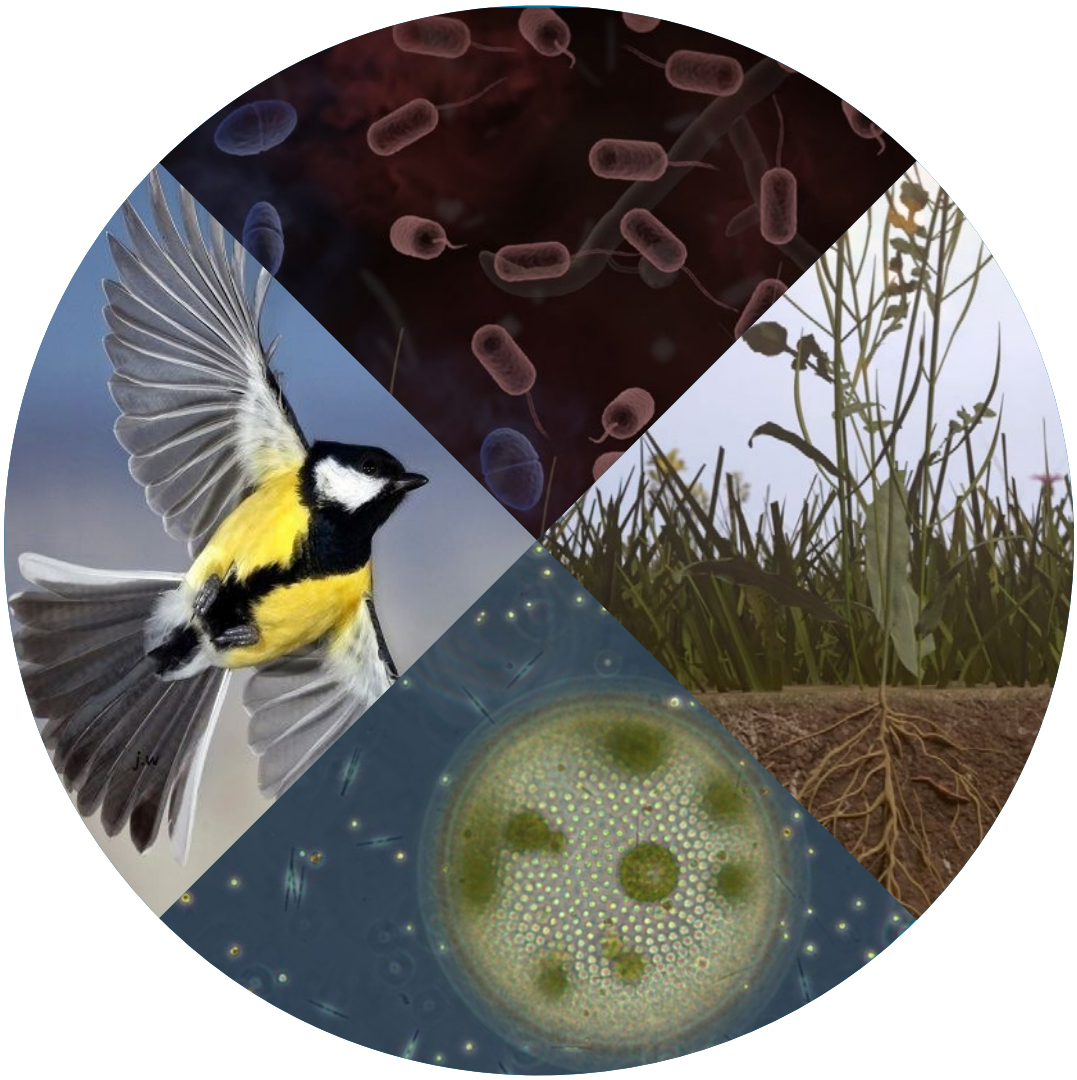
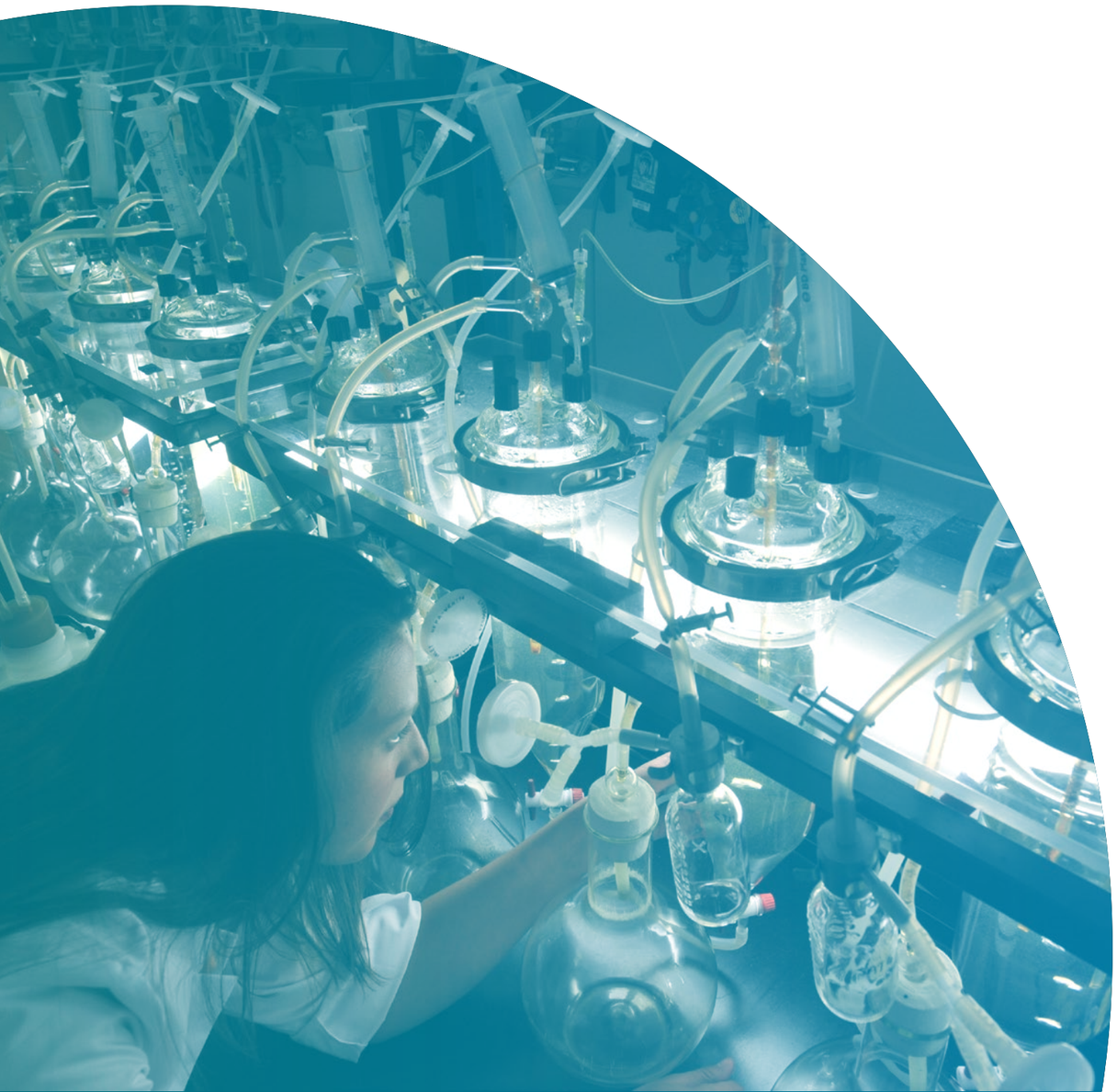
ECOLOGY

the science of the 21st century



Self-evaluation report 2012–2017

NEDERLANDS INSTITUUT VOOR ECOLOGIE (NIOO-KNAW)
NETHERLANDS INSTITUTE OF ECOLOGY (NIOO-KNAW)



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Self-evaluation report 2012–2017

Netherlands Institute of Ecology (NIOO-KNAW)

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Reading guidelines

The main text of the self-evaluation report is on the right-hand pages. On the left-hand pages you will find the associated tables, boxes, pictures and other information. Supplementary documents (e.g. Strategic Plan 2017-2025 and Bibliometric Report CWTS) are available on our dedicated peer-review web page.

CONTENTS

Box 1:

A living building

NIOO's sustainable, well-visited and award-winning building demonstrates the impact of ecology as the science of the 21st century.

It is based on innovative eco-technology and showcases the ecological research carried out within its walls. From green roof to 'golden' toilet, the message is: let's learn from nature!

NIOO's researchers have been working in the new headquarters since 2011, in laboratories and offices surrounded by greenhouses, experimental ponds and a range of other facilities. The NIOO building is also a testing ground for the latest in eco-technology: take for instance the experimental green-blue roof, the innovative application of solar power or the unconventional approach to wastewater treatment.

Our ambition is to close as many different cycles (energy, water, nutrients) as possible. Maximising biodiversity within the grounds is equally important. These things together make up what may be called 'integrated sustainability'. Inspired by ecology, this goes far beyond the usual focus on just one or two individual aspects.

The building is an architectural eye-catcher. One of the most sustainable buildings in the Netherlands, it is often held up as an example. NIOO is happy to share its experiences. In doing so, we remain true to the nature of our scientific institute. We can learn a lot from nature, and with this knowledge we can create a cradle-to-cradle building and work towards a circular economy.

The building, its natural environment and the research within it will meanwhile continue to evolve...

1. Introduction

The Netherlands Institute of Ecology (NIOO-KNAW) has a history that goes back sixty years. It is an 'all-ecologists institute' with research covering animal, plant and microbial ecology in terrestrial and aquatic environments. NIOO's research is well-known for its multidisciplinary, collaborative nature and long-term focus. The institute accommodates about 350 staff and guest researchers (excluding students), making it one of the largest institutes of the Royal Netherlands Academy of Arts and Sciences (KNAW) and home to the largest group of fundamental ecologists in the Netherlands. It has an annual budget of approximately 14 million euros.

The present self-evaluation of NIOO's research activities covers the period 2012–2017. It includes both past and present performance and future plans.

2. Mission, vision and strategy

Mission

NIOO's mission is to carry out groundbreaking fundamental and strategic ecological research in terrestrial and aquatic ecosystems, and make its ecological knowledge available to science and society.

Vision

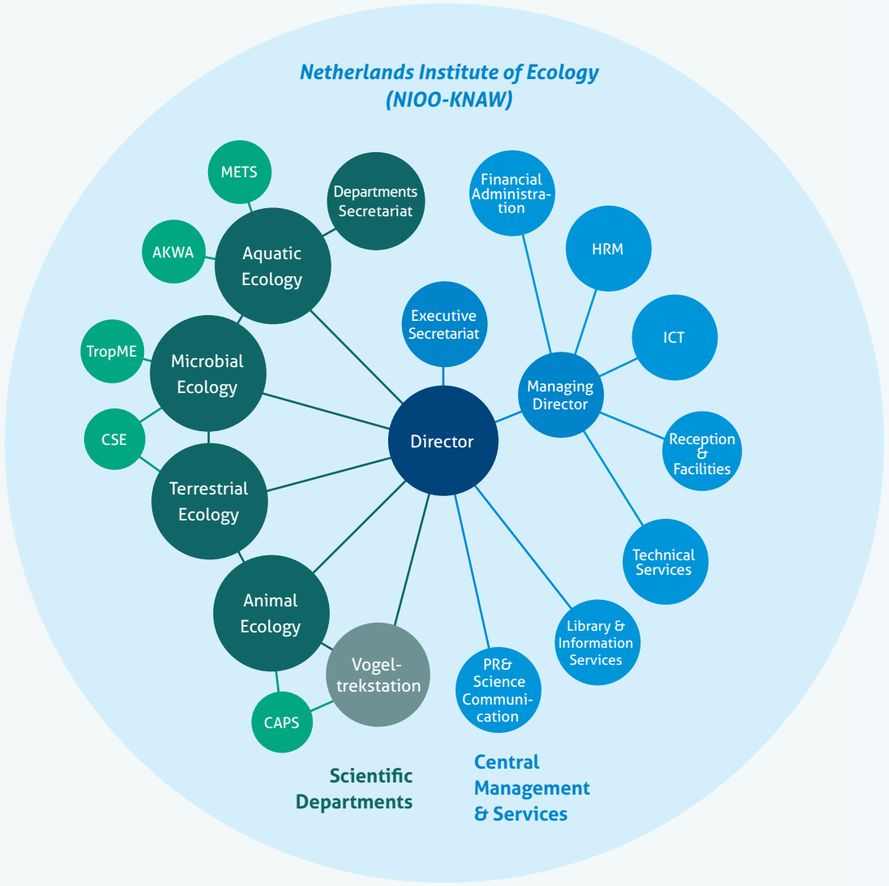
NIOO's aims are to be one of the internationally leading institutes in the fields of ecology and evolution, serve as a national and international hub for these fields, train future generations of nationally and internationally leading scientists in multidisciplinary research and outreach, and actively inform the global scientific community, stakeholders, end-users and citizens about its research.

Strategy

NIOO's strategy for accomplishing these aims is laid out in our Strategic Plan 2017–2025. This plan addresses:

1. Working on timely and interdisciplinary research themes in ecology and evolution that require a long-term approach, with the aim of becoming or remaining world-leading in these themes
2. Having an outstanding output, as reflected in high-impact, high-quality publications
3. Appointing high-quality researchers, technicians and support staff, creating and maintaining state-of-the-art facilities, and providing an open academic working environment
4. Further developing NIOO as an (inter)national ecological hub, by having special professorships at all Dutch universities with ecology in their curriculum, appointing top researchers as our research fellows, being a meeting place for top researchers, and playing an active and instrumental role in (inter)national research agendas
5. Further developing NIOO's role as an international breeding ground for new ecological talent: the place to be for young ecologists, allowing them to develop themselves to the full and move on to (inter)national top positions in science and society
6. Broadly and actively disseminating our ecological knowledge to the global scientific community, stakeholders, end-users and citizens, both NIOO-wide and through units tailored to specific stakeholders

Box 2:
Organisation chart



Vogeltrekstation / Dutch Centre for Avian Migration and Demography: see Box 4
METS, AKWA, TropME, CSE, CAPS: see Box 3

History of NIOO

NIOO originates from three research centres (marine, freshwater, and terrestrial ecology) founded by the KNAW in the 1950s as independent institutes.

These institutes joined forces in 1992 to form NIOO-KNAW, each still at its own location. In 2011, the Centre for Limnology (CL Nieuwersluis) and the Centre for Terrestrial Ecology (CTE Heteren) moved together to a new location in Wageningen.

The six departments of the CL and the CTE were merged into the four present ones. In January 2012, the NIOO Centre for Estuarine and Marine Ecology (CEME Yerseke) was transferred from the KNAW to the Netherlands Organisation for Scientific Research (NWO), and merged with Royal Netherlands Institute for Sea Research (NIOZ) to bolster Dutch sea research.

3. Organisation of the institute

3.1 Structure of the institute

Departments: NIOO has four scientific departments: Animal Ecology (AnE), Aquatic Ecology (AqE), Microbial Ecology (ME), and Terrestrial Ecology (TE). The departmental structure promotes close collaboration between researchers, which makes it possible to tackle more complex ecological questions than would be feasible for any individual researcher to do. In addition, it provides fertile ground for synergy and knowledge transfer, as well as for sharing financial and support resources, social coherence and efficient governance. During the period under evaluation, the role of senior scientists within the departments changed. Senior researchers were given greater responsibilities, which include having their own research group and seeking the most effective collaborations within the institute. A tenure-track system is in place to monitor and evaluate the performance of newly recruited senior scientists. Junior scientists can start their own junior research group when they meet specific criteria that include successful grant applications in peer-reviewed calls for research funding, and supervision of PhD students. Also, the Dutch Centre for Avian Migration & Demography (VT: 'Vogeltrekstation') is an integral part of NIOO, jointly led by NIOO and the 'Ringersvereniging' (see Box 4). For specific niches in research, NIOO has established five initiatives in close collaboration with private partners and societal stakeholders (see Box 3).

Central Management and Services: The operational management and support within NIOO is handled by Central Management & Services (CMS). CMS consists of seven sections: Financial Administration, ICT, Personnel/HRM, PR & Science Communication, Reception & Facilities, Library & Information Services, and Technical Services. In addition, administrative services are provided by the secretaries.

