



ESTIMATION OF SHORTFIN MAKO SHARK DISCARDS FROM THE SOUTH AFRICAN LONGLINE FLEET IN THE IOTC USING THE BYCATCH ESTIMATOR TOOL

CHARLENE DA SILVA^{1,2} AND WENDY M. WEST¹

Purpose

The purpose of this paper is to present preliminary estimates of shortfin mako shark dead discards from the South African pelagic longline fishery and to describe the methodology applied using the ICCAT Bycatch Estimator Tool to support reporting requirements under IOTC Resolution 25/09.

Discussions

The paper is to inform meeting members of preliminary estimates of shortfin mako shark dead discards by the South African pelagic longline fishery, derived using the ICCAT Bycatch Estimator Tool. The paper presents the methodology, key assumptions and uncertainties associated with the estimates and invites discussion on the suitability of the approach for meeting reporting obligations under IOTC Resolution 25/09 and supporting future scientific analyses.

Feedback

The paper is to request review and comments on the application of the Bycatch Estimator Tool, the treatment of post-release mortality, model selection procedure and the resulting discard estimates

Conclusion

The paper is to seek confirmation that the proposed methodology provides a suitable and transparent approach for estimating shortfin mako shark dead discards and live-release mortality for South African fisheries.

Recommendation

The paper is to seek endorsement of the methodology for estimating shortfin mako shark dead discards, for use in future annual reporting by South Africa under IOTC Resolution 25/09 and related scientific processes.

Decisions

The paper is to seek approval for the meeting to note the preliminary estimates of shortfin mako shark dead discards presented in this paper and to encourage their consideration in future bycatch and stock assessment analyses.

Abstract

*A preliminary assessment of shortfin mako (*Isurus oxyrinchus*) discards by the South African pelagic longline fleet during 2012–2025 was produced using the Bycatch Estimator Tool (BYET). Observer and logbook data were combined, and the response variable expanded to include observed dead discards plus an expected fraction of live releases (post-release mortality, $PRM = 0.294$). Candidate model families (Delta–Lognormal, Delta–Gamma, and Tweedie) were compared, each fitted with random intercepts for vessel and latlong to account for between-vessel variation and unresolved spatial structure. Model selection using BIC and DHARMA diagnostics identified a Delta–Lognormal specification retaining Year as the only fixed effect; month and fishing tactic were not retained by BIC in any of the three catch-model families (weight ≈ 0 for all candidate models including these terms). Estimated annual dead discards increased over the study period, from 116 individuals in 2012 to 26 in 2025, although annual estimates were moderately uncertain. Year-specific mean weights, derived from observer length-frequency data and a length–weight relationship, ranged from approximately 38.7 kg (2012) to 50.6 kg (2025). Applying these weights yielded an estimated dead-discard biomass of 11.9t (95% CI: 7.7–30.9t) in 2025.*



ESTIMATION OF SHORTFIN MAKO SHARK DISCARDS FROM THE SOUTH AFRICAN LONGLINE FLEET IN THE IOTC USING THE BYCATCH ESTIMATOR TOOL

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SUMMARY

*A preliminary assessment of shortfin mako (*Isurus oxyrinchus*) discards by the South African pelagic longline fleet during 2012–2025 was produced using the Bycatch Estimator Tool (BYET). Observer and logbook data were combined, and the response variable expanded to include observed dead discards plus an expected fraction of live releases (post-release mortality, $PRM = 0.294$). Candidate model families (Delta–Lognormal, Delta–Gamma, and Tweedie) were compared, each fitted with random intercepts for vessel and latlong to account for between-vessel variation and unresolved spatial structure. Model selection using BIC and DHARMA diagnostics identified a Delta–Lognormal specification retaining Year as the only fixed effect; month and fishing tactic were not retained by BIC in any of the three catch-model families (weight ≈ 0 for all candidate models including these terms). Estimated annual dead discards increased over the study period, from 116 individuals in 2012 to 26 in 2025, although annual estimates were moderately uncertain. Year-specific mean weights, derived from observer length-frequency data and a length–weight relationship, ranged from approximately 38.7 kg (2012) to 50.6 kg (2025). Applying these weights yielded an estimated dead-discard biomass of 11.9t (95% CI: 7.7–30.9t) in 2025.*

KEYWORDS

*Shortfin mako shark, *Isurus oxyrinchus*, discards, South Africa, Pelagic fisheries, Long lining, Bycatch Estimator Tool*

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1. Introduction

Following the adoption of ICCAT catch limitations in 2019 and 2021 governing retention of North and South Atlantic shortfin mako sharks (*Isurus oxyrinchus*), and reflecting similar concerns in the Indian Ocean, the IOTC adopted its first dedicated conservation measure for the species: *Resolution 25/09 On the conservation of shortfin and longfin mako sharks caught in association with IOTC fisheries*, adopted at the 29th Session of the Commission in 2025. This requires that by 1st January 2028, CPCs that report annual average catches (landings and dead discards) of shortfin mako over 1 tonne between 2020- 2023 shall present to the WPEB and SC the statistical methodology used to estimate dead discards and live releases. The Resolution further requires that as part of annual data submissions, CPCs shall provide the relevant data for IOTC mako sharks, including estimates of dead discards and live releases.

The South African fishery is largely coastal, with swordfish-directed effort concentrated in the southwest Indian Ocean (20°–30°S, 30°–40°E) and along the South African continental shelf in the southeast Atlantic (30°–35°S, 15°–18°E); consequently, the fleet operates across both the Indian and Atlantic Oceans. Pelagic longline fishing by South African vessels began in the 1960s, initially targeting southern bluefin tuna (*Thunnus maccoyii*) and albacore (*Thunnus alalunga*) (Nepgen, 1970). Domestic effort declined in the mid-1960s owing to limited market demand, while foreign fleets continued under bilateral agreements until 2002. Domestic interest re-emerged in 1995, supported by joint ventures demonstrating economic viability for tuna and swordfish; experimental permits followed in 1997, and the commercial fishery was formally established in 2005 with allocation of long-term fishing rights.

