__**Request**__: The GFSC suggests that an analysis of the seasonality of bycatch rates of spiny dogfish from WCGOP and other available data sources (e.g., ASHOP, Pikitch et al. bycatch study) should be conducted to evaluate whether the data indicate a strong seasonal availability of spiny dogfish as bycatch to fisheries. A reasonable way to do this would be **to examine haul-specific catch rates in a General Linear Model (GLM)** or delta-GLM (depending on the frequency of occurrence of dogfish in a given dataset), **with the primary factor of interest being month (or some other seasonal variable,** such as julian day bins, two month periods, etc. **as appropriate given the data) as a factor, along with appropriate covariates that were determined by the analyst.** These might include year, depth, latitude/state or region, vessel size or power, gear type, stated fishing strategy or comparable information. Alternatively, it may be feasible to explore the use of modeling frameworks such as VAST or 'sdmTMB' (see https://pbs-assess.github.io/sdmTMB/index.html) to develop this analysis. It may also be appropriate to do separate analyses by region (e.g., WA coast, OR coast, Northern CA coast), in addition, depending on data availability, in order to facilitate interpretation of model results. **As with any such model an exploration of available information and relevant covariates will require some exploratory work**, but GLMs and delta-GLMs are standard tools for any assessment analyst and the precise approach should be at the analyst's discretion.

Rationale*: The results should provide an indication, albeit imperfect as there will certainly be challenges associated with developing a conclusive result from these data sources, of the relative differences in catch rates of dogfish by fisheries participants. This alone should provide some insights to the SSC and to the PFMC (who made the formal request) with respect to how encounter and catch rates in the fisheries themselves appear to change seasonally, and thus the extent to which the model-estimated q was consistent with seasonal fluxes in catch rates. For example, if catch rates were on average 10x greater between November and March than those between April and October, then a survey estimated q greater than 0.5 for a survey that exclusively takes place between April and October may be a questionable model result. In such a scenario, there may be the potential to develop a weakly informative "upper bound" prior for catchability based on the ratio of bycatch rates during the months during which the survey takes place relative to the months in which spiny dogfish are likely to be more abundant. This request does not include an explicit request to develop such a prior, but rather will provide the SSC with a basis for considering whether such an approach might be feasible and worthwhile in light of the limited time remaining in this stock assessment cycle.*

Highlights:

- We analyzed spiny dogfish catch rates in the bottom trawl fishery, observed by the NMFS West Coast Groundfish Observer Program (WCGOP), to explore a hypothesis of potentially lower availability of spiny dogfish during the survey period than throughout the whole year due to seasonal migration.
- Generalized Linear Models, which we ran with multiple factors, showed that season, defined as survey vs non-survey weeks, was a significant predictor of dogfish CPUE. In an alternative model using month as the temporal variable, month was significant and all months were significantly different from the reference month. Due to large sample sizes (>100,000 hauls), even very small differences in variables were significant in the GLM. Raw data were also explored for catch rate trends and uncertainty, reported in tables and figures.
- GLMs were run with seasonality defined in two different ways. We defined season as being within or outside of the WCGBT Survey period, by week; which addressed the immediate question at hand: whether availability of spiny dogfish during the survey period was representative of the year. Defining survey period by week used a reasonable level of precision, and the results showed little difference in catch rate between survey and non-survey periods.
- Additionally, we defined seasonality by month. Analyzing catch rates by month showed more granularity of trend throughout the year, and larger coefficient values during four winter months (November through February), versus eight non-winter months, but examining months is misleading for the question of representativeness of survey period catch rates, since months do not align with survey start and stop dates, and thus do not adequately capture survey vs non-survey periods.
- The ratio of aggregate spiny dogfish catch rates calculated from raw data during the survey season (survey weeks) versus the entire year was 0.8994, which implies a seasonal component of WCGBTS survey catchability of around 0.9. Importantly, when this ratio was calculated as annual average, the average of the annual averages was very similar (0.8410), but showed high inter-annual variability. CPUE for survey and non-survey weeks changed ranks frequently among years.
- Fishery data, particularly for a mixed target fishery such as West Coast bottom trawl, possess multiple caveats, potentially confounding factors owing to the number of different targets pursued throughout the year and their temporal distribution, varying fisher behavior, variability in economic and weather conditions, making it challenging to reliably inform survey catchability. See text for discussion of data sources considered.
- Conclusion: Based on these results, it is difficult to make a defensible argument for a value of WCGBT Survey catchability being lower than that estimated in the assessment model (0.586).

Methods

We examined spiny dogfish catch rates in the bottom trawl fishery as observed by WCGOP from years 2002-2019, with an objective of shedding light upon a hypothesis of potentially lower availability of spiny dogfish during the survey period than throughout the whole year.

We implemented a Generalized Linear Model (GLM) to examine which factors were significant in predicting spiny dogfish CPUE in this trawl fishery sector. Due to very restricted time, the

GLM was performed without hierarchical treatment (zero vs non-zero). For the GLM, the log of the dependent variable (metric tons per hour) was used with identity link and Gaussian errors. A vanishingly small amount was added to each zero haul to enable the log of the dependent variable– half the minimum of the non-zero values was added to all the zero values (3.532e-10). Adding up all of these 57,912 adjusted zero values equals 2.045e-05, and should be quite inconsequential to results of the analysis.

There was not sufficient time to develop a VAST procedure (e.g. that would estimate an abundance index based on CPUE), nor a delta-GLM; results of hierarchical GLM would also be of less value for interpretation, separated between zero and non-zero hauls.

GLMs were run with seasonality defined in two different ways. We defined season as being within or outside of the WCGBT Survey period, by week; which addressed the immediate question at hand: whether availability of spiny dogfish during the survey period was representative of the year. Additionally, we defined seasonality by month.

We examined year, latitude (North and South of 45°46' N.), survey season and depth (fm), as factors in the GLM. The latitude of 45°46' N. (the southern border of PSMFC area 3A) represented a break identified in CPUE in the data, near Cape Falcon, OR, and reflected the much higher northern catch of spiny dogfish. Survey season was defined by weeks, as weeks 20 through 42. Defining survey season by weeks was much more precise than analyzing by month, as survey season begins and ends mid-month. In the other GLM, we examined the same factors, except we used month as the temporal (seasonal) variable, instead of survey season.

In both models, we fitted depth as a polynomial function to reflect the overall depth profile in the spiny dogfish data. The depth polynomial with a degree of eight was selected using AIC. We also included month by area interaction to reflect spiny dogfish movements within year and area. Interaction between depth and other variables was not modeled, due to concern of confounding with fishing behavior by area and time. A final model specification includes a reasonable set of variables, and shows their relative importance and contrast within them. Including additional interactions would lead to an overly complicated model, with potentially misleading results from overfitting.

Finally, using raw catch rate data, we calculated ratios of average spiny dogfish CPUE during the WCBGT Survey season, versus the full fishing year; both in aggregate with all years combined, and by year.

Results

A map of catch rates of spiny dogfish for bottom trawl fishery hauls is shown by months in Figure 1.

We found (based on GLM) that survey season was a significant predictor of dogfish CPUE ($p=<<0.05$). The output for the model is summarized in Table 1, and the contrast in estimated factor coefficients with standard errors around them is shown Figure 2. Defining survey period by week used a reasonable level of precision, and the results showed little contrast between survey and non-survey periods.

We also found (based on alternative GLM) that month was a significant predictor of dogfish CPUE (p=<<0.05, Table 2), and all months were significantly different from the reference month (January). Latitude (area) was also significant (p=<<0.05). Most years were significantly different from the reference year (2002). The GLM output for the model (with month as a factor) summarized in Table 2, and the contrast in estimated factor coefficients with standard errors around them is shown Figure 3. Analyzing catch rates by month showed more granularity of trend throughout the year, and larger coefficient values during four winter months (November through February), versus eight non-winter months, but examining months is misleading for the question of representativeness of survey period catch rates, since months do not align with survey start and stop dates, and thus do not adequately capture survey vs non-survey periods.

The ratio of average spiny dogfish catch rates as calculated from raw data (for all hauls combined, 2002-2019) during the survey season (week 20 through week 42) versus the entire year was 0.8994 (Table 3), which implies a seasonal component of WCGBTS survey catchability of around 0.9.

The average annual catch rate of spiny dogfish, calculated during survey weeks, versus non-survey weeks vary considerably among years (Table 4, Figure 4), changing rank regularly, although most values were within one standard deviation (Table 5).

Spiny dogfish CPUE (mt per hour) was highly skewed to overwhelmingly zero and near-zero values (Figure 5). This may partially reflect lack of targeting by fishers (32 hauls out of over 100,000 were declared as spiny dogfish targeted in WCGOP data). At the same time, a substantial amount of extreme catch events were present in every year and in both survey and non-survey months (Figure 6), which could reflect schooling behavior of the species, showing through sporadic extreme bycatch events.

On average, the percentage of positive hauls was higher between Nov and February (Table 7), and catch rates were higher during those four months, but with very large uncertainty intervals (Table 6, Figure 7). Percent positive hauls and catch rates among other months were similar. Mean spiny dogfish CPUE by year *and* month are shown in Table 6.

We found that when looking at only larger hauls (those with catch larger than 0.25mt and then larger than 2.5 mt), catch rates are higher in summer (Figure 8 and Figure 9), potentially indicating that larger aggregations of spiny dogfish occur during summer months.

Average annual CPUE of spiny dogfish varies considerably among years, from 0.0064 to 0.0451 mt/hr, with a mean of 0.0148, and a CV of 0.5862. Haul counts (n) were within the range of from 2,600 to 10,000 per year, with an average of 5,707.

Discussion and interpretation

Fishery catches occur primarily in the North, consistently, year-round (Figure 1), and there are high catch rates during winter as well as summer (at the time of WCGBTS survey).

GLM results generally reflected the same trends we see in summaries of raw data. Highest CPUE was in north of 45°46′ N lat.; CPUE varies substantially by year, and average CPUE per year between survey, non-survey weeks, and the whole year vary little from one another.

