Coupling Echosounder and Hydrophone Surveys at Spawning Aggregations: Relationships Between Levels of Fish Sound Production and Density

Combinando Monitoreos entre Ecosondas e Hidrófonos en las Agregaciones Reproductivas: Descubriendo Relaciones Entre el Sonido que Producen los Peces y su Densidad

Couplage D'études par Echosondeur et par Hydrophone dans les Frayères: Relations entre les Niveaux de Production de Son et de Densité de Poissons

TIMOTHY J. ROWELL[1*], DAVID A. DEMER[2], OCTAVIO ABURTO-OROPEZA[1], JUAN JOSE COTA-NIETO[3], JOHN R. HYDE[2], and BRAD E. ERISMAN[4]

[1]*Scripps Institution of Oceanography University of California San Diego, 9500 Gilman Drive, La Jolla, California 92093-0208 USA.* [*]*tjrowell@gmail.com*

[2]*NOAA Fisheries, Southwest Fisheries Science Center, 8901 La Jolla Shores Drive, La Jolla, California 92037-1508 USA.*

[3]*Centro para la Biodiversidad Marina y la Conservación A.C., Calle del Pirata, #420, Fracción Benito Juárez, La Paz, Baja California Sur, 23090 Mexico.*

[4]*Marine Science Institute, The University of Texas at Austin, 750 Channel View Drive, Port Aransas, Texas 78373 USA.*

EXTENDED ABSTRACT

Advancements in the use of acoustic methods to characterize, map, and assess spawning aggregations has expanded our understanding of the reproductive biology, life histories, and stock sizes of vulnerable species (Costa et al. 2014, Fudge and Rose 2009). The versatility of active acoustics (echosounders) has permitted the estimation of fish abundances and biomasses in challenging environments, such as reefs and estuaries (Boswell et al. 2007), while the efficiency of passive acoustics (hydrophones) to monitor the sounds produced by aggregating fishes has increasingly been embraced to identify spawning areas and periods (Rowell et al. 2015, Wilson et al. 2014). However, a logical and desirable progression to efficiently and accurately estimate fish abundances from their sounds has been hindered by the complexity of fish calling rates, fish choruses, and acoustic propagation (Locascio and Mann 2008, Schärer et al. 2012, Schärer et al. 2014). As such, a comparison between independent measurements of sound and abundance has been proposed as a feasible, initial method to determine if levels of fish sound production can be used to estimate fish abundances (Gannon 2008, Rountree et al. 2006).

In this study, we compared Gulf Corvina (*Cynoscion othonopterus*) sound levels with simultaneous measurements of densities from echosounder surveys recorded at its only known spawning aggregation in the Colorado River Delta, Mexico, to investigate empirical relationships between fish sound levels and density. The Gulf Corvina is a sciaenid endemic to the northern half of the Gulf of California that is exclusively targeted by a lucrative fishery during spawning periods, which occur prior to the full and new moons in the months of February through June (Erisman et al. 2012). Currently, the sustainability of the fishery remains in question. We conducted four days of surveys in the channels of the Colorado River Delta prior to the new moons in the months of March and April 2014. Two surveys were conducted per day, one on the outgoing and one on the incoming tide. Two hired fishing vessels were used to complete each survey; an active acoustic echosounder was configured on the first vessel to estimate Gulf Corvina densities and abundances present during each survey, and the passive acoustic equipment was installed on the second vessel to record the sounds produced by Gulf Corvina. During surveys, the two vessels progressed through the survey area together to allow measurements of sound and density to be comparable in space and time. The echosounder-equipped vessel conducted transects across the Delta channel, while the passive acoustic vessel recorded ambient sound along each echosounder transect prior to its completion. Echosounder data were calibrated and analyzed to estimate fish densities and abundance via echo counting. Passive acoustic recordings were analyzed and filtered to calculate received sound levels attributable to Gulf Corvina chorusing. Coupled measurements of fish density and sound production levels were mapped, compared, and modeled.

