a large scale. Moreover, extensive agriculture is necessary for land and water management as it keeps meadows and grassland open for waders like Great Snipes *Gallinago media*, Corncrakes *Crex crex* and other bird and amphibian species, which prefer open wet meadows (see chapter 3.8).

A future problem might be the continued excavation of peat and intensified woodcutting on behalf of the increasing demand on the world market. It is therefore not only important to protect large habitats of fens and bogs etc. as a whole but also to keep the connectivity through rivers and streams intact.
An obvious goal would be to maintain the natural water level changes in the lake as the main motor for flora diversity. Scenarios are being developed to close off certain rivers or lakes in order to maintain higher water levels to support and/or try to increase a certain fish stock. This, however, will drastically influence the whole ecosystem, perhaps not on the short-term but for sure on the long-term, in parallel to the Dutch experience.
As the economic outlook is positive, the development of eco-tourism could be an important opportunity. If deliberately planned and thought through, such a direction could play an important role in the rural development of the region. Intensive forms of recreation are available everywhere in Europe, Peipsi could become an unique example of a nature-balanced development. Esteem for natural values and knowledge of how to preserve remoteness are just the first steps into such a direction; it certainly requires a fruitful (and also transboundary) co-operation between professionals and, perhaps most of all, working together intensively with local people. The natural identity of Peipsi could become the future "trademark".

**Future outlook - IJsselmeer**

In the Dutch situation, the completeness and interaction between the landscape units is very much limited or even absent at present. The large civil engineering works have set the scene for living conditions at the low parts (De Bruin & De Jong 2007). IJsselmeer still has some "natural" pearls or hot spots, such as the Wieden-Weerribben complex of inland lakes and fens and the Oostvaardersplassen clay marsh, but even those are man-made or heavily influenced and controlled by man. The main problem of the entire region is the disconnection between the different landscape components. This makes migration complicated and sometimes even impossible for fauna, not only for the many examples of fish but also for the Otter *Lutra lutra*, and led since long time to the complete absence of larger mammals. The establishment of macrophytes (and other flora) along the shores of the large lakes has proven difficult as well. So far, natural spots are small and not or only partly connected to each other. Good initiatives already took place at the beginning of the 1990s with the introduction of the Nature Policy Plan, the conception of the Main Ecological Network "Ecologische Hoofdstructuur", (LNV-EC 2005) and reports like "Nature in the Wet Heart", Iedema *et al.* (1996). However, implementation is still at the beginning. The influence and disturbance by man is noticeable and visible everywhere. Places of silence are almost absent in the area, definitely in the land parts.

A basic quality of IJsselmeer is the open horizon above the water, but of course this only is a quality from a human perspective. On the other hand, the dark nights that still occur here are also biologically significant for migratory birds, bats and possibly insects.
In the 1990s the restoration and rehabilitation of water systems and shores in the IJsselmeer region were mainly carried out locally on the basis of isolated objectives, for example to protect a part of a shoreline, and aimed only at the support of certain species. Nowadays, the implementation of nature development projects faces the challenge of a wider approach by looking at the entire water body. A recent policy like the WFD emphasises the role of public involvement during the development of those plans. It is no longer the regional water authority alone that takes a decision, but through multiple objectives many more stakeholders have a say in the project implementation nowadays. The established uses of the water body all impose an impact on the system. Stakeholders like commercial fishery use the entire lake. Besides the effect on the foodweb (see chapter 3.4, Van Rijn & Van Eerden 2002), intensive fishery with gillnets in winter directly interferes with diving water birds which become entangled in the nets and drown. In the 1980s and 1990s an estimated 50,000 waterbirds drowned each year (Van Eerden *et al.* 1999). Recent studies estimate between 10-35,000 victims annually (Witteveen & Bos 2003), merely an effect of lower overall bird numbers and reduced fishing intensity. The Ministry of Defence uses Lake IJsselmeer as a low altitude flight zone and has artillery shooting facilities at the Afsluitdijk near Breezanddijk. So far little is known about the effects. Energy companies use the area for windmill parks. Figure 1 shows the projects that have been realised so far. Van Eerden *et al.* (2005), showed in a preliminary study the effect of wind mills, positioned just outside the dike on the use of daytime roosts by diving ducks. Shipping,

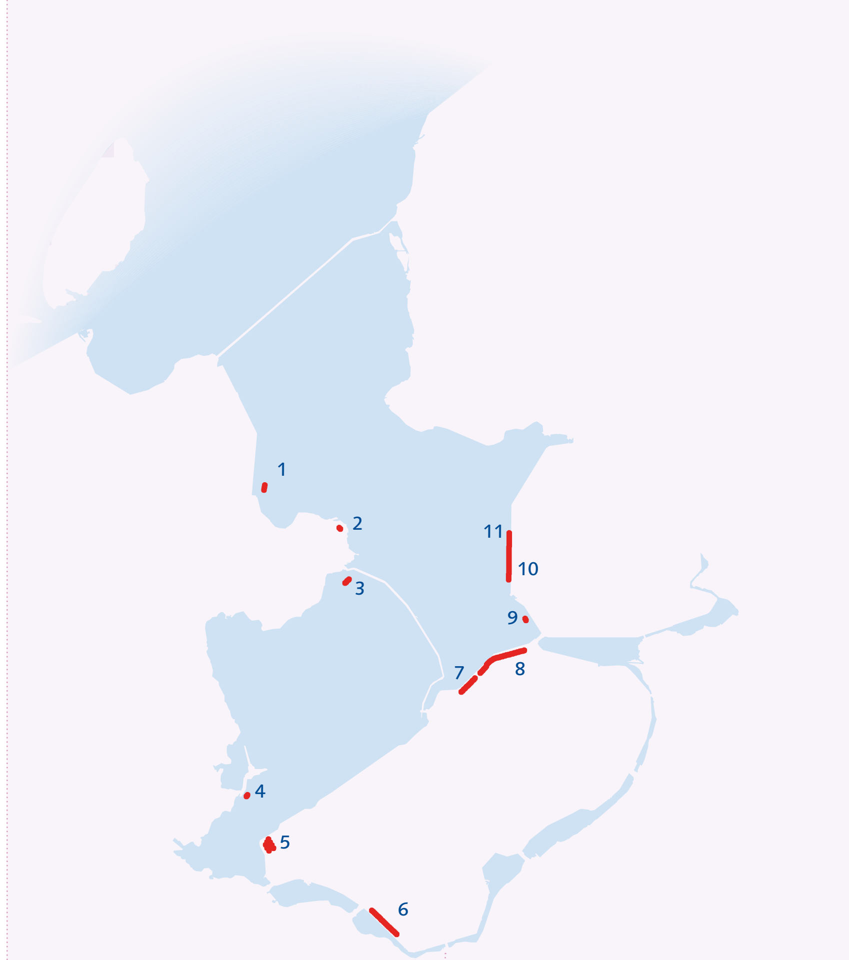



**Figure 1** *Position of windmills in the vicinity of IJsselmeer (2006). Projects inland in the polders have not been shown.*

1 *Project Lely, Medemblik, 4 turbines, 1994*
2 *Andijk waterwingebied, 2 turbines*
3 *Enkhuizen sluizen, 7 turbines*
4 *Marken, 3 turbines*
5 *Windpark Jaap Rodenburg, 10 turbines, 2000*
6 *Eemmeerdijk, 10 turbines, 1998*
7 *Windpark Harrie van Kroonenberg, 18 turbines, 1997*
8 *Windpark Irene Vorrink, 28 turbines, 1997*
9 *Zuidermeerdijk, 2 turbines*
10 *1st park Westermeerdijk, 25 turbines, 1987*
11 *2nd park Westermeerdijk, 25 turbines, 1991*

sand extraction, slurry dumping (Van Rijn *et al.* 2004) and the development of shore-based properties for recreation or permanent living also may have an impact. This is caused mainly by interaction through disturbance of water birds, either direct (by-catch of water birds, disturbing vessels, cars, obstacles, noise) or indirect effects (light sources at night (see discussion in Van Zoest 2007), changing under water visibility, effect on availability of fish, see discussion in Van Eerden *et al.* 2005). It is clear that a lot of these effects need to be quantified, also in relation to each other, as effects may add in combination.

Surely, pressure by people so close to the Randstad, the multi-million people economic centre of The Netherlands, will dictate the future prospects for the region on a larger scale. Spending most of their time in offices or on the road for the greater part of their active working lives, these people demand empty space during their days off or holidays. Silence, accessibility and landscape quality rank among the top priorities that people mention in relation to leisure activities (Goossen *et al.* 1997, De Bakker 2007). Therefore the use of water for recreational purposes is so popular and has led to intensive developments of marinas and shore-based facilities. For instance, this has resulted in some 35,000 leisure vessels (sailing boats, motor yachts) harbouring at different localities around the lakes. In 1960 the developments started with some 5000 places, by 1980 the steepest growth had taken place leading up to 20,000 vessels (Stichting Waterrecreatie Advies). This increased use already causes a heavy interaction with some natural values such as waterbirds (see Platteeuw 1995) which were recently valued under Natura 2000.

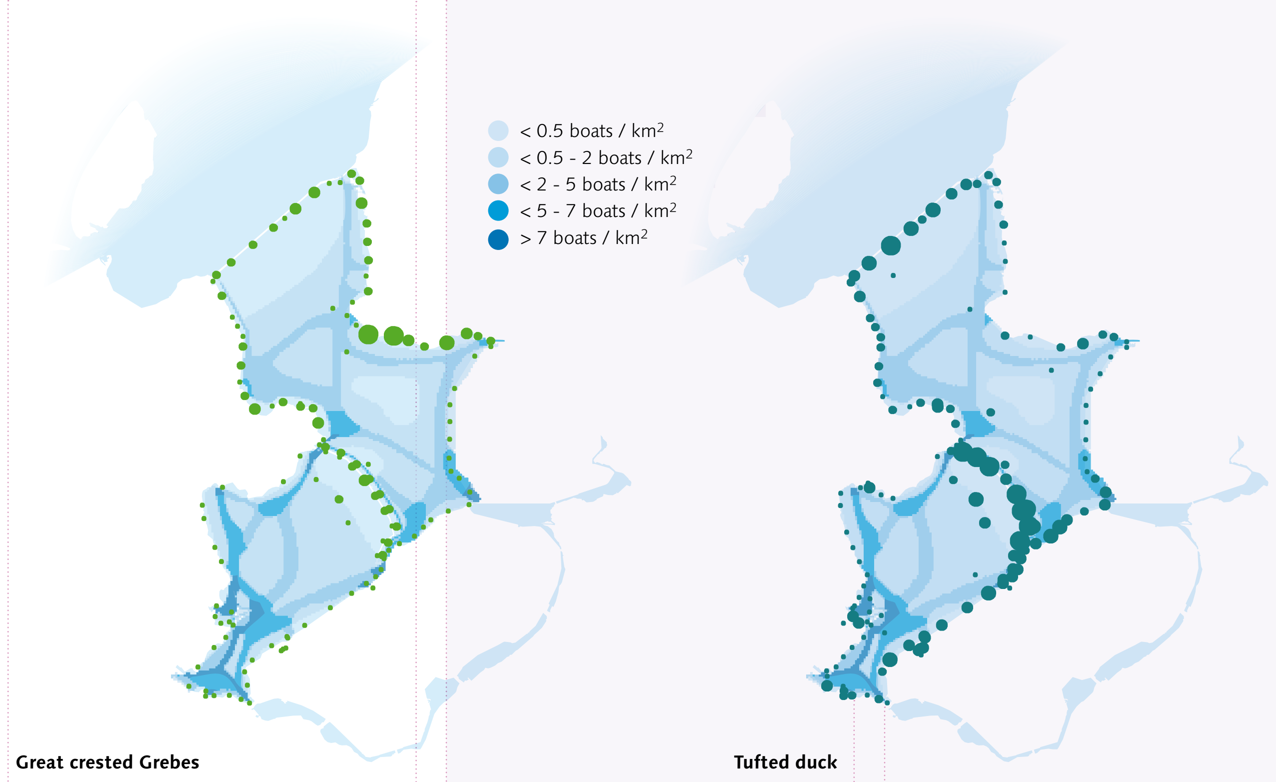



**Figure 2** *Density of recreational vessels, in boats/km2, on average sunny day in summer for the large lakes in the IJsselmeer system and distribution of Tufted Duck and Great crested Grebes in the same period. The Borderlakes have densities in the highest two classes, except for some shallow zones, which cause physical problems for sailing. Source: Stichting Waterrecreatie Advies and personal observations during aerial bird counts.*

As shown in Figure 2, the sailing routines favour certain pathways and areas of concentration, depending on the presence of harbours which determine sailing goals. A general trend of decreasing boating intensity is visible from the south to the north. In the northern and NE part of Lake Markermeer and the central and northern parts of Lake IJsselmeer there are still areas with few or zero vessels. The distribution of waterbirds in summer is partly a reflection of this pattern. Moulting Great crested Grebes *Podiceps cristatus* and Tufted Duck *Aythya fuligula* concentrate in those areas with little or no sailing traffic, that is along the Houtribdijk, the Frisian southcoast and the region of the Afsluitdijk (Figure 2). It is important to notice that moulting waterbirds require food, shelter and little disturbance as they are temporally unable to fly (30-40 days from late July-mid September).

In planning the future use of the area by recreational vessels, the zoning principle may prove a valuable tool. It may well be possible to overcome the negative effects of the high density by letting sailing boats use certain areas but avoid others. As such, the comparison of distribution maps of natural values and use by man is a preliminary step to overcome future problems and to safeguard the unique quality of IJsselmeer, including the related functions for waterbirds. Such a model has already been worked out in more detail for one part of the system, Lake Ketelmeer, in connection with the proposed establishment of zones of refuge of waterbirds (Van Eerden *et al.* 2002). Intensifying zones of use are compensated for by establishing refuge zones. Zoning of other functions such as fishery could contribute to the safeguarding of the identity and basic features of the open water area as a whole. Ideally, the combined effects of use by man would become alleviated by defining space where little or no activity occurs. This "water use plan" could help to increase the carrying capacity of the area.

# 4.6 Ecological restoration in IJsselmeer

Sophie Lauwaars & Mennobart Van Eerden

Ecological restoration in IJsselmeer has been going on since the start of the Zuiderzee project in 1930. The scope changed from terrestrial to aquatic and from small-scale to large-scale projects. So far the Oostvaardersplassen (5600 ha) was the largest freshwater marsh, which was established at landscape scale, although not in direct connection to the lake. A description is given of the projects which are planned, in progress or already have been realised in the large lakes.

