ISC/14/SHARKWG-3/08

Standardized abundance index of juvenile shortfin mako shark (*Isurus oxyrinchus*) based on a fishery-independent survey in the Southern California Bight (1994-2013)[1]

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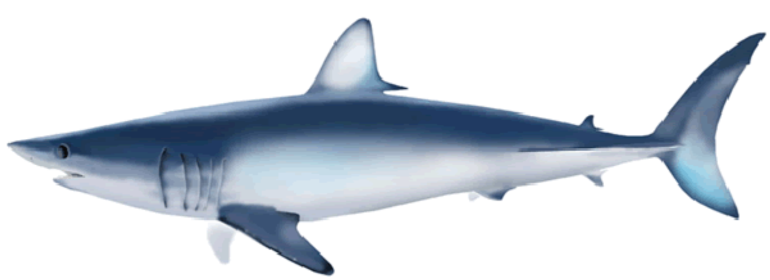

[1]Working document submitted to the ISC Shark Working Group Workshop, 19-26 November 2014, Puerto Vallarta, Jalisco, Mexico. **Document not to be cited without author's permission.**

ABSTRACT

An annual fishery-independent longline survey of juvenile pelagic sharks in the Southern California Bight (SCB) was used to estimate the local relative abundance of juvenile shortfin mako sharks (*Isurus oxyrinchus*) from 1994 to 2013 (with the exception of 1998 and 1999). The design of the survey was based on catch data from an experimental commercial shark longline fishery that operated in the SCB during the years 1988 - 1991. We used a generalized linear model to standardize catch per unit effort (CPUE) of shortfin mako sharks from the survey data, and the bootstrapping method was used to determine the confidence intervals. We found that the standardized abundance index trend was similar to the nominal CPUE trend, with a decline prior to 2000, maintaining low levels through 2011 followed by an increase in 2012 and 2013. In addition, ancillary longline sets were conducted during the annual survey cruises and those data were included in a separate juvenile shortfin mako abundance index analysis to examine potential variability when using different fishing methods. The standardized CPUE index with all data collected during survey cruises showed a similar CPUE trend as the survey data. We suggest that the working group treat this index as an alternative index for sensitivity runs or as a recruitment indicator because of the limited scope of the survey.

INTRODUCTION AND METHODS

A fishery-independent survey was initiated by the National Marine Fisheries Service, Southwest Fisheries Science Center and California Department of Fish and Wildlife to monitor trends in the relative abundance of juvenile shortfin mako and blue sharks in the SCB. The survey design was based on catch data from an experimental commercial shark longline fishery that operated in the SCB during the years 1988 - 1991. Seven fishing blocks in the SCB (Figure 1) were fished during the summer months annually from 1994 to 2013, with the exception of 1998 and 1999. The season and seven survey blocks were selected based on the times and areas of relatively high and consistent (i.e. low variability) catch rates achieved during the experimental longline fishery.

During each survey cruise, efforts were made to sample each survey block four times. Two shallow longline sets were conducted within each of the CDFW blocks: 707, 723, 742, 805, 828, 846, 848 during the first week of the survey. The set locations for the two sets within each block were at least 5 miles apart, usually conducted on the same day. Sets were started at least one mile inside of the block boundary, but could end outside the block or drift outside the block. Two additional sets were made in the same blocks during the second week of the survey, for a total of 4 sets within each survey block. Duration of sets or soak times was approximately 4 hours during daylight hours. The epipelagic water column (<75 m) was targeted. Approximately 200 “J” style hooks were deployed per set. Hooks were separated by approximately 50 feet at five (5) hooks per basket.

In addition, opportunistic ancillary longline sets were completed during years when time and funds allowed. Ancillary sets were completed both within and outside the survey blocks depending upon research objectives. In many cases, the methods were similar to survey methods. However, variations from survey methods included differences in gear such as using monofilament mainline and leaders (as opposed to steel), different hooks or different bait. Ancillary sets were conducted both during the daytime and nighttime and in some cases were set at depths below 200 m. Figure 1 shows the locations of all of the survey and ancillary longline sets done during the survey cruises.

Data collected during survey cruises was consistent between years. Several environmental observations were recorded at the beginning of longline sets. These observations included sea surface temperature (SST), depth, swell height, wind strength, wind direction, water color and cloud cover. Additionally, the time and location of first hook and last hook during both set and retrieval were recorded. Catch data was also recorded during fishing events. Catch data included species, length, sex and condition. Gear data was recorded including gangion length, gangion material, mainline length, mainline material, buoy extender length, hook type and bait type. All survey data, including catch, environmental and gear, was stored in a Microsoft Access database that is managed by a NOAA NMFS administrator.

