Northeast Fisheries Observer Program Catch Per Unit Effort Time Series for Sandbar Sharks

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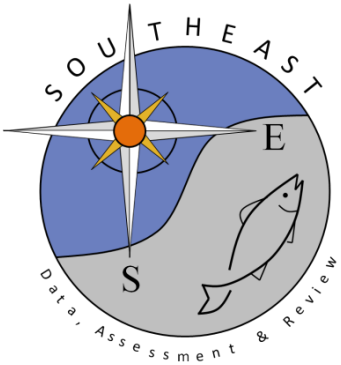

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Draft: Northeast Fisheries Observer Program Catch Per Unit Effort Time Series for Sandbar Sharks

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Abstract:

Fishery catch rates from the northeast observer program coverage of the trawl and gillnet fishery were standardized to produce catch per unit effort (CPUE) time series for sandbar sharks. Two different datasets were explored, a model with only positive trips and a model with targeted trips (e.g., zero observations). Model results varied depending on method with the targeted trips model suggesting an increasing trend since 2008, while the positive only model suggests interannual variability.

Introduction:

The Northeast Fisheries Observer Program deploys scientists on commercial vessels to collect information on catch and discards. Observers are tasked with collecting information on fishing gear, fishing location, weather, demographic information and disposition of discarded fish. The program operates from North Carolina to Canada. Sampling priorities are based on funding but a primary goal of the program is to cover enough of the fishing fleet to produce discard estimates that have a 30 % coefficient of variation. This dataset is routinely used to produce discard estimates for stock assessment in the Northeast; however, it is typically not used to produce relative abundance indices because the region is data rich with surveys and the groundfish fishery has undergone multiple management changes. However, apart from the Northeast Fisheries Science Center coastal shark longline survey that covers waters from Florida to southern New Jersey, sharks are rarely encountered in these surveys (bottom trawl, scallop dredge, etc.). Sandbar sharks have been targeted historically in the region; however, they have been prohibited since 2008. Sandbar shark bycatch continues to occur as far north as the southern Gulf of Maine where there are minimal fishery-independent data sources for sharks. This working paper develops catch per unit effort (CPUE) time series from observer data for sandbar sharks from 1995-2025.

Methods:

Observer records from the gillnet and trawl fishery were obtained from 1995 to 2025. All data explored was collected directly by the observer program (The Northeast Fisheries Observer Program and At-sea Monitoring). Data included: Number of sharks caught, fork length of captured sharks, gear type, haul duration, year of capture, month of capture, water temperature at capture, location of capture and target species (Figure 1:5). Individual shark observations were not included before 1995 due to possible species identification issues (McCandless and Mello 2021). The observer program records target species; however, sandbar sharks have been prohibited since 2008. Two different datasets were explored, a model with only positive trips and a model with targeted trips (e.g., zero observations). Zero observations were determined as fishing trips targeting large sharks (e.g., not dogfish) that did not catch sandbars.

Many methods are available to standardize CPUE (Hoyle et al. 2024). We explored using multivariate Generalized Linear Mixed Models and Generalized Additive Models (GAMs). Multivariate models allowed for the standardization of length composition data, while GAMs allowed easy implementation of non-linear trends. The response variable was the number of sandbar sharks caught per haul. Poisson, negative binomial and zero inflated distributions were explored. Spatio-temporal models were explored to account for spatial shifts in fishing effort. Random effects were explored to account for differences between gear type (e.g., trawl vs gillnet). A cubic spline was used to account for seasonal differences and different splines were explored for other covariates. Collinearity of covariates was examined using generalized variance-inflation factor (GVIF) scores. Any covariate with a score greater than three was removed, and the GVIFs were recalculated (Zuur, et al. 2012). For index standardization, Akaike Information Criterion (AIC) scores were used to determine the best-fitting model. If AIC scores were within two units of one another, the most parsimonious model was selected (Burnham and Anderson, 2004). Influence plots were created of the optimal models to understand the influence of each covariate (Bentley et al. 2012). A five-year retrospective analysis was conducted. Models were evaluated based on convergence rates and residual patterns.

Results:

Multivariate models struggled to converge so they were not considered as a viable option for a stock index. All GAMs successfully converged without any issues. Residual patterns of both models indicate some violation of normality and skewness. However, residual patterns were better for the model fit to only positive trips (Figure 6 & 7). Model selection supported including the following covariates for the targeted trips CPUE:

$$Catch = Year + s(Fishing\ duration) + s(Water\ temp) + te(Lat, Lon) + s(Gear\ type, bs = re)\ \varepsilon \sim NB(r, p)$$

Model selection supported including the following covariates for the positive only CPUE:

$$Catch = Year + s(Fishing\ duration) + s(Water\ temp) + te(Lat, Lon) + s(Gear\ type, bs = re)\ \varepsilon \sim NB(r, p)$$

Model selection supported the same covariates besides the targeted trips CPUE did not include haul duration. The targeted trips GAM explained 66% of the deviance while the positive only GAM explained 39% of the deviance. Both models suggested higher catch rates in the summer, while the targeted model suggested lower catch rates in the south (Figure 8 & 9). In contrast, the positive only model suggested higher catch rates in the south (Figure 9). For the targeted model, the inclusion of covariates had a bigger impact on annual abundance estimates, the inclusion of a seasonal covariate changed the trend since 2012 (Figure 10 & 11). Abundance trends from the targeted trip model suggest increasing relative abundance since 2008, while the positive only model suggests interannual variability (Table 1; Figure 12). The size distribution associated with each index is the same (Figure 13 & 14). Retrospective analysis of the two indices suggests a minimal retrospective pattern for the positive only index and a retrospective pattern for the targeted trip index (Figure 15).

References:

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Hoyle, S. D., Campbell, R. A., Ducharme-Barth, N. D., Grüss, A., Moore, B. R., Thorson, J. T., ... & Maunder, M. N. (2024). Catch per unit effort modelling for stock assessment: A summary of good practices. *Fisheries Research*, *269*, 106860.

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Zuur, A. F., Saveliev, A. A., & Ieno, E. N. (2012). *Zero inflated models and generalized linear mixed models with R* (p. 324). Newburgh: Highland Statistics Limited.

Table 1: Optimal model output.

Year	Model	Index	SD	Model	Index	SD
1995	Targted_trips	0.705847	0.325852	Positive	2.21879	0.175461
1996	Targted_trips	-0.55227	0.253957	Positive	1.868556	0.18145
1997	Targted_trips	-0.80666	0.258415	Positive	0.573565	0.221182
1998	Targted_trips	0.871001	0.306636	Positive	0.676954	0.218489
1999	Targted_trips	-0.08369	0.310483	Positive	1.158771	0.207345
2000	Targted_trips	-0.3992	0.278043	Positive	0.20873	0.187461
2001	Targted_trips	0.88078	0.262574	Positive	0.899507	0.18939
2002	Targted_trips	0.512494	0.265676	Positive	0.532773	0.201447
2003	Targted_trips	1.33396	0.282148	Positive	0.447222	0.261677
2004	Targted_trips	2.01282	0.358589	Positive	0.224156	0.196884
2005	Targted_trips	0.963585	0.2678	Positive	1.764017	0.172865
2006	Targted_trips	-0.68139	0.246321	Positive	1.344512	0.18953
2007	Targted_trips	0.590491	0.248517	Positive	2.248823	0.162913
2008	Targted_trips	-1.02266	0.23305	Positive	1.122236	0.186217
2009	Targted_trips	-0.57666	0.261049	Positive	0.436728	0.179417
2010	Targted_trips	1.799599	0.23941	Positive	0.966425	0.182316
2011	Targted_trips	-1.18965	0.244816	Positive	1.033747	0.193464
2012	Targted_trips	0.451586	0.264706	Positive	0.887951	0.240176
2013	Targted_trips	1.96733	0.289642	Positive	0.06433	0.191862
2014	Targted_trips	1.365478	0.262085	Positive	1.518865	0.166736
2015	Targted_trips	1.32481	0.223013	Positive	0.474387	0.16556
2016	Targted_trips	1.444366	0.229842	Positive	0.922186	0.160115
2017	Targted_trips	2.380591	0.212294	Positive	1.182672	0.155115
2018	Targted_trips	1.691075	0.222916	Positive	0.590412	0.177852
2019	Targted_trips	2.856356	0.226701	Positive	0.892829	0.166167
2020	Targted_trips	2.111351	0.231024	Positive	1.524452	0.283868
2021	Targted_trips	2.517494	0.288421	Positive	1.881298	0.224711
2022	Targted_trips	2.810226	0.280342	Positive	1.182584	0.185881
2023	Targted_trips	1.914701	0.243557	Positive	0.729107	0.164388
2024	Targted_trips	2.306673	0.221158	Positive	0.935541	0.204351
2025	Targted_trips	1.499564	0.262493	Positive	0.487873	0.253986