Shark-directed longlining developed later, with a dedicated shark fishery emerging in the 1990s; over time this activity was integrated into the broader tuna and swordfish longline sector. Shark catches in the pelagic longline fishery are constrained by a precautionary upper catch limit (PUCL) of 2,000 t dressed weight per year established in 2008 (DFFE, 2022; DFFE, 2025). Regulatory measures to discourage shark retention also apply, including prohibitions on retaining several vulnerable species (e.g. *Sphyrna* spp., *Carcharhinus longimanus*, *Lamna nasus*, *Carcharhinus obscurus*, *C. falciformis*), encouragement of live release, a ban on wire trace, prohibition of finning (sharks to be landed with fins attached), and mandatory observer coverage of 20% stratified by vessel and season. Additional measures limit targeting to less than 50% shark catch per season; vessels catching more than 60% sharks in a quarter are subsequently subject to 100% observer coverage.

These management interventions have contributed to substantial reductions in shortfin mako catches: between 2015 and 2024 catches declined by approximately 81.9% across areas reported to both ICCAT and IOTC, and by 71.2% within the ICCAT area of competence. An onboard observer programme has operated in the tuna-directed longline fishery since 1998 (Smith, 2005). Observers record species composition, size-frequency data for key taxa and detailed catch fate information; each individual is classified by condition at retrieval (e.g. alive and released in good condition, alive but injured, dead at haulback, retained) using standardised operational definitions. These condition records are essential for distinguishing live releases from dead discards and for estimating total fishing mortality, including post-release mortality.

South Africa reported average annual catches of shortfin mako exceeding 1 t during 2020–2023 and is therefore subject to the reporting obligations set out in IOTC Resolution 25/09. Therefore, the objective of this paper is to describe the methodology used to estimate shortfin mako discards in South African fisheries and to present preliminary estimates for the 2012–2025 period for the South Atlantic stocks. Subject to review and endorsement by the WPEB and SC the methodology will be applied on an ongoing basis, and updated estimates will be included annually in South Africa's data submission to IOTC.

2. Materials and Methods

2.1 Data processing

Two complementary datasets were used in this analysis: observer data providing set-level bycatch records, and logbook data providing a complete record of fleet-wide fishing effort. The time series analysed spans 2012 to 2025. Observer data were collected by onboard fisheries observers deployed on South African pelagic longline vessels operating in the IOTC convention area between 2012 and 2025. For each observed set, observers recorded the number of shortfin mako shark dead discards and live releases, categorising each event by the health status of live animals at the time of release, or by the reason for discarding in the case of dead animals. The post release mortality estimate of 29.4 (Domingo et al. 2025) was applied to the live releases to obtain total dead discarded shortfin mako sharks.

Effort was recorded as the number of hooks per set. Catches recorded in numbers, rather than weight, were used in the model as all discards and live releases observed at sea are enumerated individually.

Set-level observer records for the period 2012–2025 containing per-set species counts of dead shortfin mako discards, set effort (hook count), spatial stratum identifiers (lat-long blocks), temporal identifiers (year, month), and vessel identifiers. Logbook data included fleet-wide effort records for the same period and spatial/temporal resolution. Logbook rows represent sets (or aggregated effort units) with columns for effort (hook count), spatial and temporal strata, and vessel identifier (**Figures 1-3**).

This study estimates total discards (in number) of shortfin mako sharks using a combination of observer-collected bycatch data and fleet-wide effort records from logbooks from the IOTC region.



Figure 1. Effort across pairs of categorical variables. Grey: logbook data; Blue: observer data.

