Sea trout in the Dutch Wadden Sea and adjacent freshwater streams

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Date: July 18, 2012

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Document type:	Final report
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Educational institute:	University of Groningen, faculty of mathematics and natural sciences
Master's program:	Marine Biology – Science, Business & Policy
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Date:	July 18, 2012

Cover photo reference: picture from Reynolds, D. *Planes fly in a v, birds fly in a v, fish swim in a v.* Retrieved: July 18, 2012 from website: http://www.cartoonstock.com/cartoonview.asp?catref=dre0386

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Preface

This report is written in context of my final thesis for my Master´s program Marine Biology with a specialization in Science, Business and Policy at the University of Groningen. It concerns the fish migrations issues the Regional Water Authority Noorderzijlvest has to deal with. The goal of the internship is to integrate the ecology aspects of sea trout and the pertinent policies to elucidate the fish migration issues. This advisory report is the end product of a half year internship from January 2012 to July 2012.

I have enjoyed my time at Noorderzijlvest very much. Therefore I want to thank Jeroen Huisman of Noorderzijlvest for offering this internship opportunity and all the gained experiences during the internship. I also want to thank Eize Stamhuis and Peter Weesie of the University of Groningen for their suggestions, feedback and support. Your excellent guidance helped me at times when I got stuck or at other difficult moments during the internship. Also many thanks to all the Living North Sea partners for your input, information and the pleasant meeting in Hamburg. I want to thank my fellow intern Jessica Marchal for the feedback, discussions and fun. Also many thanks to all the employees of Noorderzijlvest for the pleasant cooperation and very nice atmosphere. Last but not least I want to thank Roy van Hezel, Arno Folkers and Frits Ebbens for the monitoring trips and fun in the laboratory.

I hope my report will help and support Noorderzijlvest in their future management plans and will trigger new ideas and enhance the knowledge regarding the fish migration issues.

Marc C. Bartelds

Groningen, July 2012

Management Summary

This report is focusing on the fish migration issues the Regional Water Authority Noorderzijlvest encounters in their management area. The increasing acknowledgement regarding fish migration issues seems to result in more and more policies pertinent to fish migration. On behalf of improving fish migration opportunities, Noorderzijlvest is removing migration barriers in their management area. At the same time, they participate in several advisory groups and projects, to share and gain knowledge regarding fish migration.

One of the important fish migration related projects is the living North Sea project (LNS). This project aims to create better fish migration opportunities in the North Sea region. Because there is a knowledge gap regarding the current status of sea trout in the (Dutch) Wadden Sea and adjacent freshwater streams, Noorderzijlvest is interested in the sea trout population size, the habitat suitability and the influence of the pertinent policies in that area. In this advisory report the findings with respect to those knowledge gaps are described.

There is very little known about the sea trout population size in the Dutch Wadden Sea and adjacent freshwater streams. A lot of monitoring is done by many organizations with many different interests. Nevertheless, no scientific organization has been able to estimate the population size in the target area. With help of Atlantic salmon models a rough indication could be made with a population size ranging from a few thousand to several hundreds of thousands in the Dutch Wadden Sea and adjacent freshwater streams.

The habitat in the Wadden Sea and adjacent freshwater streams seems to be not suitable for a sustainable sea trout population. This is primarily due to the current migration barriers that are situated in the Noorderzijlvest management area and the lack of connectivity with spawning grounds. Also with regard to other routes towards the Wadden Sea, such as for example via the IJsselmeer, the sea trout encounters many migration barriers. Without these barriers the sea trout can probably ‘survive’ in the Noorderzijlvest management area, but still there has to be a good connection with sea trout spawning grounds for a sustainable sea trout population.

The current policies are promising with regard to stimulating fish migration. There are several import directives, acts and regulations that will probably result in improved migration opportunities. Nevertheless, the current plans and policies will not completely solve the fish migration issues. There is no transnational policy that incorporates all habitats the sea trout is passing through during its life cycle.

Therefore the most important recommendation is to find participants or interested stakeholders, willing to collaborate in bringing a life cycle approach under the attention of EU policy makers. A life cycle policy approach can create better opportunities for fish migration because it changes an emphasis on policies for different habitats in different countries, into an emphasis on characteristics of migrating fish species and the habitats pertinent to their life cycle. Until then, in contrast to past policies resulting in hampered fish migration, the focus lies more on stimulating migration. In addition, the removal of migration barriers or installing fish passages must be continued as well as improvement of the water quality.

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1 Introduction

This study has been conducted on behalf of Regional Water Authority Noorderzijlvest. By arranging this internship project, Noorderzijlvest wants to obtain an insight in the sea trout population size in the Wadden Sea and adjacent freshwater streams. In this chapter the background of the internship project is described. This includes the aim, research questions and formal frame of the internship project. In the reading guide the contents of the following chapters are described.

1.1 Challenge

The Regional Water Authority Noorderzijlvest is one of fifteen collaborating participants of the Living North Sea project (LNS) (Living North Sea a, 2012). The LNS project, which is financed by the European Union, aims to promote free fish migration between sea and freshwater to sustain and promote several migrating fish species (Living North Sea c, 2012). The LNS project has identified knowledge gaps regarding fish populations depending on free movement between the North Sea and adjacent freshwater systems (Living North Sea b, 2012). The LNS has identified knowledge gaps specifically regarding the sea trout (*Salmo trutta trutta*) populations in the Dutch Wadden Sea and the adjacent freshwater streams (Huisman, 2011). These knowledge gaps include a lack of knowledge concerning the population sizes of the sea trout and to what extent the species is hampered during its migration from the spawning grounds to sea and vice versa. This internship project attempts to clarify the sea trout ecological status, the habitat suitability of the Dutch Wadden Sea and adjacent freshwater streams and to clarify whether the (inter)national policies, which are pertinent to fish migration, should be amended with regard to fish migration.

1.2 Motive

In the last century, many natural transitions from freshwater systems to marine systems have been lost in the Netherlands (Brouwer *et al.,* 2008; Lotze, 2005; Riemersma *et al.*, 2004; Schneider, 2009). In the struggle against the surplus of water, the Dutch mainland is protected by dikes, sluices, pumping stations and other barriers for the tidal currents of the sea and the excessive freshwater supply from rivers (CUR, 1999; Hartgers *et al.*, 2001; Jager, 1999). This led to strict and hardened water borders without a gradual transition from freshwater to seawater (Hartgers *et al.*, 2001; Jager, 1999). This creates problems for so called 'diadromous' fish species. Diadromous fish species are fish species that migrate between freshwater and the sea to complete their reproductive cycle (Hartgers *et al.*, 2001; Lotze, 2005). Well known examples are the sea trout, Atlantic salmon (*Salmo salar*) and European eel (*Anguilla anguilla*) (De Groot, 2002; Hartgers *et al.*, 2001). When diadromous fish species cannot succeed in their reproductive cycle, they can go extinct locally or in case of a rare species go extinct completely (Freyhof & Brooks, 2011; Monden, Unknown; Riemersma *et al.*, 2004). To prevent extinctions, it is necessary to create a situation in which diadromous fish species can migrate more freely (Monden, Unknown; Riemersma *et al.*, 2004).

According to literature, sea trout has been present in the rivers adjacent to the Wadden Sea for centuries (Brouwer *et al.*, 2008). However, the historical population sizes always remained unclear (Brouwer *et al.*, 2008; De Groot, 2002; De Laak, 2008; Lotze, 2005). To improve migration opportunities for diadromous fish, it is necessary to analyze how and why they are hampered in their migration. In many cases the causes and solutions with regard to the fish migration problems can be found in (inter)national policies since human societies want to protect themselves but often also preserve the environment. There are dozens of policies, laws and regulations related to fish migration (De Vlas *et al.*, 2011; Huisman, 2007; Marencic *et al.*, 2009; Rijkswaterstaat, 2011; RvdW, 2008; Wanningen *et al.*, 2008). However, it remains unclear whether these policies are aligned with the current fish migration issues and current ecological sea trout status. The aim of this project is to contribute to a solution regarding the international fish migration issues. By using the sea trout as a case study, the recommendations in this report can be used as an example for other fish species.

1.3 Main research questions

To realize an useful recommendation concerning what could be done to stimulate the problem solving with regard to fish migration problems, three main research questions are formulated. The research questions relate to the Wadden Sea and adjacent freshwater streams as target area for this project. The research questions are:

- *What is the sea trout population size in the Dutch Wadden Sea and the adjacent freshwater streams?*
- *Are the Dutch Wadden Sea and adjacent freshwater streams suitable for sustainable sea trout populations or how can this be improved?*
- *What are the impacts of the current national and international policies, which are pertinent to fish migration, on the status of the sea trout in the Dutch Wadden Sea and adjacent freshwater streams?*

1.4 Research methodology

The project is divided into two different components, namely an ecology and a policy component. All the research questions required an extensive literature study. First the general characteristics of the sea trout were analyzed. Primarily scientific and grey literature was used for this. Second, all the available Dutch fishery statistics, population size models and information from specialists and monitoring organizations has been collected to analyze and indicate the sea trout population size in the target area of this project. With regard to the habitat analysis, all the habitats between the nearest upstream spawning ground (in the Lower Rhine) and the Wadden Sea were analyzed in means of food, predation and (a)biotic water quality components. Whether the habitat in the Noorderzijlvest management area is suitable for sustainable sea trout populations, the future habitat requirements according to the Water Framework Directive (WFD) standards were compared with the general sea trout requirements according to scientific literature. For the third research question, many Noorderzijlvest management documents and legislation documents were analyzed. Subsequently the migration barriers in the Noorderzijlvest area have been analyzed as well as laws, regulations, policies and other useful information from the Dutch national government. Also communication with experts has taken place to gain informal and helpful information. After treating the research questions separately, the findings are integrated into one recommendation.

1.5 Formal frame of internship

The internship program of in total 28 weeks, is the completion of the society aimed field of study "Science, Business and Policy" (SBP) of the science masters at the University of Groningen. This field of study is intended for students enrolled in scientific masters, as a training for career positions in businesses, governments and non-governmental organizations aiming to familiarize themselves with either business or politics. This field of study must be seen as an orientation on a science-society job occupation. The main objective is to implement the gained scientific and business / policy knowledge and skills. The SBP program consists of two courses regarding business and policy and an internship with accompaniment weeks. The internship program started in December 2011 and ended in July 2012.

1.6 Reading guide

In the chapters with regard to the ecological component of this report, the order of analysis is starting repeatedly in the marine environments and follows the migration route towards the spawning grounds of sea trout. In chapter two, the general characteristic of sea trout in means of life cycle and indications with regard to the population size in the Dutch Wadden Sea and adjacent freshwater streams are given. In chapter three the habitat requirements of sea trout are compared with the current habitat status in all the habitats a sea trout passes through during its migration. Besides that, the nearest sea trout spawning grounds are described and analysed. In chapter four the migration hampering barriers in the migration route of sea trout are described followed by a description of the most important policies pertinent to sea trout migration in chapter five. Chapter six describes the current policy strategies and what could be an alternative with regard to policy approaches. In chapter seven the final conclusions and recommendations are given. A list of abbreviations can be found after chapter seven.

2 The sea trout

In the Netherlands the sea trout is a fairly well-known fish species by the general public. This chapter focuses on the general characteristics and other background information to give an insight in the fish species. Subsequently the global distribution, historical notifications and present monitoring results are given. These monitoring results contain the areas between the Wadden Sea and the nearest spawning ground in the Rhine, i.e. the Sieg. To estimate the population size of the sea trout in the Dutch Wadden Sea and adjacent freshwater streams, Atlantic salmon models are used to give a rough estimation of the annual number of migrating individuals. The wide range in this estimation already indicates how little is known with regard to the sea trout population size in the project area.

2.1 Background

The *Salmo trutta trutta* (Figure 1) is classified in the family Salmonidae, which includes Atlantic salmon (*Salmo salar*) and several other trout species (Brouwer *et al.*, 2008; Svendsen, 2008). It has two different life history strategies resulting in a migrating and a non-migrating form of the same species (De Laak, 2008; Winter *et al.* 2002). The migrating form is the sea trout while the non-migrating form is the brown trout (*Salmo trutta fario*; Figure 2) (De Laak, 2008; Winter *et al.,* 2002). Both have an adipose fin as recognisable characteristic that all Salmonidae species possess (Figure 3; (De Laak, 2008). Young sea trout hatch and develop in freshwater spawning areas (Figure 4; amongst others: De Laak, 2008; Winter *et al.,* 2002). They migrate to the sea or ocean to reach adulthood and migrate back upstream for reproduction (De Laak, 2008; Winter *et al.*, 2002). On the other hand, the brown trout lives during its whole life in freshwater (De Laak, 2008).

Fig.1 *Salmo trutta trutta* in adult 'sea-phase' (De Laak, 2008).

Fig.2 *Salmo trutta fario* in adult phase (Scarola, 1997).

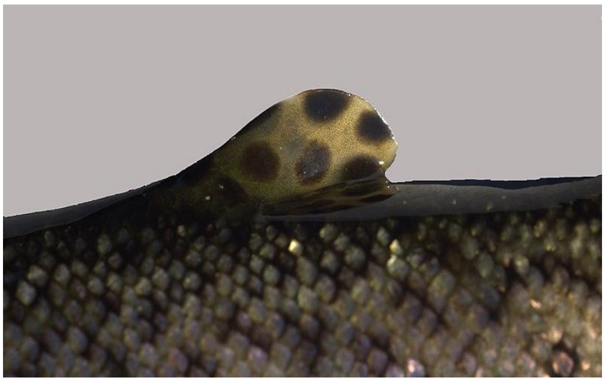


Fig.3 Adipose fin of a rainbow trout (Strauss, 2006)

Fig.4 Spawning sea trout (Hunt, 2011).

The sea trout is classified in the group of anadromous fish species, because sea trout spawn and grow up in freshwater, reach adulthood in the sea and migrate upstream to complete its life cycle (amongst others: Brouwer *et al.*, 2008). The sea trout lives freely in the water column and is not specifically restrained to the bottom of the sea, lake or river (i.e. pelagic fish species) (Jager, 1999).

2.2 Life cycle

During the life cycle of the sea trout, it develops through a series of life stages (Figure 5). A sea trout life starts with fertilized eggs lying in so called 'redd's', in gravel at the bottom of a stream or brook (De Laak, 2008). These redd's can cover an area as small as 2 m^2 to 10 m^2 and is usually excavated by movement of the caudal fin of the female parent (Brouwer *et al.*, 2008; Schneider, 2009). After hatching, the larvae stay at the spawning site until they have consumed the whole yolk sac (De Laak, 2008). In this 'alevin' stage, it subsequently feeds on plankton and microinvertebrates (Brouwer *et al.*, 2008). In the following stage the sea trout is developing into a recognizable and free moving fish. In the first free moving stage, the sea trout is called 'fry' quickly followed by the juvenile stage when the sea trout is called 'parr' (De Laak, 2008; Van der Meij *et al.*, 2005). Until maximally its third year of life, a parr stays in freshwater until its length is approximately 20 cm (Brouwer *et al.*, 2008; De Crespin & Usseglio, 2002; De Laak, 2008; Schneider, 2009). It feeds primarily on macroinvertebrates and small fish in this stage (Brouwer *et al.*, 2008; De Crespin & Usseglio, 2002; De Laak, 2008; Schneider, 2009). Parr's can be identified by their dark elliptical spots on the dorsal and lateral sides of the fish (Brouwer *et al.*, 2008; De Laak, 2008).

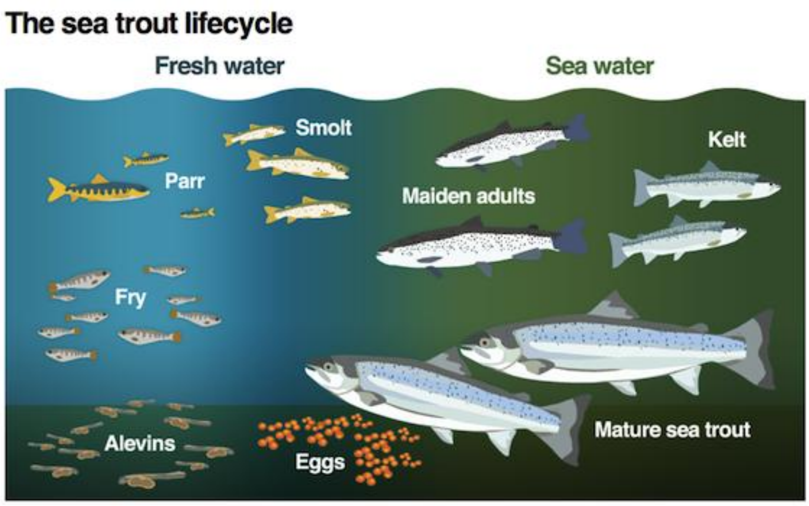


Fig. 5 The sea trout life cycle (Ferne, 2010).

Before juvenile sea trout can live in marine environments, it has to complete a physical adaptation. During the physical adaptation as a 'smolt', it increases its tolerance against marine environments (Schneider, 2009). This physical change is called 'smoltification', which usually takes place before its fourth to sixth year of life (De Laak, 2008; Schneider, 2009; Van der Meij *et al.*, 2005). The smolt is recognizable by its silver colour, caused by an increase in guanine (Brouwer *et al.*, 2008). As a young smolt, it starts its migration (usually nocturnal) towards the sea in early spring (amongst others: Brouwer *et al.*, 2008). In the marine environment it rapidly develops into an adult sea trout, feeding on Clupeiformes (Atlantic herring and sardines) and sand lance within 350 km of the coast (Brouwer *et al.*, 2008; De Laak, 2008). After one to three years in the sea, the adult sea trout is migrating upstream to its spawning ground for reproduction which is called 'homing' (De Laak, 2008; Svendsen, 2008). When it starts its homing behavior the sea trout is often called 'grilse' (Schneider, 2009; Van der Meij *et al.*, 2005). Contrary to the Atlantic salmon that often dies after reproduction, sea trout can reproduce several times over their life span (De Groot, 2002; De Laak, 2008; Schneider, 2009; Svendsen, 2008; Van der Meij *et al.*, 2005). After reproduction, a number of adult sea trout (now called 'kelt') is restarting the migration cycle together with the younger smolts, to reproduce in the following years (De Groot, 2002; Schneider, 2009; Van der Meij *et al.*, 2005).

2.3 Geographical distribution and history

Salmonids are exclusively present in the northern hemisphere (De Laak, 2008) and used to be abundant in the Wadden Sea (Vorberg *et al.*, 2005). For parts of the Netherlands, such as for example the IJsselmeer, there are sea trout fishery catches documented in the twentieth century. However, often no distinction was made between Atlantic salmon and sea trout (Van Overzee *et al.*, 2011) and according to De Laak (2008) there were already S*almo trutta* restockings in the nineteenth century in the Rhine and Meuse tributaries. De Groot (2002) describes that many caught sea trout were sold at local markets and therefore were not included in official fishery statistics. Therefore the fishery statistics from the end of the nineteenth and early twentieth century can only be used as indication. However sea trout catches have been documented by the predecessor of the Institute for Marine Resources and Ecosystem Studies (IMARES) between 1886 and 1986 (Figure 6; De Groot, 2002). Sea trout needs gravel to reproduce and since there is almost no gravel in Dutch brooks, there is no scientific consensus whether the sea trout has ever reproduced in the Netherlands or was just passing through the Dutch streams and brooks to reach the marine environments (Higler *et al.*, 2003). Regardless reproduction occurs in the Netherlands or not, De Nie (1997) described that the sea trout can be considered as an endemic fish species meaning that the species has always been present in the Netherlands (De Nie, 1997). The classification criteria for endemic species are described in chapter 5.1.

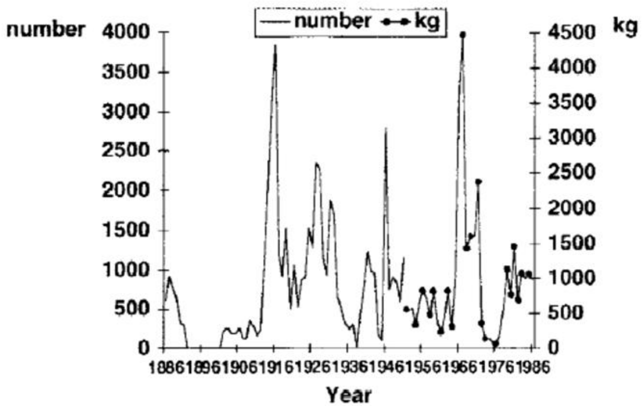


Fig. 6 Catches of sea trout (*Salmo trutta*) over the period 1886 – 1986; data not available for 1892 – 1901 (source RIVO-data, predecessor IMARES) (De Groot, 2002).

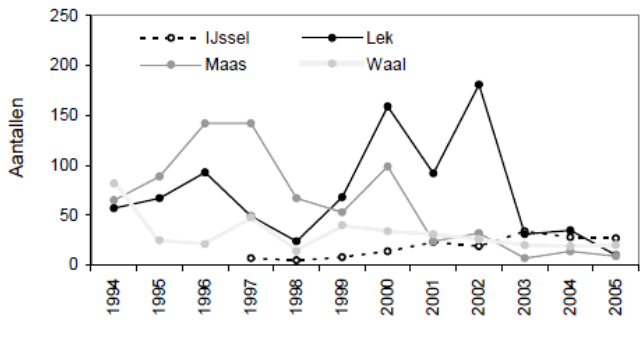


Fig. 7 Total sea trout catches in four monitored rivers from 1994 until 2005 (Jansen *et al.*, 2007). On the y-axis the total number of sea trout is given. The x-axis represents the years of monitoring.

In the major freshwater monitoring areas, there is an overall decreasing trend of sea trout catches since 1994 (Figure 7; Jansen *et al.*, 2007; Jansen *et al.*, 2008). Jansen *et al.* (2007) did not only use monitoring data but also interviews and surveys from professional fishermen. Despite restocking in upstream areas (i.e. Germany) in recent years, this trend has not changed (Jansen *et al.*, 2007). The monitoring activities in rivers such as the Rhine, are a result of a large number of international agreements (Van der Meij *et al.*, 2005). These agreements have been made in the 1990's to increase knowledge of the Atlantic salmon and sea trout (Van der Meij, Hagendoorn & Stavast, 2005). Ultimately, this knowledge will be used to improve migration opportunities for diadromous fish species (Van der Meij *et al.*, 2005). Despite all the efforts, a combination of other factors might cause or influence the decreasing trend of sea trout catches. Besides the physical migration obstacles, these are according to De Groot (2002) and Van der Meij *et. al* (2005):

- a general decrease of suitable spawning areas;
- a general decrease of habitats for food and habitats to develop in;
- river engineering on behalf of shipping transport;
- sand and gravel extraction and deteriorating water quality in the sea trout habitats.

These are exactly the factors that have high priority in some international agreements (Van der Meij *et al.*, 2005). How these factors influences the appearance of sea trout will be described in the following chapters.

2.4 Monitoring the sea trout

A lot of monitoring takes place in the Wadden Sea (Figure 8; Jager *et al.*, 2009) and in Dutch freshwater streams (Figure 9; Jansen *et al.,* 2007). These monitoring programs are commissioned and carried out by many different organizations with various interests. Not all of the monitoring sites in Figure 8 and 9 are intended for sea trout. The majority of the monitoring in the Wadden Sea is concentrated on commercially more interesting fish, crustaceans and mollusks (Jager *et al.*, 2009).

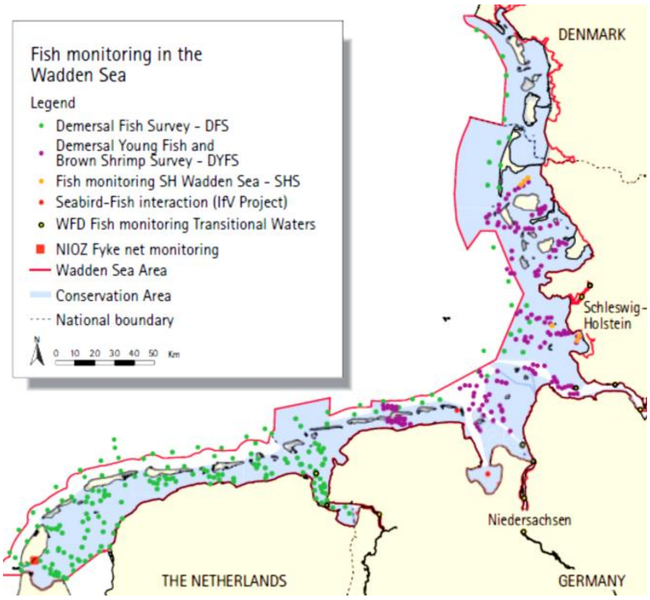


Fig. 8 Trilateral Wadden Sea Area and Conservation Area including the locations where different fish monitoring programs are carried out:

Demersal Fish Survey - DFS, Demersal Young Fish and Brown Shrimp Survey - DYFS, Fish monitoring Schleswig-Holstein Wadden Sea - SHS, Seabird-Fish interaction (IfV Project), WFD Fish monitoring Transitional Waters, NIOZ Fyke net monitoring (Jager *et al.*, 2009).

