Project 8 Final Report

Atlantic Shark Bycatch Reduction

David Kerstetter, Nova Southeastern University
Dean Grubbs, Florida State University
Stephen Kajiura, Florida Atlantic University
Timothy B. Werner, Consortium for Wildlife Bycatch Reduction

Background

Previous research on electropositive metals (as presented in previous Bycatch Consortium reports) already showed that they do not appear effective with all species tested, and that hungry or feeding aggregations of elasmobranchs often overcome their initial aversion response and will take bait from a hook even in the presence of an electropositive metal. Based on this observation, the Consortium decided to develop and test an electric decoy that might *attract* sharks away from the bait or target catch, rather than using electro-magnetic forces to *deter* elasmobranch interactions from fishing gear. All elasmobranch species are attracted to weak electric fields generated by their prey. These electrical signals can be mimicked using battery-powered electrodes, which elicit a strong attractive response from elasmobranchs to bite at the signal source. In the lab, sharks and rays have been observed to bite continually at the signal source, ignoring nearby food.

There were three components to this project:

(1) An electric decoy prototype was developed;
(2) Steve Kajiura's lab (FAU) determined the most effective electric field strength and distance from bait to successfully deter sharks from consuming bait;
(3) The electric decoy was tested in an experimental demersal longline fishery off Florida, and on board a pelagic fishing vessels operating off the southeastern US.

<u>Prototype Development</u> (D. Kerstetter, NSU)

Electric capsule prototypes were constructed consisting of PVC pipe, PVC end caps, a 1.5V 3000mAh AA lithium battery, battery contact springs, stainless steel bolts and nuts, o-rings, and a 15 k-Ohm resistor. The resulting current output of the capsule was measured at 100 μA, similar to that produced by typical prey (Figure 1). The capsule was sealed internally with epoxy and PVC cement and measured approximately 10cm long x 2.5cm diameter. The capsule was then placed inside of a 2-3mm thick neoprene tube for buoyancy and to provide a "soft" biting surface for sharks. Each battery was expected to last for approximately 30,000 hours at this current draw. The capsule is activated by contact with seawater and should be rinsed with fresh water between uses.

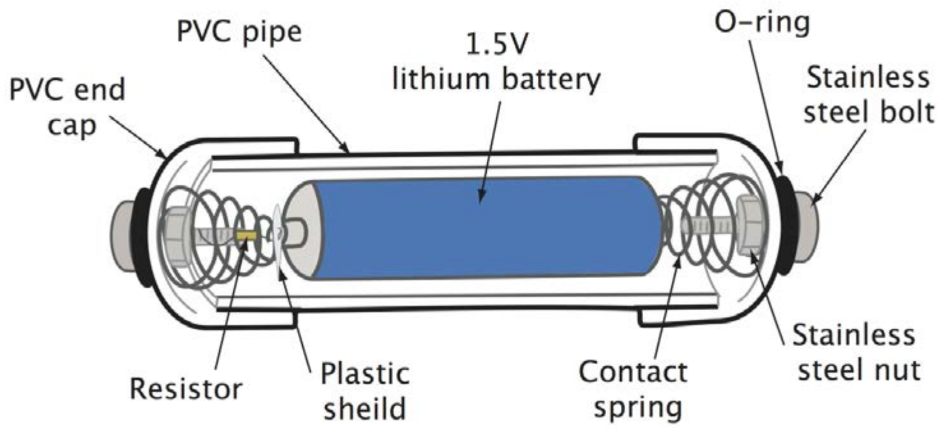

Figure 1. *Diagram of E-capsule built with ½ inch 40 schedule PVC and end caps, a 15 k-Ohm resistor, and a 1.5V Energizer Ultimate Lithium AA battery.*

<u>Electric Field Strength</u> (S. Kajiura, FAU)

The voltage of the capsule was tested at Gumbo Limbo Nature Center, Boca Raton, FL, in an electrically neutral acrylic experimental tank attached to a linear actuator (4" stroke mini-style linear actuator, Firgelli Automations) that mechanically controls the rate and depth (4 inches below the surface) the capsule was vertically dipped into the seawater. The linear actuator was attached to a linear translator (eTrack-300 Linear Stage, Newmark Systems, Inc.) controlled by a single axis stepper motion controller (NSC-1S, Newmark Systems, Inc.) that allows for accurate linear horizontal movement. The voltage was measured in line with the capsule at 10 distances: 1, 2, 3, 4, 5, 10, 15, 20, 25, and 30cm using a non-polarizable Ag-AgCl electrode and reference electrode (E45P-M15NH, Warner Instruments, Hamden, CT, USA) fitted with a seawater/agar-filled glass capillary tube. The output from the two electrodes was differentially amplified (DP-304, Warner Instruments) at 1000x, filtered (0.1 Hz - 0.1 kHz, 50/60 Hz) (DP-304, Warner Instruments & Hum Bug, Quest Scientific, North Vancouver, BC, CA), digitized at 1 kHz using a Power Lab® 16/30 model ML 880 (AD Instruments, Colorado Springs, CO, USA) and recorded using Chart™ Software (AD Instruments).

The maximum voltage measured near the 100 micro-Amps capsule of current was 0.079mV. This voltage decreased rapidly with distance from the source as predicted by the equation $y=x^{-2}$. At 3cm away from the source, the signal was barely distinguishable from electrical noise in the system. In order to more clearly observe the shape of the curve we also constructed a capsule with 100 times the output current of that tested with sharks (0.01 A). The curve produced by these measurements allows us to better observe voltage changes with distance from the source and was also found to follow the predicted decrease with distance (Figure 2).