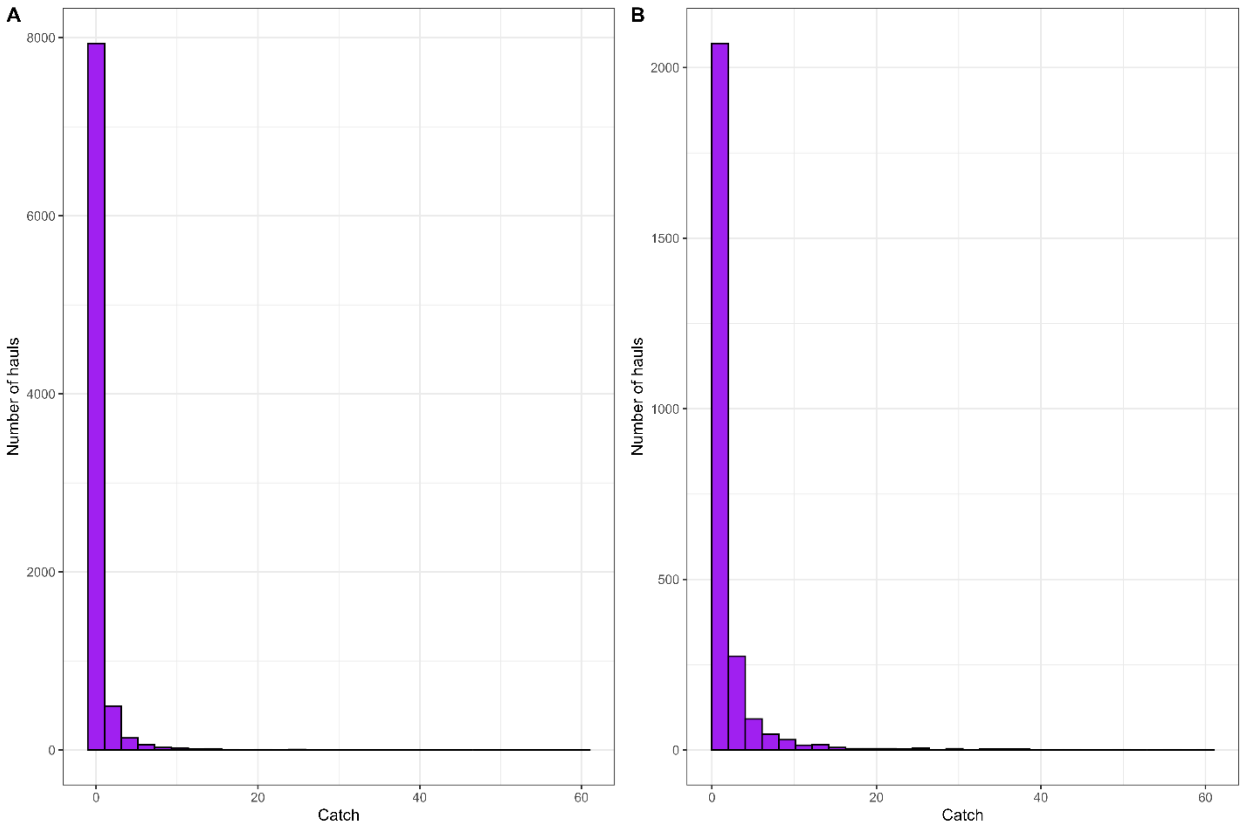
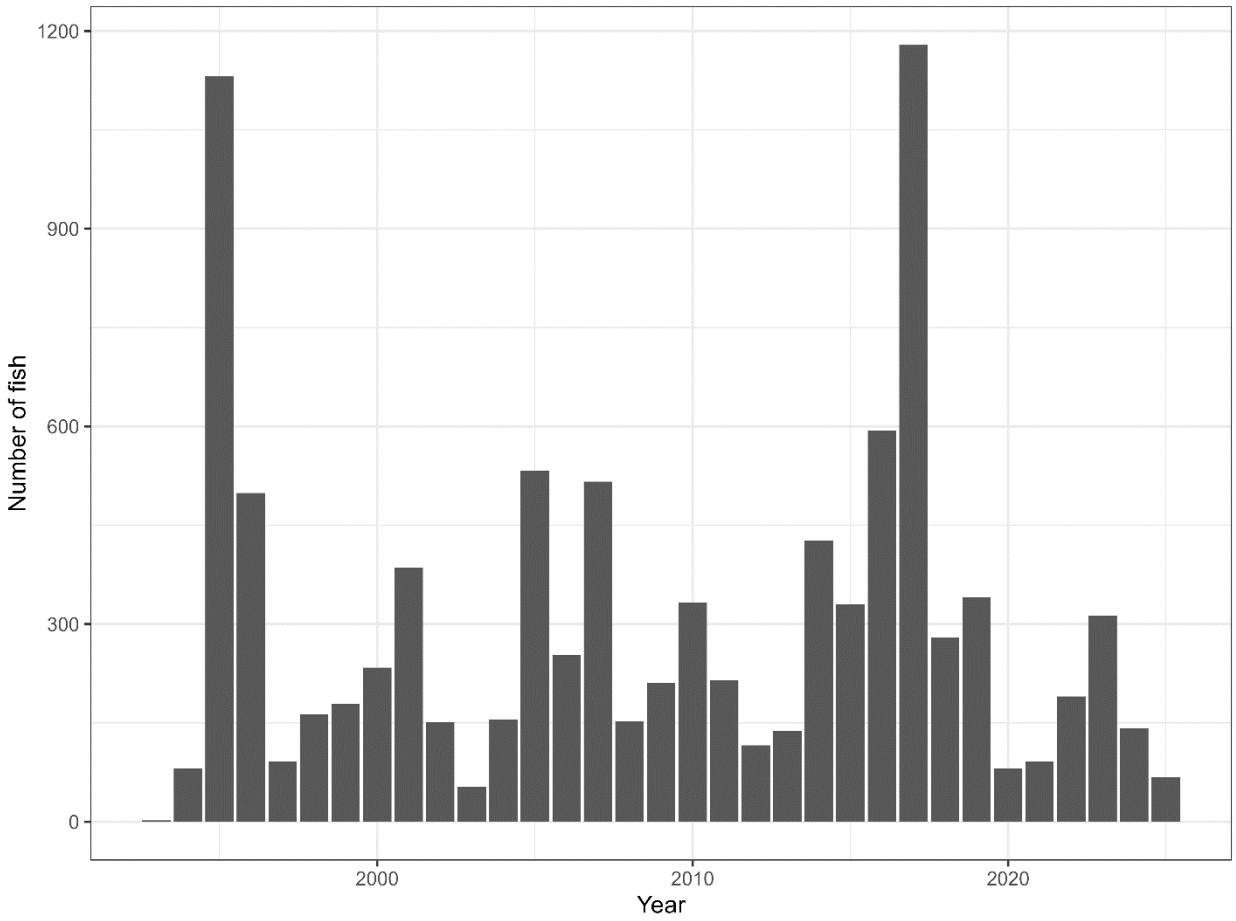


Figure 1: Histogram of catch on targeted trips (A) and positive only trips (B).



