Marine Biodiversity (2025) 55:110
https://doi.org/10.1007/s12526-025-01593-2

SENCKENBERG

EDITORIAL

The 15th International Scientific Wadden Sea Symposium—the challenge of talking about real nature in a virtual environment

Christian Buschbaum[1] · Kai Eskildsen[2] · Stefan Garthe[3] · Helmut Hillebrand[4,5,6] · Ulrike Schückel[2] · Ursula Siebert[7]

Following the long history of the International Wadden Sea Symposium, which was launched in 1975, the 15th edition was a very special one. The symposium entitled "*Importance of Science for the management of the Wadden Sea World Heritage in the context of climate change*" took place from 30 November to 2 December 2021, at a time when the coronavirus pandemic dominated all human activity worldwide, including the way scientific knowledge was shared. Since it was not possible for participants to meet in person, there were only two options: cancel the symposium or use a virtual platform. The organisers of the National Park Authority in Schleswig Holstein (Germany) with the support of the Common Wadden Sea Secretariat opted for option two, which was a good decision but presented a huge challenge. However, it was the only possible strategy for maintaining the important and intensive exchange within the trilateral scientific Wadden Sea community and for strengthening the Wadden Sea Cooperation, thereby setting the course for future research priorities and improved protection of the Wadden Sea. Despite the unusual format, it was intensively accepted and more than 200 participants joined the symposium on the virtual platform. Around fifty oral presentations and more than twenty posters, as well as breakout groups organised into six thematic sessions (1. Birds 2. Marine mammals 3. Alien species 4. Sublittoral habitats 5. Sustainable development 6. International perspective) formed the basis for discussions, cooperations and the development of visions on an overarching and interdisciplinary level. This intensive exchange between scientists, managers, politicians and nature conservation organisations resulted in recommendations for science and management, which are traditionally a product of each scientific Wadden Sea Symposium. The recommendations were presented at the symposium with the aim to improve research, monitoring and assessment and to preserve the exceptional universal value of the Wadden Sea ecosystem in the context of climate change (Fig. 1).

A further outcome of the 15th International Wadden Sea Scientific Symposium is this topical collection of articles with the overarching theme *"Biodiversity and Ecology of the Wadden Sea under changing environments"*, which aims to improve the knowledge about the current state of the biodiversity and ecology in the Wadden Sea ecosystem. A total of 12 articles has been published (ten original papers and two review articles). They deal with biodiversity patterns and dynamics of the platyhelminth fauna in different habitats, with the diversity of phytoplankton communities on a large spatial scale and with macrofaunal organisms associated with mollusc shell detritus in the subtidal zone. Other aspects are long-term developments over a time span of several decades with a focus on salt marshes, and harbour porpoise populations. An additional major theme of the topical collection is the occurrence, distribution and the overarching effects of introduced organisms including the perception of their consequences by the society. Climate change, in conjunction with increasing CO_2-concentrations, higher

✉ Christian Buschbaum
christian.buschbaum@awi.de

1 Alfred Wegener Institute (AWI), Helmholtz Centre for Polar and Marine Research, Wadden Sea Station Sylt, List, Germany

2 Schleswig-Holstein Agency for Coastal Defence, National Park and Marine Conservation, National Park Authority, Tönning, Germany

3 Research and Technology Centre (FTZ), Kiel University, Büsum, Germany

4 Institute for Chemistry and Biology of Marine Environments (ICBM), University of Oldenburg, Wilhelmshaven, Germany

5 Helmholtz Institute for Functional Marine Biodiversity at the University of Oldenburg (HIFMB), Oldenburg, Germany

6 Alfred Wegener Institute (AWI), Helmholtz Centre for Polar and Marine Research, Bremerhaven, Germany

7 Intitute for Terrestrial and Aquatic Wildlife Research, University of Veterinary Medicine Hannover Foundation, Hannover, Germany

