FINAL SUMMARY REPORT

PERFORMANCE IN 2004 AND 2005 OF AN ALTERNATIVE LEADER DESIGN ON THE BYCATCH OF SEA TURTLES AND THE CATCH OF FINFISH IN CHESAPEAKE BAY POUND NETS, OFFSHORE KIPTOPEAKE, VA:

Joseph DeAlteris and Ryan Silva

DEALTERIS ASSOCIATES INC.
P.O. Box 251
Jamestown, RI 02881

Revised 31 December 2007

This Final Summary Report is submitted to NMFS NEFSC following completion of two years of field work and the submission of data and preliminary analysis reports for each year. This report summarizes the pertinent data collected each year, and analyses the data jointly relative to the issue of sea turtle interactions and pound net catches. More complete presentations of the raw data are available in the tables and appendices of separate annual reports referenced below.

DeAlteris, J., D. Chosid, R. Silva, and P. Politis. 2004. Evaluation of the performance in 2004 of an alternative leader design on the bycatch of sea turtles and the catch of finfish in Chesapeake Bay pound nets, offshore Kiptopeake, VA. A Final Report submitted by DeAlteris Associates Inc. to NMFS NEFSC, 31 August 2004.

DeAlteris, J., R. Silva, E. Estey, K. Tesla, and T. Newcomb. 2005. Evaluation of the performance in 2005 of an alternative leader design on the bycatch of sea turtles and the catch of finfish in Chesapeake Bay pound nets, offshore Kiptopeake, VA. A Final Report submitted by DeAlteris Associates Inc. to NMFS NEFSC, 31 August 2005.

Abstract

Leaders in offshore, deep water pound nets in the Virginia portion of Chesapeake Bay incidentally take protected sea turtles. To reduce this take, federal resource managers restricted the use of traditional leaders during periods of peak sea turtle strandings. In response to these restrictions, a modified leader was developed. The top two-thirds of the traditional mesh panel leader was replaced with vertical ropes made of polypropylene rope (0.95 cm) and spaced every 61 cm. The design was tested on the eastern shore of Chesapeake Bay from May 15, 2004 to June 28, 2004. The experimental leader was slightly modified after the 2004 field trial by replacing the vertical polypropylene ropes with a hard lay Polysteel rope (0.79 cm) to further reduce the likelihood of sea turtle entanglement. This design was tested from May 5, 2005 to June 29, 2005.

Four offshore pound nets were monitored twice daily using both side scan sonar and visual inspections to identify sea turtle - pound net leader interactions. In 2004, seven sea turtles were encountered interacting with the pound net leaders in the study. Six hardshell turtles were found in the control leader and one leatherback was found in the experimental leader. In 2005, 15 hardshell turtles were found interacting with the pound net leaders in the study, all occurred in the control leader. The results of a negative binomial regression analysis on the combined 2004 – 2005 data indicate the modified leader significantly reduced sea turtle interactions.

Finfish were sampled from the nets in the study each time they were harvested. Paired samples were used to determine if the modified leader led fish into the trap as well as the traditional leader. Five species were used in the comparison: Atlantic croaker, weakfish, butterfish, harvestfish, and Atlantic thread herring. Ten paired samples were obtained over the course of the two field trials. Paired t-test and Wilcoxon matched-pairs signed-ranked test results determined that only butterfish demonstrated a significant weight difference between the two leaders, with the experimental leader harvesting significantly more than the control leader. Qualitative length frequency analysis did not reveal any substantive differences in size selectivity between the two leaders.

INTRODUCTION

Statement of Problem

The pound net fishery in the deeper waters of the Virginia portion of Chesapeake Bay incidentally takes threatened and endangered sea turtles (Lutcavage and Musick, 1985; Bellmund et al., 1987; Mansfield et al., 2001). Sea turtles become entangled or impinged in the portion of the net known as the leader, cannot reach the surface to breathe and consequently drown. The National Marine Fisheries Service (NMFS), responsible for managing marine species protected by the Endangered Species Act (ESA), implemented regulations in 2002 to reduce this take. The regulations prohibited all offshore pound net leaders in selected portions of Virginia's Chesapeake Bay from May 6 to July 15, every year, effectively shutting this portion of the fishery down during this period.

In response to this closure, pound net fishermen and the NMFS research staff proposed a modified leader design to reduce sea turtle mortality. The NMFS agreed to test this modified pound net leader to determine whether it significantly reduced sea turtle interactions with pound nets. The modified or experimental leaders were tested from May 17 to June 27, 2004 and from May 5 to June 29, 2005.

Literature Review

Sea turtles

The Chesapeake Bay is a primary foraging and development area for juvenile loggerhead (*Caretta caretta*) and Kemp's ridley (*Lepidochelys kempii*) sea turtles (Lutcavage and Musick, 1985; Bellmund et al., 1987; Musick and Limpus, 1997). Leatherback (*Dermochelys coriacea*) and green (*Chelonia mydas*) sea turtles also occur seasonally in the bay, although with far less frequency (Keinath, 1993). Loggerhead and Kemp's ridley turtles migrate into the bay as water temperatures approach 20° C (Coles, 1999) and depart with the onset of winter storms and falling water temperatures (Byles, 1988; Keinath, 1993; Coles, 1999). Sea turtles are generally present in the bay from May into November (Keinath, 1993).

Both mark and recapture and aerial survey methods have been used to quantify sea turtle populations that use the bay, with aerial surveys considered the more accurate method (Lutcavage and Musick, 1985; Bellmund et al., 1987; Byles, 1988; Mansfield et al., 2002). Based on aerial transect surveys performed from May through October, 2001, 549 to 5,169 sea turtles were estimated in the lower bay, with the highest densities occurring in June (Mansfield, 2002). These are considered to be minimum population estimates (Mansfield et al., 2002). Loggerhead turtles are recognized as being the most abundant sea turtle species in the bay (Coles, 1999).

Each year, 200-500 sea turtles strand in the lower portion of the bay, with the greatest number occurring in late May and June as the loggerhead and Kemp's ridley turtles come into the bay (Lutcavage and Musick, 1985; Bellmund et al., 1987, Mansfield et al., 2001;

Swingle et al., 2004). This alarming number of strandings initiated efforts in 1979 by the NMFS and the Virginia Institute of Marine Science (VIMS) to determine the primary source of mortality (Musick et al., 1984; Lutcavage and Musick, 1985). The VIMS has managed the Virginia Sea Turtle Stranding Network since, documenting and reporting strandings to the NMFS Northeast Region Sea Turtle Stranding and Salvage Network (STSSN). Currently, responsibility for stranded sea turtles in Virginia is shared between VIMS and the Virginia Aquarium and Marine Science Center (VAMSC). The western bay is covered by VIMS and VAMSC is responsible for the Eastern Shore and Virginia Beach area. Although the cause of death cannot be determined for the majority of stranded sea turtles, identified causes include poor health, cold stunning, boat collisions, shark predation, human induced mortality, and interactions with commercial fishing gear.

Sea turtle interactions with commercial fishing gear in Chesapeake Bay

Fisheries in Chesapeake Bay, in particular large mesh pound nets, large mesh gillnets, pot lines, and otter trawls all have documented interactions with sea turtles leading to "takes"(Musick, 1996; Mansfield et al., 2001). The bay's menhaden purse seine fishery has not been implicated in taking sea turtles but other purse seine fisheries have been (Silva, 1996). In response to these documented takes, steps were taken by the NMFS to minimize sea turtle mortality resulting from these commercial fishing activities. In 1989, the flounder trawl fishery in Virginia waters was closed due to high rates of sea turtle mortality (Terwilliger and Musick, 1995). Spatial and temporal restrictions of large mesh gill nets and pound net leaders were implemented to reduce interactions as sea turtles come into the Bay. Steps are currently being taken to assess sea turtle entanglement in pot buoy lines.

Pound nets

Introduced from New England in the 1870's, pound nets have been one of the most important commercial fish harvest methods in the bay (Reid, 1955; Hildebrand and Schroeder, 1972). Once prolific in the bay, the pound net fishery has been in decline since the early part of the 20th century. At its peak in 1930 there were 2,260 nets in the Virginia portion of the bay. In 1952 there were 1,216 nets, in 1986 there were 250 active nets, and by 2004, only 51 active pound nets remained in Virginia portion of the bay (Reid, 1955; Chittenden, 1986; Mansfield et al., 2002). Causes of this decline are primarily due to advances in gear technology, depressed fish stocks and social and political pressures that have come to bear on the fishery. However, pound nets are still one of the most productive fish harvest methods, with only the menhaden purse seine fishery and gillnet fisheries landing more pounds of finfish in the Virginia portion of the bay (Virginia Marine Resource Commission summary statistics). Other commercial pound net fisheries in the United States persist in North Carolina's Pamlico and Albemarle Sounds, New Jersey, Long Island Sound and Rhode Island. Chesapeake Bay has the largest pound net fishery in the country, with Virginia and Maryland accounting for 86% of pound net landings from 2000 through 2003 (NMFS landings data).

Pound nets are a passive, stationary fish harvest device with three primary components; leader (hedging), heart (bays or turn backs), and pound (head or trap) (Reid, 1955; DeAlteris, 1998) (Figure 1). All three components are essential to the performance of a pound net. Supported by large poles pounded into the sea floor, the leader is a wall of mesh webbing that extends from the sea floor to approximately the sea surface and may run several hundred meters in length (leader length in Chesapeake Bay may not exceed 380 m). Leader mesh size varies from 20 to 46 cm (stretched), with large mesh leaders placed in areas with strong currents to reduce destructive drag forces. In some cases, the mesh in the upper portion of the leader is replaced with vertical “stringers” spaced 15 to 46 cm apart to further reduce the effects of tide and floating debris (Reid, 1955; Bellmund et al., 1987). Large mesh and “string” leaders are often placed on “offshore” pound nets while smaller mesh leaders are generally found on “inshore” pound nets where weaker currents prevail.

Fish swimming laterally along the shoreline encounter the leader and generally turn towards deeper water to circumvent the obstruction. Although the leader mesh size is often large enough for a fish to pass through unimpeded, the visual stimulus and low frequency noise generated by the mesh webbing is enough to turn fish towards the pound, especially in schooling fishes that react en masse (Wardle, 1986; Misund, 1994).

Located at the deep end of the leader is the heart and pound portions of the net, mechanisms that further draw (heart) and trap (pound) the fish so they cannot escape (Reid, 1955; DeAlteris, 1998). Fish must enter the pound through a funnel or non-return device that tapers from the sea bed and approximately the sea surface into the pound. The pound, usually square with 6 – 13 m sides, is constructed of small mesh (approximately 5 cm stretched) to prevent gilling when the net is harvested (Reid, 1955).

Although pound nets are a relatively non-selective harvest system and land many different species, a few make up the bulk of the sold catch. Primary target species include Atlantic croaker (*Micropogonias undulatus*), weakfish (*Cynoscion regalis*), spot (*Leistomus xanthurus*) and menhaden (*Brevoortia tyrannus*) (VMRC; Reid, 1955). Other marketed species include striped bass (*Morone saxatilis*), summer flounder (*Paralichthys dentatus*), harvestfish (*Peprilus alepidotus*), butterfish (*Peprilus triacanthus*), black drum (*Pogonias cromis*), red drum (*Sciaenops ocellatus*), Spanish mackerel (*Scomberomorus maculatus*), and northern puffer (*Sphoeroides maculatus*) to name a few. The majority of marketable species are demersal, although a few, such as menhaden, butterfish, harvestfish, and Spanish mackerel are pelagic (Collette and Klein-MacPhee, 2002; Murdy et al., 1997).

Pound net - sea turtle interactions

Sea turtles generally interact with pound nets in two ways; through entrapment in the pound which is typically non-lethal or by impingement or entanglement in the leader, which is often lethal (Lutcavage and Musick, 1985). If a sea turtle becomes entangled or impinged in the leader and cannot reach the surface to breathe it will drown. Although it is clear that pound net leaders are responsible for multiple sea turtle deaths each year, it has been difficult to quantify this take. Accurate real time monitoring of pound net leaders has proven technically and logistically difficult. In addition, stranded turtles are often found in advanced stages of decomposition, making it very difficult, if not impossible, to determine the cause of death (Lutcavage and Musick, 1985; Bellmund et al., 1987). Past studies have employed aerial survey methods, surface monitoring efforts, subsurface monitoring using both scuba and sound underwater ranging (sonar) technology and strandings data to assess the extent that pound net leaders cause sea turtle mortality (Lutcavage and Musick, 1985, Bellmund et al., 1987; Mansfield et al., 2002). From these studies it has been estimated that pound nets are responsible for 3 to 33% of stranded turtles in the Bay (Bellmund et al., 1987).

Past studies designed to assess the number of sea turtle takes due to pound net leaders used aerial, surface and subsurface leader monitoring methods (Musick et al., 1984; Lutcavage and Musick, 1985; Mansfield et al., 2001). In 1983, aerial surveys monitored pound nets throughout the bay to identify spatial and temporal variability of pound net leader / sea turtle interactions. These surveys were supported by surface vessels to investigate potential interactions. Surface vessel surveys were also conducted independently of aerial surveys on nets in specific areas of the bay. Surface survey methods are relatively safe and simple, although water clarity in the bay is often poor and turtles interacting with the leader at depth cannot be detected. Scuba was used to identify turtles interacting at depths beyond visual surface detection. Two divers simultaneously swam the length of a leader at different depths looking for turtles. These early Scuba monitoring attempts were logistically difficult and dangerous due to high current flows, poor visibility and the need to be very close to the pound net gear (Musick et al., 1984). More recently, sonar was used to detect sea turtles interacting with pound net leaders (Mansfield et al., 2002). Attempts to identify various objects, including dead frozen sea turtles of various sizes, placed in pound net leaders and acoustically scanned were successful. Subsequently, using a 900 kHz side scan sonar tow fish, surveys were performed throughout the Virginia portion of the bay in an attempt to locate sea turtles interacting with pound net leaders. At least two passes were made on each pound net at a range of 10 to 20 m and a speed of 1.0 – 1.75 m/sec. Targets identified as potential sea turtles by the sonar operator were investigated at the conclusion of the two leader scans to verify the nature of the target. Targets that could not be identified by surface inspection were identified using an underwater video system. No turtle interactions were encountered during this study. Although successful in identifying objects entangled in the leader, sonar was not effective in distinguishing whether the object was a turtle, fish, flotsam or some other object. Furthermore, adverse weather conditions and high concentrations of suspended sediment rendered this survey method ineffective. However, the authors concluded that there was a strong potential for sonar to assess underwater entanglement of sea turtles in pound net leaders (Mansfield et al., 2002).

