Explorations of habitat associations of yellowedge grouper and golden tilefish

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Abstract

Yellowedge grouper (YEG) and golden tilefish (GT) are relatively sedentary, long-lived and occupy burrows, pits, and trenches in discrete habitats along a narrow fringe of the continental shelf break in the Gulf of Mexico. Both species are targets of fisheries with relatively consistent landings of approximately 400 and 180 mt, respectively, with little trend in CPUE since inception of the fishery in the late 1970s. Particularly with uninformative CPUE and constant landings, assessment models have little ability to differentiate between two competing hypotheses: that near constant landings are a result of sustainable harvest of a large or productive population or a product of unsustainable depletion of a declining population for which CPUE and landings have been hyperstable. This is problematic for sedentary, low productivity species for which serial depletion could lead to stable CPUE and landings, while overall biomass and reproductive potential declines. Bayesian priors for key assessment model quantities can often assist in distinguishing between competing hypotheses. We examine the potential to use environmental data on temperature and sediments, scientific survey data, and burrow estimates derived from early 1980's-vintage submersible video surveys to 1) estimate the potential area of habitat to provide a means of weighting CPUE indices; 2) obtain probability maps of occurrence of YEG and GT based on temperature, depth, sediment type, and other environmental factors; and 3) explore the potential to develop Bayesian prior distributions for virgin recruitment as input to SS3 modeling. Each of these three products may be of utility to the current SEDAR 22 stock assessment for these species.

Introduction

Yellowedge grouper *Epinephelus flavolimbatus* and golden tilefish *Lopholatilus* c*hamaeleonticeps* are deep-dwelling benthic-associated fishes that are targeted by substantial fisheries in the Gulf of Mexico. Both species appear to have fairly specific associations with certain habitat types. For instance, in NMFS bottom longline surveys, tilefish occur from about 120 to at least 360 m (Fig. 1) and yellowedge grouper inhabit depths from about 60 to 310 m (Fig. 2). NMFS BLL data suggest that temperature preferences for these species seems to be fairly well constrained as well. Tilefish occur from about 9 to 18 °C (Fig. 3) (see also Calay and Cook, 20XX), and yellowedge occur from about 10 to 22 °C (Fig. 4). Because both species excavate burrows, sediment characteristics are potentially important as well. Anecdotal evidence indicates that golden tilefish prefer a firm mud habitat. Yellowedge grouper also excavate burrows, but appear to have less specificity for mud habitat. These life history observations may make it possible to construct maps of the potential spatial extent of these species in the northern Gulf of Mexico based on independent observations of bathymetry, seafloor sediments, and bottom temperatures.

Furthermore, tilefish and, to a lesser extent, yellowedge grouper leave tell-tale signs of their presence in the form of burrows. Submersible dives have provided in situ video footage of the seafloor in tilefish and yellowedge grouper habitat (Fig. 5). This footage can be used to estimate the density of burrows and number of fish per burrow. From there, estimates of initial or virgin biomass may be constructed by multiplying the number of fish in a given habitat by the total area of that habitat. These estimates provide information to bound virgin recruitment (R_0)- an important parameter in the proposed stock assessment model (Stock Synthesis 3, Methot 19__).

This estimate is important because the level of virgin recruitment scales the entire population level and thus determines what fraction of the population landings represent. Given an estimate of virgin recruitment, the level of natural mortality, and a stable age distribution it is possible to derive the virgin stock numbers. Conversely, given a virgin stock number, it is possible to derive a virgin recruitment number.

In this paper we explore the relationship of yellowedge grouper and tilefish with temperatures, depth, and sediment type to obtain three products of utility to the stock assessment.

1) Maps the occurrence of YEG and GT from NMFS bottom longline surveys, in relation to various sediment types.
2) Estimates of the maximum habitat area based upon depth of occurrence by NMFS statistical area for use in weighting CPUE data.
3) Prior distribution on virgin recruitment based upon a probability map of occurrence, density of burrow and percent burrow occupancy for input to SS3

Data sources

Biological/fishery: Fisheries-related data (catch rate per unit effort, depth, temperature, location of catch, etc.) was derived from a variety of survey data included the NMFS bottom longline (BLL) survey

(Henwood et al), Galveston reef fish observer program longline and handline trips from the NMFS reef fishery observer program observer trips, and SEAMAP surveys. SEAMAP trawl surveys were excluded from the analyses because of their tendency to only capture juvenile fish in shallower water s than where adult fish are captured. To create a combined dataset we merged the NMFS bottom longline data, and the reef fish observer data over all years under the assumption that the habitat has not changed over the time period of the surveys. Data from historical longline surveys is also available but positional information was not obtained in time to enter the data for this meeting. Observed sets and sets with YEG and GT are plotted in Figure 1 and plots of the CPUE against temperature and salinity are shown in Figures 2 and 3.

Depth: Bathymetric data were obtained from the National Geophysical Data Center (http://www.ngdc.noaa.gov/). These data were interpolated onto a regular grid to produce a bathymetric map of the Gulf of Mexico.

Temperature: Gridded temperature data, representing seasonal climatology, are available from the World Ocean Atlas (http://www.nodc.noaa.gov/OC5/WOA05/pr_woa05.htmlTemperature). These data were interpolated onto the local bathymetric map. To determine the maximum potential depth for tilefish or yellowedge habitat, we examined the fisheries survey data to find the minimum preferred temperature and then calculated the depth of the appropriate wintertime isotherm along the shelf break of the northern Gulf of Mexico.

Sediments: Over 400,000 observations of sea floor sediment characteristics, collected from a variety of sources in the global dbSEABED project (http://csdms.colorado.edu/wiki/DBSEABED, Jenkins 2010), exist for the northern GoM (Fig. 4). Plots of these observations for sand, mud, gravel and rock are shown in figures 5-8). Thirteen different measured and derived quantitative sediment characteristics were included in the database and considered in this analysis: %Gravel, %Sand, %Mud, %Clay, Grainsze, Sorting, Carbonate, OrgCarbn, lShearStr, Porosity, PWaveVel, Roughness, lCritShStrs. Descriptions of these variables can be found in Jenkins (2010). Qualitative sediment variables also were included but were not used in this analysis at the current time but might be useful in later iterations.

Sediment data was assigned to the combined survey data observations by finding the closest sediment record for each variable and assigning it the starting location of the longline or handline set. This necessarily creates some error in the assignation of a sediment characteristic to the sample but a simple approach that avoided having to average or interpolate adjacent samples. After merging with the sediment data and removing observations without a latitude, longitude or depth, 2,831 observations remained from an original total of 10,407. It is likely that with some extensive attention to the missing depths, locations or sediment data could be filled.

Video survey data: Video survey data will be analyzed but these results have not been included in this document yet.

Analytical methods

Habitat area based upon min/max depth by stat area: To obtain the total potential habitat area we calculated the area between an assumed minimum and maximum depth of observation for both species by NMFS statistical area. The statistical areas were extended east, west or south to encompass the appropriate depths adjacent to the statistical areas based upon consultation with port agents and fishermen (Figure 9). We can clearly define the minimum depths for both species as the depths shallower which they are not found in any survey or observed fishing set. The maximum depths limits of YEG are likely to be well determined because the NMFS bottom longline samples the entire depth distribution over which this species appears to occur and over which it is fished (Figure 10). The maximum depths may be harder to define for golden tile as the survey does not cover the deeper extent of the distribution. As a first cut for this paper, we define the minimum and maximum depths for YEG to be 300-1200 feet (50-200 fa) and for golden tile 600-1500 feet (100-250 fa) based approximately upon the observed depths from the observer data and the NFMS bottom longline (Figures 10,11). Likely we will want to modify these depths according to informed opinion and perhaps bottom temperatures as examined below.

To obtain the habitat area a polygon corresponding to the min and max depths was overlaid on the NMFS statistical areas and the area within the polygon calculated (Figure 12). To convert locations to a set of common X and Y locations in kilometers both the polygons and stat areas were converted into Universal Transverse Mercator (UTM) coordinates using zone 16. Calculations were performed in R. These gave habitat distributions shown in figures 13 and 14 where the maximum potential habitat is a rather narrow fringe of the continental shelf.

Habitat area based upon minimum bottom temperatures: It had been documented that the minimum temperature threshold for golden tilefish is 9^{o}C and this might represent a lower limit. Winter time average temperatures at depth obtained from interpolated observations. Plots of temperature at depth indicate a clear deepening of the 9 degree isotherm off of southwest Florida which may be extend the depth distribution into deeper waters than in the northern Gulf (Figures 15,16). This extended depth distribution is supported by some observed commercial longline trips in these areas that captured GT in fairly deep water. It is curious that the NMFS BLL survey did not capture any GT from these depths and waters, however. Nevertheless we may want extend the depth distribution deeper in these waters however we have not done so yet.

