ANALYSIS OF BYCATCH IN PAPUA NEW GUINEA PURSE SEINE FISHERY

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ABSTRACT

Bycatch is an expected part of every tuna fishery, but an accurate understanding of the amount and species distribution of bycatch is an important aspect of fisheries management. In the Papua New Guinea purse seine tuna fishery, the percentage catch of billfish, mammals, turtles, sharks and rays is lower compared to WCPFC annual bycatch for the larger equatorial purse seine fishery. This discrepancy could be attributed to non-compliance of vessel operators to retain bycatch and report non-targeted species that are caught and landed. The purpose of this study is to estimate likely bycatch quantity in the PNG tuna fishery. The primary focus was to analyse total bycatch quantity of a purse seine fishery that is comparable to the WCPFC annual catch estimates. This study builds on the work carried out by WCPFC in 2017 that provided policy recommendations to commission members on managing bycatch in a way that is consistent with the CMMs and guidelines on mitigating strategies. The results have shown that the reported bycatch percentage of the PNG tuna fishery is lower than that from WCPFC from 2016 to 2020. This study seeks to address gaps within the management framework and suggest possible recommendations to improve PNG's compliance through data collection and verification of any discrepancies.

Key words: Bycatch, purse seine, tuna fishery, Papua New Guinea

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1. INTRODUCTION

The tuna industry is one of the major seafood sectors globally both in terms of value and quantity. Major species are albacore *(Thunnus alalunga),* bigeye *(Thunnus obesus),* skipjack *(Katswonus pelamis)* and yellow fin *(Thunnus albacares)*. Globally, total annual tuna catch has increased from one million tonnes in 1950 to about 7.9 million tons in 2020 (FAO, 2020). The price of tuna varies from one species to another but is generally high, with bluefin tuna the most valuable. The annual global trade value is estimated to be USD 164 billion (FAO, 2020). Tuna fisheries take place in tropical areas in the Pacific, Atlantic and Indian Oceans (ISSF, 2019). Tunas are highly migratory, crossing territorial boundaries in both international and national waters (RFMO, 2021).

Almost all fishing states in these areas have common management regimes to regulate and exploit migratory tunas. Large industrial vessels catch the migrating tunas mainly with purse seines or long-lines. Fleet of smaller domestic coastal vessels also target the tunas with various fishing gears. Fish Aggregating Devices (FADs) are sometimes used to increase catch in less time and are mostly associated with industrial vessels. FADs have a number of positive and negative impacts ranging from ecological, to economic and social issues (MRAG, 2017).

Bycatch is part of the tuna fisheries when it is caught alongside targeted species and landed as catch. Bycatch can have negative economic social impacts on fishermen and their communities, both through lower fishery productivity and contributing to population decline of protected species. Policies and measures can however not be effective if there is lack of a proper monitoring mechanism to monitor these policies (FAO, 2011).

PNG as compared to the other Pacific Island Countries (PIC) is the largest and biggest player. It is the largest in terms of its landmass (462, thousand square kilometers), with a population of 8 million with 2% annual growth (Greenfield, 2021). It has rich natural resource endowments (oil, gas, gold, copper), with an ideal geographic location to mainland Asia, and other nearby countries of Australia and Solomon Islands (Jackson, 2021). The tuna fishery is PNG's largest commercial industry. The major tuna species in PNG waters are skipjack, yellowfin, and bigeye.

PNG manages the tuna fisheries and is a major player in a block with seven neighbouring countries based on the Nauru Agreement of 1982 (Declan, 2021). The total tuna export from PNG increased over the past two years (NFA, 2021). In 2019, total export value was USD 400 million at 196,000 tons and in 2020 was valued at USD 500 million at 206,000 tons. As in other fisheries, bycatch also exists in the PNG tuna fishery, of which the majority caught are sharks and rays, marine mammals and turtles, finfish, and billfish.

The aim of this study is to analyse bycatch estimates of the tuna purse seine fishing operations in Papua New Guinea. Data was collected from two sources; catch data from landings, and a targeted questionnaire. To answer the research question: Are the observed bycatch species and quantities from the PNG purse seine fishery in line with the Western and Central Pacific Commission?

1.1. PNG fisheries boundaries and tuna fishery

Territorial waters of PNG consist of 200 Nautical Miles EEZ, see figure 1. The contiguous zone covers 24 NM, territorial waters cover the 12 NM as well the Archipelagic Waters (NFA, 2021). The EEZ and Archipelagic Waters (AW) are the traditional tuna fishing grounds.

Fishing legislation and regulation are based on the Fisheries Management Act from 1998. The National Fisheries Authority was established to regulate the fisheries sector with a mandate to manage fisheries for sustainable and equitable benefits for the nation. The fisheries are guided by the National Tuna Fishery Management and Development Plan (NTDFMP). This plan includes the licence limits, catch effort control, gear restrictions and appropriate use of Fish Aggregating Devices. Other management tools are incorporated as well in combating Illegal, Unreported and Unregulated fishing (IUU) activities (NFA, 2014).

The tuna purse seine fishery is comprised of both domestic and foreign access fleets. Domestic fleets are PNG flag vessels and Locally Based Foreign (LBF) vessels which are under a charter arrangement supporting the onshore processing sites (WCPFC, 2017). The purse seine fishery operates within the guidelines of several other Pacific arrangements, such as the Parties to the Nauru Agreement (PNA), and the Federated State of Micronesia Arrangement (FSMA) whose requirements are incorporated into the National Tuna Fisheries Development Plan (NTFDP) (Kumoru, 2004). The tuna longline fishery is licensed to fish only in PNG waters.

Tuna catches in PNG waters have been around 220 to 320 thousand tons annually. Majority of the annual catch is from purse seine fisheries with limited quantity from longline fisheries (WCPFC, 2020). In 2020, there were 64 purse seine vessels targeting skipjack and yellowfin within the EEZ of which 32 vessels were PNG flagged and 32 were Philippine flag licensed as locally based foreign fishing vessels (White, 2020). 16 longline vessels actively fish in the WCPFC conventional areas including PNG Archipelagic waters (WCPFC, 2020).

There are also vessels operating under bilateral and multilateral arrangements. The foreign flag vessels under bilateral arrangement lease the days under the Vessel Days Scheme (VDS) and take their catch overseas for processing. They are Taiwanese, Chinese, Korean, Japanese and Philippines. The US vessels are multilateral under the US treaty arrangement.