Almost all documented sea turtle and pound net leader interactions have been in the Virginia portion of the bay in the upper 3 m of large mesh (>30 cm) or string leaders in areas that experience strong currents during the May and June immigration (Lutcavage and Musick, 1985; Bellmund et al., 1987; Mansfield et al., 2002). There has been speculation on why interactions are spatially and temporally isolated. This period is the time of greatest sea turtle abundance in the lower part of the bay. Sea turtles are often emaciated and weak as they enter the bay after their migration, reducing their swimming capabilities and increasing their chance of becoming entangled or impinged in the leaders, especially in areas of high tidal flow (Musick et al., 1984; Bellmund et al., 1987). Sea turtles can also become lethargic or experience cold shock in cold water, which might be encountered in early season thermoclines that often occur in deeper water (Lutcavage and Lutz, 1997). Compounding these issues, telemetry studies performed in the early 1980's documented sea turtles aggregating around pound nets, indicating they may recognize the leader and pound as food aggregating devices. Substantiating this fact, turtles that have been removed from pound heads have returned to the same pound head after their release. Fish bones are often found in the stomach contents of stranded sea turtles, indicating they may have been feeding in or around pound nets (Lutcavage and Musick, 1985). Fish are not considered a primary food source for turtles because they are not agile or quick enough to capture them, and instead concentrate on slower prey items. However, fish are highly concentrated in the pound and may be vulnerable to predation by turtles in this environment. In addition, fish often become gilled or entangled in the various parts of the pound net, making them easy prey for foraging sea turtles. The most common prey of loggerhead turtles in Virginia is horseshoe crabs (*Limulus polyphemus*) along with other benthic invertebrates while Kemp's ridley turtles concentrate on blue crabs (*Calinectes sapidus*) (Bjorndal, 1997). Due to this diet difference, loggerheads occur primarily along channel edges and at river mouths while Kemp's ridleys are usually found in shallower, near-shore areas (Byles, 1988).

Regulatory measures and pound net leader modification

When resource managers took steps to reduce sea turtle takes in Chesapeake Bay pound nets, they targeted offshore pound nets because they had a higher take rate as compared to inshore nets (Mansfield et al., 2002). NOAA Fisheries Service banned offshore pound net leaders in the main-stem bay from May 6 to July 15 that are south of 37°19' and west of 76°13' and south of 37°13' to the Chesapeake Bay Bridge Tunnel at the mouth of the bay. These regulations limited the activity of approximately 14 pound nets in the Virginia portion of the bay (Federal Register, DOCID:fr06fe04-37). In addition to these regulations, any pound net leader outside of the restricted area must have a stretched mesh size $\leq$ 30.5 cm and cannot have vertical rope lines or "stringers." Offshore pound nets included within this restricted area were essentially closed during an important harvest period as many fish species migrated into the bay. In response to this gear restriction, affected fishermen and NMFS research staff designed a modified leader to reduce sea turtle interactions.

Objectives

1. Determine if the proposed experimental pound net leader significantly reduced observed sea turtle interactions.

2. Determine if there is a significant difference between the finfish catch of pound nets set with either the control or experimental leaders.

METHODS AND MATERIALS

Background

The modified or experimental leaders were tested during two field trial periods. The first field trial was from May 17 to June 28, 2004. The second field trial was from May 5 to June 29, 2005. The four pound nets in the study are located south of Kiptopeake State Park, Virginia, on the bay side of the Cape Charles peninsula (Figure 2). All four nets are separated by approximately 1 km. Each pound net leader is oriented perpendicular to the shoreline. The bathymetry in this part of the bay is relatively uniform, with little vertical structure. The four pound net sites were chosen based on concentrated sea turtle and pound net leader interactions observed in this part of the bay. Each pound net was assigned a number for identification purposes. The nets are oriented from north to south along Cape Charles peninsula; net 1 is the most northern net, followed by nets 2, 3 and 4. The Latitude – Longitude coordinates of the four nets are listed in Table 1.

The leader of net 1 starts approximately 600 m from shore in 5.5 m depth, extends approximately 335 m in length and ends in 9.0 m depth. The leader of net 2 starts approximately 610 m from shore in 5.7 m depth, and extends approximately 283 m and ends in 8.0 m depth. The leader on net 3 starts approximately 730 m from shore in 5.2 m depth, and extends approximately 277 m and ends in 8.9 m depth. The leader of net 4 starts approximately 370 m from shore in 1.2 m depth, and extends approximately 229 m and ends in 3.7 m depth. The funnel or non-return device starts at the sea floor and within 3–5 m of the surface for nets 1, 2, and 3 and within 2-3 m of the surface for net 4. Although there were small differences in the design and construction of the four nets, his did not affect the results of the study as experimental and control leader were alternated between all nets.

The control or traditional leader is constructed of 29 cm mesh (stretched) made from 2.5 mm (#42) nylon twine (3.0 mm (#60) twine was used on nets 2 and 3 during the 2005 field trial) dipped in anti-fouling paint (Figure 3). Anti-fouling paint is used as a preservative and to control biological growth on the nets. There is a 1 cm chain that runs the bottom and top length of the leader to prevent abrasion. The leader mesh extends from the bay floor to approximately the bay surface.

For the experimental or modified leader, the top two-thirds of the traditional mesh leader was replaced with vertical ropes spaced every 61 cm. For the first field trial the experimental leader had 1.0 cm polypropylene vertical ropes. The second field trial used a 0.8 cm hard lay, Polysteel rope dipped in anti-fouling paint. The Polysteel rope replaced the polypropylene rope to increase line stiffness and reduce the likelihood of sea turtle interactions. The bottom third of the experimental leader was constructed of 20 cm mesh (stretched) made from 2.5 mm (#42) nylon twine dipped in anti-fouling paint. There was a 1 cm chain at the top and bottom of the leader, with a 1.6 cm polypropylene at the intersection of the vertical ropes and the mesh panel (Figure 3). Like the control leader, the experimental leader extends from the bay floor to approximately the bay surface.

Experimental Design

Leaders were monitored for sea turtle interactions and finfish catches were compared for four offshore pound nets initially selected by NMFS NEFSC personnel. Two experimental and two control leaders were compared with scheduled leader switches or alternations to reduce spatial and temporal biases on the analyses. When net 1 had an experimental leader, net 3 would have an experimental leader and nets 2 and 4 would have control leaders. In 2004, it was intended that experimental leaders be placed on nets 1 and 3 and control leaders on nets 2 and 4 for the first half of the study, at which point the leaders would be switched, with nets 2 and 4 getting experimental leaders and nets 1 and 3 getting control leaders. In 2005, two leader switches were scheduled. Once turtles were first observed in the Chesapeake Bay region, the remaining study period was split into thirds, with leader switches occurring at the conclusion of the first and second thirds of the study. Leader changes were done by the pound net fishermen accompanied by a research technician. Leader changes were dependent on a calm sea state and fisherman cooperation. Under good weather and sea state conditions all leaders in the study could be changed in one day. Once the leaders were changed, it would take approximately one day for the leaders to be fully dropped and functioning as designed. To facilitate this process, a scuba diver was used to ensure the leader was functioning properly.

Leader monitoring for sea turtle interactions

Effective and consistent monitoring of both the control and experimental leaders was critical to determine if the experimental leader significantly reduced sea turtle and pound net leader interactions. Foremost, effective monitoring would determine how many sea turtles interacted with the two leader types and whether the experimental leader significantly reduced these interactions. In addition, it was important to find and remove live sea turtles found in either leader as soon as possible to minimize the injury and mortality resulting from an interaction. This is particularly relevant given the ESA permits issued for this experiment by the NMFS allotted a limited number of lethal takes before the experiment would be stopped.

In preparation for this study, American Underwater Search and Survey further substantiated the ability of acoustic side scan sonar to identify sea turtles interacting with the pound net gear below the surface by placing frozen sea turtles in the leader (these turtles were borrowed from the stranding network). For the present study, two vessels were employed to conduct leader monitoring efforts; one equipped with sonar technology (sonar boat) and the second responsible for visual survey activities, target investigation and turtle handling (dive boat).

Weather and sea state permitting, all four pound net leaders were acoustically and visually surveyed twice a day at the tail end of a high and low tidal cycle. The sonar images with the clearest definition occur when there is enough tidal flow to billow the leader and stretch the mesh. However, if the tidal flow is too strong, it is difficult and dangerous for the diver to investigate targets. Therefore, it was necessary to perform the scans when there was sufficient tidal current to billow the leader sections, but not too strong to prevent the diver from investigating targets. The scans were performed near the end of the tide to maximize the chance of locating impinged sea turtles that would likely disengage from the leader once the current switched directions.

Each leader was scanned visually three times within each tidal cycle in vessels ranging from 6-8 m in length that had sufficient open deck space to care for encountered sea turtles and room to stow dive gear and turtle handling equipment. Three individuals were stationed on the dive boat; a scuba diver to investigate targets, a back-up safety diver and a research technician. The research technician was responsible for visually monitoring the leaders. Using polarized sunglasses, visual surveys were conducted at a speed of 0.7–1.5 m/sec and from 3-6 m off the leader. During each net survey, the technician would complete a data sheet summarizing scan results in addition to recording environmental observations.

Each leader was scanned acoustically three times within each tidal cycle to maximize the potential for sonar to detect any turtles interacting with a leader. Sea state permitting, both the flood and ebb sides of the leader were scanned. The orientation of an object in the leader will determine the image reflection seen by the sonar operator. By scanning the leader from both sides multiple, the probability of detecting the turtle is maximized.

The sonar vessel, a 8 m vessel with cuddy cabin, had three individuals on board; the sonar operator, vessel operator and a research technician. A Marine Sonic 900 kHz side scan sonar fish was towed at approximately 1.5 m/sec and 10 m from the leader to obtain sonar images. Real time data was deciphered by the sonar operator. All sonar data was stored on the computer's hard drive and transferred to CDs for archiving at the end of each day. The tow fish was towed from a bar off the aft port side at a depth of approximately 1 m for nets 1, 2, and 3 and at 0.3 m for net 4 due to shoal water. Each leader pole was numbered to allow the isolation of targets identified by the sonar operator. When targets were identified by the sonar operator, they were communicated to the research technician on board who would record the location of the target. At the conclusion of the three scans, the sonar operator would identify targets that should be investigated, which were then communicated to the second research vessel. During each net survey, the research technician would complete a data sheet summarizing the scan in addition to environmental observations.

Target investigation and sea turtle handling

Once a target was identified, the dive boat would proceed to the location of the target. If possible, the target was identified visually from the surface. Otherwise, subsurface identification was necessary. A professional diver with extensive experience working underwater on pound nets was employed to investigate targets. Targets were located by the diver and the identity was noted and relayed to the sonar operator for image profiling. If possible, targets were removed from the leader to prevent them from being picked up by sonar on subsequent passes.

If a turtle interacting with the leader was encountered, the nature of the interaction was thoroughly documented and recorded. Important information included the turtle's condition, if it was impinged or entangled, the depth of the interaction, the side of the leader the interaction occurred and what the geographic coordinates were, among other items. The turtle was then removed from the leader, retained if possible using a bag net and brought on board. The health status of the turtle was assessed and handling/rehabilitation protocol detailed under the ESA permit was initiated. In addition to handling procedures, all retained turtles were identified, measured (curved carapace length and width, CCL, CCW), examined for injuries or cause of death, and scanned for the presence of passive integrated transponder (PIT) tags and clip tags. A Biomark RD-PR pocket reader was used to scan for PIT tags. During the 2005 season, core temperatures were obtained using a Fluke 50 Series II digital thermometer on all live or potentially live sea turtles. Photographs were taken to document the condition of the turtle and any physical indications that it interacted with the leader. During the 2004 trial, technicians were responsible for applying clip and PIT tags, and taking biopsy samples from live turtles. If deemed healthy and not stressed, these turtles were released. Sea turtles that were considered stressed were transferred to the VAMSC. For the 2005 season, all turtles that were found interacting with the pound net gear were transferred to the VAMSC for expert necropsy or rehabilitation procedures.

Sea turtles found floating dead in the study area were identified, measured, examined for injuries or cause of death, and scanned for the presence of PIT tags and clip tags. Photographs were taken to document the condition of the turtle and any physical signs indicating the cause of death. Fresh dead sea turtles were transferred to VAMSC for necropsy procedures. Large cow tags were attached to the left front flipper of turtles moderately or severely decomposed for identification purposes and released. All sea turtle handing was covered under permits issued to NMFS and VAMSC.

Sea turtle interaction analysis

The Poisson distribution is often used to characterize rare, discrete data (Cameron and Trivedi, 1998). Poisson regression, which is based on the Poisson distribution, will be used to compare event data for the control and experimental leaders to determine if they are significantly different ($p = 0.05$). An assumption of Poisson regression is that the rate parameter is equal to the variance. If this assumption is violated, the data is considered either overdispersed (variance is greater than the mean) or underdispersed (variance is less than the mean). Overdispersion, which is the result of clustered or contagious data, is common when dealing with social aggregations that occur in nature (McCullaugh and Nelder, 1989; Cameron and Trivedi, 1998). Overdispersion can be determined using a likelihood ratio test. If overdispersion is present, negative binomial regression can be used in place of Poisson regression. Negative binomial regression corrects for overdispersed count data often found in Poisson regression, providing a more accurate characterization of the data (Cameron and Trivedi, 1998). These methods were used to determine if the experimental leader significantly reduced sea turtle interactions.

The sample unit for this analysis was defined as 1 calendar day as long as sea turtles were deemed likely to be present in the study area and the leaders were in the water. This unit was chosen based on the monitoring schedule and was considered a reasonable unit by which to gauge the rate of sea turtle interactions with the pound net leaders in the study. Even if the leaders were not monitored due to sea state or inclement weather, discounting these days would bias the data analysis. If a sea turtle becomes entangled in a leader it is likely to remain tangled until the tissue anchoring it has deteriorated which will take several days at least (Bellmund et al., 1987). Consequently, if a leader was not monitored for a day and was excluded from the data set, the sample size would remain constant while the chance of an identified interaction increased, thereby artificially inflating the rate parameter or interaction frequency. Any turtle found interacting with a leader was attributed to the calendar day in which the turtle was found.

Finfish catch sampling

When a pound net owner harvested any of the four pound nets in the study, a research technician accompanied him to obtain a random sample directly from the catch. Samples were either taken directly from the pound by the technician, intercepted as the catch was brailed into the retaining vessel by the fishermen or once the entire catch had been removed from the pound and placed in the boat. Approximately 25 kg were removed from the catch as a representative sample of the entire catch. This sample was then stored in a fish tote or fish basket until it could be processed at the owner's fish house. Once the harvest was complete, the captain was asked to estimate the total weight of the catch. Exact weights were usually not possible because the fishermen often harvest more than one net each trip, mixing their catches together in the retaining vessel. When only one net was harvested, exact weights were obtained after the catch was processed at the fish house. In some circumstances, the entire catch was not removed from the pound, in which case the captain was asked to estimate how many pounds he left in the net. The catch left in the net was assumed to have the same composition of the catch removed from the pound, to not influence more fish from entering the pound and not escape once the net was re-set.

