Alternative Fishing Opportunities for White Shrimp and Menhaden: Testing the Efficiency of the Lampara Seine

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Abstract

Fisheries management restrictions in North Carolina have led to a loss of fishing opportunities for participants in multiple fisheries. Restrictions are often the result of bycatch or benthic habitat disturbance from certain gears. The promotion of alternative fishing gears can be an effective strategy to prevent economic loss from viable fisheries that are subject to increased regulation. This study examines the lampara seine as an alternative gear for harvesting white shrimp and Atlantic menhaden in estuarine waters of NC. The lampara seine is fished by actively locating aggregations of the target species, encircling the catch, and then retrieving the seine with a net reel. Twenty-two lampara seine hauls were conducted in the White Oak River estuary in 2013 and 2014. Among hauls that targeted white shrimp, the average shrimp catch was 12.9 kg. Bycatch was relatively low with this gear and 79% of the catch by weight was white shrimp. After omitting a single outlier haul, the weight ratio of bycatch to shrimp was 0.3:1. Further, this gear did not strongly impact the bottom. Despite successful hauls that targeted shrimp, the lampara seine was not effective at catching menhaden; in deeper water fish were able to easily escape the net after being encircled. The lampara seine could be a valuable alternative shrimp fishing gear for people that are temporarily displaced from other fisheries due to gear restrictions. This gear can be fished using most vessels that are equipped to perform gill netting or strike netting.

Introduction

The commercial fisheries of North Carolina are economically and culturally important to the coastal regions of the state. In recent years, the commercial fishing industry of NC has employed around 7000 people annually, and has had a total economic impact of 300 million dollars annually (North Carolina Division of Marine Fisheries, License and Statistics 2014). However, the number of standard commercial fishing licenses that have been issued each year has declined by over 20% in the last fifteen years. Further, the number of commercial licenses actually used each year is around half the amount observed in the mid 1990s. As a result, there has been a gradual loss of jobs from the commercial fishing sector.

One reason for declining commercial fishing participation is an increase in gear restrictions on many fisheries. Restrictions are typically enacted to protect sensitive estuarine habitats from potentially destructive gear, or they result from bycatch considerations. Bycatch results from non-selective gear, and is commonly defined as the portion of catch that is taken incidentally to the targeted species. Bycatch can be divided into discarded catch or incidental catch. Discarded catch is returned to the water due to size limits, species restrictions, or a lack of marketability. Incidental catch is non-target catch that is kept for consumption or selling. Bycatch considerations have led to major fishery restrictions in recent years. For example, estuarine large-mesh gill net fishers have faced a great deal of spatial and temporal closures, along with gear restrictions, due to bycatch of sea turtles and occasionally red drum (e.g., NC Division of Marine Fisheries, Proclamation M-36-2014; http://portal.ncdenr.org/web/mf/proclamation-m-36-2014).

Some fisheries are managed largely to minimize bycatch, an example of this is the commercial shrimp industry in NC. This is because shrimp are an annual species and stocks are resistant to overfishing (Amendment 1, NC shrimp fishery management plan 2014). The NC fishery management plan for shrimp is currently being amended due to concern over bycatch, which has been expressed by special interest groups and the general public. Over 90% of the annual shrimp catch comes from bottom trawls, which is a nonselective gear that impacts benthic habitats. Despite bycatch concerns, the shrimp fishery is the second most valuable fishery in NC (North Carolina Division of Marine Fisheries, License and Statistics 2014). Therefore, the Division of Marine Fisheries is considering many possibilities for reducing bycatch, while minimizing economic loss from North Carolina's viable shrimp fishery.

One of the multiple management strategies used for the NC shrimp fishery is the promotion of alternative fishing gears (Amendment 1, NC shrimp fishery management plan 2014). The promotion of alternative gears within a fishery can be beneficial in multiple ways. First, it can provide opportunities to a more diverse fishing community, particularly fishers who may be displaced from other fisheries due to management restrictions. Second, it can promote gear that is more environmentally sustainable and acceptable to other fisheries stakeholders. Third, it can mitigate against economic loss from a viable fishery, due to restrictions against other gears.

The lampara seine is a gear used in Florida, and it primarily targets halfbeaks and flyingfishes to be sold as bait (McBride and Styer 2002). This gear could be a valuable alternative gear in NC, because it is a selective gear with a low bycatch rate and it is designed to fish above the substrate, which results in a low level of benthic disturbance. While the lampara seine has traditionally been used to catch pelagic fishes in many parts of the world, there is evidence that suggests it might also be effective at targeting white shrimp *Litopenaeus setiferus*. White shrimp swim higher in the water column than brown or pink shrimp when disturbed (Coale et al. 1994). For example, skimmer trawls are a NC gear that take advantage of the behavior of white shrimp; while bottom trawls are more effective at catching brown shrimp, skimmer trawls fish higher in the water column and catch rates for white shrimp are four times greater than brown shrimp (Coale et al. 1994).

The purpose of this study was to evaluate the lampara seine in NC as a novel-alternative fishing gear for white shrimp, and also Atlantic menhaden *Brevoortia tyrannus*, which are a common pelagic fish that can be sold as bait. If effective, the lampara seine could serve multiple purposes for NC fisheries. First, it would provide a valuable alternative option to inshore fishers that have been temporarily displaced from other fisheries due to management restrictions. Second, it would help fulfill the goal of the shrimp fishery management plan to promote alternative gears that exhibit lower bycatch rates and reduced benthic disturbance (Amendment 1, NC shrimp fishery management plan 2014). Third, catches of menhaden would enhance local bait markets, because this fishery has largely been omitted from NC due to reasons of bycatch in large-scale purse seines (NC Division of Marine Fisheries, Proclamation M-25-2012; http://portal.ncdenr.org/web/mf/proclamation-m-25-2012).

Methods

Net specifications and fishing method

A modified lampara seine was constructed with a 101 m top line and a 91 m bottom line (Fig. 1). The entire net was made of #6 twisted poly netting, with 5/8 inch bar and

1.25 inch stretched mesh. The central portion of the net was 2.75 m in depth and consisted of a bag equipped with codend. The wings tapered to 0.6 m in depth at the ends. After the 2013 fishing season, the net was modified before being used in 2014. A triangular section was added to the base of the bag and the bottom line was shortened by 5 m to form a bottom-pan that increased retention, and each wing was extended by 27 m (Fig. 2). Due to the change in net specifications, data are presented separately for the 2013 and 2014 seasons.

Fishing was conducted aboard a 7.6 m "front-well" boat, with flat bottom and center-mounted motor; in year 2 a 6.4 m front-well boat was used. The net was fished using a technique similar to strike netting; aggregations of white shrimp or menhaden were observed at the water surface and encircled with the seine. While searching for aggregations, the net was contained in an open space at the stern, with the leading end on top, which was connected to a line containing a weight and float. The opposite-trailing end of the net remained attached to a net reel. To deploy the net, the weight was thrown overboard and the boat encircled an aggregation. The float was retrieved and the leading end of the net was attached to the net reel. Both wings were then retrieved in parallel. The body of the net opens up during retrieval and the lead lines of the wings are gradually brought together, which partially closes the bottom of the net. An online video is available showing a haul conducted with this study (https://www.youtube.com/watch?v=hbLlvTOyZkc).

