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Progress Report for Project 78: Analysis of Observer and Logbook Data Pertaining to Key Shark Species in the Western and Central Pacific Ocean

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This revision includes the following changes:

Section 1, 2 and 3: Minor typos were corrected.
Section 2: Table2 and Table 7 were updated and revised to reflect updated datasets.
Section 2: Table 6 was deleted as it duplicates the data in Table 7.
Section 2: Table 8 was deleted and the information therein was combined with Table 2.

Executive Summary

This paper presents an analysis of data for sharks caught in longline and purse seine fisheries in the Western and Central Pacific Ocean (WCPO) held by The Pacific Community – Oceanic Fisheries Programme (SPC-OFP). It represents an interim report from Project 78 to SC13, and concentrates on detailing the results to date on key sections of the project ToR. Feedback for incorporation within the final report to WCPFC Secretariat due 31st December 2017 is welcomed.

Overall the quality, with respect the key shark species, of logbook data currently held by SPC has been improving over time. The logbook data has increasing levels of spatial coverage and higher levels reporting sharks to species. For both the longline and purse seine fisheries the logbook data is useful to support analytical and indicator assessments. The quality of the observer data currently held by SPC is likewise better in recent years than the historical data. Observer data coverage is not 100% in the purse seine fishery nor does it reach the required 5% coverage level in the longline fishery but has been increasing overtime and has also increased in spatial coverage. In general the data can support analytical (or indicator) assessments for the more commonly caught species, but would require significant extrapolation to assess the less common species.

Reporting of logsheet data by fleet is highly variable, with many fleets reporting significantly less than 100%. It is difficult to identify whether logsheet data are provided for all key species given than non-reporting may be a result of a zero catch event (i.e. whale sharks in the longline fishery) or a lack of reporting. The relationship between the observer and logsheet reporting and the logsheet and aggregate reporting effect the precision in estimation of catch and potentially other stock related metrics such as distribution. Comparison of observer and logsheet data highlights that there is a large discrepancy of the rate of non-species-specific recording in the longline fishery logbook data. The general recommendation is for fishers to receive further identification training for sharks to species.

The largest gap in the currently held data is within the longline datasets, the observer data covers a fraction of the overall effort, is biased towards those fleets which have strong observer programs and is also spatially concentrated within the EEZs with little coverage on the high seas. The key mechanism to addressing the current data gaps would be an increase in observer coverage to at least the mandated 5% coverage level. Without representative coverage any reconstruction of shark catch and CPUE estimation will likely be biased. One of the difficulties with the data analysis is that there is no readily identifiable mechanism to logbook and observer sets.

Initial conclusions regarding the impact of WCPFC shark related CMMs on data quality is that these CMMs have resulted in non-reporting of catch within the purse seine fishery despite observations of catch and high levels of observer coverage. Within the longline fishery the reported catch of FAL an OCS is similar to that before the CMMs banning retention went into force.

Continuation of this work for the final report.

Although this analysis has considered coverage levels by fishery and fleet it has not provided advice on what types of analyses the data might support, including advice on appropriate modelling approaches (e.g. CPUE standardization) where data are considered sufficient. This will be included in the final report as well as any recommendations from the SC13.

1. Introduction

This paper presents an analysis of data for sharks caught in longline and purse seine fisheries in the Western and Central Pacific Ocean (WCPO) held by The Pacific Community – Oceanic Fisheries Programme (SPC-OFP). It represents an interim report from Project 78 to SC13, and concentrates on detailing the results to date on key sections of the project ToR. Feedback for incorporation within the final report to WCPFC Secretariat due 31st December 2017 is welcomed.

The framework for this study is an analysis of the potential for the available data to support indicators of fishing pressure and stock status for the designated WCPFC key shark species that are assessed and evaluated by SPC-OFP. Despite the lack of traditional fisheries statistics associated with target species (observed catch, effort, distribution, reported landings) indicator based assessments (Clarke and Harley 2010, Rice et al. 2015) and directed assessments (Rice and Harley 2012, Rice and Harley 2013, Fu et al. 2012) have been undertaken for many of the key shark species. However different data reporting patterns exist by fleet, and often the data provided are estimates of the true catch. This introduces uncertainty and potential bias to the results.

The majority of the shark catch in the pelagic fisheries of the Pacific Ocean is considered bycatch, though some directed and/or mixed species fisheries also exist. Although coastal artisanal and semi industrial fisheries often target sharks for local consumption and trade the main sources of catch and effort are the pelagic fisheries targeting tuna and tuna like species. Summaries of stock status are available in the Shark Research Plan (Brouwer and Harley 2015) which notes;

> "The shark data holdings by SPC and WCPFC are reviewed annually through the WCPFC Data Catalogue (http://www.wcpfc.int/wcpfc-data-catalogue). Relevant statistics are highlighted below. The provision of annual catch estimates for key sharks has been a WCPFC requirement since 2007. The annual coverage of shark catch data across the raised aggregate longline data set, that includes actual and estimated effort for all fleets operating in the Convention Area include sets with no reported shark catch, which will include both true zeros and non-reporting of sharks. Note that changes between zero, generic shark and key sharks reported are assumed to be changes in reporting rates and not changes in species composition of the catch. Prior to 1990 there was very little information on shark catch and what was available was not species-specific, as almost all sharks that were reported were reported to the generic shark code. Since then there has been a sustained and continuing increase in the reporting of sharks, both to generic and species-specific codes. Despite this, over the past ten years less than a third of the reporting is species-specific and it is not clear whether these reports include discards. This indicates that reporting is improving but challenges remain in assessing sharks and generating plausible catch and CPUE time series. Since 2010, however, species-specific reporting of key sharks jumped and now averages just over 50% of reported sharks, this may reflect a change in logsheet form use to the SPC extended format longline logsheet and/or WCPFC members

> developing their own logsheets that require species specific reporting. However, some fleets, while reporting key sharks to species level, may report all other sharks as SHK."

Given the nature of the catch (possibly underreported, largely estimated) and variable reporting rates of shark catch, this project aims to assess the quality of logbook and observer data currently held by SPC to identify the gaps in those data, significant implications that those data gaps imply and to identify the mechanisms to addressing these data gaps in order to support future indicator and analytical assessments of WCPO shark stocks. Much of this work has been done in the past either through assessments (Rice and Harley 2012, Rice and Harley 2013, Rice et al. 2015), estimates of catch and catch per unit effort (CPUE, Tremblay-Boyer and Takeuchi 2016), indicator analyses (Clarke et al. 2011, Rice et al. 2015) or via shark specific reports (Brower and Harley 2015). This study synthesizes the previous work where applicable and greatly expands upon it, to identify the potential of the data to support analyses for designated WCPFC key shark species (Table 1). The time frame of this analysis covers data for the years 1995:2015, unless otherwise stated.

2. Description of the data holdings and review of methods for estimating catch

Most fisheries are managed by using a catch limit related to the stock's abundance at the maximum sustainable fishing mortality rate (FMSY). For target fisheries the Fmsy is usually estimated via a stock assessment which typically uses timeseries data, to estimate current stock size and productivity. Even for populations have insufficient catch data, indices of abundance or information about life-history to conduct conventional stock assessments, data-limited methods are generally designed to use a single time series of annual catches. Estimates of catch are critical to the understanding of the impact of fisheries on target and bycatch species and their management. Two key sources of data are available within the WCPO to assess shark catches:

- SPC-held observer data from both purse seine and longline operations;
- Operational (logsheet) and aggregate shark catch data.

The primary source of shark catch data is the SPC-held observer database which, despite low coverage in all regions (Table 2) has substantial information regarding fleet operational characteristics as well as fate and condition data of captured sharks

2.1 Longline Fishery Data

Longline fishing effort in the WCPO has increased steadily over the study period (1995-2014) to approximately 1.1 billion hooks (Table 2), with nearly half of the effort occurring in the equatorial waters between 20˚ S and 20 ˚N. The measure of observer coverage is defined by "observed hooks set" and is used here because it is a common currency and allows for the standardization of observer coverage rates when undertaking analyses. In addition to the observer data, SPC holds longline logsheet (operational) and aggregated shark catch data. The operational data submitted to the SPC are at a higher spatial resolution than the aggregate data, and are useful for catch estimation, but their utility is limited by the lack of data provision by species for sharks (Table 3), especially in equatorial regions where the majority of the longline effort occurs. Aggregate data coverage is on par with the logsheet data, although coverage differs greatly throughout the region. Historical coverage rates with respect to sharks are poor partly because prior to February 2011 sharks were not amongst the species for which data provision was required (WCPFC 2013); since that time, data provision for the 14 species designated by WCPFC as key shark species is mandatory however, thresher and hammerhead sharks are each considered as a species complex for reporting purposes. A thorough examination of the SPC-held fisheries data and its utility for shark related analyses and resulting indicators of stock status can be found in Clarke et al. (2011) and Rice et al. (2015).Under CMM 2007-01, 5% observer coverage by the Regional Observer Programme (ROP) has been required since June 2012 in longline fisheries, but annual average values have been ≤1% in recent years (for the entire WCPO). With some notable exceptions (e.g. northeast and southwest of Hawaii), most observed sets occurred within Exclusive Economic Zones (EEZs). Ideally, stock assessments, indicator analyses, and calculation of indices of abundance would be based on operational-level data as its higher spatial resolution permits more comprehensive and nuanced analyses, however SPC's operational level data are geographically limited and not consistent with the spatio-temporal distribution of the fleet. Figure 1 illustrates the geographic distribution of longline logsheet data held by SPC (grey points). However, this picture is somewhat misleading as only 31% (15% over the entire time series) of the sets plotted recorded sharks. This is in contrast to the observer data (yellow points) in which 93% of the sets recorded at least one shark (red points). This discrepancy is not necessarily due to misreporting. Prior to February 2011, sharks were not amongst the species for which data provision was required (WCPFC, 2011); since that time data provision for the 14 species designated by WCPFC as key shark species has been mandatory. Figure 1 does not distinguish between key shark species and other shark species because only 36% of the reported sets recorded any species-specific shark catches (1950-2015). Clarke (2011) note that most historical species-specific shark catch data are provided by a small number of flag States. Given the relatively low level of coverage in the operational data, a more complete characterization of the longline fishery requires the use of the aggregated ($5^\circ \times 5^\circ$ grid) data. Effort and reported shark catch by flag at the aggregated level have a lower degree of spatial resolution but in most cases are raised to represent the entire WCPO longline fishery. Sets with observers present onboard, are shown for comparison (Figure 1) but have a finer degree of spatial resolution due to observer record keeping. Although shark interactions (reports of generic or species level catch) are recorded in 36% of the effort (by hooks) reported in longline logsheets (Figure 1, grey points), from 1950-2015, the level of reporting in for 1995-2015 is 61%. As a result, it is possible to use the logbook data in conjunction with the observer data to assess the number of shark interactions by fishery and the bycatch species involved in the longline fishery however there are large differences in coverage levels by fleet and EEZ which are discussed in section 3. Operational-level coverage for the longline fishery was 28% (hooks reported/aggregate hooks) over the time period 1995-2015, this along with the variable level of reporting by species complicates the use of the operational data for analyses such as estimation of total catch and catch rate over time.

2.2 Purse Seine data

Similar to the longline fishery, SPC-OFP holds logsheet data on shark catches by purse seine fisheries at both the operational and aggregate levels. However, operational-level coverage for the purse seine fishery (75% by set, 1995 - 2015) is considerably higher than for the longline fishery (28%). This factor, in combination with the more limited geographic range of the purse seine fishery, contributes to more representative operation-level coverage in the purse seine fishery than in the longline fishery.

Following implementation of the WCPFC ROP on 1 January 2010, in combination with prior observer coverage commitments by Parties to the Nauru agreement (PNA) members, 100% purse seine observer coverage is now required. Historical observer coverage in the purse seine fishery has varied between EEZs. Observer coverage rates were low, generally less than 12%, for the years 1995-2002, with coverage increasing 18%-30% for the years 2003-2009. Recent (2010-2013) annual observer coverage rates are between 73-90% for observed sets / aggregate sets (Table 4), but see Williams et al. (2017) for a more detailed analysis of purse seine observer coverage. While observer coverage of the purse seine fishery is not uniformly representative (Figure 3, orange points), it is more representative than observer coverage of the longline fishery, owing to both higher coverage levels and the more limited geographic range of the fishery (Lawson, 2011). Shark interactions are recorded in just 3.7% of purse-seine logsheets (Figure 3, grey points), a value far lower than the 36% recorded in longline logsheets. As a result, it is not possible to assess the number of shark interactions by set or the species involved using purse seine logsheet data. Although estimated shark catch in the purse seine fishery are considerably lower than the longline fishery (Lawson, 2011; SPC, 2008), it would still be expected that purse seine shark interactions are proportional to purse seine effort. However, from the discrepancies between observed and reported catch, it appears that some major fishing nations are not submitting or are under-reporting shark interactions. Purse seine observer coverage is highest around the western equatorial area near Papua New Guinea and the Solomon Islands, with little coverage extending to the central Pacific (Figure 4).

2.3 Methods for re-constructing historical shark catch

The majority of global fish stocks lack adequate data to evaluate stock status using conventional stock assessment methods, this applies especially to sharks and is certainly the case for the key shark species in the WCPO. Not all stocks can, or need to be assessed by traditional stock assessment models, and indicator based analyses have been used for the key shark species within the WCPO (Clark et al. 2011, Rice et al. 2015). While the number of fleets reporting catches of sharks to species has increased over time (Table 3) catches of sharks in purse seine and longline fisheries continue to require some level of adjustment or partial/full estimation. Estimation of unobserved shark bycatch by pelagic longline and purse seine fisheries is difficult for multiple reasons, including 1) data are generally limited in quantity and quality, 2) sharks are usually taken as bycatch or incidental catch which may be reported as ‘total sharks’, if reported at all (Camhi et al. 2008; Pikitch et al. 2008), 3) when reported, catch data are likely to be biased by underreporting, and non-reporting of discards (Camhi 2008). For example; significant under-and non-reporting of blue shark (*Prionace glauca*) in the Hawaii longline fishery have been documented (Walsh et al. 2002) despite some of the best monitoring circumstances (Walsh et al. 2005, 2007).

Multiple methods for estimating bycatch rates exist. For example, design-based or ratio-based estimators are often used for bycatch of co-occurring non-target species with similar distributions and relative catch rates as the target species (e.g., Pikitch et al. 1998; Stratoudakis et al. 1999; Rochet et al. 2002) while model-based estimators are more commonly used for predicting less frequent bycatch events (e.g., Walsh et al. 2002; Perkins and Edwards 1996). In their simplest form ratio based estimators calculate a ratio of bycatch to catch or effort from a smaller data rich data set and extrapolate to a larger dataset (e.g. the annual observed shark /tuna ratio raised by total tuna catch to estimate total shark catch). Model based methods vary but typically use a data rich period or strata to parameterize one or more models and then predict through to the data poor periods or stratum. Methods that use both design and model based approaches (Miller and Skalski 2006; Kaiser 2006) have been developed for select fisheries, there are trade offs between model based and ratio based estimates depending on the data sources, model chosen and fishery (Allen et al. 2001, Diamond 2003). The following are general descriptions of methods used for the estimation of shark catches.

Target Species Ratio based estimates. In situations where reported effort is unknown or thought to be unreliable, shark catch can be estimated based on the ratio of sharks to target catch. This ratio would be calculated at the finest scale possible (area, fleet, target species) and applied to the catch in that same strata. In practice, this method assumes that the abundance of the particular shark species is proportional to the target catch at the strata level, and that ratio is applicable to the larger data set. This also assumes that targeting does not change the ratio of shark to target species and that all sharks are correctly. The resulting estimates would then be a product of the annual target species catch and the ratio of shark to target catch (Murua et al. 2013).

Effort and CPUE based Estimates. Estimates of catches are commonly derived from the relationship between catch per unit of effort (CPUE) and total effort, with the assumption that *CATCH = CPUE/EFFORT.* This method has been applied to sharks in the WCPO (Lawson, 2011, Rice, 2012). Typically, the catches are estimated as the product of effort (hooks fished for longline or sets for purse seine) in the region and catch rates for those fisheries based on observer data. At a basic level the catch rates would be stratified by timeframe, fleet, area, target species, or other factors as the data sets pertaining to the effort and catch rates. Model based approaches, typically using generalized liner models (GLMs) or some variant such as generalized additive models (GAM), or generalized linear mixed models (GLMM), to calculating a CPUE can be used to remove the effects of one or more covariates (season, area, etc.). With model based approaches the CPUE data are typically predicted based on models fit to observer data, on a proxy data set that has the same structure (year, fishery, fleet, area etc.) as the reported effort data.

Model based approaches using reported landings. Total shark landings can be estimated directly from reported fishery data, provided that some records of shark landing do exist. This method utilizes the reported species specific shark catch to parameterize a model (typically a GLM or GAM), then uses that model to predict the catch for those records that contain no reports of shark catch. The main assumption for this process is that fishing operations in the same area/time/gear strata would, on a sufficiently broad scale, catch a similar combination of species, hence the lack of shark catch in some records reflects lack of reporting. This method is useful in situations where non-reporting or underreporting is common in sectors of the fishery, but is inherently biased towards the catch that is reported.

Dis-aggregated shark estimates. Often shark catches are reported as aggregate 'sharks', i.e. not-species specific. Estimates of the species composition of reported aggregate shark catches (SKH) can be developed based using ratios from proxy fleets, time periods and regions (or other available data). This method uses substitution rules to define the species composition based on the most similar record of species specific shark catch (Fiorellato et al. 2016). This method makes many assumptions, chiefly that fleets or vessels operating in similar areas with the same gear would have similar catch rates across target and bycatch species. Further, when no directly comparable records exist, ratios of shark to target species or the species specific breakdown of the shark species may be borrowed from adjacent years, making the assumption that species composition is static across years.

Trade Based Estimates. Estimates of shark catch based on shark fin trade data have been produced for use in assessments in the Atlantic (Clarke 2008), Indian Ocean (Clarke 2015) and WCPO (Clarke 2009). This methodology produces estimates of catches of sharks utilized in the shark fin trade but may capture only a portion of the potential shark mortality (i.e. only those sharks' whose fins are traded). Estimates by species (in number and biomass based on Hong Kong shark fin auction data and extrapolated to the global trade) in 2000 were reconstructed using triangular distributions in a Bayesian model and Markov chain Monte Carlo (MCMC) methods. These estimates were then adjusted using annual imports into Hong Kong for 1980-2011. Figures were then further adjusted based on the diminishing share of Hong Kong's shark fin trade as compared to the total global trade over the later part of the time series. Finally, these adjusted global estimates were scaled in a number of ways (by ocean area (km2), by target species catch, by longline effort and by import country of origin statistics) to represent potential shark catches in the specific ocean and fishery. It is important to note that among the assumptions used in this method the following particularly strong assumptions are highlighted by the author (Clarke 2014);

- The species composition of the sampled portion of the Hong Kong shark fin trade in Clarke et al. (2006a) is representative of global species composition.
- The species composition of the fin trade observed in 2000, and the relationships between fin sizes/weights and whole shark weights observed at that time, are constant throughout the time series.

Integrated model based estimates are also possible using statistical catch at age models (i.e. Fournier and Archibald 1982) these models combine population biology, indices of abundance and information on selectivity to estimate what the 'true' catch would have been, given the model fit to the observed plus reported landings, and indices of abundance (Aarts and Poos 2009). This approach has been developed to estimate unreported discards and uses either a fixed or flexible selectivity to reconstruct historical unreported discards in addition to the stock status. In this approach the model is fitted to the survey or observer data in combination with the known population biology, the most appropriate model is selected via likelihood or other information theoretic methods. Estimates of current and historical biomass are obtained along with estimates of discards or unreported (Casey 1996, Punt et al. 2006). These models often assume that natural mortality is constant in time, and that the survey or observer based discard information is broadly applicable to the fishery as a whole. The assumption that natural mortality is invariant over time is common in stock assessment models but may not hold if changes in predation pressure, community composition, habitat, or species distribution occur.

2.4 Biases associated with these methods and potential solutions.

Bias in the estimation of catch can arise if the observed trips within a stratum (such as year, quarter, area, gear, target species) are not representative of the other vessels within the stratum. Such bias could arise if the vessels with observers on board consistently catch more or less than other vessels, if the average trip durations change, if the vessels with observers fish in different areas (i.e. in EEZ vs outside of the EEZ), or if fishing behaviour changes with an observer on board. These types of biases can be tested for by comparing observable properties in strata having data from vessels with and without observers. This requires adequate data from observer vessels and a distribution of observer data that is representative of the fishery as a whole

When calculating catch there is often a data rich period that is used to extrapolate to the data poor period, this implicitly assumes that the conditions in the data rich period are similar enough to the data poor period that the predictions are valid. Simulation studies that use different statistical techniques such as boosted regression trees, cross validation and machine learning could be useful in these situations. Methods that account for patterns of bycatch through time and space (i.e. integrated nested Laplace algorithms) have been applied to shark and other species bycatch (Cosandey-Godin et al. 2014) to account for the spatiotemporal correlation for species that are clustered in space and time, and where bycatch varies significantly from year to year. Long-term solutions include greater observer coverage and better quality data, potentially the use of electronic monitoring could provide the type of data that would lead to greater precision in the estimation of bycatch.

In practice, the choice of estimation methodology is often dictated by the data that is available. Given the data currently available in the WCPO methods that relate species specific catch rates by fleet, area and time to the overall effort appear to make the best use of the available data. Model based methods that can account for gaps in the operational or observer data are appropriate for species with low catch rates. If possible catch rates should be based on survey or observer data from fisheries similar to the main fisheries. When possible, alternative catch histories should be developed using different methodologies and sources of data. This is one of the main advantages of the trade based catch estimate methodology, because this method starts at the global level and works down to the species level it is not subject to the patterns in reporting, through space and time, that the logbook and observer data contain.

3. Data Reporting Patterns

This section investigates the spatial and temporal quality of the logbook and observer data held by SPC, and their potential to support (indicator or assessment based) analyses of the key shark species. The coverage of observer data, in terms of the effort in WCPO purse seine and longline fisheries is examined, along with the spatial coverage of the fishing activity to examine potential biases in raised data due to unrepresentative fleet-level coverage. In turn, a comparison of logsheet coverage in comparison to aggregate (annual catch) estimates is performed to identify the potential issues and uncertainties that may be encountered when raising.

3.1 Observer coverage in purse seine fisheries

The number of sets reported in the logsheet data is compared to the number of sets within observer data to quantify the percent coverage (observer/logsheet), by flag, year and area (5˚x5˚ cell). The time frame for the analysis was 2010-2015 unless otherwise specified. The relative distribution of effort (both observed and reported) at the 5˚by5˚ cell was calculated by summing the annual effort in each cell and dividing by the maximum effort.

The overall observer coverage has ranged between 73.5 and 89.8 percent from the years 2010 to 2015. Prior to 2010 the overall coverage (observed sets / aggregate sets) was approximately 31% or less (Table 4). During 2010-2015 the majority of countries observed more that 50% of the sets, with the exception of New Zealand, the Solomon Islands and Indonesia. The same data shows that the fleets Papua New Guinea and the Philippines reported higher numbers of observed sets than logbook sets indicating that not all of the logbook data have been submitted (Table 5 observed sets /aggregate sets). Coverage by year and by fleet (Table 5) indicates that the coverage level is variable by flag and year with some years where the number of sets covered in the logbook is lower than the number of observed sets.

The spatial distribution of the observer data (Figure 6) is similar to that of the reported sets (Figure 7), and is centered in the equatorial waters between 20˚N and 20˚S. Analysis of the spatial distribution of the observer coverage indicate that the western equatorial area (near Papua New Guinea and the Solomon Islands) has the highest rate of coverage, while the central Pacific (the eastern part of the WCPO convention area) has a lower (less than 50%) rate of coverage (Figures 8-11). Although the observer coverage is biased towards the western WCPO both the spatial extent and coverage rates have been increasing over time (Figures 8-11).

The distribution of the relative effort of the observer data by 5˚ cell shows the inequality of the distribution of effort and observed effort. Of the 109 cells fished, 20 cells (18%) account for the top 85% of the total observed effort. This pattern is similar for the logbook data where 21 of the 114 cells where effort was reported account for 90.3% of the total reported logsheet effort.

3.2 Observer coverage in longline fisheries

Similar to the previous section, this section investigates the spatial and temporal quality of the longline logbook and observer data held by SPC, and investigates this quality via the overall effort reported. The number of hooks reported in the logsheet data is compared to the number of hooks observed within observer data to quantify the percent coverage (observed hooks/reported hooks), by flag, year and area (5˚x5˚cell). The relative distribution of effort (both observed and reported) at the 5˚ cell was calculated by summing the annual effort in each cell and dividing by the maximum effort.

The overall observer coverage has ranged between 2.23 and 4.49 percent from the years 2010 to 2015 (Table 2). Prior to 2010 the overall coverage ranged from approximately 1% to 3.5% across the entire fleet. The range of variation at the fleet level ranged between 0.4% to 21.6% with all flags except Kiribati having less than 10% coverage (Table 6).

The spatial distribution of the observer data (Figure 15) is similar to that of the reported logbook data (Figure 16), and is largely clustered in the EEZs, with little coverage in the high seas. This relationship between the observer data to the logbook data in not necessarily reflective of overall fishing patterns, due to the low coverage of the logsheet to aggregate data but reflective of logsheet returns Analysis of the spatial distribution of the observer coverage indicate that the area near Hawaii, French Polynesia and the Solomon Islands/Papua New Guinea have the highest rate of coverage (Figures 17-20). Spatial coverage of the observer data has been increasing over time, however there continue to be low amounts of coverage outside of EEZs and in the areas further from the coast. Fleet specific catch rates indicate that there are only 4 countries (Cook Islands, Fiji, Kiribati, and Tonga) reporting both observer data and logbook data where the observer coverage rate is in excess of 5% (Table 6).

By looking at the relative breakdown of the observed data by cell comparisons can be made on the distribution of reported effort and observed effort. The top decile of observed effort is made up of 24 cells which account for 36% of the observed effort, whereas 17% of the reported effort occurs in the top 28 cells (Figures 21 and 22). This means that the observer effort is concentrated in cells that receive the majority of the effort reported in logsheets.

3.3 Logsheet vs Annual Reports

Longline logbook data informs the annual catch estimates of sharks. In many cases catch of the key shark species is estimated based in part based on catch rates raised to the overall catch of the target species or overall effort. There is need for representative data across the major strata, (i.e. fleets, areas, time, target species etc.), so that any extrapolation could be completed via representative time frames. This section compares the logbook data to the aggregate data, in terms of target catch and effort to assess the extent to which the data are provided. Target catch was computed as the sum of yellowfin, bigeye and albacore tuna. Data were compared on an annual basis, by year and flag, and by 5˚ by 5 ˚ spatial cell, over the time frame of 2010-2015.

The logbook reported effort accounted for between 20% and 40% of the total aggregate longline effort (Table 7, Figure 23). Catch is similarly underreported on an annual basis with respect to the logsheet and the annual aggregate catch (Figure 24). Reporting by flag is highly variable with some countries averaging nearly 100% reporting and others reporting less than 5% (Table 7), overall.

Analysis of the effort and catch on a 5˚by 5˚spatial scale (Figure 25 and Figure 26) show that the majority of the cells in which both logsheet and aggregate data are reported the ratio is less than one, and that there are areas, around the Solomon Islands, Fiji, New Zealand and Tasmania where the reported logsheet data is much higher than the aggregate data both for the target catch and reported effort.

The reported effort in the purse seine fishery from the logbook data set ranges between 60% and 75% over the years 2010-2015, and between 66 and 129% over 1995-2009 (Table 8, Figure 27). The reported target catch (SKJ, BET, and YFT) to aggregate catch ranged between 92% and 170% of the aggregate catch (Table 9). By looking at the data spatially we can see that there are areas in which the logsheet data report higher effort than the aggregate data centered near the Solomon Islands and Papua New Guinea. This same area shows higher logbook effort than aggregate effort (Figure 29and Figure 30). Reported catch and discards by flag are included in the Annex 3.

The difference in coverage between longline and purse seine should give some good indications of which spp may be amenable to indicator analyses (noting that the length of the data set, in combination with the life history, may not easily support some analytical assessments)

3.4 Taxonomic reporting

The provision of annual catch estimates for key sharks has been a WCPFC requirement since 2007. Prior to that time the majority of the reported effort was associated with generic shark landings or no reports of sharks at all.

The annual reported composition of effort that included information on generic shark and key shark species was separately calculated across the logbook and observer data for the longline and purse seine fishery data sets (Figure 31 and Figure 32). These include sets with no reported shark catch, which will include both true zeros and non-reporting of sharks. Note that changes between zero, generic shark and key sharks reported are assumed to be changes in reporting rates and not changes in species composition of the catch. Records based on observed catch rates indicate that the proportion of effort (sets) that reporting generic sharks is much smaller, likely reflecting the training and resources that observers have available. The majority of the logbook data from longline fisheries between 1995 and 2015 included either data on generic shark or species specific reporting (for key shark). This is in contrast to the observer data where the majority of the observed longline effort contained records of key shark species. The majority of the reported (in logbook) purse seine sets report no shark catch (Figure 33), which is supported by the observer data from the same fishery (Figure 34).

The vulnerability of sharks is often assessed in part by examining fisheries catch trends, however the reported trends are not generally recorded on a species level. Shark catch trends aggregated at the family or genus level tend to be more stable than those trends at the species level. Simple estimates of catch were calculated by family, genus and species for the key shark species, for the longline and purse seine fisheries with the exception of whale sharks for the longline fishery. Catch was estimated by calculating the observed CPUE by year and flag and then multiplying the observed CPUE by the aggregated effort data (by flag and year). This was to assess the apparent stability of the aggregated catch trends was contrary to the species level assessment. These catch trends by family genus and species highlight which species get identified well at the species levels (e.g. BSH) and which are still reported at the genus level (e.g. Threshers, hammerheads). The general recommendation is for observers to receive further identification training for these species. Additionally, these estimated catch trends show that evaluation of catch trends may be reliable for only the most commonly occurring species within a genus.

The total reported catch (catch and discards) by key species was summarized for 2010-2015 in the purse seine and longline fishery. These data are reported as the sum total by year and by flag. Reported discards and catch for the longline fishery and reported catch rates for key shark species for the purses seine fishery were calculated by flag and year by dividing the number of sets that reported either catch or discards by the total number of sets reported by flag on an annual basis. The purse seine logbook data did not contain information on the discards of key shark species.

The aggregated catch trends for the *Carcharinidae* family (Figure 35) show that BSH is well identified, as it is the only member of the genus *Prionace*, and the trends are the same. The genus *Carcharinus* is nearly equal to the sum of the two key shark species in that family, FAL and OCS. The calculated catch by family and species for the longline fishery shows the change in the key species reporting over time. The catch of key shark species in Carcharinidae family (BSH, OCS and FAL) changed in 2012 to be dominated by catches of BSH. The longline catch of Alopiidae and Sphyrnidae are dominated by the thresher and hammerhead complexes. Simple estimates of the catch from the Family Lamnidae decrease in the proportion of the Isurus (mako sharks) genus relative to the genus Lamna (porbeagle). Catch by genus and family for the longline fisheries are presented in Figures 35-38 for the longline fishery and 39 -42 for the purse seine fishery.

The reported catch rate and discard rate of blue shark in the longline fishery has increased from 2010 to 2015. Along with blue shark the reported catch and discards of OCS and THR has increased over the same time period. The reported rate of MAK has stayed constant while the discard rate has increased. The reported total catch (catch + discards) of key shark species is dominated by blue shark for all flags and lowest for POR (Figure 43 and Figure 44).

The reporting rate (number of sets with key sharks /number of sets) of key shark species in the purse seine fishery shows non-zero catch rates for all key shark species except POR. The sharks that have the highest catch rates are RHN and FAL. Reporting rates existed for FAL prior to 2014, after which there exist no records of FAL catch in the purse seine logbook data, this is likely due to the retention ban. In addition to FAL both OCS and RHN are reported in 2010 and from 2010-2014 respectively. The Reported total catch by country is dominated by FAL, with lower levels of catch in each of the other species.

Previous analyses (Clarke et al. 2011, Rice et al. 2015) have utilized observer and logbook data to estimate indicative trends (based on CPUE) for silky shark, oceanic whitetip, mako shark, blue shark, whale sharks and porbeagle sharks. Rice et al. (2015) noted that limited inferences are possible for hammerhead and thresher shark species complexes, largely due to lack of data. These species are not commonly caught in the primary fisheries in the WCPO, and are historically not well reported. A recent study by Fu et al (2017) estimated whether the current rates of fishing mortality on bigeye thresher in the Pacific are sustainable. This was undertaken by evaluating whether current impacts from fisheries exceed a maximum impact sustainable threshold (MIST) defined based on population productivity.

3.5 Ratio of Key Shark Species to Target Tuna Species

The sum total of the individual key shark species was calculated by year, flag and by 5° cell and compared to the total target tuna catch calculated on the same scale, these values were averaged by year (for logbook and observer data) for annual comparison and 5° cell for and spatial comparison based on the observer data. This analysis was completed for the observer data and logsheet data, with separate analysis conducted for mako and blue sharks in the North and South Pacific for the longline data. The analysis was conducted as the number of sharks/(50,000 tuna), or by sharks/5000 MT of tuna for longline and purse seine data respectively. Mako and blue shark were each assessed as two separate stocks (northern and southern hemisphere) and the porbeagle considered only data south of 30°S for the longline data. Target species for the longline analysis was considered to be the sum of YFT, BET and ALB, while target species for purse seine was YFT, BET and SKJ.

The ratio of observed FAL and OCS to target tuna in the longline fishery have been declining since 2012 (Tables 10 and 11). In almost all cases the observed ratios of sharks to tuna in the longline fishery are higher than the ratios of sharks to tuna reported in the logbook data (Tables 10 and 11 for longline, Tables 12 and 13 for purse seine).. The sharks observed most frequently in the purse seine fishery are FAL and OCS (Table 12), these sharks are present in the purse seine observer data for the years 2014 and 2015, but not in the reported data. This is likely a result of the retention ban on these species. Observed catch rates of OCS and FAL in the purse seine fishery for the years 2014 and 2015 are higher than for the two previous years.

Spatial analysis for both the purse seine and longline fleets indicate areas of high catch rates for FAL near the Solomon Islands and PNG (Figure 48, and 55). Higher catch rates for the more temperate sharks (BSH and MAK) are similar between the purse seine and observer data with higher catch rates in the temperate latitudes (Figures 51, 53, 57, and 58).

3.6 Comments Regarding the Data Reporting Patterns and shark related CMMs

Four main CMMs govern the catch of sharks in the WCPO;

- CMM 2010-07. Reporting of key shark species and ' 5% rule'.
- CMM 2011-04, non-retention for OCS, entered into force on January 1, 2013
- CMM 2013-08, non-retention for CMM for SILKY SHARKS - effective from 1 July 2014.
- CMM 2014-05 bycatch mitigation via no wire trace or no shark lines, effective from 1 July 2015.

In general there has been an increase in logsheet reporting of sharks to species (Figures 31 and 33), while the increase may be in part attributable to impact of CMM 2010-07, species specific reporting also increased in the 2000's relative to the 1990s. The impact of the retention bends (CMM 2011-04 and 2013-08) has been an absence of reporting in the purse seine fishery for the years 2014 and 2015 (Table 13) fishery despite observed catch rates that are similar to the years 2012-2013 (Table 12). Reporting of FAL and OCS in the longline fishery occurred in 2014 and 2015 at a similar rate to 2013, indicating that the CMM is not adopted over the entire fleet. CMM 2014-05 entered into force on July 1st 2015 and as such there is not enough data to quantify the effect of the bycatch mitigation via the implementation of this CMM (either no wire trace use or no shark line use) As the CMMs that specify non retention for OCS and FAL continue to be implemented the importance of the observer data in both purse seine and longline fisheries will increase.

4. Evaluation of the relative spatial distribution of fishing effort and observer coverage and the effect on catch estimation and CPUE trends.

Observer coverage ratios are often less than 100% total estimates of bycatch are often calculated by using ratios of observed bycatch to target species, raised via the total annual target species catch. This simulation study investigates the relationship between observer coverage and the ability to reliably estimate parameters of interest, specifically total bycatch and catch per unit of effort (CPUE) rates through time.

This modeling effort looks at the effect of the spatial coverage of the longline and purse seine observer effort in relation to the spatial coverage of the fishing effort, and the influence of the relative match/mismatch of these two metrics on the estimation of catch and CPUE for each of the key shark species in longline and purse seine fisheries.

Previous studies have looked at the relationship between observer coverage and the error (or bias) associated with various levels of observer coverage (Babcock et al. 2003, Amande et al. 2012, Diaz et al. 2011, Komoroske 2015 and references there-in). Here we follow methods set out by Babcock et al. (2003) and Amande (2012). For each simulation exercise, the following algorithm was used:

1. Simulate a fishery (the sampling universe)

2. Simulate the observer sampling process, and repeat many times for various levels of observer coverage

3. Calculate the CPUE

3. Estimate the total bycatch for each sample at each level of coverage

4. Compare the estimated total CPUE bycatch at each coverage level to the "true" values from the simulated fishery

5. Repeat for different simulated fisheries or species

The techniques used in Amande et Al. (2012) are updated to include spatial information regarding the species distribution, effort distribution and the distribution of observer coverage. These are the main inputs to the simulations, and can (in general) represent a random process or one informed by reported fisheries and or observer data.

The relative abundance is scaled to an overall abundance that can vary (or not) in each time step to mimic a decreasing population.

The model is set up so that the time step is called 'Year' and in each of those years the distribution of effort (*sets*) is the same, but varies across each simulation. Each spatial cell has *nsets_perCell* every year, which are assigned an abundance based on the population density (either uniform or based on observer data). Each cell is then either fished or not within a time period, with (currently) 70% of the cells receiving 'effort'.

The simulator uses 420 individual 5°x5° grids nominally corresponding to the WCPO from area from -55° to 45° within the east and west borders of the WCPFC convention area. The relative distribution of the observed sets and the longline effort is drawn from the years 2010-2015, in aggregate.

Annual catch and annual mean CPUE are calculated at various levels of observer coverage, based on either uniform, random, or observer coverage (observed to aggregate effort). Within that observer coverage design, coverage can be set from 0 to 100%. Coverage levels included observer coverage rates of 1%, 5%, 10%, 20%, 50% and 100% (full coverage must be included so that the bias and error in catch can be calculated).

Catch, CPUE and Error Calculation

Catch calculation was performed by sampling the CPUE (at the specified coverage rates) to calculate an average annual CPUE and then multiply by the total effort. This value is compared to the 'total catch' obtained through the 100% sampling coverage to calculate the RMSE and Bias, which can be expressed in relative terms (Figures 4. 1 and 4.2 below).

Following the Amande et al 2013 the relative root mean square (RRMSE) is calculated as $\sqrt{(}\sum_{i=1}^{n}(x_i - x^2)/x$

and the relative bias is calculated as $RBias_{i,j} = \sum_{i,j} \frac{X_{i,j} - X_i}{X_i}$.

Where $X_{i,j}$ is the expectation of the estimates, (the true value for the simulated data or the median of 1000 samples from the observer data for the actual observer data). TheX_i is the sampled shark species CPUE or bycatch number for PS.

Models were estimated for 15 year time frame for a set (but arbitrary) level of decline over that time frame.

Results

Similar to previous studies the results indicated that the RRMSE was highest for low levels of observer coverage and the relative bias was relative bias was slightly negative at low levels of observer coverage and converging on zero rather quickly.

The effect of using the spatial distribution of the longline effort on the RRMSE was to increase it (Figure 4.9) on average. The effect of using the spatial sampling of the observer coverage decreased the amount of error, more substantially for lower levels of coverage than for higher levels. The combination of including observed sampling coverage and reported effort showed an increase in the RRMSE that was higher at lower levels of observer coverage.

Average annual difference by species distribution (Figure 4.9) shows the difference between distributional assumptions (none – species specific), with negative values indicating that use of the observed species distribution in CPUE calculation results in higher amounts of error. The use of the observed distribution of FAL results in higher amounts of error while the use of the observed distribution of OCS resulted in lower amounts of error.

This simulation study will be extended to other species and include complete results for the final draft.

5. Gaps in biological knowledge

Catch and catch rate information provide key indicator trends for sharks, and are important inputs into analytical assessments. However, for the latter, some understanding of the life history of the shark species of interest is also required.

Recent WCPO assessments of silky, oceanic white tip and blue shark (Rice and Harley 2012, Rice and Harley 2013, Rice et al 2014.) have noted that improvements in biological knowledge, including on growth, mortality, reproduction and movement (e.g. Takeuchi et al., 2016) are required to facilitate stock assessments and reduce uncertainty in assessment outputs.

Clarke et al. (2015) reviewed a worldwide database of key life history parameters from over 270 studies on blue, mako, silky, oceanic whitetip, thresher, porbeagle, hammerhead and whale shark species, detailing their associated uncertainties and prioritizing further studies. This analysis provides the basis for the development of priors for some assessment approaches, as well as sensitivity analyses for others. Overall stock structure for the hammerhead and thresher shark species remain a key gap in biological knowledge for these species in the Pacific.

6. Whale Sharks

For the purposes of this report, information on whale sharks has been retained in a separate section. Information on whale sharks is limited almost exclusively to the purse seine fishing fleet where tuna schools associated with whale sharks are either specially targeted or whale sharks are discovered to be associated with schools that were previously thought to be free school tuna aggregations. Observations of whale sharks are subject to considerable spatial and temporal heterogeneity and likely to have been affected by changes in observer coverage and reporting practices in recent years. The fate of whale sharks following interactions is also uncertain and information on key biological processes are limited. Given the current SPC data holdings only limited analysis for whale sharks in the WCPO is considered to be feasible. The background to the original work by Harley et al. (2013) (for a full description of the analysis) was initiated from a request at WCPFC9 to add whale sharks to the list of key shark species and subsequently a conservation and management measure was adopted (CMM-2012-04). Additional analyses at the spatial and temporal distribution of whale sharks in the western and central Pacific Ocean based on observer data collected from purse seine vessels (SPC, 2011).

7. Initial Conclusions and Next Steps

Overall the quality, with respect the key shark species, of logbook data currently held by SPC has been improving over time. The logbook data has increasing levels of spatial coverage and higher levels reporting sharks to species. For both the longline and purse seine fisheries the logbook data is useful to support analytical and indicator assessments. The quality of the observer data currently held by SPC is likewise better in recent years than the historical data. Observer data coverage is not 100% in the purse seine fishery nor does it reach the required 5% coverage level in the longline fishery but has been increasing overtime and has also increased in spatial coverage. In general the data can support analytical (or indicator) assessments for the more commonly caught species, but would require significant extrapolation to assess the less common species.

Reporting of logsheet data by fleet is highly variable, with many fleets reporting significantly less than 100% (Table 9 and Table 11). It is difficult to identify whether logsheet data are provided for all key species given than non-reporting may be a result of a zero catch event (i.e. whale sharks in the longline fishery) or a lack of reporting. The relationship between the observer and logsheet reporting and the logsheet and aggregate reporting effect the precision in estimation of catch and potentially other stock related metrics such as distribution. Comparison of observer and logsheet data highlights that there is a large discrepancy of the rate of non-species-specific recording in the longline fishery logbook data. The general recommendation is for fishers to receive further identification training for sharks to species.

The largest gap in the currently held data is within the longline datasets, the observer data covers a fraction of the overall effort, is biased towards those fleets which have strong observer programs and is also spatially concentrated within the EEZs with little coverage on the high seas. The key mechanism to addressing the current data gaps would be an increase in observer coverage to at least the mandated 5% coverage level. Without representative coverage any reconstruction of shark catch and CPUE estimation will likely be biased. One of the difficulties with the data analysis is that there is no readily identifiable mechanism to logbook and observer sets.

Initial conclusions regarding the impact of WCPFC shark related CMMs on data quality is that these CMMs have resulted in non-reporting of catch within the purse seine fishery despite observations of catch and high levels of observer coverage. Within the longline fishery the reported catch of FAL an OCS is similar to that before the CMMs banning retention went into force.

Continuation of this work for the final report.

Although this analysis has considered coverage levels by fishery and fleet it has not provided advice on what types of analyses the data might support, including advice on appropriate modelling approaches (e.g. CPUE standardisation) where data are considered sufficient. This will be included in the final report as well as any recommendations from the SC13.

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10. Tables

Table 1

Table 1: Species and species groupings included in the analysis

Species Label	Species Code	Scientific Name
Blue Shark	BSH	*Prionace glauca*
Hammerhead Sharks	SPN	*Sphyrna mokarran, S. Lewini, S. zygaena, and Eusphyra blochii*
Mako Sharks	MAK	*Isurus oxyrinchus, I. paucus*
Oceanic Whitetip Shark	OCS	*Carcharhinus longimanus*
Porbeagle Shark	POR	*Lamna nasus*
Thresher Sharks	THR	*Alopias supercilious, A. vulpinus and A. pelagicus*
Silky Shark	FAL	*Carcharhinus falciformis*
Whale Shark	RHN	*Rhincodon typus*

Table 2

Table 2. Observer effort (in hooks fished), reported effort and total effort in the longline fishery by year

Year	Observed Hooks (Millions)	Reported Hooks (Millions)	Total Hooks Fished (Millions)	% Observer Coverage	% Logbook Coverage
1995	2.58	182.99	599.18	0.43%	30.54%
1996	2.40	129.10	569.30	0.42%	22.68%
1997	3.15	115.41	571.33	0.55%	20.20%
1998	2.78	123.47	642.30	0.43%	19.22%
1999	2.54	172.59	732.73	0.35%	23.55%
2000	4.00	182.09	785.55	0.51%	23.18%
2001	7.25	179.63	965.40	0.75%	18.61%
2002	11.10	219.40	1,006.03	1.10%	21.81%
2003	11.67	250.98	994.32	1.17%	25.24%
2004	12.73	287.71	1,064.85	1.20%	27.02%
2005	15.81	255.34	871.62	1.81%	29.30%
2006	15.84	275.96	898.58	1.76%	30.71%
2007	15.03	334.84	1,013.16	1.48%	33.05%
2008	15.46	300.51	1,030.07	1.50%	29.17%
2009	14.94	334.06	1,112.96	1.34%	30.02%
2010	16.45	354.06	1,082.29	1.52%	32.71%
2011	20.50	396.74	1,165.69	1.76%	34.04%
2012	25.07	433.30	1,219.86	2.06%	35.52%
2013	30.00	410.12	1,007.73	2.98%	40.70%
2014	27.66	408.49	1,041.82	2.66%	39.21%
2015	20.07	421.24	1,108.67	1.81%	37.99%

Table 3

Table 3. Longline logbook reporting of sharks by species, generic shark or none.

