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The Post-release Condition of FAD Associated Silky Sharks (Carcharhinus falciformis) Caught in Tuna Purse Seine Gear

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The post-release survival of FAD associated silky sharks (*Carcharhinus falciformis*) caught in tuna purse seine gear

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Abstract

Silky sharks (*Carcharhinus falciformis*) are frequently caught in tuna purse seines set around fish aggregating devices (FADs). During a recent Bycatch Mitigation Research Cruise in the western central Pacific Ocean (WCPO) sponsored by the International Seafood Sustainabiligy Foundation (ISSF) we were able to characterize the frequency of capture and size frequency characteristics of silky sharks caught on drifting FADs and conduct experiments to assess the post-release survival of sharks released at various stages of the fishing operation. We used a combination of Pop-off satellite archival tags (PSATs) and acoustic and conventional I.D. tags to assess behavior and post-release survival. In addition, we took blood samples for analysis of various biochemical stress indicators that can be used to aid in interpretation of the post-release survival results. To establish baseline blood gas, metabolite and stress hormone levels, some sharks were caught, sampled and tagged prior to the onset of purse seine fishing operations or while still free swimming inside the net. These baseline levels can now be compared with the blood chemistry of sharks caught and released at different stages of the fishing operation. During the 31 sets of the cruise, we interacted with a total of 295 silky sharks, deployed 28 satellite tags and took blood samples from 86 sharks caught during various stages of the fishing operation. Here, we present the preliminary findings of the survival rates of a sub-set of silky sharks released with "survival Pop-off archival tags" (SPATs). Initial results indicate that sharks released in excellent condition and those that are landed early in the fishing operations have increased survival rates post-release.

Introduction

The tropical tuna fisheries of the western and central Pacific Ocean (WCPO) account for 60% of the global tuna landing and the bulk of these WCPO landings are landed by purse seine fishing on fish aggregating devices (FADs). FAD-based fisheries are currently under scrutiny because of concerns about the by-catch of sharks, non-target finfish and undersized tuna. To investigate the options for the possible mitigation of some of these by-catch issues, a research cruise was chartered by the International Seafood Sustainability Foundation (ISSF) aboard a commercial tuna purse seine vessel in the WCPO. The cruise had several objectives relating to by-catch mitigation. One of these objectives was to investigate ways of reducing the capture of sharks and of optimizing the survival of sharks captured during fishing operations. Many of these experiments are still ongoing or are in the process of data analysis. Here we present preliminary results of analysis of frequency of occurrence and size-frequency distribution of sharks encountered during the cruise and the survival success of a sub-set of sharks released after being equipped with pop-up satellite tags specifically formatted to assess post-release survival.

Silky sharks (*Carcharhinus falciformis*) comprise a significant component of the non-target catch in this fishery. This factor combined with declining trends in the catch rates and sizes of sharks landed in purse seine and longline fisheries (Clarke, 2011), points to a need for further assessment of the impacts that FAD fishing has on the population of this species. To address these concerns the silky shark catch composition was recorded and release condition and post release survival rates were assessed using a combination of blood physiology, satellite and sonic tagging technologies.

Materials and Methods

The ISSF chartered research cruise aboard the tuna purse seine fishing vessel, Cape Finisterre took place from May 22nd through July 1st 2012 in the WCPO. Fishing and tagging operations took place within the Exclusive Economic Zones (EEZs) of Tokelau, Tuvalu, Kiribati (Phoenix Islands) and the adjacent high seas pocket. During the research cruise 31 tuna purse seine sets targeting skipjack tuna (*Katsuwonus pelamis*) were conducted (Fig. 1). Sharks that were caught during these sets were tagged with a combination of satellite and conventional ID tags. Blood samples were also obtained for analysis of biochemical stress compounds. In order to establish

baseline levels of blood biochemistry and to release some sharks that were exposed to a minimal amount of handling, some sharks were captured using dip nets or baited hooks prior to onset of fishing or while they were still free swimming inside the net. Sharks targeted for tag and release were placed upside down in a padded cradle and irrigated with running seawater during blood sampling and attachment of tags.