The research technician returned to the fish house to process the sample. The sample was sorted by species and the total weight of each species was recorded using a spring scale or electronic scale used by the fishermen. Using a fish measuring board, the total length of each fish was measured, rounding down to the nearest cm. Data obtained from these samples were expanded to the captain's total weight estimate to characterize the catch. This data was then used to compare catch compositions between the experimental and control leaders.

Catch comparison analysis

High temporal variability in the bay's fish assemblage, particularly during the transitional period between spring and summer (Jung and Houde, 2002) was deemed greater than spatial variability between the nets. For this reason, samples obtained from nets 1, 2, or 3 with equal effort that were harvested on the same day were used to compare the catch performance of the two leader types. Net 4 was excluded from the catch comparison component of this study due to its very different catch performance of this net when compared to nets 1, 2, and 3 (Ott and Longnecker, 2001). This is believed due to its different geographic location inshore of nets 1, 2, and 3, and the shallower water depths.

Five fish species were selected for the catch comparison: Atlantic thread herring (*Opisthonema oglinum*), harvestfish (*Peprilus alepidotus*), butterfish (*Peprilus triacanthus*), Atlantic croaker (*Micropogonias undulatus*), and weakfish (*Cynoscion regalis*). These species were selected based on their prevalence in the samples and pertinence to assessing the catch performance of the experimental leader. Atlantic thread herring, harvestfish, and butterfish are pelagic species while Atlantic croaker and weakfish are demersal species (Collette and MacPhee, 2002; Murdy et al., 1997). The slight modification of the experimental leader between 2004 and 2005 is not expected to affect the capture of finfish, therefore, paired samples from the 2 field trials were combined.

A paired t-test was the primary method used to determine if the harvest weights of individual species were significantly different between the experimental and control leaders (p=0.05). A Shapiro-Wilks test of normality was performed on the error distribution of the paired data (p = 0.05). In instances of non-normality, the non-parametric one tailed Wilcoxon matched-pairs signed-ranked test was used (p = 0.05). A qualitative length frequency analysis for each species was used to address potential selectivity aspects of the two leader designs.

The accuracy of the captain’s catch estimate was important to accurately assess the catch performance of the two leaders. When possible, a simple analysis compared the captain’s catch estimate to exact species weights obtained when these catches were processed at the fish house. This allowed for the evaluation of the accuracy of the Captains’ estimates versus the exact weights, and whether the Captains’ estimates were consistent between the control and experimental leaders.

Environmental Conditions

Environmental data was collected to investigate possible relationships between environmental conditions and sea turtle / pound net interactions. Since sea turtles are capable of remaining submerged for many hours (in some documented cases, much longer), and have a high anaerobic capacity, it is difficult to determine when the interaction occurred (Lutz and Bentley, 1985).

Onset Tidbit temperature loggers were placed in the study area to record surface, midwater and bottom temperature trends during the trial periods. This data was collected to investigate possible correlation between water temperature and sea turtle / pound net interactions.

On June 16, 2004, an electro-magnetic current meter was used to measure current speed at the mid-point of each leader for one entire flood and ebb tidal cycle. In 2005, Aquadropp Acoustic Doppler Profiler was placed at the shore-side end of the leader on net 2, remaining for the course of the study. This instrument continuously measured current speed and direction at the bottom, mid depth and surface. This data was used to illuminate patterns in sea turtle / pound net interactions. A Raytheon DE-719 recording fathometer was used in 2004 to create depth profiles for each leader in the study.

Before each leader was scanned, sea state, tidal stage, wind direction, and secchi depth readings were also recorded.

RESULTS

Sea Turtle Interactions

A complete presentation of the sea turtle interaction data collected in 2004 and 2005 is provided in DeAlteris et al., 2004 and DeAlteris et al., 2005. Sea turtles were present in the study area when the 2004 field trial started on May 17, with four strandings already recorded by the sea turtle stranding and salvage network (STSSN). Between May 17 and June 26, 2004, 37 sea turtles were encountered in the study area, seven of which were interacting with the pound net leaders in the study (Table 2). All seven were determined to have interacted with the leader while alive. The 30 other encountered turtles, most of them dead and floating in the study area, demonstrated no evidence of interacting with the leaders (presence of net marks). The 2004 report indicates a total of 39 turtles encountered with eight determined to have interacted with a leader. The discrepancy is because the 2004 report refers to all sea turtles encountered and includes sea turtles reported by other observers (NMFS staff) prior to and during the study, but not observed by the DAI project personnel, and sea turtles observed by DAI personnel in pound net heads.

Six of the seven interactions occurred in the control or traditional leader. Six were hardshell turtles (four loggerhead, two Kemp's ridley). One of the interactions was a leatherback that became entangled with the left front flipper in a single vertical rope of an experimental leader. To investigate the relationship between vertical rope spacing and sea turtle carapace width, the curved carapace measurements were converted to straight carapace measurements. The width of the largest hardshell turtle, a loggerhead, was estimated at 54 cm (SCW) while the width of the leatherback was estimated at approximately 76 cm (Coles, 1999). The spacing of the vertical ropes is 61 cm.

Five of the interactions occurred within the first five days of the study (May 17 to May 21 2004). The last two interactions occurred on June 21, and June 23, 2004 during the final week of the study. Four of the interactions occurred on the north side or ebb side of the leader, two on the south side and one was undetermined. All seven turtles were recovered within 1.5 meters of mean low water mark in the leader. When found, two turtles were alive, two were freshly dead and three were moderately decomposed. Two turtles were identified through sonar monitoring and five were found via visual inspection. The turtles found visually had not yet been scanned with sonar. Six of the interactions were entanglements, and one was an impingement.

The likelihood ratio test of the 2004 data identified overdispersion in the event data so the negative binomial regression method was used to compare the interaction frequency between the control and experimental leaders. The negative binomial regression indicated the experimental leader had significantly fewer interactions than the control leader ($p = 0.0293$) (Table 3).

In 2004, the leader alteration schedule was not followed closely. As a result, the experimental leader had considerably more effort in the study area than the control leader. Over the course of the 41 day study, the experimental leader had 97 days of effort and the control leader had 71 days of effort.

The 2005 field period started earlier than the 2004 study in an attempt to be present before the turtles arrived in the Bay. The first turtle noted in the bay area was a foul hooked Kemp's ridley in Virginia Beach on May 18 2005 that was reported to VAMSC. Between May 7 and June 29 2005, 20 sea turtles were encountered in the study area. Fifteen of these were found interacting with the leaders in the study, all were hardshell turtles (nine loggerhead, six Kemp's ridley). In 2005 all 15 were determined to have interacted with the leader while alive (Table 4). The remaining five turtles were found floating dead in the study area. The width of the largest hardshell turtle was 56 cm. The 2005 report indicates a total of 23 turtles encountered with 20 determined to have interacted with a leader. The discrepancy is because the 2005 report refers to all sea turtles encountered and includes sea turtles observed by DAI personnel in pound net heads.

In 2005 fifteen of the interactions occurred in the control leader and were determined to have encountered the leader while still alive. The number of lethal takes exempted in the NMFS permit was reached. Consequently, all control leaders were removed on June 4 2005 and replaced with experimental leaders. No sea turtles were found interacting with the four experimental leaders for the remainder of the study. All 15 events occurred between May 24 and June 4 in the control leaders. Fourteen of the 15 interactions occurred on the north side or ebb side of the leader, and one occurred on the south side. Ten interactions occurred within 2 m of mean low water, two occurred within 3 m of mean low water and the depth of three interactions was undetermined.

Interestingly, 11 of 15 events were identified on three separate occasions as control leaders were being removed. Seven turtles (six loggerhead, one Kemp's ridley) were found interacting with the leader on net 1 while it was being removed on May 31 2005, three were alive and four were fresh dead. No sonar scans were performed on the leader that morning before the turtles were found. The next day, June 1 2005, three turtles (one loggerhead, two Kemp's ridley) were found interacting with the leader of net 3 as it was being removed, one turtle was alive and two were fresh dead. The leader was being removed as the sonar vessel was starting the morning monitoring runs. The sonar vessel was able to scan approximately half of the leader that remained in the water, at which time two turtles had already been removed. A target identified by the sonar operator was likely the third turtle that came up in the leader. On June 4 2005, a small, dead Kemp's ridley (26 cm SCW, Coles 1999) came up in the leader of net 4 as it was being removed. This leader was scanned with sonar prior to the turtle being located. No targets were identified when the net was scanned. Sonar was responsible for identifying the four interactions encountered outside of leader removal.

Since no sea turtle –pound net interactions occurred in the 2005 experimental leader it was not possible to perform regression statistics on the 2005 data set. The 2004 and 2005 data sets were combined and tested for overdispersion using the likelihood ratio test. Again, the data was significantly overdispersed. The negative binomial regression resulted in a significant reduction in sea turtle interactions (p = 0.0001) (Table 5). Combining data for the two field trials ignores the modification to the experimental leader for the 2005 field trial.

The leader alteration schedule was adhered to more closely in 2005. Over the course of the comparison period of the study (May 18 to June 4), the experimental leader had 39 days of effort and the control leader had 37 days of effort.

Environmental data

A complete presentation of the environmental data collected in 2004 and 2005 is provided in DeAlteris et al., 2004 and DeAlteris et al., 2005. From these data the following observations are made. Surface water temperature slowly increased from about 12^{o}C in early May, to about 18^{o}C in late May, and to 25^{o}C by late June. Comparing surface and bottom water temperatures, there was little evidence of strong stratification in the water column except for the brief periods. This is probably due to the strong winds during the late spring months that mix the water column.

In general, the north/south current component dominates, as this approximates the alignment of the bay. The semi-diurnal periodicity indicates that tidal current forcing dominates other forces. The maximum observed surface current was about 1 m/sec, however the mean maximum surface current was about 0.5 m/sec. Maximum surface flood (north) and ebb (south) currents are nearly similar in magnitude, however maximum bottom flood currents are greater than maximum ebb currents. Interestingly, the surface current is never slack, but minimum current occurs at mid range tide elevations. The maximum flood and ebb current coincides maximum high and low tide elevations. The effect of wind forcing on the surface current is clearly evident on occasion when wind forces will reverse the predicted tidal current. Bottom current is about one half the magnitude of surface current. While wind forcing clearly influences the surface current, there is little evidence of a wind affecting the bottom current.

Environmental data for several on of the 2005 interactions are summarized below:
On June 1 2005, there was one live sea turtle encountered at 6:15 am as the leader was removed from net 2. The highest vertical temperature gradient recorded between 3:15 am and 6:15 am was 0.51˚C (surface was colder than bottom). The strongest surface current for this same period was 0.33 m/s.

Based on sonar records, it is strongly believed that the interaction occurring on 2 June 2005, a Kemp’s ridley, was found almost immediately after it became impinged on the leader of net 2 (3:20 pm). The surface current speed at this time was 0.18 m/s and the vertical temperature gradient between the surface and bottom was 0.02˚C.

Catch Comparison

A complete presentation of the pound net fish catch data collected in 2004 and 2005 is provided in DeAlteris et al, 2004 and DeAlteris et al. 2005. During the 2004 and 2005 field periods, 107 catch samples were retained from nets 1, 2 and 3. Of these samples, 10 paired samples met the paired sample definition used in the analysis (equal effort, equal harvest date). The two pound net owners participating in the study harvested their nets based primarily on market considerations and sea state / weather conditions. Consequently, the harvests were not coordinated to maximize sample size which resulted in a relatively small sample size (Tables 5 and 6).

Atlantic thread herring

Atlantic thread herring were present in 5 of the 10 paired samples. The average estimated landings were 92 kg, with a range of 0 kg to 415 kg and a standard deviation of 151 kg. The control leader caught more pounds of Atlantic thread herring than the experimental leader in 3 of the 5 paired samples with Atlantic thread herring present (Figure 4 and Table 8). The Shapiro Wilks test indicated the error structure was not normally distributed ($p = 0.32$) so the Wilcoxon matched pairs signed rank test was used. The Wilcoxon test precludes paired samples with zero values. There were only five paired samples where Atlantic thread herring were present. Consequently, sample size was cut in half, reducing the power of this analysis. The Wilcoxon matched pairs test found no significant difference between the two leader types. There was no apparent size selectivity difference between the two leader types (Figure 4).

Harvestfish

Harvestfish were present in 5 of the 10 paired samples. The average estimated landings were 168 kg, with a range of 0 kg to 1,027 kg and a standard deviation of 359 kg. The experimental leader caught more pounds of harvestfish than the control leader in 4 of the 5 paired samples with harvestfish present (Figure 5 and Table 9). Again, the Shapiro Wilks test indicated the error structure was not normally distributed so the Wilcoxon matched pairs test was use. Like Atlantic thread herring, only 5 of the 10 samples had harvestfish present in the samples. The test indicated no significant difference between the two leader types. There was no apparent size selectivity difference between the two leader types (Figure 5).

Butterfish

Butterfish were present in relatively small amounts in each of the 10 paired samples. The average estimated landings were 27 kg, with a range of 0 kg to 132 kg and a standard deviation of 38 kg. The Shapiro Wilks test indicated the error structure was not normally distributed so the Wilcoxon matched pairs test was used, which found a significant difference between the two leader types. This difference indicated the experimental leader, and not the control leader, harvested more butterfish (Figure 6 and Table 10). There was no apparent size selectivity difference between the two leader types (Figure 6).

Atlantic croaker

Atlantic croaker was present in 8 of 10 paired samples. The average estimated landings were 2,245 kg, with a range of 0 kg to 18,845 kg and a standard deviation of 4,808 kg. The control leader caught more pounds of Atlantic croaker than the experimental leader. The Shapiro Wilks test indicated the error structure was normally distributed so the paired t-test was used. The paired t-test indicated no significant difference ($p = 0.39$) between the two leader types (Figure 7 and Table 11). There was no apparent size selectivity difference between the two leader types (Figure 7).

Weakfish

Weakfish were present in all 10 paired samples. The average estimated landings were 505 kg, with a range of 0 kg to 1,942 kg and a standard deviation of 555 kg. The experimental leader caught more pounds of weakfish than the control leader. The Shapiro Wilks test indicated the error structure was normally distributed so the paired t-test was used. The paired t-test indicated no significant difference ($p = 0.42$) between the two leader types (Figure 8 and Table 12). There was no apparent size selectivity difference between the two leader types (Figure 8).

Between the 2004 and 2005 field trials, exact weights were compared with the captain’s estimated weight 15 times. All of these comparison samples were taken from estimates and weights provided by the owner of net 1. The captain’s total catch estimates were within 15% on average of the exact weight recorded at the fish house. The captains’ estimates were consistent between the control and experimental leaders.