Although we see that CPUE during survey weeks is overall slightly lower than the whole year, and non-survey weeks, annual survey vs non-survey CPUE means change ranks regularly from year-to-year over the time series (Fig. 4), and generally are within one standard deviation of one another (Table 5), reflecting both the small difference, and the inter-annually variable nature of spiny dogfish catch rates, both overall and among seasons.

Despite the highly skewed distribution of dogfish CPUE toward zero and non-zero hauls, extreme catch or bycatch events are consistent among years and seasons, likely reflecting both fishery (lack of targeting) and schooling behavior of the species.

Whether we calculate the ratio of CPUE (survey season vs. all year) using the aggregate of all data (0.9), or taking the average of mean annual CPUE (0.84), the two metrics are very similar; and most importantly reflect the similarity of CPUE among these periods.

These findings are consistent with Taylor (2008), who based on historical tagging data, estimated movement rates of approximately 5% per year, between the U.S. coastal sub-population of dogfish, and that found along the west coast of Vancouver Island in Canada.

It is difficult to make a strong argument for a value of *q* which is lower than that estimated in the assessment model based on these results, which suggest an availability of spiny dogfish to the survey trawl of around 90 percent.

It is also important to remember the generally low suitability of fishery data for estimating a parameter such as catchability, with all of the fishery data's caveats and potentially confounding factors owing to the number of different targets pursued throughout the year, varying fisher behavior, differences among vessels, variability in economic and weather conditions, and so on.

Results of these analysis indicate that spatial dynamics of spiny dogfish may be more complex than previously thought. For instance, the map of catch rates by months suggest that there could be three potential migration curves present, each with limited latitudinal range (Figure 10). Similar patterns of limited latitudinal migrations were recently reported for Atlantic spiny dogfish, *Squalus acanthias* (Carlson et al. 2014). Timing of these smaller scale distribution shifts north and south among several groups is consistent with Taylor (2008).

We relied on bottom trawl fishery data, as other sources that we considered, including at-sea hake fishery (observed by ASHOP) midwater trawl fishery data (observed by WCGOP), and historical Pikitch study were not suitable for seasonal analysis. The Pikitch study was limited geographically to the Columbia INPFC area, while at-sea hake and midwater trawl fishery data had limited latitudinal range and limited seasonality (Figures 11-12), making each insufficient to show geographic movement through either a sufficient geographic range (coast), or seasonal range (year), respectively. The current whiting fishery season begins on May 15, and often finishes before the end of the year.

References

Carlson, A. E., Hoffmayer, E.R., Tribuzio, C.A., Sulikowski, J.A. 2014. The use of satellite tags to redefine movement patterns of spiny dogfish (*Squalus acanthias*) along the US east coast: implications for fisheries management. PLoS One 28; 9(7):e103384.

Taylor, I.G., 2008. Modeling spiny dogfish population dynamics in the Northeast Pacific (Doctoral dissertation, University of Washington).

Table 1. GLM results (with year, survey season, depth and area as factors).

Coefficients:	Estimate	Std.Error	tvalue	Pr(>|t|)
(Intercept)	-9.51E+00	1.90E-01	-50.01	<2e-16
DYEAR2003	6.71E-02	1.80E-01	0.372	0.70962
DYEAR2004	6.08E-01	1.64E-01	3.72	0.0002
DYEAR2005	2.98E+00	1.62E-01	18.358	<2e-16
DYEAR2006	1.94E+00	1.71E-01	11.376	<2e-16
DYEAR2007	1.23E+00	1.77E-01	6.945	3.80E-12
DYEAR2008	1.62E+00	1.68E-01	9.639	<2e-16
DYEAR2009	1.57E+00	1.59E-01	9.848	<2e-16
DYEAR2010	1.35E+00	1.78E-01	7.545	4.57E-14
DYEAR2011	1.35E+00	1.41E-01	9.559	<2e-16
DYEAR2012	1.42E+00	1.41E-01	10.041	<2e-16
DYEAR2013	8.30E-03	1.39E-01	0.06	0.95245
DYEAR2014	1.01E+00	1.43E-01	7.072	1.54E-12
DYEAR2015	-3.73E-01	1.44E-01	-2.592	0.00955
DYEAR2016	-6.11E-01	1.46E-01	-4.195	2.73E-05
DYEAR2017	-1.64E+00	1.46E-01	-11.258	<2e-16
DYEAR2018	-2.86E-02	1.49E-01	-0.191	0.84842
DYEAR2019	-3.61E-01	1.51E-01	-2.389	0.01691
North_45_deg_46_minSouth	-2.63E+00	1.85E-01	-14.247	<2e-16
Survey_weeksWeeks_20:42	-7.82E-01	1.04E-01	-7.523	5.40E-14
poly(AVG_DEPTH,degree=8)1	-625.1	7.90E+00	-79.174	<2e-16
poly(AVG_DEPTH,degree=8)2	-364.7	7.25E+00	-50.336	<2e-16
poly(AVG_DEPTH,degree=8)3	580.7	6.90E+00	84.108	<2e-16
poly(AVG_DEPTH,degree=8)4	-160.8	7.01E+00	-22.953	<2e-16
poly(AVG_DEPTH,degree=8)5	-170.2	6.98E+00	-24.389	<2e-16
poly(AVG_DEPTH,degree=8)6	132.1	6.90E+00	19.135	<2e-16
poly(AVG_DEPTH,degree=8)7	15.73	6.91E+00	2.277	0.02281
poly(AVG_DEPTH,degree=8)8	-54.48	6.93E+00	-7.864	3.74E-15
North_45_deg_46_minNorth:DMONTH2	-1.61E+00	1.97E-01	-8.208	2.28E-16
North_45_deg_46_minSouth:DMONTH2	-2.23E+00	1.49E-01	-14.974	<2e-16
North_45_deg_46_minNorth:DMONTH3	-3.43E+00	1.90E-01	-18.049	<2e-16
North_45_deg_46_minSouth:DMONTH3	-4.64E+00	1.40E-01	-33.169	<2e-16
North_45_deg_46_minNorth:DMONTH4	-3.82E+00	1.80E-01	-21.233	<2e-16
North_45_deg_46_minSouth:DMONTH4	-5.65E+00	1.42E-01	-39.787	<2e-16
North_45_deg_46_minNorth:DMONTH5	-6.41E+00	1.88E-01	-34.172	<2e-16
North_45_deg_46_minSouth:DMONTH5	-5.60E+00	1.57E-01	-35.568	<2e-16
North_45_deg_46_minNorth:DMONTH6	-6.37E+00	2.08E-01	-30.712	<2e-16
North_45_deg_46_minSouth:DMONTH6	-4.50E+00	1.80E-01	-24.943	<2e-16
North_45_deg_46_minNorth:DMONTH7	-5.50E+00	2.09E-01	-26.312	<2e-16
North_45_deg_46_minSouth:DMONTH7	-4.86E+00	1.78E-01	-27.348	<2e-16
North_45_deg_46_minNorth:DMONTH8	-5.17E+00	2.11E-01	-24.576	<2e-16
North_45_deg_46_minSouth:DMONTH8	-5.26E+00	1.75E-01	-30.112	<2e-16
North_45_deg_46_minNorth:DMONTH9	-1.52E+00	2.19E-01	-6.943	3.86E-12
North_45_deg_46_minSouth:DMONTH9	-5.33E+00	1.76E-01	-30.338	<2e-16
North_45_deg_46_minNorth:DMONTH10	-1.98E+00	2.17E-01	-9.136	<2e-16
North_45_deg_46_minSouth:DMONTH10	-4.02E+00	1.58E-01	-25.476	<2e-16
North_45_deg_46_minNorth:DMONTH11	-1.72E+00	2.44E-01	-7.055	1.74E-12
North_45_deg_46_minSouth:DMONTH11	-9.41E-01	1.51E-01	-6.229	4.71E-10
North_45_deg_46_minNorth:DMONTH12	-9.49E-01	2.40E-01	-3.952	7.75E-05
North_45_deg_46_minSouth:DMONTH12	-4.23E-01	1.62E-01	-2.61	0.00905

Table 2. GLM results (with year, month, depth and area as factors).