Management: Since 1999, the institute has been headed by director Prof. Dr Louise Vet. She has integral managing responsibility and is accountable to the KNAW. She leads the institute in close collaboration with the managing director (Dr Petra van den Berg) and the four department heads. This Management Team (MT) meets on a regular basis (1.5 hrs every two weeks). The institute's overall policy and research strategy is discussed during so-called Strategic MT meetings (3 hrs every two months).

Scientific Advisory Board: NIOO's Scientific Advisory Board (see photo on page 26), consisting of five international experts from different fields of expertise within ecology, advises the NIOO director on scientific strategy, e.g. through visits (prior to mid-term self-evaluation and Peer Review). Its current members are Rien Aerts (chair), Richard Bardgett, Lars-Anders Hansson, Angela Sessitsch and Ben Sheldon.

Works Council: The institute has an active works council (OC), which conducts a constructive dialogue with the management on behalf of all personnel.

Table 1 Research and other staff

For research staff, numbers represent time dedicated to research: PhD students 85%, senior scientists, tenure trackers and postdocs 90%, heads of department 80%, director 70%. FTE input of technicians and support staff is based on 100% of their employment. For more details about the number of PhD students, see Table 9.

FTE	2012	2013	2014	2015	2016	2017
Scientific staff	16.70	19.00	22.20	21.18	22.58	18.75
Postdocs	38.80	34.80	41.60	31.57	33.66	30.00
PhD students	32.50	32.60	49.90	45.80	49.99	43.39
Total research staff	**88.00**	**86.40**	**113.70**	**98.55**	**106.23**	**92.14**
Technicians	31.50	29.70	32.65	31.81	36.14	29.16
Support staff	30.90	28.70	31.95	32.53	33.47	31.30
Visiting fellows	9.60	2.20	2.50	9.52	5.35	3.67
Total staff	**160.00**	**147.00**	**180.80**	**172.41**	**181.19**	**156.27**

Table 2a & 2b Funding: FTE & expenditure

Staff (in FTE) and expenditure (in k euros). FTEs and expenditure of personnel that is not employed at NIOO but works on a personal grant are excluded.

Table 2a	2012		2013		2014	
Funding	FTE	%	FTE	%	FTE	%
1 Direct funding (KNAW/NIOO)	38.43	43.70%	44.78	48.90%	45.34	40.60%
2 Research grants	26.54	30.20%	21.12	23.10%	28.01	25.10%
3 Contract research	21.29	24.20%	20.63	22.50%	31.45	28.20%
4 Other	1.64	1.90%	5.07	5.50%	6.85	6.10%
Total funding	87.9	100%	91.6	100%	111.65	100%
	2015		**2016**		**2017**	
Funding	FTE	%	FTE	%	FTE	%
1 Direct funding (KNAW/NIOO)	49.19	46.60%	51.81	44.80%	45.68	44.80%
2 Research grants	24.47	23.20%	32.99	28.50%	32.56	31.90%
3 Contract research	28.52	27.00%	26.85	23.20%	19.92	19.50%
4 Other	3.33	3.20%	3.95	3.40%	3.76	3.70%
Total funding	105.51	100%	115.6	100%	101.92	100%

Table 2b	2012		2013		2014	
Expenditure	k €	%	k €	%	k €	%
Personnel costs	8,468.60	71.90%	9,403.80	70.20%	10,281.30	65.80%
Other costs	3,310.30	28.10%	3,997.20	29.80%	5,338.30	34.20%
Total expenditure	11,778.90	100%	13,401.00	100%	15,619.60	100%
	2015		**2016**		**2017**	
Expenditure	k €	%	k €	%	k €	%
Personnel costs	10,056.70	72.70%	10,143.14	72.30%	10,346.33	73.00%
Other costs	3,774.20	27.30%	3,890.03	27.70%	3,818.20	27.00%
Total expenditure	13,830.90	100%	14,033.17	100%	14,164.53	100%

3.2 Research staff

The FTE input of NIOO's research staff is quantified in Table 1. Staff numbers increased over the period 2012–2017. In 2014, this trend reached an unprecedented peak as a result of the large number of projects. More particularly, there was a peak in the number of postdocs employed. Fluctuations in scientific staff numbers are mainly due to overlap between retiring staff and their successors. We discuss the increase in the number of PhD students in Chapter 9: *The next generation*. NIOO has a ratio of technicians to research staff of 1:3. We greatly value the technicians, as they play a crucial role in the development and standardisation of techniques that in ecology are often labour-intensive. Furthermore, they play an important role in our ambition to be an international hub in ecological and evolutionary research, as the technicians are indispensable for providing practical training and assistance to NIOO's many international postdocs and PhD students.

In addition to the formal scientific fellows, NIOO has welcomed a large number of temporary guests from a wide variety of countries.

3.3 Funding / earning capacity

NIOO researchers have proved successful at obtaining prestigious personal grants, both national (NWO: Veni, Vidi, Vici) and international: from the EU (ERC-Advanced, Marie Curie Grants), the USA (NSF), and other nations (e.g. Chinese CSC, Brazilian FAPESP, CNPq & CAPES Science w/o Borders, South Korean, German and Colombian national funding schemes). NIOO will continue to encourage and support the efforts of researchers, both internal and external, to obtain such grants for the purpose of developing their own lines of research that will further the institute's research goals. NIOO also receives substantial grants from a diversity of national and international programmes and other sources. Examples are BE-Basic, the Dutch government's 'Top sectors' initiative, NWO-TTW (formerly STW) and the Bill & Melinda Gates Foundation, as well as several competitive EU-funded programmes in which the institute participates and/or which it coordinates. A number of these grants include public-private partnerships.

NIOO's aim since 2014 has been to obtain around 5.25 million euros annually from external sources of research funding. This should be feasible for the coming years by attracting funding from national and international research organisations such as NWO and the EU, as well as from public–private partnerships and direct collaborations with industry and private sector organisations. NIOO also seeks to attract more funding for fundamental research from international research sponsors and charity funds. In 2017, NIOO adopted a new external funding strategy for the purpose of maintaining the high level of external funding through further diversifying funding sources (i.e. in the European and the public-private domain).

Box 3

For five specific niches in research, NIOO has established initiatives together with private partners and societal stakeholders:

Aquatic Knowledge centre WAgeningen (AKWA)
AKWA is a NIOO initiative together with Wageningen University and Research, serving stakeholders such as water boards. It translates state-of-the art scientific knowledge into practical solutions for water issues and offers advice, research and training in the field of water quality and functioning of aquatic ecosystems. AKWA has increased environmental awareness and literacy through peer-reviewed publications and professional reports, online films, digital games, festivals, and media appearances.

Centre for Soil Ecology (CSE)
The Centre for Soil Ecology is a virtual centre set up by NIOO and the Environmental Sciences and Plant Sciences groups from Wageningen University and Research. NIOO took the lead in founding the Centre, which brings together the largest group of soil ecologists in a single place anywhere in the world. The Centre consists of a day-to-day board, a coordinator and members. It aims to attract multidisciplinary research projects, set research agendas, train young soil ecologists and interact with end-users and stakeholders.

Tropical Microbial Ecology (TropME)
Tropical Microbial Ecology aims to disentangle microbial communities in order to understand the functioning of tropical soil ecosystems. Microbial 'omics', bioinformatics and modelling are integrated to make better predictions about the impact of climate change, deforestation, agroforestry and agriculture on tropical soil ecosystem functioning. The results are translated into practical solutions for stakeholders, including mitigation of greenhouse gases, restoration of degraded land and sustainable strategies for crop production.

Microalgae Eco-Technological Solutions (METS)
Taking its cue from the building's innovative, decentralised sanitation system, NIOO has established an interdisciplinary line of research on sustainable and ecologically-based wastewater treatment. METS connects environmental technology with ecology and working with a diversity of stakeholders in national and international projects. The scientific focus is on mechanisms and potential of microalgae for wastewater treatment, nutrient recovery and removal of micro-pollutants such as pharmaceuticals.

Centre for Avian Population Studies (CAPS)
The Centre for Avian Population Studies was founded by five academic and non-governmental organisations in the Netherlands. The objective of CAPS is to carry out and promote research into demography and determining factors in population dynamics of birds. The resulting knowledge aids the management and protection of bird populations, and it is currently being implemented for geese, swans and oystercatchers.

4. Research expertise and future research goals

The study of complex ecological systems requires an integral research approach. This involves linking processes at different levels of biological organisation from genome to ecosystem, connecting ecological and evolutionary processes in time and space, building theoretical models to explain and predict ecological change, integrating mechanistic and evolutionary approaches, investing in and using long-term datasets, new analytical and experimental tools and – last but not least – having high-quality research teams and a first-rate infrastructure. NIOO meets all these requirements.

In 2016, the NIOO management defined seven themes (see Chapter 4.1) that address topical areas in ecology in which we aim to play an internationally important and nationally connecting role. These themes form an important instrument for successfully carrying out our mission: they direct NIOO research towards those areas where we want to become, or remain, internationally leading, and where NIOO brings in the ecological angle. Being an 'all-ecologists institute', NIOO is extremely well-placed to address these areas, as it can combine the strengths of its departments through these themes. Increased cross-departmental collaboration gives the themes further momentum.

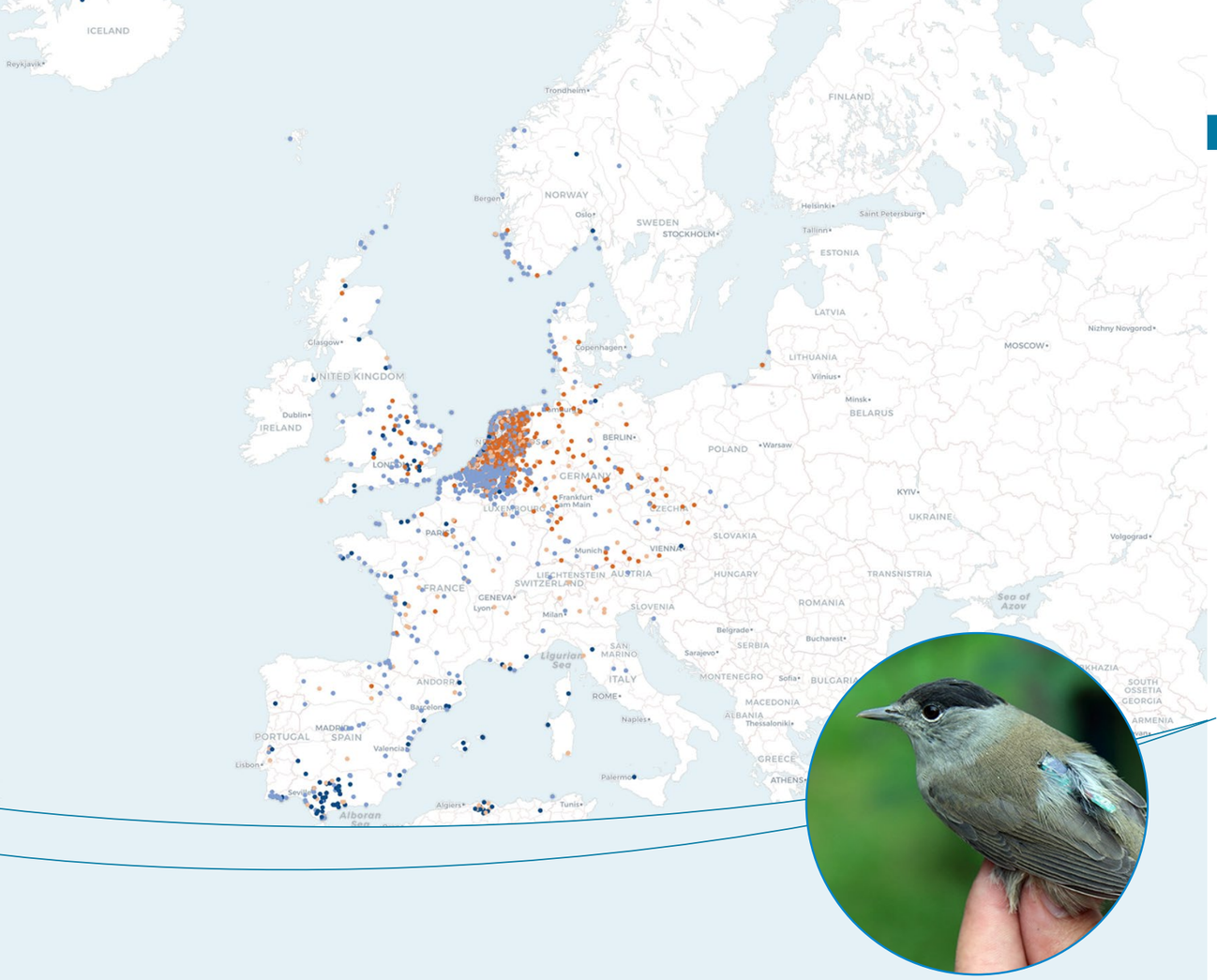
Once the themes had been defined, they were developed further through bottom-up interactions. They have already created a highly creative cross-discipline atmosphere, with several new research projects. The themes are coordinated by senior researchers, contributing to the empowerment of this important and talented group within NIOO. The themes will be evaluated in a three-year cycle, in which existing themes can be continued, discontinued or merged and new themes can be initiated. The additional flexibility this provides will help NIOO research shape the (inter)national ecological landscape. Criteria for the evaluation of the themes are the contribution they can be demonstrated or expected to make to international research, and the extent to which they foster strong cross-departmental collaborations. Finally, NIOO's strategic investments are used for exploring promising new lines of research within the themes.

Over the coming years, the research areas of the departments will continue to be the basis for NIOO's research, contributing their unique strengths to the themes. Below, we first briefly introduce each of the themes and its objectives (more in-depth descriptions of the themes can be found in our Strategic Plan). Next, we present the research areas of the departments including their future research goals.

4.1 Research themes

1. Global environmental change: All biomes of the world are increasingly influenced by global environmental changes, such as altered land and water use, atmospheric composition, climate, and urbanisation. Our key challenge is to enhance understanding of how global changes influence ecological interactions, and how this alters densities and distributions of species, functioning of ecosystems and the sustainable delivery of ecosystem services and goods.

2. Eco-evolutionary dynamics: Ecology and evolution have classically developed along separate research lines, with one line focusing on shorter and the other on longer term processes, but there is now growing evidence that evolution can also operate on shorter time scales. Our key challenge is to assess the role of evolution in ecological interactions and processes involving micro-, meso- and macro-organisms, in order to understand better how these processes influence the capacity of species to respond to changes in their (a)biotic environments.



Box 4

Vogeltrekstation (VT) – Dutch Centre for Avian Migration and Demography

VT is jointly led by NIOO and the 'Ringers-vereniging', and facilitates scientific bird ringing in the Netherlands. VT issues ringing permits and metal bird rings, and manages all ringing and re-encounter data. Most of the close to 600 bird ringers are volunteers (citizen scientists), who work within a number of standardised ringing projects aimed at gathering information on avian population-dynamic processes, movements and the spread of zoonotic diseases. VT aims to understand important drivers of population change in order to identify causes of species decline or expansion, develop early-warning systems as a tool for conservation, and study the effects of global warming on bird population dynamics using integrated population modelling and other tools. To this end, VT uses a variety of tracking techniques to study habitat use, carry-over effects, migratory connectivity and migration ecology for a variety of bird species. Currently, VT is developing a bird migration atlas (www.vogeltrekatlas.nl) which makes detailed information on bird movements based on ringing data available for interactive online viewing. In collaboration with Erasmus Medical Center (Rotterdam), VT studies the role of wild birds in the spread of avian influenza, and the transmission of arboviruses by migrant passerine birds – in particular the Usutu virus.

3. Ecological epigenetics: The classic view in evolution is that all selectable variation derives from DNA sequence, but recent studies show that heritable variation can be based as well on reversible – epigenetic - variation. Our key challenge is to assess the adaptive relevance of epigenetics to the ecology and evolution of species, and especially the role of epigenetics in interactions of species with their (a)biotic environments, in a variety of species with respect to their ecological traits.

4. Microbiomes: Microbiomes are the collective communities of microbes, their (meta)genomes, and their interactions in a particular environment. Our key challenges are to unravel the processes and mechanisms involved in microbiome diversity and assembly, and to elucidate the impact of microbiomes on the functioning of their hosts (e.g. algae, plants, insects, invertebrates, fish, birds) in natural and managed ecosystems.

5. Chemical communication: Chemical compounds released by organisms into their environment can be used as signals (infochemicals) by other organisms in food webs via sensing and processing of information, and chemical communication plays a major role underlying the functioning of food webs. Our key challenge is to understand how the exchange of chemical information shapes biotic interactions and the evolution of species in aquatic and terrestrial ecosystems.

