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Quantifying post release mortality rates of shark bycatch in Pacific tuna longline fisheries and identifying handling practices to improve survivorship

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Quantifying post release mortality rates of shark bycatch in Pacific tuna longline fisheries and identifying handling practices to improve survivorship

Melanie Hutchinson[1,2], Keith Bigelow[2] & Felipe Carvalho[2]

[1]Joint Institute for Marine and Atmospheric Research, University of Hawaii, Honolulu, Hawaii USA
[2]National Oceanic and Atmospheric Administration, Pacific Islands Fisheries Science Center, Fisheries Research and Monitoring Division, Honolulu, Hawaii. USA

Executive Summary

In pelagic longline fisheries shark bycatch rates are higher than in any other fishery and sharks are typically unwanted and discarded at sea. The post-release fate of discarded sharks is largely unobserved and could pose a large source of unquantified mortality. This study assessed post release mortality rates of blue (*Prionace glauca*), bigeye thresher (*Alopias superciliosus*), oceanic whitetip (*Carcharhinus longimanus*) and silky (*C. falciformis*) sharks discarded in two tuna target fisheries in the Western and Central Pacific Ocean. The study found that release condition and trailing gear were the two factors that had the largest effect on post release fate where animals released in good condition without trailing gear had the best survival outcomes.

Introduction

It has been estimated that two-thirds of global elasmobranch species are threatened with extinction, with overfishing identified as a major contributor (Worm et al. 2013). Thus identifying strategies that reduce the impacts that commercial fishing has on shark bycatch species is a critical fisheries science and conservation need. In pelagic longline fisheries, shark bycatch rates are higher than in any other fishery and sharks are typically unwanted and discarded at sea (Oliver et al. 2015) The post-release fate of discarded sharks is largely unobserved and could pose a large source of unquantified mortality. Additionally, the reduction of bycatch mortality is a major objective of the ecosystem approach to managing fisheries and has become a topic of interest to consumers and conservation groups (Poisson et al. 2014).

The Hawaii and American Samoa longline fisheries targeting tuna interact with several shark species, most of which are of low commercial value and are discarded at sea. In these fisheries the highest shark catch rates are; blue sharks (*Prionace glauca*), thresher (*Alopias spp.*), mako (*Isurus spp.*), oceanic whitetip (*Carcharhinus longimanus*) and silky sharks (*C. falciformis*) respectively (Walsh, Bigelow, and Sender 2009). Blue sharks comprise the largest component (>85%) of the total shark catch and in 2017, the Hawaii longline fleet caught 96,288 blue sharks, 100% of which were discarded at sea (PIFSC Data Report, 2019). A satellite telemetry study on blue sharks in the Atlantic Ocean found post release or delayed mortality occurred in 19% of the animals that were released 'alive' from swordfish target longline fishing gear (Campana, Joyce, and Manning 2009). This source of fishing mortality goes largely unaccounted for and may have large implications for stock assessments and for the overall health of shark populations worldwide. Globally, oceanic whitetip shark populations are reported to be in decline and this species is now listed in Appendix II of the Convention on International Trade in Endangered Species and as threatened globally under the United States Endangered Species Act. A study of CPUE trends in the Hawaii based longline fishery found significant declines in the relative abundance of oceanic whitetips and silky sharks since 1995 (Walsh and Clarke 2011). Furthermore, in the western and central Pacific Ocean, a stock assessment of oceanic whitetip sharks concluded the population is overfished and currently experiencing overfishing (Rice and Harley 2012).

Due to these population declines, several of the regional fisheries management organizations (RFMO) have responded with a series of conservation and management measures (CMMs) for sharks. Within the Western and Central Pacific Fisheries Commission (WCPFC) convention area, measures have called for "policies that encourage the live release of incidental catches of sharks" (CMM 2010-07), and have created species specific policies for both oceanic whitetip and silky sharks banning retention and mandating the release of any shark that is caught "as soon as possible after the shark is brought alongside the vessel, and to do so in a manner that results in as little harm to the shark as possible" (CMM 2011-04, CMM 2013-08). Banning measures are a step in the right direction but may not have the intended consequence of reducing mortality since many sharks at haul back and/or during the handling procedures to release them may incur physiological and/or physical damage that result in undocumented delayed mortalities (Tolotti et al. 2015). Effective bycatch management requires knowledge of the direct effects of fishing operations on stocks and populations subject to bycatch. There is an urgent need to estimate levels of unobservable mortality, account for these losses in stock assessment models and adopt measures to mitigate sources of unobservable mortality, such as through identifying best handling and release practices (Gilman et al. 2013).

