Electronic Monitoring Documentation of Sandbar Sharks (*Carcharhinus plumbeus*) and Depredation in the Eastern Gulf of America Commercial Reef Fish Fishery

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Introduction

The Eastern Gulf of America (EGoA) commercial bottom longline (BLL) reef fish fishery primarily targets red grouper (*Epinephelus morio*), red snapper (*Lutjanus campechanus*), yellowedge grouper (*Epinephelus flavolimbatus*), and golden tilefish (*Lopholatilus chamaeleonticeps*) across the West Florida Shelf from The Edges to the Dry Tortugas, with sandbar sharks (*Carcharhinus plumbeus*) caught as bycatch. The Center for Fisheries Electronic Monitoring at Mote (CFEMM) has been pioneering electronic monitoring (EM) in this fishery since 2016. A thorough review of the program history and data summaries can be found in Neidig et al., 2023. Industry volunteer participation has included collaborations with 24 BLL and vertical line (VL) vessels. The data reported for sandbar sharks in this paper were generated from 15 BLL vessels fishing out of ports along Florida's west coast, from Cortez to Inglis, in the EGoA, defined here as federal waters east of 88°W, from July 2016 to December 2024.

Methods

Video Review Protocol

Saltwater Inc. (SWI) (Anchorage, AK) Electronic Monitoring Unit hard drives from participating vessels were collected during dockside visits or mailed by the respective captains or vessel owners. These drives were loaded to workstations, where CFEMM staff used SWI review software to annotate the collected video footage. Sets and hauls were marked along a timeline by reading associated sensor data (hydraulic pressure and rotation). Twenty-five percent of complete set/haul events from each BLL trip were randomly selected to be reviewed. Each recorded catch event was assigned characteristics based on a series of custom dropdown menus for the reviewer to select. These variables included species identification, handling, condition on arrival, fate, and, for shark bycatch, maturity, sex, and estimated size. Detailed descriptions of CFEMM review protocols are included in Neidig et al., 2023.

Post-Review Processing

The resulting data navigated a CFEMM-established QA/QC process in which all annotated events and sensor data anomalies were reviewed by experienced staff to screen for identification errors or missing catch. Aggregated groupings of trips were further screened using R (version 4.2.1; R Core Team, 2024), applying a series of over 75 error checks to flag abnormalities. Once approved, the final data was appended to the master database in Microsoft Access™. Depth was associated with events by spatially joining locations to the raster of a digital elevation model with a resolution of 0.01 meters (National Geophysical Data Center, 2011).

Electronic Monitoring Data Analysis

A model was developed to explore fishery-dependent variables that may affect catch per haul variability beyond space and time. A zero-inflated negative binomial distribution was selected to account for both overdispersion in the count data and an excess of zero catches. The model was fitted with the pscl package (Jackman, 2024; Zeileis et al., 2008) within R, and quantile residuals were inspected with DHARMa (Hartig, 2024). Predictors for the count model included soak time (hrs) and bathymetric depth (m) at the centroid of the haul, while the predictors for the zero-inflation model only included the depth. The number of hooks deployed per set, hook sizes, and bait type could not be determined consistently enough to be used as predictors. Unique vessel identifiers were not included because vessels frequently change captains, and captain identity is not recorded, making it difficult to attribute differences in catch rates to consistent vessel-level effects.

Generalized additive models (GAMs) were used to depict potential annual and seasonal changes in catch per unit effort (CPUE) and were generated using the default *k*-values calculated by the mgcv and ggplot2 packages (Wood, 2011; Wickham, 2016) within R. These plots incorporate data up to October 2025 to provide visual guidance while avoiding the inference of trends during the terminal year of data collection. The CPUE for BLL vessels was calculated at the set/haul-level as the number of individuals caught per 1000 hook-hours:

(1) $CPUE = 1000n/ht$

where n is the number of individuals caught in the haul, h is estimated to be 750 hooks, and t is the soak time in hours from the start of the set to the end of the associated haul.

Spatial analyses were conducted in ArcGIS Pro (version 3.4.2; Esri Inc., 2024) using the Kernel Density and Optimized Hot Spot Analysis tools. Catch locations for conducting the kernel density analysis were determined by using the locations of each individual projected from WGS84 to UTM Zone 17N to convert angular degrees to linear meters. The hot spot analysis was performed at the set/haul-level on CPUE, with the locations represented as the centroid of the haul. Resulting points were then spatially joined to a 10 min x 10 min grid with the average confidence level bin (Gi Bin) score used per grid cell.

NOAA Reef Fish Observer Data Comparative Analysis

The resulting EM data were compared to data obtained from the NOAA Reef Fish Observer Program from October 2016 to October 2023. Note that in 2020, only two observer trips were conducted in the EGoA, and therefore, the data from those trips were not included in subsequent analyses due to vessel confidentiality. During this time period, nine BLL trips from six vessels were identified as exhibiting overlapping EM and observer coverage. From these nine trips, 210 sets were identified as corresponding to one another, with the recorded difference in the set start times being less than 30 minutes. Data were examined at the set/haul level to avoid differences in effort calculations, and species counts were compared to assess agreement rates across overlapping trips. Analyses were also conducted at the fleet-wide level to compare average catch rates of sandbar sharks and certain species groups and Wilcoxon rank-sum tests were used to identify significant differences. Species groups were in part defined by the 2006 Consolidated Atlantic HMS Fishery Management Plan (FMP) (NMFS, 2006). Large Coastal Sharks (LCS) were expanded to include dusky (*Carcharhinus obscurus*), night (*Carcharhinus signatus*), and bignose sharks (*Carcharhinus altimus*) due to their propensity to be misidentified as other requiem sharks within the management unit. Small Coastal Sharks (SCS) remained as defined in the FMP, and Dogfishes included species within the genera *Squalus* and *Mustelus*.

