SCIENTIFIC COMMITTEE
TWENTY-SECOND REGULAR SESSION
11-19 August 2026
Apia, Samoa (Hybrid)

AN ASSESSMENT OF THE QUANTITY OF ABANDONED, LOST, OR DISCARDED PELAGIC LONGLINE FISHING GEAR IN THE WESTERN AND CENTRAL PACIFIC FISHERIES CONVENTION AREA

WCPFC-SC22-2026-EB-WP11
11 August 2026

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Version 2 has minor editorial changes and no changes to the Methods, Results nor Discussion.

Appendix 2 now contains the correct GEN-6 form.

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An assessment of the quantity of abandoned, lost, or discarded pelagic longline fishing gear in the Western and Central Pacific Fisheries Convention Area

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Abstract

This study quantifies abandoned, lost, or discarded fishing gear (ALDFG) associated with pelagic longline fisheries in the Western and Central Pacific Fisheries Commission Convention Area (WCPFC-CA). Data from 2005–2024 were compiled from 13 WCPFC Members, Cooperating Non-Members and Participating Territories (CCMs) using two sources: (1) SPC/FFA Regional Observer Pollution Reports (Form GEN-6) from 11 CCMs (Forum Fisheries Agency members and French Polynesia), and (2) observer data from U.S. longline fisheries based in Hawai‘i and American Samoa from the Pacific Islands Region Observer Program (PIROP). A total of 9,864 observed trips were analyzed.

ALDFG incidents were reported on 4.8% of the trips analyzed (477 of 9,864 trips). Incidents occurred on 8.7% of trips covered by GEN-6 data (347 of 3,985 trips) and 2.2% of trips covered by PIROP data (130 of 5,879 trips). The higher incidence rate in GEN-6 data largely reflects documented gear discards, which are not documented in PIROP monitoring. GEN-6 records demonstrate that mainline and branchlines were the most frequently discarded items of fishing gear, whereas buoy and radio beacons were more often reported as lost or abandoned. Lost fishing gear accounted for the largest proportion of reported incidents across both datasets.

Eight ALDFG metrics were estimated from observer records: mainline length and weight, branchline length and weight, combined line length and weight, and the number of buoys and radio beacons. Analyses were conducted at the longline set level rather than the trip level because fishing effort is more consistent among sets, which typically comprise 2,500–3,000 hooks. Set level estimates were then raised to annual longline effort in the WCPFC-CA to estimate region-wide ALDFG quantities. Four alternative assumptions were applied to account for sets where observers did not document ALDFG. Under one of the more plausible scenarios, ALDFG averaged approximately 135,555 kms of mainline and branchline and approximately 1,408 metric tons (mt) of associated gear per year. These estimates are compared with published global assessments of longline gear loss. The study also includes information gathered from WCPFC CCMs regarding port-based disposal practices for retrieved or unusable fishing gear and provides recommendations for improving gear management at the end of its useful life.

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Introduction

Abandoned, Lost, or Discarded Fishing Gear as a Global Issue

Abandoned, lost, or discarded fishing gear (ALDFG) is recognized as a globally significant source of marine debris and can contribute to ghost fishing, marine litter, habitat degradation, and navigational hazards (Macfadyen et al, 2009). Its persistence and potential ecological impacts have led to increasing international attention from fisheries management organizations, governments, and environmental organizations. Despite growing concern regarding ALDFG, quantitative information on gear loss, abandonment or discard rates remains limited for many fisheries. This is particularly true for pelagic longline fisheries operating across the vast Western and Central Pacific Ocean, where observer programs provide one of the few direct sources of information on fishing gear that is abandoned, lost or discarded at sea. Appendix 1 contains a glossary of terms for this study.

Importance in Western Central Pacific Fisheries Commission Fisheries

The Western and Central Pacific Fisheries Commission Convention Area (WCPFC-CA) supports the world's largest tuna fishery. In 2024, tuna catches exceeded 3.0 million metric tons, representing approximately 54% of global tuna production. The region includes substantial catches by purse seine (71.1%), longline (7.7%) pole-and-line (5.1%) and miscellaneous gear (16.2%, Pacific Community 2025) operating across both exclusive economic zones (EEZs) and the High Seas (areas outside of national jurisdiction). In 2024, longline fisheries alone comprised 7.7% of the region’s catch from nearly 2,000 vessels not including Japan’s coastal fleets and fleets in domestic fisheries of Indonesia, Philippines and Vietnam (Pacific Community 2025), generating an estimated value of 1.10 billion USD in landed value (Vidal and Ruaia, 2025).

The longline fishery involves two main types of operation: 1) large (typically >250 Gross register tonnage (GRT)) distant-water freezer vessels which typically undertake long voyages (months), operate over large areas of the region, and typically target either tropical (yellowfin tuna (*Thunnus albacares*), bigeye tuna (*T. obesus*)) or subtropical (albacore, *T. alalunga*) species; and 2) smaller (typically <100 GRT) offshore vessels which are usually domestically-based and target different species, undertaking trips of less than one month, with ice or chill water capacity, and serving fresh or air-freight markets, or though in some instances canneries (Vidal and Ruaia, 2025).

Longline Gear Overview

Pelagic longline fishing gear is composed of a single strand monofilament mainline that is typically 3.5 to 4.0 mm diameter made from nylon that has sections suspended by surface floats and branchlines that are suspended from the mainline. Branchlines have several components, a snap that attaches the branchline to the mainline, a monofilament section of 1.8 to 2.3 mm

diameter that ends with a single baited hook and at the terminal end there may be a weight to mitigate interactions with seabirds within ~1-meter of the hook and monofilament or wire leader between the weight and hook (Figure 1). The deployment of the number of hooks between floats (HBF) determines how deep the longline will fish in the water column.

Richardson et al. (2015) analyzed more than 10,000 pollution incidents by purse seine vessels and more than 200 incidents by longline vessels characterized by "Waste Dumped Overboard as Plastics, Metal, Waste Oil, Chemicals, Old Fishing Gear and General Garbage" within the Exclusive Economic Zones (EEZs) of 25 WCPFC CCMs and the High Seas. Data were recorded on SPC/FFA Regional Observer Pollution Report GEN-6 Form (Appendix 2) and this form was last updated in 2014. From a total of 1,940 fishery observer trips from 2003 to 2015, there were 84 trips (4%) with reported longline ALDFG incidents with observer coverage. Of the 219 ALDFG incidents reported from those 84 trips, the highest reported percentages of ALDFG incidents occurred in the EEZs of Fiji (30%), Tonga (14%) and Vanuatu (13%). It should be noted that there is an imbalance in observer coverage between CCM regional programs, which leads to variable observer coverage and resulting higher EEZ percentages (i.e. those CCMs with higher observer coverage predictably report more incidents of ALDFG).

Gilman et al. (2021) assessed relative risks arising from loss of 18 fishing gear classes based on: 1) rate of production of ALDFG, 2) fishing effort and 3) adverse ecological and socioeconomic impacts of ALDFG. For tuna fisheries operating in the WCPFC-CA, the highest risk tuna gears were tuna purse seine with fish aggregating devices (Fish Aggregating Devices (FADs), 3rd in the overall rank), pole-and-line with anchored FADs (5th), and pelagic longline had a relatively low risk (11th). However, the current paucity of data around the fate of longline gear at the end of its useful life may have contributed to an artificially low "likelihood for loss" score and thus a lower risk ranking in Gilman et al.'s assessment. The Global Ghost Gear Initiative (GGGI) also has a similar gear loss risk assessment in the GGGI Best Practice Framework for the Management of Fishing Gear (C-BPF) that broadly aligns with Gilman et al. (2021), placing longlines as a moderate risk for gear loss, with a score of 3 (out of a max of 5) for both likelihood of loss and potential impact once lost (GGGI 2021).

Richardson et al. (2021) discussed major challenges around the creation of statistically robust global ALDFG estimates and presented opportunities to refine and improve estimates of lost fishing gear. In an attempt to reach a more accurate global estimate of fishing gear loss, Richardson et al. (2022) interviewed 451 fishers from seven countries about fishing effort and gear losses for multiple fisheries. For pelagic longline fisheries, surveys indicated that on average 3.33% (±0.59%) of all longline mainlines (739,583 km), 3.58% (±0.78%) of all longline branchlines (15,570,273 km), and 2.86% (±0.55%) of all longline hooks (13,993,141,840 hooks) are lost around the world each year.

Knowledge Gap

Previous studies have developed global estimates of fishing gear loss and drivers for such losses (Richardson et al 2019, 2021, 2022). However, quantitative estimates of pelagic longline ALDFG for the WCPFC Convention Area remain limited. In particular, no previous study has combined observer records from multiple WCPFC CCMs to estimate the quantity of longline gear lost, abandoned, or discarded at a regional scale. Observer programs provide a unique opportunity to quantify ALDFG because they record gear loss and discards, and the associated operational circumstances observed directly while at sea. Although observer coverage remains limited in many longline fisheries, these datasets represent the most comprehensive source of information currently available for evaluating ALDFG occurrence across the Convention Area.

Objectives

The objectives of this study are to: 1) update the Richardson et al. (2015) study with observer data from 2005 to 2024 to better characterize longline gear loss, abandonment and discard in the WCPFC-CA; 2) quantify eight ALDFG metrics from observer data, including mainline length and weight, branchline length and weight, combined line length and weight, and number of buoys and radio beacons; 3) discuss potential drivers for longline gear loss, abandonment and discard; 4) provide quantitative estimates of ALDFG for the WCPFC-CA longline fisheries which has not previously been conducted; and 5) gather information from WCPFC CCMs on management and disposal of end-of-life longline gear when vessels arrive in port.

Materials and Methods

ALDFG-related data in the WCPFC-CA were obtained from 2005 to 2024 based on two sources: 1) SPC/FFA Regional Observer Pollution Report Form GEN-6 (Appendix 2, Pacific Community 2021) from 11 WCPFC CCMs (Forum Fisheries Agency (FFA) members and French Polynesia), and 2) longline observer data from the Pacific Islands Region Observer Program (PIROP) including U.S. longline fisheries based in Hawaii and American Samoa (Appendix 3, NOAA 2024). Both GEN-6 and PIROP observer data are considered confidential, thus authorizations were obtained for data release for use in this study from 13 WCPFC CCMs (Cook Islands, Fiji, Federated States of Micronesia, Kiribati, Marshall Islands, French Polynesia, Papua New Guinea, Solomon Islands, Tonga, United States (Hawaii and American Samoa-based fisheries), Vanuatu and Samoa. GEN-6 Form data for longline fisheries are based on contributions from WCPFC CCMs and account for fishing activity that typically occurs within EEZs with a minor amount of GEN-6 data submitted from High Seas activity. The observer numbers are assumed to be accurate with no corresponding estimates of uncertainty.

The WCPFC Regional Observer Program (ROP) requires data collection when a vessel is operating on the High Seas in the Convention Area; however, GEN-6 data are not typically collected within the ROP, as it is not part of the WCPFC ROP minimum standard data fields.

Both the GEN-6 and the PIROP or U.S. data (Hawaii and American Samoa) collect data about ALDFG incidents, however, the presence of the "Comments" section in the forms creates a challenge because comments cannot be digitally inputted into in the database and therefore are not easily retrievable/accessible/categorized. Given this, two analyses were conducted on the "Comments" sections of both GEN-6 and PIROP datasets. The first reviewed the content of the "Comments" and developed criteria to bin the data into appropriate abandoned, lost, or discarded fishing gear categories. The second analysis reviewed the "Comments" again and placed each occurrence of ALDFG into appropriate categories and quantified incidents by longline set and trip.