There is a general consensus among shark and fishery scientists that there are three main factors that affect shark bycatch mortality rates in longline fisheries: 1) physiological sensitivity to stress, where impacts are species specific, 2) the amount of time an animal spends on the line, and 3) shark handling methods used to release/remove sharks from fishing gear. Many studies have identified which species are most sensitive to capture stress through physiological investigations and by quantifying at-vessel mortality rates (e.g. Beerkircher, Cortes and Shivji, 2002; Marshall *et al.*, 2012). However, the effects that shark handling and at vessel condition have on post release mortality and/or survival rates are only recently being explored (Hutchinson 2016; Musyl and Gilman 2018; M Schaefer et al. 2019). In this study we aimed to quantify post release mortality rates of blue, bigeye thresher, oceanic whitetip and silky sharks that are incidentally captured in the Hawaii deepset (HiDS) and American Samoa (AS) tuna target longline fisheries. We also investigate the effects that standard shark bycatch handling and discard practices utilized in these fisheries may have on the post release fate of discarded sharks that are in good condition at haul back of the longline gear.

Methods

To assess the factors that influence post release mortality rates of sharks discarded in Hawaii and AS tuna target longline fisheries and to identify the handling and release methods that enhance survivorship we needed to augment the data collected by Pacific Islands Regional Observer Program (PIROP) observers during shark interactions. Additional condition indices and codes for shark condition at the vessel and at release were developed (Table 1). Handling and damage codes were developed and tested, to ascertain how sharks were removed from the fishing gear and to provide details on any damage that the animal may have incurred during the process. This was an iterative process, the data codes were created with definitions and observers were at sea with Go Pro cameras to assess whether or not they interpreted the definitions accurately. This process began during the summer of 2015 and final definitions were adopted and implemented in the program in December of 2016.

To quantify post-release mortality rates of incidental blue (BSH), bigeye thresher (BTH), oceanic whitetip (OCS) and silky (FAL) sharks captured in the Hawaii Deepset (HiDS) and American Samoa (AS) tuna longline fisheries, PIROP observers were trained to tag sharks captured during normal fishing operations. Tags were placed on candidate sharks over the rail of the vessel while the shark was still in the water using extendable tagging poles. Vessel crew then removed the shark from the fishing gear via whichever release methods they typically employed. Observers recorded additional metrics specific to the tagging event and gave detailed narratives of the handling methods including: type and quantity of trailing gear, damage to animal from gear removal, how it was landed, time out of water if sharks were boarded to remove gear, time to tagging and release, SST, sex, approximate length, and anything that was of note regarding the interaction. Observers also recorded the tagging events using a GoPro camera so that scientists could validate the data that was recorded by different observers.

This study used two different satellite linked pop-off archival tag (PAT) types. Survivorship PATs (sPAT) were programmed for 30-day deployment periods to archive and then transmit binned; light, temperature and depth data to the tag manufacturer (Wildlife Computers, Inc., Redmond, WA). The tag manufacturer analyzed these data to interpret whether; the animal died (the tag sank to a depth beyond 1400 m or it sank and sat at a constant depth for > 3 days), it survived to 30 days and the tag came off as programmed or the tag came off pre-maturely (due to attachment failure) and was floating at the surface. The fate of the tag (Sinker, Completed Deployment, or Floater) and the daily minimum and maximum depth and temperature and the pop-off location are then communicated to the tag owner. These tags were placed on sharks that were alive and in good condition (AG) to get a high estimate of post release survival rates and to identify the best handling practice for maximizing survivorship potentials. To attain the low end of the post release survival rate for blue and oceanic whitetip sharks only sharks that were alive but injured (AI) or did not meet the criteria for AG or AI at the vessel were also tagged when the vessel was cutting the line.

