# MARE INCOGNITUM

## Professor Jørgen Berge of UiT, the Arctic University of Norway, on the research that is unravelling the mysteries of Arctic marine systems

Ice-covered areas of the Arctic were long presumed to be unproductive, and early scientific studies in the region generally supported this paradigm (Nansen 1906). Evidence of human settlements in the high Arctic over several thousand years, however, conflicted with these early observations and constituted a paradox as to how human populations could subsist in regions considered to be biological deserts. Further investigations revealed the existence of productivity hot spots on a par with some of the most productive places on Earth, and provided the first indications of complexity and the importance of the links between ice, ocean, and land in Arctic ecosystems.

Over the last 20 years, national and international research efforts in the Arctic have sharply increased, culminating with the third International Polar Year (IPY, 2007-2009). Highlights of the IPY work include cataloguing biodiversity from bacteria to top predators, documenting the importance of ice cover for a number of ecosystem processes, studying the relationships between physical and biotic processes on small spatial scales, describing the oceanography of previously poorly known areas, and investigating atmosphere-ice-ocean feedback relationships.

Despite this, there are still major and fundamental knowledge gaps hindering our ability to understand the Arctic as a single, linked system. Particularly considering the fact that the Arctic is undergoing change at an unprecedented rate, with a rapid loss of sea ice and increased temperatures as the most obvious examples, this constitutes a major challenge, not the least for a knowledge-based management of Arctic regions. Perhaps the most obvious and largest of these known gaps is centred around the widely accepted paradigm that Arctic marine ecosystems are best compared with a marine desert during the long and dark polar night. Just as the paradigm of the Arctic Ocean being an unproductive biotope was refuted a hundred years ago, the prevailing view of the polar night as devoid of biological activity has recently been challenged.


*Fig. 1 Light levels as seen by the human eye during the polar night at 81° (upper left, Rijpfjorden), 78° (upper right, Longyearbyen), 76° (lower left, Bear Island), and 70° (lower right, Tromsø) North. All pictures were taken onboard the RV Helmer Hanssen at local sun noon within one week in January 2013. Photo: Geir Johnsen (NTNU) and Jørgen Berge (UiT)*

### Complex behaviours

Marine ecosystem processes are direct consequences of the complex behaviours and interactions between organisms, many of which are driven by the physical environment. Accordingly, a classical paradigm in Arctic marine ecology suggests that most biological processes stop during the polar night at high latitudes due to low food availability and the lack of light. Although the polar night at high latitudes is perceived as total darkness, new data indicate that Arctic organisms nevertheless may respond to light levels undetectable by the human eye.

Recently, new research has challenged this assumption by presenting evidence of the polar night being a prime time for reproduction in a wide array of fish species, en masse vertical migration of zooplankton, and bioluminescence levels indicative of biotic activity hitherto assumed to be absent during the polar night. Combined, these recent results provide circumstantial evidence for both an endogenous and exogenous control of these poorly understood or previously unknown processes during the high Arctic polar night.

As the Arctic ice cap is reduced, new trans-Arctic shipping routes and petro-maritime activities are expected to increase in the relative near future. This increase comes with a risk of environmental accidents in areas until now sheltered from human impact. But considering the imminent gaps in knowledge concerning the marine ecosystem during the polar night, are national management authorities able to regulate these increased activities in an environmental and eco-safe way? How are we able to make realistic risk assessments on a system for which even the most basic knowledge is lacking?

### Winter ecology

The recent and unexpected discoveries under the extreme conditions of the Arctic winter reflect the historically low levels of scientific investigations during the polar night, and challenge our understanding of Arctic marine organisms and ecosystems. But

without a more fundamental perception of Arctic ecosystem function, such impacts will remain largely impossible to understand and predict. Winter ecology of Arctic marine systems, then, is a largely new field of science with the potential for radically altering our fundamental perception of basic Arctic ecosystems processes, current state of the ecosystem and connections between the biosphere, hydrosphere and cryosphere within the polar region.

The primary objective of this project is to achieve a basic understanding of Arctic biodiversity and food web structure during the polar night, and how ecological processes from reproduction and growth to trophic interactions and life history processes during this nearly unstudied time contribute to the functioning of Arctic ecosystems. We will reach this primary objective by addressing three main research questions (research units 1-3) and a fourth unit dedicated to data management, communication and outreach:
**UNIT 1:** How do physical and biological factors regulate the recently discovered processes occurring among marine zooplankton during the high Arctic polar night?;

**UNIT 2:** In the absence of light and primary production, are the biodiversity patterns and community structure of benthos during the polar night different from those observed during the polar day?;

**UNIT 3:** Climate change case studies – what are the consequences of a changing climate?; and

**UNIT 4:** Outreach, communication and data management.

Unit 1 has a focus on pelagic species, whereas Unit 2 will aim more at exploration and mapping of processes that are important within benthic communities. The third unit will combine the knowledge from 1 and 2 and will be composed of a series of targeted case studies aimed specifically at characterising the potential effects of a warming climate. Hence, a main aim of Unit 3 will be to relate the findings to IPCC climate scenarios, in order to provide advice on management and potential ecosystem implications towards policy makers. Unit 4 acts as the data management and information nerve centre of the entire operation.

