NOAA Technical Memorandum NMFS-NE-282

Comparative Study of a Bottom-Set Gillnet Designed to Reduce Sea Turtle Bycatch in the U.S. Mid-Atlantic Monkfish Gillnet Fishery

US DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Northeast Fisheries Science Center
Woods Hole, Massachusetts
May 2022

NOAA Technical Memorandum NMFS-NE-282

This series represents a secondary level of scientific publishing. All issues employ thorough internal scientific review; some issues employ external scientific review. Reviews are transparent collegial reviews, not anonymous peer reviews. All issues may be cited in formal scientific communications.

Comparative Study of a Bottom-Set Gillnet Designed to Reduce Sea Turtle Bycatch in the U.S. Mid-Atlantic Monkfish Gillnet Fishery

by Brian Galvez[1], Eric Matzen[2], Henry Milliken[2], Ellen Keane[3], Carrie Upite[3]

1 Integrated Statistics, Inc., 16 Sumner Street, Woods Hole, MA 02543
2 NOAA Fisheries Service, Northeast Fisheries Science Center, 166 Water Street, Woods Hole, MA 02543
3 NOAA Fisheries Service, Greater Atlantic Regional Fisheries Office, 55 Great Republic Drive, Gloucester, MA 01930

US DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Northeast Fisheries Science Center
Woods Hole, Massachusetts
May 2022

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

Monkfish (*Lophius americanus*) is a commercially valued species that supports a lucrative fishery in the Mid-Atlantic and Northeast regions of the United States. Primarily targeted through sink gillnets and trawls, the fishery is known to incidentally catch sea turtles and Atlantic sturgeon, both of which are protected under the Endangered Species Act. Although several years of research have demonstrated that an experimental, low-profile gillnet reduces the bycatch of Atlantic sturgeon while maintaining acceptable landings of target catch, there is a lack of information on its effects on sea turtle bycatch. In this study, we compare the difference in turtle catch between a low-profile (experimental) gillnet and a standard (control) gillnet typically used in the monkfish fishery. This study was conducted off Cape Hatteras, North Carolina, from mid-February to mid-March 2021. This location is known to have high densities of loggerhead turtles (*Caretta caretta*) in late winter/early spring, which allowed us to collect enough turtles within reasonable time and budget constraints. Over 14 days, 68 paired hauls with an average soak time of 42 minutes were completed. The control net caught 19 loggerhead turtles, and the experimental net caught 6. Following a repeated measures design, we used generalized linear mixed models with a Poisson distribution to model the dependent variable of turtle catch numbers. Fixed effects included gear type and the environmental variables of surface temperature/bottom temperature differential, time of day, depth, and wind speed. A trip identifier was included in the model as a random effect, and soak duration was included as an offset variable. The corrected Akaike Information Criterion (cAIC) was used to find the best fit model from a model suite. The model with the single fixed effect of gear type had the lowest cAIC. The estimate of gear type indicated that the experimental net reduced turtle catch by approximately 68% compared to the control net. In addition to the model results, underwater video of loggerhead turtles interacting with the experimental net was captured.

1. INTRODUCTION

1.1 Background

Sea turtles around the world have faced significant declines due to anthropogenic stressors. Although legal protections such as the United States Endangered Species Act of 1973 (ESA) have helped to slow the decline, and in fact increase some sea turtle populations, their recovery continues to be of concern. This is true for loggerhead sea turtles (Casale and Ceriani 2020; Casale et al. 2019; Le Gouvello et al. 2020; Mazaris et al. 2017; Witherington et al. 2009; Conant et al. 2009), the most common species of sea turtle in the Greater Atlantic Region (Maine through Virginia). In 2011, the National Marine Fisheries Service (NMFS) and the U.S. Fish and Wildlife Service issued a final rule (Endangered and Threatened Species…2011) that identified 9 distinct population segments (DPS) of the loggerhead sea turtle. Of the 9 DPSs, the Northwest Atlantic Ocean DPS was listed as threatened, and bycatch in fishing gear was described as one of the most significant threats to their recovery.

In the U.S. Mid-Atlantic, one type of fishing gear that threatens loggerhead recovery is the sink gillnet, particularly with mesh sizes ≥7 inches (Murray 2009, 2013, 2018). From 2007-2011, an average of 89 loggerheads per year were estimated to have been incidentally caught in sink gillnet fisheries operating in the Mid-Atlantic (Murray 2013). Of these, 52 interactions were considered mortalities (Murray 2013). Murray (2018) estimated that from 2012-2016, a total of 705 (141 annual average) loggerheads were incidentally caught in sink gillnet fisheries in Georges Bank and the Mid-Atlantic, of which 557 (approximately 112 annual average) were fatal.

The threat of sea turtle injury and mortality from the Mid-Atlantic sink gillnet fishery is a serious concern for NMFS, and the agency is working to minimize bycatch in this gear type. Research from 2010-2013 compared the bycatch rates of protected species and target catch rates between standard gillnets used in the fishery and an experimental "low-profile" gillnet designed to reduce bycatch of Atlantic sturgeon and sea turtles. Although the results of these studies showed that the low-profile net reduced sturgeon bycatch, the impacts to sea turtles could not be measured due to their absence throughout the study period and location (Fox et al. 2011, 2012, 2013; He and Jones 2013). In 2013, the NMFS Northeast Fisheries Science Center (NEFSC) and the Atlantic States Marine Fisheries Commission (ASMFC) held a workshop (NMFS and ASMFC 2013) with scientists and industry stakeholders to discuss gear modifications that may reduce sea turtle and Atlantic sturgeon bycatch while maintaining catch of target species. Of the gear modifications identified to reduce protected species bycatch, the low-profile gillnet was identified as a promising solution to reduce bycatch of sea turtles.

To better understand the effects of the low-profile gillnet on sea turtle bycatch, researchers conducted a study off the coast of Cape Hatteras, NC, in 2017, where sea turtle abundance and the probability of encounter was higher (Usher 2018). During that study, 60 paired sets were completed and resulted in 14 and 8 loggerheads and 3:3 of Kemp's ridleys caught in the control and experimental nets, respectively. Statistical analysis did not show a significant difference of turtle catch between nets, and a water temperature shift from a storm that occurred during the study period was believed to have confounded the results (Usher 2018). The final conclusions from the 2017 study were therefore inconclusive and led to the need to further investigate the question of whether the experimental low-profile gillnet reduces turtle bycatch compared to traditional gillnets used in the commercial fishery.

1.2 Research Problem

Despite the results of the Fox et al. (2011, 2012, 2013), He and Jones (2013), and Usher (2018) studies, the effects of low-profile gillnets on sea turtle bycatch were still unknown. The 14:8 control versus experimental catches of loggerheads and 3:3 of Kemp's ridleys in the 2017 study showed that the experimental gear caught fewer turtles, but the analysis did not show a statistically significant difference between gear types.

Usher (2018) noted that during the first 7 trips of the study, 10 loggerhead turtles were caught in control nets while 0 were caught in experimental nets. During the final 5 trips, 4 loggerheads were caught in control nets while 8 were caught in experimental nets. The researchers speculated that surface-bottom temperature differentials may have caused the increase in catch in experimental nets—more turtles were caught in the experimental net when bottom temperatures were greater than surface temperatures. While the statistical and analytical (i.e., temperature differential) results of this study were informative for future studies, the question of whether low-profile gillnets reduce turtle bycatch remained.

1.3 Research Purpose

The purpose of this study was to continue investigating whether the low-profile gillnet design reduces the catch of loggerhead sea turtles when compared to the standard gillnets used in the Mid-Atlantic monkfish gillnet fishery. The objectives of this study were to mimic the Usher (2018) study by:

1) conducting sea trials using traditional commercial monkfish gillnets and experimental low-profile gillnets in the southern Mid-Atlantic waters when sea turtles were known to be present;
2) determining if there is a statistically significant difference in the catch rate of loggerhead sea turtles between the 2 net configurations;
3) reviewing the total fish catch (landed and discarded) between the 2 net configurations; and
4) tagging and collecting data on all sea turtles and sturgeon caught following protocols to minimize risk of injury or mortality.

1.4 Experimental Approach

To further investigate whether the low-profile gillnet catches fewer loggerheads compared to the traditional monkfish gillnet, the nets were alternately set to allow each treatment to have an equal soak time. This alternating paired comparison method, designed to reduce gear handling time and minimize bias, was used in the previous gillnet comparison studies (Fox et al. 2011, 2012, 2013; He and Jones 2013; Usher 2018) and has been proven to be effective for catch comparison studies of different types of fishing gear. Furthermore, using the alternating set method rather than testing the different net types in a single string prevented the results from being confounded due to issues related to lack of independence that occurred in a previous iteration of this study.

2. METHODS

2.1 Gear Design

2.1.1 Gillnets

Each string of gear contained 4 panels of the same type (control or experimental). A “string” refers to the entire net from anchor to anchor, whereas a “panel” refers to an independent section of net mesh within the string. Each string has a weighted footrope (or leadline) and a floating headrope that lifts the mesh netting up in the water column to make a standing barrier for fish to get caught in. Each treatment was equipped with tie downs which were spaced at different intervals—the treatment with tie downs every 12 ft. at every float, and the control with tie downs every 24 ft. at every other float. Tie downs are made of a thin, braided cord that fastens the headrope to the footrope at a specified height, which reduces the overall height of the net and causes the net mesh to fold over itself. The folding of the net causes a “bag-effect,” which increases the efficiency of the net to catch fish. Table 1 shows the shared attributes and unique characteristics of each treatment, and Figure 1 shows a diagram of a single panel of each treatment.

