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Historical Catch Estimate Reconstruction for the Pacific Ocean based on Shark Fin Trade Data (1980-2016)

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Abstract

This paper describes a methodology to estimate silky shark catches in the Eastern and Western Central Pacific Ocean by all fleets based on a characterization of the global shark fin trade. Catch estimates using this method have been used in ICCAT blue and shortfin mako assessments, IOTC blue shark assessments, and the previous WCPFC assessment of silky sharks. Estimates were constructed using four steps. First, estimates of the number and biomass of silky shark represented in the global shark fin trade in 2000 were reconstructed using triangular distributions in a WinBUGS model. These estimates were then adjusted using annual imports into Hong Kong for 1980-2016. Figures were then further adjusted based on the diminishing share of Hong Kong's shark fin trade as compared to the total global trade in recent years. Finally, these adjusted annual global estimates were scaled in a number of ways (by ocean area (km^2), by tuna and tuna-like species catch, and by longline effort) to represent potential shark catches in the Eastern and Western Central Pacific Ocean. It is important to note that these estimates capture only a portion of the potential silky shark catches (i.e. only those sharks' whose fins are internationally traded).

1 Introduction

Under the Common Oceans (Areas Beyond National Jurisdiction (ABNJ)) Tuna Project, the Western and Central Pacific Fisheries Commission (WCPFC), with support from the United Nations Food and Agriculture Organization (FAO), is executing a programme of shark and bycatch work. One of the components of this work involves conducting Pacific-wide shark stock assessments for the bigeye thresher shark, the southern hemisphere porbeagle, the silky shark and the whale shark. The silky shark assessment aims to update a previous WCPFC assessment (Rice & Harley 2013, which used data through 2009) as well as to expand it to a Pacific-wide scale as called for by the Common Oceans (ABNJ) Tuna Project design.

The silky shark (*Carcharhinus falciformis*) has been identified by both WCPFC and the Inter-American Tropical Tuna Commission (IATTC) as being depleted and in need of management, and was recently listed on the Convention on International Trade in Endangered Species (CITES) Appendix II. This study thus provides an opportunity to update information useful to fisheries managers in the WCPFC and IATTC, both of which currently have some form of no-retention conservation and management measure (CMM) for this species. Through collaborating to analyze data from both the Western and Central Pacific Ocean (WCPO) and Eastern Pacific Ocean (EPO), the study has the potential to elucidate basin-wide patterns for this highly migratory stock.

Lack of historical catch data is often a major obstacle to the assessment of shark species, and was a limiting factor in the IATTC's recent attempt to assess the silky shark in the EPO (IATTC 2014). This paper adapts and applies a methodology previously used to produce estimates of catches of sharks utilised in the shark fin trade for the International Commission for the Conservation of Atlantic Tunas (Clarke 2008, 2016), the Indian Ocean Tuna Commission (Clarke 2015), and the Western and Central Pacific Fisheries Commission (Clarke 2009). These estimates are not direct substitutes for species-specific catch time series primarily because they capture only a portion of the potential shark mortality, i.e. only those sharks' whose fins are internationally traded. As a result, figures produced by this study should be considered minimum estimates of shark mortality in the Pacific Ocean. Nevertheless, they may be useful for comparison with other, more conventional sources of catch data or as minimum plausible estimates if other catch series are not available.

2 Materials and Methods

2.1 Data Sources

The algorithm for estimating the Pacific Ocean shark catch represented in historical shark fin trade data is based on Clarke (2008, 2009). It consists of four data components, each of which is discussed separately below:

1. Estimates, by species, of the number and biomass of sharks used in the global shark fin trade based on market sampling in 2000 (the "anchor point" estimates);
2. A standardized estimate of the quantity of shark fins imported to Hong Kong for each year of interest before and after 2000 based on customs statistics;
3. An estimate of the Hong Kong market share, relative to the global market, for each year of interest before and after 2000 based on expert judgment; and
4. Estimates of the proportion of the global total of shark fins that are derived from the Pacific Ocean (calculated using several alternative methods).

2.1.1 Component 1

The "anchor point" estimates of the number and biomass of sharks used in the global shark fin trade are taken from Clarke et al. (2006a). That study used matches of Chinese trade names and taxa from market sampling and genetic testing (Clarke et al. 2006b), in combination with 18 months of Hong Kong auction records to impute missing data and produce an annual estimate of traded fin weights by species and fin size category. These fin weights were then converted to number of sharks and biomass using a series of conversion factors. For each species, three independent estimates based on dorsal, pectoral and caudal fins, respectively, were produced and extrapolated using trade data to represent the global market. A composite estimate for all fin types was then produced using a mixture distribution computed with the density function for each fin position weighted proportional to its precision. Since a probabilistic modelling framework was applied, the results were presented as probability intervals.

Of the eleven categories of species, or groups of species, presented in that study, this analysis uses the results for silky sharks only. In number, the quantity of silky sharks utilized in the shark fin trade in 2000 was estimated at 0.795 million (95% probability interval of 0.368 – 2.008 million). In biomass, the quantity was 45,460 t (95% probability interval of 29,400 – 74,050 t). These estimates are based on shark fin trade for 2000 when Hong Kong imported 6,788 t of fins and was estimated to control 44-59% of the global market (Clarke 2004a, Clarke et al. 2006a)

2.1.2 Component 2

Standardized estimates of the quantity of shark fin imported by Hong Kong in each year since 1980 were prepared from unpublished Hong Kong government records (HKSARG 2017). Prior to 1998, Hong Kong recorded imports of shark fins in dried or frozen ("salted") categories without distinguishing between processed and unprocessed fins. In order to avoid double-counting fins returning to Hong Kong after processing in Mainland China, imports from the Mainland prior to 1998 were subtracted from total imports following methods used by TRAFFIC (1996). In 1998 Hong Kong established separate customs codes for dried and frozen (i.e. the latter listed as "salted" in commodity coding lists), processed and unprocessed fins. After 1998, only unprocessed dried and frozen fins were included in the annual totals. All frozen fin weights were normalized for water content by multiplying by 0.25 (Clarke 2004a).

Although the data series continues through to the present, changes in the commodity coding scheme in 2012, in parallel with concomitant reports of a sharp drop in both market demand and price, suggest that Hong Kong import data after 2011 may not reflect trends in shark catches to the same extent as prior data (Dent & Clarke 2015, Eriksson & Clarke 2015). This problem forces a choice between using the reduced import figures and assuming they are accurate, or making an additional adjustment to compensate for the potential biases since 2011. One way of imputing figures for 2012-2016 would be to assume that trade levels since 2011 vary in proportion to global levels of chondrichthyan capture production. This appears to be a reasonable assumption given the parallel trends in the Hong Kong import figures and the FAO-compiled global chondrichthyan capture production figures (Figure 1)[1]. Alternative values for Hong Kong shark fin imports for 2012-2016 were imputed using $H_i = H_{2011} \times \frac{C_i}{C_{2011}}$ where H_i is the annual Hong Kong import value for years i=2012 to 2016, and C_i is the FAO-compiled annual value for global capture production of chondrichthyans in year i (Table 1).

2.1.3 Component 3

Hong Kong's share of the global shark fin trade was studied in detail for 1996-2000 and was calculated from empirical data to range from 44-59% (Clarke et al. 2006a). Since reliable empirical data for estimating Hong Kong's market share in previous and subsequent years (i.e. 1980-1995 and 2001-2016) are lacking, ranges of values for these years were specified based on expert judgment.

Difficulties in estimating Hong Kong's share of the global trade in previous years (i.e. 1980-1995) are mainly due to the lack of access to customs statistics for other countries, especially Mainland China. Nevertheless, a general understanding of trade patterns in Hong Kong during the 1980s (Clarke et al. 2007) suggests that Hong Kong's market share was higher in 1980-1995 than during 1996-2000. The earliest accounts of the shark fin trade state that Hong Kong's share of world imports was 50% (Tanaka 1994, based on data through 1990) or 85% (Vannuccini 1999, based on 1992 data). A range of 65-80% was thus selected for the period 1980-1990. A transitional period for the shark fin trade in Hong Kong occurred in 1991-1995 as demand began to rise appreciably in Mainland China. It is likely that Hong Kong's share began to drop, but not to the extent observed in the period 1996-2000 (i.e. 44-59%), thus a range of 50-65% was selected.

Estimation of Hong Kong's market share since 2000 is less plagued by data gaps but still subject to a number of potential biases. Previous analysis has shown that Hong Kong imports of shark fin rose at a rate of 6% per year from 1992-2000 (Clarke 2004a), but afterwards stabilized with a slightly declining linear trend (Clarke et al. 2007). Hong Kong shark fin traders attribute this trend to a loss of market share to Mainland China. While this explanation is supported by the well-known liberalization of the Mainland China economy just prior to and as a result of entry to the World Trade Organization in December 2001, Mainland China's shark fin imports do not show a strong trend of increase since 2000. One reason for this lack of trend may be that in 2000 Mainland China began importing frozen shark fins under a category previously used only for frozen shark meat and therefore from 2000 onward frozen fins, which comprise a substantial portion of the trade, are no

[1] The FAO chondrichthyan capture production figures include rays and chimaeras as well as sharks, but it is appropriate to include rays and chimaeras because their fins are also used in the shark fin trade.

longer distinguishable in the statistics (Clarke 2004b). Complications in trade reporting by Mainland China and their implications for assessing global trade in shark fins are discussed in detail in Clarke et al. (2007). On balance it was considered that even without strong evidence of increasing imports by Mainland China, it was likely that Hong Kong's share of global trade declined sharply after 2000. A range of 30-50% was thus specified for 2001-2006 to account for the initial decline, and a lower range of 25-40% was specified for 2007-2016 as the trend is believed to have become even more pronounced including potential diversion to countries in Southeast Asia (Dent & Clarke 2015).

2.1.4 Component 4

Three methods were used for proportioning global fin trade-based catch estimates to Pacific Ocean-specific quantities. Each of the resulting indices has its own inherent biases acting over the entire time series or over portions of the time series. Therefore, when patterns appear in results derived from one proportioning method only, careful consideration of the credibility of that particular proportioning method is warranted.

The first proportioning method is based on calculating the area of silky shark potential habitat in the Eastern and Western Central Pacific relative to its potential habitat in the world ocean as a whole. This method assumes that the silky shark is evenly distributed throughout global waters between the northern-most and southern-most extent of its range. For simplicity, this range was considered to be 30°N-30°S worldwide based on indicative ranges given in Compagno (1984). Using Google Earth tools the global ocean area between 30°N and 30°S was calculated as 189.295 million km^2. The portion of this potential silky shark habitat lying within the Western and Central Pacific Fisheries Convention Area was 66.603 million km^2 and the portion within the Inter-American Tropical Tuna Convention Area was 46.410 million km^2. The area of the two convention areas together between 30°N and 30°S is smaller than the sum of their individual areas due to an overlap area of 5.847 million km^2. Therefore if taken together the WCPF and IATT Convention Areas between 30°N and 30°S extend over 107.166 km^2. Based on these figures, the ratios of Pacific to global areas are

Eastern Pacific only: $\frac{46.410\ M\ km^2}{189.295\ M\ km^2} = 0.245$

Western and Central Pacific only: $\frac{66.603\ M\ km^2}{189.295\ M\ km^2} = 0.352$

Pacific: $\frac{107.166\ M\ km^2}{189.295\ M\ km^2} = 0.566$

No plot is shown for this area-based proportioning method because the ratios are constant throughout the time series.

The second proportioning method involves scaling against a ratio of tuna and tuna-like species catches in global waters versus those in the Pacific Ocean. In previous applications of this methodology, the scale was defined using FAO capture production values for the group of target species defined as "tunas, bonitos and billfishes" in the FISHSTATJ system (FAO 2018). In this case, given that a portion of the Eastern Pacific tuna fleet shifts it's targeting in part of the year to dolphinfish (*Coryphaena hippurus;* Martínez-Ortiz et al. 2015), the catch of this species was also taken into account. In the FISHSTATJ system there were two possible categories representing this species: 'common dolphinfish' and 'dorado' ('mahi mahi' is not shown). Since the 'dorado' entries were for countries fishing in the Atlantic, only 'common dolphinfish' was included. Dolphinfish never comprised more than 2% of the total reported catch of the target species group in the Western Pacific, but in the Eastern Pacific it comprised as much as 6-8% of the total in recent years reflecting the expansion trends described in Martínez-Ortiz et al. (2015). FISHSTATJ reports capture production figures for the Northeast, Southeast, Eastern Central, and Northwest, Southwest and Western Central Pacific making it easy to separate eastern and western areas without overlap. The total capture production figures for the target species group, and the resulting ratios, are given in Table 3. As shown in Figure 2, the ratios of WCPO to EPO target species catches are quite stable throughout the time series.

The third proportioning method involved constructing an index of fishing effort. Although a number of gear types catch silky sharks, longline fishing effort was considered the best index for proportioning effort on silky sharks by ocean. The main reason for this is that longline effort is most easily standardized across oceans on the basis of hooks fished. Furthermore Lawson (2011) and Rice (2012), which estimated both WCPO longline and purse seine catches, found that the WCPO longline fishery catches 2-4 times the quantity of silky sharks as the WCPO purse seine fishery. Although catches with purse seine gear are a significant component of the global catch of silky shark, catch rates are likely to be dependent on set type (e.g. unassociated (free school) versus various types of associated sets) and these catch rates by set type are not constant across oceans (Restrepo et al. 2017). Bearing in mind that this step is not estimating the global catch--it is only partitioning the global catch to each ocean--a longline effort index was considered the best option. One practical matter limiting this method is that are no 2016 longline effort figures available for the Atlantic or Eastern Pacific Oceans at this time. Therefore, the ratios for 2015 were used for 2016 as placeholders.

The number of longline hooks (in millions) fished annually in the Western and Central Pacific was obtained from a database of raised longline effort for the WCPO maintained by the Pacific Community (CES 2017). For the Eastern Pacific, nominal longline effort has only been published for fleets from China, Japan, Korea, French Polynesia, Chinese Taipei and the United States (IATTC 2017). Effort for other fleets (i.e. last column of Table A-9 in IATTC (2017)) was imputed using the average catch rates for all other reporting fleets for a given year and added to the published total effort. Longline effort in the Atlantic has been estimated under ICCAT's EFFDIS project through 2015 only (ICCAT 2018). Longline effort data for the Indian Ocean were provided in standardized units for 1980-2016 by the IOTC Secretariat (IOTC 2018). Each of these series, as well as the sum of global longline effort, and the ratio of Eastern, Western and total Pacific Ocean effort to global longline effort are shown in Table 4 and Figure 3.

2.2 Modelling Methods

The model was implemented with Markov chain Monte Carlo (MCMC) methods using the Gibbs sampler (Gelfand and Smith 1990) via OpenBUGS software version 3.2.3 rev 1012 (Imperial College London 2014). Since the original posterior distributions presented in Clarke et al. (2006a) require many hours of computing time to replicate, simplified representations of these complex distributions were approximated using triangular distributions (Step 1). Other uncertain parameters, such as Hong Kong's share of the global fin trade (Step 3), were specified as expert judgement-based ranges with uniformly distributed random variables. The annual quantity of Hong Kong imports (Step 2) and the proportioning indices (Step 4) were based on empirical data for each year, except for the geographic area which does not vary from year to year. Although there is uncertainty in these data it is not possible to quantify the variance and thus these parameters were specified using deterministic equations. The model was executed in four steps covering each of the four data sources given above (Annex 1):

Step 1

The probability distributions representing the range of estimates of silky shark in the global trade by number and biomass (0.795 (0.368 – 2.008) million in number and 45.46 (29.40 – 74.05) t in biomass) were approximated as triangular distributions using the reported lower limit of the 95% probability interval as the minimum, the upper limit of the 95% probability interval as the maximum, and the median as the mode. The model drew a random variable from each of the triangular distributions representing each species' number or biomass in 2000 in each iteration.

Step 2

Each random variable drawn in Step 1 was multiplied by the ratio of the standardized quantity of fins traded through Hong Kong in each year from 1980-1999 and 2001-2016 (Table 1) to the quantity of fins traded through Hong Kong in 2000 (i.e. 6,788 t). This step serves to scale the global species-specific number or biomass estimates from 2000 to quantities representing trade levels in each of the other years. Due to a lack of quantitative data on trends in species composition this step assumes that the proportion of silky shark in 2000 remains constant over the years 1980-2016. This appears to be a reasonable assumption based on a recent study of shark fin trimmings, a byproduct of the shark fin trade and a possible indicator of species composition (Fields et al. 2017). The Fields et al. (2017) study found that silky shark was the second-most common species in the market in 2014-2015 comprising 5.4% (95% confidence interval of 2.1-11.4%) whereas Clarke et al. (2016b) in 2000 found silky shark to be the third-most common species comprising 3.5% (95% probability interval of 3.1-4.0%) of the shark fin market.

Step 3

Hong Kong's share in four alternative periods (S_a), i.e. 1980-1990, 1991-1995, 2001-2006 and 2007-2016, relative to its share in 1996-2000 (0.44-0.59, S) was specified as a series of uniformly distributed random variables using endpoints based on expert judgment (Section 2.1.3). The ratio of S and S_a was then computed and multiplied by the result from Step 2. The result of Step 3 is a species-specific number or biomass value representing sharks used in the global trade for each year from 1980-2016.

