2008 Project Report
Gulf of Mexico Pelagic Longline
Bluefin Tuna Mitigation Research

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Executive Summary

Research was conducted in 2008 by the Engineering and Harvesting Branch of NOAA Fisheries, Southeast Fisheries Science Center, Mississippi Laboratories to evaluate the efficacy of a new 16/0 "weak" circle hook design in reducing the bycatch of bluefin tuna in the Gulf of Mexico yellowfin tuna fishery. From 5/09/08 to 7/02/08, two commercial vessels completed 72 pelagic longline sets. Experimental hooks and standard 16/0 circle hooks were alternated on the longline with a total of 36,766 hooks set. A total of five bluefin tuna were caught during the experiment. Four were caught on the control hook with one coming from the experimental gear (75% reduction). A total of 652 yellowfin tuna were caught, with the experimental hook having a 6% higher catch rate than the standard hook. The differences in the standard and experimental hooks for bluefin and yellowfin catch rates were not significantly different. However, the failure to detect a significant difference in bluefin catch was likely due to the small sample size. Additional trials are needed to fully evaluate the potential of the new hook design to reduce the incidental take of bluefin tuna on pelagic longlines in the Gulf of Mexico yellowfin tuna fishery.

Background

Atlantic bluefin tuna (*Thunnus thynnus*) are widely distributed across the Atlantic Ocean and Mediterranean Sea. The presence of two distinct spawning areas, the Gulf of Mexico (GOM) and the Mediterranean, has led the International Commission for the Conservation of Atlantic Tunas (ICCAT) to divide the Atlantic bluefin into east and west management units.

The GOM, which is the spawning area for the western Atlantic bluefin tuna stock, has become an area of concern due to the bycatch mortality of spawning bluefin tuna associated with pelagic longline fisheries. The U.S. National Marine Fisheries Service (NOAA Fisheries) is evaluating time/area closures in the GOM to mitigate the bycatch mortality of spawning bluefin tuna. Modifying fishing gear and/or fishing practices to reduce the mortality of bluefin tuna, while maintaining catches of yellowfin tuna (*Thunnus albacares*) in the GOM directed yellowfin tuna fishery is being considered as an alternative to additional time/area closures.

Starting in 2007, the NOAA Fisheries, Engineering and Harvesting Branch of the Southeast Fisheries Science Center (SEFSC), Mississippi Laboratories conducted scientific research in consultation and cooperation with the domestic pelagic longline fleet in the GOM. The objective of the research is to develop and assess the efficacy of new technologies and changes in fishing practices in reducing the bycatch mortality of bluefin tuna in the directed yellowfin tuna fishery.

During the first year of the research, experiments were conducted aboard the NOAA research vessel *R/V Gandy* to collect data on the relative force exerted by bluefin and yellowfin tuna when captured on pelagic longline gear (NOAA SEFSC Project Report October, 2007). Treatments of three different breaking strengths of monofilament leader (64, 91, and 113 kg) were tested to determine which leader strength would effectively release bluefin tuna yet retain yellowfin. Results indicate that 64 kg and 91 kg monofilament leader were capable of releasing bluefin tuna of the sizes of fish captured.

With this information, NOAA researchers began working with hook manufacturers to develop a hook design that has less tensile strength than standard hook designs. Research conducted in 2008 evaluated the efficacy of a weaker 16/0 circle hook in reducing the bycatch of bluefin tuna by comparing it to a standard 16/0 circle hook used in the pelagic longline fishery.

Materials and methods

Hook Development

Experiments were conducted at the Lindgren Pitman tackle company to evaluate the relative strengths of hooks currently being used by the pelagic longline industry in the GOM. During the test, monofilament line was attached on one end to the eye of the hook and the other to an electronic scale. A loop of monofilament was placed over the bend of the hook. The monofilament loop was pulled at 9 kg (20 lb) increments. After being subjected to each weight increment, the tension was relaxed and the relative spread in the hook gape (deformation) was measured. This process was repeated in a stepwise progression until the gape of the hook was spread to the degree that the monofilament loop contacted the hook barb (considered straightened). Based on the results of the hook bend test with standard hooks, a weaker hook design was developed. The new hook design was then subjected to the hook bend test to ensure that the experimental hook strength was near the target strength.