Published online: 18 November 2025

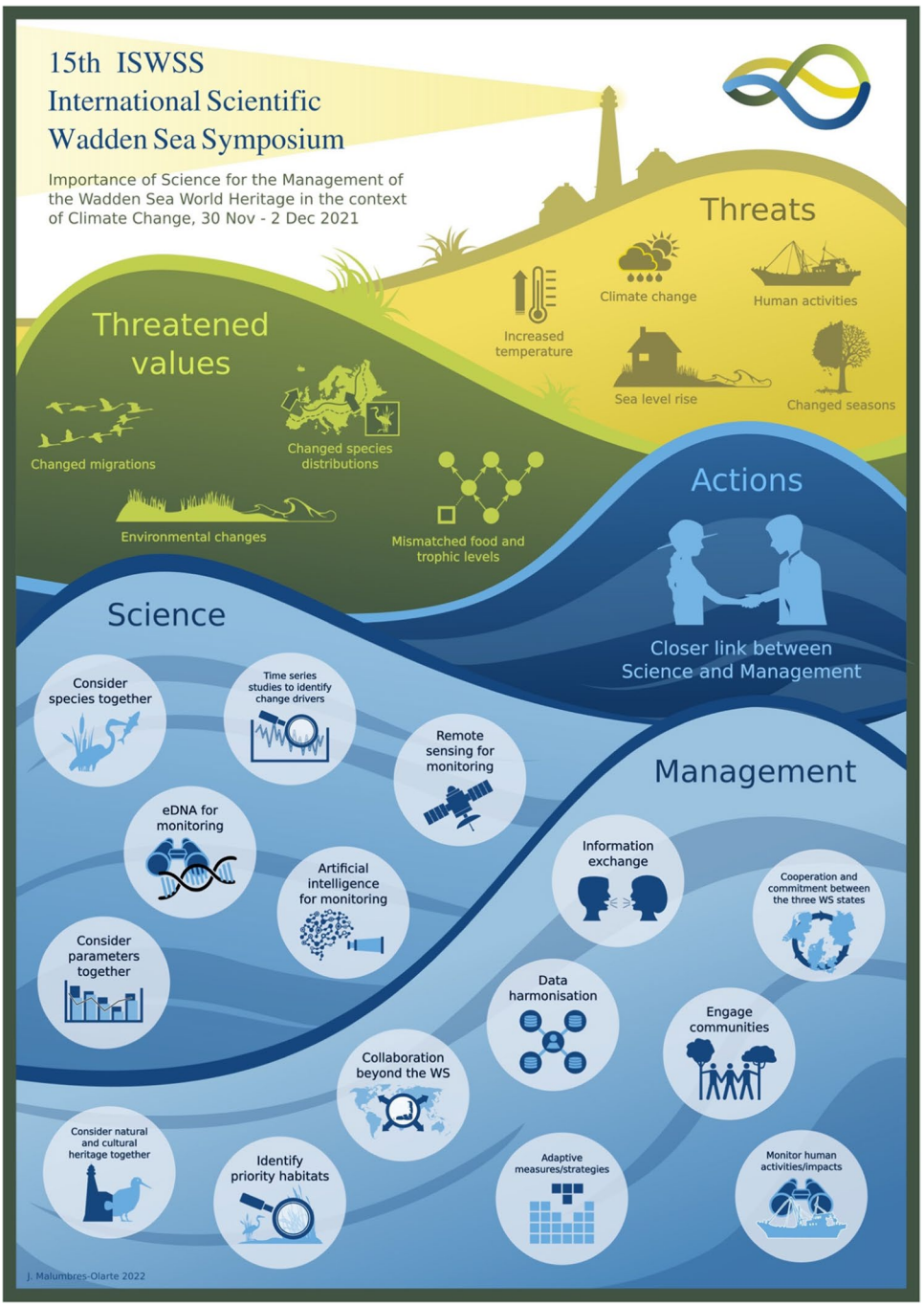

Fig. 1 Overview of the recommendations of the 15th International Wadden Sea Symposium

temperatures and sea level rise, is considered one of the greatest threats to the Wadden Sea ecosystem. In this context, it is shown how salt marsh plants, benthos-feeding waterbirds and an entire sub-region in the northern Wadden Sea are responding to the changing conditions. Finally, the diet composition in different habitats of a single fish species is presented, which could fill an important knowledge gap in fish ecology in the Wadden Sea. For a more detailed description of the contributions, they can be grouped into the following subject areas:

1) Biodiversity patterns

Armonies (2023) summarises around half a century of work on the diversity of the platyhelminth fauna near the island of Sylt in the northern Wadden Sea on the basis of a meta-analysis. The study provides an impressive list of more than 400 platyhelminth species found in this area, whose occurrence is strongly dependent on the ranges of environmental factors. In addition, nineteen newly encountered species are comprehensively described.

A similar comprehensive approach was conducted by Di Cavalho et al. (2023), who analysed long-term monitoring datasets of phytoplankton communities which cover a period of almost two decades and are provided by Dutch and German coastal stations. They used several biodiversity descriptors to identify temporal trends in phytoplankton in different areas of the Wadden Sea. The authors could show that the phytoplankton development patterns differ between the Dutch and German areas, underscoring the importance of continuous and harmonised monitoring programmes in different regions of the Wadden Sea.

A long-term analysis is also presented by Michaelis et al. (2024), who focus on a single salt marsh in the central Wadden Sea (Lower Saxony, Germany) and describing its development in terms of surface elevation, sediments, vegetation and bottom fauna under the influence of various human activities of varying intensities. This study documents in detail the succession from a bare tidal flat to a vegetated salt marsh over a time-period of 40 years and can therefore serve as an important case-study for the development of transitional habitats between sea and land in view of the accelerated sea level rise.

2) Alien species

Over the past century, more than a hundred non-native species have been introduced from overseas and have successfully established in the Wadden Sea region, where they influence native biodiversity and existing species interactions (Buettger et al. 2022; Lackschewitz et al. 2022). A non-native species that has recently appeared in the Wadden Sea is the dwarf mussel *Mulinia lateralis*, which was first discovered in European waters in 2017. Gismann et al. (2023) describe the abundance, population structure and spatial distribution of *M. lateralis* in the southern Wadden Sea and come to the conclusion that, like other introduced species, *M. lateralis* has spread eastwards via larval drift. This pattern of expansion has led to *M. lateralis* now also occurring in the northern Wadden Sea.

The general development and impact of introduced species in the Wadden Sea ecosystem were summarised in a review by Reise et al. (2023). The study provides an overview of the history of non-native species, from the first known alien species introduced by the Vikings to recent introductions, and also presents possible scenarios for the occurrence of non-native species in the future. In addition, the effects of non-native species on the structure of the food web in the Wadden Sea, as well as its habitat complexity and stability, is considered. The authors conclude from their study that introduced species have not adversely affected the ecosystem so far, but may even have improved the ability of the Wadden Sea to adapt to increasing environmental changes.

Introduced species not only influence ecological processes, but also have social impacts that have not yet been sufficiently studied in the Wadden Sea region. In a social science study, Kötter-Lange et al. (2023) investigated the extent to which introduced species affect people living on the Wadden Sea coast and how people perceive the newcomers. The exploratory study shows that, regardless of their actual impact, introduced species are generally viewed with scepticism or rejection. In this context, there are particular concerns about the loss of the intangible values of the Wadden Sea, such as its recreational potential and cultural identity.

