Project *brief*

Thünen Institute of Sea Fisheries 2024/24a

Development of a non-invasive, opto-acoustic underwater fish observatory

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- **Optical and hydroacoustic methods have so far only been used separately to observe and monitor fish stocks. Here we present a coupled hybrid system for the first time.**
- **Identification and size classification of fish and jellyfish species are carried out non-invasively and automatically with the help of AI algorithms.**
- **We have developed three different variants of the Underwater Fish Observatory (UFO) and tested them successfully in the Kiel Bight.**

Background and aim

Marine ecosystems are very dynamic systems that change continuously under the influence of a wide range of external factors. This is particularly true for marine ecosystems, which - like the North Sea and Baltic Sea - usually suffer from multiple pressures due to e.g., fisheries, climate changes and discharges of pollutants and nutrients. The potential cumulative effects of overexploitation on the one hand and the simultaneous manifestation of anthropogenic climate change on the other hand, suggest that commercially exploited fish stocks are vulnerable components of marine ecosystems. The efficient implementation of EU marine and fisheries policy for the long-term and sustainable use of our marine resources requires the provision of temporally and spatially high-resolution data on the diversity of fish species, their seasonal dynamics and the causal relationships with their biotic and abiotic environment.

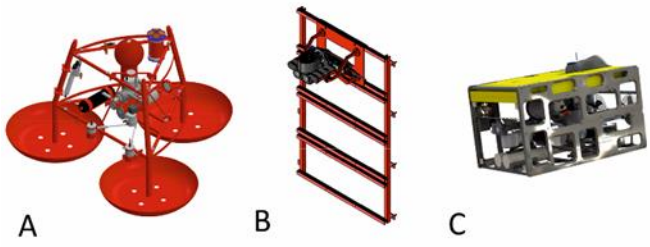

Figure 1: Illustration of the three UFO systems: (A) stationary, (B) portable, and (C) mobile (Source: Thünen Institute / Boris Cisewski).

UFOTriNet is an interdisciplinary innovation project for high-resolution, continuous, automated and non-invasive fish and environmental monitoring. This project aims to develop a cost-effective alternative to ship-based monitoring of fish stocks as a contribution to a reformed, evidence-based fisheries policy. The focus is on the development and operation of a trilateral network in the Bay of Kiel consisting of a stationary, a mobile and a portable underwater fish observatory, all three of which are modularly equipped with the same core set of opto-acoustic sensors. At the heart of all three UFO systems is a standardized automatic pattern recognition system that enables species identification, fish counting and size and weight classification with a high degree of statistical certainty.

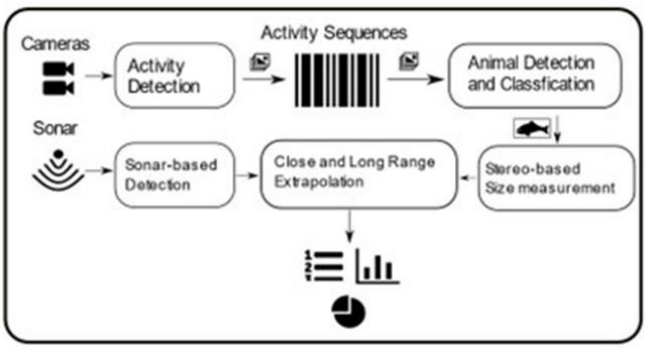

Figure 2: Documentation of the individual processing steps from data acquisition to final quantity estimation using the hybrid algorithm (Source: Thünen Institute / Gröger et al., 2024).

Approach

At the beginning of the project in May 2019, we pushed ahead with the technical optimization and further development of the stationary UFO and began developing and building the mobile and portable UFO with the corresponding device hardware. At the same time, software-based work was carried out within and between the systems. Using existing video and sonar sequences, we further developed the pattern recognition algorithms and trained them on selected fish species in the Baltic Sea. The deployment of the stationary systems and the start of data acquisition with continued development of the algorithms in the mobile system took place from May 2020.

Results and conclusion

In the UFOTriNet project, three variants of a new type of opto-acoustic underwater fish observatory (UFO) were developed, which were operated and tested in the Bay of Kiel. The different UFO systems can be used in different areas and for different questions (Fig. 1). The stationary and portable UFO (a miniaturized version of the stationary UFO) are designed either for continuous operation or for flexible routine operation in various key areas (e.g., marine protected areas, spawning grounds and wind farms) or for temporary connection (e.g., to bridge pylons, rocks, lighthouses or aquaculture facilities).