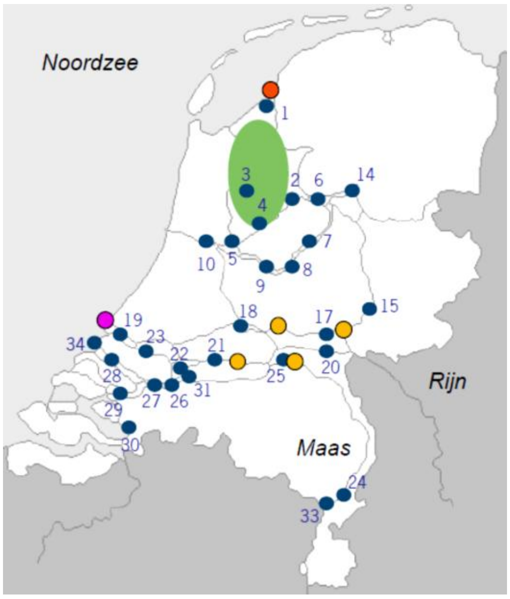


Fig. 9 Overview of monitoring sites from various monitoring programs.

The numbers represent a monitoring station, the red dot a specific diadromous fish monitoring site, the yellow dots salmon monitoring sites, the purple dot is a local monitoring site and the green area is a monitoring area for 'rare' species (Jansen *et al.*, 2007).

The Common Wadden Sea Secretariat (CWSS) describes that for development and evaluation of fish targets for the Wadden Sea, a basic reference list had to be compiled (Jager *et al.*, 2009). Therefore a species list based on data sets of demersal and benthic monitoring surveys is used for many policy conservation recommendations (Jager *et al.*, 2009). In this species list, the sea trout is one of the 150 fish species found in the Wadden Sea. In the Dutch Wadden Sea, sea trout is listed as a 'fairly common species' since 1960, but is rarely taken into account in the Quality Status Reports of the CWSS (Jager *et al.*, 2009). Remarkably, in a previous Quality Status Report of the CWSS (in 1999) sea trout was considered to be a rare species in the Dutch and German Wadden Sea and probably originated from restocked sea trout (De Jong *et al.*, 1999).

With regard to the research question: ***"what is the sea trout population size in the Dutch Wadden Sea and the adjacent freshwater streams?"***, the Quality Status Report of the CWSS in 1999 is giving an estimation for the Danish Wadden Sea only (De Jong *et al.*, 1999). According to a Danish assessment, sea trout was present in far lower numbers in the Wadden Sea and in most rivers compared to the estimated carrying capacity of the different water systems (Ejbye-Ernst and Thiil Nielsen, 1997; Thiil Nielsen *et al.,* 1997 & Sivebeak *et al.*, 1997 in: De Jong *et al.*, 1999). For the Danish Wadden Sea and adjacent rivers, they made the following sea trout population estimation for the year 2000:

> ***"The breeding stock was estimated to be 9,000 fish and the number of smolts entering the Wadden Sea was 48,000, 15% of the estimated optimal production"*** (De Jong *et al.*, 1999)**.**

According to the literature study, the estimation described in De Jong *et al.* (1999) is the only fairly precise sea trout population estimation within the whole Wadden Sea.

2.4.1 Monitoring migrating fish species in the Ems - Dollart estuary

In the northern part of the Netherlands there are no gradual transitions from marine environments to freshwater left, except for the Ems - Dollart drainage basin (RvdW, 2008; Tulp *et al.*, 2011). In the Ems - Dollart drainage basin, a pilot study to determine the (seasonal) presence of diadromous fish species was performed for three years from 1999 to 2001 (Kleef & Jager, 2002). The aim of the study was to determine the effects of an amended draining policy of the drainage pumping stations on the migrating Red List species of the International Union for Conservation of Nature (IUCN) (Kleef & Jager, 2002). At first, one monitoring location was set up at 'Groote Gat' in the Dollart in 1999 (monitoring location 'west' in Figure 10; Kleef & Jager, 2002). Also the circadian rhythm effects were taken into account in this study (Kleef & Jager, 2002). In 2000, a second location was installed (monitoring location 'Oterdum' in Figure 10) and in 2001 a third location (monitoring location 'oost' in Figure 10). The locations were simultaneously monitored over one tidal cycle, ten times a year (Kleef & Jager, 2002). The locations were chosen primarily by the 'most likely migration route' for diadromous species according to Kleef *et al.* (2002). As monitoring technique they used trawl nets (Figure 11) of 10 x 14 m. and anchored stake nets (Figure 12) of 6 x 3 m. (Kleef & Jager, 2002).

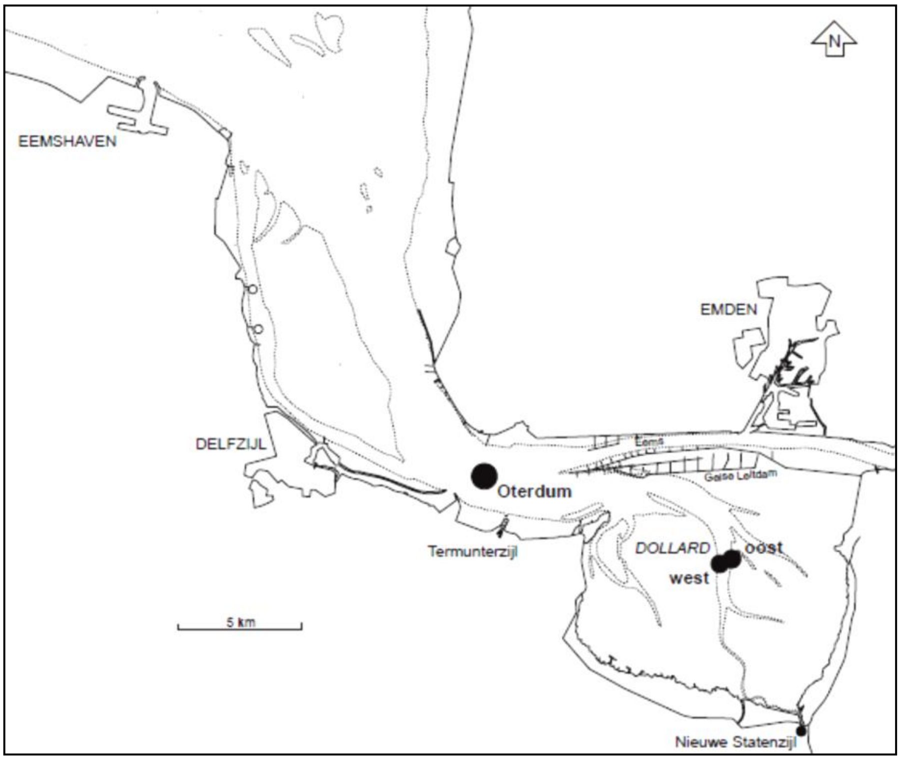


Fig. 10 The Ems - Dollart estuary with three monitoring locations near Oterdum in the Dollart (Kleef & Jager, 2002).

Fig. 11 Stow net on starboard side during monitoring at Oterdum (Kleef & Jager, 2002).

Fig. 12 Stake nets at Groote Gat in the Dollart (Kleef & Jager, 2002).

After three years of monitoring, in 9 % of the monitoring occasions sea trout was caught (Table 1; Kleef & Jager, 2002). With this indication, Kleef *et al.* (2002) consider the sea trout as a locally rare species. In their conclusion they also emphasize that the hydrodynamic circumstances of the Ems inhibited the use of methods, which should have resulted in higher sea trout captures. Besides that, Kleef *et al.* (2002) argue that a higher catching effort in salmonids would not automatically result in more catches, since they consider the salmonids as 'too rarely present' in the Ems - Dollart drainage basin. During the three year monitoring, they caught 'only a few' salmonids, which are probably restocked individuals from the river Leda (Kleef & Jager, 2002). They conclude that a sea trout population cannot exist in the Eems – Dollart drainage basin because of a lack of spawning locations upstream the river Ems (Kleef & Jager, 2002).

Table 1. The frequency of present fish species in the Ems - Dollart estuary as a percentage of the total number of monitoring occasions (N) in the period 1999 – 2001 (Kleef & Jager, 2002). The sea trout is highlighted in red and is considered to be a 'rare species' due to a 9% presence in the total monitoring occasions.

Species	Name (Dutch)	Total N= 45	Oterdum N = 16	Dollard N = 29
Diadroom				
Osmerus eperlanus	Spiering	100	100	100
Platichthys flesus	Bot	100	100	100
Gasterosteus aculeatus	3d Stekelbaars	91	94	90
Lampetra fluviatilis	Rivierprik	64	88	52
Anguilla anguilla	Paling	62	63	62
Alosa fallax	Fint	62	81	52
Liza ramada	Dunlipharder	16	31	7
Salmo sp.	Zeeforel	9	25	
Petromyzon marinus	Zeeprik	2		3

2.4.2 Long-term marine monitoring at Kornwerderzand

At the Wadden Sea side of the Afsluitdijk, a diadromous fish monitoring program is conducted since 2000 (Tulp *et al.*, 2011). The aim of this program is to investigate the trends and developments in rare diadromous fish species at the sea side of the Afsluitdijk (Tulp *et al.*, 2011). The monitoring is financed by the Dutch Rijkswaterstaat (part of the Dutch Ministry of Transport, Public Works and Water Management with the role of practical execution of the public works and water management, including the construction and maintenance of waterways and roads) (Tulp *et al.*, 2011). According to Tulp *et al.* (2011), the results of this long-term monitoring can be used for effectiveness evaluations concerning the amended pumping stations policies and a fish passage in the new pumping station complex at the Afsluitdijk (Tulp *et al.*, 2011). Between 2001 and 2009, the monitoring was conducted by an European eel fishery-business of the brothers Van Malsen. They used Fyke nets near the sluices in the Afsluitdijk at Kornwerderzand (Tulp *et al.*, 2011). Annually, during two periods of circa twelve weeks in spring and fall, the brothers Van Malsen fish at seven fish trap locations. Their catch results comprised almost 1.5 million diadromous fish (ten different species) in 2009 (Tulp *et al.*, 2011). The sea trout is caught fairly constant over the last decade (Table 2), despite a higher fishing effort and less caught sea trout in 2009 (Tulp *et al.*, 2011). Remarkably, the caught sea trout are predominantly smolts since the vast majority is smaller than 30 cm as is shown in Figure 13 (Tulp *et al.*, 2011). This indicates that the sea trout are caught probably just after passing through the pumping station (Tulp *et al.*, 2011). It remains unclear what the physical condition is of the caught sea trout.

Table 2. Overview of diadromous fish landings (total number of individuals per year) by the brothers Van Malsen. The annual number of sea trout catches are displayed in the red lines. In 2001 no distinction was made between Yellow eel and Silver eel. (Source: Tulp *et al.*, 2011).

	2001	2002	2003	2005	2006	2007	2008	2009
Yellow eel	18061	18339	11530	3982	3249	2833	2157	4036
Silver eel		714	364	77	0	27	15	54
European flounder	11215	27804	28431	9384	10457	29460	8429	13118
Three-spined stickleback	4133	5184	3536	120405	485952	114760	100462	1085111
Twait shad	102	768	2965	703	126703	407	313	147
European whitefish	1	4	50	0	0	0	0	0
Houting	1	13	22	104	19	40	19	32
River lamprey	1300	221	583	179	10	21	45	37
Smelt	64273	140124	17884	60317	148974	107325	80990	276136
Atlantic salmon	6	14	5	0	1	1	0	0
Sea trout	24	45	12	18	19	16	23	4
Sea lamprey	193	1	43	24	35	68	70	20
Total	99309	193231	65425	195193	775419	254958	192523	1378695

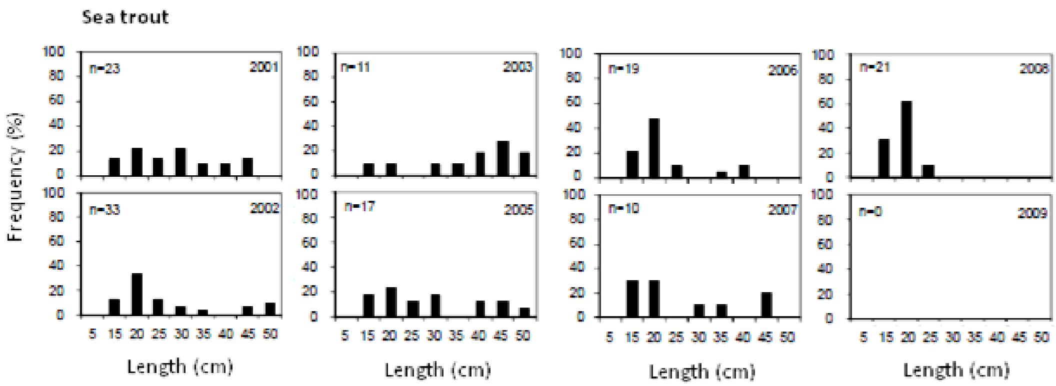


Fig. 13 Length – frequency distribution of caught sea trout in the years 2001 – 2009. The differences in numbers (n) with respect to Table 2 is caused by preservation regulations (Tulp *et al.,*2011).

2.4.3 Wadden Sea fisheries and by-catches

Jansen *et al.* (2008) have investigated the salmonid fishery catches in the Wadden Sea. Their aim was to estimate the total salmonid death rates caused by all types of fisheries in the Netherlands. The types of fisheries comprised a wide range of fisheries, from recreational angling to professional and commercial fisheries (Jansen *et al.*, 2008). Jansen *et al.* (2008) described a declining trend in the sea trout population(s) over the last decades. By extrapolating all the available monitoring results and interviewing private and recreational anglers, they made rough estimations of the Atlantic salmon population (Jansen *et al.,* 2008). To estimate the Atlantic salmon population, they also used the survival rates and traits of telemetric data of migrating sea trout (Jansen *et al.*, 2008). Jansen *et al.* (2008) concluded they probably made an overestimation of annual catch averages between 6,020 and 34,400 sea trout individuals in the Dutch Wadden Sea. However the uncertainties in the estimation by Jansen *et al.* (2008) are substantial, since the calculations are subject to non-demonstrable inputs (such as interviews). For the Atlantic salmon they made a rough population estimation in the Rhine drainage basin (Figure 14 and 15). Jansen *et al.* (2008) estimate that approximately between 500 and 17,000 Atlantic salmon smolts reach the Wadden Sea and between 300 and 600 adults start their upstream migration for reproduction each year. Although Figure 14 and 15 represent the estimations for the Atlantic salmon, the model is almost identical to the sea trout situation. Jansen *et al.* (2008) estimate that there are generally around four times more sea trout than Atlantic salmon in the Dutch Wadden Sea. A ratio of one to four would imply that approximately between 2,000 and 68,000 sea trout smolts reach the Wadden Sea and between 1,200 and 2,400 adult sea trout would start their upstream migration each year. Because these numbers are results of numerous variables, uncertainties and estimations, the number of migrating sea trout is indicative and hard to verify.

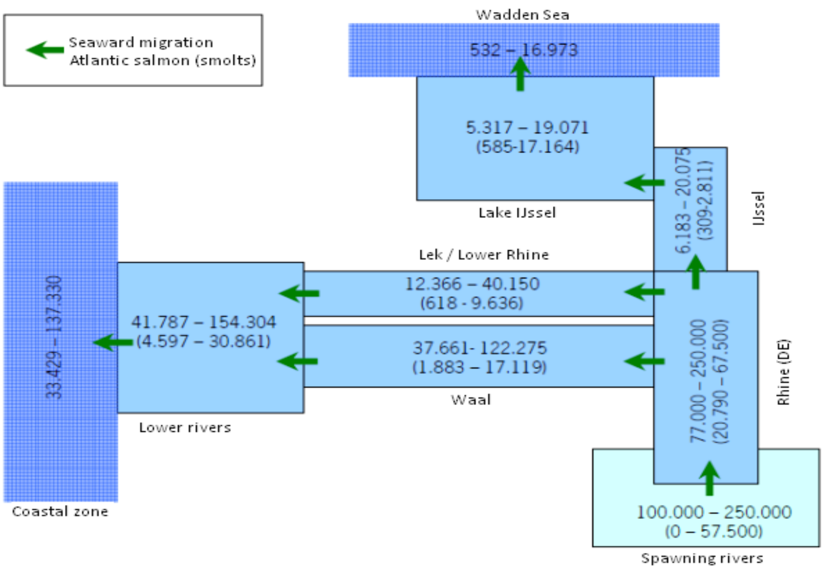


Fig. 14 Overview of extra-polated number of Atlantic salmon smolts during their migration in different regions (annual average), based on estimations and telemetric experiments. In parentheses the number of 'disappearances' per region is displayed. The number of individuals must be interpreted as rough estimations. To estimate the number of sea trout over the same route, the values must be multiplied with 4. (Translated from source: Jansen *et al.*, 2008).

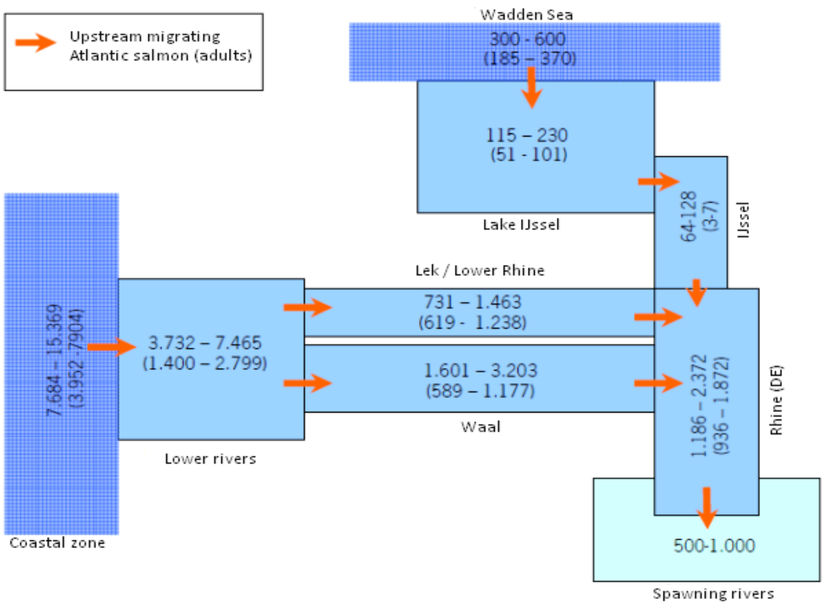


Fig. 15 Overview of extra-polated number of Atlantic salmon adults, during their upstream migration in different regions (annual average), based on the estimated number of adults that reach the spawning areas (500 – 1,000) and telemetric data. In parentheses the number of 'disappearances' per region is displayed. The number of individuals must be interpreted as rough estimations. To estimate the number of sea trout over the same route, the values must be multiplied with 4. (Translated from source: Jansen *et al.*, 2008).

The estimated number of migrating sea trout based on Jansen *et al.* (2008) is relatively consistent with the estimations Jansen *et al.* (2007) made, although they used a slightly different approach. Here, the sea trout population size was also estimated between a few thousand to tens of thousands of individuals (Figure 16; Jansen *et al.*, 2007). There were also qualitative problems with the used data for this estimation. The used 'data' and information consisted of many fishermen observations. Jansen *et al.* (2007) acknowledged that there were strong indications that the determination difficulties of the fishermen (between Atlantic salmon and sea trout) weakened the estimation. Besides that, the estimated population size shown in Figure 16 contains sea trout as well as brown trout (Jansen *et al.,* 2007). Since the distinction between the two trout species is difficult in freshwater, this makes the sea trout overview extremely complex. Telemetric experiments show that adult salmonids are able to avoid fish traps with fine mesh sizes (Jansen *et al.,* 2007). The last weakening factor is the restocking in German upstream areas. Despite the fact that restocking took place in recent years, the trend of a decreasing sea trout population is continuing (Jansen *et al.,* 2007).

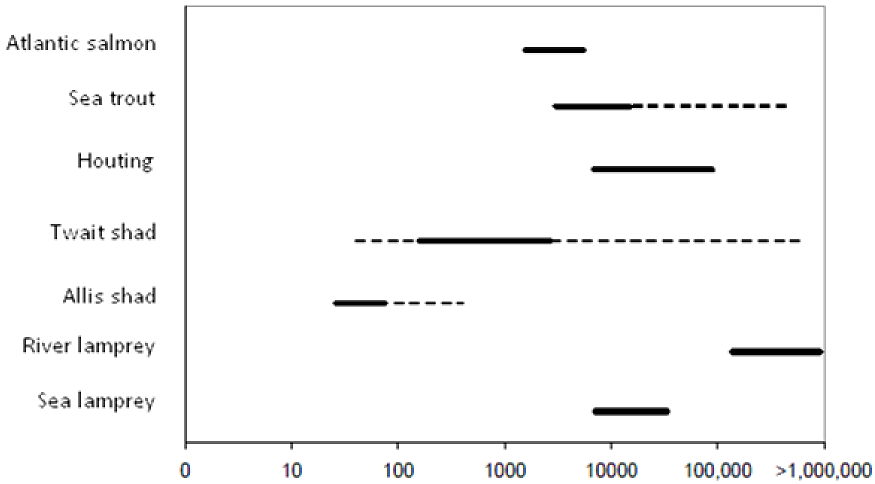


Fig. 16 Estimated total population sizes, based on expert judgments of migrating fish in the Rhine, Meuse, Scheldt and Ems drainage basin. For each species an estimated minimum spawning population and an indication of the range and estimated maximum spawning population is displayed by a black line. For some species it is difficult to set a maximum range. For example the spawning population of the twait shad is presumably small, but the total number of adults in the coastal zone is considerable. This is shown by the dotted line. With regard to the sea trout it is unclear what the ratio migrating and non-migrating trout is. (Source: Jansen *et al.,* 2007).

2.4.4 Freshwater monitoring south of Kornwerderzand in the IJsselmeer

The two water pumping complexes in the Afsluitdijk, near Den Oever and Kornwerderzand, are the only direct connections between the IJsselmeer and the Wadden Sea (Witteveen + Bos, 2009). Therefore, these two complexes are not only important for the water quantity but also for fish migration between freshwater and the marine environment (Witteveen + Bos, 2009). Because there are plans for a third water pumping station in the Afsluitdijk, Rijkswaterstaat wanted to have insight in the fish migration via the water pumping complexes (Witteveen + Bos, 2009). As method they used nets, fish traps and sonar devices to determine the composition of "outgoing and incoming fishes"

(Figure 17 and 18; Witteveen + Bos, 2009). They measured the flushing of fishes towards the Wadden Sea in 49 pumping occasions between November 2007 and June 2009 (Witteveen + Bos, 2009).

Fig. 17 Fish net at the Wadden Sea side of the water pumping station. With this net the fish moving towards the Wadden Sea is caught (Witteveen + Bos, 2009).

Fig. 18 Fish traps with a steel frame at the IJsselmeer side of the water pumping station. With these fish traps, fish moving towards the IJsselmeer is caught (Witteveen + Bos, 2009).

In the research only the total number of sea trout caught in the 'big' fish net (Figure 17) is mentioned. Over all the monitoring occasions they caught 12 sea trout individuals passing through the pumping station towards the Wadden Sea (Witteveen + Bos, 2009). This equals to approximately one sea trout per ten hours passing through one pumping tube in the pumping station. After extrapolation of the measured data, the number of sea trout that would have passed through the pumping stations at Kornwerderzand was approximately around 340,000 in the period between January 1, 2008 and Oktober 1, 2008 (Witteveen + Bos, 2009). In other words, from 12 actually caught individuals over 49 pumping occasions in 1.5 years, they calculated that in total more than 300,000 individuals would have passed the pumping station in 9 months. This seems to be an extremely high estimation. For the extrapolation they considered the measured number of sea trout swimming towards the IJsselmeer as equal to the number of sea trout that is swimming towards the Wadden Sea. Also, the pumping tube used for sea trout calculations was mainly used in spring and early summer, which is an important sea trout migration period (Jager, 1999). Besides this, they describe that it is hard to combine important factors such as diurnal and nocturnal cycles, wind conditions and pumped water volume resulting in a speculative estimation (Witteveen + Bos, 2009). Ultimately, their slightly obvious conclusion is that there is a net migration towards the Wadden Sea via the pumping station at Kornwerderzand (Witteveen + Bos, 2009).

2.4.5 Other monitoring programs in the IJsselmeer

In 1994, a monitoring program started to monitor diadromous fish species in the IJsselmeer on behalf of Rijkswaterstaat, Section IJsselmeer (Kuijs *et al.*, 2011). The objective of this monitoring is to keep track of patterns in abundance, length frequency and maturity states of ten 'rare' fish species (Kuijs *et al.*, 2011). With these data they want to see species population trends over several years. One of the monitored fish species is the sea trout. For gaining the data, Kuijs *et al.* (2011) received all the caught 'rare' fishes from all professional fishermen, working in the IJsselmeer from the period

1994 until 2001. Since 2001, a limited number of professional fishermen are participating in the monitoring program only (Kuijs *et al.*, 2011). For every fish that is handed in, the fishermen receives a financial compensation and an incentive (Kuijs *et al.*, 2011). Because the fishing effort differs per caught sea trout individual, they calculate the Catch Per Unit Effort (CPUE) since 2001 (Kuijs *et al.*, 2011). The CPUE is a relative measure of abundance and can be used to estimate absolute abundances (Jansen *et al.*, 2008). The CPUE is based on the recorded number of fish and the time the fish traps were active, resulting in a value for a catch per fish trap per 24 hours (Jansen *et al.*, 2008). In other words: the higher the CPUE, the higher the species abundance.