**Early developments**

With the reclamation of the Wieringermeer and the enclosement of the former Zuiderzee by the Afsluitdijk (Barrier dam) in 1932, the basis was laid for the fresh water Lake IJsselmeer. As a consequence of the subsequent reclamations of polders (1930-1968), about half of the area of shallow waters vanished. At the waterfront the newly reclaimed land was bordered by straight dikes with a grass cover on top and hard boulders of basalt for protection against the waves. Apart form agricultural development, forests were planted on sandy soils in the polders Wieringermeer (1930) and Noordoostpolder (1942), Van Duijn & De Kaste (1985). The islands of Urk and Schokland became part of the polder and lost their typical characteristics. In Oost Flevoland (1957) and Zuid Flevoland forests were also planted on clayey soils, together with larger new townships (Lelystad and Almere). Specific nature areas like Kievitslanden (meadow birds), Harderbroek (reed birds) and Ganzengouw (geese) were developed in these areas. Recreational facilities like beaches and marinas were developed as well. The Borderlakes developed and attracted spectacular numbers of waterbirds, especially in the first 15 years when water quality was still good. Newly created islands served as breeding places for terns and gulls, and already at that time rare breeders like Little Tern *Sterna altifrons* and Sandwich Tern *Sterna sandvicensis* occurred among the large colonies of Black-headed Gulls *Larus ridibundus* and Common Tern *Sterna hirundo* (Van Elburg 1985). After 1970 a rapid deterioration of the water quality took place, which led to the establishment of a commission "to avoid excessive algal growth". The improvement of water quality was primarily important for the vested interests in the recreational sector, although also on behalf of nature conservation a stronger plea was heard to restore the situation. The growing number of people interested in nature led to an increased interest in nature preservation as well as concern about the environment, including the waters. The Ramsar Convention (1964), the Nature Attention Year 1970 and the death of countless raptors, cormorants, terns and seals caused by the excessive use of pesticides all contributed to this renewed interest. Not only did this lead, for instance, to the establishment of 'Oostvaardersplassen', a freshwater wetland of 3600 ha in an area of Zuid Flevoland which had not yet been cultivated, the society for the preservation of this wetland also managed to carry through the enlargement of this wetland by some 2000 ha of cultivated land already designated to become productive farmland (see Vera 1988).





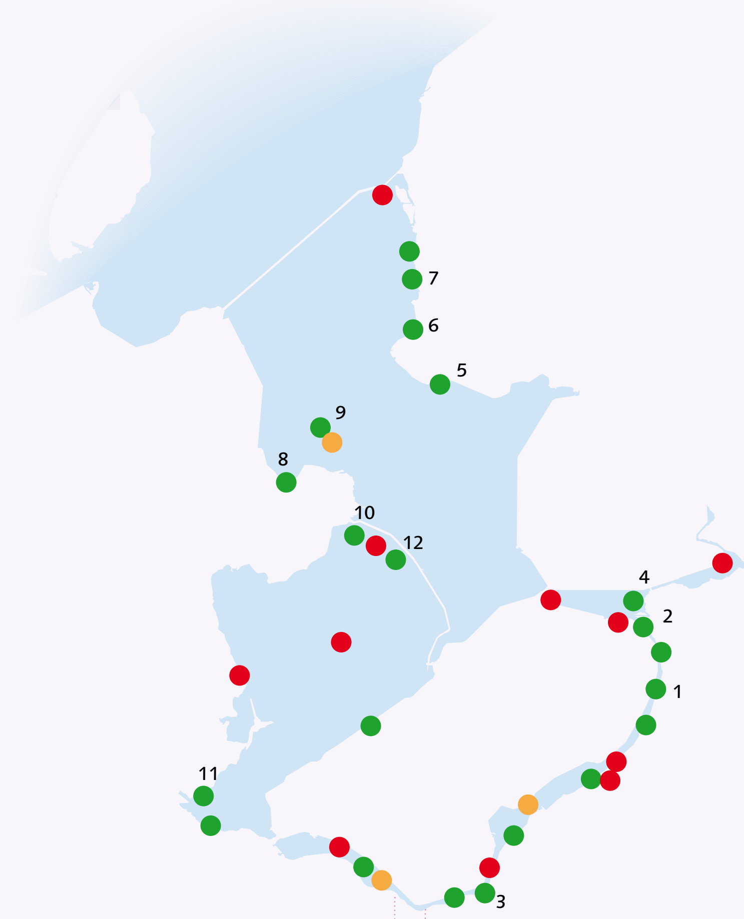



**Figure 1.** *Chart of ecological restoration projects realised (green), under construction (orange) or planned (red). Numbers indicate projects mentioned in the text.*

**From terrestrial to aquatic goals**

From 1989 onwards, ecological restoration has been an item for the waters in IJsselmeer and many nature development projects have been carried out since. In the coalition agreement of 1998 the government set aside financial means to enforce the spatial-economic main structure in The Netherlands by means of the so called ICES, later on FES programme. Aim of this programme was to (re-)develop typical wetland conditions and nature areas in combination with recreational facilities and increased flood protection in the area of the large rivers (Hofman 2001). Altogether 3000 ha of new nature was targeted in the area of IJsselmeer, as a result of the combined efforts of three ministries, the Nature Policy Plan (LNV), the SGR policy plan on spatial planning (VROM) and various policy documents on Water Management (V&W). This led to 35 projects which are shown in Figure 1.

**Borderlakes**

At first the nature development projects consisted of the establishment of new islands in the Borderlakes of Flevoland. The purpose of the various projects in the Borderlakes was to create a corridor of reed from the first lake in the southwest, Lake IJmeer, towards the north-east through the chain of lakes consisting of Eem- and Gooimeer, Nijkerkernauw, Nuldernauw, Wolderwijd, Veluwemeer, Dontermeer, Vossemeer, Ketelmeer and Zwarte Meer. Projects consisted of several small islands, some of them with planted reed and rushes and a lakeward shore protected by a concrete or basalt dam. The major purpose of the projects was to stimulate the development of water reed beds and to increase populations of birds breeding in the reed vegetation.

One of the first projects was 'Abbert' in Lake Drontermeer (15 ha, 1994-1995). Connected to a large island which had been created earlier, a series of new shallows was projected to extend the gradient between water and land. Abbert resulted in some 110 islets of sedge and reed and serves as a haunt for many dabbling ducks, geese and swans, but also for breeding Great Bittern *Botaurus stellaris*, Water Rail *Rallus aquaticus* and Sedge Warbler *Acrocephalus scirpaceus*.

Later on, in the eastern Lake Vossemeer the project 'Vossemeer' was realised (1997), consisting of many small islands of sand and clay with planted reed stolons. This resulted in a shallow water zone of 100 ha where geese and dabbling ducks breed and rest and where waders, herons like Great White Egret *Egretta alba* and raptors like Marsh Harrier *Circus aeruginosus* forage frequently. The creation of the islets was rather systematic and the relatively steep gradients prevented interaction between water and land. Although protected from the open water by a ring of low dikes, the polishing effect of erosion by waves now provides new opportunities for the establishment of more natural gradients.

Another project is Delta Schuitenbeek in Lake Nuldernauw (60ha, 2001-2005). In this project extensive reed beds were planned and planted as stolons but unfortunately almost all of them disappeared, probably eaten by water birds. The project also intended to create a by-pass from the mouth of the brook Schuitenbeek to part of the Nuldernauw just before the sluice towards Nijkerkernauw. The reason for this was the poor water quality of the brook. In the new situation, the brook runs close to the lake and makes a detour through marsh vegetation before it enters the lake in a region where its water quality causes less problems.

A project with a different focus is IJsselmonding, the delta where the River IJssel enters Lake Ketelmeer. The former estuary was embanked a long time ago (Kampereiland 1363). This reconstruction resulted in a complex of larger islands, lagoons and channels, all of which are in connection with the river as well as with the lake (800 ha, 200 ha of islands inclusive), first part in 1997, other parts in 2001-2005). Vegetation succession was natural, with reed, bulrush and willow brushwood as its main constituents, besides annual pioneers on sand- and mudflats such as Celery-leaved Buttercup *Ranunculus sceleratus*, Red Goosefoot *Chenopodium rubrum* and Golden Dock *Rumex maritimus*. This project was conceived on a landscape scale, applying different soils like sand, clay and peat, but allowing the (conditioned) process of erosion and sedimentation to take place. The area is a main haunt for thousands of waterbirds including rarities like White-tailed Eagle *Haliaeetus albicilla*, Caspian Tern *Sterna caspica* and Peregrine Falcon *Falco peregrinus*. Almost all the species for which it is a designated Natura2000 area occur in large numbers. Recently Otter *Lutra lutra* has been spotted in the area, after being reintroduced in NW Overijssel. There also is a possibility for canoes to pass through part of the area.

**IJsselmeer**

In Lake IJsselmeer along the southern part of the Frisian coast the project Mirnserklif is situated (8ha, 1993). Here, four artificial sandflats were created with slightly differing elevations relative to the water level. The flats remained unprotected, as it was considered important to allow erosive processes to further model the islets. As a result two islets are under water for most of the year, one forms an attractive resting point for waders, ducks and Spoonbills *Platalea leucorodia* and one is densely vegetated and became connected to the mainland, thus losing its island character.

In the Bocht van Molkwerum three small islands were created along the western part of the Frisian coast (9 ha, 1994-1995). Two are sandy, low islands which became rapidly overgrown with tall grasses and land reed. They serve as breeding grounds for large gulls, Herring Gull *Larus argentatus*, Lesser Black-backed Gull *L. fuscus* and occasionally Great Black-backed Gull *L. marinus*. The smallest and lowest islet is, although protected by boulders, an important

*Abbert in Lake Drontermeer, October 2007*

*IJsseldelta in Lake Ketelmeer, October 2007*

roost for waders (Curlew *Numenius arquata*, Golden Plover *Pluvialis apricaria*) and Cormorants *Phalacrocorax carbo*. In the lee side behind the islands dabbling ducks and swans find extensive shelter against the westerly winds.

Further north in It Soal near Workum, a stretch of boulders protects a sandy area of 9 ha (1995 (dam), 1997 (islands)). This area has become a major playground for various water birds. Thousands of Wigeon *Anas penelope*, Coot *Fulica atra* and White-fronted Geese *Anser albifrons* rest here. If water tables are low because of offshore winds, waders like Golden Plover, Lapwing *Vanellus vanellus*, Dunlin *Calidris alpina* and others can gather by the thousands. The boulders not only protect the area from being washed away, they also form a perfect partition from a recreation centre for windsurfers which is nearby.

In the province of North Holland near Onderdijk, a project called 'Vooroever' or 'Onderdijk' is situated along the coast of Lake IJsselmeer (100 ha, 1991 (sandbars), 1995 (small streams), 1996 (bird island)). It consists of small islands, interconnected shallows, lagoons and isolated waters. Boulders prevent the islands from erosion. The extensive shallows at the lee side of the lake collect silt, which attracts a super specialist among the waders, the Avocet *Recurvirostra avocetta*. The complex is an important breeding area where Bearded Tit *Panurus biarmicus*, Great Reed Warbler *Acrocephalus arundinaceus* and Bittern *Botaurus stellaris* can still be found along with breeding Spoonbills, Cormorants, Greylag Geese *Anser anser*, numerous Gadwall *Anas strepera* and recently also Barnacle Geese *Branta* leucopsis. The breeding gulls now consist mainly of Lesser Black-backed Gulls, the smaller gulls and terns having moved away towards Kreupel Island. The Vooroever complex, with a large area of shallow water is an important daytime roost for Wigeon, Tufted Duck *Aythya fuligula* and numerous other species.

### Kreupel Island, the ground-breeders paradise

A different kind of nature development project is the island archipelago 'Kreupel' in the western part of Lake IJsselmeer (70 ha, 2003). Since its establishment, Kreupel is very successful and at present it harbours one of the largest colonies of Common Terns in The Netherlands. It exists of a ring of 15 low lying, rather small and clay-covered islands in a lagoon-like setting of extensive shallow water, around two larger sandy plateaus consisting merely of coarse sand. These bare sand heaps have a strong relief they are up to 3 m above the average water level and have drains to prevent extensive cover by herbs.

The main purpose of this complex was to attract ground-breeding terns, gulls and rarer waders. Its position in the centre of foraging grounds (mainly Smelt *Osmerus eperlanus*), some kilometres off the coastline, guarantees sufficient protection against predators like Fox *Vulpes vulpes* or Polecat *Putorius putorius*. The foraging grounds are well within range of the terns. Foraging terns were found up to 20 km off the island. Table 1 lists the number of breeding pairs counted on the island by aerial and ground-based counts (SBB/RWS). Already in its first year, 2003, the island was colonised by the first Common Terns. In 2006 and 2007 their numbers rose to over 4000 breeding pairs. Rare breeders include Little Tern, Arctic Tern *Sterna paradisaea*, Sandwich Tern and Little Gull *Larus minutus*, besides colonies of Cormorant, Avocet and Mediterranean Gull *L. melanocephalus*. Kreupel Island has special winter visitors like hundreds of Snow Buntings *Plectrophenax nivalis* feeding on seeds of annuals and tens of Turnstone *Arenaria interpres*, a wader species which rarely occurs inland. Plans are now being worked out to create a recreational landing point close to the nature island where a limited number of people can moor their boats and view the birds from a tower, without having access to the bird island itself.





**Table 1.** *Bird numbers Kreupel island (breeding pairs), source State Forestry Service, Leon Kelder & RWS*

| | | 2003 | 2004 | 2005 | 2006 | 2007 |
|---|---|---|---|---|---|---|
| **Great crested Grebe** | *Podiceps cristatus* | - | - | - | 2? | - |
| **Cormorant** | *Phalacrocorax carbo* | - | - | 1300 | 3746 | 2925 |
| **Mute Swan** | *Cygnus olor* | - | - | - | 1 | - |
| **Greylag Goose** | *Anser anser* | - | - | 10 | 15 | 60 |
| **Barnacle Goose** | *Branta leucopsis* | - | - | - | 1 | - |
| **Canadian Goose** | *Branta canadensis* | - | - | 4 | 5 | 6 |
| **Shellduck** | *Tadorna tadorna* | - | 1 | 12 | 7 | + |
| **Egyptian Goose** | *Alopochen egypticus* | - | - | 3 | 9 | + |
| **Gadwall** | *Anas strepera* | - | - | 6 | 9 | + |
| **Teal** | *Anas crecca* | - | - | - | 2 | ? |
| **Mallard** | *Anas platyrhynchos* | - | 1 | 11 | 10 | + |
| **Pintail** | *Anas acuta* | - | 1 | 1 | 1 | 4 |
| **Pochard** | *Aythya ferina* | - | - | 4 | 5 | + |
| **Tufted Duck** | *Aythya fuligula* | - | - | 16 | 36 | + |
| **Coot** | *Fulica atra* | - | - | 7 | 22 | + |
| **Oystercatcher** | *Haematopus ostralegus* | - | - | 4 | 4 | 4 |
| **Avocet** | *Recurvirostra avosetta* | - | 40 | 115 | 115 | 70 |
| **Little ringed Plover** | *Charadrius dubius* | - | - | 7 | 5 | 4 |
| **Ringed Plover** | *Charadrius hiaticula* | - | 10 | 26 | 10 | 8 |
| **Kentish Plover** | *Charadrius alexandrinus* | - | - | 5 | 3 | 2 |
| **Redshank** | *Tringa totanus* | - | - | 3 | 2 | 1 |
| **Little Gull** | *Larus minutus* | - | 1 | - | 2 | 2 |
| **Black-headed Gull** | *Larus ridibundus* | - | 200 | 2000 | 4890 | 4830 |
| **Mediterranean Gull** | *Larus melanocephalus* | - | 1 | 3 | 42 | 30 |
| **Lesser Black-backed Gull** | *Larus fuscus* | - | - | 2 | 3 | 4 |
| **Great Black-backed Gull** | *Larus marinus* | - | | 1? | - | - |
| **Herring Gull** | *Larus argentatus* | - | 1 | 3 | 4 | 3 |
| **Sandwich Tern** | *Sterna sandvicensis* | - | - | 1 | 1 | 1 |
| **Common Tern** | *Sterna hirundo* | 300 | 1500 | 3700 | 4100 | 4200 |
| **Arctic Tern** | *Sterna paradisaea* | - | - | - | - | 1 |
| **Little Tern** | *Sterna albifrons* | - | 1 | 5 | 11 | 8 |
| **Pied Wagtail** | *Motacilla alba* | - | 1 | 1 | 2 | 2 |

### Lakes Markermeer and IJmeer

In Lake Markermeer and Lake IJmeer few nature restoration projects were carried out so far. Along with large infrastructural projects such as the construction of a naviduct near Enkhuizen and building activities of Amsterdam in IJburg, nature compensation projects were planned in proportion to the effects of the intervention.