Catch processing and analyses

All fishing was conducted within the White Oak River estuary, NC (Fig. 3). Five fishing trips that targeted white shrimp were conducted in 2013, between August 27 and September 1. In 2014, two trips were conducted that targeted menhaden, August 16 and 17, while thirteen trips between August 25 and October 4 targeted white shrimp. Catches were separated into three components: 1) target catch, which was shrimp or menhaden, 2) bycatch, which included all other fish and mobile invertebrates, and 3) benthic disturbance, which included mostly shell fragments and tunicates. Each component was weighed with a hanging-spring scale. Catches were enumerated by species and thirty individuals were measured for each species. For large catches of shrimp, numbers were estimated by counting a weighed subsample and then extrapolating with total shrimp weight. Temperature and depth were recorded for each haul. Depth was related to bycatch ratio and also weight of benthic disturbance using simple linear regression.

Results

Shrimp fishing

A total of 15 hauls were made that targeted shrimp in 2013, while only 4 were made in 2014. The lack of hauls in 2014 was due to a scarcity of shrimp aggregations. The net was generally most effective at lower tides, when shrimp were forced out of *Spartina* habitats. The boat would cruise marsh edge habitats. Large aggregations of white shrimp were clearly visible because individuals would break the surface when startled by boat noise or wake waves. Fisher experience and prior observations appeared to play an important role in searching for aggregations. Evidence of fisher experience can be seen when examining the haul locations, which were mostly clustered in a few productive areas (Fig. 3).

The catch-per-unit-effort (CPUE, expressed as average number of individuals caught per haul) of white shrimp was more than an order of magnitude greater than any bycatch species (Table 1). Thirty-one species of teleost fish were captured, but Atlantic menhaden and pinfish comprised 78% of the teleost catch by numbers. Six species of elasmobranch were captured, but CPUE values for these species were low. On four separate occasions a large individual ray was ejected from the net, prior to retrieving the bag, in order to prevent a loss of catch; the length of these individuals were estimated by sight and they were not incorporated into bycatch weight. Invertebrate bycatch, including blue crab and squid, was relatively low (Table 1).

Catch of white shrimp ranged from 0.05 to 29.7 kg, and average catch was 12.9 kg (Fig. 4). Weight of bycatch ranged from 0.4 to 11.2 kg, and average bycatch was 3.5 kg. Catch of white shrimp was significantly more variable than bycatch (variance test, F = 10.49, $p < 0.05$). The ratio of bycatch:shrimp by weight was typically below 0.6 (Fig. 5). One haul had an unusually high bycatch ratio of 60.0, which was due to the lowest catch of shrimp obtained during the study; this was also the first haul made. This outlier was removed from the regression analysis; there was no relationship between bycatch ratio and depth (slope = -0.09, SE = 0.67; t = -0.13, p = 0.90).

The size of white shrimp captured was variable, and the number of shrimp per pound ranged from 38 to 73, with an average of 51 (Fig. 6). White shrimp lengths ranged from 71 to 149 mm, with an average of 108.2 mm (Fig. 7).

Fishing was generally conducted over muddy bottom, adjacent to emergent *Spartina* grass beds. Water depth was on average 0.7 m. The net never became snagged on submerged structure during this study. No benthic disturbance material was collected in 10 out of the 19 hauls. For the remaining 9 hauls, between 0.1 and 1.0 kg of benthic material was collected, which typically consisted of dead-oyster shell or colonial tunicates. The average amount of benthic disturbance material was 0.25 kg, and the amount of benthic material was not related to depth of fishing (slope = 0.34, SE = 0.47; t = 0.71, p = 0.49).

The time required to fish the lampara seine was recorded for three hauls in 2013 and two in 2014. First, the average time required to fully deploy the net and secure both wings to the net reel for retrieval was 1 minute 45 seconds. This did not appear to be affected by the gear modification in 2014. Second, the average time required to fully fish the net, from the time when the weight was thrown overboard to when the catch was emptied from the codend into a collection basket, was 7 minutes 53 seconds in 2013, and 12 minutes 45 seconds with the modified-longer net in 2014.

Menhaden fishing

The lampara seine configured for this study was not effective at capturing adult menhaden in deeper water. Only three sets were made, each in water that was 6-7 feet deep (Fig. 3). Each of these sets successfully encircled a school of menhaden, and they were easily observable within the net. However, no menhaden were captured. Only a single bycatch fish was caught among the three menhaden hauls, a 130 mm false silverstripe halfbeak *Hyporhamphus meeki.*

Discussion

The method for shrimp fishing differs greatly between a lampara seine and the more common technique, which is bottom trawling. For example, bottom trawls are less selective about haul location and they sweep a much greater area compared to the lampara seine. Consequently, bottom trawls are capable of much larger catches. Despite differences between bottom trawls and alternative gears, such as the lampara seine, comparisons are an important step towards assessing a novel gear. Further, one of the strategies described in the amended fishery management plan for shrimp is to promote alternative fishing gears that have a lower environmental impact than bottom trawls (Amendment 1, NC shrimp fishery management plan 2014).

The weight ratios of bycatch to shrimp from lampara seine hauls were much lower than ratios observed from the NC bottom trawl shrimp fishery. There have been seven studies that have characterized the bycatch from NC bottom trawls and results have been variable (Amendment 1, NC shrimp fishery management plan 2014). Logothetis and McCuiston (2006) quantified bycatch in the southern region of the state and observed a bycatch ratio of 0.8:1. The tows examined contained an average of 55% shrimp by weight, which has been the lowest reported bycatch among NC studies. Conversely, Johnson (2003) estimated bycatch in Core Sound and the Neuse River and reported an average value of 5.7:1, and only 20% of the catch by weight was shrimp. The most recent and comprehensive work has been conducted by Brown (2009; 2010), which reported bycatch ratios of 3.4:1 in Pamlico Sound, and 3.8:1 in the southern region of NC. These two studies found that shrimp made up 21-23% of the catch by weight, suggesting that different regions of the state have a consistent bycatch rate. When the 19 lampara seine hauls from the present study are combined, 79% of the catch by weight was white shrimp. The average bycatch ratio from lampara seine hauls was 3.5:1, but if the single large outlier point is removed (haul #1) the ratio declines to 0.3:1.

