Evaluating Alternative Bait Ingredients for the Channeled Whelk Fishery

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Abstract

The channeled whelk (*Busycotypus canaliculatus*) is a large, predatory marine gastropod that supports an important commercial fishery in the United States. Fishermen catch channeled whelks in baited traps with their own unique blend of ingredients. The predominant bait in these traps is the American horseshoe crab, *Limulus polyphemus.* Horseshoe crab blood is used in the biomedical industry to test materials for contamination, meaning that horseshoe crabs are heavily exploited and are an expensive bait ingredient in the channeled whelk fishery. To determine an effective alternative and more sustainable bait that does not require *Limulus* as the primary ingredient, a series of ingredients were tested as whelk attractants: 1) *Limulus polyphemus*, 2) ground whole green crabs, 3) clam bits, 4) a mix of *Limulus* hemolymph, green crab, and gelatin, 5) ground whole green crab pieces with gelatin binder, 6) clam bits with gelatin binder, and 7) *Limulus* hemolymph with gelatin binder. The amount of time an individual whelk interacted with a bait bag containing one bait type was quantified using output from an accelerometer secured in the bait bag. 64 trials were recorded over a period of 21 hours in seawater tanks inside the UNH Coastal Marine Laboratory during October-November 2020. Together, the baits containing clam had 4.79 times more interaction than any of the other baits, making them a promising alternative to horseshoe crab. This study is the first part of a longer project and will help inform bait decisions as further lab and field tests are conducted.

Keywords:

Introduction

The channeled whelk (*Busycotypus canaliculatus*) is a large, predatory marine gastropod that supports an important commercial fishery in the United States (Edwards & Harasewych, 1988). Historically, the channeled whelk was caught primarily as a bycatch species for lobster fishermen (Glenn and Wilcox, 2012). Between 1950 and 1970, the landings for whelk (including channeled whelk and its close relative the knobbed whelk) were less than 250,000 lbs in Massachusetts (Glenn and Wilcox, 2012). Landings of both whelk species increased during the 1980's, mostly due to increases in market demand, and fluctuated from 1.5 to 2 million pounds over the next two decades due to fluctuations in lobster landings (Glenn and Wilcox, 2012). Following the crash of lobster populations in Southern New England in 2002, channeled whelk landings rose to 2.5 million pounds in Massachusetts alone, and has remained stable since then (Glenn and Wilcox, 2012).

Channeled whelk are found along the East Coast of the United States where they support commercial fisheries from Virginia to Massachusetts (Fisher and Robins, 2012). The channeled whelk is an attractive fishery species, compared to other marine gastropods, due to its high market price and demand (Glenn and Wilcox, 2012). The highest demand for channeled whelk is found overseas in Taiwan, Singapore, Hong Kong, and Japan (Kaplan and Boyer, 1992). The fishery of channeled whelks makes use of baited traps. Channeled whelk can be caught in baited traps because they feed on both live bivalves and carrion (Davis and Matthiessen, 1978). Fishermen use their own unique blend of ingredients that they place in bait bags in these traps- including green crab, blue mussels, heron, and surf clam (Fisher & Fisher, 2000). The majority of baits use pieces of American horseshoe crab (*Limulus polyphemus*) as the primary attractant in their bait which is a problem for a number of reasons (Wakefield, 2013).

The first problem with using the American horseshoe crab as bait is that their eggs are an important food source for threatened birds migrating through the region (Botton et al., 2010). Due to this, conservationists have been pushing to limit the use of horseshoe crabs in bait in recent years. Furthermore, the American horseshoe crab already has a very important use in the biomedical industry. Horseshoe crab blood is drawn and used to produce *Limulus* Amoebocyte Lysate (LAL) which is used to test for the presence of bacteria contaminants on medical equipment, including the sterile water used to produce vaccines (Krisfalusi-Gannon et al., 2018). Finally, the population of American horseshoe crabs has been declining in recent years (Smith et al., 2016). All of these factors cause the American horseshoe crab to be an increasingly expensive and unsustainable ingredient in the channeled whelk fishery.

There has been preliminary research into alternative baits that can be used instead of the American horseshoe crab (Fairchild et al,. 2019). Some preliminary tests have reported that channeled whelks are attracted to cheaper ingredients including green crabs, surf clams, and shellfish processing wastes. There is also some preliminary data showing channeled whelks may even prefer surf clams over *Limulus* (Fairchild et al., 2019). However, the behavior of the channeled whelks towards these baits has been highly variable and further study is needed to determine an ideal bait that is as effective as current *Limulus* baits (Fairchild et al., 2019).

