Design and Test of a Low Profile Gillnet to Reduce Atlantic Sturgeon and Sea Turtle Bycatch in Mid-Atlantic Monkfish Fishery

Final Report

Report title:	Design and Test of a Low Profile Gillnet to reduce Atlantic Sturgeon and Sea Turtle By-catch in Mid-Atlantic Monkfish Fishery
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This project was a collaboration of NOAA Fisheries Protected Species Branch (PSB), A.I.S Inc., the fishing industry, and UMass Dartmouth's School for Marine Science and Technology (SMAST). Henry Milliken of PSB provided general directions on the design of the experimental gillnets and the scope of the project. Rick Usher and his team at A.I.S. Inc. were responsible for vessel selection and contracting, observer coverage, at-sea data collection, and field logistics. Pingguo He and his team at SMAST provided advices on experimental designs and data collection, and were responsible for data entry, management, analysis, and drafting of this report. Sea trials were conducted on board two gillnet fishing vessels F/V "Landon Blake" and F/V "Risky Business" from the Mid-Atlantic region.

Design and Test of a Low Profile Gillnet to reduce Atlantic Sturgeon Bycatch in Mid-Atlantic Monkfish Fishery

Summary

This project was to test an experimental gillnet designed to reduce bycatch of Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*) and sea turtles while targeting monkfish (*Lophius americanus)* and winter skate *(Leucoraja ocellata*) in the inshore Mid-Atlantic region off Virginia and Maryland. The Experimental gillnets were 8 meshes deep with 24" tie-downs compared with commercial gillnets (Control) that were 12 meshes deep with 48" tie-downs. Two commercial fishing vessels, F/V "Landon Blake" and F/V "Risky Business", were contracted to do sea trials during May of 2013 with an A.I.S. Inc. observer on board each vessel to collect operational and biological data. The nets were fished in pairs; each pair of nets consisted of one control string (10 nets, 50 fm each net) and one experimental string of the same number and length. A pair of nets is set close to each other in location, set and hauled one after the other, with the same soak time, sea floor type, net direction, and other fishing ground features. Each vessel completed 50 hauls, 25 hauls of Control gillnets, and 25 hauls of Experimental nets. This provided 25 pairs of comparable hauls for each vessel. Seven Atlantic sturgeons were captured, all from the Control nets. The Experimental net significantly reduced bycatch of Atlantic sturgeon for each vessel independently and when both vessels' data were combined. The catch efficiency of the experimental nets for monkfish was inconsistent between the two vessels. There were no significant differences between the two types of nets from "Landon Blake" (p=0.60, paired t-test, two-tailed, dof=25), but the Experimental nets caught significantly less monkfish on the fishing vessel "Risky Business" (p=0.012, paired t-test, two-tailed, dof=25) and when both vessels' data were combined. The catch differences between the nets were particularly large when the catch rates were high. Length frequency and GLMM modeling indicate that the reduction in monkfish catch in "Risky Business" primarily resulted from a reduction in catch of monkfish that were less than 75 cm. There were no statistical differences in the catch of winter skate between the Control and the Experimental nets for either vessel, or when data for both vessels are combined (p>0.05).

1. Introduction

Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*) is an anadromous subspecies of sturgeon, spawning in river systems but growing and maturing in the sea. In the Northwest Atlantic, the species is widely distributed along the coast from Labrador in northern Canada to Florida in the southeast US.

In the US, the Atlantic States Marine Fisheries Commission (ASMFC) had managed Atlantic sturgeon from 1990 until populations of sturgeon were listed as "Endangered" or "Threatened" in 2012. The Atlantic Sturgeon Status Review Team (ASSRT) identified five Distinct Population Segments (DPSs) for the sturgeon population along the Atlantic Coast based on their biological, ecological, genetic, and migration/homing characteristics (ASSRT, 2007): 1) Gulf of Maine, 2) New York Bight, 3) Chesapeake Bay, 4) Carolinas, and 5) South Atlantic. The Gulf of Maine DSP was listed as "Threatened" while the other four DSPs were listed as "Endangered" under the Endangered Species Act (FR, 2012 a & b). Significant risks to the population of the Atlantic Sturgeon include: commercial fishing by-catch, water quality, vessel strikes, dredging and habitat impediments including locks and dams.

Bottom-set gillnets are recognized as the gear type that results in the most bycatch of Atlantic sturgeon and subsequent mortality. Between 1989 and 2000, gillnets targeting monkfish (goosefish, *Lophius americanus)* are reported to result in the largest amount of sturgeon bycatch 2000 *(*Stein et al., 2004; ASSRT, 2007, Miller and Shepard, 2011). Along the coast, bottom gillnet vessels that land fish in New Jersey, Delaware and Maryland had the highest sturgeon takes in relation to target species landed, especially during spring months (*ibid*).

Monkfish are distributed widely throughout the Northwest Atlantic, from the northern Gulf of St. Lawrence and Grand Bank of Newfoundland in Canada to Florida in the US. The fish primarily stick close to the benthos of all water depths from the tide line to as deep as 900 m. In the US, monkfish are primarily landed by bottom trawls (73% during 2000-2011) in the Northern Fishery Management Area (NFMA) north of Cape Cod, and by bottom gillnets (72% during 2000-2011) in the Southern Fishery Management Area (SFMA) south of Cape Cod (NOAA, 2013).

Gillnetting is one of the oldest fishing methods in the northeast US, dating back to mid-1800s, but the widespread use of gillnets coincided with the introduction of synthetic materials, especially monofilament in 1950s and 60s (He, 2006a; He and Pol, 2010). Efficient, durable and almost maintenance-free monofilament gillnets are suitable for many fish species from surface to midwater and bottom fisheries with mesh sizes that change to match the target fish sizes. Monkfish gillnets have large mesh sizes in order to target large bottom-dwelling monkfish.

Typical monkfish gillnets in the Atlantic Coast use 12” (305 mm) mesh size, and large twine sizes (e.g. 0.9 mm) to land large monkfish in varying sea conditions (Figure 1). A “standard” net is 300 feet long and 12 meshes deep. The webbing is typically hung onto a polypropylene (PP) head rope with a hanging ratio of 0.50. Tie-down nets are used for monkfish in both southern and northern management areas. Tie-down line (48” long every 4 fm along the length) reduces vertical height and results in a vertically curved net shape with extra webbing near the bottom. During commercial monkfish gillnet fishing, 10 to 20 nets are typically tied together to form a string or a fleet. A fishing vessel may fish several strings depending on vessel size, the number of crew, catch rates, and deck machinery.

Monkfish are believed to stay very close to the seabed. In an experiment comparing gillnets of different heights, He (2006b) found that catch rates for monkfish were very similar when 25-mesh, 12-mesh, or 8-mesh groundfish gillnets (6.5” mesh size) were used; however, tie-down nets caught more monkfish than regular “stand-up” gillnets. This indicates that lower profile gillnets than currently employed commercially (12 meshes deep) might be used without affecting the catch rate of monkfish.

Fox et al. (2011; 2012; 2013) tested monkfish gillnets of different configurations to reduce the bycatch of Atlantic sturgeon in the New York Bight. The first year project (Fox et al., 2011) compared gillnets with and without tie-downs (tie-down nets vs. stand-up nets), and found that stand-up nets had much lower monkfish catch rates but did not reduce sturgeon bycatch. The second year project (Fox et al., 2012) compared a 6-mesh low profile net with 24” tie-downs and the standard monkfish net, and found that both catch rates of sturgeon and monkfish were significantly reduced when using the 6-mesh nets. The third year project (Fox et al., 2013) increased the low profile gillnet to 8 meshes deep and compared with the same standard monkfish net. They did not find significant differences in the catch rates of sturgeon, nor those of target species – monkfish and winter skate (*Leucoraja ocellata*). They did find that the majority of sturgeons entangled in the nets (70%), were entangled in the top half of the net, suggesting that a lower profile net might be an effective means of reducing sturgeon bycatch. The results of the low profile gillnets not significantly reducing targeted monkfish and winter skate, along with the location of sturgeons caught in the nets are encouraging and provide rationales for further studies on lower profile nets for the fishery, especially during different seasons.

2. Project Goals and Objectives

The goal of the research was to reduce bycatch of Atlantic sturgeon and sea turtles in the Mid-Atlantic monkfish fishery through design and tests of an experimental low profile gillnet. Specific objectives were to:

- Design a low profile gillnet and compare with the commercial nets that Mid-Atlantic fishermen normally use to harvest monkfish, and
- Conduct sea trials in the Mid-Atlantic waters to test the experimental gear's effectiveness in retaining catches of the target species and reducing bycatch of sturgeon and sea turtles.

3. Research Methods

3.1 Gear design

The control nets were regular commercial monkfish gillnets used in the Mid-Atlantic region. They were 50 fm long, and 12 meshes deep, made of 0.90 mm diameter, 12" mesh size green nylon monofilament netting. The headrope was made of 3/8" polypropylene (PP) ropes with standard gillnet floats spaced at 12'. The footrope was made of 75 lbs per 600' lead line. Tie-down lines (48" in length) were spaced at 24' (Figure 1). The experimental gillnet was the same as the control net in terms of netting materials, headrope and footrope, but was 8 meshes deep instead of 12 meshes. In addition, tie-down lines in the experimental nets were spaced at 12', and were 24" in length instead of 48" spread at 24' (Figure 1). Therefore, the tie-down lines were at every float in the experimental nets while they were on every other float in the control nets. Each string of gear contained 10 nets of the same type (Control or Experimental). Each pair of nets contained one string of control net and one string of experimental net. Each vessel fished two pairs of gears. All Control and Experimental gillnets (including spare nets) were supplied by NOAA Fisheries.

3.2 Sea trials

Two commercial fishing vessels, F/V "Landon Blake" owned and operated by Thomas Danchise, and F/V "Risky Business" owned and operated by James Wescott, were contracted to do sea trials during May of 2013. The goal was to complete 25 pairs of hauls for each vessel. Both vessels were equipped with adequate machinery, permits and allocations to fish in the Mid-Atlantic monkfish fishery. Prior to signing the contracts and sea trials, the A.I.S. Project Manager inspected the vessels and a Vessel Suitability Report (VSR) was submitted to NOAA Contracting Office Representative (COR). The VSR is attached as Appendix 1.

"Landon Blake" is a 43' fiberglass vessel equipped with a 375 horsepower Caterpillar 3208 engine and has a 14' beam and a 4' draft. It has a 30" Crosley gillnet lifter and two net reel style haulers. "Risky Business" is a 45' fiberglass vessel equipped with a 640 horsepower Caterpillar engine with a 15' beam and a 4' draft. It has a 24" Crosley gillnet lifter and two net reel style haulers.

Prior to the data collection period, a meeting was held with all project participants. At the meeting, the scope of the project was reviewed and it was verified that all participants clearly understood sampling protocols and procedures. This facilitated the onboard data collection process. A tentative deployment calendar was developed with possible sail dates and data collector assignments. Prior to the start of gear deployment, the Project Manager (PM) met with each captain at his vessel. A NEFOP Pre-Trip Vessel Safety Checklist was completed for each vessel and certified that all of the safety equipment remained valid for the duration of the study.

One string of control gear was fished comparably with one string of experimental gear in pairs. Each string in the pair was set close to the other in location, with the same or similar soak time, sea floor type, and other fishing ground features and set in a similar direction. Fishing trials were conducted off the coast of Virginia and Maryland at depths between 14 and 20 fm. Fishing vessel skippers were allowed to choose fishing locations and soak time (1 to 3 days), but they were advised that each pair of nets be set in close proximity and with the same soak time. The exact fishing locations for each string can be seen in Table 1 and also plotted in Figure 2.

Both vessels began fishing on 05/02/2013. Usually two pairs of gear were hauled each day, weather permitting. “Landon Blake” finished 50 hauls (25 pairs) in 13 trips by 05/19/2013, while “Risky Business” finished the planned number of hauls in 15 trips by 05/23/2013.

3.3 Sampling and data collection

A.I.S. supplied each vessel with an at-sea observer (data collector) to sample, measure and record operational and biological data. Weather and current sea conditions, GPS locations, time/date deployed and hauled, and photographic documentation of the fishing process were recorded. Water temperature was measured by a thermometer at the water surface.

Catch and bycatch were quantified from each haul (each string of netting). Monkfish and winter skate were the dominant species. The bycatch species of primary concern were Atlantic sturgeon (no sea turtles were caught). Animals landed on board are noted in two deposition categories: “Kept” and “Discarded”. Monkfish, and other kept and discarded species from each haul were weighed to the nearest 0.1 lb using a Marel marine scale. All “Kept” monkfish were measured for their total lengths to the nearest cm and no sub-samples were taken. Legal sized fish permitted to land and in marketable condition were kept while sublegal fish, non-permitted, and non-marketable species were discarded after obtaining weights.

Atlantic sturgeon were measured (fork length and total length) and weighed when possible. Individuals were scanned for tags and released immediately if alive and in good condition. DNA samples (fin clips) were obtained for two Atlantic sturgeons that were released alive and for one deceased sturgeon that was discarded. Four other deceased sturgeons were kept (whole animal) and frozen for sampling per NOAA Fisheries directive. The position in the gillnet where sturgeons were captured was noted if possible, in terms of “shot” – the net number from the hauling end, the horizontal and vertical quarter in each net, as illustrated in Figure 3.

3.4 Cruise report

Weekly progress reports containing a summary of fishing effort and catch were composed and submitted to NOAA COR after the completion of each week's sea trials. The weekly reports kept the NOAA COR up to date on the progress so that potential problems could be discussed and resolved. The weekly progress reports are enclosed as Appendix 2.

3.5 Data management

All data collected at sea were recorded in a NOAA-approved data sheet on a haul-by-haul basis. Upon completion of each trip, the data collectors reviewed their data for accuracy and comprehensiveness and then submitted to the PM. The PM reviewed the data for missing or unclear information and worked with the data collector to resolve any issues. Following the completion of the final trip all data sheets were delivered to SMAST for data entry and analysis. The filled sheets were then scanned and are attached as Appendix 3. The data were initially entered into a Microsoft Access database, and then exported to other formats for analysis and graphing. A copy of Access database containing original data is submitted together with this report.

3.6 Data analysis

Exploratory examination of data revealed that monkfish and winter skate occupied the majority of catch, with the remaining species sharing <15% of the total weight captured. Therefore, the catch analysis concentrated on monkfish and winter skate. The study's goal was to evaluate the effectiveness of the low profile gillnet on the bycatch of Atlantic sturgeon and sea turtles to determine if their capture rates were reduced. As no turtles were captured or observed, no further comments will be made on turtles.

As there were considerable variations in soak time during the course of research both within and between vessels (ranging between 18.0 to 72.3 h), and soak time is known to affect catch, the data used for analysis were adjusted to 24-h soak, i.e. the weight of catch for the species was divided by the soak time in hours and multiplied by 24 to represent the amount of catch per 24 hours of soak time.

We analyzed the data for each vessel, comparing the regular commercial gillnets (Control, or Ctrl) and the low profile nets (Experimental, or Exp). Paired t-test was used for continuous variables (weight) applicable to all target and discard species, except for sturgeon. For sturgeon analyses, we used Wilcoxon Signed-rank Test for discrete variables – the number of sturgeon captured by different nets.

We also explored whether the data from the two vessels could be combined to increase the number of pairs and statistical power. We used the paired t-test to compare catch weight of concerned species between the two vessels for the period both vessels were fishing, i.e., between 05/02/2013 and 05/19/2013. We used Wilcoxon Signed-rank Test to compare the catch of sturgeon between the two vessels. Only the data for Control nets were used for this comparison because no sturgeons were caught in the Experimental nets for either vessel. -

We tested Effect Size of the differences between the Control and Experimental gillnets. The Effect Size indicates big or important the differences are. The Effect Size is calculated as the mean difference between the groups divided by the standard deviation of the Control group. Typically the Effect Size is interpreted as follows:

Effect Size	<0.1	0.1 – 0.3	0.3 – 0.5	>0.5
Effect	trivial	small	moderate	large

We examined whether the difference of catch was related to the length of fish for monkfish. This was the only species with sufficient number of individuals with length measurements for analysis. We used Generalized Linear Mixed Model (GLMM) using R statistical package with the following procedures.

The proportion of monkfish (Φ) kept at length (L) by the Experimental nets can be expressed for each length and each pair as:

$$\Phi(L) = N_{L,Exp} / (N_{L,Exp} + N_{L,\ Ctrl})$$

where $N_{L,Exp}$ and $N_{L,\ Ctrl}$ are number of monkfish at length L measured for the Experiment net and the Control net respectively. A value of $\Phi = 0.5$ indicates that there are no differences in the catch in numbers between two types of nets at length L. The catch at length proportion Φ(L) for monkfish from two nets was analyzed using the Generalized Linear Mixed Model (GLMM) with L as the explanatory variable, Φ(L) as the response variable; and the individual pair, vessel, depth and location as random effects, following the method described in Holst and Revill (2009) and as applied by He and Balzano (2013). The GLMM was implemented using the glmmPQL function in MASS package of the R statistical software, which uses a penalized quasilikelihood approach. A random intercept polynomial regression GLMM was used to fit curves for the expected proportions of the catch retained by the experiment net, after logit transformation, as:

$$\text{logit}[\Phi(L)] = \beta_0 + \beta_1 L + \beta_2 L^2 + \beta_3 L^3$$

The analyses began by fitting the third order polynomials followed by subsequent reductions of terms until all terms showed statistical significance ($p<0.05$) based on the Wald's test, with removal of one level of the polynomial at a time to determine the best model fit (either constant, linear, 2nd order, and 3rd order).

4. Results

4.1 Operations

Vessels fished in close proximity, with "Risky Business" about 2-3 nautical miles north of "Landon Blake". The depth of the grounds fished by the vessels ranged from 14 to 20 fm, and there were no statistical differences between depths fished by two vessels ($p=0.279$, two-tailed t-test). "Risky Business" fished in waters about 1 °C colder than that of "Landon Blake" and the differences were statistically different ($p=0.018$, two-tailed t-test). This may be due to "Risky Business" fishing slightly north of "Landon Blake". While both vessels' soak time ranged from about 18 to 72 hours, "Risky Business" had longer soak time on average than "Landon Blake" (44.6 h vs. 32.9 h), and differed statistically ($p=0.004$). For each vessel, however, there were no statistical differences in fishing depth, water temperature and soak time between the control and the experimental nets ($p>0.1$, paired t-test).