We observed large aggregations comprised of more than 1.5 million fish and elevated sound production levels distributed over 25 km of the delta. Fish densities were similar on incoming and outgoing tides (Figure 1). Conversely, fish sound production levels were significantly higher on outgoing tides (Figure 2), suggesting increases in fish calling rates during outgoing tides when spawning is known to occur. Maps of density and received sound levels over the frequency of choruses depicted similar spatial patterns on the outgoing tides, indicating that sound levels effectively mapped the distribution of the spawning aggregation. The relationship between sound levels and density varied within surveys but stabilized during the two-hour period of peak spawning (e.g. high tide to two hours after high tide), resulting in an equation to estimate densities from received sound levels during a two hour period in which calling rates were inferred to be stable. Our results support the inclusion of active acoustics into assessments of spawning stock abundance and indicate that sound levels can be used to estimate fish densities when relationships are scaled to the spatial and temporal dynamics of spawning activity. Our approach is applicable to other soniferous, aggregating fishes, providing an additional method to assess and monitor reproductive stocks using passive acoustics. We anticipate that current and future relationships between levels of fish sound production and density will be improved through a better understanding and inclusion of additional parameters that account for acoustic propagation, environmental conditions, and fish behavior.

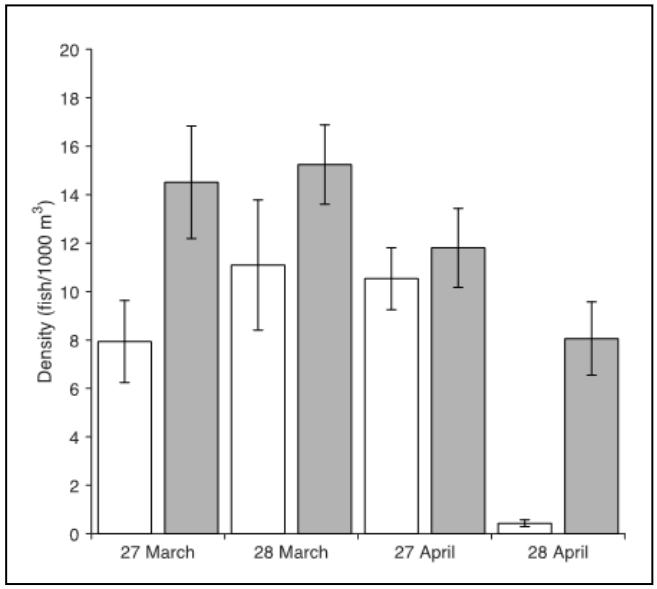

Figure 1. Mean fish density per survey on the incoming (white bars) and outgoing tides (gray bars). Error bars = 95% confidence intervals.

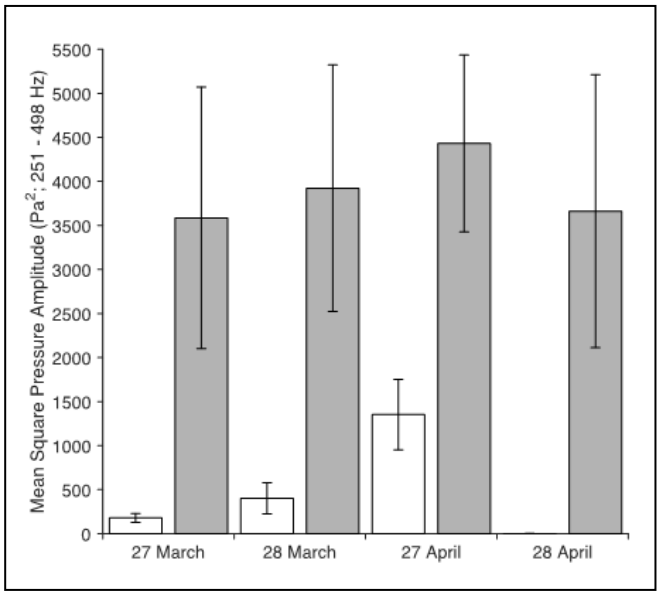

Figure 2. Mean sound level (Pa^2) over the frequency band of Gulf Corvina choruses (251 – 498 Hz) per survey on the incoming (white bars) and outgoing tides (gray bars). Error bars = 95% confidence intervals.

KEYWORDS: Passive acoustics, active acoustics, hydroacoustic surveys, Gulf Corvina, *Cynoscion othonopterus*

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