NORTHEAST CONSORTIUM
Final Report

Project Title: Design and Testing of Traps for Assessment of Abundance and Distribution of Juvenile Northern shrimp, *Pandalus borealis*, In the Western Gulf of Maine.

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Abstract:

Our objective was to develop a standard trap design that can be used in the development of trap-based surveys of juvenile Northern shrimp (*Pandalus borealis*), ≤ 1 ½ years old, in the Western Gulf of Maine for both management and research purposes. Previous research and ancillary information from fishermen supported the idea that juvenile behavior is similar to adults in that they are attracted to traps. We modified conventional lobster traps by lining the interior with 1 x 1 ½ cm mesh and fitted the tops of the traps with 3 types of shrimp "V-trough" style entry vents: a conventional 1" wide vent (Control), a ¼" narrow vent (Narrow) and a trap-wire-covered conventional vent (Wire). The wire type vent sampled significantly smaller sized shrimp species and was most effective at reducing bycatch. Overall this study yielded some interesting results demonstrating that the wire covered vent design may be the best for juvenile shrimp sampling.

Introduction:

Northern shrimp, *Pandalus borealis,* is a commercially important demersal decapod in the Northwestern Atlantic whose southern most extent of their range includes the Gulf of Maine southward to Massachusetts in depths ranging from 10-500 meters (Squire 1990). They are a migratory species with a preferred average bottom temperature approximately 1-5˚C (Haynes 1969). As protandric hermaphrodites they settle as immature juveniles, and then sexually mature as males at 2 years with a subsequent transition to females at approximately 3 ½ years of age. Adult females extrude clutches of eggs onto their abdomens during early/mid summer in deep water until they are at the most, 5 years old. During late fall/early winter the ovigerous females move inshore to shallow water for egg hatching to occur. Once egg hatching has occurred they move back offshore to deeper waters. Larvae are found in the New Hampshire/Maine coastal water column from March through June (Gordon, unpublished data). Little is known about the larval and juvenile phases of their life

history; which is where it is believed the greatest amount of natural mortality occurs. They transition from larvae to early juveniles at a carapace length of approximately 3.2 mm (Shumway 1985) and start the benthic phase of their life history. One hypothesis is that juveniles stay in the near shore habitat until they transition to males however, there is ancillary evidence that they migrate offshore soon after settling as juveniles. *Pandalus borealis* supports a winter fishery for Maine, New Hampshire and Massachusetts in order of most landings to least (Glenn et. al. 2003).

The fishery has been managed by the ASMFC since 1970 with data from several sources that track the recruitment index, spawning stock biomass and annual migration patterns. Currently, the data for the recruitment index are from two sources: the ASMFC summer survey and the NEFSC spring and autumn surveys. ASMFC conducts a summer trawl-based survey that targets all ages of shrimp with youngest approximately 1.5 years old. However, at 1.5 years these shrimp are caught with only 50% efficiency by the 1 ¼" trawl net mesh and as a consequence the juvenile catch abundance must go through the application of a selection factor to develop the predominant recruitment index used in the assessment. The Northeast Fishery Science Center catches shrimp in its spring and autumn survey using a 4.5" mesh trawl net with a ½" liner. Both surveys trawl gear use too large a mesh to effectively sample the juvenile shrimp. Juvenile shrimp have also been shown to avoid the trawl gear footropes by swimming under the gear (Wieland 2003). Furthermore, and perhaps most importantly, both surveys do not have any sampling regions that are shallower than 55m where juvenile shrimp have been found to be most abundant (Shumway 1985). These surveys do not adequately sample the incoming year classes which would allow the management process to set season limits ahead.

A trap can be deployed in the areas that are most difficult to tow a net due to rocky substrate. Furthermore, inshore regions are traditionally heavily fished for lobster during the early summer

months which is also a period of time that juvenile shrimp are hypothesized to still be inshore. A trawl net would not be able to sample those areas due to conflict with the lobster fishery. Therefore with a group of cooperative lobster fishermen setting the traps during the spring and summer, it is likely that data from the juvenile shrimp traps could be incorporated into the survey index.

Northern shrimp are difficult to manage due to their unpredictable migratory patterns and the lack of knowledge about their recruitment dynamics (Wieland 2003). Fishery landings have had drastic fluctuations since the inception of the fishery in the late 1930's. Landings have ranged from zero in the 1950's to a peak of 12,800 tons in 1969. Since then there have been peaks and troughs in landings that are understood to be the consequences of resource exploitation and various environmental factors affecting recruitment success (Clark 2000). For the 2002 and 2004 season, the Atlantic States Marine Fisheries Commission (ASFMC) recommended closure based on the lack of 4-5 year old females and no 2 year old class (what would have been <1.5 year olds during the survey) (Glenn 2003). However, in 2004 there was a compromised shrimp season that year that only lasted 40 days. More detailed information of the juvenile year class would have aided the managers in a very difficult situation. For the 2006 season, the fishery was expected to be favorable due to the high abundance of shrimp >22mm CL. The catches were indeed high but the market was not there to support the fishery.