The use of skimmer trawls as an alternative fishing gear has increased in NC since the early 1990s and they currently account for around 3% of the annual shrimp harvest (Amendment 1, NC shrimp fishery management plan 2014). Similar to the lampara seine, skimmer trawls target white shrimp by taking advantage of the more pelagic nature of this species. Less is known about bycatch with skimmer trawls, and published works consist of gear comparison studies rather than a direct examination of fisheries. However, available data suggest that the lampara seine compares favorably with skimmer trawls. Coale et al. (1994) compared bottom trawls with skimmer trawls by conducting paired tows in NC estuarine habitats. This study found skimmers to have a much lower bycatch ratio than bottom trawls when white shrimp were abundant; average bycatch ratios of 1.4:1 were reported when white shrimp catches were high (Coale et al. 1994). However, at other times the bycatch ratios were more similar between the two gears. The authors admitted that a paired comparison between the two gear types was difficult, given that the use of each gear differs in habitat, time of year, and species. Hines et al. (1999) also examined bycatch of skimmer trawls in NC and found a ratio of fish:shrimp of either 1.6:1 or 2.1:1, depending on the size of the net opening. However, this study was not conducted when white shrimp were abundant.

The bycatch ratio in lampara seine hauls was more strongly influenced by the catch of white shrimp than the catch of fish and other invertebrates. This is indicated by the significantly greater variance in shrimp catches when compared to bycatch. In other words, bycatch was relatively consistent, and hauls with higher bycatch ratios were typically the result of low shrimp catches as opposed to high catches of fish. Thus the ecological impact of this gear is probably dependent on the abundance of white shrimp in a region. Bycatch in a proposed lampara net fishery could be regulated with dynamic-spatial management, where regions are opened to fishing based on the abundance of white shrimp. A similar approach is used with the trawl-shrimp fishery in NC (North Carolina fishery management plan, shrimp 2006). However, this more intensive management strategy may not be necessary, as fishers may only use this gear when white shrimp are abundant. Multiple small catches with this gear may not be profitable because of the time required to perform a haul, which can be summarized in three steps. First, a complete set of the net takes up to 13 minutes. Second, once the catch has been obtained, it takes additional time to prepare the net for the next haul. Unfortunately the resetting time was not recorded in this study, but it was greater than 10 minutes. Third, the catch must be sorted. These three factors lead to a greater than 30 min time interval per haul. Further, as evidenced by the 2014 fishing season, low abundance of shrimp necessitates considerable searching time for aggregations.

In addition to having relatively low bycatch, discards from the lampara seine probably have a much greater chance of survival than discards from bottom trawls. Two previous studies have characterized discards from shrimp trawls in NC. Logothetis and McCuiston (2006) found that 55% of discards were either dead or appeared injured. Johnson (2003) found that 67% of discards were either dead or injured, but discard survival depended on species. For example, blue crab survival was 80%, while fish survival was only 11%. Compared to shrimp trawl tows, which may exceed two hours (Amendment 1, NC shrimp fishery management plan 2014), lampara hauls are short in duration. Further, caught individuals appear to have some freedom of movement up until the bag is brought onboard. Also, fish are much more energetic once emptied from the net compared to a bottom trawl (personal observation of the authors), which offers a longer timeframe to discard fish in a healthy condition. One critical aspect of reducing discard morality with the lampara seine is deciding if the catch is sorted before or after the seine is reset for the next haul. If the catch is sorted first, discard mortality will probably be low for many species. However, if the net is reset before the catch is sorted then a majority of the fish will probably not survive (personal observation of the authors). The high survivability of catches from the lampara seine make this an ideal gear for a live-shrimp bait fishery.

The species composition of the lampara seine bycatch was somewhat different than what has been described for the NC shrimp fishery. Bycatch from the trawl fishery has been well characterized and commonly consists of Atlantic croaker, spot, pinfish, weakfish, and blue crabs (Roelofs 1950; Diamond-Tissue 1999; Johnson 2003; Logothetis and McCuiston 2006; Brown 2009, 2010). Lampara seine bycatch was mostly young-of-the-year Atlantic menhaden and pinfish, but Atlantic croaker and spot were also common. The abundance of menhaden and pinfish in lampara catches may result from this net being fished in shallow water compared to bottom trawls. A majority of lampara bycatch was categorized as discards because fish were small and not marketable, or were sublegal, which is consistent with bycatch from the bottom trawl fishery (Logothetis and McCuiston 2006; Brown 2009, 2010). Discards of important NC recreational species were generally low, with the exception of Atlantic croaker and spot.

Disturbance to the bottom from the lampara seine when used for white shrimp did not appear to be intense. However, contact with the bottom was evident because benthic debris was collected in around half of the hauls, and small flounders such as bay whiffs were commonly caught. A majority of contact with the bottom is made in the central-bag region where the net is deepest. The wings of the seine have little contact because they are tapered and are also pulled up off the bottom during retrieval. The net was fished over unconsolidated muddy bottom and never showed evidence of digging into benthic sediment or becoming snagged during retrieval. A majority of hauls were made at low tide and in relatively shallow water, so oyster reefs were easily avoided. There was also no effect of depth on bycatch ratio or benthic disturbance. However, a limited range of depths were fished in this study, which limits the analysis of depth effects.

Shrimp fishing took place in 2013 and 2014 for this study, and the net was modified to improve the shrimp catch after the first year. However, we only had a limited ability to compare these two net designs because only four hauls were conducted in 2014. Compared to 2013, white shrimp aggregations were rare in 2014 and multiple trips were conducted where no aggregations were found. The lack of shrimp in 2014 was probably due to an extended period of heavy rain during August. Heavy rainfall is known to cause an early ocean migration of shrimp, because shrimp avoid lower salinities as they grow (Amendment 1, NC shrimp fishery management plan 2014). Despite only four hauls being conducted in 2014, some generalizations can be made about the modifications made to the net. First, the weight of bycatch per haul was similar with both net designs, suggesting that the larger net did not reduce the ability of fish to escape. Second, the modified net has potential to increase the white shrimp CPUE. For example, the shrimp aggregations we attempted to capture in 2014 were much smaller than 2013 based on the number of shrimp observed breaking the surface. Despite these smaller aggregations, two of the largest shrimp catches were obtained in 2014. Two small shrimp catches also were obtained in 2014, but these were visibly small aggregations that if observed in 2013 would have been ignored.

While the lampara seine commonly caught juvenile menhaden in shallow water, it was not effective at targeting larger-adult menhaden in deeper water. Adult menhaden were targeted near the Intercoastal Waterway. Schools of menhaden were successfully circled three times, but the fish were clearly able to swim under the net or escape under the boat. In Florida, lampara seines are used to capture halfbeaks and flyingfishes for selling as bait (McBride and Styer 2002). However, these types of fishes are strongly surface oriented and probably do not move to deeper water when threatened.

Impacts and Benefits

The lampara seine is a unique gear and provides a novel approach to shrimp fishing. This is because specific aggregations are targeted. As a result, individual hauls attempt to harvest shrimp from a very small area. Further, bycatch is greatly reduced by only setting the net in areas of high shrimp abundance. Conversely, a tow from a bottom trawl impacts a large area of benthic habitat to obtain a catch. If the approach used in this study had been to fish the net in randomly chosen areas, then the bycatch ratio would have probably been higher. However, the approach used reflected how this gear would actually be used; the selectivity in fishing locations is one of the primary advantages of the lampara seine.