6. Disease ecology: Disease ecology is an emerging interdisciplinary field of research that explores the spatiotemporal dynamics and evolution of diseases (e.g. viral, bacterial, fungal) in natural and managed ecosystems. Our challenges are to identify (a)biotic factors involved in the emergence and persistence of diseases in relation to the diversity of ecosystems, and to assess the impact of diseases on the reproduction and survival of their hosts, in order to understand and predict the impact of environmental disturbances on the distribution and dynamics of infectious diseases.

7. Restoration ecology: Attempts to restore former terrestrial and aquatic ecosystems after disturbances are often time-consuming and expensive, and many attempts fail because the original situation cannot be restored or because the restored state cannot be maintained. Our key challenge is to use basic insights emerging from studies on interactions of species with their (a)biotic environments for the restoration or creation of ecosystems to the point where they reach the desired target state. An important offshoot is improving the sustainable management of ecosystems used for agri-, horti-, and aquaculture.

4.2. Research expertise & future goals of the departments

The research of each of the departments is characterised by close collaborations, shared facilities and long-term datasets. Each department significantly contributes to several, if not all, of the NIOO-wide themes.

Department of Animal Ecology (AnE)

AnE has as its unifying theme of research the evolutionary and population ecology of animals. The department's research is aimed at understanding the causes and consequences of variation in life-history traits, including the underlying genomic mechanisms, as well as the variation in time and space of population numbers and population composition. AnE research aims to integrate processes at the level of genes, physiology, behaviour and the population, within an evolutionary framework. Much of the research takes anthropogenic changes explicitly into account, such as adaptation to climate change, the impact of climate extremes, effects of urbanisation and changes in land-use.

Scientific Highlight I:

How microbial soil life suppresses diseases

We have demonstrated that the characteristics of natural disease suppressiveness of soils are remarkably comparable to those described for innate and adaptive immunity in animals[1-3]. General suppressiveness of soils and innate immunity in animals both provide a first basal, non-specific line of defence against invading pathogens. Both the adaptive immune response in animals and specific suppressiveness of soils require time to react to the invading pathogen, are specific to that pathogen and have their own memory. Specific suppressiveness of soils is mechanistically complex, requiring enrichment and activation of microbial consortia[1,3] and antagonistic traits, in particular antifungal peptides and volatile organic compounds[4,5].

[1] *ISME Journal* 2016, 10: 265-268
[2] *Science* 2016, 352: 1392-1393
[3] *Ecology Letters* 2016, 19: 375-382
[4] *Trends in Microbiology* 2017, 25: 280-292
[5] *Ecology* 2015, 96 (8): 2042-2048

Scientific Highlight II:

Global change impacts on aquatic food webs

Global change will affect a multitude of factors acting on aquatic food web interactions, with consequences for ecosystem structure and functioning. With our unique experimental 'cosms', we have demonstrated how global change affects the elemental balance of phytoplankton[1] and the consequences for higher trophic levels including zooplankton[2] and parasitism[3]. We have furthermore shown how changes in nutrient loading alter food web interaction strengths[4] that precede catastrophic shifts in the whole ecosystem[5]. Through a combination of experimental and modelling approaches, we have vastly improved our ability to predict the impacts of global change on aquatic food webs.

[1] *Ecology* 2014, 95 (6): 1485-1495
[2] *Ecology Letters* 2015, 18 (6): 553-562
[3] *Global Change Biology* 2016, 22 (1): 299-309
[4] *Ecology* 2013, 94 (8): 1776: 1784
[5] *Nature Communications* 2015, 6: 7727

The department's research has two main objectives, which are ultimately to be integrated. In our evolutionary research, the dot on the research horizon is the transition from understanding to predicting evolution, not only for great tits (laying date; beak size) but also for winter moths and nematodes (the latter in close collaboration with our Origins Center partners, where predicting evolution is one of the 'game changers'). This will involve understanding the genotype-phenotype map, with an emphasis on the role of methylation and on the drivers of selection. To predict these, we will focus on the role of climate extremes and human induced selection (climate change and land use change). In our ecological research we will focus on forecasting population trends using integrated population models (for geese and oystercatchers, in collaboration with CAPS partners), with an emphasis on Arctic systems (for geese and swans). Our greatest challenge is to connect evolutionary and ecological dynamics for a better understanding of the population consequences of anthropogenic effects, taking evolution into account.

Department of Aquatic Ecology (AqE)

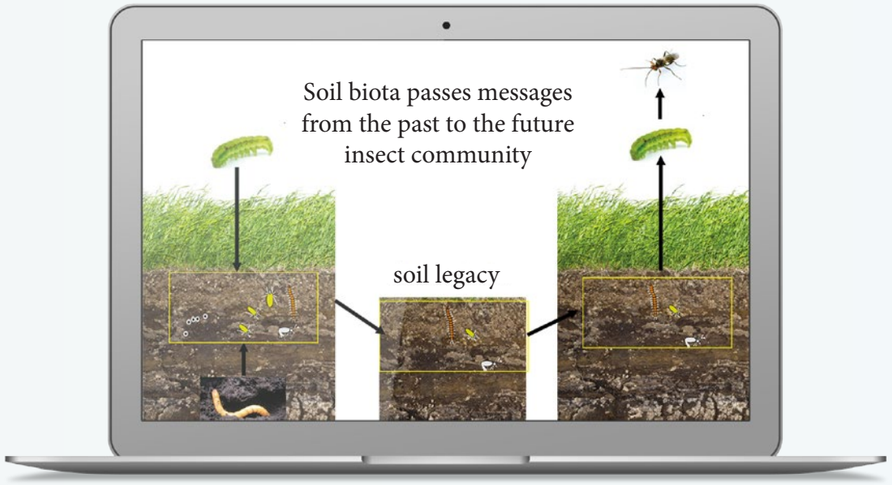
AqE aims to elucidate how ecological mechanisms, eco-evolutionary processes and abiotic factors govern the dynamics and structure of aquatic food webs. AqE emphasizes the importance of curiosity-driven research, while at the same time acknowledging the demand from society for scientific input for nature conservation and ecosystem restoration. Strategic research provides opportunities for testing research hypotheses at ecosystem level, and for exploiting knowledge for applications useful to society. AqE's main research areas are the impact of eutrophication and climate change on freshwater ecosystems, the importance of biodiversity for ecosystem resilience, and the restoration of ecosystem services.

Future AqE research will include studying the combined effects of changes in climate, nutrient regimes and land-use. These studies have strong links with our work on restoration ecology, aimed at understanding and remedying the negative consequences of global change for aquatic ecosystem functioning. It is important to know to what extent rapid evolutionary trait changes of populations, in response to global change, alter the trajectory of ecological dynamics. AqE will study the adaptive potential of plankton populations, its context dependency and its underlying drivers, as well as the potential ecological consequences. Building on our extensive expertise in chemical communication, AqE plans to study the impact of pharmaceutical disruptors on natural information flows in aquatic ecosystems. Finally, AqE aims to elucidate the importance of plankton pathogens, an often-overlooked ecological driving force in aquatic food web dynamics.

Department of Microbial Ecology (ME)

ME studies the ecology, diversity and functions of microorganisms in natural and man-made ecosystems, including native plant habitats, agriculture and aquaculture. The department's main research areas include biogeochemical cycling and greenhouse gas emissions, intra- and interspecific interactions and chemical communication, evolution of bacterial communities and plant viruses, and microbiome assembly and functioning in temperate and tropical ecosystems. By learning from nature, ME aims to provide novel and sustainable strategies for restoring key ecosystem processes and controlling major problems associated with human impact on the environment.

Present and future ME research will further disentangle the fundamental mechanisms underlying microbial community assembly and intra- and interspecific interactions in different ecosystems. The communities studied are both natural and synthetic, comprising bacteria, archaea, fungi, viruses and protists. To link microbial taxonomy and traits to functions, ME will adopt cut-



Scientific Highlight III:

Legacy effects of plant-soil feedbacks influence aboveground interactions

Plant-soil biota interactions strongly influence plant defences aboveground through historical legacy effects[1]. Feeding by aboveground and belowground insect herbivores on ragwort (Jacobaea vulgaris) plants exerts unique soil legacy effects, via herbivore-induced changes in the composition of soil fungi. These changes in the soil biota induced by aboveground and belowground herbivores of preceding plants greatly influence the pyrrolizidine alkaloid content, biomass and aboveground multitrophic interactions of succeeding plants. Therefore, plant-mediated interactions between aboveground and belowground insects are also important when they do not feed simultaneously on the same plant[2]. This work has opened new avenues for future research, e.g. to unravel how aboveground-belowground defences interact with plant diversity and plant quality[3], how they trade off[4] and evolve[5].

[1] *Journal of Ecology* 2013, 101 (2): 325-333
[2] *Ecology Letters* 2012, 15 (8): 813-821
[3] *Journal of Ecology* 2017, 105 (3): 647-660
[4] *Nature* 2017, 543 (7645): 337-345
[5] *Frontiers in Plant Science* 2013, 4: 431

ting-edge technologies (omics/post-omics, advanced analytical chemistry, imaging) in order to gain unprecedented insight into microbial community functioning in situ. These new directions will, in public-private partnerships, provide a strong basis for the development of new sustainable strategies for agriculture, aquaculture and nature restoration.

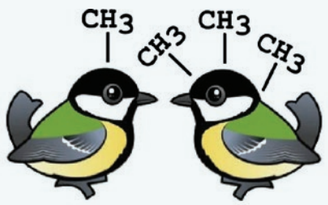
Department of Terrestrial Ecology (TE)
TE studies species, their interactions, and the consequences for community composition and ecosystem functioning in terrestrial ecosystems under global change. Research is performed from an aboveground-belowground, multitrophic interactions perspective in order to understand how ecosystems function and develop under (human-induced) changes in climate and land use, and biological invasions. TE uses an empirical approach, both from ecological and evolutionary perspectives, to develop and test novel concepts and theories. This fundamental knowledge contributes to sustainable management of terrestrial ecosystems with emphasis on nature restoration, biodiversity conservation, controlling invasions, and ecological-intensive agriculture.

The composition and functioning of terrestrial ecosystems are determined by complex aboveground and belowground interactions of factors that operate on a variety of spatial and temporal scales. To further unravel these complex processes, in our future work we will link mechanism-based understanding of aboveground-belowground interactions to processes and patterns occurring from local to larger spatial (ecosystems/continents) and from current to longer temporal (years/decades and longer) scales. Our research approaches will range from making analyses at molecular level to assessing the driving forces of community interactions and quantifying consequences for flows and fluxes of carbon and nutrients on a global scale. This will enable us to break new ground in understanding how aboveground-belowground interactions influence the composition and functioning of natural communities and ecosystems. The results we envisage will provide innovative contributions to science, and explore avenues towards a more sustainable society.

Scientific Highlight IV:

Epigenetics affects animal personality

Evolution by natural selection strongly depends on genetic variation. In contrast to nucleotide mutations, epigenetic mutations also depend on environmental changes. In the great tit (Parus major), DNA methylation levels vary among individuals, tissues and gene classes[1]. Our recent work demonstrates that historical selection is associated with methylation patterns[2], suggesting an important role for DNA methylation in vertebrate evolution. On a shorter time-scale, selection lines for personality differ in gene promoter methylation levels[3]. Hence, we show that DNA methylation is associated with genetic variation. This lays the basis for studying epigenetic mechanisms in eco-evolutionary context, and alters our ideas about how epigenetic mechanisms are involved in the evolution of trait variation.



[1] *BMC Genomics* 2016, 17: 332
[2] *Nature Communications* 2016, 7: 10474
[3] *Molecular Ecology* 2016, 25 (8): 1801-1811

5. National and international position

5.1 National hub in ecology

To understand the complex nature of ecology, NIOO takes an integral research approach, enabled by its in-house diversity of ecological disciplines, from genome to ecosystem and covering different habitats. Our unique multi-disciplinary expertise and advanced facilities place NIOO at the centre of national and international ecological science. Many (inter)national visiting scientists are attracted by our intellectual climate and research facilities. Several outstanding university scientists are research fellows at NIOO, and we are successfully attracting collaborators, visitors (on NWO or KNAW visiting professorship programmes) and graduate students.

NIOO collaborates closely with ecological research groups at all Dutch universities with ecology in their curriculum, especially through invited professorships in Wageningen (5), Utrecht (2), Leiden (3), Groningen (1) and Amsterdam (1 VU, 1 UvA). Through these special professorships, and membership of Graduate Schools (EPS, PE&RC), NIOO also contributes to MSc and PhD teaching programmes.

NIOO staff serve on national funding boards and programme committees, influencing the research agenda for the field of ecology as a whole. NIOO's position as a national hub in ecology is further strengthened by the collaborative centres NIOO has initiated, such as the Centre for Soil Ecology (CSE), Centre for Avian Population Studies (CAPS) and Centre for Wetland Ecology (CWE). NIOO is also coordinating the platform for ecological restoration of lakes (PEHM), which implements EU guidelines on ecological restoration.

NIOO has played a pivotal role in the establishment of the National Science Agenda (NWA). The NWA is the result of a unique bottom-up initiative, driven by the general Dutch public and a large number of organisations in the Netherlands. Right from the start, NIOO was actively involved in structuring and defining the agenda for all nature- and ecology-related areas. NIOO's director Louise Vet acts as a figurehead for one of the 'routes' defined by the NWA: 'The origin of life – on Earth and Elsewhere'. NIOO also plays a key role in shaping a new virtual research centre that has resulted from this 'route': the Origins Center, which aims to facilitate the route's highly interdisciplinary research. Several NIOO scientists play an important role in five of the other NWA routes: Smart liveable cities, Circular economy and resource efficiency, Sustainable food production, Environmental quality, and Water, as well as in attendant initiatives such as Nature4Life, an initiative of the Netherlands Ecological Research Network (NERN) and NecoV (Dutch-Flemish Ecological Society).

NIOO's director Louise Vet has co-founded and chairs NERN, while department head Marcel Visser has co-founded and chairs the newly founded Netherlands Society for Evolutionary Biology (NLSEB). NERN is a platform for Dutch ecologically-oriented graduate schools, universities and institutes. It organises the Netherlands Annual Ecology Meeting, a highly appreciated two-day event that brings all Dutch ecologists together, and it coordinates and oversees national PhD courses for ecologists.

5.2 International hub in ecology

NIOO scientists are at the forefront of a wide range of international research projects and networks on topics such as soil, water, climate and bio-based, collaborating with international and Dutch universities, research centres, governmental organisations, companies and other stakeholders within the EU and elsewhere (e.g. South America, China, India, Indonesia and Africa).

NIOO has been involved in, and has been leading, a vast number of *European* research (and training) projects and is currently coordinator of an EU-RTN (Marie Curie Research Training Network) on Plant Epigenetics and an EU-COST action on microbe-induced resistance to agricultural pests. NIOO is on the steering committees of two AKWA H2020 EU projects. The Aquacosm project involves a network of European AQUAtic MesoCOSM Facilities with 21 partners, where mesocosm research in marine, estuarine, and freshwater aquatic ecosystems is being synchronised. The MANTEL project is aimed at managing extreme climatic events in lakes and protecting ecosystem services, in close collaboration with stakeholders.

NIOO scientists are also at the forefront of several *global* networks, e.g. the Global Lake Ecological Observatory Network: a grassroots network of limnologists, ecologists, information technology experts and engineers, whose shared goal is to build a scalable, persistent network of lake ecology observatories. NIOO is co-founder of the Global Soil Biodiversity Initiative, which is consulted by large international institutions such as the FAO, the Convention of Biological Diversity, IPBES, etc., resulting in – among other things – Global Soil Biodiversity Assessments and the European and Global Soil Biodiversity Atlases, all aimed at informing the global society about the value of soil biodiversity. NIOO is co-founder of LTER-Netherlands (Long Term Ecosystem Research), with the Veluwe area – where much of NIOO's long-term NIOO research takes place – as one of the key LTER-NL sites since 2015. Recently, NIOO joined a global network project (NutNet) to study the effects of nutrients and grazing on biodiversity and ecosystem functioning. NIOO is increasingly using the power of Global Big Data, demonstrated by several high impact papers, e.g. on the release of huge amounts of greenhouse gases from the soil (*Nature, Science* and *PNAS*).