4.2 Catch and bycatch – general descriptions

A total of 100 strings of nets were hauled, containing 50 pairs of data (25 pairs for each vessel), between 05/02/2013 and 05/23/2013. Overall, "Landon Blake" caught 23,407.7 lbs of fish with 9,858.7 lbs of Kept monkfish and 9,815.9 lbs of Kept winter skate (Table 2a). "Risky Business" caught substantially more fish in total, for Kept monkfish and for Kept winter skate (Total: 45,770.4 lbs, Kept monkfish: 17,305.0 lbs; Kept winter skate: 21,338.8 lbs, Table 2b). A total of seven Atlantic sturgeons were caught during the sea trials. No sea turtles were caught or observed. No marine mammals were caught or interacted with the control or experimental nets on either vessel.

A total of 13 identified species (excluding Atlantic sturgeon) were encountered during the sea trials totaling 69,178 lbs, 40.9% were monkfish (28,356.2 lbs), 45.2% were winter skate (31,303.8 lbs). They accounted for more than 85% of the total catch when combined. Their catches in different types of nets and by different vessels are analyzed in detail. Other species caught in some quantities included horseshoe crab (*Limulus polypyhemus*), little skate (*Leucoraja erinacea*), spiny dogfish (*Squalus acanthias*), smooth dogfish (*Mustelus canis)*, and angel shark (*Squatina dumeril*), as listed in Table 3. The remaining species, caught in small quantities, included clearnose skate (*Raja eglanteria*), bluefish (*Pomatomus saltatrix*), summer flounder (*Paralichthys dentatus*), northern stargazer (*Astroscopus guttatus),* Atlantic menhaden *(Brevoortia tyrannus),* American lobster (*Homarus americanus*), rock crab (*Cancer irroratus*)*,* and spider crab (unspecified). They are together listed in Table 3 as "All other".

4.3 Atlantic sturgeon

Altogether seven Atlantic sturgeons were captured by the two vessels, four by "Landon Blake" and three by "Risky Business", all from Control nets. No sturgeons were caught in the Experimental gillnets. The details of sturgeon captured are provided in Table 4.

Soak times of the gillnets by which sturgeons were caught ranged from 21.8 to 72 hours. Depth ranged from 15 to 18 fm. Five of the seven were hauled back dead, while two were released alive. Those two that were alive had soak times less than 24 hours. None of sturgeons that were from gillnets soaked for more than 24 hours were alive. Mean fork length was 147 cm ranging from 133 to 167.5 cm. Sturgeon that were alive were released as soon as possible. Three sturgeons were located in the 4th vertical quarter/3rd horizontal quarter, one was located in the 3rd vertically and 4th horizontally, and the rest did not have documented positions within the gillnet.

The number of sturgeons captured was analyzed using Wilcoxon Signed Rank Test. When analyzed separately for each vessel, the reduction in sturgeon catch was statistically significant for "Landon Blake" ($p<0.001$), but not for "Risky business" ($p>0.2$). Catch rates of the Control nets for sturgeon between the two vessels were also compared by the same method, and were found not statistically different (p>0.2). Therefore we pooled the data between the vessels and tested for a sample size of 50. The reduction in the catch rates for sturgeon by the low profile Experimental was statistically significant when compared with the Control net (p<0.001). The combined data produced and Effect Size of 0.400, indicating that the effect is "moderate". Table 5 provides details of statistical results for sturgeon.

4.4 Target species

4.4.1 Catch per string

Monkfish and winter skate were target species, and shared the majority of the catch for both vessels. A haul-by-haul plot of kept catch per string of net for each species is shown in Figure 4 for "Landon Blake" and in Figure 5 for "Risky Business".

For "Landon Blake", the mean catch rates per string between the Control and the Experimental nets were comparable for both monkfish (reduced by 5.1%,) and winter skate (increased by 16.5%). The differences between the nets were not statistically significant for either species (monkfish p=0.600; winter skate p=0.080), and their effect can be considered as "small" as indicated by the Effect Size (monkfish ES=0.140; winter skate ES=0.160). Table 6 listed details of statistical tests and results.

For "Risky Business", the mean catch rates of monkfish per string were 25.3% higher in Control nets compared with the Experimental nets but mean catch rates of winter skate were higher in the Experimental nets (3.3% increase). The differences between the nets were statistically significant for monkfish (p=0.012), but not statistically significant for winter skate (p=0.520). The reduction in monkfish catch can be considered as "moderate" as indicated by the Effect Size of 0.363, but the increase in the catch of winter skate was "trivial" as indicated by the Effect Size of 0.024 (Table 6).

4.4.2 Catch per string per 24-h soak

In light of wide variations in soak time for both vessels, catch per string was also standardized to a 24-h soak. The soak-corrected catch rates for major species are provided in Table 7 and also plotted in Figure 6 ("Landon Blake") and Figure 7 ("Risky Business"). There was a general trend of catch increase per 24-h soak as the study progressed (Figure 8). In Figure 8, the gillnet string from which a sturgeon was caught is indicated (square symbol).

For "Landon Blake", the mean catch rates per string per 24-h soak between the Control and the Experimental nets was again comparable for both monkfish (reduced by 8.5%,) and winter skate (increased by 14.0%). The differences between the nets were not statistically significant for both species (monkfish p=0.334; winter skate p=0.221), and their effect can be considered as "small" as indicated by the Effect Size (monkfish ES=0.173; winter skate ES=0.135) (Table 6).

For "Risky Business", the mean catch rates of monkfish per string per 24-h soak were 22.3% higher in Control nets compared with the Experimental net, but the catch rates were almost identical for winter skate (reduced by 0.5%). The differences in catch rates between the nets were statistically significant for monkfish (p=0.012), but not statistically significant for winter skate (p=0.914). Again, the reduction in monkfish can be considered as "moderate" as indicated by the Effect Size of 0.463, but the increase in the catch of winter skate was "trivial" as indicated by the Effect Size of 0.005 (Table 6).

We evaluated whether the data from two vessels could be pooled. As "Landon Blake" had completed all hauls by 05/19/2013, and "Risky Business" continued fishing on 05/20, 05/21, and 05/23, and because of the trend of increasing catch as the study progressed, we compared catch data between the two vessels for the period when both vessels were fishing, i.e., between 05/2 and 05/19. For both kept and total monkfish and winter skate, and for both Control and Experimental strings, there were no differences in the catch rates per string per 24-h soak between the two vessels. We therefore also analyzed the pooled data from the two vessels.

When both vessels' data were combined, and for all 50 pairs including hauls that "Risky Business" fished alone on 05/20, 05/21 and 05/23, the Control strings produced 204.9 lbs on average of kept monkfish for a 24-h soak, while the experimental strings yielded 171.9 lbs, a mean reduction of 33 lbs or 16.1%. The differences were statistically different (p=0.010), and the effect can be considered as "moderate" (Table 6). For winter skate, the Control strings produced 163.8 lbs on average for a 24-h soak, while the experimental strings yielded 174.1 lbs, a mean increase of 10.3 lbs or 6.3%, but the differences were not statistically different (p=0.263), and the effect was "trivial" (Table 6).

4.4.3 Target species catch in relation to total catch

We analyzed the catch differences for monkfish (Control catch – Experimental catch) in relation to the total amount of catch in gillnets or the total amount of monkfish in the gillnet to examine if catch-related net deformation (collapse or rollup due to catch) or net saturation would affect the catch of monkfish. As the range of the total catch or the monkfish catch for "Landon Blake" was minimal, and there were no differences in the catch rates of monkfish between Control and Experimental nets, the analysis of monkfish catch differences in relation to total catch amount could not be done for this vessel. Monkfish catch differences in relation to catch amount were analyzed for "Risky Business" as there was a large range of total catch amount during the study for this vessel.

Generally, the total monkfish catch differences between the Control and the Experimental nets increased with either the total fish caught in the Control net or the total monkfish caught in the Control net (Figure 9). This illustrates that if more fish was caught in the net, the capture efficiency of the low profile Experimental net was reduced.

4.4.4 Monkfish length

Altogether 2,267 individuals of monkfish were measured for lengths, of which 824 were from "Landon Blake" and 1,443 were from "Risky Business".

The length frequency distribution of monkfish for "Landon Blake" is shown in Figure 10a, and GLMM results are shown in Figure 10b. GLMM analysis indicated that retention of monkfish by Control and Experimental nets was not length-related, and the logit-constant fit was the best fit for the data. The mean value of $N_{L,Exp}$ /($N_{L,Exp}$ + $N_{L,\ Ctrl}$) did not differ from the expected 0.5 ($p=0.497$).

The length frequency distribution of monkfish for "Risky Business" is shown in Figure 11a, and GLMM results are shown in Figure 11b. GLMM analysis indicated that retention of monkfish could best be modeled by a logit-linear model, with p-value of 0.006 for intercept indicating the Experimental net caught significantly fewer monkfish, and a p-value of 0.033 for slope indicating the reduction is significantly length-related. The model indicated that the Experimental net caught fewer monkfish smaller than 75 cm compared to the Control net, but there were no differences between the nets in the number of monkfish caught above 75 cm in length.

When lengths from both vessels were combined (Figure 12a), GLMM analysis indicated that retention of monkfish could best be modeled by logit-linear model (Figure 12b). Similar to the results from “Risky Business”, the model indicated that the Experimental net caught fewer monkfish smaller than 75 cm when compared to the Control net, but there were no differences between nets for monkfish above 75 cm in length.

4.5 Other species

In addition to monkfish, winter skate and Atlantic sturgeon, 11 other species were caught in both types of nets and by both vessels. Among those bycatch species, horseshoe crab accounted for 40% to 88% by weight on average among different types of nets and vessels (Table 4). For both horseshoe crab and for the total bycatch species, “Risky Business” caught significantly more than “Landon Blake” both for the Control nets and for the Experimental nets ($p<0.01$).

For “Landon Blake”, Experimental nets caught significantly more horseshoe crab (48.5 lbs per string vs. 27.9 lbs per string, $p=0.005$) than Control nets. However, the total catch of the 11 bycatch species combined was not statistically different between the Control and Experimental nets for this vessel (70.0 lbs per string vs. 67.7 lbs per string, $p=0.825$) (Figure 13).

For “Risky Business”, Experimental nets caught significantly more horseshoe crab (116.6 lbs per string vs. 85.9 lbs per string, $p=0.009$) than Control nets. However, the total catch of the 11 bycatch species combined was not statistically different between the Control and Experimental nets for this vessel (110.2 lbs. per string vs. 132.9 lbs per string, $p=0.095$) (Figure 14).

5. Discussion

The results indicated that the experimental low profile net reduced the bycatch of Atlantic sturgeon in the monkfish gillnet fishery in the Mid-Atlantic. Of the seven individual sturgeons captured during the sea trials, none were captured by the low profile Experimental nets. While the result was statistically significant for one of the vessels, and when the data for both vessels were combined, the sample size was too small to draw firm conclusions. This result however does provide evidence that lowering the head rope height to gillnet can reduce sturgeon bycatch.

Fox et al. (2013) tested the same low profile net in the New York Bight in November 2012, and encountered a larger number of Atlantic sturgeons in both control and experimental gillnets. While their experimental net also caught fewer sturgeons, the difference was not statistically significant. In this study that was conducted in May, none of the sturgeons caught were from the low profile nets. It may be possible that there is a behavioral difference in sturgeon that might affect their potential for capture in bottom set gillnets (D. Fox, personal communication). While we did not measure visibility of water on the grounds, differing visibility due to location, freshwater run-off, and season conditions may alter the sturgeons' ability to avoid gillnets.

While the result of sturgeon by-catch reduction from this study is very promising, a reduction of monkfish catch was also observed in the experimental nets; especially during periods where catch rates were high. "Landon Blake" had relatively lower catch rates of monkfish, winter skate and total of all species during the entire period, therefore there were no significant differences in catch rates between the Control and the Experimental nets. On the other hand, "Risky Business" experienced higher catch rates for monkfish, winter skates and all species combined. When catch rates were high, a significant reduction in monkfish catch was observed in the experimental nets. When monkfish catch rates were less than 600 lbs, or the total catch for all species was less than 1,500 lbs per string in the Control nets, there were no differences in monkfish catch rates between the Control and Experimental nets (Figure 9). By comparison, the average catch rates of monkfish in the study Fox et al. (2013) was less than 50 lbs per string, and coincidently, no differences in monkfish catch rates were observed between the control and low profile experimental nets. It is conceivable that higher catch rates require a larger gillnet webbing area in order to continue catching or retaining the fish. When monkfish are abundant, low profile gillnets may result in reduced catch. The monkfish catch rates experienced by "Risky Business" during the last 5 strings of nets between 05/19 and 05/23 (600 to 1200 lbs.) represented "commercial" catch rates. Unfortunately, great reductions in monkfish catch were experienced in the Experimental nets during that period. Therefore future research should explore low headrope height nets with sufficient number of vertical meshes, for example 12-mesh webbing with 24" tie-downs.

Using the Generalized Linear Mixed Model technique, we noticed that reductions of the catch of monkfish on the F/V Risky Business was mostly a reduction in catch of smaller fish less than 75 cm in length. There were no differences in catch rates for fish greater than 75 cm. It is possible that smaller monkfish are higher off the seabed compared with larger monkfish, but this needs further verification.

No reductions in winter skate catch were observed for both vessels, and during the periods of low or high catch rates, either per string or standardized for soak time. Skates may be closer to the seabed, and may continued to be caught when the headrope of a gillnet sinks to the bottom due to other catches on the net.

In conclusion, the low profile gillnets (8-mesh deep with 24” tie-downs) caught significantly less sturgeon than the regular 12-mesh gillnets. In fact, no sturgeons were caught by the low profile nets during the 50 pairs of comparative fishing. Catch rates of monkfish were comparable between the two nets when the catch rates were low, but significant reductions were observed in the experimental nets when catch rates were high. Additionally there were no reductions in the catch of winter skate during the entire period of fishing and by both vessels. Future research may explore low headrope height nets with sufficient number of vertical meshes such as nets with 12-mesh webbing and 24” tie-downs.

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TABLES

Table 1. Operation details during gillnet sea trials, including dates, position of nets, water depth and soak time, and weather sea conditions at the time the nets were hauled. Pair No., Trip ID, and Haul Number can be used to identify fishing conditions in subsequent table.

