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Summary of purse seine fishery bycatch at a regional scale, 2003-2017

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Executive Summary

The Western and Central Pacific Fisheries Commission (WCPFC) has a responsibility to assess the impact of fishing on non-target species. In this report, we estimate the bycatch of the large-scale purse seine fishery operating primarily in tropical waters of the WCPFC Area east of 140°E. These large vessels, typically greater than 500 tonnes carrying capacity, have been responsible for approximately 83% of the purse seine catch of the main tuna target species, skipjack, yellowfin and bigeye tuna, in recent years, a catch that has varied between 1.5 and 2 million tonnes annually since 2010. This report provides an update to the equivalent report prepared in 2017 and submitted to WCPFC SC13.

We summarise bycatches of species and species groups that provide a comprehensive coverage of finfish, billfish, shark and ray, sea turtle and marine mammal species observed in purse seine catches, updated from those provided in 2017. We do not report on seabird bycatch due to the low number of observed catch events, though these will be covered by the ongoing Project 68.

Available observer coverage for 2017 represented 20% coverage of total sets, compared with 60-75% for the period 2010-2016. As such, the bycatch estimates of 2017 should be considered preliminary.

The report concludes with recommendations to the Scientific Committee:

- The Scientific Committee note the estimates of bycatch of large-scale purse seine fleets operating in the WCPFC-CA;
- The Scientific Committee consider whether annually updated estimates of bycatch in the purse seine fishery are helpful, and whether this work should be supported in the future;
- The Scientific Committee consider whether estimates of purse seine bycatch should be made publicly available in electronic format to facilitate extraction and use of data by Commission Members, Cooperating Non-members and participating Territories (CCMs), and potentially other stakeholders.

1. Introduction

The Convention on the Conservation and Management of Highly Migratory Fish Stocks in the Western and Central Pacific Ocean[1] clearly indicates that the WCPFC has responsibilities in not only managing tuna species, but also in assessing the impact of fishing and environmental factors on non-target species and species belonging to the same ecosystem or dependent upon or associated with the target stocks (article 5d), to minimize catch of non-target species (article 5e), to protect biodiversity (article 5f), and to adopt, when necessary, Conservation and Management Measures (CMMs) for non-target species to ensure the conservation of such species (article 6c).

Hence, since the establishment of the WCPFC a number of measures on non-target species have been implemented.

- The WCPFC is maintaining an open resource that focuses on bycatch mitigation and management in oceanic tuna and billfish fisheries: the Bycatch Management Information System (BMIS, https://www.bmis-bycatch.org/) (Fitzsimmons et al., 2015).
- A resolution has been taken to encourage avoiding the capture of all non-target fish species and encourage prompt release to the water, unharmed (resolution 2005-03).
- CMMs have been taken on billfishes (CMM 2006-04 for striped marlin in the southwest Pacific, CMM 2009-03 for swordfish, CMM 2010-01 for north Pacific striped marlin), and on species of special interest: sea turtles (CMM 2008-03), sharks (CMM 2010-07, CMM 2011-04 for oceanic whitetip shark, CMM 2012-04 for whale sharks, CMM 2013-08 for silky sharks, CMM 2014-05), cetaceans (CMM 2011-03) and seabirds (CMM 2017-06).

Most of these CMMs encourage better reporting rates of the non-target species. However, even if reporting improves, data on non-target species are infrequently reported on logsheets provided by the fishing industry and the only reliable source of information on those species are observer data. The requirement for 100% observer coverage of purse seiners since 1st January 2010, as stated in CMM 2008-01, offers the possibility of providing reliable estimates of the quantities of the most frequent non-target species and data on non-target species composition for the most recent years for this fishery. We note that the requirement for 100% observer coverage applies to purse seine fishing between 10°N and 10°S. CMM 2007-01 requires a minimum of 5% observer coverage for purse seine fishing elsewhere.

Since 2010, a number of studies estimating bycatches of the tuna fisheries have been produced:

- At the global level, the FAO produced three studies on bycatch of the small scale tuna fisheries (Gillett, 2011), of the tropical tuna purse seine fisheries (Hall and Roman, 2013) and of the tuna longline fisheries (Clarke et al., 2014).
- At the regional level three studies have been conducted on edible bycatch species from the purse seine fishery (Pilling et al., 2012, 2013, 2015), on key shark species (Lawson, 2011; Rice, 2012), on non-target species interactions with the tuna fisheries (Oceanic Fisheries Programme of the Secretariat of the Pacific Community, 2010).
- At the national level two series of national reports were produced by the SPC Oceanic Fisheries Programme on longline fisheries in 2012-2014 on “Bycatches of the longline tuna fisheries” and in 2017 on “Seasonality and value of target tuna and important bycatch species in the longline fishery” (confidential, available for authorized fisheries department staff on SPC country web pages for Cook Islands, Fiji, French Polynesia, Federated States of

[1] https://www.wcpfc.int/system/files/text.pdf

Micronesia, Marshall Islands, New Caledonia, Palau, Papua New Guinea, Solomon Islands, Tonga, Vanuatu).

