

Evidence-based practice

Mantis shrimp target training for coexistence in a multi-species habitat

Erin Maroon^{1,2}, Tyler Baskin¹, Chad McKendrick II¹, Jacob Rosner^{1,3} and Cathryn Freund¹

¹Phillip and Patricia Frost Museum of Science, Miami, Florida, USA

²Loggerhead Marinelife Center, Juno Beach, Florida, USA

³Cox Science Center and Aquarium, West Palm Beach, Florida, USA

Correspondence: Erin Maroon, email; emaroon@marinelife.org

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Abstract

Mantis shrimp are remarkable animals known for their colouration and physiological abilities. However, they are difficult to keep in a multi-species setting and are thus often housed in single-individual habitats. Here, we present a behavioural training plan and procedure for target training a mantis shrimp, with the goal of conditioning it to consistently take and rely on food from aquarists. We reasoned this would help prevent it from exhibiting aggressive behaviour in a multi-species setting. We present data demonstrating that mantis shrimp can learn to target and feed within three months. The individual in this case study coexisted in a multi-species tank without harming any other animals from the time its training began until its death in late January 2024, an outcome which we believe was supported by target training, though other factors also likely contributed. Our experience and training plan may be useful for other aquariums interested in training their own mantis shrimp. We also suggest it can also inspire productive conversations with visitors about animal biology, marine biodiversity, and conservation.

Background

Mantis shrimp (Order: Stomatopoda) have exceptional visual systems (Cronin et al. 2022; Marshall et al. 2007) and a powerful appendage strike mechanism (Patek et al. 2004), which they use to immobilize their prey. Their unique physical abilities and sometimes brilliant colors make them, particularly the peacock mantis shrimp *Odontodactylus scyllarus*, intriguing aquarium animals. At the Phillip and Patricia Frost Museum of Science, we have observed that having a mantis shrimp on exhibit creates opportunities to engage aquarium visitors in conversations about animal physiology, biodiversity and marine conservation (Personal experience of E. Maroon and C. Freund 2022–2023). However, mantis shrimp can be difficult to keep in aquariums due to their territorial and aggressive nature (Dingle and Caldwell 1969; Green and Patek 2015) toward both conspecifics and other species (reviewed in deVries et al. 2021).

Target training is an important tool for caring for aquarium

animals (National Aquarium 2025; New England Aquarium 2024). The action of training itself provides enrichment (Melfi 2013; Westlund 2014) that engages animals' brains and bodies. It is useful for managing animals' diets, improving veterinary care, and even increasing educational opportunities for the public (Corwin 2012). For example, trainers at Disney's The Seas trained a cobia *Pachycentron canadum* to target and station to prevent it from overeating (Davis 2010) and target-trained spotted eagle rays *Aetobatus narinari* to reduce aggression toward aquarists during feeding time (Muraco and Stamper 2003). Target training animals housed in multi-species settings can also reduce an animal's aggressive behaviour toward heterospecifics. At the Rotterdam Zoo, aquarists found that target training pelagic sharks reduced aggressive behaviour during feeding by 80%, and anecdotal evidence (also from Disney's The Seas) that training snowflake moray eels *Echidna nebulosa* to eat from a specialized feeding apparatus at the surface of the water reduced feeding-related

aggression toward leopard snake *Zamenis situla* and zebra moray eels *Gymnomuraena zebra* (Corwin 2012; Laterveer 2006).

While there appear to be few published reports detailing target training of non-cephalopod aquatic invertebrates (but see Corwin 2012 for an anecdotal description of training a Bahamian seastar *Oreaster reticulatus*), experience suggests mantis shrimp can also be target trained for feeding within an aquarium exhibit. Scientists interested in their sensory abilities have trained mantis shrimp to perform other behaviours (Marshall et al. 1999; Marshall et al. 1996; Patel et al. 2021), and these animals are generally thought to be able to learn “quickly and reliably” (Cronin et al. 2006). In 2019, co-author J.R. and other aquarists at our institution, the Phillip and Patricia Frost Museum of Science, successfully trained a peacock mantis shrimp to target onto a small platform for feeding (J. Rosner pers. comm.) Other institutions may also have trained mantis shrimp to perform similar behaviours, though to our knowledge the process and outcomes have not yet been publicly documented.

