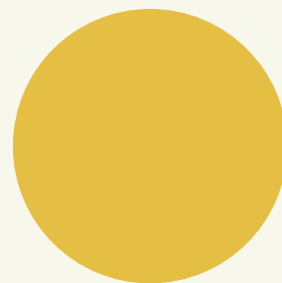


Mobilisation for healthy oceans and water

Strategic agenda for the national research programme on oceans and water



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Foreword

On 2 September 2021, Formas was tasked by the Swedish government to establish a national research programme on oceans and water. The assignment includes developing a strategic research agenda that will underpin our work in the programme. This agenda was developed during 2021 and 2022.

Formas thanks everyone who has contributed in various ways to formulating the agenda. We extend a special thanks to members of the programme committee and working group for their expertise and great dedication. We would also like to thank all the higher education institutions, research institutes, government agencies, industry associations, companies, municipalities, non-profit organisations and others who have contributed valuable input in the preparation of the agenda.

We look forward to our continued collaboration around healthy oceans and water through research and innovation.

Stockholm, December 2022

Johan Kuylenstierna
Director General of Formas

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Summary

The national research programme on oceans and water provides a solid foundation for putting water issues high on the agenda and addressing water-related challenges. The programme came about through a government mandate to Formas. As one of thirteen national research programmes, it serves as an instrument for realising the government's ambitious goals for addressing prioritised societal challenges through research and innovation. The programme will be implemented during the period 2021–2030. This strategic research agenda will be the basis for the programme's direction and activities

The programme has three thematic objectives:

- Strengthen the resilience of aquatic ecosystems.
- Develop sustainable water resource management.
- Boost society's ability to act for sustainable oceans and waters.

The programme also has three cross-cutting perspectives that grant applicants are encouraged to consider in relation to these themes: a systems perspective, open science and participation, and from local to global.

In addition, the programme contains a number of objectives stemming from Formas' mandate to establish the programme. In the area of oceans and water, the objectives of the mandate are as follows:

- Increase coordination of national research funding.
- Leverage opportunities for synergies with the EU Framework Programme for Research and Innovation and the National Committee for the United Nations Decade of Ocean Science.
- Facilitate close collaboration between researchers and stakeholders, and support the translation of research into action.
- Contribute to expertise in areas of major importance to society.

The programme is run with the support of a programme committee and a working group. Programme funding is distributed mainly through calls for proposals for research grants, innovation grants and grants for collaboration. The programme will carry out activities that translate research into action. Other activities will be carried out to monitor, and to link the programme to, international research funding. The programme will be followed up and evaluated during the course of the programme period.

1. Water-related challenges and conditions

We live in a time when human activity is impacting the earth's environment to such an extent that it is sometimes referred to as the Anthropocene or the Age of Mankind. The growing human footprint on nature has put water – the very foundation of all life on earth – under pressure. Climate change, biodiversity loss, pollution and overexploitation have serious consequences for the world's oceans, freshwater and groundwater. We are completely dependent on the values that water provides to us, and good water management is crucial for resilient ecosystems and a sustainable development of society.

The world's oceans and seas – their temperatures, chemistries, currents and life – underpin global systems that make the earth habitable. Oceans and seas cover about 70 percent of our planet, and over three billion people depend on marine and coastal biodiversity for their livelihoods.¹ These waters absorb significant amounts of carbon dioxide and help to balance the effects of climate change by absorbing heat. Overfishing, acidification, toxins and pollutants are some of the problems affecting our oceans today. The problems are global, with major regional differences. For example, the sensitive Baltic Sea has low resistance to disturbances and is one of the world's most polluted seas.

Too many people today lack access to clean water to meet their basic needs. One in three people worldwide live without access to basic sanitation, with significant consequences for human health and development.² Inadequate water management, changes in land use, and groundwater levels affected by climate change can limit the water supply for households, agriculture and industries, also in Sweden. The future drinking water supply as well as food supply are under threat. According to the UN Intergovernmental Panel on Climate Change, global warming is projected to cause substantial alterations in the water cycle at both global and regional scales. This will lead to ice melting and rising sea levels, altered precipitation patterns and water flows, torrential downpours and prolonged periods of drought, with significant implications for ecosystems and communities.³

Water has always played a vital role in society's development. Throughout the ages, human development has been closely linked to water for purposes like communication and transport routes, power and energy supply, industrial cooling systems, agriculture, hunting and fishing, and leisure. Communities also have long-standing cultural ties to water, as underwater cultural heritage sites testify to. As we progress towards a sustainable modern society, water is playing a significant role in creating the sustainable industrial production systems and energy systems needed to enable the transition to a climate-neutral society. Water also needs to be considered in housing and transportation planning, not least in light of global warming, which entails a significant need for climate adaptation.

Water is the common resource that we humans share with all other living things.

1. Sustainable development goals (2022), Goal 14: Life below water, <https://sdgs.un.org/goals/goal14>

2. Sustainable development goals (2022), Goal 6: Clean water and sanitation, <https://sdgs.un.org/goals/goal6>

3. IPCC (2021), Climate Change 2022, Mitigation of Climate Change, Summary for Policymakers, https://www.ipcc.ch/report/ar6/wg3/downloads/report/IPCC_AR6_WGIII_SummaryForPolicymakers.pdf

Water has an intrinsic value in itself, but it also raises questions about people's use of a limited resource, the importance of access to water of adequate quality and the water-related problems that extreme events can cause. The status of water can depend on policymaking in multiple countries and sectors. Measures in one place can be weakened by counterproductive activities elsewhere. Inadequate water management in one part of the world can pose a vulnerability in global value chains, and water resource management can help to shape new geopolitical landscapes and affect countries' competitiveness. Different sectors may need to work in partnership to ensure that water resources are managed efficiently and are available where needed. During widespread water scarcity, household water use also plays a major role. An uneven distribution of water resources and access to water of adequate quality can cause conflicts, both within and among countries. Significant efforts are needed to achieve water security where the population has the capacity to "safeguard sustainable access to adequate quantities of and acceptable quality water for sustaining livelihoods, human well-being, and socio-economic development, for ensuring protection against water-borne pollution and water-related disasters, and for preserving ecosystems in a climate of peace and political stability".⁴

All in all, there are many complex water challenges that require broad collaboration. In the efforts to achieve healthy oceans and water, it is important to improve knowledge and develop solutions through research and innovation that reach the relevant stakeholders and citizens.

1.1 Our assignment

Starting in 2017, the government tasked Formas, Forte and the Swedish Research Council with establishing a total of 13 national research programmes.⁵ The programmes are broad, ten-year efforts to help solve prioritised challenges and enhance collaboration among researchers, research funders and societal stakeholders. The national research programmes must be based on a national research agenda for each area, supported by a programme committee and must complement the research and innovation system as a whole. With the 2020 Research Bill, Formas was tasked with establishing and implementing a ten-year national research programme on oceans and water. The government assignment can be found in its entirety in Appendix 1.

1.2 Programme objectives

A national research programme on oceans and water creates many opportunities. It provides a solid foundation for putting water issues high on the agenda and mobilising to address challenges related to water. The long-term approach of the research programme enables strategic, organised efforts to address complex marine and water issues and opportunities for researchers and other stakeholders to continuously collaborate.

4. UN Water (2013), Water Security & the Global Water Agenda – A UN-Water Analytical Brief, United Nations University.

5. In addition to the national research programme on oceans and water, Formas has established three programmes for climate, sustainable spatial planning, and food. The Swedish Research Council has been tasked with establishing six programmes: antibiotic resistance, migration and integration, viruses and pandemics, segregation, crime and the consequences of digitalisation. Forte is in charge of the national research programme on workplace well-being, applied research on public health and mental health research.

The purpose of the programme is to coordinate research funders for marine and water issues in Sweden, and thus contribute to an efficient use of resources. A dedicated programme for oceans and water can secure funding for these important topics. At the same time, the programme complements other national research programmes, especially those focusing on climate, sustainable spatial planning and food. The programme can also serve as a platform for creating synergies with global research funding organisations, which is essential to the European Framework Programme for Research and Innovation, Horizon Europe. Moreover, the programme period is identical to the period for the UN Decade of Ocean Science 2021–2030, creating good potential for synergies.

The programme has a key role in creating collaborative partnerships between researchers and stakeholders who are affected by or have influence over a problem or solution related to water. These stakeholders can be from the public or the private sector, civil society or the general public. Close collaboration can be a means for enabling the real-world impact of research, stimulating innovative solutions, and providing significant near-term environmental and socio-economic benefits. By also investing in research-initiated projects of high scientific quality, we equip ourselves for the future by promoting insights and new breakthroughs in areas that may not yet be on people's radar. The programme's investment in research and innovation intends to provide people with new skillsets and boost their ability to cope with the challenges of today and tomorrow.

In the process of developing this strategic research agenda, many issues were identified as important for the programme to address. These have been consolidated into three central themes that serve as a basis for the national research programme's activities and are its thematic objectives.

The thematic objectives of the programme are:

- Strengthen the resilience of aquatic ecosystems
- Develop sustainable water resource management
- Boost society's ability to take action for sustainable oceans and water.

In addition, the programme contains several objectives stemming from Formas' mandate to establish the programme. Within oceans and water, the assignment's objectives are:

- Increase coordination of national research funding
- Leverage opportunities for synergies with the EU Framework Programme for Research and Innovation and the National Committee for the UN Decade of Ocean Science
- Facilitate close collaboration between researchers and stakeholders, and support the translation of research into action
- Contribute to expertise in areas of major importance to society.

