Behavioral Responses of Cultured White Abalone (*Haliotis sorenseni*) to Predatory Sea Stars in a Laboratory Experiment

Anna Thomasdotter[1], Lindsay Marks[2], Melissa Neuman[2]

1. San Jose State University 2. National Oceanic and Atmospheric Administration National Marine Fisheries Service

Background

White abalone (*Haliotis sorenseni*) was listed as an endangered species in 2001. A captive breeding program was established in 2012 which aims to enhance wild populations of white abalone through outplanting of hatchery-raised individuals (Figure 1). One of the problems faced is the relatively high mortality among outplanted captive-bred abalone as compared to wild conspecifics, likely caused by predation[1,2]. Previous research suggests that abalone exhibit a specific defense response when threatened by a predator[3], and that this response differs between captive-bred and wild individuals[4]. Furthermore, young individuals seem to be more vulnerable[5]. However, few studies have been made on the subject and none specifically targeting white abalone. We investigated whether cultured white abalone have an innate ability to respond defensively to a natural predator, if this response allows them to escape, and if the reponse changes with repeated exposure.

Research Questions

- Do hatchery-raised white abalone respond defensively to tactile cues from a potential predator?
- Does the defensive response allow the abalone to escape the predator?
- Does the abalone response change with repeated exposure to the predator?

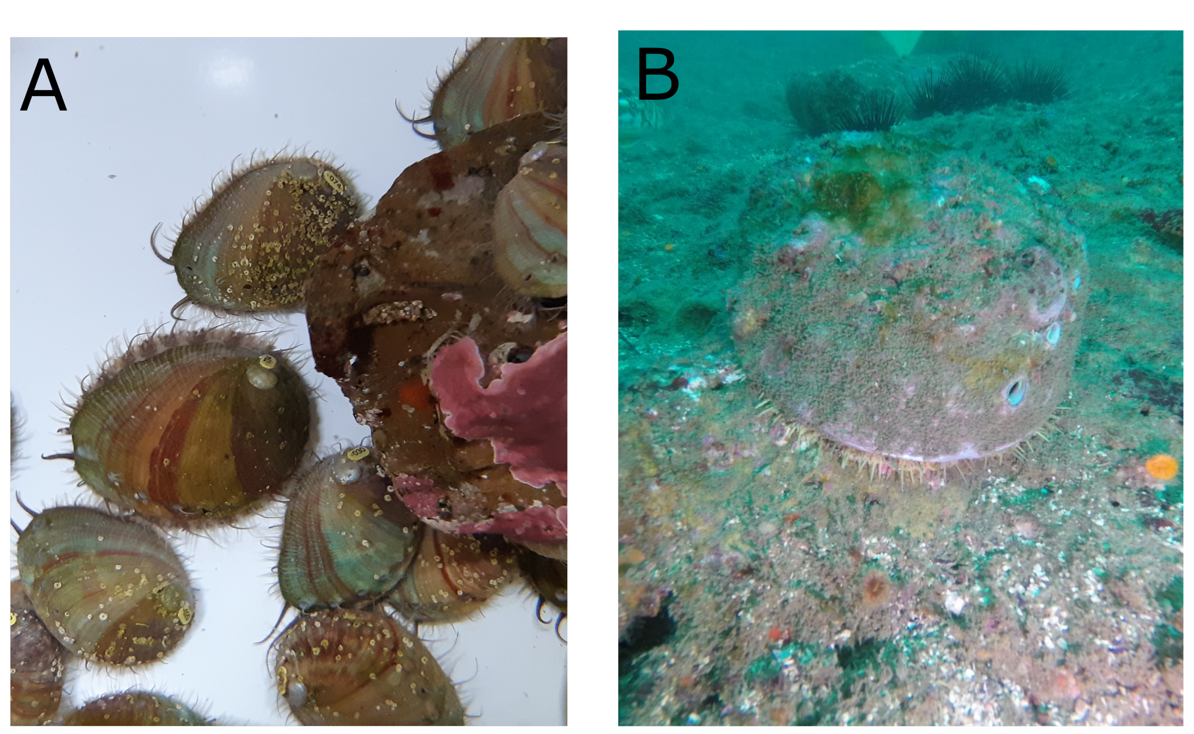

Figure 1. Cultured juvenile white abalone in a laboratory tank (A) and adult white abalone in the wild (B). Right picture by David Witting, NOAA Restoration Center.