The primary goal of this study was to test some alternative baits that are cheaper and more sustainable than *Limulus* baits, but are equally or more effective at attracting channeled whelks. To do this, a series of trials were run to look at the performance of different baits including green crabs, clams waste, and *Limulus* hemolymph (a byproduct from the medical processing waste). Both clam waste and *Limulus* hemolymph were chosen as alternative baits because they are processing wastes, making them both cheap and sustainable. European green crabs (*Carcinus maenas*) were chosen as another alternative bait because they are a highly invasive species in the Northeast United States and have negative impacts on endemic species (MacDonald et al., 2007).We predicted that the channeled whelk would be most attracted to clams, due to the preliminary data that shows the attractiveness of clams to channeled whelk.

Methods

Whelk Collection

Fifteen channeled whelks were shipped from Marine Biological Laboratory in Woods Hole, MA and twenty more were provided from commercial whelk fishermen in Martha's Vineyard, MA. Whelks were allowed to acclimate to laboratory conditions for a minimum of one week prior to experimentation. The whelks were labeled from 1-35 and their shell length, width, and height were measured to the nearest hundredth of a centimeter (mean, ±SD; length = 15.24 ± 2.54 cm, height = 7.14 ± 1.32 cm, width = 9.25 ± 1.60 cm), according to the dimensions shown in Figure 1) and identified as being legal sized in accordance with Massachusetts state regulations ("Whelks and Whelk Management.", 2021). Legal (N = 21) and sublegal (N = 12) whelks were then separated and legal sized whelks had harnesses for HOBO Pendant G Data Logger (UA-004-64) attached to the back of their carapaces as shown in Figure 2.

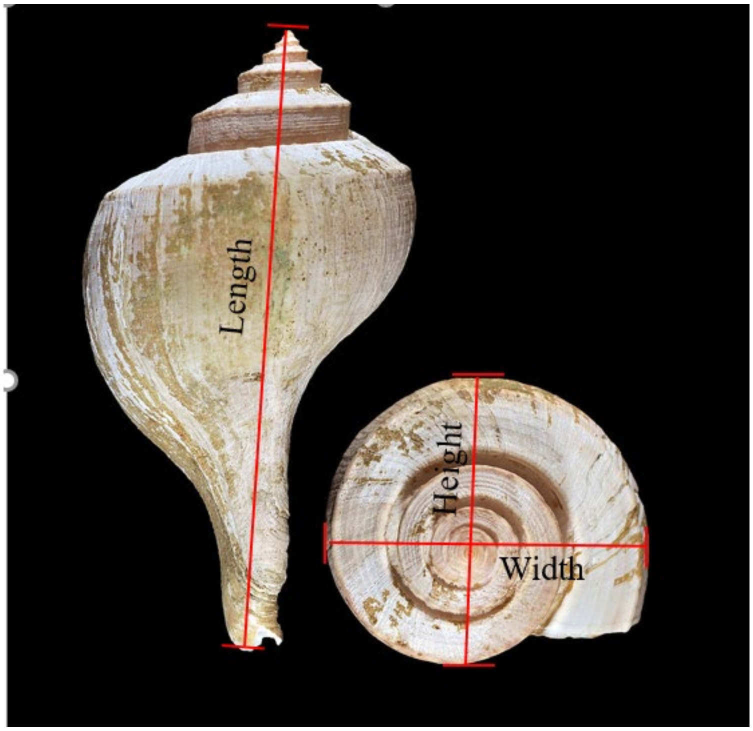

Figure 1- The dimensions for measuring the carapace length, width, and height of the channeled whelk (Gall, 2019).

Figure 2- Setup of the harnesses used for the HOBO Pendant G Data Logger accelerometer that was secured onto the channeled whelk. Harnesses were secured on roughly the same place on the back of each legal-sized whelk and accelerometers were secured at the same orientation (facing towards the pointed end of the channeled whelk's shell).