The programme's links with the EU Framework Programme for Research and Innovation are further described in Chapter 4. The mandate of the National Committee for the UN Decade of Ocean Science is described in Chapter 6.

1.3 Developing the agenda

This agenda was developed during 2021 and 2022 based on the preparatory work Formas conducted together with several other government agencies and organisations even before the programme started. This mainly consisted of Formas' input to the 2020 Research Bill,⁶ in which we proposed that Formas should be tasked with establishing a national research programme on oceans and water, as well as our final report to the government on a proposal for Sweden's contribution to the UN Decade of Ocean Science.⁷

Formas' input to the research bill describes the challenges in the field of oceans and water and justifies the need for a national research programme. The input, in turn, was largely based on another report in which Formas presented a survey of research needs and how research is organised in this area.⁸ The three overarching areas of research needs we presented were: (1) research on processes, interactions, biodiversity and impacts, (2) innovations for a thriving aquatic environment, and (3) research for the development of policy instruments, implementation and economic considerations. In the final report to the government on Sweden's contribution to the UN Decade of Ocean Science⁹, four proposals for national focus areas were presented: (1) ecosystem-based management, (2) innovation and digitalisation, (3) data and modelling, and (4) ocean literacy. Efforts within the framework of the Decade will be informed by a holistic view of water – from source to sea – and will thus include ocean, freshwater and groundwater challenges. The climate and biodiversity are integrated in all focus areas.

During the preparation of this strategic research agenda, Formas has built on these reports and the identified research needs in dialogue with researchers and stakeholders. In addition, we have considered the knowledge needs highlighted in reports on topics like climate adaptation,¹⁰ climate change in the marine environment,¹¹ groundwater¹² and sustainable water resource management.¹³ The reports and extensive dialogue have laid a foundation for the thematic objectives that the programme will address.

When Formas was tasked with developing and running a national research programme on oceans and water, a programme committee and working group were appointed in order to support the programme from strategic and operational

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6. Formas (2019), Knowledge for a sustainable transformation – A summary of Formas' recommendations for Sweden's research and innovation policy, R14:2019 <https://download/18.42353e2216d6c728b66917c3/1572860872407/R14-2019-formas-underlag-kunskap-for-hallbar-omstallning.pdf>
 7. Formas, the Swedish Agency for Marine and Water Management (SwAM) and Swedish Meteorological and Hydrological Institute (SMHI) (2020), Ett svenskt bidrag till FN:s årtionde för havsforskning för hållbar utveckling 2021–2030, Slutrapport för ett regeringsuppdrag, R3:2020, ISBN: 978-91-540-6123-5 r3-2020-ett-svenskt-bidrag-till-fns-artioende-havsforskning.pdf
 8. Formas (2019), Forskning och innovation för en livskraftig vattenmiljö – Förslag till ett nationellt forskningsprogram om hav och vatten, R10:2019, <https://formas.se/download/18.11bce16716e44cbeee150cd5/1574696810916/r10-2019-forskning-innovation-for-livskraft-vattenmiljo.pdf>
 9. Formas, the Swedish Agency for Marine and Water Management (SwAM) and Swedish Meteorological and Hydrological Institute (SMHI) (2020), Ett svenskt bidrag till FN:s årtionde för havsforskning för hållbar utveckling 2021–2030, Slutrapport för ett regeringsuppdrag, R3:2020, r3-2020-ett-svenskt-bidrag-till-fns-artioende-havsforskning.pdf
 10. Swedish Expert Council on Climate Adaptation (2022), First report for climate adaptation, https://klimatanpassningsradet.se/polopoly_fs/1.180289!/Rapport%20fr%C3%A5n%20Nationella%20experter%C3%A5det%20f%C3%B6r%20klimatanpassning%202022.pdf
 11. Formas (2019), Effekter av klimatförändringar och ökade koldioxidhalter på den marina miljön – en analys av kunskapsläget kring ekosystem, resiliens och havsförvaltning, R5:2019 <https://formas.se/download/18.2d01d90c16a5883f2b57f716/1559562766627/formas-r5-2019-klimat-forandringar-och-okade-koldioxidhalter-marina-miljoer.pdf>
 12. Roland Barthel, Deliang Chen, Kristina Seftigen, Moa Stangefelt, Markus Giese, Michelle Nygren, Peng Zhang, Tinghai Ou (2020), Vattenbrist och torka i Sverige – implikationer för grundvattenbaserad vattenförsörjning – en sammanställning av kunskaper och forskningsbehov.
 13. Swedish Agency for Marine and Water Management (2022), Ett förslag till strategi för att möta dagens och morgondagens behov av vatten för samhällsutveckling och ekosystem, 2022:3, https://www.havochvatten.se/download/18.4ae3faf1809b8c-6da69a245/1653912087296/Rapport_hallbar_vattenresursfoorvaltning.pdf

perspectives. Formas then began the process of developing the research agenda. The programme committee and working group participated actively in the development of the agenda. During the course of this work, different versions and excerpts of the draft agenda were also presented and discussed with researchers at universities and research institutes, representatives of various industry associations and interest groups, among others. In addition to the above-mentioned dialogue, a version of the agenda was posted on Formas' website for an open referral. Of the 95 referral bodies invited to comment, 29 bodies submitted replies. Formas' Research Council took part in developing the agenda through discussions at various council meetings. The agenda was formally approved by the Research Council in September 2022.

1.4 The programme's contribution to related societal goals

According to our assignment, the programme should contribute to achieving the environmental quality objectives, the generational goal and Sweden's implementation of Agenda 2030. The assignment also states that Formas should leverage opportunities for synergies with the assignment for a national committee for the UN Decade of Ocean Science, which we describe in more detail in Chapter 6. In addition, several other objectives and agreements are relevant to the ocean and water issues associated with the programme.

While water issues are important to all 17 goals of Agenda 2030, Goal 6 (Clean water and sanitation) and Goal 14 (Life below water) are particularly relevant to the national research programme.¹⁴ Partnerships, collaboration and the accessibility of research, technology and innovation are central to all national research programmes and contribute to several targets of Goal 17 (Partnerships for the goals). Through Formas' active efforts to support Sweden's implementation of Agenda 2030, the programme is well-positioned to help accomplish this.

Several of the Swedish environmental quality objectives are relevant for ocean and water issues, especially objectives 8 (Flourishing Lakes and Streams), 9 (Good-Quality Groundwater) and 10 (A Balanced Marine Environment, Flourishing Coastal Areas and Archipelagos).¹⁵ The generational goal is an overarching goal for Swedish environmental efforts. It urges us to develop a world we can entrust to future generations – one that has solved our major environmental problems. The seven “bullet points” complementing the generational goal (recovered ecosystems, biodiversity, wise management of natural resources, etc.) are well aligned with the programme's contributions.¹⁶ In 2021, the Environmental Objectives Committee, which submits proposals to the government on how the environmental goals should be achieved, issued the report “Havet och människan” (“The Sea and Humankind”). It puts forward a strategy for stepping up actions for the conservation and sustainable use of the ocean and marine resources. The strategy intends to lay a better foundation for achieving the environmental quality objective “A Balanced Marine Environment, Flourishing Coastal Areas and Archipelagos” as well as “Zero Eutrophication”. Two specific questions have informed the development of the strategy. The first

14. Sustainable development goals (2022), <https://sdgs.un.org/goals>

15. Sweden's environmental objectives (2022), <https://www.sverigesmiljomal.se/environmental-objectives/>

16. Sweden's environmental objectives (2022), the generational goal, <https://www.sverigesmiljomal.se/miljomalen/generationsmalet/>

is the connection between oceans and seas, climate change and acidification. The second is the ecosystem approach and ecosystem-based management.¹⁷

The national research programme on oceans and water also intends to stimulate the advancement of knowledge that can support efforts to comply with international agreements and conventions on the marine and aquatic environment to which Sweden is a party, as part of the programme's thematic goal of translating research into action. Examples include the UN Convention on the Law of the Sea (UNCLOS); the Helsinki Convention (HELCOM), an agreement among the Baltic Sea riparian states for safeguarding the Baltic Sea; OSPAR, a convention for the protection of the marine environment of the North-East Atlantic; and the Water Convention, hosted by UN Economic Commission for Europe (UNECE), which aims to ensure the sustainable and equitable use of transboundary waters. Given the close ties of water issues to climate change and biodiversity, knowledge development that helps to reach the goals of the Paris Agreement and UN Convention on Biological Diversity (CBD) can also be stimulated. The EU's Green Deal also includes objectives for developing a sustainable blue economy.

The programme will design efforts to contribute to the goals and agreements that are addressed in this section and will seek synergies among them. It also intends to provide scope for a focus on conflicting sustainability goals related to water that require attention and action. For example, water management often involves trade-offs between water quality, water quantity, and different social and environmental interests. Measures to improve water quality, such as dam removal, can cause the release of environmental pollutants. The climate transition requires substantial amounts of emissions-free energy, and new production methods that do not use fossil fuels are driving the need to extract raw materials and minerals that can have a significant environmental impact. Another example is the goal of increased domestic food production, which requires large amounts of water and risks leading to increased emissions to the aquatic environment.

1.5 Synergies with other national research programmes

Formas already oversees three national research programmes that focus on the challenges related to climate, sustainable spatial planning and food. These programmes cooperate regularly by conducting joint calls, raising important issues at the intersection of different programme challenges and exchanging experiences about programme operation. Formas also communicates with the national research programmes at the Swedish Research Council and Forte. The national research programme on oceans and water draws lessons from other programmes in order to build on their experience, including through evaluations of the first programmes as described in Chapter 6.