Most recently, purse seine bycatch estimates for the large scale purse seine fishery in the WCPFC Convention Area (WCPFC-CA) were presented to WCPFC-SC13 (Peatman et al., 2017), covering the period 2003 to 2016. In this update we extend the analysis to cover 2017.

2. Methods

We briefly summarise the data and the methodology used to estimate bycatches. A full description was provided in Peatman et al. (2017) and is not repeated here.

2.1. Definition of bycatch and other terminology

Bycatch

Bycatch was defined as all species except skipjack, yellowfin and bigeye, regardless of whether the individuals were retained or discarded.

School association / set type

The set types used in the analysis were sets on: anchored fish aggregating devices (aFAD); drifting fish aggregating devices (dFAD); drifting logs, debris or dead animals (log); unassociated schools (free schools - FS); live whales (whale); and, live whale sharks (whale.shk).

Large-scale purse seine fleets

SPC holds observer data for large-scale purse seiners operating in equatorial and tropical waters, referred to throughout as the large-scale purse seine fleet. The large-scale purse seine fleet accounted for > 80 % of reported catches from 2003 to 2017. We do not attempt to estimate bycatches for other purse seine fleets operating in the WCPFC Convention Area, for which SPC hold little observer data, namely: small-scale Indonesian, Vietnamese and domestic Philippines vessels; and, purse seiners operating in temperate waters.

Bycatch unit

Bycatch estimates were calculated in units of individuals for billfish, sharks and rays, marine mammals and sea turtles. Bycatch estimates for finfish (excluding billfish) were calculated in metric tonnes. These bycatch units were the most commonly used for the different species groups, and were considered to provide the most accurate dataset of observed catches in SPC's purse seine observer data holdings.

2.2. Data and methodology

To summarise, SPC's observer data holdings were used to estimate bycatch rates of finfish, billfish, sharks and rays, sea turtles and marine mammals. Estimated bycatch rates were then raised to total bycatch using reported aggregate catch and effort data. The approach used was identical to the approach of Peatman et al. (2017), except for the inclusion of observer data and aggregate catch and effort data for 2017. Observer data was extracted from SPC's master observer database on 4th July 2018. At the time of data extraction, there were comparatively low levels of observer data available for 2017 (Figure 1) due to delays in the submission of observer logbooks (Williams et al., 2018). The total number of reported sets by school association type is provided in Table 1.

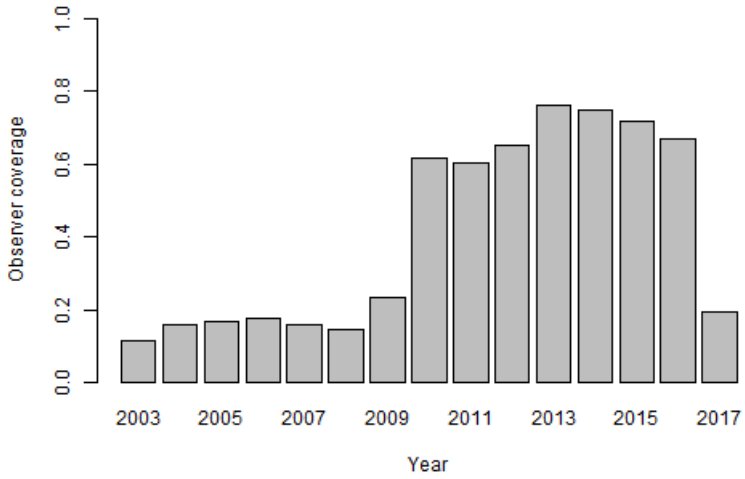

Figure 1 Annual observer coverage (proportion of sets) of large-scale purse seine fleets in the WCPFC-CA.

Table 1 Total reported sets by year and association type for large scale purse seine fleets operating in the WCPFC-CA, from 2003 to 2016. Cell colours: red = highest number of sets, green = lowest number of sets, for all years and set types combined within a table.