2.1.2 GoPro Mounts

GoPro cameras were deployed on dual camera mounts specifically designed to be quickly attached to the footrope during deployment of the net (Figure 2). Three mounts were built during the course of the research with input from the contract vessel’s captain and crew. The hardware used to build the mounts consisted of the following:

1) 1” zinc-plated perforated square tube
2) 3/8” zinc threaded rod
3) 3/8” stainless lock nuts, hex nuts, and washers
4) 3/8”x1.5” stainless hex bolts
5) Stainless steel longline snaps without swivels
6) 3/8” outer diameter fuel hose
7) Gillnet floats
8) Zip ties
9) GoPro 3M flat adhesive mounts

2.1.3 Fishing Vessel

The F/V Salvation is a custom built, 32-ft. fiberglass over wood V-hull. The 5-gross ton vessel has a 10 ft. beam, 2 ft. draft, and is powered by a 250 horsepower Honda 4-stroke outboard engine mounted on a stern bracket. The vessel was designed to fish and navigate the shallow inlets and coastal waters of North Carolina. The vessel has an aft steering station with a bow-mounted net reel that uses a stainless steel roller overhanging the bow to haul gillnets.

2.2 Experimental Design

2.2.1 Location

Similar to Usher (2018), the areas selected to deploy the nets were determined based on discussions with the vessel captain, as he was familiar with the nearshore and offshore areas southeast of Cape Hatteras. The captain has empirical knowledge of the North Carolina coastal fisheries and the locations where sea turtles are commonly found throughout the inshore waters off Cape Hatteras. In the 2017 Usher study, several meetings with all project participants were held to ensure that the researchers, captain, and crew understood the scope, goals, ESA permit requirements, and protocols (including regulatory) of the project. These details remained the same for the 2021 study, and a brief pre-trip meeting with the NMFS principal investigator and the captain was held to reaffirm the project details.

The majority of the hauls in this study occurred along an area of hard bottom south of Diamond Shoals (see depicted on NOAA nautical chart 11555 where the area is noted as a fish haven; Figure 3) in the vicinity of N 35°08’ and W 75°39’. According to the captain, this location has an artificial reef adjacent to natural hard bottom. It is known to be frequented by sea turtles during the late winter and early spring, and turtles were regularly observed on the surface during the study.

The nets were fished in the Exclusive Economic Zone outside the 3-mile state water line. The depths ranged from 58 ft. to 118 ft. (mean of 71 ft.). The locations for each set are depicted in Figure 3. The number of paired hauls each day varied from 1 to 7 and averaged 3 per day.

2.2.2 Justification of Study Occurring Outside of the Fishery

In choosing the location for the study, we concluded that the comparative analysis of the 2 gear types in the traditional monkfish grounds (located on the continental shelf from Massachusetts to Virginia) would require an unacceptable amount of time and effort to obtain a sufficient sample size of turtles to effectively test whether the experimental gear reduces turtle bycatch in the fishery. By testing the experimental gears in areas of high sea turtle abundance, we could observe the differences in turtle catch between each net type more efficiently.

In addition, this gear has previously been tested for catch retention and was shown to retain a level of monkfish catch that was not statistically different from the control gear (Fox et al. 2013; He and Jones 2013). Because the focus of the current study was to determine the catch rate of the experimental versus the traditional monkfish net for sea turtles, the observers did not collect length data of the fish caught. Rather, a tally count and estimated weight per species was recorded (see appendix).

2.2.3. Gear Deployment

Sea trials were conducted in the coastal waters southeast of Cape Hatteras, North Carolina, between February 24 and March 18, 2021, onboard the F/V Salvation. Using the ABBA scheme (Wileman et al. 1996), the control and experimental nets were set in an alternating pattern to allow each treatment to have an equal soak time. Each comparison contained 1 string of 4 control net panels and 1 string of 4 experimental net panels. The ESA permit required that all gillnets soaked for a maximum of 1 hour to prevent any sea turtle or other protected species mortality. Because of the concern that the nets might encounter large numbers of elasmobranchs, the first pair of each day was limited to a soak time of approximately 20 minutes to assess the number of elasmobranchs in the area and to allow enough time to haul back the second string within the 1-hour soak limit if many elasmobranchs were caught in the first net. The control and experimental strings were set immediately downwind of one another along a similar bottom structure and contour. For example, during a northerly wind, the first net was set in a north to south direction. Immediately after the first net was set, the second net was deployed, continuing the north-south line. Thus, for each paired set, 2400 linear ft. of net (1200 ft. of each treatment) was stretched out along the bottom in a single line in the same direction as the wind.

Generally, areas were fished depending on sea state, water temperature, and visual abundance of sea turtles at the surface. Sea states of less than 3 ft. were preferred to facilitate handling of caught turtles, and sea surface temperatures above 15.5 °C (60 °F) were selected when feasible to minimize cold stress to any turtles. Times of day when nets were set ranged from 0700 to 1630. Lastly, because the goals of this study were to collect sufficient numbers of sea turtles to accurately compare the 2 treatments, surfacing turtles were considered good indicators of local abundance which was interpreted as an area with higher catch potential.

2.2.4. Data Variables

The following data were collected for each haul:

- Date
- Time
- Trip number (individual study days on the water)
- Haul number (consecutive over the course of the study)
- Gear type (experimental or control)
- Wind speed (1 value per haul)
- Wind direction (1 value per haul)
- Water depth (individual nets)
- Soak duration (individual nets)
- Surface temperature (HOBO logger at the top of the buoy line)
- Mid-depth temperature (HOBO logger at the middle of the buoy line)
- Bottom temperature (HOBO logger at the bottom of the buoy line)
- Begin and end time of set for each net
- Coordinates for beginning and end of set/haul of each string
- Set method (e.g., bottom contour, visual)
- Number and estimated total weight of all fish caught for each haul
- Number and species of turtles caught

2.3 Environmental Conditions

All of the trips during the study occurred on days with wind speeds averaging 15 knots or less and sea states of 3 ft. or less. The median wind speed when hauling the nets was 8 knots. The sea surface temperatures ranged from 7.8 °C to 19.4 °C (44.8 °F to 64.6 °F; Figure 4), and bottom temperatures ranged from 10.4 °C to 23.5 °C (50.7 °F to 74.3 °F; Figure 4). Bottom temperatures were warmer than surface temperatures each day a turtle was caught (Figures 4 and 5). The ranges of soak duration (in minutes) and depth (in feet) fished by gear type are shown in Figures 6 and 7, respectively.

2.4 Sea Turtle Sampling and Data Collection

2.4.1 Turtle Sampling

When a sea turtle was caught, the following information was collected:

- Entanglement description and location within the net
- Protected Species ID number (assigned consecutively to turtles caught) and species name
- All measurements as required by NMFS NEFOP observer protocols (NEFOP 2019))
- Skin biopsies according to NMFS protocols

Comments regarding sea turtle behavior on deck and at release, as well as body condition, were recorded. For all sea turtles caught, photos were taken of the head, dorsal view, ventral view (if possible), any injuries, and any unique identifying characteristics. Each turtle was scanned with a passive integrated transponder (PIT) tag scanner. If a PIT tag was located, the number was recorded along with any other tags present (flipper, satellite, etc.). If no PIT tag was located, the observer inserted one. All sea turtles were also tagged with Inconel tags on their hind flippers (1 on each), and the numbers were recorded according to NMFS protocols. The sea turtle tagging information is summarized in Table 3.

2.4.2 Turtle Tagging

Using the methods outlined in Patel et al. (2018), turtle length was measured to ensure compliance with the ESA permitting requirements that the total combined weight of all transmitter attachments be less than 5% of the turtle's body mass based on length-weight models. Turtles were held on deck while a satellite tag was mounted to the carapace of each turtle using a 2-part epoxy. The satellite relay data loggers (SRDL) that were deployed were manufactured by the Sea Mammal Research Unit at University of Saint Andrews, Scotland. Each tag reported location, depth, and temperature. The transmission duty cycle was set to deliver ~1 complete temperature-depth profile per day from a deep dive. The rate of temperature and pressure recordings was set to 4 seconds. Vemco V13 tags were placed on the posterior region of the carapace with the 2-part epoxy.

2.5 GoPro Deployments

Beginning on trip 7 (March 8, 2021), GoPro cameras were attached to the lead line of the experimental nets with the goal of capturing sea turtles interacting with the nets during a soak. Three mounts containing 1 pair of cameras positioned in opposite directions were attached on a single net approximately 20-40' from each other. Although there was no standard protocol on where the mounts were placed along the net, they were mainly placed on the third string out of the net reel. The longline snaps were clipped onto the tarred hanging twine, and the mounts were lowered into the water off the bow. For the mounts to set properly on the seafloor, care was taken to confirm that they were hanging below the lead line and not tangled in the monofilament netting before entering the water. Cameras were typically set on the third haul of the day to allow enough sunlight to penetrate to the depths that were fished (70 ft. on average) and were only placed on the experimental net.