Pair No.	Trip ID	Date hauled	Weather /Sea				Control								Experimental							
			Wind		Wave	Sky	Haul	Soak	Position haul start		Position haul end		Depth	Temp	Haul	Soak	Position haul start		Position haul end		Depth	Temp
			Dir.	Spd(kt)	Hgt (ft)	Condition	No.	time (h)	Lat	Long	Lat	Long	(fm)	(°C)	No.	time (h)	Lat.	Long.	Lat.	Long.	(fm)	(°C)
F/V "Landon Blake"																						
1	LB001	5/2/13	45	18	4	pt cloudy	1	72.0	37.8097	-74.9800	37.8106	-74.9686	16	11.1	2	72.0	37.8103	-74.9686	37.8096	-74.9558	17	10.6
2	LB001	5/2/13	45	18	4	pt cloudy	3	72.0	37.8097	-74.9547	37.8092	-74.9450	17	11.1	4	72.0	37.8092	-74.9917	37.8100	-74.9825	17	10.6
3	LB002	5/5/13	45	30	8	pt cloudy	6	70.4	37.8114	-74.9803	37.8103	-74.9694	17	11.1	5	69.1	37.8083	-74.9936	37.8100	-74.9822	16	10.6
4	LB002	5/5/13	45	30	8	pt cloudy	8	71.9	37.8094	-74.9558	37.8086	-74.9444	18	11.1	7	71.1	37.8097	-74.9678	37.8119	-74.9747	18	10.6
5	LB003	5/8/13	225	5	2	pt cloudy	9	70.0	37.8094	-74.9564	37.8097	-74.9431	17	11.1	10	70.4	37.8097	-74.9672	37.8094	-74.9564	18	10.6
6	LB004	5/9/13	225	6	2	pt cloudy	12	24.5	37.8097	-74.9803	37.8094	74.9683	17	11.7	11	23.2	37.8094	-74.9928	37.8094	-74.9083	16	11.1
7	LB004	5/9/13	225	6	2	pt cloudy	14	24.2	37.8097	-74.9556	37.8094	-74.9436	18	11.7	13	23.1	37.8097	-74.9669	37.8094	-74.9561	18	11.1
8	LB005	5/10/13	225	5	1	pt cloudy	15	21.8	37.8086	-74.9703	37.8086	-74.9817	18	13.9	16	22.0	37.8089	-74.9828	37.8092	-74.9922	17	13.3
9	LB005	5/10/13	225	5	1	pt cloudy	17	23.6	37.8094	-74.9447	37.8083	-74.9572	18	13.9	18	23.9	37.8083	-74.9578	37.8092	-74.9689	19	13.3
10	LB006	5/11/13	248	15	3	cloudy	20	23.3	37.8083	-74.9828	37.8078	-74.9939	17	14.4	19	23.1	37.8083	-74.9694	37.8078	-74.9806	18	13.9
11	LB006	5/11/13	248	15	3	cloudy	22	23.4	37.8097	-74.9567	37.8092	-74.9689	18	14.4	21	23.0	37.8097	-74.9447	37.8092	-74.9550	17	13.9
12	LB007	5/13/13	0	14	2	pt cloudy	23	23.1	37.8081	-74.9706	37.8081	-74.9814	18	15.0	24	23.4	37.8078	-74.9833	37.8086	-74.9942	16	14.4
13	LB007	5/13/13	0	14	2	pt cloudy	25	23.2	37.8097	-74.9439	37.8086	-74.9553	17	15.0	26	23.5	37.8089	-74.9572	37.8083	-74.9678	17	14.4
14	LB008	5/14/13	0	12	2	pt cloudy	28	23.9	37.8081	-74.9825	37.8081	-74.9939	17	14.4	27	24.7	37.8081	-74.9697	37.8078	-74.9806	18	13.9
15	LB008	5/14/13	0	12	2	pt cloudy	30	25.3	37.8078	-74.9925	37.8081	-75.0044	-	14.4	29	24.4	37.8078	-74.9967	37.8081	-75.0069	-	13.9
16	LB009	5/15/13	180	-	3	pt cloudy	31	21.2	37.8075	-74.9667	37.8075	-74.9908	18	15.0	32	21.4	37.8078	-74.9808	37.8075	-74.9908	16	14.4
17	LB009	5/15/13	180	-	3	pt cloudy	34	21.7	37.8083	-75.0067	37.8083	-75.0169	-	15.0	33	21.4	37.8078	-74.9928	37.8078	-75.0047	16	14.4
18	LB010	5/16/13	180	7	2	pt cloudy	36	21.3	37.8083	-75.0022	37.8086	-75.0139	16	15.6	35	21.0	37.8081	-74.9903	37.8083	-75.0011	16	15.0
19	LB010	5/16/13	180	7	2	pt cloudy	38	24.4	37.8072	-75.0303	37.8067	-75.0414	15	15.6	37	24.2	37.8078	-75.0181	37.8078	-75.0292	16	15.0
20	LB011	5/17/13	0	2	1	pt cloudy	39	23.1	37.8072	-74.9900	37.8069	-75.0017	17	16.7	40	23.6	37.8075	-75.0028	37.8083	-75.0139	16	16.1
21	LB011	5/17/13	0	2	1	pt cloudy	41	23.0	37.8069	-75.0147	37.8069	-75.0267	15	16.7	42	23.3	37.8064	-75.0283	37.8061	-75.0386	16	16.1
22	LB012	5/18/13	90	5	1-2	pt cloudy	44	23.7	37.8078	-75.0028	37.8086	-75.0142	17	16.7	43	23.6	37.8069	-74.9900	37.8072	-75.0008	17	16.1
23	LB012	5/18/13	90	5	1-2	pt cloudy	46	23.7	37.8058	-75.0292	37.8094	-75.0367	15	16.7	45	23.4	37.8078	-75.0161	37.8058	-75.0275	16	16.1
24	LB013	5/19/13	180	20	6	pt cloudy	48	23.3	37.8061	-75.0267	37.8075	-75.0147	16	16.7	47	23.1	37.8053	-75.0381	37.8056	-75.0272	16	16.1
25	LB013	5/19/13	180	20	6	pt cloudy	50	26.2	37.8072	-75.0019	37.8067	-74.9894	-	16.7	49	25.5	37.8075	-75.0142	37.8078	-75.0028	-	16.1
F/V "Risky Business"																						
1	RB001	5/2/13	45	15	6	pt cloudy	3	72.0	37.8661	-74.9600	37.8675	-74.9492	17	10.0	1	72.0	37.8683	-74.9475	37.8711	-74.9231	17	10.6
2	RB001	5/2/13	45	15	6	pt cloudy	4	72.0	37.8697	-74.9364	37.8703	-74.9256	17	10.0	2	72.0	37.8711	-74.9231	-	-	17	10.0
3	RB002	5/5/13	45	30	8	pt cloudy	5	72.0	37.8650	-74.9478	37.8669	-74.9367	17	10.0	6	72.0	37.8692	-74.9214	37.8689	-74.9125	15	10.0
4	RB002	5/5/13	45	30	8	pt cloudy	7	72.0	37.8669	-74.9339	37.8689	-74.9239	15	10.0	8	72.0	37.8714	-74.9094	37.8728	-74.8992	19	10.0
5	RB003	5/7/13	135	10	3	cloudy	10	47.8	37.8728	-74.9294	37.8717	-74.9378	16	10.0	9	47.5	37.8742	-74.9164	37.8728	-74.9281	18	10.0
6	RB003	5/7/13	135	10	3	cloudy	12	48.9	37.8664	-74.9553	37.8639	-74.9656	17	10.0	11	48.7	37.8706	-74.9428	37.8667	-74.9547	17	10.0
7	RB004	5/9/13	135	5	2	clear	13	43.9	37.8744	-74.9161	37.8731	-74.9281	18	11.1	14	44.2	37.8731	-74.9292	37.8717	-74.9397	17	11.1
8	RB004	5/9/13	135	5	2	clear	15	43.1	37.8717	-74.9414	37.8694	-74.9525	17	11.1	16	43.8	37.8697	-74.9536	37.8661	-74.9464	18	11.1
9	RB005	5/10/13	225	5	1	pt cloudy	18	24.4	37.8633	-74.9444	37.8647	-74.9319	16	12.2	17	24.1	37.8617	-74.9572	37.8633	-74.9453	17	12.2
10	RB005	5/10/13	225	5	1	pt cloudy	20	24.9	37.8656	-74.9181	37.8661	-74.9083	19	12.2	19	24.7	37.8644	-74.9311	37.8658	-74.9208	14	12.2
11	RB006	5/11/13	225	10	3	rain	21	18.5	37.8572	-74.9739	37.8606	-74.6333	15	13.6	22	18.8	37.8614	-74.9617	37.8644	-74.9514	17	13.9
12	RB006	5/11/13	225	10	3	rain	23	19.0	37.8650	-74.9497	37.8669	-74.9386	18	13.9	24	19.3	37.8678	-74.9367	37.8683	-74.9269	17	13.9
13	RB007	5/12/13	225	5	3	cloudy	26	22.4	37.8639	-74.9564	37.8664	-74.9456	17	13.9	25	22.1	37.8597	-74.9675	37.8633	-74.9564	17	13.9
14	RB007	5/12/13	225	5	3	cloudy	28	22.9	37.8692	-74.9325	37.8703	-74.9203	16	13.9	27	22.7	37.8669	-74.9444	37.8686	-74.9333	18	13.9
15	RB008	5/13/13	315	15	3	pt cloudy	30	24.2	37.8514	-74.8569	37.8536	-74.8461	18	12.8	29	23.5	37.8497	-74.8694	37.8508	-74.8586	19	12.8
16	RB008	5/13/13	315	15	3	pt cloudy	32	25.6	37.8556	-74.8317	37.8564	-74.8206	19	12.8	31	24.9	37.8536	-74.8442	37.8556	-74.8336	19	12.8
17	RB009	5/15/13	5	18	4	cloudy	33	44.0	37.8561	-74.8186	37.8556	-74.8311	19	13.1	34	44.3	37.8556	-74.8319	37.8539	-74.8419	18	13.1
18	RB009	5/15/13	5	18	4	cloudy	35	44.6	37.8539	-74.8439	37.8522	-74.8553	19	13.1	36	44.9	37.8522	-74.8561	37.8514	-74.8664	18	13.1
19	RB010	5/16/13	180	8	2	clear	38	18.3	37.8444	-74.9522	37.8439	-74.9622	14	13.9	37	18.0	37.8461	-74.9411	37.8450	-74.9511	14	13.9
20	RB011	5/17/13	0	2	2	pt cloudy	40	46.7	37.8558	-74.8500	37.8569	-74.8397	19	15.0	39	46.4	37.8533	-74.8614	37.8553	-74.8517	18	15.0
21	RB012	5/19/13	180	20	5	cloudy	41	71.5	37.8436	-74.9592	37.8467	-74.9464	14	15.0	42	71.9	37.8461	-74.9461	37.8483	-74.9367	15	15.0
22	RB013	5/20/13	180	10	3	pt cloudy	43	70.2	37.8569	-74.8353	37.8539	-74.8458	20	15.0	44	70.9	37.8536	-74.8486	37.8519	-74.8581	18	15.0
23	RB014	5/21/13	180	8	2	cloudy	45	45.9	37.8528	-74.9633	37.8494	-74.9750	17	16.1	46	46.8	37.8492	-74.9758	37.8489	-74.9853	19	16.1
24	RB015	5/23/13	225	20	5	pt cloudy	47	46.7	37.8528	-74.9494	37.8508	-74.9614	15	17.2	48	47.5	37.8503	-74.9619	37.8494	-74.9719	16	17.2
25	RB015	5/23/13	225	20	5	pt cloudy	50	72.3	37.8500	-74.8564	37.8483	-74.8661	18	16.7	49	71.6	37.8531	-74.8450	37.8519	-74.8608	19	16.7

Table 2a. Catch of major species by deposition and total catch for F/V “Landon Blake”. Details of “All other species” are listed in Table 3.

F/V "Landon Blake"

Pair No.	Control (weight in lbs)										Experimental (weight in lbs)										All nets (weight in lbs)		
	Monkfish			Winter skate			All other species			All species	Monkfish			Winter skate			All other species			All species	Kept	Kept	All species
	Kept	Discarded	Total	Kept	Discarded	Total	Kept	Discarded	Total	Total	Kept	Discarded	Total	Kept	Discarded	Total	Kept	Discarded	Total	Total	Monkfish	W. skate	Total
1	234.0		234.0	504.0		504.0		46.0	46.0	784.0	181.5	2.0	183.5	626.0		626.0	2.5	44.5	47.0	856.5	415.5	1130.0	1640.5
2	142.0	23.5	165.5	489.0		489.0		40.0	40.0	694.5	351.0	29.0	380.0	621.0		621.0		38.5	38.5	1039.5	493.0	1110.0	1734.0
3	164.0	18.5	182.5	226.5	4.5	231.0		53.0	53.0	466.5	36.0	4.5	40.5	339.5	4.0	343.5		83.0	83.0	467.0	200.0	566.0	933.5
4	58.0	17.5	75.5	171.0	5.5	176.5	12.5	36.0	48.5	300.5	177.0	17.0	194.0	230.0		230.0	13.5	52.0	65.5	489.5	235.0	401.0	790.0
5	266.6	5.5	272.1	187.8	3.6	191.4	4.5	25.7	30.2	493.7	353.4	13.5	366.9	205.3		205.3		61.5	61.5	633.7	620.0	393.1	1127.4
6	154.1		154.1	42.6		42.6		19.2	19.2	215.9	181.0		181.0	127.2	5.0	132.2		33.7	33.7	346.9	335.1	169.8	562.8
7	208.7	10.9	219.6	56.2	2.7	58.9		58.6	58.6	337.1	217.1		217.1	51.8	2.0	53.8	4.3	49.8	54.1	324.9	425.8	108.0	662.0
8	292.4		292.4	52.0		52.0		27.6	27.6	372.0	152.9		152.9	88.7	2.0	90.7		64.1	64.1	307.7	445.3	140.7	679.7
9	276.4	11.2	287.6	52.1		52.1		60.4	60.4	400.1	249.9	4.3	254.2	34.7		34.7	5.5	39.9	45.4	334.3	526.3	86.8	734.4
10	170.3		170.3	47.2		47.2		41.6	41.6	259.1	234.3	7.7	242.0	25.9		25.9	13.1	54.4	67.5	335.4	404.6	73.1	594.5
11	205.8		205.8	28.5		28.5		131.4	131.4	365.7	143.8	2.0	145.8	71.7		71.7		70.8	70.8	288.3	349.6	100.2	654.0
12	284.6		284.6	70.9		70.9	50.9	92.4	143.3	498.8	307.0	5.0	312.0	99.5		99.5		156.0	156.0	567.5	591.6	170.4	1066.3
13	259.0	14.0	273.0	156.5		156.5	19.0	139.5	158.5	588.0	243.0	5.0	248.0	116.0		116.0	25.0	99.5	124.5	488.5	502.0	272.5	1076.5
14	141.8		141.8	9.5		9.5	67.7	38.6	106.3	257.6	62.1		62.1	66.8		66.8	10.0	64.6	74.6	203.5	203.9	76.3	461.1
15	429.5		429.5	25.0		25.0		34.5	34.5	489.0	177.5	11.5	189.0	58.0		58.0		65.0	65.0	312.0	607.0	83.0	801.0
16	157.0		157.0	47.5		47.5		50.0	50.0	254.5	123.5		123.5	133.0	5.5	138.5	41.0	47.5	88.5	350.5	280.5	180.5	605.0
17	180.0	4.0	184.0	180.0		180.0	90.5	53.0	143.5	507.5	127.5		127.5	76.5		76.5		33.0	33.0	237.0	307.5	256.5	744.5
18	217.5		217.5	96.5		96.5	33.0	36.5	69.5	383.5	316.0		316.0	108.0		108.0	22.5	31.0	53.5	477.5	533.5	204.5	861.0
19	205.5	4.0	209.5	127.0	4.5	131.5	87.5	21.0	108.5	449.5	326.0	4.0	330.0	98.0		98.0	21.5	39.5	61.0	489.0	531.5	225.0	938.5
20	182.5		182.5	146.0		146.0	49.5	68.0	117.5	446.0	153.0	16.0	169.0	87.5	1.0	88.5	22.5	26.5	49.0	306.5	335.5	233.5	752.5
21	151.5		151.5	77.0		77.0		42.5	42.5	271.0	136.0		136.0	57.5		57.5	62.5	83.5	146.0	339.5	287.5	134.5	610.5
22	159.5		159.5	300.0	2.0	302.0	30.0	16.0	46.0	507.5	135.5	4.0	139.5	229.5		229.5		89.5	89.5	458.5	295.0	529.5	966.0
23	115.0		115.0	340.0		340.0		96.5	96.5	551.5	152.0		152.0	274.0		274.0		50.0	50.0	476.0	267.0	614.0	1027.5
24	231.0		231.0	427.0	3.0	430.0		7.5	7.5	668.5	110.0		110.0	708.0	6.0	714.0	21.5	42.5	64.0	888.0	341.0	1135.0	1556.5
25	172.0		172.0	675.0		675.0	42.5	23.5	66.0	913.0	153.0		153.0	748.0	6.0	754.0		8.0	8.0	915.0	325.0	1423.0	1828.0
Total	5058.7	109.1	5167.8	4534.8	25.8	4560.6	487.6	1259.0	1746.6	11475.0	4800.0	125.5	4925.5	5,282.1	31.5	5313.6	265.4	1,428.3	1693.7	11932.7	9858.7	9,816.9	23407.7
Mean	202.3	4.4	206.71	181.4	1.0	182.4	19.5	50.4	69.9	459.0	192.0	5.0	197.02	211.3	1.3	212.5	10.6	57.1	67.7	477.3	394.3	392.7	936.3
SE	14.74	1.4	14.50	35.6	0.2	35.64	5.7	6.7	8.6	34.8	17.25	1.5	17.94	44.4	0.4	44.56	3.3	5.9	6.7	45.2	25.50	78.8	76.0

Table 2ab Catch of major species by deposition and total catch for F/V “Risky Business”. Details of “All other species” are listed in Table 3.

F/V "Risky Business"																							
Pair No.	Control (weight in lbs)										Experimental (weight in lbs)										All nets (weight in lbs)		
	Monkfish			Winter skate			All other species			All species	Monkfish			Winter skate			All other species			All species	Kept	Kept	All species
	Kept	Discarded	Total	Kept	Discarded	Total	Kept	Discarded	Total	Total	Kept	Discarded	Total	Kept	Discarded	Total	Kept	Discarded	Total	Total	Monkfish	W. skate	Total
1	208.3	32.0	240.3	497.0		497.0	12.0	57.0	69.0	806.3	129.0		129.0	750.0		750.0		328.2	25.5	904.5	337.3	1247.0	1710.8
2	306.0	31.0	337.0	688.0	11.0	699.0		29.0	29.0	1065.0	113.3	19.0	132.3	659.0		659.0		33.5	33.5	824.8	419.3	1347.0	1889.8
3	229.3	34.0	263.3	217.0		217.0		49.5	49.5	529.8	61.5	36.3	97.8	442.0		442.0		77.5	77.5	617.3	290.8	659.0	1147.1
4	86.0	63.8	149.8	222.5	49.5	272.0	7.0	70.0	77.0	498.8	81.5	48.5	130.0	234.0		234.0		59.0	59.0	423.0	167.5	456.5	921.8
5	410.3		410.3	234.0		234.0	9.5	105.0	114.5	758.8	141.0	12.5	153.5	244.5		244.5		34.0	34.0	432.0	551.3	478.5	1190.8
6	358.5	10.8	369.3	182.0		182.0	9.0	84.0	93.0	644.3	223.0	26.0	249.0		8.5	8.5		74.8	74.8	332.3	581.5	182.0	976.6
7	390.5	32.3	422.8	245.0	11.5	256.5		108.8	108.8	788.1	486.5	7.5	494.0	145.5	3.3	148.8	14.0	250.0	264.0	906.8	877.0	390.5	1694.9
8	433.3		433.3	151.0		151.0	1.0	23.7	24.7	609.0	185.5	3.3	188.8	186.0		186.0	8.0	187.0	195.0	569.8	618.8	337.0	1178.8
9	388.0	28.5	416.5	156.0		156.0		91.0	91.0	663.5	241.3		241.3	73.5		73.5		152.0	152.0	466.8	629.3	229.5	1130.3
10	207.9	19.5	227.4	48.3		48.3		113.3	113.3	389.0	139.8	4.5	144.3	47.5		47.5		195.0	195.0	386.8	347.7	95.8	775.8
11	137.0		137.0	34.5		34.5	11.0	95.8	106.8	278.3	90.1		90.1	58.5		58.5		127.5	127.5	276.1	227.1	93.0	554.4
12	246.8		246.8	66.0		66.0		114.0	114.0	426.8	104.2		104.2	48.0		48.0		150.5	150.5	302.7	351.0	114.0	729.5
13	155.1		155.1	21.0		21.0	5.0	91.5	96.5	272.6	211.3		211.3	59.0		59.0		91.0	91.0	361.3	366.4	80.0	633.9
14	259.1	30.8	289.9	28.0		28.0	11.5	67.5	79.0	396.9	262.6		262.6	26.5		26.5	9.0	106.5	115.5	404.6	521.7	54.5	801.5
15	250.5	30.0	280.5	169.5		169.5	9.5	130.3	139.8	589.8	196.8	3.5	200.3	157.5		157.5		57.0	57.0	414.8	447.3	327.0	1004.6
16	243.0	23.3	266.3	149.0		149.0		79.5	79.5	494.8	341.5	19.0	360.5	159.5		159.5		111.8	111.8	631.8	584.5	308.5	1126.6
17	191.5	80.5	272.0	371.0		371.0		169.0	169.0	812.0	494.2	20.0	514.2	352.0	7.0	359.0		187.8	187.8	1061.0	685.7	723.0	1873.0
18	369.8	28.3	398.1	316.5		316.5		124.5	124.5	839.1	517.5	15.5	533.0	244.0		244.0		223.0	223.0	1000.0	887.3	560.5	1839.1
19	149.5	41.0	190.5	93.5		93.5		24.6	24.6	308.6	118.0	28.5	146.5	75.5		75.5	27.0	122.5	149.5	371.5	267.5	169.0	680.1
20	846.5	70.5	917.0	468.0		468.0		152.0	152.0	1537.0	598.8	63.5	662.3	373.0		373.0		190.0	190.0	1225.3	1445.3	841.0	2762.3
21	639.0	23.0	662.0	571.5		571.5	23.0	180.5	203.5	1437.0	674.0	13.0	687.0	812.5		812.5		144.5	144.5	1644.0	1313.0	1384.0	3081.0
22	765.0	13.0	778.0	2019.0		2019.0		77.0	77.0	2874.0	502.0	11.0	513.0	2082.5		2082.5		73.0	73.0	2668.5	1267.0	4101.5	5542.5
23	593.8		593.8	497.5		497.5		167.0	167.0	1258.3	356.1		356.1	564.0		564.0	25.0	148.5	173.5	1093.6	949.9	1061.5	2351.9
24	807.0		807.0	738.5		738.5	23.0	175.0	198.0	1743.5	507.3	5.0	512.3	838.5		838.5		182.0	182.0	1532.8	1314.3	1577.0	3276.3
25	1234.5	29.0	1263.5	2313.0		2313.0	25.0	229.0	254.0	3830.5	622.0		622.0	2208.5		2208.5		236.0	236.0	3066.5	1856.5	4521.5	6897.0
Total	9906.2	621.3	10527.5	10497.3	72.0	10569.3	146.5	2608.5	2755.0	23851.8	7398.8	336.6	7735.4	10841.5	18.8	10860.3	83.0	3542.6	3625.6	21918.6	17305.0	21338.8	45770.4
Mean	396.2	24.9	421.1	419.9	2.9	422.8	5.9	104.3	110.2	954.1	296.0	13.5	309.4	433.7	0.8	434.4	3.3	141.7	145.0	876.7	692.2	853.6	1830.8
SE	55.2	3.8	55.0	113.1	4.4	113.0	1.5	10.5	11.4	166.6	39.1	3.3	39.5	116.1	0.5	115.1	1.8	14.7	13.5	142.7	88.3	227.3	307.1

Table 3. Details of catch of less important (mostly discarded) species referred to as "All other species" in Table 2a and 2b.

