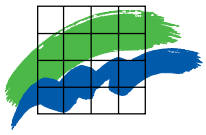
NERI

Report and activities 1999-2000



Ministry of Environment and Energy
National Environmental Research Institute, Denmark, April 2000

National Environmental Research Institute
Report and activities 1999-2000

Publisher: Ministry of Environment and Energy,
National Environmental Research Institute ©
Year of publication: 2000
Editor: Jens C. Pedersen
Translation: David I. Barry
Layout, illustrations and production:
Grafisk Værksted, NERI, Roskilde
Cover photos: Background photo: BIOFOTO/Niels Peter Holst Hansen, small photos: NERI/Inger Møller, Jørn Pagh Bertelsen, Rasmus Ejrnæs, Anna Bodil Hald, Anders Riis and NFNA/Bent Lauge Madsen
Printing: Scanprint as
Certified according to ISO 9002, ISO 14001 and the Nordic Eco-labelling scheme. EMAS (Environmental management) registered.

ISBN: 87-7772-544-1
ISSN: 0907-4120 (printed)
ISSN: 1600-0064 (electronic)
Number printed: 1,700
Number of pages: 32

Available from:
National Environmental Research Institute

or
Miljøbutikken
Information and books
Læderstræde 1-3
DK-1201 Copenhagen K
Tel.: +45 3395 4000
Fax: +45 3392 7690
E-mail: butik@mem.dk
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Nordic Ecolabel, printed matter

100% Danish recycled paper, Cyclus Offset.
Cover 250 g, contents 115 g.
Organic solvent-free vegetable printing dyes.

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Photo: CDanmark

Preface

In 1999, the National Environmental Research Institute (NERI) adopted a new strategy laying down guidelines for the Institute's work over the next 5–8 years. On this basis, NERI entered into a new 4–year result targets agreement with the Ministry of Environment and Energy at the end of 1999. The whole process around drawing up the new strategy and agreement has been extremely constructive, both internally within NERI and as regards negotiations with the Ministry and its agencies and a large number of external partners.

NERI celebrated its 10th anniversary with the conference "Danish Environmental Research 1999" held in Copenhagen on 19–20 August 1999. Around 350 environmental scientists and users of environmental research participated. The conference showed that Danish environmental research has made considerable progress during the 1990s, but that a number of challenges remain that the scientists will have to address in the coming years.

The conference also showed that numerous interinstitutional and interdisciplinary collaborations have been established within Danish environmental research, and that there is a need to sustain and promote this trend. NERI will therefore continue its efforts to help coordinate Danish environmental research so as to optimize the yield of the overall research effort.

In 1999, NERI was allotted its first research professorship with the appointment of Torkel Gissel Nielsen as Professor of Marine Biology. Announcement of research professorships at NERI is undertaken in collaboration with the Danish Research Councils, and NERI expects to be allotted a further 3–4 research professorships in the coming years.

NERI's largest department, the Department of Marine Ecology and Microbiology, has been divided as per 1 January 2000. The two resulting departments are the Department of Marine Ecology and the Department of Microbial Ecology and Biotechnology (see page 30–31).

In the very near future, the Department of Arctic Environment will move into a newly erected extension to NERI's Roskilde premises, thereby finalizing the merger with the Greenland Environmental Research Institute. The new 1,450 m^2-building primarily houses offices and laboratories for the Department of Arctic Environment, which has hitherto been located in Copenhagen. In addition, the new extension also houses the deliveries reception and a computer training classroom.

The present annual report primarily aims at providing a general account of NERI's activities, presenting results from the past year and initiatives for the coming year within selected areas where NERI's activities have "made a difference". Further analyses of the progress made can be found in NERI's annual accounts, which are available in Danish on NERI's Internet homepage: www.dmu.dk. Here is also a brief description of all the projects planned for 2000 as well as a list of the approximately 1,000 publications of various types published by NERI's scientists in 1999.

Henrik Sandbech
Director General

Hans E. Zeuthen
Chairman of the Board

Photo: CDanmark

NERI and the agricultural sector

The effect of agricultural activities on nature and the environment is a central aspect of NERI's work, both nationally and in NERI's international cooperation on research and consultancy. Agricultural activities are of particular importance in the work on nutrients, pesticides, genetically modified organisms, and landscape development. Among other things, this year's annual report focuses on agricultural emissions of ammonia (see pp. 24–25).

Danish agriculture – European agriculture

Over the past 50 years, agriculture in much of Western Europe has generally evolved in the direction of increasingly intensive farming. The use of commercial fertilizer has increased dramatically. Together with the increasing livestock density, this has led to increased input of nitrogen and phosphorus to agricultural land. Since the nitrogen and phosphorus that is not taken up by the crops either binds to the soil or is lost to the air or leaches from the soil, the result is increased pressure on the environment.

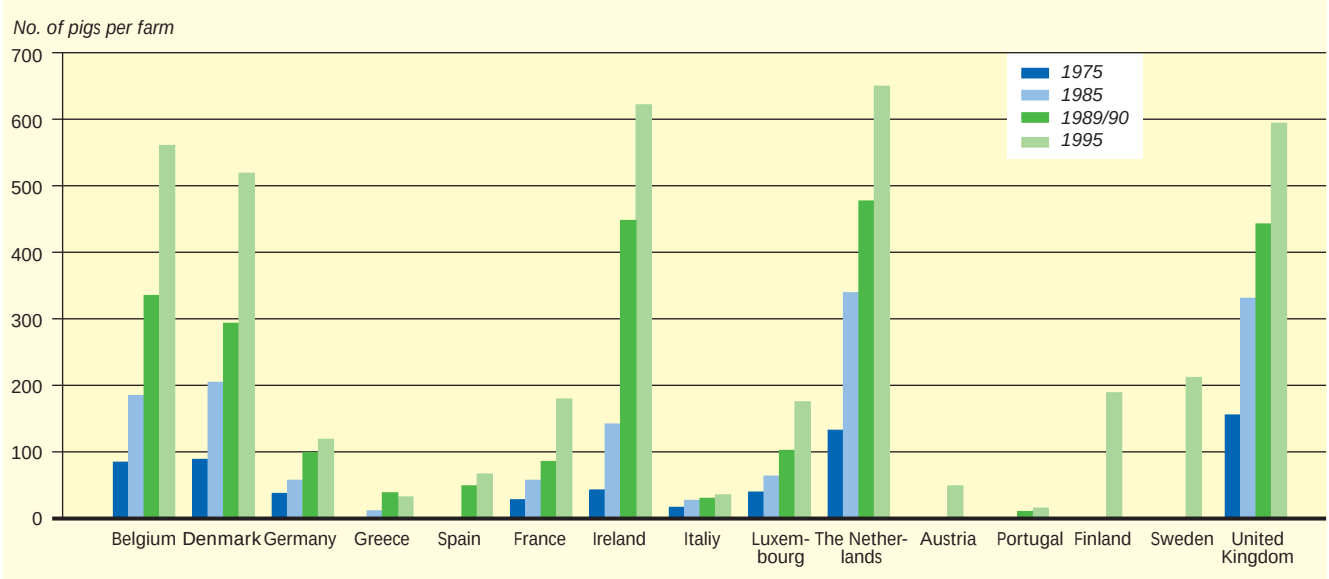
Livestock hold a central place in European agriculture, both from an economic point of view and as a major source of pressure on the environment. Over the past half century, livestock farming has undergone considerable change. In Northern and Western Europe in particular, small extensive farms have been replaced by more intensive and specialized farms. This development has taken place in step with an improvement in livestock feed and an increase in the productivity of livestock farms, and has placed new pressures on the environment in a number of areas.

The pig sector – the most intensive sector

The pig stock has increased constantly throughout the EU area since the 1970s. According to the EU Statistics Office, Eurostat, the number of pigs in the 15 EU countries has increased around 20 percent to 118 million animals in 1995. In Denmark alone, there were 11 million pigs in 1995, with the figure having reached 12 million in 1998, when some 20 million pigs were slaughtered.

Concomitantly with the increase in the pig stock, the animals have become concentrated in an increasingly smaller number of farms. This

Development in the size of pig herds in the EU over the period 1975-95. In both Denmark and a number of other European countries, the size of the average pig herd has increased many-fold. (Source: Eurostat).



development has been fully paralleled in a number of other EU countries such as Belgium, Ireland, The Netherlands and United Kingdom (see the accompanying figure). In Denmark, average herd size has thus increased from an average of 100 pigs in 1975 to over 500 in 1995, more than a five-fold increase in 20 years.

The pig stock is far from evenly distributed throughout Europe. Pig density on pig farms in The Netherlands is 47 pigs per hectare pig farm – or more than twice that in Denmark (19 pigs per hectare pig farm) and 20 times that in Austria. Expressed in terms of the total agricultural area, pig density in Denmark was 4 pigs per hectare farmland in 1995.

Specialization and the environment

The economic advantages of large-scale production have led to increasing specialization in most of Europe. Whereas around three quarters of Danish farms had both cattle and pigs in 1968, the figure was only 12 percent in 1998 (see accompanying table). Around three quarters of the cattle and pig stock is now congregated in specialized farms having only one type of animal. The percentage of farms having neither cattle nor pigs has increased over the period from 10 to 39 percent.

This specialization has also resulted in regionalization and a more uniform landscape since the crop selection on the individual farms is largely determined by the type of livestock kept. The environmental consequences are unclear, however.

Percentage of farms	1968	1982	1998
Without cattle and pigs	10	24	39
With pigs, without cattle	11	23	17
With cattle, without pigs	5	22	32
With cattle and pigs	74	31	12

Specialization in Danish agriculture (Source: Agricultural Council).

Distribution of pigs on pig farms in the 15 EU countries in 1995. While it is true that we have many pigs in Denmark, pig density is even greater in The Netherlands, where it peaks at 47 pigs per hectare pig farm. (Source: Eurostat).

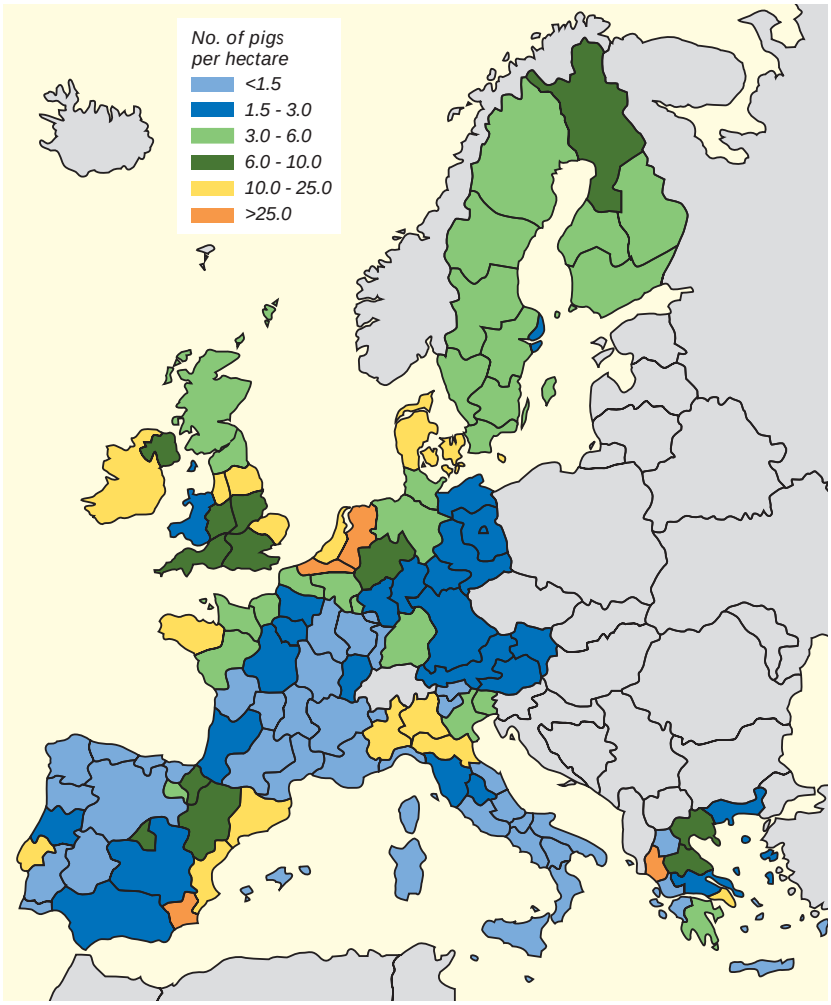
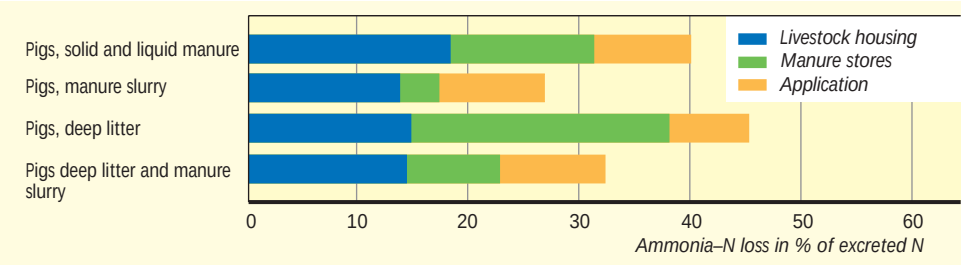


Photo: DIAS/E. Keller Nielsen

Ammonia volatilization from pig herds in livestock housing using different manure management systems. As can be seen, the conversion from traditional pig housing with solid manure and liquid manure to housing with a slurry system considerably reduces ammonia loss per pig. The saving is particularly great in connection with manure storage in slurry tanks having a cover layer as compared with manure heaps. (Model calculations – 1996 data).



