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Estimation of fishing effort in the Southern Hemisphere

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Malcolm P. Francis,
Simon D. Hoyle

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Seabird bycatch in commercial fisheries has become a major issue that has prompted considerable worldwide research and mitigation effort. New Zealand has played a leading role in such work, largely because a high proportion of the world's seabird species breed here. Several recent New Zealand studies have assessed the risk of commercial fisheries operating within the New Zealand Exclusive Economic Zone (EEZ) to seabirds that breed in the New Zealand region. This study underpins an expanded risk assessment of the impact of fisheries on seabirds throughout the Southern Hemisphere (SH). The objective was to estimate the total high seas effort expended in the SH by the main fishing methods likely to impact seabirds (surface longline SLL, bottom longline BLL, and trawl TWL). These estimates will be used in a subsequent quantitative risk assessment of SH seabirds.

Fishing effort data were sourced from five tuna Regional Fisheries Management Organisations (RFMOs) and five non-tuna RFMOs having at least partial jurisdiction over SH waters. Although the RFMO areas of responsibility cover most of the SH high seas waters, significant gaps occur in the southwestern Atlantic Ocean and the northern Indian Ocean west of Indonesia. Total SLL effort increased steadily to 1100 million hooks in 2003, and then fluctuated between 780 and 1133 million hooks per year. BLL effort has been relatively constant at an average of 63 million hooks per year since 2005. Trawl effort increased to a peak of over 17 000 tows in 2010, followed by a drop to an average of 13 000 tows since then.

SLL fishing effort has been distributed mainly between the Equator and 45 ^{o}S, and throughout the SH. Hotspots of fishing intensity included the tropical Pacific, Indian and Atlantic oceans, southern Africa, and northeastern New Zealand. By contrast, BLL fishing effort occurred mainly in higher latitudes between 45 ^{o}S and 80 ^{o}S. High intensity fishing areas occurred around Kerguelen, Heard and McDonald Islands in the southern Indian Ocean, South Georgia Island in the South Atlantic Ocean, and the Ross Sea in Antarctica. Trawl fishing effort occurred widely through the eastern Pacific Ocean off South America, the western Indian Ocean off southeastern Africa, the Tasman Sea, and the Southern Ocean southeast of South America.

To our knowledge, this is the first attempt to compile estimates of total fishing effort for the major fishing methods operating in the entire SH. Nevertheless, the effort estimates provided here under-estimate the true values substantially. Major limitations and sources of bias in the estimates are: omission of some national EEZ effort; incomplete data provision by RFMO members; incomplete reporting of effort; confidentiality issues resulting in the probable underestimation of SLL effort data provided for a number of regions, particularly the Southern Ocean, South Atlantic Ocean, southern Indian Ocean and possibly the western and central Pacific Ocean; and lack of vessel flag information for some datasets.

These limitations and data availability issues mean that the effort totals compiled here are biased low (sometimes substantially) in some regions and times, although the degree of under-estimation has probably declined through time. The next step in this project will compare effort data compiled from Vessel Monitoring System data by Global Fishing Watch with the effort totals reported here in an attempt to identify regions and time periods for which our data substantially underestimate total effort. This will enable adjustments to be made to the effort totals for use in the planned SH seabird risk assessment.

1. INTRODUCTION

Seabird bycatch in commercial fisheries has become a major issue that has prompted considerable worldwide research and mitigation effort (Anderson et al. 2011). New Zealand has played a leading role in such work, largely because a high proportion of the world's seabird species breed here. Several recent New Zealand studies have assessed the risk of commercial fisheries to seabirds that breed in the New Zealand region (e.g., Baird & Gilbert 2010, Dillingham & Fletcher 2008, Sharp et al. 2011, Richard & Abraham 2013a, 2013b, 2015, Richard et al. 2017). These studies have focused on the effects of fisheries operating within the New Zealand Exclusive Economic Zone (EEZ).

The National Plan of Action – Seabirds (Ministry for Primary Industries 2013) is the key New Zealand government policy for managing interactions between seabirds and fisheries. One goal of the NPOA is for New Zealand to work with international agencies and jurisdictions in order to reduce the mortality of New Zealand seabirds in global fisheries. This study extends the New Zealand risk assessment to consider the impact of global fisheries on the seabird species that breed in New Zealand and migrate beyond New Zealand waters. This assessment will have several outcomes. First, seabird mortalities that occur in New Zealand waters will be placed in a global context. This will help to prioritise management actions within the New Zealand region. Second, it will improve collaboration on global seabird issues with international agencies and organisations. This will give New Zealand more opportunity to engage internationally to reduce bycatch of seabirds that breed in New Zealand.

To date, most large-scale estimates of seabird bycatch have been derived by scaling up observed catch rates to total fishing effort (e.g., Anderson et al. 2011, Klaer 2012), with few researchers using model-based approaches (e.g., Yeh et al. 2013, with commentary by Phillips 2013). The method developed for New Zealand seabird risk assessments allows for species-specific assessment of bycatch, using overlap between seabird distributions and fishing effort to constrain the estimates (Richard & Abraham 2013a, 2013b, 2015, Richard et al. 2017). Compared to the approaches that have been used elsewhere, this approach is relatively sophisticated. Importantly, population information and fisheries mortalities are included within the same quantitative framework, allowing the long-term impact of the mortalities on seabird populations to be assessed. The risk assessment framework allows for total risk to be disaggregated among the component fisheries, and by spatial region, allowing for a clear prioritisation of management responses. Bringing international fisheries and seabird bycatch data into this framework will greatly increase understanding of the global seabird bycatch problem.

The overall objectives of this project are:

1. Evaluate relative exposure to commercial fisheries for seabird populations by applying a seasonally-disaggregated spatial overlap approach (i.e. accessing global seabird spatio-temporal distribution data and compiling comprehensive global fisheries effort databases).
2. Apply estimates of population Potential Biological Removal (PBR) (from the updated New Zealand EEZ seabird risk assessment, including uncertainty) and species- or guild-specific estimates of seabird vulnerability (i.e. as estimated in the updated New Zealand EEZ seabird risk assessment, modified to the extent possible by data indicative of relative seabird bycatch rates in comparable fishing effort inside versus outside the New Zealand EEZ, including uncertainty) to estimate global fisheries risk for New Zealand seabird populations.
3. For each New Zealand seabird population estimate what proportion of global fisheries risk is attributable to mortalities occurring inside versus outside the New Zealand EEZ, and what proportion is likely to be unaccounted for in the analysis (e.g. due to incomplete global fisheries data or risk from illegal, unreported and unregulated fishing).
4. For that portion of species risk outside the New Zealand EEZ, summarise the source of that risk to the extent possible, for example by Regional Fisheries Management Organisation (RFMO) (or other relevant management agency), and by fishery group, geographic area, season, vessel size, and other relevant categories.

The geographical scope of this study is restricted to the Southern Hemisphere (SH). The study is being carried out as a joint contract between the National Institute of Water and Atmospheric

Research (NIWA) and Dragonfly Data Science (Dragonfly). NIWA's involvement is restricted to objective 1, with the remaining objectives being carried out by Dragonfly in conjunction with other partners. Furthermore, in discussion with Fisheries New Zealand, Dragonfly will compile seabird distribution and bycatch data, leaving NIWA to obtain and summarise fishing effort data. In this report, we address the fishing effort requirement of objective 1. The remaining objectives will be addressed elsewhere; a preliminary risk assessment of albatrosses in SH longline fisheries has already been produced (Ochi et al. 2018).

2. METHODS

2.1 Data constraints

Data limitations and practical considerations constrained our collection of SH fishing effort data in several ways:

1. Data were sourced mainly from the high seas regions of the SH (i.e. those sea areas beyond the 200-nautical mile national EEZs). Some RFMOs, especially tuna-RFMOs (Table 1), also provided within-EEZ data in their extracts. The rules about data submission vary among RFMOs, making it difficult to generalise. For example, IOTC rules (Resolution 13/03) state that members need to report all effort for vessels over 24 m long plus effort for vessels under 24 m if they fish outside the EEZ of their flag state; hence the IOTC data extract omits data for vessels shorter than 24 m fishing within their own EEZ. Although it would be desirable to source and include all within-EEZ effort in this study, that was not practical because in many cases, that would require separate data requests to the large number of nations involved (particularly island nations of the Pacific and Indian oceans).
2. Most RFMOs impose confidentiality rules on the supply of fishing effort and catch data. Usually, this takes the form of a '3-vessel' rule under which data are only published if three or more vessels were operating in a given spatial and temporal grid cell. This causes under-estimation of total effort. If total fishing effort can be obtained for a larger spatial and temporal grid, thus avoiding the need to invoke 3-vessel rules, the finer-scale data can then be scaled up to the total effort.
3. Some RFMOs do not hold observer data, have received observer data from only some convention members, or have extremely low observer coverage. Hence, observer coverage was not readily available or useful and is not reported here.
4. Data for pot and jig fishing methods were omitted because they were not consistently available across all RFMOs and these methods are not thought to contribute significantly to seabird bycatch. Other fishing methods (e.g. handlines, dahn lines, tuna purse seine and set net) were not considered here.

2.2 Data extracts

Fishing effort data were sourced from five tuna RFMOs and five non-tuna RFMOs having at least partial jurisdiction over SH waters (see Table 1 for RFMO abbreviations). Tuna RFMOs are responsible for the management of tunas and other pelagic fish species, whereas non-tuna RFMOs are responsible for management of other, generally demersal, fish species. The tuna RFMOs cover all oceans that contain commercially-fished tunas, and they overlap with each other in some areas, notably WCPFC overlaps with IATTC in the central-eastern Pacific, and CCSBT overlaps with IOTC, WCPFC and ICCAT (Figure 1). Except for SWIOFC, the non-tuna RFMOs are contiguous with no overlaps (Figure 2). However, they do not cover the entire SH: significant gaps occur in the southwestern Atlantic Ocean and the northern Indian Ocean west of Indonesia.

We sought the following data from 1 January 2005 (for non-tuna RFMOs) or from the beginning of the time series (for tuna RFMOs) to 31 December 2016 for all fishing effort south of the Equator:

- Fishing location (5 × 5 degree latitude/longitude cells)
- Calendar year
- Quarter (Quarter 1 = January to March, etc)

- Gear type
- Flag
- Target species
- Fishing effort (numbers of vessels, fishing events, tows, sets, hooks, and fishing duration, depending on fishing method)

Anticipating that some RFMOs may face confidentiality issues in providing data at high spatial and temporal resolution, we also sought a second data extract having the same fields as the first, but at a lower spatial and/or temporal resolution that triggered fewer confidentiality rules. This second extract could then be used to scale up the data from the first extract to account for missing data.

