Acoustic Competition in the Gulf Toadfish *Opsanus beta*: Crepuscular Changes and Acoustic Tagging

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We quantified crepuscular variation in the emission rate and call properties of the boatwhistle advertisement call of Gulf toadfish *Opsanus beta* from a field recording of a natural population of nesting males in the Florida Keys. Their calls are more variable and complex than previously reported (Fig. 1). A call typically starts with a grunt followed by one to five tonal boop notes (typically two or three) and lasts for over a second. The first boop is considerably longer than later ones, and intervals between boops are relatively constant until the final interval, which approximately doubles in duration. Positions of fish are fixed for long periods, and calls are sufficiently variable that we could discern individual callers in field recordings (Fig. 1). Calling rate increases after sunset when males tend to produce shorter calls with fewer notes (Fig. 2). Analysis by number of notes per call indicates some individuals decrease the number of initial grunts and the duration of the first note, but most of the decrease results from fewer notes. To our knowledge this sort of call plasticity has not been demonstrated before in fishes. We suggest that call shortening lowers the chances of overlapping calls of other males and that the small amount of time actually spent producing sound (total on time) is an adaptation to prevent fatigue in sonic muscles adapted for speed but not endurance.

Anomalous boatwhistles contain a short duration grunt embedded in the tonal portion of the boop or between an introductory grunt and the boop (Fig. 3b, c). Embedded grunts have sound pressure levels and frequency spectra that correspond with those of recognized neighbors, i.e. we are able to identify individuals based on frequency spectrum of their grunts (Fig. 4). We therefore suggest that one fish is grunting during another's call, a phenomenon here termed acoustic tagging. Snaps of nearby pistol shrimp may also be tagged, and chains of tags involving more than two fish occur (Fig. 5). The stimulus to tag is a relatively intense sound with a rapid rise time, and tags are generally produced within 100 ms of a trigger stimulus. Time between the trigger and the tag decreases with increased trigger amplitude. Tagging is distinct from increased calling in response to natural calls or stimulatory playbacks since calls rarely overlap other calls or playbacks. Tagging is not generally reciprocal between fish suggesting parallels to dominance displays.

