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Sablefish Associations with VME Indicator Species in the NE Pacific

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Background

Sablefish (*Anaplopoma fimbria*) are the target of a long-line pot fishery in the NPFC Convention Area of the eastern North Pacific Ocean. The fishery occurs primarily at two seamounts within the NPFC CA, Cobb and Brown Bear Seamounts. In the past other seamounts have also been fished including Warwick, Eickelberg and Corn Seamounts (Figure 1).

VME indicator taxa are known to occur at all of these seamounts (see Agenda Item 7.1 - Rooper and Conrath). However, it is unknown whether there are associations of VME indicator taxa and Sablefish. Associations of VME indicator taxa with Sablefish would heighten the risk for impacts of the fishery on VME's, as it would be expected that the fishery would target areas of higher Sablefish abundance. In addition, an association between Sablefish and VME indicator taxa might indicate some dependence of Sablefish on this habitat for increased survival or growth, as has been found for some other taxa such as rockfishes (*Sebastes* spp.).

The objective of this analysis was to determine if there is a significant association between Sablefish and VME indicator taxa for the entire stock (from California to Alaska) using data collected from fisheries independent bottom trawl surveys.

Methods

Trawl Survey Data

The data used in this analysis were from bottom trawl surveys used for stock assessment in Alaska, British Columbia and along the U.S. West Coast. The bottom trawl surveys in Alaska are carried out in the summer each year in the eastern Bering Sea shelf and in alternating years in the Aleutian Islands, Gulf of Alaska and eastern Bering Sea slope. Summaries of methods and results can be found in Stauffer (2004). The years covered by the Alaska surveys were 1982-2014 an there were 3923. 12702 and 7317 individual bottom trawl hauls in the Aleutian Islands, eastern Bering Sea and Gulf of Alaska respectively. In British Columbia bottom trawl surveys are conducted in four areas (2 per year) along the BC shelf and slope (Sinclair et al. 2003). The years covered by the BC surveys were 2003-2022 and there were 6459 individual bottom trawl hauls included in the analyses. The years covered by the U.S. West Coast surveys were 1990-2021 and there were 18240 bottom trawl hauls conducted along the Washington, Oregon, and California shelf and slope during this time. In all, there were 48,641 bottom trawl survey records used in this analysis, of which 37% (17,819) captured Sablefish.

Each bottom trawl survey record contained Sablefish catch-per-unit-effort (CPUE), bottom depth, latitude and longitude of the trawl haul, as well as the CPUE of structure forming invertebrates (primarily corals and sponges). Corals and sponges were commonly identified to class or order, with some corals identified to species or family. These were summarized into eight taxonomic groups roughly corresponding to the NPFC classes of VME indicator taxa, with some additional groups as well. The four taxonomic groups identified as VME indicator taxa by the NPFC were Antipatharians (black corals), scleractinians (stony corals), Gorgonean corals (upright fan-type coral families identified by Miyamoto and Kiyota (2017), and Alcyonaceans (a group including the gorgoneans, plus some additional families of coral). Four groups that have not yet been identified as VME indicator taxa, but could potentially be added to the list are Pennatulaceans (sea whips and sea pens), Hexactinellids (glass sponges), Demosponges, Hydrocorals, and Porifera as a broader taxa (containing Demosponge, Hexactinellids and Calcareous sponges).

Since bottom trawls are known to be poor at measuring the density of structure forming invertebrates, but likely capture patterns of presence and absence very well (Rooper et al. 2016, 2018), the CPUE of these taxa were converted to presence or absence in each bottom trawl survey tow.

Data Analysis

Two similar modeling methods were used to assess the relationship between Sablefish catch and the presence or absence of structural forming invertebrates. The first method was to use a generalized additive model (GAM, Wood 2006) to assess the signficance of the relationships between the presence of VME indicator taxa and Sablefish. Sablefish are known to inhabit deeper depths (400 - 1200 m), so depth was included as a covariate. A bivariate spline was also used to model the effect of latitude and longitude across the data. Region was also included as a factor in the analysis. This variable was included to account not only for regional differences in sablefish catch, but also to account for regional differences in the gear types used on trawl surveys. In general, the gear types are similar among the different trawl surveys, but there are some differences in footrope contact, distance fished and monitoring. In addition, not all the surveys fish to the same depth (e.g. the Aleutian Islands survey only fishes to a maximum depth of 500 m). Five levels of region were used to account for the different trawl surveys; Aleutian Islands, Gulf of Alaska, eastern Bering Sea, British Columbia, Canada, and west coast of USA.