Data used for the standardized index is referred to as "Qualified data". Qualified data was exclusively from survey sets (n = 460). Qualified data had to be completed during the months of June through August. The fishing was conducted during the daytime; the first baited hook entered the water no earlier than 5:30 am and retrieval of the gear was initiated no later than 6:30 pm. Stainless steel mainline was rigged with stainless steel leaders that were terminated with a J-style hook and baited with whole mackerel.

CPUE standardization

We used a generalized linear model (GLM) to standardize CPUE that considered year, spatial blocks and temperature.

$Ln(CPUE_{ijk}+1)=I+Y_i+B_j+T_k+\varepsilon_{ijk}$

Where I is the intercept, Y is the year, B is the block, T is the temperature and ε_{ijk} is the random error term. A preliminary boosted regression tree study that examined the effects of some of the other data collected (e.g. Beaufort sea state, water color, cloud coverage, month, time of day, wind direction) suggested that temperature was the only environmental variable that contributed to CPUE variation (Xu, not published). The standardized CPUE indices (I_t) is calculated using

$$I_t = \exp(\hat{\alpha}_t + \frac{{\sigma_t}^2}{2})$$

Where $\hat{\alpha}_t$ is the year factor estimated from GLM model, and σ_t is the standard error of $\hat{\alpha}_t$. This population marginal mean calculation (Searle et al. 1980) is widely used in CPUE standardization models. The entire standardization process followed methods used in Teo et al. (2010). The CPUE was log-transformed and a small constant was added. We tested the sensitivity of using 0.1 and 0.01 for the small constant and found that the model was robust as long as either constant was chosen, which was consistent with McDaniel et al. (2006) and Teo et al. (2010).

A GLM model with block, year and temperature was created (see Appendix 1). Because there could be some potential spatial auto-correlation between blocks and temperature, we prepared a separate GLM model with only year and temperature for the working group to consider (see Appendix 2). We also did parallel runs using all the data (753 sets in total including the ancillary sets), however, including those data could have some potential biases that we have not yet explored. The objective was to explore contrast and potential variability in the CPUE standardization.

RESULTS AND DISCUSSION

The nominal CPUE calculated by set in catch of shortfin mako sharks per 100 hook hours shows a gradual decline in the 1990s reaching a low level by 2000 that was maintained until the last few years when the CPUE again reached a level comparable to those of the late 1990s (Figure 2). There is a considerable amount of variation by set in the nominal CPUE data as shown in Figure 2. The standardized CPUE with the "qualified data" (Figure 3) showed a trend similar to that of the nominal CPUE (Figure 5). There is only a slight difference between using a GLM with the block effect and without the block effect (Figure 3, Table 1). Therefore, we think it is reasonable to use either index. The standardized CPUE index with all data (including ancillary sets) collected during survey cruises also showed a similar CPUE trend (Figure 4). However, the annual estimates prior to 2000 were lower compared to those with the qualified data set. In addition, in year 2013, CPUE was declining or at least did not continue growing, compared to 2012. These results differ from the qualified data set and may be due to not fishing within the blocks that had been identified as areas of high past catch, using mono leaders and/or circle hooks, fishing deeper or at night, or using different bait. These factors have not been explored further since those sets were not designed as part of the survey, but they could be examined to derive a standardized index with a broader context in the future.

Given the limited sampling area and size range caught by this survey, relative to the population in the North Pacific, we suggest that the juvenile survey index should be considered in the stock assessment model as either an alternative index or a potential index of recruitment variability.

REFERENCES

McDaniel, J.D., Crone, P.R., and Dorval E. 2006. Critical evaluation of important time series associated with albacore fisheries (United States, Canada, and Mexico) of the Eastern North Pacific Ocean. ISC/06/ALBWG/09. Working document submitted to the ISC Albacore Working Group Meeting, November 28-December 5, 2006, National Research Institute of Far Seas Fisheries, Shimizu, Shizuoka, Japan.

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Searle, S.R., Speed F.M., and Milliken, G.A. 1980. Population Marginal Means in the Linear-Model –an Alternative to Least-Squares Means. American Statistician 34:216-221.

