ISC/25/SHARKWG-1/05

Updated blue shark CPUE from US Hawai'i longline fisheries; 2002-2023 [1]

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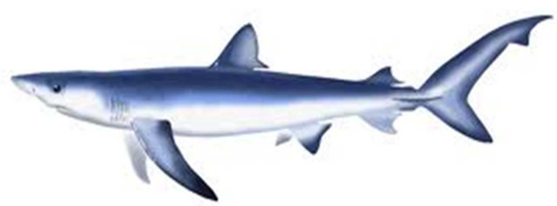

[1]Working document submitted to the ISC Shark Working Group Workshop, 27 January - 3 February 2025 (JST), Yokohama Japan. Document not to be cited without author's permission.

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Abstract

Standardized catch-per-unit-of-effort (CPUE) of blue shark *Prionace glauca* from the Hawai'i based longline fleet was updated through 2023 using the previous generalized linear modeling (GLM) approach. Standardized CPUE has declined for both the deep-set and shallow-set sectors of the fishery over the last 3 years. However, changes in the deep-set sector of the fishery, notably a switch in leader material and bait type, as well as limitations in the standardization approach used make it difficult to discern whether this decline is representative of the underlying spawning stock.

1 Introduction

Blue shark *Prionace glauca* are a pelagic shark globally distributed in subtropical and temperate waters (Nakano and Stevens, 2008). They are most often associated with the epipelagic layer (e.g., <200m depth) and are frequently encountered as a part of commercial longline fishing operations (Campana, 2016).

There are two main commercial longline fishing sectors operating around the main Hawaiian Islands, deep-set and shallow-set, both of which commonly encounter blue shark as a non-retained bycatch species. The deep-set fishery targets tropical tunas (e.g., bigeye tuna *Thunnus obesus*) via deep-setting ($\sim$ 200m) of the fishing gear during the day. The shallow-set fishery targets swordfish *Xiphias gladius* via shallow-setting ($\sim$ 60m) of fishing gear at night.

Both sectors have undergone changes to operations over the years. High interactions with protected turtle species forced a two-year closure of the shallow-set fishery (2003-2004) re-opening as transformed fishery with restrictions on hook type, bait type, and setting behavior. The deep-set fishery preempted a 2023 wire leader ban put in place to reduce shark bycatch by voluntarily switching to monofilament leaders beginning in 2021 (Figure 1). Also in 2021, the deep-set sector switched predominantly from using saury to milkfish as bait (Figure 2), likely due to economic conditions (e.g., increased cost of Pacific saury *Cololabis saira* given declines in the stock status).

This document provides an update of blue shark standardized catch-per-unit-of-effort (CPUE) using the previously used generalized linear modeling (GLM) approach (Kohin et al., 2016; Walsh and Teo, 2013) and longline observer data through 2023. However, the previously described changes to the fishery prevent the analysis of a single uninterrupted time series of fisheries data for either sector. For the deep-set sector, analysis was considered in two periods, 2002-2020 & 2021-2023, while the shallow-set only analyzed the post-closure period 2005-2023.

2 Methods

A strict update of blue shark standardized CPUE from both sectors in the Hawai'i longline was calculated following the approach taken by Walsh et al. (2013) as this was the approach used to standardize CPUE for blue shark in the two previous stock assessments (ISC, 2022, 2017). This approach is briefly described here, however readers seeking additional detail should reference the previous reports (Kohin et al., 2016; Walsh and Teo, 2013).

Blue shark CPUE was standardized using a delta-lognormal GLM approach where the standardized CPUE was calculated as the product ($\pi\mu$) of the two sub-models, noting that μ was corrected for log-transformation bias:

$$z \sim Bernoulli(\pi)$$

$$\begin{aligned} logit(\pi) =& \alpha_1 + \beta_{1,YEAR} + \beta_{1,QTR} + \beta_{1,REGION} + \beta_{1,SST} + \\ & \beta_{1,BAIT} + \beta_{1,YEAR:QTR} + \beta_{1,QTR:REGION} \end{aligned}$$

$$Y \sim Normal(\mu); \quad Y > 0$$

$$\begin{aligned} log(\mu) =& \alpha_2 + \beta_{2,YEAR} + \beta_{2,QTR} + \beta_{2,REGION} + \beta_{2,VESSEL\ LENGTH} + \\ & \beta_{2,BAIT} + \beta_{2,YEAR:QTR} + \beta_{2,QTR:REGION} \\ \mu =& exp(Y + \mathbb{V}(Y)/2) \end{aligned}$$

The standardized index is calculated as the annual means of the standardized CPUE predictions for each observation. The variance around the estimate of standardized CPUE was calculated as the variance of the two sub-models, assuming independence.

$$\mathbb{V}(\pi\mu) = \mathbb{V}(\pi) * \mathbb{V}(\mu) + \mathbb{V}(\pi) * (\mu)^2 + \mathbb{V}(\mu) * (\pi)^2$$

As noted in the Introduction, analysis was considered in two separate periods, 2002-2020 & 2021-2023, for the deep-set while the shallow-set only analyzed the post-closure period 2005-2023.

3 Results

The updated standardized CPUE was consistent with the standardized CPUE used in the previous assessment through the common period of analysis, 2020 (Figure 3). However, in more recent years since 2021 both sectors show a declining trend. Model diagnostics for each component of the delta-GLM models are shown in Figures 4 - 15.

4 Discussion

In both sectors, the standardized CPUE appears to decline in the recent period 2021 - 2023. However, changes in the deep-set sector of the fishery, notably a switch in leader material and bait type, as well as limitations in the standardization approach used make it difficult to discern whether this decline is representative of the underlying spawning stock.