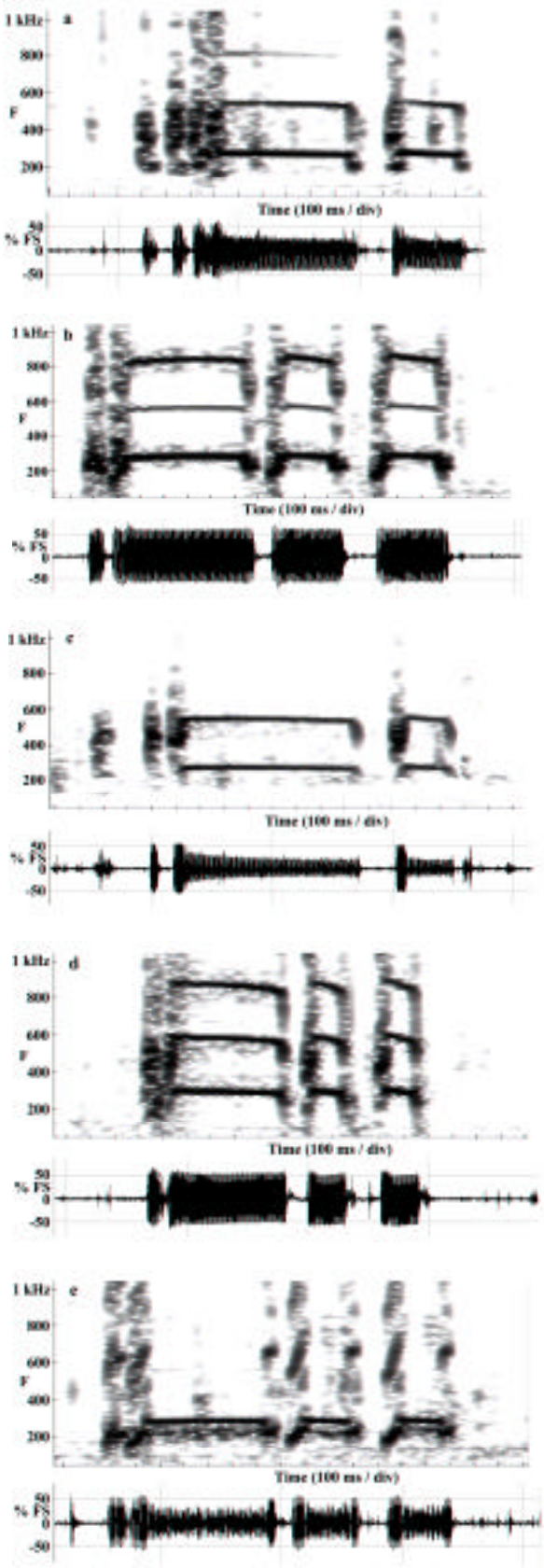

Fig. 1. Sonagrams and oscillograms from five individual *Opsanus beta*

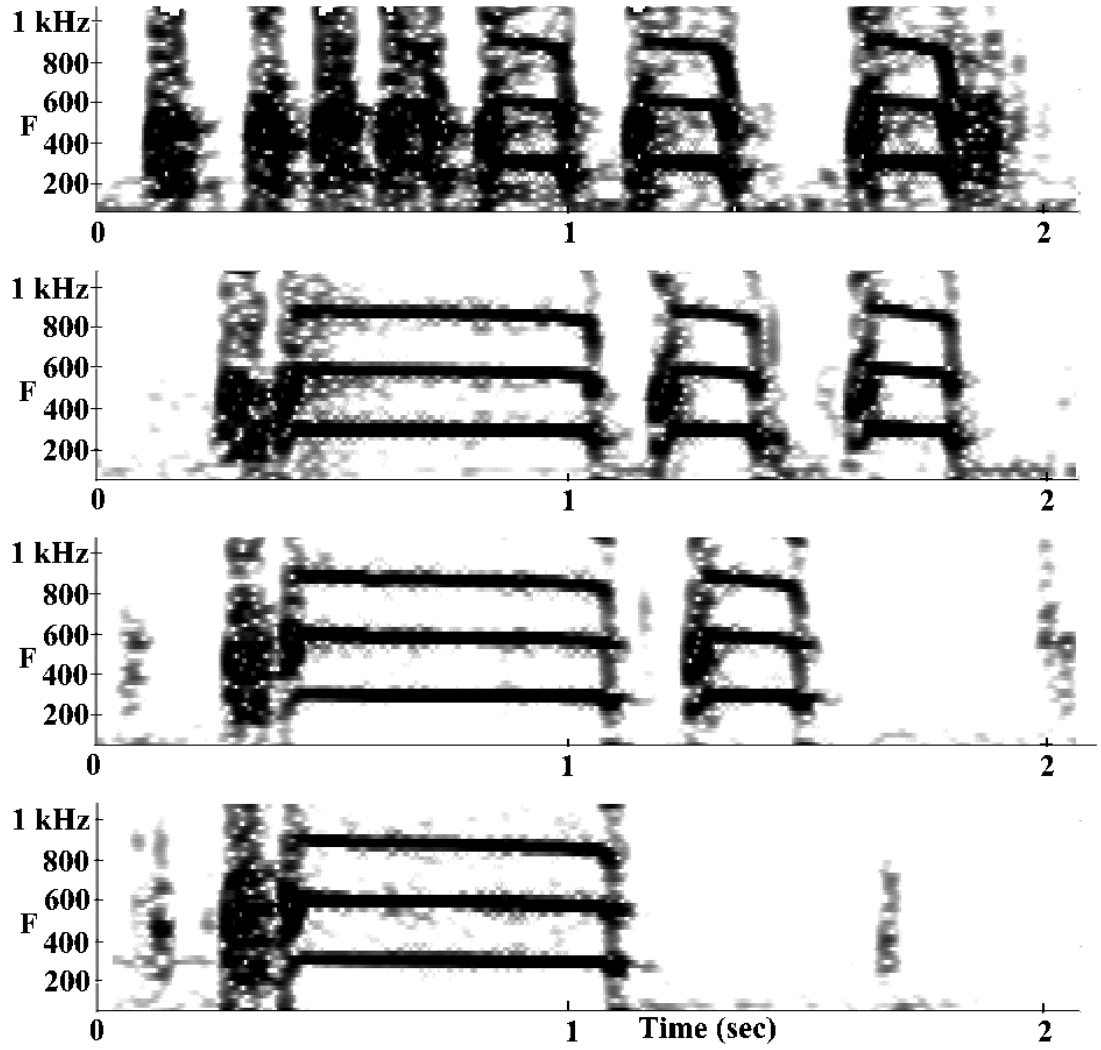

Fig. 2. Sonagrams from 4-, 3-, 2-, and 1-boop calls from an individual *Opsanus beta*.

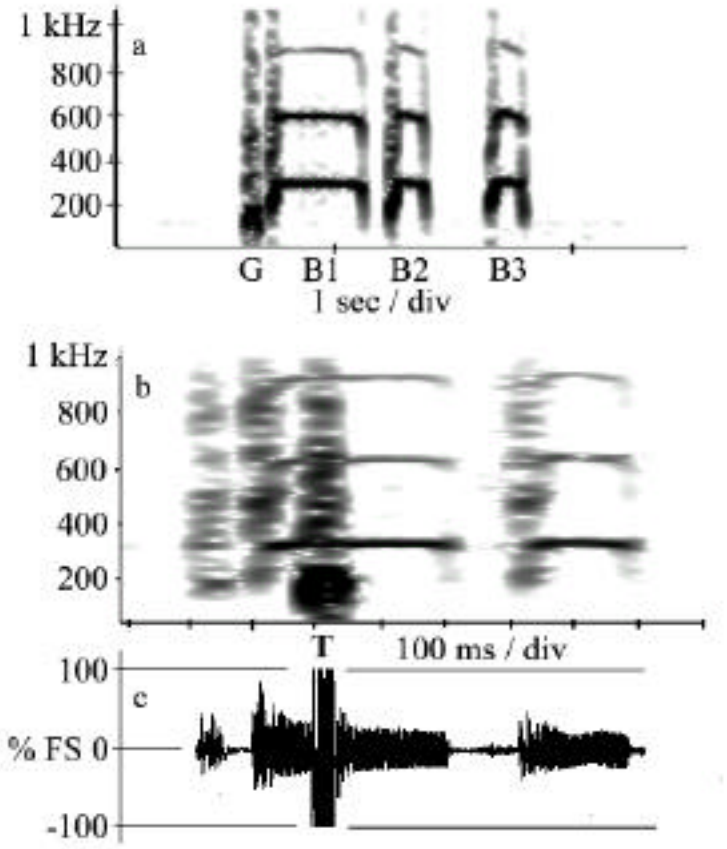

Fig. 3. Sounds of *Opsanus beta* illustrating acoustic tagging. (a) A typical boatwhistle with an initial grunt (G), a long tonal boop B1 and two shorter boops (B2 and B3). (b) Sonagram and (c) oscillogram of a boatwhistle tagged by another fish. The T marks the tag, which has lower frequency energy and greater amplitude than the boatwhistle.