Three different satellite tag types, Pop-off Archival Tags ((PAT) Microwave Telemetry Inc. Columbia, MD.), miniPAT and survival PAT or SPATs (Wildlife Computers Inc., Redmond, WA.) were externally attached to the dorsal musculature of candidate sharks. The results reported here are from a sub-set of 15 sharks that were tagged with pop-up satellite tags that were specifically designed to report on the post-release survival of the sharks. These "survival" PATs transmit a summary of the daily maximum and minimum depths and temperatures and light levels experienced by the sharks. They are programmed to transmit if the tag floats (e.g., due to attachment failure) or if the animal dies and sinks to depths greater than 1600 meters or dies and remains on the ocean floor at a constant depth. If both these cases, the tag automatically releases from the dead animal, floats to the surface and transmits its summary. These tag are pre-programmed to release from the animal after a maximum of 30 days.

Blood was taken via caudal venipuncture from sharks to quantify blood concentrations of key physiological indicators known to correlate with stress and post release mortality in other shark species; lactate, blood pH, hematocrit, glucose, heat shock protein 70 (*hsp* 70) and corticosteroids (e.g. Moyes et al., 2006; Hight et al., 2007; Heberer et al. 2010). Blood gases and chemistry were tested after collection using a portable automated blood chemistry analyzer from I-STAT. Packed Cell Volume (hematocrit) was quantified using the StatSpin hematocrit rotor and centrifuge. A 2 mL whole blood subsample was centrifuged at 10,000 g for 6 minutes to separate plasma from red blood cells and stored at -20°C for later analysis of stress hormone levels and heat shock protein expression. These assays will be conducted later in the core facility at the Hawaii Institute of Marine Biology.

Upon release all animals were observed to determine their 'release condition'. A release condition of 'Excellent (4)' was recorded for animals that swam away rapidly without any obvious signs of distress or physical trauma. Sharks released in 'Good (3)' condition swam away well but may have appeared slower or disoriented. A 'Fair (2)' condition was assigned to sharks

whose swimming appeared laborious and exhibited visible signs of trauma. Sharks in 'Poor (1)' condition were able to right themselves and made efforts to swim, while sharks released in 'Dead (0)' condition sank upside down.

Results

Results from this cruise are still being compiled, several satellite tags are still deployed or are still reporting and blood analyses are ongoing. Thus, the scope of this paper must be limited to analysis of catch composition and condition of the sharks and the post-release survival data acquired from the SPATs.

A total of 295 silky sharks (*Carcharhinus falciformis*) and one oceanic whitetip shark (*Carcharhinus longimanus*) were caught during 31 purse seine fishing sets or prior to setting on FADs during pre-assessment surveys. The sex ratio for silky sharks was 1.14 males for every female. The largest proportion of the animals were landed during the brailing phase (n = 242, Table 1). Of these sharks, 200 were released in poor condition or judged to be dead. Of the 37 sharks that were gilled in the net and landed early in the operation, 24 were released in excellent condition and 5, 2, 1 and 3 were released in good, fair, poor and dead condition respectively (Table 1).

During 6 sets we fished for sharks inside the net while they were still free swimming. Seven sharks were caught during these fishing events using hook and line gear. Each shark was released outside the cork line with a combination of blood draws and tag types (Table 2). Sharks were also caught on FADs that were fished during pre-assessment surveys of species composition and during acoustic tagging events. Ten silky sharks were caught during 4 of these events using handlines and dipnets from the workboat and were tagged with a combination of tag types and blood draws (Table 2). Three of these sharks were also implanted with acoustic tags (denoted by an * in Table 2). Twenty-nine satellite tags were deployed including 15 Survival PATs, 11 miniPATs (Wildlife Computers Inc.) and 3 MT PATs (Microwave Telemetry Inc.) and blood was drawn from 87 sharks caught during the various stages of the fishing operations (Table 2).

To date, data have been acquired from 14 of the 15 SPATs deployed. Initial inspection of the SPAT data indicates a strong correlation between survival duration and the condition of the animals at release (Table 3). Blood chemistry data are still being analyzed but initial results

show a wide range of levels of various stress-related compounds with an apparent positive correlation between the amount of stress–related compounds present and the amount of time elapsed since onset of fishing.