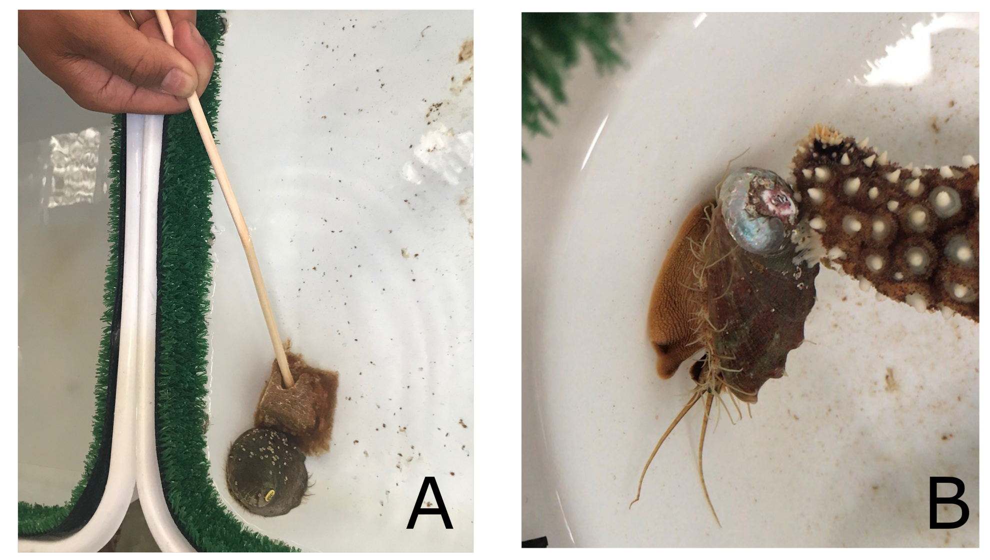

Figure 2. Stimulus in control trials with sustained sponge contact (A) and predator trials where one sea star arm touches the abalone (B).

Methods

Cultured juvenile white abalone were placed in individual experimental tanks and the abalone were allowed to acclimate for four days after relocation. Each abalone was exposed to one control trial and three consecutive predator trials, with a baseline observation period (no stimulus) of five minutes before the start of each trial. Control trials consisted of sustained contact with a natural sponge (Figure 2A). In predator trials, a natural predator - the giant spined sea star *(Pisaster giganteus)* - was added to the experimental tank with one arm touching the abalone (Figures 2B, 3). Abalone behaviors were categorized, and we recorded the time of initiation and duration of behaviors during five-minute trials. In predator trials, we also recorded the predator's behavior.

At the end of each trial, the stimulus (sponge or sea star) was removed from the experimental tank. Control trials were performed once, and predator trials repeated three times with one day in between. The experiment was replicated at two locations participating in the captive breeding program, UC Santa Barbara and The Bay Foundation, with 16 abalone used at each location.

Figure 3. Experimental setup for predator trials.

