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Assessing shark bycatch condition and the effects of discard practices in the Hawaii-permitted tuna longline fishery

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Abstract

The incidental capture of sharks in commercial fisheries targeting tuna and billfish is having a negative impact on pelagic shark populations. Recently, studies have shown that some shark species captured in longline and purse seine fisheries may sustain high levels of post-release mortality due to injuries resulting from the fishing interaction. Researchers have identified the three main factors that lead to mortality in sharks; 1) the physiology of the species where some are more susceptible to the lethal effects of stress, 2) the duration of the interaction, and 3) the methods used to release the animal. In this study and in collaboration with the Pacific Islands Regional Observer Program (PIROP), we are assessing the handling and discard practices used in the Hawaii and American Samoa-permitted tuna longline fisheries and their effects on the release condition and survivability of sharks with newly established condition criteria and handling codes that are recorded by at-sea observers. Post-release survival rates are estimated through the use of pop-off archival satellite tags (SPAT, Wildlife Computers Inc.). PIROP observers were trained in the use of the new shark-focused condition and handling codes and on methods of deploying satellite tags on sharks over the rail of longline vessels while the sharks are in the water and prior to discard. In this way we will quantitatively assess total fishery mortality and identify the best handling practices for maximizing post-release survival for sharks discarded at sea.

Introduction

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 Hawaii and American Samoa longline fisheries interact with several shark species, most of which are of low commercial value and are subsequently discarded. The highest catch rates in these fisheries consist of blue sharks (*Prionace glauca*), thresher (*Alopias spp.*), mako (*Isurus spp.*), oceanic whitetip (*Carcharhinus longimanus*) and silky sharks (*C. falciformis*), respectively (Walsh et al., 2009). Blue sharks comprise the largest component (80%) of the total shark catch and in 2012; the Hawaii

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longline fleet caught 51,856 blue sharks, 99% of which were discarded at sea. A satellite telemetry study on blue sharks in the Atlantic Ocean found discard (or delayed) mortality was 19% for animals that were released 'alive' (Campana et al., 2009). This source of fishing mortality is largely unaccounted for and may have implications for stock assessments.

Globally many pelagic shark populations are reported to be in decline. In the western and central Pacific Ocean, stock assessments for both oceanic whitetip and silky sharks concluded both populations are currently in decline, overfished, and found that overfishing is currently occurring (Rice & Harley, 2012; Rice & Harley, 2013). Oceanic whitetip sharks are now listed in Appendix II of the Convention on International Trade in Endangered Species (CITES) and the subject of a full extinction risk assessment by the United States' National Marine Fisheries Service while thresher sharks were assessed for risk of extinction last year (Young et al. 2016). Due to these population declines, several of the regional fisheries management organizations (RFMOs) have responded with a series of conservation and management measures (CMMs) for sharks. Within the Western and Central Pacific Fisheries Commission (WCPFC) convention area several of these 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 retention may not reduce mortality as much as intended, since many sharks at haul back and/or during the handling procedures to release them incur physiological and/or physical damage that results in mortality (Tolotti et al., 2015).

There is a general consensus among shark and fishery scientists that three main factors 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 struggling on the line, and 3) shark handling methods used to release/remove sharks from fishing gear. Many studies have identified species that are most sensitive to capture stress through physiological investigations and by quantifying at-vessel mortality rates (e.g. Beerkircher et al., 2002; Marshall et al., 2012). However, shark-handling effects on condition and post-release fate have never been quantified for commercial longline vessels targeting tuna. In this study we are investigating the effects of the most common shark bycatch handling practices utilized in the Hawaii and American Samoa tuna longline fisheries on release condition as recorded by observers and the post-release fate of discarded sharks with satellite tags. In collaboration with the Pacific Islands Regional Observer Program (PIROP), we have developed and tested new condition and handling codes and trained observers in their use

Table 1. Shark-caught 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.

in a small 'shark focus study'. These observers are also placing satellite tags on discarded sharks to elucidate post-release survival rates. This project will identify handling practices that have the largest effect on release condition and post-release survival rates for sharks that were in good condition prior to being discarded. In addition, by identifying the "best" shark handling practices that maximize post-release survival probabilities we can then produce guidelines that will be easily implemented into current fishing practices.

Objectives and Methods

Research Objectives

With this study we aim to fill several data gaps to reveal the post-release fate of discarded sharks and determine which handling methods maximize survival rates for four of the RFMO's key shark species; blue (BSH), bigeye thresher (BTH), oceanic whitetip (OCS) and silky (FAL) sharks. Our four main objectives are:

Objective 1: Create new data codes to collect additional information on shark bycatch at-vessel and release conditions, the methods used to dispatch them and any injuries that may have been incurred in the process in a 'Shark Focus Study'.