The three programmes on climate, sustainable spatial planning and food have each developed a strategic research agenda that forms the basis for the programmes' funding calls and other activities. These agendas include a number of themes and objectives related to oceans and water, and the national research programme on oceans and water will work closely with the other programmes to identify common challenges and appropriate areas of cooperation.

17. Environmental Objectives Committee (2021), *Havet och människan* (SOU 2020:83). Ministry of the Environment

The climate programme's strategic research agenda¹⁸ contains several topics related to water. The theme "System-integrated knowledge of climate change, ecosystems and society", for example, includes extreme weather events like heat waves, flooding, droughts and water shortages. The theme describes the need for more knowledge about how efforts to achieve the climate targets can be linked to the goals of biodiversity and well-functioning ecosystems on land and in water.

The strategic research agenda for the national research programme for sustainable spatial planning¹⁹ contains the theme "Sustainable land and water management", with goals for planning for long-term land and water use as well as land and water use adapted to climate change. Furthermore, the theme "Human health and well-being" has a goal of reducing environmental pollution in buildings, soil and water. Water safety and preparedness for extreme weather events are linked to the theme "Safety and security for people and communities", with the goal of reducing risks in the built environment.

Access to clean water is fundamental to a sustainable and competitive food system. A guiding theme in the food programme's strategic research agenda²⁰ is "Sustainable production systems", with a focus on sustainable intensification through evidence-based measures to ensure biodiversity, robust ecosystems, and soil health and function in the future. Enabling this requires new knowledge, methods and processes for building sustainable production systems that are more circular and integrated. This involves optimising the use of raw materials, inputs, land and water, while reducing waste and losses and increasing the recirculation of water, energy and nutrients.

18. Formas (2021), Knowledge for a climate transformation – Strategic agenda for the national research programme on climate, R5:2021, <https://formas.se/download/18.233f59f7180028599746d28a/1651047377997/r7-2021-knowledge-for-a-climate-transformation.pdf>

19. Formas (2021), Research for transformative spatial planning – Strategic agenda for the national research programme for sustainable spatial planning, R6:2021, <https://www.formas.se/download/18.192939ee18002a9f919914eb/1651663783066/r8-2021-research-for-transformative-and-sustainable-spatial-planning.pdf>

20. Formas (2019), Towards a sustainable and competitive food system – A strategic research agenda, R13:2019, <https://formas.se/download/18.3ac74c221715da0b5101963e/1587028554357/r2-2020-towards-a-sustainable-and-competitive-food-system.pdf>

2. Central themes

This chapter describes the themes that we identified as central to the programme during the development of the strategic research agenda. The themes describe knowledge needs and what we wish to achieve in order to provide solutions to major ocean and water challenges. The programme aims to set the course for a strategic, long-term approach, and the themes express the priority areas in which the programme will carry out its activities. The themes are relevant for basic research as well as applied research and innovation.

The themes should be viewed as complementary entities that are partly overlapping and interconnected. Under each theme, several broad sub-themes are indicated. In addition to the themes and sub-themes we outline in this chapter, three cross-cutting perspectives have been identified. These perspectives are presented in more detail in the next chapter. Overall, the themes and perspectives should serve as a guide and direction for calls and activities in the national research programme on oceans and water.

The themes and sub-themes of the agenda are as follows:

Theme 1: Strengthen the resilience of aquatic ecosystems

- Complex and dynamic ecosystems
- Effective environmental monitoring
- Science-based measures

Theme 2: Develop sustainable water resource management

- Our common water resource
- Water resource management in a changing climate
- Our essential groundwater

Theme 3: Boost society's ability to take action for sustainable oceans and water

- Governance with a holistic approach
- Community engagement and involvement
- Blue innovation

2.1 Theme: Strengthen the resilience of aquatic ecosystems

The resilience of aquatic ecosystems needs to be enhanced. Accelerating climate change and biodiversity loss present major challenges together with anthropogenic disturbances stemming from, for example, land-based industries, urbanisation and industrial operations. To strengthen the resilience of aquatic ecosystems, we need to increase our understanding of the fundamental relationships between species and ecosystems and different types of pressures. More knowledge is needed about the ability of species and populations to adapt to the new habitats shaped by climate change and other human-induced environmental changes. We also need to enhance environmental monitoring using new technologies and improve the work on various measures.

Complex and dynamic ecosystems

An ecosystem perspective – based on an understanding of the composition, structure, function and interconnection of ecosystems – is central to achieving sustainable marine and water management. We also need to consider the effects and interactions of various pressures, such as environmental pollution like metals or organic pollutants, underwater noise, the expansion of marinas, ports and other developments, the effects of dredging, invasive species and excess nutrients. Many marine ecosystems are also unstable due to prolonged overfishing and a lack of large fish near the coasts, which can lead to eutrophication-like symptoms. Species and local populations in lakes and along our coasts will have to adapt to shifting external factors, including higher temperatures as well as lower salinity, lower pH and emerging species. How species are coping with these adaptations is poorly understood. We also need to better understand what measures could be put in place to support the adaptation of local populations to their new living conditions.

Gaps in our understanding of the causal relationships between and within ecosystems, and between biotic and abiotic parts of ecosystems, as well as our limited species knowledge, currently limit actions for protecting and improving the conditions for aquatic ecosystems, which is fundamental for strengthening the resilience of ecosystems. These shortcomings also affect our ability to counteract and respond to climate change, and to preserve and enhance biodiversity. Uncertainties and gaps in knowledge about how abiotic parts of ecosystems, such as salinity and sea levels, will develop in the future also have a negative impact on this ability.

To enable predictions and identify the need for action, in-depth knowledge is needed about how different influencing factors, individually or in combination, impact ecosystems and biodiversity in different temporal and spatial scales. We need to understand and describe the complex interactions taking place both within ecosystems and in relation to the wider biogeosphere, for example with regard to the carbon storage capacity of aquatic ecosystems. Here, it is important to understand the effects of different feedback mechanisms on the atmosphere and climate.

We currently lack knowledge about how infrastructure, businesses, basic industry and energy production collectively affect the composition, structure and function of aquatic habitats, as well as how these factors in turn affect natural geochemical conditions, biodiversity and ecosystem services. An understanding of, for example, connectivity, interconnected corridors and pathways in oceans, seas, lakes and running water is vital for decisions about future energy systems, such as during the revision of Swedish hydropower plants' licenses and offshore wind farm installations.

Effective environmental monitoring

Creating resilient aquatic ecosystems requires effective environmental monitoring. Environmental monitoring is the foundation for observing the status of any changes in habitat conditions, such as the degree of variation for different species, changes in food webs, and the ecological and chemical quality of water, as well as how natural processes and human impact change the hydromorphology of water. Environmental monitoring relies heavily on research in order to identify new problems and to develop better measurement systems, analytical methods and models. Monitoring includes field measurements and remote

sensing by satellite. It is continuously being improved and developed using new technologies, such as drones with high sampling frequency, AI-based analyses of images collected in situ and DNA analyses, in order to study biodiversity. There is also potential to use marine geodata, digital twins and marine information to a greater extent for analyses and a better understanding of marine environments.

Even a resilient ecosystem undergoes natural variations and is continuously influenced by human activity. This shifting balance increases the degree of complexity when government agencies and policymakers are to establish targets that describe what a balanced ecosystem constitutes in terms of water quality and status. We have to be able to follow up, measure and monitor a balanced yet changing ecosystem using robust methods so that we can assess ecosystem resilience. Supporting this effort requires the continued development of models at different scales.

In addition to data on aquatic ecosystems, information is also needed on how ecosystems are impacted by people and processes. This can involve activities like shipping, infrastructure construction, extraction of resources from the seabed, aquaculture, the tourism and hospitality industry, and land-based activities, which affect or are affected by the aquatic environment. There is a need to develop methods for collecting and analysing this type of data and linking it to water status.

There is great potential to improve environmental monitoring through advances in technology, and to expand interdisciplinary innovation and collaboration by combining digitalisation with molecular biology methods, for example. User-friendly tools need to be developed in order for this knowledge to be used in practice by national water management organisations and other end users, and we need to understand how to best integrate this knowledge in decision-making.

Science-based measures

A variety of measures are needed to improve the status of lakes, streams, and coastal and marine environments. Although the measures can differ depending on where they will be introduced, they must be grounded in science. For Swedish waters, comprehensive measures are needed to address problems like eutrophication, environmental toxins, connectivity in watercourses and coastal areas, and the recovery of populations and habitats. Many fish stocks are almost completely wiped out and we need more knowledge about how to restore them. Through EU directives, other international commitments and national action programmes, Sweden is obliged to improve the status of Swedish waters.

Measures include not only technical solutions and physical measures in the environment, but governance instruments that are being developed under the agenda's theme of boosting society's ability to take action. This can involve chemical remediation, wetland construction, habitat restoration or the protection of high nature value areas. The increased risk of water scarcity is expected to drive the need for measures to create water retention structures in the landscape. These efforts must be integrated in legislation regulating industry, agriculture and fisheries, among other sectors. Successfully designing such measures requires robust decision-making input about the relevant challenges, including how benthic organisms are impacted by factors like overfishing, bottom trawling, dredging of contaminated sediments, and the extent of anoxic bottoms.

It is also necessary to turn our focus to assessments and improved analytical tools

for understanding the effects of the measures. Research is needed to estimate the overall effects of the measures, highlight both desirable and undesirable effects, determine potential synergies and conflicting goals among different measures, adapt and optimise action programmes, and calculate cost-effectiveness. These assessments often benefit from a multidisciplinary, cross-sectoral approach, and from applying a broad sustainability perspective that considers environmental, economic and social aspects.

