JPI OCEANS

Changing Marine Lightscapes

Concept Paper March 2023

Changing Marine Lightscapes –

Drivers, consequences, and perspectives on changes in the light environment of Europe's seas and oceans[1]

1. Background and rationale

Light is fundamental for all life in the oceans. Through evolution, marine organisms have adapted to the natural light conditions in the oceans, in terms of the amount (intensity), the colours (spectral composition) and the natural cycles (periodicity) of light. **Over the last century, the world oceans and coastal regions have seen marine lightscapes changing in two fundamental ways.**

Firstly, some regions have experienced a long-term reduction in water clarity, referred to as **Coastal Darkening** (Aksnes et al. 2009), with large-scale drivers connected to effects of climate change (more frequent and intense rainfall, increased temperatures, melting permafrost and glaciers) and other human activities, such as changes in catchments' properties and activities that increase erosion (Dupont and Aksnes, 2013; Frigstad et al., 2023, Organelli et al., 2017). A reduction in the light availability will affect all organisms that are dependent on light for photosynthesis, such as phytoplankton, benthic macroalgae and seagrasses, in addition to animals dependent on light for feeding or other purposes (Opdal et al., 2019; Capuzzo et al., 2015; Wollschlaeger et al., 2021).

Secondly, some coastal regions are experiencing a brightening of the night-time[2] light environment linked to urbanisation, on- and offshore infrastructures, fisheries, and shipping (Davies et al., 2014; Davies et al., 2020; Smyth et al., 2021). With 54% of its coastlines exposed to **artificial light at night (ALAN)**, Europe is the worst affected region in the world (Davies et al., 2014). In brief, ALAN is increasing the availability of biologically usable light to marine organisms at night, which can impact the fundamental functions of aquatic life and its evolution. The ability to cope with artificial light, especially at night, is limited for many organisms through photo-acclimation (Brunet et al 2011), while they evolved without.

Even though the primary drivers of Coastal Darkening and marine ALAN are different, the fundamental processes that govern light availability and biological responses are similar. The availability of light in the water column is controlled by the incoming radiation at the sea surface and the interaction of this light with water column constituents which determines the water's optical properties. Similarly, both Coastal Darkening and marine ALAN impact the same fundamental biological processes by altering the availability (intensity) and properties (colour, daily cycle) of light, to be used as a resource and source of information in marine ecosystems (Gaston et al. 2013). In addition to being essential for primary production and the basis of marine food webs, light also helps marine organisms decide where to live, when to reproduce, how to hide, how to find food, when to move and in which direction. **Changes in marine lightscapes have significant impacts on all these biological processes reshaping marine communities with potentially profound yet unknown consequences for ecosystem services** (Tidau et al., 2021; Marangoni et al., 2022).

There is an urgent need to understand the impact of changes in marine lightscapes on marine environment, its biodiversity and ecosystem functioning, as well as for providing ecosystem services. The drivers of change, their interactions and the responses are not fully understood, making it difficult to develop effective management strategies. Furthermore, the implications of these changes for

[1] Front page photos, top to bottom: Scientists taking river samples in Svalbard. Credit: Anne Deininger (NIVA); Credit: Thomas Charters; Sediments in the North Sea. Credit: Jeff Schmaltz, MODIS Rapid Response Team, NASA/GSFC, Lit up port at night. Credit: Dall-E.

[2] While we throughout this document refer to artificial light at *night*, this brightening may also concern the day-time light environment in northern and arctic regions.

critical ecosystem functioning and services, such as sustainable marine fisheries, are lacking. **It is therefore proposed to establish a new JPI Oceans Joint Action on Changing Marine Lightscapes** bringing together pan-European expertise across oceanography, biogeochemistry and social science to address the challenges posed by changing marine lightscapes in the 21st century. The thematic foci and planned outcomes of the proposed Joint Action are in line with JPI Oceans Strategy Framework for 2021-2025 as they include aspects of ocean health, productivity, stewardship, and governance.

This **Concept Paper** is the result of a scoping process commencing with the adoption of Light and Colour in the Ocean as a Scoping Action by the JPI Oceans Management Board on 23 February 2022. The scoping was based on proposals by Germany and Norway, which respectively have led and co-led the Scoping Action. Ten member countries have taken part in the scoping through the involvement of scientific experts: DE, DK, EE, GR, IE, IT, PL, PT, NO, and UK. The group of experts nominated by the participating countries had one in-person meeting in Brussels 6-7 September 2022, and one meeting online on 17 February 2023. A core group responsible for elaborating the Concept Paper, coordinated by Prof. Oliver Zielinski and Dr. Helene Frigstad, held several online meetings during the process. The final version of the document has been reviewed and approved by the lead countries.