Nitrogen surplus in the EU countries in 1995 calculated as the soil balance, i.e. total nitrogen input to fields (fertilizer + atmospheric deposition) minus total nitrogen removal (crops). (Source: Eurostat).

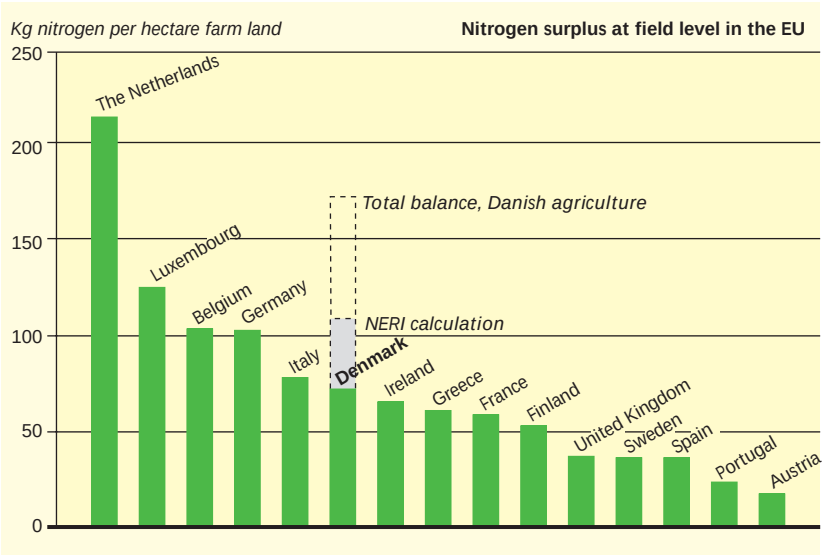
Due to uncertainties and errors, such data can only be used for general inter-country comparisons. For Denmark, the figure also shows NERI's own calculations of the field balance and DIAS's calculations of the total balance (farm gate balance) for Danish agriculture, i.e. the difference between total input (fodder, fertilizer, etc.) and removal (in produce). The difference between the total balance and the field balance is due to differences in calculation method.

For example, the increase in large-scale pig production means that it is more lucrative to manage the pigs' manure as slurry rather than separately as manure and urine, thereby concomitantly enabling farmers to considerably reduce ammonia emissions, as illustrated in the figure above.

As a result of the increasing livestock density, nutrient input to the soil in some regions of Europe is excessive, thereby placing pressure on the aquatic environment. At the same time, large areas have been drained and many of Europe's wetlands have been cultivated, thereby reducing nature's capacity to retain and remove the nutrients.

In addition, regional specialization has resulted in a situation where some farms generate more livestock manure than they are permitted to apply to their own fields, thereby necessitating that the farmers find alternative solutions. In Denmark, 47 percent of the pig farms produced a surplus of manure in 1998. Conversely, there are other areas where livestock manure is never applied to many of the fields.

As one would expect based on the size of the livestock herds, the problem in Europe is greatest in The Netherlands (see the figure below).



Nutrients

Consumption of commercial fertilizer increased in the 1960s and 1970s. Together with better plant varieties and better technology, this led to a considerable increase in agricultural yield. In the majority of EU countries, input of phosphorus peaked at the beginning of the 1980s while input of nitrogen peaked in the mid 1980s. Even though input of both nitrogen and phosphorus has decreased in recent years, agriculture remains a major source of pollution of the aquatic environment with these substances. In the case of nitrogen, attempts are being made to curtail the problem through the EU Nitrates Directive. In Denmark, the latter has been implemented through the Action Plan on the Aquatic Environment II. Corresponding initiatives have not been made for phosphorus, however.

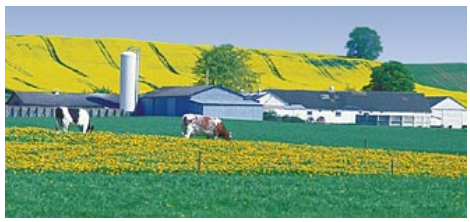


Photo: CDanmark

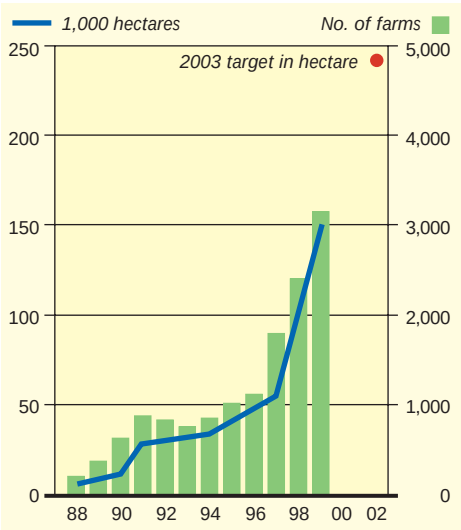
More organic farms

The agricultural sector is undergoing a transitional phase in which consideration for the environment, livestock welfare and product quality are increasingly being demanded. The number of organic farms is increasing markedly, not just in Denmark, but throughout Europe. At the European level, just under 2 percent of agricultural land was cultivated organically in 1995. The percentage of organic farms is greatest in Sweden and Austria. In Denmark there were 1,050 organic farms in 1995. In 1999, the number of organic farms had increased to 3,080, corresponding to a total of 5.6 percent of all cultivated farmland.

In Denmark, the State provides financial support for conversion from conventional farming to organic farming. This support now comprises one of the measures in the Action Plan on the Aquatic Environment II. One should bear in mind, though, that leaching of nitrogen from organic farms is not as well described as that from conventional farms.

The Danish Government's action plan on organic farming also encompasses strengthening of research. NERI participates in the Research Centre for Organic Farming, a research centre "without walls". The Centre's most important function is to initiate and coordinate research on organic farming and thereby contribute to the development of organic farming and promote sustainable development of agriculture in general.

Among other things, NERI's current activities within the Centre include projects on the consequences for nature and the economy of conversion to organic farming, as well as projects on integration of knowledge from various scientific disciplines, crop resistance to pests, and nutrient loss to the aquatic environment from organic farms. These projects all run over the period 1998-2000. The Centre is currently calling for applications within several new research programmes under which NERI has applied for support to initiate new projects in mid 2000.



The number of organic farms and farms under conversion to organic farming has increased markedly in recent years, not only in Denmark, but in the whole of the EU area. (Source: Danish Plant Directorate).

Photo: DIAS/E. Keller Nielsen

Modern pig housing. The animals' manure is a major source of nitrogen and phosphorus. In 1995, Danish pig production thus generated manure corresponding to 104,000 tonnes of nitrogen and 25,000 tonnes of phosphorus.

Photo: DIAS/E. Keller Nielsen

NERI - An evolving institution

New agreement on result targets

In 1999, NERI adopted *Strategy 2000* outlining how NERI can help facilitate sustainable societal development over the next 5-8 years. The strategy describes NERI's vision (see box) and stipulates strategic targets for the Institute.

Based on this strategy, NERI has entered into a new result targets agreement with the Ministry of Environment and Energy for the period 2000-2003. In the new result targets agreement, the main goals of NERI's work are collated under four headings: Visible results, quality, scientific expertise, and integration of knowledge.

The result targets agreement is a multi-year plan specifying result targets for the coming years. It is implemented in the form of projects, budgets and milestones in the annual work programmes. NERI's result targets agreement, strategy and current project plans are presented on NERI's Internet homepage: www.dmu.dk

NERI's vision

NERI will support sustainable development by explaining how environmental problems can be solved. This means that NERI has to be able to provide highly qualified advice and analyses in the nature, environment and energy areas based on the newest national and international scientific and technological progress. NERI provides advice to the State, Counties, Municipalities and to the private sector. NERI is to be the whole nation's environmental research institute and contribute to enhancing Denmark's international profile in the environmental area.

Photo: Klaus Holsting

Photo: NERI/Jens Christian Pedersen

Photo: WMO

Cooperation on research and education

NERI has contributed to a forthcoming national strategy for transport research expected in 2000. By way of follow-up on this strategy, the Ministry of Transport has decided to establish a sector research institution for traffic. Among other things, its research responsibilities will encompass traffic safety. NERI expects that the new institution will become an important collaborator in the traffic area.

In 1999, NERI entered into new cooperation agreements with the Danish Forest and Landscape Research Institute and the Danish Fisheries Research Institute. In addition, NERI has co-founded a society, DSAR (Danish Society for Atmospheric Research) to promote atmospheric and climate research in Denmark. NERI scientists participate in DSAR together with colleagues from Risø National Laboratory, the Danish Meteorological Institute and the Danish universities.

In the coming year, NERI expects to enter into an agreement with Copenhagen University on the establishment of a research academy within the environment and climate areas. NERI will also work for the establishment of new cooperation agreements with the Technical University of Denmark, the Royal Veterinary and Agricultural University and the Geological Survey of Denmark and Greenland. In addition, NERI has initiated discussions on closer cooperation with the Danish Institute of Agricultural and Fisheries Economics, and others.

International cooperation

NERI is becoming increasingly engaged in international cooperation on the environment. NERI thus participates actively in the cooperation with the European Environment Agency. In 1999, NERI participated in the work on drawing up a several-year IT strategy for the Agency and the European Environmental Information and Monitoring Network, EIONET. In 2000, NERI will provide advice to Bosnia-Herzegovinia, Albania and Former Yugoslav Republic Macedonia on building up their national contributions to EIONET.

In 1999, NERI was also an active partner in the European Topic Centre for Inland Waters, which serves as advisor to the European Environment

Agency. This work is expected to continue in the coming years. In addition, NERI participated in the European Topic Centres for Marine Waters, Nature Conservation and Land Cover.

NERI plays a major advisory role in helping to prepare the scientific foundation for EU Directives and Orders, and in connection with international conventions on protection of the environment.

NERI participates in the management committee for environmental research under the EU's 5th framework programme for research, technological development and demonstration, and is active in a number of European research networks in several of the programme's themes. The first round of applications has already provided NERI with the opportunity to strengthen its international activities.

Accreditation

Accreditation of sampling and analysis methods is intended to ensure that NERI complies with standardized requirements in the analysis and monitoring area and can compete nationally and internationally. The task of attaining accreditation made considerable demands on NERI's staff during the second half of the 1990s with respect to preparing the necessary documentation material. The Department of Environmental Chemistry has been accredited to undertake analyses of selected environmentally hazardous substances since 1997. In 1999, the Department of Atmospheric Environment gained accreditation to analyse air pollution, i.e. collection of samples, analyses of the collected samples of air and precipitation, and continuous measurements. The accreditation also encompasses methods for determining all the common inorganic components in air pollution.

In the coming years, NERI aims to attain accreditation for a number of further analyses, measurement methods and sampling techniques included in the national and international monitoring programmes. The Department of Marine Ecology has thus applied for accreditation of the methods used in monitoring of estuarine fjords and marine waters. Similarly, the Department of Arctic Environment has recently applied for accreditation of analyses of a number of heavy metals in biological and inorganic samples.

Photo: NERI/Jens Christian Pedersen

The programme areas form the framework for the scientific work in NERI's research departments. They are a central element in NERI's strategy, result targets agreement and work programme. The programme areas cut across NERI's departments.

PROGRAMME AREA / DEPARTMENT	Atmospheric environment	Aquatic environment and nature	Terrestrial environment and nature	Arctic and global environment	Risk assessment of chemical substances and biotechnological products	Cross-disciplinary research
Policy Analysis						■
Atmospheric Environment	■			■		■
Environmental Chemistry					■	■
Marine Ecology		■		■	■	
Microbial Ecology and Biotechnology					■	
Terrestrial Ecology			■		■	■
Streams and Riparian Areas		■		■	■	■
Lake and Estuarine Ecology		■		■	■	■
Landscape Ecology			■			
Coastal Zone Ecology			■			
Arctic Environment				■		

Production

As an indicator of NERI's productivity, the number of scientific articles, reports, publications, conference presentations and other tangible work results is calculated in relation to the effort expressed in man-years.

