NICO expedition 2017-2018: The harvest of 7 months of ocean research

On 29 November 2018, NWO and Royal NIOZ organised a post-cruise meeting of the national, multidisciplinary expedition "Netherlands Initiative Changing Oceans" (acronym NICO). The meeting provided an overview of all key research questions during the 12-leg expedition.

About 70 researchers and students came to The Hague to discuss their initial observations and findings. The overarching research theme that connected all of these studies was how changing conditions are impacting life in the oceans.

The ocean is an essential buffer for worldwide CO_2 emissions and harbours a unique but vulnerable marine biodiversity, and with the changing climate, it is vital we obtain a good understanding of how the oceans work. In December 2017, 156 researchers and students therefore started on the NICO expedition. The voyage along five Atlantic and Caribbean ocean provinces was divided into 12 legs, and each leg had its own research themes. These ranged from seafloor samples for climate research to viruses, from coral reefs to whales, and from underwater noise caused by shipping to deep-sea mining and the testing of new maritime technology.

Background

The idea for the expedition was hatched in mid-2017 when NIOZ and NWO made the research vessel the *Pelagia* available "free of charge" to the Dutch public and private sectors with an open invitation: share your ideas with us. Research proposals came from universities, research institutes, industry, TO2 institutes (applied research), NGOs (such as Ocean Cleanup) and the Dutch Ministry of Defence (mapping service).

An independent committee, led by Prof. Jack Middelburg (Utrecht University), determined the feasibility and scientific value of all proposals submitted and brought those parties together. Nearly all of the research proposals could be incorporated in the expedition. This eventually gave rise to an expedition plan that accommodated 40 different research proposals. Researchers only had to organise their own funding for the research. NIOZ and NWO took care of the logistics.

Unique character

One unique aspect of the expedition was the participation of M.Sc. students. Prof. Corina Brussaard (University of Amsterdam and NIOZ) came up with the student programme. 'The idea was to give the future generation of marine and maritime researchers a unique opportunity to join the expedition. Within three weeks we had received 110 letters from eligible students (currently involved in an M.Sc. programme in which sea research plays a role), covering all major disciplines and eight national universities. In the end, 22 master students could join the expedition. They will soon complete their studies, and then they will have an advantage because of the oceanographic research experience they gained. The student programme is definitely a fantastic spin-off of the NICO expedition.'

Another unique aspect of this endeavour was that new collaborations of researchers from different disciplines – marine geologists, (micro)biologists, chemists, physicists, ornithologists, biogeochemists as well as water engineering, law and management – were formed on a small and larger scale. Besides students and researchers, journalists, writers, movie producers, photographers and an ocean composer joined the expedition.

The multidisciplinary collaboration did not go unnoticed: 186 media productions appeared about the expedition (articles, radio and TV broadcasts) distributed across 50 different platforms. Or as NIOZ director Henk Brinkhuis put it: 'The NICO expedition has clearly brought ocean research to the attention of the general public and policymakers!'.

From samples to data

After a voyage of 7 months, the expedition ended on 28 July 2018. The hundreds of water and sediment samples collected in the freezers and refrigerators of the Pelagia now lie in the labs of the collaborating

institutes and universities, ready to be analysed. In this regard, the *Pelagia* has proved to be something of a scientific treasure ship, since the multidisciplinary, open approach of the NICO expedition will soon provide a wealth of knowledge.

During the post-cruise meeting, some researchers had questions about further collaboration and the sharing of samples. 'The samples could also be interesting for other people who were not on board, for example, for preparing new research proposals. Is there a way in which we can share the samples and data?' That is indeed the case. In the coming period, efforts will be made to optimise the data management around the NICO expedition.

A critical note from the researchers was that because of the short time notice for this expedition, it was often not possible to obtain enough funding for sample analysis. There was a general consensus that a potential second NICO expedition should have better funding options for the actual research and sample analyses, which could (partly) be obtained if the expedition is announced earlier with a longer period to submit proposals. A voice from the audience: 'That is a point for improvement if a NICO II is organised.'

Spin-off

As a result of the multidisciplinary character of the expedition, researchers were able to exchange ideas and learn from each other. 'Exactly the purpose of this NICO expedition', says NIOZ director Henk Brinkhuis. He summarises the importance of the expedition as follows: 'The NICO expedition plays an important role in firmly putting ocean research back on the Dutch national agenda. An important spin-off of the expedition is the NICO community that has arisen from the multidisciplinary cooperation. People from different organisations now know each other. The community can serve as a bottom-up platform for national collaboration. Furthermore, it is a point of contact for the ministries and the top sectors involved with marine and maritime science.'

Follow-up

A big question on the minds of all researchers: will there be a follow-up to the NICO expedition? Henk Brinkhuis: 'Obviously you cannot simply take to the sea for seven months and come back thinking that you know just about everything there is to know. Ocean research is a long-term and continuous process. Note that it is still vastly understudied! Together with NWO, we are therefore discussing possibilities for long-term, seagoing research. We aim to do that via two trajectories, namely traditional large research projects (funded, for example, from EU programmes or by government ministries) and short-term expeditions like NICO. This is because expeditions like NICO are important for the entire Dutch marine and maritime community.'

New research vessel

The Pelagia is 27 years old and needs to be replaced. Without a national ocean-going research vessel, there will be no sustainable future for Dutch sea research (and consequently no following editions of NICO). The Dutch scientific marine research and the Dutch maritime sector both belong to the international top. Such a top position can only be maintained if the necessary investments in the seagoing infrastructure are made.