Teo, S.L.H., Holmes, J., and Kohin, S. 2010. Joint standardized abundance index of US and Canada albacore troll fisheries in the North Pacific. ISC Working Paper (ISC/10-3/ALBWG/01).

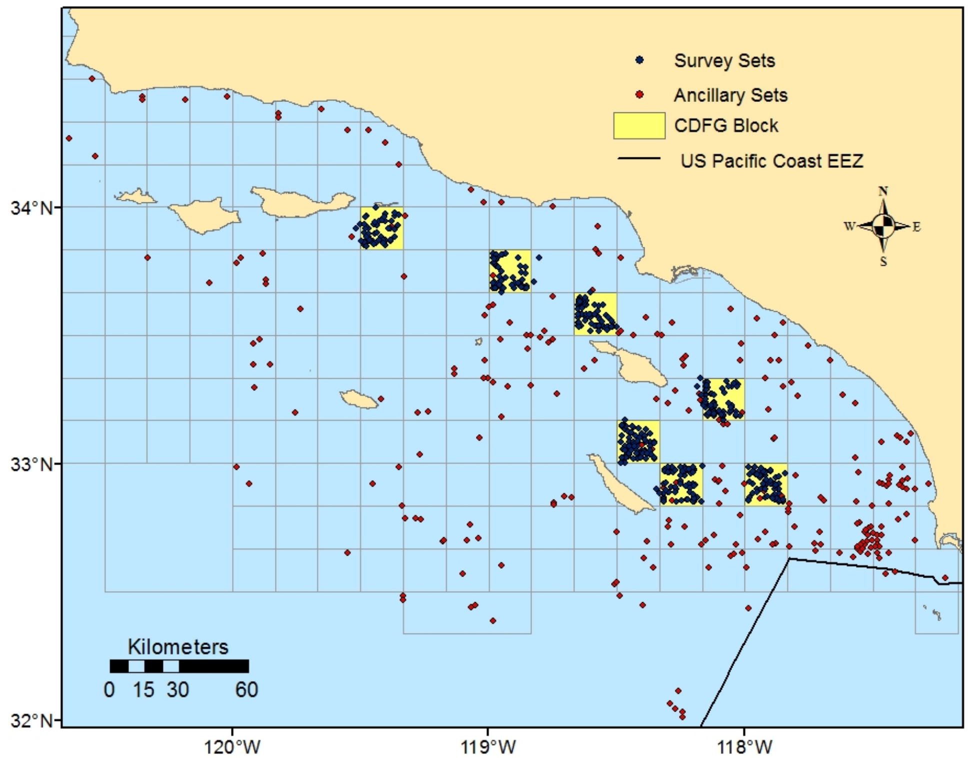

Figure 1. Map showing the seven CDFW survey blocks (707, 723, 742, 805, 828, 846, 848) in the SCB with the survey sets (dark blue dots) and ancillary sets (burgundy dots) used for deriving standardized CPUE abundance indices (from Runcie et al., in prep).

