INTERSTATE FISHERIES MANAGEMENT PROGRAM IMPLEMENTATION FOR NORTH CAROLINA

By

Kevin Brown and Blake Price

Completion Report
for
NOAA Award No.
NA 04 NMF 4740180
Segment 1

Study II

DOCUMENTATION AND REDUCTION OF BYCATCH IN NORTH CAROLINA FISHERIES

Evaluation of Low Profile Flounder Gillnet in Southeastern Pamlico Sound, NC

Conducted Under Section 10 Permit # 1446 (ESA 1973)

May 2005

Abstract

Since 1999, Pamlico Sound has been closed to large mesh gillnet fishing due to an increased number of observed sea turtle strandings and known mortality from deep water gillnet interactions. A shallow water fishery continues to operate in the fall (September – December) under authorization of a Section 10 Incidental Take Permit (Endangered Species Act 1973). The closure of the Pamlico Sound deep water region has caused severe economic hardship to the commercial fishing industry and small coastal communities along the Outer Banks and mainland side of Pamlico Sound. Further, the gillnet closure has created many user conflicts as fishermen move to different areas and fisheries. This may be having a negative impact on other federally managed finfish species. The identification of a commercial gillnet that significantly reduces or eliminates the potential for sea turtle interactions would potentially allow this economically valuable fishery to be utilized in the future. A previous study, conducted in 2002 ascertained the potential use for a modified, low profile gillnet. This experimental net proved to have the potential for a gear that would reduce sea turtle interactions, while maintaining target species catches. In this follow up study, operating under Section 10 #1446 (ESA 1973), the low profile gillnet was compared to a traditionally fished gillnet in the deep water fishing grounds of Pamlico Sound, NC. The objectives of this study were to assess the sea turtle interactions, and compare catch rates of southern flounder (*Paralichthys lethostigma*) by net type. Results indicate the flounder catches from the low profile net represented approximately 75% of the catches from the standard net. There were six sea turtle interactions through the course of this study all occurring in the standard net. There were no significant differences in species composition between the two net types. Environmental and water quality parameters were assessed to determine any relationships affecting catch. However, little variation was observed between trips to depict any discernible trends. Recommendations included expanding this study to multiple fishermen in Pamlico Sound, and allowing the commercial use of this low profile gillnet in the fall southern flounder deep water fishery.

Table of Contents

List of Tables

List of Figures

Background

The commercial gillnet fisheries operating in Pamlico Sound, NC, have had management measures imposed that restrict areas, seasons, and allowable sea turtle interactions since 2001. This area is now referred to as the Pamlico Sound Gillnet Restricted Area (PSGNRA) (Figure 1). The PSGNRA was established based upon increased sea turtle strandings in 1999 in the southeastern portion of Pamlico Sound. Investigation of the fisheries operating in the area at the time, identified the large mesh ($\geq$ 5 inch stretched) southern flounder (*Paralichthys lethostigma*) gillnet fishery and the small mesh (< 5 inch stretched mesh) spotted sea trout (*Cynoscion nebulosus*) gillnet fisheries as a likely source of sea turtle takes (Price 2004, Gearhart 2003).

Observations of gillnet fisheries indicated a shallow water large mesh fishery along the Outer Banks, a deep water large mesh fishery further from shore, and a shallow water small mesh gillnet fishery operating throughout Pamlico Sound. The large mesh fisheries both targeted southern flounder from September to December. The shallow water large mesh fishery operates in depths ranging from 6 to 11 feet in areas next to the barrier islands and the deep water fishery operated in depths ranging from 10 to 20 feet. The small mesh gillnet fisheries are composed of the runaround and set net fisheries. Target species in these fisheries generally include spotted sea trout, weakfish (*Cynoscion regalis*), and bluefish (*Pomatomus saltatrix*).

Initial monitoring of these fisheries in 1999 identified the large mesh gillnet fishery as a source of sea turtle interactions in Pamlico Sound during the months of September through December. With this information, the National Marine Fisheries Service (NMFS) issued an emergency rule closing this area to large mesh gillnet fishing operations to protect endangered and threatened sea turtles.

To maintain this economically vital flounder fishery, the North Carolina Division of Marine Fisheries (NCDMF) applied for and received an Incidental Take Permit (ITP) under Section 10 of the Endangered Species Act (ESA) in 2000. The ITP contained a comprehensive conservation plan designed to reduce sea turtle interactions by establishing restricted areas and intensive monitoring, while allowing fisheries to operate. Observations under the 2000 ITP identified the deep water region of Pamlico Sound as the primary source for sea turtle interactions. Considering this, NMFS established a permanent rule for the 2001 fishing season to close all potential fishing grounds utilized by the deep water large mesh gillnet fisheries. In 2001, NCDMF again consulted with NMFS and prepared an application for and received an ITP under Section 10 of the ESA. Restricted areas were established throughout the PSGNRA where fishermen could continue operations as stipulated in the ITP (Gearhart and Price 2003).

From 2001 to the present, NCDMF has been able to successfully manage the large mesh gillnet fisheries in Pamlico Sound from September through December. Observed levels of sea turtle interactions in gillnet fisheries remained below thresholds as established by the ITP in 2001, 2002, 2003, and 2004 (Price 2005, 2004; Gearhart and Price 2003; Gearhart 2003, 2002).

