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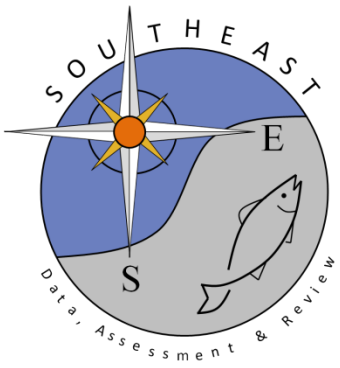

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**SEDAR 77 DATA WORKSHOP DOCUMENT**

# Standardized index of abundance for scalloped hammerhead sharks from the University of North Carolina shark longline survey south of Shakleford Banks

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***Summary***

This document details the scalloped hammerhead catch from April-November, 1981-2019, at two fixed stations in Onslow Bay south of Shackleford Banks, North Carolina. Catch per unit effort (CPUE) by set in number of sharks per number of set hooks were examined by year. The CPUE was standardized using a two-step delta-lognormal approach that models the proportion of positive catch with a binomial error distribution separately from the positive catch, which is modeled using a lognormal distribution. The majority of catches occurred during April and early May (82%), which were not consistently sampled across years due to weather and logistical constraints. The standardized relative abundance for scalloped hammerhead sharks shows a variable but overall decreasing trend through the early 1990s followed by an increasing trend throughout the remainder of the time series.

## *Introduction*

In North Carolina waters, information about sharks was limited prior to 1972. This led to the establishment of a bi-weekly longline survey (April-November, 1972-2013) conducted at two fixed stations south of Shackleford Banks in Onslow Bay, North Carolina by the University of North Carolina (UNC), Institute of Marine Sciences. The survey's objective was to define what sharks occurred in the area, their sizes, life stages, relative abundances and seasonal occurrences. Relative abundance indices from this survey have been previously generated for scalloped hammerhead covering the time period from 1972 to 2005 (Schwartz et al. 2007). In this document, the time series is updated with data through 2019, including data corrections detailing missing water hauls and missing or incorrect information pertaining to individual animal records.

## *Methods*

### Sampling gear

An unanchored longline, approximately 4.8 km long of braided nylon (about 7.6 mm diameter) was suspended by orange 1.3 m diameter polyfoam plastic floats spaced every 10 hooks, spacing between hooks was 4.5 m. Gangions were 1.8 m long of No. 2 (95 kg) porch swing chain terminating in a No. 9 Mustad tuna hook. This gear was not altered throughout the 40 + years of sampling. The number of hooks varied more during early sample years and less during later years, rarely less than 100 hooks per set. Bait was fresh fish trawled near Beaufort Inlet, North Carolina, usually consisting of spot *Leiostomus xanthus* and Atlantic croaker *Micropogonias undulatus*, occasionally pigfish *Orthopristis chrysptera* and pinfish *Lagodon rhombiodes*.

### Survey design

A bi-weekly shark survey occurred between April and November at two fixed stations 1-3.4 km south of Shackleford Banks in Onslow Bay, NC. The daily sampling protocol generally included an early morning set at the east-west (E-W) station, followed by a later set in the day at the north-south (N-S) station. The shallow (13 m) E-W set was over sandy-silt and the deeper (22 m) N-S set was primarily over sandy areas. Weather occasionally prevented occupying both stations on a single day. Soak time was one hour, to avoid longer intervals that would often produce dead or dying sharks. Surface water temperatures were recorded at the beginning of the set. Fork length and sex were recorded for each shark species caught. Any specimen that was partially eaten, damaged or lost during line retrieval was counted but not measured.

### Data Analysis

Catch per unit effort (CPUE) in number of sharks per hook were used to examine the relative abundance of scalloped hammerhead sharks caught during the UNC longline survey conducted between 1981 and 2019 in Onslow Bay, NC. The CPUE was standardized using the Lo et al. (2002) method which models the proportion

of positive sets separately from the positive catch. Factors considered as potential influences on the CPUE for these analyses were: year (1981 – 2019), month (April – November), station (E-W, N-S), and temperature (<20 deg C, 20-24 deg C, 25-29 deg C, and 30+ deg C). The proportion of sets with positive CPUE values was modeled assuming a binomial distribution with a logit link function and the positive CPUE sets were modeled assuming a lognormal distribution.