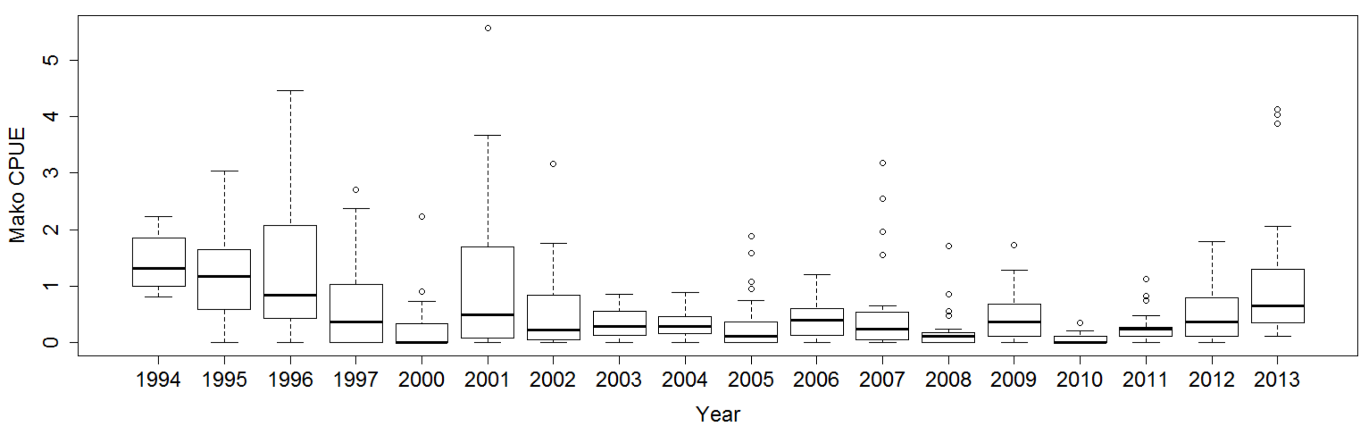

Figure 2. Boxplots of annual nominal CPUE data by set from 1994 through 2013. CPUE is calculated as the number of shortfin mako sharks per 100 hook-hours.

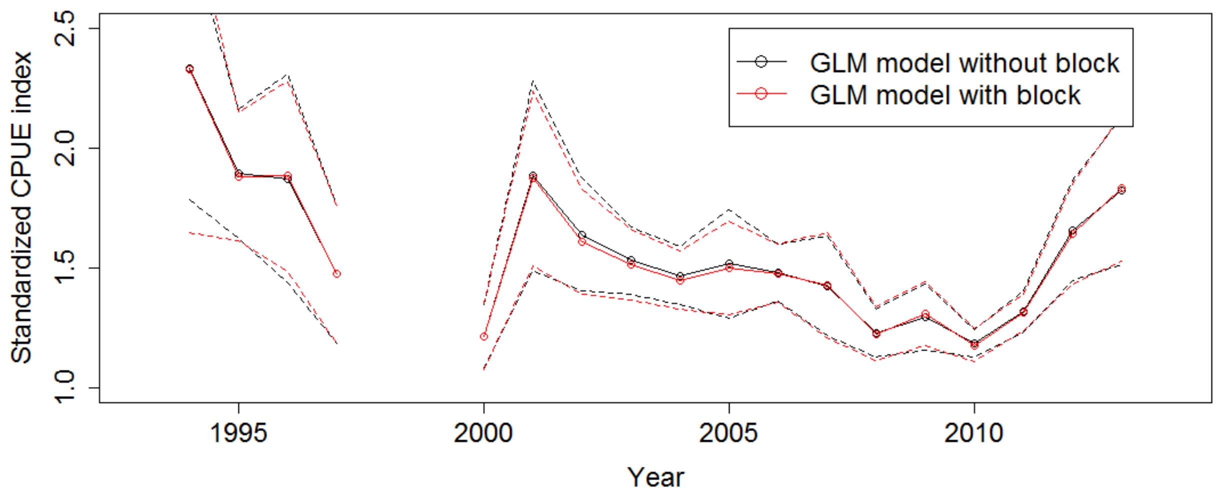

Figure 3. Standardized abundance indices of shortfin mako shark in the Southern California Bight based on a GLM model with the block effect (red line) and without the block effect (black line) using the survey sets only (n = 460). Dashed lines represent the 95% confidence intervals based on 1000 bootstrapping runs.

