ECOLOGICAL EFFECTS OF RIVER REHABILITATION METHODOLOGIES APPLIED IN EUROPE

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Summary

Pressures on the European rivers are many. Therefore great attention has to be given to the preservation of natural habitats for animals and plants. Past channelizations of the rivers have led to a decrease in habitat diversity and thus in the species diversity in European rivers.

The European Centre for River Restoration was established in 1995 in order to try to exchange experiences on different aspects of river restoration between the European countries and thereby enhance the efforts to rehabilitate European rivers.

Denmark is a typical lowland area where rivers have been channelized and dredged during the past 100 years. Today a major part of the Danish rivers are in an undesirable ecological state. Therefore revised maintenance procedures that are less harmful to the river are being introduced. River restoration projects, involving for example re-meandering and conversion of weirs to riffles, have been carried out in Denmark for almost 20 years.

Danish experiences and examples from 20 years of river rehabilitation are presented here. Special attention is given to the evaluation of the effects of different aspects of river rehabilitation.

1. Introduction

Nature in Europe is exposed to threats caused by a number of habitats such as rivers, lakes, and wetlands being reclaimed and exploited more and more intensively for agricultural production and other purposes during the last centuries. As a result of this development, several European countries have initiated restoration measures where wild fauna and flora are given high priority and where harmful impacts on ecosystems are eliminated as far as possible. The key factors driving river restoration in Europe are listed below:

1. Loss of species, habitats, and landscapes has been so great that it has become a political necessity to replace some of the lost natural values.
2. The species reserves are so small that they require larger areas or links between existing areas to survive.
3. Creation of new wetlands can buffer climate change effects.
4. Natural river and floodplain interactions can help to mitigate downstream floodings.
5. The natural “self-purification” potential of rivers, lakes, and wetlands can help to reduce agricultural diffuse pollution.

Thus, restoration of rivers and adjacent floodplains has been increasing during the last two decades in Denmark and several other European countries. In this period, several hundreds of river restoration projects have been accomplished and the European countries have gained experience both on how to develop restoration schemes and their multiple ecological effects.

Our aim with this paper is to describe and illustrate by means of Danish experience the different restoration schemes conducted in Europe. Moreover, the set-up of monitoring programs to monitor the abiotic and biotic effects of river restoration schemes will be introduced together with our present knowledge on the ecological effects.

2. European Watercourses—Ecological State and Pressures on the Riverine Environment

A wide range of human activities deteriorate river systems either directly or indirectly (Table 1). The main threats to European rivers change from catchment to catchment, but it is believed that the major factors affecting water quality (and hence biodiversity) are pollution with organic matter, nutrients, and other harmful substances. Organic matter, nutrients, heavy metals, and pesticides in rivers are derived both from point and diffuse sources and to a varying extent from catchment to catchment in Europe. In Europe, BOD concentrations above 2 mg O_2 l^{-1}, phosphorus concentrations of 50 µg P l^{-1} and nitrogen concentrations of 1 mg N l^{-1} are considered impacted by human activities. From table 2 it is evident that many European rivers have annual concentration above these values. The impact is also reflected in the concentration difference between pristine sites and impacted sites (Table 2). The quality of European rivers have been classified into four classes (good, fair, poor, and bad) depending on their water quality. About a quarter of European river reaches are classified as poor or bad. Most countries classify the quality of 50% or more of their river reaches as good or fair. Great variations do, however, exist from country to country. Iceland and Scotland have more than 95% of their river reaches classified as good and Belgian Flanders region, Czech Republic, and Poland have more than 25% of their river reaches classified as bad quality.

