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Editorial: Research and Management of Eutrophication in Coastal Ecosystems

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Editorial on the Research Topic

Research and Management of Eutrophication in Coastal Ecosystems

This Research Topic brings together 22 papers on research and management of eutrophication in coastal ecosystems. We, the editors of the Research Topic, hope the readers will find the papers as interesting as we do. We are delighted with the breadth and diversity of the papers. The Research Topic includes 18 original research papers, two reviews, a mini review, and this editorial, which span the entire palette of eutrophication themes, from inputs of nutrients and organic matter, direct effects, indirect effects, to climate change, management strategies etc. across a wide geographical range. The papers of this Research Topic are anchored in EUTRO 2018, the "Fourth International Symposium on Research and Management of Eutrophication in Coastal Ecosystems," which follows up on three earlier symposia: EUTRO 1993, EUTRO 2006, and EUTRO 2010. The broad span of topics related to eutrophication are also reflected in the keywords from the 22 papers.

The roots of EUTRO 2018, as well as EUTRO 1993, EUTRO 2006, and EUTRO 2010, extend from the first Danish Action Plan on the Aquatic Environment, which was adopted by the Danish Parliament in 1987 (Andersen, 2018). In addition to a number of measures aimed at reducing inputs of nutrients to the aquatic environment, the action plan also included a marine research programme known as "Havforskningsprogram 90" (Christensen et al., 1998; Andersen, 2012). The action plan targeted agriculture, industry and urban waste-water treatment, and the successful implementation of nutrient reduction measures led to significant reductions in the inputs of both nitrogen (**Graph 1**) and phosphorus to Danish coastal waters.

"Havforskningsprogram 90" was carried out during the years 1990–1994 and focused on inputs, turn-over, direct and indirect effects of nutrient enrichment in Danish coastal and marine waters (Christensen et al., 1998). The results of the research program, together with eutrophication research results from other parts of the world, were presented at Elsinore, Denmark, at EUTRO 1993, organized by the Danish Environmental Protection Agency in collaboration with the Commission of the European Communities, Directorate-General for Science, Research and Development. Although the concepts of marine eutrophication were discussed before EUTRO 1993, this symposium clearly contributed to its definition (e.g., Nixon, 1995) and highlighted the drivers of nutrient enrichment and eutrophication as well as the biological responses to different nutrient regimes (e.g., Duarte, 1995). EUTRO 1993 reported the experiences from the first generation of nutrient management strategies, i.e., the Danish Action Plan on the Aquatic Environments and the 50% reduction targets adopted by HELCOM and OSPAR (Andersen, 2012). The Symposium Proceedings were

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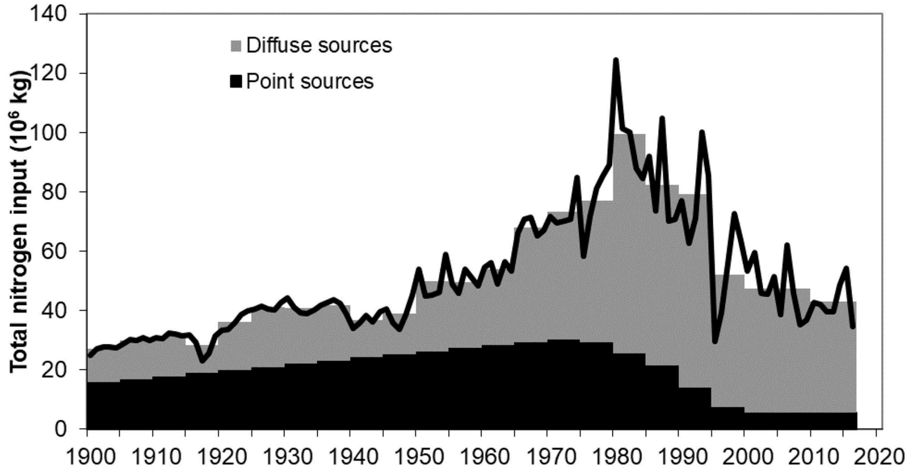

