The Cuttle Shuttle: Prediction of Prey Behavior by Cuttlefish

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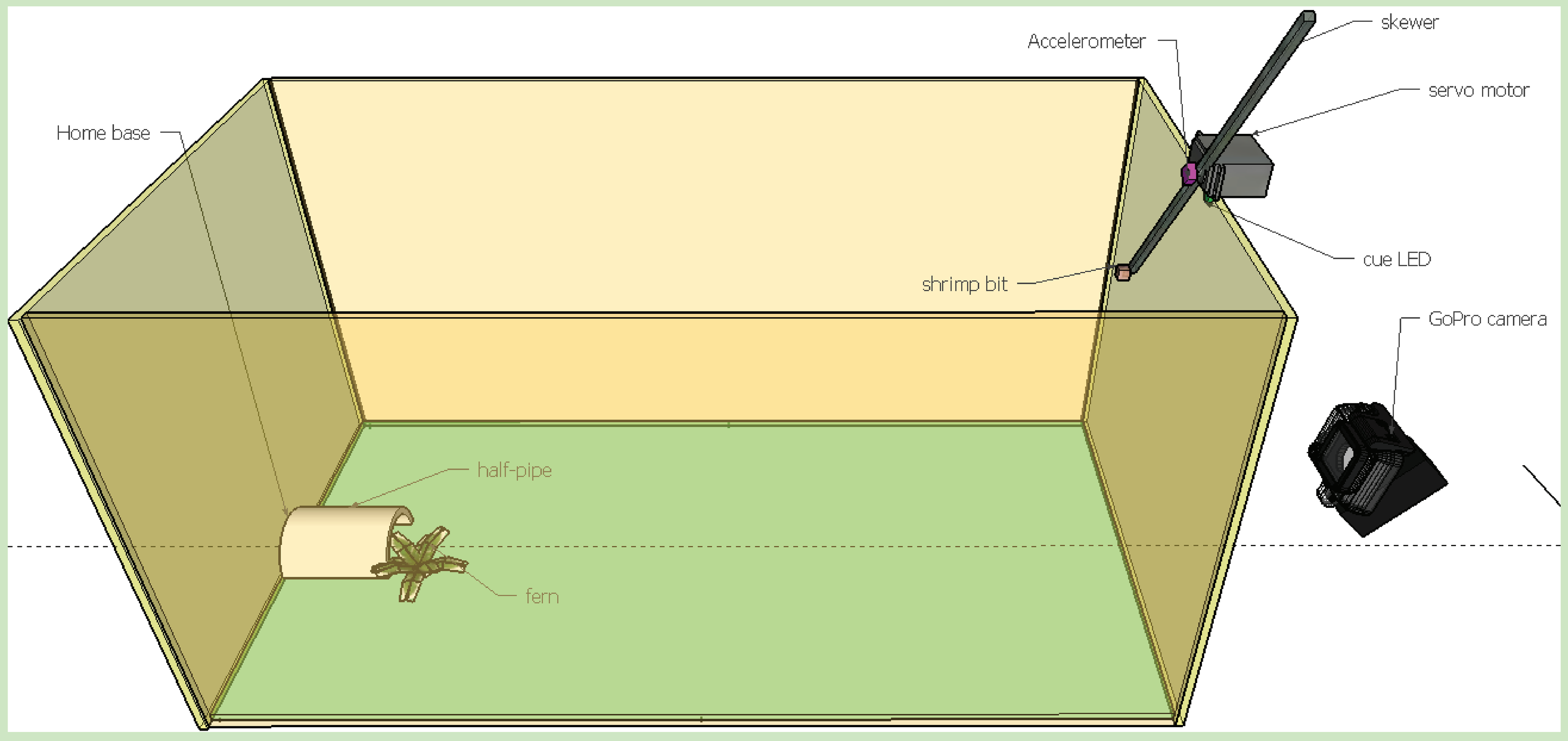
Introduction

In collaboration with the Marine Biology Lab at Woods Hole, USA, the Cuttle Shuttle was originally designed to study predictive model-making behavior by asking cuttlefish (***Sepia officinalis***) to hunt prey that moved with ever-increasing complexity. Because cuttlefish use active camouflage - their body pattern is rapidly and directly controlled by their nervous system - this species presented the possibility of directly observing the state of a brain non-invasively. Tools and methods prototyped in rats by the Kampff Lab were translated into an assay appropriate for cuttlefish, the design of which was informed by field work and laboratory studies done by the Marine Biology Lab. Our goal was to develop a quantitative method for measuring behavioral complexity while simultaneously documenting the many qualitative factors that affect behavior, namely context.

