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Trilateral Swimway Conference 2024 32nd symposium Waddenacademie

Applying scientific evidence to manage human impacts
on fish life cycles

– Conference report

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Publisher

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Background

The Wadden Sea is the largest intertidal ecosystem in the world, where nature is allowed to develop largely undisturbed. The UNESCO World Heritage property extends along the coasts of Denmark, Germany and the Netherlands. In the Wadden Sea more than 100 marine and anadromous fish species find rich food supply, important habitats and other preconditions to completing their diverse life cycles. Yet, populations of many fish species in the Wadden Sea have declined in recent decades (Tulp *et al.*, 2022, <https://qsr.waddensea-worldheritage.org/reports/fish>¹). Swimway Wadden Sea is an overarching approach for a wide variety of initiatives aiming at achieving the trilateral fish targets. These have been formulated with the aim to maintain or improve healthy fish populations in the Wadden Sea (Wadden Sea Plan²).

The first Trilateral Swimway Conference³ on “Understanding connectivity within the life cycles of coastal fish” was held in September 2019 in Hamburg, Germany, organised by CWSS and a programme committee with members of the ad hoc Working Group Swimway. In the meantime, existing monitoring data have been extensively analysed, and much relevant and excellent research on the topic has been finalised, whose results have the potential to facilitate effective and efficient conservation of fish life cycles in the Wadden Sea and beyond. The crucial task, however, is to translate this scientific knowledge into practical management action, leading to measurable improvement for fish. Important steps have been initiated e.g., the fish migration river in the Netherlands. Yet the diversity of life histories, life stages, and, thus, of the requirements of fish to their environment, remains a major challenge to implement the Trilateral Fish Targets for the Wadden Sea.

The 2024 Swimway Conference, entitled “Applying scientific evidence to manage human impacts on fish life cycles”, was held between 17-19 April 2024 in Groningen, Netherlands (see Appendix a) and attracted 152 participants from 11 countries, representing a rich diversity of institutional and educational backgrounds. The majority of participants came from the Netherlands (105) and Germany (31), four colleagues from the US and three from the UK were welcomed, as well as two from Sweden and Poland, respectively. Belgium,

¹ Tulp I., L.J. Bolle, C. Chen, A. Dänhardt, H. Haslob, N. Jepsen, A. van Leeuwen, S.S.H. Poiesz, J. Scholle, J. Vrooman, R. Vorberg, P. Walker. (2022) Fish. In: Wadden Sea Quality Status Report. Eds.: Kloepper S. *et al.*, Common Wadden Sea Secretariat, Wilhelmshaven, Germany. Last updated 06.09.2022. Downloaded 29.11.2024. qsr.waddensea-worldheritage.org/reports/fish

² Common Wadden Sea Secretariat, 2010. Wadden Sea Plan 2010. Eleventh Trilateral Governmental Conference on the Protection of the Wadden Sea. Common Wadden Sea Secretariat, Wilhelmshaven, Germany.

³ Dänhardt, A. (2019) SWIMWAYS: Understanding connectivity within the life cycles of coastal fish. Conference report, 24-26 September 2019, Hamburg, Germany. Jesteburg/ Lüllau, 82 pages. Common Wadden Sea Secretariat, Wilhelmshaven, Germany.

Brazil, Bulgaria, Canada, and Switzerland were represented by one participant, respectively. The conference took a two-tiered approach: the outcomes of the latest research on fish life cycles were balanced with contributions on the practical implementation of scientific findings to dedicated and effective conservation efforts. Learning from both successful and unsuccessful current management measures would advance our understanding of how management can be adjusted to mitigate or eliminate life cycle bottlenecks. At the same time, the advancement in research and practical applications in management are shedding light on knowledge gaps still impeding the conservation of fish life cycles. Thus, it seems logical that, like the first Swimway conference, the second Swimway conference further explored:

- Drivers of fish populations utilizing coastal marine environments during their ontogeny;
- Potential bottlenecks throughout the life cycle and, eventually;
- Effectivity and efficiency of current and foreseen management measures;
- Observed and projected impacts on estuarine fish populations through large-scale anthropogenic impacts (e. g., with regard to food, mobility, energy, fisheries) and environmental change (e. g., continuous and sudden temperature change, underwater noise, chemical pollution, eutrophication).

These topics were addressed in the conference keynote talk and in five thematic sessions (see Appendix b):

- i. Making room for fish: Ruim baan voor vissen (Chairs: Jeroen Huisman and Peter Paul Schollemma, keynote: Mike Elliott);
- ii. Essential, profitable, or coincidental: Habitat & life history of fishes (Chairs: Britas Klemens Eriksson and Andreas Dänhardt, keynote: Ulf Bergström);
- iii. Getting practical: Improving life for fish through evidence-based management (Chairs: Katja Philippart and Sara Koek, keynote: Katja Philippart);
- iv. Fish in space & time: Life cycle connectivity (Chairs: Julia Busch and Andreas Dänhardt, the planned keynote of Allert Bijleveld had to be cancelled);
- v. Coping with environmental plasticity: Ecophysiology & climate change (Chairs: Flemming Dahlke and Katja Heubel, keynote: Flemming Dahlke).

Each of these occasions was embraced by the conference participants for vivid, high-level and very productive discussions, yielding a wealth of insights, conclusions and new context.

As a result of one conference day less, there was no extra poster session possible, but many great posters that have been prepared for the conference (see Appendix c)

As a special benefit, the Swimway conference 2024 took place in close association with the Free Flow Conference earlier the same week (15-17 April 2024) also in Groningen. This facilitated the exchange between the two communities, expanded the network and provided

the opportunity to learn from each other, especially during the combined excursion programme on 17 April 2024.



Andreas Dänhardt, chair of Swimcon24's organising group, being interviewed by Ella McSweeney about the Swimway Conference at the Free Flow Conference (Photo: Katja Philippart).

Within the Trilateral Wadden Sea Cooperation (TWSC), the second Swimway Conference was held from 17-19 April 2024 in Groningen, the Netherlands. For the Waddenacademie this was the 32nd Waddenacademie Symposium. Organisers were the trilateral Wadden Sea Expert Group Swimway and the Common Wadden Sea Secretariat (CWSS), Waddenacademie, Waddenvereniging, University of Groningen, Wageningen Marine Research, van Hall Larenstein University, Danish National Park Wadden Sea, and Danish Ministry of Environment.

We thank Flonk Hotel Groningen Zuid (left) for their professional support preparing and hosting the conference, and Hotel Schimmelpenninck Huys (right) for a delicious conference dinner.



Nearly aerial picture of conference participants at Flonk Hotel Groningen Zuid (left), and front of Schimmelpenninck Huys (right), venue of the conference dinner (Photos: Andreas Dänhardt).

The financial support by TWSC/CWSS, Waddenacademie, and Waddenfonds (projects Waddentools and Ruim Baan voor vissen) is gratefully acknowledged.

Excursions

Wednesday, 17 April 2024, 12:00-13:00

Excursions during conferences usually take place in the middle or at the end, and starting a conference with an excursion day is rather unusual. In this case, however, excursion day marked the overlap between the Free Flow and Swimway Conferences, with the two communities jointly having a great time during five field trips to locations in the north of the Netherlands. In addition to being able to hold personal conferences again after the Covid pandemic, the excursions at the beginning of the conferences gave participants a break and distance from urgent daily matters, allowing them time to think with a fresh mind and focus on the conference, without the distraction of responding to e-mails, etc.

Excursion 1 “Between Sea and Source: Peizerdiep” has been organised by Sportvisserij Nederland, Staatsbosbeheer, Waterschap Noorderzijlvest, and Waddenvereniging: “Follow the route a sea trout has to swim to reach lake Lauwersmeer and the Wadden Sea from the tributaries in the province of Drenthe. The project “Fish for connection” aims to enrich the Lauwersmeer area both ecologically and economically. By reintroducing sea trout in the ecosystem and restoring their habitat, anglers are drawn to the area. Fish migration is optimised along the route from tributary to the sea, enabling other fish species to migrate as well. Multiple fish species have been tagged with acoustic transmitters, through which the migration in the area can be tracked. This shows us how well fish migration is possible in the area. During the excursion we will visit restored habitat in the tributary streams of lake Lauwersmeer in Drenthe. Here the streams meander again, gravel beds have been made and fish passages have been created to improve fish migration. The area between the streams and the sea sometimes have very opposing functions. Some land is redesigned as a water buffer, where excess water can be stored to counter droughts. Some waterways are used as a shipping route and again others make sure the city of Groningen stays dry by pumping water towards lake Lauwersmeer. We will take you through the difficulties the project encounters with these confounded interests and how by working together with different organisations we can overcome these problems. Lastly, we will visit lake Lauwersmeer and discuss how important estuarine ecosystems are and how we try to improve the connection between the fresh inland waters and the sea.”

Excursion 2 “Between Sea and Source Westerwoldse Aa” has been organised by the Regional Water Authority Hunze en Aa’s, Van Hall Larenstein University of Applied Sciences, and Wageningen University: “The Westerwoldse Aa catchment is situated in the Eastern part of the Province of Groningen and forms a section of the border between the Netherlands and Germany. Although the river and its tributaries only flow over a distance of 80km, the rivers in this catchment are considered to be part of a rich succession of varying habitats, including wetlands, flowing freshwater streams and estuaries. The system provides valuable habitat for migratory fish species and is considered to be a rather unique system for the Netherlands.

Over the last three decades, river restoration and habitat improvement work has been carried out to restore and rehabilitate large sections of the Westerwoldse Aa catchment. Resulting in over 30km of river reconstruction and 2500 hectares of new nature areas. This work, carried out by Regional Water Authority Hunze en Aa's, Province of Groningen, Prolander, Natuurmonumenten, Staatsbosbeheer, and numerous other organisations, has been completed in 2021. For more information www.ruitena.nl. To evaluate the results of the work carried out, a long-term research programme is now studying the effects of improved fish passage and habitat restoration in the Westerwoldse Aa catchment. Much of this work is undertaken as part of the Waddenfund project “Ruim Baan voor Vissen 2” (www.ruimbaanvoorvissen.nl).

During the tour, some of the fishways and habitat restoration projects were visited, where more information about the projects and monitoring results was provided by leading experts Peter Paul Schollema, Jeroen Huisman, and Donné Mathijssen.

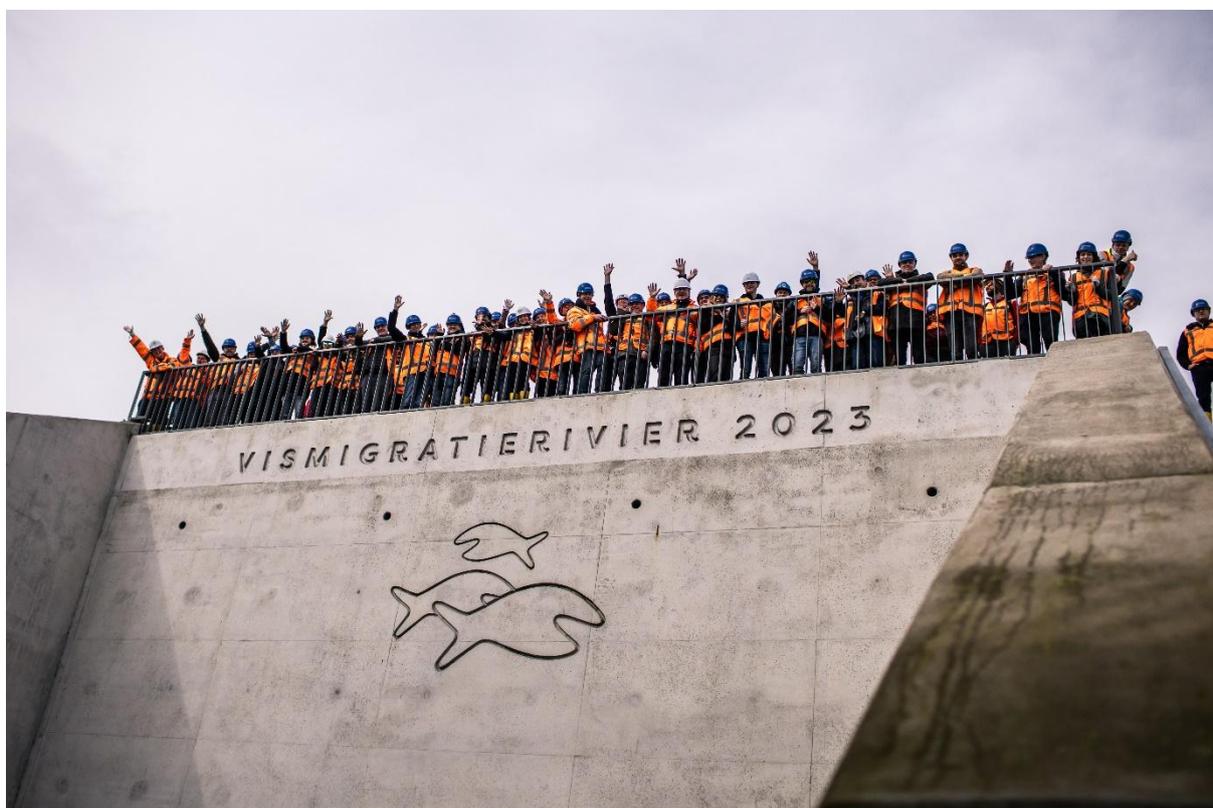


On the lookout: Enjoying perfect weather and Westerwoldse Aa's picturesque waterscape (Photo: Allix Brenninkmeijer).

