

Response of the Dock Shrimp *Pandalus danae* to Anthropogenic Noise Pollution

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ABSTRACT

Anthropogenic noise pollution has been shown to increase stress in several shrimp species. The dock shrimp *Pandalus danae* of the Eastern Pacific often lives in areas with high boat traffic, but its response to vessel noise has yet to be studied. We used recordings of boat sound and ambient noise conditions to measure behavioral parameters associated with stress in the presence of different auditory stimuli. Results showed no significant difference comparing shrimp exposed to different noise conditions or stress behaviors before and after vessel noise was played. Future research should include shrimp from different collection sites with varying sound exposure to evaluate the consistency of this pattern across the species.

INTRODUCTION

Anthropogenic noise pollution has increased exponentially since the Industrial Revolution with the rise in marine traffic and coastal development, causing significant stress for marine life (Duarte et al. 2021; Hildebrand 2009). As shipping and naval activity has increased, so has auditory congestion from motors, boat horns, and sonar (Duarte et al. 2021). Coastal development has contributed to oceanic noise pollution through pile-driving, oil drilling, and seismic surveys (Duarte et al. 2021). For organisms that produce and use sound for communication, noise pollution can significantly inhibit conspecific communication by masking natural auditory stimuli (Su et al. 2026; Hockey 1970). Similarly, predators that use sound to hunt have shown reduced efficiency when vessel noise is present (Azarm-Karnagh et al. 2023). Since noise pollution will likely persist as a threat to the livelihood of countless organisms, it is essential to understand the extent to which anthropogenic sounds negatively impact marine life.

Decapod crustaceans have been shown capable of hearing sounds ranging from 40-3000 Hz, which has significant overlap with the typical range of vessel noise (Lovell et al. 2005; Hildebrand, 2009; Popper et al. 2001). Anthropogenic noise has contributed to changes in the behavior of crustaceans (Tidau & Briffa 2016; Azarm-Karnagh et al. 2023). Exposure to pile-driving noise has shown to increase the number and volume of snaps from snapping shrimp, as well as reduce burying activity and locomotion in the Norway lobster (Tidau & Briffa 2016). Exposure to boat noise has also shown reduced burying activity and locomotion in this species, as well as disrupted eating in the Common Shore crab. In larvae, oceanic noise pollution can delay settlement and drown out sound cues from preferred settlement sites (Tidau & Briffa 2016). Research to date on auditory reception in shrimp has focused largely on the mechanisms of hearing including the role and function of the statocyst rather than the ecological implications of this hearing ability (Dinh and Radford, 2021; Radford et al. 2022; Radford & Stanley 2023).

The dock shrimp *Pandalus danae* is a common species found in coastal waters of the East Pacific (Bergström 2000). *P. danae* is a brownish shrimp often with small red or blue dots along its thorax and abdomen, and a maximum total length of 14 cm (Washington Department of Fish &

Wildlife 2026). Shrimp of the genus *Pandalus* are known to be a valuable food source for predatory fishes such as rockfish (Frid & Marliave 2010). The more extensively studied common prawn *Palaemon serratus* lives on the eastern coast of the Atlantic Ocean, but shares similar ecological and physiological characteristics to *P. danae*. Both *P. danae* and *P. serratus* rely primarily on statocysts for detecting sounds and live at similar latitude and depth ranges (Guerao & Ribera 2000; Radford & Stanley 2023; Washington Department of Fish & Wildlife 2026). When exposed to boat noise, *P. serratus* has been observed to have fewer encounters with conspecifics and spend more time resting (Tidau & Briffa 2016). Further studies have shown that this species exhibits changes in locomotion and time spent outside of shelter when exposed to boat noise, as well as a rise in proteins associated with stress (Filiciotto et al. 2016). The behavioral and ecological importance of hearing in the genus *Pandalus* has yet to be studied.

In this study, we exposed the dock shrimp *Pandalus danae* to vessel noise and monitored their behavioral responses. Specifically, we monitored tail flips, thigmotaxis, and location relative to the auditory stimulus over a period of 40 minutes. We aim to quantify the stress response of *P. danae*, if any, in response to anthropogenic boat noise. We hypothesized that exposure to boat noise would lead to a significantly higher frequency of stress behaviors compared to those observed in shrimp exposed to ambient ocean noise or no added noise.