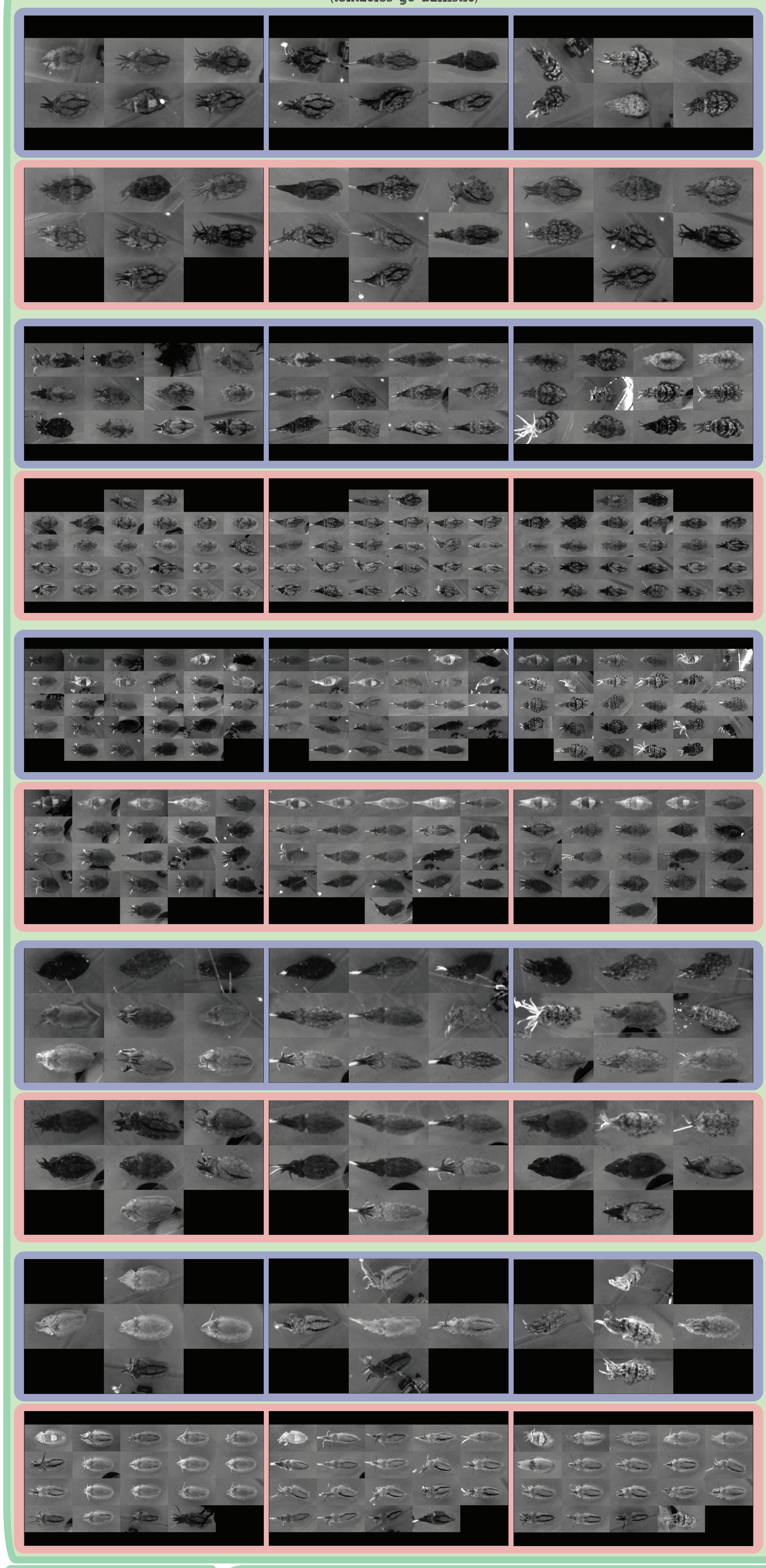
In this experiment, cuttlefish must hunt for their food 4 days out of 7, in the "hunting box" shown to the right; their prey is a piece of shrimp at the end of an arduino-controlled skewer. The prey movements went through the following steps of complexity:
- **Natural movement**: prey "wiggles" in a manner meant to imitate the movements of a live common grass shrimp (***Palaemonetes vulgaris***). Prey wiggles three times per "food offering" event.
- **Patterned movement**: prey sweeps through the hunting box in a simple parabola per "food offering" event.
- **Causal movement**: during each "food offering" event, prey either (a) moves in the same parabola as "Patterned movement" or (b) pauses for one second at the trough of the parabola, then reverses the direction of its movement.