Naviduct (70ha, 2003) was one of the first attempts to make use of the process of sedimentation and erosion in forming a nature area. Not a strict nature reconstruction area by definition, yet very successful and innovative by planning and design. A ring of sand in the shape of a horseshoe was raised behind a dam of boulders. The outflowing mix of sand and clay from the nearby naviduct re-arranged itself according to particle size and this created different soil profiles, which in turn led to different vegetation patterns. The inner lagoon collects the finest sediments, resulting in small mudflats where waders like Avocet, Spotted Sandpiper *Tringa erythropus* and dabbling ducks like Pintail *Anas acuta* forage. This project was example for the larger-scale works in the IJssel delta.

'Hoekelingsdam' near Durgerdam in the SW part of the lake was created because of compensation for building activities near Amsterdam city (IJburg). It resulted in a low sandflat in front of the dike, thus creating a shallow water zone in between and an island situation which provides nesting opportunities for ground breeding birds. Vegetation management is done outside the breeding season because of rapid colonisation. The area hosts an important breeding colony of Common Terns and Mediterranean Gulls, the largest so far north in The Netherlands with >70 pairs in 2007 (> 190 exx.). Also roosting waders like Lapwing, Golden Plover and Black-tailed Godwit *Limosa limosa* occur sometimes by the thousands, as well as many dabbling ducks. The position of this project in connection with inland wetlands such as Lake Kinselmeer and the polder IJdoorn, which is partly inundated, makes the area part of a larger complex that enforces natural values by the effect of habitat scale. Disturbance by an avian predator or a sailing boat can be easily met because of the possibility to move to different sub-areas temporarily. The expected colonisation by submerged macrophytes was minimal so far, probably because both ends of the shallow water zone are open, causing a rapid current at times of wind (Ventury effect).

Along the dike between Lelystad and Enkhuizen the project 'Houtribdijk' was realised. The main aim was protection of the dike against drifting ice which could cause considerable damage, as it did in the winters of 1984/85 and 1994/95. Curly dams of different length were made of boulders just sticking out above the water surface and forming a coil with many openings in front of the dike (Noordhuis & Van Schie, 2007). The area in between (ca 95 ha) provides shelter for thousands of diving ducks and there are some developments concerning the establishment of submerged water plants. At the most shallow southeastern end, movements of sand led to the formation of sandbanks adjacent to the dams at the lee side. A small patch of willow forest now hosts an important colony of Cormorants (since 2005, in 2007 780 pairs). An interesting feature of this area is the effect of wind on the watertables and in turn on the vegetation. The SW winds may sweep up the water 50-80 cm across the lake, causing a corresponding lowering of the water table at the southern end. The small gullies which have formed behind the dams do not silt up because of the wind-induced currents here.

**Future developments**

There is a clear trend in nature restoration projects from small-scale interventions aimed at single functions, like "reedbed enlargement" or "ground-nesting birds", towards larger projects, some of them even on a landscape scale. Kreupel, Vooroever, Naviduct and IJsseldelta are examples of such integrated projects. Of course, there is no denying the value of the contributions to nature by projects of smaller scale. However, a clear positioning of these smaller projects helps to guarantee their success and their lasting effectiveness. 'Hoekelingsdam' in Lake Markermeer/IJmeer and 'it Soal' in Lake IJsselmeer but also 'Abbert' in Lake Drontermeer are clear examples of this.

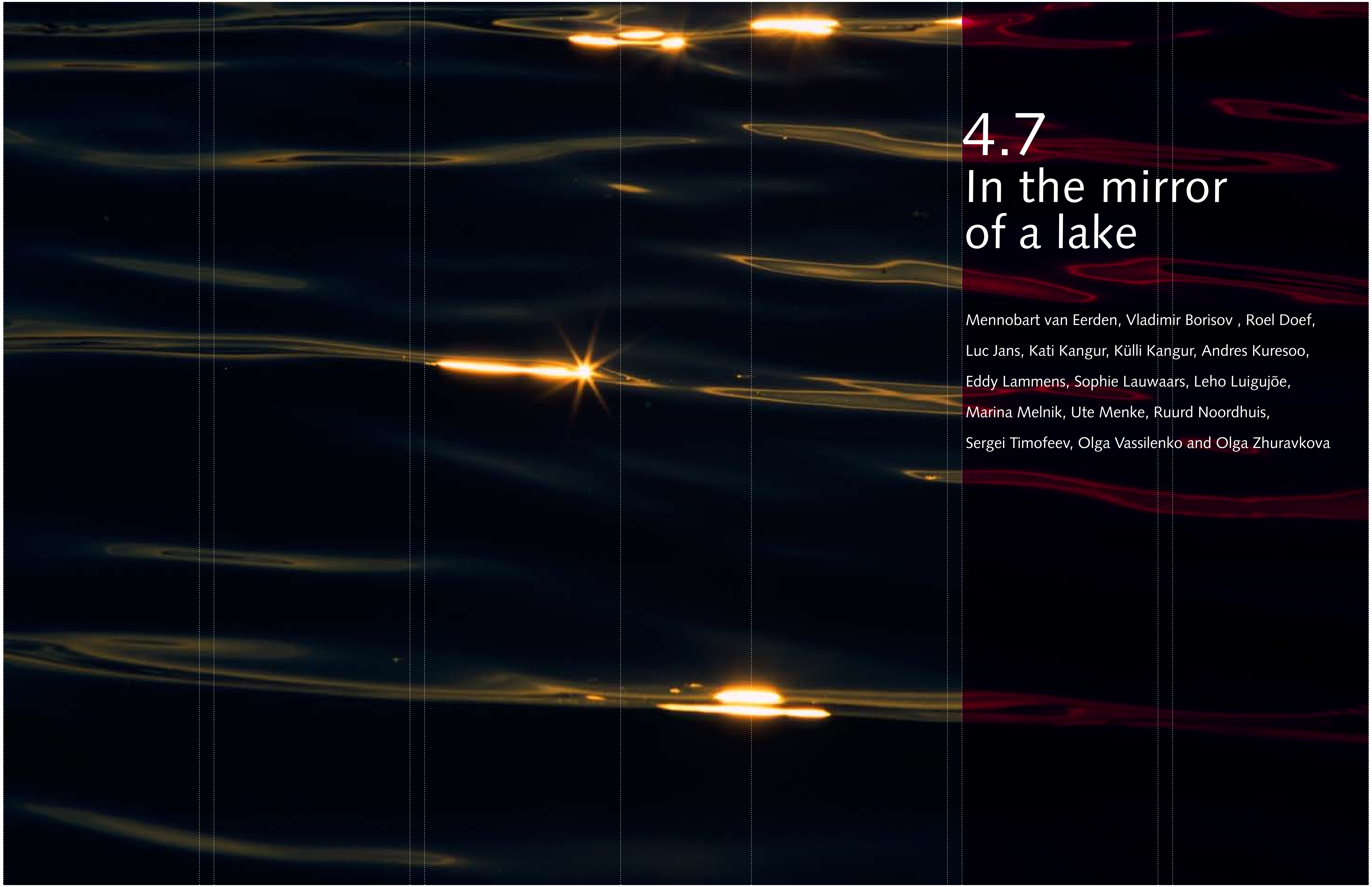
What will be the next phase in this development? A likely direction is the continuation of large-scale projects aiming at integration of functions with regard to habitat and with a greater role for natural processes. Rather than realising a definitive situation at construction, one could think of creating a framework which allows natural forces to polish and fine-tune the environmental conditions. In this way, it becomes possible to create more durable nature preservation areas while reducing construction and maintenance costs. Future challenges are the reduction of the surplus of suspended matter in Lake Markermeer, aimed at a reconstruction at the system level. In this context also the connection to the hinterland can be used to greater benefit for natural functions. Very often the complete separation of functions across the dike (nature vs agriculture) causes opposing interests and conflicts.

A similar issue is the possibility to restore the connection with the Waddenzee, part of the once famous brackish water zone that occurred in the Zuiderzee. If we could solve the stakeholder-related differences in perception of what the future outlook could be at this very large scale, we would definitely make a tremendous step forward. Sea level rise, continuous subsidence of the drained hinterland and increasing river discharges all point out the need to find integrated solutions for this complex set of issues. It is evident that we can learn from Peipsi in this respect, as will be pointed out in more detail in the next chapter.

*It Soal, Frisian coast near Workum (top), Hoekelingsdam near Durgerdam and Kreupel north of Andijk (bottom).*

**Botanical hotspot at the shores of Lake Zwarte Meer**
*Sophie Lauwaars*

The most easterly of the lakes adjoining Lake IJsselmeer is called the "Black Lake" (Zwarte Meer), referring to the peaty waters that are discharged from the hinterland. This lake has more natural features than the other "Borderlakes". It is surrounded by remnants of what used to be much more extensive wet grassland vegetation types, in particular crested dog's-tail grass and false oat-grass vegetation types, with snake's head fritillaries and marsh marigolds. The snake's head fritillary is a bulbous plant that is now very rare in the wild in The Netherlands; it is a protected species. Due to land drainage schemes and more intensive agriculture, these remnants now only exist along the edges of ditches, in verges and on dykes where there is a reduced intensity of maintenance (Dijkstra *et al.* 1988 in Breukers 1994). In this respect, the land along the banks of Lake Zwarte Meer are overshadowed by those of the "Blackwater" River (Zwarte Water) that runs into it, which has much more extensive wet grassland vegetation. In The Netherlands' statement for Natura 2000, an application was made with respect to Lake Zwarte Meer for an expansion of habitat type "H6510 lowland hay meadows *Alopecurus pratensis, Sanguisorba officinalis* subtype B", in other words false oat-grass and foxtail grass hay meadows with meadow foxtail, which includes hay meadows with snake's head fritillaries. The fact that so few of such areas remain means that the state of preservation must be considered as extremely unfavourable. A considerable amount of work needs to be done around Lake Zwarte Meer in this respect.



# 4.7 In the mirror of a lake

Mennobart van Eerden, Vladimir Borisov , Roel Doef, Luc Jans, Kati Kangur, Külli Kangur, Andres Kuresoo, Eddy Lammens, Sophie Lauwaars, Leho Luigujõe, Marina Melnik, Ute Menke, Ruurd Noordhuis, Sergei Timofeev, Olga Vassilenko and Olga Zhuravkova

Using the reference of another lake may help to position the present situation. Large shallow lakes require integrated management at a scale relevant to the size of the water body. A system-oriented approach may yield a greater result than small-scale and single issue management. Knowledge about key species and key processes is crucial in this respect.

Peipsi represents a more natural large lake system than IJsselmeer. There is much to be learned from comparative patterns and processes as well as from the differences in these two lakes. The lower external nutrient load of Peipsi was already chosen as a goal for IJsselmeer with respect to the MEP/GEP discussions in relation to the EU-Water Framework Directive. The impact of interference with the water system is another point of mutual comparison. Peipsi is less used for water recreation and shipping activities and there are almost no interferences with respect to sand extraction, deepening of shipways nor military use. These uses are important in IJsselmeer but their consequences regarding Natura 2000 site goals are barely known.
For Peipsi and IJsselmeer integrated water management is a must in a rapidly changing world. The lake is an entity as far as hydrology is concerned, the hinterland as well as connecting water bodies play an important role for the ecological functions. Therefore, integrated water management should not stop at the borders of the lake; as Peipsi has clearly shown, the connected marshes, bogs and forelands play an important role in the total system. On the other hand, the effective regulation of IJsselmeer resources and services poses a great example for managing Peipsi. The integrated approach, stakeholder involvement and legislative anchoring of the natural values of the open water may seem a burden for many of the Dutch involved in spatial planning and policy making; however, although complex and time-consuming, it still is the only way to go forward. For Peipsi, this might also be a useful approach, which tries to keep the objective of multi-purpose users without losing the identity of the system and its natural inhabitants.

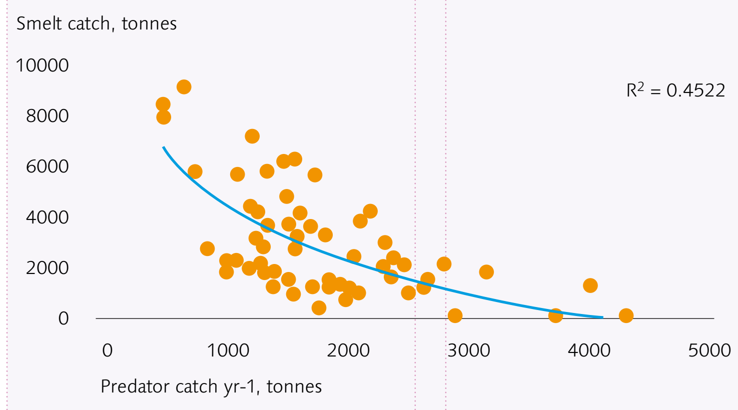
**Lakes as part of a larger system**

The watersystem approach is useful for setting the framework of reference; however, due to the different settings in which the lakes Peipsi and IJsselmeer are positioned, the reference cannot always be the goal to strive at. The densely populated IJsselmeer basin will continue to impose a pressure on the system. The negative trend in the populations of many water bird species requires clear actions and therefore, the most important lesson in this context is the role of zoning as one measure to reduce conflicts and to increase the overall carrying capacity and resilience. At the water's territory this has hardly been applied so far, except, for example, for ship traffic in relation to water depth. Given the apparent success for nature management on land (see 4.2), applying this zoning principle to large-scale water bodies would probably lead to a much better functioning of the system with respect to the attainable Natura 2000 values than can be expected if the present situation continues.
Zoning implies restrictive or no use (recreation, fishing, traffic, extraction of resources a.o.) in certain areas and concentration in other areas to optimise the overall functioning. Fishing is a major pressure on the ecosystems of these lakes. Being an extremely important player in the food web, fishery has greatly





**Figure 1.** *Total amount of Smelt caught in Peipsi against predatory fish caught the year before. The strong repressing force of predatory fish is evident, as years with large stocks lead to small catches of Smelt the year after.*




reduced the stocks of large predatory fish (see chapter 3.4). On the other hand, intensive fishery led to the availability of enormous quantities of small fish species such as Ruffe *Gymnocephalus cernuus*, on which Cormorants prey in large number (Van Rijn & Van Eerden 2001). Reducing the fishery pressure will lead to larger stocks of predators and, as a result to fewer small fish, which in turn, can feed fewer fish-eating birds (Van Eerden 1997, Lammen).
The large role of predatory fish is evident from the database of Peipsi.
By plotting the total amount of Smelt *Osmerus eperlanus* against the total predatory fish biomass extracted from the lake the year before, a strong negative relationship is revealed (Figure 1). So the predatory fish can keep the prey down (see details and discussion in Kangur *et al.* 2007). Sustainable fishery is to be aimed at in order to overcome the detrimental effects of over-fishing. As a positive result of normalising socio-economic conditions and more restrictive fishery policy, the number of small-scale fishermen decreased in favour of larger, more viable and more sustainability-oriented fishery companies (Kangur & Hämmal, 2006). This will, however, lead to the necessity of further efforts to enlarge the carrying capacity for water birds.