Models were fit in a stepwise forward manner adding one potential factor at a time after initially running a null model with no factors included (Gonzáles-Ania et al. 2001, Carlson 2002). Each potential factor was ranked from greatest to least reduction in deviance per degree of freedom when compared to the null model. The factor resulting in the greatest reduction in deviance was then incorporated into the model providing the deviance per degree freedom was reduced by at least 1% from the less complex model. This process was continued until no additional factors met the criteria for incorporation into the final model. The factor "year" was kept in all final models to allow for calculation of indices. All models in the stepwise approach were fitted using the SAS GENMOD procedure (SAS Institute, Inc.). The final models were then run through the SAS GLIMMIX macro to allow fitting of the generalized linear mixed models using the SAS MIXED procedure (Wolfinger, SAS Institute, Inc). The standardized indices of abundance were based on the year effect least square means determined from the combined binomial and lognormal components.

***Results***

A total of 342 scalloped hammerhead sharks were caught during 920 longline sets from 1981 to 2019. Scalloped hammerhead sharks ranged in length from 59 to 250 cm FL. The proportion of sets with positive catch (at least one scalloped hammerhead was caught) was 17%. There were 2 years without any scalloped hammerhead catches (1995 and 2009). The majority of catches occurred June through August (75%). The stepwise construction of each model and the resulting statistics are detailed in Table 1. Model diagnostic plots reveal that the model fit is acceptable (Figures 2 and 3). The resulting indices of abundance based on the year effect least square means, associated statistics, and nominal indices are reported in Table 2 and are plotted by year in Figure 4. The standardized relative abundance for scalloped hammerhead shows a variable but overall decreasing trend through the early 1990s followed by an increasing trend throughout the remainder of the time series (Figure 4).

***References***

Carlson J.K. 2002. A fishery-independent assessment of shark stock abundance for large coastal species in the northeast Gulf of Mexico. Panama City Laboratory Contribution Series 02-08. 26pp.

González-Ania, L.V., C.A. Brown, and E. Cortés. 2001. Standardized catch rates for yellowfin tuna (*Thunnus albacares*) in the 1992-1999 Gulf of Mexico longline fishery based upon observer programs from Mexico and the United States. Col. Vol. Sci. Pap. ICCAT 52:222-237.

Lo, N.C., L.D. Jacobson, and J.L. Squire. 1992. Indices of relative abundance from fish spotter data based on delta-lognormal models. Can. J. Fish. Aquat. Sci. 49:2515-2526.

Schwartz, F.J., C.T. McCandless, and J.J. Hoey. 2007. Trends in relative abundance for shark species caught during a UNC longline survey conducted between 1972 and 2005 in Onslow Bay, NC. SEDAR 13-DW-34. 79 pp.

Table 1. Results of the stepwise procedure for development of the UNC longline survey catch rate model for scalloped hammerhead. DF is the degrees of freedom. %DIF is the percent difference in deviance/DF between each model and the null model. Delta% is the difference in deviance/DF between the newly included factor and the previous entered factor in the model.

