

# Performance of a long lasting shark repellent bait for elasmobranch bycatch reduction during commercial pelagic longline fishing

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## Abstract

The goal of the current study is the development of a long lasting shark repellent bait to reduce elasmobranch bycatch during commercial pelagic longline (PLL) fishing. Currently, twelve preliminary at-sea trials have been completed, which have identified a candidate long lasting and effective shark repellent bait for further experimental at-sea replication. The twelve preliminary sets involved deploying different formulas (i.e. variations in the molecular weights - 16Kmw, 8K mw and 6K mw) of the water soluble binding agent polyethylene glycol (PEG) as well as variations in delivery mechanisms dimensions (i.e. changes in volume). The various PEG binders were homogenized with a proprietary chemical identified from the semio-chemical derived from decaying shark tissue (i.e. SuperPolyShark™) and tested at-sea. Preliminary trials have identified as much as a 71% reduction in shark bycatch during commercial PLL fishing with the 6.5K mw PEG with 7.5 cm x 2.2 cm (ID) cardboard tubes. Therefore, the remainder of the study (i.e. eight PLL gear deployments) will focus on experimental replication using this formula.

## Introduction

Shark bycatch is a major problem during any fishery that uses baited hooks and is not targeting sharks. A fishing hook is not selective enough to exclude sharks in favor of a target species like tuna or swordfish. Commercial pelagic longline (PLL) fishing is a substantial contributor to shark bycatch mortality (Beerkircher, 2002, Myers and Worm, 2003, Cosandey-Godin and Morgan, 2011, Rice, 2013) and shark “bycatch” often results in serious safety concerns, and adverse economic effects for commercial fishers including the following issues:

- *Reduced catch of marketable species:* Hooks occupied by shark bycatch are unavailable to

catch target fish species, which results in substantial economic loss to fishers;

- *Reduced fishing efficiency:* The capture of bycatch reduces fishing efficiency by requiring fishers to deploy more hooks and fish more hours;
- *Risk of injury:* It is dangerous for crew to handle captured sharks and there is a serious risk of injury when branch lines snap from shark bite-offs during gear retrieval; and
- *Increased effort and expenditure of time:* A majority of fishermen consider the time required to remove sharks from gear, retrieve terminal tackle (i.e. hooks, etc.) and repair and replace gear as a central concern resulting from shark interactions. The shark jaw is often slashed by knife when fishers attempt to retrieve the hook as opposed to exerting the extra effort to remove the hook properly.

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*The views expressed herein are the author's and do not necessarily reflect the views of NOAA or any of its sub-agencies.*

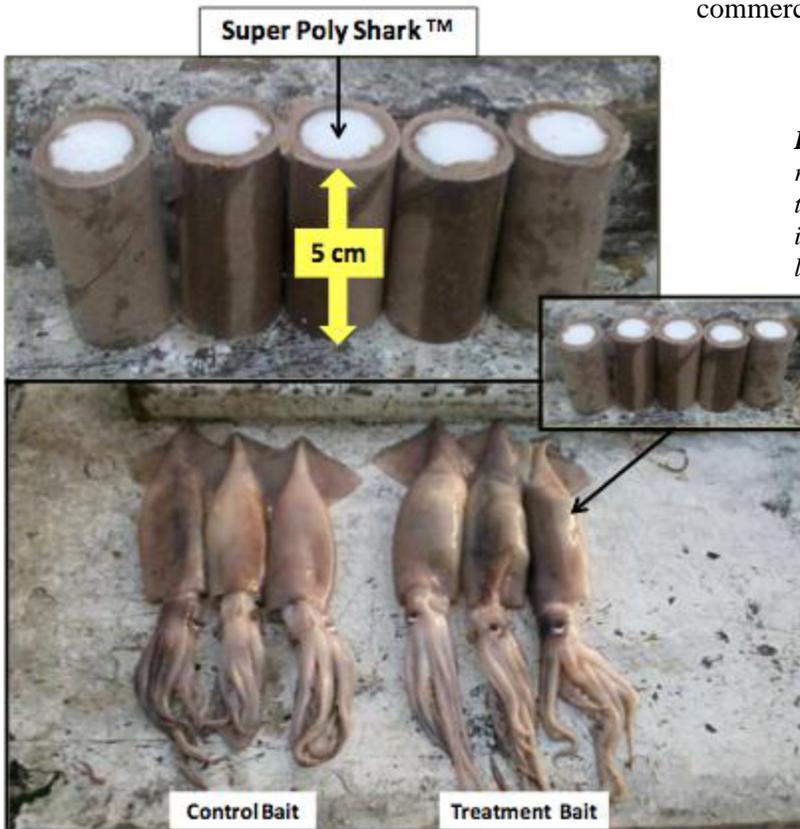
- **Damage and loss of gear:** Typical pelagic longline (PLL) hooks are expensive (\$.055 - \$.62) and substantial economic losses occur when sharks bite-off terminal tackle (e.g., baited hook, leader, weighted swivel, and line), stretch and chafe branch lines, break the main line, and/or become entangled in the gear. PLL fishers will often cut off the hook rather than deal with a live shark.

