
Nature
Life
Knowledge agenda
for research into biodiversity,
ecology and evolution

Nature 4 Life

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COLOPHON

A PUBLICATION OF Naturalis Biodiversity Center
for NERN (Netherlands Ecological Research Network) 2017
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TRANSLATION UvA talen
BOOK DESIGN Suzanne Hertogs (Ontwerphaven)
PHOTOGRAPHY Shutterstock.com, Thinkstock, Naturalis
PRINT Zwaan Printmedia
BINDER Boekbinderij Patist
FONTS Miller Text, Berthold Akzidenz Grotesk, Overlap
PAPER INLAY Lessebo Ivory Design 1.3 COVER CKB Karton

MANY THANKS TOO Edwin van Huis, Maaike Romijn, Johan Mols, Martijn Los, Arnold Tukker, Eric Schranz, Erik Smets, Esther Turnhout, Geert de Snoo, George Kowalchuk, Han Olff, Hans Cornelissen, Hans de Kroon, Hans ter Steege, Leon Lamers, Louise Vet, Marcel Dicke, Marcel Visser, Martin Wassen, Michiel Hootsmans, Peter de Ruiter, Peter van Bodegom, Peter van Tienderen, Peter Verburg, Pim Martens, René Verburg, Rien Aerts, Steve Donovan, Tjeerd Bouma, Wim van der Putten.

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TABLE OF CONTENTS

SUMMARY

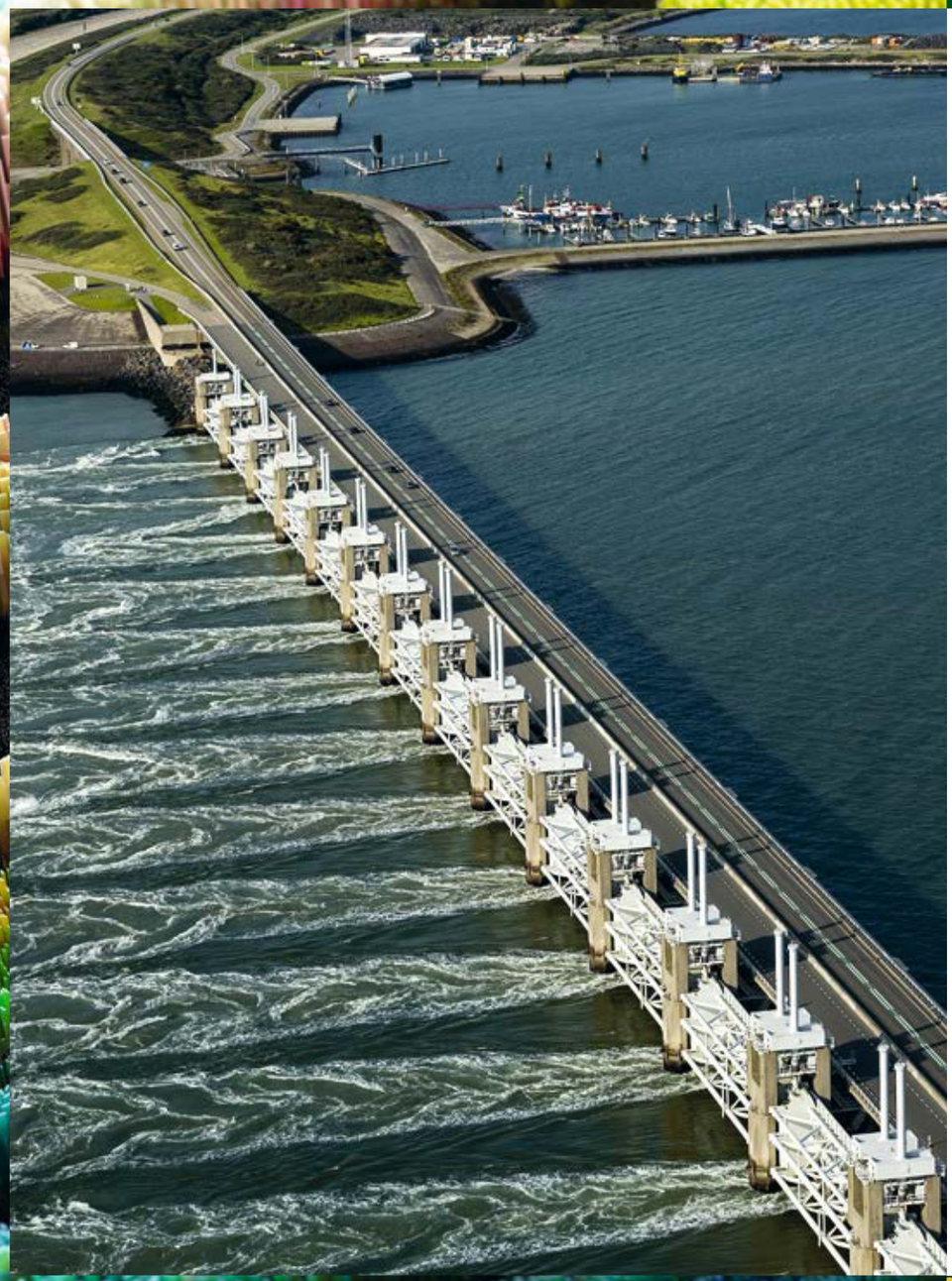
The biggest social problems that we need to find answers to in the coming decades will concern food, water, economy, climate and quality of life, health and well-being. Although these are global issues, Dutch knowledge institutions are in a great position to make a major contribution to finding appropriate solutions. The issues include: conservation and management of biodiversity in relation to climate change, land use, population growth, food security and sustainable food production, disease and pest resistance, sustainable flood protection and impacts on health.

Biodiversity research is indispensable in addressing these issues, but this is insufficiently recognised. Partly because of this, Dutch knowledge institutions whose primary focus is biodiversity research have drafted the Nature4Life knowledge agenda. The purpose of this agenda is to simultaneously provide greater focus and unite the field. Nature4Life is in line with national and international agendas, and identifies the topics that deserve extra attention and investment. Despite the fact that this type of research is of major scientific and social importance, it receives a disproportionately small share of research funding.

In drawing up and implementing this knowledge agenda, the collaborating knowledge institutions are committing themselves to a research programme which has a clear focus and is dedicated to excellent research with a great international appeal. Nature4Life aims to address the issues in a multidisciplinary and integral way, both in terms of actual research, and educating and training students and researchers.

Nature4Life also wants to evolve into an Advanced Research Centre. This would grow from a national programme with a transparent national research funding scheme and a significant contribution from companies which invest substantially in research and development. Furthermore, Nature4Life intends to invest heavily in outreach programmes and involve the general public in research through citizen science, educational projects and exhibitions.

A number of pre-conditions are essential for the implementation of the Nature4Life knowledge agenda. Some of these preconditions, such as the strong position of the Netherlands in biodiversity research, have already been met. Dutch biodiversity research is of high quality. In recent years, developments in this discipline have been closely linked to strong research sectors such as ICT, chemistry and life sciences. But that is not enough. Biodiversity research deserves more attention. To achieve this, it will be necessary to engage a large number of parties, such as the European Commission, the Ministries of Education, Culture and Science, Economic Affairs, and Infrastructure and the Environment, the Netherlands Organisation for Scientific Research (NWO), the Royal Netherlands Academy of Arts and Sciences (KNAW) and the broader research community.



Purpose and background of the Nature4Life knowledge agenda

The Nature4Life knowledge agenda aims to identify research areas that can provide answers to major social questions about food, water, economy, climate and quality of life, and health and well-being. The agenda contains three overarching, integrative scientific themes as well as a section outlining the preconditions for realising the agenda.

1.1 Purpose

Biodiversity[1] is the basis of life; it ensures resistance and resilience. Research into biodiversity is about discovering and describing species[2], variations within and interactions between species and their environment, and how ecosystems work. Ecosystem services, quality of life and the environment in the broadest sense also form an essential part of biodiversity research. Biodiversity therefore requires an interdisciplinary and transdisciplinary approach. The Nature4Life knowledge agenda aims to identify research areas that can provide answers to major social questions, including conservation and management of biodiversity, as well as a broad range of issues such as climate change, land use, population growth, food security and sustainable food production, disease and pest resistance, sustainable flood protection and impacts on health.

LONG-TERM FOCUS

Maintaining biodiversity and managing ecosystems well is essential for sustainable long-term solutions. In many social sectors, the focus tends to be on short-term solutions. This means that food production is maximised using external inputs such as fertilisers and pesticides instead of internal resources, and the quality of drinking water is ensured by technological solutions. And thus we still construct our cities without considering nature as a partner. Thanks to biodiversity, various ecosystem services can be provided. And good management and the stimulation of biodiversity can help optimise these services.

REACHING OUT TO OTHER SECTORS

This knowledge agenda outlines how research into and knowledge of biodiversity can help provide solutions to the major challenges that society faces. Nature4Life also serves as a guide to biodiversity for other sectors, so that we can improve our future prospects by having a better understanding of nature. Everyone can contribute to knowledge about biodiversity and co-own research:

1 When we use the word 'biodiversity', we are referring to the definition stated in the Convention on Biological Diversity: 'Biological diversity' means the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity withinspecies, between species and of ecosystems (www.cbd.int)

2 We use the term 'species' in the broadest sense because we are aware of the limited relevance of the biological species concept for different groups of organisms.

