TECH 797: Undergraduate Ocean Research Project

University of New Hampshire

Durham, NH

Redesign of Channeled Whelk Traps for Improved Selective Harvesting

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Abstract

A fishery in the waters around Massachusetts for the Channeled Whelk has grown to prominence in the past several decades. Channeled Whelk are a marine gastropod related to the Conch, and fishermen have been harvesting them with a basic pot trap design akin to the ones in the Lobster fishery for many years. Fishermen have needed alternatives proposed to these traps to strengthen their decreasing harvests and to reduce their increasing yield of bycatch. With increasing size regulations, there has been an increase in the amount of sorting that is necessary for a legal harvest. The research done is imperative to saving these fishermen time while out at sea and reducing the amount of handling that a sublegal sized whelk experiences, as well as reducing the bycatch from ghost fishing. One way to allow sublegal whelk out of a trap is commonly seen in lobster traps, escape vents. The escape events allow the smaller individuals to exit the trap while retaining marketable individuals. The whelk trap created will be accepted into the commercial fishing community and will retain legal sized individuals within the trap. Making the escape vent too large allows legal whelk to freely exit the trap but making the door too small means bycatch numbers are barely altered. Two main experiments were designed, one testing preferred vent shape (circle and 'gumdrop') and height (high and low), and another testing effectiveness of vent shape in an actual trap. Control tests, insert tests, and escape tests were completed to test different shape trap doors and how the whelk navigate both in and out of the trap. The circle shape and a modified circle shape that resembles a gumdrop were the two main shapes tested both at 75mm diameter. After multiple trials and review, a finalized gumdrop shape trap door design has been found to show the most significant improvements for allowing the majority of sublegal whelk to escape. The final design, among other valuable information

learned during the past year about these animals, will continue to push forward new improvements for whelk fishermen.

I. Introduction

A. Background

The Channeled Whelk, *busycotypus canaliculatus*, is a poorly understood species within the scientific community. What is known is that they are predatory marine gastropods that have been playing a role in the east coast fisheries market for decades. They are found along the East Coast from southern MA to FL (mass.gov). They are edible snails that are caught and found in shallow, nearshore environments, like near oyster beds and mud or sand flats (Nelson, 2018). The whelk features a spiraling shell with a muscular foot that protrudes at the opening that they use for locomotion. Most whelk reach maturity at 7-10 years and feed on clams, oysters, mussels, and other bivalves (Angell, 2018; Gmelin 1791).

The current trap designs used in the Massachusetts Fishery appear remarkably similar to standard lobster traps. A wire cage with an open top that allows the animals to fall inside to the bait, but not be able to leave. The current trap is designed to catch whelk of all sizes with no means of escape anywhere on the trap, differing from the standard in the lobster fishery which incorporate escape vents. This creates problems for fisherman who then must sort out the legal sized they can sell from the sublegal sized whelk that are illegal to keep. Fishermen must then pick them out at sea, using a size gauge to measure, which means longer days out at sea. This wastes time, money, and fuel. These animals face another problem with “ghost fishing”, where a trap is lost at sea and continues to harvest animals without being emptied by fishermen (NOAA Marine Debris Program). These traps have no selectivity, so when sublegal whelk enter the ghost traps, they are therefore prevented from ever reproducing. This prompts a new trap design that would entail increased haul efficiency, and decreased ghost fishing mortality.

Whelk are measured in the field by fisherman and are broken into both “legal” size whelk and “sublegal” size whelk based on national requirements. The whelk are measured by their shell in terms of length, width, and lip width. An example of a legal-size vs sublegal size whelk is shown below in Figure 1. A legal, or marketable sized Whelk is deemed such if it is at or over 79mm in shell width. The fisherman must then throw back the sublegal sized whelk that do not

Figure 1. Legal vs. Sublegal Whelk

meet these minimum criteria. According to the Massachusetts Fisheries Department, the Marine Fisheries Advisory Commission approved a plan to increase the minimum gauge size to 3 inches in 2019 continuing to biannually increase in 1/8-inch increments until the size reaches 3 and 5/8-inches in 2029 (Marine Fisheries Commonwealth of Massachusetts). This means increasing numbers of whelk are now considered to be of sublegal size.

With these increasing size limits, a new design for trapping these animals needed to be made that allowed sublegal whelk to escape the trap and survive, while retaining all the legal sized whelk fishermen need to harvest. This project went forward with the aim of fixing this issue by applying ideas from the lobster fishery and applying them to the current whelk trap design used today. Studies have been performed investigating similar responses in American

Lobster *Homarus americanus* as well as determining what vents work best for specific lobster fisheries, since the fisheries for lobster can vary in minimum size regulations (Nulk, 1979). The Nulk paper was successful in determining that different slot sizes can go with specific lobster fisheries. They were also able to determine the relationship between the animal's carapace width to carapace length to get the overall size of the animal. This study on lobsters lends this whelk project validity and gives reason to believe that it can be replicated with a different animal that is harvested in a similar manner.

