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Editorial

Hydroacoustics in Marine, Transitional and Freshwaters

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This Special Issue highlights the diverse applications and potential of hydroacoustic techniques in aquatic research and management. Focusing on assessing fish populations, monitoring habitat use and migration, and estimating fish community structure, hydroacoustics offers advantages over traditional methods, such as reduced environmental impact, improved efficiency, and high-resolution data collection. With an emphasis on Asian waters and European case studies, the issue underscores the growing importance of hydroacoustics in studying rapidly changing aquatic environments vulnerable to human-induced pressures. The contributions demonstrate the value of continued development and integration of hydroacoustic methods, inspiring further research, innovation, and collaboration in the field.

There is an increasing concern worldwide about the potential effects of human pressure and climate change on both marine and freshwater ecosystems. The need to enhance our capacity to detect, understand and predict these effects necessitates the development of cost-effective, reliable, and efficient technologies to enable the collection of rigorous scientific data. These data would allow us to determine the current status of the ecosystem and any changes that may occur. Hydroacoustics seems to be an ideal tool for sampling and surveying aquatic ecosystems because it (1) remotely senses, thus not affecting the studied object or its environment, (2) allows for the collection of a large quantity of data in a short time, (3) provides continuous, spatial (3D) information with a very high spatial and temporal resolution, and (4) is GPS-integrated, enabling easy mapping of the data. Therefore, hydroacoustics allows studying dynamic processes, spatial structures, and temporal patterns in ecological interactions that other methods do not permit.

In this Special Issue, the published papers were mainly related to applications of hydroacoustics in fisheries research and aquatic ecology, with some also addressing technical problems and monitoring. Papers related to fisheries acoustics dominated the submissions and covered all types of aquatic environments: rivers (Yangtze River [1–3], Pearl River [4], and River Thames [5]), lagoon channels (Ingril and Prévost channels [6]), natural lakes (Lake Poyang [3], Lake Stechlin [7], and Lake Dejguny [8]), artificial reservoirs (Three Gorges Reservoir [1,2]), and the sea (Mediterranean Sea [9], and South China Sea [10]). Three of the papers were related to the Yangtze River basin. Over the past few decades, the Yangtze River has experienced a severe aquatic biodiversity crisis, with a dramatic decrease in fish resources. To protect and restore aquatic resources, a 10-year fishing ban for all aquatic biota in the Yangtze River has been implemented since 2017. Due to the limitations of traditional research methods like net sampling, Lin et al. [1] aimed to demonstrate the feasibility of hydroacoustic techniques, which could be successfully used to quantify the fish density and spatial distributions in the upper Yangtze River. They used acoustics in combination with biological samplings to investigate the composition and spatiotemporal distribution of fish in the transition zone of the Three Gorges Reservoir (TGR). Their results indicated that the meandering deep channels increased habitat heterogeneity and enhanced fish abundance; therefore, these areas should receive more attention in terms of conservation in highly regulated river systems. The results of this study provided an important

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Citation: Godlewska, M.; Ye, S. Hydroacoustics in Marine, Transitional and Freshwaters. *Water* **2023**, *15*, 1674. https://doi.org/10.3390/w15091674

Received: 31 March 2023
Revised: 13 April 2023
Accepted: 17 April 2023
Published: 25 April 2023

background to support fish resource management in TGR. Lian et al. [2] in their paper "Comparison of two types of survey designs for acoustic estimates of fish abundance in the Three Gorges Reservoir, China" addressed a rather technical problem. They documented that in the mainstream of the Three Gorges Reservoir and its tributary, despite differences in their morphometric characteristics and fish species, the two types of acoustic surveys (parallel and zigzag transects) yielded fully comparable results, i.e., fish density and size distribution estimates were statistically the same. This led them to conclude that to improve efficiency and ensure safety, the triangular transect design with reliable coverage should be prioritized for hydroacoustic sampling in the Three Gorges Reservoir and similar canyon-shaped reservoirs, especially when sampling at night. Li et al. [3] in their paper "Managing water level for large migratory fish at the Poyang Lake outlet: implications based on habitat suitability and connectivity" used hydroacoustics to measure fish presence in the channel connecting Poyang Lake and the Yangtze River. Poyang Lake, the largest freshwater lake in China, holds great ecological value. It serves as the most important habitat for the four major Chinese carps and supports abundant biodiversity. Hydroacoustic surveys offered an effective tool to study the conditions of the migration pathway for the target fish and determined the preferred habitat conditions during the migration period. Hutorowicz et al. [8] in their paper "Comparison of Size Distribution of Fish Obtained from Gill Netting and the Distributions of Echoes from Hydroacoustics in Lake Dejguny (Poland)", proposed a procedure to assess the impact of various relationships used to convert acoustic target strengths (TS) to fishes total length (TL) found in the literature for different fish families or groups of species. Their idea was based on a comparison of acoustic surveys and gillnetting in coregonid Lake Dejguny (Poland). Based on the analyzed data set, they concluded that the most appropriate TS–TL relationship for fish with a TL greater than 62 mm is the relationship for multi-species communities according to Frozuzová et al. 2005 [11].