3) Climate change effects

The Wadden Sea is warming faster than many other coastal systems worldwide. Koop-Jakobsen and Dolch (2023) investigated the effects of a warmer climate with higher CO_2-concentrations and rising temperatures on salt marsh vegetation in a manipulative mesocosm experiment. The results show that the cordgrass *Spartina anglica*, which dominates the pioneer zone, responds differently in its aboveground and belowground biomass production. Enhanced CO_2-concentrations led to an increase in aboveground biomass, while belowground biomass increased at higher temperatures. The low marsh dominating sea couch grass *Elymus athericus*, by contrast, showed no response to higher CO_2-concentrations, neither in aboverground nor in belowground biomass. The different responses of salt marsh dominating plant species to changing environmental conditions are discussed in the context of a future climate scenario.

The effects of climate change are also considered by Laursen et al. (2025), who focus on benthos-feeding waterbirds in the Wadden Sea during their stop-over. The study analysed the potential factors for the overall decline of waterbirds in the Wadden Sea. It reveals that the North Atlantic Oscillation Index (NAO) and a reduced annual discharge of nutrients from rivers, which can lead to a reduction of biomass of macrozoobenthos, play an important role. Other factors, such as sea level rise and the accretion and erosion of tidal flats, mainly affect the spatial distribution of waterbirds in the Wadden Sea region.

The full range of known impacts of climate change on a specific region in the northern Wadden Sea is summarised by Buschbaum and Shama et al. (2024). The coastal morphology and hydrodynamics are influenced by sea level rise, which can alter the composition and functioning of the habitats in this area. Warming is already influencing species interactions, genetic and phenotypic adaptation mechanisms of species, and the structure of food webs. This review article shows that the effects of climate change are already clearly reflected at all levels of the Wadden Sea ecosystem.

4) Population ecology

The Wadden Sea offers a variety of habitats that are important for the reproduction and feeding of many fish populations. Schückel et al. (2024) examined the stomach contents of the hooknose (*Agonus cataphractus*) in different habitats and show that, regardless of the specific habitat type, this species mainly feeds on mobile epibenthic prey species, while infaunal organisms were rarely consumed. However, the habitat type influenced the condition of the hooknose, underscoring the importance of habitat heterogeneity in the Wadden Sea.

Scheidat et al. (2024) also used a large-scale approach investigating the spatial distribution patterns and long-term dynamics of the harbour porpoise (*Phocoena phocoena*), taking into account both the offshore area of the North Sea and the entire Wadden Sea. The results provide comprehensive information on the seasonal movements of the animals between offshore and coastal areas, but also show that some *P. phocoena* individuals using the Wadden Sea area have limited activity ranges throughout the year. This specific behaviour highlights the importance of the Wadden Sea for this species, even though it is highly mobile and also makes intensive use of the open North Sea as a habitat. In addition, the study identifies fundamental differences in monitoring activities for harbour porpoises between the countries bordering the Wadden Sea and, therefore, provides comprehensive recommendations for improved and better harmonised monitoring activities, including data collection and processing.

This topical collection highlights important aspects on how the Wadden Sea, including its organisms, species interactions and habitats, is being affected by the increasingly rapid environmental changes due to climate change. Together with the results of the breakout sessions and their recommendations, this can be an important contribution to the development of future research priorities and mitigation and management strategies to preserve the global significance and uniqueness of the Wadden Sea and its outstanding universal values.

The editors would therefore like to thank all participants of the 15th International Wadden Sea Symposium for their important contributions, as well as all authors and the reviewers for their invaluable work, which made this topical collection possible.

Funding Open Access funding enabled and organized by Projekt DEAL. Christian Buschbaum acknowledges support by the Open Access publication fund of Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung.

Declarations

Ethical approval No animal testing was performed during this study.

Conflict of interests The authors declare no competing interests.

Sampling and field studies For this manuscript, no sampling and field studies were conducted.

Data availability No additional data were collected and all data are available in the original papers.

Author contribution Conceptualization: CB; writing, review and editing: CB, KE, SG, HH, US, US. All the authors have read and approved the manuscript.