Hook Evaluation: Experimental design

Two commercial pelagic longline vessels were used to evaluate the new hook design in reducing the incidental bluefin tuna catch rate associated with pelagic longline gear in the GOM. The control treatment was an industry standard Mustad 16/0 circle hook (model 399690D) with 0° of offset, constructed of 4.0 mm steel wire with Duratin coating. The experimental treatment was a custom made Mustad 16/0 circle hook with 0° of offset, constructed from 3.65 mm steel wire with Duratin coating. Control and experimental hooks were alternated on the longline for a minimum of 450 total hooks. After the experimental portion of the gear was set, vessels were allowed to complete the set using only control hooks. Only animals caught on the experimental portion of the set were used in the analysis. The number of hooks deployed between floats differed between vessels, with one vessel deploying three hooks between floats and the other, five hooks. The number of hooks set between floats was consistent within a set. Hook spacing was consistent within a trip. Buoy lines, leader lengths and size, mainline, and leader color were consistent within a trip. Spanish sardine (75-125 g) was the primary bait used. A few sets incorporated squid bait. However, bait type was consistent within each section of gear. Other than the experimental design requirements, captains were allowed to fish normally and chose the location of fishing, length of trips, total number of hooks fished, etc.

Data Collection

All vessels participating in the experiment carried NOAA trained observers. Both the observers and the captains were well versed in the experimental design. Each observer was trained in safety; fish, marine mammal, and seabird identifications; data collection; and the operation of a pelagic longline fishing vessel. Observers collected fishery data as described by the SEFSC Pelagic Longline Observer Program (Beerkircher et al. 2002), with minor modifications to accommodate the experiment. The time and location of each section of gear was recorded as it was deployed and retrieved, as was the sea surface temperature. These data were obtained from the vessel's existing wheelhouse equipment. The section number, treatment (hook model), time on deck, and species were recorded for each animal captured. The lengths of animals caught were measured in centimeters. Length was estimated for animals which were not boated. A carcass tag applied to each fish kept was used to match the dressed weight (carcass with head and fins removed and animal eviscerated) of the fish during unloading at the dock to the particular data collected on that animal at sea.

Hooks that had been straightened with no catch were recorded as species “unknown” and the hook condition was documented. Experimental hooks that caught yellowfin tuna were tagged and retained. These hooks were compared to an unused experimental hook in order to evaluate the effects that result from the physical forces that yellowfin exert on the experimental hook design.

Statistical methods

The relationship between the catch rate (or catch probability) and the explanatory variables (hook type, mean sea surface temperature, and vessel) was investigated using generalized linear models. In particular, logistic regression analysis (with maximum likelihood estimation procedure) for binary response (bluefin tuna, yellowfin tuna, yellowfin tuna kept, swordfish , wahoo, and failed (straightened) hooks) count data was used. Some animals were caught on the portion of the gear that was not part of the experiment (i.e., not set in an alternating hook design). These data were excluded from the analysis. Sea surface temperatures were averaged for each set.

The modeling results presented used set as the experimental unit. All analyses utilized the original units of measurements (e.g., sea surface temperature). Since the probability of a species catch (per hook) for the hook types being compared is fairly small, the catch probability ratio for the two hook types was approximated from the odds ratio (corresponding to hook types) estimated from the fitted logistic regression models. Thus, subtracting the odds ratio (and confidence limits) from 1 provides an estimate of reduction rate (and related confidence limits) due to experimental hook. Approximation of relative risk for other factors also utilized odds ratio owing to low magnitude of catch probability.

Size-frequency distributions of yellowfin tuna were plotted and compared by two-sample Kolmogorov-Smirnov (KS) tests.