Logistic regression modeling of frequency of occurrence: Within this maximum habitat area based solely upon min/max depths, the realized habitat is heterogenous. Thus it is likely that the realized distribution of both species is reduced according to available habitat within the appropriate depth ranges. We used logistic regressions to develop probability maps of the occurrence against the 13 habitat variables, above and the bottom depth. To minimize the modeling of pure zeroes, we excluded all observations less than 200 feet. Only the quantitative variables were included in the logistic regression modeling along with depths in feet as a continuous variable.

Regression modeling was performed in R using the glm function with a logit link. Model selection was performed with the stepAIC() function with both forward and backward selection with the final model selected on the basis of the lowest AIC. Predictions were generated at every observed location and the predicted values plotted in space.

Results and discussion

Estimates of maximum potential habitat by NMFS statistical area were obtained based upon assumptions of the minimum and maximum depths of occurrence (Table 1). These estimates could be used to weight area-specific standardized CPUE indices when significant year*area interactions occur. It is likely that these depths may need to be revised on the basis of the temperature information and incorporation of informed opinion.

Logistic regression for golden tilefish

ANOVA table results indicated the strong effect of depth, percentage of clay, organic carbon and critical shear stress. Further the high residual deviance indicates that the selected model represents a great improvement over the null model.

	Estimate	std error	z-value	z-value	Pr(>|z|)
(Intercept)	1.09E+02	4.78E+01	2.284	0.022362	*
PWAVEVEL	-4.29E-03	2.31E-03	-1.86	0.062888	.
FISHINGDEPTH	8.30E-03	5.04E-04	16.489	2.00E-16	***
GRAVEL	-1.12E+00	4.85E-01	-2.315	0.020602	*
SAND	-1.12E+00	4.84E-01	-2.306	0.02109	*
MUD	-1.11E+00	4.83E-01	-2.291	0.021948	*
CLAY	1.79E-02	4.68E-03	3.831	0.000128	***
GRAINSZE	-2.55E-01	1.11E-01	-2.295	0.021746	*
SORTING	3.45E-01	1.62E-01	2.134	0.032805	*
CARBONATE	7.75E-03	3.51E-03	2.207	0.027337	*
ORGCARBN	7.51E-01	1.49E-01	5.028	4.95E-07	***
ROUGHNESS	1.47E+00	8.46E-01	1.732	0.083191	.
LCRITSHSTRS	1.99E-01	7.07E-02	2.808	4.99E-03	**

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
(Dispersion parameter for binomial family taken to be 1)
Null deviance: 1407.80 on 2820 degrees of freedom
Residual deviance: 696.69 on 2808 degrees of freedom

The initial model and the final logistic regression model selected on the basis of AIC for golden tile presence/absence were as follows:

Initial Model:
TileSuccess ~ PWAVEVEL + FISHINGDEPTH + GRAVEL + SAND + MUD + CLAY + GRAINSZE + SORTING + CARBONATE + ORGCARBN + LSHEARSTR + POROSITY + ROUGHNESS + LCRITSHSTRS

Final Model:
TileSuccess ~ PWAVEVEL + FISHINGDEPTH + GRAVEL + SAND + MUD + CLAY + GRAINSZE + SORTING + CARBONATE + ORGCARBN + ROUGHNESS + LCRITSHSTRS

Predictions of the probability of occurrence were obtained in space to map the probability of occurrence of golden tilefish (Figure 17).

Logistic regression for yellowedge grouper

ANOVA table results indicated the strong effect of depth, percentage of clay, organic carbon and critical shear stress. The lower residual deviance compared with the null deviance indicates that the selected model is not as good of a predicted model as the golden tile model.

	Estimate	std error	z-value	z-value	Pr(>|z|)
(Intercept)	-7.32999	2.378497	-3.082	0.002058	**
PWAVEVEL	0.002236	0.001277	1.75	0.080084	.
FISHINGDEPTH	0.005293	0.000267	19.823	2.00E-16	***
GRAVEL	0.007725	0.003921	1.97	0.048819	*
MUD	0.012596	0.004085	3.083	0.002047	**
CLAY	-0.01172	0.003087	-3.798	0.000146	***
GRAINSZE	0.111238	0.056697	1.962	0.049767	*
CARBONATE	0.011445	0.001884	6.074	1.25E-09	***
ORGCARBN	-0.13725	0.088889	-1.544	0.122567	
LSHEARSTR	-0.08631	0.057971	-1.489	0.136534	
POROSITY	-0.01567	0.00669	-2.342	0.019183	*
ROUGHNESS	-0.93292	0.527774	-1.768	0.07712	.
LCRITSHSTRS	0.142612	0.038171	3.736	0.000187	***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for binomial family taken to be 1)

Null deviance: 2973.8 on 2820 degrees of freedom
Residual deviance: 2359.1 on 2808 degrees of freedom
AIC: 2385.1

The initial model and the final logistic regression model selected on the basis of AIC for YEG presence/absence were as follows:

Initial Model:
YEG.P.A ~ PWAVEVEL + FISHINGDEPTH + GRAVEL + SAND + MUD + CLAY + GRAINSZE + SORTING + CARBONATE + ORGCARBN + LSHEARSTR + POROSITY + ROUGHNESS + LCRITSHSTRS

Final Model:
YEG.P.A ~ PWAVEVEL + FISHINGDEPTH + GRAVEL + MUD + CLAY + GRAINSZE + CARBONATE + ORGCARBN + LSHEARSTR + POROSITY + ROUGHNESS + LCRITSHSTRS

Predictions of the probability of occurrence were obtained in space to map the probability of occurrence of golden tilefish (Figure 18).

Conclusions

These preliminary results indicate that including habitat information may offer a means of identifying specific habitat within the stat areas and depths. Unfortunately the chosen models used greater than 10 of the habitat variables. It may be possible to combine some variables in a principle component analysis to reduce the total number of correlated variables.

Completing the analysis will require obtaining predicted probabilities of occurrence for the entire habitat. This could be done either by interpolating the predicted probabilities of occurrence or obtaining the values of all significant variables on a grid of prediction locations and then using the logistic regression to predict the probabilities at these locations.

Some outstanding issues remain. Notably the models predict a strictly linear increase with depth which we know is untrue for YEG and might be untrue for GT. Further other variables may not be strictly linear and a more flexible modeling approach such as GAMs might be of utility.

Literature cited

Jenkins, C.J. 2010. Seafloor Substrates. INSTAAR, University of Colorado, Boulder CO USA. [URL: "http://csdms.colorado.edu/wiki/DBSEABED"; Last edit 18 Feb 2010]

Table 1. Habitat area by NMFS statistical zone for yellowedge grouper and tilefish

stat area	Golden tile habitat area within 600-1500 feet area (km^2)	YEG habitat area within 200-1200 feet area (km^2)
1	0.0	0.0
2	3211.4	3828.4
3	3184.9	3211.4
4	4171.8	9571.1
5	3911.4	7344.6
6	148.6	961.6
7	0.0	0.0
8	7151.2	9509.2
9	7899.3	8237.4
10	2241.8	3057.8
11	1972.6	3025.0
12	0.0	0.0
13	2556.9	4406.9
14	2377.9	3761.8
15	3169.2	4776.0
16	2793.1	5051.7
17	2817.1	4999.7
18	2124.5	4411.9
19	0.0	0.0
20	3433.1	5642.7
21	2246.8	3195.8

Figure 1. NMFS bottom longline dataset locations NMFS bottom longline survey 1995-2009 in the Gulf of Mexico.

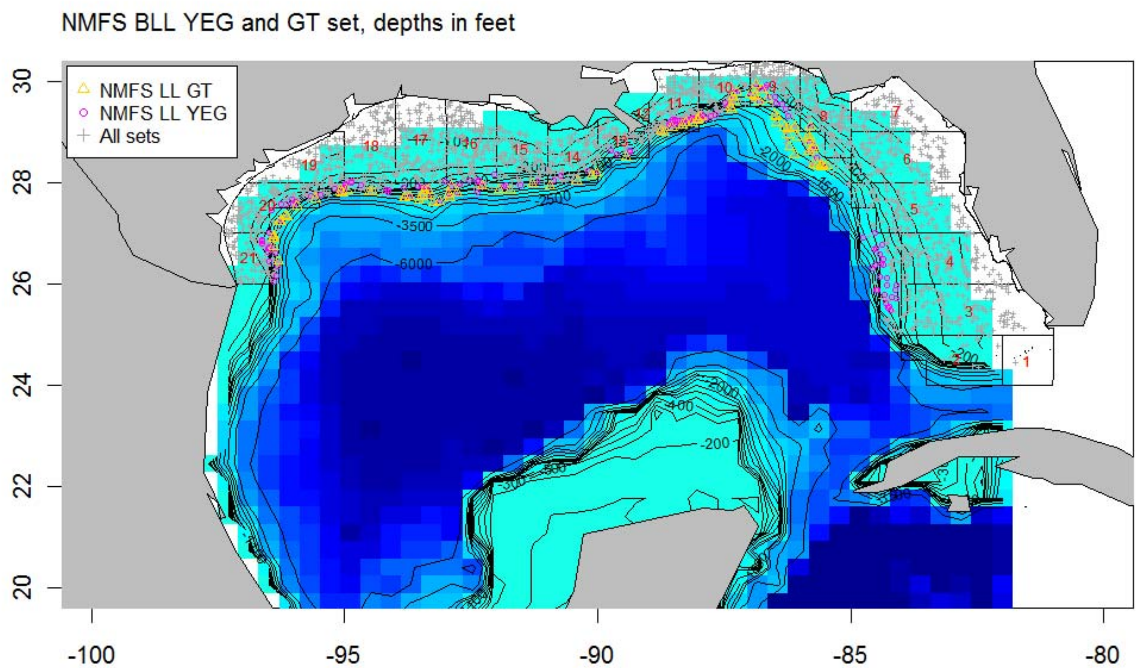

Figure 2. Temperature (Celsius) and Salinity from the NMFS Bottom Longline Survey with Tilefish Catch Rate . Grey markers are T,S - Observations. Colored markers scale in size and color by catch rate.