Table 3 Total number of sea trout caught in the IJsselmeer annually in the period 1994 – 2009 (Kuijs *et al.*, 2011).

year	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	total
sea trout	9	122	49	92	607	1222	635	940	584	278	—	412	531	247	354	346	6428

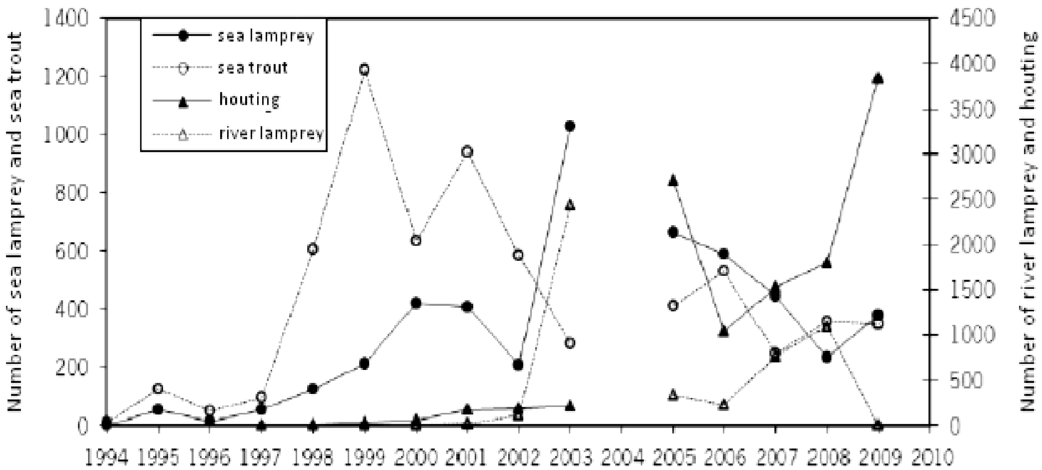


Fig. 19 Annual number of fish caught per species in the IJsselmeer without taking the catch effort into account (Kuijs *et al.*, 2011).

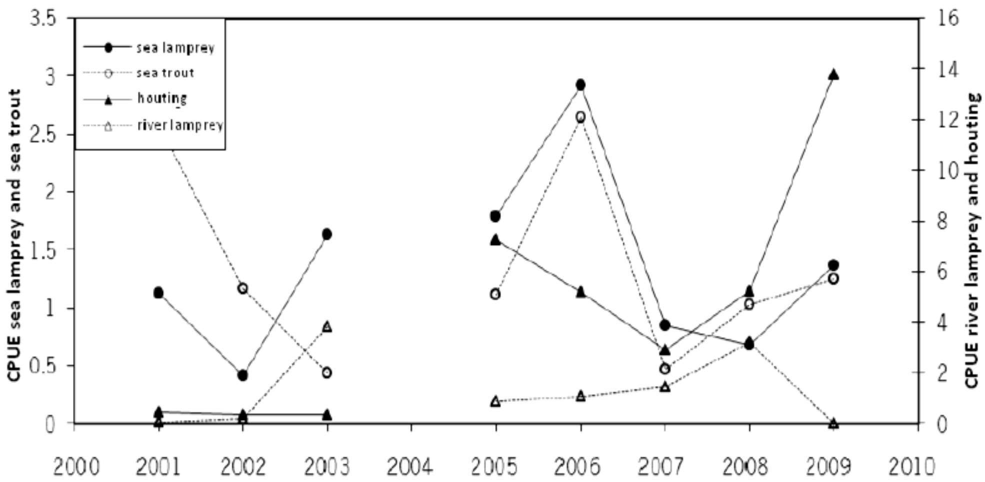


Fig. 20 Catch Per Unit Effort (CPUE) of rare caught fish per 24 hour fish trap fishing from 2000 – 2009 (Kuijs *et al.*, 2011).

As shown in Table 3 and Figure 19, there are almost 6,500 sea trout caught by professional fishermen in the IJsselmeer since the start of the program. These are mainly caught in spring and with a mean length of around 25 cm (Kuijs *et al.*, 2011). When focusing at the CPUE, there is a considerable variation in CPUE (Figure 20) that does not concur with the caught sea trout variation (Figure 19). Table 3 is also showing that far more sea trout were caught between 1998 and 2002 than before and after this time period (Kuijs *et al.*, 2011).

2.4.6 IJsselmeer fisheries and upstream Rhine monitoring

Jansen *et al.* (2008) calculated and described, besides the estimated sea trout migration towards and coming from the Wadden Sea, also the migration towards and coming from the IJsselmeer. By using all the recorded sea trout catches from every kind of fishery, an estimation of the sea trout migration in the IJsselmeer could be made. Jansen *et al.* (2008) conclude that there are approximately five times more sea trout smolts than Altantic salmon smolts in the IJsselmeer. With regard to the adults there are even nineteen times more sea trout adults than Atlantic salmon adults (Jansen *et al.,* 2008). To estimate the sea trout population size in the IJsselmeer, Figure 14 and 15 can be used again. The majority of the sea trout seems to be smolts when looking at the available length frequencies of caught sea trout (Jansen *et al.,* 2007; Jansen, et al., 2008; Kuijs *et al.*, 2011). Therefore, based on Jansen *et al.* (2008) to roughly estimate the total sea trout migration, the estimated Atlantic salmon population is multiplied by seven after the correction for overestimated fishermen catches and other variables (Jansen *et al.*, 2008). Based on Jansen *et al.* (2008), this results in an roughly estimated migration of between 37,000 and 133,000 sea trout (smolts and adults), migrating from the headwater towards the IJsselmeer each year, and between 800 and 1,600 sea trout migrating upstream from the IJsselmeer each year (Jansen *et al.*, 2008).

In the Netherlands, monitoring for diadromous fish species is done in rivers such as the Rhine and the IJssel (Figure 9). There are no monitoring programs in directly adjacent rivers and brooks of the Dutch Wadden Sea focusing on sea trout. The indirectly adjacent rivers (via the IJsselmeer) the Rhine and the IJssel, are monitored for salmonid fish species. By using the same extrapolation as for the IJsselmeer and the Wadden Sea, and by the methods and data from Jansen *et al.* (2008), a rough estimation of the migration in the Rhine can be made. Jansen *et al.* (2008) calculated that there are approximately five and a half times more sea trout in the German Rhine than Atlantic salmon. By using Figure 14 and 15 once more, this results in a rough estimation between 423,000 and 1.400,000 sea trout passing the Dutch-German border, migrating towards the marine environments. Between 6,500 and 13,000 adult sea trout from all the freshwater – marine environment transitions in the Netherlands are migrating upstream the Rhine for spawning.

2.5 Conclusion with regard to the sea trout population in the Dutch Wadden Sea and adjacent freshwater streams

With regard to the question "*what is the sea trout population size in the Dutch Wadden Sea and Adjacent freshwater streams*", the literature reveals only a small part of the current situation. Many research and monitoring is not focused at sea trout, but mostly for diadromous fish species all together. After an extensive literature study, no accurate estimation regarding the sea trout population size could be made or found. Looking at the monitoring techniques and the numerous uncertainties regarding the extrapolations, it seems to be almost impossible to estimate the sea trout population size. The calculation of the CPUE in recent years, seems to be a promising addition for the usefulness of the monitoring programs. Without the CPUE, you only know how many individuals are caught at a certain time. Generally it can be concluded that the sea trout is present in the Dutch Wadden Sea and adjacent freshwater streams, which is supported by the outcomes of the recorded monitoring results, although they are considered to be rare and there is a negative trend in appearances. Migrating sea trout are very hard to detect and therefore the sea trout presence remains a mystery.

With help of the models from Jansen *et al.* (2007 and 2008), I was able to give an indication of the annual migration between the Dutch Wadden Sea and freshwater. I must emphasize that the very wide range of 2,000 to 68,000 sea trout entering the Wadden Sea and 1,200 to 2,400 migrating back to freshwater can only be seen as an indication. This also applies for the indicated annual migration of hundreds of thousands sea trout downstream the Rhine and the 6,500 to 13,000 adults crossing the Dutch-German border to reach the spawning grounds. The ranges of the number of sea trout migrating, are already indicating a general lack of knowledge with respect to the ecological status of the sea trout. In addition, the results of the described extrapolations are in my opinion often overestimated, since the starting point of the calculations is an extremely low number of sea trout individuals. Also it is unclear what the survival rate of sea trout is in all the different environments and why or how well adult sea trout can avoid fish traps. To conclude, I suggest that there are probably a few thousand adult sea trout in the Dutch Wadden Sea and a couple of ten thousand sea trout in the adjacent freshwater streams.

3 The sea trout habitat

The sustainability of sea trout populations depend on suitable reproductive habitats (Heggenes *et al.*, 2011). Poor quality spawning habitats or scarcity of spawning habitats may affect the sea trout populations directly. The habitat use may depend on the mobility of individual fish and species, and especially salmonids are capable to respond to environmental variations (Heggenes *et al.*, 2011). The sea trout is a mobile species and exhibits a large individual and temporal variation in movement patterns and propensity to reside in a home area but also to explore (Heggenes *et al.*, 2011). To analyze whether the habitat in the Dutch Wadden Sea and adjacent freshwater streams is suitable for sea trout, the major requirements are described in this chapter. It is not possible to do a detailed analysis based on the specific ecological and chemical status of the habitats due to limited time. To determine whether the habitats in the target area of this project are suitable or not, the basic ecological needs of sea trout are given such as spawning requirements, food and predation. These are compared with the current status of the target area of this project, including the most important freshwater streams in the Noorderzijlvest management area and the pertinent (near future) policy objectives with regard to the WFD. These policy based ecological objectives are the most determining (management) force regarding the future state of the freshwater streams in the Noorderzijlvest management area and are further described in the following chapters. The analysis in this chapter includes the habitat of the nearest acknowledged spawning area, i.e. the river Sieg in the lower Rhine.

3.1 General habitat requirements for sea trout

Critical characteristics of suitable spawning grounds may vary between different river systems and geographical areas (Crisp, 1996; Louhi *et al.*, 2008;). In chapter 2 is described that sea trout deposits its eggs in the substrate in so called ‘redd’s’. Many studies describe that most critical redd site selection is depending on substrate particle sizes, water velocities, water depths (Heggenes *et al.*, 2011; Louhi *et al.,* 2008; Raleigh *et al.*, 1986). Every salmonid species usually reproduces in a different niche. For example sea trout often reproduce in the same rivers as the Atlantic salmon. However the optimal sea trout reproduction occurs in water depths, velocities and substrate size of 15–45 cm, 20–55 cms^{-1} and 16–64 mm depending on the size of the female with a decreasing survival rate closer to the minimum and maximum range

Table 4. Stream habitats used by *Salmo trutta sp.* for spawning according to several studies. (Source: Heggenes *et al.* 2011).

Depth mesohabitat	Range	15-45 cm	Louhi et al. 2008
	Range	6-82 cm	Shirvell & Dungey 1983
	Range	23-215 cm	Wollebæk et al. 2008
	Mean	25.5 cm	Witzel & MacCrimmon 1983
	Mean	31.7 cm	Shirvell & Dungey 1983
	Means	20-49 cm	Heggberget et al. 1988
	Means	27-52 cm	Zimmer & Power 2006
	Mean	103 cm	Wollebæk et al. 2008
Velocity mesohabitat	Range	20-55 cms^{-1}	Louhi et al. 2008
	Range	11-80 cms^{-1}	Witzel & MacCrimmon 1983
	Range	15-75 cms^{-1}	Shirvell & Dungey 1983
	Range	2-124 cms^{-1}	Wollebæk et al. 2008
	Mean	46.7 cms^{-1}	Witzel & MacCrimmon 1983
	Mean	39.4 cms^{-1}	Shirvell & Dungey 1983
	Means	27-55 cms^{-1}	Heggberget et al. 1988
	Means	23-50 cms^{-1}	Zimmer & Power 2006
	Mean	47 cms^{-1}	Wollebæk et al. 2008
Substrate particle size	Range	1.6-6.4 cm	Louhi et al. 2008
	Mean	0.69 cm	Witzel & MacCrimmon 1983
	Means	5-8 cm	Heggberget et al. 1988
	Mean	7 cm	Wollebæk et al. 2008
	Critical % fines < ca. 2 mm	> 10 %*	Crisp & Carling 1989
			Louhi et al. 2008
	Mean	15.2 cm	Crisp & Carling 1989
Depth in gravel of egg burial	Mean	12 cm	Heggberget et al. 1988
	Minimum	14 cm	Witzel & MacCrimmon 1983

(Crisp, 1996; Heggenes *et al.*, 2011; Louhi *et al.*, 2008). Atlantic salmon on the other hand, make redd's in deeper and higher velocity habitats (20 – 50 cm and 35-80 cms^{-1}) for an optimal reproduction (Heggenes *et al.*, 2011). In other words one can say that Atlantic salmon tends to spawn in the main stem and larger tributaries of the river system, whereas sea trout prefer smaller streams for spawning (Louhi *et al.*, 2008).

The spawning area of sea trout is well-studied and consists of a specific range of habitat features (Table 4; Heggenes *et al.*, 2011) However, for egg survival and hatching success also sufficient oxygen supply is important (Heggenes *et al.*, 2011; Raleigh *et al.*, 1986).

3.1.1 Importance of oxygen, sediment and temperature

After compiling data from nineteen studies, Louhi *et al.* (2008) conclude that oxygen concentrations and depositing fine sediments are crucial for successful hatching of salmonid eggs. With increasing water temperature in spring, the oxygen consumption of eggs increases as the embryos stage of development advances (Louhi *et al.*, 2008). In addition, the oxygen concentration in sediment is related to the permeability of the substrate and thus to the amount of deposit fines (Louhi *et al.*, 2008; Raleigh *et al.*, 1986). Most of the studies Louhi *et al.* (2008) analysed have stated that the fine sediment infiltration is critically important for egg survival when depositing sediments are finer than 2 mm. These fine sediment particles infiltrate into substrate, resulting in a reduction in the permeability of the redd and thereby lowering the oxygen supply to developing ova (Louhi *et al.*, 2008). This may result in poor egg survival or premature emergence of alevin (Crisp, 1996; Louhi *et al.*, 2008; Raleigh *et al.*, 1986). The extent of the harm caused to the eggs is depending on the particle size of depositing sediment (Louhi *et al.*, 2008; Raleigh *et al.*, 1986). Especially proportions as low as 1.5 % of very fine clay and silt (< 0.125 mm) in substrata, restrict oxygen uptake by adhering a thin coating of sediment on embryos or physically blocking the micropore canals in the egg membrane (Louhi *et al.*, 2008; Raleigh *et al.*, 1986). The fine sediment particles have more effects on developing alevin and fry. Raleigh *et al.* (1986) describe that a higher amount of fines result in less abundance of invertebrates. This influences the development of sea trout because invertebrates are the primary food in the early life stages (Raleigh *et al.*, 1986). In Figure 21 the values of three

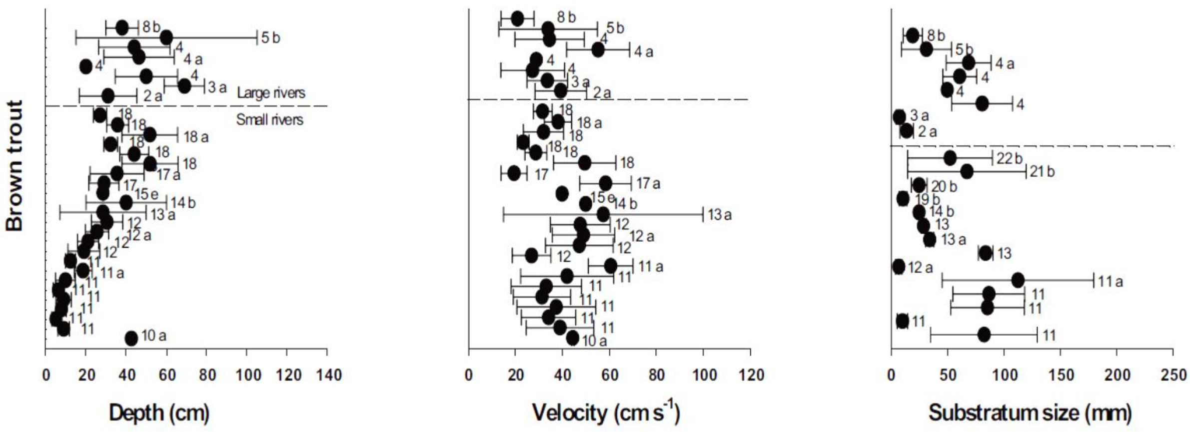


Fig. 21 Depth, water velocity and substratum composition in spawning sites of brown trout in studies reviewed (numbers refer to different studies Louhi *et al.* (2008) used). Rivers are classified based on their mean discharge, large: rivers with discharge >10m^3 s^{-1}; small: rivers with discharge <10m^3 s^{-1}. The variances, where available, are presented as standard deviation, range or index value range >0.75 s^{-1}. Otherwise plain mode or mean is used. (a: SD; b: range; c: mode; d: index value range and e: mean). (Source: Louhi *et al.*, 2008).

important spawning requirements, from the twenty-two studies Louhi *et al.* (2008) used, are displayed. The critical oxygen concentration required for successful egg incubation is displayed in Table 5.

Table 5. The oxygen concentration requirements of successful egg incubation for developmental intragravel stages, concluded in six different studies (Louhi *et al.*, 2008).

Stage of development	O_2 (mg l^{-1})	Species*	Reference
During intragravel stages	5.0	S and T	Everest *et al.* (1987)
During intragravel stages	5.0	S and T	Bjomn and Reiser (1991)
During intragravel stages	10.0	T	Rubin and Glimsäter (1996)
During intragravel stages	>7.0	S and T	Crisp (1996)
During intragravel stages	2.0–8.0	S and T	Kondolf (2000)
During intragravel stages	>7.0	S and T	Crisp (2000)

*S = Atlantic salmon, T = Brown trout.
n/a: information not available.

During the development of a sea trout, the habitat requirements differ per life stage. To oversee the water quality requirements of the developing sea trout, a brief survey of the water requirements is described per life stage after hatching.

<u>*Adult.*</u> The optimal temperature for the growth and survival of an adult *S. trutta trutta* is 12 to 19 ^{o}C (Crisp, 1996; Raleigh *et al.*, 1986). The temperature tolerance ranges from 0 to 27 ^{o}C (Crisp, 1996; Raleigh *et al.*, 1986). An adult *S. trutta trutta* usually starts its fall spawn migration at water temperatures of 6 to 12.8 ^{o}C and eventually spawns in water temperatures around 7 to 9 ^{o}C (Crisp, 1996; Raleigh *et al.*, 1986). The oxygen levels in the water are very important, as for many species. Sea trout tend to avoid water with dissolved oxygen levels less than 5 mg/l (Crisp, 1996; Raleigh *et al.*, 1986). When dissolved oxygen levels reach ≤ 3 mg/l, the lack of dissolved oxygen is lethal regardless adult or younger free moving stage (Crisp, 1996; Raleigh *et al.*, 1986). The rule of thumb is that with an increasing water temperature, dissolved oxygen saturation level in the water decreases. In addition the optimal oxygen levels are approximately ≥ 9 mg/l at temperatures ≤ 10 ^{o}C and ≥ 12 mg/l at temperatures > 10 ^{o}C (Crisp, 1996; De Laak, 2008; Raleigh *et al.*, 1986). Regarding the acidity of the water, an optimal growth of the sea trout is in water with pH of 6.8 to 7.8 (Crisp, 1996; De Laak, 2008). There is a correlation between low pH and slow growth of a sea trout (Crisp, 1996). These water quality values also apply for the following life stages unless stated otherwise.

<u>*Fry.*</u> For fry cover and shelter is essential for survival and usually comes from weeds, branches, twigs and larger stones and boulders (Crisp, 1996). Often, there is predation pressure by predatory fish such as pike in fry and post-fry stages (De Laak, 2008) but studies show that overall mortality can be less than 10% (De Laak, 2008). Once a fry is feeding, its growth is optimal in a temperature range of 7 to 15 ^{o}C, although the temperature tolerance ranges from 5 to 25 ^{o}C (Raleigh *et al.*, 1986).

<u>*Juvenile (incl. parr and smolt).*</u> The water temperature for an optimal growth is around 12 ^{o}C and a temperature between 7 to 19 ^{o}C is still a good temperature for the development of sea trout (De Laak, 2008). The tolerance is slightly higher with a tolerance range between 0 to 27 ^{o}C (Crisp, 1996). The optimal amount of dissolved oxygen is ≥ 7.0 ppm at temperatures < 15 ^{o}C and ≥ 9.0 ppm at

temperatures ≥ 15 ^{o}C (Crisp, 1996; Raleigh *et al.*, 1986). The pH tolerance ranges from 5.0 to 9.5 with an optimal pH between 6.7 to 7.8 (De Laak, 2008).

3.1.2 Trade-offs, food and predation

Whether a fish becomes a migrant or not is likely to be dependent on a trade-off between benefits and costs, resulting in either migratory behavior or residency (Svendsen, 2008). Svendsen (2008) assumes that feeding conditions at sea are often better than in freshwater in temperate zones. This may imply an advantage in terms of growth for migrants. Many fish species have indeterminate growth and fecundity, and fertility increases with body size (Svendsen, 2008). Better feeding conditions may also result in increased fitness since the fitness for female fish is strongly dependent on body size (Svendsen, 2008). The bigger the female, the higher is the fitness of the female. On the other hand migrants may experience increased mortality (by for example predation), osmoregulatory constraints and additional swimming costs (De Laak, 2008; Svendsen, 2008). According to Svendsen (2008) there seems to be a link between the juvenile physiology and future migration characteristics. Metcalfe (1998) describes that growth trajectories during sensitive periods, several months in advance of the possible migration event, are suggested to decide whether or not migration is subsequently initiated (Metcalfe, 1998 in: Svendsen 2008).

<u>*Food in freshwater.*</u> *S. trutta sp.* is considered to be a generalist regarding its feeding behavior (De Laak, 2008). The diet depends on the available habitat, season, body size and age (Klemetsen *et al.*, 2003 in: De Laak, 2008). It consists of benthic fauna and drifting food in the middle and upper water column, but it mainly preys on invertebrates (De Laak, 2008). In spring, the diet includes newly hatched insects and terrestrial fauna (De Laak, 2008). The prey size increases with the size and age of the sea trout. Parrs are selective in their prey and mainly feed on terrestrial and aquatic insect of the groups Ephemeroptera*,* Trichoptera and Plecoptera (De Laak, 2008). Smolts and adults become increasingly generalists and may become piscivores, feeding on prey sizes of approximately a third of their own body length (De Laak, 2008).

<u>*Food in marine environment.*</u> Sea trout in marine environments feed primarily on smaller fish species such as the Raitt's sandeel (*Ammodytes marinus*), the greater sandeel (*Hyperoplus lanceolatus*) and several Atherinadae species (De Laak, 2008). Older sea trout also feed on polychaetes, European sprat (*Sprattus sprattus*) and Atlantic herring (*Clupea harengus*) (De Laak, 2008). The sea trout is feeding only until its homing migration upstream for spawning (Svendsen, 2008). Usually sea trout do not eat during the upstream migration and survives on its reserves (De Laak, 2008).

<u>*Predators.*</u> Parrs and smolts are vulnerable for predation by European otters (*Lutra lutra*), cormorants (*Phalacrocorax sp.*), whitefish (Coregonidae) and northern pike (*Esox lucius*) (De Laak, 2008). Pike until 40 cm in length are food competitors to sea trout, while the larger pikes can be salmonid predators (De Laak, 2008). An Irish research showed that, in a pike population around two third of the population fed exclusively on salmonids (Mills, 1970 in: De Laak, 2008). Especially in downstream migration the sea trout is vulnerable for predation, for example due to its size (De Laak, 2008). In marine environments also seagulls (Laridae), cod (*Gadus morhua*), whiting (*Melangius melangus*) and pollack (*Pollachius pollachius*) are feeding on salmonids (De Laak, 2008). Also seals (Phocidae) are a major threat for both smolts and adult sea trout in marine environments (De Laak, 2008).

3.2 The Wadden Sea habitat

To analyse whether the Wadden Sea is a suitable habitat for sea trout, it is necessary to know how the Wadden Sea looks like and what its characteristics are. The Wadden sea consists of tidal flats and tidal channels, and is separated from the North Sea by a chain of barrier islands (Wiersma *et al.*, 2009). The shallow coastal waters of the Wadden Sea and its adjacent estuaries provide indispensable ecological functions (Jager *et al.*, 2009). They function as reproduction sites, offering maturing and feeding opportunities and they serve as an acclimatization area for migrants (Haedrich, 1982; Kerstan, 1991; Elliot and Hemingway, 2002; Elliot *et al.*, 2007: all in Jager *et al.*, 2009). Nowadays, humans influence the Wadden Sea to such an extent that the impact causes the Wadden Sea area to deviate in its morphological structure and development from the natural situation (Wiersma *et al.*, 2009). One important influence is the loss of connectivity between the mainland and the Wadden Sea by damming of the majority of the estuaries (Wiersma *et al.*, 2009). Despite the loss of brackish conditions, when sea trout is successful in migrating to the Wadden Sea the environmental conditions seems to be sufficient for growth and development (Van der Graaf *et al.*, 2009).

There is not much known about the marine life of sea trout and its marine requirements (De Laak, 2008). Therefore for this report the suitability of the Wadden Sea as a habitat is mainly analysed in means of food availability and predation pressure, bearing in mind that the sea trout is a generalist with regard to food.