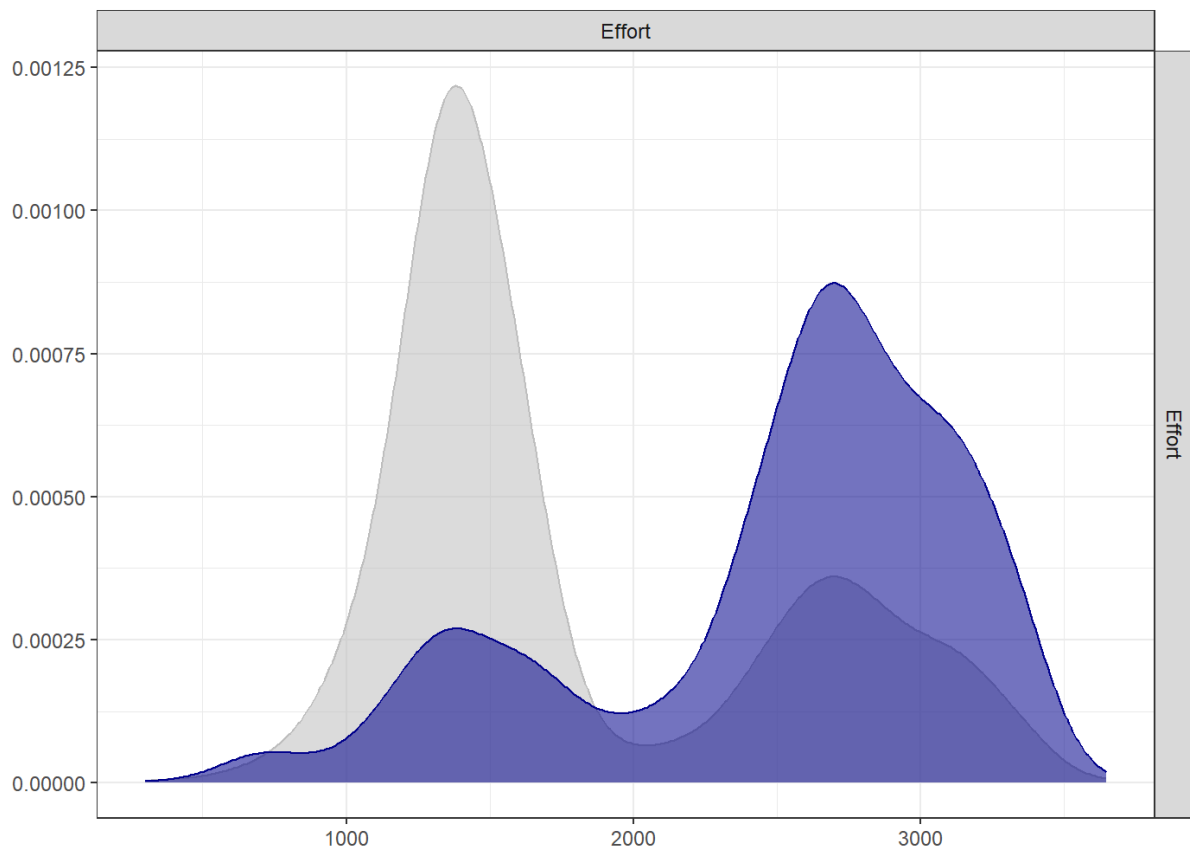


Figure 2. Effort across pairs of numeric variables. Grey: logbook data; Blue: observer data. Corr: correlation coefficient; Eff: effect size; Obs: observed difference

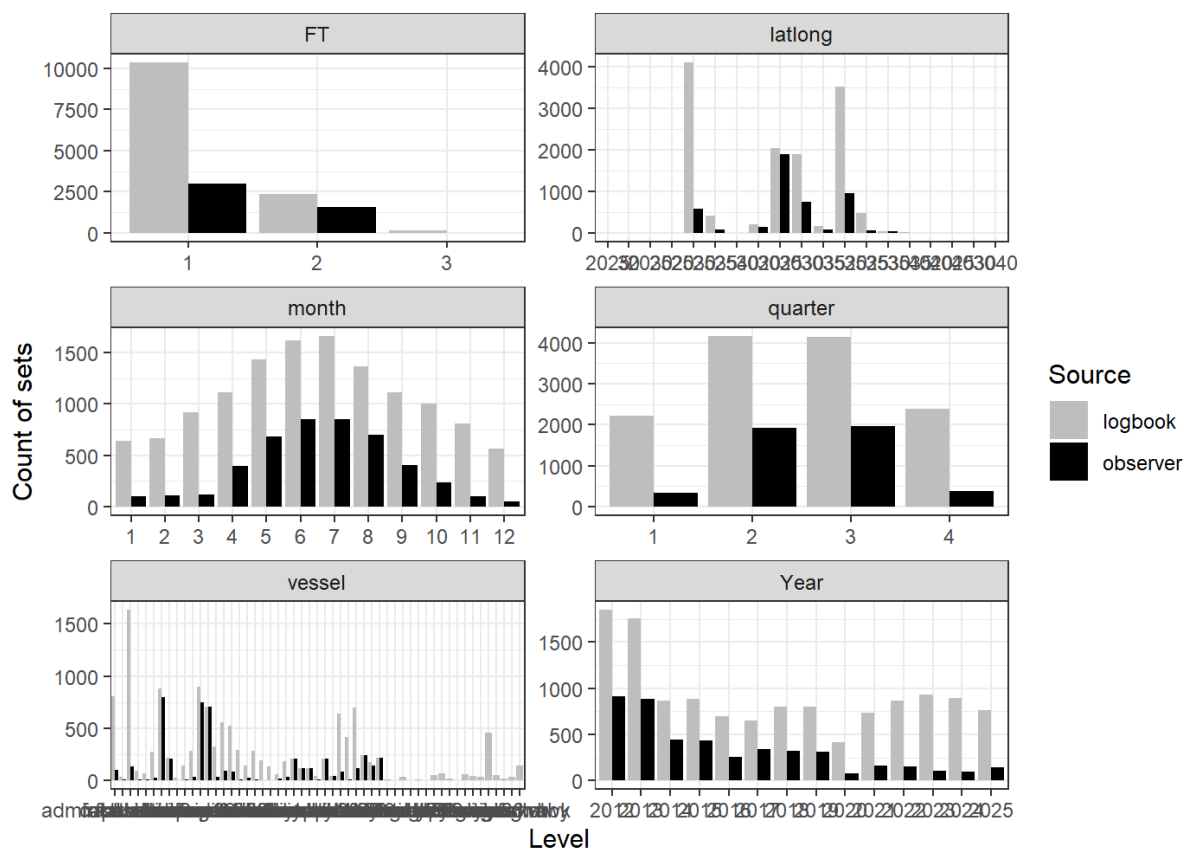


Figure 3. Counts of sets by factor levels, observed and total.

2.2 Fishing tactic Classification (FT)

Fishing tactics (FTs) were derived from the catch composition per set recorded in the observer data using principal components analysis (PCA) (Clarke and Warwick, 2001) followed by cluster analysis using CLARA (Clustering Large Applications) algorithm (Kaufman and Rousseeuw, 1990, Struyf et al., 1997). To ensure that fishing tactic assignments were directly comparable between the observer and logbook datasets, the logbook data were not clustered independently. Instead, the logbook records were projected onto the PCA space defined by the observer data, using the observer-derived variable means and standard deviations for scaling, ensuring that both datasets were expressed on the same coordinate system. Each logbook record was then assigned to the nearest observer-defined cluster centroid using a k-nearest neighbour classifier ($k = 1$), implemented in the class package in R (Venables and Ripley, 2002). This approach guaranteed that fishing tactic labels carry an identical meaning across both datasets.