Currently, NWO and NIOZ, together with the Top Sector Water and Maritime, are making plans for a new Dutch research vessel. The plans have now reached the design phase. The new ship will be larger than the Pelagia and so capable of sustaining the current developments in seagoing research and accommodating more researchers on board. The new ship will be emission-free from 2030 onwards. Researchers are contributing ideas, and fleet coordinator Wouter Kruijt as well as the National Marine Facilities (NMF) are making sure that all input is reviewed and taken into account where possible.

Leg 1: Texel - Las Palmas

From 13 to 27 December 2017, the Pelagia cruised from Texel to Las Palmas. On board were researchers from Utrecht University, VU Amsterdam and NIOZ.

Leg 1 was the start of an overarching Trans-Atlantic research programme into different organisms in the deep sea. Also during this leg, sediment cores were taken from the Atlantic seafloor that will be used to reconstruct the climate in the past. Such reconstructions enable researchers to make better predictions about the climate of the future.

Research themes

Leg 1 was part of the three-leg research programme into the consequences of changing conditions in the Atlantic Ocean. During legs 1, 2 and 8, samples were taken for overarching research into foraminifera (eukaryotic single-cell organisms with an external calcium carbonate skeleton), dinoflagellates (algae, plankton), pteropods (sea snails) and organic compounds. Throughout the entire leg, water samples were also taken at various depths. These were scanned for the parameters temperature, salinity, density and nutrients.

Initial results and findings

Besides this overarching research, sediment cores were taken from the sea floor at various locations between Texel and Las Palmas. These samples will be used to reconstruct the prehistoric climate. Proxies (derived indicators) are used to convert these new measurement values into historical data about the climate. During leg 1 of the NICO expedition, new geochemical proxies were sought.

Inigo Müller (Utrecht University): 'Our reconstruction of the past is based on the relationship between three values: the oxygen isotope $^{18}O_{benthic}$, the ice volume and the temperature of the seawater. For the reconstruction of historical seawater temperatures, we need to measure the ratio of oxygen isotopes, more specifically the fossil foraminifera (microfossils) in the sediment.

We have discovered that measuring the ^{13}C-^{18}O ratio provides the most reliable proxy (derived indicators) for our reconstruction of seawater temperatures in the past. Analysing the ^{13}C-^{18}O ratio in the samples gives us an indirect way of solving the equation oxygen isotope, ice volume and seawater, and that solution gives us the historical data we need. During the NICO expedition, our question was: can we actually find these relationships in the current seawater? And subsequently: can we use our drill cores to produce a historical reconstruction of the climate?'

Leg 2: Las Palmas - Willemstad

Leg 2 was the longest leg of the NICO expedition. During the trip from Las Palmas to Curaçao, the Pelagia remained north of the equator so that it could cruise via the mid-Atlantic Ridge towards the coast of Central America.

The plan was to investigate the ocean floor near the Amazon basin, but due to bad weather, the expedition was re-routed to the coast off Suriname. On board were researchers from the University of Amsterdam, Utrecht University, VU Amsterdam and Naturalis Biodiversity Center and NIOZ.

During the second leg, samples were taken for overarching research into foraminifera (eukaryotic single-cell organisms with an external calcium carbonate skeleton), dinoflagellates (marine plankton), pteropods (sea snails) and organic compounds. Throughout the entire leg, samples were taken at different depths that were subsequently scanned for temperature, salinity, density and nutrients.

Research themes

Between Las Palmas and Willemstad, the focus was geological-climatological research into shifting monsoon systems and dust fluxes from the Sahara. However, biological research was also carried out into the spread and growth of sea snails, megafauna (birds, flying fish, dolphins and whales) and environmental DNA (e-DNA), which is the DNA traces all animals leave behind in the water in the form of mucus, scales or faeces. Fluxes of particles and nutrients in the ocean were also investigated.

Chief scientist Frank Peeters (VU Amsterdam): 'The research into the vertical spread of plankton (including growth stages) should give us insights into the consequences of global warming, acidification and falling oxygen levels in the oceans. For example, in legs 1, 2 and 8, sea snails and foraminifera with a calcium skeleton were investigated. How does ocean acidification affect these calcium shells? Where exactly do younger and older sea snails live?

Initial results and findings

The initial findings indicate that younger sea snails live in the surface water during the day and night and so are continuously exposed to acidification. The effect of food on calcification was investigated as well as the depth at which the organisms lived. From this information, conclusions can be drawn about how sensitive the foraminifera are to changes in temperature or ocean acidification.'

'Biologists also investigated the megafauna by counting birds, fish and mammals. The researchers sat on the roof of the Pelagia for 12 hours per day to make these counts. At the same time, samples were taken for research into environmental DNA (e-DNA) and fish DNA. Where possible, e-DNA samples were also taken at the same time as the fauna observations to see whether there were any correlations between the two. One of the research aims is to use e-DNA to discover what is present at certain locations in the ocean water.

Water from the deepest part of the ocean was also pulled up to see whether useful fungi lived there. Such fungi could be used in healthcare. In the future, a new antibiotic might come from the ocean.'

During the second leg, the geologists onboard mainly investigated the dust fluxes. 'For example, does dust from the Sahara influence life in the ocean? Does the dust bring nutrients with it and consequently influence processes like eutrophication? Where dust was found in the atmosphere, DNA samples were also taken at the same time. The first results are known: DNA was indeed found in the samples where dust was present.'

However, the most unusual finding during this leg was the discovery of an unknown extinct volcano on the ocean floor. It was found with the help of a multibeam, a device that scans the ocean floor. 'The volcano is no longer active. The sediments in the crater have been well preserved. We took a core sample of the sediment-filled crater, and that reveals no less than 500,000 years of climate history.