As a consequence of drastic fluctuations the demand and infrastructure for the New England shrimp fishery has diminished. Shrimp processing plants in New England have mostly closed with the exception of one large processing plant, Cozy Harbor of Portland, Maine. Processors have generally closed down in the area due to an unreliable amount of product and because Canada supplies a large portion of the shrimp that meets the current level of demand. For example, there was no demand for the product during the 2006 season so consequently the shrimp sold in the

auction for a range of 45-50 cents per pound but went as low as 25 cents per pound. It was disappointing to the fishermen since catches were large with good market sized shrimp.

Atlantic States Marine Fisheries Commission (ASMFC) sets the fishing limits by regulating days that the fishery is open to fishing as opposed to regulating total allowable catch, as is done in other fisheries. For 2006, they set the fishery limit at 140 days with a tentative 140 day commitment to 2007, as well. Setting the season in advance is a new approach that ASMFC hopes to continue. With increased demand and a more reliable expectation of product that processors can anticipate, it is hoped the infrastructure can begin to rebuild to support the shrimp fishery.

METHODS:

Thirty-two standard lobster traps with dimensions of 36" x 21" x 13.5" with no bridges, heads or escape vents were assembled with a liner of 1.5 x 1 cm "pet screen" liner that consists of a fiberglass core coated with plastic. Careful attention while installing the liner was taken to ensure there were no gaps. Traps were weighted with "Sinko" brand cement runners. All traps had the State of Maine and Federal regulation whale entanglement equipment attached to the buoys and to the bridle.

Three "V-trough" (Figure 1) entry vent designs were tested: a control (Control) with a wide opening of 1 ¼", narrow (Narrow) with ½" opening and a wire-covered vent (Wire) with opening of 1 ¼" with the vent opening on the outside covered with the trap wire that is 1" x 1¼". V-trough material was a smooth PVC plastic sheet cut to size and assembled with strips of wood to allow for the correct inside spacing and rigidity (Figure 1). Vents were placed in the top center of the trap with the bait bag hung at the middle of the vent snug to the inside opening as is traditional. Bait consisted of menhaden and Atlantic herring.

Sampling occurred aboard the F/V Angela and Ashley, owned and operated by Bradford Parady, during two periods: 6/25/05- 7/11/05 and 9/22/05 – 10/19/05. Traps were deployed in muddy bottom habitats in depths ranging from 19-40 fathom (114-240 feet). Locations of the trap sets were in the area of Maine from the Piscataqua River, out to Northeast of the Isles of Shoals and as far north as buoy "25YL" (Figure 2). For the first set of traps, the location was determined by identifying muddy habitat with the vessels depth sounder. Location of the second set was determined through use of a beam trawl to identify aggregations of *P. borealis*. For each set of trawls, four areas no more than 1 mile apart were chosen. Traps were set in groups of four of the same vent style with 24 feet of distance between each trap (otherwise known as trawls). At each location one test trawl of either the narrow or wire vent styles were set alongside a corresponding trawl of control traps. Therefore, 8 sets of trawls (4 traps per trawl = 32 traps) were out at each sampling period. One trap per trawl was outfitted with a HOBO temperature logger sampling at a rate of one recording per minute.

Traps were set with a soak time ranging between 3-14 days with an average period of 5 days. Traps were hauled; catch recorded, re-baited and reset if they were sampling more than 20 Pandalus species. If the catch contained no more than 20 shrimp, trawls were relocated to another suitable muddy bottom location within 1 mile of the original set location. Upon retrieval, the temperature logger was downloaded and reset. Traps were re-baited and all by-catch was identified, measured by carapace width for crustaceans and by total length for finfish species in centimeters. All by-catch was returned back to the water alive. A total of the shrimp catch was weighed and a sub-sample of ½ kg was retained for lab carapace measurement. Lab processing consisted of carapace length measurements (mm) and identification to species. Carapace measurements are from the notch of the right eye socket down parallel to the end of the carapace in millimeters.

To compare the amount of shrimp catch between trap types, catch was standardized by dividing numbers caught by the length of time that the trap was in the water (CPUE). Individual comparisons of mean shrimp carapace length by trap type per set period were analyzed with ANOVA. To reduce the effect of trap location and set date, the entire data set was analyzed with ANOVA similar to the individual trials. Dunnett's tests were used to determine which of the two types were most different from the control.

Distributions of bycatch standard lengths (cm) were examined between trap types. Bycatch was also standardized with CPUE for determination of which trap was most efficient at reducing bycatch.

RESULTS

Traps were set between the dates of June 26, 2005 and October 19, 2005 and the average temperature for the set period ranged from 5.99 - 7.05 ˚C (Table 1).

Catch per unit of effort of shrimp, increased from the beginning of the set dates to the end of the experiment in October (Figure 3). The greatest catch was from the control type during the period September 22, 2005 – October 10, 2005. There were 9 species of shrimp sampled in all the traps. The most abundant species sampled were *Dichelopandalus leptocerus* and *Pandalus montagui*. *D. leptocerus* contributed greater than 60% and *P. montagui* contributed greater than 10% of the total catch in all the trap types (Figure 4). *D. leptocerus, P. montagui* and *P. borealis* were the species that had the largest carapace length (mm) for all the trap types. *D. leptocerus* and *P. montagui* had the greatest size distribution than the other species in all the trap types (Figure 5). Smallest shrimp were retained by the wire trap type with an unidentified *Lebbeus* carapace measurement as small as

2.88 cm. The largest shrimp retained in the traps was a *Pandalus borealis* with CL of 20.12 mm (Table 2).