Fishers that are most likely to use a lampara seine are those who operate from a smaller-multipurpose vessel and target different species throughout the year. The lampara seine can be effectively used on vessels that are equipped for gill netting or strike netting, which was the type of vessel used in the present study. Gill net fishers have been subject to increased management restrictions (e.g., NCDMF, Proclamation M-36-2014), and the number of trips taken with this gear in recent years has declined by around 37% since the late 1990s (North Carolina Division of Marine Fisheries, License and Statistics 2014). A primary advantage of the lampara seine to these fishers would be the ease of transferring a gear type, such as a gill net, for a lampara seine when white shrimp are observed to be abundant.

The vast majority of the annual shrimp catch is harvested with bottom trawls from deeper waters such as Pamlico Sound and the continental shelf (Amendment 1, NC shrimp fishery management plan 2014). An alternative gear such as the lampara seine could not replace the economic impact of the trawl fishery, but could have a significant regional impact. For example, channel nets and skimmer trawls are two existing alternative gears for shrimp fishing. The catch from these two gears had a combined economic value of over 1.2 million dollars in 2013 (North Carolina Division of Marine Fisheries, License and Statistics 2014). This study has shown that a lampara seine is another effective option for catching white shrimp with a relatively low amount of bycatch and bottom disturbance. Further, the sizes of shrimp caught in this study, expressed as number caught per pound, is similar to the 40-50 shrimp count that the NC DMF uses to open up southern regions of the state to bottom trawling (Amendment 1, NC shrimp fishery management plan 2014).

This study was an exploratory effort to assess the efficiency of the lampara seine. Thus, the scope of our study was limited, and we only fished in one estuarine system during two years. However, our results suggest that this gear is worth the attention of the NC Marine Fisheries Commission and the Division of Marine Fisheries. The most recent amendment draft to the shrimp fishery management plan (2014) states that, "The development of species specific gears such as shrimp pots, pounds and cast nets could reduce finfish bycatch, minimize environmental concerns and conflicts with other fisheries, and could be more cost-effective than trawling." The lampara seine would help achieve this goal of a more sustainable shrimp fishery, while also offering many inshore fishers a valuable alternative.

Extension of Results

The authors have promoted this study in multiple ways. First, a YouTube video was posted after the 2013 season (https://www.youtube.com/watch?v=hbLlvTOyZkc; also cited in Methods). The video has been viewed over 1300 times as of December, 2014. Second, biologists working for the Division of Marine Fisheries have been informed of this work. For example, Kevin Brown, a bycatch specialist for the NC shrimp fishery, came out on three fishing trips for this study. Third, the gear has been promoted by word of mouth to other NC fishers. Last, the authors are currently setting up an opportunity to present this work at a Marine Fisheries Commission meeting in 2015.

Students

No students participated with this project.

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Table 1. Summary of catch from 19 lampara seine fishing hauls that targeted white shrimp in the White Oak River estuary, North Carolina in 2013 and 2014. CPUE = catch per unit effort, represents the average catch in numbers per haul. Fork length measurements were used for fish, disc width for rays, carapace width for crabs, mantle length for squid, and rostrum to telson length for shrimp.

					Lengths			
Common name	**Scientific name**	**#caught**	**CPUE**	**CPUE (yr. 2)**	**Min**	**Max**	**Mean**	**St. Dev.**
Crustaceans and squid								
Blue crab	*Callinectes sapidus*	13	0.87	0.00	41	145	82.1	39.70
Mantis shrimp	*Squilla empusa*	2	0.13	0.00	80	96	88.0	
Squid	Unidentified	8	0.47	0.25	50	80	65.9	11.10
White shrimp	*Litopenaeus setiferus*	26653	1472.20	1142.50	71	149	108.5	12.17
Elasmobranchs								
Atlantic sharpnose	*Rhizoprionodon terraenovae*	2	0.13	0.00	295	360	327.5	
Atlantic stingray	*Dasyatis sabina*	1	0.07	0.00			280.0	
Bluntnose stingray*	*Dasyatis say*	2	0.07	0.25	400	450	425.0	
Cownose ray*	*Rhinoptera bonasus*	1	0.00	0.25			1000.0	
Roughtail stingray*	*Dasyatis centroura*	1	0.07	0.00			>1000	
Smooth butterfly ray*	*Gymnura micrura*	3	0.13	0.25	281	700	437.0	229.08
Teleost fishes								
Atlantic bumper	*Chloroscombrus chrysurus*	1	0.07	0.00			58.0	
Atlantic croaker	*Micropogonias undulatus*	178	10.60	4.75	101	260	142.1	26.38
Atlantic menhaden	*Brevoortia tyrannus*	1600	90.53	60.50	79	220	105.4	23.83
Atlantic moonfish	*Selene setapinnis*	3	0.20	0.00	44	55	50.0	5.57
Atlantic thread herring	*Opisthonema oglinum*	2	0.13	0.00	75	93	84.0	
Bay whiff	*Citharichthys spilopterus*	99	6.53	0.25	65	127	92.3	10.24
Blackcheek tonguefish	*Symphurus plagiusa*	1	0.07	0.00			95.0	
Bluefish	*Pomatomus saltatrix*	1	0.07	0.00			130.0	
Cobia	*Rachycentron canadum*	4	0.20	0.25	214	305	268.3	38.58
Crevalle jack	*Caranx hippos*	8	0.40	0.50	69	161	119.6	31.30
Fringed flounder	*Elops crossotus*	27	1.53	1.00	60	90	74.7	8.57
Gizzard shad	*Dorosoma cepedianum*	7	0.40	0.25	85	295	166.3	89.09
Gulf flounder	*Paralichthys albigutta*	1	0.07	0.00			223.0	
Inshore lizardfish	*Synodus foetens*	5	0.33	0.00	175	191	185.2	7.26

Table 1. *continued*

Common name	Scientific name	#caught	CPUE	CPUE (yr. 2)	Lengths			
					Min	Max	Mean	St. Dev.
Ladyfish	*Elops saurus*	8	0.53	0.00	226	277	252.3	18.54
Lookdown	*Selene vomer*	15	0.87	0.50	45	115	85.7	18.69
Mojarra	*Eucinostomus sp.*	2	0.07	0.25	75	75	75.0	
Oyster toadfish	*Opsanus tau*	1	0.07	0.00			115.0	
Pigfish	*Orthopristis chrysoptera*	59	3.80	0.13	65	217	106.2	41.04
Pinfish	*Lagodon rhomboides*	1032	49.73	71.50	33	186	79.9	19.89
Planehead filefish	*Stephanolepis hispidus*	2	0.13	0.00			93.0	
Red drum	*Sciaenops ocellatus*	3	0.13	0.25	242	500	337.3	141.57
Silver perch	*Bairdiella chrysoura*	29	1.67	1.00	88	208	128.9	36.21
Southern flounder	*Paralichthys lethostigma*	19	1.27	0.00	79	266	194.9	46.68
Spanish mackerel	*Scomberomorus maculatus*	1	0.07	0.00			158.0	
Speckled trout	*Cynoscion nebulosus*	1	0.07	0.00			130.0	
Spot	*Leiostomus xanthurus*	85	4.60	4.00	71	222	92.6	30.07
Striped mullet	*Mugil cephalus*	6	0.33	0.25	161	230	197.4	31.79
Tripletail	*Lobotes surinamensis*	1	0.07	0.00			290.0	
Weakfish	*Cynoscion regalis*	16	1.07	0.00	144	195	162.8	
White mullet	*Mugil curema*	138	7.27	7.25	85	150	114.3	9.01