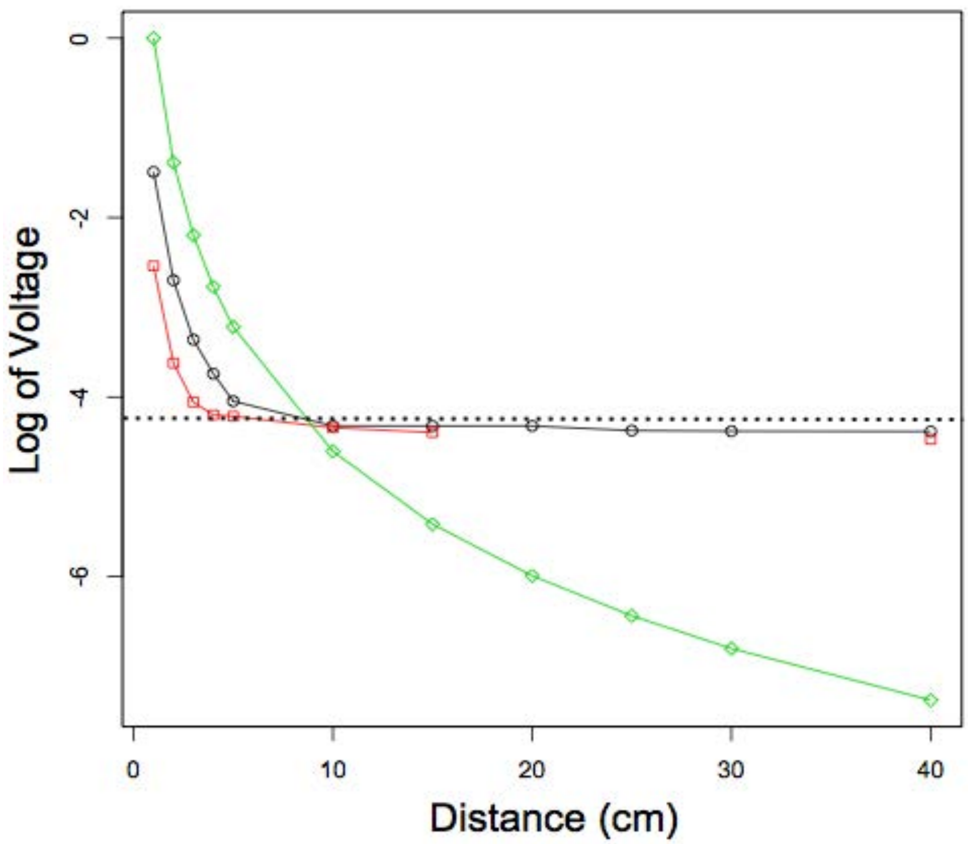

Figure 2. *Semi-log plot of the change in voltage gradient with distance from the low voltage E-capsule (producing 100 µA of current, red squares), a high voltage capsule at (0.01 A current, black circles), and the predicted curve, $y=x^{-2}$ (green diamonds). The threshold for our systems ability to distinguish signal from noise is indicated with the dotted line.*

<u>Behavioral Experiments</u> (S. Kajiura, FAU)

Methods

Responses of three species of sharks held at the Gumbo Limbo Nature Center (GLNC), Boca Raton, FL, and Scripps Institution of Oceanography (SIO), La Jolla, CA were observed. Eight juvenile and adult Bonnethead, *Sphyrna tiburo* and one lemon shark, *Negaprion brevirostris*, in a 20ft diameter tank at GLNC and four adult leopard sharks, *Triakis semifasciata*, in a 15x8ft tank at SIO were held with flow through ambient seawater. Electric capsules within neoprene tubes were attached to monofilament longline gear with a clip, short piece of monofilament and a large zip tie. Clips were then attached to the hookless leader between crimps so that the capsule would be approximately 30 cm above the hookless bait (Figure 3). This distance was chosen because it is a typical distance from which elasmobranchs have been observed to orient to prey-simulating electric signals. Food consisted of either shrimp, fish or squid, and was attached using a small zip tie secured tightly but through a small portion of the bait so it could be removed relatively easily by a shark. An identical control line was constructed with a capsule of the same size and weight with no battery power. The two lines were simultaneously lowered into the tank containing sharks at 60-100 cm apart near the middle of the water column (Figure 3). The responses of the sharks were video recorded from the surface as well as underwater whenever possible. The number of approaches where the sharks contacted and/or bit either a capsule or a bait were noted. Once a shark removed a piece of food from the lines they were removed from the water, the food was replaced, and the control and E-capsule switched from one line to the other before lowering lines back into the water for the next trial. If no response was observed for 15 minutes, a second piece of food was added to each line. A session was concluded when sharks no longer showed any interest in searching for food (20 minutes) or the prepared food was consumed.

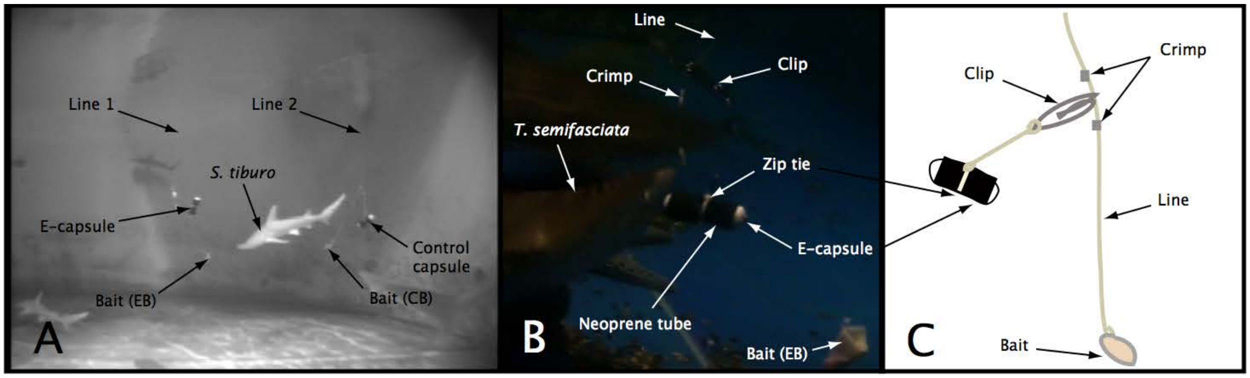

Figure 3. *Still underwater video frames showing set-up of control and experimental lines, each with a capsule and bait attached (A), and close-up of capsule attachment to the monofilament line with clip and zip tie (B and C). The shark labeled in A and B bit at the E-capsule in the frames that followed.*

Results

Five sessions consisting of 4 to 11 trials were conducted with *S. tiburo* and *N. brevirostris.* Sharks were frequently observed to contact/bite the electrical capsule and then rapidly swim away. Overall, 29 contacts/bites on the E-capsule were observed. With time and increased exposure to the experimental set-up, fleeing responses upon contact with the E-capsule were observed less frequently. Instead the sharks were more likely to continue searching for food until they found the nearby bait. This shift in behavior resulted in a decreased ratio of E-capsule contacts to bait eaten (Table 1). Two sessions consisting of 8 and 30 trials were conducted with *T. semifasciata*. Overall 18 contacts/bites on the E-capsule were recorded. Responses mirrored those of *S. tiburo* and *N. brevirostris* with a decreasing ratio of E-capsule contacts/bites to the amount of food consumed with time and experience (Table 1). While both *S. tiburo* and *N. brevirostris* were observed to contact the control capsule on a few occasions, no actual bites were seen. *T. semifasciata* did not contact the control. It is also worth noting that a teleost fish in the tank with *T. semifasciata* consumed 3 pieces of bait from the lines, but never approached or contacted the E-capsule (or control capsule). If these capsules are to be successfully employed on lines to deter elasmobranch catch without affecting, or potentially even increasing, catch of targeted teloest fishes it is important that teleosts show no adverse response to the capsules. These observations support the prediction that fishes without electrosensory systems (teleosts) will not be attracted to the capsule and thereby distracted from the baited hook.

Table 1. Number of contact/bites at E-capsule, control capsule, and bait (EB or CB) per session. The ratio of E-capsule contact/bites to food bites is also shown below and the number of trials within each session are given in parentheses. The single *N. brevisostris* contributed one E contact (session 1), one control contact (session 2), one E contact, control contact and removed one CB (session 3), and one E contact and removed one EB (session 4).