Distributions of compiled shrimp carapace length measurement data per trap type showed that overall the control type had the largest mean length of 13.05 mm with the narrow and wire mean lengths at 12.97 mm and 10.50 mm respectively. Standard deviations of the length measurements of the control, narrow and wire catch were 2.64, 2.75 and 2.43, respectively. The wire trap type had the greatest average carapace length difference from the control (ANOVA, $p < 0.0001$) (Figure 6).

Comparisons shrimp carapace lengths for each trap type by sampling period (6 sampling periods) had varying results with the wire and narrow types sampling significantly different sized shrimp than the control type (Table 2). Shrimp catch per unit effort by day soak time (CPUE) was not significantly different between the different types of traps (Wilcoxon sum of ranks test, $p=0.8948$) (Figure 8).

Bycatch consisted of crustaceans such as lobsters (*Homerus americanus*) and crabs (*Cancer irroratus)* and finfish species such as cunner (*Tautogolabrus adspersus*). Cunner and crabs were the most dominant bycatch in all the trap types (Figure 9). When the data was standardized by CPUE it is evident the control trap caught the greatest total of bycatch species versus the narrow and the wire types (Chi Square $p > 0.0206$) (Figure 10 and 11). Of the experimental types, the wire type caught the lesser amount of bycatch by 95%.

DISCUSSION:

A juvenile *Pandalus borealis* trap should be efficient at attracting and retaining younger shrimp. The traps should be proficient at excluding commercially important bycatch, such as lobsters, and capable of excluding the bycatch that will enter and consume all trapped shrimp.

Lastly, the traps should be a cost efficient sampling tool. Our results indicate that the wire covered vent type was the most efficient at capturing small Pandalid species and at excluding bycatch.

The three vent designs tested were alterations of the traditional vent used in local Northern shrimp fisheries, the "V-trough" vent. Traditionally, the commercial shrimp traps are constructed in dimensions of 36" x 21" x 13.5" of a mesh wire that is 1" x ½" , no escape vents and with the V-trough with a 1 ¼ " opening installed in the top of the trap. The juvenile traps were created from lobster wire which is slightly wider and then lined to retain anything larger than the 1 x 1 ½" cm mesh. This was to ensure that the smallest settling juvenile, ~ 7 cm, would be retained by the trap (Schumway 1985). Our original proposal called for the testing of the lining material's effectiveness in retaining the juveniles in a tank at UNH. However, we were unable to raise an adequate number of juveniles to test the liner in the lab. Fortunately, a corresponding 2005 Northeast Development Project by Principle Investigator Kelo Pinkham, tested the effectiveness of the same liner in retaining smaller shrimp in Boothbay Harbor, ME. Our observations indicate that the liner is capable of retaining shrimp as small as 2.88 cm which is adequate for juvenile *P. borealis*. Unfortunately, the majority of the catch for this experiment was not our target species, *Pandalus borealis*. Whether these traps work for juvenile *P. borealis* will be confronted in the 2007 funding for the further development of this survey tool.

During individual comparisons for each set period, both the wire and the narrow vent style were more efficient at capturing smaller shrimp than the control. However, the results were not consistent between sampling periods (Table 3). There is a great deal of variability between experimental set periods that may be due to the changing locations between trap sets, the difference in the seasonal behavior of the juvenile shrimp and the difference in behavior from the increasing temperatures (Table 1) (Apollonio 1986). Once the length data was pooled (Figure 6 & 7) it became

evident the wire openings were the most effective at retaining smaller shrimp. It is possible that the wire covering prevented the larger shrimp from entering due to their long rostrums.

Juvenile traps are intended to catch a representative sample of the surrounding area shrimp population within the area of bait attractiveness. Our original proposal intended to sample the surrounding population with a non-selective sampling gear such as a beam trawl net. That population abundance estimate from the trawl would then be used to compare what the traps were sampling to determine their efficacy. We indeed did utilize a beam trawl but it was lost at sea on the first day of deployment. However, we did get it back a few months later with the help of Klein Sidescan Sonar and University divers. It was decided to go ahead without the population estimate from the beam trawl for the first experimental set because it was still possible to test how well the traps sampled by examining the general catch between the trap types. We utilized the beam trawl for the second experimental set but found the juveniles were too deep to set the traps in their exact location. The juveniles appeared to be located too far offshore by October. Ideally sampling should occur at the onset of juvenile settlement in May.

Another important feature of the juvenile trap is that the vent should not bias the sampling rate of the trap. Average catch per unit effort between the experimental vents and the control were not significantly different, ensuring that the different vent styles were sampling at a similar rate.

The most dominant bycatch species for all the trap types were cunner (*Tautogolabrus adspersus*) and rock crabs (*Cancer irroratus*) (Table 4 and Figure 9). When the CPUE of bycatch was compared between trap types it was evident that the wire vent was most effective at reducing bycatch (Figure 8 & 11). Reduction of bycatch is important because bycatch or unwanted species can act as predators inside the trap, hence altering the sample. Species such as cunner and rock crab entered the trap and consumed the trapped shrimp. Examination of the cunner stomach contents confirmed this observation and rock crabs were observed with remains of shrimp. Any altering of

the catch, such as predation inside the trap, would bias the estimated abundance of shrimp. The narrow vent allowed some of the medium and smaller sized cunner to enter the trap. That type of vent is apparently not effective in excluding a laterally compressed shaped fish such as cunner.