Therefore, the critical need is to selectively repel sharks while not decreasing target catch (i.e. tuna and swordfish). To address this issue Rice and Stroud (2013) modified the semio-chemical shark repellent first reported by Stroud et al., (2013) and developed an innovative, time-released shark repellent (SuperPolyShark™ or SPS™; Shark Defense Technologies, LLC.) that was capable of being inserted into fishing bait (Figure 1). Rice and Stroud (2013) reported a 40% reduction in shark bycatch on repellent treated baited hooks compared to control hooks during commercial PLL fishing during the first 4 hrs of baited soak time. However, they noticed that the repellent protection of baited hooks was limited to less than twelve hours. Since PLL fishing regularly deploys gear

for > 18hrs, it was determined that further research was necessary to develop and test a longer lasting repellent. Therefore, the goal of the present study is to modify the SPS™ and test its performance as a long lasting shark repellent bait for bycatch reduction during commercial PLL fishing. To achieve the proposed goal the following objectives have been identified:

### Objectives

1. Increase the time-release capabilities for the SuperPolyShark™ repellent for longer bait protection.
2. Reduce logistical complications associated with SPS™ commercial fishery applications (i.e. develop simple pre-packaged shark repellent bait).
3. Recruit FKCC Marine Science and Technology students for internships and research assistantships.
4. Conduct twenty (20) at sea experimental PLL trials
5. Determine efficacy of improved SPS™ as a commercial shark bycatch technology.



**Figure 1.** (Top) SuperPolyShark™ repellent combined with a water soluble time-release gel capable of being inserted into the fishing bait (bottom) creating a long lasting shark repellent bait.

**Methods**

*Increase the time-release capabilities for the SuperPolyShark™ repellent for longer bait protection.*

The aim of this objective is to identify a candidate long lasting SPS™ that can then be replicated in at-sea trials to determine the efficacy of bait protection and shark bycatch reduction.

During the first reporting period of the current study (10/31/12 – 3/31/13), preliminary dissolution trials were conducted with a variety of PEG polymers and various length/diameter (l/d) dimensions of the cardboard tube. Results suggested that PEG mw and l/d ratios had a direct correlation on dissolution rates and associated repellent efficacy. Therefore, it was hypothesized that varying PEG mw and the l/d ratio of the cardboard tubes would be an effective method for varying quantity and duration of shark repellent delivered by the treated bait.

Initial preliminary trials focused on variations in the PEG mw binder, including a 16K mw PEG (one of the highest mw PEGs available on market), an 8K mw PEG and 6.5K mw PEG. The 6.5K mw PEG was the same as that used by Rice and Stroud (2013) and during those trials only the tube dimensions were varied.

As stated in the previous section, cardboard tube dimensions were varied to test the effects of changes

in volume on the duration of repellent protection of baited hooks. Variations included changes in length and inner diameter (ID). Rice and Stroud (2013) used 6.5 mw PEG in a 5cm x 1.9 cm cardboard tube. Therefore, initial trials increased the tube length from 5 cm to 7 cm and the ID from 1.9 cm to 2.2 cm thus more than doubling the volume from about 14 ml to 29.5 ml.

*Reduce logistical complications associated with SPS™ commercial fishery applications (i.e. develop simple pre-packaged shark repellent bait).*

Initially, it was believed that thawing squid (*Ilex sp.*) and inserting the SPS™ repellent into the bait was not feasible, as the integrity of the squid would be compromised. After recent attempts to refreeze bait loaded with the SPS™, it is now known that this can be accomplished with little or no degradation to the squid. Therefore, proposed trips to bait processors (e.g. Argentina) is not necessary. Funds for these trips will be reallocated to conducting further at-sea trials.