	S. tiburo and *N. brevirostris*					*T. semifasciata*	
Target	Session 1 (4)	Session 2 (4)	Session 3 (7)	Session 4 (11)	Session 5 (10)	Session 1 (8)	Session 2 (30)
E-capsule	4	8	5	9	3	5	13
Control capsule	1	1	2	0	1	0	0
Bait (EB)	2	3	5	9	7	1	13
Bait (CB)	1	0	1	6	6	4	14
Ratio	4:3	8:3	5:6	9:15	3:13	5:5	13:27

Conclusions

The electric capsule constructed produces an electric field similar to those recorded from prey and elicits a feeding response from sharks. In initial trials, the attention of the sharks was successfully diverted from nearby food. Upon contact with the E-capsule the shark quickly turned and swam away. These sharks did show evidence of learning or conditioning to the set-up as reflected in the lower number of contacts/bites at the E-capsule relative to the amount of food consumed over time. Since sharks in most longline fisheries are unlikely to encounter a baited longline hook more than once in their lifetime, this conditioned response is not likely to occur in the field. Because of the nature of this application, the initial fleeing response upon contact with the E-capsule positioned near bait is the most indicative of this devices potential success in reducing shark bycatch. These results and observations suggest that the device can indeed divert sharks from bait and may therefore reduce shark catch rates, therefore, continued research and development into the application of this electric capsule under true field conditions is warranted.

Demersal field trial (D. Grubbs, FSU)

Methods

A fishery-independent survey was employed to field-test the efficacy of using a new electric decoy as a shark deterrent. The Florida State University Coastal and Marine Laboratory longline survey was designed to assess the abundance, diversity, and seasonal habitat use of adult and juvenile coastal sharks in the northeastern Gulf of Mexico. The mainline consisted of 4.0mm monofilament with stainless steel swivels crimped in-line at 100-m intervals. The line was anchored at each end and marked by a buoy labeled with a Special Activities License number issued by the Florida Fish and Wildlife Conservation Commission. Gangions were placed on the mainline at 15-meter intervals and buoys marked the line at 20-hook intervals. For the standard fishery-independent survey, 100 gangions (25 each of four hooks sizes) were deployed and a small float is attached to the gangion to keep the bait suspended above the bottom. For trials testing the electric decoys, each set contained 60 gangions baited with bonito (*Euthynnus alletteratus*). Only one gangion configuration was used for simplicity. Due to concern over the size of the decoys and their effect on bait behavior, no float was used on the gangion, so hooks and decoys laid on the bottom. The gangion configuration consisted of a heavy duty tuna clip (quick snap, 0.148" metal, 3/16" gape) with an 8/0 heavy duty stainless steel swivel attached via two double-barrel copper sleeves to a 2.5 meter section of 3.2mm monofilament. The other ends of the monofilament were doubled for the last 25 cm to prevent bite-offs and a 16/0 black, carbon steel, circle hook was attached. A decoy was attached one meter above the hooks on 30 of the gangions and 30 of the gangions were controls containing no decoys. Treatments were alternated and soak times were one hour. The statistical unit (CPUE) was the number of elasmobranchs (sharks or rays) captured per 100 hook hours.

For this field trial, a second version of the electric decoy was constructed with a solid acrylic design ("version two") by Nova Southeastern University (NSU). The initial model of the revised design ("version 2.0") was a rectangular block of acrylic, with both screw electrodes exiting along the same side. NSU produced refined model that is both cylindrical and with screw electrodes exiting either end of the device.

Figure 4. *Side-by-side comparison of modified "version two" design for a device to attract pelagic elasmobranchs away from the baited hook on pelagic longline gear. This version is potted within solid clear acrylic to avoid leakage problems with "version 1.0" device (top), and includes a AA-size battery, a resistor, and two screws (grey arrows on diagram below) exiting the acrylic to create the electric field. The "version 2.0" is the rectangular clear block (top middle), with the screws (contact points) exiting on one side of the device. The newest "version 2.1" is similar in size in shape to the clear, cylindrical object (bottom), although constructed of clear acrylic and with contact points on either end. The "version 2.1" dummy block for the mold is included (bottom middle) to provide a sense of scale of this version of the device. The actual device is not shown.*

Results

Fifty fishery independent longline sets were conducted between 29 August 2013 and 26 September 2013. Sets were deployed in coastal waters of the eastern Florida panhandle between Ocklochonee Bay and St. George Sound (Figure 5). Average and ranges of environmental parameters (depth, temperature, salinity, dissolved oxygen, water clarity) are provided in Table 2. At least one shark was captured in 48 of the 50 sets.

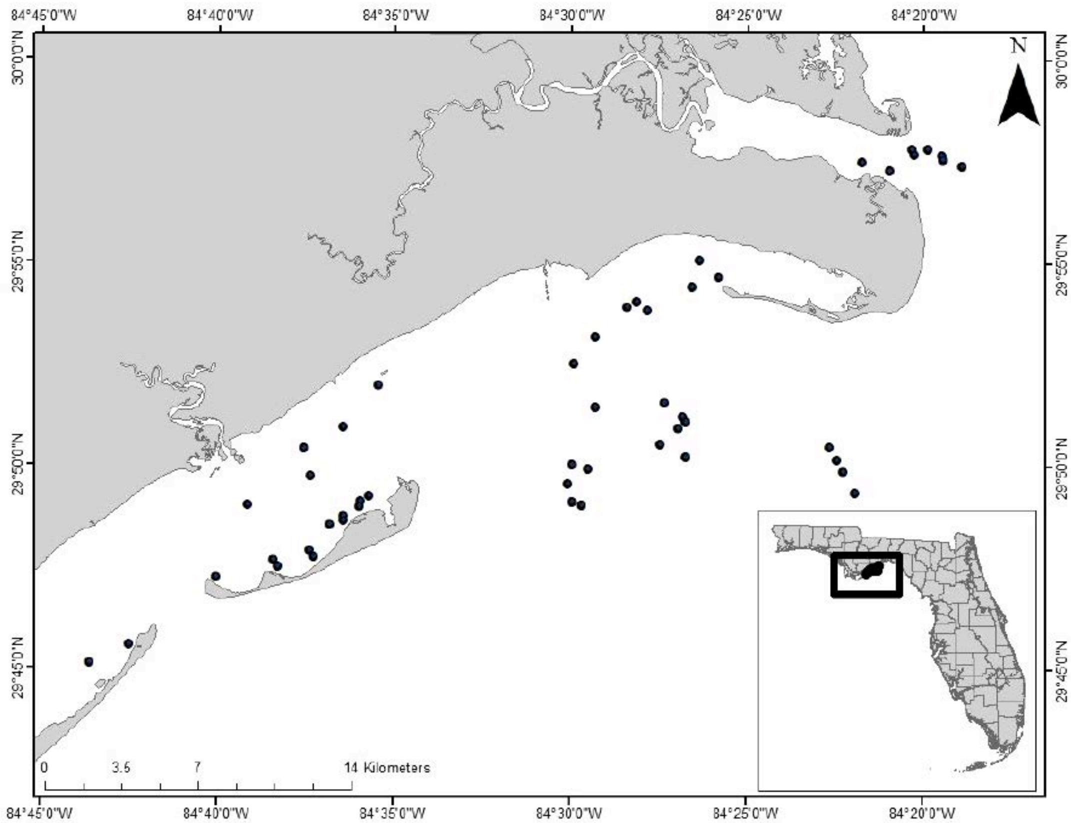

Figure 5. *Distribution of fishery-independent longline sets (N=50) made to test the effects of electric decoys on elasmobranch catch rates.*