Two of the papers were related to long-term fish monitoring, i.e., one in a river and one in a lake.

The paper by Lyons et al. [5], "An Assessment of Hydroacoustic and Electric Fishing Data to Evaluate Long Term Spatial and Temporal Fish Population Change in the River Thames, UK", reports unique results from mobile hydroacoustic surveys carried out in the River Thames between 1994 and 2018. It represents the longest single continuous and standardized application of the horizontal hydroacoustic methodology for monitoring a lowland river's fish populations. The hydroacoustic data were complemented with electric fishing results collected at the same study reaches and periods. Hydroacoustic surveys used inter-calibrated dual and split beam scientific echo sounders, with the transducers beaming horizontally across the river to provide fish abundance and distribution estimates. Hydroacoustic data demonstrated patchy spatial distribution, often associated with natural and anthropogenic habitat features. These long-standing data provide a unique opportunity to investigate temporal and spatial shifts in fish population in a river coarse fishery. The study also demonstrates the practicality and benefits of long-term, standardized hydroacoustic surveying in large, managed, lowland river systems, where other methods are unsuitable and destructive sampling is unacceptable. Such long time-series datasets can provide local fisheries managers with a comprehensive baseline to determine the potential impacts of local and national infrastructure projects on fish populations.

The paper by Braun and Mehner [7], "Size Spectra of Pelagic Fish Populations in a Deep Lake—Methodological Comparison between Hydroacoustics and Midwater Trawling", used 12 years of sampling by trawling and hydroacoustics to methodologically compare size spectra of the pelagic fish community in Lake Stechlin (Germany). Community size spectra have been frequently used for understanding the status and structure of aquatic communities. Monitoring these spectral parameters offers the potential to reveal when ecosystems are experiencing external pressures, such as intensive fishing, eutrophication, or climate change. Typically, trawling and gill netting have been used to assess the size spectra of fish communities, but these methods induce high fish mortality and are labor- and cost-intensive. Thus, the paper aimed to determine if these methods could be replaced by

remote hydroacoustic sampling. Results confirmed that hydroacoustic methods allow for a faster and more efficient assessment of the pelagic fish community in deep Lake Stechlin compared to monitoring by trawl catches. In contrast to net sampling, hydroacoustics do not induce fish mortality, and larger and shallower areas of the lake can be sampled systematically, while not underestimating large fish as trawling does. Effects of eutrophication in Lake Stechlin in recent years on fish growth rates were exclusively reflected by hydroacoustic methods. Reliable size spectra can be obtained from hydroacoustic records and may help to detect and interpret environmental changes occurring in the lake.

Understanding fish migration patterns and habitat use is essential for fisheries management, as fish movement data provide knowledge of space-use patterns in geographic and/or environmental spaces and link home ranges and habitat selection. Consequently, knowledge of the temporal and spatial movement and habitat use of target fish species during key life history stages is critical for fish population/community management, aquatic ecosystem conservation, and health improvement. There were two papers published in our issue dealing with this topic.

Zhang et al. [4], in their paper "Site Fidelity, Habitat Use, and Movement Patterns of the Common Carp (*Cyprinus carpio*) during Its Breeding Season in the Pearl River as Determined by Acoustic Telemetry" conducted a fine-scale acoustic tracking experiment on eight tagged common carps. Over the past few decades, acoustic telemetry has been widely used for studying fish movement patterns on spatial and temporal scales, particularly in freshwater areas. The results of Zhang et al.'s study provided novel information on common carp spatiotemporal movement and habitat use patterns, which have important implications for native population restoration and invasive population control/exclusion. The authors discovered an evident diurnal pattern in movement behaviors and habitat use of common carp in the wild during its breeding season, as well as a preference for natural habitats over artificial ones. The observed significant environmental effects of water temperature, water level, and river discharge on carp habitat use suggested that environmental factors should be considered in common carp population management and river ecosystem rehabilitation in the future.