A primary concern expressed by commercial fishers during the current research is the smell of the repellent treated bait. The SPS™ repellent has a very strong odor that permeates the surrounding environment. Small PLL fishing vessels typically store frozen bait in the fish hold and the fishers contracted in the current study

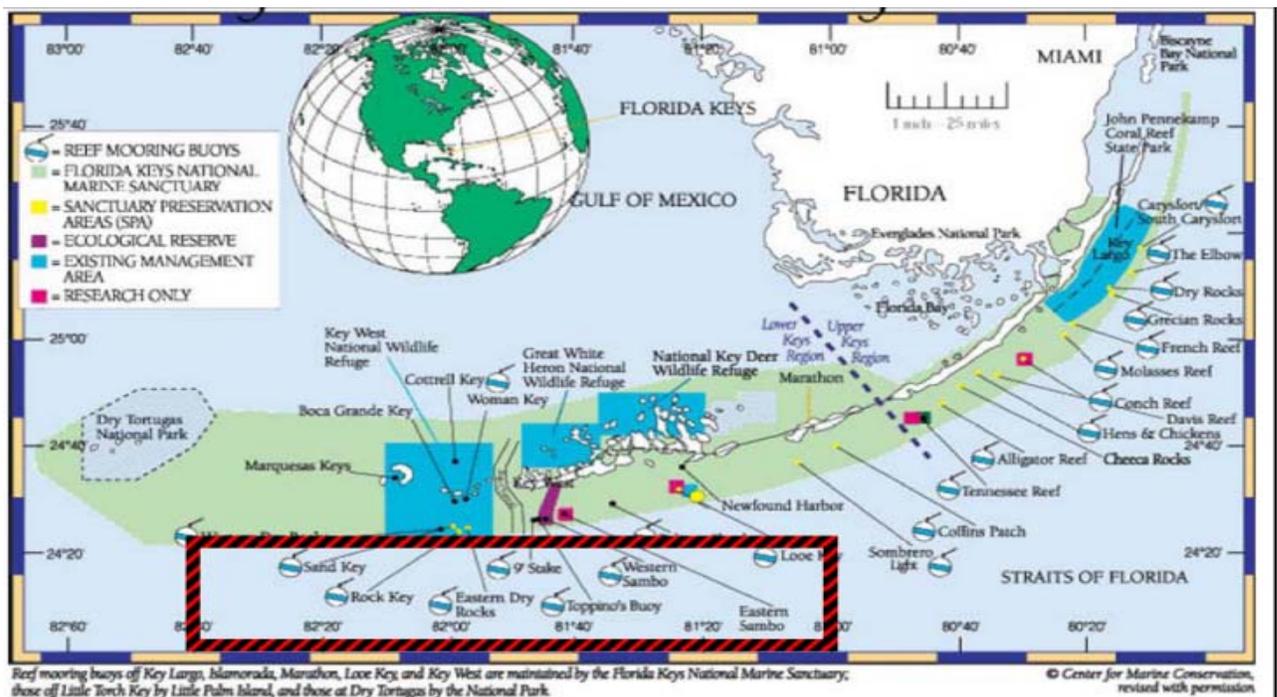


Figure 2. A map of the area in the Straits of Florida where experimental PLL gear was deployed (red/black box).

**Table 1.** Geolocation of all experimental pelagic longline fishing deployments in the Straits of Florida during the project.

Deployment Date	Set/Haul	Start Set		End Set		Start Haul		End Haul	
		Latitude (N)	Longitude (W)						
7/11/2013	1	24° 15.2	82° 50.5	24° 25.3	82° 52.8	24° 58.6	81° 55.7	24° 58.5	81° 10.5
7/12/2013	2	24° 11.0	82° 17.8	24° 54.0	81° 10.8	24° 44.4	81° 51.7	24° 44.4	81° 51.7
7/13/2013	3	24° 13'	81° 55.5	24° 00'	81° 59.8	24° 58.9	81° 56.2	24° 05.0	82° 05.8
7/23/2013	1	24° 14.0	81° 59.5	24° 16.8	82° 12.0	24° 15.9	82° 15.4	24° 11.5	82° 06.9
7/24/2013	2	24° 13.9	81° 49.8	24° 11.2	82° 00.3	24° 10.8	82° 02'	24° 15.4	81° 55.2
7/26/2013	3	24° 15'	81° 52.1	24° 14.2	82° 05.2	24° 15.7	82° 02.1	24° 11.2	81° 50.5
7/27/2013	4	24° 17.1	82° 10.2	24° 18'	82° 50'	24° 11.2	82° 13.0	24° 11.7	82° 09'
7/28/2013	5	24° 13.4	82° 18'	24° 14'	82° 03'	24° 15.5	81° 59'	24° 07'	81° 55.6
7/29/2013	6	24° 12'	81° 57'	24° 14.4	81° 53.7	24° 18.8	81° 53.8	24° 17'	81° 47.7
10/24/2013	1	24° 16'	81° 57'	24° 19.3	82° 05.4	24° 28.2	82° 07.8	24° 21.9	81° 14.1
11/1/2013	1	24° 15.6	82° 12.47	24° 02.5	82° 19.5	24° 02.9	82° 13.1	24° 11.5	82° 21.8
11/2/2013	2	24° 02'	82° 21'	24° 55'	82° 15'	24° 03.2	81° 50.6	24° 58.9	81° 57.6

Total Gear Deployments=12

have expressed a concern that the SPS™ repellent bait may affect the smell and perceived quality of their catch. Therefore, subsequent to the identification of an effective long lasting shark repellent bait, additional research will focus on an acceptable packaging process for SPS™ repellent bait.