2. Description of the proposed Joint Action

The proposal is to implement the Joint Action through a **Joint Call to respond to urgent knowledge gaps** complemented with a **Knowledge Hub that consolidates and disseminates key findings**. The proposed Joint Action will address critical gaps in our understanding of how marine lightscapes are changing, the drivers of change, the impacts of changing lightscapes on biodiversity, marine ecosystem structure, functioning and services, and will thus facilitate evidence-based policymaking for managing these changes.

Joint Call

It is expected that proposals responding to the Joint Call address the themes (A-D) below, and it is an advantage to address several of the key priorities listed under the themes. Proposals can be primarily focused on Coastal Darkening or marine ALAN or a combination of both topics, however **interdisciplinary and multi-national proposals are particularly encouraged**.

A. Observing marine lightscapes

Proposals should address one or more of the following:

- **Spatiotemporal changes in the intensities, spectral characteristics and cycles of marine lightscapes at pan-European and regional scales**
- **Innovative tools and approaches for measuring changes in marine lightscapes**
- **Novel approaches to predict future marine lightscapes**

B. Causes of change in marine lightscapes

Proposals should address one or more of the following foundational causes of change in marine lightscapes:

- **Changes in land-ocean interactions**
- **Climate change and ocean-atmosphere interactions**
- **Urbanisation and maritime industries**

C. Consequences of changing marine lightscapes

Proposals should address one or more of the following consequences of changing marine lightscapes on marine ecosystem health and biodiversity:

- **Primary production, blue carbon and marine food webs**
- **Ecosystem architecture and functioning**

- **Sustainable marine fisheries**
- **Marine organism photobiology and ecosystem consequences**
- **Marine organism movement and biogeography**
- **Light induced seasonal timing of organismal behavior**

D. Managing the impacts of changing marine lightscapes

Proposals should deliver evidence to inform tractable mitigation solutions using one or more of the following approaches:

- **Dynamic marine and maritime spatial management tools**
- **Strategies for monitoring and mitigating changes in marine lightscapes**
- **Modelling and technological innovations**
- **Novel policy interventions**
- **Awareness raising and ocean literacy**

Knowledge Hub

Consisting of experts nominated by the participating countries, the Knowledge Hub would be well placed to provide a coherent scientific structure to monitor scientific and science-policy developments and consolidate marine lightscapes as a theme throughout the implementation period of the Joint Action. While the Knowledge Hub would have no role in formulating or preparing the call, it could act as a resource group for the projects during implementation and act as a science-policy link between the research projects, JPI Oceans' participating countries and their relevant institutions. Following the finalisation of projects, the Knowledge Hub could, moreover, synthesize and consolidate key findings from the Joint Call and prepare policy advise and recommendations based on research findings. Products could also include joint publications, dissemination activities and stakeholder interventions, to inspire EU and national research agendas. Terms of Reference (ToR) reflecting the work of the Knowledge Hub will outline the expected work, structure and budget of the Knowledge Hub. The ToR will be approved by the Management Board prior to initiating the work of the Knowledge Hub

3. Outcomes and impacts

In addition to help closing key knowledge gaps under section 2, the projects should address how they will contribute to the 12 thematic areas and interconnected priority areas (Ocean health, Ocean productivity and Ocean stewardship & Governance) under the JPI Oceans Strategy Framework for 2021-2025 as well as the 2030 EU Biodiversity Strategy and the European Green Deal priorities, specifically "*putting Europe's biodiversity on the path to recovery by 2030*", "*Protecting our biodiversity and ecosystems*" and improving monitoring and implementation of relevant EU policy frameworks, such as the Marine Strategy Framework Directive (MSFD), the Water Framework Directive (WFD), and Maritime Spatial Planning.