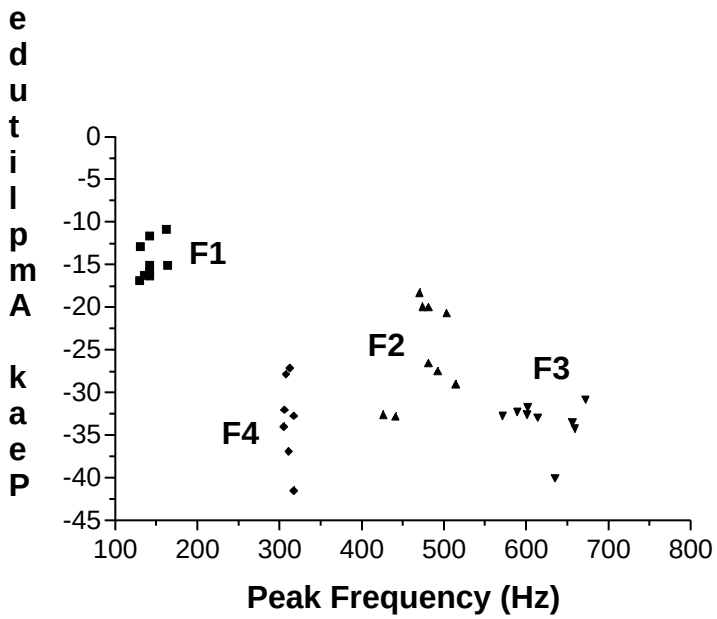

Fig. 4. Plot of peak amplitude in dB against the frequency of peak amplitude from grunt spectra for four toadfish recorded at weekly intervals.

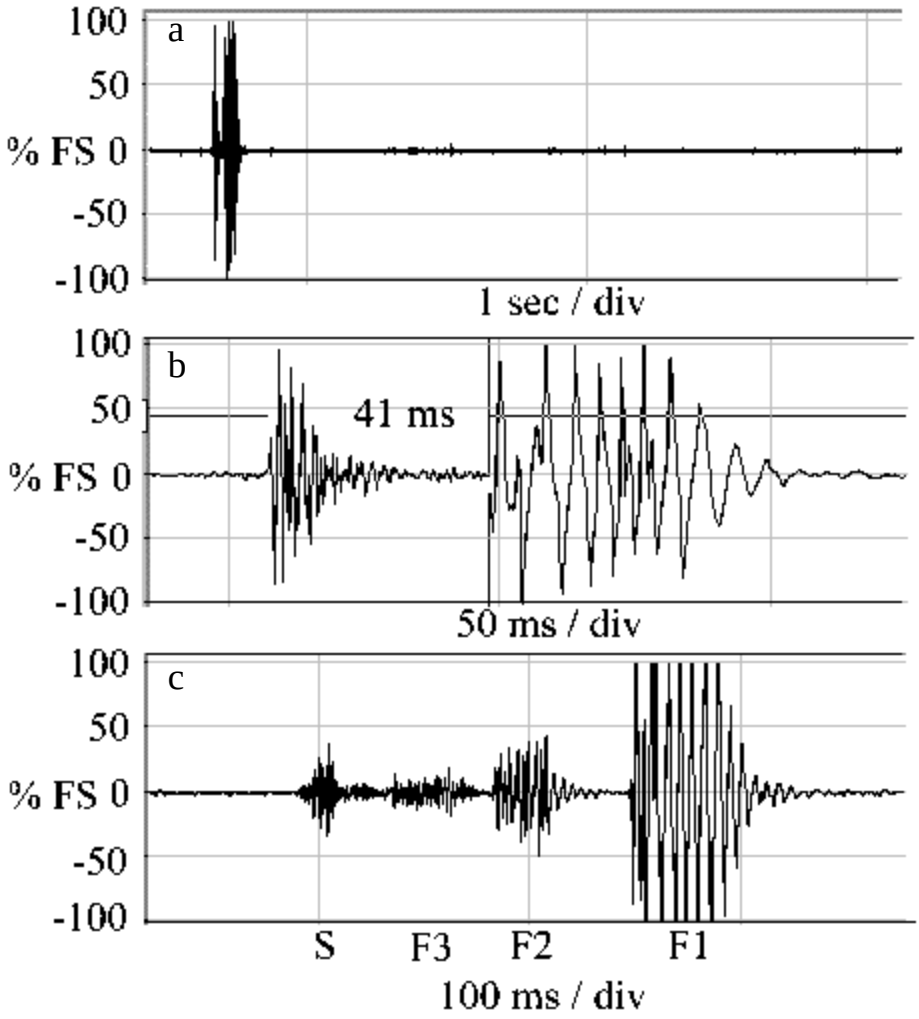

Fig. 5. Tags of shrimp snaps. (a) oscillogram of a pistol shrimp snap tagged by fish 1 with a latency of 41 ms shown in real time. (b) Same selection expanded. (c) Chain of tags initiated by a shrimp snap that is tagged by fish 3. Fish 3's grunt is then tagged by fish 2, who in turn is tagged by fish 1.