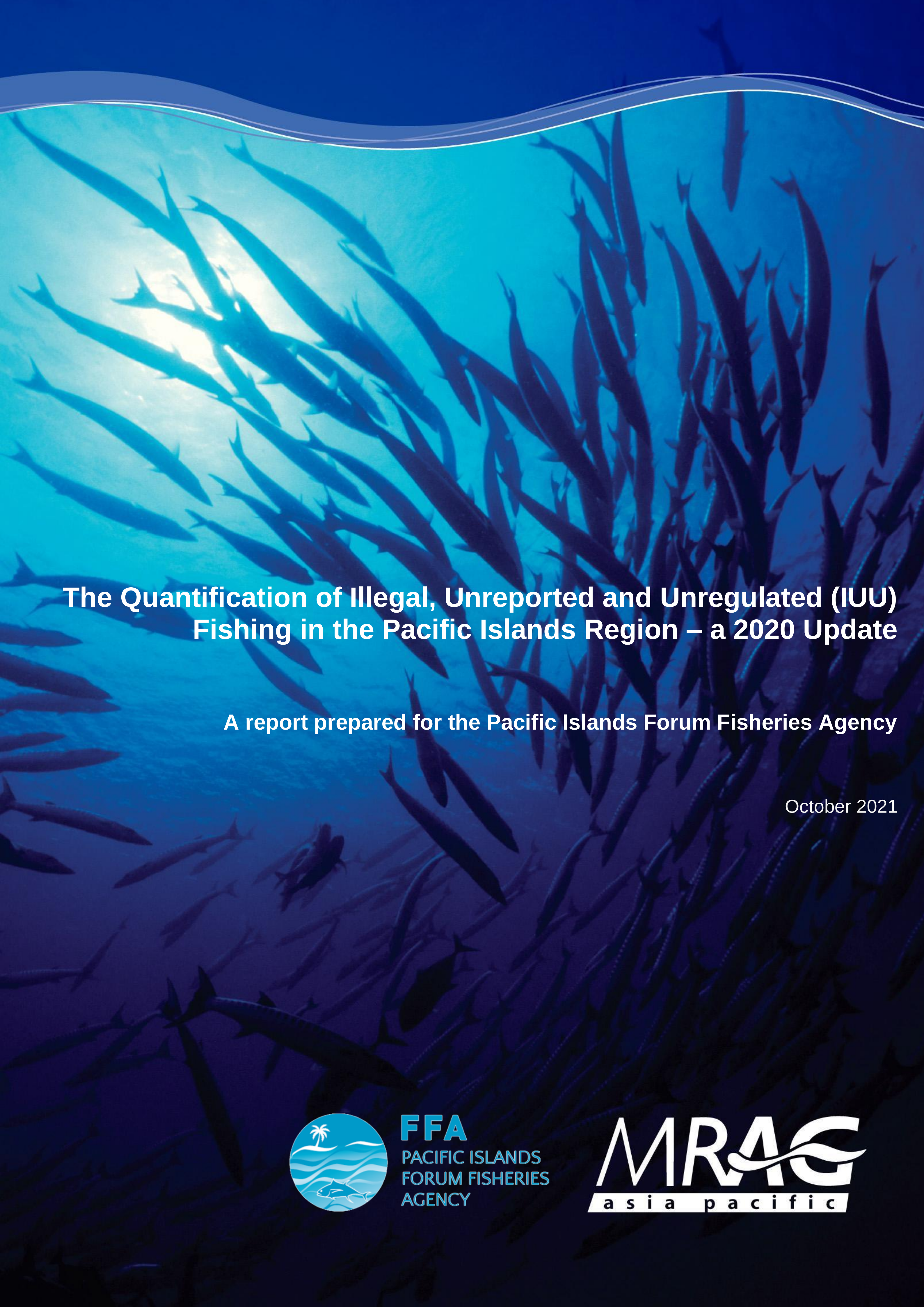

The Quantification of Illegal, Unreported and Unregulated (IUU) Fishing in the Pacific Islands Region – a 2020 Update

A report prepared for the Pacific Islands Forum Fisheries Agency

October 2021

FFA PACIFIC ISLANDS FORUM FISHERIES AGENCY

MRAG asia pacific

About MRAG Asia Pacific

MRAG Asia Pacific is an independent fisheries and aquatic resource consulting company dedicated to the sustainable use of natural resources through sound, integrated management practices and policies. We are part of the global MRAG group with sister companies in Europe, North America and the Asia Pacific.

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Acronyms and abbreviations

AI/ML	Artificial Intelligence/ Machine Learning
AIS	Automatic identification system
ALB	Albacore tuna
ALC	Automatic location communicator
BET	Bigeye tuna
BIL	Billfish
BOBLME	Bay of Bengal Large Marine Ecosystem
CCM	Members and Cooperating Non-members (of the WCPFC)
CCSBT	Commission for the Conservation of Southern Bluefin Tuna
CDS	Catch Documentation Scheme
Ci	Confidence interval
CI	Compliance Index
CMM	Conservation and management measure
EEZ	Exclusive economic zone
EM	Electronic monitoring
EPO	Eastern Pacific Ocean
EU	European Union
FAD	Fish aggregation device
FAO	UN Food and Agriculture Organisation
FFA	Forum Fisheries Agency
FFA VR	FFA Vessel Register
FSMA	Federated States of Micronesia Arrangement
GFW	Global Fishing Watch
HMTCs	Harmonised Minimum Terms and Conditions for Foreign Fishing Vessel Access
HSP	High seas pocket
IATTC	Inter-American Tropical Tuna Commission
ICCAT	International Commission for the Conservation of Atlantic Tunas
IMO	International Maritime Organization
IPOA-IUU	International Plan of Action for IUU
IUU	Illegal, unreported and unregulated fishing
LL	Longline
MARPOL	Marine pollution
MCS	Monitoring, control and surveillance
MCSWG	Forum Fisheries Agency Monitoring, Control and Surveillance Working Group
MT	Metric tonnes
NGO	Independent non-profit organization
NPM	Net profit margin
OTH	Other species
PIRFO	Pacific Islands Regional Fisheries Observer
PMSP	Pacific Maritime Security Program
PNA	Parties to the Nauru Agreement
PNAO	Parties to the Nauru Agreement Office
PS	Purse seine
RFMO	Regional Fisheries Management Organization
RFV	WCPFC Record of Fishing Vessels
RIMF	Regional Information Management Facility
RMCSS	FFA Regional Monitoring, Control and Surveillance Strategy
ROP	WCPFC Regional Observer Program
SHK	Sharks
SKJ	Skipjack tuna
SLL	Southern longline fishery
SOLAS	International Convention for the Safety of Life at Sea
SPC	The Pacific Community
SSI	Species of special interest
TLL	Tropical longline fishery
ULT	Ultra Low Temperature
USMLT	US Multilateral Treaty
UTC	Coordinated Universal Time
VDS	Vessel Days Scheme
VMS	Vessel monitoring system
WCPFC	Western and Central Pacific Fisheries Commission
WCPF-CA	Western and Central Pacific Fisheries Convention Area
WCPO	Western and Central Pacific Ocean
YFT	Yellowfin tuna

Executive Summary

BACKGROUND AND APPROACH

Illegal, unreported and unregulated (IUU) fishing is a recognised global problem that undermines the integrity of responsible fisheries management arrangements and results in lost value to coastal states (e.g. FAO, 2002; Agnew et al, 2009). The first attempt at quantifying the value and volume of IUU fishing in tuna fisheries within the Pacific Islands region was undertaken in 2016 using data from 2010-2015 (MRAG Asia Pacific, 2016). That study estimated the total volume of product either harvested or transhipped involving IUU activity in Pacific tuna fisheries was 306,440t, with an ex-vessel value of $616.11m. Nevertheless, the authors noted that the data and information underlying many of the estimates were highly uncertain and that the outputs should be seen as a 'first cut'.

In order to assess changes in the nature and extent of IUU fishing since that time, this study was commissioned as part of the Global Environment Facility-funded Pacific Islands Oceanic Fisheries Management Project II (OFMP II) to undertake a '2020 update' of the original estimates. Broadly, the aim was to undertake an 'apples vs apples' update of the original estimates, using a consistent methodology and taking into account the latest available information. The study period covered the years 2017-2019. Importantly, this preceded any COVID-19 related impacts on monitoring, control and surveillance (MCS) and IUU activity in the region.

Broadly, we used a 'bottom up' approach to quantify IUU fishing activity across key IUU risks in four categories: (i) unlicensed/unauthorised fishing, (ii) misreporting, (iii) non-compliance with other license conditions (e.g. shark finning) and (iv) post-harvest risks (e.g. illegal transhipping). 'Best estimate' and minimum/maximum range values were generated for each risk, taking into account the best available information. Monte Carlo simulation was then used to produce probabilistic estimates of IUU activity, taking into account probability distributions assigned within the minimum and maximum range values. Using this approach, estimates of IUU volume and value were developed for each of the three main fishing sectors - purse seine (PS), tropical longline (TLL) and southern longline (SLL) – and then aggregated to produce an overall estimate for Pacific Islands region tuna fisheries.

While the same basic approach to estimating IUU was used between the 2016 and 2020 studies, a number of changes were made to the information underlying estimation of individual risks. In some cases, this was driven by new information becoming available (e.g. to estimate the scope for illegal transhipment), while in other cases the information previously used to support estimates for the 2016 study was no longer available. For some risks, these changes of information had substantial impacts on the estimated volume and value between studies.

ESTIMATED VOLUME AND VALUE OF IUU FISHING

Our simulations suggest the best estimate **total annual volume of product either harvested or transhipped involving IUU activity in Pacific tuna fisheries during the 2017-19 period was 192,186t, with 90% confidence that the actual figure lies within a range of 183,809t to 200,884t. Based on the expected species composition and markets, the ex-vessel value of the best estimate figure is $333.49m. The 90% confidence range is between $312.24m and $358.17m.** For context, the estimated IUU volume figure is around 6.5% of the total WCPFC Convention Area (WCPFC-CA) catch in 2019.

This result is a considerable reduction from the 'first cut' estimates in the 2016 study of 306,440t (276,546t to 338,475t) with a best estimate value of $616.11m

($517.91m to $740.17m). The reduction was primarily driven by substantial reductions in estimates for illegal transhipping and FAD fishing during the closure period (in turn driven by the use of better and different information, respectively) as well as the removal of the 'unauthorised landings in foreign ports' risk. Overall figures were also influenced by changes in fishery dynamics (e.g. catch, effort, price).

Amongst the four categories of risk identified here, the largest contribution to the overall IUU volume was made by misreporting, accounting for 89% of the total volume. Importantly, much of this volume was driven by misreporting and misidentifying target species in the purse seine sector for which challenges exist in making accurate estimates of catch at sea. The various types of unlicensed fishing collectively accounted for 5% of overall estimated IUU volume, while non-compliance with license conditions and post-harvest offences accounted for 3% each.

Of the three main sectors assessed, estimated volume of IUU product was highest in the purse seine sector, accounting for 72% of overall volume. Nevertheless, much of the estimated volume in this sector was driven by estimates for misreporting for which mechanisms exist (through 100% observer coverage) to correct any errors in catch reports and, given the nature of access arrangements under the VDS, it is likely that economic rents associated with any misreporting would be captured anyway. This result should be seen in that context. The tropical longline and southern longline sectors accounted for 21% and 7% of the overall volume respectively. The purse seine fishery also contributed to slightly under half the overall ex-vessel of IUU product ($152.26m), although the higher market value of target species in the longline fisheries meant that TLL sector made a proportionally higher contribution by value (40%) than volume to overall estimates. The southern longline fishery had the lowest overall estimates of IUU product value (14%).

Of the main target species, yellowfin (YFT) accounted for the highest volume of IUU product, making up 33% of the total estimated IUU volume, and 25% of the ex-vessel value. The total estimated IUU volume of YFT equated to around 9.4% of the estimated total catch of YFT in the WCPFC-CA area during 2019. However, because much of the YFT volume is driven by misreporting in the purse seine fishery which is subject to 100% observer coverage, this should not result in 'unaccounted for' catch. Skipjack (SKJ) accounted for the next highest volume, making up around 27% of overall estimated volume, but only 20% of the overall ex-vessel value given its lower market price relative to other species. The total estimated IUU volume of SKJ equated to around 2.5% of the estimated total catch of SKJ in the WCPFC-CA area in 2019. Bigeye (BET) accounted for 17% of the overall estimated IUU volume, but 20% of the ex-vessel value. The proportionally higher contribution to the ex-vessel value total reflects the fact that much of the estimated IUU volume came from the longline sector which achieves relatively high market prices. The total estimated IUU volume of BET equates to around 24.3% of the estimated total catch of BET in the WCPFC-CA area during 2019. Importantly, this does not necessarily mean that 24.3% of additional BET have been taken in addition to reported figures. For example, some of the BET estimates relate to over-reporting in the purse seine fishery. Albacore (ALB) accounted for 2% of the overall estimated IUU volume and total ex-vessel IUU value. The total estimated ALB IUU volume equates to around 2.8% of the estimated total ALB catch in the WCPFC-CA area in 2019.

ANALYSIS AND MAIN MESSAGES

Apart from the headline volume and value estimates, there are a number of key messages arising from the analysis:

- **The reduction in estimates since 2016 is positive, but should be seen in context** - The overall volume and value of IUU estimated in this 2020 update are a substantial reduction on those from 2016. Broadly, this is a very positive result for the region and its MCS efforts, but should be seen in context. The 2016 estimates were a 'first cut' with highly uncertain data across a number of key risk areas. On that basis, estimates were kept deliberately broad to account for high levels of uncertainty. For the 2020 study, new information became available to estimate some risks – most notably illegal transhipping and longline misreporting – while information previously used to quantify risks for the 2016 study were not available for the current study period. Broadly, it was these changes in information base that produced the biggest overall changes in volume and value estimates. In addition, incorporating one new risk (exceeding effort limits) and removing another (unauthorised landing of catch in foreign ports) together with changes in fishing effort, catch rates and fish price also influenced overall estimates. In practice, the 2020 estimates should be seen as the next evolution in an ongoing process to refine approaches to quantify the nature and scale of IUU in the Pacific region;
- **Cooperation works** - While IUU fishing in its various guises will require ongoing attention from FFA members, there is little doubt that the MCS measures FFA members and their partners/regional secretariats have implemented over recent decades have had a profound impact on both the nature and volume of IUU fishing in the region. Cooperative regional MCS measures such as the establishment of the FFA Vessel Register and Good Standing requirement, the agreement of Harmonised Minimum Terms and Conditions (HMTCs) for foreign fishing vessel access, the establishment of the FFA Vessel Monitoring System (VMS), the development of common regional data collection protocols and forms, the establishment of regional Pacific Island Regional Fisheries Observer (PIRFO) standards and training for observers, the Niue Treaty and Subsidiary Arrangement to facilitate cooperation on MCS including information sharing and coordinated Regional Operations, amongst others, have substantially strengthened the MCS environment across all member zones compared to individual members acting alone. The relatively low estimates of IUU activity in the FFA region compared to many other parts of the world is practical evidence of the MCS framework's success;
- **Estimates continue to be dominated by the licensed fleet** - A key outcome of the 2016 study was that estimates of IUU volume and value were dominated by the licensed fleet. The 2020 update shows a similar pattern with unlicensed fishing accounting for only 5% of overall IUU activity;
- **Unlicensed fishing remains an issue at the margins** - unlicensed fishing continued to be an issue at the margins, both figuratively and literally. Overall, evidence for unlicensed fishing by vessels on the FFA VR and/or WCPFC RFV was very limited with no confirmed instances of unlicensed fishing by these vessels detected during regional operations and few national level detections/prosecutions during the study period. The main exception to this is on the fringes of the FFA region, and in particular on the western fringe adjacent to the domestic fleets of south east Asian countries, where evidence of regular incursions was stronger;
- **Priorities for strengthening MCS measures are in the longline sectors** –

Of the two main gear types operating in the Pacific Islands region, the purse seine fleet is subject to comparatively very strong MCS arrangements including 100% observer coverage, a requirement to tranship in port and a requirement for e-reporting under the Parties to the Nauru Agreement's (PNA) Vessel Days Scheme (VDS). Moreover, the majority of fishing effort occurs in EEZs subject to strong coastal State MCS. In contrast, MCS arrangements in place for the longline sector are weaker with lower observer coverage, a far higher proportion of effort on the high seas, and a higher proportion of the catch transhipped at sea which limits opportunities for port State MCS measures. Particular focus should be on strengthening measures to monitor and validate catch both on longline vessels and as it moves through the supply chain. Given the shared nature of stocks in the region, it is important that strong catch validation measures are applied across the full footprint of stocks, including on the high seas;

- **Estimates of illegal transhipping have come down, but monitoring and control remain a work in progress** - The availability of WCPFC Transhipment Declaration information together with Global Fishing Watch's (GFW) Automatic Identification System (AIS) dataset has provided considerably better information on the scope for unauthorised transhipment than was available to the 2016 study. Broadly, this has led to a substantial reduction in overall estimates of volume and value. Nevertheless, important areas of uncertainty remain in the at sea transhipment component of the longline supply chain and monitoring and control remain a work in progress. In particular, improvements are required to strengthen the implementation of the observer program such that information provided by vessels on the volume and species composition of fish transhipped can be validated against independent observer estimates;
- **'IUU' is not straightforward** – while the formal definition of 'IUU fishing' in the IPOA-IUU is relatively clear in theory, applying it for the purposes of quantifying its nature and extent presents a range of practical challenges. In addition to the inevitable uncertainties in the underlying data, resolving what should, and shouldn't, be considered in estimates frequently requires judgements that can have a large impact on overall volume and value figures;
- **Ex-vessel value is not a good indicator of actual loss to FFA members** – this is because the full value of the catch is not returned to coastal states under normal circumstances (only a proportion of total revenue is, typically through access fees). A better benchmark of revenue forgone by Pacific Island countries is likely to be the rent generated by vessels from IUU activity, however even then the nature of access arrangements such as the VDS mean that economic rents associated with many IUU activities (e.g. misreporting) is likely to be captured anyway. Taking into account estimates of profitability during the study period in the purse seine and longline sectors, as well as the likelihood that rents associated with some risks (notably misreporting in the purse seine sector) are likely to be captured through the VDS, we estimate the rent associated with ex-vessel IUU value to be $43.18m. This is a considerable reduction on the 2016 estimate ($152.67m), but may still overestimate actual loss. More accurate estimates would require additional analysis of the unique circumstances of each IUU risk.

What additional measures can be taken to better deter and eliminate IUU?

As outlined in the 2016 study, considerable efforts have been taken at the national, sub-regional (FFA/SPC/PNA) and regional levels (WCPFC) to mitigate IUU fishing in Pacific tuna fisheries. Moreover, a range of additional MCS measures have been taken since then (e.g. establishment of the Pacific Maritime Security Program - PSMP, strengthening of longline unloadings monitoring coverage in FFA member ports) which have better informed the 2020 update estimates and contributed to the lower overall estimates.

Nevertheless, ongoing uncertainties in relation to a number of key risk areas highlight priority areas for future MCS development. In the longline sectors, the priority is to strengthen measures to monitor and validate catch of licensed vessels throughout the supply chain. Despite good improvements in some areas (e.g. unloadings coverage in FFA ports), current monitoring arrangements remain limited for some fleets. Measures that could be taken to strengthen monitoring include strengthening observer coverage (for those longline fleets not meeting the 5% WCPFC benchmark, as well as FFA domestic fleets), more active cross-verification of independent data sources to identify reporting discrepancies (e.g. logsheet Vs unloading, etc), an enhanced focus on investigating reporting offences, wider use of electronic reporting and monitoring, and the development of an effective catch documentation scheme (CDS) for key species. In addition, more effective monitoring and control of at-sea transhipment is required including strengthening arrangements for the implementation of the transhipment observer program.

In the purse seine sector, notwithstanding recent complications arising from COVID-19 restrictions, the MCS arrangements in place are considerably stronger than those for longline. Priorities include continuing efforts to validate estimates of catch composition and monitoring and control of FAD usage.

1 Introduction

Illegal, unreported and unregulated (IUU) fishing is a recognised global problem that undermines the integrity of responsible fisheries management arrangements and results in lost value to coastal states (e.g. FAO, 2002; Agnew et al, 2009). Previous studies have shown that the effects of IUU fishing are often hardest felt in developing coastal states heavily reliant on fishing for income (e.g. MRAG, 2005).

Quantifying the nature and extent of IUU fishing is important in gauging potential losses suffered by coastal states, addressing uncertainties in stock assessments and planning effective monitoring control and surveillance (MCS) responses. However, by its very nature IUU fishing is secretive and difficult to estimate with accuracy (FAO, 2002; Le Gallic and Cox, 2006).

The first attempt at quantifying the value and volume of IUU fishing in tuna fisheries within the Pacific Islands region[1] was undertaken in 2016 using data from 2010-2015 (MRAG Asia Pacific, 2016). That study estimated the total volume of product either harvested or transhipped involving IUU activity in Pacific tuna fisheries was 306,440t, with an ex-vessel value of $616.11m. Nevertheless, the authors noted that the data and information underlying many of the estimates were highly uncertain and that the outputs should be seen as a 'first cut'. A key output from the study was the development of a framework for the estimation of IUU in the region that can be updated over time as information improves and circumstances change.

In order to assess changes in the nature and extent of IUU fishing since that time, this study was commissioned as part of the Global Environment Facility-funded Pacific Islands Oceanic Fisheries Management Project II (OFMP II) to undertake a '2020 update' of the original estimates. Broadly, the aim was to undertake an 'apples vs apples' update of the original estimates, using a consistent methodology and taking into account the latest available information. The Terms of Reference for the study are included at Annex 1. Consistent with the 2016 study, we have adopted the definition of IUU fishing set out in the FAO International Plan of Action (IPOA-IUU) (FAO, 2001) (Box 1).

Broadly, the report is organised into six main parts. Following this introduction, section 2 sets out the overall approach used for the study, as well as the data and information used to quantify each individual IUU activity. Section 3 provides estimates of the volume and value of IUU fishing for each main IUU activity within the three main fishing sectors examined (purse seine, tropical longline, southern longline). Section 4 looks at the estimated actual costs of IUU fishing to Pacific Island economies, while section 5 sets out the main messages arising from the analysis. Finally, section 6 looks at additional measures that may be taken to further reduce IUU fishing in the Pacific Islands region.

BOX 1: WHAT IS IUU FISHING?

Illegal fishing refers to fishing activities:

(1) conducted by national or foreign vessels in waters under the jurisdiction of a State, without the permission of that State, or in contravention of its laws and regulations;

(2) conducted by vessels flying the flag of States that are parties to a relevant regional fisheries management organization but operate in contravention of the conservation and management measures adopted by that organization and by which the States are bound, or relevant provisions of the applicable international law; or

[1] The Pacific Islands Region is considered to comprise the EEZs of FFA's 15 Pacific Island member countries and adjacent high seas areas in the tropics.

(3) in violation of national laws or international obligations, including those undertaken by cooperating States to a relevant regional fisheries management organization.

Unreported fishing refers to fishing activities:

(1) which have not been reported, or have been misreported, to the relevant national authority, in contravention of national laws and regulations; or

(2) undertaken in the area of competence of a relevant regional fisheries management organization which have not been reported or have been misreported, in contravention of the reporting procedures of that organization.

Unregulated fishing refers to fishing activities:

(1) in the area of application of a relevant regional fisheries management organization that are conducted by vessels without nationality, or by those flying the flag of a State not party to that organization, or by a fishing entity, in a manner that is not consistent with or contravenes the conservation and management measures of that organization; or

(2) in areas or for fish stocks in relation to which there are no applicable conservation or management measures and where such fishing activities are conducted in a manner inconsistent with State responsibilities for the conservation of living marine resources under international law.

2 Approach used in this study

2.1 Approaches to estimating IUU fishing

Approaches to quantifying IUU fishing can generally be grouped into two categories – 'top down' and 'bottom up' (see for example, MRAG, 2005; FAO, 2018). Top-down approaches typically use a fixed proportion (or range) of the catch, which is estimated to be IUU to arrive at an overall estimate of IUU catch volume and value. For example, Pauly & McLean (2003) provide estimates of unreported catch as a proportion of the total global reported catch in the range of 25-30%. Top-down approaches are convenient in that they can be applied to produce direct global or regional estimates of IUU catch, but should be applied with caution, given the nature and extent of IUU fishing may vary substantially from country to country, region to region and fishery to fishery.

The bottom-up approach involves analysis of more detailed information at a local scale in an effort to build a more accurate picture of IUU fishing activity and particularly the variation in vulnerability to such activity from state to state, or fishery to fishery. Estimates obtained in this way are added together to develop an overall estimate of IUU catch. The challenge with this approach is that it is time consuming and information is often very patchy and hard to collect. There are therefore many gaps to fill that require analytical methodologies of varying degrees of complexity. Even when these are used, it is still possible that some types of IUU catches will be missed, and also that some may be 'double-counted'. Nevertheless, depending on the nature and level of information available, bottom-up approaches arguably have the potential to provide more accurate estimates of IUU activity.

2.2 Overall approach

The overall approach we used for this study was the same as that used in MRAG Asia Pacific (2016). Broadly, we used a bottom-up approach, which aimed to arrive at regional-scale estimates of the volume and value of IUU fishing by first breaking down the 'IUU problem' into discrete quantifiable units, and then aggregating these up to produce a regional scale estimate. The approach is similar in part to the 'anchor points' approach described in Ainsworth and Pitcher (2005) (and later used by Agnew et al, 2009, for their global IUU study) in that we assigned 'best estimates' and minimum and maximum ('min/max') ranges of known IUU activities, and then used Monte Carlo simulations to determine the likelihood that IUU fishing would be within a certain range. However, the approach differs in that the intent is to estimate a 'typical' annual level of IUU activity within a specified timeframe, rather than produce a historical timeseries.

The approach used is consistent with advanced copies of volumes released to date of FAO's *Technical guidelines on methodologies and indicators for the estimation of the magnitude and impact of illegal, unreported and unregulated (IUU) fishing* (FAO, 2018, 2021).

Generating estimates of the volume, species composition and value of IUU fishing involved five main steps:

2.2.1 Identifying IUU risks

The first step in the analysis involved identifying the main IUU risks (e.g. unlicensed fishing, misreporting, illegal transhipping, etc.) in each of the main fishing sectors (purse seine - PS, tropical longline - TLL, southern longline - SLL). These were discussed at the project Planning Workshop (see 2.4.1) and largely carried over from the 2016 study, although one IUU risk was added (exceeding effort limits) and one was removed (landing catch in unauthorised foreign ports). Exceeding effort limits was added because evidence was available from the current study period that regionally agreed quantitative effort limits had been exceeded. Landing catch in unauthorised foreign ports was removed because the underlying nature of landing requirements were often either opaque, difficult to access (e.g. within confidential state agreements) and/or not actively enforced.

2.2.2 Determining 'best estimate' and minimum/maximum range

The next step involved identifying the information available to support estimates of IUU activity, and then using that information to determine a 'best estimate' level of activity and the most plausible min/max values. As in the 2016 study, the quality and nature of the information available varied considerably between risks. Relatively precise 'best estimates' could be assigned to some risks based on the nature of the available information (e.g. misreporting in the purse seine fishery which is subject to 100% observer coverage), while others were more subjective (e.g. unlicensed fishing).

Given the highly variable nature of the IUU risks, a basic calculation to quantify likely IUU volume and species composition was tailored to each risk based on the information available. As a general rule, an uncertain quantity (e.g. the number of days fished by vessels on the FFA Vessel Register in EEZs for which they were unlicensed) was multiplied by a known quantity (e.g. the average catch rate and species composition per day in the relevant sector) to constitute the basic equation for each risk. 'Best estimates' and min/max ranges could then be assigned to the uncertain value based on the nature and quality of information available. Min/max ranges took into account the uncertainty in the available information base (i.e. risks with more certain information had narrower ranges, risks with limited information had larger ranges).

2.2.3 Assigning likely probability distribution

Once 'best estimate' and min/max values had been assigned, a likely probability distribution of IUU activity within this range was determined. In general, triangular distributions were used where there was a reasonable level of confidence that the actual level of IUU activity was likely to be closer to the 'best estimate' than either the minimum or maximum value (Figure 1). This is consistent with the approach used by Pitcher et al (2002), Ainsworth and Pitcher (2005), and Agnew et al (2009). Uniform distributions were used where the information base was highly uncertain (e.g. shark finning in the LL sectors), although in general, we attempted to avoid these.

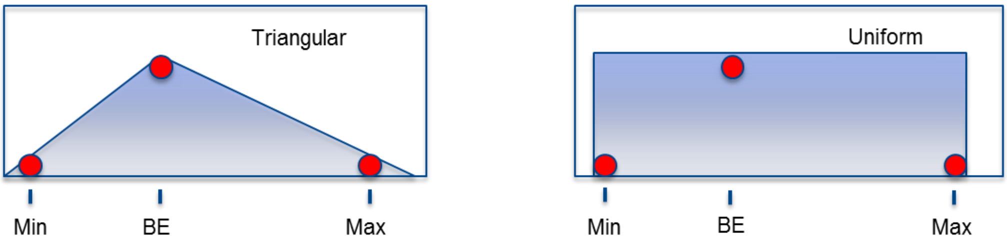
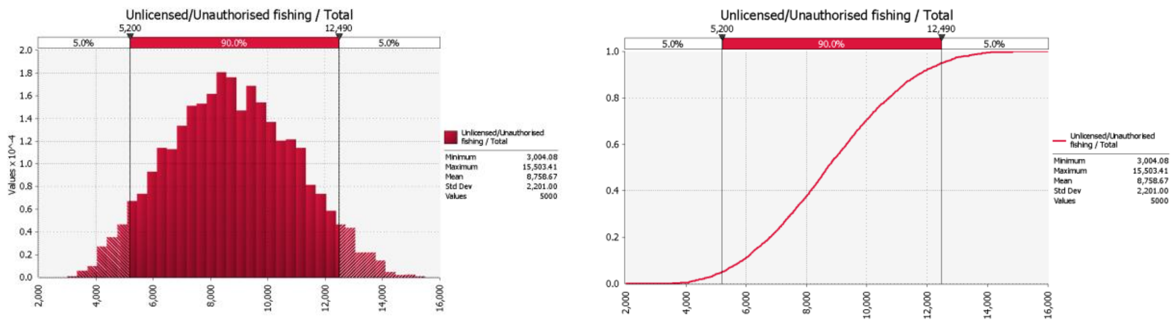


Figure 1: Example distributions of probability assigned to IUU activity. Triangular distributions were used where it was more likely the actual level of IUU activity was closer to the best estimate than either the minimum or maximum values. Uniform distributions were used where the information base was highly uncertain.

2.2.4 Monte Carlo simulations

We then used Monte Carlo simulation (using '@Risk' software) to define the relative probability that IUU volumes were within certain ranges, based on the best estimate and min/max values as well as the probability distribution assigned (Figure 2). Monte Carlo simulation is a widely-used analytical technique for calculating probability distributions of possible outcomes by performing a large number of runs (in the case 10,000), in which variables are sampled randomly from within a specified distribution. Monte Carlo simulation has previously been used by a number of authors in attempts to estimate IUU activity (e.g. Pitcher et al, 2002; Ainsworth and Pitcher, 2005; Agnew et al, 2009). The approach has a number of benefits over 'single point' or deterministic models in that it produces probabilistic results. In the context of this study, the simulations produce a probability that IUU for a given risk will be greater than a certain value.



(a) (b)

Figure 2: Example probability distribution outputs from Monte Carlo simulations using @Risk software.

Taking our example distributions in Figure 1, where Monte Carlo sampling was performed across a triangular distribution, values around the best estimate have a higher probability of occurrence than values sampled closer to the minimum or maximum range. In this way, the 'best estimate' value would be given higher weight in the ultimate probability distribution. However, where we thought there was no better chance that the actual IUU value was around the 'best estimate' than the minimum or maximum values a uniform distribution was assigned. In these cases, Monte Carlo sampling resulted in each value within the minimum and maximum range having an equal probability of occurrence (Figure 1) and given equal weight in the ultimate probability distribution.

To that end, uncertainty is factored into the estimates in three ways:

- The width of the min/max range – in most cases, the narrower the min/max range around the best estimate, the more certain the inputs;
- The probability distribution chosen for the Monte Carlo simulations – for risks in which there was a reasonable level of confidence that the actual level of IUU was likely to be closer to the 'best estimate' than the minimum or maximum values, a triangular distribution was chosen; and

- The probability distribution produced by the Monte Carlo simulation – this gives an estimate of the likelihood that the actual IUU estimate will be above or below chosen benchmarks.

2.2.5 Quantifying ex-vessel value

Based on the likely volumes and species compositions associated with each risk, we were able to calculate the likely ex-vessel value of IUU fishing activity. For each species in the three main sectors (PS, TLL, SLL), we assumed likely markets (sashimi grade for longline yellowfin; canning grade for purse seine yellowfin) and were able to generate likely market values based on known trade and market data (Annex 2). From this we calculated the likely ex-vessel value of IUU fish across each main sector and collectively. In cases where species were misidentified in logsheets, only the marginal difference in value between the actual species and the species reported was taken into account.

Notwithstanding that, despite being the most widely used figure to convey IUU catch values, simple ex-vessel or market values are not necessarily an accurate reflection of loss of value added to Pacific Island economies. This is discussed in more detail in Section 4.

2.2.6 Changes to the 2020 model

While the same basic approach to estimating IUU was used between the 2016 and 2020 studies, a number of changes were made to the information underlying estimation of individual risks. These were largely driven by either (i) better information becoming available since the 2016 study (e.g. the availability of the Global Fishing Watch [GFW] Automatic Identification System [AIS] dataset and WCPFC Transhipment Declaration dataset to assist in estimating scope for illegal transhipment) or (ii) the unavailability of information/analysis used for the 2016 study (e.g. predictive analysis of purse seine set type based on catch composition used in the 2016 study to assist in estimation of illegal FAD fishing during the closure period). For some risks, these changes of information had substantial impacts on the estimated volume and value between studies. The nature of changes made and implications are discussed in association with each risk in section 2.5.

In addition, for some risks in the 2020 model, Monte Carlo simulations were allowed to sample from a distribution informed by bootstrapped outcomes on the 'right hand side' of the equation to better reflect uncertainty in IUU catches. For example, for unlicensed fishing we assume that the catch taken during an unlicensed fishing day is likely to be the broadly the same as that taken by a licensed fisher using the same gear in the same area. In the 2016 model, to estimate the extent of unlicensed fishing, we multiplied an unknown amount (i.e. the estimated number of days unlicensed fishing) by a static 'known' amount (i.e. the average catch and species composition per day for that sector). In the 2020 model, we used the same approach to estimate the unknown amount (i.e. the estimated number of days unlicensed fishing), but allowed Monte Carlo simulations to sample from a distribution of catch volume and species composition informed by the bootstrapped mean and 95% confidence intervals of catch data reported during the study period. This approach recognises that catch and species composition will vary by vessel, location and time and was mainly used for calculations involving catch rates per day (e.g. unlicensed fishing, fishing inside closed waters).

2.3 Study period

The data and information used for this study covered the period 2017 to 2019. Consistent with the 2016 study, we have not attempted to estimate total IUU in a single snapshot year within this period. Rather, our overall estimates should be considered 'typical' annual levels of IUU fishing across each category for the period encompassed by the study (2017-2019). In general, where consistent, comparable data series have been available to estimate individual IUU activities, we have averaged these across the three year period. The specific amount of IUU occurring in each year will vary according to inter-annual factors such as overall level of effort, regulatory changes, MCS coverage, etc.

Importantly, the time period covers the years immediately prior to the COVID-19 pandemic which constrained FFA members' capacity to deliver many MCS activities (e.g. observer coverage, at sea boarding and inspections, port inspections). Accordingly, the estimates do not pick up the impacts of COVID-19 related MCS impacts on IUU.

2.4 Information collection, planning and ground-truthing

The approach and methodology described above was supplemented with a number of initiatives designed to identify, collect and ground-truth relevant information. These included:

2.4.1 Planning workshop

We commenced the study with a Planning Workshop on 9th October, 2020, involving members of the project team, FFA, SPC and PNA Office staff. The main purpose of the workshop was to agree the methodology to be used for the study, as well as to agree the scope. The main outcomes were that:

- the "Pacific Islands Region" will be defined consistent with the 2016 study – i.e. as the area below 20°N, east of 130°E and north of the southern boundary of the WCPFC Convention area, and east to the eastern boundary of the WCPFC Convention boundary (including the area of 'overlap' with IATTC Convention area). The area includes EEZs of FFA member states (excluding Australia and New Zealand) and areas of high seas[2];
- the area will exclude the Indonesian and Philippines EEZs;
- IUU estimates will be made at the level of the three main fishery sectors – PS, TLL and SLL;
- the boundary between the TLL and SLL will be 10°S (i.e. the TLL is the area within the Pacific Islands Region between 10°S and 20°N; the SLL is the area within the Pacific Islands Region between 10°S and the southern boundary of the WCPFC-CA);
- data and information used should cover the period 2017-2019; and
- the pole and line fishery would not be included in IUU estimates.

The workshop agreed that the IUU risks used in the 2016 study were still relevant in the 2020 study and covered the main IUU activities. These risks were separated into four main categories:

1. unlicensed and unauthorised fishing;
2. misreporting and non-reporting;
3. non-compliance with other license conditions (e.g. use of unauthorised gear); and
4. post-harvest risks (e.g. illegal transhipping).

A description of each of these risks is provided at Annex 3.

2.4.2 Data collection

The study was undertaken during the COVID-19 pandemic, so all data collection was undertaken remotely. Data from FFA members were collected through surveys, as well as video conferences to work through survey responses and seek member input on IUU experiences within their EEZs. Responses to the project survey were received from fisheries agencies within Cook Islands, FSM, Fiji, Nauru, Palau, PNG, RMI, Samoa, Solomon Islands, Tokelau, Tonga, Tuvalu and Vanuatu. Video conference discussions were held with representatives from Cook Islands, Fiji, FSM, Nauru, Palau, RMI, Solomon Islands, Tuvalu, Vanuatu, Australia and New Zealand. FFA member surveys focused

[2] Note that data provided by SPC for the study was only that available to FFA members, and did not include data for non-FFA members such as the French Territories. Where public domain aggregate WCPFC data was used to inform risks, some data for these areas may be included.

largely on information typically held only at the national level (e.g. outcomes of dockside inspections, prosecutions, surface patrols, etc.).

Data held regionally were provided by relevant regional agencies including FFA (VMS and aerial/surface surveillance data), SPC (logsheet, observer and unloadings data) and WCPFC (high seas transhipment data). GFW also provided access to their AIS data for the purposes of cross-referencing against reported WCPFC Transhipment Declarations.

BOX 2: MONITORING AND SURVEILLANCE IN THE PACIFIC ISLANDS REGION

Attempts to quantify the volume and value of IUU fishing of the type undertaken here – that is, to attempt to estimate all main forms of IUU fishing across each main sector, using a data driven, bottom up approach – require relatively good information across a wide range of different areas. The fact that such an exercise is possible in the FFA region is largely due to Pacific Island countries' investments over time in strong MCS mechanisms and commitment to regional coordination, cooperation and information sharing. While there are undoubtedly areas in which monitoring can be improved, the region's establishment of measures such as the FFA Vessel Register (VR), Harmonised Minimum Terms and Conditions for Access by Fishing Vessels (HMTCs), the FFA Vessel Monitoring System (VMS), standardised forms including logsheets, observer and unloading forms, 100% purse seine observer coverage, standardised regional observer training under the Pacific Islands Regional Fisheries Observer (PIRFO) Standard and regionally coordinated fisheries operations, together with centralised coordination and analysis of information through FFA, SPC and PNA has the Pacific Islands region relatively well-placed to detect, analyse and combat IUU. These measures, together with the fact that much of the fishing (particularly in the purse seine sector) occurs in EEZs, rather than the high seas, means the FFA region is better placed to undertake this type of study than many other regions internationally.

2.4.3 Ground-truthing workshop

The information used by the project team to estimate each risk, together with the basic equations and proposed minimum, best estimate and maximum range values were 'ground-truthed' at a workshop with FFA, SPC and PNA Office staff on 25th June, 2021. Proposed range values were agreed or refined based on attendees' practical experience with Pacific tuna MCS and IUU issues. This process ensured that any obvious errors or misinterpretations were picked up and added a layer of validation to the outputs.

2.4.4 Out of scope issues

Consistent with the 2016 study, there are a number of other activities that are illegal under national law or license conditions, but did not directly result in 'unaccounted for' fish and were considered out of scope. These included, for example, breaches of marine pollution (MARPOL) regulations, interactions with species of special interest (SSIs) and illegal bunkering. Nevertheless, we note that these issues remain important violations and in some cases have been implicated in the trade of illegally harvested fish products (e.g. there have been anecdotal concerns about bunker vessels facilitating the movement of shark fins to market).

2.5 Approach to quantifying individual risks

As described in 2.4.1, 'in scope' IUU risks were categorised into four basic types of activity:

1. Unlicensed fishing;
2. Misreporting (including under-reporting and misidentification);
3. Non-compliance with other license conditions; and

4. Post-harvest risks.

Approaches to quantifying each individual risk within these categories, including the information available, the basic equation to calculate the level of activity and best estimate and min/max ranges, are outlined below.

2.5.1 Unlicensed fishing

Three different classes of unlicensed/unauthorised fishing have been assessed:

1. Unlicensed fishing by vessels on the FFA VR;
2. Unlicensed/unauthorised fishing by vessels on the WCPFC Record of Fishing Vessels (RFV), but not on the FFA VR; and
3. Unregulated fishing (i.e. by vessels flagged to non-WCPFC CCMs, or vessels not authorised on the WCPFC RFV).

Classes were separated based on the information available to quantify the IUU risk. For example, vessels in the first class are all licensed in at least one FFA member EEZ and are required to have a functioning automatic location communicator (ALC) reporting to the FFA VMS. Vessels in the second class are authorised to fish on the high seas within the WCPFC-CA, but not in FFA member EEZs. These vessels are required to have a functioning ALC reporting to the WCPFC VMS. Vessels in the third class do not report to any VMS for which FFA or WCPFC have data sharing privileges and are effectively 'dark' from that point of view (albeit they may be tracked by AIS in some cases).

2.5.1.1 Unlicensed fishing by vessels on the FFA Register

This risk relates to the possibility of a vessel licensed in one FFA member EEZ fishing in another zone for which it has no license (i.e. 'border hopping'). A number of different data sources were used to arrive at 'best estimate' and min/max range estimates for this risk including:

- VMS data for each of the three sectors (PS, TLL, SLL), combined with 'compliance index (CI)' data for each vessel derived from FFA's Regional Fisheries Surveillance Centre (RFSC);
- Aerial and surface surveillance data both from regional operations during the study period as well as surveillance activities carried out at the national level;
- Observer reporting; and
- Information from FFA member surveys and interviews.

'Best estimates' and min/max ranges were assigned by estimating a proportion of the overall number of fishing days undertaken by vessels on the FFA VR in each of the three sectors likely to be fished in an EEZ for which the vessel had no license. These were then multiplied by the average daily catch rate and species composition for that sector to arrive at overall estimates of IUU volume and species composition.

Consistent with the 2016 study, 'best estimate' and min/max range figures were primarily assigned using VMS and FFA CI data. As part of their regional surveillance function, the FFA RFSC assigns each vessel for which it has visibility (i.e. all vessels on the FFA Register and vessels on the WCPFC RFV operating within FFA member EEZs, as well as vessels visible using the AIS) a CI. The CI is a number between 0 to -5 and is based on the vessel's compliance status. Vessels rated 0 are deemed to be a very low risk of undertaking IUU activity; vessels rated -4 or -5 are considered to be at very high risk of undertaking IUU activity, or have been involved in confirmed IUU activity. A CI of -3 is most frequently assigned to vessels currently located in zones for which they have no license. While many vessels with a -3 CI are simply making innocent passage through an EEZ (which is relatively easily visually detected by using VMS data), this group of vessels (together with the -4 and -5 CIs) are at higher risk of unlicensed fishing and gave us a 'starting point' to adjust based on aerial surveillance and other information.