B. Objectives and Approach

Creating a selective whelk trap is something that requires insight into how whelk behave. To learn how channeled whelk behave, a control test was the best option. The Coastal Marine Lab (CML), located in Rye, NH on the mouth of the Piscataqua River, provided an appropriate setting to observe whelk behavior and run tests. At the CML there was a 6-foot (1.82 meter) diameter circular tank, whelk trap, whelk, and bait available for use. The lighting system at the CML was programmed for sunset and sundown during the tests because they are on a diurnal programmed timer that are on or off depending on the season. Setting up the control test involved putting the available whelk into the circulatory tank with the provided standard whelk trap and adding bait inside the trap. A time-lapse camera was set up above the tank along with infrared lights so the trap could be viewed at night. This trial ran for 3 days and provided information about how and when the channeled whelk moved. This control test was run 2 times for verification and the footage was reviewed.

After the control trials were run, it was concluded that escape vents were needed to allow undersized whelk to move. Different shapes and sized escape vents had to be tested to find what the optimum design would be. Since time was limited due to water temperatures, intuition from the control tests was necessary to choose only a few designs to compare. Shapes and configurations were chosen for the insert, and slot and escape trials were run.

II. Budget and Materials

The budget for this project was funded by the New Hampshire Sea Grant and the University of New Hampshire College of Engineering and Physical Sciences. This budget was created to give access to the materials necessary to build and test trap doors, along with the equipment to record these trials. Each Mechanical and Ocean Engineering student on the project received $200.00 in funding from the department. In, there was a previously set up tank to be used along with whelk that were also provided by the CML. The following Table: 1 includes a list of the materials that were purchased for the project from the budget.

Table 1. Purchased Materials

Material	Cost	Link
Brinno Time-Lapse Camera and Tripod	$235.00	https://www.brinno.com/time-lapse-camera/TLC200
Tagging Supplies (superglue, black nail polish, sandpaper, paintbrush)	$8.97	https://www.gorillatough.com/product/gorilla-super-glue/
		https://www.sallybeauty.com/
		https://www.amazon.com/3M-Sandpaper-11-Inch-Assorted-Grit-5-Sheet/dp/B00002N6FE
Trap Supplies (mesh*, hog rings, hog ring pliers, blank inserts)	$165.75	https://newenglandmarine.com/
Trap Door Vents/New Bait bag	$11.00	https://newenglandmarine.com/
Total Spent of Budget	$420.72	

*Mesh purchased was 1.5 x 1.5 12.5G 19.5W x 24L GRN PANEL 52652 from Riverdale Mills-AQUAMESH

Since the project was designed and tested at the CML, there were resources and materials there that were used. This would include the equipment in the lab space and a 3-D printer was also utilized and available from the CEPS department to print the door model. An extensive list of all the materials and tools used can be found in the Appendix.

III. Methods

A. Whelk Setup

Prior to tagging the whelk, their shells were coated with algae, sediment, and other marine particles from being left in the tanks. The first step in tagging was to polish the shell to get a smooth surface to write on. First, paper towels were used to get the top layer of grit off the shells and to dry them. The underlayers proved tougher and could not be taken off as easily. For the underlayers, light sandpaper was used to file down the sediment and remaining algae that might be on the outside of the shell. The shells were sanded down until you could see their natural pattern but no further as then the shell itself would be filed away. The length, width, lip width, and height of the shells were then measured as shown below in Figure 2.

Figure 2. Channeled Whelk Measurements

These measurements were taken using calipers provided in the lab. After measurements were taken, each whelk was given a number in which to identify it when running our experiments. On the polished off surface of the shell, a mixture of black nail polish and super glue was used to write the whelk's corresponding number. The measuring of the length, using the measuring tape, the width using calipers, and the numbering process using the nail polish and superglue mixture is shown below in Figure 3.

Figure 3. Measuring steps: length of whelk using measuring tape, width using calipers, and numbering the whelk using nail polish/super glue mixture and paint brush

The number had no indication of size or shape, it was simply to differentiate between individuals. The final measurements for length, lip width, width, and height of each whelk are listed below in Table 2.