2.3 Discard Estimation

The annual total discarded number of shortfin mako (SMA) was estimated using the BycatchEstimator R package (Babcock, 2022; Babcock et al., 2022). This framework estimates total annual bycatch by fitting a generalised linear model (GLM) to observer data and using the fitted model to predict bycatch rates across all logbook records, thereby expanding observer-derived rates to total fleet-wide effort. Total bycatch is estimated as the sum of predicted catches across all logbook sets.

The response variable in the GLM was the number of shortfin mako sharks discarded, (as a combination of those reported dead and those released alive that would have died of post-release mortality). The high frequency of zero observations in shortfin mako discard per set motivated the use of zero-inflated observation error distribution families. In an initial exploratory phase, the candidate index distributions (Delta-Lognormal, Delta-Gamma and Tweedie). Final model choice balanced predictive performance (RMSE) with adherence to diagnostic criteria based on DHARMA residual simulations; among similarly performing distributions, the model with superior residual diagnostics was selected. Where multiple candidate specifications performed similarly on BIC, the lowest-BIC model was preferred.

For the 2012–2025 period, the Delta-Lognormal specification was retained. Cross-validation RMSE was effectively indistinguishable across the three catch models (Tweedie, Delta-Lognormal, and Delta-Gamma all returned $\text{RMSE} \approx 0.0004$), with no meaningful separation in predictive performance. DHARMA diagnostics, however, favoured the Delta-Lognormal model, which was the only candidate to show no serious departures from model assumptions: dispersion ratio ≈ 1.00 (Dispersion.p = 0.97) and Outlier.p = 0.86, with only a mild, borderline failure of the uniformity test (KS.p = 0.01).

By contrast, the Delta-Gamma showed clear diagnostic failure (KS.p < 0.001; dispersion ratio = 1.99; Dispersion.p < 0.001; Outlier.p < 0.001) and was therefore considered unsuitable. The Tweedie model also failed the uniformity and outlier tests (KS.p < 0.001; Outlier.p < 0.001), and although its dispersion ratio (≈ 0.37) technically passed the associated test (Dispersion.p = 0.82), this value deviates substantially from the expected ratio of 1, indicating likely model misspecification under this random-effects structure. The binomial family produced acceptable diagnostics on most tests (Dispersion.p = 0.49; ZeroInf.p = 0.63) but failed the uniformity test (KS.p < 0.001) and was not directly comparable on RMSE. On balance, prioritising adherence to residual diagnostics over the marginal differences in cross-validation performance, the Delta-Lognormal provided the most defensible model for inference (**Figures 6–8**).

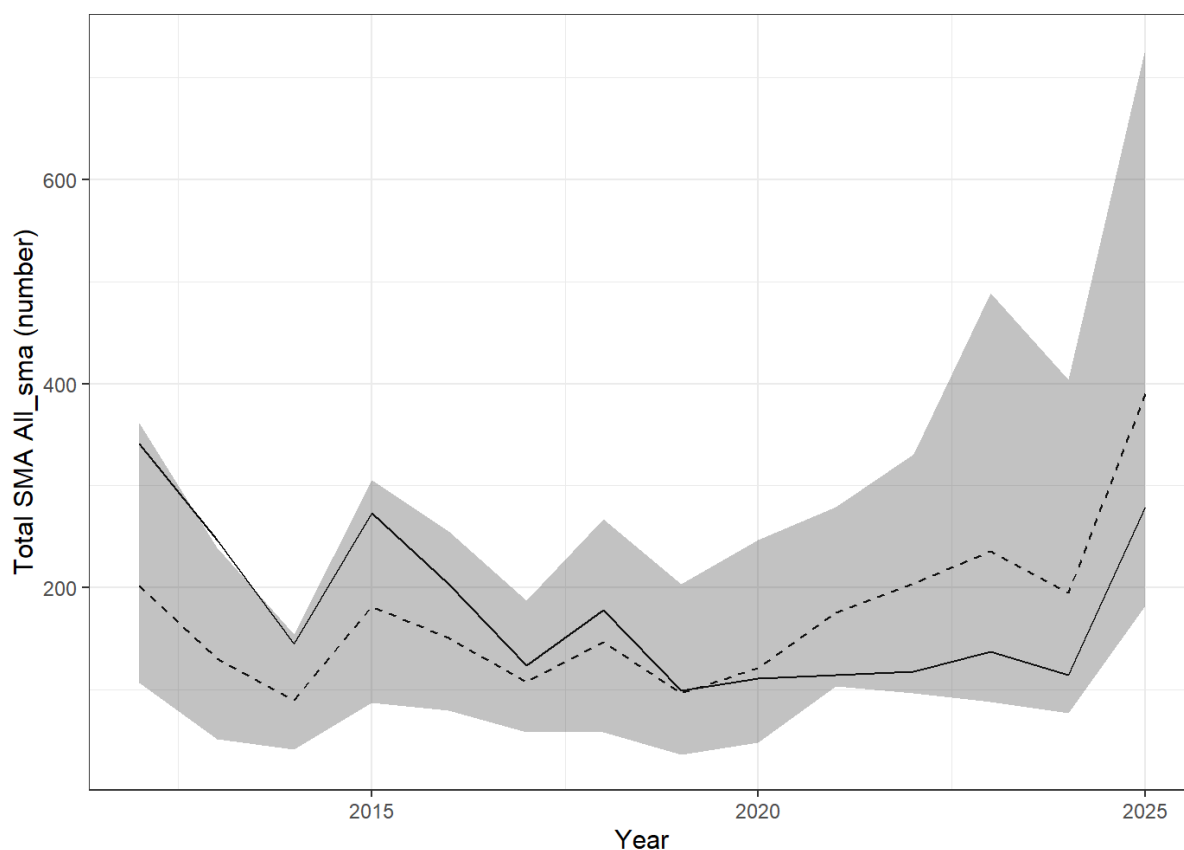


Figure 4. Estimated total bycatch from TMBdelta-Lognormal, with 95% confidence interval calculated by Monte Carlo simulation. Solid line is the best estimate, and dashed line is the mean across simulations.