GRAPH 1 | Trends in estimated total nitrogen inputs (annual and 5-year averages, partitioned into diffuse and point sources) from Denmark to the Danish Straits, including the Kattegat. Nutrient inputs are partly based on monitoring data and models (Conley et al., 2007; Riemann et al., 2016). The decline in inputs is a consequence of policies and implementation of measures targeting agriculture, industries and cities. Updated from Andersen and Conley (2009a).

published in Ophelia—International Journal of Marine Biology as Volumes 41 and 42 and included several seminal papers (e.g., Aksnes et al., 1995; Duarte, 1995; Heip, 1995; Legendre and Rassoulzadegan, 1995; Nixon, 1995; Paerl, 1995; Richardson and Heilman, 1995).

EUTRO 2006, or in full "Research and Management of Eutrophication in Costal Ecosystems—An International Symposium," took place 20–23 June 2006 in Nyborg, Denmark and was organized by the Danish Environmental Protection Agency, the Swedish Environmental Protection Agency, Fyn County and DHI Water & Environment. EUTRO 2006 followed the adoption and implementation of the EU Water Framework Directive (WFD; European Commission, 2000) and the US assessment of eutrophication in the nation's estuaries (Bricker et al., 1999). Hence, EUTRO 2006 focused not only on drivers of eutrophication and biological responses to changes in nutrient input but also on different approaches for assessing eutrophication status of coastal ecosystems. At this symposium, Nixon (2009) presented the definition of oligotrophication. The symposium also focused on different modeling tools and Decision Support Systems, e.g., the Baltic Nest system (Savchuk, 2007). EUTRO 2006 Symposium Proceedings were published in Hydrobiologia (Andersen and Conley, 2009b) and included the seminal papers Conley et al. (2009a,b) and Nixon (2009), as well as a synthesis paper by Duarte (2009).

EUTRO 2010, the "Third International Symposium on Research and Management of Eutrophication in Coastal Ecosystems" took place 15–18 June 2010 and was organized by the International Council for Exploration of the Sea (ICES), the US National Oceanographic and Atmospheric Agency (NOAA) and DHI. A synthesis paper with the title "The Eutrophication Commandments" was published by Fulweiler et al. (2012).

EUTRO 2018 "International Symposium on Nutrient Dynamics in Coastal and Estuarine Environments" took place 18–20 June 2018 in Nyborg, Denmark and marked the 25th anniversary of the first symposium. The EUTRO 2018 presentations underlined that, today, more than 25 years after EUTRO 1993, we have a conceptual understanding of both eutrophication and oligotrophication as well as documentation of management strategies having the potential to transform eutrophication trajectories toward ecosystem recovery. However, several presentations highlighted that systemic time lags may slow down recovery and that it may take decades, if not centuries, before the results of management actions are fully seen (e.g., Murray et al.).

EUTRO 2018 was comprised of seven keynote presentations, two thematic workshops, 49 oral presentations and a symposium summary. The themes for the oral presentations were:

1. Phytoplankton and harmful algae blooms
2. Assessment and management tools
3. Benthic communities
4. Land-use and nutrients
5. Mitigation, oligotrophication, and recovery
6. Monitoring, remote sensing, and modeling.

Themes for the thematic workshops were "From monitoring data to integrated assessments" and "Steps toward a harmonized assessment of eutrophication in Europe's seas." For detailed information about EUTRO 2018, please refer to the EUTRO 2018 programme and book of abstracts (Andersen, 2018).

Theme 1 included three original research papers on phytoplankton and harmful algae blooms, one from Kuwait Bay and the Northern Persian Gulf, one from the Western Iberian and one from Ireland:

- Phytoplankton data (2007–2016) from Kuwait Bay and the Northern Persian Gulf document that seasonal and interannual dynamics of plankton communities are linked to land-based inputs of nutrients as well as climate and salinity changes. The combination of nutrient inputs and a warming

climate may, moreover, have long-term consequences on the environmental conditions (Devlin et al.).
- On the Western Iberian Coast, drivers of phytoplankton biomass over the period 1998–2016 show spatial differences between the northern oceanic regions and oceanic regions. Furthermore, coastal regions responded to both offshore processes (Atlantic Multidecadal Oscillation) and coastal processes such as upwelling and inputs from upstream catchments (Ferreira et al.).
- Irish long-term monitoring data, analyzed with a newly developed phytoplankton index, provided evidence that not only does the new index perform well against current methods to determine ecological status, it also shows better agreement with other WFD parameters, both biological and physico-chemical. Use of the phytoplankton index ensures compliance with WFD method requirements and improves understanding and assessment of the eutrophication status of estuarine water bodies by linking variations in dissolved inorganic nitrogen concentration and forms, temperature, and light conditions (Longphuirt et al.).

Four papers were presented under theme 2 on assessment and management tools:

- Greenwood et al. studied eutrophic conditions in the Thames Estuary and Liverpool Bay, UK. They highlight that, despite significant reductions in nutrient loads, especially phosphorus, the currently available tools or metrics do not document significant improvements in ecological status. They, therefore, suggest including a phytoplankton life form tool in future assessments.
- Based on data and results of the second UK application of the OSPAR Common Procedure (COMP) for eutrophication, García-García et al. used this UK case study to develop a generic system to (1) evaluate an observational network from a multi-variable point-of-view, (2) introduce additional datasets in the assessment, and (3) propose an optimized monitoring program for UK marine waters.
- Friedland et al. assessed the past and current management of nutrient loads and eutrophication in the Szczecin (Oder) Lagoon, a transboundary water body shared by Germany and Poland. They conclude that it is unlikely that the lagoon can be transformed to a non-eutrophied state, even if agreed load reductions are fully implemented. They, therefore, propose mussel cultivation in the lagoon as a supplementary measure to nutrient reductions in the upstream catchment to improve water quality in the lagoon.
- Stoicescu et al. used sub-surface oxygen concentrations to assess the overall Eutrophication Status in the Gulf of Finland (Baltic Sea), examining two different indicators: (1) the HELCOM oxygen debt indicator, and (2) a novel oxygen consumption indicator. The study concludes that both indicators can be improved, especially if monitoring frequencies are increased.

Theme 3 on benthic communities contained four papers:

- The starting point for Christie et al. is the suggestion that the large-scale replacement of sugar kelp by turf algae (ephemeral, filamentous algae) in southern Norway around the year 2000 represented a possible irreversible regime shift. Based on a very large spatio-temporal dataset, the study documents that the seabed state has flipped between sugar kelp and turf algae in several areas and on temporal scales spanning from seasons to years. The paper highlights a complex spatial and temporal distribution pattern between sugar kelp and turf algae and discusses prerequisites and drivers for an irreversible regime shift or a continuation of natural fluctuations, as well as possible mitigation actions (improved coastal water quality, restoration).
- Kindeberg et al. quantify the sediment stocks of carbon, nitrogen, and phosphorus under Danish eelgrass meadows in order to help assess the role of seagrass meadows as a nature-based buffer against climate change and eutrophication. This paper also provides guidance to managers and decision-makers in selecting priority areas for climate change and eutrophication abatement initiatives.
- McGovern et al. report inter-annual changes in the occurrence of sea lettuce (*Ulva* sp.) blooms in Argideen Estuary and Courtmacsherry Bay, Ireland. Changes in agricultural practices in the upstream catchment affect macroalgae and phytoplankton bloom magnitude. Improved farm management practices may lead to a reduction in nitrogen loading on the order of 5%, but the high amounts of phosphorus stored within the catchment may, in combination with discharges from point sources, still promote increased growth of sea lettuce.
- Eelgrass (*Zostera marina*) distribution is modeled in Danish coastal waters by Staehr et al.. The model is based on essential habitat requirements for eelgrass (light availability, water temperature, salinity, frequency of low oxygen concentration, wave exposure, and sediment type). The modeled potential eelgrass distribution area in Danish was 2,204 km^2. Compared to historical estimates of around 7,000 km^2, this indicates a large potential for recovery of eelgrass meadows in Danish marine waters, provided that there are further reductions in nutrient inputs and other stressors.