Table 3 Number of scientific publications

Products		2012	2013	2014	2015	2016	2017
Scientific journal - Article		191	180	182	219	233	212
Journal Impact Factor >5		36	38	30	51	63	54
Open Access		*29%*	*45%*	*41%*	*53%*	*47%*	*52%*
International co-authorship*	#	104	108	110	138	163	144
	%	*54%*	*60%*	*60%*	*63%*	*70%*	*68%*
PhD thesis		15	4	5	9	14	10

*International co-authorship: the majority of our papers are written in collaboration with international co-authors

Table 4 Use of products

4a Via Essential Science Indicators (ESI)

	2012	2013	2014	2015	2016	2017
ESI Baselines all fields Citation per paper per year	11.11	8.36	5.62	2.77	0.57	0.41
NIOO Publications Citations per paper per year	19.22	17.89	9.96	5.71	1.48	1.25

4b All-year citation rate - citation rate for a 10-year period

Research fields All years (2006-2016)	ESI Baselines	NIOO
All fields	12.08	25.14
Environment/Ecology	12.90	22.28
Plant & Animal Science	9.28	27.35

Table 5 Marks of recognition by peers: number of invited scientific presentations and participations in editorial boards of scientific journals

Invited presentations include keynotes and invited guest lectures.

	2012	2013	2014	2015	2016	2017
Invited presentations	47	59	59	86	85	79
Editorial Boards	52	43	54	58	70	50

6. Research quality

During the review period, NIOO achieved considerable scientific successes that we summarise in Chapter 6.1–6.3. Four examples of our scientific results are highlighted in boxes, and additional highlights are presented in an appendix.

6.1 Research products for peers

NIOO publishes in the top international journals. Although our strategy is to focus on the quality of publications rather than the quantity, we see a rise in both (Table 3): more publications, but also an absolute and relative increase in the number of publications in journals with an impact factor (IF) > 5.

In the period under evaluation, NIOO published a steady number of papers in the highest IF journals, with 90 papers in total in journals with an IF > 10. We published 11 papers in *Science* (IF 37.20), 6 in *Nature* (IF 40.14) and 23 in other *Nature* journals such as *Nature Climate Change, Nature Methods, Nature Communications, Nature Plants, Nature Chemical Biology, Nature Microbiology,* and lately in *Nature Ecology & Evolution.* We also had 26 papers in *ISME Journal* (IF 9.66), 13 in *PNAS* (IF 9.66) and 7 in *TREE* (IF 15.27), with one or more papers in each of these journals every year. See the appendix for a list of selected papers.

In addition to our publications, we also provide other research products, including presentations at conferences and workshops (930 talks in the review period). We also write R-packages (ClimWin), contribute to open-source software (Bioconda) and make our genomic pipelines (https://github.com/nioo-knaw/) and genome browsers for species that we have sequenced (https://genomes.bioinf.nioo.knaw.nl/) available to the public. In addition to these examples, we have computer models (PCLake), lab techniques and valuable long-term datasets (100+ years of bird ringing, 60+ years of songbird nestboxes, 20–40 years of natural succession and nature restoration).

6.2 Use of research products by peers

The high impact of NIOO publications is confirmed by the Thomson Reuters database 'Essential Science Indicators' (ESI), which identified 78 NIOO papers as being among the highest cited papers in all categories in the last ten years. NIOO citation rates for all fields are more than two times the ESI Baseline (Table 4). For the research field Plant & Animal Science, it is in fact more than three times. See Chapter 8.5 for more elaborate benchmarking.

Over the years, NIOO has continued to keep up the high level of citation rates. For the period 2012–2017, Web of Science identifies 46 NIOO papers as being 'Highly Cited'; this means they belong to the top 1% of their field in ESI.

6.3 Marks of recognition from peers

The previous international Peer Review Committee assessed NIOO's research over the period 2005–2011 as *excellent* (Report 2012). In the past six years, NIOO has faced the challenge of maintaining this high level of performance and, where possible, improving it.

Each NIOO department is recognised for a unique selling point: Terrestrial Ecology is leading in the field of aboveground-belowground multi-trophic interactions; Animal Ecology is leading in the field of the ecological impacts of climate change; Microbial Ecology is leading in the field of soil microbiomes and their impact on ecosystem services; Aquatic Ecology is leading in the

Societal Highlight I: Discovering new antibiotics

Antibiotic resistance is increasing globally and is threatening to make ordinary bacterial infections untreatable in the future. Whole genome sequencing has revealed that many soil microorganisms possess so-called cryptic gene clusters, encoding for putative new antibiotic metabolites that are not produced under common growth conditions. In nature, antibiotics are produced after perception of specific environmental signals (stress/nutrient signals) or signals from neighbouring microorganisms (competitor sensing; [1,2]). Through genome mining[3] and by exploring interspecific microbial interactions[1,2], we have developed practical approaches[4] for the discovery of new antibiotics[5] and antimicrobial volatiles that can combat resistance against antibacterial and antifungal compounds.

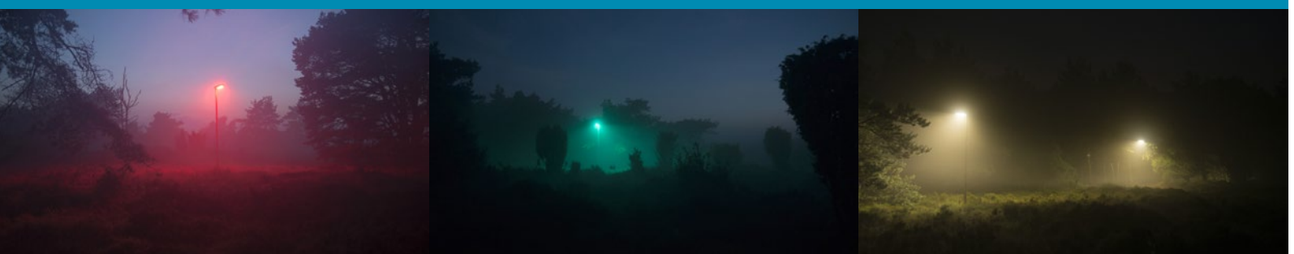
[1] *Scientific Reports* 2017, 7: 862
[2] *Microbial Biotechnology* 2017, 10: 910-925
[3] *BMC Genomics* 2015, 16: 991
[4] *Nature Chemical Biology* 2015, 11: 625-631
[5] *Environmental Microbiology* 2014, 16: 1334-1345

Societal Highlight II: Impact of artificial light at night on ecosystems

One aspect of the Anthropocene is a dramatic increase of artificial light at night. Using an experimental facility that is unique in the world, we have studied the long-term impact of this increase on flora and fauna[1]. We have found strong, spectrum-dependent effects in several species groups. In birds, we have found changes in stress and sleep patterns[2]. White and green light, but not red light, have a strong impact on the activity of vulnerable bat species[3]. Several other mammal species and moths show a strong, spectrum-dependent response to light as well. Negative effects of light at night can be mitigated by making use of the fact that impact varies for different light spectrums. The scientific output from this project is being used in new guidelines for lighting in the Netherlands.

[1] *Philosophical Transactions of the Royal Society London* B 2014, 370 (1667): 20140129
[2] *Global Change Biology* 2017, 23: 4987–4994
[3] *Proceedings of the Royal Society* B 2017, 284: 20170075

Experimental illumination with red, green and white light at one of the eight study sites in the Netherlands (see also www.lichtopnatuur.org)



field of trophic interactions in freshwater ecosystems. However, the academic reputation of any institution is also based on the combined performance of individual staff members with strong CVs. NIOO director Louise Vet and two heads of department (Wim van der Putten and Marcel Visser) are elected members of the KNAW. Visser has been on the Thomson Reuters list of Highly Cited Researchers since 2015.

Since 2012, Van der Putten and Visser have both received an ERC Advanced grant. In 2013, Ellen van Donk (head of Aquatic Ecology) received a grant from the University of Lund (Sweden) to fill the Hedda Andersson Chair. And more recently, Jos Raaijmakers (head of Microbial Ecology) was invited by the Bill & Melinda Gates Foundation to set up a large public-private collaborative research programme (PROMISE). Several NIOO scientists have received personal Veni/Vidi/Vici/Rubicon or EU-Marie Curie grants (Verhoeven, Bezemer (2), Soler, Veen (2), Morriën, Schrama, Crowther, De Deyn (2), Ferreira, Garbeva (2), Kowalchuk, Zwart, Gsell, Van Leeuwen, Kosten, Culina, Geisen & Christianen).

Recognition for NIOO's quality is also demonstrated by the many invitations NIOO scientists have received from universities for professorships (presently 13). Several NIOO senior scientists have left NIOO to become full professors elsewhere (e.g. Marc Naguib and Gerlinde de Deyn at WUR; George Kowalchuk at Utrecht University, Bas Ibelings at the University of Geneva, Nicole van Dam at iDiv Halle-Jena-Leipzig, Matthijs Vos at Potsdam University, and Maiko Kagami at Yokohama University).

Our youngest scientists have also received honours and prizes. To name just a few: Jan Kuiper received the MCED Award 2016 of the Ecological Society of Germany, Austria and Switzerland (GfÖ) for his high-impact publication in *Nature Communications*. Dedmer van de Waal received the 2016 Patrick Gentien Young Scientist Award of the International Society for the Studies of Harmful Algae (ISSHA), Annelies Veraart was awarded a Distinguished Women Scientist Fund travel grant (Dutch Network of Women Professors), as well as the Christine Mohrmann fellowship from Nijmegen's Radboud University.

NIOO scientists have initiated, or are involved in, the organisation of many national and international meetings and are frequently invited for plenary and keynote lectures at major international conferences. NIOO scientists are increasingly involved in the Editorial Boards or as chief editors of 70 journals (Table 5), including high impact factor ecological journals such as *Science, Ecology Letters, The ISME journal, Global Change Biology, Molecular Ecology, Philosophical Transactions Royal Society B, Functional Ecology, Frontiers in Microbiology, Ecology,* and *American Naturalist.*

NIOO hosts the office of the International Society for Microbial Ecology (ISME), a members' association that serves microbial ecologists and the wider community by supporting research and education. The office is responsible for the *ISME Journal* (IF 9.66 and ranked #3 in ecology / #7 in microbiology, published by partner Springer Nature) and organises the International Symposium on Microbial Ecology: the largest (2000+ delegates) and highest-valued symposium in its field.

NIOO scientists sit on the boards of many national and international scientific organisations, including the EASAC-environmental steering panel, GSBI, NSF and ERC grant review panels, Finnish and Norwegian Academy review panels; NWO Veni/Vidi/Vici/Rubicon panels, DFG, etc.

Recently, the British Ecological Society awarded NIOO director Louise Vet its highest accolade: Honorary Membership, which recognises exceptional contributions at international level to the generation, communication and promotion of ecological knowledge and solutions.

Societal Highlight III:

Pharmaceuticals disrupt natural information flows in water

Our research on how pharmaceuticals may disrupt the chemical communication between water organisms in surface waters[1] resulted in a parliamentary debate[2] on how to include these effects in EU water quality guidelines.

[1] *Reviews of Environmental Contamination and Toxicology* (2016) 238: 91-105
[2] *Rijksoverheid.* 2016

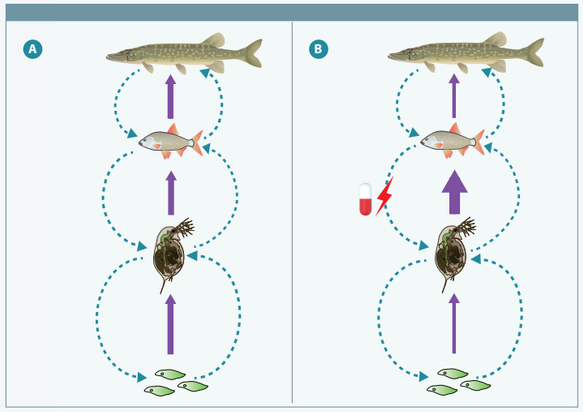


Figure A. Typical open water food chain in which energy (solid arrows) flows from algae (primary producers), via zooplankton (herbivores), planktivorous fish (primary consumers) to top predators (piscivorous fish). Within and between the trophic levels chemical cues (infochemicals) convey information (dotted arrows). B. Disruption of the natural chemical information transfer may lead to changes in trophic interactions (thickness of solid arrows) and eventually community changes.

Societal Highlight IV:

Nature restoration through soil transplantation

Based on our long-term research on plant-soil interactions, the largest private Dutch nature conservation organisation (Natuurmonumenten) is currently testing soil inoculation on a practical field scale in order to determine if it can enhance and direct nature restoration on former arable land. The work done at Reyerscamp, 190 ha of former arable farmland, has demonstrated that soil inoculation substantially enhances ecosystem development. Within eight years, depending on the source of the soil inoculum, we were able to recreate heathland and a typical dry grassland system[1]. This approach is now being applied at more than 20 restoration sites in the Netherlands. The results have been disseminated to other nature conservation organisations through workshops, field visits, a website and films[2].

[1] *Nature Plants* 2016, 2: 16107
[2] www.nioo.knaw.nl/en/soiltransplantation

7. Relevance to society

Ecological knowledge is essential for a sustainable society, and so for the future of our planet as we know it: ecology is truly the science of the 21st century. This makes disseminating our science to society an invaluable part of our mission. At a fundamental level, we work on enhancing ecological literacy. Why are nature and society so heavily impacted by climate change, changing use of land and water, and invasive species? In addition, our research is tightly linked to targeted dissemination. In our strategy we focus on direct technology transfer, policy impact and popularisation of ecology. Through technology transfer, companies are able to apply our ecological knowledge, whereas contact with policy makers is important for updating laws and regulations.

NIOO has a vigorous and long-standing commitment to societal impact. Not only is NIOO housed in a sustainable building (see Box 1) designed to translate our ecological principles in terms of architecture and construction, we also have a number of units that are tailor-made for disseminating our ecological knowledge to specific target groups (see Box 3), we have a very active outreach policy, and we actively involve citizens in our research through large-scale citizen-science projects.

NIOO provides training (presentations skills, building and using networks, use of social media, websites, films and so on) to further increase the societal impact of its research, and to assist researchers when it comes to engaging in various kinds of outreach activities. Our underlying science communication strategy identifies levels corresponding to the classifications used in Dutch and European science policy: 'Science for Science', 'Science for Competitiveness' and 'Science for Society'. The latter two are most important for societal relevance.

In Chapter 7.1–7.3, we detail our strategy on the societal relevance of our research and summarise our output. We present six boxes with highlights of our societal impact. A list of additional societal highlights can be found in an appendix.

7.1 Research products for societal groups

The institute offers a wide variety of research products. Which is the most appropriate depends on the goal and corresponding target group(s), in accordance with our strategy. For direct knowledge and technology transfer, for example, NIOO actively invests in public-private partnerships. In addition, NIOO targets potential partners by offering guided tours.

NIOO values the dissemination of its knowledge to a wider audience by popularising science, which was greatly appreciated by the 2012 Peer Review committee and the Science Advisory Board (2015). This involves open days, press releases, public lectures, film and gaming projects, active participation in public debates and social media, website news, eye-catching stands at festivals (including the popular Summerlabb partnership), school projects, well-visited tours of the NIOO building and citizen science projects. For examples of the latter, we refer to the Dutch Centre for Avian Migration & Demography, which serves all Dutch volunteer and professional bird ringers, and the annual Soil Animal Days, which are held with the help of hundreds of citizens throughout the country.

In addition to our own productions, we are proud to have international documentary maker John D. Liu as a fellow at NIOO. His main interest is in ecosystem restoration, which is a perfect match with one of our research themes. For educational gaming purposes, NIOO's Marleen Cobben, together with the PR department, has developed Climate Pursuit: a 'serious game' on climate change and evolution (www.climatepursuit.com). The game is now in the process of being licensed to an educational gaming and teacher training platform, so that it will be accessible for schools around the globe.

Table 6 Popularising science

Products	2012	2013	2014	2015	2016	2017
Publications aimed at the general public written by NIOO scientists in print and online	43	33	27	85	93	66
Reports & professional products	11	4	5	8	8	8
Serious games/simulations		1	1		1	1
Number of guided tours	34	38	26	47	38	48
Number of festival stands & open days	7	5	5	9	13	13
Widely distributed press releases	14	11	8	6	15	20
Presentations for the general public	17	27	31	46	38	32

Societal use of products	2012	2013	2014	2015	2016	2017
Visitors events & guided tours	26,000	14,000	29,000	30,000	62,000	32,000
Website pageviews	447,000	387,000	390,000	626,000	1,128,000	1,297,000
Social media use						
Followers on Twitter (total)	App. 500	App. 950	App. 1300	1925	2539	3260
Tweet views				554,299	560,482	550,343
Likes on Facebook (total)		•	•	380	615	764
Organic reach on Facebook		•	•	31,272	69,676	50,299
Views on YouTube (total)	1,171	5,566	11,272	22,855	42,456	56,900
Followers on Instagram						31

Recognition: Media appearances	2012	2013	2014	2015	2016	2017
Newspapers, magazines & news websites	441	492	505	416	549	637
Radio & TV	34	38	50	61	48	81

7.2 Use of research products by societal groups

Public-private partnerships are blossoming. In the nationwide BE-Basic programme, various STW/TTW projects including the Perspective programme 'Back to the Roots', the Bill & Melinda Gates Foundation project 'PROMISE', and NWO projects financed from the Dutch government's 'Top sectors' initiative (e.g. NWO-Groen), NIOO collaborates with a range of industrial and governmental stakeholders. Our bio-based projects are important within the government's focus on a sustainable bio-based industry, circular economy and sustainable food production. This also enables us to bolster our collaborations with strong developing countries including Brazil, Colombia, South Korea, China, Ethiopia, and India.