MATERIALS & METHODS

[1] Collection

We collected 24 shrimp off the pylons and dock at Friday Harbor Laboratories using a dipnet. Collections were done between 10 pm and midnight in late May. Shrimp were collected only if they had a minimum carapace length of 2 cm and were not carrying eggs. All 24 shrimp were stored in a sea table with a flow-through natural sea water (NSW) system for a minimum of 48 hours before testing to provide adequate acclimatization to the lab, including typical noise conditions. Shrimp were given cut scallops as food during their time in captivity.

[2] Experimental setup

We used a second flow-through sea table (60 x 90 cm) with NSW to conduct our experimental trials. We constructed a cardboard box to completely surround the tank and limit any visual stimuli for the shrimp when inside (Figure 1). One side of the box was removable to allow shrimp to be placed in the tank and easily collected once testing was complete. A webcam (1080 HD webcam, Wennyn) was hung at the top of the cardboard box and connected to a computer for a live feed. Two holes were cut on either side of the top of the box to fit one red light each (A02 LED bike tail light, Overture). Red light was chosen to reduce stress for the shrimp while allowing us adequate visibility of the tank via the webcam (Pichon et al. 2025). On the end of the sea table opposite the outflow stand pipe, we hung a speaker (Angle clip bluetooth speaker, Oontz, MA, USA) such that it was fully submerged underwater.

[3] Behavioral Trials

For each trial, one shrimp was transferred to the testing tank using a dipnet. Trials were divided into three, 20-minute segments totalling one hour in the test tank. The first 20 minutes was an acclimation period with no stimuli and no behavioral monitoring to allow adjustment to the tank and reduce post-handling stress (Takahashi 2021). The second 20 minutes was an observation period where no sound was played, but the behavior of the shrimp was monitored.

The third period was a testing period in which shrimp behavior was monitored and the appropriate auditory stimulus, if any, was played.

Shrimp were evenly divided at random into 3 testing conditions: control, ambient noise, or vessel noise. In the control condition, no additional auditory stimulus was played through the speaker and shrimp heard only the typical lab conditions. In the ambient noise condition, recordings from the Limekiln hydrophone were used to simulate typical ocean sounds at 70 decibels. In the vessel noise condition, boat engine recordings were played at 80 decibels to simulate a potentially stressful stimulus. All audio recordings were sourced from YouTube.

To quantify the potential stress response to the auditory stimulus we measured three behavioral stress parameters. First, we measured the number of tail flips observed as a generally recognized proxy for stress in shrimp (Filiciotto et al. 2016, Takahashi 2021). Second, we measured the time spent engaging in thigmotaxis. Thigmotaxis is a behavioral response in which an organism avoids open spaces, often described as “wall-hugging”. (Kohler et al. 2018, Takahashi 2021). A higher degree of thigmotaxis typically corresponds to increased stress. We defined thigmotaxis as being within 5 cm of the sea table wall. Lastly, we measured the time spent on the same side of the tank as the speaker. If an individual spent significantly less time on that side of the tank when an auditory stimulus was present, that would indicate an avoidant stress response in the shrimp (Azarm-Karnagh et al. 2023).

After testing, each subject was identified using a dichotomous key in “Marine Invertebrates of the Pacific Northwest” (E.N. Kozloff 1996) to confirm the species as *Pandalus danae*. Specimens were released off the dock in the same location as the collection at the end of each trial.

[4] Statistical analysis

Three Kruskal-Wallis tests were used to determine any significant difference in the three behavioral stress parameters between groups in the second observational period. A Wilcoxon Signed Rank test was used to measure statistical significance in thigmotaxis between the first and second observational periods within each group. All statistical analyses were performed in R with a significance threshold of 0.05.

RESULTS

[1] Thigmotaxis

Across all groups, thigmotaxis showed a decreasing trend between the first and second observation period (Figure 2). The average proportion of time spent positively thigmotactic across all three groups was 0.89 ± 0.18 and 0.84 ± 0.24 for the first and second observation periods, respectively. The largest proportion of time spent positively thigmotactic was 0.92 ± 0.18 , observed in the control group during the first observation period. The smallest proportion of time spent positively thigmotactic was 0.77 ± 0.33 , observed in the ambient group during the stimulus. A Wilcoxon signed rank test revealed no significance within any of the groups ($p > 0.05$, $N=8$).

Within the second observation period, the proportion of time spent positively thigmotactic was 0.89 ± 0.19 , 0.77 ± 0.33 , and 0.86 ± 0.19 in the control, ambient, and boat groups, respectively (Fig. 2). A Kruskal-Wallis test revealed an insignificant p-value of 0.24 when comparing thigmotaxis in the second observational period between groups ($N=8$).