2.2 Theme: Develop sustainable water resource management

This theme focuses on water as a vital yet highly threatened resource, not only for humans but for all living things. Communities need safe, secure access to good-quality water that does not compromise the viability and variety of ecosystems. Knowledge is needed about trade-offs and synergies among different sectoral and public interests and how we can reduce the pressure on our common water resource. As a result of climate change's effects on the water cycle, many key knowledge needs have arisen. More knowledge is also needed about how we can protect and manage groundwater.

Our common water resource

People's need for water is varied and vast. We need it for energy extraction, transportation, food and recreation, to name a few uses. Access to sufficient quantities of clean, usable water has until now been taken for granted in Sweden. Energy and food supply systems, for instance, have to become more resilient because of climate change and the complex energy market, as well as when a crisis strikes. We need to better understand vulnerabilities and the geopolitical consequences of water management in different parts of the world so that we can envision the opportunities and build contingencies.

Some of society's major challenges are linked to various substances, pollutants and organisms that negatively affect water quality – from nutrients like nitrogen and phosphorus to the increased occurrence of bacteria with different properties, viruses and other infectious agents, as well as pollutants such as pharmaceuticals and highly fluorinated chemicals known as PFAS. How land and water areas are used has implications for the adjoining groundwater, watercourses, lakes and seas. Forestry practices can cause soil and sludge to discharge into watercourses, and farmland affects water through nutrient leaching and erosion damage from grazing animals. Land and water use can also affect water volumes and flow rates as a result of an increased proportion of impervious surfaces.

There are major differences in water availability and water flows within our elongated country, both geographically and between urban areas and sparsely populated areas. However, compared to many other European countries, Sweden has a more favourable position in terms of water supply. Still, many different stakeholders and individuals – water utilities, agriculture, forestry, industries and residents in their homes – often use and impact the same body of water. This puts a lot of pressure on the available water resources, especially as the population increases and new businesses are established in an area. More knowledge is needed about how we can reduce the pressure on our common water resource, for example by taking water into consideration in permitting procedures, offering incentives for water-saving investments and circular solutions, and changing

attitudes and behaviours among policymakers and the general public around managing water as a limited resource.

To enable safe and fair access to water, more knowledge is needed about the division of responsibilities in water management and what measures are both effective and legitimate among the stakeholders involved. New forms of collaboration and approaches are needed to proactively manage water resources, such as through water service plans, and to gain access to real-time forecasts in order to adapt to shifting conditions.

Both water quantity and water quality are crucial for many sectors. Sweden's basic industries are completely dependent on vast amounts of water for their processes. In urban planning, the built environment and land-based industries, the focus is not only on water quantity and water levels in lakes and streams but on questions about runoff, drainage, flows and elevation. The water flows managed in the built environment have a major impact on both water quality and the local and regional water balance, making stormwater management, wastewater treatment and drinking water supply critical. Cultural heritage environments, where livelihoods have revolved around water and have impacted water flows, water quality, biodiversity and migratory fish, need to be adapted while taking into account both the water and the sensitivity of those environments.

Water resource management in a changing climate

Climate change will intensify and substantially alter the water cycle. Climate change is driving accelerated melting of the ice caps and rising sea levels, altered precipitation patterns and water flows, torrential downpours and prolonged periods of drought. Large volumes of water create problems in society, such as flooding and landslides as well as the unwanted transport of pollutants and nutrients. Shortcomings in water management, land use changes and groundwater levels affected by climate change can limit water availability for households, agriculture and industries. Yet more water is expected to be needed in forestry and agriculture as growing seasons become longer due to climate change. Extreme weather events can cause widespread human suffering, affect how communities function and cause significant disruption to ecosystems.

Oceans and seas absorb carbon dioxide and store heat, but significant portions of marine ecosystems that absorb carbon dioxide are under threat, further intensifying climate change. Global warming is driving marine heat waves and oxygen deprivation in these waters, with a significant – and at times irreversible – impact on ecosystems. Species in freshwater and salt water alike are being affected by increases in temperature and changes in oxygen levels, also negatively impacting people's quality of life.

To effectively manage the impacts of climate change on water, we need to develop knowledge that supports the work of key stakeholders. Forecasting tools, models and scenarios must be developed to increase our understanding of which geographical areas are affected by different disturbances and how changes are expected to take place over time. For example, contingency might be required to prepare for a single area being affected by both drought and flooding within a short time period. We also need to know more about how both people and ecosystems can be affected, and this knowledge must be integrated in policymaking at municipal, national, regional and global levels if we are to achieve water security.

We also need to mobilise around developing effective solutions that can meet the water challenges brought on by climate change. One such area is nature-based solutions, which leverage nature's ability to cope with challenges in society by protecting, developing or creating ecosystems in a multifunctional way. It is also essential for climate adaptation efforts in cities and communities to consider water issues during planning and development of the built environment. The integration of urban and rural areas is necessary here, since measures for solving problems in cities might need to be taken in other areas upstream. Efforts around oceans, seas and watercourses are also needed that promote both carbon dioxide uptake and increased biodiversity and coastal climate adaptation. In addition, many of the problems at sea might also need to be solved on land.

Our essential groundwater

Groundwater plays a central role in sustainable water management. In this area, more research and knowledge is needed on, for instance, the hydrological and ecological functions of groundwater in Sweden. There are significant knowledge gaps in the understanding of how groundwater recharge occurs in different types of aquifers. Examples of other vital research topics include natural and artificial groundwater recharge, and natural flow patterns of groundwater including discharge areas and natural spring flows. More than half of the drinking water produced in Sweden comes from surface water, part of it as artificial groundwater. In-depth studies are needed on variations in and effects on groundwater quality, both within individual aquifers and between different aquifers. We also need to better understand how environmental and climatic changes have affected and continue to affect significant portions of groundwater. During water shortages, for example, we use up too much groundwater, causing the ingress of salt water in coastal areas. Inland, the over-abstraction of groundwater can cause the intrusion of old salt water. For pollutants that have reached the groundwater, we need to know more about the pathways in different geological environments and the degradation and dilution of different pollutants in groundwater.

We will need to better consider the capability of individual groundwater aquifers to store water. Methods are therefore needed for actively determining and continuously calculating how much water can be abstracted from aquifers relative to precipitation and replenishment, and for assessing the effects on groundwater-dependent ecosystems. Today there is a great need for information about groundwater-dependent ecosystems in order to establish assessment criteria, among other purposes. Natural groundwater discharges in springs are thus interesting to study, along with related water flows and groundwater quality. Natural sources are used for water supply. They often have both natural and cultural heritage values and must be considered as objects worthy of protection.

Remote sensing provides an effective tool for mapping groundwater levels and abstractions over sensitive, large areas. There is high potential for development in terms of methods for both collecting and evaluating groundwater data. This includes the use of new field methods when surveying groundwater resources, performing cost-effective monitoring of groundwater quality and using AI technology in evaluations of groundwater quality and groundwater levels.

To protect our essential groundwater, we also need more information about how to best design legislation and other measures to ensure groundwater quality and how to better apply guidance for applying environmental quality standards. Groundwater considerations should also be integrated in town planning and climate adaptation efforts.

2.3 Theme: Boost society's ability to take action for sustainable oceans and water

Society needs to mobilise to collectively address the challenges we face in marine and water environments. This theme highlights three key elements of this mobilisation: develop a governance framework based on a holistic view of water and society, create a broad commitment to water issues that also engages the general public, and stimulate innovations based on the resources of oceans and seas.

Governance with a holistic approach

A sustainable management of water resources requires governance that takes into account the different needs of ecosystems and of communities. Governance entails political decisions as well as the interplay of these decisions with other influential forces in society, such as markets or civil society, and the influence of social or cultural factors. Research is needed on water policymaking processes and leadership, and how they can support evidence-based decision making. We also need to better understand the appropriate instruments at local, regional, national and international levels. This can involve research into the effectiveness of different policy instruments, interaction among policy instruments, innovative instruments and voluntary measures. In addition, we need to know more about how the law can promote the sustainable use and protection of oceans and other watercourses.

Marine and water management can only be successful if the complexity of water is taken into account. One way of accomplishing this is through the ecosystem-based management model for ocean and water resources, which takes a holistic view of species interactions and the interactions between humans and the environment. Through adaptive water management, consideration is given to how aquatic ecosystems change over time. Green infrastructure, which has been brought to the fore by the UN Convention on Biological Diversity, can also be useful for studying the habitat network for plants and animals on land and in water.

Ecosystem-based management is a fundamental principle behind several directives and conventions, including the EU Water Framework Directive and the Marine Strategy Framework Directive, and Sweden has extensive experience of this management model. However, putting ecosystem-based management into practice has proven challenging. There is a need for more knowledge about decision-making on uncertain grounds, systematic knowledge building in the management process, the responsibility and mandate of different stakeholders for taking action, and how policymakers, researchers and relevant stakeholders provide feedback to each other, such as during follow-up of implemented measures. Ecosystem-based management often also demands trade-offs between conflicting objectives, and free and open access to relevant data.

Maritime spatial planning is another area that requires knowledge building. Maritime spatial planning provides guidance on how to use the sea and how different interests, such as defence, offshore wind operations, shipping, commercial fishing and recreation, can coexist and evolve in harmony with the marine environment. The interaction between land and sea must also be taken into account. All member states in the EU must develop maritime spatial plans, which requires evidence-based input and broad stakeholder dialogues. In addition, knowledge support is needed for global efforts around maritime spatial planning that also sheds light on issues like fighting poverty.

We also need to understand how collaboration around water governance takes place. This can involve how the public and private sectors work with each other and together with other organisations, challenges and measures that cross municipal and sectoral boundaries, and different starting points for cooperation on matters like river basins or specific watercourses.