'When it comes to a liveable society in which nature, prosperity and welfare, health and well-being come together in a densely populated delta, the Netherlands could be setting an example for the rest of the world'

MONIQUE GROOTEN – WWF

'We all need to understand and recognise that natural capital is the linchpin when it comes to sustainability. We mustn't deplete the earth's resources; we should respect them and think carefully about how we are going to use them'

WIEGER DIJKSTRA – MINISTERY OF INFRASTRUCTURE AND ENVIRONMENT

'The top sectors have to recognise that they need to start doing something about biodiversity. You need to find the hooks to which you can connect'

MARCEL KLEIN – SIA

'There is good money to be earned in a high level of integration between nature and the environment'

JAN KEMPERS – HEINEKEN

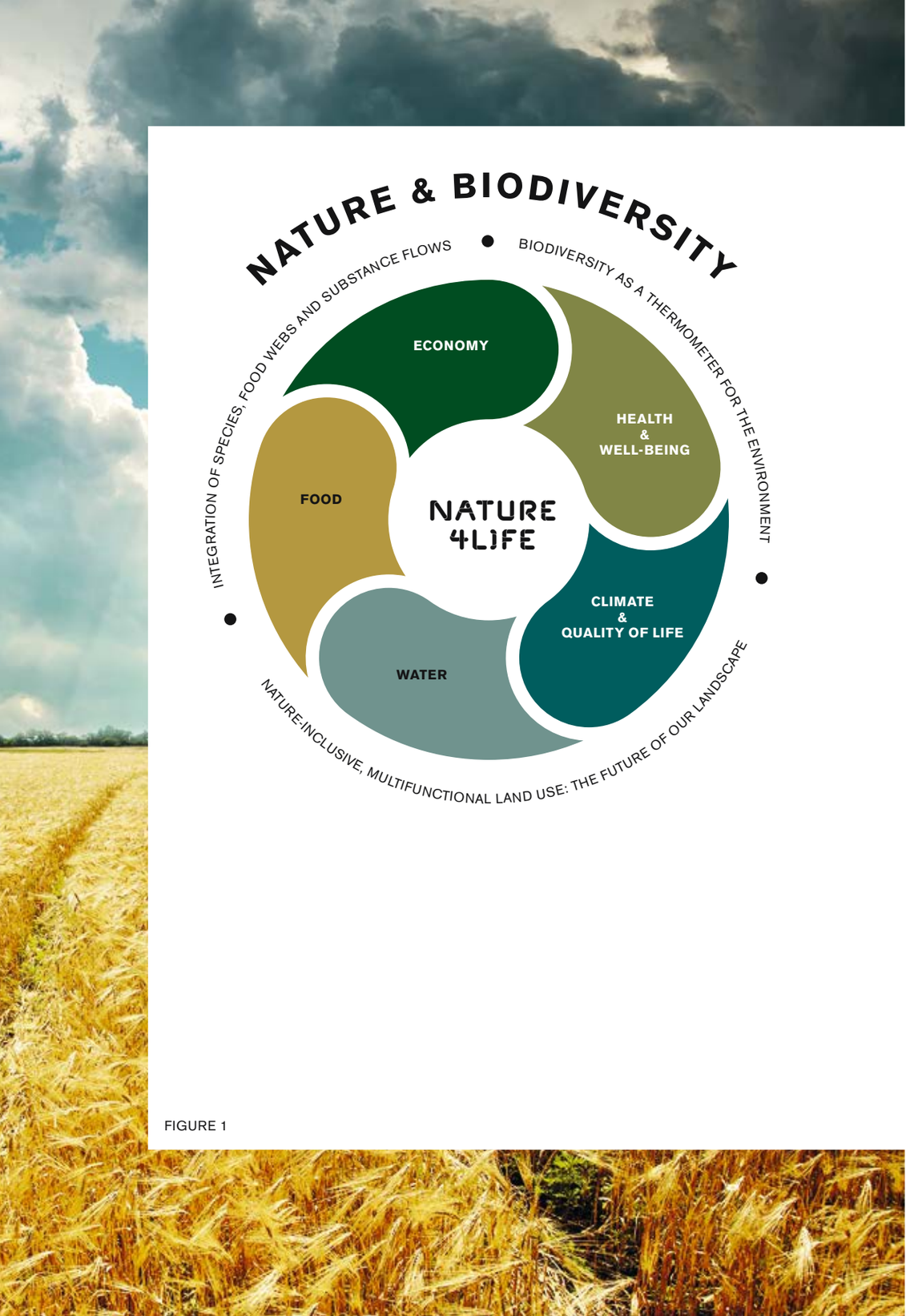


FIGURE 1

from biologists, sociologists and economists to nature conservationists, civil servants and citizens. The agenda will initially be presented to the Ministries of Education, Culture and Science, Economic Affairs, and Infrastructure and the Environment and to the Netherlands Organisation for Scientific Research. It will then be further developed in collaboration with social partners.

1.2 Background Nature4Life knowledge agenda

Nature4Life focuses on five social challenges, three scientific topics that can contribute to those challenges and the preconditions required in order to be successful in these endeavours. A broad team of scientists has identified five social challenges to which biodiversity research has the potential to make an even more significant contribution: food, water, economy, climate and quality of life, health and well-being (see also Figure 1). While each of these challenges requires specific research, Nature4Life has also identified three integral scientific topics which tackle a number of social challenges at the same time. These topics are:

1) INTEGRATION OF SPECIES, FOOD WEBS AND SUBSTANCE FLOWS

Linking the three ecological approaches to nature (also known as the 'whole ecosystem analysis') leads to a better understanding of biodiversity and to improved application of that knowledge.

2) BIODIVERSITY AS A THERMOMETER FOR THE ENVIRONMENT

Being able to better predict both positive and negative changes in the environment and biodiversity is hugely important. This requires good indicators and measuring instruments which are based on comprehensive knowledge of biodiversity and which are directly related to social needs.

3) NATURE-INCLUSIVE, MULTIFUNCTIONAL LAND USE: THE FUTURE OF OUR LANDSCAPE

Nature-inclusive, multifunctional landscaping results in resistance and resilience on land, at sea and in deltas, both in terms of the ecosystem itself and the provision of desired ecosystem services. One of the greatest challenges of our time is how we can use nature as a partner in designing sustainable long-term solutions.

BASIS FOR THE COMING YEARS

Nature4Life will use these three topics to lay a solid foundation for biodiversity research in the coming years and to provide an initial insight into the importance of this field of study for various social domains. The express purpose of this knowledge agenda is to sharpen our focus, and identify integral topics which deserve extra attention and investment.

IMPORTANT MOMENT

The knowledge agenda comes at an important moment. Today, we are faced with many challenges, from climate change, ocean acidification and the invasion of new species, to pollution and habitat loss. At the same time, we must maintain biodiversity, commit to sustainable agriculture and fishery, and ensure the provision of ecosystem services on land and at sea. Knowledge, conservation, protection and recovery of biodiversity are essential for achieving these tasks. It appears, however, that knowledge gained within the world of academia and science is not always easily accessible to public and private parties. More than that, the added value of biodiversity is now insufficiently visible on social, economic and political agendas. Nature4Life sets forth the scientific ambition to promote the acquisition and application of knowledge and innovation in business and society.

BROAD KNOWLEDGE COALITION

The Nature4Life knowledge agenda was developed under the auspices of the Netherlands Ecological Research Network (NERN)3. Researchers from various universities, research institutes, universities of applied science (via the Taskforce for Applied Research, NPRO-SIA), species organisations and representatives from other sectors are also affiliated with the network. In other words, Nature4Life has broad support. The Netherlands' impressive knowledge of biodiversity and nature, which makes the country a world leader in the field, is at the heart of the initiative. Thanks in part to the various qualities of each of the partners, and the cooperating knowledge parties, companies and social organisations, strong connections can be made. Nature4Life helps steer those connections and ensures that important questions are adequately addressed.

3 See also www.nern.nl

NATURE4LIFE IS IN LINE WITH NATIONAL AND INTERNATIONAL AGENDAS

The issue of biodiversity is included in all research and policy agendas. This is because it plays a role in many of our processes and sectors. However, this means that biodiversity as a theme in itself is usually fragmented and difficult to find. For example, fundamental questions about biodiversity featured prominently in the Dutch National Research Agenda (Nationale Wetenschapsagenda, NWA), but they were actually spread across no fewer than nine 'routes'4. The initial ideas for the Nature4Life knowledge agenda were formulated in a small group and served as a basis for input for different NWA routes. Nature4Life knowledge also contributes towards the UN's Sustainable Development Goals (SDG), the Aichi targets of the Convention on Biological Diversity (CBD), and international treaties such as the climate agreement, the Birds Directives and the Habitats Directives. Nature4Life ensures that Dutch knowledge institutions can work in a coordinated way on tackling these issues.

NATURE IS ALIVE

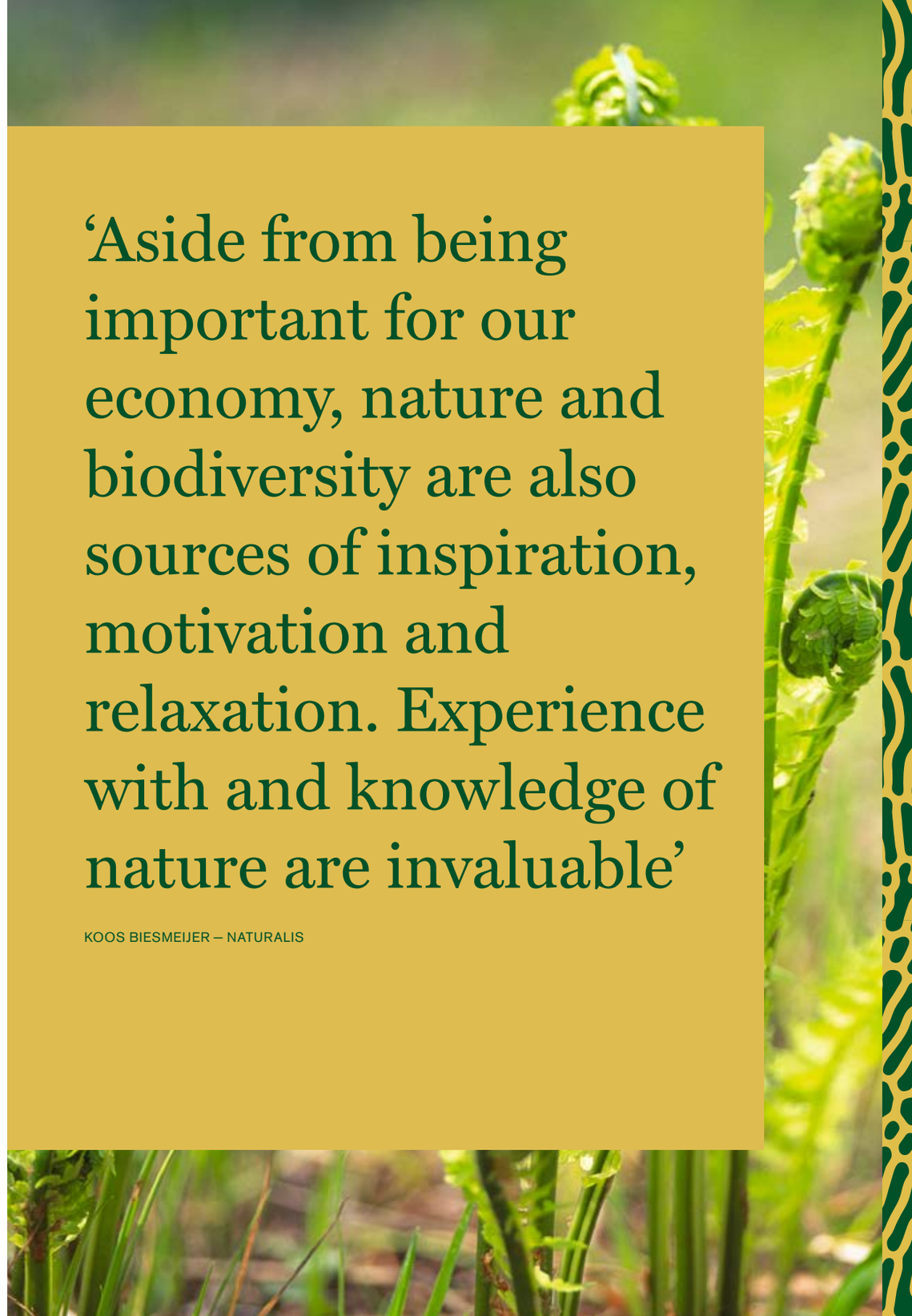
In the most literal sense, nature is life on earth. But, in fact, it is much more than that. Nature also lives among people. It is an integral part of our lives, our culture, our identity, our creativity and our inspiration. The connection that people have with nature, with biodiversity and landscapes, runs deep and is regularly expressed openly, for example, as a response to a direct, local threat such as the construction of large piggeries or building over the entire coastline. More than 100,000 people signed up to be Baywatchers for the 'Protect the Coast' initiative and not everyone was a coastal resident. The human need to have a connection with and to conserve nature is also evident from the more than 700,000 members of the World Wildlife Fund, the more than 700,000 members of the Society for the Preservation of Nature (Natuurmonumenten), the more than 130,000 'Bamboekids' and 'Rangers' (youth division of the World Wildlife Fund) and the more than 200,000 OERRR members (youth programme of the Society for the Preservation of

4 Routes in which biodiversity is at the centre include 'Quality of the environment: the values of nature, landscape, soil, climate, water and the environment', 'The origin of life: on earth and in the universe', 'Circular economy and resource efficiency', 'Sustainable Development Goals for inclusive global development' and 'Sustainable production of safe and healthy foods'. Biodiversity also plays a role in other routes such as 'The blue route', 'Smart liveable cities' and 'Resilient and meaningful societies' (urban ecology, climate control), 'Measuring and detecting: always, everything and everywhere' (genomics, e-DNA), 'Materials - Made in Holland' (circular economy, photosynthesis) and 'Healthcare research, prevention and treatment' (biodiversity and health).