Experimental Setup

Bait trials were conducted at University of New Hampshire's Coastal Marine Lab (CML) in New Castle, NH. Four circular tanks (labeled Tank 5- Tank 8) with a diameter of 0.91 meters were hooked up to a constant flow-through salt water system with water filtered through five stages (120-micron filter pad, biological filtration, 50-micron filter cartridge, activated carbon, and ultra-violet (UV)) prior to entering experimental tanks. The seawater came from the mouth of the adjacent Pisquatica River, NH. Experiments were conducted from October 17 to December 3, 2020. Water temperature (mean, ± SD; Temperature 11.0°C ± 1.8) and salinity (mean, ± SD; Salinity 35.3°C ± 0.54) was monitored daily during this time period. CML lights are programmed on a diurnal cycle with the lights on from dawn to dusk in accordance with the season.

Tanks were set up with PVC pipes secured to the top, across the diameter, to allow for the suspension of mesh bait bags (Figure 3). The bait bags were hung at around half the radius in each tank. The water flow was kept on for the duration of the trial and bubblers were placed in each tank to increase concentrations of dissolved oxygen. Two Brinno time lapse cameras were attached to Tanks 5 and 7 and set up to take a picture every four seconds for the duration of the trials. Clip-on lights with red, 60 W bulbs were attached to the tanks with the time lapse cameras (Tanks 5 and 7) to enhance visibility during nighttime recordings. Red lights were programmed to turn on 18:00-7:00 while laboratory lights were off.