Excursion 3 “Afsluitdijk & Fish migration river” has been organised by Waddenvereniging: “In 1932 the Afsluitdijk was completed. The primary purpose of the Afsluitdijk was to protect the Dutch interior from the unpredictable and often destructive forces of the sea. By closing off the, so called, Zuiderzee from the Wadden Sea the Afsluitdijk effectively transformed the

Zuiderzee into a freshwater lake. This lake is nowadays known as IJsselmeer. This freshwater reservoir provides a stable and controlled water source, which not only protects against flooding but also enabled land reclamation and agricultural development. The iconic 32km long dike incorporates locks and sluices to control the water flow and maintain navigational access. Fish migration, however, was not an important topic back in the day and migration paths were closed off by the dike.

The Fish Migration River is designed to provide a solution to this problem by opening the dike and recreating a more natural path for fish to migrate between salty and fresh water. It is a large, specially designed channel that runs parallel to the Afsluitdijk, connecting the Wadden Sea with the IJsselmeer. This encourages fish to navigate through the channel, overcoming the barrier that the Afsluitdijk presents. During this excursion you will visit the Afsluitdijk and hear about different strategies and adaptations that are made to overcome the impact the dike has on the migration of different fish species.”



One of if not the largest fish conservation project in Europe: Fish Migration River, restoring migration routes of fish through Afsluitdijk (Photo: Renske de Boer).

Excursion 4 to Texel has been organised by Waddenvereniging and Royal Netherlands Institute for Sea Research (NIOZ): “The Wadden Sea is important for many fish species. Fish make use of the shallow coastal sea during certain periods of their life, but many species also spend part of their life elsewhere. For instance, species like plaice, sole, and herring utilise the Wadden Sea as a nursery during spring and summer, while sea bass, mullet, and dab come to forage, some during the warmer months and others in colder seasons. Meanwhile,

species such as flounder, hooknose, and bull trout are year-round residents. Because we still have a limited understanding of the role of the Wadden Sea for different fish species, the project Waddentools Swimway Waddenzee ([Waddentools Swimway Waddenzee - Swimway](#)) was initiated. In the project a life-approach was chosen and different species and habitats are investigated. Researchers from the Royal Netherlands Institute for Sea Research (NIOZ) are actively engaged in this project. With a legacy spanning nearly a century, NIOZ is a well-established institution conducting research on oceanography, marine ecosystems, and environmental changes in the Wadden Sea and other marine areas. The research facilities of NIOZ are situated on the Wadden Sea island Texel. This excursion will take you all the way along the Dutch coast to the island of Texel. We will traverse the UNESCO World Heritage site Wadden Sea and visit NIOZ's research facilities on Texel. We will get the opportunity to learn more about the fish-related research in the Wadden Sea and might even get a glimpse of the daily catch of the fyke, which is used for long-term monitoring.”



On the way to Texel (Photo: Jan de Boer).

Excursion 5 “Saltmarshes as fish habitat on Schiermonnikoog” has been organised by Rijksuniversiteit Groningen and Waddenvereniging: “Embark on an excursion to the beautiful island of Schiermonnikoog. Schiermonnikoog is the smallest occupied island in the Dutch Wadden Sea and is known for its vast salt marshes. The Wadden Sea provides a range of functions for fish. A number of fish species spend their entire lives in the shallow coastal sea while others only occur during a certain life stage. For a number of fish, the Wadden Sea

provides a suitable nursery ground, with the juvenile fish benefitting from the high food availability and shelter from predators. Traditionally the monitoring of (juvenile) fish in the Wadden Sea has focused on tidal channels. The natural value of salt marshes has long been known, mainly because of their unique vegetation and function as a refuge and foraging area for (migratory) birds. Recent research shows, that salt marshes are also important for fish. Small fish – such as three-spined stickleback, herring, sprat, smelt, and goby – hide in the small coves and feed there on small animals such as bristle worms, amphipods, and shrimps. During high tide, some species swim up onto the salt marsh to hunt for amphipods. Some fish also eat insects that fall from overhanging salt marsh plants into the gully. During this excursion, findings of the project Waddentools Swimway Waddenzee ([Waddentools Swimway Waddenzee – Swimway](#)) were shared and the role salt marshes play in the Dutch Wadden Sea for fish and which management measures help to make the salt marshes a better habitat for (young) fish were explored.”



Presenting hands on field research on a Wadden Sea island: Fyke netting for investigating species-habitat-relationships in the saltmarsh creeks of Schiermonnikoog (Photo: Andreas Dänhardt).

Welcome and opening

Thursday, 18 April 2024, 09:00-11:15

The conference was jointly opened by **Sascha Klöpffer**, Executive Secretary of the Common Wadden Sea Secretariat, and **Katja Philippart**, Director of the Waddenacademie. Katja and Sascha agreed that the trilateral cooperation is an asset and a precondition to protect species in general and fish in particular in the Wadden Sea based on their life cycles and beyond legislative and administrative constraints. This is especially true in times when anthropogenic pressures on animal life cycles increase while populations and ecosystems deteriorate. Seeking to improve the knowledge base by thorough, focused, and hypothesis-driven research while making best use of the already available knowledge at any given point in time must be parallel activities to preserve our natural heritage of the Wadden Sea for future generations.

Roeland van der Schaaf, Dijkgraaf Waterschap Noorderzijlvest, welcomed the conference guests and gave impressions of the picturesque waterscape in the northern part of the Netherlands. The balance between water management through physical barriers and the connectivity of life cycles is always a crucial objective of any management consideration, especially with the challenges brought about by climate change. Successful projects and the people responsible for this success were presented, putting emphasis on communication and implementation of local knowledge.

Paddy Walker, chair of the trilateral Expert Group Swimway, welcomed the audience and put the conference into context with the trilateral fish targets, the four pillars of the Wadden Sea Swimway Vision, and the Swimway Action Programme.



Sascha Klöpffer, Katja Philippart, Roeland van der Schaaf, and Paddy Walker during the opening session, clockwise from top left (Photo: Waddenacademie).

The invited conference keynote talk was given by **Lena Bergström**, senior scientist at the Swedish University of Agricultural Sciences in the Department of Aquatic Resources and centrally involved in development of the Baltic Sea Action Plan. In her presentation, Lena shared her inspiring thoughts and experience on “**How can ecosystem-based management support coastal fish, and how can science contribute?**”. Although the implementation of ecosystem-based management is a key objective on a global scale, there is no single true definition, but the key to achieve ecosystem-based approaches is to involve nature and people by finding fora to collaborate to do what works while accepting and embracing complexity. Fish need to be made part of the game, because they are affected by management at local, national and international scales by several factors, not only fishing. Improving fisheries and environmental management would benefit both fish and people. Practically, this can be achieved by creating projects to allow expanding ideas, by developing restoration measures, by connecting neighbouring countries to resolve transboundary aspects and by engaging local policy-makers. Working in silos needs to be avoided, and a three-dimensional approach with science, practice, and policy co-evolving is needed to create synergies between a wide range of stakeholders and to facilitate quick political response to scientific advice. Managing local factors is central for achieving a good status of coastal fish, and physical loss and disturbance are key issues for most species. Spatial habitat maps and pressure maps should be developed and feed into a risk matrix to inform spatial planning and

to prioritise conservation and restoration. There are few, but increasing, opportunities to operationalise ecosystem-based management at different spatial scales, and coastal fish depend on both local, national, and international measures.



Lena Bergström offering lessons from the Baltic Sea to be learned for fish conservation and management in the Wadden Sea during her inspiring conference keynote (Photo: Waddenacademie).

Posters were introduced in one-minute poster pitches and presented throughout the conference, stimulating many good discussions and new networks during the breaks (see Appendix c).

Theme Session 1: Making room for fish: Ruim baan voor vissen

Thursday, 18 April 2024, 11:15-15:30, chaired by Jeroen Huisman & Peter Paul Schollema

The keynote talk for theme session 1, entitled “Making room for fish: Ruim baan voor vissen”, was given by **Mike Elliott** (International Estuarine & Coastal Specialists, School of Environmental Sciences, University of Hull), invitee for a keynote talk already at the first Swimway conference 2019 in Hamburg and always a surety to deep, inspiring, and entertaining talks from which to take home loads of new insights and context. No exception this time, when Mike shared his and his co-author’s Alan Whitfield’s views on “**Science and management achieving connectivity, coherence and equivalence to ensure the health of estuarine fish communities**”. The major challenge for riverine, estuarine, coastal and marine science & management is to maintain and protect ecological structure and functioning while at the same time allowing the system to produce ecosystem services from which we derive societal benefits. Management has multiple objectives such as stopping adverse causes and consequences of change, maintaining and protecting biodiversity, ecosystem structure and function, and supporting ecosystem services and societal goods, and benefits. While allowing activities and avoiding adverse consequences, past environmental mistakes/abuse need to be avoided and, where necessary, healed, not at last to enable adaptation to wider pressures such as climate change. Understanding ecosystem functioning and human dependence on it remains a key driver for appropriate policy. Likewise, an improved understanding is needed of how policy can mitigate negative impacts of climate change on estuarine connectivity.



Mike Elliott during his session keynote, provoking thoughts and giving valuable context as usual (Photo: Waddenacademie).

Presenting the case of “**Migration of silver eel through the Rozema pumping station** [...]”, **Inge van der Knaap** and co-authors describe a “**complex situation at the edge of the Dutch Wadden Sea**” in the western Dollard estuary. Asking where the tagged eel migrate, die, and survive in general and if pumping stations such as the Rozema cause delay, change in activity, and if this relates to pumping activity and flow speed, these authors were surprised to find that all 30 tagged individuals passed the pumping station and survived, despite a delay of 10.5 hours - 66 days. Just prior to passage, the silver eels increased swimming speed, while the effects of pumping on eel activity still needs further investigation.

As another case study, **Peter Paul Schollema** stressed “**The important role of monitoring during the implementation of fish migration measure at the pumping station Hongerige Wolf**”, where the benefits of a newly built fishway bypass have been investigated by means of fyke net catches and PIT tagging. The fishway is used by a large range of species that mainly matches the species composition found in the canal system and facilitates a broad range of length classes. Although the fishway is technically fully operational, the monitoring revealed lower fish numbers than expected. Further investigations will reveal optimisation potential to be realised.

Within the “**REDEEM project (Research and Development of fish and Eel Entrainment Mitigation at pumping stations)**”, **Jon Bolland** set out to understand fish and eel distribution and behaviour, assess the effectiveness of existing and new technologies to minimise entrainment / maximise safe passage, and to develop innovative measures to provide applied outcomes. The insights of his research revealed a mismatch of current technical procedures and the requirements: Fish have evolved to seek flow refuge on laterally connected floodplains. More pumps operate to increase volume of water discharged without increases in river level, artificial drains also have homogenised habitat (during winter), and flow velocities far exceed swimming capabilities of resident fish. As a result, pumping stations prevent re-colonisation from further downstream.

Willie van Emmerik and co-authors detailed the “**Migration characteristics of roach in the Westerwoldse Aa catchment**” from the Making Room for Fish 2-project, during which fish migration facilities were improved and roach was used as a model to investigate how fish utilise the water system of the Westerwoldse Aa and the migration facilities. This tagging study revealed a considerable loss of fish in the system and large differences in migration behaviour and the crucial role of sufficient sample size and the combination of survey methods to get the full picture. Gaining adequate insight into spatial use and migration in a complex system requires a larger number of fish, catch-tag-release at multiple locations, a system with sufficiently receivers, and a combination of active and passive monitoring techniques to map the fate of fish, including the role of predation and mortality after implanting the tags.

Donnè Mathijssen *et al.* addressed the “**Connection of modified inland waters and the Wadden Sea for migratory fish**”. Starting with an impressive representation of life cycles of European flounder and three-spined stickleback, these authors put the bottleneck

concept from physical obstructions to more abstract obstacles such as turbidity, low oxygen levels, and temperature and asked, to what extent do abiotic conditions pose a non-physical barrier to diadromous fish species? Based on fyke netting and concurrent measurements of abiotic factors, they concluded that on the estuarine side of the complex, fish diversity is dominated by freshwater species but numbers by diadromous species, and that freshwater discharge drives the salinity gradient further away from the coastal sluice complex. The coastal sluice complexes may not be as abrupt of a marine – freshwater transition as they may appear.

“The effects of light pollution on the behavioural and physiological rhythms of migratory fish” were presented by **Danielle Crowley** and co-workers. Fish rely on naturally occurring sources of light during migration, making them potentially vulnerable to a disruption by light pollution. Acute change of illumination affected swimming capacity of three-spined stickleback, but there were no marked differences in behaviour between diurnal and nocturnal migrators. In neither case, clear effects on the physiology could be demonstrated, but regardless of catch time or location acute exposure to artificial light had an effect on the swimming capacities of migratory three-spined stickleback in the field.