[2] Sound Avoidance

The proportion of time spent on the same side as the speaker in the second compared to the first observation period showed an increasing trend in the boat and ambient groups and a decreasing trend in the control group (Figure 3). The control shrimp spent the longest time on the same side as the speaker with an average of 12.2 ± 2.4 minutes in the second observation period (Figure 4). While the stimulus was present, the shrimp in the ambient and boat groups spent an average of 10.6 ± 7.5 and 8 ± 6.6 minutes, respectively, on the same side as the speaker. A Kruskal-Wallis test determined no significant difference between the groups ($p=0.454$, $N=8$).

[3] Tail Flips

The greatest frequency of tail flips was observed in the ambient group (Table 1), 3 out of 5 of which were from one individual. Tail flips were observed in 7 out of 24 shrimp, with one tail flip observed in the group exposed to vessel noise. A Kruskal-Wallis test showed no significant difference in tail flips between groups in the second observational period ($p=0.46$, $N=24$).

DISCUSSION

The data did not support our hypothesis as we observed no significant difference in behavior after exposing shrimp to boat noise. The majority of tail flips were observed in the first observational period, and fewer than one third of all shrimp exhibited tail flips. This behavior is typically an escape response in the presence of an immediate threat. Our tail flip counts showed no significant change in stress when vessel noise was present. This concurs with research by Filiciotto et al. which found no significant difference in tail flips when exposing *P. serratus* to vessel noise and determined that vessel noise triggered chronic rather than acute stress.

In all experimental groups, the amount of time spent positively thigmotactic decreased (Fig. 2), but no significant difference was found. This suggests that the shrimp did not experience significantly more stress when exposed to vessel noise. Additionally, no preference was shown for proximity towards or away from the source of the auditory stimulus while exposed to boat noise. Contrarily, the average time spent near the speaker increased in trials where the shrimp were exposed to noise (Fig. 3), suggesting that stress levels did not increase when shrimp were exposed to anthropogenic noise. This disagrees with previous research on *P. serratus* and other shrimp species, which found significant increases in thigmotaxis and other behavioral stress parameters in the presence of vessel noise (Su et al. 2026; Azarm-Karnagh et al. 2023; Filiciotto et al. 2016).

Although we did not control for the sex of individuals in our experiment, past research on the impact of anthropogenic noise pollution on shrimp has found no impact of sex bias on stress or sound avoidance (Filiciotto et al. 2014; Filiciotto et al. 2016). It is therefore unlikely that any sex bias had an impact in our experiment.

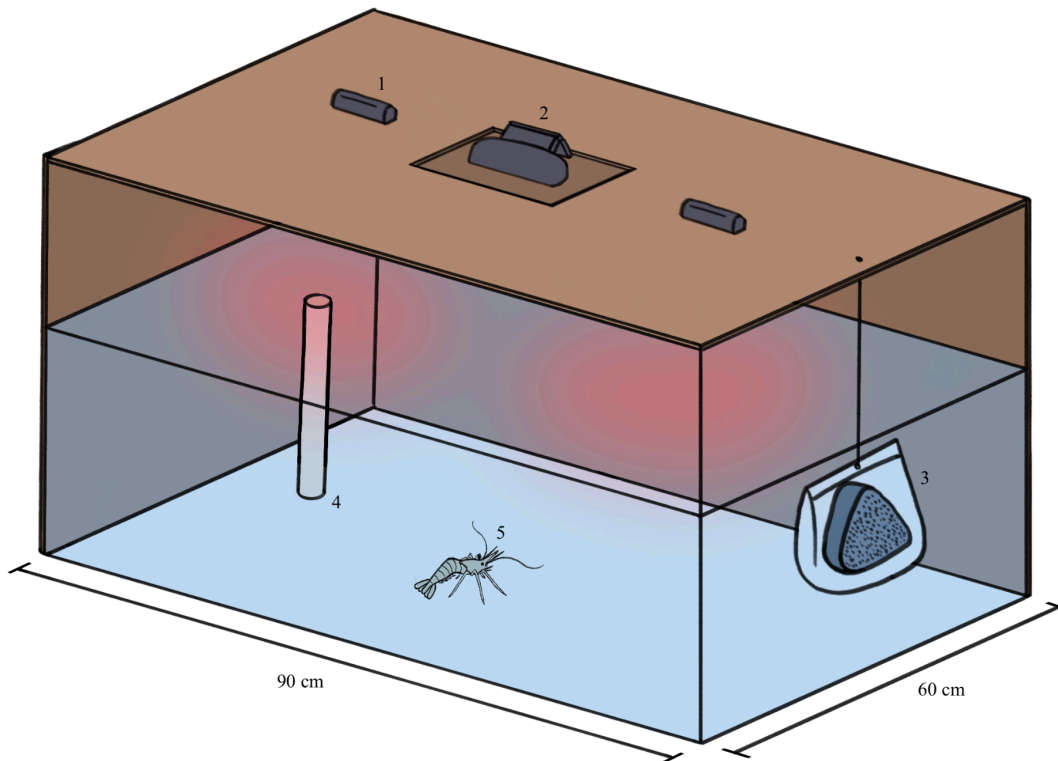
One possible explanation for the lack of significance in our data is that the shrimp were not given a sufficient amount of time to acclimate to the test tank. Previous studies had given individuals an hour to acclimate while our study had only a twenty-minute acclimation period (Azarm-Karnagh et al. 2023; Filiciotto et al. 2016). While shrimp were kept in lab conditions nearly identical to the test conditions for at least 48 hours prior to testing, it is possible that handling stress from the transfer had not fully dissipated by the start of the observational periods.

