

Trilateral Swimway Conference 2024

32nd symposium Waddenacademie

Applying scientific evidence to manage
human impacts on fish life cycles

17-19 April

Groningen, The Netherlands

Book of Abstracts





THURSDAY

18

Morning

9:30-10:15 - **Keynote:** How can ecosystem-based management support coastal fish, and how can science contribute

Lena Bergström, Swedish University of Agricultural Sciences, Department of Aquatic Resources

Coastal fish often have high socio-economic value for commercial and recreational fisheries, but they also play crucial ecological roles. Large predatory fish are important for structuring the food web. Fish that migrate between freshwaters and coast, or between the coast and open sea, are important for connecting ecosystems. Other coastal fish remain local but can be significant as predators or prey on migrating species. Climate change and a multitude of pressures affect the status of coastal fish throughout their life cycle, making it evident that broad approaches are needed for their sustainable management. Ecosystem-based management means that all decisions that affect or concern nature should apply a holistic perspective, considering the wide range of dependencies that occur among populations and their environment. It also recognizes the multiple values that ecosystems provide, and hence the trade-offs that arise under management priorities. Although few arenas are available today for operationalizing ecosystem-based management approaches for coastal fish, initiatives and research are growing. I will show examples of emerging ecosystem-based initiatives supporting coastal fish at local, national and regional levels in the Baltic Sea and of the role of science in these, including some success factors and challenges.

ROOM

1

Auditorium

MAKING ROOM FOR FISH: RUIJ BAAN VOOR VISSSEN

Chairs: Jeroen Huisman & Peter Paul Schollema

Session 1

11:15-11:45 - **Keynote:** Science and management achieving connectivity, coherence and equivalence to ensure the health of estuarine fish communities

Mike Elliott & Alan Whitfield, International Estuarine & Coastal Specialists, School of Environmental Sciences, University of Hull & South African Institute of Aquatic Biodiversity (SAIAB)

The essence of an appropriate and expected structure and function of healthy and sustainable estuarine fish communities lies in achieving and maintaining ecological connectivity between the systems. This connectivity includes a knowledge of the associated components of, and links with, the marine and catchment areas. Ensuring such a connectivity involves removing, preventing or overcoming pressures, barriers and impediments to the ecological functional connectivity along the continuum between riverine, estuarine and marine systems. Those barriers may be physical structures or related to adverse water quality. It also involves an understanding of how climate change may impact on current connectivity between estuaries and adjacent marine and freshwater aquatic ecosystems. Coherence in marine environmental management has recently been defined as the ability to have the same management and governance measures in different areas that will achieve the same outputs and outcomes of management; in contrast, equivalence has been defined as having different management and governance measures in different areas but again that will produce the same outcomes. Using estuary-associated marine, diadromous and estuarine resident fish species examples from at least Europe and southern Africa, this presentation illustrates these concepts and shows the natural and social sciences aspects required to achieve healthy and sustainable estuarine fish populations and communities.

11:45-12:00 - **Migration of silver eel through the Rozema pumping station: a complex situation at the edge of the Dutch Wadden Sea**

van der Knaap, I., van Eerbeek, J., Schollema, P. P., Huisman, J

Numerous dikes, sluice complexes, and pumping stations, form a barrier between the Dutch Sea and inland freshwater. The project 'Make way for fish 2' (RBVV2) examines specific situations in which fish have to pass such a construction on their migration route and whether or not these form a migratory barrier. One of these is the 'Rozema' pumping station which is located at Termunterzijl (Groningen) and forms a barrier between the fresh water canals and the saltwater Ems-Dollard (Wadden Sea).



Many European silver eels (*Anguilla anguilla*) have to pass this pumping station on their migration back to the Sargasso Sea. In this project, we have looked into the routes eels take that migrate toward Termunterzijl and if they pass through the Rozema pumping station. In addition, we wanted to understand if eels delay their migration or display changes in activity before they pass through the pumping station. To do so, we tagged 40 silver eels with acoustic tags (V9A) that included an accelerometer sensor measuring overall body acceleration (a proxy for activity). A network of acoustic receivers was put in place to track the tagged eels as they moved through the canal to Termunterzijl. Results show that 32 of the 40 tagged eels were detected on the Ems-Dollard and that 30 of these passed through the pumping station. We found no evidence of direct mortality and eel acceleration values remained similar after passing through the pumping station. Most eels (19/30) passed within a three day window which coincided with a period of high rainfall. Acceleration values of the eels that passed through the pumping station show a slight increase towards moment of passage, however, the data is still being analysed and final results will be presented during the conference.

12:00-12:15 - Case study pumping station Hongerige Wolf: The important role of monitoring during the implementation of fishmigration measure

Schollema, P. P.

Regional Water Authority Hunze en Aa's manages the surface water in a 213.000 hectare large area in the North-eastern part of The Netherlands. Over 160 pumping stations are in use to manage water levels in the polder systems. These play an important role in ensuring "dry feet" for the local inhabitants but also have a significant impact on fish populations. The pumping stations are a physical blockade for the free passage of fish and the canal structures needed to transport the water heavily impact the availability of suitable habitat. As part of the fishmigration plan "From Sea to Source" Water Authority Hunze en Aa's is working on possible solutions for the migration issues at pumping stations. Pumping station Hongerige Wolf is one of the locations where a new fishpass has been built to provide access from the main canal system into a large polder system. An important route for e.g. Three-Spined Stickleback (*Gasterosteus aculeatus*) and European Eel (*Anguilla anguilla*). This fish lock with attraction flow pumps has been monitored since 2021 by the use of fyke nets and PIT-tag systems. This presentation will give an insight through the eyes of a water management organisation in the construction, maintenance and monitoring of highly technical fishways and discuss questions like: What are important lessons learned during the construction? How to operate the fishpass? Do all species pass?

12:15-12:30 - REDEEM project: Research and Development of fish and Eel Entrainment Mitigation at pumping stations

Bolland, J., Wright, R.

The European eel, *Anguilla anguilla*, is widely distributed throughout European estuarine and inland waters, but concern over their decline is so great that the European Union has a regulation for their recovery (The EC Eel Regulation (1100/2007)) and the UK has specific legislation (Eels (England and Wales) Regulations 2009) for screening intakes, including pumping stations. Water is frequently pumped from or into rivers for flood protection, water level management, domestic supply, agriculture, industry and hydropower generation. Fish and eels can be entrained in pumps and water intakes, especially adult silver eels during downstream migration; providing flood protection and safe eel passage is a particular problem. However, the extent of the problem is not fully understood and gaps in our knowledge prevent identification of adequate, cost-effective mitigation measures. Researchers at the University of Hull are delivering a strategic, inter-disciplinary and collaborative project with the Environment Agency called REDEEM; Research and Development of fish and Eel Entrainment Mitigation at pumping stations. The research focuses on understanding the spatial distribution of fish and critically endangered European eel in pumped catchments and the processes that lead to entrainment. It has developed and assessed the effectiveness of altered operating regimes, physical screens, fish-friendly pumps and alternative downstream bypass channels to provide applied outcomes. The knowledge arising is anticipated to inform and revise guidance and process for protecting fish at hazardous intakes at national, European and global levels.

Chairs: Britas Klemens Eriksson & Andreas Dänhardt

11:15-11:45 - [Keynote](#): Essential fish habitats – connectivity, threats, and management

Ulf Bergström, Swedish University of Agricultural Sciences, Department of Aquatic Resources

Nature conservation and fisheries management are traditionally separated in European waters. Recent research, however, clearly demonstrates potential synergies between the two. In this talk, I will present case studies exploring the importance of fish habitats in the Baltic Sea, as well as the relative impacts of habitat-related and other pressures on fish populations. I will also show how the connectivity of coastal habitats may be mapped, and exemplify how connectivity may contribute to the resilience of fish populations and ecosystem functions. While habitat-forming vegetation benefits the reproduction of many fishes, predatory fish may at the same time contribute to maintaining healthy vegetated habitats through trophic cascades. Coastal habitats are of central importance for many fish species, but these habitats are at the same time heavily impacted by a diverse range of human activities, both local-scale pressures such as fisheries, shoreline development, dredging and boating, as well as broad-scale impacts of climate change and eutrophication. To efficiently protect essential fish habitats we need a quantitative understanding of these impacts, together with comprehensive maps of habitat distributions. Finally, I will discuss the importance of considering essential fish habitats in spatial conservation planning, to meet the objectives of EU policies and directives for the marine environment.