<u>*Macrozoobenthos.*</u> As well as in the Quality Status Report of the CWSS (Van der Graaf *et al.,* 2009), in this report macrozoobenthos is defined as invertebrate bottom fauna living on, or in the bottom, which can be retained on a sieve with a mesh size of 1 mm x 1 mm. There are about 400 macrozoobenthic species in the Wadden Sea of which a significant part concerns polychaetes (Van der Graaf *et al.*, 2009). As previously described, polychaetes are part of the sea trout diet. Polychaetes make up the rich feeding grounds for a wide variety of predatory fish and birds (Van der Graaf *et al.*, 2009). Although there are no polychaete conservation targets, the biomass of polychaetes is monitored by the CWSS (Van der Graaf *et al.*, 2009). The trend they found was an increase in the biomass of polychaetes in the Dutch Wadden and western coast of Germany. The most widespread increase concerned *Nereis succinea* (Van der Graaf *et al.*, 2009). Other polychaetes such as *Marenzelleria viridis* and *Heteromastus filiformis* increased in abundance during the last two decades. Other polychaetes such as *Scoloplos armiger* and *Arenicola marina* slightly decreased in abundance over the last two decades (Van der Graaf *et al.*, 2009). Beneficial for the sea trout is that the increase in polychaetes is mainly found at Balgzand and Groninger Wad (Figure 22; Van der Graaf *et al.*, 2009). Many scientists described the trend

Fig. 22 Map of the Wadden Sea area with the location of macrozoobenthic monitoring sites (Van der Graaf *et al.*, 2009).

of increasing polychaete abundances in the Wadden Sea (Reise, 1982; Beukema *et al*., 2002; Essink *et al*., 2006; Ens *et al*., 2004; all in: Van der Graaf *et al.*, 2009). Although there are many possible causes and relationships investigated to explain the increasing polychaetes biomass and its consequences for the Wadden Sea, for the sea trout this trend can be considered as beneficial in means of prey abundance.

Fish. Small fish are an important component of the sea trout diet in the marine environment (De Laak, 2008). Jager *et al.* (2009) describe in the Quality Status Report of the CWSS, that fish abundance usually peaks in early summer. This is the same period sea trout arrives in the marine environments (De Laak, 2008; Kuijs *et al.*, 2011). The CWSS describes that the typical Wadden Sea fish species are all still present nowadays (Jager *et al.*, 2009). Typical Wadden Sea fish fauna refer to those species regularly found in demersal fish surveys documented over the last forty years. This would mean that the prey of the piscivore sea trout is still present in the Wadden Sea. However, the occurrence of fish species depend on natural dynamics (Jager *et al.*, 2009). The CWSS acknowledges that fish abundance sometimes outranges the long-term averages which can lead to regime shifts due to natural and anthropogenic factors (Jager *et al.*, 2009). For example marine juvenile fish in the Wadden Sea reflect heavy fishing pressure in the North Sea, directly resulting in a decrease in abundance of several fish species (Jager *et al.*, 2009). Nevertheless the Wadden Sea retains its nursery function for marine juvenile and marine seasonal species, forming an important constituent of the Wadden Sea fish fauna (Jager *et al.*, 2009). The Wadden Sea fish species diversity comprises around 150 different species (Jager *et al.*, 2009). Over the last forty years, the abundance patterns suggest an increase in abundance in the 1970s, followed by a decrease in the two consecutive decades (Jager *et al.*, 2009). An overall increase was shown in the smelt, flounder, herring and sprat abundance and a decrease was found in eelpout, cod and whiting abundance (Jager *et al.*, 2009).

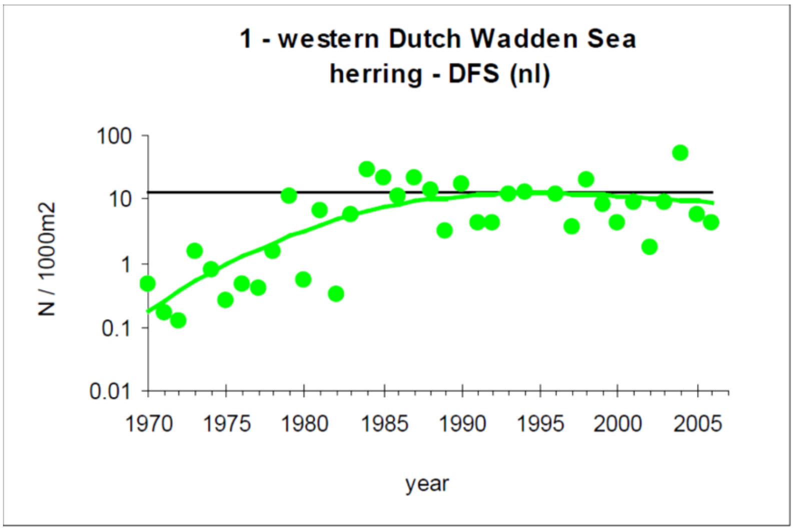


Fig. 23 Catch density (N/1000 m^2) of herring in the western Dutch Wadden Sea. The trend is indicated by a green (positive trend) line whereas the thin grey line indicates the long–term average abundance. (Source: DFS and DYFS from Bolle *et al.,* 2009 in: Jager *et al.*, 2009).

With regard to sea trout prey herring and sprat, demersal surveys showed overall significantly increasing trends in the 1970s and 1980s in the Wadden Sea (Figure 23) and since then a not significant decreasing trend in abundance (Jager *et al.*, 2009). Sometimes, both species can become extremely abundant with a majority of juveniles of a maximum length of 10 cm in some areas in the German Wadden Sea (Jager *et al.*, 2009). The CWSS describes that over the last decade no clear trend in herring abundance can be concluded, while the sprat abundance showed a slightly decreasing trend since 2000 (Jager *et al.*, 2009). Because of the lack of knowledge regarding the historic reference conditions and species abundances, it cannot be concluded whether the present status of the Wadden Sea is "good" or "deteriorating" in means of sea trout prey. The CWSS describes that juvenile herring is still found in considerable numbers, suggesting potential sea trout prey is present in the Dutch Wadden Sea (Jager *et al.*, 2009).

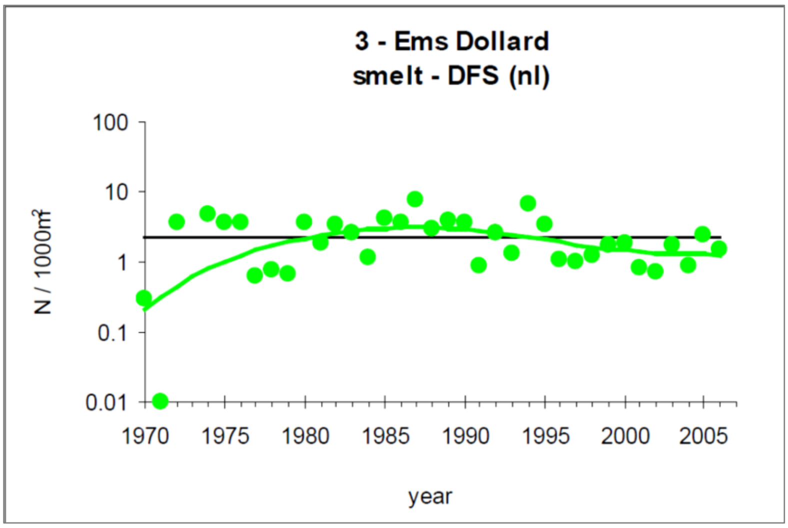


Fig. 24 Catch density (N/1000 m^2) of smelt in the Ems - Dollard. The trend is indicated by a green (positive trend) line, whereas the thin grey line indicates the long–term average abundance. (Source: DFS and DYFS from Bolle *et al.,* 2009 in: Jager *et al.*, 2009).

Smelt (*Osmeridae sp.*), which can also be seen as a potential sea trout prey according to Frose & Pauly (2007) in Jager *et al.* (2009), showed a significantly increasing trend in most of the Wadden Sea subareas over the last decades (Jager *et al.*, 2009). However, the smelt abundance in the Ems-Dollart tends to be declining in recent years, although not significantly (Figure 24; Jager *et al.*, 2009). There is no reliable information on the abundance of sandeel in the Wadden Sea due to its combined benthic (buried) and pelagic lifestyle, despite its importance as a food resource for higher trophic levels (Jager *et al.*, 2009).

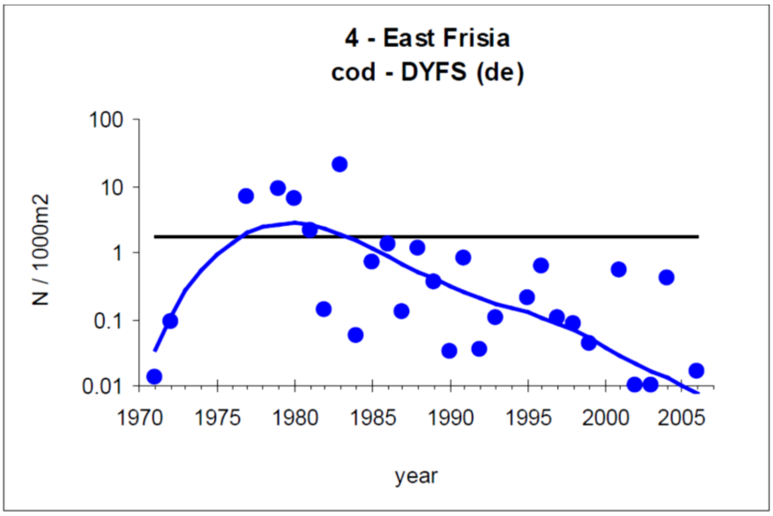


Fig. 25 Catch density (N/1000 m^2) of cod in East Frisia. The trend is indicated by a blue (neutral trend) line, whereas the thin grey line indicates the long–term average abundance. (Source: DFS and DYFS from Bolle *et al.,* 2009 in: Jager *et al.*, 2009).

The CWSS suggests that diadromous fish currently suffer more from bottlenecks in the upstream parts of the estuaries, where water quality and essential habitats are failing, than from the availability of potential prey (Jager *et al.*, 2009). Therefore, the migration problems are considered to be more influential on the occurrence and resulting in low abundances. That food may not be a restricting factor for the sea trout might also coincide with high fishing pressure on the predators of sea trout in the Wadden Sea. There might be a decreased predation risk due to coastal and offshore commercial fishing, resulting in low abundance of cod and whiting (Jager *et al.*, 2009).

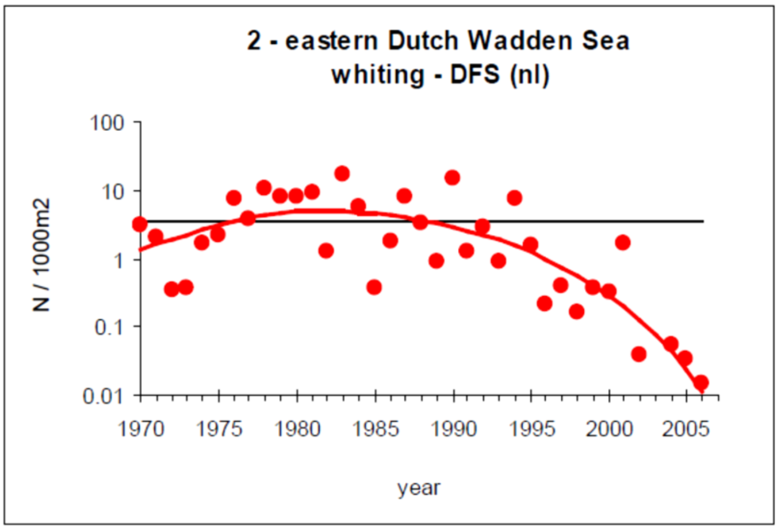


Fig. 26 Catch density (N/1000 m^2) of whiting in the eastern Dutch Wadden Sea. The trend is indicated by a red (negative trend) line, whereas the thin grey line indicates the long–term average abundance. (Source: DFS and DYFS from Bolle *et al.,* 2009 in: Jager *et al.*, 2009).

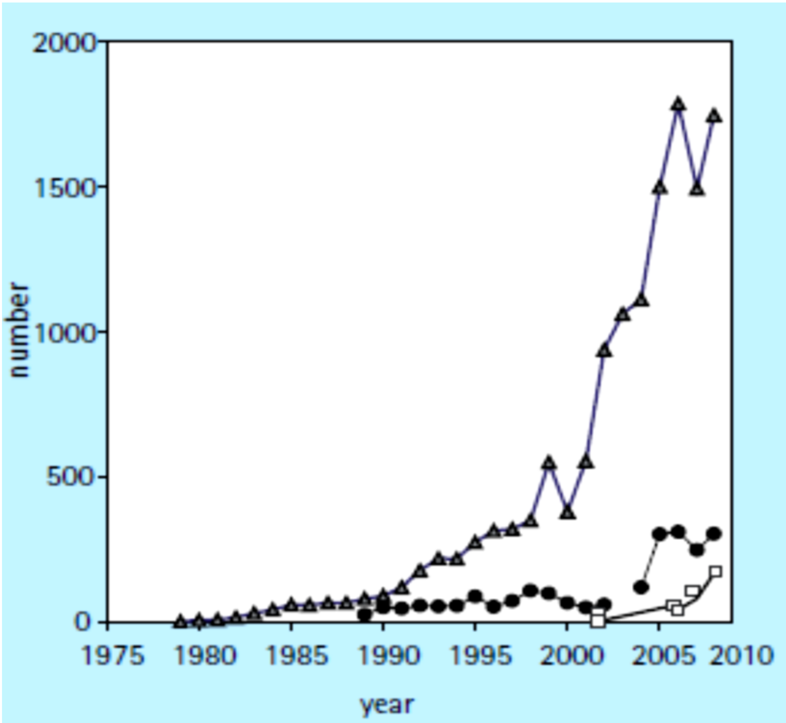


Fig. 27 Counts of grey seals in the Wadden Sea during the moult (March/April). ▲ The Netherlands (source: IMARES); ● Schleswig-Holstein and Helgoland (source: National Park Schleswig-Holsteinisches Wattenmeer; □ Niedersachsen (source: Nationalpark Niedersächsisches Wattenmeer). (Source: Reijnders *et al.*, 2009).

__Predation.__ The abundance of cod increased up to the early 1980s and steadily decreased thereafter (Figure 25; Jager *et al.*, 2009). The increase in abundance until the early 1980s is more or less equaled in the present day (Jager *et al.*, 2009). It is assumed that cod recruitment is affected mainly by overfishing and fluctuations in plankton, however the survival of larval cod also depends on mean size of its prey, seasonal timing and prey abundance (Jager, et al., 2009). The whiting abundance significantly decreased in the Dutch Wadden Sea over the last decades (Figure 26; Jager *et al.*, 2009). The whiting recruitment has been below the long-term average probably due to low stock size and environmental factors (ICES, 2008 in: Jager *et al.*, 2009).

Important marine mammals possibly feeding on salmonids in the Wadden Sea, are the harbour (or common) seal (*Phoca vitulina*) and the grey seal (*Halichoroerus grypus*) (Reijnders, *et al.*, 2009). The number of grey seals observed in the Wadden Sea has continued to increase over the last few decades (Figure 27; Reijnders *et al.*, 2009). In the Dutch Wadden Sea, the number of grey seals counted during the moult in 2008 is 1,716 (Reijnders *et al.*, 2009). The harbor seal population has prosperously recovered from the last virus epizootic in 2002 (Reijnders *et al.*, 2009). The surveys for 2003 - 2009 show that the numbers counted each year increased on average by 12.3% per year, revealing a total of more than 21,000 animals in the Wadden Sea (Reijnders *et al.*, 2009). Around 6,000 – 7,000 animals can be found in the Dutch part of the Wadden Sea (Reijnders *et al.*, 2009). With thousands of seals present in the Dutch Wadden Sea, it can be suggested that there might be enough prey but also an incredible predation pressure on the sea trout. In the 1970s there was a very low abundance of seals in the Wadden Sea (Reijnders *et al.*, 2009). Therefore, with the vast increase in abundance of the two seal species, the predation pressure on salmonids must be far higher than in the preceding decades. In addition millions of birds live in the Wadden Sea (Koffijberg *et al.*, 2009). Not all of the species present in the Wadden Sea feed on fish. According to the CWSS, the vast majority of the bird species feed on benthic organisms instead of fish (Koffijberg *et al.*, 2009). Some bird species are omnivores and occasionally feed on fish such as gull species (Mediterranean gull *Larus melanocephalus*, lesser black-backed gull *Larus fuscus*, great blackbacked gull *Larus marinus*, common gull *Larus canus* and herring gull *Larus argentatus*) and species such as the great cormorant *Phalacrocorax carbo sinensis* feed predominantly on fish (Koffijberg *et al.*, 2009). In recent years, in all these bird species an increase in population size was observed by the CWSS, except for the herring gull (Koffijberg *et al.*, 2009). The influence of the gull species on the fish stocks is suggested to be of less importance (Koffijberg *et al.*, 2009), the great cormorant on the other hand may have an influence on the fish stocks. The numbers of great cormorant increased over the last decade, but the proportion of sea trout in their diet remains unclear (Koffijberg *et al.*, 2009).

3.3 Habitat in the Noorderzijlvest management area

The Regional Water Authority Noorderzijlvest is the responsible water authority for a part of the northern Rhine delta (Figure 28 and 29; Projectgroep KRW Rijn-Noord, 2004; RWA NZV, 2010).

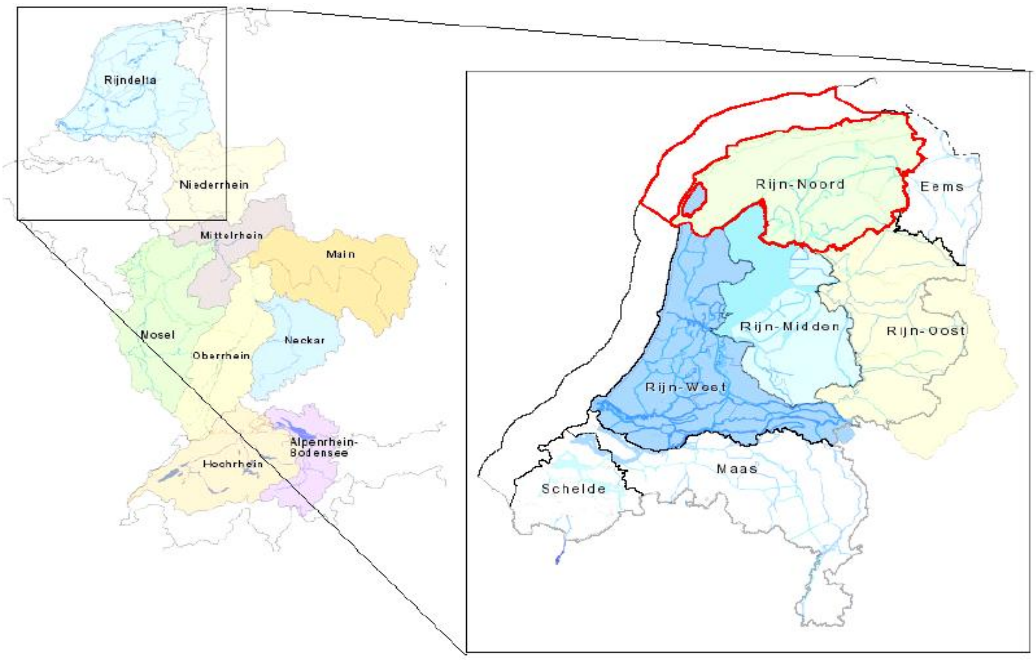


Fig. 28 Classification of international drainage basin district Rhine according to the WFD (Projectgroep KRW Rijn-Noord, 2004)**.**

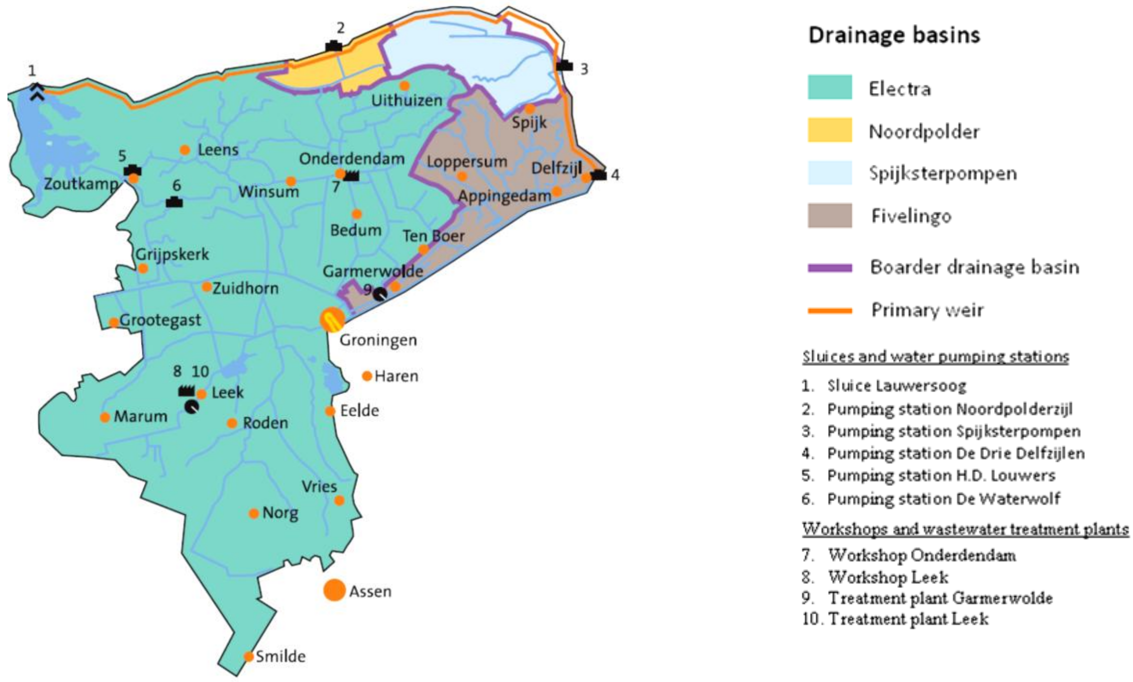


Fig. 29 Management area overview of the Regional Water Authority Noorderzijlvest. The colours indicate the different basins, the numbers indicate the locations of major sluices, water pumping stations and purification plants (RWA NZV, 2010).

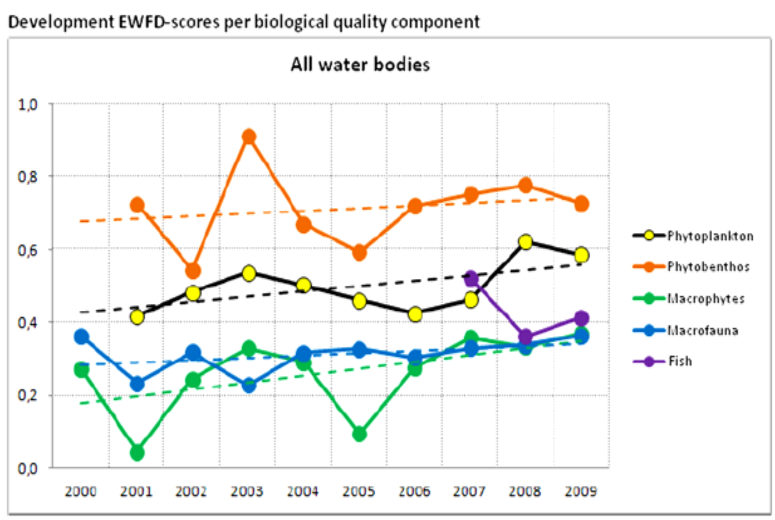


Fig. 30 Development of WFD-scores per biological quality component in the Noorderzijlvest management area. The annual mean scores of all available results per parameter are given. According to the WFD the status of a parameter is considered as 'good' when the score is ≥ 0.6 (Noorderzijlvest A., 2008). Also the linear trends are shown with exception for the parameter 'fish'. This is because fish is only monitored since a few years. (Source: Torenbeek, 2012).

The WFD standards have an important and instructing role in the controlling and managing activities of the regional water authority. Noorderzijlvest manages eleven water types and fifteen water bodies in which the lakes and rivers are the most important (Huisman & Verbeek, 2008). Amongst the water bodies there is a high variance in the characteristics and water quality (Huisman & Verbeek, 2008). Within the management area there are for example brackish conditions in the Lauwersmeer and peaty conditions in the Paterswoldsemeer (Huisman & Verbeek, 2008). The chemical and ecological quality of all the water bodies is monitored regularly (Noorderzijlvest A., 2008). The current overall water quality seems to be insufficient regarding the WFD standards as shown in Figure 30 (Noorderzijlvest A., 2008; Torenbeek, 2012). Because of the high number and different types of water bodies, not all of the water bodies are described in this report due to limited time. However, the habitat of the for sea trout migration relevant water bodies (according to Noorderzijlvest and informal communication (Huisman, 2011) are described briefly. Migration barriers and WFD parameters and guidelines are described in the following chapters.