In total, 225 elasmobranchs from 10 species were captured (Table 3) and 65% of these were captured on control hooks, compared to 35% on decoyed hooks. All ten species were captured on control hooks, but only seven species were captured on hooks with decoys. Mean catch rates were 9.74 and 5.23 sharks/100 hook-hrs on control hooks and decoy hooks, respectively. These catch rates were significantly different ($t=5.80$, t-critical$=2.01$; $p<0.0001$) and suggest catch rates on hooks containing decoys were ~47% lower than the control. Also of interest, of the 78 elasmobranchs captured on hooks containing decoys, the neoprene covering was missing from 50 (64%) of these, suggesting the sharks bit the decoy prior to being hooked.

Together, Atlantic sharpnose sharks (*Rhizoprionodon terraenovae*) and blacktip sharks (*Carcharhinus limbatus*) made up more than 75% of the sharks caught on both hook types. Only these two species were captured in sufficient numbers to test for species specific effects. Catch rates for Atlantic sharpnose sharks (*Rhizoprionodon terraenovae*) were reduced by ~61% on hooks containing decoys (1.94 sharks/100 hook-hr compared to 4.96 sharks/100 hook-hr on control hooks) and catch rates of blacktip sharks (*Carharhinus limbatus*) were reduced by ~35% (2.01 sharks/100 hook-hr compared to 3.09 sharks/100 hook-hr on control hooks) (Figures 6 and 7).

Bycatch mitigation measures are only practical if they have little or no effect on catch rates of the targeted taxa. In the case of longline bycatch, the targeted taxa are teleost fishes. The FSUCML survey methods are designed to capture sharks and only effectively catch two species of teleost fishes (*Ariopsis felis* and *Bagre marinus*). Both are marine catfishes in the family Ariidae and were the only teleosts encountered during these trials. In total, 60 catfishes were capture, and catch rates were identical (0.6 catfish / 100 hook-hr) on control hooks and on hooks containing decoys. These preliminary data suggest the electric decoys do not affect catch rates of the non-electroreceptive teleosts fishes.

Table 2. Environmental parameters for 50 longline sets to test the effect of electric decoys on elasmobranch catch rates.

Parameter	Mean	Minimum	Maximum
Minimum Set Depth (m)	3.05	0.9	7.6
Maximum Set Depth (m)	5.27	2.9	8.8
Bottom Salinity (practical salinity)	27.27	14.1	30.8
Bottom Temperature (°C)	28.88	27.6	30.1
Bottom Dissolved Oxygen (ppm)	5.40	3.68	7.33
Water Clarity (cm)	179	60	300

Table 3. Catch on test gangions including an electric decoy and on control gangions with no decoy.

Common name	Scientific name	Decoy Present	Decoy Absent
Atlantic sharpnose	*Rhizoprionodon terraenovae*	29	74
Bonnethead	*Sphyrna tiburo*	5	4
Blacktip	*Carcharhinus limbatus*	30	46
Blacknose	*Carcharhinus acronotus*	6	4
Tiger	*Galeocerdo cuvieri*	0	1
Bull	*Carcharhinus leucas*	3	7
Lemon	*Negaprion brevirostris*	2	4
Great Hammerhead	*Sphyrna mokarron*	0	2
Nurse	*Ginglymostoma cirratum*	0	1
Southern Stingray	*Dasyatis americana*	3	4
Total Elasmobranchs		**78**	**147**
Total Teleosts (Ariidae)		**30**	**30**

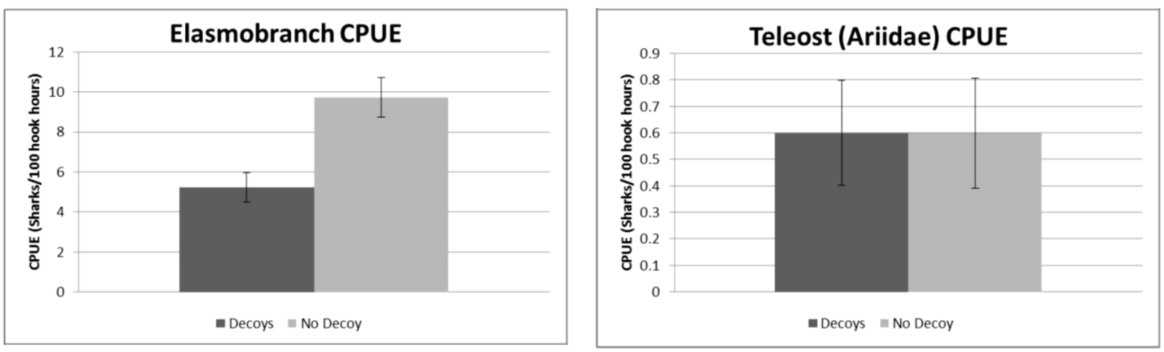

Figure 6. *Mean catch rates (animals per 100 hooks) for elasmobranchs and teleosts captured on gangions with electric decoys attached and control gangions containing no decoys.*

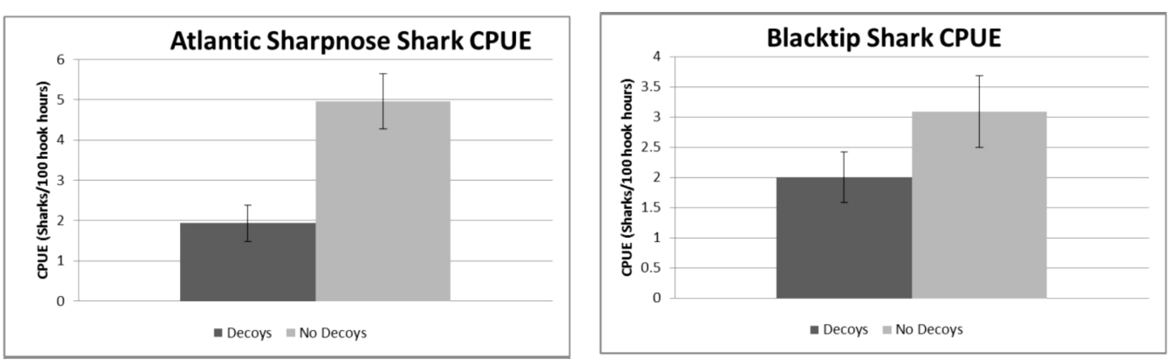

Figure 7. *Mean catch rates (animals per 100 hook hours) for Altantic sharpnose sharks and blacktip sharks captured on gangions with electric decoys attached and control gangions containing no decoys.*

While the results of the pilot study are promising, the pilot study did not contain a procedural control (i.e. hooks containing dummy, non-electric decoys). Additional sampling is also needed to test the effects on other shark species as well as teleost species. The application of any shark deterrent in a commercial setting can only take place if it doesn't affect the catch rates of the targeted bony fishes. Due to time constraints in conducting the pilot study, sampling was conducted during late summer when shark and bony fish catch rates were less than half of the rates encountered in late spring and fall. Additional sampling, with the inclusion of a procedural control, conducted during periods of high abundance will allow us to more rigorously test the effects of the decoys on catch rates of numerous shark species as well as teleosts.