11:45-12:00 - Small-scale distributions and temporal trends of two sandeel (*Ammodytidae*) species in the Dutch coastal area

Parmentier, B., Aarts, G., Brasseur, S., Couperus, B., Immler, E., van Langevelde, F., Tulp, I., Witbaard, R.

Sandeel (*Ammodytidae*) serves as a pivotal prey species for local (top) predators such as seabirds, marine mammals, and piscivorous fish in the Dutch coastal area. In this area two sandeel species co-occur: *Ammodytes marinus*, the more offshore species, and *Ammodytes tobianus*, which is a more coastal species. However, our understanding of their small-scale distributions and temporal trends in this region remains largely incomplete. This study integrates data from two sources: the NIOZ Deep Digging Dredge (DDD), which samples in areas deeper than 10 meters, and the WOT shelf survey conducted by Wageningen Marine Research, which extends to more shallow depths. The first aim of this research is to create a sandeel species-specific habitat suitability model, which will highlight important sandeel grounds and provide more detailed insights into potential differences in habitat preference. Secondly, our hypothesis suggests that *Ammodytes marinus* moves closer to the coast during favorable years, while *Ammodytes tobianus* expands its offshore distribution in less favorable years. As these two species spawn at different times, the size composition of this vital prey is expected to fluctuate annually. This potentially has consequences for single-prey-loading species such as terns, as they may struggle to adapt and gather sufficient food when prey size is reduced in specific years. This research sheds light on the dynamic interplay of these sandeel species offering valuable insights into the ecological dynamics of the Dutch coastal ecosystem.

12:00-12:15 - Fishing for sound: The soundscape of reef habitats in the Wadden Sea

Watson, M., Kok, A., van Opzeeland, I., Eriksson, B. K.

As a result of the specific physical features and biological communities that comprise a habitat, different habitats have distinct acoustic patterns, or soundscapes. Passive acoustics presents an innovative method and additional metrics for long-term monitoring of marine habitats. However, its utility requires knowledge of the naturally-occurring soundscape of a habitat, its variation over spatial

and temporal scales, and connections between the sounds and species of interest. Soundscapes are poorly described for characteristic temperate coastal habitats; such as shellfish reefs and sediment dominated systems. We show the distinct pattern of the biological soundscapes at natural reef and neighbouring sand habitat. Furthermore, we compared them to sounds of artificial reefs. These results build knowledge of biological sounds at subtidal habitats in the Wadden Sea, and are a first step toward enabling restoration of natural soundscapes in this rapidly changing ecosystem.

12:15-12:30 - Who lives in a pear tree under the sea?

Dickson, J.

Hard substrates play an important role in global marine systems as settlement surface for sessile reef-forming species such as corals, seaweeds, and shellfish. In soft-sediment systems, natural hard substrates such as stones, bedrock and driftwood are essential as they support diverse assemblages of reef-associated species. However, availability of these hard substrates has been declining in many estuaries and shallow seas worldwide due to human impacts. This is also the case in the Dutch Wadden Sea, where natural hard substrates have gradually disappeared due to burial by sand and/or active removal by humans. In addition, driftwood that was historically imported from rivers has been nullified by upstream logging and coastal damming of estuaries. To investigate the historic ecological role of wood presence in the Wadden Sea as settlement substrate and fish habitat, we constructed three meter high artificial reefs made of felled pear trees. Results demonstrate that these reefs rapidly developed into hotspots of biodiversity. Within six months, the tree-reefs were colonized by sessile hard substrate associated species, providing both shelter and food for fish. Six fish species were observed on the reefs, while only two species were caught on sandy control sites; moreover, the abundance of fish on the reefs was five times higher. Within 16 months, cuttlefish eggs and juvenile Pholis gunnelus were noted on the reefs, showing that the tree reefs are not merely fish attraction devices, but also providing spawning and nursery habitat. Individuals of the most commonly caught species, the five-bearded rockling Ciliata mustela, were larger on the reef; these patterns also hold true for common prawn, Palaemon serratus, which were also larger and ten times more numerous on the reefs. The rapid colonization of tree reefs by both sessile and mobile species shows that rapid ecological restoration may be possible in soft-bottomed systems.

THURSDAY

18

Afternoon

MAKING ROOM FOR FISH: RUIJ BAAN VOOR VISSSEN

Chairs: Jeroen Huisman & Peter Paul Schollema

Session 1
continued

ROOM

1

Auditorium

14:00-14:15 - Migration characteristics of roach in the Westerwoldse Aa catchment

van Emmerik, W., van Aalderen, R., Verspui, R.

In the project Ruim Baan voor Vissen (Make room for fishes) a migration study was carried out on roach (Rutilus rutilus) in the Westerwoldse Aa catchment near the Wadden Sea, in Groningen, the Netherlands. This catchment consists of a few streams and canals with a total length of 71 km. The catchment is divided by a number of weirs and pumping stations into segments with fixed water levels. At the mouth a tidal sluice keeps salt water outside. All weirs are equipped with fish passages. The migration options were studied using acoustic transmitters (Innovasea) and PIT tags. 31 roaches were tagged with an acoustic Innovasea transmitter and 74 with a PIT tag. Through a network of 10 hydrophones and 8 PIT-antenna fish could be tracked through the catchment. It became clear that the catchment area of the Westerwoldse Aa and the fish passes are suitable for migration of this species. The roaches passed the fish passages smoothly, however most of the roaches stayed in the downstream area and showed no migration to the upstream parts of the system. Throughout the study the majority of tagged roaches were registered at one or more Innovasea receivers or PIT antenna, but most roaches showed little migration activity. Survival rate of tagged fish is difficult to estimate, but there are some indications that mortality or predation could have had an impact on our study. The limited migration behaviour and potential impact of mortality will be discussed.

14:15-14:30 - Caught in between? Connecting modified inland waters and the Wadden Sea for migratory fish

Mathijssen, D. R.A.H., Leopold A.J. Nagelkerke, Schollema, P. P., Huisman, J. B. J., Winter, H. V., Buijse, A.

Throughout the Wadden Sea, the transition between marine and freshwater habitats range from natural, gradual transitions with brackish zones to modified, discrete transitions with sudden changes in salinity. Such discrete transitions represent a potential bottleneck for the migration of diadromous fish and may result in diadromous fish being unable to find the available hinterland. At Nieuwe Statenzijl (NSTZ), part of the Westerwoldse Aa catchment (The Netherlands), there is one such discrete marine-freshwater transition with a highly modified hinterland. To understand which species and sizes of fish try to migrate from marine to freshwater habitat at this discrete transition location, we monitored migrating fishes year-round (2022-2023) with a fine-meshed fyke. In addition, passive integrated transponder (PIT) telemetry was used to examine the migration routes of the two most abundant diadromous species: three-spined stickleback and European eel. The results of the fyke monitoring showed that during the migration period in spring, besides stickleback and eel, two other diadromous fish species were observed: flounder and smelt. Outside the migration season, freshwater fish dominated the fyke catches. The telemetry data showed that since the reconnection of the lower channels of the watershed with the upstream reaches, migration routes for three-spined stickleback remained exclusively in the lower 21 km of the watershed while for eel the distribution range started to expand to the reconnected upstream flowing waters. Further habitat improvement could potentially contribute to further expansion of the distribution of three-spined stickleback and eel. This study underlines the essential connection between marine and freshwater habitat for different diadromous fish species.

14:30-14:45 - The effects of light pollution on the behavioural and physiological rhythms of migratory fish

Crowley, D., E. Attias, J van Eerbeek, J. Huisman, H. Slabbekoorn & C. Tudorache

Light plays a key role in the functioning of some behavioural and physiological patterns in fish. However, light follows daily and seasonal rhythms in which the duration and intensity changes, meaning fish must rely on the biological clock's "connection" to the external environment to interpret and respond to changes. Dependency on rhythms raises concerns for the impact of light pollution on the biological clock as it may disrupt these rhythms, negatively impacting behaviour and physiology. This is concerning for migratory fish as natural cues related to migration may be masked, influencing energy expenditure and migration success. Using field and lab studies, we investigate the short-term consequences of light on swimming physiology and behaviour of three-spined sticklebacks. In the field, we use swim tunnels to test swimming patterns during their migration and in the lab, we test the differing migratory types to understand if they vary in swimming physiology and clock rhythmicity.