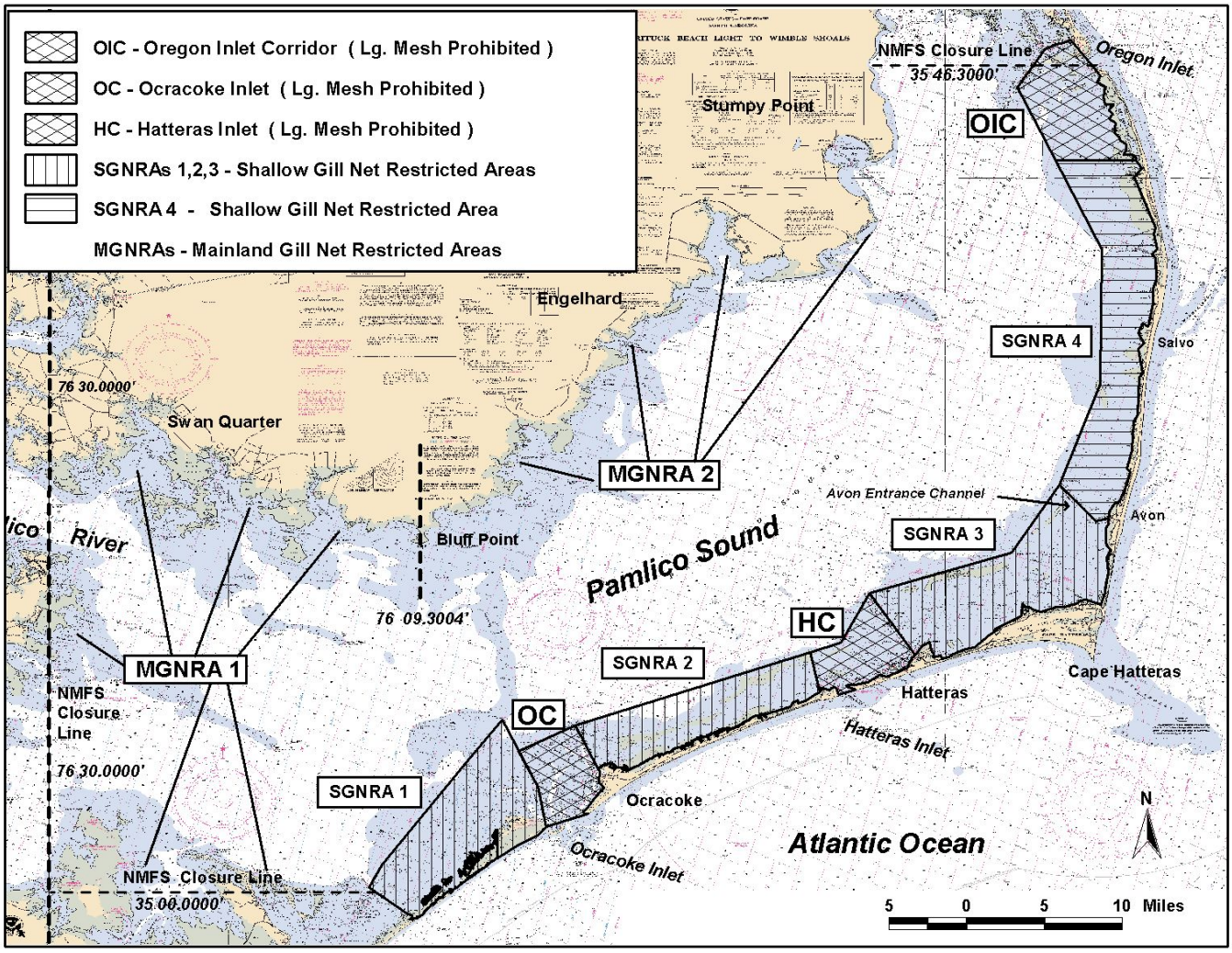

Figure 1. Map of southeastern Pamlico Sound and the 2004 Pamlico Sound Gillnet Restricted Area (PSGNRA).

Fishery Description

The Pamlico Sound large mesh gillnet fishery during the 2000 fishing season consisted of two major components that target southern flounder: a traditional shallow water fishery along the Outer Banks and a deep water fishery along a slope adjoining the main basin of Pamlico Sound. Historically, pound nets had landed the majority of North Carolina's southern flounder. However, the development and expansion of the deep water large mesh gillnet fishery in Pamlico Sound during the 1990s helped gillnets surpass pound nets as the dominant fishing gear for southern flounder.

The deep water fishery occurs from September through December with fishermen setting nets along a slope adjacent to the main basin of Pamlico Sound. Fishing depths range from 10 to 20 ft. Ocean sink gillnet boats ranging from 25 to 45 ft in length, with two-man crews were the typical vessel. Each fishing operation set between 2,000 and 3,000 yards of large mesh (5.5 to 6.5 in stretched mesh) gillnet, which were soaked for up to three days and retrieved with the aid of net reels. Sets were composed of 200 to 600 yd lengths of gillnet with most constructed of 0.5 mm twine. Net depths ranged from 8 to 12 ft with 2 to 4 ft tie downs attached to the float and lead lines at 50 ft intervals along the net. Tie downs were used in this fishery to produce a bag or pocket of webbing, which increased catch

efficiency of bottom dwelling flounder. During the 2000 fishing season there were 25 active operations in this fishery. Most trips originated from Engelhard, Swan Quarter, and Hatteras (Gearhart and Price 2003). Results of sea turtle bycatch monitoring during the 2000 fall fishing season identified the Pamlico Sound deep water flounder gillnet fishery as the fishery with most of the interactions. This fishery incorporated tie downs into their gear configuration.

Previous Gear Testing

The closure of the deep water fishery adversely affected small coastal communities along the mainland and Outer Banks side of Pamlico Sound. This prompted NCDMF to begin the process of developing a commercial large mesh gillnet configuration that would maintain acceptable levels of flounder catches, while significantly reducing or eliminating the incidental capture of sea turtles. The implication of the large mesh, tie down gillnet deep water fishery prompted NCDMF and NMFS to conduct a pilot study designed to determine the effect of tie down length on sea turtle entanglement rates. Results of the study indicated that the entanglement rate was inversely proportional to tie down length with entanglements increasing as tie down length decreased. This result was attributed to the increasing depth of the webbing pocket produced by decreasing tie down lengths. The turtle escapement rate, for turtles that entangled, decreased with the length of tie down (Gearhart and Price 2003).

Following the pilot study in 2001, two modified experimental flounder gillnet designs were evaluated (Gearhart and Price 2003). The first experimental gillnet was a low profile net with a panel height of six feet, which is half the height of a standard flounder gillnet. The second experimental net was a double leadline configuration with the float line of the net replaced by a second leadline. A standard deep water flounder gillnet with a panel height of approximately 12 feet with 3-foot tie downs placed at regular intervals throughout the net served as the control for this experimental gear testing. Thirty fishing trips were conducted between October and December 2001 aboard a commercial sink gillnet vessel on traditional deep water flounder gillnet fishing grounds in southeastern Pamlico Sound. Results of this study indicated that the low profile gillnet design has the potential to be a viable deep water fishing gear. There were no interactions with sea turtles in this gear, and while flounder catches were reduced compared to the traditional gillnet configuration, they were maintained at levels meriting further examination (Gearhart and Price 2003).

Objectives

In 2004, a follow up study was conducted to further examine the low profile gillnet configuration with the following objectives:

- Compare sea turtle catch per unit effort (CPUE) between the standard and experimental nets.
- Compare flounder CPUE between the standard and experimental nets.
- Compare non-targeted finfish species CPUE between the standard and experimental nets.
- Compare length frequency distributions of flounder and non-targeted finfish species among standard and experimental nets.

Methods

Thirty fishing trips were conducted between 22 September and 10 November 2004 to compare the target catch and bycatch in an experimental low profile gillnet with those in a traditional flounder gillnet. A commercial sink gillnet vessel was chartered to set and retrieve nets, which were soaked overnight and retrieved daily on traditional deep water, flounder gillnet fishing grounds in southeastern Pamlico Sound.

A traditionally set standard deep water flounder gillnet with a panel height of approximately 12 feet with three foot tie downs placed at regular intervals throughout the net was used for the control. The experimental gillnet was a low profile net with a panel height of six feet, which was half the height of the control net. No tie downs or additional floats were used in the low profile net (Table 1). All other characteristics were identical in both the standard and experimental nets.

Table 1. Net characteristics of the standard and experimental (low profile) gillnets evaluated in southeastern Pamlico Sound during the 2004 flounder gillnet season from 22 September-10 November 2004.