This could explain the decreasing trend observed in thigmotaxis from the first to second observational period (Fig. 2) and may have prevented us from achieving accurate results.

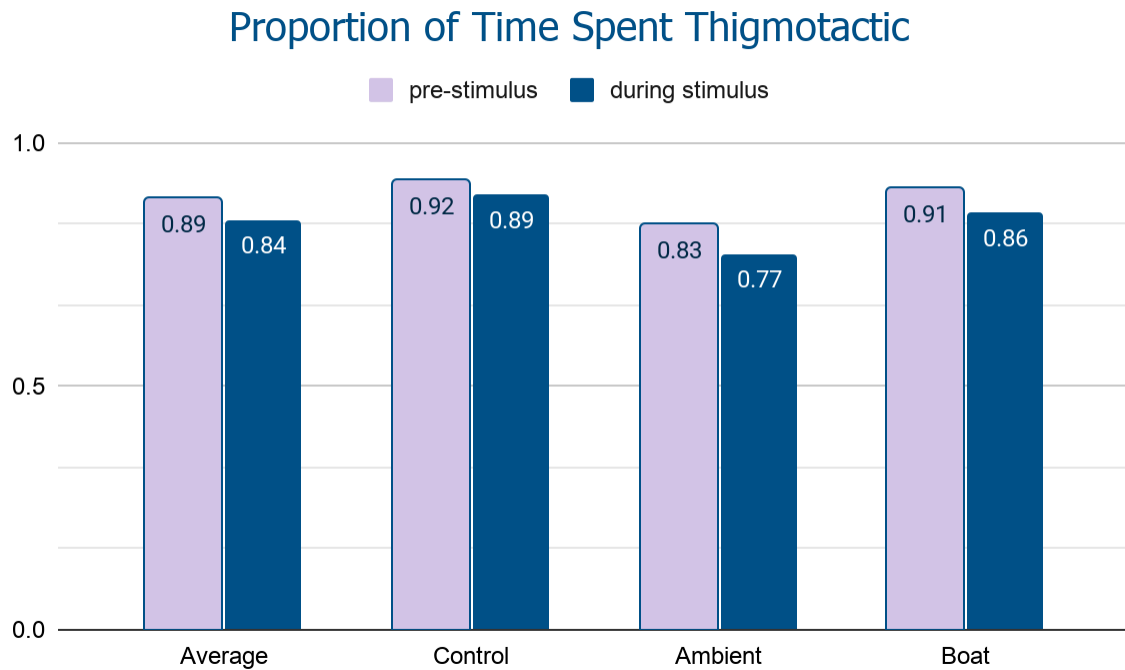
It is also possible that the differences in our results compared to Filiciotto et al., is the difference in collection site in the two experiments. Our shrimp were collected directly off of a dock very close to the surface of the water, while the *P. serratus* were collected from deeper waters using traps. The *P. danae* in our experiment had previously been living in a harbor with high amounts of vessel traffic including regular ferry activity. It is possible that this population of shrimp may be acclimated to environments with more anthropogenic noise, and thus exhibited a lesser or no stress response when presented with their natural environmental conditions prior to the experiment. The *P. serratus* in Filiciotto et al., however, may not have been previously exposed to such high volume and concentration of vessel noise, which therefore triggered a stronger stress response. Such acclimation behavior has not to our knowledge been tested or observed thus far in shrimp. However, the possibility that *P. danae* are able to acclimate to higher levels of vessel noise provides an optimistic outlook for other crustacean populations living in habitats affected by increasing levels of anthropogenic noise pollution. While increased stress responses have been associated with anthropogenic noise in other crustacean species, it is possible that prolonged exposure leads to eventual acclimatization to the higher noise levels and a corresponding decrease in stress.