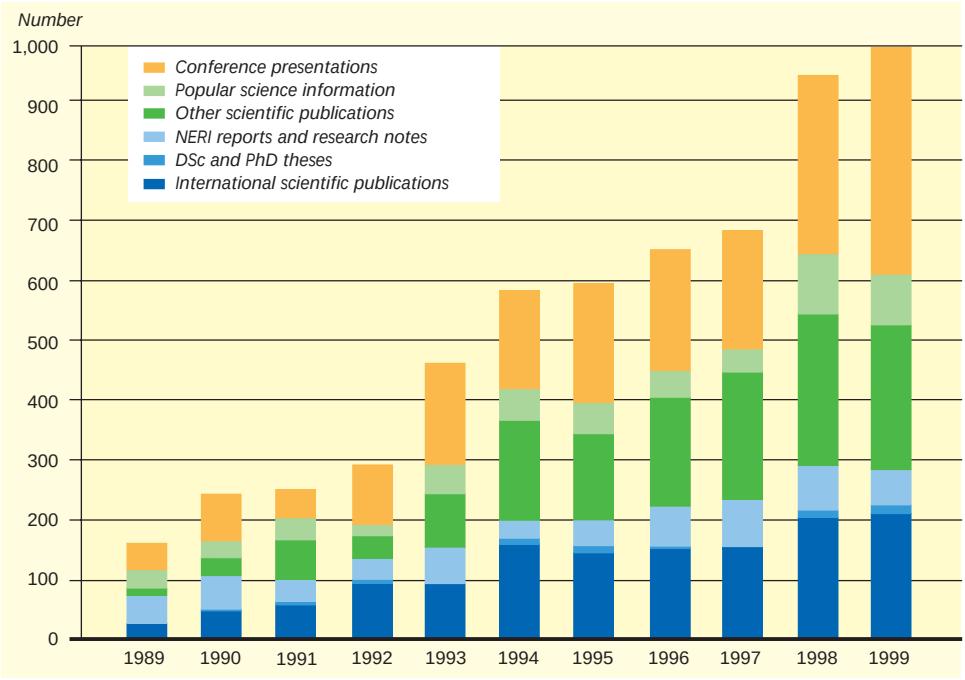
The main production figures for the period 1989-99 are shown in the accompanying graph. This clearly shows that there has been considerable growth in the number of scientific articles, reports, conference presentations, etc. since NERI's establishment. The increase in annual production over the period is attributable not only to the increasing number of staff, but also to the fact that each individual member of staff now publishes around twice as many publications as in 1989, cf. NERI's annual accounts.

A full list of publications from NERI staff members in 1999 is available on NERI's Internet homepage: www.dmu.dk

NERI's participation in the education of PhD students and undergraduate research students was enhanced considerably in the years immediately following NERI's establishment. In 1997, after several years with a declining number of new PhD projects, NERI decided to increase its involvement in researcher education. The goal is for NERI to have a permanent population of around 30 PhD students.

Visiting scientists, secondments abroad, PhD degrees awarded and masters theses completed.

	1993	1994	1995	1996	1997	1998	1999
Visiting scientists (man-months)	37	55	57	60	78	77	199
Secondments abroad (man-months)	40	31	55	38	18	15	22
PhD degrees (No.)	1	10	13	6	4	11	9
Masters theses (No.)	14	23	13	22	16	18	17



Development in the number of scientific publications, reports, conference presentations, etc.

Popular science information

In 1994, NERI launched a series of Danish language popular science theme reports entitled "TEMA-rapport fra DMU". By the end of 1999, NERI had published a total of 30 theme reports, the majority of which have been used actively in environmental education and debate. NERI aims to publish eight theme reports annually. Another important medium for information on NERI's activities is the quarterly newsletter DMUNyt, the current print run of which is just under 10,000.

NERI has had an Internet homepage since the mid 1990s to which new information is regularly added. In 1999, NERI improved the design and structure of its homepage to ensure rapid and easy access to the desired information.

New features have also been added. One can now retrieve around 200 publications in printable form (PDF files), and it is intended that all new issues of the "Technical Report" and "Theme Report" series are to be made electronically available in this way. NERI will also extend access to data on the environment and nature. Initially, the game bag statistics have been added to the homepage together with air pollution forecasts (see pp. 18-19). Soon a database of Danish vegetation types (DANVEG) will be added (see pp. 22-23) together with a summary of areas in Greenland that are vulnerable to human activities.

Prize for a well-written article

NERI Senior Scientist Betty Mogensen has been awarded a prize by the journal "Vand og Jord" for the Danish language article "Pesticides in watercourses and rainwater". In its citation, the prize committee emphasizes that Betty Mogensen "... tells about the pesticides in the parts of our environment where we do not otherwise hear much about them ... in a clear language supported by fine illustrations ...". The interested reader will also be able to see these abilities unfold on a larger scale in NERI's Danish language Theme Report No. 26: "Pesticides – use and dispersal in the environment".

Photo: NERI/Lars O. Hasselager

At the end of 1999, the Ministry of Environment and Energy published a catalogue of its easily understood books, booklets, magazines and Internet information on the environment, nature and energy entitled "Vitamins for environmental education and debate". Editing and layout of the catalogue was undertaken by NERI.

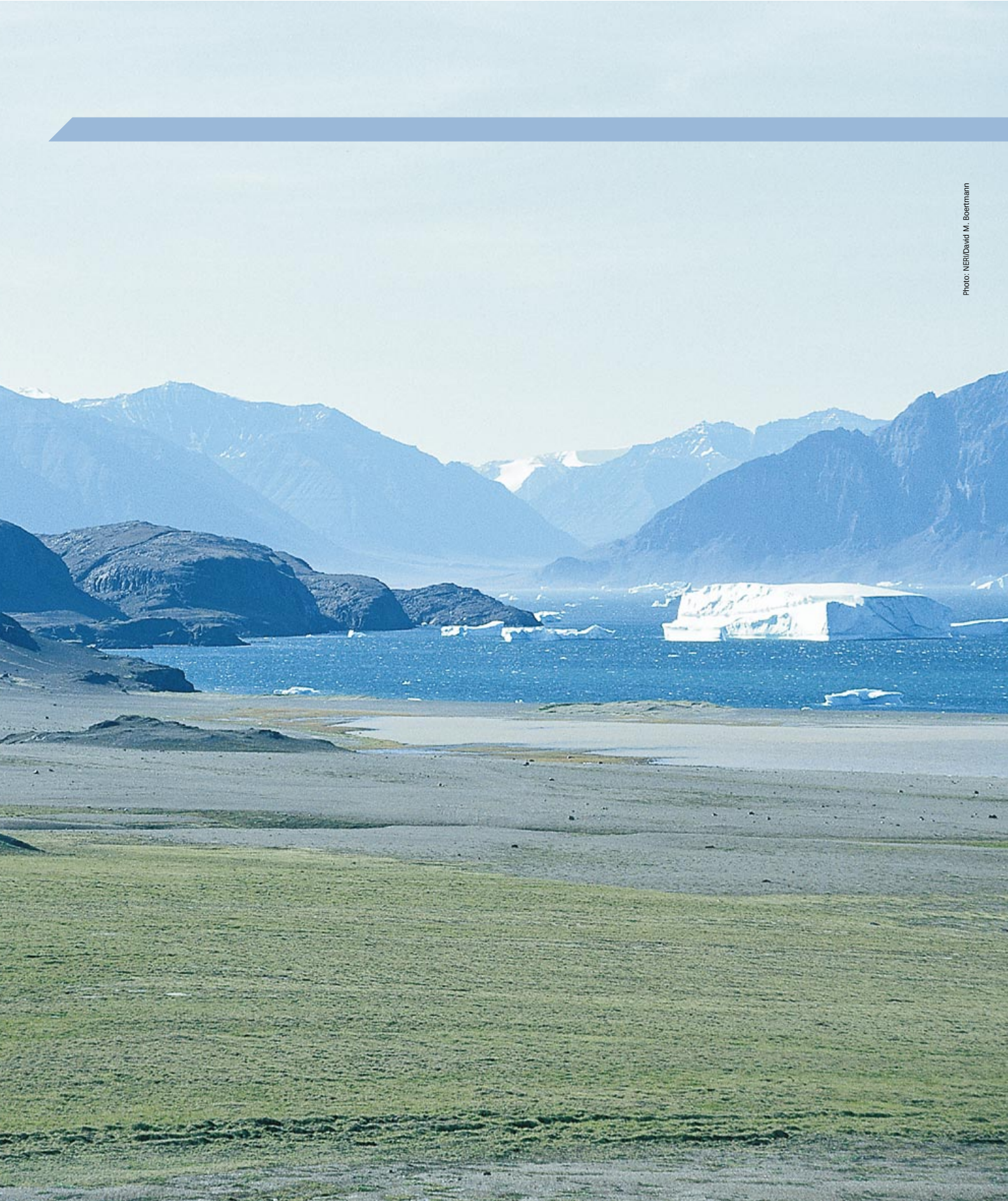


Photo: NERI/David M. Boertmann

Highlights

The following pages present NERI's six programme areas for the year 2000. Examples are given of fields in which NERI's activities have generated notable results...

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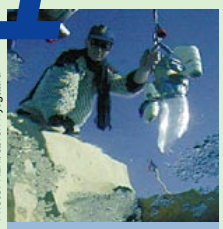

Photo: NERI/Søren Rysgaard

Arctic and global environment

2

Photo: NERI/Karsten Dahl

Aquatic environment and nature

3

Photo: 2. maj/Sonja Iskov

Atmospheric environment

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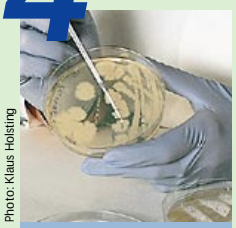


Photo: Klaus Holsting

Risk assessment of chemical substances and biotechnological products

5

Photo: NERI/Knud Tybirk

Terrestrial environment and nature

6

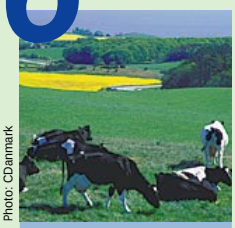


Photo: CDanmark

Cross-disciplinary research

1 Arctic and global environment

Activities in 2000

Budget DKK 23 million, of which DKK 17 million derives from contract income. 35 man-years.

Tasks:

- *Assess the environmental impact of raw materials extraction, including charting areas of particular importance for the terrestrial, freshwater and marine fauna.*
- *Investigate transboundary pollution, including participation in the international monitoring programme AMAP.*
- *Build up knowledge concerning the effects of global climate changes, including monitoring developments in the High Arctic northeast region of Greenland (Zackenberg).*
- *Investigate the effect of climate changes on the land and in lakes, watercourses, estuarine fjords and marine waters.*
- *Develop models for CO_2 exchange between the sea and air, transport to the Arctic region and biological turnover in the North Atlantic.*

In cooperation with the national TV corporation DR, NERI scientists produced a 30-minute TV documentary about the project in Young Sund. The documentary "Biology of the Ice Edge" was aired in December 1999 on the DR2 programme "Viden om". In connection with the programme, an Internet homepage was established where viewers could learn more about the project and pose questions to NERI's experts.

EXAMPLE

What is the significance of a temperature increase for life in the Arctic marine waters?

As part of the international research efforts on global changes in the environment and climate, NERI is investigating the effects on the aquatic environment in the Arctic regions. The scientists are examining the significance to the marine ecosystem and the climate of a reduction in the extent of the sea ice.

A number of observations show that the sea ice in the North Atlantic has become thinner since the 1950s and presently covers a smaller area of the sea. As a consequence, less sunlight is reflected by the sea ice and the ocean absorbs more heat, further stimulating melting of the ice. The North Atlantic is therefore one of the areas of the Earth where the marine environment will change most dramatically in the future since the sea ice plays a major role in determining how much light penetrates down into the water and hence the magnitude of marine primary production.

NERI has worked in several Arctic regions with varied sea ice and current conditions. In recent years, extensive research has been undertaken along Greenland's west and east coast, in the Greenland Sea, and in the northern so-called polynyan areas, i.e. stretches of open water in otherwise ice-covered marine waters. By comparing areas differing in sea ice thicknesses with open-water areas it is possible to model how future changes in temperature and ice conditions will affect Arctic marine ecosystems.

An example from northeast Greenland

Young Sund is one of numerous fjords on Greenland's east coast. Since 1995, NERI has coordinated a research project there involving scientists from more than 10 different institutions and departments in Denmark, Greenland, Germany, New Zealand and USA. The work is primarily supported by grants from the Danish Research Councils' Global Change Research Programme, the Carlsberg Foundation and the Commission for Scientific Research in Greenland. Young Sund is covered by an up to 1.6 metre thick layer of ice for 9-10 months of the year. The investigations are being undertaken along a transect across the outer part of the fjord and include investigations of seasonal variation in physical, chemical and biological parameters. An important project goal has been to determine the carbon and nutrient cycles.

NERI is also investigating the significance of the ice as a barrier to light and wind and as a habitat for algae and invertebrates. It may sound surprising, but the underside of the sea ice is home to a rich biological community. The activity of the sea ice algae culminates immediately before the ice breaks up in July, but their contribution to the overall primary production is modest given that they only occur for a short period and in a thin layer on the underside of the ice.

Algal primary production in the water column and on the sea floor is light-limited during the period of ice cover, but increases markedly as soon as the ice breaks up. During the period with open water, primary production is greatest in the deeper-lying pycnocline because production in the upper water masses is then limited by a lack of silicate and nitrogen salts.