Table 1. Whelk numbers and measurements of length, lip width, width, and height (all in mm). The three highlighted were considered "legal" sized

Whelk Number	Length (mm)	Lip Width (mm)	Width (mm)	Height (mm)
80	104	54	59	48
33	103	54	59	49
81	101	53	56	47
82	124	64	67	57
28	125	62	66	56
23	119	55	63	50
83	130	65	74	62
84	120	60	71	54
22	182	95	103	82
76	151	72	88	68
85	152	72	88	73
27	143	68	76	60
86	127	64	70	59
87	136	69	75	58
88	120	62	65	55
89	135	67	72	59
90	124	62	67	55
91	126	62	67	51
34	96	49	52	43
92	120	61	66	53
93	104	56	64	48
94	143	72	78	67
95	90	46	50	43
96	125	59	70	55
35	96	46	49	41
97	90	52	55	47
30	140	71	73	63
98	104	54	57	46
99	92	48	54	43
100	79	42	46	36

In total, thirty channeled whelk were tagged for use in our trials as seen above. Three of these thirty channeled whelk fit into this year's, "legal sized" category. This meant 10% of the whelk were legal sized compared to 90% that were considered sublegal sized. The largest whelk was number 22 and the smallest whelk used was number 100. Not all thirty of the whelk were used in each trial. These whelk were already at the CML and are used in other experiments going on in the lab. Since the whelk are motivated by food, it was imperative to know which whelk were being used, as well-fed whelk are not likely to be motivated. Making note of the whelk used in each trial to then give them "breaks" in between made sure they were still food motivated. When doing different trials, it was important to make note of the number of legal and sublegal whelk.

B. Experimental Setup and Trials

The CML has a flow through tank system that provides fresh oxygenated water to all the aquatic life and tanks in the building. This meant that there was no control over the temperature or clarity of the water inside of the tank. Not being able to change the temperature of the water in the tank was a limiting factor in the timeframe available for testing during this project as whelk go dormant in the fast-approaching winter. Also, the ever-changing water clarity made recording challenging as cloudy water made it almost impossible to read numbers that are painted onto a whelk's shell.

The trap used during testing was a square trap with 21-inch sides and 9 inches of depth. The top of the trap was open and there are textured plastic sheets up the sides that provide a surface for the whelk to climb on shown in Figure 4.

Figure 4. Standard Whelk Trap

The first tests run were to help gain an understanding of how the whelk traps currently work. These tests were control tests which were recorded using the camera and tripod set-up, the infrared lights, and the existing whelk trap from the CML. The objective of these control tests were to see how the whelk normally behave and interact with the traps. Horseshoe crab was used as bait and was placed inside the trap in a bait bag. The bait used was either horseshoe crab or clam bits that are frozen until use. The bait was broken apart and placed in the bait bag that could be secured to the trap or to the bottom of the tank depending on the test. The bait was removed and replaced between each trial and all the bait came from the CML.

The un-modified trap was placed in the center of the tank and whelk were placed outside the trap. The first trial was run from October 14, 2021, to October 17, 2021 (3 full days). Figure 5 shows the lights and camera/tripod set up for this trial above the 6-diameter tank.

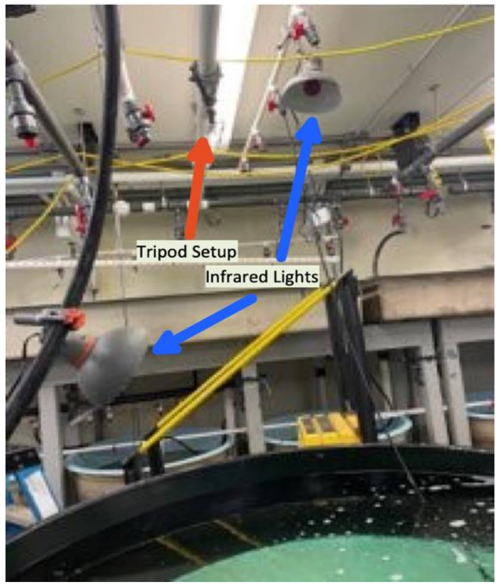

Figure 5. Control Trial Setup

After this first trial, modifications to the tank and setup were made to account for problems that had occurred. Since these control tests were supposed to be mimicking real life, sand was taken from the beach nearby and put into the tank, covering about 1 in of the bottom. The 2 infrared lights were also relocated so that in the video it is easier to see. The 2nd trial was run from October 20, 2021, to October 27, 2021, with the improved setup shown below in Figure 6.

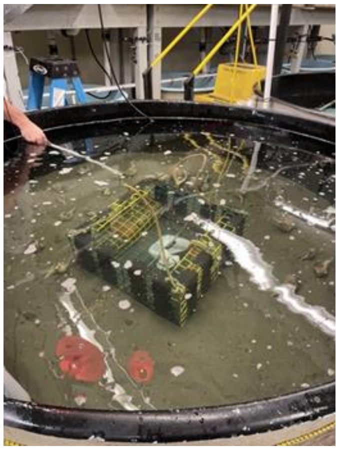

Figure 6. 2nd Trial Setup

After reviewing these trials, the trials moving forward were for modifying and testing different escape vent shapes; specifically, the circle and modified gum-drop shape. Since time for testing was limited, a way to test multiple different shapes was needed to speed this part of the design process along. To solve this problem, an “insert” was created to place inside the tank which would create sections and allow for testing of multiple different shapes at once. The first proposed model for this insert is shown below in Figure 7.