Nature). Add to that the more than one million visitors to natural history museums a year, plus the more than 25,000 volunteer nature observers, the blockbuster The New Wilderness (*De Nieuwe Wildernis*, 650,000 visitors) and the popular and well-appreciated TV shows by Freek Vonk and David Attenborough, among others, and we are left in no doubt that nature is very much alive in the Netherlands.

NATURE4LIFE AND OUR EXISTENCE

The knowledge agenda reinforces the vital importance of nature and biodiversity to our existence. Research into biodiversity, ecology and evolution has a high intrinsic value for society, in the same way as, for example, philosophy and astronomy. Just as astronomy builds upon our need to understand our place in the universe, Nature4Life research builds upon our need to understand nature and the origin of life. Nature4Life wants to inspire the young and educate people to think critically, so that they go on to play a role in increasing our understanding of nature.



‘Aside from being important for our economy, nature and biodiversity are also sources of inspiration, motivation and relaxation. Experience with and knowledge of nature are invaluable’

KOOS BIESMEIJER – NATURALIS

2

The social importance of biodiversity

A broad team of scientists has identified five social challenges to which biodiversity research has the potential to make an even more significant contribution: food, water, economy, climate and quality of life, health and well-being.

Our planet provides us with everything we need to survive – and a lot more. That was the case in the past, is more or less the case now, but may not necessarily be the case in the future. The value of the services provided by the current ecosystems is much larger than all gross national products put together and it always will be. Finding an acceptable compromise between human needs and the availability of renewable natural resources, services and products is therefore the only long-term solution.

INTERNATIONAL AGENDAS

Even in the future, nature and earth will continue to provide us with our food, water, energy and raw materials. It is therefore not surprising that 'green targets' have been firmly embedded in international agendas in addition to social (poverty reduction, health) and economic (employment, resource allocation) targets. Counteracting the loss of biodiversity on land and at sea, combating desertification, sustainable forest management, bringing an end to and reversing land degradation, and the development of a circular economy feature prominently on the UN's list of new sustainability goals. The achievement of several other goals also directly depends on biodiversity, nature and natural processes, such as ending hunger and malnutrition, making food production sustainable, increasing the availability of clean drinking water, combating climate change, preventing flooding in the most densely populated coastal areas, and, especially, for generating renewable energy, creating liveable cities and ensuring healthy ageing.

POLITICAL WILL AND AN INTEGRATED APPROACH

There is no lack of political will to achieve the green targets. The Paris climate agreement and the EU agenda attest to that. How we actually achieve those green targets is partly dependent on the innovative solutions that arise from the Nature4Life research. In short, the social, economic and biodiversity objectives constitute a whole; only such an integrated approach can give us the prospect of a longer, enjoyable stay on earth.

THE UNITED NATIONS' SUSTAINABLE DEVELOPMENT GOALS

The Nature4Life knowledge agenda indicates where and how scientific knowledge of biodiversity is important for a sustainable future and can help achieve the UN's sustainable development goals. This section focuses on five social challenges in which biodiversity research can make a significant contribution: food, water, economy, climate and quality of life, health and well-being. We discuss the challenges separately, but that does not mean they are completely separate entities. In fact, these challenges are closely linked, and the real challenge lies in using an integrated approach to tackle them.

2.1 Food: food security in the future[5]

A growing world population, coupled with the changing demands of consumers, requires greater production, better food distribution and a change in food choices. The intensification of agriculture, which has been the guiding principle over the last decades in Europe, has led to the homogenisation of agricultural methods and crops, far-reaching mechanisation, large-scale use of inputs including pesticides and fertilisers, and to the increasing size of agricultural businesses, but also to the large-scale destruction of nature and the degradation of biodiversity. At sea, more efficient fishing methods have resulted in a decline in the population of many species. In addition, the footprint of our consumption stretches far beyond our own national borders. Importing agricultural products, especially animal feed, leads to the expansion of agricultural land to the detriment of nature in, for instance, Brazil and Asia, and our demand for fish leads to overfishing in Africa.

CONSIDER THE LONG-TERM EFFECTS

Agricultural developments mainly focus on food security, and are driven by policy and economics. The long-term effects of such developments on productivity, the environment and climate are not as yet being incorporated in the development of future agricultural systems in a structural way, despite the fact that there is now increasing awareness of their importance.6

SUSTAIN NATURAL CAPITAL

It goes without saying that the only way to ensure food security for a growing population is to reduce the environmental impact of agriculture, horticulture and aquaculture, and sustain the existing level of natural capital7. These

5 'Food security' is the term used by the World Food Programme to define food availability plus food access plus food utilisation (see also www.wfp.org).

6 For example, the Ministry of Economic Affairs has made nature-inclusive agriculture a priority. The Ministry of Infrastructure and Environment is also mindful of natural capital.

7 See also Sustainable Development Goal 2: End hunger, achieve food security, and improve nutrition and sustainable agriculture.

key principles are also adopted by the Agri & Food and Horticulture Top Sectors to improve the sustainability of current practices. This involves, for example, minimising the use of water, fertilisers and pesticides, reducing nitrogen deposition and minimising the leakage of substances. At the same time, the soil structure and the level of organic matter is maintained as is water supply and biodiversity. Biodiversity can contribute to sustainably high levels of productivity by using natural processes, such as earthworms for soil permeability, and green manures for biodiverse fallow systems, for improved nutrient availability and natural pest control. Well-functioning soil systems not only provide more food, but also cleaner drinking water, cleaner air and more CO2 storage. They also have an improved buffer capacity, and thus are more resistant to diseases and pests.

A SYSTEM APPROACH IS ESSENTIAL

A system approach that takes into account ecological, social and economic aspects is essential. The effects of agriculture, fishing and aquaculture on the environment and nature, as well as the entire production chain both within and outside the Netherlands, must be taken into account. By studying complex agro-ecological and natural systems on a landscape scale, we can understand more about the operating mechanisms. We can then use these insights to design systems that lead to the optimal supply of ecosystem services and help sustain natural capital. We also need to learn from the experience with hybrid systems commonly used elsewhere, such as agro-forestry and vegetable gardens. In addition, the possibilities for reducing our ecological footprint should be taken into account. Furthermore, we also need to gain sufficient insight into the limits of increasing food production and the influence of changes in consumer preferences. Finally, land and sea are not inexhaustible; there are limits to further optimising and increasing the sustainability of agro-ecosystems. We are well aware of the fact that it will not be possible to tackle the food, energy, water, quality of life and nature challenges all at the same time. That is why it is absolutely essential that we identify the consequences of social choices. Based on these trade-offs, we can continue the social debate.

The importance of biodiversity in shaping food production and food security will increase as a result of climate change. Climate change causes the spread of species to shift or change. Crop and variety selection needs to be adapted to reflect abiotic changes in the growing season and the availability of water, and biotic factors concerning diseases, pests, pollinators and natural enemies. In short, the agricultural system of the future cannot be the same as it is today.

BIODIVERSITY FOR A RESILIENT FUTURE

Nature4Life stresses the fact that knowledge of biological diversity and its role in agriculture is essential for developing the resistant, resilient, productive agricultural systems of the future. This should lead to the use of more plants, animals, fungi and micro-organisms for our food supply; to a better understanding of how ecosystems and ecological networks work; to well-functioning soils; and to the use of natural enemies and pollinators. All these factors will allow us to reduce the use of external inputs. The Netherlands is already a leader in sustainable innovation and we can continue to build upon this strong position. By using a system approach, we now have a situation where bumblebees and natural enemies replace the chemical additives in tomato production. In the process, we are using little water and even generating energy. Opportunities are now also being seized to apply the ecological system approach in open cultivation, cattle breeding and aquaculture. However, there is a lot more to be achieved. Nature4Life can, for example, speed up the search for new crops and optimal cultivation sites. We can use evolutionary insights and methods to help us find relatives of crop plants with useful characteristics, such as resistance to drought or disease. In addition, ecological models can predict which crops can be cultivated where in future, and the extent to which fishing in our seas and rivers is still within the limits of these systems.Clearly, the use of Nature4Life's knowledge will be vital for sustainable food security in the coming decades.

2.2 Water: drinking water, fresh water, seas and oceans

Climate change and socio-economic developments are generating major challenges in terms of water availability, water safety and sustainable economic use of water infrastructure. The marine environment is also facing significant challenges such as overfishing, deep-sea mining and a rising sea level. In these examples, natural systems provide important services (and sometimes threats), but the same systems are put under severe strain due to economic activities.

PROTECT AND REPAIR DELTAS, FORESTS AND MARSHES

In the freshwater environment, the availability of adequate and clean water is one of the most important ecosystem services.8 More than 40% of the world's population does not have enough clean water. What is more, climate change, especially climate change caused by the increase in desiccation and desertification, will have a detrimental impact on the availability of drinking water, which in some areas is already scarce. One of the most important and least costly measures to counteract water scarcity is to protect and restore water-based ecosystems such as rivers, lakes, deltas, wetlands, forests and marshes. This requires a better understanding of how ecosystems work, how water quality is regulated within these systems and the surrounding areas, and how biodiversity can help retain water. By applying this knowledge appropriately, we can improve the availability of clean drinking water in the long term. Knowledge of biological diversity can also support initiatives such as saline agriculture, thereby reducing the strain on clean irrigation water.