Surface longline data from four of the tuna RFMOs were downloaded from websites as follows:

- Effort data for parties reporting to CCSBT were obtained from the website: https://www.ccsbt.org/en/content/sbt-data.
- Effort data for the eastern Pacific were obtained by download from the IATTC website: https://www.iattc.org/PublicDomainData/PublicLLTunaBillfish.zip and https://www.iattc.org/PublicDomainData/PublicLLShark.zip
- Atlantic Ocean effort data were obtained from the Task II catch and effort database on the ICCAT) website https://www.iccat.int/en/accesingdb.htm.
- Indian Ocean effort data were obtained from the IOTC website: http://www.iotc.org/documents/ce-longline.

Requests for data were sent to the remaining tuna RFMO (WCPFC) and five non-tuna RFMOs. Initial requests were sent in May 2018, and follow-up requests were made in July–October 2018 to obtain missing data or to clarify data extracts.

2.3 Data processing

Overlap between CCSBT and other tuna RFMO datasets (ICCAT in the Atlantic, WCPFC in the western Pacific and IOTC in the Indian Ocean), was dealt with as follows. Note that the CCSBT dataset does not include all the data from the overlapped areas, because some fleets only report data to CCSBT for sets that caught some southern bluefin tuna (*Thunnus maccoyii*).

- Starting with the CCSBT dataset, progressively add IOTC, ICCAT, IATTC, and WCPFC data. When adding each dataset, merge by the strata latitude, longitude, flag, year, and month (or quarter). Select and retain the larger reported effort in each stratum and record the RFMO providing the larger effort as the source.
- Use month stratification for all tuna RFMOs except WCPFC, which reported data by quarter and was therefore added last.
- Merge the IATTC shark dataset with the (standard) IATTC tuna and billfish dataset, as above. The ‘shark’ dataset contains effort that caught no tunas or billfish.
- WCPFC provided a more complete dataset without a flag field to avoid confidentiality issues. After merging the WCPFC dataset that has a flag field with those from other tuna RFMOs, merge the version of the WCPFC dataset that has no flag field. If the total effort is higher in the latter, calculate the difference and add it in a new stratum with flag ‘Unknown’ (UNK).

Vessel flag was standardised to the 3-character International Organization for Standardization country codes using the R package *countrycode* (Appendix 1). Location data were converted to 5 × 5 degree cells and dates were converted to quarters if required. Effort data were then summed by RFMO, method, flag, year, quarter, and 5 × 5 cell. Effort variables used were the number of hooks for surface longline (SLL) and bottom longline (BLL), and the number of tows for trawl (TWL). Some RFMOs also provided trawl duration but that was not consistently available. Effort data were plotted by year and a range of covariates to identify possible missing data.

For mapping purposes, fishing effort was scaled by the area of sea contained in each 5 × 5 degree cell to create an effort intensity variable. This adjusts for the decrease in cell area with increasing latitude, and reduced sea areas in cells that include land (Appendix 2).

3. RESULTS

3.1 Data availability and issues

CCSBT

The CCSBT dataset omitted data from strata that included fewer than three vessels, but no information on total effort was available for re-scaling, meaning that effort is probably underestimated. Taiwanese data prior to 1993 were deleted to remove some unrealistically high values.

IATTC

IATTC resolution C-15-07 states that the year, month, flag and five-degree aggregation data are in the public domain, so strata that included fewer than three vessels were not omitted. IATTC data were provided in two datasets: the tuna/billfish longline and shark longline datasets. Effort is expressed as the total number of hooks for any aggregation of year, month, flag and 5 × 5 degree cell with reported shark or tuna/billfish capture. Some aggregations may have tuna/billfish capture but no shark capture, and vice-versa.

ICCAT

The ICCAT dataset omitted data from strata that included fewer than three vessels, but no information on total effort was available for re-scaling, meaning that effort is probably underestimated.

IOTC

In cases when an individual vessel can be identified, the data were aggregated prior to release by time, area or flag to preclude such identification. Thus, no catch and effort data were omitted from the IOTC dataset. A small amount of IOTC effort was reported in days rather than hooks, and this was omitted.

WCPFC

The WCPFC extract that included flag as a field omitted data from strata that included fewer than three vessels to avoid potential identification, resulting in effort under-estimation. A second extract that excluded flag as a field had greater numbers of hooks in all years, and was used to fill in some missing data. However, the second extract is also incomplete because of the 3-vessel rule.

CCAMLR

CCAMLR provided TWL and BLL data. No confidentiality issues existed, and no data were excluded for that reason. CCAMLR excluded some illegal, unreported and unregulated (IUU) fishing data because of doubt about their accuracy. The CCAMLR convention area, and therefore its data extracts, includes national EEZs contained within its boundaries (see Figure 2).

SEAFO

No response was received from SEAFO to our data request.

SIOFA

For confidentiality reasons, and because of the small amount of fishing effort in many 5 × 5 cells, the SIOFA extract did not include flag. Flag was therefore set to unknown (UNK) in this study. The extract also lacked target and duration of tows. Almost half the BLL records (49% accounting for 27% of sets) lacked hook numbers, resulting in a major under-estimation of effort. Similarly, 37% of

TWL records lacked number of tows. Vessel logbooks for a major fishing flag for 2006 were lost, resulting in further under-estimation of effort in that year.

SPRFMO

SPRFMO provided data at 5 × 5 degree cell spatial resolution and quarterly temporal resolution for all flags except New Zealand. Data for the latter were obtained directly from Fisheries New Zealand and merged with the SPRFMO data. No target information was available for Australian flag effort.

To assess the completeness of the fine-resolution data extract provided by SPRFMO, we compared the annual effort totals derived from that extract (i.e. summed across 5 × 5 cells and quarters) with annual effort (all areas and quarters combined) reported independently by Members to SPRFMO (Table 2). For BLL, there was a close match between the extract and the overall totals, with the only significant discrepancy occurring in 2009 when there were substantially more hooks in the extract than in the overall total. For TWL, large amounts of effort were missing from the extract in 2007–2008; inspection of the totals by flag revealed that this was because of an absence of extract data from China, European Union and Vanuatu in 2007, and from China and Vanuatu in 2008. From 2009 onwards, there was moderate to good agreement between the two datasets, but with some under-reporting in the data extract in 2012. The overall total for 2016 was well below the data extract total for that year because of an absence of data from Vanuatu in the overall total. Thus, the data extracts appear to capture reported fishing effort well from 2009 onwards, except for TWL in 2012.

SWIOFC

No response was received from SWIOFC to our data request. However, it is unlikely that this affects our effort estimation substantially because apart from its inclusion of EEZ waters, the SWIOFC convention area completely overlaps the western half of the SIOFA convention area. Thus, the SIOFA data extract should capture the high seas data reported to SWIOFC.

3.2 Annual patterns of fishing effort

Estimated annual totals of fishing effort by RFMO and method are shown in Figures 3 and 4. The time series of SLL effort began in the 1950s and increased through until at least the 1980s; thereafter, effort continued increasing in some RFMOs, but eventually stabilised or declined from the 2000s in all RFMOs except WCPFC. BLL effort was dominated by CCAMLR, with relatively minor amounts contributed by SIOFA and SPRFMO. TWL fishing effort was also dominated by CCAMLR, but there were significant amounts of SIOFA and SPRFMO effort. CCAMLR TWL effort was relatively stable from 2005 to 2016, SIOFA effort increased up to 2010 and then stabilised, and SPRFMO effort declined from 2009 (note that SPRFMO effort was under-estimated in 2007 and 2008 as discussed in Section 3.1).

Total SLL effort was dominated by Japan and Taiwan, with Korea, Indonesia and China forming a second tier (Table 3). Japan was the dominant flag until the 1980s, with Taiwan and Korea becoming important from the 1970s and Indonesia from the 1980s. From the 1990s, Taiwan became the dominant flag as Japanese effort declined. Korean effort fluctuated considerably through time. Chinese effort increased steadily in the 2000s. In the last three years of data (2014–2016), Taiwan, China, Indonesia and Japan flagged vessels set the most hooks (in descending order). Many other flags entered the fishery from the 1980s onwards. These rankings might be affected by a significant amount of effort expended by vessels of unknown flag.

BLL effort data are available from 2005, although SPRFMO effort only began in 2007. France has contributed most of the BLL effort throughout the time series, with Great Britain, Australia and New Zealand contributing lower amounts (Table 4).

TWL effort data are also available from 2005, but SPRFMO effort only began in 2007. The most important flags contributing TWL effort have varied considerably through time (Table 5). The early

years (2005–2010) were dominated by Korea, Japan, Poland, Australia, Vanuatu and Ukraine. Since 2011, the main fishing flags have been Korea and China, with smaller amounts of effort contributed by Australia, Chile, Norway, New Zealand, Ukraine and Vanuatu. These results are potentially biased by a large amount of effort from vessels of unknown flag since 2009 (Table 5).

The estimated SH annual totals of fishing effort by method are shown in Table 6 and Figure 5. SLL effort increased steadily to 1100 million hooks in 2003, and then fluctuated between 780 and 1133 million hooks per year. BLL effort has been relatively constant at an average of 63 million hooks per year since 2005. TWL effort increased to a peak of over 17 000 tows in 2010, followed by a drop to an average of 13 000 tows since then.

3.3 Spatial patterns of fishing effort

Historically, SLL fishing effort has been distributed mainly between the Equator and 45 ^{o}S, and throughout the SH (Figure 6). Hotspots of fishing intensity included the tropical Pacific, Indian and Atlantic oceans, southern Africa, and northeastern New Zealand. In the last three years (2014–2016), effort has become more concentrated in the tropical Pacific, especially around Indonesia, Solomon Islands and Fiji, with high latitude effort becoming relatively less important, although the hotspot off southeastern Africa remained.

By contrast, BLL fishing effort in 2007–2016 occurred mainly in higher latitudes between 45 ^{o}S and 80 ^{o}S (Figure 7). High intensity fishing areas occurred around Kerguelen, Heard and McDonald Islands in the southern Indian Ocean, South Georgia Island in the South Atlantic Ocean, and the Ross Sea in Antarctica. The most recent three-year period (2014–2016) showed a similar distribution of effort (Figure 7).