Marion Nicolaus *et al.* hypothesised a **“Personality-dependent fishway use”**, tested by **“a field experiment in three-spined stickleback”**, as animal personality affects how individuals move, use and select habitat, cope with danger, are likely to be detected or captured. Using a catch and release design with PIT-tagged stickleback at Hongerige Wolf, the authors found an average passage success of 12%, with fish taking on average 5.4 days to cross after release and passage success varying by 0-23% between weeks. The passage success depended partly on phenotype. If timing of migration was purely environmentally driven, passage would not be biased, but if timing of migration follows a genetic predisposition, fishways may select for specific genotypes and thus contribute to a loss of genetic variation. Other than genetic drivers to be affecting passage success include temperature and predation at aggregation spots such as pumping stations and should be subject of future investigations.

The first session was concluded by a trilateral author team around **Jeroen Huisman**, who cautioned that **“The window in time for migratory fish in the Wadden Sea and its tributaries is getting shorter, it is time to act”**. Sea level rise will affect the coastal zone, which humans protect e.g., by means of tidal barriers. These fragment habitats and alter hydrodynamics to the detriment of fishes. Thus, restoration of fish life cycle connectivity, tidal flux, and environmental flows needs to consider changes in river hydrology and sea level rise. Fish migratory behaviour at tidal locations differs between species and between locations. Sea level rise will affect connectivity, and these effects need to be analysed in accumulation along the Wadden Sea coast. Work in progress includes an interactive map helping to assess current and future plans for coastal infrastructure, and it is recommended to extend sampling to Schleswig-Holstein and Denmark, to include other species during inward and outward migration.

Conclusions of session 1:

- RBVV2 is a project that aims to restore connectivity, improve habitats, and incorporate and combine applied research with more fundamental areas of research.
- The RBVV2 session showed that an integral project, with a mix of practical technical solutions and the use of both applied and fundamental research, can be a good way forward to ascertain science for impact.
- Sluices and pumping stations are essential in water level management but are also an important migratory bottleneck for fish migrating to and from the Wadden Sea. As there are hundreds of tidal locations in the Wadden Sea that impact connectivity in the coastal region, there is work to be done.
- There are many technical solutions but there are also many technical and ecological constraints. Ecologists need to understand the boundaries of technical solutions and translate ecological needs into measurable technical output.
- Species and locations can be highly specific. What is needed to facilitate local decision making? What is needed to acquire generic principles in design and building? In many cases some form of research, including tagging programmes, is needed in combination with simple basic monitoring, this needs to be coupled with local technical knowledge and constraints.
- Artificial light and sound maybe also be important factors in restoring connectivity and habitats. Some fish passes may favour certain behavioural traits more than others. Therefore, measures to improve connectivity may impact genotypes/phenotypes of fish. Coupling of applied research with fundamental research proved to be necessary.
- Sea level is rising, pumping stations are being built, with enormous effort and costs. It is important to include people, processes, knowledge and research as all countries around the North Sea are struggling with similar problems. Therefore, international collaboration is essential in the near future.
- Therefore, we propose a trilateral Make Room for Fish project. To combine goals and measures with on the ground research rooted in, and in collaboration with, the responsible water management organisations. To work across borders, connect and improve the Trilateral Wadden Sea. Now is the time!

Theme Session 2: Essential, profitable, or coincidental: Habitat & life history of fishes

Thursday, 18 April 2024, 11:15-15:30, chaired by Britas Klemens Eriksson and Andreas Dänhardt

Session 2 was opened by **Ulf Bergström** of the Swedish University of Agricultural Sciences, Department of Aquatic Resources, addressing “**Essential fish habitats - connectivity, threats, and management**” in his keynote address. The conservation status of marine habitats in northern Europe is overall very poor, but in contrast to the US, the habitat perspective is not widely used in European legislation. Coastal zones provide essential habitat for fish (including commercial species), especially for early life stages, because just like all kids, juvenile fish need a warm place to live, shelter from threats, and plenty of food. These traits can be found in coastal waters, which are at the same time heavily degraded, e.g., through construction, boating, and eutrophication. Habitat maps with superimposed pressure maps are the tools of choice to link habitat to species to management, and even though there is still a lack of habitat maps in the Baltic Sea (note by the author of this report: but even more so in the Wadden Sea), the development and application of species distribution models has been quite successful in recent years. These models statistically relate species distributions to environmental variables, and then use these statistical relationships to make predictions. For example, connectivity models of essential fish habitat combined with disturbance maps revealed connectivity loss from physical disturbance and poor performance of Marine Protected Areas (MPAs) in this respect. As habitat connectivity increases resilience against other stressors, the conservation of connectivity is one approach to fish conservation, together with direct habitat protection and restoration and maintaining food webs. For this, we need maps of essential fish habitat, their connectivity and pressures, yielding the basis for effective MPA network development and the co-creation of fisheries management and habitat conservation: We need to protect habitats to maintain fish stocks and restore populations of predatory fish to improve habitat status.



Ulf Bergström sharing thoughts and experiences from applying the essential fish habitat approach in the Baltic Sea during his session keynote. Great potential for the Wadden Sea as well (Photo: Waddenacademie).

Bram Parmentier and co-authors reported on “**Small–scale distributions and temporal trends of two sandeel (Ammodytidae) species in the Dutch coastal area**” and a gap of the small bottom fish biomass in the southern North Sea most likely arising from sandeels not being considered. This results in an underestimation of small fish which cannot be correct by catchability correction (false zero catch remains zero), so dedicated surveys are needed along with reliable estimates of carrying capacity to improve ecosystem models that can make predictions taking into account all potential changes.

Maryann Watson and co-authors focus on a rather untypical Wadden Sea habitat: “**Fishing for sound: The soundscape of reef habitats in the Wadden Sea.**” Introducing the concept of marine habitat soundscapes with sound being an important source of information. Fish are one of the largest groups of sound-producing vertebrates and have the greatest diversity of sonic organs. Sound is a critical information source in the ocean and can help us build a picture of subtidal habitats in a system that is highly challenging to monitor. Reef habitats have distinct soundscapes, partly from habitat-specific sound production. Thus, listening to the ocean can be an important monitoring tool, since different biological sound repertoire at the sites indicates different levels of biological activity and species make-up.

Trees are usually not among the first associations one has pondering about fish in the Wadden Sea. But **Jon Dickson** opens a new perspective “**Who lives in a pear tree under the sea?**”. In former times, the Wadden Sea area used to be vegetated. As sea level rose, the forests drowned, and we used to have a lot more “strandgut”. In recent decades, logs and stones were removed and landed by fishing trawlers. The ratio between hard and soft bottom substrate has historically been much different from what we see today, and habitat diversity

in earlier days was likely much higher, supporting also a greater species diversity. The investigation of colonisation and biodiversity development on trunks of pear trees dumped in NIOZ harbour and monitored for 2 years revealed that the wood can mimic historically present hard substrate and supports fast colonisation and usage by marine life. Each reef is unique. However, this can provide landing spots for invasive species. Practically, the wood is biodegradable (which can be both an advantage and a disadvantage), there are low-to-no carbon emissions in production, the material is cheap and readily available, and it can be built at a large scale and anywhere with any trees.

Julia Friese and colleagues takes a functional view from the German INTERFACE-project on the habitat value of intertidal saltmarsh creeks for fish, where they can find **“Worms unlimited: high benthos density relaxes diet competition between fish in intertidal salt-marsh creeks”**. The quality as feeding habitat of Wadden Sea salt-marsh creeks for fish was evaluated via measures of body condition, diet composition, prey availability and calculations of competition in four species commonly occurring in marsh creeks: herring, three-spined stickleback, common gobies, and sand gobies. Although the vegetation is rarely submerged, they cover only small areas and they are only accessible for short time periods, the creeks proved to be valuable feeding habitats for small-sized nekton – especially due to their high polychaete prey availability. This value depends also on the connectivity between habitats. As concrete management advice, large, long, wide, deep and meandering salt-marsh creeks should be protected and promoted to increase habitat size, interaction with the terrestrial system, the inundation time and, with it, the accessibility of a profitable habitat for fish.

Hannah Charan-Dixon and **Klemens Eriksson** ask **“What is the function of Dutch salt marshes for fish?”**, with special reference to the nursery function. In the past millennium, wetlands have been transformed into pastures surrounded by an impermeable hard border. This was an ecological catastrophe for migrating fish, and nowadays, there are rather semi-natural than natural salt marshes. On the basis of extensive field work using fyke netting and a wide variety of other methods, the team investigated the man-made foreshore marshes that are left and found that these lack habitat variability, but that they are still a transit habitat for marine juveniles and migrating fish. The Dutch marshes need to be managed for fish with focus on recreating the brackish water gradient and increasing water retention. Increasing meandering may be an option. Overall, creation of impermeable borders should be avoided whenever and wherever possible. The importance of wetlands internationally recognised, and restoring wetlands is the best measure of fish restoration.

Rob Kroes and co-authors made a case that **“Historic ecology of houting (*Coregonus lavaretus*) shows how migratory fish disappeared from the Rhine-Meuse delta”**. This enigmatic species is strictly protected by the European Habitat Directive, yet it is exposed to many stressors, including organic and chemical pollution, eutrophication, overfishing, river regulation, and barriers such as dams, weirs, dikes, sluices and hydropower installations. The aim of this study was to reconstruct presence and abundance of houting in

the Netherlands before and after their decline and to find out which stressors were responsible for the decline and recent recovery of houting. Houting had been present and probably abundant in the Netherlands for ages, as shown by the historic references. The general assumption that migratory fish in European rivers disappeared from numerous drivers needs nuance, and the historic sources show that big changes in river morphology and overfishing are probably the main drivers for the extinction of migratory fish like houting.

Conclusions of session 2:

- Essential fish habitat is a useful concept to translate habitat knowledge into management action, but rarely applied in the Wadden Sea.
- Map essential fish habitats and superimpose pressure maps to inform spatial management.
- Promote habitat mapping and research into functional species-habitat relationships.
- Habitat connectivity increases resilience against other stressors.
- Management advice: conserve connectivity, find, protect and restore fish habitat, maintain or restore food webs, reconcile fisheries management and habitat conservation.
- Sandeels provide huge biomass but are underrepresented in management due to knowledge gaps. This is one example how management cannot start without first closing a knowledge gap.
- Sound as a communication pathway should be integrated into fish monitoring, since it can provide crucial information, which is missed by conventional monitoring approaches such as net fishing and hydroacoustics.
- Consider wooden hard substrate to restore historical habitat assemblage and biodiversity.
- There is concrete management advice from two research projects on fish in marsh creeks:
 - Manage for large, long, wide, deep, and meandering salt-marsh creeks to increase habitat size, interaction with the terrestrial system, the inundation time and, with it, the accessibility of a profitable habitat for fish;
 - Re-create brackish water gradient and increase water retention;
 - Avoid and dismantle impermeable borders.
- Use data on historical ecology as it provides a better reference for fish abundance than official fisheries statistics alone.

Theme Session 3: Getting practical: improving life for fish through evidence-based management

Thursday, 18 April 2024, 15:00-18:00, chaired by Katja Philippart and Sara Koek

In her second keynote at a Swimway conference (the first was 2019 in Hamburg), **Katja Philippart** gave insights into the “**Consequences of climate-driven change in freshwater discharge to the sea for estuarine and diadromous fish**”. Fish are faced with multiple changes along their life cycles, several of which act as stressors. These include rising sea temperatures, dyking, damming, and obstruction of migration routes in the wake of the protection of coasts and the hinterland, and changes in freshwater discharge. Driven by supply, demand, and distribution of freshwater at land, a decline in freshwater discharge to the Wadden Sea is observed. At the same time, sea water enters higher into the estuaries (marinisation), with possible consequences for reproduction, growth, survival, and migration success of juvenile, residential, and diadromous fish. The observed decline in freshwater from the major river outflows into Wadden Sea is driven by supply, demand, and distribution of freshwater inland, which is enhanced by warming. Changes in freshwater runoff have consequences on fish migration e.g., by affecting olfactory cues and causing osmoregulatory stress due to salt water. These consequences cannot be predicted on the population level and with respect to food web interactions. But the reaction to climate change and the concurrent technical developments are expected to have impacts on fish life cycles. There are multiple claims for freshwater in the Netherlands, and the question of how freshwater will be distributed receiving increasing awareness, e. g., in the trilateral ministerial declaration and in the Dutch parliament. The good news is that we entered the stage of awareness and have identified the problem, now we need to identify solutions.



Katja Philippart opening the session by giving insights on the ecological costs of climate-induced water management measures for fish populations and communities (Photo: Waddenacademie).

The largest and most famous fish project perhaps in Europe is the fish migration river, re-enabling fish passage across the Afsluitdijk. **Wouter van der Heij** sets the stage on “**The first man-made river to benefit fish migration**”. The Afsluitdijk was finished in 1932 with the objectives to protect the Dutch coast and to claim new land for agriculture, but the genesis of this freshwater basin split the Southern North Sea and became an ecological disaster, especially for migratory fish. At the dam openings, fish were now faced with high freshwater discharge, physical blockage of their migration route into the river Rhine, high turbulence and high water velocity rate. Decades later, nature organisations, anglers and fishermen joined forces, took the initiative and developed a plan for reconnecting the Wadden Sea with the former inlet Zuiderzee/Lake IJssel. The optimal fish passage would be open all the time, suitable for both strong and weak swimmers in all layers of the water column, restoring tidal dynamics and ensuring a gradual transition from salt to fresh water while preventing salt intrusion into Lake IJssel. As of April 2024, this project is not yet finished but definitely progressed far enough to make for an exciting excursion destination.