GEN-6 Form data

On the SPC/FFA Regional Observer Pollution Report GEN-6 Form, there are three main categories of pollution incidents:

1. Waste dumped overboard: including plastics, metal, waste oil, chemicals, and general garbage;
2. Oil spillages and leakages; and
3. Abandoned or lost fishing gear: including activities of lost during fishing, abandoned, and dumped.

The GEN-6 Form includes "abandoned or lost fishing gear" as an ALDFG incident. The ALDFG incident is recorded as an activity during "setting, hauling or transiting". Observers categorized the occurrence of ALDFG for a particular longline set as "lost during fishing" "abandoned" or "dumped" in accordance with following definitions.

'Lost fishing gear' should be used when a portion of the primary fishing gear – mainline, branchline or floatline is lost and the vessel makes an attempt to recover the gear but is unable to.

'Abandoned gear' should be used where gear is lost and the vessel does not or cannot safely attempt to recover it.

'Dumped gear' is when part of the primary fishing gear (for example, the lines) is deliberately dumped as a means of disposal.

The term "dumped" is hereafter referred to as "discarded" to align with FAO terminology. For each of those three categories, observers can add descriptions under the headers "activity", "describe gear" and "estimated quantity," and can add further details in an associated "other comments section."

GEN-6 ALDFG data were collected with an unstandardized methodology. Observers reported gear description and estimated quantity in a variety of metrics, such as the reported length/weight of mainline and/or branchline abandoned, lost or discarded. For discarded gear only, observers occasionally estimated the volume of mainline and branchline discarded using multiple container reference types. For example, container references included a 5-liter and 5-gallon bucket and the amount of a 50-kg rice sack that was filled as ⅛, ¼, ½, ¾ and completely full. From the Hawaii-based longline fleet, we obtained unusable mainline and branchline gear that were disposed of in the port of Honolulu and estimated the length and weight associated with the variety of volumes. Based on an internet search, a 50-kg rice sack was assumed to contain a volume of 50-liters.

Pacific Islands Regional Observer Program (PIROP) data

Several factors informed the decision to only use U.S. deep-set fisheries in our analysis. In the U.S. Hawaii-based longline fisheries, regulations define shallow longline gear which deploys 5-14 hooks between floats (HBF) to target swordfish in what is characterized as a "shallow-set fishery" and deploys ≥15 HBF to target tunas in the "deep-set" fishery. The American Samoa longline fishery is a deep-set fishery targeting albacore (*T. alalunga*). For this analysis, PIROP data were limited to the Hawai‘i deep-set fishery by retaining only longline sets with 15 or more HBF. This restriction was necessary because subsequent raising of PIROP data to the WCPFC-CA relied on public-domain annual longline effort data, which are available by year, flag, and 5° latitude-longitude strata, and by year, month, and 5° latitude-longitude strata, but are not separated into deep-set and shallow-set fisheries (https://www.wcpfc.int/public-domain-aggregated-catcheffort-data). Shallow-set fisheries represent a small proportion of longline effort in the WCPFC-CA; for example, the Hawai‘i-based shallow-set fishery accounted for 2.23% of Hawai‘i-based longline effort from 2005 to 2024 (22,786,577 hooks of 1,018,632,469 total hooks; A. Tomita, personal communication). Including ALDFG from the Hawai‘i-based shallow-set fishery could also raise confidentiality concerns because no other WCPFC CCMs provided shallow-set ALDFG data.

Data reported by PIROP observers from 2005-2024 did not include discarded gear in the U.S. longline fisheries; however, they did record incidents as "line parted" when the mainline unintentionally breaks or separates (Appendix 3). The estimated number of longline sections retrieved, lost, or abandoned is entered in a "Comments" field.

Processing for GEN-6 and PIROP data

Commercially available monofilament mainline (4.0 mm) and branchline (2.1 mm) lengths and corresponding weight were obtained from a commercial longline product supplier in Honolulu, Hawaii and from the Lindgren-Pittman website (https://www.lindgren-pitman.com/), and thus for all ALDFG incidents reported on GEN-6 and PIROP observer forms, the diameter of the monofilament mainline and branchline was assumed to be 4.0 mm and 2.1 mm, respectively.

The available data indicates that larger amounts of fishing gear can be associated with loss and abandonment incidents during fishing. Reported ALDFG incidents were assumed to correspond to (individual) longline sets. Observers record the number of gear segments, hooks between successive floats, or HBF- that are abandoned or lost (but not discarded) during fishing.

A total of 119 incidents (11 GEN-6 and 108 PIROP) estimated the amount of monofilament. The estimation was based on HBF plus 1 multiplied by the distance between branchlines assumed to be 34.6 meters (Bigelow et al, 2006, table 1 – L (m)/hooks between floats+1, 962 (m) divided by 27.8). For GEN-6 data, the average HBF (Table 1) was obtained from observer data or from the Common Oceans workshop in 2016 (WCPFC/SPC Common Oceans (2016), table 1). For PIROP data, trip-specific estimates of HBF were provided.

Observers included the number of longline floats and/or radio beacons in their ALDFG incident reports. Observers also reported ALDFG incidents involving mainline and/or branchlines; however, the observers did not always quantify the amount of gear. For these longline sets, proxies were provided based on the mean length and/or weight of mainline and branchline that were abandoned, lost or discarded. For reports where line quantities were not estimated, the length of branchline in a given incident is estimated as the number of branchlines lost/abandoned/discarded multiplied by fleet-specific branchline length obtained from observer data associated with ALDFG incidents.

Initial analyses summed ALDFG incidents for each longline set and trip. For CCMs submitting GEN-6 data, annual longline observer effort per trip was estimated from WCPFC reports from the Technical and Compliance Committee from documents on the Status of Observer Data Management (e.g. WCPFC-TCC21-2025-IP03). For each CCM submitting GEN-6 data, the annual longline observer effort was calculated from the observed hooks divided by the number of trips (Table 1). Longline effort per trip was available for PIROP data; therefore no assumptions were made on U.S. trip effort. Analyses proceeded using sets as the sampling unit (rather than trips) because there is less variability in a set as effort typically ranges from 2,500 to 3,000 hooks per set. In contrast, CCM observed trips averaged 43,394 hooks per trip with a wide range of 20,036 to 206,642 hooks (Table 1). The length and weight of mainline and branchline per set and number of floats and radio beacons per set represents the sampling unit.

Statistical analyses

From 2005 to 2024, ALDFG was reported on 347 of 3,985 observed trips including 706 separate incidents per set. For U.S. trips, ALDFG was observed on 130 of 5,879 trips including 138 incidents on observed sets.

A Monte Carlo simulation was implemented in R (Version 4.5.0) to individually estimate annual loss of mainline length and weight, branchline length and weight, combined line length and weight, and the number of floats and radio beacons. Simulations were conducted separately for

GEN-6 and PIROP datasets as there is an imbalance in the total GEN-6 and PIROP trips and percentage of trips with ALDFG incidents (i.e. there are significantly more HI/AS trips than GEN-6 trips, and the loss rates of each are different, so they need to be considered separately). The input distributions of ALDFG incidents per set for both GEN-6 and PIROP were sampled 5,000 times for each of the two input distributions. Samples were then summed for ALDFG incidents and divided by 5,000 which produced an estimate of the mean number of ALDFG incidents per set while incorporating uncertainty from the 5,000 samples. The corresponding mean number of ALDFG incidents per set was divided by an assumed 3,000 longline hooks to enable raising based on WCPFC-CA effort.

Raised ALDFG to effort estimates in the WCPFC-CA

One of the study objectives was to raise the mainline length and weight, branchline length and weight, combined mainline and branchline length and weight, float count and radio beacon count of observed ALDFG to quantify annual estimates for the broader WCPFC-CA. Annual longline effort by year and flag in the WCPF-CA was used to stratify the effort of the 11 CCMs reporting on the GEN-6 Form and two CCMs (U.S.) using the PIROP form. This exercise allowed an estimation of the corresponding annual longline effort between those two datasets. As an example, in 2015, total effort in the WCPFC-CA was 857 million hooks. Of the estimated 857 million hooks of total effort, 246.68 million hooks of fishing effort had observer coverage, with 200.16 million hooks and 46.52 million hooks associated with the GEN-6 and PIROP datasets, respectively. Thus, for the 13 CCMs, 81.1% (200.16 of 246.68 million hooks) was calculated for the 11 CCMs reporting on the GEN-6 Forms and 18.9% (46.52 of 246.68 million hooks). The mean number of incidents per set was applied to 696 million hooks (81.1% of 857 million) for GEN-6 data and 161 million hooks (18.9% of 857 million) to estimate ALDFG incidents in the WCPFC-CA. The raised estimation procedure is illustrated in Figure 2.

A longline trip is assumed to average ~45,000 hooks (Table 1) corresponding to a total of 15 sets within a trip with 3,000 hooks per set. Additional assumptions are required for sets within a trip that had no observer documented ALDFG.

Four (4) scenarios were considered with different assumptions of GEN-6 and PIROP ALDFG per set:

- Scenario 1 - Highest ALDFG. All 15 sets in a trip are assumed to have 100% ALDFG.
- Scenario 2 - Lowest ALDFG. One of 15 sets in a trip are assumed to have ALDFG and 14 sets have zero ALDFG.
- Scenario 3 - Intermediate ALDFG. One of 15 sets in a trip are assumed to have ALDFG and 14 sets have 50% ALDFG.
- Scenario 4 - Intermediate ALDFG. One of 15 sets in a trip are assumed to have ALDFG and 14 sets have 25% ALDFG.

Scenarios 1 and 2 are considered implausible but were developed to estimate the highest ALDFG (Scenario 1) and lowest ALDFG (Scenario 2) in the WCPFC-CA. Scenarios 3 and 4 are considered more plausible and represent intermediate estimates of ALDFG in the WCPFC-CA.

Branchline - hook and longline snap loss

With respect to loss or abandonment of a branchline, the branchline, snap, weight and hook are assumed to be abandoned or lost in their entirety. With the case of a damaged branchline, the crew typically cuts and retains both the snap and hook for future use and may discard *or* retain the line and weights. As such, a conservative approach was taken within the analysis where snaps and hooks were estimated from trips with only abandoned or lost branchlines. Discarded branchlines were assumed to have snaps and hooks removed. There is no information within observed trips if weights were incorporated into the branchline; therefore, the study could not quantify the loss of longline weights, which varies among fleets to the weights used or not used for things like seabird mitigation. The number of branchlines in ALDFG was estimated by annual total branchline length divided by the mean length of 15.0 meters (Table 1) for observer data of the 13 CCMs. Observers documented ALDFG incidents as branchlines and not hooks. Thus, the number of hooks is set equal to the number of branchlines if gear was abandoned or lost. For GEN-6 data with discard ALDFG incidents, branchline length and weight were estimated and hooks were assumed to be zero because hooks were removed and not discarded. There are other causes of hook loss without branchline loss, such as shark bite offs at the hook. This study was unable to quantify actual hook loss due to such causes.

Results

Observers monitored a total of 9,864 trips with 3,985 trips providing GEN-6 data and 5,879 trips with PIROP data (Table 2). In total, there were 844 reported ALDFG incidents across 477 trips, resulting in 4.8% of all trips having at least one reported incident of gear loss, abandonment or discard. As mentioned previously, there was a difference between GEN-6 and PIROP sources: 8.7% and 2.2% of trips had ALDFG incidents from GEN-6 and PIROP; respectively. Fiji and the Hawaii-based deep-set longline fishery had the highest ALDFG reporting by observers with these two fisheries alone representing 77.6% of total observed sets. Several CCMs have greater percentages of trips with reported ALDFG incidents; however, these CCMs (e.g. FSM, Solomon Islands, Vanuatu) typically have trips of longer duration and thus the representative percentages are higher.