The first results indicate that during the last ice age far more dust from the Sahara was present in the atmosphere. That dust might have a relationship with the CO_2 cycle. More dust means more nutrients in the ocean, which results in higher production of organic substances and consequently more removal of CO_2.'

Finally, research was done into the shifting rainfall patterns in the tropics. 'Tropical zones where it rains intensely are called inter-tropical convergence zones (ITCZ). In such a zone, the rising air movements in the vicinity of the equator drive the rainfall. The ITCZ is not only shifting with the seasons but also over time. A long-term topographical shift is visible in the geological archives of the seafloor. This also applies off the coast of Suriname, where we examined sediments. These observations revealed that in the most recent part of history, Suriname was relatively dry. Initial results reveal that 60,000 to 20,000 years ago, Suriname was far wetter.

It has also become apparent that the tropical rain zone itself is shifting too. We already knew that Venezuela and the Antilles are becoming drier. However, the fact that Suriname is now becoming wetter points to a south-west shift of the rain zone. These observations are also important for the climate in Europe, although it is still too early to draw definite conclusions because we have not finished putting the puzzle together.'

Leg 3: The Caribbean Region - Lesser Antilles

From 25 January to 2 February 2018, the Pelagia cruised between Willemstad, the capital of Curaçao, and Oranjestad, the capital of Aruba. On board were researchers from the University of Amsterdam, Wageningen Marine Research, Delft University of Technology and NIOZ.

During the third leg, the focus was on mapping the underwater landscape, research into mesophotic reefs (deeper than 30 metres), groundwater seepage and deep cyanobacterial mats.

Expedition leader Petra Visser (University of Amsterdam): 'I usually investigate cyanobacteria on the shallower coral reefs. This time I was interested in the thick cyanobacterial mats off the coast of Bonaire. When our colleagues from Wageningen Marine Research went to observe these with a submarine, they discovered a black fluffy film of cyanobacteria covering the sandy bottom. That elicited many questions, such as where exactly do the cyanobacterial mats occur and how do these develop? Which species are found in the cyanobacterial mats and which effects do they have? For example, are they toxic and can they fix nitrogen?'

Research themes

'We used a camera to map the seafloor around the Lesser Antilles, not just to localise the cyanobacterial mats but also the distribution of mesophotic reefs deeper than 30 metres. We only discovered deep coral reefs to the east of Curaçao, and nowhere else. We only found the deep and thick cyanobacterial mats in the vicinity of Bonaire. That is unusual. Why is that? We think it has something to do with the morphology. For example, the coast off Kralendijk is relatively flat below the reef at 40 metres deep and gradually slopes to about 80 metres deep. This sandy zone is apparently a suitable habitat for the deep water cyanobacterial mats to persist.'

'However, the fundamental question is: how do these cyanobacterial mats develop there? You can only answer that question if you know where precisely the nutrients come from. On the island, there are many septic tanks on floors of chalk. Nutrients seep into the groundwater, and that rises up again somewhere in the ocean. Furthermore, heavy downpours occur after showers which cause nutrient run-offs from the land. The hydrologists on board will continue with the research into the possible dispersion route.'

Initial results and findings

Fleur van Duyl (co-chief, NIOZ) observed another perspective for examining the cyanobacterial mats. With the CTD measurement equipment, we made profiles of the water column (temperature, salinity and chlorophyll). This revealed a large difference between two water bodies, right at the depth where the cyanobacterial mats occur. At a depth of 50 metres, the temperature drops, salinity increases and there is more chlorophyll. The cyanobacterial mats might therefore grow specifically in this intermediate layer because it contains slightly more nutrients.

We had to take samples of the cyanobacterial mats to determine their composition. That was far from easy. We thought we could work with the sediment grabbers (tubes that bore into the sediment) but these came back empty. The sand was too hard. Next, we used a box core (heavy metal container with a large weight). That came back up with a lot of sand and other stuff, but no cyanobacteria. So what we really needed was a sort of underwater vacuum cleaner. In the end, we deployed divers from Bonaire who collected the samples from the cyanobacterial mats. We are now using the samples for molecular analysis to see which species the mats contain and what these can do. For example, we know that cyanobacteria can fix nitrogen and that they can produce toxic substances. But is that also true for the deep cyanobacterial mats?'

'Initial analyses have revealed that these deep cyanobacterial mats cannot fix nitrogen. This is probably because they obtain sufficient nutrients and because there is very little light at that depth. I also performed toxicity tests using shrimps. In the past, I used shrimps to test the toxicity of cyanobacteria on shallow corals. There I found that the cyanobacteria are toxic and sometimes extremely toxic. However, with the cyanobacteria from the deep mats, none of the shrimps died. So these are not toxic for shrimps.'

The research into the deep water cyanobacterial mats in the Caribbean region is continuing. More to follow…

Leg 4: The Caribbean region - Saba Bank

From 4 to 11 February 2018, the deep sea between Aruba and Sint Maarten was investigated. On board were researchers from Wageningen Marine Research, Delft University of Technology, Utrecht University and NIOZ.

In leg 4, the research focused on eddies in the water.

Caroline Katsman (Delft University of Technology): 'In the Caribbean water there are many large eddies with a diameter of easily 100 kilometres, which are also important for salt transport and perhaps the sea fauna as well. These eddies form in the east and become stronger on their route westwards. That last aspect is strange: usually eddies only become weaker after they have formed. Therefore at Delft University of Technology, we are working on a model study to explain the life-cycle of these eddies.'

Research themes

'The NICO expedition was a perfect opportunity to measure the vertical structure of an eddy. That has scarcely been done in the past, but such information is important for verifying a model, for example. The location of the eddies can easily be pinpointed using satellite observations. So we used that information in advance to detect eddies and to choose a good target. Biologists from Wageningen Marine Research made counts of birds and mammals to see whether there are differences in the number of animals within and outside of the eddy.'