**Keystone species, indicator species and Natura 2000: the large-scale patterns**

Birds form the most conspicuous element of the ecosystem of large lakes.
As predators and consumers of the underlying food chain, they may serve as indicators of the state of the water system.
Diving ducks depend on benthic prey, in both lakes consisting of Zebra Mussels *Dreissena polymorpha*. In IJsselmeer, *Dreissena* forms large mussel beds on the former seabed whereas in Peipsi, sedimentation of silt and detritus over thousands of years created large areas without the firm substrate required by the bigger bivalves. The carrying capacity of Peipsi is therefore naturally limited and recently it deteriorated even further in Lake Pihkva because of eutrophication. It is of the utmost importance to preserve large mussel beds and we recommend further research into how these benthos stocks can be actively managed. The newly arrived Quagga Mussel *Dreissena rostriformis bugensis* and two species of *Corbicula* in IJsselmeer cause concern with respect to the future development of the Zebra Mussel population, but they also provide possibilities to extend the food spectrum for diving ducks (A. bij de Vaate pers. comm.).

Smelt *Osmerus eperlanus* forms the most important food source for fish eaters, supplemented to some extent by small Ruffe *Gymocephalus cernuus*. Fish-eating waterbirds need underwater vision to detect and successfully persue their prey. As fish avoid clear water at daytime, intermediate light penetration yields optimal foraging conditions for fish-eating water birds. The highest numbers of Smew *Mergus albellus* occur at the murky waters of Lake Võrtsjärv, like they used to do at Lake Markermeer. Lake Markermeer recently became too turbid for fish-eating waterbirds to forage. Maintaining zones of intermediate light penetration is therefore an obvious, but perhaps not easily achieved goal. It may be considered in relation to the problem of surplus silt in Lake Markermeer. Openings in the dike would let murky water flow into Lake IJsselmeer and, at northerly winds, bring in clearer water from Lake IJsselmeer into Lake Markermeer. Large scale marsh development and the re-direction of the sediment flow would be options as well.

Plant-eaters depend on pondweed *Potamogeton spp*. in Peipsi and IJsselmeer, extended by stonewort *Chara spp*. in the Borderlakes of Lake IJsselmeer and Lake IJmeer. In Peipsi, *Myriophyllum*, reeds, sedges *Carex spp.* and rushes *Juncus spp.*, *Schoenoplectus spp.* also provide an important food source. In IJsselmeer a lot of geese, Wigeon and other dabbling ducks rely on agricultural food as well. This is partly also the case in Peipsi, especially in spring. Therefore, apart from restoring the macrophyte vegetation, an obvious goal is to monitor the developments in agriculture with respect to food quality and food availability (Nitrogen composition, drainage, re-seeding practice), and/or to consider the wetlands behind the dikes as part of the functional entity of the lake.

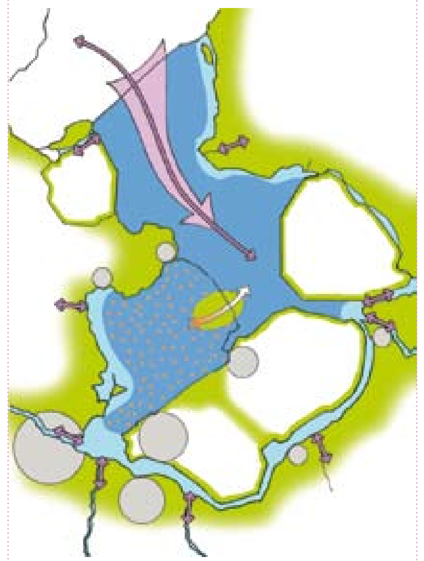
### The spatial occurrence of natural values

Fish-eaters and benthos-eaters occur at the centre of the large lakes.
They commute twice daily between roosts and offshore feeding sites. As the study established, the pattern of distribution of the different foraging guilds is related to the scale of the lake. The larger species generally are found on the more open waters, whereas their smaller relatives depend on smaller waters. These patterns are important if one is to choose management options for specific areas. We suggest to preserve open water on an appropriate scale for the larger birds, e.g. goosanders and Scaup *Aythya marila*, in the north, for their smaller relatives Smew and Tufted Duck *Aythya fuligula* in the south and for the macrophyte dependent Pochard *A. ferina* and Red-crested Pochard *Netta rufina* in the Borderlakes and at the lee fringe in Lake Markermeer.
In species for which prey attainability is so important and at the same time so unpredictable, both between years and in the course of a single year, we would expect the birds to sample their opportunities at a very large scale. For the fish-eaters this means that alternatives in the Baltic may affect the patterns of occurrence in IJsselmeer. As Peipsi is frozen over completely in most years, this lake is not considered as a direct alternative. Still, a future way of addressing these relationships is to consider larger parts of the flyway rather than single water systems or even SPA's.
Plant-eaters are present at the fringe: e.g. Pochard, Coot *Fulica atra*, Gadwall *Anas strepera* and Bewick's Swan *Cygnus bewickii*. The present situation of submerged macrophyte abundance in the Borderlakes is such that it would not be wise to connect them with the more eutrophicated water from the River IJssel, and/or the large lake. These ideas were outlined in a document aimed at integrating the different ecological potentials in a coherent future vision (Remmelzwaal, 2007). Figure 2 shows the main direction. The vision schematically addresses the current strongholds in IJsselmeer as well as the direction of future developments with respect to the identity of the different sub-zones in the system. For Peipsi such visionary work has not been carried out as yet; given the rapid developments and the complex transboundary state of the lake, such an approach would seem useful. The spatial occurence of natural values thus implies the formulation of site-specific management goals. As such the entire system will gain with respect to coherence.





**Figure 2.** *Ecological Perspective for IJsselmeer; outlined are the main directions of ecologically desired developments.*



*The land behind the dikes relates to the lake, the same holds for the connecting rivers and streams. Markermeer has a turbid centre (dots), gradually developing into the clear water zone along the lee shore (light blue). The Borderlakes have clear water as well, whereas the Frisian coast is dynamic (onshore). A large-scale dynamic marsh in connection to the lake could greatly add to the natural values and perhaps help to lower the sediment load in the water. The arrow depicts the connection between both lakes, the large arrow across the Afsluitdijk symbolises the desired ecological connection with the Waddenzee.*

### Enclosed systems and the role of scale and dynamics in large lakes

We have seen that high natural values may occur in the enclosed wetlands of recent origin. However, without active management these values are under constant pressure and tend to decline, although it may take a considerable time (15-25 years in freshwater marshes like Oostvaardersplassen, >50 years in large lakes, chapter 3.5). These rather long periods complicate the discussion and decision-making on the direction of nature management and the assessment of quantitative goals. If natural forces are absent or not effective enough in this respect, it is a matter of choice either to bring back the natural dynamics or to substitute it by management measures such as grazing and cutting (Bakker 1989, 1997, Bakker *et al.* 1997), bio-manipulation of water bodies (Meijer *et al.* 1997) or water level manipulations (Van Eerden 1995, Vulink & Van Eerden 1998).
Again, for the terrestrial ecosystems a lot of experience has been obtained in this field. For large water systems this was no option so far. Still, great benefit could be obtained if large-scale system-directed management were to be applied. The likely options concern water level management, reconnection of parts of the system and the specific use of dynamic system components such as wind-induced currents. Especially if the land-water transitions are more natural (e.g. as marshes or at least reed beds), these fluctuations have an ecological significance.
Thus, in combination with the development of more natural shores and large-scale marshes, water level management should be more natural and with more profound changes over time, not fearing the extremes unless safety or other functions become seriously affected. Peipsi has shown an overall amplitude of 3 metres, annual fluctuations of about 1 metre being normal (Jaani 2001b, Figure 3). Generally speaking, high water tables occur in spring, gradually declining towards autumn. There are, however, exceptions to this pattern (see chapter 3.9). Fluctuating water tables cause less erosion at the shores and contribute to the sustainable establishment of submersed macrophytes and a healthy reed vegetation.

Another system-oriented management goal is to reconnect systems, especially gaining value for the large lakes by restoring gradients in turbidity, trophic gradients and movements of aquatic organisms such as fishes. It would also buffer negative effects at times of stress, e.g. high temperatures, low food, ice, extreme turbidity because of large discharge by the rivers etc.
For IJsselmeer this would mean a reconnection between Lake Markermeer and Lake IJsselmeer, thus enabling migratory fish species like Smelt to exchange populations and to withdraw to refuge areas in times of stress (deeper water). Reconnection to the Waddenzee is a further elaboration of this goal, but with greatly extended effects. Especially for anadromous fish species, the possibility to pass through the locks in the Afsluitdijk is critical for their survival. New fish ladders will be applied at the new set of discharge sluices that are to be

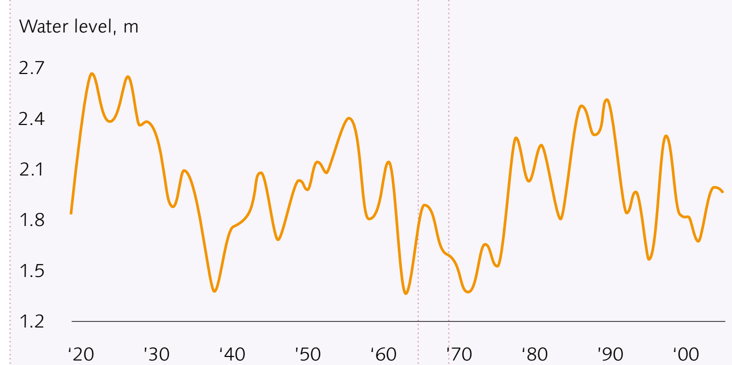



**Figure 3.** *Long-term changes in water level fluctuations in Lake Peipsi, due to changes in precipitation (from Jaani 2001). Shown is the running mean, overall fluctuation comprised 3 m! Data on water level, collected by the Estonian Institute of Hydrology and Meteorology, were available for the period 1924-2005.*

constructed. In combination with a brakish water zone these measures could greatly add to the natural potential of the IJsselmeer. For Peipsi the option of reconnection is also valid. The construction of the power station in the Narva River in the mid 1950s obstructed the passage of fish. Eel *Anguilla anguilla* for example has no possibilities to enter the lake from the Baltic, and stocked elvers are used in Lake Võrtsjärv instead (Järvalt *et al.* 2004). Given the enormous watershed of Peipsi (Jaani 2001a), restoring the connection would be of great importance for fish migration in the eastern Baltic. A brackish water zone is not relevant in this part of the eastern Baltic.

Large shallow lakes behave differently with respect to temperature fluctuations, wave formation, currents and other physical properties than smaller lakes. It is perhaps no mistake that fishermen still speak about "naar zee gaan", "to put out at sea" when they speak about Lake IJsselmeer. For the living organisms in such an "inland sea", conditions are very often harsh. High waves cause problems of orientation and flock cohesion in diving ducks. On the other hand the waves cause currents which prevent sedimentation of silt in the shallowest zones. Those currents may move the sand and form mega-ripples as they occur in front of a sandy coast at sea. The same holds for the formation of lagoons. The Raskopel lagoon in Peipsi has dimensions which correspond to the dimension of the lake, but its form resembles that of the large lagoons along the Baltic in Poland and Lithuania. Large lakes may also have beaches and beach-walls and even low dunes as in Peipsi's east coast.
Reduction of the size of the lake will affect these processes and will eventually lead to their disappearance and that of the associated ecosystem values. The construction of polders reduced the IJsselmeer by about half its original size. The dike between Enkhuizen and Lelystad, which was supposed to form the first embankment of the last polder in the Zuiderzee project, led to problems with suspended silt in Lake Markermeer. Peipsi is at present larger than IJsselmeer and its greater depth and longer maximum wave fetch imply more dynamics than is possible at present in IJsselmeer. Therefore, restoring dynamics and making appropriate use of their effects could be a challenging goal for IJsselmeer. The wind-swept currents may cause a difference in water level of more than 1 m across the dike Enkhuizen-Lelystad (Fig 4). Onshore winds causing higher water levels on one side and lower levels on the other side of the dike could be the driving force for dynamic water levels, if combined with the development of large-scale marshes. Unlike Oostvaardersplassen, this new development should form a hydrological entity with Lake Markermeer and Lake IJsselmeer. Using this potential together with (secure) openings in the dike would further enlarge the possibilities for dynamic wetland development. At this moment, projects are set up to study these possibilities in detail.

**The use of large-scale nature reconstruction**

Being already less natural from the start in 1932, IJsselmeer was deprived of many shallows and natural coastlines as a result of the embankments of the IJsselmeer polders. These took away half of the water area and resulted in steep gradients in land-water transitions. The dikes, although offering important substrate as spawning habitat for Smelt and other invertebrates (box 3.3), prevent submerged water plants to occur. Therefore, nature reconstruction may be an important tool to restore a greater degree of naturalness to the system. There is a need for shallow zones at the margins to allow water plants to develop, and for large-scale marshes, which are hydrologically connected with the lake. Such a "supermarsh" of 4000-6000 ha was proposed as a means to boost the natural quality of the lake (John Palmesino, John Lonsdale *et al.* 2005, Architectural Biennale, Rotterdam, and in press, see also Van Eerden *et al.* 2007). Peipsi has very much contributed to the ideas behind such large-scale marsh development.






**Figure 4** *Wind-swept changes in water level in Lake Markermeer at SW 6 Beaufort (source: Dirk Vlag, Rijkswaterstaat). On the other side of the Houtrib dike, a lowering of the water table occurs which is in the same order of magnitude.*

At a smaller scale, a nature development project was originally planned in Lake Veluwemeer consisting of many small islands. However, Lake Veluwemeer also has a special vegetation of *Chara*. Moreover, 19 brooks originating from upland areas of the Veluwe flow into the lake. Comparison to natural brook outlets in Peipsi pointed out that it is detrimental for the stability of the vegetation if the islands are situated in the vegetation area. The project now has a different focus, which is restoring the estuary of the brooks on the shore of Lake Veluwemeer.