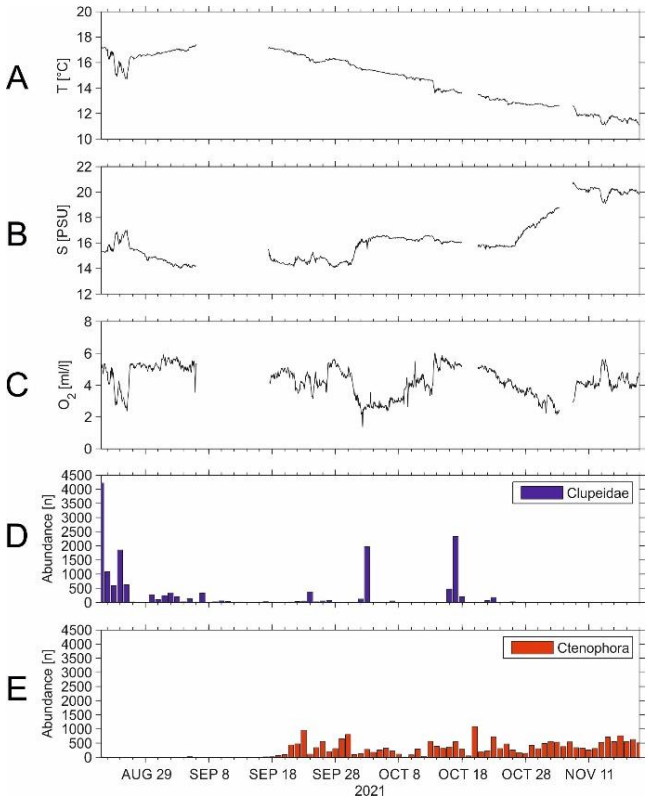

Figure 3: 86-day sample (2021/08/22 to 2021/11/16) of (from top to bottom) (A-C) temperature, salinity and oxygen, (D) abundance of Clupeidae, (E) abundance of Ctenophora derived from the Underwater Fish Observatory (Source: Thünen Institute / Gröger et al., 2024).

In contrast to these two UFO systems, which are dependent on a land connection, the mobile UFO was designed for shorter, location independent missions in remote-controlled or autonomous mode. While hydroacoustic and optical techniques have so far mainly been used individually to observe and monitor fish populations, we present a coupled hybrid system whose core unit consists of two residual light amplifying camera modules and a 2D imaging sonar. The optical near-field component is considered as a sub-sample of the spatially farther-reaching acoustic far-field component.

By coupling the optical near field and acoustic far field, meaningful hybrid data can be provided. Species affiliation and morphometric characteristics of fish and other marine organisms such as jellyfish were stereo-optically recorded and classified in the near field, blended with the acoustic activity in the medium to wide range and projected onto the entire area using a hybrid algorithm (Fig. 2). Modularity, compactness, structural integrity and multiple deployment options are decisive advantages of the trilateral UFO array compared to ship-based fish surveys.

Through the synchronised acquisition of multi-parametric abiotic and biotic data, UFO enables automatic, continuous and non-invasive long-term monitoring of various fish and other marine species and their habitats at regional hotspots. Based on an 86-day multiparametric time series (Fig. 3) showing an abrupt change from a herring and sprat dominated to a comb jellyfish dominated regime in the Kiel Fjord in summer/autumn 2021, the potential of stationary UFO for various applications is demonstrated.

Further Information

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DOI: 10.3220/PB1730973102000

Duration

5.2019-6.2023

Project-ID

2088

Publications

Gröger JP, Cisewski B, Badri-Hoeher S, Böer G, Boos K, Clemmesen C, Cojocaru A, Dauben V, Hoeher PA, Lehmann A, Matz S, Mehrtens H, Mittermayer F, Renkewitz H, Schramm H, Strickmann T, Westphalen J, Wilts T, Winkler J, Wolf D and Zenk O (2024). Development and operation of a novel non-invasive opto-acoustic underwater fish observatory in Kiel Bight, Southwestern Baltic Sea. Front. Mar. Sci. 11:1425259. https://doi.org/10.3389/fmars.2024.1425259

Böer G, Gröger JP, Badri-Höher S, Cisewski B, Renkewitz H, Mittermayer F, Strickmann T, Schramm H (2023). A deep-learning based pipeline for estimating the abundance and size of aquatic organisms in an unconstrained underwater environment from continuously captured stereo video. Sensors 23(6):3311. https://doi.org/10.3390/s23063311

Funding

Gefördert durch
Bundesministerium für Ernährung und Landwirtschaft
aufgrund eines Beschlusses des Deutschen Bundestages
Projektträger
Bundesanstalt für Landwirtschaft und Ernährung