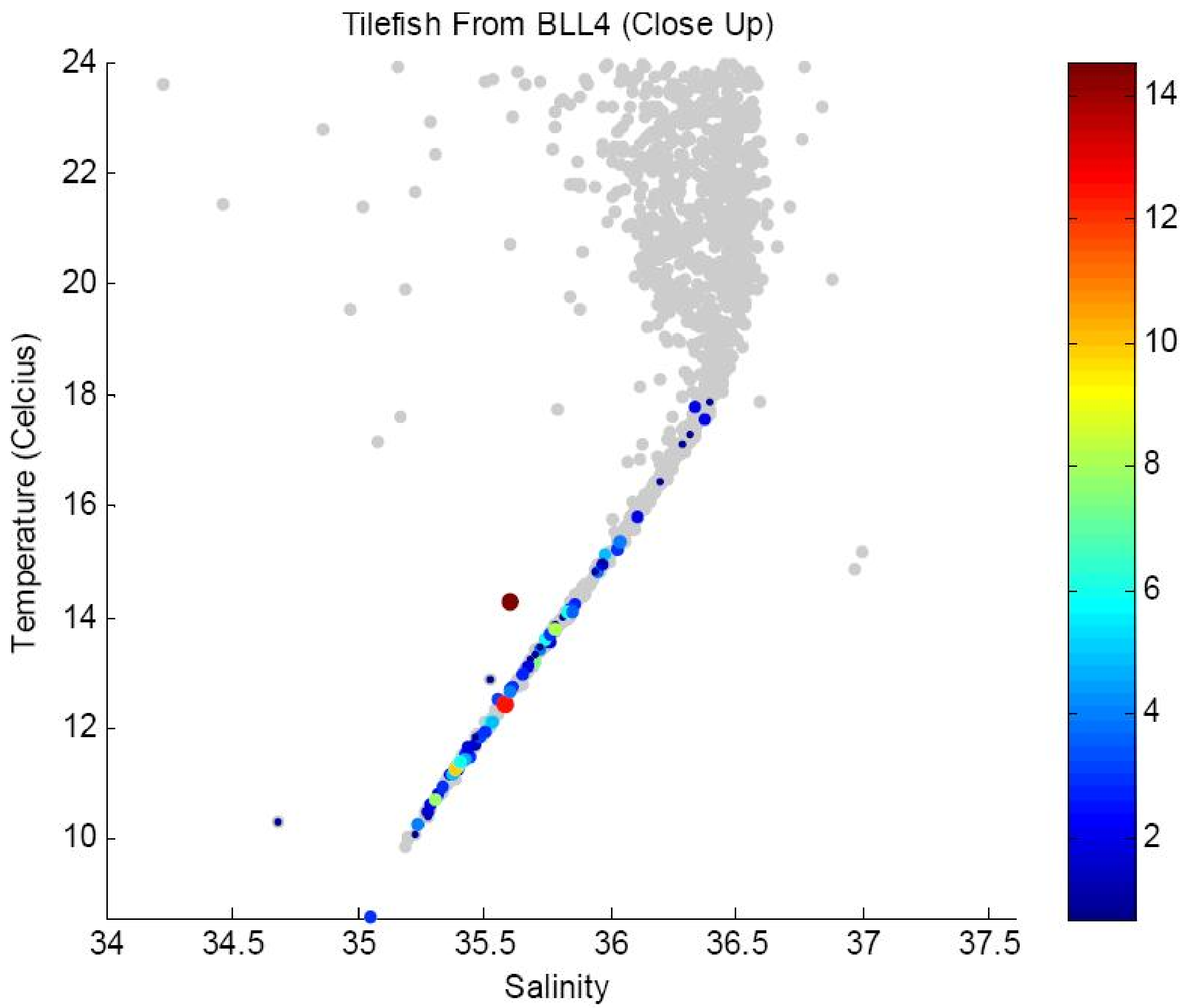

Figure 3- Distribution of Temperature (Celsius) and Salinity from the NMFS Bottom Longline Survey with Yellowedge Grouper Catch Rate . Grey markers are T,S - Observations. Colored markers scale in size and color by catch rate.