The study consisted of reviewing observer recorded data to identify longline segments as abandoned, lost, or discarded to convert gear discard quantities into mainline and branchline length and weight and impute data based on the mean of quantified longline ALDFG incidents. Of the 844 ALDFG incidents, 556 were recorded by observers, 214 were estimated from longline gear segments in incidents of abandoned and lost during fishing or converted from discarded volume and 74 were imputed mean values. Conversions for mainline and branchline length to

weight and weight to length and volumetric estimates of weight and length are provided in Appendix 4.

Of the 844 ALDFG incidents, 68 were abandoned, 189 were lost, and 587 were discarded. Possible drivers of ALDFG incidents (n=257; 119 GEN-6 and 138 PIROP) were assigned to eight different categories (Table 3). Most of the possible drivers of ALDFG incidents were unknown (n=126; 49.0%). The primary possible driver for gear loss occurs when the mainline has parted and the vessel cannot find and retrieve the gear (n=60; 23.3%). PIROP observers record when the mainline has parted in a longline set. In the Hawaii and American Samoa (the U.S./PIROP form) longline fisheries, incidents of abandonment or loss can be the result of a parted line which occurs for 45.5% of longline sets (Table 1). The secondary possible driver of gear loss incidents is when the vessel cannot locate the terminal radio buoy and the gear cannot be retrieved (4.6%). The primary possible driver for abandonment is when the gear tangles (making it difficult to recover; 14.7%) and the next most common reason relates to interaction with a drifting object (13.2%), which observers usually recorded as a dFAD.

ALDFG incidents within EEZs or High Seas reflect both GEN-6 and PIROP observer spatial coverage (Table 4). ALDFG incidents in GEN-6 data occurred in 91.4% and 8.6% in EEZs and High Seas, respectively. The highest percentages of GEN-6 incidents occurred in the EEZs of Fiji (n=247, 35.0%), French Polynesia (n=81, 11.5%) and the Marshall Islands (n=70, 9.9%) which reflects the higher number of trips monitored (Table 4). ALDFG incidents (n=138) in U.S. fisheries occurred in 52.2% (n=82) in the Hawaii and American Samoa EEZs and 47.8% (n=66) in the High Seas.

Statistical analyses

Mean estimates for the eight ALDFG metrics are presented per incident and per set in Table 5 for both GEN-6 and PIROP data. Results are reported overall and by incident type: abandoned, lost during fishing, and discarded. Overall means are not directly comparable between datasets because GEN-6 includes reported discard incidents, which reduce the overall mean estimates, whereas PIROP includes only abandoned and lost during fishing incidents. In both datasets, mean estimates per incident were highest for lost during fishing incidents. Distributions of mainline length and weight and branchline length and weight are shown for GEN-6 data in Figure 3 and PIROP data in Figure 4; all distributions are skewed to the right with infrequent larger ALDFG values.

Raised ALDFG to effort estimates in the WCPFC-CA

From 2005 to 2024, WCPFC-CA longline effort averaged 756 million hooks annually, ranging from 516 million to 989 million hooks (Figure 5). Effort peaked in 2012 and declined thereafter. For the raising analysis, annual WCPFC-CA longline effort averaged 166 million hooks for the 11 GEN-6 CCMs (range: 112–247 million hooks) and 49 million hooks for the two PIROP

CCMs (range: 31–68 million hooks) (Figure 6). Table 6 presents WCPFC-CA ALDFG estimates under the four evaluated scenarios. From 2005 to 2024, mean annual ALDFG estimates ranked from highest to lowest as Scenario 1, Scenario 3, Scenario 4, and Scenario 2. Under Scenario 4, estimated annual mainline and branchline ALDFG in the WCPFC-CA averaged 133,555 km in length (Figure 7A) and 1,408 mt in weight (Figure 7B).

Branchline - hook and longline snap loss

Annual estimates for the number of abandoned and lost, hooks in the WCPFC-CA averaged 2,080,704 hooks under Scenario 4 (Table 6, range 1,685,078–2,653,903).

Discussion

Pelagic longlining is one of the dominant fishing methods in the Pacific Ocean. Within this study period, an average of 755.9 million longline hooks were fished in the WCPFC-CA (2005–2024, https://www.wcpfc.int/public-domain-aggregated-catcheffort-data). A total of 477 of 9,854 trips had ALDFG incidents resulting in 4.8% of all trips (2005–2024). There was a difference between the 11 CCMs reporting ALDFG incidents on GEN-6 Forms and the two CCMs reporting using the PIROP form, where 8.7% and 2.2% of trips had ALDFG incidents, respectively. The differing percentages probably result from fisher behavior between fisheries as opposed to differences in data collection systems. Observers did not document any longline gear discard in the two U.S. longline fisheries (Hawaii and A. Samoa); therefore, the percentage of ALDFG incidents on trips for the U.S. (2.2%) represents only abandonment and loss and is lower than the 11 CCMs with GEN-6 reported gear discards.

Richardson et al. (2015) used the same GEN-6 observer data source as does the current study and estimated that ALDFG occurred on 4.3% of trips (84 of 1,940 trips) from 2003 to 2015, based on 1,940 trips compared to 3,985 trips in this study. Richardson et al. (2015) estimated that there were 219 ALDFG incidents compared to 706 in the current study. There is no time-series information available for ALDFG given the lack of data; however, estimates based on GEN-6 data from 2003 to 2015 (Richardson et al. 2015) are lower than current estimates from 2005 to 2024.

Substantial mainline and branchline loss and abandonment can occur in longline fisheries, while reported discard of these intact gear elements is less common. Data from U.S. and A. Samoa observer programs indicate that longline gear parts on 44.5% of sets which is frequent. The primary reason is that when the mainline has parted, the vessel cannot find and retrieve the gear. When the mainline has parted the strategy is to locate the next segment of gear. If the segment can be located, the mainline is tied together and the retrieval continues. If the next segment cannot be located, the vessel transits to the radio buoy at the end of the longline and hauls the gear in reverse. The secondary cause of gear loss in ‘lost during fishing’ incidents is when the

vessel cannot locate the radio buoy at the end and the gear cannot be retrieved. There are modern GPS/AIS longline buoys that may reduce gear loss and are preferred to radio buoys. These buoys are battery or solar powered and can transmit consistent and accurate GPS positions to the vessel. In the Hawaii-based longline fishery, vessels typically deploy 5–6 GPS/AIS buoys for improved monitoring of gear location. Radio beacons are not commonly used in contemporary pelagic longline fisheries as direction finders are difficult to procure.

Raised ALDFG to effort estimates in the WCPFC-CA

Richardson et al. (2022) interviewed 451 fishers from seven countries about annual fishing effort and ALDFG incidents across multiple fisheries. 60 longline fishermen were surveyed, including 15 fishermen each from New Zealand, Indonesia, U.S. and Peru. For pelagic longline fisheries, surveys indicated that annual global ALDFG incidents involved 3.33% (±0.59%) of all longline mainlines, 3.58% (±0.78%) of all longline branchlines, and 2.86% (±0.55%) of all longline hooks.

Considering a reference year of 2015 with 857 million hooks deployed in the WCPFC-CA, gear characteristics enabled an estimate of mainline (kms) and branchline (number and kms) and hooks deployed (Table 7). The corresponding gear loss from Richardson et al. (2022) was applied to the longline estimates and compared to the current study based on Scenario 4 estimation. There is a large disparity between estimates as the Richardson et al. (2022) loss is estimated to be ~10 times higher than the current study.

There are several factors and assumptions that may affect the accuracy of estimating abandoned, lost and discarded fishing gear. The paramount factor is observer coverage and spatial extent of observer monitoring. The WCPFC adopted longline observer coverage in Conservation and Management Measure (CMM) 2007-01[4] which was superseded by 2018-05[5]. The CMM requires that no later than 30 June 2012, Members, Cooperating Non-Members and Participating Territories (CCMs) shall achieve 5% coverage of the effort in each fishery under the jurisdiction of the Commission. Before that date, no 5% coverage requirement applied, and coverage was typically below 5% for some CCMs. Since 2022, nine CCMs have reported longline coverage via the regional observer program. Coverage remained low in 2021 and 2022 due to COVID-19 disruptions, with four of the nine CCMs achieving 5% coverage (Panizza et al. 2023). Coverage improved after 2022: eight of the nine CCMs achieved 5% coverage in 2023, and all nine reached 5% coverage in 2024 (Panizza, et al. 2025**)**. While the requirement is 5% coverage, observer monitoring for ALDFG incidents is in fact lower than the 5% coverage rate. This relatively low coverage may affect the ALDFG incident estimates for longline fisheries. Many longline studies in the WCPFC have noted that observer data are not spatially representative of the entire longline effort.

[4] https://cmm.wcpfc.int/measure/cmm-2007-01
[5] https://cmm.wcpfc.int/measure/cmm-2018-05

A further source of uncertainty is how sets with no observer-reported ALDFG incidents are treated. To assess this uncertainty, the study developed four scenarios based on different assumptions for sets without recorded ALDFG incidents. Scenarios 1 and 2 were considered implausible but were included to define upper and lower bounds for ALDFG estimates in the WCPFC-CA. Scenarios 3 and 4 provide more realistic intermediate estimates, with Scenario 3 producing higher WCPFC-CA estimates than Scenario 4.

Weight estimates for incidents and longline sets assumed a mainline diameter of 4.0 mm and a branchline diameter of 2.1 mm. However, some vessels may use smaller gear, with mainline diameters as low as 3.5 mm and branchline diameters ranging from 1.8 to 2.3 mm. If smaller-diameter mainlines or branchlines are used, estimated ALDFG weights and the corresponding WCPFC-CA mt estimates would be lower. This study used diameter estimates from the Hawaii-based longline fleet and did not attempt to characterize gear dimensions across other fleets.

Limited information is available on what happens to longline gear at the end of its useful life. Anecdotal accounts suggest that vessel operators may return unusable gear to port about once a year, but subsequent disposal pathways such as incinerators, landfill, or other forms of disposal are poorly documented and may not adequately manage end-of-life longline gear. When adequate port reception facilities or disposal pathways are unavailable, end-of-life gear sometimes makes its way back into the marine environment.

At the 22nd annual WCPFC meeting, delegates from member countries were interviewed about how ports handle unusable longline gear landed by vessels. Seven CCMs (American Samoa, Cook Islands, French Polynesia, South Korea, Marshall Islands, Tonga, and Solomon Islands) reported that unusable longline gear is disposed of on land because no alternative disposal options are available. Directed port surveys conducted in Pohnpei, Federated States of Micronesia, and Majuro, Republic of the Marshall Islands, indicated that end-of-life purse seine gear is managed through an established and largely effective private-sector system. At both sites, local firms collect, consolidate, store, and accumulate discarded purse seine webbing, floats, and associated materials prior to shipment offshore for recycling or recovery. Representatives of port authorities, environmental agencies, and fisheries stakeholders consistently characterized purse seine gear management as functional, noting that disposal at municipal dumps is prohibited and that some webbing is secondarily reused within local communities for purposes such as fencing and hammocks. In contrast, no comparable management pathway was identified for longline gear, particularly monofilament line. At both ports, disposal of fishing gear at municipal dumps is prohibited, dedicated collection infrastructure is absent, and public agencies lack the resources and mandate to manage this waste stream. Establishing a viable longline gear management system would therefore require a dedicated collection and consolidation site within the port area, a verified off-island recycling or recovery outlet, and a third-party operator responsible for material oversight, contamination control, and shipment coordination. These findings suggest that adaptation of the existing purse seine consolidation model could provide a practical mechanism for diverting longline gear from local waste streams and the marine environment.