As it relates to the standardization approach used, the approach taken by Walsh et al. (2013) does not apply best practices for standardizing CPUE data (Hoyle et al., 2024), especially as it relates to dealing with spatiotemporal variability in catch rates. While there is nothing inherently incorrect with using a delta-GLM approach, it is inappropriate to construct an index as the annual means of the standardized CPUE predictions made for each observation. This implicitly weights the index in proportion to the fishing effort which may not result in an index that is representative of the underlying stock dynamics. A more appropriate approach using delta-GLMs would follow Campbell (2015) where the index is constructed as a spatially weighted average of predicted standardized CPUE from each spatiotemporal strata defined within a “Walter’s Table” (Walters, 2003). However, even in this case, the current analysis only defined 8 spatial regions which may still be overly broad to properly capture spatial variation in catch rates. Defining smaller spatial strata, or moving to an explicit spatiotemporal modelling approach (Thorson et al., 2015) is recommended. Furthermore, explicitly modelling the spatiotemporal correlation structure can allow for more appropriate interpolation of predicted spatial catch-rates in the event that the fishing effort has shifted over time. Lastly, the approach taken by Walsh et al. (2013) should seek to account for the effects of possible catchability changes related to additional recorded covariates such as: vessel random effects, leader type, number of hooks fished, and/or hooks between floats.

Future analysis of this data in support of the upcoming 2027 stock assessment of blue shark should revisit the CPUE standardization in light of these concerns, and build on the spatiotemporal analytic approach described in Ducharme-Barth et al. (2024).

Acknowledgements

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Figures

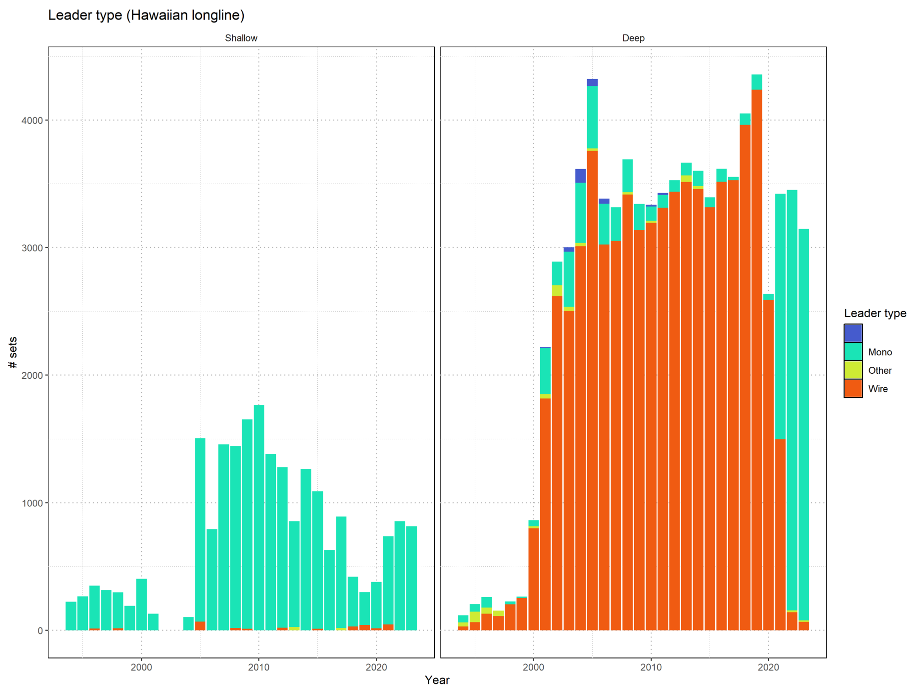

Figure 1: Distribution of sets relative to observed leader type for both sectors of the fishery over time. Sets missing a leader type are shown in dark blue.

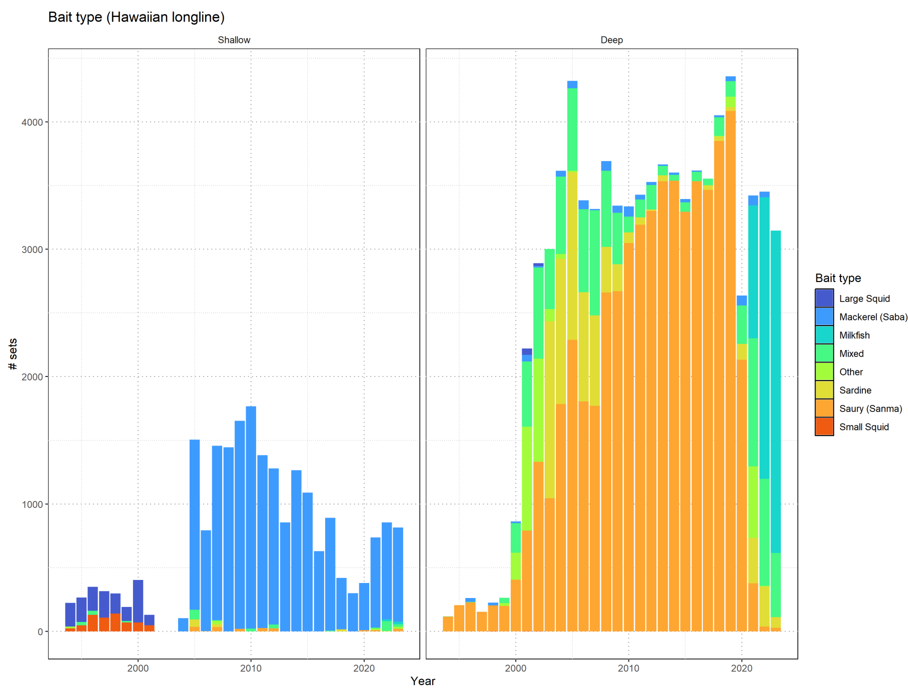

Figure 2: Distribution of sets relative to observed bait type for both sectors of the fishery over time.