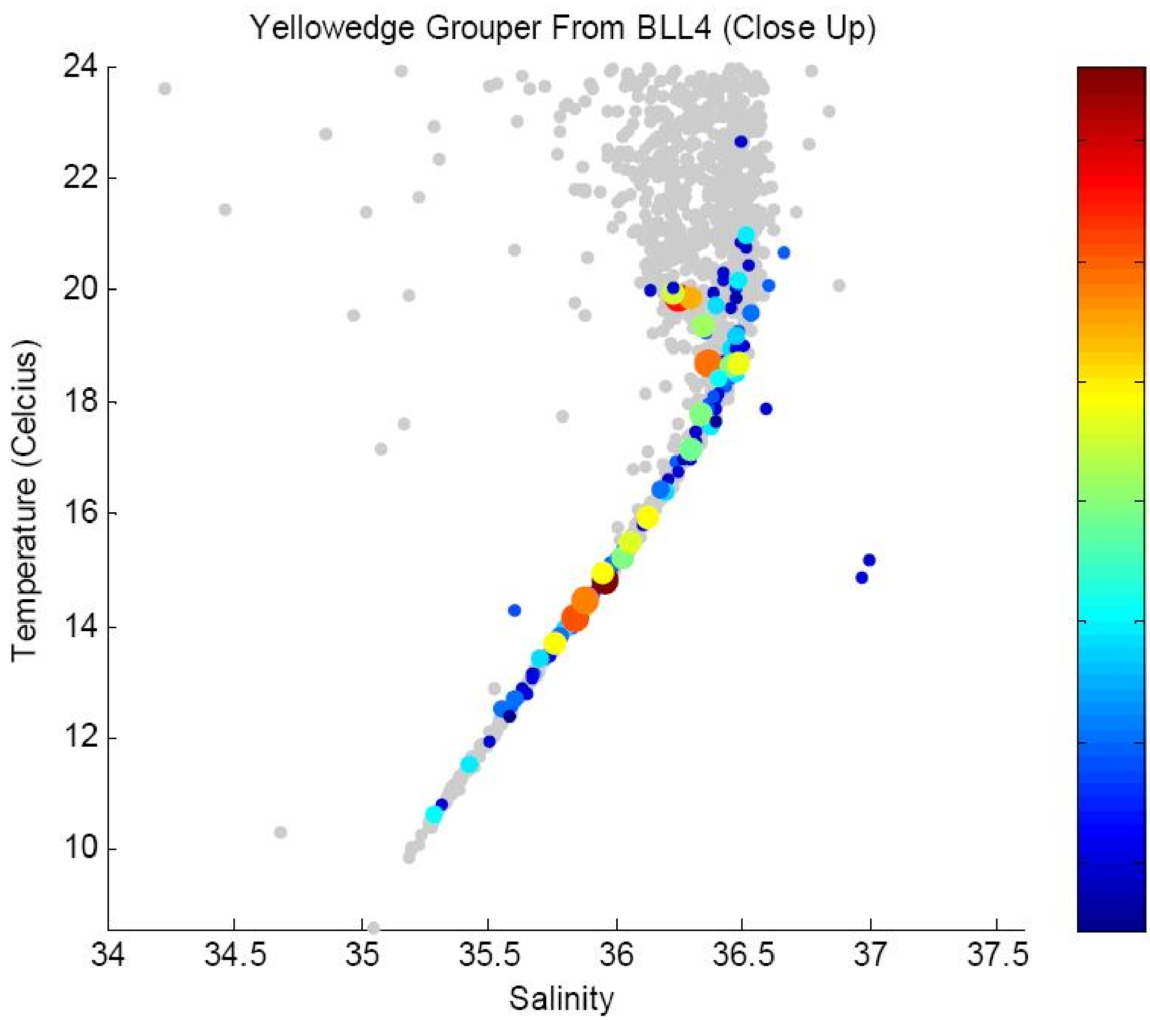

Figure 4- Distribution of bottom sediment observations from dbSEABED

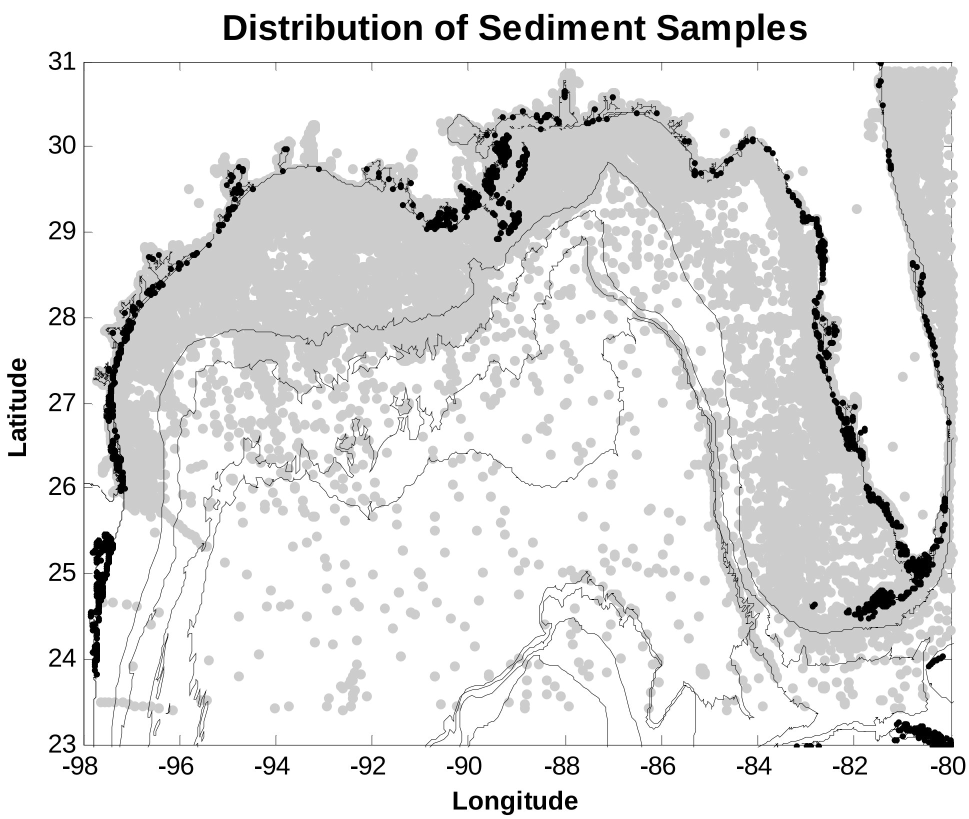

Figure 5 - Distribution of Gravel. Light grey is <25% Gravel; Medium is 25 to <50%; Dark is >75%.

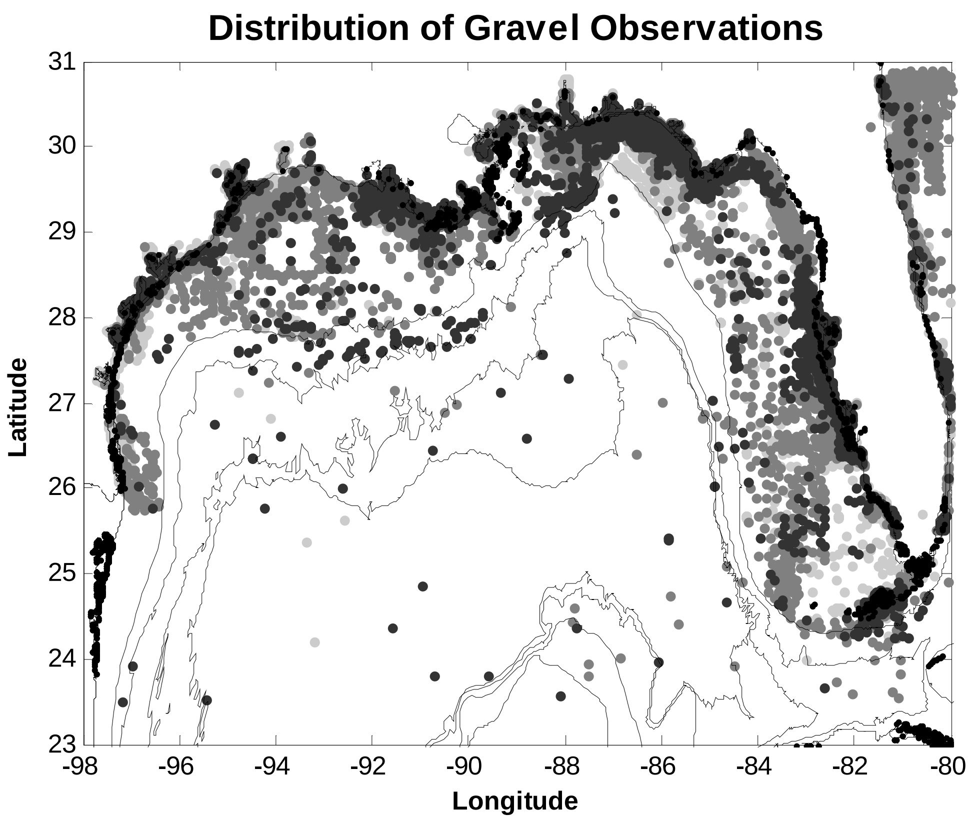

Figure 6 - Distribution of Mud. Light grey is <25% Mud; Medium is 25 to <50%; Dark is >75%.

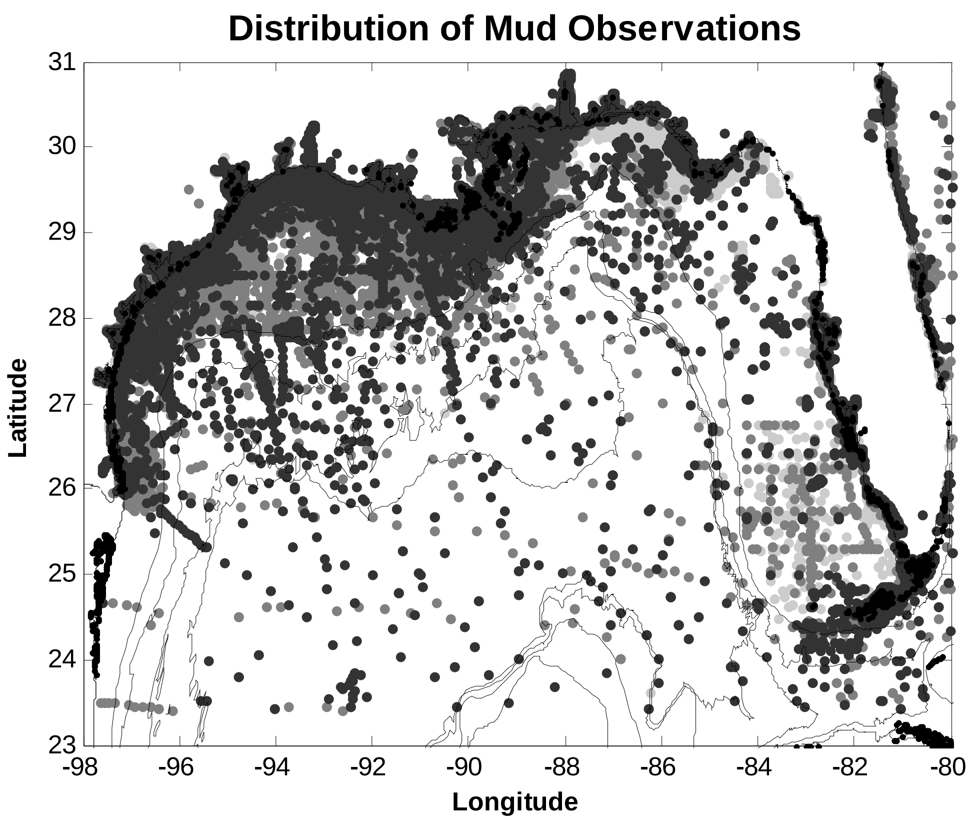

Figure 7 - Distribution of Sand. Light grey is <25% Sand; Medium is 25 to <50%; Dark is >75%.