All of the sharks that were caught during this cruise were juveniles (average total length = 113.5 cm). Sharks were assigned to age classes according to age and total length values available in the literature (e.g. Oshitani et al., 2003; Joung et al., 2008). Thirty-eight of the sharks (13.4% of the catch) were neonates and had open or visible umbilical scars. Thirty-five percent of the sharks were 1 year olds (n = 99), 40.7% were age 2 (n = 115), 10.3% were 3 year olds (n = 29) and 2 sharks were age 4 (0.71%) (Fig. 2). Age at reproductive maturity is reached after age 9 for both sexes (Joung et al., 2008).

There were significant differences found between the numbers of sharks reported as discards by the vessel's crew and those that were sampled by the scientific team (Wilcoxon signed rank test; n = 31, V = 10.5, *p*-value = 4.477e-05; Fig. 3). These differences warrant further investigation into more accurate estimation and reporting of shark bycatch by commercial vessels.

Discussion

Visual inspection of the condition of the captured sharks indicates that once brailing begins, the condition of the sharks significantly deteriorates. All sharks that were released in excellent condition were either free swimming or were gilled in the net during the earliest stages of net retrieval. All of the sharks sampled on this cruise were juveniles or sub-adults and their small size may exacerbate the decline in condition with increased handling.

To date, 14 of the 15 deployed SPATs have provided data regarding the post-release survival of the sharks. These results indicate that the SPAT technology is appropriate and cost-effective for this type of post-release survival experiment. Our tags revealed that post release survival rates in purse seine captured silky sharks are correlated with the condition of the sharks at release which in turn is correlated with the stage in the fishing operations when the shark was landed. That is, animals that were landed while still free swimming or early in the fishing operations (i.e. gilled in the net) were released in better condition than sharks landed during the brailing stages. Initial analysis of the results shows that animals that swam away in good or excellent condition had the greatest probability of survival beyond 20 days. We found 100% survival of more than 20 days

in sharks tagged with SPATs and released in 'excellent condition'. These results indicate that a key component in reducing shark mortality will be developing practices that maximize the condition of the animals when they are released. Avoiding exposing sharks to the brailing process seems central to improving their survival.

