Hydroacoustic Tools for Monitoring Shrimp Distribution, Movement, and Behavior in Natural and Built Environments

Herramientas Hidroacústicas para Monitorear la Distribución, el Movimiento y el Comportamiento del Camarón en Entornos Naturales y Construidos

Outils Hydroacoustiques pour la Surveillance de la Distribution, du Mouvement et du Comportement des Crevettes dans des Environnements Naturels et Bâtis

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EXTENDED ABSTRACT

The Challenge

Hydroacoustic sampling tools are used to survey underwater species' distributional patterns, abundance, provide bioenergetics modeling validation data, and to assess behavior. Shrimp, fish, and zooplankton species have been monitored using both echo sounding and acoustic telemetry tagging techniques within a broad range of aquatic environments, from large spatial scale studies in open systems evaluating responses to environmental variations to studies in small closed systems monitoring fine spatial scale species-specific interactions. The same basic principles of underwater sound propagation apply to both echo sounding and acoustic telemetry monitoring techniques, providing sampling advantages, but some limitations. Advantages of hydroacoustic biological sampling methodologies include the ability to measure the distribution of organisms over large spatial and temporal scales without disturbing the animals, a high sampling intensity and non-selectivity. Biological assessments employing echo sounders have a limited ability to differentiate species and to resolve targets located close to boundaries such as the surface, bottom or close to underwater structure. These limitations present particular challenges for hydroacoustic evaluations designed to evaluate demersal distributions of shrimp, particularly in regions where fish may also be present. However, resolution of shrimp distributions near the bottom and the ability to segregate shrimp densities from co-located fish aggregations using echo sounders can be optimized via the use of appropriate sampling equipment, parameters and analysis approaches.

The species and characteristics of tagged aquatic animals monitored using acoustic telemetry techniques are generally known, as each unique tag code is assigned to a physically-inspected individual handled during the tagging process. A telemetry monitoring design can provide detailed measures of species-specific distribution, survival, and behavior, but typically incorporates a smaller sample size than echo sounder sampling, due to the associated tag, labor effort, and receiver costs. Acoustic telemetry can provide a continuous record of aquatic animal movements and is well-suited for studies requiring fine scale information. Time-synchronized series of three or more acoustic tag receivers in known locations can allow the researcher to position multiple known animals in 2D or 3D space with high precision. Individual dispersed acoustic tag receivers can provide continuous detection histories of tagged fish or shrimp present within the instrument detection ranges.

This evaluation summarizes the results of two recent investigations designed to assess the ability of hydroacoustic sampling systems to quantify shrimp distribution or behavior in close proximity to the bottom or other boundaries, illustrating the resolution that can be obtained using echo sounding and acoustic telemetry techniques. These technologies may offer useful tools for monitoring of shrimp densities, distributions, and behavior in the Gulf of Mexico and Caribbean.

Marine Shrimp Mobile Echo Sounder Survey Assessment

Background — A mobile hydroacoustic survey targeting demersal northern shrimp (*Pandalus borealis*) distributions was conducted from May 26 - 29, 2017 on the Grand Banks, approximately 300 km NE of St. Johns, Newfoundland. The primary purpose of the study was to assess the ability of a three-frequency split-beam echo sounder system to quantify shrimp densities located within 1 - 20 m above the bottom. This distance represents the approximate head-rope height of bottom trawls used by the commercial shrimp fishing industry for harvest. Newfoundland commercial shrimpers have reported significantly-reduced trawl capture efficiencies in recent years during periods when seismic oil exploration activities were being conducted concurrently near the fishing grounds. One hypothesis to explain these reported reduced shrimp trawl capture efficiencies proposes that low-frequency seismic air gun transmissions may induce a startle response in demersal shrimp aggregations, resulting in their vertical dispersion higher into the water column, where they are less available to trawl interception. The primary purpose of the 2017 hydroacoustic pilot study sampling was to establish the resolution of the equipment to quantify shrimp densities located in close proximity to the bottom. Secondary objectives included assessments of the ability to segregate shrimp acoustic backscatter from mixed fish aggregation contributions potentially present in the near-bottom layer. Assuming validation of adequate hydroacoustic system near-bottom shrimp density resolution in 2017, the sampling approach may be employed in future years under controlled seismic oil exploration "on/off" conditions to evaluate potential impacts on the vertical distribution of demersal shrimp aggregations.