Three papers related to theme 4 on land-use and nutrients:

- Flo et al. introduce a tool, "Land Uses Simplified Index" (LUSI), which can be used for estimation of upstream pressures and for linking these to downstream coastal eutrophication signals. LUSI not only fulfills a methodological gap as a simple method to assess coastal pressures when information is lacking, but also complies with the requirements of the WFD for coastal pressure assessments.
- Lenhart and Große assess potential effects of planned nutrient reductions around the North Sea by combining an element tracing method (TBNT) with a biogeochemical model. The study reveals that non-linear responses in the biogeochemistry may enhance removal of nitrogen (N) from rivers through benthic denitrification in areas subject to strong nutrient load

reductions. This, in turn, may indirectly increase the removal of N from less reduced sources. Accordingly, reductions in remote sources in areas not suffering from eutrophication can have a positive effect on areas where eutrophication is a problem.

- The establishment of nutrient criteria (i.e., assessment criteria for nutrient concentrations) for European marine, coastal, and transitional waters can be supported by the statistical approach developed by Salas Herrero et al.. The approach proved sufficient for coastal lagoons but cannot stand alone when developing nutrient criteria for a variety of coastal water types.

Two papers are included from theme 5 on mitigation, oligotrophication, and recovery:

- van Beusekom et al. describe long-term trends in key eutrophication indicators in the Wadden Sea and document (1) continuously decreasing nitrogen inputs since 1977 at a rate of 2.5% per year, (2) decreasing phosphorus input from 1977 to 1990 at a rate of 8% per year with a stabilization thereafter, and (3) decreasing chlorophyll a concentrations since the 1980s.
- Long-term temporal and spatial trends in oxygen concentrations in the Chesapeake Bay show improving trends in large parts of the bay over the past three decades (1985–2016) (Zhang et al.). For the period 2000–2016, 24 segments out of 120 showed significant improving trends. However, the lack of generally improving trends across Chesapeake Bay suggests that further reductions in nutrient loading are necessary for full attainment of the criteria for oxygen concentrations.

Both papers highlight specific effects of reduced nutrient inputs and document that the two systems have started to recover.

Two papers are related to theme 6 on monitoring, remote sensing, and modeling:

- Harvey et al. analyse the effects of coastal optical properties on Secchi depth in the Baltic Sea and discuss potential implications for eutrophication management. When applying national WFD chlorophyll-a thresholds values, the study documents that Secchi depth, at least for the sub-regions studied, is not a reliable indicator for eutrophication or for changes in chlorophyll-a concentrations.
- Past, present and future eutrophication status of the Baltic Sea is assessed by Murray et al. based on a combination of monitoring data and modeling covering a 350-year period (1850–2200). The paper concludes that some Baltic Sea basins may recover from eutrophication within decades, whilst other basins will be affected by eutrophication for much longer. The paper's results confirm that the vision and goals of HELCOM Baltic Sea Action Plan, i.e., a healthy Baltic Sea unaffected by eutrophication, are possible. It should be noted, however, that this study does not include impacts of climate change.

The review papers by Boesch and Deininger and Frigstad cover two different aspects in relation to eutrophication and oligotrophication:

- Barriers and bridges in abating coastal eutrophication are reviewed by Boesch and several key lessons are identified: (1) Eutrophication abatement has proven a more recalcitrant challenge than anticipated, (2) reductions in nutrient loads have come mainly from advanced treatment of waste water and have lagged targets set for diffuse agricultural sources, (3) a synthesis of major policies, strategies, and campaigns identifies barriers inhibiting eutrophication abatement and potential bridges to overcome them, (4) outcomes of policies and strategies must be followed by both adequate monitoring and assessment activities as well as timely adjustment of the strategies if the goals are not met, and (5) climate change must be taken into account by reassessing attainable future conditions.
- Deininger and Frigstad review the concepts of "greening" (eutrophication), "browning," and "darkening" of optical properties of sea water with a special focus on the importance of terrestrially-derived organic matter. The review concludes that inclusion of all organic matter sources (also terrestrial) is important to achieve a better understanding both eutrophication and oligotrophication processes in coastal ecosystems.

