Updated model for the 2024 stock assessment of the Thornyhead complex in the Gulf of Alaska

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Executive Summary

The Gulf of Alaska (GOA) Thornyhead complex includes the shortspine thornyhead *Sebastolobus alascanus*, the longspine thornyhead *S. altivelis*, and the broadfin thornyhead *S. macrochir*. This complex is assessed on a biennial schedule in even years and is managed as a Tier 5 stock. The current method for estimating the GOA-wide Acceptable Biological Catch (ABC) in the western, central and eastern GOA management areas (i.e., WGOA, CGOA, and EGOA) uses only shortspine thornyhead caught by the bottom trawl survey (BTS) and the longline survey (LLS) in the random effects model (REMA; Hulson et al. 2021, Echave et al. 2022). This model is implemented using Template Model Builder (TMB) in the *rema* package (Sullivan et al. 2022). Model 22 estimated three area-specific process errors, one shared scaling coefficient, and additional observation error parameters for each survey (Echave et al. 2022). Following recommendations from the GOA groundfish plan team (Nov 2022 GOA PT Minutes p.7) and the SSC (Dec 2022 SSC Final Report p.48), we explored moving from three area-specific process errors to a single shared process error.

During the 2022 assessment cycle, authors' efforts focused on correcting a model issue and exploring estimation of additional observation errors, where it was found that additional observation error for both surveys was more biologically realistic then including it for either survey alone or none at all (2022 document Appendix A and presentation). Updates to the *rema* package impact how additional observation error was coded, and this updated version is what is used.

For the 2024 assessment, the authors recommend using the REMA model that estimates a single shared process error, a single scaling coefficient, and additional observation error for both surveys.

Summary of Methods

Changes in the data:
For this assessment, biomass estimates and errors from the BTS are aggregated at three depth strata (0–500m, 501–700m, and 701–1000m) for each of the three management areas (WGOA, CGOA, and EGOA) to handle missing survey strata in the time series. In the last assessment there was a single year, area, and depth strata (1999, WGOA, 701–1000m) that had a single haul and thus no reported variance, so the authors' included a CV of 0.1 for this strata. This year, we noticed that some of the survey's finer resolution strata had only a single haul, and therefore, these were not adding any calculated variance when summed to the strata used in the assessment. After discussion with the Groundfish Assessment Program (GAP), we chose to add a variance equivalent to a CV of 0.5 to all of the biomass estimates that came from a sample of one haul before they were summed to the strata used in this assessment. We believe that this increased CV

is justified considering that a single haul is being used to extrapolate biomass to entire areas. This resulted in the following changes in CV at the assessment strata level:

Year	Strata	CV Old	CV New	CV Diff
1993	EGOA (0-500 m)	0.096	0.101	0.006
1996	EGOA (0-500 m)	0.108	0.118	0.010
1999	WGOA (701-1000 m)	0.100	0.500	0.400
2009	EGOA (701-1000 m)	0.019	0.451	0.432
2011	EGOA (0-500 m)	0.099	0.114	0.015
2015	EGOA (701-1000 m)	0.005	0.452	0.447
2019	CGOA (501-700 m)	0.167	0.340	0.173
2021	EGOA (0-500 m)	0.103	0.104	0.001
2021	EGOA (501-700 m)	0.219	0.409	0.180
2023	EGOA (0-500 m)	0.141	0.146	0.005

All models run in 2024 use these updated CVs, while model runs in 2022 did not. The resulting changes have a minimal effect on model results, but slight differences in parameter estimates occurred. Under the new stratification of the GOA BTS, the issue of a single haul in a strata should be resolved beginning in 2025 (Oyafuso et al. 2022).

Changes in the assessment model methodology:
Recent diagnostics of *rema* models indicated that the Laplace approximation was failing for the estimation of additional observation errors parameters (Balstad et al. 2024). The additional observation errors were recoded from a logit transformation to a log transformation, and the *rema* package has since been updated with this change. This is reflected in Model 24.1. While this fixed issues related to estimation of the LLS additional observation error, there was still a potential issue with model convergence related to difficulties estimating the BTS additional observation error parameter. We plan to explore different ways of parameterizing the additional observation error parameters in the future.

Based on a recommendation from the GOA GPT (Nov 2022 GOA PT Minutes p.7) and the SSC (Dec 2022 SSC Final Report p.48), we present alternative model results that estimate a single shared process error (Model 24.2) rather than the three area-specific process errors in Model 24.1.