The project is run by UiT, the Arctic University of Norway, and is organised under the Mare Incognitum umbrella of projects (www.mare-incognitum.no). International partners include Russia

*Fig. 3 Bluegreen light (bioluminescence) produced by marine organisms in the intertidal zone at Svalbard during the polar night in Adventfjorden outside Longyearbyen. Why do the organisms spend their energy producing this light?*

(St Petersburg State University), Scotland (Scottish Association of Marine Sciences), Poland (Institute of Oceanology, Polish Academy of Science), and US (University of Delaware), whereas national partners include Akvaplan-niva, NTNU, UNIS, and the Arctos research network (www.arctosresearch.net).

## True frontier

The polar night has lately emerged as one of the last true remaining frontiers of science, with several new and fundamental discoveries reported within the scientific literature in the last few years. Also, several new research projects have been initiated based on these discoveries that will in the coming years secure a solid knowledge base centred around key issues of interest concerning polar night biology. The majority of these discoveries and projects are all primarily focused on the pelagic part of the ecosystem, which is natural since logistical challenges with working in the polar night have prevented in-depth studies of benthic communities.

However, and based particularly on discoveries of bioluminescence levels from the upper 20m of the water column that resembles those previously known only from the deep sea, as well as newly documented winter recruitment of benthic organisms, we aim at directing our attention more towards important benthic components of the ecosystem. By utilising both

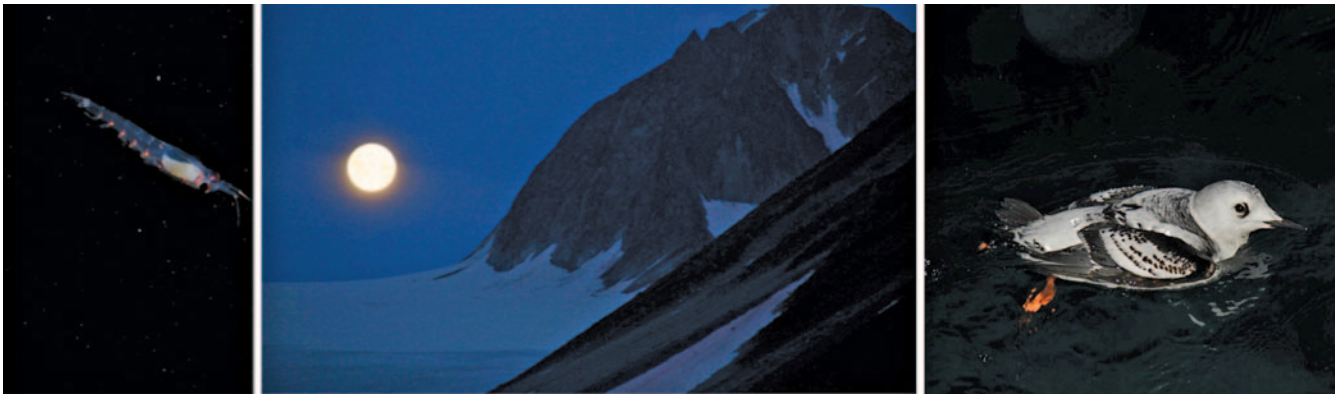

*Fig. 2 A krill, lunar light during the polar night and a black guillemot photographed* in situ *in the high Arctic Kongsfjorden in January 2010. Why are the krill migrating in the darkness? For large parts of the winter, the Moon is the strongest light source – are Arctic marine organisms werewolves that are guided by the Moon? Seabirds such as the black guillemot are more numerous in Svalbard waters than previously believed – are they feeding on the migrating krill? Or is it the bioluminescence (above) that aid their search for prey? Photo by Geir Johnsen (NTNU)*