To collect a relatively random sample of data, a snapshot of CI data for all vessels across all FFA member EEZs was provided by FFA for one day of each week during the period January 2017 to December 2019. This produced 6,263, 7,650 and 4,977 individual CI vessel ratings for the PS, TLL and SLL sectors, respectively. Of these, the proportion assigned to each CI category was identified (Figure 3), and from this, the proportion of these vessels likely to be engaged in unlicensed fishing activity was estimated based on expert judgement. Final best estimates and min/max ranges were also informed by aerial and surface surveillance, and observer information, where available.

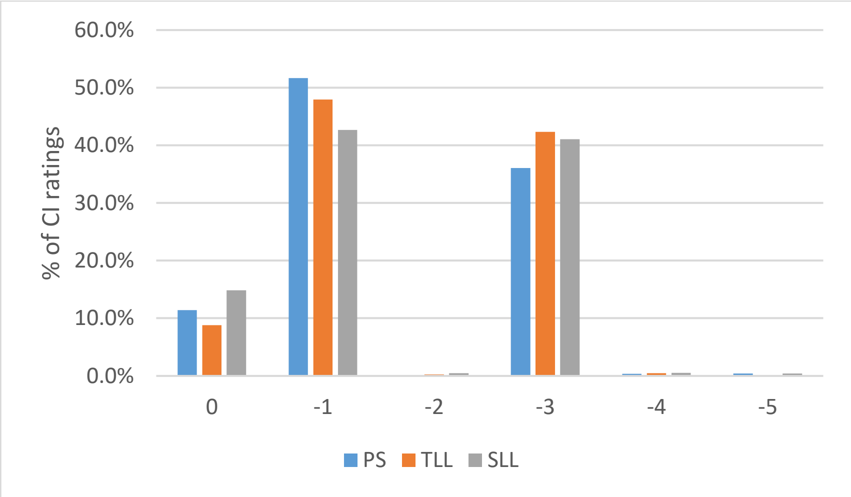


Figure 3: Proportion of total FFA compliance index (CI) ratings by sector, 2017-2019, based on a random sample of 18,890 individual CI ratings.

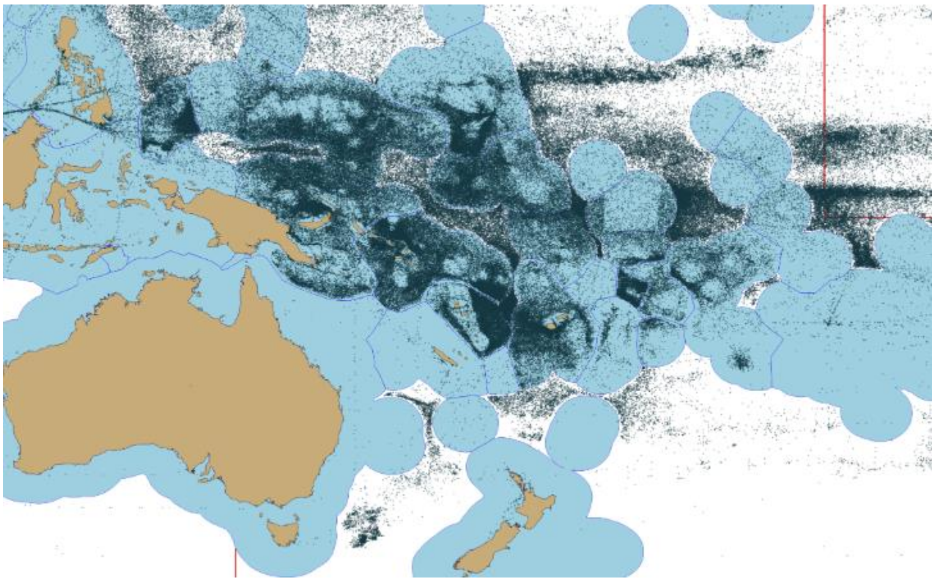


Figure 4: VMS position data sampled for vessels on the FFA Register in 2018.

Purse seine

In the purse seine sector, the ground-truthing workshop agreed that the level of unlicensed fishing activity was likely to be negligible. During the study period this sector included around 250-260 vessels, fishing an average of 42,176 days per year inside FFA member EEZs. Vessels in two fleets – the Federated States of Micronesia Arrangement[3] (FSMA) and the US Multilateral Treaty (USMLT) – are authorised to fish in each of the main EEZs and accounted for around 1/3 of the fleet during the

[3] Parties to the FSMA include FSM, Kiribati, Nauru, Palau, PNG, RMI, Solomon Islands and Tuvalu.

study period (~90-100 vessels out of ~255). Given these vessels are authorised to fish in each of the main purse seine EEZs, they are unlikely to engage in unlicensed fishing in the context of this risk.

No unlicensed fishing activity has been detected by aerial surveillance assets during the study period, vessels are polled hourly by VMS under the PNA's Vessel Days Scheme (VDS) arrangements and all vessels are subject to 100% observer coverage, which is likely to act as a strong deterrent to non-compliance. While a relatively high proportion (36%) of sampled vessels had a CI score of -3 and lower, the overwhelming majority of these are likely to have been engaged in innocent passage to transhipment ports.

In the 2016 study, the best estimate and min/max range were set based on expert judgement, taking account of available information. Delegates at the 2016 ground truthing workshop agreed that the minimum estimate should be set at 0% to account for the possibility all fishing is done in zones for which the vessel has a license, while the maximum figure should account for the possibility of slightly higher levels of unlicensed activity (0.2% of the average total days fished) and the best estimate should be set closer to the minimum (0.05%). The same basic approach was taken in the current study, however given the absence of detected IUU activity and strong MCS coverage of the purse seine sector, the ground-truthing workshop agreed that estimates for the 2020 study should be set at lower levels. Accordingly, minimum, best estimate and maximum figures were set at 0%, 0.02% and 0.1% of average total fishing days respectively.

Tropical longline

In the tropical longline sector, the inherent risks of unlicensed fishing are likely to be higher, given the larger number of vessels (650-700 longliners on the FFA VR during the study period), higher levels of effort (average of 51,177 fishing days in FFA EEZs during 2017-2019) and the operational nature of the gear which can drift many tens of nautical miles in a set. MCS arrangements for the TLL sector are generally weaker than those in the PS sector, given very low rates of observer coverage, less frequent VMS polling, and there are arguably fewer financial disincentives to unlicensed fishing. Moreover, longline vessels have typically had slightly higher rates of non-reporting to the FFA VMS than the PS sector and several instances of ALCs not reporting or having wiring rigged such that ALCs could be switched on and off[4] were detected during FFA coordinated regional operations and Pacific Maritime Security Program (PMSP) aerial patrols during the study period, which leaves open the possibility of unlicensed activity.

Nevertheless, actual evidence of unlicensed fishing during the study period is very limited. For example, aerial surveillance assets operating within 12 FFA led regional operations during the study period covered a combined surveillance footprint of 21,001,047nm^2, with no confirmed unlicensed fishing vessels detected. Similarly, surface surveillance assets within the same regional operations steamed a combined distance of 124,976nm for no confirmed detections or apprehensions of unlicensed fishing vessels. Moreover, of the FFA members providing information for the study, none had prosecuted a vessel for unlicensed fishing during the study period and, while all recognised that the risk of unlicensed fishing required constant vigilance, actual levels of unlicensed fishing were likely to be substantially less than they were several decades ago (before key MCS measures such as the FFA VMS, FFA Regional Register, aerial and surface surveillance programs, etc).

CI information showed that around 42% of days at sea during 2017-2019 were spent in EEZs for which vessels had no license, albeit the vast majority of these days are likely to be in innocent passage. Vessels considered at highest risk of IUU – i.e., those with CIs of -4 and -5 - accounted for 0.5% and 0.2% of total polls in the TLL sector, respectively.

In the 2016 study, the best estimate and min/max range for the longline sectors was set based on expert judgement, using the same process as that described for the purse seine sector above. The

[4] E.g. during Operation Tui Moana 2018.

minimum estimate of unlicensed fishing was set at 0.1% of the days fished in zones (given the absence of widespread evidence of non-compliance detected through regional operations), while the maximum range was set at 1.5% of days given the weaker monitoring arrangements in the fleet. The best estimate was set slightly towards the lower end of the min/max range. In this study, the ground truthing workshop agreed that the absence of any confirmed activity despite significant surveillance coverage, together with the relatively strong monitoring of FFA fleets and the fact many have licenses in multiple zones meant the proportions could be reduced. Accordingly, minimum, best estimate and maximum values were set at 0.05%, 0.2% and 0.5%, respectively.

Southern longline

The information base for the SLL sector was similar to the TLL sector in that no instances of unlicensed fishing were detected during regional operations in the study period, although MCS arrangements are weaker than the PS sector and observer coverage remains very low. SLL vessels fished an average of 32,596 days inside FFA EEZs during the study period. VMS and CI data showed around 41% of longline days in the SLL area were spent in zones for which the vessel had no license, although the majority of these days were likely to have been transiting to and from key SLL ports such as Suva. Vessels with CIs of -4 and -5 accounted for 0.5% and 0.4% of polls, respectively. Of the FFA members contributing information for the study, none reported prosecutions of longline vessels on the FFA VR for unlicensed fishing. This was fewer than the 2016 study when Fiji reported a total of 17 incidents of possible unlicensed fishing (picked up through port inspections during the study period), and the Solomon Islands reported 22 incidents of possible unlicensed fishing (detected by aerial/surface surveillance) (MRAG Asia Pacific, 2016).

The ground-truthing workshop agreed there was no obvious evidence to suggest the rate of unlicensed activity was likely to be different between the TLL and SLL sectors, and the proportions of overall days used for the min/max range and best estimate were the same as for TLL.

Table 1: Best estimate and min/max range for unlicensed fishing activity by vessels on the FFA VR by size and sector (by average number of days fishing per year). Percentages in parentheses represent the proportion of the total average fishing days by relevant vessels in that sector.

Sector	Min	BE	Max	Dist.
Purse seine	0 (0%)	8 (0.02%)	40 (0.1%)	Triangular
Tropical Longline	26 (0.05%)	102 (0.2%)	255 (0.5%)	Triangular
Southern longline	16 (0.05%)	65 (0.2%)	163 (0.5%)	Triangular

2.5.1.2 Unlicensed/unauthorised fishing by vessels on the WCPFC RFV, but not on the FFA Register

This risk broadly relates to the possibility of WCPFC high seas vessels fishing in FFA EEZs for which they have no license. Vessels on the WCPFC RFV report to the WCPFC VMS and are not routinely visible to FFA members on the high seas, although members may apply to view vessels within 100nm of the EEZ boundary. Members may also apply to have their zone included in the WCPFC VMS, which allows them to view WCPFC vessels while in their zone, although not all FFA members have reportedly taken up this option to date. At the regional level, FFA also requests the full suite of WCPFC VMS data for the area of operation during regional operations. However, high seas VMS data is required to be destroyed within seven days following the completion of MCS activity, so the capacity to undertake analysis of high seas vessel activity is somewhat limited.

Similar to the 2016 study, the ground-truthing workshop agreed that the main risks in this category were likely to be incursions on the fringes of FFA member EEZs by vessels ordinarily fishing the high seas, or when transiting FFA member EEZs, and on the western fringes of the FFA area by WCPFC authorised vessels that are ordinarily fishing in their own domestic waters or high seas pockets.

The information available to quantify unlicensed fishing by high seas vessels is largely limited to some VMS information (particularly during regional operations), aerial and surface surveillance data and expert judgement by practitioners in relevant areas. The basic calculation used to quantify activity in each sector was the number of unlicensed fishing days * the average catch volume and species composition for each sector per day. Average catch volume and species composition for the longline sectors was calculated based on catches within FFA member EEZs during the study period. For the purse seine sector, average catch rate and species composition was calculated based on catches in the western part of the fishery, between 130°E and 150°E, using WCPFC public domain data. Small vessels in the purse seine sector were assumed to have catch rates 1/3 of 'average' vessels.

Purse seine

In the purse seine sector, estimates of IUU activity in the 2016 study were split into 'average' and 'small' vessel categories to account for likely differences in catching capacity. The 2016 ground-truthing workshop agreed that the amount of unlicensed fishing activity by 'average' high seas vessels was likely to be very low, although agreed to include a small number of estimated IUU days to account for the possibility of some incursions. During the 2017-19 period, the overall level of high seas activity was relatively low (an average of 7,503 fishing days on the high seas with 42,176 in zone during 2017-2019; SPC, 2021), and no unlicensed fishing activity was detected by aerial surveillance during the study period. PS vessels are subject to 100% observer coverage and considerable financial disincentives exist if caught illegally fishing. While some northern WCPFC CCMs (e.g. China, Japan and Korea) have substantial proportions of their fleets on the WCPFC RFV but not on the FFA VR, all of the vessels which fish in the industrial purse seine fishery in and around the FFA member EEZs will be on the FFA VR. On that basis, the 2021 ground truthing workshop agreed there was negligible opportunity for the 'RFV only' vessels from these States to fish in FFA EEZs. Accordingly, the current study assumed no unlicensed fishing activity in this sector.

In the small vessel category, the main risk is likely to be from incursions on the western fringes of the FFA area. Of the fleets operating in this area, the Philippines has the largest number of vessels on the WCPFC RFV but not licensed in FFA member EEZs (Figure 5). This includes vessels authorised to fish in high seas pocket 1 (HSP1) under CMM 18-01[5]. Under CMM 18-01, Philippines vessels were limited to a high seas cap of 4,659 days and 36 fishing vessels. SPC (2021) indicates that actual fishing effort by Philippines flagged vessels in HSP1 averaged around 2,700 days in the 2017-19 period, while the Indonesian and Philippines fleets fished a combined average of around 2,304 days within their domestic EEZs (outside archipelagic waters) during 2017-2019. Philippines advises that all vessels fishing in HSP1 have 100% observer coverage (Anon, 2020). They also advise that vessels fishing in HSP1 are required to operate VMS, although in 2020, the Philippines was assessed for the fourth consecutive year as 'priority non-compliant' against the requirement under WCPFC CMM 14-02 to ensure fishing vessels on the high seas are fitted with an ALC which meets the WCPFC VMS requirements (WCPFC, 2020a). The extent to which this applied to vessels fishing HSP1 is not known.

While anecdotal reports of incursions exist (e.g. Palau were of the view that group seine vessels heading through the Palau EEZ to HSP1 would stop if they saw a school of fish), direct evidence of illegal activity is very limited. The 2021 ground truthing workshop agreed that estimates to account for some level of illegal activity should be maintained, although the best estimate and maximum figures should be reduced given the absence of confirmed detections, the reduction in the number

[5] During the 2017-2019 study period, the relevant tropical tuna CMMs were CMM 2016-01, CMM 2017-01 and CMM 2018-01. Each included a provision for a limited number of Philippines flagged vessels to fish in HSP1.

of vessels from some CCMs (e.g. Indonesia) on the RFV and the application of observers to the main fleet operating in HSP1.

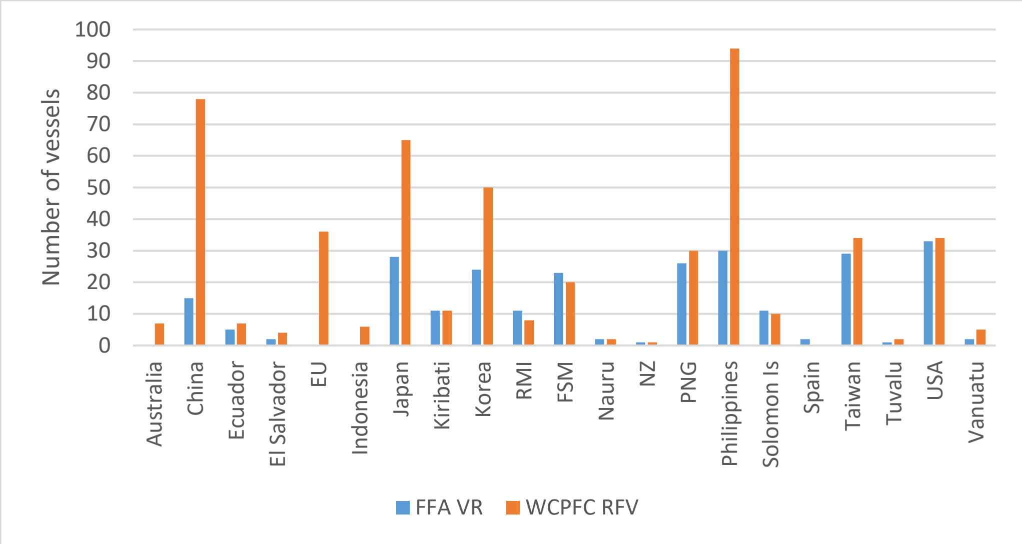


Figure 5: Comparison between number of purse seine vessels by flag on the FFA VR and the WCPFC RFV (as at November/December, 2018). Note that these numbers do not take into account chartering arrangements.

Tropical longline

Unlike purse seine, a considerable proportion of longline fishing effort occurs on the high seas (an average of 103,597 fishing days in the high seas portion of TLL area during 2017-2019 versus 51,177 in FFA EEZs), and a large number of vessels are authorised on the WCPFC RFV but not on the FFA VR (2584 vessels on the WCPFC RFV[6] with 684 on the FFA VR) (Figure 6). The evidence to support estimates of unlicensed activity is both limited and mixed. While no unlicensed fishing activity was detected by high seas vessels using aerial surveillance during 2017-2019, numerous instances have been detected during FFA-led regional operations and/or PMSP flights where vessels on the WCPFC RFV have been detected inside FFA members EEZs, but not reporting to the WCPFC VMS. For example:

- WCPFC vessels not reporting to the WCPFC VMS were detected in Palau's EEZ on multiple flights under the PMSP in 2019, while in another case the name of the vessel on the WCPFC VMS was not consistent with the sighted vessel;
- On other PMSP flights, a WCPFC longline vessel was detected inside Tokelau's EEZ and not reporting to the WCPFC VMS in 2018, while a similar incident was observed in FSM's EEZ in 2019;
- In another instance, a longline vessel not licensed in FSM's EEZ was sighted and appeared to be towing a line from the stern.

Of the FFA members interviewed for the study, RMI provided anecdotal evidence of longlines floating into their EEZs from adjacent high seas vessels.

[6] Not all vessels on the RFV may be active in the study area. Some may fish in and around their own EEZs (e.g. US vessels, Chinese Taipei vessels).

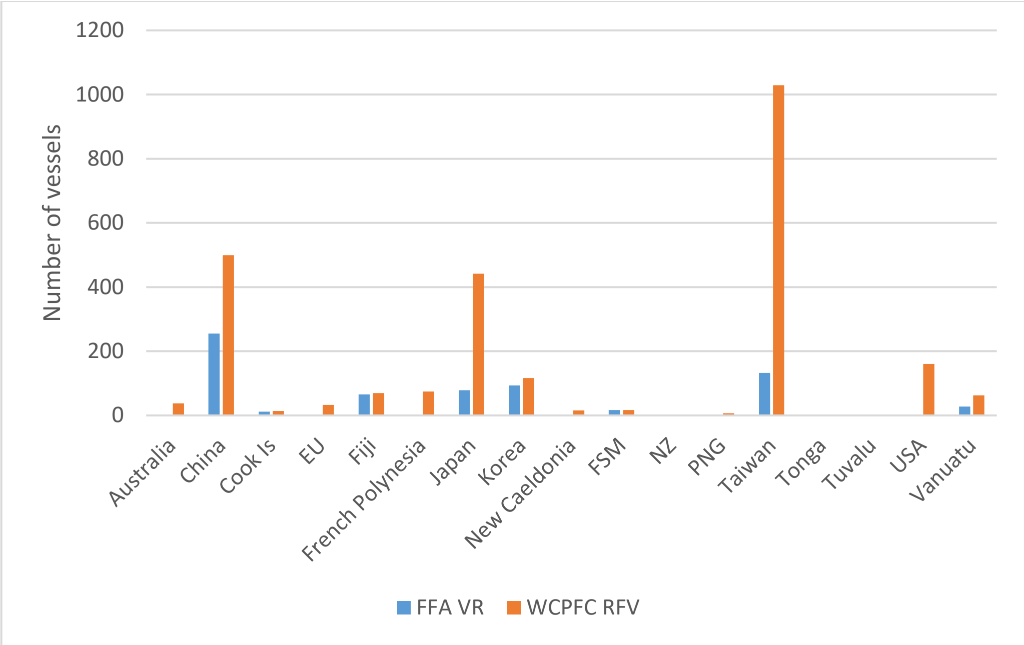


Figure 6: Comparison between number of longline vessels by flag on the FFA VR and the WCPFC RFV (as at November/December, 2018). Note that these numbers do not take into account chartering arrangements.

The main opportunities for infringement in the TLL sector are likely to be on the fringes of FFA member zones. Longline gear is inherently higher risk than PS gear, given its operational nature allows it to drift many tens of nautical miles in a set and there is relatively limited (apart from VMS) consistent MCS coverage of large parts of the high seas longline fleet (e.g. very limited observer coverage; very limited aerial/surface surveillance coverage). In 2016, the ground-truthing workshop agreed that the minimum estimate should be set at a low level, although the min/max range should be set broadly to acknowledge the high levels of uncertainty in the information base and to account for the possibility of higher rates of unlicensed fishing. To that end, estimates were set at 0.1% (min), 0.5% (best estimate) and 1.5% (max.) of total high seas fishing days, with a triangular distribution used for MC simulations (Table 2).

For this study, the evidence base was similar although there were fewer confirmed cases of unlicensed fishing during the study period. To that end, minimum and best estimate values were maintained, but the maximum value was reduced to 1% of total high seas fishing days.

Southern longline

Similar to the TLL sector, the ground truthing workshop considered the main risk of infringement was on the fringes of FFA member zones. However, overall effort is lower in the SLL sector and unlike the TLL sector, the majority of effort is within EEZs (an average of 32,596 fishing days in FFA EEZs versus 27,725 on the high seas during 2017-2019). Accordingly, the 2021 ground truthing workshop agreed that estimates should account for a lower absolute level of unlicensed fishing activity. The information base for the SLL is similar in nature to the TLL, in that no unlicensed vessels were detected by aerial surveillance between 2017 and 2019. Of the FFA members contributing information for the study, only the Cook Islands reported any confirmed instances of unlicensed fishing by vessels on the RFV (one vessel in 2019). FFA members interviewed for the study noted it was possible some longlines float into EEZs and there was uncertainty about the extent, but there were no sanctions of high seas vessels for unlicensed fishing during the study period.

The workshop agreed that the best estimate and min/max range figures should be set at the same proportions as those adopted for the TLL sector.

Table 2: Best estimate and min/max range for unlicensed fishing activity by vessels on the WCPFC RFV but not on the FFA VR by size and sector (by average number of days fishing per year).

Sector	Min	BE	Max	Dist.
Purse seine				
Small vessel	0	50	250	Triangular
Tropical Longline	104 (0.1%)	518 (0.5%)	1036 (1.0%)	Triangular
Southern longline	28 (0.1%)	139 (0.5%)	277 (1.0%)	Triangular

2.5.1.3 Unregulated fishing

For the purposes of this analysis, 'unregulated' fishing was defined as fishing by vessels flagged to States that are not cooperating members of the WCPFC, or by vessels flagged to cooperating members but which are not on the WCPFC RFV (and are therefore not authorised to fishing on the high seas inside the WCPFC-CA). The latter category is probably an extension of the standard IPOA-IUU definition of unregulated fishing, but these vessels were included because they have the same 'visibility' as other unregulated vessels and will not be reporting to any regional VMS.

Unsurprisingly, data availability for unregulated fishing was particularly weak. To that end, estimates for this risk were largely based on expert judgement using the information available including aerial and surface surveillance reports, observer sightings, previous risk assessments and anecdotal information.

Purse seine

In the purse seine sector, no unregulated vessels have been detected by aerial surveillance in recent years. The main risks appear to be incursions by Eastern Pacific Ocean (EPO) vessels on the eastern fringes of the WCPFC-CA and smaller domestic southeast Asian vessels on the western fringes (e.g. small purse seiners with support vessels fishing in Palau/PNG). Aerial surveillance coverage of both these areas, particularly in the east, is extremely limited. With no near-real time data sharing arrangement between WCPFC and IATTC (and member states), VMS data for EPO vessels is unavailable and any incursions by EPO vessels into the WCPFC area (and vice versa) are likely to go undetected.

In general, the opportunity for truly unregulated purse seine vessels (i.e. those flagged to parties other than cooperating members of the WCPFC) to fish in the WCPO undetected is likely to be negligible. This is because the main purse seine fishing countries are members of the WCPFC, and industry intelligence tracking both existing purse seine vessels and those under construction is detailed to the point that there is likely to be few, if any, 'unaccounted for' vessels.

The 2021 ground-truthing workshop agreed that the main opportunities for unregulated purse seine fishing came through incursions by EPO licensed vessels into the WCPFC-CA and by smaller, domestic purse seiners from southeast Asia on the western fringes. The basic calculation used to estimate activity was number of days unlicensed fishing * average catch rates and species composition per day in the relevant sector. Because of the likely differences in capacity between EPO vessels and smaller southeast Asian vessels, estimates were made for 'average' vessels and 'small' vessels. Catch rates for small vessels were assumed to be 1/3 of average vessels.

Estimates of unregulated activity for average vessels in the 2016 study were set at very low levels, with higher figures for smaller vessels. The 2016 workshop considered it possible that no unregulated fishing occurred, although it was more plausible that there were a small number of incursions (best estimate of 50 days, with a max. of 200 days) from EPO vessels. For the 2020 study, the ground-truthing workshop noted that although the majority of the catch of YFT and SKJ came from the eastern part of the IATTC area, considerable fishing for SKJ was undertaken near the border of the convention areas (150°W) (Figure 7). Much of this fishing in this vicinity is based on FAD-associated sets and given the prevailing equatorial current in the region flows westerly, there may be incentive for vessels to follow drifting FADs that show large biomasses on sonar buoys across the boundary. To that end, an allowance for some level of unauthorised incursions was maintained, although the evidence base remains weak. The best estimate value was reduced to account for the absence of confirmed unauthorised activity.

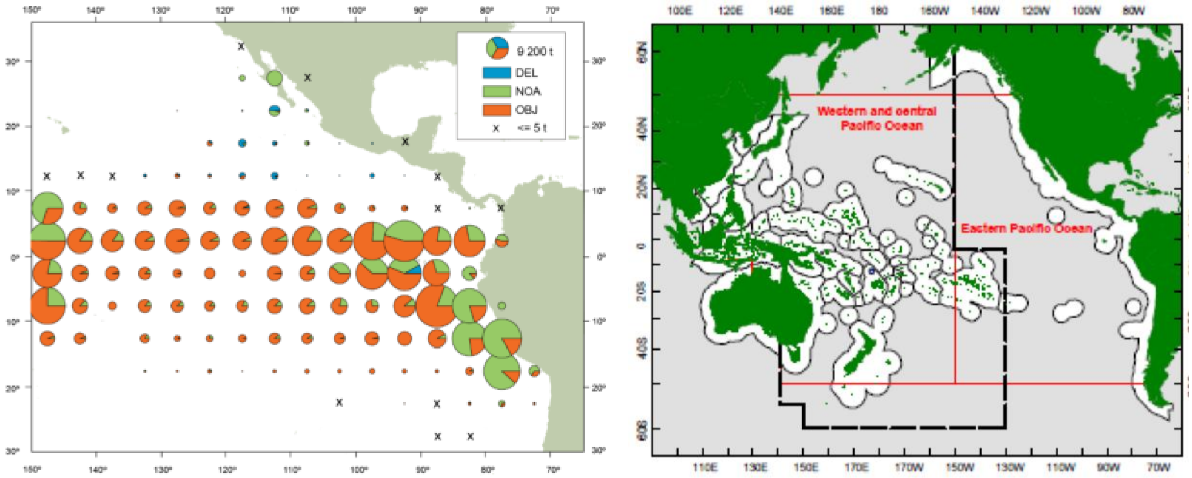


Figure 7: Distribution of catches of SKJ by set type in the IATTC area, 2019 (left panel; IATTC, 2020); WCPFC/IATTC boundaries (right panel).

On the western fringes of the study area, the level of incursions was likely to be higher, given the large number of small southeast Asian vessels that fish in this vicinity and the frequent anecdotal reports of incursions in EEZs such as Palau and PNG. Tangible evidence of unlicensed fishing was also higher for this sector than many others. Palau advised that they regularly see illegal small group seine operations from the Philippines inside their EEZ (Figure 8). These operations typically consist of an 80-100 ft catching vessel, a carrier vessel and two to three light boats to attract fish. FADs are deployed to attract fish, with the catching vessel called when a school is located. Palau advised that on a 'busy' day, a patrol may see up to five group seine operations, although some patrols report no sightings. Most of the vessels they have apprehended have between 20-100 t of product on board, although some can have >100 t. Because the vessels are not on either the FFA VR or WCPFC RFV, no VMS or AIS data are available for these vessels, so they are difficult to detect. Palau advised that much of the activity occurs in the northwest of the Palau EEZ, bordering the Philippines EEZ and the high seas pocket east of the Philippines. They also advised that aerial surveillance on its own was not effective, with vessels typically heading back into the Philippines EEZ upon sighting the aircraft. Surface patrol data from the Palau Maritime Operations Centre shows 32 FADs were destroyed by patrol vessels during 2017-2019[7]. Palau also advised that they have historically also had small group seine operations from Indonesia undertaking incursions into its EEZ, although numbers had reduced over the past five years because Palau has stationed rangers on its southwestern islands. Moreover, Indonesia introduced a moratorium in 2015 on foreign-built vessels, so the purse seine fleet largely comprises small vessels that rarely venture beyond their archipelagic waters (P. Williams, pers. comm.).

[7] Palau advised that group seine operations previously used metal FADs which were able to be sunk, but had more recently changed to plastic floats which were harder to sink.

Figure 8: An example of an unlicensed group seine operation detected in Palau's EEZ (Source: Palau Maritime Operations Centre)

While the actual number of illegal fishing days during the study period was uncertain, the evidence indicates that some level of unregulated fishing occurred. The minimum estimate was maintained at 50 days after taking into account Palau's advice that sightings during patrols were at least 'regular', best estimates were set at 175 days based on Palau's advice and the maximum figure was maintained at 500 days to account for the possibility of a much higher level of unregulated activity, including in neighbouring EEZs.

Tropical longline

Like the purse seine fishery, the main opportunities for unregulated fishing in the TLL sector came from incursions on the eastern and western fringes of the study area, although there has historically been some level of unregulated fishing by vessels not flagged to a WCPFC CCM in the longline sector. For example, two vessels flagged to Georgia were added to the WCPFC IUU list in 2010[8].

Opportunities for unregulated fishing are probably greater in the longline sector, given the larger number of vessels, the absence of high levels of observer coverage, and greater difficulty tracking movements between ocean basins amongst the fleet. Nevertheless, like the purse seine sector, the information available to support quantitative estimates of unregulated fishing is very limited.

The main opportunity for unregulated fishing on the eastern fringes is by vessels authorised to fish in the IATTC area but not in the WCPFC area. While a substantial amount of fishing occurs on the boundary of the WCPFC-IATTC areas (Figure 9), a considerable proportion of the main fleets operating in the area are authorised on both the IATTC and WCPFC regional vessel registers (Table 3; Figure 10). This limits the scope for any unregulated fishing. Given the absence of strong aerial surveillance or VMS evidence for vessels not on the WCPFC RFV, a small allowance has been included to account for the possibility of some level of unregulated activity, but have been set at relatively low levels (Table 5).

[8] https://www.wcpfc.int/doc/wcpfc-iuu-vessel-list

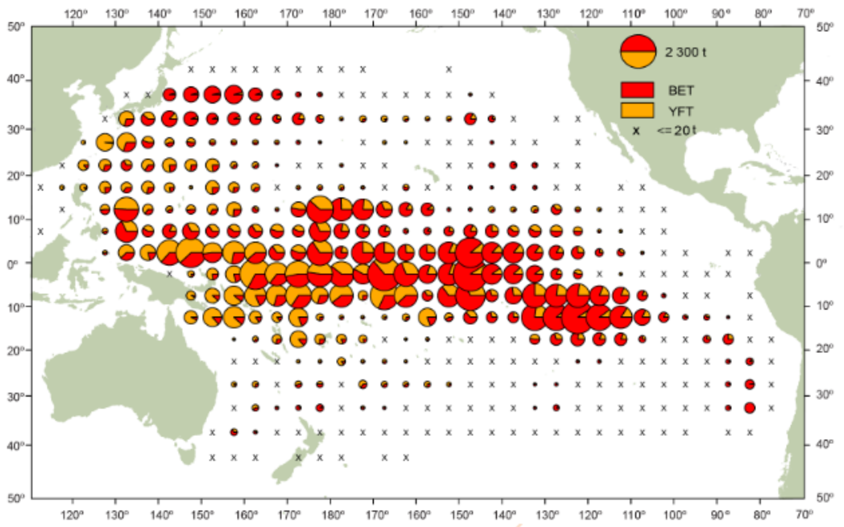


Figure 9: Distribution of average annual catches of BET and YFT in the IATTC area by Chinese, Japanese, Korean, and Chinese Taipei longline vessels, 2014-2018 (IATTC, 2020).

Table 3: Level of dual IATTC/WCPFC authorisation amongst the main longline fleets operating in the Pacific (as at April, 2021).

Flag	Vessels on IATTC RVR	Also on WCPFC RFV
Belize	1	
Chile	1	
China	418	341
Chinese Taipei	137	137
Costa Rica	2	
Ecuador	22	
EU (Germany)	1	
EU (Portugal)	12	11
EU (Spain)	92	33
Japan	187	170
Korea	103	100
Mexico	40	1
Nicaragua	1	
Panama	16	
Peru	1	
United States	38	36
Vanuatu	48	47

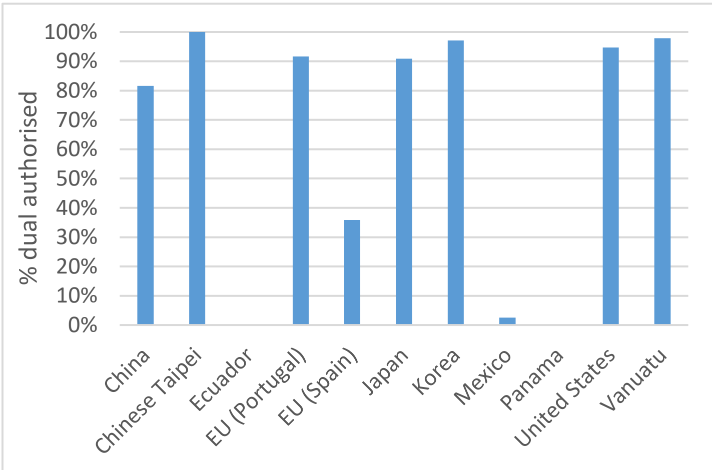


Figure 10: Proportion of longline vessels listed on the IATTC Regional Vessel Register, which are also listed on the WCPFC RFV for fleets >2 vessels (as at April, 2021).

On the western fringes, the main opportunity for unregulated fishing is by smaller domestic vessels of southeast Asian nations. For the purposes of this analysis, we have included all smaller vessels that use lines to catch tuna (e.g. handliners, pump boats, outriggers and bancas) (e.g. Figure 11). Anecdotal evidence suggests that incursions in the Palau EEZ and in the western part of the PNG EEZ are relatively frequent, and there have been a number of seizures and sightings of unlicensed vessels during the study period (by vessels targeting both tuna and demersal species). For example, during Operation Kurukuru '17 the Palau patrol vessel Remelik issued an infringement to a vessel they found allegedly secured to a FAD, while during Kurukuru '19 the PNG patrol vessel Moresby apprehended three Indonesian wooden boats. These wooden boats were handed to the Papua New Guinea National Fisheries Authority for further investigation. During Operation Rai Balang '18 the Moresby detected an Indonesian FFV in the 'dogleg' area and the Remelik apprehended an outrigger moored to a FAD. During Operation Island Chief '18 the Palau patrol vessel Kedam detected a

Philippines outrigger in the Palau EEZ. In addition, an aerial surveillance flight under the PMSP detected an illegal mother boat with multiple dinghies in the southwestern sector of Palau's EEZ that borders Indonesia during 2019.

During interviews for this study, Palau advised that most IUU activity using lines was related to Philippines outriggers (bancas) using hand lines to target tuna, although small illegal vessels were also observed in the south east pocket of the Palau EEZ close to the Indonesian border. They noted the profile of Philippines vessels had changed in the past five years with fewer larger outrigger type vessels and more metal motherships with fleets of smaller one-person bancas (called 'pakuras' in the Philippines) (Figure 11). Motherships may be >24m, while smaller pakuras are typically 6-8ft in length. SPC advised that, based on landings data from the Philippines, catch rates for similar types of vessels averaged around 1-3 fish per day, with yellowfin comprising almost all of the catch (96-98%) (e.g. NFRDI et al, 2020).

Figure 11: Mothership with one-person pakuras detected in Palau's EEZ (Source: Palau Maritime Operations Centre).

PNG also reported observations of unlicensed fishing in its EEZ close to the Indonesian border, both north and south, mostly by pump boats/type III vessels. Pump boats are typically small outrigger vessels of wooden construction, with fishing usually done by handlines and other line gear. 'Type III' is a name given to slightly larger, low slung wooden vessels, typically from Indonesia. Fishing is often done using longlines. In 2019, 20 vessels were detected during surface patrols, with four type III vessels prosecuted for fishing for tuna without a license. The remaining 16 vessels were subject to administrative sanction.

The 2021 ground-truthing workshop agreed that estimates should be set at levels which account for the possibility of higher levels of activity, with a 'best estimate' of 500 days unregulated fishing (equating to slightly >1 unregulated vessel fishing in the western fringes of the FFA area for each day of the year), with a minimum of 200 days and a maximum of 1500 (4-5 unregulated vessels for each days of the year).

Southern longline

In the southern longline sector, there is negligible scope for incursions in the west. The main opportunities for incursions are in the east and to a lesser extent in the south. Given the SLL sector has no borders with EEZs with small scale, potentially 'unregulated' fleets, small scale vessel incursions were likely to be negligible. To that end, unlike the TLL sector, we have made no provision for unregulated fishing by 'small' vessels. Estimates are made based on 'average' vessels typical in the SLL sector.

There have been a number of incidents in which vessels flagged to WCPFC CCMs, but which were not on the RFV, being sanctioned for fishing inside the WCPFC-CA during the study period. For example, a New Zealand high seas patrol in 2017 detected five vessels in the vicinity of the Louisville Ridge to the east of the New Zealand EEZ, but not on the RFV (New Zealand, 2017). The absence of WCPFC authorisation was later confirmed by their flag State and the vessels sanctioned. In addition, two Chinese flagged vessels were fined for fishing unlicensed within the WCPFC-CA adjacent to New Zealand's EEZ in 2017[9]. These vessels were also fined for misidentifying southern bluefin tuna as bigeye tuna.

The experience of the Georgian-flagged vessels on the WCPFC IUU List indicates some scope for fishing by non WCPFC CCM flagged vessels , although the numbers involved are likely to be negligible. No unregulated vessels were detected by aerial surveillance during the study period, while the majority of the major fleets operating in adjacent jurisdictions (IATTC, CCSBT) are also authorised on the WCPFC RFV (with the exception of Chinese Taipei, although these vessels may fish in other ocean basins (Table 4). Many of the CCSBT authorised vessels not on the WCPFC RFV (e.g. Indonesian, EU and South African fleets) are likely to be fishing in other areas (e.g. Indian Ocean and Atlantic Ocean).

Table 4: Level of cross-authorisation in the WCP-CA by longline vessels authorised under CCSBT Record of Authorised Vessels (as at June 2021).

Flag	CCSBT	Also WCPFC	%
Australia	31	30	97%
Indonesia	176	0	0%
Japan	83	73	88%
Korea	11	9	82%
NZ	16	1	6%
Portugal	25	10	40%
Spain	77	23	30%
Chinese Taipei	94	4	4%

Given the confirmed instances of unregulated fishing during the study period, the minimum estimate was set at 50 days to account for these vessels, the best estimate set at 100 days to account for the likelihood that other vessels may have gone undetected and 200 days to account for a higher level of activity (Table 5).

Table 5: Best estimate and min/max range for unregulated fishing activity by vessel size and sector (by average number of days fishing per year).

Sector	Min	BE	Max	Dist.
Purse seine				
Average vessel	0	20	200	Triangular
Small vessel	50	175	500	Triangular
Tropical longline				
Average vessel	20	100	300	Triangular
Small vessel	200	500	1500	Triangular
Southern longline				
Average vessel	50	100	200	Triangular

[9] https://www.nzherald.co.nz/nz/chinese-vessels-fined-825000-and-deregistered-for-tuna-offences-off-nz-coast/P2OETZSFY7BLHM5FPKFLHFDKBY/

2.5.2 Misreporting and non-reporting

Vessels authorised to fish in the Pacific Islands region have an obligation to report catch and effort accurately under a range of provisions. At the WCPFC level, the Convention (Annex 3, Article 5) requires that fishing operators "*record and report vessel position, catch of target and non-target species, fishing effort and other relevant fisheries data in accordance with the standards for collection of such data set out in Annex I of the Agreement*." Moreover, CMM 13-05 requires each CCM to ensure that "*the master of each vessel flying its flag in the Convention Area shall complete an accurate written or electronic log of every day that it spends at sea on the high seas of the Convention Area*". The details of operational reporting requirements are set out in Annex 1.3 to 1.6 of the *Scientific Data to be Provided to the Commission* (WCPFC, 2012) and include obligations to report a range of target and non-target species, as well as a range of operational details (e.g. number of hooks per set for longlines, set type for purse seine and location). At the FFA member level, the HMTCs require that vessel operators keep daily records of all catch and bycatch species, including all catch discarded at sea and all bycatch transhipped or unloaded offshore, and submit final versions of these reports to licensing countries within 45 days of trip completion (FFA, 2019).

Purse seine

In general terms, analysis of reporting behaviour by licensed vessels is best undertaken by comparing reported catch against the best available independent source/s of the same data. Consistent with the 2016 study, the best available data source to examine reporting behaviour in the purse seine sector comes from independent observer estimates. Since 2009, purse seine vessels have been subject to 100% observer coverage so there is a considerable body of independent data on vessel catch. Other potential comparative data sources such as cannery out-turn reports show promise (if collected under the appropriate conditions), but were not available for this study[10].

To allow for an examination of reporting patterns, SPC provided set-by-set and trip level logsheet and observer data for matched trips within FFA EEZs during the study period. In the case of the trip level data, trips in which the number of sets reported on the logsheet and by the observer did not match exactly were excluded. This left a total of 1930 trips for comparison purposes.

Estimating the extent of misreporting in the context of IUU in the purse seine sector is challenging because large a volume or mixed species catch can be taken at one time, and records of catch and species composition made by both the vessel and observer are *estimates* of weights made at sea. While observer estimates of weight and species composition are made using a standardised methodology (volume of brail * number and fullness of brails; grab samples to assist in determining species composition) and following standardised PIRFO training, no scales are used, so comparisons of logsheet data with that found in observer reports remain estimates vs estimates. With that in mind, and consistent with the 2016 study, two measures were taken to minimise the impact of any estimation errors:

- First, data used for comparisons were at the TRIP level – given most purse seine trips can have between 15-40 sets, using data at the trip level should help to dampen out any set level variability in estimates and provide a higher probability of any reporting differences being persistent;

[10] Under an initiative of the International Seafood Sustainability Foundation (ISSF) and participating companies, comprehensive cannery receipts data has been provided to the WCPFC for trips involving WCPFC purse seine catch by more than 20 processing companies since around 2013. See Williams (2020) for details. While this data shows promise as an independent means of validating logsheet reporting, the terms under which data was shared did not allow for access by this study.

- Second, a 10% tolerance level was applied to all comparisons – i.e. if the logsheet estimate of catch volume was within 10% of the observer estimate, we assumed this was a reasonable attempt at reporting accurately. If the logsheet estimate was >10% different to the observer estimate, this was included in estimates of misreporting.