We hypothesize that, similar to Disney’s experience of training snowflake moray eels (Corwin 2012; Laterveer 2006), effective target training could reduce aggression between mantis shrimp and heterospecifics, which may enable these animals to be more frequently housed in multi-species tanks in public aquariums. To demonstrate that target training a mantis shrimp is possible and to contribute to the small body of knowledge about target training aquatic invertebrates, here we describe our experience target training one adult peacock mantis shrimp and quantify some aspects of how the animal performed throughout the process.

We also provide a framework and behavioural plan for mantis shrimp target training for use or adaptation by other institutions. This is only a single-individual case study and does not fully address our hypothesis. However, we hope it lays a foundation for understanding how to reliably foster mantis shrimp coexistence in multi-species settings through additional studies.

Action

The mantis shrimp trained in this study was an adult female peacock mantis shrimp *Odontodactylus scyllarus* who arrived at the Phillip and Patricia Frost Museum of Science on 15 October 2022. The animal was on exhibit in a 42 x 42 x 30-inch tank for the duration of its life at the museum, including the 224-day active training period described here. The tank contained about 15 other individual fish from eight species: a sailfin tang *Zebrasoma veliferum*, yellowtail clownfish *Amphiprion clarkii*, emperor cardinalfish *Pterapogon kauderni*, royal dottyback *Pictichromis paccagnellae*, lemonpeel angelfish *Centropyge flavissima*, golden dwarf moray eel *Gymnothorax melatremus*, two yellow tang *Zebrasoma flavescens*, and several bluegreen chromis *Chromis viridis*.

The tank system had a sump plumbed directly underneath the exhibit, an in-water pump for the return, a UV sterilizer, heater, chiller, fractionator, and biological filtration balls. The system temperature was around 75 degrees Fahrenheit. Weekly water changes kept calcium in the system stable around 400 ppm, and alkalinity was held at 150 ppm as CaCO_3 by addition of sodium