Supra-catchment effects: **(External impacts acting upon the catchment)** Climate change Acid deposition
Catchment land-use change: Afforestation and deforestation Urbanization Agricultural development Land drainage/flood protection
Corridor engineering: Removal of riparian vegetation Flow regulation—dams, channelization of watercourses Dredging and mining
Instream impacts: Point source discharges of organic and inorganic matter

Thermal pollution Water abstraction Exploitation of native species

Table 1. Major anthropogenic activities affecting river systems

	Pristine sites (mean)	**Quantiles from the distribution of European rivers**		
		25%	**50%**	**75%**
Biochemical oxygen demand (BOD) (mg O_2 L^{-1})	-	1.9	2.8	4.7
Total phosphorus (µg P L^{-1})	26	59	170	366
Total nitrogen (mg N L^{-1})	0.4	0.8	2.1	4.5

Table 2. Descriptive statistics for annual mean water chemistry variables in European rivers (redrawn after Kristensen and Hansen, 1994)

Many European rivers have today been regulated to a certain degree. River regulation has been undertaken to the greatest extent in western and southern Europe. Thus in Belgium, England, and Denmark less than 20% of watercourses are still in a natural state. In contrast, the watercourses are still in a natural state in many eastern European countries. River regulation often causes major changes in river hydrology and morphology due to changes in the hydrological regime and sediment transport. The most adverse impacts stem from the building of reservoirs and river channelization. Since World War II, the rate of increase in the number of reservoirs was about 6 per year in the United Kingdom, and 20 per year in Spain. The reservoirs nowadays serve several purposes, the primary uses being the generation of hydroelectric power, irrigation, flood control, and domestic and industrial water supply. The environmental problems related to reservoir construction include contamination, eutrophication, obstruction of faunal migration, and reduction of physical and biological diversity downstream of reservoirs.

River channelization generally decreases the physical diversity of watercourses, creating more uniform physical dimensions, hydraulics, and substrata. The biological effects of such uniform river channels are therefore a reduction in the number of habitats and a consequent reduction in species number and diversity (Figure 1).