**PROPORTION POSITIVE-BINOMIAL ERROR DISTRIBUTION**

| FACTOR | DF | DEVIANCE | DEVIANCE/DF | %DIFF | DELTA% | CHISQ | PR>CHI |
|---|---|---|---|---|---|---|---|
| NULL | 621 | 645.0773 | 1.0388 | | | | |
| YEAR | 583 | 550.6883 | 0.9446 | 9.0682 | | 94.39 | <.0001 |
| STATION | 619 | 619.7537 | 1.0012 | 3.6196 | | 25.32 | <.0001 |
| TEMP | 618 | 624.4622 | 1.0105 | 2.7243 | | 20.62 | 0.0001 |
| MONTH | 613 | 591.9865 | 0.9657 | 7.0370 | | Negative of hessian | |
| YEAR + | | | | | | | |
| TEMP | 580 | 515.9402 | 0.8896 | -8.1786 | | 34.75 | <.0001 |
| STATION | 581 | 523.4322 | 0.9009 | -8.1673 | | Negative of hessian | |
| YEAR*TEMP | 502 | 442.6923 | 0.8819 | -8.1863 | | Negative of hessian | |

**FINAL MODEL: YEAR + TEMP**

**POSITIVE CATCHES-LOGNORMAL ERROR DISTRIBUTION**

| FACTOR | DF | DEVIANCE | DEVIANCE/DF | %DIFF | DELTA% | CHISQ | PR>CHI |
|---|---|---|---|---|---|---|---|
| NULL | 137 | 61.5184 | 0.4490 | | | | |
| YEAR | 101 | 40.4449 | 0.4004 | 10.8241 | | 57.88 | 0.0118 |
| STATION | 136 | 58.1509 | 0.4276 | 4.7661 | | 7.77 | 0.0053 |
| MONTH | 131 | 57.3558 | 0.4378 | 2.4944 | | 9.67 | 0.1393 |
| TEMP | 134 | 60.9601 | 0.4549 | -1.3140 | | 1.26 | 0.7391 |
| YEAR + | | | | | | | |
| STATION | 100 | 38.6598 | 0.3866 | 13.8976 | 3.0735 | 6.23 | 0.0126 |
| YEAR*STATION | 83 | 33.9470 | 0.4090 | 8.9087 | -1.9154 | 17.94 | 0.3927 |

**FINAL MODEL: YEAR + STATION**

Table 2. UNC longline survey scalloped hammerhead analysis number of model observations per year (n obs), number of positive model observations per year (obs pos), proportion of positive model observations per year (obs ppos), nominal cpue as sharks per hook (obs cpue), resulting estimated cpue from the model (est cpue), the lower 95% confidence limit for the est cpue (LCL), the upper 95% confidence limit for the est cpue (UCL), and the coefficient of variation for the estimated cpue (CV).