Community engagement and involvement

In order for efforts towards achieving sustainable oceans and water to deliver a greater impact, all of society must become involved. Research has an important role to play in improving our understanding of how this can be done, but it is also vital for researchers to work closely with the wider society. The gap between research and policymaking needs to be bridged, and the public needs to have greater access to information and be empowered to participate in and influence decision-making processes. Many different stakeholders and end users should be involved in developing and implementing research and innovation projects.

We also need initiatives and research that address communication and learning. Through transformative learning, people can change their frames of reference in a profound way and become more open to change. We need to better understand the consequences of different communication approaches, how messages reach and are interpreted by different groups, and which collaboration processes are suitable for different issues. We also need to better understand how norms, values, attitudes and habits influence people's behaviour, and how large-scale behavioural changes can be realised.

Sweden's contribution to the UN Decade of Ocean Science²¹ underscores the importance of a national initiative for raising awareness of how we humans affect the ocean and how it affects us. By involving many different types of stakeholders, such an effort can promote stewardship among citizens, create corporate engagement, and lay the foundation for laws and regulations that safeguard the marine environment. Aquatic education offers tools that can strengthen awareness of both marine and water issues in society through networking, informational material and knowledge exchange.

Blue innovation

The potential of the sea to contribute to economic development has attracted great interest around the world in recent years, with phrases like "blue economy" and "blue growth". In the EU, sustainable blue growth is part of the Green Deal and is expected to help mitigate climate change, make the economy more circular and preserve biodiversity while also creating new jobs and contributing to national economies. Blue innovation is part of this and involves innovative ways of leveraging the sea's resources. It can be about food production, new materials or renewable energy that uses resources from the sea.

Although many people think of innovation as a product or a technical solution, it is broader than that. It can include policy development and innovative policy instruments, or service innovations in which users contribute to value creation. A prerequisite for creating high-impact innovations is to understand what drives people's behaviour. Collaboration among stakeholders, with a focus on the solution's

21. Formas, the Swedish Agency for Marine and Water Management (SwAM) and Swedish Meteorological and Hydrological Institute (SMHI) (2020), Ett svenskt bidrag till FN:s årtionde för havsforskning för hållbar utveckling 2021–2030. A government-commissioned final report. R3:2020. <https://www.formas.se/download/18.23ea31d174bf101a2f136fc/1601381628002/r3-2020-ett-svenskt-bidrag-till-fns-artioende-havsforskning.pdf>

usability, application and demonstration, is also necessary. In addition, innovations should be scalable and generate real-world impact for many stakeholders.

System demonstrators serve as a tool for testing and demonstrating system changes in a real-world environment, something that is highlighted in Sweden's contribution to the UN Decade of Ocean Science.²² They offer the chance to test and develop new technical solutions, stakeholder constellations, business models, value chains, infrastructures, regulations, methods for stimulating behavioural change, the effects of change in an organisation or spatial planning, and more. System demonstrators have the potential to accelerate developments in marine food products, tourism, climate adaptation of coastal cities and communities, maritime spatial planning and policy development.

22. Formas, the Swedish Agency for Marine and Water Management (SwAM) and Swedish Meteorological and Hydrological Institute (SMHI) (2020), Ett svenskt bidrag till FN:s årtionde för havsforskning för hållbar utveckling 2021–2030. A government-commissioned final report. R3:2020. <https://www.formas.se/download/18.23ea31d174bf101a2f136fc/1601381628002/r3-2020-ett-svenskt-bidrag-till-fns-artioende-havsforskning.pdf>

3. Cross-cutting perspectives

In addition to the agenda's three themes, three cross-cutting research and innovation perspectives have been identified as particularly relevant to highlight in the national research programme on oceans and water. Formas encourages grant applicants to apply these perspectives to the agenda's themes when formulating calls for proposals, communication activities or applications for the programme's calls, for example. The perspectives and themes, along with the programme objectives, form the overall framework for implementing actions under the programme.

3.1 System perspectives

Water connects us, and serves as a link between land, air and all living things. Because it is such a fundamental cornerstone of ecosystems and communities, water-related challenges should typically not be narrowly delineated. A challenge is rarely isolated, and it can manifest itself as one or more problems that depend on multiple interconnected components. Adopting a system perspective means considering how something affects and is affected by its surrounding environment. A system perspective is holistic and can consider different types of natural, technical or social systems. It can involve including environmental stressors and consequences in widely different geographical locations or in different parts of society. A system perspective allows for capturing a diverse range of consequences for different actions, creating the potential for research to achieve greater real-world impact and the basis for sound decision support. It is vital to define transparent system boundaries, and to identify and involve key stakeholders.

3.2 Open science and participation

The successful management of aquatic ecosystems depends on open access to data from research and environmental monitoring, something which is highlighted within the framework of the UN Decade of Ocean Science. By open access, we are referring to the internationally recognised definition of FAIR: findable, accessible, interoperable and reusable. Open science is an umbrella term that includes open access to research data and scientific publications, and new ways of assessing the impact or application of research. It also means that science opens the participatory research process to different stakeholders – and that researchers can distinguish themselves in other ways besides publication metrics alone. These ways include sharing research data, spreading knowledge and engaging in dialogue with different stakeholders.

Participation in the democratic process is a cornerstone of sustainable water management. It paves the way for well-informed decision-making, mutual learning and a better understanding of different perspectives, and makes people feel involved in the decisions. This requires an equal representation of interests in terms of equality between the sexes and among various groups in society with regard to age, nationality, ethnicity, geographic location, income and ability. People also need access to relevant information about oceans and water and the chance to get involved in decision-making.

Research co-creation, in which researchers involve users early on throughout

the process, shows great potential for generating useful research results. Citizen science has also been showcased as a tool for supporting open science and participatory practices.²³ In citizen science, the public helps researchers to investigate various topics by collecting observational data and contributing in other ways. It also represents a way to bring research questions about oceans and water closer to people who would otherwise not be reached, boosting participation and open science. Open science also helps to leverage the potential of digitalisation for effective communication between researchers and the wider society, for example through the automated collection of research results that researchers can process at a later stage.

3.3 From local to global

The national research programme on oceans and water monitors and highlights the relevance of different marine and water issues at local, regional, national and global levels in order for the programme's activities to have the best possible impact. An understanding of the context of the challenges at each level is thus needed. In addition, we need to understand governance at the different levels, how the levels interact and can be coordinated, and what geopolitical consequences this can bring.

Because Sweden is so elongated from north to south and has a coastline that borders both an inland sea of brackish water and the open sea, there are regional differences both in climate and in aquatic conditions, such as differences in geology, hydrology, salinity and nutrients, which entail variations in biology and ecosystems. This means that a common challenge often needs local solutions. As mentioned earlier in an example, different areas have different conditions for artificial groundwater recharge. Furthermore, the problem of eutrophication has been noted for decades, but it is not as well known that some inland waters, especially in northern Sweden, are becoming increasingly oligotrophic (nutrient-poor). Climate change and urbanisation are also increasing the need for local and regional scenarios for flows, sea ice, land uplift and sea level rise so that we will be able to adapt.

Many countries face the challenge of how to ease the pressure on groundwater while securing access to drinking water. This can be done through desalination and the reuse of treated wastewater, among other methods. Countries can learn from each other, even if their conditions vary in terms of bedrock and precipitation, for instance. With expanded management systems, even treated wastewater that is not of drinking water quality can be leveraged for "technical use" outside households, which can enable drinking water to be saved.

Plastic and other waste in lakes, streams and oceans represents a global environmental problem. By exporting waste to countries with poor waste management, Sweden and other countries are contributing to ocean litter. Important issues in this area include recycling, replacing fossil fuel-based materials and regulating hazardous substances, as well as microplastics in seas and lakes.

23. UNESCO (2021) UNESCO Recommendation on Open Science, <https://unesdoc.unesco.org/ark:/48223/pf0000379949.locale=en>

4. International collaboration

Under Formas' mandate to establish a national research programme on oceans and water, the programme is to exploit synergies with the EU Framework Programme for Research and Innovation. In this chapter, we describe which international research and innovation funding initiatives are of particular interest for such synergies with the programme. For a description of how the programme will aim to achieve synergies with the UN Decade of Ocean Science, see Chapter 6.

The EU Framework Programme for Research and Innovation is called Horizon Europe. It is the EU's main funding instrument for research and innovation, with a total budget of 95.5 billion euros for the period 2021–2027. Horizon Europe's overarching goals are to help strengthen sustainable growth and competitiveness in Europe, tackle climate change and promote sustainable development worldwide. Horizon Europe has three main pillars: (1) Excellent Science, (2) Global Challenges and European Industrial Competitiveness, and (3) Innovative Europe. The framework programme has also launched five missions, which are strategic research and innovation initiatives that will run during 2021–2030. The mission "Restore our Ocean and Waters" is the most relevant for the programme. Formas has taken an active role in the preparations for this water-related mission, including through joint input with Mistra and Vinnova.²⁴

Part of Horizon Europe, European Partnerships bring together the European Commission, member states and associated countries, industry and other stakeholders around a common research and innovation agenda. The partnerships aim to coordinate the countries' resources to address global challenges that cannot be solved at national level but that have major consequences at local and regional levels. They are built around collaboration and shared responsibility among all partners, who are part of an agreement with the EU. This in turn means that the EU contributes financial support for the partnerships' activities.