Step 4

The final step required proportioning the annual values from Step 3 to the Eastern Pacific, Western Pacific and Pacific Ocean as a whole. Proportioning based on area used constants for the various regions over all years in the time series. The target species catch-based (Table 3 and Figure 2) and longline effort-based (Table 4 and Figure 3) proportioning methods applied unique values for each year as deterministic calculations.

The model was run for 10,000 iterations, and medians and 95% probability interval endpoints were sampled from the final 1,000 iterations.

3 Results

The algorithm outlined above will, by definition, produce the same patterns of results in number (Figures 4-6 and Annexes 2-4) and in biomass (Figure 7-9 and Annexes 5-7). This is because the same scaling factors were applied to the number and biomass anchor point estimates thus only the absolute value of the starting point for each metric differs. Furthermore, in two of the three cases (i.e. for all but the target species catch-based method) the scaling factors did not show a strong trend (Figures 2 and 3) and so the trend from the Hong Kong fin imports (Figure 1; Step 2) and the proportion of trade believed to be passing through Hong Kong (Step 3) drove the overall result. In particular, the increase in the early 2000s reflects the sharp rise in Hong Kong imports, and the reduction in the Hong Kong trade thereafter is modulated by the declining share of Hong Kong in the global trade in recent years.

In the Western Pacific the area-based proportioning method, which is constant over time, produced the lowest estimates in most years (Figures 4 and 7). The target species catch-based method generally produced the highest estimates and these were slightly less than double the area-based method. These patterns suggest that the Western Pacific produces a greater share of the world's tuna catch than would be expected given its ocean area which seems reasonable given the productivity of WCPO waters. The effort-based method closely followed the area-based method until 2006 and thereafter produced gradually higher estimates which approximated those of the target catch-based method by the end of the time series (2016). This pattern reflects the trend of increasing longline effort in the Western Pacific relative to the global longline effort since 1998 (Figure 3). Probability intervals for the three Western Pacific estimation approaches largely overlap and range as high as double their medians in the later years of the time series.

The patterns in the Eastern Pacific estimates show similar trends to those in the Western Pacific but the absolute values of the different estimation approaches have a different rank order (Figures 5 and 8): the area-based proportioning method produced the highest estimates suggesting that the region's silky shark habitat is large relative to its proportionally smaller share of global tuna/dolphinfish catch and longline effort. This may be an actual reflection of fishing practices or may result from an inability to accurately quantify this region's catches and effort. Similar to the estimates for the Western Pacific, the probability intervals for the various estimates are as high as double their medians in recent years.

Estimates for the Pacific as a whole are less divergent between the three methods (Figures 6 and 9). This suggests that the share of Pacific sharks (relative to global) is more stable between methods than is the split between WCPO and EPO between methods. For the Pacific estimates, the target species catch-based method remains higher than the effort-based method. The low estimates in the west from the area-based method combine with the high estimates in the east from the area-based method to place the area-based estimates for the Pacific as a whole intermediate to the other two series. Probability intervals for Pacific-wide estimates are not quite symmetrical around the medians with lower bounds around 50% lower than the medians and upper bounds as high as 60-80% above the medians.

Focusing on the medians for the 2008-2016 period as a basis for comparison between regions, estimates in number ranged from 0.5-0.8 million silky sharks per year in the Western Pacific, to 0.15-0.35 million silky sharks per year in the Eastern Pacific and 0.8-1.0 million silky sharks per year for the Pacific Ocean as a whole. In biomass the respective figures are 25,000-40,000 t in the Western Pacific to 4,000 to 17,000 t in the Eastern Pacific to 35,000-50,000 t Pacific-wide.

4 Discussion

Catch data for most shark species are insufficient to support stock assessment, yet concerns about the status of shark populations continue to grow. Under such circumstances, development of alternative historic shark catch time series and careful evaluation of whether these alternative series can fill some of the existing critical data gaps is a worthwhile exercise.

The estimates produced by this study were based on "anchor point" estimates derived from a shark fin trade data set compiled in Hong Kong in 2000 (Clarke et al. 2006a). To date these are the only quantitative, species-specific estimates of the number of sharks represented in the shark fin trade and represent a snapshot of the center of the global shark fin trade at that time. Using these data to estimate the number and biomass of shark catches in the Pacific Ocean requires a number of assumptions, namely:

1. The species composition of the sampled portion of the Hong Kong shark fin trade in Clarke et al. (2006a) is representative of the species composition of shark catches in Pacific offshore fisheries. As discussed in Clarke et al. (2006b), there is a lack of information to evaluate the strength of this assumption, but there are no other datasets that are considered more representative.

2. The species composition of the fin trade observed in 2000, and the relationships between fin sizes/weights and whole shark weights observed at that time, are constant throughout the time series. While some stock composition shifting would be expected over time, there are few existing data with which to explore alternative assumptions. A recent study of the species composition of the fin trimmings (by-product) trade in Hong Kong (Fields et al. 2017) is not directly comparable but shows remarkable consistency with the earlier fin-based study's species composition findings, including with regard to silky sharks.

3. Silky shark fins found in the Hong Kong shark fin trade are equally likely to derive from the Pacific as from any other ocean. This appears to be a reasonable assumption given what is known regarding the distribution of this species and the global nature of the trade.

Overlying these assumptions is the fact that estimating catches based on shark fin trade data will necessarily underestimate the true quantities of sharks caught. First, the original "anchor point" estimates are in themselves conservative because they are based only on those fins which could be confirmed to derive from the species of interest. More than half (54%) of the fins observed by Clarke et al. (2006a) could not be characterized by species and could have contained additional quantities of the species of interest (Clarke et al. 2006b). Second, only those sharks whose fins enter the international shark fin trade are enumerated. This is because there is no means in this study of accounting for mortality associated with sharks which are a) discarded dead with their fins attached; b) released with their fins attached but subsequently die due to injury or stress; or c) are retained but whose fins are either not used or used without being internationally traded. For these two reasons actual shark mortality is very likely to be greater than the estimates provided here.

Robust estimation requires use of a number of different algorithms to explore various assumptions and biases. However, this approach in combination with reporting of probability intervals rather than point estimates can lead to considerable uncertainty when drawing conclusions about the estimation results. It is thus important to discuss, qualitatively if necessary, the relative credibility of each of the five estimates (Figures 4-9 and Annexes 2-7).

Of the three proportioning methods (area, target species catch and longline effort), the most arbitrary is the area-based method. Setting catch proportional to geographic area makes the unlikely assumption that shark abundance and fishing operations are evenly distributed throughout the world between 30°N-30°S. Therefore this method would only be preferred when both target species-based and effort-based indices are considered unreliable or unrepresentative.

The target species proportioning method is most credible when the catch of sharks is expected to be proportional to the catch of target species, and when the catch reporting for target species is reliable. In both the WCPO and EPO there is the potential for fisheries to be catching sharks while targeting species other than tunas, billfishes and dolphinfishes (including fisheries targeting sharks per se), and if this is common the target species catch-based method will not be accurate. In the EPO it is known that artisanal and industrial longline fisheries operating in coastal and offshore waters catch a considerable number of sharks while targeting a mixture of species (Gonzales-Pestana et al. 2014, Martínez et al. 2015, Siu & Aires-da-Silva 2016). Furthermore, the target species catch by these gear types may be considerably underrepresented in the FISHSTATJ database due to the variable quality of fisheries statistics in the region (Siu & Aires-da-Silva 2016). The target species catch-based method is not likely to provide a robust estimate for these fisheries. In the WCPO mixed species longline fisheries exist but probably do not comprise as large a portion of the total longline catch as in the EPO.

The third method was based on effort statistics, specifically longline effort in hooks. This method is usually preferred when shark catches are primarily taken by longline gear and when longline effort data are considered to be reliable. Even though Lawson (2011) estimated that longline fisheries catch three-fold (or more) the quantity of silky sharks caught by the purse seine fishery, silky sharks are the most common shark caught in purse seine fisheries and such catches are not negligible. Therefore, for silky sharks, the longline effort-based method would be biased by changes in the relative effort of longline versus purse seine gear over time, and is not recommended for either the WCPO or EPO for this reason. The effort-based method is expected to perform particularly poorly for the EPO because the index was derived from incomplete longline effort data holdings (IATTC 2017) and so would tend to deflate the catch estimates for that region. Potential biases due to different statistical procedures applied by each t-RFMO to standardize and raise effort figures are also a drawback of this method.

Taking all of these considerations into account, it is recommended to use the area-based proportioning method for the EPO (Figures 5 and 8). In this region the effort-based approach is weakened by incomplete longline effort statistics and the target species catch-based approach may be biased by a large proportion of vessels not targeting tunas, billfishes or dolphinfishes. The same issues are present in the WCPO, but to a lesser extent. In the WCPO, longline effort estimated for the WCPFC is known to be missing effort fished by fleets from Indonesia, the Philippines and Vietnam and this compromises the effort-based silky shark catch estimates. The tuna catch estimates held by the WCPFC would be similarly compromised, but it is considered that the FAO tuna catch statistics used in this paper would be incomplete for various countries around the world yet not disproportionately under-reporting WCPO catches. Therefore, the target species catch-based estimates are considered reasonable for the WCPO (Figures 4 and 7). If a combined catch series is required for the entire Pacific, it is recommended to use the area-based method (Figures 6 and 9), or a sum of the target species catch-based efforts for the WCPO and the area-based method for the EPO.

To assess the credibility of the estimates produced in this study it is important to compare them to existing estimates of silky shark catches derived from more traditional fishery-dependent sources. For the EPO, stock assessment work by IATTC for the silky shark in 2013 produced catch series for what were considered to be northern and southern stocks (Figure 10; IATTC 2014). The catch series for the northern stock, which comprises the majority of the catch, spans 1993-2010 and varies from a low of just over 10,000 t to a high of slightly more than 16,000 t. Catches from the southern stock annually add another 2,000 t or less until 2003 and less than 1,000 t annually thereafter. In comparison to the preferred Eastern Pacific biomass trend estimated here (i.e. the area-based estimates; Figure 8), IATTC (2014) shows a decrease in catches from 1993-1998 which is not reflected in the trade-based series. However, both the magnitude and trend of the trade-based estimates post-1998 show a remarkable consistency with the IATTC (2014) series. Both datasets show an increase in the early 2000s to approximately 15,000 t, followed by a sharp decline to approximately 12,000 t in 2006 and then a quick recovery and steady increase to approximately 17,000 t at the end of the series.

For the WCPO, there are several existing silky shark catch series prepared by the Pacific Community (SPC; Lawson (2011), Rice (2012) and Peatman et al. (2017, 2018)) from observer data (Table 5; Figure 11). It is important to note that these estimates are all based on the same dataset, i.e. observer data from the WCPFC Regional Observer Programme and national observer programmes held by SPC. The variation in the estimates for any given year should thus be based on the analytical methodology alone, not due to different data sources or sampling regimes. These estimates indicate the catches by the purse seine fleet are low relative to the longline fleet and generally at or below 100,000 silky sharks per year. The most recent estimates of Peatman et al. (2017) estimate the lowest values for the purse seine fishery. Rice (2012) and Peatman et al. (2018) estimate similar magnitudes of silky shark catches in the longline fishery and their total catches (i.e. longline + purse seine) are up to 150% those of Lawson (2011). All of these SPC estimates are considerably lower than the preferred WCPO catch series produced by this study (i.e. the target species-based estimates in Figure 4; Figure 11). This is not surprising as the SPC dataset is focused on the tropical Pacific east of the Philippines and so the SPC studies could not estimate other components of the fishery, in particular the potentially large silky shark catches in the Southeast Asia region. It is also important to note that purse seine observer coverage in the WCPO was low until 2010 (see Clarke 2017, Table 8) and that longline coverage remains below the required 5% level for many fleets (Williams et al. 2017). All of the SPC combined purse seine and longline catch series as well as the trade-based series estimated in this study show sharply increasing trends in the 2000s with both the trade-based series and the Peatman et al. (2017, 2018) series peaking in 2012, followed by a sharp drop and a slight rebound.

This discussion highlights that while both trade-based and fishery-based catch estimation methods have merit, there are also some important uncertainties associated with both methods which cannot be resolved on the basis of existing information. Given the urgent need for improvement in historic catch data to support shark stock assessment, further study of these and other methods is strongly encouraged.

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Table 1. Number and biomass of silky sharks (median and 95% probability interval) used in the global shark fin trade in 2000 (Clarke et al. 2006a).

Shark Species	Number (million)	Biomass ('000 t)
Silky	0.795 (0.368 – 2.008)	45.46 (29.94 – 74.05)

Table 2. Adjusted total imports of shark fin (t) to Hong Kong, 1980-2016 (HKSARG 2017; see text for adjustment methods) and Global Capture Production for ISSCAAP group "sharks, rays and chimaeras" (FAO 2018). The "anchor point" estimate is shown in bold. Due to changes in commodity codes and a sharp curtailment of trade beginning in 2012 (Dent & Clarke 2015) import quantities recorded by Hong Kong (in red) were replaced with values imputed assuming the recent relationship between Hong Kong import quantities and FAO-reported Global Capture Production figures is maintained.

Year	Hong Kong Shark Fin Imports (t)	Global Shark Catches (t)	Year	Hong Kong Shark Fin Imports (t)	Global Shark Catches (t)	Imputed Hong Kong Shark Fin Imports (t)
1980	2,739	607,692	1999	5,824	869,744	
1981	2,741	609,311	**2000**	**6,788**	888,396	
1982	2,704	614,179	2001	6,435	858,760	
1983	2,512	562,173	2002	6,513	847,708	
1984	2,748	602,724	2003	6,960	879,345	
1985	2,613	624,012	2004	6,142	833,683	
1986	2,788	627,731	2005	5,887	776,763	
1987	3,317	661,790	2006	5,337	759,569	
1988	3,272	688,459	2007	5,798	787,637	
1989	3,003	679,241	2008	5,536	734,062	
1990	3,018	701,752	2009	5,559	761,972	
1991	3,526	723,551	2010	5,759	745,659	
1992	4,265	740,549	2011	6,175	785,008	
1993	3,856	753,331	2012	3,553	798,712	**6,282**
1994	4,144	770,017	2013	3,325	788,370	**6,201**
1995	4,706	776,535	2014	3,308	764,666	**6,014**
1996	4,513	826,809	2015	3,442	743,650	**5,849**
1997	4,868	852,323	2016	3,597	767,152	**6,034**
1998	5,196	843,100				

Table 3. Estimates of FAO-reported capture production of tunas, bonitos, billfishes and dolphinfishes globally and in the Pacific Ocean as a whole, the EPO (Eastern Central, Northeast and Southeast) and the WCPO (Western Central Pacific, Northwest, Southwest) 1980-2016 (FAO 2018). All catch values are in million t.

Year	FAO Global Catch Total	Pacific Ocean Catch Total	Pacific:: Global	Eastern Pacific Ocean (EPO) Catch Total	Western and Central Pacific Ocean (WCPO)	EPO:: Global	WCPO:: Global
1980	2.691	1.849	0.687	0.494	1.355	0.183	0.503
1981	2.724	1.808	0.664	0.515	1.293	0.189	0.475
1982	2.845	1.769	0.622	0.433	1.336	0.152	0.470
1983	3.003	1.950	0.649	0.371	1.579	0.123	0.526
1984	3.174	2.116	0.667	0.432	1.684	0.136	0.531
1985	3.275	2.068	0.631	0.589	1.479	0.180	0.452
1986	3.584	2.341	0.653	0.582	1.759	0.162	0.491
1987	3.729	2.419	0.649	0.594	1.825	0.159	0.489
1988	4.145	2.662	0.642	0.667	1.995	0.161	0.481
1989	4.164	2.703	0.649	0.662	2.041	0.159	0.490
1990	4.434	2.958	0.667	0.676	2.282	0.152	0.515
1991	4.584	3.072	0.670	0.589	2.483	0.129	0.542
1992	4.607	2.996	0.650	0.677	2.319	0.147	0.503
1993	4.707	2.849	0.605	0.602	2.247	0.128	0.477
1994	4.840	2.999	0.619	0.613	2.386	0.127	0.493
1995	4.993	3.093	0.619	0.665	2.428	0.133	0.486
1996	4.939	3.004	0.608	0.639	2.365	0.129	0.479
1997	5.218	3.295	0.631	0.761	2.533	0.146	0.485
1998	5.824	3.825	0.657	0.762	3.064	0.131	0.526
1999	5.977	3.874	0.648	0.867	3.007	0.145	0.503
2000	5.909	3.865	0.654	0.803	3.062	0.136	0.518
2001	5.862	3.851	0.657	0.889	2.962	0.152	0.505
2002	6.241	4.181	0.670	0.926	3.255	0.148	0.522
2003	6.392	4.239	0.663	1.035	3.204	0.162	0.501
2004	6.514	4.240	0.651	0.918	3.322	0.141	0.510
2005	6.660	4.293	0.645	0.916	3.377	0.138	0.507
2006	6.665	4.339	0.651	0.887	3.451	0.133	0.518
2007	6.734	4.638	0.689	0.781	3.857	0.116	0.573
2008	6.651	4.613	0.694	0.943	3.670	0.142	0.552
2009	6.769	4.648	0.687	0.979	3.670	0.145	0.542
2010	6.768	4.607	0.681	0.879	3.728	0.130	0.551
2011	6.696	4.480	0.669	0.961	3.519	0.144	0.526
2012	7.214	4.869	0.675	1.044	3.826	0.145	0.530
2013	7.345	4.945	0.673	1.042	3.904	0.142	0.531
2014	7.634	5.267	0.690	1.132	4.135	0.148	0.542
2015	7.457	5.123	0.687	1.228	3.895	0.165	0.522
2016	7.566	5.045	0.667	1.102	3.943	0.146	0.521

Table 4. Estimates of longline fishing effort (in million hooks) compiled from t-RFMO databases, and the ratio of the EPO, WCPO and Pacific effort to the global total, 1980-2016 (see text for derivation details).