| year | n obs | obs pos | obs ppos | obs cpue | est cpue | LCL | UCL | CV |
|---|---|---|---|---|---|---|---|---|
| 1981 | 26 | 7 | 0.2593 | 0.0079 | 0.0080 | 0.0041 | 0.0158 | 0.3505 |
| 1982 | 31 | 10 | 0.3226 | 0.0040 | 0.0051 | 0.0029 | 0.0090 | 0.2862 |
| 1983 | 27 | 11 | 0.4138 | 0.0066 | 0.0074 | 0.0046 | 0.0120 | 0.2457 |
| 1984 | 29 | 9 | 0.3226 | 0.0077 | 0.0071 | 0.0039 | 0.0127 | 0.2990 |
| 1985 | 27 | 7 | 0.2593 | 0.0019 | 0.0013 | 0.0005 | 0.0030 | 0.4473 |
| 1986 | 21 | 9 | 0.4091 | 0.0048 | 0.0060 | 0.0033 | 0.0110 | 0.3070 |
| 1987 | 21 | 8 | 0.3810 | 0.0051 | 0.0053 | 0.0027 | 0.0102 | 0.3386 |
| 1988 | 24 | 10 | 0.4000 | 0.0081 | 0.0073 | 0.0040 | 0.0131 | 0.3012 |
| 1989 | 25 | 2 | 0.0769 | 0.0008 | 0.0010 | 0.0003 | 0.0038 | 0.7351 |
| 1990 | 19 | 1 | 0.0526 | 0.0003 | 0.0002 | 0.0000 | 0.0013 | 1.0450 |
| 1991 | 20 | 1 | 0.0500 | 0.0003 | 0.0003 | 0.0001 | 0.0019 | 1.0422 |
| 1992 | 15 | 1 | 0.0667 | 0.0005 | 0.0004 | 0.0001 | 0.0024 | 1.0424 |
| 1993 | 14 | 3 | 0.2143 | 0.0014 | 0.0017 | 0.0006 | 0.0051 | 0.5764 |
| 1994 | 20 | 1 | 0.0500 | 0.0010 | 0.0012 | 0.0002 | 0.0064 | 1.0385 |
| 1995 | 19 | 0 | 0.0000 | 0.0000 | | | | |
| 1996 | 22 | 1 | 0.0455 | 0.0009 | 0.0008 | 0.0001 | 0.0044 | 1.0512 |
| 1997 | 24 | 1 | 0.0417 | 0.0004 | 0.0003 | 0.0000 | 0.0017 | 1.0869 |
| 1998 | 23 | 2 | 0.0870 | 0.0006 | 0.0007 | 0.0002 | 0.0027 | 0.7358 |
| 1999 | 21 | 2 | 0.0952 | 0.0057 | 0.0047 | 0.0013 | 0.0172 | 0.7246 |
| 2000 | 21 | 3 | 0.1429 | 0.0014 | 0.0017 | 0.0006 | 0.0051 | 0.5807 |
| 2001 | 13 | 1 | 0.0769 | 0.0008 | 0.0006 | 0.0001 | 0.0033 | 1.0539 |
| 2002 | 21 | 2 | 0.0952 | 0.0008 | 0.0008 | 0.0002 | 0.0030 | 0.7395 |
| 2003 | 19 | 1 | 0.0526 | 0.0011 | 0.0010 | 0.0002 | 0.0057 | 1.0422 |
| 2004 | 16 | 1 | 0.0588 | 0.0013 | 0.0011 | 0.0002 | 0.0060 | 1.0429 |
| 2005 | 18 | 2 | 0.1111 | 0.0022 | 0.0019 | 0.0005 | 0.0072 | 0.7605 |
| 2006 | 25 | 6 | 0.2400 | 0.0056 | 0.0062 | 0.0029 | 0.0133 | 0.3992 |
| 2007 | 21 | 6 | 0.2857 | 0.0052 | 0.0065 | 0.0031 | 0.0137 | 0.3846 |
| 2008 | 20 | 2 | 0.1000 | 0.0035 | 0.0026 | 0.0007 | 0.0098 | 0.7299 |
| 2009 | 15 | 0 | 0.0000 | 0.0000 | | | | |
| 2010 | 16 | 1 | 0.0625 | 0.0013 | 0.0011 | 0.0002 | 0.0061 | 1.0430 |
| 2011 | 24 | 7 | 0.2917 | 0.0041 | 0.0047 | 0.0023 | 0.0097 | 0.3672 |
| 2012 | 20 | 1 | 0.0500 | 0.0015 | 0.0017 | 0.0003 | 0.0096 | 1.0495 |
| 2013 | 16 | 6 | 0.3750 | 0.0075 | 0.0092 | 0.0046 | 0.0183 | 0.3576 |
| 2014 | 16 | 1 | 0.0625 | 0.0013 | 0.0012 | 0.0002 | 0.0065 | 1.0393 |
| 2015 | 18 | 3 | 0.1667 | 0.0028 | 0.0036 | 0.0012 | 0.0105 | 0.5763 |
| 2016 | 18 | 2 | 0.1111 | 0.0017 | 0.0016 | 0.0004 | 0.0061 | 0.7554 |
| 2017 | 12 | 2 | 0.1667 | 0.0033 | 0.0035 | 0.0010 | 0.0126 | 0.7100 |
| 2018 | 13 | 3 | 0.2308 | 0.0031 | 0.0030 | 0.0010 | 0.0088 | 0.5747 |
| 2019 | 12 | 3 | 0.2857 | 0.0067 | 0.0062 | 0.0025 | 0.0153 | 0.4790 |

Figure 1. Fork lengths (cm) of scalloped hammerhead caught during the UNC longline survey from 1981-2019.