Finally, our study also examined fewer stress parameters compared to past research on auditory stress in crustaceans. Previous studies have measured the amount of time individuals spent resting versus moving before and during exposure to vessel noise (Filiciotto et al. 2014, Filiciotto et al. 2016). Sheltering behavior, ability to successfully locate prey, and hemolymph cortisol concentration have also been used to measure stress (Su et al. 2026; Azarm-Karnagh et al. 2023; Filiciotto et al. 2016). While our behavioral data showed no significance, it is possible that chemical data such as cortisol concentration may have yielded different results. In addition to examining a wider array of behavioral stress parameters, future research may consider examining shrimp populations from different collection sites with different exposure to anthropogenic noise to determine any differences in stress when exposed to auditory stimuli.

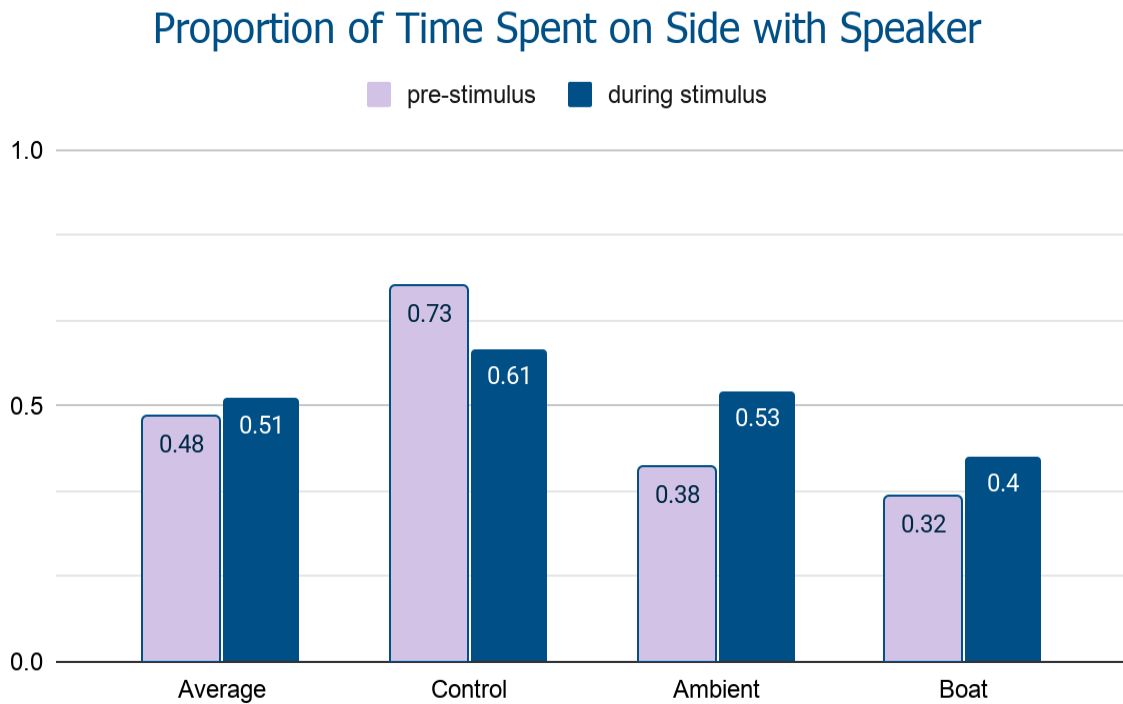
FIGURES



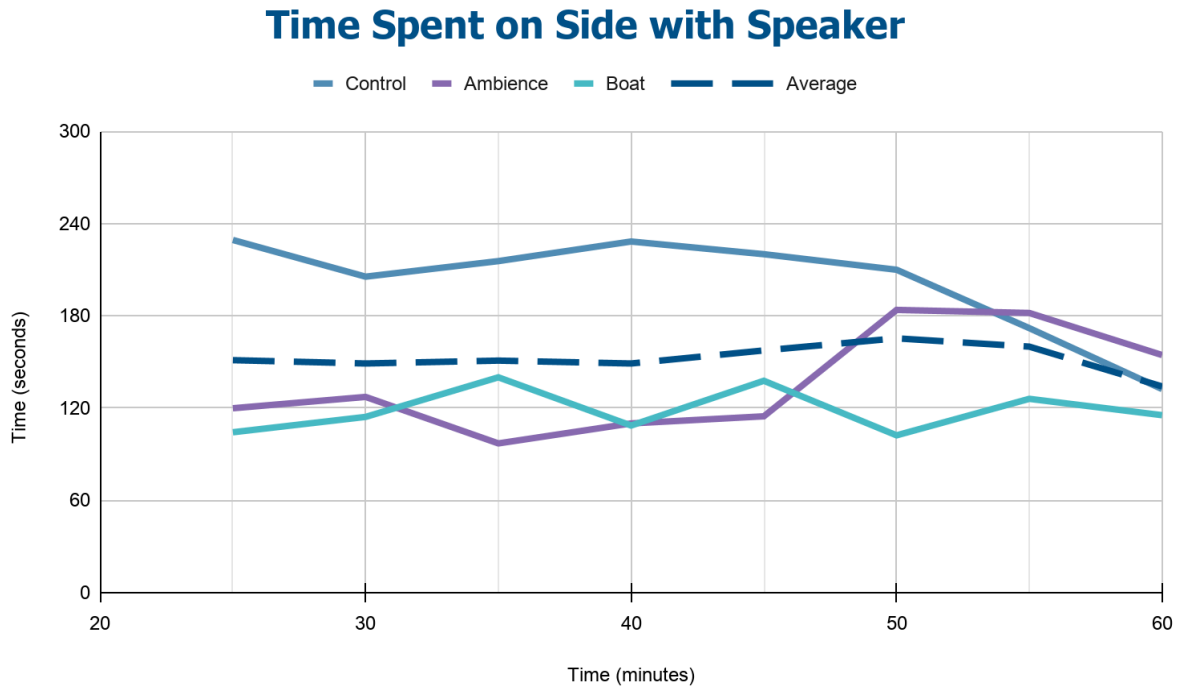
(Figure 1) Diagram of the experimental setup. A cardboard box was constructed around the test tank with a removable side for ease of adding and removing shrimp. (1) Red lights illuminating the tank through a whole cut in the top of the box. (2) Webcam with a top down view of the tank, wired connection to a laptop for live feed not shown here. (3) Speaker in a plastic bag hung by string and fully submerged in the water. (4) Outflow standpipe. (5) Hypothetical subject shrimp *Pandalus danae*.