**** largest individual for each of these species was released from net without landing, so length was estimated by sight.***

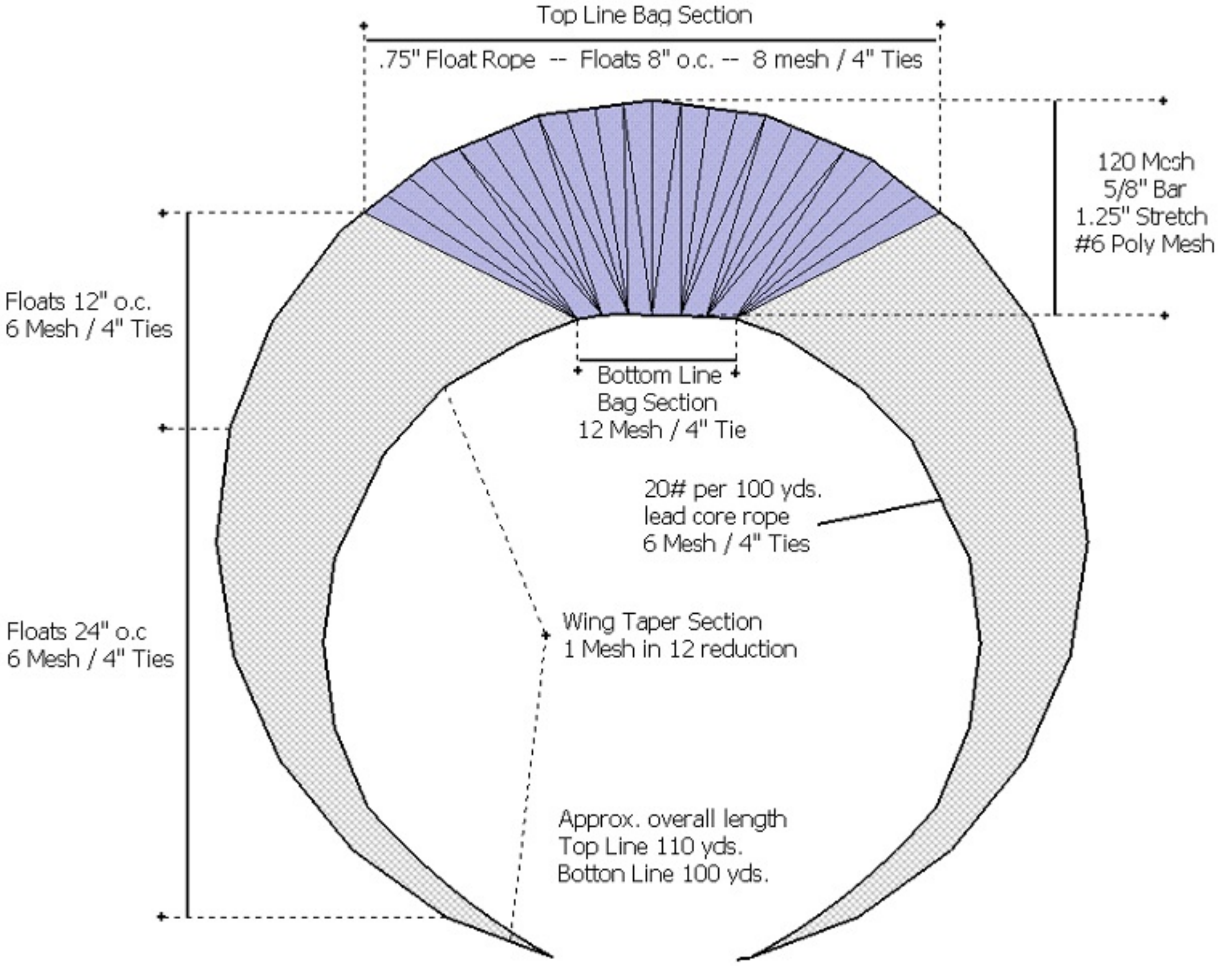

Figure 1. Net specifications for lampara seine used in 2013 for targeting white shrimp in the White Oak River estuary, North Carolina.

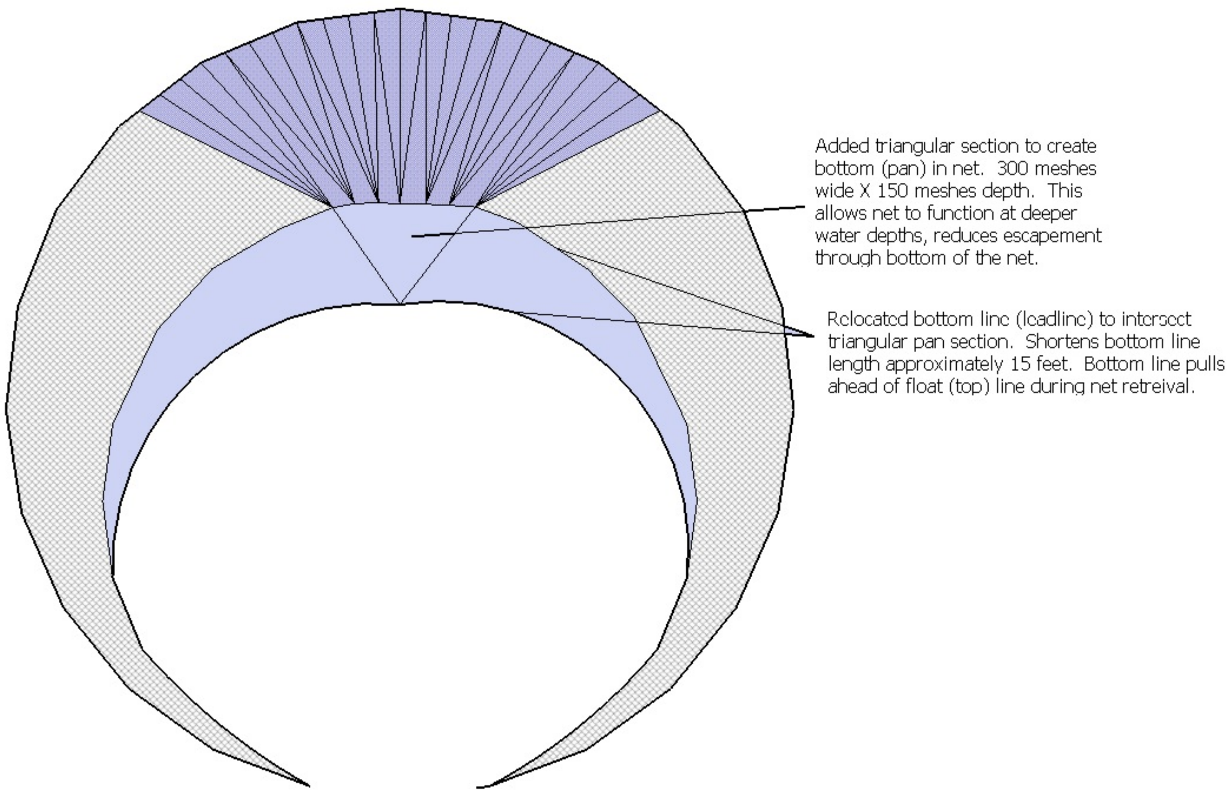

Figure 2. Net modifications for lampara seine used in 2014 for targeting white shrimp and Atlantic menhaden in the White Oak River estuary, North Carolina.