Initial results and findings

'We managed to measure an eddy, and in that respect the mission was successful. From this eddy we now know what the flow rates are, how warm and saline the eddy was compared to its surroundings, and how deep the eddy was. It turned out to be 200 to 300 metres deep, which is less deep than we had thought.

However, the biggest surprise was located under the eddy. There we found "gradient structures" with thin layers of 15 to 20 metres, each with slightly different temperature and salinity characteristics. It looked like a layered cake. This is a rare phenomenon that only occurs in the Arctic Ocean and in the tropical Atlantic Ocean. It means that just under the eddy it is very quiet, as otherwise the “different layers of the cake” would already have been mixed to become one layer.

During the leg, four automatic measurement buoys were placed (Argo floats). These float with the current under the surface and dive every three days to take measurements. We hoped that the measurement buoys would flow with the eddy we wanted to measure, but that went wrong. As, in practice, the eddy was less deep than the pre-set "parking depth" of the buoys, the eddy travelled over the buoys. However, this does not really matter since the buoys are still diving and these additional measurements are very useful for further research.

We are now processing the measurements. They are providing valuable information and comparative material for our mathematical models. The difficult question we now need to answer is whether this shallow NICO eddy is an exceptional case or whether it is normal and our model is producing eddies that are too deep. Further, the NICO eddy was found to have a shorter lifespan than we use in our model. So now we are looking at our model simulations with different eyes, and many new questions are arising. Do the properties in the vertical axis (depth, flow rate) at the birth of the eddy determine whether the eddy grows or dies out? I hope that we can measure another eddy!

Unexpected bonus: the plan was that the measurement buoys would float with the eddy, but because that eddy was far shallower than expected, the eddy quickly disappeared out of sight. Now the measurement buoys are floating with the layered "gradient structures". We hope that the measurements will give us insights into how these gradient structures develop, instead of just a snapshot at a single moment in time. That really would be unique.'

Meanwhile, the buoys are still providing the researchers with data…

Leg 5: Sint Maarten - Sint Maarten

From 13 to 25 February 2018, the Pelagia circled around the Saba Bank, an underwater elevation at 3 to 6 kilometres south of the island of Saba and 25 kilometres west of Sint Maarten. On board were researchers from Naturalis Biodiversity Center, Wageningen Marine Research and NIOZ.

In leg 5, the research focused on the deep ocean around the Saba Bank and relations with the shallow bank.

Gerard Duineveld (NIOZ): 'Over the past few decades, many studies have been done on the fauna and particularly the corals living on top of the Saba Bank at depths less than 50 metres. The coral reefs on Saba Bank belong to the most pristine reefs in the Caribbean. By contrast, little information is available about the life and conditions in the deep ocean surrounding the Saba Bank. Ocean currents and their interaction with the Saba Bank are most likely essential for the biodiverse community on the shallow top. Therefore the aim of leg 5 was to explore life and hydrography on the slopes of the Saba Bank. Also, the research considered the relationships between the shallow and deep parts of the Saba Bank, especially the currents, particles and nutrient transport.'

Research themes

'Research like this is important for gaining a better understanding of the state of the biodiversity in Dutch waters and how this can be safeguarded, as this is an international obligation. One aim of this inventory was to gain more insight into the fish fauna around the Saba Bank, especially the commercial species. We also investigated the various reasons why the quality of Caribbean reefs is deteriorating. The reef on the Saba Bank is still in a relatively good condition, however. If we can discover which factors contribute to how coral reefs on the Saba Bank regenerate themselves, then we might be in a better position to improve the health of other reefs.'

Initial results and findings

'The first results from the measurements revealed clear differences between the north and south slope of the Saba Bank. This concerns not just the composition of the fauna (the invertebrates and the fish) but also the currents, the turbulence and the concentrations of particles in the water column. What did we find? On the south side, the turbulence in the water column is stronger. On the north side, the concentration of particles in the water is far higher. This indicates the export to the ocean of particles produced on the Saba Bank. If these particles also contain nutrients, then this loss must be compensated by a supply from elsewhere. In this context, the deep and turbulent water on the south side of the Saba Bank could be an important supply route of nutrients to the coral reefs situated there.'

Leg 6: Sint Maarten - Sint Maarten

From 26 February to 10 March 2018, the research around the Saba Bank was continued. On board were researchers from Wageningen Marine Research and NIOZ.

In leg 6, the research focused on ecosystems on the Saba Bank.

Erik Meesters (Wageningen Marine Research): 'The Saba Bank is the largest undersea atoll in the Caribbean region and one of the biggest in the world (2500 km^2). Extensive coral reefs lie along a large part of the edge of the Saba Bank. The corals provide a three-dimensional structure that all of the plants and animals make use of and are therefore the building blocks of the bank.'

Research themes

'Except for the high biodiversity of corals, fish and algae, little is known about the ecological functioning of the bank and how this unique ecosystem works. As the Saba Bank is not close to large land masses, there are few influences from the land (such as eutrophication, environmental pollution, plastic waste). Research questions: which ecosystems occur where on the Saba Bank, and how do these relate to each other? How does the Saba Bank function biologically, chemically and hydrodynamically within the Caribbean region?

The various seafloor communities on the bank were mapped using underwater cameras. We performed habitat mapping for coral, sponges and algal communities. The net productivity (primary production) and the net calcium carbonate production were also measured. These measurements will help us to understand better whether the Saba Bank and other reefs in the region can keep up with the rising sea level and increasingly warmer sea.'