14:45-15:00 - Do fishways lead to artificial selection of personality types? A study in wild three-spined sticklebacks

Nicolaus M., Martin-Podevin, L., Schollema, P.P., & Huisman, J.

Fishways are structures designed to mitigate barriers blocking fish migration, but their effectiveness varies between fish species based on their morphology, physiology and/or behavior. Whether passage success also varies among individuals of the same species is largely unknown. Yet, this knowledge is crucial for conservation practices as it may lead to artificial selection of phenotypes with potentially large consequences for the populations and/or ecosystems. This study aimed to investigate whether fishways can induce a phenotypic bias in exploratory behaviour, length and timing of migration in three-spined sticklebacks (*Gasterosteus aculeatus*) in The Netherlands. 191 incoming migrants were caught in a front of a fishway, PIT tagged, measured, tested for exploratory behavior and released back. Their movement through the fishway was then monitored over 5 weeks. Results showed an average passage success of 12%, with fish taking on average 5.4 days to cross after release. Passage

success and speed of crossing were not related to exploration or length. However, timing of migration was a strong predictive factor of passage success, with late individuals being more successful and faster crossers than early individuals. Additional survival analysis using mark-recapture data revealed that this increased passage success was not explained by higher survival of late migrants but rather by increased temperatures driving higher activity levels. We discuss the implications of our findings for further conservation and management efforts.

15:00-15:15 - The window in time for migratory fish in the Wadden Sea and its tributaries is getting shorter, it is time to act

J. Huisman, N. Jepsen, A. Kühl-Stenzel, P. Schollema, L. Nagelkerke, A. Dänhardt, O.D. Finch.

The Wadden Sea is a unique coastal ecosystem. However anthropogenic impacts, such as land reclamation, have been a major driver for change. Today, most smaller tributaries along the Wadden Sea coast of The Netherlands and Germany have been equipped with tide exclusion barriers, sluices and pumping stations. As a result of these tidal barriers diadromous and estuarine fish species are hindered or blocked in their migration and tidal habitats are lost. To assist migratory fish a number of locations are fish friendly managed, using free discharge, or have been equipped with a fish pass. To ascertain current impacts on fish migration we made an inventory of the number and typology of tidal barriers in the Wadden Sea and its three larger estuaries (Elbe, Weser and Ems). In addition, we determined the number and types of fish passes and if possible, their efficiency. Our research shows that at tidal locations the window of time to freely discharge water will be reduced by sea level rise, thereby reducing the possibilities to facilitate migratory fish. Our research shows a shift from sluices towards pumping stations as a result of a reduction in free discharge. In addition, many of the tidal barriers along the Wadden Sea coast are in need of systematic overhauls as they are unfit to combat sea level rise. As such, there is a short window of opportunity to incorporate fish migration in the refurbishment or newbuild of tidal barriers in the Wadden Sea.

ROOM
2

ESSENTIAL, PROFITABLE, OR COINCIDENTAL: HABITAT & LIFE HISTORY OF FISHES

Chairs: Britas Klemens Eriksson & Andreas Dänhardt

Session 2
continued

14:00-14:15 - Worms unlimited: high benthos density relaxes diet competition between fish in intertidal salt-marsh creeks

Friese, J., Temming, A., Dänhardt, A.

The submerged vegetation of salt marshes is worldwide valued as feeding habitat for fish. In Wadden Sea salt marshes, however, the vegetated marsh surface is rarely submerged and only the creeks are regularly flooded. Knowledge of the habitat-species relationship is crucial for an effective conservation of species. We present the first evaluation of the feeding habitat quality of these salt-marsh creeks for four characteristic species: herrings, three-spined sticklebacks, common and sand gobies. Habitat-specific dietary condition, stomach contents and potential food competition – based on diet overlap and predator and prey abundances – were compared between the salt marsh, sampling four intertidal salt-marsh creeks, and the adjacent subtidal. Long-term dietary condition was similar between the two habitats, while instantaneous feeding rates tended to be higher in the marsh creeks for herring, stickleback and common goby. The diets of sticklebacks and gobies were dominated by polychaetes in the marsh creeks and by zooplankton and various benthic crustaceans in the subtidal. Herring consumed mainly copepods in both habitats. Endobenthic prey was significantly more abundant in the muddy marsh creeks, whereas abundance of planktonic prey did not differ between the habitats. Despite a higher diet overlap, low predator and high prey abundances relaxed the competition for endobenthic prey in the marsh creeks. We conclude that habitats characterized by low flow velocities and, thus, muddy sediments, such as marsh creeks, provide small fish with favourable foraging conditions through high density of endobenthic prey. The extent and availability of profitable feeding habitats is a powerful driver of fish population dynamics. Historically, coastal protection resulted in an extensive loss of marsh areas and, with it, feeding habitat for fish. Today, it may be worthwhile for the conservation of fish in the Wadden Sea to protect and promote the development of large, long, deep and easily accessible salt-marsh creeks.

14:15-14:30 - What is the function of Dutch salt marshes for fish?

Charan-Dixon, H., Ziebell, A.-C., Lamker, P., Fülep, T., Arvin, A., Merz, A., Nokise, F., Hijner, N., Brons, J., Bos, S., Maathuis, M., Tulp, I., Eriksson, B. K.

Large abundances of small and juvenile fish are present in the salt marshes of the Wadden Sea. It is not clear why these fish are attracted to the salt marshes - it could be for shelter, predator protection or food availability. To understand this better we studied fish in three Dutch salt marshes over one year. We selected marshes with a range of management strategies, from intensely grazed by livestock to nature areas with little to no interference by people. Our objectives were to investigate the effect of salt marsh management on fish, and to establish if fish are feeding in the marshes and what they might be feeding on. Using fyke nets we sampled fish once per season from each location to examine their stomach contents and their tissue stable isotope composition. Fish community composition varied seasonally, depending on life stage and guild. Furthermore, different fish species displayed distinct dietary preferences. We complemented fish collection by investigating the diversity of benthic infauna and insects and we describe the salt marsh food web from a fish's perspective. We show the effect of human modification on the food web and diets of fish in salt marshes. The aim of this research is to identify potential management improvements that could be implemented to enhance the value of salt marsh habitats for fish.

14:30-14:45 - Historic ecology of houting (Coregonus lavaretus) shows how migratory fish disappeared from the Rhine-Meuse delta

Kroes, R., Loon, E. van, Verdonschot, P., Winkel, Y., Overduin-de Vries, A., Geest, H. van der

In the Rhine-Meuse delta, decrease and extirpation of migratory fish occurred mainly before intensive data collections started in the second half of the 20th century. Therefore, it is difficult to point out specific drivers for the decline of migratory fish and which actions should be taken to restore their populations. This also applies to anadromous populations of houting (Coregonus lavaretus, a.k.a. C. oxyrinchus). Houting was abundant in the Rhine-Meuse delta before 1900, extirpated during the late 1930's and recovered after a reintroduction program in the 1990's. These radical changes in presence and abundance makes the species useful to study effects from environmental changes. To determine which sequence of anthropogenic stressors can be linked to these radical changes, we studied >10k newspaper articles, books, paintings, survey reports and specimens from natural history museums to describe the ecological history of houting in the Rhine-Meuse delta. Presence and abundance of houting was reconstructed from the early Middle Ages to present-day. Anthropogenic impact on Dutch river systems was reviewed to identify the sequence of anthropogenic drivers. Results show that houting probably started to decline around 1850, earlier than previously assumed. The decline occurred during intensifying river fisheries and large canalizing and redirecting projects but before strong deterioration of water quality and construction of barriers. Recovery of houting occurred after improvements of water quality, although river morphology and connectivity was still highly managed. We nuance the general assumption that migratory fish in European rivers suffer from a large number of drivers and discuss the usefulness of historic sources to study historic ecology of fish. We suggest that further understanding of fish ecology is needed for the success of restoration programs for houting and other migratory fish like allis shad, Atlantic salmon and European Sturgeon.