Year	Atlantic (ICCAT 2015)	Western and Central Pacific Longline Effort (CES 2017)	Eastern Pacific Longline Effort (IATTC 2017)	Indian Ocean Longline Effort (IOTC 2018)	Global Total Longline Effort	Ratio (Western Pacific Ocean : Global Total)	Ratio (Eastern Pacific Ocean : Global Total)	Ratio (Pacific Ocean: Global Total)
1980	186	647	153	267	1253	0.517	0.122	0.639
1981	198	693	157	254	1301	0.532	0.121	0.653
1982	246	643	143	302	1334	0.482	0.107	0.589
1983	192	786	147	329	1454	0.541	0.101	0.642
1984	214	660	135	301	1310	0.504	0.103	0.607
1985	260	970	130	300	1660	0.584	0.078	0.662
1986	290	762	196	333	1581	0.482	0.124	0.606
1987	203	1043	238	361	1845	0.565	0.129	0.694
1988	284	908	236	416	1844	0.492	0.128	0.620
1989	287	817	230	529	1864	0.438	0.123	0.562
1990	292	884	238	568	1983	0.446	0.120	0.566
1991	294	752	284	573	1903	0.395	0.149	0.544
1992	312	866	271	649	2098	0.413	0.129	0.542
1993	326	687	225	856	2093	0.328	0.108	0.436
1994	385	556	224	815	1980	0.281	0.113	0.394
1995	397	570	191	738	1896	0.301	0.101	0.401
1996	380	539	153	916	1987	0.271	0.077	0.348
1997	334	537	141	974	1986	0.270	0.071	0.341
1998	326	611	177	1210	2325	0.263	0.076	0.339
1999	359	699	169	1043	2270	0.308	0.074	0.382
2000	351	751	149	937	2188	0.343	0.068	0.411
2001	324	934	274	869	2401	0.389	0.114	0.503
2002	325	974	345	863	2508	0.388	0.138	0.526
2003	352	962	338	785	2437	0.395	0.139	0.533
2004	370	1032	241	908	2550	0.405	0.094	0.499
2005	288	839	174	913	2214	0.379	0.079	0.458
2006	301	866	164	854	2185	0.396	0.075	0.472
2007	348	980	119	937	2385	0.411	0.050	0.461
2008	309	1001	110	723	2143	0.467	0.051	0.519
2009	328	1078	127	709	2243	0.481	0.057	0.538
2010	311	1047	156	650	2165	0.484	0.072	0.556
2011	326	1137	188	619	2270	0.501	0.083	0.584
2012	309	1191	191	680	2371	0.502	0.081	0.583
2013	272	979	221	705	2178	0.450	0.102	0.551
2014	212	1012	198	620	2042	0.495	0.097	0.593
2015	195	1078	220	525	2018	0.534	0.109	0.643
2016	*na*	1016	*na*	549	1564	*na*	*na*	*na*

Table 5. Summary of median silky shark catch estimates (in thousand sharks) for longline (LL) and purse seine (PS) fisheries in the WCPO from various sources (see Figure 11).

	Lawson (2011)	Lawson (2011)	Lawson (2011)	Rice (2012)	Rice (2012)	Rice (2012)	Peatman et al. (2017)	Peatman et al. (2018)	Peatman et al. (2017, 2018)	Clarke (2018 (this paper from Figure 4 and Annex 3, target species catch-based method))
Year	LL	PS	LL+PS	LL	PS	LL+PS	PS	LL	LL+PS	LL+PS
1994	16,000		16,000							261,300
1995	161,000	23,800	184,800	271,970	34,480	306,450				292,500
1996	140,000	24,561	164,561	369,340	41,960	411,300				314,800
1997	135,000	28,102	163,102	118,510	73,160	191,670				343,800
1998	165,000	27,422	192,422	104,520	54,470	158,990				398,000
1999	167,000	35,172	202,172	237,160	59,520	296,680				426,600
2000	163,000	31,358	194,358	191,850	67,290	259,140				512,000
2001	149,000	35,069	184,069	241,920	50,870	292,790				609,100
2002	142,000	43,042	185,042	200,580	62,750	263,330				637,200
2003	97,000	56,544	153,544	183,570	96,100	279,670	42,951	238,945	281,896	653,500
2004	103,000	84,679	187,679	181,880	135,670	317,550	59,858	246,898	306,756	587,100
2005	114,000	78,976	192,976	134,380	83,840	218,220	55,283	238,827	294,110	559,400
2006	133,000	81,454	214,454	209,570	89,750	299,320	54,583	251,590	306,173	518,100
2007	167,000	78,999	245,999	338,400	88,990	427,390	51,385	318,992	370,377	766,600
2008	185,000	78,904	263,904	326,310	96,850	423,160	49,538	282,462	332,000	705,200
2009	189,000	69,790	258,790	389,520	99,090	488,610	42,830	403,173	446,003	695,300
2010		47,861					31,252	423,555	454,807	732,200
2011							51,947	435,988	487,935	749,500
2012							36,616	430,492	467,108	768,300
2013							41,476	191,521	232,997	759,800
2014							49,696	134,411	184,107	752,200
2015							40,323	177,214	217,537	704,500
2016							61,738	226,453	288,191	725,400

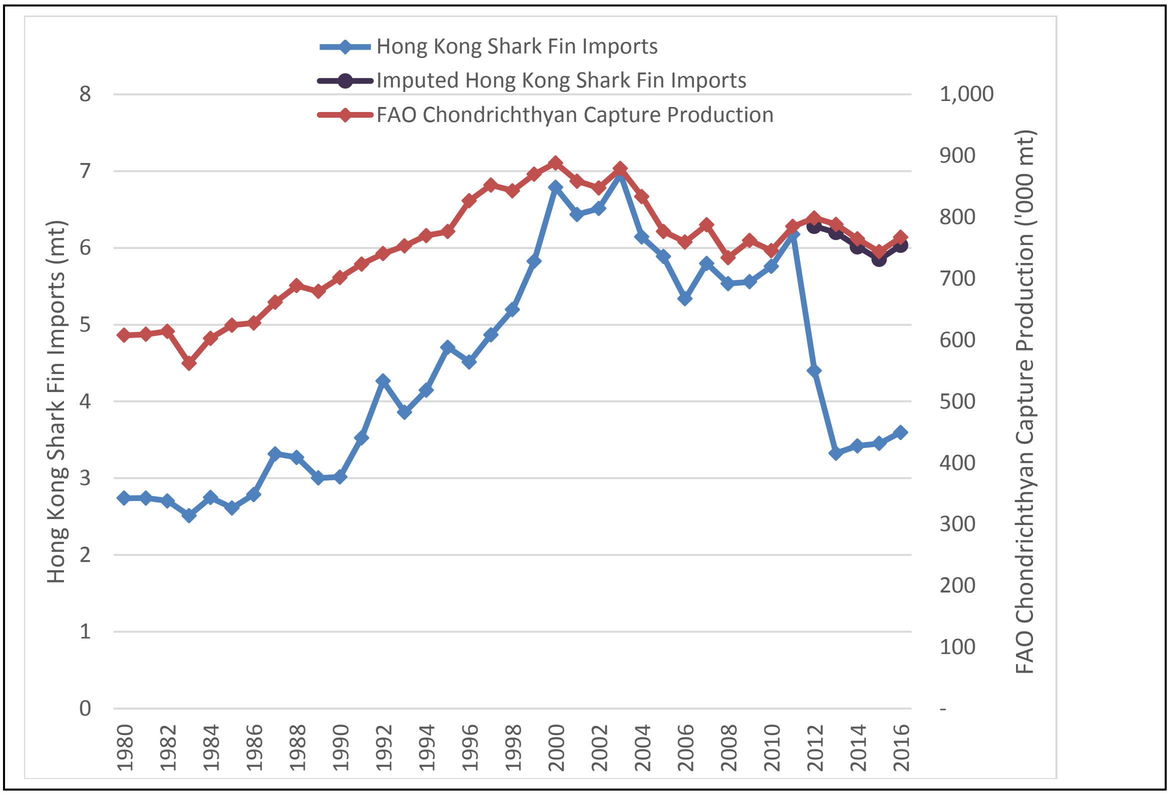

Figure 1. Annual imports of unprocessed shark fins, adjusted for water content, by Hong Kong 1980-2016 and global capture production of chondrichthyan fishes (sharks, rays and chimaeras) as reported to FAO 1980-2016.

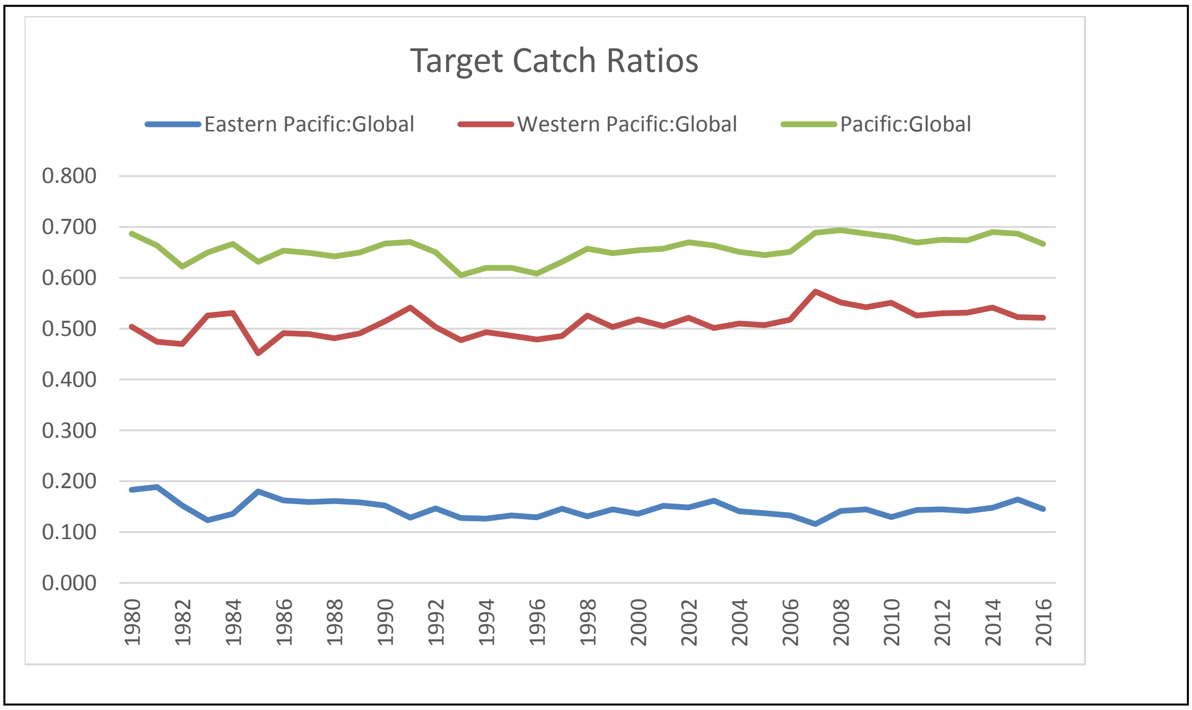

Figure 2. Annual proportion of FAO-reported capture production of tunas, bonitos, billfishes and dolphinfish in the Pacific as a whole, the Eastern Pacific and Western Pacific as a proportion of the total global catch of these species, 1980-2016 (data given in Table 3).

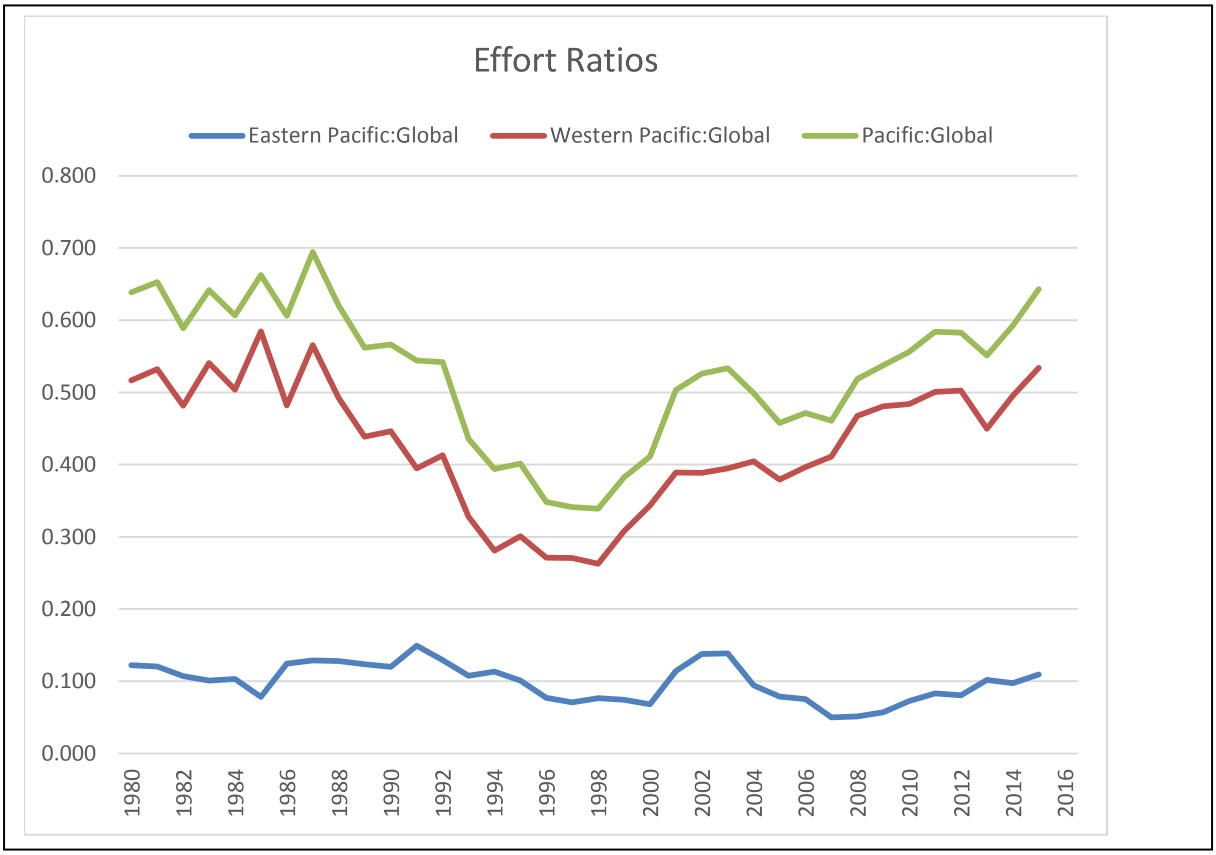

Figure 3. Annual ratios of longline effort in the Eastern Pacific, Western Pacific Ocean and Pacific Ocean (as a whole) to global longline effort, 1980-2015. Data for 2016 are incomplete (see Table 4).