UNDERSTANDING WATER SYSTEMS IS IMPORTANT

Freshwater systems such as lakes, rivers and canals provide fish for food and water for agriculture. These natural or semi-natural ecosystems also ensure that our country does not become flooded at the drop of a hat. Of course, the Dutch delta is still the drainage area for water from the Rhine and the Meuse, which regularly causes flooding problems. It is, therefore, essential that we understand how these systems work, and that we have an insight into the long-term development of water systems, and the correlation between the physical, chemical and biological aspects. Only by continuing to use knowledge of natural processes can we find innovative solutions to tackle the consequences of climate change and changing land use in the delta, and to increase the quality of the living environment for people, flora and fauna. This also includes nature-based solutions that combine economic development, water safety and nature development.[9]

INNOVATIVE, SUSTAINABLE SOLUTIONS

The marine environment of estuaries, seas and oceans is being used increasingly intensively, which is contributing to a decline in biodiversity in those areas. Traditionally, the problems arise from overfishing, bycatches and seabed disruption in the fishing industry, but pollution, disruption and climate change caused by human activity is starting to play an increasingly significant role. New activities will also start to expand enormously in the near future, for example, energy production from wind farms, sea farms which cultivate seaweed and algae, and the expansion of aquaculture and mining in the deep sea. All these activities require innovative, integrated and sustainable solutions, whereby the possibilities of and effects on nature must be front and centre. It is very important that we understand the cumulative effects of the various activities at and in the sea, and their influence on climate change, as well as how much marine ecosystems can tolerate. A better understanding of marine ecosystems will also make it easier to find sustainable solutions to the current problems and to integrate multiple functions into nature-inclusive systems.

THERE IS A GREAT DEAL OF KNOWLEDGE OUT THERE

Research into aquatic and marine environments has a long tradition within the Nature4Life community; the scientific knowledge we have of these systems is of an exceptionally high quality and sets the pace for the rest of the field. This should continue to be the case. However, the interests of nature and society in issues concerning the Wadden Sea, large rivers, seas, oceans and land have been intertwined for quite some time already. To retain our position at the forefront of this field, we must work actively towards finding sustainable solutions for these unique ecosystems. Knowledge gained through the Nature4Life domain, coupled with economic and social knowledge, can lead to nature-inclusive, multifunctional solutions for the limited space we have at our disposal.

8 See also Sustainable Development Goal 6: Ensure availability and sustainable management of water and sanitation for all.

9 Nature-based solutions are also an important topic in the Top Sector Water.

‘More people and more nature – that is only possible if agriculture and food production becomes more sustainable’

GEERT DE SNOO – LEIDEN UNIVERSITY

‘Apples, strawberries and coffee are themselves forms of biodiversity, but are also dependent on the use of biodiversity such as pollinators and natural enemies of pests’

KOOS BIESMEIJER – NATURALIS

‘There is still a lot of work to be done in the field of nature and the economy! How much biodiversity is required to sustain economic functions? How can nature contribute to economic challenges?’

KEIMPE WIERINGA – NETHERLANDS ENVIRONMENTAL ASSESSMENT AGENCY

2.3 Economy: from linear to circular

Economic activity is the foundation of our prosperity. Economic development is seen as an important way of increasing prosperity for a substantial part of the world’s population for whom poverty, hunger, inadequate health care and education are still the norm. The growing world population, combined with the limited reserves of resources and the growing awareness that there are ecological limits to growth, create new preconditions for economic activity. The climate problem requires a ban on the use of fossil fuels and new land for agricultural use is scarce. This limits the possibility of using more biomass as an alternative to fossil fuels and non-renewable raw materials. The oceans are also being overfished.

THE ECONOMY MUST BE CLIMATE NEUTRAL

We are therefore faced with the long-term challenge of transforming economic activity so that it becomes climate neutral without impairing natural resources[10]. To achieve this, we must move towards a circular economy; a system in which the creation of value takes place based on ‘use’ rather than ‘consumption’ of both biotic and abiotic raw materials. It is essential that we use these two types of raw materials without adversely affecting biodiversity; for abiotic raw materials the focus is on lifetime extension, repair, reuse and rebuilding, and for biotic raw materials the basis of circularity lies in ecosystem services that are supplied by the natural system. These biotic cycles must therefore be arranged in such a way that those ecosystem services are not affected.

A CIRCULAR ECONOMY IS BASED ON NATURAL CAPITAL

The foundation of the circular economy lies in the ecosystem services that are supplied by the natural system11. It is absolutely vital to understand how individual parts in a circular economy affect one another within the entire system, but it is also important to understand the relationship between the entire system and the individual parts. For example, the search for alternatives to fossil fuels must not cause a decline in food production because agricultural land is being used to grow biofuel crops. In production processes, the entire chain needs to be taken into consideration; from the origin of the

10 See also Sustainable Development Goal 12: Ensure sustainable consumption and production patterns.

11 These issues are reflected in the inter-top sectorial topic, the Biobased Economy.

raw materials, waste streams, transporting products and the energy that is required for the entire process, to the effects on biodiversity, on the environment and on the living and working environment for the employees and local residents. Gradually, some companies are starting to use a circular approach for the production process. There is a growing awareness, also among governments, that biodiversity and natural processes can ensure the necessary stability for and resilience of circular systems. This is important, for instance, in the treatment of waste streams, the use of residual material for generating energy and the use of cleaner water by a more sustainable agricultural sector.

CIRCULAR IS THE ONLY WAY TO ACHIEVE A SUSTAINABLE ECONOMY

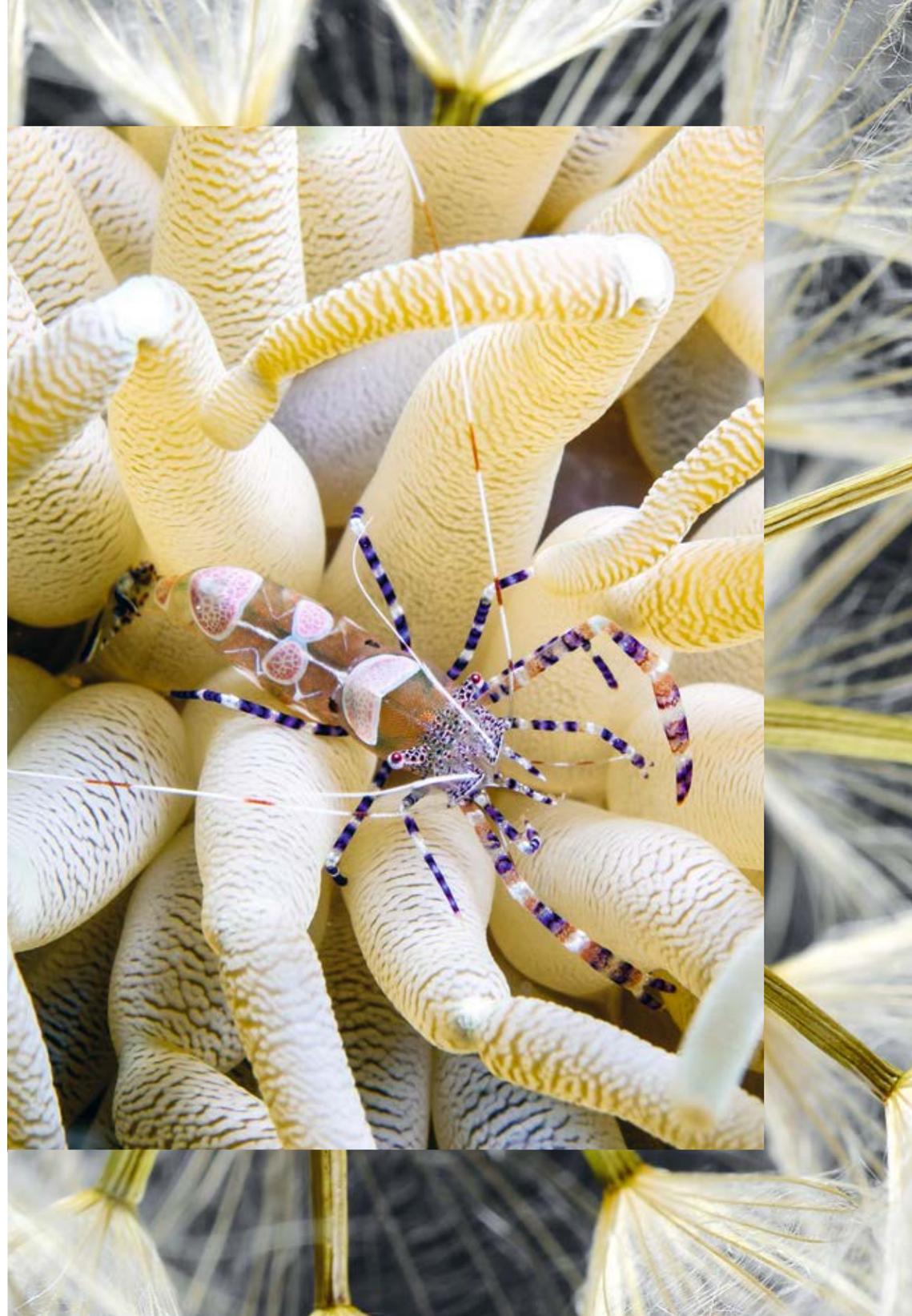
Realising the challenge of moving from a linear to a circular economy, and the extent to which this challenge can be achieved, very much depends on the speed of and commitment towards the transition from linear to circular use. When finding solutions we have a tendency to turn to new technologies and either incorporate them in existing production systems or use them to bring about organisational changes. However, knowledge about biodiversity and ecosystems is also an essential component; from the availability of materials as a basis for food, industrial products and energy, to understanding how (natural) systems work and the provision of services we need.

KNOWLEDGE MUST BE RELEVANT FOR OTHER PARTIES

Nature4Life regards contributing towards nature-based solutions for the transition to a circular economy as one of the top priorities for our field of research. To this end, existing and new knowledge needs to keep pace with the needs of other parties in the field and contribute to the further development of agendas for a circular economy, biobased economy and natural capital.

2.4 Climate and quality of life

Climate change is already affecting humans and nature, and the consequences thereof will only intensify in the future. In recent years, average temperatures have risen and weather patterns have started to change. The precise impact of these changes varies from region to region, but we will have to adjust our activities and use our surroundings differently in any case. Specifically, climate change causes the sea level to rise, is responsible for extreme weather, affects the availability of drinking water, reduces the availability of water for agricultural purposes and brings about changes in



biodiversity, all of which have an impact on the provision of ecosystem services. This leaves us with a lot of room for innovation, and to use nature and biodiversity as a source of inspiration.

VERY RAPID CLIMATE CHANGE IS AFFECTING BIODIVERSITY AND ECOSYSTEMS

Research on natural history collections teaches us that some species are shifting and that species change; they adapt. We are currently noticing that some birds are returning late from Africa, so they miss the peak in the insect population and their young increasingly go hungry. The Suzuki fruit fly, as well as many other exotic diseases and pests, have already started to feel at home in our warmer climate. We still do not know enough about the extent to which all species are able to move or adapt. Nor can we accurately predict which species will make up our ecosystems, how those systems will work, whether ecosystem services will be provided or the full scale of these processes. Nature conservation must also prepare for climate change. To do this, we will need to protect the places where the species that need protecting will be in the future. Nature4Life can facilitate this process by conducting research using predictive models and sharing knowledge.