Following up on Wouter’s overview, **Erik Bruins Slot** dedicated his presentation “**Fish Migration River Afsluitdijk, Climate adaptive construction and Research Programme**” to the monitoring programme documenting the change brought about by this construction. The fish migration river was intended to improve conditions for protected species such as houting, salmon, twaite and allis shad and sea and river lampreys, for icons like the sturgeon, for those central to trophic interactions such as stickleback, smelt, clupeids, and flounder, but also for species relevant to fisheries, both recreational (sea trout) and commercial (smelt, eel). A series of impressive aerial pictures gave an impression on the

magnitude of effort required to fulfil the agreed objectives. The research and monitoring plan foresees to collect information on whether the FMR works, e.g., with respect to increasing stocks of the migrating target species, its influence on biodiversity, on the condition of migrated fish, but also with regard to touristic and educational value. Along the way, knowledge will be developed on how the FMR can be improved and adapted to climate change.

Complex ecosystem knowledge needs to be condensed in meaningful indicators, not at last for evaluating progress towards achieving Good Environmental Status as required by European Directives, and other legal frameworks in a wider sense. **Claudia Günther** and **Katja Heubel** propose “**Fish community structure as indicator for ecosystem management**”. Indicators in use need adjustment to the specificities of the Wadden Sea environment and the available data from the fish monitoring surveys. Starting from a trait-based approach with available drivers, random forest and generalised additive models were used to identify factors affecting indicator performance. Differences in spatial structure enabled the definition of core areas for trait groups, and traits were dominated by the same eight species. Species number scales negatively with temperature in juvenile, demersal and oceanodromous fish. Seasonal water temperature patterns and practical aspects such as methodology bias (haul duration, effort correction) and sampling time must be considered e.g., for trend analyses and other interpretation of data based on abundance and species number.

Karen Brandenburg presents the application of another indicator, the “**Multi-Species Indicators (MSI) for fish in the Wadden Sea: trends since 1985**”. This indicator has been statistically constructed on the empirical basis of count data for many species groups such as birds and reptiles, and has now been applied to a long-term (1985-2022) fish data set from a demersal fish trawl. It was concluded that MSI's are a powerful tool for biodiversity trends and can be applied successfully for assessing fish in the Wadden Sea. It depends strongly on species selection and works best with longer datasets with sufficient resolution.

Taking a more integrated approach instead of focusing on taxonomic identity, **Hanna ten Brink** finds that “**Life histories matter: Tailoring conservation measures for coastal fish guilds**”. Using long term data sets on temperature, primary production, and fish abundance, the development of productivity and the effects on different guilds are investigated. It became evident that what happens to one guild is not necessarily representative for other guilds, showing that a species-specific approach remains essential in understanding causes of decline. Knowledge on the causes of decline is crucial for management decisions e.g., to improve survival in the marine environment or habitat for juvenile fish. For this understanding, not only biomass, but also growth rates and survival need to be taken into account.

In the vernacular, fish are silent. **Annebelle Kok et al.** disagree and argue that since fish sing to attract mates and repel rivals even to a degree that fish song even dominates marine soundscapes “**The potential for monitoring fish using hydroacoustics**” is harshly

underutilised and could yield information conventional monitoring methods cannot provide. For example, spawning grounds could be located non-invasively and protected. First results indicate that in agreement with the literature, fish sounds varied with daytime and season, and catches could be matched with the recorded sounds. Since in 96% of fish species sound is undocumented, thorough calibration of sounds with species requires experiments with captive animals.

After a series of hardcore scientific talks, **Julia Busch**, Programme Officer for Swimway matters at the Common Wadden Sea Secretariat, gave an overview over “**Swimway and protection of fish in the trilateral Wadden Sea Area**”, introducing the many institutions, people and their activities to implement the trilateral fish targets during the last one and a half decades. Since the last Swimway Conference in 2019, which has been organised by the then still ad hoc Working Group Swimway, many activities have been carried out, including the graphic representation of fish life cycles, a trilateral project on historical references of fish occurrence and abundance in the Wadden Sea carried out by a consortium from the Netherlands, Germany, and Denmark, UNESCO eDNA expeditions, and not at last, the organisation of the present conference together with Waddenacademie and other partners. Upcoming work includes the update of the Swimway Vision and Action Programme, the organisation of a series of practitioners workshops and webinars and the next Swimway conference, which is planned to be held in Denmark.

Emma Cordier of Wetlands International did a great job in her first ever talk in front of an international audience, giving an overview over “**The Trans-European Swimways Network and Programme**”. Networks are crucial for fish and humans alike, and knowledge about other activities worldwide are the prerequisite to link, collaborate, and learn from each other to achieve common goals. Being focused mainly on freshwater and diadromous fish, a link between the different international Swimway communities still makes much sense to join forces in pursuit to protect and restore fish life cycles. The concept of Swimways of European importance was introduced and discussed with respect to its application to marine-coastal-estuarine ecosystems such as the Wadden Sea. Focussing on collaborative work, knowledge sharing, having a stronger voice when advocating for better policies and implementation, and enabling dialogue between an array of stakeholders, the Trans-European Swimways Network Programme shares the similar objectives with the Expert Group Swimway and seems like a natural partner.

Conclusions of session 3:

- Adaptations to climate change such as flood protection and freshwater management as well as the “marinisation” of estuaries have direct consequences for fish life cycles.
- One of the largest projects of its kind, the fish migration river, aims at restoring connectivity for fish through the Afsluitdijk and follows criteria that mimic natural conditions. Despite the scope of the project, natural conditions like before dam construction cannot be fully restored.
- Meaningful indicators are needed to track progress towards Good Environmental Status, but the definition of indicators is hampered by the availability and quality of monitoring data and a lack of understanding of the underlying processes.
- There is no single best monitoring method, and the combination of monitoring methods seems mandatory for a rigorous evaluation of legal conservation targets.
- Describing and calibrating soundscapes with the fish present holds promise to supplement existing monitoring method, to yield information so far unavailable through established monitoring and to add non-invasive methods to the monitoring toolbox.
- Using hydro acoustics may help to identify habitat function.
- Frameworks such as the Wadden Sea Swimway and the Trans-European Swimways Programme indicate the importance and collaborative potential of dedicated and concerted action to protect fish life cycles.

Theme Session 4: Fish in space & time: Life cycle connectivity

Thursday, 18 April 2024, 16:15-18:00, chaired by Julia A. Busch and Andreas Dänhardt

The invited keynote talk “**From Flyway to Swimway: how can insights from bird tracking inform research on movement ecology of fish?**” by **Allert Bijleveld** had unfortunately to be cancelled at short notice.

Wadden Sea estuaries are characterised by a multitude of natural and anthropogenic stressors and a low species richness, the latter causing a higher functional importance of single species, which are generalists than specialists. No other species is so centrally important to estuarine food webs like the smelt, being at the same time heavily affected by dredging, pollution and habitat degradation in the estuaries. Therefore, **Elena Hauten** and co-authors “**Eighty-seven leagues on the Elbe: Spatial dynamics of the feeding ecology of a key species in an anthropogenically influenced estuary**”. Combining stable isotope with stomach content analysis, an ontogenetic shift from small to bigger prey and an opportunistic feeding behaviour was observed. Shallow areas in the estuary are especially important as nursery and feeding areas, making loss of these habitat a cause for population decline.

Models are a powerful tool to get an idea about processes and relationships that are empirically hard to grasp. Using a theoretical approach, **David Drewes** and colleagues investigate the “**Impacts of environmental pressure on the survival of early life stages of the European Smelt using an Individual-based modelling approach**”. Which external factors determine recruitment success, and what is the impact of climate change and more direct anthropogenic pressures on smelt in the Elbe Estuary? The IBM identified temperature and oxygen as the dominant external factors, while prey and turbulence seemed to be relatively less important. Shifts of spawning due to winter temperature variability could impact the annual cohort's survival, but a mismatch situation during first feeding is so far not confirmed by the IBM simulations.

Zwanette Jager outlines “**The case of smelt *Osmerus eperlanus* in the Dutch Western Wadden Sea**” and cautions against oversimplification of a complex story: as revealed by otolith microchemistry, the fishery targets a mixture of marine and landlocked smelt. As a consequence, smelt from Waddenzee and Ijsselmeer should be managed coherently, for which unravelling the origins is required. Sluice management should be made smelt friendly, and the smelt index should be used to regulate western Waddenzee smelt fishery. The benefits of following this advice would be reduced net ‘loss’ of smelt from Ijsselmeer to Waddenzee, improved smelt immigration and no unnatural sluice aggregations, resulting in robust smelt populations both in the Ijsselmeer and the Wadden Sea.

Jaap Vegter, biologist and fisherman, calls for establishing a more solid knowledge base by applying “**Joint fact finding in a changing estuarine gradient**” by scientists, NGOs, waterboard, and fisherfolk. What is needed is a combination of monitoring salinity, waterflow and discharge and fish, all three with sufficient spatial and temporal resolution to be used as a tool for estuarine gradient control which is both climate responsive and swimway-friendly.

In her talk “**Identifying bottlenecks to management and conservation of the tope shark (*Galeorhinus galeus*)**” the chair of the Expert Group Swimway and the Dutch Elasmobranch Society **Paddy Walker** applies the trilateral fish targets and the conceptual approach of the Swimway vision to the tope shark, a shark who uses the Wadden Sea as nursery. There is no dedicated monitoring and no indicators, and knowledge gaps on this and other elasmobranch species are too severe to apply the management circle from objectives to be addressed with measures, whose success can be controlled with monitoring that can be evaluated and feed back into fine tuning objectives. Obviously, knowledge gain must be at the core of conservation action for tope and other data-poor species.

There may be no fish species in the Wadden Sea more successful to escape the nets of fishermen and scientists than mullets. But **Jena Edwards *et al.*** succeeded to overcome these difficulty and report on “**Large-scale migration and seasonal coastal residency of European grey mullets**”. Mulletts experienced a 10-fold decrease in total catch (weight) between 1980-2012, most likely due to combined impacts of increased water temperature, destruction of coastal habitats through sand dredging for beach nourishment, and fishing, through increased predation by top predators and changes in large-scale hydrodynamic circulation. The combination of different tagging techniques revealed valuable knowledge about timing and direction of migration and arrival and departure and residency and recurrence. Mulletts are typically present in the area in summer with gradual interspecific differences of arrival and departure. Revealing the spatial and temporal features of fish life cycles as shown in this example provides the basis for superimposing pressure maps to inform spatially and temporally explicit management (as suggested by Ulf Bergström in his keynote of session 2).

Conclusions of session 4:

- Food web interactions and their ontogenetic dynamics are crucial to add the functional dimension to interpret life cycles and stressors to eventually pinpoint, mitigate or avoid detrimental consequences of human activities
- There is a multitude of theoretical and practical methods to reconstruct fish life cycles, whose applicability depends on species and life stage, and whose combination will
- Data on ecological interactions will mostly come at the cost of killing the fish
- Taxonomic identity is not always a reliable proxy of the ecology of a species, as shown in the obvious ecological differences of landlocked and diadromous smelt. Neglecting these differences would hamper effective management of human uses such as fishing
- For robust species, non-lethal techniques such as tagging are an option to investigate migration in space and time, along with measurements of ancillary parameters giving insight into the conditions during migration
- There are species for which the knowledge base is so poor that there is no empirical basis for management. Tope shark is an example. For tope and other data-poor species knowledge gain must therefore be at the core of conservation action
- Knowledge comes from diverse sources, and the utilisation of all available sources of knowledge and experience should always be preferred over considering only results of academic research while ignoring other sources of information

Theme Session 5: Coping with environmental plasticity: Ecophysiology & climate change

Friday, 19 April 2024, 09:00-10:45, chaired by Flemming Dahlke and Katja Heubel

In his session keynote, ecophysiologicalist and newly appointed professor at Hamburg University **Flemming Dahlke** set the stage for a type of bottleneck somewhat more abstract than physical barriers, showing that “**Thermal life cycle bottlenecks define climate change vulnerability of fish**”. The trinity of fieldwork, experiments and modelling is used to investigate phenotypic effects of environmental conditions on development and physiology, to evaluate organismal responses and tolerance limits, and to upscale this knowledge to population and community responses (the latter step is crucial, because one legal requirement is the proof that an activity or plan affects the state of a population in a negative way). From embryos to spawners, poikilotherms such as fish are subject metabolic and homeostatic constraints, working via an oxygen- and capacity-limitation of thermal tolerance. These mechanisms could be understood as thermal bottlenecks in fish life cycles, which could be avoided (behaviour), which could impair reproduction, development and growth (if behavioural responses are not possible), and which could lead to increased mortality, population decline and to local and, eventually, total extinction. Data on stage-specific thermal tolerance for 698 fish species revealed that narrow temperature limits of spawning and egg development are a critical bottleneck in the life cycle of marine and freshwater fish, that many species may no longer be able to reproduce in preferred locations and seasons as climate change continues, and that narrow temperature limits result from metabolic and homeostatic constraints during reproduction and early development. More interdisciplinary work on life cycle ecology to identify and protect essential habitat networks and swimways, in which ecophysiology could add new approaches and fresh ideas.