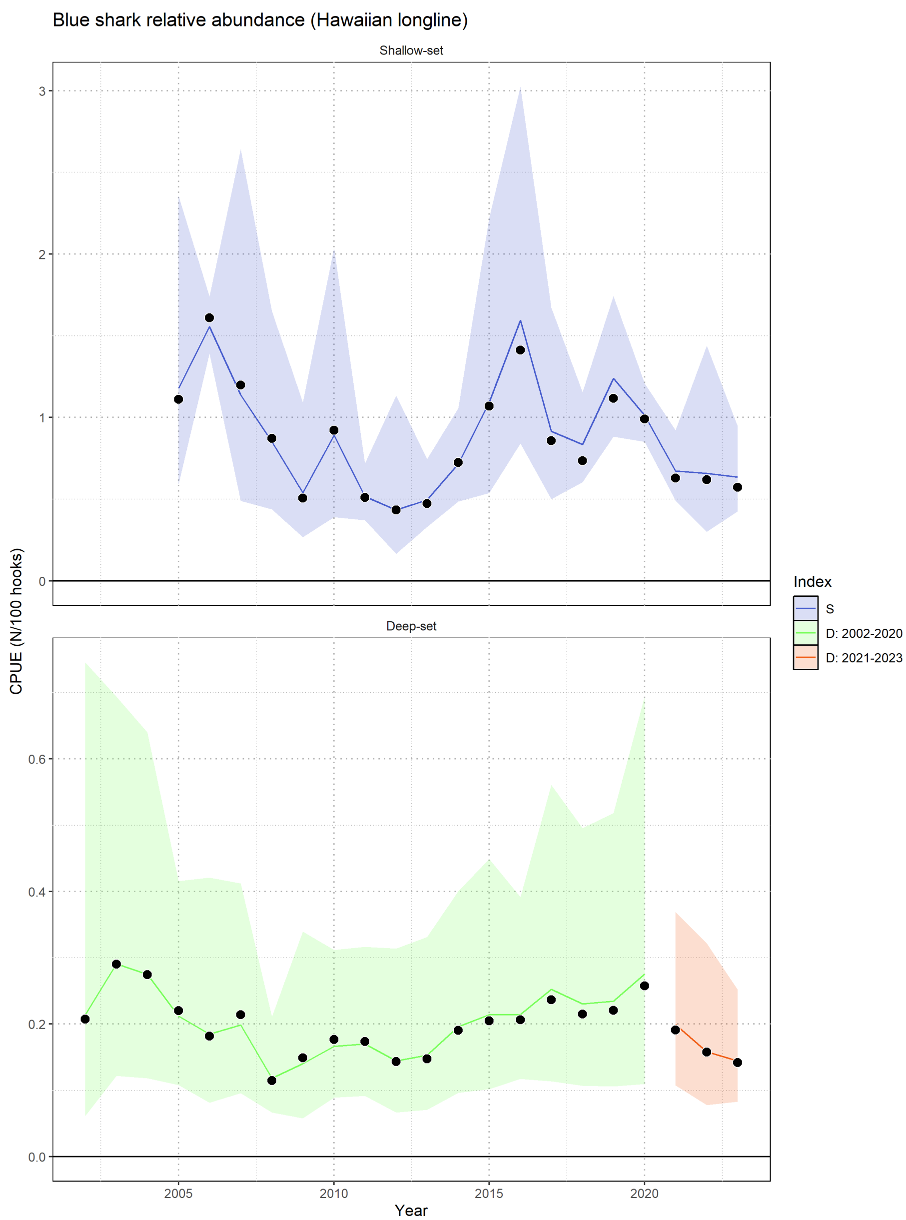

Figure 3: Standardized catch-per-unit-of-effort (CPUE) of blue shark for both sectors, deep-set and shallow-set, of the US Hawai'i based longline fishery.

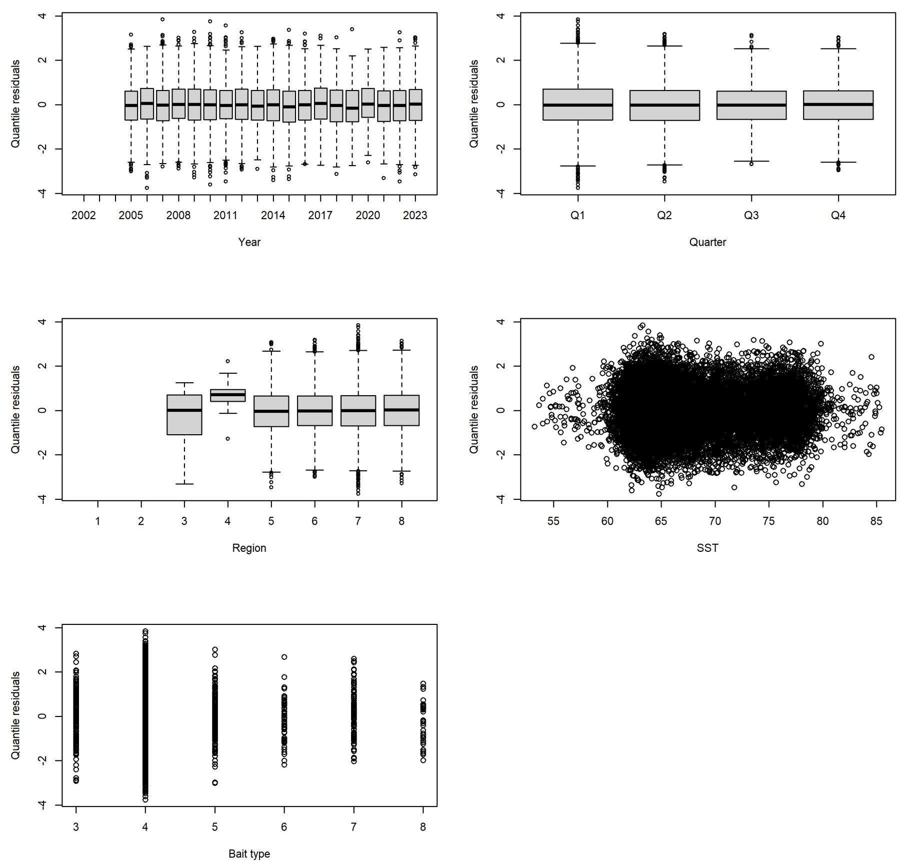

Figure 4: Diagnostics: encounter probability, shallow-set.