Results

Hook Development

The results of the experiments conducted at the Lindgren Pitman tackle company to evaluate the relative strengths of circle hooks are presented in Figure 1. Two of the hook designs and sizes that are currently being used in the GOM are the 16/0 Mustad 39960 (4.0 mm wire diameter) and the 16/0 Eagle Claw L 2048 (4.1 mm wire diameter). The tests show that these two hook designs exhibit plastic deformation (change in shape that takes a permanent set when the stresses that caused it are removed) at between 70 and 90 kg of pull. The hooks became straightened (deformed to a degree in which fish escapement is likely) at between 110 and 125 kg of pull. To evaluate the potential utility of a smaller wire diameter, a Mustad 15/0 circle hook (3.65 mm wire diameter) was tested. The test results of the 3.65 mm wire in the 15/0 hook gave indication that the strength of 16/0 hooks can be reduced by using smaller wire size. Based on these results, a Mustad 16/0 hook was constructed using 3.65 mm wire. Due to the increased leverage given by the larger hook gape of the 16/0 hook as compared to the 15/0 hook, the new design was found to have a lower strength than its 15/0 counterpart. The new hook design begins to show signs of plastic deformation at between 35 and 45 kg of pull and straightens at around 72 kg. Based on the results, 5,000 of the new 16/0 design hooks were manufactured for evaluation in the experiment.

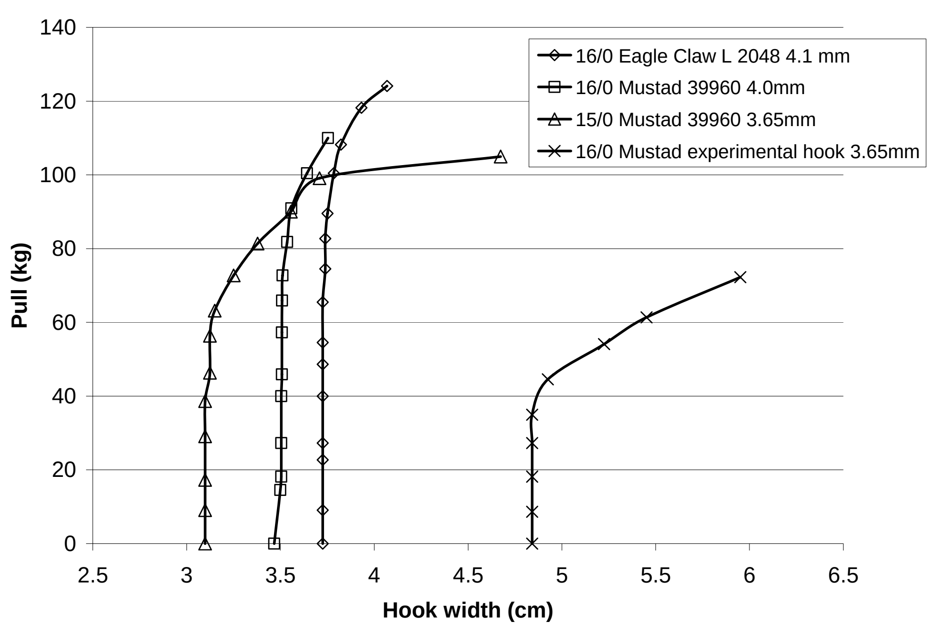

Figure 1: The result of hook strength tests conducted on three commercially available circle hooks as well as the experimental hook developed for this study. Increase in hook width corresponds to the relative bending of hooks when subjected to the corresponding force.

Hook Evaluation Results

During June-July 2008, two commercial pelagic longline vessels made 72 research sets in the northeastern GOM, fishing a total of 42,762 hooks (Figure 2). Of the hooks fished, 36,766 were involved in the experiment (18,383 of each hook type). Vessels fished an average of 594 hooks per set; the minimum number of hooks fished in a set was 450 hooks, and the maximum was 765 hooks. Surface temperature ranged from 25.4 to 30.9 °C, with an average of 28.3 °C and standard deviation of 2.5 °C. The vessels caught 36 taxa of fish, sharks and sea turtles on the experimental portion of the gear (Table 1). During the course of the experiment, four leatherback turtles were captured and released alive.

Table 1: Fish, sharks and sea turtles caught during the 2008 GOM bluefin tuna pelagic longline experiment.