Depredation Analysis

Bottom longline fishers in the EGoA often attribute depredation to the presence of sandbar sharks while fishing. To interpret broader sandbar populations' impact on the reef fish community, a preliminary investigation was conducted to assess temporal patterns and the spatial distribution of depredation in relation to sandbar sharks. Animals documented by an EM reviewer as caught in a damaged condition, whether alive or dead, were classified as depredated. Observed damage included retrieval of heads only, bodies with "rake" teeth marks, and chunks of missing flesh. Damaged gear (e.g., bent hooks), presumed "bite-offs" where the hook was removed before retrieval, and scavenging, where predators consumed fish post-release, were not included in the analyses. In some instances, reviewer notes also included the presumed species responsible for the damage.

Results and Discussion

Catch and Effort Distribution

From July 2016 through December 2024, 542 fishing trips were recorded by the EM systems, covering 4,978 sea days (Table 1). These trips, focused in the EGoA, represent approximately 8.5% coverage of the total Gulf-wide fleet and involved the review of 3,010 hauls, documenting 157,795 catch events, including 1,248 sandbar sharks. These captures occurred on 720 of the reviewed hauls (24%). Sandbar sharks in the region are the fourth most frequently caught shark species on this gear type, after dogfishes (*Squalus sp., Mustelus sp.*) and Atlantic sharpnose sharks (*Rhizoprionodon terraenovae*).

A zero-inflated negative binomial model was used to evaluate the influence of soak time and depth on the number of sandbar sharks caught per haul (Table 2). In the catch component of the model, both soak time and depth were significant predictors of catch. Soak time had a positive effect on catch ($\beta = 0.506$, SE = 0.050, $p < 0.001$), indicating that longer sets increased the expected number of sandbar sharks caught per haul. Depth had a negative effect when accounting for the bathymetric convention of negative depth values ($\beta = 0.008$, SE = 0.002, $p < 0.001$), suggesting that catch rates decreased with increasing depth. In the zero-inflation component of the model, depth was also a significant predictor ($\beta = -0.050$, SE = 0.014, $p < 0.001$), with the probability of structural zero catches increasing as depth increased. This pattern suggests that deeper sets were more likely to produce zero catches than shallow sets, likely due to the absence of sandbar sharks in the area. Because soak time was an important predictor for explaining variability in sandbar shark catch rates, CPUE is used in the subsequent analyses to better account for effort.

Sandbar shark CPUE was variable, showing little to no distinct seasonal patterns (Figure 3A) and some interannual variability (Figure 3B). The data also suggest that the average CPUE has remained consistent in recent years following a slight increase.

Sandbar sharks were recorded from 24.47° latitude to 29.52° latitude and as far west as -86.29° longitude. Catch density was highest close to the southeastern corner of the Pulley Ridge Habitat Area of Particular Concern (HAPC), east of The Edges fishery management area, and off of Boca Grande, FL (Figure 1). These individuals were encountered in depths from 36m to 243m, with an average capture depth of about 64m. A hotspot analysis resulted in multiple significant clusterings of high catches per haul that coincided with high catch densities in the northern portion of the fishing area near the Middle Grounds and the Edges, the southern portion of the fishing area between the Pulley Ridge and Dry Tortugas HAPCs, and off Boca Grande (Figure 2).

Condition on Arrival, Discard Mortality, Estimated Size, Sex, and Maturity

Of the 1,248 sandbar sharks caught, three (0.24%) arrived at the vessel dead and five arrived with an unknown condition (0.40%). The average discard mortality rate per year was 0.24% (Table 3), with the highest rate (1.39%) occurring in the 60-69.99 m depth bin (Table 4). The total discard mortality rate as reported by at-sea observers from October 2016 to October 2023 in the EGoA was 1.51% (5/331).

The majority (76.12%) of sharks were estimated to be at least 2 m long, with the remaining estimated to be between 1 m and 2 m long. Since sandbar sharks are primarily cut off at the rail due to their size and are therefore viewed from above or to the side in EM footage, sex was undeterminable for most (85.41%), but based on size, the majority were assumed to be adults (71.39%). Of the sharks where sex could be determined, 125 were male and 57 were female (Table 5).

Observer Data Comparisons

For the nine BLL trips with overlapping EM and at-sea observer coverage, sandbar sharks were recorded on 29 (13.8%) hauls via EM systems and on nine (4.3%) hauls by observers. On average, EM documented nearly one additional sandbar shark per haul compared to observers when at least one sandbar shark was identified as captured during the haul (mean bias = 0.774; Figure 4). On an annual basis, EM also recorded a higher average catch per haul of sandbar sharks in the eastern Gulf ($W = 52$, $p < 0.01$; Figure 5). When sharks were assigned to species groupings, LCS exhibited the most differences in the average annual catch per haul (Figure 6), where observers consistently recorded lower catch rates than EM in recent years. Since LCS, including sandbars, are primarily cut off at the rail (and sometimes cut off before breaking the water's surface), it is possible that they could be more easily miscounted by an observer than smaller-bodied species that are primarily brought on board before discarding, potentially leading to the lack of differences detected between SCS and Dogfishes (Figure 6).

Depredation

The rate of damaged fish caught per 1000 hook-hours over time for the EGoM BLL fishery remained relatively low (mean = 0.63 ± 0.015) and did not exhibit strong seasonal or interannual variation, but may be slowly increasing (Figure 7). Because these rates do not include bite-offs, depredation is likely underestimated.