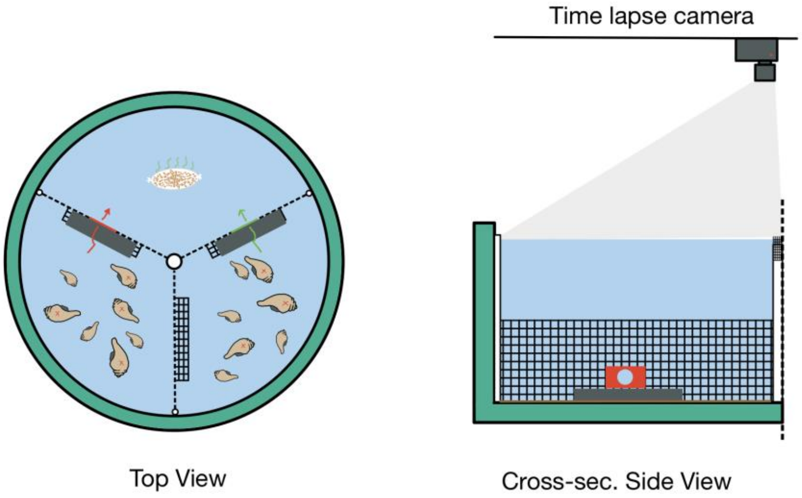

Figure 7. Trisection Insert

While different shapes were being tested the actual escape vents were situated at two different heights on each side to also allow for observations on preferred exit height. In the standard traps, there are black strips and small ramps located inside the trap for the whelk to climb up on. To mimic this, one door on both sides were elevated with a ramp. After the first trial of the insert tests ran from November 3, 2021, to November 9, 2021, modifications were made to these ramps since the whelk started to crawl under the ramp instead of over. Zip ties were added to the ramp components of the insert to prevent the whelk from continuing to climb under the ramp. The new insert component with the ramps appears as follows in Figure 8.

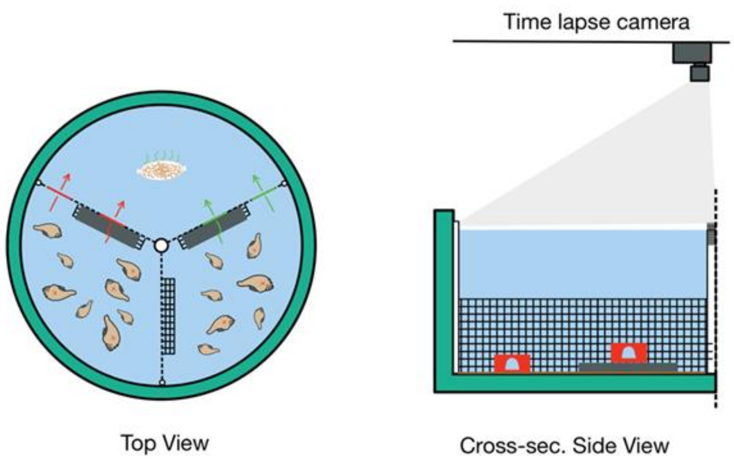

Figure 8. Re-designed trisection insert

The new insert in the tank with the lights and camera is shown below in Figure 9.

Figure 9. Photo of trisection setup test

The main objective of the insert trials was to determine if and what the whelk preferred in terms of ramp or direct access. The whelk that made it through either side of their respective section were recorded and the videos were able to show in more detail which door and how they exited. There were three more trials of these slots' tests run from November 10-11th, November 22-26th, November 26-29th, and November 29th to December 1st. From these trials the two doors most preferred were then utilized in the next sets of trials.

The last trials completed were the escape trials. These trials involved using a modified trap with a different shape trap door on either side. The two shapes used were a circle trap door and the gum drop trap door. While watching the videos, it is possible to differentiate between the two vent shapes simply by sight. This is necessary to document which vent the whelk used to exit the trap. The objective of these trials was to place whelk inside the trap at the beginning of each trial and observe which whelk exit, and through which of the two shapes they exit. These trials were run from December 1-4th, December 4-6th, and December 6-8th. The first trial, a bait bag was placed outside the trap to lure the whelk out of the trap. The configuration of these trials is shown in Figure 10.