F/V "Landon Blake"

Pair No.	Control (weight in lbs)							Experimental (weight in lbs)						
	Horseshoe crab	Spiny Dogfish	Little Skate	Smooth Dogfish	Angel Shark	All other	Total	Horseshoe crab	Spiny Dogfish	Little Skate	Smooth Dogfish	Angel Shark	All other	Total
1	35.0	1.5	4.5	0	0	5	46.0	33.5	0	4	0	0	9.5	47.0
2	15.5	15	6	0	0	3.5	40.0	31.5	0	7	0	0	0.0	38.5
3	24.0	17	8	0	0	4	53.0	48.0	7.5	14	13.5	0	0.0	83.0
4	12.0	21	3	0	0	12.5	48.5	36.0	0	11	4.5	0	14.0	65.5
5	6.3	6.8	3.4	0	0	13.7	30.2	44.1	0	5.6	8.6	0	3.2	61.5
6	9.8	0	3.5	0	0	5.9	19.2	33.7	0	0	0	0	0.0	33.7
7	34.7	9.6	1.8	0	0	12.5	58.6	49.8	0	3.75	0	0	0.5	54.1
8	19.9	0	1.2	0	6.5	0	27.6	60.7	0	0	0	0	3.4	64.1
9	47.3	4.9	3.1	0	0	5.1	60.4	38.1	0	1.8	0	0	5.5	45.4
10	39.1	0	2.5	0	0	0	41.6	52.9	0	0	0	0	14.6	67.5
11	93.7	35.5	2.2	0	0	0	131.4	48.5	0	0	22.3	0	0.0	70.8
12	27.4	7	2	0	0	106.9	143.3	138.0	0	0	0	18	0.0	156.0
13	72.0	0	1.5	0	11.5	73.5	158.5	97.0	0	2.5	0	0	25.0	124.5
14	25.8	6.3	4	0	0	70.2	106.3	56.7	0	0	0	7.9	10.0	74.6
15	6.5	27	1	0	0	0	34.5	61.5	0	3.5	0	0	0.0	65.0
16	29.0	7.5	2	0	11.5	0	50.0	46.5	0	1	41	0	0.0	88.5
17	19.5	0	5	117	0	2	143.5	33.0	0	0	0	0	0.0	33.0
18	35.0	0	1.5	33	0	0	69.5	31.0	0	0	22.5	0	0.0	53.5
19	11.0	0	0.5	87.5	0	9.5	108.5	18.5	0	1	21.5	11.5	8.5	61.0
20	54.5	8.5	5	49.5	0	0	117.5	24.0	0	2.5	22.5	0	0.0	49.0
21	23.0	0	4	0	15.5	0	42.5	70.0	0	0.5	62.5	13	0.0	146.0
22	6.5	5	1.5	31	0	2	46.0	87.5	0	2	0	0	0.0	89.5
23	44.5	23.5	6	0	21	1.5	96.5	25.0	5.5	7	0	12	0.5	50.0
24	0.0	0	1	0	6.5	0	7.5	41.5	0	1	21.5	0	0.0	64.0
25	5.5	0	5	42.5	12.5	0.5	66.0	6.5	0	1.5	0	0	0.0	8.0
Total	697.5	196.1	79.2	360.5	85.0	328.3	1746.6	1213.5	13.0	69.7	240.4	62.4	94.7	1693.7
Mean	27.9	7.8	3.2	14.4	3.4	13.1	69.9	48.5	0.5	2.8	9.6	2.5	3.8	67.7
SE	4.43	1.99	0.38	6.12	1.22	5.50	8.59	5.51	0.36	0.73	3.16	1.06	1.28	6.74

F/V "Risky Business"

Pair No.	Control (weight in lbs)							Experimental (weight in lbs)						
	Horseshoe crab	Spiny Dogfish	Little Skate	Smooth Dogfish	Angel Shark	All other	Total	Horseshoe crab	Spiny Dogfish	Little Skate	Smooth Dogfish	Angel Shark	All other	Total
1	14.0	25.5	9	8.5	0	12	69.0	14.0	3.5	8	0	0	0.0	25.5
2	14.0	6	3	0	0	6	29.0	18.0	8	0	0	7	0.5	33.5
3	32.0	5.5	6	0	0	6	49.5	71.5	0	6	0	0	0.0	77.5
4	51.0	4	0	0	0	22	77.0	59.0	0	0	0	0	0.0	59.0
5	87.0	13	5	0	0	9.5	114.5	25.5	0	2.5	6	0	0.0	34.0
6	65.5	8.5	10	0	0	9	93.0	53.0	0	1.5	13.5	0	6.8	74.8
7	97.5	3.3	0	0	8	0	108.8	237.5	0	5.5	0	7	14.0	264.0
8	13.2	6.5	2	0	0	3	24.7	162.0	10	2	13	0	8.0	195.0
9	79.0	12	0	0	0	0	91.0	152.0	0	0	0	0	0.0	152.0
10	108.5	0	4.8	0	0	0	113.3	194.0	0	1	0	0	0.0	195.0
11	46.0	28.5	0	0	21.3	11	106.8	127.5	0	0	0	0	0.0	127.5
12	91.0	23	0	0	0	0	114.0	109.5	15.5	0	0	0	25.5	150.5
13	90.5	0	1	0	0	5	96.5	91.0	0	0	0	0	0.0	91.0
14	67.5	0	0	0	0	11.5	79.0	106.5	0	0	0	0	9.0	115.5
15	121.5	0	0	0	0	18.3	139.8	44.5	0	3	0	0	9.5	57.0
16	58.0	0	1	0	20.5	0	79.5	90.5	0	0	17	0	4.3	111.8
17	166.0	0	3	0	0	0	169.0	180.5	0	0	0	0	7.3	187.8
18	105.5	9	5	0	5	0	124.5	208.0	0	0	0	9	6.0	223.0
19	21.8	0	1	0	0	1.8	24.6	84.5	0	0	57	8	0.0	149.5
20	144.0	0	0	0	8	0	152.0	190.0	0	0	0	0	0.0	190.0
21	132.0	6.5	0	65	0	0	203.5	133.5	0	0	0	11	0.0	144.5
22	72.0	5	0	0	0	0	77.0	51.0	0	14	0	8	0.0	73.0
23	103.0	5	0	17	42	0	167.0	103.5	7	0	18	38	7.0	173.5
24	152.0	7	0	16	16	7	198.0	176.0	0	6	0	0	0.0	182.0
25	216.0	0	0	25	13	0	254.0	232.0	0	0	0	4	0.0	236.0
Total	2148.5	168.3	50.8	131.5	133.8	122.1	2755.0	2915.0	44.0	49.5	124.5	92.0	97.9	3322.9
Mean	85.9	6.7	2.0	5.3	5.4	4.9	110.2	116.6	1.8	2.0	5.0	3.7	3.9	132.9
SE	10.3	1.6	0.6	2.8	2.0	1.26	11.42	13.5	0.8	0.7	2.5	1.6	1.2	13.54

Table 4. Details of Atlantic sturgeon encounter during sea trials.

Date Landed	5/2/13	5/5/13	5/7/13	5/10/13	5/14/13	5/19/13	5/19/13
Trip ID	RB001	RB002	RB003	LB005	LB008	LB013	LB013
Vessel	Risky Business	Risky Business	Risky Business	Landon Blake	Landon Blake	Landon Blake	Landon Blake
Haul#	3	7	12	15	28	48	50
Gear	Control	Control	Control	Control	Control	Control	Control
Latitude	37.86611	37.86694	37.86639	37.80861	37.80833	37.80667	37.80722
Longitude	-74.96000	-74.93389	-74.95528	-74.98111	-74.98778	-75.01778	-74.99333
Depth (fm)	17	15	17	18	17	16	-
Water temp (C)	10	10	10	13.3	13.9	16.1	16.1
Soak Time (h)	72	72	48.9	21.8	23.9	23.3	26.2
Condition	Dead	Dead	Dead	Dead	Alive	Alive	Dead
Sandflea/abrasion	No	No	No	No	Abrasion (2)	Abrasions (1)	Sandflea (1)
Deposition	Discarded	Kept	Kept	Kept	Released	Released	Kept
Weight (lbs)	-	38	65	68.9	75	-	51.6
Fork length (cm)	167.5	133	147	150	149	141	142.5
Total length (cm)	190.5	155	167	177	168	158	156
Disposition	0	0	0	0	2-abrasions	1-abrasions	2- sandfleas
Location in net	Shot 9	Shot 9	Shot 8 Horizontal 3	Shot 10 Horizontal 4 Vertical 3	Shot 4 Horizontal 3 Vertical 4	Shot 4 Horizontal 3 Vertical 4	Shot 7 Horizontal 3 Vertical 4
Notes:	Dead, but in good condition. No sandflea damage, but sandfleas were visible on gills. Completely wrapped in net from float line to lead line, but not gilled.	Completely wrapped in net from float line to lead line. Not gilled.	Not gilled, but wrapped in net parallel to lead and float lines	On the last 2 meshes of Shot 10 just before the end line	10 floats before the end of net. Gilled. Released live.	14 floats before the end of net. Gilled near lead line. Some abrasions near pectoral fin area. Blind in one eye from a previous injury as the eye socket area was covered with scar tissue. Release alive and appeared healthy. Swam away when put back in water.	12 floats from the end of the shot. Fresh dead with some sandflea damage and scavenging

Table 5. Statistical analysis of Atlantic sturgeon bycatch by different vessels and nets.

Vessel		Control	Experimental	Reduction (increase)		Significance	Effect size
		(N)	(N)	(N)	%	p	
Landon Blake							
	Number of animals	4	0	4	100	**<0.001**	
	Number of pairs	25	25				
	Mean (per string)	0.16	0	0.16	100		0.432
	SD	0.37					
Risky Business							
	Number of animals	3	0	3	100	>0.2	
	Number of pairs	25	25				
	Mean (per string)	0.12	0	0.12	100		0.364
	SD	0.33					
Both vessels combined							
	Number of animals	7	0	7	100	**<0.001**	
	Number of pairs	50	50				
	Mean (per string)	0.14	0	0.14	100		0.400
	SD	0.35					

Table 6. Statistical analysis of monkfish and winter skate catch by different vessels and different nets.

Vessel and species	Control	Experimental	Reduction (increase)		Significance	Effect Size
Landon Blake	lbs	lbs	lbs	%	p	
Kept monkfish						
Mean weight per string	202.3	192.0	10.3	5.1	0.600	0.140
SD	73.68	86.25				
Mean weight per string per 24 h	183.9	168.2	15.7	8.5	0.334	0.173
SD	90.77	85.85				
Kept winter skate						
Mean weight per string	181.4	211.3	(29.9)	(16.5)	0.080	0.160
SD	187.06	221.83				
Mean weight per string per 24 h	140.4	160	(19.6)	(14.0)	0.221	0.135
SD	145.51	179.82				
Risky Business						
Kept monkfish						
Mean weight per string	396.2	296	100.2	25.3	**0.012**	0.363
SD	276.05	195.63				
Mean weight per string per 24 h	225.8	175.5	50.3	22.3	**0.012**	0.463
SD	108.64	92.96				
Kept winter skate						
Mean weight per string	419.9	433.7	(13.8)	(3.3)	0.520	0.024
SD	565.53	575.64				
Mean weight per string per 24 h	187.2	188.2	(1.0)	(0.5)	0.914	0.005
SD	182.89	186.95				
Both vessels combined						
Kept monkfish						
Mean weight per string per 24 h	204.9	171.9	33.0	16.1	**0.010**	0.326
SD	101.31	88.64				
Kept winter skate						
Mean weight per string per 24 h	163.8	174.1	(10.3)	(6.3)	0.263	0.062
SD	165.27	182.09				

Table 7. Soak time corrected catch of monkfish and winter skate by "Landon Blake" and "Risky Business" and by Control and Experimental nets.

F/V "Landon Blake"

Pair No.	Control (weight in lbs/24h)										Experimental (weight in lbs/24)										All nets (weight in lbs/24h)		
	Monkfish			Winter skate			All other species			All species	Monkfish			Winter skate			All other species			All species	Kept	Kept	All species
	Kept	Discarded	Total	Kept	Discarded	Total	Kept	Discarded	Total	Total	Kept	Discarded	Total	Kept	Discarded	Total	Kept	Discarded	Total	Total	Monkfish	W. skate	Total
1	78.0	0.0	78.0	168.0	0.0	168.0	0.0	15.3	15.3	261.3	60.5	0.7	61.2	208.7	0.0	208.7	0.8	14.8	15.7	285.5	138.5	376.7	546.8
2	47.3	7.8	55.2	163.0	0.0	163.0	0.0	13.3	13.3	231.5	117.0	9.7	126.7	207.0	0.0	207.0	0.0	12.8	12.8	346.5	164.3	370.0	578.0
3	55.9	6.3	62.2	77.2	1.5	78.8	0.0	18.1	18.1	159.0	12.5	1.6	14.1	117.9	1.4	119.3	0.0	28.8	28.8	162.2	68.4	195.1	321.2
4	19.4	5.8	25.2	57.1	1.8	58.9	4.2	12.0	16.2	100.3	59.7	5.7	65.5	77.6	0.0	77.6	4.6	17.6	22.1	165.2	79.1	134.7	265.5
5	91.4	1.9	93.3	64.4	1.2	65.6	1.5	8.8	10.4	169.3	120.5	4.6	125.1	70.0	0.0	70.0	0.0	21.0	21.0	216.0	211.9	134.4	385.3
6	151.0	0.0	151.0	41.7	0.0	41.7	0.0	18.8	18.8	211.5	187.2	0.0	187.2	131.6	5.2	136.8	0.0	34.9	34.9	358.9	338.2	173.3	570.4
7	207.0	10.8	217.8	55.7	2.7	58.4	0.0	58.1	58.1	334.3	225.6	0.0	225.6	53.8	2.1	55.8	4.4	51.7	56.2	337.6	432.5	109.5	671.9
8	321.9	0.0	321.9	57.2	0.0	57.2	0.0	30.4	30.4	409.5	166.8	0.0	166.8	96.8	2.2	98.9	0.0	69.9	69.9	335.7	488.7	154.0	745.2
9	281.1	11.4	292.5	53.0	0.0	53.0	0.0	61.4	61.4	406.9	250.9	4.3	255.3	34.8	0.0	34.8	5.5	40.1	45.6	335.7	532.0	87.8	742.6
10	175.4	0.0	175.4	48.6	0.0	48.6	0.0	42.8	42.8	266.9	243.4	8.0	251.4	26.9	0.0	26.9	13.6	56.5	70.1	348.5	418.8	75.5	615.4
11	211.1	0.0	211.1	29.2	0.0	29.2	0.0	134.8	134.8	375.1	150.1	2.1	152.1	74.8	0.0	74.8	0.0	73.9	73.9	300.8	361.1	104.0	675.9
12	295.7	0.0	295.7	73.7	0.0	73.7	52.9	96.0	148.9	518.2	314.9	5.1	320.0	102.1	0.0	102.1	0.0	160.0	160.0	582.1	610.6	175.7	1100.3
13	267.9	14.5	282.4	161.9	0.0	161.9	19.7	144.3	164.0	608.3	248.2	5.1	253.3	118.5	0.0	118.5	25.5	101.6	127.1	498.9	516.1	280.4	1107.2
14	142.4	0.0	142.4	9.5	0.0	9.5	68.0	38.8	106.7	258.7	60.3	0.0	60.3	64.9	0.0	64.9	9.7	62.8	72.5	197.7	202.7	74.4	456.4
15	407.4	0.0	407.4	23.7	0.0	23.7	0.0	32.7	32.7	463.9	174.6	11.3	185.9	57.0	0.0	57.0	0.0	63.9	63.9	306.9	582.0	80.8	770.8
16	177.7	0.0	177.7	53.8	0.0	53.8	0.0	56.6	56.6	288.1	138.5	0.0	138.5	149.2	6.2	155.3	46.0	53.3	99.3	393.1	316.2	202.9	681.2
17	199.1	4.4	203.5	199.1	0.0	199.1	100.1	58.6	158.7	561.3	143.0	0.0	143.0	85.8	0.0	85.8	0.0	37.0	37.0	265.8	342.1	284.9	827.1
18	245.1	0.0	245.1	108.7	0.0	108.7	37.2	41.1	78.3	432.1	361.1	0.0	361.1	123.4	0.0	123.4	25.7	35.4	61.1	545.7	606.2	232.2	977.8
19	202.1	3.9	206.1	124.9	4.4	129.3	86.1	20.7	106.7	442.1	323.3	4.0	327.3	97.2	0.0	97.2	21.3	39.2	60.5	485.0	525.4	222.1	927.1
20	189.6	0.0	189.6	151.7	0.0	151.7	51.4	70.6	122.1	463.4	155.6	16.3	171.9	89.0	1.0	90.0	22.9	26.9	49.8	311.7	345.2	240.7	775.1
21	158.1	0.0	158.1	80.3	0.0	80.3	0.0	44.3	44.3	282.8	140.1	0.0	140.1	59.2	0.0	59.2	64.4	86.0	150.4	349.7	298.2	139.6	632.5
22	161.5	0.0	161.5	303.8	2.0	305.8	30.4	16.2	46.6	513.9	137.8	4.1	141.9	233.4	0.0	233.4	0.0	91.0	91.0	466.3	299.3	537.2	980.2
23	116.5	0.0	116.5	344.3	0.0	344.3	0.0	97.7	97.7	558.5	155.9	0.0	155.9	281.0	0.0	281.0	0.0	51.3	51.3	488.2	272.4	625.3	1046.7
24	237.9	0.0	237.9	439.8	3.1	442.9	0.0	7.7	7.7	688.6	114.3	0.0	114.3	735.6	6.2	741.8	22.3	44.2	66.5	922.6	352.2	1175.4	1611.2
25	157.6	0.0	157.6	618.3	0.0	618.3	38.9	21.5	60.5	836.3	144.0	0.0	144.0	704.0	5.6	709.6	0.0	7.5	7.5	861.2	301.6	1322.3	1697.5
Mean	183.9	2.7	186.6	140.4	0.7	141.0	19.6	46.4	66.0	393.7	168.2	3.3	171.5	160.0	1.2	161.2	10.7	51.3	62.0	394.7	352.2	300.4	788.4
SE	18.15	0.9	18.15	29.1	0.2	29.14	6.1	7.5	10.0	35.6	17.17	0.9	17.27	36.0	0.4	36.24	3.3	6.7	8.0	37.3	31.55	63.5	69.2