Coefficients:	**Estimate**	**Std.Error**	**tvalue**	**Pr(>|t|)**
(Intercept)	-9.52164	0.19023	-50.052	<2e-16
DYEAR2003	0.07869	0.18033	0.436	0.662557
DYEAR2004	0.6027	0.16355	3.685	0.000229
DYEAR2005	2.99007	0.16219	18.435	<2e-16
DYEAR2006	1.93591	0.17083	11.332	<2e-16
DYEAR2007	1.2443	0.17688	7.035	2.01E-12
DYEAR2008	1.61549	0.16807	9.612	<2e-16
DYEAR2009	1.54938	0.15907	9.741	<2e-16
DYEAR2010	1.34401	0.17837	7.535	4.92E-14
DYEAR2011	1.34387	0.14077	9.546	<2e-16
DYEAR2012	1.41239	0.1414	9.989	<2e-16
DYEAR2013	0.01432	0.13925	0.103	0.918105
DYEAR2014	1.01598	0.14264	7.123	1.06E-12
DYEAR2015	-0.38349	0.14395	-2.664	0.007724
DYEAR2016	-0.61139	0.1457	-4.196	2.72E-05
DYEAR2017	-1.63065	0.14608	-11.163	<2e-16
DYEAR2018	-0.0312	0.14946	-0.209	0.834654
DYEAR2019	-0.34117	0.1513	-2.255	0.024143
North_45_deg_46_minSouth	-2.62706	0.18453	-14.237	<2e-16
DMONTH2	-1.61195	0.19675	-8.193	2.58E-16
DMONTH3	-3.42676	0.18994	-18.042	<2e-16
DMONTH4	-3.81222	0.17997	-21.182	<2e-16
DMONTH5	-6.86468	0.17767	-38.637	<2e-16
DMONTH6	-7.13345	0.18125	-39.357	<2e-16
DMONTH7	-6.2587	0.18296	-34.208	<2e-16
DMONTH8	-5.93214	0.18472	-32.114	<2e-16
DMONTH9	-2.28081	0.1942	-11.745	<2e-16
DMONTH10	-2.51848	0.20521	-12.273	<2e-16
DMONTH11	-1.71393	0.24387	-7.028	2.11E-12
DMONTH12	-0.94659	0.24016	-3.941	8.11E-05
poly(AVG_DEPTH,degree=8)1	-621.91147	7.88611	-78.862	<2e-16
poly(AVG_DEPTH,degree=8)2	-366.80679	7.24233	-50.648	<2e-16
poly(AVG_DEPTH,degree=8)3	580.61296	6.9057	84.077	<2e-16
poly(AVG_DEPTH,degree=8)4	-159.71447	7.00591	-22.797	<2e-16
poly(AVG_DEPTH,degree=8)5	-171.27991	6.98113	-24.535	<2e-16
poly(AVG_DEPTH,degree=8)6	133.11536	6.90226	19.286	<2e-16
poly(AVG_DEPTH,degree=8)7	15.24981	6.91282	2.206	0.027385
poly(AVG_DEPTH,degree=8)8	-55.1925	6.929	-7.965	1.66E-15
North_45_deg_46_minSouth:DMONTH2	-0.6148	0.24657	-2.493	0.012651
North_45_deg_46_minSouth:DMONTH3	-1.20963	0.2356	-5.134	2.84E-07
North_45_deg_46_minSouth:DMONTH4	-1.83285	0.22837	-8.026	1.02E-15
North_45_deg_46_minSouth:DMONTH5	0.79763	0.22688	3.516	0.000439
North_45_deg_46_minSouth:DMONTH6	1.86802	0.23026	8.113	5.00E-16
North_45_deg_46_minSouth:DMONTH7	0.6305	0.22933	2.749	0.005974
North_45_deg_46_minSouth:DMONTH8	-0.0979	0.22846	-0.429	0.66826
North_45_deg_46_minSouth:DMONTH9	-3.8274	0.23792	-16.087	<2e-16
North_45_deg_46_minSouth:DMONTH10	-1.99706	0.24864	-8.032	9.70E-16
North_45_deg_46_minSouth:DMONTH11	0.77112	0.2867	2.69	0.007155
North_45_deg_46_minSouth:DMONTH12	0.52169	0.28902	1.805	0.07107

Table 3. Spiny dogfish average catch rates calculated for survey season (week 20 through week 42), non-survey season and the entire year (for all years combined).

	Mean	SE	N
Survey season	0.01280324	0.001011615	52228
Non survey season	0.01571525	0.000983506	50506
Year	0.01423484	0.000705895	102734
Survey season/Year	**0.89942985**		

Table 4. Average annual CPUE (mean per haul) of spiny dogfish, calculated during survey weeks, versus non-survey weeks. Most values are w/in one S.D. of one another.

Year	Non-survey	Survey	All	Survey/All
2002	0.02276779	0.01926025	0.021058	0.914623
2003	0.01321884	0.00664692	0.010329	0.643496
2004	0.01046075	0.01608786	0.013382	1.2022
2005	0.01051235	0.0692943	0.045087	1.536916
2006	0.01541151	0.01865452	0.017479	1.067239
2007	0.01334199	0.00635932	0.009452	0.672812
2008	0.01549387	0.01559429	0.015549	1.002883
2009	0.01595565	0.0066839	0.01095	0.610399
2010	0.00944747	0.00496199	0.006952	0.713771
2011	0.01825857	0.00760031	0.012767	0.595329
2012	0.02146823	0.00791999	0.014278	0.554716
2013	0.01624698	0.00408252	0.010719	0.380884
2014	0.02890651	0.00825366	0.019367	0.426177
2015	0.01007033	0.00600467	0.008207	0.731644
2016	0.00862107	0.01379425	0.011096	1.243139
2017	0.0077604	0.00497066	0.006431	0.772956
2018	0.01336901	0.02489742	0.019443	1.280543
2019	0.01707489	0.01115338	0.014152	0.788108
Mean				**0.840991**

Table 5. Average annual CPUE (mean per haul) of spiny dogfish, calculated during survey weeks, versus non-survey weeks, with standard deviation. Most values are w/in one S.D. of one another.

Year	Non-survey mean CPUE	Survey mean CPUE	StdDev non-survey	StdDev survey
2002	0.022767789	0.019260253	0.166546839	0.25024174
2003	0.013218838	0.006646923	0.068624957	0.066178131
2004	0.010460747	0.016087863	0.065983805	0.173741039
2005	0.010512349	0.069294295	0.10055901	0.575679995
2006	0.01541151	0.018654517	0.052396648	0.162070491
2007	0.013341987	0.00635932	0.043761359	0.028141967
2008	0.015493872	0.015594288	0.058033329	0.080342733
2009	0.01595565	0.006683903	0.070603449	0.038790899
2010	0.009447471	0.004961988	0.043828526	0.030012195
2011	0.018258571	0.007600306	0.188195798	0.063530955
2012	0.021468234	0.00791999	0.259784458	0.098556709
2013	0.016246976	0.004082517	0.348248988	0.028903908
2014	0.028906515	0.008253662	0.387550673	0.090434024
2015	0.010070326	0.006004673	0.186470001	0.044861283
2016	0.008621066	0.013794254	0.207965065	0.186425644
2017	0.007760404	0.004970661	0.088076093	0.090211313
2018	0.013369008	0.024897419	0.188941392	0.650539394
2019	0.01707489	0.011153381	0.183637076	0.174402409

Table 6. Number of zero and positive spiny dogfish hauls by month.

Month	N of zero hauls	N of positive hauls	Total
1	2156	3928	6084
2	3417	3969	7386
3	5689	3780	9469
4	6186	4243	10429
5	6943	3846	10789
6	6469	3585	10054
7	6500	3844	10344
8	6849	3941	10790
9	5273	3902	9175
10	4535	3492	8027
11	2285	3279	5564
12	1612	3013	4625

Table 7. Mean spiny dogfish CPUE (mt/hr) by month, among all years, 2002-2019, in the bottom trawl fishery.

Month	Mean CPUE (mt/hr)	S.D.	CV	Haul count
1	0.03483	0.44989	1292%	6084
2	0.01876	0.19375	1033%	7386
3	0.00771	0.11642	1510%	9469
4	0.01149	0.17214	1498%	10429
5	0.00560	0.08127	1451%	10789
6	0.01309	0.37377	2855%	10054
7	0.01376	0.25240	1835%	10344
8	0.01070	0.12042	1125%	10790
9	0.01811	0.21218	1171%	9175
10	0.01348	0.14505	1076%	8027
11	0.01843	0.17990	976%	5564
12	0.01996	0.23515	1178%	4625

Table 8. Mean spiny dogfish CPUE (mt/hr) by year and month, among all years, 2002-2019, in the bottom trawl fishery.

Year	Month	Mean CPUE (mt/hr)	S.D.	CV	Haul count
2002	1	0.01926	0.06937	360%	205
2002	2	0.03058	0.27381	896%	276
2002	3	0.01932	0.20914	1083%	290
2002	4	0.03128	0.14452	462%	449
2002	5	0.01054	0.03283	311%	290
2002	6	0.00809	0.03841	475%	350
2002	7	0.05787	0.52526	908%	349
2002	8	0.01044	0.04862	466%	303
2002	9	0.00160	0.01262	790%	64
2002	10	0.00428	0.01653	386%	455
2002	11	0.02089	0.10305	493%	152
2002	12	0.03471	0.09151	264%	38
2003	1	0.00867	0.06735	777%	127
2003	2	0.00609	0.02839	466%	228
2003	3	0.00131	0.00654	499%	236
2003	4	0.02495	0.10560	423%	488
2003	5	0.00171	0.00762	445%	236
2003	6	0.00103	0.00616	597%	327
2003	7	0.00450	0.03360	747%	205
2003	8	0.02404	0.14847	618%	213
2003	9	0.00491	0.01563	318%	159
2003	10	0.00653	0.01741	267%	218
2003	11	0.01879	0.05958	317%	151
2003	12	0.00863	0.01445	167%	39
2004	1	0.01028	0.03813	371%	195
2004	2	0.01484	0.05154	347%	227
2004	3	0.01126	0.10832	962%	458
2004	4	0.00929	0.03553	383%	554
2004	5	0.01446	0.08018	555%	256
2004	6	0.02128	0.07047	331%	280
2004	7	0.00980	0.03603	368%	473
2004	8	0.02572	0.30505	1186%	609
2004	9	0.01350	0.07699	570%	324
2004	10	0.00113	0.00949	840%	212
2004	11	0.00489	0.03141	642%	181
2004	12	0.00869	0.03198	368%	149
2005	1	0.01929	0.09219	478%	194
2005	2	0.00750	0.01744	233%	283

2005	3	0.00251	0.01043	416%	392
2005	4	0.02450	0.20968	856%	334
2005	5	0.01259	0.04262	339%	472
2005	6	0.08690	0.61560	708%	554
2005	7	0.09293	0.87515	942%	690
2005	8	0.02997	0.11956	399%	622
2005	9	0.11271	0.40568	360%	274
2005	10	0.00103	0.00723	703%	85
2005	11	0.00896	0.04096	457%	92
2005	12	0.00180	0.00873	485%	85
2006	1	0.02999	0.04113	137%	97
2006	2	0.01302	0.03671	282%	278
2006	3	0.00084	0.00202	241%	64
2006	4	0.00470	0.02432	518%	327
2006	5	0.00238	0.00750	315%	357
2006	6	0.01289	0.04062	315%	256
2006	7	0.02003	0.19507	974%	539
2006	8	0.01129	0.06608	585%	559
2006	9	0.03540	0.27224	769%	391
2006	10	0.02915	0.11711	402%	151
2006	11	0.03871	0.10765	278%	138
2006	12	0.03995	0.08198	205%	99
2007	1	0.02116	0.06293	297%	278
2007	2	0.01713	0.03637	212%	154
2007	3	0.00372	0.01454	391%	49
2007	4	0.01115	0.03435	308%	184
2007	5	0.00309	0.00911	295%	347
2007	6	0.01089	0.04560	419%	222
2007	7	0.00570	0.01963	344%	373
2007	8	0.00635	0.02965	467%	406
2007	9	0.00373	0.01595	428%	260
2007	10	0.01276	0.04541	356%	301
2007	11	0.01157	0.04089	354%	191
2007	12	0.01132	0.03544	313%	89
2008	1	0.04825	0.08092	168%	120
2008	2	0.03367	0.10029	298%	234
2008	3	0.00712	0.02661	374%	251
2008	4	0.00652	0.04841	743%	361
2008	5	0.00971	0.04254	438%	477
2008	6	0.00418	0.01530	366%	363
2008	7	0.00037	0.00142	387%	297
2008	8	0.00679	0.04831	711%	310
2008	9	0.04333	0.14115	326%	463