Importantly, the 10% figure is a nominal value based on an often used 'rule of thumb' in the region when examining cases of potential misreporting. There is no tolerance level specified in regional management measures, although there is a clear recognition amongst all parties that estimates made at sea will necessarily involve some degree of imprecision. To that end, the 10% tolerance applied here is essentially a 'judgement call' for the purposes of estimation. Applying a different tolerance level – e.g. 0% or 20% - would result in different outcomes. Results of the misreporting analysis should be seen in that context. Given the volumes involved in the purse seine sector, the choice of tolerance level can have important implications for overall estimates of regional IUU volume and value.

The other important assumption made in examining evidence of misreporting was that the observer's estimate was correct. While Pacific Island observers are all trained and certified according to a common PIRFO standard and estimate catch weight and species compositions according to standardised methodologies (see above), ultimately there is no guarantee their estimates of weight or species composition will be more accurate than the estimates of experienced skippers. Moreover, the challenges associated with the 'grab' sampling technique used by observers to estimate species composition have been well-documented (e.g. Lawson, 2009, 2010, 2012; Peatman et al, 2020). Nevertheless, observer data represents the best independent information available and preliminary comparisons show observer data is more closely aligned with cannery out-turn reports than logsheet data (Williams, 2020).

In examining misreporting, estimates of catch recorded by vessels and observers can vary in both volume and species composition, and there are multiple possible 'types' of misreporting. For example, where fish reported by an observer do not appear to be reported anywhere in the vessel logsheet, these may be classified as 'not reported'. Where a fish of species A appears to have been reported as species B, this may be classified as 'misidentified'. How they're classified does not affect the volume of catch misreported (the total volume of catch misreported is captured, irrespective of how they're categorised), but it does affect the potential economic loss involved. For example, 10t of YFT not reported may result in the full 'loss' of the value of the fish. If the same 10t of YFT was reported in the vessel logsheet as SKJ, only the marginal difference between YFT and SKJ is lost (in theory).

Capturing these differences has particular relevance in the purse seine sector given challenges associated with reporting of species composition in logsheets (e.g. Lawson, 2014, Peatman et al, 2017). Data provided by SPC at the trip level appeared to highlight these challenges. Across the 1930 matching trips, a relatively high proportion of logsheet estimates of total volume (i.e. across all species) were within the 10% level of tolerance compared to the observer, but this reduced progressively with individual species estimates for SKJ, YFT and BET (Figure 12). On average, logsheets overestimated the catch of SKJ while underestimating the catch of YFT and BET, although each species had instances of both underreporting and overreporting.

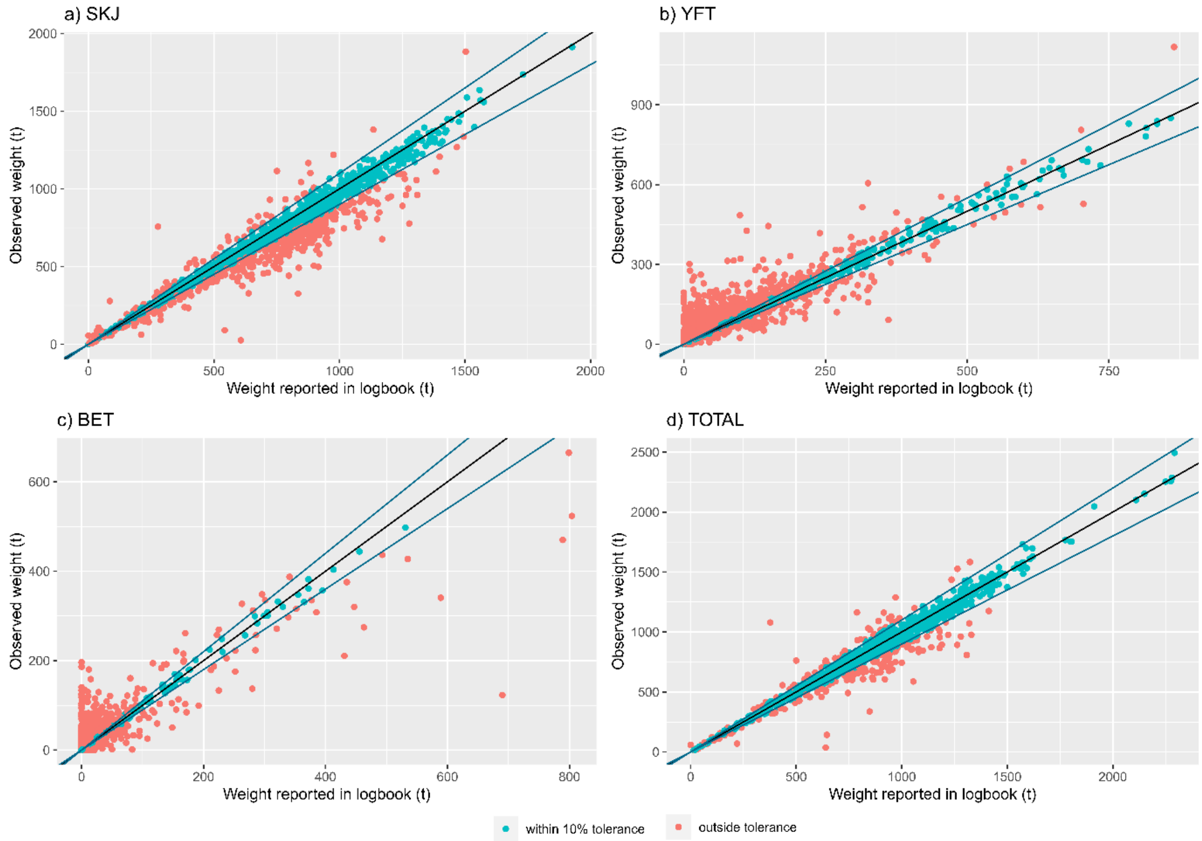


Figure 12: Comparisons of weights recorded in logsheets and observer reports for individual target tuna species and total weight at the TRIP level in the purse seine fishery, 2017-2019. (n=1930; Black lines show a 1:1 relationship between logsheet and observer estimates. Red data points are outside of the 10% tolerance level.)

To ensure consistency in the analysis during the 2016 study, a framework of decision rules was applied to categorise instances of misreporting in the PS sector. A similar approach was undertaken in this study, except that we have refined the decision rules slightly to separate out cases of over-reporting (i.e. where the logsheet recorded catches >10% higher than the observer) from cases of under-reporting (Figure 13). While the majority of cases in which the logsheet record was >10% different to the observer estimate involved under-reporting in the logsheet, there were also a proportion of cases in which the logsheet appeared to over-report catch (particularly for SKJ). To that end, a separate decision rule was added to separate out cases of over-reporting from under-reporting.

Importantly, where an instance of misreporting was >10% and triggered a decision rule, the full difference between the observer and vessel estimates was classified according to the type (under-reported, over-reported, misidentified). That is, if the difference between the observer and vessel was 11%, the full amount was recorded, not simply the excess over 10%.

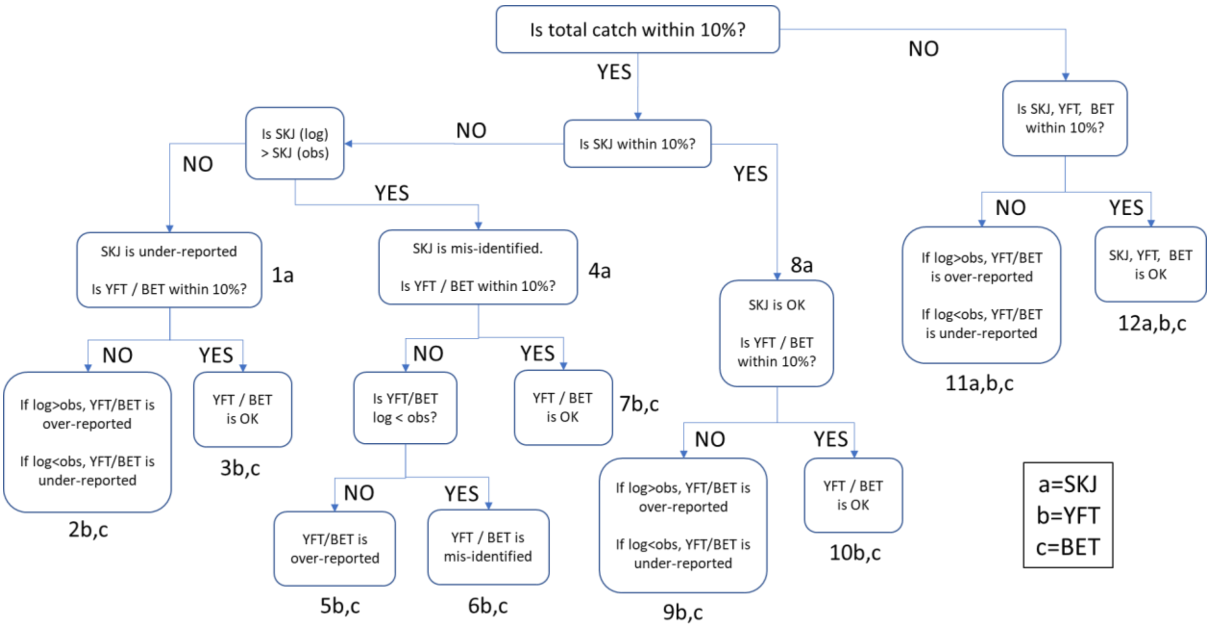


Figure 13: Decision rules used to categorise reporting offences in the purse seine fishery.

Based on the decision rules, the misreporting rate per set for each of the misreporting categories was calculated across the 1930 trips (Table 6). Given that trips had varying numbers of sets, logbook and observer data were subject to random resampling with replacement and were bootstrapped 10,000 times to generate mean misreporting rates (+/- 95% confidence intervals) for each species. These bootstrapped misreporting rates and associated 95%Cis were then scaled up across the study area based on the total number of sets during the study period to determine the total volume misreported for each species.

Non-target species (OTH) comprised only a small proportion of the total PS catch. Catches of OTH were very rarely over-reported by more than 10%, and where this occurred we assumed that the vessel's estimate was likely to have been correct (e.g. the observer may have missed a small number of other species). To that end, no allowance was made for over-reporting.

Misreporting of discards was also estimated for trips where observer estimates of discarded catch were more than 10% higher than those in logsheets. Although over-reporting of discards in the logsheet compared to the observer report did occur, this was not considered 'unreported' for the purposes of this analysis. To that end, only instances of underreporting >10% were included in estimates.

Table 6: Average rates of misreporting for each category across sample trips (in tonnes per set).

Category	SKJ	YFT	BET	OTH	Dist.
Retained catch (t/set)					
Under-reported	0.1398	0.5395	0.2337	0.0235	
Over-reported	0.5781	0.1663	0.1287	0	
Misidentified	0	0.3815	0.1722	0	
Discarded catch (t/set)					
Under-reported	0.0675	0.0082	0.0014	0.0649	

Longline

In the longline sectors, there are several ways in which catches could be misreported in logsheets:

- Under- or misreporting the number of each species taken – it is the number, rather than weight, of fish used in regional stock assessments, so accurate reporting of this figure is particularly important. Given fish are landed individually, there is little excuse to get the numbers wrong;
- Misreporting of catch weight – on the standard SPC/FFA Regional Longline Logsheet, vessels are required to record the number of retained and discarded fish, as well as an estimated weight of retained fish. Even where numbers are reported accurately, weights may be under- (or over-) reported (either deliberately or inadvertently since weight reported on the logsheet is a visual estimate). Incentives to under-report would be strong where access fees are structured around catch volumes or value, or where other quantitative catch limits apply. Underestimation of weights would be particularly important where compliance against catch-based limits (e.g. the WCPFC BET limits) was determined against estimated weights in the absence of independent verification;
- Misidentifying species – this is perhaps less of an issue in the longline sector than the purse seine sector given fish are caught individually and are generally of a larger size (and therefore easier to identify accurately), but may still be a risk, particularly where limits apply on specific species (e.g. in the case of BET, there may be a temptation to report smaller BET as YFT to stay under BET catch limits).

Given the very limited observer coverage across much of the longline fleet, and the absence of other means of independently verifying catch and effort, the information base upon which to examine misreporting is relatively weak compared to the purse seine sector.

For target tuna species retained by the vessel, the best information available against which to compare logsheet reporting is unloadings records. These are records of individually weighed fish taken by independent monitors (or by fishing companies generally overseen by independent monitors) of all fish offloaded from vessels at port. Unloadings coverage of longline vessels in FFA member ports has improved substantially in recent years and is now relatively high (~70%). However, a key weakness of the unloadings dataset is that it covers a portion of the fleet only – i.e. those vessels returning to FFA member ports to unload. To that extent it will over-represent the domestic and domestically-based fleets at the expense of long-range distant water fleets, for which there were few available independent data for comparative purposes. In the context of this study, this means that the data being used are representative of fleets subject to more intensive MCS coverage, and arguably have greater incentives for compliance. Another limitation is that monitoring may be largely focused on target tuna species, with less coverage of other species.

While there are data available for a small number of observer trips on longline vessels, coverage within FFA member waters remains very low for many fleets and there are challenges involved in making 'apples vs apples' comparisons between observer reports and logsheets in the longline sectors. In particular, because setting and hauling takes place over many hours in the longline fleet (hauling typically takes ~10-12hrs) observers are unable to monitor every hook that comes aboard. While observer data can be used to support comparisons of catch rates between the logsheet and observer (e.g. catch/hook), assumptions need to be made that catch rates of observed and unobserved hooks are consistent (which may not always hold true). Electronic monitoring (EM) has the potential to address some of these challenges, although coverage in the WCPO longline sector remains limited to a few relatively small scale trials at this stage. To that end, unloading data represents the best current opportunity to make 'apples vs apples' comparisons with logsheet data for retained species (at least for the portion of the fleet unloading in FFA member ports).

For species discarded by the vessel at sea, the information base is particularly weak, with the best available information coming from limited observer coverage and small scale EM trials. While EM information is able to provide some estimate of total number and composition of species discarded, for the reasons described above, comparisons between observer and logsheet discard reporting can only usefully be done based on catch rates. Given the relatively small scale nature of EM trials at this stage, observer catch rates were used as the primary dataset to examine reporting of discards by vessels, although estimates were triangulated against available EM trial results.

The basic equation used to estimate IUU volumes was the difference between the volumes reported in vessels logsheets and the estimated actual catch, taking into account the estimated levels of misreporting. Rates of misreporting for both retained species and discards were calculated using the data described below. Estimates were produced for each of five main species groups – ALB, BET, YFT, BIL and OTH – across both retained and discarded catch.

Given the limitations in the sample data, and the lack of independent comparative data for large sections of the WCPO LL fleet (particularly for high seas vessels), substantial assumptions have had to be made in these estimates and outcomes should be seen in that context.

Retained species

To support estimates of retained target tuna species reporting, SPC provided logsheet and unloadings data for all ‘matched’ trips in which unloadings were monitored in FFA member ports. After removing those with obvious uncertainties (e.g. trips that didn’t pass automatic data quality checks, trips in which zero values were recorded for either the logsheet or unloadings), data was available for a total of 6,227 individual trips across the 2017-2019 study period. This was a substantial improvement on the dataset available for the 2016 study for which only 564 trips were available, solely from one port (Suva).

Within the 2017-2019 dataset, trips were separated into TLL and SLL trips based on the location of fishing activity in the logsheet. Of the 6,227 trips, 3,714 were in the SLL area and 2,513 trips were in the TLL area. The key ports in which monitoring was undertaken for the SLL trips were Suva, Fiji, Apia, Samoa, Nukualofa, Tonga, and Pago Pago, American Samoa. For TLL trips, the key ports included Majuro, RMI, Pohnpei, FSM, Koror, Palau and Noro, Solomon Is.

In the TLL sector, comparisons of the numbers of target tuna recorded in logsheet vs unloadings revealed a relatively tight relationship for ALB, a slightly looser relationship for YFT and a looser relationship still for BET (Figure 14). Overall, ALB and BET were under-reported in logsheets compared to unloadings records by 4.8% and 7.1% respectively, while YFT was over-reported in logsheets compared to unloads by 5.9% (Table 7). A broadly similar pattern emerged in the SLL sector, with a tight relationship between logsheets and unloads for ALB and progressively weaker relationships for YFT and BET (Figure 15). In the SLL sector, all species were under-reported in logsheets compared to unloads, with ALB, YFT and BET under-reported by 1.5%, 8.8% and 13.4% respectively.

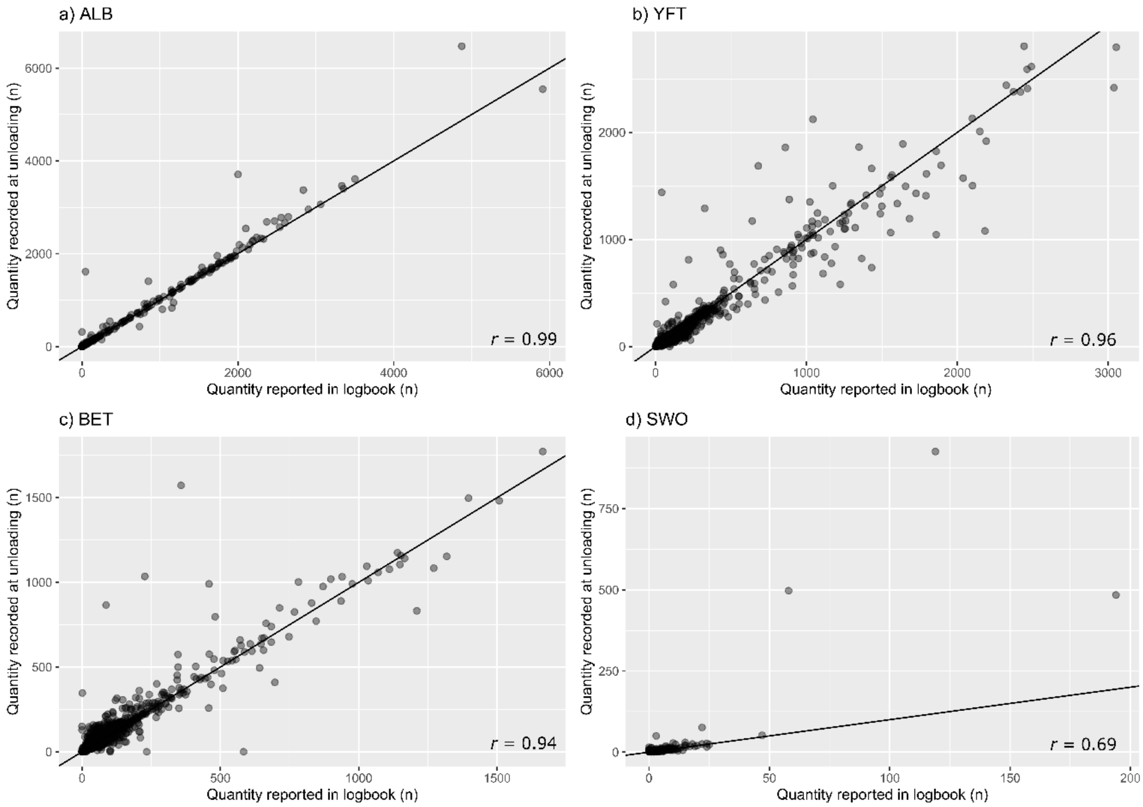


Figure 14: Comparison between numbers of target tuna species and swordfish reported in logsheet (x-axis) and recorded at unloading (y-axis) for matched trips in the TLL, 2017-2019. (n= 2513 trips for target tuna species; n=576 for swordfish; black lines show 1:1 relationship between logsheet and unloadings; r = Pearson's correlation coefficient)

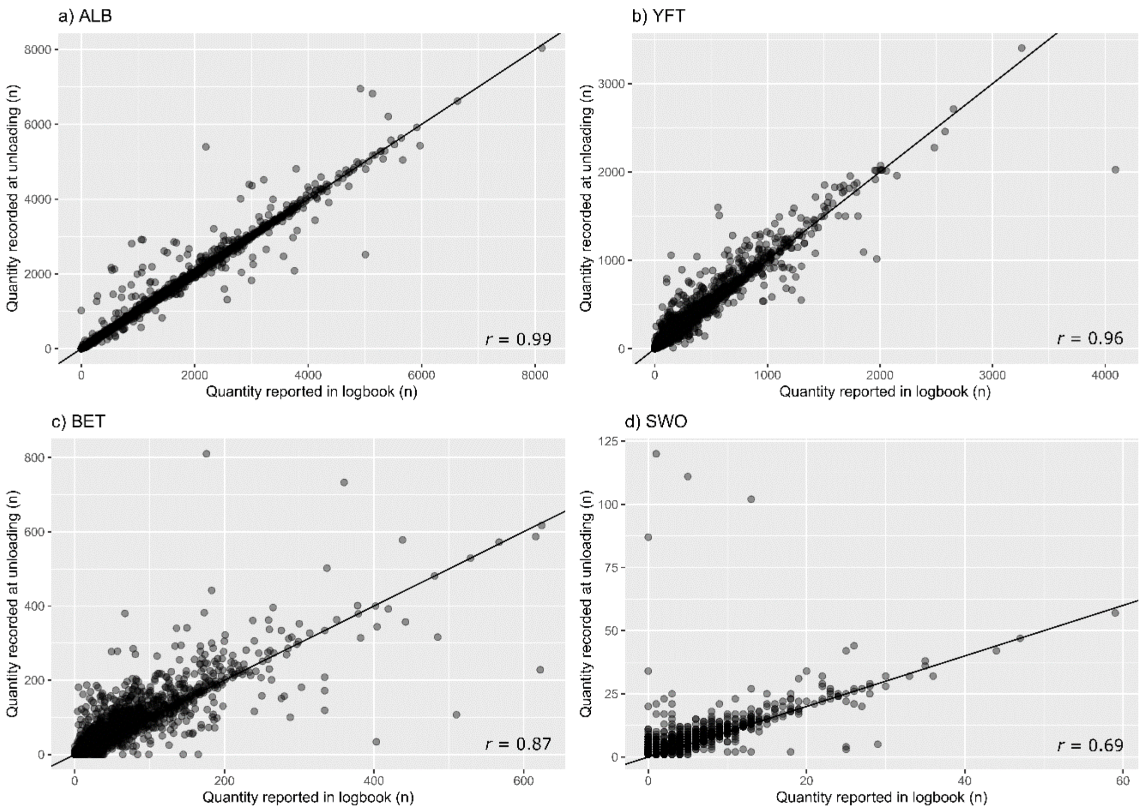


Figure 15: Comparison between numbers of target tuna species and swordfish reported in logsheet (x-axis) and recorded at unloading (y-axis) for matched trips in the SLL, 2017-2019. (n= 3714 trips for target tuna species; n=2664 for swordfish; black lines show 1:1 relationship between logsheet and unloadings; r = Pearson's correlation coefficient)

Table 7: Total numbers of fish reported in logsheets (LOG) and unloadings reports (UNL) across 2,513 matched trips in the TLL sector and 3,714 matched trips in the SLL sector.

	TLL			SLL		
Species	**LOG**	**UNL**	**% under/over**	**LOG**	**UNL**	**% under/over**
ALB	195529	205488	4.8%	3397482	3448094	1.5%
YFT	349049	329663	-5.9%	793006	869979	8.8%
BET	180430	194197	7.1%	149363	172547	13.4%

While there have generally been very few prosecutions for misreporting in the longline sector amongst FFA members, some instances of suspected or confirmed misreporting have been detected. For example, Samoa reported suspected under-reporting of BET amongst a number of Chinese Taipei longline vessels in 2019, while the Solomon Is sanctioned a vessel for misreporting in 2017. During Operation Rai Balang '18 the FSS Micronesia apprehended a Chinese-flagged longliner for misreporting catch, while during Operation Kurukuru '19 she apprehended another vessel for misreporting. In addition to these in zone offences, New Zealand high seas boarding and inspection detected a serious case of under-reporting in 2017 (New Zealand, 2017). In this case, the master of the vessel initially stated that there was no BET on board, but a subsequent search of the vessel holds revealed 5t of unreported BET (Figure 16). During subsequent questioning, the master admitted that he was keeping the BET separate 'for his own greed' with a separate running record of BET catches found in a notebook on the bridge.

Figure 16: Unreported frozen BET detected by a New Zealand high seas boarding, 2017 (NZ, 2017).

For both the TLL and SLL sectors we have used the outcomes of the logsheet vs unloadings comparisons to inform our best estimate values for misreporting and set our min/max range based on plausible scenarios to account for uncertainty in fleets not covered by unloadings data. Broadly:

- the best estimate value has been set at the value of the overall difference between logsheets vs unloadings. This assumes that patterns of reporting behaviour in fleets covered by unloadings data are broadly reflective of the full fishery;
- the minimum value has been set assuming that the unloadings results are reflective of the in-zone fleet and the remainder of the fleet reports all fish accurately. This is perhaps conservative given the evidence of misreporting described above and the incentives to under-report for some species (e.g. BET) with catch limits. Nevertheless, it reflects catch reporting to the WCPFC indicating quantitative catch limits are rarely exceeded. Minimum

values have been set taking into account the proportion of effort in zone and on the high seas in each sector;

- the maximum estimated value has been set to account for the possibility that misreporting behaviour in fleets not covered by unloadings are up to 50% higher than those that are. Maximum values have been set taking into account the proportion of effort in zone and on the high seas in each sector.

For BET, this approach produces estimates which are broadly in line with the results of EM trials in FSM, RMI and Palau, in which BET were under-reported in logsheets between 2-5% across 1052 sets (Brown et al, 2021). For ALB, the estimates are below the results of the same EM trial, which showed numbers of ALB detected by EM were up to three times higher than that reported in logsheets (albeit the EM trials were undertaken in the TLL sector where ALB catch is comparatively rarer and the total numbers of fish in the trial were not provided). To that extent, the ALB figure for TLL may be an under-estimate and highlights the considerable uncertainties in longline datasets.

The main challenge to the approach described above is for YFT in the TLL sector for which logsheet records exceeded unloadings. One possible explanation for this is that BET have been misidentified as YFT, either inadvertently or deliberately (e.g. to comply with BET catch limits). However, vessels landing to FFA member ports are typically flagged (or chartered) to Pacific Island states which are not subject to BET limits and our analysis of TLL trips showed only 5 trips (0.2%) in which YFT is larger in logsheets than unloadings and BET is smaller in logsheets than unloadings. Another possible explanation is that YFT may be sold locally by some vessels and not included in unloadings records.

The YFT results are contrary to the outcomes of the EM trial analysis described above in which YFT were under-reported in logsheets by up to 30% when compared to EM (Brown et al, 2021). Observer data in the TLL sector was limited to only 20 trips across the three years, with the attendant complications of not being able to monitor all sets, so was of limited value as a comparison.

In the absence of better independent estimates for YFT, we have set the minimum value at the difference in the unloadings comparison (-5.9%) to account for the possibility that YFT is over-reported, applied a conservative best estimate value of 0% given the conflict between the unloadings and EM results, and a larger maximum value of 20% to account for the fact that at least some evidence exists through EM trials of high rates of underreporting. We appreciate these estimates are highly uncertain however and should be updated as better data becomes available.

For billfish and other species, the data upon which to make valid comparisons with logsheets was weaker. Most monitoring of unloadings is focused only on target tuna species, with less attention paid to billfish and other species, the latter of which are often sold direct into local markets. For these species, we removed all trips for which the unloadings monitor reported zero catch from the unloadings dataset. With swordfish the only billfish included in the unloadings dataset, we used the reporting of this species as a proxy for all billfish reporting.

For swordfish in the TLL area, removing trips for which the unloadings monitor reported zero catch reduced the number of monitored trips from 2513 to 576. In the SLL area, removing the zero unloadings trips reduced the number of monitored trips from 3715 to 2664 indicating SWO were more comprehensively monitored in SLL ports. Taking only the trips in which the unloadings monitor reported some catch[11], the relationship between the two estimates was not particularly tight (Figure 14; Figure 15). The number of SWO reported in logsheets in the TLL sector was 47.4% of that reported by unloadings monitors (4005 fish), while the figure was slightly higher in the SLL sector (logsheets reported 77.9% of numbers reported by unloadings – 11,450 fish). Much of the

[11] if the unloadings monitor reported some catch, we have assumed they were tasked with reporting SWO and reported all catch accurately, although we understand this may not hold in all cases

difference in the TLL sector was driven by three individual trips for which logsheets and unloadings differed substantially. If these trips were excluded from the analysis, logsheet reporting as a proportion of unloads improved to 72.8% (i.e. 27.2% underreporting).

Unloadings numbers in the TLL sector were broadly consistent with EM trial results for Palau, where EM detected an average of twice as many billfish retained as that reported in logsheets. In contrast, they were not consistent with EM trial results from FSM or RMI, where EM numbers were only slightly higher than those in the logsheets (Brown et al, 2021).

In the absence of better information, we have used overall unloadings comparisons to inform our best estimates. The best estimate in the TLL sector has been set at the rate of under-reporting in the unloadings dataset minus the three outliers (27.2%). The min/max values were then determined using the same approach described for the main target tuna species. The same approach was taken to setting best estimate and min/max values in the SLL, although no outliers were removed. Nevertheless, given the uncertainty around the extent to which unloading monitors consistently record SWO, these numbers should be considered highly uncertain.

For other species (i.e. all species other than the target tunas and swordfish; OTH), removing the trips with no unloadings reports reduced the total monitored trips in the TLL area from 2513 to 990 and in the SLL from 3714 to 3665. For the 'monitored trips', the relationship between logsheet reporting and unloadings was tighter than SWO, but not as tight as many of the main target species (Figure 17). Overall, 30% fewer other species by number were reported logsheets than unloadings for the TLL sector (unloadings total fish = 172,365) and 20.3% fewer fish in the SLL sector (unloadings total fish = 1,057,964 fish).

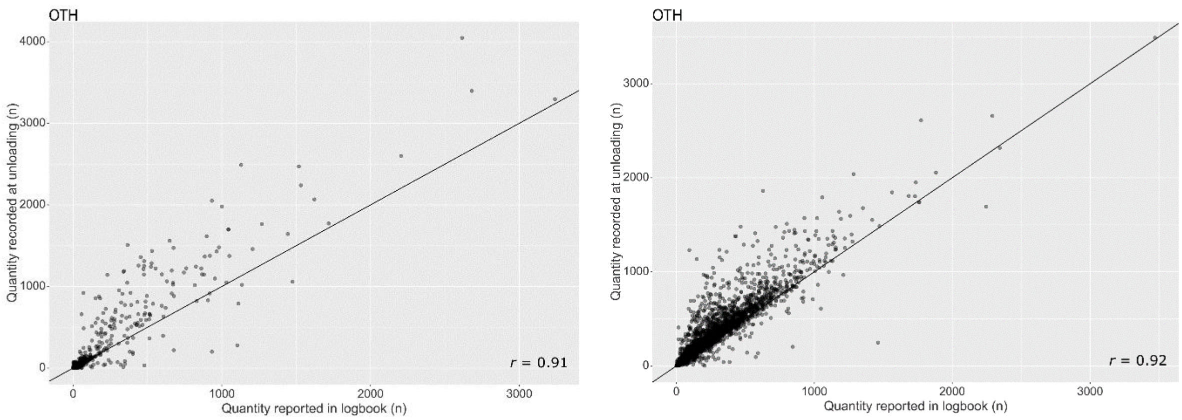


Figure 17: Comparison between numbers of other species reported in logsheet and unloadings for matched trips in the TLL (left side; n= 990 trips) and SLL (right side; n=3665 trips), 2017-2019. (black lines show 1:1 relationship between logsheet and unloadings; r = Pearson's correlation coefficient)

Results from the EM trials were more mixed for retained other species than the unloadings data, with FSM vessel logsheet and EM reports relatively close, but EM detecting around twice as many fish as logsheets in the RMI trials and up to six times as many fish as logsheets in the Palau trials (Brown et al, 2021).

We have taken a similar approach to setting best estimate and min/max values for other species as that for target species. Best estimate values were set at the overall difference between the logsheet and unloadings data, with min/max values set consistent with the approach described for target species.

Table 8: Estimated under-reporting rates of key longline species in percentage of total catch.

Species	TLL			SLL			Dist.
	Min	BE	Max	Min	BE	Max	
ALB	1.8%	4.8%	6.3%	0.8%	1.5%	1.9%	Triang.
BET	2.7%	7.1%	9.3%	6.9%	13.4%	16.7%	Triang.
YFT	-5.9%	0%	20%	4.5%	8.8%	11.0%	Triang.
BIL	10.3%	27.2%	35.7%	11.3%	22.1%	27.5%	Triang.
OTH	11.3%	30.0%	39.4%	10.4%	20.3%	25.2%	Triang.

While comparisons between logsheet and unloadings records by NUMBER have been used to estimate misreporting in the longline sectors for the reasons described above, comparisons by WEIGHT also highlight some revealing trends. Similar to the purse seine sector, weights recorded in logsheets by longline vessels are estimates made at sea. However, unlike the observer estimates used for comparison in the purse seine sector, longline unloadings are weights recorded after weighing. To that end, there should be less scope for estimation error between the two values.

An analysis of weight estimates for the key target species across both the TLL and SLL sectors shows a higher level of variability in reporting between logsheets and unloadings compared to numbers (Figure 18; Figure 19). However, unlike the comparisons by number where one species in one sector was over-reported (YFT in the TLL sector), all main target species across both sectors were underreported by weight in logsheets compared to unloadings on average (Table 9). Moreover, in all cases weight estimates for the key target tuna species were underreported by a higher proportion than by number. For example, ALB in the SLL sector were underreported by number by 1.5% and by weight 10%; BET in the TLL sector were underreported by number 7.1% and by weight 20%.

In addition to visual estimation error, one area of possible uncertainty in comparing logsheet versus unloadings weights is whether, for some species, weights are recorded by vessels as dressed weights (e.g. gilled and gutted) or whole weights. In the SPC/FFA Regional Longline Logsheet, vessel operators are advised to "*print the total amount of the whole weights for albacore, and the gilled-and-gutted weights for bigeye and yellowfin, of all fish that were caught and retained, in kilograms…*", although there is some uncertainty around the extent to which this is followed. For BET and YFT, if whole weights are recorded rather than gilled and gutted weights, this would mean logsheet weights are ~10% higher than the dressed weight recorded at unloading[12]. In practice, given the data presented in Figure 18 and Figure 19 are raw (unraised) weights for both logsheets and unloadings, if some vessels were recording YFT and BET as whole weights in logsheets this would serve to make the discrepancy between logsheet and unloadings weights larger, not smaller. Note that the uncertainties around dressed vs whole weights should not apply to ALB which are typically landed whole.

While numbers, not weights, are used for regional stock assessments, misreporting of catch weights can have important implications where logsheet data is used to monitor compliance with weight-based quantitative limits in the absence of independent validation/data correction.

[12] Note that SPC have processes in place to raise unloadings data to estimated whole weights based on known conversion factors. Estimated whole weights based on unloadings are used to adjust logsheet catch estimates where necessary.

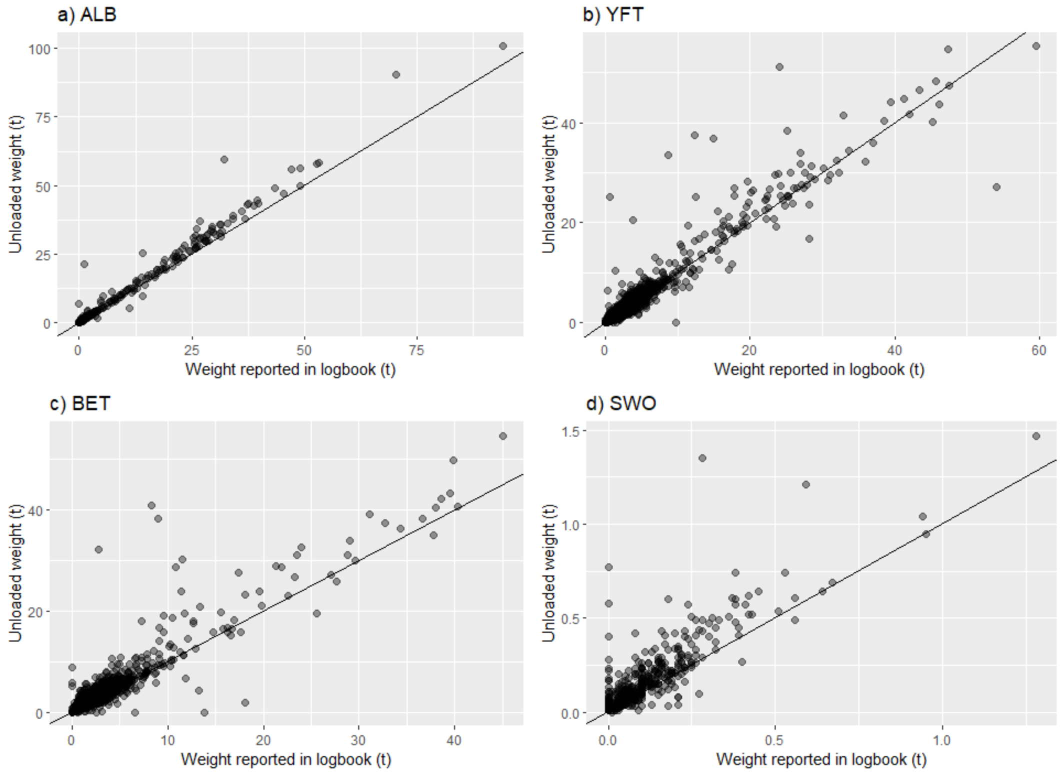


Figure 18: Comparison between weight of target tuna species and swordfish reported in logsheet (x-axis) and recorded at unloading (y-axis) for matched trips in the TLL, 2017-2019. (n= 2513 trips for target tuna species; n=576 for swordfish; black lines show 1:1 relationship between logsheet and unloadings) Note that one outlier data point has been removed from each of the YFT and BET graphs and three outliers have been removed from the SWO graph to improve clarity.

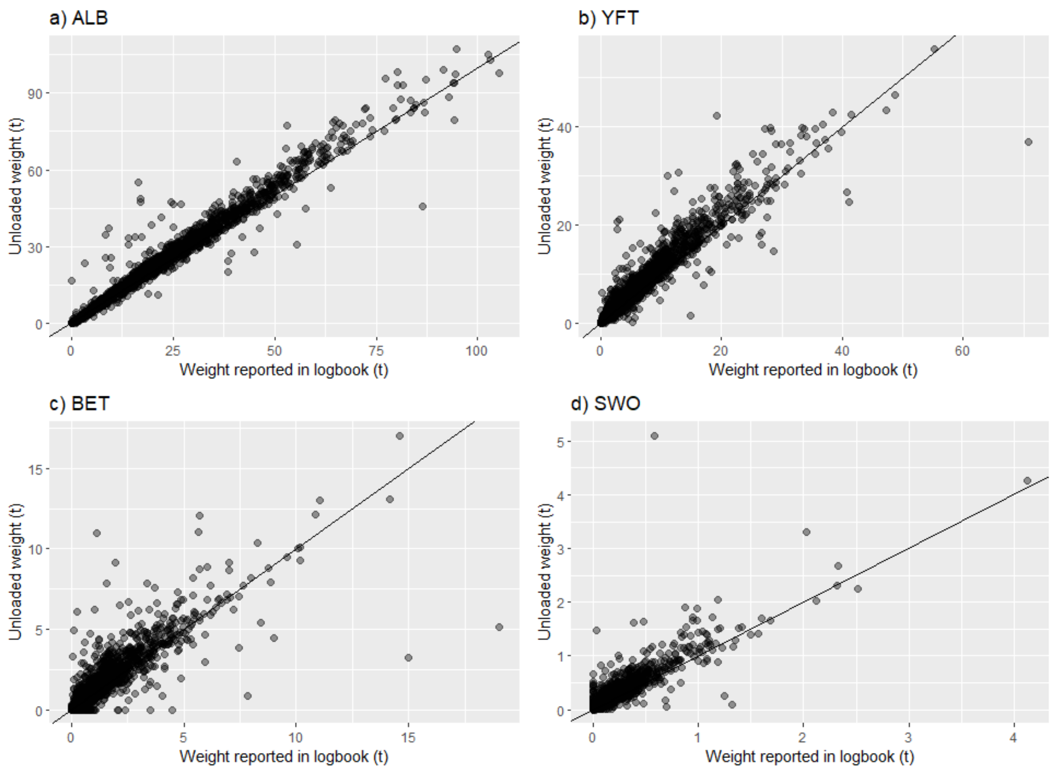


Figure 19: Comparison between weight of target tuna species and swordfish reported in logsheet (x-axis) and recorded at unloading (y-axis) for matched trips in the SLL, 2017-2019. (n= 3714 trips for target tuna species; n=2664 for swordfish; black lines show 1:1 relationship between logsheet and unloadings) Note that one outlier data point has been removed from the BET graph to improve clarity.

Table 9: Total weight of fish (in metric tonnes) reported in logsheets (LOG) and unloadings reports (UNL) across 2,513 matched trips in the TLL sector and 3,714 matched trips in the SLL sector.

	TLL			SLL		
Species	**LOG**	**UNL**	**% under/over**	**LOG**	**UNL**	**% under/over**
ALB	3,044	3,455	12%	52,201	57,874	10%
YFT	7,528	8,301	9%	14,809	18,644	21%
BET	5,712	7,140	20%	3,027	3,821	21%

Discards

Under the FFA HMTCs, vessel operators are required to: *"(a) duly complete in the English language, daily reports in the prescribed form of: (i) all catch; and (ii) by-catch by species; taken in the fishery waters of the licensing member including the high seas and shall certify that such information is true, complete and accurate; and (b) ensure that accurate records are maintained and submitted to the licensing member of all catch discarded at sea and all by-catch transhipped or unloaded offshore*". Likewise, under WCPFC CMM 13-05[13], CCMs are required to ensure vessels flying their flag provide daily catch and effort records of all species caught by the vessels and covered by relevant sections of the Scientific Data to be Provided to the Commission. To that end, we have assumed that all non-reporting of discards is technically 'unreported', although we acknowledge that domestic legal frameworks may vary.

For discarded species, the basic equation used to estimate underreporting was the proportion of underreporting for each species * the total estimated volume of discards of that species. Estimates were made for each of the TLL and SLL areas. The total volume of discards was estimated by applying the average discard rate for each species calculated through observer coverage (SPC, 2020) against the total reported volume of that species for each sector. Discard rates used for each species are set out in Table 10.

Table 10: Rates of discarding for key target and non-target species in the WCPO longline sector. (source: SPC, 2020; rates for billfish and other species carried over from SPC advice for the 2016 study)

Species	**ALB**	**BET**	**YFT**	**BIL**	**OTH**
Proportion discarded	1.0%	2.7%	2.7%	8%	39%

The available evidence indicates that reporting of discards, particularly for non-shark species, is extremely limited in the longline sector. In the analysis of RMI, FSM and Palau EM trial data described above, Brown et al (2021) reported that "*discards of tuna, billfish and turtles were almost never reported in logbooks, though EM and human observers did observe discards for these taxa*". Reporting of shark discards was relatively consistent between EM and logsheets in FSM and RMI, however the shark discard rate was around 7.7 times higher for EM compared to logsheets in Palau.

Albeit based on a small number of trips, observer data available for this study showed a similar story. In the TLL sector, YFT and BET discards were not reported by the vessel across 25 trips, while OTH species were also almost never reported (Figure 20). The ALB logsheet discard catch rate was approximately 23% of the observer catch rate, while shark discard reporting was mixed. In the SLL sector, reporting rates were similar. No discards of either BET or YFT were reported in logsheets across 72 trips, while OTH species were reported extremely infrequently (Figure 21). Logsheet

[13] https://www.wcpfc.int/doc/cmm-2013-05/conservation-and-management-measure-daily-catch-and-effort-reporting

discard catch rates for ALB were around 5% of that reported by the observer, while sharks discard reporting was again mixed.

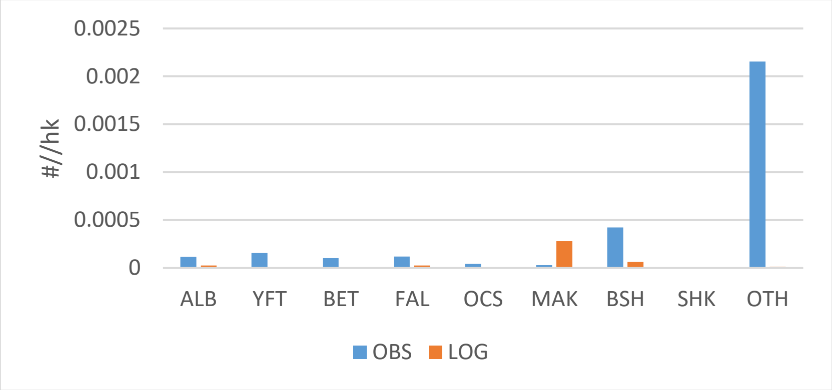


Figure 20: Comparison of catch rates for species discarded in the TLL sector (n=25 trips).