A hotspot analysis revealed clusters of high damaged fish CPUE in the central fishing area from Clearwater to Naples, FL (Figure 8). Four of the nine grid cells classified as hot spots are correlated with sandbar shark CPUE hot spots, however the species responsible for the majority of the damaged fish are largely unknown. While bite patterns can provide clues, they are often ambiguous and inconsistent. Coupled with the majority of depredation events occurring out of view of the cameras, assigning responsible species and species groups to damaged fish remains a challenge. Nevertheless, of the 249 instances out of 2,328 in which the damage could be attributed to sharks, the majority (39%) resulted from confirmed interactions with sandbar sharks. It is therefore likely that sandbar sharks play a major role in depredation.

Literature Cited

Esri Inc. (2024). *ArcGIS Pro* (Version 3.4.2). Esri Inc. https://www.esri.com/en-us/arcgis/products/arcgis-pro/overview

Hartig, F. (2024). DHARMa: Residual Diagnostics for Hierarchical (Multi-Level / Mixed) Regression Models (Version 0.4.7). https://doi.org/10.32614/CRAN.package.DHARMa

Jackman, S. (2024). pscl: Classes and Methods for R Developed in the Political Science Computational Laboratory (Version 1.5.9). Sydney, Australia.

National Geophysical Data Center, NESDIS, NOAA, U.S. Department of Commerce. (2011). *Digital Elevation Model of the Gulf of Mexico, Integrating Bathymetric and Topographic Datasets*. NOAA National Centers for Environmental Information.

Neidig, C., Lee, M., Roberts, D.E., and Schloesser, R. (2023). Characterization of the U.S. Eastern Gulf of Mexico Reef Fish Bottom Longline Catch through Fishery Collaboration with Electronic Monitoring. *Marine Fisheries Review. 85*(1-4). https://doi.org/10.7755/MFR.85.1-4.5

NMFS. (2006). Final Consolidated Atlantic Highly Migratory Species Fishery Management Plan. National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Office of Sustainable Fisheries, Highly Migratory Species Management Division, Silver Spring, MD. Public Document. pp. 1600.

R Core Team. (2024). R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/.

Wickham, H. (2016). ggplot2: Elegant Graphics for Data Analysis. Springer-Verlag New York.

Wood, S.N. (2011). Fast stable restricted maximum likelihood and marginal likelihood estimation of semiparametric generalized linear models. *Journal of the Royal Statistical Society (B)*. *73*(1):3-36. https://doi.org/10.1111/j.1467-9868.2010.00749.x

Zeileis, A., Kleiber, C., and Jackman, S. (2008). Regression Models for Count Data in R. *Journal of Statistical Software, 27*(8). https://doi.org/10.18637/jss.v027.i08

Tables and Figures

Table 1. Effort metrics by year for bottom longline vessels fishing in the eastern Gulf of America reef fish fishery, 7/2016 - 12/2024.

Year	Participating Vessels	Trips	Hauls Reviewed	Sea Days
2016	5	32	191	271
2017	5	42	242	392
2018	5	49	217	427
2019	7	48	457	495
2020	8	67	344	618
2021	11	83	400	758
2022	12	72	286	545
2023	11	80	468	779
2024	10	71	405	721

Table 2. Zero-inflated negative binomial model results.

	Estimate	Std. Error	z value	Pr(>|z|)
Count model				
Intercept	-2.184	0.187	-11.691	< 0.001
Soak Time	0.506	0.050	10.176	< 0.001
Depth	0.008	0.002	4.441	< 0.001
Log(theta)	-0.670	0.087	-7.744	< 0.001
Zero-inflation model				
Intercept	-10.034	3.165	-3.170	0.002
Depth	-0.050	0.014	-3.669	< 0.001

Theta = 0.512

Table 3. Fate by year for sandbar sharks caught on bottom longline gear in the eastern Gulf of America reef fish fishery, 7/2016 - 12/2024.

Year	Number of Hauls	Total Number Caught	Total Number Discarded	Discarded Alive	Discarded Alive - Damaged	Discarded Dead	Discarded Unknown	Retained as Bait	Discard Mortality Rate
2016	191	34	34	33	0	0	1	0	0%
2017	242	40	40	37	3	0	0	0	0%
2018	217	83	83	82	0	0	1	0	0%
2019	457	130	130	129	0	0	1	0	0%
2020	344	154	154	152	0	2	0	0	1.31%
2021	400	258	255	254	0	1	0	3	0.39%
2022	286	143	143	142	1	0	0	0	0%
2023	468	187	187	186	0	0	1	0	0%
2024	405	219	219	217	0	1	1	0	0.46%
All Years	3,010	1,248	1,245	1,232	4	4	5	3	0.32%

Table 4. Fate by depth range for sandbar sharks caught on bottom longline gear in the eastern Gulf of America reef fish fishery, 7/2016 - 12/2024.

Depth Range (m)	30-39.99	40-49.99	50-59.99	60-69.99	70-79.99	80-89.99	90-99.99	100-109.99	110-119.99	>120
Total Number Caught	79	456	180	217	124	50	15	24	35	68
Total Number Discarded	79	456	178	216	124	50	15	24	35	68
Discarded Alive	79	455	175	212	121	50	15	23	35	67
Discarded Alive - Damaged	0	0	1	0	3	0	0	0	0	0
Discarded Dead	0	0	1	3	0	0	0	0	0	0
Discarded Unknown	0	1	1	1	0	0	0	1	0	1
Retained as Bait	0	0	2	1	0	0	0	0	0	0
Discard Mortality Rate	0%	0%	0.56%	1.39%	0%	0%	0%	0%	0%	0%

Table 5. Sex and/or maturity of sandbar sharks caught on bottom longline gear in the eastern Gulf of America reef fish fishery, 7/2016 - 12/2024.