DISCUSSION

Sea Turtle Interactions

Although the low number of sea turtle / pound net leader interactions created some difficulty in the statistical analysis of this data, it is clear the modified leader significantly reduced sea turtle interactions. In addition to the significant results of the negative binomial regressions, there were other indications the modified leader worked as designed, in particular the lack of interactions in the modified leaders monitored during the last three weeks of the study after the control leaders were removed.

Although the 2005 experimental leader was modified after the 2004 field trial, the 2005 interaction data could not be analyzed with regression statistics because there were no interactions in the experimental leader. To utilize the 2005 data, it was combined with 2004 data even though the treatments were slightly different. Since the 2005 leader design is less likely to entangle a turtle, it is probable that the level of significance for the experimental leader is conservative for the combined analysis.

When the control leaders were removed from the study area in 2005 due to excessive takes, they were replaced with experimental leaders for the remainder of the study, doubling the number of experimental leaders and therefore greatly increasing the likelihood of a turtle interaction with an experimental leader. For last 24 days no sea turtles were found interacting with the experimental leaders, in contrast to the 15 turtles that were found within 12 days (24 May to 4 June) interacting with the control leader.

Furthermore, based on the sequence of interactions, it was clear that leader location was not a primary factor in the events. This was particularly apparent in the 2005 study period. When the leaders were switched on May 31 and June 1, sea turtles were found interacting with both of the control leaders (nets 1 and 3). The day after the switches were complete (June, 2), turtles were found in the control leaders on nets 2 and 4.

Finally, the only take that was attributed to the experimental leader was a large leatherback turtle that was not anticipated in the design of the modified leader. Additionally, this leatherback turtle was determined to be diseased, which may have altered its behavior. The width of this leatherback was 76 cm (SCW), while the spacing was only 61 cm. The largest hardshell turtle that was encountered during the 2004 / 2005 studies was 57 cm. The leatherback encounter was the impetus for refining the design by removing the polypropylene vertical ropes and replacing them with a stiffer hard lay rope that would be less prone to wrap around the appendage of a sea turtle. If deemed necessary, the space between the vertical ropes could be increased to further reduce the likelihood of an interaction, particularly for large sea turtles such as leatherbacks. However, the effect of this design on the capture of finfish cannot be anticipated. Furthermore, whether this additional spacing would make a significant difference in interactions would be very difficult to quantify due to the lack of interactions in the 2005 experimental leader design.

In addition to achieving the primary objective of determining whether the modified leader significantly reduced sea turtle interactions, other aspects of the nature of these interactions were observed. If future studies are conducted on sea turtle interactions with fixed fishing gear, the use of underwater video could greatly increase the amount of information that documents the nature of the interaction

The statistical analysis of the 2004 and 2005 data indicate overdispersed or clustered data. Although it has been thoroughly documented that sea turtle strandings and leader interactions are highest early in the season when they move into the bay (Lutcavage and Musick, 1985; Bellmund et al., 1987), the clustered data indicate the interactions are isolated on an even finer temporal scale. Between 2004 and 2005, there were 59 leader comparison days. Of the 11 days that interactions occurred, five of them were multiple interaction days. The clustered interactions suggests that the interactions are episodic in nature, which would either indicate there are unique environmental circumstances leading to these events, or that aggregations of sea turtles are encountering the leaders. It has been postulated that strong currents and cold shock caused by high vertical temperature gradients are likely environmental factors that lead to sea turtle and pound net leader interactions (Lutcavage and Musick, 1985; Mansfield et al., 2002). However, the current meter and temperature logging device data neither show particularly strong current speeds nor high temperature gradients in the study area when the interactions occurred. It is estimated that the live turtles encountered during the study were not in the leader for more than 3 hours or they would have likely perished (Lutz and Bentley, 1985; Lutcavage and Lutz, 1997). The maximum current speeds preceding the interaction of the live turtles do not exceed the documented swimming capabilities of either loggerhead or Kemp’s ridley turtles (Wyneken, 1997). In addition, there were no large temperature gradients present in the study area when the encounters occurred. Consequently, it does not seem that current speeds overwhelmed or cold shock reduced the swimming capabilities of the turtles that encountered the pound net leaders. These conclusions are based on a relatively small sample size of sea turtle and pound net interactions. Since environmental conditions at the interaction site do not appear to have been the cause of these interaction events, it is possible the rate at which turtles encountered the leader increased during short periods of time, indicate that the turtles were aggregated in some manner during the periods the clustered events occurred, or that the turtles are generally stressed early in the season upon entering Chesapeake Bay and are unable to swim away from the leaders as they approach them. It is worth noting that four of the five multiple interaction days consisted of both loggerhead and Kemp’s ridley turtles, indicating overlap in habitat use, at least during the early part of the season.

A conspicuous aspect of these interactions was that 18 of 21 occurred on the north side or ebb side of the leader (one was undetermined), particularly since the current meter demonstrated the flood current to be stronger than the ebb current (DeAlteris et al., 2005). There is a large breakwater made of scuttled concrete merchant marine ships just north of net 1, which creates a large scale hydrodynamic disturbance that may increase sea turtle and pound net leader interactions on the north side of net 1. However, the other leaders in the study are a considerable distance from these concrete ships, making it an unlikely cause of interactions on the north side of the leader. It has been demonstrated that sea turtles in the Bay move in relation to tidal cycles and exhibit philopatry both within and between seasons (Byles, 1988), but this data may indicate a spatial movement pattern in this part of the bay where both loggerhead and Kemp's ridley turtles consistently move from north to south along the eastern shore. This pattern may be spatially and temporally isolated, but it may be indicative of a larger movement pattern within the bay.

Another interesting facet of these interactions was the depth at which they occurred, that is all the interactions with the leader occurred within 2-3 m of the sea surface referenced to Mean Low Water (MLW). Of the 19 interactions where depth was determined, 17 were within 2 m of the MLW on the leader and 2 were within 3 m of this mark. The propensity for turtles to become entangled or impinged near the surface has been related to steep thermoclines in the spring (Mansfield et al., 2002). It is likely that the configuration of the leader in addition to tidal forces is largely responsible for turtles interacting with the leader near the surface. The leader panel billows outward in response to tidal forces, creating a bag in the net. A turtle, which feeds almost exclusively on benthic invertebrates (Bjorndal, 1997), will likely encounter the leader at or near the bay floor. When it attempts to surface for air, it will likely be pushed down current into the bag as it swims upwards. This upward / down-current movement will cause the turtle to encounter the leader as it tapers back up current. This taper will create an obstacle over the turtle, hindering it from reaching the surface. This obstacle may precipitate in the turtle either becoming impinged or entangled. It should be noted that inshore net leaders often have significant bagging from tidal forces as well; the plausible reason turtles do not become entangled or impinged in these nets is due to the weaker inshore currents (Lutcavage and Musick, 1985; DeAlteris et al., 2004). Although the experimental leader also billows in response to tidal forces, the spacing in the vertical ropes in the upper two-thirds portion of the leader should allow turtles to pass unimpeded.

Monitoring Effectiveness

Sea turtle interactions were identified via sonar, visual inspection and leader removal. Sonar was the primary monitoring method, and was responsible for identifying interactions in both the 2004 and 2005 study periods. Questions were raised about the effectiveness of sonar when seven turtles came up in the leader of net 1 on May 31 2005, three turtles came up in the leader on June 1 2005, and 1 turtle came up in the leader of net 4 on June 4 2005. All of the turtles that came up in the leaders were either alive or freshly dead, indicating they had likely been in the leader less than 12 hours (Lutcavage and Lutz, 1997). These interactions would have occurred well after the last sonar scans of the previous day. No sonar passes were made on net 1 before the leader was removed, therefore it is impossible to relate these events to the effectiveness of sonar. Approximately 1/2 of the leader of net 3 was scanned once before it was pulled. One priority target was identified which was likely the third turtle that was pulled out of that leader. Therefore, sonar would have likely identified this turtle. However, sonar did conduct three scans according to protocol on net 4 on May 4 2005, prior to the leader being removed with a dead turtle entangled in it. This was the smallest turtle encountered during the two field seasons, a Kemp's ridley (26 cm SCW, Coles, 1999). A previous study found that sonar was effective at identifying interacting turtles that were larger than 35 cm SCW (Mansfield et al., 2002).

The success of sonar is also related to the ability of the research technician to accurately isolate the location of the target and for the scuba diver to locate the target based on the information provided by the sonar operator and research technician. Scuba investigation was an effective method for investigating targets, although labor intensive, particularly given the high number of targets that were identified on a daily basis and the poor visibility prevalent in the bay. It was not uncommon for the diver to investigate several targets on each net during any given monitoring session. If possible, image profiling should be used in future efforts to locate turtles interacting with fixed commercial fishing gear to reduce the number of identified targets that need to be investigated. Although the use of video to identify targets was found to be less effective and more difficult when deployed in unsteady sea states, high current flow or low light conditions, it would likely prove useful for targets that were relatively close to the surface on calm days.

Due to poor water clarity, visual monitoring was limited to observing the top 1 - 2 m of the leader, which was worthwhile given most of the interactions occurred close to the surface. Although most sea turtles were identified via visual inspections in 2004 and 2005, the sonar was effective in uniquely identify several interacting sea turtles, that were not identified in the visual surveys.

Catch comparison

The nature of the new leader design created speculation as to whether it would lead pelagic species as well as the traditional leader. Although landings from offshore pound nets in this portion of the bay are dominated by demersal species, pelagic fishes are also landed. For this reason, the results from the analysis of the 3 pelagic species were particularly pertinent to the second objective of this study. Unfortunately, landings of the pelagic fishes were sporadic. This variation was exposed in the non-normal residual distribution for all three species and absence of harvestfish and Atlantic thread herring from half of the paired samples. The experimental leader consistently harvested as much, if not more, than the control leader. It is likely that visual stimuli and low frequency noise generated by the vertical ropes caused the schooling pelagic fishes to avoid the obstruction created by the vertical ropes in the experimental leader (Wardle, 1986, Misund, 1994).

Although well over a hundred samples were retained over the course of the two experimental seasons, due to the uncoordinated harvest of the pound nets, only 10 paired samples were used to compare the catch performance of the two leader types. Due to this relatively small sample size, it is difficult to state with certainty that the catch performance between the two leaders is the same. However, these results clearly indicate that the catch from pound nets fitted with the experimental leader was comparable to the catch from nets fitted with the traditional leader.

CONCLUSIONS

Based on the statistical analyses and supporting qualitative observations, the experimental leader achieved the two primary objectives of this study: significantly reducing sea turtle bycatch, while not significantly affecting the capture of finfish. Additional pound net sites, a higher allowable take and a coordinated harvest schedule would have substantially increased the strength of these conclusions. The reduction in sea turtle mortality attributed to the modified leader should provide sufficient evidence to resource managers to allow restricted pound net fishermen to use the modified pound net leaders during current regulated periods.

LITERATURE CITED

Bellmund, S.A., J.A Musick, R.C. Klinger, R.A. Byles, J.A. Keinath, and D.E. Barnard. 1987. Ecology of Sea Turtles in Virginia. VIMS Special Scientific Report No. 119. Virginia Institute of Marine Science. 48 pp.

Bellmund S.A. 1988. Assessing Environmental Stress on the Loggerhead Sea Turtle (Caretta caretta) in Virginia Waters. MA Thesis. College of William and Mary, Virginia. 70 pp.

Bjorndal, K.A. 1997. Foraging Ecology and Nutrition of Sea Turtles. In: Lutz P.L., J.A. Musick (editors). The Biology of Sea Turtles. pp. 199-221

Byles R.A. 1988. Behavior and Ecology of Sea Turtles from Chesapeake Bay, Virginia. PhD Dissertation. College of William and Mary, Virginia. 112 pp.

Cameron, A.C. and Trivedi, P.K. 1998. Regression Analysis of Count Data. pp. 1-37.

Chittenden, M.E. 1989. Sources of Variation in Chesapeake Bay Pound-Net and Haul-Seine Catch Compositions. North American Journal of Fisheries Management, 9, pp. 367-371.

Coles W.C. 1999. Aspects of the Biology of Sea Turtles in the Mid-Atlantic Bight. PhD Dissertation. College of William and Mary, Virginia. pg. 38, 72

Collette, B.B. and G. Klein-MacPhee (eds.). 2002. Bigelow and Schroeder's Fishes of the Gulf of Maine, 3rd edition. pp. 158-160, 435-445, 540-545

DeAlteris, J. 1998. Introduction to Fisheries Technology for Scientists and Fishermen. University of Rhode Island, Kingston, Rhode Island. pp. 14.

DeAlteris, J., D. Chosid, R. Silva, and P. Politis. 2004. Evaluation of the performance in 2004 of an alternative leader design on the bycatch of sea turtles and the catch of finfish in Chesapeake Bay pound nets, offshore Kiptopeake, VA. A Final Report submitted by DeAlteris Associates Inc. to NMFS NEFSC, 31 August 2004.

DeAlteris, J., R. Silva, E. Estey, K. Tesla, and T. Newcomb. 2005. Evaluation of the performance in 2005 of an alternative leader design on the bycatch of sea turtles and the catch of finfish in Chesapeake Bay pound nets, offshore Kiptopeake, VA. A Final Report submitted by DeAlteris Associates Inc. to NMFS NEFSC, 31 August 2005.

Hildebrand S.F., and W.C. Schroeder. 1972. Fishes of Chesapeake Bay. Smithsonian Institution, Washington DC.

Jung, S., and E.D. Houde. 2002. Evaluating Temporal and Spatial Variability in Biomass, Species Assemblage and Diversity of Fishes in Chesapeake Bay, USA. International Council for the Exploration of the Seas (ICES), CM 2002/L:13

Keinath, J.A. 1993. Movements and Behavior of Wild and Head-Started Sea Turtles. Ph.D. Dissertation. Virginia Institute of Marine Science, College of William and Mary, Gloucester Point, VA, 206 pp.

Keinath, J.A., D.E. Barnard, J.A. Musick, B.A. Bell. 1994. Kemp's ridley sea turtles from Virginia waters. Bjorndal, K. A., Bolton, A. B., Johnson, P. A., and Eliazar, P. J. (Compilers). In: Proceedings of the 14th Annual Symposium on Sea Turtle Biology and Conservation. NOAA Technical Memorandum NMFS-SEFSC-351, 70, 1994.

Lutcavage, M.E. 1981. The Status of Marine Turtles in Chesapeake Bay and Virginia Coastal Waters. MA Thesis. College of William and Mary, Virginia.

Lutcavage M.E., and J.A. Musick. 1985. Aspects of the Biology of Sea Turtles. Copeia, 1985(2). pp. 449-456.

Lutcavage, M.E. and P.L. Lutz. 1997. Diving Physiology. In: Lutz, P.L. and J.A. Musick, (eds.). The Biology of Sea Turtles. pp. 165-19

Lutz, P.L. and T.B. Bentley. 1985 Adaptations to diving in the sea turtle. Copeia 1985. pp. 671-679

Mansfield K.L., J.A. Musick, R.A. Pemberton. 2001. Characterization of the Chesapeake Bay Pound Net and Whelk Pot Fisheries and Their Potential Interactions with Marine Sea Turtle Species. Final Report, National Marine Fisheries Service, Woods Hole, MA. Contract #: 43EANFO30131.

