



WHERE THE WATERS MEET

The secret of underground rivers on the coast

ON EXPEDITION

A walk along the beach at low tide. Dried sand crunching beneath your feet. But sometimes you sink in and your shoes get wet – a matter of no consequence to the walker but a conundrum to the scientist: Where does the wetness come from? Is there fresh groundwater flowing beneath the surface into the sea?

The mixture does it

This kind of submarine groundwater discharge is currently being investigated by staff from ZMT and Jawaharlal Nehru University (JNU) on the German island of Spiekeroog and Odisha beach in India. The work by the two institutions is funded by the Alexander von Humboldt Foundation under its Research Group Linkage Programme. “We want to compare our field research results in the mixing zones between salt water and fresh water which not only occur at river mouths but also on the beach,” explains Nils Moosdorf who coordinates the project at ZMT. Zones like this in beach areas – be they in the chilly north of Germany or the tropical heat of India – are known as subterranean estuaries. They are of great importance with regard to nutrient pollution in coastal areas. Groundwater and fresh water flowing into the sea contain nitrate, for instance, from agricultural fertilisers, which can accelerate the growth of algae in the sea. “One day, we’d like to be able to say precisely how many nutrients really are flushed into the ocean each year via the groundwater along a roughly one-kilometre-long stretch of beach,” says Moosdorf. But as long as the subterranean processes in the mixing zones have not been elucidated, we are still a long way from being able to make relevant statements regarding coastal protection.

It all happens on the last few metres

Nutrients are not simply transported into the oceans by groundwater. “A lot can happen on the last few metres,” explains Moosdorf. “In this intermediate zone, chemical reactions can occur that convert nitrate, for example, into gaseous nitrogen so that it no longer reaches the ocean.” This would be an advantage when it comes to coastal pollution, but it still can’t be reliably calculated for extended stretches of coast. Moreover, due to the tides the subterranean estuary moves around. This changes the discharge processes which are now supposed to be studied in depth by this German-Indian collaboration. [>MORE](#)

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A WALL IN THE WAVES

Other oceans – divergent developments

Some three million years ago, the Central American Isthmus (CAI), the land bridge between Central and South America, closed. This not only had an impact on the evolution of land animals, which could now migrate freely across the entire American continent, but also on marine animals, which were now unable to cross between the two newly formed oceans. Previously connected marine populations were permanently separated, and sister species, known as geminate species, started to diverge: one in the Tropical Eastern Pacific and the other in the Tropical Western Atlantic.

The separation of the oceans caused changes in water temperature, productivity, salinity and oxygen levels on each side of the isthmus. The ability to adapt to the specific environmental conditions of each ocean was decisive for the persistence and resilience of the two newly forming species.

A natural experiment for investigation

During decades of research involving DNA sequencing, several species pairs of this kind have been identified. "This sets the stage for an unparalleled natural experiment of repeated marine adaptation and evolution," explains Oscar Puebla who coordinates the DFG research project Fishstransisthm at ZMT. Together with its partner organisation the Smithsonian Tropical Research Institute in Panama, ZMT is now using this groundwork to investigate six geminate sisters in-depth by sequencing their entire genomes. This requires first extensive fieldwork in both oceans. DNA sequencing then considers two aspects: apart from the normal random genetic change over the generations of a population, changing

environmental conditions also trigger adaptive changes in the genome. Genetic predispositions that prove advantageous are passed on whilst disadvantages are filtered out. This process of natural selection leaves traces in the genome that can be identified.

"We are using this natural experiment to learn about the future adaptability of species to climate change," says Puebla. An important question is whether each sister species is now adapted to the ocean in which it lives. If that's the case, it should have lower survival if transplanted to the other side of the CAI. Of course, this can only be a thought experiment because one cannot swap species as in the children's classic, Lisa and Lottie. But the question flows into various laboratory experiments. In aquariums in Panama, for example, scientists can subject the two sister species to the same environmental conditions, for example temperature, and analyse the effect on each species.

Short- und long-term adaptation

The genetic change in the geminate species reflects a long phase of adaptation to new environmental conditions brought about by the formation of the CAI. Interestingly, however, the Eastern Pacific species also had to adapt to short-term environmental fluctuations. Upwelling regions in the Tropical Eastern Pacific subject the water in certain places to sudden drops in temperature of as much as 12 degrees. "With a view to climate change, we also want to investigate how short- and long-term adaptation interact to build species resilience," says Puebla.

In the DFG research project, FISHTRANSISTHM, ZMT explores the genomic bases of marine adaptation and resilience in geminate fish species together with the Smithsonian Tropical Research Institute and Auburn University.

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WELCOME TO THE ZMT ACADEMY

Ready for the next career step? The ZMT Academy offers support with a portfolio of continuing education opportunities and individual advice. A conversation with the new leadership duo, Carolin Müller and Tim Dudeck

What is the ZMT Academy?

TIM DUDECK: We are ZMT's point of contact for early-career development for students, doctoral and postdoctoral researchers. We provide information, support and further training on topics that are relevant to research projects but not always directly addressed: How do I manage my time and data? How do I present my research understandably and usefully outside of academia? But we also consider early career researchers' (ERCs) individual career steps: What skills should I continue to develop? How do I write an attractive CV or a convincing project application? What sort of career could I have outside of academia?