*Recruit FKCC Marine Science and Technology students for internships and research assistantships.*

An internship was created for the purpose of this project. The intern’s primary responsibility was to assist the Principle Investigator (PI) and the Research Assistant (RA) in collecting and analyzing data.

Additional internship duties included compilation of relevant literature which culminated with a final report that was submitted in December 2013.

*Conduct twenty (20) at sea experimental PLL trials.*

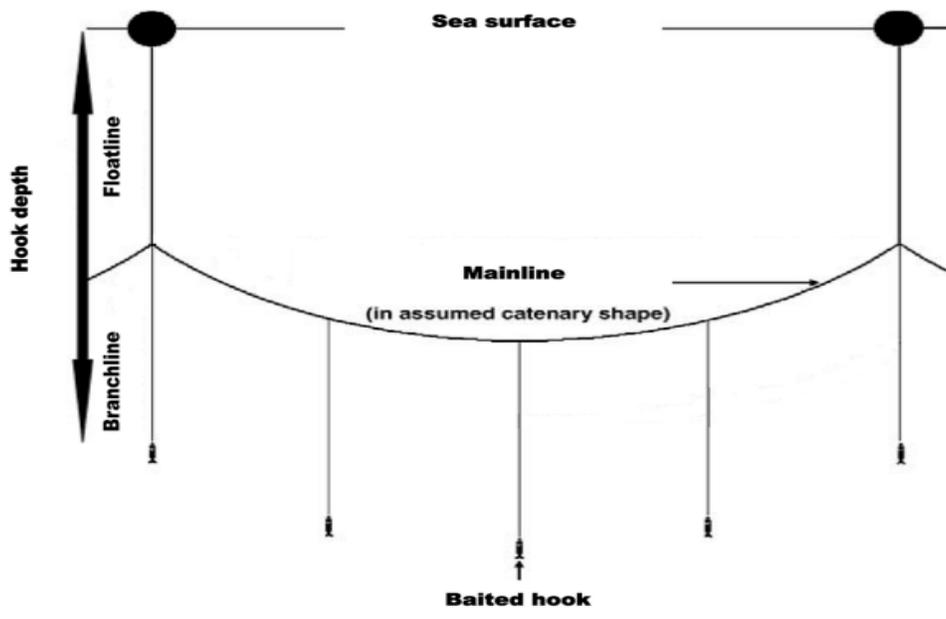
The current study proposed twenty (20) experimental PLL gear deployments in the Straits of Florida in an area bounded roughly by 24° 20’ - 25° 00’ N and 81° 00’ - 82° 40’ W (Figure 2). A total of twelve experimental PLL gear deployments have been conducted (Table 1) and deployed a total of 4,134 experimental hooks (Table 2).

**Table 2.** Experimental gear information, overall shark bycatch and sea surface temperature information during all experimental pelagic longline fishing in the Straits of Florida during preliminary trials.

Date	Set/Haul	Bait	Repellent Polymer	Dimensions (cm)		Exp. Hooks Deployed			Shark Bycatch (%)	Avg. Surface Water Temp (°C)
				Length	Inner Diameter	(Control+ Treatment)	Control Hooks	Treatment Hooks		
7/11/2013	1	SQ	SPS	16K	7.5 x 2.2	400	200	200	-50%	28.9
7/12/2013	2	SQ	SPS	16K	5 x 2	304	152	152	-22%	29.5
7/13/2013	3	SQ	SPS	16K	5 x 2	353	179	179	-22%	28.9
7/23/2013	1	SQ	SPS	5K	5 x 2	378	189	189	50%	29.2
7/24/2013	2	SQ	SPS	5K	5 x 2	390	195	195	0%	29.2
7/25/2013	3	SQ	SPS	5K	5 x 2	500	150	150	-57%	29.6
7/27/2013	4	SQ	SPS	5K	5 x 2	300	150	150	-49%	30
*7/28/2013	5	SQ	SPS	5K	5 x 2	500	150	150	-40%	30
*7/29/2013	6	SQ	SPS	5K	5 x 2	204	102	102	-50%	30.3
10/24/2013	1	SQ	SPS	6.5K	7.5x2.2	400	200	200	-71%	28.9
11/1/2013	1	SQ	SPS	6.5K	7.5x2.2	400	200	200	-29%	27.7
*11/2/2013	2	SQ	SPS	6.5K	7.5x2.2	400	200	200	200%	27.9
<b>Total Gear Deployment = 12</b>				<b>Total</b>		<b>4134</b>	<b>2067</b>	<b>2067</b>	<b>-25%</b>	