2.6 Statistical Analysis

The study was treated as a repeated measures design, with a pair of nets (i.e., haul) being the experimental unit and all other covariates being equal for each paired haul from 1 to 68 (details below). Thus, a generalized linear mixed model (GLMM) was considered appropriate in this case (Proudfoot et al. 2018). Using R statistical software version 4.0.3 (The R Project for Statistical Computing), the data were modeled using GLMMs with the Poisson distribution using the log link function. The models were fitted using the ‘glmer’ function in the ‘lme4’ package (Bates et al. 2015). The fixed effects included in the model were gear type, average depth, temperature differential (calculated as surface temperature minus bottom temperature), time of day, and wind speed. Trip number was set as a random effect, and soak duration was included as an offset. Including trip as a random effect in the model helped to explain the variance in turtle catch for each trip. Since haul number was treated as the experimental unit, the depth and time of day were averaged for each pair of nets. For example, if net 1 was set at 10:00AM in 70 ft. of water and net 2 was set at 10:10AM in 80 ft. of water, the averaged values assigned to both nets would be 10:05AM at 75 ft. of water. Temperature differential was considered equal for each paired haul because temperature data loggers were only placed on a single buoy line on 1 net, and the values were assigned to both nets. Similarly, wind speed was only collected on the deployment of the first net of a haul and was, therefore, the same for each pair of nets.

A suite of candidate GLMMs was created based on what were hypothesized to be the most influential variables relating to turtle catch (Table 2). Using the “cAIC4” package in R (Säfkin et al. 2021), the conditional Akaike Information Criterion (AIC) scores (cAIC) were evaluated, and the model with the lowest cAIC was determined to be the most parsimonious that best explained the rate of loggerhead turtles caught during the study. The best fit model was checked for overdispersion and zero-inflation.

3. RESULTS

The project commenced with the first trip on February 24, 2021, and ended with the final trip completed on March 18, 2021. Sixty-eight paired hauls of the control and experimental gears were completed during the 12 trips. The trip identification numbers, date of trip, and number of hauls for each type of gear are summarized in the appendix.

3.1 Data Analysis

3.1.1 Sea Turtle Catch

A total of 25 loggerhead sea turtles were caught in the 136 (68 paired) gillnet sets during the study. Nineteen loggerheads were caught in the control net, and 6 were caught in the experimental net. All sea turtles were caught alive and released with no noticeable injuries. Eleven of the 25 loggerheads caught in the net did not get sampled because they either fell out of the net at the surface, were too large to safely bring aboard, or another turtle was already on board for sampling. The remaining 14 loggerheads brought on board were measured for curved carapace length (notch to notch and notch to tip) and width (CCL and CCW, respectively), vent to tip of tail, and Inconel flipper and PIT tags were applied (no turtles had previously applied tags). The co-investigator attached satellite tags on 6 of the 14 sampled turtles, and 2 of the 6 were fitted with the Vemco tags. CCL and CCW of the 14 loggerheads sampled ranged from 57.5 to 79 cm and 54.9 to 74 cm, respectively (Table 3).

3.1.2 GLMM

We modeled the dependent variable of loggerhead catch and compared 7 candidate models using the cAIC. Model 6, the simplest model, had the lowest cAIC and was considered to be the most parsimonious (Table 4). The estimates on the link (log) and response scales are shown in Table 5, and interpretations of the estimates are explained below.

3.2 Catch

3.2.1 Total Fish Catch

The majority of all teleost and elasmobranch species caught during the study were released unless they were commercially valuable and could be legally landed under federal and state permits registered to the F/V Salvation. The following species were encountered during the study: cownose ray(*Rhinoptera bonasus*), southern stingray (*Hypanus americanus*), butterfly ray, angel shark (*Squatina squatina*), sand tiger shark (*Carcharias taurus*), tiger shark (*Galeocerdo cuvier*), white shark (*Carcharodon carcharias*), smooth hammerhead shark (*Sphyrna zygaena*), dusky shark (*Carcharhinus obscurus*), sandbar shark (*Carcharhinus plumbeus*), and black drum (*Pogonias cromis*). Due to the short soak duration, the catch rates were generally low except on trip 14, haul 1, when the control net caught an estimated 350 pounds of sharks, rays, and finfish including angel sharks, dusky sharks, sand tiger sharks, butterfly rays, cownose rays, southern stingrays, and black drum. Trip 14, haul 1, using the experimental net, caught an estimated 200-pound sand tiger shark and 350 pounds of black drum. A list of species caught and estimated weight ordered by trip, haul, and net type can be found in the appendix.

3.2.2 Other Species

No other species protected under the ESA or the Marine Mammal Protection Act were caught during the study.

3.3 Video Footage of Sea Turtle-Gillnet Interactions

Thanks to the high visibility at depth (~70 ft) for the majority of the study, 12 turtle-gillnet interactions with the experimental net were captured on film. Here, we defined a turtle-gillnet interaction as whenever a turtle physically touched any part of the net or as any occurrence where a turtle’s behavior was altered due to the proximity of the net. Although 12 interactions were filmed, none of the videos showed a turtle being entangled in the net, and none of the hauls when turtles were filmed resulted in a turtle catch. Instead, all of the videos showed some sort of avoidance behavior. Two main types of avoidance behavior were observed: 1) encountering the headrope as an obstacle and swimming over the headrope, and 2) encountering the net as an obstacle and crawling/swimming along the length of net without touching it. These videos show how some wild loggerhead turtles interact with gillnets and how water clarity likely plays a role in gillnet avoidance behavior. A web link to the video, which is entitled *Going Low to Reduce Sea Turtle Bycatch,* can be found on the NOAA NEFSC Gear Research webpage under the section titled “Low Profile Gillnets”..

4. DISCUSSION

The primary objective of this study was to determine if there was a statistically significant difference in loggerhead catch between the control and experimental nets. The GLMM results showed that the experimental net decreased loggerhead catch by approximately 68%. The 68% reduction in the experimental net can be interpreted as the expected percent reduction of loggerhead catch when using the experimental net as opposed to the control net.

In addition, we were able to capture GoPro video footage of loggerhead turtles interacting with the experimental net. What we believe to be the first of their kind, these videos provide valuable insight into the stimulus-induced and avoidance behaviors of sea turtles when they are stopped by or observe the gillnet (prior to physical interaction), respectively. In addition, the videos suggest that vision and water clarity likely play a role in sea turtle avoidance behavior of gillnets.

Although the sea turtle catch comparison results of the different gear types in Usher (2018) were not statistically significant, our findings align with the reduction rates of the low-profile gillnet during that study (14:8 control:experimental). Due to the nature of the data and the research question, we found that a modeling approach rather than significance testing via a t-test was the most appropriate in this case. Because the data are counts, the use of the Poisson distribution was considered to be the best option. Therefore, the results of the best fit GLMM are more reliable and realistic indicators of turtle catch and also allowed for other covariates to be included in the analysis. However, it should be noted that the model predicted rate of loggerhead catch is based on the exposure variable of soak duration. Considering the exposure variable, the turtle catch rates were also dependent on the turtle density per unit area during the time the study occurred. Therefore, if the model is to be used to predict turtle catch rates in other areas at different times of the year, we believe that the known or predicted turtle density for the area of interest should be considered to increase the accuracy of the model predictions.

Usher (2018) speculated that the surface-bottom temperature differentials may have influenced the loggerhead catch rates during their study. Specifically, the researchers posited that more turtles were caught in the experimental net when bottom temperatures exceeded surface temperatures. Given that this was speculative, more data were needed to determine if this theory held true during the current study. Including the temperature difference as a single variable in the model suite allowed us to determine whether it had a significant effect on turtle catch. The results from the most parsimonious model (model 6) showed that temperature differential did not significantly influence loggerhead catch rates. Unlike the temperature differentials observed in the Usher (2018) study, where turtles were caught on trips when surface temperatures exceeded bottom temperatures and vice versa, surface temperatures during the 2021 study rarely exceeded bottom temperatures. Thus, although the 2018 study found that the shift in temperature differentials after a storm may have caused an increase in turtle catch in the experimental net, the results from this study do not support that theory.

The videos that captured turtle-gillnet interactions and subsequent avoidance behavior were enlightening to the overall study and its research and management implications. Citing Nagasaki (2013), Usher (2018) speculated that because loggerhead turtles use vision to forage, water clarity may play an important role in the observed catch of turtles in both gillnet types. With the caveat that 5 turtles were seen on film swimming directly into the net yet avoided entanglement, we believe that the turtle behavior observed in the videos supports the theory that turtle catch in gillnets is influenced by their ability to see the net. The 2 observed avoidance behaviors (avoiding and swimming over the headrope and crawling/swimming along the length of the net without touching it) suggest that the sea turtles use vision to avoid the nets. However, it is important to note that the instances where turtles swam directly into the net also suggest that their vision does not always help them to avoid the nets. Due to the depths of where the study occurred, it was not possible to use traditional methods for determining water clarity/turbidity at the seafloor. As proposed by Usher (2018), future studies will explore novel methods of measuring visibility at depth to better understand turtle catch as it relates to visibility.

Furthermore, even with 12 observed turtle-gillnet interactions, none of the turtles viewed in the videos were caught in the net. Based on the ratio of the observed turtle-gillnet interactions to turtle catch, we speculate that the total amount of turtle catch was a small fraction of the number of times that turtles interacted with either net type. This finding suggests that even with high rates of turtle-gillnet interactions, the low-profile net is more effective at reducing the rate of loggerhead catch compared to the control net. Considering 1) the number of observed turtle-gillnet interactions, and 2) the total length of experimental gillnet observed on film (~100 ft out of 1200 ft, or ~8%), we assume there were many more unobserved turtle-gillnet interactions along *both* nets. The fact that cameras were only used on the experimental net but recorded multiple interactions, combined with the fact that the experimental net caught 3x fewer turtles than the control net, we can assume with reasonable confidence that there were many more unobserved interactions that did not result in a catch. Considering the catch results (19:6, control:experimental), we therefore theorize that the experimental net will always catch fewer turtles than the control net, most likely due to the significant decrease in net area. To prove this assumption in the future, we recommend that cameras be mounted along both nets during paired sets to better evaluate the efficiency of each net at catching turtles. It is also important to note that the results of this study only apply to daytime sets and that the bycatch reduction performance of the low-profile net is yet to be determined when ambient light is not present (i.e., during overnight soaks).