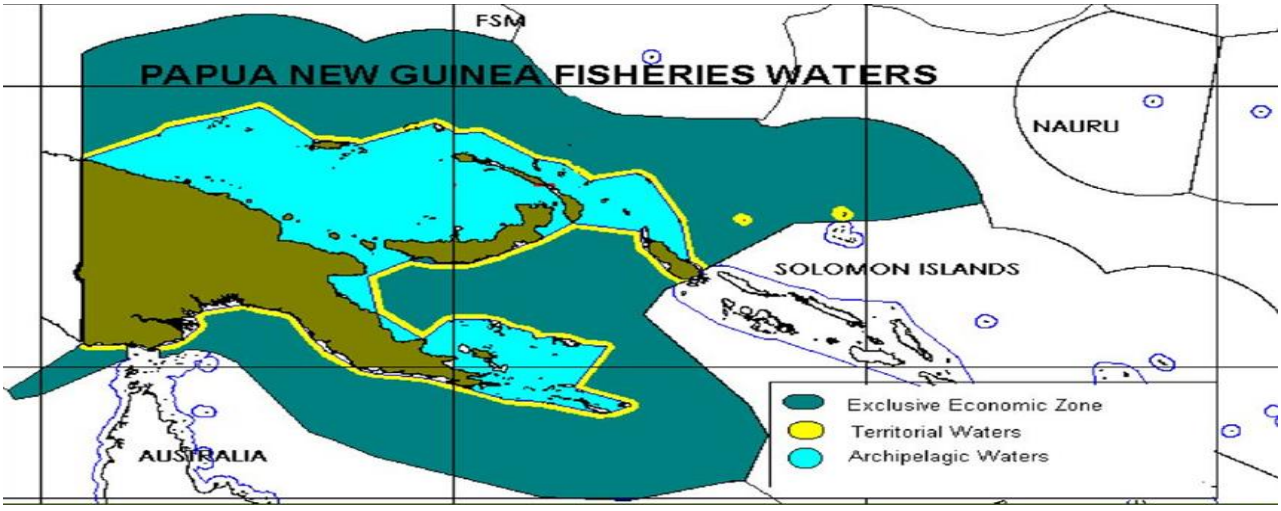

Figure 1. Papua New Guinea fisheries waters boundaries (WCPFC, 2017).

1.2. Purse seine fisheries

The purse seine fleet is the major fleet in terms of PNG tuna catches. The target species are skipjack tuna and yellowfin tuna. The fishing effort of the 37-vessel fleet in 2020 was estimated at 6,000 days, an increase by almost 1,600 days from the year 2019, see table 1 (WCPFC, 2020). The total annual tuna catch increased sharply from 1999 to 2004 and again past 2015, along with increased effort. The four major species in the fisheries are skipjacks (SKJ), yellowfins (YFT), bigeyes (BET) and albacores (ALB); the Pacific BlueFin (PBF) is excluded. In 2020, the total estimated catch was 180,000 tons, composed of 109,000 tons of skipjack, 70 tons of yellowfin and 480 tons of bigeye, all caught in the WCPFC convention area, see figure 2.

Table 1. Annual catch and effort estimate for the PNG purse seine fleet by primary species for the WCPFC Conventional area from 2016 - 2020 (WCPFC, 2020).

Year		2016	2017	2018	2019	2020 Provisional
Number of vessels					61	37
Effort (days)		5,283	7,380	7,797	4,365	6,059
Catch (mt)	Albacore	10	10	17	-	5
	Bigeye	10,345	8,523	7,174	3,880	483
	Pacific Bluefin	-	-	-	-	-
	Skipjack	201,161	179,124	209,631	195,213	109,191
	Yellowfin	90,280	118,847	94,694	66,296	70,839
	Total	**307,280**	**313,466**	**319,006**	**265,389**	**180,513**

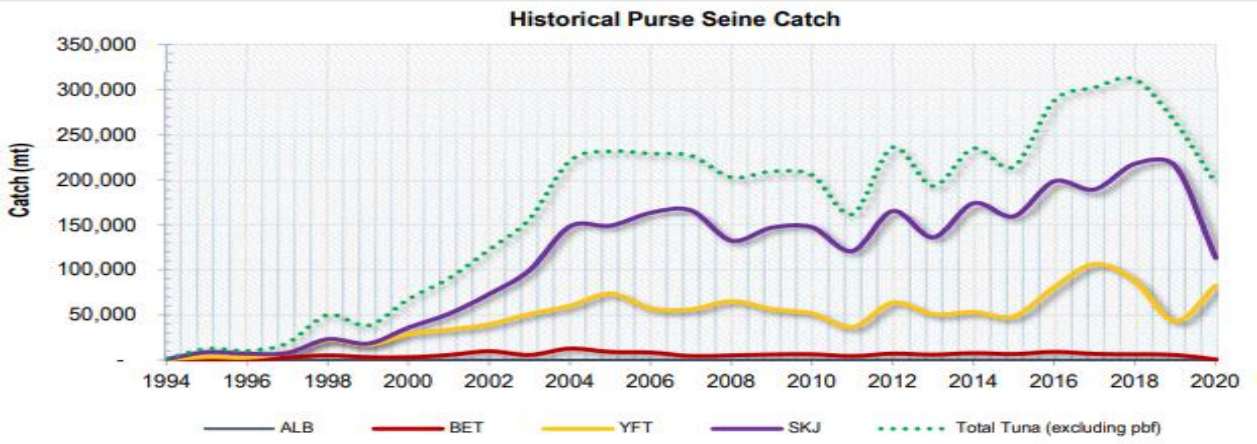

Figure 2. Historical annual catch for the PNG purse seine fleet by primary species in the WCPFC Conventional area (WCPFC, 2020).

Fishing efforts in the PNG purse seine fleet have increased from 2015 to 2016 and again past 2017 to 2018 and declined in 2019 (table 2) based on targeted species. The total catch gradually

increased from 2015 to 2018 and declined in 2019. In general, catch decreased inside the EEZ after 2010. Due to the introduction of the PNG Vessel Day Scheme, few licensed vessels were operating in the following years (below 2010 level, in figure 3).

Table 2. Annual catch and effort estimate for purse seine in PNG waters from 2015 to 2019 (SPC 2020).

Year	2015	2016	2017	2018	2019 Provisional
Effort (fishing days)	1,708	2,573	3,801	3,772	2,270
Total catch (mt)	127,519	182, 928	269,643	246,715	143,478

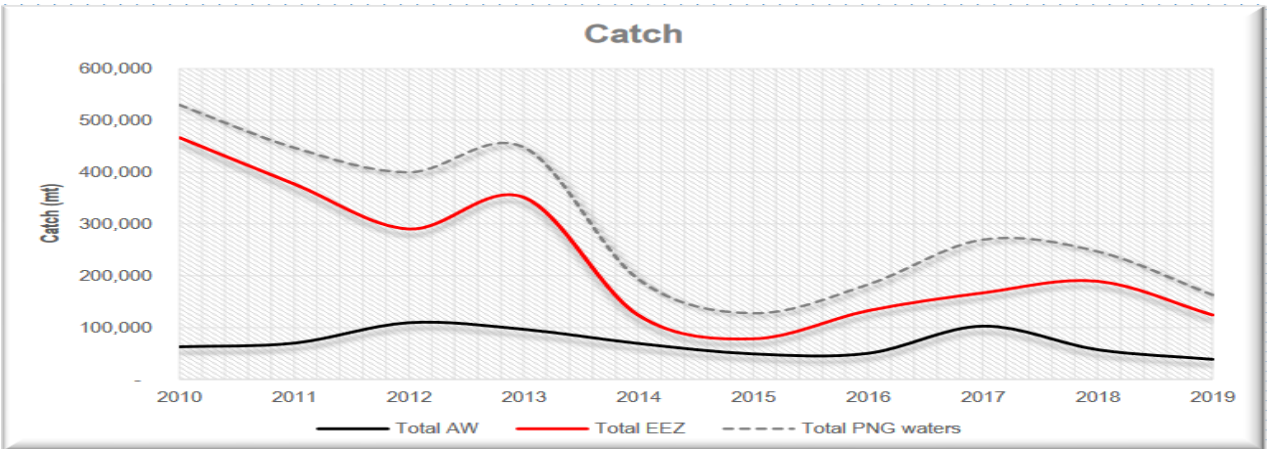

Figure 3. Overall purse seine catch & effort inside PNG waters from 2010 – 2020 (SPC 2020).