Pelagic Field Trials (D. Kerstetter, NSU)

Methods

The first batch of 150 capsules were deployed on a NOAA cruise off of California in the spring of 2011. However, they experienced an extremely high failure rate (>75%). The design was revised (see Figure 4) and a second batch of 100 capsules was made to test durability.

The second batch produced was still of the original PVC construction but intended to be more durable and less prine to water leakage. Capsules were assembled in the laboratory and allowed to set for a minimum of 24 hours, then encased in a neoprene sleeve to achieve neutral buoyancy when deployed. Capsules with neoprene sleeves were attached to a 6-inch leader and snap for attaching to the longline gangion (Figure 7). Capsules were deployed on commercial longline gear for 5 sets, all with 13 to 17 hour soak times. For the first set, the capsules were places on alternating gangions in the last two sections of gear deployed. For each subsequent set, the remaining working capsules were places in the final section of gear on alternating gangions.

The decoys were tested aboard the commercial pelagic longline vessel F/V *Day Boat One* (home port: Fort Pierce, FL), which targeted swordfish and yellowfin tuna in the Florida East Coast pelagic statistical area during five sets (hauls) in October 2011 using nighttime-soaking gear that targeted the depth range of 30-40 fathoms (*ca.* 60-80 meters). A graduate student of Dr. Kerstetter carried out the trial.

Figure 7. Completed capsule with neoprene sleeve, attachment clip, and leader

Upon haulback of the gear, each capsule was examined for potential bite marks and to see if an animal was caught on the hook that had a capsule on the leader. Hooked species were identified and their status (dead, alive, hook location) recorded.

Results

Observed vessel hauls:

Haul 1: 100 capsules set, 27 no longer working, 14 chewed, 4 lost, 55 still working
- Elasmobranchs: 1 bigeye thresher shark caught with working capsule
- Swordfish: 1 caught on leader without capsule
- Tunas: 2 caught with capsules, 1 caught on leader with lost capsule, 4 caught on leaders without capsule

Haul 2: 55 capsules set, 10 no longer working, 4 chewed, 41 still working
- Elasmobranchs: 1 tiger shark caught on leader with capsule (capsule not tested to confirm it was working properly)
- Swordfish: 1 caught with shark damage on leader with capsule (capsule was not chewed)
- Tunas: 1 caught with whale damage on leader without capsule

Haul 3: 41 capsules set, 4 no longer working, 3 chewed, 34 still working
- Elasmobranchs: None caught
- Swordfish: None caught
- Tunas: 1 caught on leader without capsule, 1 caught on leader with capsule

Haul 4: 34 capsules set, 1 no longer working, 2 chewed, 3 lost, 28 still working
- Elasmobranchs: None caught
- Swordfish: 1 caught on leader with working capsule
- Tunas: 2 caught on leaders with working capsules, 1 caught on leader without capsule

Haul 5: 28 capsules set, 1 no longer working, 1 chewed, 26 still working
- Elasmobranchs: None caught
- Swordfish: 3 caught on leaders without capsules
- Tunas: None caught

Although elasmobranch bycatch in this region during this calendar quarter was lower than usual (the average CPUE for Quarter 4 in the FEC region is 0.83/1000 hooks for years 1992-2000; Beerkircher et al., 2002), the function of this trip was to evaluate the rigor of the second design after the numerous failures observed during the July field testing in California. The main problem again appears to have been water leakage within the capsule, even with the revised second design, resulting in high numbers of failures (see Figure 8; the left Y axis is the number of capsules deployed, while the right Y axis is the percent failure). This prompted design changes, as discussed above in the section on the FSU demersal field trials.

Discussion

Based on the results of this first trial, it is hard to conclude whether the capsules resulted in a decrease of elasmobranch bycatch. The results show that a total of 24 capsules had been bitten (potentially by other species including pelagic sharks), which would be an extremely high number of sharks than would normally be attracted to the gear. This raises the question of whether these capsules may be attracting additional sharks to the gear that would not normally be attracted to it. As for the targeted species (swordfish and tunas), the capsules did not appear to affect catch rates.

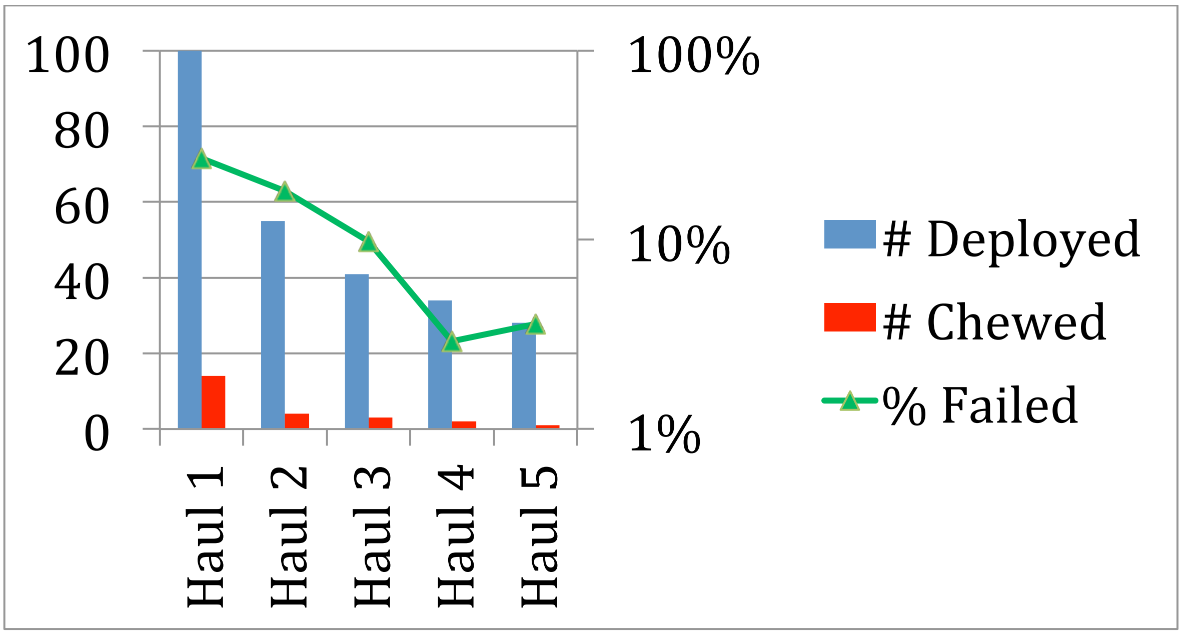

Figure 8. *Number of capsules deployed, numbers of capsules chewed, and percent failure rate per haul.*