Net Characteristics	Standard	Low Profile
Webbing		
Mesh size (in)	6	6
Material	Monofilament	Monofilament
Twine diameter (mm)	0.57	0.57
Mesh depth	25	12
Floatline	5/16 in. poly with one gillnet float per fathom	5/16 in. poly with no additional floatation
Leadline	65 lb/100 fathom	65 lb/100 fathom
Tie Down	3 feet/5 fathom	none
Net Length (yards)	300	300

Net Sets

On each fishing trip, four matched pairs of nets were retrieved for a total of 2,400 yards per trip comprised of 1,200 yards of standard and 1,200 yards of test net. Nets were set so that each 600 yard shot contained a 300 yard length of both the standard and test nets (Figure 2). Nets were set in relatively shallower (inshore; IN1 and IN2 below) waters and in deeper (offshore; OUT1 and OUT2 below) waters to discern any depth or water quality related trends (Figure 2). For example, the IN1 net set contained a total of 600 yards comprised of 300 yards of standard and 300 yards of low profile net. The orientation of the net type relative to depth was also alternated each day to eliminate the confounding effects of net type versus depth (Figure 2).

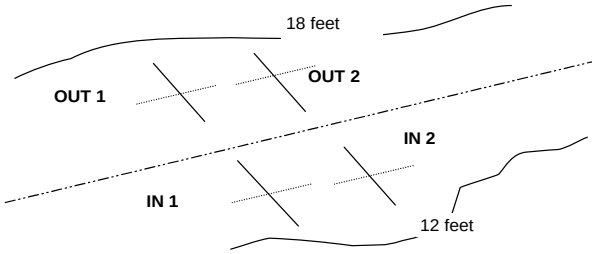

Figure 2. Diagram of the experimental set configuration for the standard and experimental nets during the 2004 (September-December) experimental gear testing conducted in the deep water of Pamlico Sound NC.

Data Collections

An NCDMF observer was present during each retrieval of the nets. Information obtained included date, location, depth, catch, bycatch and effort data for each net type within each haul. Specifically, the observer attempted to count, measure and weigh all species at the net level. Water quality parameters were also collected and included: dissolved oxygen (mg/L), temperature (°C), and salinity (ppt). These data were coded, verified, and entered into the NCDMF mainframe biological database.

Power Analysis

In 2002, NCDMF contracted a statistician, Dr. Don Holbert (East Carolina University) to assist in designing this study. Specifically, NCDMF was interested in obtaining an estimate for the number of matched pairs and turtle interactions that would be necessary to achieve statistical significance. The null hypothesis for this experiment says that there is an equal probability of observing the same catches in either net type. A power analysis was conducted to determine the approximate number of matched pairs that would be required to detect an 80% reduction in turtle catch with a test of significance (Figure 3, Table 2). This analysis determined that 120 matched pair sets would provide 80% power to detect an effect of this size (Holbert 2002).

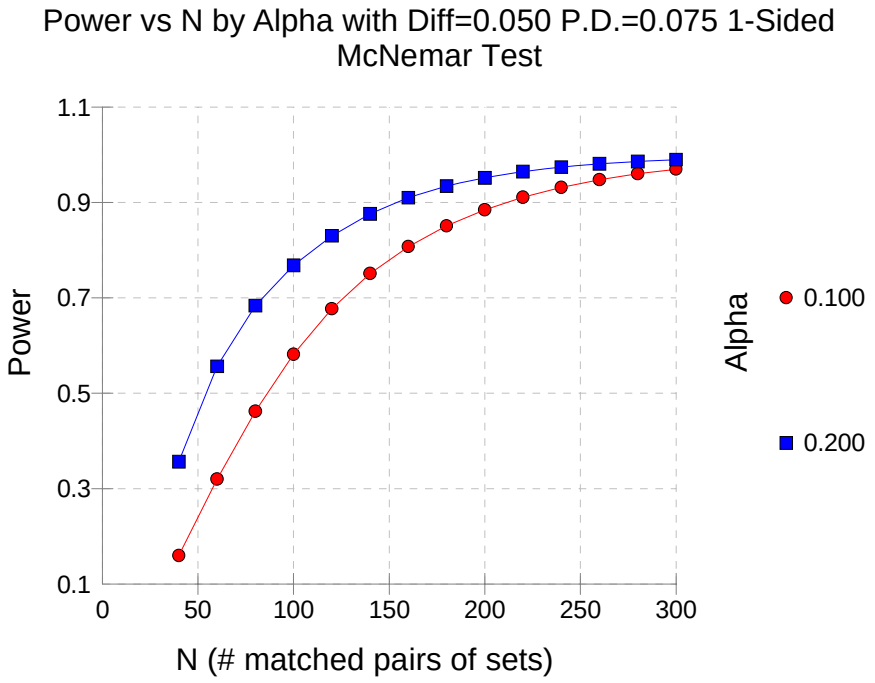

Figure 3. The power for various numbers of matched pairs for significance tests conducted at α=0.1 or α=0.2. Provided by Dr. Don Holbert (East Carolina University).

Table 2. Sample size (N) necessary to achieve 80% power to detect specified reduction in sea turtle interactions. Provided by Dr. Holbert (East Carolina University).

pd (proportion of discordant pairs) and α	20% reduction p_{12}-p_{21}=0.0125	40% reduction p_{12}-p_{21}=0.025	60% reduction p_{12}-p_{21}=0.0375	80% reduction p_{12}-p_{21}=0.05
pd=.025,α=0.1	N > 825	N ~ 340	******	******
pd=.025,α=0.2	N ~ 575	N ~ 240	******	******
pd=.05,α=0.1	N > 1000	N ~ 410	N ~ 190	N ~ 140
pd=.05,α=0.2	N ~ 1000	N ~ 300	N ~ 140	N ~ 100
pd=.075,α=0.1	N > 1000	N ~ 600	N ~ 275	N ~ 160
pd=.075,α=0.2	N > 1000	N ~ 400	N ~ 190	N ~ 120

In order to determine the number of interactions required for statistical significance in this study, the best estimate of the rate of interactions (3/48 or 0.0625) obtained from the previous gear testing study was utilized. An 80% reduction in this would correspond to a rate of 0.0125 (about 1% of the experimental net sets catching a turtle) (Holbert 2002).

With these data, and in further consultation with NMFS, a Section 10 Permit (#1446) (ESA 1973) was granted to NCDMF allowing a total of 21 sea turtle interactions comprised of Kemp's ridley (*Lepidochelys kempii*), loggerhead (*Caretta caretta*), or green sea turtles (*Chelonia mydas*). Of these, nine were authorized lethal takes. Additionally, two live and one lethal sea turtle takes of hawksbill (*Eretmochelys imbricata*) and/or leatherback (*Dermochelys coriacea*) sea turtles were allowed under this permit. If these thresholds were exceeded, the experiment would be terminated.

Results

Catches

For analyses, catch was divided into three strata: target (flounder), bycatch (all finfish except flounder), and turtles. The standard nets caught an average 10.7 kg of flounder per set, while the low profile net caught an average of 8.1 kg of flounder per set. Thus the test net caught approximately 75% of the flounder compared to the standard net flounder catches (Figure 4). There was a similar trend observed with the bycatch in the standard and test nets where the test net bycatch represented about 82% of the standard net bycatch (Figure 4).