Initial results and findings

'Part of the research on the Saba Bank was aimed at mapping gradients from a depth of 15 to 28 metres. The focus was on net calcification, organic matter (bio)deposition and mineralisation, and on the oxygen dynamics in the boundary layer above the floor. Initial findings: between 15 and 30 metres deep the habitats on the hard surface were net NO_x sources (NO_3 + NO_2). In addition, the NO_x concentrations close to the floor proved to be always higher than the levels in surface water. By way of comparison, the measurement station on the soft substrate was the only place where no increase in NOx was measured.

However, there is far more to discover. The bank has an area of 2500 km^2 and is, therefore, the largest nature reserve in the Kingdom of the Netherlands. Furthermore, it lies entirely underwater, and so it will take a while before we have mapped everything. There are still new things to be discovered, such as the enormous sinkholes in the Luymes Bank, a part of the Saba Bank. On the floor, we have spotted mysterious depositions that require further research. We also discovered very healthy coral reefs in some parts of the bank that appear to have escaped all negative consequences of climate change. Healthy coral reefs are essential for tourism, coastal protection and fishing, and consequently also good for the islands and their economies.'

Leg 7: Sint Maarten - Nassau

From 12 March to 4 April 2018, the Pelagia cruised from Sint Maarten to Nassau. On board were researchers from Utrecht University and NIOZ.

During leg 7, the research focussed on the impact of the Mississippi and Atchafalaya rivers on the carbon cycle in the sea and the development of oxygen-depleted zones in the Gulf of Mexico.

Zeynep Erdem from NIOZ: 'In the distant past there were periods of de-oxygenated oceans on earth and those periods can be discerned in the floor of the open ocean. I now want to investigate how oxygen-depleted zones develop in the current ocean system and how we can see these in the sediment.'

Research themes

'The main aim of this leg was to obtain insights into the carbon cycle. If organic material, i.e. carbon, flows into the sea from the land then what happens to it? Does it break down or does it sink, and how far does it end up into the sea? Organic matter originating from the land has a different composition than organic matter produced in the sea. The second aim of the research was "dead zones". These are large zones without oxygen that arise due to algal blooms and the breakdown of these, as a result of which all of the oxygen from the sea is used up. The development of the de-oxygenated zones starts somewhere around March and April. Initially, we also wanted to investigate the biological production and breakdown of methane, an important greenhouse gas, on the seafloor of this area. Unfortunately, we did not have enough time to do that research.'

Initial results and findings

'We chose a transect of 15 to 2000 metres deep to sample the water column. We sampled a trajectory from the river mouth (with much input from the land) to the open sea (without input from the land). In the shallow part, we found minimum oxygen conditions, but we were still too early in the season to be able to follow the lack of oxygen in the deeper parts as well. The oxygen-free zone develops later in spring when the algae grow rapidly. We subsequently placed a sediment trap to capture the sinking sediment so that we can compare different seasons. In September, an American research vessel picked up the sediment trap for us. We will share several of our samples with the Americans.

My research is now focusing on the changing input of the Mississippi River in the past. For this, we took a sediment core that covers the past 20,000 years. We can use specific properties of the sediment to examine how the climate changed in the past. We are looking at temperature changes in relation to the ice age as well as variations in the input from the Mississippi River. We can subsequently use this information in computer models that we are developing to predict the future climate.'

Leg 8: Nassau - Galway

From 6 April to 28 April 2018, the Pelagia cruised from Nassau across the Atlantic Ocean to Galway, on the coast of Ireland. On board were researchers from the University of Groningen, University of Amsterdam, Utrecht University, Naturalis Biodiversity Center and NIOZ.

During leg 8, a lot of interrelated research took place. The central theme was the ecological consequences of changing conditions in the Atlantic Ocean. All of the researchers on board wanted to gain a better understanding of how gradients (temperature, nutrient and light) influence the species they were interested in.

Chief scientist Corina Brussaard (NIOZ and University of Amsterdam): 'Several large ocean currents traverse the Atlantic Ocean. Each current has its own temperature, salinity and concentration of nutrient salts. Conditions such as light, temperature and current also change per location. These conditions determine the living environment of the marine organisms, from microscopic unicellular algae to minuscule crustaceans and large sea snails.'

Research themes

'One of the studies was aimed at the temperature in the past, using the organisms that lived in the ocean sediment. Another study focused on sea snails because these are sensitive to acidification. A third study focused on algae. These have been investigated a lot in the past, but this study used a new research method that makes use of stable isotopes. The researchers also examined dimethyl sulphide (DMS) levels. This is an anti-greenhouse gas that is released by algae, especially when they die. It is subsequently converted into sulphate that causes water molecules in the atmosphere to form drops, which ultimately leads to cloud formation.
I investigated what exactly causes algae to die. Do they mainly die due to grazing or also due to viral infections? I hypothesised that if more algae die as a result of viral infections, then more DMS will be produced.
Another topic studied was mixotrophy. Mixotrophs are organisms that are both primary producers and predators. There are far more mixotrophs in the ocean than we ever realised. So algae, for example, are not just primary producers but sometimes predators too (they eat bacteria). The opposite is also true: some tiny animals can also be producers, for example, if they use the chloroplasts of their prey.'

Initial results and findings

'We made the first measurements of algal mortality due to viral infections on the other side of the ocean (i.e. western Atlantic Ocean). Initial results reveal that mortality due to viral infections is incredibly important and comparable to that caused by grazing. Further north, we see more production than losses, which fits the formation of the spring algal bloom. There is considerable interest in understanding the formation and bloom dynamics, as ultimately algae serve as food for fish and people (algae form the base of the food chain). Furthermore, infected single-cell algae in the uppermost water column are immediately digested. This means that the nutrients are released and that other species can use these to grow. This is vital for large parts of the ocean that are nutrient-limited throughout the year (tropics) or during the summer (temperate latitudes). The impact of viruses on the ecosystem is becoming increasingly apparent. Ecosystem models scarcely consider this factor and our leg 8 research shows the need for these models to be modified. In concrete terms, this means we have overestimated how rich we are: a lot of organic material simply goes in another direction than the grazer-fish trajectory.'