Year	None	Sharks	Species
1950	0%	100%	0%
1951	0%	100%	0%
1952	100%	0%	0%
1953	100%	0%	0%

1954	100%	0%	0%
1955	100%	0%	0%
1956	100%	0%	0%
1957	100%	0%	0%
1958	95%	5%	0%
1959	96%	4%	0%
1960	96%	4%	0%
1961	95%	5%	0%
1962	93%	7%	0%
1963	93%	7%	0%
1964	95%	5%	0%
1965	96%	4%	0%
1966	95%	5%	0%
1967	95%	5%	0%
1968	91%	9%	0%
1969	93%	7%	0%
1970	93%	7%	0%
1971	94%	6%	0%
1972	96%	4%	0%
1973	93%	7%	0%
1974	95%	5%	0%
1975	90%	10%	0%
1976	94%	6%	0%
1977	92%	8%	0%
1978	91%	9%	0%
1979	81%	19%	0%
1980	73%	27%	0%
1981	67%	33%	0%
1982	71%	29%	0%
1983	85%	15%	0%
1984	81%	19%	0%
1985	67%	33%	0%
1986	83%	17%	0%
1987	59%	40%	0%
1988	61%	39%	0%
1989	66%	34%	0%
1990	71%	29%	0%
1991	67%	31%	2%
1992	66%	31%	3%
1993	62%	35%	3%
1994	25%	46%	28%

1995	23%	52%	25%
1996	27%	48%	25%
1997	28%	50%	22%
1998	27%	47%	26%
1999	28%	49%	23%
2000	28%	50%	22%
2001	48%	35%	17%
2002	37%	43%	20%
2003	36%	40%	24%
2004	25%	47%	28%
2005	24%	49%	27%
2006	25%	47%	28%
2007	20%	54%	26%
2008	10%	62%	28%
2009	7%	66%	27%
2010	8%	53%	39%
2011	11%	55%	34%
2012	13%	44%	43%
2013	18%	37%	45%
2014	22%	38%	39%
2015	23%	36%	40%

Table 4

Table 4: Observer and Operational coverage for the purse seine fishery

Year	Observed Sets	Logbook Sets	Aggregate Sets	% Observer Coverage (Obs./Agg.)	% Opperational coverage (Log./Agg.)
1995	1,870	14741	15,350	12%	96%
1996	3,011	17695	14,404	21%	123%
1997	2,459	18001	24,678	10%	73%
1998	2,608	19290	27,684	9%	70%
1999	1,677	17196	22,715	7%	76%
2000	2,000	16514	22,181	9%	74%
2001	2,354	17724	26,629	9%	67%
2002	3,460	20867	30,003	12%	70%
2003	3,673	20126	20,522	18%	98%
2004	5,362	23288	29,907	18%	78%
2005	6,272	23471	29,400	21%	80%
2006	6,126	22129	26,635	23%	83%
2007	6,032	23571	27,826	22%	85%
2008	6,286	24825	33,426	19%	74%
2009	10,928	28458	35,100	31%	81%
2010	32,371	27516	44,050	73%	62%
2011	32,293	30672	41,114	79%	75%
2012	37,016	33697	41,219	90%	82%
2013	41,649	31302	50,064	83%	63%
2014	38,063	32079	53,043	72%	60%
2015	33,751	30019	45,199	75%	66%

Table 5 Observer Coverage by Year and Fleet (Observed Purse Seine Sets / Aggregate Sets)

Year	CN	EC	ES	FM	ID	JP	KI	KR	MH	NZ	PG	PH	SB	SV	TV	TW	US	VU
1995				11.6		4.9	52.8	4.4			**122.4**					16.5	23.1	16.8
1996				2.9		4.6	36.8	9.7		36.2	84.8	3.3				86.8	34.0	
1997						1.7	23.1	4.3		22.3	45.4	14.6				8.2	26.7	5.9
1998				17.7		1.2	23.3	5.4			22.3		5.1			13.4	21.3	3.6
1999				8.5		0.7	75.0	7.4			10.4	2.9	9.4			9.2	17.8	2.1
2000				27.6		2.6	8.2	6.5		7.1	10.5	5.3	25.0			10.8	23.8	
2001				10.7		2.9	6.0	2.8	4.1	6.8	11.5	27.9	8.5			7.3	26.7	
2002	13.5			20.6		1.9	69.7	1.1	10.9		62.0	82.3	54.3			4.2	20.2	
2003				18.5		3.9	93.5	4.4	17.2	2.5	**109.2**	93.7	37.0			2.6	27.5	3.1
2004				21.6		3.4	46.9	9.6	22.9	2.4	55.3	**204.1**	34.9			9.0	28.2	11.9
2005	6.6			19.6		3.1	30.9	5.9	31.0	5.2	68.9	**189.4**	11.1			12.1	21.6	18.4
2006	5.0			26.6		4.6	85.2	6.2	60.4	3.0	74.4	**214.1**				6.4	25.1	14.7
2007	8.6			19.6		4.1	23.2	5.2	57.4	0.5	74.0	**245.9**	11.7			11.1	20.6	17.8
2008			7.1	25.4		3.1	34.6	6.4	59.1	4.2	45.1	**117.5**	29.4			9.8	22.8	12.3
2009	14.1		1.1	23.5		17.0	34.9	10.5	57.3	18.8	76.4	**238.6**		4.7	21.9	18.2	38.8	37.2
2010	65.0	68.4	61.8	69.7	1.8	71.5	75.1	57.3	64.2	21.0	94.5	**269.1**	8.5	71.5	86.4	52.6	94.7	**107.8**
2011	41.4	57.5	17.9	86.2		89.9	54.8	66.3	51.2	30.4	**142.5**	**256.8**	12.9	53.5	64.4	64.9	95.3	**107.7**
2012	73.0	28.4	18.6	68.1		**138.0**	70.8	65.6	71.8	47.1	**165.1**	**207.0**	29.8	4.6	71.6	74.2	88.0	76.7
2013	69.3	65.5	**102.9**	14.7		**149.6**	63.9	72.8	89.9	34.2	**136.1**	**262.7**	14.7	70.7	53.7	64.8	92.4	61.8
2014	60.9	68.6	76.0	70.6		82.1	57.0	44.9	83.1	27.2	77.6	**127.8**	36.4	85.9	47.2	55.0	94.4	48.0
2015	**130.0**	**208.1**	41.9	83.1		69.2	49.9	77.9	70.6	16.2	90.0	**221.7**	38.7	42.1	67.1	63.1	76.5	67.6

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Table 6

Observer coverage percent by year and flag for the longline fishery.

Year	AS	AU	CK	CN	FJ	FM	GU	JP	KI	KR	MH
1995			1.4%	0.2%	0.9%	0.3%	9.0%	0.7%			
1996			6.7%	0.2%	0.4%	0.9%	4.0%	0.5%			
1997		0.5%		0.6%	0.5%	1.5%	10.5%	0.8%			
1998	0.0%			0.5%		0.7%	8.0%	0.5%		0.1%	
1999		0.0%		0.2%	1.1%	0.5%		0.5%		0.1%	
2000				0.2%		1.0%	0.0%	0.4%			
2001		0.7%		0.9%		0.9%		0.3%			
2002	1.1%	5.6%	0.7%	0.0%	0.3%	0.7%		0.4%		0.3%	
2003		4.9%	0.0%	0.5%	1.2%	0.8%		0.4%		0.1%	
2004		7.3%		0.5%	0.6%	2.3%		0.0%		0.0%	
2005		11.2%		0.8%	2.6%	4.4%		0.5%		0.3%	
2006		10.3%		2.0%	2.5%	11.4%		0.3%		1.0%	
2007		6.0%	0.2%	1.5%	1.9%	1.2%		0.5%		0.5%	
2008		9.5%	0.9%	0.3%	2.6%	1.0%		0.2%	9.1%		1.8%
2009		6.3%	1.8%	0.4%	1.3%			0.4%			0.5%
2010		3.6%	1.6%	0.1%	0.8%			0.2%			
2011		6.4%	1.7%	0.1%	1.2%			0.1%	0.6%	0.3%	
2012		6.0%		1.1%	0.7%			0.3%		1.0%	
2013		6.6%	7.7%	2.0%	3.6%	1.9%		0.3%		2.7%	3.7%
2014		2.9%	4.6%	2.4%	6.5%	8.4%		0.4%		1.3%	
2015		1.3%	6.4%	0.6%	9.3%	2.0%		0.7%	3.8%	2.8%	

Year	NC	NZ	PF	PG	PW	SB	TO	TW	US	VU	WS
1995		2.7%						0.0%	3.6%	0.4%	
1996	4.0%	4.8%		1.9%			5.2%	0.2%	4.5%		
1997		5.0%	2.2%					0.2%	3.3%		
1998	1.1%	3.6%					3.6%	0.2%	3.7%		0.0%
1999	0.7%	0.5%		1.0%			0.8%	0.1%	3.2%		0.0%
2000		0.5%		1.5%	3.9%		1.1%	0.2%	11.6%		3.4%
2001	0.7%	3.5%		4.5%				0.0%	23.4%		0.5%
2002	2.3%	1.4%	1.0%	3.3%				0.2%	25.3%		
2003	2.4%	6.0%	2.5%	2.9%				0.1%	22.6%		
2004	2.4%	11.9%	1.7%	2.7%			7.0%	0.1%	26.2%		
2005	1.2%	2.7%	1.6%	5.6%			0.7%		33.5%		
2006	2.6%	2.5%	3.6%	4.5%			8.0%	0.0%	25.8%		0.3%
2007	2.6%	4.2%	1.6%	1.6%			3.4%	0.0%	28.3%		
2008	3.1%	4.2%	2.6%	5.9%			8.7%	0.1%	32.7%		
2009	7.8%	4.6%	6.0%				4.9%	0.1%	32.1%	0.2%	
2010	8.4%	4.7%	6.0%	0.9%			2.6%	0.1%	48.7%	0.5%	
2011	6.7%	3.3%	3.9%	4.1%		1.7%		1.0%	48.4%	1.9%	0.2%
2012	4.3%	3.3%	4.9%	7.5%		9.1%	0.8%	2.3%	41.5%	0.0%	
2013	4.2%	2.4%	5.0%	8.2%		7.7%		2.9%	36.5%	2.6%	0.6%
2014	6.0%	3.0%	4.5%	6.1%			3.2%	2.4%	32.2%	1.0%	
2015	4.2%	4.1%	3.2%				8.1%	1.1%	18.9%	1.4%	0.8%

Table 7 Longline logbook coverage (logbook/aggregate) effort

Year	AU	BZ	CK	CN	ES	FJ	FM	GU	ID	JP	KI	KR	MH	NC	NU
1995	0.903	1	1	0.771		0.714	0.642	1	0	0.28	0.833	0.45	0.636	0.385	
1996	0.955	1	1	0.725		0.382	0.571	1		0.187	1	0.317		0.403	
1997	1.001	1	1	0.76		0.79	0.645	1		0.155		0.304		0.495	
1998	0.954	0.993		0.616		1	0.571	1		0.118		0.291		0.715	
1999	0.964	0.926		0.304		0.858	0.575	1		0.173		0.43		0.652	
2000	0.932	1		0.365		0.622	0.5	1		0.151		0.385		0.772	
2001	0.88	0.977	1	0.479		0.731	0.624			0.107		0.28		0.704	
2002	0.894	0.32	1	0.278		0.936	0.438			0.083		0.272		0.682	
2003	0.846	0.124	1	0.235		0.898	0.625			0.133	1	0.224		0.682	
2004	0.857	0.305	0.891	0.256	0.884	0.779	1		0.003	0.101	1	0.323	1	0.944	
2005	1	0.546	0.997	0.379	0.835	1	1		0.007	0.142		0.174		0.991	0.968
2006	0.933	0.769	1	0.299	0.983	1	1		0.007	0.172		0.393		0.892	0.718
2007	1	0.291	0.998	0.38	0.985	1	0.207		0.001	0.172		0.614	0.6	0.919	1
2008	1	0.41	1	0.262	0.796	0.975	0.763		0.004	0.153	1	0.35	0.773	0.941	1
2009	1	0.364	1	0.379	0.931	1	0.724			0.138		0.404	0.486	0.941	0.158
2010	1		0.802	0.422	0.576	1.001	0.985			0.185		0.313	0.597	0.899	1
2011	1		0.814	0.549	0.783	0.981	0.519		0.008	0.168	1	0.289	0.684	0.994	
2012	1	0.245	0.521	0.403	0.779	1.004	0.463		0.015	0.158	0.628	0.3	1	0.963	
2013	1	0.046	1	0.54	0.947	0.999	1		0.014	0.134	0.998	0.281	1	1	
2014	1	1	1	0.653	0.765	1	1.001		0.017	0.134	1	0.801		1	
2015	1		0.53	0.652	0.626	1.004	1		0.001	0.107	1	0.924	1	0.687	

	NZ	PF	PG	PH	PT	PW	SB	SN	TO	TV	TW	US	VN	VU	WS
1995	0.655	0.639	0.259								0.135			1	
1996	0.574	0.648	0.638						1		0.161			1	
1997	0.735	0.761	0.991	0.028					0.255		0.115	0.002		1	
1998	0.695	0.85	0.662	0.005					0.189		0.122	0.004		1.485	0.153
1999	0.783	0.834	0.703						0.238		0.107				0.206
2000	0.822	0.828	0.723			0.486			0.624		0.145			1	1
2001	0.747	0.734	0.816			0.242			0.695		0.066			0.943	0.134
2002	0.766	0.785	0.961	0.029					0.852		0.118			0.524	0.206
2003	0.706	0.847	0.998	0.018					1		0.167			0.494	0.398
2004	0.622	0.755	0.857			0.143			1		0.17		0	0.978	0.512
2005	0.733	0.759	0.907						0.734	1	0.171		0.001	0.971	0.415
2006	0.751	0.8	1					1	0.834		0.174			0.972	0.299
2007	0.909	0.768	0.847					0.995	0.866		0.142	0.5		0.924	0.237
2008	0.622	0.79	0.773						0.914		0.141	0.538		0.951	0.22
2009	0.844	0.778	0.476						0.889		0.146	0.53		0.958	0.367
2010	0.818	0.722	0.946	0.023			0.015		0.665	1	0.198	0.534		0.974	0.527
2011	0.684	0.689	0.386	0.098			0.145		0.617	0.744	0.217	0.624		0.897	0.547
2012	0.779	0.757	1	0.055			0.978		0.36	1	0.205	0.626		0.851	0.816
2013	0.825	0.857	1	0.055			1		1	1	0.286	0.634		0.67	0.725
2014	0.704	0.779	1		1		0.053		1	1	0.255	0.604		0.839	0.952
2015	1	0.889	0.905		1		0.059		1	0.622	0.205	0.697		0.756	0.981

Table 8. Reported and Aggregate sets from the Purse seine fishery.

Year	Reported Sets (logbok)	Aggregate Sets	Ratio
1995	14741	15350	0.96
1996	17695	14404	1.229
1997	18001	24678	0.729
1998	19290	27684	0.697
1999	17196	22715	0.757
2000	16514	22181	0.745
2001	17724	26629	0.666
2002	20867	30003	0.695
2003	20126	20522	0.981
2004	23288	29907	0.779
2005	23471	29400	0.798
2006	22129	26635	0.831
2007	23571	27826	0.847
2008	24825	33426	0.743
2009	28458	35100	0.811
2010	27516	44050	0.625
2011	30672	41114	0.746
2012	33697	41219	0.818
2013	31302	50064	0.625
2014	32079	53043	0.605
2015	30019	45199	0.664

Table 9. Ratio of reported target catch to aggregate target catch for the purse seine fishery by flag

Year	CN	EC	ES	FM	FR	ID	JP	KI	KR	MH
1995				1.237			1.471	4.147	1.657	
1996				1.017	1		1.603	4.503	1.925	
1997				1.009			0.593	2.146	1.033	
1998				1.034			0.509	1.474	1.001	
1999				1.172			0.559	4.904	1.136	
2000				1.896			0.493	2.396	1.392	0.69
2001				1.057			0.738	1.926	0.947	1
2002	0.889			0.964			0.675	2.301	0.947	0.982
2003	1.482			1.28			1.128	3.399	1.67	1.002
2004	0.598		0.884	0.936			0.892	3.063	1.039	1
2005	0.717		0.687	0.997			0.65	4.466	1.126	1.001
2006	0.626			1.518			0.958	2.349	1.098	1.019
2007	0.817	0.589	0.097	1.431			1.008	1.291	1.085	1.04
2008	0.446	0.594	0.296	1.43			0.693	1.305	0.997	1.172
2009	0.752	1.604	0.696	1.092			0.514	0.831	1.061	1.08
2010	0.745	1.108	0.579	1.168		0.48	1.072	0.913	0.985	1.084
2011	0.618	1	0.869	1.051			1.33	0.802	1.192	0.877
2012	0.856	0.945	0.756	1.001			1.69	1.072	1.174	1.085
2013	0.772	0.024	0.928	1.356			0.612	1.169	1.051	1.059
2014	0.778	1.211	0.915	0.927			0.791	1.027	0.905	1.192
2015	0.71	2.415	1.044	0.924			0.77	1.067	1.019	0.997

Year	NZ	PG	PH	SB	SV	TV	TW	US	VU
1995	5.063	6.14	0.413	1.247			3.259	1.247	1.545
1996	2.43	6.621	0.568	1.192			7.169	0.918	1.632
1997	1.157	2.511	1.225	1.149			1.531	0.917	0.929
1998	0.668	1.592	1.296	1.254			1.034	0.972	0.888
1999	0.71	1.612	1.591	1.067			1.1	0.969	1.026
2000	0.541	1.566	1.814	1.755			1.265	1.021	1.065
2001	0.684	1.32	1.313	1.244			0.965	0.964	0.987
2002	0.54	1.509	1.97	1.452			0.984	0.936	0.988
2003	0.897	2.639	1.504	1.116			1.837	1.293	1.094
2004	0.421	1.174	5.678	1.319			1.075	1.027	0.933
2005	0.56	1.363	2.029	0.773			1.105	0.968	0.867
2006	0.792	1.293	3.502	1.113			1.069	1.037	1.026
2007	0.644	1.369	5.032	1.334			1.194	1.042	0.914
2008	0.668	1.281	2.656	1			1.18	1.006	0.875
2009	0.847	1.308	5.185	0.981	0.3	0.744	1.045	1.113	1.236
2010	0.495	0.949	4.66	1	0.6	0.951	0.918	1.03	1.4
2011	0.45	1.456	2.451	0.973	1	0.949	1.013	1.003	1.024
2012	0.534	1.497	2.804	0.849	1	0.971	0.971	1.005	1.261
2013	0.171	1.477	2.038	0.94	0.2	0.955	0.9	0.993	1.098
2014	0.156	0.895	1.352	0.769	0.1	0.983	0.907	0.992	0.931
2015	0.241	1.042	2.72	0.85	0.5	1.006	0.947	0.955	0.746

Table 10. Ratio of observed key shark to target species in the longine fishery by year.

Year	FAL_ratio	OCS_ratio	THR_ratio	SPN_ratio	BSH_N_ratio	MAK_N_ratio	BSH_S_ratio	MAK_S_ratio	POR_ratio
2010	0.0352	0.0064	0.0107	6.00E-04	0.7389	0.0407	0.0608	0.007	0.0883
2011	0.058	0.0057	0.0157	9.00E-04	0.4026	0.0232	0.0593	0.0114	0.093
2012	0.1105	0.0077	0.0124	0.0025	0.3121	0.0209	0.0655	0.0089	0.043
2013	0.0654	0.0045	0.01	0.0016	0.2895	0.0218	0.0682	0.0071	0.0131
2014	0.0488	0.0033	0.0146	9.00E-04	0.3154	0.0204	0.0753	0.005	0.0253
2015	0.0185	0.0027	0.0023	2.00E-04	0.0113	0.0032	0.0783	0.0059	0.3264

Table 11:

Ratio of reported (logbook) key shark species to target species in the longline fleet aggregated by year

Year	FAL_ratio	OCS_ratio	THR_ratio	SPN_ratio	BSH_N_ratio	MAK_N_ratio	BSH_S_ratio	MAK_S_ratio	POR_ratio
2010	0.003	0	0.001	0	0.062	0.004	0.035	0.005	0.028
2011	0	0	0.001	0	0.05	0.003	0.071	0.008	0.079
2012	0	0	0.001	0	0.05	0.002	0.055	0.006	0.106
2013	0.002	0.001	0.001	0	0.049	0.003	0.031	0.02	0.034
2014	0.005	0.001	0.003	0	0.058	0.004	0.033	0.005	0.018
2015	0.001	0.002	0.003	0	0.062	0.004	0.015	0.002	0

Table 12

Ratio of observed key shark species to target species in the purse seine fleet aggregated by year

Year	FAL_ratio	OCS_ratio	BSH_ratio	MAK_ratio	POR_ratio	THR_ratio	SPN_ratio	RHN_ratio
2010	0.5815	0.0108	2.00E-04	0.001	NA	7.00E-04	0.004	0.0049
2011	1.393	0.0118	0.003	8.00E-04	NA	0.052	0.0017	0.0027
2012	0.2799	0.0109	1.00E-04	0.0032	NA	3.00E-04	3.00E-04	0.0038
2013	0.474	0.0032	5.00E-04	1.00E-04	NA	2.00E-04	3.00E-04	0.0028
2014	0.4148	0.0038	3.00E-04	2.00E-04	NA	9.00E-04	3.00E-04	0.0017
2015	0.4827	0.0045	6.00E-04	6.00E-04	2.00E-04	3.00E-04	5.00E-04	0.0022

Table 13

Ratio of reported key shark species to target species in the purse seine fleet aggregated by year

Year	FAL_ratio	OCS_ratio	BSH_ratio	MAK_ratio	POR_ratio	THR_ratio	SPN_ratio	RHN_ratio
2010	0.2263	0.0019	1.00E-04	5.00E-04	NA	0.0046	0.001	0.7052
2011	1.176	0.0014	0.0048	3.00E-04	NA	5.00E-04	0	0.436
2012	0.3483	0.0026	0.0024	NA	NA	0.0029	4.00E-04	0.7143
2013	0.3483	0.0018	2.00E-04	8.00E-04	NA	0.0079	1.00E-04	0.4389
2014	NA	NA	0.0679	0.0022	NA	0.001	5.00E-04	0.1938
2015	NA	NA	NA	NA	NA	NA	NA	NA

11. Figures

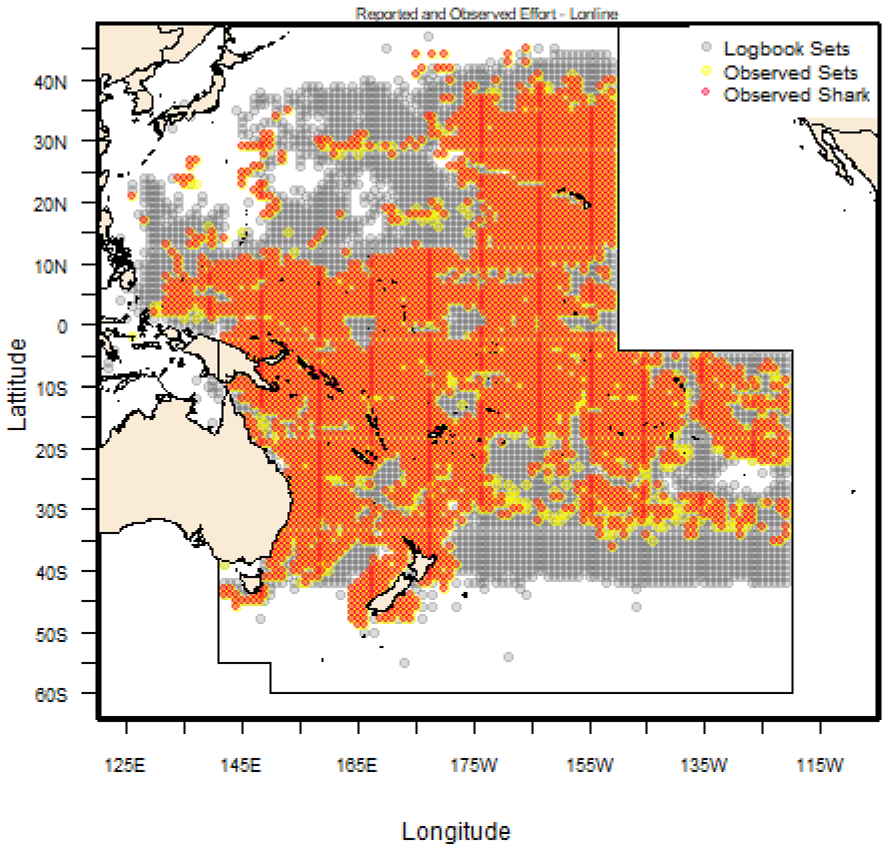

Figure 1. Reported and observed longline sets, with observed sharks for the longline fishery 1995 :2015.

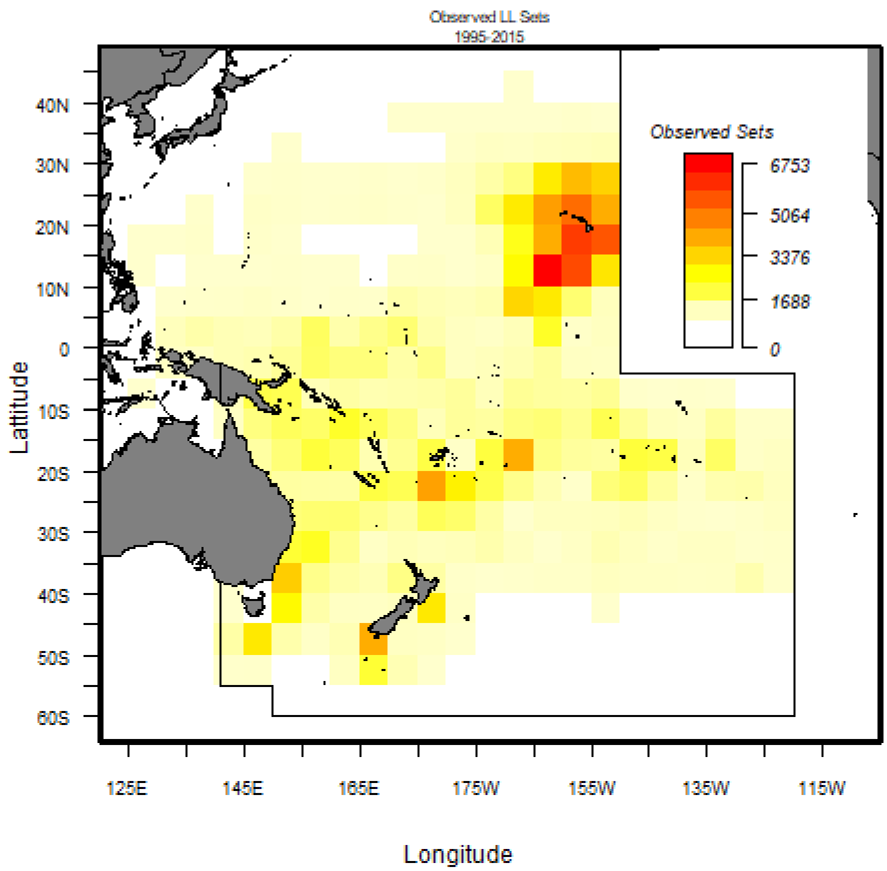

Figure 2. Total observed sets by 5 degree square for the longline fishery.

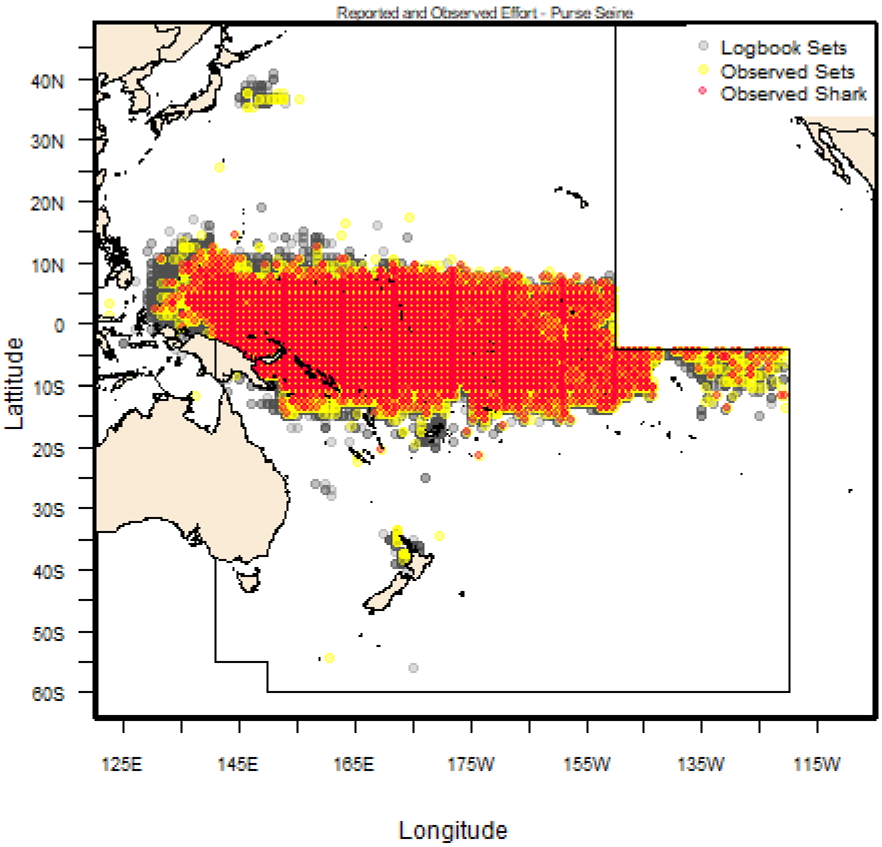

Figure 3.. Logbook reported, observed sets and observed shark sets for the purse seine fishery, 1995-2015.

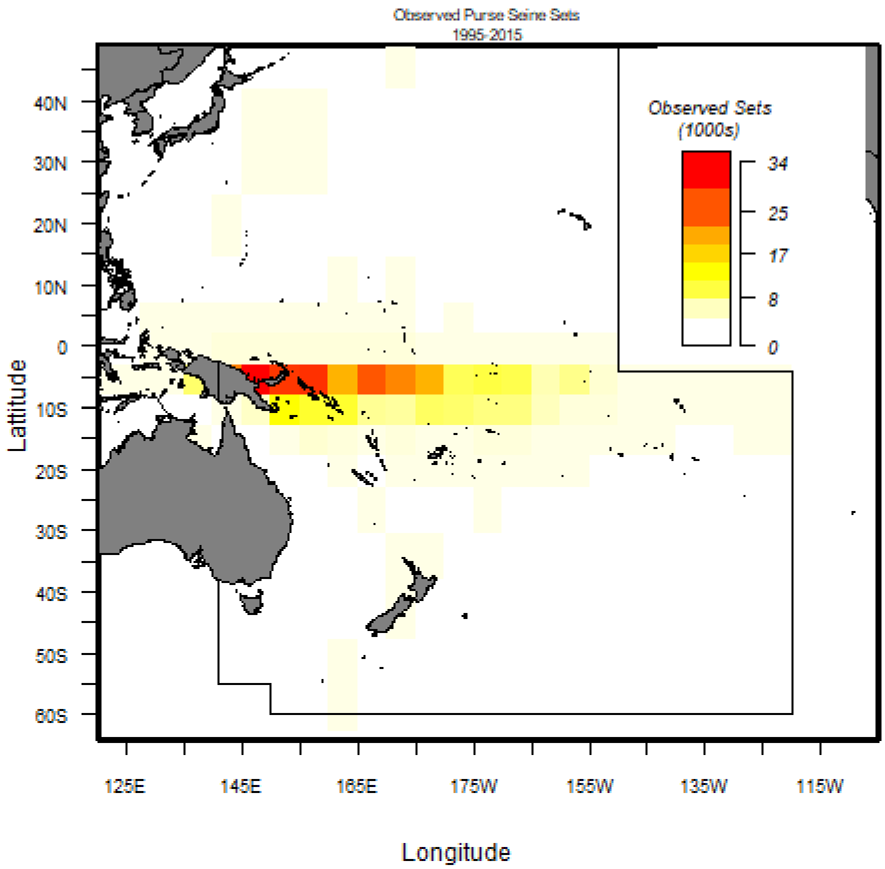

Figure 4. Observed sets (1000s) in the purse seine fishery 1995 2015.

Figure 4. Observed sets in the purse seine fishery.

Figures Section 3.1

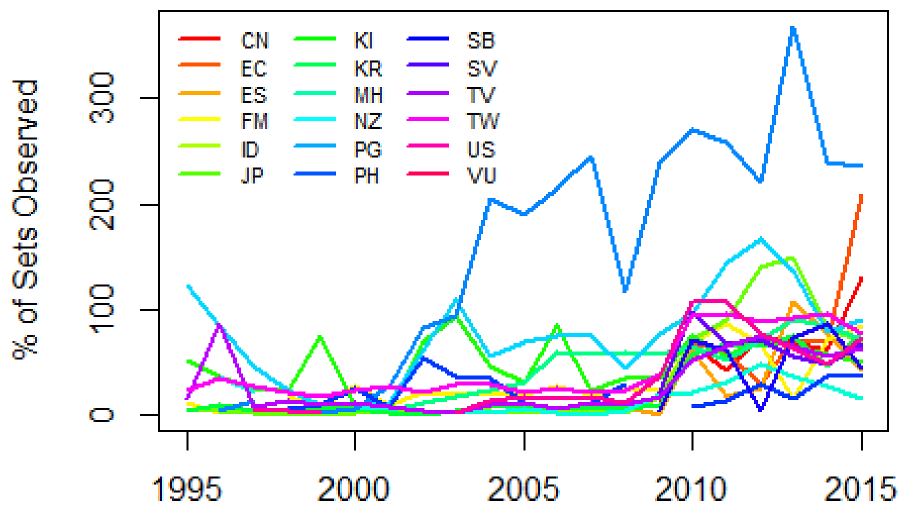

Figure 5. Percent observer coverage by flag (Observer data / Operational data).

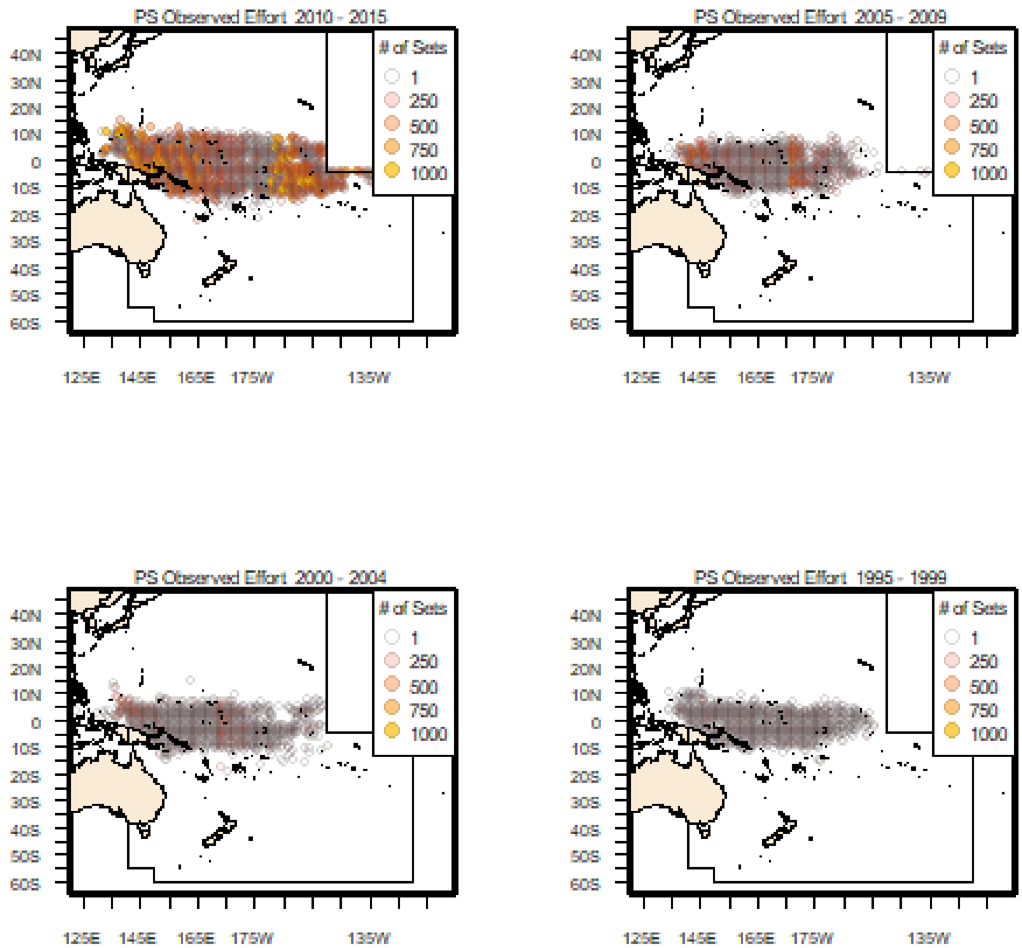

Figure 6. Spatial distribution of the observed purse seine sets by 5 year block.

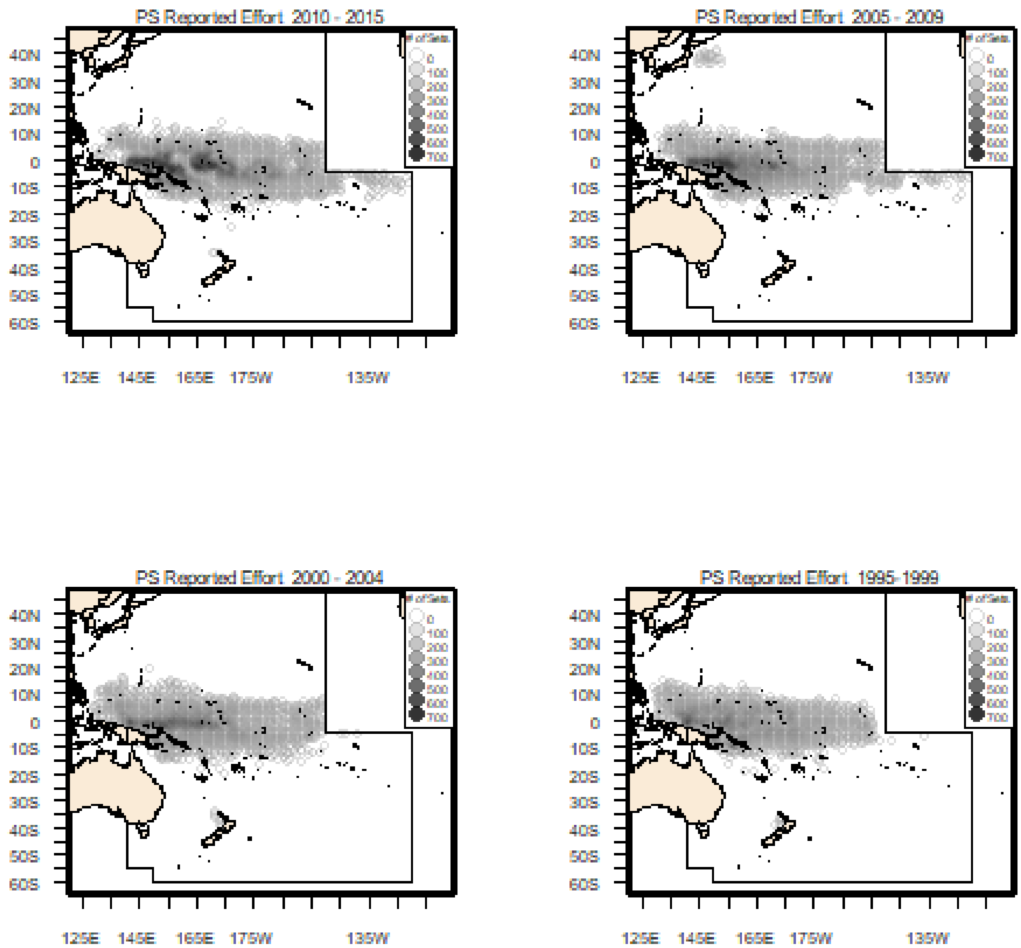

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Figure 7. Reported purse seine effort by 5 year time frame.

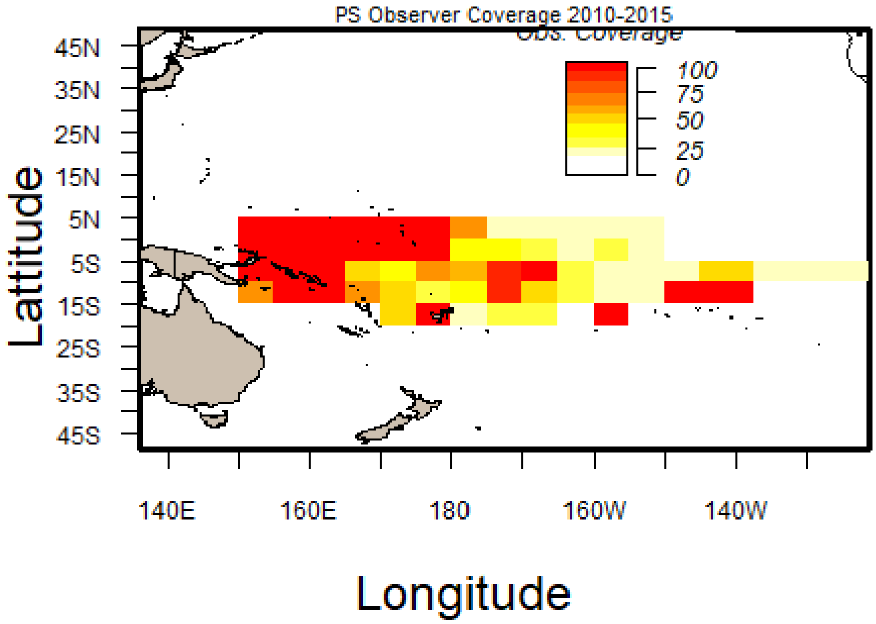

Figure 8. Spatial distribution of the observer coverage for the purse seine fishery 2010-2015.

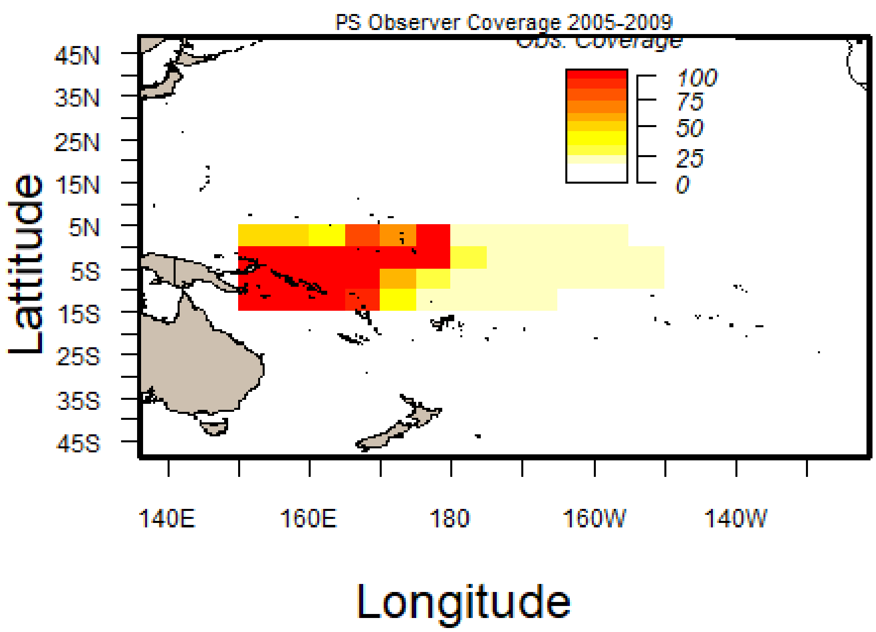

Figure 9. Spatial distribution of the observer coverage for the purse seine fishery 2005-2009

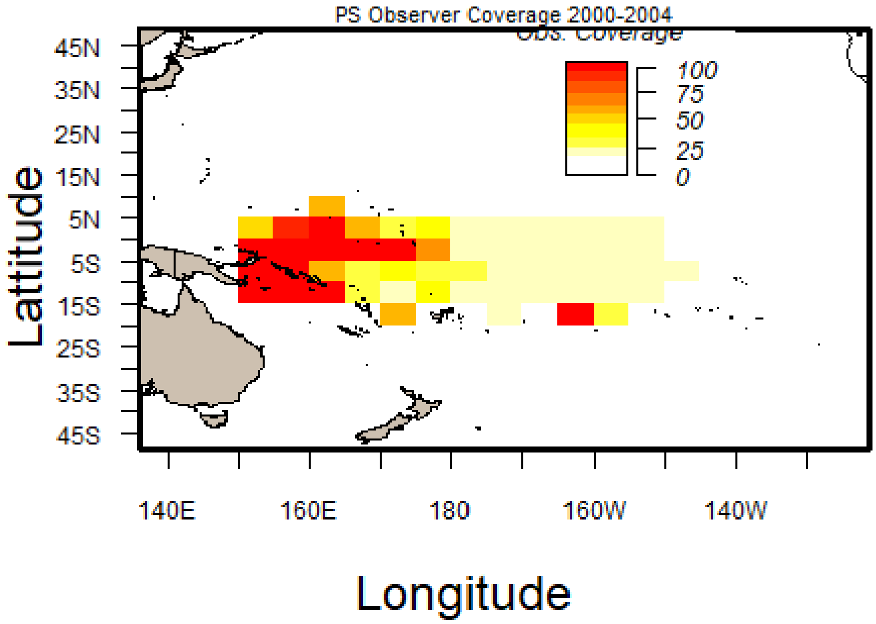

Figure 10. Spatial distribution of the observer coverage for the purse seine fishery 2000-2004.

