



PROJECT
Sustainable Management of Tuna Fisheries
and Biodiversity Conservation in the ABNJ

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REDUCING ECOSYSTEM IMPACTS OF TUNA FISHING

Report of the Expert Workshop on Shark Post-Release Mortality Tagging Studies

REVIEW OF BEST PRACTICE AND SURVEY DESIGN

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PROCEEDINGS





Seeking to generate a catalytic change, the *Global sustainable fisheries management and biodiversity conservation in the Areas Beyond National Jurisdiction Program* was approved by the Global Environment Facility (GEF) under the lead of the Food and Agriculture Organization of the United Nations (FAO) in close collaboration with two other GEF agencies, the United Nations Environment Programme (UNEP) and the World Bank, as well as other partners.

Focusing on tuna and deep-sea fisheries, in parallel with the conservation of biodiversity, the ABNJ Program aims to promote efficient and sustainable management of fisheries resources and biodiversity conservation in ABNJ to achieve the global targets agreed in international fora.

The five-year ABNJ Program is an innovative, unique and comprehensive initiative working with a variety of partners. It consists of four projects that bring together governments, regional management bodies, civil society, the private sector, academia and industry to work towards ensuring the sustainable use and conservation of ABNJ biodiversity and ecosystem services.



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1 Introduction

The purpose of fisheries management is to control the mortality rates of exploited populations within sustainable, or otherwise acceptable, limits. Proper fishery management thus requires that the mortality due to fishing activities be accurately estimated and taken into account in population status assessments and management measures. Mortality due to fishing activities has long been synonymous with catch but there is a growing recognition that catch statistics, particularly those representing landed catch, may greatly under-represent the actual number of fish removed from the current and future stock. This is especially true for fishes such as sharks which may be discarded (whole or in part) or released in large numbers either because of regulations or lack of market demand. In many cases, discarded or released sharks are often not enumerated at all; if they are enumerated there is often no record of their condition; and even if there is a record of their condition that condition may not be a reliable predictor of their survival. As a result, there is considerable uncertainty about the number of sharks killed through fishing activities and this uncertainty leads to a lack of clarity in defining and refining shark conservation and management.

The Areas Beyond National Jurisdiction (ABNJ, or Common Oceans) Tuna Project is a Global Environment Facility (GEF)-funded, FAO-implemented programme of work designed to encourage and reinforce sustainable tuna fisheries. The ABNJ Tuna Project addresses a number of aspects of global tuna fisheries including supporting a systematic application of a precautionary and ecosystem-based approach to management, reducing illegal fishing and improving compliance, and mitigating adverse impacts of bycatch on biodiversity. Under the third component, the Western and Central Pacific Fisheries Commission (WCPFC) is leading work on shark data improvement, shark assessment and management, and bycatch mitigation. The need for better estimates of mortality for sharks in tuna fisheries cuts across each of these themes. Therefore, in addition to working toward improving the data collected by fishers and observers, the ABNJ Tuna Project has identified that tagging studies designed to quantify the survival of discarded/released sharks are required to provide critical new inputs for assessment and mitigation studies. In particular, such studies will assist in evaluating whether existing WCPFC conservation and management measures (CMMs) prohibiting retention of all oceanic whitetip (*Carcharhinus longimanus*, OCS), silky (*C. falciformis*, FAL) and whale (*Rhincodon typus*, RHN) sharks are effective in reducing mortality and conserving these shark stocks. In support of such work, the European Union (EU) recently granted WCPFC additional funding for shark post-release mortality (PRM) tagging studies.

In order to design a shark PRM tagging study having optimal scientific rigor, cost-effectiveness and consistency with past and ongoing studies, the WCPFC, in partnership with the Pacific Community (SPC) decided to convene an expert workshop to advise on these issues. The goal of the exercise was to provide a set of scientifically robust and practical protocols for shark PRM studies in general, as well as a specific design for the ABNJ- and EU-funded work which addresses the technical objectives and can be achieved with the available budget and timeframe. A workshop format was proposed in order to take full advantage of existing experience with PRM studies across species and fisheries, thereby avoiding common mistakes and duplication and maximizing the value of available resources. The workshop was announced in September 2016 under WCPFC Circular 2016/51 which called for nominations of scientists with direct experience in the subject and/or an affiliation with WCPFC member countries.

The National Institute of Water and Atmospheric Research (NIWA) of New Zealand graciously offered to host the workshop at its facilities at Greta Point, Wellington. Experts representing six WCPFC member countries, two non-governmental organizations with WCPFC observer status, a

number of academic and technical experts, and representatives of WCPFC, SPC and the Inter-American Tropical Tuna Commission (IATTC) convened for the workshop from 21-24 January 2017 (**Annex A**). The workshop was chaired by Neville Smith of SPC and rapporteured by Shelley Clarke of WCPFC. The report represents the record of the meeting and was agreed by participants on the final day of the workshop and finalized through circulation.

In opening remarks the Chair noted that the objective of the workshop is to advise on proposed studies of survival rates for promptly discarded sharks caught by WCPFC fisheries. These studies should assist in evaluating the effectiveness of WCPFC no-retention measures and in better estimating fishing mortality in assessments. The Chair also noted that to achieve this, PRM estimates must reflect actual fishery practices, not best practices for handling sharks that maximize survival. If the PRM estimates resulting from this study are of concern, then a recommendation arising from this work could be to improve onboard handling by fishers through education and/or monitoring. In other words, this workshop seeks to advise on how to study PRM; estimating PRM will be a future exercise once the data from this study become available. The output of this workshop is intended to provide the basis for a protocol to conduct the WCPFC studies and assist with design of future PRM studies.

2 Context and Design Issues

2.1 Background and Objectives

S. Clarke (WCPFC) provided an opening presentation on the background and objectives to the WCPFC's shark PRM studies as follows:

The ABNJ Tuna Project is a five-year project slated to end in December 2018, therefore all studies must be completed and reported by that date. Although the ABNJ Tuna Project has provided a budget of \$250,000 to the WCPFC for shark PRM work, all funding is designed to be used for tag costs with no separate allocation for vessels, fuel or other logistical support for the study. Furthermore, there are no dedicated funds for reporting of the results, although Dr Clarke in her role as Technical Coordinator-Sharks and Bycatch as well as SPC as a partner in the ABNJ Tuna Project are able to assist in some capacity with the completion of the study. There is also the potential to devote the last of four workshops under the bycatch mitigation component of the project to estimating shark PRM rates from the data obtained through the tagging study. It was noted that in addition to the ABNJ Tuna Project funding, the WCPFC recently received a grant from the European Union in the amount of €400,000 for shark PRM studies. Although the requirements of the two funding sources are slightly different, the idea is to use them in a synergistic manner to understand shark PRM and its implications for mitigation measures, e.g. no-retention measures, and population status assessments. The major difference in the two funding sources is that the EU funding is prioritized for tagging silky and oceanic whitetip sharks, with a secondary priority on thresher and porbeagle sharks, whereas the ABNJ Tuna Project funding can be used to fund PRM tagging of any WCPFC key shark species. The EU funding provides for three dedicated tagging technicians to embark on three trips each on commercial fishing vessels in order to apply tags purchased by either funder. In addition to advising on the technical specifications of tags to be used, Dr Clarke highlighted that one of the main issues to be discussed in the workshop is the allocation of samples (i.e. tags) across species and fleets, noting that depending on which criteria are prioritized different allocations could result. The importance of looking ahead to using the data to derive estimates that are useful for management was also emphasized.

In discussion, participants noted that although it has not been included in the budget, there may be a need to compensate vessels for fish lost due to the study. It was clarified that the budget has some flexibility in it, particularly for the operational costs of getting tags on sharks. Participants also noted that the dual objectives of the project, i.e. providing advice on no-retention measures and for stock assessment, might argue for slightly different design factors.

2.2 Keynote Addresses on Setting the Scene

The workshop began with two keynote presentations providing context for specific sampling design work planned for later in the week. The first keynote presentation was given by F. Poisson (IFREMER) containing an overview of existing studies and the key uncertainties. The author provided the following summary of the presentation:

The mortality of discarded fish bycatch is an important issue in fisheries management of commercial stocks and species of conservation concern. Discard mortality rates in specific fisheries are rarely known. The presentation reviewed the various approaches that have been used to examine the post-release mortality (PRM), and to investigate the fate of elasmobranchs after their release after capture. Four main approaches were considered:

survival tanks, laboratory studies, electronic tagging, blood chemistry; the advantages and the drawbacks of each approach were presented. There has been an increased use of electronic tags to better understand and quantify PRM, especially for larger pelagic sharks. Discard survival varies with a range of biological attributes (species, size, sex) as well as the range of factors associated with capture (e.g. gear type, soak time, catch mass and composition, handling practices and the degree of exposure to air and any associated change in ambient temperature). Key uncertainties remain when scientists want to estimate the discard survival including: Over what period should any observed mortality be attributed to the original capture process? Can we really assess a shark's condition with the naked eye? How can we assess the long term physiological traumas which can affect the feeding and swimming behaviour, growth, the immune system or reproductive biology?

It was noted that conservative assumptions about the magnitude of PRM might have the opposite effect when entered into a stock assessment model (e.g. high release mortality implies higher productivity). Participants discussed the duration of the tagging experiment and whether long-term mortalities represented fishing-related mortality or natural mortality. Participants were referred to a useful paper by Benoit et al. (2015) simulating the effect of various levels of fishing and natural mortality, including delayed mortality onset. A total length of 80-120 cm was considered a reasonable minimum size for attaching popup tags to sharks, but the appropriate value may depend on the species.

S. Campana (University of Iceland) made a keynote presentation on PRM and its relevance for shark management for which he provided the following summary:

PSAT tagging studies demonstrate that shortfin mako, porbeagle and blue shark range widely across many national boundaries in the North Atlantic, but spend up to 92% of their time on the high seas, where they are caught and discarded in large numbers by swordfish and tuna fishing fleets from a large number of nations. Discarded sharks which die after release cause huge problems for stock assessment and management, since they represent unrecorded fishing mortality whose absence will bias perceptions of stock status, fishing mortality, biomass, recruitment and sustainable yield. Post-release mortality (PRM) becomes increasingly important as the scale of discarding increases; discard rates approach 100% for blue shark. Discards are particularly problematic in Atlantic high seas fisheries, since discards are not monitored and there are no shark allocations or mortality limits by country. Incorporation of PRM estimates into the stock assessment would allow more realistic estimates of sustainable yield and biological reference points. National allocations of high seas shark mortality (landings plus hooking and post-release mortality) are possible if sustainable yield is pro-rated based on national catch allocations of tuna and swordfish. Improvements in the assessment and management of large pelagic sharks are possible if catch and discard reporting in high seas fisheries could be enforced across all member countries, hooking and PRM were to be incorporated into the stock assessments, and international observers could be present on 10% of the high seas fleet.

Discussion centred around the types of data that need to be collected, and how those data can be used in a stock assessment. It was noted that viable assessments are required in order to use the PRM estimates. However, some Pacific shark stock assessments are already available (though not necessarily accepted), and others are underway, and they will ultimately be able to use the estimates gathered in the planned PRM study. Reported landings should be validated with observer data, and the extent of under-reporting, if any, estimated.