Copepods and other grazers rapidly exploit the enhanced production of algae. Previous studies in the Arctic have indicated that copepods are primarily responsible for grazing the algae. However, NERI's investigations have now shown that bacteria and unicellular grazers (ciliates and heterotrophic dinoflagellates) in the water phase play a central role for the turnover of carbon and nutrients in the Arctic region.

Furthermore, the investigations have shown that the rate at which dead algae etc. are mineralized is of the same magnitude as in Danish coastal waters. This indicates that the bacteria are adapted to the constant low temperature and that the turnover rate is primarily determined by the availability of organic matter.

Massive walruses are a prominent feature of the fauna in Young Sund. Scientists from the Greenland Nature Institute, NERI and the Royal Veterinary and Agricultural University are therefore studying their migration, behaviour and energetics. The aim is to elucidate the significance of sea ice cover and mussel production for the walrus. To study these factors, walruses have been fitted with satellite transmitters and depth metres to enable their behaviour and migration to be followed. Finally, the walruses have been labelled with a stable, nonradioactive isotope to facilitate study of their energy consumption. In addition, numerous measurements have been made of the depth distribution of the benthic invertebrates. The investigations have shown that mussels are present in large numbers and that they too have adapted to a constantly low temperature. Furthermore, the investigations revealed that the walruses do not restrict themselves to Young Sund when foraging for food, but within a short space of time can also be observed at other feeding grounds many kilometres away from the fjord.

If the sea ice recedes

A preliminary analysis of the results from the field sites around Greenland and from other studies indicates that algal production increases when the open–water period is prolonged. The scientists therefore expect that a reduction in the extent of the sea ice will immediately result in enhanced production of algae and the smaller faunal members of the food chain (see accompanying figure).

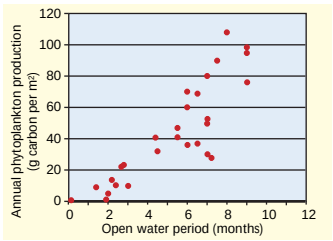
The changes in the marine waters will affect the CO_2 concentration in the atmosphere and hence the climate because algal photosynthesis draws CO_2 down into the sea where it is incorporated into the cells. When the algae have used up the nutrients in the upper water layers they sink to the depths of the sea. Due to stratification of the seawater, the carbon in the deep-sea becomes relatively isolated from the atmosphere. Without photosynthesis in the ocean, however, the CO_2 pool in the deep-sea would be released to the atmosphere and the concentration in the atmosphere would increase markedly. This is referred to as the ocean's biological pump.

If the reduction in the extent of the sea ice enhances algal production and hence transport of carbon down to the deep-sea, the sea will absorb more CO_2 from the atmosphere, thereby attenuating the global increase in temperature.

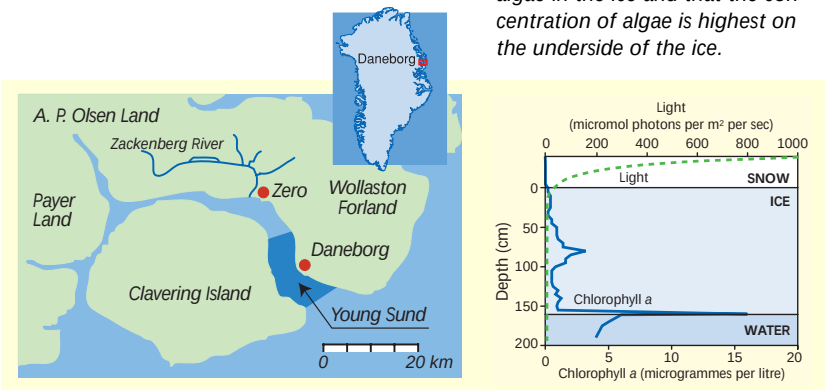
New activities

In the coming period, NERI scientists will use the extensive data material from the various Arctic locations to analyse the effect of changed ice conditions on production in the sea.

The results of NERI's investigations will be used to model the impact of global increases in temperature on the Arctic aquatic environment. All the work on nutrient and organic matter cycling will be completed in 2001 – the work on the walrus will continue to 2003, though.



In Arctic marine waters, algal production directly depends on the duration of the ice-free period. Data from 30 studies collated by NERI.



Changes in light intensity and concentration of algae (chlorophyll a) down through the snow and ice on the surface of Young Sund in June 1999. Note that there are algae in the ice and that the concentration of algae is highest on the underside of the ice.

Photo: NERI/Søren Rysgaard

Sample collection through a hole in the ice. Young Sund is covered by ice 10 months of the year. In order to be able to study life in the fjord, the scientists have first to saw holes through the metre-thick ice.

2 Aquatic environment and nature

Activities in 2000

Budget DKK 51 million, of which DKK 28 million derives from contract income. 105 man-years.

Tasks:

- *Undertake research on biodiversity and models for nutrient transport and cycling, integrating physical, chemical and ecological factors.*
- *Optimize and develop methods for rehabilitating nature and assessing the environmental consequences of aquaculture, fishery and raw materials extraction.*
- *Develop tools for assessing the quality of aquatic nature and environment.*
- *Monitor the aquatic environment by collecting, processing and collating national monitoring data, assist in the evaluation of the Action Plan on the Aquatic Environment II, and predict the effects of other political measures directed at the aquatic environment.*

EXAMPLE

Toxic substances in marine paints

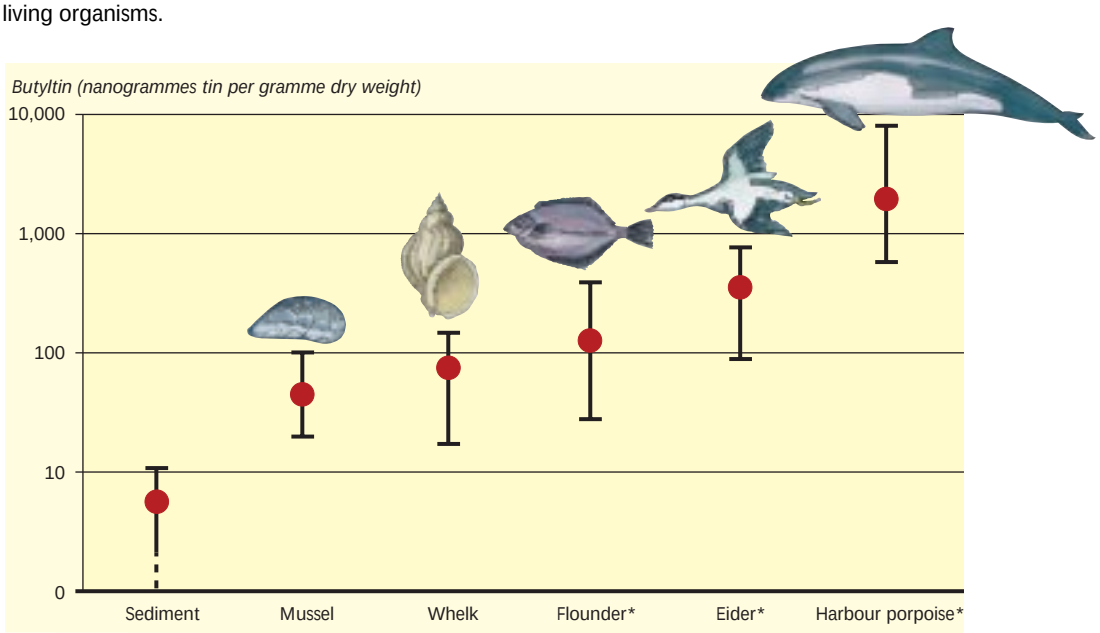
NERI has focused its attention on the toxic substances added to hull paints to prevent the hulls becoming fouled with algae and invertebrates. When the ships sail, these so-called antifouling agents are released to the water where they can have undesirable effects on the fauna and flora. The main problems are associated with the use of tributyltin (TBT), which is one of the most environmentally harmful substances known to science. Apart from TBT, a number of other toxic substances are also used in marine paints although work is currently going on to develop alternatives.

Boat owners have been familiar with the problem since ages past. If one leaves a ship lying in the water, the hull rapidly becomes overgrown by algae and invertebrates. This enhances fuel consumption, which is expensive for the shipping companies and detrimental to the environment. To overcome the problem, one or more antifouling agents are normally added to marine paints. They work by being toxic to the algae and invertebrates that attach themselves to the hull. Unfortunately, though, they are also toxic to other living organisms.

TBT is one of the most effective antifouling agents presently known, but is also one of the most toxic substances deliberately added to the sea. Today, TBT is widespread throughout the marine environment. In harbours and shipping channels with a high density of ship traffic, TBT concentrations have been recorded that far exceed the level harmful to living organisms. A concentration of around 1 nanogramme per litre seawater causes hormonal disturbances in certain species of marine snails, with the females developing male sexual characteristics (imposex or intersex). In Denmark, the county authorities and NERI have found such disturbances in 10 species of marine molluscs. Imposex is widespread throughout Danish marine waters. In the very sensitive species red whelk, all the females collected from the inner Danish marine waters exhibited imposex.

With the support of the National Forest and Nature Agency, NERI has investigated the occurrence of butyltin (TBT and its degradation products) in the marine food chain. It transpires that butyltin accumulates up the food chain. Some of the highest concentrations are found in our native whale, the harbour porpoise. NERI has also detected high concentrations in Danish fish and birds.

Photo: NERI/Karsten Dahl



The highest concentrations of butyltin are found at the top of the food chain. The figure shows the results of measurements made in the Belt Sea in 1998 and 1999. The vertical lines indicate the interval between the highest and lowest measurements.

** The concentration is measured in the liver.*

Laboratory experiments have indicated that TBT and its degradation products can suppress the immune system of animals and man. A group of American scientists have found significantly increased liver concentrations of butyltin in sea otters that have died of infections. In other foreign investigations, worryingly high concentrations of butyltin have been detected in human blood (whole-blood samples). In Denmark, NERI has detected butyltin in human liver samples, but it is unknown whether it derives from TBT or from other sources of pollution such as plastic and silicone materials.

Regulation and alternatives

The use of antifouling agents is presently subject to a variety of regulations. In Denmark and many other countries, TBT has long been prohibited for use on ships of less than 25 metres. Internationally, the UN International Maritime Organization (IMO) has just adopted a ban on the application of TBT-containing hull paints on all ships from the year 2003. With respect to pleasure boats, Denmark has banned use of the commonly used antifouling agents Diuron and Irgarol from 1 January 2000. This ban will be followed up by a general ban on the use of environmentally hazardous substances in hull paints from the year 2003.

Several alternatives to the toxic antifouling agents are currently being worked on. Industry is working to develop less toxic antifouling agents as well as mechanical methods such as hull washers and so-called underwater boat garages, a type of protective bag that is pulled over the boat's hull when it is lying in harbour.

At the end of 1999, NERI published a Theme Report entitled "Hull paints – an environmental problem" describing the main antifouling agents, focusing on their occurrence and effects in the environment. The report also examines the administrative and political initiatives to limit their environmental impact. The report was presented at a Theme Day attended by county authorities, industry, environmental science institutes, etc.

As part of the current national aquatic environment monitoring programme, NOVA 2003, the county authorities and NERI are investigating marine concentrations and effects of antifouling agents. In this connection, NERI participated in a series of international performance evaluations. The results showed that NERI was among the best laboratories in Europe as regards determination of TBT and its degradation products in seawater, sediment and mussels.

New activities

In the coming year, NERI will continue the work on charting the dispersal and effects of environmentally hazardous substances in the marine environment, including antifouling agents. With support from the EU, the Nordic Council of Ministers and others, NERI will participate in projects on the ecological consequences of hull paints. Finally, NERI will continue to work on developing advanced methods for determining the occurrence, fate and effect of new antifouling agents in the environment.

Photo: NERI/Jan Damgaard

Photo: Danish Sailing Association

Photo: Danish Sailing Association

Photo: NERI/Signe Foverskov

This issue of NERI's "Theme Report" series focuses on toxic substances in hull paints. The main problems are attributable to the use of TBT (tributyltin), which is one of the most environmentally hazardous substances polluting the sea. Apart from TBT, a number of other toxic substances are also used in hull paints.

3 Atmospheric environment

Activities in 2000

Budget DKK 17 million, of which DKK 9 million derives from contract income. 34 man-years.

Tasks:

- *Undertake research on air pollution and atmospheric chemistry.*
- *Develop models for the dispersal of air pollution at the local, regional and global scale.*
- *Monitor air pollution.*
- *Participate in national and international cooperation on setting limit values, standardizing models and measurement methods.*
- *Exchange results, disseminate results via Internet and text-TV, etc.*

Three-day air pollution forecasts are now available on NERI's Internet homepage at address: luft.dmu.dk. Here one can see how air pollution is expected to develop on Jagtvej, a main traffic artery in Copenhagen.

Photo: NERI/Per Schrøder

EXAMPLE

Air pollution forecasts

NERI has started making air pollution forecasts. A three-day forecast is now available for the most important harmful substances on NERI's Internet homepage. Among other things, the forecasts can warn of the exceedence of critical limits for air pollution. In addition, NERI expects the forecasts to be particularly useful for people with respiratory disorders.