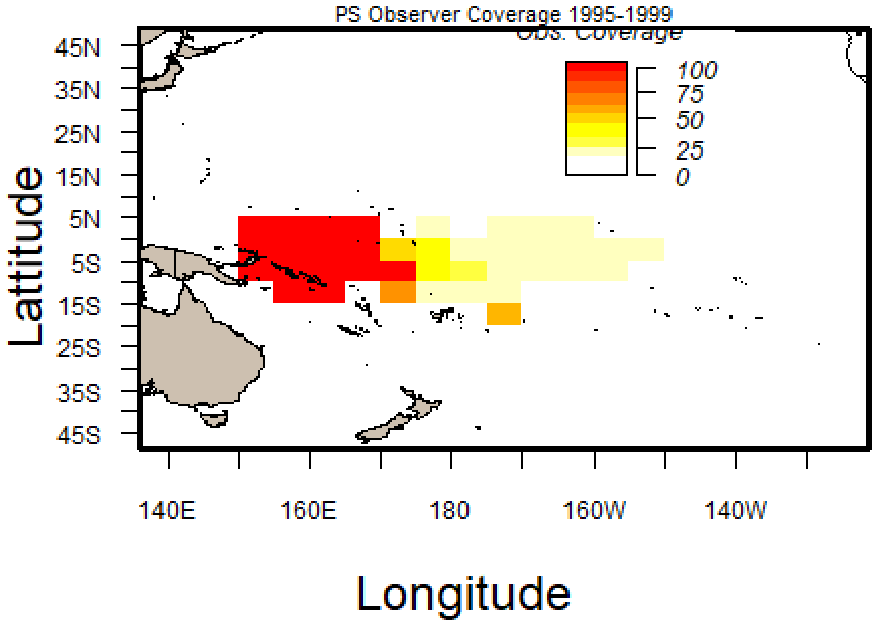

Figure 11. Spatial distribution of the observer coverage for the purse seine fishery 1995-2009.

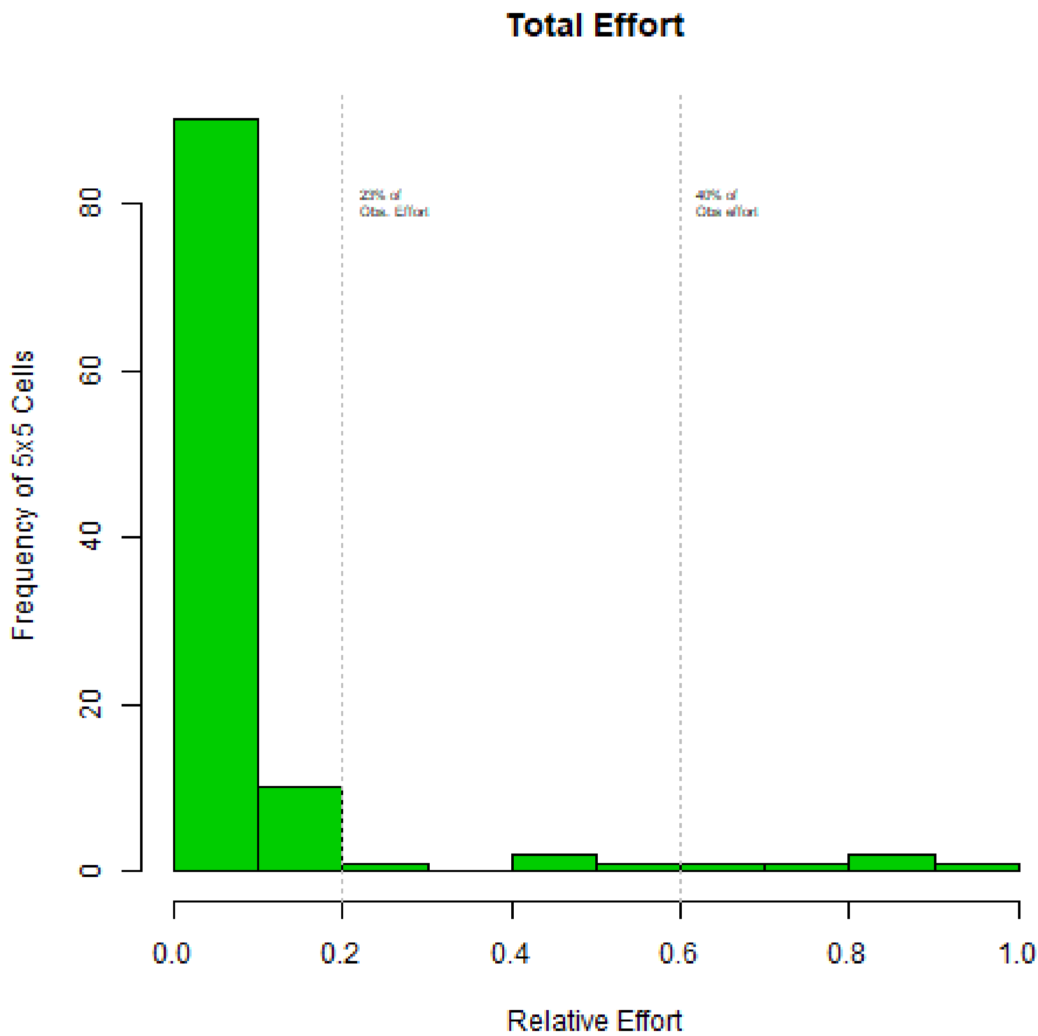

Figure 12. Distribution of the relative effort of observer data.

Relative distribution of logsheet effort. :

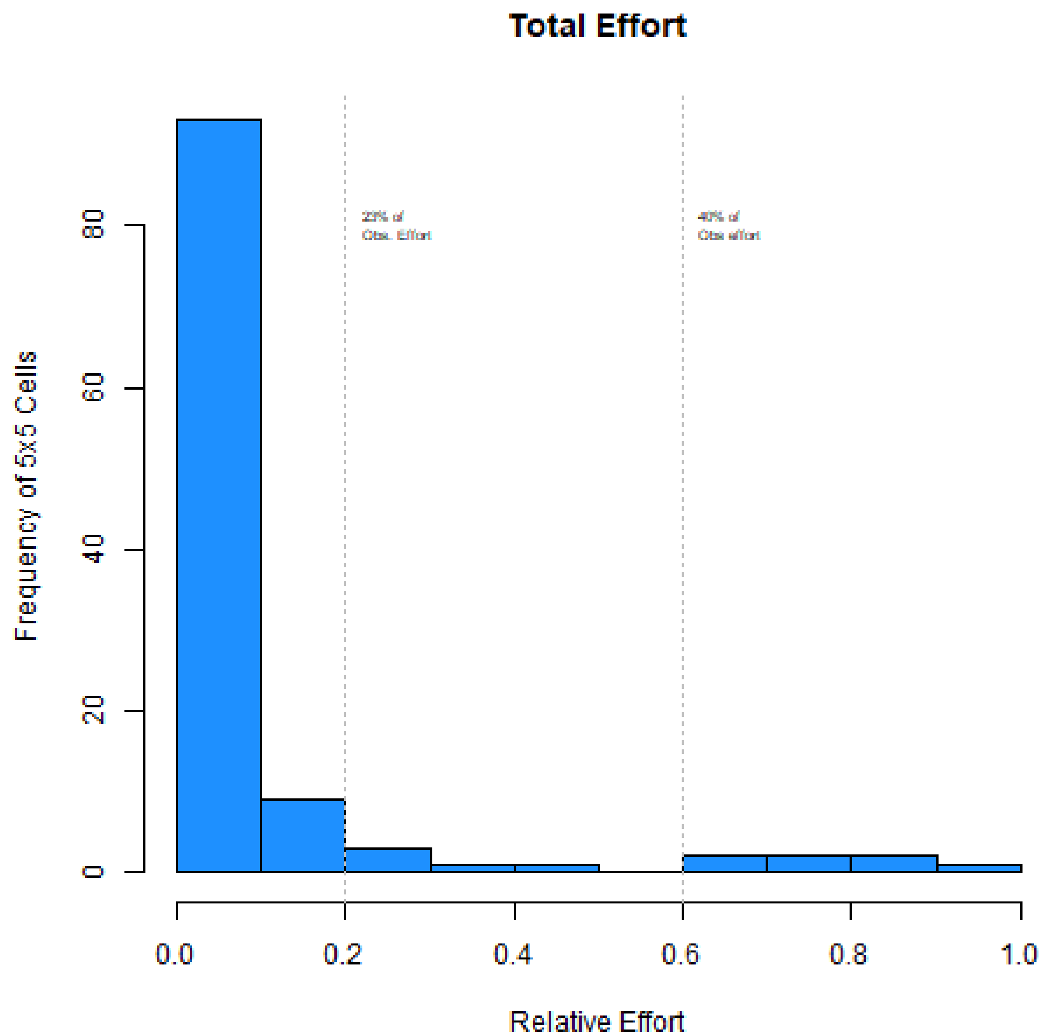

Figure 13. Relative distribution of logsheet effort.

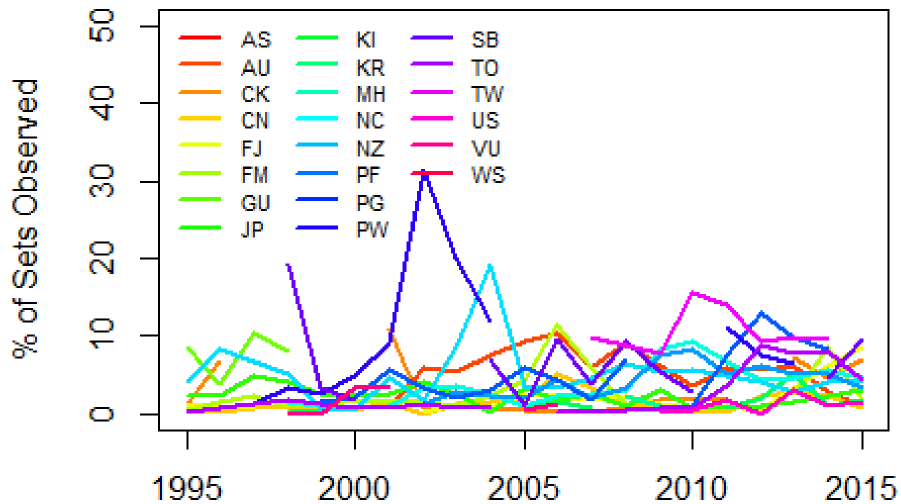

Figure 14. Percent coverage by year and flag, longline fishery. For the years 1995-2015.

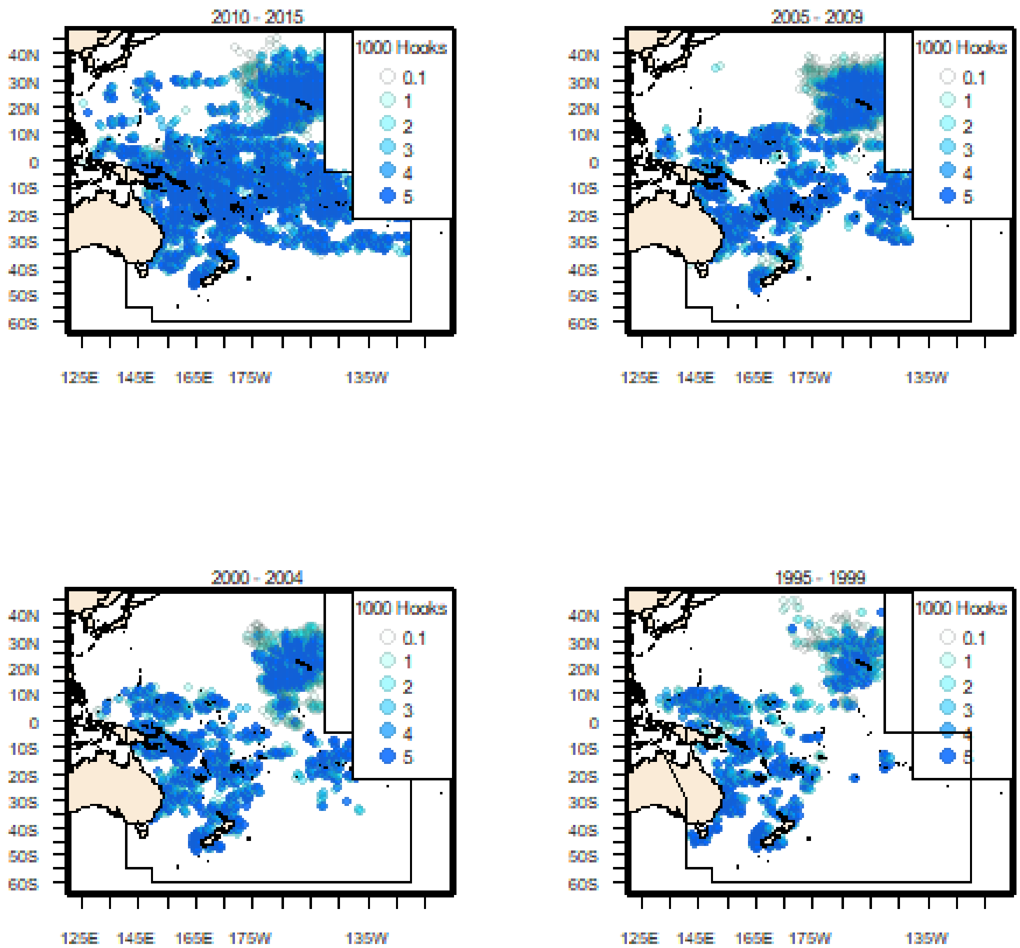

Figure 15. Observed longline (1000s' of hooks) effort by time block 1995, points indicate individual observed sets, darker areas indicate higher amounts of observed effort.

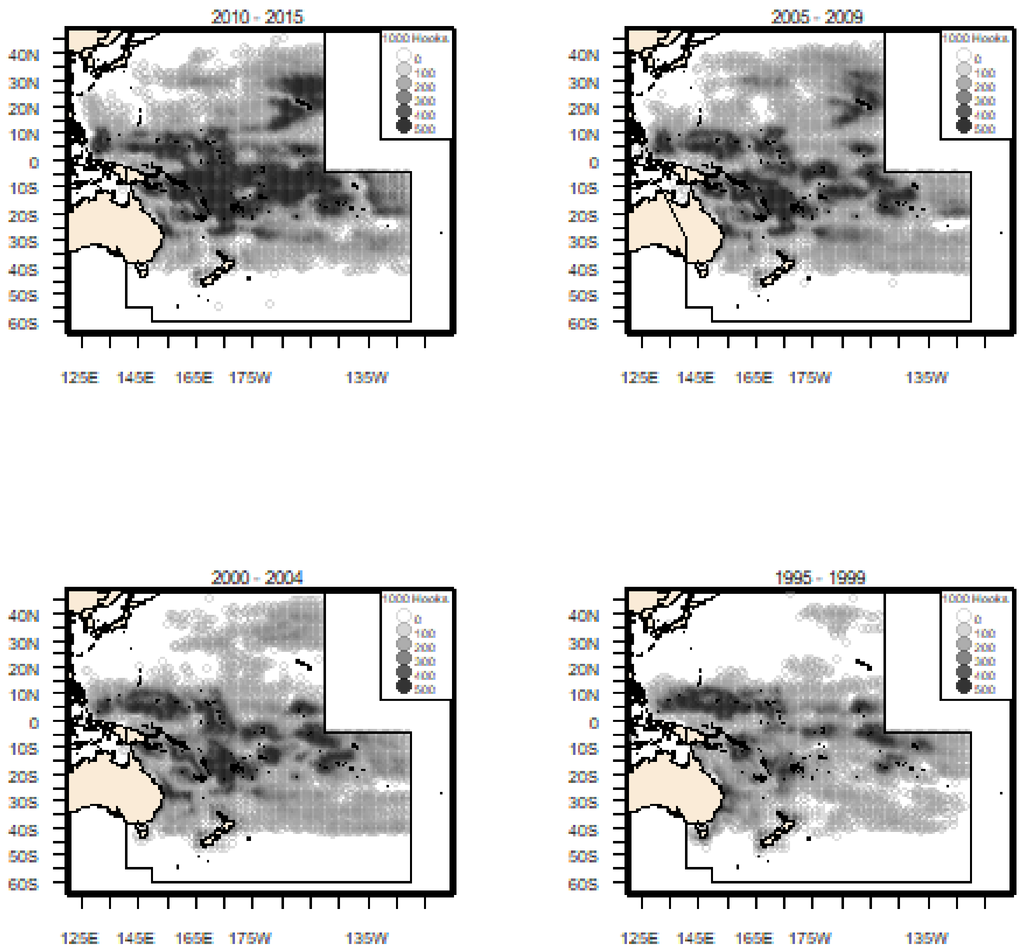

Figure 16. Reported longline (1000s' of hooks) effort by time block 1995, points indicate individual reported sets, darker areas indicate higher amounts of reported effort.

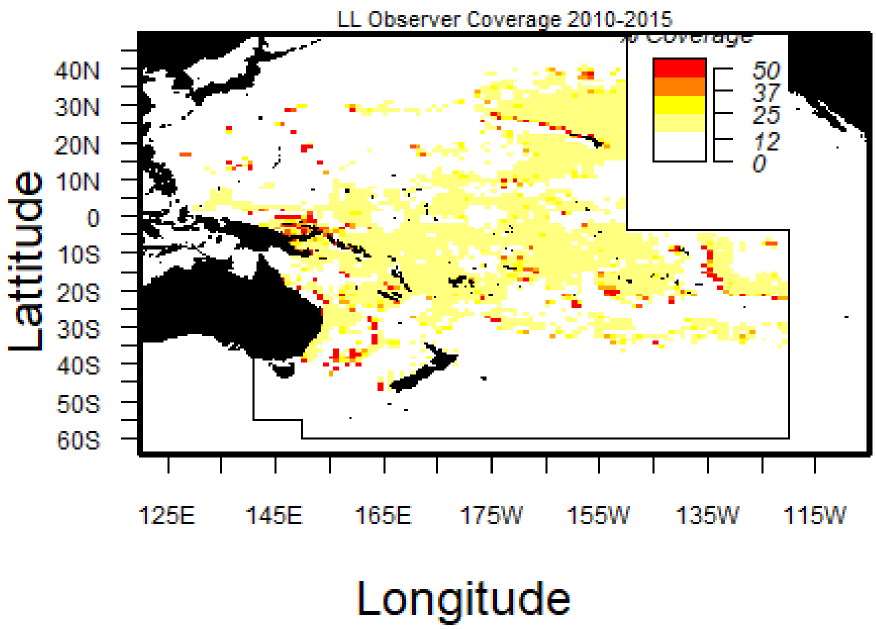

Figure 17. Longline observer coverage at the 1degree square spatial resolution, 2010-2015.

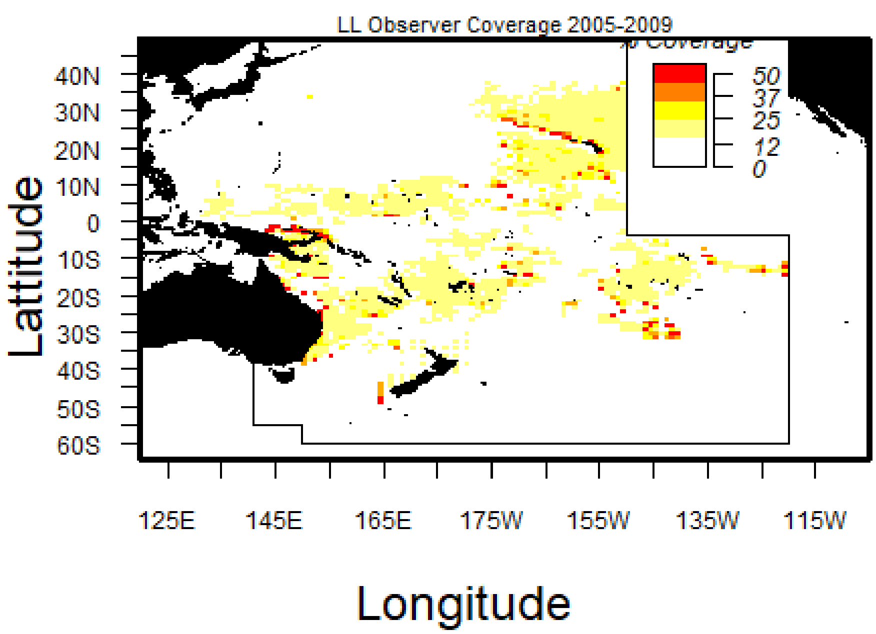

Figure 18. Longline observer coverage at the 1degree square spatial resolution, 2005-2009.

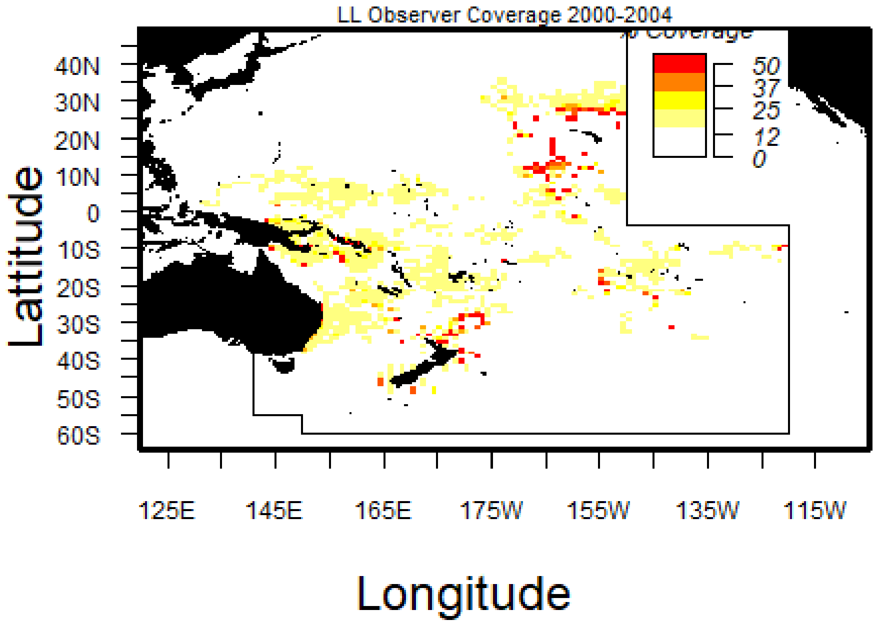

Figure 19. Longline observer coverage at the 1degree square spatial resolution, 2000-2004.

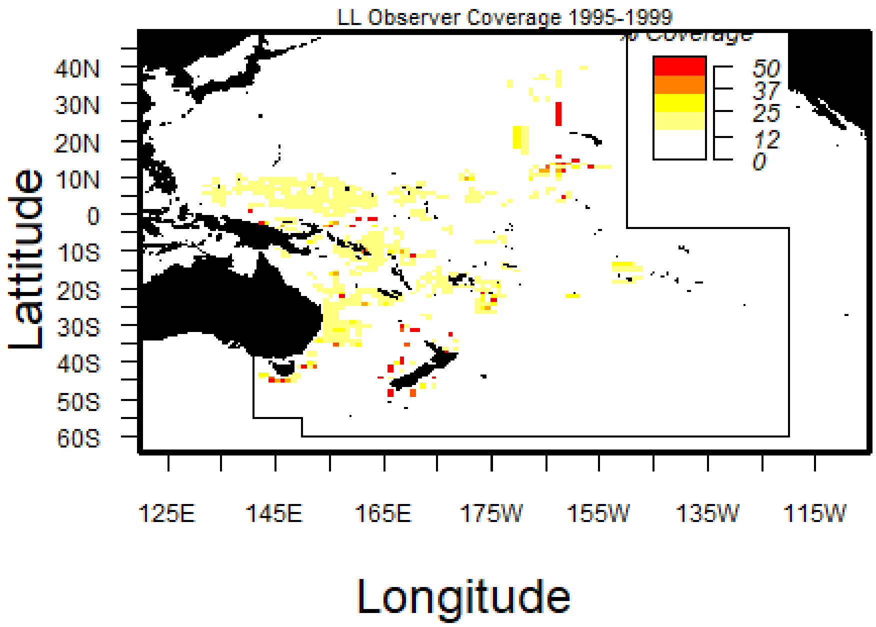

Figure 20. Longline observer coverage at the 1degree square spatial resolution, 1995-1999.

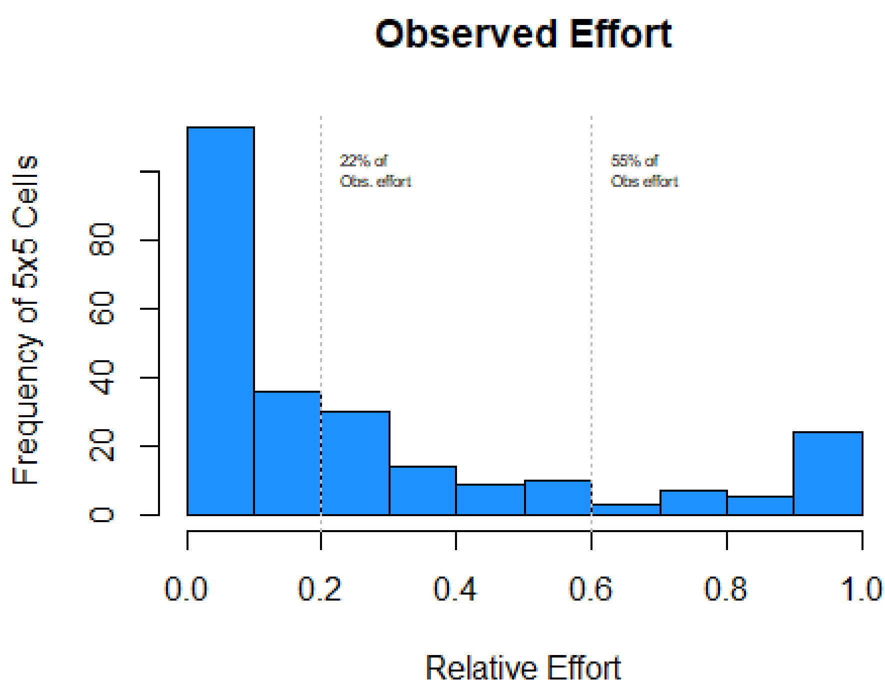

Figure 21. Frequency of total the relative frequency of the total logbook effort observed in the longline fishery

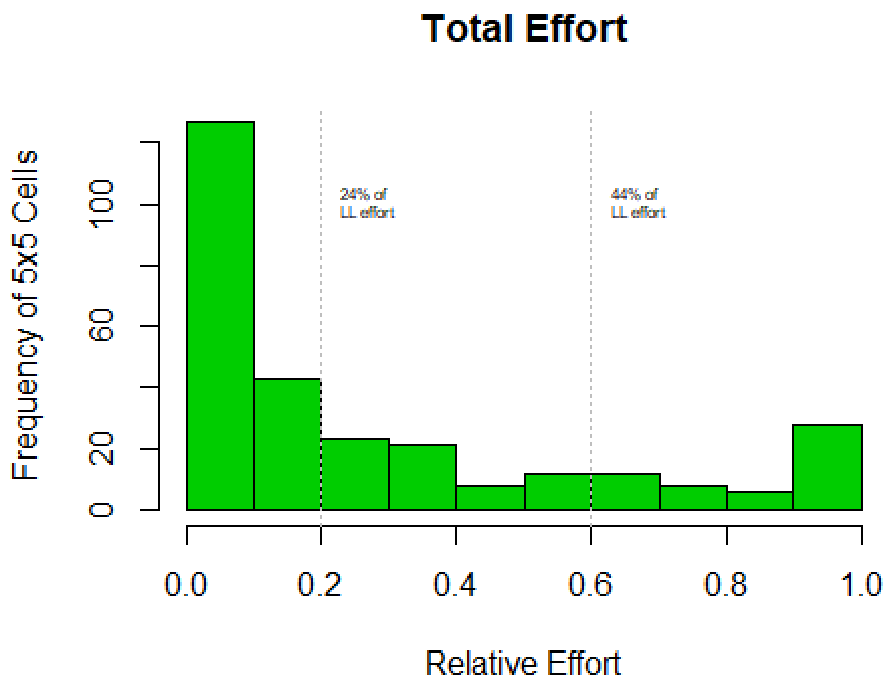

Figure 22 Frequency of total the relative frequency of the total logbook effort reported in the longline fishery.

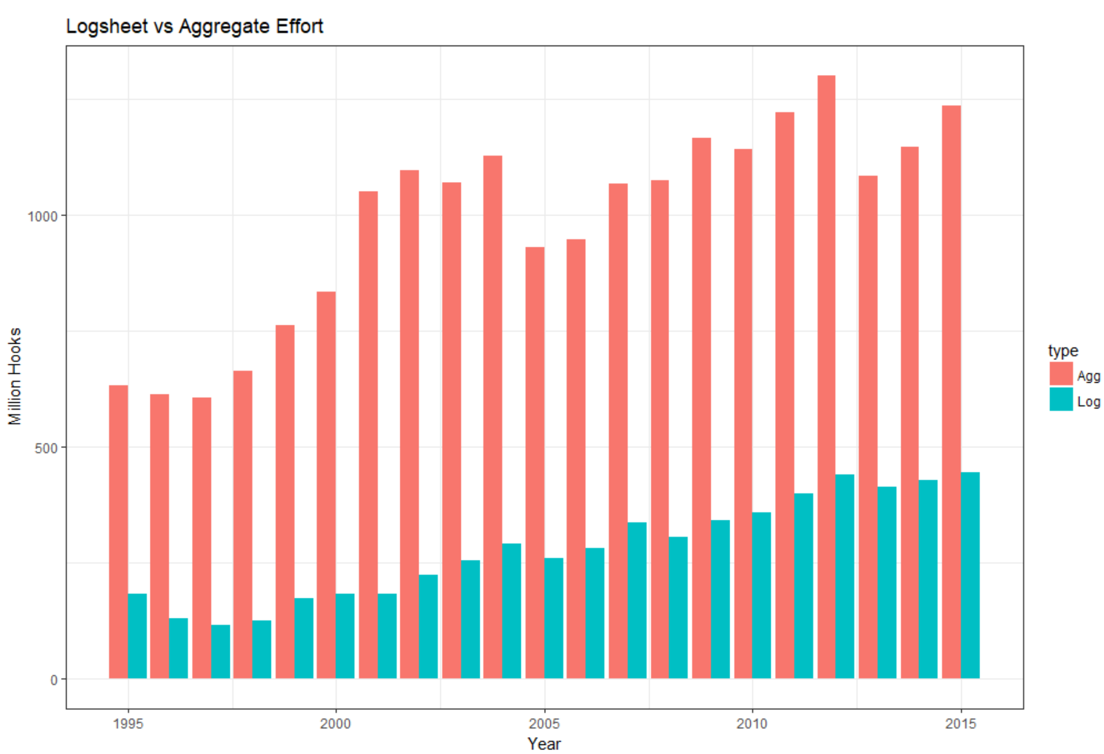

Figure 23. Comparison of logsheet vs aggregate effort for the longline fishery for all fleets operating in the WCPO 1990-2015.

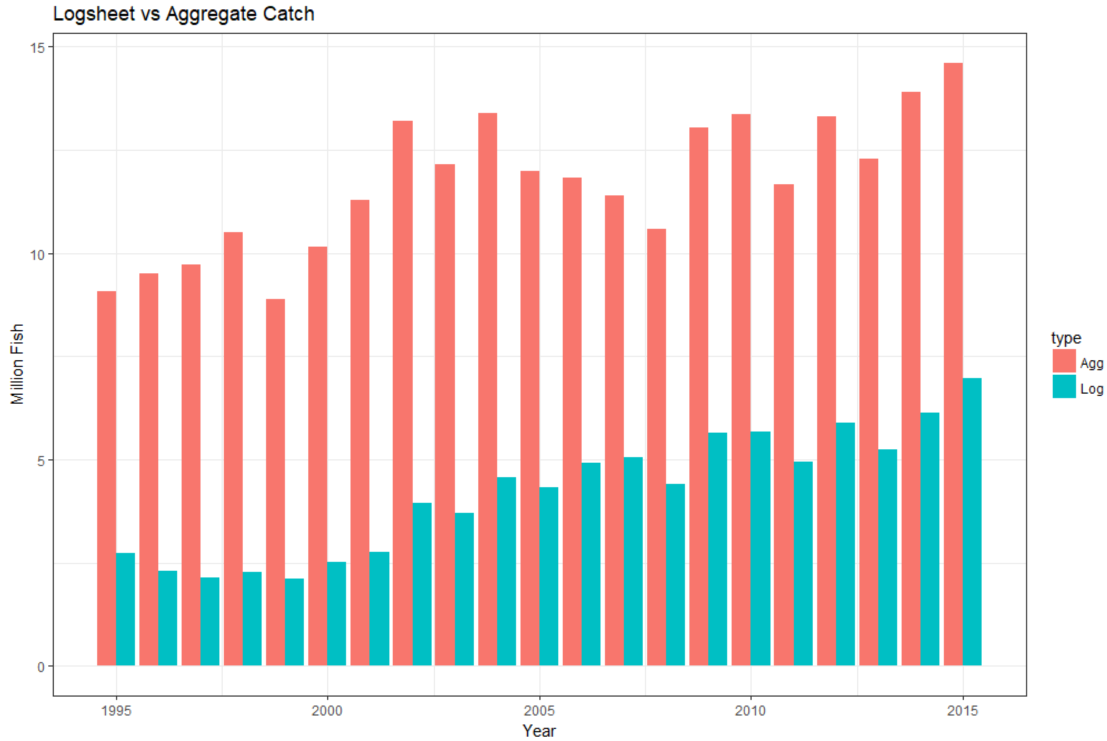

Figure 24. Comparison of logsheet vs aggregate catch of target species (YFT, BET, & ALB) for the longline fishery for all fleets operating in the WCPO 1990-2015.

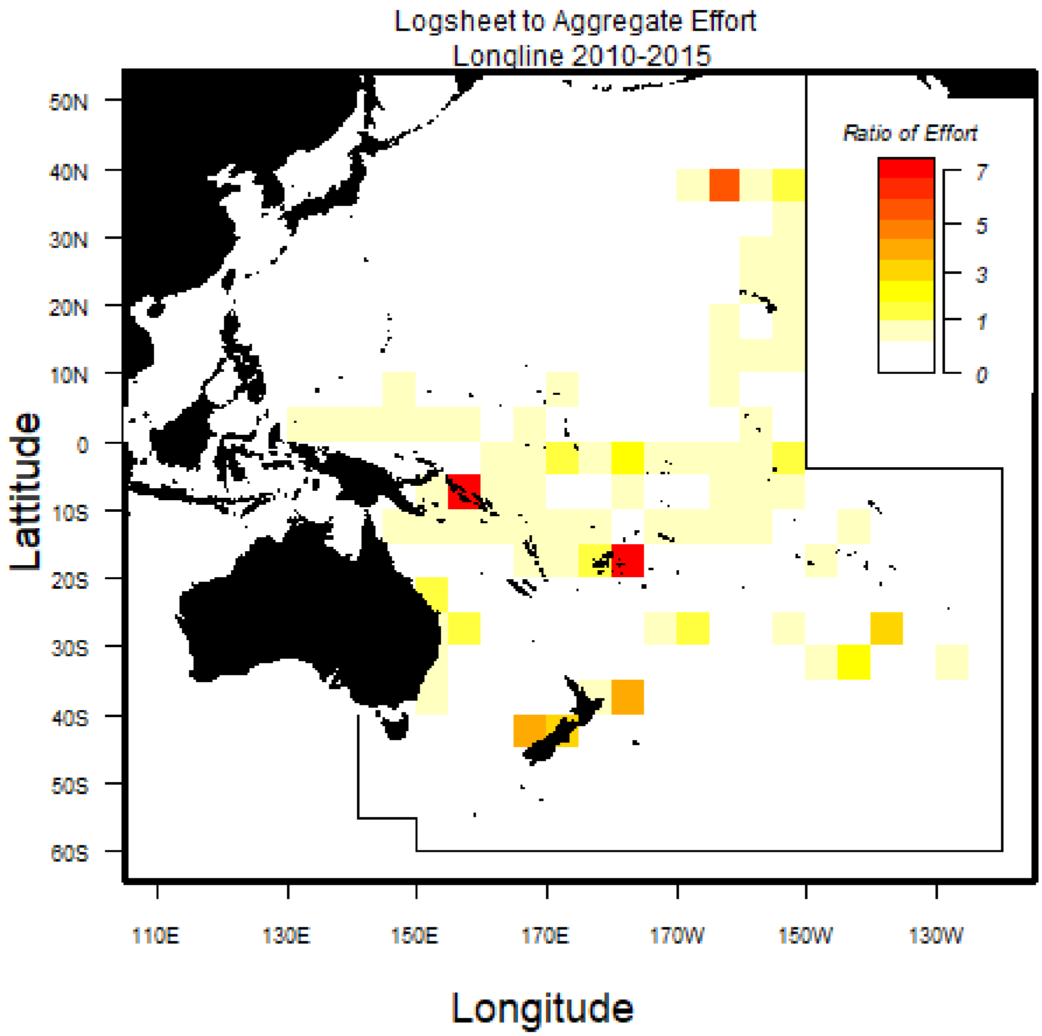

Figure 25. Comparison of logsheet vs aggregate effort for the longline fishery for all fleets operating in the WCPO 1990-2015.

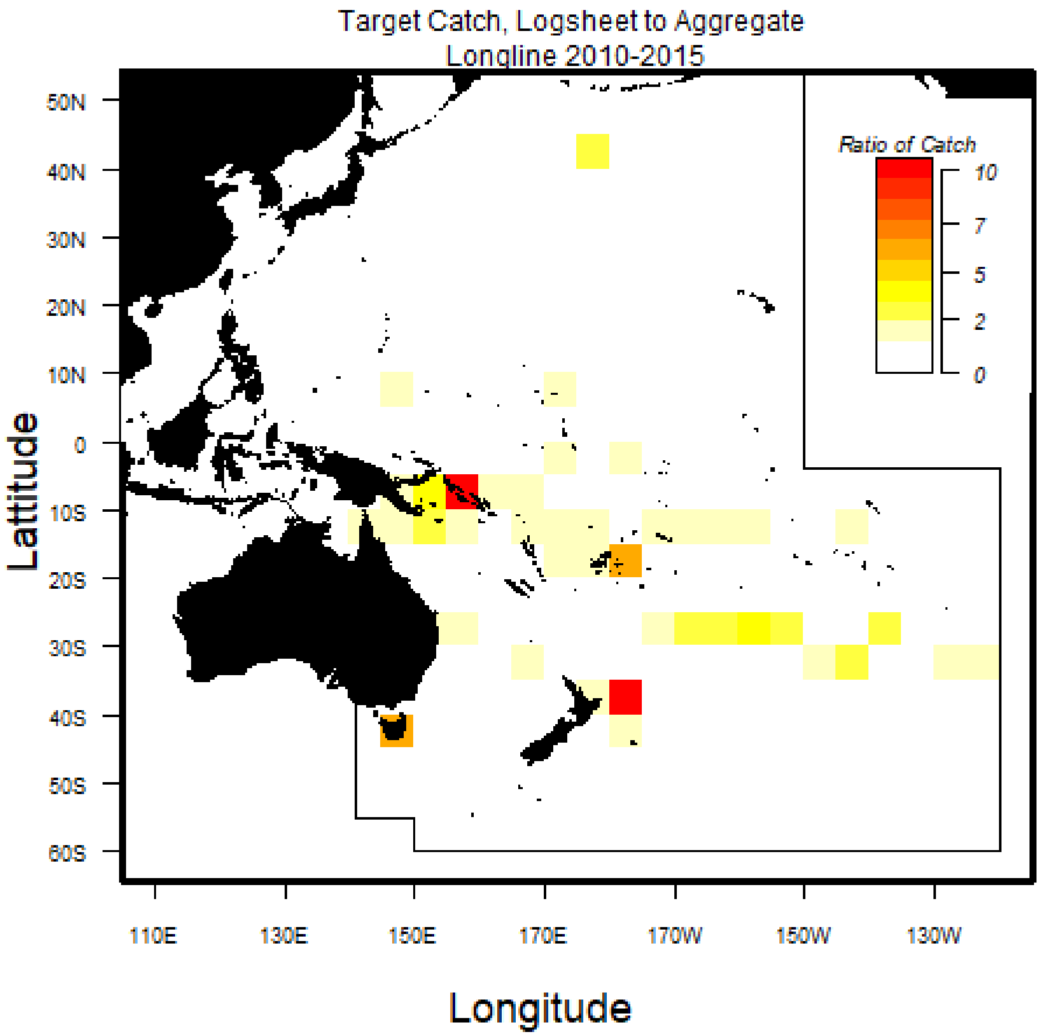

Figure 26. Comparison of logsheet vs aggregate catch of target species (YFT, BET, & ALB) by 5˚x5˚ cell for the longline fishery for all fleets operating in the WCPO 1990-2015.

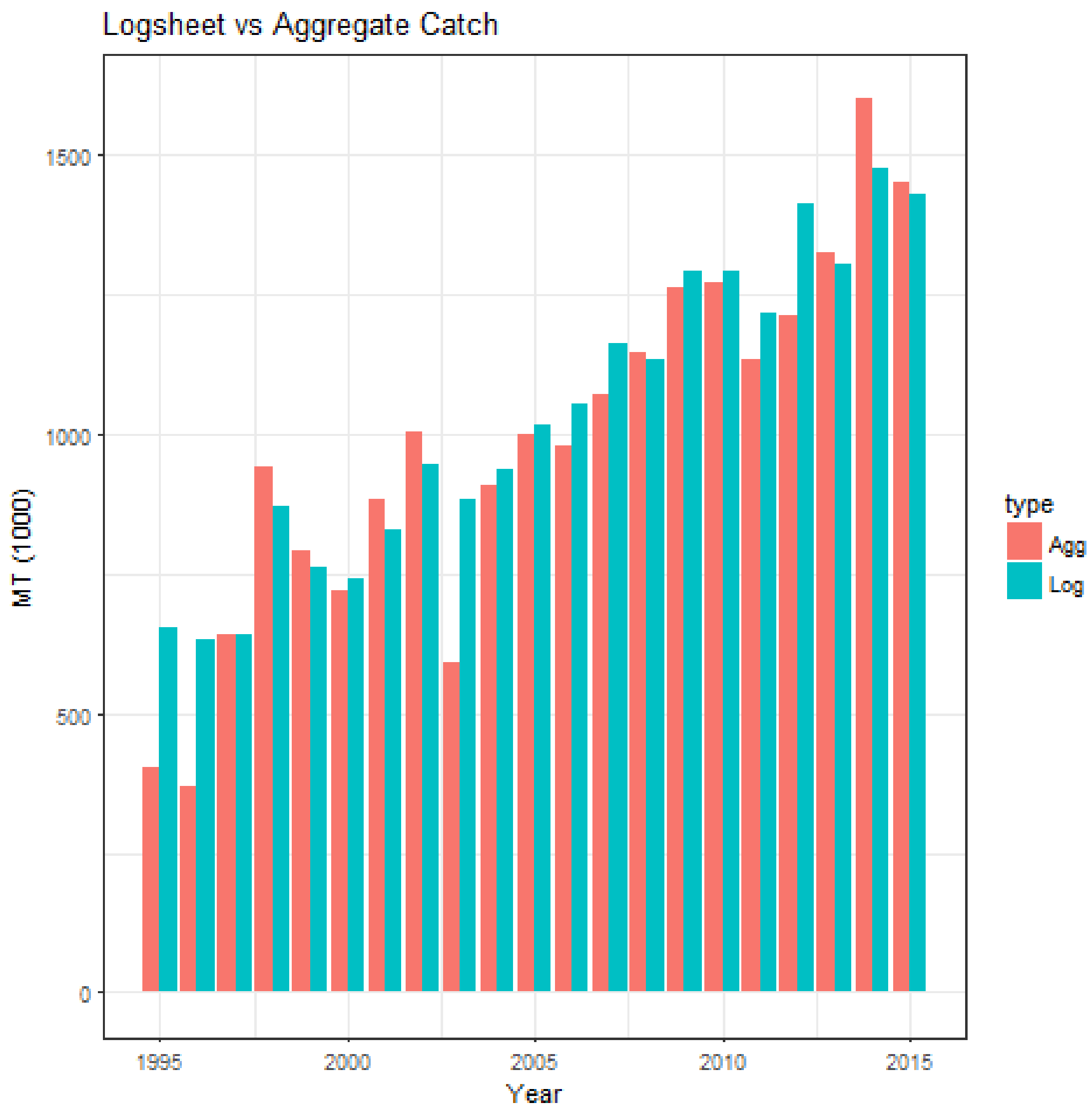

Figure 27. Comparison of reported and aggregate target catch (YFT, SKJ & BET), purse seine vessels opperating in the WCPO region.