Sex and/or Maturity	Total	Percent
Known Adult - Undetermined Sex	891	71.39
Unknown Maturity and/or Sex	175	14.02
Male	125	10.02
Female	57	4.57

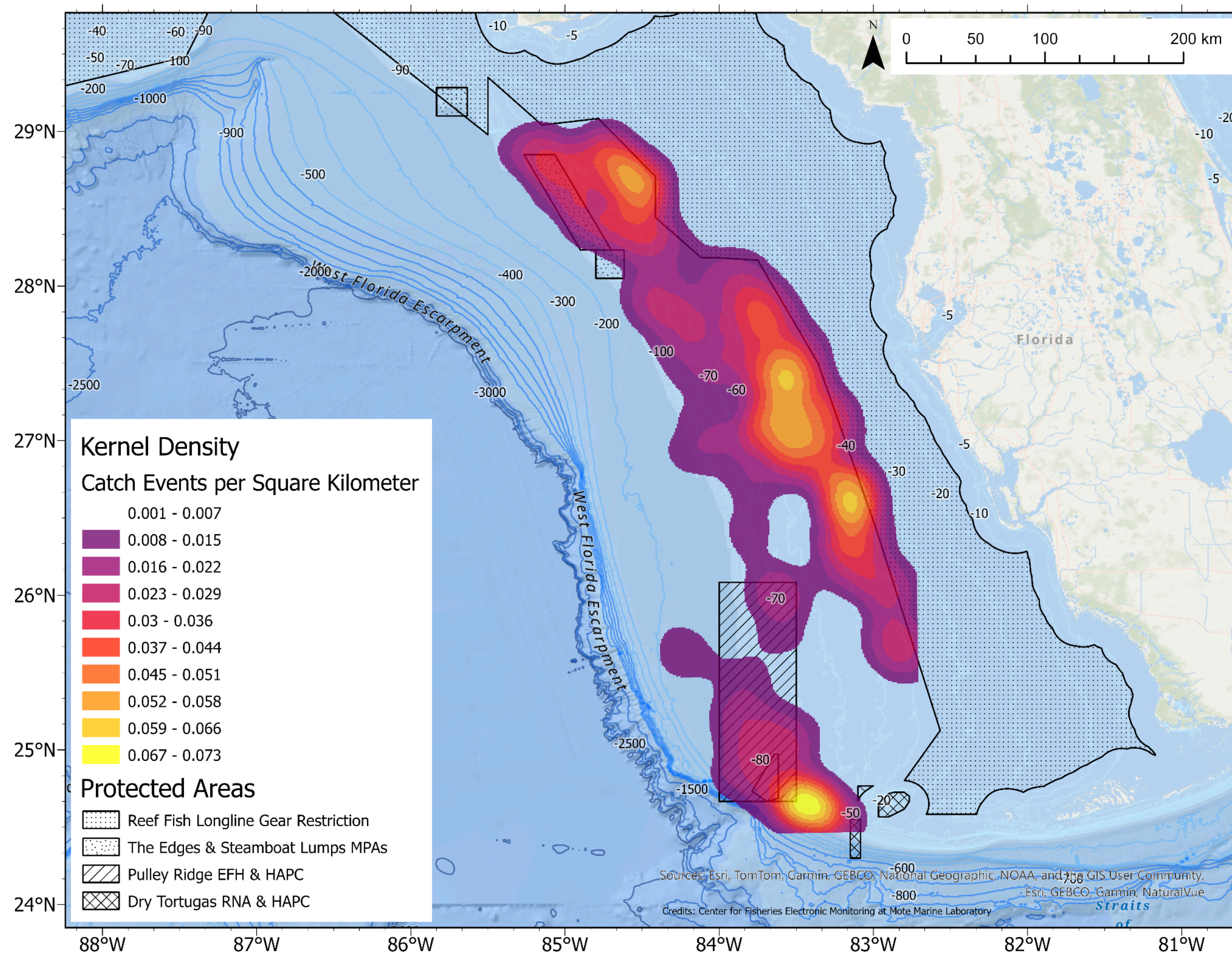

Figure 1. Kernel density of sandbar shark bottom longline catch events recorded in the eastern Gulf, 7/2016 - 12/2024.