TWL fishing effort in 2007–2016 occurred widely through the eastern Pacific Ocean off South America, the western Indian Ocean off southeastern Africa, the Tasman Sea, and the Southern Ocean southeast of South America (Figure 8). High fishing intensity occurred around South Georgia Island, South Orkney Island and the Antarctic Peninsula. The most recent three years (2014–2016) showed a more-restricted distribution of trawl effort than for the longer time period (Figure 8).

4. DISCUSSION

To our knowledge, this is the first attempt to compile estimates of total fishing effort for the major fishing methods operating in the entire SH. Nevertheless, the estimates provided here under-estimate the true effort substantially. Major limitations and sources of bias in the estimates are:

1. Omission of large amounts of artisanal fishing effort. Only 'industrial' fishing effort has been estimated here.
2. Omission of some national EEZ effort.
3. Omission of South Atlantic BLL and TWL fishing effort north of the CCAMLR boundary. We were unable to obtain southeastern Atlantic effort data from SEAFO, and the southwestern Atlantic is not represented by a non-tuna RFMO. However, in future some of the missing data could be obtained by direct communication with individual nations; for example, with Brazil for their large surface longline fishing effort and with Falkland Islands for their large trawl fishing effort.
4. Incomplete data provision by RFMO members. Comparison of data extracts with other sources indicated that some members did not provide data to RFMOs, particularly in the earlier years of the time series (e.g. SPRFMO TWL effort, see Section 3.1). However, data provision to RFMOs appears to have improved through time, and this issue has become less important in recent years.
5. Incomplete reporting of effort. In some cases (notably SIOFA, see Section 3.1), information on hook numbers and tow numbers was not available for high proportions of the reported effort, so we could not include the effort in our totals. Data collection by Brazilian agencies is reported to have declined from about 2007 and ceased after 2012 (Barreto et al. 2016, 2017), resulting in a significant under-estimation of effort in recent years (note, however, that Brazilian SLL effort

data obtained from ICCAT appear to have begun declining even earlier, in the early 2000s [see Table 3]).

6. Confidentiality issues resulted in the probable underestimation of SLL effort data provided for a number of regions, particularly the Southern Ocean (CCSBT), South Atlantic Ocean (ICCAT), southern Indian Ocean (SIOFA) and the western and central Pacific Ocean (WCPFC). In the SIOFA Convention Area, relatively few vessels fished in many of the strata (i.e. 5 × 5 degree cell and quarter), and SIOFA did not provide flag information with its data extract. This compromises the usefulness of the SIOFA data for the seabird risk assessment, which is stratified by flag (E. Abraham, Dragonfly, pers. comm.). The three-vessel rule removes a higher proportion of effort in areas where there is less effort, so is likely to have more impact on SLL effort at higher latitudes.

The above limitations and data availability issues mean that the effort totals compiled here are biased low (sometimes substantially) in some regions and times, although the under-estimation has probably declined through time. The magnitude of any bias can be estimated in a number of ways. Other sources of total effort (e.g. member country reports of total fishing effort to RFMOs) might be available with which to assess the completeness of the data extracts, and scale up the effort totals accordingly; this approach was successfully applied to SPRFMO data in this study (see Section 3.1).

A better reality check would be to use estimates of high seas fishing effort, by method, from Vessel Monitoring System (VMS) data published online by Global Fishing Watch (GFW) (https://globalfishingwatch.org/map/). This would provide a cross-check against the magnitude and location of the recent fishing effort identified in the present study, although we recognise that not all vessels operate VMS, that some vessels periodically turn off their VMS, and that the fishing method and activity of vessels determined from the applied algorithms may be incorrect. The next step in this project, to be carried out by Dragonfly, will compare GFW fishing effort data with the effort totals reported here in an attempt to identify regions and time periods when our data substantially underestimate total effort. This will enable adjustments to be made to the totals for use in the planned seabird risk assessment.

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6. REFERENCES

Anderson, O.R.; Small, C.J.; Croxall, J.P.; Dunn, E.K.; Sullivan, B.J.; Yates, O.; Black, A. (2011). Global seabird bycatch in longline fisheries. *Endangered Species Research, 14(2)*, 91–106.

Baird, S.J.; Gilbert, D. J. (2010). Initial assessment of risk posed by trawl and longline fisheries to selected seabird taxa breeding in New Zealand waters. Final Research Report held by Fisheries New Zealand, Wellington, New Zealand.

Barreto, R.; Ferretti, F.; Flemming, J.M.; Amorim, A.; Andrade, H.; Worm, B.; Lessa, R. (2016). Trends in the exploitation of South Atlantic shark populations. *Conservation Biology 30*: 792–804.

Barreto, R.R.; Bornatowski, H.; Motta, F.S.; Santander-Netoe, J.; Vianna, G.M.S.; Lessa, R. (2017). Rethinking use and trade of pelagic sharks from Brazil. *Marine Policy 85*: 114–122.

Dillingham, P.W.; Fletcher, D. (2008). Estimating the ability of birds to sustain additional human-caused mortalities using a simple decision rule and allometric relationships. *Biological Conservation, 141(7)*, 1783–1792.

Klaer, N.L. (2012). Estimates of total seabird bycatch by Atlantic pelagic longline fisheries from 2003 to 2006. *Marine Fisheries Review, 74(3)*, 14–20.

Ministry for Primary Industries (2013). National Plan of Action – 2013 to reduce the incidental catch of seabirds in New Zealand Fisheries. Ministry for Primary Industries, Wellington. 59 p.

Ochi, D.; Abraham, E.; Inoue, Y.; Oshima, K.; Walker, N.; Richard, Y.; Tsuji, S. (2018). Preliminary assessment of the risk of albatrosses by longline fisheries. WCPFC Scientific Committee 14th regular session WCPFC-SC14-2018/EB-WP-09 Rev. 1. 24 p

Phillips, R.A. (2013). Requisite improvements to the estimation of seabird by-catch in pelagic longline fisheries. *Animal Conservation, 16(2)*, 157–158.

Richard, Y.; Abraham, E.R. (2013a). Application of Potential Biological Removal methods to seabird populations. *New Zealand Aquatic Environment and Biodiversity Report, 108.*

Richard, Y.; Abraham, E.R. (2013b). Risk of commercial fisheries to New Zealand seabird populations. *New Zealand Aquatic Environment and Biodiversity Report, 109.*

Richard, Y.; Abraham, E.R. (2015). Assessment of the risk of commercial fisheries to New Zealand seabirds, 2006–07 to 2012–13. *New Zealand Aquatic Environment and Biodiversity Report, 162.*

Richard, Y.; Abraham, E.R.; Berkenbusch, K. (2017). Assessment of the risk of commercial fisheries to New Zealand seabirds, 2006–07 to 2014–15. *New Zealand Aquatic Environment and Biodiversity Report, 191*.

Sharp, B.R.; Waugh, S.M.; Walker, N. A. (2011). A risk assessment framework for incidental seabird mortality associated with New Zealand fishing in the New Zealand EEZ. Unpublished report held by Fisheries New Zealand, Wellington.

Yeh, Y.M.; Huang, H.W.; Dietrich, K.S.; Melvin, E. (2013). Estimates of seabird incidental catch by pelagic longline fisheries in the South Atlantic Ocean. *Animal Conservation, 16(2)*, 141–152.

Tables

Table 1: List of tuna and non-tuna Regional Fisheries Management Organisations (RFMOs).

Type	Code	Regional Fisheries Management Organisation
Tuna RFMO	CCSBT	Commission for the Conservation of Southern Bluefin Tuna
	IATTC	Inter-American Tropical Tuna Commission
	ICCAT	International Commission for the Conservation of Atlantic Tunas
	IOTC	Indian Ocean Tuna Commission
	WCPFC	Western and Central Pacific Fisheries Commission
Non-tuna RFMO	CCAMLR	Commission for the Conservation of Antarctic Marine Living Resources
	SEAFO	South East Atlantic Fisheries Organisation
	SIOFA	Southern Indian Ocean Fisheries Agreement
	SPRFMO	South Pacific Regional Fisheries Management Organisation
	SWIOFC	Southwest Indian Ocean Fisheries Commission

Table 2: Comparison of 'extract' effort totals provided by SPRFMO in the fine-resolution data extract (5 × 5 degree cells and quarters) with overall 'Total' effort (all areas and quarters combined) reported independently by Members to SPRFMO. The ratio of the latter to the former is shown in bold font. Bottom longline effort is in thousands of hooks and trawl effort is in days fished.

Method	Data source	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Bottom longline	Extract	230	762	705	333	413	349	594	379	745	718
	Total	230	751	507	333	443	349	594	379	745	710
	Total/Extract	**1.0**	**1.0**	**0.7**	**1.0**	**1.1**	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**
Trawl	Extract	238	1476	2936	2006	1199	699	628	853	897	885
	Total	3385	3195	3014	1918	1263	853	698	911	904	574
	Total/Extract	**14.2**	**2.2**	**1.0**	**1.0**	**1.1**	**1.2**	**1.1**	**1.1**	**1.0**	**0.6**

Table 3: Southern Hemisphere reported surface longline fishing effort (millions of hooks).