In comparison, total effort increased by 2,000 days from 2016 to 2018 then declined from 2019 to 2020 by the number of vessels fishing within the WCPFC convention area. While in PNG, effort has also increased by 100 days from 2016 to 2017 and then declined from 2018 to 2019 with the number of vessels. Both fishing areas have a similar trend, likely due to the El Nino season causing migratory stocks to migrate to the high seas' eastern pockets.

1.3. Longline fisheries

The longline fisheries have been around 1% of PNG tuna fisheries, 900 to 2400 tons annually. The fishing effort of the 6-vessel fleet in 2020 was estimated at 5,700 hooks, which is a major drop from 2,300 hooks in 2019, see table 3 (WCPFC, 2020). The target species are yellowfin (YFT) and albacore (ALB), with limited quantities of skipjack (SKJ) and bigeye (BET). The total annual tuna catch, without the Pacific Bluefin (PBF), increased sharply from 2000 to 2004, but declined again sharply after 2012. The overall catch decline was a result of 53 active vessels pulling out in 2003 and 22 vessels pulling out in 2013 due to high cost of operation through air freight export into the Japanese sashimi market (figure 4).

Table 3.Annual catch (mt) and effort estimates for the PNG tuna long line fleet by primary species for the WCPFC Conventional Area from 2016 to 2020 (WCPFC, 2020).

Year		2016	2017	2018	2019	2020 (Provisional)
Number of vessels					15	6
Effort (Hooks)		15,057	40,610	52,149	8,103	5,746
Catch (mt)	Albacore	80	689	196	686	13
	Bigeye	86	47	87	243	5
	Skipjack	2	2	2	26	0
	Pacific Bluefin	0	0	0	0	0
	Yellowfin	728	1,249	2,070	947	129
	Total tuna	**896**	**1,987**	**2,355**	**1,902**	**147**

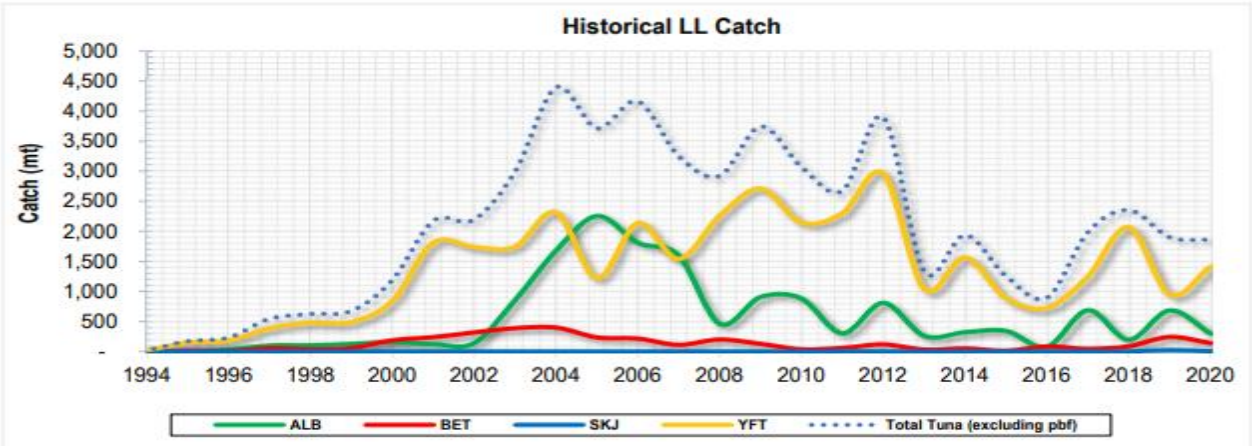

Figure 4. Historical annual catch for the PNG long line fleets by primary species in the WCPFC Conventional Area (WCPFC, 2020).

Comparing that to PNG waters, the fishing effort increased dramatically from 2015 (169,000 hooks) to 2019 (1,500,000 hooks). The total catch increased sharply from 2015 to 2019 (table 4).

Table 4. Annual catch and effort estimate for the PNG tuna long line fleet in PNG waters from 2015 to 2019 (SPC report).

Year	2015	2016	2017	2018	2019 Provisional
Effort (hooks)	169,381	783,281	1,205,382	897,793	1,553,678
Total catch (mt)	1,489	5,241	6,617	6,389	6,437

In general, catch by long line fishers in PNG after 2015 was the result of PNG giving access to foreign vessels to fish in the country's waters under Foreign Bilateral Arrangements in figure 5.

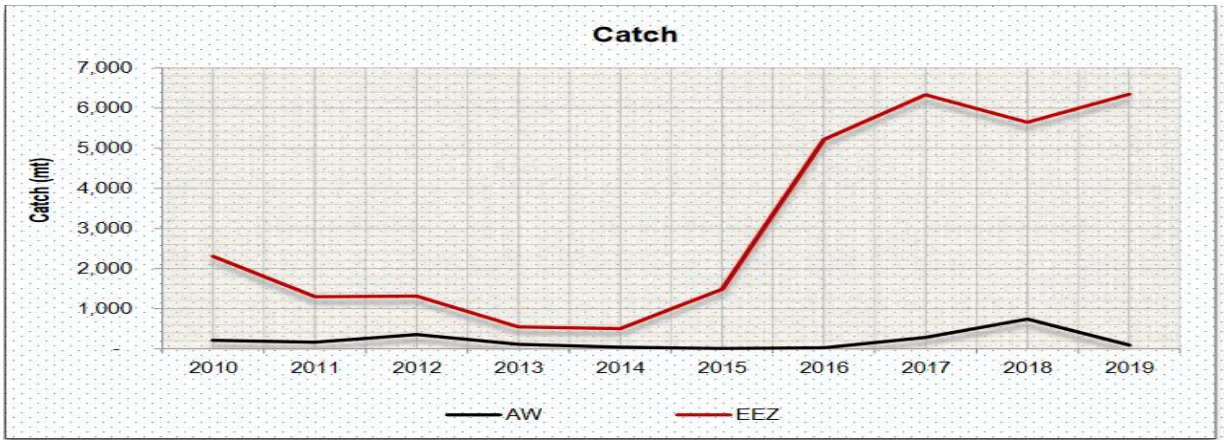

Figure 5. Figure 5. Overall long line catches inside PNG waters from 2010 - 2019 (SPC report).

In comparison, total catch increased by 1,500 mt from 2016 to 2018 and declined from 2019 to 2020 by 1,000 mt, with the number of vessels fishing within the WCPFC convention area. While in PNG, catches also increased by almost 1,000 mt from 2016 to 2017 with the number of vessels and declined by 100 mt from 2018 to 2019 with the number of vessels. This has illustrated that there were more vessels fishing within PNG EEZ during the increasing period than the conventional areas.