Finally, categorical variables representing the presence or absence of VME indicator taxa. In the first GAM the four identified VME indicator taxa from NPFC were considered; Alcyonaceans, Gorgoneans, Antipatharians and Scleractinians. It should be noted that the families included as Gorgoneans are a subset of the Alcyonacean taxa, thus is was not appropriate to include both variables in the same model. Separate models were run, one including only Alcyonaceans and one including only Gorgoneans. The model including the larger group (Alcyonaceans) explained more variability than the model including the Gorgoneans, so the Gorgonean-only model was not included. The CPUE data were log-transformed and $\frac{1}{2}$ of the minimum positive CPUE added to the CPUE to account for zero catches. The final equation for the GAM was:

$$CPUE = s(Depth) + s(Longitude, Latitude) + Region + Alcyonacean + Antipatherian + Scleractinian + \epsilon$$

In the second GAM more specific taxa were used to examine the effect of VME indicator taxa on CPUE of Sablefish. Here Antipatharians, Gorgoneans, Scleractinians, Pennatulaceans, Hexactinellids, Demosponges and Hydrocorals were used, so that

$$CPUE = s(Depth) + s(Longitude, Latitude) + Region + Antipatherian + Gorgonean + Scleractinian + \\ Pennatulacean + Hexactinellid + Demosponge + Hydrocoral + \epsilon$$

For each GAM backwards stepwise elimination of non-significant variables (judged by the approximate p-values <0.5 and no further reduction in OBRE score with their removal) were eliminated until only significant variables remained in the model.

Based on the results of the GAM modeling, the significant variables were included as covariates in a spatially explicit model using the sdmTMB package (Anderson et al. 2022). The sdmTMB package fits spatial models using generalized linear mixed effects models, where spatial effects can be specified as Gaussian Markov random fields and fixed effects can be included as covariates. The model is fit in template model builder (TMB) using the R-INLA package. The random (spatial) effects are fit on a spatial mesh object (Figure 2) that uses a minimum cutoff distance (in this case 10 km) to cluster the observations in space. In addition to the random spatial effects, this model contained significant variables from the best-fitting GAM above. The sdmTMB model was fit using a tweedie error distribution.

Results

The best-fitting GAM with the NPFC VME indicator taxa explained about 60% of the variability in Sablefish CPUE (Table 1). However, none of the VME indicator taxa effects were significant in the analysis. Depth and the bivariate term (longitude and latitude) explained the most variability, with region as the final significant variable (Figure 3). Sablefish CPUE was highest at depths between 500 and 1100 m and significantly lower in British Columbia than in other regions, however, this may be interpreted as an effect of gear or survey area coverage rather than as an abundance effect.

The best-fitting GAM using the more specific taxonomic categories (Antipatharians, Gorgoneans, Scleractinians, Pennatulaceans, Hexactinellids, Demosponges and Hydrocorals) resulted in a similar result for the depth and spatial terms (Table 2). The model explained ~60% of the variability in the data again, but with marginal improvement in the GCV score. The improvement was the result of a number of significant invertebrate factors included in the model. For this model, the presence of hexactinellid and demosponges were associated with a decrease in Sablefish CPUE. The presence of Scleractinians was also associated with a decrease in CPUE of Sablefish. However, Pennatulaceans had a significant and positive impact on the presence of Sablefish in trawl survey data (Figure 4).

The model using sdmTMB showed reasonable performance in explaining patterns of Sablefish CPUE. The residuals were mostly normal indicatign the Tweedie distribution was a good fit to the data (Figure 5). The spatial patterns in residuals showed no apparent trends over space (Figure 6). The model captured the effect of depth well, in that it showed the peak Sablefish catch at depths of about 500 - 1100 m (Figure 7). Finally, the spatial model showed the same patterns in terms of the effects of invertebrate presence on Sablefish CPUE (Figure 8). In this case again, only the effect of Pennatulaceans was positive and the magnitude of the effect was small. However, the effect was distinguishable from zero, as opposed to the effects of the other invertebrate species, where the 95% confidence intervals on the parameter estimates included zero (Figure 8).

Conclusions

The data from trawl surveys on the west coast of North America throughout the Sablefish range indicate that none of the VME indicator species have a significant impact on Sablefish CPUE. Scleractinian (stony coral) presence was associated with a decrease in abundance of Sablefish.

The data showed that sea whips and sea pens (pennatulaceans) were the only structure forming taxa that had a positive effect on Sablefish catch. This likely reflects the preference for soft substrates for both the fish and the invertebrate, rather than a particular dependence of sablefish on sea whips. In part this conclusion is based on the evidence from a number of previous studies that show Sablefish occur across a wide variety of benthic habitat types including both hard and soft substrates (e.g. Krieger et al., Stein et al. 1992, Yoklavich et al. 2000)

Regardless of the mechanism of the association between Sablefish and Pennatulaceans, it might be expected that areas with Pennatulaceans would be fished to larger extent than areas without Pennatulaceans due to the potential for higher catch rates of Sablefish in these substrates.

References

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Tables

Table 1. Results of GAM predicting the CPUE of Sablefish in bottom trawl survey data using NPFC VME indicator taxa (Antipatharians, Scleractinians, and Alcyonaceans.