Year	AGO	ARG	AUS	BLZ	BRA	CHN	COK	CUB	ESP	FJI	FSM	GBR	GIN	IDN	JPN	KIR	KOR	MDG	MDV	MUS	MYS	MYT	NCL	NIU	NZL	PAN	PHL	PNG	PRT	PYF	REU	RUS	SEN	SLB	SYC	THA	TON	TUV	TWN	UNK	URY	USA	VCT	VEN	VUT	WSM	ZAF	Total
1952	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.5
1953	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.7
1954	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	28.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.5
1955	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	27.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.7
1956	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	39.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	43.2
1957	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	51.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	55.4
1958	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	50.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	56.6
1959	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	61.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	66.7
1960	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	92.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	95.0
1961	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	123.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	129.3
1962	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	148.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	156.9
1963	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	172.8	0.0	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	183.8
1964	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	167.2	0.0	5.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	7.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	180.1
1965	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	175.3	0.0	11.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.7	12.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	202.5
1966	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	195.5	0.0	20.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.7	14.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	245.3
1967	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	170.4	0.0	29.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	24.7	14.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	240.0
1968	0.0	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	182.3	0.0	29.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	75.1	14.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	302.2
1969	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	171.1	0.0	31.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	88.9	11.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	303.7
1970	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	165.5	0.0	32.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	88.9	13.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	300.0
1971	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	176.0	0.0	49.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	119.7	14.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	359.8
1972	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	156.6	0.0	79.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	127.5	14.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	378.6
1973	0.0	0.0	0.0	0.0	0.0	0.0	2.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	182.8	0.0	108.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	132.8	12.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	439.0
1974	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	166.4	0.0	139.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	149.7	11.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	467.2
1975	0.0	0.0	0.0	0.0	0.8	7.4	0.0	3.3	0.0	0.0	0.0	0.0	0.0	0.0	163.0	0.0	60.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	110.3	13.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	358.6
1976	0.0	0.0	0.0	0.0	1.2	24.1	0.0	2.6	0.0	0.0	0.0	0.0	0.0	0.0	189.1	0.0	89.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	109.8	17.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	433.6
1977	0.0	0.0	0.0	0.0	2.8	19.4	0.0	2.6	0.0	0.0	0.0	0.0	0.0	0.0	190.8	0.0	106.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	129.0	19.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	470.5
1978	0.0	0.0	0.0	0.0	2.7	13.9	0.0	4.2	0.0	0.0	0.0	0.0	0.0	2.6	193.3	0.0	79.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	140.3	19.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	456.1
1979	0.0	0.0	0.0	0.0	2.5	17.1	0.0	8.0	0.0	0.0	0.0	0.0	0.0	4.7	217.7	0.0	76.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	139.1	24.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	489.3
1980	0.0	0.0	0.0	0.0	2.5	13.7	0.0	1.3	0.0	0.0	0.0	0.0	0.0	14.4	283.4	0.0	116.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	146.1	22.9	0.0	0.0	0.0	0.0	0.0	0.0	0.3	600.9
1981	0.0	0.0	0.0	0.0	2.4	5.3	0.0	0.3	0.0	0.0	0.0	0.0	0.0	22.0	287.4	0.0	107.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.0	0.0	0.0	0.0	0.0	0.0	146.5	22.3	0.5	0.0	0.0	0.0	0.0	0.0	0.4	595.9
1982	0.0	0.0	0.0	0.0	3.9	18.9	0.0	0.4	0.0	0.0	0.0	0.0	0.0	32.4	266.1	0.0	90.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	189.4	22.2	2.9	0.0	0.0	0.0	0.0	0.0	0.1	626.7
1983	0.0	0.0	0.0	0.0	4.1	10.6	0.0	1.1	0.0	0.0	0.0	0.0	0.0	51.0	247.6	0.0	83.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.2	0.0	0.0	0.0	139.4	15.6	5.4	0.0	0.0	0.3	0.0	0.0	0.7	560.3
1984	0.0	0.0	0.0	0.0	3.6	12.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	39.8	268.0	0.0	71.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.6	0.0	0.0	0.0	124.1	14.4	11.4	0.0	0.0	0.3	0.0	0.0	1.3	548.8

Table 3 (continued): Southern Hemisphere reported surface longline fishing effort (millions of hooks).

Year	AGO	ARG	AUS	BLZ	BRA	CHN	COK	CUB	ESP	FJI	FSM	GBR	GIN	IDN	JPN	KIR	KOR	MDG	MDV	MUS	MYS	MYT	NCL	NIU	NZL	PAN	PHL	PNG	PRT	PYF	REU	RUS	SEN	SLB	SYC	THA	TON	TUV	TWN	UNK	URY	USA	VCT	VEN	VUT	WSM	ZAF	Total
1985	0.0	0.0	0.0	0.0	1.9	1.5	0.0	1.6	0.0	0.0	0.0	0.0	0.0	65.2	263.5	0.0	92.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.2	0.0	149.1	14.7	8.3	0.0	0.0	0.3	0.0	0.0	0.0	599.6
1986	0.0	0.0	0.0	0.0	3.0	1.3	0.0	0.3	0.2	0.0	0.0	0.0	0.0	76.5	294.9	0.0	93.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	196.3	10.8	2.7	0.0	0.0	0.3	0.0	0.0	0.0	679.4
1987	0.0	0.0	1.4	0.0	4.4	1.3	0.0	0.4	9.1	0.0	0.0	0.0	0.0	108.2	294.2	0.0	88.4	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	0.0	0.0	0.0	0.0	0.0	0.0	255.6	11.1	2.0	0.0	0.0	0.0	0.0	0.0	0.0	777.6
1988	0.0	0.0	1.3	0.0	4.8	0.7	0.0	0.0	2.7	0.0	0.0	0.0	0.0	89.6	304.4	0.0	76.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	244.2	9.9	1.3	0.0	0.0	0.0	0.0	0.0	0.0	735.7
1989	0.0	0.0	4.1	0.0	4.7	0.5	0.0	0.0	4.7	0.0	0.0	0.0	0.0	73.4	264.8	0.0	58.5	0.0	0.0	0.0	0.0	0.0	0.6	0.0	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	248.7	10.9	1.1	0.0	0.0	0.0	0.0	0.0	0.0	673.9
1990	0.0	0.0	2.2	0.0	5.2	0.0	0.0	0.6	6.2	0.0	0.0	0.0	0.0	74.8	262.2	0.0	63.3	0.0	0.0	0.0	0.0	0.0	1.8	0.0	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	278.9	10.1	0.9	0.0	0.0	0.0	0.0	0.0	0.0	707.6
1991	0.0	0.0	6.6	0.0	7.0	0.0	0.0	0.0	4.8	0.9	0.0	0.0	0.0	73.7	292.4	0.0	66.5	0.0	0.0	0.0	0.0	0.0	1.5	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	341.3	7.4	0.5	0.0	0.0	0.0	0.0	0.0	0.0	804.2
1992	0.0	0.0	14.0	0.0	10.0	0.0	0.0	0.0	6.6	2.0	0.0	0.0	0.0	90.7	268.0	0.0	68.3	0.0	0.0	0.0	0.0	0.0	0.9	0.0	3.3	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	332.5	7.2	0.7	0.0	0.0	0.0	0.0	0.0	0.0	804.6
1993	0.0	0.0	16.8	0.0	15.7	0.0	0.0	0.0	21.0	3.2	0.0	0.0	0.0	61.9	266.8	0.0	67.9	0.0	0.0	0.0	0.0	0.0	0.3	0.0	2.6	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	432.1	10.6	0.3	0.0	0.0	0.0	0.0	0.0	0.0	899.7
1994	0.0	0.0	17.1	0.0	6.5	0.0	0.0	0.0	23.9	5.1	0.0	0.0	0.0	30.9	299.2	0.0	73.7	0.0	0.0	0.0	0.0	0.0	1.8	0.0	2.5	0.0	0.0	0.0	0.0	3.4	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	388.5	10.2	0.3	0.0	0.0	0.0	0.0	0.0	0.0	864.2
1995	0.0	0.0	9.7	0.0	8.9	0.0	0.0	0.0	34.0	6.1	0.0	0.0	0.0	34.5	272.3	0.0	70.1	0.0	0.0	0.0	0.0	0.0	0.8	0.0	4.6	0.0	0.0	0.0	0.0	4.9	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	315.7	11.4	0.7	0.0	0.0	0.0	0.0	2.3	0.0	777.5
1996	0.0	0.0	4.7	0.0	5.5	0.0	0.0	0.0	30.3	6.0	0.0	0.0	0.0	57.6	260.7	0.0	75.7	0.0	0.0	0.0	0.0	0.0	0.7	0.0	2.7	0.0	0.0	0.0	0.0	5.5	3.1	0.0	0.0	0.0	0.3	0.0	0.0	0.0	248.9	11.7	0.9	0.0	0.0	0.0	0.0	2.7	0.0	717.2
1997	0.0	0.0	6.6	0.0	4.5	0.0	0.0	0.0	31.3	7.4	0.0	0.0	0.0	46.1	252.9	0.0	77.4	0.0	0.0	0.0	0.0	0.0	0.3	0.0	3.5	0.0	0.0	0.4	0.0	6.5	3.4	0.0	0.0	0.0	0.3	0.0	0.5	0.0	257.0	10.9	0.9	0.2	0.0	0.0	0.0	6.3	0.0	716.5
1998	0.0	0.0	10.8	0.0	13.8	0.0	0.0	0.0	28.8	6.7	0.0	0.0	0.0	60.7	257.0	0.0	76.0	0.0	0.0	0.0	0.0	0.0	2.8	0.0	5.3	0.1	0.0	0.4	0.0	8.1	4.3	0.0	0.0	0.0	0.3	0.0	1.7	0.0	321.3	14.2	1.2	0.9	0.0	0.0	0.0	9.7	0.2	824.3
1999	0.0	0.0	13.9	0.0	12.2	6.5	0.0	0.0	28.6	8.2	0.0	0.0	0.0	62.2	206.8	0.0	88.4	0.0	0.0	0.0	0.0	0.0	4.9	0.0	8.7	0.4	0.0	1.3	0.0	9.9	4.7	0.0	0.0	0.0	0.4	0.0	2.6	0.0	390.9	16.1	1.0	0.7	0.0	0.0	0.0	11.0	0.4	879.6
2000	0.0	0.0	16.2	0.0	12.1	18.4	0.0	0.0	24.3	19.5	0.0	0.0	0.0	72.2	206.4	0.0	97.6	0.0	0.0	0.0	0.0	0.0	5.0	0.0	9.0	0.4	0.0	1.7	0.0	12.1	4.0	0.0	0.0	0.0	2.1	0.0	2.2	0.0	364.3	19.7	0.8	1.6	0.0	0.0	0.2	0.4	1.7	891.9
2001	0.0	0.0	18.5	0.0	16.5	21.5	0.0	0.0	25.6	27.0	0.0	0.0	0.0	68.7	221.0	0.0	104.6	0.0	0.0	0.2	0.0	0.0	4.0	0.0	12.8	0.0	0.0	4.6	0.0	12.8	4.4	0.0	0.0	0.0	2.1	0.0	3.3	0.0	411.3	20.5	1.0	5.6	0.0	0.0	0.2	5.3	1.3	992.8
2002	0.0	0.0	19.1	4.1	8.8	45.9	0.2	0.0	25.9	30.9	0.0	0.0	0.0	76.2	227.8	0.0	111.2	0.0	0.0	0.3	0.0	0.0	3.5	0.0	13.4	0.0	0.0	4.5	0.0	12.8	4.2	0.0	0.0	0.0	0.2	0.0	4.6	0.0	408.1	34.6	1.1	12.3	0.1	0.0	12.2	7.3	2.6	1071.8
2003	0.0	0.0	18.8	6.3	3.4	75.7	3.0	0.0	26.8	37.4	0.0	0.0	0.0	72.8	216.7	0.0	105.6	0.0	0.0	0.9	0.0	0.0	5.8	0.0	13.7	0.0	1.8	5.7	0.0	17.4	4.2	0.0	0.0	0.0	6.5	0.0	3.7	0.0	400.7	35.0	2.6	12.9	0.0	0.0	12.7	8.0	2.4	1100.2
2004	0.0	0.0	13.0	0.0	5.9	58.1	7.1	0.0	32.2	49.7	0.0	0.0	0.0	95.2	207.5	0.0	79.3	0.0	0.0	0.8	0.0	0.0	5.2	0.0	10.2	0.0	1.1	8.0	0.0	22.4	2.6	0.0	0.0	0.0	12.6	0.0	0.8	0.0	335.5	44.9	3.7	11.1	0.0	0.0	16.4	5.4	1.6	1030.3
2005	0.0	0.0	10.8	0.0	7.3	60.7	6.3	0.0	28.8	44.0	0.0	0.0	0.0	45.7	202.9	0.0	75.5	0.0	0.0	1.2	0.0	0.0	4.0	0.0	4.7	0.0	0.1	7.3	0.0	20.6	3.6	0.0	0.0	0.0	12.0	0.0	3.0	0.0	268.4	36.8	1.9	10.0	0.0	0.0	24.3	3.8	3.8	887.6
2006	0.0	0.0	9.9	1.4	7.0	84.9	6.5	0.0	27.4	45.5	0.0	0.0	0.0	55.4	195.2	0.0	46.3	0.0	0.0	1.2	0.0	0.0	1.8	0.0	4.0	0.0	4.8	7.1	0.0	18.8	3.0	0.0	0.0	0.0	11.7	0.0	3.6	0.0	213.9	41.5	1.2	13.1	5.8	0.0	30.8	4.8	1.5	848.3
2007	0.0	0.0	9.0	2.4	2.7	83.3	4.5	0.0	26.5	44.4	0.0	0.0	0.0	72.1	203.1	0.0	47.8	0.0	0.0	1.1	0.0	0.0	3.5	0.0	3.7	0.0	6.0	6.3	0.0	17.8	4.3	0.0	0.0	0.0	12.8	0.0	3.0	0.0	200.8	41.2	0.9	16.3	4.7	0.0	24.6	7.3	4.9	854.9
2008	0.0	0.0	8.2	1.5	2.9	118.2	4.2	0.0	23.8	38.6	0.0	0.0	0.0	78.7	169.3	0.0	46.6	0.0	0.0	0.7	0.0	0.0	4.2	0.0	3.2	4.9	3.2	4.5	0.5	17.9	3.1	0.0	0.0	0.0	1.7	0.0	1.1	0.0	154.1	33.0	0.8	13.3	6.7	0.0	24.4	6.9	4.6	780.6
2009	0.0	0.0	9.2	1.5	2.1	123.9	4.8	0.0	26.4	44.8	0.0	0.0	0.0	106.1	145.0	0.0	56.9	0.0	0.0	0.0	0.0	0.0	4.2	0.5	3.5	0.0	3.0	4.7	9.2	16.4	3.6	0.0	0.0	0.0	3.8	0.0	0.0	0.0	242.3	36.9	2.2	13.8	7.9	0.0	31.4	7.4	4.7	916.3
2010	0.0	0.0	8.2	122.0	1.9	113.5	4.9	0.0	28.0	50.3	0.0	0.0	0.0	93.3	141.4	0.0	60.3	0.0	0.0	0.3	0.0	0.0	3.3	0.0	3.3	0.0	2.3	5.4	3.0	16.5	3.8	0.0	0.0	39.8	3.5	0.0	0.0	0.0	282.4	40.7	0.0	11.3	0.1	0.0	37.7	8.1	5.2	1090.2
2011	0.0	0.0	6.7	1.2	3.2	103.5	7.1	0.0	34.5	64.2	0.0	0.0	0.0	98.2	126.4	1.5	62.2	0.0	0.0	0.3	0.0	0.0	3.2	0.0	4.0	0.0	5.8	7.3	3.8	17.6	3.8	0.0	0.0	7.8	2.6	1.0	0.0	0.4	339.6	47.6	0.7	9.3	0.0	0.0	22.6	5.8	6.1	997.8
2012	0.0	0.0	7.1	166.7	4.3	179.0	12.7	0.0	27.8	62.6	0.3	0.0	0.0	86.0	130.6	1.8	55.5	0.0	0.0	0.2	0.0	0.0	3.7	0.0	3.5	0.0	1.8	10.0	0.0	16.1	3.4	0.0	0.0	0.7	1.7	0.0	0.0	3.8	235.0	53.3	0.3	11.0	0.0	0.0	43.5	6.7	4.3	1133.5
2013	0.0	0.0	6.9	11.5	4.3	182.0	4.3	0.0	24.8	54.4	1.6	0.0	0.0	71.2	116.3	1.0	64.3	1.6	0.1	0.2	1.8	0.0	3.5	0.0	2.9	0.0	3.6	2.7	0.0	16.6	4.0	0.0	0.0	0.0	2.7	0.0	0.0	0.6	243.2	50.2	0.3	9.1	152.4	0.0	43.0	5.6	4.8	1091.5
2014	2.1	0.0	6.8	5.5	4.1	150.8	3.0	0.0	23.4	42.5	0.0	0.1	0.0	100.0	100.8	0.5	57.9	1.5	0.0	0.1	2.7	0.0	3.1	0.0	3.0	0.0	0.0	3.8	1.5	17.5	3.6	0.0	0.0	108.6	13.5	0.0	0.5	0.8	243.5	48.8	0.0	7.5	0.1	0.0	28.7	3.1	3.0	992.1
2015	1.9	0.0	8.4	0.8	1.3	162.0	3.9	0.0	23.4	38.8	4.3	0.4	0.0	85.1	90.9	4.8	56.9	1.6	0.0	0.2	3.4	0.0	2.7	0.0	2.2	0.0	0.0	1.7	2.2	18.1	3.5	0.0	0.0	105.2	14.3	0.0	0.3	0.8	198.2	50.3	0.0	7.3	0.0	0.0	46.6	3.7	3.1	948.2
2016	0.1	0.0	7.9	0.9	0.0	125.6	7.8	0.0	24.2	47.6	5.7	0.3	0.0	99.9	90.3	1.3	62.3	1.5	0.8	0.5	0.0	0.0	4.0	0.0	2.3	4.5	0.0	3.0	1.7	17.2	3.7	0.0	0.0	0.0	24.5	0.0	0.5	0.5	250.9	45.8	0.0	6.4	0.1	0.0	23.8	4.5	2.2	872.2

