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Alternate catch estimates for silky and oceanic whitetip sharks in Western and Central Pacific Ocean

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1 Overview

This paper follows from the estimation of catch rates and catches of key shark species submitted the Western and Central Pacific Fisheries Commission (WCPFC) Scientific Committee (SC7, Lawson 2011). The developments presented here include additional analyses of the SPC data holdings for oceanic whitetip sharks (*Carcharhinus longimanus*; OCS) and silky sharks (*Carcharinus* falciformis; FAL) caught in longline and purse seine fisheries in the Western and Central Pacific Ocean (WCPO).

Oceanic whitetip and silky sharks are some of the most commonly caught bycatch species in pelagic tuna longline and purse seine fisheries, however the quantity and quality of historical shark catch data are often poor (Camhi et al. 2008, Clarke et al 2011). A main driver of this is that sharks have long been considered non-target species and as such are often either inaccurately recorded in vessel logbooks or entirely un-recorded. A surge in the shark fin trade in the 1990s (Clarke 2009), combined with the practice of shark finning (i.e. retention of fins while discarding the carcasses at sea), has led to increased interest in the impact of fishing on shark populations (Clarke et al. 2007, Clarke and Harley 2010, Lawson 2011). At a basic level management plans rely on estimates of catch to assess this impact despite high levels of discards and low reporting (Clarke 2007, Clarke and Harley 2010).

The framework for this analysis is to construct additional alternate inputs for stock assessment (WCPFC-SC8-2012/SA-WP-06 & WCPFC-SC8-2012/ SA-WP-07) based on an estimated catch and an index of abundance based on standardized catch per unit of effort (CPUE). SPC holds longline observer records from 1985 to recent years, however oceanic whitetip sharks were not identified to species until 1995, hence the dataset used in this analysis spans the years 1995-2009. Recent work by Clarke et al (2011) has noted the gaps in observer data in terms time, space, reporting rate and identification with respect to sharks.

2 Utility of alternate catch trends

Catch estimates by Lawson (2011) are regarded as the best estimates of catch for OCS and FAL in the WCPO and underlie the reference case model run in the stock assessments presented to the Scientific Committee at this year's meeting (Rice and Harley 2012, 2012b). Alternate catch trends were desired for the sensitivity runs with respect to the reference case mode run (Rice and Harley 2012, 2012b) due to the low observer coverage in the longline fleet (<1% in recent years), and the gaps in the time, space, reporting rate and identification with respect to sharks. These alternate catch estimates help assess the relative importance of the catch in relation to other model inputs and parameter values.

3 Difference from previous catch trends

This study follows Lawson (2011) in many respects, most notably in the structure of the catch estimation process based on the intuitive assumption that $Catch = Effort * CPUE$. Both studies estimate a CPUE grid (surface) over latitude and longitude and multiply annual estimates of catch by this grid to estimate annual catch. Details of the main differences between this study and Lawson (2011) are given below, in summary the main difference can be broken down into differences in data input and differences in model parameterization.

3.1.1 Differences in input data

The longline observer data were validated (records with missing values for key explanatory variables removed) and trimmed to include only relevant data from the species 'core' habitat. This was done to reduce the already excessive number of zeros in the data, i.e. zero catch where you would expect not reasonably expect to catch oceanic whitetip sharks. Environmental data about temperature, salinity, moon phase, and depth of the 27˚C isotherm downloaded from the GODAS database (GODAS 2011) were matches to the set by set observer data.

Because oceanic whitetip sharks and silky sharks are an epi-pelagic tropical species all sets that occurred in water colder than 25˚C were discarded, this left 90% of non-zero catch for OCS for (Figure 1), and 95%of the non-zero catch for FAL. The effect of hooks between floats (a proxy for depth) was investigated independently and sets with greater than 30 hooks between floats were discarded, this left 80% of the sets with non-zero catch (Figure 2). National affiliation of the fishing vessel was included in the data set, and only those nations that had greater than 100 sets since 1995 were used. The last variable that resulted in a culling of the data set was based on the positive CPUE for unidentified sets (sets where the target is marked as unidentified) as a function of national affiliation. Vessels whose flags had an average positive CPUE over 3 times the mean CPUE of all the other nations were removed from the bycatch longline data under the premise that these vessels were targeting sharks.