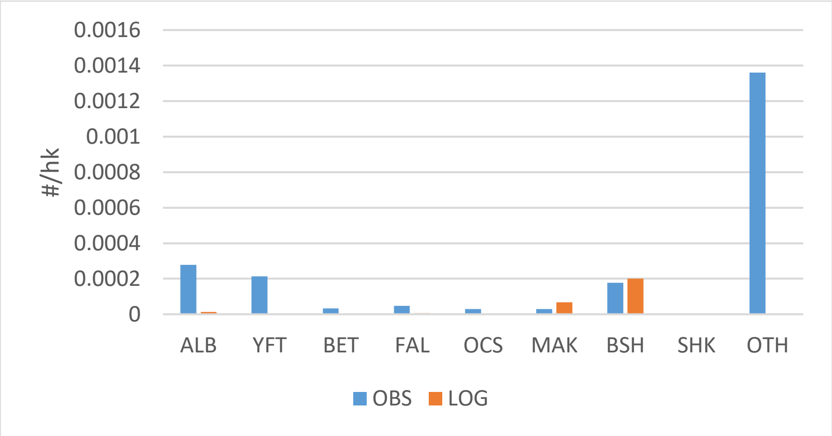


Figure 21: Comparison of catch rates for species discarded in the SLL sector (n=72 trips).

For the purposes of this study, we set the maximum discard under-reporting figure for BET, YFT and BIL at 99% to account for the few vessels that report discards (Table 11). For ALB and OTH, we set the maximum figure to 95% given that, in the case of ALB the logsheet catch rate was only 5% of the observer catch rate in the SLL, and in the case of OTH, some shark species appear to be reported well in some jurisdictions. The best estimate figure was set at 95% to account for the possibility that a larger number of vessels (than those for which records were available for this study) report discards. The minimum figure was set at 70% to account for the possibility that some fleets report discards, although based on the available data this figure may be very conservative.

Table 11: Estimated under-reporting rates of key longline species in percentage of total discards.

Species	Min	BE	Max	Dist.
Discarded catch				
ALB	70%	90%	95%	Triang.
BET	70%	95%	99%	Triang.
YFT	70%	95%	99%	Triang.
BIL	70%	95%	99%	Triang.
OTH	70%	90%	95%	Triang.

2.5.3 Non-compliance with other license conditions

2.5.3.1 Fishing on a FAD when not authorised

Setting on a Fish Aggregation Device (FAD) when not authorised is principally an issue for the purse seine sector, although the license conditions of many FFA members restrict longlining around anchored FADs to restrict access to other sectors (artisanal, purse seine). In the context of this project, we have maintained the definition of a FAD used in the 2016 study, namely that a FAD is "... *any object or group of objects, of any size, that has or has not been deployed, that is living or non-living, including but not limited to buoys, floats, netting, webbing, plastics, bamboo, logs and whale sharks floating on or near the surface of the water that fish may associate with*" (WCPFC, 2009). To that end, we have not attempted to estimate the level of illegal FAD fishing in the LL sector, and there is general acknowledgement the level of IUU activity is likely to be very small.

In the purse seine sector, setting on schools associated with floating objects is prohibited under CMM 20-01 (and predecessors) during the months of July to September. During the study period, additional arrangements were also in place for a fourth month closure as well as a closure of two additional sequential months in the high seas. Nevertheless, we are aware that some flag states provide exemptions for their vessels to fish on FADs during the closure and this represents a key source of uncertainty in the available data.

In the 2016 study, the main source of data used was an analytical study by Hare et al (2015) who developed an approach using observer catch sampling and other factors to retrospectively predict purse seine set type. In their analysis, they used a series of models based on tuna species composition, tuna length, bycatch species composition and non-sampling variables (e.g. temporal and spatial variables) to predict set type. Using their best performing model, they estimated that an average of 11.6% of sets identified as 'unassociated' during the FAD closure periods between 2009 and 2012 were likely to be associated, with a minimum rate of 7.1% in 2010 and a maximum rate of 15.9% in 2012. However, this analysis has not been repeated during this study period.

To that end, the best available information for the current study comes from observer reporting. Given the 100% observer coverage requirement in the PS sector, observer data should be very representative. However, the approach used represents a substantial departure to the approach used in 2016 and results should be seen in that context.

To examine scope for illegal FAD setting, SPC provided data on all instances of observer FAD set reporting during relevant closure periods which met the following criteria:

- FAD closure months as July, August and September for these years
- FAD fishing is any set on natural drifting LOG (no beacon), drifting FAD and anchored FAD
- Charter and flagged vessels for PNA member countries are exempt when fishing on FADs in their home waters (e.g. see footnote 1 in CMM 2018-01)
- Fleets choosing the IATTC measures in the WCPFC-IATTC Overlap area (EU-Spain, Ecuador and El Salvador) are excluded
- Kiribati fishing in the adjacent high seas areas is excluded (see para 17. in CMM 2018-01)
- Fleets that were exempt from high seas FAD closure due to PS BET catches within the limit in 2016 (see footnote 5 in CMM 2016-01)[14].
- Tropical fishery only, outside Archipelagic waters.

[14] One fleet thought it was open to fishing on FADs for the whole year and it could be interpreted that way.

After screening data, a total 42 FAD sets were reported by observers during the FAD closure period: 6 sets during 2017, 9 during 2018 and 27 during 2019 (albeit 18 of these were fished by a single vessel which may have been chartered to Kiribati and therefore exempt).

The basic equation used to estimate IUU catch for this risk was the estimated number of illegal FAD sets * average catch rates and species composition for associated sets. Considerable economic incentives exist to fish on FADs during the closure period (i.e. higher average catch rates; higher proportion of successful sets) and some degree of illegal setting on FADs likely occurs. During the timeframe covered by the 2016 study, the US Government fined a number of vessels a total of over $6m for setting or fishing on FADs during the FAD closure period[15], while during this study period FSS Palikir apprehended a Taiwanese PS vessel for alleged illegal fishing on a FAD during the closure period during Operation Kurukuru 2017.

In the absence of an updated catch composition study similar to Hare et al (2015), the best estimate value was set at the average number of FAD sets reported by observers during the closure period (Table 12). The minimum value was set to account for the possibility that a number of those sets were possibly undertaken by a chartered vessel with exemptions. The maximum value was set at five times the best estimate value to account for the possibility of unreported FAD sets during the closure period. Importantly, the change in approach to the 2016 study results in a very pronounced reduction in estimates of illegal FAD sets.

Table 12: Best estimate and min/max range for illegal FAD fishing in the purse seine sector (by number of sets during the FAD closure period likely to be sets on floating objects).

Sector	Min	BE	Max	Dist.
Purse seine	8	14	70	Triangular

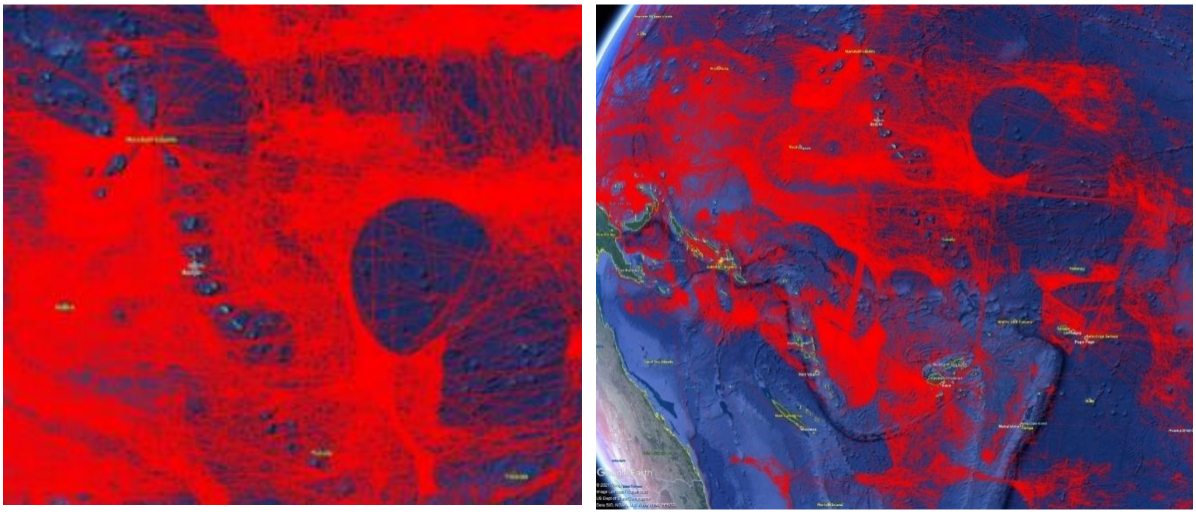
2.5.3.2 Fishing inside closed waters

The majority of FFA members have a number of closed waters provisions, particularly for foreign licensed vessels. Most commonly these take the form of closures around islands (and or reefs) (e.g. 12nm) to reserve these areas for customary and artisanal fishing, or closures to foreign fishing in archipelagic waters (e.g. Solomon Islands, Fiji). Some FFA members also have closures for other purposes (e.g. Kiribati has established the Phoenix Islands Protected Area which has prohibited commercial fishing since 2015[16]).

The information available to support estimates of the extent of fishing inside closed waters was largely limited to VMS data and anecdotal reports. Most FFA members interviewed for the study considered the issue to be relatively minor in the overall scheme of IUU activity. VMS track information, albeit not definitive (in that detects only the presence of a vessel, not whether fishing occurred) appears to show high levels of compliance with closed waters provisions (Figure 22).

[15] http://www.nmfs.noaa.gov/ole/newsroom/stories/13/04_090413_purse_seine_fad_case.html

[16] https://worldheritageoutlook.iucn.org/explore-sites/wdpaid/555512002



(a) *(b)*

Figure 22: VMS tracks showing (a) purse seine and (b) longline vessel activity adjacent to closed areas in 2017-2019.

The basic calculation used to estimate the level of IUU activity in closed areas within FFA member waters was the estimated number of days fishing * average catch rate and species composition for the sector. Whereas in the 2016 study, the numbers of days was estimated as an absolute number, here days were estimated as a proportion of total days average fished in FFA member EEZs in each sector during the study period. The proportion of fishing days was estimated using expert judgement. Catch composition and catch rates inside closed waters were assumed to be the same as the broader fishery.

Purse seine

For the purse seine sector, the available evidence suggests the level of illegal fishing is likely to be negligible. No instances of illegal fishing inside closed waters have been detected by aerial surveillance during regional operations in recent years, VMS data appears to show high levels of compliance with closed waters, 100% observer coverage is likely to act as a deterrent to non-compliance, and no prosecutions or sanctions for purse seiners contravening closed waters provisions were reported by FFA members during the study period. While a number of FFA members interviewed for the study noted that complaints are occasionally received from local communities of vessels 'fishing' inside closed waters, follow up investigations and checks of VMS tracks almost universally indicate no fishing activity (e.g. vessels are sheltering from weather etc).

The ground-truthing workshop agreed that it was possible that some very minor level of illegal activity was occurring though the best estimate and min/max ranges should be set at negligible levels (Table 13). The minimum and best estimates were retained at similar levels to the 2016 study, while the maximum value was reduced (from 50 days to 20 days) to account for the absence of confirmed activity and the strong disincentives to non-compliance in place.

Tropical longline

For the tropical longline sector, the scope for illegal activity is likely to be higher, largely as a result of higher numbers of vessels and fishing days, as well as the operational nature of the gear which can drift tens of nautical miles in a set. Moreover, the limited observer coverage means the disincentives are likely to be lower than purse seine. Nevertheless, as with purse seine, the available evidence for illegal activity appears to be limited. VMS data appears to show high levels of avoidance of closed areas, and anecdotal evidence suggests the number of detections and prosecutions have been low.

FFA members interviewed for the study indicated very low levels of fishing inside closed waters, although FSM reported one case of a longline vessel fishing inside a closed area around Chuuk in 2019 and PNG reported detecting longline vessels fishing inside closed waters during aerial surveillance. As with purse seine, occasional unconfirmed anecdotal reports are received from island communities, although follow up investigations have provided limited evidence of actual fishing inside closed areas.

Southern longline

In the southern longline sector, the evidence suggested the level of illegal activity is likely to be low. VMS information appears to show a high degree of avoidance of closed waters, and no vessels have been detected by aerial surveillance during regional operations fishing inside closed waters between 2017 and 2019. Likewise, of the FFA members interviewed for the study few reported problems, although the Cook Is reported three vessels allowing longlines to float into a closed area in 2020.

Based on the available evidence, the ground-truthing workshop agreed that estimates should account for the possibility that some level of illegal activity occurs, but that overall estimates should be set at low levels.

Table 13: Best estimate and min/max range for illegal fishing activity within closed waters inside FFA member zones (by number of days fishing per year).

Sector	Min	BE	Max	Dist.
Purse seine	0 (0%)	8 (0.02%)	20 (0.05%)	Triangular
TLL	26 (0.05%)	51 (0.2%)	205 (0.4%)	Triangular
SLL	16 (0.05%)	33 (0.2%)	130 (0.5%)	Triangular

2.5.3.3 Shark finning

Shark finning is defined here as the practice of removal and retention of the fins while discarding the carcass at sea. During the study period, CCMs were required under WCPFC CMM 10-07 to ensure their vessels "*have on board fins that total no more than 5% of the weight of sharks on board up to the first point of landing*", or alternatively require that their vessels land sharks with fins attached to the carcass[17]. Although some FFA members go further than this by prohibiting the retention of sharks (e.g. Palau, RMI), CMM 10-07 effectively the practice of shark finning throughout the Pacific Islands region.

Quantitative information on shark finning is largely limited to analysis of regional observer information, together with boarding and inspection reports from national level compliance programs. In the purse seine sector, the proportion of sharks reported finned by observers has decreased substantially over time, with only a very small numbers being reported during 2017-2019 (Figure 23). In the longline sector, which takes a higher volume of sharks overall, the proportion of finned sharks on observed trips decreased substantially from 2009 onwards with only very small proportions reported as finned during the study period (Figure 23). Nevertheless, rates of observer coverage in the longline fishery remain very low and there is likely to be a strong 'observer effect', where vessels avoid non-compliant behaviour while the observer is present.

[17] Noting that possession of some shark species is prohibited under different CMMs, CMM 19-04 now requires that sharks be landed "with fins naturally attached to the carcass".

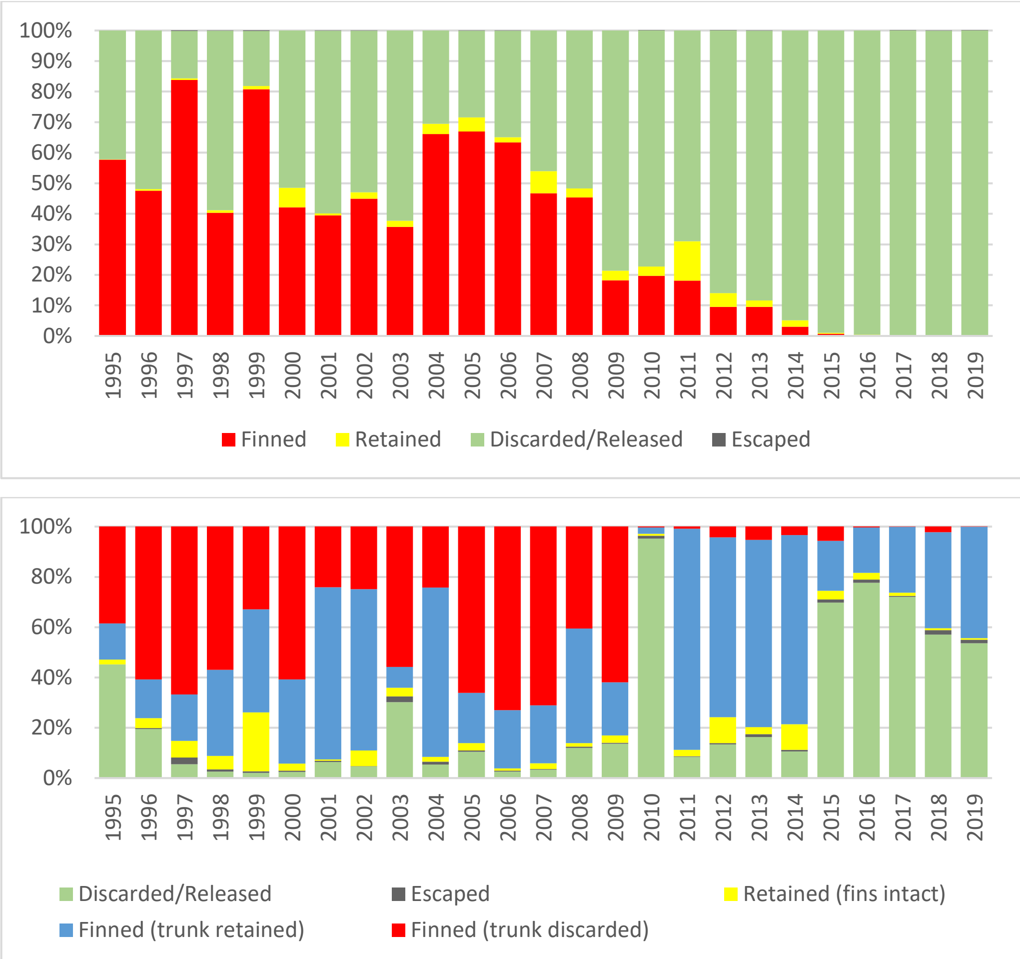


Figure 23: Fate of sharks in the purse seine sector (top panel) and the longline sectors (bottom panel) as reported by FFA member observers, 1995-2019 (Data source: SPC). Purse seine observer coverage has varied over this time series, but has been ~ 100% from 2010 onwards. In the longline sectors, observer coverages rates have been very low over this timeseries, particularly during 2009-2015 when more observer effort was directed towards the purse seine sector. To that end, caution is required when interpreting the longline sector data.

For the purposes of our analysis, we have assumed that all instances of finning where the trunk has been retained have been undertaken legally.

Given the considerable disparity in observer coverage, we have used slightly different approaches to estimate rates of illegal finning in each sector. In the purse seine sector, given the 100% observer coverage requirement, we have used observer reports as a direct measure of finning. The estimated weight of fins was calculated using the estimated number of finned sharks*the average weight per shark*a nominal wet weight fin:carcass ratio of 5%. We acknowledge this fin:carcass ratio will not hold for all sharks (see for example, Francis, 2014), although this is the ratio adopted by WCPFC in CMM 10-07. Estimated wet weight of fins taken was multiplied by a nominal ex-vessel price of $8/kg for fins (although this will vary by species and fin size and information on actual prices paid was limited)[18]. Based on observer reports, the average number of sharks finned across the 2017-19 period was 12.

[18] Assuming a ~40% dry weight to wet weight ratio for fins, $8/kg wet weight will equate to $20/kg dry weight.

While purse seine vessels are subject to 100% observer coverage, discussions with experienced observers indicated that there are times and/or areas on board the vessels where finning may occur out of sight of the observer. For example, finning may occur on deck during hauling and brailing in areas out of sight of the observer, during transfer of fish between brine wells and dry wells or below deck as fish move through conveyors and chutes. Quantitative evidence on the extent to which this might occur however is absent. Given the potential for some level of unobserved finning to occur, we have used the average observer reported figures here as the minimum value. The best estimate value was set at 3x the minimum and the maximum was set at 10x the minimum to account for the possibility of a higher level of unobserved finning. Nevertheless, we note that these estimates remain uncertain.

In the longline sector, the information available was both limited and mixed. Observer coverage is considerably lower than the purse seine fishery (<5% in many FFA EEZs), and no DWFN observer data was available for this study. Estimates for the 2016 study were informed by an analysis of the fate of sharks across longline fisheries in the WCPFC area (including estimates of finning; Rice et al, 2015), although the same information was not available for the current study period.

Anecdotal information from a number of FFA members indicated that rates of shark finning may have decreased in recent years. For example, Fiji advised that as a result of NGO pressure, a number of the larger logistics carriers (e.g. Maersk, Air Fiji) stopped carrying fins in the mid-2010s. As a result, local shark fin exporters closed their operations, with most vessels now releasing all sharks. FSM advised that they'd seen less shark finning since the introduction of a prohibition on sharks in 2015. RMI indicated they hadn't seen any substantial evidence for widescale finning, albeit uncertainties remained, while the Solomon Is also indicated they hadn't detected much evidence of finning during patrols.

Some reports also indicate that a combination of public pressure from NGO pressure on key airlines and logistics service providers to stop carrying shark fin, NGO campaigns in target markets against shark finning, the addition of a number of shark species to the CITES list, a decision by the Chinese Government to prohibit shark fin soup at official functions and a number of high profile celebrities publicly vowing not to eat shark fin soup has reduced market demand in China and Hong Kong up to 80%[19]. Moreover, studies of consumer attitudes in Hong Kong indicate declining consumption of shark fins over the past decade (e.g. Ho and Shea, 2021), while Dent and Clarke (2015) also concluded that, based on trends to 2012, the shark fin import trade into Hong Kong and mainland China would continue to contract.

Nevertheless, information from other FFA members indicated potentially higher rates of finning, at least amongst some fleets. For example, in one case in Samoa in which a quantity of frozen shark fin and semi-processed shark fin 'noodles'[20] were found on a longline vessel during an inspection in Apia in 2018, the captain advised during interview that all captains within his company fleet did it. He advised that both senior officers and crew were involved, with all getting a share of the returns. In another case, Tonga advised that a New Zealand Air Force patrol during OP-NORPAT 19 detected a longline vessel in Tonga's EEZ with a quantity of dried and processed shark fins on board. Upon inspection of it, and another vessel from the same company, shark fins were found and confiscated

[19] WildAid, (2018); https://thediplomat.com/2013/12/no-more-shark-fin-soup-at-ccp-banquets/; https://blogs.scientificamerican.com/food-matters/fin-the-end-putting-a-stop-to-the-consumption-of-shark-fin-soup/; https://www.aljazeera.com/features/2014/4/10/shark-fin-soup-sales-plunge-in-china; https://www.scmp.com/news/hong-kong/economy/article/2089229/chinas-biggest-airline-bans-shark-fin-cargo

[20] DNA testing revealed these to be oceanic white-tip shark (*Carcharhinus longimanus*)

from both. Moreover, information from charges laid against other vessels fishing in the region suggest the practice may be prevalent in other fleets[21].

In addition, some recent media reports indicate the shark fin trade remains very active in Hong Kong[22], while other markets are emerging or bigger than previously known (e.g. Southeast Asia; Dent and Clarke, 2015; WildAid, 2018). Another recent study of the origins of silky shark fins in markets in Hong Kong and Guangzhou (China) between 2014 and 2017, confirmed that all fins sampled came from the Indo-Pacific region (Cardenosa et al, 2020) (although these may be taken outside the study area and within legal frameworks).

Given the uncertainty in the underlying data and the conflicts in the available information, we have kept our estimates of finning in the longline sector deliberately broad. Our basic approach was to first estimate the overall shark catch in our study area by scaling down the WCPFC-CA wide estimates of shark catch produced by Peatman and Nichol (2020) based on relative levels of effort inside and outside the study area. Next we apportioned the estimated catch into the TLL and SLL areas based on relative effort. From these estimates, we estimated the proportion of sharks which were discarded based on observer data on shark fate provided by SPC (~38% of sharks retained; ~1% escaped; ~61% discarded)[23]. From the estimated volumes discarded we applied minimum and maximum estimates of the proportion likely to have been finned. Given the substantial uncertainty in the underlying information, a uniform distribution was used for Monte Carlo simulations (accordingly, a best estimate value was not required).

The minimum value was set at 5% in recognition that the available FFA observer data (showing around 1.3% of discarded sharks were finned) is likely to be subject to at least some level of 'observer effect' and no information was available for high seas longline vessels which are arguably subject to less intensive MCS. To that end, the 1.3% of sharks reported finned by observers is likely to be unrealistically low. The maximum figure was set at 40% (of discarded sharks) taking into account the testimony from apprehended vessels indicating a wider problem and to account for the possibility of a higher level of finning. These proportions were applied in both the TLL and SLL areas given the absence of information to indicate a difference in finning rates between the two. Nevertheless, these estimates remain highly uncertain and should be refined in future iterations of the model, subject to better information being available.

Table 14: Min/max proportion of discarded sharks finned in the longline sectors.

Sector	Min	BE	Max	Dist.
Longline	5%	NA	40%	Uniform

2.5.3.4 Use of non-prescribed gear

Non-compliance with gear use provisions is largely an issue for the longline sectors rather than purse seine. In the longline sectors, the main issue relates to the use of wire trace and 'shark hooks' (lines running directly off longline floats or branchlines) which are prohibited under most FFA member license conditions. During the study period, CMM 14-05 also required CCMs require their vessels to either not use wire trace and/or not use shark hooks. Both wire trace and shark hooks are

[21] https://www.justice.gov/opa/pr/owner-japanese-fishing-vessel-charged-unlawful-trafficking-shark-fins

[22] https://www.theguardian.com/environment/2020/jul/06/shark-finning-why-the-oceans-most-barbaric-practice-continues-to-boom

[23] Note that we assumed all sharks retained complied with CMM10-07, even if fins were removed, and sharks reported as 'escaped' were not finned.

predominantly used to target sharks. The information available to quantify the use of wire traces/shark hooks is relatively weak and largely limited to isolated boarding and inspection reports, dockside monitoring reports and observer reports.

Given sharks are the main target species where wire trace/shark hooks are used, the basic equation used to calculate the level of illegal take is the proportion of the overall shark catch taken while using illegal wire traces/shark hooks. In light of the economic incentives to catch sharks, the 2016 ground-truthing workshop agreed that it was at least likely that some use of wire trace/shark hooks occurs and the min/max range should be set broadly to take into account the uncertainty in the information base. No evidence was available to suggest that illegal use of wire trace/shark hooks is higher in either the TLL or SLL sector.

Of the FFA members interviewed for the study, most reported no detection of wire traces amongst local fleets, although the Solomon Is reported one case detected during a surface patrol in 2017. Fiji noted that no wire traces had been detected through dockside inspections and the market for shark fins had become more limited than in recent years. Others also reported limited evidence of wire trace usage, although very limited information is available on the use of wire traces in the high seas longline fleet.

Given the very limited evidence for the use of wire trace and shark hooks, the ground-truthing workshop agreed that estimated proportions of IUU take could be reduced substantially on the 2016 figures. To that end, the minimum was set at 0.5% to acknowledge some level of usage, while the maximum was set at 5% to account for the possibility of a higher level of undetected usage amongst fleets with limited MCS coverage (Table 15). The best estimate was set closer to the minimum estimate.

Table 15: Best estimate and min/max proportion of sharks taken using non-prescribed gear.

Sector	Min	BE	Max	Dist.
TLL	0.5%	2%	5%	Triangular
SLL	0.5%	2%	5%	Triangular

2.5.3.5 Vessels exceeding catch/effort limits

This is a new IUU risk added since the 2016 estimates. In practice, a number of quantitative limits on catch and/or fishing effort are applied to either flag States or individual vessels as part of management arrangements within the Pacific Islands region. For example, in the purse seine fishery, effort limits (expressed as a number of fishing days) are applied both in zone through the PNA's VDS as well as in non-PNA EEZs and the high seas under CMM 20-01 and its predecessors. In the longline fishery, flag State based catch limits are applied for some species (e.g. bigeye tuna), while for some others (e.g. albacore, striped marlin) limits are applied on the number of vessels able to target the species within certain areas.

At the WCPFC level, flag State compliance with CMMs is examined through the Compliance Monitoring System (CMS). Based on the available evidence, the level of CCM compliance with each obligation is categorised (through a collective judgement of members) according to one of a number of categories ranging from 'compliant' to 'priority non-compliant' where members consider a serious breach has occurred. CCMs may also be assessed as 'capacity assistance needed', where assistance is required to help support implementation of the measure, or 'not assessed', where consensus is not reached on the compliance status of a member. For the purposes of this study, we have included in our estimates only instances where CCMs have been judged by WCPFC members as being priority non-compliant.

In the purse seine fishery, two flag States have been assessed as priority non-compliant against high seas fishing effort limits over the 2017-2019 period[24]. The total number of days for which flag States have exceeded limits is known. Our estimates for this risk are based on the average number of days for which high seas allocations have been exceeded across the three years * the average purse seine catch rate and species composition per day.

In the longline sector, one flag State has been assessed as priority non-compliant against south Pacific albacore vessel limits during the study period. The total number of excess vessels are known. Moreover, the total catch of south Pacific albacore for the relevant year in which the breach occurred is also known. Our estimates for this risk then are based on the proportion of the total catch likely to be taken by the 'excess' vessels (assuming catch was equally distributed across all vessels). This was then averaged across three years to account for the fact that no non-compliance was detected for the remaining two years of the study period. Given the geographic nature of the vessel limit (i.e. south of 20ºS), this risk applied only to the SLL sector.

2.5.4 Post-harvest risks

2.5.4.1 Illegal transhipping

Under the FFA HMTCs, transhipment at sea is prohibited for foreign vessels (except for authorised group seiners in PNG). The practice has also reportedly been prohibited for domestically-flagged vessels across most FFA member EEZs, although some limited forms of at-sea transhipment are allowed in some EEZs (e.g. Fiji allows catch consolidation of fresh fish amongst domestic longline vessels to facilitate efficient transfer of catch to market. In Fiji's case no transfer to carriers is allowed, and any catch consolidation requires prior authorisation from the Ministry of Fisheries).

Under WCPFC CMM 09-06, transhipment at sea by purse seine vessels is prohibited (except for authorised PNG and PH flagged group seiners and NZ flagged domestic vessels), while transhipment on the high seas is allowed for other vessels (including longline) which have received approval from their flag State (after meeting requirements set out in the CMM). All transhipments at sea require an observer from the WCPFC ROP on the receiving vessel[25], and the submission of a WCPFC Transhipment Declaration by both the offloading and receiving vessel for each transhipment.

Historically there have been challenges in tracking transhipping behaviour with WCPFC (2013) noting "*the limitations of the WCPFC VMS to the high seas make it impossible for the Commission to track carriers throughout the Convention Area. Therefore transhipping maybe occurring at sea inside national waters with no reports being received, or if received by the individual member countries no regional analysis of this data is presently available*" and moreover that "*there continues to be a problem in knowing what carriers coming into the Convention area are intending to do, it is not known if all carrier vessels transhipping at sea are carrying an observer, as it is impossible for the Commission Secretariat to know how many carriers intend to tranship at sea. VMS checks on carriers show that many do not have observers when they are viewed on the high seas however it is not known if these carriers are transiting to ports to tranship therefore not requiring an observer, or whether they intend to tranship at sea either in a EEZ or on the high seas*."

For the 2016 study, the information base supporting estimates of illegal transhipping was highly uncertain, particularly in the longline sectors. Notwithstanding the longstanding requirement under CMM 09-06 to place observers on the receiving vessel, very few observer reports had been

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[24] Note that one additional flag State was assessed as priority non-compliant in two WCPFC Compliance Monitoring Reports, but subsequent analysis demonstrated that actual levels of fishing did not exceed effort limits.

[25] With the exception of transhipments to receiving vessels <33m, and not involving purse seine or frozen longline caught fish. In this case, the observer can be either on the catching or receiving vessel.

submitted to the WCPFC to allow for cross-referencing against transhipment declarations submitted by fishing vessels and carriers. Moreover, FFA member visibility of high seas VMS data was limited. To that end, estimates of illegal transhipping were largely based on expert judgement, supplemented where possible with very limited aerial and surveillance data and preliminary analysis of AIS and VMS data. Min/max range estimates were kept deliberately broad to account for the high level of uncertainty.

For the 2020 update, the information base has improved somewhat, although not to the extent that estimates can be made with high confidence. Information available from observers placed on high seas transhipment carriers remains very limited, meaning there continues to be very little capacity to cross-reference either the number of transhipments reported by longliners/carrier vessels or the volume and species composition of fish transhipped. Moreover, although observer coverage of the high seas longline fleet has improved, it remains relatively low (~5%) in the context of monitoring compliance, data collection protocols do not provide for independent estimates of the transhipped catch and no data from high seas longline observer programs was available for this study. In addition, given the expense associated with undertaking MCS activities on the high seas, aerial and surface surveillance coverage of high seas areas remains relatively low.

Nevertheless, two forms of data were available for the 2020 update that allowed for more informed estimates:

- The WCPFC Transhipment Declaration dataset, which provides information on transhipments reported to the WCPFC by offloading and receiving vessels under CMM 09-06 including offloading and receiving vessel names, date and location of transhipment and volumes, species composition and product type transhipped (e.g. whole round, gilled and gutted, headed, gilled and gutted, etc); and
- The Global Fishing Watch (GFW) AIS dataset, which provides fine scale spatial position information at relatively high frequency (position reports every few minutes) for all vessels within the study area transmitting via AIS.

Importantly, while FFA has required all foreign fishing vessels to be fitted with AIS as a precondition of registration on the FFA VR since July 2015, AIS coverage for fishing vessels within the WCPFC-CA is not comprehensive. Under SOLAS regulation V/19 - *Carriage requirements for shipborne navigational systems and equipment,* AIS is compulsory only for some vessel classes on some voyages (e.g. vessels >300 GT on international voyages). Moreover, fishing vessels are exempt, AIS units are able to be manually switched off and actual transmission rates can be influenced by the remoteness of the location or the quality of the transmitting unit. Nevertheless, around 70% of vessels >24m on the WCPFC RFV have been matched to AIS records in the GFW database. This does not mean that vessels will be transmitting at all times, but does mean a relatively high proportion have some level of AIS functionality.

To that end, we were able to cross-reference 'encounters' (defined as a carrier vessel and a fishing vessel that are within 500 meters of each other for at least 2 hours and traveling at < 2 knots, while at least 10 kilometers from a coastal anchorage) and 'loitering events' (defined as a carrier vessel travelling at < 2 knots for at least 1 hour, while at least 20 nautical miles from shore) identified in the GFW AIS dataset against transhipments reported to the WCPFC to identify the sub-set of 'unmatched' encounters/loitering events[26]. In this context, examining loitering events by carriers is important because rates of AIS usage are generally higher on carriers than fishing vessels. An unexplained loitering event by a carrier may provide an indication of transhipment where the fishing vessel/s were not transmitting via AIS.

[26] To prevent duplicate events, any loitering event that overlapped in time with an encounter of the same vessel, or was within 4 hours of an encounter by that same vessel, was removed from the total event count.

Broadly, the following process was used to (i) match AIS encounters and loitering events to reported WCPFC transhipment events (to identify 'unreported' encounters/loitering events which were of particular interest), (ii) nominally classify those events by fishery type (purse seine, TLL, SLL), (iii) calculate an estimated total number of encounters from loitering data and (iv) back-calculate likely transhipment volumes and species composition from each of the TLL and SLL areas from matched AIS/WCPFC data.

GFW provided their dataset of all AIS-detected encounters and loitering events for all registered fishing carrier vessels within the study area in the years 2017-2019. Encounters and loitering events were categorised according time 'bins' of 2-4hr, 4-12hr, 12-24hr and 24hr+ in the case of encounters and 1-2hr, 2-4hr, 4-12hr, 12-24hr and 24hr+ in the case of loitering events to provide an indication of the length of the event[27]. In total, 7,306 events were detected, with the distribution of encounters/loiters according to time bin and sector set out in Table 16. The geographical distribution of events according to event type and duration is shown in Figure 24.

Table 16: Encounters and loitering events detected via AIS in the study area, by region and duration, 2017-2019 (Data source: GFW). (Note, the 'Topical' area matches the TLL boundaries; the 'Southern' area matches the SLL boundaries)

Duration	**Tropical**		**Southern**	
	Encounter	Loitering	Encounter	Loitering
1-2hr	0	917	0	56
2-4hr	471	1106	134	71
4-12hr	553	1787	180	167
12-24hr	161	782	55	105
>24hr	24	678	15	44
Total	1209	5270	384	443

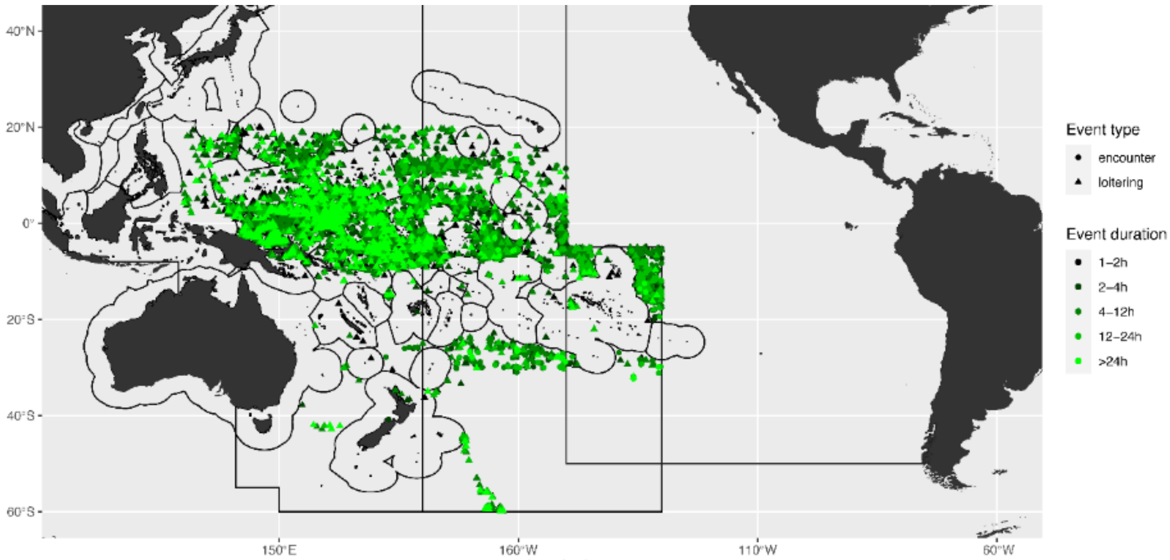


Figure 24: Distribution of AIS detected encounters/loiters within the study area, 2017-2019 (Data source: GFW)

The details of all high seas transhipments reported to the WCPFC through Transhipment Declarations under CMM 2009-06 during 2017-2019 were sourced from the WCPFC Secretariat

[27] The GFW dataset underlying dataset includes encounters >2hr only, so no 1-2hr encounter data were available. Nevertheless, these events would be captured in the 1-2hr loitering data because a 1-2hr encounter is, in effect, a 1-2 loitering event for both the carrier and fishing vessel in very close proximity. To that end, the absence of 1-2 hr encounter data should not substantially affect capacity to match against WCPFC Transhipment Declarations.

through FFA. Details provided included the name, flag and IMO number of offloading and receiving vessels, the date and latitude/longitude of transhipment and the volume of catch offloaded by species and product type (e.g. whole round, gilled and gutted, etc). In total, 3,337 transhipment events were reported to the WCPFC during the 2017-2019 period within the study area. The geographical spread of events is shown in Figure 25.

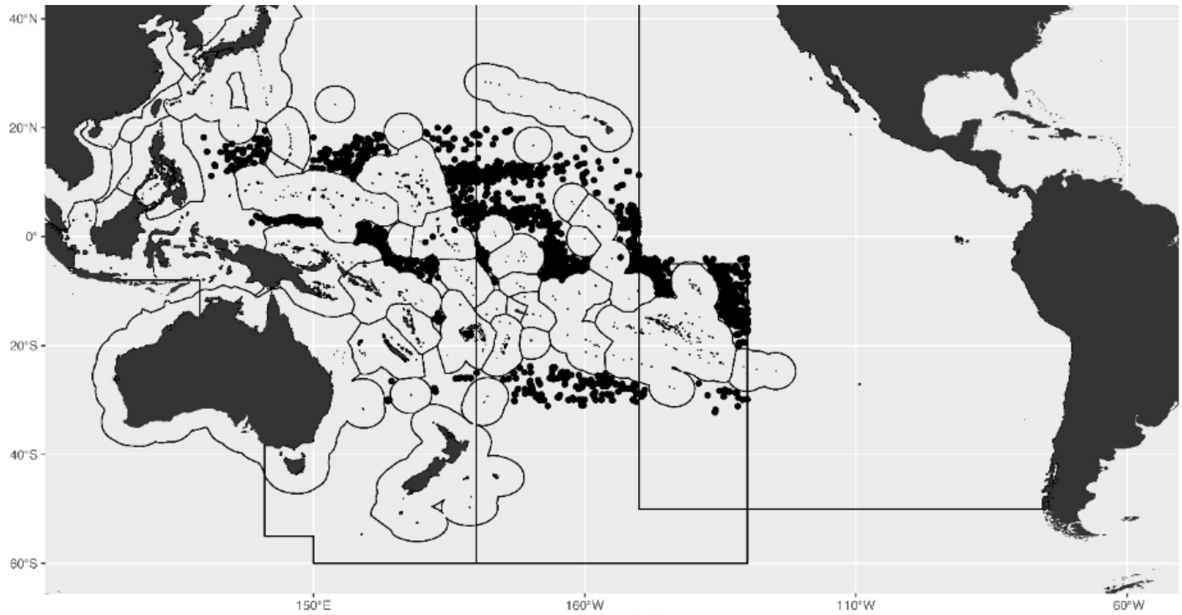


Figure 25: Geographic distribution of high seas longline transhipment events within the study area reported to the WCPFC, 2017-2019. (Data source: WCPFC)

AIS events were matched against WCPFC reported transhipment events using the process described in Annex 4. Broadly, events were considered a match if both the name of the carrier and fishing vessel matched, the date of the WCPFC Transhipment Declaration was within one day either side of the start/stop time of the AIS event and the location was within a specified distance (between 119km and 378km depending on the duration of the event – see Annex 4)[28]. Using this process, we were able to successfully match 2334 of the 3337 WCPFC reported transhipments (70%) (Figure 26).

[28] Although these distances were fairly 'liberal', the manually reported nature of the WCPFC Transhipment Declarations and the mismatched format between WCPFC positions (manually reported lat/long in degrees and minutes) and AIS positions (automatically reported lat/long to decimal places, with the position taken to be the middle position of the event) meant that a wider distance was required to achieve a good match rate.

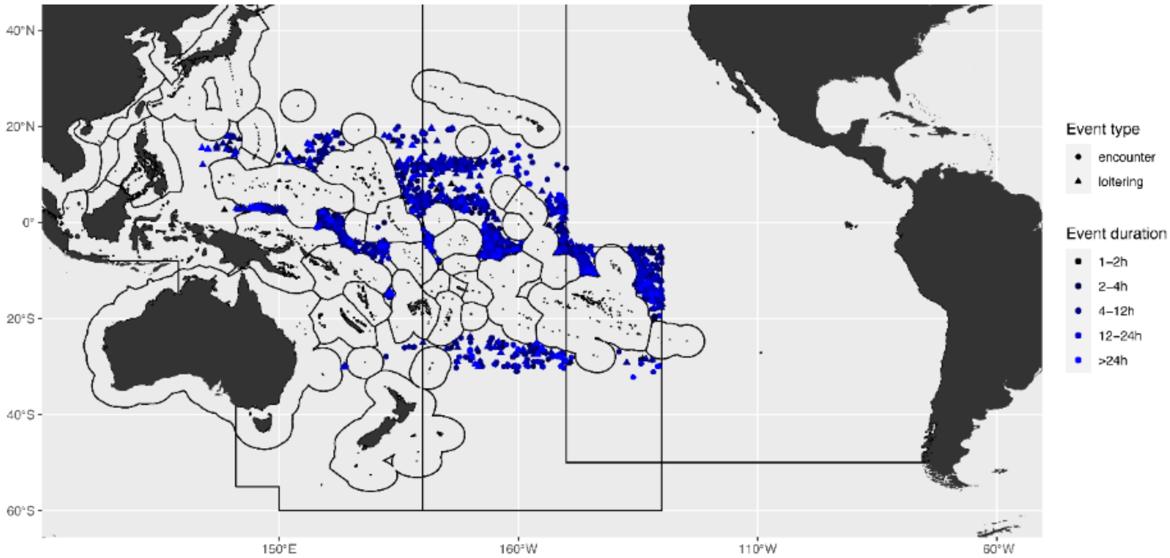


Figure 26: Reported WCPFC transhipments able to be successfully matched to AIS encounters/loitering events.