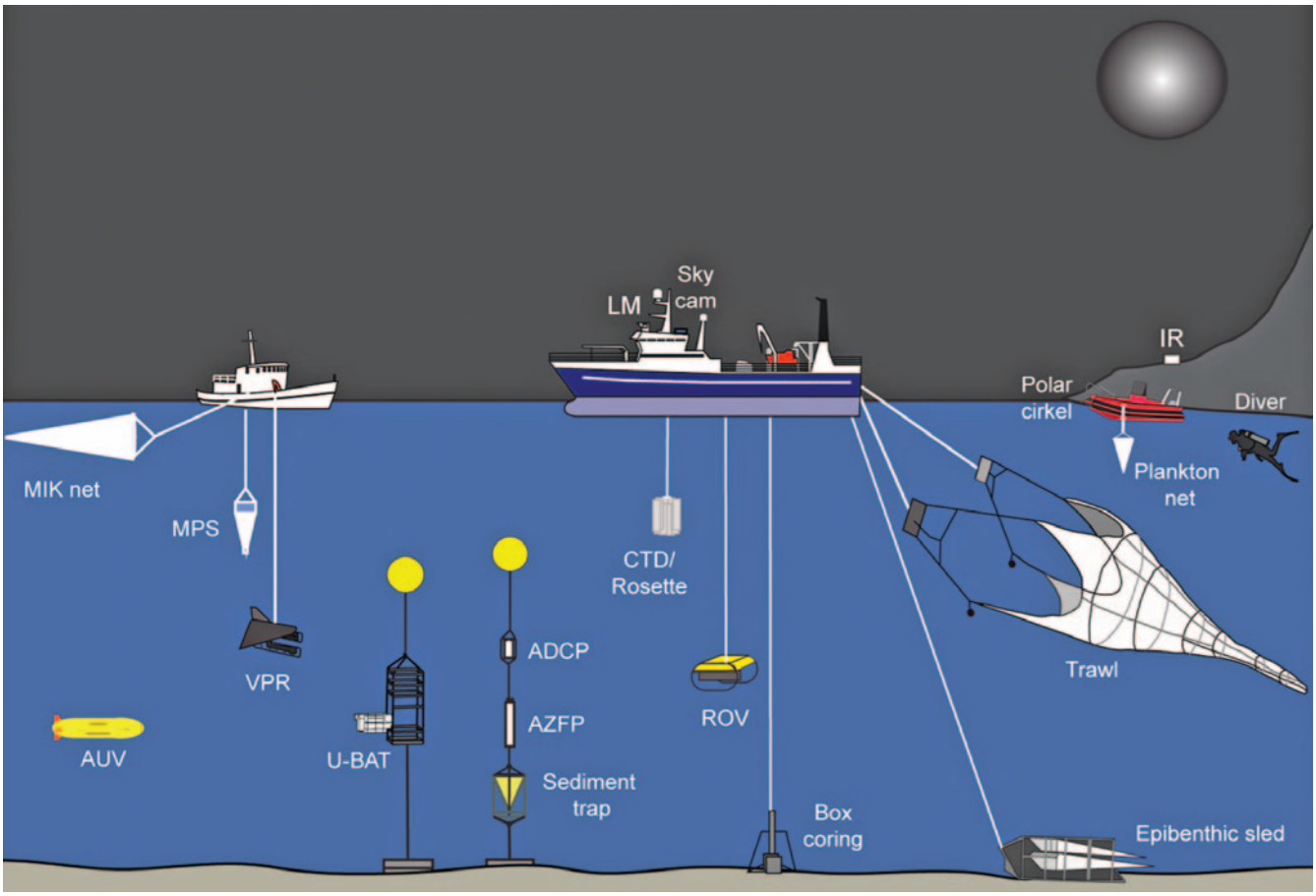


*Fig. 4 Schematic of the scientific equipment and platforms used for the Mare Incognitum field campaign. Boats from left to right: Ulla Rinmann for medium sized equiment, Helmer Hanssen for all large equiment and Polar cirkel (open boat) to deploy light equipment. Equipment/sensors left to right, MIK (Methot-Isaacs-Kidd net) for large zooplankton; AUV: Autonomous Underwater Vehicle; MPS (Multiple Plankton Sampler) for medium sized zoopkankton; VPR (Video Plankton recorder) for picture identification of migrating zooplankton; U-BAT for* in situ *measurements of bioluminescence; ADCP (Acoustic Doppler Current Profiler) for characterising vertical migration patterns; AZFP (Acoustic Zooplankton Fish Profiler) for characterising vertical migration pattern; LM (Light Meter and photon counter) for characterising the light climate; CTD (Conductivity-Temperature-Depth) sensor with water bottles for eater mass characterisation; Sky Camera for taking pictures of the celestial dome; ROV (Remotely Operated Vehicle) for underwater installations and sampe collections; IR (infra-red) camera for both counting seabirds and safety (detecting polar bears as well as monitoring activities at sea)*

knowledge and infrastructure/sampling campaigns developed among the large group of partners, we will conduct basic and fundamental new research to achieve a more comprehensive understanding of Arctic biodiversity during the polar night, and how ecological processes from reproduction and growth to trophic interactions and life history processes during this nearly unstudied time contribute to functioning of Arctic ecosystems.