Latitude and longitude were truncated to the nearest 1˚; this location information was used to calculate the association with a 5˚square (referred to hereinafter as cell). Date of set was used to calculate the year, month, quarter and trimester of the set. Set time was used to calculate the time category of the day in sixths starting at midnight. A non-target data set was a result of the filtering data sets according to these rules as well as filtering the sets where sharks were the intentional target. This was done under the premise that the factors leading to non-zero catch rates for shark targeting would be different than those that lead to non-zero catch rates for not targeting.

Although a much smaller proportion of the overall dataset, the targeting sets represent significant shark catch. Therefore the dataset was examined with respect to variables relating to whether sharks were the intentional target of the set. Oceanic whitetip shark CPUE was plotted as a function of the variables sharkline, shark bait, shark target against date of set. Inspection of these covariates led to the separation of shark-targeting sets and non-targeting (bycatch) sets (Rice 2012, 2012b). Shark targeting sets were deemed to be sets where the observer had marked that the set was intentionally targeting sharks of any species, whether shark bait was used, or whether shark lines were used.

The results of these filtering rules are in Table 1.

The only restriction placed on the purse seine observer data was that the set occurred within the rectangle defined by 7˚N and -12˚S Latitude and 139˚W to 192˚E. The purse seine data was separated into two fisheries, one based on associated sets and one based on unassociated sets.

3.1.2 Differences in model parameterization

Delta log-normal (DLN) models (Lo et al. 1992, Dick 2006) were fit to the prepared data sets, for an overview of the DLN modelling process and catch estimation see Lawson (2011). This study followed a fundamentally similar approach to Lawson (2011), but applied the DLN model differently due to the differences in the cleaned data (this study) and the full dataset (Lawson 2011). For example the data had been trimmed with respect to hooks between floats in the current study so this covariate was not included in the model. Lawson (2011) parameterized latitude and longitude as a multivariate spline which effectively constricted these two variables to a single two dimensional variable, whereas this study included latitude and longitude as univariate splines.

Lawson (2011) applied the DLN model with spline on the time component (parameterized as year_month), this effectively estimates the effect of time on the overall CPUE, but incorporates this effect into the overall estimation of predicted CPUE surface (across latitude and longitude). This study estimated a discrete annual effect (year estimated as factor) allowing the catch estimation to incorporate annual deviations in the CPUE.

4 Methods

The resulting datasets were standardized using generalized linear models (McCullagh and Nelder 1989) using the software package R (www.r-project.org). An annual CPUE surface was predicted for the fishery based on the DLN model in call cases except for the silky shark longline fisheries which were modelled with the negative binomial due to difficulty fitting the DLN (Figure 3 the unassociated purse seine sets and silky sharks for year 2000 are used as an example throughout). All models included year as a factorial covariate and latitude and longitude as factorial covariates (silky shark longline fisheries) or as univariate splines where the degrees of freedom were determined based on AIC.

A surface of overall annual effort based on the SPC OFP effort records (Williams and Terawasi 2011) was then created by proportioning the effort to 5˚x5˚ square based according to the reported latitude and longitude (Figure 4). The unit of effort for the purse seine fisheries was number of set; for the longline fisheries the unit of effort was 1000 hooks deployed. Due to the fact that the reported effort rarely (if ever) indicates shark targeting, the level of effort was split at 95% for the bycatch longline and 5% for the target longline. Catch estimates by species and fleet were calculated by multiplying the CPUE surface by the effort surface with respect to space (latitude and longitude) and time. This produced an annual catch surface (Figure 5), which was summed to provide an annual catch estimate (Figure 6 & Table 2).

