Robert Arlinghaus

Illustration: Adobe Stock/Kletr

Where Do the Fish Go?

Fish often react surprisingly to environmental factors such as angling. Fish tracking uses modern technologies to show why this is the case – and provides important insights in terms of the behavioural biology of fish populations and fisheries management.

There has long been a desire to be able to conduct behavioural research on carp, pike and perch under natural conditions in lakes and rivers involving the precise measurement of the behaviour of fish populations, yet it still poses considerable challenges. While satellite-controlled remote sensing has revolutionised the analysis of the terrestrial environment, there are no such high-resolution methods for use underwater. Unfortunately, GPS technology does not penetrate water, while echo sounding and video tracking can only be applied on a localised basis: these methods simply do not allow detailed tracking of the behaviour of mobile fish in a river or lake, let alone in the ocean. Early technologies for locating fish such as radio telemetry were either very labour-intensive or only worked in freshwater because the salt water blocked the radio waves.

The alternative ultrasound technique allows detection in salt water, but this was limited to "presence-absence" analyses: after all, it is practically impossible to set up a sufficient number of underwater receiving stations in the oceans to allow the life of the fish to be observed in high resolution. By contrast, smaller lakes do offer the possibility of mapping fish life at the ecosystem level using modern ultrasound detection. The principle is based on the retrospective analysis of detections at as many receiving stations as possible. The fish wears an active ultrasound transmitter that emits ultrasound signals (e.g. at a frequency of 76 kHz) at a high pulse rate (e.g. every 5–10 seconds) over a period of several months (or even years, depending on battery size).

Big fish: two pikes (Esox lucius) *under water.*

Receiving stations (hydrophones) are distributed throughout the lake like a network and save the relevant signals with a time stamp. If the signal carries further information – such as the water depth of the fish or water temperature during signal transmission – this information is also stored. The ultrasonic signal is received by hydrophones further away just milliseconds later. The exact position of the fish can then be calculated in very high resolu-

Illustration: AG Arlinghaus

For the purpose of tracking, the fish wears an active ultrasound transmitter that emits ultrasound signals (e.g. at a frequency of 76 kHz) at a high pulse rate (e.g. every 5–10 seconds) over a period of several months (or even years, depending on battery size).

tion based on these minimal time differences of signal arrival at precisely calibrated hydrophones. Considerable effort is required to install, maintain and calibrate such a system, so research waters where complete recording of fish behaviour can be carried are still rare worldwide. As far as we know there are currently a maximum of five active projects.

The Berlin working group led by fisheries scientist Robert Arlinghaus installed a system of this kind in a lake in Brandenburg back in 2009, transforming the lake into an open-air aquarium so as to better understand the behaviour of the fish at the level of an entire ecosystem and in particular at a higher resolution. Every few months the data was downloaded, processed on the computer and converted into fish positions with a very high spatio-temporal resolution. A treasure trove of data!

The research team, funded by the German Ministry of Education and Research in this case, was also able to use a comparable technology in coastal areas off Majorca. As compared to conventional telemetry methods, where each fish had to be located manually requiring a huge amount of effort, the workload was by no means reduced on this project, however: it was simply shifted from the field to the computer. This is because it draws on Big Data, with several million detections in short periods of time – a volume of data that takes some handling. In particular, location errors have to be eliminated, and if a fish swims into aquatic plants or coral reefs, its signal disappears, too – these data gaps have to be dealt with constructively. Nevertheless, the new technology allows unprecedented insights and revolutionises our understanding of life under water.

The aim of research in the Working Group for Integrative Fisheries Management (IFishMan) at the Humboldt-Universität zu Berlin and the Leibniz Institute of Freshwater Ecology and Inland Fisheries (IGB) is to answer both fundamental research questions about fish behavioural biology in field conditions in natural waters and also pursue application-oriented questions for practical fisheries management, such as how fish behave in response to environmental factors. One of these environmental factors is fishing, specifically angling, which has interested the working group for 20 years.