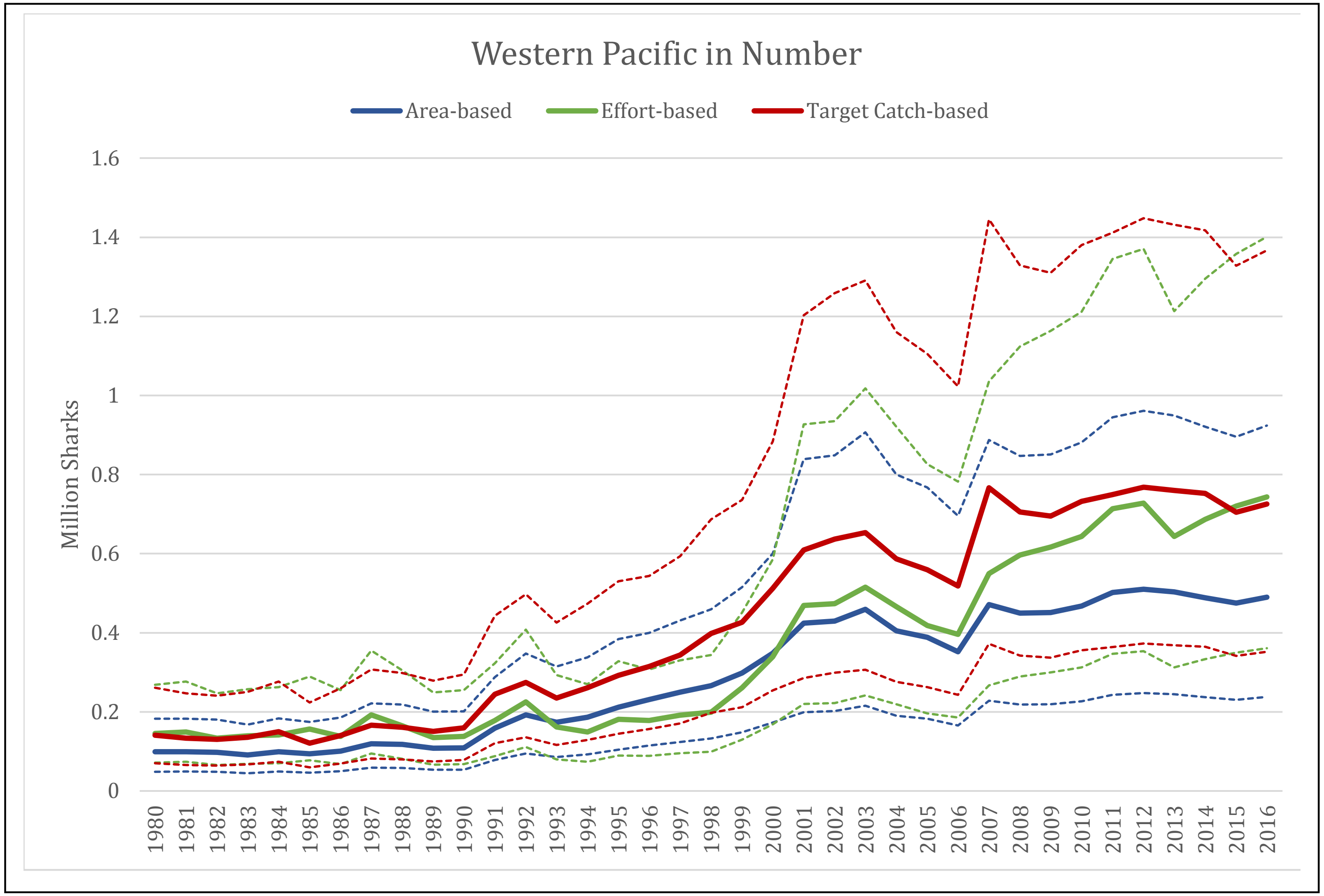

Figure 4. Annual median (solid line) and 95% confidence interval (dashed lines) estimates for silky shark (in million sharks), using area, longline effort and target species catch proportioning methods to scale the number of sharks present in the global shark fin trade to those derived from the WCPO, 1980-2016.

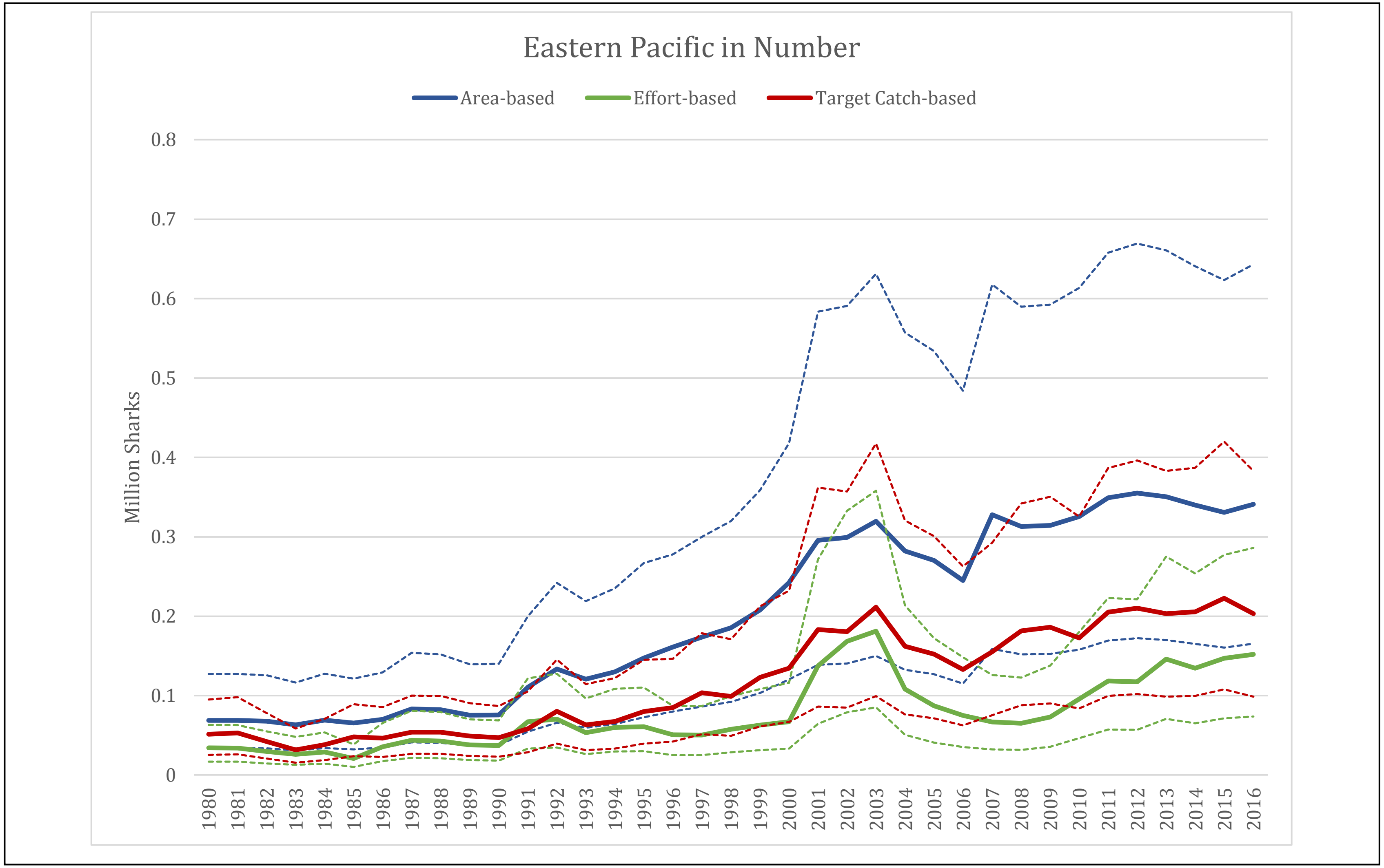

Figure 5. Annual median (solid line) and 95% confidence interval (dashed lines) estimates for silky shark (in million sharks), using area, longline effort and target species catch proportioning methods to scale the number of sharks present in the global shark fin trade to those derived from the EPO, 1980-2016.

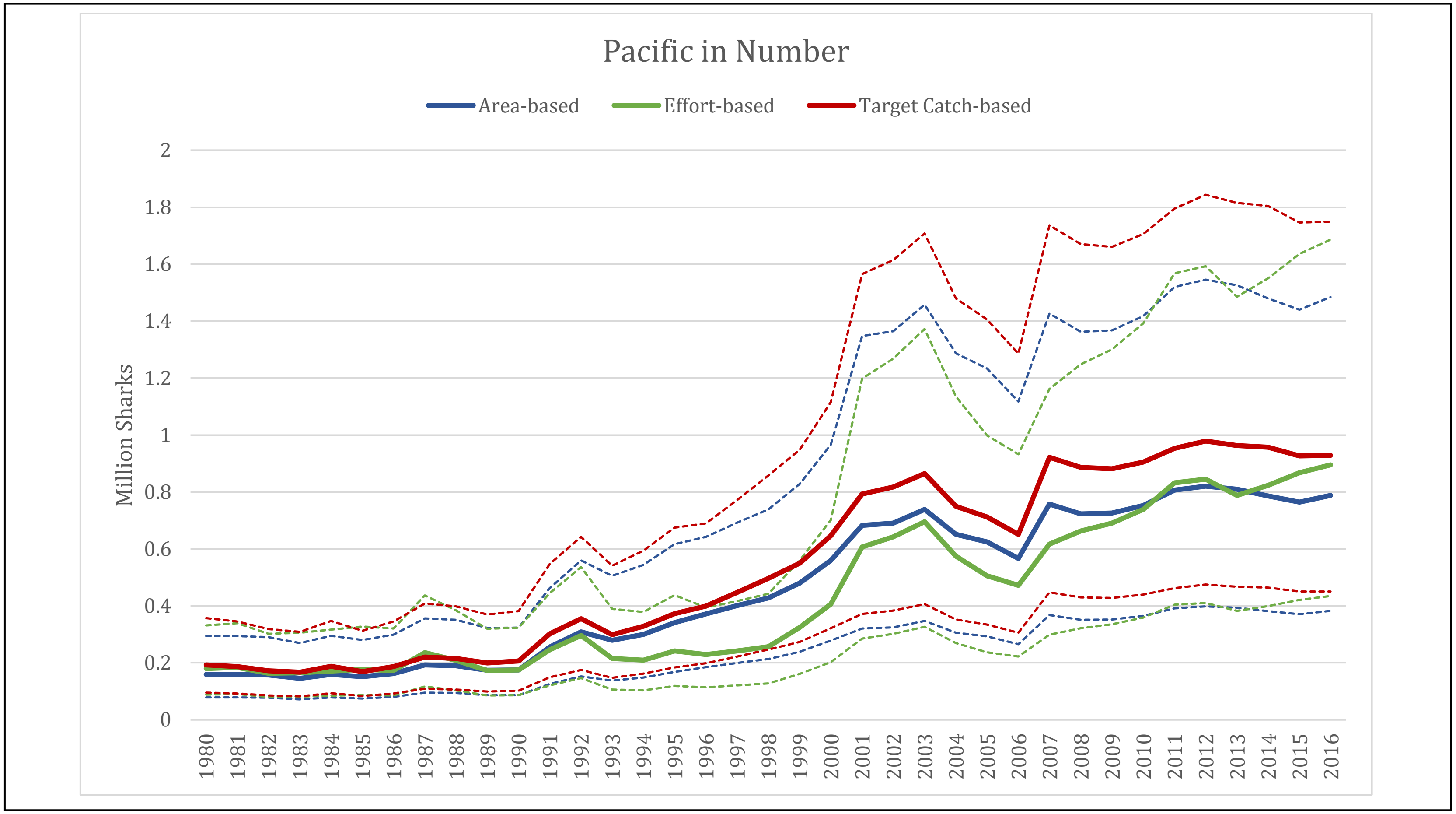

Figure 6. Annual median (solid line) and 95% confidence interval (dashed lines) estimates for silky shark (in million sharks) using area, longline effort and target species catch proportioning methods to scale sharks present in the global shark fin trade to those derived from the Pacific Ocean as a whole, 1980-2016.

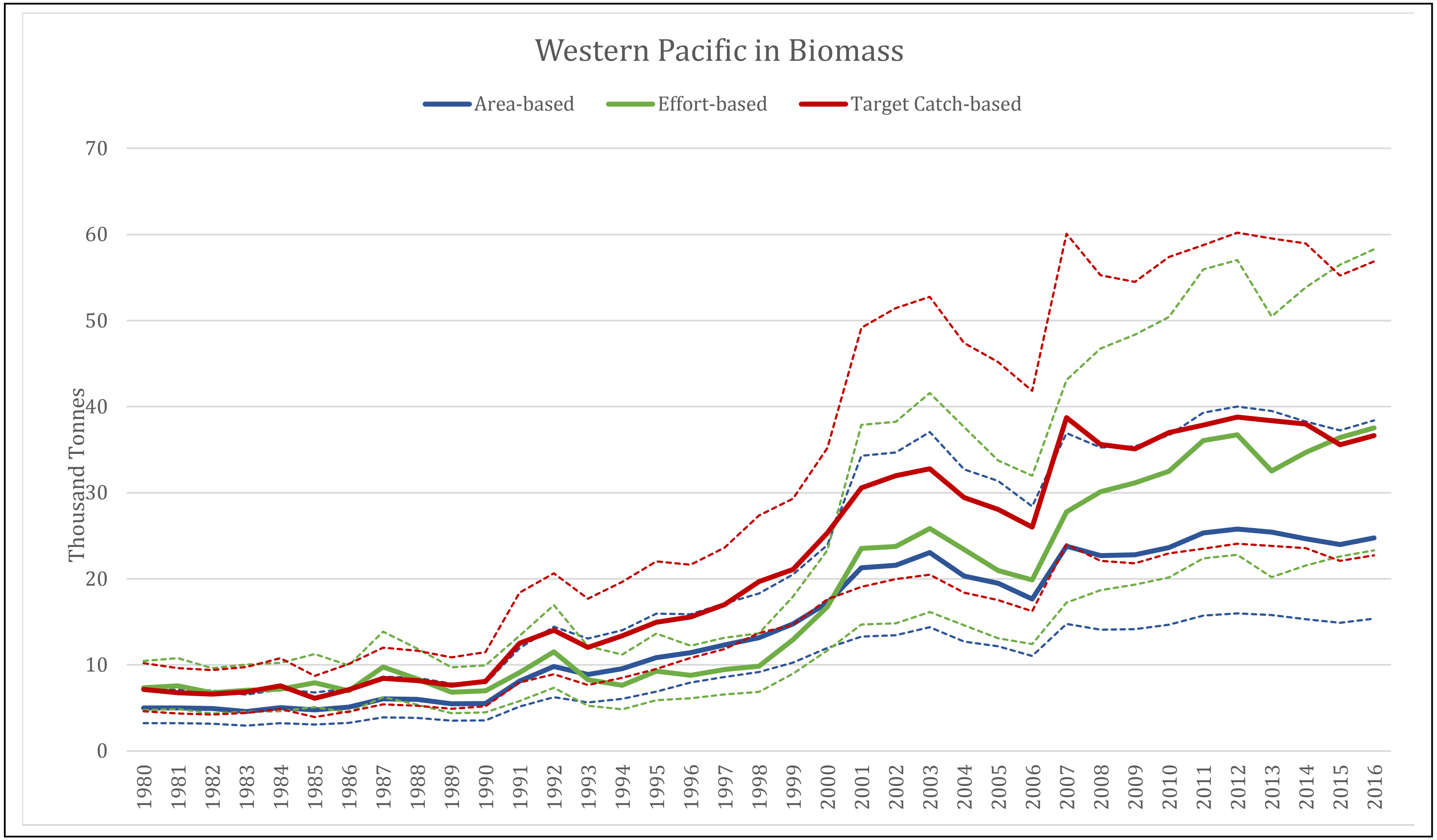

Figure 7. Annual median (solid line) and 95% confidence interval (dashed lines) estimates for silky shark (in thousand t) using area, longline effort and target species catch proportioning methods to scale the sharks present in the global shark fin trade to those derived from the WCPO, 1980-2016.

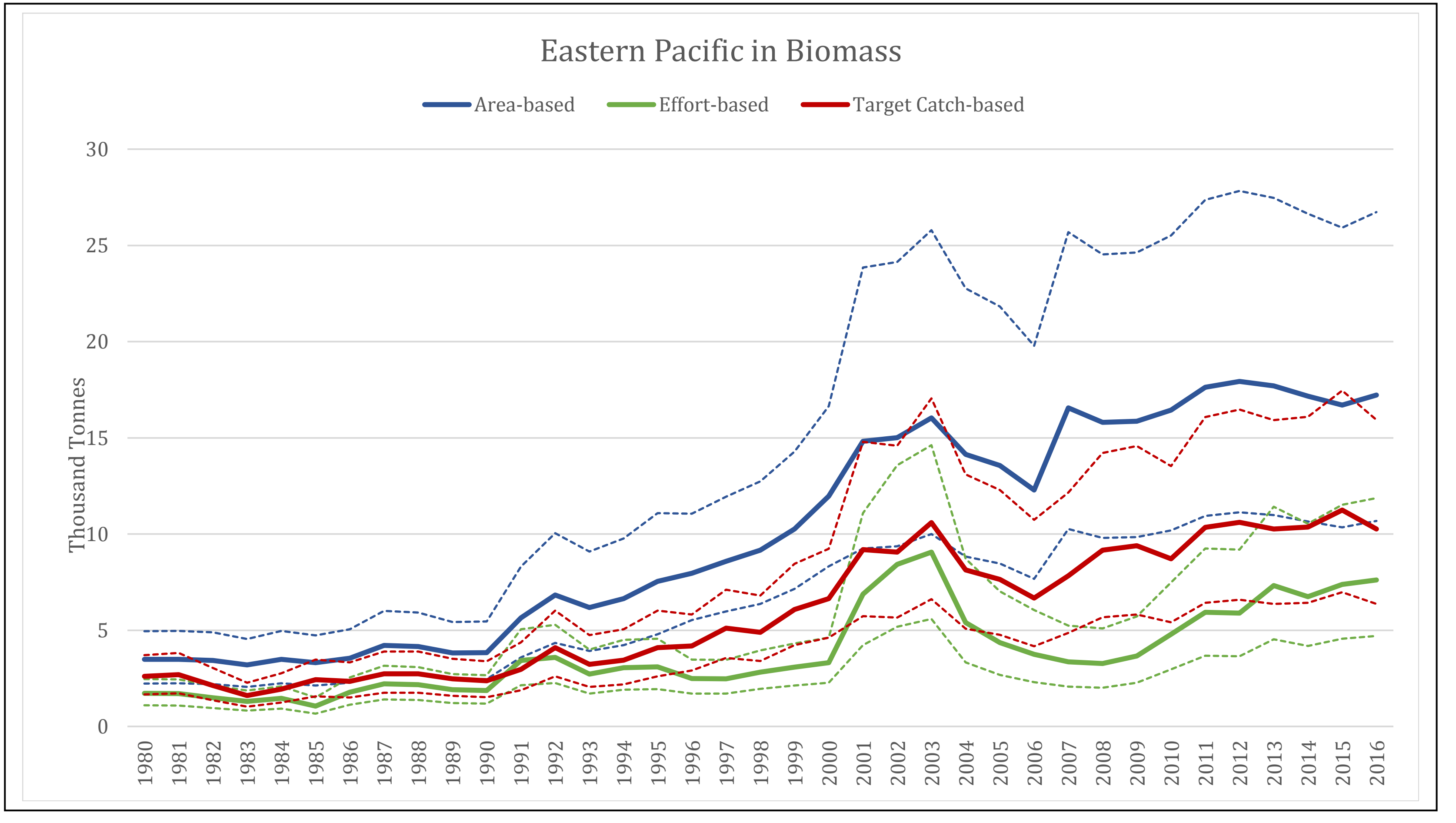

Figure 8. Annual median (solid line) and 95% confidence interval (dashed lines) estimates for silky shark (in thousand t) using area, longline effort and target species catch proportioning methods to scale the sharks present in the global shark fin trade to those derived from the EPO, 1980-2016.