5 Model Results

The combined estimates of catch for FAL and OCS for each of the purse seine and longline fleets (associated and un-associated, bycatch and target respectively), are in shown in Table 2. A comparison between the estimates from this study and that of Lawson (2011) is presented in Figure 5.

6 Acknowledgements.

Member countries that provided data, Tim Lawson for methods and Shelton Harley for helpful comments during the review process.

8 References

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9 Figures

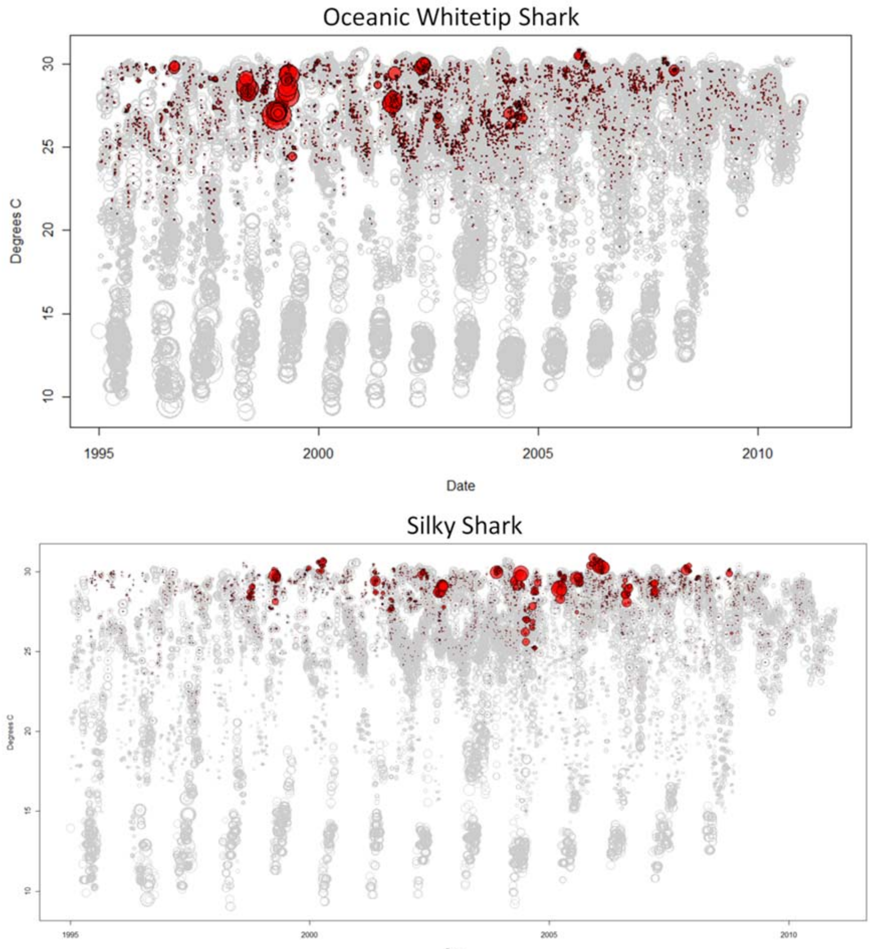

Figure 1. Longline CPUE for oceanic whitetip sharks (top panel) and silky shark (bottom panel) as a function of time (x axis) and degrees centigrade (bottom). Red circles are scaled proportional to the maximum observed CPUE value. Grey circles are scaled proportional to the maximum number of hooks observed.