Year	aFAD	dFAD	log	FS	whale	whale.shk	Total
2003	2,644	3,576	7,051	17,043	29	18	30,361
2004	2,899	4,776	13,289	11,162	33	2	32,161
2005	3,223	3,982	9,842	19,494	39	4	36,584
2006	2,067	4,931	11,118	15,309	28	9	33,462
2007	2,117	5,539	8,971	19,648	64	11	36,350
2008	3,084	10,423	4,887	22,718	70	10	41,192
2009	3,058	11,370	6,779	22,803	88	9	44,107
2010	2,355	6,848	3,797	38,191	260	18	51,469
2011	2,925	15,243	3,641	30,305	155	1	52,270
2012	2,765	13,405	4,438	36,609	136	9	57,362
2013	2,178	12,110	3,498	38,014	99	5	55,904
2014	1,701	13,932	2,780	38,802	81	4	57,300
2015	1,260	10,264	2,074	33,710	132	9	47,449
2016	1,205	10,676	2,192	31,811	160	13	46,057
2017	609	13,841	1,703	33,315	228	54	49,750

3. Bycatch estimates

Estimates of bycatch for the large-scale purse seine fleet are provided in Table 2, aggregated across finfish (excluding billfish), billfish, sharks and rays, marine mammals and sea turtles. It is important to note that these bycatch estimates do not include bycatches of (smaller-scale) Indonesian, Vietnamese and domestic Philippines purse seiners, and Japanese and New Zealand purse seiners operating in temperate waters (see Section 2.1).

Table 2 Estimated annual bycatch for large-scale purse seine fleets. Median bycatch (med), and lower (low) and upper (high) 95 % confidence intervals, are provided for finfish (excluding billfish) in metric tonnes (mt), and, billfish, sharks and rays, marine mammals and turtles in number of individuals (n).

	Finfish (mt)			Billfish (n)			Sharks (n)			Marine mammals (n)			Turtles (n)		
Year	Low	Med	High	Low	Med	High	Low	Med	High	Low	Med	High	Low	Med	High
2003	5,176	5,567	6,066	6,258	6,691	7,356	56,525	60,122	64,220	415	819	1,505	218	323	443
2004	9,125	9,604	10,160	6,401	6,754	7,209	67,766	71,209	74,744	1,035	1,620	2,405	77	129	199
2005	7,445	7,881	8,397	6,244	6,608	7,206	59,739	62,502	65,456	438	779	1,364	129	190	264
2006	7,224	7,614	8,049	6,063	6,386	6,859	57,361	59,821	62,406	946	1,458	2,129	119	171	234
2007	6,845	7,317	7,848	6,555	6,878	7,356	54,603	57,553	60,719	653	1,212	2,174	194	275	383
2008	5,351	5,785	6,344	6,275	6,613	7,134	53,956	56,987	60,292	627	1,258	2,273	160	227	305
2009	5,942	6,275	6,654	6,563	6,850	7,214	45,987	47,959	50,052	1,114	1,631	2,369	196	260	337
2010	5,071	5,148	5,231	5,863	5,960	6,077	35,870	36,390	36,944	392	472	575	198	214	230
2011	4,469	4,550	4,639	6,596	6,707	6,845	56,958	57,828	58,722	504	585	694	356	378	403
2012	4,593	4,673	4,759	8,786	8,881	8,999	43,875	44,414	44,966	546	639	756	264	282	301
2013	4,711	4,789	4,872	8,448	8,516	8,594	47,091	47,543	48,037	756	825	912	300	314	330
2014	4,694	4,790	4,893	9,048	9,120	9,210	58,140	58,611	59,109	326	381	456	195	209	224
2015	4,440	4,500	4,564	7,650	7,713	7,786	45,428	45,848	46,292	377	435	513	203	216	229
2016	5,499	5,554	5,614	5,840	5,907	5,987	66,905	67,475	68,064	273	334	421	148	160	172
2017	3,558	3,808	4,129	6,619	6,901	7,341	75,996	79,019	82,322	257	427	722	97	148	219

3.1.Finfish

Estimated total finfish bycatch for large-scale purse seine fleets peaked in 2004 at 10,000 tonnes, declining to approximately 5,000 tonnes from 2010 onwards (Table 3). Over the period 2003 to 2017, rainbow runner accounted for approximately half (48 %) of total finfish bycatch. Mackerel scad, oceanic triggerfish, frigate & bullet tuna and mahi mahi together accounted for 42 % of total finfish bycatch.

Log sets accounted for the highest proportion of finfish bycatch from 2003 to 2010, after which drifting FAD sets accounted for the majority of bycatch (Table 4). The main driver in the declining trend in estimated finfish bycatch from 2003 to 2010 was the strong reduction in log sets over this period (Table 1), which tend to have the highest probability of finfish bycatch presence (Peatman et al., 2017).

Table 3 Median finfish bycatch estimates (metric tonnes) by species/species group for the large-scale purse seine fleets. Species/species group accounting for less than < 2% of total finfish bycatch have been grouped in to 'others'.