2.3 Information on Tag Types

M. Francis (NIWA) and K. Schaefer (IATTC) collaborated to provide a review of tag types and their advantages and disadvantages. The authors summarized their presentation in the following abstract and in *Table 1*:

Four manufacturers produce popup satellite archival tags that could be used for experimental estimation of post-release mortality (PRM): Wildlife Computers (WC), Microwave Telemetry (MT), Lotek (LO) and Desert Star (DS). The advantages and disadvantages of these tags were tabulated and compared. The cheapest tag (DS, SEA-TAG LOT) lacks a depth sensor and relies on temperature gradients to infer mortality, and it is not clear whether a tag on a sinking, dead shark would activate its emergency release quickly enough to prevent crushing of the tag. Poor performance of DS tags mean that they are not a good candidate for this study. LO PSATLIFE tags are relatively new to the market and have little track record from which to judge their performance. Furthermore, they have no emergency depth-related release mechanism that would activate for a sinking, dead shark. Hence the LO tag is not suitable for estimating PRM mortality. The WC sPAT tag and the MT high rate x-tag are suitable for estimating mortality and these manufacturers' products have relatively good performance histories. The WC sPAT is less than 60% of the price of the MT x-tag when taking into account the associated costs of Argos transmission fees and tethers (\$US2000 versus ca. \$US3500). The x-tag archives depth and temperature data at 5 min intervals, but the sPAT only provides daily minimum and maximum depth and temperature. Future sPAT development will add archiving capability but that feature is at least six months away for confirming mortality events. The sPAT has a depth-activated emergency release set at 1750 m, and the x-tag has one set at 1250 m; the latter may be too shallow if any of the target species normally dive to such depths. Other features of the two tags are similar. Four different tether materials and three main anchor types (with two sizes for two of the anchors) are commonly available, but there is little information on the relative performances of these. Coating or painting of the tag to prevent biofouling needs to be considered, but there is no information on the efficacy of these methods.

Table 1. Comparison of selected tag types considered by the workshop.

Brand	Wildlife Computers	Wildlife Computers	Microwave Telemetry	Lotek	Desert Star
Model	sPAT	miniPAT	High rate x-tag	PSATLIFE	SEA-TAG LOT
Price (\$US)	2000	3950	3600	1950	1347 (incl 20% for tag replacement)
Discount	None	3750 (50-99 units); 3550 (100+ units)	3200 for 25+ units	1755 for 50-99 units, 1658 for > 100 units	1247 for 50-249 units
Duration	30 days. Due 6-12 months: user programmable to 45 and 60 days	Unlimited but durations > 9 months are rarely achieved	30 days	14, 28, 56 days	User-determined. Can be set at the factory, or user-set but the latter requires 'starter kit' of PC, docking station and software
Argos fees included	Y	N	N	N	Y (1 month post-release)
Tether included	Y (3 anchor options)	Y	N	Y	N
Auto deploy	Y	Y	Y	Y	Y
Weight in air	60	60	40	89	42
Length	125	124	121	125	178
Inferred mortality	Depth > 1700 m; tag at constant depth > 24 hr; no light change	User responsibility from raw data provided	User responsibility from raw data provided	User responsibility from raw data provided	Low temp gradient for specified number of days (shark dead on sea floor or floating at the surface), low temp exposure (shark in water colder than expected), period of darkness (in deep water/under an obstruction / caught and in a hold)
Emergency release	Depth > 1700 m; tag at constant depth > 24 hr	Depth > 1800 m; tag at constant depth > specified time	> 1250 m, 4 days at constant depth (customisable?)	3 days constant depth (customisable). No max depth release but rated to 2000m and would likely operate to 3000 m	Constant depth (based on temp gradient); minimum temp for specified time (e.g. < 10 deg for 30 mins)
Data available	Daily min/max depth, min/max temp, light change (yes/no). Due 6-12 months: time series depth data at 10 min intervals	Geolocation, depth and temp time series and histograms	Time series of depth, light and temperature at 5 min intervals	Time series of depth and temperature at 5 mins. Daily min/max depth, min/max temp, light, geolocation processed onboard	Geolocations, light, min/max/mean temperature, max temp rate. Reason for release. No depth.
Other	NEW VERSION IN 6-12 MONTHS: Should allow for reward payment (e.g. \$100-200) if tag is returned, as can download full high-res archived data. May get 1 tag in 5 returned? Pinger for radio tracking of tag after pop-up but unlikely to be useful in large open spaces (range ~ 2 km). Time cost in fitting tracks. GPE3 track in WC Portal low cost; UKFSST fitting high cost.	Should allow for reward payment (e.g. \$100-200) if tag is returned, as can download full high-res archived data. May get 1 tag in 5 returned? Pinger for radio tracking of tag after pop-up but unlikely to be useful in large open spaces (range ~ 2 km). Time cost in fitting tracks. GPE3 track in WC Portal low cost; UKFSST fitting high cost.		Dummy tags for testing \$350; price of dummy tags applied to purchase of functional tags. Max depth release 1-2 years away from production. Mortalities in deepwater will not report and rate will be biased low.	Solar powered (no battery), average transmission duration 5 months. Mortalities in deepwater may not report if sink rate exceeds min temp response rate and mortality rate will be biased low. SEATAG-3D records depth and transmits time series; emergency release at 1850 m. ~\$2200 per unit for > 50 tags. 210 mm long x 60 g weight

Workshop participants agreed that a popup satellite archival tag was required to estimate PRM, and that a 30-day deployment period was a minimum to cover the expected period of fishery mortality. Wildlife Computers (WC) and Microwave Telemetry (MT) have established a good track record in tag performance, but Lotek (LO) and Desert Star (DS) are new on the scene with less experience. DS tags are the cheapest and include Argos time, but have had a high failure rate and are not currently recommended. WC's sPAT tag is undergoing development and will have additional features within 6-12 months, including user-programmed deployment period up to 60 days. Tag weight and length are not major issues. Hydrodynamic drag is more important. A surprisingly high proportion of tags are eaten by other predators (presumably either bitten off the shark or when floating at the surface). DS SEA-TAG LOT has no depth sensor, and uses temperature to infer immobility/death. It will pop up if it detects a large temperature gradient (e.g. 10 degrees in 30 min) but the tag might be crushed by then. Geolocation is available from DS. Another DS tag, SEATAG-3D, is like the WC miniPAT and has a depth sensor but is quite a big tag. The LO PSATLIFE tag has a major limitation in not having an emergency depth release to prevent a tag being crushed when a dead shark sinks into deep water.

Literature meta-analyses of tag failures indicate that WC and MT popup tags have been improving through time. Although no analysis was available for the last five years, tag failure is expected to be less than 10%. Premature release, usually through anchor or tether failure, or tag predation, is likely to exceed 50% but this is not considered a significant problem for the shorter deployments (30-60 days) used for PRM studies. Most tag loss occurs 6-12 months after tagging.

The group briefly discussed the variety of tag tethers, anchors, tag hydrodynamics, tag insertion location on the shark, ancillary use of photo-identification, and disinfection of tags and tagging gear but deferred these topics until later in the workshop.

It was suggested that the WC mark-report tag might be suitable for PRM estimation, but it lacks a depth sensor and provides only temperature data and popup location, and is not much cheaper than an sPAT.

2.4 Shark Stress and Implications for Post Release Mortality Studies

D. Bernal (University of Massachusetts) described developments in the field of shark physiology and their implications for understanding PRM in a presentation he summarized as follows:

Research on fishing-related stress indicates that the post-release survival of sharks captured with commercial longline (both pelagic and demersal) and purse seine, and with recreational gear may be impaired due to significant physiological disruptions related to the capture event. The magnitude of the stress response in sharks is both species-specific and gear-specific, but there is growing evidence that there is a direct correlation between time on the line (i.e. degree of struggle) and post-release mortality. Recent work using shark blood taken at the time of capture shows that the values for some ions (e.g., sodium, chloride, magnesium, calcium, potassium) and metabolites (e.g., glucose, lactate) significantly change with time-on-the-line and are elevated when compared to values taken from relatively unstressed specimens during captive studies. There is increasing evidence that the level of several stress markers (e.g., magnesium, potassium, lactate) measured in the blood of sharks at the time of capture may be indicative of whole-animal physiological condition and may be used as predictors of post-release mortality. However, these relationships are complex and each shark species presents a unique suite of capture-related physiological stress response. For example, while some shark species (i.e. dusky sharks) captured in demersal longline gear show a large

physiological stress response after 3-5 hours on the line and have both a high at-vessel and post release mortality, other closely related species (i.e. sandbar sharks) captured on the same gear show little signs of physiological stress, even after 12 hrs on the line. In summary, the growing understanding of shark physiology suggests that post-release mortality, both immediate and delayed (weeks to months later), may to be tightly linked to the nature, severity, and duration of the stress imposed, as well as the metabolic capacity of the species and its ability to recover from the capture event. These latter attributes vary widely between shark species and even between closely related taxa. For these reasons, there is a critical need for the assessment of species-specific physiological responses to capture stress with the aim of decreasing the impacts of any fishery interaction and aiding in more sustainable fisheries.

In the discussion it was clarified that apparent inter-annual variability for silky sharks in purse seine nets is related to set size; that in turn translates into time spent in the sack. Shark size is also important but most samples are from the same age cohort and so size-related variability is difficult to assess. Potassium is an important indicator of elevated mortality risk but whether it has a direct affect is unknown; studies to test this by injecting potassium into live sharks have not been done because of lack of funding. The results of experiments suggest that fight time for sharks such as threshers should be limited in sport fisheries. To avoid sample degradation, working with blood is the best option, and samples should be immediately frozen or processed.

2.5 Assessing Shark Condition

M. Hutchinson (NOAA-Joint Institute of Marine and Atmospheric Research, University of Hawaii) provided an overview of practices for assessing shark condition based on a review of the literature and her own research. She summarized her presentation as follows:

Most studies have found that species, interaction time and type (fishery specific), sea surface temperature (SST), sex and size are related to condition at release and PRM. Behavioural and physical indicators of condition were better predictors of fate than reflex impairment or reflex action mortality predictors (RAMP). There was consistent agreement across studies that swimming activity at the vessel and at release, whether or not there were external signs of injury and the hooking location, when taken together, were excellent predictors of PRM rates. A previous study on PRM rates of juvenile silky sharks captured in the WCPO tuna purse seine fishery showed that condition codes correlate to lactate concentrations and could be used to predict mortality rates for all sharks encountered during the survey. Sharks that were landed through the brailing operation had 92.2% mortality. An ongoing condition, handling and PRM tagging study being conducted in the Hawaii and American Samoa based tuna longline fisheries and carried out by trained NMFS observers on commercial trips was also described. Key findings to date are that most sharks are discarded by cutting the line leaving a range of 0.3 to 15 meters still attached to the animal, including a wire leader and 45 gram weighted swivel. Despite several issues with tags provided by the manufacturer they show high survivorship for all shark species (blue, bigeye thresher, oceanic whitetip and silky) for all sharks that were released in good condition. It was recommended to consider the fishery, database restrictions – ease of implementation, clarity to reduce subjectivity, generality for comparative purposes, validation of PRM rates by condition index with PSATs, and recording of trailing gear when designing and applying condition indices. The following factors were considered important when assessing shark survival: species specific physiology, interaction time (on a line, in a net, time in air), handling/dispatch methods, SST, sex, size, release location, hook location; physical condition (at capture and release), activity level (at capture and release), and quantity of trailing gear. It was also recommended to agree on, in advance,

definitions for at-vessel mortality and post-release mortality as well as quantify any thresholds, for example for high and low survivorship.