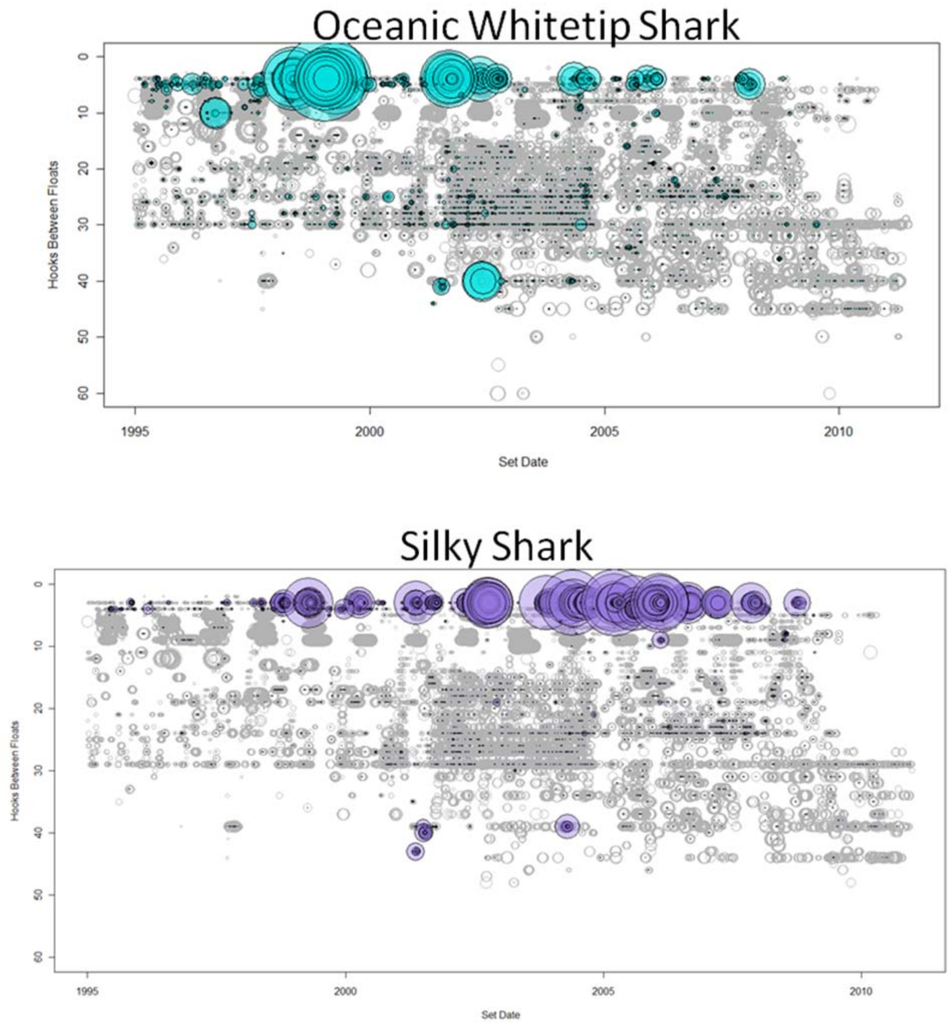

Figure 2. Longline CPUE for oceanic whitetip sharks (top panel) and silky shark (bottom panel) as a function of time (x axis) and hooks between floats (bottom). Circles are scaled proportional to the maximum observed CPUE value. Grey circles are scaled proportional to the maximum number of hooks observed.