Scientific Name	Common Name	Discarded	Kept
Thunnus albacares	YELLOWFIN TUNA	182	474
Alepisauridae	LANCETFISH SPP	551	1
Coryphaena	MAHI MAHI	51	420
Euthynnus pelamis	SKIPJACK	145	
Thunnus atlanticus	BLACKFIN TUNA	107	
Acanthocybium solandri	WAHOO	8	76
Lepidocybium flavobrunneum	ESCOLAR	19	64
Auxis rochei rochei	MACKEREL, FRIGATE	62	
Sarda sarda	BONITO	62	
Xiphias gladius	SWORDFISH	48	8
Carcharhinus falciformis	SILKY	31	
Makaira nigricans	MARLIN, BLUE	29	
Carcharhinus plumbeus	SANDBAR	25	
Sphyraenidae	BARRACUDA	23	
Tetrapturus albidus	MARLIN, WHITE	22	
Bramidae	POMFRET SPP	14	
Istiophorus platypterus	SAILFISH, ATLANTIC	12	
Galeocerdo cuvier	TIGER	12	
Chondrichthyes	SHARK	8	
Carcharhinus obscurus	DUSKY	6	
Thunnus thynnus	BLUEFIN	4	1
Isurus paucus	MAKO LONGFIN	4	
Rajiformes	RAY, PELAGIC	4	
Isurus oxyrinchus	MAKO SHORTFIN	2	2
Dermochelys coriacea	LEATHERBACK	4	
Thunnus obesus	BIGEYE TUNA		2
Strongylura marina	BILLFISH	2	
Prionace glauca	BLUE	2	
Ruvettus pretiosus	OILFISH	2	
Myliobatidae	RAY, MANTA	1	
Mola mola	SUNFISH, OCEAN	1	
Carcharhinus longimanus	WHITETIP OCEANIC	1	
Lampris guttatus	OPAH		1
Alopias vulpinus	THRESHER COMMON	1	
Tetraodontidae	PUFFER SPP	1	
Sphyrna lewini	HAMMERHEAD SCALLOPED	1	

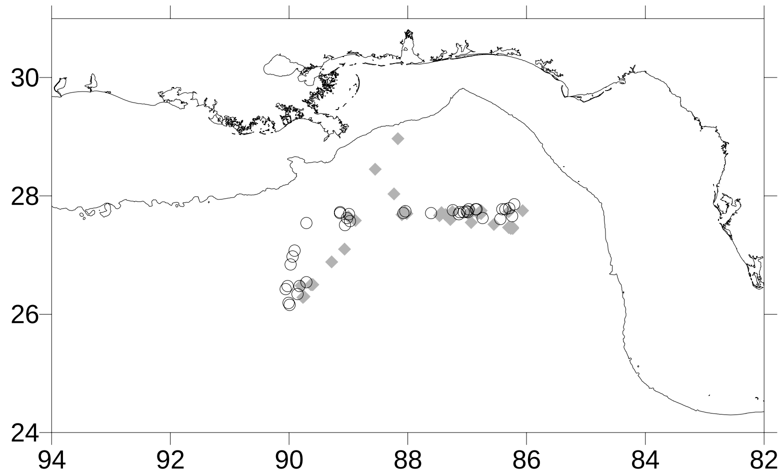

Figure 2: Geographical effort distribution for vessel 1 (diamonds) and vessel 2 (circles).

Yellowfin tuna is the primary target species in the GOM fishery. The vessels landed a total of 656 yellowfin tuna of which 474 were retained for market. Yellowfin tuna caught during the experiment averaged 63 cm in length (range 50–172 cm). The mean weight of yellowfin retained was 38.2 kg (range 11.4–73.2 kg). The experimental hook caught more yellowfin tuna than the control hook (6.5% increase), as well as a higher number of yellowfin tuna that were retained for sale (1.3% increase) (Figure 3). The effect of the experimental hook on both classifications of yellowfin was not significant ($p > 0.4$) (Table 2). The effect of the experimental hook for individual vessels ranged from a 10% decrease to a 25% increase in total yellowfin tuna catch. However, yellowfin models failed to detect a significant vessel effect ($p > 0.58$).