In Honolulu, Hawai‘i, the Center for Marine Debris Research (CMDR) has partnered with Hawaii Longline Association to provide a bin for recycling the Hawaii-based longline fleet's unusable monofilament nylon fishing line. Currently the fleet places their unusable monofilament into a bin. When the bin is full the CMDR picks up the material, sorts it for cleanliness and removes metal, and stores it as future recycling in Hawaii. Some of the monofilament fishing gear is reduced in size by shears and sent to H-Power where it is incinerated free of charge to produce electricity. In Hawaii, ALDFG is also collected from a Bounty Project that has removed 90 mt of mainly trawl and aquacultural gear since November 2022.

To resolve existing data gaps, improve estimates of abandoned, lost and discarded fishing gear, address potential gear loss drivers, and enhance end-of-life gear management pathways for longline fisheries in the WCPFC Convention Area, the following recommendations are suggested:

1) **Increase longline observer coverage.** The WCPFC adopted longline observer coverage in Conservation and Management Measure (CMM) 2007-01[6] which was superseded by 2018-05[7]. The CMM requires that no later than 30 June 2012, Members, Cooperating Non-Members and Participating Territories (CCMs) shall achieve 5% coverage of the effort in each fishery under the jurisdiction of the Commission. Observer data are not spatially representative of the entire longline effort distribution. An increase in observer coverage, including the adoption of a timeline to reach 100% coverage, would lead to a more robust and conclusive dataset around ALDFG incidents and allow the effective implementation of management measures and international agreements.
2) **Explore opportunities to capture ALDFG indicators via electronic monitoring.** Fleets are rapidly adopting electronic monitoring (EM) technologies to improve transparency and ensure compliance with management measures. Longline fleets could expand the scope of EM indicators to examine ALDFG incidents, including quantities and drivers.
3) **Extend ALDFG reporting to the entire WCPFC ROP.** Regional Observer Pollution Reports (Form GEN-6) have been submitted from 11 WCPFC members (Forum Fisheries Agency members and French Polynesia). The WCPFC could incorporate the use of GEN-6 forms into ROP protocols and across the entire Convention Area/across all regional CCMs, leading to a more robust and conclusive dataset around ALDFG incidents.
4) **Extend ALDFG reporting to additional WCPFC fleets.** Extending reporting requirements beyond the FFA, French Polynesia and U.S. to capture the distant-water fishing nations (e.g. Japan, Korea, Taiwan and China) would lead to a more robust and conclusive dataset around ALDFG incidents.

[6] https://cmm.wcpfc.int/measure/cmm-2007-01
[7] https://cmm.wcpfc.int/measure/cmm-2018-05

5) **Update the GEN-6** and PIROP forms. The GEN-6 form was last updated in 2014, and both the GEN-6 and PIROP forms could be updated to facilitate analysis. To improve reporting consistency for gear descriptions and quantities- responses should be standardized, either through check boxes or by providing example responses, such as descriptions; mainline, branchline, beacon, hooks, etc. on the second page of the GEN-6 form where instructions for completing the report are provided. On the GEN-6 form, the "comment" field could be replaced with "reason for ALDFG incident" and include a series of check boxes like "gear parting", "unknown entanglement", "entanglement with existing/legacy ALDFG", "snag on submerged feature", "entanglement with active gear", "operator error", "vessel traffic", etc.
6) **Require observer training on ALDFG reporting.** Observer training could be adapted to include a specific module on reporting ALDFG incidents. Enhanced training could lead to more consistency across observer reports, which would simplify interpretation of datasets and data results.
7) **Request authorization for the release of observer journals that may contain ancillary data to inform ALDFG estimations.** To capture any overflow from their reporting forms, FFA observers use journals to log additional observations about incidents reported on longline trips. For this study, authorization was not provided for the review of the FFA journals as a release was not requested. The content and usefulness of journal observations to further inform analyses of ALDFG incidents is unknown and probably differs among observers. It would be beneficial to analyze a subset of observer journals to assess potential usefulness. Since the journals are considered confidential, perhaps SPC could undertake an analysis of a subset of observer journals for any additional data related to ALDFG incidents.
8) **Identify opportunities for improving gear management at the end of its useful life to prevent discard or incidental loss.** In regions with less developed waste management systems, end-of-life gear is often left on beaches or portside. Storms, including wind, waves and stormwater, can release this gear back into the marine environment. In ports of landing that lack disposal for fishing gear, vessels may be incentivized to discard end-of-life gear at sea or in nearshore environments. CCMs could consider identifying circumstances and their respective port facilities and possible end-of-life gear management options. CCMs could work jointly to recognize opportunities and barriers to improving port reception facilities, in collaboration with the private/fishing sector local and international NGOs.

Acknowledgments

We thank the observers who collected ALDFG data from longline fisheries in the WCPFC-CA. We are also grateful to the 13 WCPFC CCMs that authorized access to GEN-6 and PIROP data. SPC-OFP and PIROP provided extensive observer data management support and analytical advice. Neil Kanemoto (Pacific Ocean Producers) provided longline gear advice and assisted with gear conversions, and Melanie Hutchinson (IATTC) provided Figure 1.

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Table 1. Statistics for 13 WCPFC CCMs on mean annual longline effort (2005–2024), hooks per trip and longline branchline length.

Vessel flag	Mean annual (2005-2024) effort (hooks)	Mean annual (2005-2024) hooks per trip	Observed vessel flag	Branchline length (m)
Cook Islands	4,022,265	79,792	Cook Islands	12.4
Fiji	40,665,649	42,194	Fiji	14.0
FSM	10,055,016	108,185	FSM	19.9
Kiribati	3,774,069	206,642	Kiribati	17.8
Marshall Islands	3,232,368	20,036	Marshall Islands	22.3
French Polynesia	15,036,658	28,054	French Polynesia	9.2
Papua New Guinea	3,226,843	114,806	Papua New Guinea	16.8
Solomon Islands	21,524,251	112,940	Solomon Islands	17.6
Tonga	139,566	48,265	Tonga	14.3
Vanuatu	9,694,724	158,751	Vanuatu	18.0
Samoa	6,460,309	48,265	Samoa	9.7
U.S.	48,548,215	34,044	Hawaii	12.6
			American Samoa	10.8
Weighted mean (sum annual effort/sum trips)		45,394	Mean	15.0

Table 2. Trips by flag from GEN-6 observer data for 11 CMMs and U.S. observer data (PIROP - Hawaii and American Samoa) within the WCPFC-CA.

Observed vessel flag	Number of trips	Number of GEN6 pollution incidents	Number of GEN6 ALDFG incidents	Number of trips with GEN6 ALDFG incidents	Percentage of trips with ALDFG
Cook Islands	94	80	18	10	10.6%
Fiji	2,037	871	343	177	8.7%
FSM	129	228	80	29	22.5%
Kiribati	51	15	3	3	5.9%
Marshall Islands	256	300	50	32	12.5%
French Polynesia	826	152	83	36	4.4%
Papua New Guinea	96	219	35	16	16.7%
Solomon Islands	70	295	58	18	25.7%
Tonga	192	71	8	3	1.6%
Vanuatu	177	211	26	21	11.9%
Samoa	57	26	2	2	3.5%
Total	3,985	2,468	706	347	8.7%
	Number of trips		Number ALDFG incidents	Number of trips with PIROP ALDFG incidents	
Hawaii	5,622		110	105	1.9%
American Samoa	257		28	25	9.7%
Total	5,879		138	130	2.2%
	Number of sets	Mainline parted - Yes (%)	Mainline parted - No (%)		
Hawaii	76,083	34,236 (45.0%)	41,847 (55.0%)		
American Samoa	7,685	3,031 (39.4%)	4,654 (60.6%)		
Total	83,768	37,267 (44.5%)	46,501 (55.5%)		

Table 3. Categorization of the potential drivers of abandoned, or lost during fishing incidents in 257 activities (119 Gen-6 and 138 PIROP) of Abandoned and Lost During Fishing.

Abandoned fishing gear		
Category		
1	Gear abandoned to start next longline set	1
2	Mainline gear separated	3
3	Interaction with a seamount	3
4	Interaction with a drifting object, usually a dFAD	9
5	Unknown reason	38
6	Operator error	1
7	Something very heavy on gear	3
8	Large gear tangle	10
Total		68

Lost fishing gear		
Category		
1	Line parted and could not find and retrieve gear	57
2	Unknown reason	88
3	Could not find the end radio buoy to retrieve backwards	12
4	Operator error (e.g. poor snap placement, branchline dropped into the ocean)	7
5	Something very heavy on gear	2
6	Gear cut or stolen by another vessel	10
7	Gear caught on propeller	9
8	Lost due to rough seas or strong current	4
Total		189

Table 4. Instances of abandoned, lost, or discarded pelagic longline gear (ALDFG) from GEN-6 and PIROP data for Exclusive Economic Zones (EEZs) and High Seas.

EEZ or High Seas	Number of GEN-6 ALDFG incidents in EEZ or High Seas
Australia	1
Cook Islands	37
Fiji	247
FSM	29
Kiribati	3
Marshall Islands	70
Niue	4
French Polynesia	81
Papua New Guinea	35
Solomon Islands	54
Tokelau	5
Tonga	25
Tuvalu	22
Vanuatu	32
High Seas	61
Total	706

EEZ or High Seas	Number of GEN-6 ALDFG incidents in EEZ or High Seas
Hawaii	50
American Samoa	22
High Seas	66
Total	138

Table 5. Six metrics of abandoned, lost, or discarded pelagic longline gear (ALDFG) as mean estimates per incident and mean estimates per longline set that considered positive incidents within a trip.

GEN-6 mean per incident (n=706)						PIROP mean per set (n=138)			
	Mean						Mean		
	All	Abandoned	Lost during fishing	Discarded			All	Abandoned	Lost during fishing
Mainline length (meters)	560.5	335.2	2,714.9	346.8		Mainline length (meters)	3,891.6	5,620.9	3,726.9
Mainline weight (grams)	7,538.2	4,519.7	36,648.6	4,656.0		Mainline weight (grams)	52,533.2	75,876.6	50,309.9
Branchline length (meters)	448.5	380.0	1,788.6	308.8		Branchline length (meters)	1,363.6	1,915.0	1,311.1
Number of branchlines	29.9	25.3	119.2	20.6		Number of branchlines	90.9	127.7	87.4
Branchline weight (grams)	1,965.5	1,654.7	7,669.2	1,372.8		Branchline weight (grams)	5,847.1	8,211.3	5,621.9
Mainline plus branchline length (meters)	1,009.0	715.2	4,503.5	655.5		Mainline plus branchline length (meters)	5,255.3	7,535.9	5,038.1
Mainline plus branchline weight (grams)	9,503.7	6,172.7	44,317.7	6,020.0		Mainline plus branchline weight (grams)	58,380.2	84,087.8	55,931.9
Number of buoys (n=359)	0.508	0.618	4.422	0.072		Number of buoys (n=585)	4.239	5.583	4.111
Number of radio beacons (n=20)	0.028	0.018	0.188	0.012		Number of radio beacons (n=35)	0.254	0.167	0.262
GEN-6 mean per set (n=653)									
Mainline length (meters)	606.0	354.6	3,109.8	377.8					
Mainline weight (grams)	8,150.0	4,778.8	41,979.3	5,063.4					
Branchline length (meters)	484.8	450.6	1,777.9	357.9					
Number of branchlines	32.3	30.0	118.5	23.9					
Branchline weight (grams)	2,125.1	1,958.7	7,623.2	1,587.0					
Mainline plus branchline length (meters)	1,090.9	715.2	4,503.5	655.5					
Mainline plus branchline weight (grams)	10,275.1	6,737.5	49,602.5	6,650.4					
Number of buoys (n=359)	0.550	0.654	5.018	0.654					
Number of radio beacons (n=20)	0.031	0.019	0.020	0.015					

Table 6. Mean annual estimates (2005–2024) within the WCPF-CA of abandoned, lost, or discarded pelagic longline gear (ALDFG) mainline length and weight, branchline length and weight, mainline length plus branchline length, mainline weight plus branchline weight and number of buoys and radio beacons. Four (4) scenarios were considered in raised GEN-6 and PIROP ALDFG estimates to the WCPFC-CA.