F/V "Risky Business"

Pair No.	Control (weight in lbs/24h)										Experimental (weight in lbs/24h)										All nets (weight in lbs/24h)		
	Monkfish			Winter skate			All other species			All species	Monkfish			Winter skate			All other species			All species	Kept	Kept	All species
	Kept	Discarded	Total	Kept	Discarded	Total	Kept	Discarded	Total	Total	Kept	Discarded	Total	Kept	Discarded	Total	Kept	Discarded	Total	Total	Monkfish	W. skate	Total
1	69.4	10.7	80.1	165.7	0.0	165.7	4.0	19.0	23.0	268.8	43.0	0.0	43.0	250.0	0.0	250.0	0.0	109.4	8.5	301.5	112.4	415.7	570.3
2	102.0	10.3	112.3	229.3	3.7	233.0	0.0	9.7	9.7	355.0	37.8	6.3	44.1	219.7	0.0	219.7	0.0	11.2	11.2	274.9	139.8	449.0	629.9
3	76.4	11.3	87.8	72.3	0.0	72.3	0.0	16.5	16.5	176.6	20.5	12.1	32.6	147.3	0.0	147.3	0.0	25.8	25.8	205.8	96.9	219.7	382.4
4	28.7	21.3	49.9	74.2	16.5	90.7	2.3	23.3	25.7	166.3	27.2	16.2	43.3	78.0	0.0	78.0	0.0	19.7	19.7	141.0	55.8	152.2	307.3
5	206.0	0.0	206.0	117.5	0.0	117.5	4.8	52.7	57.5	381.0	71.2	6.3	77.6	123.5	0.0	123.5	0.0	17.2	17.2	218.3	277.3	241.0	599.3
6	176.0	5.3	181.3	89.3	0.0	89.3	4.4	41.2	45.6	316.2	109.9	12.8	122.7	0.0	4.2	4.2	0.0	36.9	36.9	163.8	285.8	89.3	480.0
7	213.5	17.7	231.1	133.9	6.3	140.2	0.0	59.5	59.5	430.9	264.2	4.1	268.2	79.0	1.8	80.8	7.6	135.7	143.3	492.4	477.6	212.9	923.2
8	241.3	0.0	241.3	84.1	0.0	84.1	0.6	13.2	13.8	339.1	101.6	1.8	103.5	101.9	0.0	101.9	4.4	102.5	106.8	312.2	342.9	186.0	651.3
9	381.6	28.0	409.7	153.4	0.0	153.4	0.0	89.5	89.5	652.6	240.3	0.0	240.3	73.2	0.0	73.2	0.0	151.4	151.4	464.9	621.9	226.6	1117.5
10	200.4	18.8	219.2	46.6	0.0	46.6	0.0	109.2	109.2	374.9	135.8	4.4	140.2	46.2	0.0	46.2	0.0	189.5	189.5	375.8	336.2	92.7	750.8
11	177.7	0.0	177.7	44.8	0.0	44.8	14.3	124.3	138.6	361.0	115.0	0.0	115.0	74.7	0.0	74.7	0.0	162.8	162.8	352.5	292.8	119.4	713.5
12	311.7	0.0	311.7	83.4	0.0	83.4	0.0	144.0	144.0	539.1	129.6	0.0	129.6	59.7	0.0	59.7	0.0	187.2	187.2	376.4	441.3	143.1	915.5
13	166.2	0.0	166.2	22.5	0.0	22.5	5.4	98.0	103.4	292.1	229.5	0.0	229.5	64.1	0.0	64.1	0.0	98.8	98.8	392.4	395.6	86.6	684.4
14	271.5	32.3	303.8	29.3	0.0	29.3	12.1	70.7	82.8	416.0	277.6	0.0	277.6	28.0	0.0	28.0	9.5	112.6	122.1	427.8	549.2	57.4	843.7
15	248.4	29.8	278.2	168.1	0.0	168.1	9.4	129.2	138.6	584.9	201.0	3.6	204.6	160.9	0.0	160.9	0.0	58.2	58.2	423.6	449.4	329.0	1008.6
16	227.8	21.8	249.7	139.7	0.0	139.7	0.0	74.5	74.5	463.9	329.2	18.3	347.5	153.7	0.0	153.7	0.0	107.8	107.8	609.0	557.0	293.4	1072.8
17	104.5	43.9	148.4	202.4	0.0	202.4	0.0	92.2	92.2	442.9	267.7	10.8	278.6	190.7	3.8	194.5	0.0	101.7	101.7	574.8	372.2	393.1	1017.7
18	199.0	15.2	214.2	170.3	0.0	170.3	0.0	67.0	67.0	451.5	276.6	8.3	284.9	130.4	0.0	130.4	0.0	119.2	119.2	534.5	475.6	300.7	986.1
19	196.1	53.8	249.8	122.6	0.0	122.6	0.0	32.3	32.3	404.7	157.3	38.0	195.3	100.7	0.0	100.7	36.0	163.3	199.3	495.3	353.4	223.3	900.1
20	435.0	36.2	471.3	240.5	0.0	240.5	0.0	78.1	78.1	789.9	309.7	32.8	342.6	192.9	0.0	192.9	0.0	98.3	98.3	633.8	744.8	433.4	1423.7
21	214.5	7.7	222.2	191.8	0.0	191.8	7.7	60.6	68.3	482.3	225.0	4.3	229.3	271.2	0.0	271.2	0.0	48.2	48.2	548.8	439.5	463.0	1031.1
22	261.5	4.4	266.0	690.3	0.0	690.3	0.0	26.3	26.3	982.6	169.9	3.7	173.7	704.9	0.0	704.9	0.0	24.7	24.7	903.3	431.5	1395.2	1885.9
23	310.5	0.0	310.5	260.1	0.0	260.1	0.0	87.3	87.3	657.9	182.6	0.0	182.6	289.2	0.0	289.2	12.8	76.2	89.0	560.8	493.1	549.4	1218.8
24	414.7	0.0	414.7	379.5	0.0	379.5	11.8	89.9	101.8	896.0	256.3	2.5	258.8	423.7	0.0	423.7	0.0	92.0	92.0	774.5	671.1	803.2	1670.5
25	409.8	9.6	419.4	767.8	0.0	767.8	8.3	76.0	84.3	1271.5	208.5	0.0	208.5	740.3	0.0	740.3	0.0	79.1	79.1	1027.9	618.3	1508.1	2299.4
Mean	225.8	15.1	240.9	187.2	1.1	188.2	3.4	67.4	70.8	499.9	175.5	7.5	182.9	188.2	0.4	188.5	2.8	93.2	91.9	463.4	401.3	375.3	963.3
SE	21.7	3.0	21.9	36.6	0.7	36.5	0.9	7.6	8.0	51.6	18.6	2.0	18.9	37.4	0.2	37.3	1.5	10.7	11.8	43.5	35.9	73.4	92.8

FIGURES

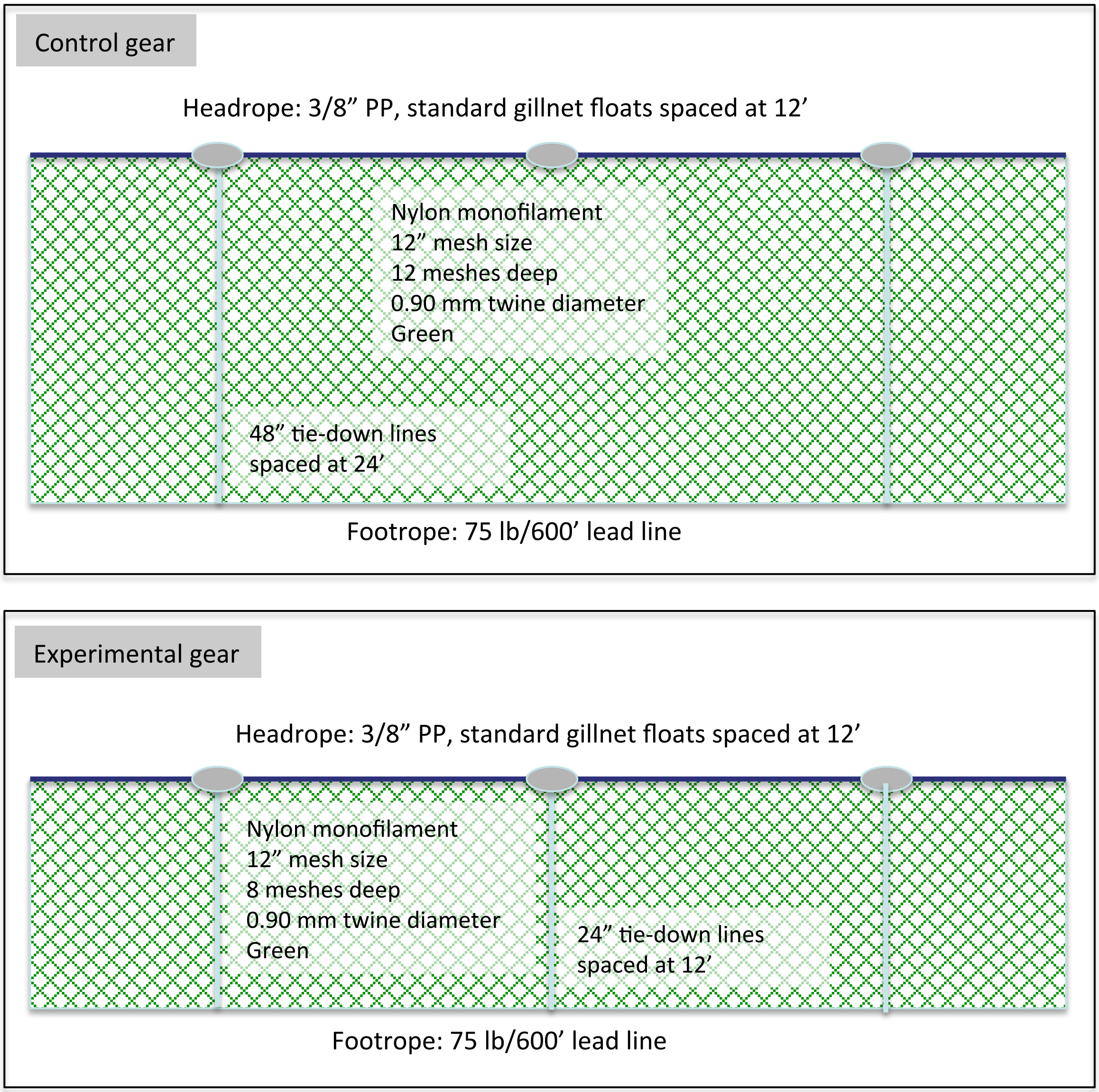


Figure 1. Specification and rigging of the Control and the Experimental gillnets.

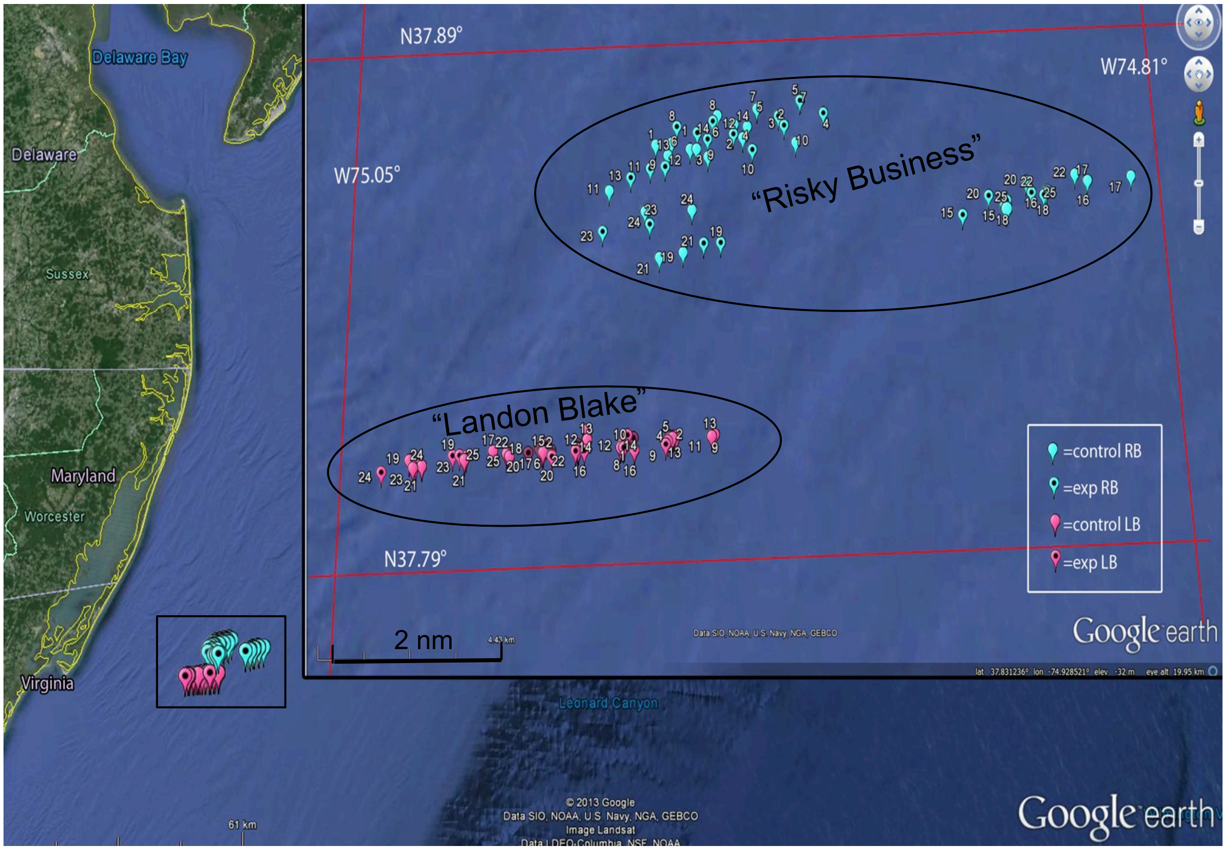


Figure 2. Location of Control and Experimental monkfish gillnets deployed and hauled by F/V "Landon Blake" and F/V "Risky Business" during May 2013.

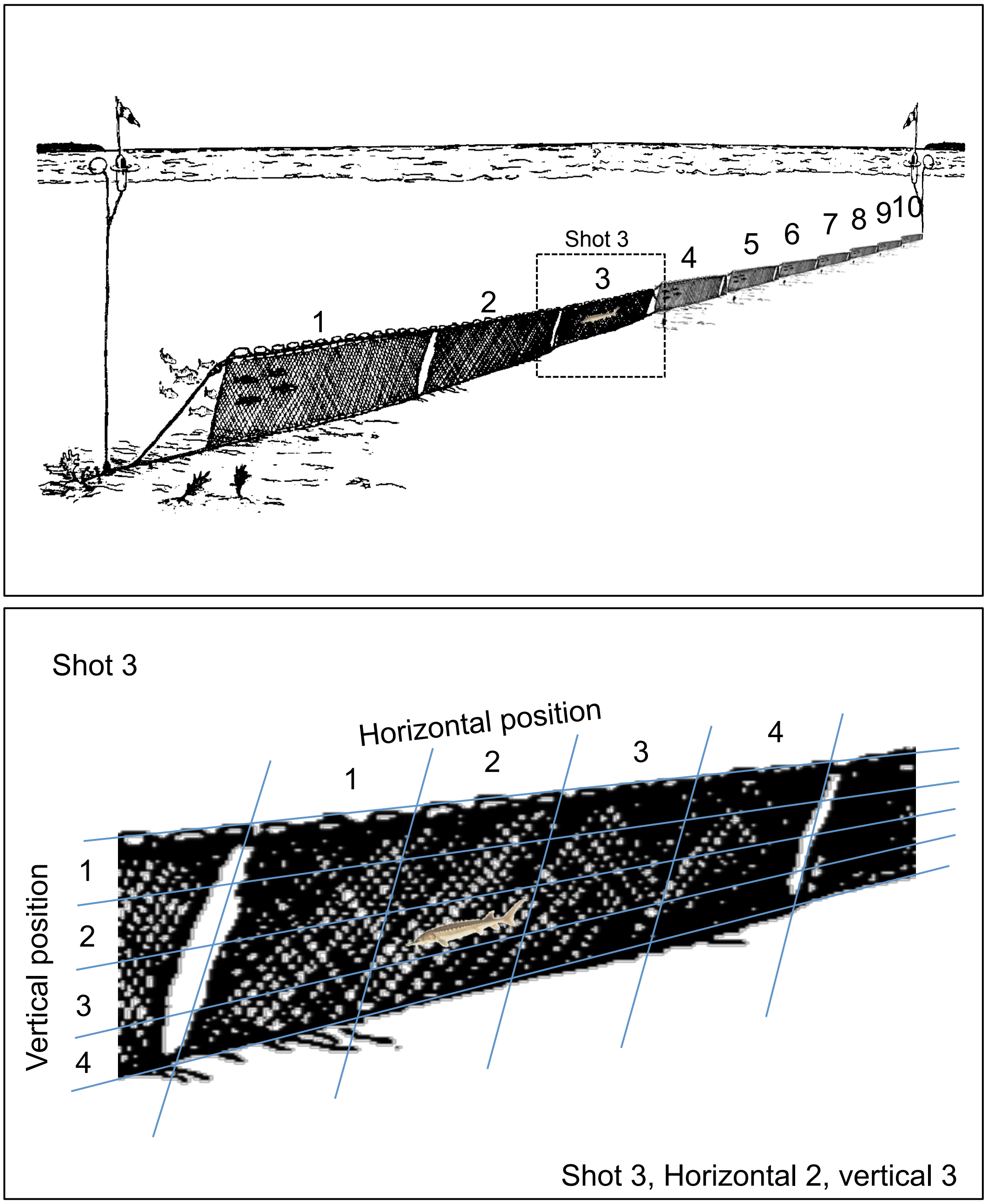


Figure 3. Illustration of identification of the location in the gillnet where an Atlantic sturgeon was caught. In this example, the sturgeon capture location is noted as "Shot 3, Horizontal 2, Vertical 3".

