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Editorial: Climate Change and Light in Aquatic Ecosystems: Variability & Ecological Consequences

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Editorial on the Research Topic

Climate Change and Light in Aquatic Ecosystems: Variability & Ecological Consequences

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Light is a key variable in nearly all ecosystems on Earth, both in the terrestrial and the aquatic domain. It shapes the ecological niche of organisms in various ways, either by providing visual information for orientation, predation, and reproduction (McFarland, 1986), or–most importantly–providing the energy for photosynthesis and thus primary production, which is eventually transferred to higher trophic levels. With the nine articles in this Research Topic, we aim to raise awareness on the importance of light for aquatic ecosystems, both freshwater and marine, as well as on present and future changes of light availability induced by climate change. As an introduction to the Research Topic, we provide herewith some background on how climate change affects the aquatic light environment and describe the specific themes covered in these articles.

In aquatic habitats, light propagation is more complex than on land, as the water itself–in contrast to air–is a strong attenuator of light, especially in the red part of the visible light spectrum (Kirk, 2011). The consequence is a decrease in light intensity with water depth and a simultaneous shift in wavelength composition toward a higher proportion of shorter wavelengths, one of the reasons why very clear water appears blue. In addition to this general principle, the presence of substances with their specific optical properties further modify the underwater light field, causing greenish, yellowish, or brownish waters. The most relevant of these optically active substances (OAS) are phytoplankton, that have different photosynthetic and photoprotective pigments, colored dissolved organic matter (CDOM), as well as non-living organic and inorganic particles (e.g., detritus and suspended mineral particles). They determine the inherent optical properties (IOP; e.g., absorption and scattering) of the water which, together with the ambient light conditions, govern the apparent optical properties (AOP; e.g., diffuse attenuation or water color). Analytically, AOP and IOP are related by the radiative transfer equations (Mobley, 1994), however, as their solution is rather complex and computationally expensive, for certain applications less complex empirical or semi-analytical models can be sufficient as shown by Gonçalves-Araujo and Markager.

The interplay of the optical properties of the water and the OAS creates highly characteristic underwater light climates to which the organisms living within are adapted. Changes in these conditions propose a challenge to these organisms and might induce alterations of community structures and, eventually, ecosystem functioning. A number of studies have observed a trend toward reduced light availability, thus "darker" waters in aquatic ecosystems. In freshwater systems, this phenomenon is well-studied and known as brownification, since there, the reduced light availability is mainly caused by increased input of terrestrial CDOM (Pace and Cole, 2002; Graneli, 2012 and references therein). A "coastal darkening" has also been observed in certain marine environments, such as fjord systems or shallow shelf seas (Aksnes et al., 2009; Dupont and Aksnes, 2013; Capuzzo et al., 2015). Mustaffa et al. report that input of terrestrial CDOM to coastal waters can also negatively impact phytoplankton growth due to reduced light availability, with consequences possibly propagating to the next trophic level. Nevertheless, the effects of such temporally and/or spatially variable terrestrial CDOM input might differ between freshwater and marine systems. In addition to CDOM input, increased particle loads have also been considered as drivers of darker coastal waters. This includes both increased resuspension of available sediments and input of new particulate material by glacial melting and increased erosion on land (Walling, 2009). Besides these climate change-related impacts, there are also direct human activities like trawling, sand extraction, and coastal engineering measures that can contribute to reduced light availability (Palanques et al., 2001). However, other effects of altered light climate on higher trophic levels occur besides those indirectly mediated via phytoplankton. Williamson et al. show that the light attenuation attributed to darker waters can directly shape the ecological niche of higher trophic levels such as zooplankton by altering other environmental factors like temperature, oxygen, and UV radiation regimes, while showing minor impact on the phytoplankton.

Eventually, it is the interplay of (variable) light conditions on different scales with other factors such as nutrients that controls phytoplankton responses such as photosynthetic adjustments, adaptations in pigments, biomass production, and taxonomical composition. The interplay of these factors are considered in Marzetz et al. and Petty et al.. Knowledge about these interactions is important to (i) understand ecosystem functioning in general and (ii) make predictions regarding the consequences of ongoing changes induced by climate change and eutrophication, which has implications in the management of freshwaters and the prevention of increasingly widespread cyanobacterial harmful algal blooms. Manipulation of the light regime via artificial "darkening" is explored by Gaskill et al. as an alternative or complementary strategy to achieve a decrease in cyanobacterial biomass or a change in community structure toward non-toxin producing phytoplankton.