3.3.1 Habitat quality of the Lauwersmeer

The Lauwersmeer is a manmade lake with brackish water in the northwest of the Noorderzijlvest management area. The depth and water conditions are subject to seasonal fluctuations and it is therefore enclosed by big floodplains (Noorderzijlvest A., 2008). The variable water conditions affect the present communities, resulting in fluctuating spatial population sizes (Noorderzijlvest A., 2008). At the riverbanks there are big plains with vegetation, such as several reed species. In the open water submerged water flora can be found (Noorderzijlvest A., 2008). The associated fauna, i.e. water insects and fish, is depending on and interacting with other (a)biotic factors such as turbidity, depth and nutrient loads (Noorderzijlvest A., 2008). Now and then fish species such as the twait shad, river lamprey and smelt are found, using the Lauwersmeer as habitat for their development or for passing through because of their migration (Noorderzijlvest A., 2008). A summary of the ecological and chemical status of the Lauwersmeer, according to the WFD standards is shown in Table 6 and 7. The Lauwersmeer has a high phosphor and nitrogen input originating from the local agriculture (Noorderzijlvest A., 2008). This eutrophication is a major point of attention and is amongst other factors contributing to the moderate ecological and chemical status of the Lauwersmeer (Noorderzijlvest A., 2008).

Table 6. Ecological status Lauwersmeer according to WFD standards (Noorderzijlvest A., 2008).

	Condition in 2008	Management in 2008
Algae	Moderate	Moderate
Water vegetation	Moderate	Moderate
Water insects	Moderate	Moderate
Fish	Moderate	Moderate

Table 7. Chemical mean values Lauwersmeer according to WFD standards (Noorderzijlvest A., 2008).

	Actual values	**Expected values in 2015**	**Prevailing standard**	**Concept national standard (2008)**	**Actions needed**
N (mg/l)	2.95	2.73	2.2	1.8	Yes
P (mg/l)	0.31	0.29	0.15	0.11	Yes
Transparency (m)	0.48		0.40	0.60	Yes
Chloride (mg/l; 90-perc.)	700->5,000		200	1,000-5,000	No
Oxygen (mg/l; 10-perc.)	8.9		5	6-9	No

3.3.2 Habitat quality of the Reitdiep

The Reitdiep is directly adjacent to the Lauwersmeer. The ecological and chemical water quality is according to WFD standards moderate (Noorderzijlvest A., 2008). Also in this river, eutrophication is a problem for the ecological and chemical status (Noorderzijlvest B., 2008). Water vegetation is present but scattered, which has its influence on the fauna (Noorderzijlvest B., 2008). Examples of the different flora are within the genus *Callitriche, Potamogeton* and *Sagittaria* (Noorderzijlvest A., 2008). Macrofauna is somewhat restricted to benthic and demersal organisms. Fish species such as burbot (*Lota lota*), stone loach (*Barbatula barbatula*) and gudgeon (*Gobio gobio*) are abundant. A summary of the ecological and chemical status of the Reitdiep according to the WFD standards is shown in Table 8 and 9.

Table 8. Ecological status Reitdiep according to WFD standards (Noorderzijlvest B., 2008).

	Condition in 2008	Management in 2008
Water vegetation	Poor	Poor
Water insects	Poor	Poor
Fish	Poor	Moderate

Table 9. Chemical mean values Reitdiep according to WFD standards (Noorderzijlvest B., 2008).

	Actual values	Expected values in 2015	Prevailing standard	Concept national standard (2008)	Actions needed
N (mg/l)	3.63	3.36	2.2	4	No
P (mg/l)	0.96	0.89	0.15	0.19	Yes
Transparency (m)	0.30		0.40	0.50	Yes
Chloride (mg/l; 90-perc.)	80-360		200	400	No
Oxygen (mg/l; 10-perc.)	5.54		5	6-9	Yes

3.3.3 Habitat quality of the Damsterdiep

The Damsterdiep is an artificial water body, i.e. canal, between the cities of Delfzijl and Groningen. The ecological and chemical water quality is moderate according to the WFD standards (Noorderzijlvest A., 2008). Some components such as 'fish' and 'water insects' are suggested to be poor. Although depending on dry or wet years, there is also an eutrophication problem in this canal (Noorderzijlvest A., 2008). Compared to the Reitdiep, the Damsterdiep is more affected by flushing from surface waters, resulting in a higher annual fluctuation in nitrogen and phosphorus values (Noorderzijlvest A., 2008). The banks are mainly covered by reed species and there is almost no submerged flora (Noorderzijlvest A., 2008). According to an analysis conducted by Noorderzijlvest, there are many opportunities for an increase in abundance and development of bank vegetation (Noorderzijlvest A., 2008). In sheltered areas *Stratiotes* species can be found and the water authority is managing the canal increasingly environmentally friendly, meaning that the anthropogenic influences tend to be reduced (Noorderzijlvest A., 2008). Macrofauna, fish and flora may benefit from this approach. Some fish species which can be found are pike, perch (*Perca fluviatilis*), roach (*Rutilus rutilus*) and rudds (*Scardinius erythropthalmus*). Recently the pumping station De Drie Delfzijlen has been made 'migration friendly' for fish and a gradual freshwater-seawater gradient has been restored (Noorderzijlvest A., 2008). A summary of the ecological and chemical status of the Reitdiep according to the WFD standards is shown in Table 10 and 11.

Table 10. Ecological status Damsterdiep according to WFD standards (Noorderzijlvest A., 2008).

	Condition in 2008	Management in 2008
Algae	Moderate	Moderate
Water vegetation	Moderate	Moderate
Water insects	Poor	Moderate
Fish	Poor	Moderate

Table 11. Chemical mean values Damsterdiep according to WFD standards (Noorderzijlvest A., 2008).

	Actual values	**Expected values in 2015**	**Prevailing standard**	**Concept national standard (2008)**	**Actions needed**
N (mg/l)	3.3	3.1	2.2	3	Yes
P (mg/l)	0.55	0.5	0.15	0.2	Yes
Transparency (m)	0.44		1	0.9	Yes
Chloride (mg/l; 90-perc.)	150-900		200	>300	No
Oxygen (mg/l; 10-perc.)	9.2		5	6-9	No

3.3.4 Habitat quality of the Peizerdiep

The Peizerdiep can be divided into the source of the river (from now on called 'headwater') and the lower course of the river. **The headwater** has according to the WFD standards a poor ecological and chemical water quality (Noorderzijlvest A., 2008). The drainage of the headwater is low and its dynamic flow has been restrained through the years (Noorderzijlvest A., 2008). However the headwater still has an asymmetric profile through woodlands and less anthropogenic disturbed areas (Noorderzijlvest A., 2008). There are trees and branches hanging over and sandy- and gravel bars can be found in the headwater (Noorderzijlvest A., 2008). There are small rapids and river parts with low velocity. Because of its flow through this diverse environment, a lot of organic materials can be temporarily present in some parts of the headwater (Noorderzijlvest A., 2008). Also because of the habitat diversity there is a high variation in distinctive flora, water insects and fish (Noorderzijlvest A., 2008). Just as the other water bodies, the eutrophication caused by agriculture is a problem, although this also depends on the periodical circumstances, i.e. wet or dry years (Noorderzijlvest A., 2008). A summary of the ecological and chemical status of the Peizerdiep headwater according to the WFD standards is shown in table 12 and 13.

Table 12. Ecological status Peizerdiep headwater according to WFD standards (Noorderzijlvest A., 2008).

	Condition in 2008	Management in 2008
Water vegetation	Poor	Poor
Water insects	Poor	Poor
Fish	Poor	Poor

Table 13. Chemical mean values Peizerdiep headwater according to WFD standards (Noorderzijlvest A., 2008).

	Actual values	**Expected values in 2015**	**Prevailing standard**	**Concept national standard (2008)**	**Actions needed**
N (mg/l)	2.8	2.6	2.4	4	No
P (mg/l)	0.15	0.13	0.15	0.12	Yes
Chloride (mg/l; 90-perc.)	34		200	40	Yes
Oxygen (mg/l; 10-perc.)	6		5	6-9	No

Despite the suggested 'moderate' results of Table 14, with an overall description of 'poor' the **lower course of the Peizerdiep** seems to have an insufficient ecological and chemical water quality according to the WFD standards (Noorderzijlvest A., 2008). The drainage is low and the dynamic flow of the river has been more restrained, however the surroundings regarding the woodlands and other vegetation is not very different from the headwater (Noorderzijlvest A., 2008). Just as in the headwater, also the periodically input of nutrients by agriculture is a primary concern. In the lower course especially phosphate needs attention regarding the water quality (Noorderzijlvest A., 2008). A summary of the ecological and chemical status of the lower course of the Peizerdiep according to the WFD standards is shown in Table 14 and 15.

Table 14. Ecological status lower course of the Peizerdiep according to WFD standards (Noorderzijlvest A., 2008).

	Condition in 2008	Management in 2008
Water vegetation	Moderate	Moderate
Water insects	Moderate	Moderate
Fish	Moderate	Moderate

Table 15. Chemical mean values lower course of the Peizerdiep according to EWFD standards (Noorderzijlvest A., 2008).

	Actual values	Expected values in 2015	Prevailing standard	Concept national standard (2008)	Actions needed
N (mg/l)	2.4	2.2	2.2	4	No
P (mg/l)	0.17	0.16	0.15	0.14	Yes
Chlorofyl (µg/l; summer)	22		100	<50	No
Transparency (m)	0.41		0.1	0.4 – 0.6	No
Chloride (mg/l; 90-perc.)	27		200	150	No
Oxygen (mg/l; 10-perc.)	5.7		5	6-9	Yes

3.4 Habitat in Rhine delta and lower Rhine

The Rhine is with a total length of approximately 1,250 km one of the longest rivers in Europe (Uehlinger *et al.*, 2009). Nine countries are in part or entirely situated within the Rhine catchment, namely Austria, Belgium, France, Germany, Italy, Liechtenstein, Luxemburg, the Netherlands and Switzerland (Figure 31; Uehlinger *et al.*, 2009). The drainage area is around 185,260 km^2 with an

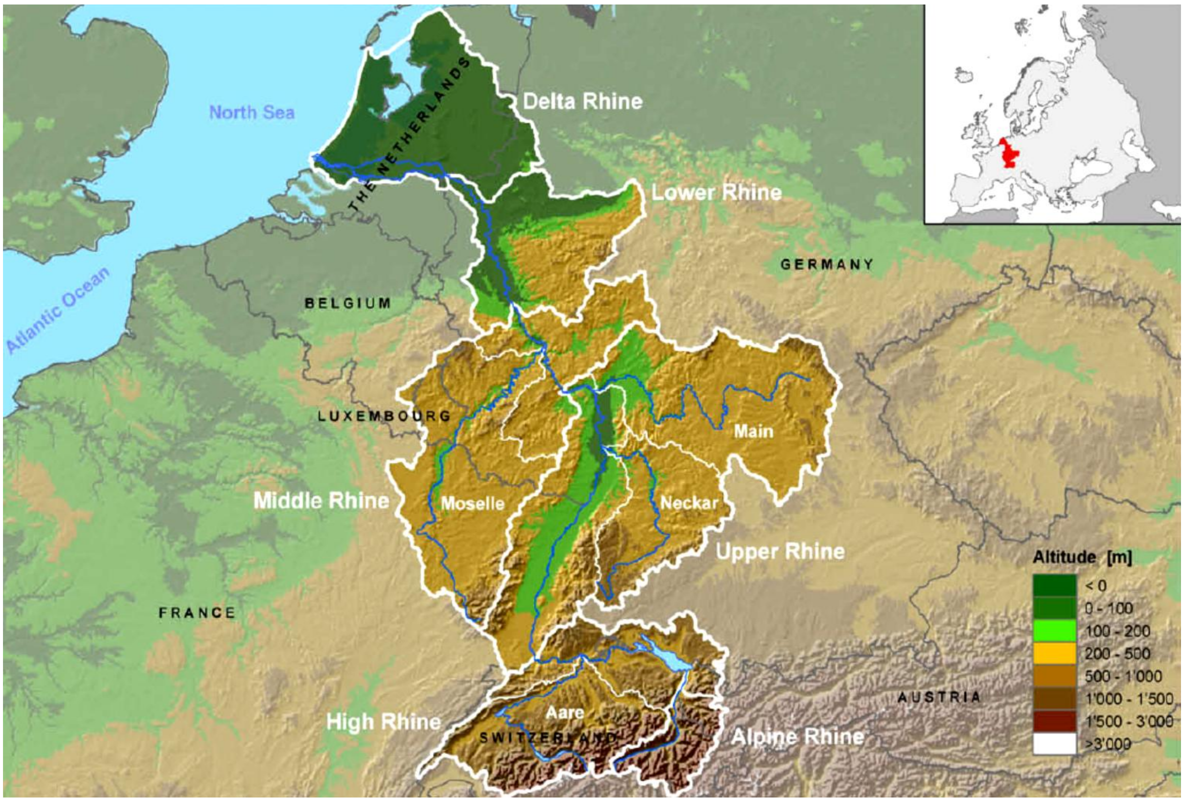


Fig. 31 Digital elevation model of the Rhine River Basin (Uehlinger *et al.*, 2009).

average discharge of about 2,300 m^3/s (Uehlinger *et al.*, 2009). A few of the most important economic regions of Europe are located at the Rhine resulting in a lot of shipping traffic (Uehlinger *et al.*, 2009). The Rhine can be split up into six different parts as is shown in Figure 31. In this report only the Rhine Delta and the Lower Rhine will be described because of limited time and because the general acknowledged nearest sea trout spawning areas can be found in the lower Rhine, i.e. the river Sieg (amongst others: De Groot, 2002; De Laak, 2008; Uehlinger *et al.*, 2009; Van der Meij *et al.*, 2005).

3.4.1 The Rhine Delta habitat

The water quality and sediment in rivers, canals and harbours in the Rhine Delta used to be moderately to heavily contaminated due to (trans)national and local water pollution (De Laak, 2008; Uehlinger *et al.*, 2009). The continuous industrial, communal and agricultural discharge of pollutants and recurrent flooding resulted in the deposition of large amounts of particulate-bound toxic substances in floodplains along the delta (Uehlinger *et al.*, 2009). This caused a decreasing biodiversity, especially over the last century (Uehlinger *et al.*, 2009). In particular (macro)fauna was and is suffering from the pollutants and has not recovered from anthropogenic disturbances yet (Uehlinger *et al.*, 2009). The pollution that has been accumulated over the last century is still present in river sediments and floodplain deposits (Uehlinger *et al.*, 2009). Therefore the floodplain soils keep the heritage and risks of earlier river pollution. Today respectively, 65, 45 and 35% of soil samples from floodplain along the rivers Waal, Nederrijn and IJssel exceed environmental quality standards for one or more contaminants (mainly metals) (Uehlinger *et al.*, 2009). In the last decades, much effort has been made to decrease the input of pollutants and to increase the overall quality of the Rhine (Uehlinger *et al.*, 2009). However, the persistent organic substances and (heavy) metals are continuously redistributed and mixed or covered by cleaner sediment and consequently, are still present in the river system (Uehlinger *et al.*, 2009). Nevertheless, the diversity of habitats with associated flora and fauna is still impressive and diverse. The floral and faunal diversity is strongly depending on the habitat. Uehlinger *et al.* (2009) describe that the diversity is declining towards the sea. One example is the macroinvertebrates diversity as displayed in Figure 32. The species richness seems to be highest in the High Rhine and the species richness in the delta is far lower compared to the headwater.

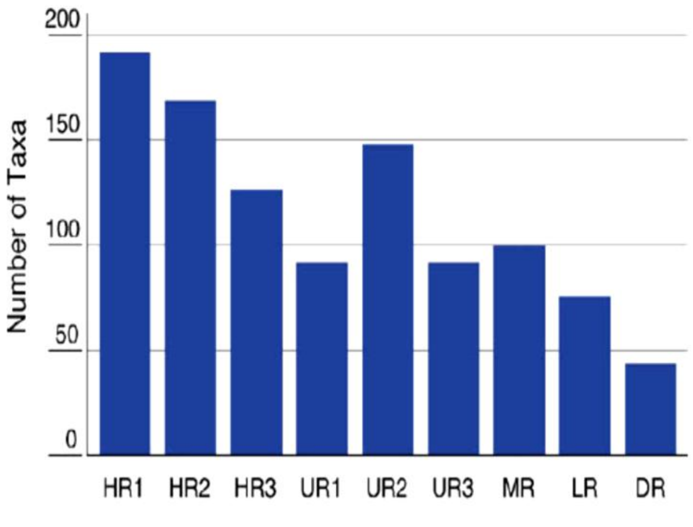


Fig. 32 Taxa richness of macroinvertebrates along the Rhine between the lower Lake Constance and the sea. The same taxonomic level has been applied for all Rhine sections. HR1 = High Rhine between Lake Constance and Aare confluence. HR2 = High Rhine between Aare confluence and beginning of the navigable reach. HR3 = High Rhine navigable reach. UR1 = southern Upper Rhine: Grand Canal. UR2 = southern Upper Rhine: Restrhein. UR3 = northern Upper Rhine. MR = Middle Rhine. LR = Lower Rhine. DR = Delta Rhine. (Modified from Buwal, 2002 in Uehlinger *et al*, 2009).

In the Rhine Delta, where sandy substrate prevails, invertebrates are characterized by a diverse Chironomid and Oligochaete fauna (Uehlinger *et al.*, 2009). For example *Kloosia pusilla* and *Robackia demeijeri* reach high densities in habitats with fast currents (Uehlinger *et al.*, 2009). Oligochaetes are dwellers of the navigation channel while Tubificidae are frequent in low current areas. On solid substrates (groynes and bank riprap) *Corophium curvispinum* and the Chironomid *Dicrotendipes nervosus* are frequently found (Uehlinger *et al.*, 2009). The brackish water zone mainly hosts euryhyaline species such as *Corosphium multisetosum*, *C. volutator* and palaemonidae shrimp species (Uehlinger *et al.*, 2009). In the Rhine Delta several fish species disappeared and the remaining fish species decreased in abundance over the last century (amongst others: De Laak, 2008; Uehlinger *et al.*, 2009). Hence, not only in total numbers also in diversity the Rhine Delta deteriorated. The decrease in diversity and abundance coincided with the increasing pollution, habitat loss by river engineering and the construction of migration barriers (De Laak, 2008; Uehlinger *et al.*, 2009). The Rhine used to be the European river with the largest Atlantic salmon population but with the closure of the Afsluitdijk, construction of sluices in the water bodies, development of highly industrialized areas and the intense shipping traffic, almost all migratory fish species decreased in abundance or became extinct (De Laak, 2008; Uehlinger *et al.*, 2009). Uehlinger *et al.* (2009) also describe that the recurrence of the Atlantic salmon reflects an improved water quality in the Rhine although the number of salmon is still small, compared to their abundance in the nineteenth century. Nowadays the most abundant fish species are roach, bream, pike, perch and ruffe (Uehlinger *et al.*, 2009). Besides the predation by bigger piscivorous fish such as the pike, the Eurasian otter can be considered as a noxious fish predator (Uehlinger *et al.*, 2009). Today they are only present in the Dutch part of the Rhine, only as a result of reintroduction and habitat restoration activities, but they remain rare and vulnerable (Uehlinger *et al.*, 2009). The grey heron (*Ardea cinerea*) and the great cormorant are according to Schneider (2009) the major avifaunal predators for juvenile sea trout.

3.4.2 The Lower Rhine habitat

The nearest acknowledged spawning areas for salmonids are in the Lower Rhine drainage basin (Schneider, 2009). An often mentioned example in literature is the river Sieg. The Sieg is a tributary of the river Rhine where many projects are carried out for reintroduction and restocking of the sea trout and Atlantic salmon populations (Schneider, 2009; Van der Meij *et al.*, 2005). The river flows through the German federal states of North Rhine-Westphalia and Rhineland-Palatinate. The chemical conditions of the Lower Rhine and its tributaries are similar with the Rhine Delta (Uehlinger *et al.*, 2009). Just as the Rhine Delta, the entire Lower Rhine suffered from heavy pollution, primarily from sewage outfall from the industrial centres in the Ruhr district (Uehlinger *et al.*, 2009). Also the mining industries dumped wastewater in the Rhine, causing a high salinity of the water (Uehlinger *et al.*, 2009). When the withdraw of drinking water from the Rhine became very problematic, measures were taken to increase the water quality (Uehlinger *et al.*, 2009). The river channel in the Lower Rhine has a width up to 500 m, the prevailing substrate is gravel and sand substrate occurs locally (Uehlinger *et al.*, 2009). According to Uehlinger *et al*. (2009), the annual mean water temperature of the Lower Rhine and Rhine Delta increased over the last century and is currently around 14 ^{o}C. The concentrations of phosphate and nitrogen decreased the last decades after changing the wastewater legislations. Phosphate concentrations are around 0.077 mg/l and remain relatively constant along the entire Lower Rhine (Uehlinger *et al.*, 2009). Nitrogen concentrations increase downstream up to 3 mg/l at the Dutch-German border (Uehlinger *et al.*, 2009). In the Lower Rhine high salinity and turbidity influence the occurrence of several macrophytes (Uehlinger *et al.*, 2009). Experiments show that for example *Potamogeton lucens*, *P. perfoliatus* and *P. nodosus* are highly sensitive to increased salinity and therefore it influences the occurrence of insects which act as food for smolts (Uehlinger *et al.*, 2009). Common zooplankton in the Lower Rhine includes the genera *Brachionus*, *Keratella* and *Polyarthra* (Uehlinger *et al.*, 2009). The abundance of zooplankton (>1,000 individuals/l), crustaceans (mainly *nauplii*, up to 178 individuals/l) and Cladocerans (*Bosmina spp.* and *Daphnia spp.*, up to 25 individuals/l) increases downstream, towards the Dutch-German border (Uehlinger *et al.*, 2009). Similar as in the Rhine Delta, the same fish species and (avifaunal) predators are present in the Lower Rhine (Uehlinger *et al.*, 2009).

3.5 Nearest possible spawning grounds: the river Sieg in the Lower Rhine

The migration routes of diadromous fish have been cut off at several places by migration barriers such as weirs, sluices and pumping stations (Brouwer *et al.*, 2008). The connection with the probable spawning grounds contain many bottlenecks, which prevent the migrating fish to reach the suited reproduction sites. To ensure a successful sea trout migration between the nearest spawning grounds and the Wadden Sea, it is necessary to know the most promising migration route and where the migration is hampered. In the Netherlands, water authorities are working at migration obstacles to make them ‘migration friendly’ (Riemersma & Kroes, 2004). This means that at the barriers, fish passages or other constructions are built to ensure a successful migration of the diadromous fish. However a good connection with the spawning grounds (without barriers) is essential. In the previous subchapters is described that the Noorderzijlvest management area is part of the Rhine drainage basin. The literature study suggests that sea trout spawning grounds are not situated in the Netherlands, probably due to unsuitable abiotic factors (amongst others: Jager, 1999; Jansen *et al.*, 2008; Kroes *et al.*, 2008). The nearest Rhine tributary with suitable spawning grounds is the river Sieg in Germany (De Laak, 2008; Jansen *et al.*, 2008; Schneider, 2009). Therefore I suggest that the easiest way to re-establish the sea trout lifecycle is to fully reconnect the Sieg with the marine environment. Therefore the Sieg is used as nearest spawning ground habitat in this report.

3.5.1 The Sieg habitat

The river Sieg (Figure 33) is one of the larger tributaries of the river Rhine in North Rhine-Westphalia and Rhineland-Palatinate, with a total length of 155 km and a drainage area of 2,832 km^2 (Jansen *et al.*, 2008; Meyer *et al.*, 2008). Over the last few years, projects to restore salmonid spawning grounds have been carried out (amongst others: De Laak, 2008; Jansen *et al.,* 2008).

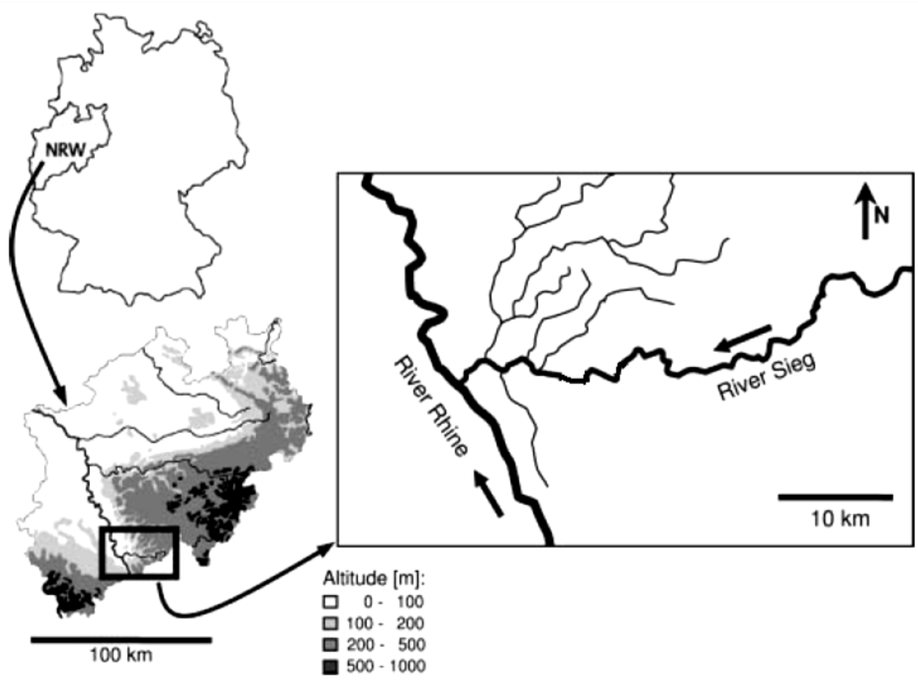


Fig. 33 River Sieg in North Rhine-Westphalia. Depicted is the downstream area of the Sieg catchment area with smaller tributaries (Meyer *et al.*, 2008).