2. LITERATURE REVIEW

2.1. Bycatch

Bycatch is an inevitable, though unfortunate part of tuna fisheries. Bycatch is defined as “any catch of species pelagic or demersal (fish, sharks, marine mammals, turtles, sea birds etc) other than or non-targeted species. Incidental catch can be regarded as the same” (SPC, 1993). Global estimated bycatch has been increasing since the 1990s from 28 million tonnes to 38.5 million tons in 2009 (Davies, et al, 2009). In 2014, bycatch was observed at 81.5 million tons (FAO, 2016). Considering that juveniles caught by small pelagic fisheries such as sardines and anchovies are not reflected in estimates of most tropical countries, and large-scale bycatch such as turtles, cetaceans and seabirds were not quantified in existing systems or research, total bycatch is likely much higher than these estimates (Davies, et al, 2009).

Bycatch raises conservation challenges for fisheries, one of which is that there are still no clear solutions (Lobo, 2012). Even though past efforts have been put forward to realise measures of minimizing fisheries impacts on bycatch, this challenge remains unchanged in the development of several regional and subregional frameworks within the RFMO/A having Conservation Management Measures to mitigate risk in addressing the bycatch issue. Multiple methods can be applied to understand the underlying mechanisms, in which accurate data is crucial in order to quantify the abundance of species caught as bycatch and the resulting vulnerability of different fisheries (Lobo, 2012).

The other problem contributing to this conservation challenge lies in data collection, whether there is no proper data recorded, non-dissemination of information, or discrepancies in data collected. These data issues make it difficult to form sound knowledge about bycatch statistics, which can in turn be used to identify and quantify capture of specific species (Kennelly, 1995).

Catches of other species in tuna fishery have not been covered explicitly and estimates of discards (weight) have only been included in total catch by species in 2017, noting that estimates of bycatch have not yet been included. Recent studies have also used observer data to better estimate bycatch in the long line and purse seine fishery.

In the WCPFC convention area, the main industrial fishing methods employed are long line, pole and line, purse seine and troll. Most individual fleets are "chartered" according to the WCPFC (CMM-2019-08) on charter notifications (WCPFC, 2021). It is important to encourage better reporting rates of non-targeted species capture (bycatch) by members including non-contracting parties. However, even if reporting improves, data on non-targeted species are infrequently reported on log sheets by the fishing industries compared to observer coverage data information. PNGs obligation as a member to provide updated reports to the commission to ensure that statistics are set at benchmarks in compliance with guidelines under the (CMM-2019-08).

A report produced in 2017 (Peatman, et al, 2021) observed that observer coverage was 20% of total sets, compared with 60-75% for the period 2010 – 2016. From the findings the following recommendation were made:

- The Scientific Committee notes the estimates of bycatch of large-scale purse seine fleets operating in the WCPFC-CA;
- The SC considers whether annually updated estimates of bycatch in the purse seine fishery are helpful, and this work should be supported in the future by members and;
- The SC considers 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 (CMMs), and potentially other stakeholders.

This study will build on above recommendation No. 2 to analyse bycatch quantities in comparison to the WCPFC statistical annual estimates to see whether PNG bycatch is in line with these or not. Other comparisons will also include the participating members of the Nauru Agreement Unit of Assessment that will cover finfish and billfish bycatch species.

The purse seine fishing activities have increased within PNG waters over the past years and this increase is predicted to double over the next 10 years (Nicol, et al., 2009). The total tuna catch by Papua New Guinea's purse seine fishery was 265, 469 mt in 2019 and 198, 361 mt in 2020, a decline of 14.4% (WCPFC, 2021). In 2018, longline catch was 2,155 mt, which declined to 1,900 mt in 2019, a decrease of 88%. (WCPFC, 2020).

A study carried out by Skyrme, et al (2018), estimated Unit of Assessment (UoA) primary focus was WCPFC and PNA by species of different categories as secondary for bycatch species. Total

percentage catch of (finfish) was estimated at 0.10%; blue marlin was 0.031%, black marlin was 0.061%, mackerel scad at 0.011%, striped marlin at 0.005%, frigate tuna at 0.004% and mahimahi at 0.003%. The total percentage catch of Billfish was at 0.011%; rainbow runner at 0.006%, Kawakawa 0.005%. Statistics of the WCPFC on estimated annual finfish bycatch have also shown the estimate group for the large-scale equatorial purse seine fishery from 2003 to 2020.

The PNG tuna fishery accounts for 20-30% of the WCPO and 10% of global tuna catch (NFA, 2021). Seeing PNGs steady increase in estimated tuna catche, it is certain that associated bycatch has also continued to increase. Papua New Guinea's total annual catch was around 200 thousand to 300 thousand tons. A preliminary annual report from National Fisheries Authority Catch Documentation and Certification revealed that bycatch species landed by purse seine fishers in 2018 was 308 mt (0.12% of total) and increased to 1,290 mt (0.5%) in 2019. The species were rainbow runner *(Elagatis bipinnulata),* albacore *(Thunnus alalunga),* marlin *(Istiophoridae*, swordfish *(Xiphias gladius),* wahoo *(Acanthoscybium solandri),* mahimahi *(Coryphaena hippurus)* and mackerel scad *(Scomber scombrus).* However, this number is likely an underestimation.

In PNG, only tuna catch is recorded by species. Other data is recorded without species specific identifiers when it is landed. This study intends to analyse bycatch by species, quantifying how many bycatch species are caught within PNG waters in the tuna purse seine fishery and quantifying catch estimate, along with the type of fishing gear and size used.

2.2. Fishing Aggregating Devices & bycatch

Fishing Aggregating Device use is increasing among fishing fleets worldwide, with an estimate of 100,000 FADs deployed annually (Scott & Lopez, 2014). FADs are technological devices that imitate the natural objects that attract dense schools of fish. Primarily these are buoys with bait (NFA, 2002). There are two types of FADs: anchored FADs that are used at the small scale and artisanal level, and drifting FADs (dFAD) that are used by larger industrial purse seine fleets.

Although they can be found at the surface at most times, non-targeted species, including rainbow runner, mahimahi, sharks, and billfish are also commonly attracted to FADs (Anderson & Gates, 1996). In the world oceans, total bycatch using FADs has been higher than when targeting fish caught in free swimming schools including target tuna discards that have increased from 2000 to 2010. The Atlantic has recorded 80%, followed by Indian at 30%, Eastern Pacific at 20% and Western Pacific at 17% in table 5.

Table 5. Observed bycatch composition by weight in each (tons per 100 t of target tunas landed). Modified from Dagom et al. (MRAG, 2017).