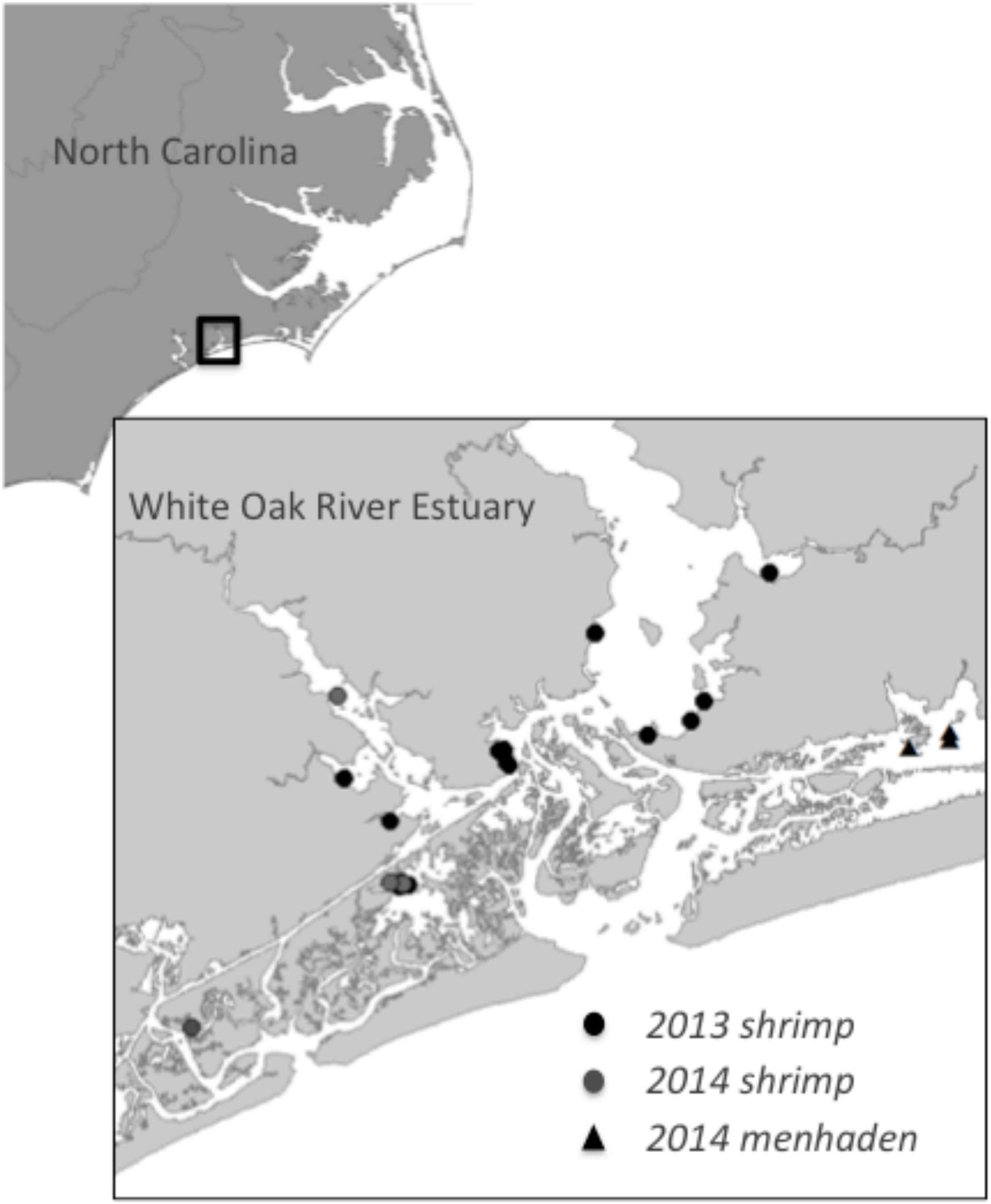

Figure 3. Fishing haul locations (*n* = 22) for a lampara seine within the White Oak River estuary, North Carolina. White shrimp were targeted in 2013 and 2014, and Atlantic menhaden were targeted in 2014. Note, multiple hauls in certain areas obscures some points.