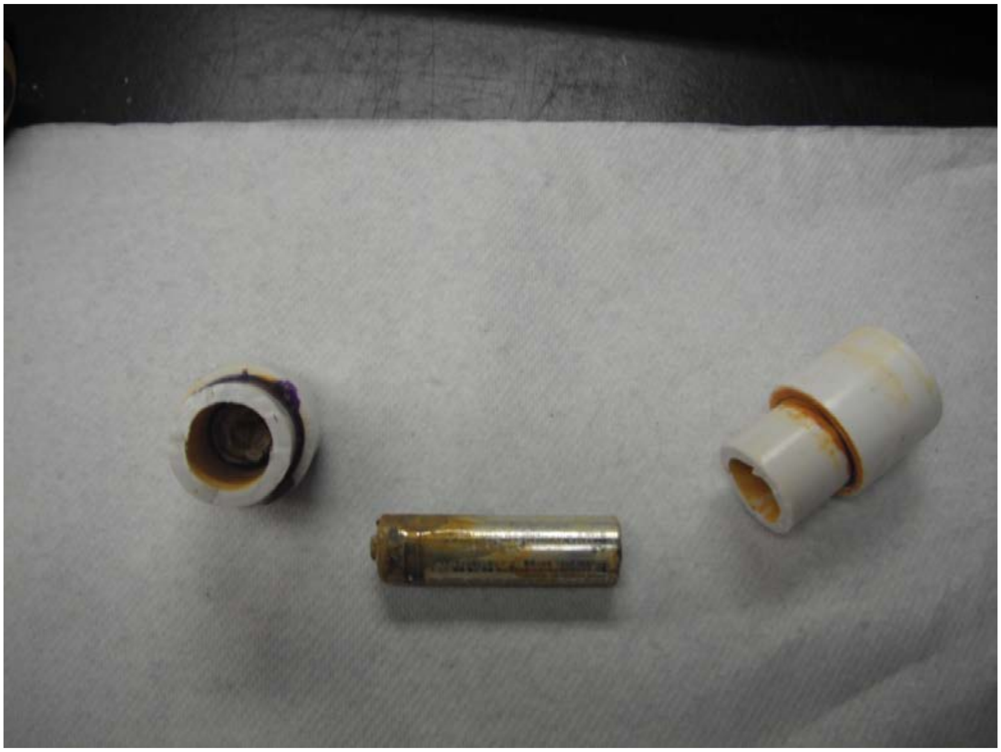

Figure 9. *Failed capsule cut open, showing water leak damage.*

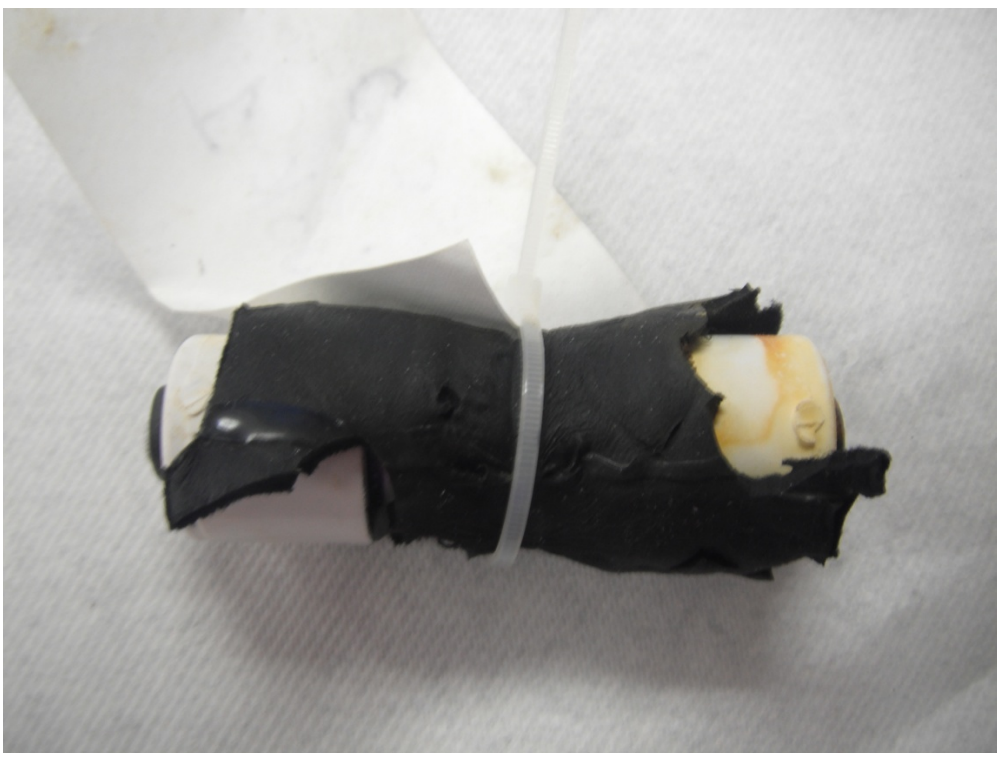

Figure 10. *Chewed capsule*

Figure 11. *Tiger shark caught on a leader with a capsule.*

Pelagic Field Trials – Phase II (D. Kerstetter, NSU)

Methods

As with the demersal field trial, for the next phase of pelagic trials used the new cylindrical model of the electric decoy. On the negative end of the battery, a 15-ohm ½ Watt resistor was soldered to a stainless steel screw, and on the positive end of the battery, coiled stainless steel wire was soldered to an eye screw. The entire device was then encased in clear acrylic with only the two screw ends being exposed. In seawater, the completed circuit generates a constant electrical field of ~ 1.8mV.

For preliminary field-testing, 70 devices were constructed and fitted with a neoprene sleeve that acted as a bite indicator. These devices where then attached to gangions on the eye screw end of the device. These gangions were 2.5 m long and made using 3.2 mm monofilament. The upper portion of the gangion was fitted with a heavy-duty tuna clip (quick snap, 0.148" metal, 3/16" gape) with an 8/0 heavy-duty stainless steel swivel attached via two double-barrel copper sleeves. Additionally, the bottom portion of the monofilament attaching the device (hereafter, the "gangion") was doubled to prevent the occurrence of a bite-off. Figure 12 illustrates the deployment configuration for the trials.

Two sets of trials were conducted aboard a commercial pelagic longline vessel (F/V *Joshua Nicole*; homeport of Fort Pierce, FL) in the Florida East Coast pelagic statistical area, *ca.* 250 km east of Merritt Island, Florida. A total of 12 sets of *ca.* 600 hooks were fished in two trips, using size 16/0 and 18/0 circle hooks attached to clear, 400 lb test monofilament leaders *ca.* 14 fathoms (*ca.* 28 m) in length. The mainline was broken into five sections, each with 120 hooks and *ca.* 6 km in mainline length. Each section had two sub-sections of 60 hooks each, separated by polyball floats. The sections were deployed in numerical order and hauled back in reverse. The bait was whole squid (except for some hooks during the second trip that used whole Atlantic mackerel), and the night deployments also utilized blue/green chemical lightsticks.