Species	Atlantic 2003 – 2007		Indian 2003 - 2007		Western Pacific 2005 - 2010		Eastern Pacific 2000 - 2009	
	FSC	dFAD	FSC	dFAD	FSC	dFAD	FSC	dFAD
Target tunas (discards)	0	61	3.5	17.4	-	-	25.3	68.7
Other tunas	20.8	67.7	5.9	9.2	0.3	2	5.1	10.4
Bony fishes	0.8	17	1.5	19.7	0.8	13.7	0.7	10.4
Billfish	5.1	2.6	0.4	0.7	0.7	0.5	0.8	1.1
Rays	1.4	0.2	0.2	0.2	-	-	1.4	1.9
Total bycatch	28.4	89.3	8.3	35.8	2.6	17.4	8.4	23.8
Ratio FAD/FSC	3.1		4.3		6.7		2.8	

2.3. Objectives

The objective of this study is to examine and describe the overall bycatch of the tuna purse seine fishery within PNG waters. The aim is to analyse whether bycatch estimates from purse seine fishing operations in Papua New Guinea's tuna fishery are aligned to the WCPFC total.

2.3.1. Specific objectives:

i. Identify the quantity of bycatch retained, recorded, and landed onshore in PNG by purse seine fleets in comparison with the WCPFC total.
ii. Identify the capabilities of the purse seine vessels to land bycatch onshore.
iii. Examine missing links in the current Fisheries Management Act and National Tuna Fisheries Development Plan to enhance measures of compliance and reporting mechanisms.

3. METHODOLOGY

The research draws upon fisheries observer data, and eLogbook data to establish bycatch trends of PNGs tuna purse seine fishery. Qualitative data was gathered through an interview questionnaire process. Key Informants were identified through collaboration and interviews were facilitated with relevant co-workers employed in the National Fisheries Authority, particularly fisheries port coordinators within the Catch Certification and Documentation Unit and fisheries observers from respective ports. Due to time constraints, not as much information was collected as hoped.

3.1. Quantitative method

Collected data was compiled to illustrate the following: (i) type of vessels engaged to catch bycatch, (ii) total catch landings from 2019 - 2020, (iii) bycatch species caught by purse seine fishers in PNG waters and WCPFC conventional areas, sought from 1993 – 2020.
Using MSexcel, data were then compared with other regional bodies like WCPFC, PNA and SPC. It was then analysed to assess total landings and catch trends with the number of species identified.

Country reports such as the Fisheries Management Act, the Fisheries Strategic Plan, and the National Fisheries Tuna Development Plan were also used.

3.2. Qualitative method

Twenty-two primary structured questions in four parts were administered through random interviews to key respondents and non-random representatives based on their general understanding about the topic. Questionnaires were designed and then emailed to four NFA colleagues who then collated data and completed the form. There were two fisheries port inspection coordinators with two fisheries observers who were engaged as respondents during the interviews. The feedback was used to evaluate the vessel capabilities of the purse seine, how much quantity of bycatch that are caught in the fisheries waters, hindrances that are faced, and lastly the legislative and regulatory framework. Questionnaires can be found in appendix 1.

Therefore, activities of bycatch data collection (e.g., at landing sites and onboard vessels and mapping), must promote the use of standardized methods and effective communication (through websites and information must be considered at the national level).

4. RESULTS

This chapter is two-fold; 1) data analysis and 2) analysing questionnaire. The data result will cover (i) purse seine overall landings in fishing ports with targeted species; (ii) bycatch percentage catch composition for purse seine compared to WCPFC, (iii) tuna landings between PNG and WCPFC and; (iv) bycatch trend between WCPFC and PNG. The questionnaire results will cover (i) type of fishing gear, (ii) vessel capabilities, (iii) legislative framework.

4.1. Quantitative data

The data analysed were collected from authority data log sheets. Tuna landings catch estimates with catch trends from 2003 to 2020. Bycatch estimates from 2016 to 2020. Data collected were from the National Fisheries Authority data log sheet.

4.1.1. Catch by Port

The map in figure 6 shows the landing ports where tuna catches are landed in Papua New Guinea to be processed.

Figure 6. Map of PNG showing fishing landings ports https://papua-new-guinea-political-map.

Overall landings for 2019 in table 6 was 140 thousand tons. Skipjack was 106 thousand tons, followed by yellowfin at 35 thousand tons, bigeye was 1 thousand tons, bonito was 0.3 tons. The total landing major ports were Madang with 73 thousand tons, followed by Lae port with 49 thousand tons and finally Wewak with 20 thousand tons. The three targeted species with the highest record catch were skipjack tuna, yellowfin tuna and bigeye tuna.

Table 6. Total landings by port of targeted species in 2019 (NFA excel data spreadsheet).

Ports	Skipjack (mt)	Yellowfin (mt)	Bigeye (mt)	Bonito (mt)	Total
Lae	36,124	12,235	504	159	49,022
Madang	52,634	20,120	670	130	73,554
Wewak	17,407	3,267	228	0	20,902
Overall total	**106,165**	**35,622**	**1,402**	**289**	**143,478**

Overall landings for 2020 in table 7 was 122 thousand tons. Skipjack was 81 thousand tons, yellowfin was 38 thousand tons, bigeye was 2 thousand tons, bonito was 1 thousand tons. The major total landing major ports were Lae port with 52 thousand tons, followed by Madang port at 45 thousand tons and Wewak port with 24 thousand tons.

Table 7. Total landings by port of targeted species in 2020 (NFA excel data spreadsheet).

Ports	Skipjack (mt)	Yellowfin (mt)	Bigeye (mt)	Bonito (mt)	Total
Lae	33, 022	18,319	543	550	52,434
Madang	29, 437	15, 280	665	459	45,841
Wewak	18,396	4, 596	1,051	0	24,584
Overall total	**81,396**	**38,195**	**2,259**	**1,009**	**122, 950**

4.1.2. PNG total bycatch

The total estimation of bycatch species caught within PNG waters by purse seine fishers from 2016 to 2020 was 4,000 mt. Over the period of 2016 to 2020, sharks and rays accounted for 51%, followed by finfish at 48%, billfish at 3% and mammals and turtles at 0.7% (table 8).

Table 8. Bycatch species classification for purse net fishing gears in metric tons from 2016 to 2020 (NFA excel data spreadsheet).

Year	Species classification			
Purse seine				
	Finfish (mt)	Billfish (mt)	Sharks and rays (mt)	Mammals and turtles (mt)
2016	713	24	130	2.2
2017	565	39	478	1.3
2018	403	32	423	21
2019	95	33	671	4
2020	180	19	323	0.4
Total	**1,956**	**114**	**2,025**	**28.9**
Percentage catch	**48%**	**3%**	**51%**	**1%**

4.1.3. WCPFC total bycatch

The total estimation of bycatch species caught within the conventional area by purse seine fishers from 2016 to 2020 was 440,000 mt. Over the period of 2016 to 2020, billfish accounted for 6%, followed by mammals and turtles and finfish at 2% and sharks and rays at 78% in table 9.

The data provided was from the WCPFC purse seine fishery annual catch estimates from 2003 to 2020.

Table 9. WCPFC purse seine annual bycatch estimates from 2016 to 2020 (WCPFC, 2020).

Year	Species classification			
	Purse seine			
	Finfish (mt)	Billfish (mt)	Sharks and rays (mt)	Mammals and turtles (mt)
2016	6,584	6,152	70,873	2,203
2017	3,895	6,621	81,639	2,436
2018	72	6,113	79,898	2,000
2019	57	5,626	98,771	2,113
2020	125	4,898	93,347	2,430
Total	**10,676**	**29,410**	**392,585**	**11,182**
Percentage catch	**2%**	**6%**	**78%**	**2%**

The overall tuna catch in PNG waters was 955, 000 mt from 2016 to 2020 as compared to the catches within the WCPFC conventional area at 1,240,000 mt. Tuna catches within the WCPFC conventional area peaked in 2018 at 320,000 mt and declined to approximately 180,000 mt in 2019 onwards. While catches in PNG waters peaked at 270,000 mt in 2017 then declined to approximately 250,000 mt in 2018 onwards (figure 7).