As the study progressed, we learned that most sharks were released by cutting the line with varying amounts of trailing gear still attached to the animal (Table 2). MiniPATs (Wildlife Computers, Inc., Redmond, WA) were used to assess the long-term effects of trailing gear on survivorship of incidental blue sharks. The miniPAT archives light, temperature and depth time series data but the sampling intervals and deployment periods can be programmed by the tag owner. These tags were programmed for 180 (n=2) and 360 (n=10) day deployment periods with 10 minute sampling rates and placed on sharks that were AG at the vessel and released by cutting the line.

Fishery participation in the study was voluntary so observers were only asked to tag a small number of sharks (2–3) per trip to ensure that vessels did not represent a large burden for participating in the project and to avoid trip specific biases in the data.

The covariates most probably associated with the survival time in days were investigated by using the Kaplan-Meier and Cox proportional hazard models in the “survival” package using R (R Core Team, 2019). The predictor variables considered for use in the survival modelling included; Species, Fishery, Catch Condition, Release Condition, Handling Code, Trailing Gear, Approximate Fork Length, Ratio of Trailing Gear to Approximate Fork Length, and Sex. Fishery and Sex had to be removed because OCS were the only species tagged in both fisheries and the sex was undetermined for most animals (Table 3).

Results

Observers collected shark condition and handling data on 19,572 incidental elasmobranchs captured during 148 fishing trips that occurred between January 2016 and June 2019 on 76 different vessels. During 111 of these trips, 148 sharks were tagged by observers and fishers. The handling and damage data recorded by trained observers indicated that most sharks (93.22%, Table 2) are released by cutting the branchline. In the Hawaii-based tuna fishery this means that most sharks are released with an average of 9.02 meters of trailing gear, which typically includes a stainless-steel hook, 0.5 m of braided wire leader, a 45-gram weighted swivel and monofilament branchline, ranging in length from 1.0 – 25.0 m (Figure 1). Sharks released by cutting the line in American Samoa are released with an average of 3.038 m of trailing gear which is composed of a stainless-steel hook to an all monofilament line ranging in length from 1.0 – 9.0 m (Figure 1). Some species are released with more trailing gear than others (Figure 2). This is primarily due to when the fishers are able to ascertain that the catch is a shark and not a target species. The behavior of some species often predicts where the line will be cut, for example blue sharks surface far away from the vessel and are easy to identify so the line is often cut further away from the vessel than for some other species.

Observers based in American Samoa tagged FAL (n = 31) and OCS (n= 17, Table 4). In the HiDS fishery observers tagged BSH (n = 44), BTH (n = 28) and OCS (n = 17) with sPATs (Table 4). Observers also tagged BSH (n = 12) with miniPATs programmed for 180 and 360 day deployments (Table 5). Two of the sPATs were shed immediately (one BSH and one FAL) and could not be used in analyses and are not included in Table 4. There were 10 sPATs that reported mortalities that had to be removed from analyses due to either a manufacturer malfunction (some tags were negatively buoyant with the leader and thus, if shed early would have falsely indicated a mortality; n = 7) or the effect of the tagging event could not be ruled out after video review (n=3). Results from the sPAT deployments showed that survivorship to 30 days is relatively high (93.1%) for sharks captured in good condition (Table 4). This may be an overestimate of survival rates because we had to discard ten of the mortalities that occurred in the study and we tagged a disproportionate number of animals in good condition. Survival rates are also higher for all species that are released by cutting the line (96.2%) than when gear is removed (83.3%). Gear removal requires additional handling and animals are sometimes brought on deck (sometimes using a gaff) and exposed to air which may impact release condition. Some are pulled up to the fish door where hooks are cut out. Gear removal is infrequent (Table 2) and depends on the size of the animal and the vessel's operating procedures as large sharks are typically left in the water.