For the past couple of years, NERI has published the daily monitoring results for selected air pollutants on the Internet and text-TV. Recently these measurements have been supplemented by a forecast of how the air pollution will develop over the coming three-day period. The forecasts are available on NERI's Internet homepage. The forecasts for Copenhagen go right down to street level. One can see how pollution with nitrogen oxides, benzene and carbon monoxide is expected to develop over the coming three-day period along both sides of the major traffic artery Jagtvej. The difference in the level of air pollution on the two sides of a road can be up to sixfold depending on the wind direction. The pollution is always worst on the lee side.

NERI will use the system to provide warnings to the population and the affected counties and municipalities when exceedence of critical threshold levels is likely. NERI expects the forecasts to be of particular use to people suffering from allergy, asthma and other respiratory disorders. People without respiratory disorders can also benefit from the forecasts, however, for example to plan their activities so that they spend more time indoors and are less active when pollution levels are high. NERI also hopes to be able to use the models in foreign cities where the need for an early warning of air pollution can be considerably greater than in Copenhagen, and where it could be necessary to plan measures to curtail traffic.

Finally, the forecasts will also be useful in connection with accidents where pollution is spread into the air, for example from chemical factories, nuclear power plants, etc.

How can air pollution be predicted?

The foundation for the new forecasts is a weather forecast and a set of models for the dispersal and chemical transformation of air pollution at various scales (European, national, town, street).

Photo: CDanmark

The dispersal models have been developed by NERI. The air pollution forecasts are thus a natural continuation – with respect to both development and use – of NERI's work on air pollution models over the past 20 years, as well as of international developments in the area. The models have become increasingly better at describing the chemical and physical processes, just as their spatial and temporal resolution has improved. Finally, the development of faster computers has enabled integration of the different models enabling, for example, background concentrations to be incorporated when making calculations at street level. The step from here to making forecasts is therefore "just" to apply the models to relevant weather forecasts and calculate the expected air pollution during the coming three-day period – which NERI now does four times daily.

Weather and air pollution forecasts

The weather forecast is based on a Yugoslavian/American model (ETA) that has been further developed in Greece and by NERI for use in Europe, and which uses publicly available American weather data. The availability of weather data on the Internet and of faster computers has made the production of weather forecasts a reasonably manageable task. NERI cooperates with the Danish Meteorological Institute with regard to forecast quality assurance.

While the air pollution forecasts can obviously never be better than the data on which they are based, they have nevertheless become very reliable. NERI has been working with air pollution forecasts on an experimental basis since August 1998. Experience shows that the forecasts are reasonably precise. NERI has thus been able to forecast the air concentrations of nitrogen oxides, carbon monoxide and benzene at NERI's monitoring station on Jagtvej in Copenhagen with great accuracy (see accompanying figure). Correspondingly, the forecasts in September 1999 were able to predict an episode of high air ozone concentration three days in advance with an accuracy of one hour. Moreover, the forecasts predicted the maximum ozone concentrations with a precision of 10 percent. On average, the forecasts can presently predict air pollution with an accuracy of 15-20 percent depending on the period and nature of the pollution.

The future: Cooperation to improve the forecasts

In the coming years, NERI will further develop the forecasts, among other things so as to be able to describe trends in the levels of particulates and accidental releases from nuclear power plants, and to extend the forecasts to more towns and streets. NERI will also work to improve the quality of the forecasts and to integrate them in the nationwide programmes for monitoring air pollution.

The development of the forecasts has been partly based on input from collaborators in the Danish Society for Atmospheric Research (DSAR), which held its first seminar in October 1999. Here, scientists from NERI and colleagues from the Danish Meteorological Institute, Risø National Laboratory and the universities discussed and compared models and approaches and planned future cooperation. NERI and the Danish Meteorological Institute have recently initiated a series of joint seminars on aspects of modelling.

"Air-Sea Exchange: Physics, Chemistry and Dynamics" is the title of an international book published at the end of 1999. The exchange of substances between the air and the sea plays an important role for pollutants such as ammonia and carbon dioxide. The book was edited by Gerald Geernaert, Director of the Department of Atmospheric Environment.

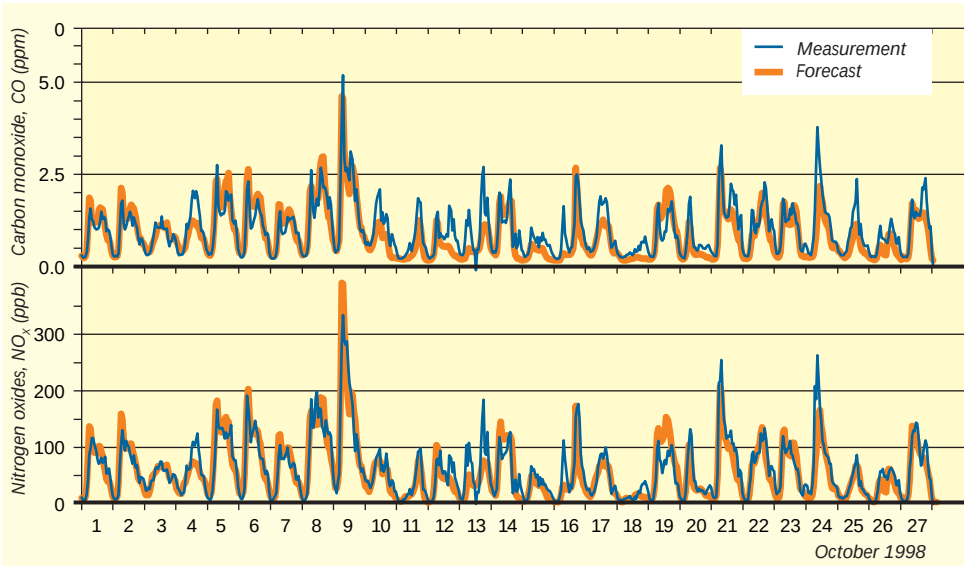


Photo: 2. maj/Sonja Iskov

Comparison of NERI's forecasts for air concentrations of carbon monoxide and nitrogen oxides with actual measurements from Jagtvej in Copenhagen (mean values per hour).

4 Risk assessment of chemical substances

Activities in 2000

Budget DKK 45 million, of which DKK 23 million derives from contract income.103 man-years.

Tasks:

- *Undertake research on the occurrence, availability, conversion/degradation and transport of chemical substances in the environment, as well as their effects on the flora, fauna and ecosystems as a basis for risk assessment.*
- *Develop test systems and establish environmental quality criteria.*
- *Develop methods for analysis and sampling.*
- *Develop models for ranking chemical substances.*
- *Undertake research on the fate of microorganisms and transfer of genes.*
- *Develop test systems and methods for risk assessment of genetically modified plants.*

Photo: NERI/Jørn Pagh Bertelsen

The new method was initially developed to rank pesticides according to their occurrence in the environment. However, NERI expects that it will be possible to develop the method to also rank the substances according to their environmental effects.

EXAMPLE

New method for identifying which substances are most harmful

NERI scientists are working on developing a simple new principle for identifying which xenobiotic substances have most impact on the environment. NERI expects that in a few years, authorities and enterprises will be able to use the new method to rank most groups of xenobiotic substances.

For the authorities, conducting a complete risk assessment of all the chemical substances in use would present an overwhelming task. There is consequently considerable interest in methods for identifying which chemical substances pose the greatest threat to the environment – based on simple information, that is!

As part of their work on methods for risk assessment of chemical substances, NERI scientists have tried to assess substances with unknown properties on the basis of related well-investigated substances. By comparing several different parameters simultaneously it is possible to achieve a so-called partial order rank.

While partial order ranking is trivial when only a few elements are to be ranked, its strength lies with problems involving many elements such as is the case with the ranking of xenobiotic substances. The method's forte is in areas where there is relatively great uncertainty or a sparsity of knowledge, and where a decision has nevertheless to be made, as is exactly the case with xenobiotic substances.

Among other things, the scientists have tested the method to examine 30 commonly used pesticides included in a major Swedish study. Measurements were mainly made on drainwater from a 9 km^2 catchment comprised of drained moraine clay of a type that is also very widespread in Denmark. The investigations showed that it is possible to rank the pesticides' in relation to their occurrence in the water using three different parameters simultaneously. The three parameters were:

(1) The area sprayed
(2) The dose (kg/ha)
(3) The substance's ability to bind to the soil.

The ranking was evaluated by investigating how many of the ranks were correct compared with the measurements. The result was that over 87 percent were correct, which is surprisingly good for such a relatively simple ranking procedure – and only one percent were definitely in conflict with the data.

Photo: DJAS/Henry Rasmussen

The method's potential

The perspective in this new work is that provided that the dose, the expected sprayed area and the substance's ability to bind to the soil are known, it will be possible to immediately predict the occurrence of a new pesticide based on well-investigated pesticides. Work still needs to be done to collect and interpret data from different agricultural areas, however.

NERI is also working on developing the method to compare different uses of pesticides. For example, the total consumption of pesticides in different years can be compared. This means that it will be possible to investigate whether a given development in agriculture will increase or decrease the occurrence or impact of pesticides in the environment.

Occurrence and impact are not necessarily related, however, since the various pesticides have very different effects. It would seem possible, though, to utilize one or more parameters describing the pesticides' environmental effects in the ranking process. In general, the number of parameters the method can "bear" primarily depends on the number of substances to be ranked. The greater the number of substances to be ranked, the greater the number of parameters that can be incorporated in the analysis.

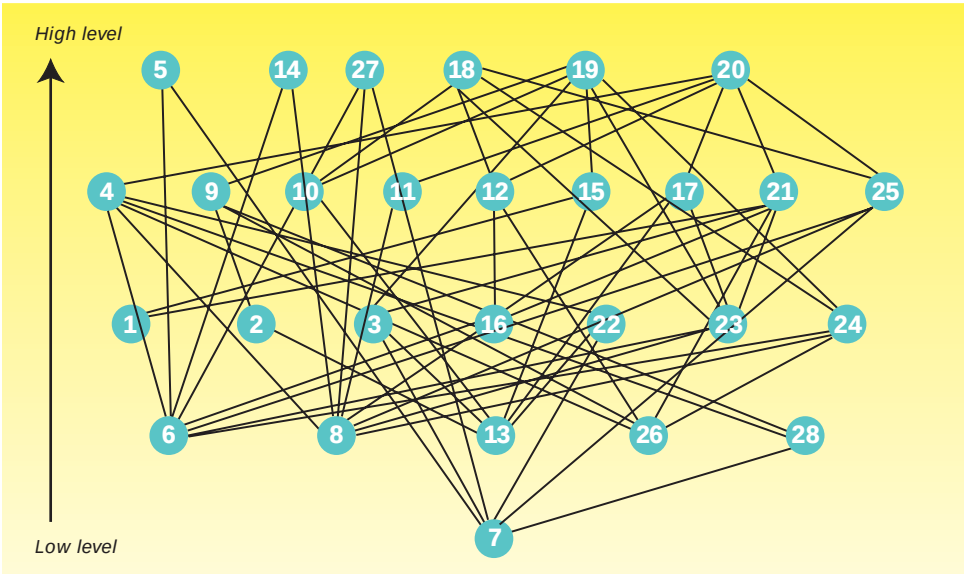
The future: More uses

The new ranking method seems to have great potential as regards complex decisions, but no one single method can stand alone. In most cases, it will be necessary to supplement with an expert evaluation.

In the coming year, NERI will test the method in various contexts, among others in connection with an OECD project aimed at developing indicators for assessing impact on the aquatic environment. In addition, NERI has just begun a new four-year project that will focus further on the use of different types of mathematical models in connection with risk assessment of chemical substances.

Photo: Klaus Holsting

1	*2,4-D*	8	*Deltamethrin*	15	*Fluroxypyr*	22	*Methabenzthiazuron*
2	*Benazolin-ethylester*	9	*Dichlorprop*	16	*Ioxynil*	23	*Pendimethalin*
3	*Bentazone*	10	*Dimethoate*	17	*Isoproturon*	24	*Phenmedhipham*
4	*Cloridazon*	11	*Esfenvalerate*	18	*MCPA*	25	*Pirimicarp*
5	*Clopyralid*	12	*Ethofumesate*	19	*Mecoprop*	26	*Prochloraz*
6	*Cyfluthrin*	13	*Fenitrothion*	20	*Metamitron*	27	*Propiconazol*
7	*Cypermethrin*	14	*Fenpropimorph*	21	*Metazachlor*	28	*Triadimenol*



Pesticides ranked according to their possible occurrence in surface water. The calculation predicts that the substances uppermost in the diagram are those most likely to leach into the watercourses.

The model calculation is based on three sets of information, namely the dose (kg active substance per hectare), sprayed area and the substance's ability to bind to the soil (K_{OC}). The information derives from a southern Swedish study and hence is not necessarily fully comparable to Danish conditions. Note that not all the substances are interconnected. Two substances are only connected if one of the two is better or worse than the other with regard to all three sets of information. Some substances are compared with each other in the diagram through other substances. Thus No. 9 is compared with No. 13 in the sense that No. 9 is compared with No. 2 and No. 2 is compared with No. 13.