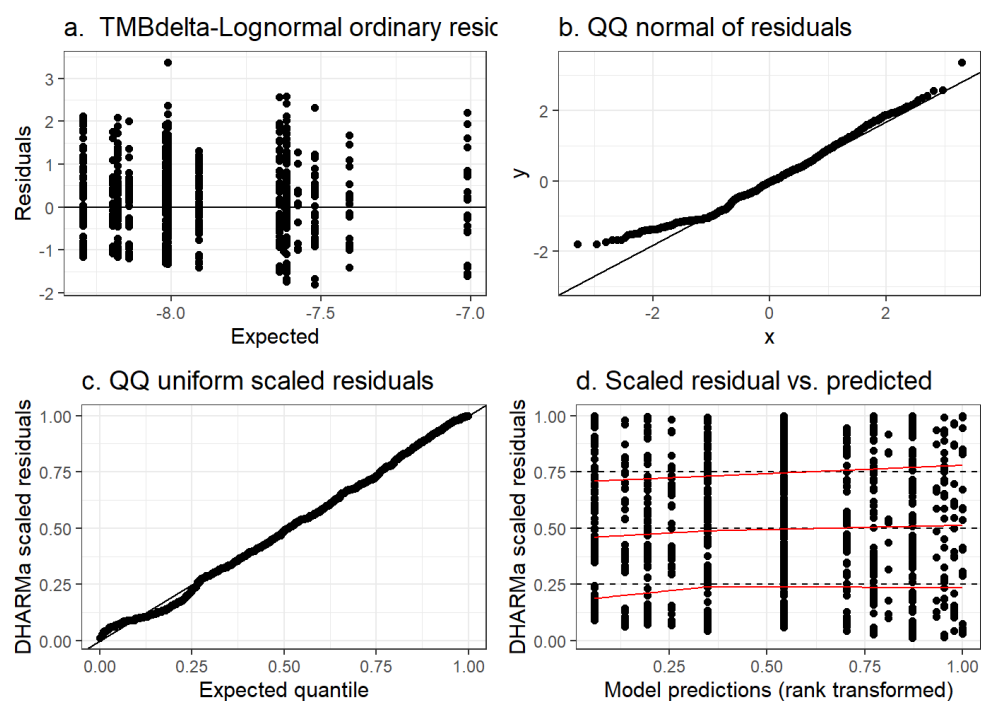


Figure 5. Residuals for the BIC best model for TMBdelta-Lognormal, showing the ordinary residuals (a,b) and DHARMA scaled residuals (c,d).

The modelling workflow fitted a complex specification (*YEAR*, *MONTH*, *FISHING TACTIC (FT)* as categorical predictors) and a simple specification (*YEAR* only), with intermediate models generated automatically and the best-supported structure selected by BIC. Effort (hooknr) was included as the explanatory covariate underlying catch rate, and *VESSEL* identity and *LATLONG* grid were modelled as random intercepts to account for between-vessel and unresolved spatial variation, respectively. The sampling unit was the set (unique set identifier). Analyses were conducted in R (v4.5.1; R Core Team 2025).

2.3 Total discard estimates (*t*)

Length-frequency data for shortfin mako (SMA) from observer records in the IOTC region (2012–2025) were used to derive annual mean individual weights. For each year, measured fork lengths (FL) were binned into 5 cm size classes, and a count-weighted mean FL was computed across classes. Mean weight (kg) was then calculated from the species-specific length-weight relationship of Groeneveld et al. (2014): $TW = 0.349 \times 10^{-4} \times FL^{2.76544}$.

Year-specific mean weights were applied as a fixed multiplier to the modelled annual discard totals, including the point estimate and both bounds of the 95% confidence interval, to produce annual biomass estimates (*t*). For years in which the length-frequency sample comprised fewer than 50 measured individuals, the year-specific mean weight was considered unreliable and was replaced with a pooled mean weight calculated from length-frequency data across all years combined, to avoid biomass estimates being unduly influenced by small, potentially unrepresentative annual samples. Sample sizes for the length-frequency data ranged from 7 to 1,134 individuals per year; years falling below the 50-individual threshold (2021, 2022, 2025) used a pooled multi-year mean weight in place of a year-specific estimate.

Because a single, fixed mean weight (year-specific or pooled) is applied uniformly to the point estimate and both confidence bounds, the relative uncertainty (CV) of the biomass estimate in a given year is numerically equivalent to that of the corresponding numeric discard estimate, only the absolute magnitude, not the precision, of the estimate changes upon conversion to biomass. This approach does not incorporate uncertainty in the mean weight itself, which may arise from length-frequency sample size or interannual variation in size composition, and represents an additional source of uncertainty not currently propagated into the biomass confidence intervals. Biomass estimates should therefore be interpreted as conditional on the observed (or pooled) size composition for each year, rather than as fully propagated estimates incorporating both abundance and individual-weight uncertainty.

3. Results and Discussion

During the period 2012 to 2025, of the 12,904 sets recorded in the Logbook data, 4,613 were observed, representing an overall observer coverage rate of 35.7%. During this period, a total of 659 shortfin mako sharks were reported as released dead in the Observer dataset (average per year = 47.1, SD = 41.8). Dead discards declined from 133 individuals reported in 2015 to 26 in 2025. During the same period, 2,638 shortfin mako sharks were reported as released alive and in good condition (average per year = 188.0, SD = 199.5). Similarly to dead discards, live releases also declined over this period, from 418 in 2015 to 94 in 2025. However, this apparent decline coincides with a substantial reduction in observer coverage over the same period: coverage was consistently above 49% from 2012–2015, but fell sharply from 2020 onward, ranging between 10.3% and 21.7% in 2020–2025 (compared to 36–52% in 2012–2019). As raw interaction counts are directly dependent on how many sets were observed, the declining trend in reported dead and live releases is confounded by declining observer coverage and should not, on its own, be interpreted as evidence of a real decline in shortfin mako interaction rates. This is precisely the confound the model-based (bycatchFit) approach is intended to correct for, by standardising catch per unit effort rather than relying on raw observed counts.