Sea surface temperature effect for yellowfin tuna was highly significant ($p < 0.0001$). The odds of catching yellowfin tuna increased by a multiplicative factor of 1.19 per one degree Fahrenheit (0.56^{o}C) increase in sea surface temperature (Table 2). Extrapolations of the effects of sea surface temperatures outside of the range observed were not appropriate.

A two-sample Kolmogorov-Smirnov test comparing the length distribution of yellowfin tuna caught failed to detect a significant difference between the tuna caught on control and experimental hooks (Figure 4.) The maximum difference between the cumulative distributions, D, is 0.0249 with a corresponding p of 1.000

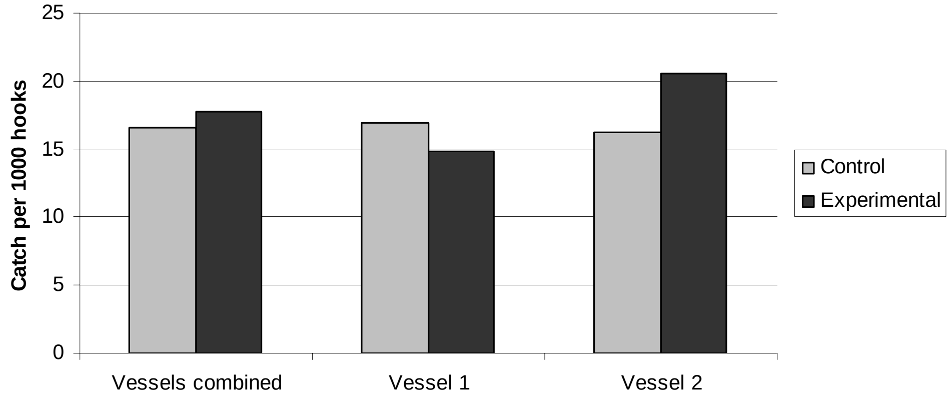

Figure 3: Total yellowfin tuna CPUE for the control and experimental hooks.

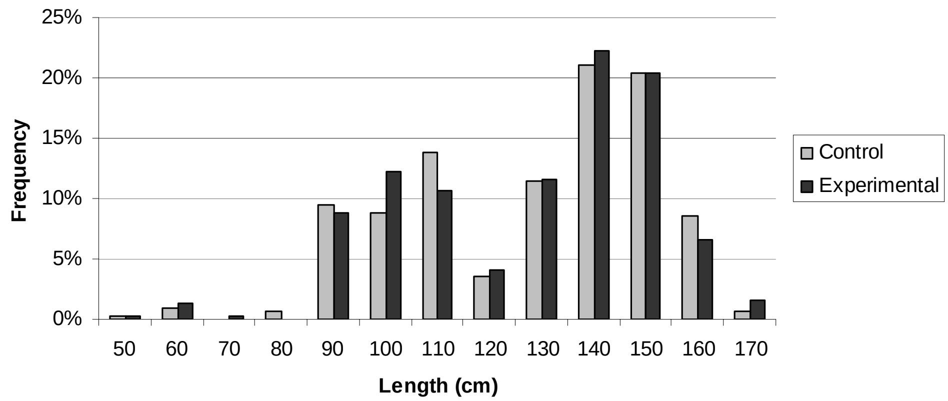

Figure 4: Yellowfin tuna length distribution for the control and experimental hooks.

Only one of the vessels involved with the experiment caught bluefin tuna. A total of five bluefin were caught, of which one was caught on an experimental hook. The observer noted that the one bluefin caught on the experimental hook had straightened the hook almost to the point of releasing the fish. The average estimated length of all bluefin caught was 239 cm (range 200–264 cm). One fish was retained for sale which weighed 249 kg (dressed weight). Of the five bluefin landed, four were alive with the one mortality occurring on a control hook. The 75% reduction in bluefin observed with the experimental hook was not statistically significant ($p = 0.2149$). The sea surface temperature effect was marginally significant ($p = 0.0992$).