In summary, our work reveals that the low-profile gillnet significantly reduces turtle catch when compared to the standard gillnet typically used in the Mid-Atlantic monkfish fishery. The GLMM results show that turtle catch is mainly influenced by gear type. The turtle-gillnet interaction videos may be the first video evidence of wild sea turtles interacting with a gillnet in the ocean and show how turtles react when confronting the low-profile gillnet. The practical implications of these findings suggest that the low-profile gillnet can play an important role in reducing loggerhead bycatch in the U.S. monkfish gillnet fishery and perhaps other gillnet fisheries around the world.

TABLES AND FIGURES

Table 1. Shared and individual attributes of the control and experimental gillnets compared in this study.

Both Treatments	Control	Experimental
4 x 300 ft. panel length Headrope: 3/8” polypropylene rope with standard gillnet floats spaced 12 ft. apart Footrope: 75 lb/600 ft. of leadline Nylon monofilament 12” mesh 0.90 mm twine	12 meshes deep 48” tie-down lines spaced every 24 ft. at every other float	8 meshes deep 24” tie-down lines spaced every 12 ft. at every float

Table 2. List of candidate general linear mixed models (GLMMs) that were compared using Aikake Information Criterion (cAIC). # LH caught refers to the number of loggerheads caught; gear refers to net type (experimental or control); depth (units in feet); temp_dif refers to surface temperature minus bottom temperature in degrees Celsius; timeOfday refers to hour of the day; soak duration is in minutes; (1|trip) refers to the random effect of trip.

Model #	Model Configuration
1	log(# LH caught) ~ intercept + gear + avg depth + temp_dif + timeOfday + wind speed + (1|trip) + offset(log(soak duration))
2	log(# LH caught) ~ intercept + gear + avg depth + temp_dif + timeOfday + (1|trip) + offset(log(soak duration))
3	log(# LH caught) ~ intercept + gear + avg depth + temp_dif + (1|trip) + offset(log(soak duration))
4	log(# LH caught) ~ intercept + gear + avg depth + (1|trip) + offset(log(soak duration))
5	log(# LH caught) ~ intercept + gear + temp_dif + (1|trip) + offset(log(soak duration))
6	log(# LH caught) ~ intercept + gear + (1|trip) + offset(log(soak duration))
7	log(# LH caught) ~ intercept + gear + timeOfday + (1|trip) + offset(log(soak duration))

Table 3. Data table for hauls when loggerheads were caught. No other species of turtle were caught during the study.

Date	Trip #	Haul #	Set Time	Gear	ID	Notch to Notch Length (cm)	Notch to Tip Length (cm)	Width (cm)	Flipper (Iconel) Tag # (LEFT/RIGHT)	PIT Tag #
2/24/2021	1	3	10:38	control	CC01	76	77.3	74	MMJ220/MMJ219	982.000365
3/4/2021	4	1	7:31	control	CC02	69.5	71	65.5	MMJ179/MMJ180	982.000365
3/4/2021	4	2	10:21	control	CC03	67	69	64.5	MMJ181/MMJ182	982.000365
3/4/2021	4	5	12:43	control	CC04	NA	NA	NA	NA	NA
3/6/2021	5	3	9:25	control	CC05	NA	NA	NA	NA	NA
3/6/2021	5	5	11:32	control	CC06	53	57.5	54.9	MMJ183/MMJ184	982.000365
3/6/2021	5	6	13:14	experimental	CC07	73.5	73.5	74	MMJ185/MMJ186	982.000365
3/7/2021	6	2	8:18	experimental	CC08	NA	NA	NA	NA	NA
3/8/2021	7	1	7:14	control	CC09	NA	NA	NA	NA	NA

3/8/2021	7	2	8:16	control	CC10	65.5	66	63.5	MMJ187/MMJ188	982.000365
3/8/2021	7	3	10:09	experimental	CC11	77.5	78.2	73.7	MMK094/MMK095	982.000365
3/8/2021	7	3	10:15	control	CC12	NA	NA	NA	NA	NA
3/8/2021	7	4	12:04	experimental	CC13	62.5	63.5	61.5	MMK082/MMK088	982.000365
3/10/2021	9	1	7:16	control	CC14	NA	NA	NA	NA	NA
3/10/2021	9	3	9:00	experimental	CC15	58.5	59.5	56.5	MMJ222/MMJ223	982.000365
3/10/2021	9	3	9:05	control	CC16	74	75	68	MMJ224/MMJ225	982.000365
3/10/2021	9	3	9:05	control	CC17	NA	NA	NA	NA	NA
3/10/2021	9	6	12:40	experimental	CC18	65.5	66	64.7	MMK090/MMK093	982.000365
3/11/2021	10	2	8:30	control	CC19	66	67	64.25	MMK096/MMK183	982.000365
3/11/2021	10	3	9:54	control	CC20	NA	NA	NA	NA	NA
3/11/2021	10	6	12:32	control	CC21	NA	NA	NA	NA	NA

3/11/2021	10	6	12:32	control	CC22	NA	NA	NA	NA	NA
3/12/2021	11	1	6:23	control	CC23	78	79	73.5	MMJ226/MMJ227	982.000365
3/17/2021	13	2	10:55	control	CC24	NA	NA	NA	NA	NA
3/17/2021	13	3	11:56	control	CC25	74.5	76	73	MMJ228/MMJ229	982.000365
			Total							
			Control	19						
			Experimental	6						

Table 4. Akaike Information Criterion (cAIC) table of the general linear mixed model (GLMM) model suite.

Model Number	cAIC	Delta cAIC	cAIC Weight	Log Likelihood
6	128.78	0.00	0.40	-56.41
4	129.93	1.72	0.17	-56.24
5	130.44	1.85	0.16	-56.41
7	130.45	2.11	0.14	-56.39
3	131.00	2.95	0.09	-56.20
2	132.30	5.02	0.03	-55.98
1	133.66	7.11	0.01	-56.43

Table 5. The estimates, standard errors, deviance, and 95% confidence intervals of the fixed effect estimates, including the estimates on the link (log) and response scales. The variance and standard deviation of the random effect is shown below the fixed effects estimates. The rescaled estimates were obtained by raising e to the log estimates. For example, to convert the intercept from the log scale to the response scale, calculate e(-5.2056) to obtain 0.0055.

		Fixed Effects		
Parameter (log scale)	**Estimate**	**Std. Error**	**95% Conf. Int.**	**Deviance =** 125.8
*Intercept**	-5.2056	0.3482	(-6.1228, -4.6283)	
*Gear** (Experimental)*	-1.1527	0.4683	(-2.1624, -0.2917)	
(response scale)	**Estimate**			
Intercept	0.0055		(0.0022, 0.0098)	
Gear (Experimental)	0.3158		(0.115, 0.747)	
		Random Effects		
Group	**Variance**	**Std. Deviation**	**Groups**	**No. of Obs.**
*Trip****	0.4403	0.6635	12	136

**Intercept* – The expected catch rate of loggerhead turtles per minute in a control net when fixed and random effects are set to 0.

***Gear (Experimental)* – The estimate of the experimental gear listed in Table 5 is the expected increase in loggerhead catch rate relative to the control gear. The expected number of loggerheads caught in the experimental gear *decreases* by a factor of $e^{(-1.1527)}$ = ~0.316 or ~68% ((0.316 – 1) x 100)). Therefore, we conclude that loggerhead catch rates were ~68% less in the experimental net compared to the control net.

****Trip* – Trip number was included as a random effect and was used to account for possible within-trip dependency across hauls.