So, starting with individual projects of a limited scale, we now have to take up the challenge to restore the large lakes. Nature reconstruction works should aim at their contribution to the entire system rather than to the local benefit of the project itself.

**In the mirror of a lake**

At present the water quality levels in Peipsi and IJsselmeer approach the same order of magnitude (chapter 3.1). The cumulative effect of many years of water purification and the use of phosphate free detergents in households has led to this situation. In the case of Peipsi, the trend shows an increase in nutrient inflow to the system. Further deterioration of the lake ecosystem poses a risk to the biodiversity and stability of the lake as well as to the resources and services it provides to the communities that live on its shores and far beyond. The water purification plants in Pskov and Gdov are insufficient to treat all wastewater that enters the lake. As such the situation bears parallels to that of the Borderlakes of IJsselmeer. Although at a much smaller scale, the increased nutrient load caused a collapse of that system in the 1970s and it was only after tremendous effort and costs that the original situation was re-established in the second half of the 1990s.

In The Netherlands, three major wetlands hold most of the fish-eating water birds in winter: IJsselmeer/Markermeer, Grevelingen and Krammer Volkerak (cf Van Eerden 1997). The latter two are parts of former estuaries which were recently closed off, with fish stocks not yet in equilibrium. For Scaup, Smew and Goosander, IJsselmeer is the most important wintering area. Both lakes and the Borderlakes provide space for different species. The entire complex needs to be considered as one water system to judge future developments. The present situation is that 6 different Special Protected Areas were created, each with different goals and management plans. Many species of water birds are on the decline, not only in Lake IJmeer and Lake Markermeer but also in Lake IJsselmeer. Integrated action is required to prevent further deterioration. We propose to consider the entire complex of lakes, rather than to judge the individual water bodies separately.

Peipsi and IJsselmeer, comparable but also different. We were able to compile a lot of insights and information on both systems. Cross-referencing provides an extra perspective on one's own system; in-depth studies on the spot alone, although extremely useful, are unable to solve all problems encountered.
As authors we look back on a series of fruitful years working on either side of the Baltic/North Sea at two remarkable lakes. We hope that the project may contribute to the further sustainable development of the areas, with a strong role for a healthy and valuable ecosystem.

To summarise, we list the following 10 recommendations/statements as outlined in the previous chapters and above:

**1** Integrated water management is a must in a rapidly changing world. The hinterland within the basin needs to be explicitly taken into account. Aiming at larger scale ecological objectives is necessary to reach the required level of large lake management.
**2** Zebra Mussels and Smelt are keystone species in the water system and need special attention in future research and management of these lakes.
**3** In future, a larger role for deeper water at the centre of the lakes in IJsselmeer seems appropriate to counteract the sedimentation load and to provide temperature buffers for sensitive fish.
**4** Large-scale, system-oriented nature reconstruction may be an important tool to re-establish natural processes in the system and hence to boost the natural values.
**5** Restoring dynamic processes such as wind-induced currents and using these in nature development projects could boost the carrying capacity of the system.
**6** Connecting the large water bodies of Markermeer/IJmeer and IJsselmeer provides buffer capacity for fish and benthos and restores important gradients in the lake system (turbidity, nutrients, oxygen, migratory fish).
**7** Water level management should aim at a more natural fluctuation through the seasons as well as over the years.
**8** Zoning is a viable measure to reduce conflicts over the open water and to increase the overall carrying capacity for Natura 2000 goals.
**9** Sustainable fishery needs to be established to avoid devastating effects of overfishing. This will require, however, further efforts to enlarge the carrying capacity for water birds.
**10** Peipsi and IJsselmeer should face each other longer, for mutual benefit.

*14 November 2007, Lelystad, Tartu, Pskov*

# Summary

# Peipsi en IJsselmeer: een samenvatting

Sinds de vaststelling van de Kaderrichtlijn Water in December 2000 zijn alle EU lidstaten verplicht hun nationale waterlichamen te monitoren, te evalueren en waar nodig herstelplannen te maken. Een belangrijk onderdeel van de evaluatie is de vaststelling van referentiewaarden voor de gewenste toestand van een waterlichaam. Het meer Peipsi bleek het meest geschikt als referentie voor het IJsselmeer.
Een vergelijkende studie van beide meren werd georganiseerd om de beheerders van beide meren te helpen met het opstellen van beheerplannen. Dit project werd opgezet in de verwachting dat het tot wederzijdse voordelen zou leiden. Een beschrijving van de huidige toestand en van het recente ecologische functioneren van Peipsi zou het beheer van het IJsselmeer ondersteunen bij het opstellen van realistische en waar mogelijk ambitieuze doelstellingen voor de KRW en voor de Vogel en Habitat Richtlijn. Omgekeerd zou het intensief beheerde IJsselmeer een bron van inspiratie en informatie kunnen zijn voor het toekomstige beheer van Peipsi.
Over het algemeen bleek deze veronderstelling juist. Gedurende het project hebben bestuurders en watermanagers uit Estland, Rusland en Nederland de beide meren regelmatig bezocht. Deze bezoeken speelden een belangrijke rol in het verkrijgen van inzicht in de overeenkomsten en verschillen tussen de beide watersystemen. Studiereizen werden georganiseerd, vooral om kennis uit te wisselen maar ook om de communicatie en de samenhang binnen het project te verbeteren. Communicatie was van doorslaggevend belang in deze internationale context, niet alleen tussen leden van de projectgroep, maar ook met de beheerders van alle drie de landen en met belanghebbenden die geïnteresseerd zijn in de uitkomsten van het onderzoek. Gezamenlijk veldwerk diende als een bron van inspiratie. De schaal, verhouding, vorm en orde van elementen, evenals de relaties tussen de samenstellende elementen, bijvoorbeeld van het landschap, vormen een verzameling referentiegegevens die een waardevolle aanvulling bieden op theoretische kennis.

**Algemene kenmerken**

Peipsi en IJsselmeer hebben veel overeenkomsten, maar zij verschillen ook in veel opzichten. Beide meren zijn ondiep en dat onderscheidt hen van andere grote meren in Europa. Ze liggen beiden tussen 50° en 60° noorderbreedte. De weersomstandigheden zijn echter verschillend, vooral in de winter. Beide meren zijn ingedamd, maar ze verschillen sterk wat betreft de waterstandbeheersing. Bovendien vindt in het IJsselmeer nog maar sinds 75 jaar sedimentatie in een afgesloten milieu plaats, terwijl dit proces in Peipsi al meer dan 8.000 jaar aan de gang is.
De drie landen die aan de twee meren grenzen, Rusland, Estland en Nederland, hebben een gezamenlijke historie die verbonden is aan de meren. In de Middeleeuwen maakten verschillende steden in deze landen deel uit van de Hanze handelsorganisatie. In het recentere verleden maakten beide meren vergelijkbare ontwikkelingen door op het gebied van scheepvaart en visserij. Tegenwoordig vormen verschillen in bevolkingsdichtheid en ruimtebeslag de voornaamste reden waarom IJsselmeer en Peipsi zich in een verschillend tempo ontwikkelen. In Rusland en Estland werden de afgelopen tien jaar veel landbouwgronden verlaten, terwijl de ruimtevraag in Nederland nog groter werd dan voorheen. Ook wordt het IJsselmeer intensief gebruikt voor recreatie en zelfs woningbouw, terwijl Peipsi veel ongerepter is gebleven.

**Vergelijking van de meren**

De ecologische toestand van een meer wordt door vele factoren beïnvloed. Een van de belangrijkste factoren is de nutriëntenvracht. In Peipsi was de totale P-concentratie altijd laag, maar sinds de jaren negentig is ze gestegen; het doorzicht verminderde, zij het met enige vertraging. In het IJsselmeer was de totale P-belasting altijd vrij hoog, maar tegenwoordig is deze lager dan ooit eerder werd gemeten, dus op het eerste gezicht lijkt de ecologische toestand beter dan ooit. Voor de beheerder van het IJsselmeer is het belangrijk te weten wat de verwachtingen zijn als de nutriëntenvracht nog verder afneemt, waardoor het voedselweb en daarmee ook de voedingscondities voor vogels kunnen veranderen.
Een ander belangrijk kenmerk is de biodiversiteit. In het IJsselmeergebied zorgen de dammen en sluizen die de verschillende grotere en kleinere meren van elkaar scheiden voor aanzienlijke ruimtelijke verschillen in de soortensamenstelling van flora en fauna. Deze verschillen zijn ook verbonden met ruimtelijke verschillen in waterdiepte, sedimentatietype en waterkwaliteit. Echter, deze biodiversiteit wordt tot op zekere hoogte bedreigd door uitheemse soorten. In de omgeving van Peipsi en Pihkva is de natuurlijke biodiversiteit groter, vooral wat betreft de oevergebonden en terrestrische habitats in het achterland (vennen, hoogvenen en bos).

**Vissen en vogels**

Er is een grote overeenkomst in aantal soorten vissen in Peipsi en IJsselmeer. De verschillen tussen de vispopulaties in Peipsi en IJsselmeer en hun exploitatie toont aan dat het minder voedselrijke Peipsi een grotere opbrengst heeft dan het IJsselmeer. De afwezigheid van Paling in Peipsi wordt gecompenseerd door hoge opbrengsten van Snoek, Baars en Snoekbaars. Ook de opbrengst van Spiering is in Peipsi hoger dan in het IJsselmeer. In beide meren zijn de vispopulaties overbevist en heeft de klimaatverandering een overwegend negatief effect op Spiering en Kleine Marene en een positief effect op Snoekbaars. Ondanks de toegenomen nutriëntenvracht in Peipsi verminderden de vangsten vanwege een sterk top down effect van Snoekbaars. Het is zeer onwaarschijnlijk dat een verdere afname van nutriënten in het IJsselmeer tot op het niveau van Peipsi tot lagere visvangsten zal leiden. Het is belangrijker de intensiteit van de visserij in beide meren terug te brengen naar een niveau dat de ontwikkeling van evenwichtige vispopulaties toestaat. Afgezien daarvan zal de klimaatverandering grotere effecten hebben dan een vermindering van de voedingsstoffen. Opwarming van de aarde heeft invloed op het paaigedrag en op het slagen van de opgroei van zalmachtigen, met name Kleine en Grote Marene, maar mogelijk ook Spiering. Aan de andere kant zijn de ontwikkelingen gunstig voor Snoekbaars.

Watervogels vormen een opvallend deel van de fauna van Peipsi en IJsselmeer. Dezelfde soorten gebruiken beide meren als voedsel- en rustgebieden en, aangezien Peipsi bevriest, alleen IJsselmeer voor overwintering. Echter, het voorkomen van voedsel en de beschikbaarheid ervan verschillen aanzienlijk in beide meren. Duikeenden zijn bijvoorbeeld in beide meren aangewezen op Driehoeksmossels. Deze mosselen vormen grote mosselbanken op de voormalige zeebodem van het IJsselmeer, maar zij kunnen geen vaste ondergrond vinden in de grote delen van Peipsi die in de loop van duizenden jaren bedekt raakten door sedimentatie van slib en detritus. Visetende watervogels, die op zicht jagen, moeten in het IJsselmeer hun foerageergebied zoeken tussen de grenzen die worden gesteld door algenbiomassa en zwevende stof, terwijl de vogelaantallen in Peipsi niet worden gelimiteerd door het doorzicht. Voor plantetende vogels is de beschikbaarheid van waterplanten in Peipsi sterk bepaald door fluctuaties van de waterstand, terwijl het vaste waterpeil in het IJsselmeer leidt tot gedeeltelijke overexploitatie van voedselbronnen.

**Landschappelijke kwaliteiten**

Landschappelijke patronen rond IJsselmeer en Peipsi weerspiegelen in sterke mate de verschillende mate van menselijk gebruik. In het IJsselmeergebied werd de oorspronkelijke situatie sterk veranderd ten gunste van landbouw of verstedelijking. Bij Peipsi daarentegen zijn nog steeds grote gradiënten van de oorspronkelijke landschappen aanwezig. Daarom kan Peipsi dienen als een referentiegebied voor de natuurlijke situatie rondom het IJsselmeer. De oevermorfologie, de gradiënten en de verbondenheid tussen de landschappen tonen de oorsprong van waaruit het IJsselmeergebied zich heeft ontwikkeld.
Grote vogelconcentraties treden in de herfst op aan de oostelijke oevers van Peipsi. Meer dan 50 jaar werden jaarlijks tellingen van zichtbare vogeltrek gehouden. Het vangen en ringen van trekvogels onthulde aanvullende informatie over populatiestructuur en trekwegen. Grote veranderingen werden vastgesteld in de aantallen trekvogels, met name in de aantallen van bosbewonende zangvogels, die dramatisch achteruit gingen. Aan de andere kant vertonen bepaalde soorten watervogels een opgaande lijn, vooral plantetende ganzen en zwanen maar ook de Kauw, allemaal soorten die voor een groot deel afhankelijk zijn van landbouw habitat in het westen. In het IJsselmeergebied veranderden de vogeltrekroutes door de aanleg van polders en dammen.
De manier waarop een gebied in biologische zin functioneert, hangt samen met de achterliggende landschappen en habitatkwaliteit. De vergelijking van het voorkomen van bepaalde soorten kan inzicht verschaffen in de mate van compleetheid van een habitat. Vooral als gebieden vergeleken worden op een grote schaal, kunnen conclusies in deze context worden getrokken.
De verdeling van dieren die een sterke band hebben met landschappelijke kwaliteiten, zoals reptielen, amfibieën en zoogdieren, toont aan dat Peipsi over het algemeen meer soorten kent. Vooral de grotere soorten die een grootschalig habitat nodig hebben ontbreken in het IJsselmeergebied. Dit verschil is terug te voeren op de afwezigheid van grootschalige moerassen en van natuurlijk achterland in het IJsselmeergebied.
Natuurlijke waterstandfluctuaties zijn gunstig voor oeverplanten zoals Riet en Mattenbies. Bij Peipsi zijn deze planten langs alle oevers dominant. Ze komen voor op diepten tot 1,5 m en breiden zich naar het water toe uit. In het IJsselmeer zijn de oevers vaak steil en kunstmatig, waardoor de ontwikkeling van natuurlijke vegetatie wordt voorkomen. Waar er nog steeds natuurlijke gradiënten voorkomen, lijken de vegetatiepatronen op die in Peipsi, zij het op een beperktere schaal. Met name Mattenbies is zeldzaam en komt alleen voor in het Zwartemeer en lokaal in de Randmeren en langs de Friese Kust. Deze soort is indicatief voor waterstandschommelingen, die in het IJsselmeer worden veroorzaakt door de invloed van de wind.
De verslechterende waterkwaliteit in het meer Pihkva leidt tot de afname van fonteinkruiden. Hetzelfde gebeurde in de jaren zeventig in het IJsselmeergebied in de Randmeren. Hier zijn intussen echter de waterplanten massaal teruggekeerd dankzij de toepassing van waterzuiveringsinstallaties en doorspoelen met schoon polderwater in de winterperiode. In de jaren negentig kwamen kranswieren *Characeae* weer terug en blijft het water langdurig helder, ook door de teruggekeerde driehoeksmossels.