A mini review by Duarte and Krause-Jensen advocates for a broader, more comprehensive approach to reduce eutrophication that considers all major pathways of nutrient budgets of coastal ecosystems, i.e., nutrient inputs, where intervention is most commonly deployed, nutrient export, sequestration in sediments, and nitrogen emissions to the atmosphere as N_2 gas (denitrification). The proposed supplementary management levels involve local-scale hydrological engineering to increase flushing and nutrient export from (semi)enclosed coastal systems, ecological engineering such as sustainable aquaculture of seaweeds and mussels to enhance nutrient export and restoration of benthic habitats to increase sequestration and denitrification in sediments. These ecosystem-scale interventions should be complemented with policy actions to protect benthic ecosystem components.

The papers included in this Research Topic not only take stock of progress regarding our understanding of eutrophication and oligotrophication of coastal marine waters but also represent a perspective on the future. From the results presented at EUTRO 2018, it is obvious that eutrophication trends have been reversed in some coastal systems, e.g., Chesapeake Bay (Zhang et al., 2018), the Danish coastal waters (Riemann et al., 2016), the Baltic Sea (Murray et al.), the Wadden Sea (van Beusekom et al.), and that these systems now display an oligotrophication phase, with various degrees of recovery and restoration toward a more natural ecosystem structure and functioning. We expect a growing number of scientific publications focusing on ecosystem-based management strategies, reduction of loads, oligotrophication and recovery in the coming years.

Today, we understand that individual coastal ecosystems respond in idiosyncratic ways to changes in nutrient inputs and that these systems are controlled by multiple stressors, including, but not limited to nutrient inputs and climate change. Thus, eutrophication cannot be abated only through reduction in nutrient loading. Additional management strategies targeting other controlling factors and stressors and considering effects of climate change are also required. It is also important to recognize that recovery processes may span several decades.

In 2023, we plan to follow up on EUTRO 2018 and this Research Topic by organizing EUTRO 2023, the "Fifth International Symposium on Research and Management of Eutrophication in Coastal Ecosystems." The EUTRO 2023 symposium is in the planning stage and will take place in Nyborg, Denmark in June 2023. EUTRO 2023 will be organized by institutions representing scientists from universities and research organizations, as well as practitioners from competent authorities and stakeholder organizations.

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All authors contributed to designing and writing this editorial based on a draft prepared by JA.

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REFERENCES

Aksnes, D. L., Ulvestad, K. B., Balino, B. M., Berntsen, J., Egge, J. K., and Svendsen, E. (1995). Ecological modelling in coastal waters: towards predictive physical-chemical-biological simulation models. *Ophelia* 41, 5–36. doi: 10.1080/00785236.1995.10422035

Andersen, J. H. (2012). *Ecosystem-based management of coastal eutrophication. Connecting science, policy and society* (Ph.D. thesis). University of Copenhagen, 56 + annexes. Available online at: http://www.bi.ku.dk/bibliotek/phd/Jesper%20Andersen.pdf

Andersen, J. H. (ed.). (2018). "EUTRO 2018," in *4th International Symposium on Research and Management of Eutrophication in Coastal Ecosystems: Programme and book of abstracts. 18-20 June 2018* (Nyborg), 49. Available online at: https://www.researchgate.net/publication/325783533_4th_International_Symposium_on_Research_and_Management_of_Eutrophication_in_Coastal_Ecosystems_Programme_and_book_of_abstracts

Andersen, J. H., and Conley, D. J. (2009a). Eutrophication in coastal marine ecosystems: towards better understanding and management strategies. *Hydrobiologia* 629, 1–4. doi: 10.1007/s10750-009-9758-0

Andersen, J. H., and Conley, D. J. (eds.). (2009b). Eutrophication in coastal ecosystems. *Hydrobiologia*. 629:269. doi: 10.1007/978-90-481-3385-7

Bricker, S., Clement, C. G., Pirhalla, D. E., Orlando, S. P., and Farrow, D. R. G. (1999). *National Estuarine Eutrophication Assessment: Effects of Nutrient Enrichment in the Nation's Estuaries*. Silver Spring, MD: NOAA, National Ocean Service, Special Projects Office and the National Centers for Coastal Ocean Science. Available online at: https://repository.library.noaa.gov/view/noaa/1693/noaa_1693_DS1.pdf

Christensen, P. B., Møhlenberg, F., Lund-Hansen, L. C., Borum, J., Christiansen, C., Larsen, S., et al. (1998). The Danish marine environment: has action improved its state? *Havforsk. Miljøstyrelsen* 62:120.