2008	10	0.01180	0.06560	556%	341
2008	11	0.01197	0.04421	369%	163
2008	12	0.01781	0.04928	277%	157
2009	1	0.02706	0.07401	274%	246
2009	2	0.02882	0.07462	259%	278
2009	3	0.01516	0.04908	324%	305
2009	4	0.00818	0.03607	441%	496
2009	5	0.01347	0.08619	640%	676
2009	6	0.00388	0.02484	640%	694
2009	7	0.00887	0.03265	368%	307
2009	8	0.00516	0.01457	282%	341
2009	9	0.00378	0.01499	396%	384
2009	10	0.00370	0.01818	491%	290
2009	11	0.02209	0.11417	517%	261
2009	12	0.00639	0.02550	399%	236
2010	1	0.02108	0.06824	324%	133
2010	2	0.01547	0.05498	355%	219
2010	3	0.00972	0.04500	463%	264
2010	4	0.00341	0.01038	305%	264
2010	5	0.00457	0.03161	691%	525
2010	6	0.00673	0.03484	517%	401
2010	7	0.01023	0.04847	474%	314
2010	8	0.00191	0.00717	375%	209
2010	9	0.00061	0.00287	472%	271
2010	10	0.00457	0.02575	563%	193
2011	1	0.06724	0.42837	637%	473
2011	2	0.04249	0.32458	764%	625
2011	3	0.00693	0.05153	744%	699
2011	4	0.00206	0.00976	473%	928
2011	5	0.00116	0.00615	529%	1029
2011	6	0.00688	0.06136	892%	930
2011	7	0.00811	0.05347	659%	946
2011	8	0.01475	0.10709	726%	1060
2011	9	0.00352	0.01271	362%	925
2011	10	0.00744	0.04836	650%	689
2011	11	0.01341	0.06424	479%	483
2011	12	0.01445	0.08326	576%	767
2012	1	0.02950	0.17036	577%	426
2012	2	0.04671	0.31722	679%	496
2012	3	0.00990	0.08532	862%	733
2012	4	0.02916	0.45309	1554%	1062
2012	5	0.00297	0.02960	998%	999
2012	6	0.00388	0.01627	420%	1009

2012	7	0.00498	0.02928	588%	960
2012	8	0.00358	0.02143	598%	1023
2012	9	0.01726	0.18942	1097%	894
2012	10	0.01672	0.14974	896%	601
2012	11	0.01283	0.05009	391%	507
2012	12	0.02099	0.07021	335%	462
2013	1	0.07424	0.99502	1340%	651
2013	2	0.00615	0.02838	462%	689
2013	3	0.00452	0.06418	1421%	1468
2013	4	0.00197	0.00848	429%	924
2013	5	0.00344	0.01338	389%	942
2013	6	0.00254	0.01907	751%	837
2013	7	0.00427	0.02354	551%	882
2013	8	0.00135	0.00556	412%	1104
2013	9	0.00218	0.00806	370%	709
2013	10	0.01139	0.05762	506%	958
2013	11	0.02991	0.18735	626%	586
2013	12	0.01637	0.09494	580%	508
2014	1	0.07035	0.76761	1091%	768
2014	2	0.04442	0.41540	935%	746
2014	3	0.00620	0.07482	1207%	966
2014	4	0.02424	0.22262	919%	830
2014	5	0.01467	0.26015	1774%	789
2014	6	0.00463	0.01489	322%	721
2014	7	0.00550	0.02230	405%	855
2014	8	0.01652	0.18087	1095%	857
2014	9	0.01176	0.06708	570%	709
2014	10	0.00548	0.02492	455%	488
2014	11	0.00797	0.02150	270%	422
2014	12	0.00763	0.01887	247%	303
2015	1	0.01271	0.10518	828%	953
2015	2	0.00286	0.01330	466%	853
2015	3	0.00260	0.02304	887%	932
2015	4	0.00821	0.11583	1410%	575
2015	5	0.00422	0.08351	1977%	870
2015	6	0.00500	0.02528	505%	714
2015	7	0.00493	0.01455	295%	715
2015	8	0.00269	0.00825	307%	629
2015	9	0.01074	0.02181	203%	525
2015	10	0.00929	0.02579	278%	551
2015	11	0.04273	0.55322	1295%	423
2015	12	0.01161	0.02249	194%	159
2016	1	0.01544	0.16686	1081%	336

2016	2	0.00367	0.05448	1485%	668
2016	3	0.00107	0.00411	386%	619
2016	4	0.00347	0.05587	1611%	937
2016	5	0.00132	0.00543	412%	716
2016	6	0.00219	0.00970	443%	694
2016	7	0.00520	0.01892	364%	698
2016	8	0.02340	0.22100	945%	707
2016	9	0.03288	0.34839	1060%	704
2016	10	0.00907	0.03737	412%	494
2016	11	0.01506	0.16600	1103%	334
2016	12	0.03804	0.62018	1630%	364
2017	1	0.00472	0.01613	342%	335
2017	2	0.00241	0.01426	593%	562
2017	3	0.00812	0.14867	1830%	613
2017	4	0.00516	0.08922	1728%	724
2017	5	0.00081	0.00394	486%	664
2017	6	0.00146	0.00536	368%	627
2017	7	0.00128	0.00609	476%	701
2017	8	0.00110	0.00570	519%	648
2017	9	0.00789	0.06056	767%	802
2017	10	0.02037	0.22411	1100%	580
2017	11	0.01457	0.09019	619%	409
2017	12	0.01414	0.06057	428%	525
2018	1	0.02752	0.14034	510%	259
2018	2	0.00495	0.01149	232%	260
2018	3	0.00343	0.01607	469%	508
2018	4	0.00330	0.02172	659%	531
2018	5	0.00428	0.03806	889%	621
2018	6	0.06853	1.49820	2186%	526
2018	7	0.00348	0.01577	454%	527
2018	8	0.00812	0.09725	1198%	596
2018	9	0.03477	0.51971	1495%	737
2018	10	0.01793	0.15270	851%	738
2018	11	0.01106	0.05152	466%	620
2018	12	0.05241	0.51648	985%	369
2019	1	0.01499	0.03432	229%	288
2019	2	0.00997	0.07082	711%	310
2019	3	0.02772	0.34895	1259%	622
2019	4	0.00239	0.01473	616%	461
2019	5	0.00476	0.02579	542%	523
2019	6	0.00715	0.06886	963%	549
2019	7	0.00519	0.06257	1207%	513
2019	8	0.00169	0.02165	1280%	594

2019	9	0.00732	0.04271	583%	580
2019	10	0.03936	0.37871	962%	682
2019	11	0.02170	0.09563	441%	451
2019	12	0.02197	0.06360	289%	276