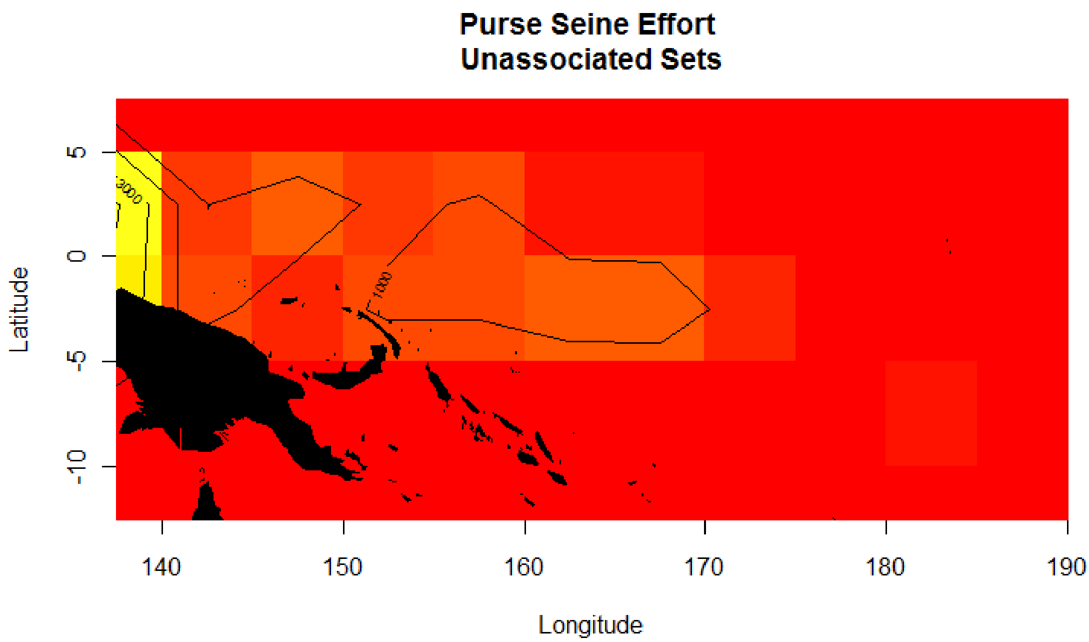

Figure 3. Effort (numbers of sets) of unassociated purse seine sets in the year 2000. Lighter colours indicate higher values.

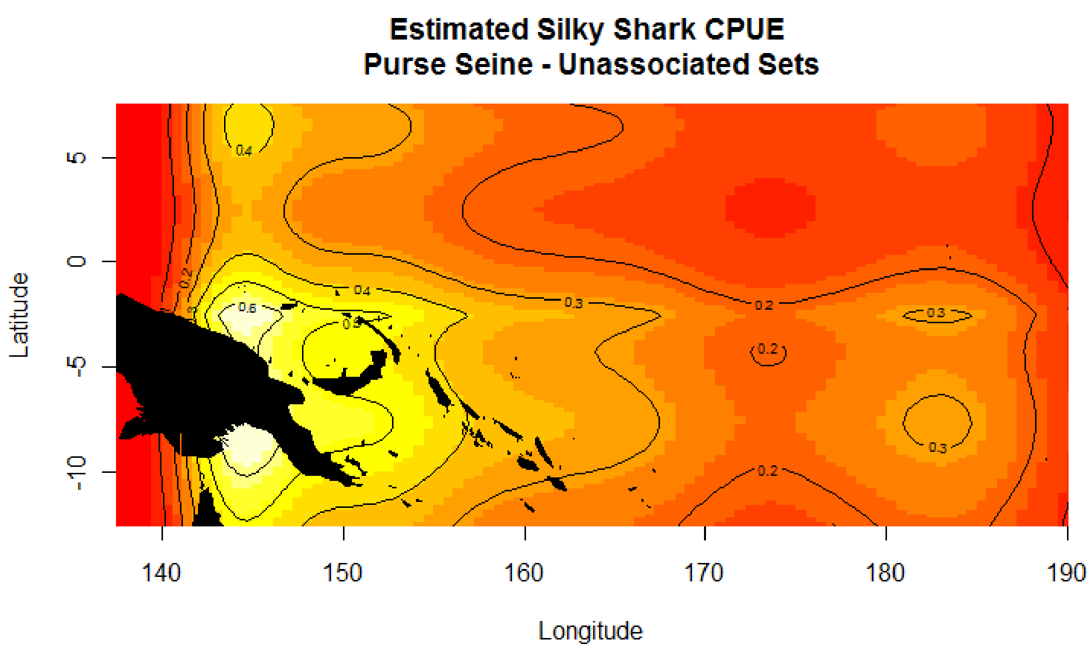

Figure 4. Estimates of Silky shark CPUE (sharks per set) based on the DLN model for the unassociated sets in the purse seine fishery in the year 2000. Lighter colours indicate higher values.