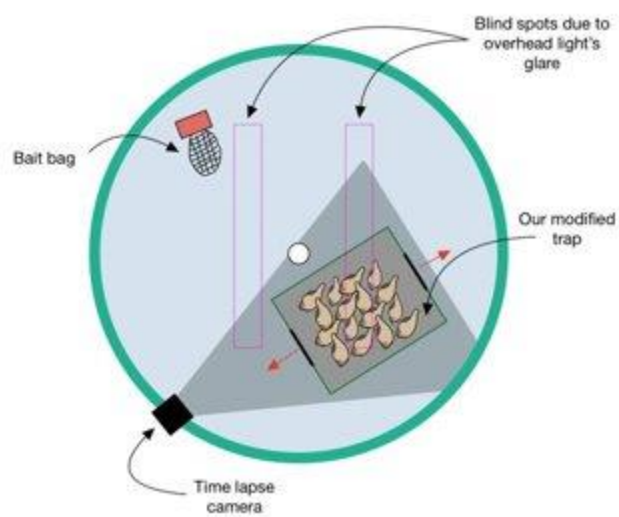

Figure 10. Escape trial drawing

After the first trial ran, the bait bag was removed for the other two trials to see if the whelk would still be motivated to move out of the trap without the bait. These trials had a similar configuration just without the bait bag present. Pictured below, in Figure 11, is the setup view.

Figure 11. Photo of escape trial setup

After these trials were run, further analysis and data collection could be completed, and these setups were understood and documented for future work.

C. Whelk Behavior/Temperature Analysis

While running trials and monitoring their behavior, the temperature of the water inside the tank was measured. By placing the thermometer onto the trap, itself during testing, the decline in water temperature was monitored for correspondence with when the whelk start to go dormant. The tank temperature started at around 13 degrees Celsius and steadily decreased during testing until the whelk were dormant. This temperature was around 8 degrees Celsius. Pictured below in Figure 12 is the thermometer that was latched onto the trap during trials starting on November 11, 2021.

Figure 12. Thermometer used to monitor water temperature (in degrees Centigrade) in the tank

Since the temperature was being monitored and the whelk's movement was being recorded, more information could be determined about their behavior.

D. Data Analysis

To record the whelk's behavior during the tests, we use a Brinno TLC200 Pro time lapse camera. This camera was chosen for the experiment because it offers custom timelapse time intervals, has a 112˚ field of view, captures in 720P HDR, and is battery powered so we could place it anywhere and not have to worry about a power source. The camera was outfitted with a water-resistant housing and a tripod mount to allow it to be mounted on the pipes running on the ceiling above the test tank. An infrared light lamp was also clamped on the pipes over the tank so at night there would be sufficient light to view the whelk during the night hours, but whelk cannot detect this wavelength of light, so it would not disturb them. The camera used a 32-gigabyte SD card for storage of the video files, and this provided a straightforward way to download the videos off the camera and onto our personal computers for analysis. The timelapse footage for each recording was output as .AVI files and all video content was downloaded to a 32-gigabyte flash drive kept in the laboratory, so in the case of any video footage being lost, we would have a backup of the data.

Once the timelapse footage was downloaded onto a personal computer, the .AVI file was opened in QuickTime player. The footage was viewed at 300x speed so that the whelk's movements would be accelerated. This turned a three-day experimental trial into a few minutes of footage. The team would watch the video footage and record which whelk traveled through each slot and that data would then be input into an excel document. When reviewing the footage, it was realized that they crept along the bottom, siphons first, and wagging back and forth. Knowing their motor functions helped in deciding the size and shape of the slots and where in the trap it would be implemented.

E. Slot Prototypes

The prototype for the slots would be 3D printed in Kingsbury Hall classroom S178. The modeling software that was used is the most recent version of SolidWorks, in which the final design of the slot was created. Figure 15 shows current industry slots for lobster traps and Figure 13 shows the improved model for whelk specific behavior.

Figure 13. SolidWorks rendering of final slot design

While conducting the slot and escape trials, shapes were cut into slot blanks. Figure 14 shows the slot blanks before having any vent shape. Using circular drill bit attachments allowed the slots to be cut into the right sized shapes for both the circular and gumdrop shape slots. The shapes being tested were chosen as one being the natural shape of the channeled whelk (circular) and one allowing for normal movement when passing through (gumdrop) as not to deter the individuals from exiting. The gumdrop shape was developed after watching the footage back of our control tests. The cut-out bottom was implemented to account for this wagging motion as they went through.