In addition, restocking of Atlantic salmon and sea trout occurred by the release of thousands of salmonid smolts in the Sieg (De Laak, 2008; Jansen *et al.*, 2008; Van der Meij *et al.*, 2005). Despite the migration barriers in the Rhine, there have always been natural populations of salmonids in the Sieg and its tributaries (Jansen *et al.*, 2008; Schneider, 2009; Van der Meij *et al.*, 2005). Jansen *et al.* (2008) describe that the Sieg and its tributaries are even the most important spawning rivers for salmonids. The natural salmonid populations in the Sieg benefitted from the shorter migration distance to the marine environments (compared to higher upstream populations), since they encountered less migration barriers during their migration (De Laak, 2008; Jansen *et al.*, 2008; Schneider, 2009). In 2007, the estimated natural sea trout population size was around 180 reproducing individuals (Schneider, 2009). According to Schneider (2009), the Sieg is by far the best accessible and has the largest salmonid spawning areas (Figure 34). The first 100 km of the Sieg, adult sea trout can migrate upstream without problems and hindrance (Jansen *et al.*, 2008). This is also because North Rhine-Westphalia and Rhineland-Palatinate are making serious efforts to increase the habitat quality for the salmonids since 2000 (Schneider, 2009).

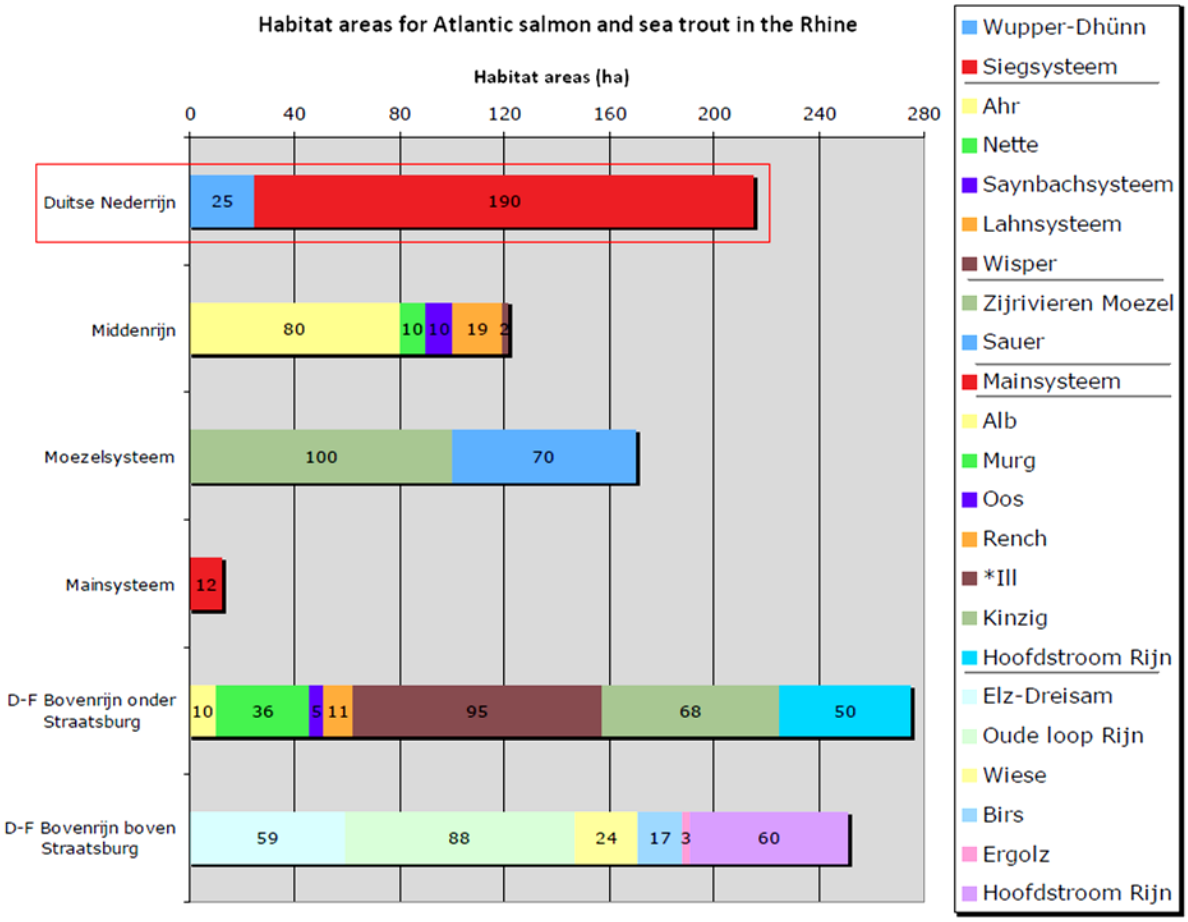


Fig. 34 Current and accessible habitats (in means of potential spawning and juvenile development habitats) for Atlantic salmon and sea trout in the Rhine system, differentiated by basins and tributaries (in hectare). The German Lower Rhine is highlighted in red. The Sieg system is the red bar within the German Lower Rhine. *Ill: including the tributaries Thur and Lauch, where no accessibility restorations are planned. (Source: Schneider, 2009).

A study conducted by Meyer *et. al* (2008), showed that the Sieg system satisfies the set of previously described constraints. For example concerning the sediment composition, their results show that gravel (≥ 2 mm - ≤ 63 mm according to Meyer *et al.* (2008)) was clearly the dominant grain size at their three study sites (Buelgenauel, Merten and Herchen; Figure 35). In addition, Meyer *et al.* (2008) describe that the average water temperature is around 6 ^{o}C in winter and the dissolved oxygen levels are (almost always) significantly above the threshold value of 5 mg/l. In summer, only in the warmest weeks the oxygen levels get below the threshold value. This coincide with the migration behavior because studies showed that one of the migration triggering forces might be the oxygen levels (personal communication R. Campbell during LNS meeting in Hamburg, March 2012). With regard to the available nutrition and predation, generally the Sieg provides sufficient amounts of food for the sea trout (Schneider, 2009). Predation seems not to be a major problem. In the Sieg system, predators such as the grey heron and pike are present but also the wels catfish (*Silurus glanis*) is according to Schneider (2009) a present predator (although the wels catfish is not abundant).

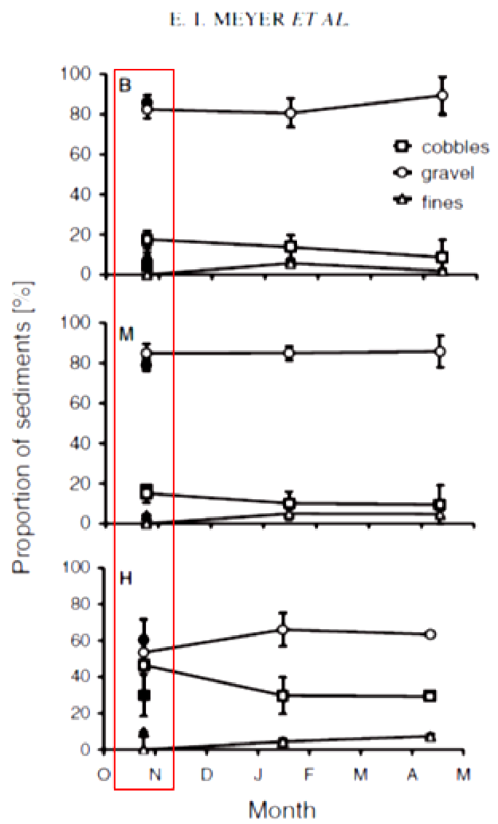


Fig. 35 Proportion of sediment fractions during the study period 2001/2002 at Buelgenauel (B), Merten (M) and Herchen (H). The highlighted and filled symbols represent the sediment fractions. The open symbols represent the sediment fractions after a cleaning operation. Size fractions were cobbles (≥ 63 mm), gravel (≥ 2 mm to < 63 mm) and fines (< 2 mm, including silt and clay) (Meyer *et al.*, 2008).

3.6 Conclusion whether the Dutch Wadden Sea and adjacent freshwater streams are suitable for sustainable sea trout populations

When comparing the ecological habitat requirements of the sea trout and the current habitat circumstances in the target area of this report, I conclude that sea trout can probably 'survive' during its downstream and upstream migration. I use the term 'survive' because the habitat characteristics are near the lower limits of the sea trout requirements. For example, sea trout prefer oxygen levels around 12 mg/l at water temperatures higher than 10 °C (Crisp, 1996; Raleigh *et al.*, 1986). In the rivers situated in the Noorderzijlvest management area, which usually have higher water temperatures than 10 °C, the amount of oxygen is not coming near that level of oxygen. Also, the rivers in the Noorderzijlvest management area suffer from eutrophication, which might negatively influence the well-being of sea trout.

When keeping in mind that sea trout becomes more and more a food generalist during its life stage development, food is supposedly not a limiting factor for the suitability of the analyzed habitats. Some important insect groups are reasonably present, although currently prey in terms of fish is not sufficient according to the WFD fish diversity standards. Nevertheless, the efforts of Noorderzijlvest with the aim to increase the flora and fauna diversity is probably beneficial for the sea trout presence. Predation might be an inhibitory force in the Wadden Sea because of the presence of thousands of seals, and the predation by piscivorous fish and birds might support that predation pressure.

With regard to the reproduction in the freshwater streams, the literature suggests that it is almost impossible for sea trout to reproduce closer to the marine environments than the river Sieg. The egg survival is unmistakably important for a sustainable population, but the ecological circumstances in means of oxygen, substrate size (further described in chapter 5) and velocity are only suitable in upstream (i.e. German) Rhine tributaries. Therefore to conclude, when looking at the ecological requirements of a sustainable sea trout population, the migration route between the Sieg and the Dutch Wadden Sea contain reasonably suitable habitats. The habitat in the Noorderzijlvest management area comprises just sufficient circumstances for a sea trout to life in. However, in the following chapter is described why a sustainable sea trout population is not possible, based on other factors than the ecological circumstances.

4 Noorderzijlvest migration barriers

This chapter focuses on the activities of Noorderzijlvest with regard to the preservation of the environment and protection of the community. Noorderzijlvest is a governmental organization, responsible for the water management in the northern part of the Netherlands. Their responsibility comprises the water quality and quantity in the western part of the province of Groningen, northwestern part of the province of Drenthe and the Frisian part of the Lauwersmeer (Noorderzijlvest C., 2012). The extent of the management area is around 144,000 ha and twenty municipalities are (partly) situated within the management area (Noorderzijlvest C., 2012). Because a significant part of the management area is below sea level, hundreds of water barriers such as weirs, pumping stations, sluices and dikes were built to prevent floodings (Table 16; Waterschap Noorderzijlvest, 2009). In the management area, eutrophication caused by agriculture is negatively influencing the water quality for many decades. Therefore this is a point of focus for the Water Authority (Noorderzijlvest A., 2008; Waterschap Noorderzijlvest, 2009). The manmade barriers have caused a fragmentation of rivers affecting migrating fish (Kroes *et al.*, 2006). Since the introduction of the WFD some migration bottlenecks have been solved, however there are still many bottlenecks for migrating fish (Noorderzijlvest D., 2012). Step by step barriers are being modified to create better fish migration opportunities (Noorderzijlvest D., 2012). However, a big problem for the creation of better migration opportunities is the budget. The construction of for example fish passes is very expensive while Noorderzijlvest is restricted to a limited budget (Noorderzijlvest C., 2012; Noorderzijlvest D., 2012; Waterschap Noorderzijlvest, 2009). Therefore, the probability that all migration obstacles will be removed or that barriers have fish passages in the near future is not that high. With help of European and national grants, some of the migration barriers are under construction or are planned to make them more 'migration friendly' in the future (Huisman personal communication, 2012; Noorderzijlvest D., 2012).

Table 16. Noorderzijlvest organizational information (Noorderzijlvest C., 2012)

Management area	144,000 ha.
Inhabitants	Ca. 375,000
Municipalities within area (partly or entirely)	20
Employment	264.4 fte *
Budget (2010)	€ 65.1 million
Pumping stations	150
Weirs	580
Sluices	51
Fish passages	12
Primary barrage (seawall)	65.8 km.
Sewage treatment	53,000,000 m^3
Lowest point in area	-2 m. Normaal Amsterdams Peil (NAP)**
Highest point in area	+ 13 m. Normaal Amsterdams Peil (NAP)**

*** Fulltime equivalent**
**** Normaal Amsterdams Peil is also known as Amsterdam Ordnance Datum**

The migration barriers were built to protect the community (Huisman personal communication, 2012). This chapter focuses on these migration barriers. It should be noted that only the barriers in the management area of Noorderzijlvest will be described. There are thousands of barriers in the possible migration routes of sea trout (amongst others: Kroes *et al.*, 2008), although Van der Meij *et al.* (2005) describe that the river Rhine is almost completely free of migration barriers). Therefore it is not possible to describe all the barriers from the Wadden Sea to the river Sieg.

4.1 Migration barriers in the Noorderzijlvest management area

Noorderzijlvest, Regional Water Authority Hunze & Aa's (the eastern neighboring water authority of Noorderzijlvest) and the Angling Federation Groningen-Drenthe are participants in the workgroup "Vismigratie" (translation: "Fish migration") (Riemersma & Kroes, 2004). In this workgroup the participants discuss and publish their joint vision on what the present status of the migration barriers is. Furthermore, what could be done to solve the problems caused by these barriers within their capacities is discussed and published. Their shared opinion was that the ecological restoration of their water systems and the associated problems that arise with ecological restorations, required a more structured approach than it has been the case (Riemersma & Kroes, 2004). This structured approach is comprehend the following activities:

- mapping of migration barriers;
- formulate possible measures to solve migration problems;
- estimation of the costs;
- setting priorities.

This approach has already been formulated in 2004 and the timeframe target to reach these goals was 10 years (ending in 2015) (Riemersma & Kroes, 2004). The year 2015 was chosen because of the deadline to meet the WFD standards, which is also 2015. The WFD dictates that all the water systems have to be sufficient (according to the WFD standards) in the year 2015 (Riemersma & Kroes, 2004). Since 'fish' is a single parameter in the directive, fish migration problems must be solved by then according to the WFD (Riemersma & Kroes, 2004). To realize the goals for improving the fish migration, two plans of action were formulated. The first one comprehended the stand-still principle, meaning that further degradation of the fish migration possibilities must be stopped and new opportunities for migration restoration should be utilized (for example when renovating pumping stations or when building new structures) (Riemersma & Kroes, 2004). The second plan of action concerned the priority areas and structures. The target is to completely solve the fish migration problems at the most important migration bottlenecks in 2015 (Riemersma & Kroes, 2004). Priority areas are subdivided in three implementation phases:

- Phase 1: 2004 – 2007 (highest priority to solve)
- Phase 2: 2008 – 2011 (intermediary priority to solve)
- Phase 3: 2012 – 2015 (lowest priority to solve)

The degree of priority is based on the ecological urgency to create better fish migration opportunities combined with the biodiversity and abundance of present fish species (Riemersma & Kroes, 2004). In the management area of Noorderzijlvest ninety-three priority migration barriers are selected that must be solved in 2015 (Figure 36, Riemersma & Kroes, 2004).

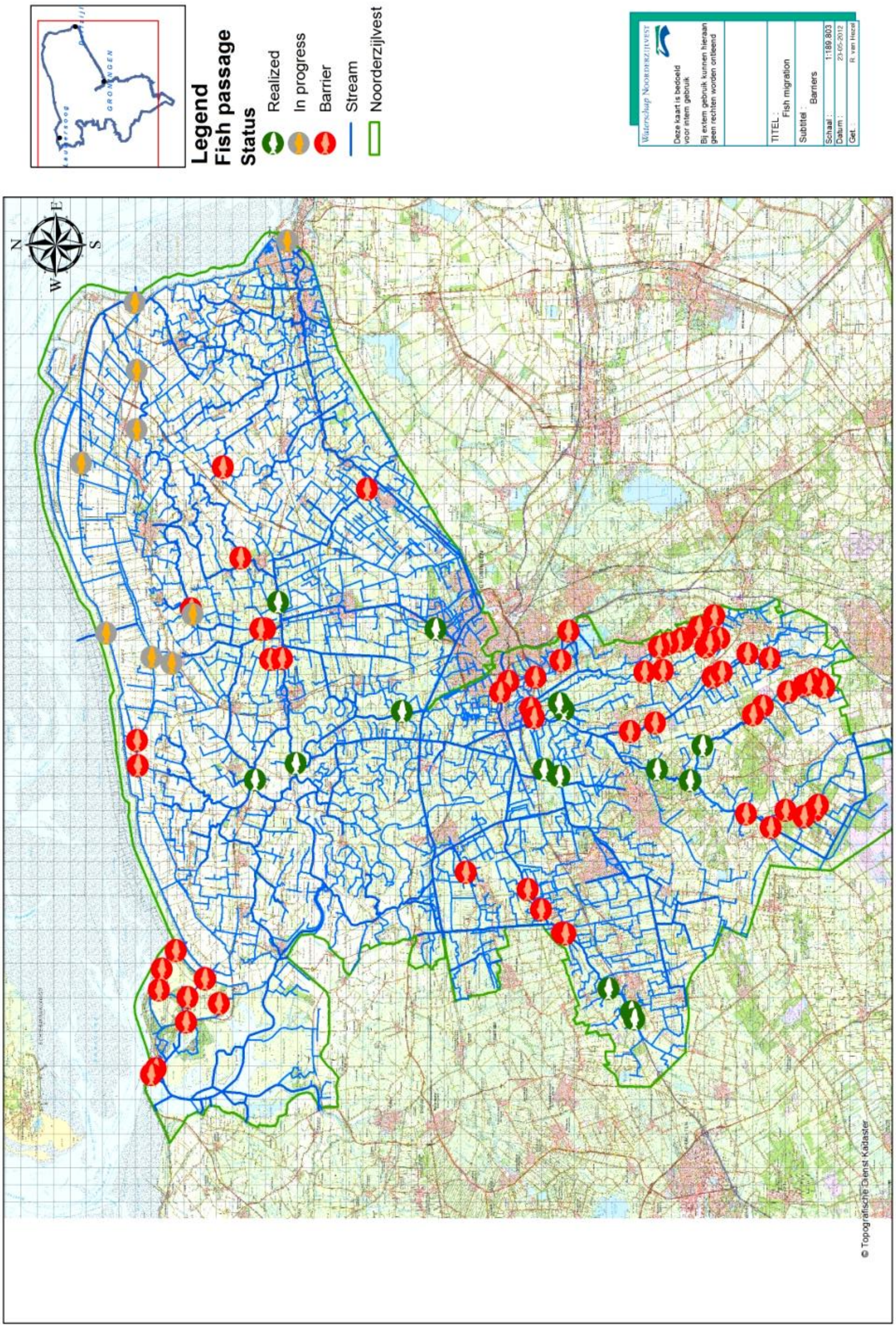


Fig 36. Map of the fish migration barriers in the Noorderzijlvest management area. The map indicates the most important structures that hamper fish migration. A red label represents a migration barrier that is still hampering migration, a grey label represents a migration barrier which is under construction to make it 'migration friendly' by for example constructing fish passages and a green label represents a former barrier.

Today, around fifteen fish passages have been realized, nine are in progress and the rest is planned for the near future (internal geographic information system (GIS) data of Noorderzijlvest). Although there are still many migration barriers, not all barriers are equally hampering the fish migration. The sea trout is a fairly fast moving fish that can pass higher obstacles than other migrating fish (De Laak, 2008; Riemersma & Wintermans, 2009). A plan that is executed as much as possible is to re-meander brooks and small rivers (Riemersma & Kroes, 2004). By re-meandering most of the barriers can be removed because the current is being intercepted by the meandering difference in altitude (Riemersma & Kroes, 2004). A problem with re-meandering is that it is not applicable for all the water systems. It is impossible to re-meander canals and bigger rivers which are used by shipping transport (Riemersma & Kroes, 2004). After all, besides the general economic importance of shipping transport, ships need certain depths and might not be able to navigate through high velocity meandering streams. Therefore re-meandering is not realistic for water systems with for example sluices (Riemersma & Kroes, 2004). On the other hand, re-meandering of small brooks with low discharge is currently done by Noorderzijlvest when geographically and financially possible (Riemersma & Kroes, 2004). Depending on the available space next to or around a barrier, there are several options for creating fish passages (Figure 37). One option, which is not commonly used by Noorderzijlvest, is a simple bypass or secondary channel by which the weir has not to be modified or removed (Huisman personal communication, 2012). A disadvantage of a simple bypass is that it might not be suitable for the majority of the migrating fish species due to for example high current velocity (Riemersma & Kroes, 2004; Riemersma & Wintermans, 2009). There are many other examples of fish passages such as fish ladders, vertical-slot fish passages and fish elevators (Riemersma & Kroes, 2004; Riemersma & Wintermans, 2009). They all have different designs and work with different techniques just as different fish species have different requirements to be able to pass a barrier (Riemersma & Wintermans, 2009). Most of the fish passages Noorderzijlvest construct, are fish ladders and fish sluices (internal GIS data of Noorderzijlvest) (Riemersma & Wintermans, 2009). Nevertheless, the type of fish passage is completely depending on the local environment, the diversity of migrating fish species and the financial costs (Riemersma & Wintermans, 2009).

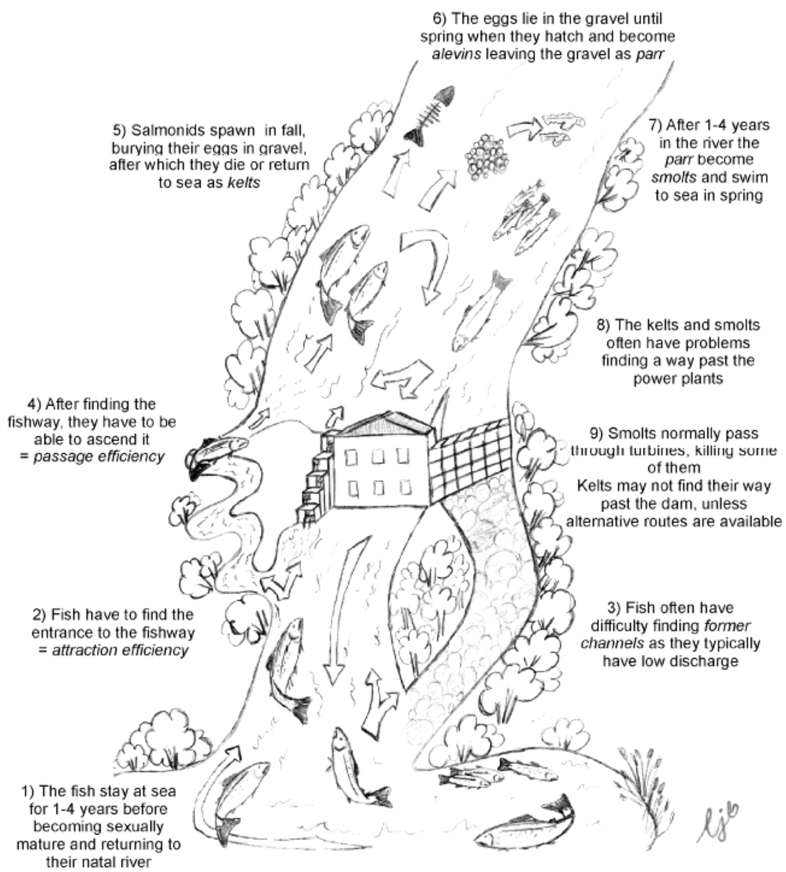


Fig. 37 A schematic overview of migrating salmonids in a regulated river and problems they encounter during different life stages (1-9) Source: (Calles, 2005).

4.2 Conclusion whether the Dutch Wadden Sea and adjacent freshwater streams are suitable for sustainable sea trout populations or how can this be improved

In chapter 3, I concluded that the ecological habitat circumstances are just suitable for sea trout with regard to the most probable migration route. This chapter shows that, although the ecological circumstances might allow a sustainable sea trout population, this will probably not be possible because of the migration barriers. Near the freshwater – marine environment transitions, still all migration hampering barriers are present. When looking at Figure 36, the sea trout has no chance of passing all the migration barriers. That Noorderzijlvest and other water authorities are trying to do something about the migration hampering barriers is a good development. However, when only in this little part of a sea trout migration route are that many hampering barriers, you can imagine how many barriers there are over the whole migration route of a sea trout.

Therefore, overlooking the results of chapter 3 and 4, I do not consider the Dutch Wadden Sea and adjacent freshwater streams as suitable for sustainable sea trout populations. This is due to the just sufficient ecological habitat circumstances in combination with the lack of possibilities for sea trout to succeed in their reproduction cycle. This will probably last until at least one complete migration route is free of hampering barriers or until fish passages are built at every migration barrier.