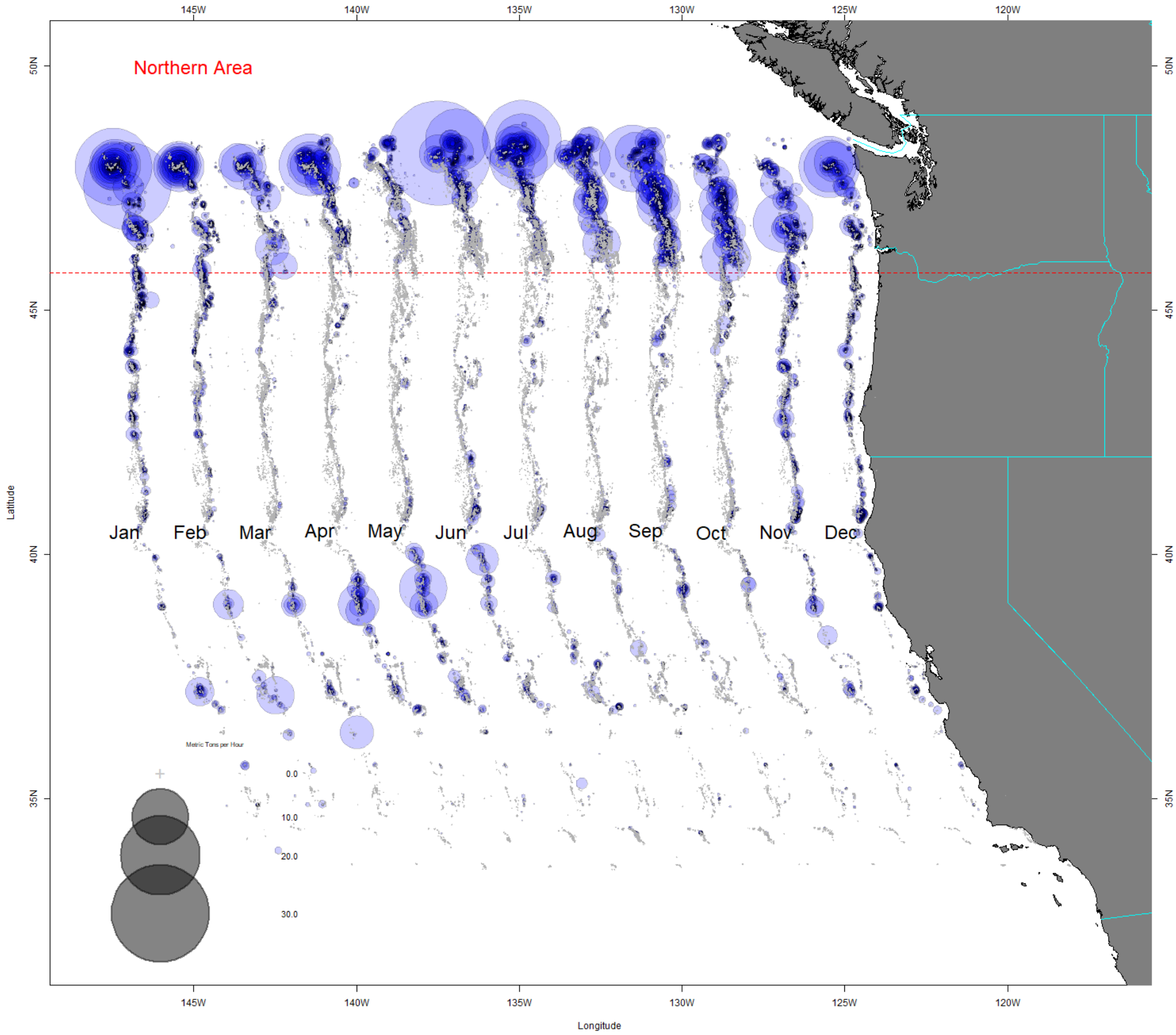

Figure 1. Map of catch rates for bottom trawl fishery hauls (as observed by WCGOP) by month (2002-2019 combined).

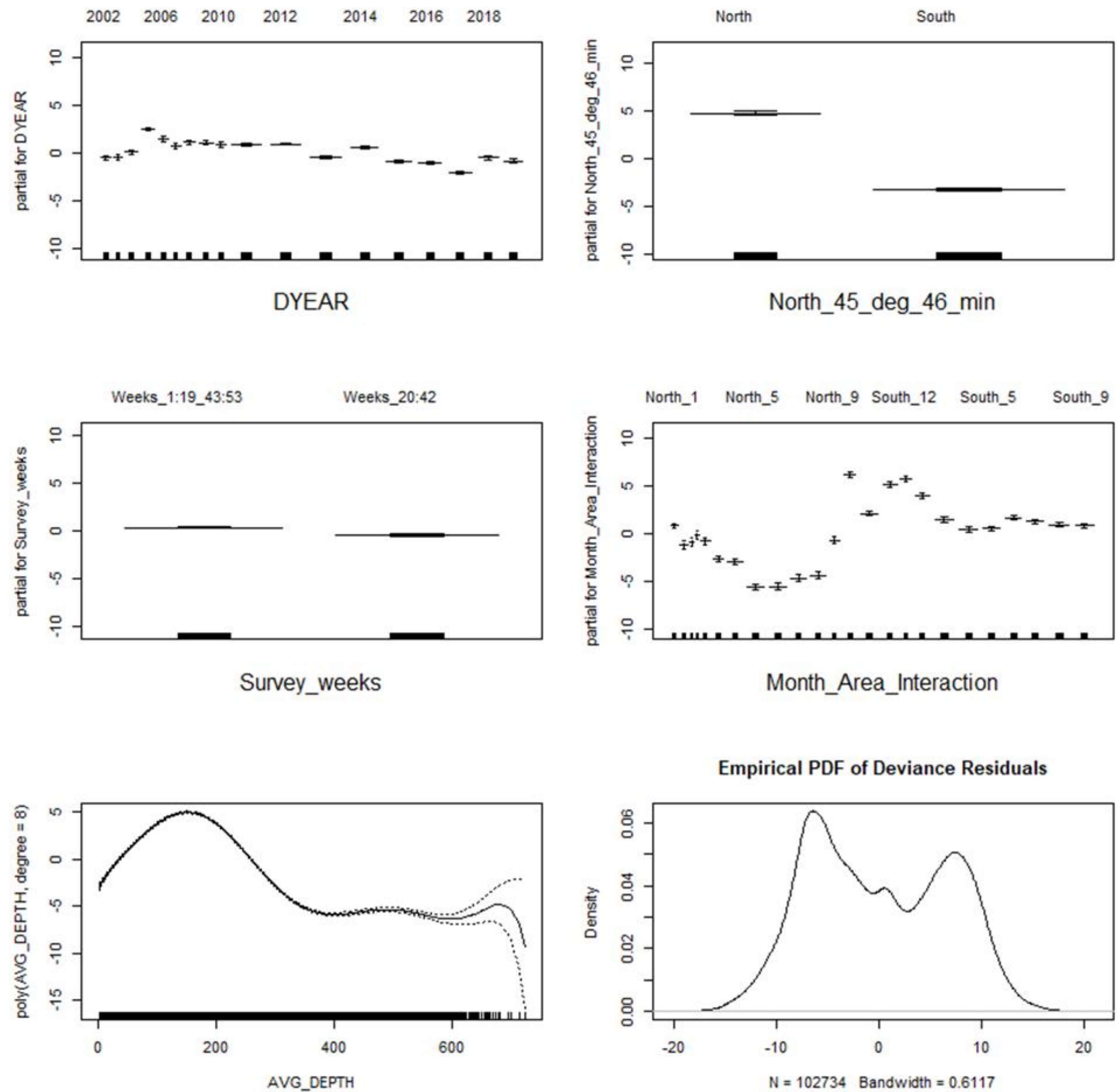

Figure 2. GLM output showing contrast in estimated coefficients for individual years, areas, survey vs non-survey weeks; uncertainty is expressed as standard error, which are very small since the N is large. In the model with the survey weeks as a factor, fewer degrees of freedom are used, and the month-area interaction is included to fully show the difference in months within area. Within the figure, R's default treatment contrasts, which sets the first level within a categorical factor to zero, are changed to the contrasts that sum to zero so that all levels within a factor are shown. (Applying R's plot.Gam() function to the glm() output does this automatically.)

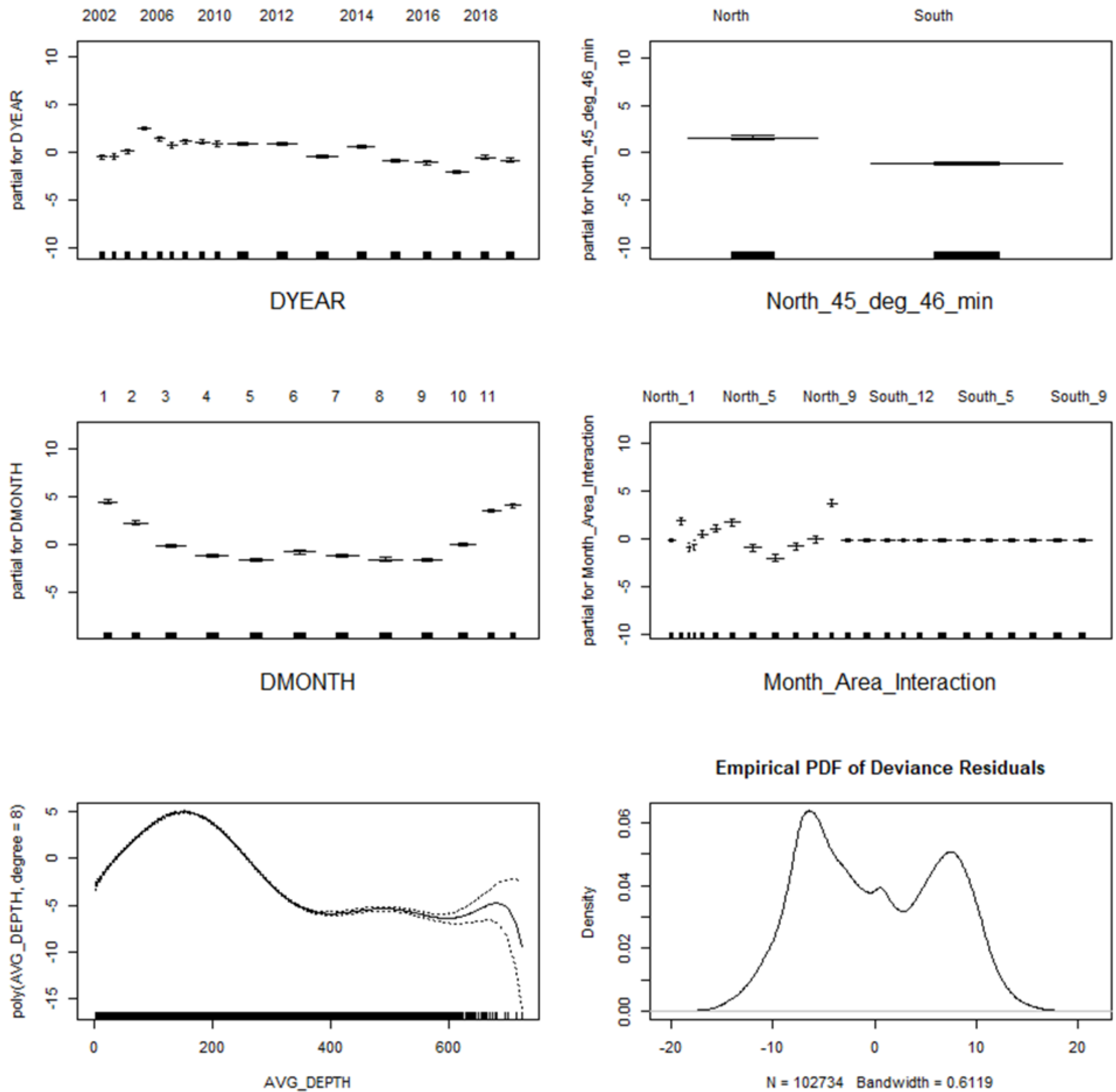

Figure 3. GLM results showing contrast in estimated factor coefficients (these are not catch rates); uncertainty is expressed as standard error, which are very small since the N is large. For the month-area interaction (middle right panel), degrees of freedom become exhausted, and as a result, the Southern area-months are all forced to be zero.