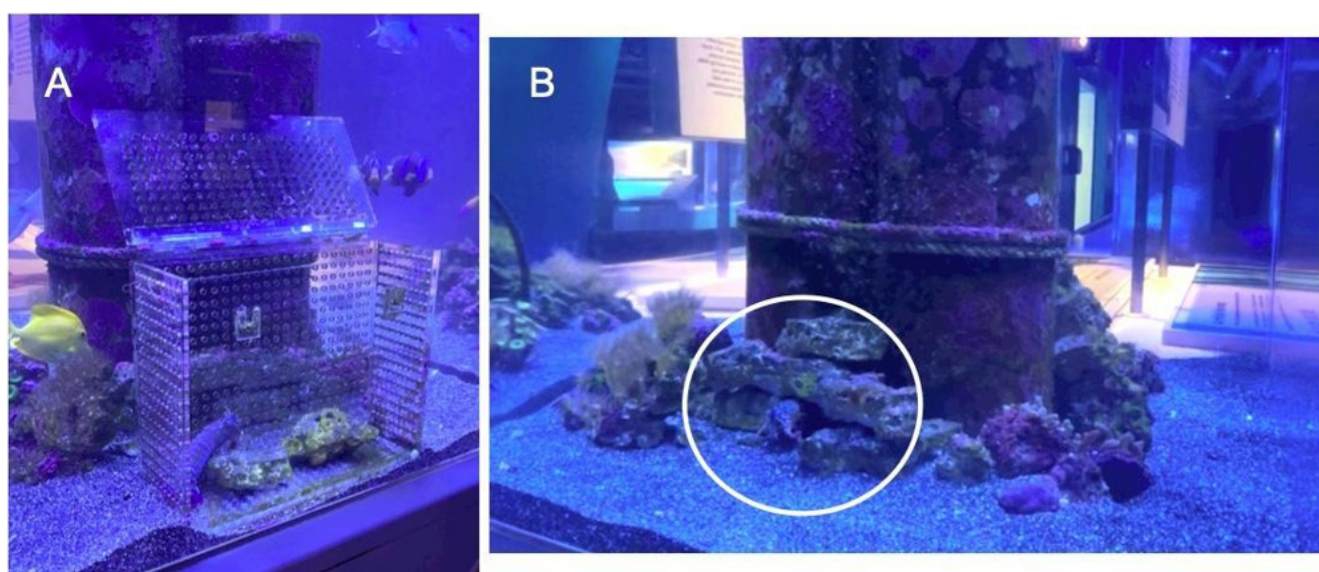


Figure 1. (A) The mantis shrimp in its tank and the acrylic holding container. The animal is visible in the bottom left of the container. This image was taken on 19 April 2023, the day it completed stage 7 of the training plan and was released from the holding box. (B) The mantis shrimp inside a trainer-provided hiding place within the tank after its release from the acrylic holding container. This hiding place may have helped reduce the need for the mantis shrimp to exhibit aggressive behavior toward heterospecifics.

Table 1. Mantis shrimp behavioural plan developed for this study. The animal fasted twice per week throughout the training period.

Stage	Behavioural approximations	Criteria for completion	Date completed
1	Mantis shrimp eats prepared food from inside holding container from the feeding stick.	Mantis shrimp eats at least 4 days/week for 2 weeks.	29 October 2022
2	Mantis shrimp eats prepared food from inside holding container from the feeding stick with target within eyesight.	Mantis shrimp eats at least 4 days/week for 2 weeks.	12 November 2022
3	Mantis shrimp eats prepared food from inside holding container from the feeding stick with target touching the holding container.	Mantis shrimp eats at least 4 days/week for 2 weeks.	16 January 2023
4	Target placed in system, touching holding container, then food is presented within 2 seconds in same spot each time and mantis shrimp feeds.	Mantis shrimp eats at least 4 days/week for 2 weeks. Responds to target in the same corner within 30 seconds for 2 weeks.	5 February 2023
5	Target placed in system, touching holding container, then food is presented within 10 seconds in same spot each time and mantis shrimp feeds.	Mantis shrimp eats at least 4 days/week for 2 weeks. Responds to target in the same corner within 30 seconds for 2 weeks.	25 February 2023
6	Target placed in system, touching holding container, then food is presented within 2 seconds in new location each time and mantis shrimp feeds.	Mantis shrimp eats at least 4 days/week for 2 weeks. Responds to target in new locations around holding container each time within 30 seconds for 2 weeks.	17 March 2023
7	Target placed in system, touching holding container, then food is presented within 10 seconds in new location each time and mantis shrimp feeds.	Mantis shrimp eats at least 4 days/week for 2 weeks. Responds to target in new locations around holding container each time within 30 seconds for 2 weeks.	19 April 2023
8	Release from holding container, no predatory responses to other tankmates. Target placed in system, then food is presented within 2 seconds in comfort areas and mantis shrimp feeds.	Mantis shrimp eats at least 4 days/week for 2 weeks. Responds to target outside holding container each time within 30 seconds for 2 weeks.	13 May 2023
9	Release from holding container, no predatory responses to other tankmates. Target placed in system, then food is presented within 2 seconds anywhere in exhibit and mantis shrimp feeds.	Mantis shrimp quickly responds to target in any location. Eats regularly.	27 May 2023

bicarbonate between water changes. During the initial phases of its training, the shrimp was confined to a 12 x 10 x 6-inch acrylic holding container within the larger tank (Figure 1A). The acrylic was ¼ inch thick, and a grid of holes was machined into the faces of the container to allow water flow.