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94 Figure 2: Sandbar shark catch by year.

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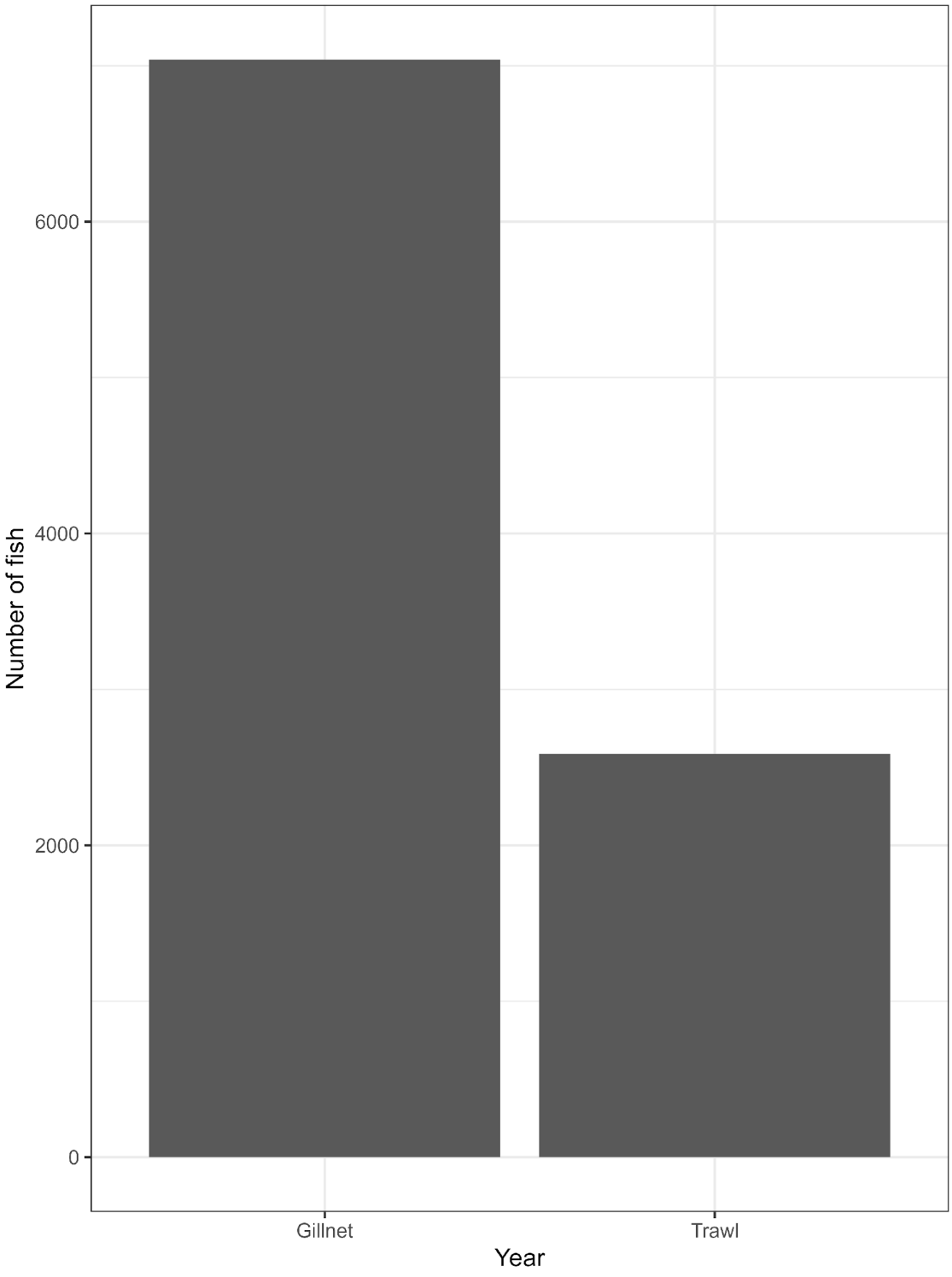


Figure 3: Sandbar shark catch by gear type.