Term	df/edf	F	p-value
Region	4	328.42	<0.0001
Depth	8.779	1673.357	<0.0001
(Longitude,Latitude)	28.6	254.804	<0.0001
residual	48502.621		
GCV	3.3642		
Deviance explained	57.5%		

Table 2. Results of GAM predicting the CPUE of Sablefish in bottom trawl survey data using structure forming invertebrates (Antipatharians, Scleractinians, Gorgoneans, Pennatulaceans, Hydrocorals, Hexactinellid sponges and Demosponges). Only Pennatulaceans, Demosponges, Hexactinellids and Scleractinians were included in the best-fitting model.

Term	df/edf	F	p-value
Hexact	1	3.13	0.07703
Demo	1	15.15	1e-04
Whip	1	55.64	<0.0001
Stony	1	2.74	0.09777
Region	4	333.4	<0.0001
Depth	8.787	1622.614	<0.0001
(Longitude,Latitude)	28.604	251.116	<0.0001
residual	48498.609		
GCV	3.3595		
Deviance explained	57.6%		

Figures

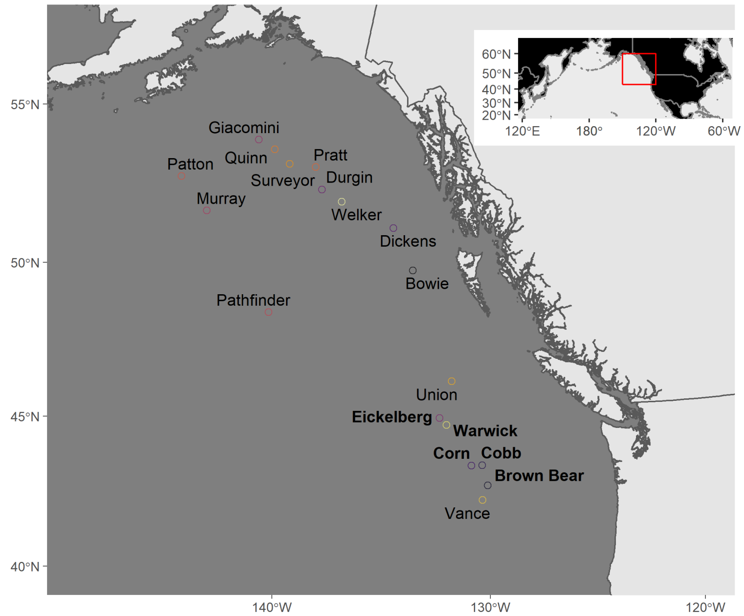


Figure 1: Eastern North Pacific Ocean showing named seamounts where Sablefish have been captured in commercial fishing activity. Bold names indicate those seamounts that are currently fished by the Canadian fleet

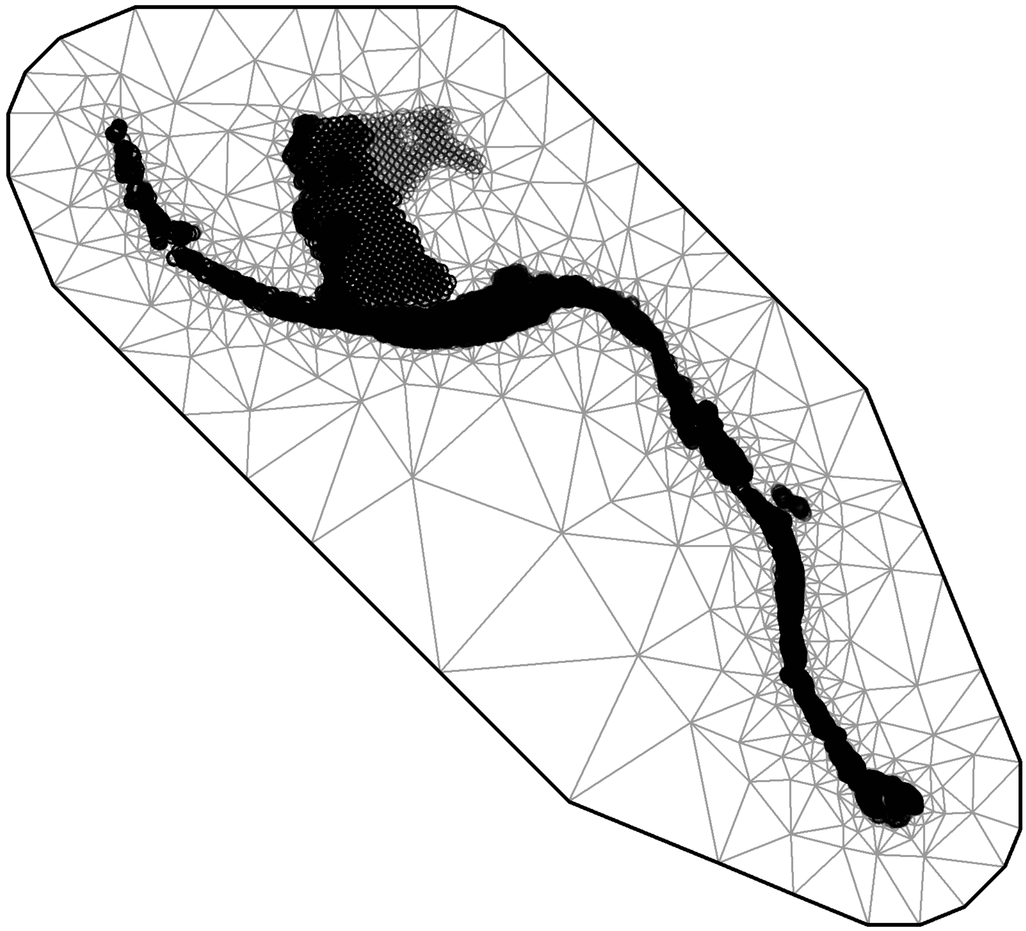


Figure 2: Spatial mesh used in sdmTMB modeling.