(Figure 2) Proportion of time spent < 5cm from the tank wall across all groups both pre-stimulus and with the stimulus present (if applicable). Values are rounded to the nearest hundredth for simplicity. A Kruskal-Wallis test comparing the frequency of thigmotaxis in the second observational period found no significant difference between groups ($p=0.2439$, $N=8$). A Wilcoxon signed rank test determined no significant difference in thigmotaxis between pre-stimulus and with the stimulus present within any of the experimental groups ($p > 0.05$, $N=8$). (Standard deviation pre-stimulus: Average=0.18, Control=0.18, Ambient=0.23, Boat=0.14; Standard deviation during stimulus: Average=0.24, Control=0.19, Ambient=0.33, Boat=0.19)



(Figure 3) Proportion of time spent on the same side of the tank as the speaker both pre-stimulus and with the stimulus (if applicable). Written proportions are rounded to the nearest hundredth. A Kruskal-Wallis test determined no significant difference between groups ($p=0.454$, $N=8$). (Standard deviation pre-stimulus: Average=0.38, Control=0.21, Ambient=0.36, Boat=0.43; Standard deviation during stimulus: Average=0.3, Control=0.19, Ambient=0.38, Boat=0.33)



(Figure 4) Average time spent on the same side of the tank as the speaker across both observational periods. Observations recorded and illustrated in five minute intervals. Auditory stimulus (if applicable) was played beginning at the 40-minute mark. The first 20 minutes is omitted as no observations were recorded during the acclimation period.

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(Table 1) Number of total observed tail flips within each group pre-stimulus and with stimulus (if applicable). A higher amount of tail flips typically corresponds to a higher stress level. A Kruskal-Wallis test comparing tail flips with the stimulus present found no significant difference across groups ($p=0.4616$, $N=24$).

	Pre-stimulus	With stimulus
Control	1	3
Ambient	2	3
Boat	0	1

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