Chairs: Katja Philippart & Sara Koek

15:00-15:30 - [Keynote](#): Consequences of climate-driven change in freshwater discharge to the sea for estuarine and diadromous fish

Katja Philippart, Martin Baptist, Kees Bastmeijer, Thomas Bregnballe, Christian Buschbaum, Piet Hoekstra, Karsten Laursen, Sonja van Leeuwen, Albert Oost, Mathias Wegner, Robert Zijlstra, Waddenacademie and other

In 2018, 2019, 2020 and 2022, north-western Europe was faced with extreme droughts. Amongst others, these droughts resulted in a reduction in the outflow of the main rivers (Arlau, Bongsieler Kanal, Eider, Elbe, Ems, Lake IJssel, Miele, Weser) to the Wadden Sea particularly in spring (March-May). During this season, the average outflow declined from ca. 300 m³ per sec in the late 1990s to ca. 175 m³ per sec in the late 2010s. So far, climate-driven impacts on Wadden Sea fish has been focusing on the relationship between warming and the decline of juvenile fish and, consequently, the nursery function of this shallow coastal sea. The decline in freshwater discharges to the Wadden Sea may have an additional effect on its fish, specifically on estuarine, nursery and diadromous species. If the Wadden Sea changes from an estuarine area to a marine lagoon, the specific habitats for estuarine fish might get lost. Such a change could also have an effect on larvae of marine juvenile species for which the Wadden Sea is a nursery area, because they use the estuarine circulation for transport to coastal waters with freshwater as a cue. For diadromous fish, a decline in the salinity gradient during their migration period will make it more difficult for them to find their way from the open sea to rivers and other freshwater discharge points. Storage of freshwater on land (e.g., by means of sluices and dams) will also hamper the access of these fish to their spawning grounds (anadromous) or growing areas (catadromous). The success of fish migration (including restoration efforts such as the Fish Migration River) relies on the amount and open access of freshwater to the sea. The consequences for estuarine and diadromous fish should, therefore, be taken into account when addressing the freshwater balances of the Wadden Sea area.

FISH IN SPACE & TIME: LIFE CYCLE CONNECTIVITY

Chairs: Julia Busch & Andreas Dänhardt

16:15-16:45 - [Keynote](#): From Flyway to Swimway: how can insights from bird tracking inform research on movement ecology of fish?

Allert Bijleveld, Royal Netherlands Institute for Sea Research

Like many bird species, fish use the Wadden Sea for different purposes and only during part of their life cycle. Therefore, an understanding of fish population dynamics and conservation in the Wadden Sea cannot be seen in isolation. The Flyway and Swimway concepts acknowledge this life-cycle approach across large spatial scales. Over the past decades, largely driven by technological advancements and tracking abilities above the surface, a wealth of research has provided important scientific and conservation insights for migratory birds. In this presentation, I will highlight some Flyway research, underscore contemporary research questions, and discuss how bird conservation in the Wadden Sea needs a Flyway perspective. Using these insights, I will discuss how Flyway research can inform a research agenda on the movement ecology of migratory fish, and that for understanding the declines and increases of many fish populations in the Wadden Sea, the area should not be seen in isolation but as part of the Swimway.

16:45-16:55 - Eighty-seven leagues on the Elbe: Spatial dynamics of the feeding ecology of a key species in an anthropogenically influenced estuary

Hauten, E., Biederbick, J., Koll, R., Theilen, J., Thiel, R., Fabrizius, A., Jensen, K., Grønkjær, P., Möllmann, C.

Estuaries provide highly productive habitats that are exploited by aquatic consumers in multiple ways, such as food sources, nursery grounds or migration routes. At the same time, these systems are shaped by natural and anthropogenic stresses, which leads, for instance, to low species richness and high production rates of individual species. In the Elbe estuary, the European smelt (*Osmerus eperlanus*) is a key species as it accounts for 96 % of the overall fish abundance. However, the population has declined in recent years. In our study, we investigate intraspecific competition and food preferences between juvenile and adult fish at five stations along the Elbe in spring using stable isotope analyses and stomach content data, as some aspects of smelt's feeding ecology remain unclear. Our results indicate overall high intraspecific competition, overlapping food preferences and little ontogenetic shift between the life stages. Young smelts are more frequently foraging on smaller prey such as copepods, whereas adults show increasing piscivorous feeding behavior. Overall, smelt uses estuarine food sources in a generalist way with mysids and gammarids being important prey organisms. Spatial analyses of carbon isotopes indicate that freshwater and brackish areas are highly important feeding areas for juvenile smelt. Older fish show a broader isotopic niche width, indicating multiple dietary carbon sources and thus a greater migration radius, which could lead to competition avoidance. Our study contributes to a better understanding of the feeding ecology of key species in highly anthropogenically influenced estuaries, considering the European smelt in the Elbe as an example. The outcome of our study could serve as a basis for improving the management of key estuarine species and therefore contribute to their conservation.

16:55-17:05 - Impacts of environmental pressure on the survival of early life stages of the European Smelt using an Individual-based modelling approach

Drewes, D., Schrum, C., Daewel, U., Pein, J.

The anadromous living European Smelt (*Osmerus eperlanus*) is a commonly observed fish in the German estuaries of Elbe, Ems and Weser. The substantial amount of biomass of smelt and its ecological role as a "wasp-waist" species makes the fish a key-species of these ecosystems. However, recent findings suggest a rapid decrease of the smelt populations in all German estuaries. Causes of this population decrease were widely discussed and suggestions range from the impact of climate change due to warmer temperatures, changes in the food availability to the increased anthropogenic usage of all three estuaries. To investigate possible drivers of mortality of early life stages we present an Individual-Based model (IBM) for the European Smelt. The IBM includes the egg development, endogenous feeding (yolk-sac stage), the transition of the 0+ larvae to exogenous feeding and the subsequent growth. The necessary physical and biological forcing is provided using a coupled physical-biogeochemical (SCHISM (Semi-implicit Cross-scale Hydroscience Integrated System Model) in combination with ECOSMO) ecosystem model. Using the output of several scenarios that incorporate possible effects of future climate change and continuous anthropogenic use of the Elbe estuary, a Lagrangian particle-tracking scheme is used to calculate the route of the individuals during their lifetime. Based on the particle's trajectory, the individual's growth and survival is estimated. Further, the model allows to determine important processes that impact the individuals survival throughout its lifetime. We present the model validation along with a dedicated parameter sensitivity study on the individual's survival. Further, first results using the realistic forcing fields from the Elbe Estuary are presented.

17:05-17:15 - The case of smelt *Osmerus eperlanus* in the Dutch Western Wadden Sea

Jager, Z.

In the Wadden Sea, the anadromous smelt (*Osmerus eperlanus*) is regarded as an important species in the ecosystem. In the Scheldt, Ems and other Wadden Sea estuaries, the anadromous form still occurs as such. However, in the western Wadden Sea, the anadromous form may to some extent coexist with a freshwater form ('binnenspiegeling'), that originated in Lake IJssel after the construction of the closure dam Afsluitdijk in 1932. The smelt migration from Wadden Sea to Lake IJssel has been investigated to some extent. However, less is known of the reverse (and probably unintentional) migration from Lake IJssel to the Wadden Sea or of the exchange of smelt between different parts of the Wadden Sea. And how this affects the sustainable smelt population(s) in the western Wadden Sea. The assessment of a small-scale smelt fishery in the western Wadden Sea, to obtain a nature permit, became a serious issue leading to a court case. To resolve the dispute, detailed information on the Wadden Sea landings was compared with smelt recruitment indices in Lake IJssel and showed exceptionally strong correlation, leading to the hypothesis that the fishery is harvesting merely the surplus production of small smelt that is flushed to the Wadden Sea (being mature 'binnenspiegeling') and which may not succeed to return to Lake IJssel for reproduction, despite the intended application of adapted sluice management at Afsluitdijk. Different views are highlighted, with implications and recommendations for management and suggestions for adequate monitoring and the investigation of specific questions regarding smelt.

17:15-17:25 - Joint fact finding in a changing estuarine gradient

Vegter, J. E.