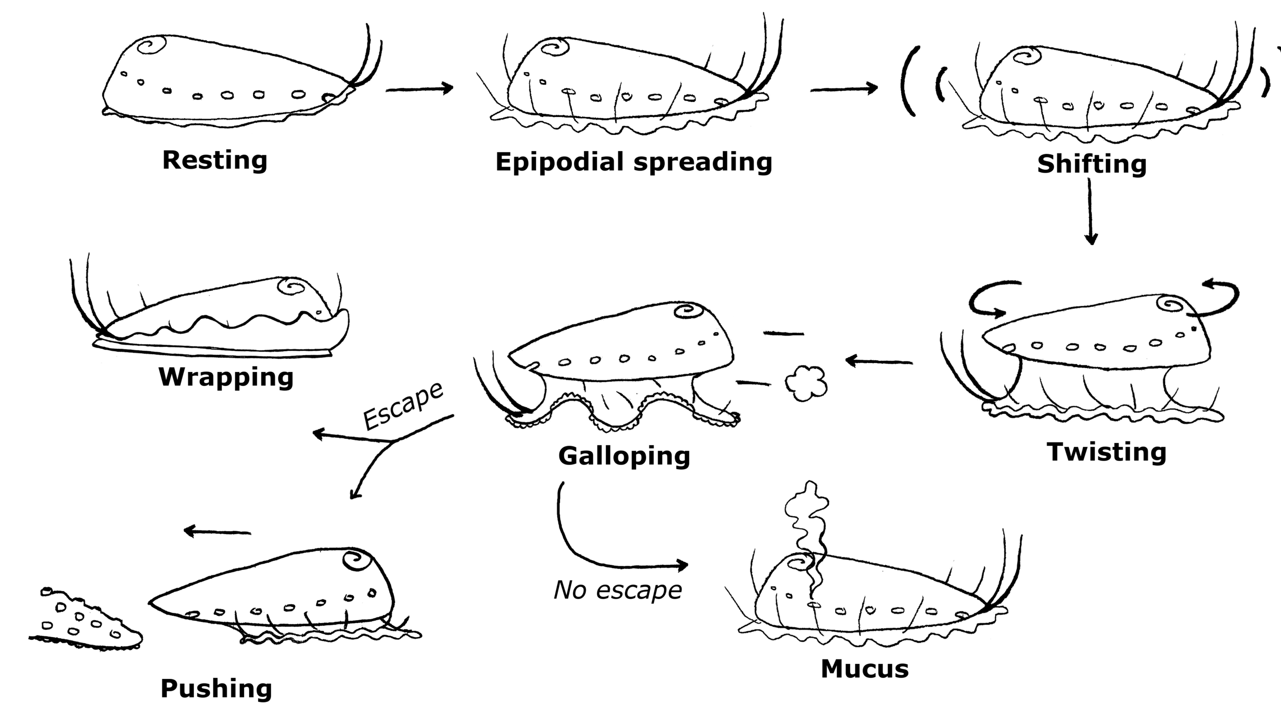

Figure 4. General sequence of defensive behaviors observed in predator trials.

Results

In all predator trials, abalone exhibited some type of defensive behavior (Figure 4). The behaviors differed between predator trials and baseline or control trials (Figure 5). A larger portion of the predator trials consisted of stronger defensive behaviors, as opposed to resting or clamping in non-predator trials. Specific behaviors were generally exhibited in a predictable order (Figure 4). Wrapping occurred in less than 50% of predator trials, and mucus excretion and pushing in less than 20%.Time until escape, i.e. breaking of contact between abalone and predator, was significantly different between the first and consecutive predator trials at both study locations (Figure 6; Repeated-Measures ANOVA $_{\text{trial (fixed) x tank (random)}}$, $F_{2,60.46} = 19.55$, $p < 0.001$). Additionally, all abalone escaped during the second and third predator exposure.