The partnerships "A climate-neutral, sustainable and productive blue economy" (SBEP) and Water4All are of particular interest for the national research programme on oceans and water. SBEP is described as the blue arm of the EU's Green Deal that aims to support the transition to a sustainable blue economy through marine research and innovation,²⁵ while Water4All focuses on long-term water security for all.²⁶ Other relevant partnerships are the ones addressing biodiversity, urban development and chemicals, such as Biodiversa+, Driving Urban Transitions Towards a Sustainable Future (DUT) and Partnership for the Assessment of Risks from Chemicals (PARC).

Swedish involvement in the European Partnerships includes active participation in both strategic and operational activities. With the support and cooperation of other government agencies, Formas has already taken a highly active role in the preparatory work for the partnerships, the design of strategic directions, joint funding calls and other activities. For example, we have been a driving force for open science and for research that supports the advancement of ecosystem-based

24. Formas, Mistra and Vinnova (2020), A contribution to the design phase for the Horizon Europe mission for healthy oceans, seas, coastal and inland waters.

25. JPI Oceans (2022) Sustainable Blue Economy Partnership, <https://www.jpi-oceans.eu/en/sustainable-blue-economy-partnership>

26. European Partnership Water4All – Water Security for the Planet (2022), <https://water4all-partnership.eu/>

management and enhances our capacity to take action on sustainable oceans and water, which aligns with the national research programme's mandate for oceans and water. Formas has a coordinating role in Water4All for activities in the partnership that aim to increase collaboration among researchers, policymakers, stakeholders and consumers, which also includes the pursuit of open science. In SBEP, we play a leading role in developing methods and models for the entire water value chain, from source to sea. We have central roles in Biodiversa+, as vice-chair of the entire partnership, and in DUT, as coordinator of a work package on circular urban economy that includes green and blue water challenges in urban environments. As coordinator of the various partnership work packages, we lead efforts in some of the programmes and assume an operational role in planning and implementing calls for research funding and other activities that help to disseminate research results and achieve real-world impact. Formas also actively participates in the Partnership for the Assessment of Risks from Chemicals (PARC).

Because many water-related research needs are global or regional in nature, it will be important for the national programme on oceans and water to identify relevant partnerships beyond the European research and innovation landscape. For example, knowledge building around the Baltic Sea can benefit from the cooperation between the programme and the other coastal countries, and valuable lessons can be learned through global partnerships that extend beyond Europe's borders. Formas has actively contributed to regional research partnerships through the Baltic Sea and North Sea Research and Innovation Programme (Banos), to name one example. We also have ties with the Nordic research partnership NordForsk and the international partnership Belmont Forum, which promotes transnational research on global environmental change.

The national research programme on oceans and water will act as a springboard for Swedish involvement in international activities within marine and maritime research. The programme can, for example, support the collaboration and coordination of international activities on the part of Swedish agencies and organisations, serve as a guide for prioritising calls and other activities in the European Partnerships, or design initiatives at national level that can boost the competitiveness of Swedish researchers in international calls.

As Figure 1 illustrates, the national research programme on oceans and water is a foundation for Swedish efforts in the European partnerships Water4All and SBPE, based on coordination with Formas' other national research programmes on food, climate and sustainable spatial planning. It is also essential for the programme to create synergies with the UN Decade of Ocean Science and the five EU missions.

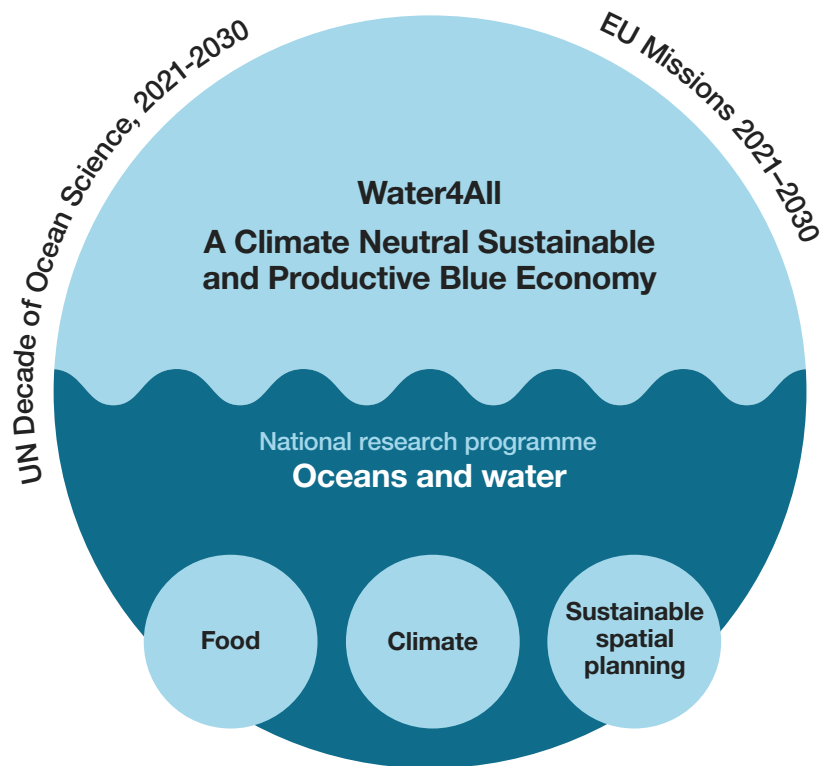


Figure 1. Links between the national research programme on oceans and water, with close ties to Formas' other three national research programmes, and relevant international initiatives for marine and water research.

5. The national funding landscape

One of the objectives of the national research programme on oceans and water is to streamline coordination of national research funding in this area. Funding for marine and water research can be sought from several government research funders as well as other organisations, such as private and public foundations or industry associations. In addition, Swedish researchers receive significant research funding from the EU and other international organisations.

The programme actively encourages synergies and collaboration among funders of water-related research and innovation. The programme's committee includes a number of Swedish research funders who have been identified as particularly relevant to the field and other stakeholders who provide key input on shaping research funding. Several of these funders are also responsible for data that can serve as a valuable resource in research that affects oceans and water. The following section provides a general description of the role of these funders in the research and innovation system, focusing on their funding activities for ocean and water research.

The **Swedish Energy Agency** pursues society's transition to a sustainable energy system and is Sweden's largest funder of energy research. It provides information and analyses on the supply and use of energy in society and has the overall responsibility for the energy transition. The agency offers a wide range of tools, from basic research to market introduction, and receives research appropriations of approximately SEK 1.4 billion annually.²⁷ Examples of water-related research funded by the Swedish Energy Agency include hydropower, offshore wind power, ocean energy and shipping. The agency funds the Swedish Hydropower Centre, a centre of expertise tasked with developing new knowledge about topics like the balance between the environmental impact of hydropower and electricity generation. The agency is also involved in research programmes like the Future Electrical System, which includes water-related research, and the Maritime Programme. It also takes part in international initiatives, such as the Clean Energy Transition Partnership (CETP), which address marine and water issues. The Swedish Energy Agency also works on strategic innovation programmes and their successors, Impact Innovation, which has a clear sustainability profile.

Formas is a government research council that provides nearly SEK 2 billion annually in funding for research and innovation within the environment, spatial planning and land-based industries.²⁸ Across all of Formas' activities, the research is assessed on the basis of both scientific quality and real-world impact. In addition to the national research programme on oceans and water, Formas funds water research through its biggest call, the annual open call, which is for completely research-initiated projects. This means that researchers propose their own research ideas within Formas' areas of responsibility. The review panel in the annual open call that assesses water research proposals predominantly funds research in the natural sciences and technology, but also in the social sciences and the humanities.

27. Swedish Energy Agency (2022), Stöd till affärsidéer, test och internationalisering, <https://www.energimyndigheten.se/forskning-och-innovation/stod-till-affarsideer-test-och-lansering/>

28. Formas (2022), Funding, <https://formas.se/en/start-page/about-formas/what-we-do/funding.html>

Formas also funds innovation, for example through the strategic innovation programmes and Impact Innovation. It oversees three additional national research programmes on climate, sustainable spatial planning and food, which also include water issues to some extent. The agency also actively pursues water issues in the EU's partnerships "A climate-neutral, sustainable and productive blue economy" (SBEP) and Water4All.

The Swedish Agency for Marine and Water Management (SwAM) is responsible for the conservation, restoration and sustainable use of Swedish lakes, seas and watercourses. It drives and mobilises support around the implementation of environmental policy and works to achieve the sustainable management of fishery resources.²⁹ The agency does not have its own research funds, but it is a key player in marine and water research in Sweden in several ways. Together with the Swedish Environmental Protection Agency, SwAM is tasked by the government to ensure that the environmental research appropriation is awarded to research projects that support the work of both agencies.³⁰ Furthermore, SwAM identifies and coordinates research needs related to its mandate and interacts with research and development funders both within and outside Sweden, for example in marine and water-related partnerships under the EU's framework programme for research and innovation.³¹ In addition, the agency supports research and development in fish management through water and fishing fee funds.

The government has also established several research foundations, including **Mistra**, the Foundation for Strategic Environmental Research, which is particularly relevant for the programme. Mistra promotes robust environments for environmental research by funding long-term programmes of four or eight years.³² In the programme, interdisciplinary collaboration as well as cross-sectoral collaboration between researchers and companies, government agencies and other stakeholders take place. The programmes aim to generate valuable real-world impact and bolster Swedish competitiveness. Mistra provides approximately SEK 200 million in research funding annually.

The Swedish Environmental Protection Agency is a government agency with broad oversight of environmental issues that pursues the development and implementation of environmental policy in Sweden, the EU and around the world.³³ The agency is responsible for issues related to the climate, air, soil, biodiversity, contaminated areas, waste, environmental monitoring, and hunting and game, issues that overlap with those addressed by several of the national research programmes. Through the environmental research appropriation (roughly SEK 97 million in 2022), the Swedish EPA funds research that supports both its own work and that of SwAM.³⁴ Research applications are reviewed both from a scientific perspective and their relevance for environmental efforts.