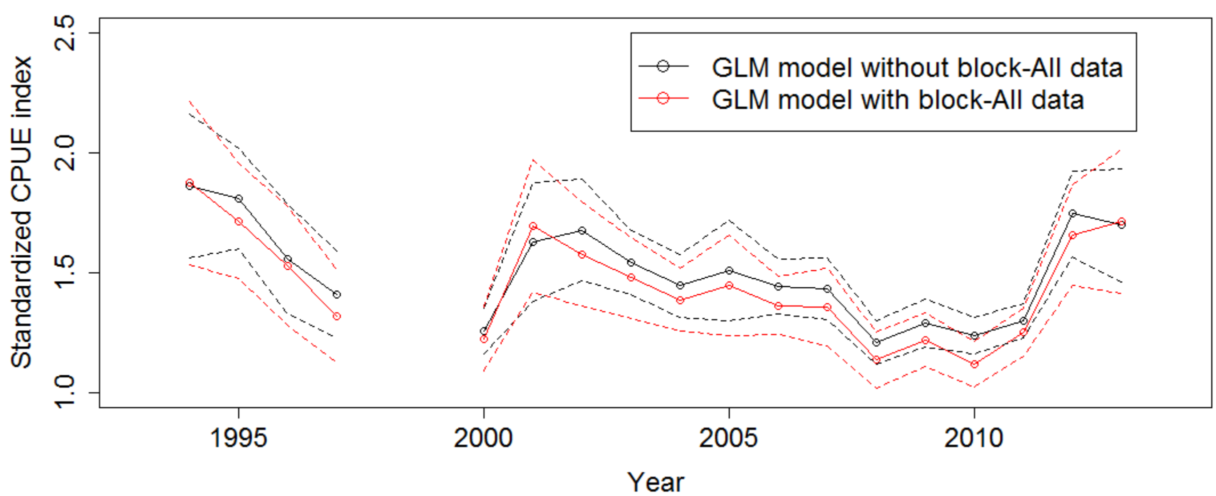

Figure 4. Standardized abundance indices for shortfin mako shark in the Southern California Bight when using all data (survey and ancillary sets, n = 753). Solid lines show a GLM model with the block effect (red line) and without the block effect (black line). Dashed lines represent the 95% confidence intervals based on 1000 bootstrapping runs.

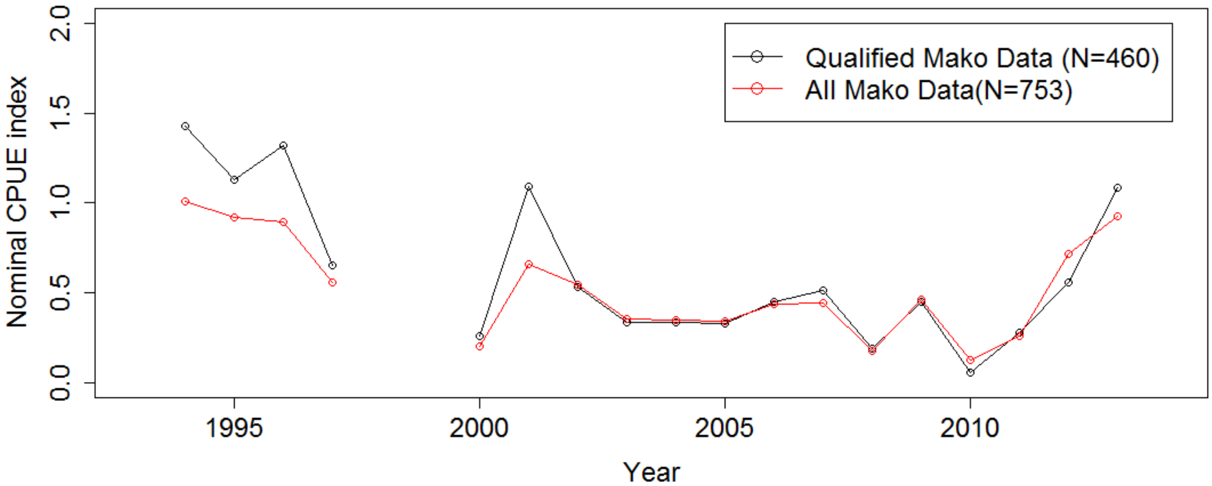

Figure 5. Nominal CPUE indices for the qualified shortfin mako data (black line) and all data (red line).

Table 1. Standardized CPUE for juvenile shortfin mako shark based on a GLM model from 1994 to 2013.

Year	Standardized CPUE			
	Qualified Data	Qualified Data	All Data	All Data
	logCPUE~ Year+Temperature	logCPUE~ Year+Temperature +Block	logCPUE~ Year+Temperature	logCPUE~ Year+Temperature +Block
1994	2.330878	2.328370	1.861996	1.873582
1995	1.894073	1.880685	1.809163	1.716197
1996	1.872472	1.884065	1.558007	1.527362
1997	1.475156	1.474594	1.409517	1.320421
2000	1.212430	1.215461	1.256757	1.223580
2001	1.885563	1.874654	1.627826	1.694054
2002	1.639449	1.607449	1.677107	1.577438
2003	1.530745	1.513283	1.541515	1.479383
2004	1.468109	1.448338	1.446404	1.387406
2005	1.518467	1.499810	1.510877	1.445682
2006	1.480198	1.476088	1.442724	1.361898
2007	1.425407	1.426151	1.432536	1.354971
2008	1.228564	1.225490	1.208388	1.135673
2009	1.294748	1.307387	1.290789	1.221156
2010	1.186476	1.178212	1.237289	1.119448
2011	1.318653	1.315671	1.301491	1.251933
2012	1.656233	1.644082	1.745538	1.655653
2013	1.822779	1.833259	1.697545	1.713263