MORE PEOPLE ARE LIVING IN CITIES

Cities provide many people with a place to live, work and be entertained. The combination of climate change, an increasingly urban population and a rise in economic activity makes the task of designing sustainable urban areas considerably more difficult. The concept of ecosystem services can play an important role and serve as a link between the different domains. Maintaining and developing ecosystem services can help improve the climate resilience of cities, the adaptability of the environment, and living conditions in urban areas. This might include tackling risks and offering services related to heat, available drinking water, particulate matter and flooding. For example, parks in and nature areas surrounding cities play an important role in regulating the temperature and humidity levels in cities. Green roofs are another example, which are used to help control peaks in storm water runoff. Cities also have to provide space for relaxation and recreation. The Lingezegen Park between Arnhem and Nijmegen is a good example of this. It combines water buffering and water purification through natural vegetation with recreation and the production of biofuel from harvested aquatic plants.

DIVERSITY OF FUNCTIONAL PROPERTIES IS IMPORTANT

For many ecosystem services, the direction in which biodiversity is changing or being optimised by humans is more important than (changes in) biodiversity itself. Tropical rainforests dying off as a result of climate change has a huge impact on our climate because much less carbon is being absorbed. The same is also true when tropical rainforests are replaced by a species-rich savannah, as predicted by various climate models. It is important to emphasise the fact that integrated planning is the only way to achieve a viable, climate-friendly environment. An integrated plan sets out the preconditions as well as the social, economic and ecological needs, and brings them together to create a homogeneous, environmental vision.

INCORPORATING KNOWLEDGE IS THE NEXT STEP

Nature4Life research contributes to outlining the effects of climate change on biodiversity and ecosystems. However, knowledge of how species adapt to climate change and how new combinations of species will function as an ecosystem is still very limited. The next step is to incorporate our knowledge about natural systems into the design of sustainable solutions. To this end, particular attention must be paid to the transfer of knowledge, especially in relation to solutions that are required by society, such as adequate nature management and the provision of services to ensure the quality of life in cities. In addition, the Nature4Life community can make a significant contribution to the joint development of nature-inclusive, multifunctional solutions for using the limited space we have at our disposal (see 3.3), taking into account the ecological, social and economic conditions we have identified together.

‘The destruction of biodiversity and ecosystems is ‘simply’ a problem of design. Nature has been functioning well without us for 3.8 billion years. We can learn a lot from that. The only sustainable economy is one that fits into the planet’s economy: circular, solar energy and based on diversity’

LOUISE VET – NETHERLANDS INSTITUTE OF ECOLOGY

2.5 Health and well-being

Good health and well-being are significant achievements of our welfare society. However, these have not yet reached everyone, not in the Netherlands and certainly not in other parts of the world. Therefore, improving health and well-being remains one of the main goals for the Dutch government[12] as well as internationally[13]. Biodiversity, ecosystems and nature are at the heart of human health and well-being.

MANY ASPECTS OF BIODIVERSITY HAVE NOT YET BEEN PROPERLY EXPLORED

Firstly, a great deal of medicine and medical solutions continue to come from natural resources. Insights into races in nature can help to reduce pathogen resistance, and to discover and develop new antibiotics. Metabolomics and other new techniques promise major benefits for finding new medicines, especially in combination with the search for candidate chemicals in nature. Many aspects of biodiversity have not yet been properly explored in this area and, since all species have had to defend themselves against diseases and parasites for millions of years already, there are many possibilities.

NOT ENOUGH IS KNOWN ABOUT THE ECOLOGY OF VECTOR-BORNE DISEASES

Secondly, our health, and the health of people living in the tropics even more so, is partly determined by the extent to which vector-borne diseases[14] spread. We still do not know enough about the ecology of the spread of these diseases, nor the extent to which stable and biodiverse ecosystems can help prevent outbreaks. The magnitude of the challenge will only continue to grow, since in many areas climate change will lead to exposure to new diseases, and to combinations of diseases as pathogens and vectors expand their reach.

BIODIVERSITY IS IMPORTANT FOR PREVENTION

Thirdly, biodiversity and nature can also be important for prevention. Our government also believes that prevention is better than cure. Our ability to prevent obesity, cardiovascular disease, lung disease and other diseases depends partly on the maintenance of a clean and accessible natural environment. For example, air pollution was responsible for the premature death of 240,000 people in the EU in 2010; diseases can also be spread by environmental, soil and water pollution. Natural, well-functioning ecosystems and green infrastructure can help reduce these risks.

BIODIVERSITY CONTRIBUTES TO HEALTH

A stay in a natural environment also reduces stress, and accelerates mental and physical recovery. Being actively engaged in and with nature improves both health and social cohesion. In short, biodiversity not only provides the ecosystem services on which health is based, such as providing healthy food, clean air and clean water, it also makes a direct contribution to health by providing relaxation, inspiration and recreational opportunities. However, the precise relationship between both is still insufficiently clear. This calls for more research on the links between biodiversity on the one hand, and health and medical practice on the other hand. Here, the direct link between the scope and type of biodiversity, and health (physical, mental and social) is central.

BIODIVERSITY SHOULD PLAY A CENTRAL ROLE

Nature4Life believes that it is vital to further investigate the role of biodiversity's contribution to health and well-being in the Netherlands and beyond. One of the practical ways to do this is to give diversity and ecosystem services a key role in designing our future (urban) landscapes and to conduct research into effective, nature-inclusive solutions as part of this (see also 3.3).

12 The motto of the Ministry of Health, Welfare and Sport is 'The Netherlands healthy and well'.

13 'Ensure healthy lives and promote well-being for all at all ages' is the UN's Sustainable Development Goal 3.

14 Vector-borne diseases are diseases transmitted by, for example, mosquitoes or ticks.

3

Nature4Life research themes

The five social challenges require specific knowledge and research, and are all directly interconnected. In order to be able to make the best possible contribution to these issues, in addition to investigating the challenges individually, Nature4Life is also devoting attention to a number of integrated research themes. In the coming years, the Nature4Life community wants to focus on the following research themes:

1) Integration of species, food webs and substance flows.
2) Biodiversity as a thermometer for the environment.
3) Nature-inclusive, multifunctional land use: the future of our landscape.

3.1 Integration of species, food webs and substance flows

Our understanding of biodiversity and ecosystems partly depends on how well we put together a conceptual model. To do this, it is essential to completely connect ecosystems research with different perspectives also known as the whole ecosystem analysis. Current research into ecosystems is broadly characterised by three different approaches that are still insufficiently interconnected: species (biodiversity); food webs (interactions); and substance flows (biogeochemical cycles). Each organism and each species has a specific role in the complex system and has a role to play in every approach. However, at the moment it is difficult to connect questions and results from one approach with other approaches. For example, a good understanding of the carbon cycle in one system says nothing about species diversity or the organisation of the food web in this system. Conversely, it is by no means always clear how species diversity relates to the functioning of an ecosystem.

SPECIES

The first approach is the study of biodiversity between and within species, and in space and time. Patterns are explained by both internal and external processes. This involves both the emergence of novelties through mutations, gene duplication or genome duplication influenced by natural selection (evolution). Further, we must integrate geographical patterns now and in the future which are under the influence of climate and landscape and in relation to species characteristics such as size and environmental tolerances.

FOOD WEBS

The second approach is the study of interactions between organisms. In food webs, the focus is on the interactions between plants, herbivores, predators and detrivores. In terms of the spread of diseases and pests, it concerns interactions between pathogens, pests, vectors and hosts. Many plants are also directly dependent on mutualism (win-win interactions) with, for example, mycorrhizas fungi, natural enemies of herbivores and pollinators. Based on the network of interactions, we can then deduce the dynamics and stability of such interacting systems, and whether and when balances and tipping points can be expected in the event of changes (environment, climate, invasion of species, *etc*.).

SUBSTANCE FLOWS

The third approach concerns the study of the biogeochemical cycles of carbon and other elements, and their mutually stoichiometric relations. For example, we must determine the role of organisms or micro-organisms in the construction and degradation of complex organic compounds, thus determining energetic and other local-scale fluxes, and the (model-based) scale-up in space and time. Such analyses demonstrate how terrestrial, aquatic and marine systems function in the interaction between biosphere, geosphere and atmosphere.

NEW METHODS

Each of these three approaches has received a significant boost in recent years due to the arrival of new, innovative methods. Molecular technology, for example, makes it possible to detect and identify species to a previously unattainable level of detail. And satellites, citizens and new sensors are increasingly being used for observation. In addition, metagenomics and eDNA provide insights into species communities and their interactions in food webs. We are getting an increasingly accurate picture of substance flows thanks to isotope research and the use of sensors at a micro level (for example, in water and in soil) and at a macro level (for example, using satellites or other remote sensing techniques). Thanks to these new techniques and technologies, it is possible to collect ever more specific data in ever larger quantities.

HOW ARE WE GOING TO TACKLE ‘INTEGRATION OF SPECIES, FOOD WEBS AND SUBSTANCE FLOWS’?

Obviously, it is a huge challenge to set up such an integrated approach for highly complex systems. It is not just about integrating the approach within Nature4Life biodiversity research. The social sciences must also be involved because humans have a huge effect on biodiversity and nature on earth.

UNDERSTANDING AND PREDICTING CHANGES

One thing that we can do already is conduct an analysis of terrestrial, marine and aquatic systems (still relatively simple at the moment) based on all detectable organisms (and, if necessary, aggregated in ‘metagenomes’), identifying their interactions and the resulting fluxes. This requires a combination of observation, experimentation and modelling. Questions that need to be asked and answered include what are the key processes that influence the fluxes in the system and what are the key species? To what extent do species’ responses to change differ, and how does this affect the stability of interaction

networks and the functioning of ecosystems? What are sensitive indicators for major changes? To what extent is there redundancy in the species composition and can one species be replaced by another, from the perspective of trophic cascades and substance flows?

