Scientists develop new method of estimating fish movements underwater

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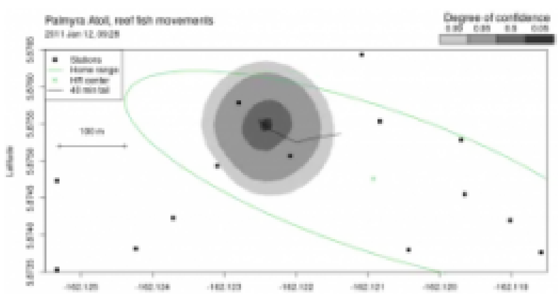


This still shot from an animation shows the confidence regions for tracking a fish.

How do you track a fish? There's no "Google Maps" for finding fish. The radio signals that are the backbone of traditional GPS cannot pass through seawater. But sound travels remarkably well, so scientists often use acoustic telemetry to estimate an individual fish's location. That means attaching an acoustic transmitter to a fish and then using a network of stationary underwater listening stations to monitor for the short clicking sounds that these tags emit. When a fish swims near to a receiver, its click is heard, and its individual code number is recorded.

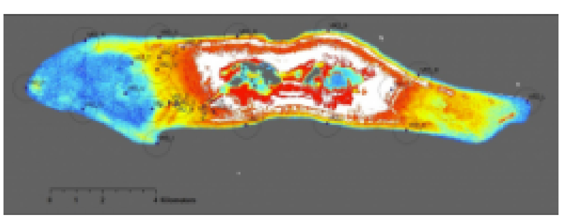
Knowing your uncertainty

Even with this clicker-listener observation network in place, though, there's much uncertainty about a fish's whereabouts at any given time.

To date, most researchers have used ad hoc methods to analyze their data, and typically have not quantified uncertainty.

"In science, knowing how certain or uncertain you are is often the prime objective," said Kevin C. Weng, manager of the Pelagic Fisheries Research Program at the University of Hawai'i at M?noa and a graduate faculty member in the Department of Oceanography. "We're used to knowing within 20 feet where you can find that bison, wolf or bird. But underneath the ocean surface, we don't have the luxury of using GPS. So marine scientists use sound, which results in much lower accuracy."

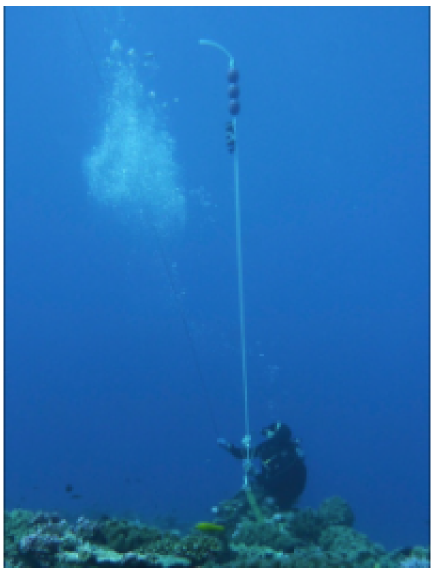
But what is that accuracy? Martin W. Pedersen, a UH M?noa postdoctoral fellow from Denmark, explains: "In the traditional tracking system, a fish is generally assigned the position of the receiver that detected it, even though the fish might be anywhere in that receiver's detection range. And if none of the receivers have heard from the fish for a while, no positions are assigned, even though the network may be providing some, albeit uncertain, information about the fish's whereabouts. For example, we could possibly estimate how far a fish could travel in a certain time since it was last heard, and could also infer locations where it isn't, due to the lack of detections."



Map of monitoring stations at Palmyra Atoll.

A new statistical framework

Rethinking the traditional, ad hoc approach, Pedersen and Weng have proposed a new state-space model for analyzing fish movement data collected by marine observation networks. Their new model was recently published in the scientific journal *Methods in Ecology and Evolution*. Its goal is to quantify the uncertainty associated with this imperfect locating system, and to improve its accuracy.



Underwater listening stations track acoustic data.

"Previous methods were not formulated with the fish, ocean and acoustics in mind," said Pedersen. "They therefore do not exploit all available information, such as the biology of the fish limiting its range of possible movement."

Pedersen and Weng's new state-space model for estimating individual fish movement is two-part—one part that models the fish behavior, and one that models the detection of that behavior.

"It tells us how the fish is moving," said Pedersen. "Does the fish swim in straight lines? Does it have a particular home range, or center of attraction, for its movements?"

Researchers field-tested the model with fish at the spectacular Palmyra Atoll.

The second part of the model estimates the likelihood of detecting a fish—incorporating the detection probability, environmental noise, and both presence and absence data. When receivers are located close to each other, it can even help researchers triangulate positions. Acoustic telemetry works in much the same way that cell tower networks pin down the location of your mobile phone: The distance from your phone (or the fish tag) to several cell towers (or acoustic receivers) is measured, and circles of that radius are drawn around each tower (receiver). Where the circles intersect—that's you (or the fish).

The observation model also uses negative data, or the lack of detections, in combination with the behavior model to estimate how far the fish may have traveled while undetected. "Knowing where the fish is not located actually tells you a lot about where it is located, and with our new method, we are able to utilize that information and achieve a better accuracy," Pedersen said.

Does it work in the real (underwater) world?

To field-test their model, the researchers turned to the spectacular tropical reef setting of Palmyra atoll in the central Pacific Ocean—home to myriad fish, sharks, manta rays, whales and turtles.

With monitoring data collected for coral reef fish from 51 underwater observer stations at Palmyra Atoll, Pedersen and Weng used their state-space model to develop contour maps that provided a visual representation of the confidence regions for the locations of the fish over time, along with a home range estimate.

Researcher checks underwater listening station.

During daylight hours, fish locations were estimated with a 95% confidence region radius of 50 meters, at their most accurate.

By reducing the uncertainties associated with underwater location tracking, Pedersen and Weng hope to provide researchers and marine managers with better information to help support marine conservation activities for reef fish and other threatened species.

"It helps us to better understand how they feed, breed and rest," Weng said. "Ultimately, more accurate movement information will help us to conserve these species."

More information: Pedersen, M. W., Weng, K. C. (2013), Estimating individual animal movement from observation networks. *Methods in Ecology and Evolution*. DOI: 10.1111/2041-210X.12086

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