In January 2014 we began the largest co-ordinated field campaign focusing on the marine polar night ever conducted. The campaign is co-ordinated with a new MSc and PhD course on underwater robotics (www.unis.no), and will contain a wide array of sampling platforms and sensors (Fig. 4). Specifically, we are aiming our attention towards three themes: the importance of biological light (bioluminescence); hunting for werewolves; and the benthic life.

**1) The importance of bioluminescence (light produced by living organisms) for life in the dark**

Bioluminescence is a feature characteristic for all deep sea environments, and is generally used both for communication and for attracting prey. Some organisms also use it as a defensive 'weapon' against potential predators. Bioluminescence ('morild' in Norwegian) is also known as a night time phenomenon from shallow waters around the planet, but the unique light climate of the Arctic polar night (total darkness) make this a specifically conspicuous and potentially important process for the entire Arctic marine community.

A very large fraction of the Arctic marine organisms that live in the water column are able to produce such light – looking down into the water column during the polar night is sometimes as looking into a sparkling upside down galaxy with blue lights blinking and moving in all directions. What implications does this have, and is it connected to predators finding food in the otherwise dark ocean? Understanding which organisms produce this light and why, will bring us much closer to our main ambition of understanding how marine organisms meet the challenges of surviving the total darkness of the Arctic polar night.

**Main objective:** What is the ecological significance of bioluminescence in the polar night?

**Secondary objectives:**

- Map (temporal and spatial) distribution of bioluminescence *in situ;*
- Characterise (spectral and intensity) the bioluminescence signal *in situ* and *in vivo;*

*Fig. 5 Mass occurrence of benthic organisms (caprellid amphipods, right) observed on kelp during the polar night. Are they actively migrating into the shallow during the dark winter? Why? Autonomous underwater vehicle (AUV) deployed in Ny-Ålesund (left). This and other high tech platforms and instruments are an essential part of the campaign. Photo: G. Johnsen (NTNU)*

- Seafloor mapping (distribution of benthic organisms including both bioluminescent and biolum-detecting species); and
- Who can detect bioluminescence?

**2. Are there werewolves in the Arctic?**

Diel vertical migration (DVM) of zooplankton is a characteristic feature of the world's oceans and lakes, and has been claimed to be the largest synchronised movement of biomass on the planet. In short, DVM is the behaviour in which organisms hide down in the dark deep layers of the ocean during the day, while swimming up into the surface layers to feed during the night. In general, this phenomenon is therefore linked to changes in solar illumination during a 24 hour cycle. In the Arctic, recent research has revealed that many organisms retain this behaviour during the long polar night, despite that fact that there is no sunlight.

Why do the organisms retain a behaviour that involves migrating several hundreds of metres up and down each day during a time of year when the light climate is indifferent, both between day and night as well as between the deep and shallow? In other words, why do they retain this behaviour when the shallow is just as dark as the deep? What drives the vertical migration of Arctic organisms – are they responding to lunar light, which during the polar night is at least during periods of full moon the prevailing light source in the sky? Or alternatively, is it an internal biological clock that regulates a behaviour of the zooplankton (e.g. krill) that is not directly linked to their environment?

**3. Benthic life during the dark – optimal time for reproduction, or just resting?**

All our knowledge regarding Arctic benthic organisms is derived from studies carried out in the light part of the year. Are benthic organisms active during the polar night? Do many of them migrate towards shallower waters? In the absence of light and primary production, are the biodiversity patterns and community structure of benthos during the polar night different from those observed during the polar day?

Recent studies have demonstrated unexpected activity in the pelagic zone during the polar night. These include diurnal vertical migration without apparent light cues, diverse patterns of bioluminescence by pelagic organisms, and foraging by organisms previously assumed to be primarily visual predators.

Benthic communities, however, have rarely been studied during the polar night, and hyperbenthic communities, those organisms living in the bottom several meters of the water column, have been even less investigated. This latter group may in fact include both overwintering zooplankton as well as the organisms that are performing DVM even during the polar night. The main objective of this part is to determine the structure and function of Arctic seafloor communities during the polar night.

Main research questions within the project at large therefore include how different communities and habitats potentially differ throughout the year, and how these differences may affect the food chains of the high Arctic marine systems during the polar night. As more and more research is providing compelling evidence against our previous conception of an unproductive and dormant marine system during the polar night, Marine Night will be an important tool to provide much needed knowledge to the benefit of both management and policy makers. But most importantly, Marine Night will provide important insights into a system that until recently has remained a dark spot on our 'map of knowledge', and we will continue to unravel some of the most fascinating and interesting questions yet to be answered concerning marine life at high latitudes. Ultimately, this will be a valuable contribution to a knowledge-based management of the region in an era when considerable attention is directed towards the vast and unused resources held within the Arctic.

Mare incognitum
Unraveling the mysteries of Arctic marine systems

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