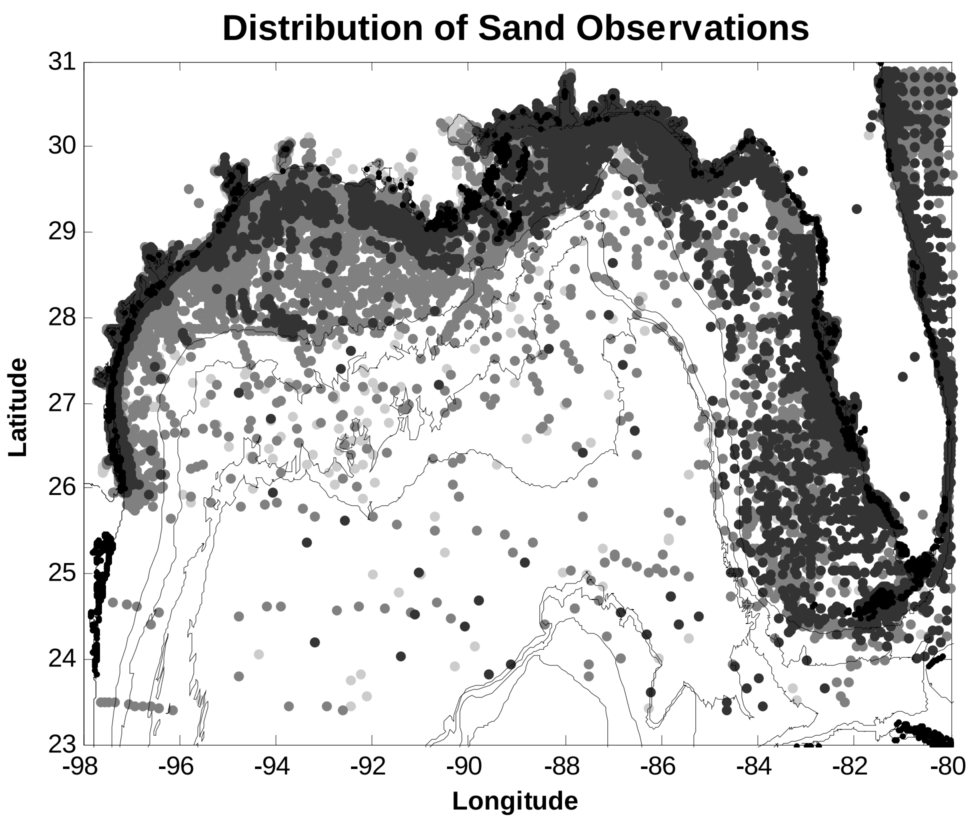

Figure 8 - Distribution of 'Exposed Rock'. Light grey is <25% Rock; Medium is 25 to <50%; Dark is >75%.

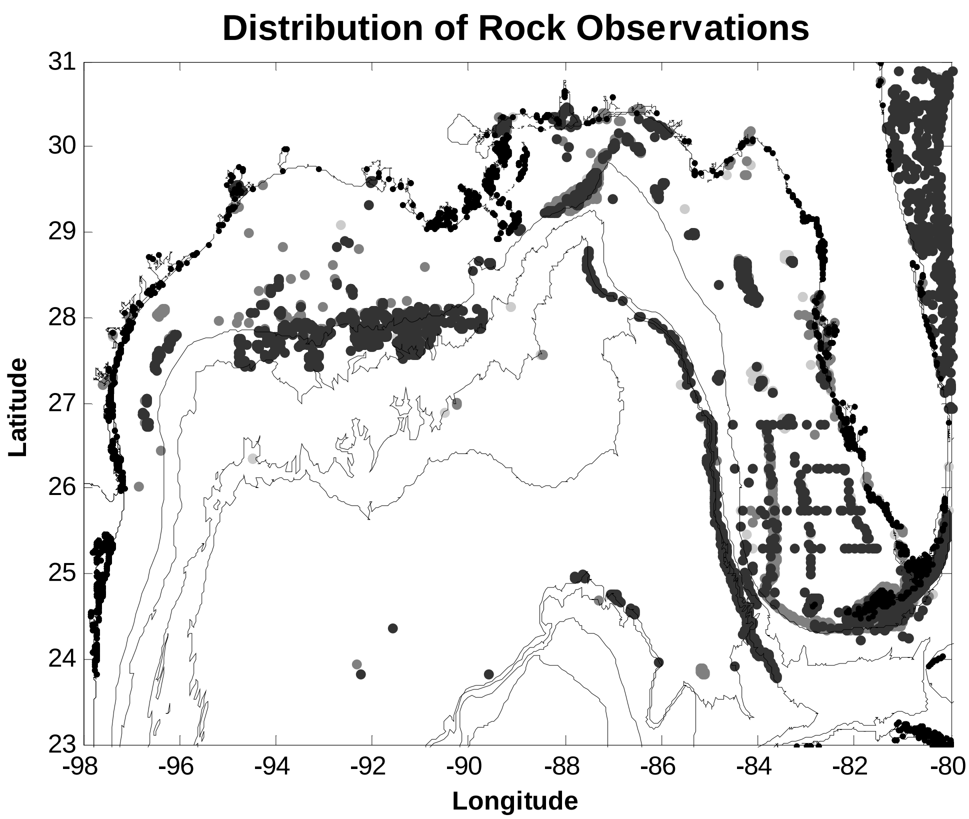

Figure 9. Extensions of NMFS statistical areas.

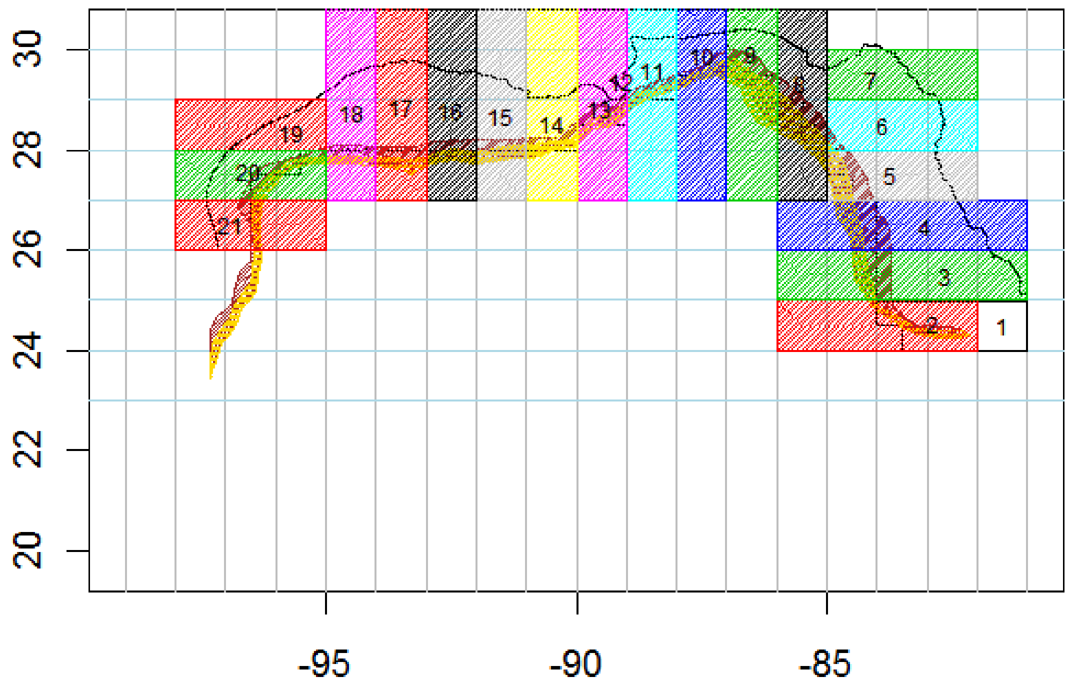

Figure 10. Depth of all observations and depth of positive observations of yellowedge grouper and golden tilefish sets. Maximum depth of positive observation was 1272 feet for golden tile and 1461 feet for yellowedge grouper.

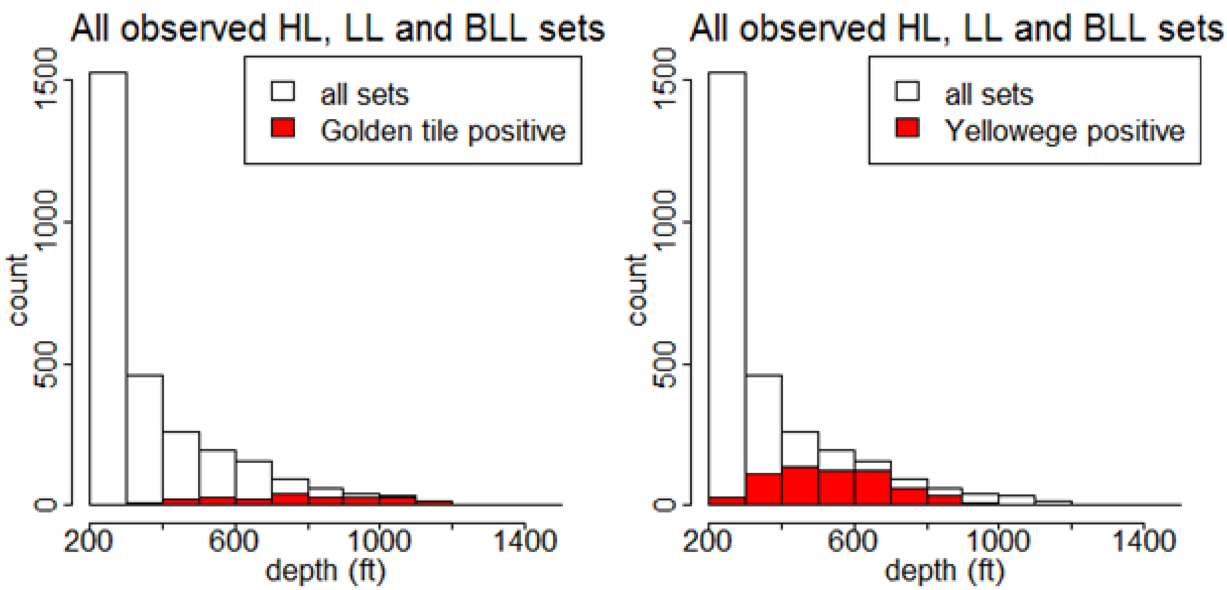

Figure 11. Presence/absence of YEG and golden tilefish from longline observer data by depth. Lines are the depth ranges used to define the habitat area.