Meanwhile, we are working together with colleagues from the United States on the first publication about this viral lysis data.

Leg 9: Galway - Texel

From 30 April to 22 May 2018, the Pelagia travelled from Galway to the Whittard Canyon, a system of underwater gorges in the Gulf of Biscay, and to the cold-water reefs on the Rockall Bank, west of Ireland. On board were researchers from the Westerdijk Fungal Biodiversity Institute, Aarhus University in Denmark and NIOZ.

Leg 9A: Rockall Bank

The first part of leg 9 started off near the west coast of Ireland, where we can find a shallow bank in the north-east Atlantic Ocean which is called “Rockall Bank”. On the slope of the bank, at a water depth of 600 to 900 m, there are mounds of up to 300 metres, as high as the Eiffel Tower. These mounds have been formed by slow-growing corals and now are one of the largest coral banks in the world. They are home to many species including sponges and fish.

Research themes

How is it possible that corals live in such cold and dark oceans? Where do the organisms get their energy from? That is an important quest of the ATLAS project. The scientists on board for leg 9A want to find out how these cold-water coral reefs make a living in this hostile environment. Chief Scientist Dick van Oevelen: "Not only are we interested in the corals in the present ocean, but we also want to know whether they will be able to survive if the climate keeps changing."

Computer simulations of the dynamics of the water in the area suggest that the tide plays an important role in the transport of energy-rich food particles to the corals. The researchers had two hypotheses for the food supply of the cold-water corals: 1. Production on the shallow Rockall Bank and transport along the seafloor to the corals and 2. Episodic vertical transport of algae from the surface ocean. In 2017, a team of scientists from NIOZ deployed moorings, a line with instruments moored to the bottom with a 600-kg weight, to measure currents and food particles during an entire year.

Initial results and findings

During leg 9A of the NICO expedition, these moorings were recovered. Van Oevelen: "We were happy to find out that the instruments worked and collected a lot of data. We are now in the process of processing and analysing that data, a big task. Preliminary findings, however, show that some of the dynamics are clearly different between Bank station and Oreo mound and we found evidence for vertical water movements above the coral mounds. These findings may indicate that vertical organic matter transport possibly supplies food to the corals. We are now working on the integration of our data with predictive models and will try to include the sensitivity of the cold-water coral systems to climate change. This full bag of data will definitely keep us busy for the next year(s)!

Leg 9B: Whittard Canyon

During leg 9B, the Whittard Canyon to the west of Ireland was investigated. The research focussed on particle transport processes.

Furu Mienis from NIOZ: 'The Whittard Canyon forms an important link between the shallow, productive continental slopes and the nutrient-poor deep sea. Via underwater gorges such as the Whittard Canyon, organic material is captured and transported to the deep sea where it can be stored for a longer period of time. We want to know whether the canyon is a motorway or a storage space for organic matter, which forms an important food source for deep-sea species. Therefore, we also want to know whether the life on the floor of the canyon benefits from these high nutrient concentrations.'

Research themes

'Research questions: are these deep gorges actually enriched in carbon and where does the carbon ultimately end up? Which processes are responsible for bringing the material there and does the fauna benefit from this? Finally, where is the material eventually deposited? Does it end up in the deep sea or does it remain in the shallower parts of the canyon, where it is reused in the carbon cycle?

Ad Wiebenga from the Westerdijk Fungal Biodiversity Institute was also on board, and he investigated fungi in the deep sea (https://nico-expeditie.nl/blogs/schimmels-die-algen-afbreken). He took samples from the sediment clouds that swirl around in the water to discover whether these contain fungi as well. It is suspected that symbiotic relationships exist between the fungi and bacteria on these swirling sediment particles. Evidence for this still needs to be found though.'

Initial results and findings

'During the cruise, the emphasis was on processes that influence particle transport. Somehow or other particles must be brought to the deep sea, which can be related to continuous processes like internal waves or episodic processes, like storms or fisheries. The topography of the canyons plays a major role in this because it interacts with the flow of the water, creating enhanced turbulence and mixing. The question is which factors are responsible for particle transport.

A coincidental bonus during our research into the occurrence of particle transport was that we could also examine the effect of Hurricane Ophelia that reached the coast of Ireland last year. What did we find? Due to the hurricane and the material that it stirred up a lot of material passed through the canyon in one go. Several episodes like this were observed during the year and we can therefore conclude that the canyon system is very active.'

We also examined the destination of the material. We found a “depot centre” at a depth of 2000 metres in the canyon, a storage place where everything is deposited. We used a video camera to observe the fauna there. We are interested in discovering how the interaction between the factors food, current and temperature influences the spread of living organisms. Our first conclusion is that the canyon contains more food and life than the slopes next to it. Unfortunately, besides more food and life, we can also see more pollution there, especially plastics.

More to follow…

Leg 10: Texel - Amsterdam

From 24 May to 6 June the Pelagia was back in the North Sea. On board were researchers from Naturalis Biodiversity Center, the Westerdijk Institute and NIOZ.

During leg 10, the biodiversity in the North Sea was investigated.

Rob Witbaard from NIOZ: 'During leg 10, we investigated the biogeochemical exchange of the North Sea floor. I was interested in the population of ocean quahogs (Arctica islandica) in the northern North Sea. I was there 20 years ago, and now I had the chance to sample these bivalves again. I can use this information to estimate good population parameters, such as mortality, survival and growth rates.'