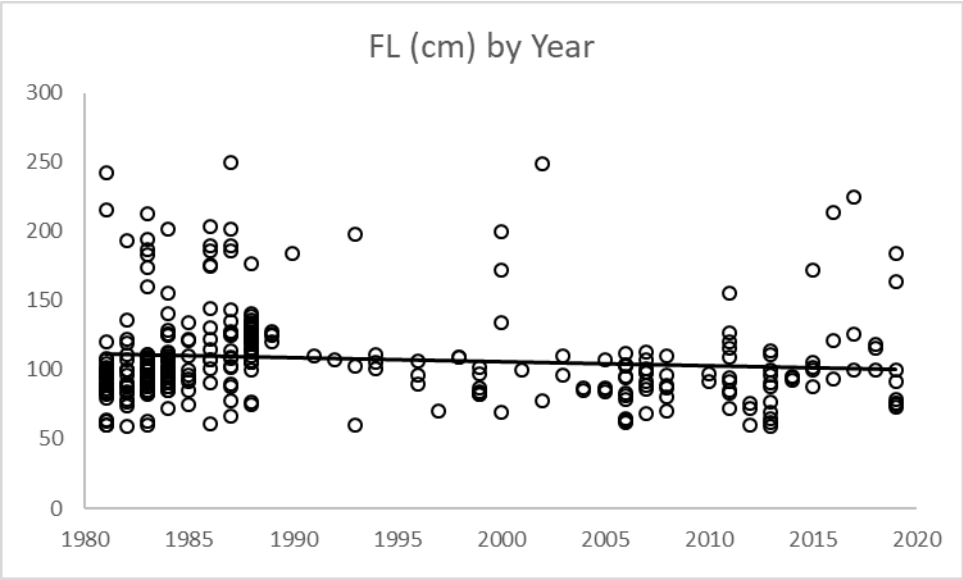



Figure 2. UNC scalloped hammerhead model diagnostic plots for the binomial component.