Each research initiative is assigned a dedicated team of employees who monitor the researchers' progress. This way, the Swedish EPA and SwAM ensure the uptake and application of research results in their own operations.³⁵

29. Swedish Agency for Marine and Water Management, About us, <https://www.havochvatten.se/en/our-organization/about-swam.html>

30. Swedish Agency for Marine and Water Management, Environmental research appropriations, grants and calls

31. Swedish Agency for Marine and Water Management, Forskning - Planering, förvaltning och samverkan, <https://www.havochvatten.se/planning-forvaltning-och-samverkan/program-projekt-och-andra-uppdrag/forskning/forskning.html>

32. Mistra, About Mistra, <https://www.mistra.org/om-mistra/>

33. Swedish Environmental Protection Agency, About us, <https://www.naturvardsverket.se/om-oss/om-naturvardsverket/>

34. Swedish Environmental Protection Agency, Environmental research appropriation, <https://www.naturvardsverket.se/om-miljoarbetet/forskning/miljoforskning/miljoforskningsanslaget>

35. Swedish Environmental Protection Agency, Environmental research appropriation, <https://www.naturvardsverket.se/contentassets/a6202bb-d9b8b484aa66bffc0efb26fa9/broschyr-miljoforskningsanslaget-2018.pdf>

The Swedish Polar Research Secretariat coordinates and promotes Swedish polar research by organising and supporting research expeditions to the polar regions, overseeing research infrastructure and conducting funding calls.³⁶ The agency pursues a responsible, sustainable development of the polar regions and greater international exposure for Swedish polar research. The research mainly focuses on the polar regions of the Arctic and Antarctica, but it also includes the subpolar regions and the Swedish mountains.

The Swedish Space Agency is responsible for funding research and development as well as research infrastructure for national and international space activities in Sweden.³⁷ The agency also represents Sweden in international space cooperation, in particular within the framework of the European Space Agency (ESA), and disseminates knowledge about space to the general public. Space research can support marine and water research through environmental monitoring using satellite data, for example.

The Geological Survey of Sweden (SGU) is the managing authority on issues concerning bedrock, soil and groundwater and is tasked with providing the public with geological information.³⁸ SGU works for a sustainable development of society that ensures a fit-for-purpose use and development of land and water areas as well as mineral and natural resource sectors that are viable and responsible. SGU is responsible for the environmental quality objective “Good-Quality Groundwater”, operates Sweden’s groundwater network, addresses continental shelf matters and is in charge of decommissioning and safety measures to minimise the environmental consequences of state-owned facilities – areas of activity that directly affect or touch upon issues raised in this agenda. The agency is also tasked with promoting and supporting targeted basic research and applied research within the earth sciences. Research funding is generally announced for one thematic area per year. SGU also participates in national and international research projects.

The Swedish Transport Administration oversees strategic infrastructure planning for road traffic, rail traffic, shipping and aviation, as well as for the construction and operation of national roads and railways.³⁹ Although the agency does not serve primarily as a funding organisation, it initiates research and innovation that is needed based on its activities. During 2018–2029, the Swedish Transport Administration will invest approximately SEK 8 billion in research and innovation. These funds will be distributed across all modes of transport and will help shape a cohesive, scalable transport system that can leverage new technology and digitalisation for emissions-free transport. The agency’s research and innovation activities are divided into seven theme-based portfolios; the maritime sector is one such theme that may be of particular interest to the field of oceans and water.⁴⁰

The Swedish Research Council is Sweden’s largest research funding organisation, allocating nearly SEK 8 billion annually for research and research infrastructure.⁴¹ It supports research of the highest scientific quality in all

36. Swedish Polar Research Secretariat, About the secretariat, <https://www.polar.se/en/about-the-secretariat/>

37. Swedish National Space Agency, About us, <https://www.rymdstyrelsen.se/en/about-us/>

38. Geological Survey of Sweden, About SGU, <https://www.sgu.se/en/about-sgu/>

39. Swedish Transport Administration, About us, <https://bransch.trafikverket.se/en/startpage/about-us/Trafikverket/>

40. Swedish Transport Administration, Information about research and innovation projects, <https://fudinfo.trafikverket.se/fudinfoexternwebb/pages/AnsokanStart.aspx>

41. Swedish Research Council, Swedish research in figures, <https://www.vr.se/english/analysis/swedish-research-in-figures.html>

scientific disciplines.⁴² Most of the funds go to basic research projects in which the researchers themselves can choose the focus area. The council's funding for marine and water research is distributed mainly through annual open calls for research projects, but also through topic-specific and career-oriented support, as well as through calls for environmental and collaboration funding and bilateral research collaboration. It also funds research infrastructure both within and outside Sweden. The council established two national research programmes in 2017 (migration and integration, antibiotic resistance) and was tasked with establishing four additional national research programmes with the 2020 Research Bill (viruses and pandemics, crime, segregation, the consequences of digitalisation).

Vinnova is Sweden's innovation agency and is tasked with bolstering Sweden's innovation capacity and contributing to sustainable growth in line with Agenda 2030.⁴³ For 2022, Vinnova's block grant for research and innovation was SEK 3.4 billion.⁴⁴ Vinnova operates in ten priority areas.⁴⁵ Five of these address sustainability issues (sustainable industry, sustainable food systems, sustainable mobility, sustainable precision health, sustainable built environments) and the rest concern innovation capabilities. The agency is the national contact authority for the EU's framework programme for research and innovation and is tasked with strengthening Swedish participation in the programme, including within oceans and water. Vinnova runs strategic innovation programmes together with the Swedish Energy Agency and Formas, who together oversee 14 out of 17 programmes, as well as the successor Impact Innovation.

Two other research funding organisations relevant to oceans and water that are not part of the programme committee are **Svenskt Vatten** and the **Swedish Geotechnical Institute** (SGI). Svenskt Vatten is a trade association representing water and wastewater organisations. It finances applied research and development within the members' areas of activity through the municipalities' own research and development programme, Swedish Water Development.⁴⁶ SGI is an expert body involved in research, knowledge transfer and collaboration. Its mandate in areas like climate adaptation, coastal erosion and polluted zones have many linkages to water.⁴⁷

42. Swedish Research Council, Our mandates, <https://www.vr.se/english/mandates.html>

43. Vinnova, Our mission, <https://www.vinnova.se/en/about-us/our-mission/>

44. Appropriation directions for 2022 budget year for Vinnova, N2021/3054, N2021/3042 (partly), N2021/00542

45. Vinnova, Ten areas for a sustainable future, <https://www.vinnova.se/en/our-activities/changing-for-a-sustainable-future/>

46. Svenskt Vatten, Så jobbar vi med forskning, <https://www.svensktvatten.se/forskning/sa-jobbar-vi-med-forskning-svu/>

47. SGI, About SGI, <https://www.sgi.se/en/about-sgi/>

6. Programme implementation

In this chapter, we describe how the programme will be implemented, based on the direction stated in this strategic research agenda, with a focus on organisation, activities, and follow-up and evaluation.

6.1 Organisation

The national research programme on oceans and water intends to be a unifying knowledge platform for relevant stakeholders and actors, enabling long-term strategic research and innovation efforts on these topics, both nationally and internationally.

In accordance with the government's assignment to Formas (see Appendix 1), a programme committee has been set up consisting of the relevant research funding organisations as well as SwAM and SGU. In addition to these two organisations, the committee includes the following research funding organisations: The Swedish Energy Agency, Mistra, the Swedish Environmental Protection Agency, Swedish Polar Research Secretariat, Swedish Space Agency, Swedish Transport Administration, Swedish Research Council and Vinnova. The purpose of the committee is to coordinate funding for oceans and water research and thus form the basis for prioritising national and international initiatives. Under Formas' leadership, the committee (with the support of an external chair) will assist in formulating, implementing and regularly updating this strategic research agenda.

To support the activities of the national research programme, a working group has been set up consisting of representatives from government agencies in the programme committee as well as other relevant agencies and stakeholders in the area of oceans and water. The composition of the working group varies according to the needs of the committee and the opportunities for stakeholders to participate.

Work within the national research programme on oceans and water will be coordinated with Sweden's implementation of the UN Decade of Ocean Science. There is a solid foundation for mutual support and leverage, as Formas has also been tasked by the government to establish and host a national committee for the Decade.⁴⁸ This committee (not to be confused with the committee for the national research programme on oceans and water) is tasked with disseminating information about the Decade to promote awareness, engagement and collaboration, giving advice about national priorities and providing suggestions for activities, as well as communicating the results of the activities. The national research programme on oceans and water and activities related to the Decade are also intended to mutually strengthen the coordination of efforts in research and innovation both within and outside Sweden. The committee consists of government agencies that are not research funders and of an NGO, thus complementing the committee for the national research programme on oceans and water, which consists primarily of relevant research funding organisations.

48. Formas (2022), National Committee for the UN Decade of Ocean Science, <https://formas.se/en/start-page/about-formas/what-we-do/national-committee-for-the-un-decade-of-ocean-science.html>

A programme roadmap, known as programme logic, will be developed to support the programme's implementation. This programme logic will preliminarily describe what challenges the programme stems from, what efforts need to be implemented to address these challenges, the expected results and long-term effects of these initiatives, and the goals these effects can help to achieve.