SQ= Squid

\* Indicates haul back with less than five elasmobranch total



**Figure 3.** Schematic illustration of typical near-surface pelagic longline (PLL) gear configuration used during the current study (Reproduced from Rice et al. 2012).

The F/V Outlaw targets swordfish using shallow water near-surface PLL fishing methods similar to those reported in Rice et al. (2012), with PLL gear (i.e. mainline and hooks) buoyed near the surface by a variety floats (Figure 3). Fishing depth was very consistent and was determined to be approximately 32 m deep. The fishing depth was calculated from the floatline (approx. 20 m) and leader (12 m) length. All experimental fishing used large squid (*Illex sp.*) as the bait for insertion of repellent. All experimental fishing used 16/0 circle hooks and fluorescent light sticks approximately 2 m from the baited hook.

Each branch line (i.e. gangion or fishing leader) was fastened to the mainline using a hook-timer (Lindgren-Pitman, Inc.). This allowed for calculation of the time each animal spent on the hook, strike-time, and gear soak-time. All gear was deployed passively, at sunset, from the stern as the vessel moved forward and retrieved the following morning around 8AM. All experimental fishing employed the “reverse-haul” strategy with the first hook deployed being the last hook retrieved during haul back. Given the duration of the time required for gear deployment (avg. approx. 3.5 hrs) and gear retrieval (variable depending on the catch but usually around 6 hrs), this contributed substantially to the soak time with some hooks soaking more than 18 hours. In order to ensure equal probability of a fish encountering the baited hook (i.e. equal catchability), control and treatment baited hooks were alternated along the entire length of the longline gear, thus creating a homogeneous distribution of control and treatment hooks during each experimental gear deployment.

Determine efficacy of improved SPS<sup>TM</sup> as a commercial shark bycatch technology.

Previous shark repellent bait research resulted in a 35% reduction in elasmobranch bycatch during commercial. The percent reduction of elasmobranch bycatch is determined by comparing catch on control bait (i.e. bait without SPS<sup>TM</sup> inserted) versus treatment baits. Calculations employ the following formula:

$$\left\{ \frac{\text{Absolute value (control catch - treatment catch)}}{(\text{control catch} + \text{treatment catch})/2} \right\} \times 100$$

## Results

Although various formulas and dimensions were deployed during preliminary trials, the SPS<sup>TM</sup> treated baits resulted in an overall reduction in elasmobranch (i.e. sharks and pelagic rays) bycatch by 39% on treatment hooks compared to control hooks across all trials (Figure 4). The initial trial with 16K mw PEG in the 29.5 ml cardboard tube (i.e. 7.5 cm x 2.2 cm ID) demonstrated an overall bycatch reduction of 50% (Figure 5 – Left) and as much as a 67% shark bycatch reduction within the 0-4 window (Figure 5 – Right). Subsequent trials with the 16K mw PEG in the 14 ml volume (5 cm x 2 cm ID) demonstrated about a 22% reduction in shark bycatch (Table 2). The 16K mw PEG had very slow dissolution rates with many baits returning to the fishing vessel with SPS<sup>TM</sup> undissolved (Figure 6).

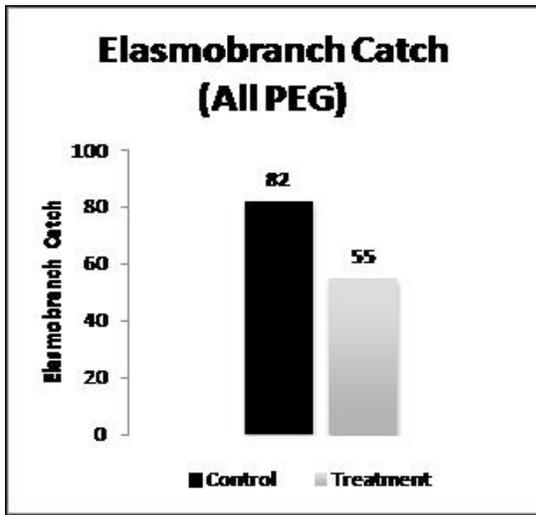


Figure 4. Total elasmobranch catch (i.e. sharks and pelagic rays) on control and repellent treated bait regardless of SPS™ PEG binder. The data indicate a 39% reduction in shark catch on treatment hooks compared to control hooks.