Conley, D. J., Carstensen, J., Aertebjerg, G., Christensen, P. B., Dalsgaard, T., Hansen, J. L. S., et al. (2007). Long term changes and impact of hypoxia in Danish coastal waters. *Ecol. Appl.* 17, S165–S184. doi: 10.1890/05-0766.1

Conley, D. J., Carstensen, J., Vaquer-Sunyer, R., and Duarte, C. M. (2009a). Ecosystem thresholds with hypoxia. *Hydrobiologia* 629, 21–29. doi: 10.1007/s10750-009-9764-2

Conley, D. J., Paerl, H. W., Howarth, R. W., Boesch, D. F., Seitzinger, S. P., Havens, K. E., et al. (2009b). Controlling eutrophication: nitrogen and phosphorus. *Science* 323, 1014–1015. doi: 10.1126/science.1167755

Duarte, C. M. (1995). Submerged aquatic vegetation in relation to different nutrient regimes. *Ophelia* 41, 87–112. doi: 10.1080/00785236.1995.10422039

Duarte, C. M. (2009). Coastal eutrophication research: a new awareness. *Hydrobiologia* 629, 263–269. doi: 10.1007/s10750-009-9795-8

European Commission (2000). *Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 Establishing a Framework for Community Action in the Field of Water Policy*. Official Journal of the European Union, L327, 1–72.

Fulweiler, R. W., Rabalais, N. N., and Heiskanen, A. S. (2012). The eutrophication commandments. *Mar. Pollut. Bull.* 64, 1997–1999. doi: 10.1016/j.marpolbul.2012.07.025

Heip, C. (1995). Eutrophication and zoobenthos dynamics. *Ophelia* 41, 113–136. doi: 10.1080/00785236.1995.10422040

Legendre, L., and Rassoulzadegan, L. (1995). Plankton and nutrient dynamics in marine waters. *Ophelia* 41, 153–172. doi: 10.1080/00785236.1995.10422042

Nixon, S. W. (1995). Coastal marine eutrophication: a definition, social causes, and future concerns. *Ophelia* 41, 199–219. doi: 10.1080/00785236.1995.10422044

Nixon, S. W. (2009). Oligotrophication and the macroscope. *Hydrobiologia* 629, 5–19. doi: 10.1007/s10750-009-9759-z

Paerl, H. W. (1995). Coastal eutrophication in relation to atmospheric nitrogen deposition: current perspectives. *Ophelia* 41, 237–259. doi: 10.1080/00785236.1995.10422046

Richardson, K., and Heilman, J. P. (1995). Primary production in the Kattegat: past and present. *Ophelia* 41, 317–328. doi: 10.1080/00785236.1995.10422050

Riemann, B., Carstensen, J., Dahl, K., Fossing, H., Hansen, J. W., Jakobsen, H. H., et al. (2016). Recovery of Danish coastal ecosystems after reductions in nutrient loading: trends and time lags. *Estuar. Coasts* 39, 82–97. doi: 10.1007/s12237-015-9980-0

Savchuk, O. and Wulff, F. (2007). Modelling the Baltic Sea eutrophication in a decision support system. *Ambio* 36, 141–148. doi: 10.1579/0044-7447(2007)36[141:MTBSEI]2.0.CO;2

Zhang, Q., Murphy, R. R., Tian, R., Forsyth, M. K., Trentacoste, E. M., Keisman, J., et al. (2018). Chesapeake Bay's water quality condition has been recovering: insights from a multimetric indicator assessment of thirty years of tidal monitoring data. *Sci. Total Environ.* 637–638, 1617–1625. doi: 10.1016/j.scitotenv.2018.05.025

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.