Figure 14. Slot blank prior to cutting

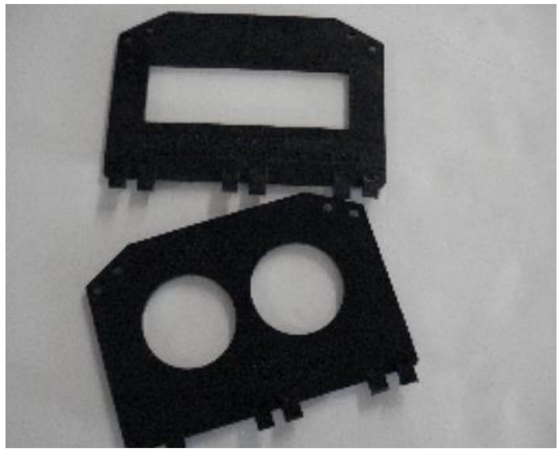

Figure 15. Lobster trap slots currently available to fisherman

IV. Results

A. Control Tests

Table 2. Control Test Results

							Gumdrop Vents					Circle Vents					
Trial	Start Date	End Date	Total Duration (hh:mm)	Total Number Whelks	total Number Legal Size Whelks	Total Number Sublegals	Number Whelks Through Vent	Mean Size Whelks	Number Legal Whelks	Number Sublegal Whelks	% Sublegals Thru Gumdrop Vent	Number Whelks Through Vent	Mean Size Whelks	Number Legal Whelks	Number Sublegal Whelks	% Sublegals Thru Circle Vent	
Ctrl 1	10/14/21	10/17/21	54:06														none when into trap
Ctrl 2	10/21/2021	10/24/21		8	2	6											all went into the trap

B. Insert Trials

Table 3. Insert Trial Results

							Gumdrop Vents					Circle Vents					
Trial	Start Date	End Date	Total Duration (hh:mm)	Total Number Whelks	total Number Legal Size Whelks	Total Number Sublegals	Number Whelks Through Vent	Mean Size Whelks	Number Legal Whelks	Number Sublegal Whelks	% Sublegals Thru Gumdrop Vent	Number Whelks Through Vent	Mean Size Whelks	Number Legal Whelks	Number Sublegal Whelks	% Sublegals Thru Circle Vent	
ST 1	11/3/21	11/9/21	79:55:00	22	2	20	0	0	0	0	0	0	0	0	0	0	none went to other section
ST 2	11/10/21	11/11/21	8:21	22	2	20	2	63.5mm	0	2	10	2	71mm	0	2	10	
ST 3	11/22/21	11/26/21	67:19:00	22	2	20	7	66.67mm	0	7	35	3	72.5mm	0	3	15	
ST 4	11/26/21	11/29/21	47:55:00	22	2	20	2	86.5mm	0	2	10	2	72.5mm	0	2	10	
ST 5	11/29/21	12/1/21	48:19:00	22	3	19	1	70.00mm	0	1	5	0	-	0	0	0	this was #96
MEAN											12					7	
ST DEV											13					7	

C. Exit Trap Trials

Table 4. Exit Trial Results

							Gumdrop Vents					Circle Vents				
Trial	Start Date	End Date	Total Duration (hh:mm)	Total Number Whelks	total Number Legal Size Whelks	Total Number Sublegals	Number Whelks Through Vent	Mean Size Whelks	Number Legal Whelks	Number Sublegal Whelks	% Sublegals Thru Gumdrop Vent	Number Whelks Through Vent	Mean Size Whelks	Number Legal Whelks	Number Sublegal Whelks	% Sublegals Thru Circle Vent
ES 1	12/1/21	12/4/21	54:00:00	14	2	12	4	69.5mm	0	4	33	3	70mm	1	2	17
ES 2	12/4/21	12/6/21	43:00:00	16	2	14	6	62.67mm	0	6	43	3	61mm	0	3	21
ES 3	12/6/21	12/8/21	42:22:00	16	2	14	2	68.5mm	0	2	14	4	70.5mm	1	3	21
MEAN											30					20
ST DEV											15					3