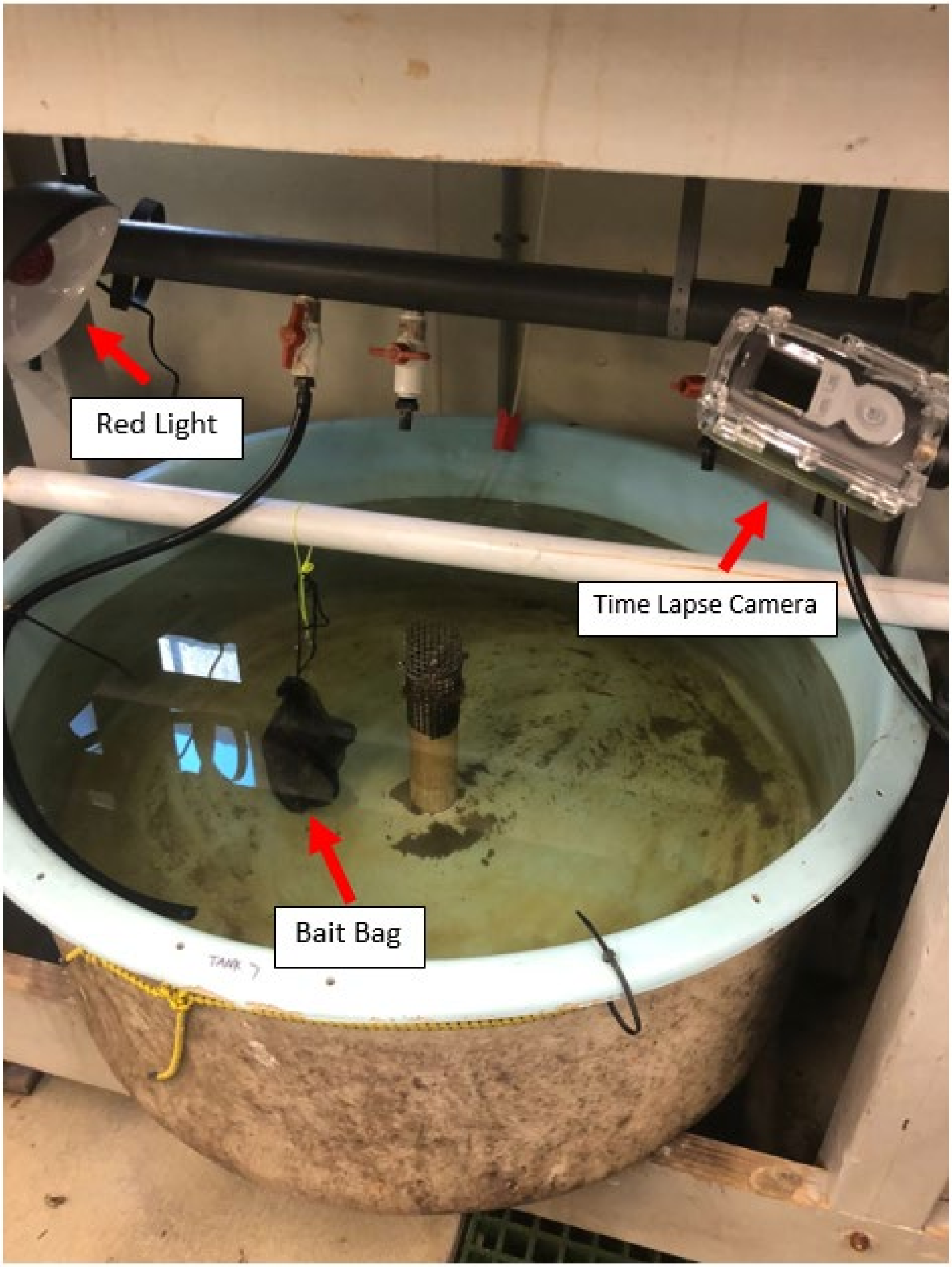

Figure 3- An example of the set up of one of the four three-foot tanks at the CML. Tanks 5 and 7 included cameras and red lights, while Tanks 6 and 8 had an identical set up minus the cameras and lights.

Bait Trials

Each of the 64 trials ran from 15:00pm-11:00am. Whelks were randomly assigned to bait trials, while ensuring that each whelk was not used in consecutive trials. The following eight baits were tested: 1) 1/3rd of a *Limulus polyphemus* (Horseshoe Crab) (n=10), 2) ground whole green crab (*Carcinus maenas*) (n=10), 3) clam processing waste (n=10), 4) mix of *Limulus* hemolymph (processing waste of the biomedical industry), green crab, and gelatin (n=9), 5) ground whole green crab with gelatin binder (n=5), 6) clam processing waste with gelatin binder (n=4), 7) *Limulus* hemolymph with gelatin binder (n=10)and, 8) an empty bait bag as a control (n=11).

All baits were thawed for 3 hours prior to experimentation. Whole frozen horseshoe crabs, *Limulus polyphemus*, were crushed and broken into thirds following common practices utilized by whelk fishermen in Martha's Vineyard. A thawed third of the *Limulus polyphemus* was weighed (mean, ± SD; weight 134.0g ±88.6) and was placed in a bait bag with a HOBO data logger and a 25g weight which were both anchored to the bottom of the bag. The bait mix containing *Limulus* hemolymph (processing waste of the biomedical industry), green crab, and gelatin was formulated into small pucks (mean, ± SD; weight 80.7g ± 5.0). One bait mix puck was placed in a bait bag with the HOBO data logger and the weight. The clam (mean, ± SD; weight 76.4g ± 3.4), ground whole green crab (mean, ± SD; weight 72.0g±10.7) , clam with gelatin binder (mean, ± SD; weight 74.7g ±0.4), ground whole green crab with gelatin binder were (mean, ± SD; weight 74.7g± 1.1), and *Limulus* hemolymph with gelatin binder (mean, ± SD; weight 74.9g ± 0.3) were weighed and placed in the bait bag with the HOBO data logger and weights. The HOBO data logger and the weights were secured to the bottom corner of the bag with zip ties to ensure consistent orientation of the logger and minimize the amount of motion caused by water flow in the tanks. Whelks were acclimated to experimental tanks for 2 hours prior to the start of the trial and addition of the bait bags at 15:00 pm.

The HOBO data loggers in both the bait bags and on the channeled whelk were set up to measure acceleration in the x, y, and z direction every 4 seconds from 15:00 pm through 11:00 am. The BRINNO time lapse cameras were set up to take an image every 4 seconds for the same duration. Following the completion of each trial, each tank was drained and rinsed thoroughly before being refilled. The bait bags were additionally emptied, rinsed, and left to soak in salt water until the baits were thawed enough to be added again.

Data Analysis

The accelerometer data from the HOBO data loggers attached to the bait bags was the primary source of data used for analysis. First, the differences in the combined acceleration value (x,y, and z) was calculated for each time point (acceleration in g = $\sqrt{((X_2-X_1)^2+(Y_2-Y_1)^2+(Z_2-Z_1)^2)}$). This provided a value that indicated the change of acceleration from one time point to the next, and in doing so, eliminated values that were simply due to the bait bag being tilted to one side or the other. The combined acceleration was then graphed as a time series. The graph was used to identify the baseline acceleration value that was always present and did not result from any movement. We referred to this as the "flag value". All values above the flag value were flagged, allowing for the "background noise" present in the sample due to acceleration from the bait bag swinging in the water current to be ignored. This process flagged only the minutes when the bait bag was moving as a result of the whelk attempting to consume the bait. Using the flagged values, the total minutes the whelk spent interacting with the bait bag was calculated for each hour and then summed over the entire trial period to give the total interaction time of the channeled whelk with the baits in each trial.