Mansfield K.L., E.E. Seney, J.A. Musick. 2002. An Evaluation of Sea Turtle Abundances, Mortalities, and Fisheries Interactions in the Chesapeake Bay, Virginia. Final Report, National Marine Fisheries Service, Gloucester, MA. Contract #: 43-EA-NF-110773.

Mansfield K.L., E.E. Seney, M.A. Fagan, J.A. Musick, K.L. Frisch, A.E. Knowles. 2002. An Evaluation of Interactions Between Sea Turtles and Pound Net Leaders in the Chesapeake Bay, Virginia. Final Report, National Marine Fisheries Service, Gloucester, MA. Contract #: EA1330-02-SE-0075.

McCullagh, P. and J.A. Nelder. Generalized Linear Models 2nd ed. 1989. pp. 193.

Misund, O.E. 1994. Swimming Behaviour of Fish Schools in Connection with Capture by Purse Seine and Pelagic Trawl. In: Ferno, A., and S. Olsen (editors). Marine Fish Behaviour in Capture and Abundance Estimation. pp. 97.

Murdy E.O., and R.S. Birdsong, J.A. Musick. 1997. Fishes of Chesapeake Bay. Smithsonian Institution, Washington DC. 280 pp.

Musick J.A., R. Byles, R.E. Klinger, S.A. Bellmund. 1984. Mortality and Behavior of Sea Turtles in the Chesapeake Bay. Summary Report, National Marine Fisheries Service, Gloucester, MA. Contract #: NA80FAC00004. 22 pp.

Musick J.A. 1996. Interaction of Fisheries with Sea Turtles and Marine Mammals in Virginia. In: Berger T. (editor), Proceedings of the Workshop on the Management of Protected Species/Fisheries Interactions in State Waters. Special Report No. 54 of the Atlantic States Marine Fisheries Commission, Richmond, VA. pp. 74-84.

Musick J.A., and C.J. Limpus. 1997. Habitat Utilization and Migration in Juvenile Sea Turtles, In: Lutz P.L., J.A. Musick (editors). The Biology of Sea Turtles. pp. 137-154.

Ott, R.L. and M. Longnecker. 2001. Statistical Methods and Data Analysis, 5th edition. pp. 299-308.

Reid G.K. 1955. The Pound Net Fishery in Virginia Part 1 – History, Gear Description, and Catch. Commercial Fisheries Review. 17(5). pp. 1-15.

Silva L.A. 1996. State Fishery Interaction with Protected Species from Maine to Florida. In: Berger T. (editor), Proceedings of the Workshop on the Management of Protected Species/Fisheries Interactions in State Waters. Special Report No. 54 of the Atlantic States Marine Fisheries Commission, Richmond, VA. pp. 64-72.

Swingle W.M., S.G. Barco, C.T. Harry, C. Trapani. 2004. Sea Turtle Stranding Response on Virginia's Eastern Shore. Final Report, National Marine Fisheries Service, Gloucester, MA. Contract #: EA133f-04-SE-0652. 9 pp.

Terwilliger K., J.A. Musick (co-chairs), Virginia Sea Turtle and Marine Mammal Conservation Team. 1995. Management Plan for Sea Turtles and Marine Mammals in Virginia. Final report to the National Oceanic and Atmospheric Administration. 56 pp.

Wardle C.S. 1986. Fish Behavior and Fishing Gear. In: Pitcher T. (editor). The Behavior of Teleost Fish. Pp. 463-495.

Wyneken, J. 1997. Sea Turtle Locomotion: Mechanisms, Behavior and Energetics. In: Lutz, P.L. and J.A. Musick, (eds.). The Biology of Sea Turtles. pp. 165-198

Wynne K., M. Schwartz, G. Mix. 1999. Guide to Marine Mammals and Turtles of the U.S. Atlantic and Gulf of Mexico. Rhode Island Sea Grant, University of Rhode Island, Narragansett, RI, pp. 96-109

Table 1. Specifications of pound nets 1-4, and latitude and longitude coordinates of the leader, heart and head of each pound net.

Pound net specifications	Net 1	Net 2	Net 3	Net 4
Leader length (m)	355	283	277	229
Latitude of leader start	37-09.673	37-09.221	37-08.664	37-08.311
Longitude of leader start	75-59.270	75-59.025	75-58.834	75-58.575
Latitude of leader end	37-09.588	37-09.165	37-08.624	37-08.297
Longitude of leader end	75-59.454	75-59.192	75-59.019	75-58.711
Traditional leader mesh size (cm)	28	28	28	28
Traditional leader twine size (mm)	2.5	2.5	2.5	2.5
Latitude of end of head	37-09.568	37-09.175	37-08.627	37-08.290
Longitude of the end of the head	75-59.466	75-59.220	75-59.049	75-58.734
Mesh size in the head (cm)	4.5	4.8	4.8	4.8

Table 2. 2004 sea turtle pound net leader interaction summary

DATE	SPECIES	NET #	LEADER TYPE	SIDE OF LEADER	DEPTH OF INTERACTION (m)
05/17/04	Kemp's ridley	2	Control	North	1.2
05/17/04	Loggerhead	2	Control	unknown	unknown
05/18/04	Loggerhead	2	Control	North	1.2
05/19/04	Kemp's ridley	2	Control	North	1.2
05/21/04	Loggerhead	4	Control	North	unknown
06/21/04	Loggerhead	1	Control	South	1
06/23/04	Leatherback	2	Experimental	South	1.2

Table 3. Negative binomial regression on 2004 interaction data.

```
                  Distribution         Negative Binomial
                  Link Function                  Log
                  Dependent Variable               y
                  Observations Used              168


                     Class Level Information

                    Class           Levels          Values

                    leader          2               0 1


                         Criteria For Assessing Goodness Of Fit

             Criterion                DF         Value        Value/DF

             Pearson Chi-Square       166      160.4343        0.9665
             Scaled Pearson X2        166     160.4343         0.9665
             Log Likelihood                   -25.7246


                         LR Statistics For Type 1 Analysis

                         2*Log                     Chi-
              Source     Likelihood       DF       Square    Pr > ChiSq

              Intercept  -56.2013
              leader     -51.4491         1        4.75      0.0293
```

Table 4. 2005 sea turtle / pound net leader interaction summary

DATE	SPECIES	NET #	LEADER TYPE	SIDE OF LEADER	DEPTH OF INTERACTION (m)
05/24/05	loggerhead	1	Control	North	1.2
05/27/05	Kemp's ridley	1	Control	North	2.1
05/31/05	loggerhead	1	Control	North	1.8
05/31/05	loggerhead	1	Control	North	1.8
05/31/05	Kemp's ridley	1	Control	North	1.2
05/31/05	loggerhead	1	Control	North	1.2
05/31/05	loggerhead	1	Control	North	1.2
05/31/05	loggerhead	1	Control	North	unknown
05/31/05	loggerhead	1	Control	North	unknown
06/01/05	Kemp's ridley	3	Control	South	unknown
06/01/05	Kemp's ridley	3	Control	North	2.7
06/01/05	loggerhead	3	Control	North	1.2
06/02/05	loggerhead	4	Control	North	1.2
06/02/05	Kemp's ridley	2	Control	North	1.2
06/04/05	Kemp's ridley	4	Control	North	1.2

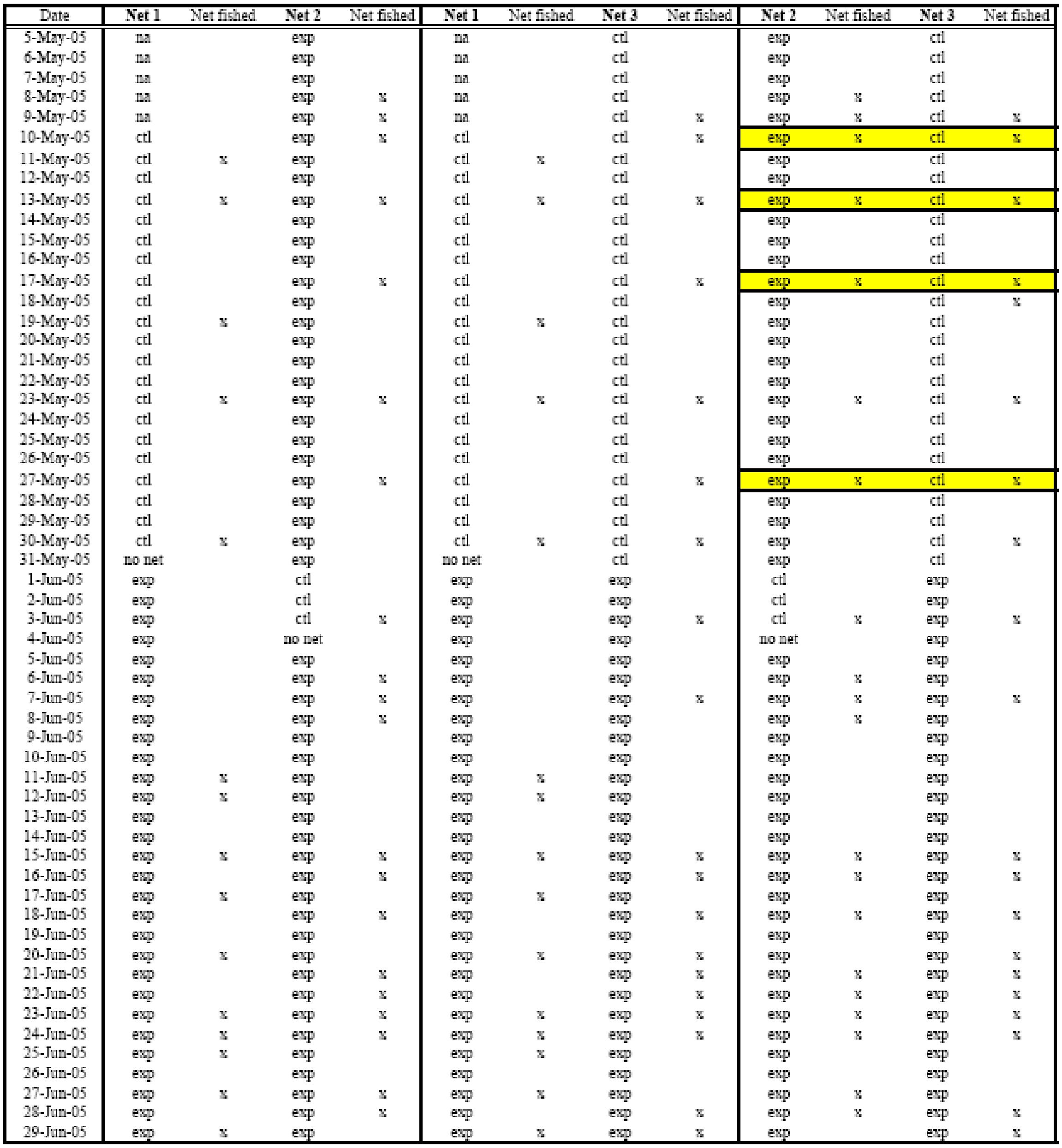
Table 5. Negative binomial regressionanalysis on 2004 and 2005 sea turtle interaction data.

```
          Data Set             WORK.POUNDNET20042005
          Distribution            Negative Binomial
          Link Function                  Log
          Dependent Variable               y
          Observations Used              244


               Class Level Information

             Class      Levels        Values

             leader        2          0 1


            Criteria For Assessing Goodness Of Fit

     Criterion                   DF         Value      Value/DF

     Pearson Chi-Square         242       260.5444       1.0766
     Scaled Pearson X2          242       260.5444       1.0766
     Log Likelihood             -46.1221


             LR Statistics For Type 1 Analysis

                2*Log                   Chi-
     Source     Likelihood      DF     Square    Pr > ChiSq

     Intercept   -107.3233
     leader      -92.2441        1      15.08       0.0001
```

Table 6. 2004 Catch comparison sample calendar

Date	Net 1	Net fished	Net 2	Net fished	Net 1	Net fished	Net 3	Net fished	Net 2	Net fished	Net 3	Net fished
17-May-04	exp		cont		exp		exp		cont		exp	
18-May-04	exp	X	cont	X	exp	X	exp		cont	X	exp	
19-May-04	exp		cont		exp		exp		cont		exp	
20-May-04	exp	X	cont		exp	X	exp		cont		exp	
21-May-04	exp		cont		exp		exp	X	cont		exp	X
22-May-04	exp		cont		exp		exp		cont		exp	
23-May-04	exp		cont		exp		exp		cont		exp	
24-May-04	exp		cont		exp		exp		cont		exp	
25-May-04	exp	X	cont	X	exp	X	exp	X	cont	X	exp	X
26-May-04	exp		cont	X	exp		exp	X	cont	X	exp	X
27-May-04	exp		cont	X	exp		exp	X	cont	X	exp	X
28-May-04	exp		cont	X	exp		exp	X	cont	X	exp	X
29-May-04	exp		cont		exp		exp		cont		exp	
30-May-04	exp		cont		exp		exp		cont		exp	
31-May-04	cont		exp		cont		exp	X	exp		exp	X
1-Jun-04	cont	X	exp	X	cont	X	exp	X	exp	X	exp	X
2-Jun-04	cont		exp		cont		exp	X	exp		exp	X
3-Jun-04	cont		exp	X	cont		exp	X	exp	X	exp	X
4-Jun-04	cont	X	exp	X	cont	X	exp	X	exp	X	exp	X
5-Jun-04	cont		exp	X	cont		exp	X	exp	X	exp	X
6-Jun-04	cont		exp	X	cont	X	exp	X	exp	X	exp	X
7-Jun-04	cont	X	exp		cont	X	exp	X	exp		exp	X
8-Jun-04	cont	X	exp		cont	X	exp	X	exp		exp	X
9-Jun-04	cont		exp	X	cont		exp	X	exp	X	exp	X
10-Jun-04	cont		exp		cont		exp	X	exp		exp	X
11-Jun-04	cont	X	exp	X	cont	X	exp	X	exp	X	exp	X
12-Jun-04	cont	X	exp	X	cont	X	exp		exp	X	exp	
13-Jun-04	cont		exp		cont		exp		exp		exp	
14-Jun-04	cont		exp		cont		exp	X	exp		exp	X
15-Jun-04	cont		exp		cont		exp		exp		exp	
16-Jun-04	cont	X	exp	X	cont	X	exp		exp	X	exp	
17-Jun-04	cont		exp	X	cont		exp		exp	X	exp	
18-Jun-04	cont	X	exp	X	cont	X	exp		exp	X	exp	
19-Jun-04	cont		exp	X	cont		exp		exp	X	exp	
20-Jun-04	cont		exp		cont		exp		exp		exp	
21-Jun-04	cont	X	exp		cont	X	cont		exp		cont	
22-Jun-04	cont		exp	X	cont		cont	X	exp	X	cont	X
23-Jun-04	cont		exp	X	cont		cont		exp	X	cont	
24-Jun-04	cont	X	exp		cont	X	cont	X	exp		cont	X
25-Jun-04	cont		exp		cont		cont	XX	exp		cont	XX
26-Jun-04	cont		exp		cont		cont		exp		cont	
27-Jun-04	cont		exp		cont		cont		exp		cont	