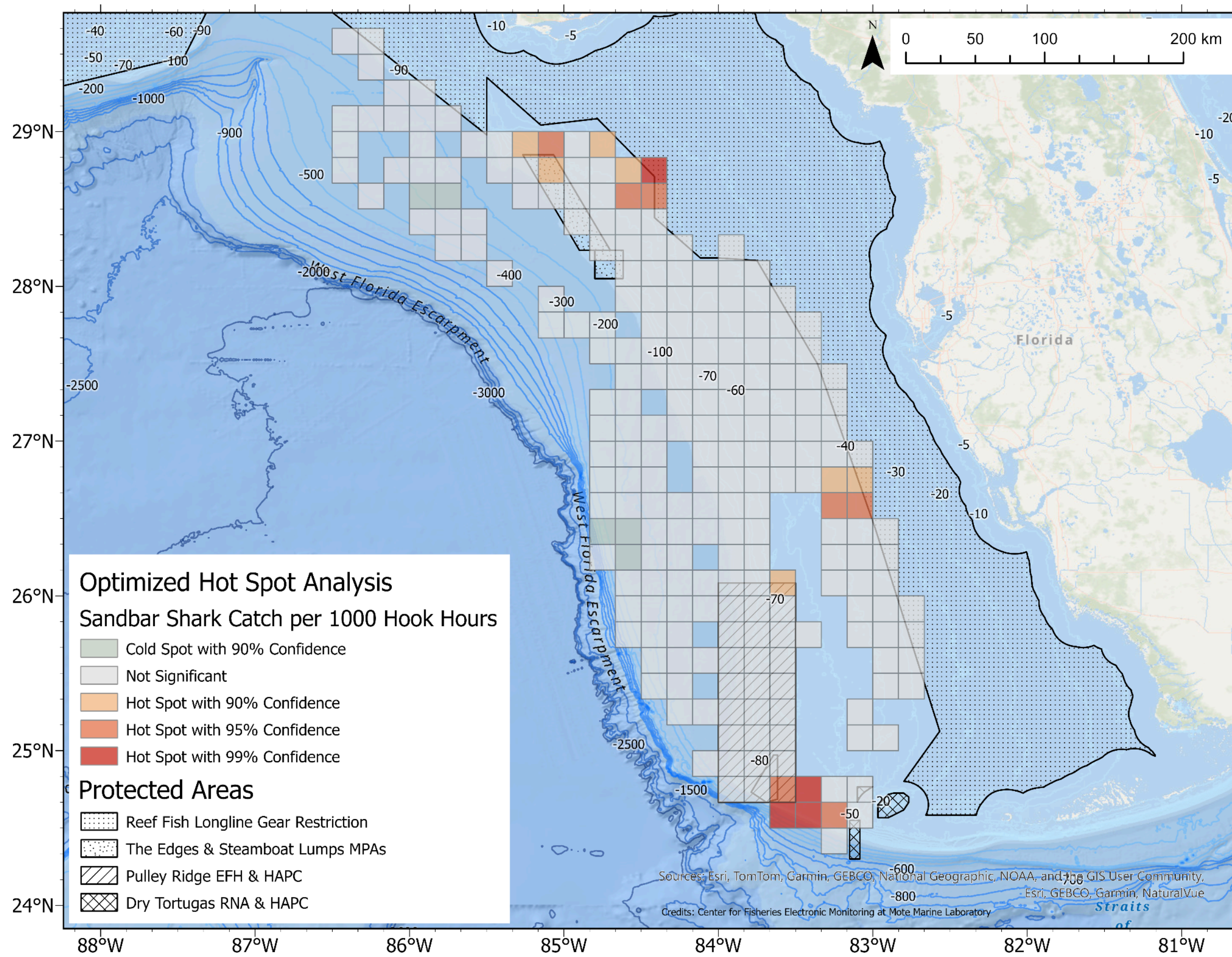

Figure 2. Hotspot analysis for sandbar shark catch per 1000 hook hours in the eastern Gulf bottom longline fishery with a grid cell size of 10 x 10 min, 7/2016 - 12/2024.

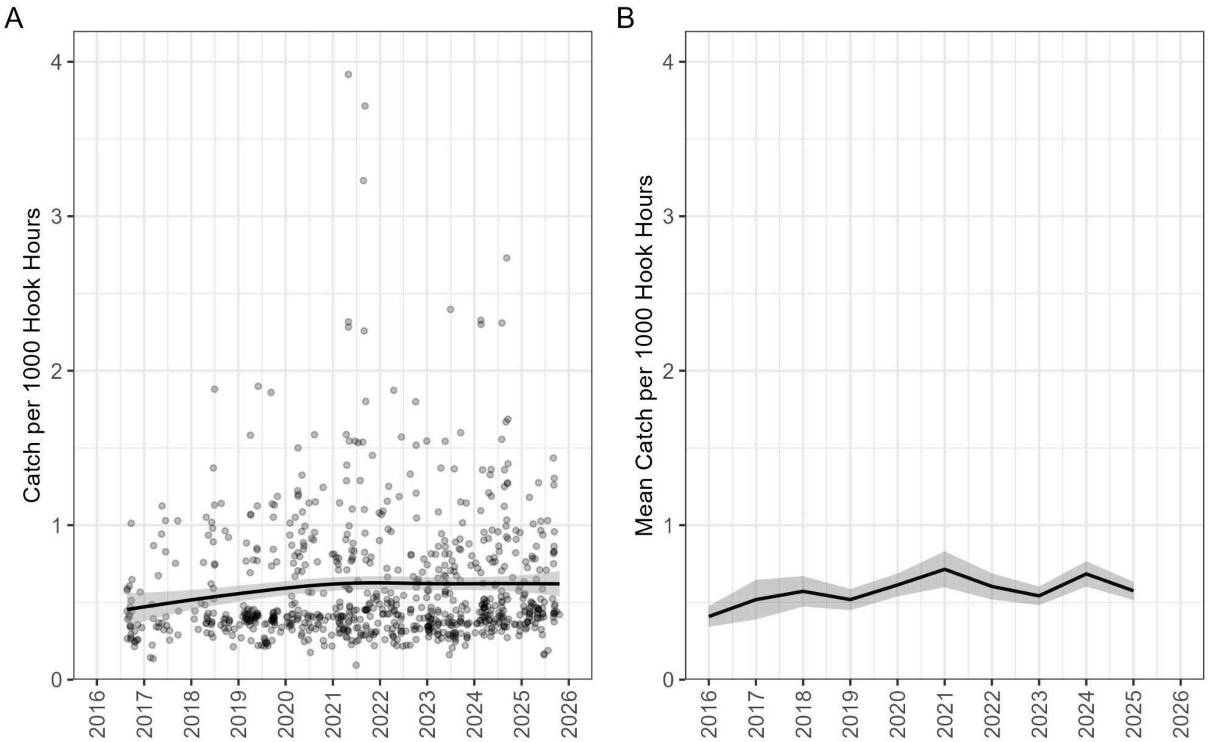

Figure 3. A) Sandbar shark catch per unit effort GAM, where each point represents one haul, and B) average catch per unit effort per year for the eastern Gulf reef fish bottom longline fishery, 7/2016 - 10/2025.