Year	Rainbow runner	Mackerel scad	Oceanic triggerfish	Frigate & bullet tunas	Mahi mahi	Wahoo	Kawakawa	Others	Total
2003	2,435	718	593	763	352	79	89	459	**5,567**
2004	4,527	1,218	1,329	805	613	167	160	687	**9,604**
2005	3,605	1,319	995	694	435	108	100	555	**7,881**
2006	3,748	1,200	1,012	397	519	96	71	503	**7,614**
2007	3,480	1,168	920	736	327	127	130	342	**7,317**
2008	2,855	733	577	571	416	175	93	272	**5,785**
2009	2,973	961	622	364	521	164	188	422	**6,275**
2010	2,542	810	716	183	367	102	64	353	**5,148**
2011	2,327	469	453	267	311	167	201	344	**4,550**
2012	2,049	620	424	348	367	170	174	510	**4,673**
2013	1,886	955	527	430	437	139	157	248	**4,789**
2014	1,778	890	369	822	351	180	173	215	**4,790**
2015	2,257	914	402	186	343	76	61	252	**4,500**
2016	3,006	1,143	641	161	145	82	96	273	**5,554**
2017	1,987	567	422	98	292	112	64	223	**3,808**
Species totals	**41,457**	**13,686**	**10,002**	**6,826**	**5,796**	**1,945**	**1,823**	**5,658**	**87,857**

Table 4 (left) Total estimated finfish bycatch in metric tonnes (median, and lower and upper 95 % confidence intervals) for large-scale purse seine fleets. Average annual bycatch rates by set and '000 metric tonnes of target catch are also included. (right) Proportion of annual estimated finfish bycatch (metric tonnes) by association type.

	Estimated bycatch			Bycatch rate per	
Year	Low	Median	High	set	'000 mt
2003	5,176	5,567	6,066	0.183	5.59
2004	9,125	9,604	10,160	0.299	9.02
2005	7,445	7,881	8,397	0.215	6.61
2006	7,224	7,614	8,049	0.228	6.21
2007	6,845	7,317	7,848	0.201	5.39
2008	5,351	5,785	6,344	0.140	4.13
2009	5,942	6,275	6,654	0.142	4.11
2010	5,071	5,148	5,231	0.100	3.46
2011	4,469	4,550	4,639	0.087	3.23
2012	4,593	4,673	4,759	0.081	2.83
2013	4,711	4,789	4,872	0.086	3.02
2014	4,694	4,790	4,893	0.084	2.67
2015	4,440	4,500	4,564	0.095	2.85
2016	5,499	5,554	5,614	0.121	3.52
2017	3,558	3,808	4,129	0.077	2.64

Year	aFAD	dFAD	log	FS	whale	whale.shk
2003	13.7%	14.3%	67.1%	4.9%	0.0%	0.0%
2004	8.5%	11.3%	78.1%	2.2%	0.0%	0.0%
2005	10.9%	14.1%	69.7%	5.3%	0.0%	0.0%
2006	5.6%	16.2%	74.7%	3.5%	0.0%	0.0%
2007	8.1%	18.9%	67.5%	5.4%	0.0%	0.0%
2008	14.4%	38.8%	42.3%	4.5%	0.0%	0.0%
2009	10.3%	37.0%	47.7%	5.0%	0.0%	0.0%
2010	9.2%	41.3%	41.7%	7.8%	0.0%	0.0%
2011	9.8%	55.6%	26.0%	8.5%	0.0%	0.0%
2012	12.0%	39.8%	36.5%	11.7%	0.0%	0.0%
2013	16.8%	38.8%	36.8%	7.5%	0.0%	0.0%
2014	25.1%	40.3%	27.0%	7.7%	0.0%	0.0%
2015	12.6%	50.1%	32.0%	5.3%	0.0%	0.0%
2016	8.6%	58.4%	27.2%	5.8%	0.0%	0.0%
2017	4.5%	64.2%	21.2%	10.0%	0.1%	0.0%

3.2. Billfish

Estimated total billfish bycatch for large-scale purse seine fleets remained in the region of 6,500 individuals from 2003 to 2011. In 2012 billfish bycatch increased to 9,000 individuals, before decreasing from 9,000 individuals to 7,000 individuals from 2013 to 2017 (Table 5). Blue marlin accounted for half of total billfish bycatch over the period 2003 to 2017, with black marlin and striped marlin accounting for 26 % and 11 % respectively. (Note that recent, as yet unreported, genetic analyses suggest that historically billfish identified as black marlin by observers in some fisheries may actually be blue marlin. A caveat is that the sample sizes involved in the genetics work are small.)

Unassociated sets and sets on drifting FADs accounted for the highest proportion of billfish bycatch from 2008 onwards, with log sets and unassociated sets accounting for the highest proportion of billfish bycatch before 2008 (Table 6). The increase in billfish bycatch in 2012 and 2013 was mainly driven by the increase in sets on unassociated schools in these years (Table 1).

Table 5 Median billfish bycatch estimates (individuals) by species/species group for large-scale purse seine fleets. Species/species group accounting for less than < 2% of total billfish bycatch have been grouped in to 'others'.