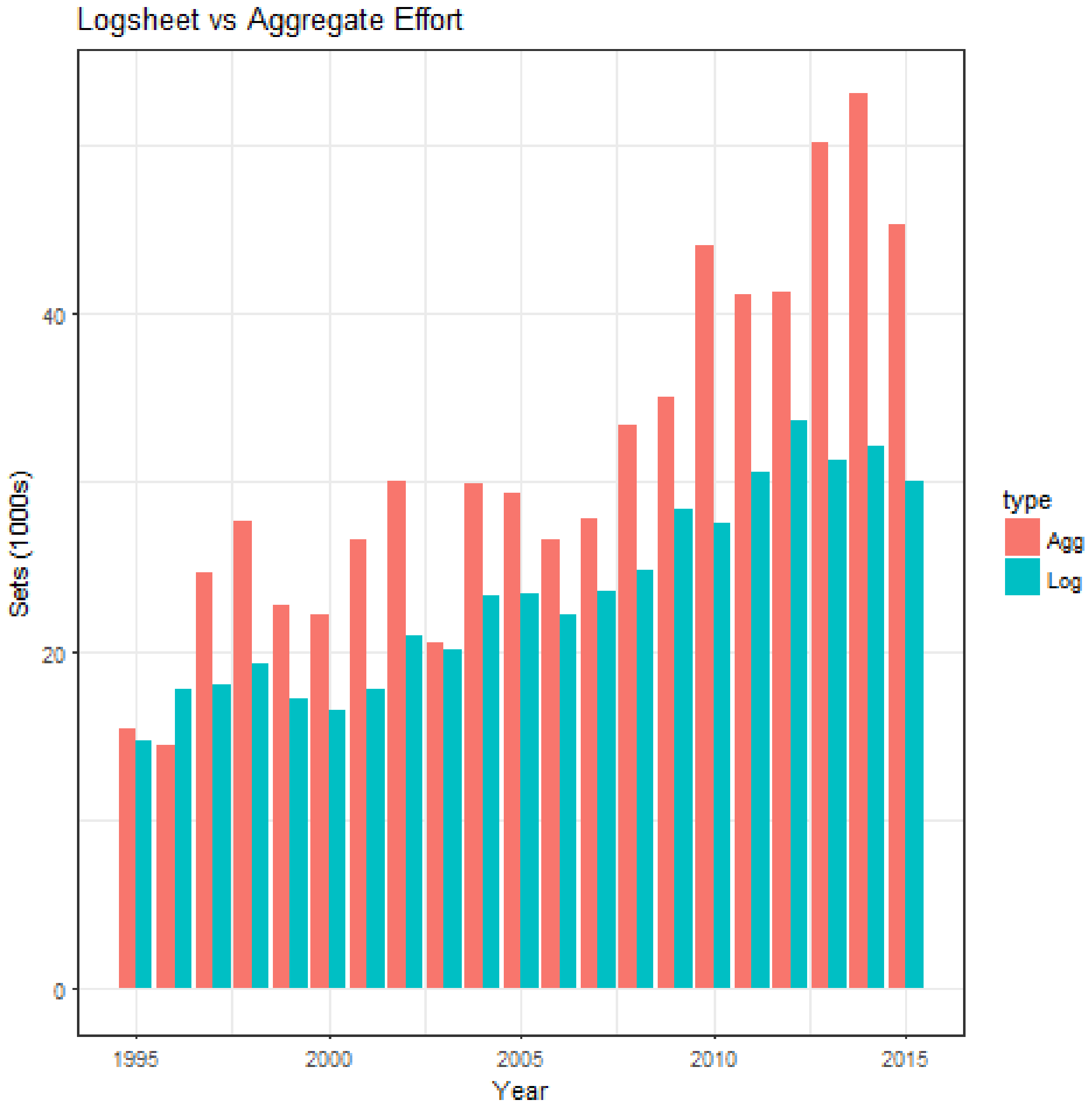

Figure 28. Comparison of reported and aggregate effort (100s of sets), purse seine vessels operating in the WCPO region.

Target Catch - Logbook vs Aggregate_5x5 :

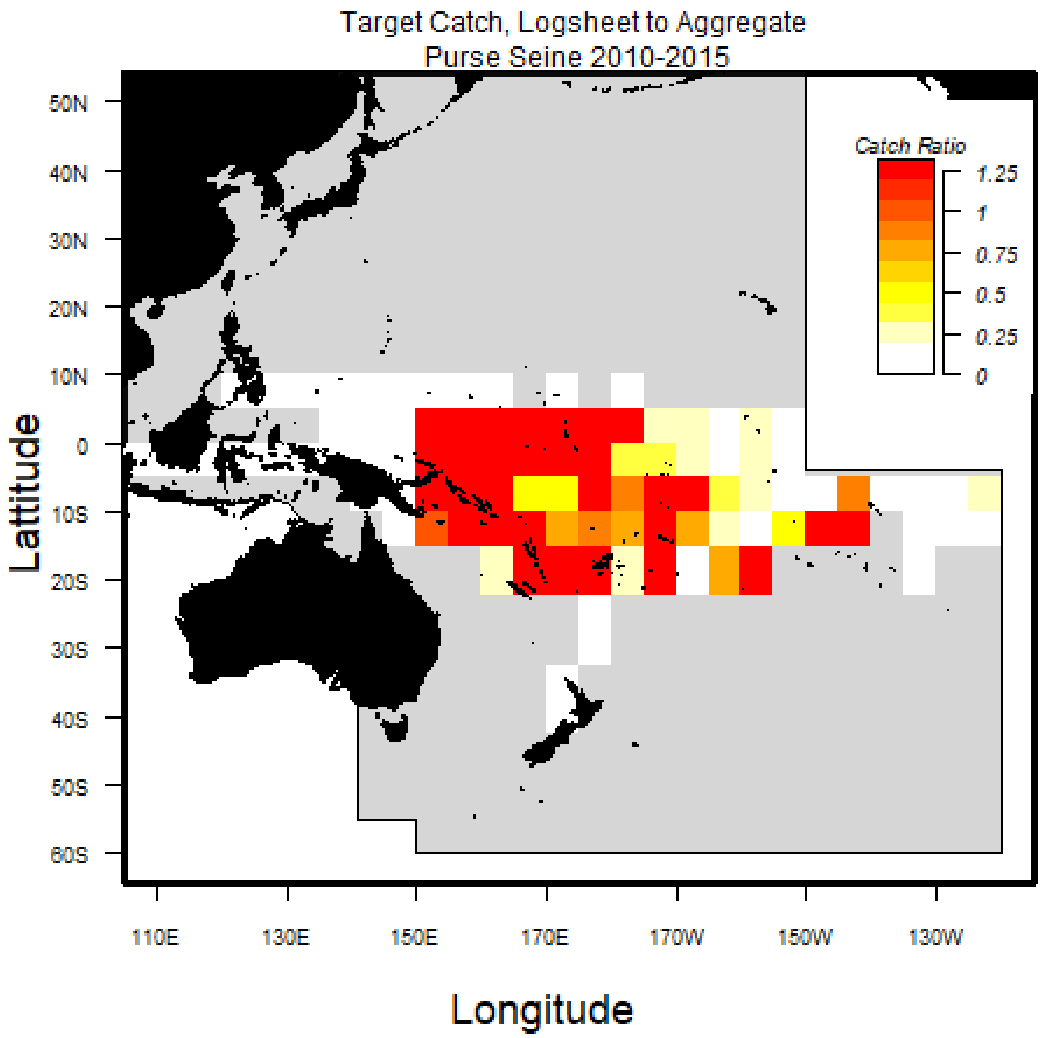

Figure 29. Comparison of reported and aggregate target catch (YFT, SKJ & BET), by 5 degree cell for vessels in the purse seine fishery 2010-2015.

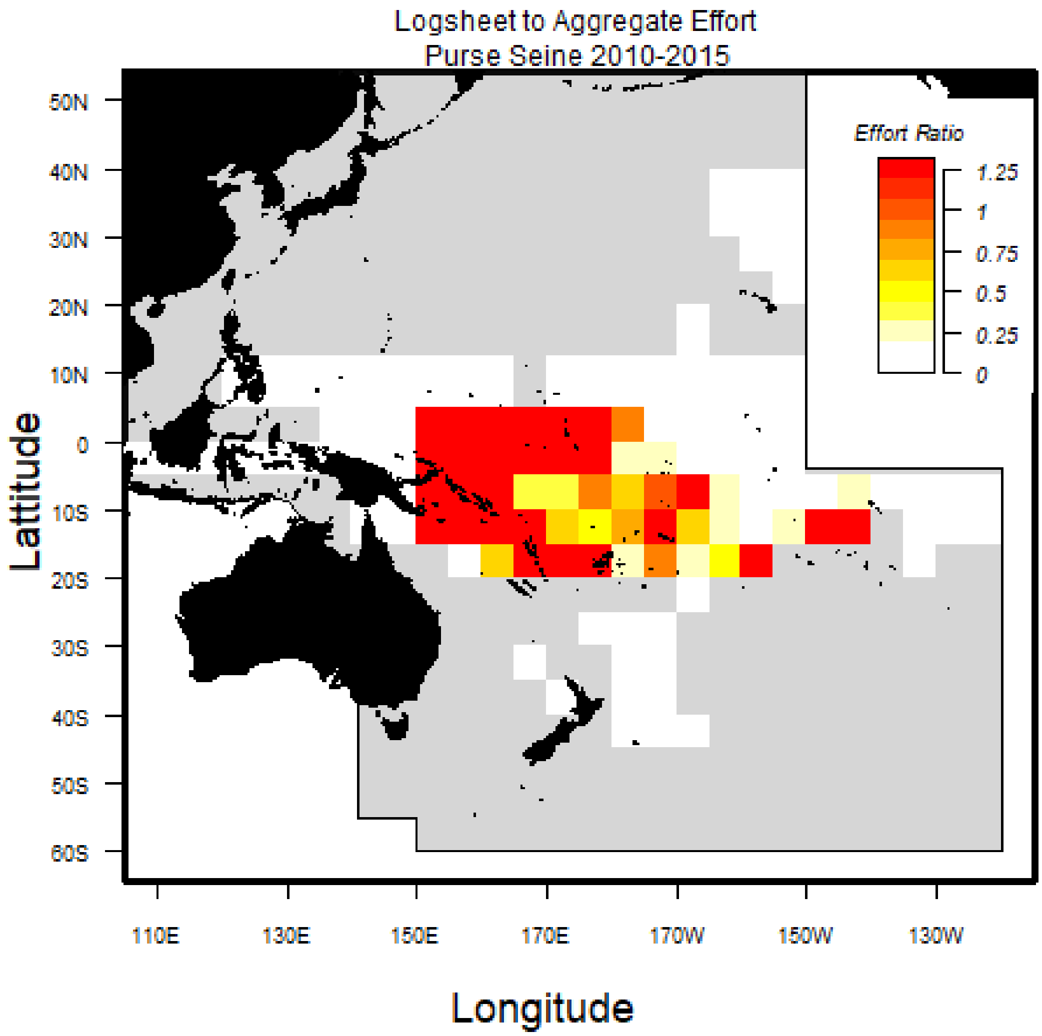

Figure 30. Comparison of reported and aggregate effort, by 5 degree cell for vessels in the purse seine fishery 2010-2015.

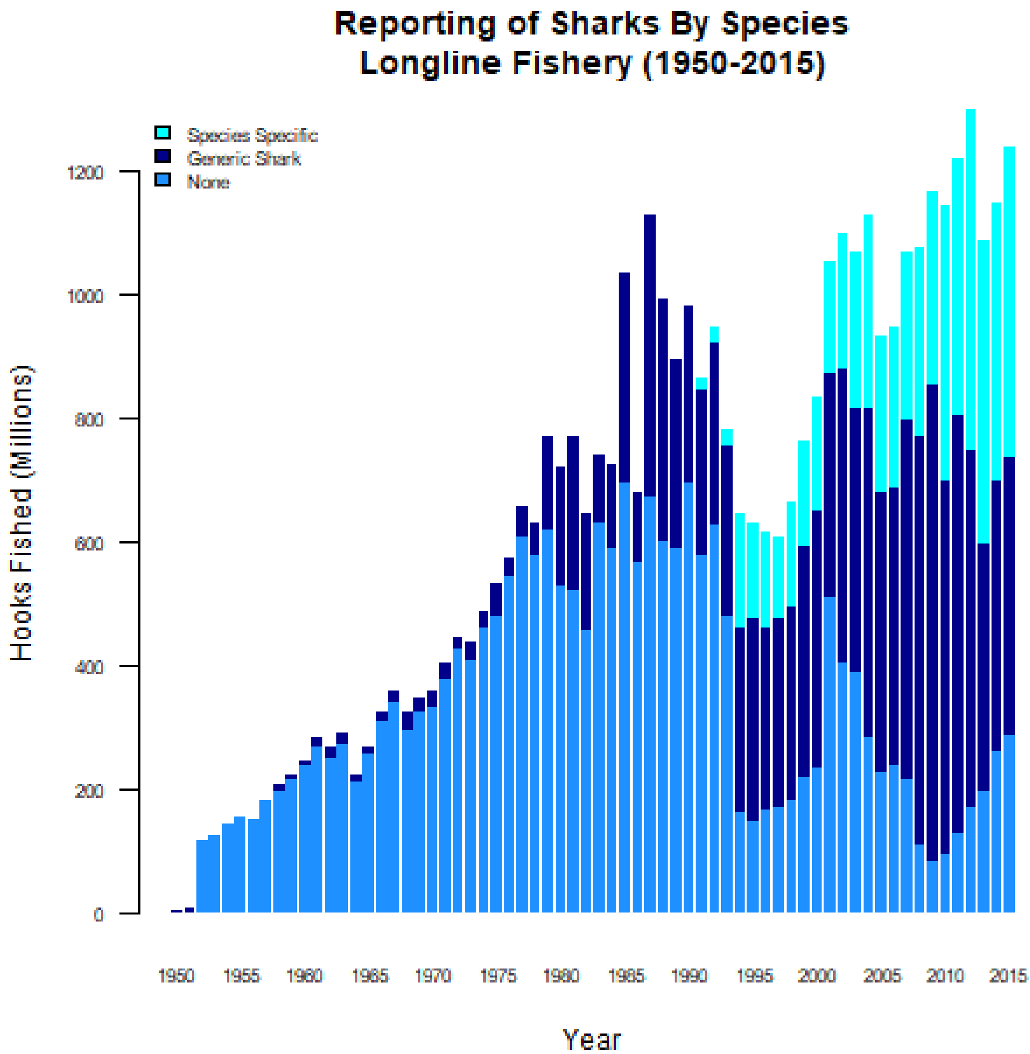

Figure 31. Reporting of sharks; by species, generically, or not at all. Longline vessels operating in the WCPO region 1950-2015.

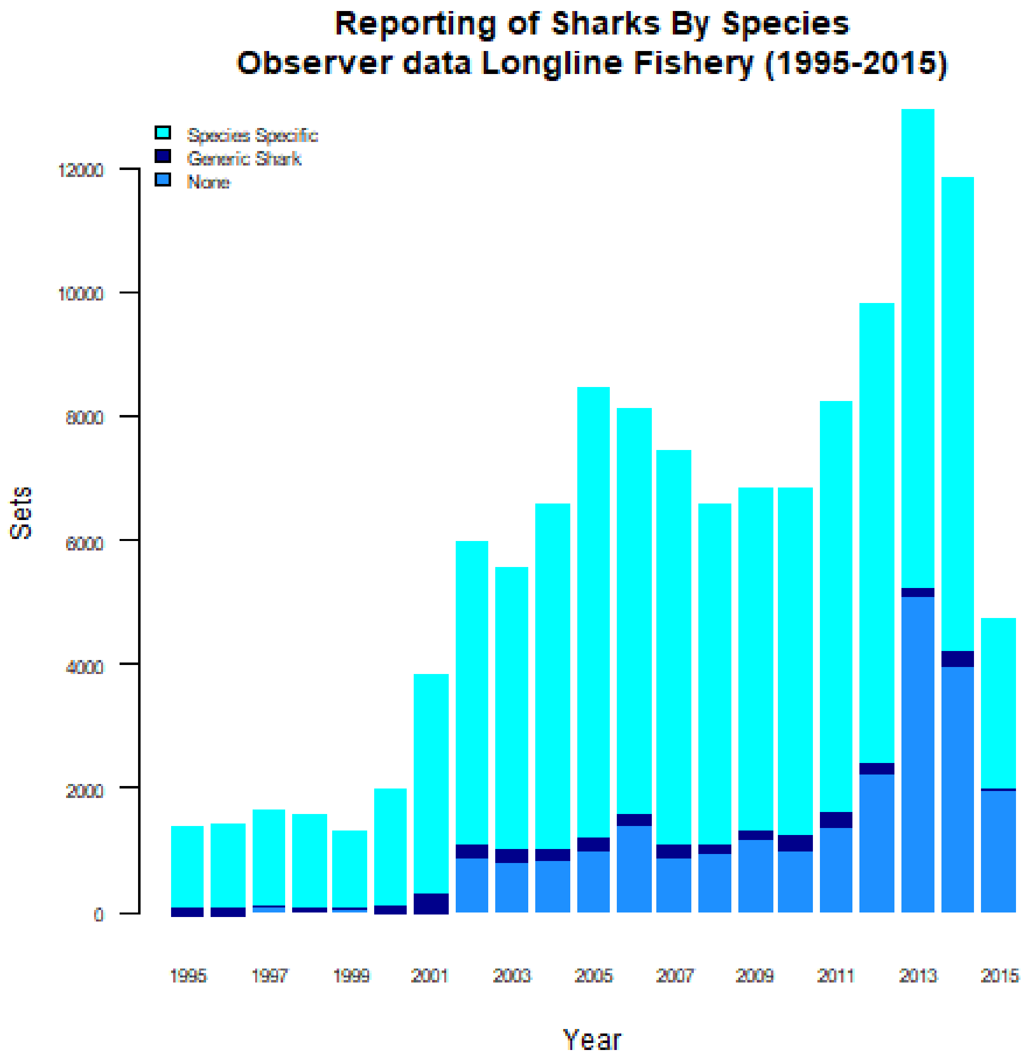

Figure 32. Recording of sharks based on observer data; by species, generically, or not at all. Longline vessels operating in the WCPO region 1995 - 2015.

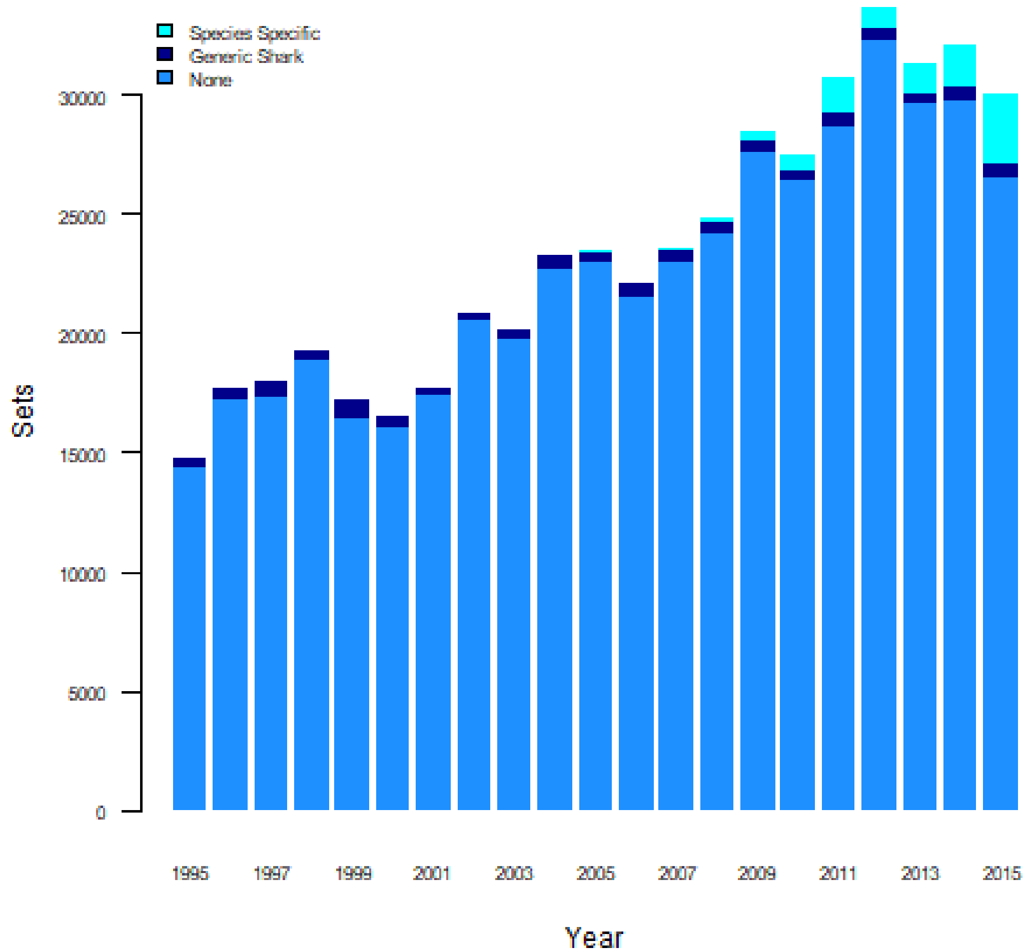

Figure 33. Reporting of sharks by species, generically or non-reporting from logbook data in the purse seine fishery, 1995-2015.

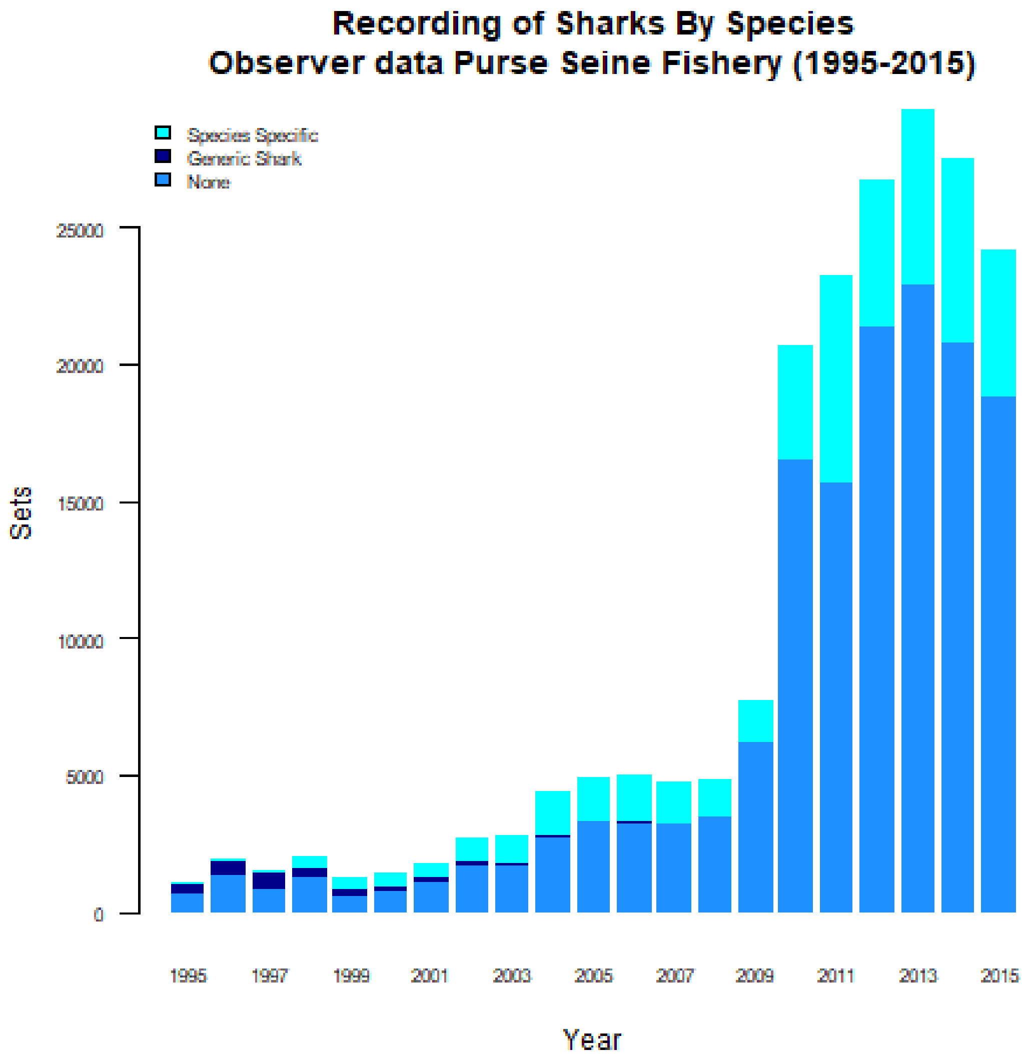

Figure 34. Recording of sharks by species, generically or non-reporting from observer data in the purse seine fishery, 1995-2015.

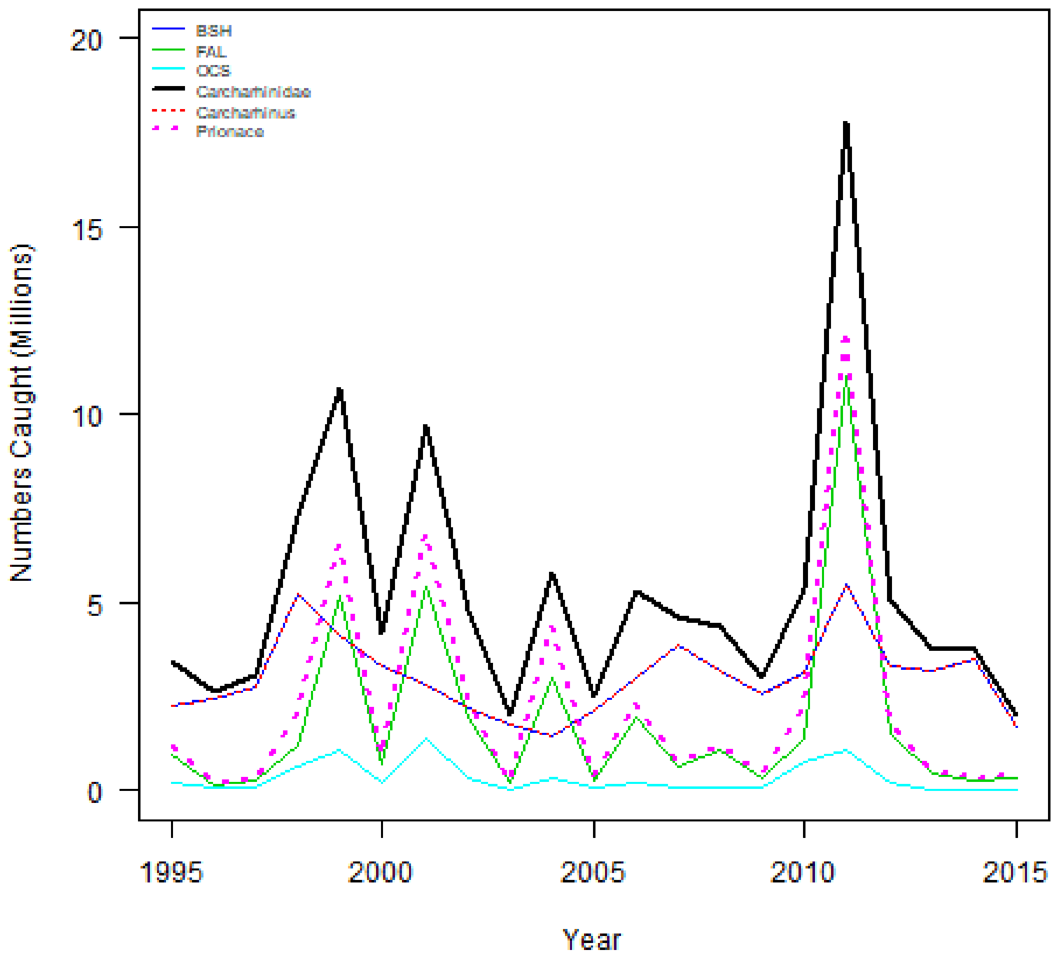

Figure 35. Catch by Family Genus and Species- longline fishery, Carcharinidae family.

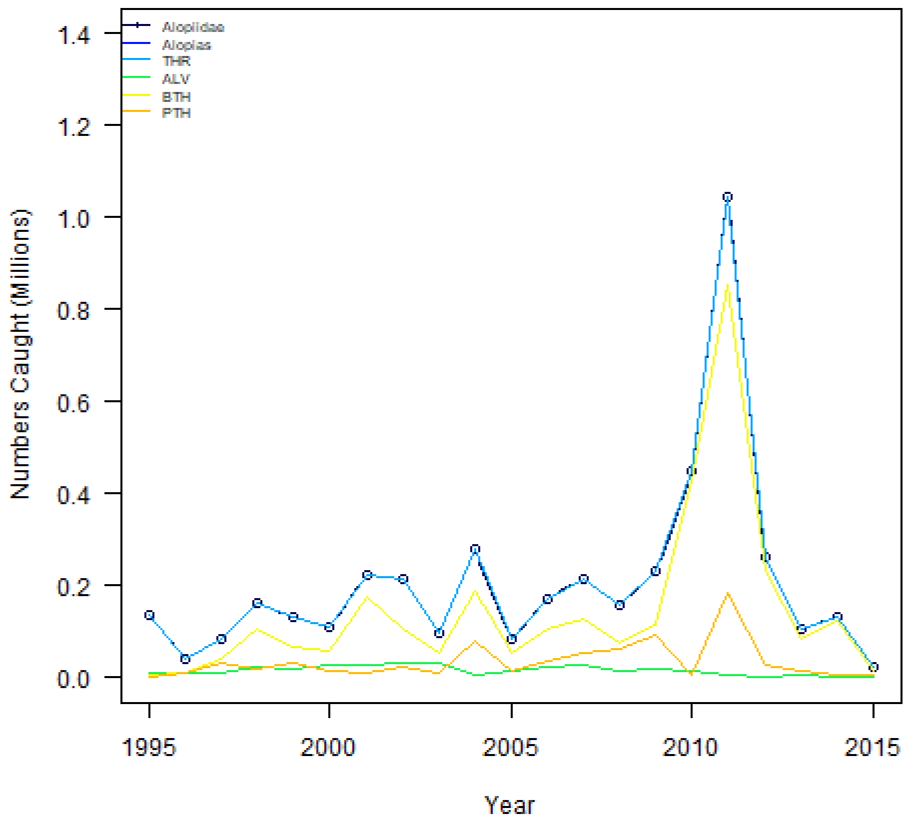

Figure 36 Estimates of catch by Family Genus and Species- longline fishery, Alopiidae family.

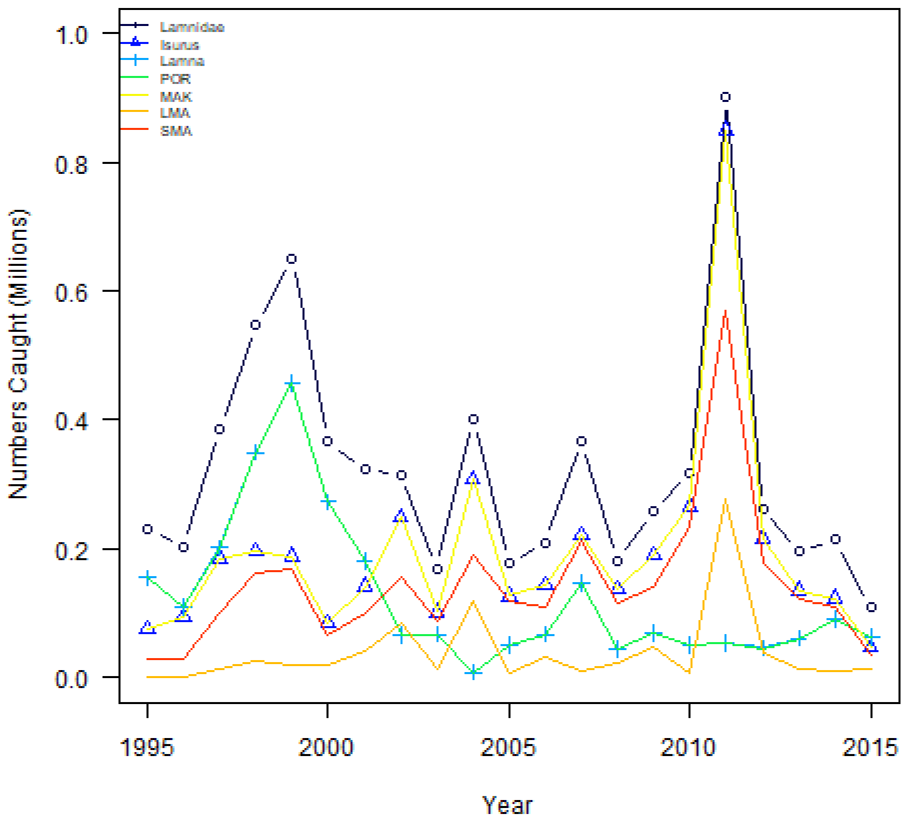

Figure 37. Estimated catch by family, genus and species, Lamnidae family, longline fishery.

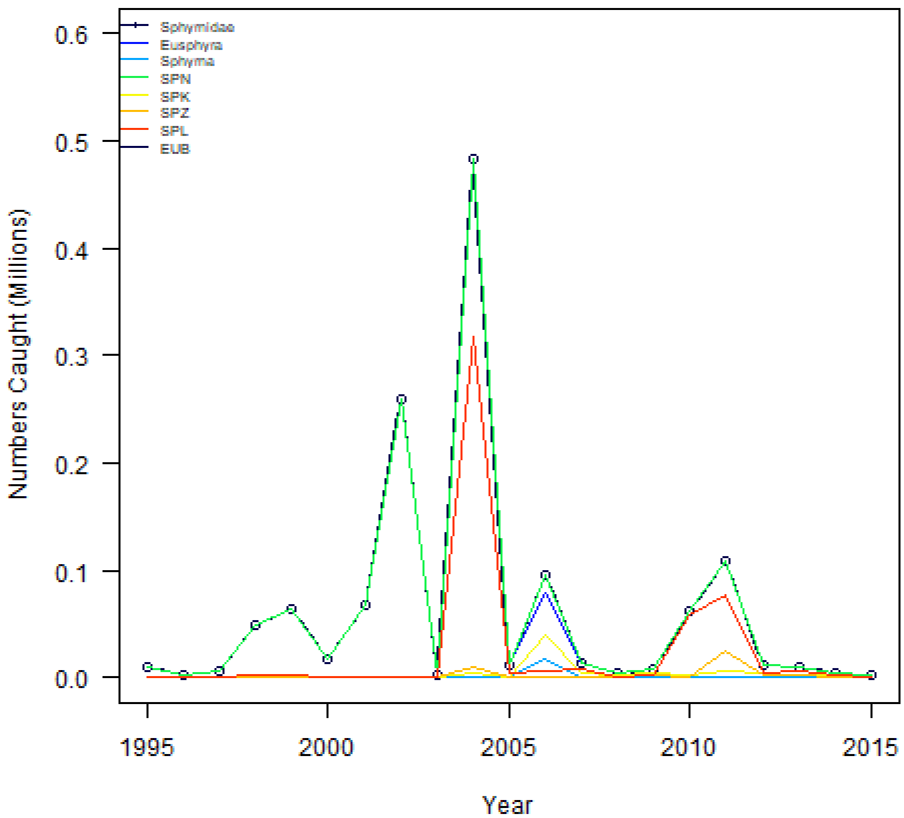

Figure 38. Estimated catch by family genus and species, Sphyrnidae family, longline fishery.

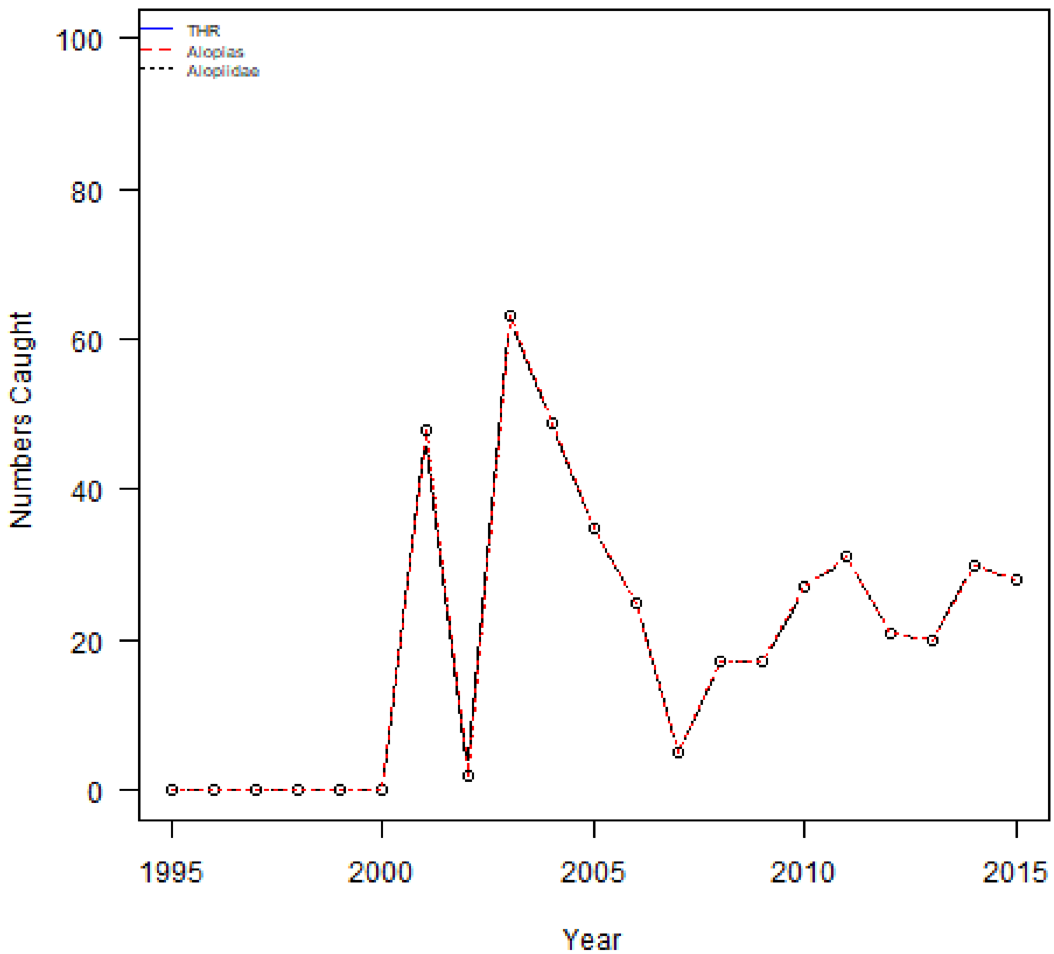

Figure 39. Estimated catch by family genus and species, Alopiidae family, purse seine fishery

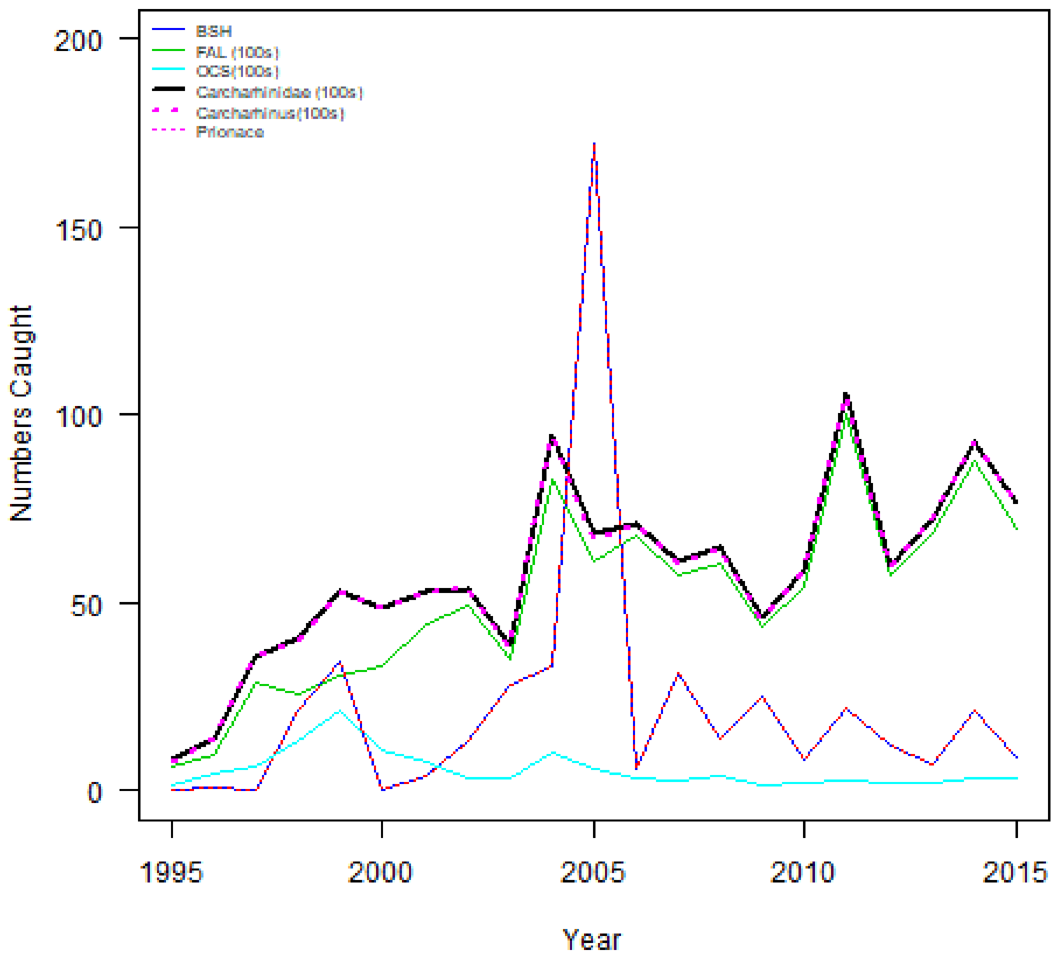

Figure 40. Estimated catch by family genus and species, Carcharinidae family, purse seine fishery

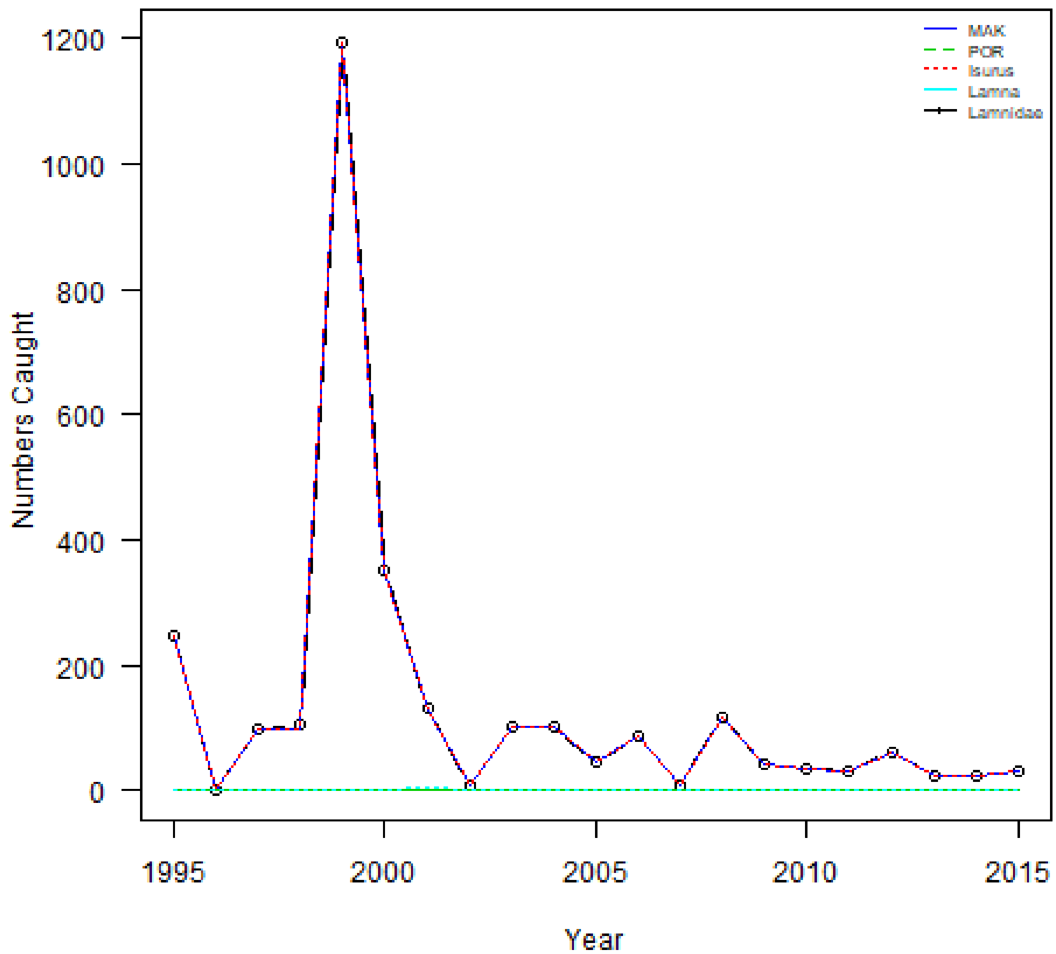

Figure 41. Estimated catch by family genus and species, Lamnidae family, purse seine fishery

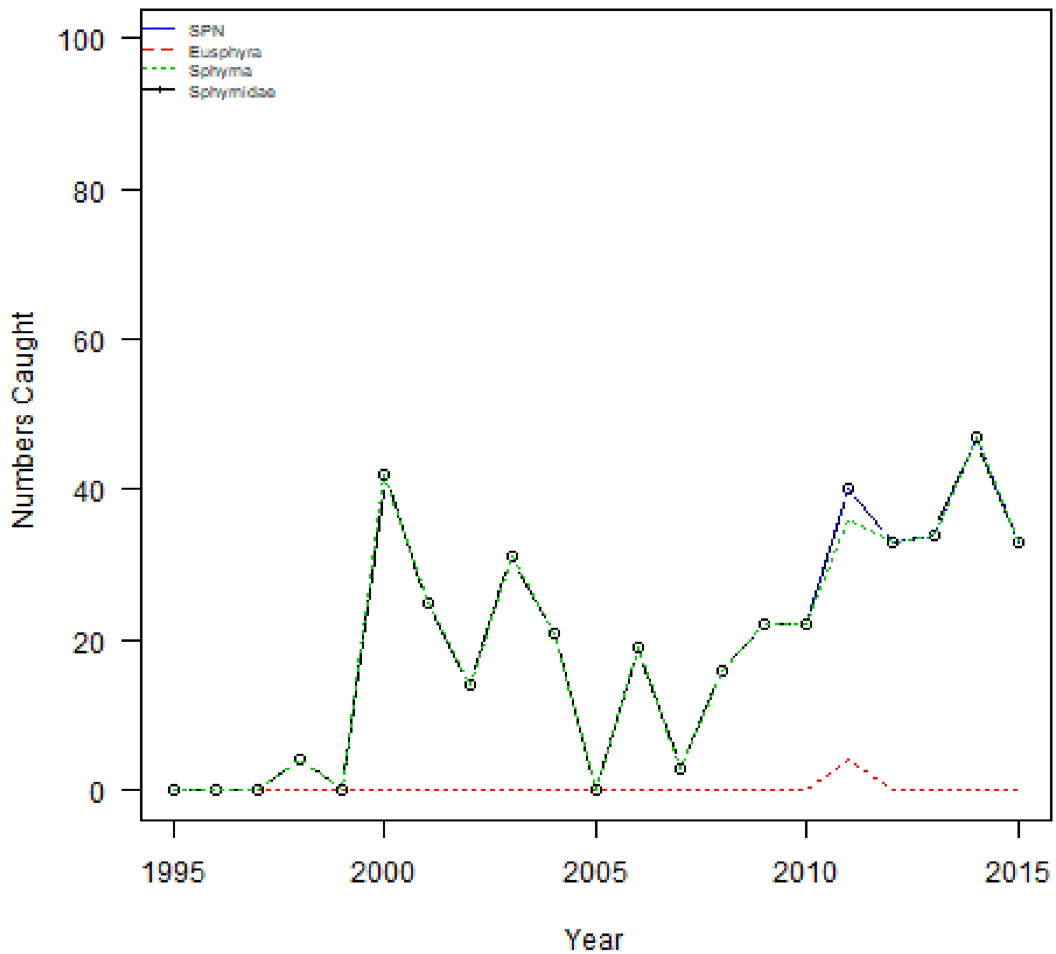

Figure 42. Estimated catch by family genus and species, Sphyrnidae family, purse seine fishery

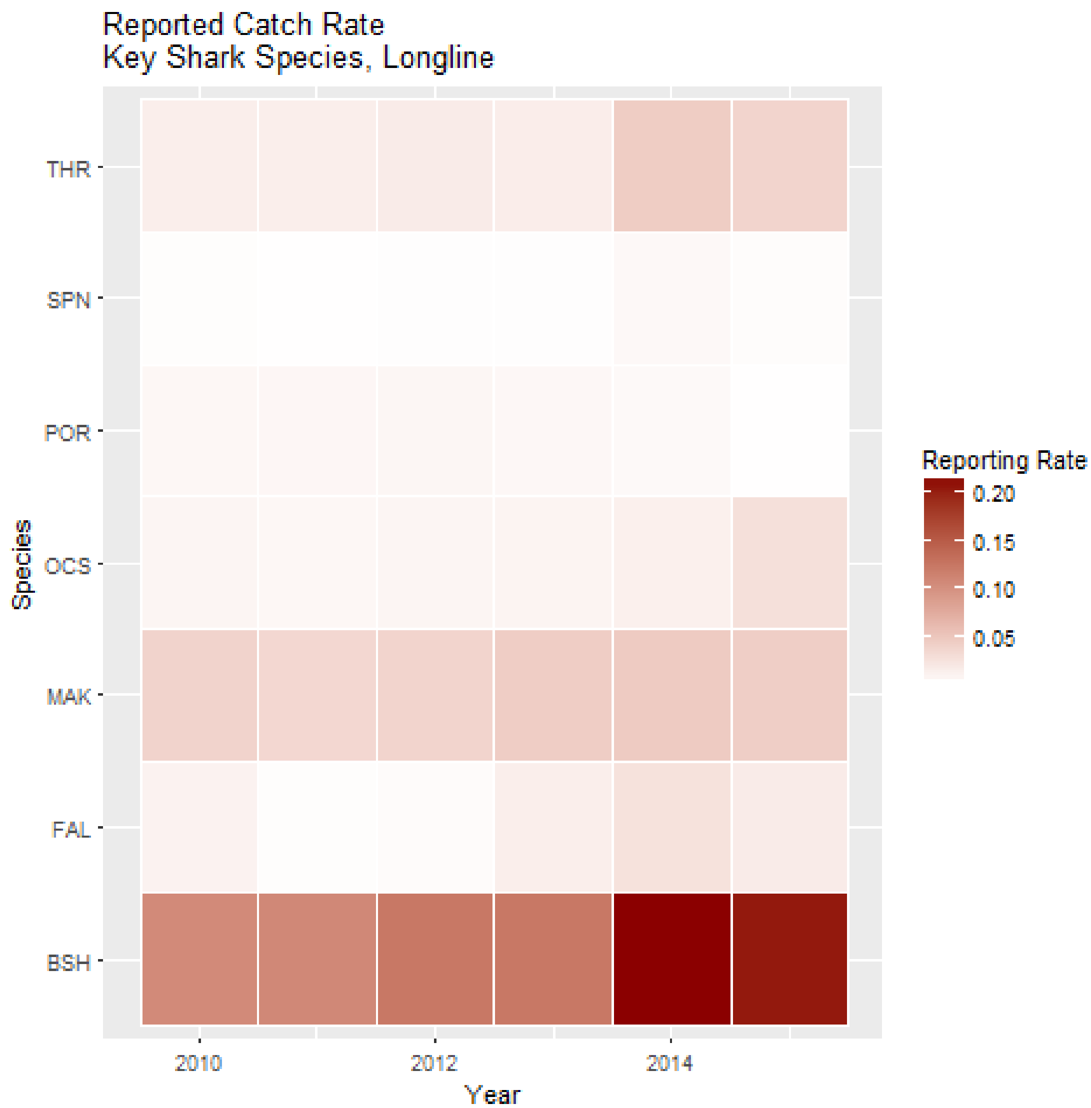

Figure 43. Reported Catch Rate of Key Shark Species by Year, longline vessels.