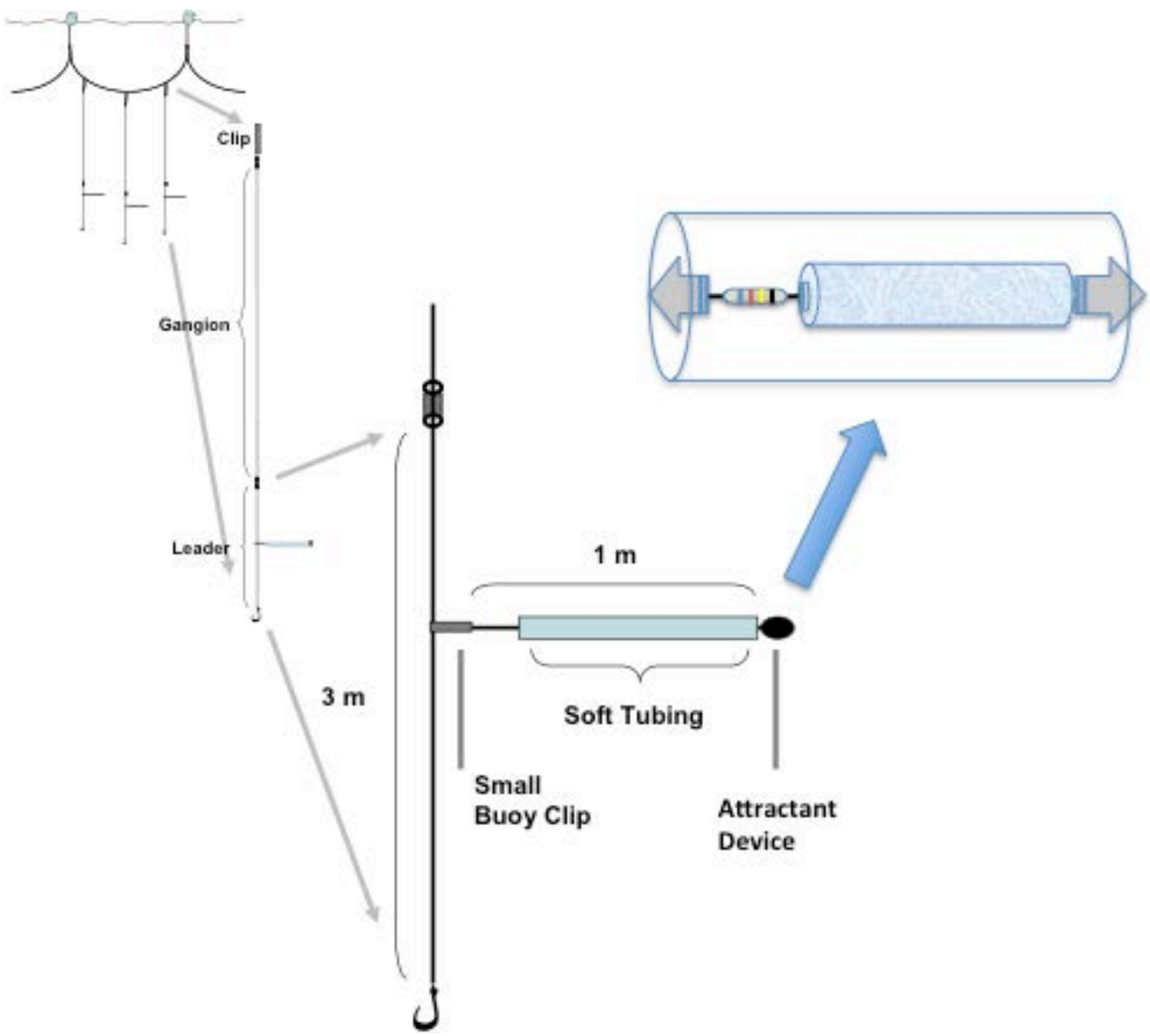

Figure 12. *Deployment schematic for the second phase of electric decoy deployment on pelagic longline gear. Note that three-hook baskets are used here for clarity and are not representative of the setting method used by the Southeastern U.S.-based Atlantic pelagic longline fleet, which usually uses five-hook baskets when targeting swordfish. The actual placement of the device (i.e., the length of soft tubing on attachment tether and the height above the baited hook) will be determined based on further discussions with elasmobranch specialists associated with the project.*

For these trials, a sub-section was chosen from either section 1 or 2 from the overall set to maximize "soak time" (the actively fished period). Thirty devices were tested at a given time and hung on every other hook line in the designated test sub-section. A total of 12 sets were performed. All field data were recorded at sea by Mr. Hornbeck (NSU graduate student) on forms used by the NMFS Pelagic Observer Program, including documentation of each caught animal. Photocopies of these datasheets are available upon request.

Results

1st pelagic field trial: After device deployments, 12 devices had the bite indicators (the neoprene covers) missing, 12 devices had bite marks, and two devices were pulled off the gangion. One other device was sacrificed by the crew (it was on a leader that caught a bluefin tuna), and two devices were lost during the soak period because the leader had been severed above the point where the devices had been attached, possibly due to bite-offs. Fish caught within the test sub-section on leaders with devices: 1 bluefin, 2 bigeye, and 1 dolphinfish; fish caught within the test sub-section on lines without devices: 1 yellowfin, 1 blue marlin, 1 bigeye, 6 swordfish, 1 tiger shark, and 1 manta ray. Other teleost species caught by the vessel included oilfish, albacore, snake mackerel, white marlin, and blackfin tuna, while other elasmobranchs included shortfin mako shark, common thresher shark, oceanic whitetip shark, and pelagic stingray, as well as 15 carcharhinid sharks (unidentified to species, but likely dusky or silky sharks). See Tables 4 and 5 for full results broken into test versus non-test, as well as landings for the trip as a whole.

2nd pelagic field trial: A voltmeter was brought on this trip and devices were tested regularly to ensure sufficient charge. Indicators were checked regularly and zip ties were used to ensure that indicators didn't come off due to drag. In the test section, four sharks were caught on control lines, but very few other fishes were observed (i.e., low target CPUEs). One swordfish had extensive damage and one shark had damage indicating a possible shark encounter. Nine devices had bite indications, one device was pulled off the gangion, and nine devices had the indicators (the neoprene sleeve) removed. Outside of the test sections, 21 sharks were caught, including thresher, blue, and night sharks. Two albacore, one wahoo, and one swordfish were retrieved on the gear during this 2nd field trial with the type of damage strongly suggesting a possible shark encounter.

Analyses

Due to the low sample sizes, no statistical analyses were conducted on the results of the 1st or 2nd field trials. However, the CPUEs for the target species were similar between the test leaders (with device gangions) on the two field trials and both the control leaders within the same section and the leaders throughout the rest of the sets. Additionally, no elasmobranchs were caught within the tested sub-sections on test leaders for any of the 12 sets during those field trials.