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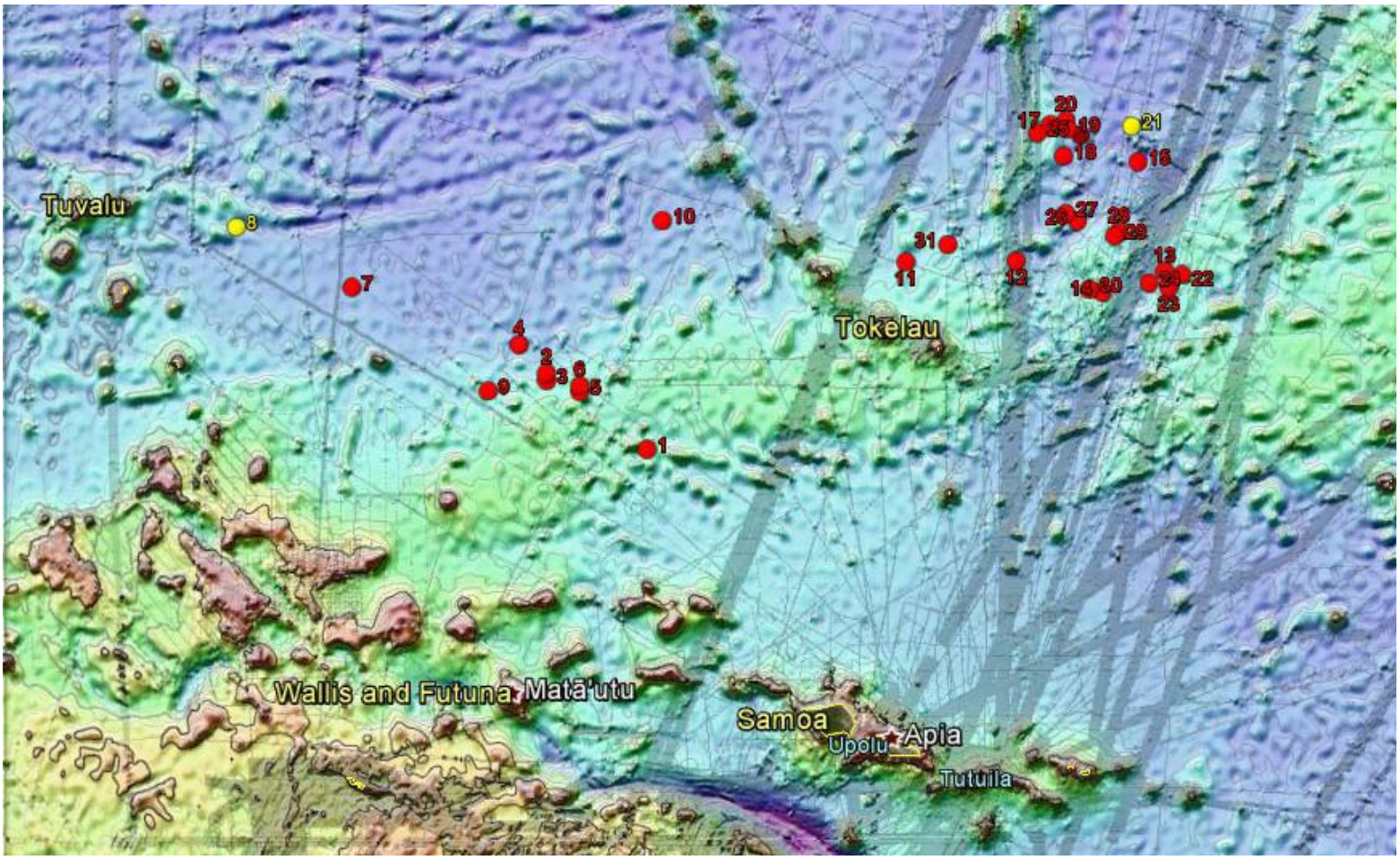

Figure 1. Map of set locations and set numbers on drifting FADs in the WCPO (in red), and locations of sets on free schools (in yellow). No sharks were caught on the free school sets.

Release condition of sharks landed during each stage of fishing ops								
Release Condition	Pre-Assessment of FAD	Inside the Net	Gilled in the Net	First Brail	Later Brail	Spill	Wet Deck	Total
Excellent (4)	9	6	24	0	0	0	0	39
Good (3)	1	0	5	1	9	0	0	16
Fair (2)	0	1	3	5	12	0	0	21
Poor (1)	0	0	1	7	25	0	2	35
Dead (0)	0	0	3	14	142	4	2	165
Unknown	0	0	1	3	15	0	1	20
Total	10	7	37	30	203	4	5	296

Table 1. The release condition of each shark caught during the course of the research cruise is shown according to the stage in the fishing operations in which it was landed.

Sharks tagged and/or blood drawn by stage of fishing ops						
Tag Types	Pre-Assessment of FAD	Inside the Net	Gilled in the Net	First Brail	Later Brail	Total
Survival PAT	1 (1)	2 (0)	5 (4)	6 (4)	1 (1)	15
MiniPAT	3** (0)	2 (0)	6 (5)	0	0	11
MT PAT	0	0	2 (2)	0	1 (1)	3
Blood Drawn	6*	3	9	15	36	69
Total for each stage	10	7	22	21	38	98

Table 2. Sharks tagged and/or blood drawn by stage of fishing operations. Numbers in parentheses indicate the number of animals tagged that also had blood drawn. Each * symbolizes a shark that was also implanted with an acoustic tag.