6.2 Programme activities

Programme funding is distributed primarily through calls. The calls can be carried out within the programme or together with other Swedish or international organisations. The programme offers various forms of funding, such as research grants, innovation grants and collaboration funding. The programme committee is involved in developing the focus for calls carried out within the programme. Formas' Research Council takes the decision to open the calls.

The programme will carry out activities that facilitate close collaboration between researchers and stakeholders and that help to translate research into action. This can involve inviting members of ongoing or completed projects to conferences, seminars and other events to provide new insights and support the real-world impact of research and innovation. We can also initiate and compile research reviews to highlight the state of knowledge and knowledge needs in priority areas.

The programme's activities also aim to monitor and link the programme to international research funding. This is described in Chapter 4.

6.3 Follow-up and evaluation

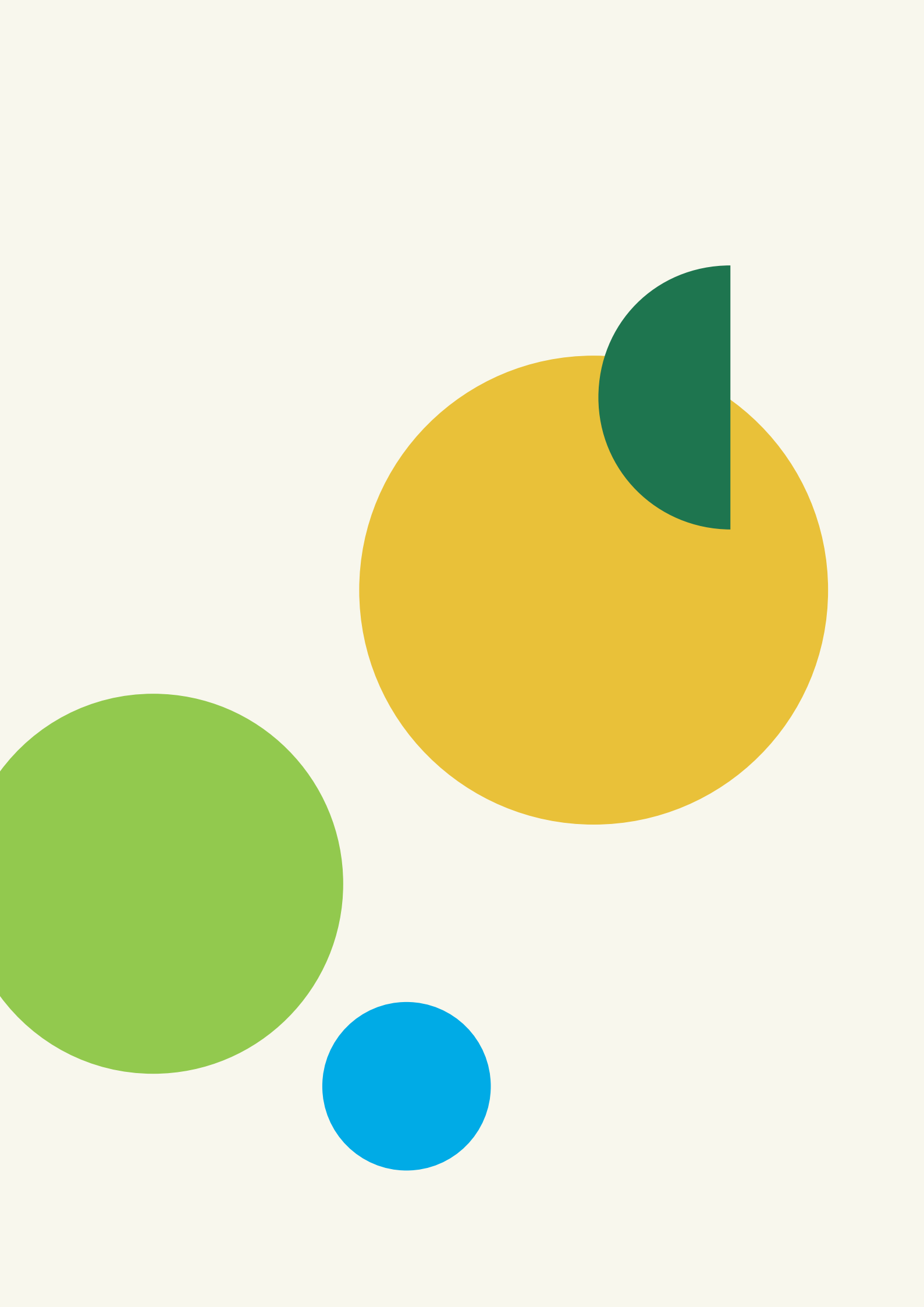
In accordance with the assignment, Formas follows up on the programme each year and reports on it to the Government Offices. We continuously monitor the initiatives and activities implemented, including calls, projects and communication activities.

During the ten-year programme period, the programme will be evaluated. The evaluation will be organised and implemented in dialogue with the programme committee, the working group and other national research programmes. Lessons will be drawn from the two previous evaluations of national research programmes; the first focused on examining the effectiveness and efficiency of the organisation and governance of Formas' three national research programmes starting in 2017⁴⁹, and the second evaluation assessed the potential to achieve the expected results and effects in the first seven national research programmes of the Swedish Research Council, Forte and Formas.⁵⁰ Both evaluations were formative and provided recommendations for developing the programmes.

The strategic research agenda and programme logic will be revised during the programme period. Evaluations, research proposals, or major changes in the national or global context can be cause for making reprioritisations and revisions in the programme. When the agenda is revised, the research-performing organisations and stakeholders should be informed.

49. Ramboll (2020), Utvärdering av Formas nationella forskningsprogram, Formas R4:2020.

50. Erik Arnold, Göran Melin och Josefine Olsson (2022), A Formative Meta-Evaluation of Seven Swedish National Research Programmes 2017-2021, Report: R8:2022, Faugert & Co/Technopolis Sweden and Technopolis Ltd.



Appendix 1. Formas' government assignment

Excerpt from Government decision of 2021-09-02, M2021/01625, providing a mandate to establish a national research programme on oceans and water.

Mandate to establish a national research programme on oceans and water

The government's decision

The government tasks the Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning (Formas) with establishing a national research programme for oceans and water valid through 2030, in accordance with the government decision of 18 May 2017 (02017/02404).

Background

In its input to the research and innovation policy bill, Formas proposed establishing a national research programme for oceans and water (N12019/01956). In its bill "Research, freedom, future – knowledge and innovation for Sweden" (Govt. Bill 2020/21:60), the government stated its intention to task Formas with carrying out a ten-year national research programme on oceans and water. On 17 December 2020, the Riksdag adopted an overarching goal for Sweden's implementation of Agenda 2030 (Govt. Bill 2019/20:188, Report 2020/21:FiU28, Communication 2020/21:154).

Clean water is a vital yet highly threatened resource. Reliable access to water is affected by, and is necessary for, drinking water production, agriculture, forestry, aquaculture, industrial manufacturing and energy supply. In recent years, shifting precipitation patterns and droughts have caused more water supply problems in different parts of Sweden and the world, something that is expected to become a more common problem in a warmer climate. All water (groundwater, freshwater and seawater) is interconnected and is affected by the terrestrial environment. Oceans and water bodies are affected by climate change and ocean acidification. This has already had an impact on ecosystems and often amplifies the effects of other pressures and environmental problems, such as eutrophication, littering and pollution from hazardous substances, affecting biodiversity, coastal communities, fisheries and other maritime activities. As a result, ocean and water issues have been put at the top of the global agenda.

The Baltic Sea is one of the world's most polluted seas, and the Øresund strait is one of the world's busiest shipping lanes. However, we know much less about the ocean and its resources than we do about land areas and the atmosphere.

Funding for marine and water research is currently fragmented among multiple funding bodies, and the challenges are not fully being addressed by the existing national research programmes.

More about the assignment

The programme should enable the conditions for a strategic, long-term holistic approach to oceans and water in order to achieve the environmental quality objectives, the generational goal and Sweden's implementation of Agenda 2030. It should facilitate close collaboration between researchers and stakeholders.

In accordance with the government's decision of 18 May 2017 (U2017/02404), the programme should have a programme committee that, under Formas' leadership, can assist with the formulation, implementation and regular updating of the programme's strategic research agenda.

The programme committee should include relevant research funding organisations as well as the Swedish Agency for Marine and Water Management and the Geological Survey of Sweden.

The programme is tasked with improving knowledge of and the foundation for the effective planning and ecosystem-based management of oceans and water while taking climate change into account. It should include research that improves the understanding of both natural processes and their interactions, such as pressures and effects on the environment and climate, as well as the productive capacity of ecosystems, which are not covered by existing national research programmes. Furthermore, research is needed on appropriate instruments at local, regional, national and international levels and other implementation considerations, as well as innovation support for the viability of the marine and aquatic environment and more efficient use of water resources and of marine and aquatic resources. The programme should also help ensure the supply of expertise in areas of vital importance to society.

In carrying out its assignment, Formas should exploit opportunities for synergies with the EU Framework Programme for Research and Innovation and the mandate of the National Committee for the UN Decade of Ocean Science (M2020/00704).

At least SEK 10 million of appropriation 2:2, "Forskningsrådet för miljö areella näringar och samhällsbyggande: Forskning", in expenditure area 20 should be used in 2021 for implementation of the programme.



Ett forskningsråd för hållbar utveckling
A Research Council for Sustainable Development

Formas is a government research council for sustainable development. We fund research and innovation, develop strategies, and conduct analyses and evaluations. Our areas of activity are the environment, agricultural sciences and spatial planning. We conduct systematic reviews that aim to make it easier for Sweden to achieve our environmental goals. We also communicate about research and research results.

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