Project proposals submitted to the JPI Oceans Joint Action on Changing Marine Lightscapes are expected to deliver knowledge that contributes to several of the following scientific, societal or technological outcomes:

Scientific and technological outcomes:

- Better knowledge basis of drivers and spatiotemporal variation in changing marine lightscapes
- Ability to predict and model future changes in marine lightscapes, including digital twins
- Improved tools and technologies to support relevant policy frameworks

Policy and societal outcomes:

- Roadmap for implementation of changing marine lightscapes as an indicator in management policies and monitoring programmes (MSFD, WFD) and as an Essential Ocean Variable of GOOS
- Decision support systems and scenarios for stakeholders and policy makers
- Improved understanding of implications for ecosystem services and restoration actions

Awareness and citizen science

- Increased European and international recognition and public awareness of the extent and impacts of changing marine lightscapes
- Explored public perception of lightscapes and the willingness to reduce artificial light at night when informed about the consequences (compared to for example safety measures)
- Increased public understanding of issues like sky brightness, water colour and underwater light levels ensured through citizen science activities

Economic:

- Estimations of socio-economic costs of changes in marine lightscapes, including implications for recreation, tourism, fisheries and aquaculture
- Explored effects of an expanding renewable energy production sector and other green initiatives on marine lightscapes

4. Added value, potential links and other programmes

The proposed Joint Action on Changing Marine Lightscapes, with the two sub-topics Coastal Darkening and marine Artificial Light at Night (ALAN), is an emerging and under-studied area that is crucial in the context of ocean health, marine pollution, and biodiversity loss and respective marine spatial planning. These topics will become increasingly important and fit with JPI Oceans' strategic positioning in setting forward-looking agendas by driving new research to inspire national and European agenda topics. The Joint Action will generate transversal knowledge for a better understanding of light environment in the coastal and oceanic waters. The Joint Action will also lead to highly novel scientific publications and dissemination activities on the pan-European and global drivers, their impacts on the marine ecosystems and their services, together with policy implications and mitigation measures, that would be difficult to achieve through nationally funded projects or in the current Horizon Europe landscape.

Funded projects should be encouraged to build on or link with ongoing initiatives, projects and programmes related to changing marine lightscapes. To promote collaboration and a comprehensive approach, cross-national and pan-European initiatives are particularly encouraged. Additionally, to ensure efficient use of resources, synergies with existing coastal/marine observation infrastructures (e.g., JERICO-S3, eLTER, Biogeochemical-Argo), modelling and remote sensing services (e.g., Copernicus marine, Digital Twins of Destination Earth initiative) should be sought.

Funded projects of a JPI Oceans Joint Call may wish to communicate results with consortia with a more general aquatic focus funded through HORIZON-CL6-2023-BIODIV-01-2: *Impact of light and noise pollution on biodiversity*. The focus of the HEU-call is on management of the co-occurring impacts of sensory pollutants in aquatic ecosystems (light and noise). The proposed JPI Oceans Joint Action on Changing Marine Lightscapes is distinctly unique in being the first to specifically tackle the ecological impacts and drivers of changing marine lightscapes that result from both Coastal Darkening and marine ALAN. As such the scope of the Joint Action is far broader than sensory pollution, incorporating impacts on marine primary production and ecosystem services. Further, the proposed joint action places equal emphasis on daytime and night-time marine lightscapes, while HORIZON-CL6-2023-BIODIV-01-2 focuses exclusively on the night-time and does not facilitate synergies between the needs for knowledge on overall changes in marine lightscapes. At the same time, the proposed call is more focused than the HEU call by concentrating on the marine environment and on light only, thus complimenting the projects from the Joint Action on Underwater Noise.

In addition to ensuring complementarity with the HEU-call HORIZON-CL6-2023-BIODIV-01-2: *Impact of light and noise pollution on biodiversity,* the Joint Action shall seek synergies with existing initiatives, including the Sustainable Blue Economy Partnership, and the Driving Urban Transition Partnership.

5. Leadership and Resourcing

The lead and co-lead for the proposed Joint Action is to be determined by the JPI Oceans Management Board. The Joint Call will be managed by designated Funding Agencies from the lead countries. The Call Secretariat, run by these Agencies, will handle the evaluation process and all communications with Coordinators regarding their applications. Scientific lead of the Knowledge Hub is proposed to be shared by two scientific experts from the lead and co-lead participating countries.

The funding model for the joint call is the Virtual common pot, where after a joint call and a common evaluation, the national Funding Partners will fund the partners from their own countries participating in the projects selected for funding. Applicants from countries not funding this call are encouraged to participate with their own resources. All joint activities are funded on an ad hoc, voluntary basis. The Funding Partners aim to fund the highest-ranked proposals according to the criteria and procedures stated in the description of the call and the Annexes. The Funding Partners aim at funding a balanced package of proposals with respect to the scientific themes specified in the call, strategic considerations, and national participation.

The financing of the activities of the Knowledge Hub, including participation of experts, will be detailed in the terms of reference (ToR).

6. References

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