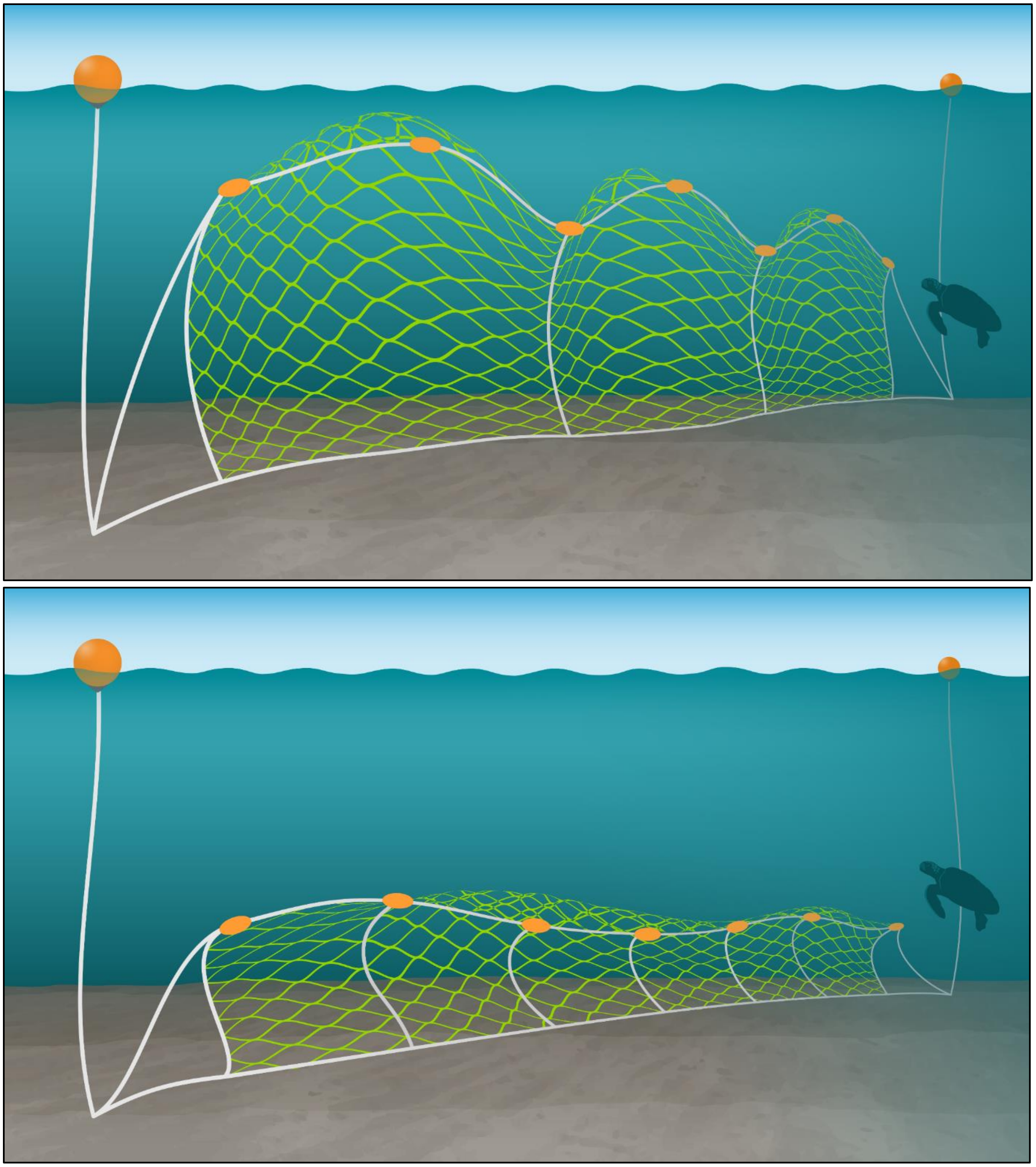

Figure 1. Diagram of a single panel of the control and experimental nets. A string would be 4 of these panels tied together. The white vertical lines on the net are the tie downs. Top: control net; bottom: experimental net. Image credit: Aline Design LLC, Hawai'i.

a. b. c.

Figure 2. Photos of the dual GoPro mounts used to attach to gillnets: a. diagonal view; b. side view; c. top view

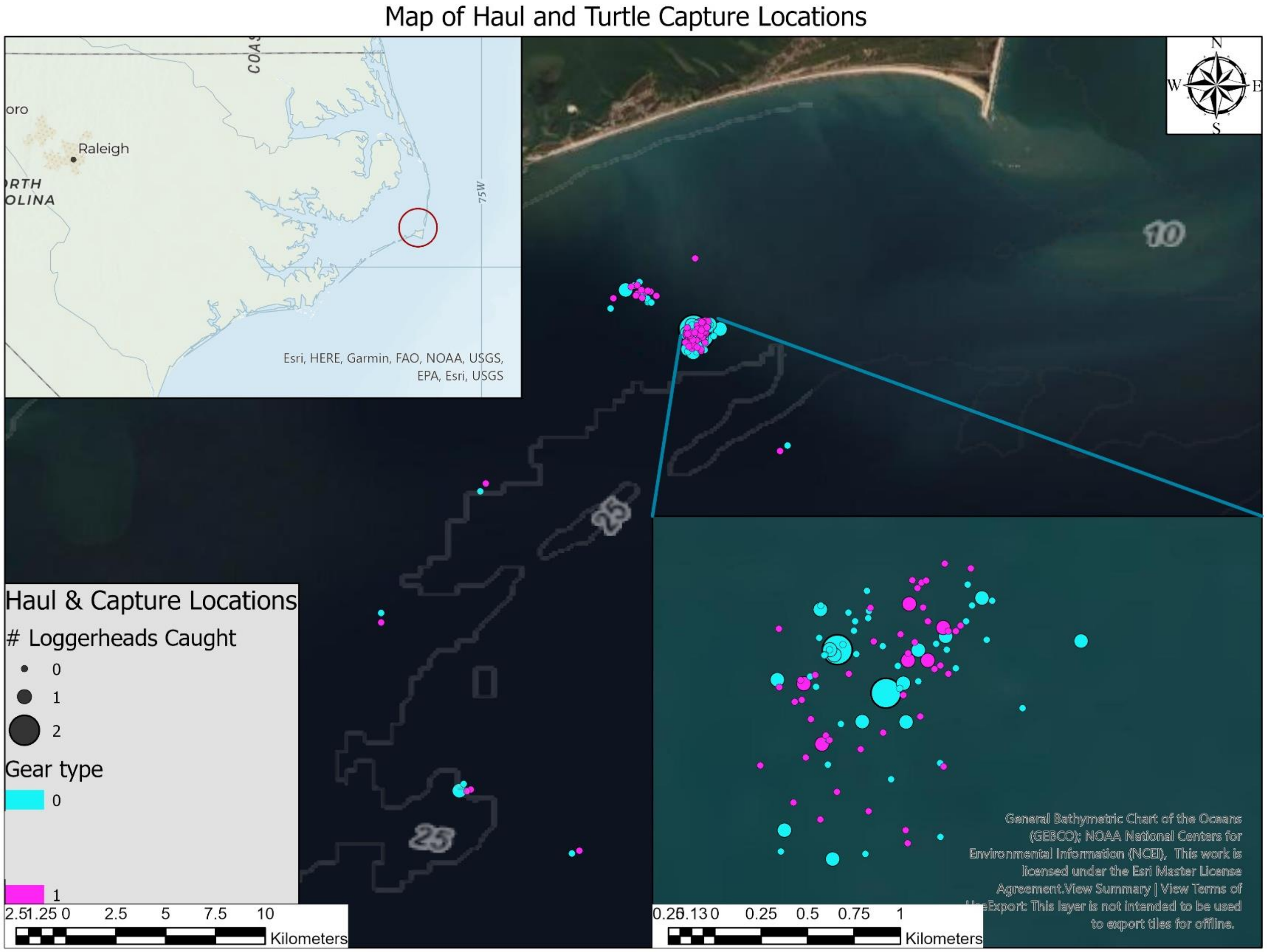

Figure 3. Map of haul locations and turtle catch locations. Gear type: 0 refers to the control net and 1 refers to the experimental net.

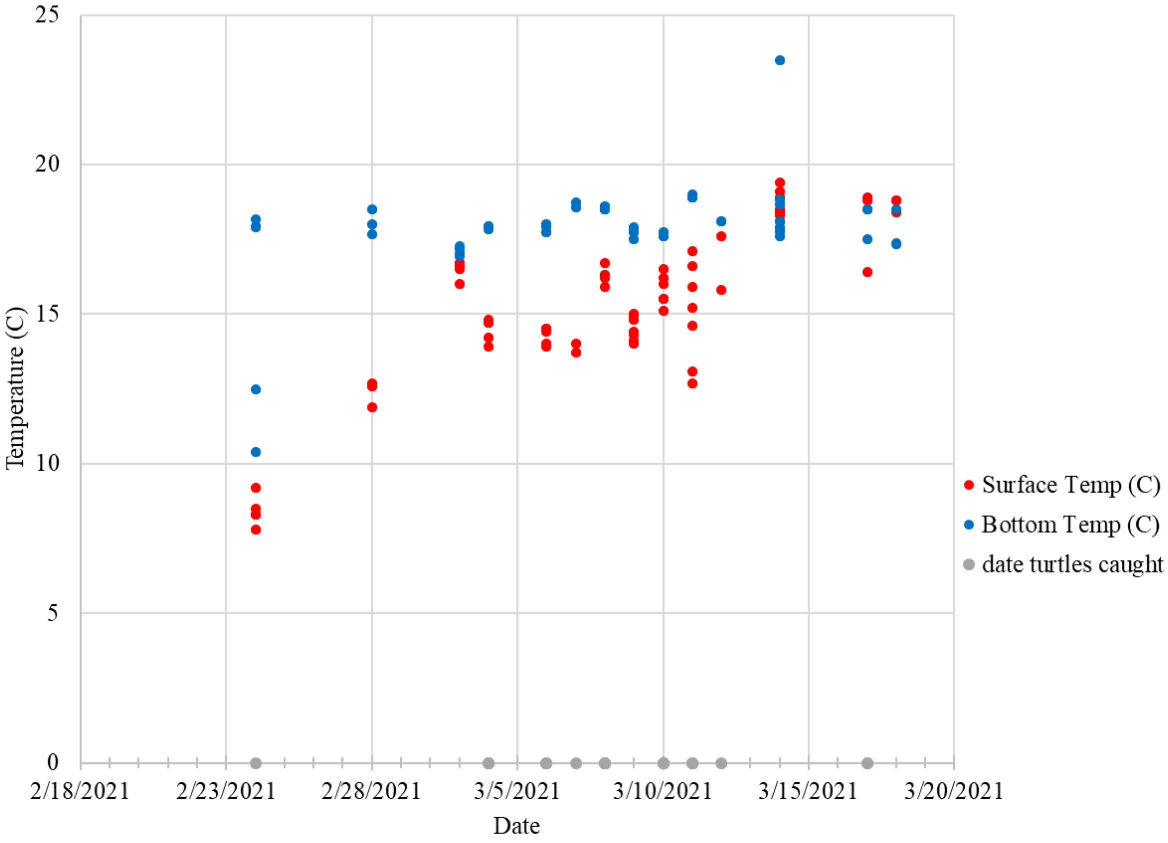

Figure 4. Raw surface and bottom temperatures for individual hauls on each trip. Gray dots on the x-axis represent dates when turtles were caught.