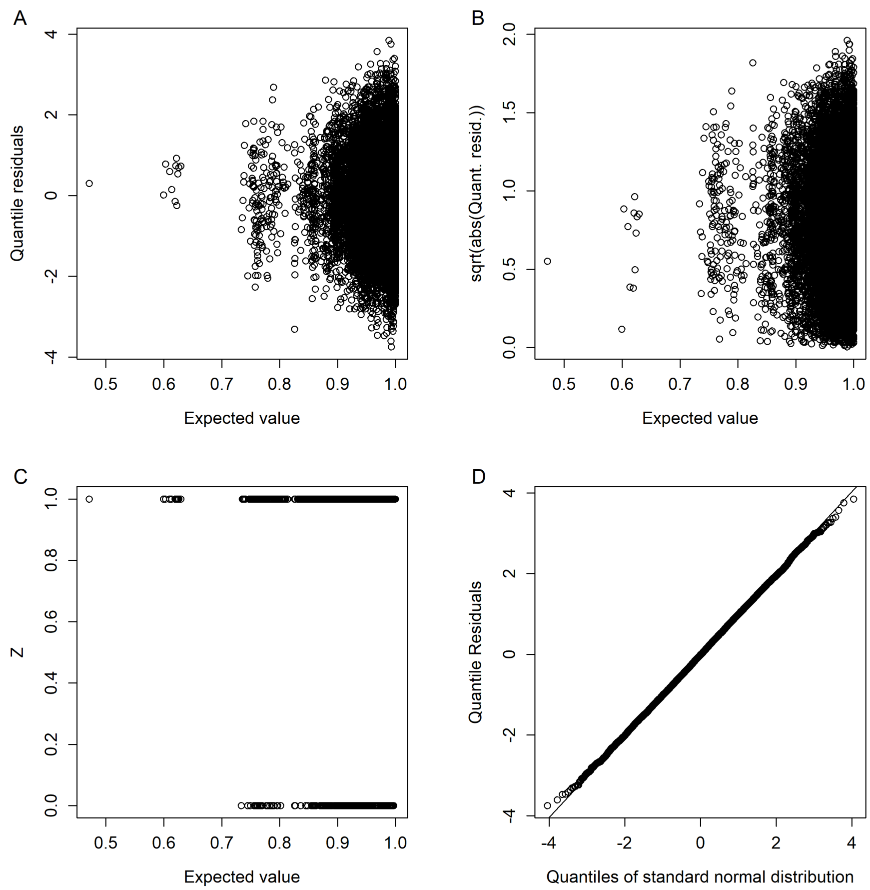

Figure 5: Diagnostics: encounter probability, shallow-set.