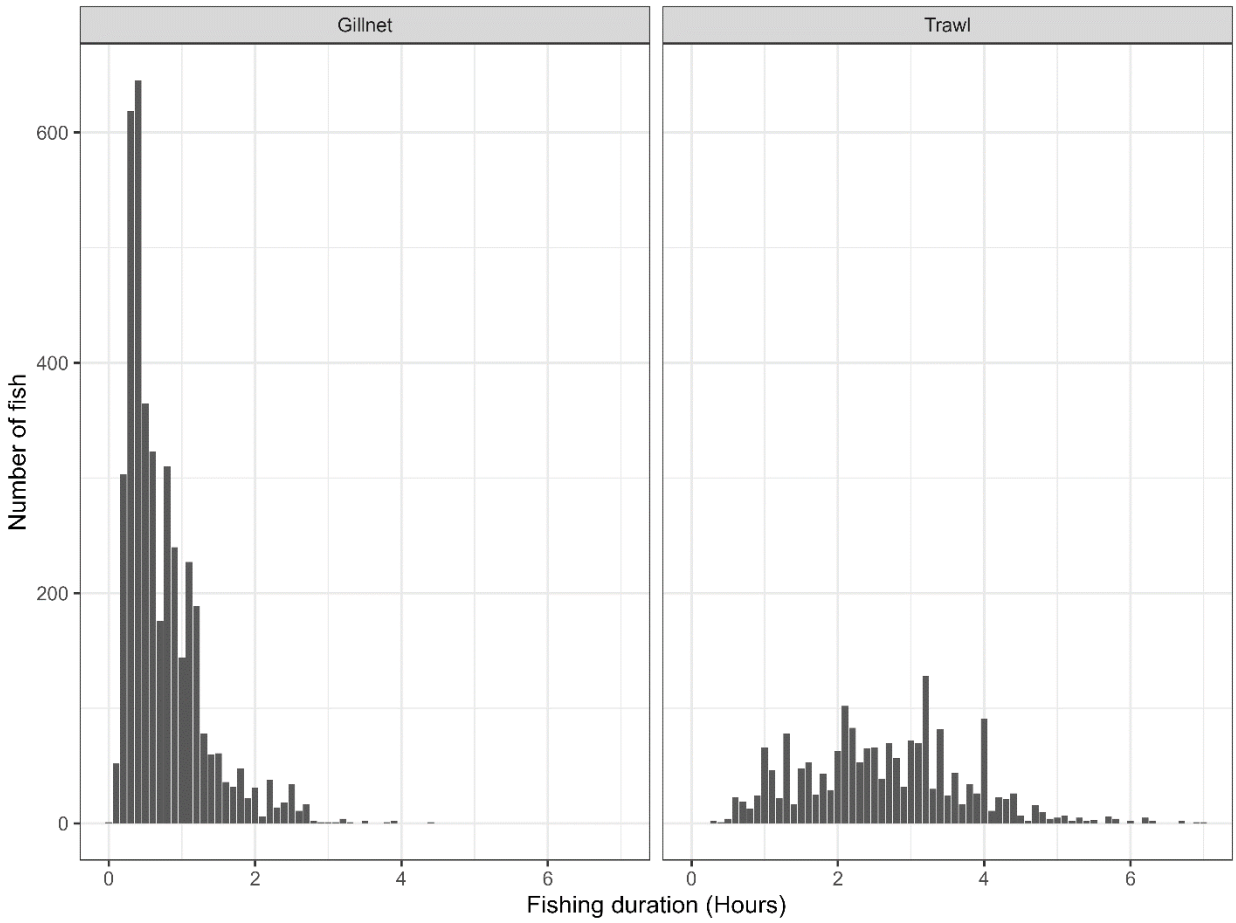
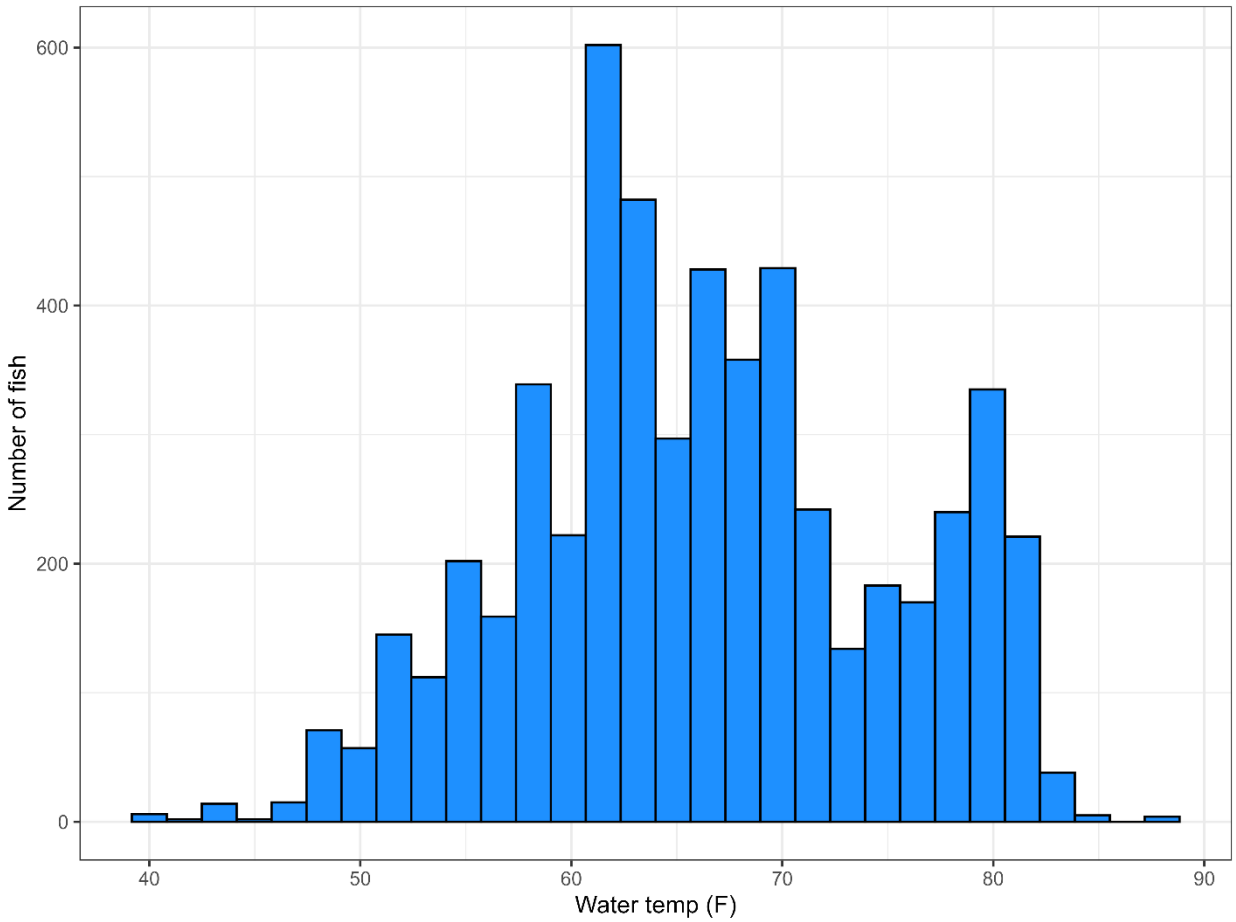


Figure 4: Fishing duration of hauls that caught sandbar sharks.



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105 Figure 5: Water temperature at fishing locations that caught sandbar sharks.

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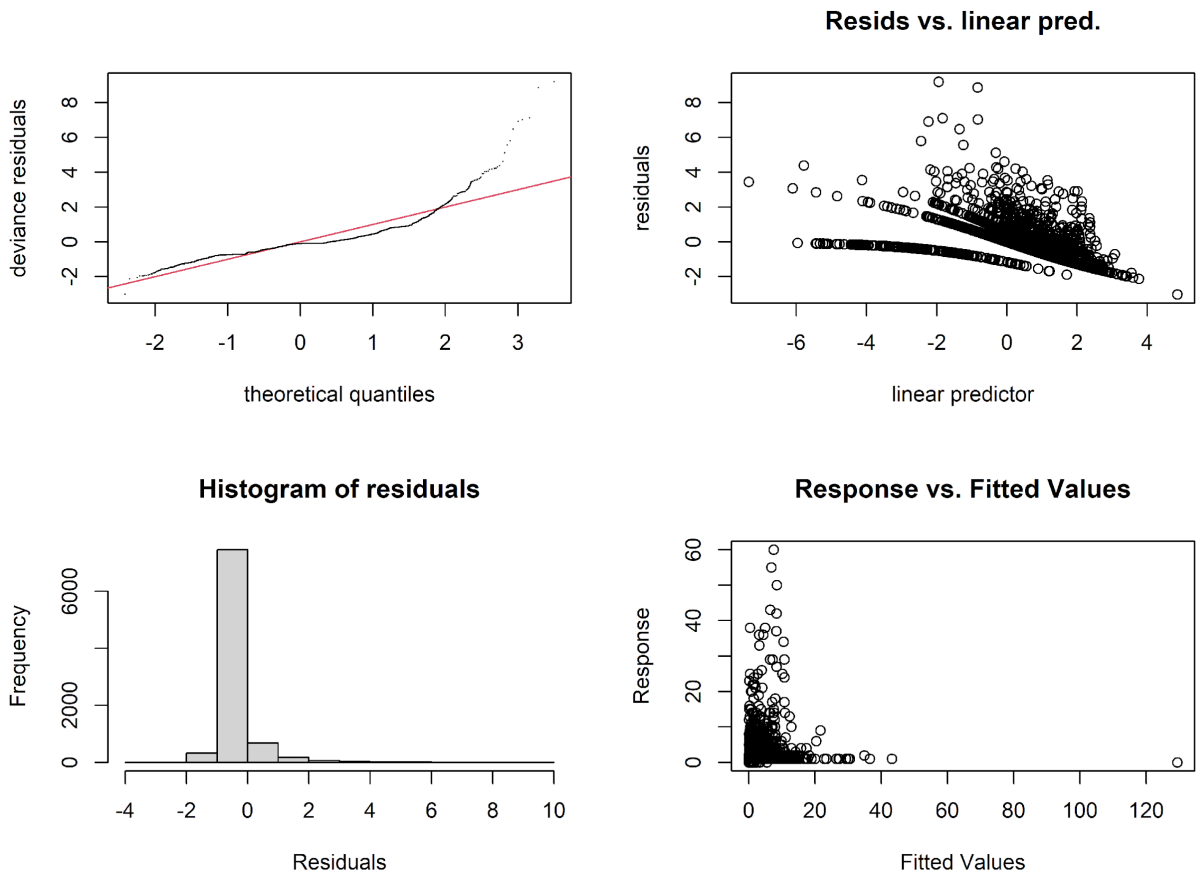

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108 Figure 6: Residual plots for optimal GAM fit to targeted trips.