The two-survey random effects models presented use the following naming conventions:

Model	Process Errors	Additional Observation Error
22	Area-specific (3)	LLS & BTS
24.1	Area-specific (3)	LLS & BTS (updated *rema*)
24.2	Shared (1)	LLS & BTS (updated *rema*)

Summary of Results

The primary suggested change is transitioning from a model with three area-specific process errors to one with a single shared process error, but we have also included updates to some CV calculations and use of the updated *rema* package. We compared the previously accepted model (Model 22) with the same three-process error model that recoded additional observation errors from a logit transformation to a log transformation and used updated CVs (Model 24.1). The parameter and error estimates remained nearly the same from Model 22 to Model 24.1, though some very slight changes were introduced after updating CVs as described above (Table 1). Model 24.2 transitioned from three process errors to one. The shared process error (0.119) estimated by Model 24.2 was very similar to the values estimated by Model 24.1 for the CGOA (0.116) and EGOA (0.104), but it was almost half that of the Model 24.1 estimated process error of 0.225 for the WGOA (Table 1). Therefore, the changes in the predicted biomass for the EGOA and CGOA were minimal, but in the WGOA, the change lead to a slightly smoother trend (Figure 1). Overall, the predicted biomass for the GOA is similar for these models (Figure 2). Note that the current parameterization of the extra survey observation error parameters are dependent on the observed CVs (Figure 3). Model 24.2 estimated more additional observation error for the trawl survey compared to Model 24.1, while the additional observation error parameter for the longline survey was similar for both models (Table 1 and Figure 3). We hope to explore alternative parameterizations for the additional observation error in the future.

Recommendation and Rationale

Observation errors (i.e., CVs) that are provided by both the BTS and the LLS are small, though consecutive surveys occasionally report big shifts in biomass estimates. Additional observation errors allow for more biologically realistic process error. We know that the LLS is not surveying small shortspine thornyhead as well as the BTS because the hook size is too large for their mouths. Length samples indicate no shortspine thornyhead < 20-cm were caught in the LLS but were present in the BTS (Figure 4). We also know that the BTS has not regularly sampled deeper than 500m, and when it did, catch rates seem to drop much more with depth than they do in the LLS (Figure 5). The BTS will not sample deeper than 700 m in its current two-vessel configuration, so we do not expect to get biomass estimates for these deeper strata in the future (personal communication from GAP staff). As shown in the 2022 assessment cycle (2022 document Appendix A and presentation), and supported by each survey's shortcoming, we believe inclusion of additional observation error for both surveys remains justified.

For 2024 the authors recommend Model 24.2, which estimates a single shared process error, a single scaling parameter, and additional observation errors for LLS and BTS. This alternative model is responsive to GOA GPT and SSC recommendations that ask for justification when using multiple process errors, and we do not have a strong justification to maintain use of the multiple process errors included in Model 24.1.

Literature Cited

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Sullivan, J., C. Monnahan, P. Hulson, J. Ianelli, J. Thorson, and A. Havron. 2022. REMA: a consensus version of the random effects model for ABC apportionment and Tier 4/5 assessments. Plan Team Report, Joint Groundfish Plan Teams, North Pacific Fishery Management Council. 605 W 4th Ave, Suite 306 Anchorage, AK 99501. Available through the Oct 2022 Joint GPT e-Agenda.

Tables

Table 1. Fixed effects parameter estimates, standard errors (SE), and 95% lower and upper confidence intervals (LCI and UCI, respectively) for the models considered in this analysis. Process error (PE) variances are listed first, followed by scaling parameters (q) and additional observation errors (+OE) by survey (i.e., bottom trawl survey = BTS and longline survey = LLS).