Bycatch in the WCPFC conventional area peaked at 16,000 mt in 2016 and steadily declined to 8,000 mt by 2020. Average estimates for PNG were steady at 1,000 mt from 2016 to 2020.

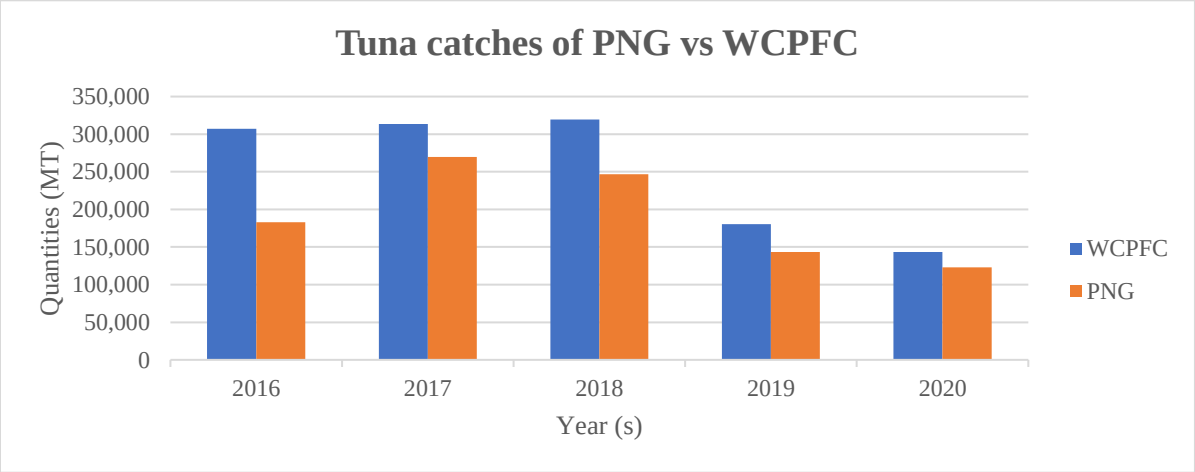

Figure 7. Total tuna catch for purse seine from 2016 to 2020 in the WCPFC conventional area and PNG fisheries waters (WCPFC, 2020).

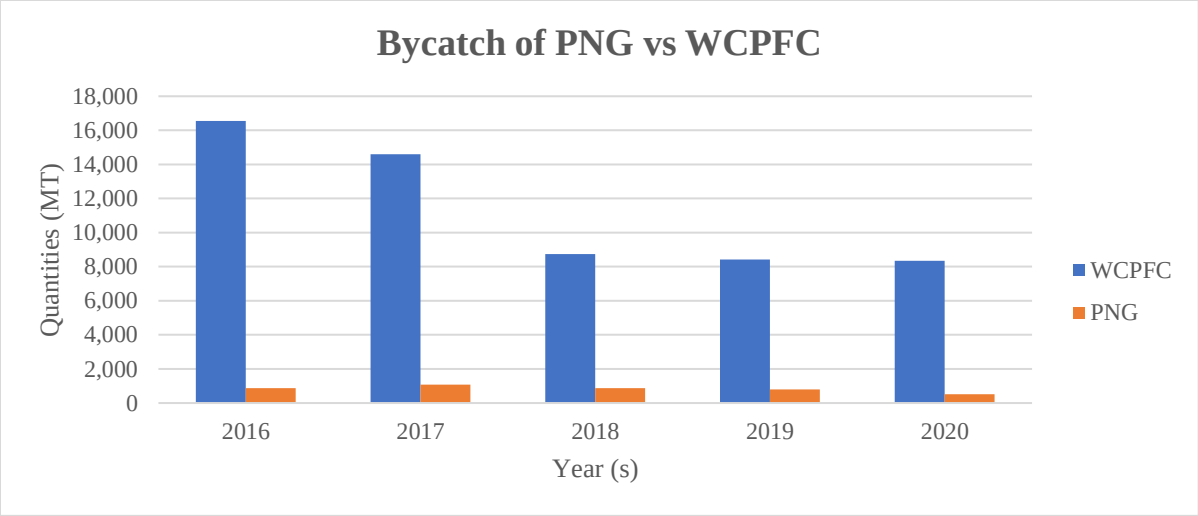

Figure 8. Total bycatch trend between WCPFC and PNG (NFA excel data spreadsheet).

Table 10. The observed catches of key bycatch species for purse sein fishers in PNG waters species landed by purse seine (NFA excel data spreadsheet).

Finfish	**Billfish**	**Sharks and rays**	**Mammals and turtles**
Barracudas	Black marlin	Bigeye thresher shark	Green turtle
Bullet tuna	Blue marlin	Bronze whaler shark	Hawksbill turtle
Frigate tuna	Indo-Pacific Sailfish	Great hammerhead	Indo-pacific bottleneck dolphin
Kawakawa	Striped marlin	Grey fish shark	Leatherback turtle
Mackerel scad	Swordfish	Mantas devil shark	Loggerhead turtle
Ocean sunfish		Oceanic whitetip shark	Marine turtles
Ocean triggerfish		Pelagic stingray	Melon-headed whale
Pacific bluefin tuna		Pelagic thresher shark	Minke whale
Rainbow runner		Shark ray skates	Olive ridley turtle
Wahoo		Silky shark	Pygmy killer whale
Mahimahi		Silvertip shark	Rough -tooted dolphin
		Stingray butterfly rays	Sei whale
		Tiger shark	Sperm whale
		Whale shark	
		Winghead shark	

4.2. Qualitative Questionnaire

These are the results from qualitative questionnaires administered to four people through interviews. The questionnaire can be found in appendix 1.

4.2.1. Types of fishing gear used

Common fishing gear used by purse seine fishers in PNG is listed in table 12.

Table 11. Fishing gear used by the purse seine fishery (Interview questionnaire).

Vessel name	Gear type	Size
Purse seine	Purse seine net	2000m long, 200 m in diameter and 250 m deep

4.2.2. Vessel capabilities

Tuna purse seine fleets have high catchability rates for their respective vessel sizes and storage capacities and depending on the nature of the operations. Vessels have storage capacity that ranges from 500 mt to 2000 mt, with an average length of 50 – 100 m. When asked about vessel capabilities for landing, one respondent stated;

> *"Purse seine fishing has the capabilities to catch and unload bycatch. On average a purse seine catches and unloads between 2 to 6 metric tons of bycatch per fishing trip. While fishing is predominantly a purse seine operation, between 2019 and 2020 there were about six (6) long line vessels licensed to catch, therefore its capacity to catch and land bycatch is minimal"*
>
> (personal communication, 10th January 2022).