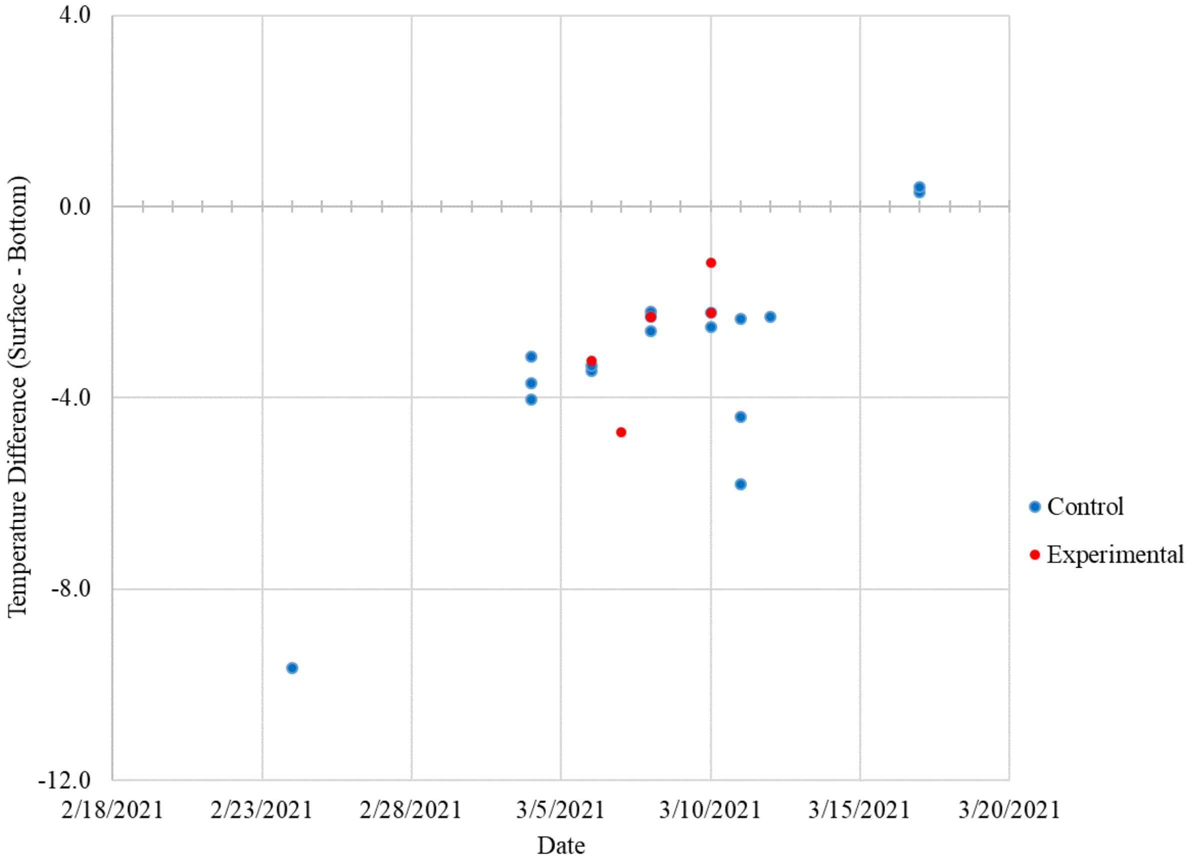

Figure 5. Temperature difference (surface temperature minus bottom temperature) on days loggerheads were caught. Negative values represent days when bottom temperatures are greater than surface temperature. These computed values were used as a covariate in statistical analysis.

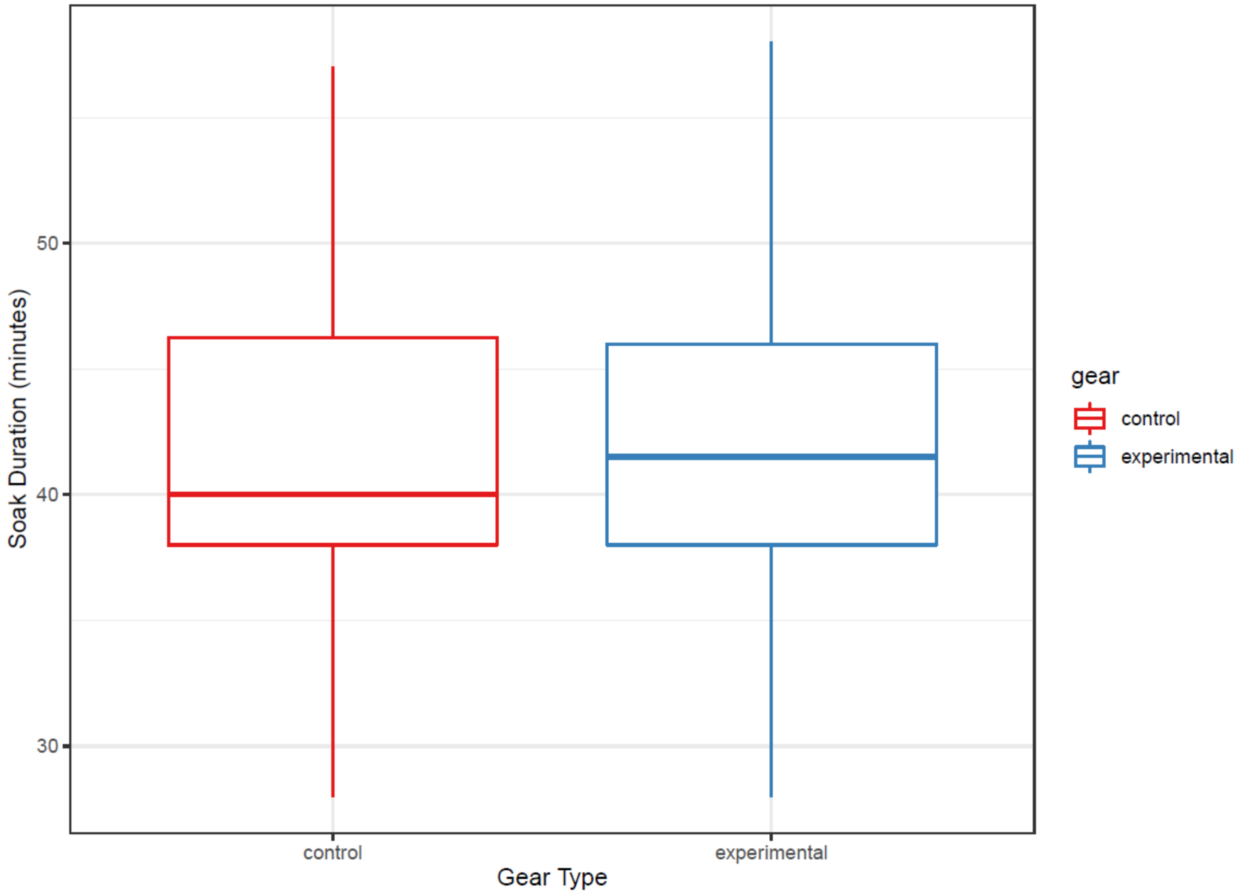

Figure 6. Boxplot of soak duration by gear type. Slight differences in soak duration were caused by differences in fish catch between nets—an increase in fish catch typically caused an increase in soak duration. The boxes range from the first to the third quartile of the distribution and the median is indicated by the line in the center of the boxes. The whiskers extending from the first and third quartiles extend to the most extreme data points.