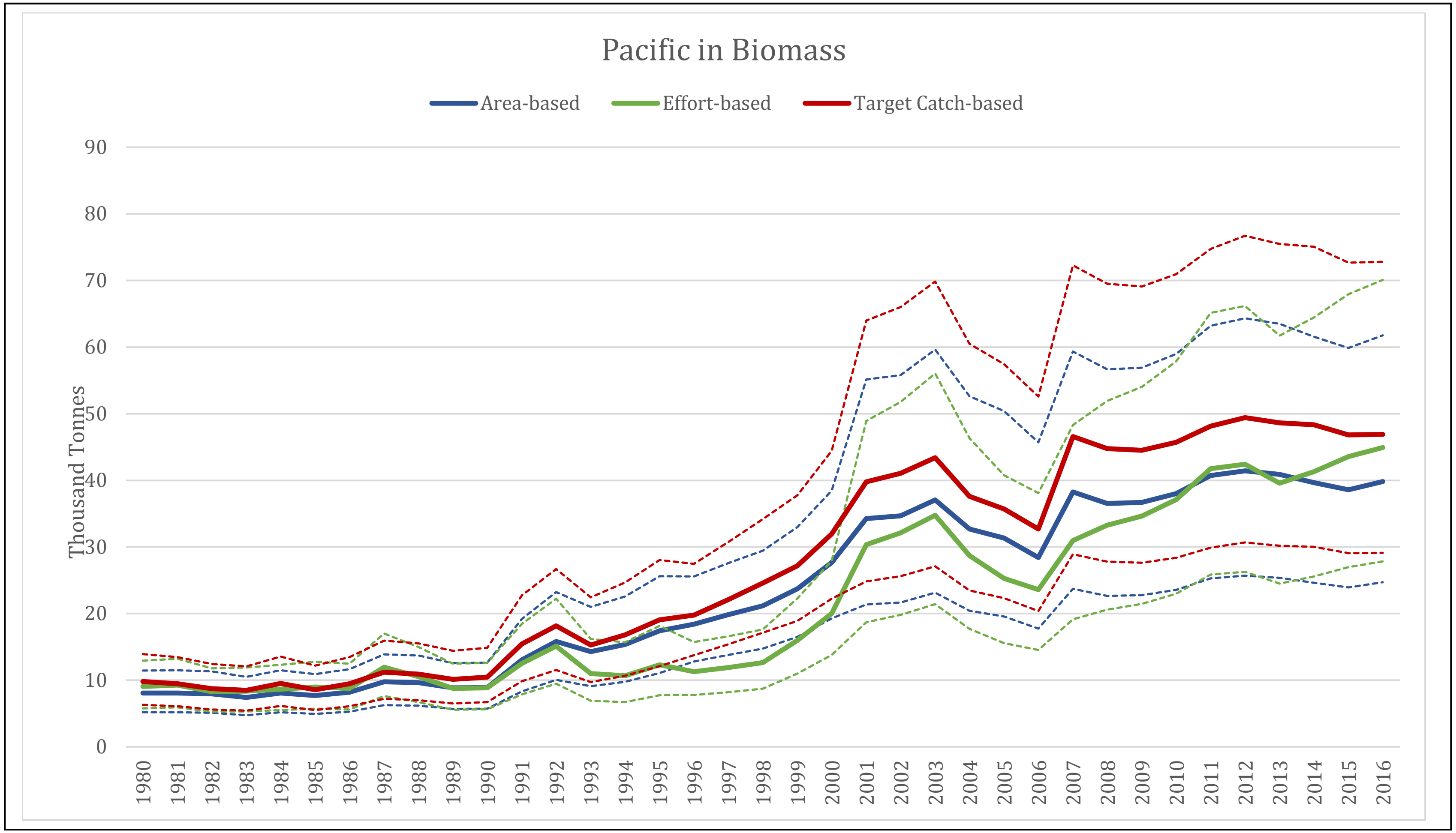

Figure 9. Annual median (solid line) and 95% confidence interval (dashed lines) estimates for silky shark (in thousand t) using area, longline effort and target species catch proportioning methods to scale the sharks present in the global shark fin trade to those derived from the Pacific Ocean as a whole, 1980-2016.

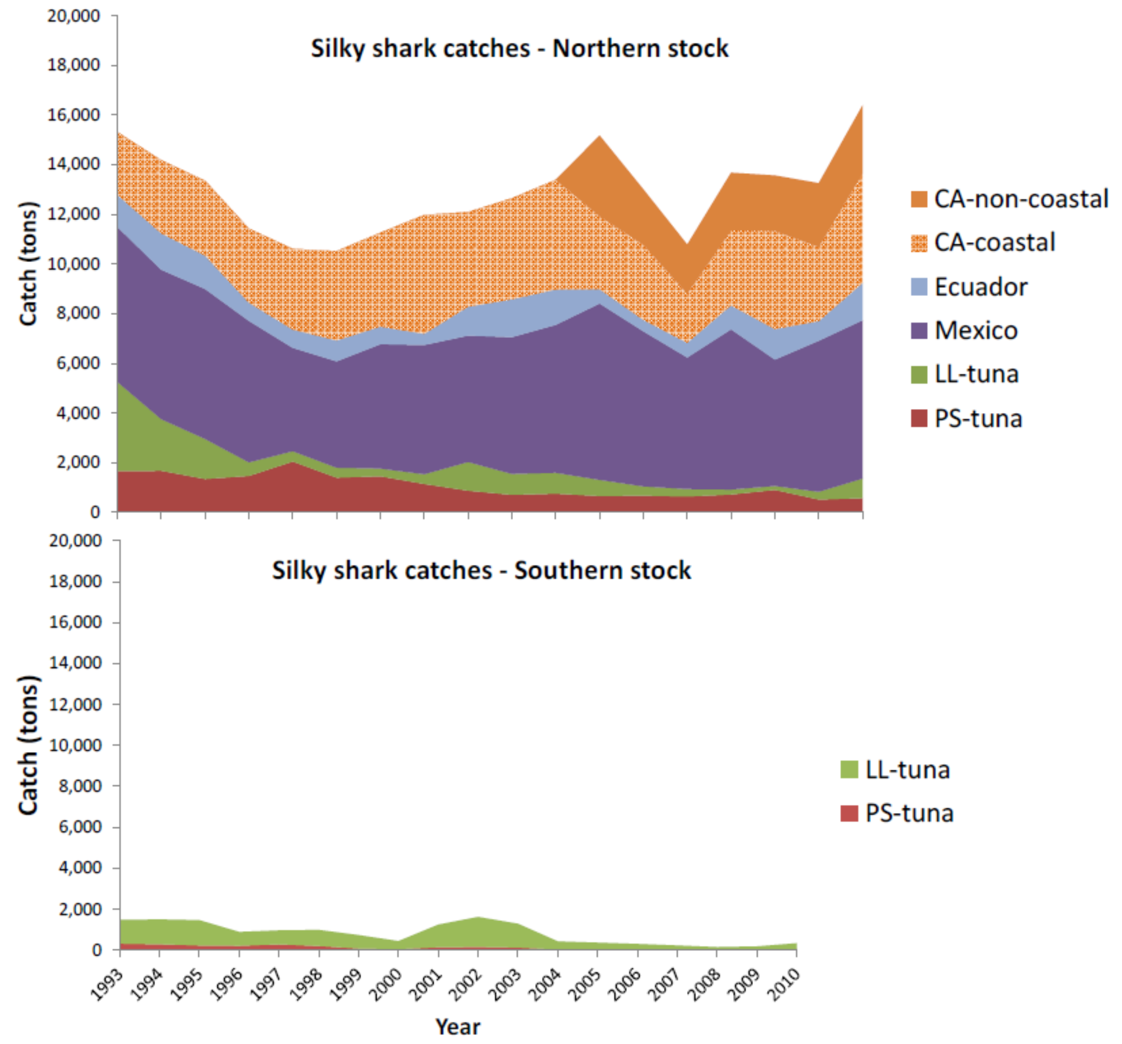

Figure 10. Catch estimates for silky shark catches (in t) in the Eastern Pacific Ocean, 1993-2010 (from IATTC 2014).

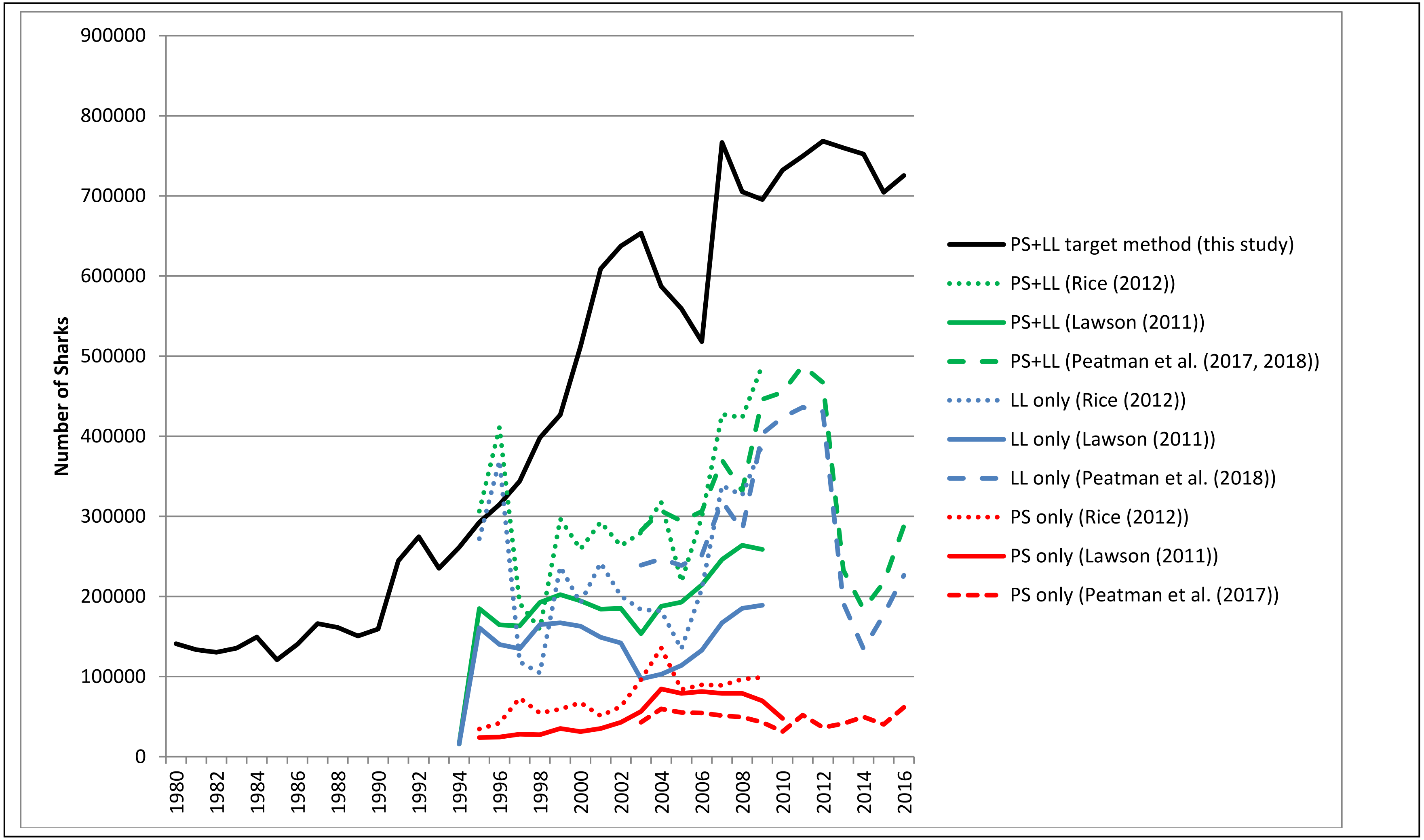

Figure 11. Median estimates for silky shark catches (in number of sharks) for the Western and Central Pacific Ocean from various sources, 1980-2016 (see Table 5).

Annex 1. WinBUGS code

```
model
{
	#these are HK's assumed share of the global totals in each period
	shar8090~dunif(0.65,0.80)
	shar9195~dunif(0.50, 0.65)
	shar9600~dunif(0.44,0.59)
	shar0006~dunif(0.30,0.50)
	shar0716~dunif(0.25,0.40)

for (z in 1:11){
	ratio[z] <- shar9600/shar8090
	}
for (z in 12:16){
	ratio[z] <- shar9600/shar9195
	}
for (z in 17:21){					#for 1996-2000 (this is the base period)
	ratio[z] <- 1
	}
for (z in 22:27){					#2001-2006
	ratio[z] <- shar9600/shar0006
	}
for (z in 28:37){
	ratio[z] <- shar9600/shar0716			#2007-2016
	}


#for (g in 1:1) {					#this is a triangular distribution
#	rv[g]~dunif(0,1000)
#	x[g]<-rv[g]/1000

#	gate[g]<-((trimode[g]-trimin[g]) / (trimax[g]-trimin[g]))
#	A[g]<-min(x[g],gate[g])				# find out whether x is higher or lower than criterion
#	B[g]<-equals(x[g],A[g])		# if x IS lower then B will be 1, if x>calculation then B will be 0
#	C[g]<-equals(B[g],0)		# sets C to zero if B=1 or sets C to 1 if b=0; so B and C are binary and opposite

#	draw[g]<-(B[g]*(trimin[g]+sqrt(x[g]*(trimode[g]-trimin[g])*(trimax[g]-trimin[g]))))
#		+(C[g]*(trimax[g]-sqrt((1-x[g])*(trimax[g]-trimode[g])*(trimax[g]-trimin[g]))))


#this is a triangular distribution for 2000 (number (N) and then biomass (B))
for (d in 1:2) {
	rv[d]~dunif(0,1000)				#uninformative prior
	x[d]<-rv[d]/1000
		gate[d]<-((trimode[d]-trimin[d]) / (trimax[d]-trimin[d]))
	A[d]<-min(x[d],gate[d])			# find out whether x is higher or lower than criterion
	B[d]<-equals(x[d],A[d])			# if x IS lower then B will be 1, if x>calculation then B will be 0
	C[d]<-equals(B[d],0)		# sets C to zero if B=1 or sets C to 1 if b=0; so B and C are binary and opposite
	draw[d]<-(B[d]*(trimin[d]+sqrt(x[d]*(trimode[d]-trimin[d])*(trimax[d]-trimin[d]))))
		+(C[d]*(trimax[d]-sqrt((1-x[d])*(trimax[d]-trimode[d])*(trimax[d]-trimin[d]))))
	for (h in 1:37) {
		scaled[d,h] <- draw[d] * (HKimport[h]/HKimport[21])
		share[d,h] <- scaled[d,h] * ratio[h]	#scale by whether HK's share was more or less than in 2000
		areapropW[d,h] <- share[d,h] * GISW[d]		#area scalling for WCPO
		areapropE[d,h] <- share[d,h] * GISE[d]		#area scaling for EPO
		areapropP[d,h] <- share[d,h]* GISP[d]		#area scaling for Pacific as a whole
		tunapropW[d,h] <- share[d,h] * tunaW[h]		#scale by total tuna catch (FISHSTAT) for WCPO
		tunapropE[d,h] <- share[d,h] * tunaE[h]		#scale by total tuna catch for EPO
		tunapropP[d,h] <- share[d,h] *tunaP[h]
		hookpropW[d,h] <- share[d,h] * LLW[h]		#scale by LL hook effort for WCPO
		hookpropE[d,h] <- share[d,h] * LLE[h]		#scale by LL hook effort for EPO
		hookpropP[d,h] <- share[d,h]* LLP[h]
		}
	}
}
```

```
#DATA
list(

#NUMBER OF SHARKS (in millions) and BIOMASS (in '000 t)
trimin=c(0.368,29.94),          #FAL low number in millions/ biomass in '000t
trimode=c(0.795,45.46),         #FAL median number/biomass
trimax=c(2.008,74.05),          #FAL high number/biomass

HKimport=c(
2739,2741,2704,2512,2748,                    #HK adjusted imports 1980-2016
2613,2788,3317,3272,3003,
3018,3526,4265,3856,4144,
4706,4513,4868,5196,5824,
6788,6435,6513,6960,6142,
5887,5337,5798,5536,5559,
5759,6175,6282,6201,6014,5849,6034),

GISW=c(0.352,0.352),
GISE=c(0.245,0.245),
GISP=c(0.566,0.566),

tunaW=c(
0.503,0.475,0.470,0.526,0.531,
0.452,0.491,0.489,0.481,0.490,
0.515,0.542,0.503,0.477,0.493,
0.486,0.479,0.485,0.526,0.503,
0.518,0.505,0.522,0.501,0.510,
0.507,0.518,0.573,0.552,0.542,
0.551,0.526,0.530,0.531,0.542,
0.522,0.521),

tunaE=c(
0.183,0.189,0.152,0.123,0.136,
0.180,0.162,0.159,0.161,0.159,
0.152,0.129,0.147,0.128,0.127,
0.133,0.129,0.146,0.131,0.145,
0.136,0.152,0.148,0.162,0.141,
0.138,0.133,0.116,0.142,0.145,
0.130,0.144,0.145,0.142,0.148,
0.165,0.146),

tunaP=c(
0.687,0.664,0.622,0.649,0.667,
0.631,0.653,0.649,0.642,0.649,
0.667,0.670,0.650,0.605,0.619,
0.619,0.608,0.631,0.657,0.648,
0.654,0.657,0.670,0.663,0.651,
0.645,0.651,0.689,0.694,0.687,
0.681,0.669,0.675,0.673,0.690,
0.687,0.667),

LLP=c(
0.639,0.653,0.589,0.642,0.607,
0.662,0.606,0.694,0.620,0.562,
0.566,0.544,0.542,0.436,0.394,
0.401,0.348,0.341,0.339,0.382,
0.411,0.503,0.526,0.533,0.499,
0.458,0.472,0.461,0.519,0.538,
0.556,0.584,0.583,0.551,0.593,
0.643,0.643),

LLE=c(
0.122,0.121,0.107,0.101,0.103,
0.078,0.124,0.129,0.128,0.123,
0.120,0.149,0.129,0.108,0.113,
0.101,0.077,0.071,0.076,0.074,
```

```
0.068,0.114,0.138,0.139,0.094,
0.079,0.075,0.050,0.051,0.057,
0.072,0.083,0.081,0.102,0.097,
0.109,0.109),

LLW=c(
0.517,0.532,0.482,0.541,0.504,
0.584,0.482,0.565,0.492,0.438,
0.446,0.395,0.413,0.328,0.281,
0.301, 0.271,0.270,0.263,0.308,
0.343,0.389,0.388,0.395,0.405,
0.379,0.396,0.411,0.467,0.481,
0.484,0.501,0.502,0.450,0.495,
0.534,0.534))
```