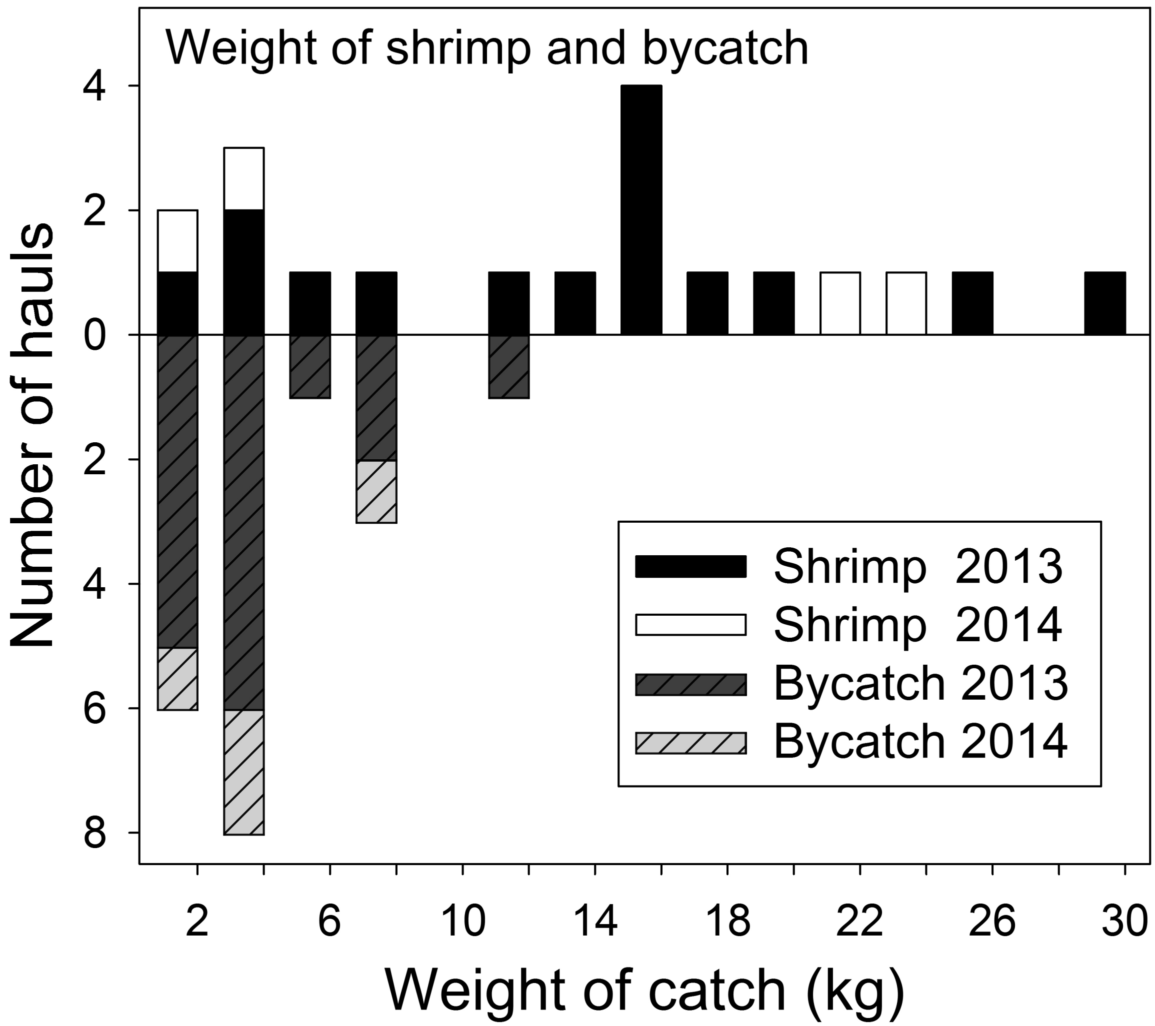

Figure 4. Weight of white shrimp catches and bycatch from 15 lampara seine hauls conducted in 2013 and 4 in 2014 within the White Oak River estuary, North Carolina.

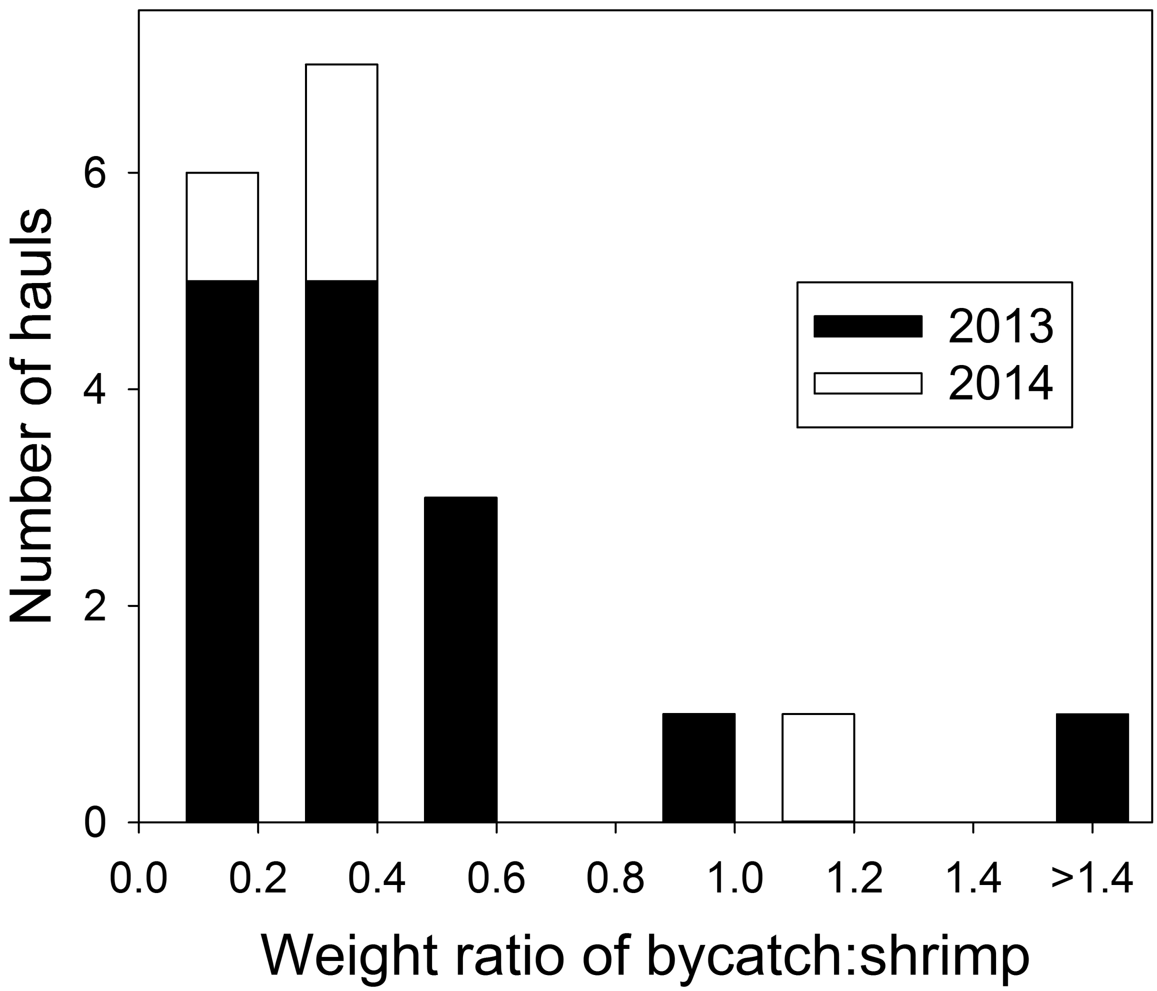

Figure 5. Weight ratios of bycatch to white shrimp from 15 lampara seine hauls conducted in 2013 and 4 in 2014 within the White Oak River estuary, North Carolina. Note, the haul that is indicated as having a bycatch:shrimp ratio that was >1.4 had a value of 60.0.