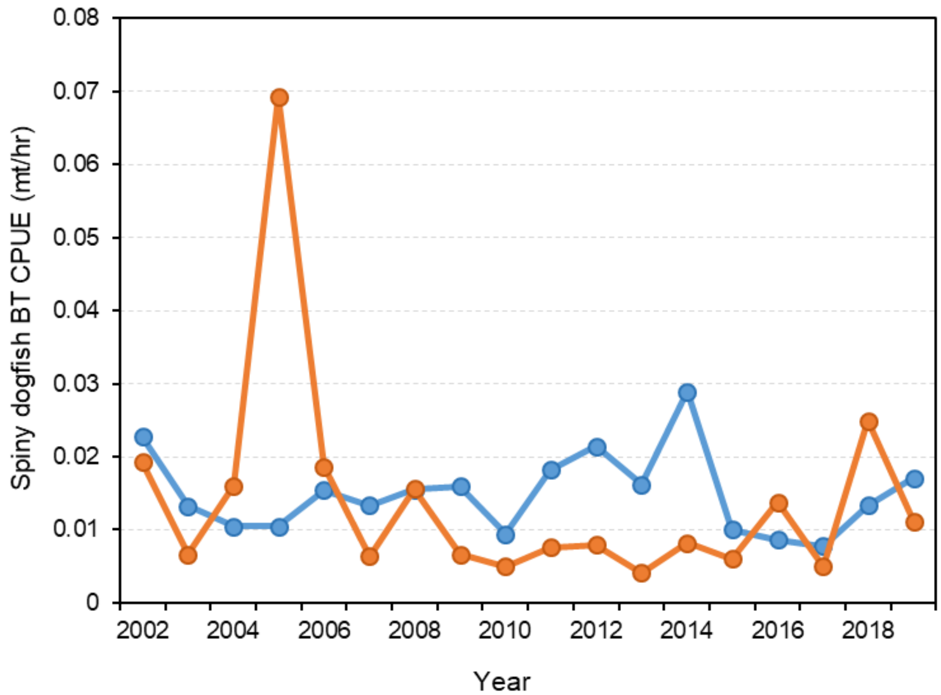

Figure 4. Average annual CPUE of spiny dogfish, calculated during survey weeks, versus non-survey weeks. Orange = survey weeks, blue = non-survey weeks. Most values are w/in one S.D. of one another.

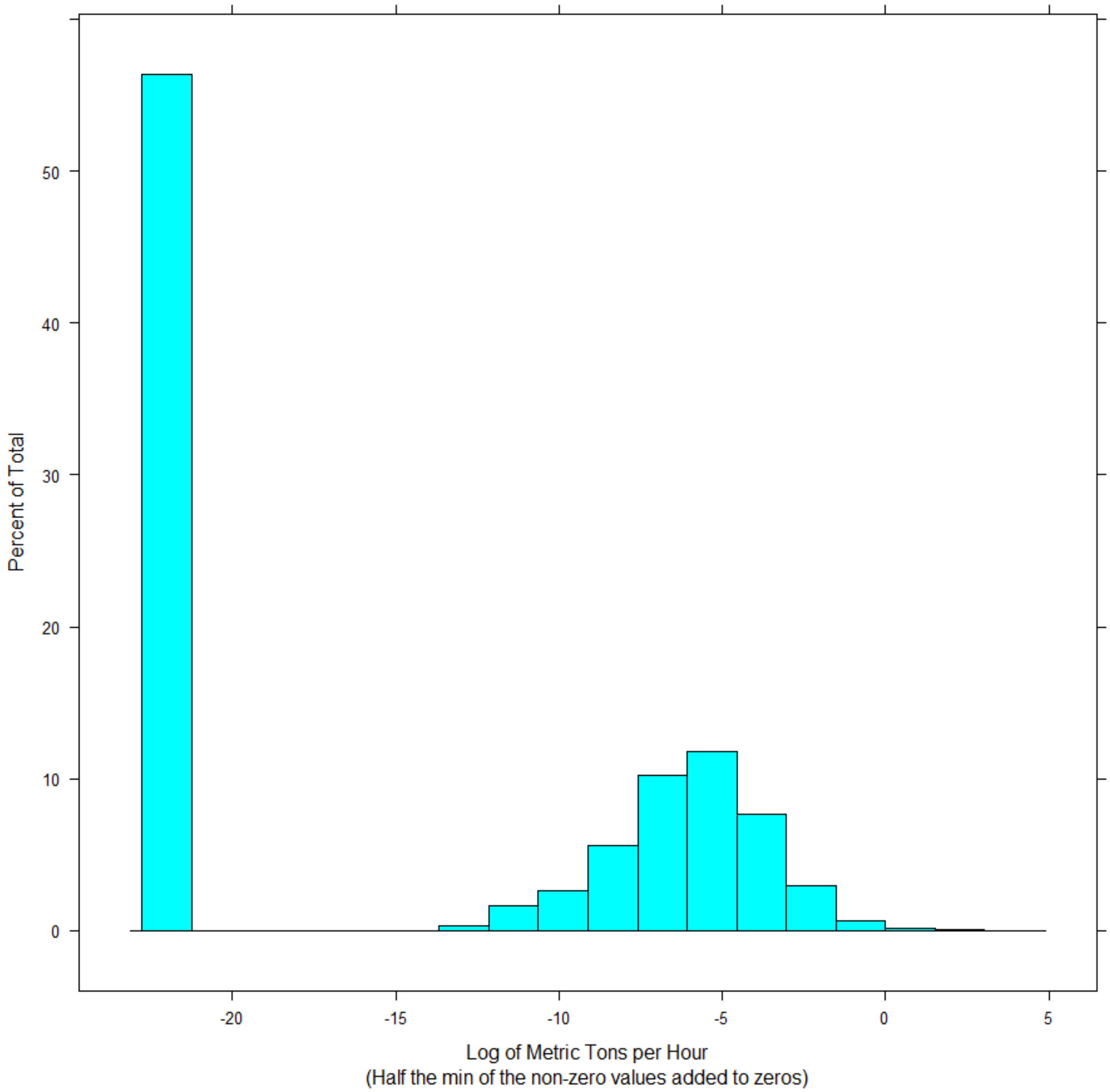

Figure 5. Histogram of spiny dogfish catch rates.

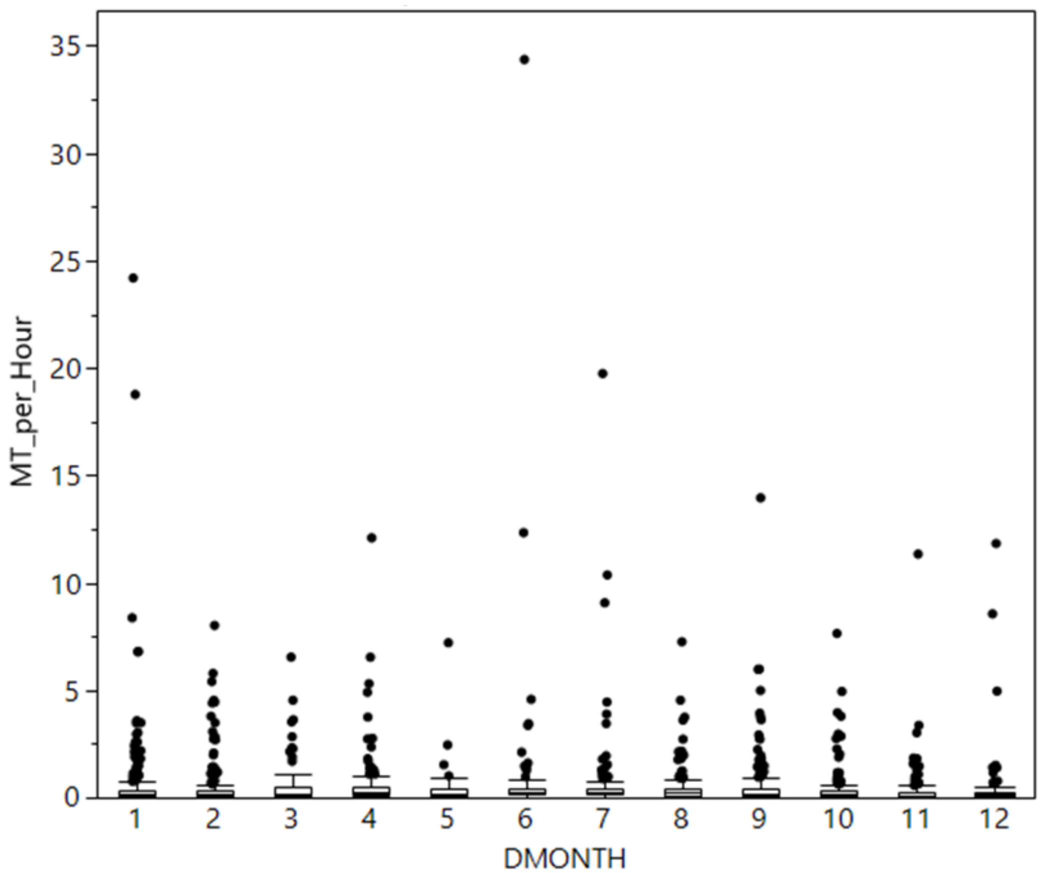

Figure 6. Spiny dogfish CPUE by haul (showing all hauls, zero and positive).

