Tracking 3-Dimensional Fish Behavior With A New Marine Acoustic Telemetry System

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Introduction

Marine acoustic telemetry has advanced our understanding of the behavioral ecology of marine life, but telemetry position error, and restrictions on the number of targets that can be tracked simultaneously, have limited the scale and scope of movement, interaction, and connectivity research required for effective management of protected marine species.

We have developed a marine acoustic telemetry system, including tags, receivers, and software, capable of tracking up to 500 targets simultaneously over a large area (>1km) and with sub-meter accuracy. A prototype is currently being demonstrated in a study of Copper rockfish (*Sebastes caurinus*; Fig. 1) microhabitat selection in a marine preserve at Friday Harbor, WA, and results from this work will contribute to an identified critical research need in Puget Sound rockfish conservation.

Copper Rockfish, courtesy of WDFW

Project Milestones:

- ✓ Finalize tag design
- ✓ Complete tag range and performance testing
- ✓ Finalize hydrophone mount design
- ✓ Capture and tag 10 Copper Rockfish
- ✓ Deploy 4 hydrophones, cabling, and receiver hardware
- ❑ ~~Complete high-resolution photomosaic habitat mapping~~
- ❑ Analyze telemetry and habitat data to estimate home range and resource selection.

Study Site

All field research was conducted in the Friday Harbor Marine Preserve (Fig. 2), located in Washington State's San Juan Islands. The islands are in the northern reach of the state, at the eastern end of the Strait of Juan de Fuca. The preserve is also adjacent to the University of Washington's Friday Harbor Marine Laboratory.

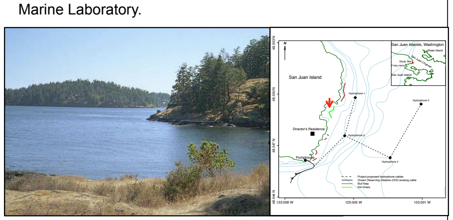
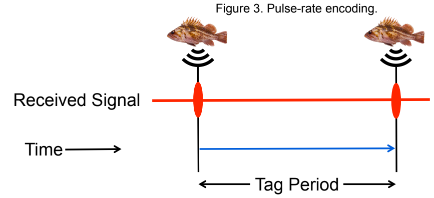


Figure 2. Shady Cove, Friday Harbor Marine Preserve (L) and a plan view of the study area showing the original hydrophone locations (R) with a red arrow showing the approximate location and orientation of the photograph.

Methods

Pules-rate Encoding. The new marine tags use the interval between each transmission to detect and identify the tag (Fig. 3). The use of "pulse-rate encoding" provides increased detection ranges, improved signal-to-noise ratios and pulse-arrival resolution, and decreased position variability when compared with binary-phase encoding.

Figure 3. Pulse-rate encoding.



Tag Positioning & Identification. Acoustic tag positioning operates on the same principle as the Global Position System (GPS). The acoustic tag transmits a signal which is received by at least four hydrophones (Fig. 4). By knowing the positions of the four hydrophones and measuring the relative signal arrival times at the hydrophones, the locations of the tags can be estimated.

Each tag is programmed with a unique pulse-rate (Fig. 3) to track movements of individual tagged fish. To be accurately positioned in three-dimensions a tag must be detected on at least four hydrophones. Three-dimensional tag coordinates with sub-meter accuracy are achieved using hydrophones located in known positions, at different vertical planes and within direct line of sight of the tag (Fig. 5). As the signal passes through the four beams, the difference in the arrival time of each pulse is used to triangulate the exact location of the tag. In this way, a swimming path for each tagged fish is mapped and presented in a three-dimensional display.

Figure 4. Deep-water hydrophone deployment. The yellow arrow points to the hydrophone.

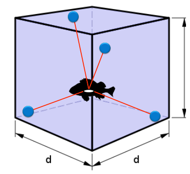


Figure 5. Hydrophone geometry for 3-dimensional tag positioning.

Fish Capture & Tagging. Copper rockfish were captured in hand nets by teams of three divers (Fig. 6) and placed in darkened cages for ascent. This technique has many advantages; it is surprisingly easy to implement, ideally targets only fish of the desired species and size, minimizes handling time, and minimizes the risk of opportunistic predation. The use of darkened cages reduces fish stress, and a slow ascent rate, 0.05 meters/second, reduces the severity of barotrauma.

Acoustic tags were surgically implanted in the intracoelemic cavity (Fig. 7). Tags were activated, tested, and sterilized the day prior to surgery. Rockfish length and weight were measured and recorded at the surface, and the fish were immediately immersed in a tricaine methanesulfonate (MS-222) 0.1mg/ml seawater anesthetic bath, buffered 1:2 with sodium bicarbonate.

Upon reaching a surgical plane of anesthesia, verified by a firm pinch of the caudal peduncle, a 2mg/kg dose of ketaprofen was injected in the dorsal musculature to reduce post-surgical inflammation. The fish was then transferred to the surgical cradle and intubated via the buccal cavity to provide a 0.05 g/ml dose of maintenance anesthetic and maintain gill moisture (Fig. 7).

A 6.5 cm incision was made 1 cm forward of the anus, offset from midline by 1cm, and the tag was inserted into the intracoelemic cavity (Fig. 7). The incision was closed with Maxon 3-0 monofilament absorbable suture in a simple interrupted suture pattern.

To reduce the impact of barotrauma, tagged rockfish were immediately returned to the point of capture in a cage. They were subsequently released by divers after recovering from anesthesia.

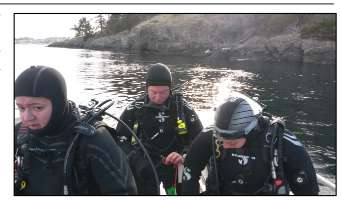


Figure 6. Scientific Diver team ready for fish-capture.

Figure 7. Surgeon completing the incision with surgical scissors prior to inserting the tag in an anesthetized Copper rockfish.

Early Results

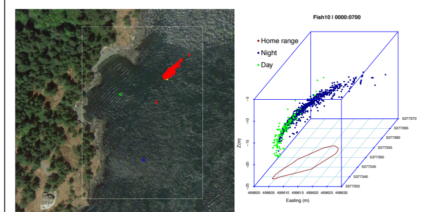


Figure 9. Plan (L) and 3-D (R) views of telemetry data from a single tagged fish showing.

The sample of telemetry data above shows a clear diel pattern in habitat use, and a home range size consistent with previous research. The next step, habitat use analysis, relies on utilization distributions (UD's) to calculate individual home ranges, quantify home-range overlap, and determine resource selection as a function of habitat-based predictors at the individual and population level. This approach has the benefit of incorporating all the available telemetry data, accommodating autocorrelation, and treating the individual animal, rather than individual telemetry points, as the experimental unit.

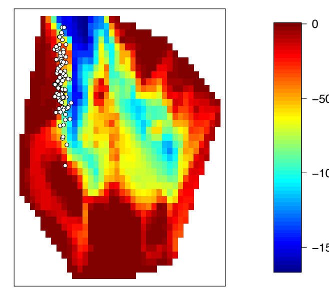


Figure 9. Two-meter resolution bathymetric map of the study area (depth in meters) with simulated fish telemetry data.

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