In conclusion, our results indicate that the wire covered V-trough vent is the most effective at retaining smaller shrimp species and in the reduction of bycatch/predators. The next steps will be to ensure that the traps are efficient at sampling *Pandalus borealis* in particular and that they effectively represent the surrounding shrimp population. We have submitted and been awarded funding for the next steps in creating this survey tool.

This survey tool will serve two primary functions: development of a juvenile index necessary for the longevity of the fishery and to provide a tool that will effectively sample this early life history stage that will lead to greater understanding of the recruitment dynamics (Richards 1996). Preliminary results of Gulf of Maine water circulation modeling suggest that the larvae that are likely to be retained and therefore recruited are those that end up in the very inshore environments. Is the inshore where most of the juveniles are located? When and at what size would they start to move further offshore? What is the influence of bottom temperature on juvenile distribution, growth and migration patterns? By informing managers of conditions that are beneficial for optimal growth and distribution, answers to these questions would be most helpful to the development of an efficient fishery. A juvenile shrimp trap would help to fill in this "black box" of juvenile shrimp stages.

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A valuable scientific collaboration was made with Bradford Parady during this project. Bradford played a key role in trap development/construction and his knowledge of the local benthic topography made setting the traps in preferred habitat possible. Bradford's knowledge of the local waters made the second time we used the beam trawl a success.

Future Research Recommendations:

The wire-covered vent trap showed promising results in its ability to retain smaller shrimp and exclude bycatch. However, we must demonstrate those same results with the target species *P. borealis*. An estimate from a trawl net that yields abundance of shrimp per swept area must be compared to the trap catch to determine the efficiency of the trap in attracting and retaining juveniles. During previous trap studies it was discovered that a predator often times will position itself on the top of the trap to consume shrimp as they approach (pers. comm. Dr. Pingguo He). A camera should be used to observe the trap while it fishes to see if any predators linger and to observe shrimp behavior. Lobsters are known to enter and exit a trap at will (Watson 2001); do shrimp exhibit the same behavior? Rates of saturation for the traps must also be determined; is there a minimum time that the traps should be allowed to fish in order to accumulate the most representative catch? These research questions have already been funded for 2007 by Northeast Consortium.

Table 1: Set date, haul date, and soak time; average temperature and Latitude and Longitude for each trial period of trap testing.

Set date	Haul date	Soak time (days)	Trawl ID	Average temp (˚C)	Latitude (N)	Longitude (W)
6/26/2005	6/29/2005	3	626_629	n/d	N43 03.916	W70 34.180
6/29/2005	7/5/2005	6	629_705	5.99	N43 03.916	W70 34.180
7/5/2005	7/11/2005	6	705_711	6.17	N43 03.916	W70 34.180
9/22/2005	9/28/2005	6	922_928	n/d	N43 01.931	W70 29.700
9/28/2005	10/5/2005	7	928_105	6.23	N43 01.931	W70 29.700
10/5/2005	10/19/2005	14	105_1019	7.05	N43 00.827	W70 29.772

Table 2: Minimum and maximum length measurements for each species sampled

Species	Minimum (CL (mm))	Maximum (CL (mm))
B. payeri	7.12	9.38
D. leptocerus	3.02	20.05
E. fabricii	3.85	10.23
L. groenlandicus	5.42	12.35
L. microceros	3.89	7.26
L. polaris	3.69	12.44
Lebbeus UNK	2.88	4.57
P. borealis	7.02	20.12
P. montagui	4.6	19.04

Table 3: Comparisons of mean shrimp carapace length (mm) measurements between trap types per sampling period. P-values with an asterisk are significant values.

Sample date	Comparison	Level	Dunnett's LSD Positive values= significant difference	P-value
06/29/05	Control/Narrow	Control Narrow	t- test	0.0009*
07/05/2005	Control/Narrow/Wire	Control Narrow Wire	-1.240 0.452 -0.360	1.0000 0.0030* 0.2365
07/11/05	Control/Narrow/Wire	Control Narrow Wire	-1.220 0.298 -0.290	1.0000 0.0079* 0.1956
09/28/05	Control/Narrow/Wire	Control Narrow Wire	-0.340 0.760 1.283	1.0000 <0.0001* <0.0001*
10/05/2005	Control/Narrow/Wire	Control Narrow Wire	-0.350 0.557 3.272	1.0000 <0.0001* <0.0001*
10/19/2005	Control/Narrow/Wire	Control Narrow Wire	-0.410 -0.370 2.035	1.0000 0.9631 <0.0001*

Table 4: Total count of bycatch by species per trap type.

	Trap Type		
Species	control	narrow	w ire
Cancer irroratus	391	6	3
deep red spider crab	1	0	0
Gadus morhua	2	1	0
Homerus americanus	39	0	5
Mahogany clams	6	0	0
Melanogrammus aeglefinus	0	0	1
Myxine glutinosa	4	0	0
Sebastes fasciatus	5	4	0
starfish	1	0	4
Tautogolabrus adspersus	118	45	7
Urophycis chuss	11	0	0
w helk	26	7	23
Total Bycatch per Trap	604	63	43

Table 5: Nonparametric test results for bycatch CPUE by trap type.

Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
control	73	4087.00	55.9863	2.782
narrow	11	416.500	37.8636	-1.584
wire	17	647.500	38.0882	-2.005

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
7.7618	2	0.0206

Figure 1: The following pictures are of the vent's that were constructed with different entry opening sizes and one was a large entry but with the wire continuous across the top of the vent.

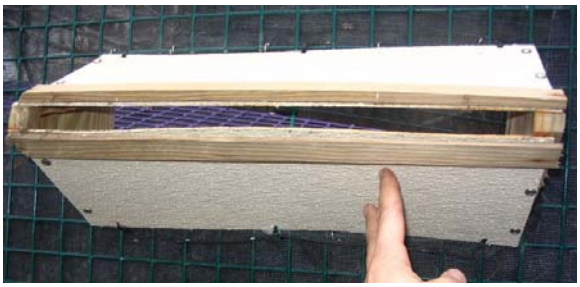
Top view of the Narrow type vent:	Side view of a vent mounted in top panel of trap:
End view of the "V-trough" style vent:	Bottom or inside of trap view of the narrow type vent: 

Figure 2: Locations of traps for both deployment periods. First deployment was from June 26, 2005 – July 11, 2005 and second deployment was from August 22, 2005 – October 19, 2005.

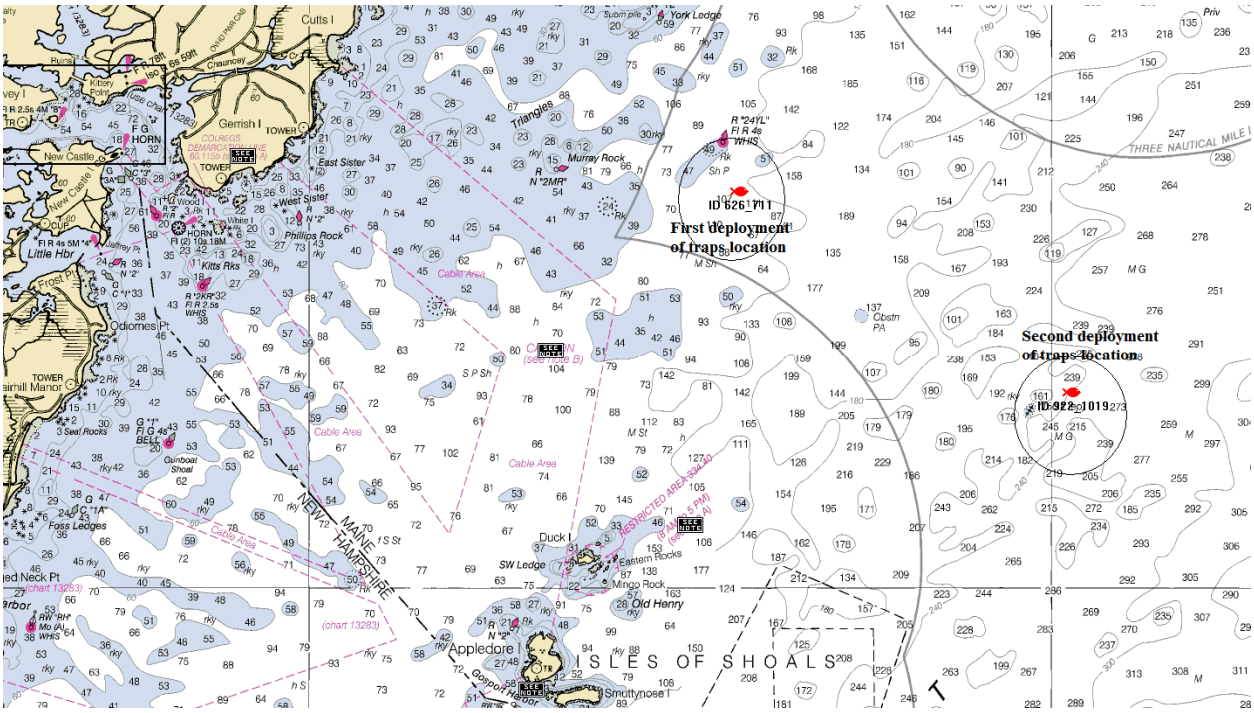


Figure 3: Average catch per unit effort (CPUE) of shrimp species sampled per trap type at each sampling period.

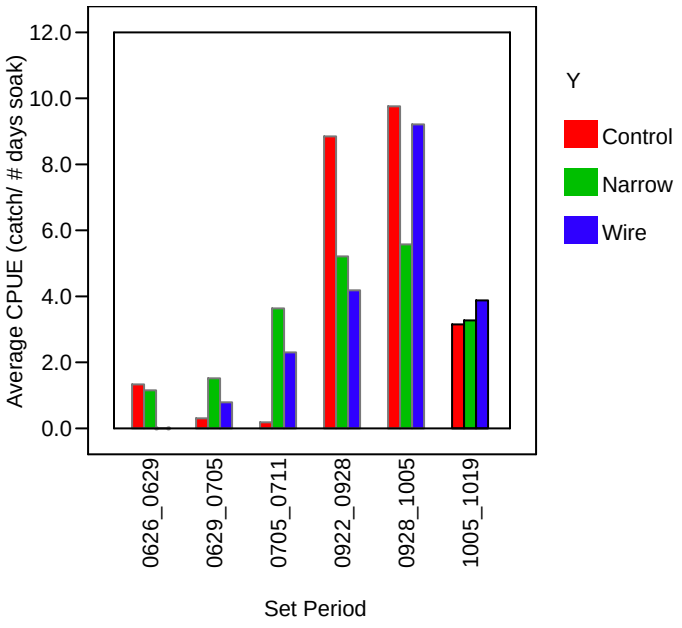


Figure 4: Percent of total shrimp catch contribution by species for each trap type.