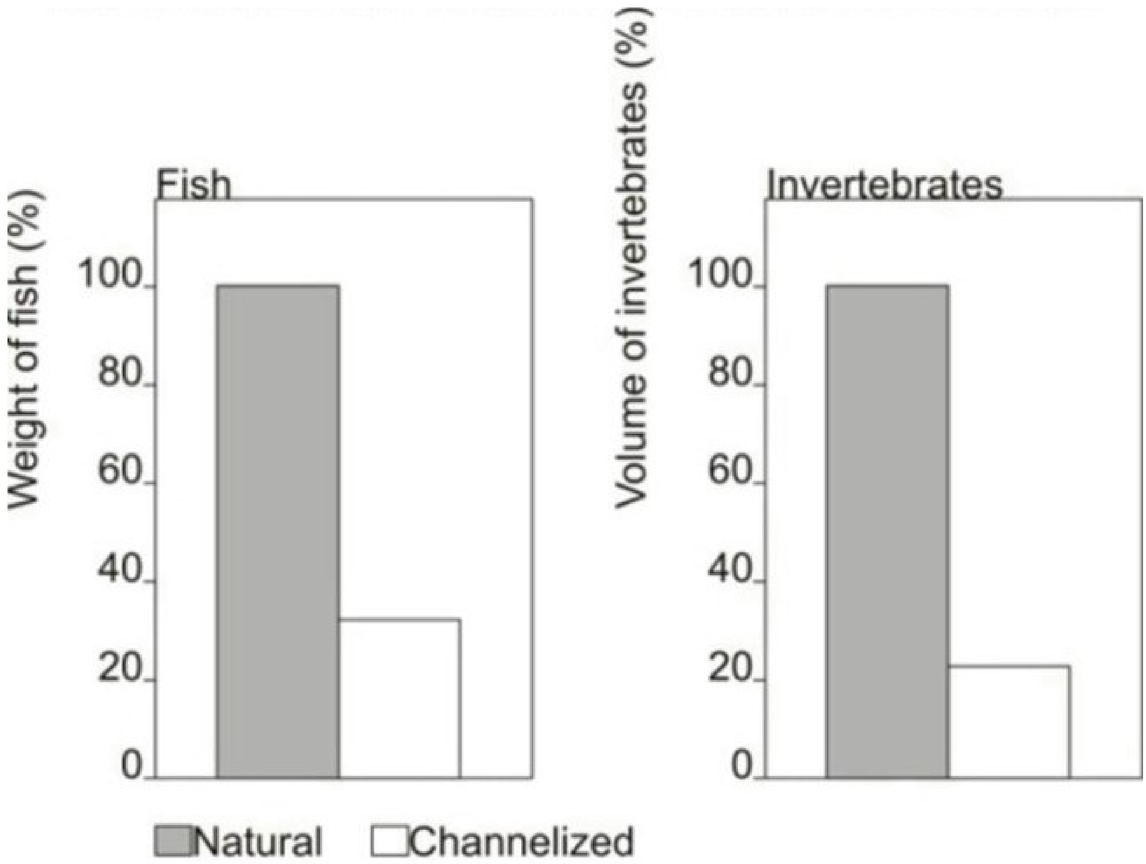

Figure 1. Species diversity in channelized and natural rivers
(adapted from Hansen and Kristensen, 1994)

3. River Rehabilitation in Europe

Restoration of rivers and their floodplains has been acknowledged as necessary by the European Union (EU) during the last decades, and the EU has already funded a number of isolated river restoration projects. To learn and act according to knowledge and experience already gained there is, however, a need for an international organization to collect and disseminate such information. Consequently in 1995, the EU co-funded the establishment of the European Centre for River Restoration (ECRR) with the overall objective to support the development of river restoration as an integral part of sustainable water management throughout Europe in a cost-efficient way. This will be done by exchanging knowledge and experience on river restoration, thereby enhancing restoration of rivers and their floodplains. In order to obtain a useful overview of river restoration projects undertaken in Denmark a classification system has been developed and a database established.

3.1 Development of a European Centre for River Restoration (ECRR)

European rivers and their floodplains are used for many purposes and are among those habitats most severely affected by human activity. As a consequence, both water and river habitat quality have been seriously degraded in numerous European rivers throughout the past century as a result of poor physical conditions. In Denmark, for example, less than 5% of the rivers have been left in a natural physical state.

The EU has, however, realized the importance of biodiversity, and has thus put the issue high on its political agenda. Nature restoration is presently identified as one of the measures to improve and maintain European biodiversity. Consequently, restoration of rivers and their floodplains has been acknowledged by the EU as an essential tool for future improvements of degraded riverine ecosystems and restoration should thus become an integrated part of European water management. Many river restoration projects have thus been carried out throughout Europe during the last 10–20 years resulting in wide environmental benefits.

River restoration can be costly. In Europe as a whole several million EURO (€) are presently spent on river restoration every year. It can, however, also be relatively cheap provided certain options are selected. It is therefore of vital importance to share knowledge and experience on the subject, and to identify where restoration measures result in the desired physical, ecological, and economic benefits. However, in order to learn and act according to knowledge and experience already gained, an international organization is needed to collect and disseminate such information. Therefore, in 1995, the EU co-funded the establishment of the European Centre for River Restoration (ECRR), with the overall objective to support river restoration in a cost efficient way, as an integral part of sustainable water management throughout Europe. This will be accomplished by exchanging knowledge and experience through newsletters, Internet home pages, databases, workshops, meetings, and conferences, thereby enhancing restoration of rivers and their floodplains throughout Europe in the most cost-efficient way.

Four European institutions (National Environmental Research Institute (NERI) in Denmark, Rijksinstituut voor Integraal Zoetwaterbeheer en Afvalwaterbehandeling (RIZA) (In English: Institute for Inland Water Management and Waste Water Treatment) in the Netherlands, Deutsche Vereinigung für Wasserwirtschaft, Abwasser und Abfall e.V. (DVWK) (In German: German Association for Water, Wastewater and Waste) in Germany, and River Restoration Centre (RRC) in the UK) have for some time worked on the further development of the Centre with the objective of it truly becoming a European center with partners in each country throughout the continent. In 1998 the EU funded further development of the ECRR. Today the ECRR has members throughout the European continent.

3.2 A Database on River Restoration Projects

One of the objectives of the ECRR is to obtain a useful overview of river restoration projects undertaken in order to guide future projects in the right direction. To accomplish this it is important to undertake systematic collection of project statistics and information. Therefore, the Centre in cooperation with the Danish counties, has developed a river restoration classification system and created a database on Danish river restoration projects.