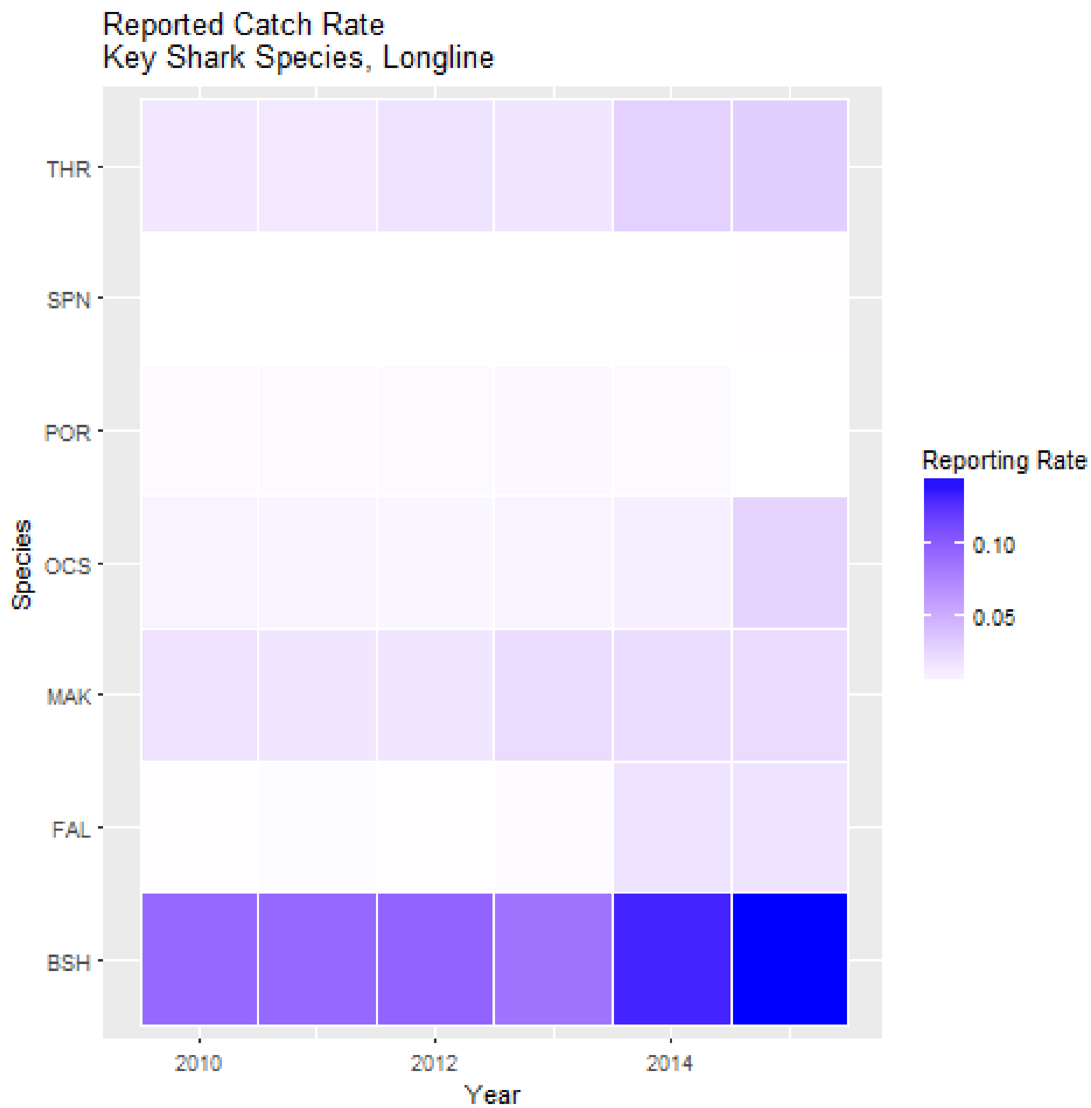

Figure 44 Reported Discard Rate of Key Shark Species by Year

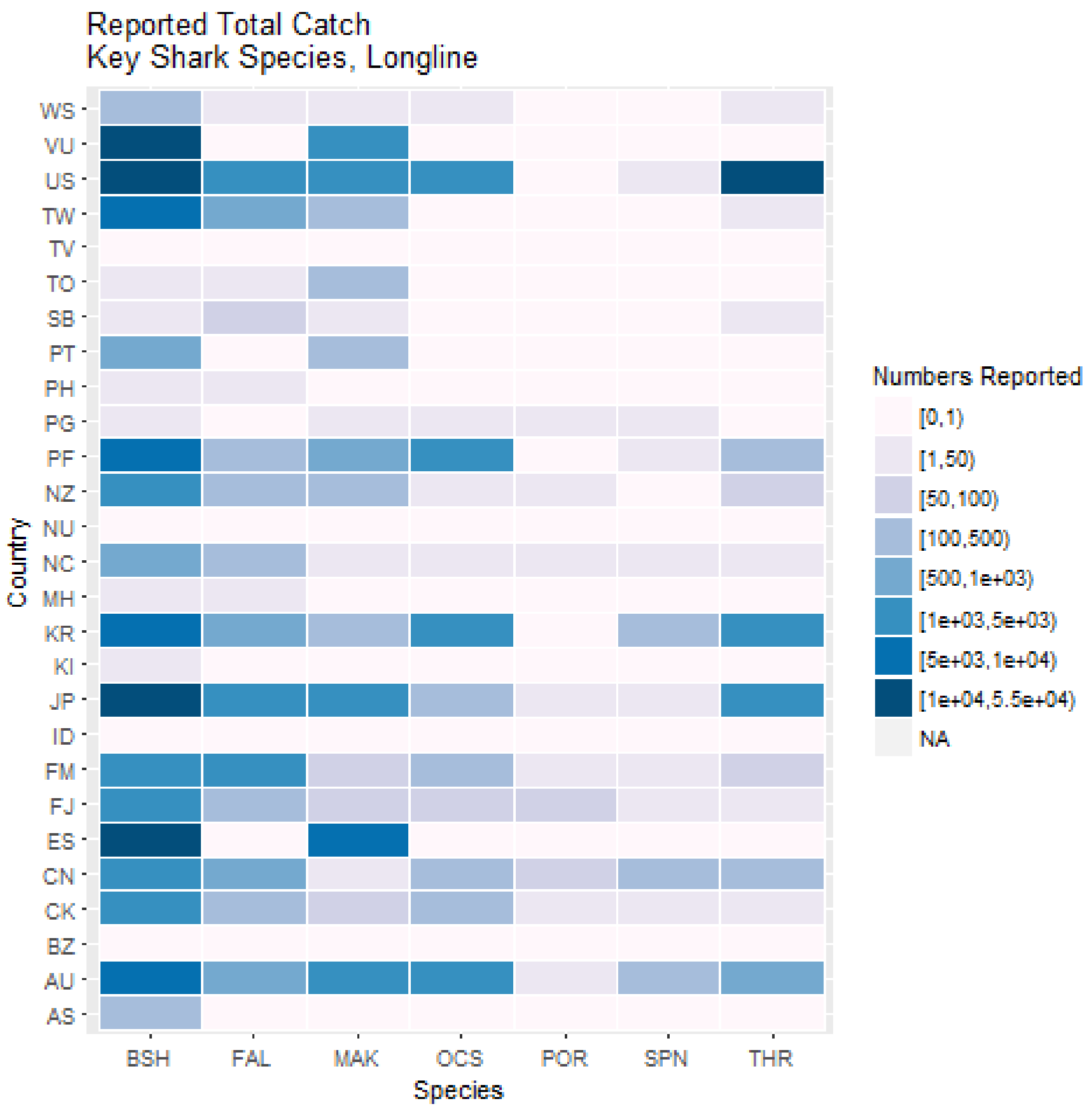

Figure 45. Reported Total Catch of Key Shark Species By Year

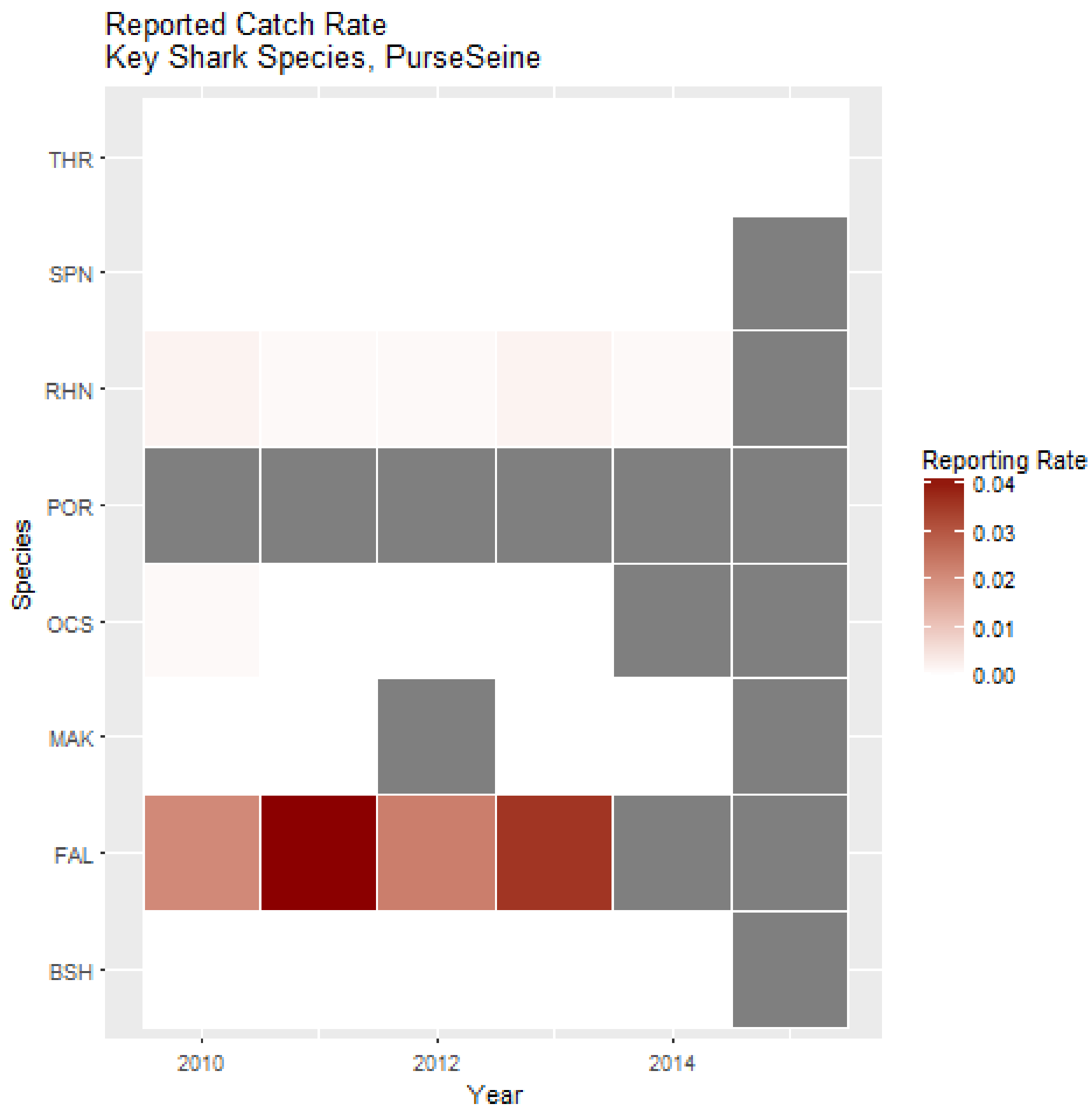

Figure 46. Reported Catch Rate of Key Shark Species by Year, purse seine vessels

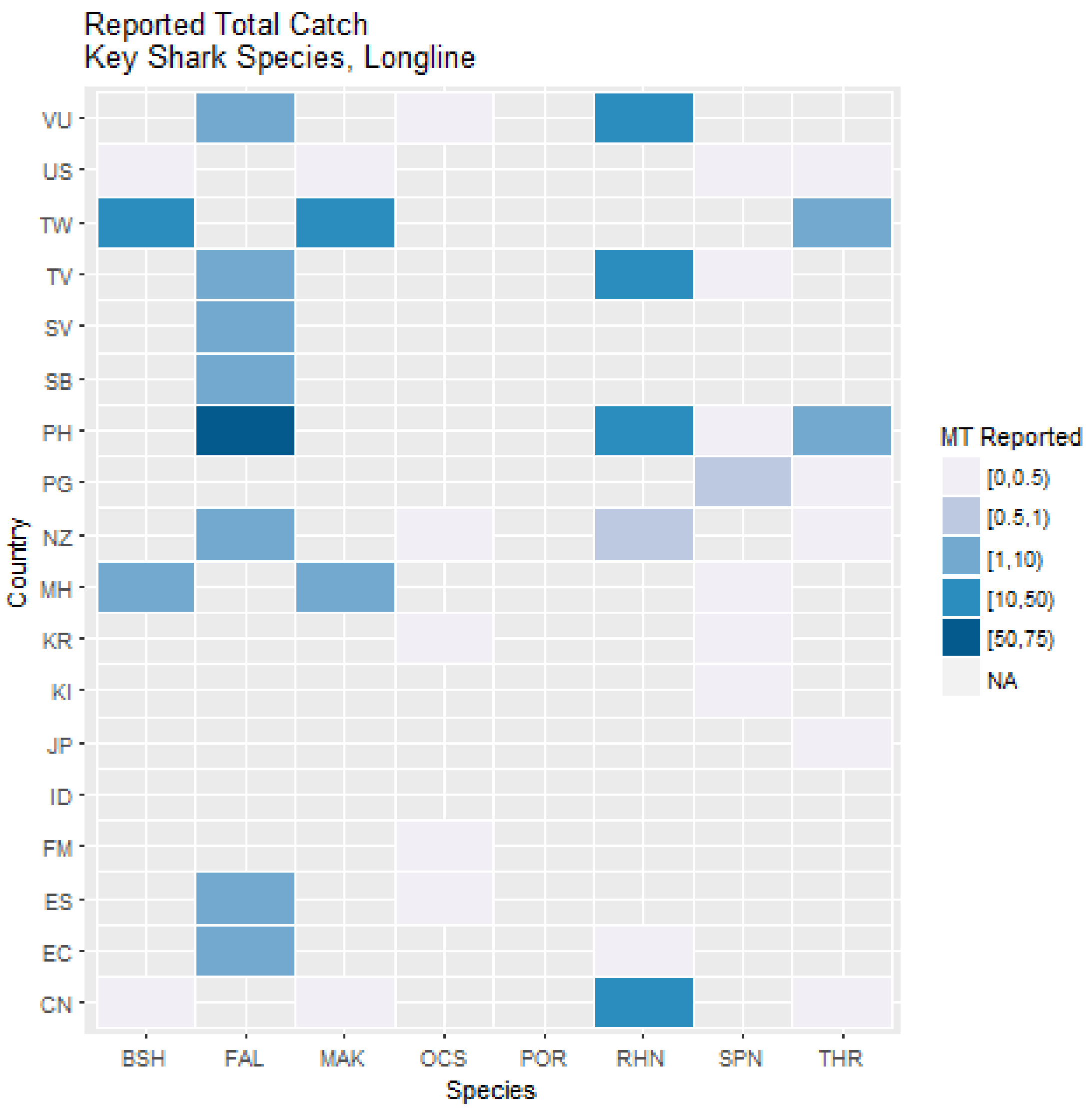

Figure 47. Reported total catch (retained + discarded) for the period 2010-2015 , longline vessels

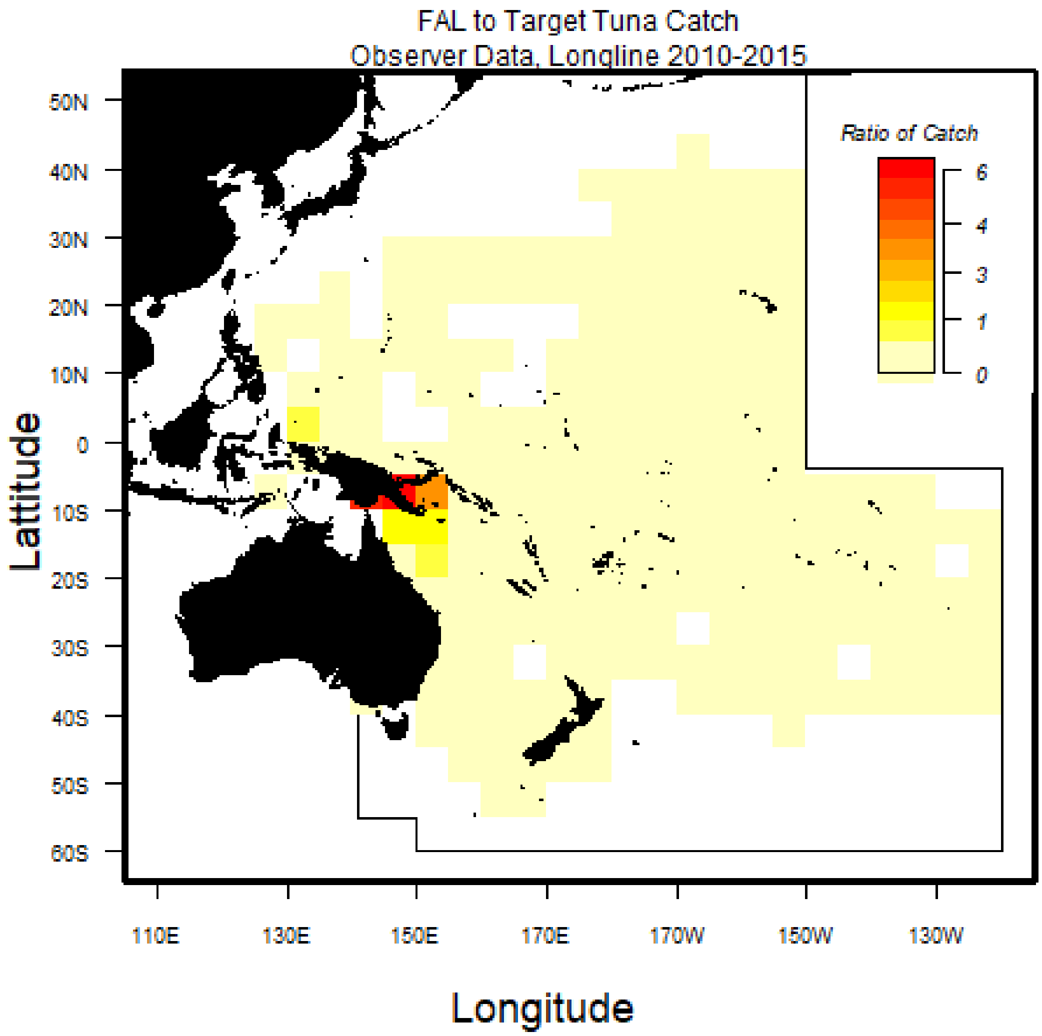

Figure 48. Maps of FAL to target tuna catch, longline vessels 2010-2015 (in units of 50,000 tuna).

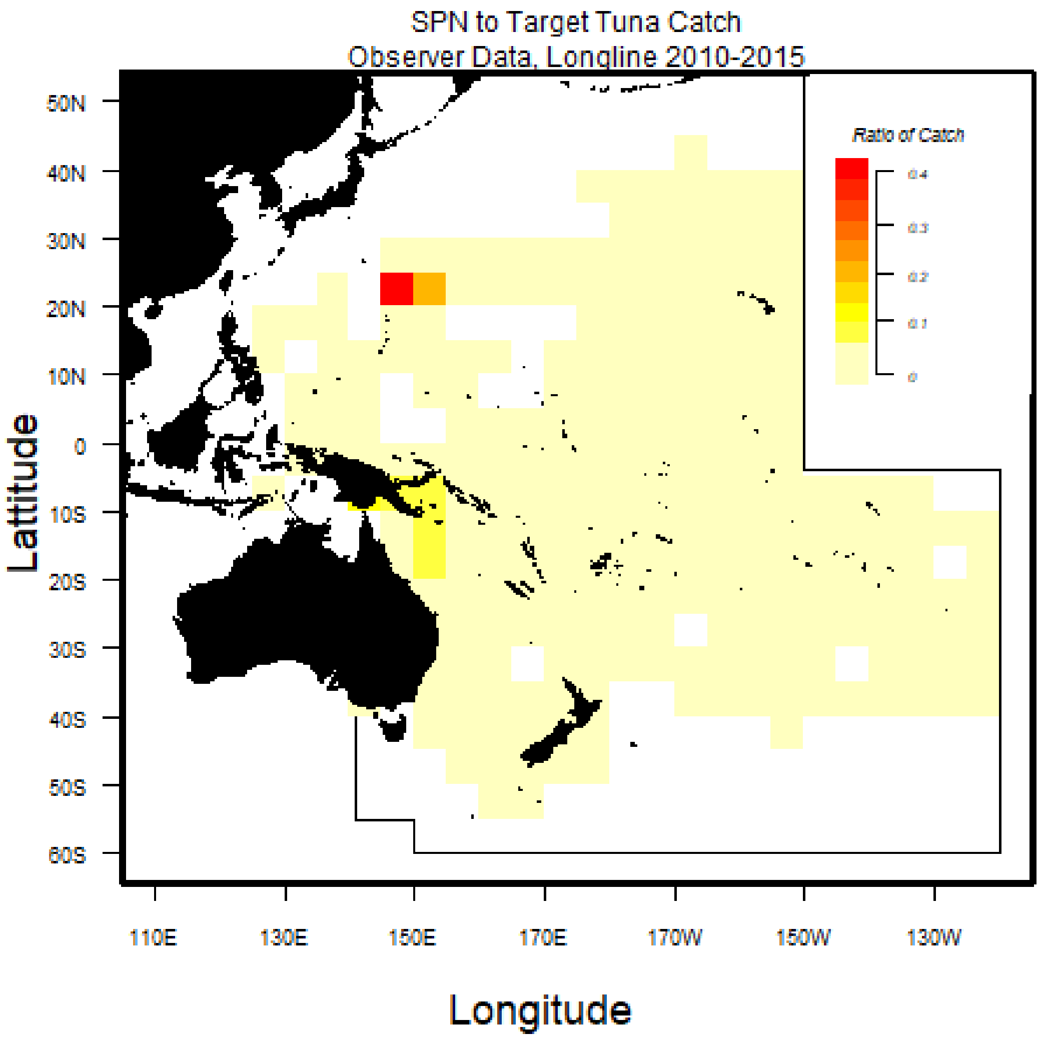

Figure 49.Maps of SPN to target tuna catch, longline vessels 2010-2015 (in units of 50,000 tuna).

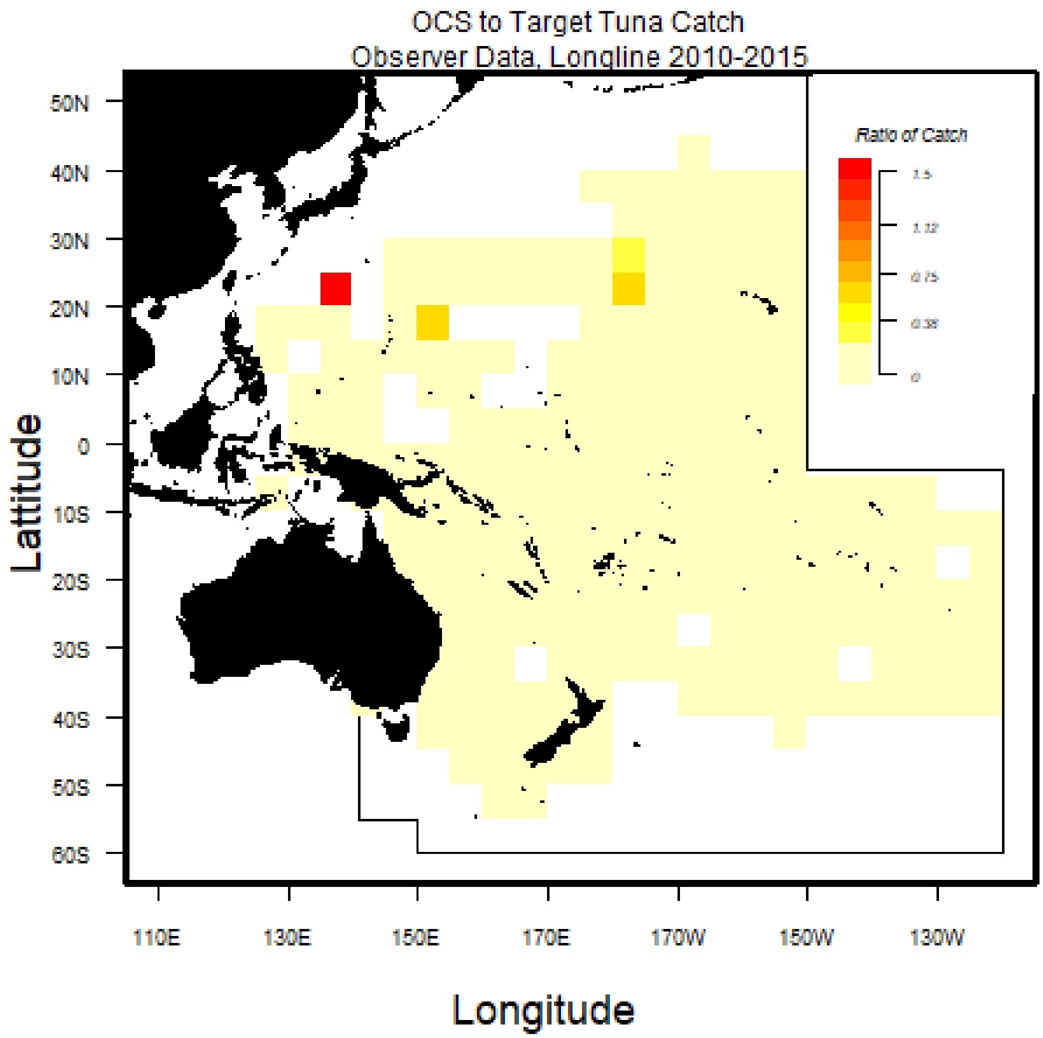

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Figure 50. Maps of OCS to target tuna catch, longline vessels 2010-2015 (in units of 50,000 tuna).

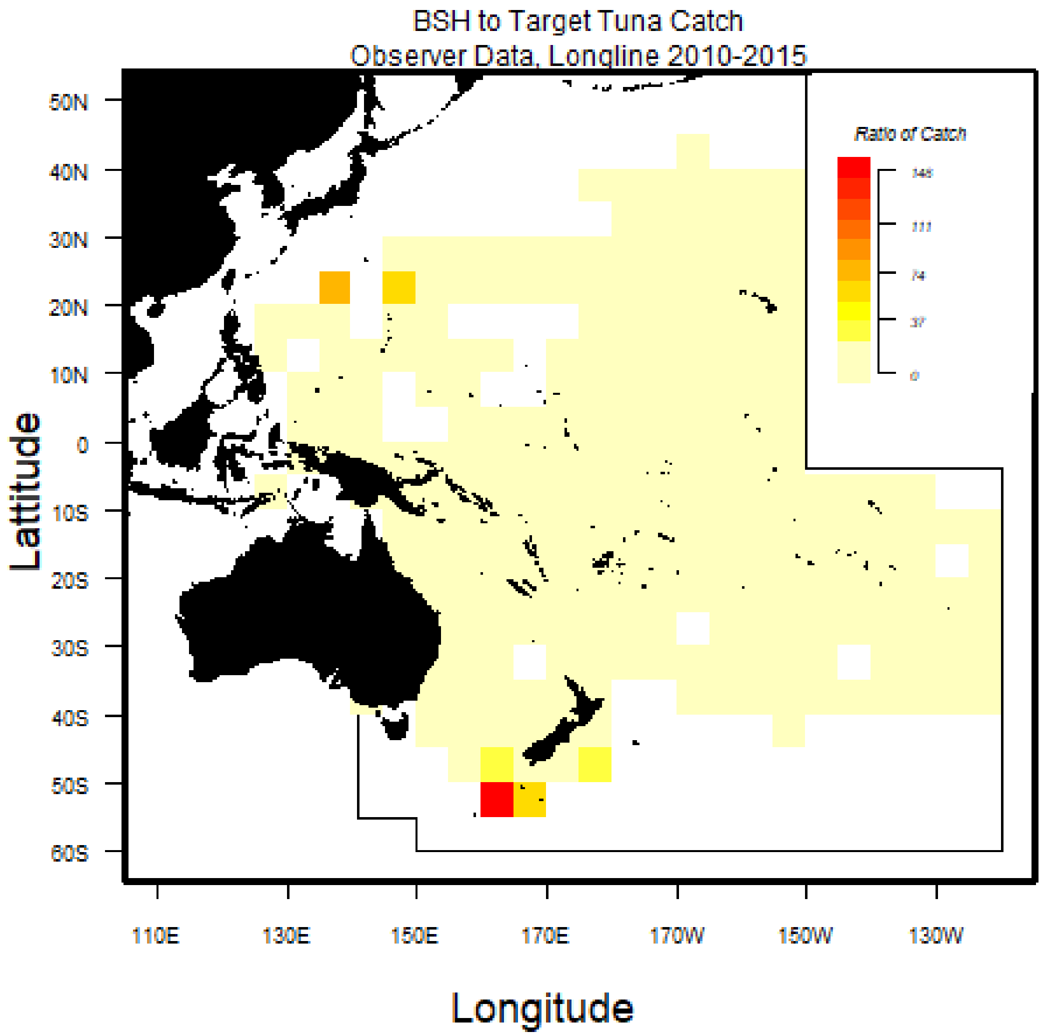

Figure 51. Maps of BSH to target tuna catch, longline vessels 2010-2015 (in units of 50,000 tuna).

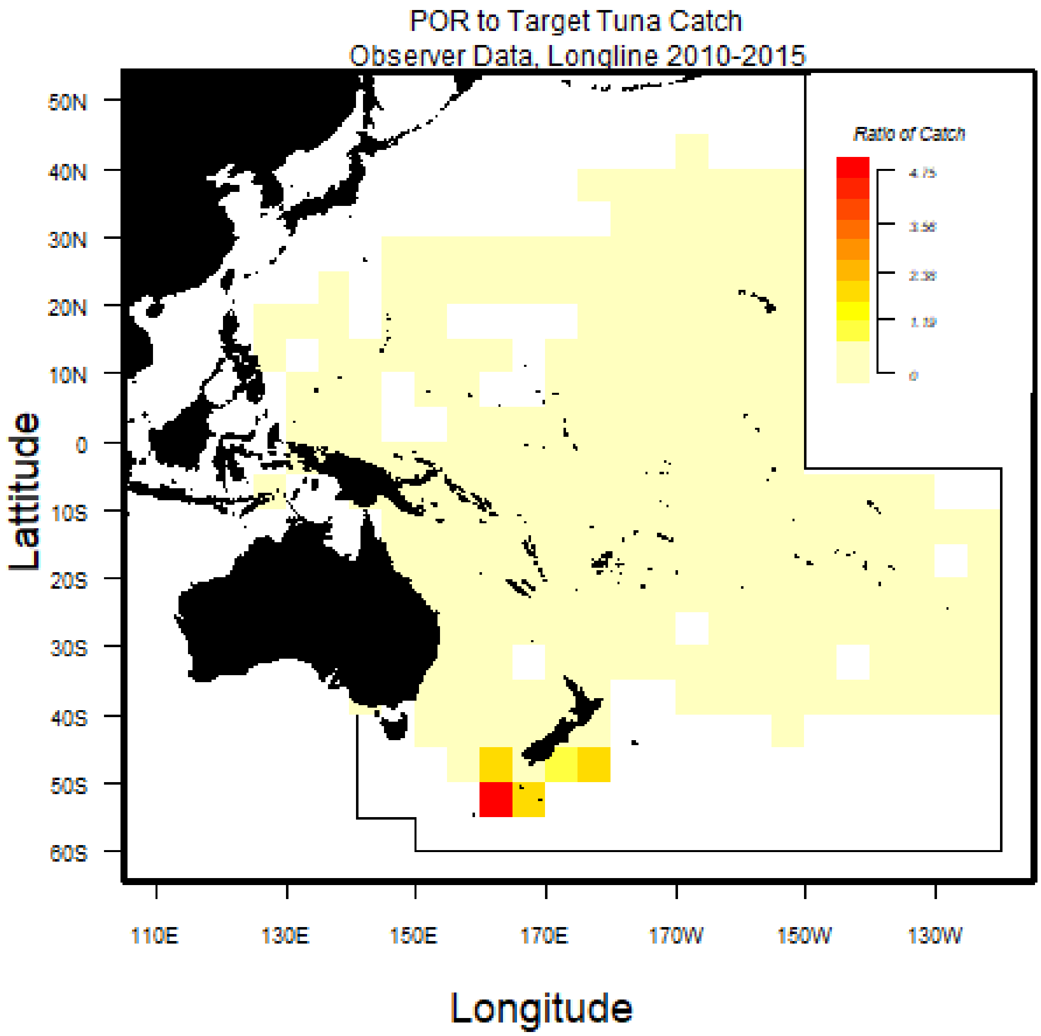

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Figure 52. Observed catch of POR to target tuna (in units of 50,000).

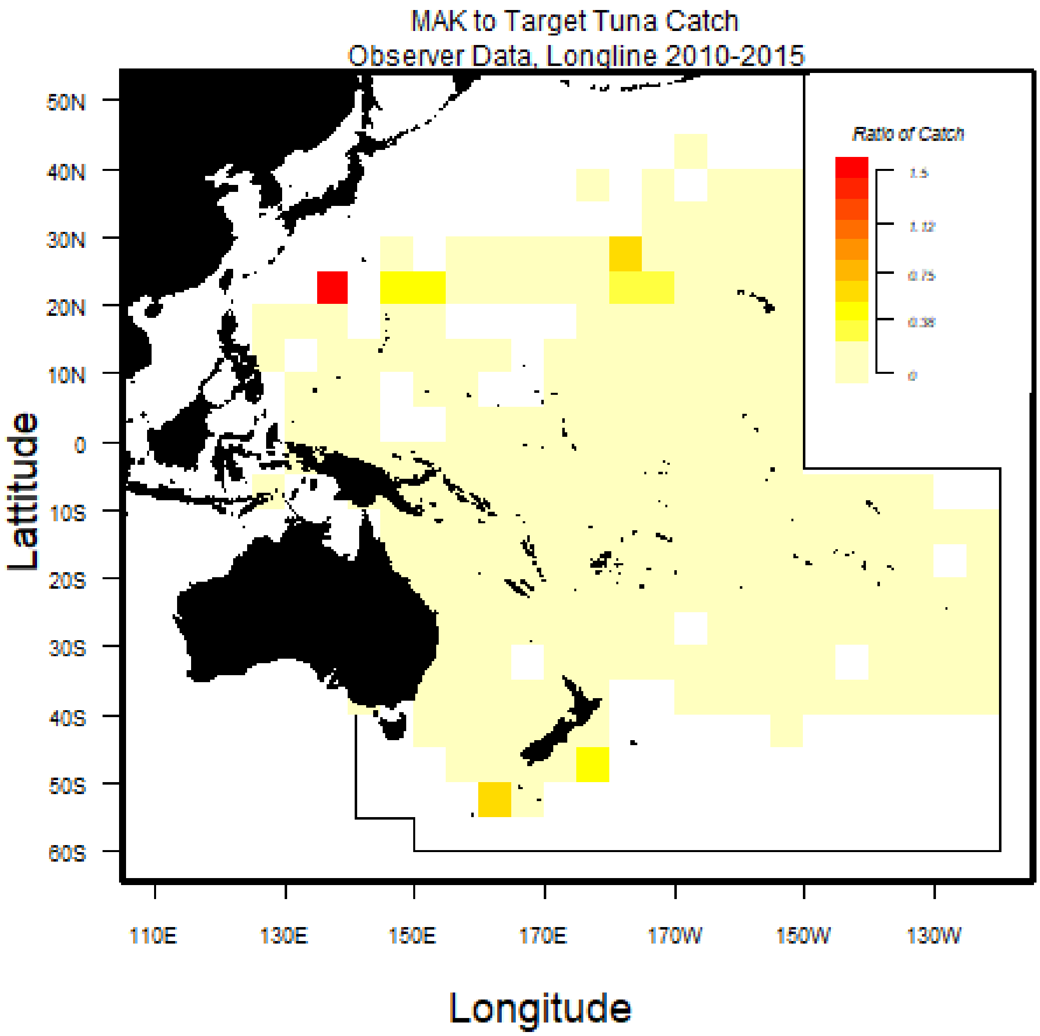

Figure 53. Maps of MAK to target tuna catch, longline vessels 2010-2015 (in units of 50,000 tuna).

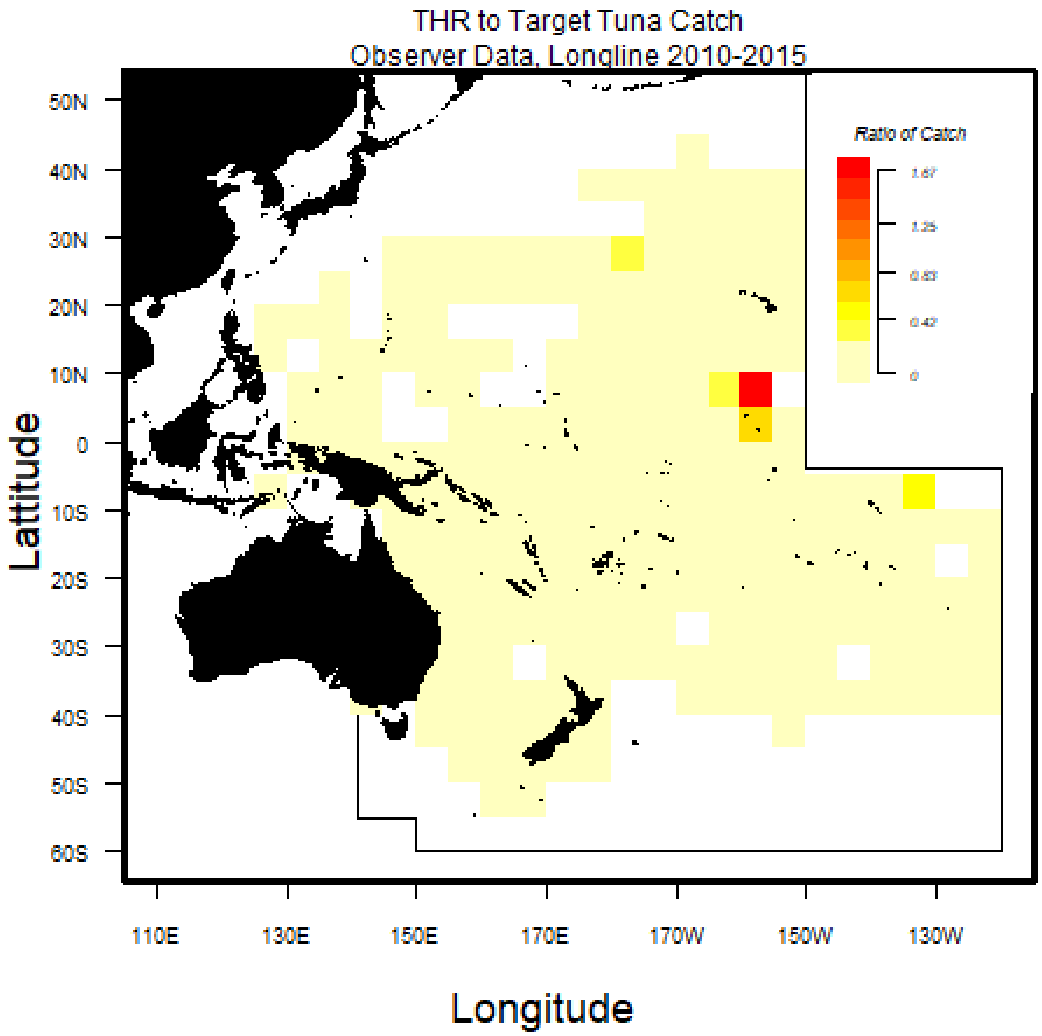

Figure 54. Maps of THR to target tuna catch, longline vessels 2010-2015 (in units of 50,000 tuna).