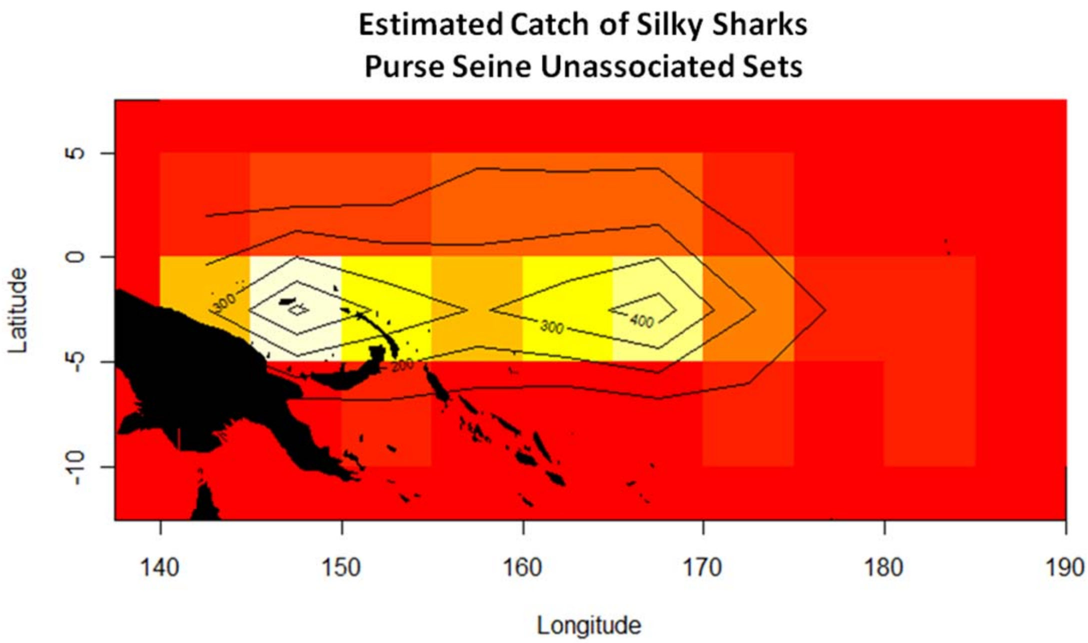

Figure 5. Estimated catch of silky sharks in the year 2000 in unassociated sets for the purse seine fishery. Lighter colours indicate higher values.