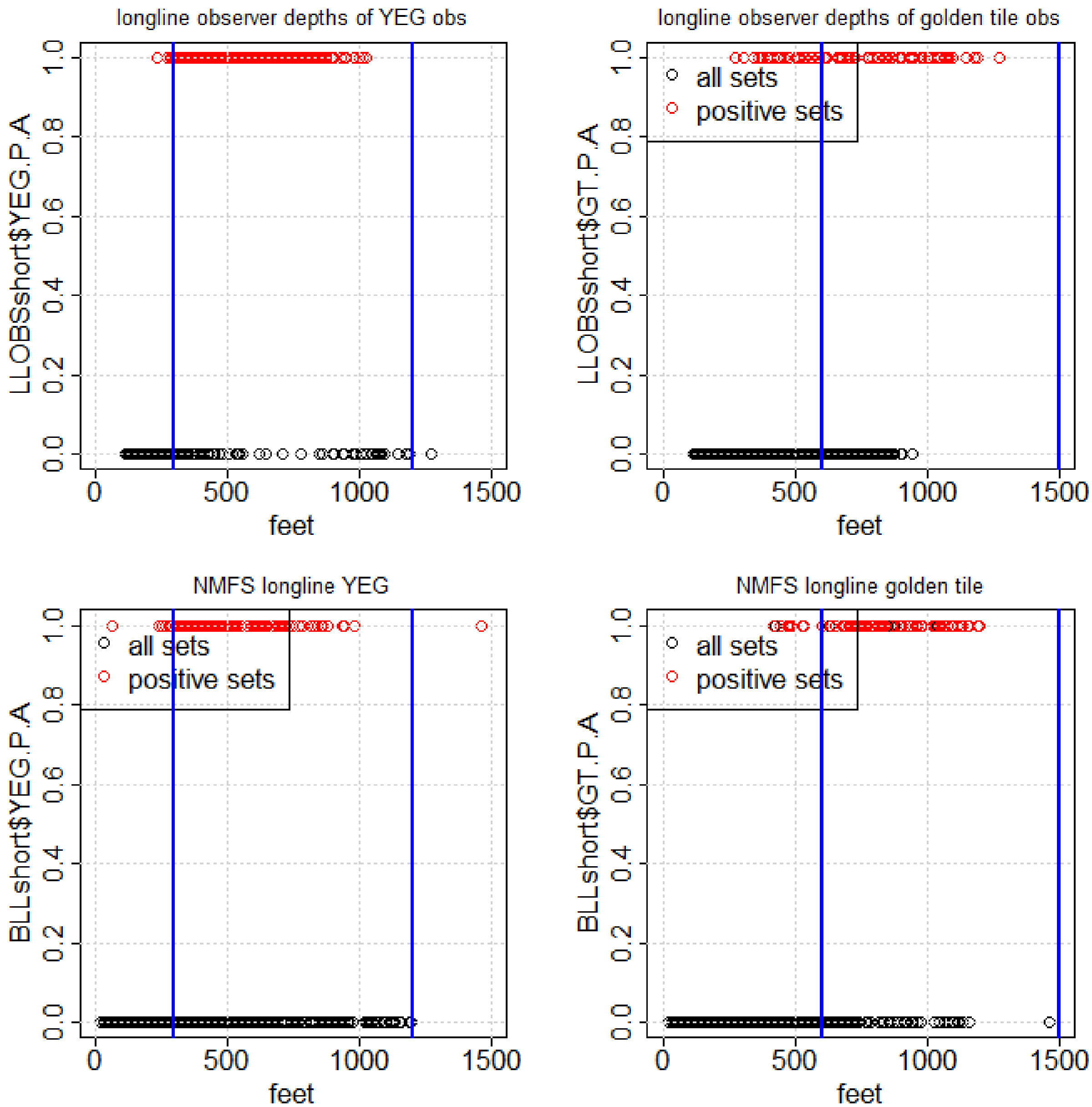

Figure 12. Intersection of depth contours and stat zones.

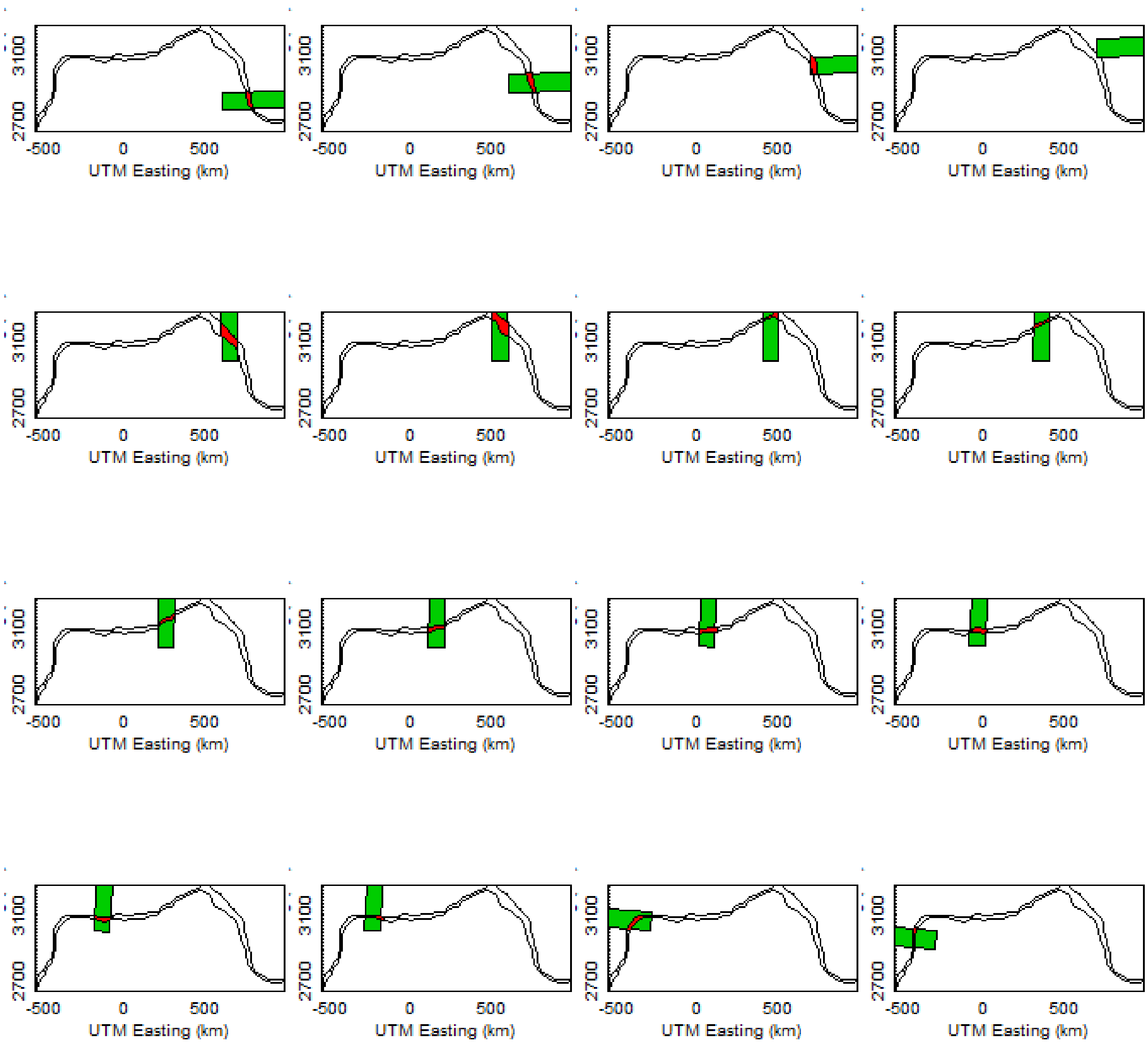

Figure 13. Habitat delineation based upon depth between 300 and 1200 feet (50 and 200 fa) for YEG.