**Integratie en scenario's**

Tussen de meren Pihkva en Peipsi werden significante ruimtelijke gradiënten gevonden voor de totale concentraties fosfaten en nitraten. Deze gradiënten staan in relatie tot gradiënten in de dichtheid van algen, het doorzicht en gedeeltelijk ook van zooplankton. Voor bodemfauna zijn deze gradiënten helemaal niet duidelijk. Voor vissen verschillen de gradiënten per soort, hetgeen niet te maken schijnt te hebben met de verschillen in de beschikbaarheid van voedsel. Het verschijnsel is eenvoudiger te verklaren op grond van de paaiplaatsen van de verschillende soorten.

Een recente toename van de nutriëntenvracht, met name fosfaat, deed het verschil tussen Pihkva en Peipsi toenemen. Pihkva is veranderd in een eutroof meer, dat meer lijkt op het IJsselmeer wat betreft de totaal-P, chlorofyl-a en het doorzicht. Het is echter nog steeds een natuurlijk meer met een fluctuerend waterpeil en de bijbehorende natuurlijke oevers. Daardoor lijkt het erop dat de veranderingen in de vispopulaties sterker worden gecontroleerd door waterpeilfluctuaties dan door eutrofiering. Het is nog onduidelijk of de veranderingen in de nutriëntenvracht meer invloed hebben dan de klimaatveranderingen.
De patronen van biodiversiteit op het land zijn gerelateerd aan de kenmerken van het landschap rondom de meren. Voor de vergelijking hebben we ons geconcentreerd op broedende vogels in een raster rondom beide meren met cellen van 20x20 km. Vogelsoorten in de verschillende rastercellen werden gerelateerd aan habitat types. Het bleek dat met name de laagveenmoeras- en hoogveen complexen drager zijn van biodiversiteit, naast de qua grondwaterstand natuurlijke bossen. Peipsi telt meer soorten dan het IJsselmeergebied, een teken dat het ecosysteem rond Peipsi completer is. Toch bleken de zonering en de intensief beheerde wetlands rondom het IJsselmeer, hoe gefragmenteerd ook, de aanwezigheid van zeldzame en kwetsbare soorten veilig te kunnen stellen. Het is duidelijk dat het voedselweb in beide meren zal veranderen door zowel de klimaatverandering als het beheer. Een minder intensieve visserij zal leiden tot een groter aantal roofvissen en een geringer aantal vis-etende vogels. Vanwege de complexe onderlinge samenhangen tussen de componenten kunnen deze trends echter niet eenvoudig worden uitgetekend voor de verschillende groepen of soorten. Modellering kan helpen bij het voorspellen van de toekomstige ontwikkelingen.
Het toekomstige ecologische functioneren van Peipsi en IJsselmeer zal in grote mate worden beïnvloed door ontwikkelingen die te danken zijn aan klimaatverandering en veranderingen in het landgebruik. Voor beide gebieden wordt een schets gepresenteerd van de voornaamste trends met hun effecten op flora, fauna en de ecologische functies. Eerst beschrijven we de trends in relatie tot autonome ontwikkelingen, met name de klimaatverandering. Vervolgens komen de deels daarmee samenhangende effecten als gevolg van veranderend landgebruik aan de orde.

**Conclusies en aanbevelingen**

Uit een voorspelling van de voornaamste druk door mensen op de milieucondities blijkt dat de toenemende populatiedruk in het IJsselmeergebied een evenwichtig beheer in de nabije toekomst noodzakelijk maakt. Zonering van het open water met betrekking tot de verschillende gebruiksvormen zou enorm kunnen bijdragen aan het behalen van de Natura 2000 doelen in het watersysteem. In Peipsi ligt de toenemende druk op het watersysteem op dit moment op het niveau van toenemend gebruik van natuurlijke bronnen en verslechterende milieucondities, hetgeen reden geeft tot zorg.
Gelukkig zijn er wel al een aantal stappen gezet. In het IJsselmeer is het ecologisch herstel al aan de gang sinds het begin van het Zuiderzeeproject in 1930. Het bereik veranderde van landgebonden naar watergebonden doelen en van kleinschalige naar grootschalige projecten. Tot nu toe zijn de Oostvaardersplassen (5600 ha) het grootste zoetwatermoeras dat werd ingericht op landschappelijke schaal, hoewel niet in directe verbinding met het meer. We beschrijven de projecten die gepland, in uitvoering of al gerealiseerd zijn in de grote meren. Wat Peipsi betreft ligt de nadruk op de gecombineerde inspanningen om de waterkwaliteit te verbeteren en natuurbescherming ook wettelijk verder te verankeren. Er is al een begin gemaakt met grensoverschrijdend beheer, maar de toekomstige samenwerking moet verder worden uitgebreid om effectief te kunnen zijn.
Ten slotte worden tien aanbevelingen genoemd ter bevordering van de duurzame ontwikkeling van beide gebieden. De aanbevelingen variëren van integraal waterbeheer, de zonering van gebruik en duurzame visserij tot het herstel van de dynamische processen in het IJsselmeer en grootschalig, systeemgericht natuurherstel. Herstel van de overgangen tussen land en water, van de hydrologische samenhang en de natuurlijke waterpeilfluctuaties behoren wat dat betreft tot de meest belangrijke maatregelen.





# Summary

Since the approval of the Water Framework Directive in December 2000, all EU member states are obliged to monitor, evaluate and, if necessary, make restoration plans for their national water bodies. An important aspect of the evaluation is the establishment of reference conditions for the desired state of a water body. Lake Peipsi was identified as the most appropriate reference for Lake IJsselmeer.
A comparative study of both lake systems was organised to help water managers in both lakes in setting up management plans. This project was set up in the expectation that it might lead to mutual benefit. A description of the current status and the recent ecological functioning of Lake Peipsi would support the management of Lake IJsselmeer in setting realistic as well as ambitious goals for the WFD as well as Birds and Habitats Directive. On the other hand, the intensively managed IJsselmeer would be a source of inspiration and information for future management of Lake Peipsi.
On the whole, this idea proved correct. In the course of the project, government officials and water managers of Estonia, Russia and The Netherlands paid regular visits to both lakes. These visits played an important role in gaining insight in the similarities and differences between the two water systems. Study tours were organised, mainly to exchange knowledge but also to improve communication and project coherence. Communication was of vital importance in this international setting, not only among participants in the project group, but also with managers in all three countries and with stakeholders interested in the outcome of the project. Joint fieldwork served as a source of inspiration. The scale, proportion, shape and order of elements, as well as relationships between components, for instance of the landscape, form a set of reference data that offer a powerful addition to theoretical knowledge.

**General features**

Lake Peipsi and Lake IJsselmeer have a lot in common, but they differ in many ways as well. Both lakes are shallow, which sets them apart from other big European lakes. They are both situated between 50° N and 60° N. Weather conditions, however, are different, especially in winter. Both lakes are dammed, but they differ greatly in water level regulation. Also, in Lake IJsselmeer freshwater sediments have been deposited for only 75 years, whereas in Lake Peipsi this process has been going on for more than 8,000 years.
The three countries that border the two lakes, Russia, Estonia and The Netherlands, have old ties related to the lakes. In medieval times, several cities in these countries were part of the Hansa trading organisation. In more recent times both lakes experienced similar developments in shipping and fishing. Nowadays, differences in population density and in pressure on the land are the main reason why Lake IJsselmeer and Lake Peipsi are developing in different ways. In Russia and Estonia, many agricultural fields were abandoned during the last decade, while in The Netherlands pressure on the land has become even greater than before. Lake IJsselmeer is intensively used for recreation and even housing, whereas Lake Peipsi is much more pristine.

**Lakes Compared**

The ecological status of a lake is influenced by many variables, one of the most important being nutrient load. In Lake Peipsi, total P-concentration has always been low, but it increased since the 1990s; transparency decreased, showing a delayed response. In Lake IJsselmeer total P used to be quite high, but nowadays it is lower than ever measured before, so the ecological situation seems to be better than ever at first sight. For the water manager of Lake IJsselmeer it is important to know what to expect if the nutrient load decreases even further, causing the food web to change and changing feeding conditions for birds as well.
Another important variable is biodiversity. In the IJsselmeer area, the dams and sluices that separate the various larger and smaller lakes contribute to considerable spatial differences in species composition of flora and fauna. These differences are also connected to spatial differences in depth, sediment type and water quality. However, biodiversity is threatened to some extent by invasive species. In Lake Peipsi-Pihkva, natural biodiversity is greater, especially with regard to the shore-related and terrestrial habitats in the hinterland.

There is a large correspondence in the abundance of fish species in Peipsi and IJsselmeer. The differences between the fish communities in Peipsi and IJsselmeer and their exploitation show that the less eutrophic lake Peipsi has a higher yield than IJsselmeer. The lack of Eel in Peipsi is compensated by high yields of Pike, Perch and Pikeperch. Also the yield of Smelt is higher in Peipsi than in IJsselmeer. In both lakes the fish communities are overexploited and climate change has a dominant negative effect on Smelt and Vendace and a positive effect on Pikeperch. Despite the increase in nutrient load in Peipsi, the catches went down because of a strong top down effect of Pikeperch. It is very unlikely that the further decrease in nutrients in IJsselmeer to the level of that in Peipsi will lead to lower fish catches. It is more important to reduce the intensity of fishery in both lakes to a level that allows balanced fish populations to develop. Apart from that, climate change will have more pronounced effects than nutrient reduction. Global warming affects the spawning and the success of larval recruitment of salmonid species, especially Vendace and Peipsi Whitefish, but possibly also Smelt. On the other hand Pikeperch is favoured.

Waterbirds form a conspicuous part of the fauna of both Peipsi and IJsselmeer. The same species use both lakes as stopover sites and, because Peipsi is frozen over, only IJsselmeer as a wintering site. However, food abundance and food availability differ considerably in both areas. Diving ducks, for instance, depend on Zebra Mussels in both lakes. These mussels form large beds on the former seabed in IJsselmeer, but they can't find firm substrate in the large parts of Peipsi which were covered by sedimentation of silt and detritus over thousands of years. Fish eating waterbirds, which hunt on sight, have to choose their foraging areas in IJsselmeer between the limits set by algal blooms and suspended silt, whereas in Peipsi water transparency is not limiting bird numbers. For herbivorous birds, the availability of macrophytes in Peipsi is strongly determined by water level fluctuation, while in IJsselmeer the fixed water table leads to partly over-used food stocks.

### Landscape quality

Landscape patterns in IJsselmeer and Peipsi strongly reflect the different degrees of human occupation. In IJsselmeer, the original situation was altered considerably in favour of agricultural use or urbanisation. By contrast in Peipsi, large gradients of the original landscapes are still present. Therefore, Peipsi can serve as a reference area for the natural situation in the IJsselmeer area. The coastal forms, the gradients and the connectivity among the landscapes demonstrate the origin from which the Dutch situation has evolved.
Massive bird concentrations occur at the eastern shores of Lake Peipsi in autumn. During more than 50 years, annual counts of visible migration were performed. Catching and banding of migrants revealed additional information about population structure and migratory routes. Great changes were recorded in the number of migrants, especially in the number of forest dwelling songbirds, which declined dramatically. On the other hand, some species of water birds tend to increase, especially herbivorous geese and swans but also Jackdaw, all of which are species that rely on agricultural habitat in the west to a large extent. In IJsselmeer, bird migration routes have changed because of construction of polders and dams.
The way an area functions biologically relates to the underlying landscapes and habitat components. Comparing the occurrence of certain species may yield insight into the degree of habitat completeness. Especially if areas are compared at a very large scale, conclusions can be drawn in this context. The distribution of animals which have a strong link to the quality of the landscape, i.e. reptiles, amphibians and mammals, shows that Peipsi generally has more species, but the more so in the larger species which require large-scale habitat. The absence of large-scale marshes and a natural hinterland in IJsselmeer are responsible for this.
Natural water level fluctuations are beneficial for emergent macrophytes such as Reed and Bulrush vegetation.
In Peipsi these plants are dominant along all shores. They occur at depths up to 1.5 m and show a lakeward expansion. In IJsselmeer, shores are often steep and artificial, which prevents the development of natural vegetation. Where more natural gradients still occur, vegetation patterns resemble those in Peipsi, although on a more limited scale. Bulrush especially is scarce and is only present in Lake Zwartemeer and locally in the Borderlakes. This species is indicative of hydrodynamic fluctuations, which in IJsselmeer are caused by wind effects.
The deteriorating water quality in Lake Pihkva leads to the decrease of pondweeds. The same was the case in IJsselmeer and the Borderlakes in the 1970s. Here, however, some weeds returned thanks to purification plants and winter flushing with clean polder water. In the 1990s stoneworts *Characeae* reappeared.

### Integration and scenarios

Between Lake Pihkva and Lake Peipsi, significant spatial gradients were described for total phosphorus and total nitrogen concentrations. These gradients relate to gradients in density of algae and transparency and partly also of zooplankton. For zoobenthos this gradient is not clear at all. For fish it is different per species, which appears unconnected to possible differences in food availability; it is more easily explained by the spawning places of the different species.
A recent increase in nutrient load, particularly phosphorus, increased the difference between Lake Pihkva and Lake Peipsi. Lake Pihkva has changed into a more eutrophic lake, more similar to IJsselmeer when considering total P, chlorophyll-a concentration and transparency. However, it is still a natural lake with a fluctuating water level and associated floodplains. Therefore the dynamics of the fish populations seem to be controlled more by water level fluctuations than by eutrophication. It is still unclear whether the changes in nutrient load are more important than the changes in climate.
Biodiversity patterns on land are related to environmental characteristics of the landscape around the lake. For comparison we focused on breeding birds in a grid of 20x20 km. Bird species in the individual grid cells were related to habitat type. Peipsi had more species than IJsselmeer, reflecting a more complete ecosystem. Still, zoning and the intensively managed wetlands around IJsselmeer, although highly fragmented, guarantee the presence of rare and vulnerable species.
It is clear that the food web in both lakes will change according to both global warming and management. A lower fishery pressure will lead to more predators and fewer fish-eating water birds. However, because of the complex interrelationships of the components, these trends are not easily outlined for specific groups or species. Modelling exercises may help to forecast future developments.





The future ecological functioning of Peipsi and IJsselmeer will be greatly influenced by the developments due to climate change and changes in land use. For both regions an outline is presented of the main trends with their effect on flora, fauna and the ecological functions. First we examine the trends in relation to autonomous developments with a main focus on climate change. Next, the related effects due to expected changes in land use are discussed.
A prognosis of the major pressures by man on the environmental conditions is given.
In IJsselmeer the increasing pressure by people requires a balanced management in the near future. By zoning the open water with respect to the different forms of use, the Natura 2000 values in the system could profit tremendously. In Peipsi the increasing pressure on the system is at present at the level of increased use of natural resources and deteriorating environmental conditions, which causes concern.