The Reitdiep-Lauwerszee river- and tidal system will face changes in waterflow and water management, which will affect swimway functions and options for restoring an estuarine gradient. These could be negative, but may give opportunities for improvement. Many fish data are available but not always comparable. And we lack insight in the physical behaviour of the local estuarine gradient. The new Waddensea Worldheritage Centre (WEC) will, from april '25 onwards, act as a thriving fieldstation and workshop to optimize cooperation of stakeholders involved in fish monitoring and management. WEC will do this with its partners in education, research and fisheries. More joint fact finding by scientist and fisherfolk together will be arranged, as was initiated before by the Integrated Fisheries Foundation (SGV). We will discuss benefits and hazards. In our presentation we will compare methods and techniques applied in different projects in the same area. Our question is: can we share collectively established methods without losing the value of earlier data sets? For fish data to be used effectively in restoring 'swimways' we will advocate integrated fish and salinity monitoring along this specific estuarine gradient; inland and alongshore. Creating a fieldlab and teaching facility should serve training of future managers and fisherfolk and provide a meeting point to share all this with all groups and interests involved: the 'Ecocampus'. Based on results of a four year fish monitoring, while comparing these with other projects in the same basin, as well as practical examples of successful joint fact finding we will present a framework for reaching the ambitions.

17:25-17:35 - Identifying bottlenecks to management and conservation of the tope shark (*Galeorhinus galeus*)

Walker, P.

The three countries bordering the Wadden Sea (Denmark, Germany and the Netherlands) collaborate in a Trilateral Cooperation. They have identified five targets for fish species in the Wadden Sea to ensure healthy populations of all species which use the area as part or all of their life-cycle. These targets are aimed at guaranteeing suitable conditions for reproduction and growth and/or to allow individuals to migrate to freshwater and vice versa, depending on the species. One of the targets is aimed at endangered species such as sturgeon, sharks and rays. The target is to ensure "favourable living conditions for endangered fish species". However, bottlenecks for these species may be outside the coastal area and require management which goes beyond national boundaries to ensure the

completion of their life cycle. The tope shark (*Galeorhinus galeus*) has been identified as a focal species for the Trilateral targets, being both a representative of the functional group of adventitious and migratory species, as well as being an endangered species. Tope has been classified by IUCN (International Union for the Conservation of Nature) as being critically endangered globally and is on Appendix II of the Convention on Migratory Species. ICES (the International Council for the Exploration of the Sea) provides fisheries advice for tope across its distributional range in the North-east Atlantic. However, there are no management measures in place to date. Research has been carried out into the seasonal migratory patterns and reproductive biology of tope and the Wadden Sea and coastal areas have been identified as a potential nursery area. This paper will explore how the available scientific knowledge on the population dynamics of the tope shark (*Galeorhinus galeus*) can be used to identify bottlenecks and to inform management plans and conservation measures in order to manage human impacts on its life cycle.

17:35-17:45 - Large-scale migration and seasonal coastal residency of European grey mullets

Edwards, J. E., Buijse, A. D., Winter, H. V., Bijleveld, A. I.

Found in temperate and subtropical waters worldwide, grey mullets (family *Mugilidae*) are common across coastal, brackish, and fresh water habitats where they have supported fisheries dating back millennia. Despite their widespread occurrence and commercial importance, almost nothing is known about the movement ecology of grey mullets. In the coastal European waters of the Wadden Sea, a lack of knowledge of the seasonal occurrence, home range size, and migratory behaviours has hindered management efforts in the face of local declines for one species, the thicklip grey mullet (*Chelon labrosus*), spurring the need for additional research. To address this knowledge gap and expand our knowledge of the movements of grey mullets in general, we tagged 129 individuals from three species with acoustic transmitters and data storage tags to monitor their movements both within the Wadden Sea and across their broader migratory ranges. Movement data collected from both telemetry types will be used to determine both the role of the Wadden Sea as a seasonal foraging ground for grey mullets, and to identify important habitats and movement pathways in both coastal and offshore regions. These data will improve fundamental knowledge of mullet life histories and will guide the conservation and management of grey mullets in this important ecosystem.

ROOM

2

GETTING PRACTICAL: IMPROVING LIFE FOR FISH THROUGH EVIDENCE-BASED MANAGEMENT


Chairs: Katja Philippart & Sara Koek

**Session 3
continued**

16:15-16:25 - The first man-made river to benefit fish migration

van der Heij, W.

The 30 km long Afsluitdijk, constructed between 1927 and 1932, is seen as one of the biggest ecological disasters in The Netherlands. Destroying the Wadden sea ecosystem and still causing unprecedented effects on marine life. Making restoring the ecological connection and softening the hard barrier between saline and fresh water one of the major goals when plans were made for a new, stronger Afsluitdijk between 2006 - 2011. Budget cuts however put all this ambition aside and a bare reinforcement of the dike was chosen. Nature organizations, anglers and commercial fishermen grabbed the invitation of incorporating add-ons and presented the idea of a Fishmigration river. More than ten years later the Afsluitdijk is being reinforced but at the same time a hole is made in that same dike to let fish like salmon, eel and sturgeon pass. An innovative, 4-kilometer-long, winding fish-passage through the iconic Afsluitdijk reconnecting the Wadden Sea and Lake IJssel for migratory fish. It's the very first man made tidal river on the border of salt- and freshwater. Within a few years, diadromous fish will be able to swim freely through the meandering river. In this way the fish can accustom to either the fresh or the salt water. It also makes sure that no salt water reaches Lake IJssel, which was an important requirement to protect the agricultural and drinking water functions of the lake. The river has different flow rates, meaning that both strong and weak swimmers can move through the river. It is estimated that about 200 locations worldwide would benefit from the Vismigratierivier approach.



16:25-16:35- Fish Migration River Afsluitdijk, Climate adaptive construction and Research Programme

Bruins Slot, E.


Many estuarine barriers were built worldwide in response to sea level rise, flooding, and salinization. These barriers severely decreased ecosystem functioning and connectivity for fish. In 1932, a large tidal barrier consisting of a 32 km long dam was constructed in the former estuary Zuiderzee that connected the Wadden Sea with the northern river Rhine branch IJssel. This resulted in a large freshwater Lake IJsselmeer. Excess freshwater is discharged through two sluice complexes in the dam during low tide when water level in Lake IJsselmeer is higher than in the Wadden Sea. As a result, estuarine habitats disappeared and fish migration from sea to freshwater is severely obstructed. Small diadromous fish strongly rely on incoming tidal currents for their upstream migration by using Selective Tidal Stream Transport (STST). Current management protocol does not allow for salt water intrusion into IJsselmeer due to drinking water intake and agricultural use. Therefore, upstream passage is restricted to small temporal windows during discharge events with water currents surmountable only for strong swimmers. To restore fish migration between the Wadden Sea and Lake IJsselmeer a uniquely designed fish passage has been developed called the 'Fish Migration River' (FMR). This fishway is an 'man-made' technical system artificial river of several kilometres long incoming and outgoing tidal currents and enables diadromous fish to pass barrier Afsluitdijk. It's the example of innovative Dutch Delta Watermanagement 21th century. The system is a technical 'state of the art' nature-based design. Meant for large scale fish passage the recover fish populations as a link in the foodweb en biodiversity. Circulair construction has recently started and is foreseen to be completed in 2025. An extensive abiotic and biotic monitoring program will be carried out to evaluate and optimize the future functioning of the FMR. Fish Migration River is the next step in ecologic engineering after opening the other front door in the Rhine system 'Haringvlietdam' and creating fish habit in lake IJssel Markerwadden. And will followed by even more 'open' systems like: 'Lauwersmeer' and 'Wieringerhoek'. Focus on the technical eco-hydraulic system, construction and climate adaptive design of the system, Research & Monitoringsprogram, try-out and operation: life cycle approach of our migrating fish.

16:35-16:45 - Fish community structure as indicator for ecosystem management

Günther, C., Heubel, K.