Methods — The HTI Model 244 Echo Sounder employed during the 2017 Newfoundland pilot shrimp assessment study simultaneously sampled 38, 120, and 200 kHz transducers, providing synchronous measures of shrimp and fish biomass from the 50 m transducer vehicle towing depth to the bottom. Water depths varied from 250 - 350 m within the survey area. The echo sounder was configured to transmit using a 10 ms frequency-coded FM slide/chirp transmit signal outputting a 0.18 ms pulse duration, providing high spatial target resolution and improved signal-to-noise characteristics relative to a conventional continuous wave echo sounder sampling transmission (Ehrenberg and Torkelson, 2000). Approximately 280 km of survey transects were sampled on the grounds. A second commercial fishing vessel conducted paired bottom trawling activities in association with the hydroacoustic sampling efforts to provide shrimp and fish species composition information.

Results — The preliminary results of the 2017 Newfoundland shrimp assessments determined that quantitative measures of shrimp and fish biomass would be resolved above a distance of approximately 1.5 meters above the bottom. The concurrent paired trawling efforts indicated a preponderance of shrimp in the near-bottom region in some paired samples. The trawl species composition is currently being compared to the acoustic backscattering data collected at the three frequencies to assess the potential to segregate shrimp and fish densities, evaluating published models, including (Stanton et al. 1996). A statistical analysis framework and survey sampling designs are also being developed to quantify potential changes in demersal shrimp density distributions with depth under controlled seismic test "on/off" conditions in future study years.

Marine Shrimp Acoustic Telemetry 3D Positioning Feasibility Study

Background — Eight dock shrimp (*Pandalus danae*) were tagged with HTI Model 795 acoustic tags and tracked within an eight hydrophone array at the University of Washington Friday Harbor Laboratory over a 24 h period from August 15 - 16, 2007. All tagged shrimp were continuously detected and their 3D target positions were recorded over a 24 h period. The instrumented study area was approximately 100 m^2 and consisted of an inshore dock and offshore breakwater, both incorporating pilings utilized as shrimp habitat. The individual dock shrimp were captured from pilings within the instrumented study area, tagged, and released.

The experiment was staffed by students and instructors as part of the 2017 Bioacoustics Workshop and was primarily designed as a training exercise in the implementation of marine 3D acoustic telemetry monitoring systems. Dock shrimp were selected as the monitored species based on their immediate availability at the site and the opportunity to evaluate the ability to successfully tag this species and monitor their movements over time.

Methods — An HTI Model 290 Acoustic Tag Receiver connected to eight fixed hydrophones was deployed on the dock and breakwater structure, with the hydrophones deployed in near-surface and near-bottom pairs at each corner of the study area. Hydrophone locations within the 3D survey grid were established by direct measurement and reciprocal speed-of-sound delay measurements between all hydrophones. Acoustic tags programmed to report unique ID codes at 2.000 to 2.161 second intervals were attached to the dorsal side of each shrimp carapace using cyanoacrylate glue. Tagged shrimp were subsequently released near the center of the hydroacoustic array and continuously tracked in real-time over the following 24-h period. A detailed description of the theory of operation and implementation of the 3D acoustic telemetry system is provided in Ehrenberg and Steig (2003).

Results — Tagged shrimp 3D positions at approximately 2-sec intervals were simultaneously recorded over the 24-h monitoring period, with estimated precision of < 0.2 m in the X, Y and Z (depth) domains. The 3D track visualizations produced for each tagged shrimp indicated consistent periodic vertical movements in the water column adjacent to the dock structures, potentially associated with tidal state. All tagged shrimp demonstrated fidelity within 10 - 30 m of their release locations over the monitored period. These results indicate that it is feasible to acoustically-tag shrimp and continuously map their movements in fine-scale with high precision using appropriately placed surrounding hydrophones.

KEYWORDS: Hydroacoustics, shrimp, *Pandalus borealis,* distribution, vertical movement

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