Initially, only sharks that were alive and in good condition (AG) were tag candidates and later some tags were allocated for BSH and OCS that were alive but did not meet the criteria for AG. These animals would have been characterized as either Alive (A) or Alive but Injured (AI; see Table 1 for definitions). Most OCS are typically captured in AG condition (54.6%) or they are dead (33.6%; Table 6) so encounter rates with OCS in compromised conditions was too uncommon to get the desired quantities of tags on these animals. Despite this limitation mortality rates were found to be somewhat higher for individuals that did not meet the AG criteria.

All of the BTH mortalities (n = 3) were animals that had been tail-hooked, while four other BTH were also tail-hooked, they survived to 30 days. All FAL tagged in AS survived the interactions. Two of the four OCS mortalities were sharks that did not meet the AG criteria and were in compromised conditions and both were captured in AS. The two mortalities for OCS in AG condition were captured in both the HiDS and AS fisheries.

The results of the long-term tag deployments (miniPATs) showed that delayed mortality rates are quite high. Of the twelve tags that were deployed two did not report and were not included in any subsequent analysis. Of the ten tags that reported, two survived and eight tags indicated mortalities. Three of the animals died immediately while the remaining five deaths occurred between 15 – 188 days post release (Table 6). One of these was a tag that was ingested by a thermo-regulating animal on day 28 of the deployment. There were also two SPATs that reported light, depth and temperature data indicating the tags had been ingested and later regurgitated. These occurred on days 19 for a BSH that had the gear removed and day 17 for a tail-hooked BTH that was released with three meters of trailing gear (Table 4). All three of these were considered to be mortalities although it is understood that there are other scenarios where an ingested tag does not necessarily reflect a mortality.

The Kaplan Meier and Cox proportional hazards models were used to assess the survivorship data. Table 3 shows all the predictor variables that were originally considered for the model. Sex and fishery were removed since the fishery effect would only have impacted oceanic whitetip sharks since they were the only species tagged in both fisheries and the sex was only recorded for a small proportion of the tagged animals. A full model was created with the remaining six variables and variables were sequentially excluded using a backwards stepwise methodology, leaving release condition and trailing gear as the only retained predictors having the greatest impact on post release survival times (Table 7).

Discussion

Longline fisheries have been shown to have the largest impact on pelagic shark populations due to the scale and magnitude of fishing effort around the globe. As some shark populations have been assessed and found to be in decline due to overfishing, finding strategies that can reduce this impact are increasingly important. In regions where sharks are not retained and are discarded at-sea, understanding post release fate and the identification of handling practices that can improve post release survival is paramount. This study used satellite linked pop-off archival tags to elucidate post release fate for four of the most frequently captured and discarded shark species (blue, bigeye thresher, oceanic whitetip and silky sharks) in two tuna target longline fisheries in the Pacific Ocean. Our findings show that sharks that are released in good condition without large quantities of trailing gear had the highest survival rates post release. Thus minimizing handling time and trailing gear improves shark survival odds at release.

Releasing sharks with large quantities of trailing gear is not only energetically costly and may lend some animals more susceptible to predation but it could also present an entanglement hazard. Mortalities that would be due to the trailing gear may then occur outside the 30-day window of the deployment period of the survivorship PATs used in this study. This detail may have broad implications for the determinations of post release mortality rates derived from survivorship tags since most survival studies use tags with 30 – 60 day deployment periods (this study; Musyl & Gilman, 2018; WCPFC 2019). It is nearly impossible to point directly to trailing gear as a cause of mortality. Yet this study and the WCPFC (2019) study both show that longer trailing gear have a greater impact on survivorship.

Quantitative estimates of post release fate are important to improving stock assessments and population projections. Studies like this need to be conducted in fisheries that interact with shark populations to ascertain robust estimates of fishing mortality and to find ways of mitigating some sources of mortality. Many sources of mortality will be fishery specific due to operational and gear configuration characteristics. In this study we were not able to tease apart the fishery specific impacts on shark mortality rates since only OCS were tagged in both the AS and HiDS fisheries.