Following these first analysis steps, camera checks were performed on the trials with camera footage (N = 31). The time lapse footage was analyzed for the total amount of time spent interacting with each bait type and the times during the trial when the whelks were interacting with the bait bags. This analysis was then used to go back and determine a flag value in the accelerometer data that reflected the times and total amount of interaction that matched the camera data. When this camera check flag value was compared to the flag value calculated by the accelerometer data processing, the camera check flag value was slightly higher in all trials. To correct for this error, the difference between the camera check and accelerometer flag value for each trial with camera footage was taken and averaged (average difference = 0.018 g ± 0.002). The average difference between flag values was added to the original flag value of all trials to correct for errors using the accelerometer data. This analysis gave a corrected value of total interaction time that was used for subsequent analysis.

The time to first touch was also calculated for each trial. Time to first touch was calculated by measuring the difference between the time when the whelks first started interacting with the bait (the first flag value in the accelerometer data) and the time when the trial first started at approximately 15:00. The time to first touch and the total interaction time was averaged for each bait type. Then, One-Factor ANOVAS and Post-Hoc Tukey Tests were run on the averages to determine if there were significant differences between different bait types.

Results

Total Interaction Time

The average total amount of time the channeled whelks spent interacting with the clam processing waste with binder was significantly (P = 0.002) higher than all other baits (Figure 4). Clam processing waste with binder had an average of 60.25 ± 37.09 minutes of interaction for the entire 20 hour trial. Although not significantly different from the other baits the clam processing waste had the second most interaction with an average of 17.00 ± 6.20 minutes. Together the baits containing clam had 4.79 times more interaction than any of the other baits. There was no significant difference in the average total interaction time of any of the other baits tested (Figure 4). Trials run with nothing in the bait bag had the next highest total interaction time, then green crab, then *Limulus* binder. The baits with the lowest three average total interaction times were horseshoe crab, green crab with binder, and finally the mix pucks.

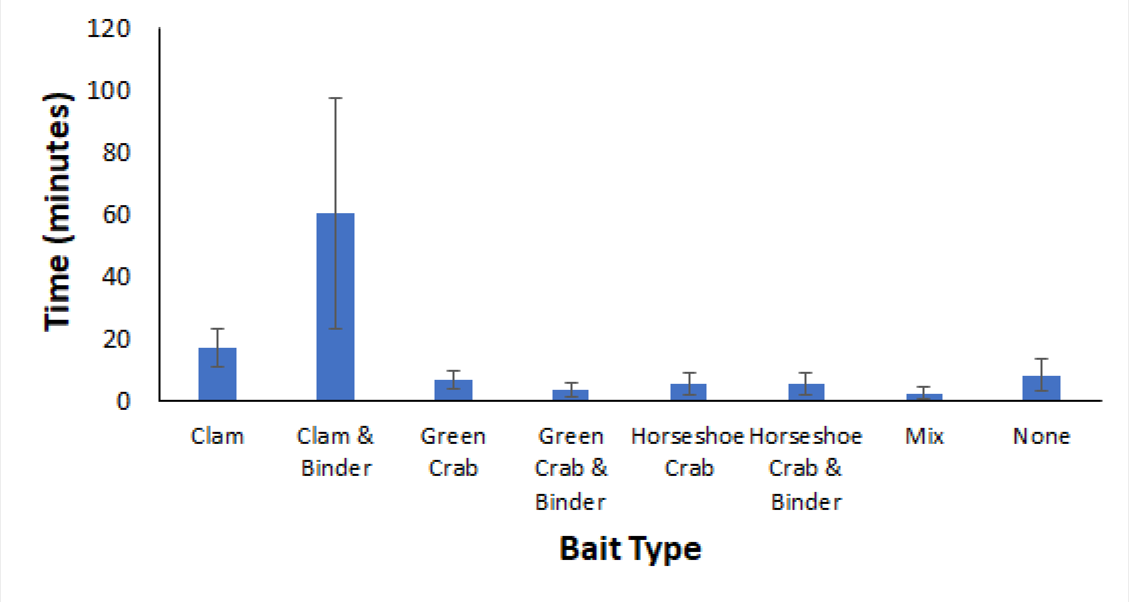

Figure 4- The average total amount of time the channeled whelks spent interacting with each bait type. Clam with binder had significantly higher interaction time compared to all of the other baits tested.