Ecophysiologicalist Flemming Dahlke setting the stage for the conferences' last session, offering a new perspective on life cycles and bottlenecks (Photo: Waddenacademie).

In their talk, **Bass Dye** and co-workers focused on the interaction between food and temperature via metabolism to “**Disentangle[ing] the effects of food level and temperature—dependence on the performance of Wadden Sea fish in different guilds**”. Applying individual-level energy budget models to five-bearded rockling, representing a boreal estuarine resident, and thinlip mullets, representing a Lusitanian opportunist, the authors found that resource level has a greater influence than temperature, and that at identical resource levels the effect of temperature depends on species, size, and guild. Other than growth, the number of offspring (lifetime reproductive success), condition and lifespan are also suitable as performance metric. Higher temperatures may represent one loss of the nursery function of the Wadden Sea, as they leave the area and may be thus deprived of other benefits still present in the Wadden Sea.

Victor Odongo reports on insights from the only fish monitoring programme along the Wadden Sea coast which combines spatial and seasonal resolution and pelagic and demersal sampling with the same trawl, enabling insights into “**Community structure and diversity changes for fish in the Sylt–Rømø Bight, northern Wadden Sea, as a response to climate variability and depth**”. Of the 55 species sampled between 2007 and 2019, only 22 accounted for 95% of the total abundance. Seasonal fluctuations were stronger than long-term trends, a thought-provoking finding with direct relevance to data from seasonally unresolved samplings. Another lesson learned from the seasonal sampling was that fish diversity is highest diversity in the seasonal transition phases, and usually low at higher temperatures. Intertidal flats provide extra feeding/refuge grounds for juvenile fish. The crucial role of season and temperature driving immigration/ emigration and, thus,

biodiversity patterns such as dominance highlights the relevance of spatially and seasonally resolved sampling, which is much less common than obviously required.

Due to their omnipresence and sheer abundance, common gobies are highly relevant to the Wadden Sea food web. Research on factors driving their populations is thus common sense. **Jacqueline Bruhy** report on the “**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**”. Mesocosm experiments revealed that gobies can adapt their metabolism to higher temperatures, and that higher temperatures affect males and females differently, while a T-dependent trade-off favouring reproduction over growth as hypothesised could not be shown. Across the T-spectrum applied, no lethal effects were observed, and metabolic processes, growth and condition could cope with a wide T-range. These findings confirm the eurythermal nature of this species and indicate a high adaptability and resilience against thermal extremes.

After we learned about the function of Dutch salt marshes for fish, **Margot Maathuis** widens the horizon by asking the more general question “**What role does the Wadden Sea play in the life cycle of small pelagic fish?**” Although SPFs represent the wasp-waist of the North Sea ecosystem and are key drivers also in the Wadden Sea food web, they have not been the focus of research and management. Catch composition, length-frequency analyses, maturation status and genetic analyses of herring, sprat, anchovy, and smelt from spatially and temporally resolved stow net and trawl samples were used to derive habitat function of the Wadden Sea and origin of the juvenile herring. The findings confirmed earlier studies that herring, sprat and anchovy use the Wadden Sea both as nursery and spawning ground, while adult smelt is only present in the WS outside spawning season and uses the area mainly as nursery. The results show that population structure and seasonal events need to be known to be taken into account in management.

Conclusions of session 5:

- Ecophysiology offers crucial insights for fish conservation, yet this branch of ecological research is still somewhat underrepresented in conservation and management.
- In addition to physical barriers, thermal extremes represent serious bottlenecks in fish life cycles with the potential to become effective at all levels of response to the environment, from behavior (avoidance & redistribution) over sub-lethal effects on reproduction, development and growth, to increased individual mortality affecting population dynamics and extinction risk, both local and total, in the long run.
- Temperature is a structuring force of the fish community.
- Disentangling the effects of temperature and seasonal phenomena on biodiversity metrics, stage-specific occurrence and abundance patterns requires seasonally resolved surveys .
- Many fish species still utilise the Wadden Sea for multiple life history objectives such as nursery and spawning, among them several species with a central relevance of the food such as gobies, clupeids and smelt.
- The functionality of a warming Wadden Sea depends on the specific thermal tolerance and adaptability of species, with eurytherm generalists being more adaptive and resilient towards change than stenotherm specialists.
- Fundamental research combining field studies, experiments and modelling is the backbone to produce the knowledge that then needs to be applied and transferred. Including societal aspects should not come at the expense of neglecting the scientific foundation, so adequate funding of both the foundation and the application needs to be granted

Lessons learned, final discussion and wrap-up

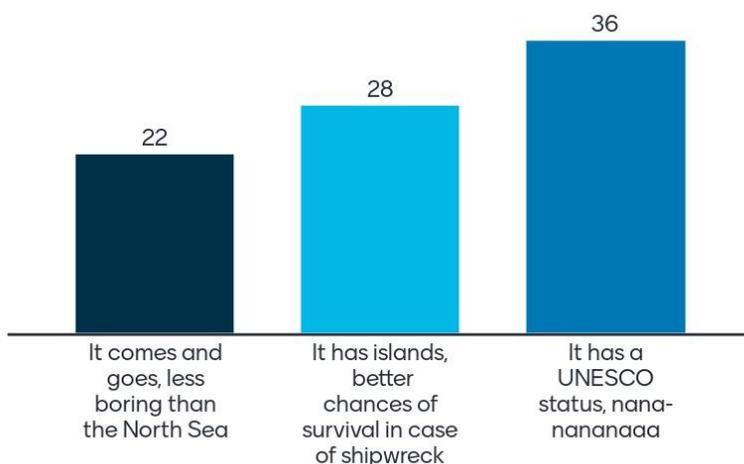
Friday, 19 April 2024, 11:30-12:30

The last session of the conference was traditionally dedicated to the most important of all questions: What did we learn, what does it mean, and where do we go from here? A mentimeter poll served quite well to maintain fun and high spirits in the audience (see below), before we tried to make sense of the wealth of new information during the final discussion.

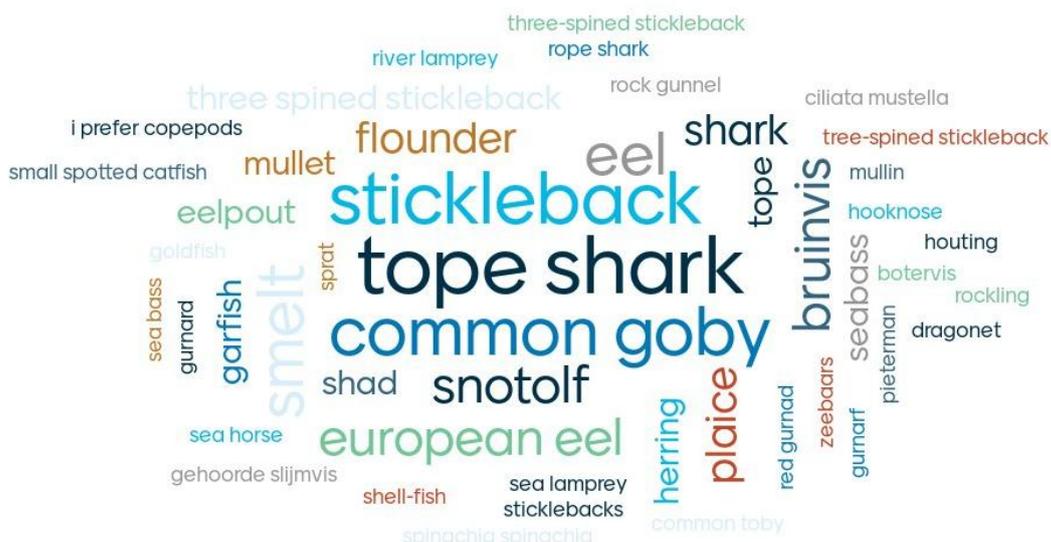
Mentimeter poll

The poll was made up of 13 questions, some of which were not too serious and served to test the technical functionality, some yes/no and some open. Here's what came out:

1. Why is the Wadden Sea better than the North Sea? (88 responses)



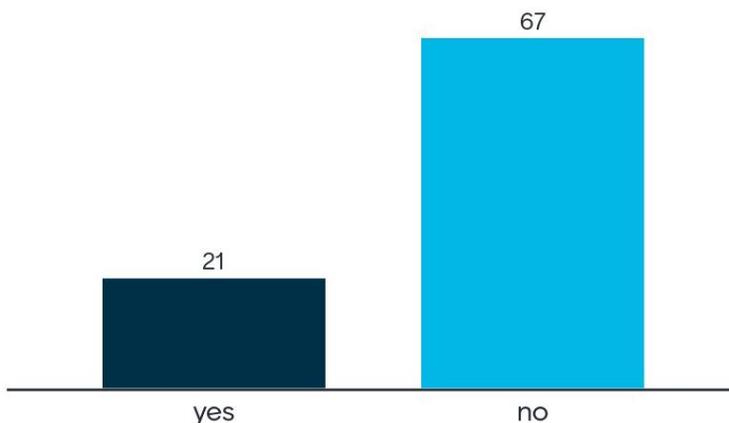
2. Which fish species is the most beautiful in the Wadden Sea? (118 responses)



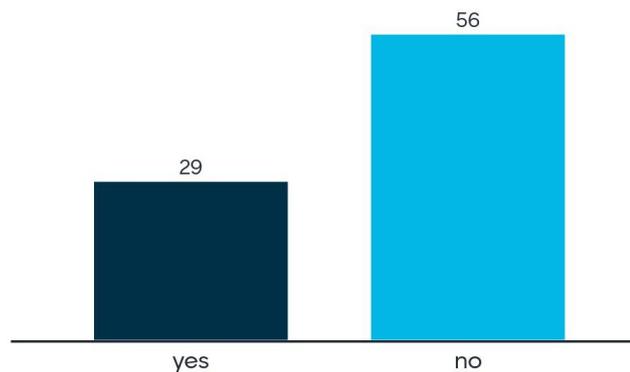
3. Which fish species is the most numerous in the Wadden Sea? (117 responses)



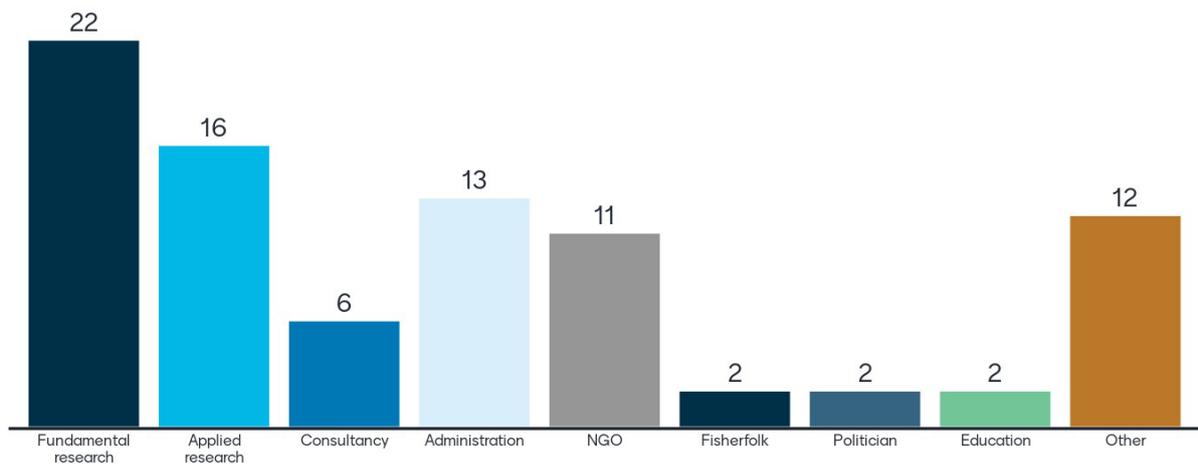
4. Did you attend the Swimway conference 2019 in Hamburg? (88 responses)



5. Did you attend the FFR earlier this week? (85 responses)



6. In which field are you currently working? (86 responses)



7. Who is missing? (76 responses)



communities together worked well (in particular when considering a probably larger fraction of Free Flow Conference participants during the excursions).

The majority of guests were scientists in the wider sense, but the second most abundant group were those working in administration. Given that the application gap was clearly identified as the biggest obstacle to effective fish conservation, the abundance of this stakeholder group was indeed good news, as was the strong representation of NGOs. A clear task for the conference organisers is to get more fisherfolk, politicians and education people to attend future Swimway conferences. Among the serious entries on who was missing were the water authorities (although we had a dijkgraaf give one of the welcome addresses), more policy makers, the fishing industry, port authorities, and Danish participants. This latter point may take care of itself when the next Swimway conference will be held in Denmark.

The results of the conference perceived as most striking were related to knowledge and mapping of habitat, acoustics and soundscapes as novel monitoring methods, and the ecophysiological perspective on life cycles and bottlenecks. These results were quite similar to the topics about which the conference caused change of mind.

According to the mentimeter participants, bigger budgets should be made available for habitat and connectivity mapping and restoration, hydroacoustics and soundscapes, and the application of research results.