At the beginning of the training process, study co-authors J.R. and E.M. developed a nine-stage behavioural training plan with the ultimate goal of conditioning the mantis shrimp to consistently take and rely on food from aquarists (Table 1). The behavioural plan taught the animal the desired behaviour through a series of slow and increasingly complex steps, or “shaping by successive approximations” (Association of Zoos and Aquariums and American Association of Zoo Keepers n.d.; Pryor and Ramirez 2014). It was designed to adhere to Disney’s S.P.I.D.E.R. philosophy (Disney’s Animals, Science and Environment Animal Enrichment Program n.d.; Mellen and Sevenich MacPhee 2001) and align with the Association of Zoos and Aquariums guidance on shaping plans (AZA Animal Welfare Committee and AZA Behavior Scientific Advisory Group 2026). We reasoned that training the animal to expect food from aquarists would help prevent it from exhibiting aggressive behaviour toward heterospecifics sharing its tank. E.M. oversaw the mantis shrimp’s training as the primary trainer.

Training began upon the animal’s arrival at the museum on 15 October 2022 (Table 1). The animal was trained and offered food five days per week for the duration of the training period; it was neither trained nor fed (i.e., fasted) on the other two days. Fasting mantis shrimp in aquariums is important to avoid overfeeding and to maintain them at healthy bodyweights. Overfeeding can cause excessive growth in these animals, leading to incomplete

molts and mortality (J. Rosner, pers. comm.). The behavioural training plan and all training processes were approved by both the museum’s Vice President of Animal Programs and veterinarian. Our decision to write this case study did not influence how the animal was trained or cared for. Institutional Animal Care and Use Committee approval does not apply to non-cephalopod invertebrates and thus was not required for this work.

Starting at the initiation of stage 3 of the behavioural training plan on 17 November 2022, we recorded each training session on an iPhone set up outside of the exhibit. In most cases the recording captured the entire training interaction from the time the target entered the water until the mantis shrimp performed all desired behaviours. After the animal completed the nine-stage training plan, we used these recordings to evaluate its training performance. Specifically, we calculated orientation time to the target, positioning time at the target, and the lag time between orienting and positioning as indicators of task acquisition. We defined orientation as the point when the animal had both eyes on the target and made any forward movement and positioning as the point at which the animal was stopped in front of the target while maintaining orientation. In an animal undergoing behavioural training, lag time, or response latency, can be used as an indicator of memory (Jahn-Eimermacher et al. 2011) and training retention. It signifies the likelihood of a behaviour being maintained when environmental or training processes change.

Data collection and analysis

Following the mantis shrimp’s formal completion of the nine-step behavioural plan on 27 May 2023, study co-authors E.M.,