This process then left 5,068 'unreported' AIS encounters/loiters (i.e. unable to be matched to a transhipment event reported to the WCPFC) and 1003 unmatched WCPFC transhipments (i.e. transhipments reported to the WCPFC but unable to matched to an AIS event).

For the purposes of our estimations, we have assumed these latter events are legal and no IUU fishing has occurred. However, in practice there are a number of ways in which laws may be broken. In particular, the volume and species composition of catch transferred may be misreported (e.g. to obscure catches for species which there are catch limits – e.g. BET) and the location of transhipment may be misreported (e.g. transhipments occurring in EEZs may be reported on the high seas).

On the former risk (misreporting catch volume), despite a requirement for 100% observer coverage on all receiving vessels involved in high seas transhipments in the WCPFC area, our capacity to independently verify volumes and species compositions of high seas transhipments remains very weak. There are no agreed minimum data fields for transhipment observers and very few observer reports are provided to the WCPFC. Accordingly, there is no capacity to compare volumes and species compositions reported by observers against those reported by vessels. To that end, the assumption that all unmatched reported transhipments were all legal and no IUU occurred may be generous. Although a separate dataset was provided by WCPFC detailing the volumes and species compositions of catch transferred on Transhipment Declarations by both the carrier and fishing vessel (for 1642 matched transhipments), there is limited independence in this process and anecdotal information from transhipment observers indicates that the standard practice is for the carrier to accept the fishing vessel estimate. Perhaps unsurprisingly, for around 87% of transhipments, the volumes and species composition by product type matched exactly between the fishing and carrier vessel (and many of those that didn't appeared to be driven by clerical errors – e.g. decimal points missing).

On the latter risk (misreporting location of transhipment), the fact that over 1,000 WCPFC reported transhipment events could not be matched to a corresponding AIS event suggests there is scope for this, although there are a range of plausible reasons a match may not be found. In addition to the reasons AIS may not be transmitting described above (e.g. switched off, out of range), the nature of WCPFC Transhipment Declaration position reporting (lats/longs reported in degrees and minutes; position manually reported by vessels) means there may be sufficient inconsistency with automatically generated AIS positions (reported in minutes, seconds and decimals) to be outside of the distance radius used for our matches. Indeed, the WCPFC Secretariat's own analysis of variance between VMS position and locations of transhipments reported in Transhipment Declarations (Transhipment Events, or TEVs) "*shows discrepancies of 100km or more for 100 TEV's associated* *with 86 fishing vessels and 249 TEVs associated with 23 carriers. The range of variance is 100km up to, in a few cases, several thousand kilometers with 8 instances where the variance exceeds 1,000kms and 20 instances for carriers*" (WCPFC, 2020b). Our analysis of the carriers for which reported WCPFC transhipments were unable to be matched to an AIS event indicated that many of the events were associated with smaller, older carriers. To this end, it is possible that many of the 'non-matches' resulted from these vessels using older and less powerful (Class B) AIS transmission devices. The distribution of these events is broadly similar to the matched events (Figure 27) indicating no geographic trend in the capacity to match to AIS events.

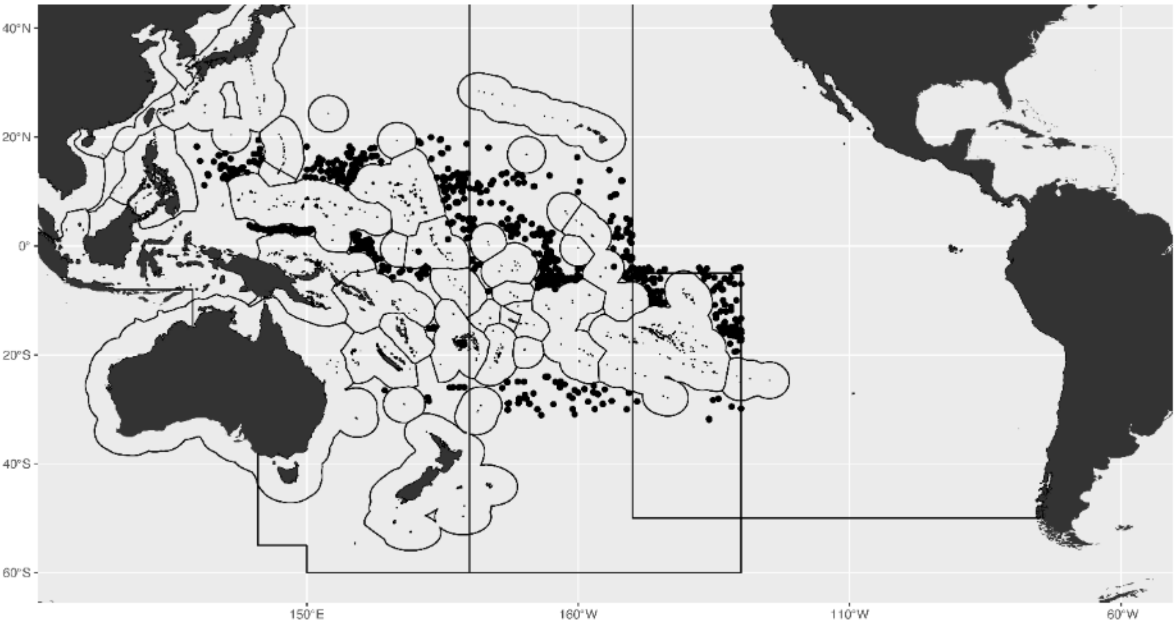


Figure 27: Geographic distribution of reported WCPFC transhipment events unable to be matched to AIS events. Note, transhipments above 20°N are outside of the study area.

Of the 5,068 'unreported' AIS encounters/loitering events during 2017-2019, these were associated with 227 individual carrier vessels. Although there can be some cross-over, carrier vessels transhipping fish in the study area can broadly be categorised into two types: (i) carriers associated purse seine, or canning grade, transhipments and (ii) carriers associated with longline transhipments, typically capable of freezing fish to temperatures required for sashimi markets (~<-50°C). In general, there is little incentive for longliners (particularly those targeting sashimi grade fish) to tranship catch to purse seine carriers because they are typically not geared to hold fish at lower temperatures required for sashimi markets. Moreover, there are practical complications associated with at sea transhipments from small longline vessels to larger purse seine carriers. Likewise, there is little incentive for ULT longline carriers to accept canning grade purse seine fish because the higher volumes involved fill up precious space required for ULT product. This separation of purse seine and longline carrier operations may not hold in all situations – two of the 227 carriers had confirmed encounters at sea with both purse seine and longline fishing vessels – but is a useful general rule of thumb to examine risks associated with different types of operation.

To get some sense of the proportion of unreported AIS events in each fishery sector, each of the 227 individual carriers was nominally categorised into one of three operational types, based on vessel activity during the study period and other indicators:

- Purse seine – these were vessels that frequently visited key purse seine transhipment ports in the Pacific (e.g. Majuro, Pohnpei, Rabaul, Tarawa) and key canning centres (e.g. Bangkok, Songkhla); had confirmed encounters with purse seine vessels at sea; did not receive fish in high seas transhipments reported to the WCPFC; were otherwise known as purse seine carriers from previous research (e.g. MRAG Asia Pacific, 2019)

- Longline – these were vessels that had received fish in high seas transhipments reported to the WCPFC; had frequent encounters with longline vessels at sea (almost always on the high seas) and typically a large number of loitering events amongst confirmed encounters; typically returned to key ports where sashimi grade tuna is sold/processed (e.g. Japanese ports, Busan), rarely calling to port in the Pacific Islands; were otherwise known as longline carriers from previous research (e.g. MRAG Asia Pacific, 2019);
- Unspecified – these were carriers that could not easily be assigned into one of the two categories above. Many of these appeared to be carriers focused largely on transhipments in other fisheries (e.g. squid from the eastern Pacific Ocean; other seafood species in the north Pacific Ocean) who made a very small number of loitering events while transiting through the study area. Others appeared to be focused on carrying non-seafood products (e.g. a number of carriers made very regular and direct runs between the Philippines and Japan), making small number of loitering events (often not deviating from their course) in the study area. In general, these vessels had very few encounters with purse seine or longline vessels in the study area.

Example AIS tracks for nominal longline and purse seine carrier vessels are shown in Figure 28.

Figure 28: Example tracks from nominal longline carrier (top) and purse seine carrier (bottom).

Of the 5,068 unreported AIS events (Figure 29):

- 3,408 (67%) were attributed to purse seine carriers (only 19 of these events occurred south of 10^{o}S);
- 1,012 (20%) were attributed to longline carriers in the TLL area;
- 127 (2.5%) were attributed to longline carriers in the SLL area;
- 352 (7%) attributed to unspecified carriers in the TLL area; and
- 169 (3%) attributed to unspecified carriers in the SLL area.

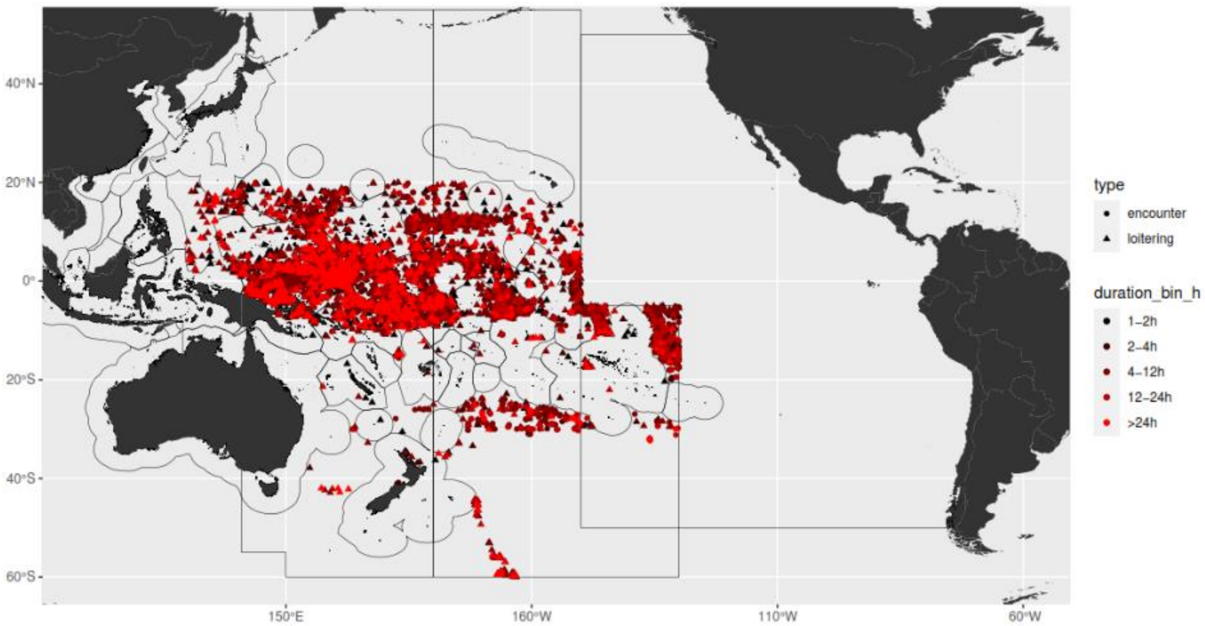


Figure 29: Geographic distribution of AIS encounters/loiters unable to be matched to reported WCPFC transhipments.

The type and duration of event across the sectors is set out in Table 17 below:

Table 17: Unmatched AIS events according to sector and duration, 2017-2019.

Sector	1-2hr	2-4hr		4-12hr		12-24hr		24hr+		Total
	Loit.	Enc.	Loit.	Enc.	Loit.	Enc.	Loit.	Enc.	Loit.	
Purse seine	587	59	663	38	1024	0	513	0	524	3408
Longline - TLL	171	111	218	60	299	3	82	0	68	1012
Unspecified – TLL	58	1	72	0	97	0	55	0	69	352
Longline – SLL	21	19	22	12	27	5	12	1	8	127
Unspecified - SLL	23	1	16	0	64	0	42	0	23	169

For loitering events, there is uncertainty around whether an actual encounter between vessels took place and, if so, how many and over what duration? Data on the duration of actual encounters from matched WCPFC transhipment events indicates that there is a much higher likelihood that actual encounters will be shorter rather than longer in nature (Figure 30), and that longer loitering events are more likely to constitute a series of shorter encounters than a single longer one. These results were ground truthed with experienced IATTC transhipment observers who have experience with transhipment practices in the WCPFC-CA.

On that basis, for the purposes of estimation, we have assumed the following for loitering events:

- Loitering events 1-2hr, 2-4hr, 4-12hr = 1 encounter
- Loitering events 12-24hr = 2 encounters
- Loitering events 24-72hr = 3 encounters.

Nevertheless, this is an important area of uncertainty which should be addressed in future iterations of the study, should better information on carrier behaviour become available (e.g. through observer reports).

To estimate the volume and species composition of fish transhipped during any IUU transhipment event, we have assumed that the encounters in the 12-24hr and 24-72hr events above are 4-12hr encounters. The alternative would be to assume they are 1-4hr events, which is likely to be an equally legitimate assumption, although this ultimately makes limited difference to the overall volume and species composition estimates.

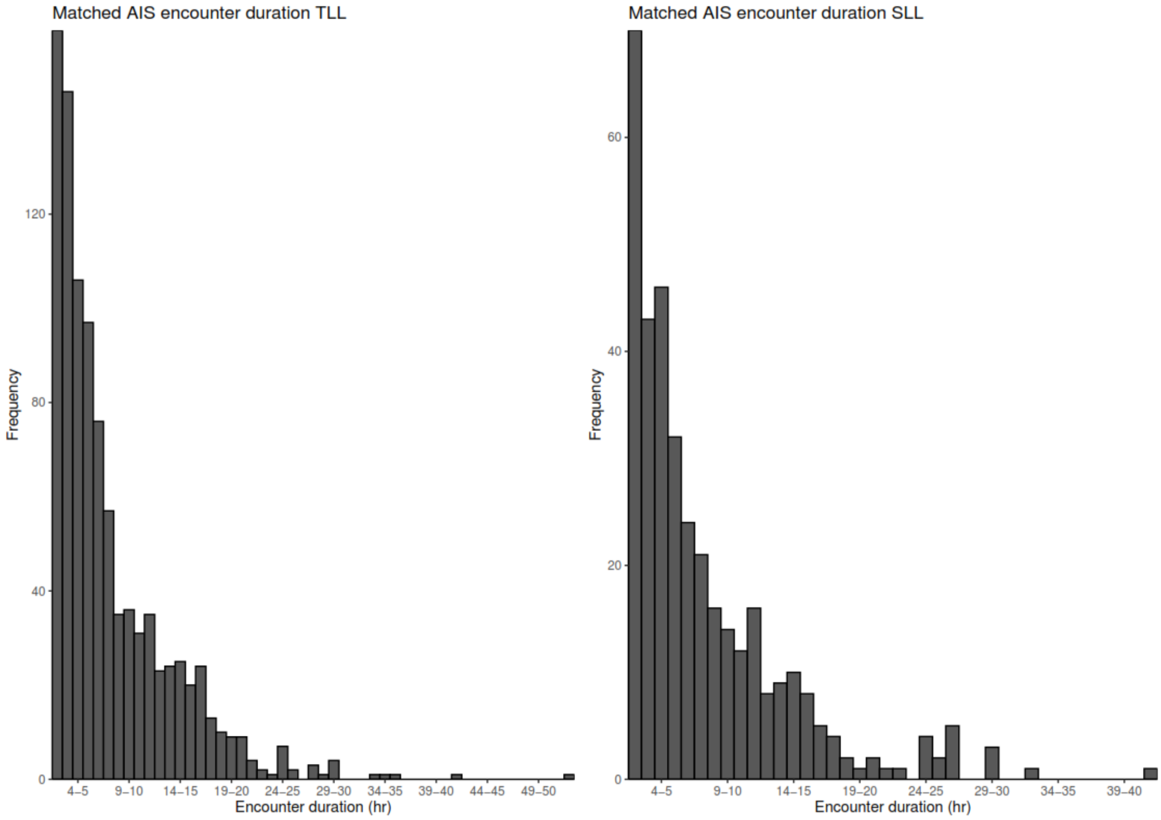


Figure 30: Duration of AIS encounters matched to reported WCPFC transhipment events.

This process then produced a total estimate of encounters by carrier type, duration and area that had not been reported by the WCPFC and provided some indication of the scope for unauthorised transhipment/s to take place. Nevertheless, there are many reasons why carrier (and other) vessels come together at sea which do not involve transhipment. In the high seas longline sector, vessels are often away from their home ports for 18 months+ and rely on meetings at sea with carrier vessels to resupply provisions, bait, gear, spare parts and exchange crew amongst other things (MRAG Asia Pacific, 2019). Although fishing vessels tend to tranship at the same time as receiving supplies, it is not uncommon for meetings at sea to happen without fish transfer. Likewise, in the purse seine sector vessels will often meet up at sea with carriers to exchange crew, take on salt (important for making brine), spare parts and other provisions.

To that end, the dataset of cross-referenced 'unreported' encounters/loitering events was used as a 'starting point' only, with best estimates and min/max ranges chosen based on additional analysis of the characteristics of each sector and encounter type.

Purse seine

In the purse seine sector, the basic calculation used to estimate illegal transhipment activity was the estimated number of illegal transhipments * the average volume and species composition per transhipment. Average volumes of tuna per transhipment were provided by SPC.

Despite the relatively high number of at sea encounters/loitering events, for purse seine vessels, opportunities (and incentives) for illegal transhipment were assumed to be negligible. Transhipment at sea is almost universally prohibited, vessels are subject to 100% observer coverage, considerable financial disincentives exist to non-compliance (for example by tying up vessels caught transhipping at sea) and vessels are subject to 100% VMS coverage, with frequent polling associated with the VDS. Moreover, the nature of the transhipment operation, which typically lasts 3-4 days, means the chances of detection and sanction are higher than in the longline sector (particularly given the 100% observer coverage).

Consistent with the 2016 study, no instances of illegal transhipping by purse seiners have been detected by aerial surveillance in recent years, and no illegal transhipments were reported by observers on GEN-3 forms examined.

To that end, the ground truthing workshop considered it plausible that as few as zero illegal transhipments occurred in the purse seine fishery in any given year, but it was possible a very small number occurred. Accordingly, the best estimate was also set at 0 with a maximum at 10 to account for the possibility of some transhipments (Table 19). A triangular distribution was used for Monte Carlo simulations.

Tropical Longline

In the longline sectors, the basic calculation to estimate IUU volume was the estimated number of illegal transhipments in each time bin in each sector * the average volume and species composition per transhipment for each time bin/sector. Because WCPFC Transhipment Declarations do not currently record a start/stop time of transhipment, to get an indication of the volume and species composition of catch transferred within each time bin, we 'back-calculated' this using information from transhipments matched between AIS encounters and reported WCPFC transhipment events (i.e. for each sector/time bin, average volume and species composition of catch transferred was calculated based on the matched WCPFC transhipments/AIS encounters within each sector/time bin). The estimated average volumes and species composition transhipped in each time bin/sector are set out in Table 18.

Table 18: Average volume of each species transhipped in each 'time bin' in the TLL and SLL sectors. Note that volumes reported in dressed weights (e.g. gilled and gutted, gutted and headed) were raised to whole weights using standard conversion factors.

Time bin	YFT	BET	ALB	BIL	OTH
TLL					
1-4 hr	14.24	18.15	6.75	4.94	1.28
4-12 hr	20.89	30.77	10.30	7.35	1.81
12-24 hr	50.70	71.65	18.67	18.73	6.95
24 - 72 hr	55.68	68.25	39.67	18.53	31.80
SLL					
1-4 hr	2.44	4.31	33.28	1.59	2.75
4-12 hr	4.11	4.57	42.53	4.63	3.76
12-24 hr	7.39	21.93	86.55	9.61	2.82
24 - 72 hr	11.46	45.18	81.83	21.36	20.25

As discussed above, there are a range of legitimate reasons why longline vessels meet with carriers at sea which do not involve transfer of fish. Data on the extent to which this occurs in the WCPFC area is not available unfortunately (given the unavailability of observer data), however analysis of 30 ICCAT ROP transhipments reports (ICCAT, undated) over the 2017 – 2019 period indicates that for each transhipment at sea involving transfer of fish, approximately 0.27 'non-fish transfers' occurred (or alternatively, for every 3-4 transhipments involving a transfer of fish, 1 non-fish transfer occurred)[29]. While there may be minor differences in the operation of the carrier/longline fleets in the Atlantic vs the Pacific, this provides a ballpark figure of how many encounters at sea not involving fish transfer to expect (these events would show up as loitering events on AIS).

Given the weaknesses in the monitoring/reporting of transhipments in the high seas tropical longline sector, estimates of IUU activity were ultimately based on a proportion of unmatched AIS detected encounters for which there was some possibility of IUU activity. The ground-truthing workshop agreed that the scope for IUU activity in the longline sectors was considerably higher than the purse seine sector given the (relatively short) operational nature of the transhipment activity and the absence of effective reporting on interactions at present.

Nevertheless, evidence for actual IUU events is very limited. There have been no confirmed instances of illegal transhipping detected by aerial or surface surveillance through FFA-led regional operations or national operations throughout the study period in the TLL area (albeit transhipment occurs on the high seas which is subject to less surveillance activity). Moreover, FFA members interviewed for the study provided limited anecdotal evidence for illegal transhipment events within their zones. Despite the absence of reporting, the presence of WCPFC observers on receiving vessels is likely to act as a deterrent to illegal activity, and we also note that, in practice, many carrier vessels engaged in high seas transhipment activity in the WCPO will also carry an observer from the IATTC program to allow flexibility to tranship in both zones (which would increase deterrence). Moreover, the ratio of unmatched AIS events detected amongst nominal 'longline carriers' compared to WCPFC reported transhipments (1139 unmatched AIS events to 3337 reported WCPFC transhipment events) is in the ballpark of the ratio observed in the ICCAT area (1:3-4).

While it is plausible that some level of illegal transhipment occurs, given the absence of direct evidence of IUU activity, the best estimate and minimum range figures were set at low levels. For carriers nominally categorised as longline, the minimum and best estimate proportion of unmatched AIS detected events (i.e. encounters, plus estimated encounters per loitering event) assessed to involve IUU activity were set at 0% and 5% respectively. For carriers categorised as 'unspecified', minimum and best estimate values were set at 0% and 3% respectively on the basis that there was less evidence these vessels were involved in longline transhipments and many of the detected AIS loitering events appeared to be relatively brief stops in a direct line transit through the WCPO. Given the uncertainty around reporting and gaps in AIS coverage, the maximum range figure was set at a higher level to account for the possibility of a higher level of undetected IUU activity. To that end, the maximum figure was set at 20% for longline carriers and 10% for unspecified carriers. These numbers were summed to produce estimates of IUU transhipping events in each time bin.

One type of potential 'transhipment' activity that has not been accounted for in the estimates is longliner to longliner transfers of fish at sea. This may occur, for example, where a fleet of associated vessels are working in the same area and one vessel is assigned to collect fish from others for delivery to a transhipment carrier, or if the vessel is returning to home port. There would be financial incentives for this type 'catch consolidation' if it allowed the offloading vessels to continue fishing for longer periods. The extent to which this occurs in practice is unknown, although WCPFC's Transhipment Analysis Tool indicates that longliner to longliner meetings at sea occur more frequently than meetings between other combinations of vessels (e.g. longliner/carrier, longliner/bunker) (WCPFC, 2019). To that end, the estimates presented here may underestimate overall fish transfers between vessels.

[29] 30 trips for which data were available on ROP (fish transfer) and 'non-ROP' (non-fish transfer) were selected amongst trips 201 to 235 (ICCAT, undated).

Southern Longline

In the SLL sector, a similar process was used to arrive at minimum, best estimate and maximum range estimates as that described for the TLL sector above. In practice, we assumed there was no difference in the likelihood of illegal transhipment activity in the southern sector of the longline fishery compared to the tropical sector. The same minimum, best estimate and maximum range estimates were used for nominal longline and unspecified carriers, albeit these produced lower overall estimates of IUU activity given the substantially lower level of transhipment activity in the SLL sector.

Like the TLL sector, actual evidence for illegal transhipment activity in the SLL sector was very limited, although Samoa reported suspected illegal transhipments between four vessels at sea in 2019, together with under-reporting of BET.

Table 19: Best estimate and min/max range for illegal transhipping (by average annual number of illegal transhipments).

Sector	Min	BE	Max	Dist.
PS	0	0	10	Triangular
TLL				
1-4hr	0	9.6	37.7	Triangular
4-12hr	0	16.3	62.3	Triangular
12-24hr	0	0.1	0.2	Triangular
24-72hr	0	0	0	Triangular
SLL				
1-4hr	0	1.4	5.5	Triangular
4-12hr	0	3.6	13.0	Triangular
12-24hr	0	0.1	0.3	Triangular
24-72hr	0	0	0.1	Triangular

Broadly, this process produced estimates of illegal transhipping that were considerably lower than the less data-driven estimates in 2016.

3 Estimates of the volume and value of IUU fishing

This section sets out the main outcomes of simulation modelling based on the 'best estimate', min/max ranges and likely probability distribution for each risk described above. Consistent with the 2016 study, volume and ex-vessel value figures are generally discussed in terms of the 'best estimate' value and the 90% confidence range value. The 'best estimate' value in reality is the 'expected value' generated from simulation modelling. The expected value is a weighted average of the different potential values each risk could have and the associated probability of each value[30]. The 90% confidence range is the range, based on the inputs to the model, simulation modelling suggests there is a 90% chance the actual IUU figure lies within. Another way of looking at it is that there is a 95% chance the actual IUU figure is above the lower end in the range, and a 5% chance it is higher than the higher end. The ex-vessel values are based on the figures outlined for each product in Annex 2.

3.1 Overall estimates

Our simulations suggest the best estimate **total volume of product either harvested or transhipped involving IUU activity in Pacific tuna fisheries during the 2017-19 period was 192,186t, with 90% confidence that the actual figure lies within a range of 183,809t to 200,884t. Based on the expected species composition and markets, the ex-vessel value of the best estimate figure is $333.49m. The 90% confidence range is between $312.24m and $358.17m.** That is, there is a 95% chance the figure is greater than $312.24m and a 5% chance the figure is greater than $358.17m, based on the simulations described above. For context, the estimated IUU volume figure is around 6.5% of the total WCPFC-CA catch in 2019.

This result is a considerable reduction from the 2016 study estimate of 306,440t (276,546t to 338,475t) with a best estimate value of $616.11m ($517.91m to $740.17m). The reduction was primarily driven by substantial reductions in estimates for illegal transhipping and FAD fishing during the closure period (in turn driven by the use of better and different information, respectively) as well as the removal of the 'unauthorised landings in foreign ports' risk. Overall figures were also influenced by changes in fishery dynamics (e.g. catch, effort, price).

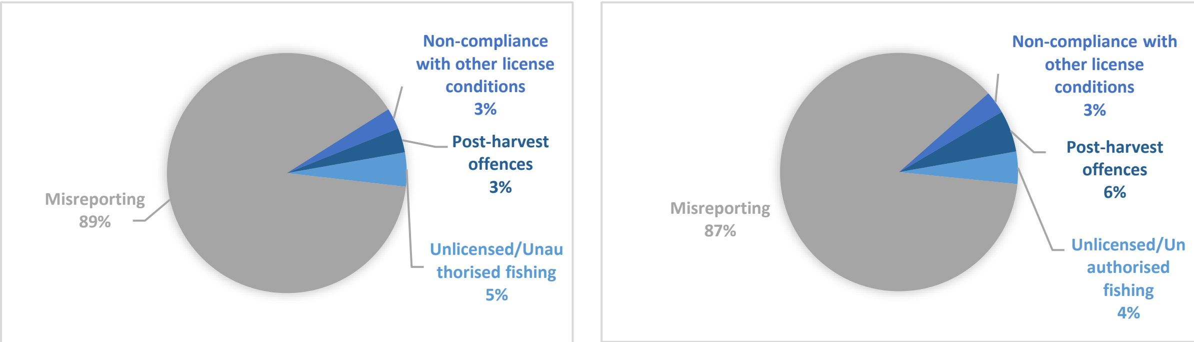
3.1.1 By risk type

Amongst the four categories of risk identified here, the largest contribution to the overall IUU volume was made by misreporting, accounting for 89% of the total volume (Table 20; Figure 31). Importantly, much of the volume associated with misreporting was driven by estimated misreporting and misidentifying target species in the purse seine sector for which challenges exist in estimating catch at sea. In turn, the higher ex-vessel prices received for longline product meant a higher effective price per tonnage for post-harvest risks than other risks. The various types of unlicensed fishing collectively accounted for 5% of overall estimated IUU volume, while non-compliance with license conditions and post-harvest offences accounted for 3% each.

[30] For example, an identified risk resulting in 10MT of catch with 20% probability, 50MT with 60% probability, and 120MT with 20% probability would result in an expected value of 56MT ([10*0.2]+[50*0.6]+[120*0.2]). This expected value is important because whilst 50MT might have seemed a logical value to discuss because of its 60% probability, 56MT takes into account the other possible values of that risk.

Table 20: Estimated total IUU volumes and ex-vessel value in Pacific Islands region tuna fisheries, by risk category.

Risk	BE (t)	90% range (t)	BE ($)	90% range ($)
Unlicensed fishing	8,828	5,457 – 12,779	$14.62m	$10.01m – $19.93m
Misreporting	171,548	165,096 – 178,079	$289.80m	$271.71m – $311.77m
Other license conditions	5,504	4,488 – 6,787	$10.22m	$8.38m – $12.25m
Post-harvest risks	6,307	2,708– 10,924	$18.85m	$9.69m – $29.30m



(a) *(b)*

Figure 31: Contribution of each risk category to total estimated IUU (a) volume and (b) value in in Pacific Islands region tuna fisheries.

Amongst the risk categories, the largest changes compared to the 2016 study came in the ‘other license conditions’ and post-harvest risks. Best estimate volumes of non-compliance with other license conditions declined substantially from 88,480t (to 5,504t), largely as a result of changes in the information base and methodology used to calculate FAD fishing during the closure period. Similarly, estimated volumes of post-harvest risks declined substantially from 39,580t (to 6,307t), principally as a result of new information available to estimate the scope for illegal transhipping, but also because the risk associated with landing catch into unauthorised foreign ports was not included in this study. By contrast, the estimated volumes associated with misreporting offences remained largely similar to the 2016 estimates, while estimates for unlicensed fishing declined slightly.

3.1.2 By sector

Of the three main sectors assessed, estimated volume of IUU product was highest in the purse seine fishery, accounting for 72% of overall volume (Table 21; Figure 32). Estimated IUU volumes in this sector were largely driven by misreporting, which is challenging to quantify in the context of IUU (see section 5). Moreover, given the nature of access arrangements under the VDS, it is likely that economic rents associated with any misreporting would be captured anyway. This result should be seen in that context. The tropical longline and southern longline sectors accounted for 21% and 7% of the overall volume respectively.

The purse seine fishery also contributed to slightly under half the overall ex-vessel value of IUU product ($152.26m), although the higher market value of target species in the longline fisheries meant that TLL sector made a proportionally higher contribution by value (40%) than volume to overall estimates. The southern longline fishery had the lowest overall estimates of IUU product value (14%).

Table 21: Estimated total IUU volume and value in each of the main sectors.

Sector	BE (t)	90% range (t)	BE ($)	90% range ($)
Purse seine	138,834	133,240 – 144,957	$152.26m	$145.06m – $160.18m
TLL	39,718	33,594 – 46,023	$134.91m	$115.42m - $158.48m
SLL	13,634	12,565 – 14,642	$46.32m	$42.51m - $49.98m

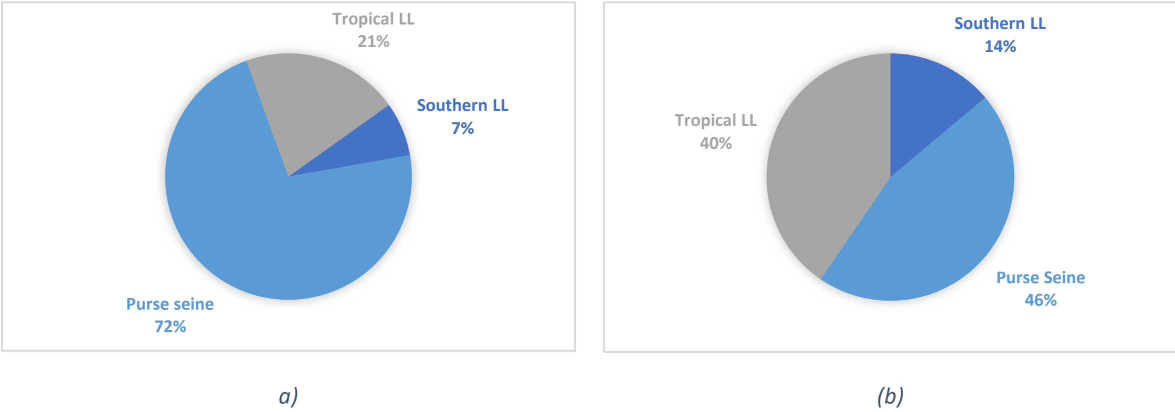


Figure 32: Contribution of IUU (a) volume and (b) value in Pacific Islands region tuna fisheries by main sector.

The largest change since the 2016 estimates was in the TLL sector, which fell from an estimated volume of 59,637 and value of $272.55m. This was largely driven by substantial reductions in the estimates of illegal transhipping, smaller reductions in estimated misreporting and the removal of the risk associated with landing catch in unauthorised foreign ports. Estimated IUU volumes and values also fell in the purse seine and SLL sectors. In the purse seine sector, volumes fell from 212,895t principally as a result of the revised methodology for estimating unauthorised FAD sets during the closure. Estimates in the SLL sector also fell substantially, for similar reasons to the TLL sector.

3.1.3 By species

Of the main target species, yellowfin accounted for the highest volume of IUU product, making up 33% of the total estimated IUU volume, and 25% of the ex-vessel value. The total estimated IUU volume of YFT equated to around 9.4% of the estimated total catch of YFT in the WCPFC-CA area during 2019. However, because much of the YFT volume is driven by under-reporting and misidentification on logsheets (e.g. YFT misidentified as SKJ) in the purse seine fishery and this sector is subject to 100% observer coverage (and catch sampling) which is used to adjust regional catch figures, this does not necessarily result in 'unaccounted for' catch. Moreover, as described above, because of the nature of the effort-based VDS under which the purse seine sector is managed, misreporting of catch is unlikely to result in actual losses to coastal States (see section 4). The ex-vessel value of YFT was roughly proportional to its volume, with lower ex-vessel prices achieved for canned product in the purse seine sector balancing out higher prices achieved in the longline sectors.

Skipjack accounted for the next highest volume, making up around 27% of overall estimated volume, but only 20% of the overall ex-vessel value given its lower market price relative to other species (Table 22; Figure 33). The total estimated volume of IUU SKJ equated to around 2.5% of the estimated total catch of SKJ in the WCPFC-CA area in 2019. The significant majority of the SKJ volume was driven by misreporting in the purse seine fishery.

Bigeye accounted for 17% of the overall estimated IUU volume, but 20% of the ex-vessel value. The proportionally higher contribution to the ex-vessel value total reflects the fact that much of the estimated IUU volume came from the longline sector which achieves relatively high market prices. The total estimated IUU volume of BET equates to around 24.3% of the estimated total catch of BET in the WCPFC-CA area during 2019. Importantly, this does not necessarily mean that 24.7% of additional BET have been taken in addition to reported figures. For example, some of the BET estimates relate to over-reporting in the purse seine fishery.

ALB accounted for 2% of the overall estimated IUU volume and total ex-vessel IUU value. The total estimated ALB IUU volume equates to around 2.8% of the estimated total ALB catch in the WCPFC-CA area in 2019. Much of the estimated volume of IUU ALB comes from estimates of misreporting in the longline fishery for which information remains uncertain.

Billfish and other species (including shark fins) accounted for 3% and 18% of the estimated IUU volume and 10% and 23% of the estimated ex-vessel IUU value respectively. Much of the value of the other species category was driven by estimates of misreporting in the longline sectors.

Table 22: Estimated total IUU volumes and ex-vessel value of each main species in Pacific Islands region tuna fisheries.

Species	BE (t)	90% range (t)	BE ($)	90% range ($)
SKJ	51,296	46,646 – 56,365	$65.81m	$59.85m – $72.32m
YFT	62,811	58,953 – 67,452	$83.64m	$73.45m – $101.79m
BET	32,923	31,452 – 34,383	$65.27m	$56.89m - $73.33m
ALB	3,403	2,936 – 3,860	$8.16m	$7.04m – $9.25m
BIL	6,117	4,822– 7,252	$33.20m	$26.17m – $39.36m
OTH	35,636	31,202 – 39,555	$77.41m	$67.38m – $86.24m

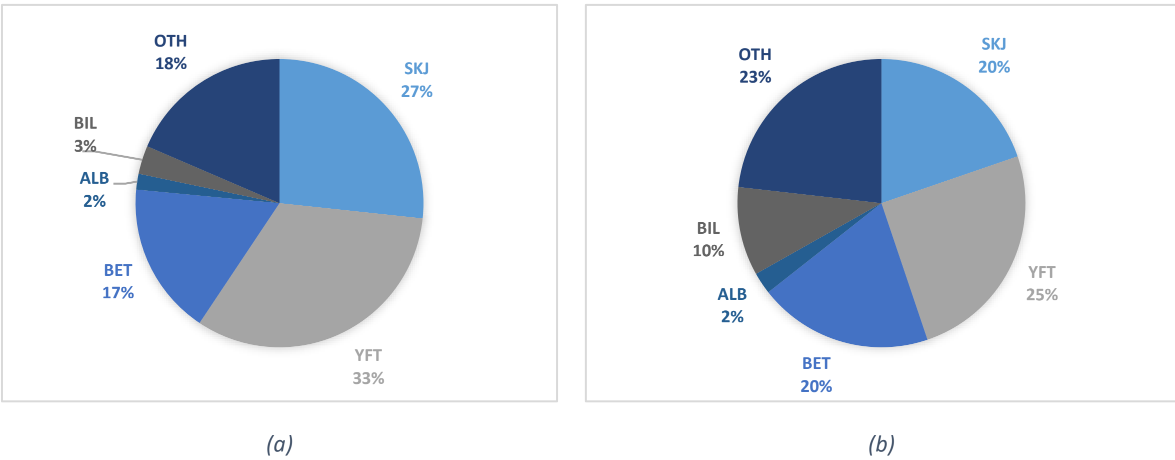


Figure 33: Proportion of each main species in the overall estimates of IUU (a) volume and (b) value in Pacific Islands region tuna fisheries.

In terms of volumes, the proportional contribution of each species to overall IUU volume was relatively stable against the 2016 estimates. In both studies, SKJ and YFT accounted for the highest proportion of estimated IUU product at around 30% each, largely driven by misreporting estimates in the purse seine fishery and to a lesser extent the longline sectors. BET and OTH accounted for the next highest volumes in both studies, although the proportional contribution of OTH species was slightly higher in the 2020 update. The contribution of each species group to value estimates was also relatively stable, although BET fell from 28% to 20% (largely driven by the reductions in estimates of illegal transhipping).

3.2 Purse seine fishery

3.2.1 Overall

The best estimate volume of IUU product in the purse seine sector is 138,834t, with a 90% confidence range of 133,240t to 144,957t. This represents around 6.7% of the estimated total purse seine catch in the WCPFC-CA area in 2019. Based on the expected species composition and markets, the ex-vessel value of the best estimate figure is $152.26m. The 90% confidence range is between $145.06m and $160.18m.

Table 23: Estimated total IUU volumes in the purse seine sector, by risk category.

Risk	BE (t)	90% range (t)
Unlicensed fishing	7,730	4,366 – 11,624
Misreporting	123,687	121,210 – 126,207
Other license conditions	4,161	3,234 – 5,392
Post-harvest risks	3,256	247 – 7,584

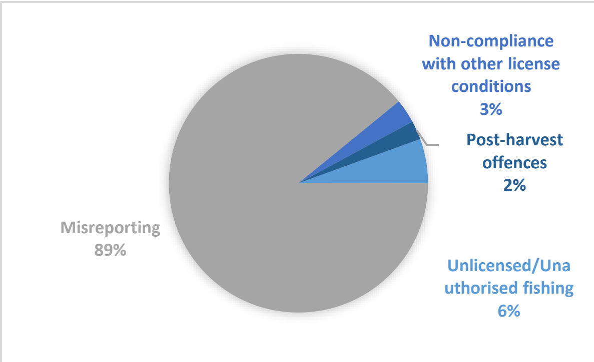


Figure 34: Contribution of each risk category to total estimated IUU volumes in the purse seine sector.

Table 24: Estimated total IUU volumes in the purse seine sector, by species.

Species	BE (t)	90% range (t)
SKJ	51,296	46,646 – 56,365
YFT	56,334	54,851 – 57,875
BET	26,792	25,960 – 27,641
OTH	4,411	4,131 – 4,701

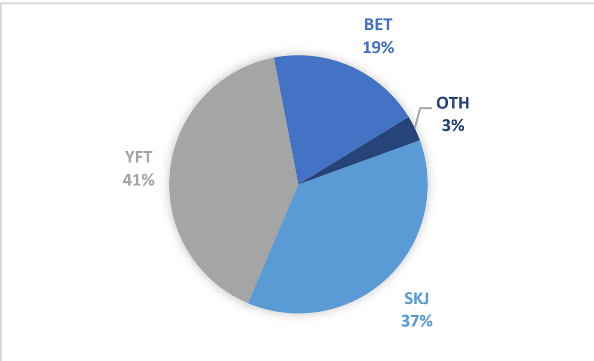


Figure 35: Total estimated volume of each species involved in IUU activity in the purse seine sector.

The largest contributor to the total estimated IUU volume and value is misreporting, accounting for 89% the estimated IUU volume (Table 23; Figure 34). This was largely driven by estimates of over-reporting of SKJ and under-reporting of YFT and BET. Importantly, while discrepancies between logsheet and observer reporting have been well-documented, SPC use observer derived estimates of species composition (grab samples adjusted for selectivity bias) to produce corrected estimates of PS catch by species which are used in the regional stock assessments and the WCPFC official annual catch estimates by species and gear. Moreover, the nature of the VDS means that rents associated with any misreported catch is likely to be captured by coastal anyway. To that end, because systems are in place to both correct logsheet entries for scientific purposes and rents are likely to be captured, the impact of misreporting in the purse seine sector is far less impactful than volume estimates would indicate.

The next highest contributors were the unlicensed fishing offences and non-compliance with other license conditions' group of risks at 6% and 3% respectively. Post-harvest risks accounted for a very small proportion of overall estimated IUU volume.

YFT and SKJ accounted for the highest proportion of overall estimated IUU volume at 41% and 37% respectively, with BET the next highest contributor at 19% (Table 24; Figure 35). The proportion of YFT and BET is higher than in 'normal' purse seine catch composition and is driven by higher rates of misreporting of these species.

Overall estimates of IUU volume and value in the purse seine sector are lower than in 2016, largely driven by substantial reductions in estimates of FAD fishing during the FAD closure period.

3.2.2 Unlicensed/unauthorised fishing

The best estimate value of unlicensed and unauthorised fishing in the purse seine sector is 7,730t (90% confidence range of 4,366t – 11,624t). For context, this value represents around 0.4% of the estimated total purse seine catch in the WCPFC-CA area in 2019.

Based on the expected species composition and markets, the ex-vessel value of the best estimate figure is $10.12m.

Table 25: Estimated IUU volumes associated with unlicensed/unauthorised fishing in the PS sector, by risk type.