Table 4: Southern Hemisphere reported bottom longline fishing effort (millions of hooks).

Year	ARG	AUS	CHL	ESP	FRA	GBR	JPN	KOR	NAM	NOR	NZL	RUS	UKR	UNK	URY	ZAF	Total
2005	0.5	1.7	3.5	6.0	32.2	7.4	0.7	1.9	0.0	1.1	2.6	2.4	0.0	0.4	2.0	1.6	64.0
2006	0.7	1.7	2.0	6.1	31.5	7.8	1.1	2.7	0.0	0.8	4.2	0.9	0.0	0.0	2.7	3.0	65.2
2007	0.6	1.9	1.2	3.3	32.2	8.1	1.7	4.2	1.9	0.7	4.8	1.5	0.0	0.1	1.6	5.5	69.2
2008	0.0	3.7	1.2	4.1	27.6	9.4	1.6	3.1	1.1	0.0	4.9	0.6	0.0	0.1	2.7	3.9	64.0
2009	0.0	4.4	1.5	4.4	27.7	8.7	1.2	4.9	0.0	0.0	5.9	0.0	0.0	0.0	2.6	2.8	64.1
2010	0.1	3.7	1.2	4.8	28.9	7.5	1.6	6.4	0.0	0.0	4.8	0.4	0.0	0.3	0.9	3.1	63.8
2011	0.0	4.8	1.0	0.8	27.2	8.0	2.0	4.1	0.0	0.1	4.1	1.7	0.0	0.5	0.3	1.7	56.3
2012	0.0	4.8	0.9	1.6	27.1	7.4	2.0	3.6	0.0	0.6	4.6	1.4	0.0	0.5	0.0	2.0	56.6
2013	0.0	7.3	1.2	0.7	26.5	6.9	2.1	2.6	0.0	0.8	6.9	1.5	0.6	0.7	0.0	2.3	60.0
2014	0.0	9.6	1.4	0.8	24.0	6.4	1.6	0.9	0.0	1.0	3.9	1.3	0.6	0.6	0.6	1.6	54.1
2015	0.0	17.4	1.3	0.8	22.9	5.5	1.8	2.7	0.0	0.5	4.2	2.3	1.6	2.7	1.0	2.1	66.7
2016	0.0	16.1	1.3	1.3	26.2	5.8	1.8	3.7	0.0	0.3	4.1	2.0	1.6	3.4	1.1	2.2	70.8
Total	2.0	77.1	17.7	34.7	333.9	89.0	19.3	40.7	3.0	5.8	55.0	15.8	4.4	9.3	15.5	31.6	754.7

Table 5: Southern Hemisphere reported trawl fishing effort (number of tows).