Two other species that are commonly retained for sale and have the potential to straighten the experimental hook are swordfish (*Xiphias gladius*) and wahoo (*Acanthocybium solandri*). Fifty six (56) swordfish were caught during the experiment, and eight were retained for sale. Eighty-four (84) wahoo were caught, with 76 retained for sale. The point estimates for the effect of the experimental hook are an increase of 7.4% in swordfish and a 23.5% decrease in wahoo. The statistical analysis failed to detect an experimental hook effect for either species ($p > 0.22$).

Table 2: Odds ratio estimates from the model for yellowfin tuna, bluefin tuna, swordfish, and wahoo.

Effect	Odds Ratio	95% Wald confidence limits		*p*
Total yellowfin tuna (count)				
Hook type	1.065	0.912	1.243	0.4289
Mean surface temp.	1.188	1.144	1.234	<.0001
Vessel	0.987	0.842	1.158	0.8737
Yellowfin tuna retained for sale (count)				
Hook type	1.013	0.844	1.216	0.8888
Mean surface temp.	1.112	1.067	1.159	<.0001
Vessel	1.054	0.874	1.270	0.5822
Bluefin tuna (count)				
Hook type	0.250	0.028	2.236	0.2149
Mean surface temp.	0.737	0.513	1.059	0.0992
Vessel*	-	-	-	-
Swordfish (count)				
Hook type	1.074	0.636	1.815	0.7891
Mean surface temp.	0.810	0.726	0.904	0.0002
Vessel	1.347	0.796	2.279	0.2664
Wahoo (count)				
Hook type	0.765	0.496	1.182	0.2281
Mean surface temp.	1.164	1.050	1.289	0.0038
Vessel	1.041	0.669	1.621	0.8578

*Analysis of vessel effect not appropriate. Only one vessel had a bluefin tuna catch.

During the experiment, observers recorded nine control hooks and 76 experimental hooks that had been straightened to the degree for which the animal escaped. The rate at which this occurred between hook designs was highly significant ($p < 0.0001$) (Table 3). One vessel accounted for the majority of the straightened hooks of both types (8 control, 49 experimental) and a significant vessel effect was detected ($p = 0.0118$). Observations of 150 experimental hooks that successfully landed yellowfin tuna indicate approximately 27% of the experimental hooks that landed yellowfin had some degree of deformation evident. The degree of distortion ranged from barely detectable to hooks that had been straightened almost to the point of releasing the fish (Figure 5). The weight distribution of retained yellowfin tuna caught on experimental hooks that were unaffected and deformed (to some degree) is presented in Figure 6. A Kolmogorov-Smirnov test comparing the size-frequency distributions shows a marginally significant difference in the weight compositions between yellowfin tuna that did not deform the experimental hooks and ones that did ($p = 0.067$).

Table 3: Odds ratio estimates from the model for straightened hooks.

Effect	Odds Ratio	95% Wald confidence limits		*p*
Straightened hooks (animal escaped)				
Hook type	8.474	4.246	16.915	<.0001
Mean surface temp.	0.977	0.891	1.071	0.6161
Vessel	0.555	0.351	0.878	0.0118

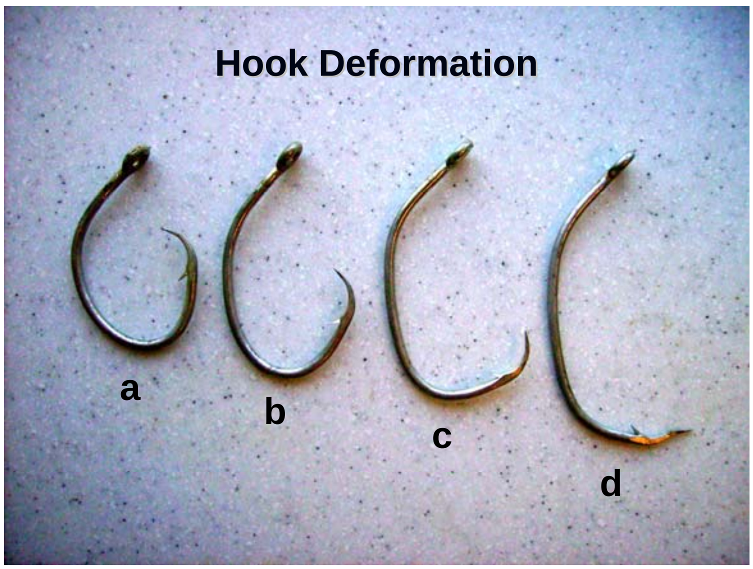

Figure 5: Examples of experimental hooks with varying degrees of deformation, (a) hook that landed a yellowfin with no bending evident, (b) yellowfin caught with minor deformation, (c) yellowfin caught with major deformation, (d) hook straightened, animal escaped.