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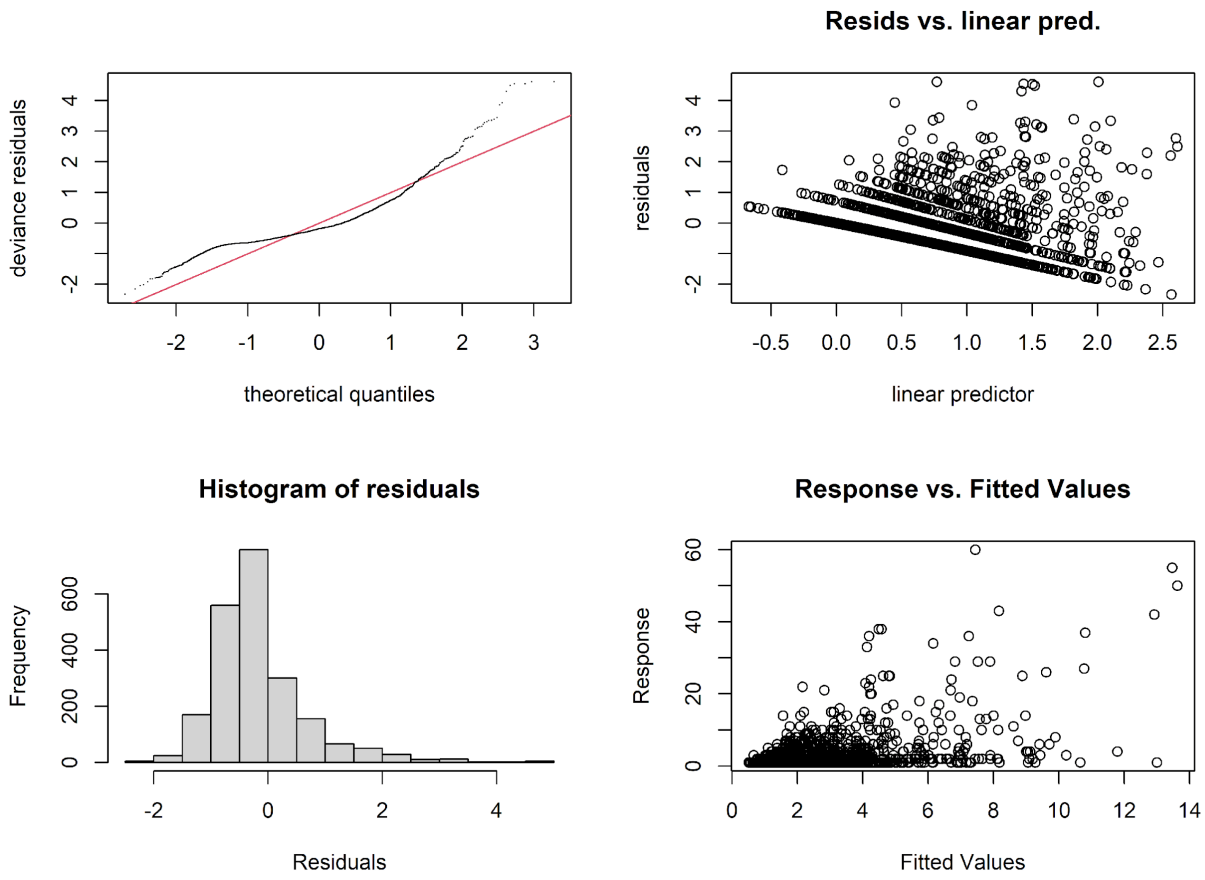

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111 Figure 7: Residual plots for optimal GAM fit to positive only trips.