Year	Blue marlin	Black marlin	Striped marlin	Sailfish (indo-pacific)	Swordfish	Others	Total
2003	2,500	2,477	672	729	113	172	**6,691**
2004	2,914	2,301	561	693	139	124	**6,754**
2005	3,150	1,688	703	864	146	37	**6,608**
2006	3,040	1,734	643	637	230	81	**6,386**
2007	4,179	1,414	563	402	208	86	**6,878**
2008	3,708	1,697	495	503	126	58	**6,613**
2009	3,352	1,679	984	493	187	136	**6,850**
2010	2,725	1,613	767	563	133	153	**5,960**
2011	3,176	1,802	886	609	145	84	**6,707**
2012	4,513	2,272	1,182	566	175	169	**8,881**
2013	4,219	2,450	1,175	421	105	144	**8,516**
2014	4,969	2,173	1,152	571	116	134	**9,120**
2015	4,777	1,498	982	268	63	120	**7,713**
2016	3,592	1,208	710	258	78	57	**5,907**
2017	4,343	1,599	535	331	47	24	**6,901**
Species totals	**55,159**	**27,606**	**12,010**	**7,909**	**2,011**	**1,581**	**106,485**

Table 6 (left) Total estimated billfish bycatch in individuals (median, and lower and upper 95 % confidence intervals) for large-scale purse seine fleets. Average annual bycatch rates by set and '000 metric tonnes of target catch are also included. (right) Proportion of annual estimated billfish bycatch (individuals) by association type.

	Estimated bycatch			Bycatch rate per	
Year	Low	Median	High	set	'000 mt
2003	6,258	6,691	7,356	0.220	6.72
2004	6,401	6,754	7,209	0.210	6.34
2005	6,244	6,608	7,206	0.181	5.54
2006	6,063	6,386	6,859	0.191	5.21
2007	6,555	6,878	7,356	0.189	5.07
2008	6,275	6,613	7,134	0.161	4.72
2009	6,563	6,850	7,214	0.155	4.49
2010	5,863	5,960	6,077	0.116	4.01
2011	6,596	6,707	6,845	0.128	4.76
2012	8,786	8,881	8,999	0.155	5.38
2013	8,448	8,516	8,594	0.152	5.38
2014	9,048	9,120	9,210	0.159	5.08
2015	7,650	7,713	7,786	0.163	4.89
2016	5,840	5,907	5,987	0.128	3.75
2017	6,619	6,901	7,341	0.139	4.79

Year	aFAD	dFAD	log	FS	whale	whale.shk
2003	5.9%	15.2%	36.1%	42.6%	0.1%	0.1%
2004	4.9%	17.0%	56.1%	22.0%	0.1%	0.0%
2005	4.7%	13.9%	40.6%	40.6%	0.1%	0.0%
2006	4.0%	16.8%	47.7%	31.5%	0.0%	0.0%
2007	3.8%	21.3%	34.1%	40.5%	0.2%	0.0%
2008	4.9%	36.6%	17.9%	40.4%	0.2%	0.0%
2009	4.4%	37.0%	22.7%	35.7%	0.2%	0.0%
2010	3.8%	23.5%	14.6%	57.1%	0.9%	0.1%
2011	4.9%	41.7%	11.1%	42.0%	0.4%	0.0%
2012	3.2%	34.0%	11.4%	51.2%	0.2%	0.0%
2013	1.9%	35.3%	11.8%	50.8%	0.2%	0.0%
2014	1.0%	39.7%	6.7%	52.4%	0.2%	0.0%
2015	1.8%	29.8%	7.9%	60.2%	0.3%	0.0%
2016	3.1%	36.1%	10.5%	49.7%	0.5%	0.0%
2017	1.4%	42.2%	6.2%	49.6%	0.5%	0.1%

3.3. Sharks and rays

Estimated total shark bycatch displayed a generally declining trend from 2004 to 2010, reducing from 70,000 to 36,000 individuals per year, and an increasing trend from 2012 to 2016 when it reached 68,000 individuals (Table 7). Shark bycatch estimates from 2010 to 2014 were variable, averaging 50,000 individuals, before increasing to 80,000 individuals in 2017. Silky shark accounted for 88 % of estimated shark bycatch from 2003 to 2017, with mantas and mobulid rays, and oceanic whitetip accounting for 5 and 1.6 % respectively.

Log sets accounted for the highest proportion of sharks and rays bycatch from 2003 to 2007, with drifting FAD sets accounting for the highest proportion from 2008 onwards (Table 8). The declining trend in shark bycatch from 2003 to 2007 was a result in the decline in log sets (Table 1), which had the highest probability of catching silky sharks (Peatman et al., 2017). The relatively low levels of shark bycatch in 2010 and 2015 was driven by the reduced number of drifting FAD sets in these years, which have a relatively high chance of catching silky sharks. Conversely, the high shark bycatch in 2011 was due to the increase in drifting FAD sets, along with a general increase in the chance of catching silky sharks in that year regardless of set type.

Table 7 Median shark bycatch estimates (individuals) by species/species group for large-scale purse seine fleets. Species/species group accounting for less than < 2% of total shark bycatch have been grouped in to 'others'.