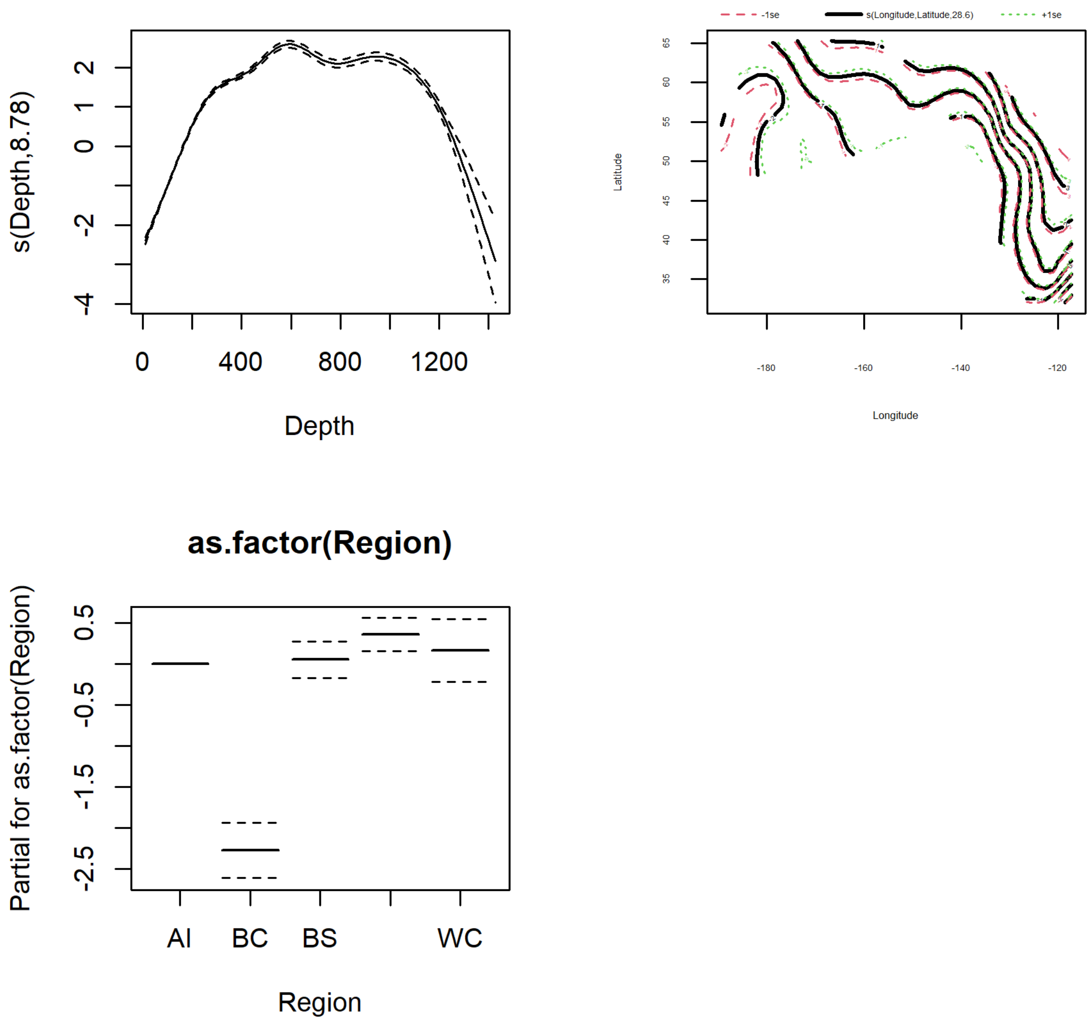


Figure 3: Significant effects in generalized additive model predicting Sablefish CPUE with NPFC VME indicator taxa (Antipatharians, Scleractinians and Alcyonaceans). All VME indicator taxa were not included in the best-fitting model.