	Scenario 1	Scenario 2	Scenario 3	Scenario 4
	Assumption - all 15 sets in a trip	Assumption - 1 of 15 sets in a trip	Assumption - 1 of 15 sets in a trip	Assumption - 1 of 15 sets in a trip
	have 100% ALDFG	has 100% ALDFG, 14 sets with zero ALDFG	has 100% ALDFG, 14 sets with 50% ALDFG	has 100% ALDFG, 14 sets with 25% ALDFG
	For illustrattion of highest	For illustrattion of lowest	For illustrattion of intermediate	For illustrattion of intermediate
ALDFG loss (mean 2005-2024)	WCPFC estimates. Plausible-No	WCPFC estimates. Plausible-No	WCPFC estimates. Plausible-Yes	WCPFC estimates. Plausible-Yes
Mainline length (kms)	396,231	26,160	183,225	91,534
Mainline weight (mt)	5,319	351	2,449	1,220
Branchline length (kms)	184,258	12,399	87,184	43,821
Branchline weight (mt)	809	54	377	188
Mainline plus branchline length (kms)	580,489	38,559	270,409	135,355
Mainline plus branchline weight (mt)	6,128	404	2,825	1,408
Number of buoys	42,306	2,807	19,685	9,852
Number of radio beacons	2,504	168	1,200	595
Number of branchlines	12,283,881	826,602	5,812,282	2,921,416
Number of hooks	8,814,659	592,583	4,148,590	2,080,704
Branchline %	1.64	0.11	0.78	0.39
Hook %	1.19	0.08	0.56	0.28

Table 7. Comparison of annual ALDFG loss in the WCPFC-CA from Richardson et al. (2022) and the current study.

Mainline length	30,640,606	kms				
Based on HBF +1(31) * distance between hooks (34.6-m) * gear segments (28,556,667)						
Branchline and hook number	857	million				
Branchline length (15m * branchline number)	12,855,000	kms				
Loss (Richardson et al. 2022)			Loss - this study, scenario 4 with 15 sets in a trips, assumed as one longline set of 100% and 14 sets of 25% ALDFG			
Mainline loss	3.30	percent (%)	Mainline loss	0.30	percent (%)	
Mainline loss	**1,011,140**	**kms**	**Mainline loss**	**91,534**	**kms**	
Branchline loss	3.58	percent (%)	Branchline loss	0.39	percent (%)	
Branchline loss (number)	**28.97**	million	**Branchline loss (number)**	**2.92**	**million**	
Branchline loss (length)	**434,499**	**kms**	**Branchline loss (length)**	**43,821**	**kms**	
Hook loss	2.86	percent (%)	Hook loss	0.39	percent (%)	
Hook loss	**24.51**	**million**	**Hook loss**	**2.08**	**million**	

Figure 1. Branchline and components used in pelagic longline fishing. The weight may or may not be incorporated depending on seabird mitigation requirements.

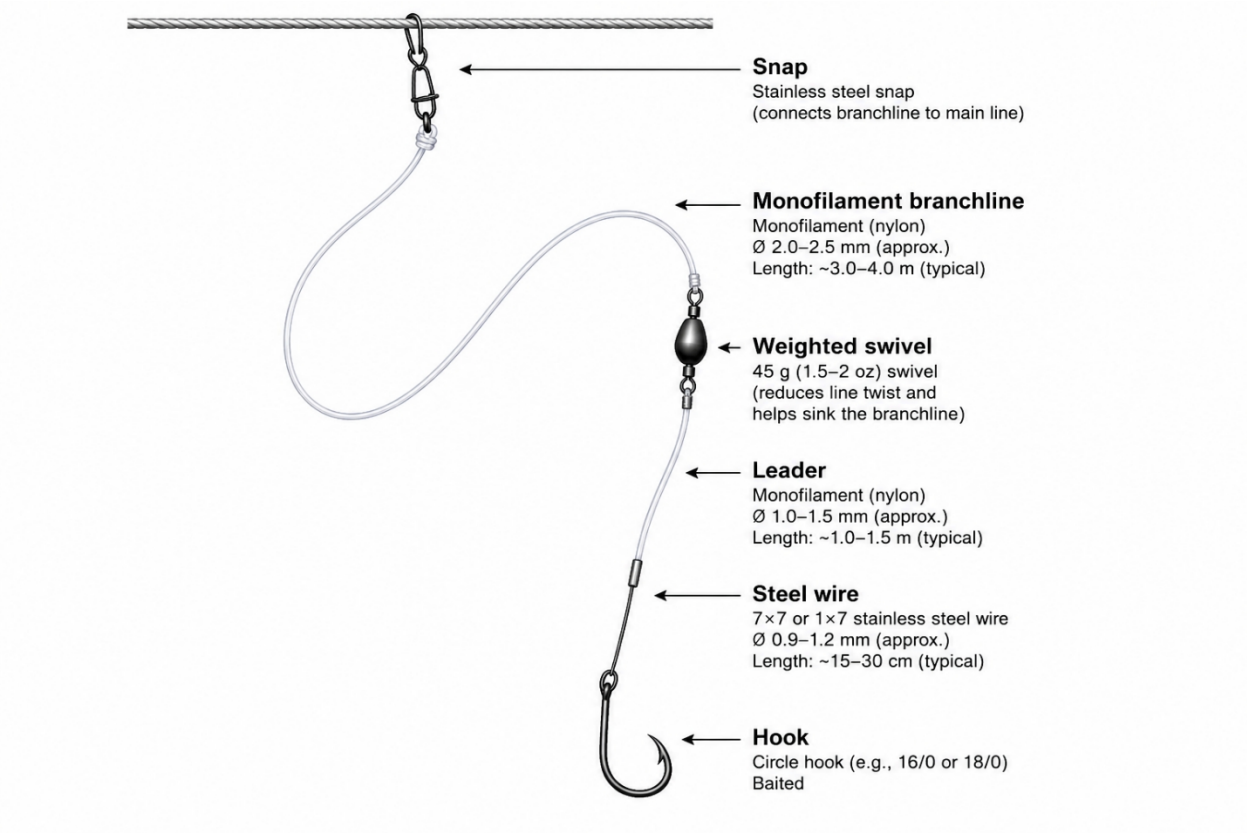
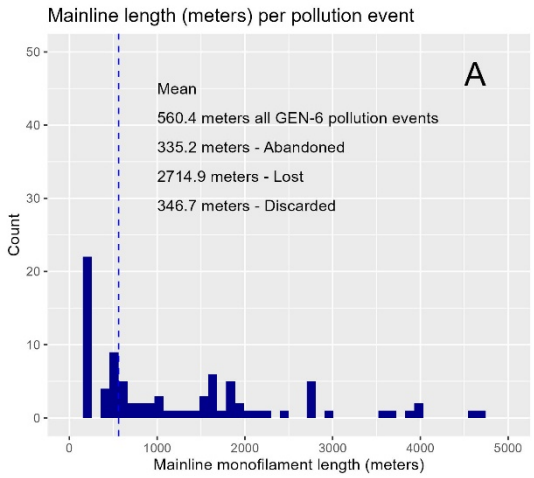


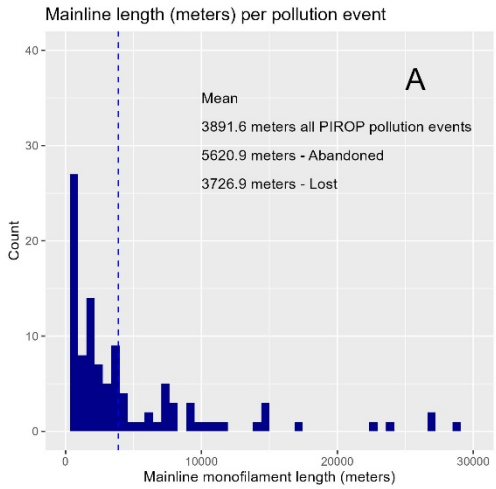
Figure 2. Processing of GEN-6 and PIROP data and raising ALDFG to WCPFC-CA.

Example – Mainline length (meters) and reference year 2015

GEN-6 706 ALDFG incidents



PIRO 138 ALDFG incidents



Sample each distribution 5,000 times
Sum all values and divide by an assumed longline set effort of 3,000 hooks

Scale to 2015 WCPFC-CA longline effort of 857 million hooks

11 CCMs with GEN-6 data had 81.1% of effort and were raised to the 857 million hooks

2 U,S, CCMs with PIROP data had 18.9% of effort and were raised to the 857 million hooks

A procedure was applied to mainline weight, branchline length and weight, number of buoys and radio beacons

Analyses proceeded with the four assumptions for longline sets within a trip that had no observer documented ALDFG

Figure 3. Mean estimates per incident for mainline length (A) weight (B), branchline length (C) and weight (D) of abandoned, lost, or discarded pelagic longline gear (ALDFG) for 11 members (GEN-6 data) in the WCPFC-CA.