The Wadden Sea is the habitat of diverse fishes and serves different functions for species that tolerate both, marine and brackish salinities. Tracking changes in this varied fish community over time to identify potential anthropogenic stressors, is a basis for ecosystem management. As part of the BmBF-funded project iSeal, we analyzed the spatio-temporal changes in the community structure, by applying a machine learning algorithm (Random Forest) in combination with an inferential multivariate statistical approach to long-term data of German fish surveys. Species, diversity indices, and trait-based responses were examined. We focused on potential influences of fisheries and climate change (temperature, salinity). Fishing intensity was estimated using a combination of logbook and VMS data, which provided spatial and seasonal resolution of shrimp and mussel fisher activity. In addition to fishing intensity, catch size was also tested as a variable, taking into account the amount of biomass removed. Preliminary analyses show changes in the fish community over time, but also highlight the importance of seasonally resolved time series for the German Wadden Sea to track changes in the phenology of migratory species. The results of this study will be used to develop indicators of the status of the Wadden Sea fish community and to define thresholds that can be used for ecosystem management (Marine Strategy Framework Directive).





16:45-16:55 - Multi-Species Indicators (MSI) for fish in the Wadden Sea: trends since 1985

Brandenburg, K., Bogaart, P.

Biodiversity indicators are increasingly used to monitor biodiversity trends across various habitats and scales. The most commonly employed indicators involve the combined population trends of specific species, collectively known as multi-species indicators (MSIs). These MSIs encapsulate changes in selected species or species groups, offering insights by calculating and combining mean geometric indices. Prominent examples of MSIs include the global Living Planet Index, the European Grassland Butterfly Indicator, and the European Wild Bird Indicators. The Central Bureau of Statistics Netherlands (CBS) has further refined the MSI methodology and publishes multiple MSIs through the 'Compendium voor de leefomgeving' (CLO) website. These MSIs provide a comprehensive overview of the biodiversity status in the Netherlands across various spatial scales. MSIs are also computed for distinct species groups within the Wadden Sea, including fish. The Demersal Fish Survey data is used to calculate MSIs for all fish species and nursery fish species. The findings reveal a general decline in fish abundances within the Wadden Sea from 1985 to 2022, with four species showing an increase, thirteen experiencing a decrease, and six exhibiting uncertain trends. However, this decline stabilized around 2006, with no significant further declines observed. Notably, nursery fish populations saw a pronounced decline, with six out of eight species showing a moderate to strong decrease during the study period. However, the common sole exhibited a moderate increase in abundance since 2010. Further differentiation in MSI's among fish species can help to identify the specific traits at risk of disappearing in the Wadden Sea. Using a MSI approach can help scientists, conservationists and decision makers to better understand the dominant factors influencing biodiversity in different regions, including the Wadden Sea, and adjust policy.

16:55-17:05 - Life histories matter: Tailoring conservation measures for coastal fish guilds

ten Brink, H., van Leeuwen, A.

Coastal systems worldwide are under high anthropogenic pressure. At the same time, coastal zones form essential habitats to sustain entire ecosystems. For example, many fish species of commercial interest utilize the coastal zone as nursery habitat (marine juvenile guild), while resident species spend their entire lifecycle in the coastal zone (resident guild). These distinct life histories mean that changes in coastal ecosystems will affect fish guilds differently. In this study we explore guild-specific impacts of stressors such as habitat loss and mortality. We developed size-structured population models that capture the entire life history of individual fish and explicitly account for the different guild-specific life-histories. Our findings reveal that information on the entire life-cycle of species (including their guild) is crucial to tailor conservation and management approaches. For example, while resident fish always profit from coastal habitat restoration, marine juveniles benefit only when they have access to high quality offshore areas.

17:05-17:15 - The potential for monitoring fish using hydroacoustics

Kok, A., Watson, M., van Opzeeland, I., Eriksson, B. K.

Fish populations in coastal ecosystems are under threat by human disturbance. In order to document and manage fish population trends, long-term monitoring is needed. A large group of fish species produce sound during spawning, opening up a novel method to record their presence. Passive acoustic monitoring (PAM) is becoming an increasingly popular method to document abundance and diversity of sound-producing fish. The non-invasiveness, relatively low-cost and independence of weather conditions make PAM attractive compared to traditional methods. However, current applications of PAM suffer from a lack of species identification and are time-limited by manual analysis of the recordings. We explored the potential for PAM to document fish diversity by conducting a literature review of the current status of the field. Additionally, we combined acoustic recordings with traditional catches and camera trap data in shallow waters of the Dutch coast. Together, these data sets point out the potential of the method and the limitations that need to be overcome to live up to this potential. With a larger database of sound types linked to species and effective automated analysis algorithms, PAM has the potential to drastically increase our knowledge of fish ecology.

17:15-17:25 - Swimway and protection of fish in the trilateral Wadden Sea Area

Busch, J. A.

For more than 40 years, Denmark, Germany and the Netherlands have jointly collaborated to protect the Wadden Sea as one ecological entity in the Trilateral Wadden Sea Cooperation (TWSC). Already in 2010, Danish, Dutch and German fish experts developed conservation objectives for fish – the so-called trilateral fish targets in the Wadden Sea Plan. Since then, trilateral efforts for fish conservation increased. Since 2019, a Swimway group is working on improving the situation for fish in the Wadden Sea – from 2021 as permanent Expert Group Swimway of the TWSC. This goal is to be achieved by fostering collaboration on the implementation of the fish targets and to provide an overarching Swimway approach: Swimway Wadden Sea is this overarching approach – an umbrella – for a wide variety of initiatives related to achieving trilateral fish targets (<https://swimway.waddensea-worldheritage.org>). The main benefit of Swimway activities will be the identification of population bottlenecks and the translation of this knowledge into effective management and conservation measures. Closing these knowledge gaps will help to improve effective conservation.

17:25-17:35 - The Trans-European Swimways Network and Programme

Cordier, E.

To address the myriad threats facing migratory fish species in Europe, Wetlands International Europe, along with partners from the World Fish Migration Foundation, IUCN, and UNEP-WCMC, established the Trans-European Swimways Network (TEN-S). This Network brings together stakeholders to foster international cooperation in improving knowledge and guidance, as well as raising the profile of fish migration and strengthening policies for their protection. TEN-S has collaboratively produced a Trans-European Swimways Programme which outlines the key threats and opportunities for migratory freshwater fishes, and provides a framework for action over the coming years.

One of the first major actions has been the development of criteria and its application for the identification of the Swimways of European Importance (SEIs). We acknowledge that not all corridors for migratory fishes can be protected, and so there is a need for a prioritisation of habitats. The goal of SEIs is to create an inventory of key river stretches as “hotspots” for barrier removal and other conservation measures to protect migratory fish species. Drawing on the Global Swimways approach, SEIs will be based on biological, economic, and cultural criteria.

As a starting point in 2023, SEIs were identified according to preliminary biological criteria based on IUCN Red List data at different geographic scales, combined with data from key European and EU legislation. Classifying the data according to species richness of migratory fish resulted in over 400 SEIs, which are currently being further refined and analysed. This presentation will showcase TEN-S, its work on identifying SEIs and the rest of the Programme.

FRIDAY

19

Morning

COPING WITH ENVIRONMENTAL PLASTICITY: ECOPHYSIOLOGY & CLIMATE CHANGE

Chairs: Flemming Dahlke & Katja Heubel

Session 5

9:00-9:30 - Keynote: Thermal life cycle bottlenecks define climate change vulnerability of fish

Flemming Dahlke, Sylke Wohlrab, Martin Butzin, Hans-Otto Pörtner, University of Hamburg & Alfred Wegner Institute for Polar and Marine Research

The vulnerability of species to climate change depends on the most temperature-sensitive life stages, but for major animal groups such as fish, life cycle bottlenecks are often not clearly defined. We used observational, experimental, and phylogenetic data to assess stage-specific thermal tolerance metrics for 694 marine and freshwater fish species from all climate zones. Our analysis shows that spawning adults and embryos consistently have narrower tolerance ranges than larvae and non-reproductive adults and are most vulnerable to climate warming. The sequence of stage-specific thermal tolerance corresponds with the oxygen-limitation hypothesis, suggesting a mechanistic link between ontogenetic changes in cardiorespiratory (aerobic) capacity and tolerance to temperature extremes.