3.1. Spatiotemporal estimate (2012–2025) using ByET

The spatiotemporal distribution of shortfin mako (SMA) discarded by the South African pelagic longline fleet for 2012–2025 was estimated using the Bycatch Estimator. The most parsimonious model selected by BIC contained *YEAR* as the only fixed effect (Table 1), with the lowest BIC and the largest BIC weight (1.0), providing the best trade-off between goodness-of-fit and model complexity, in addition delta BIC of the other models were far higher than that of year. This specification clearly outperformed all models incorporating *FISHING TACTIC (FT)* or *MONTH*, none of which received meaningful BIC support (weight = 0.0 for all). *VESSEL* and *LATLONG* were both specified *a priori* as random intercepts across all candidate models, rather than being tested for inclusion via BIC, to account for between-vessel variation and unresolved fine-scale spatial structure respectively, the latter reflecting sparse observer coverage at the level of individual latlong cells, which precluded treating spatial location as a fixed effect.

An alternative run, in which the spatial covariate was aggregated into two broad regions (north and south of 35°S) rather than treated as a random effect at the level of individual *LATLONG* cells, retained region as a significant fixed-effect predictor in the best-supported model. This indicates that spatial structure in shortfin mako discard rates is real and detectable, but that its representation is sensitive to how finely the spatial covariate is resolved: coarse aggregation into two regions provides enough observations per level to support a stable fixed-effect coefficient, whereas the sparsity of individual

LATLONG cells is more appropriately absorbed by a random intercept, which can borrow statistical strength across sparse, unevenly sampled levels rather than requiring each one to be independently estimable. However, because the South African shortfin mako assessment will be run annually for both IOTC and ICCAT, a decision was made to retain a consistent model structure, *VESSEL* and *LATLONG* as random intercepts, across both analyses, rather than adopting different spatial treatments for each region.

This decision was further reinforced by experience from the recent update incorporating 2025 data into the ICCAT model (updated from da Silva and West 2025), which demonstrated that year-on-year changes in data volume and observer coverage can materially affect model selection outcomes. Because the BycatchEstimator framework re-fits and re-selects the best-supported fixed-effect structure each time new data is added, comparing candidate models afresh via BIC rather than carrying forward a fixed formula, the addition of a single year's data can shift which spatial representation is favoured, even when the underlying biological process has not changed. If the "best" model structure were allowed to vary from year to year, each annual update would require re-justifying and re-presenting a revised methodology to the relevant trFMOs, undermining both reproducibility and the comparability of estimates across years. Specifying *LATLONG* as a random effect (alongside *VESSEL*), rather than testing it as a fixed effect subject to annual re-selection, fixes the model's overall structure across years, so that only the estimated coefficients, not the model formula itself is updated as new data becomes available. This simplifies the annual reporting process and avoids the need to present a revised methodology at each trFMO meeting.

Table 1. Model selection for **Delta-Lognormal GLM**.

Model	AIC	BIC	Delta-BIC	weight	R2
Year	2722.1	2796.6	0.0	1.0	0.09
Year + FT	2724.0	2808.4	11.8	0.0	0.09
Year + month	2699.0	2828.0	31.4	0.0	0.13
Year + FT + month	2702.4	2841.4	44.8	0.0	0.13

The final modelled estimated total discard for 2025 was 279 individuals (95% CI 182.4–727.5; SE = 143.6; CV $\approx$ 0.37) (**Table 2**). Observed and predicted values showed a weak positive correlation ($r = 0.3$; $r^2 \approx 0.09$), indicating that the model explains only a small fraction of the variance in individual observations, consistent with the expected behaviour of a rate-based model applied to highly variable, overdispersed catch data at the level of individual sets rather than aggregated totals. A standard correlation test (e.g. cor.test) confirms this association is weak. Other candidate models showed similarly weak correlations, suggesting a comparable ability to track observed set-level variability; this metric is therefore not a useful basis for discriminating between candidate models and was not weighted heavily in final model selection. (Figures 5–6).

Table 2. Annual estimated shortfin mako dead discards (2012–2025): number of individuals with 95% CI and CV; corresponding biomass (t) using year-specific mean weights (Delta-Lognormal model, CIs from Monte Carlo).

Year	Total est discards (#)	Total LCI	Total UCI	CV	Total est discards (t)	Total est discards LCI (t)	Total est discards UCI (t)
2012	341.2	107.1	361.1	0.33	13.42	4.2	14.2
2013	247.1	52.1	239.1	0.36	9.57	2.0	9.3
2014	144.9	41.3	154.8	0.32	6.01	1.7	6.4
2015	273.6	87.1	305.2	0.31	12.31	3.9	13.7
2016	203.5	80.1	255.4	0.31	9.72	3.8	12.2
2017	123.8	58.5	187.4	0.35	4.59	2.2	7.0
2018	178.6	58.3	267.1	0.37	6.17	2.0	9.2
2019	99.3	36.4	203.9	0.45	4.27	1.6	8.8
2020	111.3	48.5	246.5	0.41	5.63	2.5	12.5
2021	114.9	103.4	279.2	0.27	4.88	4.4	11.9
2022	118.2	97.2	331.3	0.30	5.02	4.1	14.1
2023	137.2	88.4	488.4	0.42	6.24	4.0	22.2
2024	114.9	77.1	404.1	0.48	5.64	3.8	19.9

2025	279.2	182.4	727.5	0.37	11.85	7.7	30.9
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The smallest point estimates occur in 2019 (99.3) and 2020 to 2024 remained relatively low (111.3 to 114.9), while the largest estimate for a decade is 2025 (279.2) (**Table 2**).