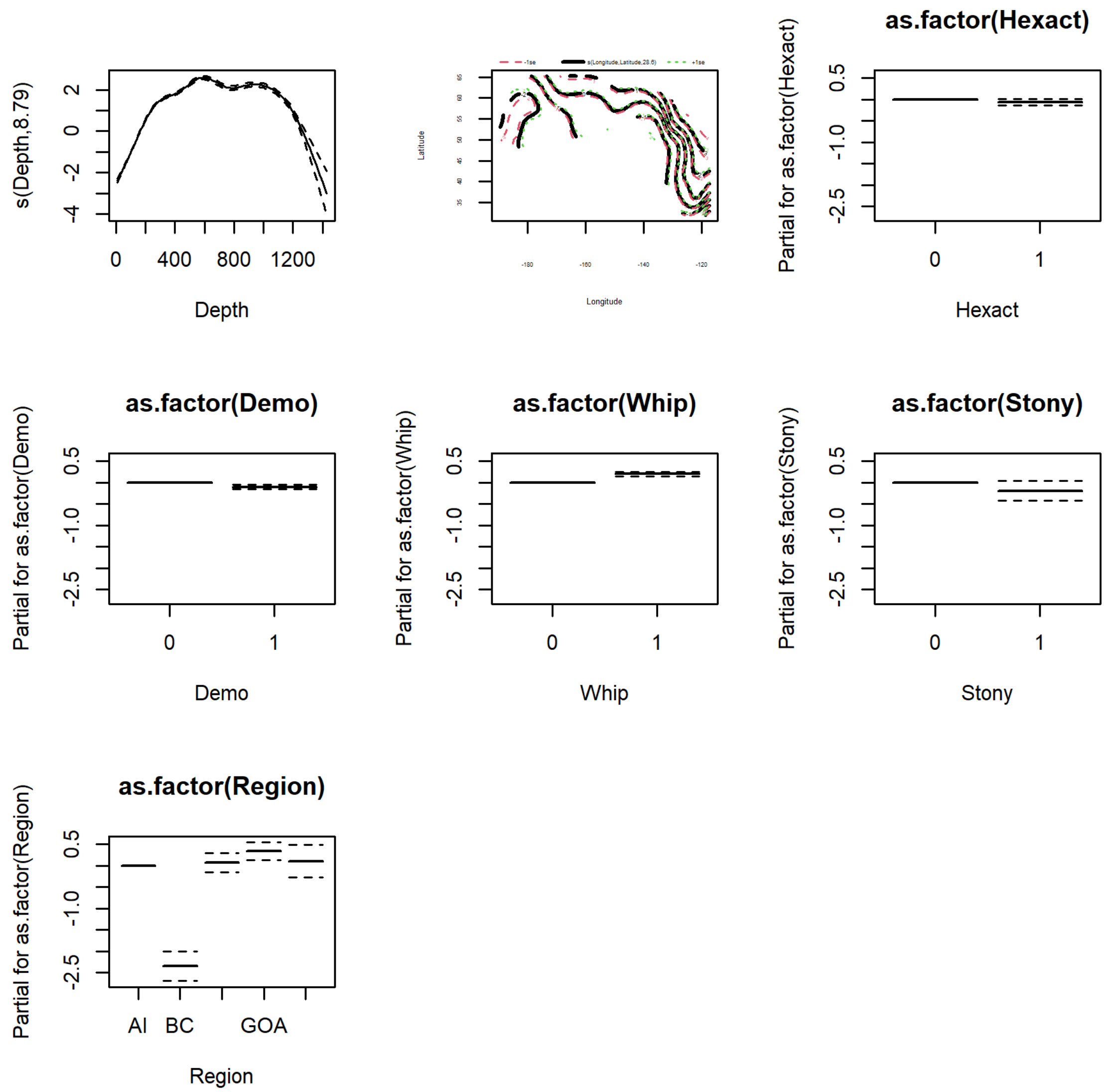


Figure 4: Significant effects in generalized additive model predicting Sablefish CPUE with structure forming invertebrates (Antipatharians, Scleractinians, Gorgoneans, Pennatulaceans, Hydrocorals, Hexactinellid sponges and Demosponges). Only Pennatulaceans, Demosponges, Hexactinellids and Scleractinians were included in the best-fitting model.