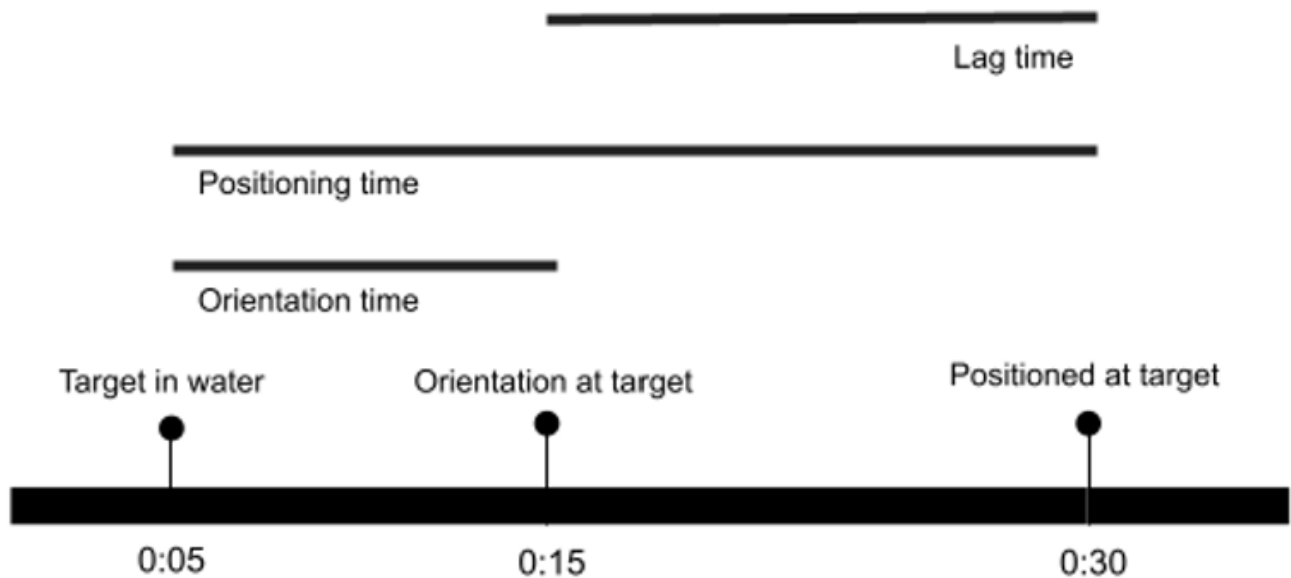


Figure 2. Visual depiction of how we calculated orientation time, positioning time, and lag time from the three time stamps recorded by video observers. Orientation time was the time in seconds between the target entering the water and the animal orienting to the target (in this example, 10 seconds), positioning time was the time in seconds between the target entering the water and the animal being positioned at the target (25 seconds), and lag time was the time between orientation and positioning (15 seconds).

C.M., and T.B. watched each training session video to collect data to evaluate orientation time, positioning time, and lag time throughout the training process. We included three observers to capture expected inter-observer variability. All three were experienced aquarists with knowledge of animal behaviour, but each had a different relationship to the animal. We anonymized their responses for reporting: Observer A periodically assisted with its care throughout the study period, observer B was primarily responsible for its day-to-day husbandry, and observer C was not directly involved in its care. Observers collected indicator data from 82 training sessions. While most videos were watched and scored by all three observers, due to personal reasons a minority were only scored by two.

Observers were instructed to record three time-stamps from each video: the time when any portion of the target appeared in the frame in the water (designated as the time the target was placed in the water), the time when the mantis shrimp oriented to the target, and the time when it was positioned at the target. From these time stamps, we calculated orientation time, position time, and lag time for each observation of each video (Figure 2).

To examine how orienting and positioning time varied across the training period, we calculated the mean orienting and positioning times recorded for each training session. We paid special attention to the number of mean orienting and positioning times > 10 seconds within each stage. The 10 second cutoff is arbitrary, but we felt it was a reasonable proxy for “good” training performance. Because lag time encompasses both orientation and positioning, and because only looking at mean times could obscure meaningful variability between observers, we did not average lag times across

all observers. Instead, we created three generalized additive models, one for each observer, to describe the trajectories of their lag time measurements. This approach allowed us to both draw conclusions about the mantis shrimp’s task acquisition and retention across the training period and demonstrate similarities and differences in observer interpretations of its behaviour.

Consequences

The mantis shrimp began its behavioural training on 15 October 2022, and completed the plan 224 calendar days later, on 27 May 2023 (Figure 3). It passed through stages 1, 2, and 9 in the shortest amount of time (14 calendar days). This was also the least amount of time possible for the animal to spend in those stages, as they were defined by a two-week time frame. Stage 3 took the shrimp the longest to complete (65 calendar days).

The mantis shrimp demonstrated the longest and most variable mean orienting and positioning times in stage 3 (Figure 4). Mean orienting times during this stage ranged between 0-259 seconds (Figure 4A) and mean positioning times between 2-272 seconds (Figure 4B). Despite this wide range, the shrimp oriented to the target within an average of 10 seconds in over 50% of stage 3 training sessions ($n=12/23$) and in 95% of stage 4-9 training sessions ($n=56/59$). It positioned itself at the target within an average of 10 seconds in 43.5% of stage 3 training sessions ($n=10/23$); this number jumped to 84.8% of stage 4-9 training sessions ($n=50/59$). This pattern of the mantis shrimp taking a longer time to acquire an early skill than needed to acquire subsequent skills is consistent with Harlow’s concept of learning set formation (Harlow, 1949).