Scientific progress of the past five years was greatest for juvenile and adult fish. This is not surprising given the ecological of the Wadden Sea for most fish species occurring in the area, but given the thermal sensitivity of eggs and larvae research on the early life stages seems urgently required.

The overwhelming majority did not agree that reducing stressors is the only effective measure to improve the living conditions for fish. This result would have perhaps been different when asked for “one the most effective ways”. However, given that reducing stressors is mostly a tough and all too often an impossible task, it is good news that there seem to be alternatives to improve life for fish.

Finally, the most important question about which measures to take yielded good input for a checklist for the responsible authorities about what needs to be done.

- Protect and restore fish habitat, e. g., eelgrass and salt marshes
- Provide new habitat
- Reduce chemical pollution
- Protect/close areas and establish no take zones where natural processes are allowed
- Restore connectivity removing dams, opening dykes, managing sluices and installing large-scale fishways
- Raise awareness through education, communication and development of ocean literacy

- Improve fishery practice and selectivity of catch methods
- Evaluate and adapt policies
- Reduce anthropogenic impacts, e.g., fishing, dredging, underwater noise

This rather generic list is in no specific order and suggests no priorities. Yet, it may be a good starting point to get explicit and help relevant actors join forces.

Conclusions and lessons learned

In a perfect world, the conservation of nature and species would not be necessary, because human activity would not harm nature and the environment in any way. The second-best solution would be that the responsible and mandated **authorities** would have **access** to and **be aware** of the **best available knowledge anytime** to put it to widest possible application. During the conference, it became obvious that this cannot be taken for granted (yet), but that there is both a lot of potential and already good examples. All too often, however, there is a mismatch between what we want to do on paper and what we actually do. Many different protection measures and ways to implement them are known, but somewhere along the way between preserving the information and ideas on paper and making them become reality they get lost, often with a lack of political will involved. A big gap is the apparent lack of a “**coat hanger**”, a metaphorical link to policy makers receptive and willing to implement scientific advice. This direct dialogue between science and policy is largely missing, but it does not necessarily need to be organised by scientists but by moderators linking the huge amount of knowledge we already have to political objectives. The overarching concept is ecosystem-based management, which could also be framed as a path rather than as a goal.

In the course of the discussion, **authority** representatives **asked for ideas on measures and offered cooperation** to implement them, showing that scientific conferences such as Swimcon24 can provide valuable opportunities for such crucial discourse. Being obliged to implement legally binding objectives, administrations and authorities may be trapped in descriptors and indicators at species level and focus on a few species, while more ecosystem-based and holistic, full life cycle approaches are needed. In many instances, the knowledge and insights are already at hand, in others there is not enough knowledge to even start. Speeding up knowledge transfer and a leap in development on how we measure and evaluate Good Environmental Status is clearly needed. We are not starting from zero, and much has already been achieved. **New management plans such as those for the Natura 2000 sites represent the opportunity to include advice on measures fish, which would help the authorities organise the political backing.**

A crucially important advice was to **allow** more **natural dynamics** and bring them back where they were lost, because natural dynamics are the guiding principle of National Parks and the Trilateral Wadden Sea Cooperation, but first and foremost an essential requirement **for the Wadden Sea to take care of itself**. Bringing back natural dynamics will promote a process that can be understood as **passive restoration**. Where this does not work, e. g., in some salt marsh areas, **active restoration** may be the tool of choice. Direct recommendations in this respect were derived from the two salt marsh presentations: **Promote large, long, wide, deep and meandering salt-marsh creeks with an estuarine gradient to increase habitat size, interaction with the terrestrial**

system, the inundation time and, with it, the accessibility of a profitable habitat for fish.

The organisational level of conservation also needs to be considered, especially when it comes to decisions about what should be prioritised. The protection of species and populations is a legal obligation in all three Wadden Sea countries, but we need to take a **systems perspective** when following the path of ecosystem-based management. Measures such as restoring habitats should embrace whole communities and the entire system.

Scientists must be aware of their duty to actively help their results to be applied as needed and to support taking up scientific results. Likewise, the authorities should always seek active contact to the research community and formulate their needs as clearly as possible. In many instances, these communication pathways are already in place, such as with the Trilateral Expert Group Swimway. However, it should be a goal for the fish community to get from the stage where authorities during conferences ask the scientists what to do to the point where during such conferences presentations are given about cases where this communication worked and where scientific results have been successfully put to practice. In this respect, **there was a lot to learn from the Free Flow Conference** held at the beginning of the conference week: building on the empirical knowledge base that fish life cycles are impaired by physical migration obstacles, an international movement has developed taking care of removing dams, weirs and other barriers to liberate fish migration. The diversity of actors, approaches and magnitudes of the projects, from small, hands-on restoration by citizens to “heal their rivers” to multi-million-dollar projects coordinated by state authorities. It should be noted, that applying scientific results to management practice does not mean that scientific independence is compromised. But the interface between independent science and the application of its results is less well developed than it could be and should be.

There were many good, practical and already very detailed ideas from the **first Swimway Conference** that arose from the thought experiment what could be done with five million Euros to improve the situation for fish. **Habitat maps** were ranked top priority to be created (“*produce ten maps for ten species in the next ten years*”), with additional maps on fish distribution (aligned to specific life cycles), restoration requirements and bottlenecks to be put on top, supplemented with species fact sheets (e.g., on recruitment, mortality, life cycle sensitivity, cuescape, etc.) and historical information derive future target scenarios where conservation and development should be heading and to address the shifting/moving baselines phenomenon. Stacked on top of each other, these maps would then provide the spatially and temporally explicit information needed to implement measures immediately. Three concrete project ideas were suggested: 1) Bottleneck maps. For this, habitats (including sea floor), fish distribution, stressors, physico-chemical parameters and climate change scenarios are needed; 2) Species interactions (another year of the stomach to collect diet data?): focus on flagship species; 3) Research and define historical references on fish in the Wadden Sea to identify and consider shifting/moving baselines in setting targets and goals.

One of the most striking results from both Swimway Conferences was the obvious need of mapping habitats and stressors (aka bottleneck maps). Creating **multi-dimensional bottleneck maps** from size and distribution maps of fish habitats shall be constructed from spatial information on various scales and sources, including fishermen's knowledge. Habitats should be grouped & clustered according to their specific function (e.g., for spawning or feeding), and connectivity between habitats should be identified/mapped to capture the entire habitat mosaic relevant for the focal species and life stages. With fish habitat maps as the first layer, maps of other features relevant to closing the fish life cycle can be superimposed. These can be classified as natural (physical environment, predators) and anthropogenic (climate change, underwater noise, dredging, dumping, fisheries, migration barriers and habitat loss). From the resulting "stack of layers", bottlenecks within fish life cycles can be identified as a first step to find ways to mitigate them. Natural bottlenecks cannot and should not be managed, anthropogenic bottlenecks need to be managed, provided they are relevant to fish population dynamics. For example, fisheries, migration barriers and habitat loss are probably the most important. These stressors are regional or even local and can be managed, e.g., by removing barriers blocking migration, by restoring habitats and by making the fishery sustainable (e.g., through reducing bycatch by technical means). More abstract types of bottlenecks can also be addressed, e.g., those arising from management, legislation and economic interests: What or who is it that is causing a bottleneck? Why we are not successful, why do the problems prevail? Identifying bottlenecks is the basis to identify causalities and interests why there are anthropogenic bottlenecks, identify socio-economic drivers, barriers and opportunities, which potentially affect bottlenecks (positive and negative) and identify scope for getting rid of the bottlenecks.

Applying the framework of essential or critical habitat successfully used elsewhere (<https://www.habitat.noaa.gov/protection/efh>⁴), this approach will establish an important link from habitat to species to management. It will facilitate translating habitat knowledge in the wider sense (protection and restoration of habitats, habitat networks and connectivity between habitats, mapping and evaluation of local pressures) into management actions, identifying hot spots for management intervention, and promoting adaptive management required under changing conditions.

Bottleneck maps, defined as stacks of habitat maps, fish distribution maps and maps of environmental parameters including anthropogenic stressor, should obviously be a thematic priority of future calls for trilateral research projects in the Wadden Sea.

⁴ **National Oceanic and Atmospheric Administration (NOAA). (2022)** Essential Fish Habitat. Last updated 19 April 2022. Office of Habitat Conservation. Retrieved from: <https://www.habitat.noaa.gov/protection/efh>

Next steps and utilisation of conference outcomes

The most important next step to make best use of the conference outcomes will be to link with the responsible authorities and develop a portfolio of evidence-based, realistic and testable measures to protect fish life cycles. It became evident that, several crucial knowledge gaps notwithstanding, there already is enough knowledge to implement practical fish protection in the Wadden Sea and adjacent estuaries, and that the responsible and mandated authorities would welcome advice on how to do that.

From the conference lessons and supported by the network of scientists, authorities, NGOs, practitioners – the community in short- a catalogue of practical measures to protect fish along the Wadden Sea coast and the adjacent estuaries should be developed. The species list from the latest Wadden Sea Quality Status Report (QSR) and the allocation of species to functional groups in it may serve as a start, from where specific threats could be identified along with ways to eliminate these threats if possible, but at least to make them transparent and as concrete as possible (who needs to change behaviour in which way?). Given the prominence of diadromous species within the Wadden Sea fish assemblage, additional colleagues from the mandated authorities need to be involved in a second step.

The next Swimway conference, which has been invited to Denmark for 2026 or 2027, may be organised along the topic of practical implementation of fish protection measures in the Wadden Sea. In order to further develop the function of Swimway conferences as way to facilitate the dialogue between science, authorities and policy makers, the next conference should be planned even more prudently to provide dialogue opportunities between “the right” people. To this end, the conference could be structured in three thematic sessions, each one feeding from the outcomes of the previous session: Session 1: Presentations on new results and research (hardcore, independent science, whose presenters are asked to formulate their academic conclusions so that they are suitable and accessible for application); Session 2: Link between research results and their application by means of presentations and discussion between researchers and representatives of the responsible and mandated authorities (prudent choice of invited guests is crucial in this respect, and this would be the place where scientific research is confronted with administrative reality); (the intersection of the two would then be the input into) Session 3: Identification of concrete implementation (needs thorough documentation).

This process will successively help to make clear who needs to do what by when and why. A best practice of this iterative process could be established to put best-available knowledge to widest possible application and review and revise regularly while gaining new input and updated knowledge to feed into the process.

An external perspective on Wadden Sea matters by our guests from Sweden

In order to get an external perspective on Wadden Sea issues and the chance to learn lessons from other coastal marine ecosystems, Lena and Ulf Bergström of the Swedish University of Agricultural Sciences, Department of Aquatic Resources were invited to give keynote talks at the Swimway conference. This not only yielded a wealth of new insights and „aha!-moments“ about how differently (and how similarly) it’s done elsewhere, but also provided valuable discussions about things that people working in the Wadden Sea may not be aware of.

Lena and Ulf were unequivocally perceived as a big gain to the conference, and we are very happy that they also found the conference and the excursion very rewarding. Here are some thoughts they shared afterwards:

“The conference showed a wide range of interesting research on fish biology and on how fish react to different environmental pressures, which is needed to inform on measures to improve the living conditions for fish. This knowledge should be transferrable to the Baltic Sea. It is also interesting that the species of the Wadden Sea are the same as in Baltic Sea coastal areas but they live under quite different ecological conditions, so it would be interesting to have comparative ecological studies. On a general level, we noted that the presentations had a very high standard. It would have been interesting to add more about the connection between the Wadden Sea and North Sea, which is also important for many species’ life cycles. The uptake of research results in management is an obvious gap, as it was also discussed at the conference, and it will be interesting to see how this ambition develops. The conference also gave new contacts for potential future research collaboration on fish status assessment, ecosystem valuation and fish ecology.”

Ulf adds: “Lena already brought up some points that the two of us had discussed, for example the interesting fact that you have the same species as we do but some of them in quite different environments (such as herring and stickleback), and that it seems a bit surprising that not too much has happened in management despite the vast knowledge base you have. Judging from the participation at the meeting you must have as many, if not more, fisheries ecologists working on the Wadden Sea than in the whole Baltic, which is something like ten times larger.

Perhaps one way of getting the public as well as managers and policy makers to understand the importance of measures to strengthen fish stocks could be to focus communication on well-known species that people have a relation to (as food, through recreational fisheries, as food for birds or seals etc.). Now a lot of the presentations we heard were focusing on small and not so well-known species, and it is a challenge getting “normal” people to take an interest in these for their own sake – at least that is my experience from the Baltic.