Model	**Parameter**	**Estimate**	**SE**	**LCI**	**UCI**
22	WGOA PE	0.224	0.068	0.124	0.406
22	CGOA PE	0.115	0.036	0.063	0.212
22	EGOA PE	0.105	0.032	0.058	0.191
22	q	0.602	0.022	0.561	0.647
22	BTS+OE	0.180	0.052	0.101	0.308
22	LLS+OE	0.145	0.024	0.104	0.199
24.1	WGOA PE	0.225	0.069	0.123	0.412
24.1	CGOA PE	0.116	0.036	0.063	0.213
24.1	EGOA PE	0.104	0.032	0.057	0.191
24.1	q	0.604	0.022	0.562	0.650
24.1	BTS+OE	0.183	0.053	0.104	0.322
24.1	LLS+OE	0.144	0.024	0.104	0.201
24.2	Shared PE	0.119	0.027	0.077	0.185
24.2	q	0.610	0.024	0.564	0.659
24.2	BTS+OE	0.226	0.043	0.156	0.327
24.2	LLS+OE	0.146	0.025	0.105	0.203

Figures

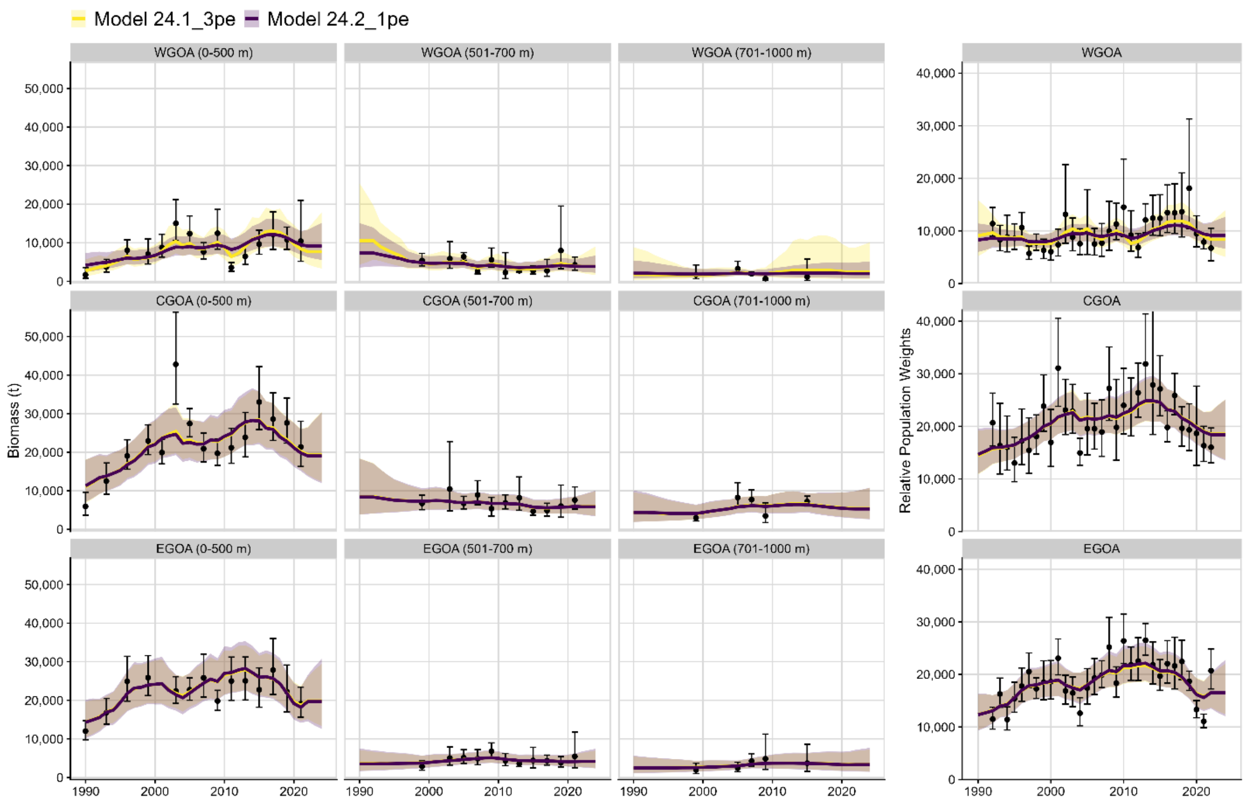

Figure 1. Two-survey random effects (REMA) model fits to Gulf of Alaska shortspine thornyhead rockfish bottom trawl survey biomass (9 panels on the left) and longline survey relative population weights (3 panels on the right) by western, central, and eastern GOA (WGOA, CGOA, and EGOA) management area. The points and error bars are the design-based survey estimates, and the lines with shaded regions are the model predictions and 95% confidence intervals from the REMA model. Results are shown for Model 24.1 in yellow and Model 24.2 in purple.