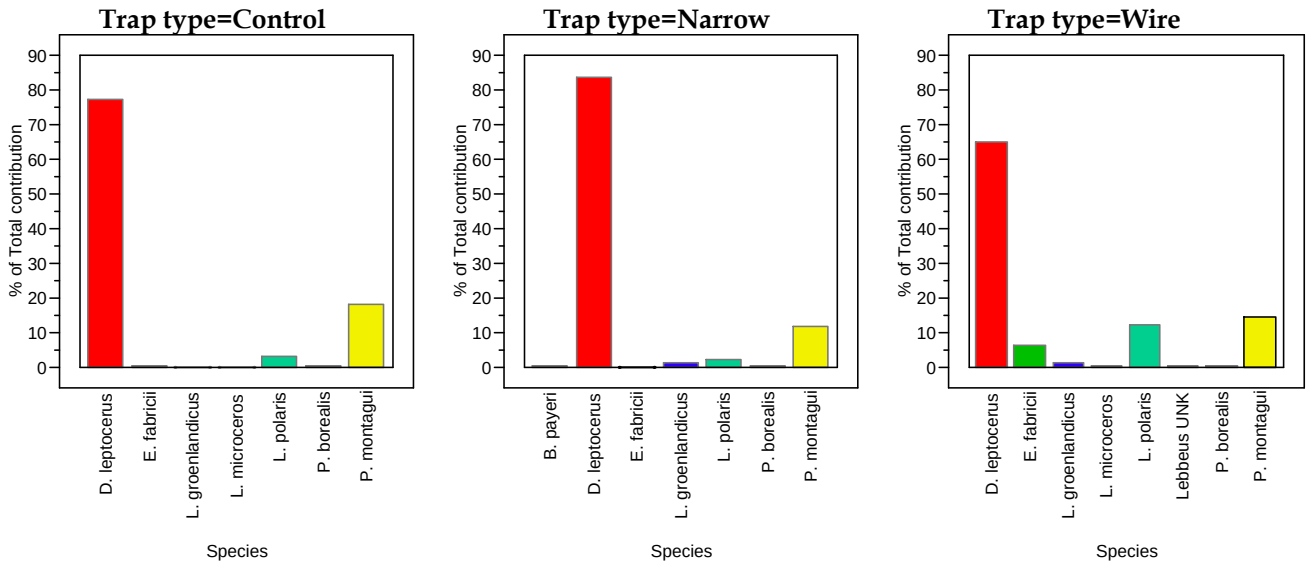


Figure 5: Carapace length measurements for each species sampled by each trap type.

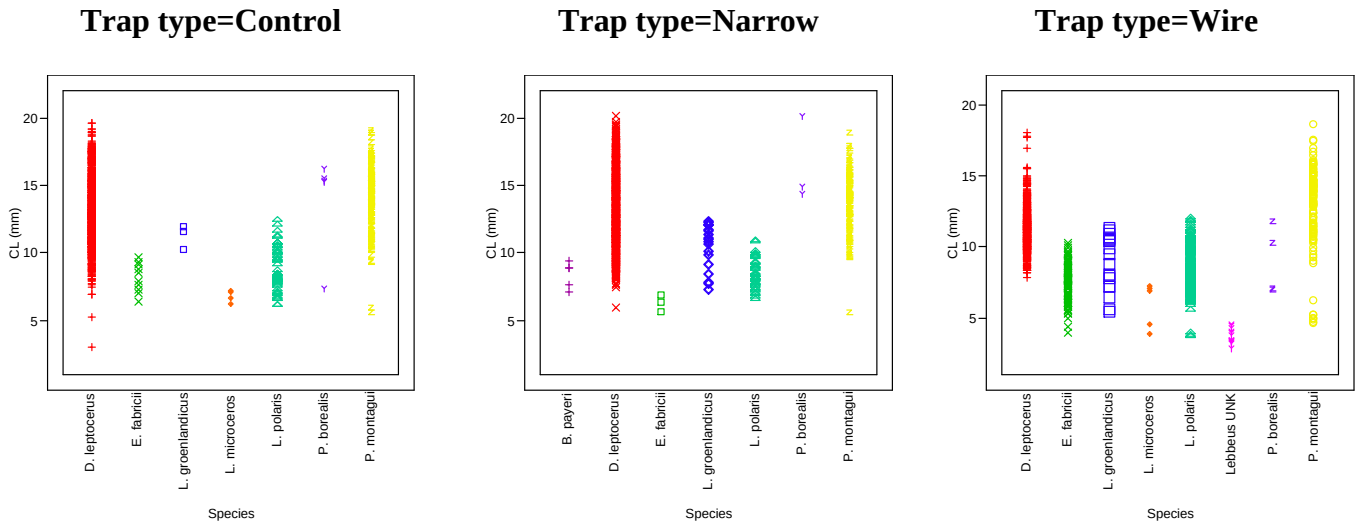
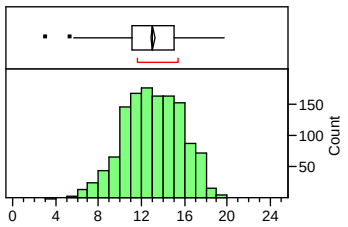