4.2.3. Legislative framework

The protection of the tuna fishery and the marine ecosystem it depends on is key but can never be achieved without a robust and effective legislative framework. As bycatch is a major challenge for the Papua New Guinea fishery, activities to mitigate it must be aligned to have a clear goal and purpose. When asked is there something that limits vessel compliance with regulations, a respondent stated:

> *"The management measures of purse seines only cover species of special interest (endangered species like sharks, rays, sea turtles, dolphin, whales etc.). Others that are not species of interest are not specified, and it's not reflected under the licence condition as having commercial value. Hence, there is lack of enforcement on it. It is too general and not specific enough to enforce the bycatch. The licence condition only mentioned that all catch must be recorded, making more emphasis on the non-target species"*
>
> (Personal communication, 08th January 2022).

Indeed, certain applications within the framework remain lacking to ensure commercial vessels (mainly purse seine) comply with bycatch regulatory conditions. That contributes to non-compliance of reporting non-targeted species to conditions of the licences. Another respondent mentioned that;

> *"It is important to note that bycatch is not targeted species of any large-scale commercial fishing operation. The purse seines and are solely designed to catch, handle and store tuna species. Meaning fisheries management Act 1998 (Amended 2015 – 16) is not explicit on bycatch species although the Application of the Act under the section 29 (2).*
>
> (Personal communication, 07th January 2022).

Incorporating specific requirements of retaining and recording bycatch into licensing conditions and penalising non-compliance will certainly assist the authority to monitor the situation in order to address social, economic and environmental issues.

5. DISCUSSION

5.1. Tuna catches and fishing gears

5.1.1. Tuna catches

The PNG purse seine fishery has a lot of transshipment activity, so leakages occur in Madang, Lae and Wewak ports. The Madang port is the major port where most vessels go to land most of their catch with a total of four processing plants that process the major species of tuna.

The tuna industry in the Western and Central Pacific Ocean (WCPO) is one of the largest and most productive fisheries in the world. The WCPO contributes to the global catch supply with an estimated 2,869,648mt of tuna. According to the provision data from the WCPFC Scientific Committee (WCPFC, 2015), this represents about 83% of the total Pacific Ocean catch and 60% of the total global catch, whereas PNG itself contributes around 20-30% of these catches.

Tuna caught within Papua New Guinea's EEZ has declined by 8% from an estimated 143,000 mt in 2019 to 122,000 mt in 2020. Skipjack made up 70% of the catch, followed by yellowfin at 24%, Bigeye at 0.9% and bonito at 0.2% in 2019. In 2020, Skipjack was 66%, yellowfin 24%, bigeye 0.9% and bonito 0.8%. The major species with the highest value remain skipjack, yellowfin and bigeye.

In the WCPFC conventional area, tuna catch has also declined by 19%, from 265,000 mt in 2019 to 180,000 mt in 2020. In 2019, Skipjack made up 43% of the catch, followed by yellowfin at 15%, and bigeye at 0.8%. In 2020, Skipjack was 24%, followed by yellowfin at 16%, and bigeye at 0.1%. Major species were skipjack and yellowfin with limited quantities of bigeye. The decline in catch has resulted in decrease in the number of purse seine vessels in PNG waters.

5.1.2. Fishing gear

The purse seine net gear is larger and can be up to 2000 metres long and 200 metres in diameter and 250 metres deep to encircle the schools of tuna. The bottom of the net is closed by holding the wire cable to prevent the fish from escaping. This method of fishing has a higher rate of catching both targeted species as well as bycatch species. In the pacific region, tuna purse-seine fishing operations target skipjack and yellowfin, but as is common with large-scale fishing methods, bycatch is an unavoidable part of the operation. Purse seine bycatch includes undersized yellowfin and bigeye tuna, wahoo, rainbow runner, mah mahi, frigate mackerel, and triggerfish.

Occasionally, sea turtles, cetaceans and sharks interact with purse seine gear which sometimes results in mortality.

The results show that bycatch caught by the purse seine vessels operating within the PNG EEZ includes Barracuda, Bullet tuna, Frigate tuna, Kawakawa, Mackerel scad, Ocean scad, Ocean sunfish, Ocean triggerfish, Pacific bluefin tuna, Rainbow runner, Wahoo and Mahi Mahi (finfish); Black marlin, Blue marlin, Indo-Pacific striped marlin, and swordfish (billfish); thresher shark, bronze whaler shark, great hammerhead, grayfish shark, Oceanic whitetip shark, Pelagic whitetip shark, pelagic thresher shark, sharks rays skates, silky sharks and silver tip sharks (sharks and rays); green turtle, hawksbill turtle, Indo-Pacific bottlenose dolphin, Leatherback turtle, loggerhead turtle, marine turtles, melon-headed whale, minke whales, Olive ridley turtle, Pygmy killer whale, and rough-toothed dolphin (turtles and mammals).

The major species caught as bycatch using purse nets within PNG waters were sharks and rays with 2,000 mt, followed by finfish at 1,900 mt, billfish at 100 mt and mammals and turtles 29 mt. Vessels in the greater WCPFC reported 29,000 mt billfish, followed by mammals and turtles at 10,000 mt and sharks and rays 5,000 mt.

This shows that billfish make up a higher proportion of the bycatch within the conventional area, while sharks and rays make up the majority of bycatch in PNG waters. It is important to note that in most cases it is unpredictable to quantify non-targeted species caught by purse net fishing gear and the contribution of this bycatch to the effects of IUU fishing and to adverse effects on marine ecosystems. Assessing these risks, considering the gear type and size, is paramount for proper policies and measures to be put in place to mitigate higher catch mortality.

5.2. Bycatch species in tuna fisheries and FADs

5.2.1. Bycatch species

The bycatch species composition was compared between Western and Central Pacific Commission, Parties to the Nauru Agreement and Papua New Guinea.

Bycatch mortality rates have continued to raise concerns over fishing methods and behaviours of fishers by the WCPFC, who have been advocating members to comply with their CMMs. This prompted the Authority in late 2014 to undertake a major reform in addressing Conservation Management Measures consistent with Commission guidelines and other regional partners such as EU regulations to combat IUU fishing. Since then, a significant shift in implementation has been seen, with an increase of bycatch landings from the period of 2016 onwards.

5.2.2. Fishing Aggregated Devices

Bycatch, or non-targeted species, are also associated with schools of tuna aggregating under floating objects. This has been observed by fishers and imitations of these objects have been useful for fishermen in using evolving technologies to catch more than free sets swimming in schools.

FADs also contribute to increased tuna catch where fishers can maximise benefits, however, this also causes high catch rate of bycatch. The usage is much more than the free-swimming schools (Anderson & Gates, 1996).

5.3. Vessel capabilities and legislation framework

5.3.1. Vessel capabilities

Purse seine vessels operating in the region of the PNG EEZ vary in size, averaging about 75 metres, with a capacity between 500 to 2000 tons of fish in refrigerated wells. With their high carrying capacity, vessels have the ability to land high quantities of non-targeted species.

However, percentage catch data indicated that the landing of bycatch species (billfish, sharks and rays and mammals and turtles) decreased within the period of 2016 to 2020. The carrying capacity of purse seine vessels equips them to fish for longer voyages, so there is a reluctance to store non-targeted species, and thus a tendency to ignore regulations regarding catch, landing and reporting. Imposing stringent consequences could make the vessels more obliged to record, land and report all non-targeted species caught along with target species.