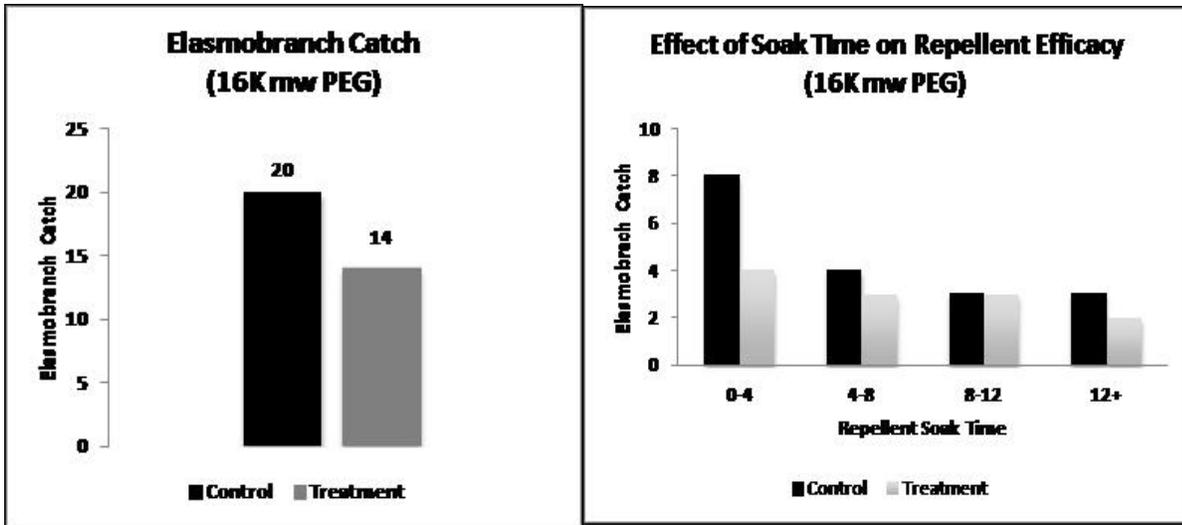


Figure 5. (Left) Overall elasmobranch catch (i.e. sharks and pelagic rays) on control and repellent treated bait (8K mw PEG). (Right) Temporal analysis of catch on control and repellent treated hooks.

Figure 6. Photo of SPS™ (16K mw PEG) showing the minimal amount of repellent dissolution after more than 12 hr. soak.



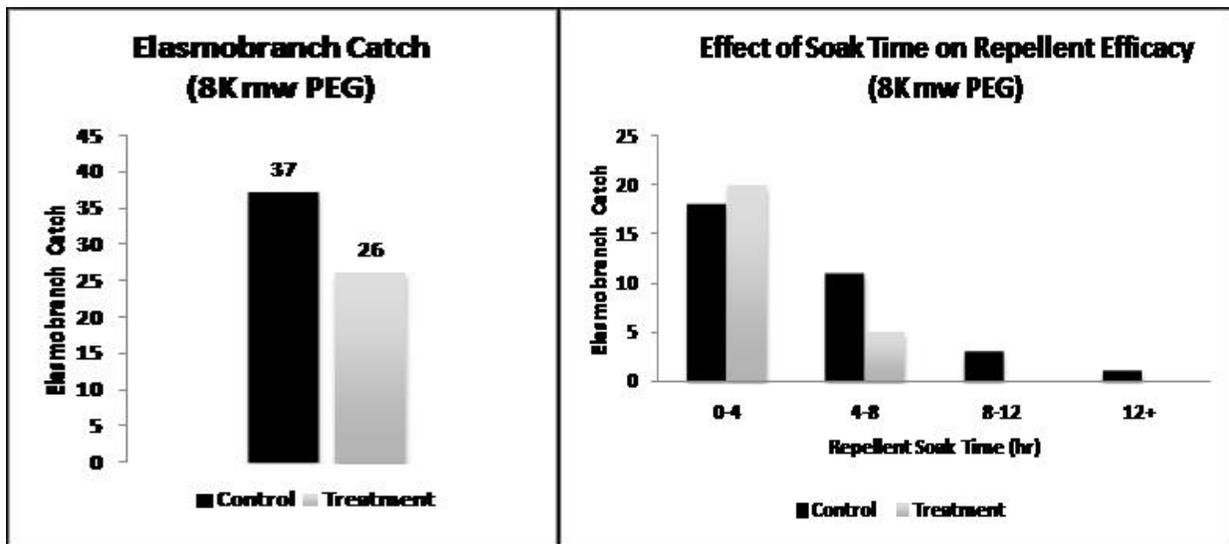


Figure 7. (Left) Overall elasmobranch catch (i.e. sharks and pelagic rays) on control and repellent treated bait (8K mw PEG). (Right) Temporal analysis of catch on control and repellent treated hooks.