Participants discussed that they usually aim to take blood from untagged sharks, and vice versa. In the Hutchinson study many animals were in such poor condition that the blood taking likely had a null effect. Hutchinson noted that validating blood levels through the use of satellite tags in a subsample was necessary when determining survival thresholds in blood chemistry parameters. In longline fisheries, assessing shark condition visually is difficult as they are often not brought on deck, and the observer only sees them for a few seconds. Sharks are classified as being in “good” condition if they are seen to be swimming, active with no external signs of injury, and are not foul-hooked. Sharks are classified as alive when signs of life are present or they do not meet the criteria for alive and in good condition or alive but injured (see **Annex B** for the codes being used). Experiments are planned on oceanic whitetip sharks to examine the effect of trailing gear and leader material. The amount of leader left on the shark is determined by subtracting the length of leader left attached after cutting off the shark from the original leader length. Problems were experienced with some tags sinking when they had an RD1800 tether-severing device, but this problem has been overcome with the development of a new emergency depth release in the nose-cone of WC tags. Studies should consider three mortality sources: at-vessel mortality, handling mortality and PRM mortality, although many studies don’t account for handling mortality or consider it minimal.

2.6 Statistical Issues

An introduction to important issues to consider in the statistical design of fish survival studies was presented by A. Dunn (New Zealand Ministry of Primary Industries (MPI)) and T. Peatman (SPC) and summarized by the authors as follows:

Sharks caught in longlines or purse seiner commercial fisheries are often discarded and released, and are likely to suffer trauma and hence mortality. However, any PRM of animals released alive is usually unseen and unobserved. Methods that allow quantification of the PRM of sharks are often difficult to undertake and expensive. Hence, there is a need to ensure that the information content of experimental effort and funds is maximised by using optimal experimental designs. In general, when conducting an experiment we should be explicit about the parameters we are trying to measure; determine the sample size required to ensure that we have a high chance of measuring the parameter to the required precision; and identify the confounding and correlated variables that we need to account for to ensure we do not bias the answer. Existing estimates of shark mortality (e.g. Ellis et al. (2016) appear to vary across vessels, gear types, location (spatially), seasonally, by onboard handling practice, and by species. This would suggest that a single point estimate is unlikely to be sufficient for estimating PRM across an entire fishery. In general, previous studies have estimated PRM using either (i) a measure of total mortality at the end of some observations period (for example one month), and assuming zero mortality thereafter; or (ii) using observations of the time of mortality for individuals to estimate survival using survival analyses. Survival analyses provide a more powerful method for both analysing changes in survival over time and evaluating the differences between explanatory factors (e.g. gear, handling practice, condition at release) on survival. An important aspect of the design is the sample size of the experiment. Small sample sizes make inference uncertain as confidence intervals are large. For example, assume that we sampled 10 animals ($n=10$) and 2 die, the point estimate of PRM would be 20% mortality. And the 95% confidence intervals from the low sample size are extremely wide, in this case 3% to 56%. Increasing the sample size improves the precision, for example with

n=100, and PRM=20%, then the 95% CIs are 13-30%; and with n=1000, and PRM=20%, then the 95% CIs are 18-22%. Additional factors (e.g. gear, handling practice, condition at release) will result in an increase in sample size to achieve the same power. We conclude that power analyses should be used to assess sample size requirements in the design of these studies, especially as resources are limited and tags are expensive to purchase and deploy. Simulation studies can assist in determining the best or optimal sampling designs for a given experimental question and limited resources.

The group discussed the conflict between achieving adequate sample sizes and the high cost of tags. Stratification of the sampling design is important but many factors can influence PRM and including many strata will excessively reduce sample size within strata.

2.7 Integrating with Commercial Fishing Operations

K. Schaefer (IATTC) provided a presentation on integrating a shark tagging experiment for estimation of PRM with commercial longline fishing operations in the Eastern Tropical Pacific which he summarized as follows:

Pelagic longline vessels authorized by the Inter-American Tropical Tuna Commission (IATTC) to fish in the eastern Tropical Pacific Ocean (ETP) consist of 1,106 distant water longline vessels (21-59 m) from China, European Union (EU), Japan, Korea, and Taiwan, 159 vessels (9-47 m) from Mexico, 884 vessels (4-92 m) from central America (Belize, Costa Rica, Guatemala, Nicaragua, Panama and El Salvador), 53 vessels (17-57 m) from Ecuador, and 159 vessels (6-30 m) from the United States. Silky sharks are the predominant species of shark captured by those fleets when operating in the ETP, and the vast majority are caught by Mexican and Central American fleets. The EU solicited and funded a proposal by IATTC to investigate the post-release mortality of silky sharks captured by commercial longline vessels operating in the ETP and the International Seafood Sustainability Foundation (ISSF) also provided financial and in kind support. Initial logistical steps for setting up the ETP silky shark tagging program included: 1) Establishing favorable relations with scientists working on sharks in countries of interest, 2) obtaining cooperation from the Chief Administrators of the National Fisheries Agency of that country, 3) confirming in-country observers or scientific staff available to go to sea on vessels to conduct tagging activities, 4) developing memorandums of understanding (MOUs) with the National Fisheries Agency regarding details of the agreement pertaining to tagging activities and responsibilities of each party. Issues addressed with national longline fishing association(s) and Owners/Captains of longline vessels included: 1) Convince manager(s) to cooperate with the project, 2) determine the commercial value for silky sharks caught and landed, and then determine an acceptable amount to provide as a financial incentive to the Owner/Captain for each shark tagged and released, 3) request the in-country collaborating scientist meet with captains of suitable vessels to discuss the project, and seek their cooperation to allow the tagging to take place by an observer/scientist during commercial trips. Training and materials were provided to observers/scientists who would be doing the tagging, including: a) shark species identification guide, b) tag release data sheets and instructions, c) operation and instructions of digital camera for recording each shark tagging event, d) tagging applicator usage, and anchor placement instructions, and e) a sufficient financial reward to the observer/scientist for each shark properly tagged along with all required data fields completed, and photographs and/or video of the tagging event recorded. The experimental design included deploying 34 Wildlife Computers (WC) miniPATs. MiniPATs were chosen over sPATs for evaluating potential delayed mortality beyond 30 d, and obtaining additional useful information on movements. 17 miniPATs are intended to be

deployed from domestic longline vessels operating out of Puntarenas, Costa Rica, and 17 from those operating out of Manta, Ecuador by trained observers/scientists from those countries. Five or six miniPATs are to be deployed on silky sharks during any given longline fishing trip. Only sharks between 125 to 175 cm fork length, classified as alive in good condition at the time they are landed will be tagged. No more than three silky sharks captured during a single longline set will be tagged. WC provided miniPATs rigged with tethers and anchors, which included their small titanium anchor and 300 lb braided stainless wire, and crimped connections. All sharks will be brought aboard the vessels for tagging to ensure: 1) proper tag attachments, 2) removal of hooks and/or the gangion, 3) accurate length measurement, sex determination, and evaluations of condition when landed and released. The sharks are to be tagged and released as quickly as possible, preferably less than 3 minutes from the time they are landed on deck. A shark tag/release data form was designed to be completed with all relevant information surrounding the capture, tagging, and release of each specimen. Survival or mortality events are determined by using the depth and temperature records transmitted from miniPATs and received through Argos.

In discussion, K. Schaefer clarified that development of MOUs between IATTC and collaborating partners, and other critical logistical considerations, took several months in advance of when the tagging experiments were initiated. Financial compensation to the longline vessel owner and/or captain for their assistance in tagging and releasing sharks during commercial trips is recommended. Sharks were tagged on board longline vessels, assuming that is how they would be handled by fishermen who attempt to retrieve their hooks and leaders before release of sharks. This handling method also ensured proper anchor/tag attachments, accurate length measurements, and sex and condition determinations.

The current IATTC conservation measure for silky sharks (C-16-06) states there should be no retention by purse seine vessels, and for longline vessels (which do not have national licenses to target sharks) retained catches of silky sharks should not exceed 20% of the total weight of the landed catch. One participant voiced concern about only tagging sharks which are alive and in good condition when aiming to estimate PRM as such estimates may be used inappropriately by managers.

B. Leroy (SPC) presented a comparable view of PRM tagging studies from commercial vessels in the Western and Central Pacific Ocean which he summarized as follows:

This presentation attempted to highlight Pacific countries where shark tagging experiments could be implemented with some efficiency. The observer coverage is not uniform and the number of hooks observed allow identifying Fiji as a Pacific island country to target with 19% observer coverage (as of 2015). Also the Fiji longline fleet encompasses many different types of longline vessels, some of which are equipped with an e-monitoring system along with an observer. Other countries of higher interest for this study are American Samoa, Australia, Cook Islands, Hawaii, New Zealand and French Polynesia due to their CPUE of shark species of interest and the quality of their observer programmes. The presentation also emphasized the importance of tagging under “in situ” conditions, with observers trained “in real conditions” during longline sets onboard a commercial vessel or appropriate training vessel. Tags deployed with a combination of dedicated tagging technicians and properly-trained observers, if possible onboard vessels equipped with an EM system, was suggested as a possible plan.

E-monitoring is considered very beneficial and participants wondered if that should be a pre-requisite for a tagging vessel. Head-mounted GoPro cameras (or similar) would be even better

ways of documenting tagging events. Small vessels have difficulty taking technicians onboard, and the group discussed the advantages of having the skipper deploy tags instead of observers. Some skippers have proven very helpful and competent. At-sea training is considered highly desirable, whether the tagger is a technician or skipper. ISSF is developing a training video and it will be available for this project, but that is no substitute for live training.

3 Experience from Past and Current Studies

3.1 Characterizing Longline Fishing Fleets in the Western and Central Pacific Ocean

T. Peatman (SPC) provided a brief summary of WCPFC longline fisheries based on raised logsheet and observer data held by SPC from 2010 to 2015 as follows:

Total flag-specific longline catch and effort was presented. China, Japan, Korea, Chinese Taipei and the EU member states accounted for the majority of total longline effort for the time period covered. Although these countries in most cases have existing observer coverage at some level, none of these national observer data are provided to WCPFC or SPC. For the remaining flags, maps of nominal catch rates were used to identify regions where key shark species have frequently been caught, using observer data. Additionally, logsheet and observer data were used to identify flags that could be targeted for tag releases, based on the following criteria:

- *contributions to reported catches, and estimated discards, of key shark species – i.e. flags with the greatest potential contributions to post-release mortality;*
- *effective catch rates of key shark species, considering only sharks that were discarded – i.e. flags with the highest catch rates of taggable sharks; and,*
- *the expected ease of deploying tagging effort.*

Participants queried and discussed the data holdings for the WCPFC and how it can inform PRM study design. T. Peatman clarified that more than half the effort and catch of some key shark species derives from distant water fishing nations for which there is little or no observer data. The catches referred to were those provided by the countries themselves to the WCPFC. Specific areas in which there is high fishing effort but low or no observer coverage were discussed. It was noted that although there is a requirement to record shark condition at discard, there are few such data. This may be a data submission/data assimilation error and should be investigated. Statistics by species showing total catch and total alive, as well as observer coverage, were shown and participants discussed potential anomalies caused by low or uneven coverage levels of observer data and/or reporting rates. Nevertheless, some hotspots for some species were preliminarily identified and then investigated further. Participants were also referred to the recent WCPFC sea turtle analysis¹ for a useful longline gear characterization data summary.

3.2 Experience in Purse Seine Fisheries

3.2.1 Round Table Presentations

D. Itano (Fisheries Consultant) organized a round table session on PRM experience in purse seine fisheries consisting of nine presentations. Summaries of the presentations as prepared by the authors are shown below and summarized in *Table 2*:

¹ <http://www.fao.org/3/a-bq849e.pdf> (see Table 1)

M. Hutchinson (NOAA-JIMAR) presented descriptions of the purse seine fishing procedure and PRM of juvenile silky sharks by fishing stage. To identify the stage in the fishing operation when sharks sustain the injuries that lead to mortality, sharks were sampled at each stage, including after having been encircled but while still free swimming. We found that mortality occurs as soon as sharks have been confined in the sack and survival rates were reduced to less than 8%. Animals that had been tagged while still free swimming and released outside of the net showed 100% survival. While sharks that were landed entangled in the net and released showed survival rates of 68.4%. We also found that total mortality rates were not predicted by set size (mortality rate = $0.622 + 0.00233$ total catch $F_{1,26} = 2.39$, $P = 0.134$, $r^2 = 0.084$). This was explained when observations of silky shark behaviour were made underwater using SCUBA. We saw that silky sharks sank to the bottom of the net at later stages of the operation (during sacking up), were unable to ram ventilate and thus drowned. Therefore sharks landed through the brailing operations are unlikely to survive post release and any efforts to reduce mortality in this fishery should be focused on avoidance or releasing sharks from the open net.