Table 7. 2005 Catch comparison sample calendar



Date	**Net 1**	Net fished	**Net 2**	Net fished	**Net 1**	Net fished	**Net 3**	Net fished	**Net 2**	Net fished	**Net 3**	Net fished
5-May-05	na		exp		na		ctl		exp		ctl	
6-May-05	na		exp		na		ctl		exp		ctl	
7-May-05	na		exp		na		ctl		exp		ctl	
8-May-05	na		exp	x	na		ctl		exp	x	ctl	
9-May-05	na		exp	x	na		ctl	x	exp	x	ctl	x
10-May-05	ctl		exp	x	ctl		ctl	x	exp	x	ctl	x
11-May-05	ctl	x	exp		ctl	x	ctl		exp		ctl	
12-May-05	ctl		exp		ctl		ctl		exp		ctl	
13-May-05	ctl	x	exp	x	ctl	x	ctl	x	exp	x	ctl	x
14-May-05	ctl		exp		ctl		ctl		exp		ctl	
15-May-05	ctl		exp		ctl		ctl		exp		ctl	
16-May-05	ctl		exp		ctl		ctl		exp		ctl	
17-May-05	ctl		exp	x	ctl		ctl	x	exp	x	ctl	x
18-May-05	ctl		exp		ctl		ctl		exp		ctl	x
19-May-05	ctl	x	exp		ctl	x	ctl		exp		ctl	
20-May-05	ctl		exp		ctl		ctl		exp		ctl	
21-May-05	ctl		exp		ctl		ctl		exp		ctl	
22-May-05	ctl		exp		ctl		ctl		exp		ctl	
23-May-05	ctl	x	exp	x	ctl	x	ctl	x	exp	x	ctl	x
24-May-05	ctl		exp		ctl		ctl		exp		ctl	
25-May-05	ctl		exp		ctl		ctl		exp		ctl	
26-May-05	ctl		exp		ctl		ctl		exp		ctl	
27-May-05	ctl		exp	x	ctl		ctl	x	exp	x	ctl	x
28-May-05	ctl		exp		ctl		ctl		exp		ctl	
29-May-05	ctl		exp		ctl		ctl		exp		ctl	
30-May-05	ctl	x	exp		ctl	x	ctl	x	exp		ctl	x
31-May-05	no net		exp		no net		ctl		exp		ctl	
1-Jun-05	exp		ctl		exp		exp		ctl		exp	
2-Jun-05	exp		ctl		exp		exp		ctl		exp	
3-Jun-05	exp		ctl	x	exp		exp	x	ctl	x	exp	x
4-Jun-05	exp		no net		exp		exp		no net		exp	
5-Jun-05	exp		exp		exp		exp		exp		exp	
6-Jun-05	exp		exp	x	exp		exp		exp	x	exp	
7-Jun-05	exp		exp	x	exp		exp	x	exp	x	exp	x
8-Jun-05	exp		exp	x	exp		exp		exp	x	exp	
9-Jun-05	exp		exp		exp		exp		exp		exp	
10-Jun-05	exp		exp		exp		exp		exp		exp	
11-Jun-05	exp	x	exp		exp	x	exp		exp		exp	
12-Jun-05	exp	x	exp		exp	x	exp		exp		exp	
13-Jun-05	exp		exp		exp		exp		exp		exp	
14-Jun-05	exp		exp		exp		exp		exp		exp	
15-Jun-05	exp	x	exp	x	exp	x	exp	x	exp	x	exp	x
16-Jun-05	exp		exp	x	exp		exp	x	exp	x	exp	x
17-Jun-05	exp	x	exp		exp	x	exp		exp		exp	
18-Jun-05	exp		exp	x	exp		exp	x	exp	x	exp	x
19-Jun-05	exp		exp		exp		exp		exp		exp	
20-Jun-05	exp	x	exp		exp	x	exp	x	exp		exp	x
21-Jun-05	exp		exp	x	exp		exp	x	exp	x	exp	x
22-Jun-05	exp		exp	x	exp		exp	x	exp	x	exp	x
23-Jun-05	exp	x	exp	x	exp	x	exp	x	exp	x	exp	x
24-Jun-05	exp	x	exp	x	exp	x	exp	x	exp	x	exp	x
25-Jun-05	exp	x	exp		exp	x	exp		exp		exp	
26-Jun-05	exp		exp		exp		exp		exp		exp	
27-Jun-05	exp	x	exp	x	exp	x	exp		exp	x	exp	
28-Jun-05	exp		exp	x	exp		exp	x	exp	x	exp	x
29-Jun-05	exp	x	exp		exp	x	exp	x	exp		exp	x

Table 8. Catch comparison results: Atlantic thread herring

ATLANTIC THREAD HERRING paired samples						
date	net	leader type	weight (kg)	net	leader type	weight (kg)
5/26/04	2	ctl	81	3	exp	220
5/27/04	2	ctl	300	3	exp	58
6/7/04	1	ctl	0	3	exp	0
6/8/04	1	ctl	415	3	exp	393
6/12/04	1	ctl	9	2	exp	5
6/16/04	1	ctl	5	2	exp	362
5/10/05	3	ctl	0	2	exp	0
5/13/05	3	ctl	0	2	exp	0
5/17/05	3	ctl	0	2	exp	0
5/27/05	3	ctl	0	2	exp	0

Table 9. Catch comparison results: Harvestfish

HARVESTFISH paired samples						
date	net	leader type	weight (kg)	net	leader type	weight (kg)
5/26/04	2	ctl	0	3	exp	2
5/27/04	2	ctl	0	3	exp	0
6/7/04	1	ctl	448	3	exp	928
6/8/04	1	ctl	160	3	exp	54
6/12/04	1	ctl	0	2	exp	11
6/16/04	1	ctl	0	2	exp	1027
5/10/05	3	ctl	0	2	exp	0
5/13/05	3	ctl	0	2	exp	0
5/17/05	3	ctl	0	2	exp	0
5/27/05	3	ctl	0	2	exp	0

Table 10. Catch comparison results: Butterfish

BUTTERFISH paired samples						
date	net	leader type	weight (kg)	net	leader type	weight (kg)
5/26/04	2	ctl	0	3	exp	132
5/27/04	2	ctl	57	3	exp	48
6/7/04	1	ctl	7	3	exp	9
6/8/04	1	ctl	0	3	exp	2
6/12/04	1	ctl	1	2	exp	7
6/16/04	1	ctl	0	2	exp	54
5/10/05	3	ctl	1	2	exp	4
5/13/05	3	ctl	55	2	exp	114
5/17/05	3	ctl	19	2	exp	26
5/27/05	3	ctl	0	2	exp	7

Table 11. Catch comparison results: Atlantic croaker

ATLANTIC CROAKER weight comparison		
t-Test: Paired Two Sample for Means		
	Control	Experimental
Mean	2412.82	2077.377797
Variance	13946990.09	34793789.82
Observations	10.00	10
Pearson Correlation	0.78	
Hypothesized Mean Differer	0.00	
df	9.00	
t Stat	0.28	
P(T<=t) one-tail	**0.39**	
t Critical one-tail	1.83	
P(T<=t) two-tail	0.79	
t Critical two-tail	2.26	

ATLANTIC CROAKER paired samples

date	net	leader type	weight (kg)	net	leader type	weight (kg)
5/26/04	2	ctl	0	3	exp	0
5/27/04	2	ctl	0	3	exp	0
6/7/04	1	ctl	3662	3	exp	0
6/8/04	1	ctl	2682	3	exp	0
6/12/04	1	ctl	6940	2	exp	374
6/16/04	1	ctl	10722	2	exp	18845
5/10/05	3	ctl	4	2	exp	348
5/13/05	3	ctl	18	2	exp	312
5/17/05	3	ctl	49	2	exp	894
5/27/05	3	ctl	51	2	exp	0

Table 12. Catch comparison results: Weakfish

WEAKFISH weight comparison		
t-Test: Paired Two Sample for Means		
	Control	Experimental
Mean	484.28	525.24
Variance	420916.44	230576.20
Observations	10.00	10.00
Pearson Correlation	0.42	
Hypothesized Mean Difference	0.00	
df	9.00	
t Stat	-0.21	
P(T<=t) one-tail	**0.42**	
t Critical one-tail	1.83	
P(T<=t) two-tail	0.84	
t Critical two-tail	2.26	

WEAKFISH paired samples						
date	net	leader type	weight (kg)	net	leader type	weight (kg)
5/26/04	2	ctl	0	3	exp	281
5/27/04	2	ctl	1025	3	exp	1774
6/7/04	1	ctl	189	3	exp	279
6/8/04	1	ctl	129	3	exp	141
6/12/04	1	ctl	0	2	exp	374
6/16/04	1	ctl	0	2	exp	597
5/10/05	3	ctl	125	2	exp	87
5/13/05	3	ctl	1942	2	exp	468
5/17/05	3	ctl	389	2	exp	585
5/27/05	3	ctl	1045	2	exp	666