Conclusions and Recommendations

In this study we show post release survival rates are high to 30 days for BSH, BTH, FAL and OCS if they are in good condition at release and if trailing gear is minimized. We found that the amount of trailing gear left on an animal has an effect on post release survival potential for multiple species and correlated with high delayed mortality rates of BSH (beyond 30-days). Because most sharks are released by cutting the line that they are captured on, making recommendations to remove as much trailing gear as possible will enhance post release survival rates. In the WCPFC, no-retention measures for silky and oceanic whitetip sharks may have the intended effect of reducing mortality if the measure included recommendations to reduce the amount of trailing gear left on animals to less than one body length.

References

Beerkircher, Lawrence, Enric Cortes, and Mahmood Shivji. n.d. "Characteristics of Shark Bycatch Observed on Pelagic Longlines off the Southeastern United States." Accessed December 3, 2017. http://aquaticcommons.org/9741/1/mfr6443.pdf.

Campana, Steven E, Warren N Joyce, and M J Manning. 2009. "Bycatch and Discard Mortality in Commercially Caught Blue Sharks Prionace Glauca Assessed Using Archival Satellite Pop-up Tags." *Marine Ecology Progress Series* 387: 241–53. https://doi.org/10.3354/meps08109.

Gilman, E., P. Suuronen, M. Hall, and S. Kennelly. 2013. "Causes and Methods to Estimate Cryptic Sources of Fishing Mortalitya." *Journal of Fish Biology* 83 (4): 766–803. https://doi.org/10.1111/jfb.12148.

Hutchinson, Melanie R. 2016. "Assessing Shark Bycatch Condition and the Effects of Discard Practices in the Hawaii-Permitted Tuna Longline Fishery." WCPFC-SC12-2016/ EB-WP-07.

M Schaefer, Kurt, Daniel Fuller, Alexandre Aires-da-Silva, Jose M Carvajal, Jimmy Martinez, and Melanie R Hutchinson. 2019. "Post-Release Survival of Silky Sharks (Carcharhinus Falciformis) Following Capture by Longline Fishing Vessels in the Equatorial Eastern Pacific Ocean." *Bulletin of Marine Science* 95 (July). https://doi.org/10.5343/bms.2018.0052.

Marshall, Heather, Lyndsay Field, Achankeng Afiadata, Chugey Sepulveda, Gregory Skomal, and Diego Bernal. 2012. "Hematological Indicators of Stress in Longline-Captured Sharks." *Comparative Biochemistry and Physiology. Part A, Molecular & Integrative Physiology* 162 (2): 121–29. https://doi.org/10.1016/j.cbpa.2012.02.008.

Musyl, Michael K., and Eric L. Gilman. 2018. "Post-Release Fishing Mortality of Blue (Prionace Glauca) and Silky Shark (Carcharhinus Falciformes) from a Palauan-Based Commercial Longline Fishery." *Reviews in Fish Biology and Fisheries* 28 (3): 567–86. https://doi.org/10.1007/s11160-018-9517-2.

Oliver, Shelby, Matias Braccini, Stephen J. Newman, and Euan S. Harvey. 2015. "Global Patterns in the Bycatch of Sharks and Rays." *Marine Policy* 54: 86–97.

https://doi.org/10.1016/j.marpol.2014.12.017.

Poisson, François, John D Filmalter, Anne-Lise Vernet, and Laurent Dagorn. 2014. “Mortality Rate of Silky Sharks (Carcharhinus Falciformis) Caught in the Tropical Tuna Purse Seine Fishery in the Indian Ocean.” *Canadian Journal of Fisheries and Aquatic Sciences* 71 (6): 795–98. https://doi.org/10.1139/cjfas-2013-0561.

R Core Team (2019). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

Rice, Joel, and Shelton Harley. 2012. “Stock assessment of oceanic whitetip sharks in the western and central Pacific Ocean. SA-WP-06, Eighth Regular Session of the Scientific Committee of the Western Central Pacific Fisheries Commission. Busan, Korea.”