Risk	BE (t)	90% range (t)
Unlicensed fishing – FFA VR	609	151 – 1,218
Unlicensed fishing – WCPFC RFV - small	1,268	314 – 2,550
Unreg. – 'average'	2,789	536 – 6,013
Unreg. - small	3,064	1,301 – 5,272

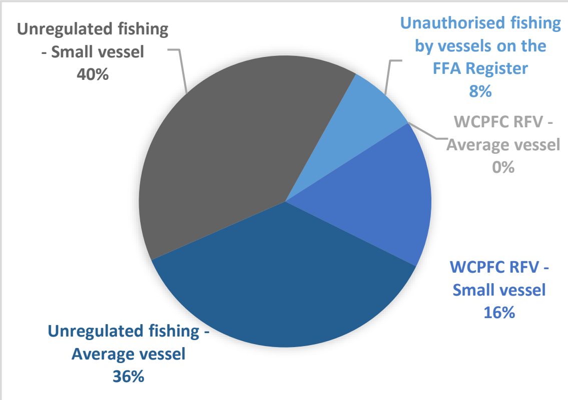


Figure 36: Contribution of each risk to total estimated IUU unlicensed/unauthorised fishing volumes in the PS sector.

Unregulated fishing by small vessels (principally domestic south east Asian fleets) was the main contributor, accounting for 40% of the expected volume (Table 25; Figure 36). This was based on an assumption of relatively frequent incursions in the western fringes of the FFA area. Nevertheless, there remains considerable uncertainty about the actual level of activity, which should be refined in future versions of the model. Unregulated fishing by average class vessels accounted for the next highest proportion of estimated IUU activity at 36%, with small vessels on the RFV at 16%. Unauthorised fishing by vessels on the FFA Register which are subject to 100% observer coverage is expected to account for negligible volumes of IUU product.

Overall, these results represent a small increase on the 2016 estimates, driven largely by slightly higher estimates of incursions by unregulated vessels in the western part of the FFA area and higher catch rates during the 2017-19 period.

3.2.3 Misreporting

The overall volume of misreported product according to the decision rules used in this study was 123,687t (121,210t to 126,207t). Importantly, these volumes include both underreported and misidentified product, as well as overreported product.

The main contributors to overall misreporting volumes were overreporting of SKJ (23%) and underreporting of YFT (21%) (Table 26; Figure 37). Taking into account both overreporting and underreporting, SKJ was relatively overreported in logsheets, with YFT and BET relatively underreported. The decision rules used in this study also identified cases where YFT and BET appeared to be misidentified in logsheets (typically YFT/BET reported as SKJ). Misidentification of YFT and BET accounted for 15% and 7% of overall misreported volume respectively. These results are broadly consistent with previous analyses which have shown relative overreporting of SKJ and under-reporting of YFT in the fishery (e.g. Hampton and Williams, 2011; Williams, 2020).

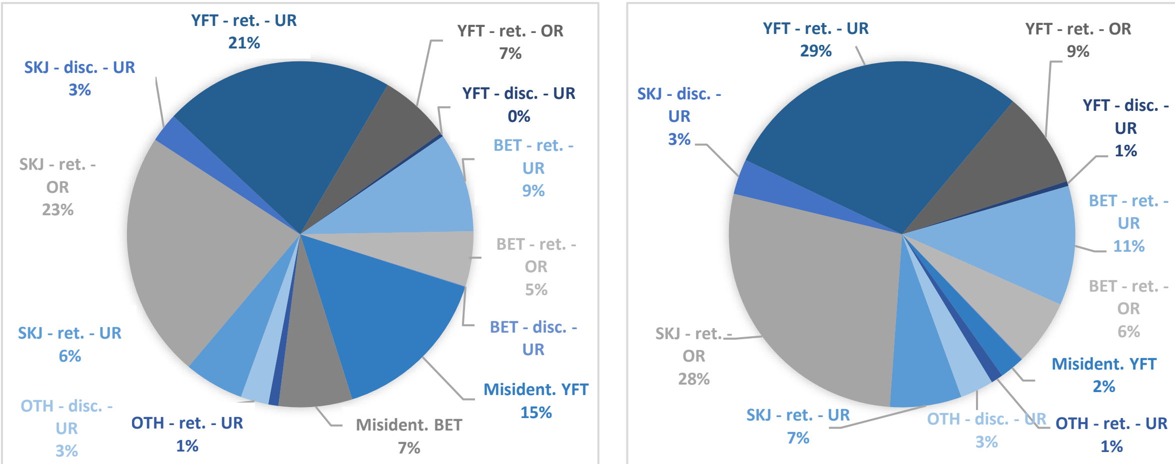
Table 26: Estimated total misreporting in the purse seine sector, by species and fate.

Species	BE (t)	90% range (t)	BE Value ($)
Misreported			
SKJ			
Retained - underreported	6,909	6,208 – 7,622	$8.86m
Retained -overreported	28,526	26,709 – 30,366	$36.60m
Discarded	3,392	2,932 – 3,886	$4.35m
YFT			
Retained - underreported	26,578	25,799 – 27,355	$38.43m
Retained -overreported	8,206	7,766 – 8,652	$11.87m
Discarded	417	317 - 524	$0.60m
BET			
Retained - underreported	11,519	11,114 – 11,926	$14.78m
Retained -overreported	6,365	5,817 – 6,925	$8.17m
Discarded	72	55 - 92	$0.09m
OTH			
Retained - underreported	1,165	1,043 – 1,291	$1.49m
Discarded	3,220	2,968 – 3,484	$4.13m
Misidentified			
YFT	18,817	17,969 – 19,675	$3.07m
BET	8,499	8,024 – 8,982	-

In value terms, the main contributors to ex-vessel value were underreporting of YFT and overreporting of SKJ, accounting for 29% and 28% of overall value respectively. Misidentifying YFT and BET contributed to proportionally less than their volume because only the marginal difference in ex-vessel value between SKJ and YFT/BET was taken into account (given YFT/BET were almost always misidentified as SKJ). In the case of BET, the price assumed for SKJ and BET in the purse seine sector was the same, so the marginal difference was zero. The overall ex-vessel value of misreported product was $132.45m.

The overall volume of misreported product was similar to the 2016 estimates (123,687t vs 118,678t), although the revised decision tree used in this study allocated volumes to slightly different categories. Most notably, the decision tree separated out instances of underreporting and overreporting, so volumes associated with overreporting are new. Other key differences include a reduction in estimates of unreported discards across each of the three main target tuna species (SKJ/YFT/BET), a reduction in misidentification of YFT/BET and an increase in unreported OTH species discards.

The overall value of misreported product has increased slightly compared to the 2016 study ($132.45m vs $114.41m), although much of this was driven by increases in assumed prices for SKJ in the current study ($1,283 vs $1,100).



(a) *(b)*

Figure 37: Proportion of each risk type/species category to total (a) volume and (b) value of misreporting in the purse seine sector. (UR = underreported; OR = overreported; misident. = misidentified)

3.2.4 Non-compliance with other license conditions

The group of risks categorised as non-compliance with other license conditions accounted for around $5.45m in estimated ex-vessel value.

Table 27: Estimated total volumes of IUU product associated with non-compliance with other license conditions in the PS sector, by risk category.

Risk	BE (t)	90% range (t)
Unauthorised FAD fishing	1,405	562 – 2,615
Closed waters	355	107 – 630
Exceeding effort limits	2,401	2,223 – 2,578
Shark finning (wet fin weight)	0.07	0.03 – 0.12

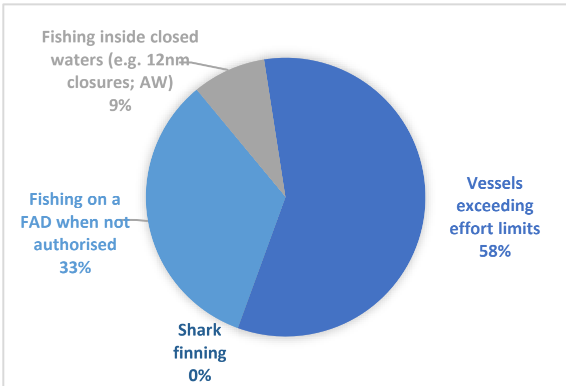


Figure 38: Contribution of each risk to total estimated IUU value ($) associated with the 'non-compliance with license conditions' risks in the PS sector.

Of these, exceeding effort limits accounted for slightly over half of the estimated value, with fishing on a FAD when not authorised accounting for 33% and fishing inside closed waters accounting for 9% (Figure 38). Shark finning accounted for negligible levels of IUU activity. The latter result is not surprising given the relatively small amount of sharks taken in the fishery and the very low rates of finning reported by observers, particularly in recent years.

Overall volume and value have reduced substantially compared to the 2016 study for the 'other license conditions' group of risks. The largest change has been for unauthorised FAD fishing, which was driven by changes in the estimation approach (which used observer reports rather than an analysis of likely set type based on species composition; Hare et al, 2015). Estimates of shark finning have also reduced based on observer data (even accounting for the possibility of some unobserved finning).

3.2.5 Post-harvest risks

Our simulations suggest that IUU activity in the post-harvest sector involves product with a likely ex-vessel value of around \$4.25m (\$0.32m – \$9.89m). This was solely related to estimates of illegal transhipping, and was driven by maximum estimates set to account for the possibility of some small degree of illegal transhipping. In practice, there is wide acknowledgement that the scope for illegal transhipping in the purse seine sector is negligible, so it is possible these figures overstate actual values.

3.3 Tropical Longline Fishery

3.3.1 Overall

The best estimate volume of IUU fishing in the tropical longline fishery is 39,718t, with a 90% confidence range of 33,594t to 46,023t. Based on the expected species composition and markets, the ex-vessel value of the best estimate figure is \$134.91m. The 90% confidence range is between \$115.42m and \$158.48m. That is, there is a 95% chance the figure is greater than \$115.42m and a 5% chance the figure is greater than \$158.48m, based on the simulations used here.

This represents a substantial reduction in both value and volume on the 2016 estimates (best estimate values of 59,637t and \$272.55m respectively), largely driven by reductions in estimates of illegal transhipping and non-compliance with other license conditions (e.g. use of non-prescribed gear), as well as the removal of the 'unauthorised landings in foreign ports' risk.

Table 28: Estimated total IUU volumes in the TLL sector, by risk category.

Risk	BE (t)	90% range (t)
Unlicensed fishing	761	477 – 1,055
Misreporting	35,721	29,790 – 41,756
Other license conditions	641	369 – 955
Post-harvest risks	2,595	1,102 – 4,404

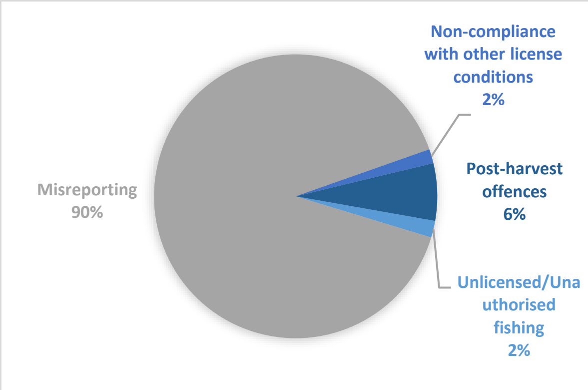


Figure 39: Contribution of each risk category to total estimated IUU volumes in the TLL sector.

Table 29: Estimated total IUU volumes in the TLL sector, by species.

Species	BE (t)	90% range (t)
ALB	1,194	872 – 1,528
BET	5,012	3,788 – 6,186
YFT	4,207	732 – 8,666
BIL	4,406	3,153 – 5,482
OTH	24,898	20,542 – 28,761

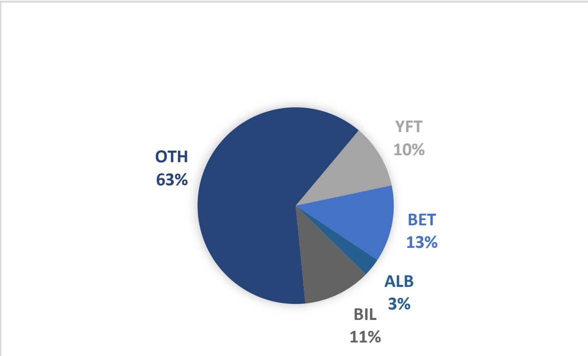


Figure 40: Total estimated volume of each species involved in IUU activity in the TLL sector.

The largest contributor to the total estimated IUU volume and value is misreporting, which accounts for 90% of estimated total IUU volume (Table 28; Figure 39). Estimates of misreporting are heavily influenced by the uncertainty in the underlying data and the resulting broad min/max ranges used. The next largest contributor was post-harvest risks, accounting for 6% of total volume. Much of this is driven by the remaining uncertainty around the extent of illegal transhipping. Getting better information on both misreporting and illegal transhipping would assist future versions of the model as well as in understanding the extent to which both contribute to IUU activity in the TLL sector.

Unlicensed fishing and non-compliance with other license conditions each accounted for 2% of overall volume.

The main changes from the 2016 estimates were the substantial reduction in the estimates of post-harvest risks (reduction in illegal transhipping and removal of the landing fish in unauthorised foreign ports risk – collectively reduced from 23,567t to 2,595t), as well as the reduction in estimates of non-compliance with other license conditions (primarily use of non-prescribed gear). Broadly, these reductions contributed to the higher overall proportion of volume and value contributed by misreporting offences.

3.3.2 Unlicensed/unauthorised fishing

The best estimate value of unlicensed and unauthorised fishing in the TLL sector is 761t (90% confidence range of 477t – 1,055t). Based on the expected species composition and markets, the ex-vessel value of the best estimate figure is $3.52m (90% confidence range is between $2.19m - $4.90m).

This is a reduction on the 2016 best estimates of 1,521t and $7.52m, largely driven by a reduction in estimates of unlicensed fishing for vessels on the FFA VR.

Table 30: Estimated total IUU volumes in the TLL sector, by risk category.

Risk	BE (t)	90% range (t)
Unlicensed fishing – FFA VR	107	47 – 179
Unlicensed fishing – WCPFC RFV	463	202 - 739
Unreg. – 'average'	117	45 - 207
Unreg. - small	73	34 - 125

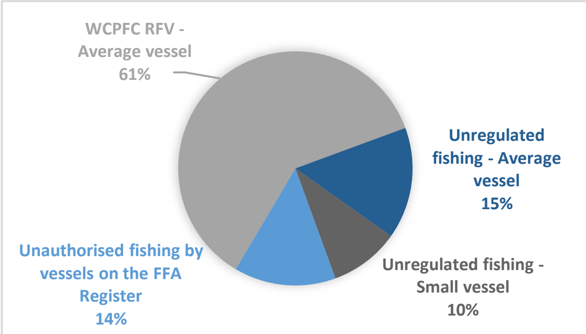


Figure 41: Contribution of each risk to total estimated IUU volumes in the TLL sector.

Unauthorised fishing by vessels on the WCPFC RFV was the main contributor to the overall volume of IUU product, accounting for 61% of the estimated IUU volume (Table 30; Figure 41). Unregulated fishing by 'average' vessels (in essence, vessels not on the WCPFC RFV), by vessels on the FFA VR and by small vessels (as defined here which includes the domestic fleets of south east Asian countries) accounted for 15%, 14% and 10% of overall volume respectively. The largest proportional change to any category from the 2016 estimates was for vessels on the FFA VR, which were previously estimated to account for around 41% of IUU activity. The reduction has largely been driven by a reduction in the estimated proportional of unlicensed activity (based on surveillance outcomes during the study period) and updated estimates of overall fishing effort.

3.3.3 Misreporting

Notwithstanding substantial improvements to unloadings coverage amongst FFA members in recent years, estimates of misreporting in the longline fishery remain characterised by high levels of uncertainty. Independent means of verifying logsheet reporting remain limited and even where independent means exist (e.g. observers), there are uncertainties in the data which make 'apples vs apples' comparisons difficult. Logsheet and observer coverage is lower than that in the purse seine sector and there are few opportunities for dockside inspection for some fleets (e.g. high seas longline fleets which can remain at sea for up to two years). As a result, while our estimates have been informed by the best available quantitative information (primarily comparisons of logsheets vs unloadings for fleets unloading at FFA member ports), a relatively high degree of uncertainty remains around reporting patterns amongst some fleets.

The overall volume of misreported product (both retained and discarded) estimated through our simulations was 35,721t (29,790t to 41,756t).

Of the retained product, the main contributor to overall volume was OTH species, which accounted for 56% of under-reported, retained product (Table 31). The next highest contributor was BIL at 16%, followed by BET at 14% and YFT at 10%. ALB accounted for only around 3% of estimated misreporting of retained species. Of the discarded product, OTH accounted for 81% of the estimated unreported discards. YFT and BET were the next highest contributors on 6% each. ALB accounted for only 0.7% of estimated discarded unreported catch.

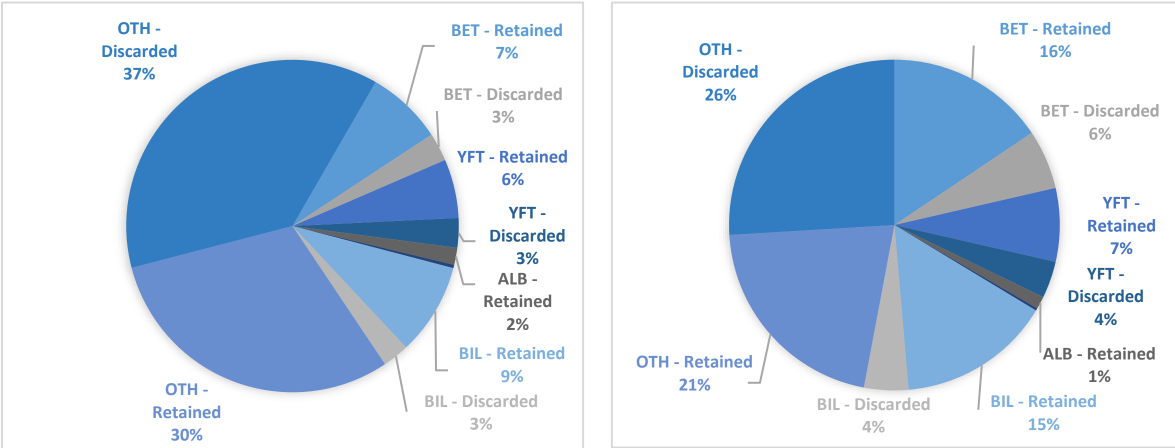
Amongst the retained catches, the main changes from the 2016 study were a reduction in estimated underreporting for both BET and YFT, an increase in the underreporting estimate for ALB and a substantial increase in the underreporting estimate for other species. Amongst the discards, large reductions in underreported volumes of the main target tuna species (BET, YFT, ALB) were driven by reductions in the estimated percentage of discarding of these species in the fishery generally (down from 5% in the 2016 study to 2.7% for YFT and BET during the 2017-19 period - i.e. estimated rates of underreporting remained very high, but overall volumes of discards were lower).

Collectively, the volumes estimated as unreported by this study are not insignificant. The total volume of retained and discarded BET represents around 8.7% of the average reported BET catch in the TLL study area between 2017 and 2019. Of the remaining species, the combined retained and discarded unreported catch represents 7.1%, 31.4% and 60.1% of the average longline catch in the TLL area between 2017 and 2019 for YFT, BIL and OTH respectively. Importantly, unloadings data are used to adjust the logsheet data where there is under-reporting and the adjusted logsheet data are aggregated and used in the stock assessments. To that end, a proportion of misreporting/underreporting is corrected at least for annual catch estimates and the aggregate data available for stock assessments.

Table 31: Estimated total under-reporting in the TLL sector, by species and fate.

Species	BE (t)	90% range (t)	BE % 2017-19 TLL av. catch
Retained			
ALB	590	361 – 783	4.3%
BET	2,646	1,619 – 3,515	6.4%
YFT	2,045	-1,358 – 6,479	4.7%
BIL	3,196	1,955 – 4,244	24.4%
OTH	10,839	6,630 – 14,396	26.9%
Discarded			
ALB	118	104 - 128	0.9%
BET	984	851 – 1,081	2.4%
YFT	1,027	887 – 1,127	2.4%
BIL	923	797 – 1,013	7%
OTH	13,353	11,782 – 14,531	33.17

In value terms, the main contributor to ex-vessel value was under-reporting of OTH, both retained and discarded, accounting for 26% and 21% of overall value respectively (Figure 42). Of the main target tuna species, underreporting of retained and discarded BET collectively accounted for 22% of overall value, while YFT accounted for 11%. The overall ex-vessel value of misreported product was $115.73m.



(a) (b)

Figure 42: Contribution of each species/fate combination to total (a) volume and (b) value of misreporting in the TLL sector.

Importantly, as discussed above, there are substantial limitations in the data available for the LL sectors. Until better systems of independent verification are put in place across all fleets, it is possible that rates of misreporting in the LL sectors are either higher or lower than those reported here. Given the absence of effective MCS coverage on many fleets and the incentives for under-reporting, there appears more scope for higher, rather than lower, rates of under-reporting.

3.3.4 Non-compliance with other license conditions

The group of risks categorised as non-compliance with other license conditions accounted for around $2.5m in ex-vessel value. This is a substantial reduction from the 2016 estimate of $17.02m, largely driven by a reduction in estimates of the use of non-prescribed gear (e.g. wire traces) which was highly uncertain in the previous study.

Table 32: Estimated total volumes of IUU product associated with non-compliance with other license conditions in the TLL sector, by risk category.

Risk	BE (t)	90% range (t)
Non-prescribed gear (sharks)	441	191 – 737
Closed waters	79	34 – 191
Shark finning (wet fin weight)	121	36 - 206

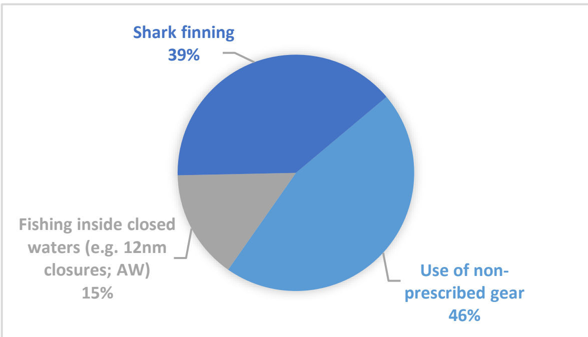


Figure 43: Contribution of each risk to total estimated IUU value ($) associated with the 'non-compliance with license conditions' risks in the TLL sector.

Of these, the use of non-prescribed gear contributed the largest volume of estimated IUU product (all sharks) and around 46% of the total predicted best estimate value (Table 32; Figure 43). Shark finning accounted for 19% of volume, with a best estimate value of 121t of wet fin weight (assuming 5% of total weight), although this figure would be the highest volume if the full wet weight of the shark body is taken into account (~2,420t). Overall, the best estimate ex-vessel value of shark fins taken from finned sharks was $0.97m, accounting for around 39% of the total value of this group of risks.

Fishing inside closed waters accounted for only a minor contribution to the total IUU volume and value.

3.3.5 Post-harvest risks

Our simulations suggest that IUU activity in the post-harvest sector involves product with a likely ex-vessel value of around $13.19m, although estimates remain highly uncertain (Table 33). This represents a substantial reduction on the 2016 estimate of $116.58m, driven both by a reduction in estimates of illegal transhipping (on the basis of better information) and removal of the landing catch in unauthorised foreign ports risk.

Table 33: Estimated total volumes of IUU product involved in post-harvest IUU activity in the TLL sector.

Risk	BE (t)	90% range (t)	BE ($)	90% range ($)
Illegal transhipping	2,595	1,102 – 4,404	$13.19m	$5.58m - $22.41m

The total volume of product involved in post-harvest risks was estimated at 2,595t, with average volumes and species compositions per time period back-calculated from matched WCPFC Transhipment Declarations and AIS data.

While this assessment has resulted in a substantial reduction in estimates of illegal transhipment activity through better transhipment declaration and AIS data, with the availability of additional information from WCPFC transhipment observers and other analytical sources, future assessments may be able to confidently estimate the extent of this risk.

Unlike some of the other risks, there is a reasonable chance of ‘double counting’ if, for example, underreported catch is also illegally transhipped. This is obviously very difficult to quantify without better information on both risk areas, but should be considered further in future versions of the model.

3.4 Southern Longline Fishery

3.4.1 Overall

In the southern longline fishery, the best estimate volume of IUU product is 13,634t, with a 90% confidence range of 12,656t to 14,642t. Based on the expected species composition and markets, the ex-vessel value of the best estimate figure is $46.32m. The 90% confidence range is between $42.41m and $49.98m. That is, there is a 95% chance the figure is greater than $42.41m and a 5% chance the figure is greater than $49.98m, based on the input values used in the model.

Table 34: Estimated total IUU volumes in the SLL sector, by risk category.

Risk	BE (t)	90% range (t)
Unlicensed fishing	338	232 – 448
Misreporting	12,140	11,140 – 13,064
Other license conditions	702	490 – 943
Post-harvest risks	455	199 – 762

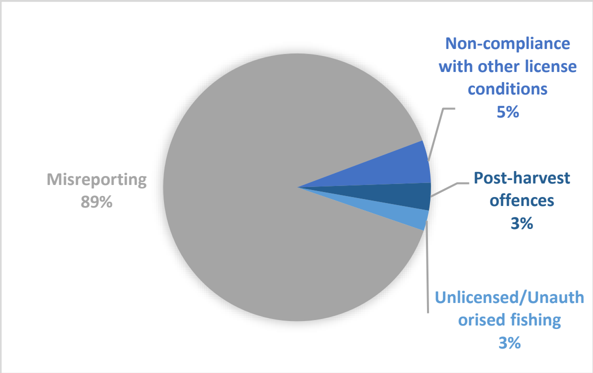


Figure 44: Contribution of each risk category to total estimated IUU volumes in the SLL sector.

Table 35: Estimated total IUU volumes in the SLL sector, by species.

Species	BE (t)	90% range (t)
ALB	2,208	1,872 – 2,534
BET	1,119	852 – 1,345
YFT	2,269	1,772 – 2,695
BIL	1,710	1,338 – 2,026
OTH	6,327	5,571 – 7,025

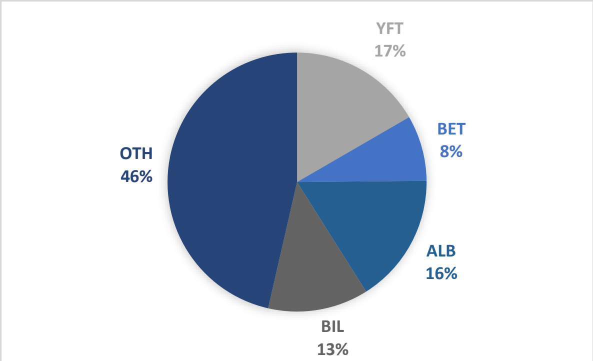


Figure 45: Total estimated volume of each species involved in IUU activity in the SLL sector.

Like the TLL, the dominant contributor to the total estimated IUU volume and value is misreporting accounting for around 89% of the total best estimate value (Table 34; Figure 44). Again, to a large extent this is driven by the uncertainties in reporting behaviour associated with the fleet not covered by unloadings at FFA ports and broad range of values assigned. The remaining risk groups contributed roughly equal amounts to overall volumes, with non-compliance with other license conditions, post-harvest offences and unlicensed fishing accounting for 5%, 3% and 3% of estimated total volume respectively.

Amongst the species, the OTH species group accounted for highest proportion of estimated IUU volume at 46%. YFT and ALB made up 17% and 16% respectively, while BIL made up 12% and BET made up 8% (Table 35; Figure 45).

These outcomes represent a substantial change from the 2016 results, largely driven by the reduction in the estimates of post-harvest risks. The reduction in the estimates of illegal transhipping (driven by better information) and the removal of the 'landing catch in unauthorised foreign ports' risk have the effect of both reducing overall volumes as well as changing the relative contribution of each risk type to overall IUU estimates. On that basis, the contribution of post-harvest risks to overall IUU estimates has decreased from 36% to 3%, while misreporting has increased from 57% to 89% (despite the fact that estimates of misreporting volumes have also reduced).

3.4.2 Unlicensed/unauthorised fishing

The best estimate value of unlicensed and unauthorised fishing in the SLL sector is 338t, with a 90% confidence range of 232t to 448t. Based on the expected species composition and markets, the ex-vessel value of the best estimate figure is $0.98m.

Table 36: Estimated total IUU volumes in the SLL sector, by risk category.

Risk	BE (t)	90% range (t)
Unlicensed fishing – FFA VR	79	34 - 133
Unlicensed fishing – WCPFC RFV	144	64 - 230
Unregulated	114	68 - 169

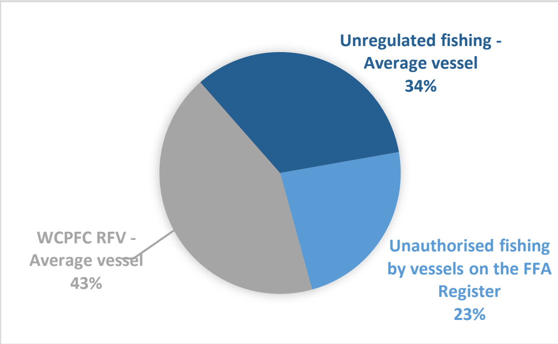


Figure 46: Contribution of each risk to total estimated IUU volumes in the SLL sector.

Unauthorised fishing by vessels on the WCPFC RFV was the main contributor to the overall volume of IUU product, accounting for 43% of the estimated IUU volume (Table 36; Figure 46). Unregulated fishing and unauthorised fishing by vessels on the FFA Register accounted for 34% and 23% respectively.

Overall, the 2020 estimates represent a reduction on the 2016 estimates, with overall volumes falling from 799t in 2016. This was largely driven by a reduction in the estimate of unauthorised fishing by vessels on the FFA Register from 566t to 79t. The change was driven both by a reduction in the proportion of estimated IUU days as well as a reduction in estimated effort in FFA EEZs in the SLL area. Estimates of unauthorised fishing by vessels on the RFV and unregulated fishing were broadly consistent with the 2016 results.

3.4.3 Misreporting

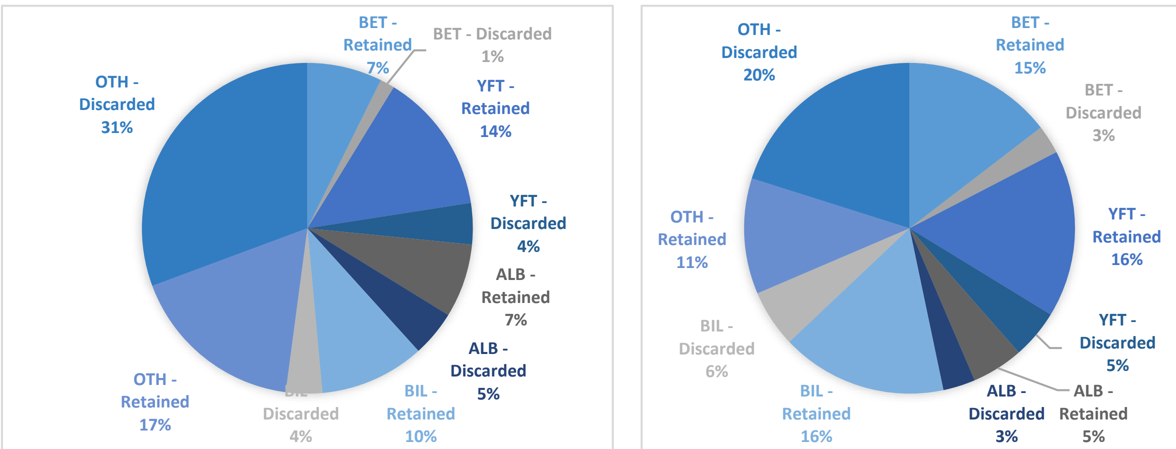
The overall volume of misreported product (both retained and discarded) estimated through our simulations was 12,140t (11,140t to 13,064t).

Of the retained product, the main contributors to overall estimated IUU volume were OTH, YFT and BIL accounting for 31%, 25% and 18% of the unreported retained product respectively (Table 37). BET and ALB both accounted for around 13% of estimated unreported product. Of the discarded product, OTH accounted for 69% of the estimated unreported discards. ALB was the next highest on 10%, followed by YFT and BIL accounting for 9% and 8% respectively. Overall, OTH species (retained and discarded) accounted for close to half of the estimated unreported catch by volume (Figure 47).

Table 37: Estimated total under-reporting in the SLL sector, by species and fate.

Species	BE (t)	90% range (t)	BE % 2017-19 SLL av. catch
Retained			
ALB	876	615 – 1,096	1.4%
BET	890	625 – 1,114	12.3%
YFT	1,675	1,176 – 2,096	8.1%
BIL	1,245	874 – 1,558	20.3%
OTH	2,093	1,470 – 2,619	18.6%
Discarded			
ALB	547	482 – 595	0.9%
BET	171	148 – 188	2.4%
YFT	490	423 – 538	2.4%
BIL	431	373 - 473	7.0%
OTH	3,722	3,284 – 4,051	33.1%

In value terms, the main contributor to ex-vessel value was discarding of OTH species, accounting for 20% of overall value, and not reporting of retained YFT, BIL and BET which accounted for 16%, 16% and 15% respectively (Figure 45). The overall ex-vessel value of misreported product was $41.62m ($38.03m - $45.07m).



(a) (b)

Figure 47: Contribution of each species/fate combination to total (a) volume and (b) value of misreporting in the SLL sector.

Overall, the 2020 update figures represent a reduction in both volume of value of misreported product. Estimated volume has reduced from 19,336t to 12,140t, while value has reduced from $67.59m to $41.62m. There are a range of factors contributing to this result. Most notably, estimates in 2016 were highly uncertain with very broad min/max range figures used. Although substantial uncertainties remain in the 2020 update figures, better information from unloadings data has allowed us to take a more data-driven approach to best estimates and reduce the range of min/max estimates. Changes to both catch and prices between the two estimates will also influence overall figures.

Amongst the individual species, the largest change in the retained catch was for BET which reduced from 1,506t in 2016 to 890t in 2020. This was largely driven by a smaller estimated proportion of unreported catch, based on unloadings data. Of the discarded species, estimates broadly reduced across the board. This was primarily driven by changes in the proportion of discards within the fishery (i.e. fewer fish were discarded), rather than changes in reporting behaviour, with very few discards of target tuna species recorded in vessel logsheets (Figure 21).

3.4.4 Non-compliance with other license conditions

The group of risks categorised as non-compliance with other license conditions accounted for around $2.30m ($1.53m - $3.13m) in ex-vessel value.

Of these, the use of non-prescribed gear (wire traces) contributed the largest volume of estimated IUU product (all sharks), and around 39% of the total predicted best estimate value, albeit estimates remained highly uncertain (Table 38; Figure 48). Shark finning accounted for the next highest value, with a best estimate wet fin weight value of $0.76m (assuming 5% of total weight). If the total weight of sharks finned is taken into account, the likely volume of catch is around 1,900t. Vessels exceeding quantitative limits, in this case limits on the numbers of vessels authorised to fish for southern ALB south of 20ºS, accounted for the second highest volume at 202t. Fishing inside closed waters accounted for only a very minor contribution to the total IUU volume and value.

Table 38: Estimated total volumes of IUU product associated with non-compliance with other license conditions in the SLL sector, by risk category.

Risk	BE (t)	90% range (t)
Non-prescribed gear (sharks)	346	150 – 579
Closed waters	58	25 – 104
Exceeding vessel limits	202	-
Shark finning (wet fin weight)	95	29 - 162

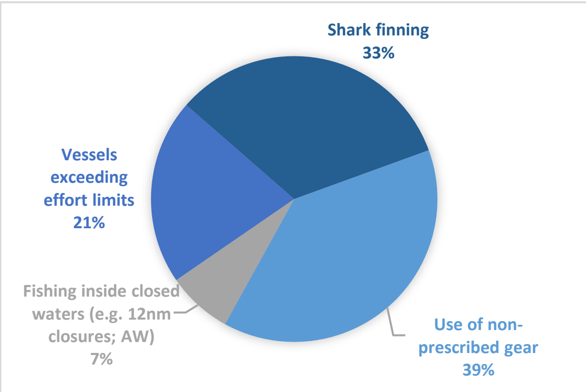


Figure 48: Contribution of each risk to total estimated IUU value ($) associated with the 'non-compliance with license conditions' risks in the SLL sector.

Consistent with the TLL sector, the main change from 2016 in this category in the SLL sector was the reduction in estimates of the use of non-prescribed gear. The 2016 estimates were based on extremely limited information and necessarily kept min/max range estimates broad. The 2020 update figures remain highly uncertain but were reduced in recognition of the absence of evidence of wire trace usage amongst dockside and at sea inspections.

3.4.5 Post-harvest risks

Our simulations suggest that IUU activity in the post-harvest sector involves product with a likely ex-vessel value of around $1.41m ($0.62m - $2.35m) (Table 39). Consistent with the TLL sector, this represents a substantial reduction on the 2016 estimate of $43.1m, driven both by a reduction in estimates of illegal transhipping (on the basis of better information) and removal of the landing catch in unauthorised foreign ports risk.

Table 39: Estimated total volumes of IUU product involved in post-harvest IUU activity in the SLL sector.

Risk	BE (t)	90% range (t)	BE ($)	90% range ($)
Illegal transhipping	455	199 – 762	$1.4m	$0.63m - $2.35m

The total volume of product involved in post-harvest risks was estimated at 455t, with average volumes and species compositions per time period back-calculated from matched WCPFC Transhipment Declarations and AIS data.

While this assessment has resulted in a substantial reduction in estimates of illegal transhipment activity through better transhipment declaration and AIS data, with the availability of additional information from WCPFC transhipment observers and other analytical sources, future assessments may be able to confidently reduce estimates of this risk further.

Unlike some of the other risks, there is a reasonable chance of 'double counting' if, for example, underreported catch is also illegally transhipped. This is obviously very difficult to quantify without better information on both risk areas, but should be considered further in future versions of the model.

3.5 Double counting

In any 'bottom up' approach such as this where IUU risks are quantified at a fine scale, there is potential for some 'double counting' to occur. For example, if 10t of fish were harvested illegally in an EEZ for which the vessel wasn't licensed, those same fish were then not reported in vessel logbooks, and also illegally transhipped, there is potential for those same fish to be picked up in estimates three times. To that extent, the estimates produced here could be considered an overestimate.

Nevertheless, there is a reasonable basis to suggest that the extent of double counting is likely to be relatively small in the context of the overall estimates. In the main, double counting is likely to be confined to overlaps across the four risk categories – e.g. unlicensed fishing and misreporting, or misreporting and illegal transhipping – rather than within risk categories. Because overall unlicensed fishing and post-harvest risks produced relatively small IUU estimates the potential for double counting across categories is reduced (albeit this may not be the case for the longline sectors). Moreover, for many of the unlicensed fishing and 'breaching license condition' risks (unlicensed fishing by vessels on the FFA Register, fishing in closed waters), there is a reasonable prospect that the catch would have been recorded in logbooks, at least to the extent that normal reporting occurs. This would also serve to reduce the potential for double counting.

On that basis we have not attempted to analytically reduce our estimates to account for double counting, but readers should bear the potential for this to occur in mind.

4 What are the 'real' costs and benefits of IUU fishing?

4.1 What is the real impact on Pacific Island economies?

As discussed above, ex-vessel values or market values are the most commonly used metrics by which the economic size of the IUU problem is measured, but neither is a particularly good indicator of the real impact of IUU fishing on Pacific Islands. This is primarily for two reasons:

- Firstly, the full value of the fish taken illegally would not be returned to Pacific Island countries under normal circumstances. For example, a single longline vessel may turn over $1m in revenue during a year, but the costs of production mean that only a relatively small percentage of turnover is retained as profit. License fees are typically calculated either directly or indirectly on vessels' economic profit[31] (or capacity to pay), and therefore from the original $1m in turnover the license fees returned to the Pacific Island country may be in the order of $10,000 - $ 30,000[32] (putting aside any indirect benefits gained from transhipment, provisioning, etc). Put another way, if an amount of IUU activity with an ex-vessel value of $1m was eliminated such that an additional vessel could be sustainably licensed in a fishery, the additional amount of revenue expected by the Pacific Island country would be between US$ 10,000- $30,000 per new entrant in license fees. The implications of these 'real' impacts on Pacific Island countries should be taken into account in future MCS planning; and
- Second, while some activities are illegal, they may not necessarily result in direct losses to Pacific Islands. Misreporting in the purse seine fishery managed under the VDS is a good case in point. Under the VDS, fishing companies compete in a (relatively) open market for a limited number of VDS days. The vessel's capacity to pay, and therefore the price received by the Pacific Island country, is influenced by the catch and profitability of the catching vessel. This, in turn, will be driven by actual catches made by the vessel, rather than those reported on the logsheet (if in fact these are different). To that end, economic profits from actual catches (including any component not included in logsheets) could be expected to be incorporated into prices paid for VDS days in a competitive marketplace and is an important benefit of the VDS as currently structured. Moreover, in the purse seine fishery 100% observer coverage allows for accurate estimation of actual catches independent of logsheet reporting. This means that logsheet reported catches can be adjusted and the full economic value of the catch factored into the setting of benchmark VDS prices.

Taking these issues into account, this section provides an initial indication of a more likely 'real' impact on Pacific Island economies associated with the estimated volumes of IUU activity reported here.

Rather than ex-vessel values, a better benchmark of revenue forgone by Pacific Island countries is likely to be the rent generated by vessels from IUU activity. In general terms, 'rent' is the residual left over after production and capital costs, capital provisions and normal profits are deducted from the revenue generated from the sale of the fish, and could be expected to be returned to coastal states under efficient access fee arrangements.

For this analysis, the forgone rent or 'economic profit' can be estimated using the Net Profit Margin (NPM) of the vessels involved in the fishery. NPM is simply a measure of the proportion of revenue

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[31] Super profits take into consideration the cost of capital and are those above and beyond what an industry's normal profit should be based on its level of risk.

[32] Average access fees for the longline fishery are in the order of US$ 13,500 (southern longline) and US$ 20,000 (northern longline) (Banks 2021).

which can be considered actual profit[33] and is expressed as a percentage. Once the NPM has been estimated, increases in revenue from IUU activity can then be converted into foregone rent.

In the purse seine sector, the most recent economic modelling estimates from PNA estimate the average NPM of 28% (PNA, 2020). This is lower than the profit margin in the period 2013-2015, which were then 43% (Banks, 2015).

In the longline sector, there was less detailed information available on specific vessel's economic performance. However, the longline fleet in general could be categorised into three main groups: industrial longline vessels >40m, northern Taiwanese and Chinese flagged ULT vessels <40m, southern Taiwanese and Chinese flagged ULT vessels <40m. Using FFA's Vessel Register, it was estimated the proportion of vessels in each group were 11%, 67%, and 21% respectively. Taking into account each category's estimated NPM, the weighted average for the fleet's NPM was 15.1%, as compared with 14.54% in the period 2013-2015. The weighted average across the northern (industrial longline vessels and < ULT northern) and southern fleets was 17.4% and 1.4% respectively. Profit margins in the southern ULT fishery are very low because of the higher dependency on lower value albacore and correspondingly low catches of bigeye tuna (~7% as compared to 40-48% in the northern longline fishery).

Based on the ex-vessel values calculated in this study, Table 40 sets out the potential revenue forgone by Pacific Island countries in the form of lost rent or economic profit from each sector. Importantly, given the very high likelihood that any rents associated with misreporting in the purse seine sector would be captured through the VDS, these figures have not been included in estimates of lost rent. This is a change to the 'first cut' approach used in the 2016 study, but is more reflective of the actual situation. Moreover, although estimates associated with the remaining risks in the purse seine sector have included, there is a strong argument that rents associated with many (e.g. FAD fishing during the closure) would be captured as well. To that end, the estimates set out below may still be an overestimate potential for loss in this sector.

Moreover, estimates of lost rent in the longline sector may also overstate actual losses because (i) some catch will be taken on the high seas for which Pacific Island countries do not currently collect rents, and (ii) because a general rent value for each of the TLL and SLL sectors has been applied based on a weighted average price from typical catch in each sector; however, non-target species and discards make up a higher proportion of the estimated IUU volume here.

Table 40: Estimated IUU ex-vessel values compared with potential 'real' revenue forgone by Pacific Island countries in the form of rent, or economic profit, by fleet sector.