D. Temperature Plots

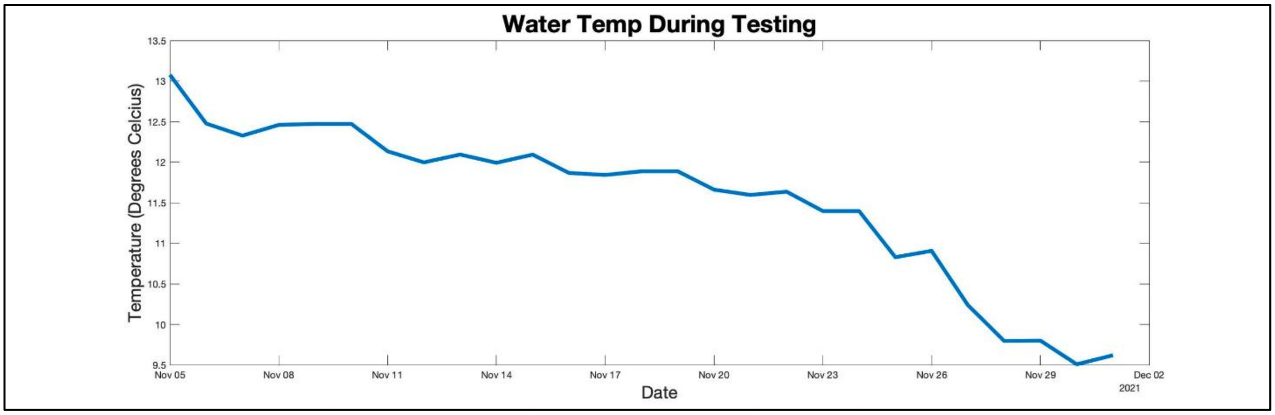

Figure 16. Tank water temperature plot

V. Analysis

A. Control Tests

The first control test yielded no results but allowed for a good first analysis of the current standard whelk traps. After watching the video footage from the first trial, the camera and light's position needed to be changed for the next trials since the view was obscured. The whelk seemed to not like the current tank set-up, so sand was added to the bottom of the tank from the beach near the CML. About an inch of sand was added to the tank and was present for all other testing. After the second control test, all the whelk were able to escape. This allowed for observation of how the whelk navigate the trap and proved that escape vents would be needed to improve the current trap model.

B. Insert Trials

The following, Table 6 shows the Chi-square tests run on these insert results with the p-values for the insert test.

Table 6. Chi-Square Test Results for Insert Trials

Insert Trials	**Chi Square**
Gum Drop	0.01
Circle	0.01
Sum	0.01
Chi-Square Dist.	0.91

The insert trials allowed for testing of multiple shapes and ramp preferences. All 5 trials let no legal sized whelk through. The first insert trial had no whelk go through the vents as they got trapped under the ramp. The ramps were clamped down with zip ties and the other 4 trials allowed sublegal whelk to escape. By watching these videos, the specific sublegal whelk and their movements were tracked to allow for a better analysis over the best shapes to test during the exit trap trials. The p-value for these tests was 0.01 from the Chi-Squared statistics test. This is less than 0.05 which means there was a significant enough preference for one shape over the other, which for these tests was the gumdrop over the circle shape.

C. Exit Trap Trials

Exit trap trials provided vital insight about the size of escape vent that is required for efficient selection. The circle vents, even with the opening being smaller than legal size, allowed a few legal whelk to escape. Even with the circle vent being large enough for legal welk to escape, the gumdrop vent still had more sublegal whelk passing through. This could show a preference of shape that whelk will pass through. Once statistical analysis was completed, these results yielded that the gumdrop was preferred during the exit trap trials. The following, in Table 7, are the results of the Chi-Square distribution tests run for the exit trap trials.

Table 7. Chi-Square Results for Escape Trials

Escape Tests	Chi Square
Gum Drop	0.01
Circle	0.01
Sum	0.02
Chi-Square Dist.	0.89

Again, the p-value, 0.02, is less than 0.05 so there was statistical significance for the gumdrop shape over the circle shape. Both Chi-Square distributions meant that the likelihood of the whelk choosing one shape over the other was statistically significant. From the data, the gumdrop had seemed preferred from the trials run during this project.

D. Temperature Plots

Using the temperature data provided, the plot shown in Figure 16 was created using MATLAB. This plot shows the change in water temperature over time, averaged daily, that the whelk trap was in the water. Whelk are thought to go dormant around 8 degrees Celsius, and this value appeared to line up with what was observed. The trials started when the water was around 13 degrees Celsius.

V. Discussion

The control test runs provided insight to how whelk normally behave when entering and inside of a trap. This provided analysis used to further improve the testing setups. After the first control test, it was clear that the overhead lights were positioned improperly for optimum video recording. The lights and camera were then reoriented, and video was much easier to interpret. The footage recorded showed that whelk are much more active at night, and that they moved point first with the tip of the shell swaying back and forth. Their activity was observed through observations made throughout the video analysis process. This was valuable knowledge to have when trying to design an escape vent that would easily allow undersized whelk to exit a trap.

Insert trial results encouraged the further refinement of the size of escape vent created. The divided tank allowed for multiple different shapes and heights from the sand to be tested at once giving more results in the short trial periods. It was observed after the first trial test that the whelk preferred to not use the ramp because they were getting stuck underneath it. The ramps were closed off and the whelk were then able to use one of the shapes as the trials persisted. A more in-depth analysis of this ramp vs no ramp preference may be for future work but from the insert trials a preference of no ramp and the gumdrop and circle were observed.