5 Terrestrial environment and nature

Activities in 2000

Budget DKK 42 million, of which DKK 29 million derives from contract income. 84 man-years.

Tasks:

- *Undertake research on how agriculture, land use, air pollution and recreational activities affect nature.*
- *Undertake analyses of habitat conditions for plants and animals, biodiversity, soil quality and landscape and coastal zone ecology with a view to establishing criteria for and indicators of nature quality and sustainable nature management principles.*
- *Investigate the effects of human activities, including the erection of wind turbines.*
- *Monitor selected biotopes and populations of plants and animals, including registering the annual game bag and disseminating the results, among other ways via the Internet.*

Photo: NERI/Rasmus Ejrnæs

EXAMPLE

Nature quality – a nature management tool

In recent years, Danish nature management has experienced an increasing need for standardized methods for assessing nature quality. NERI has therefore collaborated with the Danish Forest and Landscape Research Institute and the Geological Survey of Denmark and Greenland on a three-year research project to develop terms and methods. The work on operationalization of the term nature quality is being continued in several ongoing projects.

Nature management in Denmark has a considerable need for tools to focus and evaluate the efforts currently being made to preserve and recreate valuable natural ecosystems. The need is greatest in the Counties and in the National Forest and Nature Agency, although the Municipalities and consultancy firms in the private sector also demand tools able to integrate the scattered knowledge from investigations of the occurrence of plants and animals. Together with a number of other actors in this area, NERI is thus working to operationalize the term nature quality, in the first instance in the recently completed project "Indicators of nature quality". This project is pioneering on two fronts. Firstly, it presents the first overview of terrestrial nature in Denmark in the form of an interactive database. Secondly, it contributes an analysis and definition of the objectives of management of the vulnerable nature.

The results of the project are summarized in an issue of NERI's Technical Report series and were recently presented to users at a seminar in Silkeborg. The aim of the project was to develop methods for assessing nature quality in the freshwater, marine and terrestrial environments. As part of the project, four general criteria for nature quality were identified, namely wildness, nativeness, continuity (spatial and temporal) and authenticity. The scientists refrained from studying criteria related to recreative value, aesthetics and ethics from the very beginning – even though such criteria can be important in the political decision-making process. Thus it is possible for a natural ecosystem to have a low biological nature quality while at the same time being a nice landscape or in some way attractive to users.

Nature management officials can use the new nature quality criteria to establish biological objectives for areas where consideration for nature is accorded high priority. At the same time, the scientists have developed indicator-based tools to follow whether the objectives are being fulfilled.

How can nature quality be determined?

With regard to the aquatic environment, there is a long tradition for establishing quality objectives and using indicators to regularly evaluate environmental quality. A good example is watercourses, whose pollutional state is assessed from the macroinvertebrates present. In the NERI project, the stream scientists demonstrated that the existing indicator systems could be used to assess the quality of both the nature and the environment. The system is not yet fully developed, however. Among other things, one cannot yet distinguish how the individual physical, chemical and biological factors affect nature quality. NERI is therefore in the process of developing methods and tools that will be able to describe the optimal natural state as a basis for evaluating the impact of various types of pressure.

In the terrestrial area, the scientists have also made considerable progress on cataloguing Denmark's nature and developing methods to assess nature quality. Among other things, NERI has developed a database of Danish vegetation types (DANVEG) summarizing the plant communities occurring in Denmark. The database is interactive. It can tell which plant species are able to grow in an area if the habitat conditions are typed in. Conversely, DANVEG can also tell the type of natural ecosystem present if a list of the plants present in an area is typed in. The database can be coupled to a geographic information system that can show the distribution of ecosystem types in the landscape, for example in a county. DANVEG has been tested by county authorities and Danish botanists. NERI cooperates continually with users to improve the user interface and the database's functions.

In the coming months, DANVEG will be made available for nature management officials and other interested parties via NERI's Internet homepage.

New activities

NERI is continuing efforts to develop methods for assessing terrestrial nature quality in several ongoing projects. The work on systematizing the rather dispersed information available on Danish nature is being continued in a project on the development of an integrated environmental information system for the nature area. Moreover, research on nature quality is being conducted at the Centre for Changing Landscapes under the Danish Environmental Research Programme.

One of the objectives of these projects is to further develop the models so that they can assess the nature quality of Danish plant communities. In this context, the ecosystem types in DANVEG are used as reference material for the development of a model that based on the list of plants in an area will be able to tell whether the area is affected by man and impoverished as a result of draining, cultivation or fertilization, or whether it belongs to a valuable type of natural habitat, e.g. heath, semi-natural grasslands, mire or bog.

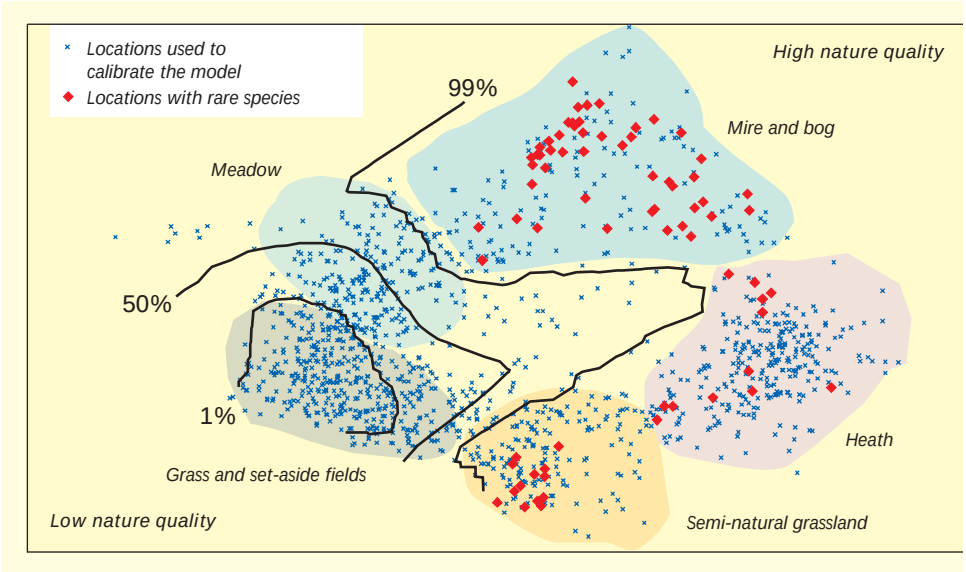
The scientists have also investigated the ability of the model to identify the most valuable types of natural ecosystems, i.e. areas that contain the most rare or threatened species. This test encompassed 78 vegetation analyses from the period 1945–1980 containing a total of 23 species presently characterized as extinct, endangered or vulnerable on the Danish Red List of threatened species. The model predicted that all 78 analyses belonged to the group of valuable natural ecosystems (see accompanying figure). It is worth noting that the rare species from the Red List were first deleted from the species lists so as not to influence the model's predictions. This is a sound principle because there are many valuable meadows, semi-natural grasslands and heaths that do not contain species included on the Red List.

NERI aims to improve the developed tools so as to make them even more useful in routine nature management.

Photo: GEUS/Peter Friis Møller

Forest in Kjellerupdal near Silkeborg. The nature quality of this forest is high. The soil is pristine, the plants have established themselves and the species are native to Denmark.

Photos: NERI/Rasmus Ejrnæs



Model for identifying valuable natural ecosystems

The figure summarizes the variation in vegetation at more than 1,000 locations (blue dots) from DANVEG and an ongoing NERI project. The contour lines on the figure indicate the probability that a location belongs to the group having a high nature quality.

6 Cross-disciplinary research

Activities in 2000

Budget DKK 17 million, of which DKK 7 million derives from contract income. 38 man-years.

Tasks:

- *Build up scientific expertise to compare data, knowledge and models at different levels of detail and aggregation, to describe discharges, transport, turnover and environmental effects, and to evaluate regulatory mechanisms and initiatives in the environment and nature areas. The work focuses on environmental problems in relation to transport, land use, agriculture, energy and industry.*
- *Develop tools for assessing consequences and priorities in the environment area.*

Data and information are largely derived from NERI's other programme areas supplemented with social science knowledge and data.

Photo: NERI/Knud Tybirk

Competitive plants such as grasses and nettles grow well at high nitrogen levels, crowding out other plants.

Denmark's "trade balance" for ammonia in 1996 (1,000 tonnes nitrogen per year). The figure shows emissions and deposition on the Danish land mass as well as ammonia "imports" and "exports".

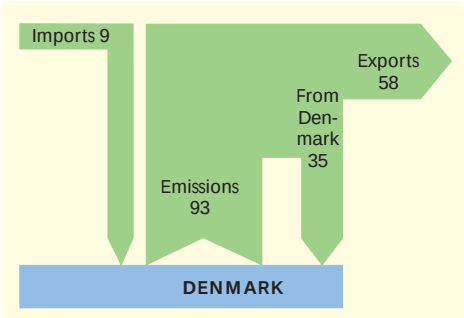
EXAMPLE

Ammonia – a complicated national and international problem

When livestock density is high, ammonia may be present locally in markedly increased quantities – unfortunately also outside the farmers' fields. The majority of the ammonia disperses over large distances, including to foreign countries. NERI and the Danish Institute of Agricultural Sciences have now charted these emissions for use in the political negotiations on an action plan to limit agricultural emissions of ammonia.

Ammonia can have untoward effects in nature because it easily causes overfertilization on both land and at sea. A certain amount of ammonia will always volatilize from agriculture, especially where there are livestock herds. Farmers can reduce the amount of volatilization in various ways, however, and much has in fact already been achieved.

The political agreement on the 1998 Action Plan on the Aquatic Environment II states that an action plan to limit agricultural emissions of ammonia is to be put before Parliament. NERI, the Danish Institute of Agricultural Sciences and the National Forest and Landscape Research Institute have jointly prepared three subreports containing updated knowledge and data material for use in the political negotiations. In addition, a fourth subreport has been prepared on the economic aspects of measures to limit ammonia volatilization. The reports are available on NERI's Internet homepage. Just recently, it has been agreed that the ammonia problem is to be included in the evaluation of the Action Plan on the Aquatic Environment II at the end of the year 2000.



Many figures

On average, each hectare of land in Denmark receives about 15 kg nitrogen from the air annually. Two thirds of this is ammonia derived from agricultural sources. The final third is nitrogen oxides derived from combustion i.e. transport and power production. Even though Denmark is a "net exporter" of ammonia (and nitrogen oxides), a third of the nitrogen deposited on Denmark derives from abroad.

A new international agreement on ammonia, nitrogen oxides, sulphur and volatile organic compounds (VOCs) was signed in Gothenburg on 1 December 1999. According to this, European emissions of nitrogen oxides are to be reduced by 41 percent by the year 2010 relative to the 1990 level, while emissions of ammonia are to be correspondingly reduced by 17 percent.

The ammonia mainly derives from livestock herds, namely 70,000 tonnes out of the total Danish emissions of 93,000 tonnes. Despite the fact that the number of livestock has increased in the 1990s, ammonia emissions from livestock have been reduced by approx. 10,000 tonnes during the decade.

This is attributable to a combination of improved utilization of the animal feed, enhanced use of liquid manure (see page 6) and the fact that farmers are increasingly spreading their livestock manure in the spring and more rapidly ploughing it into the soil.

Around one quarter of the ammonia emitted is deposited again within 1 km of the source. It is thus important to take into account particularly vulnerable types of natural habitat when siting large livestock farms. The remainder of the ammonia is transported over long distances, and a considerable part of it leaves the country (approx. 60 percent). NERI is therefore working on describing the dispersal and deposition of ammonia at the local, national and European levels.

With our present knowledge and the known technological possibilities, NERI and the Danish Institute of Agricultural Sciences believe that Danish agriculture will probably be able to reduce ammonia emissions by a further approx. 20-50 percent. A reduction of this magnitude will be

relatively expensive, however, as it will require changes to much of the existing animal housing and machinery.

Changes in agriculture

It is clear that all prognoses of pollution from an activity will be sensitive to changes in the sector. The National Forest and Nature Agency has therefore asked NERI to investigate the significance of a decrease or increase in the total number of pigs. The analysis shows that a change in the size of pig production will mainly affect nature through a change in ammonia emissions. A 30 percent increase in pig production will thus enhance the ammonia load by 4–14 percent depending on the region. In this context, it should be remembered that nitrogen input to most natural ecosystems is already excessive.

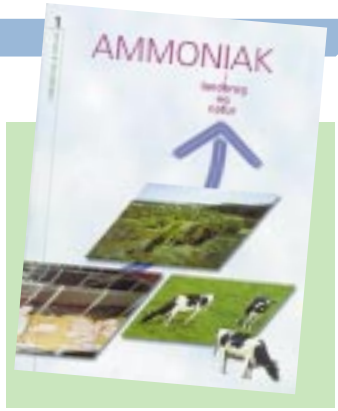
NERI has also examined the effect of the EU agricultural reform, the so-called Agenda 2000, that is to be gradually implemented up to 2006. The reform includes reductions in price support and compensation in the form of hectare and livestock support. NERI believes that these market-oriented measures will only have small albeit positive effects on the environment.