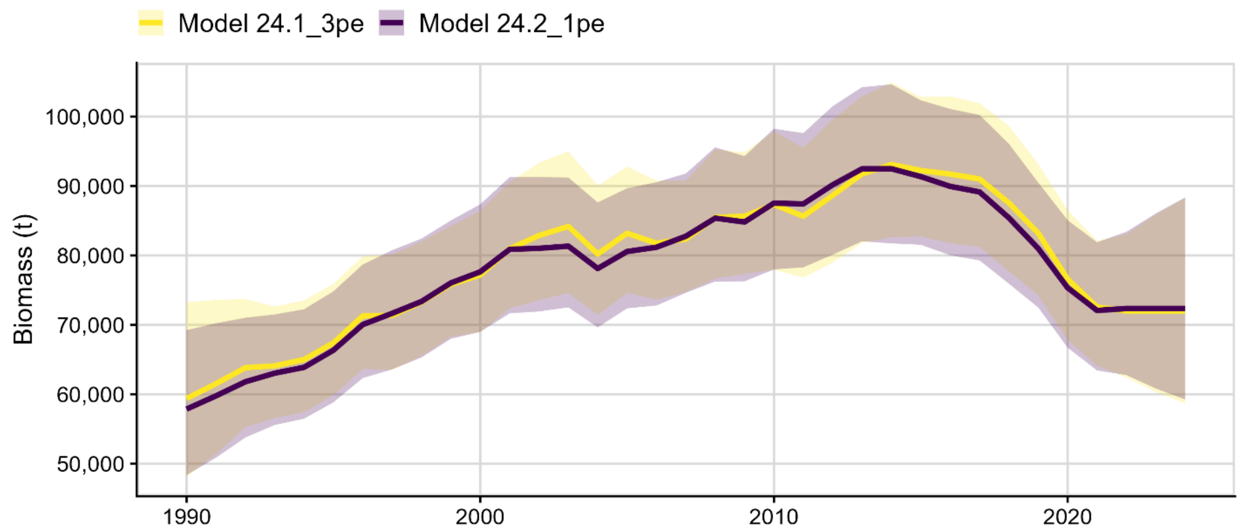

Figure 2. Two-survey random effects (REMA) model fits to Gulf of Alaska shortspine thornyhead rockfish bottom trawl survey biomass and longline survey relative population weights, where the shaded regions are the model predictions and 95% confidence intervals from the REMA model. Results are shown for Model 24.1 in yellow and Model 24.2 in purple.

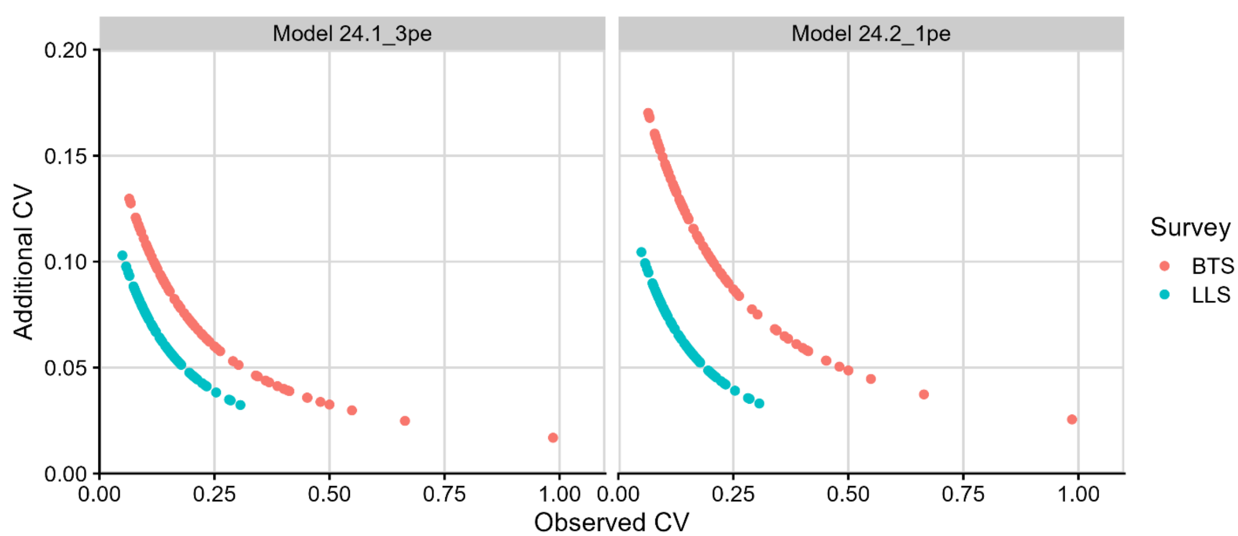

Figure 3. Additional CV being estimated by model (area-specific process error on the left and shared process error on the right) relative to the observed CV by strata for Gulf of Alaska shortspine thornyhead rockfish from the bottom trawl survey (BTS) and the longline survey (LLS).