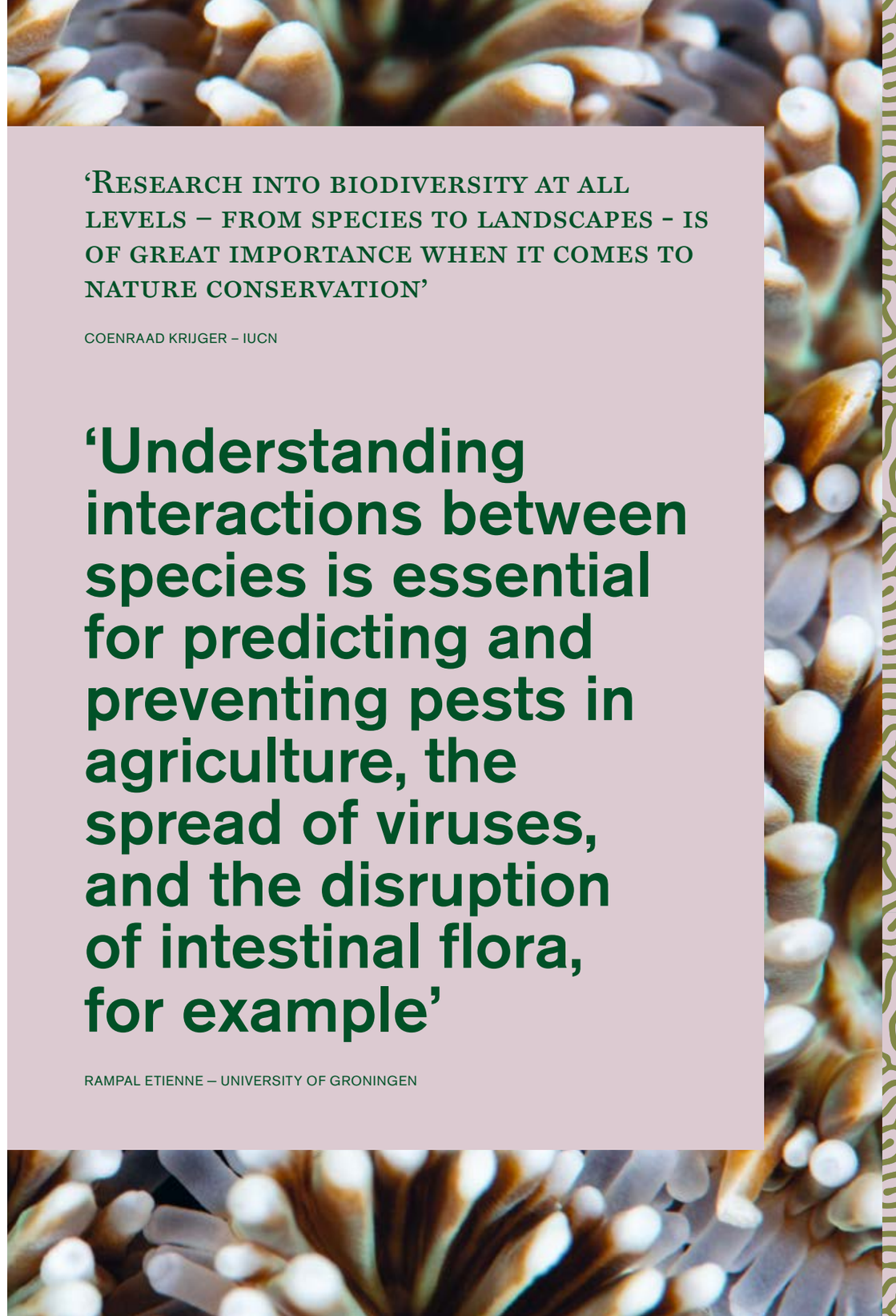
Finally, the spread of organisms will start to shift due to the combination of climate change and changes in land use (global change). As a result, organisms will disappear and appear, and new interaction networks and whole new ecosystems will emerge. New food sources will develop and new pests will crop up. Existing equilibriums will disappear, sometimes slowly, sometimes abruptly. Patterns in production, consumption, decomposition and predation will change. All of this will have an impact on the cycles of substance flows. Understanding and predicting these changes can help to address the social challenges.

WORLD-CLASS RESEARCH

The research community has the essential expertise to tackle each of the three approaches. That expertise is world-class. Therefore, in the Netherlands there is a unique opportunity to address this complex scientific challenge and bring these fields together. This requires commitment from the parties concerned. Initially, the focus must be on a small number of systems so as to shape the integration of the concepts.

INTEGRATED APPROACH

An integrated approach to biodiversity, from species to ecosystems, is also particularly valuable as a basis for finding solutions to social challenges. In this regard, it is essential that the Nature4Life approach and terminology correspond to those used by the socio-cultural and economic domains. After all, there is a high degree of mutual dependence between them. For example, questions as to whether biodiversity is actually being protected and whether new food varieties are being grown are, to a large extent, dependant on social, economic and policy processes. To the same extent, safeguarding food harvests and other natural products (e.g., fishes and fisheries) directly depends on our understanding of the interactions in the system. The question of whether the interaction network can accommodate changes also plays a vital role here, as do policy decisions and the socio-economic context at a local, national and international level. One example is the implementation of the new climate treaty, which calls for measures to adapt to and mitigate climate change. The choice of measures is directly dependent on our understanding of the biogeochemical cycles we have to use to prevent, for example,



‘Research into biodiversity at all levels – from species to landscapes - is of great importance when it comes to nature conservation’

COENRAAD KRIJGER – IUCN

‘Understanding interactions between species is essential for predicting and preventing pests in agriculture, the spread of viruses, and the disruption of intestinal flora, for example’

RAMPAL ETIENNE – UNIVERSITY OF GRONINGEN

over-fertilisation or loss of soil fertility and algal blooms. The applicability of Nature4Life solutions depends on how well socio-economic aspects have been incorporated into the approach from the very beginning.

3.2 Biodiversity as a thermometer for the environment

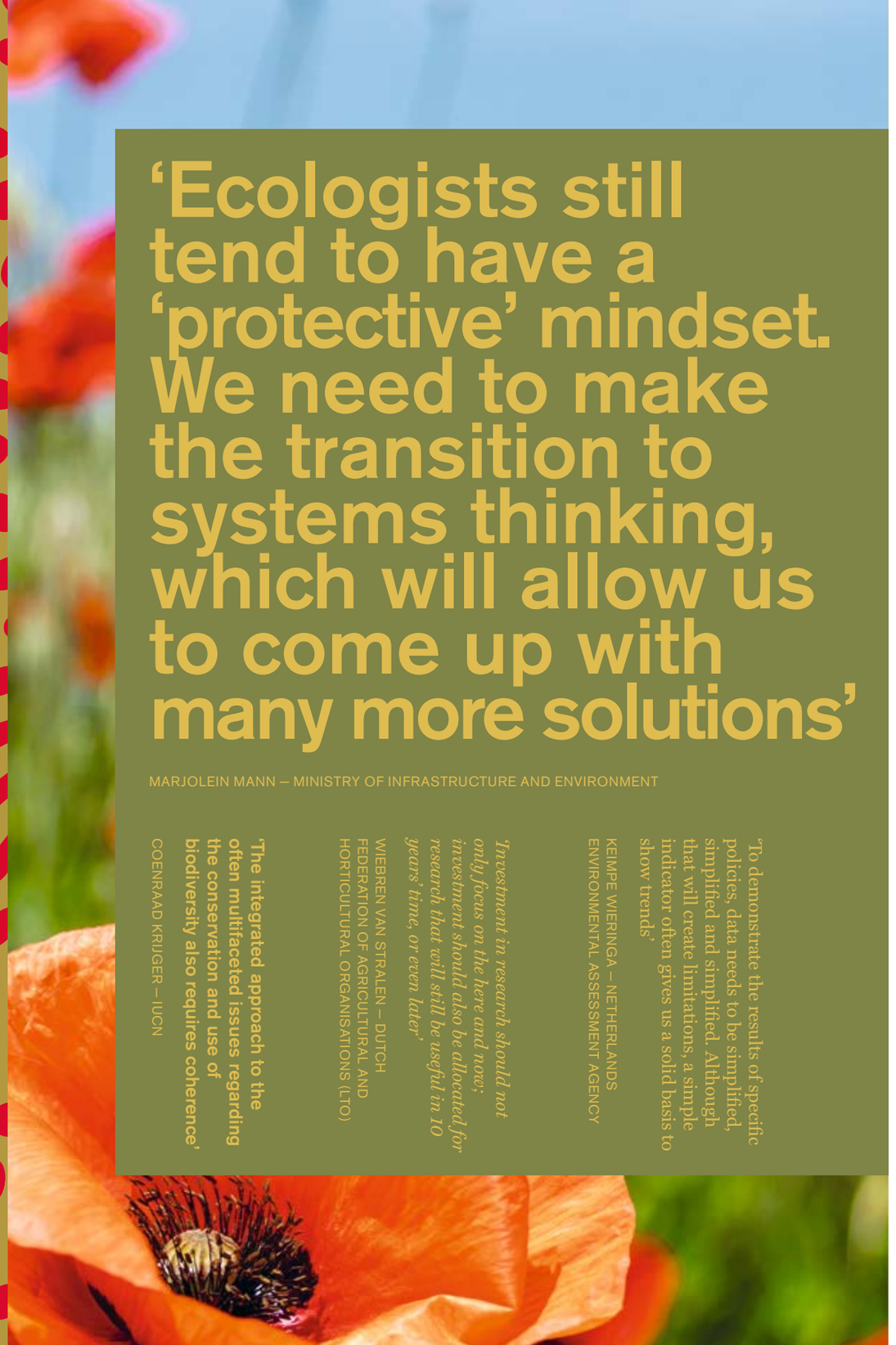
Human activity can have a huge impact on the disappearance of species and changing ecosystems. Methods that measure these effects are essential for designing more effective measures, and for substantiating and implementing those measures. This involves methods that measure current conditions as well as models which can predict, for example, the influence of changes in climate or land use. Making a proper diagnosis of the current situation and trends in connected, natural and social systems is not only a scientific, but also a social and political issue. The development of indicators and measurement methods must therefore be directly linked to both ecological, social and policy priorities. After all, we measure what we value and we value what we measure. A smart and well-informed choice of trends and indicators which need to be measured can act as an early warning system, whereby action can be taken quickly in the event that too much strain is put on (resilience and resistance of) biodiversity, ecosystem services or planet earth as a whole.

HOW ARE WE GOING TO TACKLE 'BIODIVERSITY AS A THERMOMETER FOR THE ENVIRONMENT'?

We can use existing knowledge to model relationships and predict the presence of species, functional characteristics and their quality indicators. This emphatically requires the use of new developments, for example, in the field of sensors (from chips to satellites), big data and data mining. All of these elements combined will allow us to gain an understanding of what we actually need to measure in order to be able to say something about the state of the species, landscapes and the services that both provide.

MEASURING AND PREDICTING TRENDS

Indicators and models are required to measure and predict trends in the development of species and populations. Causal links are also made with the underlying ecological processes and abiotic variables. In this way, changes in biodiversity can be compared to the impact thereof on essential ecosystem services such as clean water, clean air and healthy soil. For example, predic-



‘Ecologists still tend to have a ‘protective’ mindset. We need to make the transition to systems thinking, which will allow us to come up with many more solutions’

MARJOLEIN MANN – MINISTRY OF INFRASTRUCTURE AND ENVIRONMENT

‘To demonstrate the results of specific policies, data needs to be simplified, simplified and simplified. Although that will create limitations, a simple indicator often gives us a solid basis to show trends’

KEIMPE WIERINGA – NETHERLANDS ENVIRONMENTAL ASSESSMENT AGENCY

‘Investment in research should not only focus on the here and now; investment should also be allocated for research that will still be useful in 10 years’ time, or even later’

WIEBREN VAN STRALEN – DUTCH FEDERATION OF AGRICULTURAL AND HORTICULTURAL ORGANISATIONS (LTO)

‘The integrated approach to the often multifaceted issues regarding the conservation and use of biodiversity also requires coherence’

COENRAAD KRIJGER – IUCN

tive models can determine whether a point of no return will be passed or how the provision of ecosystem services can be optimised. These are issues that concern society as a whole and which require a set of instruments to be able to use biodiversity as a thermometer.