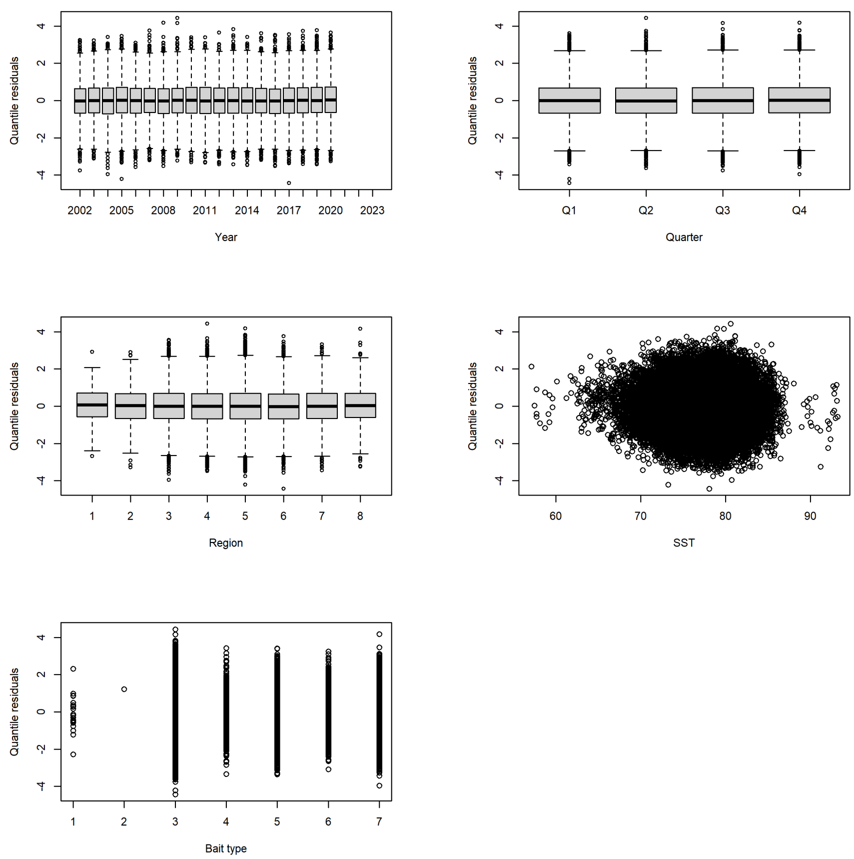

Figure 6: Diagnostics: encounter probability, deep-set 2002-2020

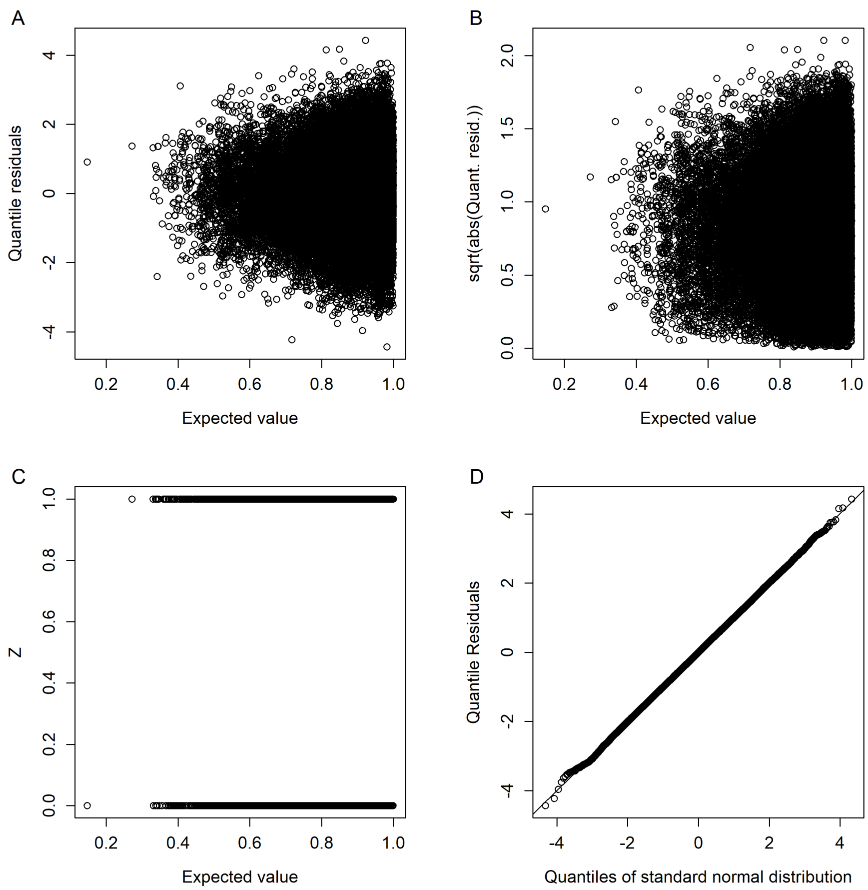

Figure 7: Diagnostics: encounter probability, deep-set 2002-2020

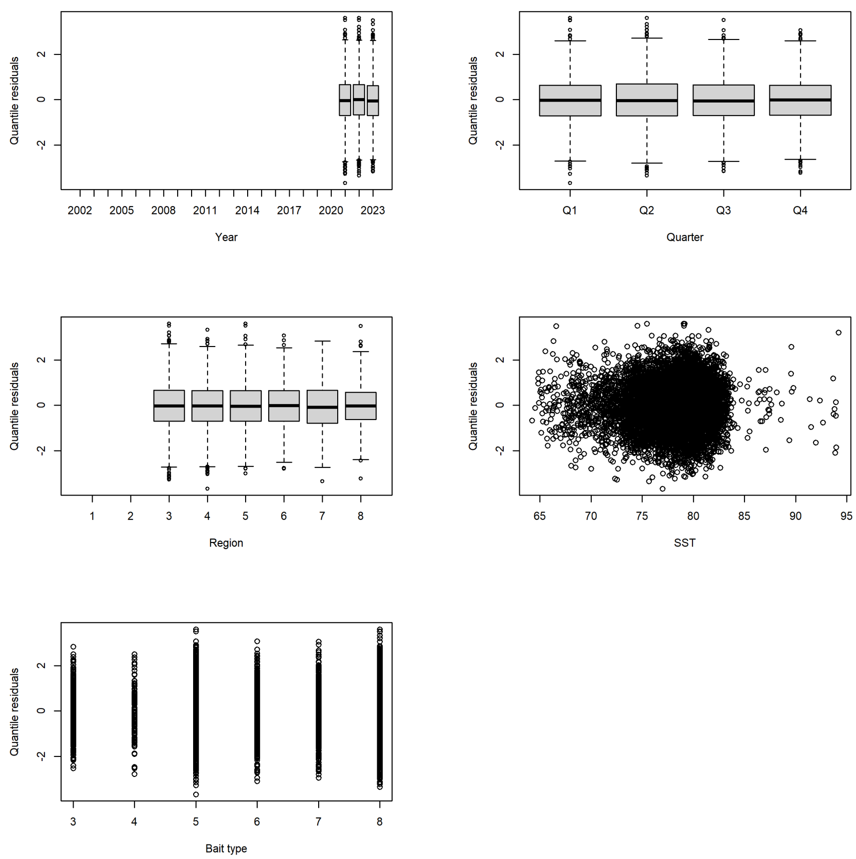