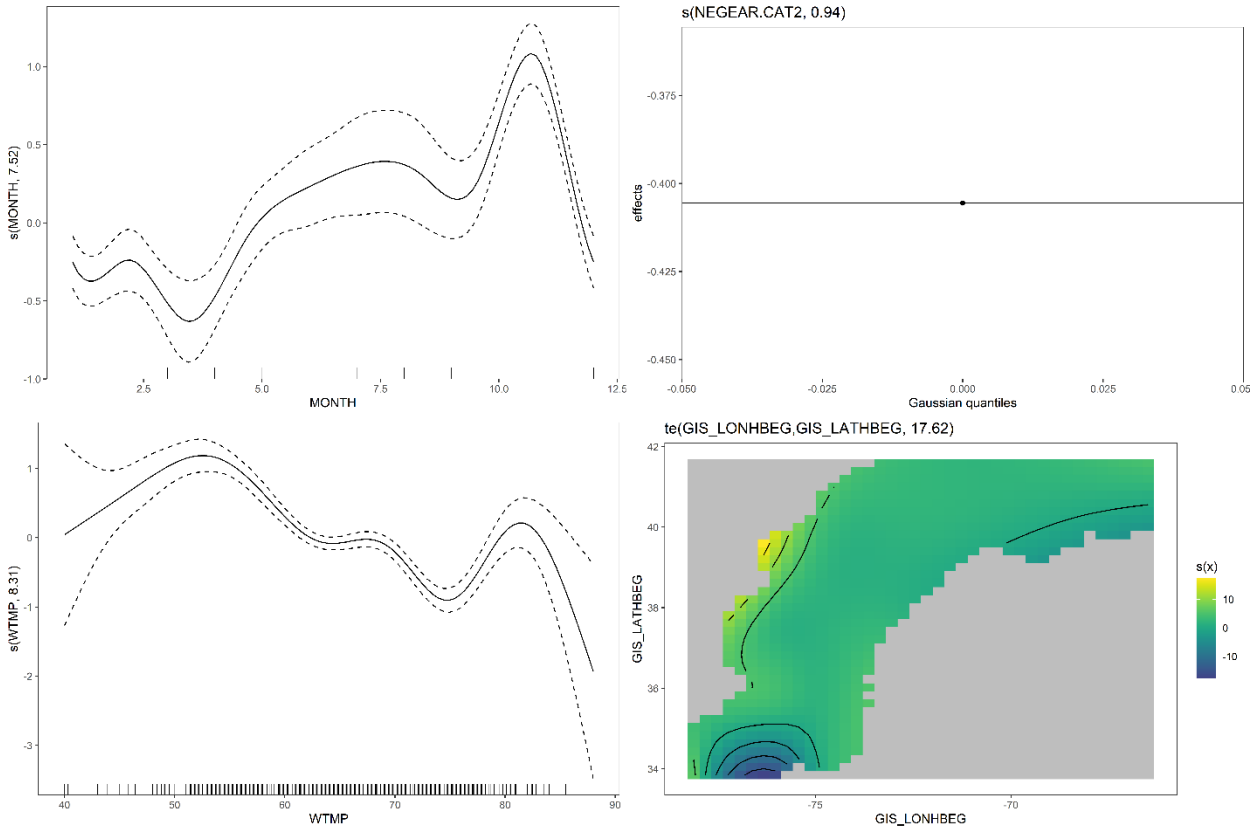
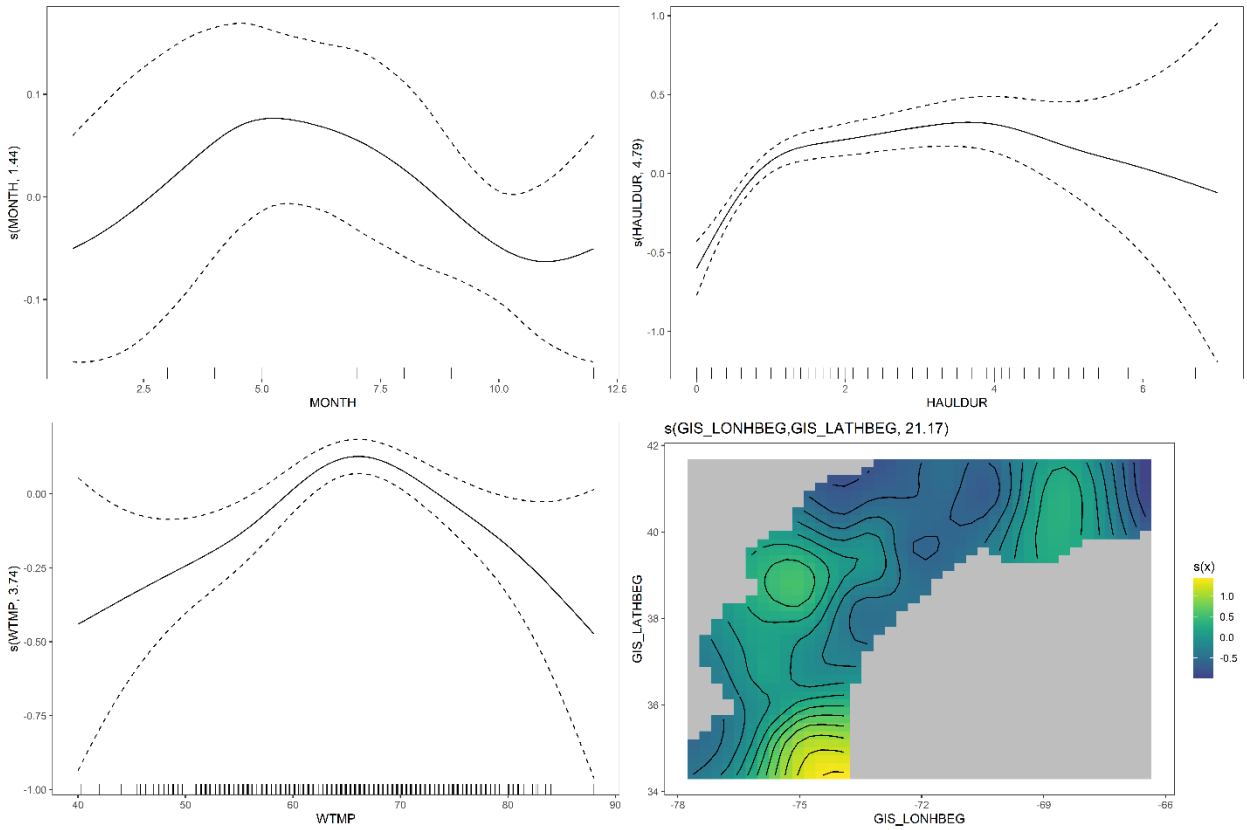


Figure 8: Influence of covariates from the targeted trip optimal GAM.



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115 Figure 9: Influence of covariates from the positive only optimal GAM.

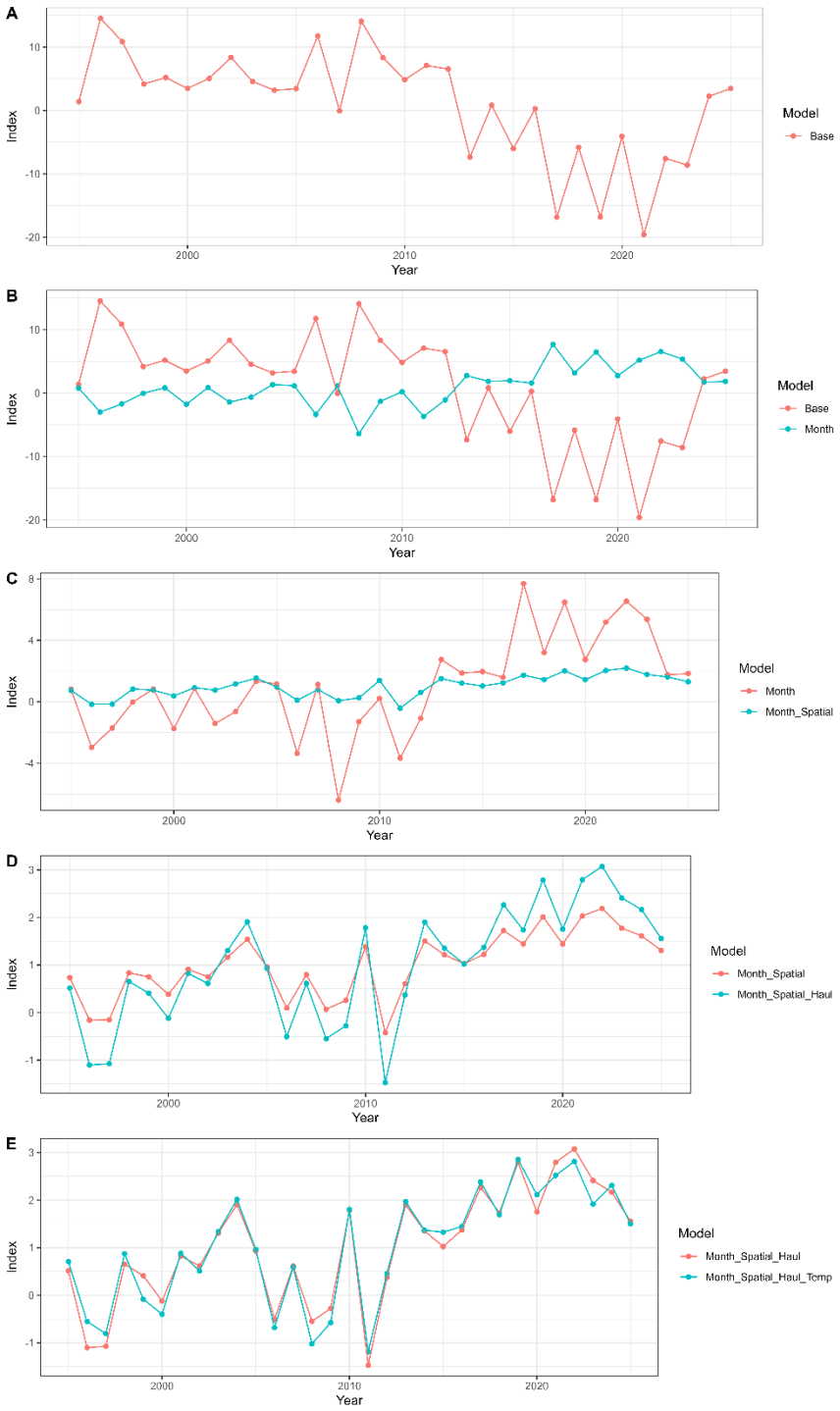
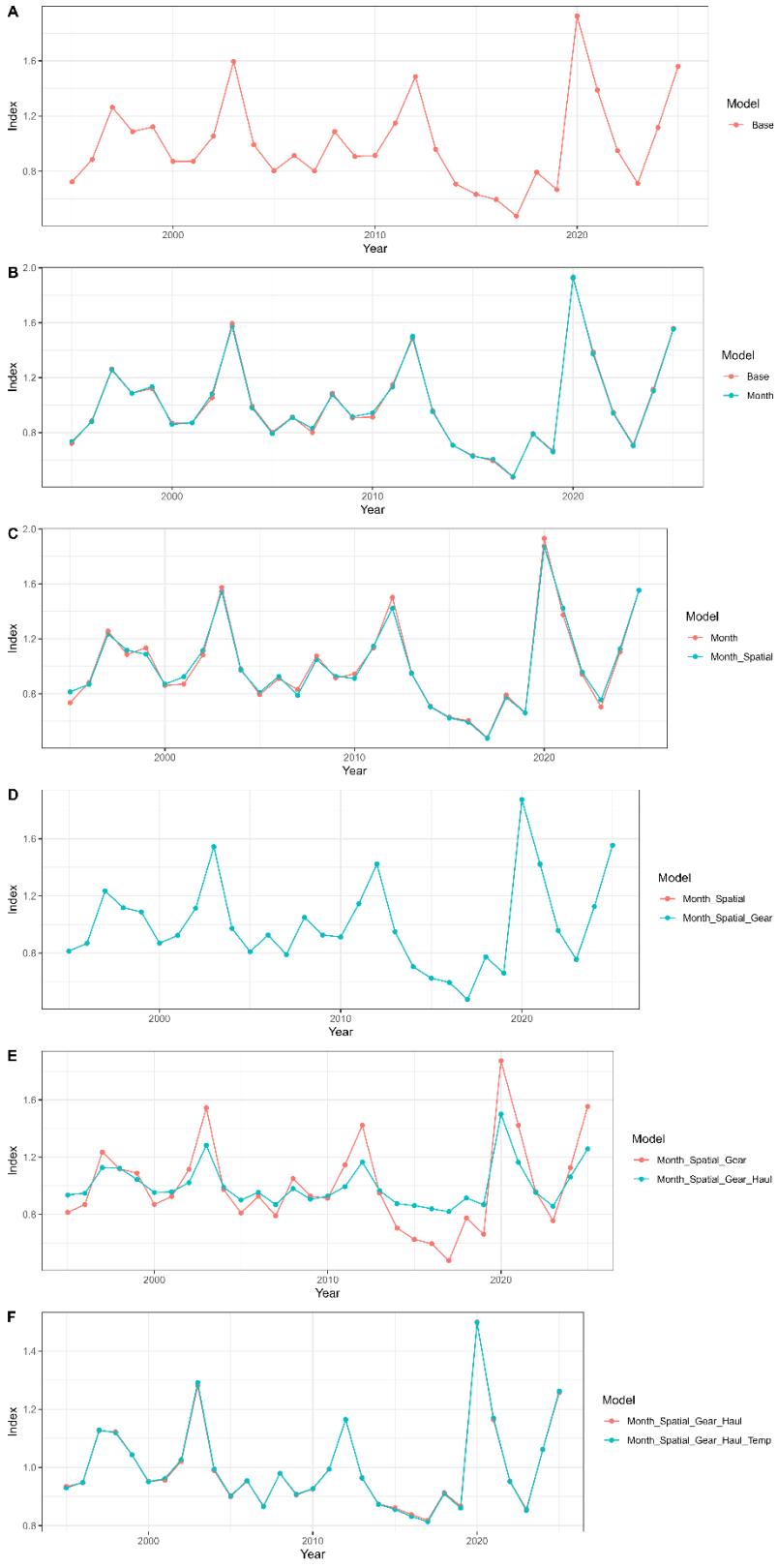