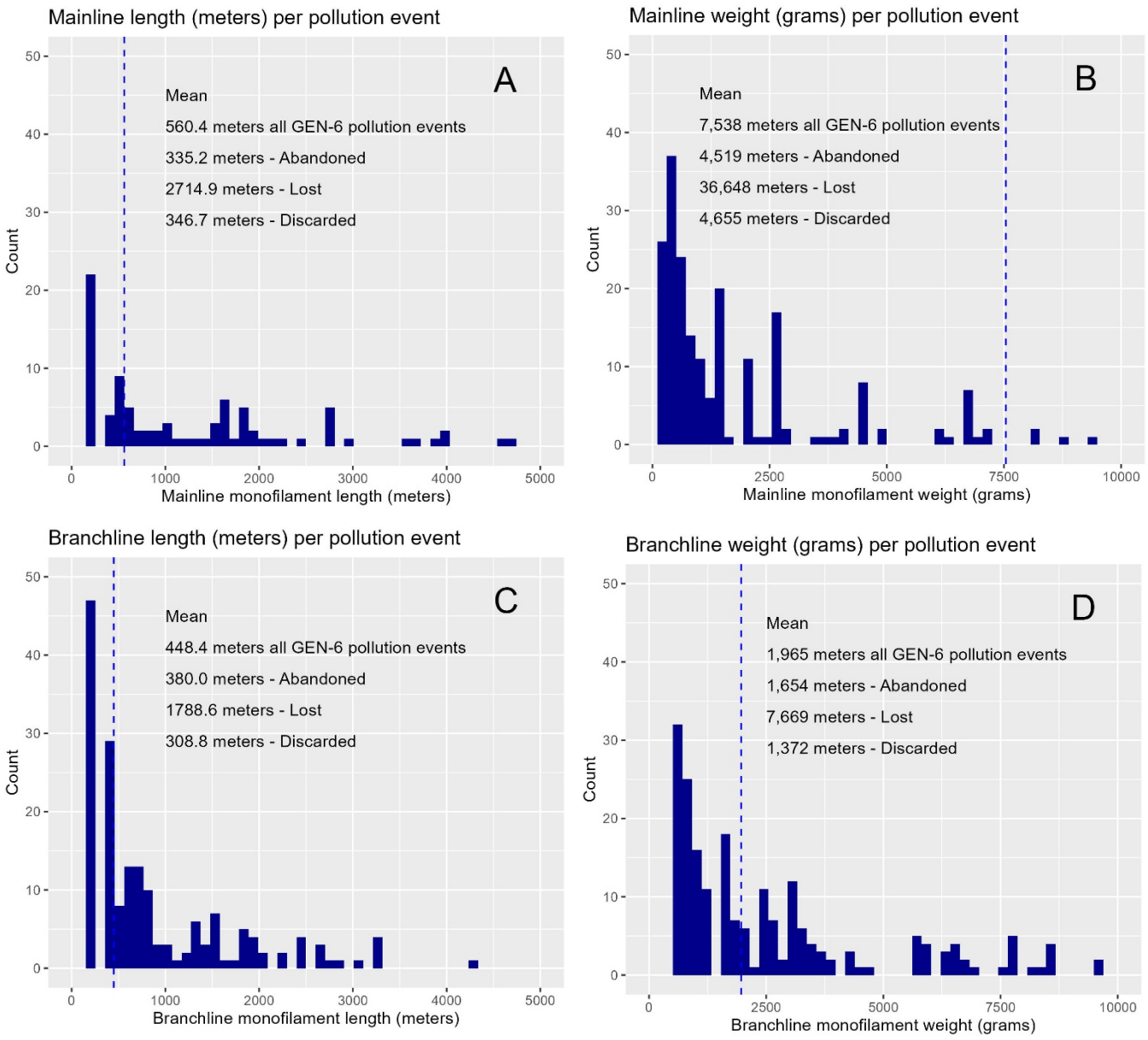


Figure 4. Mean estimates per incident for mainline length (A) weight (B), branchline length (C) and weight (D) of abandoned, lost, or discarded pelagic longline gear (ALDFG) for two members (PIROP data) in the WCPFC-CA.

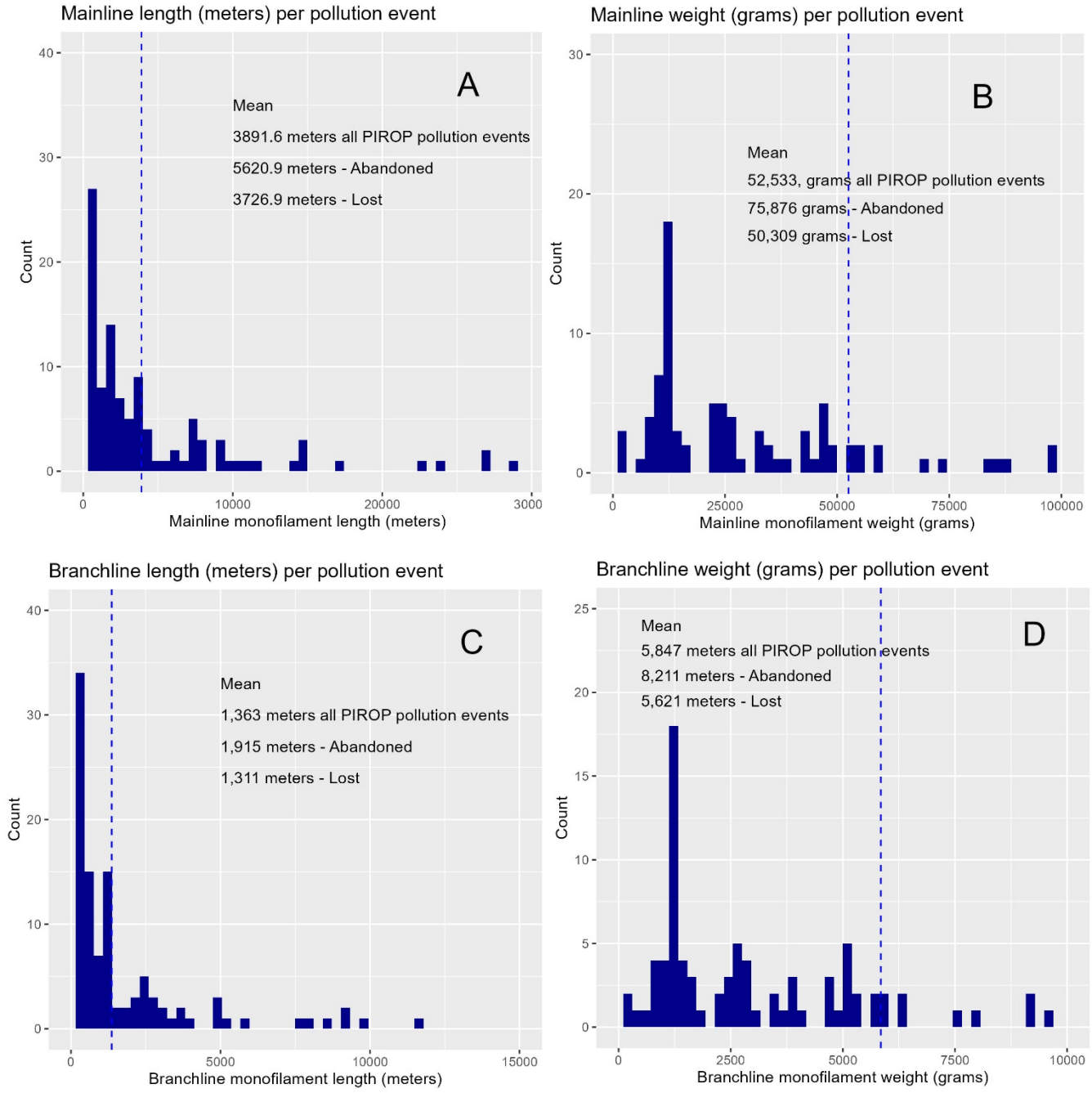


Figure 5. Longline effort (hooks) based on aggregated Year and Month 5º latitude and 5º longitude data in the WCPFC-CA (2005–2024).

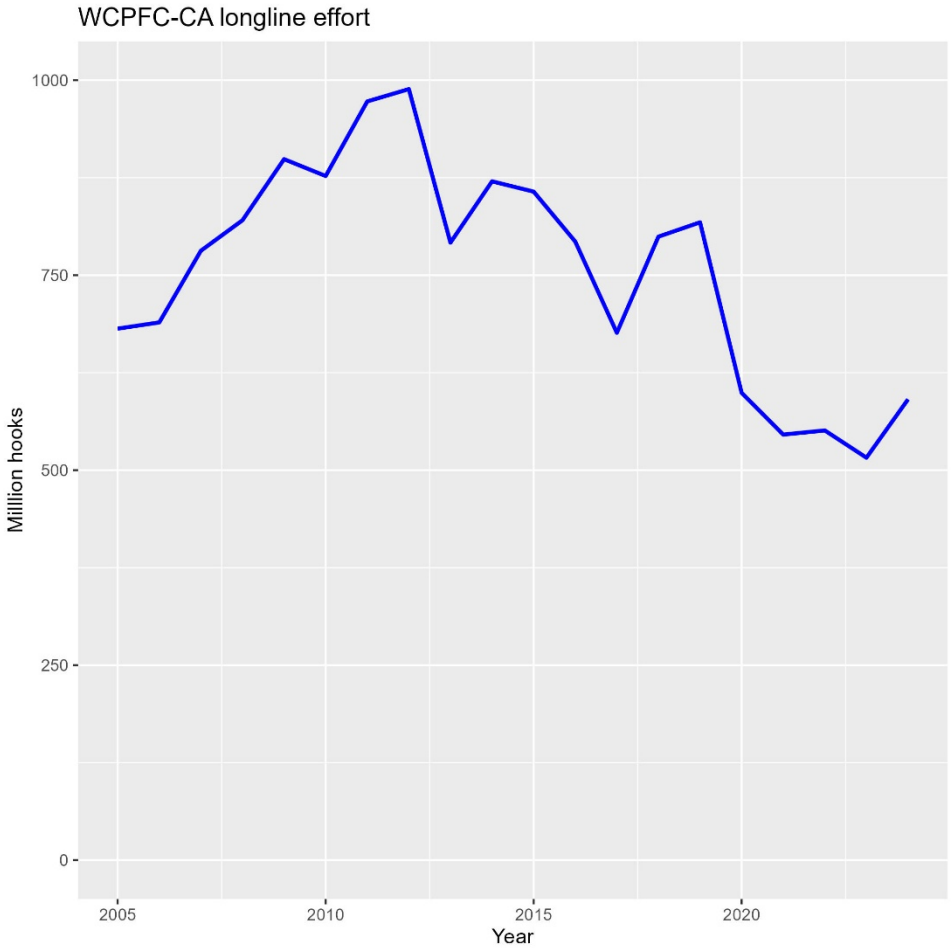


Figure 6. Longline effort (hooks) based on aggregated Year and Month 5º latitude and 5º longitude data in the WCPFC-CA (2005–2024) for 11 CCMs (members) with GEN-6 data and additional observer PIROP data from the U.S. (Hawaii and American Samoa).