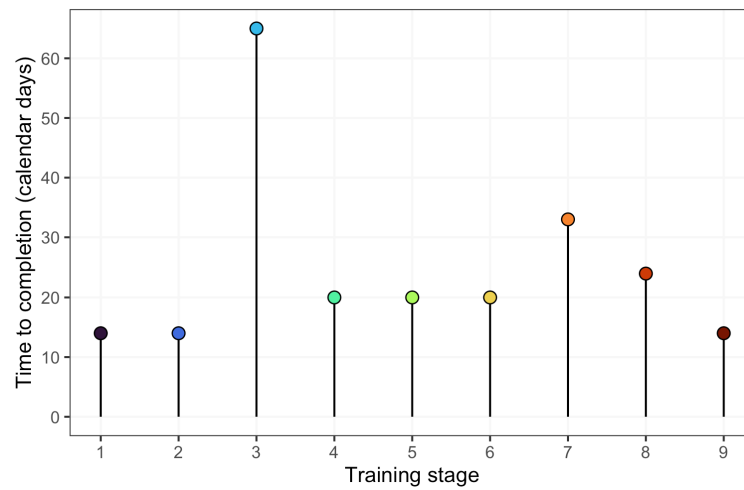


Figure 3. Number of calendar days the mantis shrimp spent in each stage of the behavioural training plan.

Once it learned the initial skill of taking food while the target was in eyesight and touching the holding container (Table 1), it was able to demonstrate the desired behaviour in later stages more quickly, even when the location and timing of target and food presentation changed.

Generally, lag times showed a similar pattern to orienting and positioning times (Figure 5). They were most variable in stage 3, decreased rapidly toward the end of this stage, and stayed relatively low for the remainder of the training period. The generalized additive models highlight some differences between

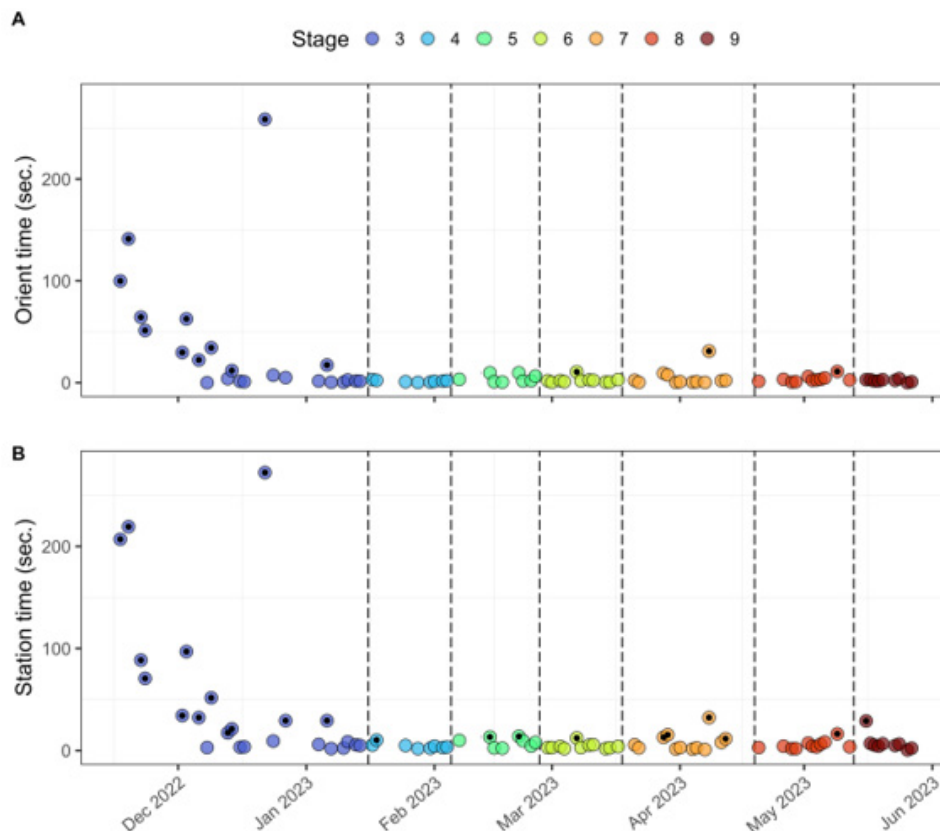


Figure 4. Orienting and positioning times for each training session (averaged across observers) during the training period. Dashed vertical lines represent stage transitions and star marks the mantis shrimp's release from the acrylic holding container. Black dots denote training sessions with mean orienting or positioning times >10 seconds.