Time to First Touch

The time to first interaction did not vary significantly between baits (P = 0.343) (Figure 5). Although not significant, the clam processing waste had the shortest average time to first touch with the bait in the tank; with a gap of 4.45 ± 1.41 hours between the time the bait was added and the whelks interacting with it. The clam processing waste with the gelatin binder had a delay of 5.72 ± 3.71 hours which was 2 hours faster than the next fastest time of interaction. The time to first touch in the bait bags with no bait (none) and the bags with horseshoe crab was both around 8 hours. The next shortest time to when the whelk first began interacting with the bait bag occurred with the gelatin binder and mix bait. Finally, the two baits that channeled whelk took the longest to begin interacting with were green crab and green crab with binder.

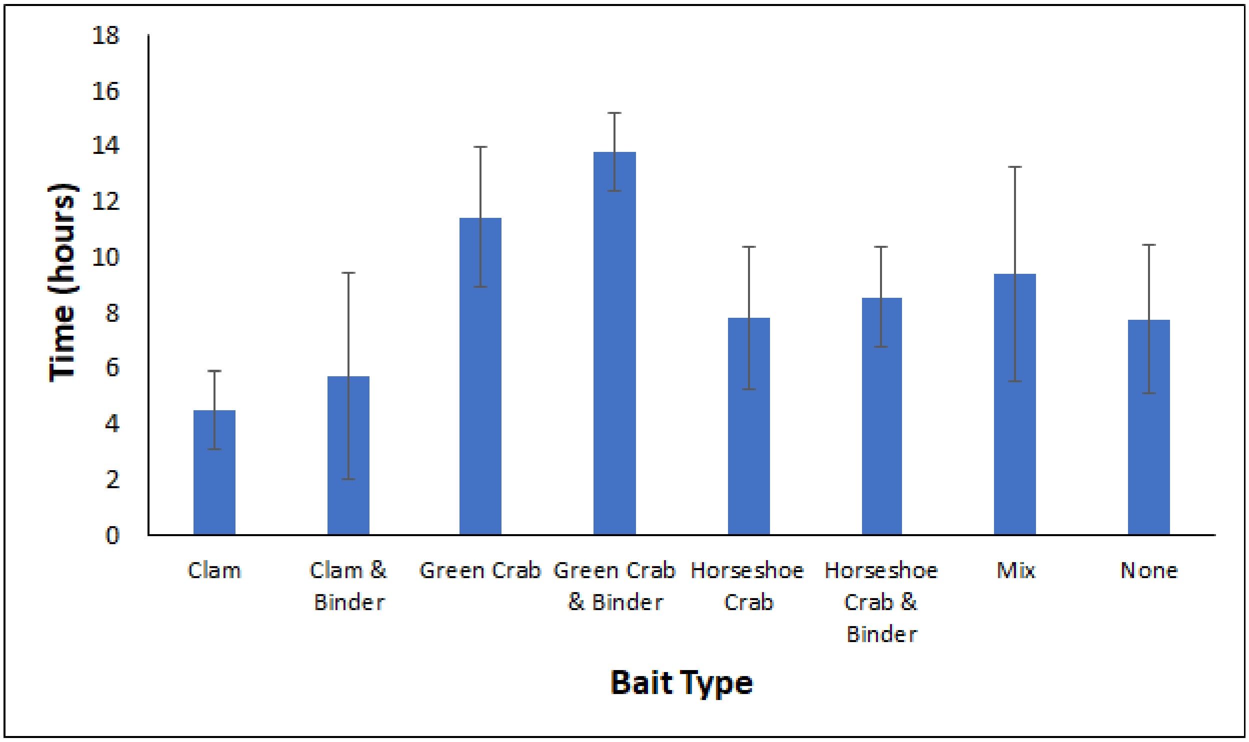

Figure 5- The average time it took for the channeled whelk to first start interacting with each bait type or “the time to first touch”.