The metric for success was simple - did the cuttlefish catch the prey, or not? The more nuanced behaviors that accompanied this straightfoward metric have given rise to the following questions, which we hope to answer by analyzing the experiment's video dataset:
- Does the cuttlefish display a reliable sequence of body patterns while hunting?
- If so, can we predict contextual details from an analysis of the body patterns alone?
- What are the firing dynamics of cuttlefish tentacles?

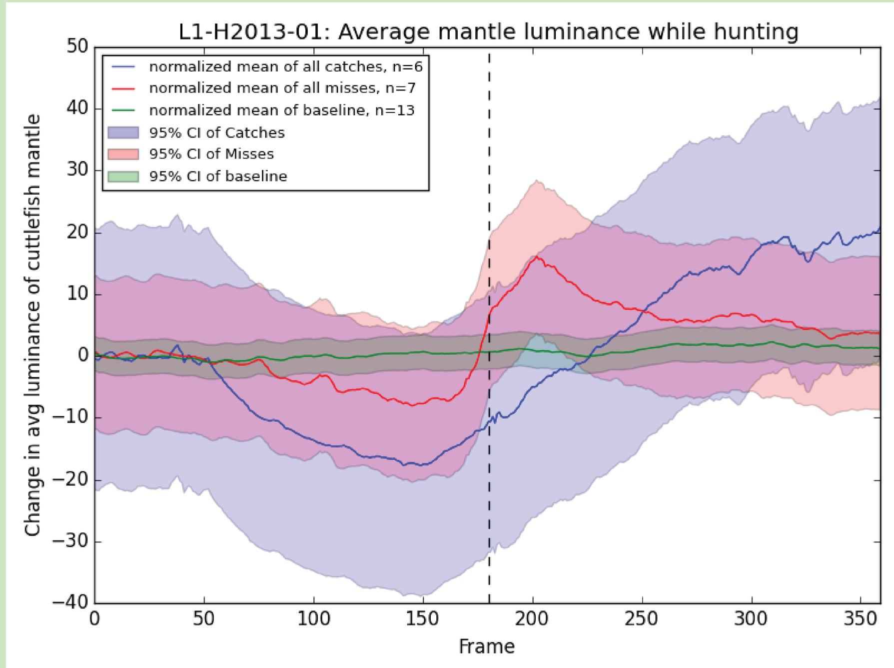


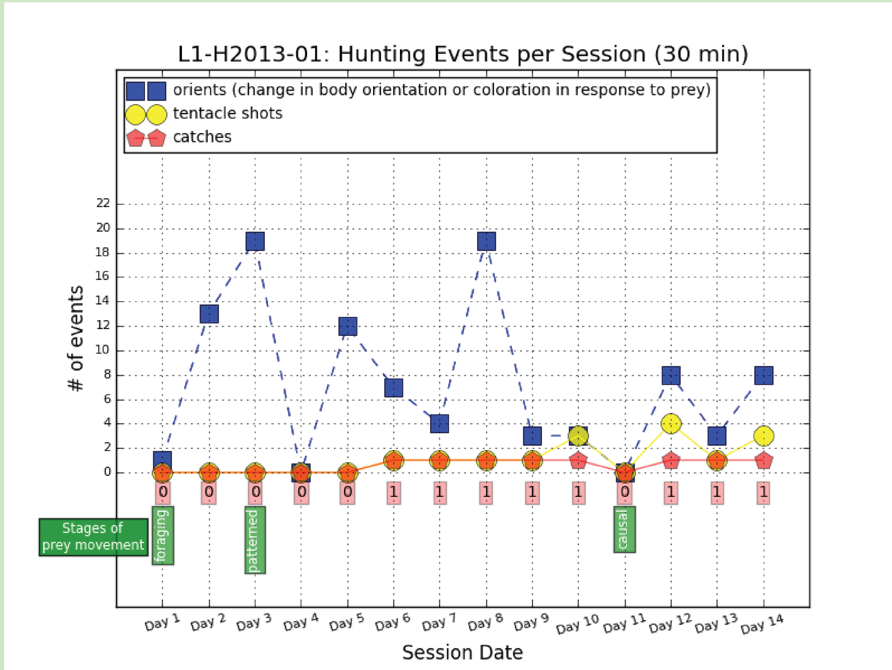
Results

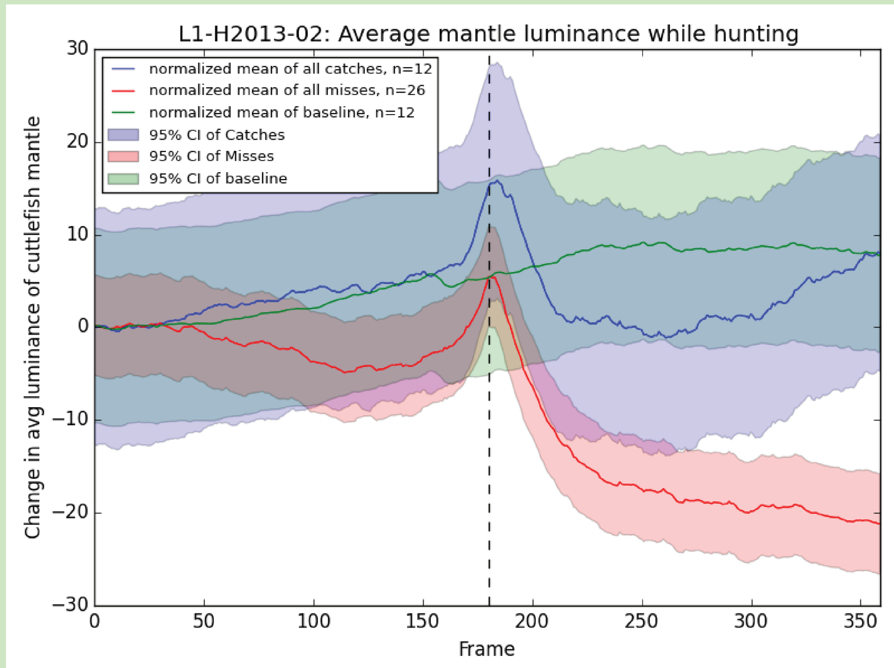
Frame 0 | Frame 180 (tentacles go ballistic) | Frame 360