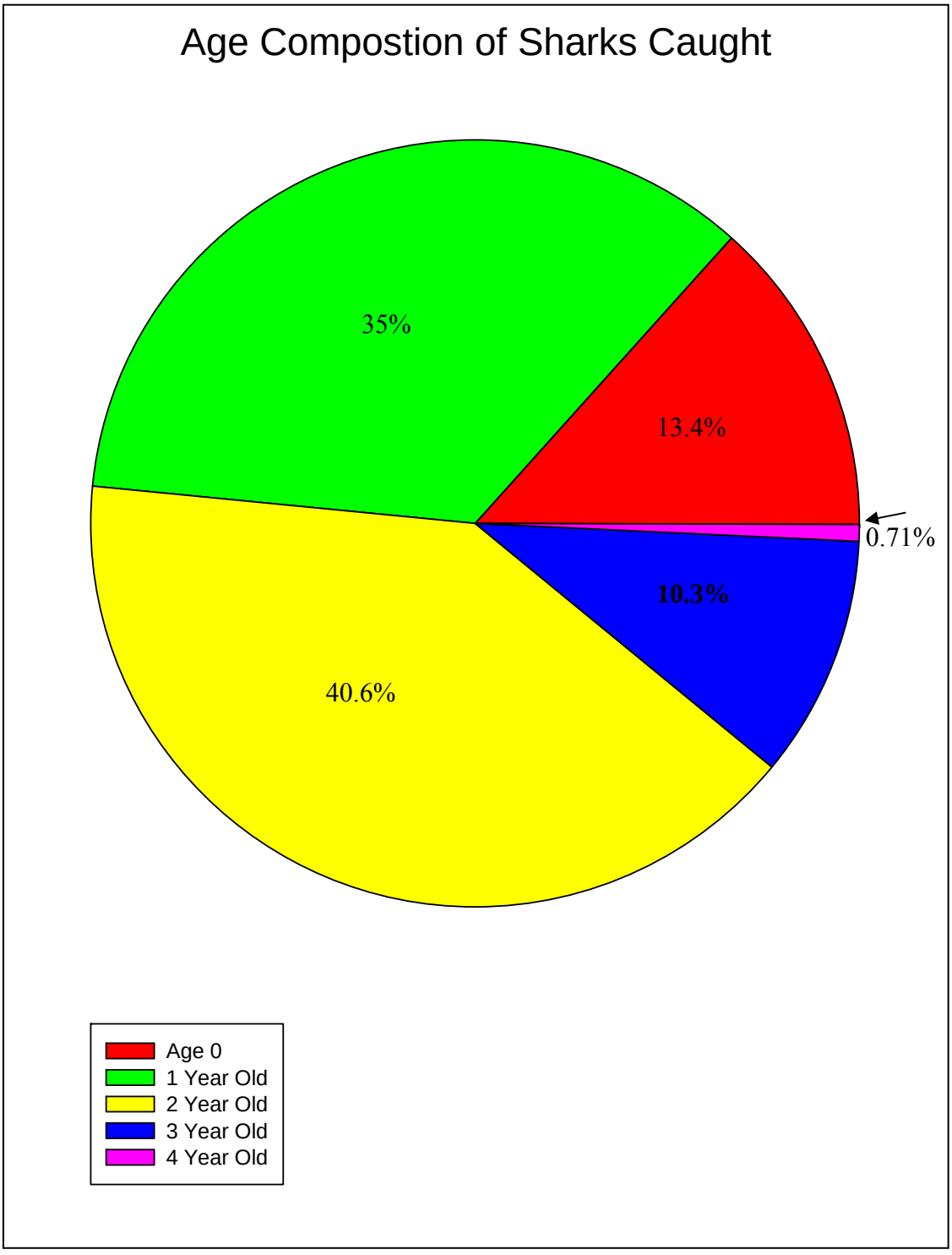

Figure 2. Age composition of all silky sharks measured. Ages were derived using the total length of sharks and correlated to age values available in the literature.

Release Condition	Animals Released with SPATs	Survival: ≤ 1 Day	Survival: 1 ≤ 10 Days	Survival: 10 ≤ 20 Days	Survival: 20 ≤ 30 Days
Excellent (4)	6	0	0	0	6 (100%)
Good (3)	1	0	0	1 (100%)	0
Fair (2)	2	1 (50%)	0	0	1* (50%)
Poor (1)	3	3 (100%)	0	0	0
Dead (0)	3	3 (100%)	0	0	0

Table 3. The release condition and survival times of all sharks tagged with Survival Pop-off Archival Tags (SPATs). (The * denotes a tag that is still deployed at the time of publication).