*F. Poisson (IFREMER) described how scientists aboard French purse seine vessels recorded the number and condition of silky sharks (*Carcharhinus falciformis*) caught during three fishing cruises in the Indian Ocean. A sample of 31 individuals that showed signs of life were tagged with satellite tags to investigate their PRM. The majority of individuals (95%) were brought on board using the brailer. Combining the proportion of sharks that were dead (72%) and the mortality rate of those released (48%), the overall mortality rate of brailed individuals was 85%. A few individuals (5%) were not brailed as they were entangled and landed during the hauling process. The survival rate of these individuals was high, with an overall mortality rate of meshed individuals of 18%. The combination of these two categories led to an overall mortality rate of 81%. This high value reflects the harsh conditions encountered by sharks during the purse seine fishing process. Consequently, methods that prevent sharks being brought on board are a priority for future investigations, but good handling practices should also be promoted as they could reduce mortality by at least 19%. In order to collect the relevant information during the fishing operation, two scientists were needed. The first one stood on the upper deck close to the hopper while another one stayed on the lower deck next to the conveyor belt to localise and to remove the sharks. Nevertheless, 18 sharks were discarded by the crew and could not be observed and were therefore removed from the study. Recording all the relevant information on each individual (brailed, entangled, brought from the lower or upper deck, brailer number) requires at least 2 persons or more. Finding an appropriate and safe spot on the deck to tag sharks in good condition can be also a challenge.*

In a following presentation, F. Poisson (IFREMER) explained that elasmobranchs are an important component of the French tropical tuna purse seine fishery bycatch but are usually thrown back into the sea. Fishers interact with various types of elasmobranchs. A diversity of discarding practices within the fleet were reported; some practices were considered suitable, others needed to be adapted and improved and others simply had to be banned. The majority of the crews were likely to improve their handling practices if they were presented with practical suggestions that were quick and easy. Combining scientific observations and empirical knowledge from skippers and crew, a manual, providing appropriate handling practices to ensure crew safety and increase the odds of survival for released animals has been developed and disseminated. This guide is available in French, Spanish and English and has been widely disseminated around the world in 2012. An updated version could be considered in collaboration with the experts of the workshop.

H. Murua (AZTI-Tecnalia) presented an overview of best practices for safe release being routinely implemented by the EU tuna purse seiners operating in the Atlantic, Indian and Pacific Oceans with the objective to reduce the bycatch of sharks, turtles and other megafauna. The best practices by the EU fleet are applied through: (i) the use of non-entangling FADs and (ii) the application of best practices for safe release of the sharks, turtles and other megafauna. The progress of the implementation of the best practices are verified based on information collected through a 100% coverage observer program for the EU fleet. Training workshops are organized with observers aiming to improve their skills in collecting information to verify the good practices and a handbook of instructions for observers is used, which includes information on animal releases (including the disposition of the released animal) and on the material of the FAD. When non-conformities with the best practices are identified, remedial actions are agreed with vessel owner companies to correct handling and release procedures.

D. Itano (Fisheries Consultant) presented a summary of projects designed to release silky sharks encircled by purse seine gear prior to the end of net retrieval and concentration of catch in the sack. These projects were carried out on purse seine bycatch mitigation cruises supported by the ISSF in collaboration with tuna industry partners. Silky sharks were observed to collect in a dynamic bend of the net formed by the net hauling process and separate vertically from tuna in the net during a research cruise in the equatorial WCPO. A panel of net at this location was designed that could be opened to allow sharks to exit the net and later closed to prevent tuna from escaping. Unfortunately, silky sharks were generally unwilling to exit the net at this stage of the fishing process. The experiment was repeated in the Gulf of Guinea purse seine fishery where a shallow thermocline and shallow net resulted in no clear separation of tuna and sharks further limiting the possibility of using this system to selectively release sharks from the net. A “backdown” procedure developed to release porpoise while retaining tuna that was developed in the EPO purse seine fishery was evaluated as a potential way to release sharks and other bycatch species during a bycatch mitigation cruise supported by the ISSF, IATTC and the fishing industry. The backdown procedure was performed during nine sets on FADs and floating objects in the EPO that succeeded in releasing dolphinfish and wahoo while not losing significant amounts of target tuna species. Unfortunately, the cruise was conducted off of Peru in a region devoid of silky sharks so the system could not be properly evaluated for shark mitigation. It is intended to repeat the experiment in the equatorial EPO, where silky sharks are common, if suitable industry partners can be identified.

M. Francis (NIWA) described a PRM study of protected spinetail devilrays (Mobula japonica) in the New Zealand skipjack tuna purse seine fishery. Mobulid rays are protected in New Zealand, but the spinetail devilray Mobula japonica is caught as bycatch in skipjack tuna purse seine fisheries. Observers tagged ten rays with popup archival tags (seven miniPATs and three sPATs) to obtain preliminary information on their post-release survival, and spatial and vertical movements. Eight of the ten tags reported data, and five of those rays died within 1–4 days of release. All five rays that died had been brought aboard entangled in the bunt. The three surviving rays were all brailled aboard with the tuna catch. One surviving ray remained near New Zealand for 2.7 months during summer, and the other two migrated 1400–1800 km northward to tropical waters near Vanuatu and Fiji at minimum speeds of 47 and 63 km.day⁻¹ at the end of summer. Observations of ray vigour at release did not correlate with survival: one surviving ray did not swim but sank when released, whereas all of the rays that died swam away vigorously on release. sPAT tags provide daily minimum and maximum temperature

and depth, which are useful as a coarse measure of animal habitat, though not nearly as useful as the high resolution (1 minute or less) data provided by miniPAT tags.

H. Murua (AZTI-Tecnalia) described how tropical tuna purse seiners can involuntarily encircle whale shark during sets without observing them due to whale sharks' associative behaviour to tunas. The impact of purse seine fisheries on whale sharks has been observed to be very low based on observer and logbook data with most of the encircled whale sharks being released alive to the sea. However, until recently no studies of post-release mortality of whale sharks were carried out. This study provides information on post release mortality of the encircled whale sharks in purse seiners operations based on electronic tagging. Six incidentally encircled female whale shark >8 m were tagged and released alive following the best practice guidelines for the whale shark between May and September 2014 in the eastern tropical Atlantic Ocean. Five tags transmitted data: three popped up as programmed (30 days), while two surfaced prematurely (one after 21 days and the other after 71 days but showed no sign of unusual behaviour. These observations based on five large individuals (total length >8 m), show that 100 % whale sharks survive when released with the proposed method. This presentation also shows that whale sharks can be tagged from purse seine vessels.

H. Murua (AZTI-Tecnalia) also gave an overview of a research cruise conducted on the tuna purse seine vessel Mar de Sergio in the eastern tropical Atlantic Ocean during March-April 2016 with the objective to investigate the feasibility of sharks being fished and released from the net before they are brailed onboard during normal fishing operations. Fishing sharks from inside the net and releasing them outside the net, a system suggested by some skippers, can be a simple and good mitigation technique. The proportion of silky shark encircled that were fished, tagged and released in the study was 21% (11 out of 53) and the data collected from pop-up tags shows that 100% of those sharks released survive for 21 days. The percentage of silky sharks fished and released can probably be increased by improving shark fishing and releasing techniques.

B. Leroy (SPC) discussed a whale shark tag deployment plan in Papua New Guinea (PNG) initiated in December 2014 (NOAA-Fisheries et al. 2015). Initially five tags+ tagging poles provided by the United States were transferred to SPC and then to the National Fisheries Authority (NFA) of PNG in February and March 2015. A PNG Marine Scientific Research Committee permit application was submitted prior to the experiment. The response from the Committee as relayed by NFA staff in mid-2015 was that no permit was required as the work was to be done by PNG nationals on PNG vessels. In June 2015 15 PNG observers were trained in tagging of whale sharks at courses in Port Moresby, Rabaul and Madang. The training was conducted by SPC and one of the PNG Observer Trainers. At this time it was decided that the tags were to be kept by the Observer Coordinators for distribution to trained observers. Five additional PSAT tags were given to PNG during the SC11 meeting (August 2015) but no additional tagging poles. Discussions at other regional meetings in November 2015 identified that no deployments had occurred at that time. A decision was taken to distribute the tags to the trained observers rather than the Observer Coordinators in an attempt to create more opportunities for deployment. By February 2016 using this strategy only 1 trip happened with a trained observer and tag (from Rabaul) on a PNG domestic vessel. In June 2016 progress was again discussed with the PNG Observer Trainer which identified the opportunity to undertake a further observer training in Lae. In July 2016, during a trip to PNG (tagging experiment on the FTV Pokajam) discussions were held with PNG NFA staff about extending the pool of observers capable of deploying satellite tags on whale sharks. NFA staff agreed with the idea and also recommended that it would be best to try to train additional

observers in Lae. To support this five additional tagging poles were sent to NFA in November 2016. Unfortunately a training planned for Lae in October 2016 did not occur because the Observer Trainer was busy doing other more prioritised tasks. Further recent attempts to have this training occur have identified funding as a possible issue. Most recently, regional arrangements relating to the deployment of non-national observers on domestically flagged vessels has been identified as one deployment issue, along with regional co-ordination of the deployments. Future work on this programme needs to be redesigned with these issues taken into account.

Table 2. A summary of post-release studies for sharks captured in purse seine fisheries. Species codes: FAL=silky shark, SPL=scalloped hammerhead shark, OCS=oceanic whitetip, RMT=mobulid rays, RHN=whale shark.

Species	Presenter	Tag Types and Numbers	Post-Release Mortality Findings	Other issues studied	Lessons Learned?	Comments	References
FAL	Hutchinson	11 mini PATS 15 sPATs 71 X-tags (total n=97)	Total mortality 84% for sharks landed on deck and subsequently released (entangled during net haul and brailed)	86 blood samples (17 PAT tagged AND blood sampled)	Very high mortality once sharks have been confined to the sack. Blood Lactate best predictor of mortality; set size doesn't affect mortality rates due to FAL behavior of burying themselves at the end of the net haul.	Designed to identify mortality rates at various stages of purse seine process; different mortality estimation methods compared to Poisson 2014a. Our estimates of PRM would be biased and underestimated if we used similar analysis methods to estimate PRM because of differences in study design.	Hutchinson et al. 2015
FAL	Poisson	31 mini PATS (100-150 days)	Overall total mortality of 85% with 48% PRM for sharks released from the deck		Need to find a safe location to tag and observe shark bycatch; protocols aren't always followed, esp. when handling >1 shark, impossible for one person, need at least 2 or more.	Similar mortality rates compared to Hutchinson but mortality calculated differently	Poisson et al. 2014a, 2016
FAL, SPL	Eddy	13 PSATs for FAL; 3 PSATs for SPL	Total mortality: (at vessel+PRM) 92% FAL PRM: 73% brailed FAL 62% brailed + snagged FAL 100% brailed SPL			Designed to identify mortality rates after capture in PS	Eddy et al. 2016
	Poisson			Mortality reduction best practices		Looking for funding to update and expand work	Poisson et al. 2014b
ALL	Murua	NA	NA	Spanish purse seine best practices		Need to harmonize condition codes and best practice recording across t-RFMOs	Goñi et al. 2015a,b

Table 2 (cont.). A summary of post-release studies for sharks captured in purse seine fisheries.