Further development of the Danish classification system will lead to other European countries establishing similar databases. The various national databases will subsequently be compiled and updated under the auspices of the ECRR, with information eventually being made accessible on the Internet and via a Geographic Information System (GIS). The database is based on a classification system that differentiates between “Types” and “Methods.” Each restoration project is divided into one of three types according to the overall objectives of the project based on the extent of restoration within the river system. Each “type” encompasses a number of “methods” that have been used to achieve the objective of the project.

During the last decade Danish regional and national authorities have accumulated considerable experience and know-how regarding management and restoration of our rivers and river valleys. Up to and including the year 2000, over 1000 river restoration projects have been carried out in the Danish counties. In addition, a substantial number of restoration projects have been carried out by the Danish municipalities and private organizations. The reminder of this article focuses on Danish experience and examples.

4. River Rehabilitation in Lowland Streams—Danish Examples

With a total length of approximately 65 000 km, or 1.5 per square kilometer of land area, streams are an important component of the Danish landscape. About 50% of all streams are considered to be natural in their origin; the others originate as ditches and drainage channels. The ecological condition of streams and their associated riparian areas is closely linked to the development of agricultural production, which until the late 1950s was the main contributor to the Danish economy. Today agriculture encompasses 62% of the total land area, but employs only 5% of the workforce in Denmark.

Total stream length increased during the nineteenth century owing to the construction of drainage ditches. When tile drainage replaced drainage ditches the total stream length decreased again. About half of the agricultural land is now drained with tiles. As a consequence of this there has been a considerable loss of wetlands and lakes throughout the past two centuries.

Most natural Danish streams have been modified. They are straight and deeply incised; the banks collapse and there is considerable sand transport along the bottom; the bottom is sandy, soft and uniform, without coarse substrate or vegetation. Nearly all streams have suffered from rigorous maintenance practices. Straightening and channelization of streams have not taken place to any great extent since the late 1960s; the last major land reclamation scheme was the straightening of the River Skjern in the early 1960s. Streams have lost their natural physical properties not only through straightening, widening and deepening, but also because of harsh maintenance practices. Nearly all streams have been repeatedly dredged and weed thoroughly cut—a practice introduced to avoid flooding and increase the drainage of agricultural land.

During the last two decades river restoration projects have been initiated in order to improve the physical, chemical, and biological conditions in Danish streams. The Action Plan for the Aquatic Environment focused on reducing nutrient loading to the freshwater and saltwater ecosystems. The Watercourse Act of 1982 initiated new maintenance procedures for the majority of Danish streams. Monitoring of programs was set up to evaluate the physical, chemical, and biological effects of some restoration projects and a national monitoring program has focused on the effects of lower nutrient loading on invertebrates and chemical components.

During the past decade restoration projects have been accompanied by monitoring programs to access the effects on the physical and biological environment. The data from these studies are presented as case studies in this article.

4.1 The Ecological State of Danish Streams

About 35 000 km of Danish streams are considered natural in their origin. Today, as a result of channelization and culverting, and traditional harsh stream maintenance such as repeated dredging and weed cutting, only 10% have retained their natural meandering channel.

County authorities are responsible for setting quality objectives for Danish streams. Thus 5% of Danish streams are designated as areas of special scientific interest, whereas 66% and 29% are designated as fish waters and streams with eased objectives, respectively. The water quality of Danish streams is expressed by a pollution index ranging from unpolluted streams (I) to heavily polluted streams (IV) (Table 3).

		Quality objective	Minimum stream pollution index (Water quality class)
Rigorous objectives	**A**	Area of special scientific interest	II
General objectives	**B_1**	Salmonid spawning and fry production area	II
	B_2	Salmonid water	II
	B_3	Cyprind water	II
Eased objectives	**C**	Streams to be used for drainage purposes only	II-III
	D	Streams affected by Waste water	II-III
	E	Streams affected by Groundwater abstraction	II-III
	F	Streams affected by Ochre	

Table 3. Quality objectives in Danish streams

The larger Danish streams generally have a better quality than the smaller streams—water quality classes of III and IV are less frequent in the larger streams, in comparison to values of I and II (Figure 2).