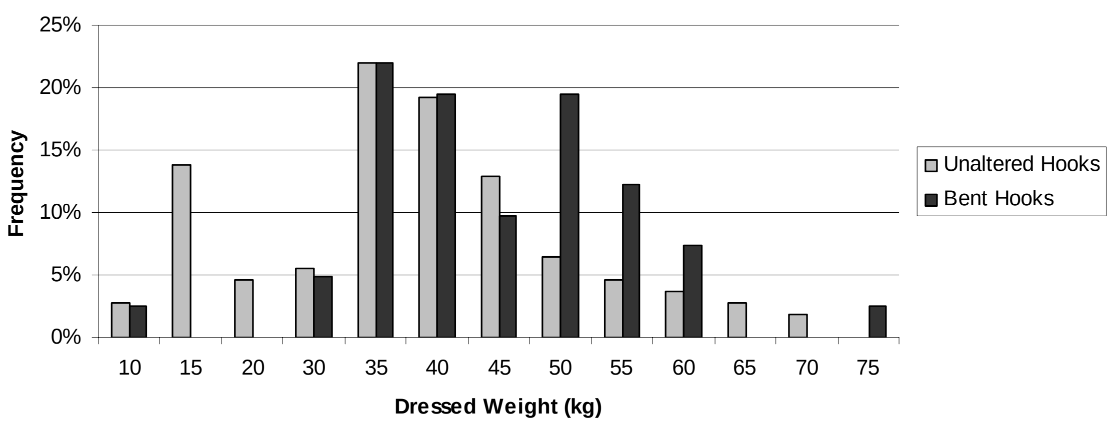

Figure 6: Yellowfin frequency distribution by weight class for unaltered (not deformed) and deformed hooks.

Discussion

The estimated takes of spawning size bluefin tuna by the GOM pelagic longline fishery have raised concerns that this fishery may be impacting efforts to recover the western Atlantic bluefin tuna stocks. Data presented suggest a weaker circle hook design may have the potential to mitigate this issue while maintaining the target catch of yellowfin tuna.

A total of five bluefin tuna were caught during the experiment. Although the sample size was not sufficient to demonstrate a significant difference between the control and experimental hooks, the 75% reduction rate is consistent with expectations of the new hook design. All five bluefin tuna caught came from one vessel, even though the two vessels participating in the experiment fished in close proximity of one another. A possible indication as to why one of the vessels caught no bluefin is the fact that eight of the nine control hooks that had been straightened during the experiment occurred on this vessel. Additionally, the same vessel had a significantly higher proportion of straightened experimental hooks. The higher rate of straightened hooks (both designs) give indication that fishing practices (e.g., gear configuration, hauling practices) may have an effect on escapement rate. However, we have thus far been unable to draw firm conclusions about the effect which fishing practice has on the results of this experiment.

We found no significant difference in the catch rate of yellowfin tuna for the experimental hooks as compared to the experimental design. On the other hand, some yellowfin tuna (27%) demonstrated the ability to apply enough force to deform the experimental hooks to varying degrees, suggesting the likelihood that a small portion of yellowfin may be capable of escaping from the new hook design. The deformation of experimental hooks was disproportionately higher among large yellowfin tuna (> 40 kg dressed weight), which supports the belief that tuna escapement with the experimental hooks is a function of size and strength.

It is our plan to continue this study in order to obtain a sufficient sample size to evaluate the potential of this conservation gear in reducing the incidental take of bluefin tuna in the GOM longline fishery. Additionally, we hope to increase the number of vessels and geographical range of the effort in order to assess the effect that varying fishing practices have on the effectiveness of the experimental hook design.

References

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