China

Partnership for Observation of the Global Ocean

INSPIRING A NEW APPROACH TO AQUACULTURE ON HAINAN ISLAND

A Sino-German team is using ocean observations to guide coastal water quality improvements on the Chinese island of Hainan, supporting conservation strategies for essential marine habitats and protecting vital ecosystem services

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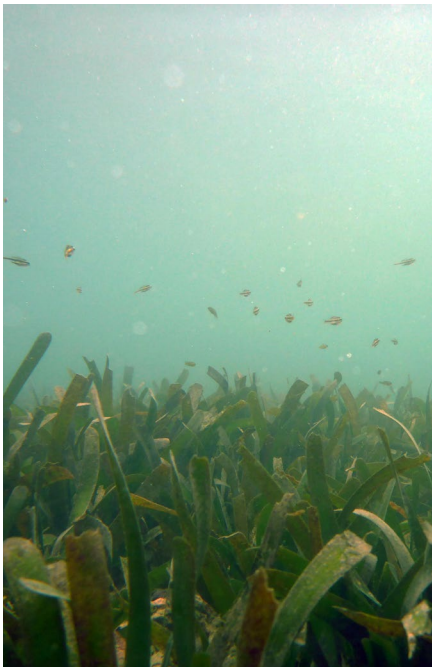
Home to misty mountains and tropical rainforests, the southern Chinese island of Hainan also boasts a wondrous coastline stretching for more than 1500 kilometres. The island's plentiful bays, serene natural harbours, and productive coastal waters sustain a rich diversity of ocean life, support lives and livelihoods, and are a major draw for the island's burgeoning tourism trade.

But at the same time, pressures from rapid population growth, human activities, and anthropogenic climate change have degraded coastal ecosystems, causing previously untold carnage for essential habitats such as mangrove forests, coral reefs, and seagrass meadows. These impacts undermine the supply of essential ecosystem services and threaten natural resources, effects that a Sino-German team has spent the past 15 years observing, studying, understanding, and trying to reduce.



WHERE ARE ALL THE FISH?

In 2006, a team of international experts including Tim Jennerjahn, a senior scientist at the Leibniz Centre for Tropical Marine Research (ZMT), took a glass bottomed boat out to coral reefs off the coast of Sanya, Hainan's southernmost city.

Jennerjahn recalls being awestruck by the majestic beauty of the surrounding environment, yet a coral reef ecologist on the voyage immediately sounded an alarm.

"He asked where all the fish had gone," says Jennerjahn, who co-launched an initiative in the mid-2000s that manifested in the inter- and transdisciplinary projects LANCET[1], ECOLOC[2], and TICAS[3] which have brought together a wide range of project partners across China and Germany. "Amidst the corals, there were some fishes here and there, yet the explosions of diversity that one normally sees in reef environments were largely missing: they were clearly not in good shape."

1 Land-Sea Interactions in Coastal Ecosystems of Tropical China

2 Environmental change affecting COastal ecosystems of tropical China during the Anthropocene: Landward vs. OCeanic influence

3 Tackling environmental change Issues of China's coastal Aquatic Systems: Networking, capacity building and knowledge exchange

Further surveys supported the team's worst fears: habitats along Hainan's coastline were under considerable strain – not just reefs, but other important marine havens such as mangrove forests and seagrass meadows.

"Hainan's coastal habitats provide a wide range of essential ecosystem services such as coastal protection, carbon storage, biodiversity, and are a vital buffer to the pressures of population growth, industrial activity, and climate change," says Jennerjahn. "These initial surveys sparked a series of long-term Sino-German collaborative projects to better understand the impact of human influences on Hainan's coastline that could be disturbing the health of coastal ecosystems. Our initial assumption was that these vital habitats were being degraded largely as a result of human waste and agricultural runoff from fertilisers. But our long-term observations of coastal water quality, sediments, and land use patterns have revealed a much more complex picture."

A traditional foe of coastal water quality is waste from factories and farms. Yet the team's observations – which included a diverse range of long-running initiatives that span coastal water sampling, satellite images, physical environment measurements, and sediment core drilling – have pointed squarely at another major source of environmental degradation: the island's unbounded aquaculture ponds. "Extensive aquaculture sites along coastlines is commonplace in South East Asia, and is an important source of food and income for local communities," Jennerjahn explains. "But they can come at a high cost to the environment: the east coast of Hainan alone has lost more than two thirds of its mangrove forests to aquaculture, predominantly for the cultivation of grouper and shrimps.

"Wastewater is often discharged untreated into the sea, where it can lead to eutrophication or end up in the food chain. This can create conditions that are hostile to marine life, and ultimately threaten entire coastal ecosystems. One consequence of the high nitrogen input is an over-fertilisation of coastal waters, and one impact of this can be excessive algal blooms, which can disrupt the delicate balance of the ecosystem and set in play processes that starve the ocean of oxygen. Combined with other pollution sources from people, farms, and shipping, we saw that large quantities of nitrogen were accumulating in bays and lagoons, as well as affecting other key parts of the coastline."

REPLACING A SINK WITH A SOURCE

The eutrophication of coastal waters is widely recognised as a serious threat to marine ecosystems around the world. Large quantities of pollutants entering the environment untreated can cause populations of algae and phytoplankton – which thrive on nitrogen – to spike, blocking out sunlight, and causing aquatic plants to die. Dead plant matter is then consumed by bacteria, which can deplete oxygen in the sediment, creating anoxic conditions that are largely hostile to marine life. Shading from above and intoxication from below leads a die-off of essential seagrass habitats.

The removal of an ecosystem that previously acted as a buffer against nitrogen from human activities suddenly makes habitats such as fringing coral reefs vulnerable to the effects of eutrophication. "If you remove a sink, the mangrove forest, and replace it with a source, the aquaculture ponds, you can imagine it has a large-scale effect on the environment," Jennerjahn says. "Our observations indicated that this is exactly what has happened in Hainan's coastal waters. But the ocean environment was poorly characterised

and to address such large-scale problems it is crucial we understand how the environment is changing over a long time period – and why."

Scientists working on the projects have developed and utilised a wide range of ocean observation methods across a period now spanning more than 15 years. Dedicated voyages collect regular samples from coastal waters, coral reefs, seagrass meadows, and aquaculture ponds. Teams gather specimens of algae, seagrass, mussels, crabs, and fish to assess how their biology is being affected by environmental change. Bespoke detectors and floating chambers are used to measure physico-chemical parameters such as pH, dissolved oxygen, salinity, temperature, and carbon dioxide emissions. Trace gases such as carbon dioxide, carbon monoxide, methane, and nitrous oxide are monitored using techniques such as infrared spectrometry, which is used to reveal quantities of organic chemicals present in the water. Sediment cores are drilled in coral and the seabed to reconstruct the history of nitrogen and other mineral deposits over time. And historical satellite data is used to analyse the alarming proportions of mangrove areas converted to aquaculture ponds over the past five decades.

"These extensive observations, taken over a long period of time, have delivered datasets that can enable researchers to better understand the root causes of environmental degradation," Jennerjahn explains.

"Through them we are building a more detailed understanding of ecosystem structure and function and how habitats are being affected by direct human activities and climate change. They have shown in stark detail the loss of mangrove forests to brackish water aquaculture ponds over time, the negative effects of untreated wastewater from aquaculture facilities, and the demise of essential habitats such as seagrass meadows, which are declining in both abundance and diversity, and in some cases disappearing altogether."

KEY THRESHOLDS FOR SEAGRASS SURVIVAL

One example of the power of these observations came when a team of scientists on the programme wanted to understand how pollutants were affecting seagrass. Seagrass meadows are formed of plants that resemble terrestrial grass yet are more closely related to orchids and lilies. They play essential roles in nurturing marine life, filtering pollutants from the waters, and locking carbon from the atmosphere.

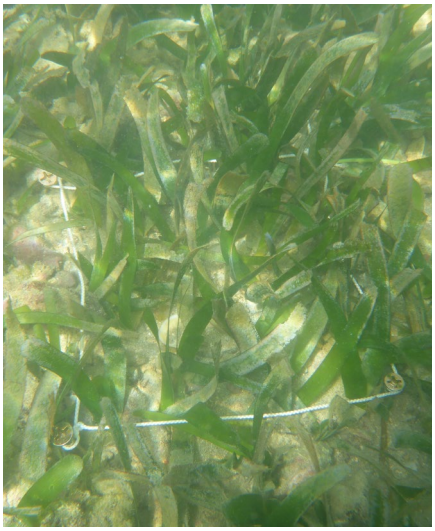
Jennerjahn's PhD student Esther Thomsen was tasked with monitoring three key seagrass sites off Hainan's coast that the team had observed a decade earlier. Yet when she began her investigations , she had to update her team with some distressing news. "Esther called to report that two of the three seagrass meadows had almost vanished," Jennerjahn recalls. "This was a very upsetting event to witness first-hand, however our atlas of ocean observations provided a unique opportunity to better understand the conditions under which seagrass dies.

"Pulling together readings from sediment cores, satellite images, and a vast range of environmental measurements in space and time, we were able to determine thresholds for seagrass survival based on the nitrogen content present in the water. At concentrations just above 100 micrograms of dissolved inorganic oxygen per litre of seawater, seagrasses will start to disappear. This was the first time a threshold value for long-term nitrogen pollution had been identified above which the seagrass meadow habitat can

no longer recover. Understanding what is going on and why it is happening is especially important when one considers how interconnected these ecosystems are. That's what makes our long-running observations so powerful: when we can identify such thresholds, we can then make clear recommendations about how things can be improved."

Another key branch of the initiative has been the development of dedicated channels of dialogue with stakeholders in Hainan, spanning environmental authorities, aquaculture farmers, nature reserve managers, media, politicians, school children, and citizen scientists.

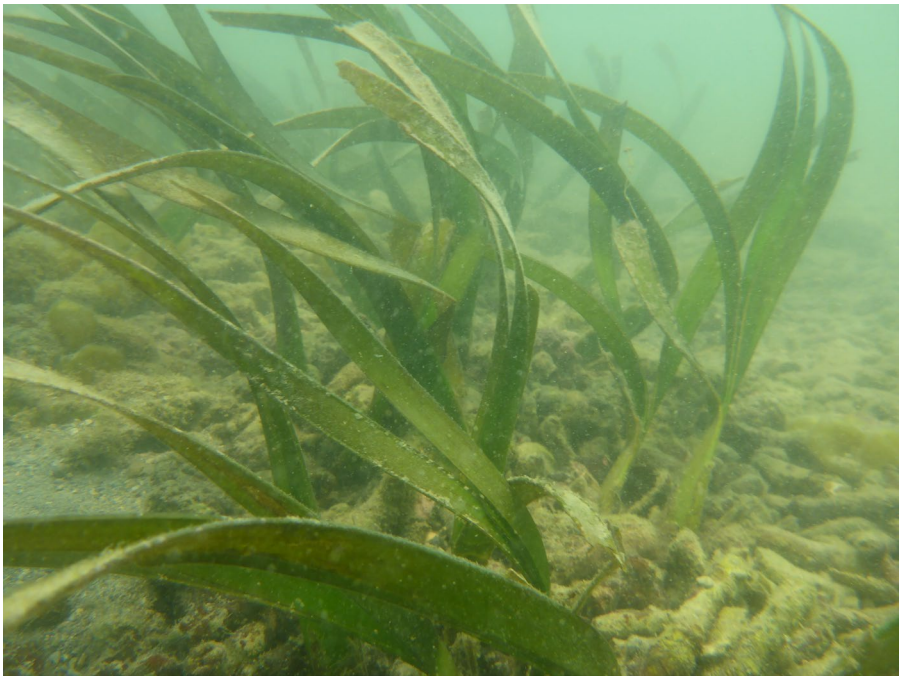
"The ultimate goal of our work is to help solve the problems afflicting Hainan's tropical ecosystems, and to address these challenges we need both to generate scientific knowledge and also encourage concrete actions from policymakers and other non-scientific stakeholders," says Jialin Zhang, who coordinates the TICAS project, which is specifically aimed at stimulating such knowledge exchange. "We need to ensure they understand the threats facing these key habitats and are engaged in the production of scientific knowledge, so that collectively we can understand the situation, identify possible responses, and outline what action to take."



LINKING SCIENCE AND SOCIETY

Zhang describes her role as a 'knowledge broker': amongst her responsibilities are the delivery of stakeholder workshops, policy briefs, and factsheets that decision makers and the wider public can use to understand and engage with the research. One example is dedicated training for aquaculture pond managers to reduce the impacts of the process on the surrounding waters. "Levels of pathogenic bacteria in the water can depend heavily on how aquaculture pond operators treat their runoff," she says.

"Over the long-run, poorly managed facilities can have devastating effects on the marine environment, and have been linked to further fragmentation of mangrove forests, loss of seagrass, reductions in gastropod diversity, and damage to corals. But through this initiative we want to spread an important message: that something can be done about it. For example, facilities that operate sealed ponds, reduce their use of agrochemicals and artificial feed, treat effluents, and address microbial imbalances at source, can reduce the impacts of pollution entering the wider environment and the release of greenhouse gases."



On the other hand, the research is also enabling the team to outline key priorities, informed by the outcome of studies. "Recommendations include things we need to address, such as avoiding further mangrove fragmentation and reducing and/or treating aquaculture effluents

and municipal sewage, and things we need to do more of, such as citizen science, public engagement, and increasing our observations of Hainan's coastal environment," Zhang explains.

"To do this effectively, we need to build dialogue and trust between a wide range of stakeholders – both scientific and non-scientific. One way we do this is through stakeholder workshops, where we bring people together to work on these issues. On the other hand, we need to identify the stakeholders out there who might be interested in this scientific knowledge and look at ways we can work together. It can take time: you have to build relationships, get to know people and their work, and then you can start doing great things together."

While science is often measured on metrics of papers and citations, the impact of science and society initiatives can be harder to quantify. Yet Zhang points to clear benefits of developing such a dedicated approach: water quality guidelines and fishing moratoria developed by Hainan's environmental agency; large numbers of aquaculture facility managers learning how to manage and treat pollutants; outreach activities and citizen science projects that support members of the public in understanding the importance of vital habitats such as seagrass meadows and even actively contribute to the research.

"There is still a long way to go, but we can make a big difference with this approach," she says.

"People are becoming more aware of the coastal problems that Hainan faces and the kind of actions they need to take to lessen these impacts.

Hainan is such a beautiful place – it would be a catastrophe if its coastal waters were ruined by human activities. Our long-term monitoring programme has revealed there are strong influences from human activities that are not immediately visible from the surface. We want people to see that, understand their implications, and act."

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Written by Adam Gristwood

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