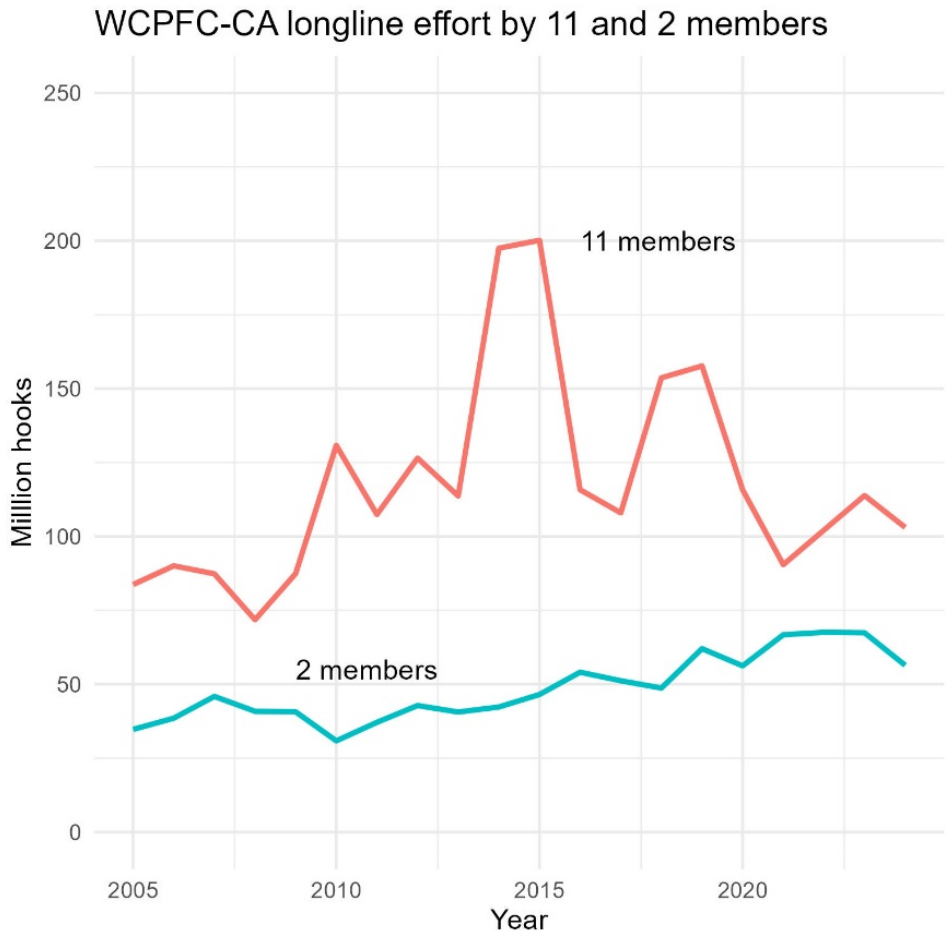
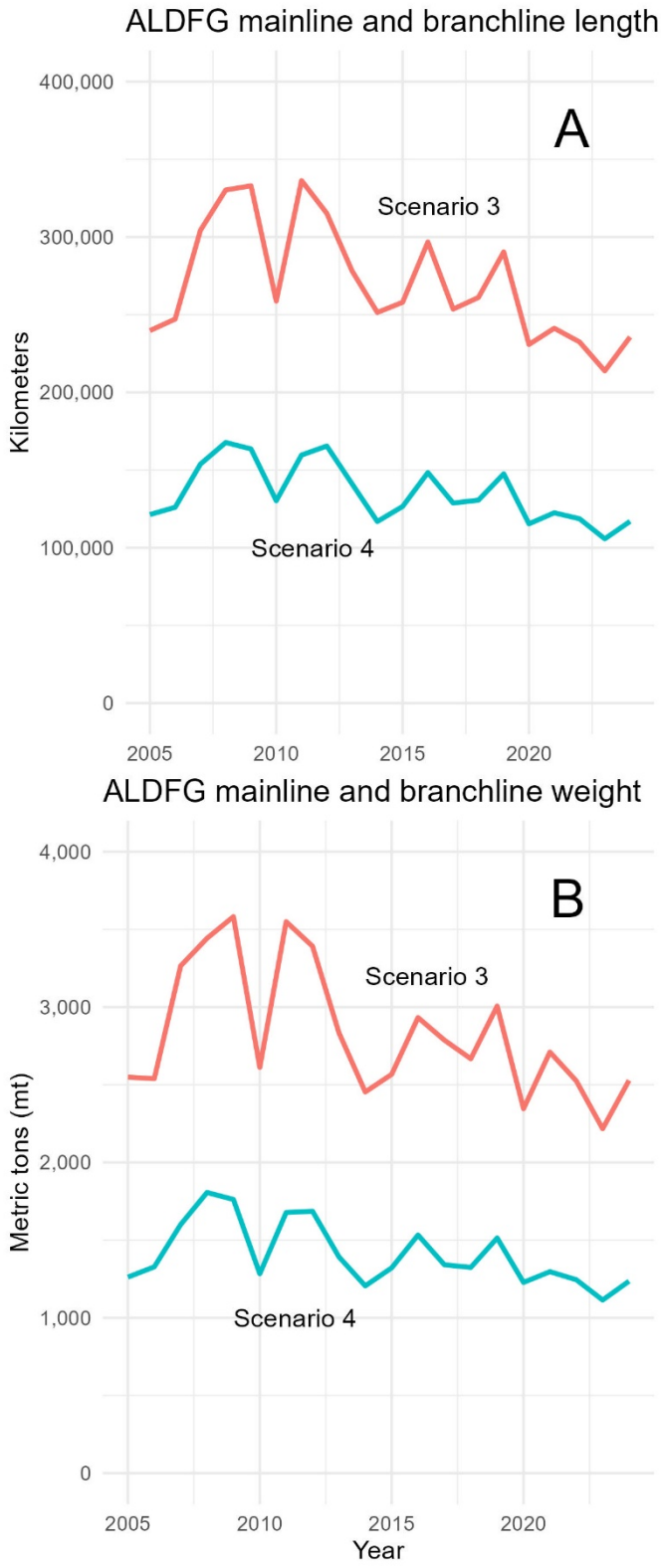


Figure 7. Annual estimates of mainline and branchline length (A) and weight (B) as abandoned, lost and discarded fishing gear (ALDFG) in the WCPFC-CA. Illustration is based on Scenario 3 and 4 in the raising methodology.



Appendix 1

Glossary of Terms

Abandoned, Lost, or Discarded Fishing Gear (ALDFG)
A collective term describing fishing gear that, for a variety of reasons, is no longer under the control of its owner/operator and is released into the marine, coastal, or aquatic environment.

Abandoned Gear
Fishing gear over which that operator/owner has control and that could be retrieved by owner/operator, but that is deliberately left at sea due to force majeure or other unforeseen reason s (FAO, 2019).

ALDFG Incident
An observer-reported event involving abandoned, lost, or discarded fishing gear. The term is used throughout this study to distinguish gear-related incidents from other marine pollution events recorded by observer programs.

Branchline
A secondary fishing line attached to the mainline that typically includes a snap, monofilament line, hook, and in some fisheries a weight and leader.

CCM (Member, Cooperating Non-Member, or Participating Territory)
The term used by WCPFC to collectively refer to countries and territories participating in the Commission and its conservation and management measures.

Discarded Gear
Fishing gear that is released at sea without any attempt for further control or recovery by the owner/operator. Referred to as "Dumped Gear" in the GEN-6 observer form and "Discarded Gear" in this study per FAO definition.

EEZ (Exclusive Economic Zone)
The maritime area extending up to 200 nautical miles from a coastal state's baseline in which the coastal state has sovereign rights over natural resources.

End-of-Life Fishing Gear
Fishing gear that has reached the end of its useful life or is damaged beyond repair.

Fishing Effort
A measure of fishing activity, typically expressed as numbers of hooks deployed, longline sets, fishing days, or trips. In this study, annual longline hook deployments were used for regional scaling of ALDFG estimates.

GEN-6 Form
The Regional Observer Pollution Report form used by SPC/FFA observer programs to record marine pollution incidents, including abandoned, lost, and discarded fishing gear.

Ghost Fishing
The continued capture or entanglement of marine organisms by lost, abandoned, or discarded fishing gear.

High Seas
Marine waters beyond national Exclusive Economic Zones (EEZs).

Hooks Between Floats (HBF)
The number of hooks deployed between successive surface floats on a pelagic longline. HBF is a primary determinant of fishing depth.
Longline Set
A single deployment of pelagic longline gear. In this study, the longline set was used as the primary sampling unit because fishing effort is more consistent among sets than among trips.
Lost Gear
Fishing gear over which the owner/operator has accidentally lost control and that cannot be located and/or retrieved by the owner/operator (FAO, 2019).
Mainline
The primary monofilament line from which branchlines are suspended in a pelagic longline fishery. Typical diameters range from approximately 3.5–4.0 mm.
Monofilament
A single-strand synthetic fishing line, typically manufactured from nylon or similar polymers, used as the primary material for longline mainlines and branchlines.
Observer Coverage
The proportion of fishing activity monitored by onboard observers. Observer coverage is typically expressed as the percentage of fishing effort or trips monitored.
PIROP (Pacific Islands Regional Observer Program)
The observer program responsible for collecting fisheries observer data from U.S. Hawaii-based and American Samoa-based longline fisheries used in this study.
Pollution Incident
An observer- reported event involving the discharge, loss, abandonment, or discard of material at sea.
Radio Buoy
A floating device deployed at the end of a longline set to assist with locating and recovering fishing gear. Loss of a terminal radio buoy can contribute to gear loss.
ROP (Regional Observer Program)
The WCPFC Regional Observer Program monitors certain fishing operations occurring on the High Seas and provides fisheries observer data for compliance and scientific purposes.
Raised Estimate
An estimate derived by scaling observed data to a larger fishery or geographic area using known fishing effort. The term "raised" is commonly used in fisheries science and is preferred over "extrapolated" in this study.
WCPFC-CA (WCPFC Convention Area)
The geographic area covered by the Convention on the Conservation and Management of Highly Migratory Fish Stocks in the Western and Central Pacific Ocean.

SPC/FFA REGIONAL OBSERVER POLLUTION REPORT

FORM GEN-6

REVISED MARCH 2014

OBSERVER NAME	VESSEL NAME	OBSERVER ID NUMBER	PAGE OF

- fill in one form for each pollution incident -

INCIDENT DETAILS

Ship's DATE and TIME DD	MM	YY	hh	mm	LATITUDE (dd°mm.mmm')	N / S	LONGITUDE (ddd°mm.mmm')	E / W	EEZ / HARBOUR

WIND DIRECTION	WIND SPEED	SEA CONDITIONS (C, S, M, R)	CURRENT : (knts and direction °)	OBSERVER'S VESSEL ACTIVITY

NAME OF OFFENDING VESSEL	IRCS	TYPE OF VESSEL	YOUR POSITION FROM OFFENDING VESSEL Compass Bearing	Distance (nautical miles)

WASTE DUMPED OVERBOARD

Material *Tick each box that applies*		Describe Type	Describe Quantity
Plastics			
Metals			
Waste oil			
Chemicals			
General garbage (*within 12 miles of shoreline*)			
de scri			

OIL SPILLAGES AND LEAKAGES

Source	*Tick each box that applies*	Visual Appearance / Colour	Describe Area and Quantity
Vessel Aground / Collision			
Vessel at Anchor / Berth			
Vessel Underway			
Land based source - Describe source			
Ot he			

Abandoned or Lost Fishing Gear

Source	Activity	Describe Gear	Estimate Quantity
Lost during fishing			
Abandoned			
Dumped			

Other comments:

W	**Y / N**
Did you take any photos?	**Y / N**
If ,,	

MARPOL Regualations - state

It is illegal for any vessel to discard any form of plastics into the sea at anytime.

It is illegal for any vessel to discard any form of oil into the sea at anytime.

It is illegal for any vessel to dump any form of rubbish into the sea within 12 nautical mile of the sea shore.

Revised March 2014

Notes on FORM GEN-6

POLLUTION REPORT

Remember - Fill in one form for each pollution incident. There might be more than one per day.
If forms run out, report this on the last form and continue recording pollution infringements in diary.

Observer Name	Put first name first, and your family name last.
Vessel Name	Record the full name of the vessel. Do not use any abbrevations.
Observer ID Number	Use the number assigned by the observer programme e.g. AA 03-01
Page of	Number all GEN-6 pages in sequence from the start until the end of the trip
Date of Incident (dd/mm/yy)	Date pollution seen in day, month and year. *Use ship's time as defined in other observer data collection forms*
Time (00.00 hrs)	Report the time using the 24hr clock.
Latitude / Longitude	Record the GPS positon of the host vessel when the pollution was first seen.
EEZ / Harbour	Record the EEZ or, for shorebase staff, mark port or Harbour name here.
Wind Direction	The prevailing wind direction. Use degree eg. 90 degrees for an east wind
Wind Speed	Record the prevailng wind speed.
Sea Conditions	C- Calm, S- Slight, M- Moderate, R - Rough.
Current (knts and direction)	If the vessel has a current meter find out what the current strength is.
Observer's vessel activity	State the host (observer's) vessel activity at the time of the pollution incident. Some activities to consider might be: fishing; transhipping; bunkering; transitting; aground.
Name of offending vessel	Make an effort to record the complete and proper name of offending vessel. Be careful not to make any spelling mistakes which may make it difficult to prosecute the vessel if the report goes through legal proceedings.
IRCS	The international callsign is marked in large letters on the side of the boat.
Type of vessel	Consider the full vessel and aircraft codes on the front of Form GEN-1.
Your positon from offending vessel.	vessel. The radar can be used to get an extact distance in nautical miles. Otherwise give best estimate and note if it is the observer's or someone
	WASTE DUMPED OVERBOARD
Material	Tick each correct box to show which types of materials were dumped. Only tick two or more materials if vessel has dumped more than one material type over at the same time - e.g.: it dumped plastic and metal at 10:00hrs. If plastic was dumped at 10:00hrs and metal at 16:00hrs - record separately.
Describe type	Give as good a description as possible of the type of dumped material. E.g.: - plastic bags; bait boxes plastic strapping; bait boxes plastic bags; etc.
Describe Quantities	Give a best estimate of the amount dumped. Sometimes this will be easy - e.g., 12 metal oil drums were dumped. At other times the material might be too far away to see the amount. If it is too far away then estimate the amount as well as possible and make note that it is only a rough estimate at
	OIL SPILLAGES AND LEAKAGES
Source	Tick to indicate where the spillage or leak came from
Visual Appearance / Colour	Describe the colour/ thickness/depth of the spill as well as able.
Describe Area and Quantity	Give a best estimate of the size of the spill. The boat could be a size reference - e.g.: it was 4 times bigger than the boat.
	Abandoned or Lost Fishing Gear
Lost during fishing	Lost by host vessel. Describe activity when gear lost (setting/hauling/soak)
Abandoned	For any fishing gear abandoned by another vessel and found by host vessel
Dumped	For any gear dumped by host vessel, see above.