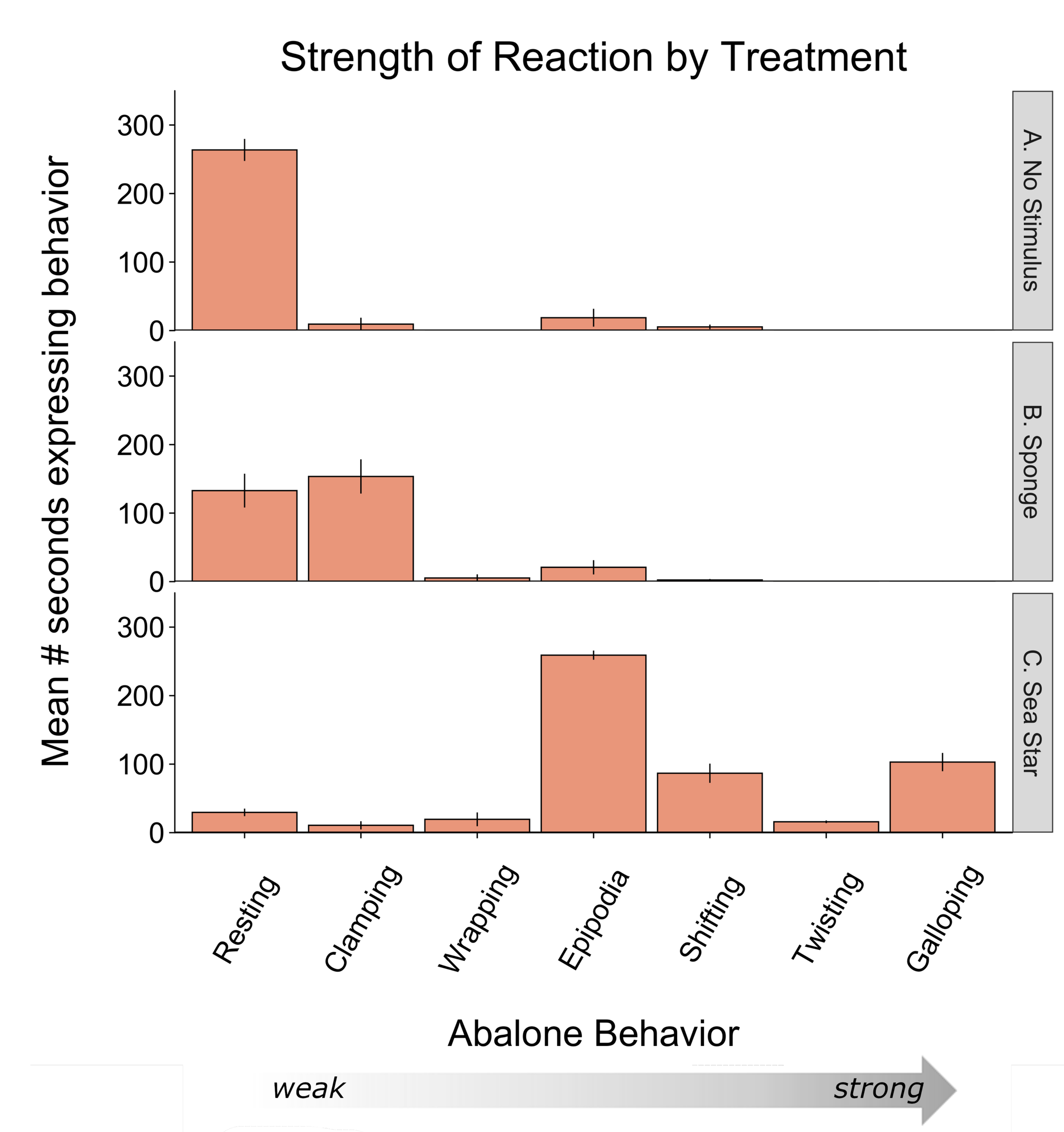

Figure 5. Mean time spent expressing each behavior by abalone in A. Baseline observations, B. Control trials, and C. First predator trial. N=32 abalone. Error bars represent standard error.