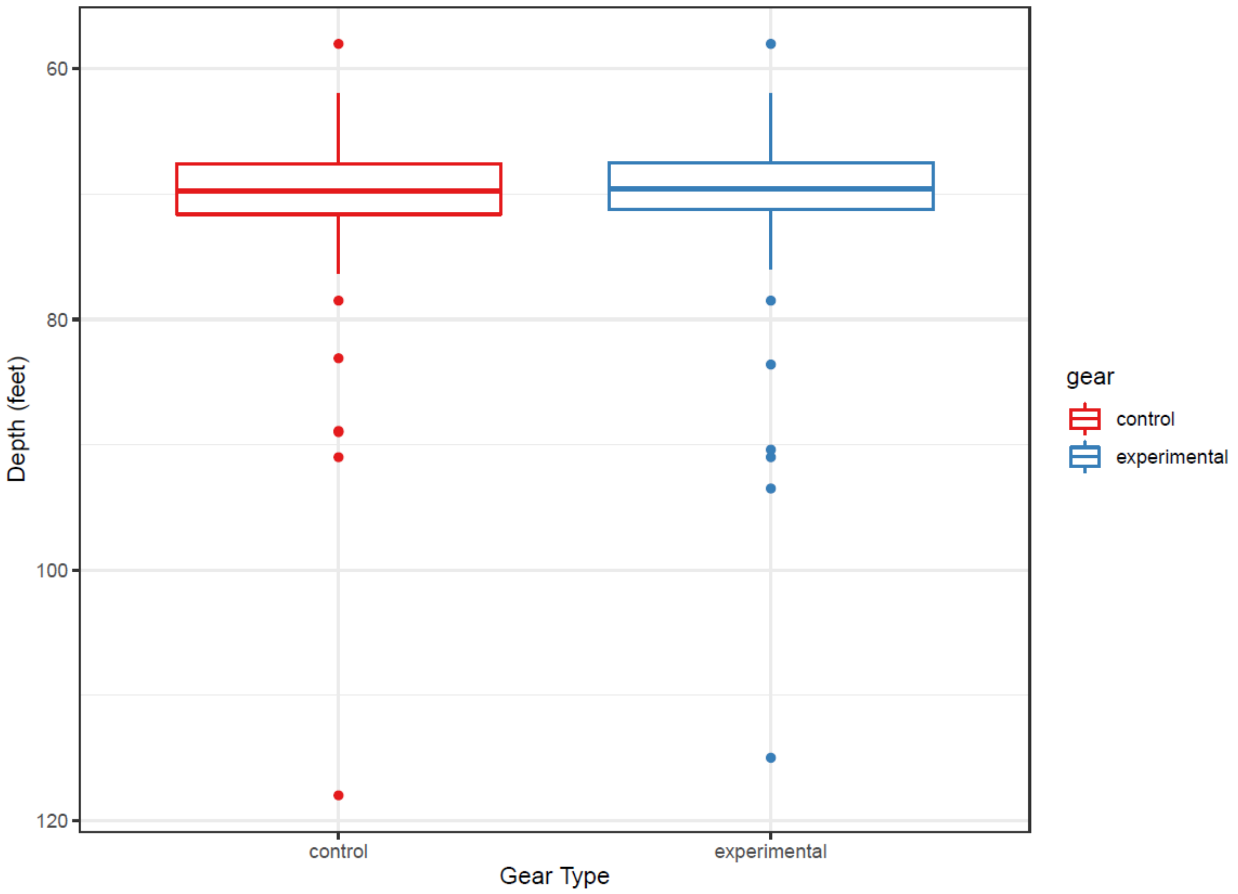

Figure 7. Boxplot of depth by gear type for all days of the study. The boxes range from the first to the third quartile of the distribution and the median is indicated by the line in the center of the boxes. The whiskers extending from the first and third quartiles extend to the most extreme data points. Dots represent outliers that exceed 1.5x the interquartile range.

REFERENCES

Bates D, Maüchler M, Bolker B, Walker S. 2015. Fitting linear mixed-effects models using lme4. J Stat Softw. 67(1):1-48.

Cameron AC and Trivedi PK 2009. Microeconometrics Using Stata. College Station, TX: Stata Press.

Casale P, Brost M, Leone EH, Ceriani SA, Witherington BE. 2019. Conservation implications of sea turtle nesting trends: elusive recovery of a globally important loggerhead population. Ecosphere. 10(11):1-19.

Casale P and Ceriani SA. 2020. Sea turtle populations are overestimated worldwide from remigration intervals: correction for bias. Endanger Species Res. 41:141-151.

Conant TA, Dutton PH, Eguchi T, Epperly SP, Fahy CC, Godfrey MH, MacPherson SL, Possardt EE, Schroeder BA, Seminoff JA, et al. 2009. Loggerhead sea turtle (*Caretta caretta*) 2009 status review under the U.S. Endangered Species Act. Report of the Loggerhead Biological Review Team to the National Marine Fisheries Service; August 2009. p. 222.

Endangered and Threatened Species; Determination of Nine Distinct Population Segments of Loggerhead Sea Turtles as Endangered or Threatened, 76 F.R. Sect. 58867 (2011).

Fox DA, Armstrong JL, Brown LM, Wark K. 2011. Gillnet configurations and their impact on Atlantic sturgeon and marine mammal bycatch in the New Jersey Monkfish fishery: year 1. Completion report for sturgeon gillnet study to National Marine Fisheries Service (NMFS). NOAA NMFS. Contract No. EA133F-10-RQ-1160. p. 30.

Fox DA, Armstrong JL, Brown LM, Wark K. 2012. The influence of sink gillnet profile on bycatch of Atlantic sturgeon in the mid-Atlantic. Completion report for sturgeon gillnet study to National Marine Fisheries Service (NMFS). NOAA NMFS. Contract No. EA133F-10-SE-3358. p. 31.

Fox DA, Armstrong JL, Brown LM, Wark K. 2013. Year three, the influence of sink gillnet profile on bycatch of Atlantic sturgeon in the mid-Atlantic. Completion report for sturgeon gillnet study to National Marine Fisheries Service (NMFS). NOAA NMFS. Contract No. EA133F-12-RQ-0697. P. 27 pp.

He P and Jones N. 2013 Design and test of a low profile gillnet to reduce Atlantic sturgeon and sea turtle bycatch in the mid-Atlantic monkfish fishery. Final Report to National Marine Fisheries Service (NMFS). NOAA NMFS. Contract No. EA133F-12-SE-2094. p. 40.

Le Gouvello DZM, Girondot M, Bachoo S, Nel R. 2020. The good and bad news of long-term monitoring: an increase in abundance but decreased body size suggests reduced potential fitness in nesting sea turtles. Mar Biol. 167(8):112.

Mazaris AD, Schofield G, Gkazinou C, Almpanidou V, Hays GC 2017. Global sea turtle conservation successes. Sci Adv. 3(9).

Murray KT 2009. Characteristics and magnitude of sea turtle bycatch in US mid-Atlantic gillnet gear. Endanger Species Res. 8:211–224.

Murray KT. 2013. Estimated loggerhead and unidentified hard-shelled turtle interactions in mid-Atlantic gillnet gear, 2007-2011. US Dept Commer Northeast Fish Sci Cent Tech Memo 225. 26 p.

Murray KT. 2018. Estimated bycatch of sea turtles in sink gillnet gear. US Dept Commer Northeast Fish Sci Cent Tech Memo 242. 164 p.

Narazaki T, Sato K, Abernathy KJ, Marshall GJ, Miyazaki N. 2013. Loggerhead turtles (*Caretta caretta*) use vision to forage on gelatinous prey in mid-water. PLoS One.

[NEFOP] Northeast Fisheries Observer Program. 2019. Handbook for fisheries observers and providers. 78 p.

[NMFS] National Marine Fisheries Service and Atlantic States Marine Fisheries Commission (ASMFC). 2013. Workshop on sea turtle and Atlantic sturgeon bycatch reduction in gillnet fisheries. Jan 22-23, 2013; Ocean City, MD. p. 48.

Patel SH, Barco SG, Crowe LM, Manning JP, Matzen E, Smolowitz RJ, Haas HL. 2018. Loggerhead turtles are good ocean-observers in stratified mid-latitude regions. Estuarine, Coastal and Shelf Science. 213:128-136.

Proudfoot JA, Lin T, Wang B, Tu XM. 2018. Tests for paired count outcomes. Gen Psychiatr. 31(1):46-51.

The R Project for Statistical Computing. 4 Apr 2022. The R Foundation; [Accessed October 10, 2021. Accessible at: https://www.R-project.org/

Säfken B, Rügamer D, Kneib T, Greven S. 2021. Conditional model selection in mixed-effects models with cAIC4. J Stat Softw. 99(8):1-30.

Usher R. 2018. Bottom-set gillnet comparative gear study to reduce sea turtle bycatch. Final Report to National Marine Fisheries Service (NMFS). NOAA NMFS. Contract No. EA-133F-14-SE-3694. p. 52.

Witherington B, Kubilis P, Brost B, Meylan A. 2009. Decreasing annual nest counts in a globally important loggerhead sea turtle population. Ecol Appl. 19(1):30-54.

Wileman DA, Ferro RST, Fonteyne R, Millar RB. 1996. Manual of methods of measuring the selectivity of towed fishing gears. Copenhagen, Denmark: International Council for the Exploration of the Sea (ICES). ICES Cooperative Research Report No. 215. p. 126 pp.

APPENDIX

List of species caught and estimated weight ordered by trip, haul, and net type. Blank spaces indicate when the net was empty upon retrieval.

Date	**Trip**	**Haul**	**Gear**	**Species Caught 1**	**Species Caught 1 Est. Total Weight (lb.)**	**Species Caught 2**	**Species Caught 2 Est. Total Weight (lb.)**	**Species Caught 3**	**Species Caught 3 Est. Total Weight (lb.)**	**Species Caught 4**	**Species Caught 4 Est. Total Weight (lb.)**
2/24/2021	1	1	control								
2/24/2021	1	1	experimental								
2/24/2021	1	2	control								
2/24/2021	1	2	experimental								
2/24/2021	1	3	control	southern stingray	20						
2/24/2021	1	3	experimental	cownose ray	50						
2/24/2021	1	4	control								
2/24/2021	1	4	experimental								
2/24/2021	1	5	control								
2/24/2021	1	5	experimental								
2/28/2021	2	1	control	sand tiger shark	100	southern stingray	20				
2/28/2021	2	1	experimental								
2/28/2021	2	2	control	southern stingray	40						

2/28/2021	2	2	experimental	southern stingray	60	thresher shark	NK				
2/28/2021	2	3	control								
2/28/2021	2	3	experimental	tiger shark	90						
3/3/2021	3	1	control	cownose ray	15						
3/3/2021	3	1	experimental	cownose ray	10						
3/3/2021	3	2	control	butterfly ray	20	southern stingray	15				
3/3/2021	3	2	experimental	cownose ray	12						
3/3/2021	3	3	control	southern ray	35						
3/3/2021	3	3	experimental	sandbar shark	10	southern stingray	25				
3/3/2021	3	4	control								
3/3/2021	3	4	experimental								
3/3/2021	3	5	control								
3/3/2021	3	5	experimental								
3/3/2021	3	6	control								
3/3/2021	3	6	experimental	butterfly ray	50						
3/3/2021	3	7	control								
3/3/2021	3	7	experimental								
3/4/2021	4	1	control	angel shark	50	southern stingray	40				
3/4/2021	4	1	experimental								
3/4/2021	4	2	experimental								
3/4/2021	4	2	control	cownose ray	10						
3/4/2021	4	3	control	sand tiger shark	200						
3/4/2021	4	3	experimental								
3/4/2021	4	4	control	butterfly ray	15						