Initial results with 8K mw PEG with the 14 ml cardboard tube were highly variable between trials (Table 2). Temporal analysis revealed more sharks captured on repellent treated hooks during the initial 4 hour window, although the overall results indicated bycatch reduction of 34% (Figure 7). Dissolution rates were highly variable with 8K mw PEG with SPS™ dissolved in some baits and not dissolved in others.

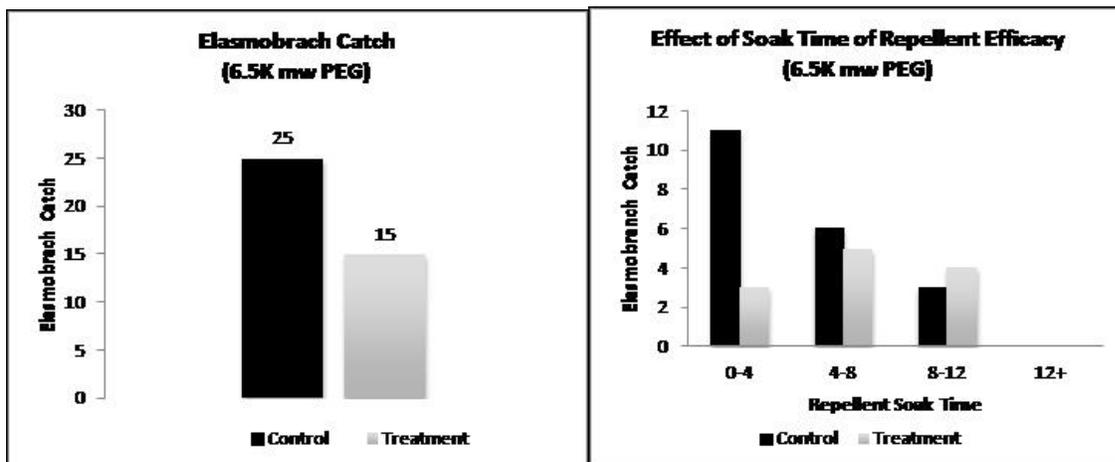
The SPS™ mixed with the 6.5K mw PEG in a 29.5 ml cardboard tube demonstrated a 50% bycatch reduction across all trails, which was the highest overall bycatch reduction reported (Figure 8 - left). Temporal analysis revealed a 114% reduction in shark bycatch on repellent treated hooks during the initial 4 hour window (Figure

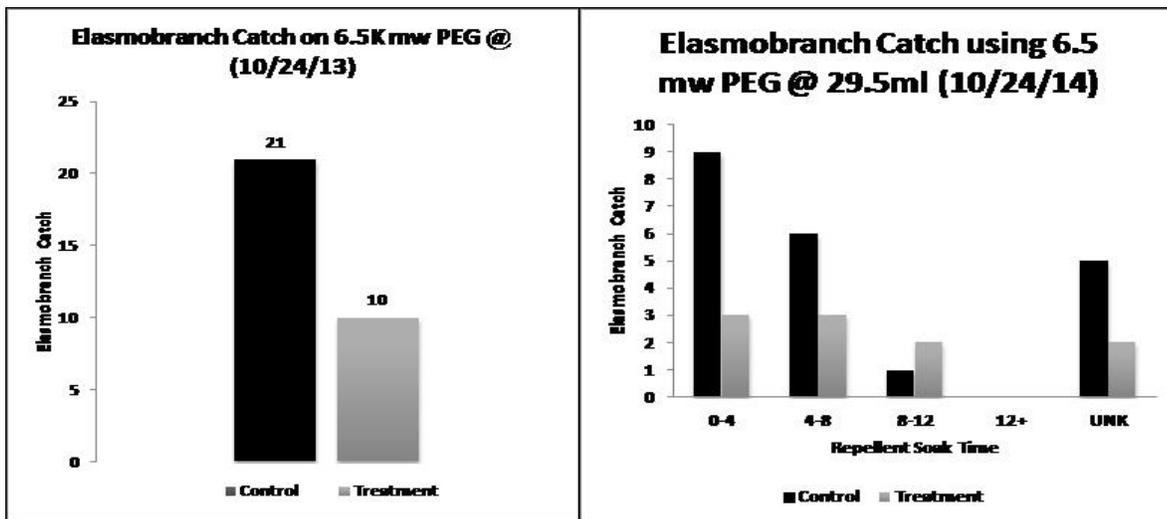
8 – Right), and the highest bycatch reduction during an individual gear deployment at 71% (Figure 9)