Scenario-based climate projections considering the most critical life stages (spawners and embryos) clearly identify the temperature requirements for reproduction as a critical bottleneck in the life cycle of fish. By 2100, depending on the Shared Socioeconomic Pathway (SSP) scenario followed, the percentages of species potentially affected by water temperatures exceeding their tolerance limit for reproduction range from ~10% (SSP 1–1.9) to ~60% (SSP 5–8.5). Efforts to meet ambitious climate targets could therefore benefit many fish species and people who depend on healthy fish stocks.

9:30-9:45 - Disentangling the effects of food level and temperature-dependence on the performance of Wadden Sea fish in different guilds

Dye, B., ten Brink, H., van Leeuwen, A.


Water temperature is a major driver determining fishes' ability to thrive/survive in a habitat. Over the last 20 years, mean water temperature in the western Dutch Wadden Sea has increased with $>1.5^{\circ}\text{C}$ resulting in a changing habitat function of this crucial fish nursery area. Survey data have elucidated species composition and changes therein, but much less is known about species physiology. To better understand how water temperature and resource availability affect life history processes at the individual level, we developed a species-specific, temperature dependent, energy budget model. The model framework tracks the allocation of available energy from food to different life history processes such as maintenance, development, growth, and reproduction, as organisms grow and progress through different life stages. We studied the individual energetics of five species representing contrasting fish guilds and found that responses to environmental conditions varied among species and are depending on individual size.

Our findings suggest that even small increases in water temperature can have significant effects on the physiology and life history of Wadden Sea fish species, which may ultimately impact their population dynamics and interactions with other species in the ecosystem.

9:45-10:00 - Community structure and diversity changes for fish in the Sylt-Rømø Bight, northern Wadden Sea, as a response to climate variability and depth

Odongo, V., Asmus, H., Boersma, M., Lebreton, B., Horn, S.

Coastal marine ecosystems are highly productive, rich in biodiversity, and have supported valuable coastal fisheries for centuries. These ecosystems have undergone tremendous changes over the last decades and considerable seasonal variations due to climate change. Long-term and seasonal variations in the biodiversity and community structure of fish in the Sylt-Rømø Bight (SRB), the northern Wadden Sea were analyzed using the monthly juvenile fish monitoring data from 2007 to 2019. These were linked to sea surface temperature (SST) variations whereas fish dispersal in the benthic and pelagic habitats was related to the changes in water depth. Inter- and intra-annual community structure variations were observed but strong dissimilarities were between summer and winter seasons; similarity percentage (SIMPER) at 67.54%, analysis of similarity (ANOSIM) $R=0.63$, $p=0.0001$, and Jaccard's coefficient = 0.58. Significant dissimilarities occurred between years with severe winters and relatively warm winters. However, no significant variations occurred between autumn and spring communities. Species richness (S) varied seasonally but significantly between autumn and spring and autumn and summer. Generalized Linear Models showed that SST explained the highest variability in S in the pelagic realm at 10.6% and 4.24 % in the benthic while changes in depth explained 1.71% and 2.31%, respectively. Evenness (J) decreased with an increase in SST in both habitats. J increased with depth in the benthic and in areas that were protected by the coastline in the pelagic realm, contrary to areas exposed to strong water currents. Simpson's Index of Diversity and Shannon Wiener Index decreased with an increase in SST and no significant effects of depth variations. These diversity changes are a reflection of the sensitivity of juvenile fish to changes in short- and long-term oceanographic processes and the significance of shallow coastal systems to fish dispersal that needs contemplation in the conservation and management measures.



10:00-10:15 - Impact of Ocean Warming and Invasive Species on the Physiology and Energy Allocation Strategy of the Common Goby from the Wadden Sea – A Mesocosm Approach

Bruhy, J., Joly, L. J., Heubel, K.

Ocean warming (OW) poses a global threat to marine fish, compounded by various other stressors like invasive species. While most OW research focuses on economically valuable species, it is crucial to include studies encompassing a broader range of species and ecosystem complexities. The present study centered on the common goby, *Pomatoschistus microps*, a potential keystone species in the Wadden Sea coastal regions. Large-scale mesocosm experiments simulating a 3 °C temperature increase and introducing native blue mussel beds or invasive oyster reefs were conducted in Sylt, Germany. Species were collected from the Wadden Sea and maintained in near-natural conditions from March to June 2023. Biometric measurements, organ weights, and respiration assessments were performed once a month to unveil the energy allocation strategies of the common goby. While the invasive community had a minor influence on common goby's response, the OW effect was significant. Fish under warming conditions adjust their energy allocation, with temporarily increased metabolism and a subsequent shift towards growth (specific growth rate). To a lesser extent and with disparities between sexes, elevated temperatures also heightened energy allocation towards storage (Fulton's condition factor and hepatosomatic index) and reproduction (gonadosomatic index). Particularly males under warming exhibited higher investment into reproduction. This research provides critical insights into how climate change driven OW shapes the energy allocation strategy in the common goby, emphasizing the species' resilience and potential to persist in the face of forthcoming climate change. However, future consequences arising from these shifts in energy allocation for the common goby population remain unknown, highlighting the need for further studies to assess multi-stressor effects and better insight in potential ecological consequences.

10:15-10:30 - What role does the Wadden Sea play in the life cycle of small pelagic fish?

Maathuis, M.A.M., Berg, F., Couperus, B., Poos, J J., Tulp, I.

Most fish species use several habitats to complete their life cycle, with coastal areas often playing a crucial role, serving as nursery, feeding, and/or spawning areas. While the nursery function for bottom-dwelling species in the Wadden Sea has been extensively studied, the function of the Wadden Sea in the life cycle of small pelagic fish (SPF) has received little attention to date. This lack of attention hampers the understanding of the Wadden Sea ecosystem, given that SPF are the dominant component of the overall fish biomass and serve as important food source for higher trophic levels. We studied the role of the Wadden Sea in the life cycle of Atlantic herring (*Clupea harengus*), European sprat (*Sprattus sprattus*), smelt (*Osmerus eperlanus*) and European anchovy (*Engraulis encrasicolus*) through monthly stow net and seasonal trawl surveys. We wanted to know what life phases of which species are present in the Wadden Sea and notably if there are still remnants of the historic Zuiderzee spawning aggregations present. Our study shows that small pelagic fish use the Dutch Wadden Sea primarily as juvenile habitat, with herring being the dominant marine juvenile representative. We found that juvenile herring predominantly originate from southwestern waters, like the English Channel, supported by both monthly length frequency distributions and genomic analysis. The Wadden Sea still provides spawning grounds for herring and anchovy, with limited spawning observed for sprat. While smelt can complete nearly its entire life cycle in the Wadden Sea, it depends on connectivity to freshwater for spawning. Understanding these functions is crucial for identifying bottlenecks and implementing effective conservation and management strategies.

10:15-10:30 Poster Presentations**10:30-11:15 1-minute pitches, poster session****Growth and activity levels of the common goby, *Pomatoschistus microps*, in response to increasing temperatures**

Christian Olesen, Heubel, K.

Within the framework of the iSeal project, this study investigates the ecological consequences of elevated temperatures, mirroring IPCC projections for the next 80 years, on common gobies (*Pomatoschistus microps*) in the Wadden Sea. In a mesocosm setup mimicking entire mussel bed communities as a typical habitat for goby reproduction, gobies were exposed to three temperature regimes: Ambient, Ambient + 1.5°C, and Ambient + 3°C for three months (April - June) on the island of Sylt. This was done to shed light on the expected impact on growth, resting metabolism and behavior on an ecologically important species under future temperature scenarios. Gobies subjected to higher temperatures displayed substantial increases in both length and weight. However, surprisingly, only little differences were found in resting respiratory rates among treatments, illustrating the complex responses of these coastal fish to warming oceans. Furthermore, behavioral assays were carried out to examine how temperature affects swimming, resting, activity and exploratory behavior among common gobies. This research offers vital insights into how climate change may impact this ecologically significant species, contributing to the broader understanding of how climate change can influence coastal ecosystems, specifically within the unique and ecologically important setting of the Wadden Sea.