3/4/2021	4	4	experimental	sand tiger shark	200						
3/4/2021	4	5	control								
3/4/2021	4	5	experimental								
3/6/2021	5	1	control	southern ray	55	angel shark	30				
3/6/2021	5	1	experimental	cownose ray	10						
3/6/2021	5	2	control	southern ray	20	smooth hammerhead shark	10				
3/6/2021	5	2	experimental	cownose ray	10	southern ray	25				
3/6/2021	5	3	control	sand tiger shark	480	cownose ray	10	southern ray	65		
3/6/2021	5	3	experimental	sand tiger shark	30	southern ray	75				
3/6/2021	5	4	control								
3/6/2021	5	4	experimental	southern ray	30	cownose ray	40				
3/6/2021	5	5	control	angel shark	40	southern ray	15	cownose ray	15	sand tiger shark	150
3/6/2021	5	5	experimental	angel shark	35	cownose ray	55	white shark	175		
3/6/2021	5	6	control	southern ray	50	butterfly ray	25				
3/6/2021	5	6	experimental	southern ray	70	cownose ray	30				
3/7/2021	6	1	control	southern ray	70	smooth hammerhead shark	20	cownose ray	20		
3/7/2021	6	1	experimental	southern ray	50	cownose ray	30	butterfly ray	30		
3/7/2021	6	2	control	southern ray	55						
3/7/2021	6	2	experimental	southern ray	95	cownose ray	40				
3/8/2021	7	1	control	southern ray	25						

3/8/2021	7	1	experimental	angel shark	50	southern ray	20	butterfly ray	15		
3/8/2021	7	2	control	smooth hammerhead shark	10						
3/8/2021	7	2	experimental	southern ray	15						
3/8/2021	7	3	control	smooth hammerhead shark	5	southern stingray	20	cownose ray	10		
3/8/2021	7	3	experimental	cownose ray	10						
3/8/2021	7	4	control								
3/8/2021	7	4	experimental	southern ray	15	cownose ray	10				
3/8/2021	7	5	control	tiger shark							
3/8/2021	7	5	experimental								
3/9/2021	8	1	control								
3/9/2021	8	1	experimental	angel shark	50						
3/9/2021	8	2	experimental								
3/9/2021	8	2	control	butterfly ray	10	cownose ray	15	sand tiger shark	200		
3/9/2021	8	3	control								
3/9/2021	8	3	experimental								
3/9/2021	8	4	control	cownose ray	15						
3/9/2021	8	4	experimental								
3/9/2021	8	5	control								
3/9/2021	8	5	experimental	southern stingray	5						
3/9/2021	8	6	control	cownose ray	15						
3/9/2021	8	6	experimental								
3/9/2021	8	7	control								
3/9/2021	8	7	experimental								
3/10/2021	9	1	control								
3/10/2021	9	1	experimental								

3/10/2021	9	2	control	cownose ray	10						
3/10/2021	9	2	experimental	southern ray	10						
3/10/2021	9	3	control								
3/10/2021	9	3	experimental								
3/10/2021	9	4	control	angel shark	50						
3/10/2021	9	4	experimental	cownose ray	20						
3/10/2021	9	5	control								
3/10/2021	9	5	experimental	sand tiger shark	20						
3/10/2021	9	6	control	cownose ray	10						
3/10/2021	9	6	experimental								
3/11/2021	10	1	control	cownose ray	15	southern ray	10				
3/11/2021	10	1	experimental								
3/11/2021	10	2	control	cownose ray	20	southern ray	10				
3/11/2021	10	2	experimental	southern ray	30	cownose ray	30	angel shark	10		
3/11/2021	10	3	control	cownose ray	10						
3/11/2021	10	3	experimental								
3/11/2021	10	4	control	cownose ray	10						
3/11/2021	10	4	experimental	southern ray	20						
3/11/2021	10	5	control	cownose ray	10	southern ray	5				
3/11/2021	10	5	experimental								
3/11/2021	10	6	control								
3/11/2021	10	6	experimental	southern ray	10	cownose ray	10				
3/11/2021	10	7	control	smooth hammerhead shark	5	tiger shark					
3/11/2021	10	7	experimental	southern ray	12						
3/12/2021	11	1	control								
3/12/2021	11	1	experimental								
3/12/2021	11	2	control								
3/12/2021	11	2	experimental								

3/14/2021	12	1	control								
3/14/2021	12	1	experimental	angel shark	20						
3/14/2021	12	2	control	cownose ray	10	southern ray	10				
3/14/2021	12	2	experimental								
3/14/2021	12	3	control								
3/14/2021	12	3	experimental								
3/14/2021	12	4	control								
3/14/2021	12	4	experimental	cownose ray	5						
3/14/2021	12	5	control								
3/14/2021	12	5	experimental								
3/14/2021	12	6	control	southern ray	25						
3/14/2021	12	6	experimental								
3/14/2021	12	7	control								
3/14/2021	12	7	experimental								
3/17/2021	13	1	control	angel shark	80						
3/17/2021	13	1	experimental								
3/17/2021	13	2	control								
3/17/2021	13	2	experimental								
3/17/2021	13	3	control	butterfly ray	5						
3/17/2021	13	3	experimental	southern ray	15						
3/18/2021	14	1	control	angel shark	100	dusky shark	90	sand tiger shark	20	butterfly ray	35
3/18/2021	14	1	experimental	cownose ray	10	sand tiger	200	black drum	350		
3/18/2021	14	2	control	cownose ray	10						
3/18/2021	14	2	experimental	butterfly ray	10						
3/18/2021	14	3	control	sandbar shark	15	butterfly ray	10				
3/18/2021	14	3	experimental								

Procedures for Issuing Manuscripts in the Northeast Fisheries Science Center Reference Document (CRD) and the Technical Memorandum (TM) Series

The mission of NOAA's National Marine Fisheries Service (NMFS) is "stewardship of the nation's ocean resources and their habitat." As the research arm of the NMFS's Greater Atlantic Region, the Northeast Fisheries Science Center (NEFSC) supports the NMFS's mission by "conducting ecosystem-based research and assessments of living marine resources, with a focus on the Northeast Shelf, to promote the recovery and long-term sustainability of these resources and to generate social and economic opportunities and benefits from their use." Results of NEFSC research are largely reported in primary scientific media (e.g., anonymously peer-reviewed scientific journals). However, to assist itself in providing data, information, and advice to its constituents, the NEFSC occasionally releases its results in its own series.

NOAA Technical Memorandum NMFS-NE – This series is issued irregularly. The series typically includes: data reports of long-term field or lab studies of important species or habitats; synthesis reports for important species or habitats; annual reports of overall assessment or monitoring programs; manuals describing program-wide surveying or experimental techniques; literature surveys of important species or habitat topics; proceedings and collected papers of scientific meetings; and indexed and/or annotated bibliographies. All issues receive internal scientific review, and most issues receive technical and copy editing.

Northeast Fisheries Science Center Reference Document – This series is issued irregularly. The series typically includes: data reports on field and lab studies; progress reports on experiments, monitoring, and assessments; background papers for, collected abstracts of, and/or summary reports of scientific meetings; and simple bibliographies. Issues receive internal scientific review, and most issues receive copy editing.

CLEARANCE

All manuscripts submitted for issuance as CRDs must have cleared the NEFSC's manuscript/abstract/webpage review process. If your manuscript includes material from another work which has been copyrighted, you will need to work with the NEFSC's Editorial Office to arrange for permission to use that material by securing release signatures on the "NEFSC Use-of-Copyrighted-Work Permission Form."

For more information, NEFSC authors should see the NEFSC's online publication policy manual, "Manuscript/Abstract/Webpage Preparation, Review, & Dissemination: NEFSC Author's Guide to Policy, Process, and Procedure."

STYLE

The CRD series is obligated to conform with the style contained in the current edition of the United States Government Printing Office Style Manual; however, that style manual is silent on many aspects of scientific manuscripts. The CRD series relies more on the CSE Style Manual. Manuscripts should be prepared to conform with both of these style manuals.

The CRD series uses the Integrated Taxonomic Information System, the American Fisheries Society's guides, and the Society for Marine Mammalogy's guide for verifying scientific species names.

For in-text citations, use the name-date system. A special effort should be made to ensure all necessary bibliographic information is included in the list of references cited. Personal communications must include the date, full name, and full mailing address of the contact.

PREPARATION

Once your document has cleared the review process, the Editorial Office will contact you with publication needs—for example, revised text (if necessary) and separate digital figures and tables if they are embedded in the document. Materials may be submitted to the Editorial Office as email attachments or intranet downloads. Text files should be in Microsoft Word, tables may be in Word or Excel, and graphics files may be in a variety of formats (JPG, GIF, Excel, PowerPoint, etc.).

PRODUCTION AND DISTRIBUTION

The Editorial Office will perform a copy edit of the document and may request further revisions. The Editorial Office will develop the inside and outside front covers, the inside and outside back covers, and the title and bibliographic control pages of the document.

Once the CRD is ready, the Editorial Office will contact you to review it and submit corrections or changes before the document is posted online. A number of organizations and individuals in the Northeast Region will be notified by e-mail of the availability of the document online.