Year	Silky shark	Mantas & mobulids	Oceanic whitetip shark	Elasmobranchs nei	Others	Total
2003	43,892	2,196	2,123	10,150	1,642	**60,122**
2004	60,886	2,520	2,503	4,077	1,101	**71,209**
2005	56,242	2,196	1,481	1,769	733	**62,502**
2006	55,466	1,857	642	1,088	678	**59,821**
2007	52,708	2,208	967	822	761	**57,553**
2008	50,378	2,663	1,233	1,367	1,168	**56,987**
2009	43,758	2,068	428	768	830	**47,959**
2010	31,578	2,599	676	654	870	**36,390**
2011	52,639	2,790	520	1,159	704	**57,828**
2012	36,985	4,948	479	663	1,326	**44,414**
2013	41,887	3,617	414	806	810	**47,543**
2014	52,432	3,576	677	940	967	**58,611**
2015	39,634	2,991	520	1,978	713	**45,848**
2016	60,899	4,006	498	1,508	546	**67,475**
2017	72,261	3,440	721	2,036	438	**79,019**
Species totals	**751,645**	**43,676**	**13,882**	**29,787**	**13,287**	**853,282**

Table 8 (left) Total estimated shark bycatch in individuals (median, and lower and upper 95 % confidence intervals) for large-scale purse seine fleets. Average annual bycatch rates by set and '000 metric tonnes of target catch are also included. (right) Proportion of annual estimated shark bycatch (individuals) by association type.

	Estimated bycatch			Bycatch rate per	
Year	Low	Median	High	set	'000 mt
2003	56,525	60,122	64,220	1.980	60.38
2004	67,766	71,209	74,744	2.214	66.89
2005	59,739	62,502	65,456	1.708	52.39
2006	57,361	59,821	62,406	1.788	48.81
2007	54,603	57,553	60,719	1.583	42.39
2008	53,956	56,987	60,292	1.383	40.68
2009	45,987	47,959	50,052	1.087	31.40
2010	35,870	36,390	36,944	0.707	24.47
2011	56,958	57,828	58,722	1.106	41.02
2012	43,875	44,414	44,966	0.774	26.92
2013	47,091	47,543	48,037	0.850	30.01
2014	58,140	58,611	59,109	1.023	32.66
2015	45,428	45,848	46,292	0.966	29.05
2016	66,905	67,475	68,064	1.465	42.81
2017	75,996	79,019	82,322	1.588	54.80

Year	aFAD	dFAD	log	FS	whale	whale.shk
2003	8.5%	18.5%	57.9%	15.1%	0.0%	0.0%
2004	5.2%	18.0%	69.9%	6.9%	0.0%	0.0%
2005	6.4%	17.0%	62.3%	14.2%	0.0%	0.0%
2006	4.3%	19.1%	65.8%	10.8%	0.0%	0.0%
2007	4.2%	21.8%	57.5%	16.3%	0.2%	0.0%
2008	7.7%	42.8%	32.0%	17.4%	0.1%	0.0%
2009	5.1%	43.3%	38.7%	12.8%	0.1%	0.0%
2010	5.7%	35.2%	31.8%	26.5%	0.7%	0.0%
2011	5.2%	54.8%	20.2%	19.5%	0.3%	0.0%
2012	5.1%	43.1%	25.6%	26.0%	0.3%	0.0%
2013	2.6%	49.0%	24.1%	24.1%	0.2%	0.0%
2014	2.1%	55.4%	17.8%	24.5%	0.2%	0.0%
2015	5.7%	51.1%	20.0%	22.9%	0.3%	0.0%
2016	4.5%	46.1%	15.5%	32.9%	0.9%	0.1%
2017	1.6%	55.2%	11.0%	31.4%	0.7%	0.1%

3.4.Other species of special interest (marine mammals & turtles)

Estimated total turtle bycatch displayed a generally increasing trend from 2004 to 2013, from 130 to 390 individuals per year (Table 9). Turtle bycatches then declined from 2014 to 2017. Green turtle (24 %), olive ridley (23 %), loggerhead (20 %) and hawksbill turtles (16 %) accounted for the majority of turtle bycatch from 2003 to 2017 (Table 9). From 2003 to 2005, marine turtles nei (predominantly turtles - unspecified) accounted for more than 60 % of estimated turtle bycatch. Observers recorded the vast majority of turtle bycatch at a species level from 2006 onwards. Unassociated sets accounted for the highest proportion of turtle bycatch, with the exception of 2004 to 2006 where log sets accounted for the highest proportion (Table 10).

Bycatch of marine mammals displayed strong interannual variability, though bycatch was generally higher from 2003 to 2009 (averaging 1,200 individuals), and lower from 2010 to 2017 (averaging 500 individuals per year). Log sets accounted for the highest proportion of marine mammal bycatch from 2003 to 2008, with drifting FAD sets accounting for the highest proportion from 2009 onwards (Table 11), as a result of the change in the proportions of log and drifting FAD sets in the region (Table 1).