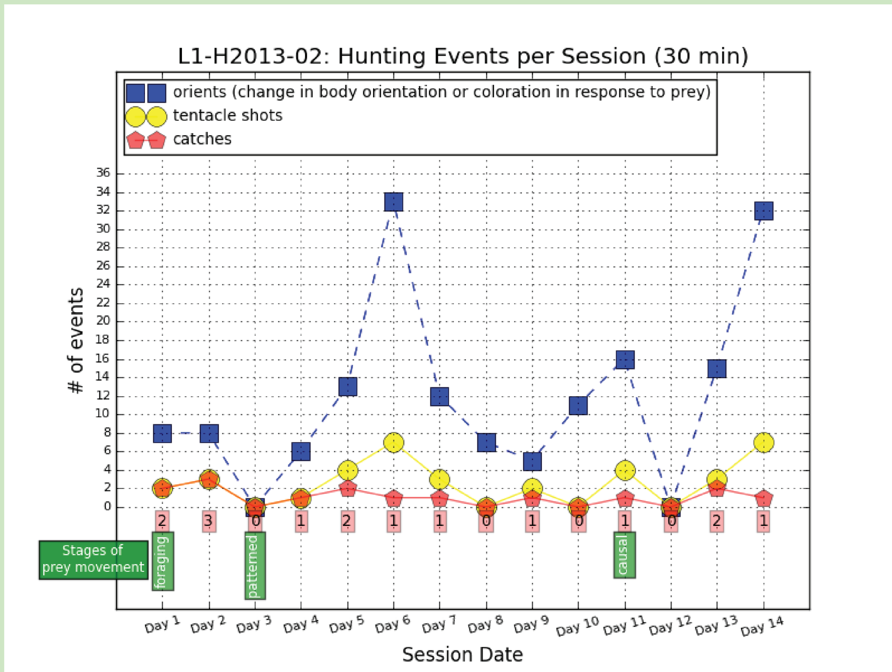


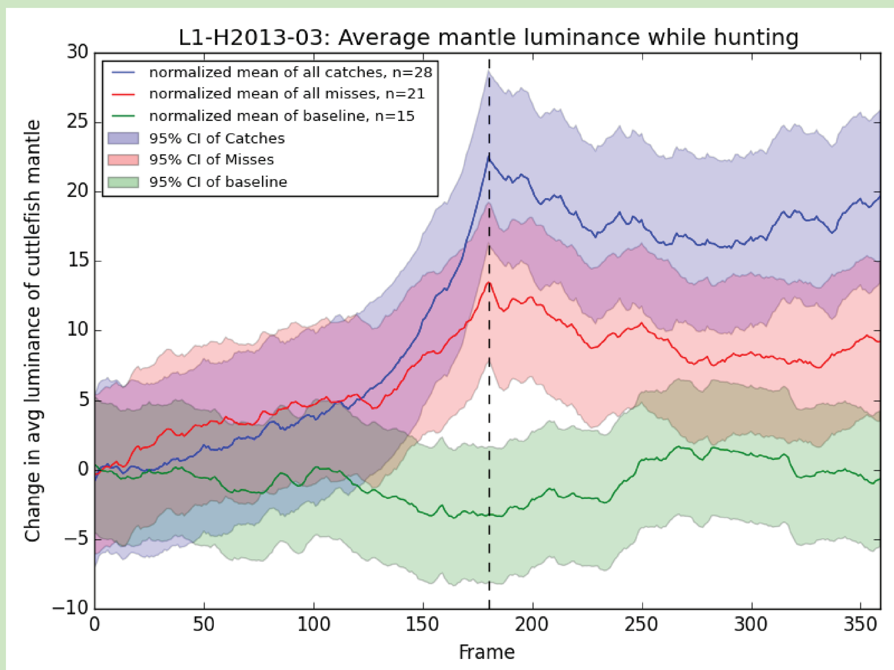
Videos used in analysis were obtained from an overhead PointGrey Flea3 camera (not shown in setup diagram). The full raw video dataset can be found online here: https://goo.gl/BgOCzv. Processed clips can be found here: https://goo.gl/Em6aG2