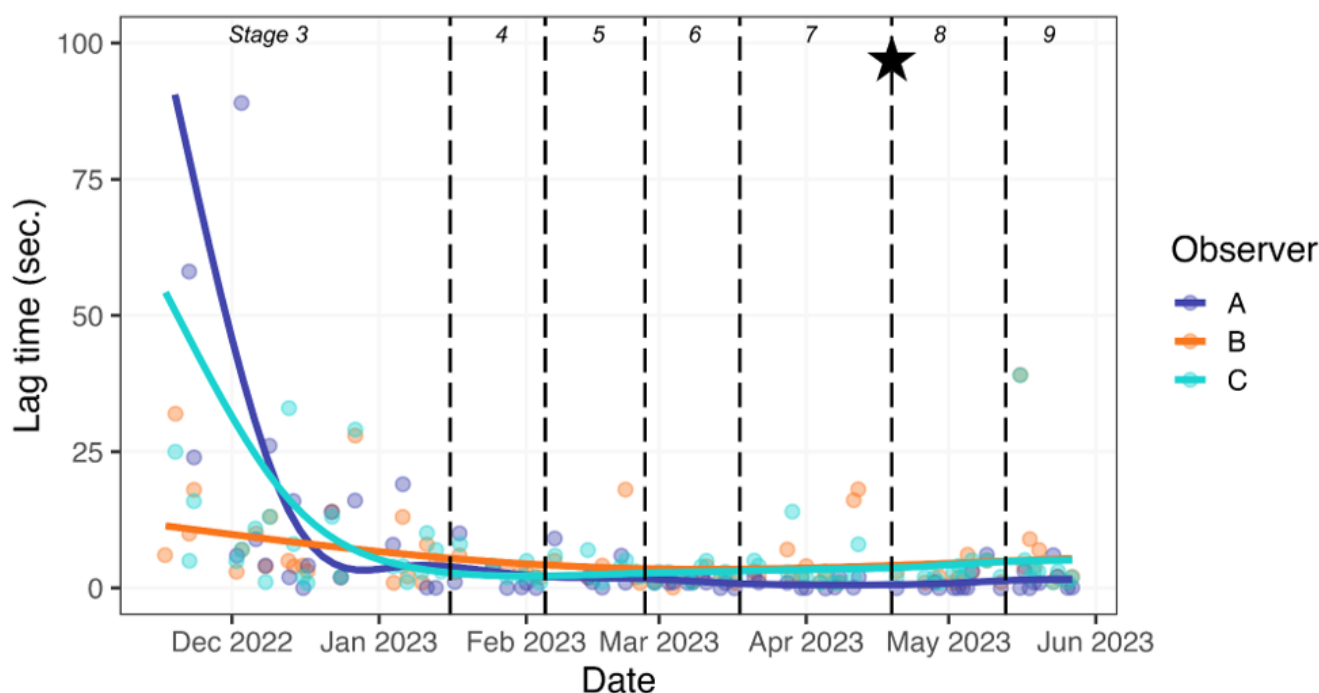


Figure 5. Recorded lag times and modeled lag time trajectories, per observer. Stages are denoted in italics at the top and vertical dashed lines mark stage transitions. The star denotes the mantis shrimp's release from the holding container.

the observers' interpretations of the mantis shrimp's training performance, especially in stage 3. Observers A and C recorded much longer lag times at the beginning of stage 3 than observer B did, and therefore their data showed a much steeper decline in lag time toward the end of stage 3. From stage 4 onward, all three observers' data show a similar pattern of lag times holding generally consistent between approximately 0 (positioning coincident with orientation) and 5 seconds.