THE QUALITY OF AN ECOSYSTEM

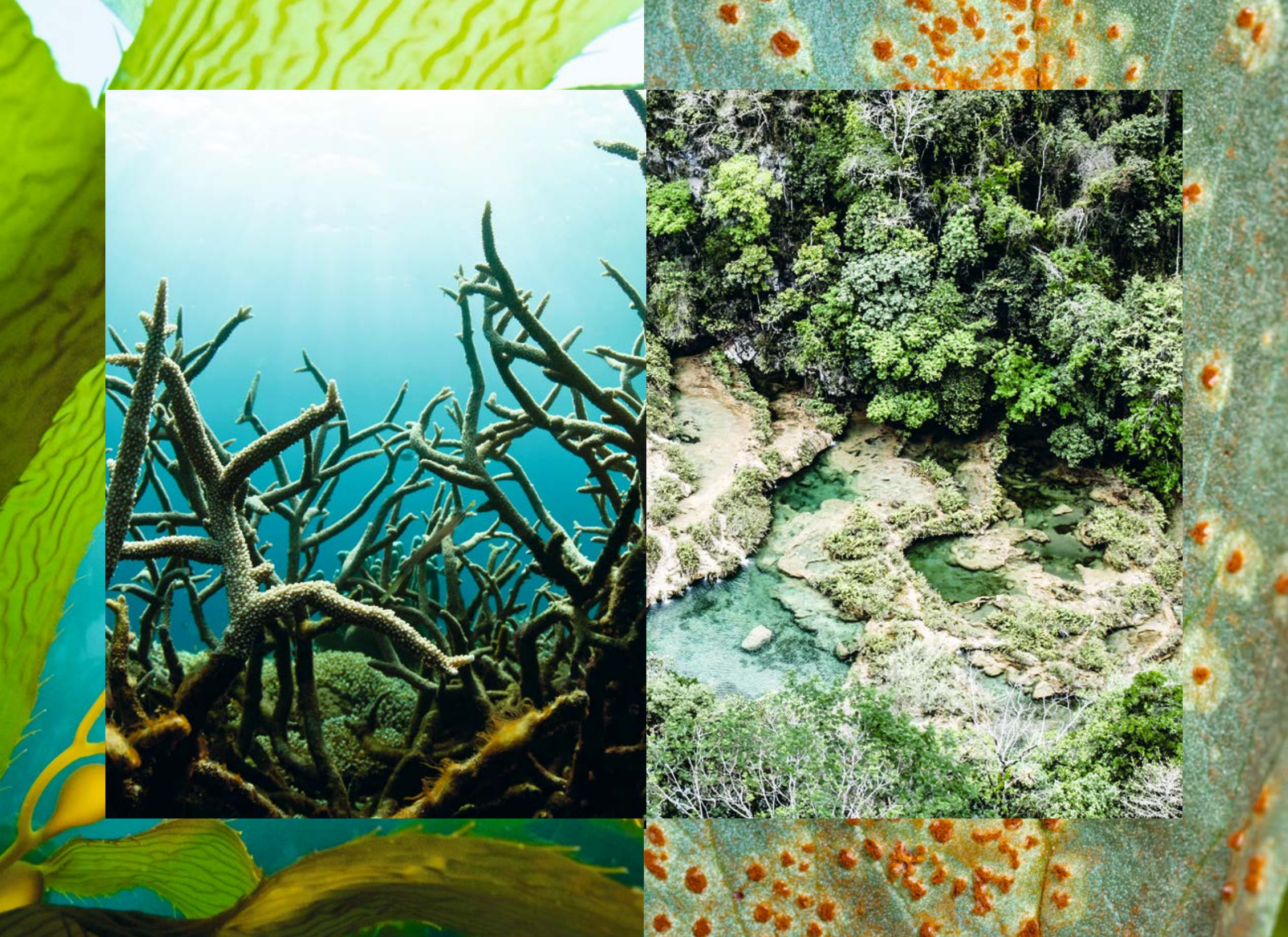
Related to this is the question of what we understand by the quality of an ecosystem or ecosystem service and who determines when that quality is sufficient. This must be investigated before we can formulate a well-quantified picture of developments in species (that are important for humans), ecosystems and ecosystem services. Then we can diagnose, for example, the current state of our biodiversity and nature, the underlying causes of shifts or the effects of environmental or agricultural measures on nature.

3.3 Nature-inclusive, multifunctional land use: the future of our landscape

The third research theme identified by Nature4Life is research into and the development of nature-inclusive solutions for multifunctional land use with sufficient resistance, resilience and regenerative capacities to cope with changes. In other words, knowledge of biodiversity is essential for designing our future landscapes in which working, living, nature and security are guaranteed. While the focus of this approach is on land use, we realise that this aspect also plays a role in economic chains and business processes. In many cases, but certainly not always, this will also be expressed in more pressure on the limited space.

SMART SOLUTIONS FOR LIMITED SPACE

Of course, there will be areas where one of the functions will take precedence. This is the case, for example, for working or living in a city or for food production in the countryside. But even in these situations, we need to improve sustainability by integrating other functions and linking to neighbouring areas which have other key functions. For a large part of the Netherlands, and increasingly in other areas of the world, we will have to come up with smart solutions to give shape to the many claims on the limited space. For example, which landscape will be able to cope with the forthcoming energy transition, the issues of water safety and the various biodiversity challenges – all at the same time?



INSIGHTS FOR PRECONDITIONS

Nature4Life will generate insights for identifying the preconditions for both maintaining the (desired) biodiversity and ensuring the provision of essential ecosystem services. To achieve this, we need to determine which ecosystem services are required where and which other claims will arise. We will then be able to judge the extent to which it will be possible to meet all these claims based on smart land use planning and by integrating knowledge of biodiversity. And we should also be able to indicate the areas in which society will have to make choices. Our contribution to this discussion will help us connect to other domains.

HOW ARE WE GOING TO TACKLE 'NATURE-INCLUSIVE, MULTIFUNCTIONAL LAND USE'?

Firstly, we need to fill important gaps in our knowledge about ecosystem services. Secondly, there must be a greater understanding of the demand for and use of ecosystem services. And thirdly, the possible solutions must be tested in practice.

FILLING KNOWLEDGE GAPS

The extent to which nature-inclusive, multifunctional land use strategies actually result in provisioning of ecosystem services depends on the availability of scientific knowledge and on integrating this use into new earnings models, e.g. sustainable agriculture and natural capital. In addition, there is a need to understand the effect of such strategies on the social system, e.g. involvement of NGOs, government, citizens, farmers and other landowners. Consequently, research needs to address the relationships between government and non-government actors, and contribution of different forms of knowledge (scientific and non-scientific).

SYSTEM APPROACH WITH A LONG-TERM PERSPECTIVE

Knowledge about biodiversity and ecosystem services will then be used to develop a system approach with a long-term perspective, based on a better understanding of how ecological, social and economic processes and factors influence each other. Biodiversity research has, for the most part, been limited to its own domain, yet it has long been known that unspoilt nature is the exception to the rule and that human influence partly determines what nature looks like. The changes are coming thick and fast, and are unpredictable to some extent. This is precisely why we have to focus on gaining a better understanding of the dynamics of the entire system. This should then lead to a deep understanding of mutual interdependence and potential solutions for using space. We should also then be able to better assess the effects of choices in the long term.

TESTING IN PRACTICE

Solutions on the drawing board are great, but options for space utilisation need to be studied and tested on the ground and in the field. That is why we propose setting up a number of living labs for nature-inclusive, multifunctional land use. Here, the various disciplines can work together to solve local or regional issues and to test possible solutions in practice. For example, a living lab in a rural area can test the extent to which nature-inclusive agriculture can be an alternative to current agriculture in the long term. Similar questions need to be asked in urban areas. In addition to biodiversity, this also involves a healthy living environment (good air and water quality) and recreational opportunities, and how we can combine water storage, work and living functions creatively. In the living labs, farmers, residents, nature conservationists, governments and other stakeholders can come together to find common solutions. The living labs are also the focus of research, whereby a regional problem can be studied in an integrated and interdisciplinary manner. Ideally, this knowledge and process should be incorporated into spatial planning issues, such as developing an environmental vision for the Dutch landscape.

Preconditions for implementing the Nature4Life knowledge agenda

A number of preconditions are essential for the implementation of the Nature4Life knowledge agenda. Some of these preconditions have already been met in our country, for example, our strong position in biodiversity research. Furthermore, Nature4Life wants to reach out to related disciplines and form a broad coalition with social partners. Nature4Life's integrated approach must also be incorporated into the education programmes for students and researchers. Nature4Life also wants to reflect the issues on international agendas. Finally, Nature4Life wants to communicate and share its knowledge.

4.1 Strong position of biodiversity research

In the Netherlands, research into biodiversity, ecology and evolution is of a very high standard. We are among the very best in the world in these fields. This position is the result of decades of investment in research and education by the government, knowledge institutions, individual researchers and teachers. This valuable position deserves to be cherished and to be used to address the challenges we face in the 21st century. It is therefore necessary to continue investing in research into biodiversity and into how ecosystems work. For most ecosystems, very little is known about the food webs they are based on, and which processes influence their structure and dynamics. We know little or next to nothing about most species in the ecosystems, let alone their relationships. This kind of knowledge is important for a better understanding of life on our planet and for a sustainable future. This also requires good infrastructure which makes biodiversity data more accessible[15]. In addition, our research can only really have an impact if we collaborate with other research domains and social partners from the outset.

GETTING BIODIVERSITY ON THE RESEARCH AGENDA

The profile and status of biodiversity research deserves to be raised among national and international financiers of scientific research, including the Netherlands Organisation for Scientific Research (NWO). Nature4Life is committed to achieving this, and shall contribute its expertise to help plan and implement programmes in which more attention is paid to biodiversity. The field must be well organised for the implementation of the ambitious Nature4Life knowledge agenda to be a success. The Netherlands Ecological Research Network (NERN) will play a pivotal role in this.

4.2 Reaching out to related domains for interdisciplinary research

Most issues about biodiversity and its application are complex, and involve ecological, socio-cultural and politico-economic aspects. There is little unspoilt nature left on the planet, and there is nature in the Netherlands both thanks to and in spite of humans. Nature4Life is aware of this, and this knowledge agenda should also be seen as an attempt to reach out to other disciplines to develop and work on true interdisciplinary approaches together. We have to start by listening to and understanding other insights, other knowledge systems and other values. In order to be able to achieve this, knowledge from the various disciplines must be more available and easily accessible to researchers outside the community which is directly involved. The systems thinking, which is ingrained in ecologists working methods and processes, can help shape interdisciplinary research.