5 The policies that concern sea trout directly or indirectly

This chapter focuses on the extent to which the sea trout is affected by current policies. The policies that are described in this report are only the most 'important' fish (i.e. sea trout) migration policies and legislations. Another selection criterion is that the relevant policy falls under the administration or directly ordaining the responsibilities of Noorderzijlvest regarding fish migration. At last, official documents such as memorandums and enforcement strategy documents are analyzed to determine the importance of the selected policies in the management plans of Noorderzijlvest. Numerous national and international policies are associated to the target area (Dutch Wadden Sea and adjacent freshwater streams) (InterWad, 2010). Most of those policies acknowledge the importance of migrating fish. However, they describe the migration problems in a general sense and recommend that 'something should be done about it' (Kroes *et al.*, 2006). What also stands out is that policies are increasingly focused at the implementation of international laws by national and regional authorities (Kroes *et al.*, 2006). EU directives are transposed into national legislation and may support existing national legislation, which serve national interests concerning management of flora and fauna and also the economic interests of the country (Kroes *et al.*, 2006). Ultimately seven policies are considered to be the most important regarding this report, whereby the European Water Framework Directive is regarded to be the most important and is described in more detail. The most important policies in order of importance with respect to sea trout migration are:

- The European Water Framework Directive (2000)
- The Habitat Directive (1992) - Nature Conservation Act (1998) - Flora and Fauna Act (1998)
- The European Eel Directive (2002)
- Decree of the Committee of ministers of the Benelux Economical Union for "Free Fish Migration" (2009)
- The Dutch Water Act (2009)

Remark: the Flora and Fauna Act and the Nature Conservation Act will probably be combined and integrated into a new 'Nature Act' in 2013 (Verburg, , 2009). Because the new act is not approved yet by the Dutch Parliament, the current two Acts in force are being described in this report.

5.1 The European Water Framework Directive (Directive 2000/60/EC)

The WFD is the most important directive Noorderzijlvest has to work with (amongst others: Noorderzijlvest, 2010). In nearly all official management plans and policy documents of Noorderzijlvest, the WFD is described in and used for implementation strategies. The WFD came into force in December 2000 (amongst others: Regionaal Bestuurlijk Overleg Rijn-Noord, 2004). The aim of this directive is to protect the inland surface waters, transitional waters, coastal waters and groundwater within the individual national borders of the European Union (Brouwer *et al.*, 2008; Kroes *et al.*, 2006; Kroes *et al.*, 2010; Min. V&W, 2008; Regionaal Bestuurlijk Overleg Rijn-Noord, 2004). The WFD is valid for all Member states of the EU, although the Member states have a certain liberty in determining how the WFD is integrated in their own national legislations (Kroes *et al.*, 2006). The objectives of the WFD relate to chemical and biological quality components (amongst others: (Kroes *et al.*, 2010). Per water type (such as canals, lakes and brooks) there are ecological objectives with respect to the status of aquatic plants, macrofauna, algae and fish that must be accomplished in the year 2015 (Brouwer *et al.*, 2008; Min. V&W, 2008). Consequently, it ensures that (Kroes *et al.*, 2006):

- Aquatic ecosystems and areas directly dependent on these ecosystems are preserved from further deterioration;
- The aquatic environment is improved, e.g. through substantial reduction in discharges and emissions;
- The sustainable use of water is promoted based on long-term protection of available water resources;
- Groundwater pollution is reduced considerably.

With regard to the aquatic fish stocks, which is an important ecological factor, the quality is evaluated by the diversity of fish species, species abundance and year class distribution (Brouwer *et al.*, 2008; Huisman, 2007; Kroes *et al.*, 2010; Min. V&W, 2008). By decentralization, the WFD imposes management responsibility to the water authorities and other governmental authorities concerning the fish stock management (Huisman, 2007; Min. V&W, 2008). For the implementation of the WFD goals, there are minimum requirements per water type within the Noorderzijlvest management area (Brouwer *et al.*, 2008; Huisman, 2007). The fish stock is suggested to be a result of factors such as geography, climate, hydromorphology, season, succession stage and many others (Backx *et al.,* 2008). A single fish species can only be included in the local reference fish list when the species is considered to be 'indigenous' or 'naturalized' (Backx *et al.*, 2008). Backx *et al.* (2008) describe that the two criterions for a 'indigenous' or 'naturalized' status are:

- The species successfully settled (without human help) before 1900 and is still present without human help;
- The species is, without human help (active help, such as introduction), locally present for at least ten years after 1900.

The ecological monitoring programs are instruments to determine the fish status and had to be implemented in the River Basin Management Plans ever since 2009 (Kroes *et al.*, 2006). The defined targets for each basin must be attained by December 22, 2015 when the results of ecological monitoring will be compared with the relevant targets (Kroes *et al.*, 2006). Under extraordinary circumstances, the deadline in 2015 may be maximally extended to 2027 (Brouwer *et al.*, 2008; Min. V&W, 2008).

5.1.1 Brief description of WFD methodology

The WFD dictates how the Noorderzijlvest goals and measures must be defined (Noorderzijlvest A., 2008). The objectives that have to be achieved are being expressed in ecological goals (Noorderzijlvest A., 2008):

- Maximal Ecological Potential (MEP);
- Good Ecological Potential (GEP).

To determine the ecological goals, the circumstances in 2000 outlined the possibilities for qualitative improvements. The ecological quality is illustrated and defined by the so called 'Ecological Quality Ratio' (EQR-scale) (Noorderzijlvest A., 2008). This relative scale ranges from 0 to 1, with 1 being the highest ecological level. For every water body, a specific EQR had to be determined (Noorderzijlvest A., 2008). Figure 38 is a graphic illustration of the EQR scale.

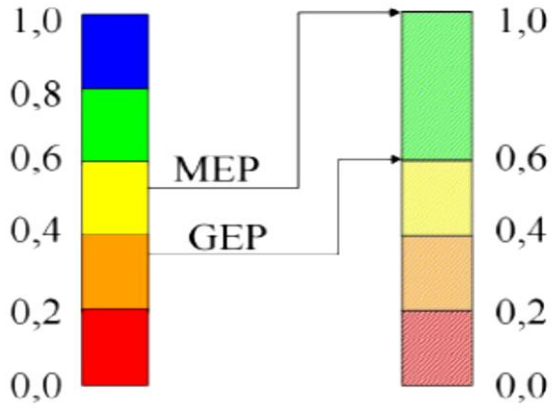


Fig. 38 MEP, GEP and deduced requirements: EQR-scale. According to the WFD, the EQR result is always between 0 and 1. The lower limit of a 'good' value is 0.6 according to GEP. For MEP the lower limit is 1.0. The colours represent a certain status (which is also used in chapter 3). The colour and related status is:

- Blue - very good
- Green - good
- Yellow - moderate
- Orange - poor
- Red - bad

(Noorderzijlvest A., 2008; Pot & Pelsma, 2007).

5.1.2 Sea trout status in the WFD

Within the determined fish objectives, there are several groups classified by their migration behavior (Kroes *et al.*, 2008). The sea trout is (together with Atlantic salmon, sea lamprey and others) classified into the group 'diadromous species 1: migrating from and towards the sea and from and towards upstream rivers in surrounding countries' (e.g. Germany, Belgium and France) (Kroes *et al.*, 2008). According to Kroes *et al.* (2008), sea trout is migrating through at least eight water body types, namely R7, R8, R15, R16, K1, K2, K3 and O2. The different types imply (Siebelink, 2005):

R7 Low velocity river / tributary with sand or clay sediment
R8 Tidal freshwater with sand or clay sediment
R15 High velocity small river with gravel sediment
R16 High velocity river / tributary with sandy or gravel sediment
K1 Polyhaline coastal water
K2 Sheltered polyhaline coastal water
K3 Euhaline coastal water
O2 Estuarium with poor tidal elevation

According to the standards of the WFD, the water bodies in the Noorderzijlvest management area are not suited for the sea trout. Of the water bodies described in chapter 3, only a part of the Reitdiep corresponds with the needed water types sea trout pass through (Hartman *et al.*, 2008; Huisman & Verbeek, 2008; Torenbeek, 2012). According to the WFD standards (Siebelink, 2005; Torenbeek, 2012), the water bodies described in chapter 3 are classified as (Huisman & Verbeek, 2008):

Lauwersmeer:	M30 (Brackish water)
Reitdiep:	R7 and M14 (Shallow buffered pool)
Damsterdiep:	M14 and M20 (Moderate deep lake)
Peizerdiep:	R4 (Permanent low velocity headwater on sand) and R12 (low velocity in lower course on peaty sediment)

With these classifications according to the WFD standards, it seems that there is no suitable habitat for migrating sea trout in the Noorderzijlvest management area. On the other hand, the WFD standards are very static while the ecological circumstances might be far more dynamic.

5.2 The Habitat Directive (1992) - Nature Conservation Act (1998) - Flora and Fauna Act (1998)

In the Netherlands, the main laws for nature conservation are the Nature Conservation Act and the Flora and Fauna Act (Ministry of Agriculture, Nature and Food Quality, 2005). These two acts can be considered as a Dutch interpretation of the European Bird and Habitat Directives (Ministry of Agriculture, Nature and Food Quality, 2005). Subsequently, these directives can be considered as the basic principle for Natura 2000, which is described below (Brouwer *et al.*, 2008; Huisman, 2007; Min. V&W, 2008).

Within the borders of the European Union there are several, very diverse ecosystems with high biological and economic value (Huisman, 2007). To connect all the separate ecosystems, the Natura 2000 has been introduced to implement strict nature protection measures (Brouwer *et al.*, 2008; Huisman, 2007). The major aim of Natura 2000 is to protect and restore biodiversity within the natural areas (Brouwer *et al.*, 2008; Huisman, 2007; Min. V&W, 2008). The principle of Natura 2000 is the Bird Directive (1979) and Habitat Directive (1992) (Brouwer *et al.*, 2008; Huisman, 2007; Min. V&W, 2008). The Bird Directive plays a minor role in the fish migration issues since it describes restrictions concerning the protection of bird species (Huisman, 2007), the Habitat Directive on the other hand is very important in the fish migration problem context (Brouwer *et al.*, 2008; Min. V&W, 2008). The Habitat Directive describes several fish species, which are considered important for biodiversity of a certain habitat and therefore each government has to designate specific protection areas (Brouwer *et al.*, 2008; Huisman, 2007). This must be done to protect the (local) natural habitat and the fish species it harbours, because these two components are considered to be related with water quality and quantity (Brouwer *et al.*, 2008; Huisman, 2007; Min. V&W, 2008).

In the Netherlands, nature areas are protected under the Nature Conservation Act (Ministry of Agriculture, Nature and Food Quality, 2005). The act dictates which activities are allowed in protected nature areas and under which conditions (Ministry of Agriculture, Nature and Food Quality, 2005). It also defines a duty of care for everyone in or dealing with nature areas, i.e. actions which might cause damage must be avoided (Ministry of Agriculture, Nature and Food Quality, 2005).

The Flora- and Fauna Act specifically describes the protection of endangered flora and fauna per species in the Netherlands (Brouwer *et al.*, 2008; Huisman, 2007). This is regardless whether the species occurs in nature reserves or not (Ministry of Agriculture, Nature and Food Quality, 2005). The

Flora and Fauna Act is describing measures to restore and protect the endemic Dutch species, meaning that it is prohibited to catch or kill protected species such as the European river lamprey (*Lampetra fluviatilis)* (Brouwer *et al.*, 2008). In general, the act prescribes a hands-off policy for the protected species, which means that it is prohibited to pick up, dig up, catch or disturb a protected species in any way (Ministry of Agriculture, Nature and Food Quality, 2005). Until today, the sea trout is not included in the Fauna Act (Min. LNV, 2005).

A supporting assessment of the Flora and Fauna Act is the European Red List of the International Union for Conservation of Nature and Natural Resources (IUCN) (Ministry of Agriculture, Nature and Food Quality, 2005). This assessment is a review of the conservation status of several thousand European species (dragonflies, butterflies, freshwater fishes, reptiles, amphibians, mammals and a several groups of beetles, molluscs, and vascular plants) according to the IUCN regional Red Listing guidelines (Freyhof & Brooks, 2011). It is based on frequency of sightings and / or evidence of a downward trend, identifying those species that are threatened with extinction at a regional level (Freyhof & Brooks, 2011; Ministry of Agriculture, Nature and Food Quality, 2005). The IUCN Red List Criteria is the world's most widely accepted system for measuring extinction risks and is generally used for appropriate conservation actions to improve the status of a species (Freyhof & Brooks, 2011; Ministry of Agriculture, Nature and Food Quality, 2005). The Minister of Agriculture, Nature and Food Quality periodically updates the list for species in the Netherlands, although the Red List does not have a legal status and species on the list are not automatically protected (Ministry of Agriculture, Nature and Food Quality, 2005). A legal status can only be created when a species is incorporated in the Flora and Fauna Act (Ministry of Agriculture, Nature and Food Quality, 2005).

The IUCN categorized the sea trout as 'least concern' species in Europe and 'vulnerable' in the Netherlands (De Nie, 1997; Freyhof & Brooks, 2011). The indication of 'least concern' means that the species is relatively common and abundant (IUCN, 2011). To be classified as 'vulnerable' (the lowest of the three IUCN threatened categories; Figure 39), a species must undergo a reduction in population size of at least 30% over ten years or three generations, with a serious risk of eventually ending up in categories such as 'endangered' or 'critically endangered' (Freyhof & Brooks, 2011; IUCN, 2011). At the same time, the species must have a restricted geographic range and a continuing decline, or have a small and declining population size (Freyhof & Brooks, 2011).

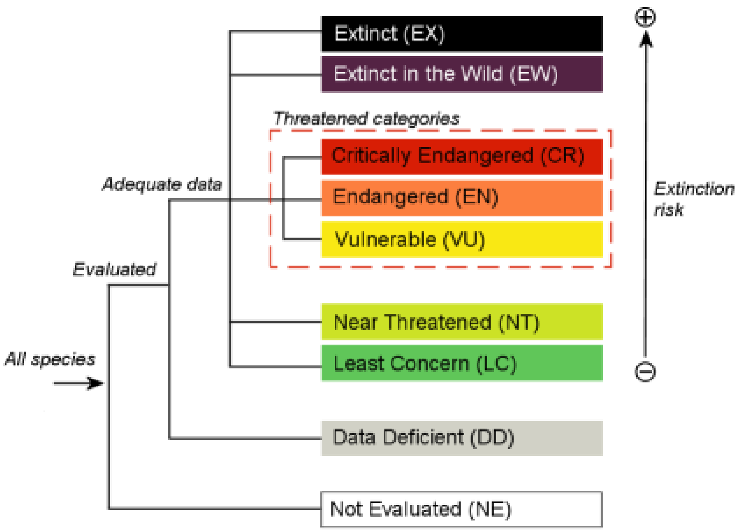


Fig. 39 IUCN Red List Categories at regional scale (Freyhof & Brooks, 2011).

5.3 The European Eel Directive (2002)

The European Eel Regulation is a species specific regulation (Van Weeren, 2010). The regulation requests EU Member States to prepare and implement Eel Management Plans in order to achieve an increase in adult (Silver) eels returning to sea (Ministry of Agriculture, Nature Management and Food Quality, 2009). The directive is aiming at collective European restoration measures to put a stop to the downward development of the eel population (Riemersma & Kroes, 2004). As a result the Dutch government made an eel management plan (Riemersma & Kroes, 2004), showing the national restoration measures (restoration of gradual marine – freshwater transitions), to share information and cooperation activities by stakeholders (Riemersma & Kroes, 2004). In the Dutch management plan, the northern part of the Netherlands is considered to be very important in the migration opportunities of the eel (Riemersma & Kroes, 2004). The objectives include measures that should result in:

- more eels developing into Silver eel phase;
- more Silver eels reach the Atlantic ocean;
- more Glass eels successfully reach freshwaters.

Although this directive is only focusing on the Atlantic eel, the sea trout benefits from this directive. An important measure of this directive is to remove migration barriers (Riemersma & Kroes, 2004). With the implementation plans of the national and regional authorities, the removal of eel migration barriers also create better sea trout migration opportunities.

5.4 Decree of the Committee of ministers of the Benelux Economical Union for “Free Fish Migration” (2009)

In the Benelux (abbreviation for Belgium, The Netherlands and Luxembourg) decree “Free Fish Migration”, the members agreed to take measures that stimulate the migration opportunities for migrating fish species such as European eel, Atlantic salmon, sea trout and European flounder (*Platichthys flesus*) in the Rhine, Meuse and Scheldt drainage basins (CMBWU, 2009; Huisman, 2007). The decree emphasizes the protection of European fish species and migration opportunities (Benelux Unie, 2009). Therefore, it connects and combines several different policies and acts such as the WFD and Habitat Directive (Benelux Unie, 2009). To stimulate the fish migration, several specific measures are described such as (CMBWU, 2009; Huisman, 2007):

- prohibition of below minimum body size fishing;
- closed fishing seasons;
- reintroduction and restocking of fish species;
- measures to create higher fish welfare (for example fish passes);
- prevent the making of new barriers.

Noorderzijlvest takes these measures into account and combines them, when implementation responsibility lies with Noorderzijlvest, with the proposed measures of the previously described policies (Huisman, 2007). Particularly the measure to create higher fish welfare in means of fish passages is an important point of attention, as described in chapter 4. The most important policy that is combined with these objectives and measures is the WFD (Van Weeren, 2010).

5.5 The Dutch Water Act (2009)

The Dutch National Water act is a new act, which combines and replaces eight strongly outdated laws regarding water quality (CDR, 2009; Ministry of Transport, Public Works and Water Management, unknown). The Water Act is based on the assumption that the integral management should be done for the whole water systems, which is called the 'water system approach' (CDR, 2009; Ministry of Transport, Public Works and Water Management, unknown). This means that in one act the management for surface water, groundwater, water storage areas, barrages and other barriers is treated (CDR, 2009). It can more or less be seen as an extension of a collection of European directives (CDR, 2009; Ministry of Transport, Public Works and Water Management, unknown). The Water Act also includes a National Waterplan and related Basin-management plans (CDR, 2009). Once every six years, the intended policy plans are evaluated and determined for the succeeding six years (CDR, 2009). This creates a framework for modernization of Dutch water management. The water authorities are obliged to meet a number of important water quality requirements (Ministry of Transport, Public Works and Water Management, unknown). This act is important for the sea trout because the water drainage management and management concerning migration barriers is integrated in this act (CDR, 2009). Regional water authorities are controlling the water drainage and therefore every modification at migration barriers (in favor of migrating sea trout) must coincide with the Water Act (CDR, 2009).

5.6 Role of Noorderzijlvest in the policy context and conclusion

In the policy context, Noorderzijlvest is positioned in different stages of a policy cycle. As described in the previous subchapters, Noorderzijlvest has to take many different types of policy instruments and management plans into account. It is hard to work at all subjects and objectives at the same time. In consequence, it works according to the "*Relative Attention Model*", meaning that the execution timeframe of management plans is subject to political and public urgencies of society (because of a scarcity of resources and attention possibilities) (internal communication H. Bergsma, process manager water system management, 2012; Hoogerwerf & Herweijer, 2008). When analyzing the activities of Noorderzijlvest, it seems that the execution of the different plans and objectives regarding the fish migration issues can be classified into different policy cycle stages. A policy cycle is a political, cyclical process to analyze the development of a policy item. It includes the following stages (Hoogerwerf & Herweijer, 2008):

1) Agenda setting
2) Issue identification
3) Policy design
4) Policy determination
5) Implementation
6) Evaluation

Today, the activities with regard to (for example) the WFD can be classified in the implementation stage. Noorderzijlvest is implementing the intended plans and trying to successfully achieve the ecological goals imposed by the WFD (Noorderzijlvest, 2010). On the other hand, the Water Act is still in the determination stage, as the exact details still need to be approved and completely adopted in the daily activities of Noorderzijlvest (Noorderzijlvest, 2010). This demonstrates that the fish migration problems might be well acknowledged by the authorities (international, national and regional), however the assumed positive effects of the individual policies will probably be visible after the evaluation stages of the related polices. In other words whether the conservation and restoration activities are successful or not, can only be concluded when the intended measures are completely carried out. The ongoing monitoring of ecological parameters such as fish species, is slightly providing a view on the ecological development. The sea trout is not found anywhere in the Noorderzijlvest management area, but other diadromous fish species are more observed in the monitoring since the beginning of the monitoring activities (source: internal monitoring data sets of Noorderzijlvest). It seems that the fish migration hampering policies of the past (by building protection measures for society such as weirs and pumping stations, by virtue of for example the preceding policies of the Water Act), are replaced or at least altered to undo or attenuate the current fish migration problems for a future with less migration problems and higher fish stocks.

6 The Living North Sea project, opportunities and discussion

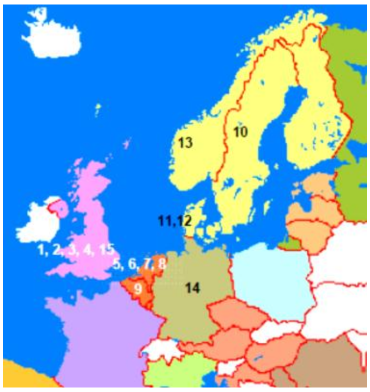
Effective legislation and policy are crucial to protect species and their natural habitats. When analyzing whether the present activities of Noorderzijlvest (through participating in the Living North Sea project) are well suited for the migration problems, it is necessary to know which stakeholders are involved in the problem solving process and what the added value of participating is. Subsequently, a suggestion can be made which stakeholder(s) should have been included and what 'other' actions might contribute to the process of creating better fish migration opportunities. Therefore this chapter explains which role Noorderzijlvest plays in the LNS problem solving process and which actions Noorderzijlvest can take to increase the chance of success in solving the migration issues in their management area. The LNS project plays an important role in this process according to Noorderzijlvest (Huisman personal communication, 2012). Therefore the opportunities are focused on the activities and functioning of the LNS project, to contribute to the fish migration problem solutions on a European level.

6.1 The Living North Sea project

Noorderzijlvest is aware of the social, economic and environmental importance of migrating fish (LNS, 2010; Maltby, unknown). They have been asked by leading beneficiaries of the LNS project to participate in their joint effort to (Maltby, unknown):

- find the migration routes of diadromous fish species;
- develop better and innovative migration measures, such as passages or sluice management;
- influence the future policy at a regional, national and international level and informing the general public.

The Living North Sea is a project in which fifteen partners from seven different countries participate (Figure 40; (LNS, 2010). The idea behind the project is that each participating partner or country



The partners of project Living North Sea are:
1. Association of Rivers Trusts, United Kingdom
2. Environment Agency, United Kingdom
3. The Tweed Foundation, United Kingdom
4. CMCZM Centre for Marine and Coastal Zone Management, Univ.of Aberdeen, United Kingdom
5. Regional Water Authority Hunze en Aa's, The Netherlands
6. Regional Water Authority Noorderzijlvest, The Netherlands
7. Regional Water Authority Waternet, The Netherlands
8. Royal Dutch Angling Organization, The Netherlands
9. INBO – Research Institute for Nature and Forest, Belgium
10. Municipality of Falkenberg, Sweden
11. Odense Municipality, Denmark
12. DTU Aqua National Institute for aquatic resources, Denmark
13. Norwegian Institute for Nature Research (NINA), Norway
14. The Johann Heinrich von Thünen-Institute (vTI), Institute of Fishery Ecology – FOE, Germany
15. Centre for Environment, Fisheries and Aquaculture Science (CEFAS), United Kingdom

Fig. 40 Countries and project partners of the Living North Sea project (LNS, 2010)

alone cannot solve the problems concerning fish migration in the North Sea waters (LNS, 2010). Although the (environmental and political) circumstances are very diverse between the partners, they all pursue the same common aims to 1) use *Sustainable Coastal Zone Management* techniques for key migratory fish species of the North Sea countries and 2) share existing knowledge between countries, sectors and partners, on fish populations and migratory fish routes and to identify the essential gaps in knowledge (LNS, 2010). Measures taken in one country might influence fish populations in the other country. Hence the LNS project tries to make long lasting changes that economically, environmentally and socially important migratory species, whose stocks are shared between nations, are managed in the North Sea region (LNS, 2010). That is why the LNS project cooperates on an European level (LNS, 2010). It is one of the projects of the North Sea Program 2007-2013, which in turn is funded by the Interreg IVB Program (Figure 41; LNS, 2010). Interreg is a Community initiative that aims to stimulate interregional cooperation in the European Union (Maltby, unknown). It started in 1989 and is financed by the European Regional Development Fund (ERDF) European Union. The Living North Sea project is operational from 2007 – 2013 (Maltby, unknown).

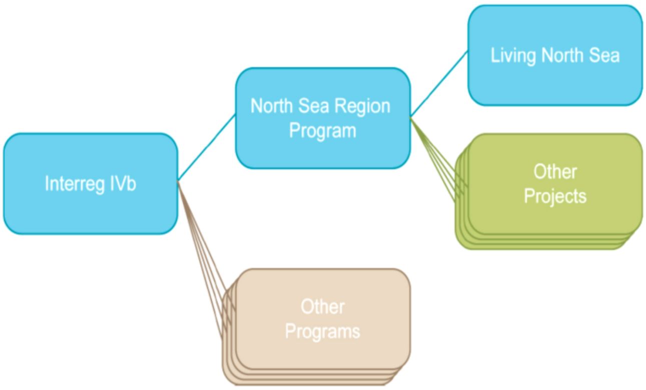


Fig. 41 European Cooperation: relationship Living North Sea, North Sea Region Program and Interreg IVB (LNS, 2010).