Tolotti, Mariana Travassos, Pascal Bach, Fábio Hazin, Paulo Travassos, and Laurent Dagorn. 2015. “Vulnerability of the Oceanic Whitetip Shark to Pelagic Longline Fisheries.” *PLoS ONE* 10 (10): 1–17. https://doi.org/10.1371/journal.pone.0141396.

Walsh, William A, Keith A Bigelow, and Karen L Sender. 2009. “Decreases in Shark Catches and Mortality in the Hawaii-Based Longline Fishery as Documented by Fishery Observers.” *Marine and Coastal Fisheries* 1: 270–82. https://doi.org/10.1577/C09-003.1.

Walsh, William A, and Shelley C Clarke. 2011. “William A. Walsh 2,” no. July.

Worm, Boris, Brendal Davis, Lisa Kettemer, Christine a. Ward-Paige, Demian Chapman, Michael R. Heithaus, Steven T. Kessel, and Samuel H. Gruber. 2013. “Global Catches, Exploitation Rates, and Rebuilding Options for Sharks.” *Marine Policy* 40 (July): 194–204. https://doi.org/10.1016/j.marpol.2012.12.034.

Table 1. Shark Condition Codes and Criteria

Condition Codes	Definition
D = Dead	Animal showed no signs of life. This code is also the **default** condition when an animal's disposition cannot be established
AI = Alive but injured	Animal was alive but there was clear evidence of serious injury. The serious injury category is met when **ONE OR MORE** of the following injury criteria exists: **1)** the hook has been swallowed (e.g. the bend of the hook is not in the tissue surrounding the jaw but has been ingested posterior to the esophageal sphincter or deeper), **2)** bleeding is seen from the vent and/or gills, **3)** stomach is everted (please specify in comments), or **4)** other damage (e.g. depredation, entangled in gear) occurred prior to hook/gear removal.
AG = Alive in good condition	Animal appears lively and healthy with no obvious signs of injury or lethargy (animal should appear active). This condition code is used when **ALL** of the following criteria are observed and met: **1)** no bleeding, **2)** shark is lively and actively swimming, **3)** not upside down and/or sinking, **4)** no external injury, **5)** not hooked in the esophagus, stomach or the gills.
A = Alive	Animal was observed to exhibit signs of life, but its level of activity or injury could not be established or the criteria for the AG or AI codes are not met. This code is the **default** for any **live** animals that could not be further categorized for any reason including the animal was too far away to discern whether or not the AG or AI criteria were met.

Table 2. Handling methods used to release sharks in both HiDS and AS during shark research trips.

Handling & Damage Codes Used	Proportion
Line Cut	93.22%
Escaped	3.01%
Jaw Damage	1.78%
Gear Removed	1.36%
Other	0.463%
Part Removal†	0.172%

†Part removal indicates a tail-hooked thresher that had a portion of the tail removed to recover the embedded hook.

Table 3. Potential explanatory variables for the Cox models to test effect on survival.

Variable	Levels, definitions & issues
Species	BSH, BTH, FAL, OCS (FAL excluded)
Fishery	HiDS, AS (Only OCS were tagged in both fisheries)
Catch Condition	AG, A, AI, D
Release Condition	AG, A, AI, D
Handling Code	Line Cut or Gear Removed
Approximate Length	Estimated (animals tagged in water)
Trailing Gear	Length of gear left on the animal
Ratio of trailing gear to body length	TG / Approximate length
Sex	M, F, U (Most were unsexed)

Table 4. Survivorship PAT results.

