# Female Abundance and Spawning Prospects Drive Sound Production in a Territorial Male Grouper: Implications for Monitoring Fish Spawning Aggregations

# La Abundancia de Hembras y las Perspectivas de Desove Motivan la Producción de Sonidos en Machos Territoriales de una Especie de Meros: Implicaciones para el Monitoreo de las Agregaciones Reproductivas de Peces

# L'abondance des Femelles et les Perspectives de Frai Conduisent à la Production de Sons Chez un Mérou Territorial Mâle: Implications pour la Surveillance des Agrégations de Frai

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## EXTENDED ABSTRACT

Research focused on sound production by male fish during reproductive periods has identified a growing assemblage of species that produce sounds during or prior to spawning, which may function to attract females to male territories, communicate information about reproductive fitness, and coordinate spawning at fish spawning aggregations (FSA; Brantley and Bass 1994, Rowe and Hutchings 2004, Vasconcelos et al. 2012, Rowell et al. 2015, Erisman and Rowell 2017). When the sources of sounds are known and the behavioral contexts are understood during reproductive periods, the monitoring of sounds at FSAs can facilitate an ability to crudely infer spatio-temporal patterns of spawning and abundance in the absence of visual surveys (Rowe and Hutchins 2006, Rowell et al. 2012, Rice et al. 2017, Rowell et al. 2017). However, challenges in calibrating counts of detected fish sounds for time-varying, environmental effects on detectability (e.g. background noise) has limited the evaluation of relationships between sound production and levels of courtship behaviors, spawning, and abundance (Küsel et al. 2011, Helble et al. 2013, Marques et al. 2013). Therefore, to understand what drives male sound production during reproductive periods and assess whether patterns of recorded sounds during long-term acoustic monitoring correspond to changes in courtship behaviors, spawning, and abundance, data of detected sounds need to be calibrated for factors that affect the detectability of sounds over time within the environment as the detection range of sounds may vary given transient conditions at recording sites, effectively changing the number of males that are capable of being monitored (Helble et al. 2013). Once calibrated for detection ranges and the number of males present within those respective ranges known, estimates of sound production per individual (i.e. sound production rates) can be calculated by dividing the total number of sounds detected by the number of males present within the detection range of the recorder in discrete time periods (Marques et al. 2013). After which, sound production rates can be compared to other datasets, such as visual observations, to determine if changes in sound production are associated with measures of courtship, spawning, and abundance of males and females (Johnson et al. 2018).

In this study, we used propagation modeling (RAMGeo) and detection theory to estimate rates of sound production from uncalibrated levels of detected sounds produced by territorial, male Gulf grouper (*Mycteroperca jordani*) during visual displays directed towards females as part of spawning bouts at a FSA within Cabo Pulmo National Park, Mexico (Rowell et al. 2019). Ambient sound was recorded with a SoundTrap 300 at the FSA during the month of May 2017 at an interval of 1 minute every 5 minutes. The spatial distribution of male territories was recorded by divers using GPS devices to estimate their ranges from the acoustic recorder and the number of males effectively monitored per hour given varying detection ranges over time. Rates of sound production per male per hour was estimated by dividing the total number sounds detected during long-term acoustic monitoring by the number of males within the detection range of the recorder per hour, based off acoustic propagation modeling and detection theory. Divers conducted visual surveys of a focal male and recorded rates of courtship behaviors (head shakes and burst rises), spawning rushes, and the number of females encountered within male territories per hour at the location of long-term acoustic monitoring during the hours of 1600-1800 Mountain Standard Time (MST). Estimated rates of sound production were compared to diver observed rates of courtship, spawning, and numbers of females within male territories during hours in which surveys were conducted. Correlations between rates of sound production and observations were performed using Spearman rank correlation tests.