Table 9 Median turtle bycatch estimates (individuals) by species/species group for large-scale purse seine fleets.

Year	Green turtle	Olive ridley turtle	Loggerhead turtle	Hawksbill turtle	Leatherback turtle	Marine turtles nei	Total
2003	38	37	0	25	0	217	**323**
2004	0	16	0	15	12	84	**129**
2005	37	7	30	17	0	94	**190**
2006	20	63	26	30	13	14	**171**
2007	98	64	55	29	5	18	**275**
2008	41	36	100	32	8	7	**227**
2009	52	62	85	45	6	5	**260**
2010	58	40	56	43	7	9	**214**
2011	76	130	81	75	7	9	**378**
2012	73	78	57	50	6	17	**282**
2013	94	67	69	63	8	12	**314**
2014	63	51	29	44	9	13	**209**
2015	84	48	49	25	4	5	**216**
2016	41	44	35	19	14	5	**160**
2017	27	42	34	32	5	3	**148**
Species totals	**803**	**784**	**706**	**543**	**104**	**513**	**3,495**

Table 10 (left) Total estimated turtle bycatch in individuals (median, and lower and upper 95 % confidence intervals) for large-scale purse seine fleets. Average annual bycatch rates by set and '000 metric tonnes of target catch are also included. (right) Proportion of annual estimated turtle bycatch (individuals) by association type.

	Estimated bycatch			Bycatch rate per	
Year	Low	Median	High	set	'000 mt
2003	218	323	443	0.011	0.32
2004	77	129	199	0.004	0.12
2005	129	190	264	0.005	0.16
2006	119	171	234	0.005	0.14
2007	194	275	383	0.008	0.20
2008	160	227	305	0.006	0.16
2009	196	260	337	0.006	0.17
2010	198	214	230	0.004	0.14
2011	356	378	403	0.007	0.27
2012	264	282	301	0.005	0.17
2013	300	314	330	0.006	0.20
2014	195	209	224	0.004	0.12
2015	203	216	229	0.005	0.14
2016	148	160	172	0.003	0.10
2017	97	148	219	0.003	0.10

Year	aFAD	dFAD	log	FS	whale	whale.shk
2003	7.1%	16.4%	23.0%	53.5%	0.0%	0.0%
2004	18.4%	0.0%	49.0%	32.6%	0.0%	0.0%
2005	9.5%	5.4%	54.2%	30.3%	0.5%	0.0%
2006	6.9%	19.7%	41.9%	31.5%	0.0%	0.0%
2007	5.0%	12.4%	22.6%	59.6%	0.4%	0.0%
2008	6.7%	14.5%	4.7%	73.8%	0.4%	0.0%
2009	3.4%	23.7%	34.9%	37.5%	0.4%	0.0%
2010	2.2%	11.5%	9.9%	76.4%	0.0%	0.0%
2011	3.1%	33.3%	7.1%	55.9%	0.5%	0.0%
2012	5.2%	22.3%	18.6%	53.5%	0.4%	0.0%
2013	3.3%	18.2%	11.6%	66.6%	0.3%	0.0%
2014	1.9%	22.3%	12.7%	63.1%	0.0%	0.0%
2015	3.7%	24.5%	9.7%	62.1%	0.0%	0.0%
2016	3.5%	21.3%	5.9%	68.7%	0.6%	0.0%
2017	0.0%	7.6%	3.8%	87.6%	1.0%	0.0%

Table 11 (left) Total estimated marine mammal bycatch in individuals (median, and lower and upper 95 % confidence intervals) for large-scale purse seine fleets. Average annual bycatch rates by set and '000 metric tonnes of target catch are also included. (right) Proportion of annual estimated marine mammal bycatch (individuals) by association type.

	Estimated bycatch			Bycatch rate per	
Year	Low	Median	High	set	'000 mt
2003	415	819	1,505	0.027	0.82
2004	1,035	1,620	2,405	0.050	1.52
2005	438	779	1,364	0.021	0.65
2006	946	1,458	2,129	0.044	1.19
2007	653	1,212	2,174	0.033	0.89
2008	627	1,258	2,273	0.031	0.90
2009	1,114	1,631	2,369	0.037	1.07
2010	392	472	575	0.009	0.32
2011	504	585	694	0.011	0.42
2012	546	639	756	0.011	0.39
2013	756	825	912	0.015	0.52
2014	326	381	456	0.007	0.21
2015	377	435	513	0.009	0.28
2016	273	334	421	0.007	0.21
2017	257	427	722	0.009	0.30