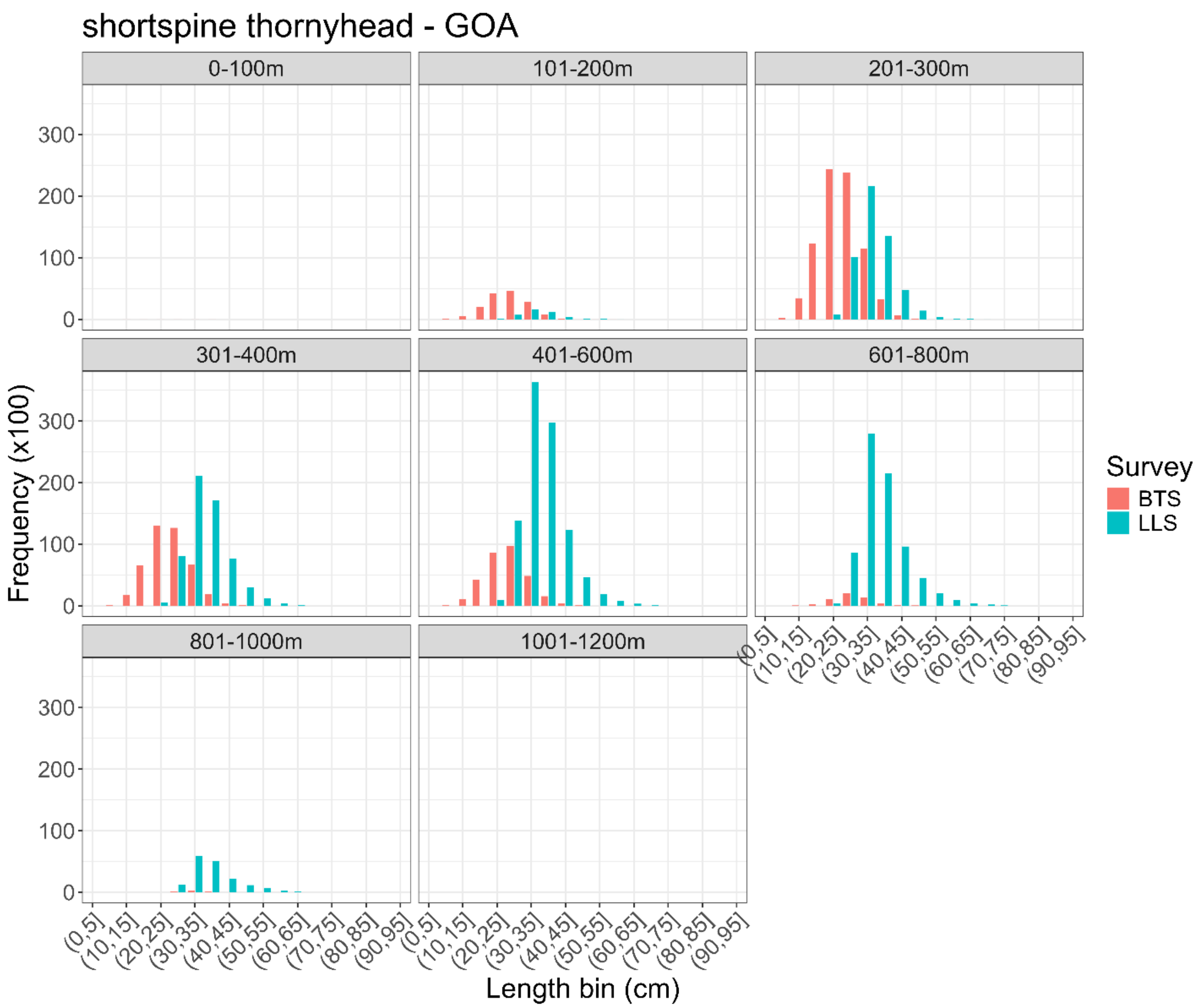

Figure 4. Length frequency (5-cm bins) of shortspine thornyhead by depth bins from the bottom trawl survey (BTS) and the longline survey (LLS).