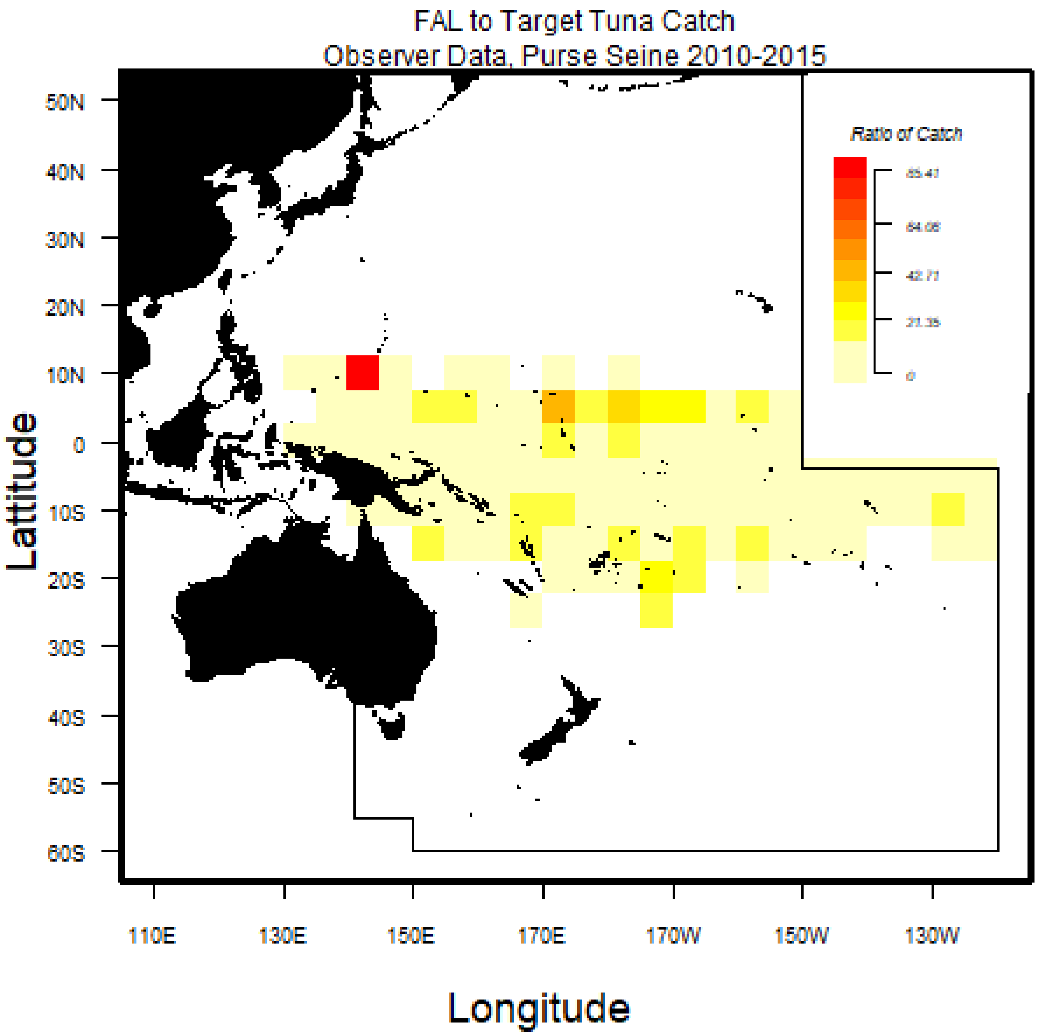

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Figure 55. Maps of FAL to target tuna catch, purse seine, 2010-2015 (in units of 50,000 tuna).

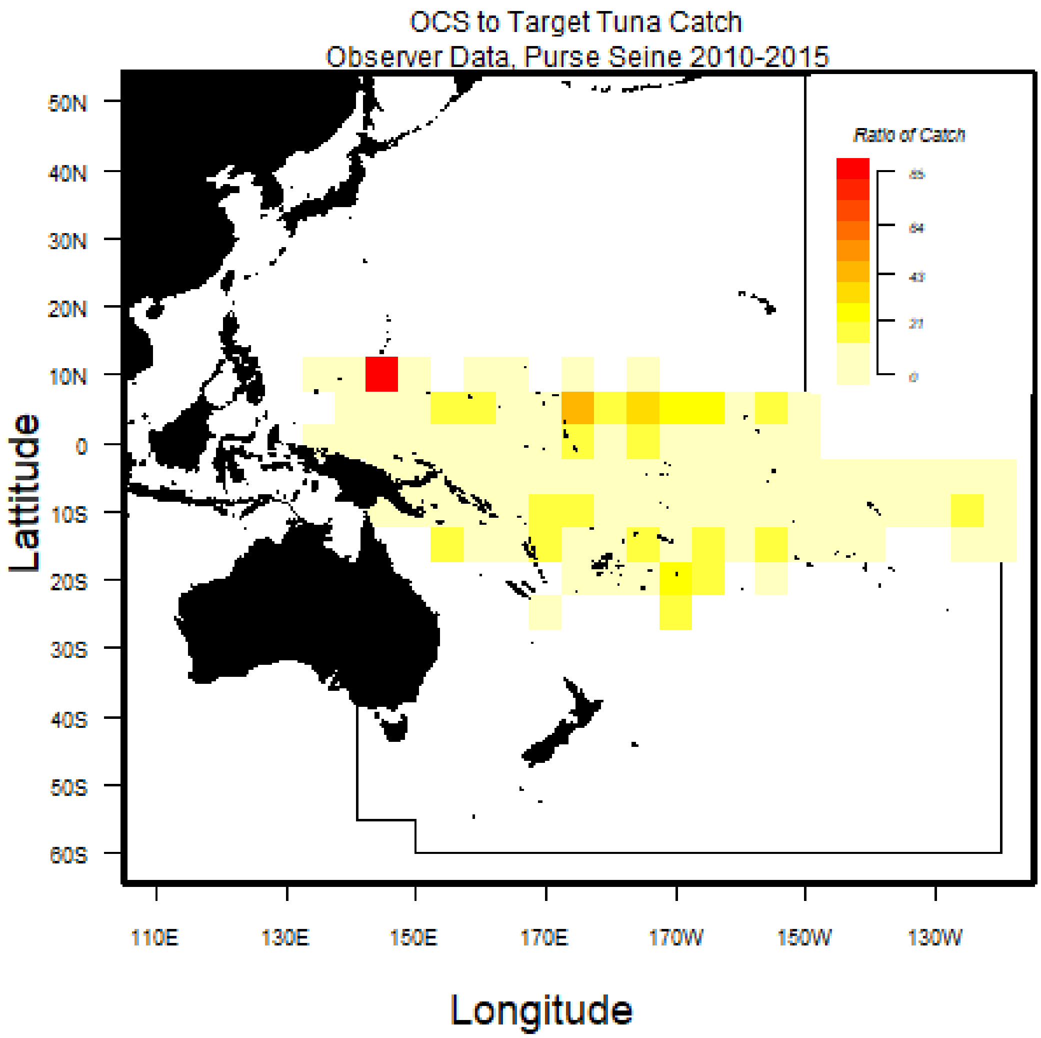

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Figure 56. Maps of OCS to target tuna catch, purse seine, 2010-2015 (in units of 5000MT tuna).

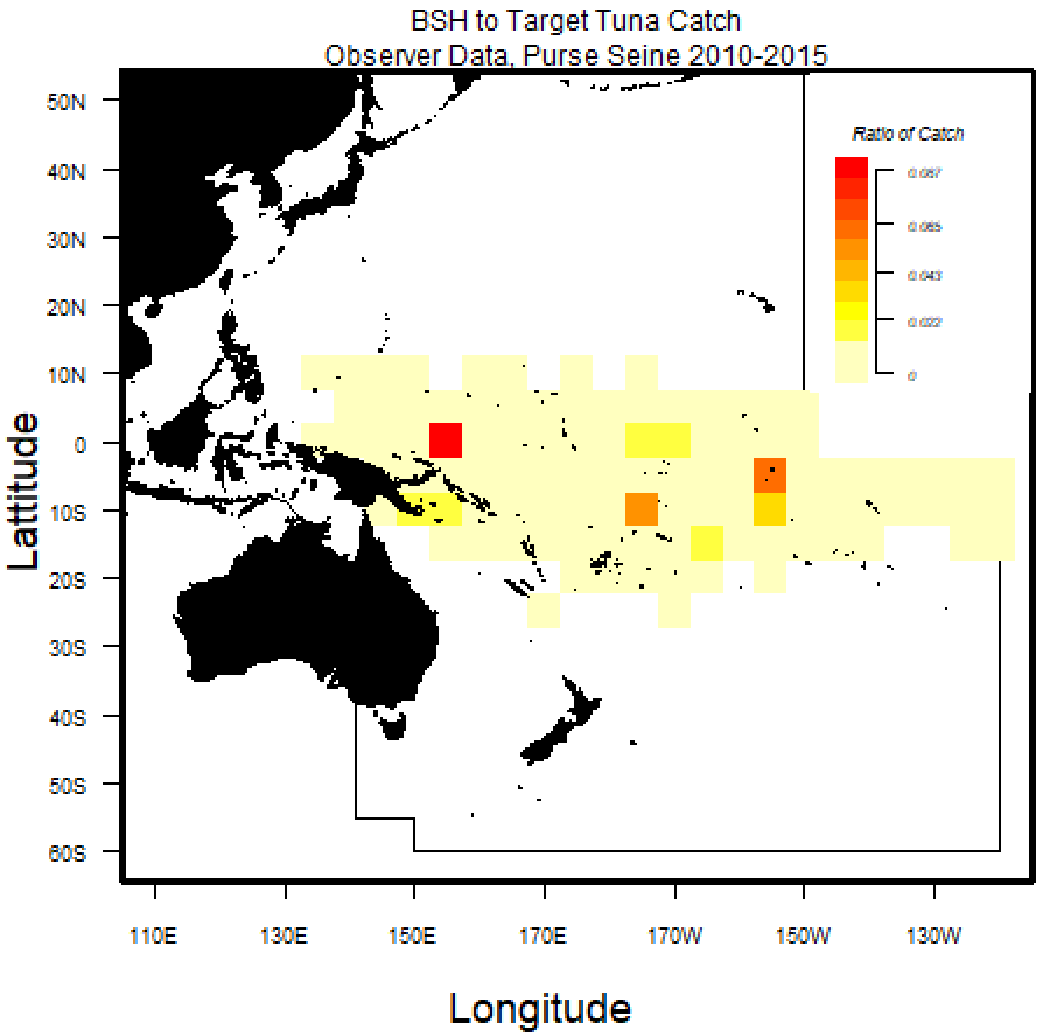


Figure 57. Maps of BSH to target tuna catch, purse seine, 2010-2015 (in units of 5000 MT of tuna).

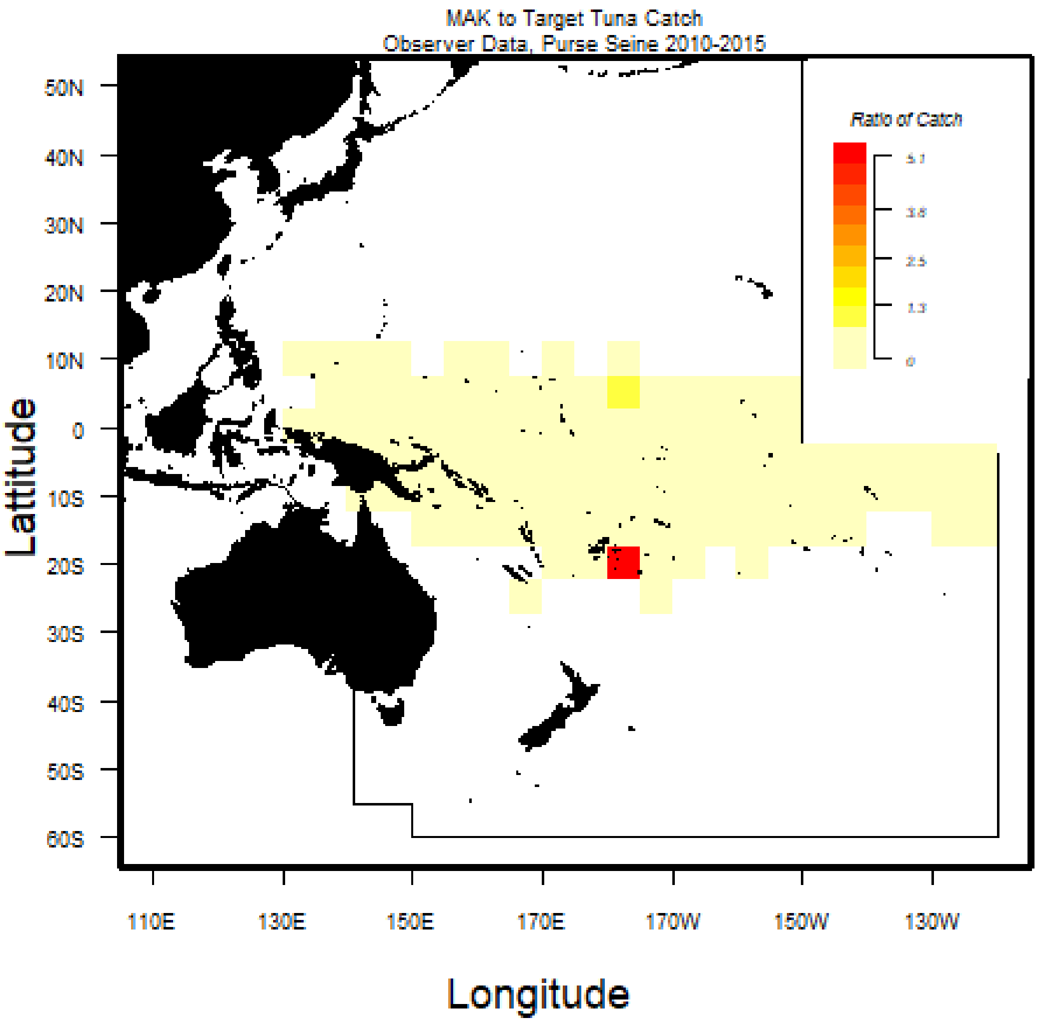


Figure 58. Maps of MAK to target tuna catch, purse seine, 2010-2015 (in units of 5000MT tuna).

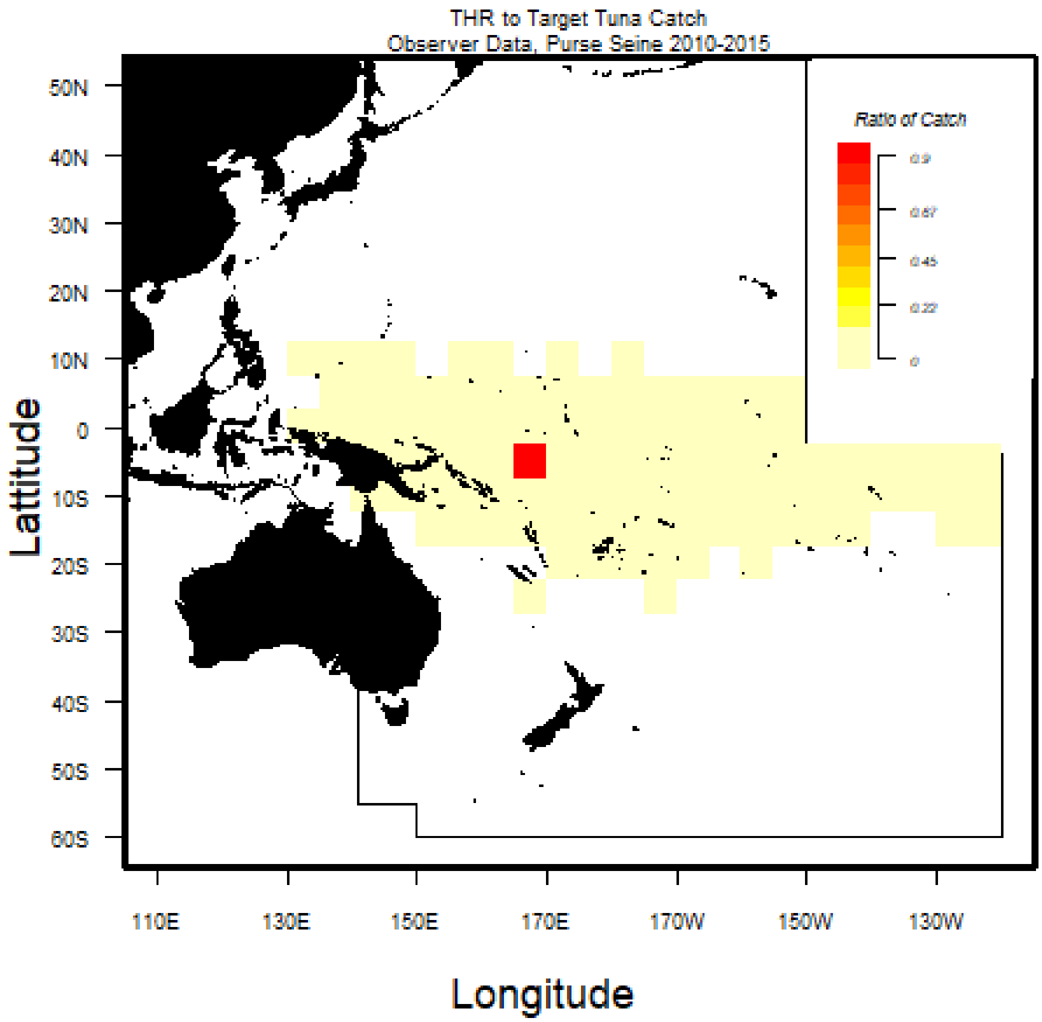


Figure 59. Maps of THR to target tuna catch, purse seine, 2010-2015 (in units of 5000MT tuna).

Section 4 Figures Evaluation of relative spatial distribution of fishing effort, catch and CPUE.

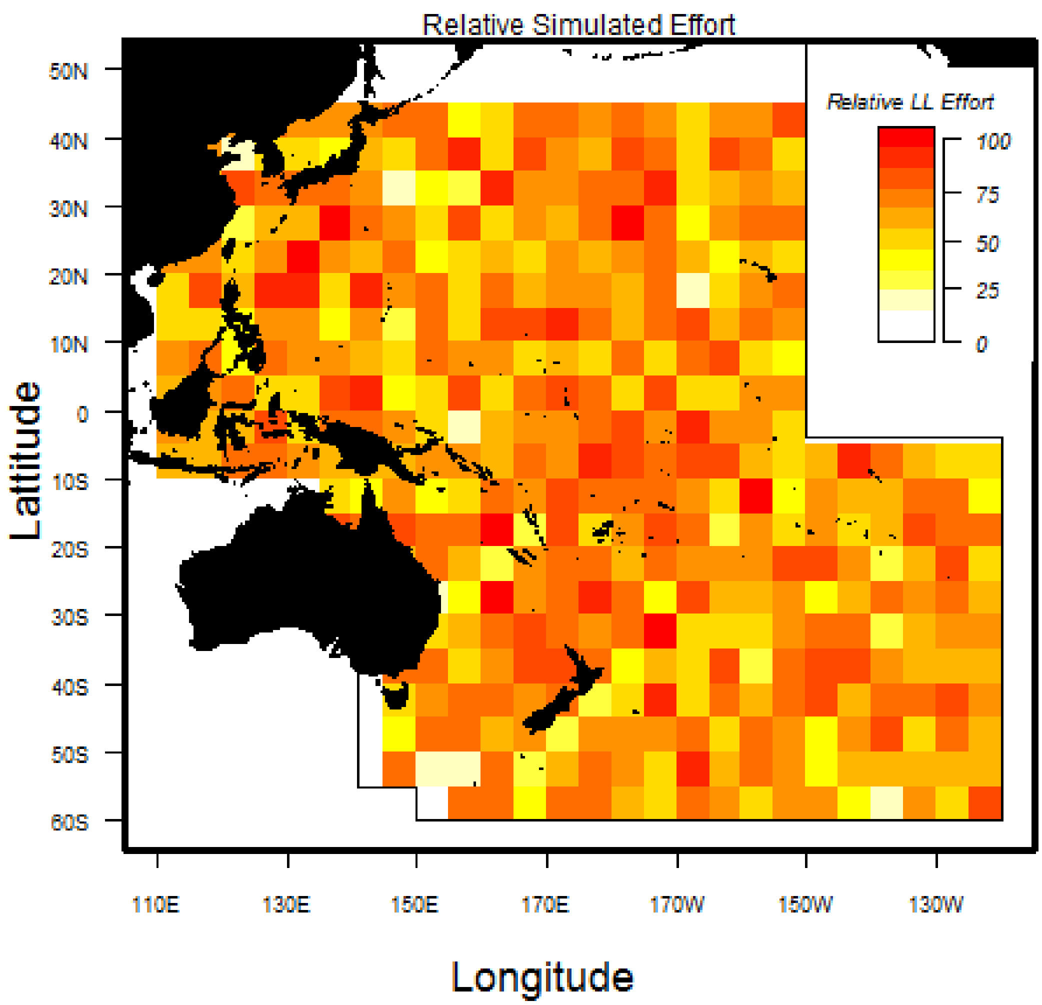


Figure 4.1 Random distribution of effort :

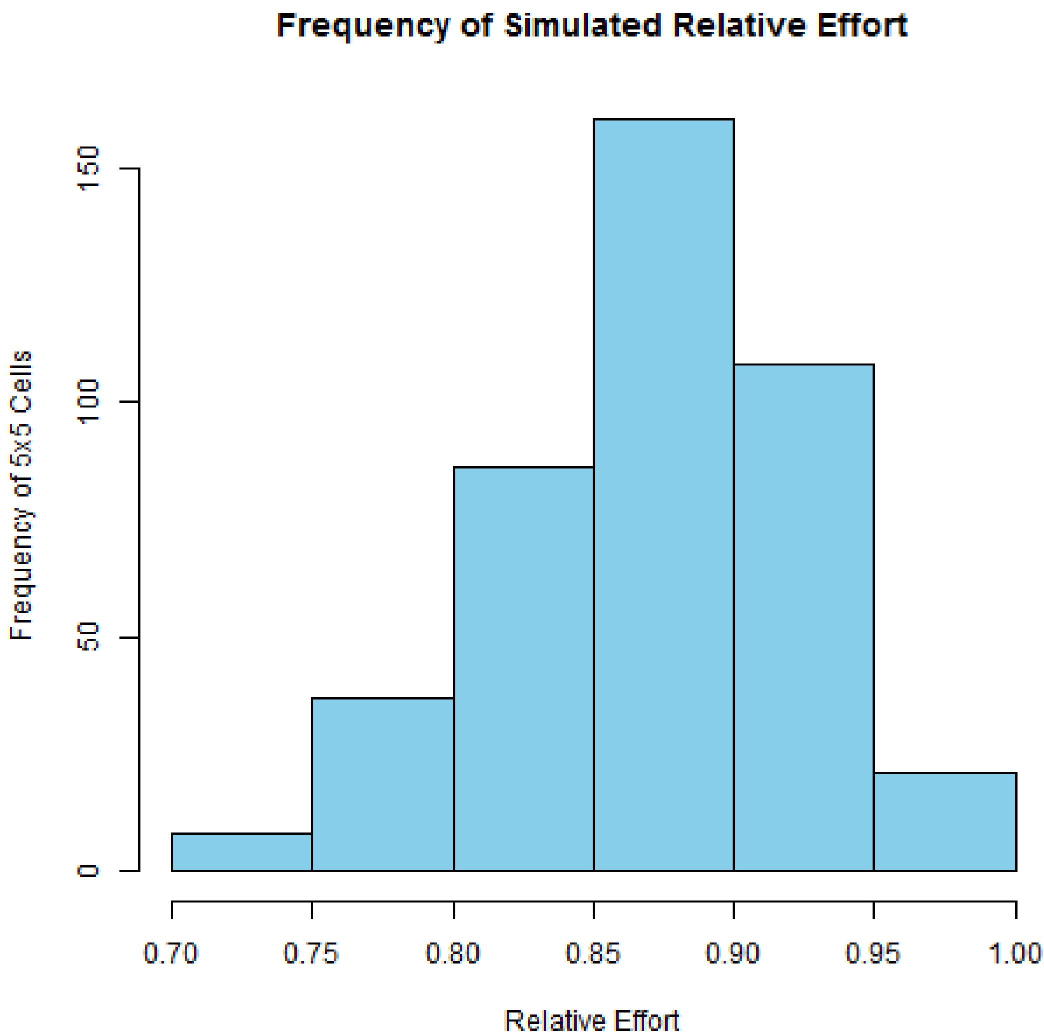


Figure 4.2 Frequency distribution of the simulated relative effort for random processes.

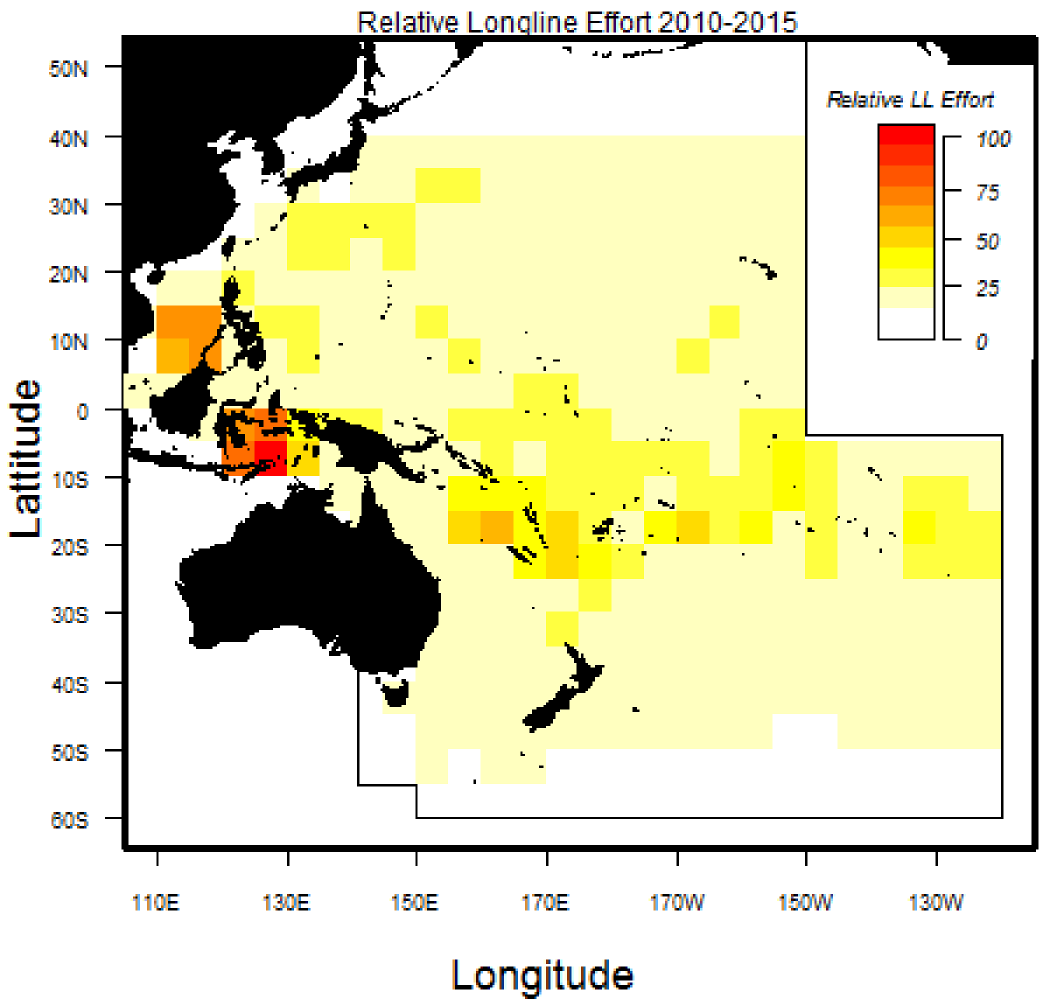


Figure 4.3 Relative distribution of the reported longline effort 2010-2015.

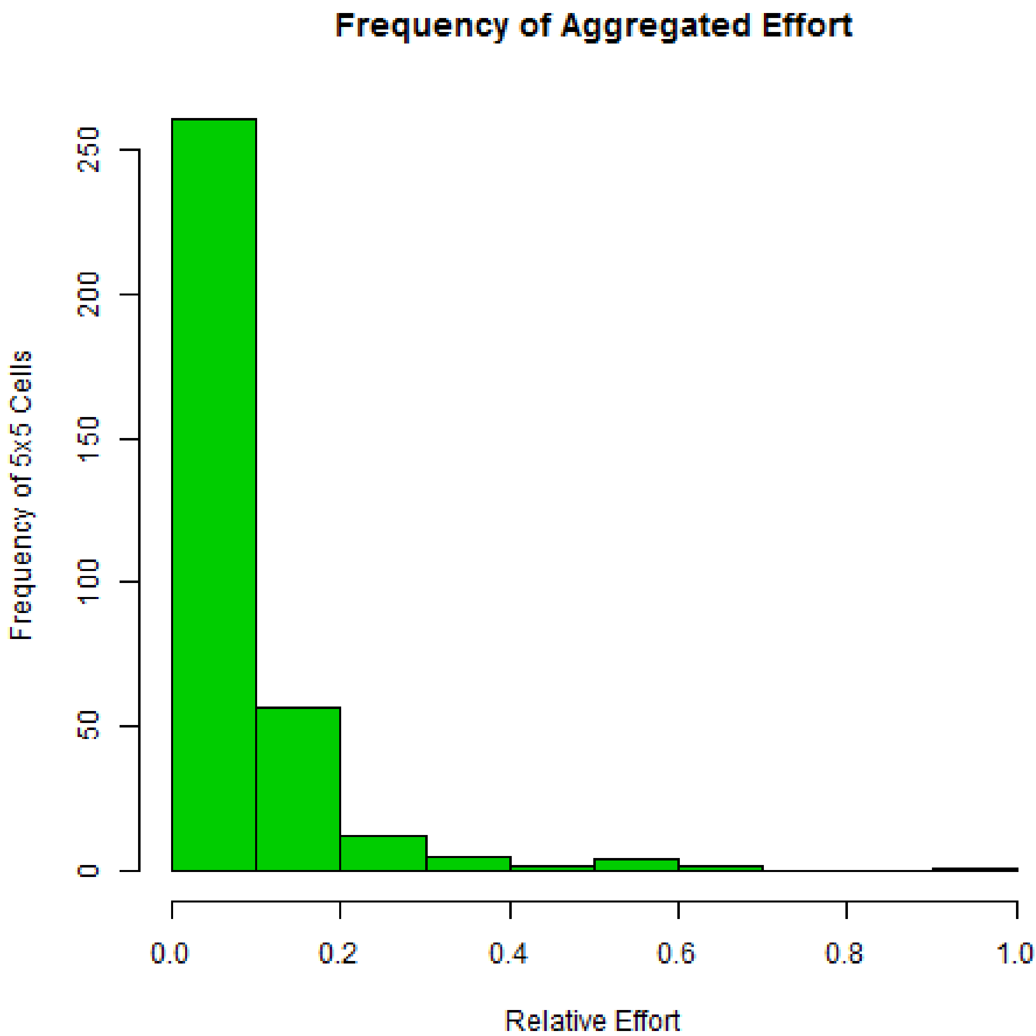


Figure 4.4 Frequency distribution of relative effort based on 5x5 degree spatial cell.

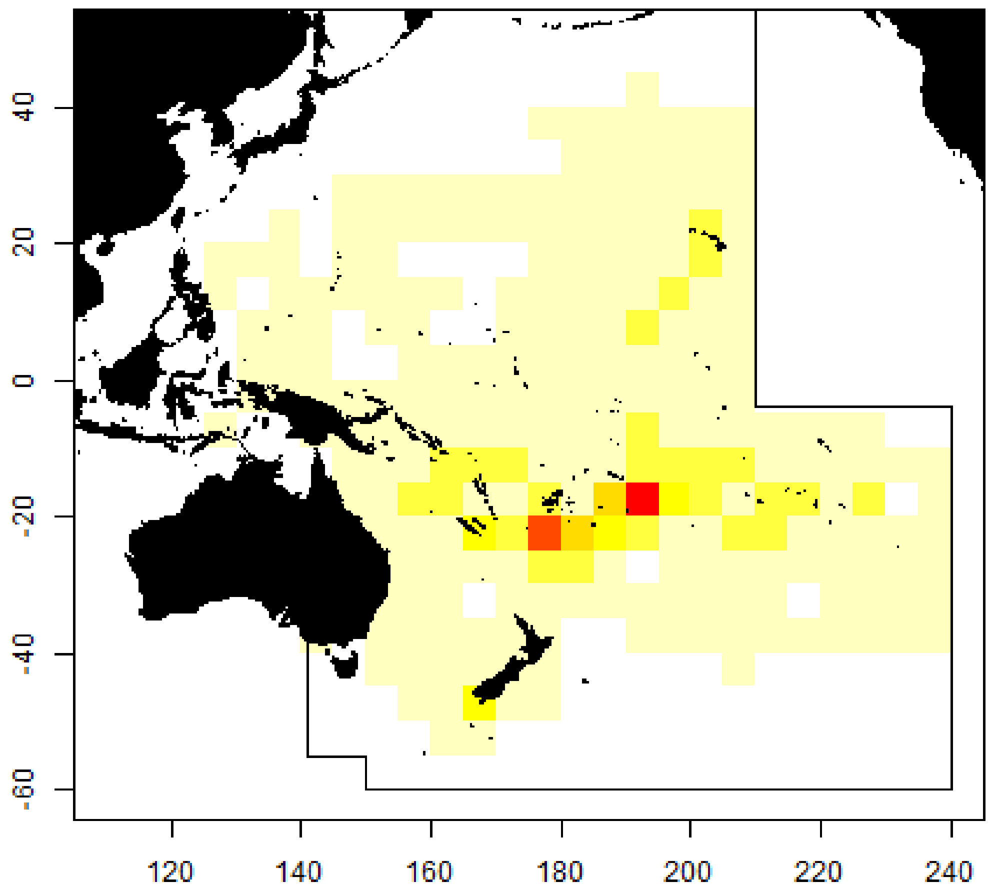


Figure 4.5 Relative observer effort 2010-2015.

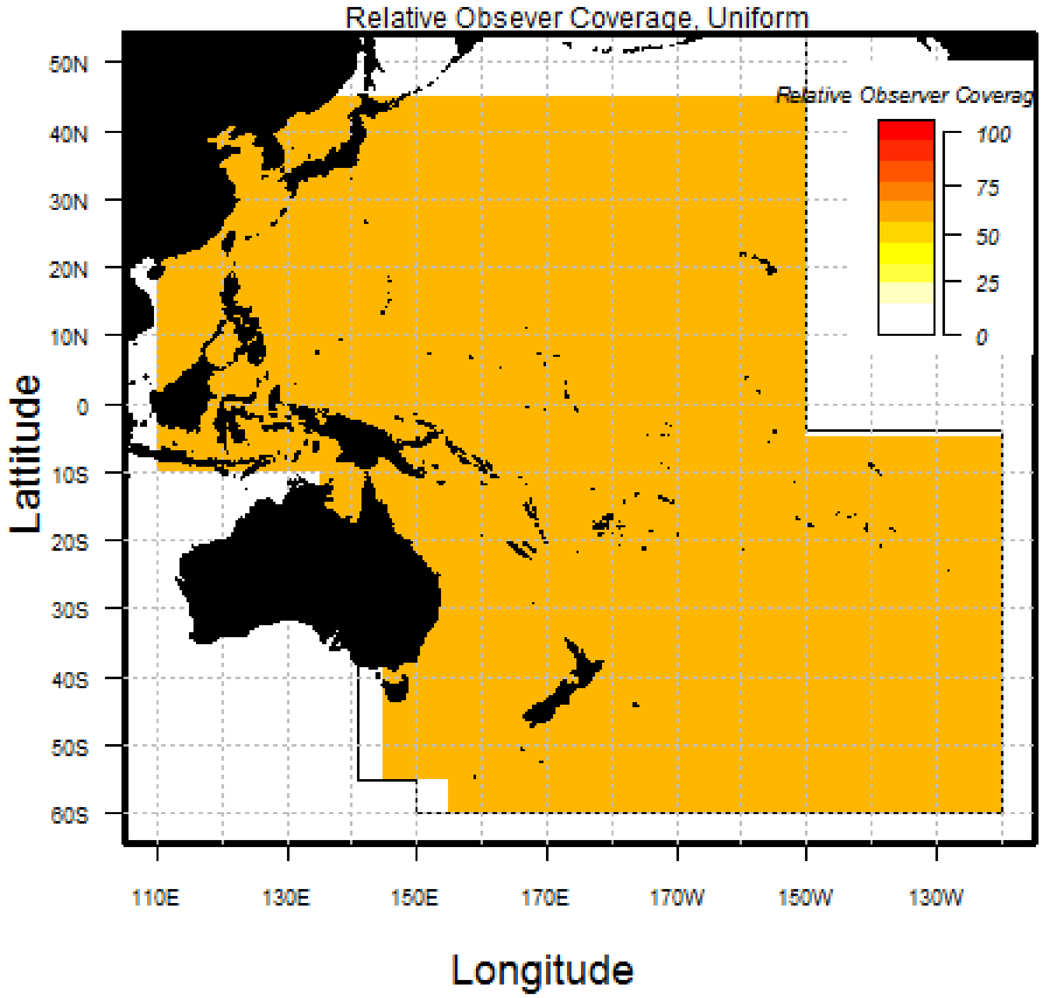


Figure 4.6 Uniform observer coverage

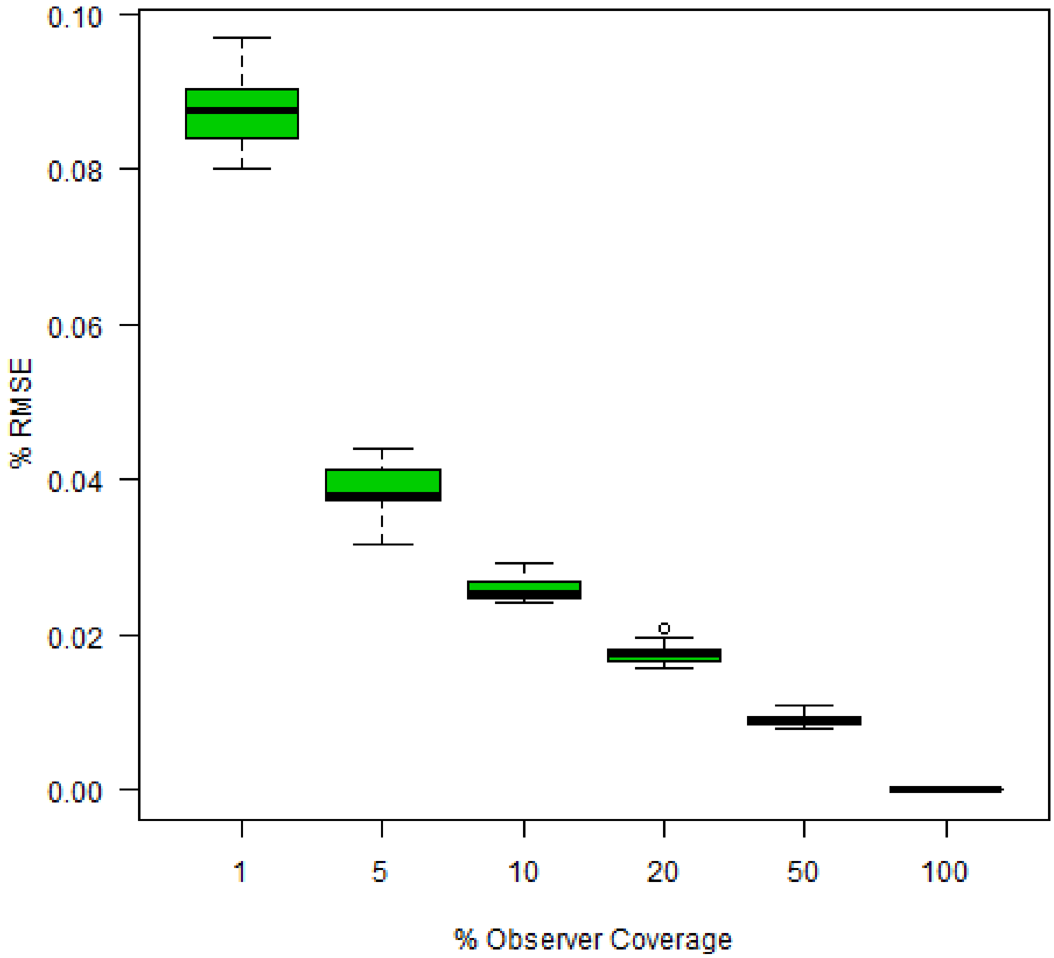


Figure 4.4 7 RMSE as a function of observer coverage for the scenario assuming uniform distribution of species, effort and sampling.

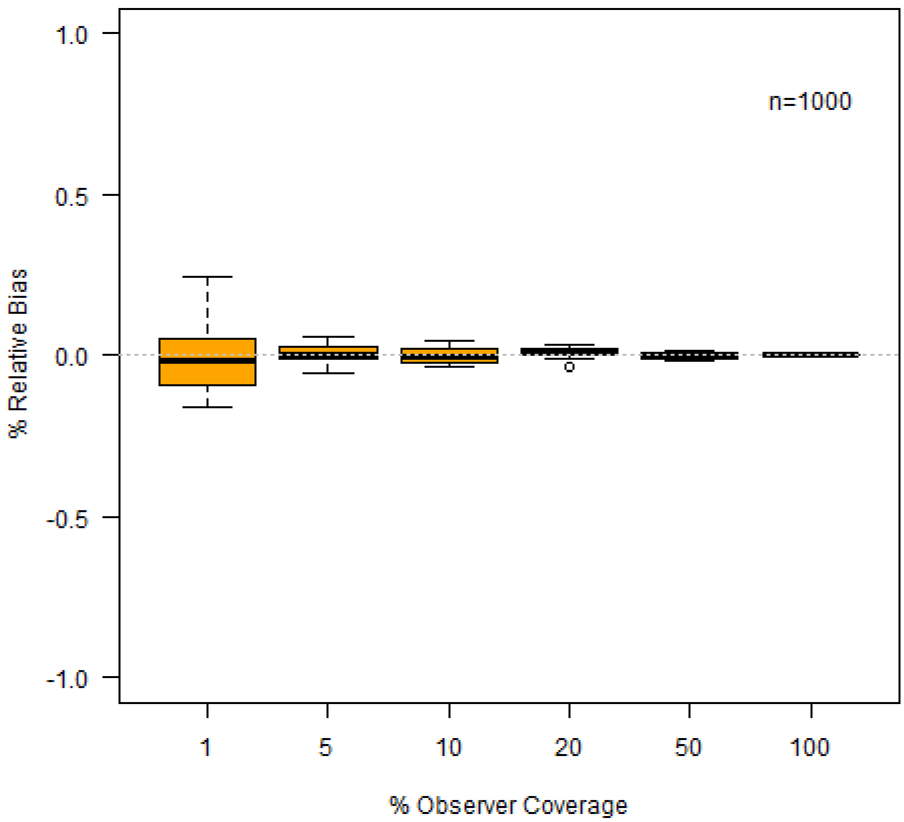


Figure 4.8 Relative bias as a function of observer coverage for the scenario assuming uniform distribution of species, effort and sampling.

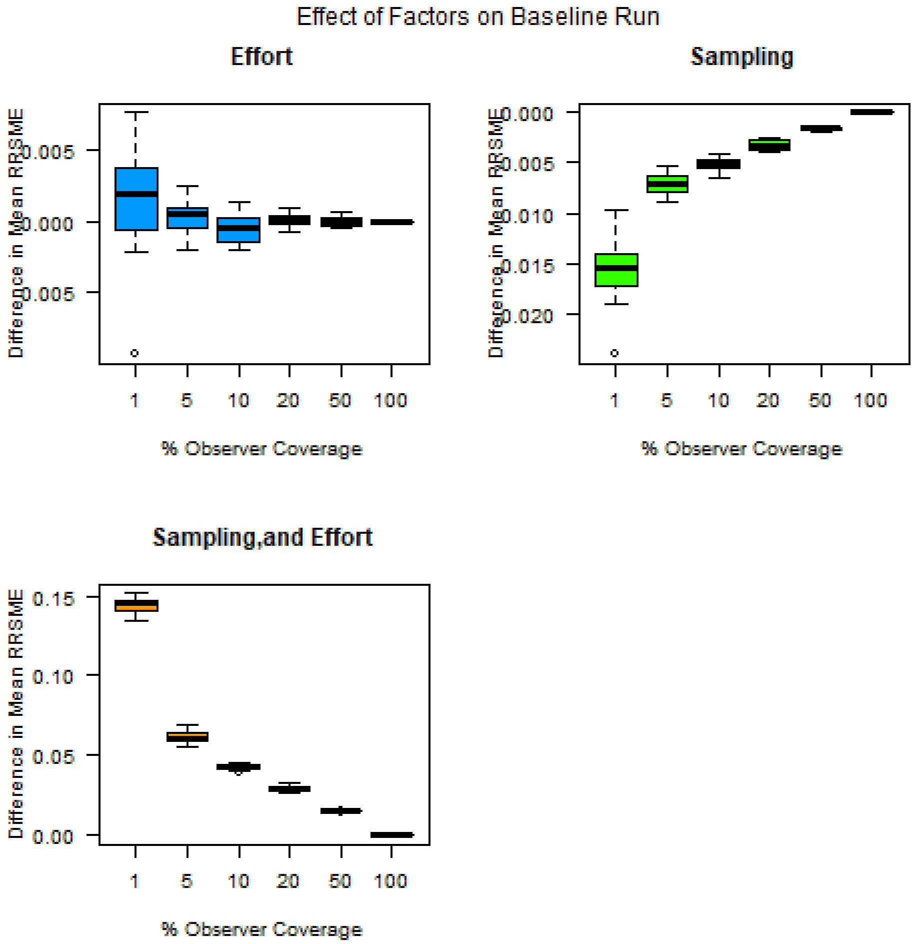


Figure 4.9 Effect of non random sampling, effort, and sampling and effort on the RRMSE across various coverage rates.