Figure 8: Diagnostics: encounter probability, deep-set 2021-2023

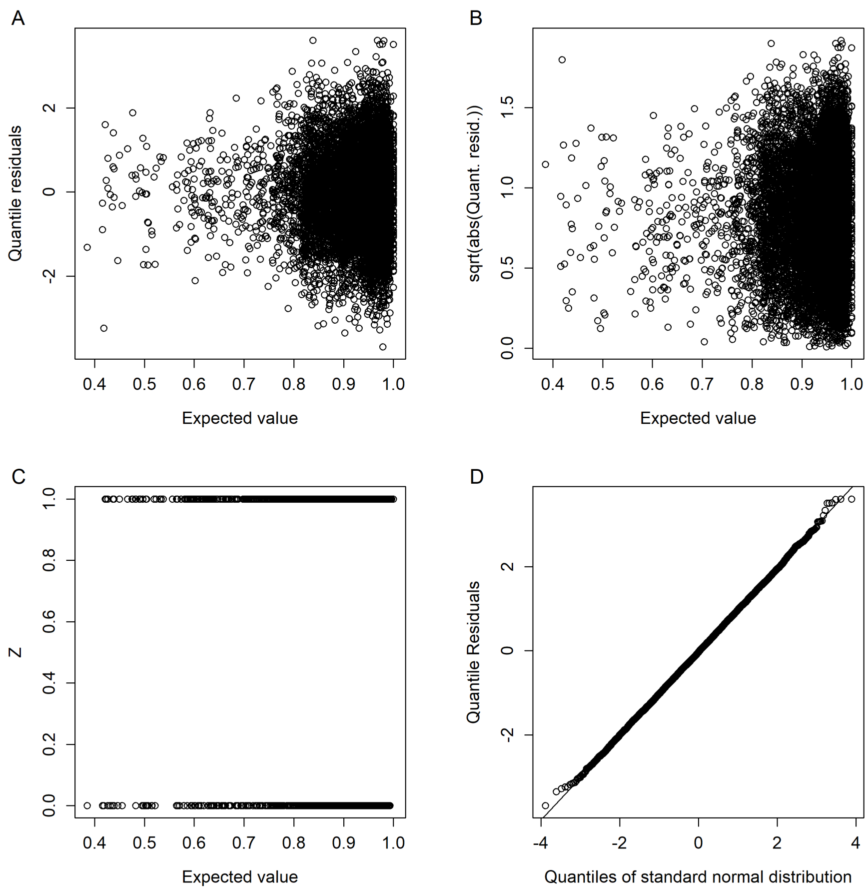

Figure 9: Diagnostics: encounter probability, deep-set 2021-2023

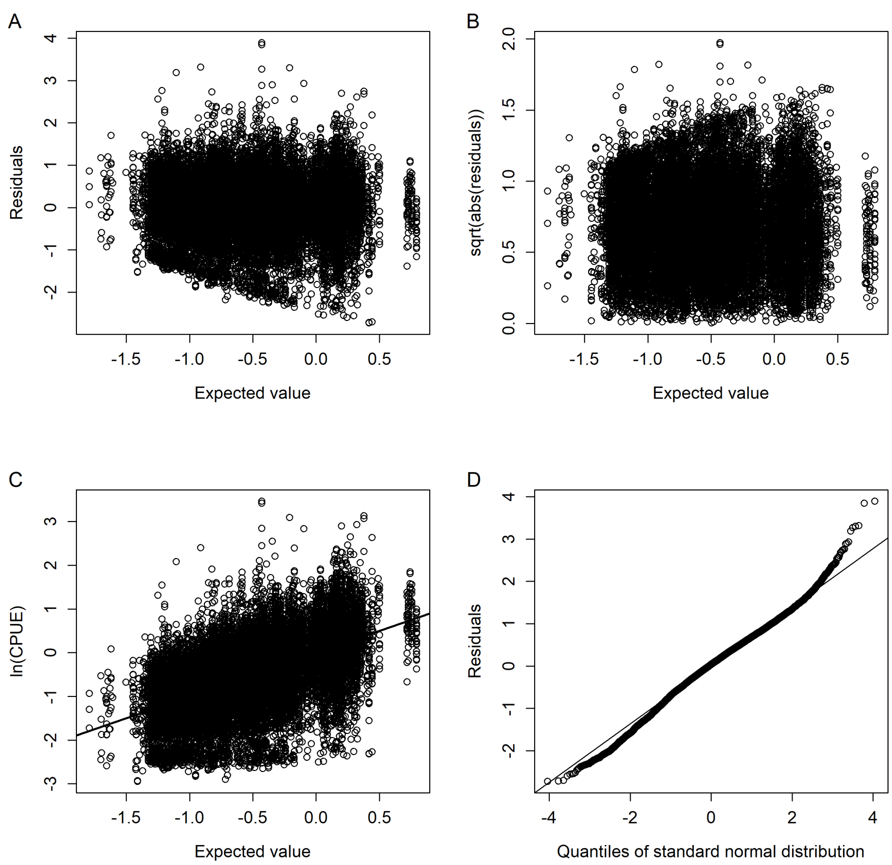

Figure 10: Diagnostics: positive catch, shallow-set.