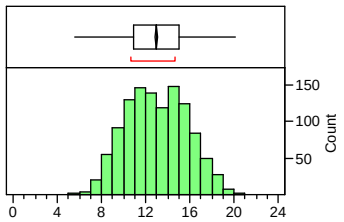
Figure 6: Distributions and statistics of carapace length (mm) measurements of total shrimp catch per trap type for June-October, 2005.

Trap type= Control
CL (mm)



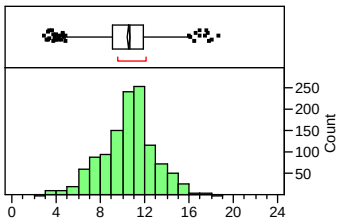
Mean	13.05
Std Dev	2.64
Std Err Mean	0.073
upper 95% Mean	13.19
lower 95% Mean	12.90
N	1303

Type= Narrow
CL (mm)



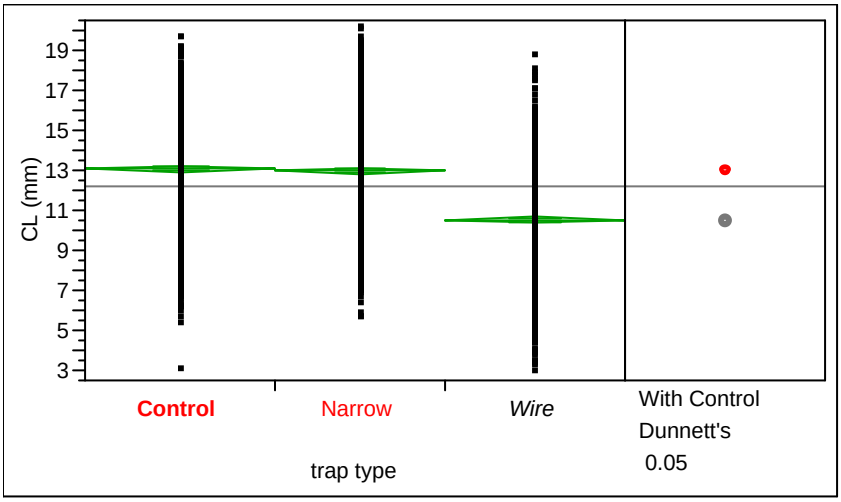
Mean	12.97
Std Dev	2.75
Std Err Mean	0.08
upper 95% Mean	13.13
lower 95% Mean	12.81
N	1159

Trap type= Wire
CL (mm)



Mean	10.50
Std Dev	2.43
Std Err Mean	0.06
upper 95% Mean	10.64
lower 95% Mean	10.37
N	1229

Figure 7: Carapace length (mm) data for all shrimp species per trap vent type. The green lines are confidence interval diamonds that are very shallow due to the large amount of data. ANOVA results from the Dunnett's test of all shrimp carapace lengths by trap type is demonstrated by the red and gray circles to the right; red circle and text means those types are not significantly different and gray means that vent type is significantly different. Distance between the circles indicates magnitude of significance.



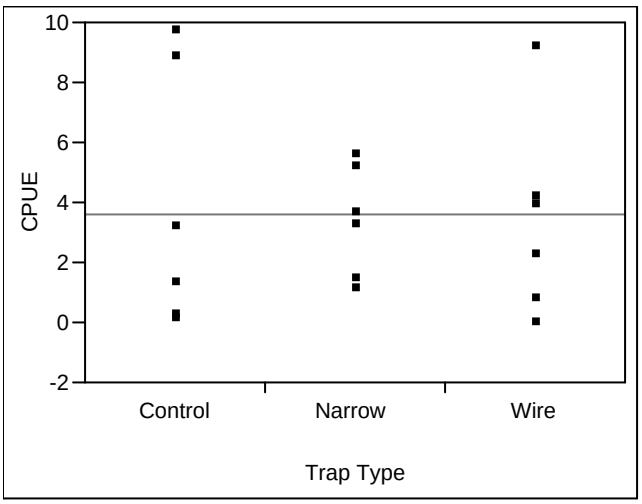
Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
trap type	2	5160.647	2580.32	377.914	<.0001
Error	3688	25180.658	6.83		
C. Total	3690	30341.305			

Comparisons with a control using Dunnett's Method

Level	Abs(Dif)-LSD	p-Value
Control	-0.23	1.0000
Narrow	-0.16	0.7008
Wire	2.313	<.0001

Figure 8: Oneway analysis of all shrimp CPUE by trap type



Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
Control	6	54.000	9.0000	-0.234
Narrow	6	62.000	10.3333	0.421
Wire	6	55.000	9.1667	-0.140

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
0.2222	2	0.8948

Figure 9: Average CPUE of bycatch species for each trap type.