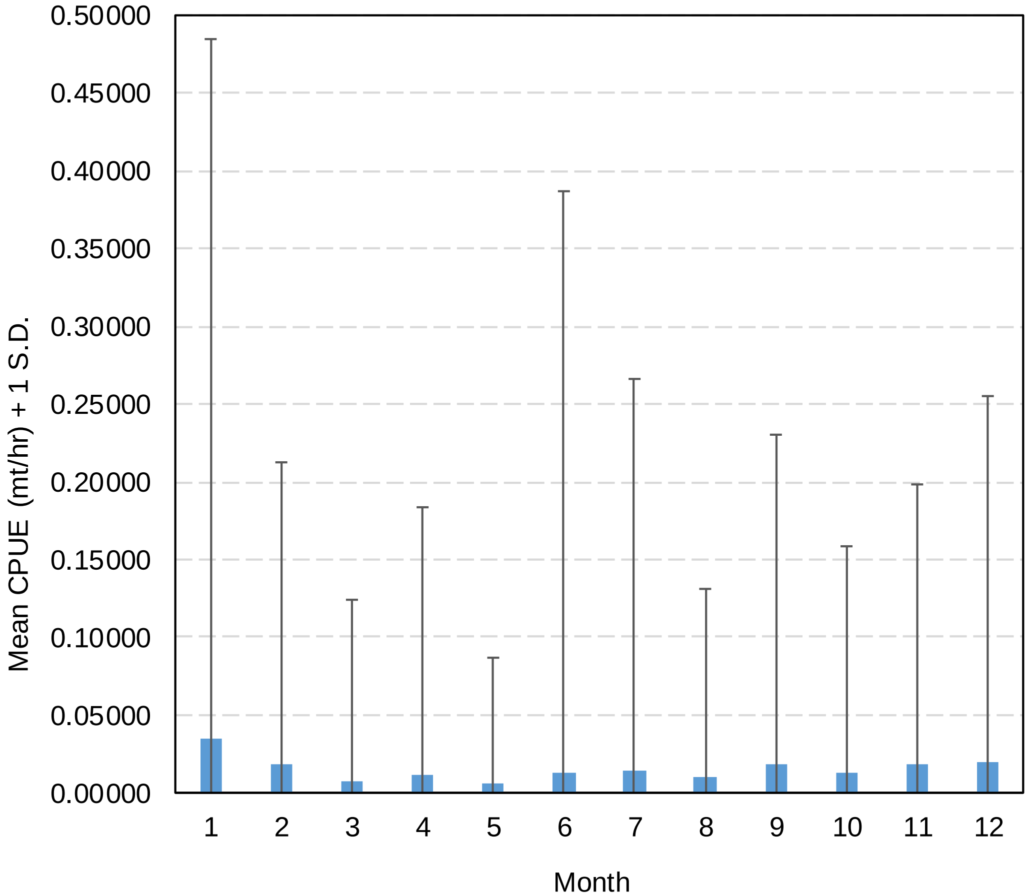

Figure 7. Mean spiny dogfish CPUE (mt/hr) by month, +-1 S.D., among all years, 2002-2019, in the bottom trawl fishery.

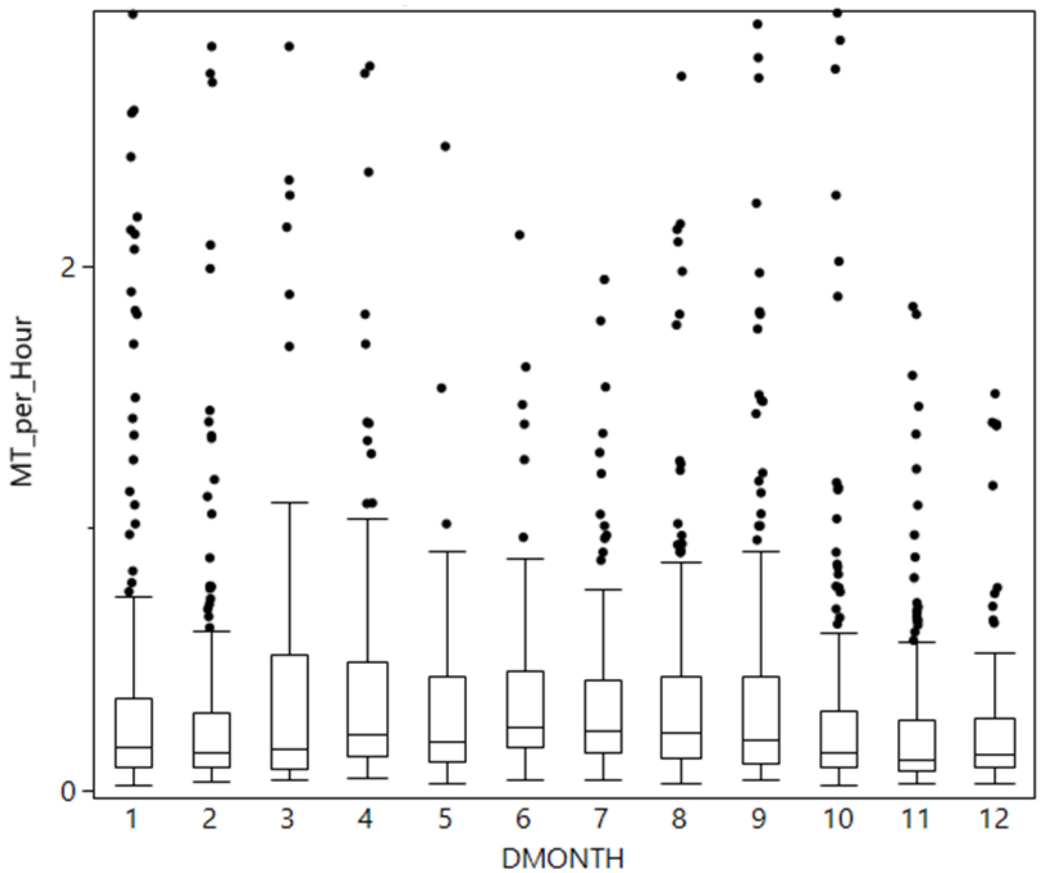

Figure 8. Spiny dogfish CPUE by haul, showing only hauls with catch of 0.25 mt or larger (reduced y axis max to not show most outliers).

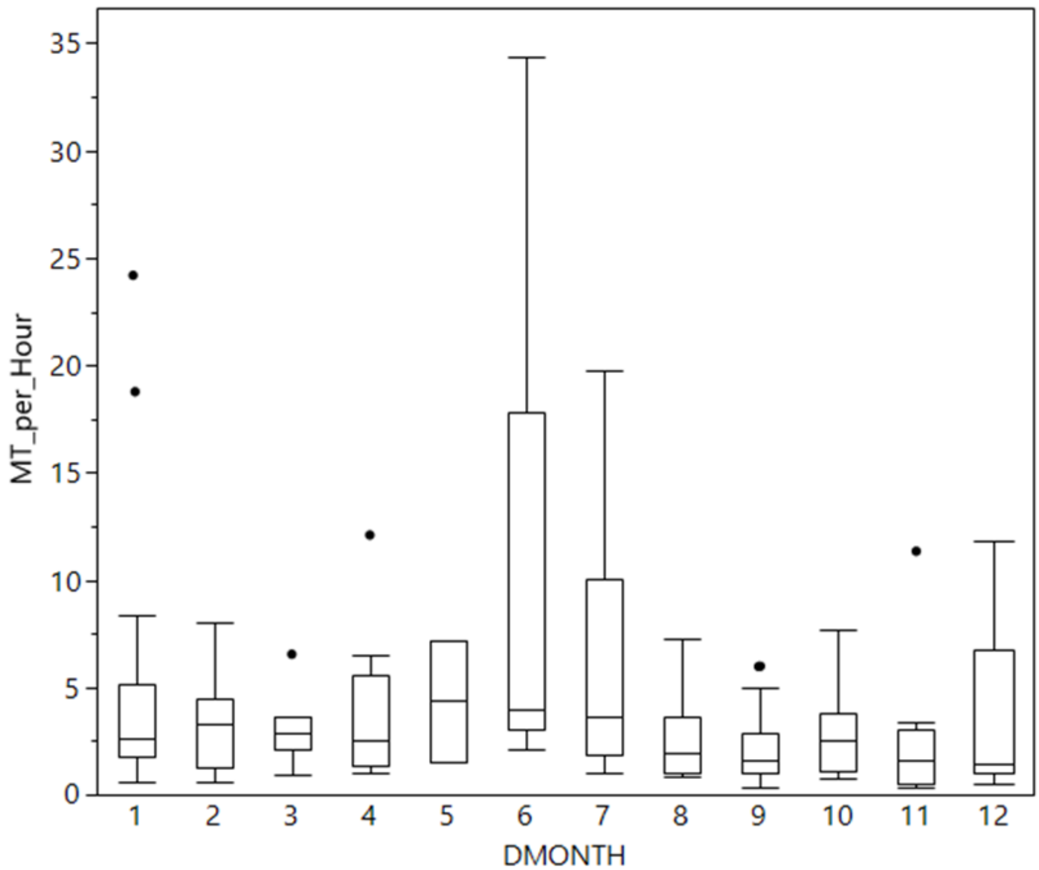

Figure 9. Spiny dogfish CPUE by haul, showing only hauls with catch of 2.5 mt or larger (reduced y axis max to not show most outliers).