Research themes

'The overall theme was biodiversity, and various researchers worked on this. I investigated the biodiversity of the seafloor life and focussed on the ocean quahog. Lodewijk van Walraven from NIOZ was on board to look for jellyfish polyps. Little is known about how and where jellyfish reproduce. At all stations along the route, we fished in the water column to examine which species of jellyfish occurred there. Researchers from Naturalis Biodiversity Center collected individual animals for their reference collection. We also tried to further develop techniques that use environmental DNA (e-DNA). For example, we examined fish e-DNA to find out if a water sample can be used to determine which fish are swimming in it.

Kelli Griffith (Westerdijk Institute) focused on the presence of fungi in seawater. To be honest, we do not really know a great deal about that. Finally, Karline Soetaert and Emil de Borger from NIOZ examined the exchange processes (fluxes) between the seafloor and the water above it. One such process is the leaching of nutrients. The aim of this research is to gather data for models.'

Initial results and findings

'For the first time, polyps were discovered of a certain jellyfish species. This jellyfish species was already known in the North Sea, but the polyps had previously never been seen. That was quite a spectacular finding! Meanwhile, I now have a reasonable picture of the data I collected about the organisms that live on the seafloor. What did we find? Most species are found in the south of the North Sea. The further north you go, the deeper the water becomes and the fewer species you see. There is a species there which is so dominantly present that it accounts for much of the biomass: the ocean quahog. It is present at a level of 20 kg wet weight per 20 square metres. If you remove this species, you have far less biomass.

In the southern North Sea just above the Wadden Islands, there are many different species and lots of individuals. All of these are somewhat smaller species. Furthermore, as I can compare the results with 20 years ago, I now have good estimates for the mortality in the ocean quahog population.

Why is that important? Within OSPAR (https://www.ospar.org/) the ocean quahog has been designated as a threatened species that requires extra attention. The population we studied is reasonably undisturbed. If you have estimates for mortality (i.e. survival), then you can examine whether the figures for the same species are very different in the southern North Sea. You must also be able to scale up the figures: after all, you need basic values. The ocean quahog is a vulnerable species because it can become very old. The age of the oldest ocean quahog ever found is estimated to be between 405 and 410 years. In the southern North Sea, the species suffered severely in the past from heavy bottom trawling. That type of fishing is now banned, but did that have a positive influence on the mortality in the area? These are questions for long-term research.'

Leg 11: Texel - Horta

From 3 July to 17 July 2018, the Pelagia cruised from Texel to Horta. On board were researchers from MARIN, Leiden University and NIOZ.

During leg 11, the research focused on underwater sound caused by ships.

Jos Koning (MARIN): 'During the voyage from Oudeschild (Den Helder) to Horta (the Azores) we investigated the sound that ships generate. We travelled through the English Channel and made the first measurement at the edge of the continental plate. Halfway through the voyage to Horta and just off the Azores, we repeated the measurements. We were interested in the noise that the ship generates when it travels at different power levels. We wanted to establish how that sound varies under different weather and water conditions, and we wanted to compare those measurements with the background noise at the location concerned.'

Research themes

'Research into the underwater sound produced by ships takes place regularly, but the results are often not published due to military or commercial interests. Therefore, the research during the NICO expedition was an exceptional opportunity. The shared dataset can be jointly used by MARIN, TNO, NIOZ and Leiden University.

MARIN is interested in the underwater noise from the ship propeller and the engine and their effects on the ship. This information is important for the design of quieter and more efficient ships. I was interested in how much noise a ship actually makes and which parts of the ship play a key role in this. We did all of the measurements on board the moving ship. On this occasion, we also registered the vibrations and sound close to the propeller and engine. For the sound recordings outside of the ship, we used two hydrophones supplied by TNO. TNO usually determines the effect of the ship noise by making measurements in the water of the noise from passing ships. During the NICO expedition, we combined both approaches.

Researchers from the Institute of Biology at Leiden University also had an unusual research question: they wanted to know the character of the noise that comes from the ship. Hans Slabbekoorn: currently, our understanding of vessel sound and potential impact on marine animals is limited to a number of key measurements, such as the sound level and the frequency range. Now, however, we were able to explore the nature of vessel sound in much more detail and relate it to ship manoeuvres and angles of approach. This information may turn out to be relevant for behavioural disturbance of fish or marine mammals and, if so, we may also be close to finding the key to mitigation.

Initial results and findings

'We had hoped to experience many different types of weather during the two-week cruise. Then we could have investigated the effect of the swell on the underwater sound, for example. However, during the entire period we only had fantastic summer weather, and now we only have “fine weather” measurements.

Another question was whether in the very broad sound spectrum, other sound sources could be heard besides those of the ship. For example, can you detect whales? Initially, that appeared not to be the case. If the ship is in the vicinity, then you only hear the ship because it makes a considerable amount of noise. During the measurements near the Azores, we did, however, take measurements at an increasingly greater distance from the ship. Nevertheless, we still kept hearing the ship. You have to make a considerable effort to cut out the noise from the ship.

What next? We have collected a lot of data, but we will not be able to process that until next year. MARIN and TNO funded the measurement methods during the NICO expedition, but a budget for further analysis was not immediately available. That will now happen in 2019.'

Leg 12: Horta - Terceira

From 17 July to 28 July 2018, the Pelagia cruised from Horta to Terceira on the Azores. On board were researchers from Leiden University, University of Amsterdam, TNO and NIOZ.

Leg 12 focused on hydrothermal vent and the food of whales. The research can be summarised in four words: minerals, ecosystem, plastic and sound.