What support do you provide?

CAROLIN MÜLLER: One of the cornerstones of the ZMT Academy is our continuing education portfolio: courses, training and workshops – online and on site. We don't evaluate performance at all, which makes for a trusting and stress-free atmosphere, because we also care about our ERCs' mental health; they are usually under a lot of pressure to succeed. We can provide orientation and structure in the form of bundled resources, reduce people's job interview anxiety or discuss conflicts with project partners.

TIM DUDECK: We really focus on personal as well as structured support – from onboarding via project progression to career planning. We approach people, ask them how things are going over a coffee, listen and are always available. We especially want international researchers to feel visible from the moment they join ZMT and be able to air any questions they have outside of their research group.

Who decides on the courses?

CAROLIN MÜLLER: As the new leaders, our aim is to develop the courses collaboratively, bottom-up. To create a meaningful, appropriate portfolio we address our target groups directly, at events and in surveys: What have we missed so far? What worked well?

TIM DUDECK: The idea is not only for our ERCs to assimilate the knowledge provided but also to pass on their own expertise in courses and thus acquire teaching experience. At the same time, we keep an eye on what the universities in Bremen and Oldenburg are offering as well as other international institutions and graduate schools with which we cooperate. We want to create synergies and connect our junior researchers.

What role is played by alumni?

TIM DUDECK: ZMT has built a group of almost 1,000 alumni spread around the world and we also want to reinforce their feeling of community through the ZMT Academy. They all have expertise that is helpful for our early career researchers. By continuously cooperating with alumni and ZMT Friends, we preserve valuable knowledge and make it available for the long term.

CAROLIN MÜLLER: We would like to revive this strong network and use it to increasingly recruit speakers, course leaders or even project partners – outside of academia, too, potentially in politics or NGOs – always in the spirit of ZMT's mission and goals: research, capacity building and consultancy on the sustainable use of tropical coastal ecosystems.

The ZMT Academy is a hub for building academic competence, personal development and social exchange amongst early career researchers working at ZMT. [>MORE](#)

Change of leadership at IOI Germany



Rebecca Lahl is the new head of the International Ocean Institute (IOI) Germany taking over the position from ZMT director Raimund Bleischwitz. Since the 1970s, the IOI has been campaigning for the conservation of the oceans and their resources worldwide. The independent, non-profit organisation conducts training and capacity building in Ocean Governance. In the person of Rebecca Lahl, who not only has immense experience in knowledge sharing, capacity building, political work, education and stakeholder engagement but is also co-lead of ZMT's Programme Area 5, Ocean Literacy, Equity and Leadership, it is once again a ZMT member of staff at the helm of the IOI – thus continuing many years of productive partnership between the IOI and ZMT. [>MORE](#)

ZMT AND THE CLIMATE TARGETS

COP29: Managing coastal ecosystems

Marine researchers who want to help co-design the future of the oceans can now take part in a special course on the Ocean Teacher Global Academy (OTGA) platform: the UNESCO Co-Design Training Course for actions in the Ocean Decade supports the marine research community in co-designing a project that could lead to co-producing and sharing knowledge. The aim is to develop a proposal that can be submitted for endorsement by the Ocean Decade. The course drew inspiration from a pilot project and is a joint initiative of ZMT and UNESCO's Intergovernmental Oceanographic Commission (IOC). [>MORE](#)

OECM: Alternative conservation areas

In implementing the Global Biodiversity Framework (GBF), which was one of the topics discussed at COP 16 in Cali, Colombia, ZMT research on the potential of other effective area-based conservation measures (OECMs) is highly relevant to the conservation of biodiversity. If 30 percent of the world's land and sea areas are to be protected globally by 2030, marine protected areas, known as MPAs, will not be

sufficient. An international research team headed by ZMT scientist Estradivari produced a promising new study of OECMs in Indonesia that could become a further means of achieving global biodiversity goals. The Indonesian government and various interest groups used the new research findings to underpin the country's progress in achieving national and international conservation goals. The study also provides a model for other countries that want to integrate different region-related management practices into their nature conservation. [>MORE](#)

Promising: mangrove reforestation

Within 20 to 40 years, newly planted mangrove forests can already sequester three-quarters of the carbon captured by naturally growing mangrove stands. This impressive finding in a new international study involving ZMT, which is also relevant to climate protection, underscores the potential of mangrove reforestation to efficiently sequester carbon. The international team of 24 researchers from 12 countries published the results of analysing 40 years of extensive datasets in the journal *Science Advances*. Mangrove forests have been the subject of successful, promising research at ZMT for decades. [>MORE](#)



The **Mangrove Future Day** in Berlin in December 2024 sought to focus on discussing and communicating these far-reaching insights into the value of mangrove forests for potential solutions to the climate and biodiversity crises. Together with WWF Germany and Berlin Zoo, ZMT had invited many scientists, political decision-makers and representatives of society to the capital to draw attention to the urgency and wealth of opportunity for conserving and reforesting mangrove forests in the Tropics. The event not only discussed strategies for sustaining the future of mangrove forests but also initiated partnerships for more education and communication on the topic. promising research at ZMT for decades. [>MORE](#)