Analyses of variance were conducted for the total weight of the target catches and bycatch. Variables included in the model were date, location (inshore matched pair, offshore matched pair), net type, location within the set (inshore, offshore), as well as interactions among the variables (Holbert 2005). Net type was found to have a significant effect on the catches of target ($p < 0.001$) and bycatch ($p = 0.021$) species. Date was also found to be significant in target ($p < 0.001$) and bycatch ($p < 0.001$). There was a slight increase in the total weight captured towards the latter part of the fishing season (Figure 5).

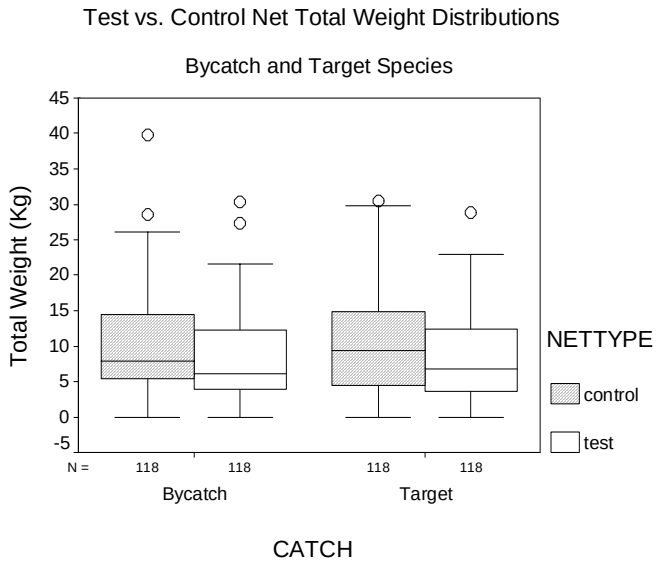

Figure 4. Bycatch and target (flounder) catches by weight (kg) for a standard deep water flounder gillnet with tie downs (control) and a low profile gillnet without tie downs (test) during the 2004 (September-December) experimental gillnet testing conducted in the deep water of Pamlico Sound.

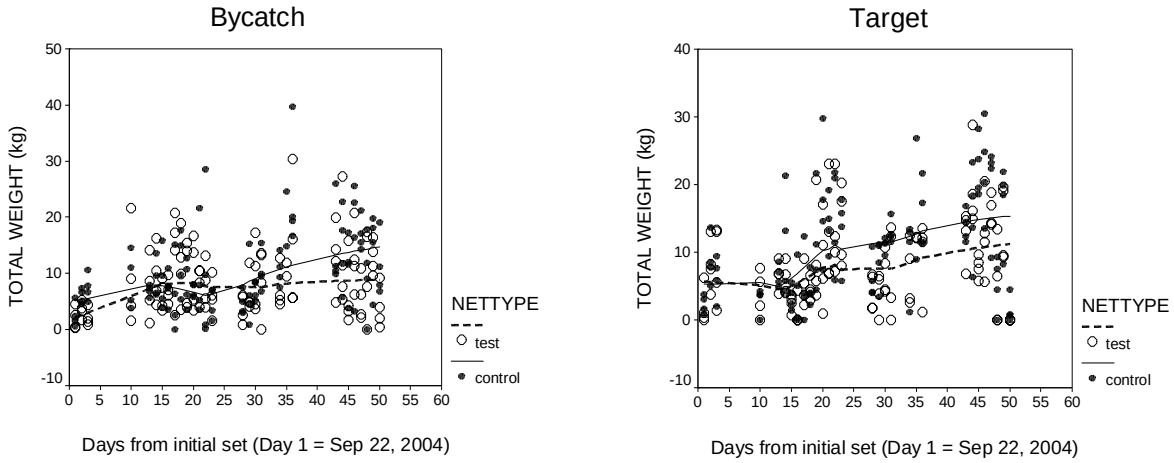

Figure 5. Total weight of bycatch and target by day, where day represents the days from the initial set during the 2004 (September-December) experimental gillnet testing conducted in the deep water of Pamlico Sound.

Catch Per Unit Effort (CPUE)

The CPUE was calculated for the standard and test nets for flounder catches and bycatch (Table 3). The catch per unit effort was defined as: total catch (weight (kg) or number) / (yards fished * soakdays). The CPUE's were calculated per 100 yards of gillnet set. Flounder CPUE in both weight and number were higher in the standard net (Table 3). The flounder catches in the test net represented 75% of the catch of the standard net. However, the flounder catches in the test net were relatively high with approximately three pounds of flounder observed for every 100 yards of gillnet set (Table 3). In

contrast, there was slightly more bycatch observed by weight in the test net. By number, the CPUE was higher in the standard net (Table 3).

Table 3. Catch per unit effort (CPUE) by weight and number for target species (flounder) and bycatch per 100 yards/soakday, during the 2004 (September-December) experimental gillnet testing conducted in the deep water of Pamlico Sound.

Catch	Net Type	CPUE (weight)	CPUE (number)
Flounder			
	Control	4.02	4.59
	Test	2.98	3.31
Bycatch			
	Control	1.28	8.48
	Test	1.37	6.86

Species Composition

The predominant species observed in the standard net was flounder, which represented greater than 75% of the total weight (Table 4). Significant numbers of weakfish, kingfish (*Menticirrhus* spp.) and bluefish were observed. There was also an increased number (n = 1,139) of Atlantic menhaden (*Brevortia tyrannus*) observed in the standard net. A relatively high number of horseshoe crabs (*Limulus polyphemus*) and rays (*Rajiformes*) were counted from the standard net. There were six sea turtles observed in the standard net comprised of five Kemp's ridleys and one loggerhead (Table 4). The six sea turtle interactions included four mortalities, all comprised of Kemp's ridley sea turtles.

Similar catch composition was observed from the low profile (test) gillnet (Table 5). In the test nets, flounder predominated the catches and represented more than 68% of the total weight. Dominant species by number were comparable to those observed in the standard nets (Table 4, 5). There were no sea turtle interactions in the low profile (test) nets (Table 5).

There were more than 4,200 individuals from at least 30 species observed in the standard net, while nearly 3,300 individuals from at least 26 species were observed in the test nets (Table 4, 5). This trend was observed for all target catches, most bycatch and all turtle catches. In general, species composition between the standard and experimental nets was similar with the standard net catching more individuals and a few more species (Table 4, 5).

Table 4. Relative biomass (kg) and number of individuals collected by a standard flounder gillnet with tie downs (control) for 30 trips, during the 2004 (September-December) experimental gillnet testing conducted in the deep water of Pamlico Sound.