Increased light, although in general favorable for primary production, is, however, not always beneficial for aquatic organisms. Short wave radiation such as UV-A and UV-B can damage genetic material, thus acting as a stressor by putting the intracellular repair mechanisms under pressure. Overmans and Agustí. consider the relevance of UV exposure for non-motile organisms living in shallow areas (e.g., corals) that are also being stressed from rising temperatures due to climate change.

To assess the long-term effects of changing underwater light levels on a broad spatial scale, numerical models are a powerful tool, provided that the propagation of light is reasonably well-represented. The majority of models use a parameterization of light attenuation based on the distribution of phytoplankton, which is a suitable approach for open ocean environments. Models that account for inorganic particulate matter, however, are shown by Thewes et al. to perform considerably better in optically complex coastal waters. To further improve model performance, Wollschläger et al. have developed light parameterizations that account for all OAS and their spectrally variable optical properties, while being computationally affordable.

As it can be seen by the variety of research fields that are addressed by the contributions to this Research Topic, the issue of light variability in aquatic ecosystems is certainly a complex one. It becomes clear that light availability as well as light quality are key parameters for aquatic organisms across different scales and that their effects on the ecosystems have to be considered in interaction with multiple environmental variables. The presented studies highlight that we need a better grasp of the implications that climate change and human activities pose on both the timing and the magnitude of altered light conditions on our aquatic ecosystems on local, regional, and global scales. The papers collected here give an overview about the several important aspects of this topic and show the current state of research.

AUTHOR CONTRIBUTIONS

JW provided the first draft of the manuscript. All authors contributed equally to its finalization.

REFERENCES

Aksnes, D. L., Dupont, N., Staby, A., Fiksen, O., Kaartvedt, S., and Aure, J. (2009). Coastal water darkening and implications for mesopelagic regime shifts in Norwegian fjords. *Mar. Ecol. Prog. Ser*. 387, 39–49. doi: 10.3354/meps08120

Capuzzo, E., Stephens, D., Silva, T., Barry, J., and Forster, R. M. (2015). Decrease in water clarity of the southern and central North Sea during the 20th century. *Glob. Chang. Biol*. 21, 2206–2214. doi: 10.1111/gcb.12854

Dupont, N., and Aksnes, D. L. (2013). Centennial changes in water clarity of the baltic sea and the north sea. *Estuar. Coast. Shelf Sci*. 131, 282–289. doi: 10.1016/j.ecss.2013.08.010

Graneli, W. (2012). "Brownification of lakes," in *Encyclopedia of Lakes and Reservoirs: Encyclopedia of Earth Sciences Series*, eds L. Bengtsson, R. W. Herschy, R. W. Fairbridge (Dordrecht: Springer).

Kirk, J. T. O. (2011). *Light & Photosynthesis in Aquatic Ecosystems, 3rd Edn*. New York, NY: Cambridge University Press.

McFarland, W. N. (1986). Light in the sea - correlations with behaviors of fishes and invertebrates. *Integr. Comp. Biol*. 26, 389–401. doi: 10.1093/icb/26.2.389

Mobley, C. D. (1994). *Light and Water: Radiative Transfer in Natural Waters*. London: Academic Press.

Pace, M. L., and Cole, J. J. (2002). Synchronous variation of dissolved organic carbon and color in lakes. *Limnol. Oceanogr*. 47, 333–342. doi: 10.4319/lo.2002.47.2.0333

Palanques, A., Guillén, J., and Puig, P. (2001). Impact of bottom trawling on water turbidity and muddy sediment of an unfished continental shelf. *Limnol. Oceanogr*. 46, 1100–1110. doi: 10.4319/lo.2001.46.5.1100

Walling, D. E. (2009). *The Impact of Global Change on Erosion and Sediment Transport by Rivers: Current Progress and Future Challenges*. Paris: UNESCO

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