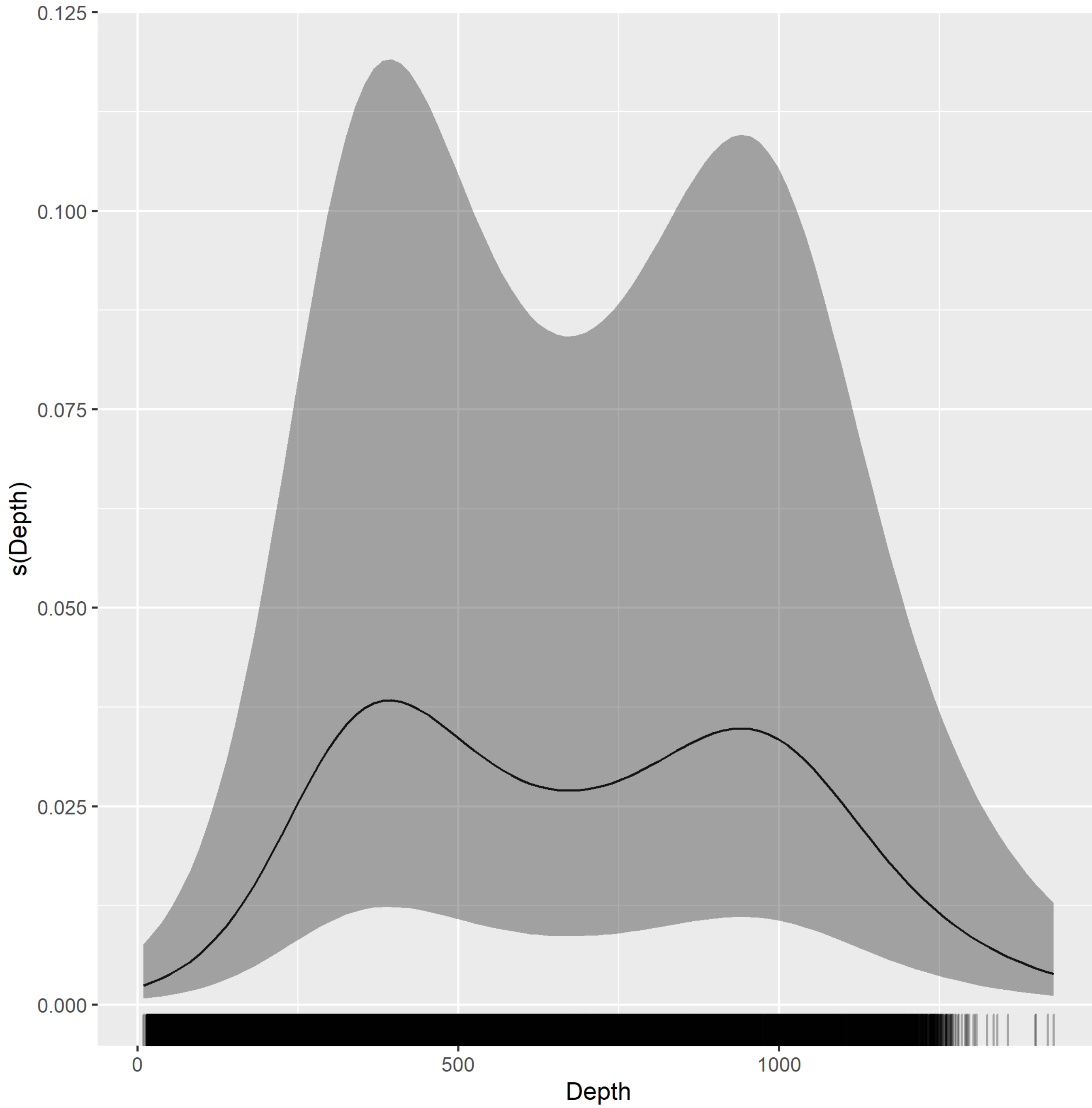


Figure 5: Partial effect of depth on CPUE in the sdmTMB model of Sablefish distribution.