Year	AUS	CHL	CHN	COK	DEU	FRA	FRO	GBR	JPN	KOR	LTU	NLD	NOR	NZL	PER	POL	RUS	UKR	UNK	USA	VUT	Total
2005	1303	14	0	0	0	0	0	21	1505	901	0	0	0	0	0	736	0	2162	1079	163	474	8358
2006	1451	347	0	0	0	48	0	192	1875	4287	0	0	57	0	0	989	0	1207	70	0	0	10523
2007	1488	370	0	10	0	0	0	69	1426	3463	0	0	607	415	0	1333	0	0	204	0	0	9385
2008	1094	42	0	0	272	0	0	185	1888	3567	275	268	79	214	0	1369	127	565	68	0	1731	11744
2009	843	0	2331	0	377	0	0	159	903	3924	238	295	133	535	0	1484	306	0	2026	0	1356	14910
2010	1004	14	1856	0	221	35	145	56	1528	4585	165	104	673	1006	0	1863	200	0	2996	0	886	17337
2011	762	359	1892	0	25	0	0	10	1599	3784	0	22	536	962	0	1178	208	0	2236	0	273	13846
2012	1275	747	849	0	0	0	0	107	903	3818	0	0	499	592	0	0	0	0	1953	0	562	11305
2013	933	618	3043	0	0	0	0	48	0	4757	198	0	748	816	82	0	0	440	1588	0	358	13629
2014	561	793	3875	0	181	0	0	29	0	4919	0	204	573	403	180	0	0	405	2078	0	392	14593
2015	234	663	3281	0	0	67	0	72	0	2437	188	200	529	980	0	0	82	712	2755	0	435	12635
2016	451	286	4612	0	152	0	0	45	0	2654	0	0	909	985	0	54	0	446	1823	0	180	12597
Total	11399	4253	21739	10	1228	150	145	993	11627	43096	1064	1093	5343	6908	262	9006	923	5937	18876	163	6647	150862

Table 6: Southern Hemisphere reported fishing effort by method and year. SLL, surface longline; BLL, bottom longline; NA, not available.

Year	SLL hooks	BLL hooks	Trawl tows		Year	SLL hooks	BLL hooks	Trawl tows
1952	5.5	NA	NA		1985	599.6	NA	NA
1953	11.7	NA	NA		1986	679.4	NA	NA
1954	30.5	NA	NA		1987	777.6	NA	NA
1955	30.7	NA	NA		1988	735.7	NA	NA
1956	43.2	NA	NA		1989	673.9	NA	NA
1957	55.4	NA	NA		1990	707.6	NA	NA
1958	56.6	NA	NA		1991	804.2	NA	NA
1959	66.7	NA	NA		1992	804.6	NA	NA
1960	95.0	NA	NA		1993	899.7	NA	NA
1961	129.3	NA	NA		1994	864.2	NA	NA
1962	156.9	NA	NA		1995	777.5	NA	NA
1963	183.8	NA	NA		1996	717.2	NA	NA
1964	180.1	NA	NA		1997	716.5	NA	NA
1965	202.5	NA	NA		1998	824.3	NA	NA
1966	245.3	NA	NA		1999	879.6	NA	NA
1967	240.0	NA	NA		2000	891.9	NA	NA
1968	302.2	NA	NA		2001	992.8	NA	NA
1969	303.7	NA	NA		2002	1071.8	NA	NA
1970	300.0	NA	NA		2003	1100.2	NA	NA
1971	359.8	NA	NA		2004	1030.3	NA	NA
1972	378.6	NA	NA		2005	887.6	64.0	8358
1973	439.0	NA	NA		2006	848.3	65.2	10523
1974	467.2	NA	NA		2007	854.9	69.2	9385
1975	358.6	NA	NA		2008	780.6	64.0	11744
1976	433.6	NA	NA		2009	916.3	64.1	14910
1977	470.5	NA	NA		2010	1090.2	63.8	17337
1978	456.1	NA	NA		2011	997.8	56.3	13846
1979	489.3	NA	NA		2012	1133.5	56.6	11305
1980	600.9	NA	NA		2013	1091.5	60.0	13629
1981	595.9	NA	NA		2014	992.1	54.1	14593
1982	626.7	NA	NA		2015	948.2	66.7	12635
1983	560.3	NA	NA		2016	872.2	70.8	12597
1984	548.8	NA	NA					
					Total	37386.2	754.8	150862

Figures

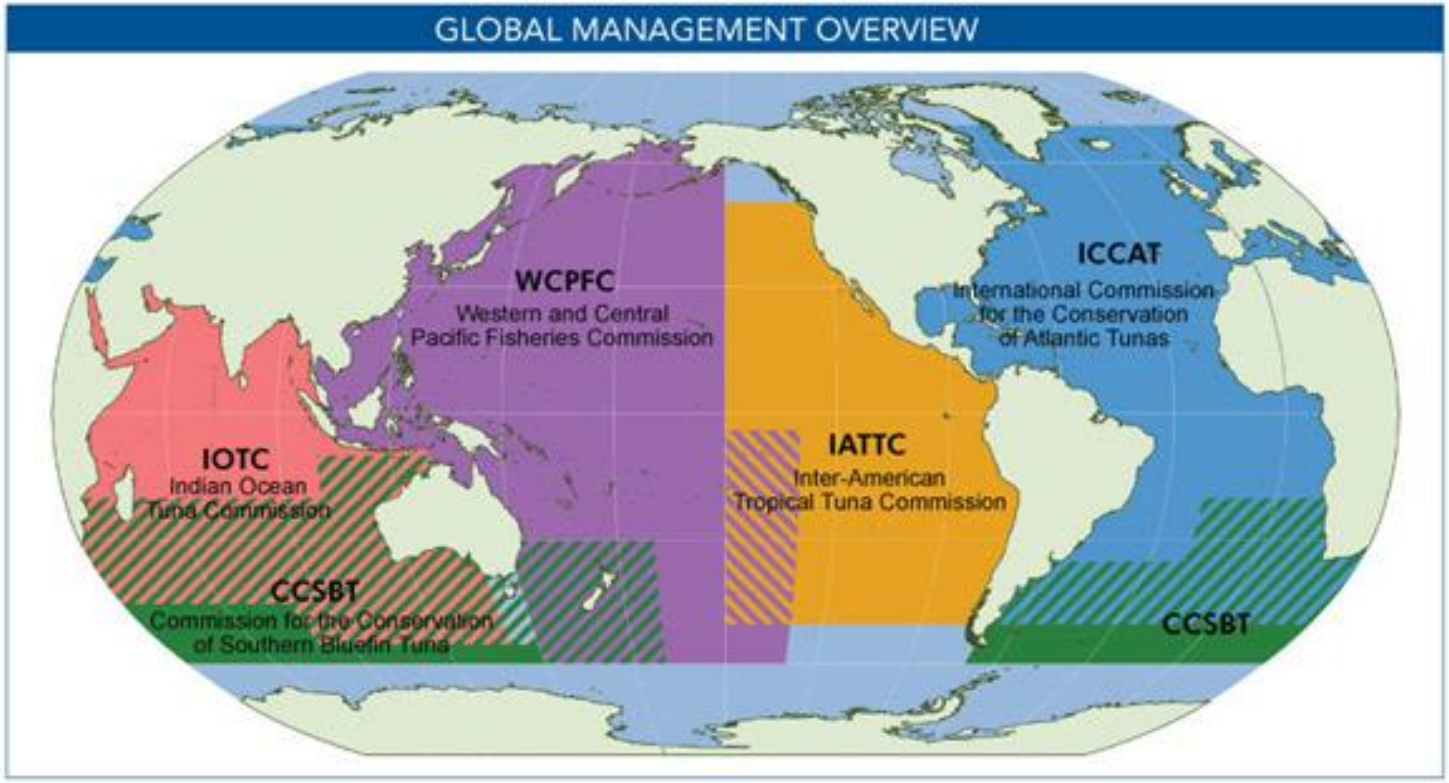

Figure 1: Map of the boundaries of the tuna RFMO convention areas. Source: Pew Charitable Trusts (https://www.pewtrusts.org/en/research-and-analysis/fact-sheets/2012/02/23/faq-what-is-a-regional-fishery-management-organization). See Table 1 for RFMO abbreviations.

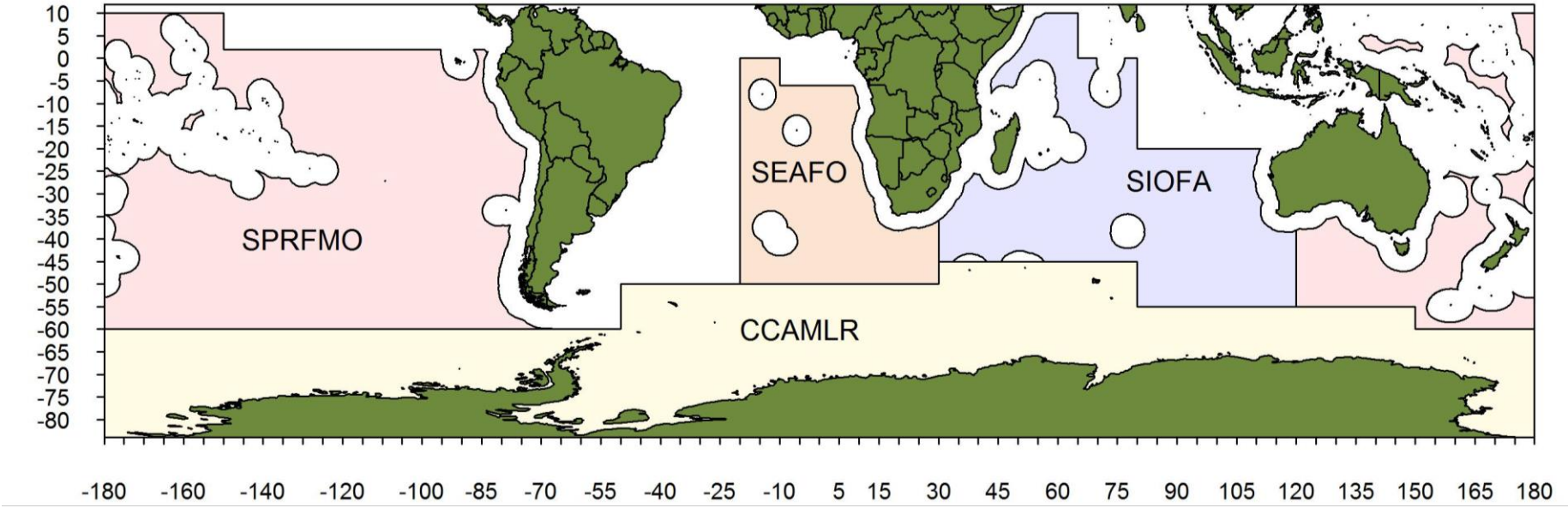

Figure 2: Map of the boundaries of the Southern Hemisphere non-tuna RFMO convention areas. The CCAMLR convention area includes national EEZs contained within its boundaries, but the other illustrated RFMOs do not. The SWIOFC convention area is not shown: it overlaps the western half of the SIOFA convention area, and includes national EEZs. See Table 1 for RFMO abbreviations.