Sector	Weighted average price (all species)*	Revenue (ex-vessel)		Estimated rent	
		BE ($)	90% range ($)	BE ($)	90% range ($)
Purse seine	1,317	$152.26m	$145.06m - $160.18m	$5.59m	$3.75m – 7.68m
TLL	5,348	$134.91m	$115.42m - $158.48m	$36.98m	$31.28m - $42.85m
SLL	3,248	$46.32m	$42.51m - $49.98m	$0.61m	$0.56m - $0.66m
Total		$333.49m	$312.24m - $358.17m	$43.18m	$37.20m - $49.33m

Note: * Appendix 2 shows weighted price calculations

[33] NPM=Vessel Profit/Vessel Revenue

Importantly, these estimates are not intended to be definitive and are presented mainly to highlight the point that ex-vessel values are not an effective way of measuring the 'real' impact on Pacific Island countries. More accurate estimates would require additional analysis of forgone economic profits and consideration of the unique circumstances of each fishery and risk (e.g. is the rent captures anyway? is the revenue solely through access fees, or is revenue also lost to onshore processing?).

Moreover, the figures don't take into account any indirect costs associated with IUU fishing – for example, the potential to generate additional uncertainty in regional stock assessments. Should additional uncertainty require more precautionary management approaches (e.g. purse seine effort needs to be reduced because of higher uncertainty in bigeye stock assessments), the costs to FFA members could be significant. To that end, FFA members have a very strong interest in ensuring strong mechanisms are in place to validate catch throughout the supply chain.

4.2 What is the benefit of IUU fishing to vessels?

The other important consideration in the economics of IUU fishing is the benefit to the vessel, which is different to the rent forgone by Pacific Island countries. This is because both the vessel owner's profit and the crew wages need to be taken into account.

Estimates of economic profit consider catch revenue and the cost of that catch. The cost of that catch includes the cost of labour. For some crew, especially senior officers, wages are paid based on a share of catch revenue and an incentive exists for these officers to maximise revenue because increased revenue equates to increased pay. However, for others (e.g. longline deck hands; some South East Asian purse seine crew), wages are paid at a fixed daily rate. In these cases, one of the only incentives for the crews to maximise revenue is through shark finning where the crews are known to receive a share of these revenues. On this basis, the vessel's IUU benefit is the economic profit *plus* the incentive wages.

The difference between forgone economic profit to coastal states and overall benefits to the vessel is important when considering the level of fines to set for an infringement. For example, if fines were set based on economic profit alone, a residual incentive still exists for the crew to infringe. Accordingly, fines need to be set at a level that sufficiently outweighs the full benefit of IUU activity received by the vessel.

5 Analysis and main messages

Apart from the headline volume and value figures, there are a number of key messages arising from the analysis. These include:

The reduction in estimates since 2016 is positive, but should be seen in context

The overall volume and value of IUU estimated in this 2020 update are a substantial reduction on those from 2016. Broadly, this is a very positive result for the region and its MCS efforts, but should be seen in context. The 2016 estimates were a 'first cut' with highly uncertain data across a number of key risk areas. On that basis, estimates were kept deliberately broad to account for high levels of uncertainty. As outlined in the 2016 report, some of the key benefits from the study were the development of an approach to estimating IUU and an associated model that could be updated over time as better information became available and highlighting key risk areas where information was limited.

For the 2020 study, new information became available to estimate some risks – most notably illegal transhipping and longline misreporting – while information previously used to quantify risks for the 2016 study were not available for the current study period. Broadly, it was these changes in information base that produced the biggest overall changes in volume and value estimates. For example, new information became available to estimate the extent of illegal transhipment in the form of GFW's AIS dataset as well as the WCPFC Transhipment Declaration dataset. The combination of these two information sources allowed for more informed estimates, a narrowing of the min/max range values and ultimately a substantial reduction in estimates of IUU activity (from 34,530t to 6,306t). In contrast, information used for the 2016 study to estimate the extent of FAD fishing during the closure period (namely a retrospective analysis of likely set type based on catch composition and other parameters) was not repeated for the current study period. That required a change of estimation approach (based on observer data) which also resulted in a substantial reduction in estimated IUU volume and value.

In addition, there were a number of other changes which influenced the overall results:

- The addition of one risk and removal of another – as discussed above, one new risk was added for the 2020 study (exceeding effort limits), while one risk assessed in 2016 was removed (unauthorised landing of catch in foreign ports);
- Changes in fishing effort – these are important where best estimates and min/max ranges are based on a proportion of overall effort (e.g. in estimates of unlicensed fishing activity). In these cases, even where the estimated proportion of IUU activity remains the same, a reduction in total effort will reduce IUU estimates (and vice versa);
- Changes in catch rate – these are important for risks estimated as a catch per unit effort (day/set). Increases in catch rate may produce overall increases in estimated IUU volume, even if the number of IUU units remains the same (and vice versa).
- Changes in fish price – while these won't influence overall IUU volume (except to the extent that they influence incentives for IUU activity), they will change overall value figures. Broadly, purse seine prices used in this study have increased slightly from those in 2016, while in the longline sector BET and ALB prices have increased slightly and YFT has decreased to account for a higher proportion of frozen vs fresh product.

To that end, while the reduction in overall volume and value estimates should be welcomed, caution is required in interpretation and changes should be examined in the context of each risk. In practice, the 2020 estimates should be seen as the next evolution in an ongoing process to quantify the nature and scale of IUU in the Pacific region. A summary of the main changes between the 2016 and 2020 studies is provided in Table 41.

Table 41: Summary of changes in 'best estimate' IIUU volume between the 2016 and 2020 studies.

IUU Risk	PS			TLL			SLL			Comments
	2016	Change	2020	2016	Change	2020	2016	Change	2020	
Unlicensed fishing										
Unlicensed fishing by vessels on the FFA VR	851t	↓	609t	621t	↓	107t	566t	↓	79t	V. limited evidence for unauthorised fishing
Unlicensed fishing by vessels on the WCPFC RFV	Av: 455t Sm: 2,253t	↓	Av: NA Sm:1,268t	382t	↔	463t	159t	↔	144t	
Unregulated fishing	Av: 1,625t Sm: 3,575t	↔	Av: 2,789t Sm: 3,063t	Av: 142t Sm: 376t	↓	Av:117t Sm: 73t	74t	↗	113t	
Misreporting	118,678t	↔	123,687t	29,327t	↗	35,721t	19,336t	↓	12,140t	Better LL unloadings coverage
Non-compliance with other license conditions										
FAD fishing	81,338t	↓↓	1,405t	NA		NA	NA		NA	Change in estimation approach, based on observer reporting.
Fishing in closed waters	390t	↔	355t	80t	↔	79t	72t	↔	58t	
Shark finning	14.75t (ww)	↓↓	0.07t	412t (ww)	↓	121t (ww)	112t (ww)	↔	95t (ww)	LL estimates highly uncertain
Use of non-prescribed gear	NA		NA	4,978t	↓↓	440t	1,367t	↓↓	346t	Less evidence, anecdotal concern for unauth. gear
Exceeding effort limits	NA	New	2,401t	NA		NA	NA	New	202t	New risk added in 2020
Post-harvest risks										
Illegal transhipping	3,725t	↔	3,256t	20,537t	↓↓	2,595t	10,268t	↓↓	455t	New information available (GFW AIS/WCPFC Transhipment Declarations)
Unauthorised landing of catch in foreign ports	NA		NA	3,030t		NA	2,020t		NA	Not assessed in 2020
Overall ex-vessel value	$225.20m	↓	$152.26m	$272.55m	↓	$134.91m	$118.36m	↓	$46.32m	

Cooperation works

While IUU fishing in its various guises will continue to require attention from FFA members, there is little doubt the MCS measures FFA members and their partners have implemented over recent decades have had a profound impact on both the nature and volume of IUU fishing in the region. In particular, cooperative regional MCS measures such as the establishment of the FFA VR and Good Standing requirement, the agreement of HMTCs which ensure all foreign vessels are required to meet common minimum standards for access, the establishment of the FFA VMS, the development of common regional data collection protocols and forms (logsheets, observers, unloadings, etc) together with centralised storage/analysis through FFA/SPC/PNAO, the establishment of regional PIRFO standards and training for observers, cooperative regional MCS training, the Niue Treaty and Subsidiary Arrangement to facilitate cooperation on MCS including information sharing, coordinated aerial surveillance through the PMSP and undertaking coordinated Regional Operations with analytical support through the RFSC, amongst others, have substantially strengthened the MCS environment across all member zones and acted as an effective ‘force multiplier’ compared to individual members acting alone.

Importantly, many of these measures have been able to implemented highly cost effectively, built largely on regional agreement alone. For example, the requirement for Good Standing on the FFA VR means that an offence undertaken in one member’s waters risks the vessel being locked out of all members’ waters. In practice, this fundamentally changes the risk/reward equation for non-compliance, creating a very strong deterrent for relatively little cost.

While it is difficult to predict what the IUU situation would be like in the absence of the cooperative measures described above, there seems little doubt the picture would be quite different. The fact that the nature of IUU fishing in the FFA region is different to many other areas of the world – i.e. more nuanced non-compliance with license conditions rather than more egregious forms of IUU fishing such as unlicensed fishing – is practical evidence of the MCS framework’s success.

The available evidence also indicates that the cooperative approach to MCS taken by FFA members has the region well-placed in relative terms internationally in the fight against IUU fishing. While a different methodology was used, one recent study in the Asia Pacific Fisheries Commission (APFIC) region estimated illegal fishing landings of around 6.6 million tonnes, valued at US$23.3bn in 2019 (Wilcox et al, 2021). The study noted that the proportion of estimated illegal landings varied by species, with sharks reaching ‘50% or more’. While the proportion of illegal landings of tuna were smaller, estimated value was still around US$1.6bn. A separate study in the Bay of Bengal Large Marine Ecosystem (BOBLME) area estimated average levels of IUU catch at between 4.5 million tonnes and 15 million tonnes, valued at US$6-21bn (BOBLME, 2015). Amongst the various species groupings, illegal and unreported catches of tunas, bonitos and billfishes were estimated to be between 29% and 86% in excess of the reported catch. By contrast, as discussed above, the total estimated IUU volume here is 6.5% of the total WCPFC-CA catch in 2019 (and 2.3% if purse seine misreporting is discounted).

Estimates continue to be dominated by the licensed fleet

A key outcome of the 2016 study was that estimates of IUU volume and value were dominated by the licensed fleet. The 2020 update shows a similar pattern with unlicensed fishing accounting for only 5% of overall IUU activity. As outlined in the 2016 study, this finding has important implications for future MCS investments and priorities given ‘we know about’ the licensed fleet (i.e. they are tracked on VMS and in the purse seine fishery have 100% observer coverage) and are not having to invest very substantial amounts of money in new assets and technologies to ‘find’ dark targets. Rather, many of the types of IUU challenges associated with the licensed fleet can be monitored through more modestly priced MCS arrangements (e.g. observers, dockside inspections, EM).

Unlicensed fishing remains an issue at the margins

Consistent with the outcomes of the 2016 study, unlicensed fishing continued to be an issue at the margins, both figuratively and literally. Overall, evidence for unlicensed fishing by vessels on the FFA VR and/or WCPFC RFV was very limited with no confirmed instances of unlicensed fishing by these vessels detected during regional operations (despite aerial surveillance collectively covering in excess of 21,000,000 nm^2) and few national level detections/prosecutions during the study period. While some instances of high seas vessels being sighted in zone while not reporting on VMS have occurred and estimates have accounted for the possibility of some small level of undetected activity, the available evidence suggests relatively high levels of compliance amongst registered vessels.

The main exception to this is on the fringes of the FFA region, and in particular on the western fringe adjacent to the domestic fleets of south east Asian countries. In this area, evidence of regular incursions was stronger, with unregulated vessels (e.g. small group seine operations, bancas) detected and apprehended during regional and national operations.

Importantly, the absence of substantial unlicensed fishing activity is likely to be. To a large extent, the product of investment in MCS and regional cooperation amongst FFA members, and external partners, over time (e.g. through the FFA VMS, VR and Good Standing requirements, HMTCs, Regional Operations, NTSA, Pacific Patrol Boat program, QUAD surveillance support, etc). A number of interviewees noted that unlicensed fishing was much less of an issue now than it was '20 years ago'. Given the expense associated with MCS measures directed at detecting unlicensed fishing (e.g. aerial/surface surveillance) and the relative absence of confirmed cases in recent years, there may be a tendency to want to 'economise' on some of these measures. However, it is important to recognise that the presence of aerial and surface surveillance (together with VMS and other measures) is likely to provide an essential (albeit difficult to quantify) deterrent to non-compliance, the absence of which would invite higher levels of offending.

Priorities for strengthening MCS measures are still in the longline sectors

While the purse seine sector accounts for higher volumes of IUU fish based on parameters used here (much of which is associated with misreporting, discussed below), in practice the sector is subject to comparatively very strong MCS arrangements. The requirement for 100% observer coverage, frequent VMS polling, compulsory e-reporting for vessels on the PNA VDS Register and the requirement to tranship catch in port means that the sector is very closely monitored. Moreover, the fact that there are only around ~250 large scale purse seine vessels and the large majority of fishing effort occurs in EEZs subject to strong domestic legal frameworks means the sector is both more practically monitorable and subject to stronger control arrangements. Even where issues such as misreporting do occur, the MCS measures in place mean they can be picked up and corrected.

By contrast, MCS arrangements in place for the longline sector are comparatively weaker. The sector is subject to far lower levels of observer coverage, other forms of monitoring (e.g. EM) are yet to be widely applied, a far higher proportion of effort occurs on the high seas not subject to coastal State law, and a higher proportion of the catch is transhipped at sea which limits opportunities for port State MCS measures. Previous studies have indicated a preference for fishing on the high seas by some distant water fishing nation (DWFN) longline vessels both to avoid paying coastal State access fees, as well as avoiding stronger coastal State MCS regimes (MRAG Asia Pacific, 2019).

To that end, the main priorities for future MCS development across the FFA region, including the adjacent high seas, are in the longline sector. Particular focus should be on strengthening measures to monitor and validate catch both on longline vessels and as it moves through the supply chain. While important steps towards strengthening monitoring of longline vessels in FFA member ports have been taken in recent years with improvement in unloadings coverage, the low rate of observer (or other monitoring) coverage together with limitations in high seas transhipment monitoring arrangements mean there is uncertainty around whether existing arrangements could detect all forms of 'leakage'. Robust measures to validate catch volume and species compositions are particularly important where quantitative catch limits are used (e.g. for BET). Moreover, FFA members with interests the purse seine fishery have a strong interest in ensuring effective catch monitoring in the longline sector given uncertainties in stock assessments resulting from misreporting, or actual stock declines (e.g. in BET), can mean the imposition of costly management measures to constrain mortality in the purse seine sector. Possible measures to strengthen longline catch monitoring arrangements are discussed in Section 6 and Annex 5.

Importantly, given the shared nature of stocks in the region, strong measures to monitor and validate catches should be applied across the full footprint of stocks, including the high seas. This is important both for stock management as well as ensuring stronger in zone MCS measures don't simply displace vessels onto the high seas.

Estimates of illegal transhipping have come down, but monitoring and control remain a work in progress

The availability of WCPFC Transhipment Declaration information together with GFW's AIS dataset led to a narrowing of the minimum and maximum range estimates for illegal transhipment and a substantial reduction in overall estimates of volume and value. Nevertheless, important areas of uncertainty remain in the at sea transhipment component of the longline supply chain and monitoring and control remain a work in progress. In particular, despite the requirement for 100% observer coverage on all receiving vessels under CMM 09-06, minimum fields for observer data collection are yet to be agreed and very little of the data collected by observers is made available to the WCPFC Secretariat. To that end, there is little or no capacity to independently validate the detail of Transhipment Declarations submitted to the Secretariat by offloading and receiving vessels (the majority of which are identical). Given the importance of at sea transhipment in moving species subject to quantitative limits through the supply chain (e.g. BET), the absence of independent validation is an important limitation in the MCS regime.

Estimating purse seine misreporting in the context of 'IUU' is challenging

While misreporting in the purse seine sector accounted for a relatively high proportion of overall volume and value estimates based on the parameters used here, in practice estimating misreporting in the context of 'IUU' is challenging and considerable care is required in interpretation. Large volumes of catch may be taken at one time, involving multiple species, and the vessel logsheet entry is a visual estimate made at sea. While observers make independent estimates of catch and species composition using a regionally standardised approach, no scales are used so ultimately the logsheet versus observer comparison is a comparison of estimates versus estimates. While we have attempted to account for estimation error by using data at the trip level (such that variation in set level reporting should 'dampen out' over the course of the trip) and applied a tolerance level of 10%, the level of tolerance applied is, in essence, a judgement call and the approach relies on an assumption that the observer's estimate is correct (which may not hold in all circumstances). Applying a different level of tolerance (e.g. 5%, 20%) would produce different results and, given the volumes involved in the purse seine sector, will have a substantial impact on overall volume and value. To that end, the results of the purse seine misreporting analysis should be seen in that context.

As discussed in section 3.2, the requirement for 100% observer coverage (which allows for any reporting errors to be picked up and corrected) and the nature of the VDS (which means any rents associated with misreported catch are likely to be collected anyway), mean that the practical impact of misreporting in the purse seine sector will be less than what the IUU volume and ex-vessel value figures would otherwise indicate. Nevertheless, accurate estimates of catch volume and species composition are important for both stock assessments and the ongoing management of the VDS and ongoing efforts towards ensuring precise estimates of catch composition should be encouraged. We note that ongoing work is being undertaken to improve estimates of purse seine species composition as part of WCPFC's Project 60.

A few points worth reiterating

In addition to those key messages arising from this study, there are a number from the 2016 study that remain relevant and are worth reiterating in brief here:

- **'IUU' is not straightforward** – while the formal definition of 'IUU fishing' in the IPOA-IUU is relatively clear in theory, applying it for the purposes of quantifying its nature and extent presents a range of practical challenges. In addition to the inevitable uncertainties in the underlying data, resolving what should, and shouldn't, be considered in estimates frequently requires a judgement call. The example of purse seine misreporting described above is a case in point, but there are a range of others. For example, if a purse seine vessel deploys a drifting FAD that travels through a zone for which it has no license, is that illegal fishing? And if so, how should we quantify it? If a vessel fishes under a license but fails to submit their logsheet until after the legally required deadline for submission, should that be considered unreported? How these questions get resolved can have a very large influence on the overall results.
- **More accurate estimates of IUU activity require stronger monitoring and better coordination of relevant statistics –** while the information base available to this study was an improvement on the 2016 study, considerable uncertainty remains around a number of key risks. Reducing uncertainty will require stronger monitoring, particularly of the longline sector, as well as a greater emphasis on the collection of relevant, quantifiable statistics associated with each risk. While some of this may require 'new' initiatives (e.g. better access to transhipment observer data, EM), in some cases it will simply require better use of existing facilities. For example, comprehensive statistics on numbers of aircraft and surface platforms used, 'on task' aerial surveillance hours, surface platform hours underway and other metrics are kept for each of the regional operations in the region, however only very limited, summary statistics have been kept to date on the outcomes in the way of infringements detected and prosecutions arising. Most outcomes are reported simply as the overall number of contacts/infringements detected, with little detail on the type of vessel or infringement. From an IUU quantification and MCS analysis point of view, this limits the value of an otherwise potentially very useful dataset. We understand that having access to information on surveillance outcomes relies on FFA members providing follow up information to the Secretariat and efforts to this end should be redoubled.

6 What additional measures can be taken to better understand and eliminate IUU fishing?

As outlined in the 2016 study, considerable efforts have been taken at the national, sub-regional (FFA/SPC/PNA) and regional levels (WCPFC) to mitigate IUU fishing in Pacific tuna fisheries. Many of these are likely to have been highly effective at achieving their intended purpose (e.g. the FFA and WCPFC VMS, the FFA Regional Register, the FFA HMTCs, the Pacific Patrol Boat Program, Niue Treaty and subsidiary agreements, 100% observer coverage in the purse seine fishery, etc) and will have contributed to the relatively low estimates of IUU fishing across a number of sector/categories. Moreover, a range of additional MCS measures have been taken since the 2016 study (e.g. establishment of the PMSP, strengthening of longline unloadings monitoring coverage) which have better informed the 2020 update estimates and contributed to the lower overall estimates.

Nevertheless, ongoing uncertainties in relation to a number of key risks highlight areas where additional measures could be taken to strengthen incentives for voluntary compliance, reinforce deterrents to non-compliance and improve monitoring throughout the supply chain.

Ultimately the most practical mix of MCS arrangements to deal with IUU fishing will be a function of the balance between the likely effectiveness of the measure in treating priority risks, practicality of implementation and overall costs. A summary of possible additional MCS measures that can be taken to further mitigate IUU fishing in WCPO tuna fisheries is provided in Annex 4. This table was included in the 2016 study and has been updated here. The main features and benefits of each MCS activity are described, together with the relative costs and risk categories that they're likely to address. A suggested level of priority is also given taking into account the main IUU issues identified in this report as well as issues such as likely effectiveness and implementation costs.

A discussion of the main needs and relative priorities in each fishery is included below. For convenience both longline sectors are discussed together given future needs are likely to be similar.

6.1 Longline

6.1.1 Strengthening catch monitoring

The priority in the longline sector is to strengthen measures to monitor and validate catch of licensed vessels throughout the supply chain. Despite good improvements in some areas (e.g. unloadings coverage in FFA ports), current monitoring arrangements remain weak for some fleets (limited observer coverage, limited availability of transhipment observer reports, limited capacity to inspect high seas vessels), meaning that opportunities for independent verification of catches is limited.

There are a number of measures that could be taken to strengthen monitoring throughout the supply chain. Many of these are integrated to the extent that they serve both scientific and compliance purposes. While the costs and benefits of each measure should considered, we note that many can be implemented relatively cost effectively, or at neutral cost to FFA members if cost recovered. Key measures include:

- Strengthening observer coverage for those longline fleets not meeting the 5% WCPFC benchmark, as well as FFA domestic fleets;
- More active cross-verification of independent data sources to identify discrepancies (e.g. logsheet Vs unloading, etc). This is most likely to be achieved through enhanced use of information management systems, supported by stronger analytical capacity in national and regional agencies (e.g. reports are available in the Tufman 2 / DORADO systems that compare longline logsheets with unloadings data at the trip level. These reports can be

produced at the COMPANY level and then a meeting scheduled with the fishing company representatives to ask them to explain the discrepancies);
- Enhanced focus on detecting and investigating reporting offences, including the use of administrative sanctions for 'minor' offences and strong sanctions for major offences;
- Development and implementation of a catch documentation scheme (CDS) for key species;
- Electronic reporting and monitoring; and
- Stronger monitoring and control of at-sea transhipment, including more effective implementation of observer monitoring arrangements.

6.1.2 Transhipment regulation and monitoring

While the availability of WCPFC Transhipment Declaration and AIS information has improved our understanding of the scope for unauthorised transhipments for this study, in practice transhipment monitoring and regulation in the WCPO remains a work in progress. The absence of any centralised regional accounting of unloads means that it is difficult to reconcile reported catches with transhipments/unloads, and the absence of transhipment observer information means there is little capacity to independently verify vessel transhipment reporting. To that end, important uncertainties around the transhipment process and the movement of longline product through the supply chain remain.

Key measures that might be taken to strengthen monitoring and control of transhipment include:

- strengthening arrangements for the implementation of the transhipment observer program (e.g. minimum data fields should be agreed; all observer data should be provided to the WCPFC to allow for validation of vessel transhipment declarations; data sharing arrangements should be agreed between WCPFC/IATTC);
- requiring those CCMs who authorise vessels to tranship on the high seas to submit tangible plans detailing the steps they will take to encourage their vessels to tranship in port (consistent with CMM 09-06);
- agreeing amongst the WCPFC membership the circumstances under which it is impractical for a vessel to tranship in port, and requiring CCMs to apply these rules;
- strengthening monitoring on offloading vessels (e.g. EM may be applied as a condition of authorisation to tranship on the high seas) and examining the utility of EM on carrier vessels;
- requiring all CCMs which authorise vessels to tranship on the high seas to submit evidence of the processes and mechanisms they use to verify transhipment information submitted by their vessels (consistent with CMM 09-06); and
- stronger monitoring of transhipment activity through integrated analytical approaches (e.g. combining VMS/AIS data, observer e-reporting, EM, machine learning techniques); and
- requiring carrier vessels to report meetings with vessels at sea that do not involve a transfer of fish.

In parallel, there may be benefit in requiring reporting of all in port unloads for product taken within the WCPFC-CA, which would potentially allow for reconciliation of catch reported in logsheets against that entering the next stage of the supply chain. A similar recommendation was made by McCoy (2012).

6.1.3 Non-compliance with other license conditions

Collectively the 'non-compliance with other license condition risks' accounted for around 2.5% of the total longline IUU activity, and slightly higher in value terms when shark finning is included. The main contributor in both the TLL and SLL sectors were the use of non-prescribed gear and shark finning, albeit estimates of both remain highly uncertain. Key measures that may be taken to improve our understanding of non-compliance with license conditions include:

- Strengthening observer coverage;
- Electronic monitoring;
- Risk-based dockside compliance inspections.

6.1.4 Unlicensed fishing

The three forms of unlicensed fishing assessed here collectively accounted for only around 2% of total estimated IUU activity by volume in the longline sectors. Of these, the main contributor was unlicensed fishing by vessels on the WCPFC RFV, which accounted for around 55% of overall volume for both sectors combined. While the results of this study suggest that other forms of IUU activity deserve greater attention, maintaining an effective level of deterrent is important to guard against higher levels of unlicensed fishing in future (and uncertainties remain over the extent of high seas longline fleet incursions into EEZs). Additional measures that might be taken include:

- Requiring entry and exit reports for all vessels upon entry to/exit from the WCPFC CA to allow for an accounting of which vessels should be reporting on VMS;
- Electronic monitoring (which, matched with VMS, could detect fishing activity and position);
- Additional analysis of VMS/AIS information to identify potential illegal fishing activity (this could be combined with artificial intelligence/machine learning approaches to detecting illegal fishing behaviour);
- Stronger monitoring of ALC activity (e.g. active intervention where an ALC appears to be non-responsive and a real time public list of ALCs manually reporting); and
- Use of synthetic aperture radar (satellite imagery).

For areas where unregulated fishing is a particular problem (e.g. the western fringes of the study area), partnering with source countries to strengthening awareness amongst fishing communities of maritime boundaries and penalties for illegal fishing may be effective. Moreover, the use of novel surveillance tools such as satellite imagery may assist in supplementing more conventional aerial and surface surveillance, although these would need to partnered with surface assets for effective apprehensions.

6.2 Purse seine

Notwithstanding recent complications arising from COVID-19 restrictions, the MCS arrangements in place for the purse seine fishery are considerably stronger than those for longline. Vessels are subject to 100% observer coverage, are required to tranship in port which allows for the application of dockside inspections and monitoring, are required to e-report under the VDS, and the majority of effort occurs in EEZs subject to coastal State laws. Moreover, the fact that there are fewer vessels makes them logistically easier to monitor. Nevertheless, there are a number of measures FFA members may wish to consider to enhance monitoring and control in some areas.

6.2.1 Catch verification

A key uncertainty in the purse seine fishery is the extent to which catch reported on vessel logsheets and observer estimates reflect the actual catch. Both sets of data reflect estimates made at sea and are subject to their own inherent biases (e.g. Lawson, 2010; Hampton and Williams, 2011). In most cases, the first time purse seine catches are weighed is during sorting at canneries, where catches are graded accurately into species and size class. The results of the catch weighing and sorting process is reflected in 'outturn reports', which set out the catch weights and size classes in the catch by species.

Provided data is collected consistent with the conditions outlined in Williams (2020) (e.g. adequate traceability, accounting for partial unloads, etc), the use of outturn reports (potentially as part of a CDS) shows promise as a valuable independent estimate of catch at the trip level (at least for retained target species). These could be compared to both vessel and observer estimates to identify discrepancies at the trip and overall level (given the mixing of sets and wells on carrier vessels, verification on a set by set basis is unlikely). We note that this idea is not new and has been the subject of a WCPFC CMM (09-10), which still on the books. We also note that the practicality of a CDS is currently being examined through FFA's (NZ funded) Catch Documentation and Enhancing Compliance Project.

An additional (and complementary) measure would be to encourage the use of crane scales (dynamometers) during the process of transhipment and unloading to strengthen verification of total weight reporting (see for example Hosken et al, 2020). These are currently being examined as part of the unloading monitoring initiatives in many port States, supported by FFA's (NZ funded) Pacific Islands Port State Measures Project. We also note that broader efforts to improve estimates of catch composition in the purse seine sector are also underway through WCPFC's Project 60 (Peatman et al, 2020).

6.2.2 FAD tracking and management

Although estimates of FAD fishing during the closure have been substantially reduced in this study compared to the 2016 study (largely as a result of a revised methodology), there remains a clear case to strengthen the registration and tracking of FADs deployed within the WCPFC area. FAD numbers have increased over time and sonar buoy technology has improved dramatically, such that FAD usage amongst the industrial purse seine fishery is substantially influencing fishery, and potentially stock, dynamics. Stronger registration and tracking arrangements will provide a stronger basis upon which to monitor the influence of FAD numbers, density and technology on fishery dynamics, as well as better monitor compliance with management measures such as FAD limits and closures. Stronger registration and tracking will also support efforts to minimise the environmental impacts of beaching and marine debris.

We note that very good progress towards this end has been made by PNA Parties through FAD-registration and tracking work conducted to date and agreement of a 4th Implementing Arrangement governing FAD buoy registration, tracking and information sharing[34].

[34] https://pnatuna.com/sites/default/files/4IA%20Resolution_2020.pdf

7 References

Agnew DJ, Pearce J, Pramod G, Peatman T, Watson R, et al. (2009) Estimating the Worldwide Extent of Illegal Fishing. PloS ONE 4(2): e4570. Doi:10.1371/journal.pone.0004570

Ainsworth, C.H. and Pitcher, T.J. (2005) Estimating illegal, unreported and unregulated catch in British Columbia's marine fisheries. *Fisheries Research* 75, 40–55.

Anon (2020). Philippines: Annual Report to the Commission Part 1: Information on Fisheries, Research, and Statistics. Scientific Committee Sixteenth Regular Session. Online Meeting 11 –20 August 2020. WCPFC-SC16-AR/CCM-20 (Rev.01).

Banks, R. (2015). PNA Economic Indicators. Unpublished - confidential: Richard Banks, Economic Advisor to PNAO.

BOBLME (2015) Review of impacts of Illegal, Unreported and Unregulated fishing on developing countries in Asia. BOBLME-2015-Governance-15.

Brown, C., Desbiens, A., Campbell, M., Game, E., Gilman, E., Hamilton, R., Heberer, C., Itano, D. and Pollock, K. (2021). Electronic monitoring for improved accountability in western Pacific tuna longline fisheries. Marine Policy 132 (2021).

Cardeñosa, D., Fields, A., Babcock, E., Shea, S., Feldheim, K., Kraft, D., Hutchinson, M., Herrera, M., Caballero, S. and Chapman, D. (2020). Indo-Pacific origins of silky shark fins in major shark fin
markets highlights supply chains and management bodies key for conservation. Conservation Letters. 2020. https://doi.org/10.1111/conl.12780.

Dent, F. & Clarke, S. (2015). State of the global market for shark products. FAO Fisheries and Aquaculture Technical Paper No. 590. Rome, FAO. 187 pp.

FAO (2001). International Plan of Action to Prevent, Deter and Eliminate Illegal, Unreported and Unregulated Fishing. Rome, FAO. 2001. 24p.

FAO (2002). Implementation of the International Plan of Action to Prevent, Deter and Eliminate Illegal, Unreported and Unregulated Fishing. FAO Technical Guidelines for Responsible Fisheries. No. 9. Rome, FAO. 2002. 122p.

FAO (2018). Technical guidelines on methodologies and indicators for the estimation of the magnitude and impact of illegal, unreported and unregulated (IUU) fishing. Volume 2 – Guiding Principles and Approaches. Advanced copy. 50pp. (available at: http://www.fao.org/3/CA0458EN/ca0458en.pdf)

FAO (2021). Technical guidelines on methodologies and indicators for the estimation of the magnitude and impact of illegal, unreported and unregulated (IUU) fishing. Volume 3.1: A Practical Guide for Undertaking IUU Fishing Estimation Studies. Advanced copy. (available at: http://www.fao.org/3/cb3175en/cb3175en.pdf)

FFA (2019). The Harmonised Minimum Terms and Conditions for Foreign Fishing Vessel Access. As amended by FFC110 (May 2019)

Francis, M.P. (2014). Estimation of fin ratios and dressed weight conversion factors for selected shark species. New Zealand Fisheries Assessment Report 2014/68. 31 p.

Hampton, J. and Williams, P. (2011). Misreporting of purse seine catches of skipjack and yellowfin-bigeye on logsheets. Scientific Committee Seventh Regular Session. 9-17 August 2011 Pohnpei, Federated States of Micronesia. WCPFC-SC7-2011/ST-WP-02

Hare, S. R., Harley, S.J. and Hampton, W.J. (2015). Verifying FAD-association in purse seine catches on the basis of catch sampling. *Fisheries Research* 172: 361–372.

Ho, K. and Shea, S. (2021). Comparison Report: the 2009/10, 2014/15 and 2019/20 surveys of shark consumption habits and attitudes in Hong Kong. 41 p. (http://www.bloomassociation.org/en/wp-content/uploads/2021/06/2019-20-Shark-fin-sociological-survey-comparison-report.pdf)

Hosken, M., Blaha, F. and Lasi, F. (2020). Estimation of variability in Purse Seine catch weights. Scientific Committee Sixteenth Regular Session. Online Meeting 11 –20 August 2020. WCPFC-SC16-2020/ST-IP-10.

IATTC (2020). Report on the Tuna Fishery, Stocks, and Ecosystem in the Eastern Pacific Ocean in 2019. 203pp.

ICCAT (undated). ICCAT Transhipment ROP Reports (https://iccat.int/en/ROP.html)

Lawson, T.A. (2009). Selectivity bias in grab samples and other factors affecting the analysis of species composition data collected by observers on purse seiners in the Western and Central Pacific Ocean. Working Paper SC5–ST–WP–03. Fifth Regular Session of the Scientific Committee of the WCPFC, 10–21 August 2009, Port Vila, Vanuatu.

Lawson, T.A. (2010). Update on the estimation of selectivity bias based on paired spill and grab samples collected by observers on purse seiners in the Western and Central Pacific Ocean. Working Paper ST-WP–2. Sixth Regular Session of the Scientific Committee of the WCPFC. Nuku'alofa, Tonga. 10–19 August 2010.

Lawson, T.A. (2012).Estimation of the species composition of the catch by purse seiners in the Western and Central Pacific Ocean using grab samples and spill samples collected by observers. Working Paper SC8–ST–WP–03. Eighth Regular Session of the Scientific Committee of the WCPFC, 7–15 August 2012, Busan, Korea.

Lawson, T (2014). Comparison of the species composition of purse-seine catches determined from logsheets, observer data, market data, cannery receipts and port sampling data. WCPFC-SC10-2014/ST-WP-02.

Le Gallic, B. and Cox, A. (2006) An economic analysis of illegal, unreported and unregulated (IUU) fishing: Key drivers and possible solutions. *Marine Policy* 30, 689–695.

McCoy, M. (2012). A Survey of Tuna Transhipment in Pacific Island Countries: Opportunities for Increasing Benefits and Improving Monitoring. 70pp.

MRAG, Ltd. (2005) Review of Impacts of Illegal, Unreported and Unregulated Fishing on Developing Countries. Final Report to DFID. July 2005. 178pp.

MRAG Asia Pacific (2016). Towards the Quantification of Illegal, Unreported and Unregulated (IUU) Fishing in the Pacific Islands Region. 93pp.

MRAG Asia Pacific (2019). WCPO Transhipment Business Ecosystem Study. 110pp. (https://www.m2cms.com.au/uploaded/5/Pew%20WCPO%20Transhipment%20Report%20-%20final.pdf)

New Zealand (2017). MCS Activities carried out by New Zealand. Technical and Compliance Committee. Thirteenth Regular Session. 27 September – 3 October 2017. Pohnpei, Federated States of Micronesia. WCPFC-TCC13-2017-DP-07. 29 September 2017.

NFRDI, BFAR and SPC (2020). Availability of Catch Estimates from the Other Commercial Fisheries in The Philippines. Scientific Committee Sixteenth Regular Session. Online Meeting 11 –20 August 2020. WCPFC-SC16-2020/MI IP-17.

Pauly D. and J. Maclean (2003). In a perfect ocean. Island press.

Peatman, T., Satoh, K., Matsumoto, T., Caillot, S., and Smith, N. (2017). Improving the quality of Japanese purse seine catch composition estimates: a Project 60 collaboration. Scientific Committee Thirteenth Regular Session. Rarotonga, Cook Islands 9–17 August 2017. WCPFC-SC13-2017/ST-WP-03.

Peatman, T. and Nichol, S. (2020). Updated Longline Bycatch Estimates in the WCPO. Scientific Committee Sixteenth Regular Session. Online Meeting 11 –20 August 2020. WCPFC-SC16-2020/ST-IP-11.

Peatman, T., Williams, P. and Nichol, S. (2020). Project 60: Progress Towards Achieving SC15 Recommendations. Scientific Committee Sixteenth Regular Session. Online Meeting 11 –20 August 2020. WCPFC-SC16-2020/ST-IP-04.

Pitcher, T.J., Watson, R., Forrest, R., Valtysson, H., Guenette, S., (2002). Estimating illegal and unreported catches from marine ecosystems: a basis for change. *Fish Fish.* 3, 317–339.

PNA (2020). PNA Economic Overview. Working Paper to the Palau Arrangement.

Rice, J., Tremblay-Boyer, L., Scott, R., Hare, S. and Tidd, A., (2015) Analysis of stock status and related indicators for key shark species of the Western Central Pacific Fisheries Commission. WCPFC-SC11-2015/EB-WP-04-Rev 1. Scientific Committee Eleventh Regular Session Pohnpei, Federated States of Micronesia 5-13 August 2015.

SPC (2020) Estimates of Annual Catches in the WCPFC Statistical Area. Scientific Committee Sixteenth Regular Session. Online Meeting 11 –20 August 2020. WCPFC-SC16-2020/ST IP-1

SPC (2021). Catch and effort tables on tropical tuna CMMs. Development of a new tropical tuna measures workshop 1. (TTMW1). 26-30 April, 2021. WCPFC-TTMW1-2021-IP02. 26 March 2021.

WCPFC (2009). Conservation and Management Measures for Bigeye and Yellowfin Tuna in the Western and Central Pacific Ocean. CMM 2008-01.

WCPFC (2012). Scientific Data to be Provided to the Commission. (As refined and adopted at the Ninth Regular Session of the Commission, Manila, Philippines, 2-6 December 2012).

WCPFC (2013). Executive Director's Report on Operational Technical and Compliance Issues to the TCC. Technical and Compliance Committee Ninth Regular Session 26 September – 1 October 2013 Pohnpei, Federated States of Micronesia. WCPFC-TCC9-2013-08 9th September 2013.

WCPFC (2019). Annual Report on WCPFC Transhipment Reporting. Technical and Compliance Committee. Fifteenth Regular Session. 25 September – 1 October 2019. Pohnpei, Federated States of Micronesia. WCPFC-TCC15-2019-RP03. 17 September 2019.

WCPFC (2020a). 2020 Final Compliance Monitoring Report (Covering 2019 Activities). Commission Seventeenth Regular Session. Electronic Meeting 8 – 15 December 2020. WCPFC17-2020-fCMR. 15 December 2020.

WCPFC (2020b). Annual Report on WCPFC Transhipment Reporting. Technical and Compliance Committee. Sixteenth Regular Session. Electronic Meeting. 23 – 29 September 2020. WCPFC-TCC16-2020-RP03_rev1. 10 December 2020.

Wilcox, C., Mann, V., Cannard, T., Ford, J., Hoshino, E. and Pascoe, S. 2021. A review of illegal, unreported and unregulated fishing issues and progress in the Asia-Pacific Fishery Commission region. Bangkok, FAO and Hobart, CSIRO. https://doi.org/10.4060/cb2640en

WildAid (2018). Sharks in Crisis: Evidence of Positive Behavioral Change in China as New Threats Emerge. 28 p.

Williams, P. (2020). An update on cannery data with potential use to the WCPFC. Scientific Committee Sixteenth Regular Session. Online Meeting 11 –20 August 2020. WCPFC-SC16-2020/ST IP-03 rev. 2

Annex 1: Terms of Reference

THE QUANTIFICATION OF IUU FISHING IN THE PACIFIC ISLANDS REGION – A 2020 UPDATE

A. Background

Illegal, unreported and unregulated (IUU) fishing is a major contributor to declining fish stocks and marine habitat destruction. Globally, IUU fishing takes many forms both within nationally-controlled waters and on the high seas. While it is not known for sure how much IUU fishing is taking place, some previous global estimates have suggested that IUU fishing accounts for about 30 per cent of all fishing activity worldwide.

Strong governance of the high seas through regional fisheries management organizations (RFMOs) is integral to reducing illegal fishing activities. An increasing number of RFMOs are using port and trade measures to discourage IUU fishing activity. Measures include not allowing vessels suspected of fishing illegally to dock or unload in a country's port, developing IUU lists of vessels taking part in illegal fishing activities.

Up until 2016, previously published 2009 IUU loss estimates for the WCPFC region are somewhere in the region of 750,000 million to 1.5 Billion US dollars a year. In 2016, FFA supported the preparation of a detailed study undertaken by MRAG Asia, Pacific (Towards the Quantification of Illegal, Unreported and Unregulated (IUU) Fishing in the Pacific Islands Region) [35].

This study provided the following summary:

- Our simulations suggest the best estimate total volume of product either harvested or transhipped involving IUU activity in Pacific tuna fisheries is 306,440t, with 90% confidence that the actual figure lies within a range of 276,546t to 338,475t. Based on the expected species composition and markets, the ex-vessel value of the best estimate figure is $616.11m. The 90% confidence range is between $517.91m and $740.17m. That is, there is a 95% chance the figure is greater than $517.91m and a 5% chance the figure is greater than $740.17m.
- Of the three main sectors assessed, estimated volume of IUU product was highest in the purse seine fishery, accounting for 70% of overall volume. Estimated IUU volumes in this sector were largely driven by reporting violations and illegal FAD fishing during the closure period. The TLL and SLL sectors accounted for 19% and 11% of the overall volume respectively. In the TLL sector, IUU volumes were largely driven by misreporting (49% of total TLL volume) and post-harvest risks (39%), principally illegal transhipping. Estimates of both misreporting and illegal transhipping were, in turn, influenced by high levels of uncertainty. Similar results were achieved in the SLL sector, with misreporting and post-harvest risks accounting for 57% and 36% of overall estimated IUU volume respectively.
- By contrast, the TLL sector accounted for the highest ex-vessel value of IUU product ($272.55m) given the higher market value of its target species. This sector accounted for around 44% of overall estimated IUU value, while the purse seine sector accounted for 37%. The SLL sector had the lowest overall estimates of IUU product value (19%).
- Of the four main IUU risk categories assessed, reporting violations and noncompliance with other license conditions (e.g. illegal FAD fishing; use of non-prescribed gear) accounted for 54% and 29% of the total estimated IUU volume respectively. Post-harvest risks (mainly illegal transhipping) accounted for 13% of the estimated volume but 27% of the estimated value. This was driven by higher estimates of illegal transhipping in the longline sectors which receive proportionally higher prices for product. Unlicensed fishing accounted for only 4% of the estimated overall volume.
- Amongst the main target species, skipjack accounted for the largest proportion of total estimated IUU volume (33%), but a lesser proportion of the total estimated ex-vessel value (18%). The total estimated IUU volume of SKJ (100,730t) equated to around 5.1% of estimated total SKJ catch in the WCP-CA in 2014. Yellowfin accounted for the next highest volume (96,126t), making up 31% of the total estimated

[35] The Pacific Islands region is considered to comprise the EEZs of FFA island member countries, French territories and adjacent high seas areas

IUU volume, and 27% of the ex-vessel value. The total estimated IUU volume of YFT equated to around 15.8% of the estimated total catch of YFT in the WCP-CA during 2014. Much of this is driven by estimates of misreporting in the purse seine fishery which is subject to 100% observer coverage, and therefore may result in little unaccounted for catch. Bigeye also accounted for 19% of the overall estimated IUU volume, but 28% of the ex-vessel value. The total estimated IUU volume of BET equates to around 35% of the estimated total catch of BET in the WCP-CA in 2014. Importantly, this does not necessarily mean that 35% of additional BET have been taken in addition to reported figures. For example, a substantial proportion of the overall IUU BET estimates come from estimates of illegal transhipping, the product for which may still be reported in logsheets. ALB accounted for 4% of the overall estimated IUU volume and 6% of the total ex-vessel IUU value. The total estimated ALB IUU volume equates to around 9.4% of the estimated total ALB catch in the WCP-CA in 2014, although a substantial proportion of this related to post-harvest offences for which information was uncertain.