NIOO initiatives such as AKWA, CSE, CAPS (see Box 3), and NIOO's multi-partner projects on nutrient cycle/wastewater treatment with algae, roof vegetation, urban biodiversity development, and nature restoration, are all geared towards solving environmental issues through direct knowledge transfer to participating stakeholders. Examples are the 'Green Deal Green Roofs' with GOs; Community of Practice (STOWA); direct interactions between AKWA and METS and water boards; joint ecosystem restoration practices with NGO Natuurmonumenten, etc. In addition, dissemination is increasingly used to set research agendas and propose new research directions.

In 2016 and 2017, NIOO filed three new patent applications based on NIOO inventions. One patent has already been licensed to a company for commercial exploitation. For two others recently filed, an active commercialisation strategy is currently being developed in consultation with companies and/or academic research partners. A previous NIOO patent has served as the basis for the creation of Microlife Solutions BV, a spin-off company under the holding of BioDetectionSystems BV.

NIOO scientists also aim to positively influence the policies of societal, private company, NGO and governmental stakeholders. NIOO's director currently chairs a major national initiative on the recovery of biodiversity, with stakeholders from science, nature organisations, the agro-chain, companies, banks and retail (Deltaplan Biodiversiteitsherstel). She also strategically advises Dutch governmental agencies and Dutch and European politicians on environmental issues, circular and bio-based economy, e.g. through KNAW 'Science for Parliament' meetings and lectures, and at EU level through the Environmental Steering Group of EASAC. NIOO presently leads an EASAC report on Soils at Risk.

Another example is our 'Light on Nature' project; the scientific output of this project is being used directly to mitigate effects of public lighting as the results are implemented in the national guidelines for the deployment of illumination in and near natural areas in the Netherlands, and in the general guidelines on illumination of larger roads. The PCLake computer model is a valuable resource for freshwater management in the Netherlands. Furthermore, our efforts within the framework of the national science agenda NWA ensure close connections with societal groups.

Societal Highlight V:
Surveillance network for arboviruses in wild birds

Birds can become infected with a large number of viruses, many of which have (sub)tropical origins and may be hazardous to human health. When birds migrate to temperate regions in spring, they can introduce such arboviruses or their infected vectors, potentially leading to local establishment. Countrywide surveillance for arboviruses in migratory birds was started in 2016, in collaboration with the Erasmus Medical Centre and relying on our network of well-trained citizen scientists. In its first year, this surveillance network identified two tropical viruses that were new to the Netherlands. The identification of one of these — the Usutu virus — preceded an actual outbreak of the virus by five months[1,2]. This underlines the importance of surveillance as an early warning system.

[1] *Eurosurveillance* 2016, 21 (45): [30291]
[2] *Eurosurveillance* 2017, 22 (4): [30452]

Societal Highlight VI:
Why poop is actually gold

Re-using nutrients is vital if we are to make our society 'futureproof' by closing cycles. Phosphate mines, for instance, will be depleted in the coming century. And our current toilet systems require large volumes of costly 'waste' water. At NIOO, an experimental on-site sanitation system[1] is being studied that makes use of microbes and microalgae[2] to harvest nutrients - the 'gold' - and use them as fertiliser. A bonus could be better purification of medicine residues that will otherwise wreak havoc on aquatic ecosystems[3]. To create social awareness of this issue and make people (re)think, NIOO has featured its innovative toilet system at many festivals, on guided tours and in media appearances. This prompted the Dutch government to nominate NIOO as one of the finalists in its National Icons competition in 2016. Meanwhile, in Ecovillage Boekel – a Dutch grassroots initiative – we will test the system for practical use in collaboration with its residents and social scientists.

[1] *Environmental Science and Technology* 2015, 49 (20), 12450-12456
[2] *Frontiers in Microbiology* 2017, 8, 1742
[3] *Journal of Hazardous Materials* 2016, 304, 84-92

7.3 Marks of recognition from societal groups

NIOO scientists regularly receive recognition for their positive societal impact. Our PhD student Jasper Wubs, to name just one, was awarded the 'Silver Parnassia' prize for the valuable contribution of his soil transplantation research to the practice of nature restoration. Our postdoc Kamiel Spoelstra was honoured with a lifetime achievement award from the Dutch Mammal Society. And when Hans van Veen, our previous head of Microbial Ecology, retired, he received a royal decoration. Meanwhile, NIOO director Louise Vet made the top ten of the nation's Sustainable 100, and PhD student Rascha Nuyten was included in the Sustainable 100's 'young' edition.

For journalists, our research is a ready source of reliable and newsworthy stories. The large number of media appearances by NIOO researchers clearly reflects this, from regional tv and radio to international newspapers (Table 6). In addition, our researchers are frequently asked for lectures, art projects, public events, citizen science projects and other collaborations, by a wide variety of societal groups, organisations and companies, as well as by the government. NIOO has fulfilled many requests for advice within the Netherlands, e.g. concerning bird flu outbreaks, blue-green algae problems and (soil) biodiversity and climate change issues. The same is true internationally, with Tom Crowther speaking at an FAO conference on carbon storage in soil, and head of Microbial Ecology Jos Raaijmakers being approached by the Bill & Melinda Gates Foundation to help solve agricultural problems in Africa – a request that has since been developed into a fully-fledged research project.

In collaboration with business partners, Wageningen University, the water sector, GOs and NGOs, NIOO has initiated a number of innovative projects to mimic nature's circular economy. One such project, METS, which explores the potential of microalgae for wastewater treatment (with a pilot in the NIOO building), was shortlisted for the Dutch government's National Icons scheme in 2016. Research for this project is conducted in collaboration with the University of São Paulo, Brazil, and has now been extended to New Delhi, India, in a major public-private collaboration. Additional building-related projects are research on the development and functioning of green-blue roofs, and biodiversity in urban areas.

With its cutting-edge eco-technological projects linked to NIOO research, the NIOO building (see Box 1) has not only been a trailblazer for innovative sustainable buildings, as demonstrated by the many prizes it has won (e.g. Sustainable Architecture Award 2011; FIABCI Prix d'Excellence The Netherlands 2012 in the category 'Sustainable Development'; 2012 Golden Pyramid State Prize for excellence in commissioning work in architecture), it has also helped to advertise our ecological research and the importance of ecology in general. The building embodies NIOO's vision of being inspired by and learning from nature, which has been instrumental in creating a broad societal awareness of the benefits healthy ecosystems and biodiversity bring to humanity.

Box 5:

SWOT analysis

SWOT analysis is an important tool for evaluating and improving our strategies.

Internal organisation	**NIOO's strengths** - Excellent research output; NIOO scores well above the world average - Largest group of ecologists in a single location conducting fundamental, multidisciplinary integrative research, from gene to ecosystem - Long-term studies (20 - >50 years) on avian populations, aquatic and terrestrial communities and ecosystems - Strong experimental approach, from plot to global scales and from field to highly controlled lab environments - Recognised as hub in national ecological and evolutionary research landscape - Trains young researchers who go on to be leaders in their field - Effective outreach strategy for optimal exposure and knowledge transfer to a range of stakeholders, end-users and the general public	**NIOO's weaknesses** - No programme within NIOO that enables talented, non-tenured researchers to develop their own lines of research in the longer term - Spreading research efforts too thin? - Gender balance at higher research staff levels (i.e. senior scientists and department heads) - Not enough attention for acquisition of overhead generating projects necessary to make strategic investments - Limited resources for providing rigorous in-house support for large research grant applications
External context	**NIOO's opportunities** - Renewed interest in fundamental knowledge about ecology and evolution - Increasing and widespread interest in 'learning from nature' for a more sustainable agriculture and a more bio-based and circular economy - Opportunities for public-private collaborations, partly through specific units - Increasing interest in citizen science, and NIOO already has ample experience - Seven NIOO-wide themes help foster an integrative research environment and allow flexibility in NIOO's research	**NIOO's threats** - Focus of policymakers and national funding schemes on applied research and research with short-term economic valorisation possibilities - Increase in requirements by national funding schemes for direct co-funding by industry and private partners - Proliferation of government rules, regulations and demands for compliance, requiring more time and effort from supporting staff and academics - Innovative strategic research budget under pressure from recent and future governmental budget cuts - Increasing and worrisome costs of facilitating Open Science

8. Viability

To demonstrate NIOO's viability, we will discuss our human resource management, financial resources, infrastructure and innovative capacity, in combination with a SWOT analysis (Box 5) and benchmark comparison.

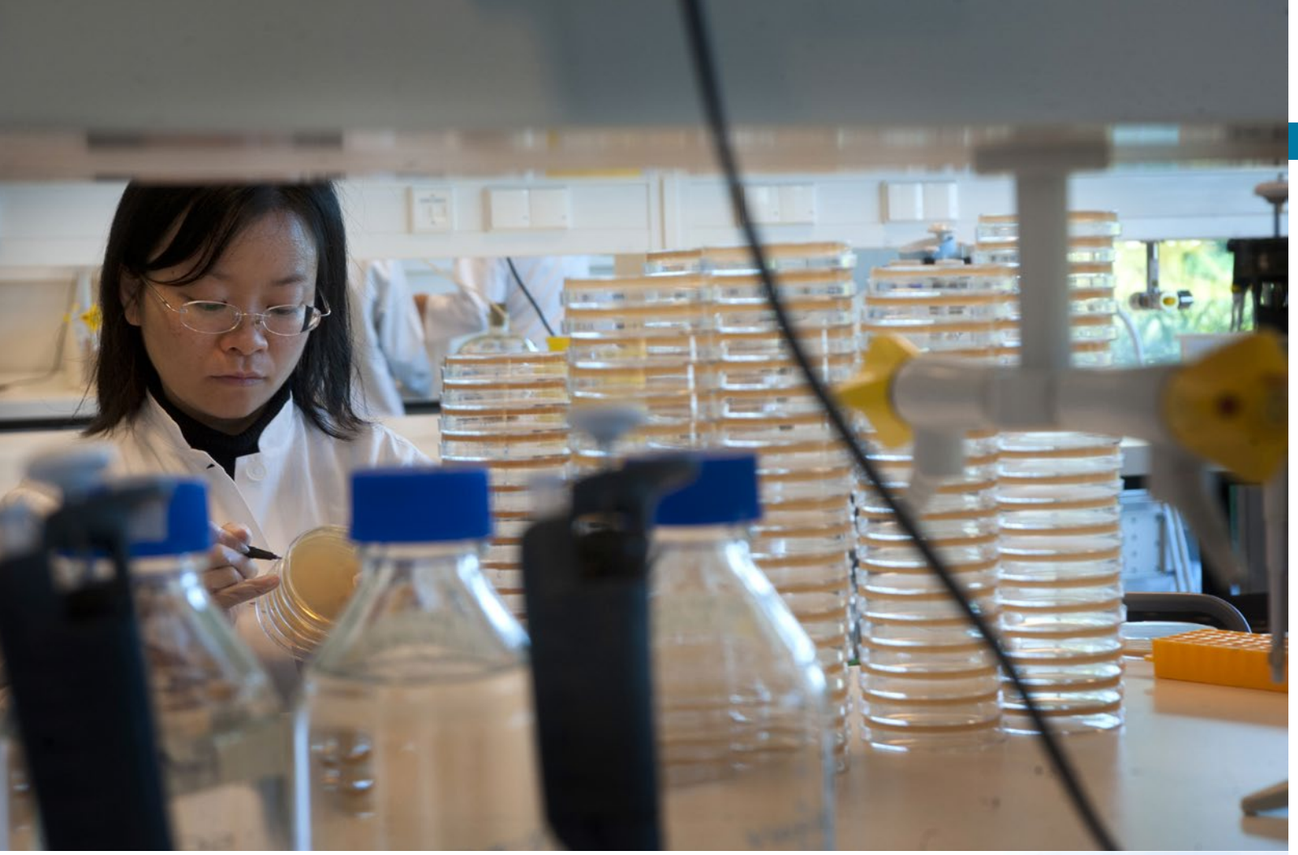
8.1 Human resource management

NIOO's main capital is its people. NIOO's management tries to create a positive and stimulating academic and social environment, in which people are encouraged to excel. Collaboration and an open, inspiring atmosphere are important values. The highly positive outcome of an employee satisfaction survey in 2015 underlined the success of these efforts. NIOO has an active personnel policy. A Strategic Personnel Plan is used for recruitment and professional development within the organisation. Senior scientists and research assistants in permanent positions provide continuity of expertise for the core research areas. Temporary researchers working on externally funded research projects bring in specific expertise and dynamics. The Strategic Personnel Plan is also used to ensure that there is sufficient support to keep up with NIOO's research needs, e.g. through the current reallocation of funding for assistants to support the Bioinformatics unit. Performance of all staff members is subject to annual appraisals, which focus on competence building and professional development. In addition to research training, training in professional skills is offered through programmes within and outside the KNAW, funded from NIOO's training budget. Specialised training programmes in management and leadership skills are available for junior group leaders and senior researchers.

The age distribution of NIOO staff (see Figure 1) allows for timely replacement of senior researchers. Between 2013 and 2017, NIOO actively invested in anticipating retirements by finding successors well in advance. In addition, we made arrangements with retiring staff and senior staff successfully promoted to positions at other academic institutions to remain involved in NIOO research. This has contributed to the influx of scientific staff (see Table 1). Recruitment of senior researchers is through a challenging tenure-track procedure (on average one per year). To facilitate better gender distribution (see Figure 1), all women applicants who meet the minimal requirements during the selection procedure for a tenure-track position are invited for an interview. For temporary positions, we proactively search for and select the best international candidates. NIOO policy is to recruit and train the most talented young ecological researchers from institutions in and outside the Netherlands, building on their ambition to deliver the new national and international leaders in ecology.

During the period under evaluation, senior researchers were strongly encouraged to run and further develop their own lines of research within departments, and to shoulder the managerial and financial responsibility that comes with this. NIOO also handed this important group of researchers leadership of the seven NIOO research themes (12 out of 16 senior researchers are involved in this). We consider scientific support by excellent technicians a major asset of NIOO that greatly contributes to our success. For this reason, NIOO actively stimulates and invests in training to keep technicians' knowledge and skills state-of-the-art, and securely embed this knowledge within the organisation in the longer term.

Research collaborations and social interaction are encouraged through activities organised by both employees and management. The departments hold weekly meetings, and at NIOO's Monday seminars, invited speakers provide a variety of perspectives on key scientific and societal



topics in ecology. Social activities for all research and support staff are organised on a regular basis. Every two years, we organise the NIOO Research Days, a two-day event away from NIOO for all NIOO scientists and technicians which focuses on science but with a strong social component.

The head of the Department of Aquatic Ecology will retire in the near future, and the Institute will seek a strong, internationally renowned candidate in the field of Aquatic Ecology as her replacement, in order to further enhance the strong reputation of both the department and NIOO as a whole. We will actively approach outstanding candidates, preferably women, and commence one year before the department head retires. This procedure has proved successful with previous replacements, e.g. for head of the Department of Microbial Ecology.

For the succession of Louise Vet as director of NIOO, a clear procedure has been defined by the KNAW. There will be an international search for a strong candidate, in accordance with a search profile for which NIOO's Strategic Plan 2017–2025 will serve as an important guideline. The chosen candidate will be expected to focus on further developing the high level of NIOO's research, its outreach to science and society, and its intellectual vitality as a centre for talented researchers to work, grow and interact. The search will commence a year before the director's retirement, ensuring a smooth transition from the current to the new director.