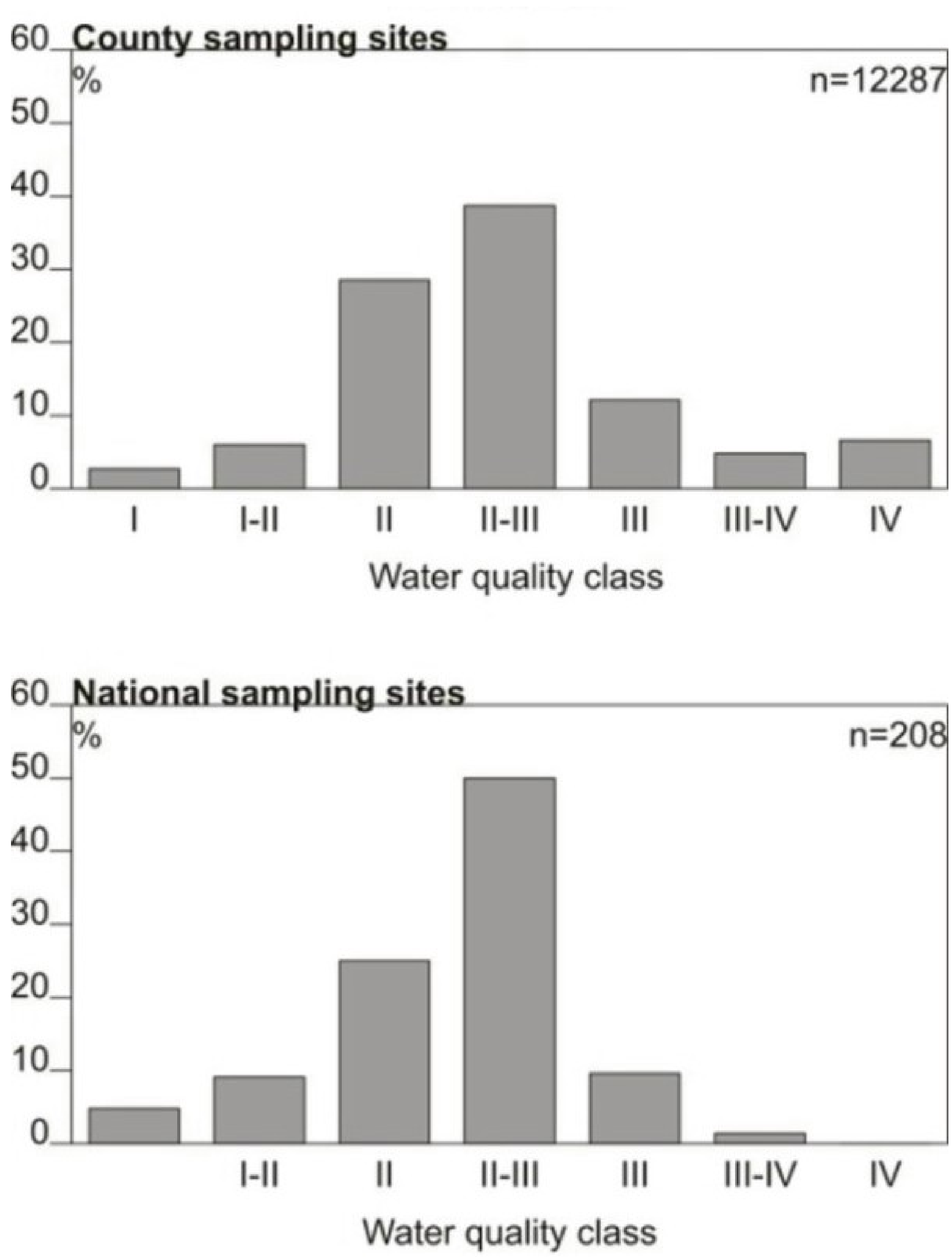

Figure 2. Water quality class distributions for (a) larger (width > 2 m) and (b) smaller (width < 2 m) Danish streams

About 24 500 km of Danish streams have quality objectives. The county authorities monitor the quality of the stream using macroinvertebrate community surveys. Based on these surveys streams are assigned a pollution index value, which is compared to the value set forth by the quality objective in order to check fulfillment of the objective.