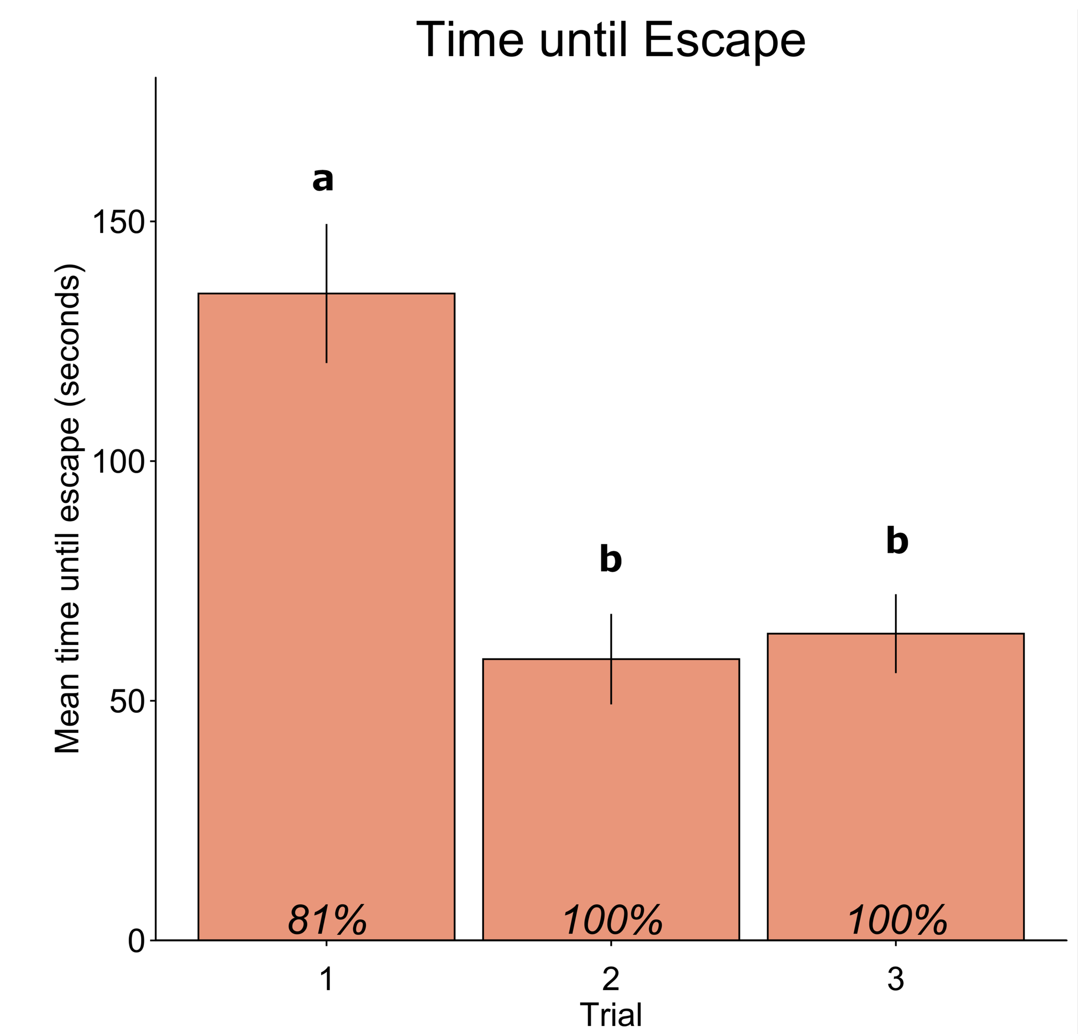

Figure 6. Bar plot of mean time (± SE) until no contact between abalone and sea star (i.e., time until abalone escaped) in each of three consecutive predator trials. N=32 abalone. Percentages represent proportion of trials in which abalone escaped the predator. Letters differentiate statistically significant differences between trials (Tukey pairwise comparison, p<0. 001).

Conclusions

White abalone have an innate ability to detect the presence of *P. giganteus* and respond defensively to predator stimulus. While type of behavior and duration varied between individuals and trials, exhibited behaviors seemed to occur in a predictable pattern. Furthermore, preliminary data suggest that abalone improve their ability to break contact with the predator after multiple exposures. In the second and third predator trials, all abalone managed to break contact (i.e., escape) and did so significantly faster than in the first trial. This suggests that predator exposure could potentially improve captive-bred abalone's ability to avoid predation, which could enhance their survival in the wild and further the success of the captive breeding program.

Acknowledgements & References

This project was supported by the National Research Council and part of a CSU COAST undergraduate internship with NOAA's Protected Resources Division in Long Beach, CA. Travel funds were generously provided by CSU COAST and Associated Students, SJSU.

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