Objective 2: Quantify post-release survival rates for BSH, BTH, OCS, FAL sharks that are in good condition at the vessel using pop-off archival satellite tags (PAT).

Objective 3: Identify the shark bycatch handling and release methods that maximize post-release survival.

Objective 4: Produce outreach materials including a 'best practices' handling and discard methods handbook for distribution to industry, managers, conservationists and stakeholders.

Table 2. Handling and damage code definitions.

ES = Escaped	Shark/ray freed itself (e.g. throws the hook, breaks the line or becomes disentangled from the gear).
LC = Line Cut	Shark/ray is released by the crew cutting any portion of the branchline. In the comments please specify the quantity and type of gear **still attached to the animal**. For example, if the line is cut below the weight and swivel note the length of leader left attached in feet (e.g. 7 feet). If the branchline is cut above the weight or swivel please specify that in the comments (e.g. leader, weight, 3 feet of branchline).
SL = Shark Line	At the fish door of the vessel the shark is attached to a short line which lifts the animal to the cutout to remove the hook. They may lift the shark and drop it so that the hook tears out or lift the shark and cut the hook out. Many fishers will cut the lip to remove the hook. If they must cut the jaw please use the CO code to describe that both a shark line (SL) was used and that the jaw was damaged (JW).
DL = Drag Line Employed	If the shark/ray is connected to a long line at the stern of the vessel and dragged until the line breaks, the hook becomes dislodged or the shark comes off the line. Please record in the comments sections if there are portions of jaw still attached to the hook when it is retrieved or the animal is drug for a long period of time record the time.
JW = Jaw Damaged	Anytime a shark/ray's jaw is cut or damaged to remove the gear. This would include sharks/rays whose jaws are removed in part or wholly or if the shark's jaw is cut to remove hook.
PR = Part Removal	If any part of a shark/ray other than the jaw is cut or removed to retrieve the gear. This would include partial or complete removal of any portion of a fin, tail, spine or other body part. Tail hooked Thresher sharks that get their tails (any portion of it) cut off, and stingrays that get their "stingers" cut off are common examples covered by this code. If a shark/ray disposition is undetermined, the default Release code for this handling method is AI.
DH = Dehooker Removed Gear	This code is only used when a dehooking device successfully removes the gear from a shark/ray without the use of any other handling methods.
OT = Other	This code is only used when the handling technique you wish to describe is not covered by any other code, and must be accompanied by comments describing the situation (e.g. a bang stick, firearms).
CO = Comment	This code is used when there is more than one code that needs to be employed to describe either the damage and/or handling situation.
DN = Disposition Not Observed	Use this code when you did not see the dispatch and or handling methods used to remove the shark from the gear.

Shark Focus Study

In an effort to address shark CMMs and to encourage the live release of incidental sharks in the longline fishery, Pacific Islands Fisheries Science Center (PIFSC) scientists and the PIROP developed and tested additional data collection codes for at sea observers to record for shark interactions beginning in April 2015. Previously, the catch condition recorded for sharks was either alive or dead and return condition was recorded as alive, dead or kept. With the new codes we are attempting to gain a more comprehensive picture of the at-vessel condition and how the handling and discard methods affect release condition. Table 1 defines the catch-and-release condition codes and Table 2 outlines the new handling and injury codes. During the summer of 2015 these codes were tested and refined during nine trips where observers used GoPro videos to record the interaction and assess their comprehension and the clarity of the code definitions. In January of 2016, the Shark Focus Study was implemented and observers trained in the use of the codes (Tables 1–2) now record the additional data during their trips.

Tagging Study

Shark survival and best handling practices will be verified through the use of ‘survival’ pop-off archival tags (SPAT; Wildlife Computers Inc. Redmond, WA.). The tags include an external guillotine device to sever the connection to the leader at a depth of 1800 m. The post-release fate is determined using transmitted depth records obtained when the tags come off and float to the surface. A tag that goes to 1800 m would indicate a dead shark that is sinking in the water column. If the transmitted data shows that a tag sat at a constant depth for 3 consecutive days that is also considered to be consistent with a dead animal on the seafloor. If the tag goes to the full deployment period of 30 days then pops up and reports data contrary to these situations, then the animal is considered to have survived the fishing interaction and post-release period.

NMFS Pacific Island Region Observers deploy the SPATs on sharks captured during normal fishing operations. We will compare the two methods of shark handling most commonly used in the longline fishery: **1. Cut the line** - this method leaves different amounts of trailing gear attached to the shark. **2. Gear removal** - the shark is brought onboard (via various techniques) or to the fish door and the hook or a portion of the gear is removed. Satellite tags are placed on candidate sharks by observers trained in shark tagging over the rail of the vessel while the shark is still in the water with the use of a long tagging pole (Figure 1). Vessel crew, then remove the shark from the fishing gear via whichever release methods they typically employ (Table 2). Observers also record additional data fields specific to the tagging event and give 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, time to release, etc.). Due to the cost-limiting factor in satellite tagging studies only sharks that are alive and in good condition (AG) at haul-back are tag candidates. In this way we can produce best case scenario estimates of survival. Twenty-eight tags have been allocated for each species where 14 are placed on sharks released with the line cut and 14 are placed on sharks where the vessel removes the gear. Blue, bigeye thresher and oceanic whitetip sharks are being tagged in the deep-set (tuna target) sector of the Honolulu based fishery and silky sharks are tagged during tuna trips operating from American Samoa.