FTZ - Transdisciplinary Center for Wadden Sea and Coastal Research: Coastal Ecology Group

Katja Heubel & team

The Research and Technology Centre West Coast (FTZ) is a central facility of Kiel University. It pursues interdisciplinary coastal research mainly in shallow water areas and estuaries. Research results are translated into concepts and strategies for sustainable coastal management and used for decision-making for future marine protection concepts. The "Coastal Ecology" group addresses research questions on non-commercial fish ecology, its role in food webs, sediment-benthos-soundscape interactions in different Wadden Sea habitats, predator-prey interactions, mussel bed communities, and climate change. For our studies, we analyze time series and monitoring data, conduct laboratory-controlled and mesocosm experiments, and develop new monitoring approaches (eDNA). Our focus is on the analysis of potential impacts of invasive species, fisheries, climate change and anthropogenic underwater noise on the structure and functioning of food webs and selected key species. We will use these insights to refine concepts for an assessment of the good ecological status of the Wadden Sea. I introduce recent and ongoing projects and group members and research interests.

Impact of heatwaves on the reproductive behaviour of the common goby

Cindy Meyer, Heubel, K.

Marine heatwaves, short periods of extremely elevated sea temperatures, have become increasingly frequent due to global climate change. Understanding their impact on marine ecosystems is crucial for predicting ecological responses. This study investigates the influence of heatwaves on the reproductive behaviour of the common goby (*Pomatoschistus microps*), a small, intertidal fish. Common gobies are one of the most abundant fish species in the Wadden Sea. As a secondary consumer, they play an important role in the food web rendering an essential prey for predators such as commercially fished fish and mammals like seals and harbour porpoises. Therefore, shifts in gobies' reproductive decisions and its population level consequences can be used as an indicator for community changes caused by climate change in the future Wadden Sea. However, not only increased temperature per se, also the seasonal timing of heatwaves during gobies' reproductive cycle may be relevant. We predicted (i) a postponement of mating decisions for heatwaves hitting prior to mating during nest-building and mate choice and (ii) an increased need of paternal care activities and risk of brood loss for heat waves hitting after mating. Through a controlled laboratory experiment, common



gobies were exposed to simulated marine heatwave conditions hitting the reproductive cycle at two different sensitive time points of reproductive decision-making: facing a heat wave either during nest building and courtship, or after mating during paternal care. We collected data on nest building, mating success, clutch size, and paternal care, hatching success and filial cannibalism. We discuss our results on how marine heatwaves influence the reproductive behaviour of the common goby, contributing to our understanding of the direct responses of marine organisms to changing oceanic conditions. Such studies are crucial for predicting the resilience of coastal ecosystems in the face of ongoing climate change and can aid in developing conservation strategies and sustainable management practices for vulnerable marine species.

Gfl Fish Atlas showing all fish species in the trilateral Wadden Sea area

Heiko Brunken, Woltmann, I.

The Gfl Fish-Atlas, jointly published by the German Ichthyological Society (Gfl e.V.) and the Bremen University of Applied Sciences, now includes for the first time all marine fish species of the Trilateral Wadden Sea Cooperation between the Netherlands, Germany and Denmark. This includes 122 species, in addition to the marine and diadromous species considered "established", as well as rarer species such as stray visitors, first records or records from neighbouring areas. Worthy of mention are, for example, records of the Lipophrys pholis (first record in Germany), the bluefin tuna *Thunnus thynnus*, the slender driftfish *Cubiceps gracilis* (first record in the North Sea) or more recent occurrences of the shortnose seahorse *Hippocampus hippocampus*. The data come from literature research and selective database queries (GBIF, OBIS, PANGEA), as well as from distribution data entered directly into Atlas (Citizen Science). For all species, in addition to distribution data, further species information such as diagnostic characteristics, species descriptions, photos or references to further literature are available. Numerous links lead directly to the cited literature sources and thus facilitate further research. The atlas is freely available at < <https://biodiv-atlas.de/fische/#!/home>>. After registration, it is possible to enter your own distribution data via a user-friendly input mask both via PC and via smartphone (Android, iOS). The atlas was created using the Biodiversity Warehouse software of the Bremen University of Applied Sciences. It is hosted at the Alexander Koenig Research Museum in Bonn and is a use case in the NFDI4Biodiversity research project (National Research Data Infrastructure for Biodiversity). The work on the atlas is currently done exclusively on a voluntary basis. The current version of the atlas is in German. A translation into English and possibly other languages is being sought, as is the search for cooperation partners in the Wadden Sea area.

Distribution and potential nursery function of the Dutch Wadden Sea for tope sharks (*Galeorhinus galeus*)

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Sharks, skates, and rays are highly susceptible to over-exploitation due to both targeted and incidental capture by fisheries and a suite of life history characteristics that result in low rates of productivity. In addition to these traits, highly migratory behaviours pose particular challenges for conservation and management as wide-ranging movements and large home ranges may span across jurisdictional boundaries and overlap with one or more areas of high fishing pressure. The tope shark (*Galeorhinus galeus*) is classified by the IUCN Red List as Critically Endangered and is known to undertake broad-scale movements throughout continental and pelagic European waters where it encounters threats posed by incidental fisheries capture and environmental change. The identification and classification of nursery habitats is an important tool to improve conservation and management for elasmobranch populations, including highly migratory shark species. Using historical catch records from recreational angling and fisheries bycatch we here provide evidence to support the existence of a pupping area and nursery ground for tope sharks in the Dutch Wadden Sea and adjacent coastal North Sea waters. Given its designation as a UNESCO World Heritage Site, we discuss the management implications of the Wadden Sea's role as a nursery for this vulnerable migratory species.

Feeding ecology of European smelt (*Osmerus eperlanus*) in the German Wadden Sea and the estuaries of Weser and Elbe

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The European smelt (*Osmerus eperlanus*) is an important mesopredator in the Wadden Sea. During its ontogeny, its diet changes from plankton to benthos and small fish. Smelt itself is preyed by larger fish and breeding sea birds, such as the common tern. From about January to March, smelt migrate into the rivers to spawn. The larvae and juveniles then migrate with the river current towards the sea, using the brackish habitats of the estuaries as nursery grounds. The adult, spawned smelt die or migrate back to the Wadden Sea, where they remain until the next spawning season. In this way, smelt connect estuarine and marine coastal foodwebs during their ontogeny. Although there are various studies on the feeding habits of smelt larvae and juveniles in the estuaries and on the diet of smelt in the Baltic Sea, knowledge about the feeding habits of smelt during spawning and in different regions of the Wadden Sea is scarce. Various stressors, such as habitat loss and climate change, could alter the different feeding environments of this species in the future, leading to temporal or spatial mismatch in prey. Understanding the temporal and spatial dietary requirements of this species is important to understand the impact of environmental changes on smelt in the future and the impact of smelt predation on lower trophic levels. We analysed smelt stomach contents from the Demersal Young Fish Survey, from a smelt monitoring programme from the river Elbe and from commercial fishery catches from the river Weser. Preliminary results on diet composition and nutritional status of smelt considering habitat, season, size class, sex and maturity stage are presented.



Biodiversity in Marine Shellfish Culture

Lotte Bouwman

Wild mussels are important marine ecosystems engineers because they form complex biogenic habitats. Although mussels on commercial mussel plots provide similar biogenic habitats, little is known about the effects of mussel aquaculture on biodiversity and associated ecosystem services. This study aims to fill this knowledge gap by investigating the ecological role of mussel aquaculture plots for biodiversity, particularly for species at higher trophic levels. During the 2021 optimisation of musselplots in the Wadden Sea, new musselplot locations were commissioned. The unique opportunity arose of sampling locations both prior (T0) and following (T1-T3) the commencement of utilization as a commercial mussel plot. In total, circa 120 sampling locations spread over 6 new mussel plot blocks are monitored from 2018 to 2026. This longitudinal dataset, part of the PhD project 'Biodiversity in Marine Shellfish Culture', encompasses the transition from seabed to commercial utilization and is hypothesized to yield insights on the effects of mussel culture on biodiversity, for all faunal classifications, including infauna, epifauna and pelagic fauna.

Furthermore, the project will examine the effects of commercial mussel culture on biodiversity more closely, in a series of specifically designed experiments and surveys that will be conducted in the Eastern Scheldt. These experiments aim to determine the ecological role of commercial mussel culture for different species, with a focus on mobile species at higher trophic levels such as crustaceans and fishes. Through this comprehensive approach, we aim to enhance our understanding of the implications of mussel aquaculture on marine biodiversity and ecosystem functioning.





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