8.2 Financial resources

NIOO's financial resources consist of an annual lump-sum payment from the Ministry of Education through the KNAW and a variety of external funding sources. The lump sum (8.6 million euros in 2018, excluding the KNAW housing budget) is used to finance NIOO's permanent scientific and support staff, general material costs and research infrastructure. External funding sources provide funding for NIOO research projects (see also Chapter 3.3). In addition to covering direct project expenses from external funding, NIOO aims to obtain an average of 10% reimbursement for indirect costs. This goal is challenging, considering the limited opportunities for funding indirect costs in fundamental research programmes. The budget NIOO receives from the KNAW has not kept up with increases in costs over the last period. Nationally agreed salary increases for all personnel, and increasing material and ICT costs, have been only partly compensated in the KNAW budget (personnel), or have not been compensated. Moreover, NIOO and other KNAW institutes were confronted with substantial structural cuts in this budget in 2014 and 2017. This situation is a threat to NIOO's potential for investing in new projects and research infrastructure in the coming years. A structural budget increase is necessary to allow NIOO to realise its ambitions for the next period.

8.3 Infrastructure

Since its move to Wageningen, NIOO has invested significantly in its research infrastructure, which is state-of-the-art. It includes four well-equipped laboratories: molecular, microbial, chemical analytical, and aquatic. There are also unique, climate-controlled facilities for bird housing and experiments, a phytotron for all plant, soil and insect research, greenhouses, and advanced aquatic experimental equipment such as limnotrons and experimental ponds. A priority in our strategy is to obtain or reserve sufficient funds for maintaining this first-rate infrastructure. A well-functioning Apparatus Committee investigates and monitors the presence, status and use of all of NIOO's durable equipment, and advises the NIOO management about the possibilities regarding shared use and new investments. Each year, NIOO reserves a budget of about €375,000 for new equipment and infrastructure. Activities requiring equipment that is

Table 7 Benchmark institutions

To compare NIOO's output with that of other research institutes, we considered the 861 institutions in the ESI database that score above the citation threshold for the subject area 'Environment/Ecology'*. The threshold for 'Environment/Ecology' is 3,782; NIOO's total number of citations over the 10-year period is 22,909. The average number of citations per paper over a ten-year period in this subject area is 12.95; NIOO's ESI-score of 27.44 citations per paper is twice the average. We selected only research institutes that are comparable with NIOO, i.e. no universities as these differ in function (education), organisation and scope. We also considered the ecological scope of the institutes, making sure all four NIOO departments (aquatic, terrestrial, animal and microbial ecology) were covered.

	Institutions	Countries-Territories	Web of Science Documents	Cites	Cites/Paper	Top Papers
62	SMITHSONIAN TROP RES INST	PANAMA	1026	30337	29.57	57
99	NETHERLANDS INST ECOL	NETHERLANDS	835	22909	27.44	25
136	NERC CTR ECOL & HYDROL	UK	2812	71738	25.51	104
141	ROTHAMSTED RES	UK	460	11657	25.34	23
240	CSIRO	AUSTRALIA	4029	90646	22.50	152

* The ESI database uses information from Web of Science; it gives an overview of the statistics for papers and citations over a 10-year rolling period, and is updated every two months. Annualized expected citations rates (= averages of citations per paper) serve as baselines for assessing the impact of papers in a subject area.

Table 8 Benchmark by CWTS

The Centre for Science and Technology Studies (CWTS) in Leiden has conducted an independent research performance analysis of our output (see appendix). This table shows the essential citation indicators for the period 2012–2016.

Period	P	TCS	MCS	MNCS	PP (top10)	MNJS	Prop selfcits
2007-2016	1,582	16,066	9.48	1.78	0.21	1.69	0.24
2012-2013	319	4,247	13.31	1.73	0.22	1.67	0.24
2013-2014	333	4,175	12.54	1.78	0.20	1.82	0.23
2014-2015	369	3,400	9.21	1.65	0.17	1.66	0.26
2015-2016	418	2,450	5.86	1.82	0.21	1.65	0.27

P: Total number of publications of a research group

TCS: Total number of citations of the publications of a research group (self-citations not included)

MCS: Average number of citations of the publications of a research group (self-citations not included)

MNCS: Average normalised number of citations of the publications of a research group (self-citations not included)

PPtop 10%: Proportion publications of a research group belonging to the top 10% most frequently cited publications in their field (self-citations not included)

MNJS: Average normalised citation score of the journals in which a research group has published (self-citations not included)

Prop selfcits: Proportion of self-citations

very expensive or subject to frequent obsolescence are outsourced (e.g. sequencing, transcriptomics, metabolomics). Following a recommendation by the previous Peer Review committee, NIOO has established a well-functioning bioinformatics facility (see also Chapter 11: *Data storage, data use and Open Access).*

8.4 Innovative capacity

NIOO's flexibility and innovative capacity is guaranteed by the substantial number of externally financed temporary staff, the acquisition capacity of NIOO's permanent research staff and the broad infrastructural possibilities for conducting all kinds of ecological research. NIOO strives to continue to reserve an annual budget of €350,000 for strategic investments in exciting new high-potential research initiatives: since 2016 specifically for projects within the NIOO themes. Our long-term studies are a treasure that we value and will continue to value. They have been demonstrated on a number of occasions to add significantly to our innovative capacity, by answering very recent questions and identifying increasingly important temporal and spatial trends that require high-quality long-term datasets.

8.5 CWTS benchmarking

The Centre for Science and Technology Studies (CWTS) in Leiden has conducted an independent research performance analysis of our output. The results are presented in a separate report that also details the procedure and terminology used. CWTS concludes that NIOO is doing very well, with impacts well above the world average. NIOO's total output comprises more than 1,500 (Web of Science) papers in ten years (2007–2016), and has grown steadily during this period. The institute's high impact is visible in the average number of citations and the top 10% most frequently cited publications (MNCS and PPtop10 respectively) (see Table 8; Table 7 for comparison). The MNCS averages at nearly 78% higher than the world average, while the impact as measured by the PPtop10 is more than twice as high as expected at 0.21. About the cooperative trend, CWTS remarks: "The average number of organisations in publications where NIOO-KNAW was involved increased gradually from less than 3 to more than 5 in ten years. In the research fields where NIOO-KNAW is active, the world average increases from less than 2 to 2.7 organisations per publication during the same period."

Table 9 PhD success rate

Enrollment				Graduated After*				Total		
Starting year	Male	Female	Total	≤ 4,5 y	≤ 5,5 y	≤ 6,5 y	≤ 7,5 y	Graduated	Not yet finished	Discon-tinued
2017	8	6	14					0	14	
2016	5	10	15					0	15	
2015	9	7	16	1				1	15	
2014	3	8	11	3				3	8	
2013	8	8	16	3	1			4	12	
2012	8	6	14	5	8	1		14		
2011	1	9	10	2	6	1		9		1
2010	3	3	6		4	1		5		1
2009	0	5	5	1	4			5		
2008	2	6	8	4	3	1		8		
Total	47	68	115	19	26	4	0	49	64	2

* Many PhD candidates finish writing their PhD thesis within four years. Due to organisational reasons such as waiting times at universities, many of these students formally graduate in four years and a few months.

9. The next generation

Training the next generation of international ecological researchers is a fundamental part of NIOO's strategy. There has been a significant increase in the number of PhD candidates at NIOO since 2011. Nearly twice as many PhD students now start each year: between January 2008 and January 2012, 7.25 PhD candidates per year enrolled, while between January 2012 and January 2018, the number rose to 14.3 PhD candidates per year (Table 9). The increase is mainly attributable to the start of several major research projects, a one-off influx when the new head of department of Microbial Ecology started at NIOO, and the transition to a new system that encourages senior researchers to form their own research groups within the departments.

Since 2008, 49 PhD candidates have graduated. Nearly all NIOO PhD candidates graduated within 4 or 5 years (see Table 9), with a mere two candidates discontinuing their PhD. After obtaining their degree, most candidates leave for a research position in academia abroad (44%) or continue their research in academia in the Netherlands (26%). After their PhD, 17% obtain a position in the commercial sector and 9% at (semi-)governmental or non-profit organisations. 4% of the candidates graduate with their career destination (as yet) unknown. Many NIOO PhD students will later go on to hold prestigious research positions. Examples include Christiaan Both and Raymond Klaassen (Prof. at University of Groningen), Suzanne Wilken and Elly Morriën (University of Amsterdam), Gerlinde De Deyn (Prof. at Wageningen University), Paul Kardol (Associate Prof. at Umea University), Miquel Lürling (Associate Prof. Wageningen University & Research) and Dedmer van de Waal and Kees van Oers (Senior Scientists at NIOO).

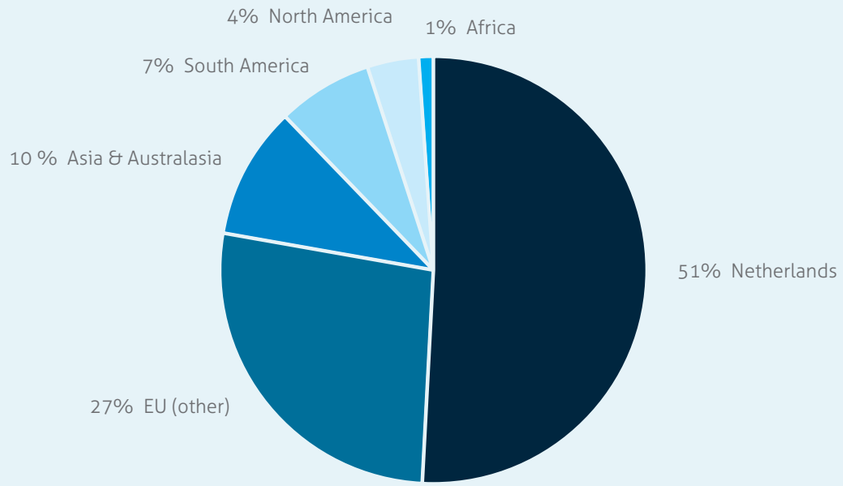
All NIOO PhD students are members of one of two high-quality graduate schools: either Production Ecology & Resource Conservation (PE&RC) or Experimental Plant Sciences (EPS). The Netherlands Ecological Research Network (NERN) coordinates and watches over the national PhD courses for ecologists, and NIOO PhD students can participate in all these courses. NIOO actively monitors the training and performance of its PhD students with a solid training and supervision plan, a go/no go decision within the first year (which is also reported to the KNAW) and annual appraisal interviews. PhD students are encouraged to participate fully in scientific discussions at our weekly seminars, to speak at meetings, to interact with international experts, and to start publishing as early as possible during their PhD. We provide PhD students with a personal training budget of €1500 to finance workshops and training in professional as well as personal skills on the basis of individual needs. In addition, the KNAW has set up a series of training courses targeted at PhD students, which they can follow free of charge. For specialised individual training, PhD students may also apply for funding from the NIOO training budget. NIOO PhD students are offered a financial incentive of €450 to deliver their thesis within four years.

PhD students are actively involved in NIOO's extensive outreach programme: they work stands at festivals, give guided tours of the NIOO building and participate in press releases, school projects and citizen science projects. This helps them learn to communicate about their research with non-peers.

NIOO provides training in research, transferable skills and career development to all young scientists in a number of ways: there is a NIOO PhD and postdoc platform for exchanging knowledge and boosting professional and social interaction. Postdocs are encouraged to develop their own research lines, e.g. through Veni and Vidi project proposals. And if they meet the NIOO criteria, postdocs can become independent 'junior group leaders'. NIOO also invests strongly in transferable skills such as supervision, working with private companies and writing high-impact papers and grants (e.g. in the form of workshops during the NIOO Research Days as mentioned in Chapter 8.1). In addition, the various collaborative centres that NIOO has initiated provide job opportunities for postdocs who wish to continue their (research) career outside academia. NIOO's director regularly organises lunches with PhDs and postdocs, where 6-7 researchers from different departments mix and discuss research and career matters.

Figure 1 Age and gender distribution at NIOO in relation to salary levels

Figure 2 Nationalities of NIOO's scientists.



10. Diversity & inclusiveness

The diversity and inclusiveness policy laid out by the KNAW states that diversity and inclusiveness lead to more creativity, multidisciplinary innovation, balanced decisions and optimal use of everyone's capacities. NIOO endorses this policy.

All ages are represented at NIOO, each with its specific needs and corresponding policies. As an example of the latter, NIOO organises regular lunch meetings for PhD students and postdocs where they can exchange thoughts with the director and each other (see also Chapter 9). The age composition of NIOO's personnel is typical for an institute of its kind, as can be seen in Figure 1, with a strong representation of young scientists.

NIOO's dynamic research community also carries a very diverse, international signature, with at least 20 nationalities represented at most times. About half the people are of Dutch origin, one quarter is from elsewhere in the EU, 10% from Asia & Australasia and smaller numbers are from South-America, North-America and Africa (Figure 2). This international signature is something the institute cherishes, and encourages during recruitment.

NIOO fosters a research environment in which women and men are equally valued. With a female director, head of department, managing director, KNAW president, and many other highly visible women, role models for young, aspiring women are as plentiful as those for men. The NIOO director acts as a mentor. A grant from the specialised NWO funding programme Aspasia has provided an extra boost for the development of female high-potentials.

11. Research integrity

NIOO aims to ensure scientific integrity through an open research culture with high levels of interaction between researchers. In 2014, we set up a Research Integrity Advisory Board to stimulate awareness of research integrity issues at the institute. All departments are represented on this Board, and representatives can be consulted by all department members on compliance issues. The principles and procedures regarding research integrity have been clearly stated on the NIOO intranet. They include subscribing to the Netherlands Code of Conduct for Scientific Practice, organising regular workshops and seminars on research integrity, providing confidential contact points for questions, and a mechanism for reporting complaints either to the KNAW's Academy Institutes Scientific Integrity Complaint Procedure Committee or the Netherlands Board on Research Integrity. We have held several mandatory workshops on Research Integrity for permanent staff, postdocs and PhDs, in which anonymous dilemmas were discussed (including some brought up by the group itself).

12. Data storage, data use & Open Access

The Open Science movement is rapidly changing scientific practice. The adoption of Open Science tools and principles has been slow in ecology and evolution, despite its unparalleled benefits. NIOO has played a leading national and international role in further implementing Open Science in ecology and evolution. We have represented the (previously under-represented) ecology and evolution community at Open Science events, and organised workshops at international and national conferences, as well as an international symposium on 'Ecology and Open Science'. We have furthermore published a number of papers on the application and potential pitfalls of Open Science in ecology and evolution. We aim to fully embrace the benefits of an Open Research process and the open data ecosystem, and to apply these data to wide-ranging ecological questions that could otherwise not be addressed. As such, NIOO is establishing itself as leader of the ecological community when it comes to the principles and opportunities of Open Science, and thus as a major contributor to the Open Science movement overall.

Open Access is the preferred way of publishing. Both NIOO and the KNAW have invested in facilities to publish OA (Open Access Fund). However, the struggle continues to increase the percentage of OA papers, due to both strict demands by publishers and the large amounts of money involved.

Since 2006, NIOO has its own data archive, in which all researchers can store their data, and since 2013 we require all researchers to archive any data underlying peer-reviewed articles. We are currently working on setting up an infrastructure for the FAIR storage (Findable – Accessible – Interoperable – Reusable) of raw and processed data. Future research will increasingly require investments to manage and store the vast and increasing amounts of 'omics' and other data, and to further develop bioinformatics tools and pipelines for dedicated analyses. NIOO-ICT efficiently stores data in-house, which has proven to be greatly cost-effective compared to outsourcing. NIOO-wide bioinformatics services are provided by two bioinformaticians who work closely together with ICT and Library & Information Services for data storage.

13. Concluding remarks

NIOO's ambition for the coming ten years is to develop further as a national and international hot spot for outstanding ecological and evolutionary research, which elucidates how complex changes in nature take place. Unravelling these complex interactions in nature will enable NIOO to develop new concepts in ecology, with applications that include more sustainable food production, counteracting biodiversity loss, and promoting mitigation of and adaptation to global changes in climate and land and water use, as well as urbanisation and introduced exotic species.

In order to realise this ambition, NIOO aims to be an inspiring centre for young scientific talent, nurturing them and preparing them for (inter)national top positions in science and society. Nationally, NIOO aims to expand its role in stimulating and connecting ecological research at universities and other national knowledge centres. Ecology is the science of the 21st century, as it is of profound importance to understanding and responding to the myriad challenges our society faces. NIOO is determined to take a leading role in this exciting and essential endeavour.