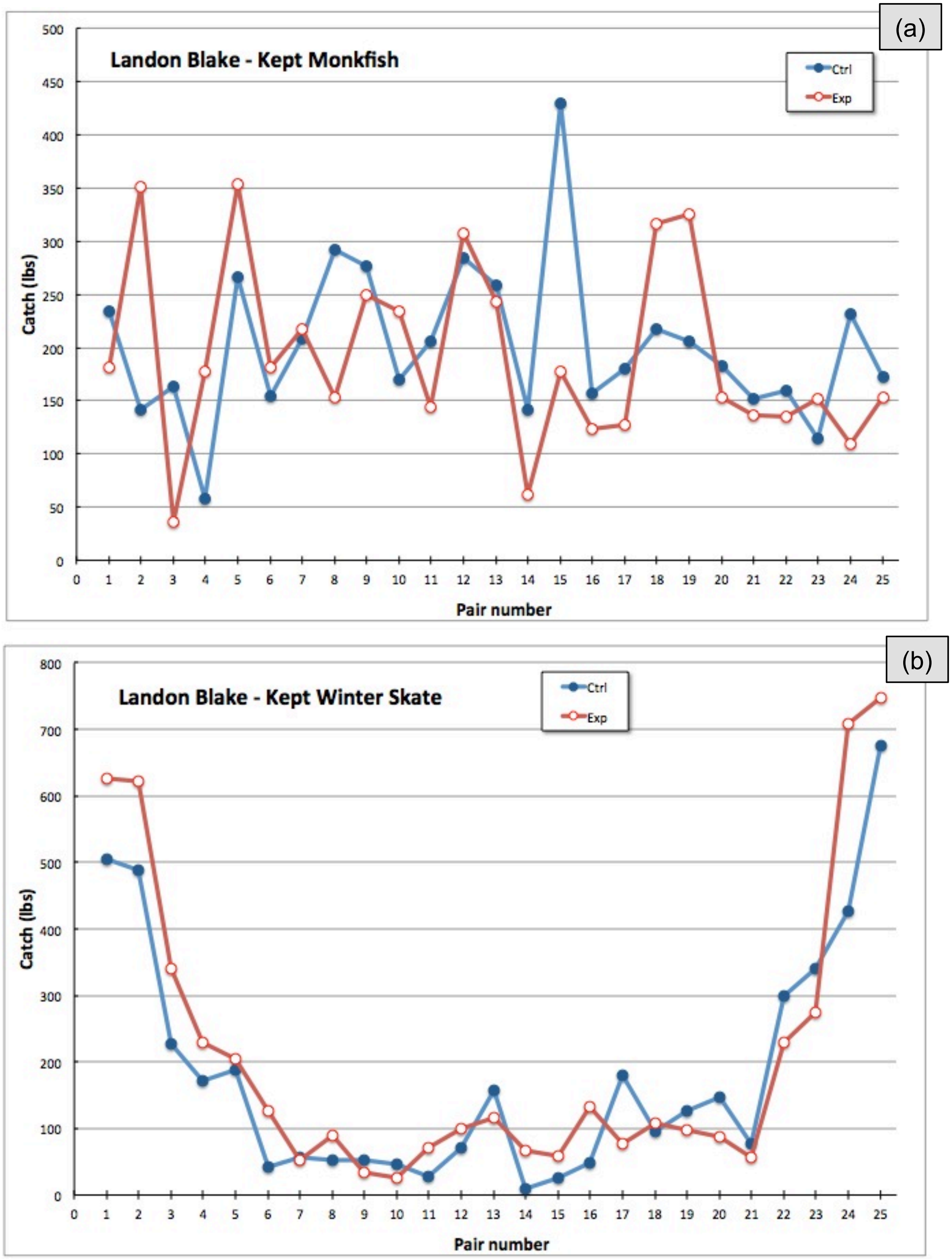
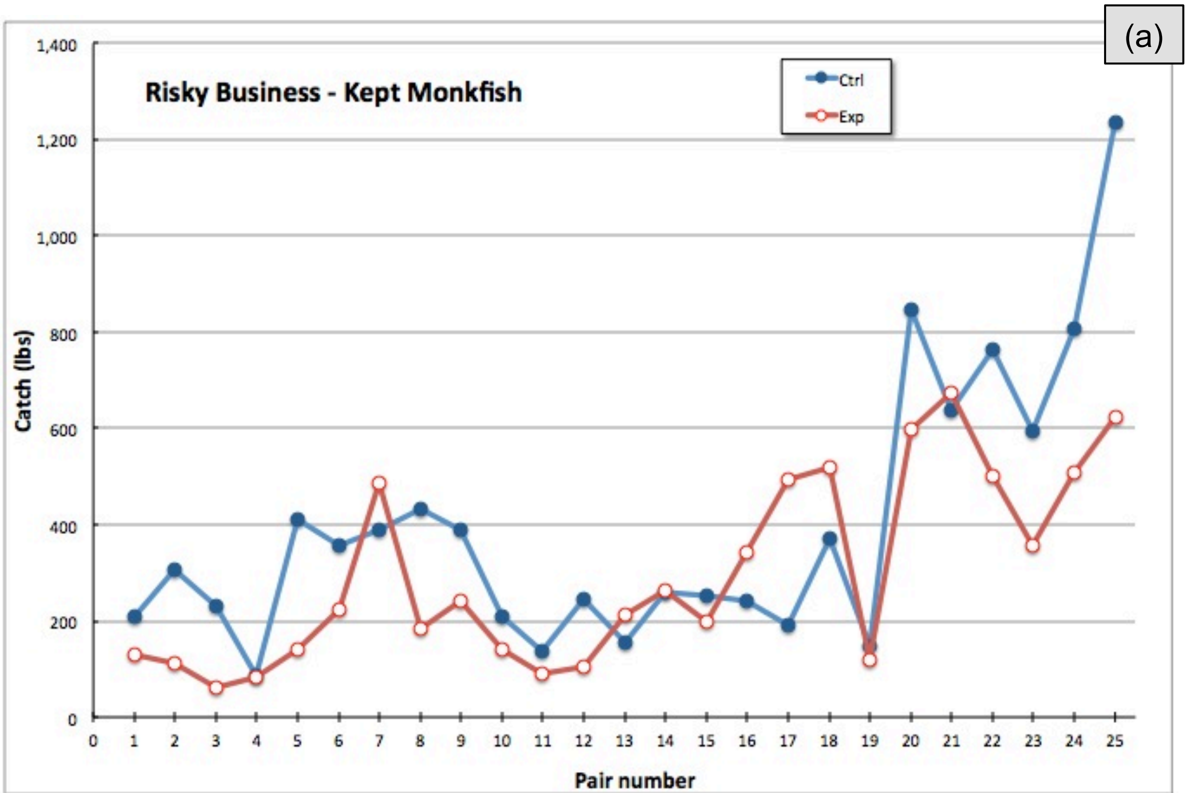


Figure 4. Haul-by-haul of “Kept” monkfish (a) and winter skate (b) per string by “Landon Blake”. Ctrl – Control, Exp – Experimental.



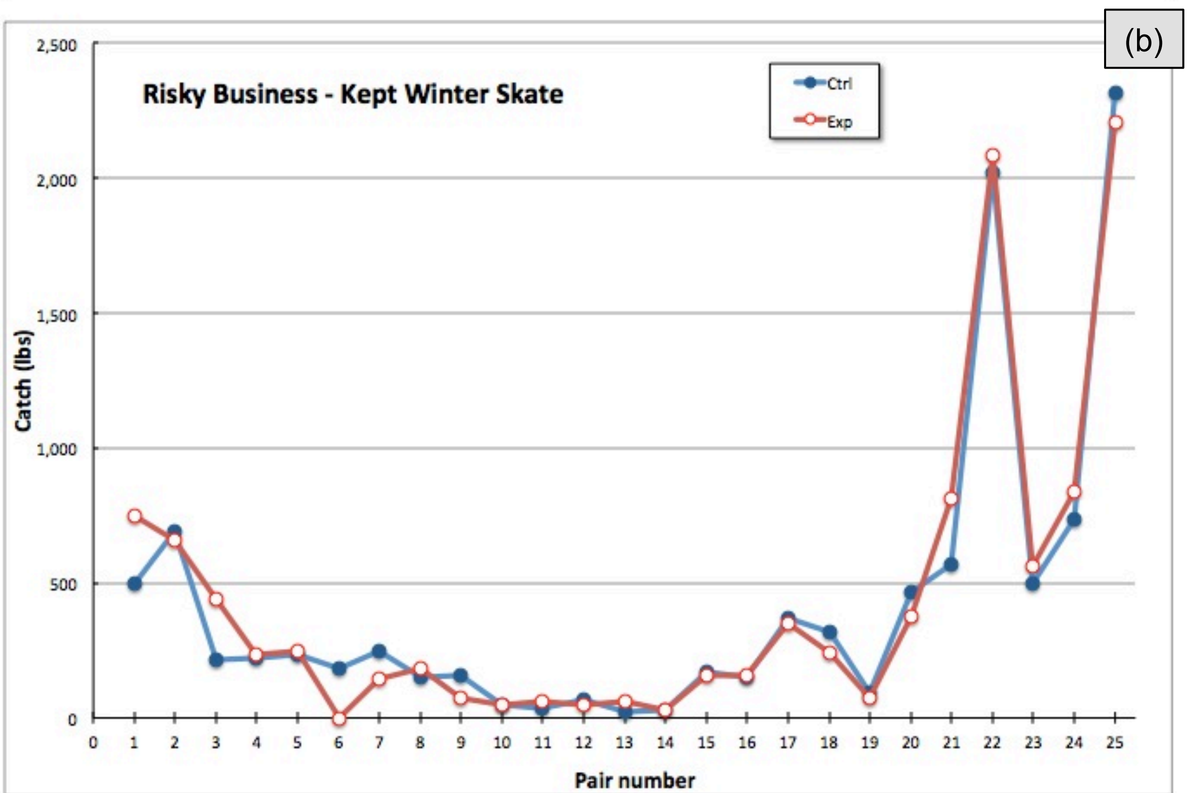
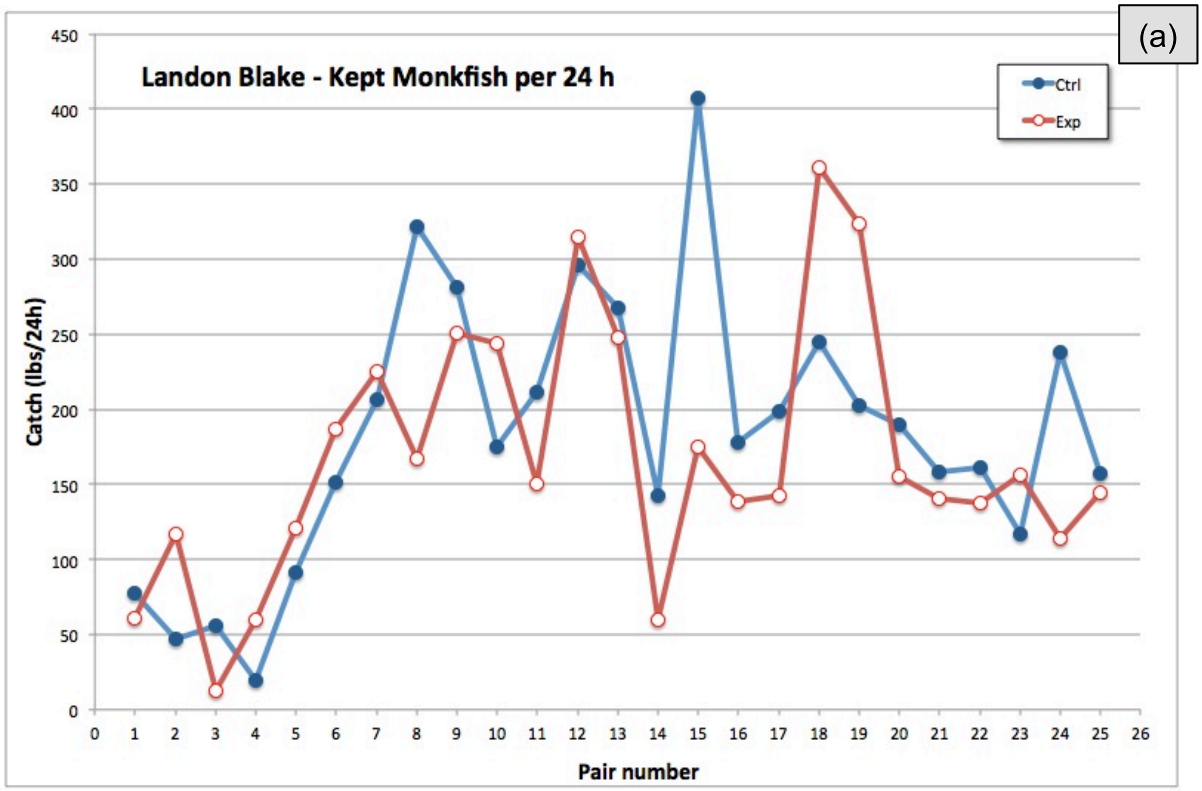


Figure 5. Haul-by-haul catch of “Kept” monkfish (a) and winter skate (b) per string by “Risky Business”. Ctrl – Control, Exp – Experimental.



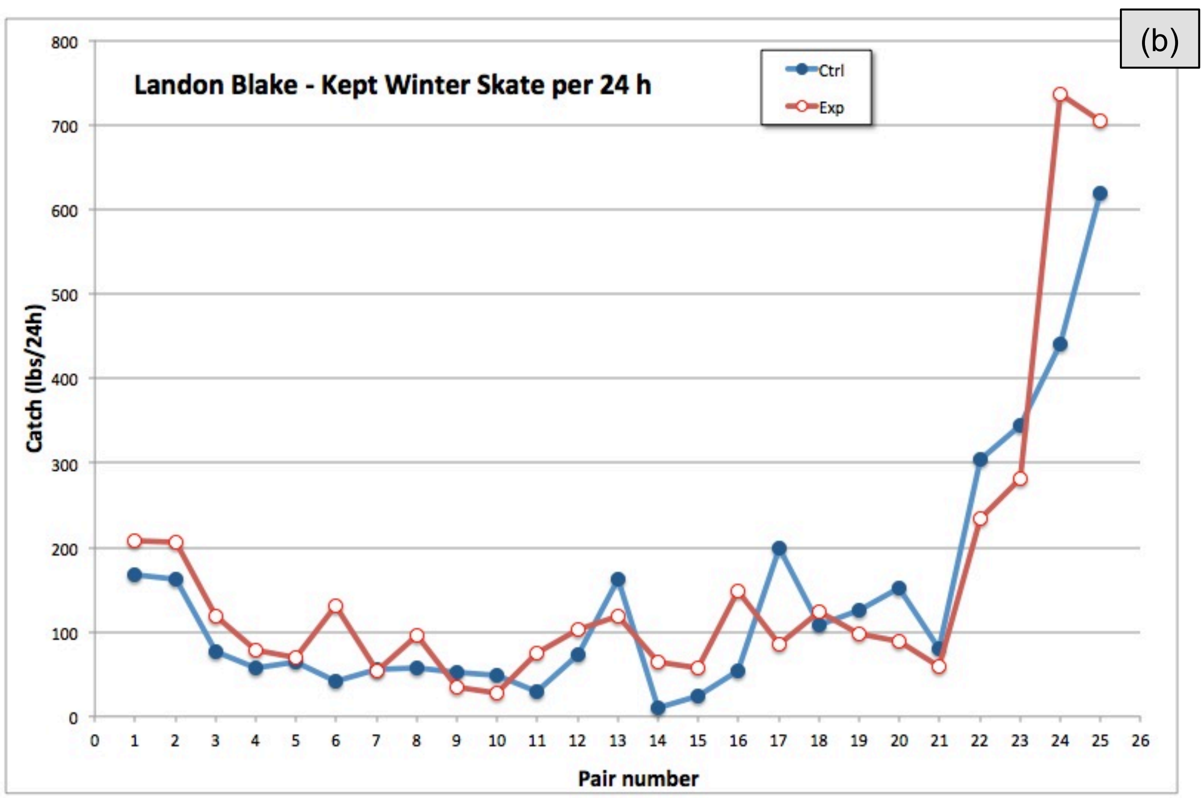
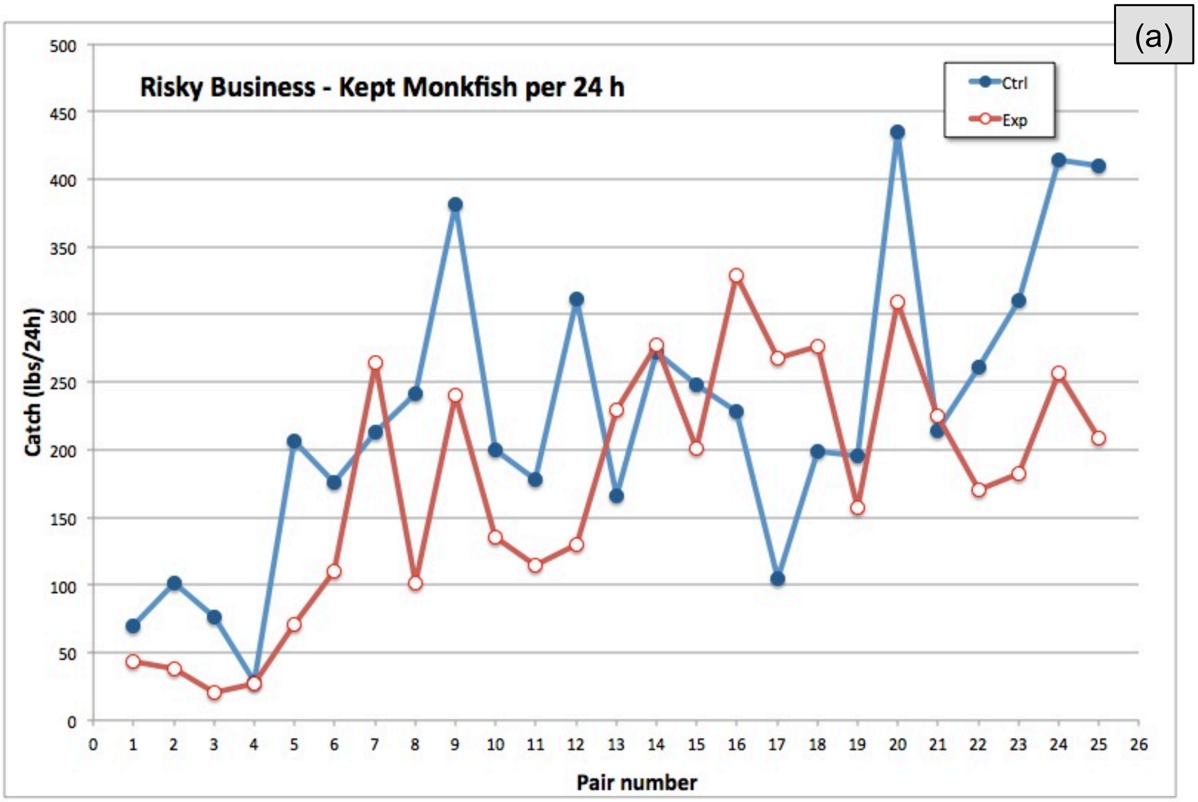


Figure 6. Haul-by-haul catch of "Kept" monkfish (a) and winter skate (b) per string per 24-h soak by "Landon Blake". Ctrl – Control, Exp – Experimental.



