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Using acoustic telemetry to measure fine-scale movement and interactions of marine animals: implications for Marine Protected Areas

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Summary
Proper management of Marine Protected Areas requires information about the movement, interactions and connectivity of marine animals. Marine acoustic telemetry has provided incomplete information about these behaviors due to the large positional errors and limits on the number of targets that can be tracked simultaneously. Based on a proven system designed for freshwater application, the architecture of the marine acoustic tag receiver system retains the functionality of the existing system including processing techniques that allow simultaneous tracking of multiple targets (up to 500 simultaneously) with high precision. The system can be used to discern fine-scale movement and resource selection by marine organisms.

Introduction
Throughout the world's oceans, populations of many marine species have been severely depleted through overexploitation and other anthropogenic impacts (Worm et al., 2006). Recognition of these impacts, combined with the current depleted state of many marine populations, has encouraged a shift in resource management to an ecosystem-based approach, focused on rebuilding depleted populations while protecting and restoring impacted ecosystems (US Commission on Ocean Policy, 2004).

Current marine research needs require improvements in the ability to investigate the ecology of marine populations on small spatial scales to examine issues such as physical impacts of structures, species-specific interactions, invasive species and many others. Resolution of fine-scale animal movement and interactions is particularly important for studies of the effects of coastal structures such as oil platforms, hydrokinetic and wind turbine installations. Habitat studies in other nearshore environments, including Marine Protected Areas (MPAs), coral reefs, and seagrass beds, will also benefit from the ability to investigate species-specific behavior and distribution with high precision. In the case of MPAs, providing protection has proven difficult when so little is known about the *in situ* behavioral ecology of many of these marine species.

Materials and Methods
The marine tagging system uses a fixed array of underwater hydrophones to track movements of fish implanted with acoustic tags. As fish approach the study area, the transmitted signal from each tag is detected and the arrival time recorded at several hydrophones within the array. The differences in tag signal arrival times at each hydrophone are then used to calculate a three-dimensional position. The tags are pulse-rate or period-encoded not the binary-phase encoding used by all other systems. It is this pulse-rate encoding that differentiates the system under development from all others and provides the opportunity for improving the current capabilities of marine acoustic tagging systems.

The acoustic tags are unique in that they utilize "pulse-rate encoding" which provides increased detection ranges, improved signal-to-noise ratios and pulse-arrival resolution, and decreased position variability when compared to other types of acoustic tags (Ehrenberg and Steig 2003). Pulse-rate encoding uses the interval between each transmission to detect and identify the tag (Figure 1). Each tag is programmed with a unique pulse-rate to track movements of individual tagged fish.

Detection on one hydrophone confirms the presence of an acoustic tag, but to be accurately positioned in three-dimensions a tag must be detected on at least four hydrophones (Figure 2). 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. As an acoustic tag 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.

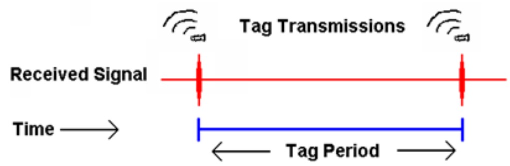

Figure 1. Pulse-rate interval also referred to as the "Tag Period" or "ping" rate is the interval between each tag transmission.

The principle that is used for determining acoustic tag positions is the same principle that accurately determines positions using the Global Position Satellites (GPS). The acoustic tag transmits a signal which is received by at least four hydrophones. By knowing the positions of the four hydrophones (using GPS) and measuring the relative signal arrival times at the hydrophones, the locations of the tagged fish can be estimated. Testing of this system will include a demonstration study of microhabitat preference and effect on the home ranges of Copper rockfish (*Sebastes caurinus*) to be completed in Fall 2014.

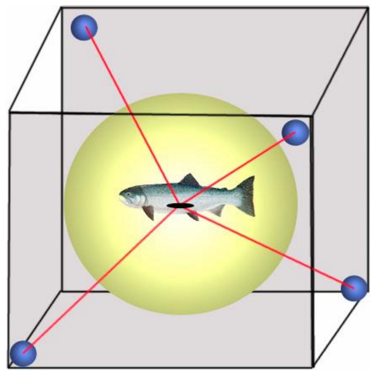

Figure 2. Positioning of an acoustic tag in three dimensions with a four-hydrophone array.

Results and Discussion

Puget Sound Copper rockfish (Sebastes caurinus), and rockfish species generally, have undergone significant declines in their abundance, density, and spawning potential since the 1970's. They are now protected by various fishing regulations and spatially explicit management approaches, including existing and proposed regulatory Marine Protected Areas and no-take Conservation Areas. Copper rockfish demonstrate clear preferences for natural high relief, rocky habitat and vegetated nearshore habitat. The influence of these habitats on the distribution of rockfish is a topic of interest for those tasked with assigning protection to critical habitat and subsequently assessing its effectiveness (Palsson et al. 2009).

This project will develop a prototype marine large-area, sub-meter resolution system and demonstrate its capabilities by explaining copper rockfish habitat requirements and their impacts on individual home-range. These types of studies are useful for developing mechanistic home-range models. In light of the continuing and changing pressures on seascapes from extractive activities such as fishing and marine energy development, these types of models will play an increasingly important role in marine management.

References

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