The exit trials were used to determine if there was a significant preference overall for the gumdrop or the circle. From the statistical tests and analysis, the gumdrop was favored with enough statistical significance. While this is true, much more testing would be needed to understand the whelk's full preferences because we were only able to replicate our experiments for one month. Since the ratio of legal to sublegal whelk (3:27 respectively) used in each trial was unbalanced and many of the trials yielded little to no results, further testing needs to be done before a finalized design could be used in the field.

After analyzing the slot and escape trials, a decision could be made on the size and shape of the physical slot component that would be implemented in the design. The legal minimum width of the whelk to be harvested is 3.125 in. (79mm). The size of the slot should be smaller than the legal minimum width of the whelk but not so small that it does not reduce fisherman labor while on the boat. The goal and future goal for this project is to improve the harvesting by allowing the sublegal whelk to exit, but still prevent the legal whelk from escaping. This means a balance is needed in which testing proves sublegal whelk can exit the trap while legal whelk cannot. While the results for these trials prove sublegal whelk can leave and prefer the gumdrop shape, many of the trials still yielded little to no results and the ratio of legal to sublegal was skewed. The sublegal whelk that did leave do not represent the majority of sublegal whelk that were used in the trials. Only an average of about 30% or fewer of the sublegal whelk escaped using one of the escape vents. Even though that leaves some legal individuals to be able to exit, the data supports the slot design chosen that will decrease the number of whelk needed to be sorted when the traps are retrieved. This will then increase haul efficiency and decrease fisherman labor while still out at sea.

The slot should be designed with a sort of clip feature in which to secure the slot onto the side of the trap. This would make attachment and removal of the slots when needed easier for fisherman when doing maintenance on or constructing new traps. Furthermore, when legal size increases again, fisherman can easily make sure their gear is in accordance with the minimum size regulation at all times. The slot is to be placed towards the bottom so that exiting the trap is seamless for the whelk of sublegal size. In addition to the clips, other measures will be taken into consideration for the design of the slot so that in case the clips were to break, the slot would remain attached to the trap wall. Various materials will also be considered for printing. For now, since the only manufacturing ability available is 3D printing, the focus will remain on various filament types.

Future iterations of the model could include an extension spring mechanism that keeps the slot in place using the force of the spring. The opposing force of tensioning the spring on the wire cage will lock the slot into place so it will remain attached. A design for this was thought of but was never modelled as, given the time left in the project, it was beyond the scope of this year's objectives. Future work may also include working with local fishermen to gather their input and see how the modified traps would be used in the field.

VII. Conclusion

The slots from this year's work will provide the help necessary to fisherman with their hauls while keeping the whelk populations healthy and sustainable for years to come. To reduce the number of legal whelk that escape the trap, the final slot size was reduced to 75mm. This will not prevent legal sized whelk from leaving completely but will greatly reduce the amount of labor for fisherman when they manually measure the whelk with the slides. The gumdrop shape was implemented given the results of the chi-squared tests. The material of the slot that was produced was acrylonitrile butadiene styrene (ABS) plastic, a quite common material used in general 3D printing practice. However, polylactic acid (PLA) is recommended for mass production as it is biodegradable and does not leech toxins. This will allow the part to break down if the trap were to be abandoned in the water whether accidentally or intentionally abandoned. From immediate results and statistical analysis, the gumdrop was preferred from these trials. Further work and testing would need to be done to further prove and expand on the objectives to support whelk fishermen. Behavioral analysis could also benefit the overall understanding of whelk and what their preferences are.

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IX. Appendix

Full materials list:

-highlighted in yellow were materials purchased from the budget (see Budget and Materials)

-not highlighted include all the materials/tools available at the Coastal Marine Lab

X3 superglue
X1 black nail polish
X1 sanding paper
X1 tin plate to mix superglue and nail polish
X1 paintbrush
-paper towels
-boards
-measurer
-zip ties (small and large)
-paper meter stick
X2 red lights (w/ clamps)
X1 flash drive
X40 lobster trap door designs
X2 whelk trap
X1 bait bag (must leave out bait to defrost and be cut up)
-bait (either horseshoe crab or blended clam)
X1 water resistant camera housing/ camera-- Camera- brinno TLC 200 PRO HDR time lapse camera
X1 camera tripod-- TIME LAPSE weather resistant housing for TLC 200 PRO--- ATH120 from brinno
X3 large zip ties (from CML)
X4 AAA batteries for camera- rechargeable
X3 shovels
X7 buckets
X1 Bundle of mesh: 1.5 x 1.5 12.5 G 19.5W x 24L GRN PANEL
25 each 52652 from Riverdale Mills - AQUAMESH
X1 bungee cord
X1 bunch of rope
X1 electrical tape
X1 bag of hog rings
X1 hog ring crimper
X6 bricks
X1 scrap wood