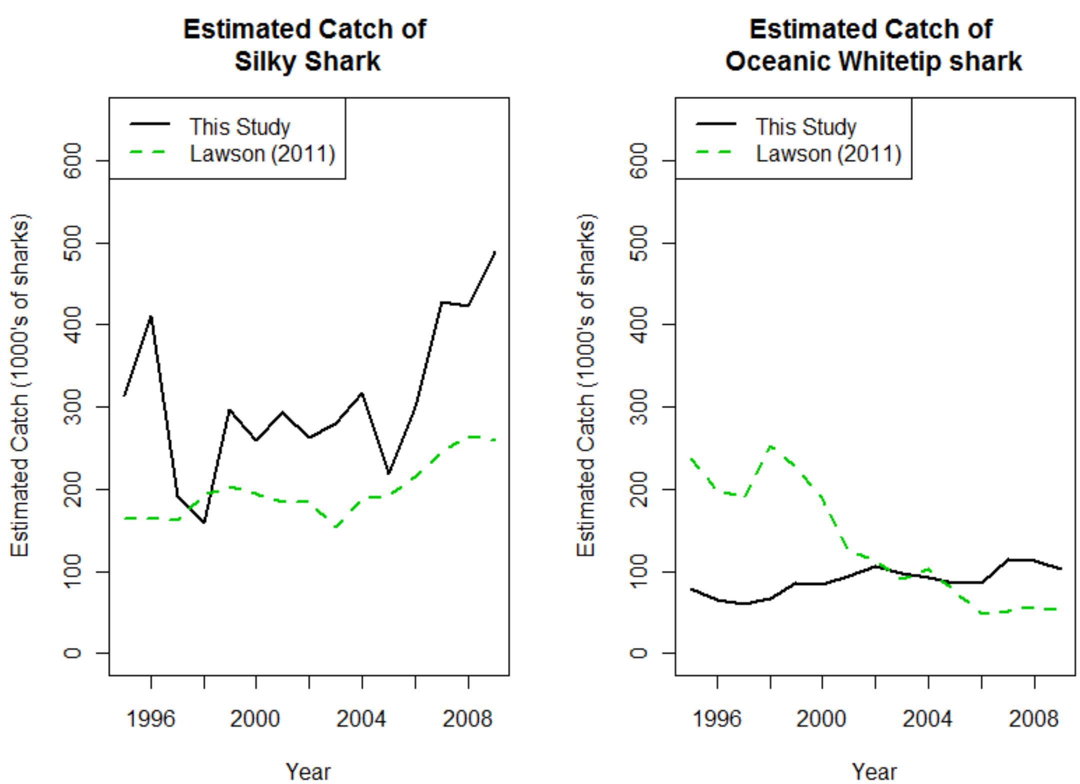

Figure 6. Estimated catches of silky shark (left panel) and oceanic whitetip sharks (right panel) based on estimates from this study and Lawson 2011.

10 Tables

Table 1. Filtering Rules for the longline dataset

Filtering rules for the Bycatch Data

Number of Records	Number removed	Filtering Rule	Number of Oceanic Whitetip Sharks	Number of Silky Sharks
35307	2467	remove sets with marked as target sets	8337	14657
34995	312	remove data from Flags w/ less than 100 sets	8201	14460
19093	15902	remove sets with associated temeratures <=25 degrees	6671	13995
13274	5819	remove sets with >30 hooks between floats	4957	12866
12567	707	remove sets with high CPUE where target is 'unidentified'	4841	9127
12542	25	remove sets in 2010	4840	9123

Filtering Rules for Target data sets.

Number of Records	Number removed	Filtering Rule	Number of Oceanic Whitetip Sharks	Number of Silky Sharks
3775	33999	Keep Shark Bait, shark line or shark target	6407	45752
		of which		
		2467 Marked *Target*		
		1935 Marked *Sharkline*		
		1987 Marked *Sharkbait*		

Table 2. Estimated catch (1000's of sharks) of silky shark and oceanic whitetip shark in the WCPO by fishery.

	Silky Shark				Oceanic Whitetip Shark			
	Longline		Purse Seine		Longline		Purse Seine	
Year	Bycatch	Target	Associated	Unassociated	Bycatch	Target	Associated	Unassociated
1995	255.37	16.60	29.40	5.08	71.05	5.61	1.40	0.98
1996	92.26	277.08	37.22	4.74	57.30	5.23	1.69	0.86
1997	96.46	22.05	69.35	3.81	52.23	4.60	2.74	0.65
1998	79.68	24.84	48.66	5.81	59.67	4.76	1.82	0.74
1999	214.95	22.21	56.16	3.36	76.59	6.34	2.23	0.64
2000	174.19	17.66	60.78	6.51	74.28	5.69	2.39	1.09
2001	219.92	22.00	44.36	6.51	83.42	7.66	1.67	0.89
2002	160.74	39.84	57.46	5.29	92.02	10.60	2.17	0.75
2003	138.00	45.57	90.11	5.99	83.34	8.66	3.67	1.78
2004	150.51	31.37	131.04	4.63	78.99	6.91	5.33	0.75
2005	105.04	29.34	76.49	7.35	73.36	7.80	3.08	1.10
2006	175.80	33.77	83.26	6.49	74.67	7.08	3.25	0.85
2007	291.57	46.83	80.52	8.47	101.86	8.22	3.23	1.05
2008	304.31	22.00	86.63	10.22	102.23	7.03	3.40	1.06
2009	189.21	200.31	90.11	8.98	89.34	9.00	3.41	1.17