Annex 2. Silky shark estimates in number (million sharks) for the area-based estimation method

	Eastern Pacific						Pacific						Western Pacific					
	mean	sd	MC error	2.50%	median	97.50%	mean	sd	MC error	2.50%	median	97.50%	mean	sd	MC error	2.50%	median	97.50%
1980	0.07246	0.02465	7.76E-04	0.03394	0.06875	0.1272	0.1674	0.05696	0.001792	0.0784	0.1588	0.2938	0.1041	0.03542	0.001115	0.04876	0.09877	0.1827
1981	0.07251	0.02467	7.76E-04	0.03396	0.0688	0.1273	0.1675	0.057	0.001794	0.07846	0.1589	0.294	0.1042	0.03545	0.001115	0.0488	0.09884	0.1828
1982	0.07154	0.02434	7.66E-04	0.0335	0.06787	0.1255	0.1653	0.05623	0.001769	0.0774	0.1568	0.29	0.1028	0.03497	0.0011	0.04814	0.09751	0.1804
1983	0.06646	0.02261	7.12E-04	0.03113	0.06305	0.1166	0.1535	0.05223	0.001644	0.07191	0.1457	0.2694	0.09548	0.03249	0.001022	0.04472	0.09059	0.1676
1984	0.0727	0.02473	7.78E-04	0.03405	0.06897	0.1276	0.168	0.05714	0.001798	0.07866	0.1593	0.2947	0.1045	0.03554	0.001118	0.04892	0.0991	0.1833
1985	0.06913	0.02352	7.40E-04	0.03238	0.06558	0.1213	0.1597	0.05433	0.00171	0.0748	0.1515	0.2803	0.09932	0.03379	0.001063	0.04652	0.09423	0.1743
1986	0.07376	0.02509	7.90E-04	0.03455	0.06998	0.1294	0.1704	0.05797	0.001824	0.07981	0.1617	0.299	0.106	0.03605	0.001135	0.04963	0.1005	0.186
1987	0.08775	0.02986	9.40E-04	0.0411	0.08325	0.154	0.2027	0.06897	0.00217	0.09495	0.1923	0.3558	0.1261	0.0429	0.00135	0.05905	0.1196	0.2213
1988	0.08656	0.02945	9.27E-04	0.04054	0.08213	0.1519	0.2	0.06804	0.002141	0.09366	0.1897	0.3509	0.1244	0.04231	0.001332	0.05825	0.118	0.2183
1989	0.07945	0.02703	8.51E-04	0.03721	0.07537	0.1394	0.1835	0.06244	0.001965	0.08596	0.1741	0.3221	0.1141	0.03883	0.001222	0.05346	0.1083	0.2003
1990	0.07984	0.02716	8.55E-04	0.0374	0.07575	0.1401	0.1845	0.06276	0.001975	0.08639	0.175	0.3237	0.1147	0.03903	0.001228	0.05373	0.1088	0.2013
1991	0.1176	0.04006	0.00118	0.05454	0.1105	0.2001	0.2717	0.09255	0.002727	0.126	0.2552	0.4624	0.169	0.05756	0.001696	0.07836	0.1587	0.2876
1992	0.1423	0.04846	0.001428	0.06597	0.1336	0.2421	0.3286	0.112	0.003298	0.1524	0.3087	0.5593	0.2044	0.06962	0.002051	0.09479	0.192	0.3478
1993	0.1286	0.04381	0.001291	0.05965	0.1208	0.2189	0.2971	0.1012	0.002982	0.1378	0.2791	0.5057	0.1848	0.06295	0.001854	0.0857	0.1736	0.3145
1994	0.1382	0.04708	0.001387	0.0641	0.1298	0.2352	0.3193	0.1088	0.003205	0.1481	0.3	0.5434	0.1986	0.06765	0.001993	0.0921	0.1866	0.338
1995	0.157	0.05347	0.001575	0.07279	0.1475	0.2671	0.3626	0.1235	0.003639	0.1682	0.3407	0.6171	0.2255	0.07682	0.002263	0.1046	0.2119	0.3838
1996	0.1673	0.05407	0.001677	0.08004	0.161	0.2779	0.3864	0.1249	0.003874	0.1849	0.3719	0.642	0.2403	0.07768	0.002409	0.115	0.2313	0.3993
1997	0.1804	0.05832	0.001809	0.08633	0.1737	0.2998	0.4168	0.1347	0.004178	0.1994	0.4012	0.6925	0.2592	0.08379	0.002599	0.124	0.2495	0.4307
1998	0.1926	0.06225	0.001931	0.09215	0.1854	0.32	0.4449	0.1438	0.00446	0.2129	0.4282	0.7392	0.2767	0.08944	0.002774	0.1324	0.2663	0.4597
1999	0.2159	0.06978	0.002164	0.1033	0.2078	0.3586	0.4987	0.1612	0.004999	0.2386	0.48	0.8285	0.3101	0.1002	0.003109	0.1484	0.2985	0.5153
2000	0.2516	0.08132	0.002522	0.1204	0.2422	0.418	0.5812	0.1879	0.005826	0.2781	0.5594	0.9657	0.3615	0.1168	0.003623	0.173	0.3479	0.6006
2001	0.315	0.1171	0.003383	0.1387	0.2955	0.5837	0.7276	0.2706	0.007817	0.3205	0.6826	1.348	0.4525	0.1683	0.004861	0.1993	0.4245	0.8386
2002	0.3188	0.1185	0.003424	0.1404	0.2991	0.5907	0.7365	0.2739	0.007911	0.3243	0.6909	1.365	0.458	0.1703	0.00492	0.2017	0.4297	0.8487
2003	0.3407	0.1267	0.00366	0.15	0.3196	0.6313	0.787	0.2927	0.008454	0.3466	0.7383	1.458	0.4894	0.182	0.005258	0.2156	0.4592	0.907
2004	0.3006	0.1118	0.003229	0.1324	0.282	0.5571	0.6945	0.2583	0.007461	0.3059	0.6516	1.287	0.4319	0.1606	0.00464	0.1902	0.4052	0.8004
2005	0.2881	0.1072	0.003095	0.1269	0.2703	0.534	0.6657	0.2476	0.007151	0.2932	0.6245	1.234	0.414	0.154	0.004447	0.1823	0.3884	0.7672
2006	0.2612	0.09714	0.002806	0.115	0.2451	0.4841	0.6035	0.2244	0.006483	0.2658	0.5662	1.118	0.3753	0.1396	0.004032	0.1653	0.3521	0.6955
2007	0.3459	0.1247	0.003697	0.159	0.3278	0.6177	0.7992	0.2881	0.008542	0.3674	0.7573	1.427	0.497	0.1792	0.005312	0.2285	0.4709	0.8875
2008	0.3303	0.1191	0.00353	0.1518	0.313	0.5898	0.7631	0.2751	0.008156	0.3508	0.723	1.363	0.4746	0.1711	0.005072	0.2182	0.4497	0.8474
2009	0.3317	0.1196	0.003545	0.1525	0.3143	0.5923	0.7662	0.2762	0.008189	0.3523	0.726	1.368	0.4765	0.1718	0.005093	0.2191	0.4515	0.8509
2010	0.3436	0.1239	0.003672	0.158	0.3256	0.6136	0.7938	0.2861	0.008484	0.3649	0.7522	1.418	0.4937	0.1779	0.005276	0.227	0.4678	0.8816
2011	0.3684	0.1328	0.003938	0.1694	0.3491	0.6579	0.8512	0.3068	0.009097	0.3913	0.8065	1.52	0.5293	0.1908	0.005657	0.2433	0.5016	0.9452
2012	0.3748	0.1351	0.004006	0.1723	0.3552	0.6693	0.8659	0.3121	0.009255	0.3981	0.8205	1.546	0.5385	0.1941	0.005755	0.2476	0.5103	0.9616
2013	0.37	0.1334	0.003954	0.1701	0.3506	0.6607	0.8547	0.3081	0.009135	0.3929	0.8099	1.526	0.5316	0.1916	0.005681	0.2444	0.5037	0.9492
2014	0.3588	0.1293	0.003835	0.165	0.34	0.6408	0.829	0.2988	0.00886	0.3811	0.7855	1.48	0.5155	0.1858	0.00551	0.237	0.4885	0.9206
2015	0.349	0.1258	0.00373	0.1604	0.3307	0.6232	0.8062	0.2906	0.008617	0.3706	0.7639	1.44	0.5014	0.1807	0.005359	0.2305	0.4751	0.8953
2016	0.36	0.1298	0.003848	0.1655	0.3411	0.6429	0.8317	0.2998	0.008889	0.3824	0.7881	1.485	0.5173	0.1864	0.005528	0.2378	0.4901	0.9237

Annex 3. Silky shark estimates in number (million sharks) for the target species catch-based estimation method

	Eastern Pacific						Pacific						Western Pacific					
	mean	**sd**	**MC error**	**2.50%**	**median**	**97.50%**	**mean**	**sd**	**MC error**	**2.50%**	**median**	**97.50%**	**mean**	**sd**	**MC error**	**2.50%**	**median**	**97.50%**
1980	0.05412	0.01841	5.80E-04	0.02535	0.05135	0.09499	0.2032	0.06913	0.002175	0.09517	0.1928	0.3566	0.1488	0.05062	0.001593	0.06968	0.1411	0.2611
1981	0.05594	0.01903	5.99E-04	0.0262	0.05307	0.09817	0.1965	0.06687	0.002104	0.09205	0.1865	0.3449	0.1406	0.04783	0.001505	0.06585	0.1334	0.2467
1982	0.04438	0.0151	4.75E-04	0.02079	0.04211	0.07789	0.1816	0.06179	0.001944	0.08506	0.1723	0.3187	0.1372	0.04669	0.001469	0.06427	0.1302	0.2408
1983	0.03336	0.01135	3.57E-04	0.01563	0.03165	0.05855	0.176	0.05989	0.001885	0.08245	0.167	0.3089	0.1427	0.04854	0.001528	0.06682	0.1354	0.2504
1984	0.04036	0.01373	4.32E-04	0.0189	0.03829	0.07082	0.1979	0.06734	0.002119	0.0927	0.1878	0.3473	0.1576	0.05361	0.001687	0.0738	0.1495	0.2765
1985	0.05079	0.01728	5.44E-04	0.02379	0.04818	0.08913	0.178	0.06057	0.001906	0.08339	0.1689	0.3125	0.1275	0.04339	0.001365	0.05973	0.121	0.2238
1986	0.04877	0.01659	5.22E-04	0.02284	0.04627	0.08559	0.1966	0.06689	0.002105	0.09207	0.1865	0.345	0.1478	0.05029	0.001583	0.06923	0.1402	0.2594
1987	0.05695	0.01938	6.10E-04	0.02667	0.05403	0.09994	0.2325	0.07909	0.002489	0.1089	0.2205	0.4079	0.1751	0.05959	0.001875	0.08203	0.1662	0.3074
1988	0.05688	0.01935	6.09E-04	0.02664	0.05397	0.09983	0.2268	0.07717	0.002429	0.1062	0.2152	0.3981	0.1699	0.05782	0.00182	0.0796	0.1612	0.2982
1989	0.05156	0.01754	5.52E-04	0.02415	0.04892	0.09048	0.2105	0.0716	0.002253	0.09857	0.1997	0.3693	0.1589	0.05406	0.001701	0.07442	0.1507	0.2788
1990	0.04953	0.01685	5.30E-04	0.0232	0.047	0.08693	0.2174	0.07396	0.002327	0.1018	0.2062	0.3815	0.1678	0.0571	0.001797	0.07861	0.1592	0.2945
1991	0.06192	0.02109	6.22E-04	0.02872	0.05817	0.1054	0.3216	0.1096	0.003228	0.1492	0.3021	0.5473	0.2602	0.08863	0.002611	0.1207	0.2444	0.4428
1992	0.08536	0.02908	8.57E-04	0.03958	0.08018	0.1453	0.3774	0.1286	0.003788	0.175	0.3546	0.6423	0.2921	0.09949	0.002931	0.1354	0.2744	0.497
1993	0.0672	0.02289	6.74E-04	0.03116	0.06312	0.1144	0.3176	0.1082	0.003187	0.1473	0.2984	0.5405	0.2504	0.0853	0.002513	0.1161	0.2352	0.4261
1994	0.07165	0.02441	7.19E-04	0.03323	0.06731	0.1219	0.3492	0.119	0.003505	0.162	0.3281	0.5943	0.2781	0.09475	0.002791	0.129	0.2613	0.4733
1995	0.08521	0.02903	8.55E-04	0.03952	0.08005	0.145	0.3966	0.1351	0.00398	0.1839	0.3726	0.6749	0.3114	0.1061	0.003125	0.1444	0.2925	0.5299
1996	0.08807	0.02847	8.83E-04	0.04214	0.08477	0.1463	0.4151	0.1342	0.004161	0.1986	0.3995	0.6897	0.327	0.1057	0.003278	0.1565	0.3148	0.5433
1997	0.1075	0.03476	0.001078	0.05145	0.1035	0.1786	0.4647	0.1502	0.004658	0.2224	0.4473	0.7721	0.3572	0.1155	0.00358	0.1709	0.3438	0.5934
1998	0.103	0.03329	0.001032	0.04927	0.09911	0.1711	0.5165	0.1669	0.005177	0.2471	0.4971	0.858	0.4135	0.1337	0.004145	0.1978	0.398	0.687
1999	0.1278	0.0413	0.001281	0.06113	0.123	0.2123	0.5709	0.1845	0.005723	0.2732	0.5495	0.9486	0.4432	0.1433	0.004443	0.2121	0.4266	0.7363
2000	0.1397	0.04514	0.0014	0.06682	0.1344	0.232	0.6716	0.2171	0.006732	0.3213	0.6464	1.116	0.5319	0.1719	0.005332	0.2545	0.512	0.8838
2001	0.1954	0.07267	0.002099	0.08606	0.1833	0.3621	0.8446	0.3141	0.009073	0.372	0.7924	1.565	0.6492	0.2414	0.006974	0.2859	0.6091	1.203
2002	0.1926	0.07161	0.002069	0.08481	0.1807	0.3569	0.8718	0.3242	0.009365	0.3839	0.8179	1.615	0.6792	0.2526	0.007296	0.2991	0.6372	1.259
2003	0.2253	0.08377	0.00242	0.0992	0.2113	0.4174	0.9219	0.3428	0.009903	0.406	0.8649	1.708	0.6966	0.2591	0.007483	0.3068	0.6535	1.291
2004	0.173	0.06434	0.001859	0.07619	0.1623	0.3206	0.7988	0.2971	0.008581	0.3518	0.7494	1.48	0.6258	0.2327	0.006722	0.2756	0.5871	1.16
2005	0.1623	0.06036	0.001743	0.07148	0.1523	0.3008	0.7586	0.2821	0.008149	0.3341	0.7117	1.406	0.5963	0.2217	0.006405	0.2626	0.5594	1.105
2006	0.1418	0.05274	0.001523	0.06245	0.133	0.2628	0.6941	0.2581	0.007456	0.3057	0.6512	1.286	0.5523	0.2054	0.005933	0.2432	0.5181	1.023
2007	0.1638	0.05904	0.001751	0.0753	0.1552	0.2925	0.9729	0.3507	0.0104	0.4472	0.9218	1.737	0.8091	0.2916	0.008647	0.3719	0.7666	1.445
2008	0.1914	0.06901	0.002046	0.08801	0.1814	0.3419	0.9356	0.3373	0.01	0.4301	0.8866	1.671	0.7442	0.2683	0.007954	0.3421	0.7052	1.329
2009	0.1963	0.07076	0.002098	0.09024	0.186	0.3505	0.9301	0.3352	0.00994	0.4276	0.8813	1.661	0.7338	0.2645	0.007842	0.3373	0.6953	1.31
2010	0.1823	0.06572	0.001949	0.08382	0.1728	0.3256	0.9551	0.3443	0.01021	0.4391	0.905	1.706	0.7728	0.2786	0.008259	0.3553	0.7322	1.38
2011	0.2165	0.07806	0.002314	0.09955	0.2052	0.3867	1.006	0.3626	0.01075	0.4625	0.9533	1.796	0.791	0.2851	0.008454	0.3636	0.7495	1.412
2012	0.2218	0.07996	0.002371	0.102	0.2102	0.3961	1.033	0.3722	0.01104	0.4747	0.9785	1.844	0.8108	0.2923	0.008666	0.3728	0.7683	1.448
2013	0.2144	0.0773	0.002292	0.09858	0.2032	0.3829	1.016	0.3663	0.01086	0.4672	0.963	1.815	0.8019	0.289	0.00857	0.3686	0.7598	1.432
2014	0.2168	0.07813	0.002317	0.09965	0.2054	0.3871	1.011	0.3643	0.0108	0.4646	0.9576	1.805	0.7938	0.2861	0.008484	0.3649	0.7522	1.418
2015	0.235	0.08472	0.002512	0.108	0.2227	0.4197	0.9786	0.3527	0.01046	0.4499	0.9272	1.747	0.7435	0.268	0.007947	0.3418	0.7045	1.328
2016	0.2145	0.07733	0.002293	0.09863	0.2033	0.3831	0.9801	0.3533	0.01048	0.4506	0.9287	1.75	0.7656	0.276	0.008182	0.352	0.7254	1.367