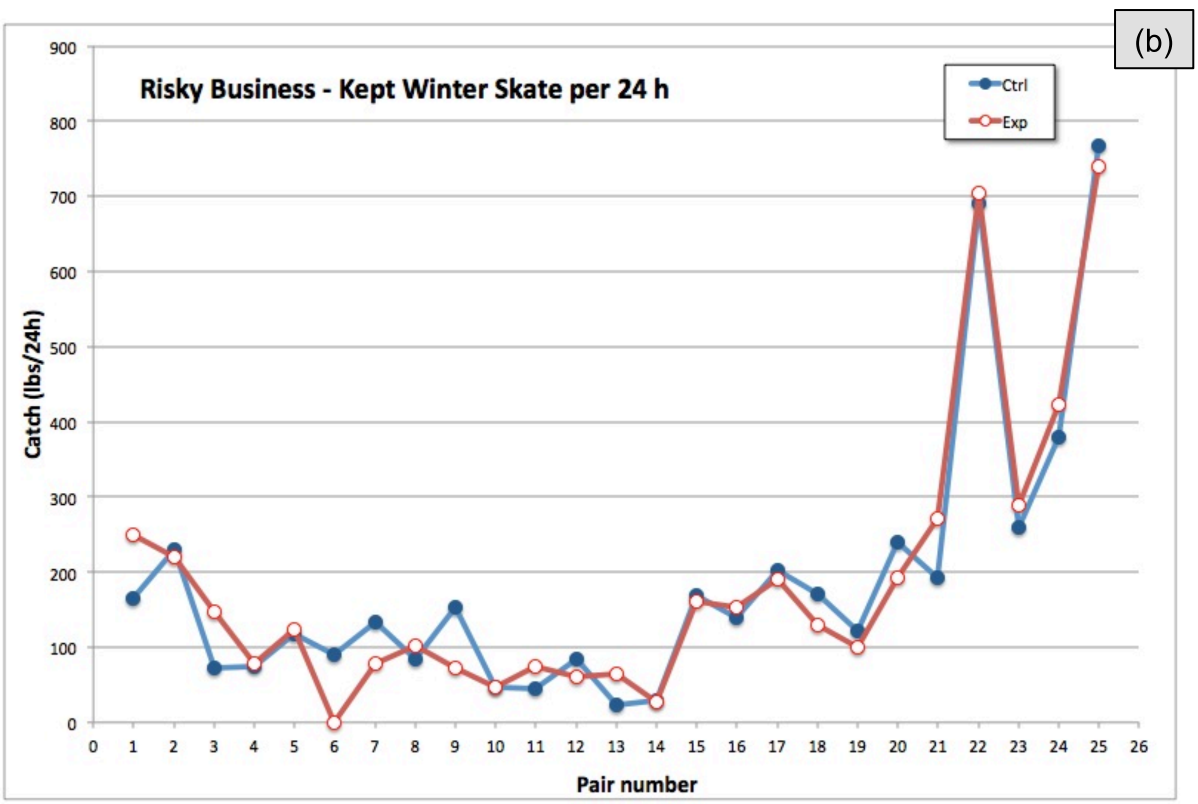


Figure 7. Haul-by-haul catch of "Kept" monkfish (a) and winter skate (b) per string per 24-h soak by "Risky Business". Ctrl – Control, Exp – Experimental.

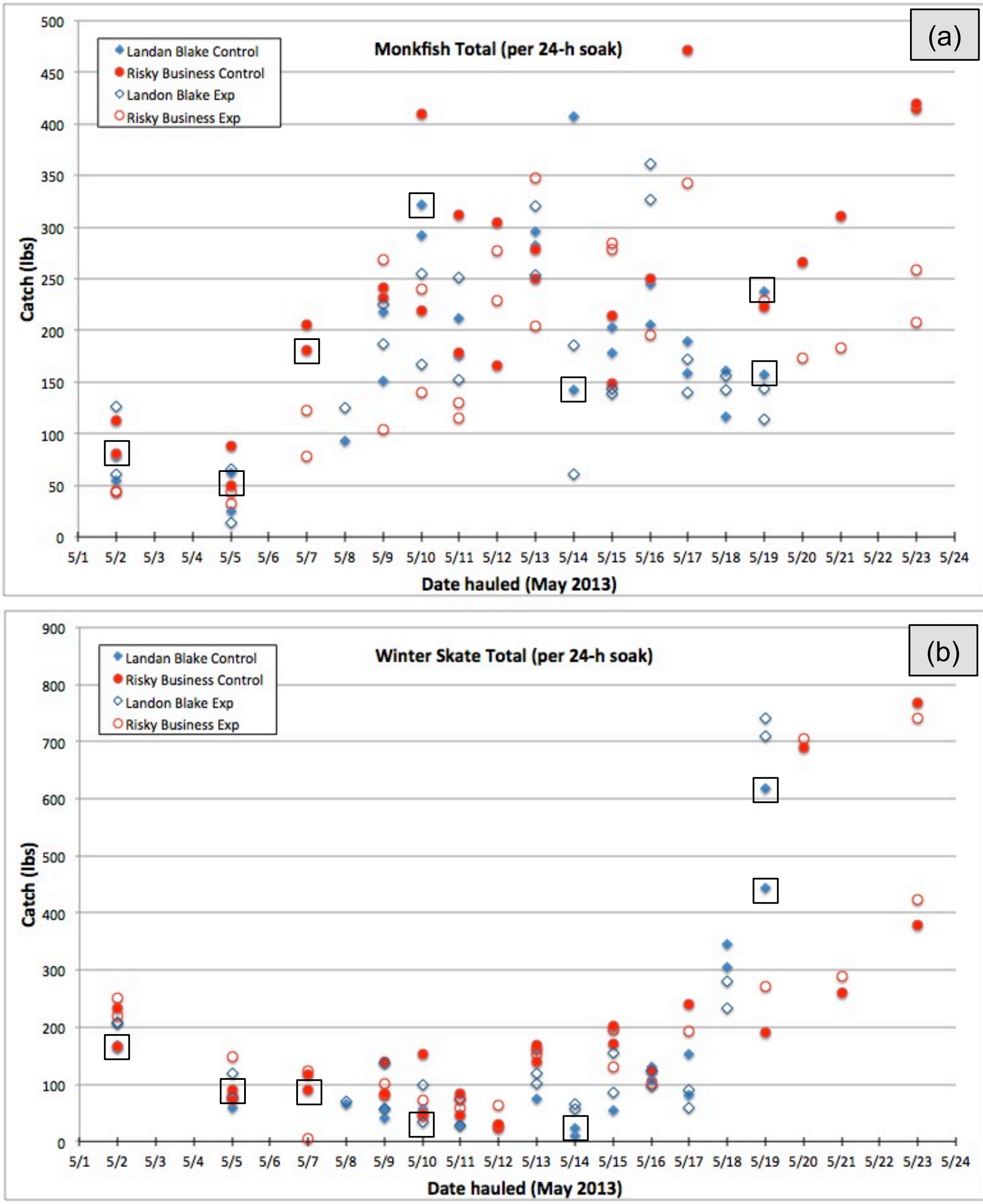
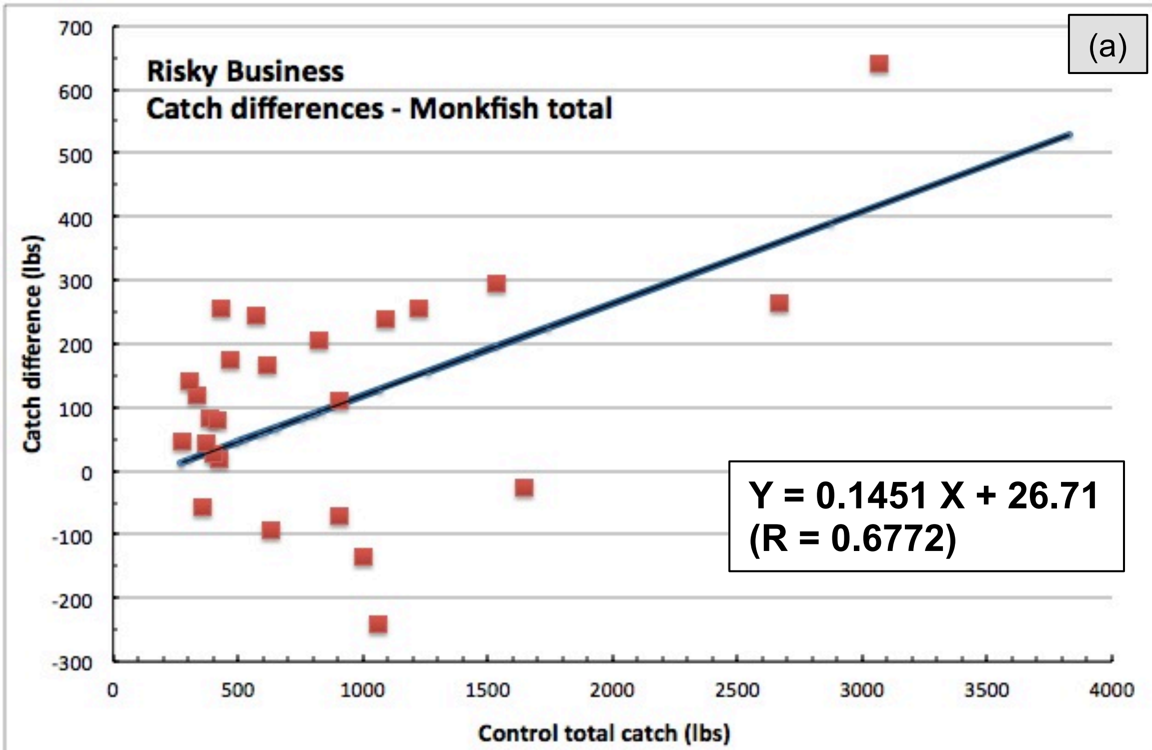


Figure 8. Catch of total monkfish (a) and winter skate (b) by two vessel by date illustrating increasing in catch as the season progressed. Squares indicate the string where a sturgeon was caught.



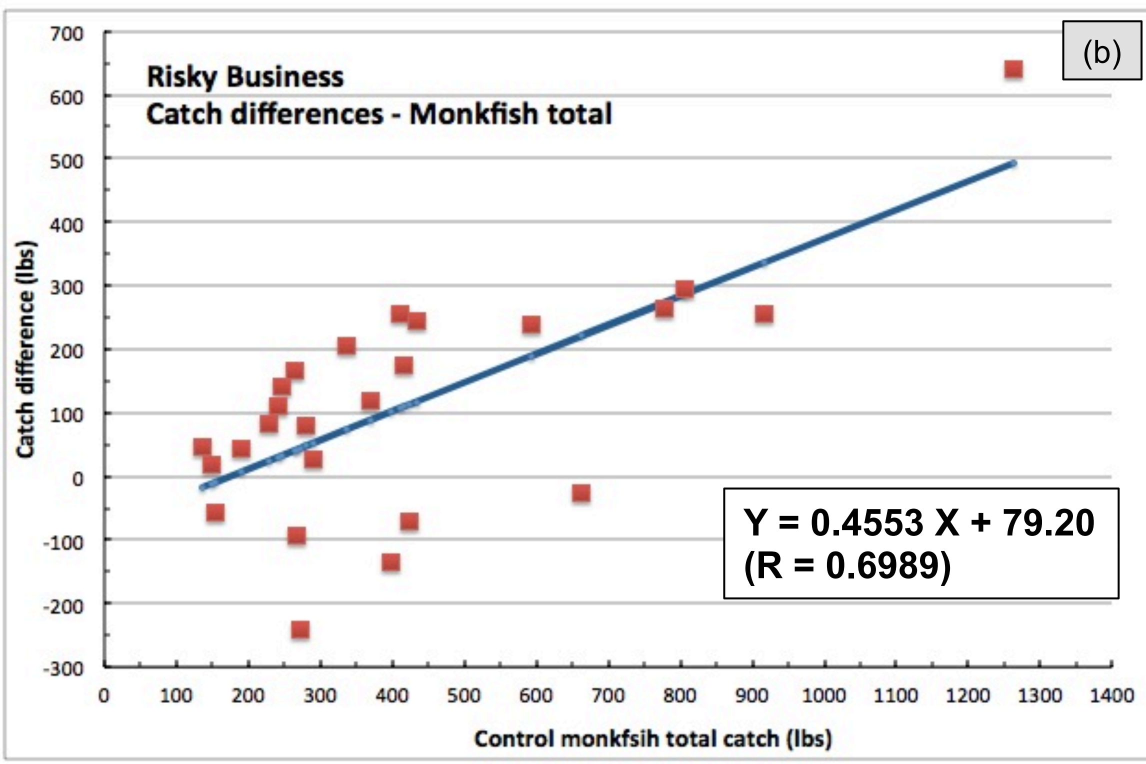


Figure 9. Catch differences between Control and Experimental nets for each pair of net for total monkfish (Kept + discarded) per string in relation to total catch weight of the Control net (top) and to the total monkfish catch in the Control (bottom). Blue lines are linear regression lines.

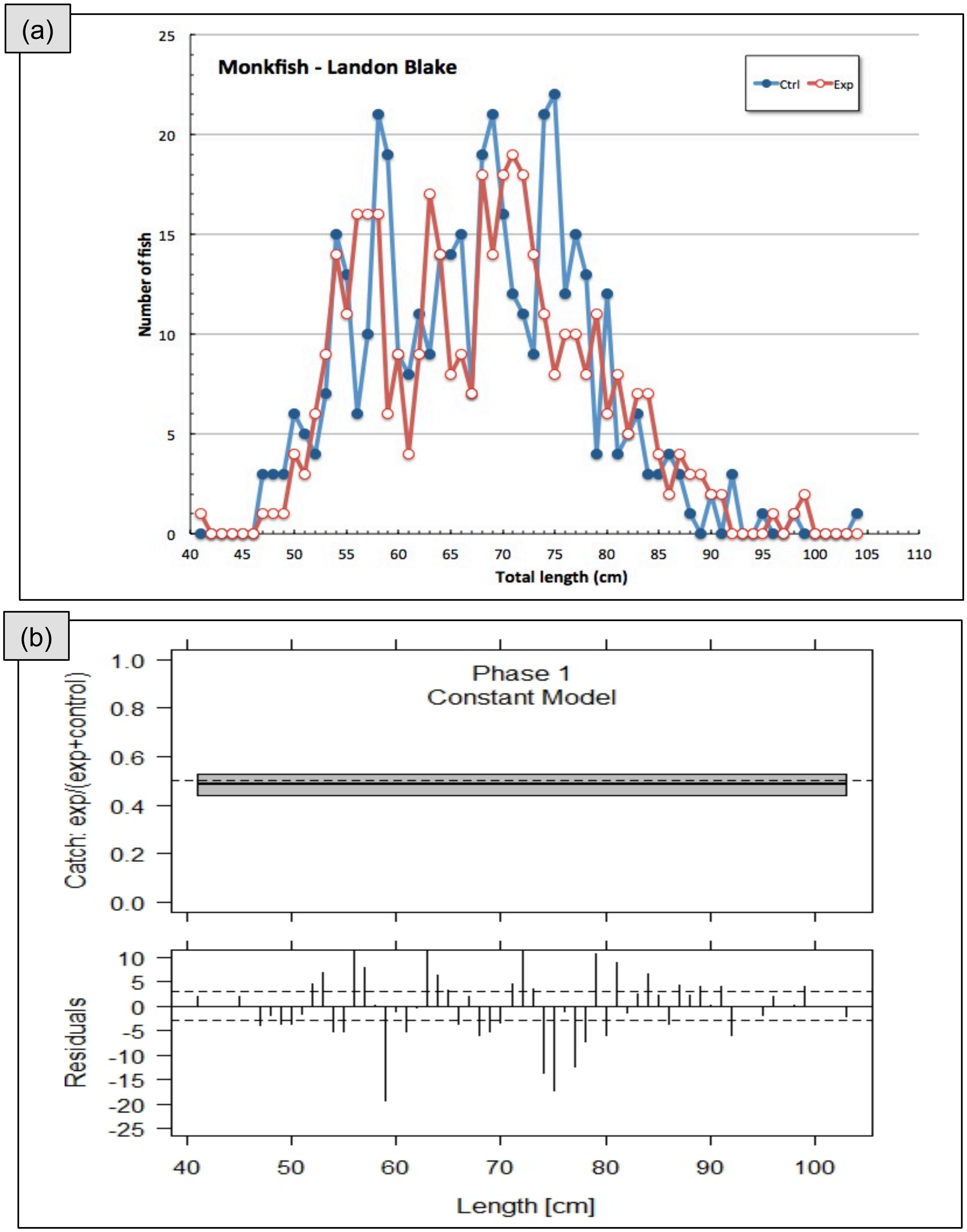


Figure 10. Length frequency distribution of monkfish from Control and Experimental nets (a) and GLMM modeling results (b) for "Landon Blake".