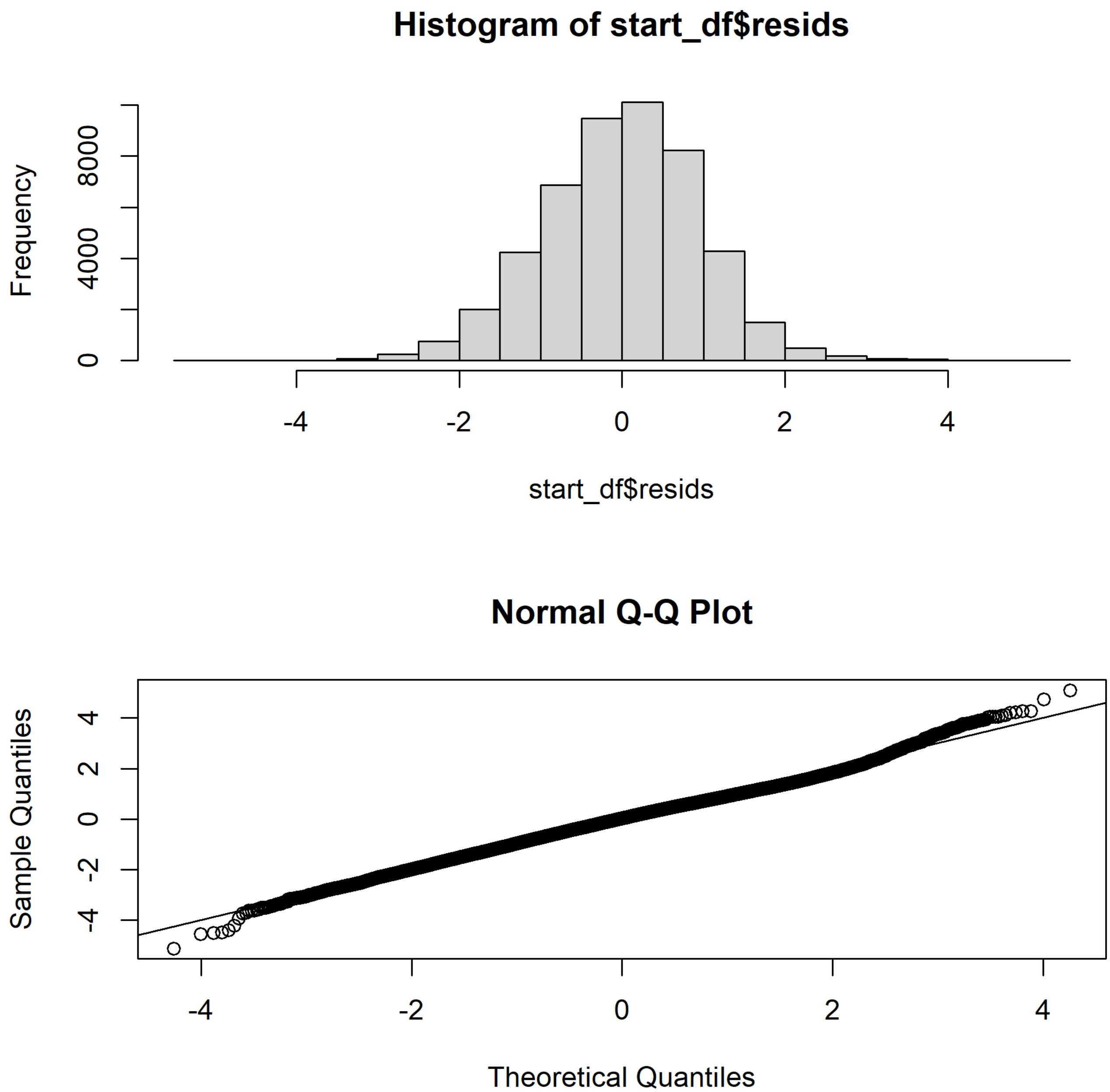


Figure 6: Histogram and qqnorm plot of sdmTMB residuals from model of Sablefish CPUE