INVESTING AND COLLABORATING

Nature4Life argues that a significant investment is needed for interdisciplinary and transdisciplinary research into biodiversity, which directly corresponds to the previously described social challenges and the overarching topics. The collaboration with other partners, already initiated by Nature4Life, must also be actively expanded.

4.3 Broad coalition and new alliances with social partners

The agenda was developed under the auspices of NERN, but has a strong multidisciplinary character. It also incorporates overlaps with society and policy-making. Representatives from the corporate world as well as social and public organisations were actively approached to consider and explore their vision of, interest in and need for the Nature4Life knowledge agenda. The initiative has been widely supported and mirrors the challenges with which various partners will be confronted in the coming years. However, major steps still need to be taken for the agenda to appeal to other partners. Special attention must be paid to cooperation with:

Nature conservation: to adequately protect biodiversity in the future and to monitor the effectiveness of that protection.

Government: to support the integration of (knowledge of) biodiversity into policies, such as nature-based solutions, natural capital and well-being, and to shape and implement international treaties that have been signed.

Agricultural sector: because sustainable food production is the only long-term solution.

Spatial planning: in order to keep our cities liveable, safe and enjoyable in the future.

15 Examples of such collaborations include the NIEBA initiative on the Dutch Roadmap and the DiSSCo initiative of European Natural History Museums.

‘The various scientific subdomains disappear when people from those different subdomains start to work together’

TON DE NIJS – NETHERLANDS NATIONAL INSTITUTE FOR PUBLIC HEALTH AND THE ENVIRONMENT

‘An ecologist has added value if she can tell an interdisciplinary story –so a story which also incorporates social and economic aspects. That all comes together in the same space’

WIEGER DIJKSTRA – MINISTRY OF INFRASTRUCTURE AND ENVIRONMENT

‘Data sharing agreements are very important! Scientists often don’t want to share data, and that can be an obstacle. Cooperation, not exclusion, can take us forward’

MONIQUE GROOTEN – WWF

‘If you are going to bring worlds together, you have to make sure that people can actually talk to each other. That is an art in itself, which can help you discover more about other people’s worlds’

JAN KEMPERS – HEINEKEN

Healthcare: because prevention is better than cure and a green, natural environment has many health benefits.
Citizens: because awareness and citizens’ initiatives are increasingly forming the basis for change. Citizen science can play a vital role, also as a source of data and research.
Industry: since knowledge about nature as a solution is essential for making the necessary transformation from a linear to circular economy.

4.4 Broader training for young researchers

Integrating scientific disciplines all starts during student education programmes. By encouraging students to look at things from a broader perspective from the outset, scientific research can have a greater social impact and result in concrete applications sooner. Programmes should not only focus on substantive expertise, but also on personal development. As a result, researchers will be able to play a leading role in developing nature-inclusive solutions. Personal development aspects include communication and presentation skills, leadership, and political and administrative sensitivity. Our research schools can address this challenge and incorporate it into their programmes.

4.5 Internationalisation of Nature4Life

Nature4Life is a national knowledge agenda which, in the first place, identifies the importance of research into biodiversity for the Netherlands, including the Caribbean Netherlands. However, Nature4Life knowledge does not stop at our borders. Our research into coral reefs, African savannahs and tropical rainforests is also world-class; all are global concerns. The agenda therefore has a strong international character. Nature4Life ties in with the European Horizon 2020 agenda (including ERA networks such as BiodivERsA), and with global scientific bodies such as Belmont Forum and Future Earth, as well as international bodies such as the CBD and IPBES.

CONNECTING TO GLOBAL DEVELOPMENTS

For Nature4Life to have the biggest possible impact, it is essential to organise activities which reflect global developments, since Dutch knowledge can be globally applicable. As an initial step, Nature4Life is talking with Brazilian researchers about collaborating on research projects.

4.6 Publicising Nature4Life and sharing knowledge

Policy makers and the general public rarely have access to scientific publications. The wonderful stories about plants, animals, interactions, behaviour and survival should reach the wider public more often. Only then will the general public be stimulated to participate in research in the form of civil science, for example. From primary school onwards, sustainability and seeing nature as a partner must be engrained into pupils as being the logical vision for the future. In addition, interdisciplinary cooperation requires knowledge to be shared with other disciplines. Nature4Life researchers are already doing this, but more can still be done.

PROVIDING INFORMATION FOR POLICY-MAKING

Nature4Life will also pay more attention to the science policy interface, that is, preparing important information for policy makers. The amount of information gained from scientific research is difficult for researchers to keep track of, let alone policy makers. Nature4Life will summarise information about relevant nature and biodiversity topics for policy makers and social partners. These short policy documents will be written by PhD students and postdocs, under the guidance of professional staff, as part of their education.

4.7 Where do we go from here?

This knowledge agenda is the result of an intensive process in which the field has shown willingness and its ability to reach a concerted and coordinated approach. That was essential, given the enormous impact that social issues have on this domain, but also because it is precisely this field that is left behind in research funding in the Netherlands.

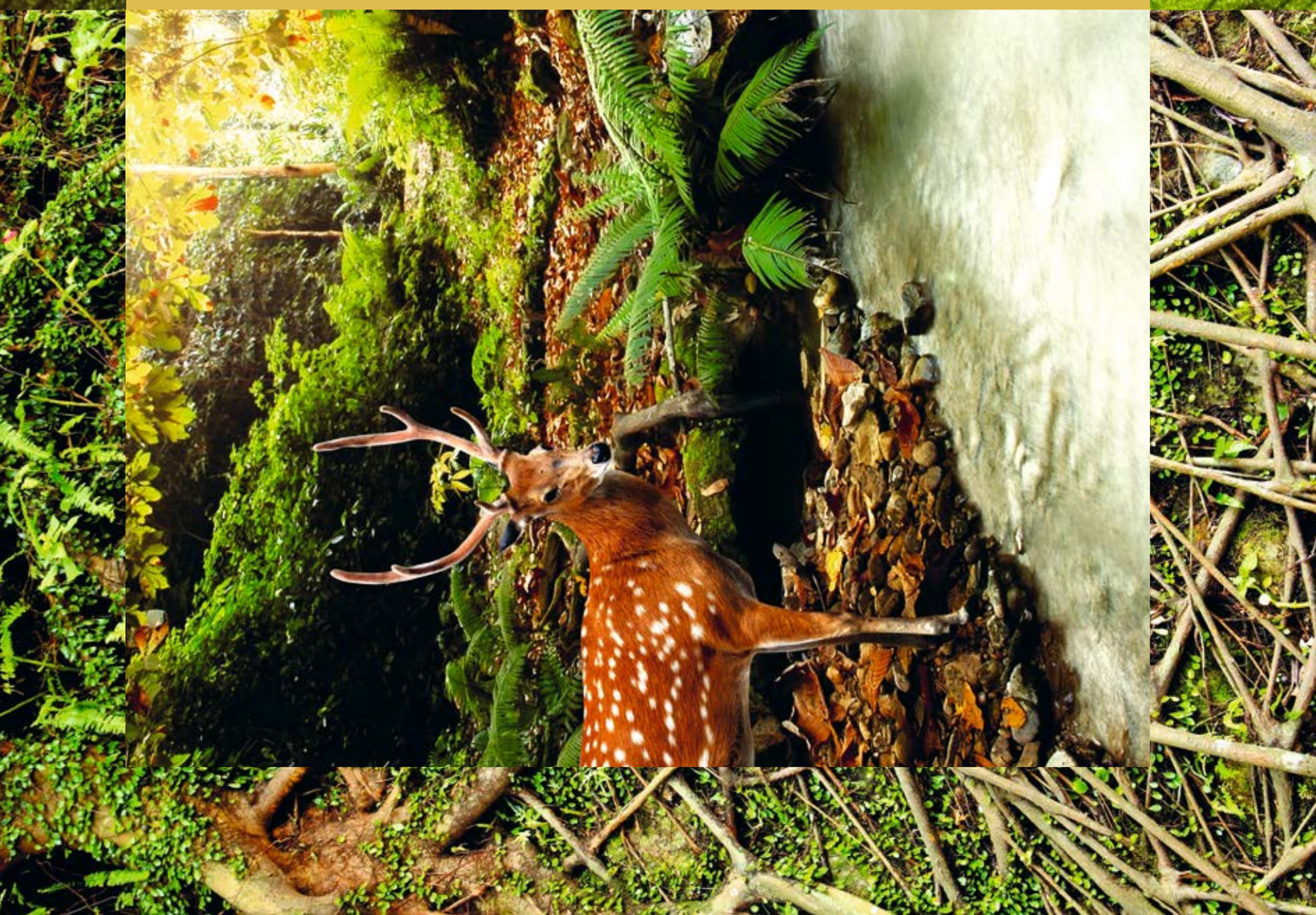
Delivering this agenda is not the end, but rather the beginning of a development that will lead to higher-level research in the Netherlands that will have a much bigger impact. That is why Nature4Life will continue to develop initiatives and ensure that the ambitions mentioned in this report are also realised.

‘It is important to develop knowledge-based connections. For example, the creative industry is inspired by biomimicry designs’

ROLF BOSSERT – SIA

‘The help you give to policy makers needs to be better, so you also have to take governance into account; which aspects of policies are working and which aren’t? And you also have to consider the relationships between nature, biodiversity, economy and society’

KEIMPE WIERINGA – NETHERLANDS ENVIRONMENTAL ASSESSMENT AGENCY



The following items are listed on Nature4Life's action list:

Transform Nature4Life into an Advanced Research Centre
An Advanced Research Centre is an interdisciplinary public-private collaboration between a number of knowledge institutions and industry. The partners work together to draw up a national research programme in collaboration with policy makers and research financiers. They invest in excellent research and form part of large European research infrastructures such as LifeWatch and DiSSCo.

Develop an outreach programme
There are a number of things we can do to promote social engagement: joint exhibitions; connecting with outreach programmes of partners such as the IVN (Institute for Environmental and Sustainability Education) and centres for environmental education; or having a media presence. For Nature4Life, citizen science is an important means of engaging citizens in all aspects of research.

Collaboration with universities of applied science and international exchanges
In order to optimise the use of Nature4Life's expertise to protect and use biodiversity outside the Netherlands, we need to see an increase in internationalisation and exchange opportunities at organisations such as NWO and Nuffic.

Establish contact with ministries
We want to set up a contact institution which will facilitate regular consultations with the Ministries of Education, Culture and Science, Economic Affairs, and Infrastructure and the Environment regarding funding, governance and ambitions.

Ask NWO to comment on Nature4Life
Nature4Life is a national programme to which all the knowledge institutions active in this field have committed. It is up to the NWO to address this agenda and the ambitions set out therein, thereby laying the foundations for multi-annual funding.