Shark Species	**Condition**	**Line Cut**		**Gear Removed**		**Usable Tags**	**Survival rate (LC & GR)**
		Survivor	Mortality	Survivor	Mortality		
Blue	AG	13 (92.9%)	3^2	10 (90.9%)	1*	25	**92%**
	A	7 (77.8%)	3^1	-	-	9	
	AI	4 (66.7%)	2	-	-	6	
Bigeye Thresher	AG	18 $_{[1]}$ (94.7 %)	$5^{4}_{[1*]}$	$3_{[3]}$ (60%)	$2_{[2]}$	24	**87.5%**
Oceanic Whitetip	AG	19 (95%)	2^1	3 (75%)	2^1	24	**91.7%**
	A	3 (75%)	1	1 (50%)	1	6	**66.7%**
	AI	1	-	-	-	1	
Silky	AG	25 (100%)	1^1	4 (100%)	0	29	**100%**
Total Tagged		90	17	21	6		
Tags Removed		0	9	0	1		
Totals		90	8	21	5	124	**89.5%**
Survival rate (AG)		**96.2%**		**83.3%**			**93.1%**

In parentheses are the proportion of tagged animals that survived to 30 days or when the tag came off. Numbers in superscripts indicate the number of tags that were removed from survivorship analysis due to either tag manufacturer malfunction or due to tagger influence. An additional two tags are also not included here, due to attachment failures on day 1 on a BSH and a FAL. BTH that were tail-hooked are shown as subscripts in brackets.

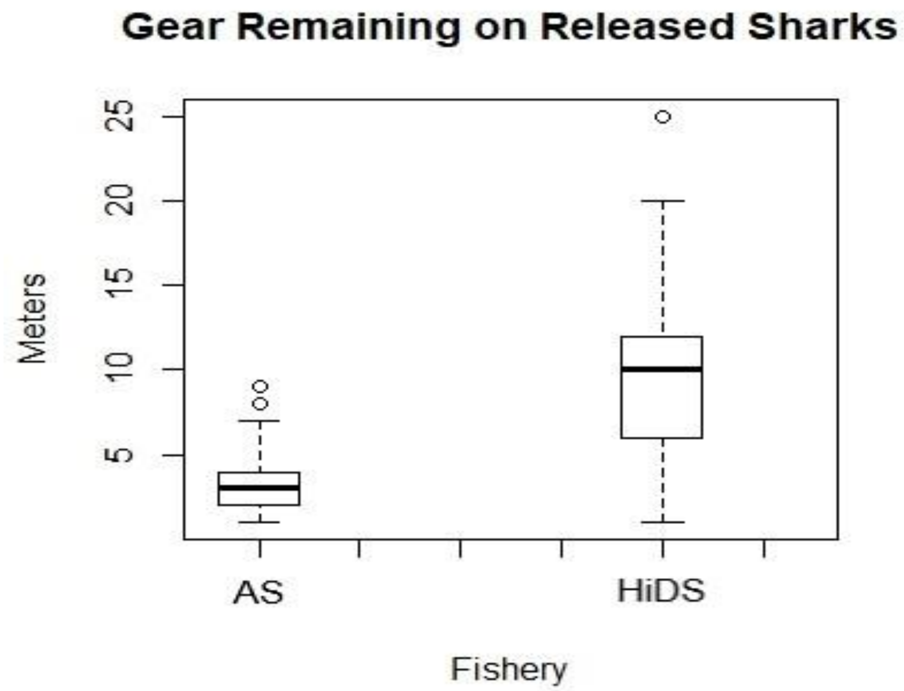

Figure 1. Range in length of trailing gear estimated to remain on sharks discarded in the American Samoa (AS) and Hawaii Deep-set (HiDS) tuna longline fisheries.