Year-to-year variability is substantial, and many years have overlapping 95% confidence intervals; most years exhibit high relative uncertainty (CVs frequently ≥ 0.3 –0.5), indicating low precision for single-year estimates (Table 2). The 2025 point estimate (279.2 individuals) is markedly larger than the immediately preceding years (2020–2024: 99.3–137.2 individuals), though it remains within the range observed earlier in the time series (e.g. 2012: 341.2; 2015: 273.6). The 2025 estimate also carries high uncertainty (CV ≈ 0.37) and a wide confidence interval (182.4–727.5), so its magnitude and particularly whether it represents a genuine recent increase or reversion toward earlier levels should be interpreted with caution.

Annual totals estimated by the three model families (delta-Gamma, delta-Lognormal and Tweedie) follow broadly similar year-to-year trajectories (**Figure 6**), indicating a consistent temporal signal regardless of distributional choice. The relative width of each model's confidence band varies over the time series rather than favouring one model consistently. In the earlier part of the series (notably 2012, 2015, and 2017), the Tweedie formulation produces substantially wider confidence intervals than the delta models, while delta-Lognormal and delta-Gamma remain closely aligned. From approximately 2021 onward, this pattern reverses: the delta-Lognormal band widens considerably relative to the other two models, most notably in 2023 and 2025, coinciding with the period of reduced observer coverage and smaller length-frequency samples discussed above. Substantial overlap among the models' 95% confidence bands for most years implies that differences in point estimates are generally not statistically decisive; therefore, residual diagnostics and goodness-of-fit tests were used to inform the final model choice rather than relying on pointwise differences alone.

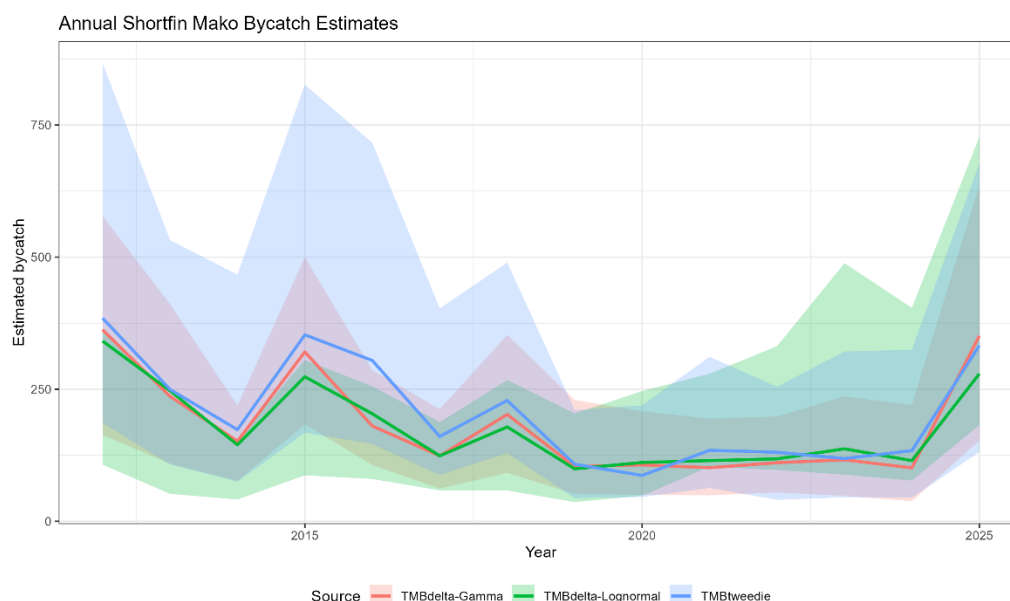


Figure 6. Estimated total bycatch from delta-Lognormal, delta-Gamma and Tweedie models run, with 95% confidence interval calculated by Monte Carlo simulation.

Unlike month and fishing tactic, vessel and spatial location (*LATLONG*) were not tested for inclusion via BIC but were specified a priori as random intercepts in every candidate model, reflecting the sparse, unevenly sampled structure of both covariates. This approach was adopted in preference to treating either as a fixed effect: an earlier specification aggregating spatial location into two broad regions (north and south of 35°S) did retain region as a significant fixed-effect predictor, indicating that real spatial structure exists in shortfin mako discard rates, but the fine-scale *LATLONG* factor used in the final model does not have enough observations per level to be reliably estimated as a fixed effect, and is instead more appropriately absorbed through a random intercept that borrows strength across sparse spatial cells. A parallel argument applies to *VESSEL*, where activity is unevenly distributed across a comparatively small number of vessels with highly variable levels of observed effort.

Retaining *LATLONG* as a random effect rather than a coarser fixed-effect region also has a practical benefit for repeated annual reporting: because model structure is fixed a priori rather than re-selected via BIC each year, the addition of new data does not risk shifting the preferred spatial representation from year to year, avoiding the need to re-justify a revised methodology at each tRFMO meeting. Tagging and length-frequency studies document frequent cross-boundary movement by shortfin mako (da Silva et al. 2025; Parker et al. 2017); consequently, a fixed spatial domain and resolution could mask genuine spatial patterns if individuals and fishing effort move across management boundaries. Future analyses should evaluate alternative spatial domains, resolutions, and random-effect structures to assess the sensitivity of results to the choice of spatial representation.

The non-selection of FT under BIC is ecologically informative. Following changes in permit conditions, CITES Appendix II listing (and permitting requirements) and market constraints, the economic incentives to retain sharks have changed and discarding behaviour may be increasingly influenced by regulatory and market drivers. The absence of FT from the BIC-preferred model does not imply FT is biologically irrelevant; rather, with the current data FT did not improve model fit sufficiently to overcome the BIC penalty for increased complexity.