Scientific Name	Common Name	Total Number	% Number	Total Weight	% Biomass
Paralichthys lethostigma	southern flounder	1,462	34.71	1,284.70	75.28
Archosargus probatocephalus	sheepshead	43	1.02	77.10	4.52
Cynoscion regalis	weakfish	226	5.37	75.45	4.42
Menticirrhus spp.	kingfishes	245	5.82	65.40	3.83
Pomatomus saltatrix	bluefish	145	3.44	61.60	3.61
Pogonias cromis	black drum	28	0.66	59.30	3.48
Brevoortia tyrannus	Atlantic menhaden	1,139	27.04	41.00	2.40
Limulus polyphemus	horseshoe crab	431	10.23	28.00	1.64
Paralichthys dentatus	summer flounder	10	0.24	6.70	0.39
Chaetodipterus faber	Atlantic spadefish	8	0.19	4.10	0.24
Paralichthys albigutta	Gulf flounder	4	0.09	1.60	0.09
Leiostomus xanthurus	spot	3	0.07	1.20	0.07
Micropogonias undulatus	Atlantic croaker	1	0.02	0.30	0.02
Neogastropoda stenoglossa	conchs	11	0.26		
Busycon spp.	whelks	2	0.05		
Squatina dumeril	Atlantic angel shark	1	0.02		
Rajidae	skates	143	3.40		
Raja eglanteria	clearnose skate	4	0.09		
Dasyatidae	stingrays	258	6.13		
Gymnura spp.	butterfly rays	2	0.05		
Rhinoptera bonasus	cownose ray	12	0.28		
Synodus foetens	inshore lizardfish	2	0.05		
Triglidae	searobins	2	0.05		
Lagodon rhomboides	pinfish	5	0.12		
Sciaenops ocellatus	red drum	3	0.07		
Astroscopus spp.	stargazers	4	0.09		
Citharichthys spp.	whiffs	1	0.02		
Caretta caretta	loggerhead sea turtle	1	0.02		
Lepidochelys kempi	Kemp's ridley sea turtle	5	0.12		
Phalacrocorax auritus	double-crested cormorant	11	0.26		
Totals		**4,212**	**100.00**	**1,706.45**	**100.00**

Table 5. Relative biomass (kg) and number of individuals collected by a modified low profile flounder gillnet (test) without tie downs for 30 trips, during the 2004 (September-December) experimental gillnet testing conducted in the deep water of Pamlico Sound.

Scientific Name	Common Name	Total Number	% Number	Total Weight	% Biomass
Paralichthys lethostigma	southern flounder	1,063	32.4	955.8	68.2
Archosargus probatocephalus	sheepshead	36	1.1	86.8	6.2
Menticirrhus spp.	kingfishes	229	7.0	72.7	5.2
Pogonias cromis	black drum	34	1.0	72.1	5.1
Pomatomus saltatrix	bluefish	125	3.8	54.3	3.9
Cynoscion regalis	weakfish	145	4.4	51.0	3.6
Limulus polyphemus	horseshoe crab	284	8.7	46.7	3.3
Sciaenops ocellatus	red drum	3	0.1	34.3	2.5
Brevoortia tyrannus	Atlantic menhaden	951	29.0	20.0	1.4
Paralichthys dentatus	summer flounder	5	0.2	3.5	0.3
Chaetodipterus faber	Atlantic spadefish	10	0.3	2.0	0.1
Leiostomus xanthurus	spot	7	0.2	1.8	0.1
Scomberomorus maculatus	Spanish mackerel	1	0.0	1.4	0.1
Micropogonias undulatus	Atlantic croaker	1	0.0	0.1	0.0
Neogastropoda stenoglossa	conchs	5	0.2		
Busycon spp.	whelks	4	0.1		
Mustelus spp.	sharks	1	0.0		
Rajidae	skates	151	4.6		
Raja eglanteria	clearnose skate	1	0.0		
Dasyatidae	stingrays	200	6.1		
Rhinoptera bonasus	cownose ray	3	0.1		
Synodus foetens	inshore lizardfish	4	0.1		
Orthopristis chrysoptera	pigfish	2	0.1		
Lagodon rhomboides	pinfish	7	0.2		
Astroscopus spp.	stargazers	5	0.2		
Phalacrocorax auritus	double-crested cormorant	2	0.1		
Totals		**3,279**	**100.0**	**1,402.4**	**100.0**

Discards

Species disposition was recorded by: fish kept, unmarketable discards, and regulatory discards. In the standard net, Atlantic menhaden, stingrays, and horseshoe crabs dominated unmarketable discards (Table 6). There were only ten unmarketable flounder from the standard nets. Regulatory discards from the standard net consisted of flounder, weakfish, red drum (*Sciaenops ocellatus)*, cormorants (*Phalacrocorax auritus)*, and loggerhead and Kemp's ridley sea turtles. There was a total of 53 flounder regulatory discards form the standard nets (Table 6).

Unmarketable and regulatory discards observed in the test nets depict similar trends and species composition except there were no sea turtle takes (Table 7). The standard net caught considerably more undersized flounder (regulatory discards) than the low profile net (n=53 standard, n=16 low profile) (Table 6, 7). Reduced discards were observed for target species and bycatch in the low profile (test) nets.

Table 6. Tabulation of total catch and discards by number and species status (kept, unmarketable, regulatory discards) in the standard net in southeastern Pamlico Sound NC, 2004 (September-December).

Species	Fish Kept	Unmarketable	Regulatory Discard	Total
flounders	1,413	10	53	1,476
Atlantic menhaden	0	1,139	0	1,139
horseshoe crab	261	170	0	431
stingrays	0	258	0	258
kingfishes	158	87	0	245
weakfish	115	52	59	226
bluefish	51	94	0	145
rays	0	143	0	143
sheepshead	27	16	0	43
black drum	18	10	0	28
cownose ray	0	12	0	12
conchs	3	8	0	11
double-crested cormorant	0	0	11	11
Atlantic spadefish	3	5	0	8
pinfish	0	5	0	5
Kemp's ridley sea turtle	0	0	5	5
clearnose skate	2	2	0	4
stargazers	0	4	0	4
spot	3	0	0	3
red drum	0	2	1	3
whelks	0	2	0	2
butterfly rays	0	2	0	2
inshore lizardfish	0	2	0	2
searobins	0	2	0	2
Atlantic angel shark	0	1	0	1
Atlantic croaker	1	0	0	1
whiffs	0	1	0	1
loggerhead sea turtle	0	0	1	1
Totals	**2,055**	**2,027**	**130**	**4,212**

Table 7. Tabulation of total catch and discards by number and species status (kept, unmarketable, regulatory discards) in the test net in southeastern Pamlico Sound NC, 2004 (September-December).

Species	Fish Kept	Unmarketable	Regulatory Discard	Total
flounders	1,030	22	16	1,068
Atlantic menhaden	0	951	0	951
horseshoe crab	174	110	0	284
kingfishes	159	70	0	229
stingrays	0	200	0	200
rays	0	151	0	151
weakfish	85	26	34	145
bluefish	37	88	0	125
sheepshead	27	9	0	36
black drum	19	15	0	34
Atlantic spadefish	2	8	0	10
pinfish	0	7	0	7
spot	5	2	0	7
conchs	1	4	0	5
stargazers	0	5	0	5
whelks	0	4	0	4
inshore lizardfish	0	4	0	4
cownose ray	0	3	0	3
red drum	0	0	3	3
pigfish	0	2	0	2
double-crested cormorant	0	0	2	2
sharks	0	1	0	1
clearnose skate	0	1	0	1
Atlantic croaker	0	1	0	1
Spanish mackerel	1	0	0	1
Totals	**1,540**	**1,684**	**55**	**3,279**

Length Frequencies

There was no significant difference in the length frequencies of flounder in the standard and test nets (Figure 6). Total lengths of flounder in the standard net ranged from 48 mm to 562 mm with an average of 403 mm. Similarly, flounder in the test net ranged from 215 mm to 605 mm with an average of 406.1 mm. No discernible differences in the length frequencies of flounder in the standard and test net were observed.