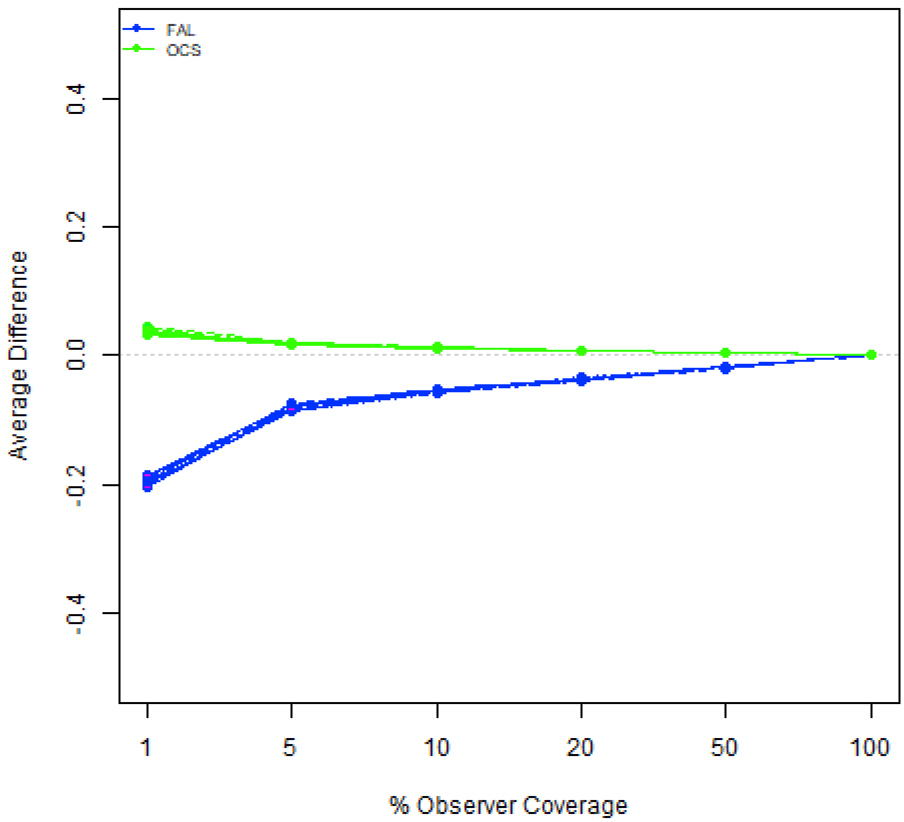
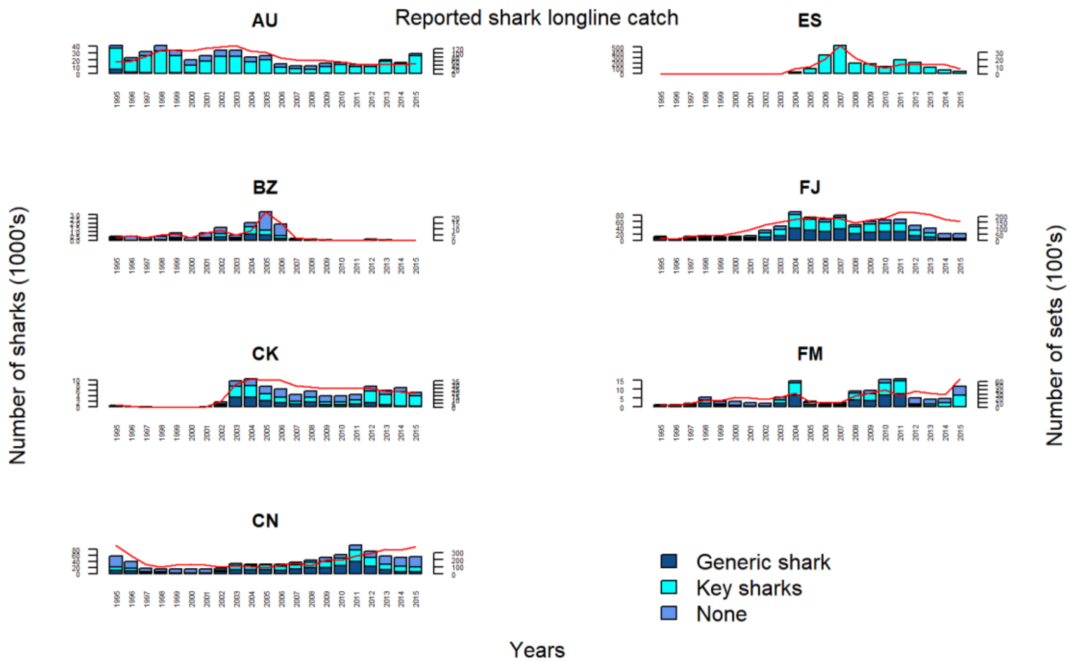


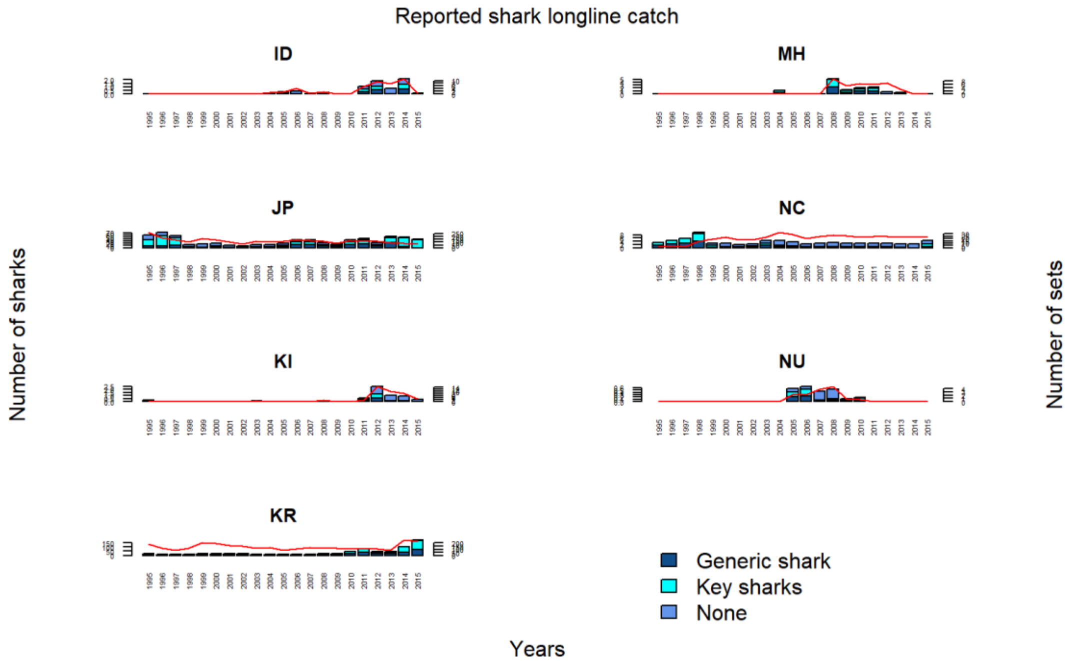
Figure 4.10 Average annual difference by species distribution. Lines represent the difference between distributional assumptions (none – species specific), with negative values indicating that use of the observed species distribution in CPUE calculation results in higher amounts of error.

Annexes

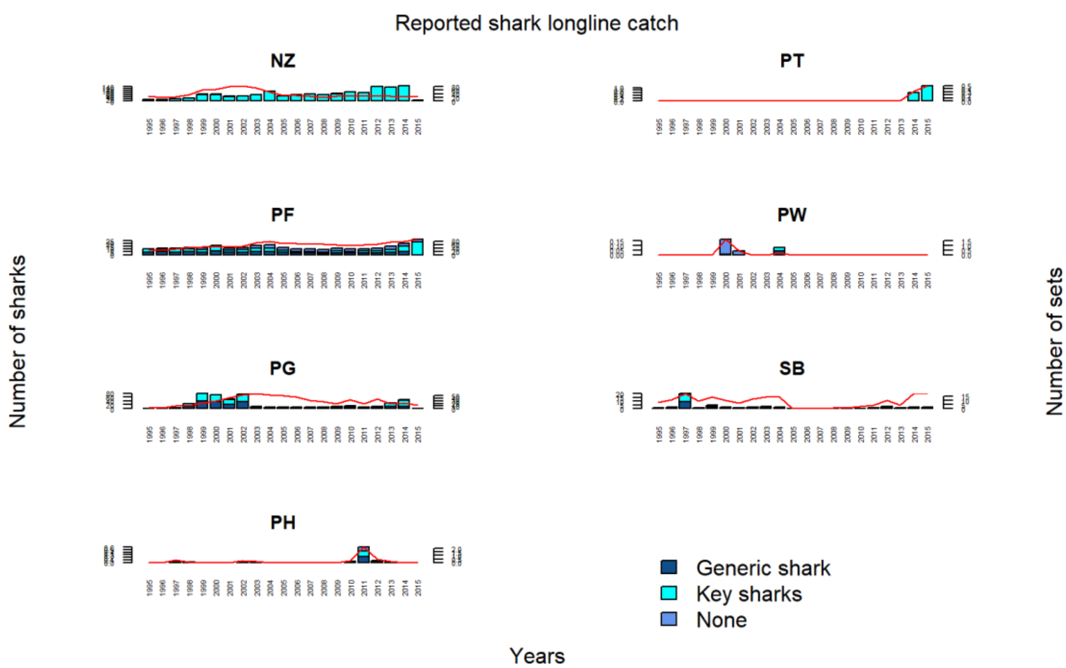
Annex 1 Detailed Taxonomic Reporting for the longline fleet.



Reported LL Taxonomic 1:



Reported LL Taxonomic 1:



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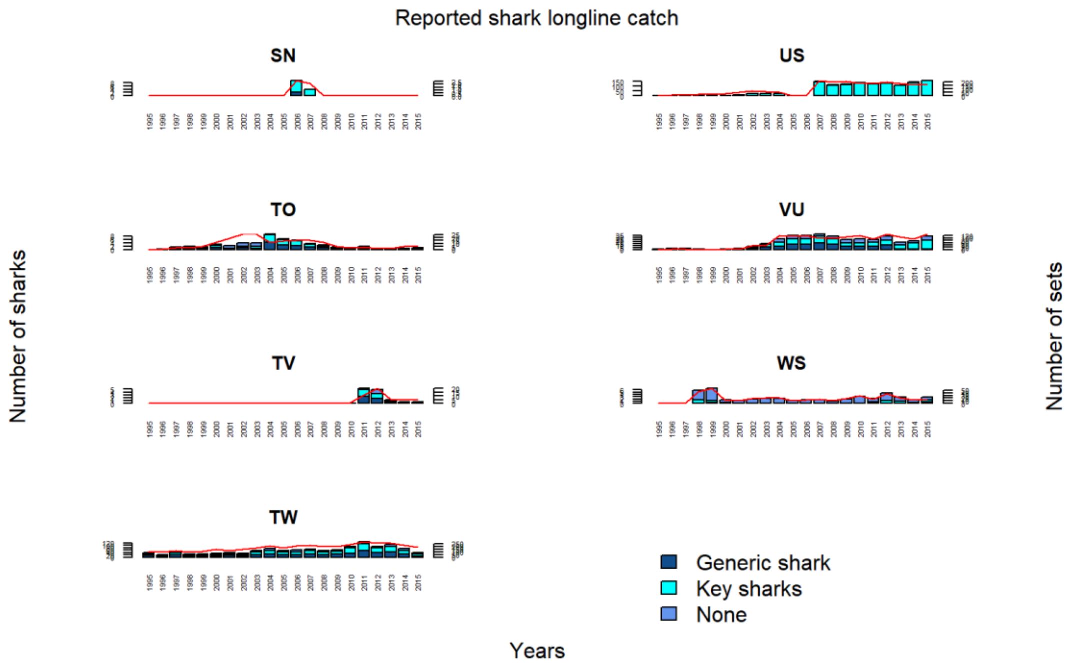
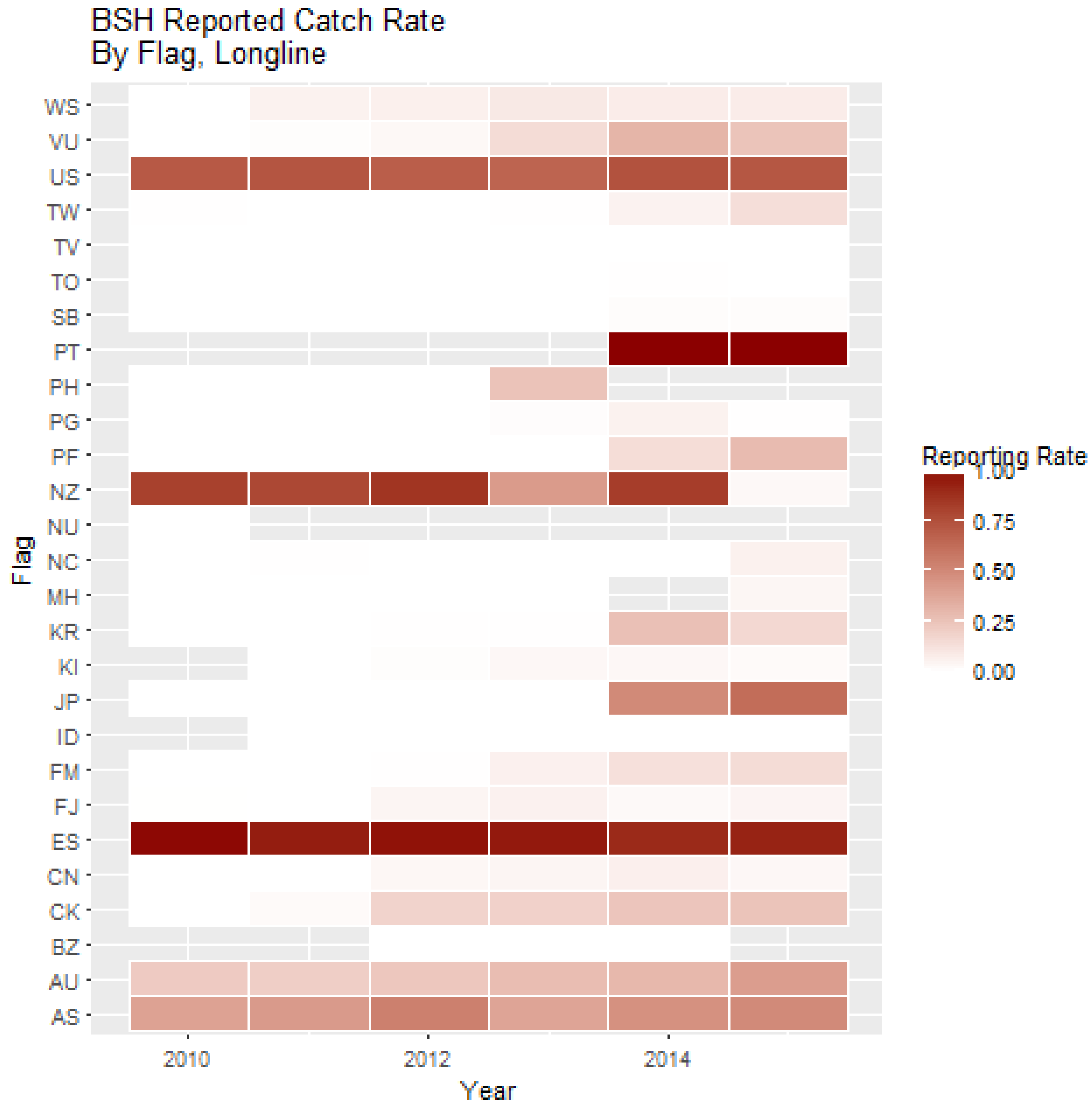
Reported LL Taxonomic 1:



Annex 2 Reported Catch and discard rate by species and flag, Longline.

BSH Reported Catch Rate:



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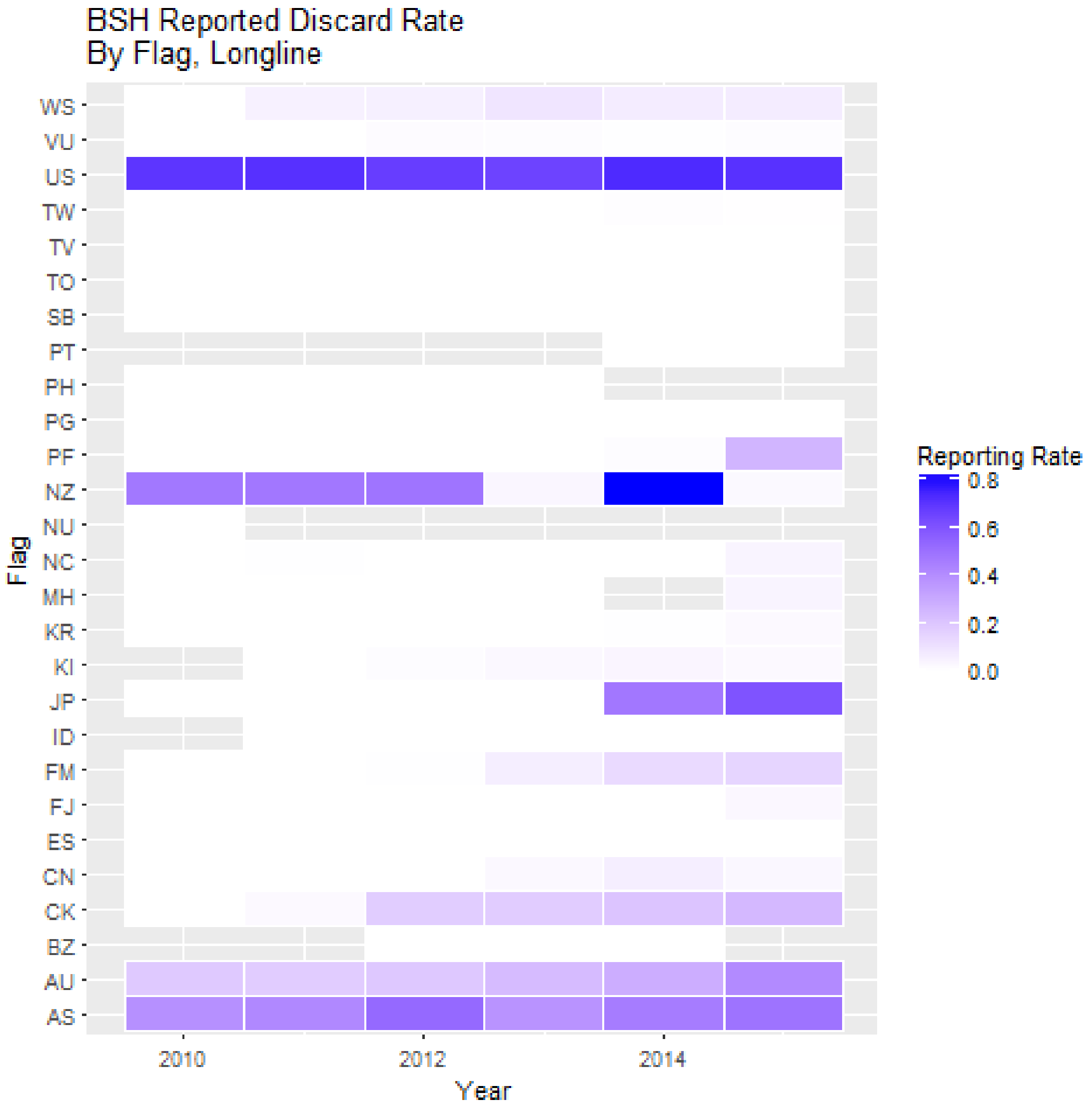
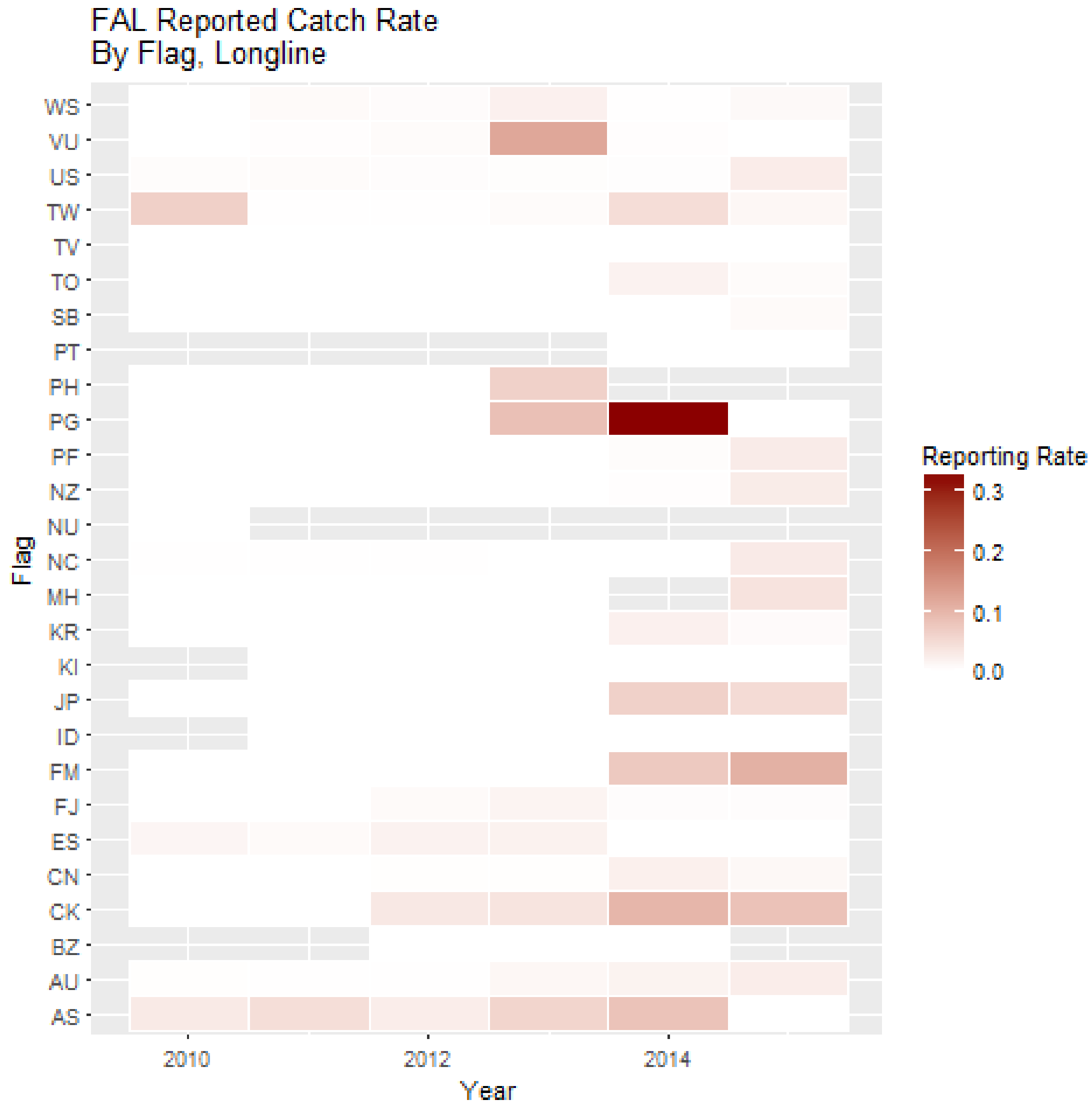
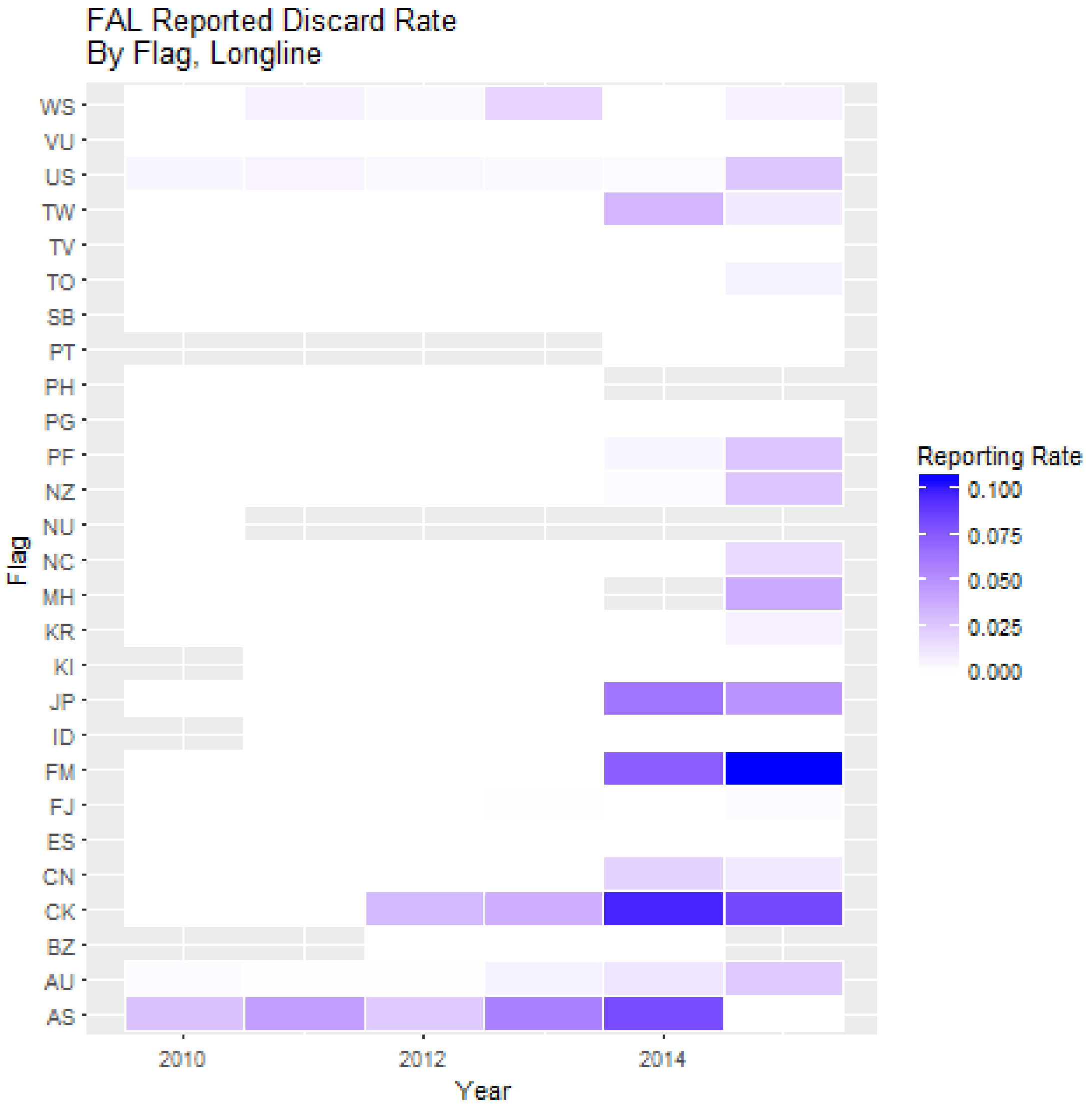
BSH Reported Discard Rate:



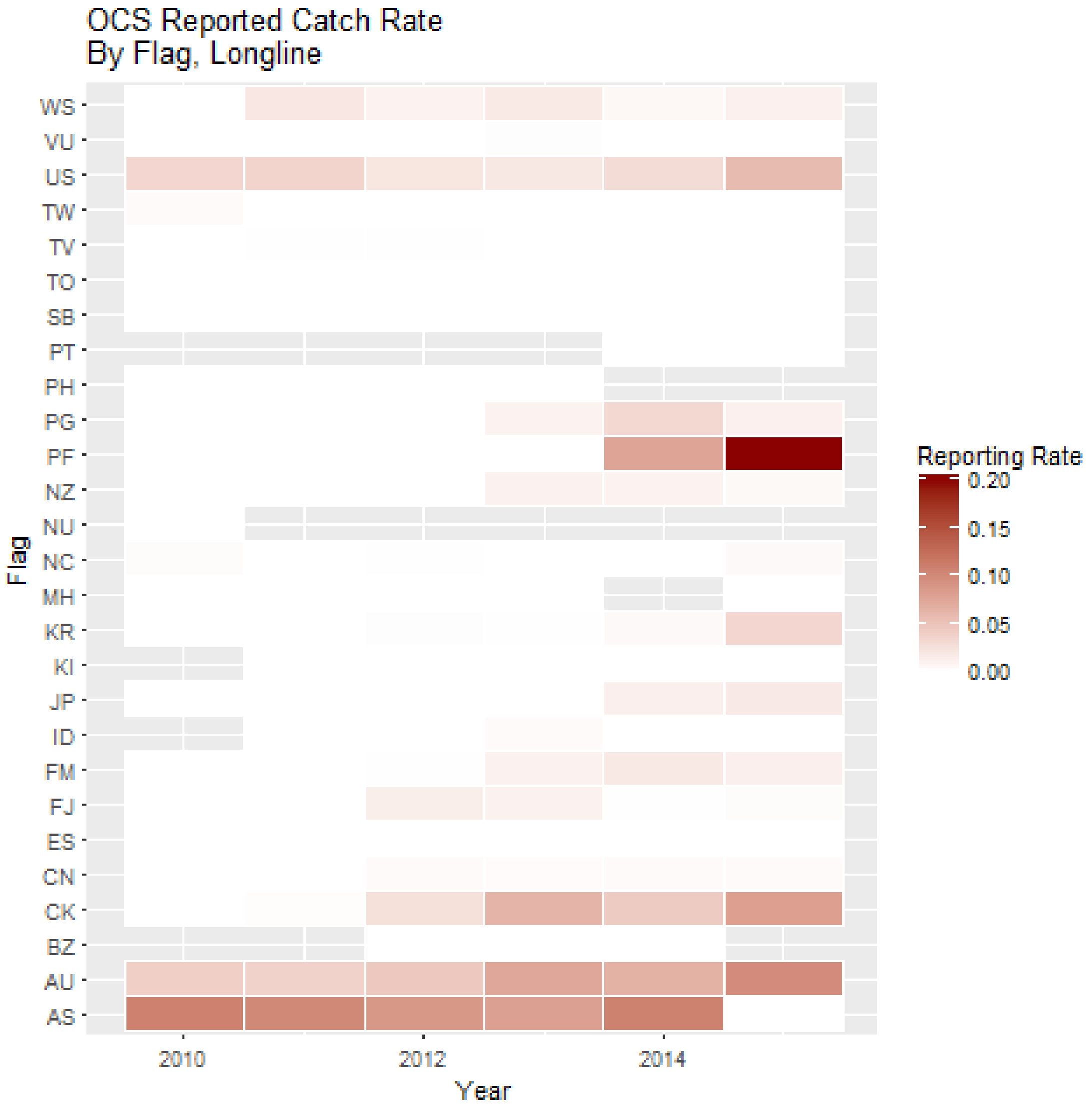
FAL Reported Catch Rate:



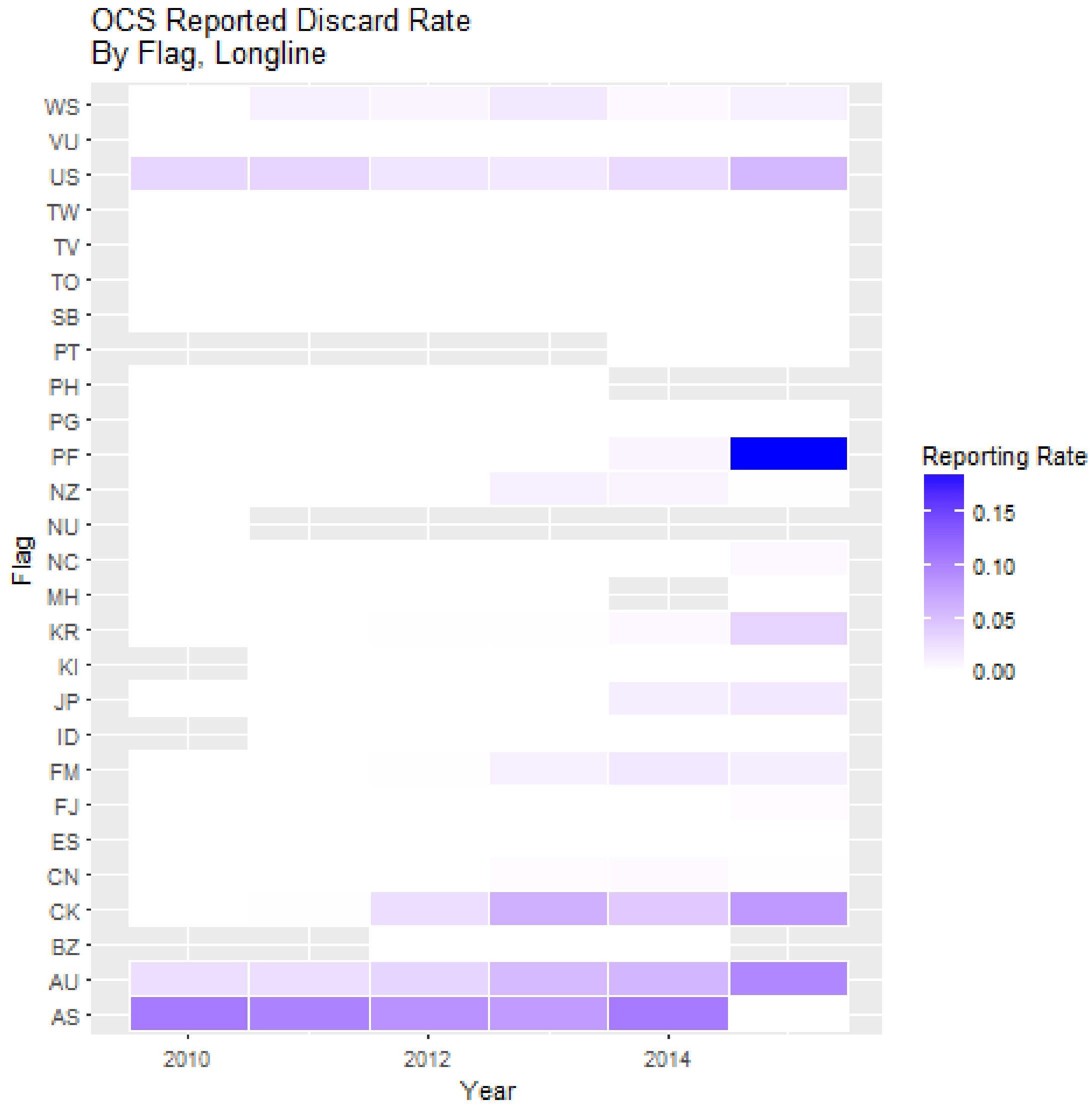
FAL Reported Discard Rate:



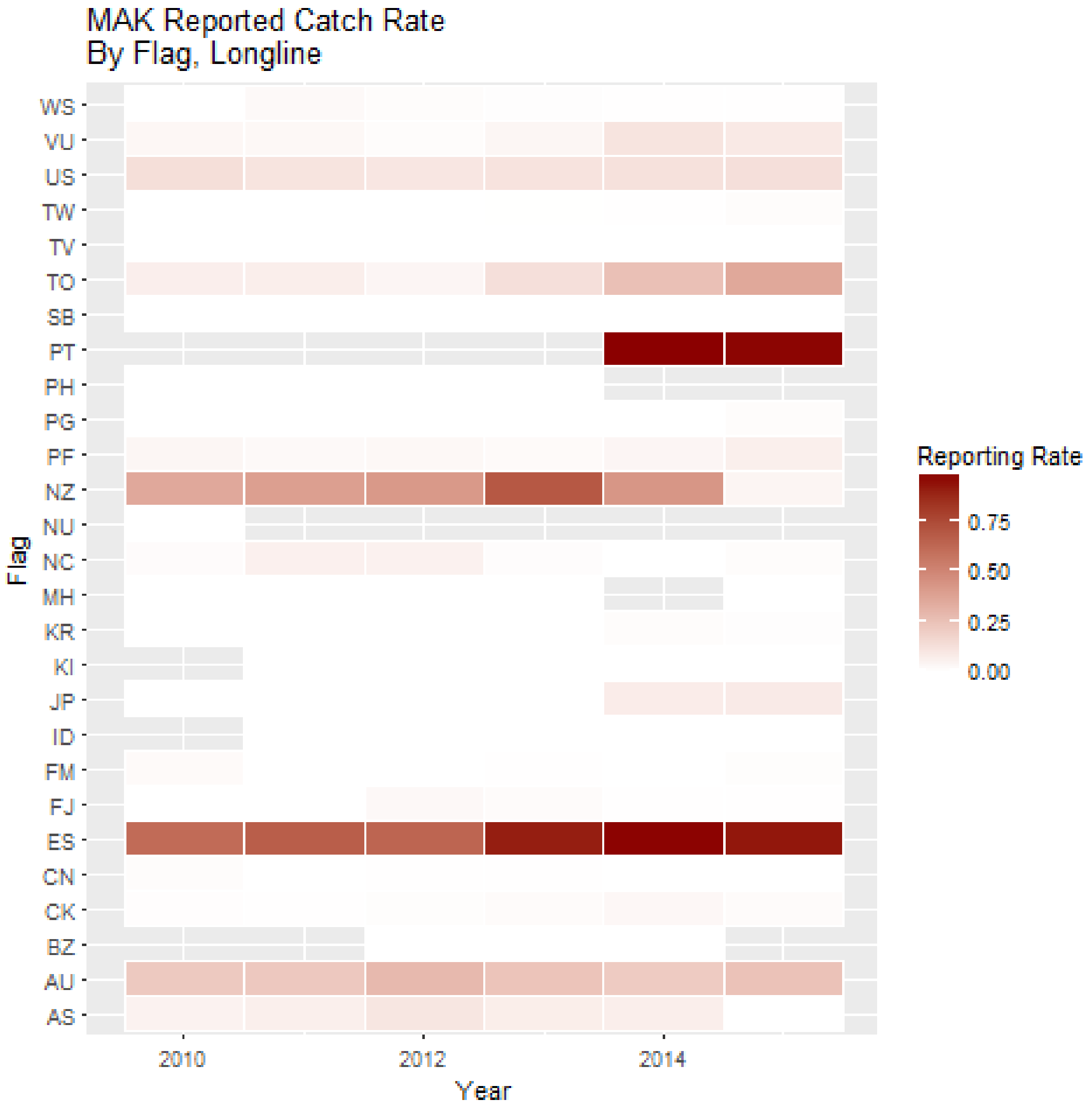
OCS Reported Catch Rate:



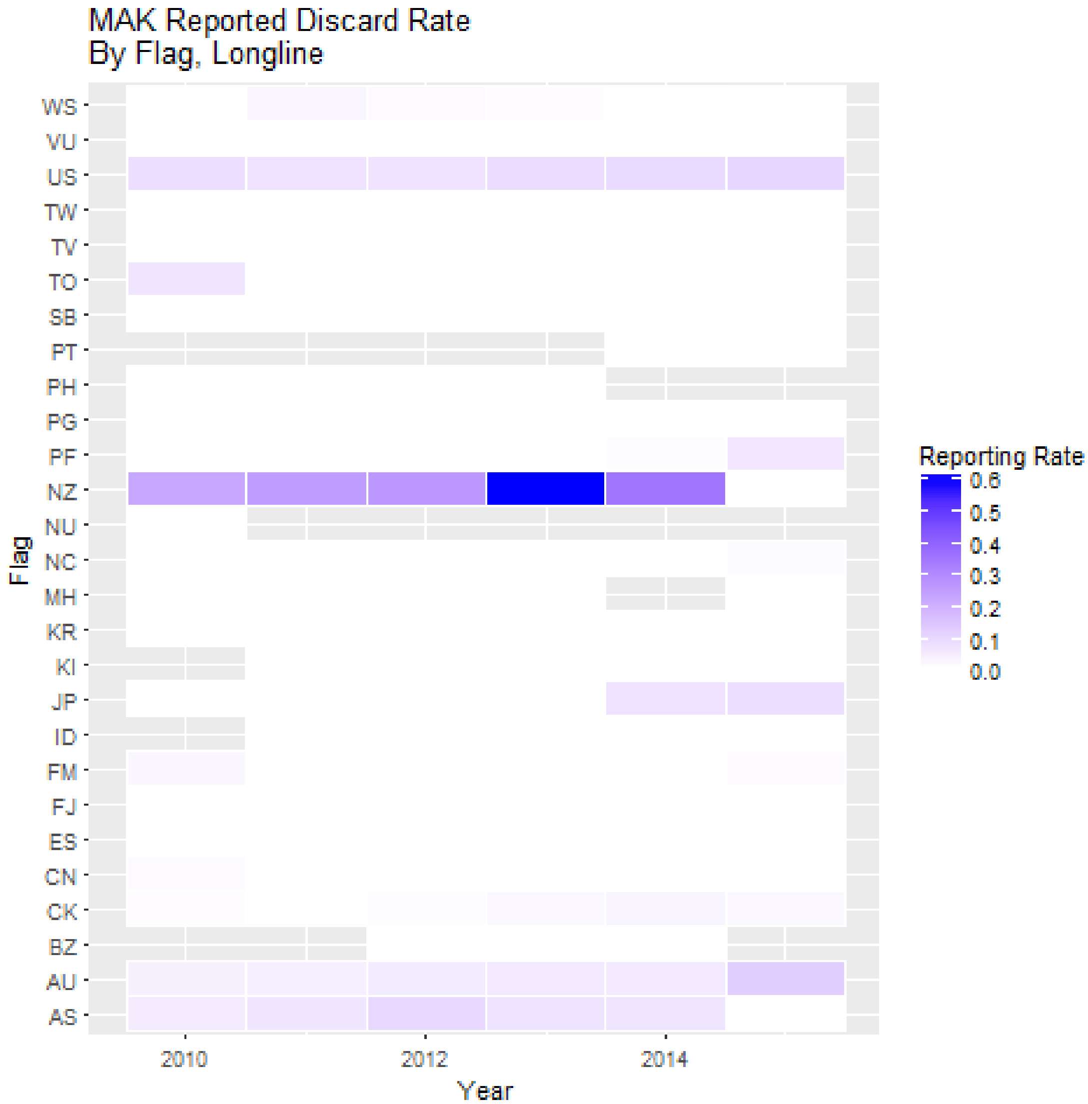
OCS Reported Discard Rate:



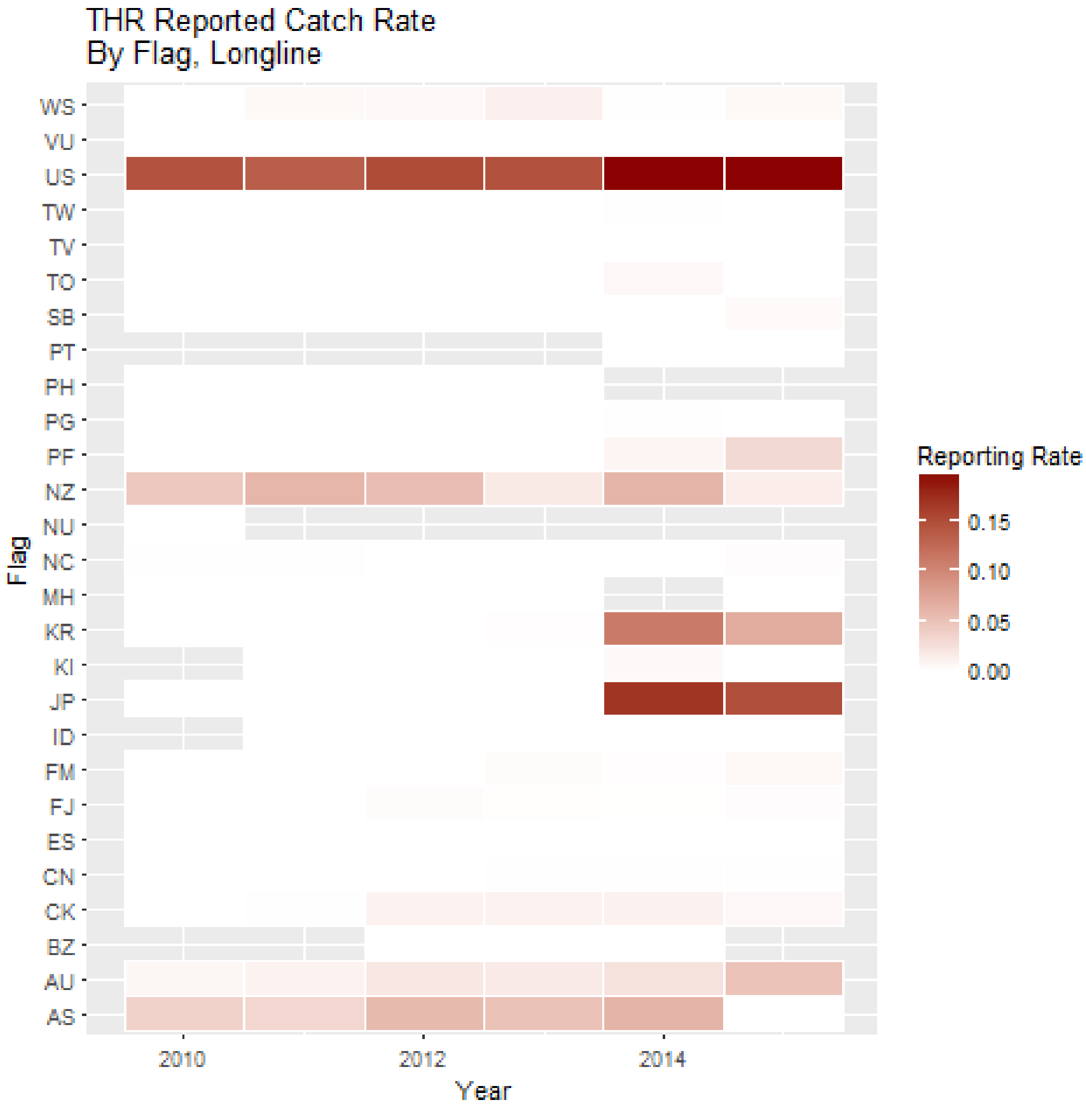
MAK Reported Catch Rate:



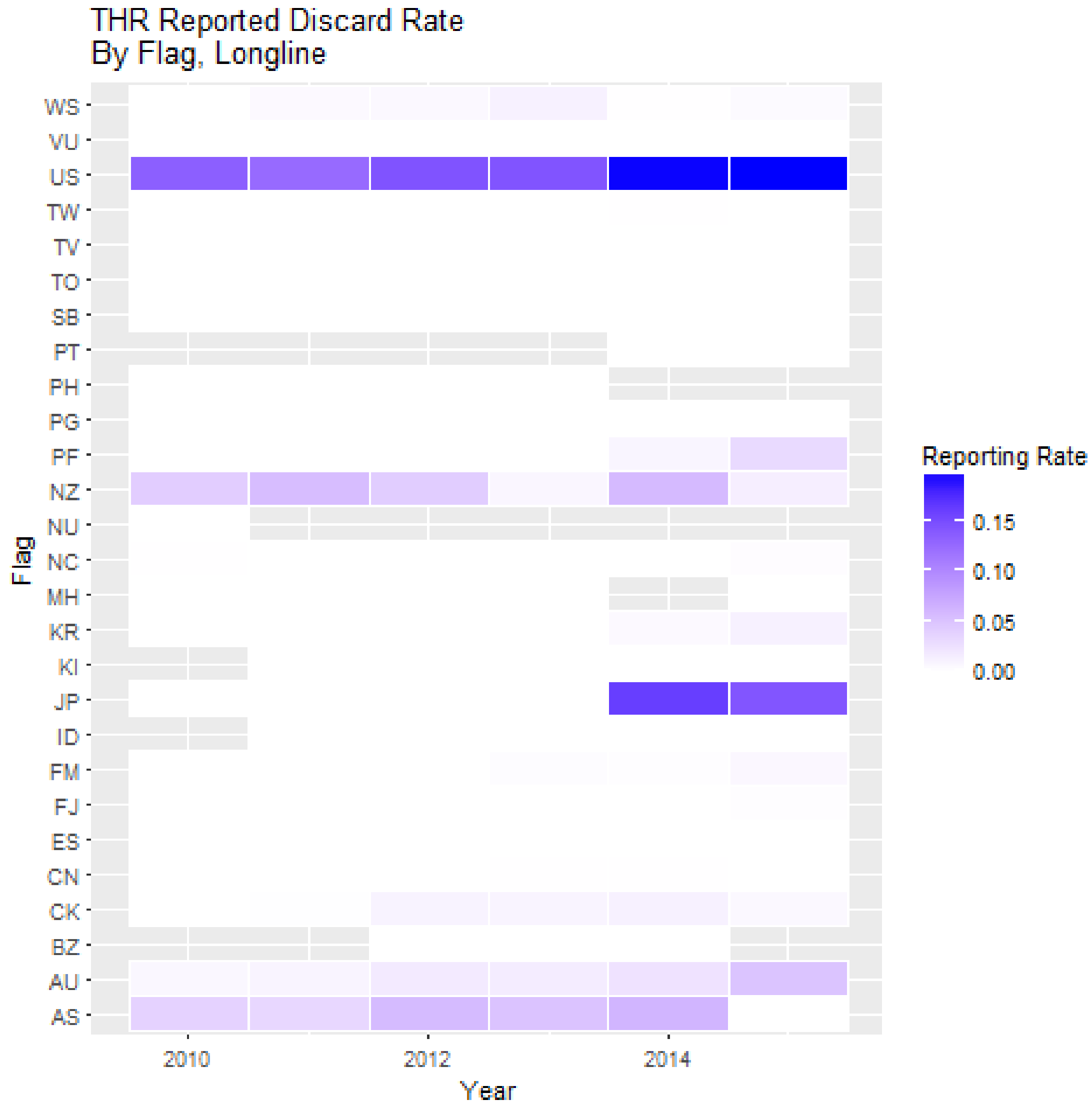
MAK Reported Discard Rate:



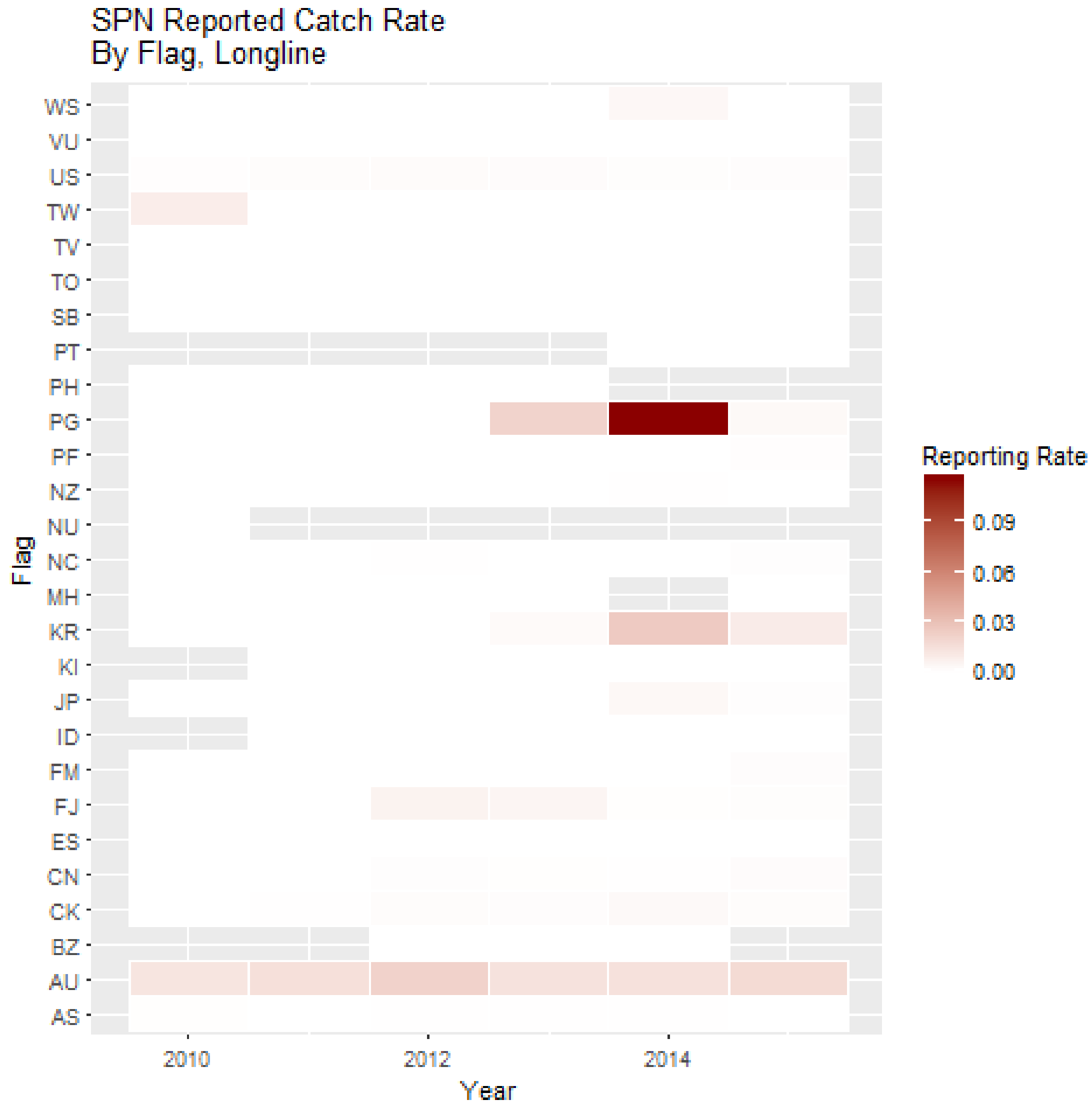
THR Reported Catch Rate:



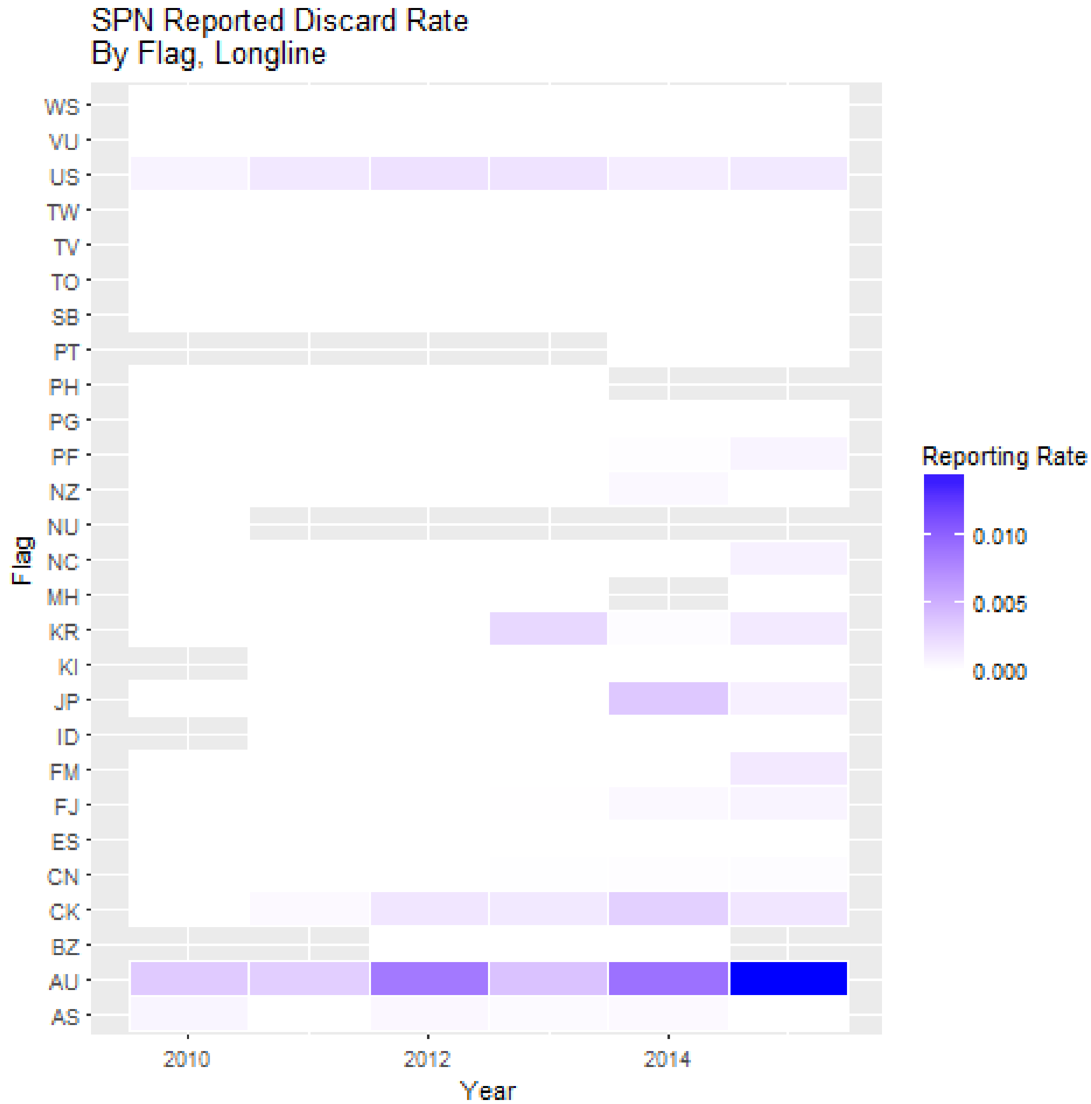
THR Reported Discard Rate:



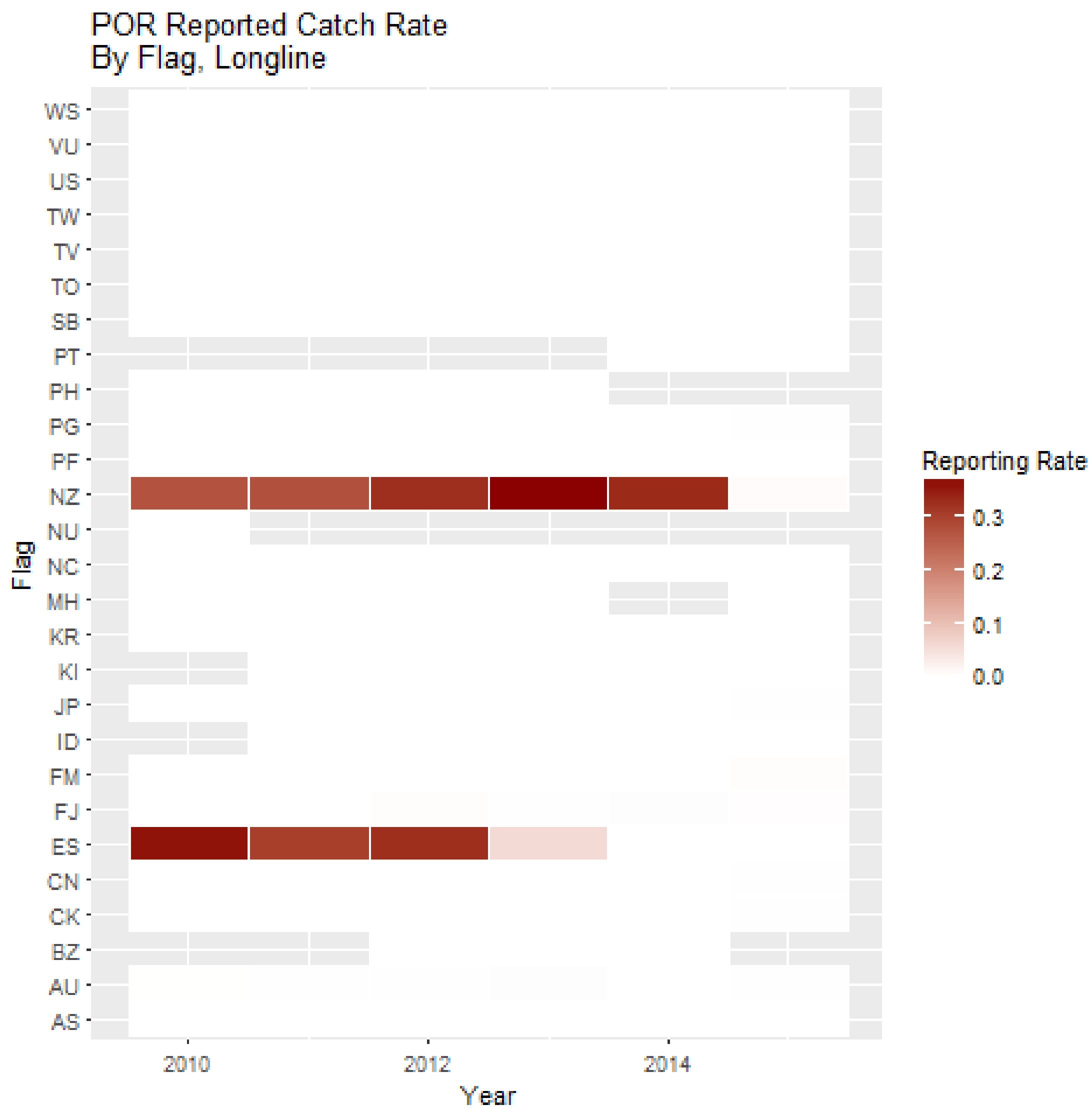
SPN Reported Catch Rate:



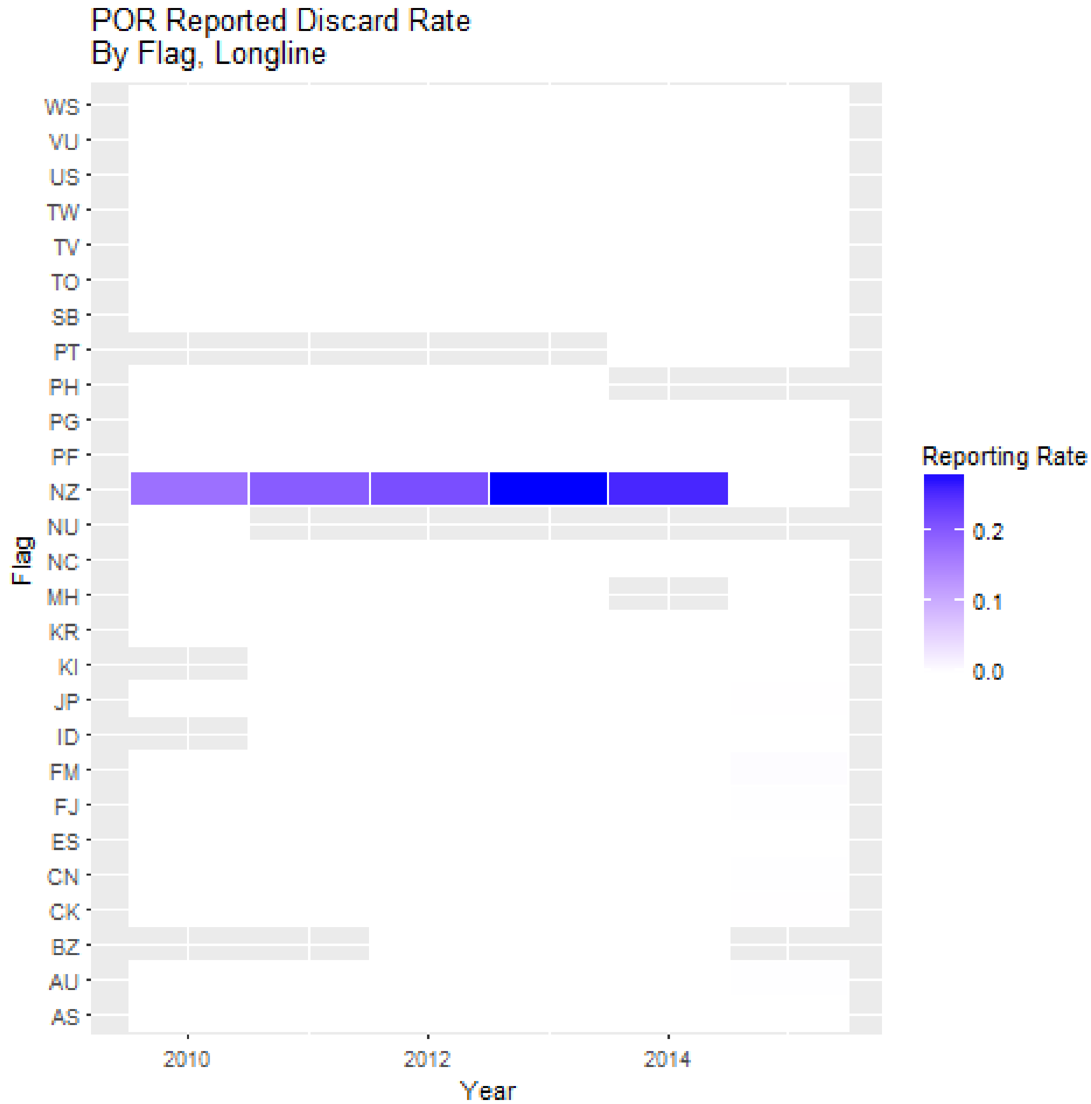
SPN Reported Discard Rate:



POR Reported Catch Rate:

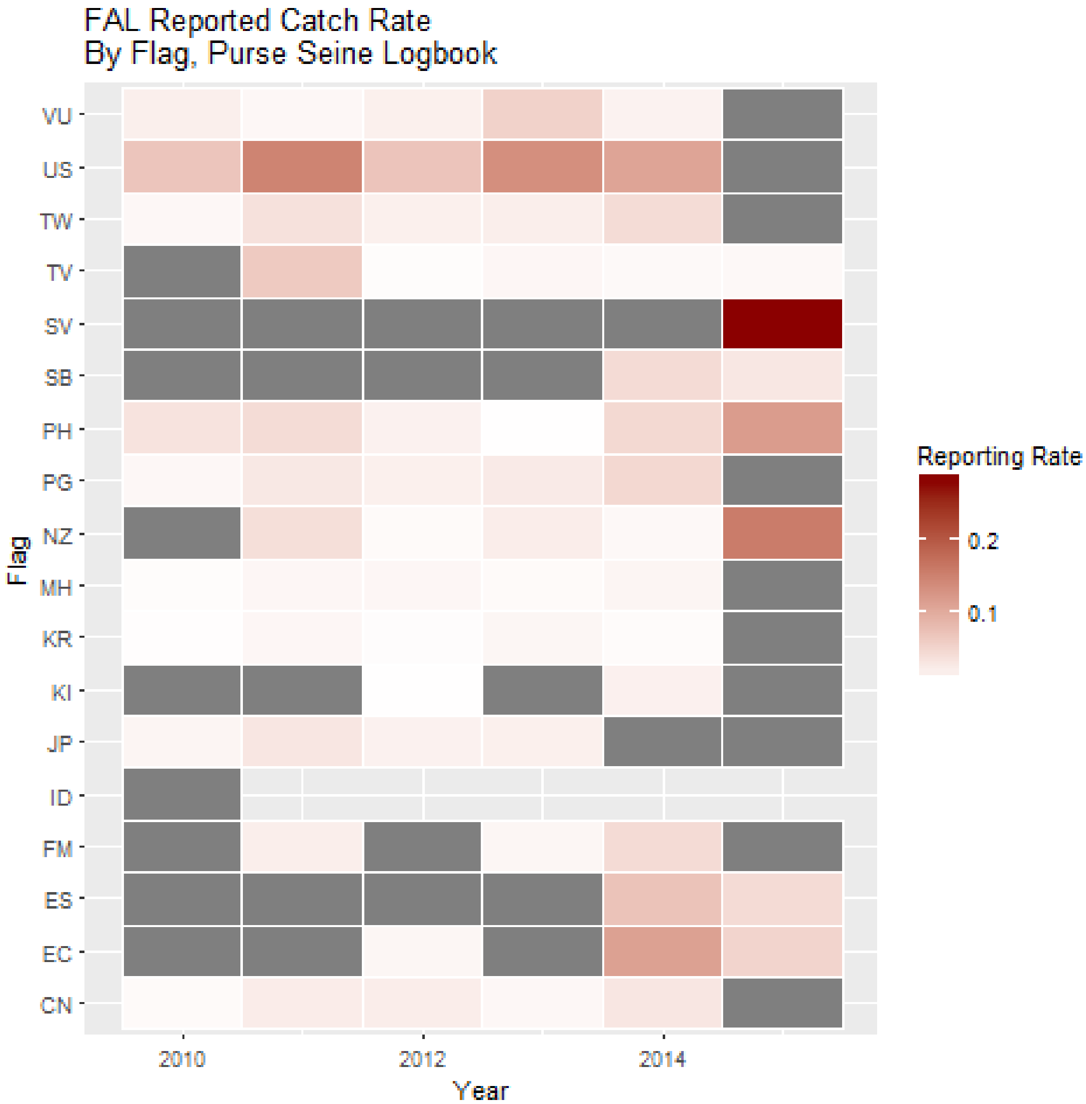


POR Reported Discard Rate:

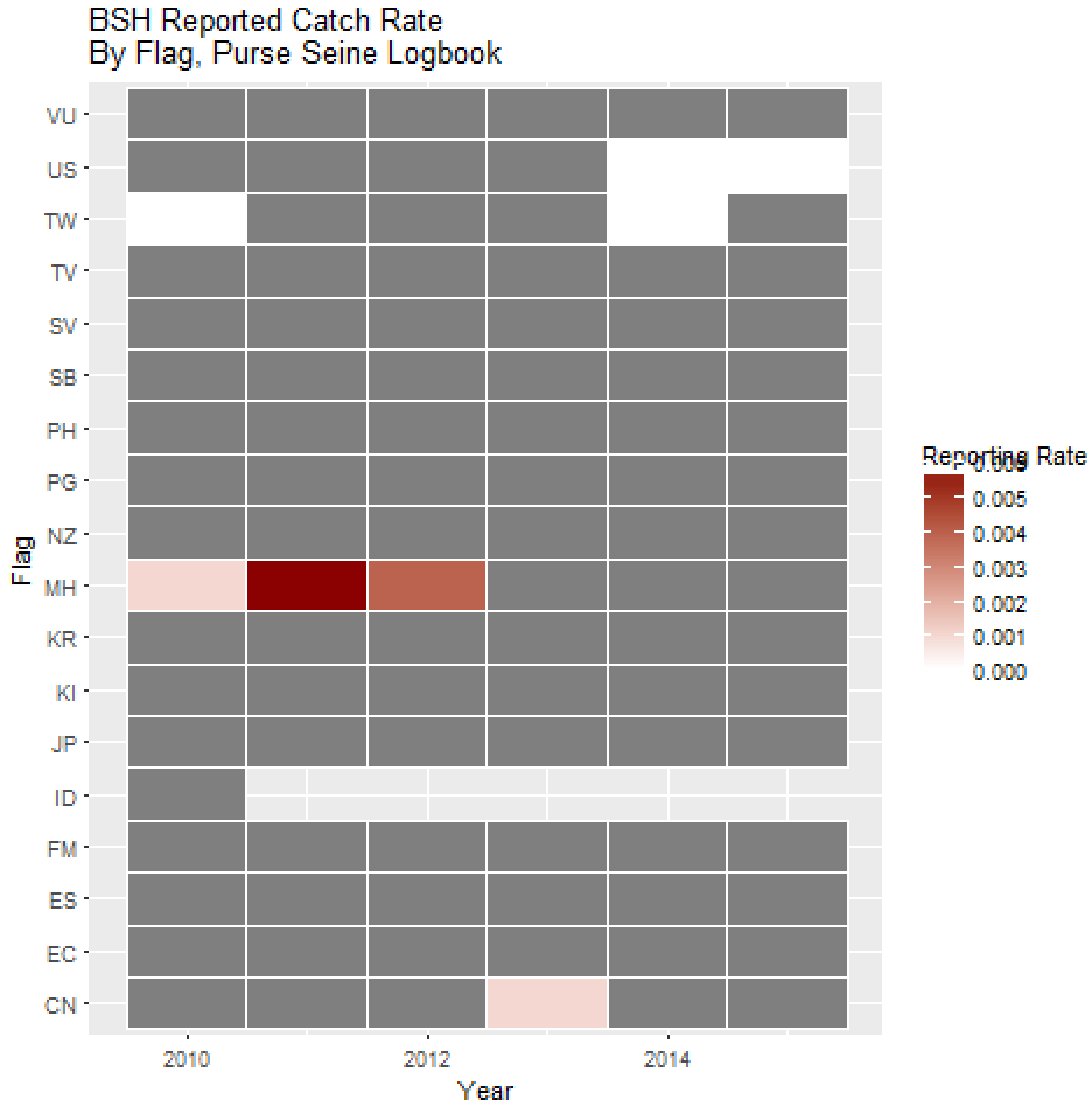


Annex 3 Reported Catch and discard rate by species and flag, Purse Seine

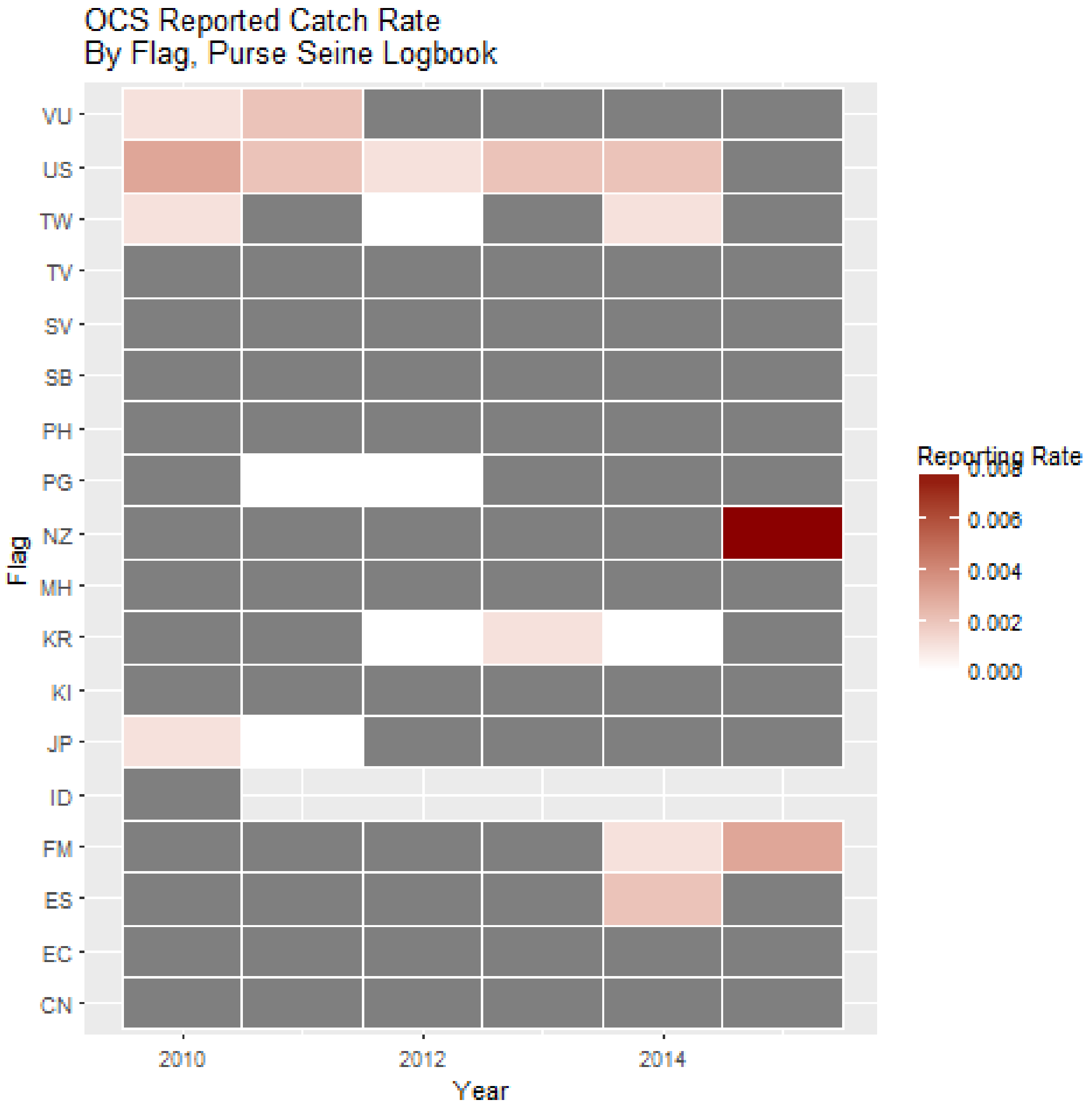
FAL Reported Catch Rate:



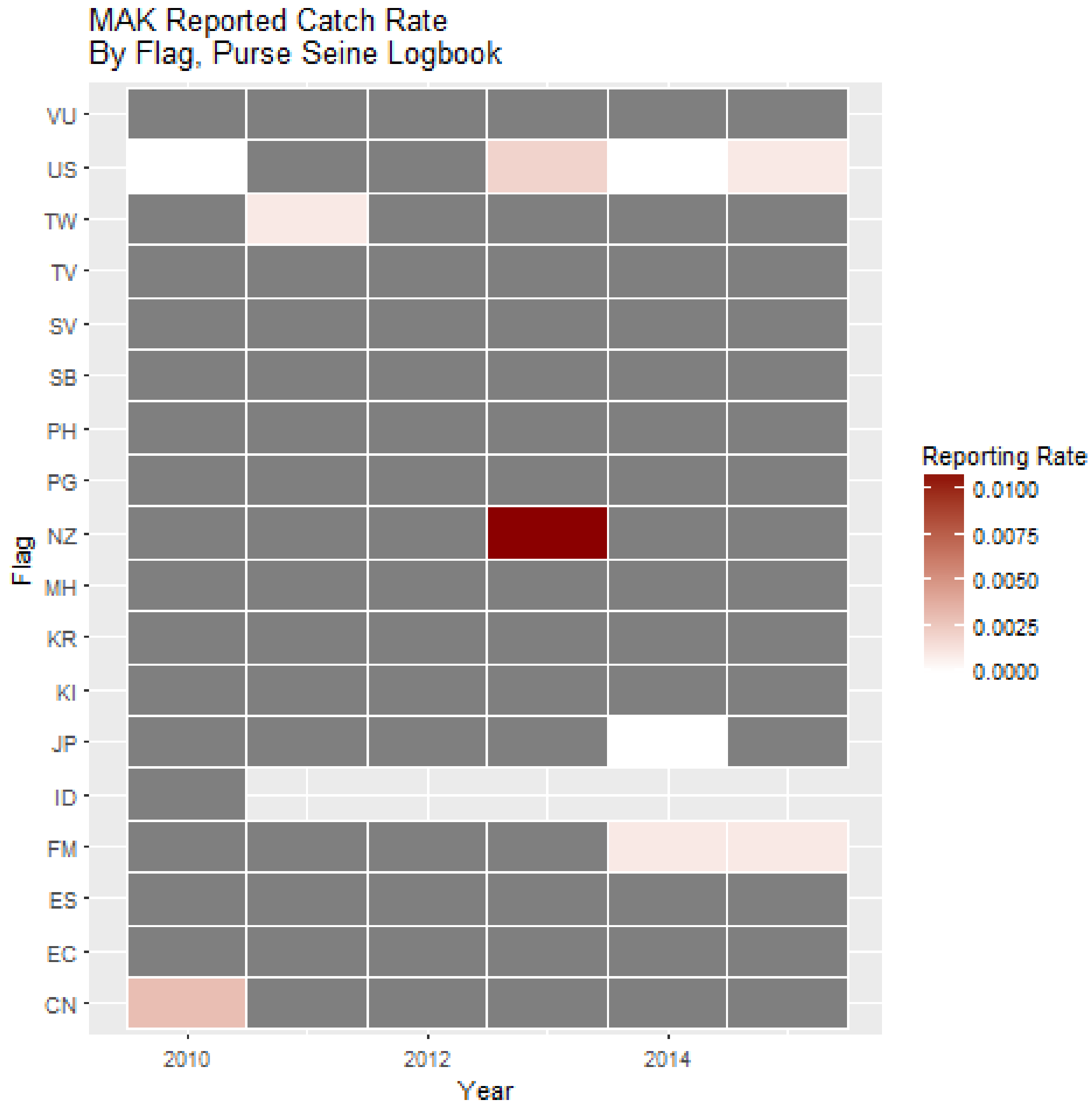
BSH Reported Catch Rate:



OCS Reported Catch Rate:



MAK Reported Catch Rate:



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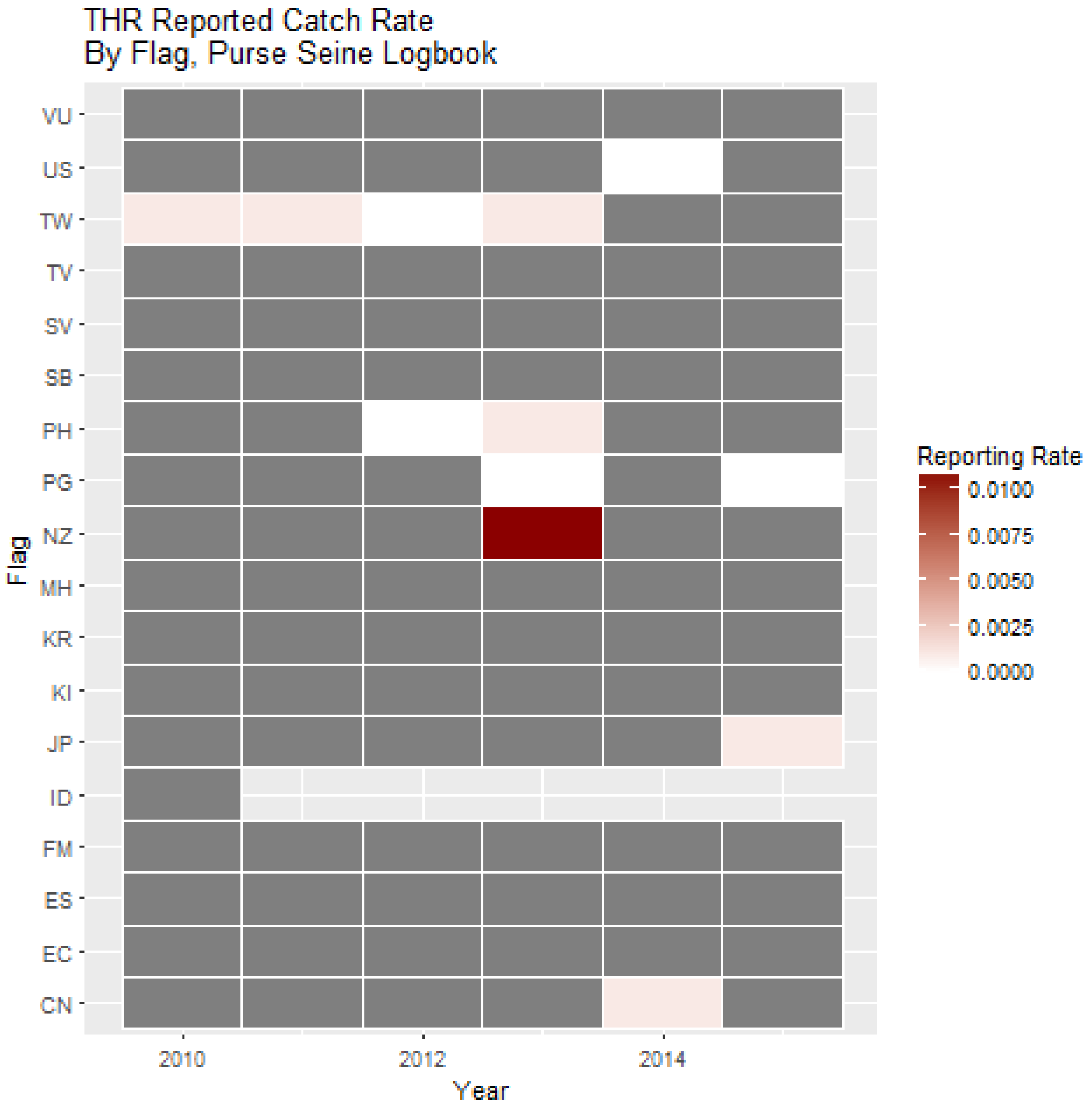
THR Reported Catch Rate:



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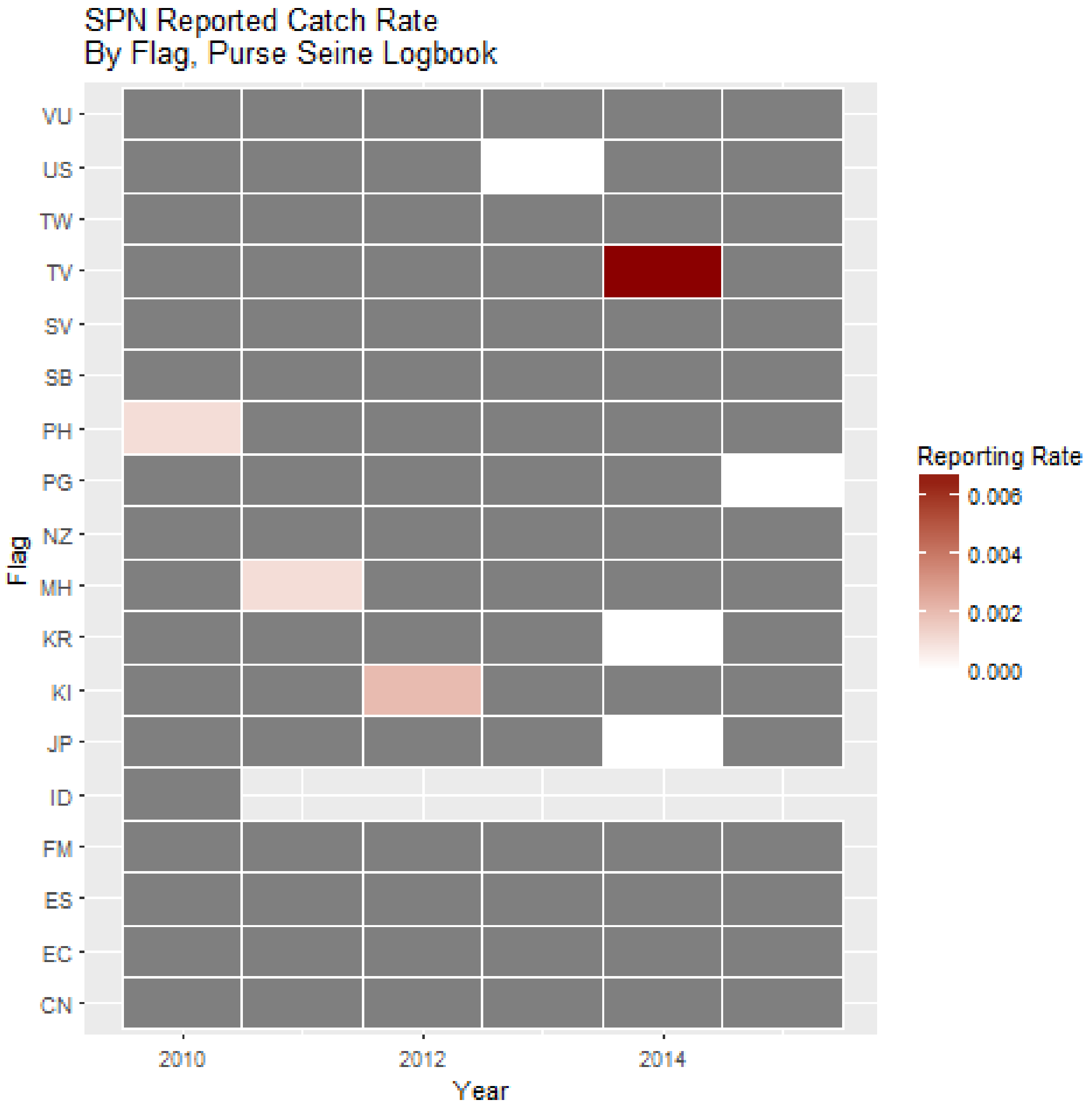
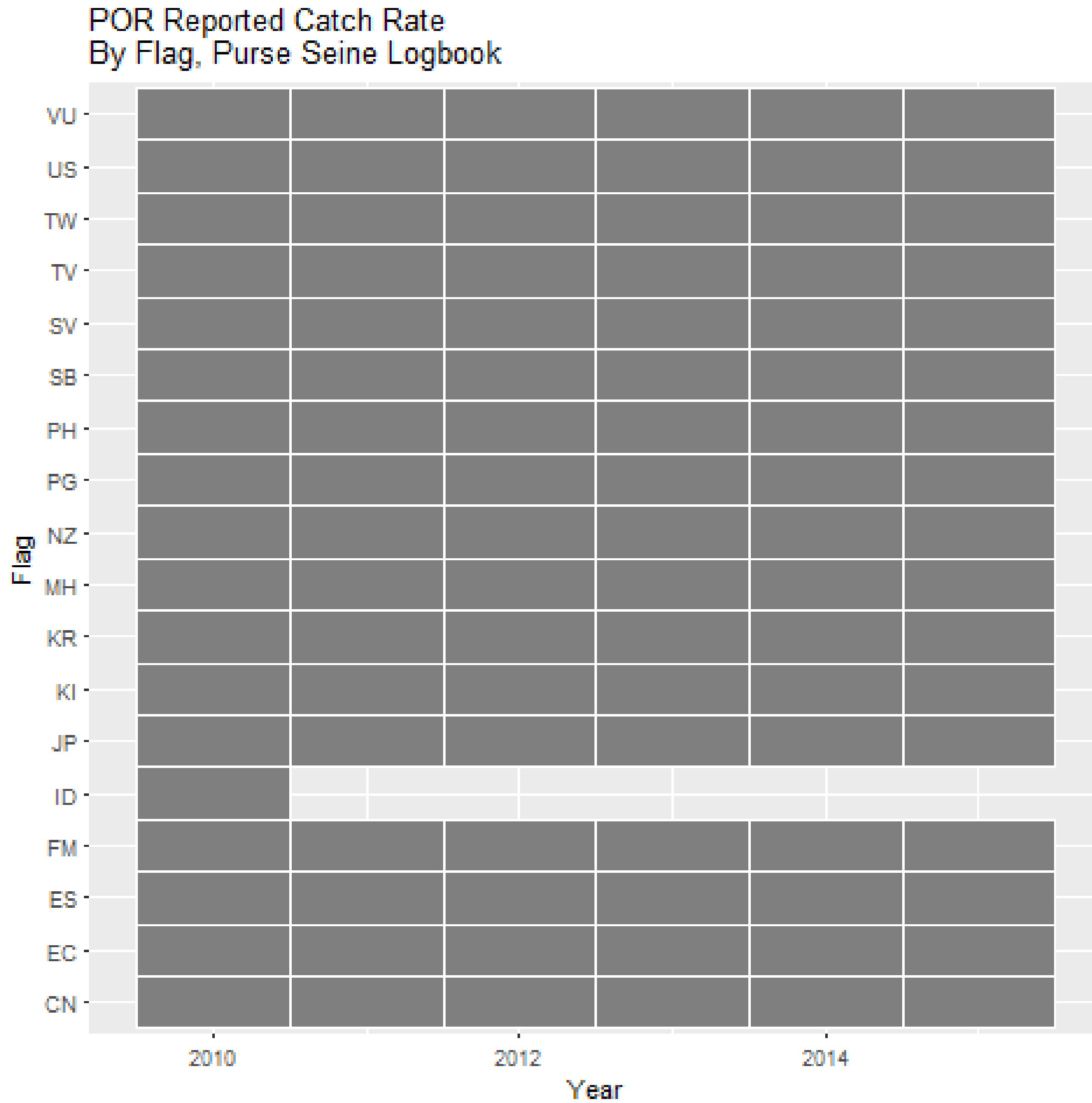
SPN Reported Catch Rate:



POR Reported Catch Rate:



RHN Reported Catch Rate: