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Telltale furrows:
What the Baltic Sea seafloor reveals about bottom trawling

To what extent does bottom trawling impact the seafloor of the Baltic Sea—and how quickly does it recover? Two new studies from the Leibniz Institute for Baltic Sea Research Warnemünde (IOW) show that the marks on the seafloor provide a much clearer picture of the actual impact than vessel position data alone. Using high-resolution echo sounder measurements and AI, the researchers reveal previously insufficiently recorded impacts and also document surprisingly rapid changes of the seafloor condition. Furthermore, they found strong indications of fishing violations in a marine protected area. The study results were published in the journals "Ecological Informatics" and "Anthropocene."

The seafloor as a record of fishing impacts

Bottom trawling is one of the most significant forms of direct human interference with the seafloor. Nets are dragged along the bottom, and heavy net-opening devices – known as "otter boards" – in particular can leave deep furrows. This stirs up sediments, alters habitats and harms benthic organisms. However, it is often difficult to determine the extent to which individual marine areas are affected. Standard methods of monitoring fishing activity based on Automatic Identification System (AIS) vessel data have gaps: Especially smaller fishing vessels, which play an important role in the western Baltic Sea, are not reliably detected by established monitoring systems.

A team around IOW marine geoscientists Mischa Schönke and Peter Feldens, which also included scientists from the Thünen Institute of Baltic Sea Fisheries, has therefore adopted a different approach: Rather than just investigating where fishing vessels have been operating, the researchers analysed the fishing gear marks on the seafloor. Their research shows how this can be used to record spatial and temporal changes in trawl marks and to gain new insights into the regeneration of the seabed.

"AIS vessel position data tell us where fishing boats have been active. However, they do not necessarily reveal the extent to which the seafloor was actually impacted. The marks in the sediment, on the other hand, provide us with direct evidence of physical changes – even in areas where information on fishing activities is patchy," explains Mischa Schönke, lead author of the study published in *Ecological Informatics*.

Thousands of cubic metres of trawl furrows – and an unexpected finding

Fishing intensity in the western Baltic Sea has changed significantly in recent years. In particular, due to the largely discontinued fishing for cod, bottom trawling declined markedly in many areas from 2022 onwards. This presented the researchers with a rare opportunity to investigate how this reduction in fishing pressure is reflected on the seafloor and whether the first signs of ecological recovery are visible.

From 2020 to 2024, the IOW team surveyed an area of up to 4.7 km² in the Fehmarn Belt each year using a high-resolution multibeam echo sounder. The device scans the seabed using sound waves and can measure its surface structure down to the centimetre. Based on the volume of detectable trawl furrows, the researchers calculated a so-called Trawling Index, which quantifies the physical damage to the seafloor.

The results revealed significant changes: In 2021, the researchers recorded a furrow volume of approximately 5,067 m³ across an area of around 3.4 km². By 2022, the volume had fallen to just 1,108 m³ across a comparable area – a decline of almost 80 %. At the same time, the share of areas with no detectable trawl marks rose from merely 14 % in 2021 to as much as 65 % in subsequent years. What is noteworthy is that this trend is not reflected in the AIS vessel position data. This direct comparison of the two methods – the first to be carried out over five consecutive years – thus demonstrates how an assessment solely based on vessel movements can greatly fail to capture the actual changes on the sea floor.

The repeated surveys also show that trawl marks can disappear almost entirely within a year. To investigate whether this also means that the communities on the seafloor recover, the team carried out accompanying sampling of benthic invertebrates such as mussels, worms and crustaceans. The number of individuals, biomass and species composition fluctuated considerably, without revealing any consistent trend over time. Whilst species diversity did show a correlation with trawling intensity, biological recovery has not yet been conclusively demonstrated, as other environmental factors also influence these seafloor communities.

AI detects trawl marks across large areas

The findings from the Fehmarn Belt raise the question to what extent this new method of trawling impact monitoring can be applied to other areas of the Baltic Sea. This is where the second study comes in: Using a specially trained neural network that automatically recognises trawl marks in digital depth maps, the IOW team analysed around 1,069 km² of seafloor in the Mecklenburg Bay, the Kiel Bay, the Arkona Basin and the Fehmarn Belt. The data, collected between 2016 and 2025, were mainly derived from publicly available surveys by the Federal Maritime and Hydrographic Agency (BSH). This allows large areas of the seafloor to be investigated systematically without having to map all trawl marks manually.

“What’s exciting is that we can now utilise existing survey data to address an entirely new research question. With the help of AI, trawl marks can be mapped fairly efficiently, even across large seafloor areas. This provides an important additional source of information for assessing the impact of fishing,” explains Peter Feldens, lead author of the study published in *Anthropocene*.

The results reveal significant spatial variations: In the Mecklenburg Bay, evidence of trawl fishing was found in more than 80 % of the surveyed grid squares, and in the Kiel Bay, in more than 90 %. In the central Arkona Basin, by contrast, almost 40 % showed no discernible marks. Additionally, striking circular areas, some over 500 metres wide and free of trawl marks, are evident in the Mecklenburg Bay. These coincide with depressions formed by rising gases or other fluids within the sediment. Fishers presumably avoid these areas because they pose a risk to their fishing gear.

Telling scars in a marine protected area

The importance of recording temporal changes on the seafloor in great detail with the new methodology is also demonstrated by a further comparative analysis of the Fehmarn Belt Marine Protected Area: Between 2024 and 2025, the average area proportion covered by trawl marks rose from 9 % to 22 % – thus more than doubling between the two surveys. This is particularly noteworthy because mobile bottom trawling has been banned there since December 2024. The AIS vessel position data of 2025 corroborate this increase of fishing activity. However, not every trawl furrow can be unambiguously dated, as furrows can remain visible for months. The findings therefore provide conclusive indications of illegal fishing after the ban came into force, but do not constitute irrefutable evidence for every single incident.

Better detection means better protection

Together, the two studies show that by using acoustic surveys and AI-assisted trawl mark analysis, the actual impact of bottom trawling on the seafloor can be assessed in much greater detail and over a much wider area than was previously possible. “Both methods can help to identify hotspots of damage and better assess the effectiveness of conservation measures,” Mischa Schönke and Peter Feldens agree. However, the methods are not equally effective everywhere, for example in sandy areas, where trawl marks disappear particularly quickly. Furthermore, the disappearance of the furrows does not necessarily indicate a recovery of the seafloor's ecological functions. “Future studies should always combine the new methods with biological and geochemical measurements in order to better assess whether, and under what conditions, seafloor habitats can regenerate sustainably,” the two IOW researchers conclude.

Original publications:

Mischa Schönke, Inken Schulze, Mayya Gogina, Christian von Dorrien, Daniel Oesterwind, Peter Feldens (2026): *What AIS misses and Acoustics reveal: Monitoring seafloor disturbance and recovery from bottom trawling in the southern Baltic Sea over five years.* Ecological Informatics, doi.org/10.1016/j.ecoinf.2026.103638

Peter Feldens, Inken Schulze, Jacob Geersen, Elisabeth Seidel, Svenja Papenmeier, Aicha Naumann, Daniel Oesterwind, Mischa Schönke (2026): *Spatiotemporal variations in trawling intensity in the German Baltic Sea Basins based on bathymetric data.*
Anthropocene, doi.org/10.1016/j.ancene.2026.100574

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