Acoustic propagation modeling and detection theory coupled with observations of males within fixed territories along a longitudinal gradient at the site revealed that between two to five males were effectively monitored by the long-term acoustic recorder in any given hour as the detection range of Gulf grouper sounds varied depending on ambient conditions of background noise. Environmentally calibrated, estimated rates of sound production differed from raw levels of detected sounds. Thus, patterns of detected sounds differed from patterns of rates of sound production and were not indicative of

sound production at the site, highlighting the importance of incorporating detection theory into acoustic monitoring efforts at FSAs prior to making inferences about patterns in courtship, spawning, and abundance. Rates of sound production were greatest prior to sunset when females migrated to male territories, courtship commenced, and spawning occurred. Rates of sound production were not correlated to courtship behaviors (Spearman Rank; head shakes: $r_s(38) = 0.01$, $p = 0.95$; burst rises: $r_s(38) = 0.29$, $p = 0.07$) but were correlated to observed rates of spawning and females encountered within male territories (Spearman Rank; spawning rushes: $r_s(38) = 0.48$, $p = 0.002$; females encountered: $r_s(38) = 0.52$, $p < 0.001$), indicating that female presence and increased opportunities to spawn largely drive sound production in some territorial male groupers during reproductive periods (Figure 1). This study found that once calibrated for environmental effects and detection capabilities, changes in rates of fish sound production can be used to infer levels of spawning activity and the abundance of both sexes at FSAs, thereby supporting the continued use of passive acoustics to monitor FSAs of soniferous species. Future efforts that seek to monitor species recovery or decline at FSAs should evaluate the importance of detectability at the site and the spatial distribution of sound producers prior to designing acoustic monitoring methods and estimating changes in patterns of abundance and spawning.

KEYWORDS: Gulf grouper, *Mycteroperca jordani*, fish sound production, acoustic propagation, passive acoustics

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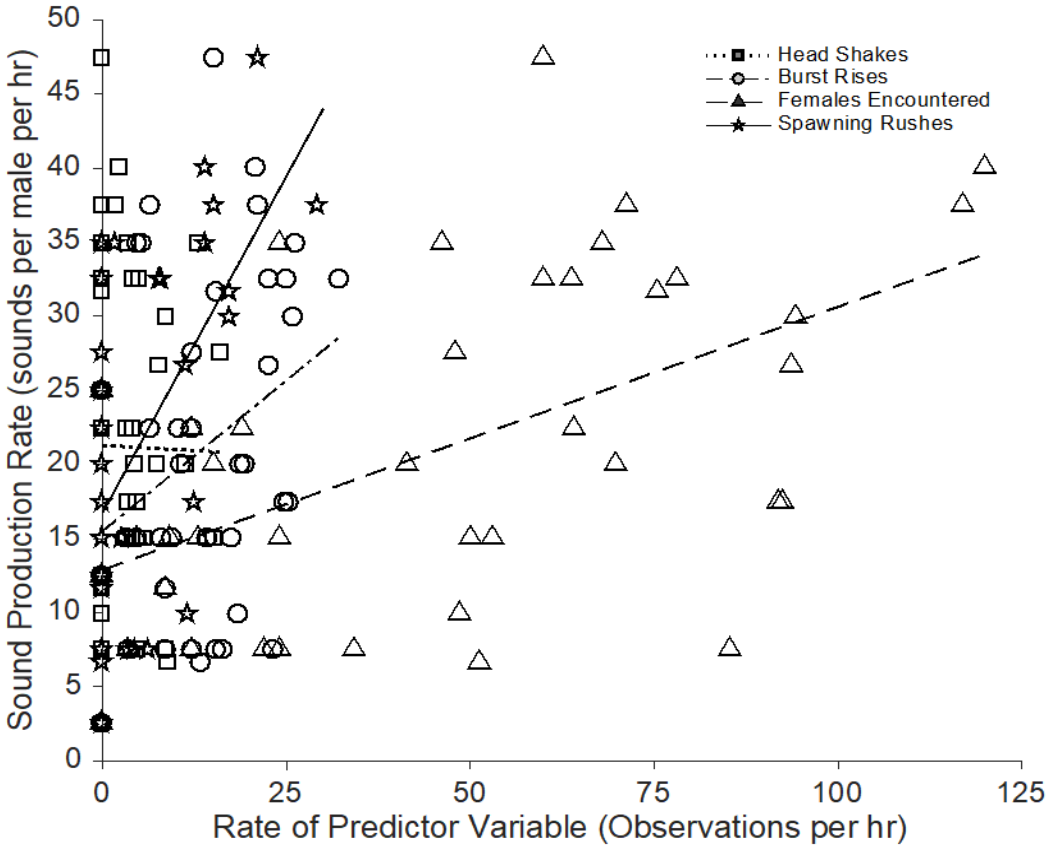


**Figure 1.** Relationships between hourly rates of sound production and observations of behaviors and females from 1600 – 1800 MST. Rates of females encountered and spawning rushes were positively correlated to rates of sound production. Regression lines were fitted with generalized linear models.

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