Species	Presenter	Tag Types and Numbers	Post-Release Mortality Findings	Other issues studied	Lessons Learned?	Comments	References
FAL, OCS	Itano/ Schaefer	NA	NA	Bycatch mitigation, best practices	Release panel functioned but need to test stimulus for them to exit panel; best chance in areas of deep thermocline; backdown needs more trials in area with silky sharks	Projects developed to test ways to remove encircled sharks that have not been impacted by fishing process; need to test other methods	Restrepo et al. 2016
RMT	Francis	7 miniPATs, 3 sPATs	8 tags transmitted, 5 died post release (fish that were entangled) and 3 survived (sampled from brail) (62.5% PRM)	Movements	Visual assessments correlate poorly with survival	Best practices handling and release methods developed and being introduced with the fleet by DOC	Francis and Jones 2016
FAL	Murua	11 pop-up tags	All 11 sharks survived for at least 21 days	Techniques for removing from the net	Fishing sharks from the net is an effective way to aid their survival;	Techniques can probably be improved	Sancristobal et al. 2016
RHN	Murua	6 PSATs on 8-12 m females	5 tags transmitted; at 21 – 71 days; all survived (0% PRM)	Movement	Program tags for as long as possible (if no cost for doing so)	Provides evidence of effectiveness for one safe release method; (there may be other as yet undocumented); plan to continue work	Escalle et al. 2016
RHN	Leroy	10 PSATs, 10 tagging poles (not deployed)	NA	NA	Opportunistic tagging with observer programs difficult and complicated.	Tags and poles in stuck in PNG, admin issues preventing deployment.	

3.2.2 Discussion

There was considerable dialogue related to the variability in methods used for purse seine fisheries and how they could affect post-release mortality. For example, hopper use is limited in the Western and Central Pacific Ocean and there are multiple ways, in which the crew will handle sharks that are entangled in the nets. M. Hutchinson clarified that in the Hutchinson et al. (2015) study sharks tagged at FADs that were not set upon and sharks that had been encircled by the net exhibited 100% survival while entangled animals exhibited 68% survival, 16.7% survival in the first brail, and 6.67% survival in later brails. Total mortality was 84.2% and the size of the catch per set did not have an effect on mortality.

Participants did note different levels of post-release mortality across studies with some levels as high as 85% whereas some results suggest post-release mortality as low as 52%. Discussion suggested that different methods of assessing post-release fate and protocols of handling on deck (e.g. removing entangled sharks and how long they remained on deck before being discarded) likely caused the varying mortality rates.

Best practices for handling and release need to be more widely promoted. AZTI-Tecnalia is verifying the implementation of best practice in Spanish purse seiners but some difficulties and challenges are apparent for the WCPFC and IATTC where the observer programs are administered through the Secretariats. AZTI-Tecnalia is in communication with IATTC/WCPFC Secretariats in order to get access to the data and, and to the extent possible, to modify the observer template to collect the information needed to verify the code of best practices. For example, different classification codes are used by observers from those programmes and AZTI-Tecnalia in some cases. There is a need for harmonization.

More information was provided on the potential for safe release of sharks after being encircled by purse seine gear. In an ISSF study a release panel (i.e. 10m flap) which can be opened or closed was placed in the net. However, most sharks would not exit the net when it was opened. This study observed varying degrees of aggregation of silky shark and separation of sharks from tuna inside the net. The panel could not be opened on some sets due to potential loss of tuna. The issue was particularly evident in regions having a shallow thermocline where a clear separation of sharks and tuna was not observed.

The backdown procedure used for the safe release of dolphins associated with tuna in the EPO purse seine fishery was trialled as a potential method to release silky sharks and other non-target species during an ISSF/IATTC bycatch reduction cruise. Some non-target species were successfully released but no silky sharks were encountered so the method could not be properly assessed for shark mitigation.

In relation to PRM of whale sharks captured in purse seines off the west coast of Africa, the author noted that whale sharks can be released by placing a cable below the sack and whale shark and attaching it to the corkline on the other side of the shark. Pulling the cable causes the whale shark to “roll” over the top of the corks on the purse seine. A video demonstrating this technique was viewed. Results of satellite tagging suggest survivorship was 100% for the five tagged whale sharks. There are attempts to carry out similar studies elsewhere but there are some issues with logistics. It was noted that ICCAT is the only tuna RFMO that does not have a conservation and management measure prohibiting setting on whale sharks.

3.3 Experience in Longline Fisheries

3.3.1 Round Table Presentations

P. Rogers (South Australia Research and Development Institute (SARDI)) convened a round table discussion of experience with PRM studies in longline fisheries consisting of seven presentations. Summaries of the presentations as prepared by the authors are shown below and summarized in Table 3:

*S. Campana (University of Iceland) described a recent PRM study of pelagic sharks caught as bycatch in commercial longlines in the Northwest Atlantic. On the basis of more than 21,000 fisheries observer records and the results of 109 popup satellite archival tags (PSATs), all sources of fishing-induced mortality (harvest, capture, and post-release) were estimated for blue sharks (*Prionace glauca*), shortfin mako (*Isurus oxyrinchus*) and porbeagle (*Lamna nasus*) in the Canadian pelagic longline fishery between 2010 and 2014. Sharks were tagged based on condition, with tags split between healthy and seriously injured sharks. Most sharks were tagged onboard, but some were tagged with poles while in the water. The post-release mortality rate varied between 10-31%, with porbeagle and mako having the highest mortality rate. Overall, about one half of the hooked porbeagles and makos died during or after fishing, with most of the post-release mortality occurring within two days of release. The motivation for the study was provided by the CITES listing of porbeagle and, in particular, conditions associated with the Marine Stewardship Council certification of the swordfish fishery, which ensured the full cooperation of the fishing industry. Questions remaining to be addressed are the relative benefits of tagging in water compared to onboard, the specificity of post-release mortality estimates to season and location, and the selection of easy-to-apply predictive variables for mortality.*

C. Heberer (The Nature Conservancy (TNC)) introduced an ongoing study in Palau focused on circle hook width and shark PRM. Blue and silky sharks were chosen due to concern about a possible downward trajectory in population sizes and due to paucity of information on PRM rates for these species at low latitudes. Condition codes of 'Excellent/Green', 'Alive but spent', 'Alive but weak', and 'Dead' are being applied. A sample size of 54 blue and 54 silky sharks is intended as this is expected to result in ~30% power in the estimate. Variables being evaluated include hook depth class, hooking location, hook size (14/0, 16/0, 18/0), location, sex, size, and trailing gear left. It was also noted that dissolved oxygen and time spent hooked are also very important but these are rarely measured due to logistical challenges and costs. Large sharks are gaffed in mouth and brought aboard for tagging; small sharks are not gaffed but lifted aboard. All sharks are tagged with trailing gear left on. A total of n=83 sharks have been tagged with sPAT tags and results are being analysed.

C. Heberer (TNC) also presented an update on TNC's cooperative electronic monitoring (EM) project designed to develop the institutional capacity of Pacific Island fisheries management authorities to integrate EM systems into national and regional observer and monitoring, control and surveillance (MCS) programs. The project to date has installed EM systems on five vessels in the Federated States of Micronesia (FSM), four vessels in Palau, and three vessels in Okinawa, Japan. Plans are in place to install EM systems on six vessels in the Republic of the Marshall Islands (RMI) and eight vessels in the Solomon Islands (SI). EM data review centers to convert EM records to EM data and upload them to the SPC TUBS database have been established in Palau and plans are underway to establish additional centers in FSM, RMI, and SI. TNC has sponsored a contest (via Kaggle) to develop an algorithm that can automatically detect sharks, turtles and tunas with the intent to shorten the video review time. The

algorithm will be made available in open-source format at no cost to Fisheries Agencies and EM Service Providers for enhancement of review software.

Finally, C. Heberer (TNC) reviewed common thresher shark PRM research in the southern California recreational fishery. The studies found that a large proportion of the threshers are tail-hooked, have increased fight times and cannot ram ventilate when hauled in backwards. In the first phase of the study 50 thresher sharks were captured using trolling and 94% were tail-hooked with an average fight time of 72 min. Twenty sharks were tagged with PSATs with five sharks dying, 14 sharks surviving for at least ten days and one tag not reporting, for a PRM estimate of 26%. The study concluded that all five sharks with fight times >85 min did not survive and plasma lactate and hematocrit were significantly elevated with increased fight time. The second phase of the study investigated PRM in two modes of capture: tail hooking with trailing gear left on, and catch and release with mouth-based angling techniques. For trailing gear, nine PSATs were deployed with one shark surviving 90 days, one premature tag release after 62 days, six sharks dying within five days after release and one shark dying after 81 days for a PRM of 77%. Of seven thresher sharks captured using mouth-hook methods and tagged with PSATs, all survived.

M. Hutchinson (NOAA-JIMAR) discussed issues and possible solutions that she encountered during the course of her PRM study for sharks discarded in the Hawaii and American Samoa based tuna longline fisheries. Tag recalls, false mortalities, problems with tag applicators bending and rendering tagging poles useless, and retention of good observers that have been trained in the tagging protocols have slowed progress of the project. Additionally, interaction rates of oceanic whitetip and silky sharks are infrequent so they haven't been able to get tags on either of these species at the frequency anticipated. She also provided advice on budgeting for additional costs and extra tagging implements (poles, titanium bushings, tag applicators, tag boxes). She suggested asking Wildlife Computers to increase the auto-deploy parameters to a depth of 10 m to avoid accidental deployment of SPATs in heavy seas. She suggested the use of the small titanium anchors which are knife sharp to allow tagging over the rail of the vessel. She advocated for specific leaders lengths of 13 cm. Finally, she stressed the importance of using some means of video recording the tagging events (GoPros or EM) for quality control.

P. Rogers (SARDI) presented a recent study on post-release survival and predation of school shark, *Galeorhinus galeus*, off southern Australia. Bycatch of marine mammals in the commercial shark gill-net sector of the Southern and Eastern Scalefish and Shark Fishery (SESSF) recently led to a need to assess the use of demersal long-lines as an alternative method to target gummy shark (*Mustelus antarcticus*). School shark (*Galeorhinus galeus*) is occasionally taken as bycatch when targeting gummy shark and managed under a southern stock rebuilding strategy. Pop-up satellite archival tags (PATs) were used to investigate the post-release survival, movements, and habitat use of female school shark (147–170 cm total length) following capture, landing, gear removal and release from automatic longlines in the Great Australian Bight. The at-vessel mortality rate was 25%. Satellite telemetry data showed all lively school sharks survived the capture, onboard handling and release processes. School sharks mostly moved offshore and across the continental shelf in south to south-easterly directions. Vertical habitats reflected use of thermocline depths of 50–100 m where water temperatures ranged from 15–21° C. Two PATs provided data we interpreted as indicative of tag ingestion and regurgitation by endothermic predators. The PAT ingestions may also be indicative of additional post-release mortality.