Discussion

As discussed during prior research, there remains a strong reluctance by the fleet to testing these devices, due to concerns about changes in the behavior of the gear and the concern that deploying them would result in lower target catches. A combination of weather, small vessels (limited observer space), and other logistical difficulties resulted in a later start to the field trials than planned. However, this suspected gear behavior change was not evident to the captain of this fishing vessel after the 1st six-set trip, nor the 2nd six-set trip, and he and the vessel owner both indicated a desire to participate in future fieldwork.

It is noteworthy that the design change to the capsule itself – i.e., the embedding of the battery and resistor assembly completely within clear acrylic – did solve all of the prior leakage problems and made them relatively easy to assemble. The vessel crew also found them easy to deploy and rugged enough for continued commercial use.

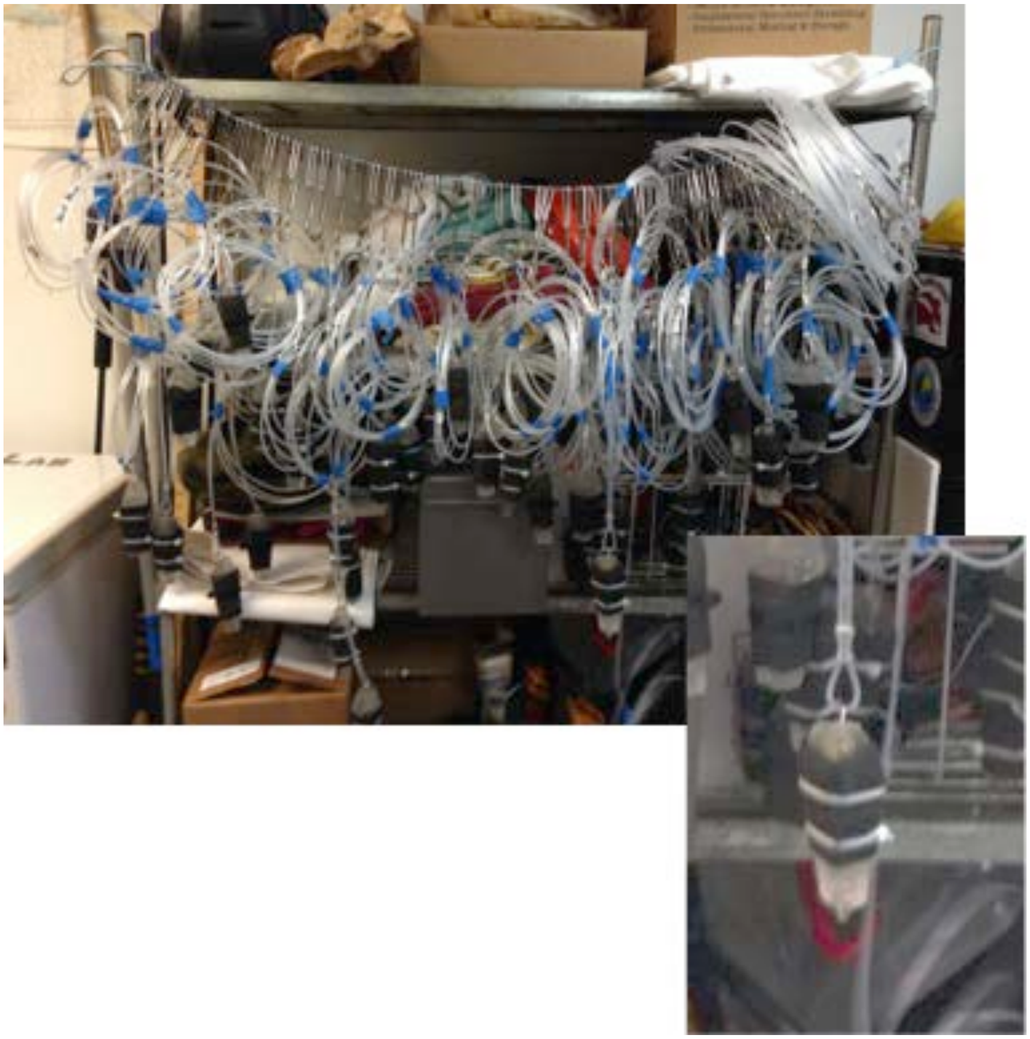

Figure 13. *A row of devices, including a close-up shot of a single device. Note the double-length of monofilament used to construct the gangion.*

Table 4. Total catches for the test sub-sections in the two field trials aboard the commercial pelagic longline vessel F/V *Joshua Nicole*. Results are presented in the format of [catch 1st trials]/[catch 2nd trials]; if no numbers listed, no catch of that species occurred in either of the two trials.

Common Name	Scientific Name	Test Gangion Captures	Control Gangion Captures
Swordfish	*Xiphias gladius*	-/-	6/2
Bigeye tuna	*Thunnus obesus*	2/-	1/-
Bluefin tuna	*Thunnus thynnus*	1/-	
Yellowfin tuna	*Thunnus albacares*		1/-
Dolphinfish	*Coryphaena hippurus*	1/-	
Blue marlin	*Makaira nigricans*		1/-
Tiger shark	*Galeocerdo cuvier*		1/-
Manta ray	*Manta* sp.		1/-
Unknown shark			-/2

Table 5. Total catches, including test sub-sections and remaining sections for the two field trials aboard the commercial pelagic longline vessel F/V *Joshua Nicole*. Results are presented in the format of [catch 1st trials]/[catch 2nd trials]; if no numbers listed, no catch of that species occurred in either of the two trials. For dolphinfish, the "#" symbol indicates total dressed weight landed, not individual fish.

Common Name	Scientific Name	Releases or Discards	Landings
Swordfish	*Xiphias gladius*	1/2	10/15
Bigeye tuna	*Thunnus obesus*		24/-
Bluefin tuna	*Thunnus thynnus*		1/-
Yellowfin tuna	*Thunnus albacares*		1/-
Albacore tuna	*Thunnus alalunga*	-/2	20/-
Blackfin tuna	*Thunnus atlanticus*	1/-	
Dolphinfish	*Coryphaena hippurus*		319#/-
Wahoo	*Acanthocybium solandri*	-/1	
Oilfish	*Ruvettus pretiosus*		2/-
Snake mackerel	*Gempylus serpens*	2/-	
Blue marlin	*Makaira nigricans*	7/-	
White marlin	*Kajikia albida*	3/-	
Tiger shark	*Galeocerdo cuvier*	1/-	
Oceanic whitetip shark	*Carcharhinus longimanus*	1/-	
Common thresher shark	*Alopias vulpinas*	1/1	
Shortfin mako shark	*Oxyrinchus isurus*		1/-
Manta ray	*Manta* sp.	2/-	
Blue shark	*Prionace glauca*	-/1	
Unidentified shark		-/16	
Unidentified hammerhead		-/1	
Pelagic stingray	*Pteroplatytrygon violacea*	1/-	

References

Beerkircher, L.R., E. Cortes, and M. Shivji. 2002. Characteristics of shark bycatch observed on pelagic longlines off the southeastern United States, 1992-2000. *Marine Fisheries Review* 64 (4) 40-49.