Supplementary notes on Marpol Regulations

Note: Vessels may dump garbage as close as 3 nautical miles to the shore if they have a 'comminuter' onboard (a machine that shreds garbage to tiny pieces).

Otherwise they cannot dump garbage within 12 nm of the coast. Report on all vessels dumping within 12nm of the coast. We can check if they have a comminuter onboard later.

Country Codes

AS	American Samoa	MH	Marshall Islands
AU	Australia	NR	Nauru
CK	Cook Islands	NC	New Caledonia
EC	Ecuador	NZ	New Zealand
FM	Fed. States of Micronesia	NU	Niue
FJ	Fiji Islands	MR	Northern Mariana
FR	France	PW	Palau
PF	French Polynesia	PG	Papua New Guinea
GU	Guam	PH	Philippine
ID	Indonesia	RU	Russia
IW	International Waters	SB	Solomon Islands
JP	Japan	TW	Taiwan
TO	Kingdom of Tonga	TK	Tokelau
KI	Kiribati	TV	Tuvalu
KR	Korea	US	United States
CN	Mainland China	VU	Vanuatu

7. Set and Haul

General Instructions

The Set and Haul form captures basic fishing effort data from longline sets. Complete one for each set of gear deployed. If the vessel makes multiple sets in the same day, record each set of gear on a separate form with its own set number. Make sure to record catch from each set on separate forms. A set of gear is defined by the *begin set* and an *end set* followed by the vessel relocating or ceasing setting operations.

If the information for any data element is not available or applicable, leave the field(s) blank and describe the situation in the Comments section. If you need additional space, use your Documentation Notebook.

NOTE: Observers must monitor the entire first hour of the setting of gear and the entire haul back/ gear retrieval process.

Data Elements

Set No. – Number the sets consecutively, beginning with 01. This header information is needed on subsequent forms.

Set Information Blocks

Begin Set

Date – When the setting operations start (the first piece of gear goes into the water).

Time – The exact time when the setting operations start using the 24-hour clock. This is defined by the first piece of fishing gear entering the water (usually a radio buoy). *DO NOT* round the time to the nearest 5 minutes, 10 minutes or 15 minutes. Document any situations preventing you from obtaining exact times.

Latitude – Latitude of the vessel at the beginning of the setting operations. Enter degrees, minutes, and tenths of minutes. Enter N in the trailing block for the northern hemisphere, and S for the southern hemisphere (ex: 21° 18.3' N). Obtain positions from the vessel's GPS unit. Most vessels have multiple GPS receivers. Pick one and use that same one for each time you need positions.

Longitude – Longitude of the vessel at the beginning of the setting operation. Enter degrees, minutes, and tenths of minutes. Enter E in the trailing block to indicate East longitude and W for west longitude (ex: 157° 55.3'W). Obtain positions from the vessel's GPS unit.

DO NOT *record positions obtained from the captain or logbook without noting the reason for this in the comments section.*

Weather Code – A two-digit code that indicates the weather conditions at the beginning of the setting operation. Reference tables are in your manual and at the bottom of the form.

Beaufort Scale – A two-digit number, 00-10 describing sea conditions at the beginning of setting operations. Reference tables are in your manual and at the bottom of the form.

Sea Surface Temperature – Record the sea surface temperature to the nearest 0.1° F. Use the vessel's thermometer. If the vessel's thermometer is broken, leave this blank.

End Set

Complete the elements with the same instructions from the Begin Set as appropriate for this section.

Haul Information Blocks

Begin Haul

Date – When the haul back operation began (when the first piece of gear came out of the water). This is usually a radio buoy. Complete the remaining elements as appropriate for this section.

End Haul

Date – When the haul back operation ends (when the last piece of gear, usually a radio buoy, comes out of the water). Complete the elements as appropriate for this section

Set/Haul Events

Haul Back Direction Code – A two-digit code that indicates which end the vessel started hauling the gear from. If the haul back commences more than five (5) floats from an end, select 03 (other) describing the float number and situation in the comments section.

Line Parted? – If the mainline unintentionally broke (parted), place a check mark in the box. Do not count instances when the crew cuts the line to make a repair.

No. of Sections Retrieved – If the mainline parts, enter the number of pieces hauled back. If the mainline parts n times and all sections are retrieved, use the formula (n+1) to calculate the number of sections retrieved. Describe the amount of any portion of the main line that is lost and an approximate number of lost hooks.

Protected Species Interactions – Place a check in the box if a protected species comes up in the gear hooked or entangled during the observed portion of the set or haul. Record a brief statement about the interacted species in the comments section of this form.

Note: There should be a record of this event on the protected species event form if you saw the animal becoming hooked or entangled.

Comments – Used to describe any incident that did not fit the available data element choices. Example situations could include:

- If there are any blank data elements, describe why you were unable to collect the information.
- If you run out of room on a form, indicate that there are notes elsewhere (*i.e.,* documentation notebook).
- Record any unknown objects/animals in this section, with the hook and float number whenever possible for these situations.
- Record a very brief statement about protected species

interactions, for example: leatherback sea turtle, float 45/hook 19, hooked and released injured.

- If the vessel hauls more than 1 basket in reverse order following a line part.
- If you have a sighting of a, short-tailed albatross.

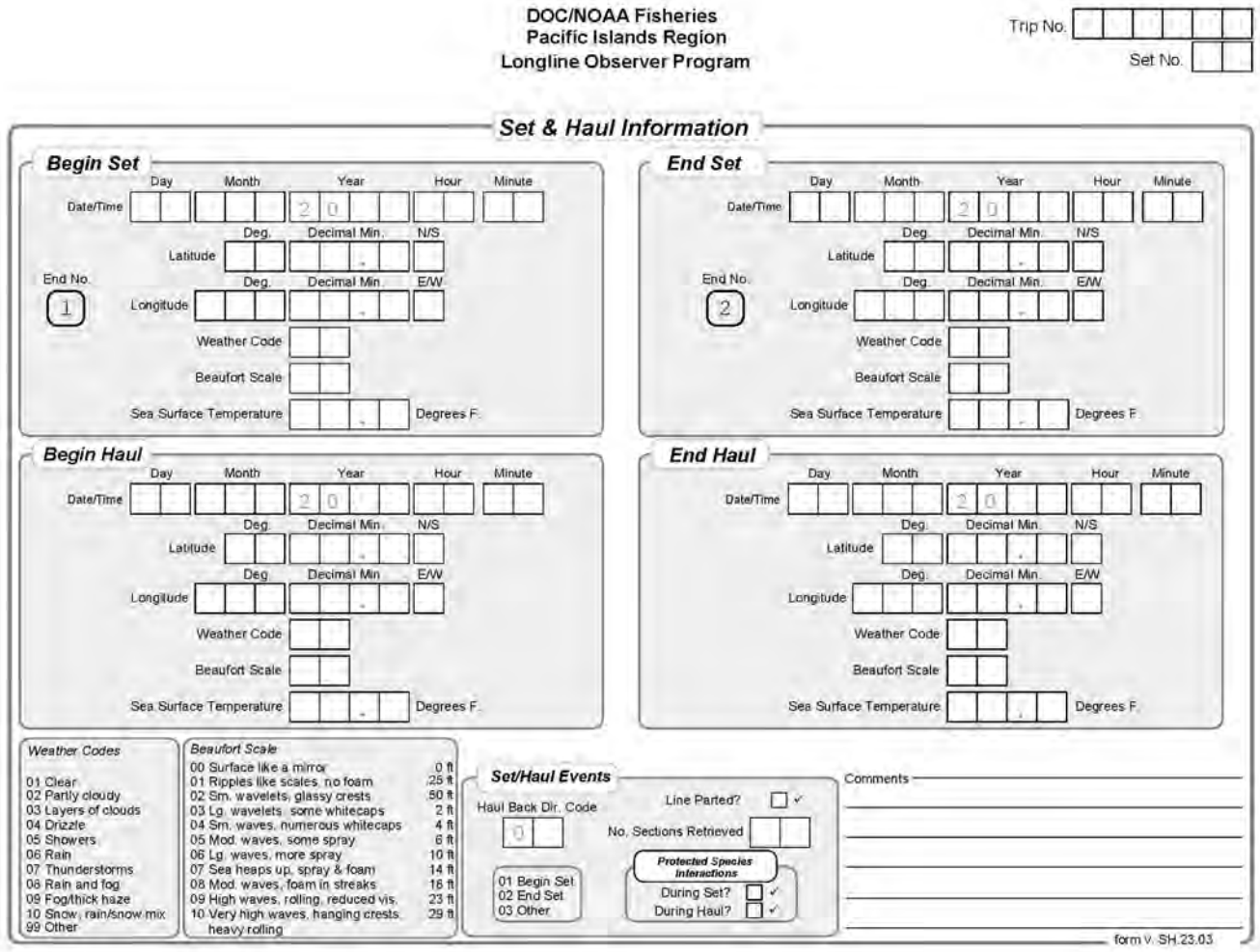


Figure 8: Example form Set & Haul.

Appendix 4. Longline gear conversions between length and weight for monofilament mainline and branchline including volumetric conversions.

Metrics of longline components					
	Monofilament description	Weight (kgs)	Length (meters)	Country of origin	
Mainline	4.0 mm	25 kgs	1,852 meters (1 nautical mile)	Japan, Korea and Taiwan	
Mainline conversion weight (grams) to length (meters)					
meters = grams * 1,852/25,000					
Mainline conversion length (meters) to weight (grams)					
grams = meters * 25,000/1,852					
Two branchlines considered					
	Monofilament description	Weight (kgs)	Length (meters)	Country of origin	
Branchline #1	2.1 mm	2.268 (5 pounds)	502.9 meters (550 yards)	Japan, Korea and Taiwan	
		4.5196 (1,852/502.9)	1,852 meters (1 nautical mile)		
Branchline grams per 1852 meters		**8,351.9**			
2,2268 grams * 1,852/502.92					
	Monofilament description	Weight (kgs)	Length (meters)	Country of origin	
Branchline #2	2.1 mm	2.268 (5 pounds)	557.8 meters (610 yards)	Japan, Korea and Taiwan	
		4.5196 (1,852/557.8)	1,852 meters (1 nautical mile)		
Branchline grams per 1852 meters		**7,530.4**			
2,2268 grams * 1,852/557.80					
Average of branchline #1 and #2					
Branchline grams per 1,852 meters		**7,941.1**			
For comparison (not used) - interpolation of Lingred-Pittman of 2.0 and 2.3 mm branchline is 7,669.0 grams per 1,852 meters					
Reference https://www.lindgren-pitman.com/					
Brachline conversion weight (grams) to length (meters)					
meters = grams * 1,852/7,941.1					
Branchline conversion length (meters) to weight (grams)					
grams = meters * 7,941.1/1,852					
Mainline in a 50-liter (50-kg) flour sack					
Length (m)	641.2				
Weight (grams)	7,235				
Branchline in a 50-liter (50-kg) flour sack					
Length (m)	1.208.2				
Weight (grams)	6,261				