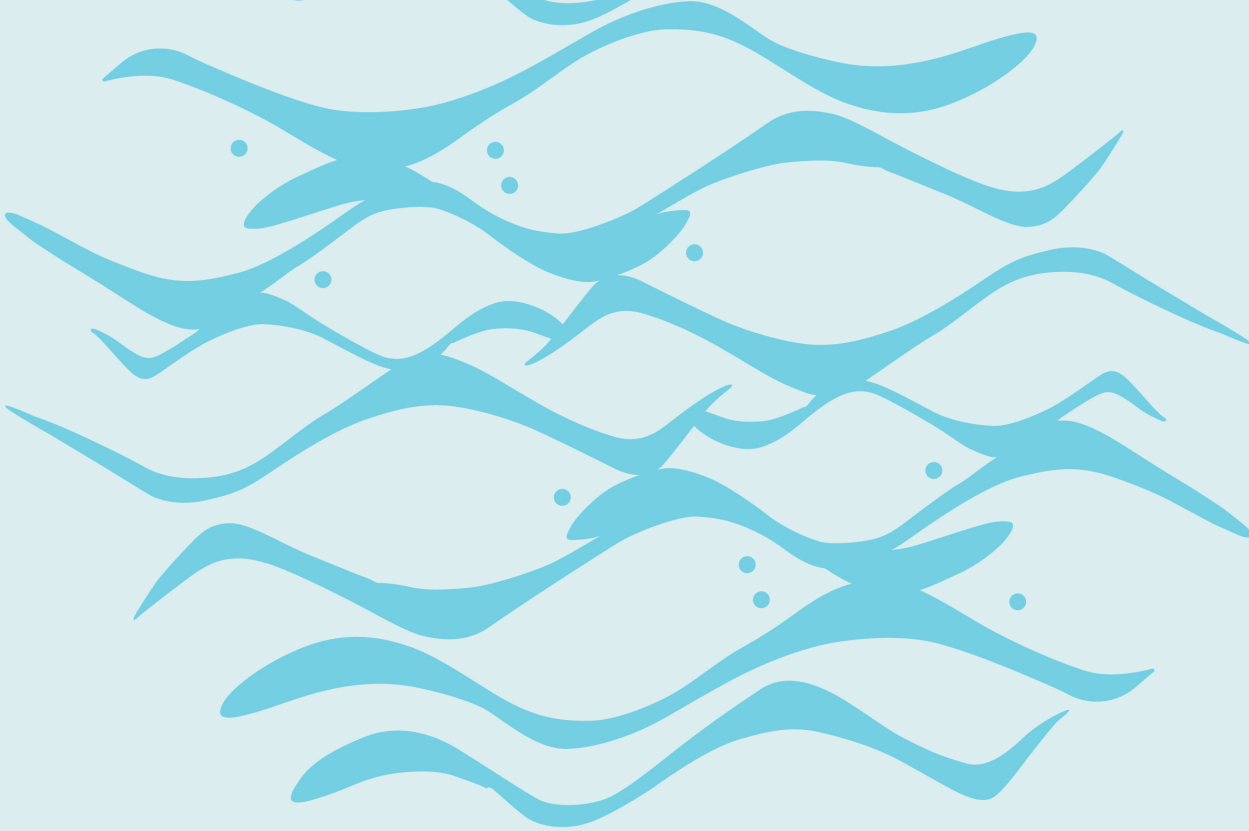
Food and Agriculture Organization of the United Nations

The EAF-Nansen Programme Science Plan

Supporting the application of the Ecosystem Approach to Fisheries (EAF) management considering climate and pollution impacts (2017–2021)



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Food and Agriculture Organization of the United Nations (FAO)

Rome, 2020

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Contents

Acronyms and abbreviations

ABNJ	Areas beyond national jurisdiction
ASCLME	Agulhas and somali currents large marine ecosystem
BCC	Benguela Current Convention
CCLME	Canary current large marine ecosystem
CECAF	Fisheries Committee for the Eastern Central Atlantic
COREP	Regional Commission of Fisheries of Gulf of Guinea
EAF	Ecosystem Approach to Fisheries
EEZ	Exclusive economic zone
FAO	Food and Agriculture Organization of the United Nations
FCWC	Fishery Committee for West Central Gulf of Guinea
GCLME	Guinea Current Large Marine Ecosystem
GEF	Global Environment Facility
IAEA	International Atomic Energy Agency
ICES	International Council for the Exploration of the Sea
IMR	Institute of Marine Research
IOC	Intergovernmental Oceanographic Commission
LME	Large marine ecosystem
Norad	Norwegian Agency for Development Cooperation
NORM	Naturally occurring radioactive materials
OSPAR	Convention for the Protection of the Marine Environment of the North-East Atlantic
POP	Persistent organic pollutants
RFB	Regional fishery body
RFMO	Regional fisheries management organization
SEAFO	South East Atlantic Fisheries Commission
SAPPHIRE	ASCLME Strategic Action Programme Policy Harmonisation and Institutional Reform
SRFC	Sub-Regional Fisheries Commission
SWIOFC	South West Indian Ocean Fisheries Commission
SWIOFP	South West Indian Ocean Fisheries Project
UN	United Nations
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
WIOMSA	The Western Indian Ocean Marine Science Association

Preface

This document describes the overall principles and main thematic areas of the EAF-Nansen Programme's Science Plan, including the use of the research vessel (R/V) *Dr Fridtjof Nansen* as a key tool for fieldwork. The document summarizes identified knowledge and research needs and is used as the overall framework for planning science-related activities of the EAF-Nansen Programme.

This document was prepared based on a series of consultations held with national and international partners that laid the basis for this Science Plan, including:

- An initial scoping meeting with potential United Nations (UN) and global/regional partners in Paris in 2012.
- A stakeholder consultation with current partners in connection with the EAF-Nansen Annual Forum in Dar es Salaam in 2013.
- A technical workshop with participation of international partners (including the Norwegian Institute of Marine Research (IMR), the United Nations Environment Programme (UNEP), the Intergovernmental Oceanographic Commission of UNESCO (IOC-UNESCO), the International Atomic Energy Agency (IAEA), Grid-Arendal, coordination units of African Large Marine Ecosystem projects and others) in Bergen in June 2015 that laid the basis for this Science Plan.
- Regional consultations with partners held to ensure that regional and national priorities are adequately addressed, and to ensure ownership of the Programme and the Science Plan by its stakeholders. These included meetings organized in collaboration with the Benguela Current Convention (BCC) for South West Africa (Cape Town, November 2015), with the South West Indian Ocean Fisheries Commission (SWIOFC) for the South Western Indian Ocean (Durban, South Africa, January 2016), and with the Fishery Committee for the Central Eastern Atlantic (CECAF) for North West Africa and the Gulf of Guinea (Praia, Cape Verde, October 2016).
- Annual Forum of the EAF-Nansen Project in Abidjan in October 2016.

Gabriella Bianchi (previously with the Food and Agriculture Organization of the United Nations (FAO), and now IMR) was responsible for the preparation of the document and coordination of inputs from different partners. Substantive comments were received by FAO staff (Kwame Koranteng, Merete Tandstad and Pedro Barros), and several IMR scientists (Katherine Michalsen, Svein Sundby and Olav Kjesbu). Harald Loeng (IMR) contributed to the final review.