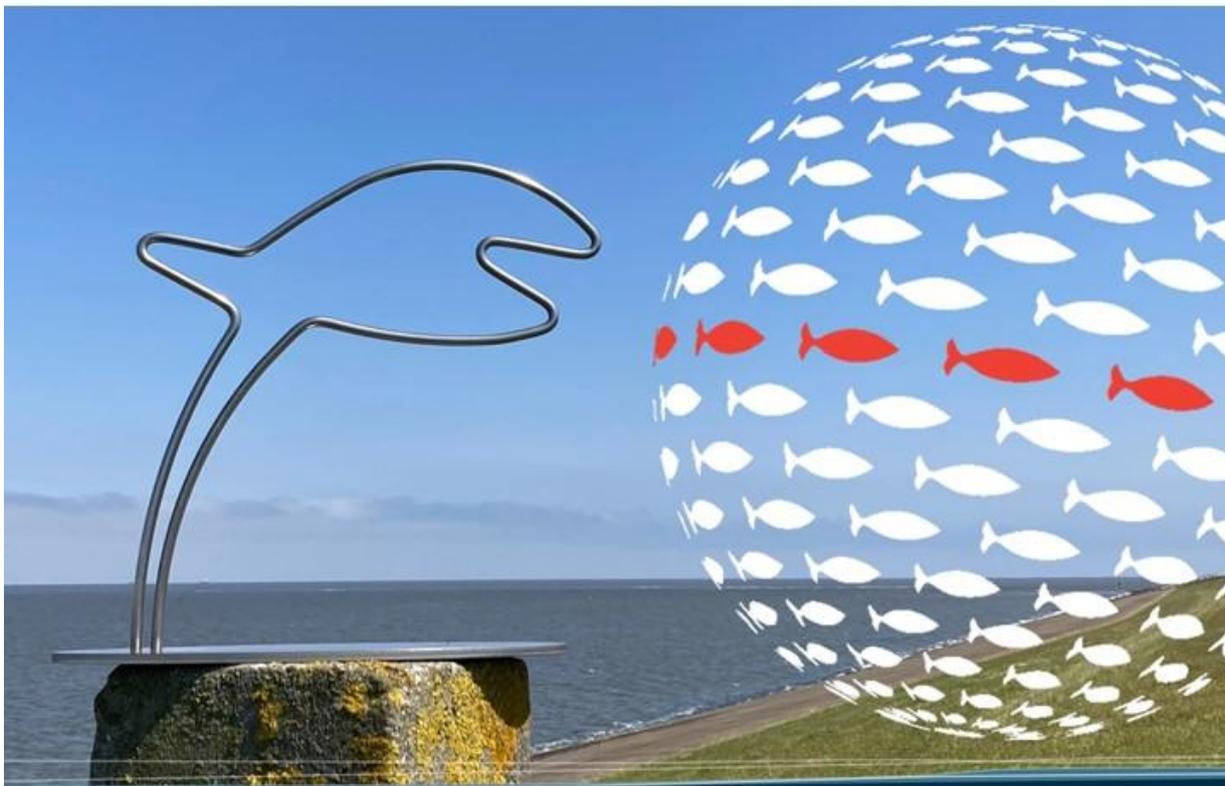
Something that really struck us was how heavily affected the Wadden Sea is from different human activities, with hardly any pristine habitats left. We got to understand the challenges connected to habitat restoration in this area, but given the 30by30 goal and the (hopefully⁵) coming EU restoration law there will be a strong push in that direction. You definitely know quite enough to start implementing measures, and it will be interesting to follow the development in the Wadden Sea in the future.”

Tack så mycket för din värdefulla input. Vi ser fram emot att träffa dig på framtida Swimway-Konferenser!⁶

⁵ In the meantime, the European restoration law has been adopted in summer 2024, with national implementation plans due in fall 2025.

⁶ Translation: “Thanks so much for your valuable input. We look forward to seeing you at future Swimway conferences!”

Appendix a: Programme



Trilateral Swimway Conference 2024

32nd symposium *Waddenacademie*

Applying scientific evidence to manage
human impacts on fish life cycles

17-19 April
Groningen, Netherlands

Conference booklet
and Programme



unesco
World Heritage Site

WADDEN SEA
WORLD HERITAGE

swimway
wadden sea

Programme



WEDNESDAY

17

JOINT EXCURSIONS WITH FREE FLOW CONFERENCE

Excursion Day

Between Sea and Source: Peizerdiep (Excursion 1)

- Meeting place is bus station, Groningen, at 8:30. Bus will leave at 9:00, be at the meeting place at least 15 minutes before departure.
- Planned return to Oosterpoort is by 19:00.
- Organised by Sportvisserij Nederland, Staatsbosbeheer, Waterschap Noorderzijlvest, Waddenvereniging

Between Sea and Source Westerwoldse Aa (Excursion 2)

- Meeting place is bus station Groningen, at 8:30. Bus will leave at 9:00, be at the meeting place at least 15 minutes before departure.
- Planned return to Oosterpoort is by 19:00.
- Organised by Peter Paul Schollema (Regional Water Authority Hunze en Aa's), Jeroen Huisman (Van Hall Larenstein University of Applied Sciences), Donné Mathijssen (Wageningen University)

Afsluitdijk & Fish migration river (Excursion 3)

- Meeting place is bus station, Groningen, at 8:30. Bus will leave at 9:00, be at the meeting place at least 15 minutes before departure.
- Planned return to Oosterpoort is by 19:00.
- Organised by Waddenvereniging

Texel - Researching fish in the Wadden Sea (Excursion 4)

- Meeting place is bus station, Groningen, at 7:30. Bus will leave at 8:00, be at the meeting place at least 15 minutes before departure.
- Planned return to Oosterpoort is by 19:00.
- Organised by Waddenvereniging, Royal Netherlands Institute for Sea Research (NIOZ)

Saltmarshes as fish habitat on Schiermonnikoog (Excursion 5)

- Meeting place is bus station, Groningen, at 7:30. Bus will leave at 8:00, be at the meeting place at least 15 minutes before departure.
- Planned return to Oosterpoort is by 19:00.
- Organised by Rijksuniversiteit Groningen, Waddenvereniging

 <p>THURSDAY 18 Morning</p>	<p>09:00-11:15 - OPENING & CONFERENCE KEYNOTE - FULL PLENARY</p> <p>8:30-9:00 - Registration</p> <p>9:00-9:30 - Opening and welcome addresses</p> <ul style="list-style-type: none"> Sascha Klöpffer, CWSS/TWSC Executive Secretary of the Common Wadden Sea Secretariat Katja Philippart, Chair of the Waddenacademie Roeland van der Schaaf, Dijkgraaf Waterschap Noorderzijlvest <i>Welcome and housekeeping:</i> Paddy Walker, on behalf of the Expert Group Swimway <p>9:30-10:15 - Keynote: How can ecosystem-based management support coastal fish, and how can science contribute</p> <ul style="list-style-type: none"> Lena Bergström, Swedish University of Agricultural Sciences, Department of Aquatic Resources <p>10:15 - 10:30 - 1-minute poster pitches</p>	<p>Welcome</p>
	<p>45-minute coffee break</p>	
	<p>11:15-12:30 - PARALLEL SESSIONS (Room 1 & Room 2 - see schedule below)</p>	
<p>ROOM 1 Auditorium</p>	<p>MAKING ROOM FOR FISH: RUIM BAAN VOOR VISSEN</p> <p>Chairs: Jeroen Huisman & Peter Paul Schollema</p> <p>11:15-11:45 - Keynote: Science and management achieving connectivity, coherence and equivalence to ensure the health of estuarine fish communities</p> <ul style="list-style-type: none"> Mike Elliott & Alan Whitfield, International Estuarine & Coastal Specialists, School of Environmental Sciences, University of Hull & South African Institute of Aquatic Biodiversity (SAIAB) <p>11:45-12:00 - Migration of silver eel through the Rozema pumping station: a complex situation at the edge of the Dutch Wadden Sea</p> <ul style="list-style-type: none"> van der Knaap, I., van Eerbeek, J., Schollema, P. P., Huisman, J <p>12:00-12:15 - Case study pumping station Hongerige Wolf: The important role of monitoring during the implementation of fishmigration measure</p> <ul style="list-style-type: none"> Schollema, P. P. <p>12:15-12:30 - REDEEM project: Research and Development of fish and Eel Entrainment Mitigation at pumping stations</p> <ul style="list-style-type: none"> Bolland, J., Wright, R. 	<p>Session 1</p>
<p>ROOM 2</p>	<p>ESSENTIAL, PROFITABLE, OR COINCIDENTAL: HABITAT & LIFE HISTORY OF FISHES</p> <p>Chairs: Britas Klemens Eriksson & Andreas Dänhardt</p> <p>11:15-11:45 - Keynote: Essential fish habitats – connectivity, threats, and management</p> <ul style="list-style-type: none"> Ulf Bergström, Swedish University of Agricultural Sciences, Department of Aquatic Resources <p>11:45-12:00 - Small-scale distributions and temporal trends of two sandeel (<i>Ammodytidae</i>) species in the Dutch coastal area</p> <ul style="list-style-type: none"> Parmentier, B., Aarts, G., Brasseur, S., Couperus, B., Immler, E., van Langevelde, F., Tulp, I., Witbaard, R. <p>12:00-12:15 - Fishing for sound: The soundscape of reef habitats in the Wadden Sea</p> <ul style="list-style-type: none"> Watson, M., Kok, A., van Opzeeland, I., Eriksson, B. K. <p>12:15-12:30 - Who lives in a pear tree under the sea?</p> <ul style="list-style-type: none"> Dickson, J. 	<p>Session 2</p> 

THURSDAY

18

Afternoon

1.5-hour lunch break

14:00-15:30 - PARALLEL SESSIONS (Room 1 & Room 2 - see schedule below)

ROOM

1

Auditorium

MAKING ROOM FOR FISH: RUIM BAAN VOOR VISSSEN

Chairs: Jeroen Huisman & Peter Paul Schollema

Session 1
continued

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

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

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.

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

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.

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.

15:15-15:30 Discussion & wrap-up of session

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.

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.

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, Verdonshot, P., Winkel, Y., Overduin-de Vries, A., Geest, H. van der

14:45-15:00 Discussion & wrap-up of session

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

Chairs: Katja Philippart & Sara Koek

Session 3

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

45-minute coffee break



THURSDAY

18

Afternoon

ROOM

1

Auditorium

16:15-18:00 - PARALLEL SESSIONS (Room 1 & Room 2 - see schedule below)

FISH IN SPACE & TIME: LIFE CYCLE CONNECTIVITY

Chairs: Julia Busch & Andreas Dänhardt

Session 4

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

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., Fabrizio, A., Jensen, K., Grønkjær, P., Möllmann, C.

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.

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

- Jager, Z.

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

- Vegter, J. E.

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

- Walker, P.

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.

17:45-18:00 Discussion & wrap-up of session

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.

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

- Bruins Slot, E.

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

- Günther, C., Heubel, K.

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

- Brandenburg, K., Bogaart, P.

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

- ten Brink, H., van Leeuwen, A.

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

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

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

- Busch, J. A.

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

- Cordier, E.

17:35-18:00 Discussion & wrap-up of session



19:00-22:00 -
Conference dinner at
Schimmelpenninck
Huys Groningen
Bus transfer available
- See page 6
for more details

FRIDAY

19

Morning

COPING WITH ENVIRONMENTAL PLASTICITY: ECOPHYSIOLOGY & CLIMATE CHANGE

Chairs: Flemming Dahlke & Katja Heubel

FULL PLENARY

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 Wegener Institute for Polar and Marine Research

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.

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.

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.

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.

10:30-10:45 Discussion & wrap-up of session

45-minute coffee break

11:30-12:30 - Lessons learned from single sessions, final discussion, wrap up

Wrap-up

12:30-12:45 - Thanks, final remarks, closing of the conference and farewell

Concluding lunch

Practical information for guests of the Swimway Conference 2024

WEDNESDAY

17

Excursions will start and end at Groningen main train station, and food and drinks are taken care of for excursion day. There will be an e-mail two weeks before excursion day with all relevant information for the day, including

- Time and place of departure and arrival
- Programme of the day
- Description of what to expect
- Practical tips what to bring and what to wear
- Contact details of your excursion coach

Public transfer from and to Flonk hotel or any other place in Groningen can easily be found with the app "9292.nl", downloadable from <https://9292.nl/>. Beautiful cities like Groningen are never finished, so car drivers may want to check road availability at groningenbereikbaar.nl/en.

THURSDAY

18

Thursday will be the intellectually most demanding day of the conference week (see programme). So make sure going to bed early the night before and having a decent breakfast in the morning.

Registration desk and coffee bar open at 08:15, welcoming you to the venue. Being aware that conferences are only as good as their coffee breaks, we foresaw these to be longer than usual, allowing for discussions, networking and digesting the input from the sessions. The scientific programme will end no later than 18:00, and there will be a bus transfer from Flonk hotel to (near) Schimmelpenninck Huys leaving at 18:30, where we will have our well-deserved conference dinner. Please note that we have not organized busses going back to the hotel. You can find your way back with the help of 9292.nl. Taxis and small busses can be ordered at Taxi: Arriva +31 (0)513 655 855.

FRIDAY

19

The last conference day will start at 09:00 in the full plenum (no parallel sessions on Friday). After the first and only coffee break of the day, we will try and jointly wrap up the conference, compile the lessons learned, identify the progress being made and the steps that need to be undertaken so we can make good progress until the next Swimway conference. For this, we need each and everyone in the room, so please make sure to plan your departure only AFTER lunch.

Social media coverage: [#SwimCon24](#) and [#happywaddensea](#).