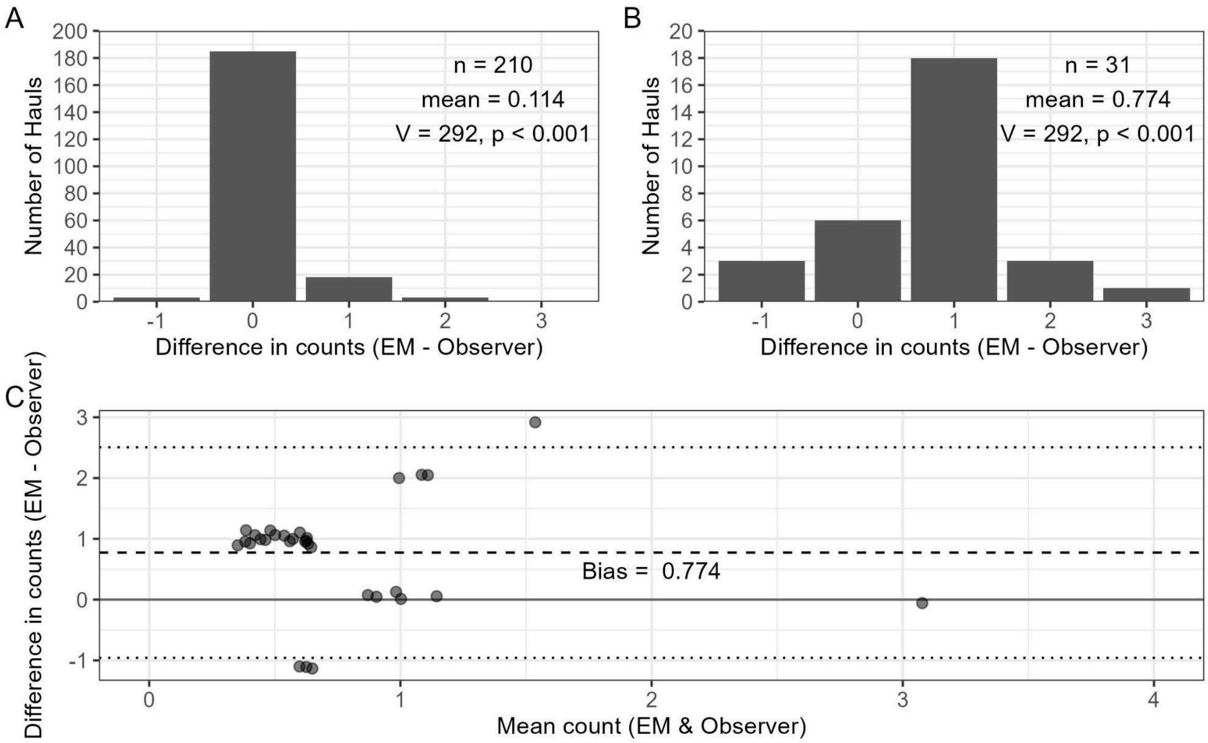

Figure 4. A) Frequency plot of the difference (EM - Observer) in number of sandbar sharks counted per haul for matched bottom longline hauls where the annotations denote Wilcoxon signed-rank test results. B) Frequency plot of the difference (EM - Observer) in number of sandbar sharks counted per haul for matched bottom longline hauls where at least one sandbar shark was identified by either EM or an Observer. C) Bland-Altman agreement plot of the difference in counts and mean count for electronic monitoring and observer data, where each point is jittered and represents one haul in the instances where at least one sandbar shark was identified by either EM or an Observer (*n*=31), the dashed line represents the average bias, and the dotted lines represent the limits of agreement.