Annex 4. Silky shark estimates in number (million sharks) for the longline effort-based estimation method

	Eastern Pacific						Pacific						Western Pacific					
	mean	sd	MC error	2.50%	median	97.50%	mean	sd	MC error	2.50%	median	97.50%	mean	sd	MC error	2.50%	median	97.50%
1980	0.03608	0.01228	3.86E-04	0.0169	0.03423	0.06332	0.189	0.0643	0.002023	0.08852	0.1793	0.3317	0.1529	0.05202	0.001637	0.07162	0.1451	0.2683
1981	0.03581	0.01218	3.83E-04	0.01677	0.03398	0.06285	0.1933	0.06576	0.002069	0.09052	0.1834	0.3392	0.1575	0.05357	0.001686	0.07375	0.1494	0.2763
1982	0.03124	0.01063	3.35E-04	0.01463	0.02964	0.05483	0.172	0.05851	0.001841	0.08055	0.1632	0.3018	0.1407	0.04788	0.001507	0.06592	0.1335	0.247
1983	0.0274	0.009321	2.93E-04	0.01283	0.02599	0.04808	0.1741	0.05925	0.001864	0.08156	0.1652	0.3056	0.1467	0.04993	0.001571	0.06873	0.1392	0.2575
1984	0.03056	0.0104	3.27E-04	0.01431	0.029	0.05364	0.1801	0.06128	0.001928	0.08436	0.1709	0.3161	0.1496	0.05088	0.001601	0.07005	0.1419	0.2625
1985	0.02201	0.007488	2.36E-04	0.01031	0.02088	0.03862	0.1868	0.06355	0.002	0.08748	0.1772	0.3278	0.1648	0.05606	0.001764	0.07718	0.1563	0.2892
1986	0.03733	0.0127	4.00E-04	0.01748	0.03542	0.06551	0.1824	0.06207	0.001953	0.08545	0.1731	0.3202	0.1451	0.04937	0.001554	0.06796	0.1377	0.2547
1987	0.0462	0.01572	4.95E-04	0.02164	0.04384	0.08109	0.2486	0.08457	0.002661	0.1164	0.2358	0.4362	0.2024	0.06885	0.002167	0.09478	0.192	0.3551
1988	0.04522	0.01539	4.84E-04	0.02118	0.04291	0.07937	0.2191	0.07453	0.002345	0.1026	0.2078	0.3844	0.1738	0.05914	0.001861	0.08142	0.1649	0.3051
1989	0.03989	0.01357	4.27E-04	0.01868	0.03784	0.07	0.1822	0.062	0.001951	0.08535	0.1729	0.3198	0.142	0.04832	0.001521	0.06652	0.1347	0.2493
1990	0.03911	0.01331	4.19E-04	0.01832	0.0371	0.06863	0.1845	0.06276	0.001975	0.08639	0.175	0.3237	0.1453	0.04945	0.001556	0.06807	0.1379	0.2551
1991	0.07153	0.02436	7.18E-04	0.03317	0.06719	0.1217	0.2611	0.08896	0.002621	0.1211	0.2453	0.4444	0.1896	0.06459	0.001903	0.08793	0.1781	0.3227
1992	0.0749	0.02552	7.52E-04	0.03474	0.07037	0.1275	0.3147	0.1072	0.003158	0.1459	0.2956	0.5356	0.2398	0.08169	0.002407	0.1112	0.2253	0.4081
1993	0.0567	0.01931	5.69E-04	0.02629	0.05326	0.09649	0.2289	0.07797	0.002297	0.1061	0.215	0.3895	0.1722	0.05866	0.001728	0.07985	0.1618	0.293
1994	0.06375	0.02172	6.40E-04	0.02956	0.05989	0.1085	0.2223	0.07572	0.002231	0.1031	0.2088	0.3783	0.1585	0.054	0.001591	0.07352	0.1489	0.2698
1995	0.06471	0.02204	6.49E-04	0.03001	0.06079	0.1101	0.2569	0.08752	0.002578	0.1191	0.2413	0.4372	0.1928	0.06569	0.001935	0.08943	0.1812	0.3282
1996	0.05257	0.01699	5.27E-04	0.02515	0.0506	0.08734	0.2376	0.0768	0.002382	0.1137	0.2287	0.3947	0.185	0.05981	0.001855	0.08853	0.1781	0.3074
1997	0.05229	0.0169	5.24E-04	0.02502	0.05033	0.08687	0.2511	0.08117	0.002517	0.1202	0.2417	0.4172	0.1988	0.06427	0.001993	0.09514	0.1914	0.3304
1998	0.05974	0.01931	5.99E-04	0.02859	0.0575	0.09926	0.2665	0.08614	0.002671	0.1275	0.2565	0.4427	0.2067	0.06683	0.002072	0.09892	0.199	0.3435
1999	0.0652	0.02108	6.54E-04	0.0312	0.06275	0.1083	0.3366	0.1088	0.003374	0.161	0.3239	0.5592	0.2714	0.08772	0.00272	0.1298	0.2612	0.4509
2000	0.06983	0.02257	7.00E-04	0.03341	0.06721	0.116	0.4221	0.1364	0.004231	0.2019	0.4062	0.7012	0.3522	0.1139	0.003531	0.1685	0.339	0.5852
2001	0.1466	0.0545	0.001574	0.06454	0.1375	0.2716	0.6466	0.2405	0.006946	0.2848	0.6067	1.198	0.5001	0.186	0.005372	0.2202	0.4692	0.9267
2002	0.1796	0.06677	0.001929	0.07908	0.1685	0.3327	0.6844	0.2545	0.007352	0.3014	0.6421	1.268	0.5049	0.1877	0.005423	0.2223	0.4736	0.9355
2003	0.1933	0.07187	0.002076	0.08512	0.1813	0.3582	0.7411	0.2756	0.007961	0.3264	0.6953	1.373	0.5492	0.2042	0.0059	0.2419	0.5153	1.018
2004	0.1153	0.04289	0.001239	0.0508	0.1082	0.2137	0.6123	0.2277	0.006577	0.2697	0.5744	1.135	0.497	0.1848	0.005338	0.2189	0.4662	0.9209
2005	0.09291	0.03455	9.98E-04	0.04092	0.08717	0.1722	0.5387	0.2003	0.005786	0.2372	0.5053	0.9982	0.4457	0.1658	0.004788	0.1963	0.4182	0.826
2006	0.07997	0.02974	8.59E-04	0.03522	0.07502	0.1482	0.5033	0.1872	0.005406	0.2216	0.4721	0.9326	0.4222	0.157	0.004536	0.1859	0.3961	0.7824
2007	0.0706	0.02545	7.55E-04	0.03246	0.0669	0.1261	0.6509	0.2346	0.006957	0.2992	0.6168	1.162	0.5803	0.2092	0.006202	0.2668	0.5499	1.036
2008	0.06876	0.02478	7.35E-04	0.03161	0.06515	0.1228	0.6997	0.2522	0.007478	0.3217	0.663	1.249	0.6296	0.2269	0.006729	0.2894	0.5966	1.124
2009	0.07717	0.02781	8.25E-04	0.03547	0.07312	0.1378	0.7283	0.2625	0.007784	0.3348	0.6901	1.301	0.6512	0.2347	0.00696	0.2994	0.617	1.163
2010	0.101	0.0364	0.001079	0.04642	0.09568	0.1803	0.7798	0.2811	0.008334	0.3585	0.7389	1.392	0.6788	0.2447	0.007255	0.3121	0.6432	1.212
2011	0.1248	0.04499	0.001334	0.05738	0.1183	0.2229	0.8782	0.3166	0.009386	0.4037	0.8322	1.568	0.7534	0.2716	0.008052	0.3464	0.7139	1.345
2012	0.1239	0.04467	0.001324	0.05697	0.1174	0.2213	0.8919	0.3215	0.009532	0.41	0.8451	1.593	0.768	0.2768	0.008208	0.3531	0.7277	1.371
2013	0.154	0.05552	0.001646	0.07081	0.146	0.2751	0.8321	0.2999	0.008893	0.3825	0.7884	1.486	0.6796	0.245	0.007263	0.3124	0.6439	1.213
2014	0.1421	0.05121	0.001518	0.06531	0.1346	0.2537	0.8685	0.3131	0.009282	0.3993	0.8229	1.551	0.725	0.2613	0.007748	0.3333	0.6869	1.295
2015	0.1553	0.05596	0.001659	0.07138	0.1471	0.2772	0.9159	0.3301	0.009789	0.4211	0.8679	1.636	0.7606	0.2742	0.008129	0.3497	0.7207	1.358
2016	0.1602	0.05773	0.001712	0.07363	0.1518	0.286	0.9449	0.3406	0.0101	0.4344	0.8953	1.687	0.7847	0.2828	0.008387	0.3607	0.7435	1.401

Annex 5. Silky shark estimates in biomass (in '000 t) for the area-based estimation method

	Eastern Pacific						Pacific						Western Pacific					
	mean	sd	MC error	2.50%	median	97.50%	mean	sd	MC error	2.50%	median	97.50%	mean	sd	MC error	2.50%	median	97.50%
1980	3.522	0.7252	0.01935	2.241	3.488	4.961	8.137	1.675	0.0447	5.176	8.057	11.46	5.06	1.042	0.0278	3.219	5.011	7.128
1981	3.525	0.7258	0.01936	2.242	3.49	4.965	8.143	1.677	0.04474	5.18	8.063	11.47	5.064	1.043	0.02782	3.221	5.014	7.133
1982	3.477	0.716	0.0191	2.212	3.443	4.898	8.033	1.654	0.04413	5.11	7.954	11.31	4.996	1.029	0.02745	3.178	4.947	7.037
1983	3.23	0.6651	0.01775	2.055	3.199	4.55	7.462	1.537	0.041	4.747	7.389	10.51	4.641	0.9556	0.0255	2.952	4.595	6.537
1984	3.534	0.7276	0.01941	2.248	3.499	4.977	8.164	1.681	0.04485	5.193	8.083	11.5	5.077	1.045	0.02789	3.23	5.027	7.151
1985	3.36	0.6919	0.01846	2.137	3.327	4.733	7.762	1.598	0.04265	4.938	7.686	10.93	4.828	0.994	0.02652	3.071	4.78	6.8
1986	3.585	0.7382	0.0197	2.281	3.55	5.05	8.282	1.705	0.0455	5.269	8.201	11.67	5.151	1.061	0.0283	3.277	5.1	7.255
1987	4.265	0.8783	0.02343	2.713	4.224	6.008	9.854	2.029	0.05414	6.268	9.757	13.88	6.128	1.262	0.03367	3.898	6.068	8.632
1988	4.207	0.8664	0.02312	2.677	4.166	5.927	9.72	2.001	0.0534	6.183	9.625	13.69	6.045	1.245	0.03321	3.845	5.986	8.515
1989	3.862	0.7951	0.02122	2.456	3.824	5.439	8.921	1.837	0.04901	5.675	8.834	12.57	5.548	1.142	0.03048	3.529	5.494	7.815
1990	3.881	0.7991	0.02132	2.469	3.843	5.466	8.966	1.846	0.04926	5.703	8.878	12.63	5.576	1.148	0.03063	3.547	5.521	7.854
1991	5.726	1.234	0.03354	3.595	5.653	8.313	13.23	2.851	0.07748	8.305	13.06	19.2	8.226	1.773	0.04818	5.165	8.123	11.94
1992	6.926	1.493	0.04057	4.348	6.838	10.05	16	3.448	0.09372	10.05	15.8	23.23	9.95	2.145	0.05828	6.247	9.825	14.45
1993	6.262	1.349	0.03668	3.931	6.183	9.09	14.47	3.118	0.08473	9.082	14.28	21	8.996	1.939	0.05269	5.648	8.883	13.06
1994	6.729	1.45	0.03942	4.225	6.644	9.769	15.55	3.35	0.09106	9.761	15.35	22.57	9.668	2.084	0.05663	6.07	9.546	14.04
1995	7.642	1.647	0.04476	4.798	7.545	11.09	17.65	3.805	0.1034	11.08	17.43	25.63	10.98	2.366	0.06431	6.893	10.84	15.94
1996	8.132	1.477	0.041	5.541	7.961	11.07	18.79	3.413	0.09472	12.8	18.39	25.57	11.68	2.123	0.0589	7.96	11.44	15.9
1997	8.771	1.594	0.04422	5.976	8.587	11.94	20.26	3.682	0.1022	13.81	19.84	27.58	12.6	2.29	0.06354	8.587	12.34	17.15
1998	9.362	1.701	0.0472	6.379	9.166	12.74	21.63	3.93	0.1091	14.74	21.18	29.44	13.45	2.444	0.06782	9.165	13.17	18.31
1999	10.49	1.907	0.05291	7.15	10.27	14.29	24.24	4.405	0.1222	16.52	23.73	33	15.08	2.739	0.07602	10.27	14.76	20.52
2000	12.23	2.222	0.06167	8.334	11.97	16.65	28.26	5.134	0.1425	19.25	27.66	38.46	17.57	3.193	0.0886	11.97	17.2	23.92
2001	15.31	3.833	0.1052	9.259	14.83	23.86	35.37	8.856	0.2431	21.39	34.26	55.12	21.99	5.508	0.1512	13.3	21.3	34.28
2002	15.49	3.88	0.1065	9.371	15.01	24.15	35.79	8.963	0.2461	21.65	34.67	55.78	22.26	5.574	0.153	13.46	21.56	34.69
2003	16.56	4.146	0.1138	10.01	16.04	25.8	38.25	9.579	0.2629	23.13	37.05	59.61	23.79	5.957	0.1635	14.39	23.04	37.07
2004	14.61	3.659	0.1004	8.837	14.15	22.77	33.76	8.453	0.232	20.42	32.7	52.61	20.99	5.257	0.1443	12.7	20.33	32.72
2005	14	3.507	0.09627	8.47	13.57	21.83	32.35	8.102	0.2224	19.57	31.34	50.42	20.12	5.039	0.1383	12.17	19.49	31.36
2006	12.7	3.179	0.08728	7.679	12.3	19.79	29.33	7.345	0.2016	17.74	28.41	45.71	18.24	4.568	0.1254	11.03	17.67	28.43
2007	16.83	4.02	0.13	10.27	16.56	25.7	38.87	9.287	0.3002	23.73	38.25	59.36	24.17	5.776	0.1867	14.76	23.79	36.92
2008	16.06	3.838	0.1241	9.809	15.81	24.54	37.11	8.867	0.2866	22.66	36.52	56.68	23.08	5.515	0.1783	14.09	22.71	35.25
2009	16.13	3.854	0.1246	9.85	15.87	24.64	37.27	8.904	0.2878	22.75	36.67	56.92	23.18	5.538	0.179	14.15	22.81	35.4
2010	16.71	3.993	0.1291	10.2	16.44	25.52	38.61	9.225	0.2982	23.57	37.99	58.97	24.01	5.737	0.1854	14.66	23.63	36.67
2011	17.92	4.281	0.1384	10.94	17.63	27.37	41.4	9.891	0.3197	25.28	40.73	63.22	25.75	6.151	0.1988	15.72	25.33	39.32
2012	18.23	4.356	0.1408	11.13	17.94	27.84	42.11	10.06	0.3253	25.71	41.44	64.32	26.19	6.258	0.2023	15.99	25.77	40
2013	17.99	4.299	0.139	10.99	17.71	27.48	41.57	9.933	0.3211	25.38	40.9	63.49	25.85	6.177	0.1997	15.79	25.44	39.49
2014	17.45	4.17	0.1348	10.66	17.17	26.65	40.32	9.633	0.3114	24.62	39.67	61.58	25.07	5.991	0.1937	15.31	24.67	38.29
2015	16.97	4.055	0.1311	10.36	16.7	25.92	39.21	9.369	0.3029	23.94	38.58	59.89	24.39	5.827	0.1883	14.89	23.99	37.24
2016	17.51	4.184	0.1352	10.69	17.23	26.74	40.45	9.665	0.3124	24.7	39.8	61.78	25.16	6.011	0.1943	15.36	24.75	38.42