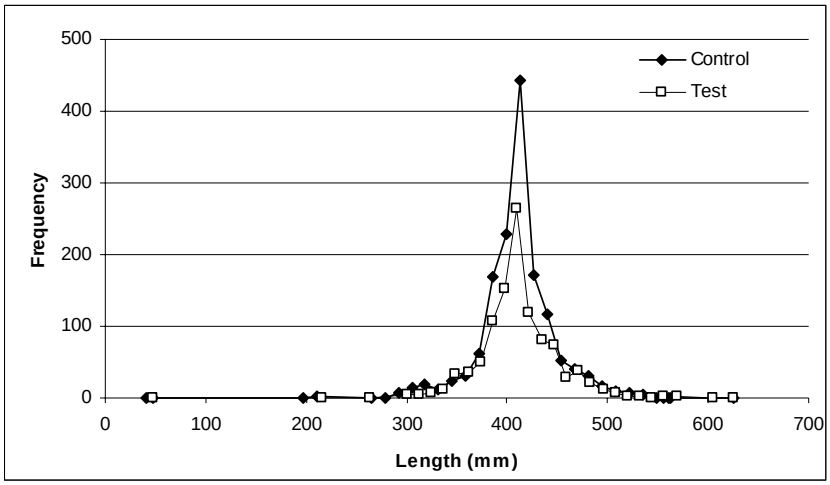

Figure 6. Length frequencies of flounder in the standard and experimental nets during the deep water experimental gear testing in Pamlico Sound NC, 2004 (September-December).

Water Quality

The water quality parameters of temperature, dissolved oxygen, and salinity were recorded to ascertain potential relationships between catch, bycatch, and environmental variations. Depth was also recorded for each net set. There was little variation among these data throughout the study (Figure 7). The mean dissolved oxygen content and salinity ranged from 7 mg/L– 8.8 mg/L, and 17 ppt – 19 ppt, respectively. Similarly, nets were deployed in depths ranging from approximately 4.5 m to 5. 2 m (Figure 7). Slight increases in target catches and bycatch were observed in cooler, deeper, more saline waters towards the end of the study (Figure 7).

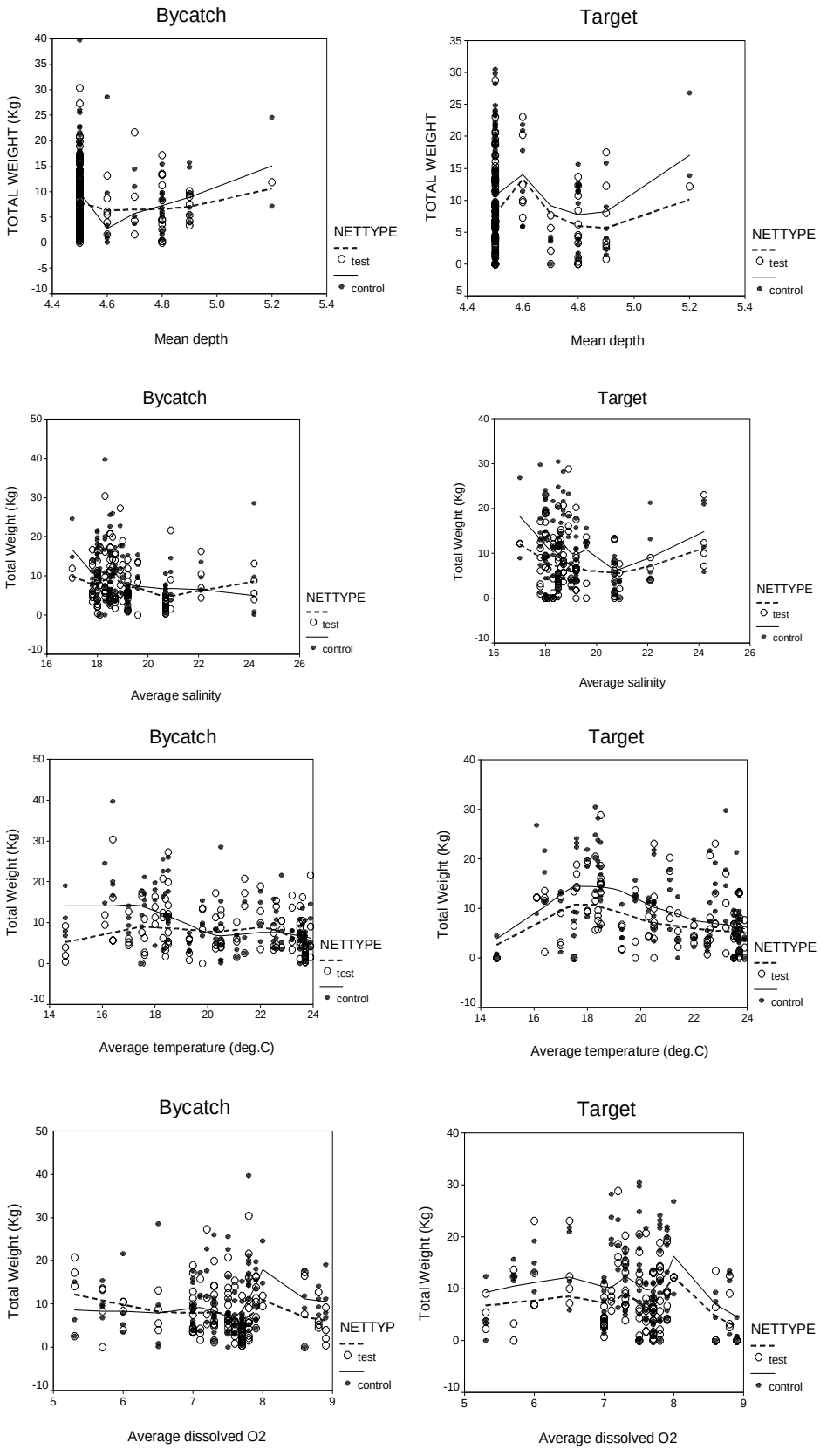

Figure 7. Total weight (kg) of bycatch and target species by depth (m), salinity (ppt), temperature (^{0}C), and dissolved oxygen (mg/L) during the deep water experimental gear testing in Pamlico Sound, 2004 (September-December).

Turtle Bycatch

There was one loggerhead and five Kemp's ridley sea turtle interactions during the study. The loggerhead and one of the Kemp's were released alive in good condition. The other four Kemp's ridleys were mortalities (Table 8). All six of the interactions were observed in the standard nets. The majority (83%) of the interactions occurred on net sets located northwest of Hatteras Inlet in approximately 15 feet of water (Figure 8). There was one Kemp's ridley observed further south behind Ocracoke Island in approximately 16 feet of water (Figure 8).