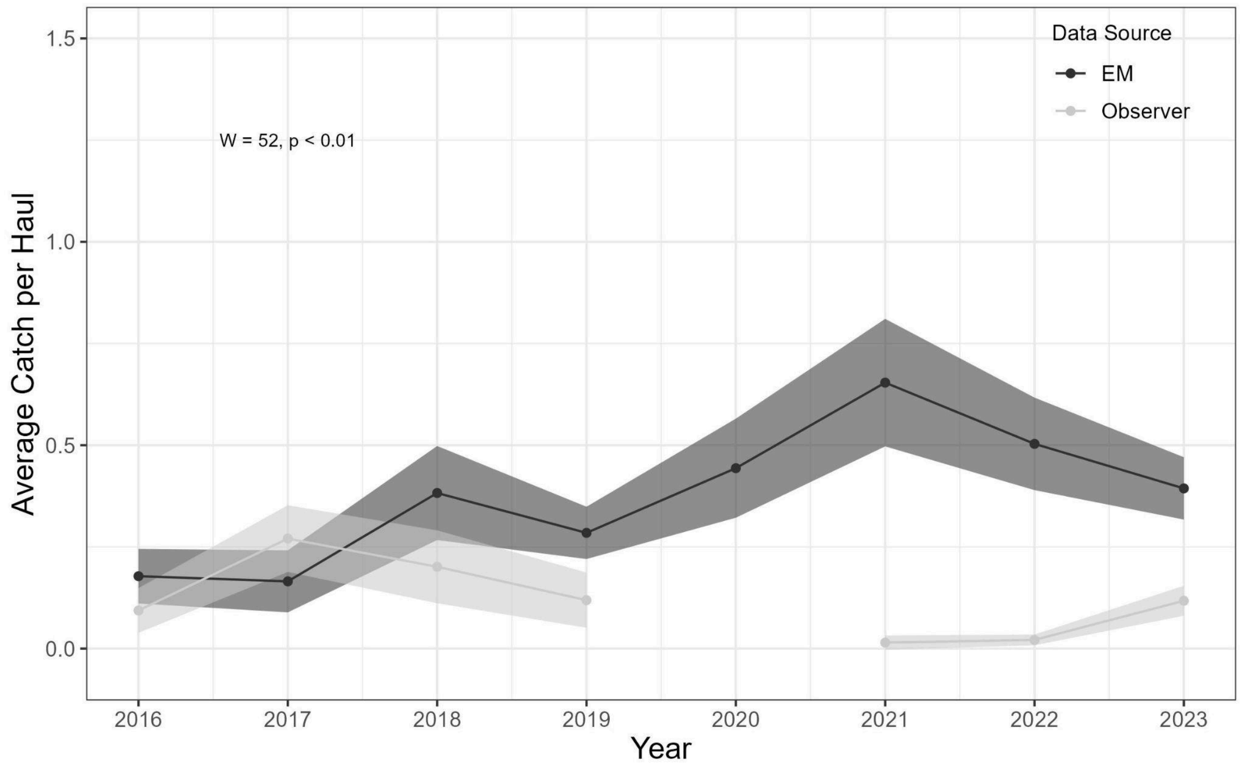

Figure 5. Average annual sandbar shark catch per haul for bottom longline vessels fishing in the eastern Gulf, as documented through electronic monitoring or an at-sea observer, where the ribbons denote the 95% confidence intervals and the annotations denote Wilcoxon rank-sum test results.

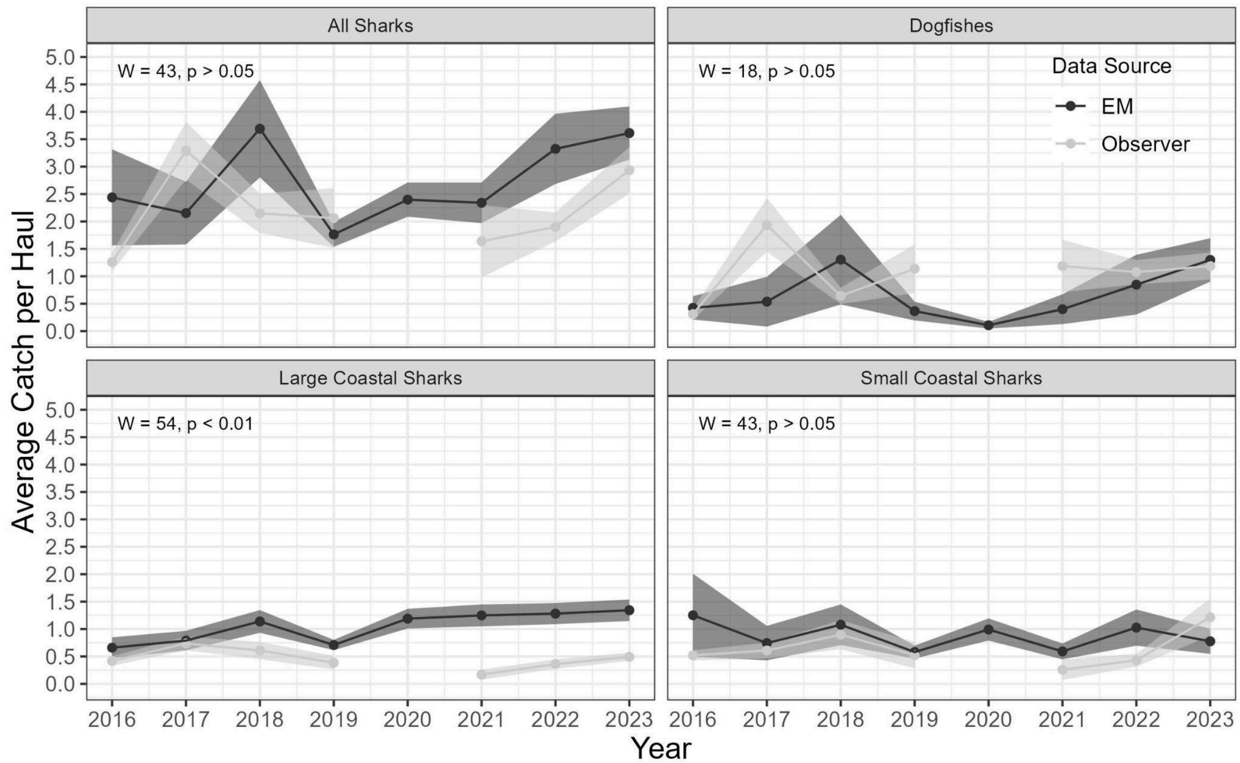

Figure 6. Average annual catch per haul of major species groups for bottom longline vessels fishing in the eastern Gulf, as documented through electronic monitoring or an at-sea observer, where the ribbons denote the 95% confidence intervals and the annotations denote Wilcoxon rank-sum test results.