14 Glossary

ALW: Earth and Life Sciences (formerly a division of NWO). As of 1 January 2017, the earth and life sciences belong to the new NWO Science domain.
AKWA: Aquatic Knowledge centre WAgeningen (part of the NIOO Department of Aquatic Ecology)
AnE: NIOO Department of Animal Ecology
AqE: NIOO Department of Aquatic Ecology
AquaCOSM: A European H2020 network connecting aquatic mesocosm facilities with 37 installations in twelve countries
BE-Basic: A national programme aimed at developing solutions for replacing fossil fuels with biomass and other bio-based resources as the basis for the energy and chemical industries
Beleef de lente: Website hosted by BirdLife International the Netherlands (Vogelbescherming Nederland) which lets the general public look at breeding birds via webcams. AnE moderates the webcam for the great tit
Bill & Melinda Gates Foundation: Foundation focused on health, poverty, and opportunity, which supports work and research in more than 100 countries
Bioconda: a channel for the conda package manager specialising in bioinformatics software
BIOEN: the Brazilian FAPESP 'Program for Research on Bioenergy'
CAPES: Dutch-Brazilian cooperative programme for academic employees
CAPS: Centre for Avian Population Studies
CEME: NIOO's former Centre for Estuarine and Marine Ecology, Yerseke, the Netherlands
CL: NIOO's former Centre for Limnology, Nieuwersluis, the Netherlands
ClimWin: computer programme to detect and visualise periods of climate sensitivity for a given biological response
CMS: Central Management and Services (part of NIOO)
CNPq: The Brazilian National Council for Scientific and Technological Development
CSC: China Scholarship Council
CSE: Centre for Soil Ecology (joint research NIOO and WUR), Wageningen, the Netherlands
CTE: NIOO's former Centre for Terrestrial Ecology, Heteren, the Netherlands
CWE: Centre for Wetland Ecology, the Netherlands
CWTS: Centre for Science and Technology Studies, the Netherlands
DFG: Deutsche Forschungsgemeinschaft
EASAC: European Academies' Science Advisory Council
EPS: Graduate School Experimental Plant Sciences
Erasmus MC: Erasmus University Medical Center, based in Rotterdam, the Netherlands
ERC: European Research Council
ESF: European Science Foundation
ESI: Essential Science Indicators
EU-COST: European Cooperation in Science and Technology, programme of the European Union
EU-RTN: Marie Curie Research Training Network of the European Union
FAPESP: São Paulo Research Foundation, Brazil
FTE: Full-time equivalent
GLEON: Global Lake Ecological Observatory Network
GSBI: Global Soil Biodiversity Initiative
H2020: EU Research and Innovation programme Horizon 2020
IPBES: Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
ISME: International Society for Microbial Ecology
KNAW: Royal Netherlands Academy of Arts and Sciences
KRW/WFD: EU Water Framework Directive (Kader Richtlijn Water)
Light on Nature: Project on the impact of artificial light on flora and fauna in the Netherlands, funded by the Technology Foundation STW, Philips Lighting and the Dutch Oil Company NAM and led scientifically by AnE and Wageningen University
LTER: Long-Term Ecosystem Research, network of research sites
LTO: Dutch farmers' organisation
MANTEL: H2020 EU project on Management of Climatic Extreme Events in Lakes and Reservoirs for the protection of ecosystem services
ME: NIOO Department of Microbial Ecology
METS: Micro-algae Eco-Technological Solutions, unit at NIOO
MLS: Micro Life Solutions; NIOO's spin-off company focusing on the discovery of novel bio-based products from natural resources
MT: NIOO's Management Team
Natuurmonumenten: Dutch organisation for preserving nature, landscape, and cultural history
NecoV: Dutch-Flemish Ecological Society
NERN: Netherlands Ecological Research Network
NETLAKE: Networking Lake Observatories in Europe
NIOO: Netherlands Institute of Ecology (NIOO-KNAW)
NIOZ: Royal Netherlands Institute for Sea Research
NLSEB: Netherlands Society for Evolutionary Biology
NSF: National Science Foundation, USA
NWO: Netherlands Organisation for Scientific Research
NWA: National Science Agenda of the Netherlands (Nationale Wetenschapsagenda), based on questions from the Dutch public
Origins Center: NWA-funded centre for the study of origins and evolution of life, planets and the universe
PEHM: Platform Ecologisch Herstel Meren
PE&RC: Research school Production Ecology & Resource Conservation
Radboud University Nijmegen: University of Nijmegen, the Netherlands
Ringersvereniging: Dutch society for bird ringing
Rubicon: NWO's grant programme for encouraging talented young researchers to dedicate themselves to a career in postdoctoral research. Followed by Veni, Vidi, Vici
RuG: Rijksuniversiteit Groningen (University of Groningen), the Netherlands
SAB: NIOO's Scientific Advisory Board
SOVON: Dutch Centre for Field Ornithology
STOWA: Foundation for Applied Water Research
STW: former Technology Foundation for the transfer of knowledge between the (technical) sciences and users in the Netherlands. On 1 January 2017, STW became the new NWO Domain 'Applied and Engineering Sciences' (TTW)
TE: NIOO Department of Terrestrial Ecology
Topsectors: Dutch governmental programme to strengthen the country's nine top sectors, connecting government, business, universities, and research centres via 'innovation contracts'
TropME: Tropical Microbial Ecology, unit at NIOO
TTW: NWO division Applied and Engineering Sciences (Toegepaste en Technische Wetenschappen)
UL: Leiden University, the Netherlands
UU: University of Utrecht, the Netherlands
UvA: University of Amsterdam, the Netherlands
Veni, Vidi, Vici (VVV): NWO fellowships for talented postdocs (Veni, Vidi) or more advanced (Vici) researchers
Vogeltrekstation (VT): Dutch Centre for Avian Migration & Demography
VU: Vrije Universiteit (VU University) Amsterdam, the Netherlands
WoS: Web of Science
WUR: Wageningen University and Research, the Netherlands

Appendices

Additional scientific highlights

Animal Ecology

- We have sequenced, assembled and annotated the genome of the great tit[1], a model species in ecology and evolution, along with its transcriptome and epigenome. We have thereby produced, and now use, the most complete genomic toolbox for any wild avian species to date, which is particularly valuable in view of the long-term field and DNA data-sets we have[2].
  [1] *Nature Communications 2016, 7: 10474*
  [2] *BMC Genomics 2016, 17: 332*

- We have demonstrated that migratory animals play an important role in coupling biodiversity and ecosystem functioning in a worldwide network[1]. We have investigated in detail the scope for adjustment of bird migration to rapid climate warming[2]. We study this using calibrated loggers that measure both location and body acceleration, allowing us to link behaviour to place and time.
  [1] *Science 2014, 344 (6179): 1242552*
  [2] *Global Change Biology 2017, 23: 4058-4067*

- We have developed a new approach and accompanying statistical toolbox to identify the critical time period during which climate variables most strongly affect biological variables[1,2]. This already popular method provides deeper insights into the mechanisms underlying biological response to climate change, and allows for more accurate projections of the future impact of climate change.
  [1] *Methods in Ecology and Evolution 2016, 7 (10): 1246-1257*
  [2] *Plos ONE 2016, 11 (12): e0167980*

- By using the state-of-the-art digital radio-tagging system 'Encounternet', combined with a grid of receivers placed at the study site, we have been able to combine unprecedented data on the spatial movements of several personality-typed individuals at the same time with their social connectivity in a natural population of wild great tits[1-3].
  [1] *Animal Behaviour 2014, 98: 95-102*
  [2] *Journal of Avian Biology 2017, 48 (5): 650-659*
  [3] *Ecology & Evolution 2017, 7 (3): 918-927*

Aquatic Ecology

- We have combined paleo-data with information from modern-day exclosure experiments and modeling, and demonstrated that the loss of large herbivores (defaunation) strongly impacts landscape structure, broad-scale nutrient cycling across aquatic-terrestrial boundaries and the functioning of freshwater and marine submerged ecosystems.
  PNAS 2016, 113 (4): 847-855

- Using dynamical models of lake ecosystems that vary in complexity, we have developed new theory on competition among aquatic macrophytes, linking theory on food web dynamics and theory on alternative stable states, and expanding theory on alternative stable states to include large lake ecosystems.
  Nature Communications 2015, 6: 7727

- We have disclosed the role of understudied ecological interactions, more specifically intraguild predation, mixotrophy, parasitism, and chemical communication, in aquatic ecosystem functioning.
  Ecology Letters 2013, 16(2): 225-233

- We have demonstrated the adaptive capacity of zooplankton to stoichiometric mismatch with their food sources. This was done by experimentally investigating micro-evolutionary trait shifts at the population level, as well as by studying species compositional shifts at the community level.
  Ecology Letters 2015, 18(6): 553-562

Microbial Ecology

- We have unravelled the impact of Amazonian deforestation on the taxonomic and functional changes in soil bacterial communities, with a significant increase in copiotrophic bacteria in tropical forest soil exposed to slash-and-burn.
  Molecular Ecology 2015, 24(10): 2433-2448

- We have established the new concept of the 'sapro-rhizosphere', where secondary consumption of fungi provides a major source of nutrition for rhizosphere bacteria. This process represents a novel component of current soil food web models.
  Soil Biology & Biochemistry 2016, 102: 14-17

- We have elucidated the ecological importance of microbial volatiles in belowground interactions between microbes and between microbes and higher organisms (protists, plants). Microbial volatiles have been shown to play key roles in the feeding behaviour of protists, and in alterations of root architecture and biomass of different plant species.
  ISME Journal 2017, 11: 817-820

- We have demonstrated the importance of microbial interactions for global biogeochemistry through disruption of the nitrogen cycle upon exposure of soils to the greenhouse gas methane. Such trait-based competitive microbial interactions have the potential to modulate important environmental processes such as nitrogen leaching, eutrophication and the emission of greenhouse gases.
  ISME Journal 2014, 8: 2397-2410

Terrestrial Ecology

- In a large-scale, 6-year-old field experiment on ex-arable land, we showed[1] that application of soil inocula not only promotes ecosystem restoration, but that different origins of soil inocula can also steer development of the plant community towards different target communities, varying from grassland to heathland vegetation.
  [1] *Nature Plants 2016, 2: 16107*

- Studying secondary succession on abandoned arable land, we have demonstrated a compositional shift in soil biota, preceded by tightening of the belowground networks, that corresponds with enhanced efficiency of carbon uptake. The implication of these findings is that the efficiency of nutrient cycling and carbon uptake in soil can be increased by a shift in fungal composition and/or fungal activity, without an increase in fungal to bacterial biomass ratio.
  Nature Communications 2017, 8: 14349

- We have demonstrated in a global study that a business-as-usual climate scenario would drive the loss of 55 ± 50 petagrams of carbon from the upper soil horizons by 2050. This is a conservative assumption of the response of soil carbon to warming.
  Nature 2016, 540 (7631): 104–108

- We have developed epiGbs, a reduced representation bisulfite sequencing method for cost-effective exploration and comparative analysis of DNA methylation and genetic variation in hundreds of samples de novo. This method uses genotyping by sequencing of bisulfite-converted DNA followed by reliable de novo reference construction, mapping, variant calling, and distinction of single-nucleotide polymorphisms (SNPs) versus methylation variation.
  Nature Methods 2016, 13 (4): 322-324

Scientific Advisory Board together with NIOO's management, October 2017

Additional societal highlights

Animal Ecology

- In an immediate response to the avian influenza outbreak in the Netherlands in 2014, we, together with VT, sampled wild birds to establish whether the highly pathogenic H5N8 virus was circulating in wild birds. This attracted huge media attention, and the discovery of the virus in a wigeon featured in the news overview of the year (2014) by the national public broadcaster NOS[1].
  [1] *NOS* News of the year 2014: http://nos.nl/video/2011076-journaal-jaaroverzicht-van-2014.html

- We participate in the BirdLife Netherlands (Vogelbescherming) national webcam project 'Beleef de lente'. We have written daily blogs on the comings and goings visible on the great tit webcam[1], which has had more than 1 million unique visitors per year, illustrating the huge impact the project has had on citizens. We also run a project in our study area Bennekomse Bos to inform the general public about our nest box research via a smart-phone application[2]. We have contributed to many radio and national TV programmes, including 'Kennis van Nu' on the barnacle goose[3] and 'Het Klokhuis' on the great tit[4].
  [1] www.vogelbescherming.nl/beleefdelente/koolmees
  [2] www.nioo.knaw.nl/nl/nestkast
  [3] www.dekennisvannu.nl/site/special/De-vlucht-van-de-Brandgans/12#!/
  [4] www.hetklokhuis.nl/tv-uitzending/2911/Koolmees

- A European Goose Management Platform has been established under the auspices of AEWA (The African-Eurasian Migratory Waterbird Agreement). One of the platform's top priorities is to establish a Population Management Plan for the barnacle goose, in order to resolve conflicts with agriculture while maintaining its favourable conservation status. NIOO and CAPS partners play a pivotal role in the population modelling.
  www.unep-aewa.org/en/news/next-steps-agreed-establishment-european-goose-management-platform-under-aewa

- Much of our research makes use of citizen science. In the 'Licht op Natuur' project, part of the data is collected this way. For the Oystercatcher project (Wadertrack) we receive > 25000 oystercatcher resightings per year by the public[1]; for Bewick's swans this is > 1500 resightings[2]. We collaborate with groups of citizen scientists who check nest box populations (NESTKAST). For this, we obtain data from >15000 nest boxes[3].
  [1] www.wadertrack.nl
  [2] www.geese.org/Ganzen/index.jsp
  [3] www.nioo.knaw.nl/nl/calendar/2e-landelijke-dag-nestkast

Aquatic Ecology

- The Marker Wadden is a newly built archipelago in Lake Markermeer, meant to improve the lake's ecological quality and further develop its ecosystem services. Together with the largest Dutch NGO, Natuurmonumenten, we study the construction of this iconic new ecosystem[1].
  [1]www.naturetoday.com/intl/en/nature-reports/message/?msg=23685
  (NatureToday is a news platform aiming to inform society on topical developments in nature. Biologists of nature organisations and knowledge institutes in the Netherlands, including NIOO, publish two stories per day)

- We have established strong links with water boards, consultancies and knowledge institutes ('the golden triangle') on ecosystem modelling with PCLake and PCDitch[1]. To create synergy between this national consortium and the international community of aquatic ecosystem modelers (AEMON)[2] we have appointed a 0.5 FTE model coordinator embedded at AKWA (Aquatic Knowledge Centre Wageningen).
  [1]www.stowa.nl/projecten/PCLake_en_PCDitch
  [2]www.sites.google.com/site/aquaticmodelling/

- The PhD projects under the NWO umbrella theme 'Biodiversity at work'[1] have demonstrated how fundamental research can be used to respond to pressing societal themes, including the impact of invasive species[2] and integrated management of biodiversity on the landscape scale. Insights have been shared in meetings with stakeholders from water- and nature management and policymakers, at symposia, through YouTube videos[3], and in professional and scientific publications.
  [1]www.nwo.nl/en/research-and-results/programmes/Research+Programme+Biodiversity+Works
  [2] www.nioo.knaw.nl/en/press/exotic-species-arent-all-bad
  [3] youtu.be/4w9X9jrJ754; youtu.be/Hg67d2aPICU

- Through the EU COST action NETLAKE[1] and the project "Ecosystem services of manmade lakes"[2], we have engaged citizen scientists in lake monitoring, gaining new context and perspectives, allowing us to scale up our research to water catchments and entire landscapes. We launched a worldwide survey and a citizen science campaign (2016-2017) on microplastics, decomposition and sedimentation in 28 lakes.
  [1]www.nioo.knaw.nl/en/netlake; www.nioo.knaw.nl/en/netlake-citizen-science
  [2]www.nioo.knaw.nl/en/ecosystem-services-deep-sand-pits-desapit

Microbial Ecology

- Soil, plant and fish microbiome analyses have resulted, in close collaboration with different stakeholders, in the identification of specific microorganisms for application in agriculture, horticulture and aquaculture, to reduce the use and adverse environmental impact of fungicides.
  ISME Journal 2014, 8: 2002–2014
  back2roots.nioo.knaw.nl/

- Funded by the Bill & Melinda Gates Foundation, the ME department has developed the project 'PROMISE', which uses the department's microbial expertise to improve the livelihood of subsistence farmers in Sub-Saharan Africa by increasing crop yields. This research programme aims to use an ecosystems approach to identify microbial consortia that can, in conjunction with resistance breeding and soil management practices, interfere with the disease cycle of *Striga*, one of the most devastating parasitic weeds of sorghum and other essential food crops in Africa.
  www.promise.nioo.knaw.nl