Future activities

In the coming years, NERI will support the work on drawing up an action plan for ammonia and accord higher priority to the development of tools to assess the dispersal and effects of ammonia.

In the first instance the scientists will develop models for the emission, dispersal, deposition and effects of ammonia on the local scale for use in environmental impact assessments etc. In addition, NERI has developed a new model for dispersal and deposition of ammonia and nitrogen oxides that county authorities can use. To describe dispersal and deposition of ammonia at the national level, a new version of the model KONSEKVENS has been developed. The model enables users to study the effects of changes in ammonia emissions at the county and country levels on deposition on the Danish land mass and Danish inner marine waters. In the new version, the user can choose the area for which deposition is to be calculated.

At the national level, NERI and the Danish Institute of Agricultural Sciences are following the development in ammonia emissions from agricultural sources. This work is to be reported in connection with the mid-term evaluation of the Action Plan on the Aquatic Environment II at the end of 2000.



At the end of 1999, NERI and the Danish Institute of Agricultural Sciences published a popular science report "Ammonia in agriculture and nature" based on the main technical report. It explains what damage ammonia causes in nature and what the agricultural sector can do to reduce the emissions.

What is a critical load?

Critical loads are the scientists' best estimate of how sensitive an ecosystem is to air pollution. Since the early 1980s, international conferences have been held on the effects of air pollution on nature. NERI arranged the conference "Critical Loads Copenhagen" held from 21-25 November 1999 under the auspices of the UN-ECE.

The effect of air pollution depends both on the magnitude of loading and on the sensitivity of the ecosystem. The critical load for ammonia is thus lower on sandy ecosystems (e.g. pine forests, heaths) than on nutrient-rich locations (e.g. beech forests, meadows).

Photo: DJF/Jens Petersen

Loss of ammonia from Danish livestock in 1996 (tonnes nitrogen per year). The farmer can reduce ammonia volatilization from livestock manure by minimizing the time that the manure is in contact with the air. This applies to livestock housing, manure heaps, slurry tanks, and during application.

	Stables	Stores	Field application	Grazing animals	Total
Cattle	6,900	7,300	11,800	2,000	28,000
Pigs	16,400	6,400	9,400	0	32,200
Poultry	2,200	2,100	900	0	5,300
Fur animals	3,500	200	300	0	4,000
Horses and sheep	200	100	200	200	700
Total	*29,300*	*16,200*	*22,500*	*2,200*	*70,200*

Green accounts

Photo: NERI/Jens Christian Pedersen

Photo: NERI/Jens Christian Pedersen

In recent years, NERI has taken a number of initiatives to intensify environmental management based on the Institute's environmental action plan. The main emphasis is on the consumption of energy, water and paper, but waste and purchases of chemicals have been included since 1997 and transport was added in 1998.

A study of staff commuting between home and work showed that in 1998, NERI's employees travelled an average of 52 km daily to go to and from work. Two thirds of this transport took place by car. In 1999, NERI followed up this analysis with a transport plan. The aim is to minimize the environmental impact of transport to and from work as well as that of official journeys.

In summer 1999, NERI began construction of an extension to the Roskilde premises to house the Department of Arctic Environment and other activities. Compared with NERI's older buildings the new extension offers a number of environmental improvements such as better control of ventilation, low-energy windows and panelling of wood instead of PVC.

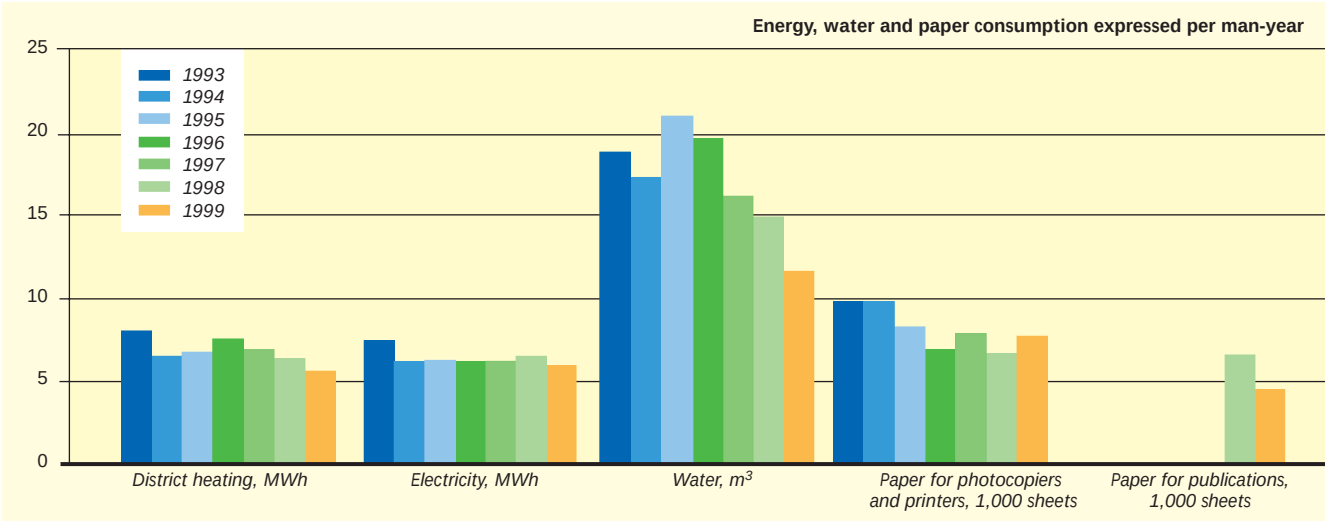
Consumption and trends

The development in NERI's consumption of energy, water and paper is shown in the accompanying figure. More detailed green accounts are included in NERI's annual accounts.

Since 1996, annual consumption of district heating has been reduced by 6-8 percent. Consumption of electricity also fell slightly in 1999, while water consumption has fallen considerably since 1995. These improvements should be seen as the result of concerted efforts to reduce consumption. The relatively large fall in water consumption is partly attributable to conversion to toilets with a small flushing volume and to improvements to the laboratory washing machines.

The consumption of paper for photocopying and printing appears to vary from year to year because it is normally purchased in relatively large quantities. Seen over a longer period, consumption seems to have been roughly constant over the period 1995-99. The paper used is exclusively recycled paper.

Development in NERI's consumption of heat, electricity, water and paper.



Additional paper is consumed by NERI in the form of publications printed externally – at environmentally certified printing firms. NERI expects paper consumption for this purpose to eventually fall due to the increasing number of publications that are exclusively published electronically. Paper consumption for the publication of this annual report has thus been halved by now only publishing the list of staff publications electronically. Moreover, NERI has decided that in future the annual accounts will only be published electronically.

The development in waste generation by NERI is shown in the accompanying table. The amount of combustible waste has increased whereas the trend for the more problematic waste fractions appears to be stable – taking into account the inter-annual variation which is due to marked differences in experimental activity, for example in the pesticides area.

With regard to chemicals NERI is focusing on the substitution of hazardous substances with less hazardous substances. Thus the use of phenol has been replaced by salicylic acid while the use of chromosulphuric acid for cleaning glassware has ceased.

New activities

In the coming year, efforts to enhance environmental management in NERI will concentrate on implementing the above-mentioned transport plan. A first step will be the purchase of software to improve the possibilities for arranging car pooling. In addition, NERI will examine the possibilities for curtailing travel activity between the Institute's various premises, for example by purchasing video conferencing equipment. Finally, NERI will contact the regional transport companies to achieve better public transport service to the Institute's premises.

Photo: NERI/Jens Christian Pedersen

Car pooling. In practice, most employees travel to and from work alone. NERI will now change this by purchasing a database that will make it easier for staff to find someone to travel with.

Ordinary waste	**1997**	**1998**	**1999**
Combustibles	23,855	26,520	34,340
Noncombustibles (landfill)	560	6,680	4,800
Recyclable paper	9,458	10,420	4,900
Recyclable cardboard	4,442	6,240	13,340
Glass	-	300	200
Electronic scrap	350	1,070	560
Maculate	39	100	155
Ordinary waste (total)	*38,704*	*51,330*	*58,295*

Microbiological waste	**1997**	**1998**	**1999**
Microbiological waste (total)	*2,703*	*3,800*	*3,490*

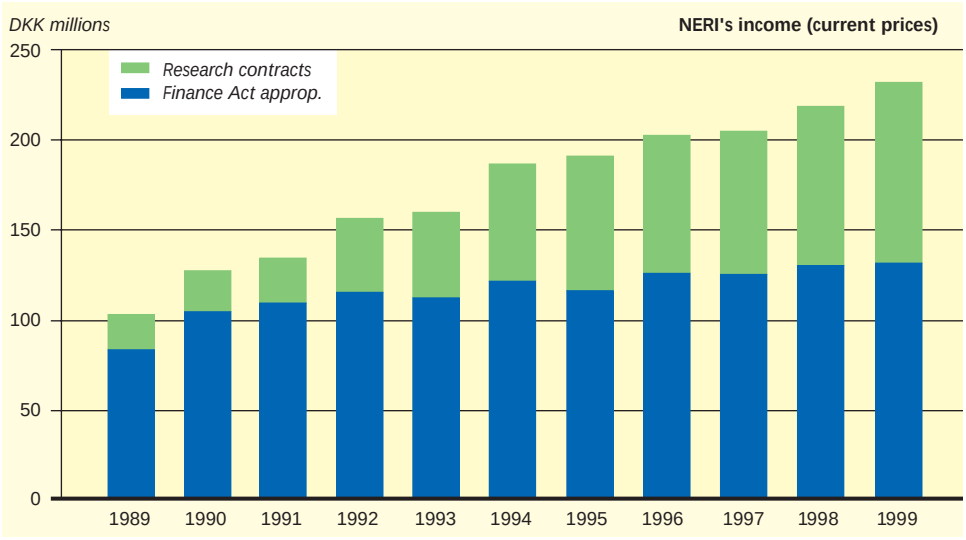
Chemical waste	**1997**	**1998**	**1999**
Mineral oils	28	0	0
Organic chemicals containing halogens or sulphur	354	158	342
Organic solvents lacking halogens or sulphur	718	1,025	854
Organic chemicals lacking halogens or sulphur	1,888	1,070	2,218
Mercury-containing waste	33	26	33
Reactive waste	0	18	0
Pesticide-containing waste	181	3,868	778
Inorganic chemicals	1,257	972	709
Other	1,587	852	2,011
Chemical waste (total)	*6,046*	*7,989*	*6,945*

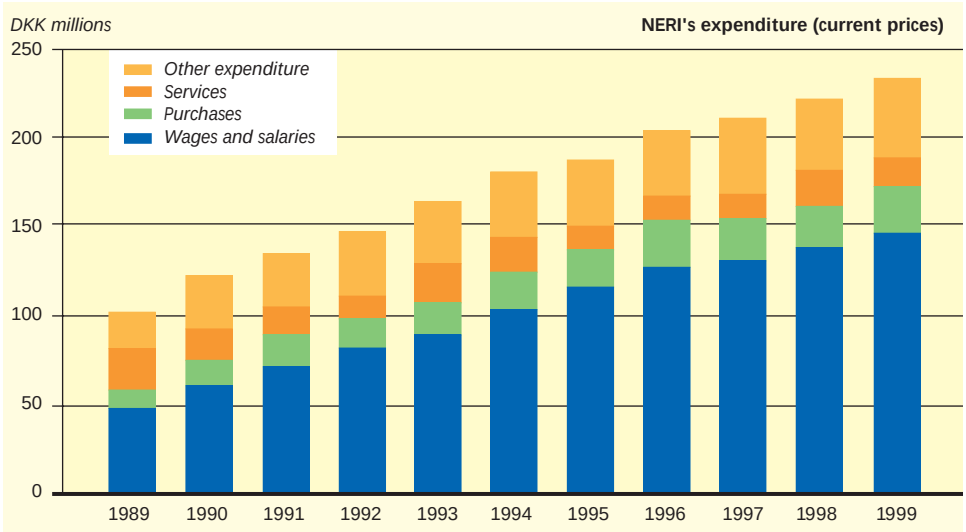
Waste generation by NERI in 1997–1999 (kg).

Economy and personnel

Expressed in real terms, NERI's appropriation under the Danish Finance Act has remained largely constant over the period 1991-2000. It should be noted, however, that the appropriation has only been maintained at this level due to the addition of new tasks and the associated funding. Since NERI's establishment in 1989, external financing in the form of programme and contract research has more than doubled expressed in real terms. In 1999, NERI's appropriation under the Danish Finance Act was DKK 131 million, roughly the same as in 1998. External financing amounted to DKK 102 million, an increase of approximately DKK 12 million. Total operating costs were DKK 231 million, which represents a 5 percent increase relative to 1998.

NERI's staff has grown from 200 man-years in 1989 to 454 man-years at the end of 1999.