Our experience and data lead us to three conclusions about the target training process with this mantis shrimp. The first two we wish to highlight are that the animal (1) learned to orient to and position at the target within three months and (2) maintained the trained behaviour even after its environment changed (Figure 4, Figure 5). To our knowledge, this is the first time the target training process has been systematically documented and quantified for a mantis shrimp in a public aquarium setting. The only comparable study we are aware of trained mantis shrimp of the species *Neogonodactylus oerstedii* on targets of varying color and shape and found that ~25% of subjects consistently selected the right target after four weeks of training (Patel et al. 2021). Since ours was a single-animal case study, we cannot say whether our conclusions would hold with other individuals. However, this is not the first time the co-authors of this study have trained a mantis shrimp; as previously mentioned, in 2019 J.R. helped train a peacock mantis to target onto a small, bright blue platform for feeding. The training mechanisms were very similar to those we present here. The trainers started with the platform on the ground and moved it successively upward through the water column as

training progressed. When training was complete, the mantis shrimp would perch on the platform anywhere on exhibit while it was fed (J. Rosner, pers. comm). Thus, we are confident that mantis shrimp can be reliably target trained.

Our third conclusion is that experts with differing levels of familiarity with the animal agreed on its general learning pattern, though there was expected variability between observers. All three recorded longer orienting, positioning, and lag times in stage 3 followed by rapid declines to relatively steady values for the remainder of the training plan (stages 4-9). However, it is clear from the lag time trajectories shown in Figure 5 that there was a difference between observers during stage 3. Observers A and C observed longer lag times at the beginning of the stage, and thus a steeper decrease as training progressed, than did observer B. This is likely explained by the observers' levels of familiarity with the animal. Observer B was the primary aquarist caring for the shrimp, whereas observers A and C were not responsible for its day-to-day husbandry. Observer B was likely more attuned to slight changes in the animal's behaviour associated with orienting and positioning.

We originally pursued this training to condition the mantis shrimp to expect food from aquarists, which we reasoned would prevent the animal from behaving aggressively toward heterospecifics within the multi-species tank. The mantis shrimp was released from its holding container at the end of training stage 7 on 19 April 2023, after which it maintained its orientation and positioning behaviours (Figure 4, Figure 5). We did not continue recording training sessions after the animal formally completed its training plan. However, we can anecdotally report that the trained

behaviours were maintained and that the shrimp showed no aggression toward other animals in its tank. This continued until the animal's death in late January 2024 due to a failed molt, at which point it had coexisted in the multi-species exhibit with no incidents of aggression toward heterospecifics for more than nine months. We cannot claim this was a direct effect of the training as we did not measure aggression throughout the training process. Furthermore, the mantis shrimp was provided with enrichment in the form of small rocks and barnacles as well as a proper hiding place that may have reduced the need for defensive aggressive behaviours (Figure 1B). However, we feel confident that the target training, at minimum, helped prevent aggression toward heterospecifics. We hope other aquariums apply this training plan to their mantis shrimp to test whether our experiences and findings are generalizable.

While there are still more specific questions on this topic to be answered, our experience demonstrates it is possible for a mantis shrimp to be safely exhibited in a multi-species tank. This ability is positive for both an animal and an institution. Safely inhabiting a multi-species setting better recreates wild conditions than a single-species tank does, allowing a mantis shrimp to exhibit natural behaviours, experience inter-specific interactions, and likely have access to more physical space. At educational institutions such as aquariums and science museums, the act of target training can also create a useful point of connection between staff and visitors. Viewing live animal training demonstrations or engagements has been shown to increase dwell times and foster more positive experiences for visitors (Anderson et al. 2003; Lyon et al. 2024). We have observed that aquarium visitors and supporters are generally fascinated by mantis shrimp and their unique abilities (Monterey Bay Aquarium 2024). This makes these animals useful entry points for longer discussions about biological concepts such as animal communication, aggression, and sensory biology (Jutte 1997), as well as marine biodiversity and conservation.

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