Table 8. Sea turtle interactions observed by net type, date, species, and disposition during the 2004 (September-December) experimental gear testing conducted in the deep water of Pamlico Sound.

Date	Net Type	Species	Carapace Length (cm)	Condition
10/6/2004	Control	Kemp's ridley	52.0	Dead
10/13/2004	Control	Kemp's ridley	49.5	Dead
10/19/2004	Control	Kemp's ridley	55.9	Alive
10/21/2004	Control	Kemp's ridley	27.0	Dead
10/22/2004	Control	Kemp's ridley	52.0	Dead
11/9/2004	Control	Loggerhead	66.0	Alive

Hypothesis Test to Compare Interactions in Test and Standard Nets

A follow up analysis was conducted to ascertain the statistical significance of turtle interactions by net type, either standard or experimental (Holbert 2005). From the 120 matched pairs of gillnet sets, there were no turtle interactions in 114 of these. In the remaining six matched pairs, there were turtle interactions in the standard net, but not the experimental net (Table 9).

Table 9. Sea turtle interactions matrix by net type depicting the total number of matched pairs during the 2004 (September-December) experimental gear testing conducted in the deep water of Pamlico Sound.

		Experimental Net Takes	
		Yes	**No**
Control Net Takes	**Yes**	0	6
	No	0	114
Total Matched Pairs			**120**

The null hypothesis for this experiment states either net type (standard or experimental) has an equal probability of capturing sea turtles, and the McNemar's test was utilized to test this (Holbert 2005, Rao 1998). The research hypothesis from this study is one-sided such that the observation of sea turtle interactions in the standard net is significantly ($p = 0.016$) more likely than interactions in the experimental net. From these data, the observed point estimate (± 95% confidence limits) for the difference "Probability {Turtle Interaction in Test Net} – Probability {Turtle Interaction in Standard Net}" is 0.05 ± 0.04 (Holbert 2005).

Sea Turtle Interactions Impact

Combining the results from previous gear testing conducted in southeastern Pamlico Sound, NC, an estimate of the interaction probability by net types can be estimated. The combined (from previous gear testing and this study) estimated proportion of standard net sets where a turtle interaction occurs is estimated to be 0.054 or 5.4% (Gearhart and Price 2003; Holbert 2002, 2005). This means, for example, for every 1000 standard net sets, there would be about 54 sea turtle interactions. Applying the lower limit of the confidence interval (0.01) suggests that for every 1000 sets of the experimental net, there would be approximately 44 sea turtle interactions, resulting in a reduction of 10 sea turtle takes. However, using the observed point estimate from this study (0.05) as the difference in catch proportions, then every 1000 sets of the experimental net would result in about 4 sea turtle interactions, resulting in a savings of 50 turtles trapped per 1000 sets (Holbert 2005).

Applying a mean effort component to the example above allows an estimated number of takes per unit effort to be calculated. For example, assume that fishermen set 2,000 yards of low profile gillnet, 1,000 times over the course of a season, with each set soaked overnight. Standardizing the net soak time to one day would result in four turtles for every 2 million yards of gillnet effort (yards * soakdays), where 1,000 trips multiplied by 2,000 yards per trip equals 2 million. That calculates to an estimate of 0.0002 turtles per 100 yards of low profile gillnet effort.

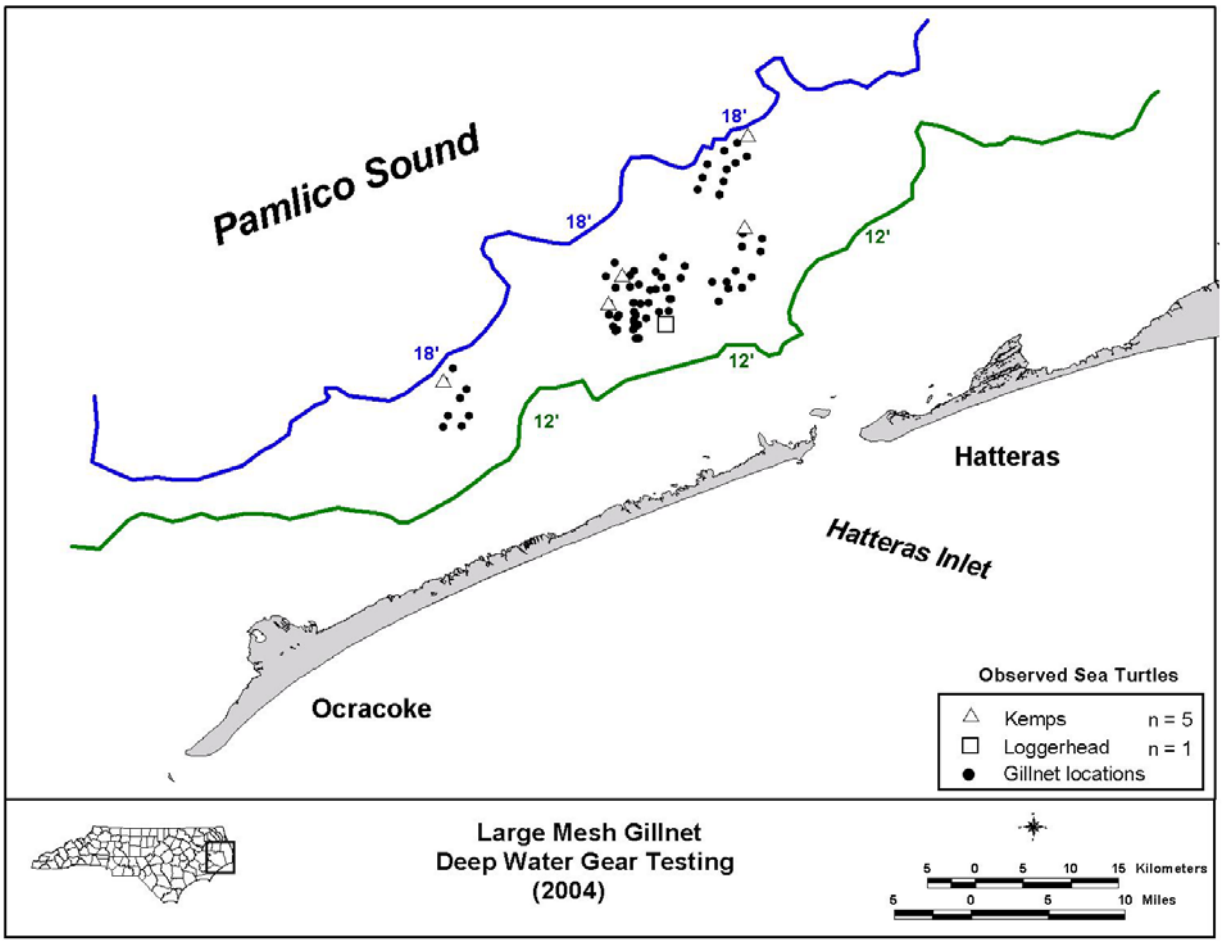

Figure 8. Locations of experimental flounder gillnet sets and sea turtle interactions in southeastern Pamlico Sound NC, 2004 (September-December).