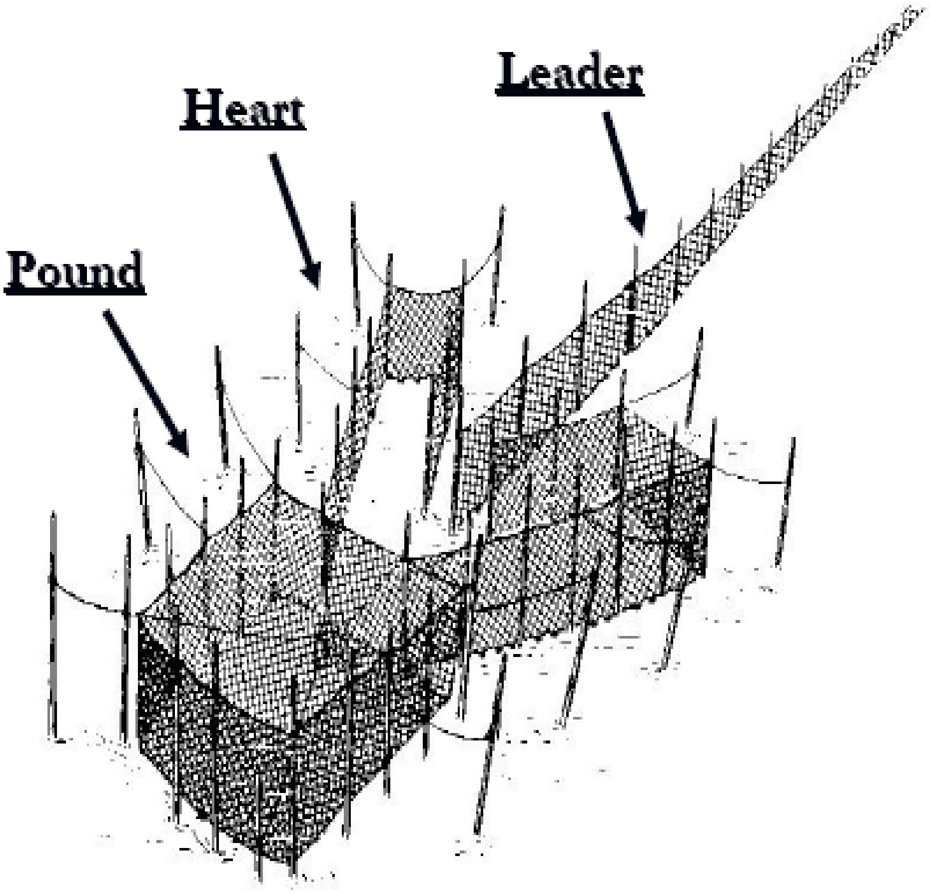


Figure 1. Pound net diagram

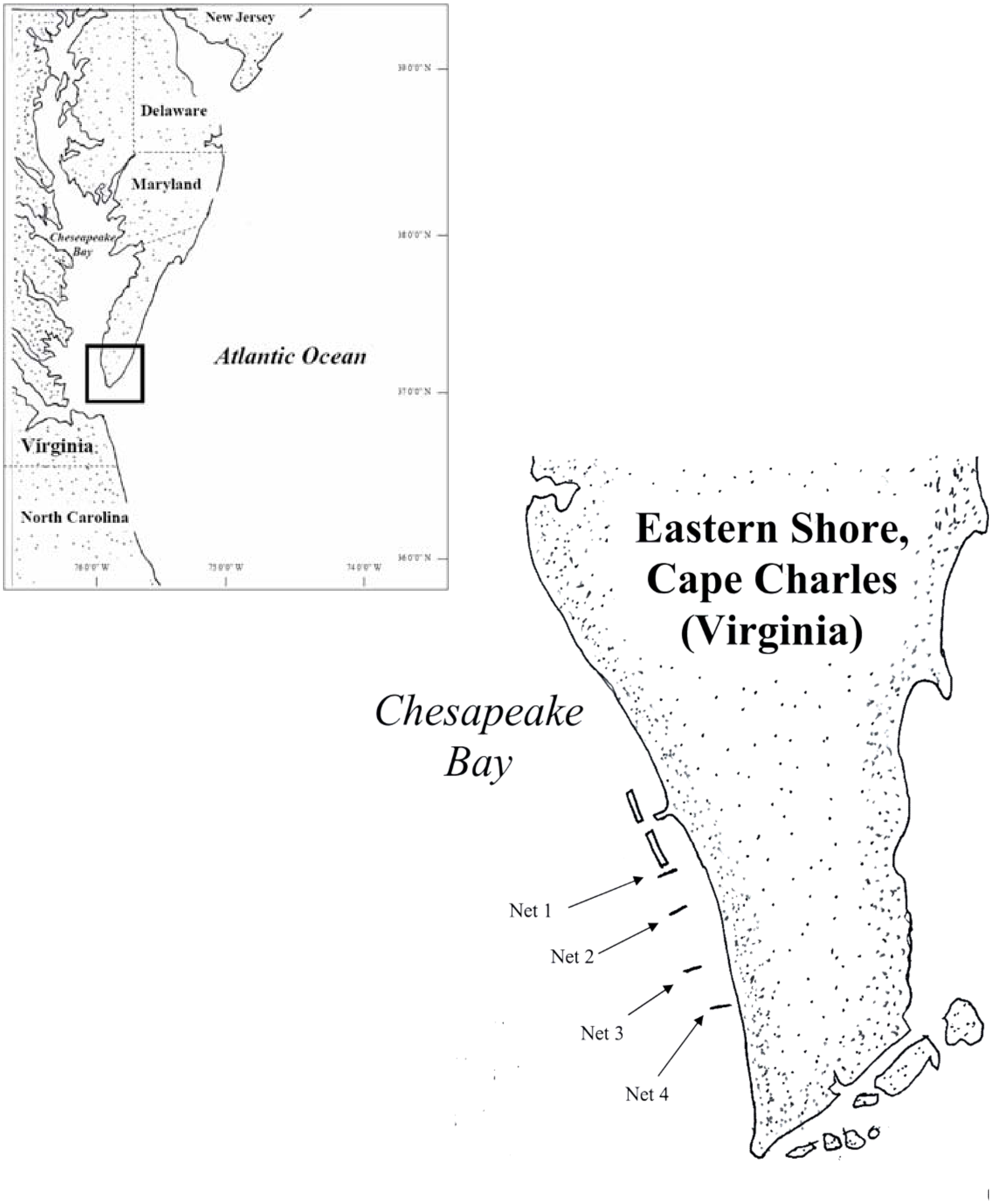
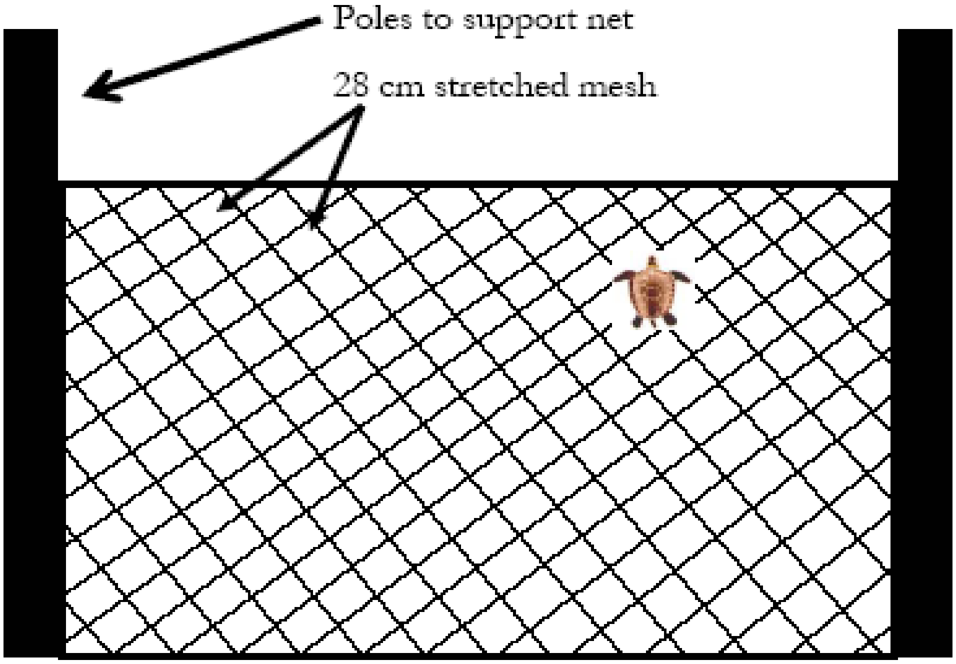
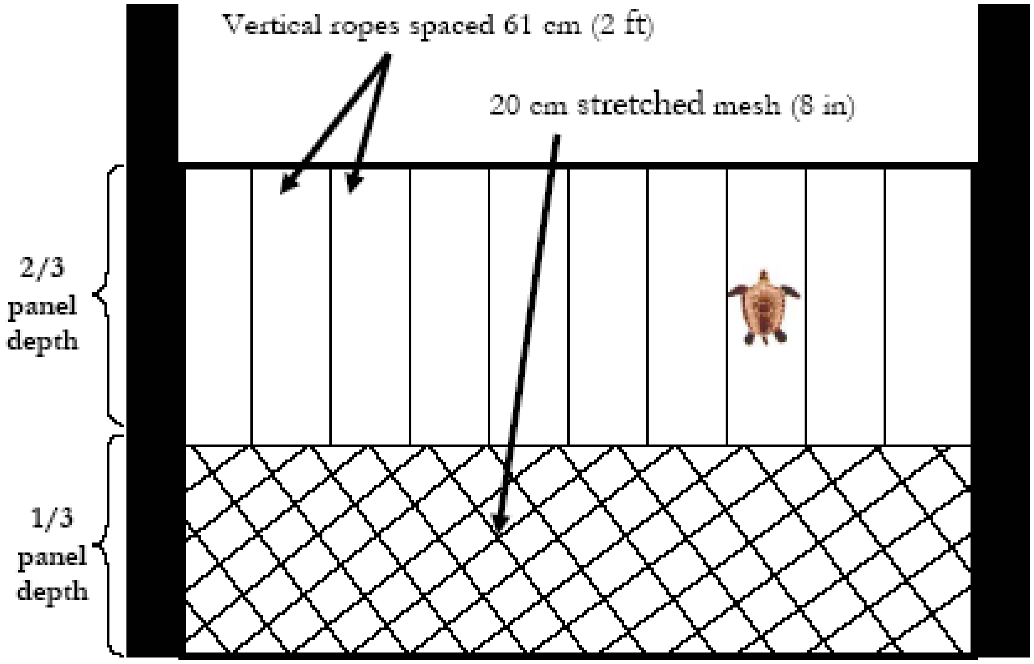


Figure 2. Map of study area showing the pound net locations

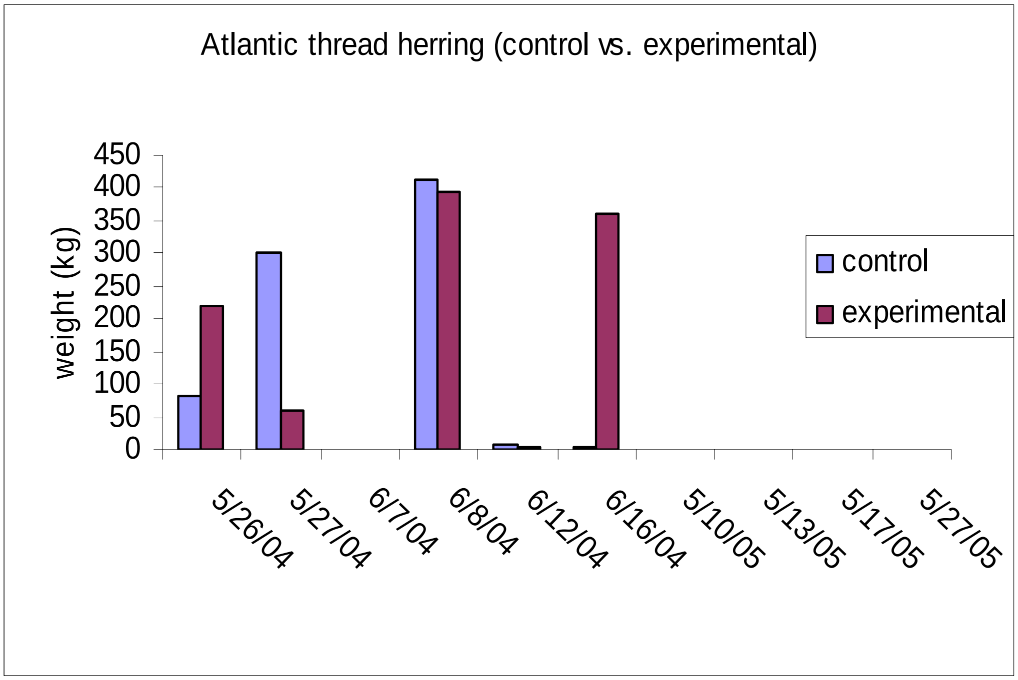


Control Pound Net Leader



Experimental Pound Net Leader

Figure 3. Panel diagram of traditional or control and experimental pound net leaders



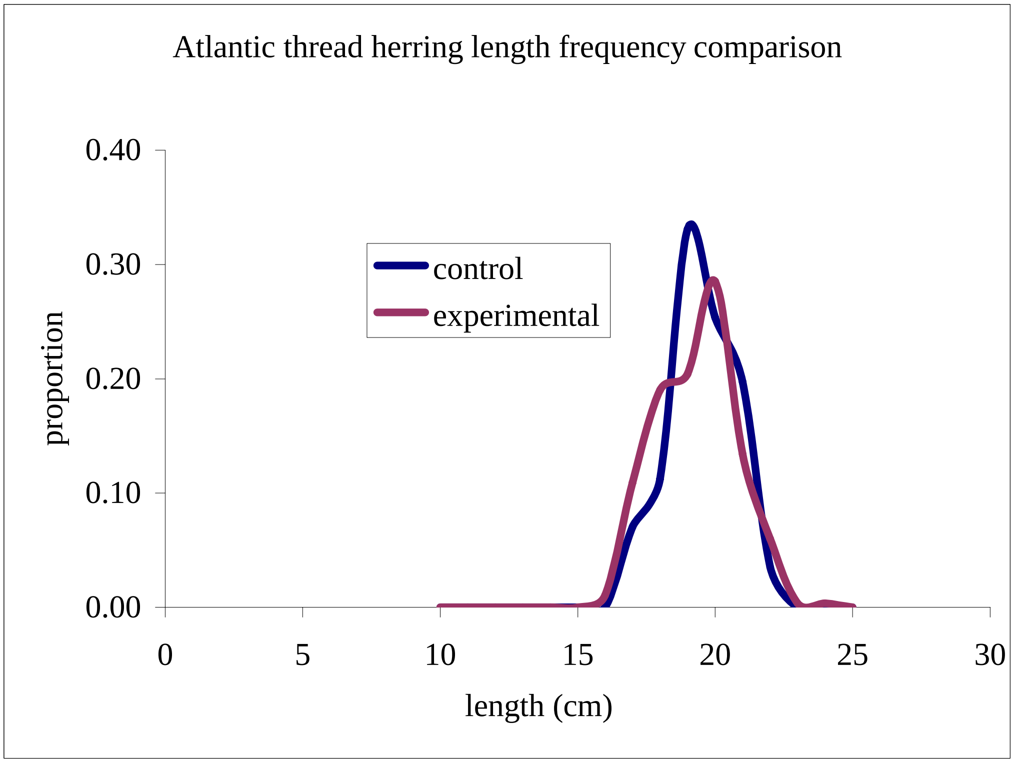
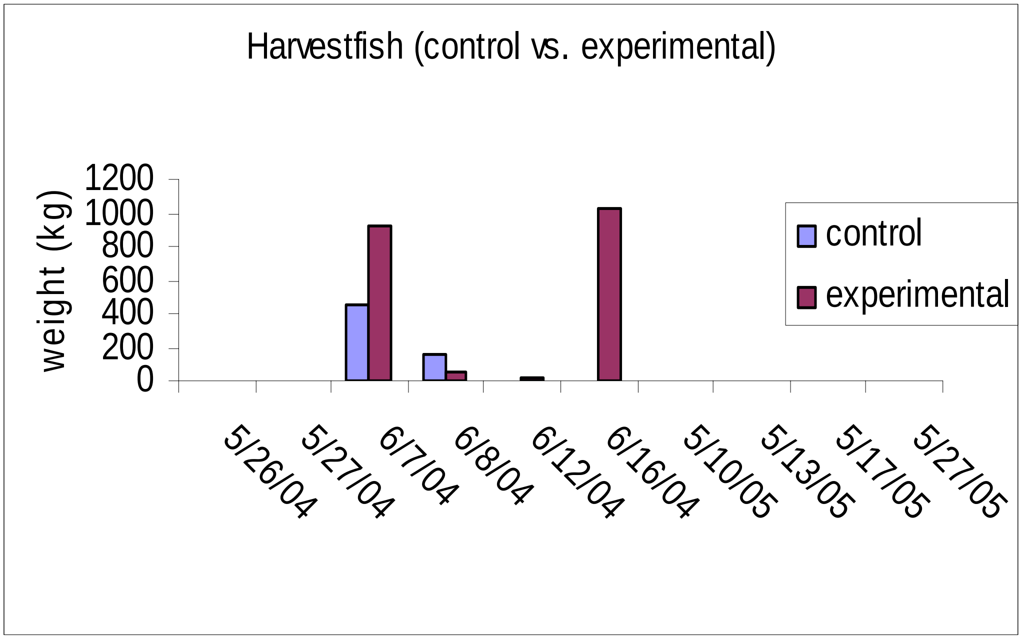


Figure 4. Atlantic thread herring sample weights and length frequencies



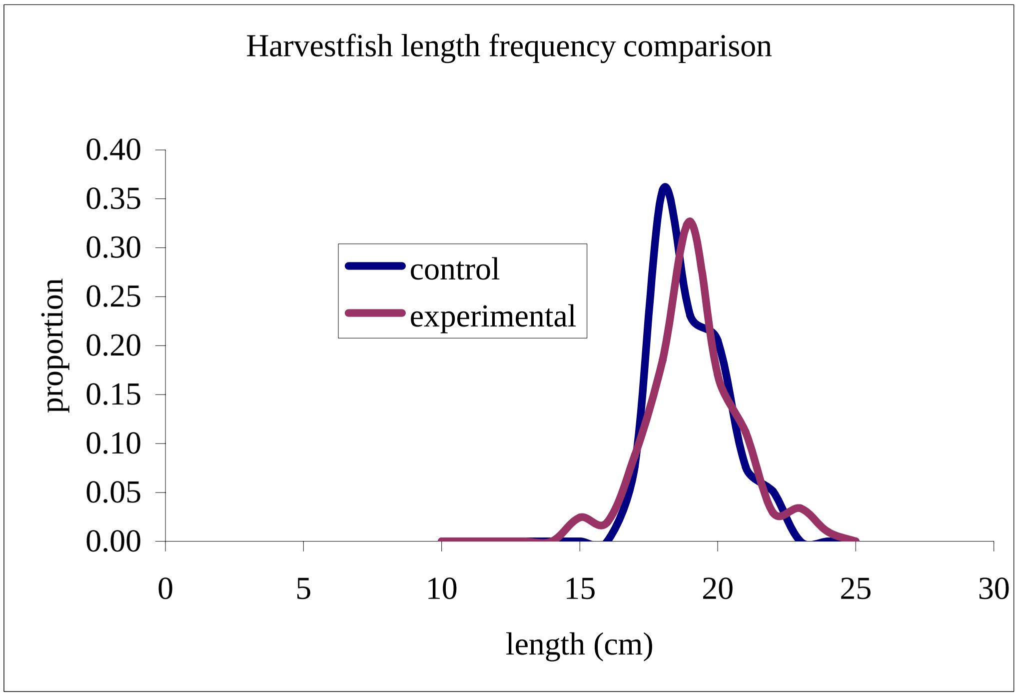
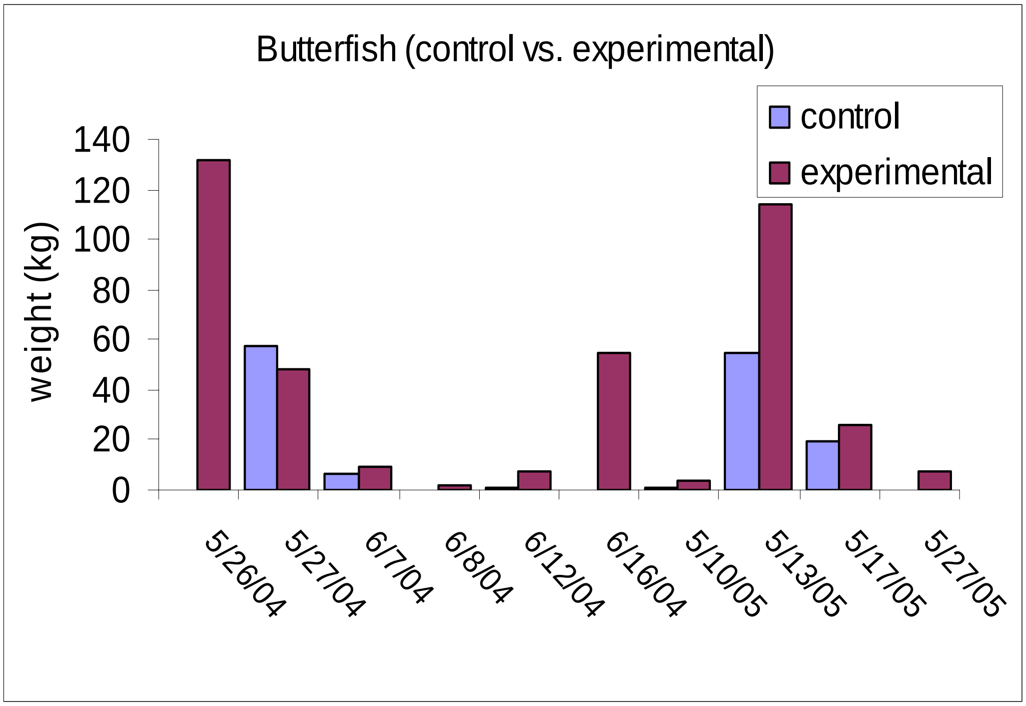