### Discussion

The primary goal of the present study is to create a concentrated shark repellent insert that demonstrates improved bait protection (i.e. longer lasting and higher percent shark bycatch reduction) and allows for improved incorporation into the squid bait. Modification of the SPS™ repellent bait resulted in several lessons learned. The 16K mw PEG would not fully dissolve in the water even after 12+ hours of soak

Figure 8. (Left) Overall elasmobranch catch (i.e. sharks and pelagic rays) on control and repellent treated bait (6.5K mw PEG). (Right) Temporal analysis of catch on control and repellent treated hooks. Notice the substantial difference between control and repellent treated bait during the 0-4 hr window.





**Figure 9.** (Left) Elasmobranch catch (i.e. sharks and pelagic rays) on control and repellent treated bait (SPS<sup>TM</sup> 6.5K mw PEG) during 10/24/13 gear deployment. The observed % difference in shark bycatch between control and treatment hooks during this gear deployment was the highest reported for all preliminary trials (i.e. 71%). (Right) Temporal analysis of catch on control and repellent treated hooks. Notice the substantial bycatch reduction reported for the 0-8 hr window.

time, possibly leaving repellent still unused. The 8K mw PEG was the next variable tested and fully dissolved during at sea trials, but the results were highly variable (i.e. +50% to -67% shark bycatch reduction) and the observed dissolution rate during preparation of the SPS<sup>TM</sup> was highly unpredictable. Therefore, the PI opted to return to the previous 6.5K mw PEG employed by Rice and Stroud (2012), but opted to lengthen the cardboard tubes and increase the inner diameter thus doubling the SPS<sup>TM</sup> volume in the bait. Although this delivery mechanism produced the highest overall average bycatch reduction across trials (i.e. average 50%) and appears very promising as a candidate for further at-sea trials, the longer cardboard tubes (7 cm) are more difficult to insert and require larger squid bait. In addition, during the batch preparation of the 6.5 mw PEG SPS<sup>TM</sup> some of the repellent inserts were exposed to high humidity and water during a heavy rain storm while some remained unexposed. When the unexposed inserts were deployed during at-sea trials (10/24/14; Table 2), the results demonstrated the best shark bycatch reduction recorded at -71% (Figure 8).

When considering the temporal repellent efficacy for the various treatments, the 16K mw PEG demonstrated a 67% reduction in shark bycatch within the 0-4 hour window but faded to 28% in the 4-8 hr window (Figure 5). This is most likely a result of the very slow dissolution rate and the associated inadequate and slow

release of repellent. On the contrary the 8K mw PEG initially revealed more sharks captured on repellent treated baits within the 0-4 hr window, but improved to a -75% shark bycatch reduction in hours 4 - 8 hr window. As previously stated the 8K mw PEG was very unstable during production of the SPS<sup>TM</sup> displaying both fast and slow dissolution rates.

The 6.5K mw PEG produced an initial reduction of 114% in the first 4 hours, which faded to 18% in the subsequent 4 hours across all trials. The subsequent loss of repellent potency is likely from the 6.5 mw PEG that was exposed to water prior to deployment (i.e. the first batch). During preparation of the following batch, care was taken to reduce the risk of batch exposure to water. Analysis of the performance of that specific batch showed a bycatch percent reduction by 100% in the first 0-4 hr followed by a 67% reduction during the 4-8 hr window.

## Conclusion and Future Work

Due to the very slow dissolution of 16K mw PEG SPS<sup>TM</sup> and the unstable character of the 8K mw PEG SPS<sup>TM</sup>, these formulations will not be examined during the remaining at-sea trails in the current study. At-sea trials with 6.5K mw PEG SPS<sup>TM</sup> in the 29.5 ml volume demonstrated very high shark bycatch reduction rate with some trials revealing a doubling of bycatch

reduction from that reported by Rice and Stroud (2012). Combined with the observed stability of the formula and efficacy within the 0-8 hr window, all further at-sea trials will employ the 6.5K mw PEG with SPS™ at 29.5 ml formulation.

Additional at sea trials will: (1) increase replication and improve the robustness of findings of the current study, (2) add to the knowledge of the SPS™ baits efficacy and any potential for greater shark bycatch reduction. In addition, further effort focused on appropriate packaging and commercialization SPS™ in an efficient and cost effective manner, will make the technology more available to commercial PLL fishing vessels.

### Acknowledgements

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