6.2 Role of Noorderzijlvest in the LNS project

The LNS project is divided into four work packages. For each of the work packages, other LNS participants are responsible for the outcome of that work package. The work packages are (Figure 42; LNS, 2010):

- Project Management
- Policy and Communication
- Transnational Knowledge Development
- Innovative Solutions

The Project Management work package is led by the Association of Rivers Trusts and includes the organization of all steering group meetings and relevant trainings (LNS, 2010). The Policy and Communication work package is led by Noorderzijlvest and the Centre for Marine & Coastal Zone Management of the University of Aberdeen (LNS, 2010). Noorderzijlvest is the overall coordinator of this work package and the University of Aberdeen contributes its particular expertise to develop Integrated Sustainable Coastal Zone Management plans and shares technical information between partners and the public (LNS, 2010). The responsibility for the Transnational Knowledge Development lies with all partners by contributing to the aggregation of knowledge of the whole region to understand the knowledge gaps. This involves organizing workshops and collecting and sharing data regarding fish migration (LNS, 2010). The Innovative Solutions work package is led by the INBO Research Institute for Nature & Forest (Belgium), although all partners are considered to cooperate and participate (LNS, 2010). This includes organizing workshops to identify the problems for migratory fish, uploading data into a geographical information system (GIS), organize relevant workshops to integrate knowledge and the dissemination of solutions (LNS, 2010).

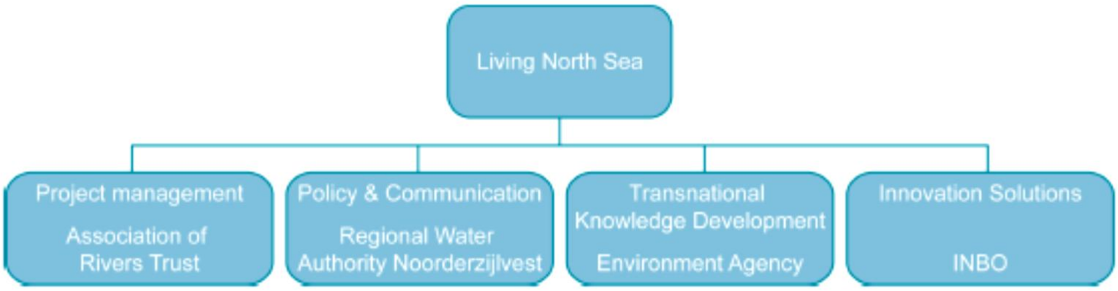


Fig. 42 The four work packages of project Living North Sea (LNS, 2010)

The work package activities of Noorderzijlvest are very diverse. Noorderzijlvests responsibility includes (Noorderzijlvest, 2009):

- developing communication plans;
- arranging press releases;
- inventorise the wishes and needs for creating maps of fish species and fish migration barriers;
- develop communication strategies;
- arrange meetings with magazines and newspapers for articles on fish migration;
- appear or participate in television shows treating fish migration subjects;
- informing and consulting project partners.

Around seven or eight employees of Noorderzijlvest are working part-time at the work package responsibilities (Noorderzijlvest E., 2012). Based on the workforce participation (more than 2000 working hours) (Noorderzijlvest E., 2012), Noorderzijlvest is a very important stakeholder in the process of the LNS. Especially considering the important and necessary internal and external contacting.

Arguing what the exact added value of participation in the LNS project is, it can be concluded that there are several benefits. The first benefit is sharing and gaining knowledge (Noorderzijlvest E., 2012). Gained experience in handling certain difficulties, such as specific operational fish passage difficulties or lobbying difficulties with external stakeholders, is shared between the LNS participants. Also European funding to create better fish migration circumstances is an important benefit (Noorderzijlvest E., 2012). The third major benefit is the network of the LNS (LNS, 2010). Every participant has its own network in the broadest sense of the word. With a combined network of all participants, it might be easier for a LNS participant to contact actors from another network. In other words, it results in a lower external communication and collaboration threshold. A collaboration such as the LNS project also increases their influence on policymakers (nationally and internationally) (LNS, 2010). A single stakeholder has much less input in planning and decision making, therefore is it very helpful to find parties with the same opinion and vision for policy advising.

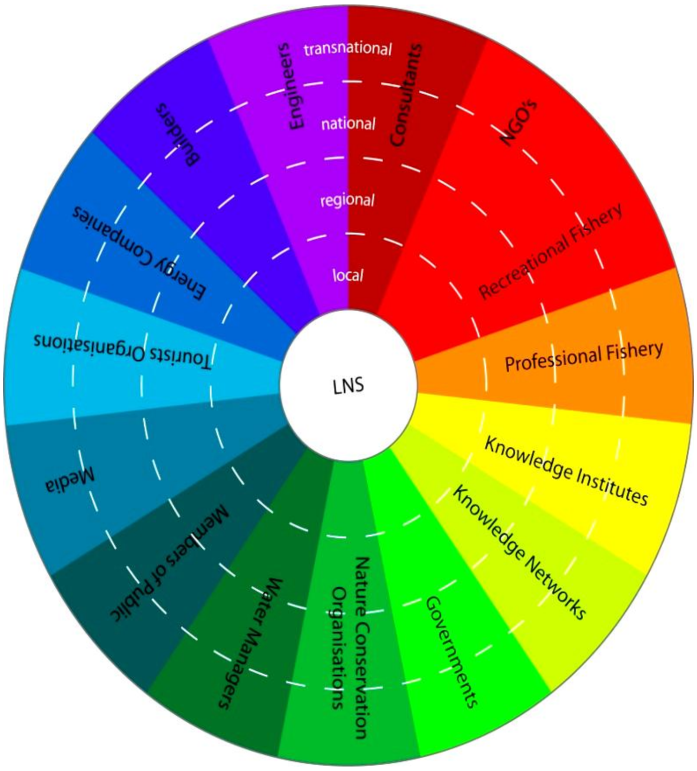


Fig. 43 Fifteen stakeholder categories operating in four policy levels. The more than 150 separate stakeholders of the LNS participant are classified in at least one of the categories. Within every category there are stakeholders with varying opinions regarding the LNS and its objectives (Dupon, 2010; LNS, 2010).

6.3 External stakeholders

To propagate the importance of fish migration, it is necessary to know who the external stakeholders are. By determining the important stakeholders, an effective communication or lobby plan can be made how to achieve the better fish migration opportunities. As previously described, every LNS participant brings in their own network but also their own external stakeholders. Therefore it is helpful to demarcate and to focus on the most important collective stakeholders. After the demarcation, the communication strategy to reach the objectives can be much better determined. The LNS has identified more than 150 stakeholders, but not every stakeholder is equally important (LNS, 2010; internal stakeholder analysis documents). The stakeholders can be classified into 15 main categories with four operational levels (Figure 43; Dupon, 2010; LNS, 2010). Also the individual LNS participants can be classified into a separate category. For example Noorderzijlvest is classified as a governmental organization while INBO Research Institute for Nature & Forest is categorized as a knowledge institute.

Considering the sea trout, all categories comprise stakeholders that can directly or indirectly influence the sea trout quality of life. This can be done by for example increasing knowledge (in the broadest sense of the word), changing public opinions or emphasize the importance of sea trout migration (economically, environmentally and socially) and by making policies and legislations. Ultimately, the governments are the stakeholders that must be advocate of fish migration stimulating measures, since they can modify or make legislation. Of course it is always better when all stakeholders support fish migration stimulation measures but this is probably impossible because of the different interests. When overlooking the current legislation regarding fish migration, it seems that there is an increasing understanding of the necessity to increase fish migration opportunities if 'we' do not want the migrating fish species to go extinct. This can be concluded by the activation of the in chapter 5 described policies, in which fish has become an important parameter.

6.4 Opportunities and discussion

The process of how the LNS project wants to create better fish migration opportunities is 'roughly' displayed in Figure 44. According to the communication and management plans of the LNS project, this is the course of actions, which should result in improved fish migration circumstances and the increase of the diadromous fish migration (LNS, 2010; LNS, 2011). It gives a good overview of how and what the processes and states are, which must lead to less migration hampering. Nevertheless, there are more opportunities that are not mentioned in the plans, strategies and analyses.

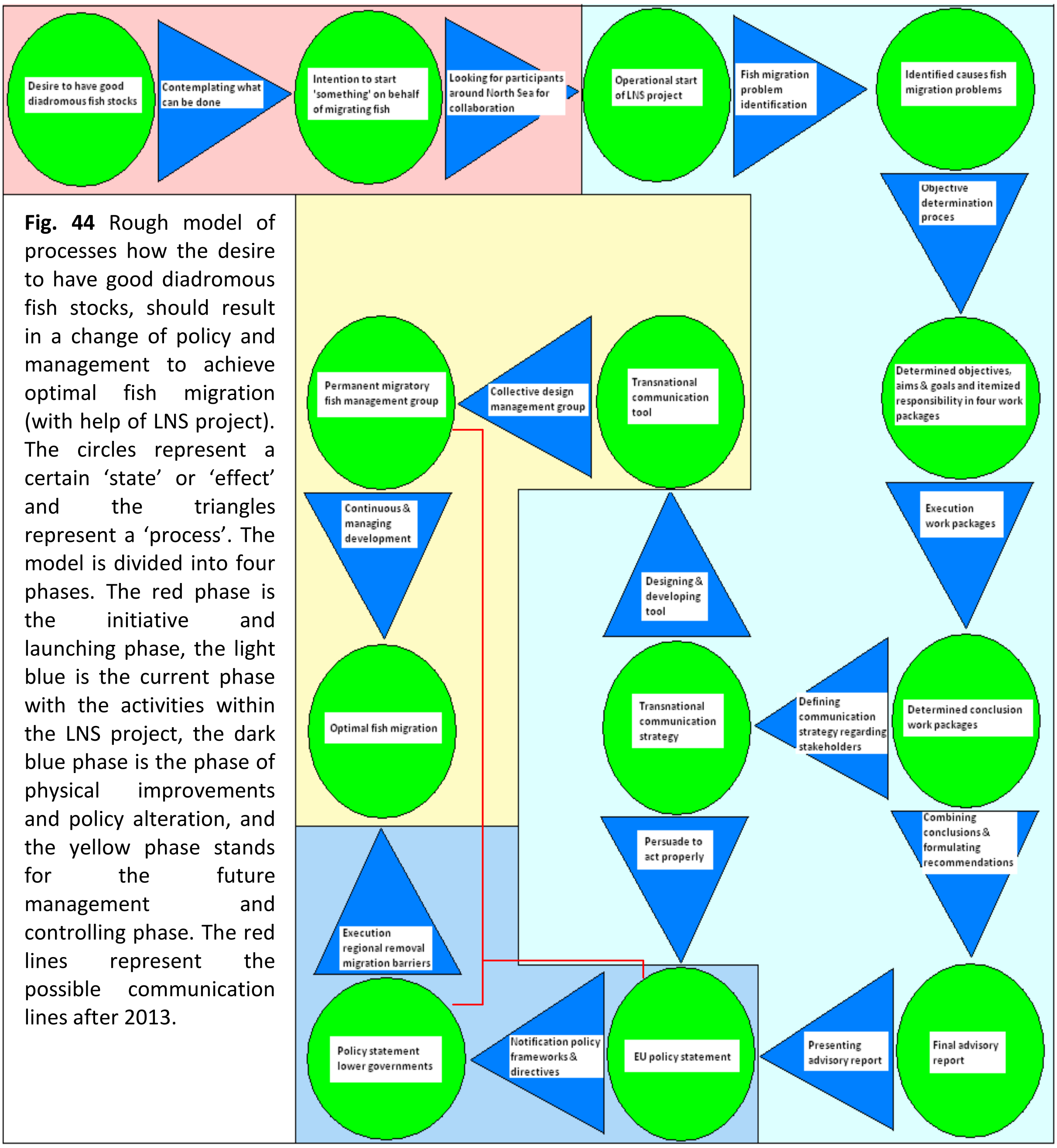


Fig. 44 Rough model of processes how the desire to have good diadromous fish stocks, should result in a change of policy and management to achieve optimal fish migration (with help of LNS project). The circles represent a certain 'state' or 'effect' and the triangles represent a 'process'. The model is divided into four phases. The red phase is the initiative and launching phase, the light blue is the current phase with the activities within the LNS project, the dark blue phase is the phase of physical improvements and policy alteration, and the yellow phase stands for the future management and controlling phase. The red lines represent the possible communication lines after 2013.

The LNS project focuses on stakeholders and countries around the North Sea (Dupon, 2010; internal stakeholder analysis document, 2012). However, sea trout and other diadromous fish species are not restricted by national borders and life in different habitats during its life cycle. There are four Dutch participants in the LNS project and the sea trout is a target species of the LNS project (LNS, 2010).

However, literature indicate that the sea trout and other salmonids reproduce upstream the “Dutch” bigger rivers, outside Dutch territory. The sea trout is considered to just passing through the Netherlands (Higler *et al.*, 2003). This causes a policy and management error and may not completely solve the migration barrier problems. Because the LNS project is funded by the North Sea Region Program, only parties around the North Sea are ‘allowed’ to actively participate in the LNS project (Huisman, personal communication 2012). It specifically focuses on regional development around the North Sea. For countries such as Denmark or the United Kingdom, this is not a problem since the whole life cycle of a sea trout can take place within their national borders. This does not apply for the Netherlands. The extensive stakeholder analysis shows that managing authorities of the upstream sea trout reproduction grounds, which are necessary to improve the Dutch situation, are not identified and included. To create circumstances resulting in more and improved fish migration in the Netherlands, all the authorities that are managing habitats pertinent to different sea trout life cycle stages should be involved (Figure 45). This means that at least leading stakeholders from the neighbouring German states (for instance North Rhine-Westphalia and Rhineland-Palatinate because of the Sieg) should be involved in the project. On the other hand, the EU funding regulations do not allow involving participants outside the project area (Huisman, personal communication, 2012). Therefore, in this case it can be suggested that the international policies are obstructing a complete fish migration solution in the Netherlands. Removing only a certain number of migration barriers out of the entire sea trout migration route, for example between freshwater and the marine environment, probably does not solve the whole fish migration problem. A significant solution would be to create circumstances of free fish migration along the entire sea trout migration route.

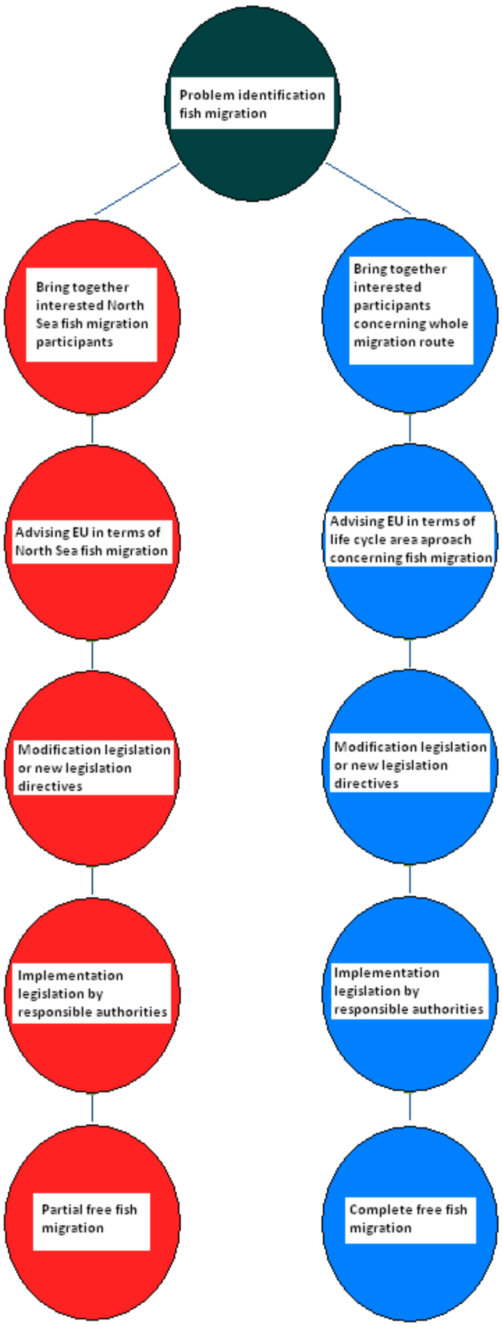


Fig. 45 Simplified overview of the interpreted goal settings of the LNS project. The left side of the figure represents the probable incomplete solution where the LNS project is heading for as a result of the North Sea Program regulations. To the right is the alternative life cycle area approach visualized. By getting the responsible authorities for all sea trout life cycle habitats involved, the probability of a comprehensive solution might increase.

Hence, when the policies and target fish species characteristics cannot be combined properly, there might be a few options that could increase the chance of success:

- get the managing authorities of the spawning areas in especially Germany involved in the migration barrier solution process, to align the plans, intentions and actions;
- recommend a life cycle area approach policy with regard to the fish migration problems in the LNS advisory report directed to the EU.

At the moment, policies such as the WFD dictate that a certain fish biodiversity must be achieved (Higler *et al.*, 2003). Fish species such as the sea trout migrate through different habitats for a large part of their life. When sea trout is seen as a biodiversity component, it remains unclear to which habitat it belongs to. Does it belong to the spawning habitats, to the freshwater – marine environment transition habitats or even other habitats? The WFD and other policies are not sufficiently discussing this policy bottleneck. To achieve free fish migration, an advice to improve fish migration should relate more to ecological characteristics of determined policy parameters, i.e. fish characteristics, instead of political and policy boundaries since diadromous fish species have no national boundaries. Kroes *et al.* (2006) describe the opportunities of a river basin approach. This river basin approach is considering a rivers drainage basin as a basic principle for a fish migration policy or legislation. By approving and implementing this type of approach in policies, all the freshwater migration barriers are seen as one big problem for which a complete and integrated solution must be found (Kroes, Gough, Schollema, & Wanningen, 2006). This approach seems to be an excellent idea, although the marine habitat of diadromous fish species is not (fully) included. Therefore, a suggestion could be to include the marine habitat. This would result in an life cycle approach, covering all habitats with regard to the sea trout life cycle. A disadvantage is that with such a comprehensive approach, many different managing authorities will be involved. This requires a lot of collaboration and dialogue. Adding this advice in the LNS advisory report might bring this approach more under attention of stakeholders that can influence the policy agenda of the EU (and subsequently also decentralised governments). Although it might takes time before policy suggestions are discussed, it is worthwhile emphasising that the chance of success in solving fish migration problems will be higher when looking at all interacting causes.

7 Project conclusion and recommendation overview

7.1 Project conclusion

This aim of this report is to contribute to a solution with regard to the international fish migration problems. The LNS project has identified a knowledge gap with regard to the sea trout status in the Dutch Wadden Sea and adjacent freshwater streams. Noorderzijlvest is one of the LNS participants and has a special interest in knowledge regarding the sea trout population size in the Dutch Wadden Sea and adjacent freshwater streams and subsequently, in their own management area. This is because by this report, Noorderzijlvest wants to contribute new knowledge to the LNS project, which can potentially contribute to a solution with regard to the fish migration problems in the North Sea region. Therefore, in this report sea trout is used as a case study for the general fish migration problems. Ultimately, this report tries to clarify the current status of the sea trout and policies pertinent to sea trout migration. Although the river Rhine is not directly adjacent to the Wadden Sea, it is inevitable to involve the Rhine in the analyses. This is mainly because the nearest sea trout spawning grounds are located in the Sieg, a tributary of the Rhine. This indicates that the sea trout migration problems in the Dutch Wadden Sea and adjacent freshwater streams are not restricted to the Netherlands. To fully understand the sea trout status the nearest spawning locations, or in other words where the migration begins, must be included in the analyses. The conclusions with regard to the three main are described separately.

What is the sea trout population size in the Dutch Wadden Sea and the adjacent freshwater streams?

The sea trout population in the Dutch Wadden Sea and adjacent freshwater streams appears to be a big mystery. Even though there are many monitoring activities with sea trout catches every now and then, scientists have never been able to estimate the sea trout population size accurately. In recent years, the calculation of the Catch Per Unit Effort is a method that is used more often. Maybe with help of the CPUE, the sea trout population size can be estimated more accurately in the near future. With help of Atlantic salmon models of Jansen *et al.* (2007 and 2008), I was able to give a rough indication of the sea trout population size. The indication that annually 2,000 to 68,000 sea trout enter the Dutch Wadden Sea, 1,200 to 2,400 sea trout migrate back to freshwater as well as the probably several hundreds of thousands sea trout migrating downstream the Rhine and the 6,500 to 13,000 adults crossing over the Dutch-German border to reach the upstream spawning grounds, comprehend huge ranges. These ranges are already indicating a general lack of knowledge with respect to the sea trout population size. Therefore, I conclude that there are probably a few thousand adult sea trout in the Dutch Wadden Sea and a couple of ten thousand sea trout in the adjacent freshwater streams.

Are the Dutch Wadden Sea and adjacent freshwater streams suitable for sustainable sea trout population or how can this be improved?

In my opinion, the Dutch Wadden Sea and adjacent freshwater streams are not suitable for a sustainable sea trout population. This is based on the just sufficient ecological status of the habitats, with regard to the WFD standards and the huge number of migration barriers, which are present today and probably also in the future. The habitat use by sea trout is subject to many (a)biotic interactions and the development of fish migration friendly policies seems to be beneficial for sea trout. Food and predation might not be the biggest problem. On the other hand, the low amount of oxygen in the Noorderzijlvest management area almost inhibit the sea trout to live in the freshwater streams under the administration of Noorderzijlvest. This is supported by the WFD water type classification, because the required water types pertinent to sea trout differ substantially from the water types in the Noorderzijlvest management area. The WFD water type classification is also indicating that it is impossible for a sea trout to reproduce in the Noorderzijlvest management area or maybe even elsewhere in the Netherlands. This is mainly because of the fine sediment size and the lack of gravel, combined with the low dissolved oxygen levels. A sustainable sea trout population starts with the right conditions for the first life stage, i.e. the egg development, which needs coarse sediment or gravel and high amounts of dissolved oxygen. The Sieg is probably the nearest reproduction site, but it is almost impossible for a sea trout to pass the migration barriers. There are still many migration barriers and the freshwater streams in the Noorderzijlvest area are not (well) connected with the river IJssel, which is the nearest Rhine tributary in the Netherlands. A more suitable migration route for sea trout is probably via the IJsselmeer, since it is directly connected with the spawning grounds. The Wadden Sea is probably a suitable habitat for sea trout because of good biotic circumstances, but sea trout would only survive one generation because the barriers hamper the needed life cycle migration. When the streams in the Noorderzijlvest management area would be free of barriers, and the connection with spawning areas would be optimised, there might be opportunities for migrating sea trout to migrate through the streams managed by Noorderzijlvest.

What are the impacts of the current national and international policies, which are pertinent to fish migration, on the status of the sea trout in the Dutch Wadden Sea and adjacent freshwater streams?

The current policies are positively influencing the sea trout migration opportunities. There are several objectives and aims that must lead to improved fish migration and bigger fish stocks. However, the problem that policies, acts and regulation are not overlooking the whole migration route of sea trout remains. There are opportunities for improvement, but for the Netherlands a balance between community protection (by dikes, barriers et cetera.) and fish migration has not been achieved yet. The most important opportunity is to collaborate with the managing authorities along the migration route of migrating fish species. A life cycle policy approach can create better opportunities for fish migration because it changes an emphasis on policies for different habitats in different countries, into an policy emphasis on characteristics of migrating fish species and the habitats pertinent to their life cycle. Until then, in contrast to past policies resulting in hampered fish migration, the focus lies more on stimulating migration. The future policy evaluations will show whether the current policies will result in more fish and sea trout migration.

7.2 Recommendation overview

The recommendations addressed to Noorderzijlvest are:

- Remove all the migration barriers and or install fish passages in the freshwater streams, as well as in the freshwater – marine environment transitions within the Noorderzijlvest management area. Although the budget will probably not allow this to be finished in the near future, priority lies with the barriers hampering the probable migration routes, such as the barriers at the freshwater – marine environment transitions.

- Improve the ecological and chemical water quality in freshwater streams under the administration of Noorderzijlvest. The current policies are already triggering the improvement of the water quality and will therefore be achievable in the near future.

- Execute more intensive fish monitoring activities to identify the fish stock sizes. Without the knowledge with regard to what the fish stocks sizes are, it is not possible to detect problems with fish stocks or sufficiently implement pertinent policies.

- Introduce and put on the policy agenda the life cycle policy approach to EU advisory groups and projects (such as the LNS), which can influence the policy making stakeholders. This is necessary for emphasizing the need for a comprehensive policy solution for transboundary fish migration problems. An opportunity is to involve the theory of this approach in the advisory report of the LNS project. When the LNS advisory report aims to improve and promote fish migration, it is inevitable to emphasize the need for a solution dealing with the problems over the whole migration route of diadromous fish species.

List of abbreviations

BENELUX	Customs union of Belgium, the Netherlands and Luxembourg
CPUE	Catch Per Unit Effort
CWSS	Common Wadden Sea Secretariat
DFS	Demersal Fish Survey
DYFS	Demersal Young Fish and Brown Shrimp Survey
ERDF	European Regional Development Fund
EU	European Union
EQR	Ecological Quality Ratio
GEP	Good Ecological Potential
GIS	Geographic Information System
IfV Project	Seabird-Fish interaction
IMARES	Institute for Marine Resources and Ecosystem Studies
IUCN	International Union for Conservation of Nature
LNS	Living North Sea project
MEP	Maximal Ecological Potential
NIOZ	Royal Netherlands Institute for Sea Research
NZV	Regional Water Authority Noorderzijlvest
QSR	Quality Status Report
SBP	Science Business and Policy study track
SD	Standard Deviation
SHS	Fish monitoring Schleswig-Holstein Wadden Sea
WFD	(European) Water Framework Directive

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