Figure 5. Harvestfish sample weights and length frequencies



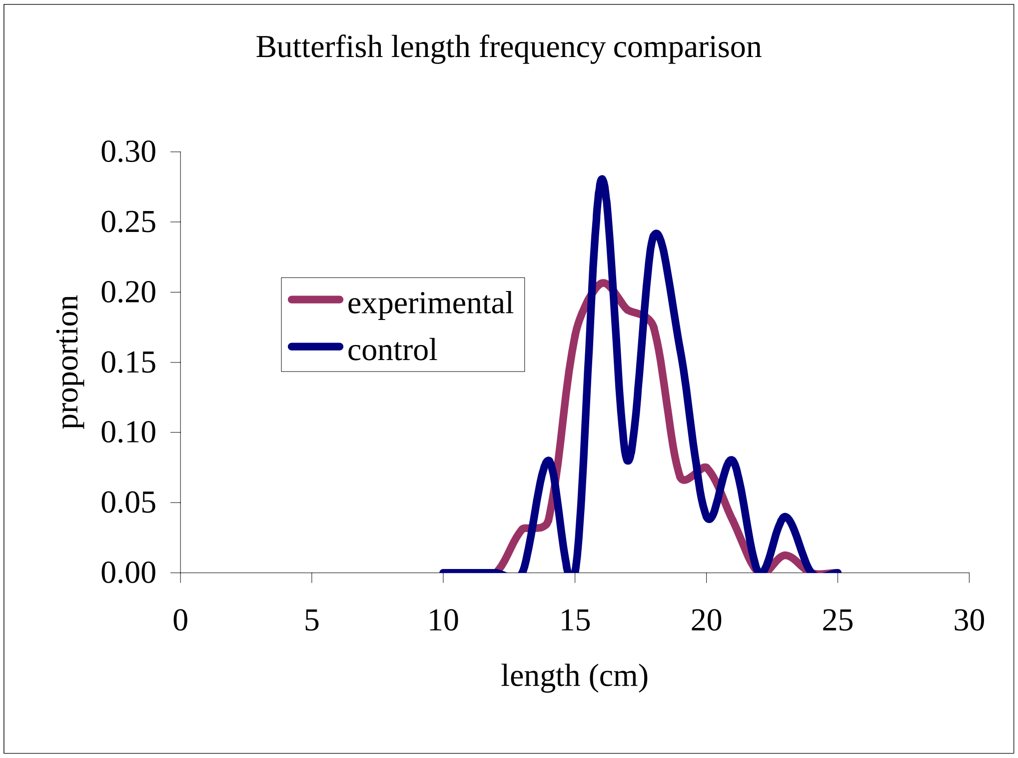
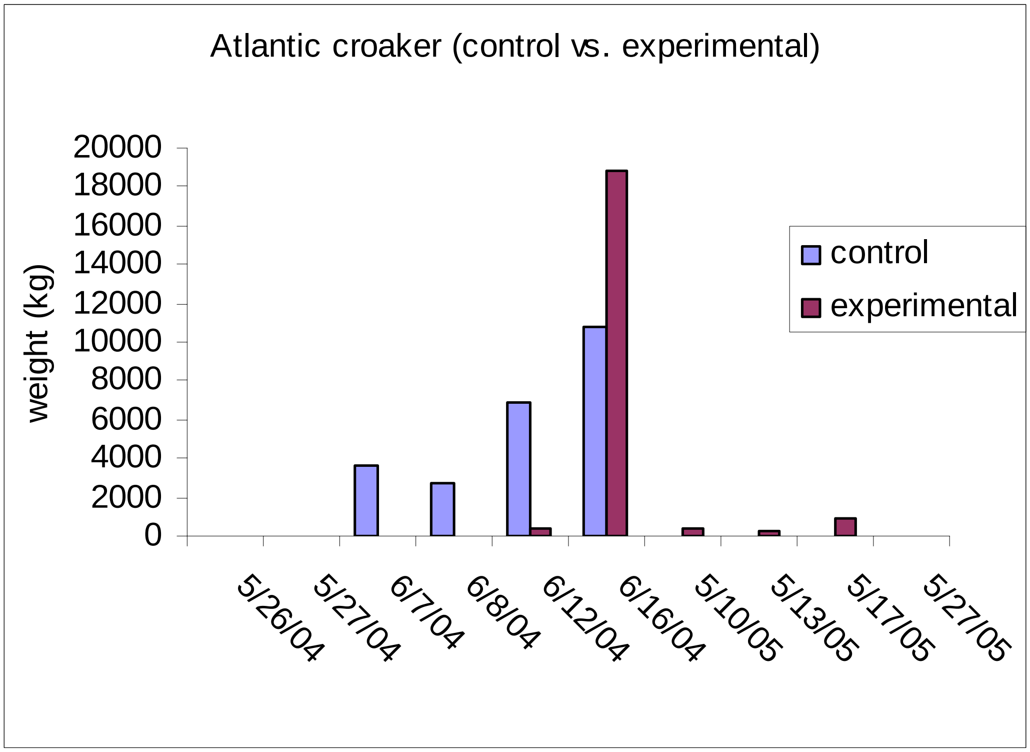


Figure 6. Butterfish sample weights and length frequencies



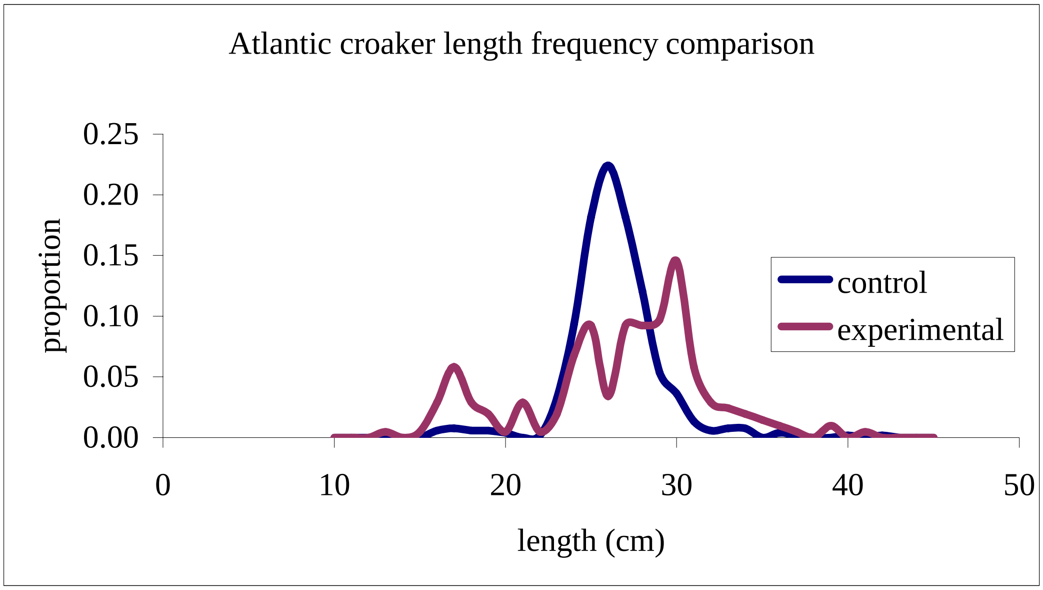
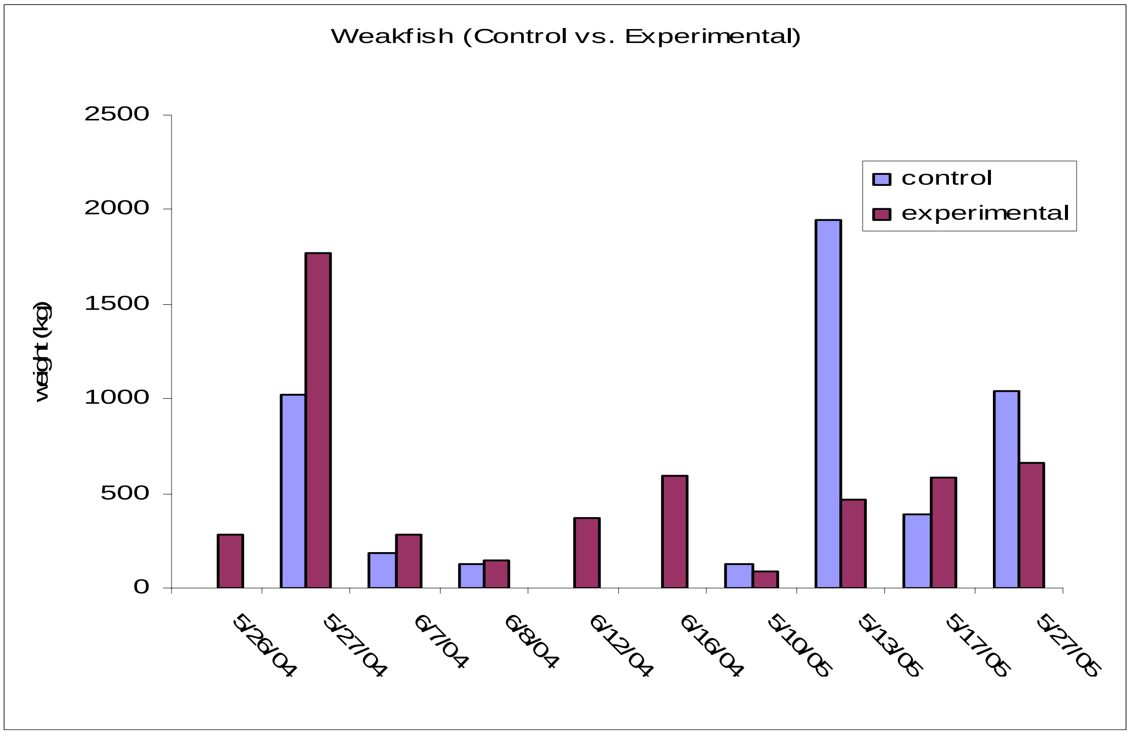


Figure 7. Atlantic croaker sample weights and length frequencies



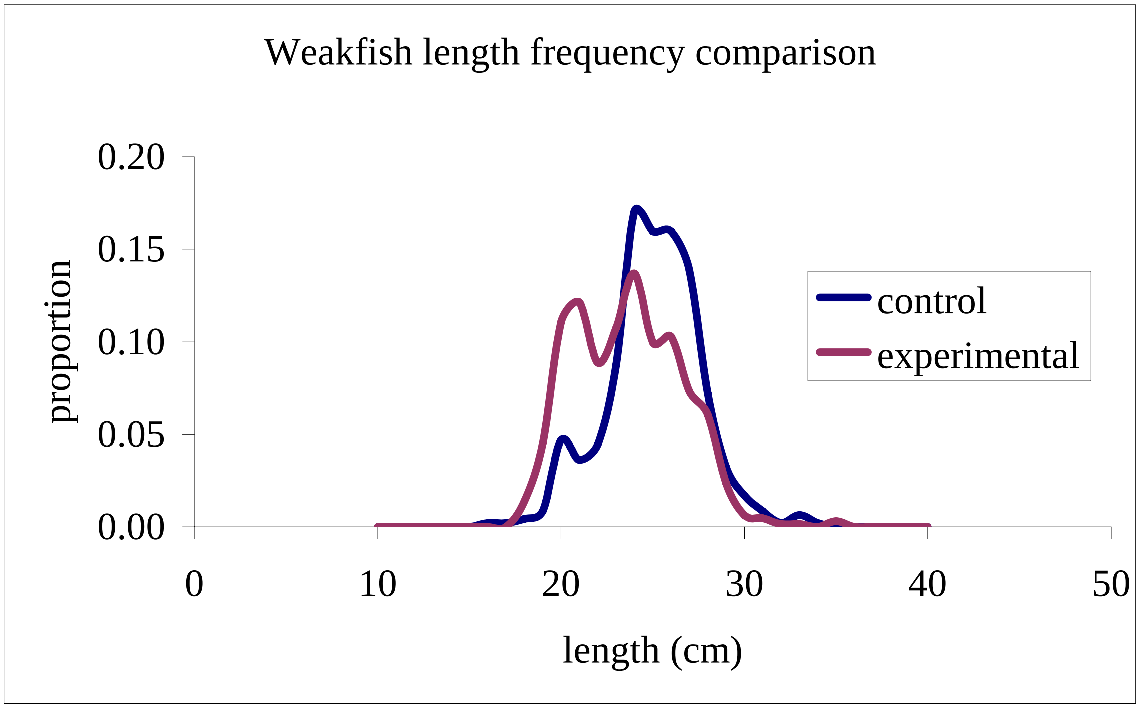


Figure 8. Weakfish sample weights and length frequencies