Results and Expected Outcomes

Observer trainings on the use of the data codes and on tagging techniques began in January 2016. Three trainings have been conducted, two for Honolulu-based observers and one in Pago Pago for those in American Samoa. As of July 15, 31 shark focus study trips have been debriefed where the additional codes have been used. Observers have been deployed with tags on 24 trips and 22 vessels are voluntarily participating in the study. At present, 29 tags have reported data, 4 tags are presumably still on sharks and 18 tags are at sea with observers (Table 3). It is too early in the study to make any inferences regarding survival rates or best handling practices.

Each vessel utilizes different means of discarding unwanted shark bycatch. Of the release methods that have been identified, cutting the branch line that a shark is caught on is the most widespread technique in both the Hawaii and American Samoa-based longline fisheries. This method leaves different amounts of trailing gear still attached to the animal, where the fishers typically cut the line as soon as they ascertain it is a shark which is often very close to the snap (red x in Fig. 2). In the deep set sector of the Hawaii longline fishery, branch lines are typically constructed of monofilament and are an average of 12.5 m long, interrupted by a 45 gm weighted

Figure 1. Image from an observer placing an SPAT on a blue shark over the rail of a longline vessel during a deep-set tuna trip.

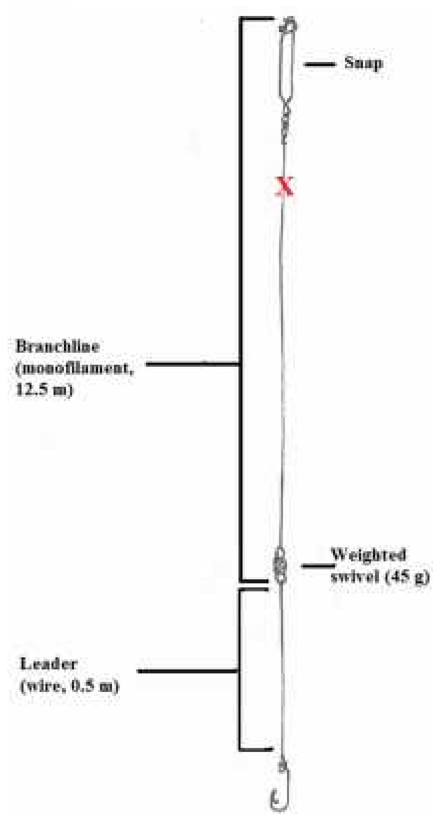
Table 3. Tag deployments on sharks in 'AG' condition and results to date.

Shark Species	Line Cut		Gear Removed		*in situ*	Total
	S	M	S	M		
Blue	8	1	3	0	4	16[1]
Bigeye thresher	7	3	2	0	0	12
Silky	1	1	0	0	0	2
Oceanic whitetip	0	1	1	0	0	2
Tags at sea						18
Totals	16	6	6	0	4	51

[1]One of the tags on a blue shark (included in the total) was shed early and the post-release fate cannot be determined. Tags that are '*in situ*' are tags currently on sharks where 'tags at sea' are tags that have been sent on longline trips with observers for deployment.

swivel and a 0.5 m braided wire leader connected to a stainless steel circle hook (Figure 2). Trailing gear poses an entanglement hazard, is energetically costly and the embedded hook can also pose a health hazard thereby reducing long-term survival and overall fitness for a population. In the Atlantic, 3% of recaptured blue sharks were found with retained hooks and the lesions produced by the hooks were severe, including oesophageal perforation and partial obstruction, gastric perforation, necrotizing and proliferative gastritis and peritonitis, hepatic laceration with hepatitis and secondary bacterial infections (Borucinska et al., 2002).

Figure 2. Branchline diagram.



The post-release mortality rates of discarded sharks are largely unknown, unaccounted for and may have large implications for stock assessments. This study will generate robust estimates of discard and post-release mortality rates for BSH, BTH, OCS and FAL that are in good condition prior to being discarded in tuna longline fisheries and may enhance fishing mortality estimates utilized by data providers and stock assessment scientists. Data generated in this study may also improve stock assessment models as methods to incorporate discard survival parameters and tag-integrated assessment models are developed (e.g. Carvalho et al. 2015, Goethel et al. 2015).

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