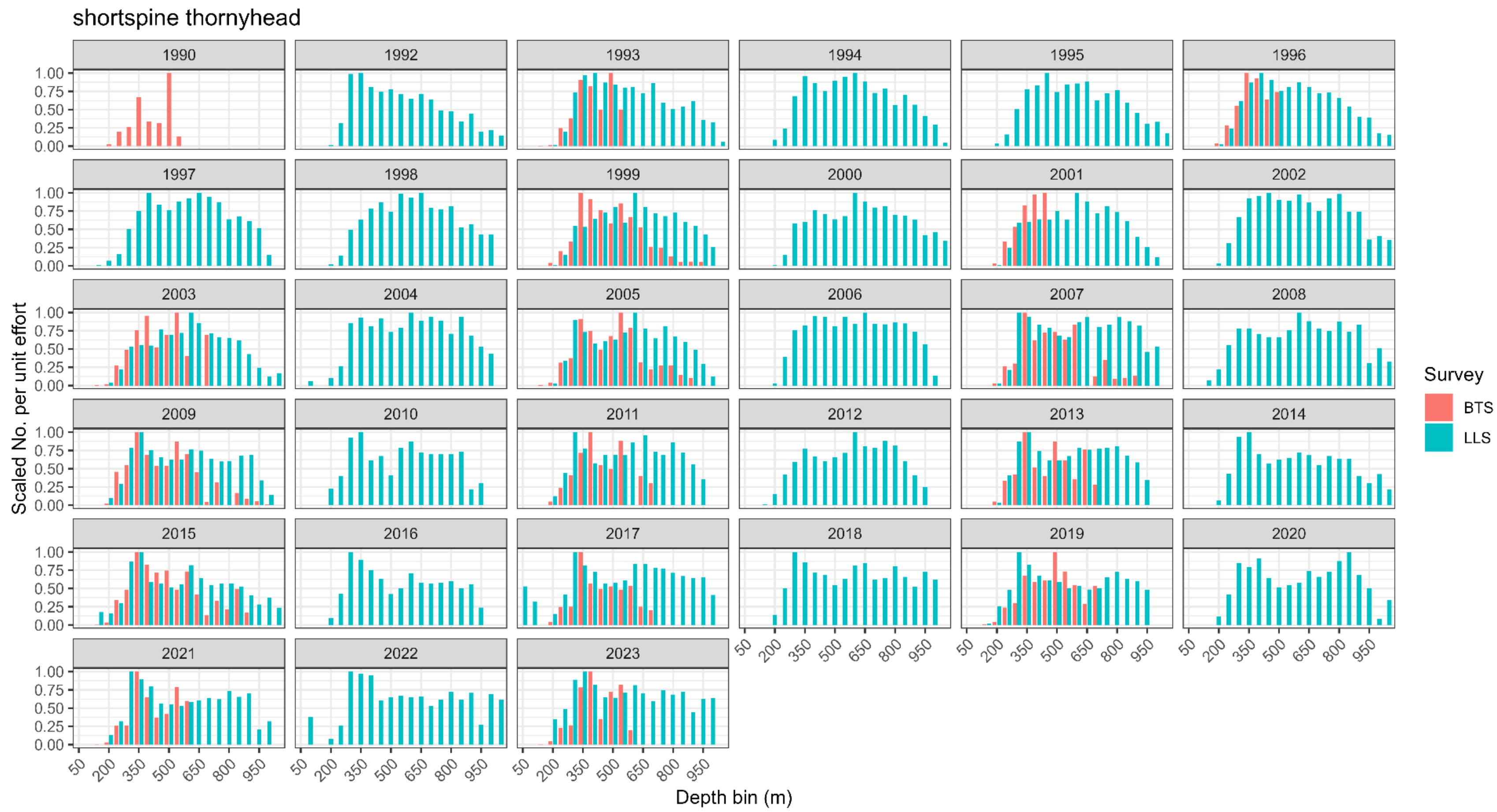

Figure 5. Annual catches of shortspine thornyhead by 50-m depth bins from the bottom trawl survey (BTS) and the longline survey (LLS), where each year is scaled to the maximum number of fish caught per unit of effort.