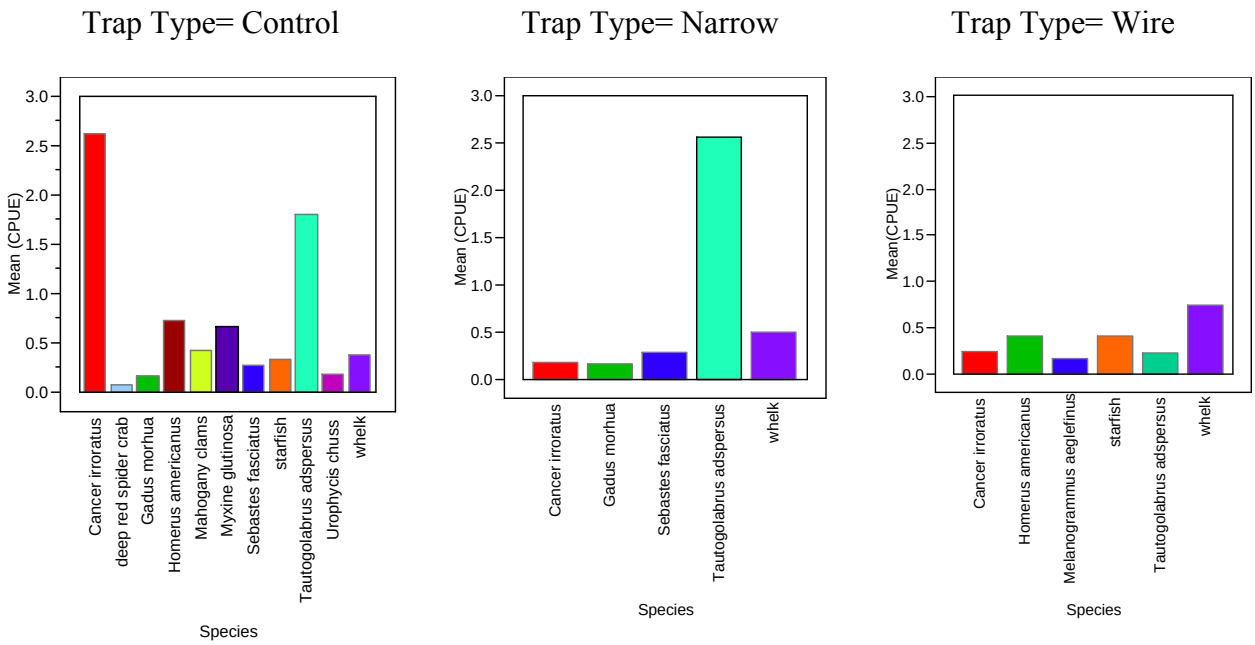


Figure 10: Total Bycatch CPUE per trap type

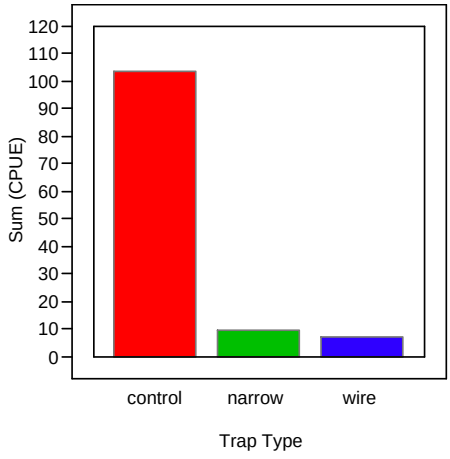
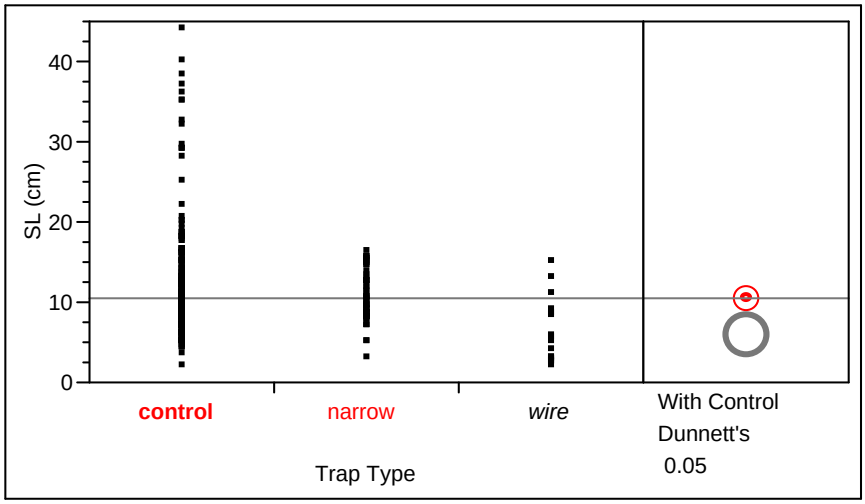


Figure 11: Oneway analysis of standard length of bycatch by trap type. Differences between levels were analyzed with Wilcoxon Rank Sum and Dunnetts test.



1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
17.7826	2	0.0001

Comparisons with a control using Dunnett's Method

Control Group = control

|d|	Alpha
2.24136	0.05

Level	Abs(Dif)-LSD	p-Value
control	-0.61	1.0000
narrow	-1.34	0.9806
wire	1.978	0.0002

Positive values show pairs of means that are significantly different.

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