Sound production in the tiger-tail seahorse *Hippocampus comes*: Insights into the sound producing mechanisms

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Acoustic signals of the tiger-tail seahorse (*Hippocampus comes*) during feeding were studied using wavelet transform analysis. The seahorse "click" appears to be a compounded sound, comprising three acoustic components that likely come from two sound producing mechanisms. The click sound begins with a low-frequency precursor signal, followed by a sudden high-frequency spike that decays quickly, and a final, low-frequency sinusoidal component. The first two components can, respectively, be traced to the sliding movement and forceful knock between the supraorbital bone and coronet bone of the cranium, while the third one (purr) although appearing to be initiated here is produced elsewhere. The seahorse also produces a growling sound when under duress. Growling is accompanied by the highest recorded vibration at the cheek indicating another sound producing mechanism here. The purr has the same low frequency as the growl; both are likely produced by the same structural mechanism. However, growl and purr are triggered and produced under different conditions, suggesting that such "vocalization" may have significance in communication between seahorses.
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I. INTRODUCTION

Acoustic origin of sound produced by fish has been linked to the different morphological structures of the sound producing mechanism (Kaatz, 2002; Kasumyan, 2008). A variety of fish make sounds through stridulation, swim bladder pulsation, hydrodynamic movement, tendon vibration, and air release, often creating a consistent sound pattern (Fine *et al.*, 1977; Kaatz, 2002; Fine and Parmentier, 2015).

The clicking sound has been reported in seahorses when the fish is introduced to a new surrounding (Fish, 1953), during courtship and mating (Fish and Mowbray, 1970; Colson *et al.*, 1998; Anderson, 2009; Anderson *et al.*, 2011; Oliveira *et al.*, 2014), inter-male competition (Colson *et al.*, 1998), and more commonly, feeding (Fish and Mowbray, 1970; Bergert and Wainwright, 1997; Colson *et al.*, 1998; Anderson, 2009). Two mechanisms have so far been hypothesized to explain the origin of the feeding click. The first is the stridulatory mechanism that involves the supraoccipital bone rubbing against the coronet bone (Fish and Mowbray, 1970; Colson *et al.*, 1998), while the second is cavitation or the formation and sudden implosion of vapour cavities in water in the buccal cavity due to a rapid pressure change (James and Heck, 1994). Colson *et al.* (1998) tested and concluded that the clicking sound made by the seahorse was stridulatory in nature. They surgically removed the hind ridge of the supraoccipital bone and found a decrease in the clicking frequency. Although Colson and co-workers' work might support the stridulatory mechanism even through extreme manipulation to impair it, the nature of the clicking sound or how it is generated has never been investigated in detail.

Swim bladder pulsation creates a growling sound in fish that has been recorded in several taxa, including Ophidiidae, Holocentridae, Sciaenidae, Carapidae, Pomacentridae, and Scorpenidae (Ladich and Fine, 2006; Ramcharita *et al.*, 2006; Parmentier and Diogo, 2006; Parmentier *et al.*, 2006a; Parmentier *et al.*, 2006b; Lobel *et al.*, 2010; Fine and Parmentier, 2015). However, it has never been investigated in seahorses, although Kaatz (2002) had reported that it is one of two main types of sound produced in syngnathids. Anecdotal evidence of body quivering may point to the possible pulsations of the swim bladder in the seahorse (Masonjones and Lewis, 1996) as similarly reported in other species of fish (Ripley and Lobel, 2004; Amorim, 2006). Recently, Oliveira *et al.* (2014) reported a stress-associated growling sound in *Hippocampus reidi*, presumably emanating from the swim bladder although they found no evidence of extrinsic swim bladder muscles.

In this study, we recorded and analysed the feeding click of the seahorse (*Hippocampus comes*) using spectral and

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