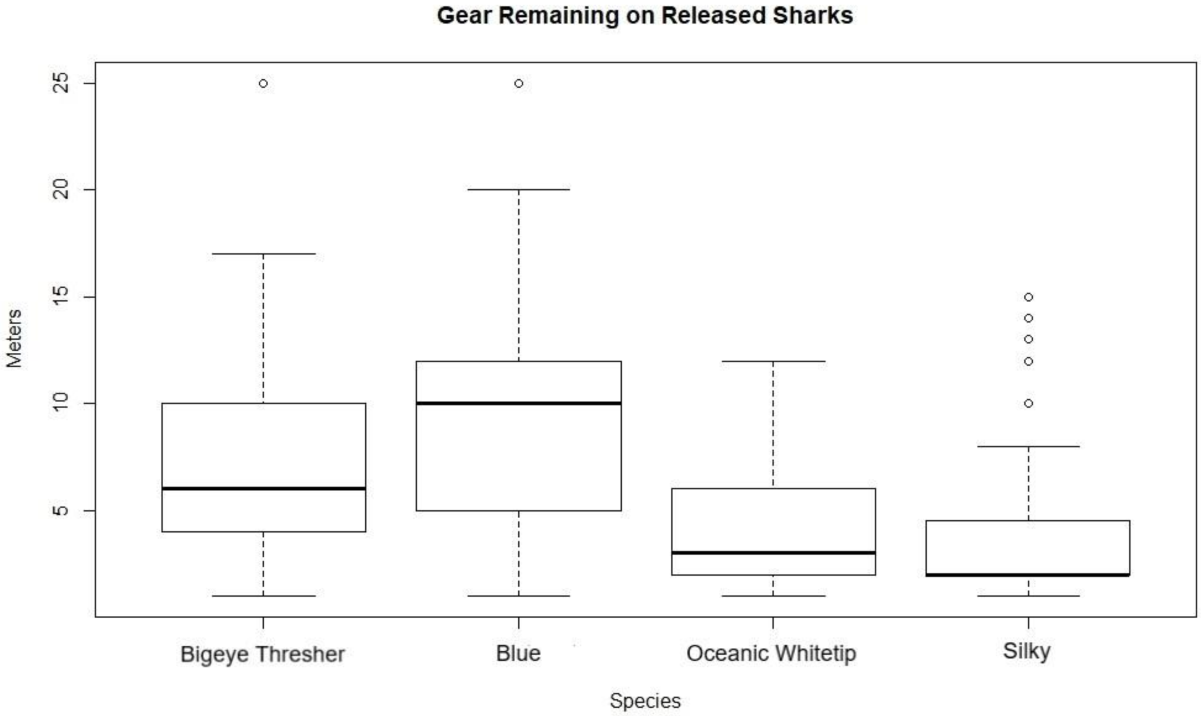

Figure 2. Length of trailing gear estimated to remain on shark species commonly discarded in both the American Samoa (AS) and Hawaii Deep-set (HiDS) tuna longline fisheries combined.

Table 5. Results of long-term survival assessments of blue sharks released by cutting the line from vessel in the Hawaii Deep-set longline sector. Trailing gear from the hook includes; 0.5 m stainless steel braided wire leaders to a 45-gram weighted swivel to the monofilament branchline of varying lengths as recorded in the trailing gear column below.

BSH ID	Tag Fate	Days	Trailing gear (m)	Approx fork length (ft.)
16P1632	Mortality	15	14	6
16P1603	Survivor	180	10	5
16P1604	Mortality	87	6	5
16P1633	Survivor	312	4	7
16P1607	Mortality	1	11	7
16P1606	Eaten	28	11	8
16P1630	Non-reporter	NA	1	7
16P1602	Mortality	114	17	8
16P1639	Mortality	1	4	4
16P1635	Mortality	1	12	5
16P1378	Non-reporter	NA	13	7
16P1379	Mortality	188	13	7

Table 6. Shark condition proportions at haul back for blue (BSH), bigeye thresher (BTH), silky (FAL) and oceanic whitetip (OCS) sharks for all research trips in both tuna longline fisheries.

Species	Alive in Good Condition	Alive	Alive but Injured	Dead
BSH	65.0%	23.1%	5.1%	7.0%
BTH	50.7%	14.6%	5.7%	28.9%
FAL	58.4%	3.8%	2.0%	35.8%
OCS	54.6%	6.6%	5.2%	33.6%

Table 7. Results of Cox Proportional Hazard models to test the effect of variables on survival for the tagging data set. The least informative variables were removed by stepwise backward removal using an AIC criterion. The retained variables are indicated at the top of the table, and removed variables are shown in the lower part of the table along with the improvement in the AIC criterion that resulted from their removal.

Retained variables:			AIC	N
Release condition, TrailinGear			148.78	92
Removed variables:			Delat AIC	
snood.ratio			1.22	
Apx.length			1.89	
Species			3.03	
Caught_cond			3.47	