5.3.2. Legislation framework

While the PNG fisheries legislative framework does support and administer the WCPFC Conservation and Management Measures to regulate its own fishery, bycatch is still a major concern in terms of catch, landings and reporting.

As prescribed in the National Tuna and Fisheries Management Plan in accordance with section 8 paragraph (1), “provisions of this plan guarantee licensing conditions to any licence issued for fishing tuna.” The condition gives the mandate for licences to be issued based on specific requirements that are met by the fishing operators (NFA, 2014).

Section 14 of the plan on possible adverse environmental effects only covers the Conservation Management Measures, hence does not specify retaining, recording and reporting any bycatch in the provision under the pretext of those vessels that are fishing in the EEZ and AW prescribed in section 43 of the Act with licensing condition in 5.1 and 5.2 (NFA, 2016). This has resulted in a tendency to misreport bycatch species that in most cases are not verified between the fisheries observer onboard using eLogbook and the vessel operator using catch registry when landing takes place.

The current legal framework has been established, but there is still room for improvement. The draft Fisheries Management bill (2019) to be finalised for enactment and adoption of the new Fisheries Act is currently under development, followed by a review and update of the Fisheries Regulation are crucial with the goal of having this problem effectively managed.

5.4. Lessons learned to support legislative framework

5.4.1. Capacity building

With evolving technologies and approaches, fishers are using many different types of fishing gear and techniques to catch a wide variety species. Fisheries traceability systems are a potential tool that can help tracks bycatch in several ways: using human observers on board to record and report any bycatch that is caught, electronic technologies to record and transmit data, logbook information that fishermen are required to submit, and voluntary surveys of fishermen on the bycatch that is caught.

With PNG observer roles to monitor fishing operations within PNG waters, training in knowledge and skills to respond to innovations in fishing methods is vital. Capacity building through training and development is the key component to boost observers' ability by imparting knowledge of the latest fishing gears, methods, technologies, and scientific knowledge about species.

5.4.2. Strengthening cooperation amongst stakeholders

Collaboration for PNG through the National Fisheries Authority is not working effectively. Information dissemination and sharing of scientific knowledge must be enhanced as stipulated in the legislative framework. Fishing industry, fishing communities, provincial authorities and relevant government agencies, researchers, and academics must work together in partnership to solicit support from other regional and subregional bodies to manage challenges to the sustainability and development of the fisheries sector.

6. CONCLUSIONS AND POLICY RECOMMENDATIONS

This study posed the question, how well does the Papua New Guinea governance framework line up with the existing WCPFC regulations regarding bycatch mitigation strategies and guidelines to address (CMM-2019-08) on the gathering of data regarding non-targeted species? The results show that even though the purse seine fishery catch has been higher between 2016-2020, the overall percentage of bycatch has been lower than that of the WCPFC estimates.

Challenges include non-compliance by vessel operators to adhere to regulations requiring reporting all catch, including non-targeted species, data discrepancies between vessel operators and fishery observers. Therefore, standardized methods of bycatch data collection (e.g., at landing sites and onboard vessel and mapping) must be promoted along with communication of bycatch data and information at the national level.

With these issues identified, a few recommendations are presented to enhance the management measures in the National Tuna Fisheries and Development Plan to overcome the identified shortcomings both nationally and within the region:

1) Review the legislative framework to incorporate provisions on effective measures regarding bycatch catch, retention and reporting.
2) Enhance collaboration amongst stakeholders at the national, regional and international levels to conserve and sustain ocean resources.
3) Increasing capacity building incentives through training and development of fisheries observers to build knowledge and skills that complement the monitoring of existing and new management regulations.

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APPENDIX 1. QUESTIONNAIRE USED FOR INTERVIEWS

Part A: Fishing Gear

1. What is the fishing gear used to catch the by-catch?
    a) Purse seiner
    b) Long-liner
2. How many vessels from your experience were engaged in by-catch in the past 2 years?
    a) Purse Seiner
    b) Long-liner
3. Do both the fishing vessel have the capabilities to bring the by-catch for landing and transshipment?
    a) Purse seiner
    b) Long-liner
4. What is the procedure applied to vessels involved in the direct landing and transshipment of by-catch? (e.g., reporting or recording using eLogbook or log sheet)
    a) Purse seiner
    b) Long-liner
5. In the past five (5) years, how have you seen the trend of vessels catching by-catch?
    a) If increasing for purse seine, why?
    b) If decreasing for purse seine, why?
    c) If increasing for long line, why?
    d) If decreasing for long line, why?
6. If they are not landed or transhipped, are they discarded while fishing at sea?
    a) Purse seiner
    b) Long-liner

Part B: Landing Of By-Catch Species (Observer Recordings)

1. How are the by-catches recorded when it is landed and transhipped?
    a) Purse seine
    b) Long-liner

2. Which vessel mostly have the storage capacity to store by-catch for landing and or transshipment?

a) Purse seiner

b) Long-liner

3. Is there any hindrance out there that is causing both vessels not to store the by-catch and bringing them for landing? (e.g., not enough carrying capacity, limited ice for preservation etc.).

a) Purse seiner

b) Long-liner

4. What are some encounters in the data recording between observer and master fishermen or owner of the vessel in terms of reporting of by-catch?

a) Purse seiner

b) Long-liner

Part C: Estimated Catch by Species

1. Name the species of by-catch or others caught in EEZ and AW? Please add if more than five (5) species.

a) Purse seiner

b) Long-liner

2. From those by-catch species, what is the most common species that is caught during a fishing trip? If not, per annum

a) Purse seiner

b) Long-liner

3. What is the total estimated volume caught from all that is landed per fishing trip? If not, per annum

a) Purse seiner

b) Long-liner

4. Do you think these species will add value to the communities for income generating opportunities?

a) Purse seiner

b) Long-liner

5. How would you rate from 1-3 the quality of by-catch when landed and transhipped? Please tick the boxes with the names.

a) Purse seine

b) Long-liner

6. What is the unit price for each species that is sold at the local market when it is landed by each vessel each trip? Please list them.

a) Purse seiner

b) Long-liner

7. How would you rate the sale of by-catch fish in the local market or to the consumers? Write species name and tick the box.

a) Purse seine

b) Long-liner

Part D: Legislative & Regulatory Framework

1. Is there something that is causing them not to manage all by-catches for landing & transshipment? (e.g. limited enforcement in the licensing conditions, lack of management measures etc.)

a) Purse seiner

b) Long-liner

2. In your best opinion, explain the gaps in the legislation framework governing by-catch resulting in challenges, inefficiency or prevent access to produce catch data?

a) Purse seiner

b) Long-liner

3. If the regulatory framework is lacking, what is your view to help improve the framework resulting in increasing value of the by-catch rather than reducing food loss?

a) Purse seiner

b) Long-liner

4. In your general view, has there been any awareness on maximizing utilization as in consumption value adding by income generation about the by-catch that is landed?

a) Purse seiner

b) Long-liner

5. Do you think stakeholder awareness to build best practices is a paramount step as a means of evaluating impacts of by-catch?

Explain why?