The adoption of IOTC Resolution 25/09 on the conservation of shortfin and longfin mako sharks, which introduces new retention conditions modelled on similar ICCAT measures, is likely to increase the number of releases in the future.

The annual fork length (FL) distributions of shortfin mako sharks from the observer dataset between 2012 and 2025 are shown in **Figure 7**. Length-frequency distributions were broadly unimodal in the earlier part of the series (2012–2018), while several more recent years (2019–2021, 2023, 2025) show wider distributions with a pronounced right-hand tail or secondary shoulder, most notably in 2021, indicating a less consistent size structure in the sampled catch in these years, consistent with the smaller and, in three years, pooled length-frequency samples discussed above. Mean lengths (vertical lines; red = year-specific mean, blue = pooled fallback mean for 2021, 2022, and 2025) were centred around approximately 145–160 cm FL for most years, with 2016, 2020, and 2024 standing out as comparatively larger-mean years (approximately 165–175 cm FL), and 2017 and 2018 comparatively smaller (approximately 145–150 cm FL). No consistent directional trend toward increasing or decreasing body size was evident across the full study period, though the increased spread and right-skew in several recent years' distributions may in part reflect reduced and less representative sampling rather than a genuine shift in population size structure.

Modelled estimates (**Table 2**) indicated that total discards in 2025 were 11.9 t (95% CI: approximately 7.7–30.9 t). However, this estimate should be interpreted with caution, as uncertainty accumulates across multiple stages of the analysis, including variability and limitations within the observer dataset, assumptions and error associated with the modelling process, and additional uncertainty introduced through the application of length–weight relationships to convert size observations into biomass estimates. Accordingly, the confidence intervals presented likely capture only part of the total uncertainty, and the true uncertainty associated with discard biomass estimates may be greater.

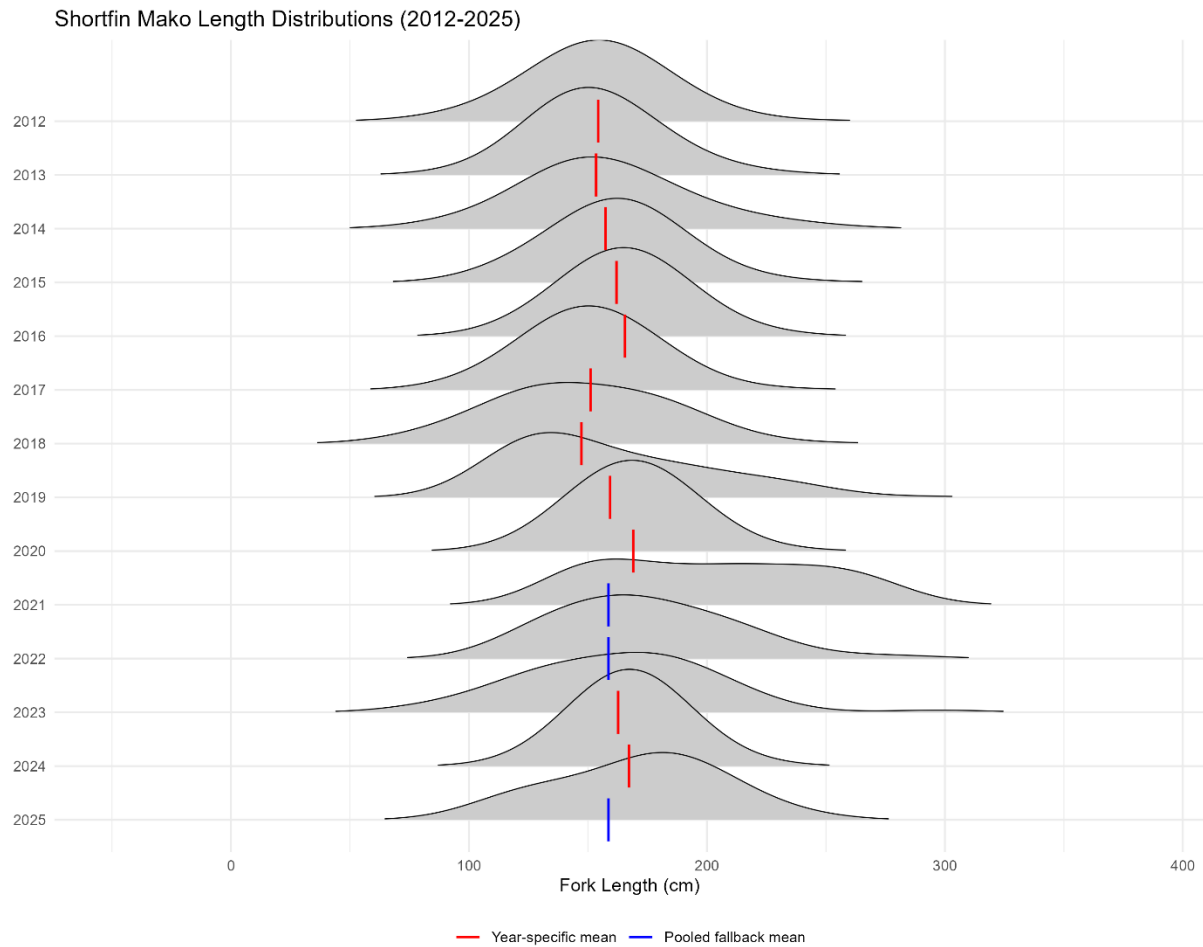


Figure 7. The length frequency distribution of retained shortfin mako sharks sampled by observers, for 2012-2025, vertical red lines indicate the mean lengths using data, vertical blue lines indicate that the fall-back method was used in cases with less than 50 measurements.

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