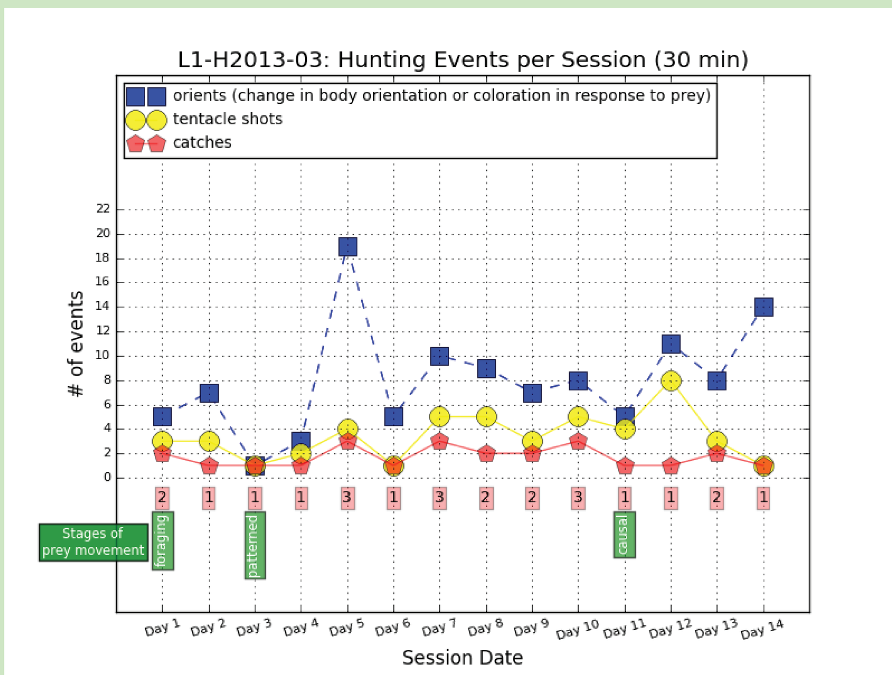


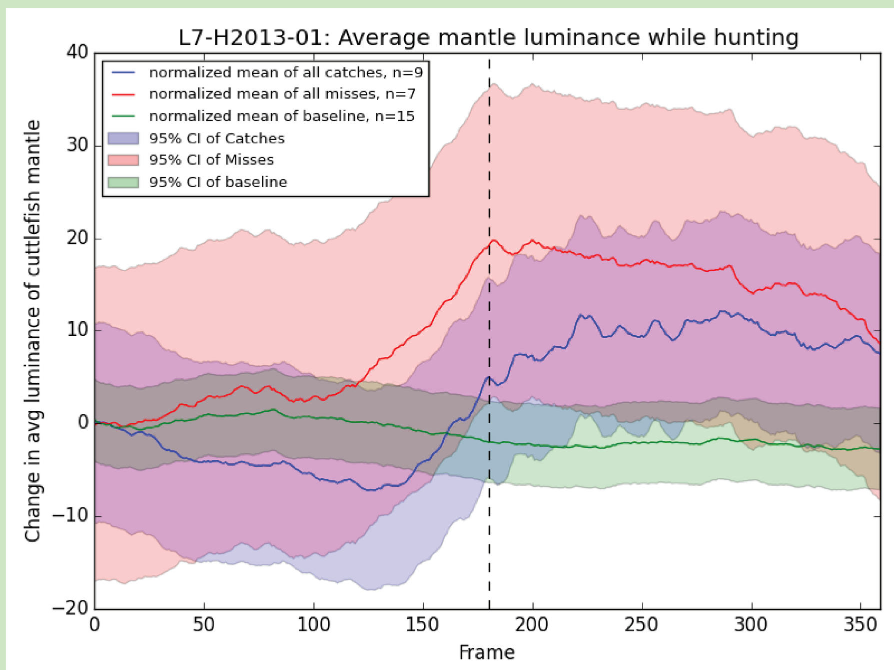


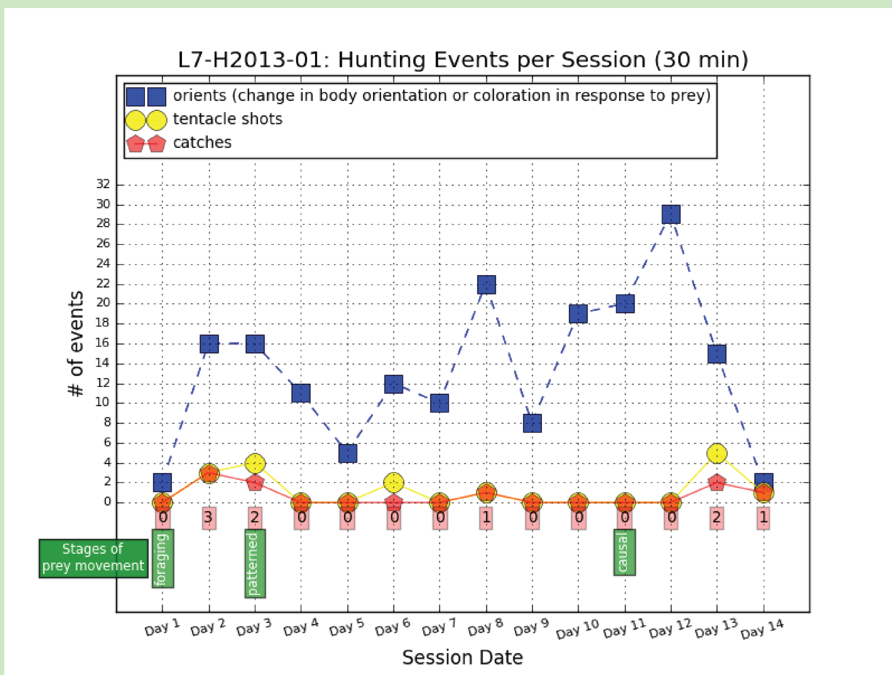


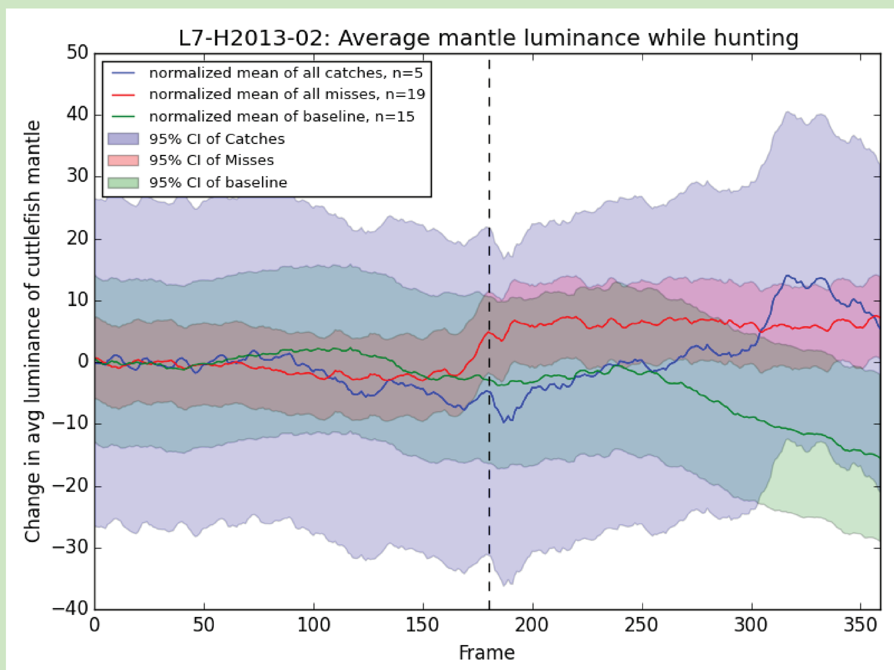


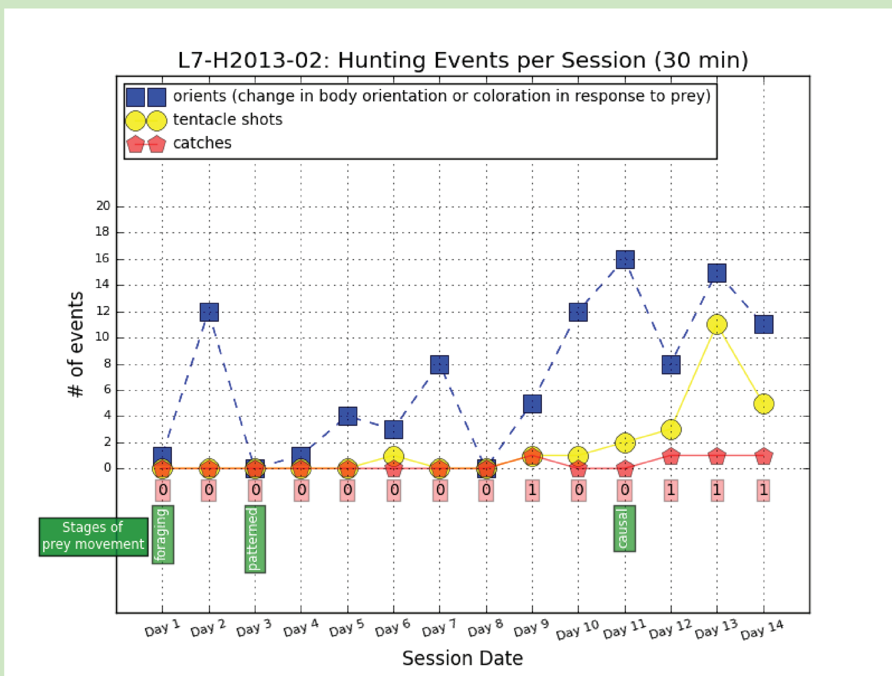












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Next Steps: We will continue exploring this dataset by taking mantle luminance measures at other time points of interest, such as moments when the cuttlefish "orients" (changes body position, orientation, or coloration rapidly) towards a change in its environment, or when the tentacles "peek" but do not shoot ballistically. We will also assess the body pattern by other metrics besides luminance, such as contrast and spatial frequency.

This dataset strengthens the possibility that cuttlefish body patterns can be used to non-invasively assess the internal state of the cuttlefish, and more experiments to probe this idea would make a natural follow-up experiment. A field from which we plan to take inspiration for behavioral assessments is the field of infant cognition, where behavioral measures, such as length of gaze, is used to assess what a non-verbal subject knows about the world. In infant cognition, experiments try to violate the expectations of the subject and then observe whether the subject acknowledges said violation. These kinds of behavioral experiments would translate well to the cuttlefish, and provide a plethora of low-hanging fruit for comparative neuroscience.