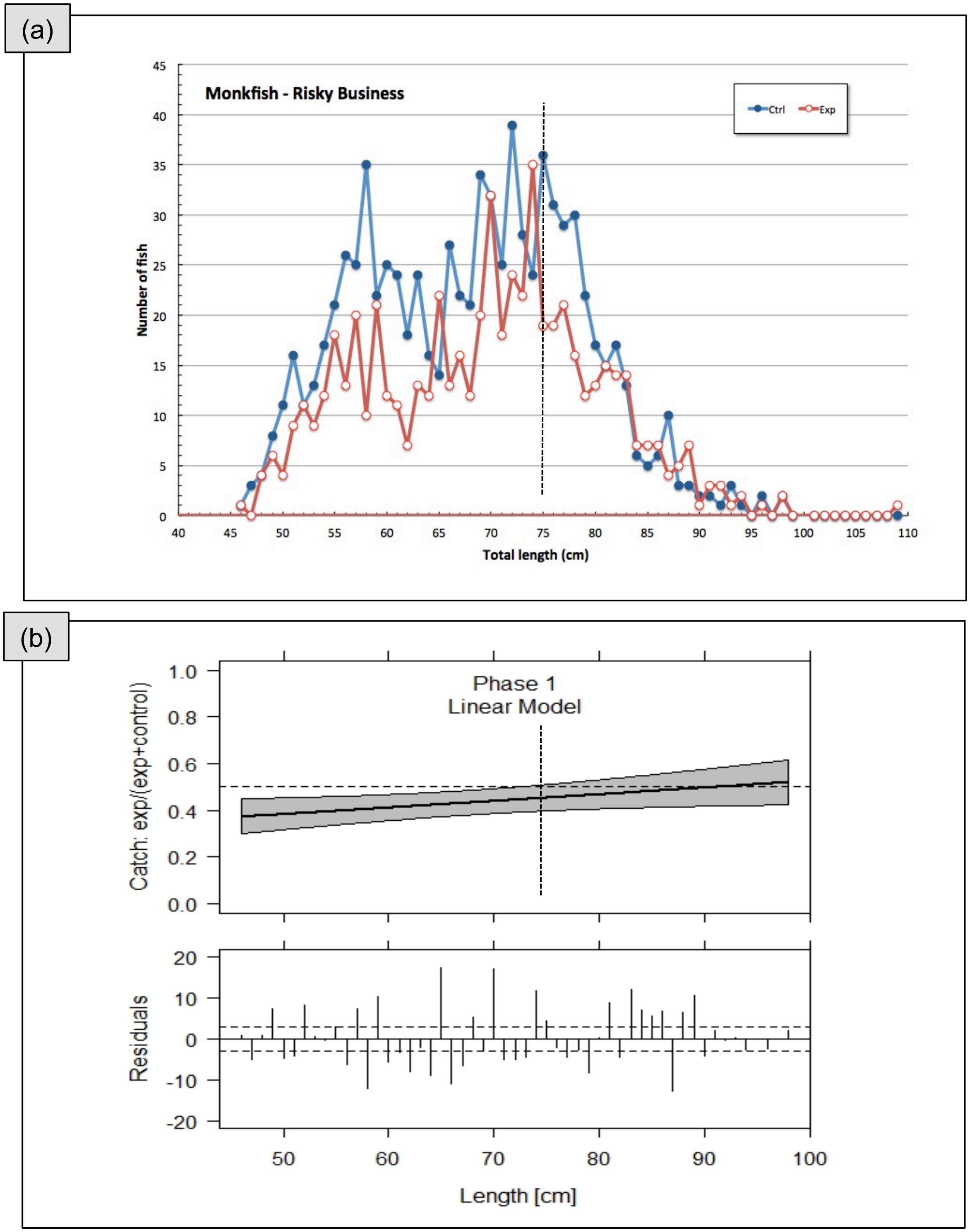


Figure 11. Length frequency distribution of monkfish from Control and Experimental nets (a) and GLMM modeling results (b) for “Risky Business”. Vertical dashed lines indicate the length below which the Experimental net catch less number of fish than the Control net.

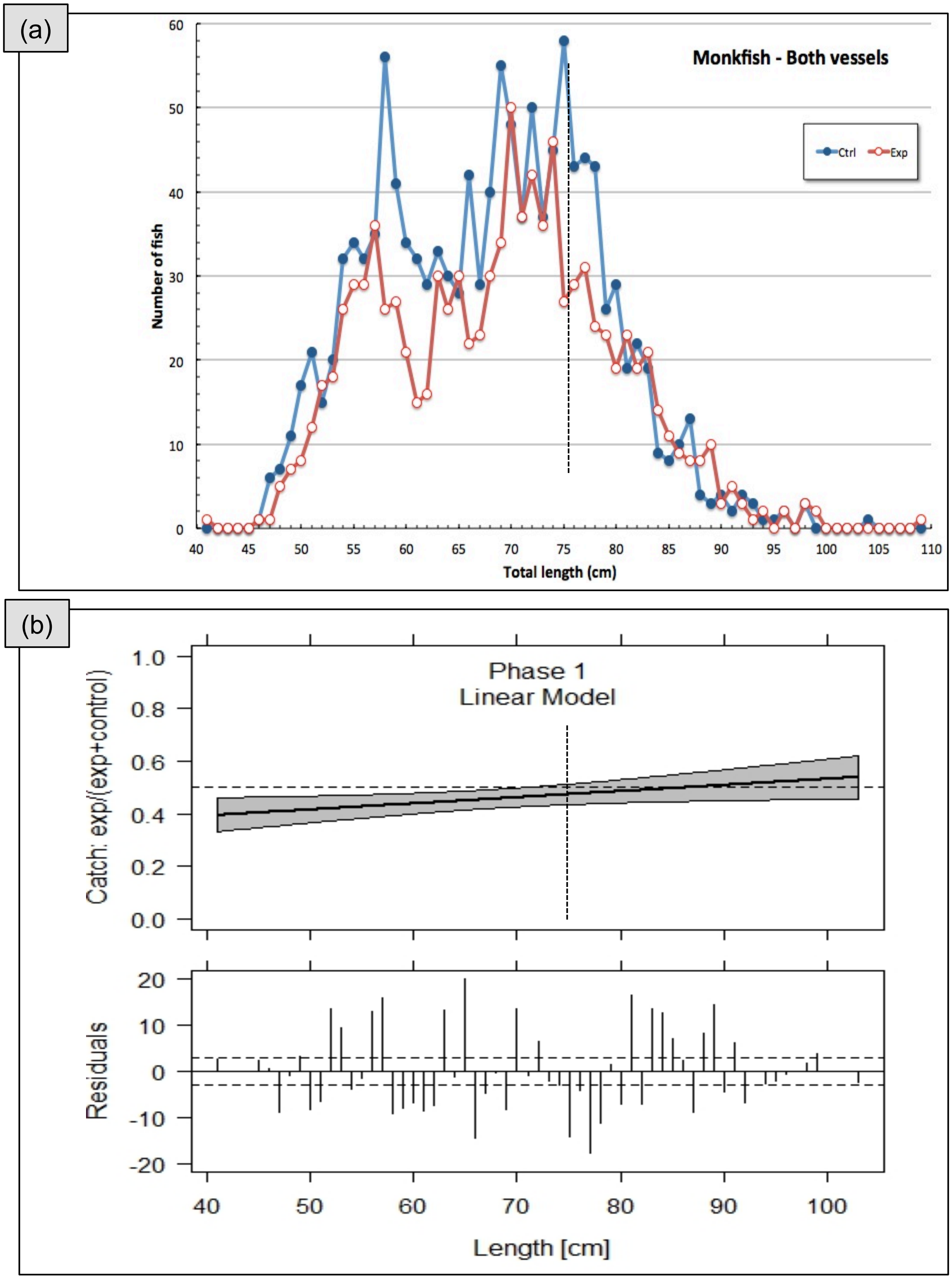
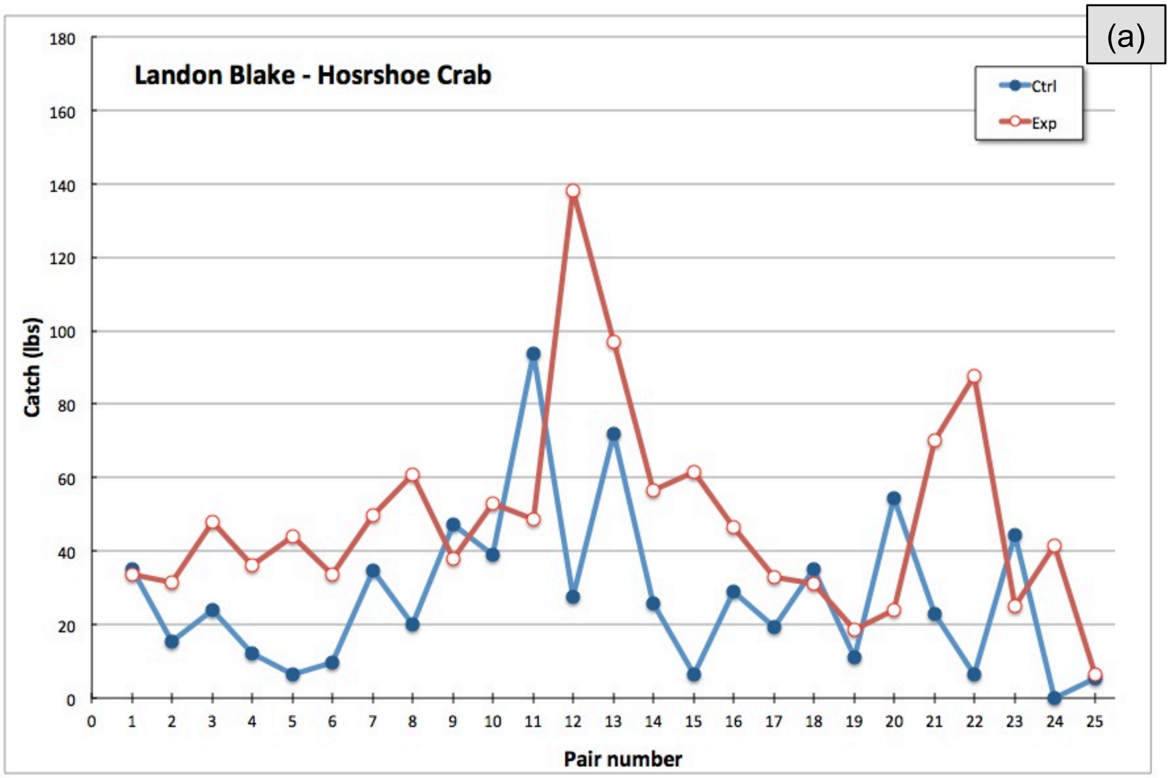


Figure 12. Length frequency distribution of monkfish from Control and Experimental nets (a) and GLMM modeling results (b) for both vessels combined. Vertical dashed lines indicate the length below which the Experimental net catch less number of fish than the Control net.



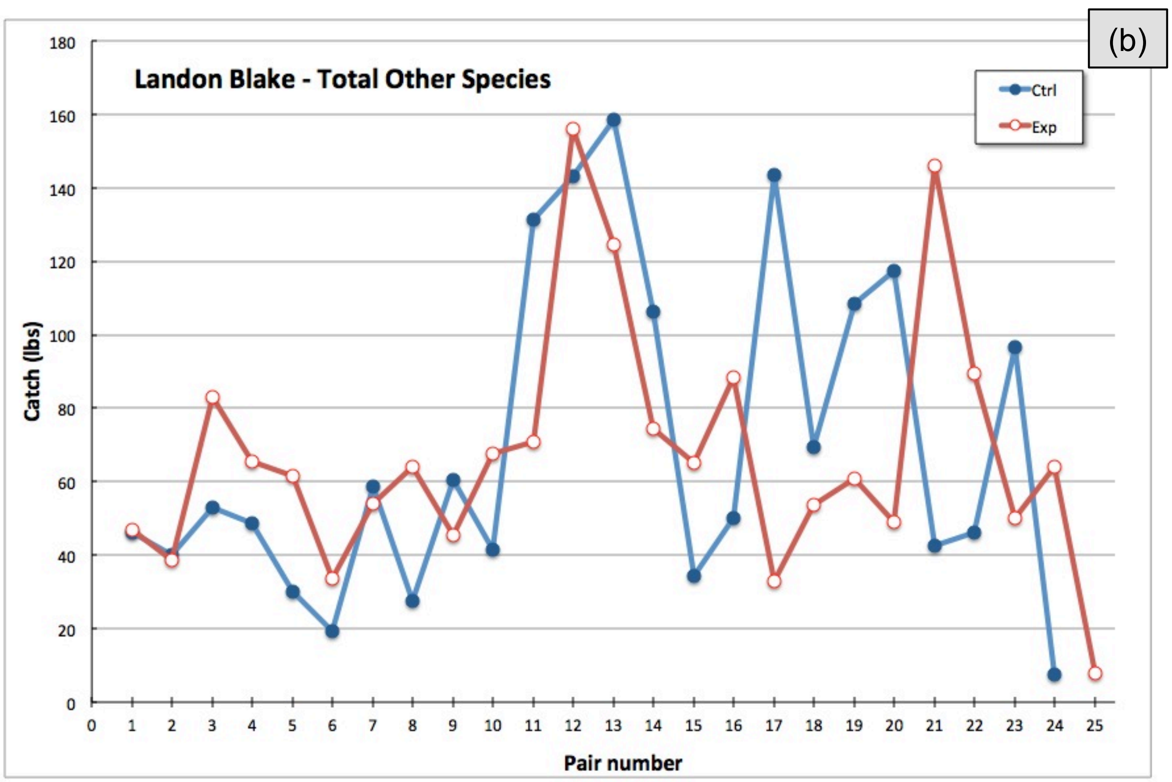
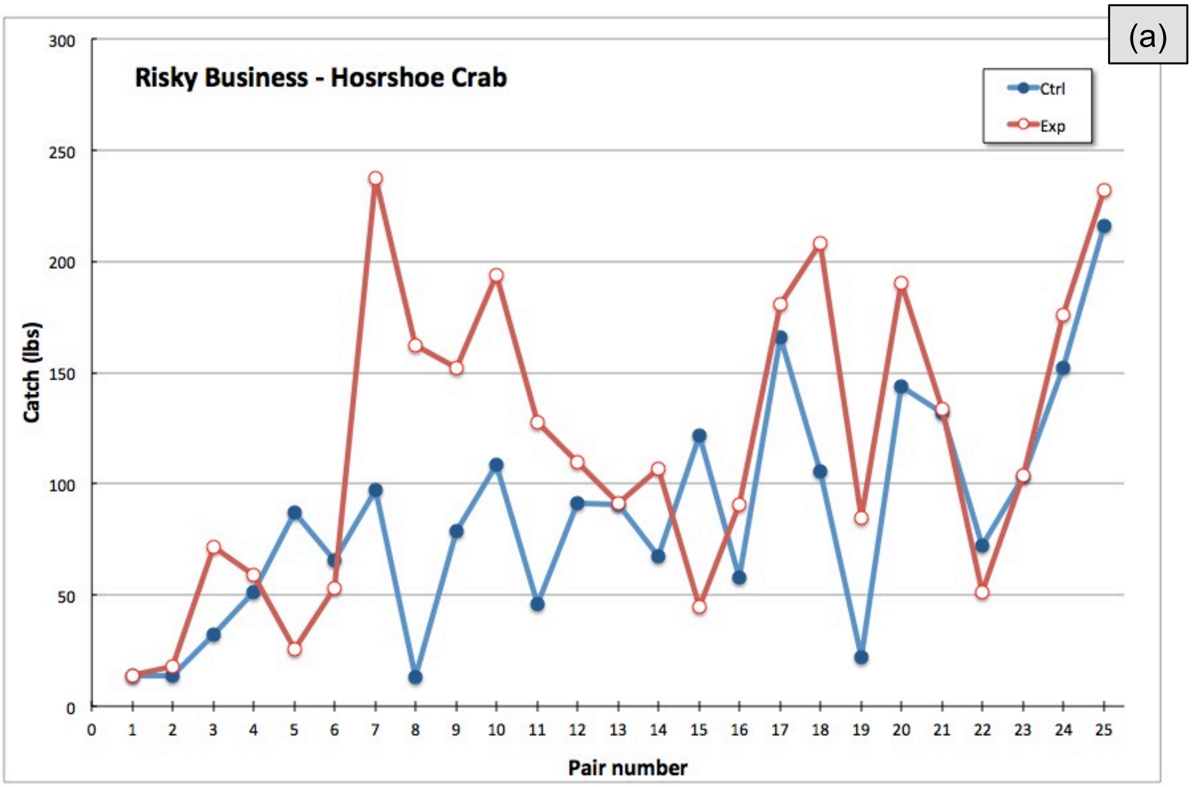


Figure 13. Haul-by-haul comparison of catch of horseshoe crab (a) and “total other species” (b) for “Landon Blake”.



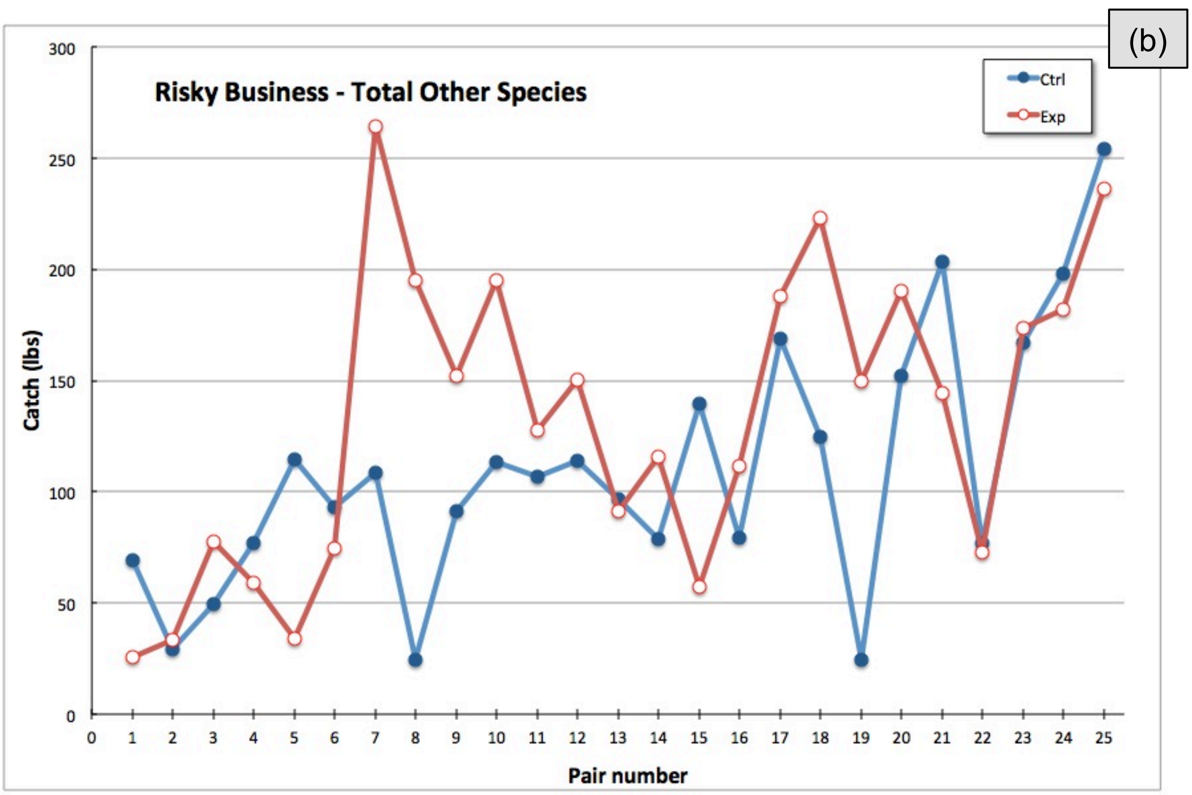


Figure 14. Haul-by-haul comparison of catch of horseshoe crab (a) and “total other species” (b) for “Risky business”.