Figure 10: Influence style plots for year effect estimates from the targeted trips optimal GAM (Bentley et al. 2012).



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121 Figure 11: Influence style plots for year effect estimates from the positive only optimal GAM (Bentley et
122 al. 2012).

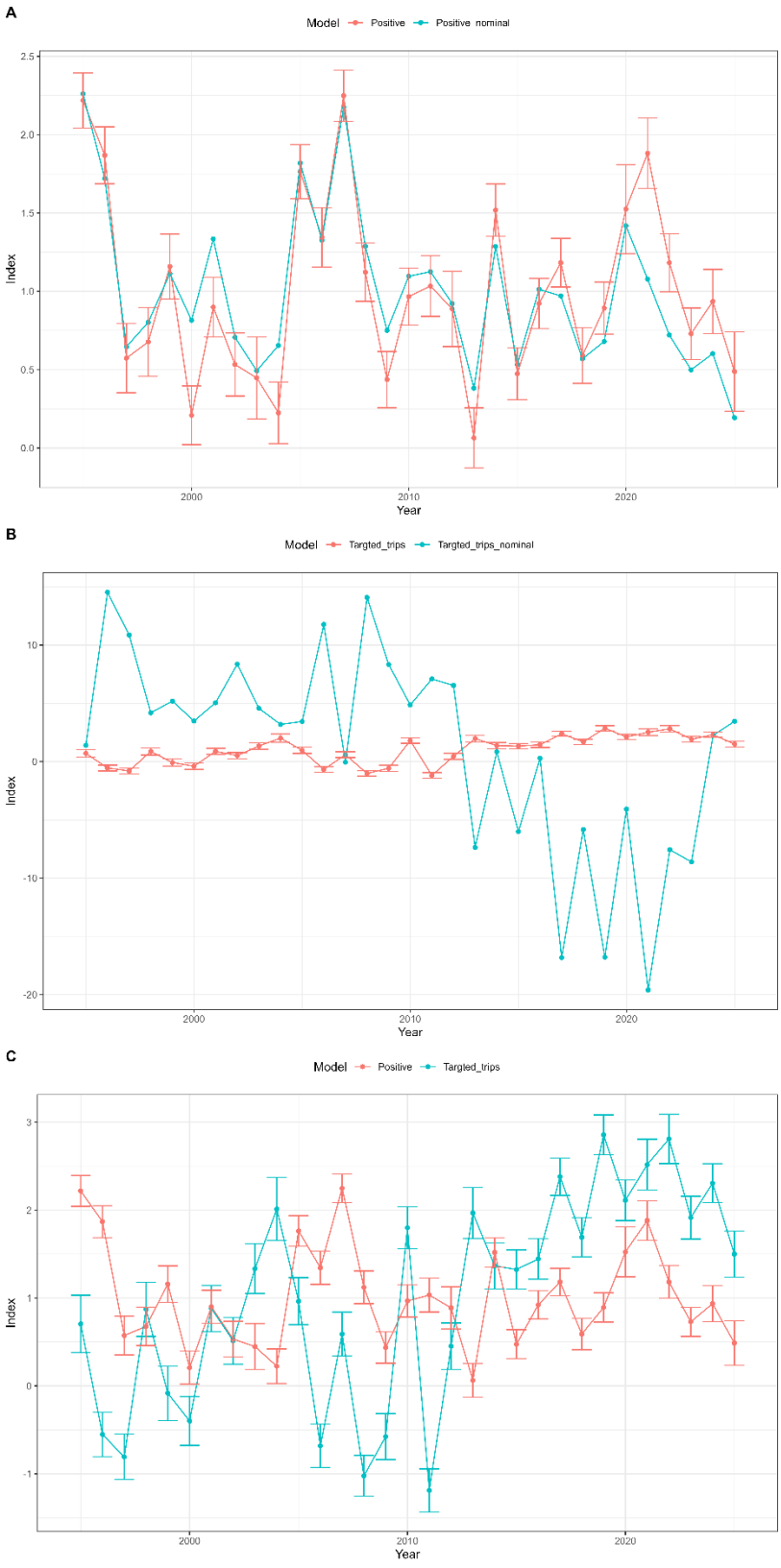
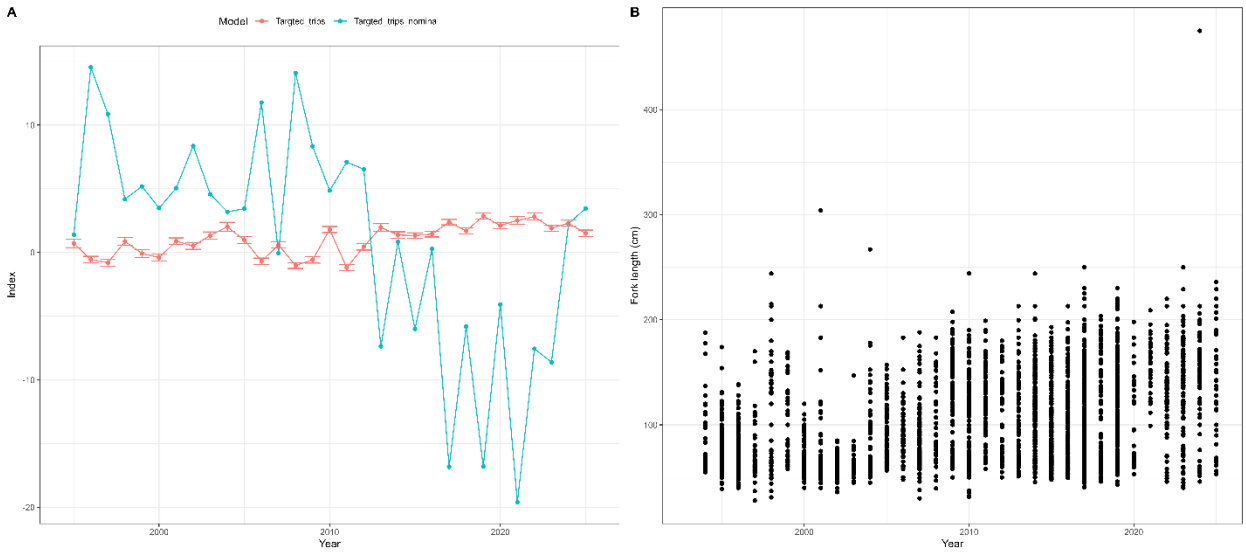