References

Armonies W (2023) Platyhelminth fauna of the island of Sylt: a meta-analysis of distributional patterns and description of 19 new species. Mar Biodivers 53:17. https://doi.org/10.1007/s12526-022-01309-w

Buettger H, Christoph S, Buschbaum C, Gittenberger A, Jensen K, Kabuta S, Lackschewitz D (2022) Alien species. In: Kloepper S et al (eds) Common Wadden Sea Secretariat. Wilhelmshaven, Germany. qsr.waddensea-worldheritage.org/reports/alien-species

Buschbaum C, Shama LNS, Amorim FLL, Brand S, Broquard CMA et al (2024) Climate change impacts on a sedimentary coast – a regional synthesis from genes to ecosystems. Mar Biodivers 54:64. https://doi.org/10.1007/s12526-024-01453-5

Di Cavalho JA, Rönn L, Prins TC, Hillebrand H (2023) Temporal change in phytoplankton diversity and functional group composition. Mar Biodivers 53:72. https://doi.org/10.1007/s12526-023-01382-9

Gismann L, Wenke L-K, Uhlir C, Arbizu PM, Wehrmann A (2023) Status and occurrence of the non-indigenous dwarf surf clam *Mulinia lateralis* (Say, 1822) in the central Wadden Sea (southern North Sea) - a systematic survey. Mar Biodivers 53:83. https://doi.org/10.1007/s12526-023-01381-w

Koop-Jakobsen K, Dolch T (2023) Future climate conditions alter biomass of salt marsh plants in the Wadden Sea. Mar Biodivers 53:41. https://doi.org/10.1007/s12526-023-01347-y

Kötter-Lange K, Lienhoop N, Buschbaum C (2023) Effects and perception of marine introduced species by stakeholders in the Wadden Sea – an exploratory approach. Mar Biodivers 53:58. https://doi.org/10.1007/s12526-023-01358-9

Lackschewitz D, Reise K, Buschbaum C, Karez R (2022) Neobiota der deutschen Nord- und Ostseeküste. Eingeschleppte Arten in deutschen Küstengewässern. LLUR SH - Gewässer D25, Flintbek, Germany, 394

Laursen K, van Beusekom JEE, Bregnballe T, Kleefstra R, Frikke J, Günther K, Hälterlein B, Hornman M, Ludwig J, Meyer J, Scheiffarth G, Pedersen CL, Møller AP (2025) Climate and de-eutrophication affect abundance of benthos-feeding waterbirds in the Wadden Sea during stop-over. Mar Biodivers 55:66. https://doi.org/10.1007/s12526-025-01554-9

Michaelis H, Arens S, Ladage F (2024) Forty years of a salt marsh formation in the Wadden Sea: surface elevation, sediments, vegetation and bottom fauna. Mar Biodivers 54:32. https://doi.org/10.1007/s12526-024-01421-z

Reise K, Buschbaum C, Lackschewitz D, Thieltges DW, Waser AM, Wegner KM (2023) Introduced species in a tidal ecosystem of mud and sand: curse or blessing? Mar Biodivers 53:5. https://doi.org/10.1007/s12526-022-01302-3

Scheidat M, Vrooman J, Teilmann J, Baltzer J, Thøstesen CB, Diederichs B, Dietz R, Geelhoed SCV, Gilles A, IJsseldijk LL, Keijl GO, Nabe-Nielsen J, Ruser A, Schnitzler J, Sveegaard S, Siebert U (2024) Harbour porpoise (*Phocoena phocoena*) in the Wadden Sea World Heritage Site and requirements for trilateral monitoring. Mar Biodivers 54:42. https://doi.org/10.1007/s12526-024-01428-6

Schückel S, Rothmeyer J, Jaklin S, Heubel K, Schückel U (2024) Diet composition of the hooknose (*Agonus cataphractus*, L.) in different habitats of coastal waters in the German Wadden Sea (southern North Sea). Mar Biodivers 54:66. https://doi.org/10.1007/s12526-024-01455-3