In 45% of the 21 200 km of streams examined in the period 1993–1996, the objectives set by the counties was not fulfilled. The percentage of fulfillment varies with stream size. A larger percentage (47%) of streams wider than 2 m fulfill their objectives, compared with only 37% in smaller streams (width < 2 m). This corresponds to the difference in water quality described above.

The primary factors responsible for the lack of fulfillment are wastewater pollution (50%) and the poor physical condition of the streams (25%). The remaining 25% is caused by factors such as seasonal drying and ochre (Figure 3).

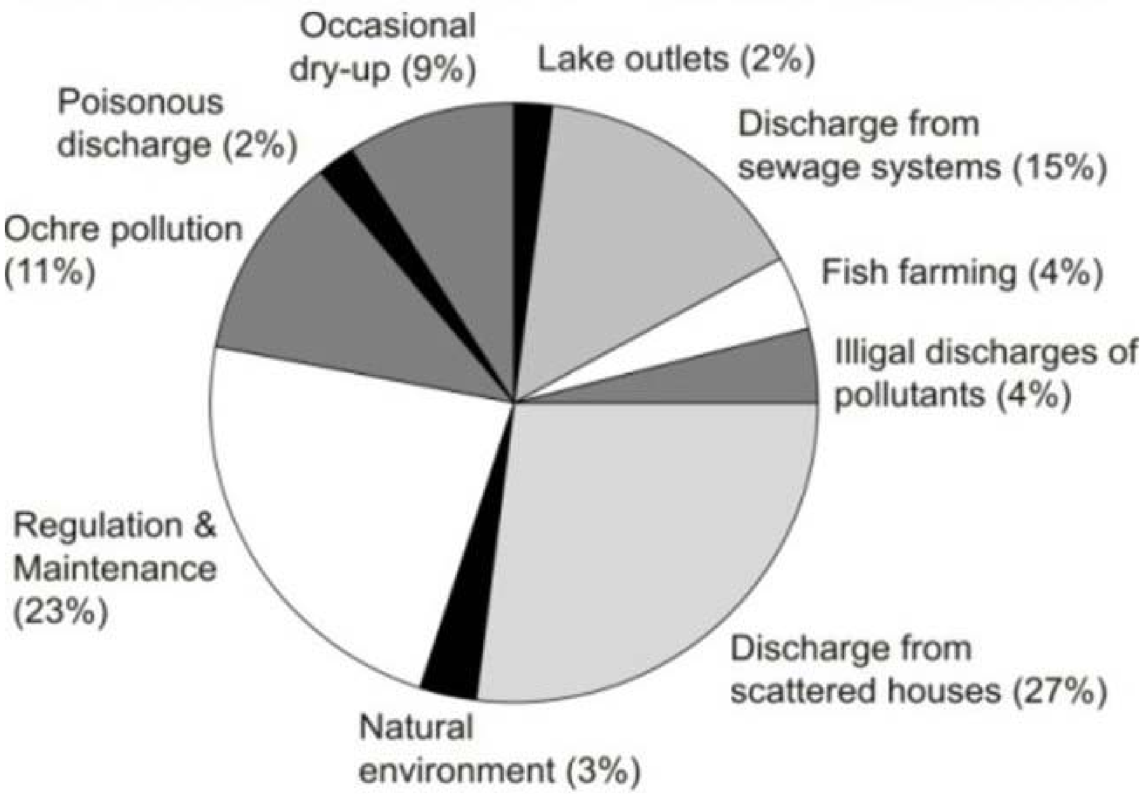

Figure 3. Primary factors responsible for the unsatisfactory water quality in Danish streams

The steps taken in Denmark towards improving the quality streams are:

- Improvement of sewage treatment.
- Prohibition of farm effluents.
- Reduction in leakage from septic tanks.
- Reduction in diffuse pollution from the open land.
- Change in maintenance procedures.
- River restoration.