F. Poisson discussed a dedicated research programme (SELPAL), conducted in collaboration with the fishing industry, which was established to describe the activity of the French artisanal longline fishery targeting Atlantic bluefin tuna (Thunnus thynnus) in the Mediterranean Sea. This programme assesses the scale of fishery impacts on various taxa, whilst studying the ecology of pelagic stingray (Pteroplatytrygon violacea), which is by far the most abundant elasmobranch species taken as bycatch in many tuna and swordfish longline fisheries in the Mediterranean Sea. Without a clear understanding of the at-vessel mortality or post-release survival of discarded individuals, the impact of this fishery cannot be fully assessed. The objectives of the study were to quantify these parameters for this species and to develop a manual to provide appropriate handling practices to ensure crew safety and increase the survivability of released individuals. In addition, the efficiency of different types of dehookers were tested. Ten mark-and-recapture tags (mrPATs), were attached to pelagic stingray to study their behaviour after release. This study aimed also at exploring horizontal and vertical movements of the blue shark (Prionace glauca) with Splash, SPOT and MiniPAT tags. The post release mortality for this species was investigated using MiniPAT and sPAT tags.

Table 3. A summary of post-release studies for sharks captured in pelagic longline fisheries. Species codes: BSH=blue shark, SMA=shortfin mako shark, POR=porbeagle shark, FAL=silky shark, ALV=common thresher shark, BTH=bigeye thresher shark, OCS=oceanic whitetip shark, GAL=school shark, PLS=pelagic stingray.

Species	Presenter	Tag Types and Numbers	Post-Release Mortality Findings	Other issues studied	Lessons Learned?	Comments	References
BSH, SMA, POR	Campana	WC Pat4, MK-10, X-tags, 37 BSH, 26 SMA, 33 POR	BSH (healthy 0%, injured 33%) SMA (healthy 30%, 33% injured) POR (healthy 10%, 75% injured)		Tag sharks on deck: quick, effective, and no bias; Skippers can be very good taggers; no sig. diff. in PRM between sharks released in water vs from deck	“injured” = hooked in the gills, bleeding from gills, swallowed hook or other bleeding; Used the Domeier anchor; soak time was 8-11 hrs; mostly circle hooks	Campana et al. (2016)
BSH, FAL	Heberer	sPAT (~50 on each spp.); stratified by hook size and condition	In progress	Hook width, trailing gear and proposed deep/shallow set trials	Dissolved oxygen and time on hook important	Braided shock absorbers on the leader (prevent flybacks), influencing where they cut the line, could be a biofouling surface	In progress
-	Heberer	-	-	EM and integrating with database	Could be useful to tag from vessels which already have EM (time stamp tag events for the record)		In progress
ALV	Heberer	WC MK 10 (n=7)	PRM (tail hooked 77%, mouth hooked 0%)	Circle hook use, recreational fishery management	Where the shark is hooked is critical. Time on the hook is important for tail-hooked sharks.		Heberer et al. (2010) Sepulveda et al. (2015)
BSH, BTH, OCS and FAL	Hutchinson	10 mini PATs; 152 sPATs (BTH=28, FAL=28 (AS only), OCS=28, BSH=68)	In progress		Autostart needs to be more conservative; 13 cm leader lengths; weaknesses in gear lead to add'l costs (poles, applicators, pins, boxes); participate in debriefing	Observer retention, deployment management is demanding; better to do training in the field	Hutchinson (2016)
GAL	Rogers	WC MK-10 (n=10)	PRM of healthy sharks (0%)	Susceptibility to LL equipment; vertical habitat use	20% of tags lost to predation (probably lamnids)	No injured sharks tagged	Rogers et al. (2017)

Table 3 (cont.). A summary of post-release studies for sharks captured in pelagic longline fisheries.

Species	Presenter	Tag Types and Numbers	Post-Release Mortality Findings	Other issues studied	Lessons Learned?	Comments	References
PLS, BSH	Poisson	PLS (10 WC MR tags, 10 TDRs and 1 sPAT) BSH (sPAT, MiniPAT, splash and spot, n=40)	in progress	Release techniques; differences between different de-hookers; smartphone app, bycatch logbook	Compensation for fisher may be important	Importance of safe handling guides	

3.3.2 Discussion

Initial dialogue related to the study in the northwest Atlantic and was focused on the method of tagging, i.e. boating the shark or tagging in the water, and if there were differences in mortality for sharks tagged by scientific observers or by vessel captains. The procedure of tagging on the deck was confirmed to be relatively rapid (2-3 mins) and was not seen to affect the PRM estimates. It was confirmed that there was no difference in tagging quality between fishers or trained observers and if the method is rapid tagging on the deck is appropriate. Questions and discussion related to the effect of hook type, season and other factors, but the sample sizes were too low to test statistically. It was noted that there could be long-term mortality effects when tagging on deck with due to damage to the internal organs.

The boating method also resulted in discussion related to the tagging head to be used on the archival satellite tag. Depending on the shark, the Domeier anchor was noted as being difficult to penetrate unless the metal applicator pin was made longer to assist penetration through the skin and fin rays. There are also issues with tag applicators bending, especially for sharks with thicker skin (e.g., oceanic whitetip shark or females). This can be avoided by tagging sharks on the deck where an incision can be made prior to tag insertion but boating the animal may not always be possible. If tagging is to be done in the water, Wildlife Computers makes a smaller titanium anchor that is very sharp and will readily penetrate the skin. It was generally agreed that the satellite tag should have a single anchor with a short tether (~13 cm).

Following the presentation on a PRM study in Palau, there was discussion related to the benefits of conducting a power-analysis to help with the cost-benefit of deploying tags. Sampling design (i.e. the number of strata to be covered) as it relates to the number of variables was discussed and it was agreed not to over-parameterize the model as it will become more difficult to distinguish meaningful variables.

There was some discussion related to the use of electronic monitoring and whether the presence of EM on the vessel would be necessary to ensure that tagging is done according to agreed protocols. It was noted that the role of the observer may be different if there is EM on the vessel, for example, the use of EM can expand observer coverage and free observers for other activities, such as tagging, which EM will never replace.

It was noted on several occasions the importance of developing and identifying the best practices for tagging sharks. There are multiple hidden costs that need to be considered; for example, replacing tagging poles, shipping, insurance, tagging pins, tag boxes and organizing materials. Observer training is extremely important and staff must be fully trained in tagging sharks prior to deployment. It was agreed that only the best “super” observers should be used for the project.

4 Best Practice Principles for PRM Study Design

4.1 Survey Design: Stratifying by Species and Fisheries

With input from statisticians A. Dunn (MPI) and T. Peatman (SPC), participants noted the following points as important considerations in sampling design and stratification:

- a. Power analyses should be used to assess sample size requirements for PRM studies to ensure sufficient statistical power to meet the study objectives.
- b. The sensitivity of total mortality estimates to uncertainty in PRM estimates depends on the proportion of the catch that is discarded and the proportion of those discards that are alive. If PRM is low compared to total mortality, increasing sample size will have little effect in reducing uncertainty in total mortality.
- c. If the sample size is too low, such as may occur in opportunistic sampling of rare species, the resulting estimates would have insufficient statistical power to know if the detected effect is real.
- d. Some increase in statistical power can be gained through applying Kaplan-Meier survival analysis curves to the same number of samples.
- e. Decisions on the appropriate number of tags to deploy can be informed by statistical power analyses, but will also depend on the desired number of strata to sample and available budget, and these decisions will in turn depend on the scope of the research questions being posed and management objectives to be addressed.
- f. It is important to include as many of the relevant strata as possible (e.g. do not sample one species in just one fleet if your intention is to extrapolate those results across all fisheries for the species). However, it should be noted that there is an inherent trade-off between available sample size and number of strata.
- g. When choosing strata, species, fleet/gear characteristics and condition/handling practices are likely to be among the most important factors. Seasonality and target species (of the fishing vessel) are likely to be secondary considerations.
- h. Factors which cannot be included as strata in the design can be accounted for by including them as explanatory variables in the analysis of the data. Sea surface temperature, soak time, size of the fish and length of trailing gear are likely to be important in this regard.
- i. When tagging rare species of great conservation concern, such as oceanic whitetip shark, it would be more appropriate to apply miniPATs or a similar kind of tag that can track for longer times (i.e. more than 6 months) and provide location and depth data to inform about habitat and movements. In addition, given the increased expense of the tag and the desire not to harm the animals, trauma-minimizing handling procedures different to those usually encountered on a commercial fishing vessel are preferred. These types of studies are useful and recommended but are incompatible with the main objectives of the WCPFC study.
- j. The analysis of the survey results may consider collapsing categories (e.g. condition classes or other correlated variables), and thus achieve higher statistical power, if the data suggest this is appropriate.
- k. Practical considerations such as access to vessels, length of trip, value of the tag-target species, vessel configuration, etc. may influence the number of strata that can realistically be sampled and should be taken into consideration.
- l. While a larger number of condition classes would be desirable in a statistical sense, in order to allow for comparisons among studies, many of which have used only one or two conditions, it may be useful to limit the number of condition classes. The condition classes should also be as consistent as possible with those used in other datasets, e.g. observer data, which may be used for extrapolating the study results across the fishery/region.

- m. Although it would be useful to obtain information on the survival of sharks which are alive but dying, it could reasonably be assumed that such sharks will die and thus the tag does not convey much additional information.
- n. The study should develop a clear and consistent definition of a shark which is so severely injured that it should not be tagged.
- o. It is important to select sharks for tagging in a randomized manner for several reasons including the need to provide for a range of soak times experienced by tagged sharks. There is a need to consider which randomization protocol would be best for PRM studies and potentially to devise different strategies for different fleets.
- p. It is important to acknowledge that no data will be provided by a portion of deployed tags for a variety of reasons, thus some allowance for this should be made in the experimental design. Recent experience suggests this may range from 5-10%.

4.2 Deployment Protocols: Handling and Data Recording

The workshop's discussion of deployment protocols was greatly informed by the work of M. Hutchinson (NOAA-JIMAR). As a group the following points were considered and noted:

- a. Crew members and skippers can be very good shark taggers if properly trained; one study showed that there was no difference in PRM between sharks tagged by crew versus scientists.
- b. Although studies may wish to emulate the handling the fishermen usually employ for sharks, the act of tagging will cause that handling to differ to some extent. Both handling and tagging may thus affect the likelihood of the shark surviving.
- c. Advantages and disadvantages of tagging in-water and on deck were considered and are shown in **Annex C**.
- d. Some participants initially considered that tagging the shark in the water would result in less trauma to the shark. However, videos revealed that some in-water tagging may also result in considerable trauma. Any handling practices leading to excessive trauma would be expected to reduce survival.
- e. In order to maximize the value of tagging studies it is recommended to minimize the pool of personnel doing the tagging and to make sure that pool is thoroughly trained and skilled.
- f. It would usually be preferable in a study of PRM arising from existing fishing practices to tag the shark either on deck or in the water depending on where the fishermen would normally handle the shark. However, it should be considered that there may be cases when tagging the shark in this way increases the health and safety risk to the crew.
- g. Some studies have shown that at-sea coding of shark condition may correlate poorly with survival. Therefore, the tagger should use codes as appropriate but also describe the condition in text and use video if possible so that an onshore assessment of shark condition can also be made (see codes being used in the NOAA-JIMAR study in **Annex B**).
- h. A total length of 80-120 cm was considered a reasonable minimum size for attaching popup tags to sharks, but the appropriate value may depend on the species. Participants noted that 100 cm TL (used in the NOAA-JIMAR study) is probably appropriate for silky and shortfin mako sharks but suggested investigating observer-collected length frequencies to verify this.
- i. Tag weight and length are not considered to be major issues, though hydrodynamic drag may be a concern.
- j. A surprising number of tags are eaten by other predators—presumably either bitten off the shark or taken when floating at the surface. This needs to be taken into consideration when interpreting tag profiles.