Sabine Gollner from NIOZ: 'The hydrothermal sources in the mid-Atlantic Ridge near the Azores form a unique ecosystem. It contains organisms that you do not find anywhere else. Hydrothermal sources are seen as a possible birthplace of life on earth. They therefore provide insights into the evolution of life. Hydrothermal sources are also interesting for deep-sea mining due to the minerals they contain. In that case, you need to know which animals live there and how the ecosystem works as otherwise, you will not know what will be damaged as a result of the mining activities.'

Research themes

'In the past, people thought that the sources were isolated and that they had little influence on the surrounding systems in the deep sea. However, several years ago we discovered that this is not the case. Nevertheless, the role of hydrothermal systems on ocean ecosystems is still largely unknown. It is clear that there are a lot of minerals and nutrients. The research must demonstrate what the influence of the hot water source is on the bioavailability of important minerals such as iron and phosphate. This research concerns the presence of minerals (in other words: the effects on and the availability for the ecosystem), biodiversity, noise and plastics.

We were also interested in dispersal processes as we do not understand yet how often tiny creatures cross large regions hostile to settlement to arrive at distant sources. The landscape of sound (“soundscape”) around the hydrothermal sources may play a key role in explaining the unexpected connectivity. Not only adult animals but also many larvae or a variety of taxa are known to respond to acoustic variation in the water by approaching or avoiding particular sound spectra. Researchers from TNO and Leiden University eavesdropped on the potentially critical cues by deploying a sensitive underwater microphone to a depth of 2.5 kilometres.

The second part of the leg focused on whale ecology. What food do the whales eat in the resource-rich water around the island of Terceira? Fleur Visser from the University of Amsterdam and NIOZ and Henk-Jan Hoving (GEOMAR, Kiel, Germany) explored the deep water layers that they knew were visited by foraging Risso dolphins and pilot whales by using deep sea camera glides, special fishing techniques and water samples for DNA extraction. In the same area, Frans-Peter Lam from TNO examined how you can detect and localise whales acoustically by using floating sonobuoys from the military world.'

Initial results and findings

Initial findings? 'It is striking how dynamic the system is in terms of minerals. The minerals that are deposited from the hydrothermal sources influence the availability of essential minerals such as phosphate. We know which groups of animals live directly at the hydrothermal sources, but we still do not know which species are in the sediment samples that we took at a greater distance from the hydrothermal source. As for the plastics research: microplastics were also found to be present in the middle of the Atlantic Ocean, both on the surface and at a depth of 100 metres. Sediment was also sampled for research into microplastics, but the results from this are not known yet.

In terms of sound, detailed acoustic measurements are planned for March and April 2019, but considerable variation was already apparent during a quick screening through the recordings. Not only were sounds of echolocation activity and vessel noise from the Pelagia still recorded at a depth of 2.5 kilometres, but we also repeatedly “caught” the explorative clicks of an echolocating sperm whale. A detailed comparison of sound spectra from close to and further away from hydrothermal sources should shed light on the potential for acoustic homing for the unique deep-sea fauna at these places. This is work for Hans Slabbekoorn from Leiden University in collaboration with Sander van Benda-Beckmann at TNO.
(https://www.universiteitleiden.nl/nieuws/2018/08/met-een-microfoon-de-diepzee-in)

The search for whale prey items yielded interesting views on octopuses and very good samples of nutritious deep-sea fishes and krill. The water samples for DNA extraction were filtered in an extensive team effort, with contributions from scientists from all institutes and even the journalists. DNA analyses will be performed by the researchers from Kiel. Last but not least, the military sonobuoys were proven to be suitable for use in whale ecology research.

Epilogue

The scientific discoveries resulting from the data collected during the NICO expedition can be expected in the months and years to come. Some initial findings and observations at the end of the 7-month-expedition are:

- A previously unknown inactive volcano was discovered at the mid-Atlantic Ridge. In its crater - filled with pelagic sediments - a core was taken to study the nature of past ocean and atmosphere changes. The sediments from this geological archive provide detailed clues to changes in ocean circulation and monsoon driven Sahara dust export.
- Unusual cyanobacterial mats were found that suffocate coral reefs off the coast of Bonaire, while remarkably healthy coral reefs were discovered near the Saba Bank, the largest Dutch nature reserve.
- Research into the health and productivity of Caribbean coral reefs has major implications for the sustainability of economic activities: how can the reefs be kept healthy while still allowing commercial fishing to take place? And how can the sustainable management of the reefs be combined with their role as a tourist attraction?
- Eddies in the Caribbean were found to be less deep than predicted in computer models.
- Viruses are important mortality agents for algae and bacteria but with a very different impact on energy and matter flow than the traditional grazing. We therefore need to rethink ocean ecosystem models.
- Ocean fungi were found that could be used in developing new medicines or fuel.
- A canyon off the west coast of Ireland was found to contain a surprising amount of food and life, but also plastic.
- Plastic was even found in hydrothermal vents in the Azores, the very sources where life on earth possibly first evolved. These hydrothermal sources are biological hotspots and at the same time contain minerals that are of interest for deep-sea mining.

These are just a few of the first findings and observations from the NICO expedition. It exemplifies just how little we still know about the oceans, despite our dependence on them in terms of climate, food and natural resources.

The missing knowledge has high societal and economic relevance. For example, we still know far too little about the ecological impact of deep-sea mining to make responsible use of the ocean's mineral resources. Also, more knowledge of North Sea ecosystems is warranted to allow sound sustainable fishing as well as viable wind farms and other offshore activities. Overall, the NICO expedition has managed to rally a growing number of hands on deck for Dutch maritime and marine research so that key discoveries can be made that benefit both science and society.