Year	aFAD	dFAD	log	FS	whale	whale.shk
2003	31.1%	2.3%	58.7%	7.6%	0.3%	0.0%
2004	8.3%	18.1%	62.5%	8.9%	2.3%	0.0%
2005	17.0%	5.4%	71.9%	5.6%	0.0%	0.0%
2006	8.1%	18.0%	57.0%	16.9%	0.0%	0.0%
2007	12.9%	20.3%	44.1%	21.8%	0.9%	0.0%
2008	16.9%	32.7%	46.0%	4.0%	0.4%	0.0%
2009	10.8%	38.6%	35.7%	14.8%	0.1%	0.0%
2010	22.0%	37.3%	16.3%	20.9%	3.5%	0.0%
2011	14.4%	57.5%	9.3%	17.3%	1.6%	0.0%
2012	6.4%	44.6%	31.5%	16.5%	1.0%	0.0%
2013	5.9%	60.7%	23.2%	9.8%	0.4%	0.0%
2014	10.6%	33.3%	27.0%	28.1%	1.1%	0.0%
2015	5.1%	58.9%	21.0%	13.9%	1.2%	0.0%
2016	13.9%	45.1%	20.1%	19.4%	1.5%	0.0%
2017	12.0%	32.3%	16.9%	26.9%	12.0%	0.0%

3.5.Uncertainty in catch estimates

Uncertainty in bycatch estimates was highest for 2003 to 2009, when observer coverage was comparatively low, with substantial reductions in uncertainty for 2010 to 2016 as a result of the increase in observer coverage (Figure 1). Estimates of bycatch for 2017 had relatively high uncertainty, due to the low levels of available observer coverage when the data extracts were made. The magnitude of uncertainty in bycatch estimates was primarily a function of how frequently the species were observed, with higher uncertainty for species that were more rarely caught. Finfish bycatch estimates had 95 % confidence intervals of ± 7 % for 2003 to 2009, and ± 2 % from 2011 to 2016 (Table 4). Billfish bycatch estimates had 95 % confidence intervals of ± 6 % for 2003 to 2009, and ± 1.2 % from 2010 to 2016 (Table 6). Shark and ray bycatch estimates had 95 % confidence intervals of ± 5 % for 2003 to 2009, and ± 1.1 % from 2010 to 2016 (Table 6). Sea turtle bycatch estimates had 95 % confidence intervals of 35 % for 2003 to 2009, and 6 % for 2010 to 2016 (Table 10). Marine mammal bycatch estimates had 95 % confidence intervals of 54 % for 2003 to 2009, and 17 % for 2010 to 2016 (Table 11).

4. Discussion

This report provides an update to Peatman et al. (2017), and summarises bycatch estimates for the large-scale purse seine fleet operating in the tropical and equatorial waters of the WCPFC-CA. We provide summaries of bycatches of species and species groups that provide comprehensive coverage of finfish, billfish, shark and ray, sea turtle and marine mammal species observed in purse seine catches. We did not estimate seabird bycatch due to the low number of observed catch events, though we note that seabird bycatch and mortalities will be estimated as part of the ongoing Project 68 (Peatman and Smith, 2018).

Available observer data for 2017 provided coverage of approximately 20% of sets, and as such the bycatch estimates for 2017 should be considered preliminary. For comparison, the observer coverage for 2016 was 40% for the dataset analysed by Peatman et al. (2017). The relatively low level of observer coverage for the terminal year was largely due to the delayed submission of observer logbooks (Williams et al., 2018).

There were approximately 7,000 observed sets from 2003 to 2017 that were recorded by observers as sets on schools associated with whales or whale sharks, compared with 1,800 sets reported in aggregate data. The simulations use reported aggregate effort to raise from catch rate estimates to estimated bycatch, and as such will result in substantial under-estimation of whale and whale shark bycatch. Future work should consider the reallocation of an appropriate portion of reported effort (e.g. free school sets) to whale and whale shark sets when estimating bycatches to account for this. We note that catch rates of other species are also higher on whale and whale shark sets compared to free school sets, e.g. silky shark (Peatman et al., 2017).

Recent review of available observer data has indicated that some GEN-II records from 2003 to 2010 had not been successfully migrated to SPC's existing master observer database (Peatman et al., 2018). Work is currently ongoing to ensure that these additional records are migrated to the master observer database, though we note that the expected number of additional records is low.

Finally, we note a range of species considered in this report are also caught in longline fisheries in the WCPFC-CA. A summary of bycatch of longline fisheries in the WCPFC CA is provided by Peatman et al. (2018).

5. Recommendations

We recommend that:

- The Scientific Committee note the estimates of bycatch of large-scale purse seine fleets operating in the WCPFC-CA;
- The Scientific Committee consider whether regularly updated estimates of bycatch in the purse seine fishery are helpful, and whether this work should be supported in the future;
- The Scientific Committee consider whether estimates of purse seine bycatch should be made publicly available in electronic format to facilitate extraction and use of data by CCMs, and potentially other stakeholders.

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