Annex 6. Silky shark estimates in biomass (in '000 t) for the target species catch-based estimation method

	Eastern Pacific						Pacific						Western Pacific					
	mean	sd	MCerror	2.50%	median	97.50%	mean	sd	MCerror	2.50%	median	97.50%	mean	sd	MCerror	2.50%	median	97.50%
1980	2.631	0.5417	0.01445	1.674	2.605	3.706	9.876	2.034	0.05426	6.283	9.779	13.91	7.231	1.489	0.03973	4.6	7.16	10.19
1981	2.719	0.5599	0.01494	1.73	2.692	3.83	9.553	1.967	0.05248	6.077	9.459	13.46	6.834	1.407	0.03754	4.347	6.767	9.625
1982	2.157	0.4442	0.01185	1.372	2.136	3.039	8.828	1.818	0.0485	5.615	8.741	12.43	6.67	1.373	0.03665	4.243	6.605	9.396
1983	1.622	0.3339	0.00891	1.032	1.606	2.284	8.557	1.762	0.04701	5.443	8.473	12.05	6.935	1.428	0.0381	4.412	6.867	9.768
1984	1.962	0.4039	0.01078	1.248	1.942	2.763	9.62	1.981	0.05285	6.12	9.526	13.55	7.659	1.577	0.04208	4.872	7.584	10.79
1985	2.469	0.5083	0.01356	1.57	2.444	3.477	8.654	1.782	0.04754	5.505	8.569	12.19	6.199	1.276	0.03406	3.943	6.138	8.732
1986	2.371	0.4881	0.01302	1.508	2.347	3.339	9.555	1.968	0.0525	6.078	9.462	13.46	7.185	1.479	0.03947	4.571	7.114	10.12
1987	2.768	0.57	0.01521	1.761	2.741	3.899	11.3	2.327	0.06208	7.188	11.19	15.92	8.513	1.753	0.04677	5.416	8.43	11.99
1988	2.765	0.5693	0.01519	1.759	2.738	3.895	11.03	2.27	0.06057	7.014	10.92	15.53	8.26	1.701	0.04538	5.255	8.179	11.64
1989	2.506	0.516	0.01377	1.594	2.482	3.53	10.23	2.106	0.0562	6.507	10.13	14.41	7.723	1.59	0.04243	4.913	7.647	10.88
1990	2.408	0.4958	0.01323	1.532	2.384	3.391	10.57	2.176	0.05805	6.721	10.46	14.88	8.158	1.68	0.04482	5.189	8.078	11.49
1991	3.015	0.6497	0.01766	1.893	2.977	4.377	15.66	3.375	0.09171	9.831	15.46	22.73	12.67	2.73	0.07419	7.953	12.51	18.39
1992	4.155	0.8956	0.02434	2.609	4.103	6.033	18.37	3.96	0.1076	11.54	18.14	26.68	14.22	3.064	0.08328	8.927	14.04	20.64
1993	3.271	0.705	0.01916	2.054	3.23	4.749	15.46	3.332	0.09057	9.708	15.27	22.45	12.19	2.627	0.07141	7.654	12.04	17.7
1994	3.488	0.7518	0.02043	2.19	3.444	5.064	17	3.664	0.09958	10.67	16.79	24.68	13.54	2.918	0.07931	8.502	13.37	19.66
1995	4.148	0.8941	0.0243	2.605	4.096	6.023	19.31	4.161	0.1131	12.12	19.06	28.03	15.16	3.267	0.08879	9.518	14.97	22.01
1996	4.282	0.7779	0.02159	2.917	4.192	5.828	20.18	3.666	0.1017	13.75	19.76	27.47	15.9	2.889	0.08016	10.83	15.56	21.64
1997	5.227	0.9497	0.02635	3.561	5.117	7.115	22.59	4.104	0.1139	15.39	22.12	30.75	17.36	3.155	0.08755	11.83	17	23.64
1998	5.006	0.9095	0.02524	3.411	4.901	6.815	25.11	4.562	0.1266	17.11	24.58	34.18	20.1	3.652	0.1013	13.7	19.68	27.36
1999	6.211	1.128	0.03131	4.232	6.08	8.454	27.76	5.043	0.1399	18.91	27.17	37.78	21.54	3.914	0.1086	14.68	21.09	29.33
2000	6.789	1.234	0.03423	4.626	6.647	9.242	32.65	5.932	0.1646	22.25	31.96	44.44	25.86	4.698	0.1304	17.62	25.32	35.2
2001	9.497	2.378	0.06529	5.744	9.199	14.8	41.05	10.28	0.2822	24.83	39.76	63.98	31.55	7.902	0.2169	19.08	30.56	49.18
2002	9.36	2.344	0.06434	5.661	9.066	14.59	42.37	10.61	0.2913	25.63	41.04	66.03	33.01	8.267	0.2269	19.97	31.98	51.45
2003	10.95	2.742	0.07526	6.621	10.6	17.06	44.81	11.22	0.308	27.1	43.4	69.83	33.86	8.479	0.2328	20.48	32.8	52.77
2004	8.409	2.106	0.05781	5.086	8.145	13.1	38.82	9.722	0.2669	23.48	37.61	60.51	30.42	7.617	0.2091	18.4	29.46	47.4
2005	7.888	1.975	0.05423	4.771	7.641	12.29	36.87	9.233	0.2535	22.3	35.71	57.46	28.98	7.257	0.1992	17.53	28.07	45.17
2006	6.892	1.726	0.04738	4.168	6.676	10.74	33.74	8.448	0.2319	20.4	32.68	52.58	26.84	6.722	0.1845	16.24	26	41.83
2007	7.966	1.903	0.06153	4.864	7.838	12.17	47.32	11.31	0.3655	28.89	46.56	72.27	39.35	9.402	0.3039	24.03	38.72	60.1
2008	9.311	2.225	0.07192	5.685	9.162	14.22	45.51	10.87	0.3515	27.78	44.78	69.5	36.2	8.648	0.2796	22.1	35.61	55.28
2009	9.547	2.281	0.07374	5.829	9.394	14.58	45.23	10.81	0.3494	27.62	44.51	69.09	35.69	8.527	0.2756	21.79	35.11	54.5
2010	8.868	2.119	0.06849	5.414	8.725	13.54	46.45	11.1	0.3588	28.36	45.71	70.95	37.58	8.98	0.2903	22.95	36.98	57.4
2011	10.53	2.516	0.08135	6.431	10.36	16.09	48.93	11.69	0.3779	29.88	48.15	74.73	38.47	9.192	0.2971	23.49	37.85	58.76
2012	10.79	2.578	0.08333	6.587	10.62	16.48	50.22	12	0.3879	30.67	49.42	76.71	39.44	9.422	0.3046	24.08	38.8	60.23
2013	10.43	2.492	0.08055	6.368	10.26	15.93	49.43	11.81	0.3818	30.18	48.64	75.49	39	9.318	0.3012	23.81	38.37	59.56
2014	10.54	2.519	0.08143	6.437	10.37	16.1	49.15	11.74	0.3796	30.01	48.36	75.07	38.61	9.225	0.2982	23.57	37.99	58.97
2015	11.43	2.731	0.08829	6.979	11.25	17.46	47.59	11.37	0.3676	29.06	46.83	72.69	36.16	8.641	0.2793	22.08	35.58	55.23
2016	10.43	2.493	0.08059	6.371	10.27	15.94	47.67	11.39	0.3682	29.11	46.91	72.81	37.24	8.897	0.2876	22.74	36.64	56.87

Annex 7. Silky shark estimates in biomass (in '000 t) for the longline effort-based estimation method

	Eastern Pacific						Pacific						Western Pacific					
	mean	sd	MC error	2.50%	median	97.50%	mean	sd	MC error	2.50%	median	97.50%	mean	sd	MC error	2.50%	median	97.50%
1980	1.748	0.3638	0.009719	1.103	1.732	2.467	9.153	1.906	0.05091	5.777	9.072	12.92	7.432	1.53	0.04083	4.728	7.36	10.47
1981	1.735	0.3611	0.009647	1.095	1.719	2.449	9.361	1.949	0.05206	5.908	9.278	13.21	7.654	1.576	0.04205	4.869	7.579	10.78
1982	1.513	0.315	0.008416	0.9551	1.5	2.136	8.329	1.734	0.04632	5.257	8.256	11.76	6.841	1.409	0.03758	4.352	6.774	9.635
1983	1.327	0.2762	0.00738	0.8375	1.315	1.873	8.434	1.756	0.04691	5.324	8.359	11.91	7.133	1.469	0.03919	4.537	7.063	10.05
1984	1.48	0.3082	0.008233	0.9343	1.467	2.09	8.724	1.816	0.04852	5.506	8.646	12.31	7.269	1.497	0.03994	4.624	7.198	10.24
1985	1.066	0.2219	0.005928	0.6728	1.056	1.505	9.047	1.883	0.05031	5.71	8.966	12.77	8.009	1.649	0.044	5.095	7.931	11.28
1986	1.808	0.3764	0.01006	1.141	1.792	2.552	8.836	1.84	0.04914	5.577	8.758	12.47	7.053	1.452	0.03875	4.487	6.984	9.935
1987	2.238	0.4659	0.01245	1.412	2.218	3.159	12.04	2.506	0.06696	7.599	11.93	17	9.836	2.025	0.05404	6.257	9.74	13.86
1988	2.19	0.456	0.01218	1.383	2.171	3.092	10.61	2.209	0.05901	6.697	10.52	14.98	8.449	1.74	0.04642	5.375	8.367	11.9
1989	1.932	0.4022	0.01074	1.219	1.915	2.727	8.826	1.838	0.04909	5.571	8.748	12.46	6.904	1.422	0.03793	4.392	6.836	9.724
1990	1.894	0.3943	0.01053	1.195	1.877	2.674	8.934	1.86	0.04969	5.639	8.854	12.61	7.065	1.455	0.03881	4.494	6.996	9.951
1991	3.47	0.7555	0.02057	2.155	3.433	5.052	12.67	2.758	0.07511	7.87	12.53	18.44	9.231	1.99	0.05407	5.796	9.115	13.4
1992	3.634	0.7912	0.02154	2.257	3.595	5.29	15.27	3.324	0.09052	9.484	15.1	22.23	11.67	2.516	0.06838	7.33	11.53	16.95
1993	2.75	0.5989	0.01631	1.709	2.721	4.004	11.1	2.418	0.06584	6.898	10.99	16.17	8.383	1.807	0.0491	5.263	8.277	12.17
1994	3.093	0.6734	0.01834	1.921	3.06	4.503	10.78	2.348	0.06394	6.699	10.67	15.7	7.718	1.663	0.04521	4.846	7.621	11.2
1995	3.139	0.6835	0.01861	1.95	3.106	4.57	12.46	2.714	0.0739	7.742	12.33	18.15	9.389	2.023	0.05499	5.895	9.27	13.63
1996	2.547	0.4693	0.01304	1.719	2.494	3.477	11.51	2.121	0.05893	7.767	11.27	15.71	8.995	1.634	0.04535	6.129	8.806	12.24
1997	2.533	0.4668	0.01297	1.709	2.481	3.458	12.16	2.242	0.06229	8.21	11.91	16.61	9.666	1.756	0.04874	6.586	9.464	13.16
1998	2.894	0.5333	0.01482	1.953	2.834	3.951	12.91	2.379	0.0661	8.711	12.64	17.62	10.05	1.826	0.05067	6.848	9.839	13.68
1999	3.158	0.582	0.01617	2.131	3.093	4.312	16.3	3.005	0.08349	11	15.97	22.26	13.19	2.397	0.06651	8.989	12.92	17.96
2000	3.383	0.6234	0.01732	2.283	3.313	4.619	20.44	3.768	0.1047	13.8	20.02	27.92	17.12	3.111	0.08633	11.67	16.76	23.31
2001	7.098	1.791	0.04922	4.238	6.875	11.09	31.32	7.903	0.2172	18.7	30.34	48.92	24.31	6.087	0.1671	14.7	23.54	37.88
2002	8.696	2.194	0.06031	5.193	8.424	13.58	33.15	8.364	0.2299	19.79	32.11	51.77	24.54	6.145	0.1687	14.84	23.77	38.24
2003	9.36	2.362	0.06491	5.589	9.067	14.62	35.89	9.057	0.2489	21.43	34.77	56.06	26.69	6.685	0.1835	16.14	25.86	41.6
2004	5.586	1.41	0.03874	3.336	5.411	8.725	29.65	7.483	0.2056	17.71	28.72	46.32	24.15	6.048	0.166	14.61	23.4	37.64
2005	4.5	1.136	0.03121	2.687	4.359	7.028	26.09	6.583	0.1809	15.58	25.27	40.75	21.66	5.425	0.1489	13.1	20.98	33.76
2006	3.873	0.9773	0.02686	2.313	3.751	6.049	24.37	6.15	0.169	14.55	23.61	38.07	20.52	5.139	0.1411	12.41	19.88	31.98
2007	3.421	0.8242	0.02661	2.079	3.358	5.238	31.55	7.599	0.2453	19.16	30.96	48.29	28.23	6.744	0.218	17.23	27.77	43.11
2008	3.332	0.8027	0.02591	2.024	3.27	5.101	33.91	8.169	0.2637	20.6	33.28	51.91	30.62	7.316	0.2365	18.7	30.13	46.77
2009	3.74	0.9009	0.02908	2.272	3.67	5.725	35.3	8.503	0.2745	21.44	34.64	54.04	31.67	7.567	0.2446	19.34	31.16	48.37
2010	4.894	1.179	0.03805	2.973	4.803	7.492	37.79	9.104	0.2939	22.96	37.09	57.85	33.01	7.888	0.255	20.16	32.49	50.42
2011	6.049	1.457	0.04704	3.675	5.937	9.26	42.56	10.25	0.331	25.86	41.77	65.16	36.64	8.755	0.283	22.37	36.05	55.96
2012	6.005	1.447	0.0467	3.648	5.894	9.194	43.22	10.41	0.3361	26.26	42.42	66.17	37.35	8.925	0.2885	22.81	36.75	57.05
2013	7.465	1.798	0.05805	4.535	7.327	11.43	40.32	9.714	0.3136	24.5	39.58	61.73	33.05	7.897	0.2553	20.18	32.52	50.48
2014	6.885	1.659	0.05354	4.183	6.757	10.54	42.09	10.14	0.3273	25.57	41.31	64.44	35.26	8.425	0.2723	21.53	34.69	53.85
2015	7.524	1.813	0.05851	4.571	7.385	11.52	44.39	10.69	0.3452	26.96	43.56	67.95	36.99	8.839	0.2857	22.59	36.4	56.5
2016	7.762	1.87	0.06036	4.716	7.619	11.88	45.79	11.03	0.3561	27.82	44.94	70.1	38.16	9.119	0.2948	23.3	37.55	58.29