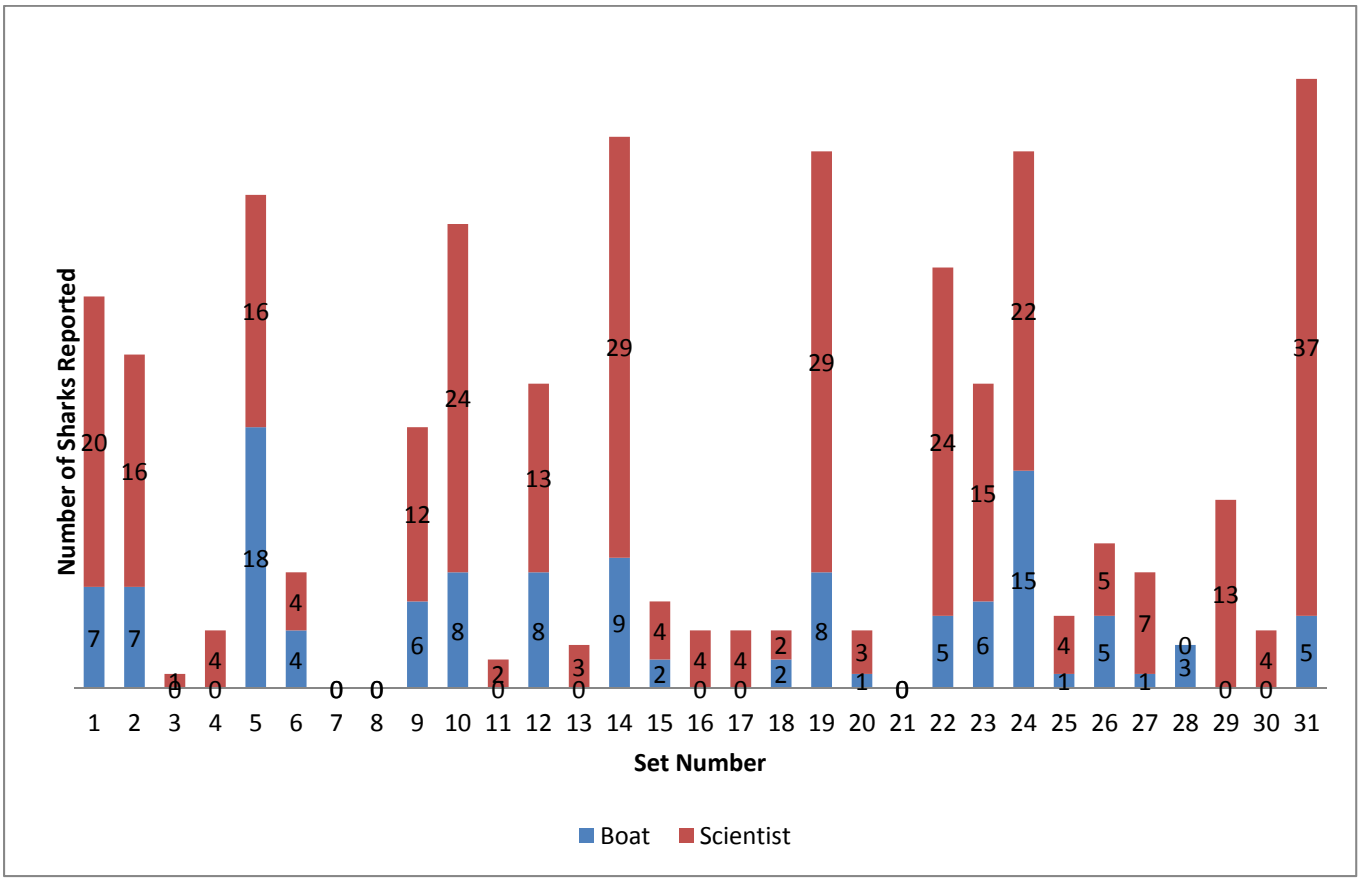

Figure 3. The number of sharks reported as caught by the boat (in blue) compared to those observed by the scientific party (red) for each set.