- k. The tag anchor should be placed in the shark in the dorsal musculature just at the base of the dorsal fin. The tag anchor should be placed at a 45° angle to the body (in both longitudinally and transverse dimensions, i.e. with the tag angled backwards and upwards) and across the midline of the shark to pass through the rigid basal fin elements and anchor on the opposite side of the dorsal fin. Do not place the tag anchor anywhere near the head or the gills.
- l. Whether to try to tag in heavy seas should be carefully considered as the probability of misplacing the tag will be higher and the tag may be more likely to shed (though this is less important in short-term mortality studies).
- m. Rewards for archival tag returns on the order of US\$250 were recommended as the process of retrieving the tag can provide additional data as well as the potential for the tags to be re-used.
- n. Electronic monitoring can be helpful in determining the characteristics of the fishing operation during which the shark tagging occurs and can also monitor whether the tagging technician followed the appropriate protocols. However, head-mounted GoPro cameras (when light is adequate) or a Nikon CoolPix (at night or in low light) would be the most useful way of documenting each tagging event. In any case, there should always be as much debriefing as possible of the tagger as this can provide critical information to interpret the tag data.
- o. Managing the deployment and return of tags in a study like this can be a time-consuming job and it requires dedicated resources. The tag deployment coordinator should also plan to spend time managing the reported data in a database.
- p. There is really no substitute for at-sea training of tagging personnel, though tagging dead sharks or other suitable media have been used when training resources are limited.
- q. It is critical to find the right place on the vessel to work and to be prepared for the contingency of dealing with more than one shark on deck at a time. One or two people may not be sufficient.
- r. The vessel should, when feasible, remain in gear during tagging in the water so that the shark continues to swim. Otherwise the shark's position will be erratic and it will be difficult to tag.
- s. It may be necessary to compensate some fishermen for the release of the shark, especially for fleets or vessels that usually retain that species.

4.3 Equipment Selection

The table prepared by M. Francis (NIWA) and K. Schaefer (IATTC) was used as the basis for further discussion of tag types and additional essential hardware for tagging studies with the following conclusions drawn:

- a. The workshop discussed various components of tags and developed a recommended design for assembling PAT leaders for short-term shark PRM study deployments (**Annex D**).
- b. Most expert shark taggers recommend either the Domeier or Ti (titanium) tag anchors. Since the Ti anchor is sharper it may be preferred for in-water tagging. The Domeier anchor's lesser ease of penetration can be overcome by making an incision in the skin when tagging from the deck or when using a modified applicator involving a stainless steel tip when tagging in the water.
- c. Based on experience, experts recommended building tethers yourself, to avoid gear problems, but note this may have implications for tag warranties. However, self-constructed tethers may be problematic for inexperienced tether-builders.

- d. Some experts use stainless steel tethers whereas others recommended fluorocarbon or monofilament tethers.
- e. The proper crimp size, material and tool, given the leader material being used, are essential.
- f. The use of shrink wrap on the tether to record tag reward and reporting details was recommended. Return information can be added to the shrink wrap to provide data on the ultimate fate of the shark.
- g. The use of chaffing protection on the tether/anchor joint design was recommended.
- h. The length of the exposed applicator pin may need to be adjusted depending on the size of the shark being tagged in order to reduce over- or under-insertion of the tag anchor.
- i. When conducting a PRM study it is important to adequately budget and plan for equipment breakage and other unanticipated costs (e.g. tagging poles, applicators, pins, boxes, insurance especially during shipping and storage).
- j. To avoid premature activation the autostart function on tags should be pre-programmed conservatively by the manufacturer (e.g. such that the tag will not turn on until it reaches a depth of 10m).
- k. The use of short-term PATs is appropriate if concerns about long-term mortality, e.g. from trailing lines left on the shark, are not of concern. If this is a concern, e.g. when wire branch lines are used, PAT tags capable of reporting for nine months are preferred.
- l. If only acute mortality is of interest then short-term PATs' with 30-day deployment should be adequate. Delayed mortality (e.g. beyond 30 days) may be due to organ trauma from physical impacts, infection, entanglement impacts or feeding problems, but these delayed mortalities will be difficult to distinguish from natural mortality. Tag shedding and tag predation are larger issues for longer deployments. In long-term deployment of tags, bio-fouling coatings should be applied.
- m. Wildlife Computers has communicated that the sPAT will be upgraded to allow up to 60 day reporting, and times series of depth and temperature, in the next 6-12 months.
- n. Regardless of type, tags should always be programmed for as long a time period as possible (if there is no cost for doing so and if data transmission is not compromised).
- o. It was recommended to have tags delivered in batches, rather than all at once, in order to take advantage of ongoing technological developments and to also recognize the staggered nature of deployment.

5 Recommendations

5.1 Recommended Survey Design

The following survey design was recommended by the workshop:

Objective	<p>To measure shark post-release mortality (PRM) using electronic tags for sharks released or discarded in WCPFC fisheries to obtain estimates of PRM which can be used to:</p> <ul style="list-style-type: none"> • construct PRM estimates for the Convention Area (fleet by fleet using observer condition codes and gear characteristics to extrapolate as necessary); • inform questions about no-retention measures; and • assist with catch reconstructions.
Timeframe	Field work and analyses must be completed by December 2018
Budget	\$250,000 (ABNJ-tags only); €400,000 (EU-tags + tag deployment support)
Fishery Sector	<p>The workshop agreed that the focus of the study should be the longline sector because shark PRM in the purse seine sector has been studied in the Western and Central Pacific Ocean (WCPO). Total mortality (at-vessel + PRM) has been consistently estimated to be high in purse seine fisheries, with PRM a relatively minor component. In contrast, the longline fishery is less well-studied, catches a wider range and greater number of shark species, and is more likely to have a diverse range of practices (gear, soak time, handling) that affect PRM.</p>
Species	<p>The workshop considered all of the WCPFC key shark species as candidates for the study, and took into account the EU's first-tier and second-tier priority species (silky and oceanic whitetip, and thresher and porbeagle, respectively).</p> <p>Silky shark (FAL) was selected for this study because data on PRM of this species would be useful both in assessments of total removals for stock assessments and in evaluation of the WCPFC no-retention measure. This species is also of regional and global conservation concern. The WCPFC study results will complement the results of ongoing studies by NOAA-JIMAR, IATTC and TNC/Palau Bureau of Marine Resources (TNC-PBMR).</p> <p>Shortfin mako shark (SMA) was also selected for this study because data on PRM for this species would be useful in assessments of total removals for stock assessments such as that planned by ISC for the North Pacific. This species has been listed as a WCPFC key shark species since 2009, is one of the most commonly captured sharks in the longline fisheries of the WCPO, and is encountered in all regions that observers have sampled. According to ecological risk assessments SMA has a highly vulnerable life history, and its PRM was identified as a priority topic for further research in a recent regional workshop reviewing its status (Bruce 2014). Studies of SMA PRM are underway in the Atlantic but not in other oceans (to our knowledge).</p> <p>Oceanic whitetip shark (OCS) was given careful consideration due its high level of global conservation concern and the need for PRM information to inform about the effectiveness of management measures and stock status. However, low catch rates of this species make it unlikely that this study could obtain enough samples to draw statistically significant conclusions within budget and time constraints.</p>

	<p>Furthermore, it was recommended that a more expensive tag type and different tagging procedures be used for OCS, making it unlikely that OCS could be tagged opportunistically when tagging other species. For these reasons, it was decided that tags would be allocated to OCS only if they were unable to be attached to FAL or SMA. Such unused tags could be passed to NOAA-JIMAR, which is currently conducting an OCS PRM study in the Hawaii tuna longline fishery. Tags would be deployed in the tuna fishery in American Samoa under this project to compare PRM estimates in complementary fisheries which use different leader materials (wire versus monofilament).</p> <p>Blue shark (BSH) was discussed but not prioritized due to lack of immediate conservation concern. It was noted that the NOAA-JIMAR and TNC-PBMR studies are investigating PRM in blue shark and these should provide useful information for future stock assessments.</p> <p>Other species such porbeagle and thresher sharks, many of which are observed to be caught in too low a frequency to be viable sampling targets other than in some very specific areas, were not considered in detail.</p>
Sample Size	<p>Statisticians advised that the sensitivity of total mortality estimates to uncertainty in PRM estimates depends on the proportion of the catch that is discarded and the proportion of those discards that are alive. If PRM is low compared to total mortality, increasing sample size will have little effect in reducing uncertainty in total mortality. Minimum sample sizes of 100 per species were considered optimal for this study, given that species-specific differences are expected to be large. For stratification within species a minimum sample size of 40 was considered acceptable for this study. This had to be balanced against the desired number of strata to be sampled for practical reasons given the project budget.</p>
Tags	<p>Experts in shark tagging considered a number of tag types from four manufacturers. Experience from a range of studies suggested that Wildlife Computers (WC) tags are the most functional, have high data recovery rates, and are considered the most appropriate for this study. sPATs (survival pop-up archival tags) report mortality events for up to 30 days following deployments. According to the manufacturer this will be extended to 60 days within the next 6-12 months. WC miniPATs can report depth, temperature and position estimates for in excess of one year. The cost of sPATs is currently about half that of miniPATs. As sPATs are adequate for the current study objectives and are cost-effective it was decided to select them for this study.</p>
Tag Reporting Period	<p>Reporting for 30 days was considered adequate for recording acute mortality events but a 60-day period would be preferred if the tag cost remained the same. Wildlife Computers sPATs are expected to allow this 60-day reporting period within the next year, therefore it was recommended to upgrade to these tags as soon as they become available and can be considered reliable.</p>
Deployment Logistics	<p>In order to obtain data that are representative of commercial fishing operations, tags should be deployed from commercial longline vessels, fishing per their usual practice. Tags will be deployed by trained and experienced tagging technicians and/or observers allowed sufficient time to focus on tagging. Budget provisions for three technicians on three trips each have been made, along with (a) part-time tag deployment coordinator(s). It is considered important to prioritize the proper placement of tags by a limited number of highly trained personnel, rather than to</p>

	<p>distribute the tags widely and risk reducing data quantity and quality. Vessels with electronic monitoring capabilities and the use of independent recording equipment by taggers would provide a useful check that the proper deployment protocols were followed.</p>
<p>Sampling Protocols</p>	<p>NOAA-JIMAR has recently developed and is implementing robust sampling protocols for shark PRM studies in US Pacific longline fleets. Most components were agreed to be applied to the WCPFC study to ensure data quality and consistency with NOAA-JIMAR study results. IATTC is also implementing protocols similar to the NOAA-JIMAR protocols. Some differences were recommended for this study, one of which was a modification in the design of the tether. As the aim is to replicate commercial fishing conditions, the shark should be tagged on deck if the vessel routinely hauls sharks onboard, or in the water if not. Sharks greater than 100 cm TL, and considered to be alive and without a clearly fatal injury (to be defined later), will be tagged in a randomized manner, with the observer providing more detail on the injury and status of the shark.</p>
<p>Fleet/Gear Strata</p>	<p>It was considered important from a practical point of view to initiate the study with the assistance of a long-established and well-run longline observer programme with experience in shark tagging, and the support of tagging technicians. Shark PRM tagging experience in such observer programmes supplemented by tagging technician skills and experience can then be transferred to other national observer programmes through train-the-trainer opportunities, thereby expanding the sampling programme. Observer programmes that frequently encounter SMA or FAL were thus considered for the study. New Zealand has one of the highest catch rates of SMA in the region and could deploy tags through its observer programme without an intensive training programme. For the second phase, Fiji is home to one of the region's largest longline fleets catching both FAL and SMA. It is expected that the Fiji fleet may not be representative of the larger freezer longliners operating in the equatorial region, therefore, another national observer programme which can serve as a proxy for those vessels, such as FSM or RMI, should also be engaged. In order to allow for knowledge transfer between observer programmes, and assign sampling strata for the selected species that are as representative as possible of WCPO longline fleets given total sample size constraints, the following strata were identified:</p> <p>FAL (n=100): Fiji fresh longliner (50%), FSM freezer longliner (50%) SMA (n=100): New Zealand (33%), Fiji fresh longliner (33%), FSM freezer longliner (33%)</p> <p>The total sample size would be approximately 200 tags which, at an estimated, fully-loaded cost of \$2200 per tag (and allowing for a buffer for equipment loss/breakage, fish payments and tag return rewards), would expend the allotted budget for tags. Opportunities to work with ABNJ (Common Oceans) Tuna Project partner Fiji Tuna Boat Owners Association (which has strong connections with New Zealand's Solander fishing company) and is implementing the ABNJ electronic monitoring trial will be sought.</p> <p>Tags that cannot be deployed in these fisheries will be re-allocated, either within other strata defined here, or offered to the NOAA-JIMAR programme to tag OCS sharks in American Samoa. Opportunities to refine the design will be monitored.</p>

Other Data to Collect	Tagging technicians should collect all the relevant data that observers collect and in addition, lat/long at every hour of the set and at the tagging location, as well as for every shark caught record the hook shape and manufacturer code for size, bait type, leader and branchline material, leader length, branchline weight amount, and presence of light attractor. There should be further consideration of consistent protocols for estimating length of sharks in the water (e.g. using a gamefish trailing tape).
Use of Data	PRM data for FAL and SMA will be extrapolated, to the extent practical, using gear characteristics and other explanatory variables, across fleets to provide both fleet-specific and WCPO integrated estimates for each species. Kaplan-Meier survival curves will be used, as appropriate, to increase the power of limited sample sizes. Predictors are expected to include soak time, shark size, hooks between floats (a proxy for depth), and sea surface temperature.