Venue: [Flonk Hotel Groningen Zuid, Laan Corpus den Hoorn 300, 9728 JT Groningen](#), The Netherlands
Conference dinner: [Hotel Schimmelpenninck Huys, Oosterstraat 53, 9711 NR Groningen](#)

Room reservation: For conference guests there are special discounts available with the discount code [WaddenacademieXflonk](#). You may also want to check rates via booking.com

The conference is organised by the trilateral Wadden Sea Expert Group Swimway and Common Wadden Sea Secretariat (CWSS), Waddenacademie, Waddenvereniging, University of Groningen, Wageningen Marine Research, and van Hall Larenstein University.

Organiser & sponsors

The conference is funded by TWSC/CWSS, Waddenacademie, and Waddenfonds (projects Waddentools and Ruim Baan voor vissen).



Appendix b: Book of Abstracts

Conference 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

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Thursday, 18 April 2024, 09:30-10:30

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 recognises the multiple values that ecosystems provide, and hence the trade-offs that arise under management priorities. Although few arenas are available today for operationalising 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.

Session 1: Making room for fish: Ruim baan voor vissen

Thursday, 18 April 2024, 11:15–15:30

Session keynote: Science and management achieving connectivity, coherence and equivalence to ensure the health of estuarine fish communities

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Thursday, 18 April 2024, 11:15-11:45

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.

Migration of silver eel through the Rozema pumping station: a complex situation at the edge of the Dutch Wadden Sea

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Thursday, 18 April 2024, 11:45-12:00

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.

Keywords: European eel, pumping station, acoustic telemetry, migration behaviour

Case study pumping station Hongerige Wolf: The important role of monitoring during the implementation of fishmigration measures

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Thursday, 18 April 2024, 12:00-12:15

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 fish migration 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?

REDEEM project: Research and Development of fish and Eel Entrainment Mitigation at pumping stations

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Thursday, 18 April 2024, 12:15-12:30

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.

Migration characteristics of roach in the Westerwoldse Aa catchment

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Thursday, 18 April 2024, 14:00-14:15

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.

Caught in between? Connecting modified inland waters and the Wadden Sea for migratory fish

Donné R.A.H. Mathijssen, Leopold A.J. Nagelkerke, Peter Paul Schollema, Jeroen B.J. Huisman, Hendrik V. Winter, Athonie Buijse

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Thursday, 18 April 2024, 14:15-14:30

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.

The effects of light pollution on the behavioural and physiological rhythms of migratory fish

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Thursday, 18 April 2024, 14:30-14:45

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.

Do fishways lead to artificial selection of personality types? A study in wild three-spined sticklebacks

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Thursday, 18 April 2024, 14:45-15:00

Fishways are structures designed to mitigate barriers blocking fish migration, but their effectiveness varies between fish species based on their morphology, physiology and/or behaviour. 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 behaviour 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.

Keywords: fishway, animal personality, three-spined stickleback, Gasterosteus aculeatus, passage success

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

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Thursday, 18 April 2024, 15:00-15:15

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 new build of tidal barriers in the Wadden Sea.

Session 2: Essential, profitable or coincidental: Habitat and life history of fishes

Thursday, 18 April 2024, 11:15–15:00

Session keynote: Essential fish habitats – connectivity, threats and management

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Thursday, 18 April 2024, 11:15-11:45

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.

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

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Thursday, 18 April 2024, 11:45-12:00

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 favourable years, while *Ammodytes tobianus* expands its offshore distribution in less favourable 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.

Fishing for sound: The soundscape of reef habitats in the Wadden Sea

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Thursday, 18 April 2024, 1200-1215

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.

Keywords: passive acoustics; soundscapes; Wadden Sea; fish habitat

Who lives in a pear tree under the sea?

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Thursday, 18 April 2024, 12:15-12:30

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 colonised 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 gunellus* 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 colonisation of tree reefs by both sessile and mobile species shows that rapid ecological restoration may be possible in soft-bottomed systems.

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

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Thursday, 18 April 2024, 14:00-14:15

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.

What is the function of Dutch salt marshes for fish?

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Thursday, 18 April 2024, 14:15-14:30

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.

Historic ecology of houting (*Coregonus lavaretus*) shows how migratory fish disappeared from the Rhine-Meuse delta

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Thursday, 18 April 2024, 14:30-14:45

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.

Key words: fish migration, historic ecology, houting

Session 3: Getting practical: Improving life for fish through evidence-based management

Thursday, 18 April 2024, 15:00 –18:00

Session keynote: Consequences of climate-driven change in freshwater discharge to the sea for estuarine and diadromous fish

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Thursday, 18 April 2024, 15:00-15:30

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.

The first man-made river to benefit fish migration

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Thursday, 18 April 2024, 16:15-16:25

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 organisations, anglers and commercial fishermen grabbed the invitation of incorporating add-ons and presented the idea of a Fish migration 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.

Fish Migration River Afsluitdijk, Climate adaptive construction and Research Programme

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Thursday, 18 April 2024, 16:25-16:35

Many estuarine barriers were built worldwide in response to sea level rise, flooding, and salinisation. 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 in biodiversity. Circular 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 optimise 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.

Fish community structure as indicator for ecosystem management

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Thursday, 18 April 2024, 16:35-16:45

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 analysed 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).

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

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Thursday, 18 April 2024, 16:45-16:55

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 stabilised 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.

Life histories matter: Tailoring conservation measures for coastal fish guilds

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Thursday, 18 April 2024, 16:55-17:05

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 utilise 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.

The potential for monitoring fish using hydroacoustics

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Thursday, 18 April 2024, 17:05-17:15

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.

Swimway and protection of fish in the trilateral Wadden Sea Area

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Thursday, 18 April 2024, 17:15-17:25

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.

The Trans-European Swimways Network and Programme

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Thursday, 18 April 2024, 17:25-17:35

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.

Session 4: Fish in space and time: Life cycle connectivity

Thursday, 18 April 2024, 16:15–18:00

Session keynote: From Flyway to Swimway: how can insights from bird tracking inform research on movement ecology of fish?

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Thursday, 18 April 2024, 16:15-16:45

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.

Unfortunately, this talk had to be cancelled on short notice

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

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Thursday, 18 April 2024, 16:45-16:55

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 behaviour. 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.

Impacts of environmental pressure on the survival of early life stages of the European Smelt using an Individual-based modelling approach

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Thursday, 18 April 2024, 16:55-17:05

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.

Keywords: Individual-based modelling, European Smelt, Elbe Estuary

The case of smelt *Osmerus eperlanus* in the Dutch Western Wadden Sea

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Thursday, 18 April 2024, 17:05-17:15

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 ('binnenspiering'), 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 'binnenspiering') 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.

Joint fact finding in a changing estuarine gradient

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Thursday, 18 April 2024, 17:15-17:25

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 field station and workshop to optimise 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 field lab 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.

Identifying bottlenecks to management and conservation of the tope shark (*Galeorhinus galeus*)

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Thursday, 18 April 2024, 17:15-17:25

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 can be used to identify bottlenecks and to inform management plans and conservation measures in order to manage human impacts on its life cycle.

Keywords: tope shark, management, trilateral fish targets

Large-scale migration and seasonal coastal residency of European grey mullets

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Thursday, 18 April 2024, 17:15-17:25

Found in temperate and subtropical waters worldwide, grey mullets (family Mugilidae) are common across coastal, brackish, and freshwater 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.

Session 5: Coping with environmental plasticity: Ecophysiology and climate change

Friday, 19 April 2024, 09:00–1030

Session keynote: Thermal life cycle bottlenecks define climate change vulnerability of fish

Dahlke, F., Wohlrab, S., Butzin, M., Pörtner, H.-O.

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Friday, 19 April 2024, 09:00–09:30

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.

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

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Friday, 19 April 2024, 09:30-09:45

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°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.

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

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Friday, 19 April 2024, 09:45-10:00

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 analysed 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. Generalised 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.

Keywords: Biodiversity, fish dispersal, tidal range, coastal ecosystems, climate warming, seasonal variations

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

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Friday, 19 April 2024, 10:00-10:15

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 centred 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.

From plankton to plate: diet and feeding ecology of herring (*Clupea harengus*) and sprat (*Sprattus sprattus*) in the Dutch Wadden Sea

Margot Maathuis, Sophie Valk, Xantia van den Brink, Bram Couperus, Martijn Keur, Anieke van Leeuwen, Reindert Nijland, Serdar Sakinan, Ingrid Tulp, Valerie van der Vorst & Jan Jaap Poos

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Friday, 19 April 2024, 10:00-10:15

Small pelagic fish (SPF) are crucial in marine food webs, transferring energy from plankton to higher trophic levels. Zooplankton and SPF are tightly linked to the environment. Especially in the light of climate change, detailed food web studies are essential to understand ecosystem functioning and species dynamics. In the Wadden Sea, Atlantic herring (*Clupea harengus*) and European sprat (*Sprattus sprattus*) are the dominant SPF species. Although several general food web studies have been conducted in the Dutch Wadden Sea, there remains a lack of detailed research concerning the diet and feeding ecology of herring and sprat in this coastal ecosystem, including seasonal variability. Furthermore, recent and structural zooplankton monitoring in the Dutch Wadden Sea is lacking. We conducted a year-long, monthly study on the feeding ecology of herring and sprat in the Dutch Wadden Sea, and analysed stomach contents and zooplankton samples using DNA metabarcoding, which enabled identifying degraded prey. Our findings address intra- and interspecific variations in diet and prey selection, both in space and time. This is the first comprehensive study on seasonal dynamics of zooplankton and SPF diet in this important coastal ecosystem.

Keywords: diet, DNA metabarcoding, small pelagic fish, feeding ecology, zooplankton

Appendix c: Poster presentations

Thursday, 18 April 2024, 09:30-09:45: 1-minute poster pitch

Poster presentations in the 45-minute coffee breaks

Growth and activity levels of the common goby, *Pomatoschistus microps*, in response to increasing temperatures

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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 behaviour 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, behavioural assays were carried out to examine how temperature affects swimming, resting, activity and exploratory behaviour 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

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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 analyse 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

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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.

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

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The GfI Fish-Atlas, jointly published by the German Ichthyological Society (GfI 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://biodivatlas.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

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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 mussel plots in the Wadden Sea, new mussel plot locations were commissioned. The unique opportunity arose of sampling locations both prior (T₀) and following (T₁-T₃) the commencement of utilisation 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 utilisation and is hypothesised 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.

Appendix d: Press release

International conference on fish migration research in the Wadden Sea concluded

Groningen (Netherlands), 19 April 2024

150 leading fish migration experts from the Wadden Sea region gathered in Groningen, Netherlands, from 17-19 April 2024 for the second Trilateral Swimway Conference. Dedicated to understanding and preserving diverse fish life cycles in the world's largest tidal flats system, the symposium featured the latest research advancements alongside discussions on practical measures to uphold and restore the viability of fish populations within the Wadden Sea. Today, the 3-day event, which was set within the Waddenacademie Symposium series, was concluded with a discussion on how to tackle the multifaceted challenges confronting migrating fish through management.

“At this conference experts from various disciplines were given a platform to discuss the most recent scientific research and new insights on management measures”, says Paddy Walker, Chair of the Expert Group Swimway of the Trilateral Wadden Sea Cooperation. “Our symposium highlighted how important it is to consider the ecosystem and its inhabitants as a whole and how significant it is to preserve and restore natural dynamics in the Wadden Sea for us all.”

“The health of our trilateral migratory fish strongly relies on the connectivity between open sea, the Wadden Sea, and inland waters”, adds Katja Philippart, Director of the Waddenacademie. “Knowledge on the relationships between these pathways and the needs of fish during different phase in their life cycle is crucial for effectively addressing present and future hurdles along their way.”

At the conference, the experts concluded that the visibility of fish as an essential component of the Wadden Sea has drastically improved since 2019, when the inaugural Swimway Conference was held. In order to protect fish in this World Heritage Site, there is a common understanding that it is essential to continue protecting and improving their environment. Further, science has progressed in the persist to provide information on potential management measures. During the conference, authorities, stakeholders, and managers shared the sense of urgency to jointly act based on our current state of knowledge.

The translation of scientific knowledge to management actions, where conferences such as this one play a major role, can lead to measurable improvement for fish. The process is a cornerstone of the Trilateral Wadden Sea Cooperation’s Swimway Vision built on research and monitoring, policy, measures, stakeholder involvement, and communication and education.

The 2024 Swimway Conference was organised by the Trilateral Expert Group Swimway, the Common Wadden Sea Secretariat (CWSS), Waddenacademie, Waddenvereniging, the University of Groningen, Wageningen Marine Research, van Hall Larenstein University, Danish National Park Wadden Sea, and Danish Ministry of Environment in the framework of the Trilateral Wadden Sea Cooperation. The next Swimway conference is expected to be organised in Denmark in three years' time.

About the Wadden Sea

The Wadden Sea is the largest tidal flats system in the world, where natural processes proceed largely undisturbed. It extends for 500km along the coasts of Denmark, Germany, and the Netherlands. For its globally unique geological and ecological values the Wadden Sea is listed by UNESCO as World Heritage. Nowhere else in the world is there such a dynamic landscape with a multitude of habitats, shaped by wind and tides. Global biodiversity is reliant on the Wadden Sea. In the framework of the Trilateral Wadden Sea Cooperation, Denmark, Germany, and the Netherlands take on the responsibility of preserving this irreplaceable ecosystem for the benefit of present and future generations.

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