Discussion

The closure of the Pamlico Sound to the fall large mesh gillnet fishery in 1999 has created significant economic hardship to the commercial fishing industry and small coastal communities along the Outer Banks and mainland side of Pamlico Sound. The closure has also created a multitude of user conflicts as fishermen relocate into other fisheries. This effect may be having a significant negative impact on other federally managed finfish species.

The closure of Pamlico Sound in 1999 was established to reduce the number of sea turtle strandings in this area during the fall of every year. The management measures put in place by NCDMF, in consultation with NMFS have been successful in reducing strandings, characterizing the commercial gillnet fishery, and establishing a long-term monitoring program to continually assess protected species and commercial fishing gear interactions. This has allowed NCDMF and NMFS to adaptively manage this region to minimize sea turtle interactions, while allowing an economically valuable fishery to operate. However, the historically highly productive deep water fishing grounds remain closed. The identification of a modified commercial gillnet that could significantly reduce or eliminate the potential for sea turtle interactions in deep water may allow these viable fishing grounds to

be utilized by the commercial industry in the future. This would assist in alleviating the economic burden the small coastal communities and commercial industry have experienced in the last five years. It may also contribute to decreased user conflicts and ultimate increases in other federally managed finfish stocks.

The current and previous gear testing studies show great promise for the use of a low profile, large mesh gillnet in the deep water fishing grounds throughout Pamlico Sound. There have been no sea turtle interactions in the low profile gillnets and the flounder catches, while reduced comparably, have been at a level that may be acceptable and worthwhile to the commercial industry. The problem with the historical standard large mesh gillnet deployed in this region was primarily two fold. First, these nets were approximately 12 feet deep fishing a significantly greater portion of the water column and thereby increasing the chance for sea turtle interactions. Secondly, a common technique in fishing these gillnets was to place three or four feet tie downs regularly throughout the net. Tie downs create a pocket of webbing, and while potentially increasing target finfish catches, tie downs simultaneously increase the entanglement rate and subsequent mortality of sea turtles.

The low profile gillnet configuration tested here eliminated these problems. First, the amount of webbing was reduced by 50% creating a panel height of approximately six feet. This means that the net fished directly on the bottom in a relatively small portion of the water column. Secondly, unlike traditionally used gillnets in this region, there was no addition floatation (corks) on the top line. Thus, the actual vertical height of the net from sea floor to floatline was even further reduced. Finally, there were no tie downs in this net, which eliminated the "bag effect," and allowed this gear to fish more vertically in the water column. These factors combined have greatly reduced if not eliminated the potential for sea turtle bycatch in the deep water fishing grounds of Pamlico Sound.

Previous experimental gillnet testing and this study were conducted in the fall months of 2002 and 2004, respectively. Two commercial fishermen have facilitated both of these studies. Therefore, it is the intent of NCMDF to expand this study in 2006 to multiple commercial fishermen in varying locations throughout the deep water regions of Pamlico Sound. Should this final low-profile experimental gillnet testing depict similar results, federal and state fishery managers will have the responsibility to discuss the implementation of the low-profile gillnet into the fall flounder gillnet fishery throughout Pamlico Sound.

Recommendations

Results of this study indicate that the low profile gillnet design has the potential to be a viable deep water fishing gear that significantly reduces sea turtle bycatch, while maintaining an acceptable level of targeted catch. Based on these results, NCDMF recommends the following:

- Conduct further testing on the low profile gillnet design in deep water with the use of multiple commercial fisherman to expand this study design to other commercial fishers in the deep water region.

- Consider reopening of the deep water regions of southeastern Pamlico Sound, should the results from a follow-up study confirm a significant reduction in sea turtle interactions with the low profile gillnet design.

Acknowledgements

The North Carolina Division of Marine Fisheries would like to sincerely thank the following agencies and individuals for assisting in this study:

This research would not have been possible without an incidental take permit under Section 10 of the ESA (1973). There were multiple people involved in this process from the National Marine Fisheries Service Office of Protected Resources (NMFS – OPR). NCDMF would like to thank Carrie Hubbard and Therese Conant (NMFS – OPR) Silver Spring, MD, and Dennis Klemm (NMFS – OPR) St. Petersburg, Fl. for their assistance, consultation, and completion of this permit. The NMFS – OPR has worked with NCDMF on multiple related projects, and we greatly appreciate their willingness to continue collaborative efforts.

Simultaneously, NCDMF would like to thank Dr. Don Holbert, East Carolina University, Department of Biostatistics, for assistance with the study design and follow up analyses from these data. Dr. Holbert is a statistician, who has a great interest in fisheries and has been involved with numerous fisheries research projects applying statistical merit to study design, implementation, and presentation of results.

Finally, this work could not have been conducted without the use of a knowledgeable and experienced commercial fishermen, one such as Mr. Teddy Gibbs, Engelhard, North Carolina. Mr. Gibbs has been commercial fishing throughout Pamlico Sound for more than 20 years, and his practical experience, and knowledge facilitated the success of this project.

Literature Cited

Gearhart J. 2001. Sea turtle bycatch monitoring of the 2000 fall flounder gillnet fishery of southeastern Pamlico Sound, North Carolina. Completion Report for ITP 1259. North Carolina Department of Environment and Natural Resources, Division of Marine Fisheries. 26pp.

Gearhart J. 2002. Sea turtle bycatch monitoring of the 2001 fall flounder gillnet fishery of southeastern Pamlico Sound, North Carolina. Completion Report for ITP 1348. North Carolina Department of Environment and Natural Resources, Division of Marine Fisheries. 44pp.

Gearhart J. 2003. Sea turtle bycatch monitoring of the 2002 fall flounder gillnet fishery of southeastern Pamlico Sound, North Carolina. Completion Report for ITP 1398. North Carolina Department of Environment and Natural Resources, Division of Marine Fisheries. 39pp.

Gearhart J. and B. Price. 2003. Evaluation of modified flounder gillnets in southeastern Pamlico Sound, NC. Completion report for NOAA award no. NA 16FG1220 segment 1. North Carolina Department of Environment and Natural Resources, Division of Marine Fisheries.

Holbert D. 2002. Power analysis considerations relative to proposed study of turtle catch in the deep water flounder fishery in Pamlico Sound (Prepared by Don Holbert, East Carolina University, Summer 2002)

Holbert D. 2005. Follow-up and results of the study that was conducted based on the Planning and Power Analysis (Holbert 2002). Prepared by Dr. Don Holbert, East Carolina University, February 2005.

Price B. 2004. Sea turtle bycatch monitoring of the 2003 fall flounder gillnet fishery of southeastern Pamlico Sound, North Carolina. Completion Report for ITP 1398. North Carolina Department of Environment and Natural Resources, Division of Marine Fisheries. 26pp.

Price B. 2005. Sea turtle bycatch monitoring of the 2004 fall flounder gillnet fishery of southeastern Pamlico Sound, North Carolina. Completion report for ITP 1398. North Carolina Department of Environment and Natural Resources, Division of Marine Fisheries. 27 pp.

Rao PV. 1998. Statistical Research Methods in the Life Sciences. Brooks-Cole Publishing.