Fortunately, some steps have already been taken. In IJsselmeer ecological restoration has been going on since the start of the Zuiderzee project in 1930. The scope changed from terrestrial to aquatic and from small-scale to large-scale projects. So far the Oostvaardersplassen (5600 ha) was the largest freshwater marsh established at landscape scale, although not in direct connection to the lake. A description is given of the projects that are either planned, in progress or already realised in the large lakes. For Peipsi, emphasis is put on combined efforts to improve basic water quality and to further legislate nature protection. Transboundary management has already started, but future co-operation needs to be extended in order to be effective.

Finally, ten recommendations are listed to further the sustainable development of both areas. They range from the need for integrated water management, zoning of activities and establishing sustainable fishery, to restoring dynamic processes in IJsselmeer and large-scale, system-oriented nature reconstruction. Restoring the land-water transitions, the hydrological connectivity and more natural water level fluctuations are among the most crucial in this respect.

## Kokkuvõte

Veepoliitika Raamdirektiivi heakskiitmisest 2000. aasta detsembris lasub kõikidel EL liikmesriikidel kohustus jälgida, hinnata ja vajaduse korral koostada plaan riigi veekogude seisundi parandamiseks. Hindamiseks on oluline leida veekogule foonitingimused, kuhu poole püüelda veekogu majandamisel. IJsselmeerile on Peipsi järv võrdluseks kõige kohasem.

Mõlema järve majandamise eest vastutajate abistamiseks viidi läbi järvesüsteemide võrdlev uuring. Peipsi praeguse seisundi ja eelnevate muutuste kirjeldus annab hea aluse Veepoliitika Raamdirektiivi ning Linnu ja Elupaiga Direktiivi realistlike eesmärkide seadmiseks IJsselmeeri puhul. Teisalt on intensiivselt majandatud IJsselmeeri olukord inspiratsiooni- ja infoallikaks Peipsi majandamisel.

Uurimistöö kinnitas sellise võrdluse asjakohasust. Projekti käigus olid mõlemad järved nii Eesti, Vene kui ka Hollandi ametnike ja veespetsialistide tähelepanu all. Vastastikuste uurimisreiside käigus leiti sarnasusi ja erinevusi kahe järve vahel. Külastuste käigus jagatud teadmised aitasid parandada nii teadlaste kui ka erinevaid maid esindavate ametnike omavahelist suhtlust ja ühist arusaamist järvede seisundist. Infovahetus oli oluline rahvusvaheliste kontaktide loomiseks mitte ainult projektiliikmete vahel, vaid ka kolme maa veehaldusspetsialistide ja huvigruppide esindajate seas. Ühine välitöö oli inspireeriv ja andis väärtuslikku lisa teoreetilistele teadmistele ökosüsteemi komponentide vastastikustest suhetest ja proportsioonidest.

### Üldiseloomustus

Peipsil ja IJsselmeeril on küll palju ühist, kuid mõnes aspektis on nad ka erinevad. Mõlemad järved on madalad, mis eristab neid teistest Euroopa suurjärvedest. Nad asuvad 50° ja 60° põhjalaiuse vahel. Ilmastikutingimused erinevad eriti talvel. Mõlemal järvel on tamm, kuid Peipsi veetase sõltub looduslikest tingimustest, IJsselmeeris on see inimese poolt reguleeritud. IJsselmeeri mageveesetted on ladestunud viimase 75 aasta jooksul; Peipsis on see protsess toimunud juba üle 8000 aasta.

Kolmel järve-äärsel maal on ajalooliselt kujunenud tihedad sidemed järvedega. Keskajal kuulusid mitmed nende järvede äärsed linnad Hansa kaubandusvõrgustikku. Hilisemal ajal on arenenud mõlemal järvel sarnaselt laevandus ja kalandus. Kaasajal on asustustiheduse ja maakasutuse erinevused peamiseks põhjuseks, miks Peipsi ja IJsselmeeri arenguteed on erinevad. Venemaal ja Eestis on viimasel kümnendil palju haritavaid maid maha jäetud. Samal ajal on Hollandis maakasutus isegi intensiivistunud. IJsselmeeri kasutatakse puhkemajanduses ja isegi elamuehituseks, teisalt Peipsi on jäänud looduslikumaks.

### Järvede võrdlus

Järve ökoloogilist seisundit mõjutavad mitmed tegurid, millest üks tähtsamaid on toitesoolade sissevool. Peipsis on üldfosfori kontsentratsioon olnud alati madal, kuid alates 1990ndatest on see tõusnud. Samal ajal on vee läbipaistvus vähenenud, näidates ajalise nihkega vastusreaktsioone. IJsselmeeris on üldfosfori tase olnud küllaltki kõrge, kuid praegu on see madalam kui kunagi varem, viidates ökoloogilise seisundi paranemisele. IJsselmeeri veemajandusspetsialistidele on tähtis teada, mida võib oodata, kui toitesoolade koormus veelgi väheneb, põhjustades muutusi toiduahelates ja muutes lindude toitumistingimusi.

Teine oluline näitaja on bioloogiline mitmekesisus. IJsselmeeri piirkonnas eraldavad tammid ja lüüsid suuremaid või väiksemaid järveosasid, põhjustades floora ja fauna liigilise koosseisu suuri ruumilisi erinevusi. Need erinevused on samuti seotud vee sügavuse, sette tüübi ja veekvaliteedi ruumiliste erinevustega. Teatud määral ohustavad bioloogilist mitmekesisust ka võõrliigid. Peipsi-Pihkva järves on looduslik liigiline mitmekesisus suurem, eriti kui arvestada kaldalähedasi ja maismaa elupaiku järve ümbruses.

Peipsi ja IJsselmeeri kalaliikide arvukus on suures osas sarnane. Järvede kalakoosluste ja nende kasutamise erinevused näitavad, et madalama troofsustasemega Peipsi järv annab kõrgemat saaki kui IJsselmeer. Angerja puudumist Peipsis kompenseerivad haugi, ahvena ja koha kõrged saagid. Ka tindisaak on Peipsis kõrgem kui IJsselmeeris. Mõlema järve kalakooslused kannatavad ülepüügi all. Kliimamuutustel on valdavalt negatiivne mõju tindile ja rääbisele, kuid positiivne mõju kohale.

Vaatamata toitesoolade koormuse suurenemisele Peipsis on saagid langenud koha tugeva ülaltlähtuva (top-down) mõju tõttu. On vähetõenäoline, et biogeenide koormuse edasine vähenemine Peipsi tasemele vähendaks kalasaake IJsselmeeris. Olulisem on vähendada kalanduse intensiivsust mõlemas järves sellise tasemeni, mis võimaldaks tasakaalustatud kalapopulatsioonidel areneda. Sellele vaatamata on kliimamuutustel tugevam mõju kui toitesoolade koormuse vähendamisel. Globaalne soojenemine mõjutab lõhilaste, eriti rääbise ja Peipsi siia, kuid võimalik, et ka tindi kudemise ja vastsete arengu edukust. Teisalt mõjub see kohale soodsalt.

Veelinnud moodustavad märkimisväärse osa nii Peipsi kui ka IJsselmeeri faunast. Samad liigid kasutavad mõlemat järve peatuspaigana, ja kuna Peipsi on külmunud, siis ainult IJsselmeeri talvituspaigana. Kuid toidu hulk ja kättesaadavus erinevad oluliselt mõlemas piirkonnas. Näiteks sukelpardid sõltuvad mõlemas järves rändkarbi kättesaadavusest. Need karbid moodustavad suuri kogumikke IJsselmeeris endisel merepõhjal, kuid nad ei leia kindlat substraati suurel alal Peipsis, mis on kaetud tuhandete aastate jooksul settinud muda- ja detriidikihtidega. Kalatoidulised veelinnud, kes kütivad nägemismeele abil, peavad oma küttimisalad IJsselmeeris valima vastavalt vetikaõitsengutele ja hõljuva muda piiravale toimele. Seevastu Peipsis ei piira vee läbipaistvus lindude arvukust. Peipsis mõjutavad veetaseme kõikumised suurtaimestiku kättesaadavust taimtoidulistele lindudele. IJsselmeeris on veetase fikseeritud ja toiduvarud osaliselt ülekasutatud.

Peipsi ja IJsselmeeri ümbruse maastikud peegeldavad inimkasutuse iseloomu. IJsselmeeri ümbruses on loodusmaastikud tugevasti ümber kujundatud põllumajanduse või linnastumise mõjul. Peipsis seevastu on originaalmaastike suured gradiendid ikka veel nähtavad. Seepärast võib Peipsit käsitleda IJsselmeeri piirkonna loodusliku olukorra võrdlusalana. Kaldavormid, gradiendid ja ühendusteed erinevate maastikuvormide vahel näitavad situatsiooni, millest Hollandi olukord on kunagi lähtunud.

Sügiseti esinevad ulatuslikud linnukogumikud Peipsi idarannikul. Enam kui 50 aasta jooksul on tehtud igaaastasi nähtava rände loendusi. Rändlindude püük ja rõngastamine on andnud täiendavat informatsiooni populatsiooni struktuuri ja migratsiooniteede kohta. Rändlindude arvukuses on täheldatud suuri muutusi, eriti metsas elavate laululindude arvukuses, mis on dramaatiliselt vähenenud. Teiselt poolt on mõnede veelinnuliikide, eriti taimtoiduliste hanede ja luikede, aga ka kaelushaki, arvukus suurenenud. Kõik need liigid sõltuvad põllumajanduslikest elupaikadest Peipsist läänepoolsetel aladel. IJsselmeeri piirkonnas on lindude rändeteed muutunud poldrialade ja tammide ehitamise tõttu.

Ala bioloogiline toimimine on seotud selle pinnavormide ja elupaiga komponentidega. Mõne liigi esinemise võrdlus annab aimu elupaiga täiuslikkusest. Selles kontekstis võimaldab Peipsi ja IJsselmeeri piirkondade väga suurtes mastaapides võrdlemine teha olulisi järeldusi. Maastiku kvaliteedist oluliselt sõltuvate loomaliikide, nt roomajate, kahepaiksete ja imetajate levik näitab, et Peipsi ümbruses on üldiselt rohkem liike, kes nõuavad suuremõõtmelisi elupaiku. Selle põhjuseks on laiaulatuslike märgalade ja looduslike rannaalade puudumine IJsselmeeri piirkonnas.

Looduslikud veetaseme kõikumised on soodsad kaldaveetaimestiku nt pilliroo ja kõrkja kasvule. Need taimed domineerivad Peipsi rannaaladel. Nad esinevad kuni 1,5 meetri sügavusel ja levivad piki kallast. IJsselmeeri kaldad on järsud ja sageli kunstlikud, mis takistab looduslikku taimestiku arengut. Kohtades, kus siiski looduslikumad gradiendid esinevad, sarnaneb taimestik vähesel määral Peipsi omaga. Hundinui on eriti harv ja esineb ainult Zwartemeeris ja kohati Borderlakes'is. See liik on eriti indikatiivne hüdrodünaamilistele kõikumistele, mis IJsselmeeris on tingitud tuule mõjust.





Veekvaliteedi halvenemine Pihkva järves viib penikeelte vähenemiseni. Sama nähtus esines IJsselmeeris ja Borderlakes'is 1970ndatel aastatel. Siiski mõned penikeele liigid on tänu puhastusseadmetele ja talvisele puhta poldriveega üleuhtmisele taastunud. 1990ndatel ilmusid taas mändvetikad (Characeae).

### Lõimumine ja stsenaariumid

Pihkva ja Peipsi järve vahel on täheldatud üldfosfori ja üldlämmastiku kontsentratsiooni olulisi ruumilisi gradiente. Need gradiendid seonduvad ka vetikate hulga, vee läbipaistvuse ning osaliselt zooplanktoni gradientidega. Kalade puhul on see liigiti erinev, mis ei ole niivõrd seotud toidu kättesaadavuse võimalike erinevustega, kuivõrd just kudemisalade levikuga erinevate liikide jaoks.

Toitainete, eriti fosfori koormuse suurenemine on tinginud erinevuste süvenemist Peipsi ja Pihkva järve vahel. Pihkva on muutunud eutroofsemaks, IJsselmeeriga sarnasemaks kui arvestada üldfosfori ja klorofüll-a sisaldust ning vee läbipaistvust. Siiski on tegemist loodusliku järvega, kus veetase kõigub ja sellega on seotud üleujutusalad. Seetõttu näib kalapopulatsioonide dünaamika olevat rohkem kontrollitud veetaseme muutuste kui eutrofeerumise poolt. Veel on ebaselge, kas muutused toitainete koormuses on olulisemad kui muutused kliimas.

Bioloogiline mitmekesisus maismaal on seotud järve ümbritseva maastiku keskkonnanäitajatega. Võrdlemiseks keskendusime me 20x20 km ruudustikus pesitsevatele lindudele. Peipsis oli rohkem liike kui IJsselmeeris, mis peegeldab ökosüsteemi suuremat täiuslikkust. Üksikute ruudustiku osarakkude linnuliigid olid seotud elupaiga tüübiga. Eriti oluline oli rabade ja madalsoode olemasolu. Ehkki IJsselmeeri ümbrus on tugevasti fragmenteeritud, tagavad tsoneerimine ja märgalade intensiivne majandamine haruldaste ja tundlike liikide püsimise.

Peipsi ja IJsselmeeri ökoloogiline funktsioneerimine tulevikus sõltub suuresti kliima ja maakasutuse muutustest. Mõlema piirkonna jaoks on visandatud põhitrendid seoses nende mõjuga floorale ja faunale ning ökoloogilisele toimimisele. Esiteks vaadeldakse piirkondade arengutrende seoses kliimamuutustega. Seejärel selgitatakse maakasutuse muutuste võimalikku mõju.

Samuti antakse hinnang põhiliste inimtekkeliste survetegurite mõju kohta keskkonnatingimustele. IJsselmeeri piirkonnas nõuab suurenev inimsurve tasakaalustatud majandamist. Avavee tsoneerimine erinevate kasutusvormide suhtes võib anda suurt tulu Natura 2000 eesmärkide saavutamiseks. Peipsi puhul teeb muret tugenev surve ökosüsteemile: loodusressursside ulatuslikum kasutamine halvendab keskkonnatingimusi.

Mõned positiivsed arengud on ka täheldatavad. IJsselmeeri ökoloogiline taastamine on toimunud alates Zuiderzee projekti algusest 1930. aastal. Fookus on nihkunud maismaa projektidelt veeprojektide suunas ja väikesemahulistelt projektidelt mastaapsemate projektide suunas. Senini on Oostvaardersplassen (5600 ha) suurim magevee märgala, ehkki see ei ole otseselt järvega seotud. Raamatus kirjeldatakse planeeritavaid, juba käigusolevaid ja realiseeritud suurjärvede projekte. Peipsi puhul on põhirõhk suunatud kombineeritud jõupingutustele, et parandada vee kvaliteeti ja anda enam seadusandlikku jõudu looduskaitsele. Piiriülese majandamisega on juba alustatud, kuid tulevikus tuleb koostööd tõhustada.