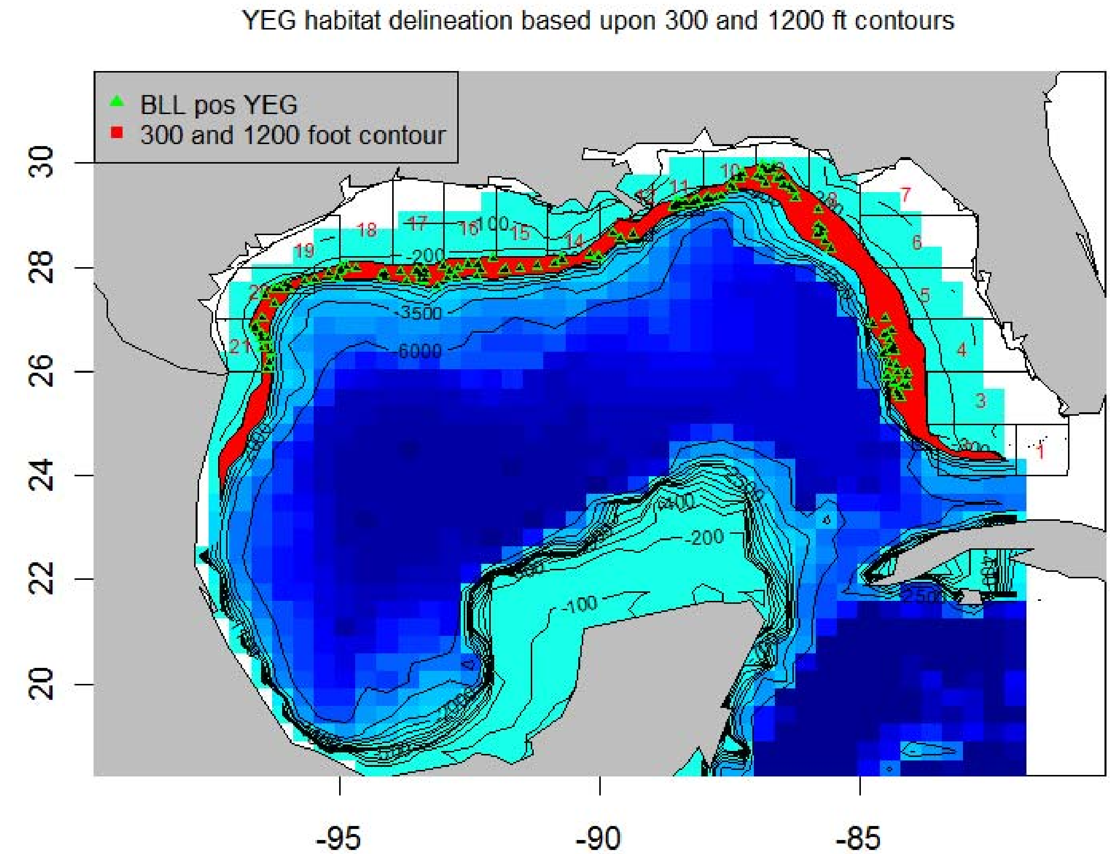

Figure 14. Habitat delineation based upon depth between 600 and 1500 feet (100 and 250 fa) for GT.

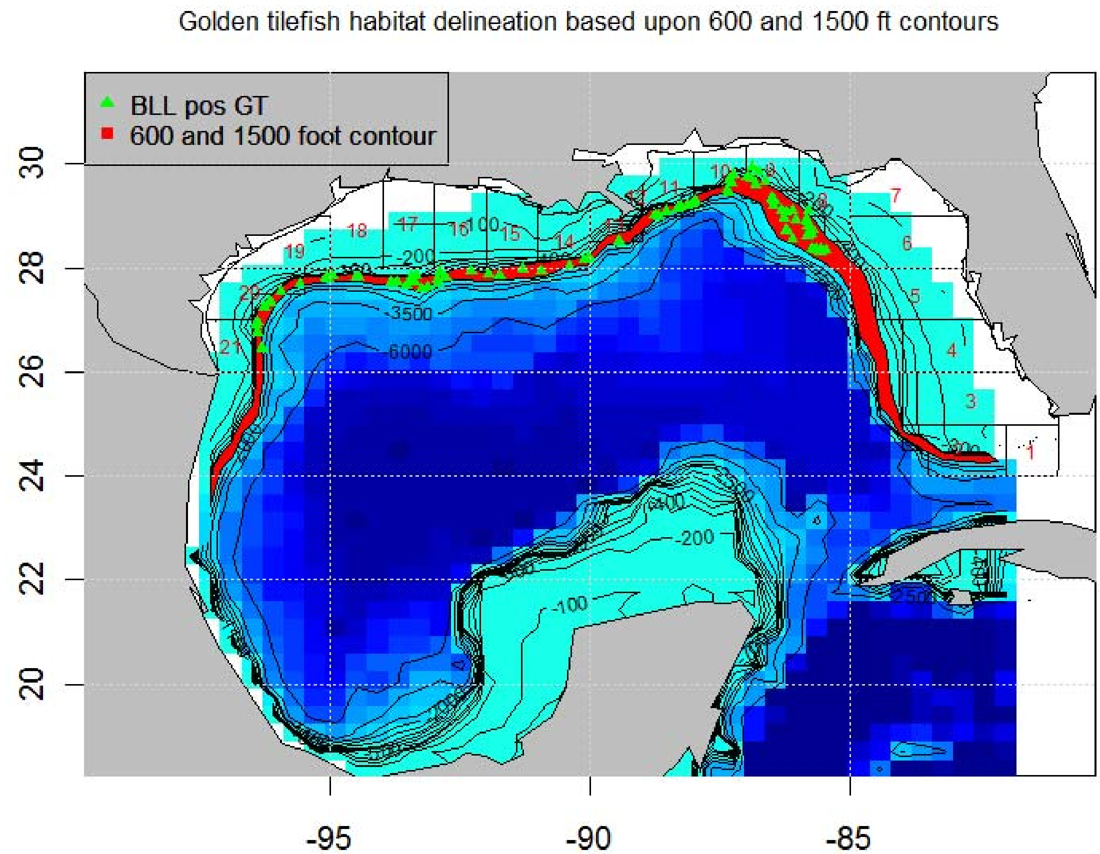

Figure 15. Water temperatures (^{o}C) at depth from world oceanographic atlas data. Points are bottom longline set locations.