5.2 Other Recommendations

In summarizing the discussions throughout the workshop, participants highlighted the following key points as recommendations for future work:

1. The survey design produced by the workshop provides a suitable basis for WCPFC’s shark PRM study. In proceeding with the study, WCPFC and SPC should follow the general principles identified in the best practice guidelines as well as the specific recommendations for the survey design. Finer-scale details may require additional data analysis and/or further expert consultation to elaborate in order to ensure the success of the study.
2. The best practice guidance developed through the workshop’s expert discussions may be of interest and value to other fisheries management organizations responsible for shark assessments, as well as to the research community as a whole. This workshop report should be made available in the public domain and presented to consultative bodies (e.g. scientific committees of t-RFMOs) as appropriate.
3. With the limited resources available to the WCPFC study the scope of work is necessarily confined to a subset of the species and fleets of interest. Therefore, current and prospective efforts to study other sharks and fisheries should be supported through collaboration, consultation and, if possible, meta-analysis of study results. In particular, it is noted that oceanic whitetip and blue shark are species with important data gaps and further studies of biology, habitat and fishery interactions, including PRM studies are highly recommended. Opportunities to encourage and collaborate with such studies should be pursued.
4. While safe release techniques were not the focus of this workshop, discussions repeatedly turned to these topics due to the inherent relationship between mitigation and mortality. Ongoing work to document and improve handling and safe release technologies and techniques will be critical in advising fisheries managers on potential actions to respond to the results of this study and, as necessary, take action to reduce shark mortalities. One example of this would be further investigation of techniques for cutting sharks free while still obtaining accurate species-specific identifications and reducing the amount of trailing gear left on the shark.

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Annex A. Workshop Participants List

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Annex B. Codes used to record sharks' condition at the vessel, the handling methods, and the condition at release for NOAA-JIMAR's ongoing PRM study.

December 23, 2016

MEMORANDUM FOR: Pacific Islands Regional Observer Program

FROM: Kevin Busscher
Operations Coordinator

SUBJECT: Shark Focus Study - Caught Condition, Kept/Return
Condition and Damage/Handling Codes in the Tuna and
Swordfish Longline Fisheries

Data Update Circular No. 116

Background:

Sharks are a large component of the bycatch in pelagic longline fisheries and are typically discarded at sea where the post release condition is unobserved and survival rates are unknown (Gilman et al. 2012). This source of fishing mortality goes largely unaccounted for and has substantial implications for stock assessments and the overall health of shark populations worldwide. 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) the amount of time an animal spends struggling on the line, 2) shark handling methods used to release/remove sharks from fishing gear and 3) species specific resilience; some species are more physiologically sensitive to capture stress than others (Clarke et al. 2014). Several studies have identified which species are most sensitive to capture stress through physiological investigations and quantifying at-vessel mortality rates (e.g. Beerkircher et al., 2002; Marshall et al., 2012). However, the effects of shark handling on post release mortality or survival rates have never been quantified for commercial longline vessels during typical fishing operations. In this study we will begin to identify the effects of handling on release conditions. In addition, we aim to identify the shark bycatch handling and release methods that maximize post-release survival. These efforts and the results from this study will ensure that the PIROP is in compliance with shark specific conservation and management measures.

Only selected observers will participate in this study. Only collect data for this study if you have been assigned to do so.

SAMPLING PROTOCOL

For all sharks and rays captured, record the following codes on the Catch Log to describe the animal's condition at the vessel, the handling methods, and the condition at release. Try to record a video of each shark handling event.

Caught Condition Codes

D = Dead - Animal showed no signs of life. This code is also the **default** condition when an animal's disposition cannot be established.

AI (Sharks and Rays only) = Alive 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 (Sharks and Rays only) = 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 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.

Kept/Return Codes

D = Dead - Animal showed no signs of life upon return. This code is also the default condition when an animal's disposition cannot be established.

AI (Sharks and Rays only) = Alive Injured - Animal was returned alive but there was clear evidence of serious injury. The serious injury category is met when **ONE OR MORE** of the following criteria are observed: **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, or **3)** stomach is everted (please specify in comments), **4)** other damage from handling occurs. This code should also be used if the animal is boarded through the use of a gaff or grappling hook. Gaffed animals should have a brief comment on where the gaff was embedded e.g. head, gills, back, pectoral fin, etc.

AG (Sharks and Rays only) = Alive, in Good condition - Sharks released in good condition will swim away rapidly and with vigor (animal will be active). They will **NOT** appear lethargic or disoriented or show any obvious signs of injury or physical trauma. This condition code is used when **ALL of the following criteria are observed and met:** 1) no bleeding, 2) shark is lively and able to swim away, 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 upon return, 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.

RU = Returned Unobserved

Handling & Damage Codes ('Damaged' column on the Catch Log)

These codes have been developed to help us depict the handling and release methods that are being used on sharks and rays. These will be expanded to include the damage that sharks and rays may incur during the handling process. Handling codes are only to be used on sharks and rays. Any animal with a caught code of Dead should not have a handling code but can have a damage code. If an animal has both damage and handling codes, please record the first type of handling that occurred in the Damaged column, then mark the comment box and explain the situation in the comments section of the Catch Log. Please do not use 'ND' for sharks or rays that are alive at capture in this column. At the very least we are interested in how the animal was released from the fishing gear.

Handling Codes

ES = Escaped – Shark/ray freed itself (e.g. throws the hook, breaks the line or becomes disentangled in the gear).

LC = Line Cut - Shark/ray is released by the crew cutting any portion of the branchline. In the measurements column please specify the quantity of gear **still attached to the animal**. For example, if the line is cut at the snap, note the total length of the trailing gear left attached to the animal rounded to the nearest meter (e.g. 12 meter branchline, 45 g weight and 0.5 m leader, hook = 13) in the third measurement column. Measurement type is gear length, the reference code is GL.

GR = Gear Removal – The fishermen attempt or successfully remove the fishing gear from the animal. Some fishermen may bring the shark to the fish door of the vessel and lift and drop it so that the hook tears out **or** lift the shark and cut the hook out **or** bring them onto the deck near the cutout **or** a combination these. To remove the gear, fishermen may also cut the lip to remove the hook. If they must cut into the jaw or pieces of the jaw come off as a result of the handling please use JW code to record the jaw was damaged (JW) during the interaction. Furthermore, if there was more damage to the shark during the interaction (e.g. they gaffed the animal to bring it on board) please mark the comments box and describe the handling and damage to **live** animals. When gaffs are used please note the location where the gaff was embedded (e.g. body, gills, eye, mouth, etc).

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 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. This code would not refer to any situation covered by the JW 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, spine).

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.

MEASUREMENTS and GENDER

Measure sharks when possible. Use O for out of protocol measurements and AL (Fork Length, whole feet) for all sharks that are not brought onboard. Record the gender when possible.

Do not ask the crew to board live sharks.

COMMENTS SECTION

Within the instructions above there are several circumstances where the use of comments has been prescribed. The following is a list of examples when comments will be necessary (providing comments is not however, limited to this list); the stomach is everted, if the animal is gaffed, amount of time on a drag line, if there are both damage and handling codes, if parts of the jaw come off with the hook when the drag line or shark lines are used, the amount of line/ gear left on the animal, when the ‘Other’ code was used.

PHOTO LOG

For each shark video taken with the GoPro, record on a separate line GP in the Photo Caption/ Short Description block after the description of the video.

Your previous efforts at collecting data and samples are greatly appreciated by PIFSC scientists. Please continue your commitment towards high quality data and sample collection.

Distribution:

Selected PIROP Observers

S. Arceneaux	E. Forney	L. Jantz	J. Kelly	S. Kostelnik
J. Marchetti	R. Kupfer	J. Lee	M. Marsik	F. O'Neill
B. Miyamoto	J. Peschon	C. Smith	E. Phillips	J. Vincent
M. Hutchinson	K. Apiki	M. Miller	L. Rassel	S. Van Gent

Annex C. A summary of the costs and benefits of tagging sharks in the water or on deck provided by M. Hutchinson (NOAA-JIMAR) during the workshop.

Tag on deck		Tag in water	
Benefits	Costs	Benefits	Costs
Good tag placement leading to increased tag retention times	Additional handling during landing (often through the use of a gaff. Gaff placement could lead to additional trauma)	Minimizes handling artifact	Harder to tag
Ease of tagging	Stress	Safety	Stress during misses
	Exposure to air	Reduced time at the vessel	Reduced retention due to poor placement
	Potentially dangerous to have a large shark on deck		
	Not an actual handling practice in some fisheries		

Annex D. Tag Leadering Instructions and Materials for Short-term PAT Deployments in Shark PRM Studies

Materials:

- Leadering Materials labelled with Reward and Contact information
- Heat shrink tubing black 1/8 x 12 inches (goes over monofilament)
- Heat shrink tubing black 3/16 x 6 inches (goes over crimps)
- Monofilament leader (Momoi X-Hard 300 lb. test, 1.8mm)
- Double barrel crimps sized for monofilament leader
- LIROS-Aramide Braided Cord (1 mm) or similar sized heavy Spectra braided line
(To cover monofilament leader)
- Chafing material (plastic tubular "line saver" for fishing leaders)
- Anchor type: Wildlife Computers small Titanium dart

Instructions:

1. Loop monofilament around base of nose cone on the tag.
2. Add double barrel copper crimp(s)
3. Slip monofilament into LIROS-Aramide Braided Cord (1 mm)
4. Slip small piece of 3/16 heat shrink tubing over crimps under nose cone. Add small 1/8 heat shrink material over the leader to the crimps.
5. Heat to shrink both pieces using heat shrink gun.
6. Add another small piece of 3/16 tubing to anchor end of leader.
7. Slide double barrel copper crimps or stainless crimps onto base of leader.
8. Add chafing material or stainless thimble to anchor end of leader
9. Loop leader with chafing material around anchor.
10. Crimp sleeves with hand crimper (mono) and slide the piece of heat shrink over the crimps
11. Carefully apply heat using heat shrink gun.