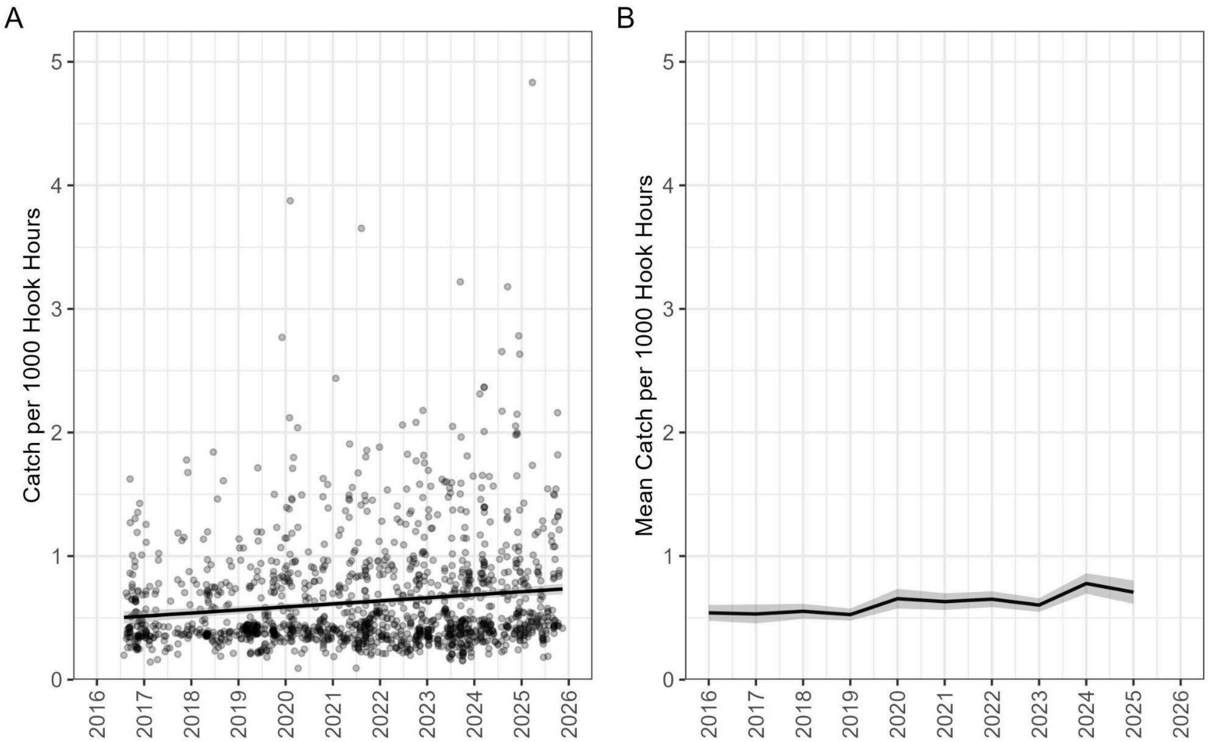

Figure 7. A) Depredated species catch per unit effort GAM, where each point represents one haul, and B) average catch per unit effort per year for the eastern Gulf reef fish bottom longline fishery, 7/2016 - 10/2025.

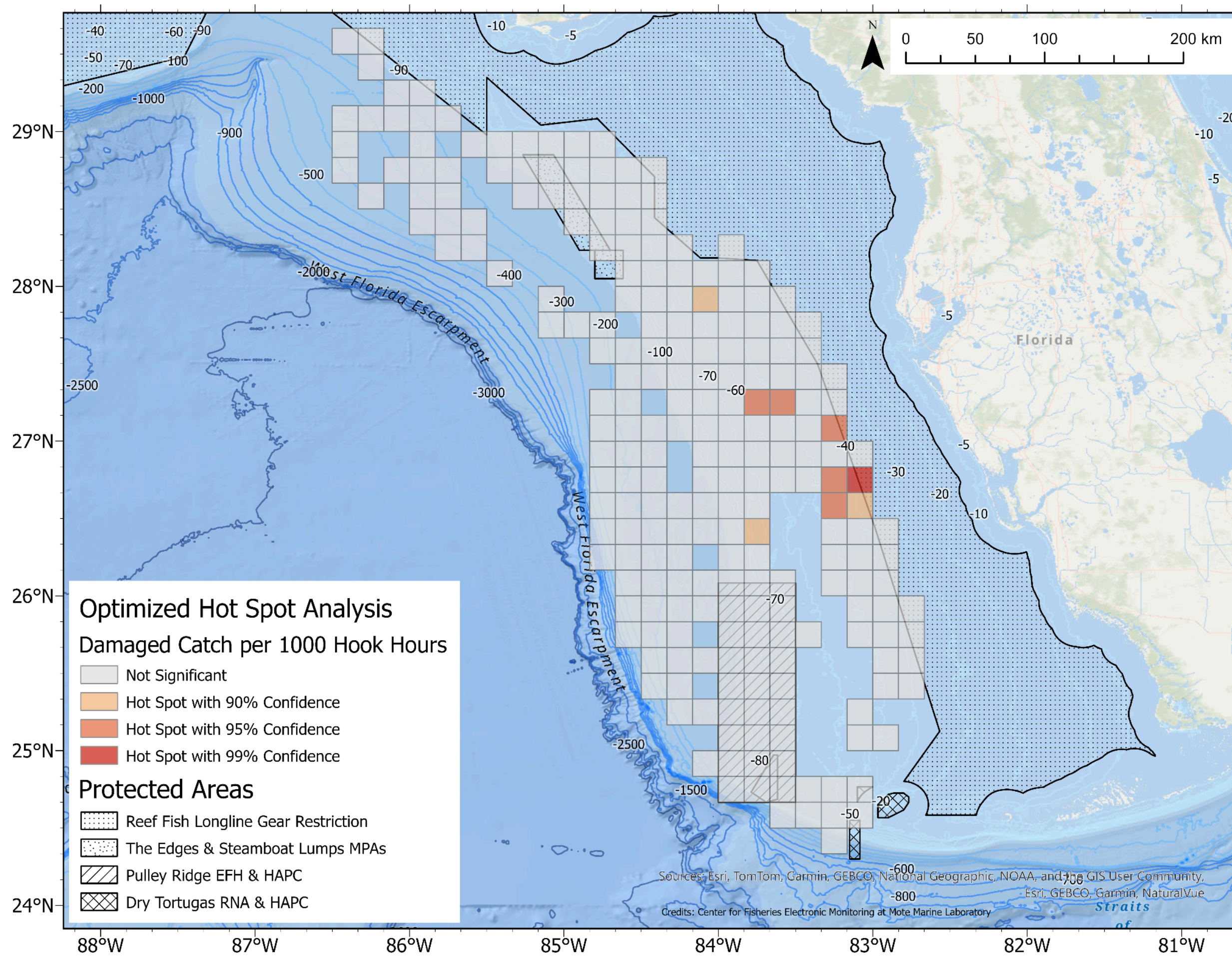

Figure 8. Hotspot analysis for damaged catch per 1000 hook hours in the eastern Gulf bottom longline fishery with a grid cell size of 10 x 10 min, 7/2016 - 12/2024.