Raamatu lõpus on esitatud 10 soovitust mõlema piirkonna säästlikuks arenguks. Need kätkevad soovitusi integreeritud veemajanduseks, tsoneerimiseks ja jätkusuutliku kalamajanduse kujundamiseks, dünaamiliste protsesside taastamiseks IJsselmeeris ja suureulatuslikeks looduse taastamise projektideks. Maismaa-vee üleminekute ja hüdroloogiste ühendusteede taastamine ning looduslähedasemate veetaseme kõikumiste loomine on selles osas kõige olulisemad eesmärgid.

# Краткое содержание

С момента вступления в силу Водной Рамочной Директивы в декабре 2000 г., все страны-члены соглашения обязаны проводить наблюдения, оценивать и, если необходимо разрабатывать планы работ, направленные на улучшение состояния своих водных объектов. Важным аспектом подобной оценки является определение эталонных (референтных) условий для каждого конкретного водоема. Псковско-Чудское озеро является наиболее подходящим возможным эталонным водоемом для озера Эйсселмеер.

В помощь специалистам по водным ресурсам, вовлеченным в создание планов управления для данных озер, было организовано сравнительное изучение обоих озерных систем. Ожидается, что реализация данного проекта должна принести выгоду всем вовлеченным сторонам. Описание современного состояния и недавних изменений экологических характеристик Псковско-Чудского озера может оказать поддержку в процессе управлении озером Эйсселмеер в ходе постановки реалистичных, а также амбициозных целей, направленных на выполнение условий Водной Рамочной Директивы и Директивы по Птицам и Биотопам. С другой стороны, опыт интенсивного управления озером Эйсселмеер, может стать источником вдохновения и информационной поддержки для управления Псковско-Чудским озером в будущем.

В общем и целом, эта идея сработала. В ходе проекта сотрудники государственных структур и специалисты по водным вопросам из Эстонии, России и Нидерландов совершали регулярные визиты в регионы обоих озер. Данные визиты сыграли важную роль в получении представления о сходствах и различиях между двумя водными экосистемами. Были организованы учебные поездки, в основном с целью обмена знаниями, а также для улучшения коммуникации и согласованности проекта. Коммуникация играла решающую роль в данном международном сотрудничестве, не только между участниками проекта, но также и среди управленцев из стран-участников проекта и природопользователей, заинтересованных в результате проекта. Совместные полевыеисследования послужили источником вдохновения. Масштаб, пропорция, структура и порядок элементов, а также взаимоотношение компонентов, например, ландшафтных, сформировали набор референтных данных, которые послужили мощным дополнением к теоретическим знаниям.

**Общая характеристика**

Между озерами Псковско-Чудское и Эйсселмеер много общего, но также существует и много различий. Оба озера мелководны, что выделяет их из ряда других крупных Европейских озер. Оба водоема располагаются между 50° и 60° северной широты. Погодные условия, тем не менее, различаются, особенно зимой. Оба озера зарегулированы плотинами, но по механизму регуляции уровня они различаются очень значительно. Также, в озере Эйсселмеер накопление пресноводных донных отложений происходило только в течение 75 лет, в то время как в Псковско-Чудском озере этот процесс продолжается уже более 8 000 лет.

Три страны, расположенные в регионах двух озер, Россия, Эстония и Нидерланды, имеют древние экономические связи. В средневековье, некоторые города в данных странах были членами Ганзейской торговой организации. В недавнем прошлом оба озера использовались сходным образом для судоходства и рыболовства. В настоящее время, различия в плотности населения и нагрузке на земельные ресурсы являются основными причинами того, почему озера Псковско-Чудское и Эйсселмеер развиваются различными путями. В России и Эстонии, многие бывших сельскохозяйственные угодья в последние десятилетия перешли в разряд бывших сельскохозяйственных земель, в то время как в Нидерландах нагрузка на земельные ресурсы увеличивается. Озеро Эйсселмеер активно используется для рекреации и для строительства, в то время как Псковско-Чудское озеро гораздо более естественное.

**Сравнение озер**

На экологический статус озера влияет многие составляющие, наиболее значимым среди них является биогенная нагрузка. В Псковско-Чудском озере всегда были незначительные концентрации общего фосфора, но концентрации начали увеличиваться с начала 1990-х гг., прозрачность падает, что является ответной реакцией водоема. В озере Эйсселмеер концентрации общего фосфора довольно высоки, но в настоящее время они несколько ниже, чем измеренные ранее. Таким образом, экологическая ситуация оказывается даже лучше, чем может показаться с первого взгляда. Для специалистов по водным ресурсам работающих на озере Эйсселмеер важно знать, что их ожидает, если биогенная нагрузка в ближайшие годы будет продолжать снижаться, вызывая изменения структуры пищевой цепи и, следовательно, изменяя условия кормежки птиц.

Другой важной составляющей является биоразнообразие. В регионе озера Эйсселмеер плотины и шлюзы, разделяющие водоем на ряд крупных и мелких озер,вызывают значительные пространственные различия видового состава флоры и фауны. Причиной этого являются также различия в глубинах, типах донных отложений и качестве воды. Кроме того, биоразнообразие находится в определенной мере под угрозой внедрения инвазионных видов. Псковско-Чудское озеро обладает более богатым естественным разнообразием видового состава, особенно это касается прибрежных и удаленных от побережья внутренних биотопов.

Псковско-Чудское озеро и Эйсселмеер имеют аналогичный видовой состав рыб. Различия между рыбными сообществами и объемом улова на Псковско-Чудском озере и Эйсселмеер показывает, что менее эвтрофное Псковско-Чудское озеро обладает большими рыбными запасами, чем Эйсселмеер. Отсутствие угря в Псковско-Чудском озере компенсируется высокими запасами щуки, окуня и судака. Запасы снетка в Псковско-Чудском озере выше, чем в Эйсселмеер.На обоих озерах рыбные сообщества подвергаются чрезмерной эксплуатации. Изменение климата оказывает доминирующий негативный эффект на запасы снетка и ряпушки, и положительный эффект на запасы судака. Несмотря на увеличение биогенной нагрузки на Псковско-Чудское озеро, их уловы сократились в связи с сильным прессом судака. Однако не похоже, что дальнейшее сокращение биогенов в Эйсселмеер до уровня концентрации биогенных компонентов Псковско-Чудского озера приведет к снижению уловов рыбы. Очень важно снизить интенсивность рыболовства на обоих озерах до уровня, который в дальнейшем позволит популяциям рыб развиваться сбалансировано. Кроме того, изменение климата будет иметь более значимый эффект, чем сокращение биогенной нагрузки. Глобальное потепление оказывает влияние на нерест и на успешное выживание лососевых видов рыб, особенно ряпушки и чудского сига, но возможно и снетка. С другой стороны судак будет находиться в более выгодных условиях.

Водоплавающие птицы составляют значительную часть фауны как Псковско-Чудского озера, так и озера Эйсселмеер. Одни и те же виды останавливаются наданных озерах во время миграций, а из-за того, что Псковско-Чудское озеро замерзает зимой, в качестве места зимовки используется только озеро Эйсселмеер. Хотя наличие обильного и доступного корма на озерах значительно различается. Нырковые утки, например, используют дрейссену в качестве корма на обоих озерах. Эти моллюски образуют обширные скопления на бывшем морском дне в Эйсселмеер. Однако на больших участках дна Псковско-Чудского озера, покрытых иловыми отложениями и детритом, который образовывался в течение тысячелетий, дрейссена не может найти твердого субстрата. Выбор кормовых территорий на Эйсселмеер рыбоядными водоплавающими птицами, условия охоты которых зависят от наличия света, зависит от ограничений связанных с цветением водорослей и наличием взвешенного ила, в то время как на Псковско-Чудском озере прозрачность воды не является фактором, ограничивающим численность птиц. На Псковско-Чудском озере колебания уровня воды является фактором, ограничивающим распространение макрофитов, что важно для растительноядных птиц, в то время как на Эйсселмеер зафиксированный уровень воды иногда приводит к чрезмерному использованию кормовых запасов.

Особенности ландшафтных характеристик Эйсселмеер и Псковско-Чудского озера напрямую отражают степень освоенности территорий человеком. На Эйсселмеер, естественные условия были значительно видоизменены в результате сельскохозяйственного воздействия и урбанизации. В отличие от Эйсселмеер на Псковско-Чудском озере, все еще присутствует большое разнообразие естественных ландшафтов. Таким образом, Псковско-Чудской водоем с естественными условиями может служить для Эйсселмеер референтным объектом. Особенности береговой линии, разнообразие и взаимосвязь ландшафтов Псковско-Чудского озера, демонстрирует природное состояние, к которому стремиться голландской объект.

Осенью на восточном побережье Псковско-Чудского озера образуются массовые концентрации птиц. В течение более 50 лет, здесь проводятся ежегодные визуальные наблюдения за миграцией птиц. Отлов и кольцевание птиц-мигрантов предоставляет дополнительную информацию о структуре популяций и маршрутах миграции. Были отмечены значительные изменения численности мигрантов, особенно лесных певчих птиц, которые значительно сократили свою численность. С другой стороны, численность некоторых видов водоплавающих птиц имеет тенденцию к увеличению, особенно это касается растительноядных гусей и лебедей, а также галок, т.е. тех видов, которые в большой степени зависят от наличия сельскохозяйственных биотопов на западе. В Эйсселмеер строительство польдеров и дамб изменило маршруты миграции птиц.

Биологические функции территории зависят от характера ландшафтов и компонентов биотопов. Сравнительный анализ мест обнаружения отдельных видов может дать представление о характере полноты биотопа. Особенно интересные выводы можно сделать при сравнении данных на крупномасштабных территориях. Характер распространения животных имеет устойчивую связь с качеством ландшафтов. В регионе Псковско-Чудского озера, в общем,количество видов рептилий, амфибий и млекопитающих выше, но это также связано с тем, что крупным видам требуются обширные биотопы. Отсутствие большого количества крупных болотных массивов и природных прибрежных полос на Эйсселмеер является причиной меньшего числа видов.

Естественные колебания уровня воды оказывают положительное влияние на полупогруженные макрофиты, такие как заросли тростника и камыш. В Псковско-Чудском озере данная растительность доминирует на всем побережье. Они обнаруживаются на глубине до 1,5 метров и имеют тенденцию к дальнейшему расширению площадей распространения. В Эйсселмеер берега часто крутые и искусственные, что не способствует развитию природной растительности. Там, где еще присутствуют условия, приближенные к природным, характер растительности напоминает побережье Псковско-Чудского озера, но в более мелком масштабе. Камыш особенно редок и присутствует только на озере Звартемеер, местами также в Бордерлейкс. Этот вид является индикатором гидродинамических колебаний, которые в озере Эйсселмеер вызываются ветровым воздействием.

Ухудшение качества воды в Псковском озере приводит к сокращению площадей распространения рдеста. Подобный процесс имел место в Эйсселмеер и в Бордерлейкс в 1970-х гг. Хотя, благодаря растительности, способствующей очищению воды, и зимнему смыву чистых вод с польдеров, некоторые виды растений возвращаются. В 1990-х гг. сюда вернулись харовые водоросли (Characeae).

**Интеграция и сценарии**

Как в Псковско-Чудском озере, так и в Эйсселмеер, был обнаружен значительный пространственный градиент концентраций общего фосфора и общего азота. Эти пространственные градиенты связаны с градиентами плотности водорослей и прозрачности, и частично с зоопланктоном. Для зообентоса подобный градиент практически не отмечен. Для рыб это зависит от вида, и, похоже, не связанно с возможными различиями доступности корма, а лучше объясняется расположениями мест нереста различных видов.

Недавнее увеличение биогенной нагрузки, особенно по фосфору, увеличивает различие между Псковским и Чудским озером. Псковское озеро приобретает более эвтрофные черты, и больше походит на озеро Эйсселмеер в плане концентраций общего фосфора, хлорофилла-а и прозрачности. Хотя это по-прежнему природный водоем, с естественными колебаниями уровня воды и прилегающими заливными лугами. Таким образом, динамика популяции рыб, возможно, регулируется в большей степени колебаниями уровня воды, чем эвтрофикацией. Все еще неясно, являются ли изменения биогенной нагрузки более значимыми, чем изменения климата.

Характер распространения биоразнообразия на суше в регионе озер связан с экологическими характеристиками ландшафтов. Для сравнения мы сфокусировались на анализе распространения гнездящихся птиц в пределах квадратов (20x20 км). В Псковско-Чудском озере видовой состав оказался богаче, чем в Эйсселмеер, что обусловлено полнотой экосистемы. Распространение отдельных видов птиц в квадратах связывалось с типом биотопов, особенно с наличием разных типов водно-болотных угодий. Все же, хоть и очень фрагментарно, зонирование и интенсивное управление водно-болотными угодьями в регионе озера Эйсселмеер дает гарантию присутствия редких и находящихся под угрозой исчезновения видов.

В будущем экологические функции Псковско-Чудского озера и Эйсселмеер будут в значительной мере зависеть от изменений, связанных с климатом и характером землепользования. Для обоих регионов разработана схема основных трендов и их влияния на флору, фауну и экологические функции. Сначала мы изучили тенденции, связанные с автономными разработками с основным упором на изменение климата. Далее обсуждались эффекты, связанные с ожидаемыми изменениями в землепользовании.

Сделан прогноз основных видов человеческого воздействия на экологические условия. Для региона Эйсселмеер возрастающее влияние человека требует в ближайшем будущем сбалансированного управления. При зонировании акватории на предмет различных видов пользования, данные системы Natura 2000 могут принести огромную пользу. Для Псковско-Чудского озера воздействие на экосистему продолжает возрастать и в настоящий момент находится на уровне интенсивного использования природных ресурсов и ухудшения экологических условий, что вызывает озабоченность.

К счастью определенные меры уже принимаются. В Эйсселмеер восстановление экологических условий проводится с момента начала в 1930 г. проекта «Заудерзее». Область проведения мероприятий переместилась с суши на воду, и с мелкомасштабных - на крупномасштабные проекты. До настоящего момента Оостерваардерсплассен (площадью 5600 га) было крупнейшим пресноводным болотным массивом, который был создан на ландшафтном уровне, хотя и не имел непосредственной связи с озером. Дается описание проектов для крупных озер, которые запланированы, реализуются или уже реализованы. Для региона Псковско-Чудского озера акцент сделан на совместные усилия, направленные на улучшение основного качества воды и на дальнейшее улучшение законодательных природоохранных основ. Трансграничное управление уже было стартовало, но необходимо продолжать дальнейшее сотрудничество для того, чтобы сделать его более эффективным.

Наконец, дается список из десяти рекомендаций, направленных на дальнейшее устойчивое развитие обоих регионов. К ним относятся мероприятия, начиная от потребностей в интегрированном управлении водными ресурсами, мероприятий по зонированию и созданию условий для устойчивого рыболовства, до возрождения динамических процессов в Эйсселмеер и крупномасштабного, системно-ориентированного преобразования природы. Наиболее важным в данном аспекте выглядит восстановление переходных зон между сушей и водой, гидрологической связанности и, приближенных к природным условиям, колебаний уровня воды в озере.

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