Figure 12: Comparison of optimal models.



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127 Figure 13: Nominal and optimal GAM for targeted trips with associated size composition.

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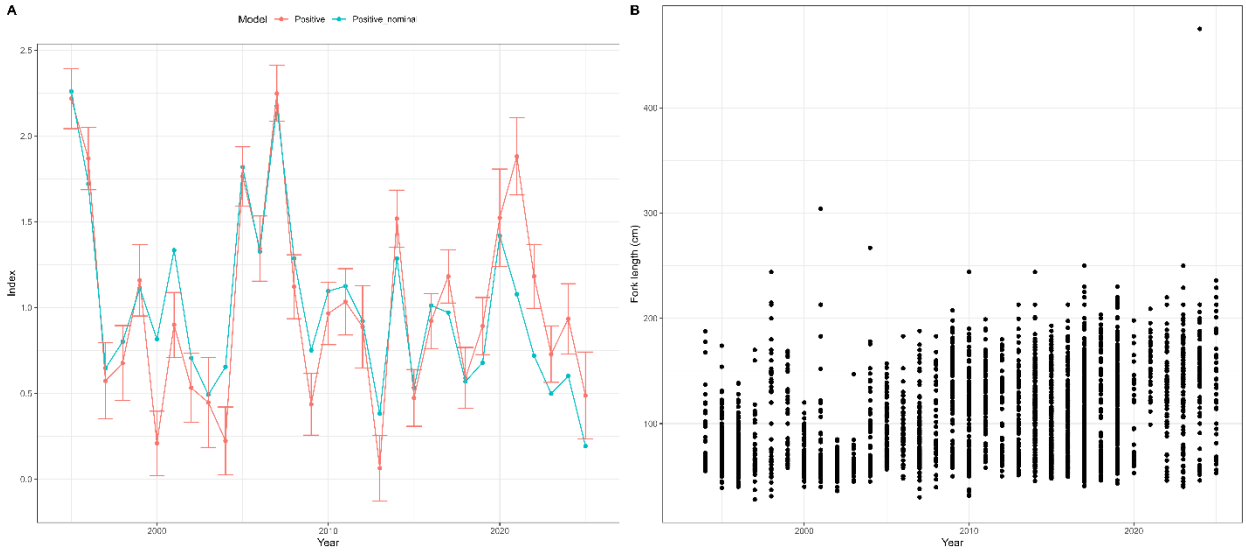

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130 Figure 14: Nominal and optimal GAM for positive only trips with associated size composition.

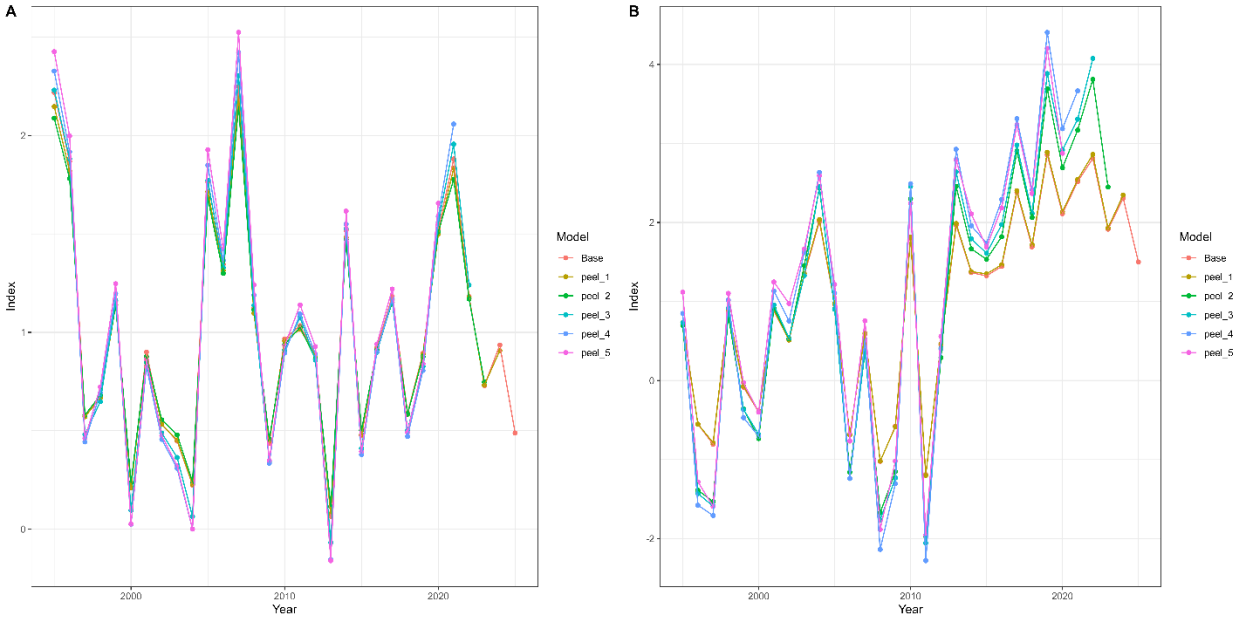

Figure5: Five-year retrospective analysis for positive only trips (A) and targeted trips (B).