- We have contributed to the development of a bio-based economy by investigating the impact of plant residues on greenhouse gas emissions from soils. This was communicated in literature and to the general public, politicians and policy makers via the *Science for Environment Policy* newsletter of the European Union, which has advocated our research as a valuable step towards climate-friendly agriculture.
  Global Change Biology Bioenergy 2017, 9 (12): 1707-1720

Terrestrial Ecology

- Life on Earth, including human life, depends on soils and soil biodiversity. In order to increase public awareness and stimulate policies that will safeguard soil biodiversity and the attendant ecosystem services, we support international initiatives (Global Soil Biodiversity Initiatives, European and Global Soil Biodiversity Atlases) and we are leading several Global Soil Biodiversity Assessments and an EASAC project group on Soils at Risk.
  esdac.jrc.ec.europa.eu/content/global-soil-biodiversity-atlas

- Field studies have shown strong effects of associative learning on parasitoid foraging success. This learning ability of parasitoids holds great promise for the optimisation of biological pest control, having rarely been explored and applied until now. We aim to boost parasitoid efficacy for the control of citrus mealybugs by developing a method for training parasitoids with mealybug-induced crop volatiles upon their release into the field / greenhouse. We also collaborate with the Koppert Biological Systems company on how to stop hyperparasitoids, to protect the parasitoids and crops.
  www.nioo.knaw.nl/en/news/hyperparasitoids

- Together with our Centre for Soil Ecology (CSE), we have set up the annual national Soil Animal Days citizen science project, as well as soil organism 'passports' and blogs, to communicate the relevance of soil biodiversity to a wider audience. This project is now evolving into a network of research and societal organisations (such as IVN nature education, NL Greenlabel hub with 175 green business partners, professional association of Dutch biologists NIBI) supporting this important goal.
  www.bodemdierendagen.nl

Selected papers

Year	Paper	IF	Altmetrics
2012	Kostenko, O., Van de Voorde, T. F. J., Mulder, P. P. J., Van der Putten, W. H., & Bezemer, T. M. (2012). Legacy effects of aboveground–belowground interactions. *Ecology Letters*, 15(8), 813-821. DOI: 10.1111/j.1461-0248.2012.01801.x	17.949	13
2013	Gsell, A. S., De Senerpont Domis, L. N., Verhoeven, K. J. F., Van Donk, E., & Ibelings, B. W. (2013). Chytrid epidemics may increase genetic diversity of a diatom spring-bloom. *ISME Journal*, 7(10), 2057-2059. DOI: 10.1038/ismej.2013.73	9.267	1
	Reed, T., Grotan, V., Jenouvrier, S., Saether, B. E., & Visser, M. E. (2013). Population growth in a wild bird is buffered against phenological mismatch. *Science*, 340(6131), 488-491. DOI: 10.1126/science.1232870	31.477	46
	Van Asch, M., Salis, L., Holleman, L. J. M., van Lith, B., & Visser, M. E. (2013). Evolutionary response of the egg hatching date of a herbivorous insect under climate change. *Nature Climate Change*, 3(3), 244-248. DOI: 10.1038/NCLIMATE1717	15.295	32
	Wilken, S., Huisman, J., Naus-Wiezer, S. M. H., & Van Donk, E. (2013). Mixotrophic organisms become more heterotrophic with rising temperature. *Ecology Letters*, 16(2), 225-233. DOI: 10.1111/ele.12033	13.042	6
2014	Bauer, S., & Hoye, B. J. (2014). Migratory animals couple biodiversity and ecosystem functioning world-wide. *Science*, 344(6179), 122552. DOI: 10.1126/science.1242552	33.611	42
	Daebeler, A., Bodelier, P. L. E., Yan, Z., Hefting, M. M., Jia, Z., & Laanbroek, H. J. (2014). Interactions between Thaumarchaea, Nitrospira and methanotrophs modulate autotrophic nitrification in volcanic grassland soil. *ISME Journal*, 8, 2397-2410. DOI: 10.1038/ismej.2014.81	9.302	2
	De Senerpont Domis, L. N., van de Waal, D. B., Helmsing, N. R., Van Donk, E., & Mooij, W. M. (2014). Community stoichiometry in a changing world: combined effects of warming and eutrophication on phytoplankton dynamics. *Ecology*, 95(6), 1485-1495. DOI: 10.1890/13-1251.1	4.656	9
	Van de Waal, D. B., Smith, V. H., Declerck, S. A. J., Stam, E. C. M., & Elser, J. J. (2014). Stoichiometric regulation of phytoplankton toxins. *Ecology Letters*, 17(6), 736-742. DOI: 10.1111/ele.12280	10.689	14
2015	Declerck, S. A. J., Malo, A., Diehl, S., Waasdorp, D., Lemmen, K., Proios, K., & Papakostas, S. (2015). Rapid adaptation of herbivore consumers to nutrient limitation: eco-evolutionary feedbacks to population demography and resource. *Ecology Letters*, 18(6), 553-562. DOI: 10.1111/ele.12436	10.772	9
	Gaston, K. J., Visser, M. E., & Hölker, F. (Eds.) (2015). The biological impacts of artificial light at night: the research challenge. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 370(1667), [2014.0133]. DOI: 10.1098/rstb.2014.0133	5.847	45
2015	Ho, A., Reim, A., Kim, S. Y., Meima-Franke, M., Termorshuizen, A. J., De Boer, W., ... Bodelier, P. L. E. (2015). Unexpected stimulation of soil methane uptake as emergent property of agricultural soils following bio-based residue application. *Global Change Biology*, 21(10), 3864-3879. DOI: 10.1111/gcb.12974	8.444	2
	Kuiper, J. J., van Altena, C., de Ruiter, P. C., Van Gerven, L. P. A., Janse, J. H., & Mooij, W. M. (2015). Food-web stability signals critical transitions in temperate shallow lakes. *Nature Communications*, 6, [7727]. DOI: 10.1038/ncomms8727	11.329	14
	Lawson, C. R., Vindenes, Y., Bailey, L., & van de Pol, M. (2015). Environmental variation and population responses to global change. *Ecology Letters*, 18(7), 724-736. DOI: 10.1111/ele.12437	10.772	20
	Navarrete, A. A., Tsai, S. M., Mendes, L. W., Faust, K., De Hollander, M., Cassman, N., ... Kuramae, E. E. (2015). Soil microbiome responses to the short-term effects of Amazonian deforestation. *Molecular Ecology*, 24(10), 2433-2448. DOI: 10.1111/mec.13172	5.947	11
	Visser, M. E., Gienapp, P., Husby, A., Morrisey, M., de la Hera, I., Pulido, F., & Both, C. (2015). Effects of Spring Temperatures on the Strength of Selection on Timing of Reproduction in a Long-Distance Migratory Bird. *PLoS Biology*, 13(4), [e1002120]. DOI: 10.1371/journal.pbio.1002120	8.668	22
2016	Bakker, E. S., Gill, J. L., Johnson, C. N., Vera, F. W. M., Sandom, C. J., Asner, G. P. A., & Svenning, J. C. (2016). Combining paleo-data and modern exclosure experiments to assess the impact of megafauna extinctions on woody vegetation. *Proceedings of the National Academy of Sciences of the United States of America*, 113(4), 847-855. DOI: 10.1073/pnas.1502545112	9.423	135
	Crowther, T. W., Todd-Brown, K. E. O., Rowe, C. W., Wieder, W. R., Carey, J. C., Machmuller, M. B., ... Bradford, M. A. (2016). Quantifying global soil carbon losses in response to warming. *Nature*, 540(7631), 104-108. DOI: 10.1038/nature20150	38.138	1033
	Frenken, T., Velthuis, M., De Senerpont Domis, L., Stephan, S., Aben, R. C., Kosten, S., ... Van de Waal, D. B. (2016). Warming accelerates termination of a phytoplankton spring bloom by fungal parasites. *Global Change Biology*, 22(1), 299-309. DOI: 10.1111/gcb.13095	8.444	11
	Laine, V., Gossmann, T. I., Schachtschneider, K. M., Garroway, C. J., Madsen, O., Verhoeven, K. J. F., ... Groenen, M. A. M. (2016). Evolutionary signals of selection on cognition from the great tit genome and methylome. *Nature Communications*, 7, [10474]. DOI: 10.1038/ncomms10474	11.329	111
	McLean, N., Lawson, C. R., Leech, D., & Van de Pol, M. (2016). Predicting when climate-driven phenotypic change affects population dynamics. *Ecology Letters*, 19(6), 595–608. DOI: 10.1111/ele.12599	10.772	31

Year	Paper	IF	Altmetrics
2016 (cont.)	Raaijmakers, J. M., & Mazzola, M. (2016). Soil immune responses. *Science*, 352(6292), 1392-1393. DOI: 10.1126/science.aaf3252	34.661	71
	Van der Voort, M., Kempenaar, M., van Driel, M., Raaijmakers, J. M., & Mendes, R. (2016). Impact of soil heat on reassembly of bacterial communities in the rhizosphere microbiome and plant disease suppression. *Ecology Letters*, 19(4), 375-382. DOI: 10.1111/ele.12567	10.772	16
	Van Gurp, T. P., Wagemaker, N. C. A. M., Wouters, B., Vergeer, P., Ouborg, J. N. J., & Verhoeven, K. J. F. (2016). epiGBS: reference-free reduced representation bisulfite sequencing. *Nature Methods*, 13(4), 322-324. DOI: 10.1038/nmeth.3763	25.328	70
2017	Aben, R. C. H., Barros, N., van Donk, E., Frenken, T., Hilt, S., Kazanjian, G., ... Kosten, S. (2017). Cross continental increase in methane ebullition under climate change. *Nature Communications*, 8(1), [1682]. DOI: 10.1038/s41467-017-01535-y	12.124	103
	De Boer, W. (2017). Upscaling of fungal-bacterial interactions: from the lab to the field. *Current Opinion in Microbiology*, 37, 35-41. DOI: 10.1016/j.mib.2017.03.007	6.234	9
	Lameris, T. K., Scholten, I., Bauer, S., Cobben, M. M. P., Ens, B. J., & Nolet, B. A. (2017). Potential for an Arctic-breeding migratory bird to adjust spring migration phenology to Arctic amplification. *Global Change Biology*, 23(10), 4058-4067. DOI: 10.1111/gcb.13684	8.444	92
	Maynard, D. S., Bradford, M. A., Lindner, D. L., van Diepen, L. T. A., Frey, S. D., Glaeser, J. A., & Crowther, T. W. (2017). Diversity begets diversity in competition for space. *Nature Ecology and Evolution*, 1, [0156]. DOI: 10.1038/s41559-017-0156	-	151
	Morriën, E., Hannula, S. E., Snoek, B., Helmsing, N. R., Zweers, H., De Hollander, M., ... van der Putten, W. H. (2017). Soil networks become more connected and take up more carbon as nature restoration progresses. *Nature Communications*, 8, [14349]. DOI: 10.1038/ncomms14349	11.329	184
	Perez, J. E., Carrion, V. J., Bosse, M., Ferrão, L. F. V., De Hollander, M., Garcia, A. A. F., ... Raaijmakers, J. M. (2017). Linking rhizosphere microbiome composition of wild and domesticated Phaseolus vulgaris to genotypic and root phenotypic traits. *ISME Journal*, 11, 2244-2257. DOI: 10.1038/ismej.2017.85	9.328	14
	Schmidt, R. L., de Jager, V. C. L., Zühlke, D., Wolff, C., Bernhardt, J., Cankar, K., ... Garbeva, P. V. (2017). Fungal volatile compounds induce production of the secondary metabolite Sodorifen in Serratia plymuthica PRI-2C. *Scientific Reports*, 7, [862]. DOI: 10.1038/s41598-017-00893-3	5.228	123
	Schulz-Bohm, K., Geisen, S., Wubs, E. R. J., Song, C., De Boer, W., & Garbeva, P. V. (2017). The prey's scent – volatile organic compound mediated interactions between soil bacteria and their protist predators. *ISME Journal*, 11, 817-820. DOI: 10.1038/ismej.2016.144	9.328	56

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Year	Paper	IF	Altmetrics
2017	Teurlincx, S., Velthuis, M., Seroka, D., Govaert, L., van Donk, E., Van de Waal, D. B., & Declerck, S. A. J. (2017). Species sorting and stoichiometric plasticity control community C:P ratio of first-order aquatic consumers. *Ecology Letters*, 20(6), 751-760. DOI: 10.1111/ele.12773	10.772	12
	Tyc, O., Song, C., Dickschat, J., Vos, M., & Garbeva, P. V. (2017). The Ecological Role of Volatile and Soluble Secondary Metabolites Produced by Soil Bacteria. *Trends in Microbiology*, 25(4), 280-292. DOI: 10.1016/j.tim.2016.12.002	9.5	43
	Van de Pol, M., Jenouvrier, S., Cornelissen, J. H. C., & Visser, M. E. (2017). Behavioural, ecological and evolutionary response to extreme climatic events: Challenges & directions. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 372(1723), [134]. DOI: 10.1098/rstb.2016.0134	5.847	35
	Wubs, E. R. J., van der Putten, W. H., Bosch, M., & Bezemer, T. M. (2016). Soil inoculation steers restoration of terrestrial ecosystems. *Nature Plants*, 2, [16107 (2016)]. DOI: 10.1038/nplants.2016.107	10.3	134

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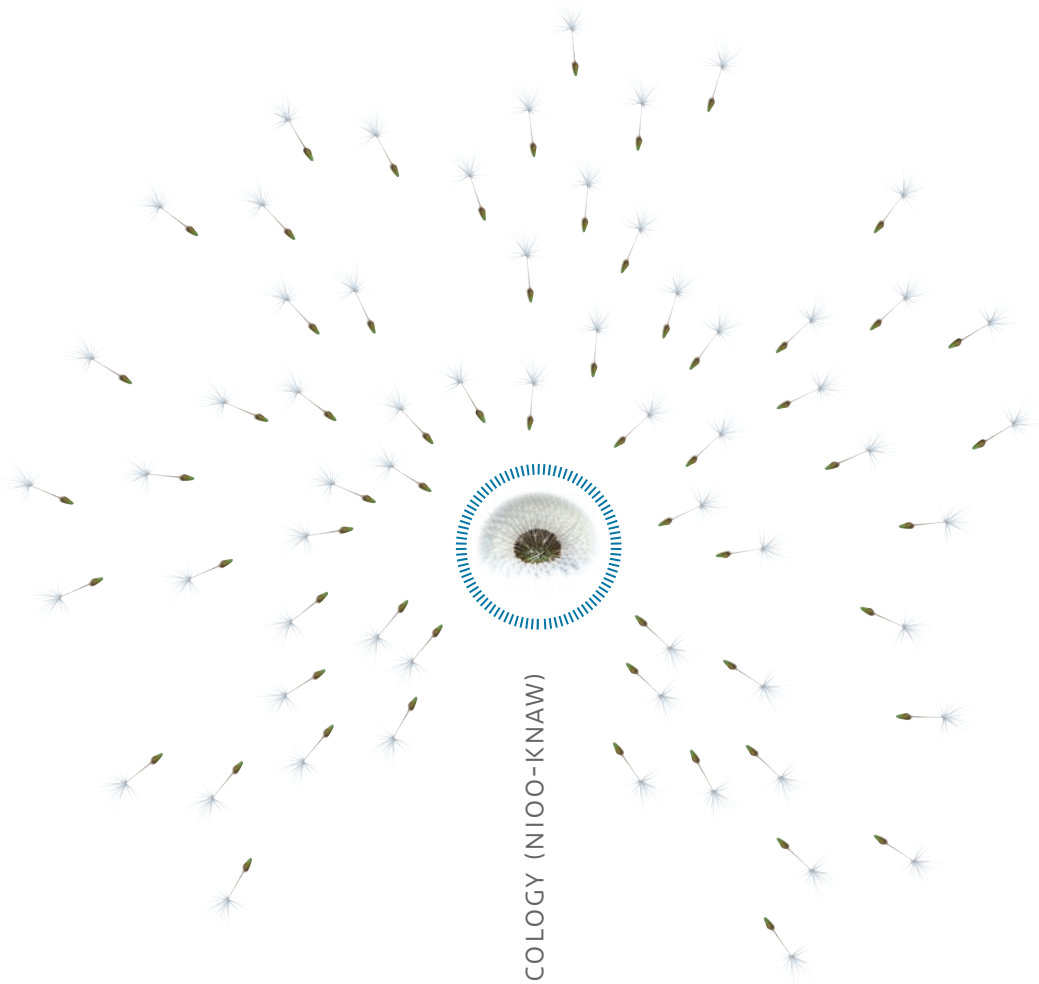

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