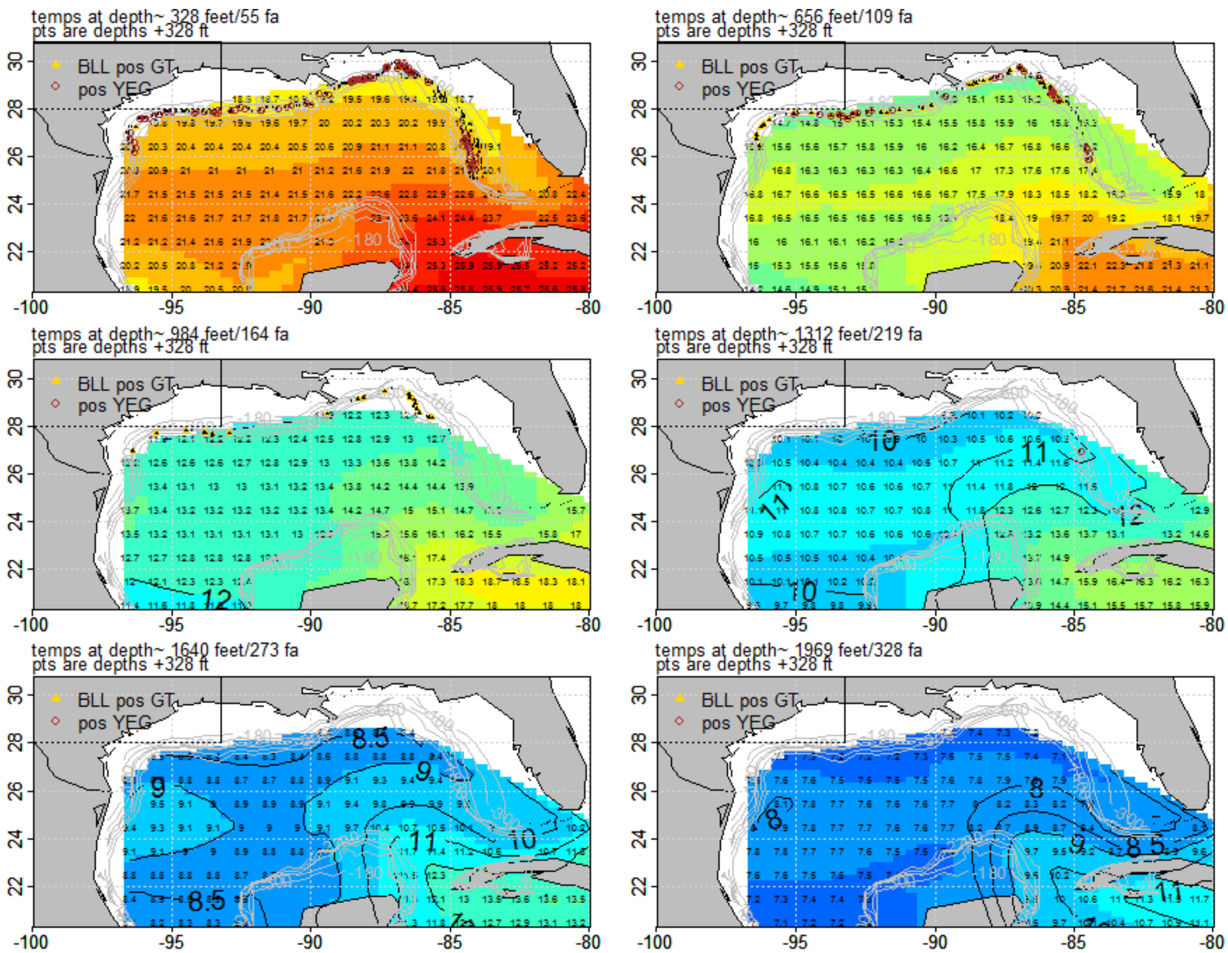

Figure 16. Water temperatures (^{o}C) at depth from world oceanographic atlas data.

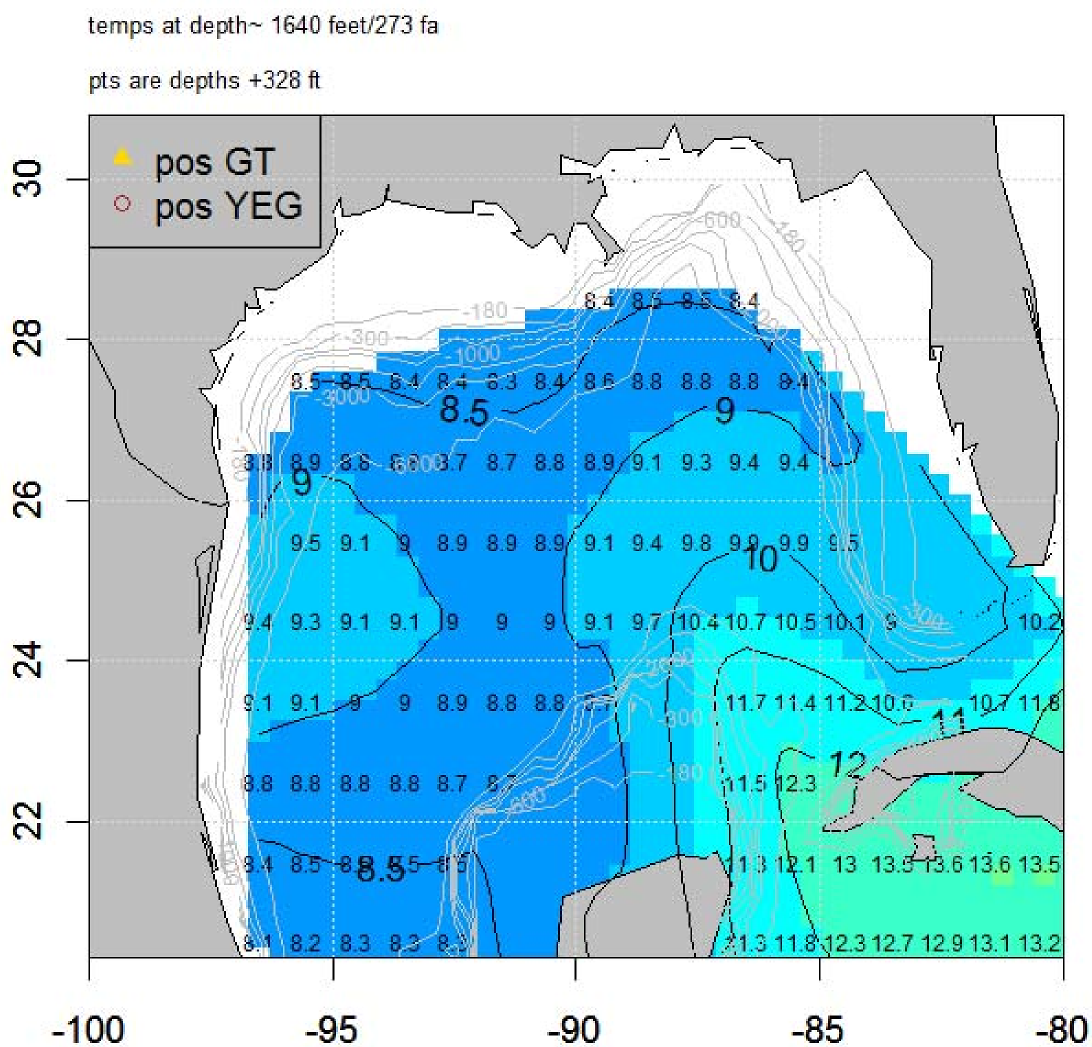

Figure 17. Mapping of logistic regression of golden tile presence/absence on habitat factors.

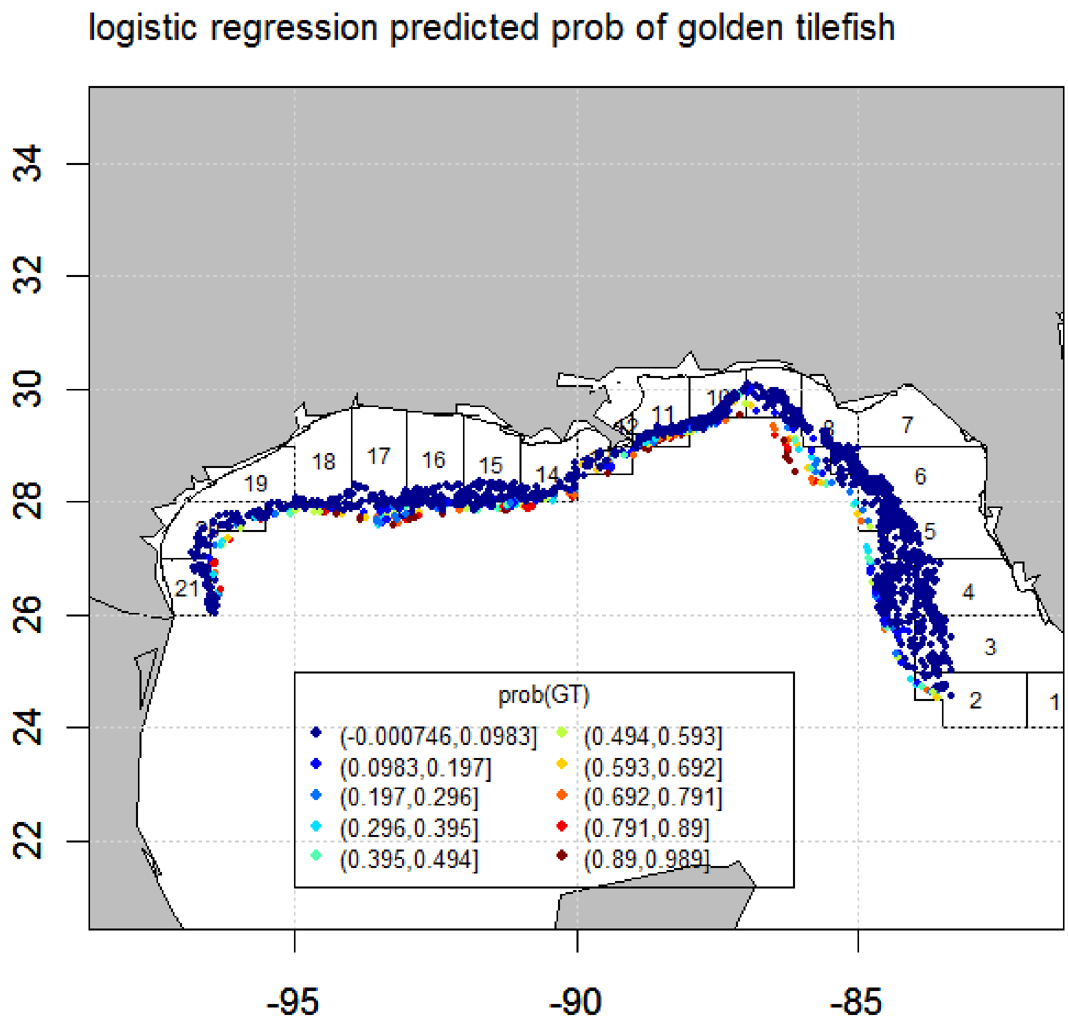

Figure 18. Mapping of logistic regression of yellowedge grouper presence/absence on habitat factors.