Appendix 1. GLM results summary for Figure 3 - CPUE standardization with year, temperature and block effect based on the qualified data (n = 460).

```
Call:
glm(formula = mako.model, family = gaussian, data = mako.data.select)

Deviance Residuals:
     Min        1Q    Median        3Q       Max
-0.81971  -0.20307  -0.04253   0.14617   1.16988

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept) -0.59044    0.34362  -1.718 0.086478 .
year.f1995  -0.21353    0.17293  -1.235 0.217588
year.f1996  -0.21174    0.17387  -1.218 0.223997
year.f1997  -0.45679    0.17678  -2.584 0.010106 *
year.f2000  -0.65005    0.17106  -3.800 0.000166 ***
year.f2001  -0.21674    0.17115  -1.266 0.206082
year.f2002  -0.37052    0.17268  -2.146 0.032468 *
year.f2003  -0.43089    0.17324  -2.487 0.013261 *
year.f2004  -0.47475    0.17169  -2.765 0.005941 **
year.f2005  -0.43983    0.17617  -2.497 0.012921 *
year.f2006  -0.45577    0.17132  -2.660 0.008106 **
year.f2007  -0.49019    0.17025  -2.879 0.004191 **
year.f2008  -0.64183    0.17063  -3.762 0.000193 ***
year.f2009  -0.57714    0.17134  -3.368 0.000826 ***
year.f2010  -0.68117    0.17153  -3.971 8.42e-05 ***
year.f2011  -0.57082    0.17088  -3.340 0.000911 ***
year.f2012  -0.34799    0.17177  -2.026 0.043402 *
year.f2013  -0.23907    0.17022  -1.404 0.160914
Temperature  0.06795    0.01540   4.412 1.30e-05 ***
block.f723   0.02627    0.05926   0.443 0.657719
block.f742  -0.02414    0.05932  -0.407 0.684255
block.f805   0.16652    0.05968   2.790 0.005507 **
block.f828   0.09954    0.05747   1.732 0.083989 .
block.f846   0.03972    0.05886   0.675 0.500179
block.f848   0.14377    0.05782   2.487 0.013282 *
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 0.1007074)

    Null deviance: 62.225  on 444  degrees of freedom
Residual deviance: 42.297  on 420  degrees of freedom
  (15 observations deleted due to missingness)
AIC: 267.61

Number of Fisher Scoring iterations: 2
```

Appendix 2. GLM results summary for Figure 3 - CPUE standardization with year and temperature effect for survey sets (n = 460).

```
Call:
glm(formula = mako.model, family = gaussian, data = mako.data)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-0.7623  -0.2149  -0.0457   0.1582   1.2395

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept) -0.66245    0.34285  -1.932 0.053995 .
year.f1995  -0.20752    0.17535  -1.183 0.237301
year.f1996  -0.21899    0.17591  -1.245 0.213870
year.f1997  -0.45748    0.17927  -2.552 0.011062 *
year.f2000  -0.65362    0.17333  -3.771 0.000186 ***
year.f2001  -0.21202    0.17365  -1.221 0.222780
year.f2002  -0.35188    0.17530  -2.007 0.045344 *
year.f2003  -0.42049    0.17584  -2.391 0.017223 *
year.f2004  -0.46227    0.17425  -2.653 0.008278 **
year.f2005  -0.42854    0.17883  -2.396 0.016990 *
year.f2006  -0.45407    0.17378  -2.613 0.009294 **
year.f2007  -0.49179    0.17265  -2.848 0.004606 **
year.f2008  -0.64040    0.17311  -3.699 0.000244 ***
year.f2009  -0.58793    0.17325  -3.394 0.000755 ***
year.f2010  -0.67526    0.17412  -3.878 0.000122 ***
year.f2011  -0.56963    0.17330  -3.287 0.001097 **
year.f2012  -0.34170    0.17434  -1.960 0.050647 .
year.f2013  -0.24588    0.17242  -1.426 0.154581
Temp.C.      0.07494    0.01486   5.044 6.76e-07 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 0.104037)

    Null deviance: 62.225  on 444  degrees of freedom
Residual deviance: 44.320  on 426  degrees of freedom
  (15 observations deleted due to missingness)
AIC: 276.4

Number of Fisher Scoring iterations: 2
```

Appendix 3. Diagnostics for the standardized CPUE GLM with block number, temperature and year factor.