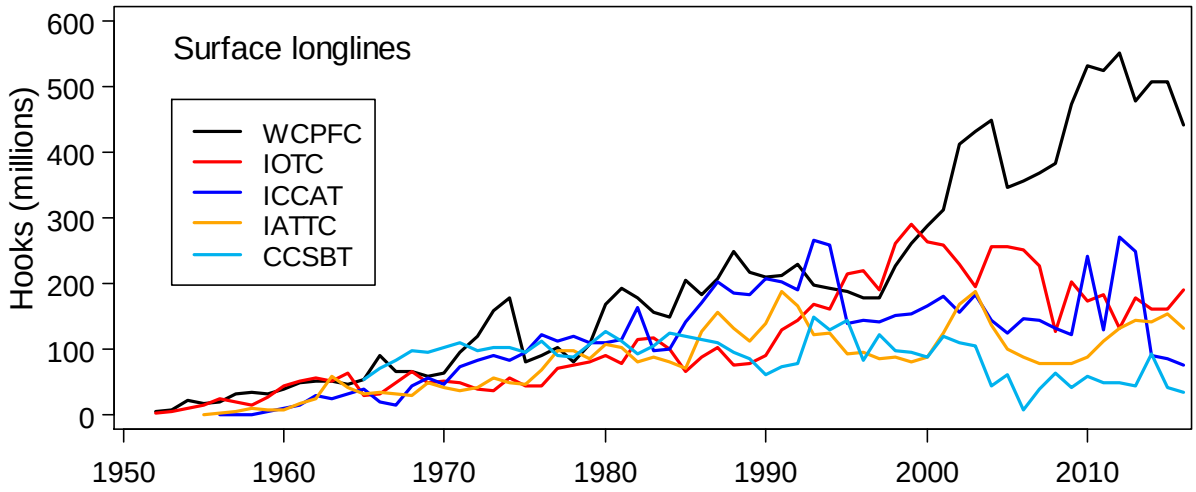

Figure 3: Southern Hemisphere reported surface longline fishing effort by RFMO and year.

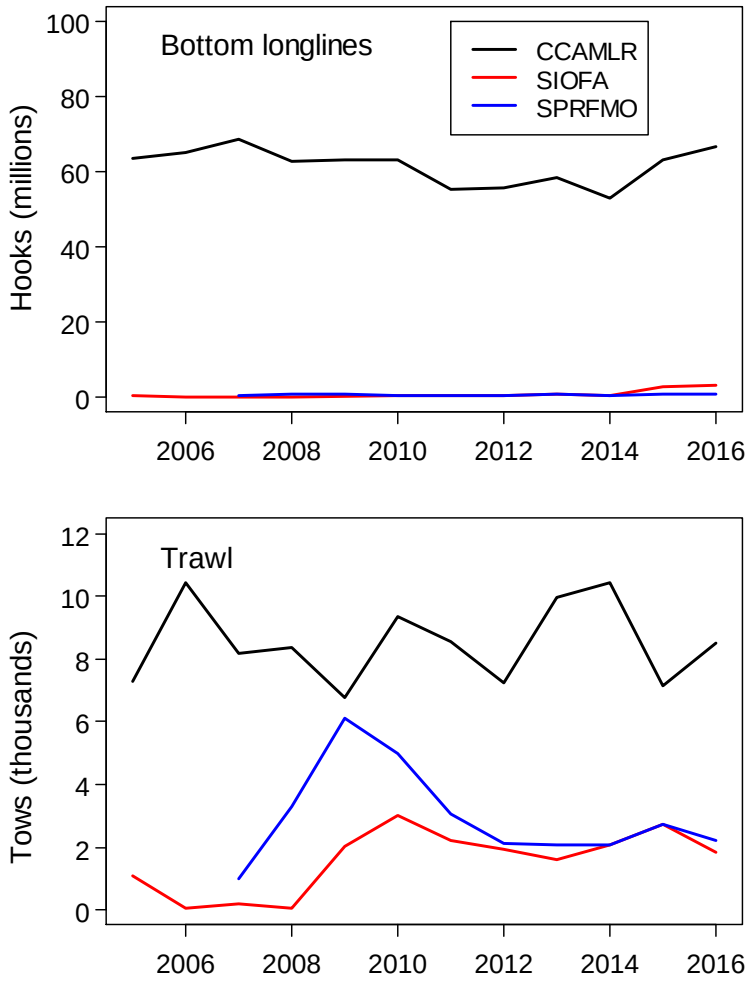

Figure 4: Southern Hemisphere bottom longline and trawl fishing effort by RFMO and year.

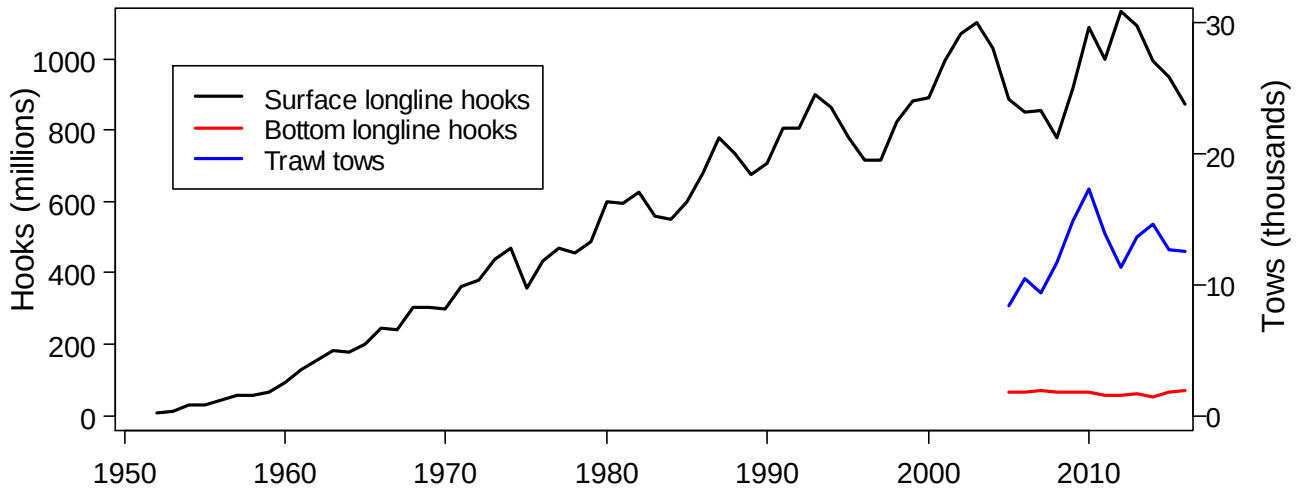

Figure 5: Southern Hemisphere reported fishing effort by method and year (all RFMO regions combined).

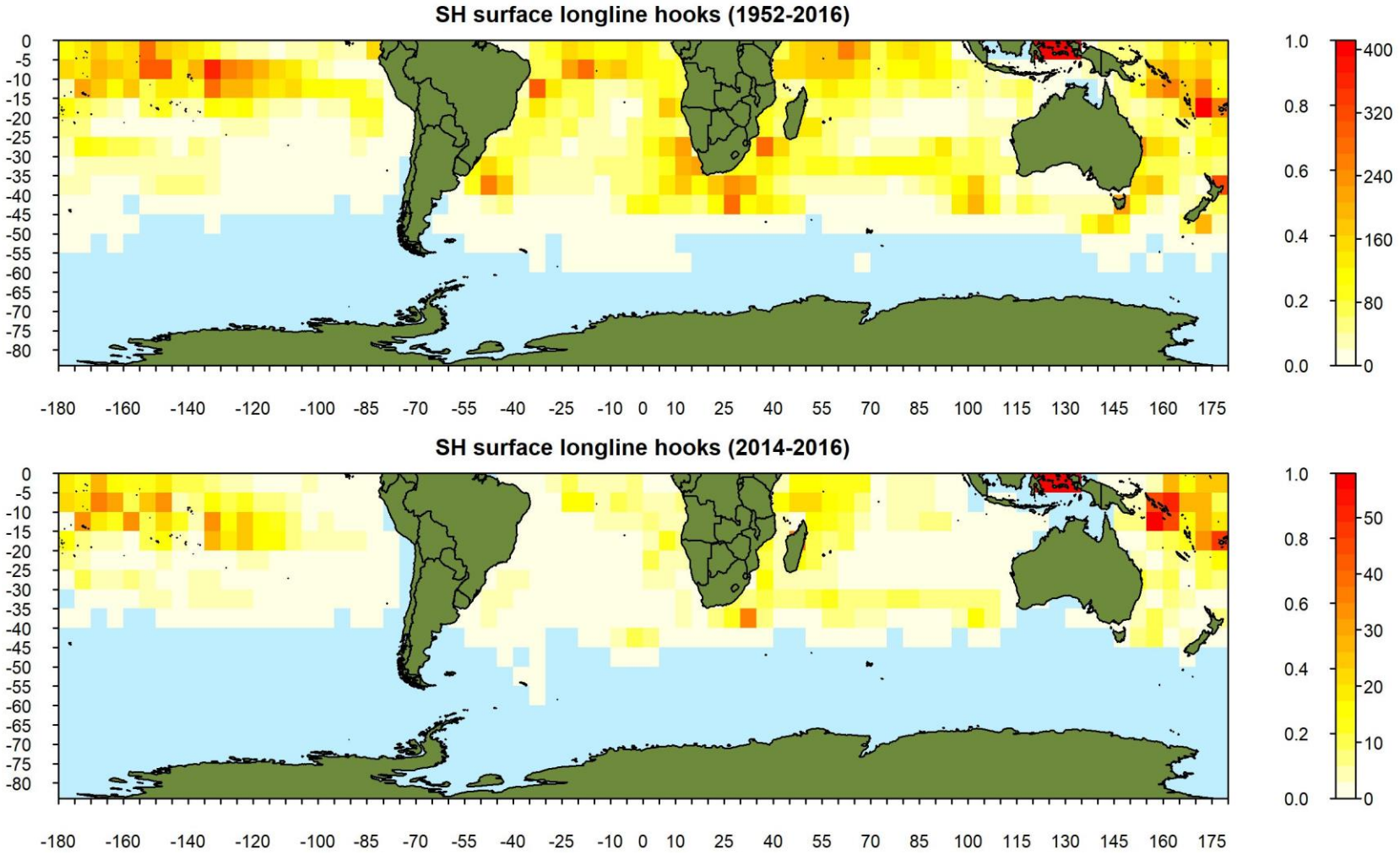

Figure 6: Southern Hemisphere reported surface longline fishing intensity (hooks set per square kilometre of ocean) for (top) the full time series, and (bottom) the most recent three years (2014–2016). Three cells in Indonesia (0–5 ºS, 120–135 ºE) with large amounts of effort were down-weighted to equal the next largest intensity because they dominated the map and prevented illustration of fishing intensity elsewhere. Colour legends are shown in relative (left) and absolute values (right).