The Science Plan serves as a guidance on the scope and principles of research work under the EAF-Nansen Programme for national and international, present and future partners.

Summary

This Science Plan complements the project document for the Nansen Programme (Supporting the Application of the Ecosystem Approach to Fisheries (EAF) management considering climate and pollution impacts). It provides greater details on the main research areas, principles to be applied and regions that the Programme covered during the first five years of its activity.

Three main research areas are identified, dealing with impacts of fishing, oil/gas activities and presence of contaminants, and climate variability and change on marine resources and ecosystems. These research areas are further subdivided into 11 main themes.

Data used for the research activities are collected through the surveys with the R/V *Dr Fridtjof Nansen*, including the data collected during the previous phases of the Nansen Programme. These will be completed by other data sources, as it may be required.

As the scope of the research activities expand, it is recognized that social and economic aspects of fishery systems need to be incorporated into the knowledge base. This Science Plan, however, only covers natural science aspects, while the social and economic components will be addressed separately.

The *Dr Fridtjof Nansen* - one of the most advanced marine research vessels studying the state of our oceans.

1. Introduction

Background

Since 1975, Norway, FAO and partners, through different phases of the Nansen Programme, have been supporting developing countries in their efforts to improve food security through efficient fisheries research and management. Fisheries and environmental surveys with the R/V *Dr Fridtjof Nansen* have been an important and integral part of the Programme throughout all its stages. The Programme has evolved into a unique mechanism for cooperation, knowledge generation, and exchange of technology, and lessons learned in developing regions, particularly in Africa. Overall, evaluations of the past phases have proved the initiative to be relevant, well performing and successful.

Since 2006, the Programme has been executed by FAO, in close collaboration with IMR, with the goal of contributing to improved fisheries management and the implementation of the EAF.

Based on the decision in 2012 to build a new research vessel, FAO was asked to develop a new Programme document, covering a period of five years' work. The new phase of the Nansen Programme was intended to continue to strengthen regional and country specific efforts towards reducing poverty and creating conditions that would support the achievement of sustainable food and nutrition security through the application of the EAF. This new phase, referred to as the EAF-Nansen Programme, commenced in May 2017 with a new research vessel. The Programme continues to support fisheries research and management institutions in the partner countries in their efforts to manage fishery resources in a sustainable manner, while also considering pollution and climate change impacts.

The Programme is designed around three main areas of work:

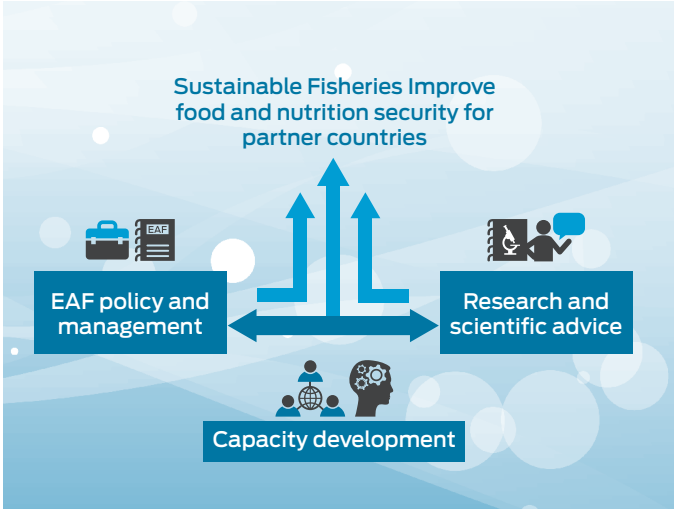
(1) **strengthening the knowledge base** for the sustainable management of fisheries in the face of increasing fishing pressure, climate variability and change, pollution and other anthropogenic stressors;

(2) **supporting improved fisheries policy and management** in line with the EAF, including taking into consideration the risks and opportunities related to climate change and other environmental variability;

(3) **developing capacity** at the institutional and human resources levels, including the promotion of gender equality and effective participation of women in all the Programme's activities.

Capacity building is an important and cross-cutting component of the Programme, and it is therefore integrated in most of the planned outcomes and outputs of the Programme.

FIGURE 1. Main areas of work of the EAF-Nansen Programme.



This Science Plan in particular provides guidance for the research work to be delivered under the Outcome 1 related to "strengthening the knowledge base."

The main drivers of marine ecosystems' change are:

- **Fishing pressure and demand for fish products** that keep increasing in most areas of the developing world. Also, lack of information on the state and dynamics of fish resources, their productivity and the impact of fisheries on them strongly limit effective management.
- **Increasing discharge of contaminants and increasing offshore activity**, such as oil exploration, pollution from land- and ocean- based activities and microplastics are perceived as a new threat to marine life. At the same time, available knowledge on the actual impacts of contaminants on seafood, on the one hand, and of its nutritional value, on the other hand, is very limited, which prevents administrations from taking appropriate action.
- **Climate variability and change** that is expected to affect marine ecosystems' structure and functioning in various ways, for example nutrient availability to the euphotic zone, distribution and migration of species and fish production. Because climate change impacts vary between regions, each area needs to be carefully observed. In particular, there is conflicting information in relation to the consequences of climate change on coastal upwelling, a crucial element in the biological production of many areas of the African coastal zone and the effects of these on fisheries structure and productivity.

Ecosystem characterization has been included as a cross cutting theme to provide a systemic view of marine ecosystems.

Aboard the R/V Dr Fridtjof Nansen.

Knowledge-based decision-making in fisheries and the role of the EAF-Nansen Programme

One of the key principles of the EAF is that decision-making related to issues that are perceived as important for the sustainability of a fishery/ecosystem should not be delayed, while awaiting further data or information i.e. precautionary measures should be taken immediately, based on the "best available knowledge," including traditional ecological knowledge. This is consistent with the precautionary approach. However, the current situation of limited knowledge on impacts of fisheries in many regions, and of impacts of external drivers on marine resources and ecosystems may result in taking more conservative measures than necessary. For example, the precautionary approach could entail reducing resource harvesting far below what could be the maximum sustainable yield in a situation of uncertainty on the actual resource status.

Furthermore, the high level of uncertainty of the possible impacts of climate change and other external drivers on marine resources and ecosystems does not allow coastal countries to get prepared for changes that might have significant impacts on communities, national economies and ecosystems overall.

The EAF-Nansen Programme therefore bases its structure on the notion that knowledge on marine ecosystems and on the effect of fisheries and other human activities on them, including on their biodiversity and dynamics, is a fundamental element for decision-making in a situation where the use of ocean is increasing. In this context, improved knowledge is seen as an essential aspect of the EAF-Nansen Programme.

Given the huge challenge of covering various aspects of marine ecosystem dynamics, the Programme collaborates closely with other research initiatives to ensure maximum coordination and the best use of available resources.

Biological sampling of the trawl catch in Ghana, 2019.

Promoting uptake of science in decision-making

A key challenge is to ensure that the knowledge generated through scientific work is used as a basis for decision-making. To effectively use science in management and decision-making, pathways and mechanisms for incorporating scientific information into these processes need to be established. It is also critical to apply approaches for trans-disciplinary knowledge exchange towards sustainable use and management of natural resources. The Programme employs specific guidelines for such a trans-disciplinary knowledge exchange. It is recognised that the EAF has the potential to significantly enhance the sustainability of fisheries. Policy makers are paying closer attention to the ecological impacts of fishing (expanding beyond target species to non-target species, food web and habitats). In order to implement this approach in decision-making, a set of scientific data and derived information is needed.

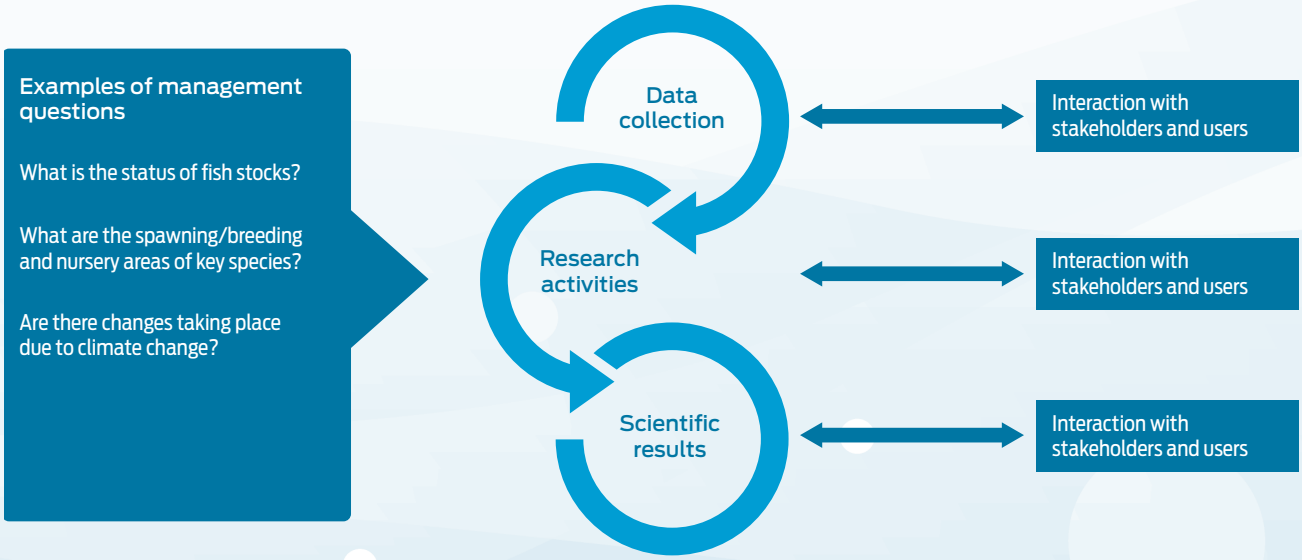
The EAF-Nansen Programme is working to ensure that the collected data can be developed into information needed to support the decision-making process at national, regional and global scales. At national level, there is a need to support the development of policy frameworks and pathways that allow for the incorporation of the relevant information into the decision-making process (e.g. fisheries management cycle and fisheries management plans consistent with the EAF). In addition, ecosystem-based fishery management plans are important, in order to consider the interconnections between species, their physical and biological environments, and different types of human impact.

One of the strengths of the EAF-Nansen Programme is its ability to work at different levels of fisheries governance systems, and thereby increase the probability that the links between the knowledge generated by the Programme and its uptake by management are established. At the national level, the Programme, through the EAF process, engages multiple actors when working on scientific research products, in order to generate awareness about these products and to enhance their legitimacy. Furthermore, it is particularly important to ensure a continuous dialogue with end-users in government throughout the duration of the Programme. This guarantees that the end-product is relevant and supports the achievements of agreed objectives in a given context. It is also important to work in close consultation with fishers and fishing communities and other stakeholders who may need to adhere to possible new measures, or who could be impacted by them. Strengthening or establishing a regular management cycle of knowledge-based decision-making, a must in fisheries management, will contribute to establishing the right processes for uptake of knowledge into decision-making.

The Programme pays attention to the individual context of the end-users in governments, to tailor the scientific research products in a way that ideally suits their specific needs and challenges (management questions). The idea is that the scientific knowledge and its uptake by the users should not be a linear process, but rather something that is produced and taken up through an inclusive and interactive process that plays out amidst a complex web of actors and issues (Figure 2). In this context, the EAF-Nansen Programme can serve as a platform for knowledge exchange among its partners.

The above is valid also at regional and global level. Close collaboration with Regional Fishery Bodies (RFBs), Regional Fisheries Management Organizations (RFMOs), Regional Seas Programmes (RSP), multi-sectoral organizations such as the BCC and other partners such as the Large Marine

FIGURE 2. Scientific activities respond to demands from management and are carried out in close collaboration with stakeholders and users.

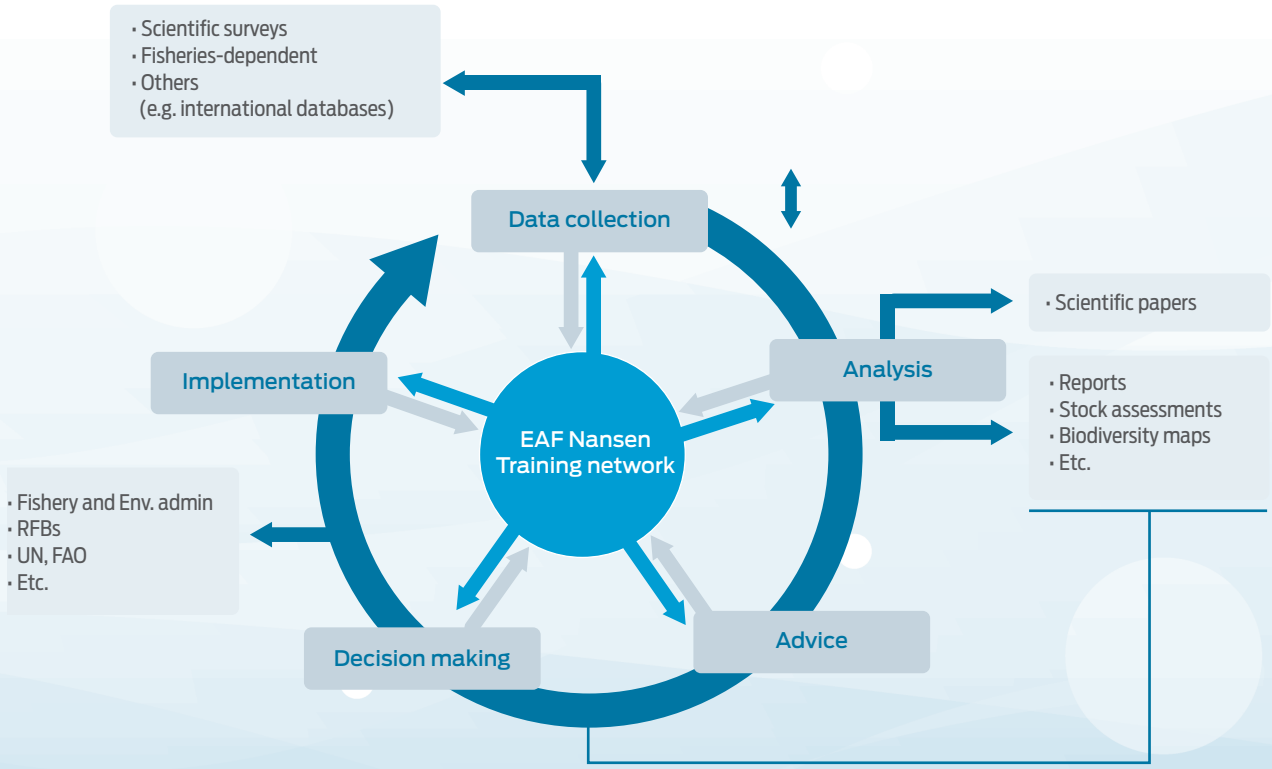


Ecosystem projects, e.g. in designing, delivering and using the knowledge generated by the Programme is considered essential for improving uptake at the regional level. In designing the EAF-Nansen Programme and its Science Plan, these partners have been consulted at different stages of its development. FAO is in a very good position to ensure optimal coordination and collaboration with regional programmes and mechanisms around Africa, given that several programmes fall under FAO's responsibility, or are implemented in partnership with FAO.

Likewise, on a global scale, close collaboration with relevant Inter Governmental Organizations (e.g. IOC-UNESCO, UNEP, IAEA), and international research partners and financial mechanisms/ organisms/bodies (e.g. the Global Environment Facility (GEF), the African Development Bank and the World Bank) should ensure maximum application of the data and scientific knowledge generated by the Programme. An overview of the transition from data collection to fisheries management decisions is presented in Figure 3.

The seafloor of St Lazarus Bank, during the Myanmar Ecosystem Survey in 2015.

FIGURE 3. Science management cycle, as promoted by the EAF-Nansen Programme.



2. Main research areas

Considering that this Science Plan is an integral part of a development programme, it is important to ensure that research activities address the development objectives set for the EAF-Nansen Programme. Therefore, in order to identify main research areas under the Programme, a set of principles has been established. This is presented in Box 1.

The science activities proposed in the new phase of the EAF-Nansen Programme can be classified under the following three main research areas:

1) fishery resources, associated/impacted species and fisheries (mapping the distribution and assessing the abundance, structure and dynamics of main fishery resources, including understanding of the key biological parameters and the impacts of fisheries);
2) understanding the impacts of oil/gas activities, land-based pollution, including marine debris and micro-plastics;
3) understanding the impacts of climate change on fish stocks and ecosystems, including setting up monitoring systems.

Figure 4 provides conceptual framework for the main topics of the Science Plan, showing that fishery resources are at the centre of the Programme's work. The Science Plan, however, aims at explaining the impacts of various stressors (not only fisheries) on them. Furthermore, the need to expand the

BOX 1: Principles for identifying main research areas

1) Sustainable fisheries management is at the heart of the EAF-Nansen Programme, and improving knowledge on distribution, abundance and structure of main stocks and the effects of fisheries on them will be given priority.
2) The research should improve understanding of key biological parameters, the role of fishery resources in the broader ecosystem context, how they are affected by fishing pressure as well as by climate variability and change and the impacts of fisheries and other stressors on resources and the environment.
3) Research should primarily address regional issues (e.g. shared fishery resources/stocks) but could be "localized" in nature (e.g. study of recruitment processes for any important regional stock).
4) The EAF-Nansen Programme should operate primarily within countries' Exclusive Economic Zones (EEZs), but work in the Areas Beyond National Jurisdiction (ABNJ) can also be included in collaboration with RFMOs.
5) Research activities are expected to take cognizance of and be coordinated with national, regional and international fisheries and marine research programmes.
6) Research should primarily be linked to management needs, either tactical (short-term) or strategic (long-term), and/or as contributing to "global public goods." This means that some research activities may not be addressing immediate needs but can be important in the long-term.

understanding of the marine ecosystems, their properties and dynamics is addressed. Ecosystem baselines and monitoring systems will be put in place, from which data can be generated to understand the system dynamics, including the effects of anthropogenic or other external stressors. Information generated by the Science Plan is expected to be useful for fisheries administrations, and more generally, in the context of marine spatial planning/ecosystem-based management.

The above-mentioned conceptual framework translates into three main research areas, in turn subdivided into a total of 11 themes (Figure 5), one of which is cross-cutting. International research teams contribute to the development and implementation of each theme.

FIGURE 4: Conceptual framework of the research to be undertaken as part of the EAF-Nansen Programme Science Plan.

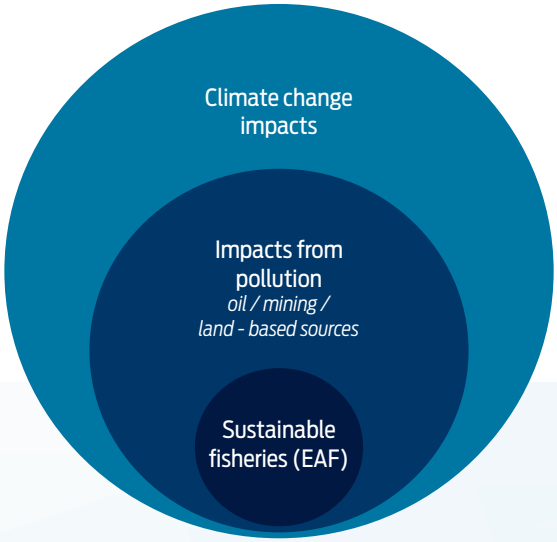
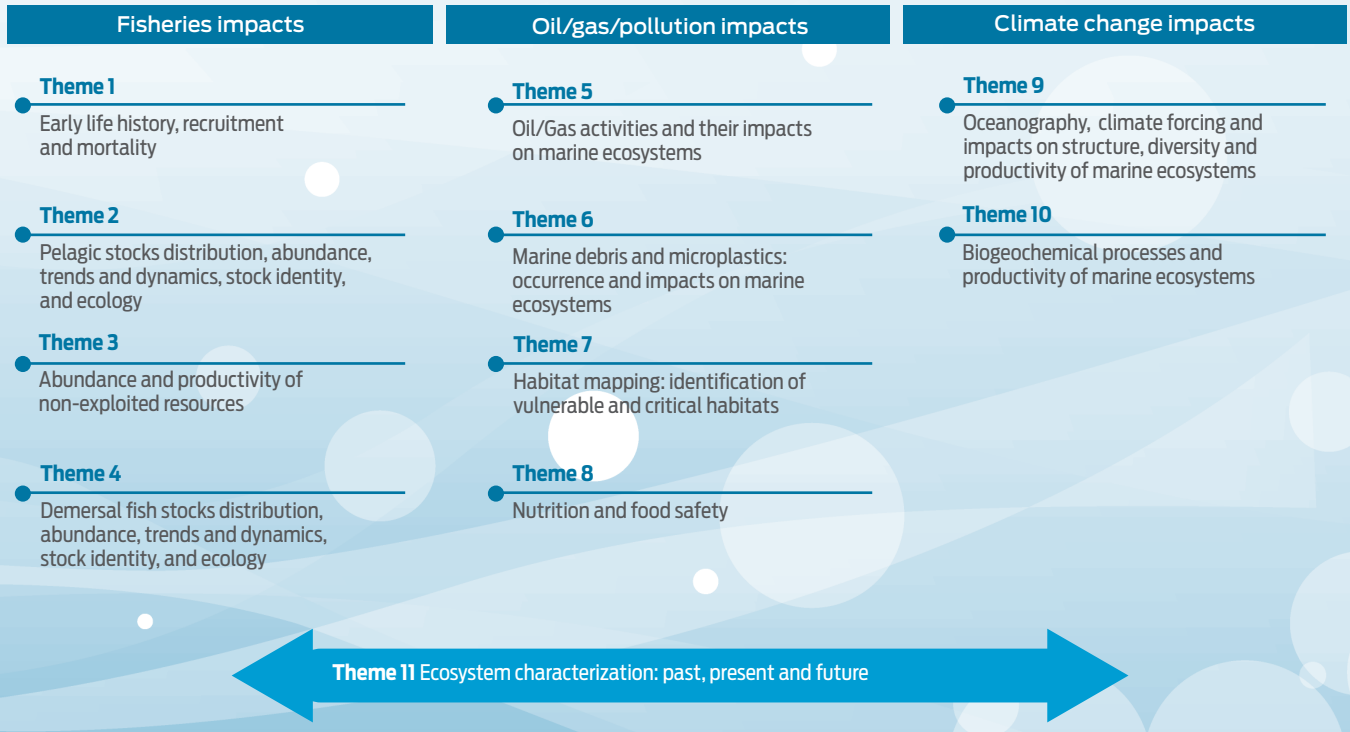


FIGURE 5. Research topics and themes.



TOPIC 1

Sustainable fisheries

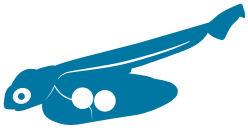
Fisheries are complex, socio-ecological systems that operate in a dynamic environment. Managing them sustainably requires significant efforts and investments, particularly in terms of data and information needed. The implementation of the EAF has added new challenges to resource management, because the knowledge base for decision-making needs to be wider than under traditional fisheries management systems that focused more on targeting stocks dynamics and less on broader ecosystem considerations. Given the interest in finding new resources, mesopelagic fish have recently received much attention, especially with the recent estimates indicating a biomass of at least one order of magnitude higher than previous estimates of about 1 000 million tonnes. There are some concerns over the validity of these estimates, because very little is known of the biology, ecology, diversity, and productivity of this group of fish.

Over the years, the Nansen Programme has already provided valuable data and training for a number of countries and regions, and the R/V *Dr Fridtjof Nansen* continues to play an instrumental role in providing data and information on the abundance, distribution, and habitats of key fishery resources, filling the knowledge gaps, which is necessary for their sustainable management.

Examples of key management questions addressed include:

- Is the exploited stock distributed beyond national boundaries and therefore shared?
- What is stock status (in relation to carrying capacity and sustainability)?
- What are the main variables that control the distribution and abundance of key exploited fisheries species? Where are critical habitats (spawning and recruitment areas) of target populations?
- What is the diversity and ecological role of mesopelagic fish?
- What is the potential of non-exploited resources (e.g. mesopelagic fish)?
- What indicators can be cost-effective in the management of tropical multi-species fisheries?

THEME 1 Early life history, recruitment and mortality

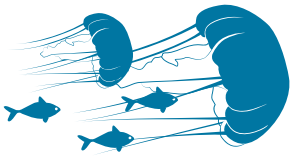


Contributes to improving knowledge on early life history characteristics of exploited fish stocks, including determining their spawning and nursery grounds, and the ecology of their early life stages. This information is particularly critical to determine zonal attachment in the context of shared stock management, understanding stock dynamics and for overall ecosystem-based management. This theme also includes work on plankton abundance, diversity and ecology.

THEME 2 Pelagic stocks distribution, abundance, trends and dynamics, stock identity, and ecology

Deals with abundance estimation, distribution, dynamics, stock identity and ecology of pelagic species, putting emphasis on shared stocks. While the R/V *Dr Fridtjof Nansen* will also be used to extend existing time series of pelagic stock biomass, responsibility for monitoring shared stocks is taken by the countries bordering respective regions. The EAF-Nansen Programme continues its work towards strengthening capacity of the countries involved in monitoring and assessing their resources.

THEME 3 Abundance and productivity of non-exploited resources



Covers fish resources that are not yet or only marginally exploited, such as mesopelagic fish. Focus is on increasing understanding of the biology, diversity and ecological role that mesopelagic fish play as the basis for its sustainable use. Efforts will be put into improving existing biomass estimations. This theme also covers jellyfish, aiming to enhance the understanding of their ecological role and dynamics, particularly in areas where they are believed to be increasing in abundance.

THEME 4 Demersal fish stocks distribution, abundance, trends and dynamics, stock identity, and ecology

Is about abundance estimation, distribution, stock identity and ecology of demersal fish. As for pelagic fish, the EAF-Nansen Programme supports developing knowledge on stock identity, particularly in case of large or commercially important stocks. Assessment and ecology of highly diverse tropical systems also constitute a focal area for this theme. However, for these resources and ecosystems, the approach is different. Methods specifically developed for assessing tropical fish, both at the species and at the community level, receive greater attention, including use of data-poor assessment tools.

Examples of links to management:

a) **Feeding research results into the national assessment and management process in the partner countries and into regional assessment working groups**. Results from the surveys can be integrated in national stock assessement work that forms the basis for decision-making in fisheries management. Furthermore, regional mechanisms for stock assessment (Working Groups) exist as part of FAO RFBs. The Programme supports these efforts, including ensuring integration of the knowledge gained from the surveys and the research work described above into regional assessments. This work will result in regional resource assessments and related advice for managing shared stocks.

b) **Establish platforms for dialogue between scientists, managers, and stakeholders**. Mechanisms that are part of existing regional collaborative efforts are strengthened to ensure integration of research results into the management process.

c) **Provide biological information for integrated assessments of fisheries (including social, economic and environmental considerations)**. Integrated assessment of fisheries is part of the EAF process, and the knowledge gained through Themes 1-4 will be used for these assessments. Strengthening the understanding of the relationship between ecological and human aspects of fishery will also be considered here (e.g. bio- economic analysis of fisheries).

© Tor Ensrud

Sorting the benthos catch during the bottom habitat survey in Northwest Africa in 2020.

TOPIC 2

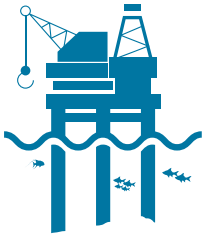
Oil/gas, pollution impacts

This research topic aims at increasing knowledge on impacts of key pressures on marine ecosystems. It includes three themes, one related directly to oil/gas and mining activities (Theme 5), one to marine debris and microplastics (Theme 6) and one to bottom habitats (Theme 7). It also aims to address nutritional aspects of seafood. Theme 8 covers several aspects related to the nutritional properties of seafood, i.e. in relation to its value (e.g. micronutrients, fatty acids, proteins), to the threats posed by the presence of contaminants, and issues of biosecurity.

Examples of key management questions addressed include:

- How can meaningful baselines be established and the state of the environment be monitored while oil/gas extraction activities take place?
- Does pollution have an impact on productivity of fish stocks?
- Are there areas of concentration of marine debris that may affect fishery resources, ecosystems, or fishing activities?
- Are microplastics entering the food web and affecting food productivity and its safety?
- What is the nutritional value of different types of seafood?
- Are there vulnerable bottom habitats that may be affected by human activities?

THEME 5 Oil/gas activities and their impacts on marine ecosystems



Supports setting up coastal/offshore environmental monitoring baselines as the basis for monitoring trends over time and to assess the possible impact of oil/gas/mining activities.
Such environmental monitoring covers both the water column and benthic habitats. The results may be used to develop and report on national environmental indicators for these industries. As part of this theme, eco-toxicological studies will be carried out on fish and marine organisms collected from water, sediments and benthos, with the help of internationally accredited laboratories.

THEME 6 Marine debris and microplastics: occurrence and impacts on marine ecosystems

Addresses specifically the extent to which marine debris and microplastics are present in marine ecosystems within the marine areas to the Programme's interest. Recent studies (Rochman et al., 2015) have shown that presence of anthropogenic debris is ubiquitous also in the marine environment, and that a high percentage of fish samples from Indonesia and California contained plastic particles in their stomachs. The EAF-Nansen Programme aims to build knowledge on marine debris and microplastics at sea, mainly through mapping and identifying hot spots of concentration of microplastics, using the R/V *Dr Fridtjof Nansen* opportunistically throughout its range of deployment.

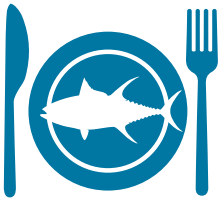
THEME 7 Bottom habitat mapping

Provides information on bottom habitats, and particularly on the presence of vulnerable habitats, for which special care is required when planning activities that may affect them. This theme is related to Theme 5 in that it generates knowledge that can be used for environmental assessment of impact from oil/gas/mining activities. However, this activity is also important for identifying vulnerable marine ecosystems, which is equally of interest for fisheries management. Bottom habitat studies are primarily focused on deep-sea ecosystems in the

ABNJ, where knowledge on species and habitat diversity is still very poor, while international pressure exists to limit impacts by fisheries on vulnerable marine ecosystems. However, and where there may be interest by coastal states, preliminary studies within countries' EEZs can be conducted.

THEME 8

Nutrition and food safety



Aims at improving knowledge on the nutritional value of fish in the areas surveyed by the R/V *Dr Fridtjof Nansen*. The results will enable national food authorities to evaluate the beneficial effects of nutrients against any potentially negative effects of contaminants or biological hazards. Furthermore, the collected samples will be used to document levels of chemical contaminants and occurrence of microplastics, microorganisms, and parasites in different regions.

Examples of links to management:

a) Assessing the impacts of oil and gas activities at sea provides information to fisheries administrations to allow them to act vis-à-vis responsible agencies, when negative impacts are demonstrated. Furthermore, supporting the establishment of monitoring systems for the oil and gas industry has relevance for environmental management.

b) Documenting presence of microplastics and marine debris at sea does not have direct management implications. However, it can be used for awareness raising.

c) Knowledge on the presence of abandoned or lost fishing gear can be directly used in fisheries management to improve fishing practices.

d) Information on nutritional value and/or presence of contaminants in seafood is of direct relevance to fisheries administrations.

© Diana Zaera

Sharing the catch with local fishermen in Angola, 2015.

e) Information gained through Theme 7 (Habitat mapping) is of relevance to the management of demersal fisheries in order to reduce the impacts of fishing on bottom habitats. Knowledge on the presence of vulnerable habitats is also relevant in the context of marine spatial planning and environmental management.

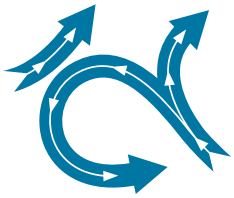
TOPIC 3:
Climate change impacts

While climate change is projected to affect marine ecosystems globally, knowledge on the actual impacts at regional and local level is still very poor. Climate change can affect marine ecosystems in many ways, including currents and overall oceanographic features, primary productivity, recruitment, mortality, and distribution of marine organisms. The intensity of climate change impacts may vary significantly in different systems and regions.

Examples of key management questions addressed include:

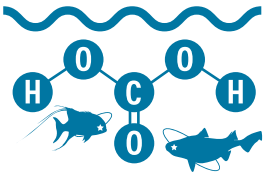
- Are there changes taking place in the marine environment that could be attributed to climate change?
- What is the contribution of climate-related drivers to explain changes in the distribution, migration patterns and abundance of fish stocks?
- What are the main climatic drivers in the different sub-regions bordering the African continent, and what are the expectations of change as a result of global climate change?
- How will climate change affect coastal upwelling processes geographically and spatially?
- How will climate change affect ocean biogeochemical processes that impact biological and fish production, such as nutrient enrichment oxygen depletion and ocean acidification? How will food webs change as a result of climate change in tropical equatorial regions versus the east-boundary upwelling regions?

THEME 9 Impacts of climate variability and change on structure, diversity, and productivity of marine ecosystems.



Looks into the possible impacts of climate change on ecosystem structure and functioning in different ways. For example, appropriate high-resolution ocean models can be developed to improve understanding of ecosystem structure and functioning in general, and to investigate the effects of different harvesting strategy on food web dynamics or the effects of regional climate change on the drift of fish eggs and larvae. By using species distribution models, predictions can be made on possible changes in the distribution of communities as a result of changing environmental conditions. This theme is linked closely with Themes 1, 2 and 4.

THEME 10 Climate change and biogeochemical processes



Focuses on understanding how climate variability and change affect ocean biogeochemical processes. This is addressed by conducting studies on nutrient enrichment/ eutrophication, deoxygenation, primary production and calcium carbonate formation. Increased effort is put on the effects of hypoxia and ocean acidification on marine ecosystems. A key question is to understand how these processes will be altered with climate change and the resulting impacts on marine life, and what possible mechanisms of adaptation may develop. Another key issue is to address how the synergistic effect of low-oxygen and acidic waters is impacting marine organisms. Baseline studies are required to assess change in the chemical environment. The focus of this theme is on the use of new and historical data on oxygen and carbonate system at key coastal sections from shallow nearshore regions, close to large river mouths, out to oceanic and mesopelagic layers in the offshore regions.

Examples of links to management:

a) The significance of the knowledge generated through this theme is mainly at the strategic level.

Scientists from Sri Lanka and Thailand collecting seawater samples for water column observations during the Mesopelagic Survey in the Bay of Bengal in 2018.

b) Understanding whether major changes in marine ecosystems, including in productivity and distribution of major resources, are taking place or are expected to do so, supports countries in their efforts to prepare for and adapt to climate change.

CROSS-CUTTING

While the Science Plan builds around the three main research areas described above, an integrated knowledge on overall ecosystem properties and functions, and the compounded effects of human activities on the marine environment are also required in order to use marine ecosystems (more) sustainably. The knowledge generated through the EAF-Nansen Programme, combined with other existing knowledge, can be integrated into sectoral analysis and planning, and/or as part of overall marine spatial planning. Furthermore, the knowledge generated supports the development of monitoring systems at ecosystem level. The Programme contributes to this process by combining the knowledge acquired through the surveys with the R/V *Dr Fridtjof Nansen*, including in the past, and other knowledge already available in the literature or produced through analysis supported by the EAF-Nansen Programme or other partners. This work is the first step towards integrated ecosystem assessments and monitoring that today forms the basis for establishing sustainable governance of ocean-based activities.

Examples of key management questions addressed include:

- What are the main properties and attributes that characterize a given marine ecosystem?
- What are the major drivers of change of marine ecosystems having implications for their productivity and resilience?
- What are the compounded effects of various anthropogenic activities on ecosystem structure and functioning?
- What are the key indicators that can support the establishment of a monitoring system at ecosystem level?

THEME 11 Ecosystem characterization: past, present, and future

Is a cross-cutting theme that addresses an integrated understanding of ecosystem structure and functioning, including impacts of human activities on them (ecosystem characterization). From a perspective of renewable resources, information on main ecological characteristics, identification of bio-regions and zones of particularly sensitive or ecologically important areas is key to the process of coordination, planning and development, not only in relation to fisheries-related activities, but more broadly to any activities at sea. Ecosystem characterization can facilitate description of main ecosystem features, including in a spatially defined manner, which can also provide the basis for ecosystem monitoring. This can also be used to detect possible climate-related impacts. An example of a possible output from ecosystem characterization is presented in Box 2.

In summary, the knowledge gained from all the other research themes contributes to ecosystem characterization. The ecosystem characterization can be the basis for setting baselines at ecosystem level, selecting indicators and setting up monitoring systems (as illustrated in figure 6).

FIGURE 6. Conceptual framework linking management to ecosystem-level monitoring.

BOX 2: Example of an output from ecosystem characterization activity

1. Abundance, distribution and key biological parameters of main fishery resources (from Theme 1).
2. Geomorphology and sediment characterization to understand and document the relationship between geomorphology and sedimentology and key species distribution.
3. Oceanography (including setting baselines for pH levels, identification of retention areas and local upwelling, internal tides and waves, etc.) to understand and monitor system dynamics.
4. Biological communities, e.g. plankton, nekton (especially fish), benthos, seabirds to understand and document species composition, abundance and distribution as the basis to maintain species diversity, including identification of vulnerable habitats/ecosystems and hotspots of biodiversity.
5. Ecosystem processes: to identify and understand key ecosystem processes related to productivity/resilience of ecosystems, to sustain fisheries productivity and ecosystem health. These include, for example, availability of food at various trophic levels, physical and biological aspects of recruitment processes, juvenile fish predation (including cannibalism), apex predation and overall trophic relationships.
6. Ecosystem services. How to optimize the use of the resources, integrating ecological and socio-economic aspects, to provide long-term benefits to society.
7. Mapping "threats" to the ecosystems. Identification of potential sources of impacts (e.g. unsustainable fishing, aquaculture, pollution, tourism, oil, mining, shipping, as climate variability and change, ocean acidification disasters, diseases, introduced/invasive species etc.) and their effect on the ecosystem.
8. Spawning/breeding and nursery grounds. Locate spawning/breeding and nursery.

Deployment of the VAMS (Video Assisted Multi Sampler) for environmental monitoring in Mozambique, 2018.

3. Implementation

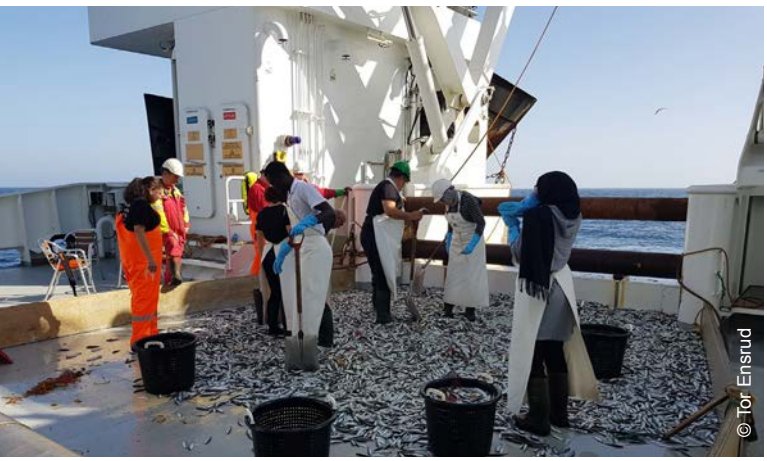
Implementation of the Science Plan is a result of collaborative efforts by all the Programme's partners in the countries where surveys take place, as well as with regional and international institutions, as appropriate.

The geographical and institutional scope of the partnership depends on the research topic. For example, in relation to research on shared stocks, the collaboration is mainly at the regional level, because the results are relevant in the context of regional management of shared stocks. On the other hand, work on the occurrence of microplastics in the marine environment has an inter-regional character, starting with exploration of areas of higher concentration that may require further attention.

To take full advantage of the huge amount of data and samples collected, the inclusion of PhD and Master students is of primary importance. Efforts are being made in this respect to either their full, or part-time engagement.

4. Synergies with other programmes

The EAF-Nansen Programme continues the excellent collaboration with Regional and Sub-regional Fisheries Bodies. Examples of successful collaboration include: CECAF, SWIOFC, the Fishery Committee for West Central Gulf of Guinea (FCWC), the Regional Commission of Fisheries of Gulf of Guinea (COREP) , the Sub-Regional Fisheries Commission (SRFC), and RFMOs (South East Atlantic Fisheries Organization (SEAFO) and Southern Indian Ocean Fisheries Agreement (SIOFA)).



Sampling the catch in Morocco during the transboundary demersal survey in 2020.

In the Benguela current ecosystem off southwest Africa, the EAF-Nansen Programme works closely with the BCC to implement regional activities in relation to fisheries research, management and capacity development. Furthermore, the Programme continues to collaborate, and build synergies, with large marine ecosystem (LME) programmes in the area covered by the Programme. These include: the Agulhas and Somali Currents LME (ASCLME), Canary Current LME (CCLME) and Guinea Current LME (GCLME) around Africa, and the Bay of Bengal LME Project (BoBLME) in South Asia.

Highly productive areas are also found in the Gulf of Guinea and particularly in the region off Côte d'Ivoire, Ghana, Togo and Benin. The main resources in these regions, and related ecosystems, are shared among the respective coastal countries, thus requiring joint management of these resources and providing adequate knowledge. The EAF-Nansen Programme has over the years collaborated with all these regions in various ways. However, except for the Benguela region, the collaboration happened on an ad-hoc basis and mainly only covered resource

Over five tonnes of jellyfish (Chrysaora fulgida) were caught in a single trawl by the Dr Fridtjof Nansen off Namibia in 2017.

and ecosystem assessments, and recently fisheries management in line with the EAF. At present, all these regions are part of the LME programmes and the opportunity exists for creating strong synergies and collaboration with them.

As these LME programmes advance on the implementation of their Strategic Action Programmes, the EAF-Nansen Programme can provide support to research, capacity development, policy and management efforts in close collaboration with these Programmes, thus considerably strengthening the probability of achieving desirable outcomes and impacts. It should be noted that the overall objectives of these programmes are fully consistent with the goals of the EAF-Nansen Programme.

Co-funding of research activities through regional or national research funds is welcome. For example, collaboration with the Western Indian Ocean Marine Science Association (WIOMSA) supports research projects, using data collected through the surveys with the R/V *Dr Fridtjof Nansen.* Ongoing initiatives in South Africa (National Research Fund through the University of Western Cape) have made funding available for research activities linked to the EAF-Nansen Science Plan. Collaboration with other UN organizations, such as the IAEA, has also been established.

5. Surveys with the R/V *Dr Fridtjof Nansen*

The new R/V *Dr Fridtjof Nansen* is well-equipped for advanced multidisciplinary marine research and has been fully available for the Programme's use as of May 2017. This state-of-the-art vessel has significantly enhanced capacity in relation to its predecessors.

The vessel represents the main tool for data collection and information on fishery resources and ecosystems, in order to produce knowledge on their status for sustainable management and policy making.

Key research priorities, where use of the R/V *Dr Fridtj of Nansen* provides comparative advantages, include:

- Knowledge on transboundary resources and ecosystems to support a regional approach to shared resources management (mainly in the productive upwelling regions of West Africa).
- Identification of potential new resources (mainly in high productive areas off West Africa).
- Setting baselines for biodiversity, including in areas where oil/gas activities are developing or are being planned (selected locations) and ABNJ.
- Knowledge on the extent to which emerging issues such as pollution, microplastics and marine debris or climate change are impacting marine ecosystems (opportunistic sampling wherever the vessel operates).
- Work in the Indian Ocean in support of the 2nd International Indian Ocean Expedition, including resource status.
- With the expanding scope of the research to be carried out in the context of the EAF-Nansen Programme, and to support implementation of the Science Plan, survey objectives and related sampling strategy have been expanded in

Capabilities	Former	Present
Length overall (m)	56.8	74.5
Beam (m)	12.5	17.4
Draft (m)	6.6	6.4
Main engine (kW)	1 980	4 500
Gross Registered Tonnage	1 444	3 900
No of cabins	23	32
No of berths (beds)	28	45
No of laboratories	3	7
Lecture room/auditorium	No	Yes
ICES 209 noise class	No	Yes
Dynamic positioning system	No	Yes
Work boat	No	Yes
Marine mammal/seabird observatory	No	Yes

FIGURE 7. Main features of the new *Dr Fridtjof Nansen* and comparison with the former vessel.

support of research on life cycle, stock identity, trophic relationship of pelagic fish, and associated environmental conditions.

- Attention is given to emerging issues such as the actual abundance of mesopelagic fish, as a possible new resource, the role of jellyfish in the pelagic ecosystem; occurrence of microplastics and ocean acidification; levels of nutrients in fish, in relation to nutritional security; and environmental contaminants, including emerging contaminants and microorganisms in fish, considering pollution and food safety. All surveys are expected to contribute to the themes described in the Science Plan. The R/V *Dr Fridtjof Nansen* is a key tool for achieving the Programme's results.

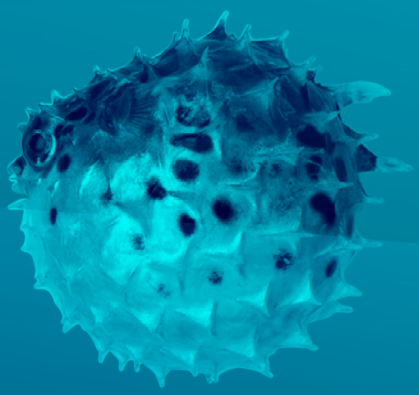
The R/V *Dr Fridtjof Nansen* is operating in close collaboration with national and regional partners, to ensure that the data collection and research are fully coordinated with other efforts and to address key knowledge gaps. The new R/V *Dr Fridtjof Nansen* is a modern, well-equipped and large vessel that allows for multidisciplinary research, covering various aspects of resources, environmental and ecosystem research. Overall, the use of the vessel is most relevant in productive regions, or while carrying out specific mapping activities (such as in ABNJ), where the vessels which operate in the high seas conduct oil/gas/mining explorations. The survey areas identified for the period of the Programme's activities are presented in Table 2, with explanation of the rationale.

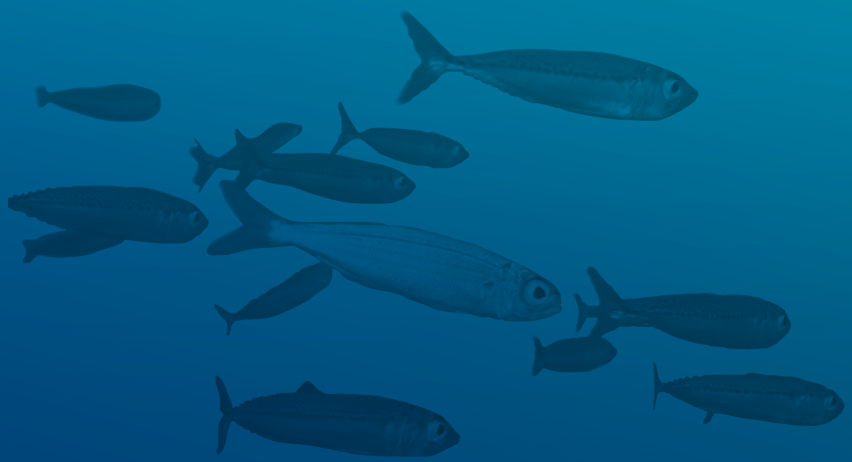
TABLE 1. Planned survey programme 2017-2021

2017	2018	2019	2020	2021
West Africa	**Indian Ocean**	**West Africa**	**West Africa**	**Indian Ocean**
Shared stock status, distribution, biology and stock identity.	Status of fishery resources and ecosystems (East Africa and Bay of Bengal).	Shared stock status, distribution, biology and stock identity.	Shared stock status, distribution, biology and stock identity.	Status of fishery resources and ecosystems (tentative).
Mesopelagics	Mesopelagics	Mesopelagics	Mesopelagics	
	ABNJ (Mascarene)	ABNJ (SEAFO)	ABNJ (Sierra Leone Ridge)	

TABLE 2. Main research areas and regions where the surveys are implemented and expected outputs 2017-2021

Main research area	Region	Expected main outputs
1) Fishery resources and ecosystems		
i. Biomass and distribution of main transboundary stocks	Canary Current, Gulf of Guinea, South-west Africa (from Cape Lopez southward, including the Benguela)	i Synoptic information on stock distribution and abundance
ii. Life cycle investigations and stock identity	Current, Eastern part of the BOBLME	ii. Information on recruitment/nursery areas of main stocks and biophysical parameters related to them
iii. Overview of resource status, distribution and diversity	East Africa and Bay of Bengal (including selected island States)	iii. Status of resource abundance and diversity (to follow trends and be repeated with intervals)
iv. Identification of new fishery resources (e.g. mesopelagics)	East and West Africa, BOBLME	iv. Knowledge on abundance and distribution of new resources (e.g. mesopelagics)
2) Oil/Gas, pollution (including marine debris and microplastics)		
i. Environmental assessment (oil/gas and mining)	Ad-hoc required (e.g. northern Mozambique, southern United Republic of Tanzania, Ghana etc)	i. Maps of vulnerable habitats and significant ecological areas (to be part of EIAs), baselines on water/sediment quality for environmental monitoring
ii. Level of hazardous substances in bottom habitats and fish and nutritional value	Opportunistic sampling in all regions	ii. Reports in occurrence of hazardous substances in bottom habitats and fish. Establishing nutritional value of key resources
iii. Distribution of marine debris, including microplastics	Opportunistic mapping and sampling of microplastics and marine debris as part of any survey	iii. Maps of density of marine debris and microplastics
iv. Bottom habitat mapping	Selected areas (Mauritius-Seychelles joint management area etc.), ABNJ (Sierra Leone Ridge, SEAFO, SIOFA)	iv. General mapping of bottom habitats, detailed mapping of vulnerable and critical habitats
3) Climate variability and change		
Impacts of climate variability and change on resources' abundance and distribution, on productivity and ecosystem functioning	All regions	i. Studies on trends on key species and climate-change related indicators ii. Baseline of biochemical properties iii. Biophysical models in selected regions iv. Support establishment of monitoring lines in selected regions to monitor ecosystem variability and change





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