Discussion

Clam processing waste with binder was the most attractive bait to whelks. The channeled whelk spent significantly more time interacting with clam processing waste with the gelatin binder compared to any other bait tested. This includes the current major attractant used in the channeled whelk fishery, horseshoe crab. Considering clam processing waste is much cheaper and more sustainable than horseshoe crab, the high amounts of time the channeled whelks spent interacting with the bait suggests that clam processing waste is a potential alternative for the channeled whelk fishery. In addition, the significant difference between the time of interaction between the clam processing waste with and without the binder indicates that the addition of a binder may preserve the bait allowing it to be attractive for longer. However, this pattern did not seem to hold true with other bait types with and without binders. Both green crab and horseshoe crab were run with and without their binders, and there was no significant difference observed in the total interaction time of these baits. This may be due to low sample sizes in the binder trials making it difficult to determine the relationship between the baits with and without binder, or may indicate that clam processing waste is especially unstable and requires a binder to remain attractive unlike the other bait types. Further trials both in the lab and the field will help determine the importance of a binder in channeled whelk fishery baits.

The lack of response for the horseshoe crab bait, which is traditionally used by the fishery, could have been due to the frozen horseshoe crab utilized being stale from prolonged time in the freezer. However, *Limulus* hemolymph with gelatin binder also did not significantly attract the whelks which may indicate that horseshoe crab results cannot be attributed solely to stale horseshoe crab bait. The apparent lack of attraction of channeled whelk to the *Limulus* hemolymph may also be due to the additional processing the *Limulus* hemolymph and binder went through before being used as a bait. Horseshoe crab bait utilized every part of the horseshoe crab (shell, flesh, etc.) while the *Limulus* hemolymph with binder was made with only horseshoe crab blood processed by the biomedical industry. Previous research on a mud snail found that the primary chemoattractant in horseshoe crabs is concentrated in its eggs, making it likely that the *Limulus* hemolymph lacked the chemicals that normally attract channeled whelks (Ferrari and Targett, 2003). More research utilizing fresh horseshoe crab will be run in future bait trials to determine whether freezing the horseshoe crab reduces its attractiveness to the channeled whelks.

While total interaction time varied significantly between bait types, there was no significant difference in the time to first touch. For example, while the channeled whelk were most attracted to the clam processing waste with a binder, they did not approach this bait faster than other baits. One possible reason why the time to first touch did not vary significantly is due to the daily rhythms of the channeled whelks. Channeled whelks are considered to be nocturnal, with feeding activity occurring primarily during the night (Rohrkasse and Atema, 2002). In most trials, even though the bait was added to the tank in the late afternoon (15:00), the whelks did not approach and begin interacting with the bait until the lights went out. Feeding occurred mostly during the night/ early morning which supports the view of channeled whelks as nocturnal animals. This nocturnal behavior made it difficult to compare baits, because the whelks would not begin interacting with the baits until night regardless of how attracted they were to them. In the future, adding the baits at night could help determine which bait the whelks were first attracted to.

There were a number of flaws in methodology that may have impacted both the total interaction time and the time to first touch. The biggest possible source of error in data analysis was determining the flag value for the accelerometer data. Tanks were left flowing for the course of each trial and the setup at CML did not allow for the flow of water to be standardized between tanks and trials. This led to a lot of variation in the background noise of the accelerometer data; further complicated by the changes in water flow that occurred twice for each trial due to CML pump backflow and maintenance. Another problem in the methodology was that the negative control trials run with no bait in the bait bags had a higher average total interaction time compared to some trials with bait bags. Although most of the “none” trials had zero minutes of interaction as expected, in a few of the trials the channeled whelk spent up to nearly an hour interacting with the bait bags. It is possible that the bait bags contained some residual scent from previous trials. In the future, bait bags should be thoroughly rinsed and soaked in clean water for at least an entire trial period to ensure the scent is gone. Another possibility is that the channeled whelks may have had an aversion to some of the bait types, which could be determined with further testing with a more careful methodology. The final problem is that many of the baits tested had low trial numbers which may explain the high standard errors observed in the experiment.

Overall, this study suggests that clam with binder is the most promising alternative to horseshoe crab for channeled whelk fishery bait. This study is the beginning part of a larger study on the bait preference of channeled whelk that will include both further laboratory and field tests. The preliminary trials we completed will certainly help guide how the methodology in future laboratory tests should be modified. For example, in future laboratory tests, the tank flow should be turned all the way off to minimize background noise and reduce error in analysis. In addition, two bait bags should be added to each tank- one with the bait being tested and one empty bait bag to serve as a negative control. Data from this negative control bag can then be subtracted from the bait bag containing the bait to subtract out any remaining background noise in the tanks. Finally, fresh horseshoe crabs should be used and the bait bags should be more thoroughly rinsed between bait trials.

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