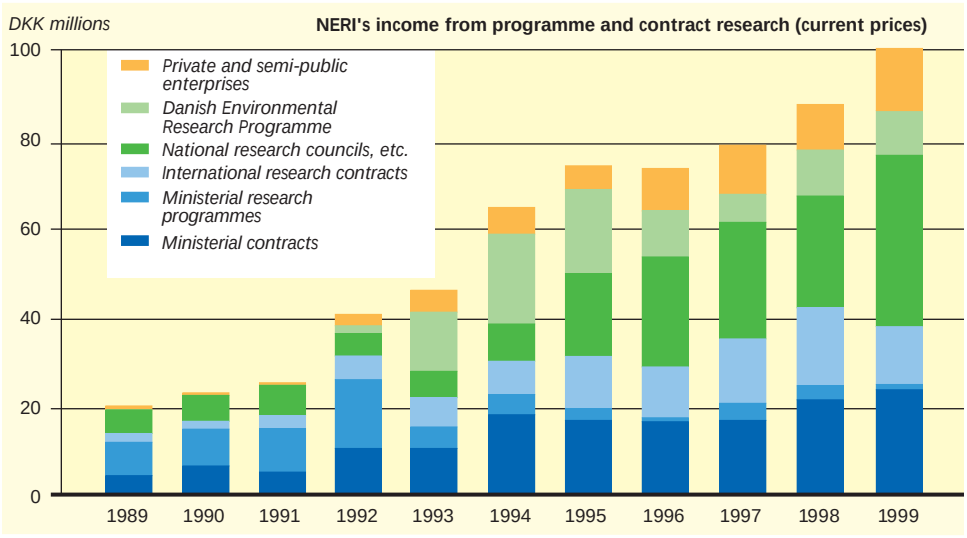




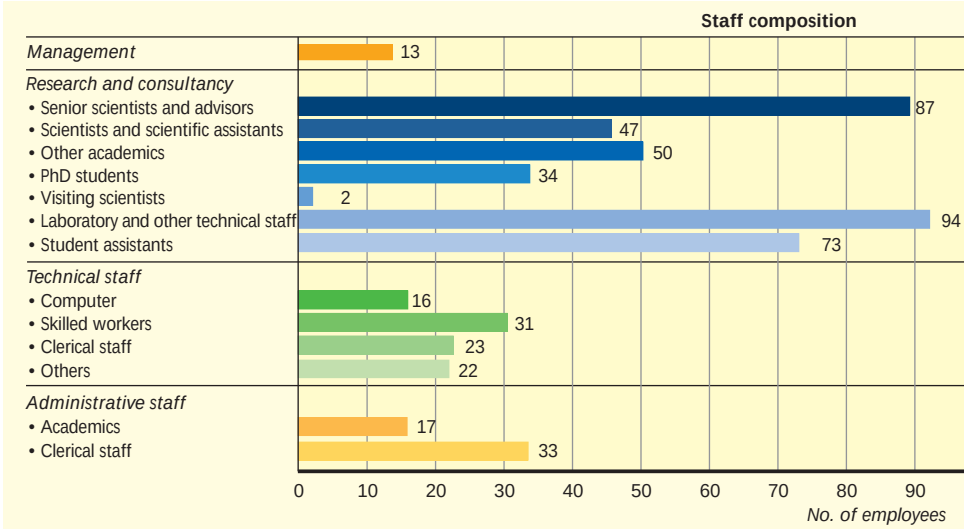
In 1999, NERI's income totalled DKK 233 million, of which DKK 131 million comprised the appropriation under the Danish Finance Act while the remaining DKK 102 million derived from programme and contract research. Total operating costs in 1999 amounted to DKK 231 million, excluding interest and depreciation and expected VAT reimbursements. The budget surplus of DKK 2 million will be carried forward to 2000.

The following obtained the PhD degree in 1999:

- *Christian Glahder*
- *Tove Hels*
- *Jan Juul Jensen*
- *Steen Solvang Jensen*
- *Anders Mosbech*
- *Marianne Bruus Pedersen*
- *Carsten Stenholt*
- *Elisabetta Vignati*
- *Peter J. Aastrup*



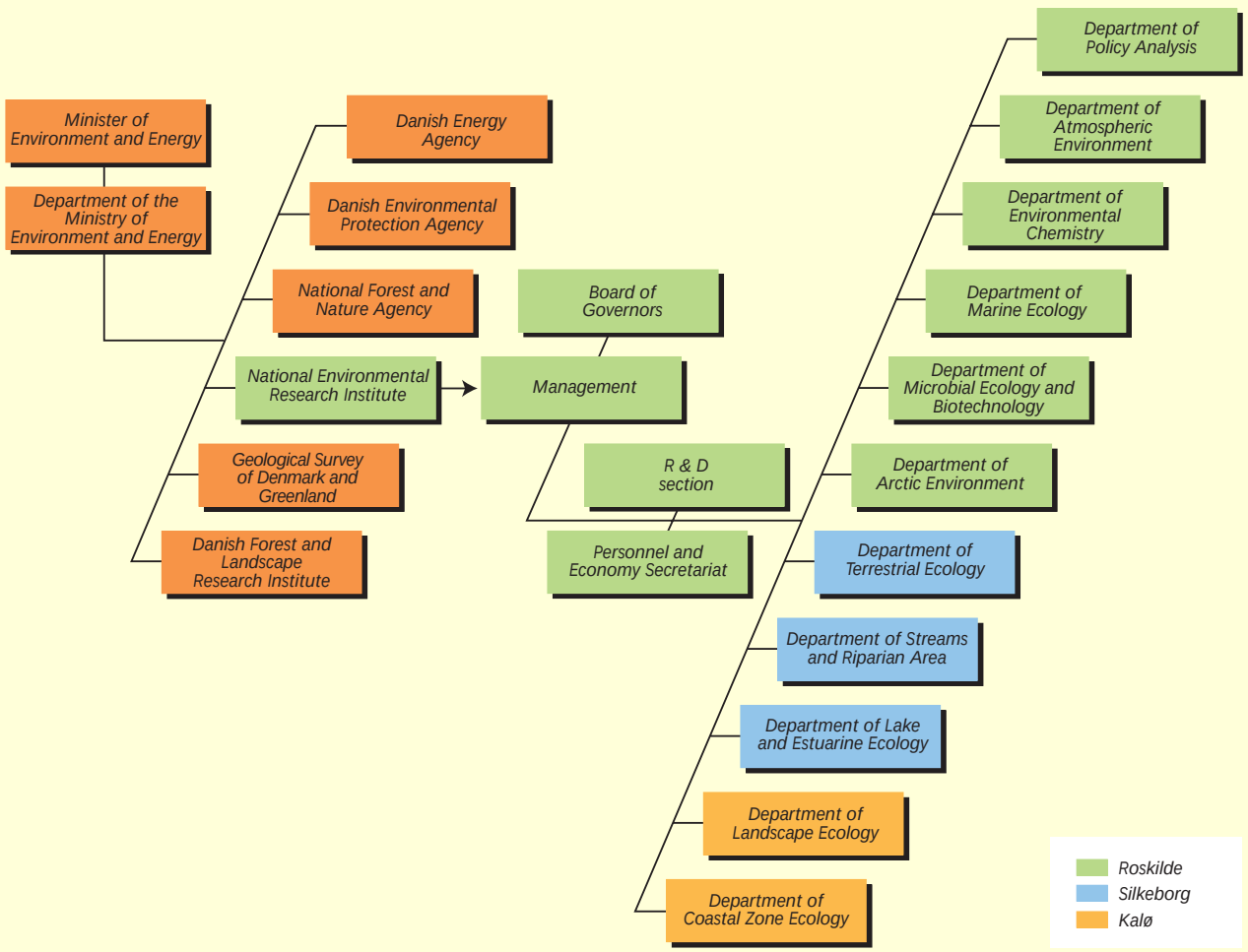
Development in NERI's total income from programme and contract research apportioned by source.



The number of employees as of 31 Dec. 1999. Total manpower in 1999 amounted to 454 man-years.

NERI's structure

NERI is an independent research institute under the Danish Ministry of Environment and Energy. Strategic management is the responsibility of NERI's Board of Governors while day-to-day management is the responsibility of the Director General. The scientific activities are organized under eleven research departments.



NERI's Board of Governors

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Professor
Chairman

Katherine Richardson Christensen
Professor
Aarhus University

Steen Gade
Director General
Danish Environmental Protection Agency

Niels Elmegaard
Academic, NERI

Jytte Heslop
Environmental Director
Aarhus County Council

Henrik Toft Jensen
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Roskilde University

Svend Krarup
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I. Krüger A/S

Anna Lise Mortensen
Environmental Manager
Brdr. Hartmann A/S

Jens Peter Simonsen
Deputy Director General
National Forest and Nature Agency

Birgit Søborg
Technician, NERI

Vibeke Vinten
Head of Division
National Association of Local Authorities in Denmark

NERI's Management

Henrik Sandbech, Director General, MSc
Peter Koefoed Bjørnsen, Deputy Director General, PhD
Torben Moth Iversen, Deputy Director General, MSc

Personnel and Economy Secretariat

Director of Secretariat: Signe Nielsen, BL

Responsibilities: Economy; legal aspects of funding; budgets; legal assistance; personnel management; organizational development; real estate management; records; switchboard; internal service functions.

Department of Policy Analysis

Director of Research Department: Hanne Bach, MSc

Research activities: Analysis of complex environmental problems involving environmental, technological and economic aspects; development of models, methods and tools within the fields of nutrient and organic matter cycling, environmental economics and sector analysis. National Focal Point for Air Emissions. Part of the "Centre for Analysis of Environment, Economy and Society".

Department of Atmospheric Environment

Director of Research Department: Gerald L. Geernaert, PhD

Research activities: Development of meteorological dispersion models; pollutant transformation and deposition; vehicular emissions; charting of air pollution levels; impact of air pollution on forests; greenhouse effect; air pollution in the Arctic; exposure of the general public.

Department of Environmental Chemistry

Director of Research Department: Lars Carlsen, Professor, DSc

Research activities: Investigation, analysis and modelling of the occurrence, transport and fate in the environment of environmentally hazardous substances; analyses for the Danish Environmental Protection Agency; analyses in connection with the Oil Pollution Contingency Task Force; reference laboratory for xenobiotics; development of sampling and analysis methods.

Department of Marine Ecology

Director of Research Department: Bo Riemann, Professor, DSc

Research activities: Environmental monitoring; National Focal Point for Marine Data; studies on marine ecosystem structure and function, eutrophication of marine and estuarine waters, fate and effects of environmentally hazardous substances, biological oceanography, modelling of marine ecosystems and coupling between sediment and the water column.

Department of Microbial Ecology and Biotechnology

Acting Head of Research Department: Niels Kroer, PhD

Research activities: Risk assessment of genetically modified organisms and microbial pesticides; survival, activity and effects of released microorganism; gene dispersal; microbial diversity; microbial remediation of pollution.

Department of Arctic Environment

Director of Research Department: Hanne Petersen, MSc

Research activities: Environmental assessment and monitoring of mineral resource activities in Greenland; baseline studies and analyses of heavy metals; charting of areas of significance for marine and terrestrial mammals and birds; effects of disturbances on the flora and fauna; responsibility for the biological part of the Climate Monitoring Programme at Zackenberg (northeast Greenland).

Department of Terrestrial Ecology

Director of Research Department: Hans Løkke, PhD

Research activities: Investigation of the risks associated with the release of genetically modified plants; organic farming; terrestrial ecotoxicology, including the effects of pesticides and other chemical substances; determination of critical loads; charting of the effects of air pollution on vegetation and sensitive ecosystems.

Department of Streams and Riparian Areas

Acting Head of Research Department: Lars M. Svendsen, PhD

Research activities: Investigation of biological, physical and chemical conditions in watercourses and riparian areas, including stream restoration and development of watershed models; coordination of NERI's activities in relation to the European Environment Agency; National Focal Points for Freshwater Data, Agricultural Catchment Data and Hydrometric Data; European Centre for River Restoration.

Department of Lake and Estuarine Ecology

Director of Research Department: Kurt Nielsen, MSc

Research activities: Investigation of relationships between nutrient turnover and biological structure in freshwater lakes, brackish lakes and estuarine fjords; development of restoration methods; National Focal Points for Freshwater Data and Marine Data; coordination of NERI's remote sensing and GIS activities, including development of an Area Information System (AIS).

Department of Landscape Ecology

Director of Research Department: Jesper Fredshavn, PhD

Research activities: Investigation of the effects of land use and production practices on wild animals and plants in the agricultural landscape; development of methods and models within population and landscape ecology, including remote sensing and telemetry; classification of habitat quality; development of integrated landscape models for describing the quality of the natural environment.

Department of Coastal Zone Ecology

Director of Research Department: Henning Noer, PhD

Research activities: Investigation of coastal water bird populations in relation to human activities; managing international databases for goose and seaduck monitoring data; species and habitat monitoring; development of population ecology models; development of strategies for the exploitation and preservation of coastal zone species and habitats.