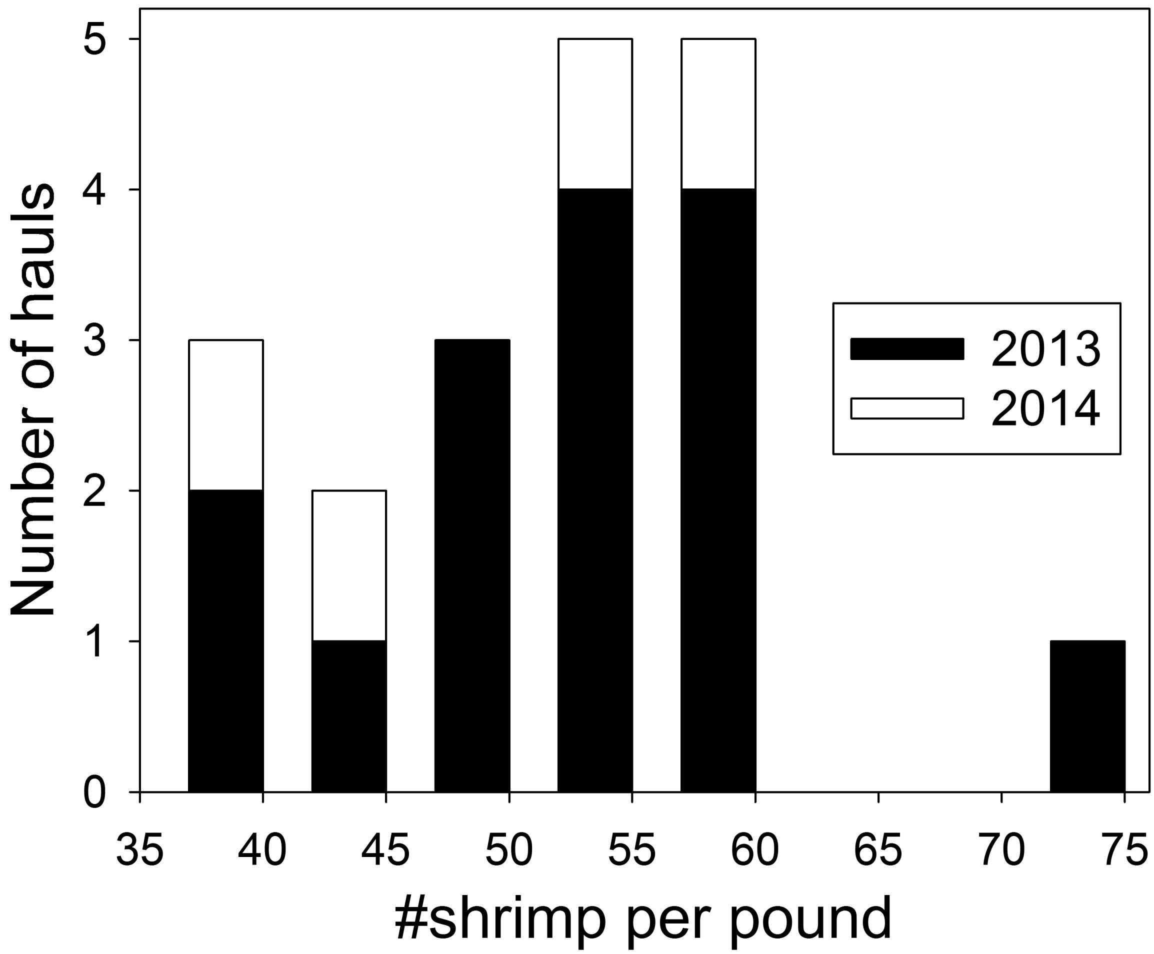

Figure 6. Number of white shrimp per pound from catches of 15 lampara seine hauls conducted in 2013 and 4 in 2014 within the White Oak River estuary, North Carolina.

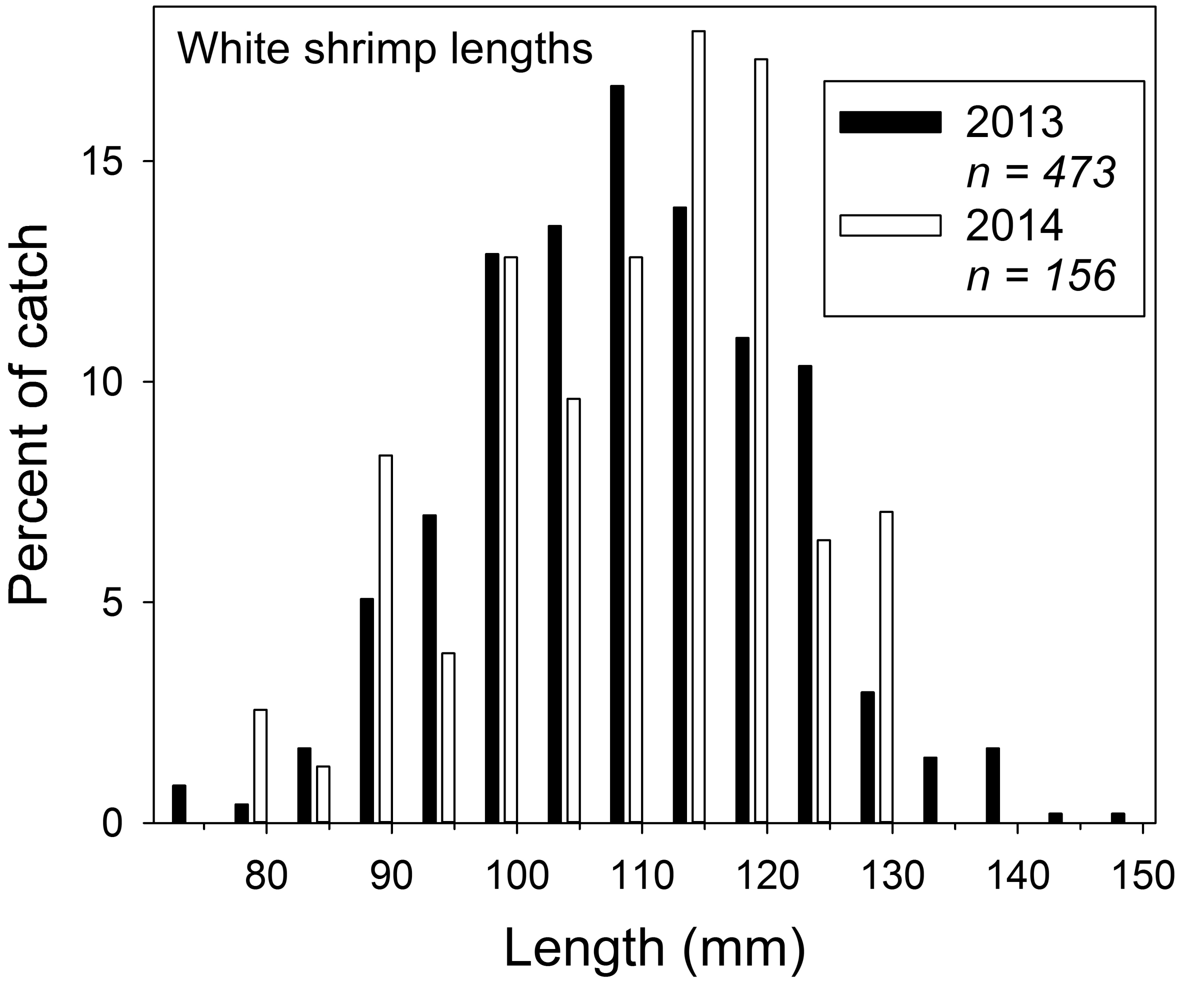

Figure 7. Lengths of white shrimp from 15 lampara seine hauls conducted in 2013 and 4 in 2014 within the White Oak River estuary, North Carolina. Lengths were measured from the anterior tip of the rostrum to the posterior end of the telson.