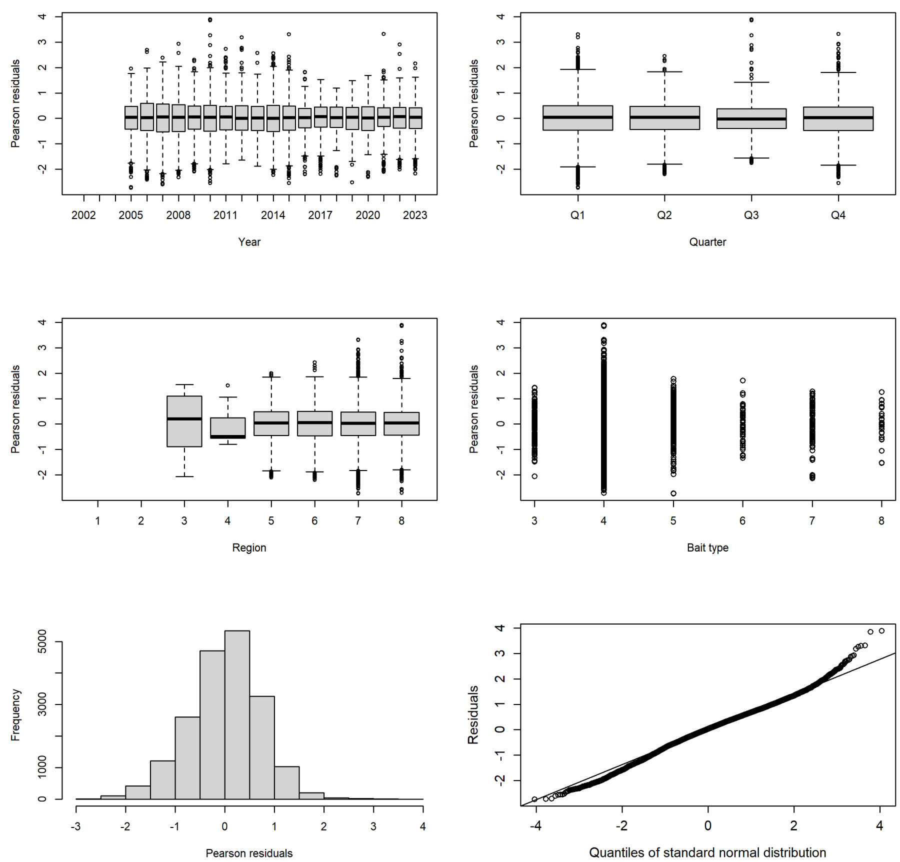

Figure 11: Diagnostics: positive catch, shallow-set.