Brehmer et al. [6], in their paper "Short-range movement pattern of amphidromous lagoon fish schools: ecological applications", used high-resolution multi-beam sonar to estimate the movements of pelagic fish schools in two Mediterranean lagoon channels, located in the south of France. The authors proposed a new method to estimate the relative abundance of different groups of schooling species in a lagoon, based on the relationship between school velocity and species. Their results provided novel and interesting perspectives in ecological studies of pelagic fish schools. First, the information they provided enhanced our knowledge of both fish school displacement and migration processes, which are essential to improve our understanding of ecosystem functioning and mesoscale modeling. Second, the size structure of the fish community can be innovatively inferred from this approach, as it is a fishery-independent sampling method. According to the authors, both the straightness index and exploratory swimming speed should be proposed as indicators for various ecological applications: to discriminate fish school species, characterize their behavioral motivation (feeding, spawning, and migration), identify the structure of the fish community into size groups, and provide elementary information on fish activity rates for fish bio-energetic models.

Two of the papers focused on the application of hydroacoustics in the marine environment. The paper by Bozroudi et al. [9] "Effect of Subsurface Mediterranean Water Eddies on Sound Propagation Using ROMS Output and the Bellhop Model" was related to ocean dynamics and the characteristics of its processes using acoustic wave propagation. It concentrated on the influence of subsurface oceanic eddies on sound propagation. Ocean processes, such as eddies, can locally modify the upper ocean density structure, causing significant changes in the acoustic properties of the ocean. Determining the influence of eddies on acoustic wave characteristics at reception was the first step to inverting the acoustic signals received and retrieving the eddies' hydrological characteristics. The inves-

tigation of sound signal propagation in the Northeastern Atlantic Ocean in the presence of four long-lived Mediterranean Water eddies (so-called Meddies) indicated that this inversion, in order to retrieve the hydrological structure of the eddies, seems visible and is planned for future work.

The paper by Yuan et al. [10] was devoted to acoustical conditioning on fish and its application in marine farming. Changes in the environment due to human activities have led to the degradation of habitats and a reduction in fishery resources. Marine ranching is an important means of conserving resources and repairing damage to the environment. Acoustic conditioning taming technology is one approach used to effectively control fish stocks in marine ranching. The principle of acoustic conditioning taming technology is based on the auditory characteristics of fish. Using the method of "played sound and feeding bait" simultaneously, the experimental fish can establish a temporary neural connection between the sound signal and food through repeated training. Acoustic conditioning taming with 400 Hz of square wave proved to be effective within a few days both in the laboratory and in an open-sea area. Thus, using acoustic conditioning can achieve the purpose of attracting dispersed individual fish into a group through sound signals, to effectively control fish behavior, and enable the catching of fish with fishing gear.

The ten papers on this research topic primarily focused on Asian waters (five papers) and the rest were on different case studies in European countries. The possible reason for this domination could be that Asian waters are among the most rapidly changing and progressively impacted by nutrient enrichment and climate change. Another reason is that hydroacoustic methods have been used as a standard in America and Europe for a long time, while in Asia, hydroacoustics was introduced much later, and the use of this technology is still expanding [12].

In conclusion, this Special Issue highlights the diverse applications and potential of hydroacoustic techniques in aquatic research and management. The findings demonstrate the effectiveness of these methods in various areas, such as assessing fish populations, monitoring habitat use and migration, and estimating fish community structure. Additionally, the advantages of hydroacoustics over traditional sampling methods, including reduced environmental impact, improved efficiency, and continuous high-resolution data collection, are emphasized. The focus on Asian waters and European case studies underscores the growing importance of hydroacoustics in studying rapidly changing aquatic environments, particularly those most vulnerable to human-induced pressures. As hydroacoustic technology advances, researchers and resource managers will gain a deeper understanding of aquatic ecosystems, leading to informed decision-making and effective conservation strategies. Ultimately, these contributions highlight the value of continued development and integration of hydroacoustic methods in aquatic research and management, and we hope they inspire further research, innovation, and collaboration in the field.

Author Contributions: Writing—original draft preparation, M.G.; writing—review and editing, S.Y. and M.G. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the National Key Research and Development Program of China (no. 2019YFD0900603).

Conflicts of Interest: The authors declare no conflict of interest.

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