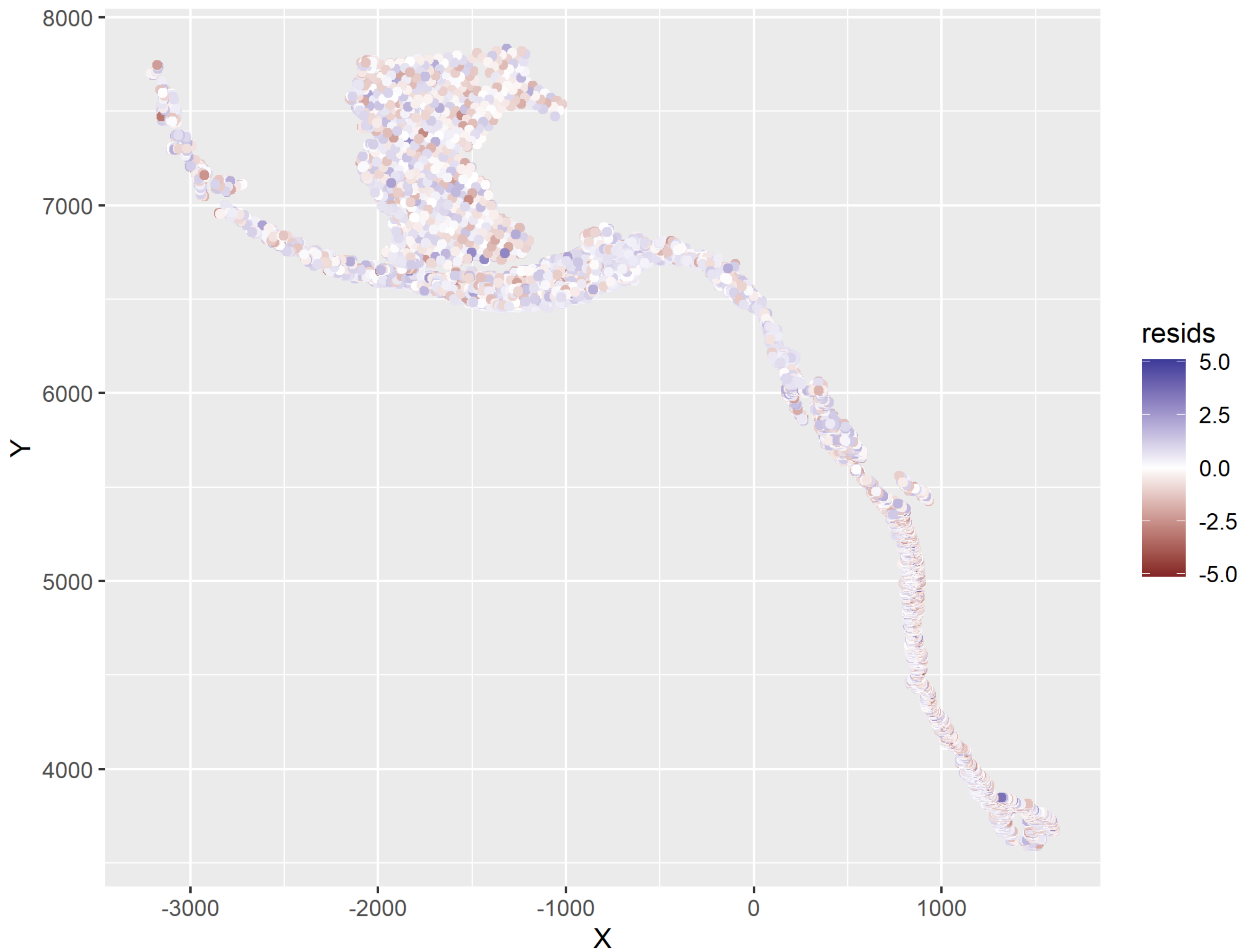
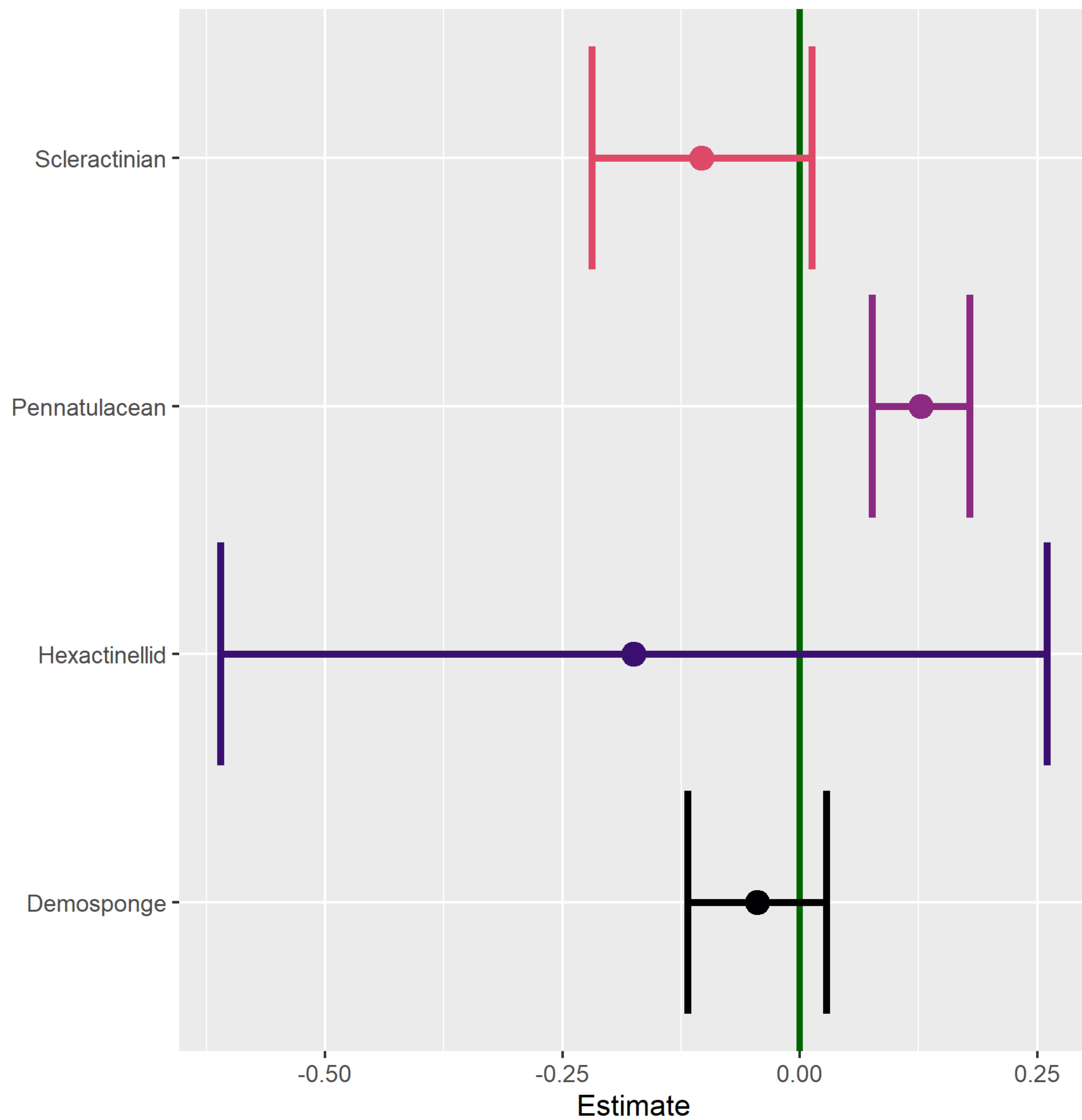


Figure 7: Map of sdmTMB residuals from model of Sablefish CPUE through its domain.



\begin{figure}[H]
\caption{Parameter estimates and 95% confidence intervals for parameter estimates from sdmTMB model predicting the CPUE of Sablefish using structure forming invertebrates.} \end{figure}