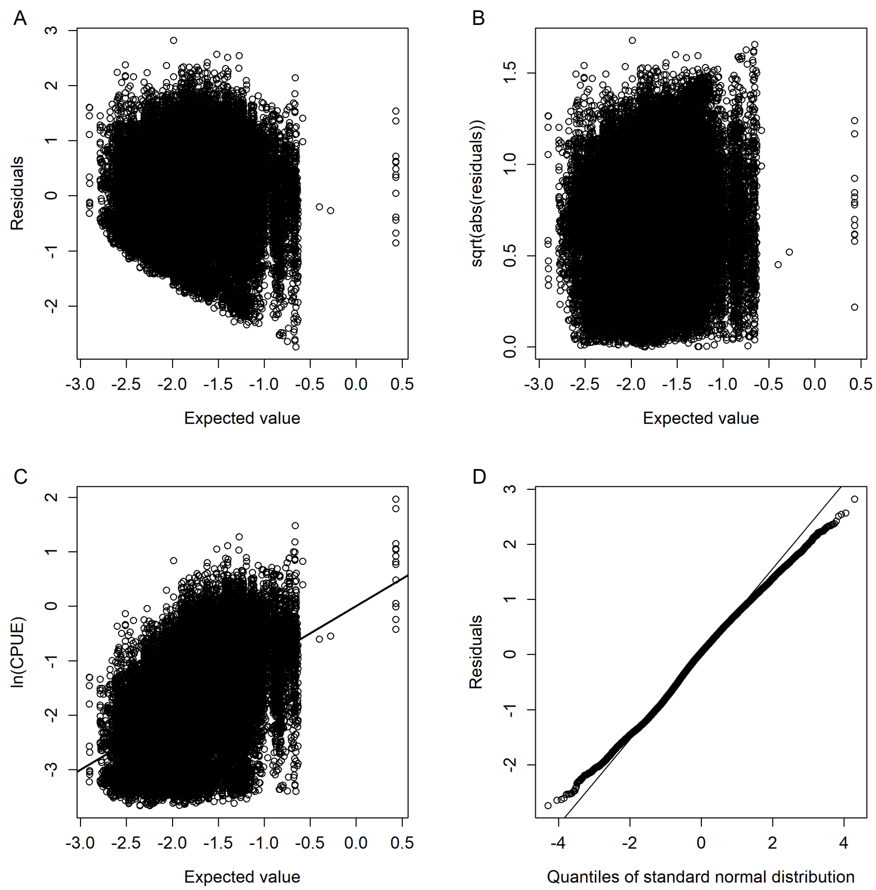

Figure 12: Diagnostics: positive catch, deep-set 2002-2020

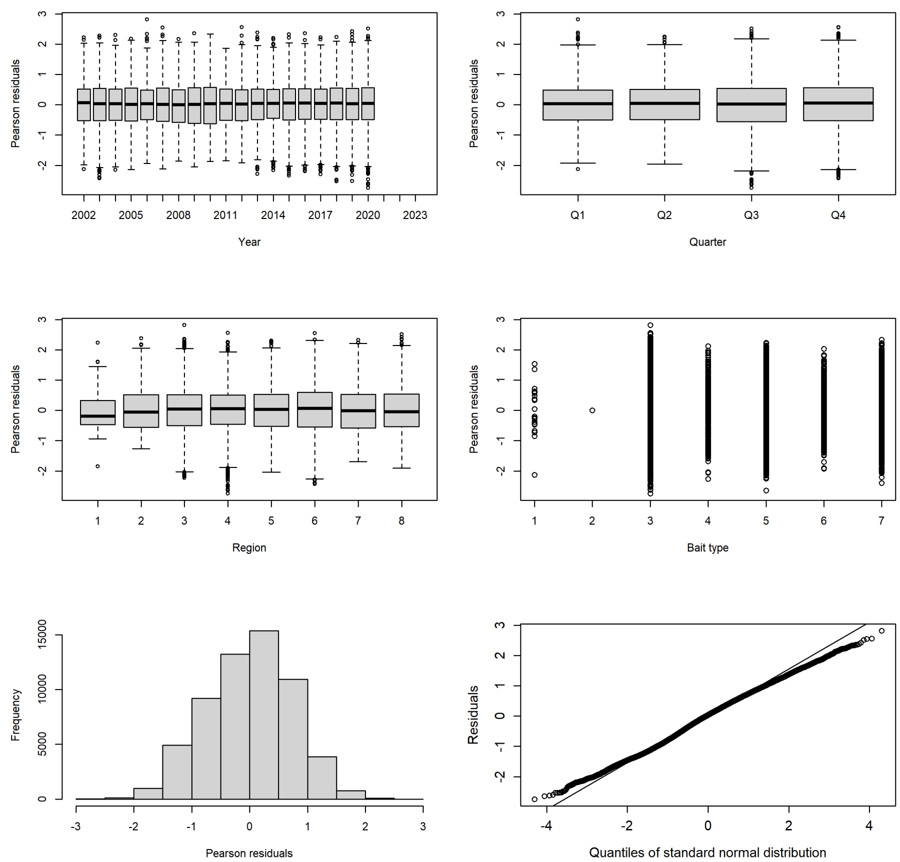

Figure 13: Diagnostics: positive catch, deep-set 2002-2020

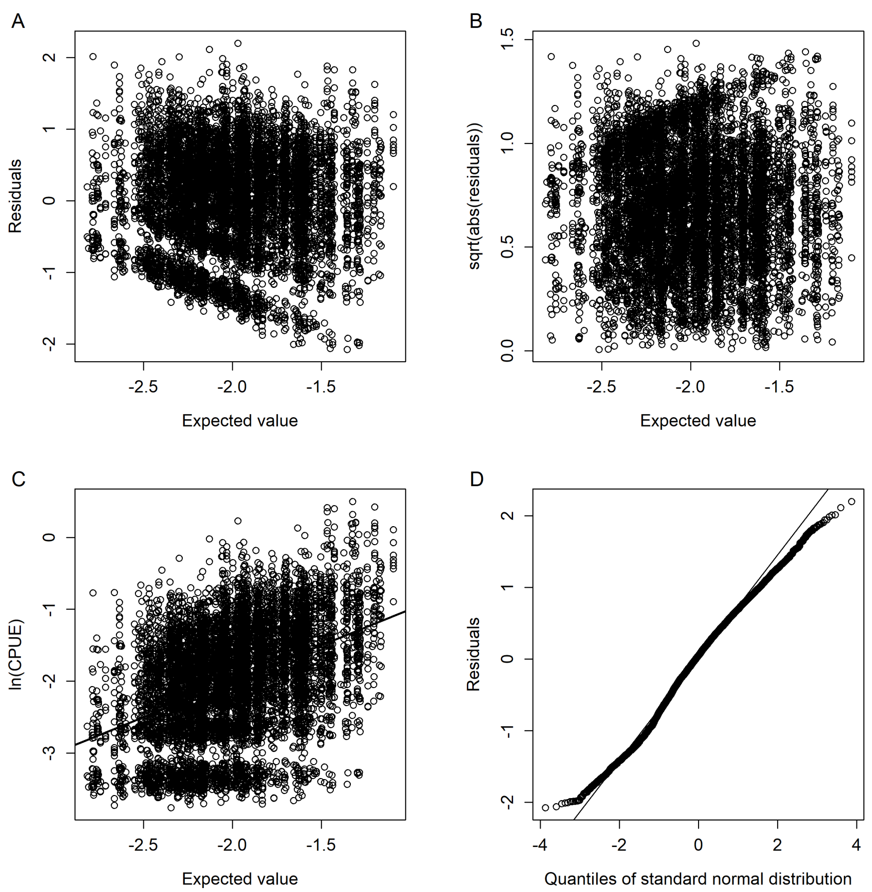

Figure 14: Diagnostics: positive catch, deep-set 2021-2023

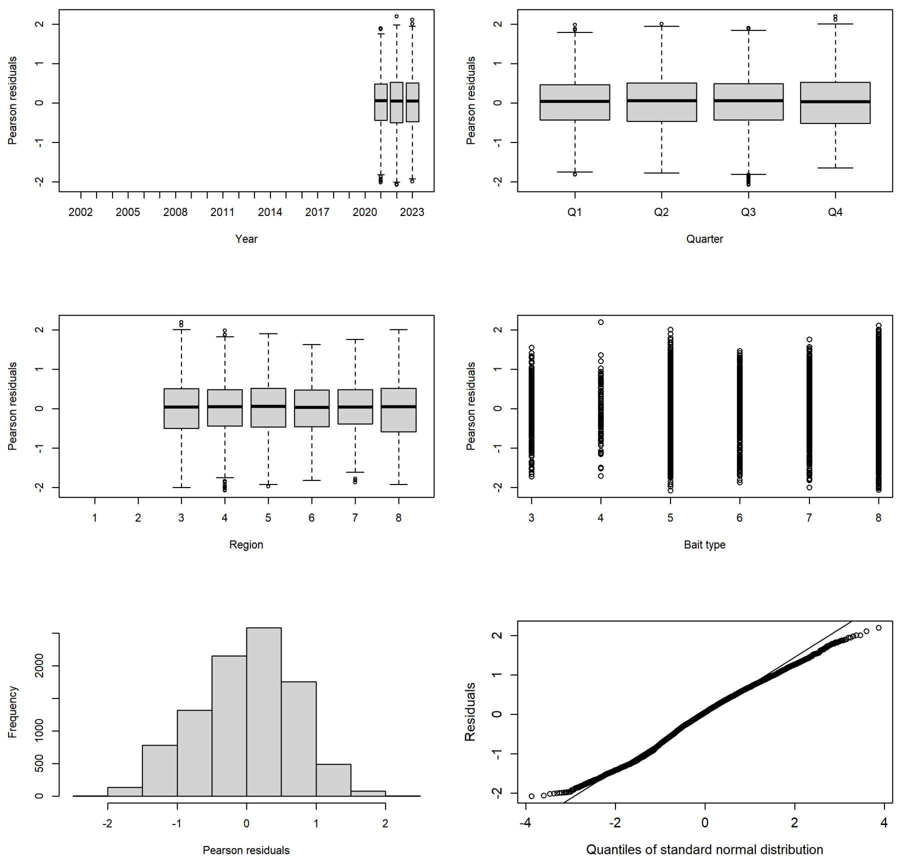

Figure 15: Diagnostics: positive catch, deep-set 2021-2023