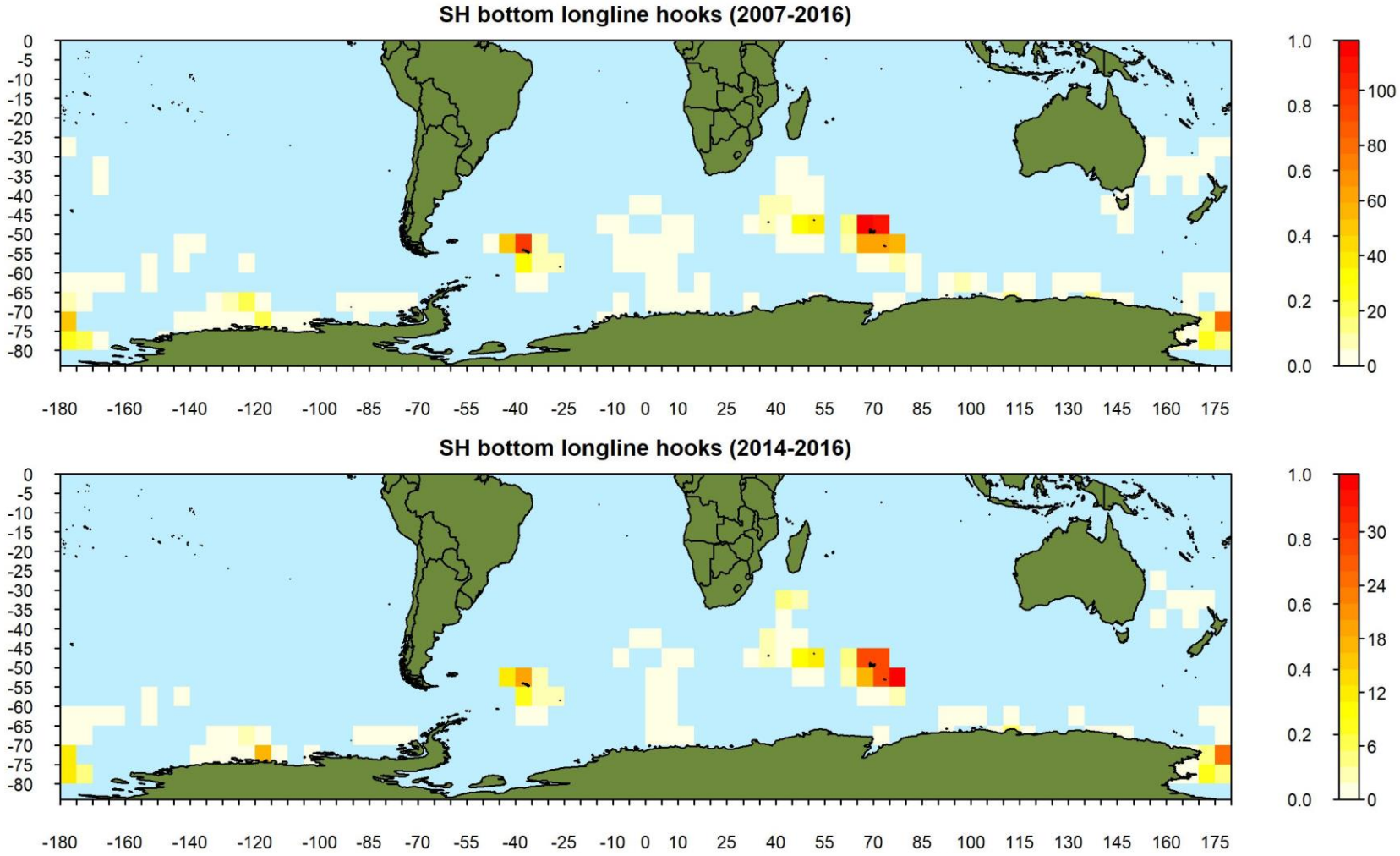

Figure 7: Southern Hemisphere reported bottom longline fishing intensity (hooks set per square kilometre of ocean) for (top) the full time series, and (bottom) the most recent three years (2014–2016). Colour legends are shown in relative (left) and absolute values (right).

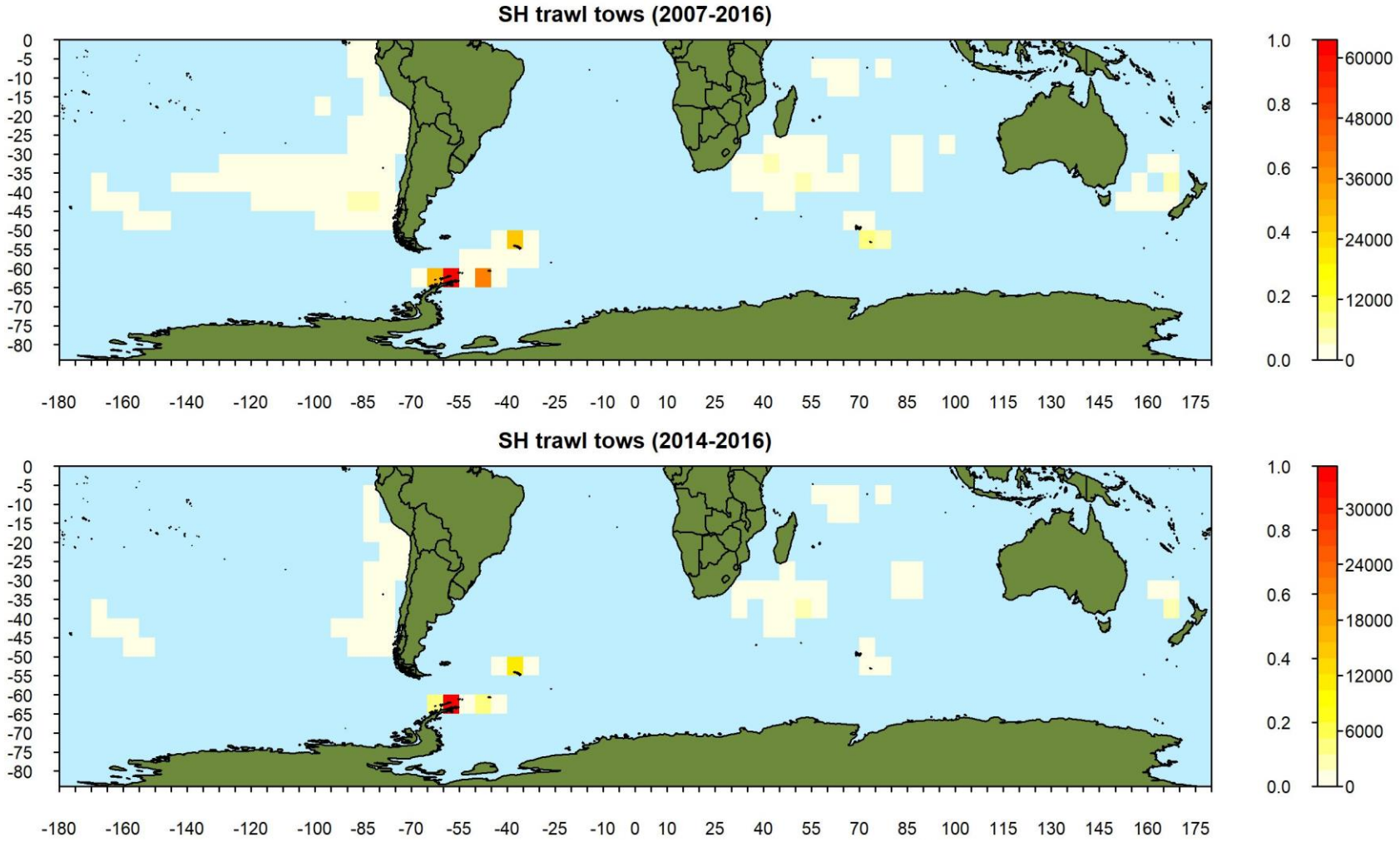

Figure 8: Southern Hemisphere reported trawl fishing intensity (tows per square kilometre of ocean) for (top) the full time series, and (bottom) the most recent three years (2014–2016). Colour legends are shown in relative (left) and absolute values (right).

Appendices

Appendix 1: Country codes

Code	Country		Code	Country
ARG	Argentina		NIU	Niue
AUS	Australia		NLD	Netherlands
BLZ	Belize		NOR	Norway
BRA	Brazil		NZL	New Zealand
CHL	Chile		PAN	Panama
CHN	China		PER	Peru
COK	Cook Islands		PHL	Philippines
CUB	Cuba		PNG	Papua New Guinea
DEU	Germany		POL	Poland
ESP	Spain		PRT	Portugal
FJI	Fiji		PYF	French Polynesia
FRA	France		REU	Réunion
FRO	Faroe Islands		RUS	Russia
FSM	Micronesia		SEN	Senegal
GBR	United Kingdom		SLB	Solomon Islands
GIN	Guinea		SYC	Seychelles
IDN	Indonesia		THA	Thailand
JPN	Japan		TON	Tonga
KIR	Kiribati		TUV	Tuvalu
KOR	South Korea		TWN	Taiwan
LTU	Lithuania		UKR	Ukraine
MDG	Madagascar		URY	Uruguay
MDV	Maldives		USA	United States
MUS	Mauritius		VCT	St. Vincent & Grenadines
MYS	Malaysia		VEN	Venezuela
MYT	Mayotte		VUT	Vanuatu
NAM	Namibia		WSM	Samoa
NCL	New Caledonia		ZAF	South Africa

Appendix 2: Matrix of ratios used to scale up fishing effort to account for the variable amount of sea area within each 5 × 5 degree cell.