In Germany, there are 3–4 million anglers who set out to catch fish in their free time. Most lakes and rivers in this country are used by anglers. Many fish make acquaintance with a fishing hook in the course of their lifetime, such as when they are caught as young, immature fish and then put back in the water again. Not all fish are equally catchable, however, even within one species. Angling involves the selection of certain size classes and behavioural types of fish, and the animals learn from their experience to avoid fishing hooks in the future. But how does this process work exactly?

For many waters, there is no reliable information on how many fish are caught and taken away for consumption. Yet this knowledge is important so as to be able to derive recommendations for sustainable management. Here, modern fish detection technology allows unprecedented insights into previously hidden behaviour that offer (mostly) surprising findings.

For example, the winter biology of most native fish species is poorly understood and modern fish detection has enabled a number of commonly held beliefs to be revised. For example, it became evident that carp actively swam around in shoals during the day in winter. Until now, it was assumed that as warmth-loving fish, carp go into a kind of hibernation in the cold months. One study proved that the pike, a predatory fish, does not move to the deeper and therefore warmer areas of the water in winter but instead prefers shallow waters as its habitat.

In all the fish species studied – carp, catfish, pike, perch – the working group was able to identify persistent behavioural differences, i.e. specific individuals differed consistently throughout the year based on characteristics such

Receiving stations are distributed underwater like a network and save signals with a time stamp. Further information on water depth and temperature can be recorded, too.

Illustration: AG Arlinghaus

as activity or exploration, despite all the seasonal adaptations to changing temperatures over the course of the year. This provided clear evidence for the existence of behavioural types ("personalities") in fish in the field.

New insights are gained when behavioural data are combined with other individual data, for example in relation to the fish's diet or reproductive success. Here, the research team makes use of stable isotope methods or genetic methods. This revealed that perch who are consistently more active even during adolescence also show different feeding patterns as compared to adults, and that there is a close correlation between behavioural traits, growth, life history and diet.

Another study, likewise application-oriented in approach, looked into the controversial issue of fish feeding by anglers. Many anglers who pursue peaceful fish such as bream or carp use feed to improve their chances of success. The aim is to attract the fish to the fishing spot. Using the automated telemetry system at the Brandenburg research lake, it was shown that both carp and other bottom-oriented species such as tench accepted the new bait very quickly and subsequently showed up regularly at the feeding points – a kind of feed-induced taming occurred.

However, parallel fishing experiments indicated that at the same time there was a rapid decrease in fishability. The carp apparently learn very quickly to evade anglers' attempts to lure them – a phenomenon which the working group calls "angling-induced

Fishing is generally regarded as a relaxing, contemplative pastime, but when researching fish behaviour, hands-on action is required: here, preparations for installing an underwater measuring station.

Illustration: AG Arlinghaus

Screenshot: DFG bewegt / www.youtube.com/watch?v=zifRTURfk7c

Diverse media and channels can be useful in gaining insights into the living environment of fish. Communicator Award winner Robert Arlinghaus often draws on the benefits of visual methods, depending on the target group.

shyness syndrome". Accompanying laboratory work identified the same mechanism: the carp learned to distinguish between baits with and without hooks and simply spat out the baits with hooks. Telemetry work in the field also showed that the fish did not shun the feeding grounds, however, as many anglers believe. They continued to stay at the feeding sites with particularly abundant food, but avoided being caught.

The field of fish behaviour research has developed dynamically in recent years. It is a good example of how interdisciplinary collaboration between researchers in fish biology and fisheries ecology, data analysis and network research, statistics and electrical engineering can lead to huge leaps in knowledge in terms of what is happening underwater. The close connection between basic and application-oriented research has a major role to play here. This combination is not least important when it comes to putting findings swiftly into practical application.

International cooperation is also of great importance to both past and future projects. Many projects now have diverse groups in different countries working together (e.g. European Tracking Network, Lake Telemetry Network) to collate data from different lakes for appropriate replication. Only then are the results generalisable.

With regard to research funding, it would be desirable if there were more programmes to establish and maintain the necessary research infrastructure since it is hardly possible to build and sustain the complex technology in the long term based on project cycles of only three years. After all, it is only by supporting the work with technicians and making sometimes considerable investments in equipment that it is possible to generate extensive data sets, eradicate errors and make the data usable for research. Fisheries research could benefit from this in the long term.

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