Analysis and main message:

- Apart from the headline volume and value figures, there are a number of key messages arising from the analysis: The estimates of IUU volume and value generated here are lower than most commonly quoted estimate of IUU fishing in the WCPO region ($707m – $1.557b), although these studies are not 'apples Vs apples' comparisons. The previous study (Agnew et al, 2009) used a 'top down' approach that looked at IUU fishing across a suite of species wider than tuna (e.g. demersal fish, shrimp) as well as including parts of Indonesia and the Philippines (across FAO Area 71). Relatively high levels of IUU fishing in coastal states on the western Pacific seaboard influenced the overall results;

- Estimates of IUU are dominated by the licensed fleet - assuming catch transhipped illegally is taken by licensed vessels, IUU fishing by the licensed fleet accounts for over 95% of the total volume and value of IUU activity estimated here. This proportion rises to 97% if unlicensed fishing by vessels that are otherwise authorised to fish in the Pacific Islands region (i.e. they are on the FFA RR or WCPFC RFV) are considered part of the 'licensed' fleet. This is consistent with previous studies and has important implications for MCS planning and investment;

- Ex-vessel value is not a good indicator of actual loss to FFA members – this is because the full value of the catch is not returned to coastal states under normal circumstances (only a proportion of total revenue is, typically through access fees) and because of their nature, some risks may not necessarily result in direct losses. In general, a better measure of the actual impact on coastal states is likely to be the economic rent lost as a result of IUU activity.

- Based on the most recent estimates of profitability in the WCPO purse seine and longline sectors, we estimate **the rent associated with IUU product estimated here is around $152.67m.** Nevertheless, because of the nature of access arrangements in Pacific tuna fisheries, it is possible that much of the rent associated with IUU activity is captured anyway, and this estimate either overstates, or is at least at the upper end of, actual impacts on the real economy. For example, in the purse seine fishery, there is a good argument that the competitive nature of the bidding process under the VDS means that rents generated through IUU activity would be captured in the prices that fishing companies are prepared to pay for fishing days and are therefore not lost to Pacific Island countries. This is perhaps less the case for the longline sectors where current access arrangements are probably less efficient at capturing rent;

- Stronger catch monitoring arrangements are required in the longline sector – mechanisms to independently verify catch in the longline sectors are limited for many fleets. Additional measures are required to strengthen confidence in catch reporting and compliance with catch-based CMMs and generate better estimates of IUU activity;

- 'IUU' is not straightforward – while the IPOA-IUU definition of IUU is clear in theory, applying it for the purposes of quantification is not always straightforward. Interpretations on what is, and is not, considered IUU for the purposes of quantification can substantially influence results; More accurate estimates of IUU activity require stronger monitoring and coordination of relevant statistics – the information available to support quantification of many risks was relatively limited and largely confined to expert judgement. Achieving more accurate estimates of IUU activity will require stronger monitoring and analysis, and the coordination of relevant statistics. While in some cases, this may require 'new' initiatives, in many cases it will simply require more effective use of existing facilities;

- Strong in zone MCS arrangements must be mirrored on the high seas – the outcomes of this study argue for stronger monitoring of catch and transhipment activity across all sectors, and in particular the longline sectors. Given the shared nature of stocks in the region, stronger MCS arrangements in zone should be mirrored on the high seas;
- Future IUU risks – the nature of IUU fishing is dynamic and influenced by the mix of incentives and disincentives, as well as changes in the regulatory environment. Future iterations of the IUU model developed here will need to take changes in the nature of IUU fishing into account.

FFA and SPC have a team of personnel associated with aspects of this work (including information management, data streaming and comparative analysis, VMS, Observers and catch certification). The current study proposes the recruitment of an IUU quantification specialist team to work with the designated FFA personnel on an agreed methodology to provide a detailed updated report towards the improved quantification of IUU fishing. This would examine both the volume and landed value of IUU catches, as well as general estimates of the impact on Pacific Island countries, and the economic costs to them, of different components of the IUU catch.

B. The Regional Monitoring Control and Surveillance Strategy (RMCSS) – 2018 – 2023 and Performance Indicators

The RMCSS was formally endorsed by the Forum Fisheries Committee in 2018. The Strategy provides a clear policy focus for FFA's MCS activities until 2023. The RMCSS contains four priority objectives, each of which has direct relevance to the development and maintenance of FFA's existing regional MCS framework:

i. Regional standards are in place for effective and efficient MCS systems;

ii. Quality information is available and accessible to national and regional officials to assess IUU risks and plan MCS activities;

iii. Procedures established and operationalised to conduct effective MCS activities; and

iv. Effective compliance and enforcement through efficient use of available information, analyses and intelligence, achieved through whole of government engagement.

Each priority objective contains corresponding activities requiring implementation by FFA Members and the FFA Secretariat, as well as seeking support from other partners (e.g. PNAO and SPC). In addition, the priority objectives are underpinned by Members' commitment to develop or review their national MCS plans, encompassing the broader suite of MCS tools and activities required at the national level.

Monitoring, evaluation and learning (M&E) is a critical component of the RMCSS, requiring constant and detailed attention from both Members and the FFA Secretariat alike. This M&E contains two broad components:

(a) Activity monitoring (national and regional); and

(b) Strategic monitoring (regional performance against RMCSS' goal to reduce IUU fishing).

A framework of RMCSS performance indicators has been developed in 2019 and is now available for application and will be fully utilised and applied in the current study.

C. Terms of Reference

1. Provide a summary of previous IUU quantification work undertaken in the WCPFC region and review the methodology applied to this work.

2. Review the information available through SPC and FFA to support comparative data analysis (including log sheets, observer reports, VMS, AIS, landing inspections, catch certification, MCS operations, Regional Information Management Systems(RIMF) and national Information Management Systems (IMS); and develop a robust and statistically sound methodology that makes best use of this information to quantify the volume and landed value of IUU catches, identifying clearly the different components of illegal, unreported and unregulated fishing catches.

3. Review the information available on the context of populating the RMCSS performance indicators and give consideration to the current status of implementation of the Regional Monitoring, Control and Surveillance strategy (RMCSS) and the regional capacity to effectively manage IUU fishing.

4. Use all available information to provide a model for the nature and extent of IUU fishing in Pacific Island tuna fisheries and estimate the volume and gross landed value of catches involved. Take account of SPC data sources and data streaming (either through work directly at SPC or from remote sourcing) and areas of potential data gaps in preparing the proposed methodology and conducting the analysis.

5. Examine the impacts of IUU fishing on Pacific Island countries, and develop estimates of the economic losses that they incur as a result of this level of IUU fishing (for example potential access fee revenue lost, impacts on the profitability of domestic fishing operations, etc.).

6. Give consideration to the costs and benefits of further improvements to IUU monitoring, detection and elimination.

7. Work in close consultation with a nominated team of FFA/SPC staff and advisers so as to ensure all available relevant information is utilised in the preparation of the study findings and report.

D. Anticipated Outputs

The summary report should include:

- A clear statement of the methodology used to undertake the quantification process.
- An outline plan summary as to how this work has been effectively carried out as a desktop study.
- A detailed analysis of the application of the methodology in considering the nature and extent of IUU fishing in the WCPFC. This should include consideration of the context of the newly developed Performance Indicators for the Regional MCS Strategy (2018 – 2023) and mechanisms for benchmarking IUU mitigation against FFA operation MCS activities under major donor projects.
- An updated estimation of volumes of IUU fishing and a valuation of the estimated costs to the WCPFC region from IUU fishing.
- A review of the currently available IUU detection toolbox applications and consideration of further refinements.
- Consideration of risk profiles for the key areas of IUU offending and options for the further refinement of mitigation strategies.

The principal output from the study will be a detailed technical report and associated appendices that comprehensively address the terms of reference and provide a solid methodology for the estimation of IUU quantification.

The report should also provide recommendations to the Secretariat as to what additional activities or actions could be taken for ongoing estimates of IUU quantification and the increased eradication of IUU activity in Pacific Islands region.

The consultants will be required to submit a draft report for comment and review, and take account of comments before compiling the final report.

Annex 2: Ex-vessel values

Table 42: Ex-vessel market value by species (US$/MT)

	SKJ	YFT	BET	ALB	BIL	OTH	SHK Fin[#]
Purse Seine*	1,283	1,446	1,283			1,283	$20,000
Tropical Longline**		4,064	6,819	2,397	5,427	2,250	$20,000
Southern Longline		4,064	6,819	2,397	5,427	2,250	$20,000

Source:

* BKK weighted average sourced from Pacific fleets less US$ 250 adjustment for C&F;

** Japan Customs and Excise C&F frozen less US$1,000/MT (ULT container transport rate)

dry weight (~$8/kg wet weight, assuming 40% dry weight to wet weight ratio)

	Weighted price US$ / MT	Average rent / MT	%
Purse Seine*	$ 1,317	$369	28
Tropical Longline**	$ 5,348	$931	17.4
Southern Longline	$ 3,248	$45	1.4

Source: PNA Economic model

Annex 3: IUU Activity descriptions

Table 43: IUU activity descriptions

Risk/Activity	IUU	
Unlicensed/unauthorised fishing		
Unauthorised fishing by vessels on the FFA Vessel Register	I	This activity involves fishing by vessels on the FFA Vessel Register (i.e. licensed in at least one FFA member EEZ and therefore reporting via VMS to FFA) in an EEZ for which they have no valid license or authority to operate. This could colloquially be referred to as 'border hopping'.
Unauthorised fishing by vessels on the WCPFC RFV but not on the FFA Vessel Register	I	This activity involves fishing by vessels registered on the WCPFC RFV, but not licensed in any FFA member EEZ, in jurisdictions for which they have no valid license or authority to operate. This could involve, for example, a CCM vessel authorised to fish on the high seas who fishes in an FFA member EEZ.
Unregulated fishing	URG	In the context of this study, we have broadly considered unregulated fishing to be undertaken by vessels not on the WCPFC RFV. This could occur either when (i) a vessel flagged to a State who is not a member of the WCPFC fishes inside the Convention area, or (ii) a vessel flagged to a WCPFC CCM but which is not on the WCPFC RFV fishes in an area for which they are not authorised. This latter circumstance is perhaps more accurately categorised as 'illegal fishing' in the context of the FAO IUU definition, although we have included it here because these vessels are not reporting to either the FFA or WCPFC VMS and are the same as non-CCM vessels from a 'visibility' point of view.
Misreporting		
Misreporting of target species	URP	Misreporting of target species can include both non-reporting (or under-reporting) and mis-identifying (reporting one species as another species). In the purse seine sector, this could include reporting yellowfin as skipjack for convenience, or under-reporting the amount of skipjack taken. In the longline sector, this may include failing to report discarded target species, or under-reporting both number and weight of target species. All catch, both retained and discarded, is required to be reported under the FFA Harmonised Minimum Terms and Conditions for Foreign Fishing Vessel Access (HMTCs)[36].
Misreporting of byproduct species	URP	This is the same as above but for non-tuna species.
Non-compliance with license conditions		

[36] http://www.ffa.int/system/files/HMTC%20FFC77%20Approved_0.pdf

Use of non-prescribed gear	I	This occurs when a vessel uses fishing gear other than that allowed for under their relevant license or authority to operate. In the longline sector, for example, this may include using wire traces where such apparatus is prohibited.
Fishing on FAD when not authorised (PS only)	I	This occurs when a vessel fishes on a FAD or floating object in contravention of agreed FAD-closure measures, or in contravention of an agreed FAD management plan.
Fishing inside closed waters within EEZs	I	This occurs when a vessel fishes within areas to which they are prohibited under license conditions or other arrangements. This would include, for example, fishing within areas around islands closed under license conditions in most FFA member EEZs.
Shark finning	I	This occurs when a vessel removes and retains the fins of a shark while discarding the carcass at sea in contravention of regional or national conservation and management measures.
Exceeding catch/effort allocations	I	For the purposes of this study, we have included circumstances in which WCPFC CCMs have been assessed priority non-compliant against WCPFC catch, effort or vessel limits.
Post-harvest IUU		
Illegal transhipping	I	This occurs when a vessel tranships catch in contravention of relevant license conditions or other regional agreements.

Annex 4: WCPFC Transhipment Declaration/AIS matching procedure

Data sets used

GFW AIS data:

As mandated by the International Maritime Organization, it has been a requirement for commercial shipping vessels registered at 300 gross tons or more on international voyages, to broadcast on AIS since 2004 (IMO 2015). The use of AIS is not mandated for fishing vessels, yet an increasing number of flag and coastal States are mandating its use through their own national or regional fisheries regulations (e.g. FFA have required AIS as a precondition of registration on the FFA VR since July 2015). AIS devices broadcast vessel location along with other information, including identity, course, and speed.

AIS data within our study area from 2017-2019 was supplied by GFW. GFW uses publicly broadcasted AIS data to estimate vessel information and vessel activity, including fishing, encounter, and loitering events, based on registry database information, or as defined by a convolutional neural network (Kroodsma et al. 2018). An encounter event occurs when two vessels are within 500 meters of each other for at least 2 hours while traveling at < 2 knots, and at least 10 kilometres from a coastal anchorage (Miller et al. 2018). A "loitering" event occurs when a carrier vessel travelled at speeds of < 2 knots for at least an hour, while at least 20 nautical miles from shore (see Miller et al. 2018 for original methodology, however the original minimum of 8 hours has been changed to one hour for the purposes of this study).

WCPFC Transshipment Declarations:

Through FFA, the WCPFC Secretariat provided information reported on Transhipment Declarations submitted to the Secretariat for all events within the WCPFC-CA during 2017-2019. The information provided was broadly that required to be reported on Annex 1 of CMM 09-06 and included vessel names, callsigns, and IMO numbers of carrier and fishing vessels involved in each transshipment, and the date and location (latitude and longitude recorded in degrees and minutes) of each reported transshipment event.

WCPFC transshipment composition and quantity:

In addition to the information above, the WCPFC Secretariat also provided data on species composition and product types for a selection of 1675 transshipment events that occurred in the study area from 2017-2019. This dataset contained species-specific transshipped weights according to their product type: whole; filleted; gilled and gutted; gilled, gutted, and tailed; gutted and headed; gutted only; or dressed. Species-specific product weights were converted to approximate landed weights according to species-specific product-conversion factors for ALB, YFT, BET, SKJ, BLM, BUM, SWO, MLS, and DOL in Annex II of WCPFC Project 90 Update (2020). For LAG, OIL, ANY, LEC, BSH, and SHK conversion factors were not available and thus raw product weights per transshipment were used. As such, landed weight estimates of OTH transshipped are conservative. For each transshipment event, the approximate landed weight was subsequently summarized into the following categories: ALB, BET, YFT, BIL (sum of SWO, BLM, BUM, MLS) and OTH (LAG, OIL, ANY, LEC, BSH, DOL, SKJ, SBF, SFA, PBF).

Matching procedure

GFW AIS and WCPFC transshipment declaration datasets were matched using the below procedure and accompanying R code in R 1.4.1106.

Preliminary analysis suggested that WCPFC transshipment dates were occasionally incorrect by 1 day, whereby AIS data indicated the same carrier and fishing vessel meeting in the same location of a reported WCPFC transshipment one day earlier/ later than the reported event. This may occur due to differences in the recorded time zone of the WCPFC transshipment (local time vs. UTC), or because of differences in when the date was recorded relative to the transshipment (i.e., at the start, mid-point, or end of transshipment – which can span multiple days/ occur overnight). To accommodate these cases, we allowed a 24hr error window around each WCPFC reported transshipment date and included a distance cutoff to reduce the amount of 'false positives' which were returned when we allowed dates to fluctuate by 24hrs.

Additionally, a single location rounded to the nearest minute of longitude/latitude is reported to the WCPFC for each transshipment. Due to similar unknowns in data recording (i.e., if location was recorded at start, mid-point, or end of transshipment), potential incorrect rounding up/down of coordinates, and the fact that the location of GFW AIS events is recorded as the midpoint of the event (which can span up to 100nm for a loitering event that occurs across multiple days), we allowed for a 111km rounding error (approximately 1 degree of longitude at the equator) to ensure any errors made in location recording did not result in a non-match.

Therefore, to be considered a 'match', the carrier ship name, callsign, and/or IMO reported on the WCPFC transhipment declaration must have matched the respective GFW AIS information, and the date of the transhipment must have matched the GFW AIS event date (i.e., encounter/loiter date), or be within 24 hr of the GFW AIS event. Additionally, to be considered a 'match', each WCPFC transhipment must be less than or equal to the following distances from the AIS event:

- For a 1-2hr event - 119km (1 degree of longitude rounding = 111km + 2knts for 2 hrs = 4nm ≈ 8km)
- 2-4hr – 126km (1 degree rounding = 111km + 2knts for 4 hrs = 8nm ≈ 15km)
- 4-12hr – 156 km (1 degree rounding = 111km + 2knts for 12 hrs = 24nm ≈ 45km)
- 12-24hr – 200km (1 degree rounding = 111km + 2knts for 24 hrs = 48nm ≈ 89km)
- >24hr – 378km (1 degree rounding = 111km + 2knts for 72 hrs = 144nm ≈ 267km)

This produced a list of AIS matched WCPFC transshipments, a list of non-matched WCPFC transshipments, and a list of non-matched AIS event.

Calculation of average transhipment species composition and volume

In order to determine the quantity and composition of each reported transshipment we paired WCPFC transshipment composition and quantity data with the dataset of AIS matched WCPFC transshipments. To determine the average weight of ALB, BET, YFT, BIL and OTH offloaded per transshipment, we averaged the approximate landed weights per time bin according to the matched GFW event information. Because loitering events may or may not include a transshipment of fish, we used encounter events only to determine these averages.

Data caveats

This analysis relies on AIS data and therefore is limited to carrier vessels that transmit AIS data and do so by providing accurate vessel identity information. AIS data can be tampered with, but GFW does implement methods to help correct for false AIS data. Low satellite coverage of high-density areas can also limit the collection of AIS data, although the high seas WCPFC Convention Area has relatively strong Class-A AIS coverage. AIS data tends to be more limited for vessels equipped with Class-B AIS devices (Kroodsma et al. 2018). AIS device class often depends on flag State regulations, vessel length, and vessel purpose. Because of the limitations of AIS data, lack of complete and accurate public vessel databases and registries, and limitations of modelling estimations, the AIS detected encounter, and loitering data are represented as accurately as possible but should be considered restrained estimates based on these limitations (see Kroodsma et al. 2018, Miller et al. 2018, and https://globalfishingwatch.org/ for further information).

Snippets of R code used to match WCPFC transhipment information and GFW AIS data.

Code prepared by JR Lowe (MRAG-AP) and TD White (GFW)

Import data and attach packages.

````
```{r}
wcpfc <- read.csv("WCPFC_transhipment.data_2017-2019.csv", header= T)
gfw <- read.csv("GFW_AIS.data_2017-2019.csv", header= T)

#attach packages
library(stringr)
library(sqldf)
library(dplyr)
library(tidyr)
library(lubridate)
library(geosphere)
library(purrr)
library(ggplot2)
library(ggmap)
library(maps)
library(mapdata)
library(ggpubr)
library(sf)
library(maptools)
library(forcats)
```
````

Code for cleaning and normalizing vessel names.

````
```{r}
#make vessel name upper case
wcpfc$VesselName_clean<-toupper(wcpfc$CARRIER_Vessel_Name)
#remove spaces
wcpfc$VesselName_clean<-gsub(pattern = "\\s", replacement = "", x = wcpfc$VesselName_clean)
#remove periods
wcpfc$VesselName_clean<-str_replace(wcpfc$VesselName_clean, "NO.", "NO")

#repeat for FVs
wcpfc$FISHING_Vessel_Name_clean <-toupper(wcpfc$FISHING_Vessel_Name)
wcpfc$FISHING_Vessel_Name_clean <-gsub(pattern = "\\s", replacement = "", x =
wcpfc$FISHING_Vessel_Name_clean)
wcpfc$FISHING_Vessel_Name_clean <- str_replace(wcpfc$FISHING_Vessel_Name_clean,
"NO.", "")
```
````

Format date columns to POSIXct format.

````
```{r}
wcpfc$tev_Occured_Date_clean <- strptime(wcpfc$tev_Occured_Date, format= "%d-%b-%y")
wcpfc$tev_Occured_Date_clean<-as.POSIXct(wcpfc$tev_Occured_Date_clean)
gfw$event_start<-as.POSIXct(gfw$event_start)
gfw$event_end<-as.POSIXct(gfw$event_end)
```
````

Join GFW and WCPFC datasets using vessel name, IMO, and/or callsign, and date

````
```{r}
#Specifiy distance function to help identify false positives. The below function calculates
Haversine distance (accounting for Earth's radius, which only matters for large distances) for use
with purrr
calc_dist_km <- function(mean_lon, mean_lat, Longitude, Latitude) {
  p1 <- c(mean_lon, mean_lat)
  p2 <- c(Longitude, Latitude)
  r <- 6378.137
  distance <- geosphere::distHaversine(p1, p2, r)
  distance
}

#allow for 24hr play in dates in WCPFC data - explained in Methods
gfw2 <- gfw %>% mutate(
    start_range1 = as.Date(event_start - lubridate::hours(24)),
    end_range1 = as.Date(event_end + lubridate::hours(24)))
gfw2$start_range1<-as.POSIXct(gfw2$start_range1)
gfw2$end_range1<-as.POSIXct(gfw2$end_range1)

#Join GFW and WCPFC dataframes
GFW_WPCFC_Match <- sqldf("SELECT a.*,
                b.*
                FROM wcpfc AS a, gfw2 AS b
                WHERE (a.VesselName_clean=b.carrier_shipname
                OR a.CARRIER_IMO_Number=b.carrier_imo OR
a.CARRIER_IRCS=b.carrier_callsign)
                AND (a.tev_Occured_Date_clean>=b.start_range1
                AND a.tev_Occured_Date_clean<=b.end_range1)")

 # calculate distance using function defined above
  g1 <- GFW_WPCFC_Match %>%
  mutate(distance = purrr::pmap_dbl(
    .l = list(
      mean_lon,
      mean_lat,
      Longitude,
      Latitude),
    .f = calc_dist_km)) %>%
  group_by(event_start, event_end, mean_lat, mean_lon, event_duration_hr)

#filter according to distance cut-offs - see Methods for reasoning.
matched.1_2hr <- g1 %>% filter(duration_bin_h == "1-2h" & distance <= 119)
matched.2_4hr <- g1 %>% filter(duration_bin_h == "2-4h" & distance <= 126)
matched.4_12hr <- g1 %>% filter(duration_bin_h == "4-12h" & distance <= 156)
matched.12_24hr <- g1 %>% filter(duration_bin_h == "12-24h" & distance <= 200)
matched.24hr.plus <- g1 %>% filter(duration_bin_h == ">24h" & distance <= 378)
g1 <- rbind(matched.1_2hr , matched.2_4hr, matched.4_12hr, matched.12_24hr,
matched.24hr.plus)

gfw_matches<-gfw
gfw_matches$wcpfc_match<-NULL
gfw_matches$wcpfc_match[c(gfw_matches$id %in% g1$id)]<-'Match'
gfw_matches$wpfc_match[c(!gfw_matches$id %in% g1$id)]<-'No_Match'
gfw.matches.T <- gfw_matches %>% filter(wcpfc_match=="Match")
gfw.matches.F <- gfw_matches %>% filter(wcpfc_match=="No_Match")
````
````

```
###repeat filtering procedure for WCPFC data because 1 AIS loitering event can equate to
multiple WCPFC transhipments###

#filter for matching neighbor/ FV or, in the case of loitering, na=neighbor
g2 <- GFW_WPCFC_Match %>% filter(neighbor_shipname==FISHING_Vessel_Name_clean |
is.na(neighbor_shipname) | neighbor_imo==FV_IMO_Number | neighbor_callsign==FV_IRCS)
%>%
  # calculate distance using function defined above
  mutate(distance = purrr::pmap_dbl(
    .l = list(
      mean_lon,
      mean_lat,
      Longitude,
      Latitude),
    .f = calc_dist_km)) %>%
  group_by(event_start, event_end, mean_lat, mean_lon, event_duration_hr)

#filter according to distance cut-offs - see Methods for reasoning.
matched.1hr <- g3 %>% filter(duration_bin_h == "1-2h" & distance <= 119)
matched.2hr <- g3 %>% filter(duration_bin_h == "2-4h" & distance <= 126)
matched.4hr <- g3 %>% filter(duration_bin_h == "4-12h" & distance <= 156)
matched.12hr <- g3 %>% filter(duration_bin_h == "12-24h" & distance <= 200)
matched.24hr <- g3 %>% filter(duration_bin_h == ">24h" & distance <= 378)
g3 <- rbind(matched.1hr , matched.2hr, matched.4hr, matched.12hr, matched.24hr)

wcpfc_matches <- wcpfc
wcpfc_matches$gfw_match <- NULL
wcpfc_matches$gfw_match[c(wcpfc_matches$tev_ID %in% g3$tev_ID)]<-'Match'
wcpfc_matches$gfw_match[c(!wcpfc_matches$tev_ID %in% g3$tev_ID)]<-'No_Match'
wcpfc.matches.T <- wcpfc_matches %>% filter(gfw_match=="Match")
wcpfc.matches.F <- wcpfc_matches %>% filter(gfw_match=="No_Match")

#combine WCPFC matched df with GFW event duration information for later plotting of maps.
wcpfc.matched <- g3 %>% filter (tev_ID %in% wcpfc.matches.T$tev_ID)

#create summary dataframes of matched and non-matched AIS events to inform estimates.
GFW_non.match_summary_type <- gfw.matches.F %>% mutate(sector = ifelse(mean_lat>-
10,"TLL", "SLL")) %>% group_by(sector, type, duration_bin_h) %>%
  summarise(events = n())
GFW_match_summary_type <- gfw.matches.T %>% mutate(sector = ifelse(mean_lat>-10,"TLL",
"SLL")) %>% group_by(sector, type, duration_bin_h) %>%
  summarise(events = n())
```
````
```

Determining average offload rate and species composition per time bin and sector (TLL and SLL) - product weights previously converted to approximate landed weights using method described in *WCPFC transshipment composition and quantity:*

````
```{r}
RVD <- read.csv("WCPFC_aproximate.landed.weights_from.product.transhipments.csv")
catch.conversion <- g3 %>% left_join(RVD, by = "tev_ID")
catch.conversion$gfw_match <- NULL
catch.conversion$gfw_match[c(catch.conversion$tev_ID %in% wcpfc$tev_ID)]<-'Match'
cc.T <- catch.conversion %>% filter(gfw_match=="Match") %>% filter(OTH != "NA")
write.csv(cc.T, "wcpfc.matches.T_with_RVD.csv")
```
````

References:

Kroodsma, D. A., Mayorga, J., Hochberg, T., Miller, N. A., Boerder, K., Ferretti, F., et al. (2018). Tracking the global footprint of fisheries. Science 359, 904–908. doi:10.1126/science.aao5646.

Miller, N. A., Roan, A., Hochberg, T., Amos, J., and Kroodsma, D. A. (2018). Identifying Global Patterns of Transshipment Behavior. Front. Mar. Sci. 5:240. doi:10.3389/fmars.2018.00240.

WCPFC (2020) Project 90 update: Better data on fish weights and lengths for scientific analyses. Scientific Committee Sixteenth Regular Session

Annex 5: Possible additional measures to strengthen MCS arrangements

Table 44: Possible measures to strengthen MCS arrangements.

MCS Measure	Description/analysis	Relative cost	Risk addressed				Priority	
			Unlicensed fishing	Misreporting	Non-compliance with license conditions	Post-harvest risks	PS	LL
Monitoring								
Strengthening observer coverage	This measure is particularly relevant to the LL sectors. Current coverage rates are low across most fleets, although many fleets have meet their 5% coverage targets under CMM 20-01 (and predecessors) in recent years (pre-COVID-19). Observer data provides important information to calibrate vessel reporting, as well as monitoring compliance with other key license conditions (e.g. reporting SSI interactions, use of non-prescribed gear, etc). Indirectly, the presence of an observer on board is also likely to act as a deterrent to non-compliance.	High, but cost-neutral to FFA members if cost recovered						
Dockside inspections	Dockside inspections for compliance purposes is potentially a very cost effective method of monitoring catch reporting, as well as compliance with other license conditions (e.g. shark finning, non-prescribed gear, etc). The relatively concentrated nature of unloading and transhipping opportunities in Pacific Island countries lends itself to efficient dockside monitoring.	Moderate, but cost-neutral to FFA members if cost recovered						
Unloadings monitoring	For vessels calling into FFA member ports, monitoring of unloadings is an efficient way to verify catch reporting. Discrepancies between unloadings and logsheet reporting can be identified through information management systems. 'Minor' reporting offences may be dealt with through education or administrative sanctions, while major misreporting can be subject to stronger sanction. SPC use unloadings data to correct longline logsheet entries where necessary, so the widest possible coverage is preferred.	Moderate						
Electronic monitoring	Electronic monitoring (EM) has significant potential as a cost effective complement to human observers, particularly on the longline fleet which struggles to accommodate additional crew. EM is likely to be particularly beneficial in monitoring long-range DWFN LL vessels which rarely	High, but cost-neutral to FFA						

MCS Measure	Description/analysis	Relative cost	Risk addressed				Priority	
			Unlicensed fishing	Misreporting	Non-compliance with license conditions	Post-harvest risks	PS	LL
	call into to Pacific Island ports, meaning that it is both difficult to place an observer and opportunities for dockside inspections are limited. Successful trials have also been run in recent years on a number of FFA member domestic LL vessels. These have shown considerable potential although cost and logistical practicalities need to be worked through. The presence of an on board camera is likely to act as a deterrent to non-compliance. EM technology has already been successfully applied in a range of analogous fisheries worldwide (e.g. the Australian Eastern Tuna and Billfish Fishery). While the highest priority for EM is the LL fleet, the technology also has important application in PS fleets in providing independent verification of fishing activity and in strengthening observer safety, as well as compliance with license conditions (e.g. pollution).	members if fully cost recovered						
Catch Documentation Scheme (CDS)	Catch documentation schemes (CDS) have been used by a number of RFMOs in an effort to better monitor catches through the supply chain and mitigate against the infiltration of IUU product. The concept of a WCPFC CDS has long been discussed, and some preparatory work has been undertaken[37]. A number of FFA members have also introduced domestic schemes (e.g. PNG). A WCPFC CDS would assist in addressing some of the key areas of uncertainty in the longline supply chain (e.g. misreporting, illegal transhipment), as well as contribute to conservation efforts around some of the main stocks (e.g. BET).	Moderate						
Optimising use of VMS	The two VMS systems operating in the Pacific (FFA and WCPFC) are a central tool to monitor the location and activity of licensed fishing vessels, although arguably are not yet being used to their full potential. Information sharing arrangements are yet to be agreed between some neighbouring FFA members (meaning that vessels in neighbouring waters are not seen by FFA members until they enter their own waters), while a number have yet to 'flick the switch' to allow monitoring of WCPFC vessels within 100nm of their own EEZ or include their EEZs in the Commission VMS. Optimising the use of the existing VMS systems is an extremely cost effective way of enhancing visibility of licensed vessels, and assisting with MCS planning and	Low						

[37] https://meetings.wcpfc.int/meetings/cds-iwg03

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	prioritisation. Other improvements include making optimal use of alerts and geofencing at the national level.							
FAD registration and tracking	FAD usage and technology have both increased substantially over the past couple of decades, so getting a better handle on key metrics such as FAD number, density and distribution provides an important insight into fishery (and potentially stock) dynamics. Satellite buoy registration and tracking arrangements will also improve capacity to monitor regulatory FAD requirements, such as FAD limits and FAD sets during the close period, while also better positioning FFA member to avoid, and if necessary respond to, FAD beaching events. PNA Parties have made very good progress with satellite buoy registration and tracking and have agreed a 4th Implementing Arrangement to further formalise these measures.							
Catch verification through trade/cannery data	'Outturn' reports generated by canneries have the potential to provide an accurate catch weight and species composition, broken down by size, and potentially provide a promising additional avenue to verify purse seine catch composition. The use of cannery data to verify logsheet estimates has long been discussed (e.g. it was envisaged in WCPFC CMM09-10, which is still in force), and has been investigated in detail through SPC. Provided certain conditions around traceability and other issues can be met (see Williams, 2020), the use of outturn reports appears to be a potentially valuable tool in establishing accurate catch records of sectors ultimately delivering to canneries (e.g. purse seine, ALB LL).	Low						
Analytical tracking of potential transhipments	The use of analytical tools incorporating VMS, AIS and other data to track fishing behaviour, including transhipment, has improved substantially in recent years. Both FFA and WCPFC have versions of 'transhipment analysis' tools (FFA – Transhipment and Bunkering Tool; WCPFC – Transhipment Analysis Tool), while the use of Global Fishing Watch's data underpinning it's Carrier Vessel Portal has substantially improved the quality of data available to understand the scope for unauthorised transhipments for this study, compared to 2016. While AIS is not yet compulsory across all fishing vessels, ongoing near-real time analysis of AIS and VMS data – particularly when combined with other MCS tools (e.g. transhipment observer e-reporting, EM on carriers, port State measures) – has the potentially to substantially improve our understanding and monitoring of the at sea transhipment component of the supply chain.	Low (given VMS/AIS systems already exist)						

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	The use of AIS/VMS data also lends itself to the development of artificial intelligence/machine learning approaches to more automatically detect potentially unauthorised behaviour. These AI/ML type approaches could also be used to help detect on other types of 'transhipment' such as catch consolidation between LL vessels.							
Control								
Sanctions	An effective sanctions regime is an essential component of any effective MCS regime. Ultimately the cost of the sanction needs to outweigh the benefits of the offence to a sufficient extent that it acts as a significant deterrent to non-compliance. Sanctions are largely applied at the national level and require reviews at the national level.	Low						
Administrative penalties for 'minor' offences	A consistent feature of this and the 2016 study is that the licensed fleet is likely to be the main contributor to IUU fishing, and many of the infringements committed are likely to be considered relatively 'minor' by relevant authorities (e.g. minor misreporting offences). Available information suggests that many of these offences are not actively prosecuted at the national level, in part because of the high costs involved in taking (criminal) action through the court system. Administrative penalties (e.g. on the spot fines) offer a potentially practical and cost effective alternative to sanctioning for 'minor' offences. Fines for offences such as 'minor' misreporting, or delayed logbook submission, sends an important signal to licensed operators that compliance with license conditions is required, and non-compliance is not tolerated, however minor. Anecdotal reports from FFA members who have implemented administrative fines such as Fiji indicate they have successfully reduced minor offences. While effective governance and oversight systems are required to ensure the power to issue fines is not abused, administrative sanctions could potentially be applied cost effectively with considerable effect.	Low						
Stronger monitoring and control of transhipment at sea	Both this study and its 2016 predecessor highlighted at sea transhipment as a key area of uncertainty in the LL supply chain. While both carrier and fishing vessels are tracked using VMS, both are required to submit transhipment declarations and the receiving vessel is required to carry an observer, in practice very few, if any, observer reports have made their way to the WCPFC, meaning capacity to independently validate vessel reports remains very limited. The main CMM governing at sea transhipment in the WCPFC CA (CMM 09-06) was agreed over a							

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	decade ago and is currently under review. While we recognise that many FFA members would prefer a simple prohibition on all at sea transhipments, if the practice remains authorised in some form there are a range of practical reforms available to improve monitoring and control (some of which remain outstanding items from the existing CMM). These include: • Strengthening arrangements for the implementation of the transhipment observer program (e.g. minimum data fields should be agreed; all observer data should be provided to the WCPFC to allow for validation of vessel transhipment declarations; data sharing arrangements should be agreed between WCPFC/IATTC); • Requiring those CCMs who authorise vessels to tranship on the high seas to submit tangible plans detailing the steps they will take to encourage their vessels to tranship in port (consistent with CMM 09-06); • Agreeing amongst the WCPFC membership the circumstances under which it is impractical for a vessel to tranship in port, and requiring CCMs to apply these rules; • Strengthening monitoring on offloading vessels (e.g. EM may be applied as a condition of authorisation to tranship on the high seas) and examining the utility of EM on carrier vessels; • All CCMs which authorise vessels to tranship on the high seas should submit evidence of the processes and mechanisms they use to verify transhipment information submitted by their vessels (consistent with CMM 09-06); and • Stronger monitoring of potentially unauthorised transhipments through analytical approaches described above.							
'No-go' areas in closed waters	While fishing inside closed waters (e.g. 12nm closures around islands) was estimated to be very limited by this study, the offence itself can be socially and politically important at the local level (particularly if vulnerable, isolated communities are affected). One option which has been used effectively elsewhere (e.g. to protect 'scallop replenishment areas' in Queensland, Australia) is to make closed areas around islands/communities 'no-go' areas for large scale licensed vessels. This may work in areas for which vessels otherwise have no reason to be in (e.g. small areas around communities that are not otherwise anchoring sites for vessels, etc). Under this option, the presence of the vessel in the closed area detected by VMS would constitute an offence. It	Low						

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	would not be necessary to visually detect the vessel fishing, which saves surface and aerial surveillance costs. Prosecutions based on VMS evidence alone have been generated in other jurisdictions who have similar provisions.							
Surveillance								
Aerial surveillance capacity	Aerial surveillance is a valuable tool to target a number of risks identified in this report (e.g. illegal transhipping, unlicensed fishing), and arguably one of the only effective ways to detect some risks such as unregulated fishing. The capacity to undertake aerial surveillance also likely acts as an (unquantified) deterrent to some forms of illegal activity (e.g. unlicensed fishing, illegal transhipment, fishing inside closed waters). Nevertheless, aerial surveillance is typically extremely expensive (~$15,000 – $25,000/air hour) and the costs and benefits should be weighed carefully before investing in this over other MCS measures. The key question for MCS decision makers in the Pacific is if there is a limited pool of MCS resources available, is it best directed at expensive aerial surveillance, or could the same money achieve greater benefits being targeted at higher priority issues using more cost effective approaches? The other key question obviously is whether some of those risks identified as relatively minor at present would increase in the absence of the deterrent effect provided by aerial surveillance. Ultimately, some level of ongoing aerial surveillance will be important to continue to act as a deterrent to unlicensed and unregulated fishing and FFA have added valuable capacity since the 2016 study with the acquisition of a dedicated surveillance aircraft under the PMSP. Given the apparently relatively low levels of unlicensed fishing activity and the expense associated with aerial surveillance, the ongoing challenge for MCS planners in the Pacific will be to determine the appropriate level of aerial surveillance to continue to deliver an effective deterrent without diverting potential MCS resources away from other important MCS areas. Given the limited data available on unlicensed fishing, knowing when you've met this balance is no easy task.	Very high						
Surface surveillance	Surface surveillance has benefits over aerial surveillance in that it addresses a wider range of risks (including non-compliance with a number of license conditions), although is likewise very expensive and covers less area.	Very high						

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Satellite monitoring	Satellite monitoring potentially has utility for areas that are unable to be cost-effectively accessed by conventional aerial and surface surveillance (e.g. the far eastern part of the Pacific islands region), although large numbers of high resolution images may be cost prohibitive and may not be sufficiently definitive to support successful prosecutions on their own. Satellite images may be best used to support existing intelligence (e.g. where there is analytical evidence of unlicensed and satellite images would assist prosecution).	Varies according to number and resolution of images						
Support measures								
Strengthening the use of information management technology	Existing MCS arrangements in the Pacific (e.g. logsheets, observers, unloadings monitoring, VMS, at sea boarding and inspection, dockside inspection, etc) generate multiple data sources that can be cross-verified for compliance discrepancies (e.g. observer vs logsheet vs unloads) and analysed for national and regional trends. Considerable investment has been made in strengthening information capability across the region through programs such as TUFMAN, TUBS, FIMS and RIMF. While more could probably be done, many of the necessary tools to strengthen national and regional MCS effectiveness appear to be in place. The main need appears to be to ensure officers at the national level are adequately trained in their use and that follow up action is taken at the national level on the outcomes.							
Strengthening analytical capacity, national and regional; intelligence-driven MCS	FFA members are almost universally characterised by having very large EEZs, with limited resources to undertake MCS. In that context it is essential that limited MCS resources are deployed in the most cost effective manner. Strengthening capacity at the national level to analyse relevant MCS information to determine and direct resources to the highest priority areas both strengthens targeting and avoids wasting resources on low priority issues. The capacity for effective analysis is strongest where there are robust information management platforms (see above) and strong national/regional coordination (see below). The case for analysis of MCS at the regional level is clear given the shared nature of stocks and the multi-licensed nature of many fleets.							

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	The benefits of high quality analysis has been evident through the use of Intelligence Analysis Cells in Regional Operations, and should ultimately lead to a culture of more intelligence-driven MCS.							
MCS coordination, national and regional	In most FFA member countries, responsibility for MCS activity is distributed across multiple agencies (fisheries, marine law enforcement/navy/police, attorney general, etc). Ensuring effective coordination (joint risk assessment and tasking, sharing VMS data, sharing license lists, pre-and post-patrol briefings, etc) across these entities is essential to supporting an efficient MCS regime in country. Moreover, given the shared nature of stocks and the highly mobile nature of fishing vessels within the Pacific, effective coordination at the regional level is well-recognised.							
Stronger collection/coordination of MCS statistics	Analysing the effectiveness of MCS measures and tracking trends over time requires consistent collection of important metrics on MCS coverage (e.g. aerial surveillance hours, surface surveillance days at sea/nm steamed; dockside inspections undertaken, etc) and outcomes (e.g. vessel contacts, infringements detected by vessel and nature of offence, etc). Our experience is that while coordination of some statistics is good for some areas of regional MCS (e.g. good statistics are captured around surveillance coverage during FFA led Regional Operations; good information is kept on many activities at national level – e.g. port inspections), other useful statistics are not centrally coordinated (e.g. number of fisheries related surface patrols undertaken at the national level outside Regional Operations). Moreover, data on the outcomes of MCS activities is often very limited (e.g. simply a number of possible infringements, with no detail on the type of infringement, type of vessel, etc). At the FFA level, we understand collection of data on the outcomes of regional MCS activities is reliant on members providing the data, however efforts to develop and maintain a consistent set of insightful and 'trackable' MCS statistics should be prioritised.							
Prosecutions and violations information	As a subset of the measures above, centralised storage and analysis of prosecution and violation information across the FFA member states would assist in MCS planning, would facilitate information sharing and learning (particularly given many vessels are licensed across multiple FFA EEZs) as well as better estimating IUU activity. FFA has previously coordinated a							

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	'Prosecutions and Violations' (P&V) database which was used for this purpose. The database has now been incorporated into the Regional Information Management Facility (RIMF), but we understand entry of P&V records is voluntary and coverage levels have been variable. FFA members should continue to be actively encouraged to contribute P&V records to the database, with analysed information on trends and issues fed back via the MCSWG and other forums.							
Cost recovery	Although not specifically an MCS skill, the capacity to design and implement effective cost recovery regimes to fund effective MCS arrangements is an essential component of an overall MCS regime. There is little doubt that additional MCS arrangements are required on a range of fleets and the burden for funding improved MCS should not fall to FFA members. Training and mentoring on the theory and practice of cost recovery should be encouraged in the region.							

Keys:

Risks addressed:

	Highly effective at addressing risk
	Partially effective at addressing risk
	Not effective at addressing risk

Priority:

	High priority taking into account risks/costs/practicality
	Medium priority taking into account risks/costs/practicality
	Low/Nil priority taking into account risks/costs/practicality