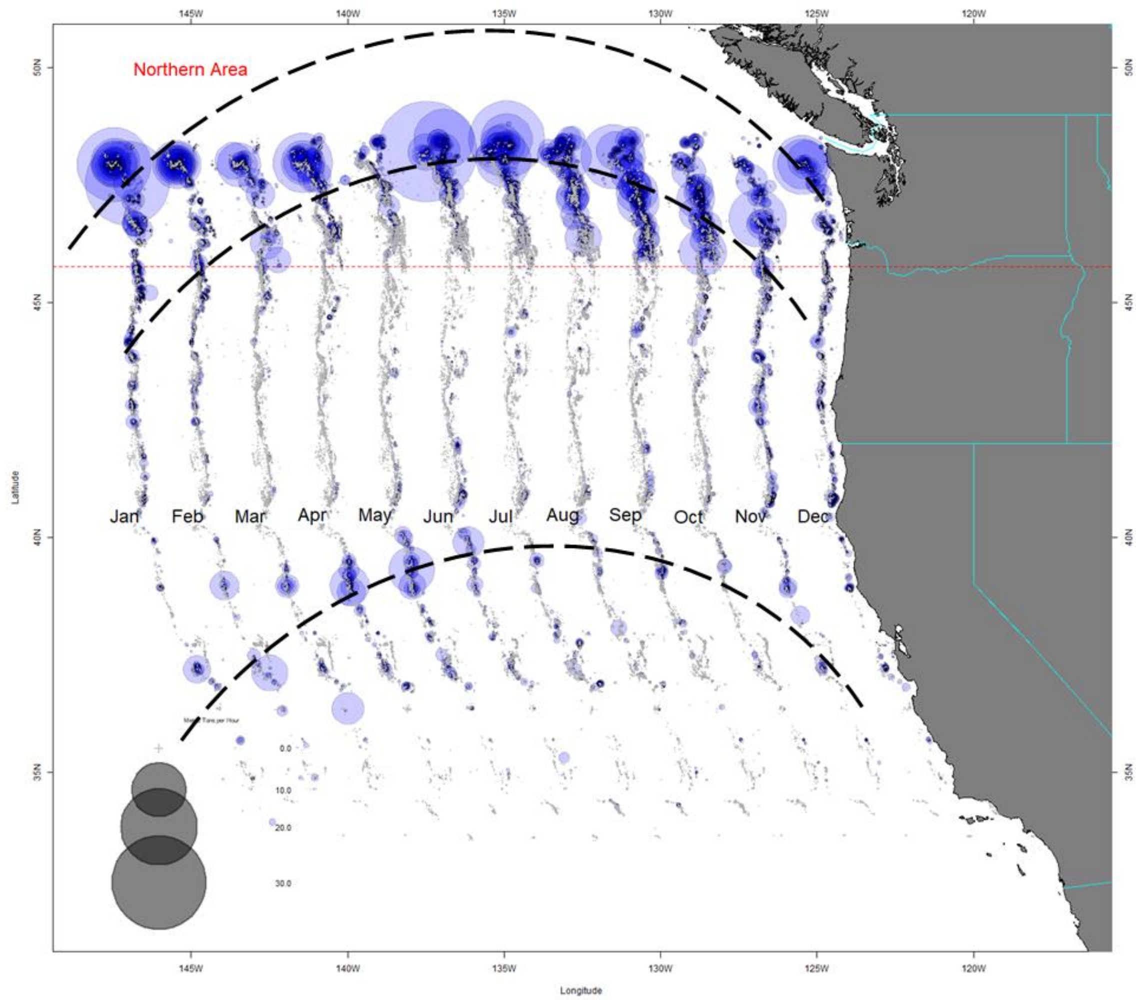

Figure 10. Map of catch rates for bottom trawl fishery hauls (as observed by WCGOP) by month with three potential migration curves shown with dashed lines.

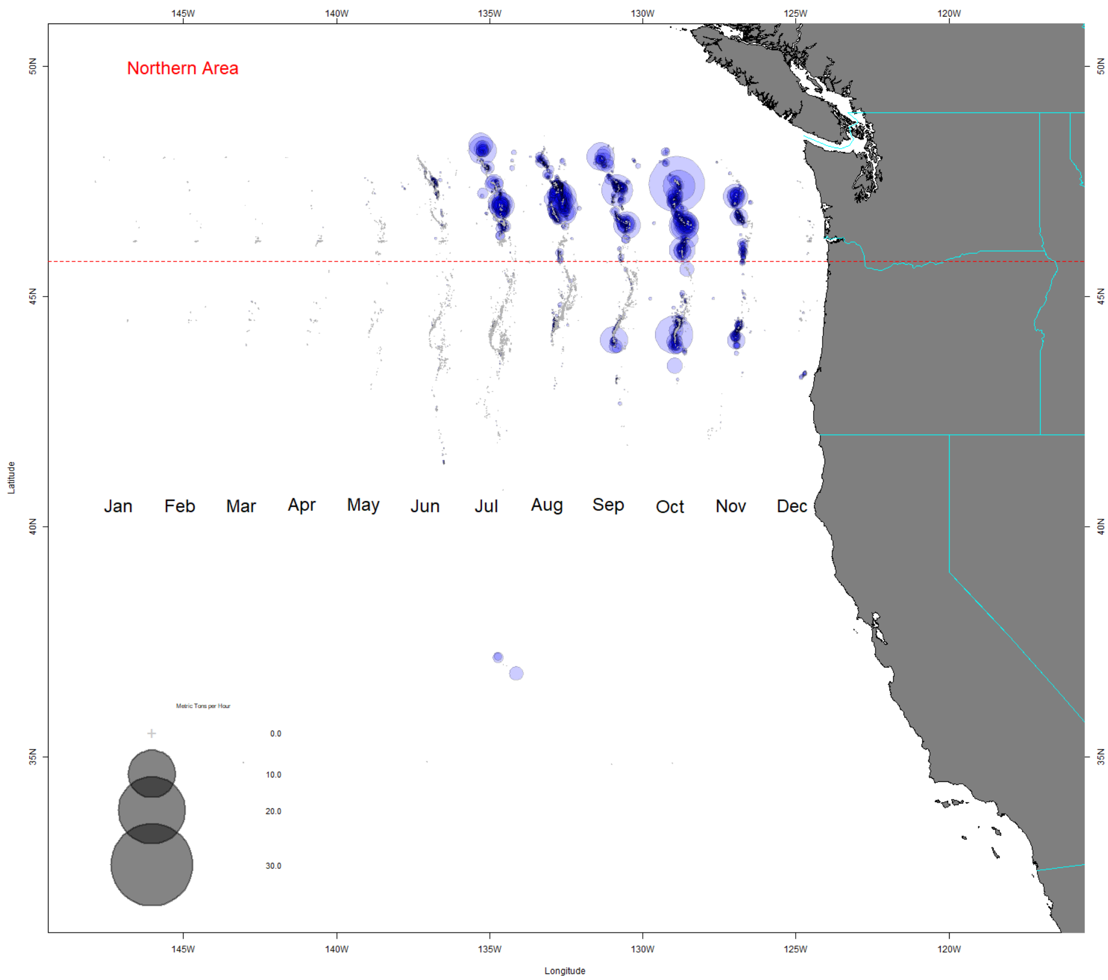

Figure 11. Map of catch rates for midwater trawl fishery hauls (as observed by WCGOP) by month (2002-2019 combined).

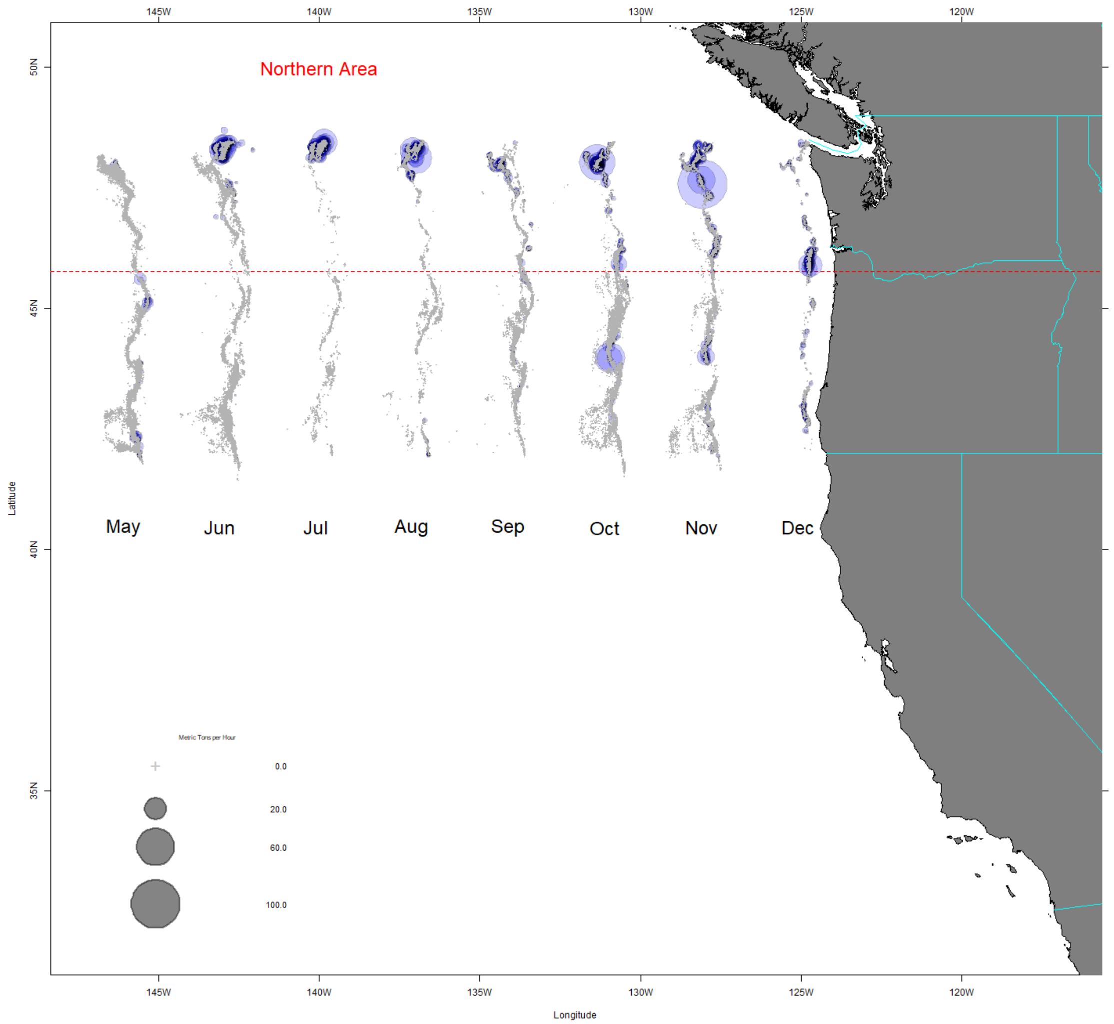

Figure 12. Map of catch rates for at-sea hake fishery hauls (as observed by ASHOP) by month.