The first main step was to improve sewage treatment and 96% is now treated biologically (20%) or chemically (76%). Initiatives are put forth to reduce point source pollution in the open land, which is responsible for 50% of all cases of unsatisfactory conditions in the streams.

The chemical water quality of Danish streams has been monitored at approximately 270 monitoring stations since 1989. The water quality of larger Danish streams has improved considerably over the past 20 years, although organic matter discharges from small sewage treatment plants and scattered households still contribute significantly to the poor water quality of many small Danish streams. Concentrations of diffuse phosphorus and nitrogen in Danish streams have declined by 5% over the past 20 years, whereas loadings from sewage treatment plants declined by 86% and 65% for phosphorus and nitrogen, respectively, in the same period.

The importance of the physical conditions has been documented by an assessment of county monitoring data for period 1989–1992 at approximately 6000 stream localities. A significant ($P < 0.01$) negative relationship was found between the degree of regulation and water quality class (Figure 4a), as well as positive relationship between the presence of coarse substrate and the water quality class (Figure 4b).

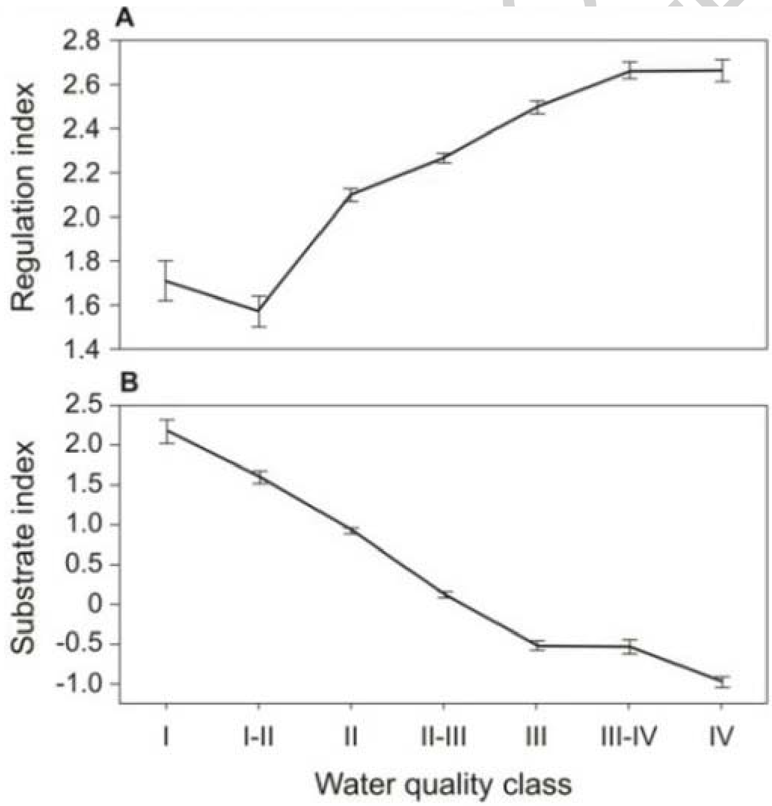

Figure 4. Relationship between stream regulation and water quality class and between substrate index and water quality class

The higher the regulation index the more regulated the stream is. Very poor water quality is associated with a high degree of regulation, whereas physically diverse streams generally have better water quality. A high value of the substrate index indicates diverse substrate in the stream, which is associated with very good water quality (Figure 4).

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Biographical Sketches

Morten Lauge Pedersen MSc (Ph.D. student), scientist at the National Environmental Research Institute, Denmark. Major research fields: physical conditions and habitats in streams; surface and groundwater hydrology and nutrient dynamics in watersheds; hydrological modeling; hydrological, geomorphological, and hydrochemical aspects of river restoration; physical habitat surveys in rivers; monitoring of freshwater, data analysis, and reporting.

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