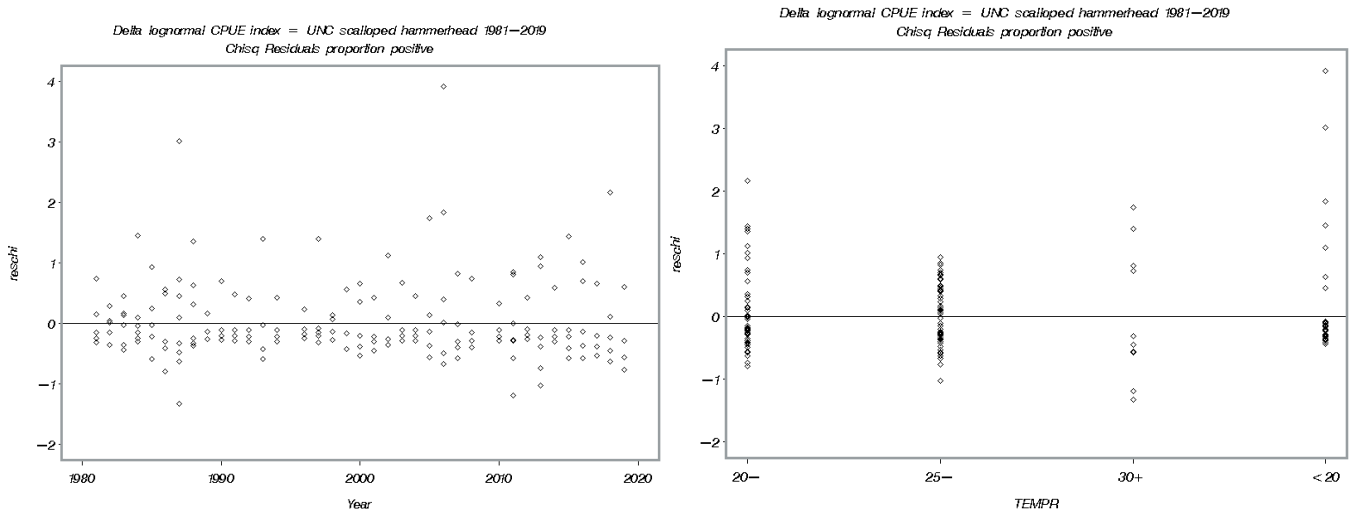
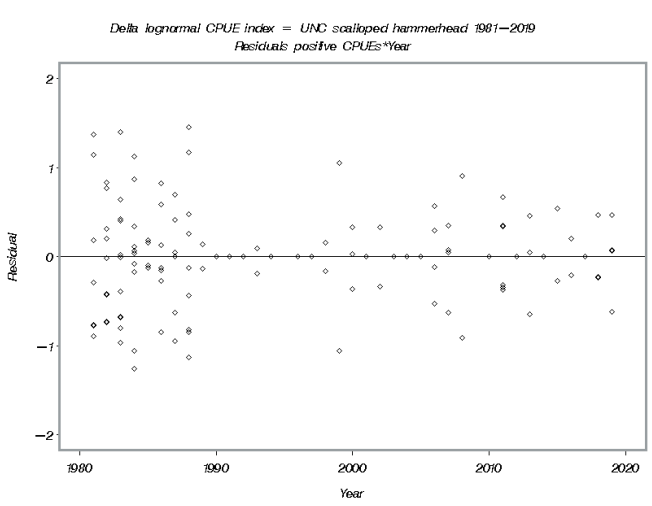
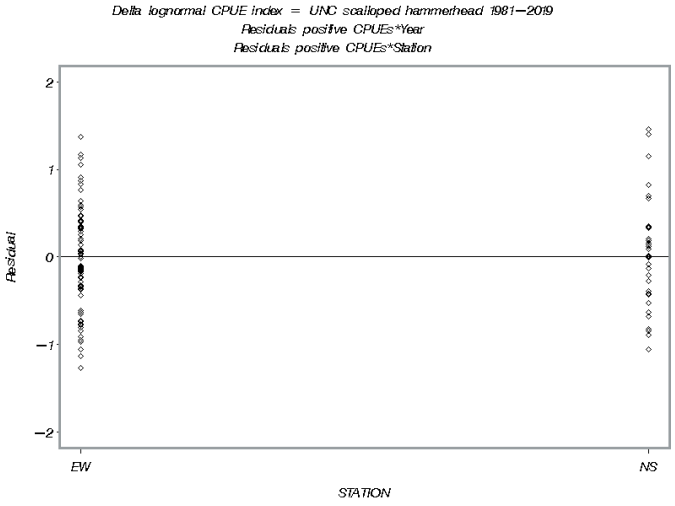
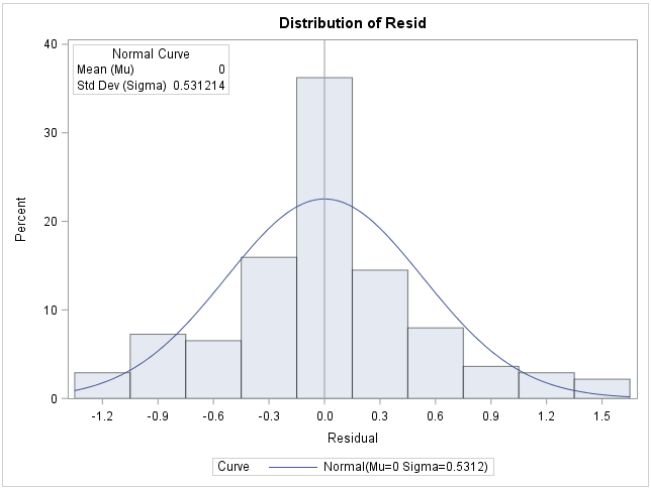


Figure 3. UNC scalloped hammerhead model diagnostic plots for lognormal component.



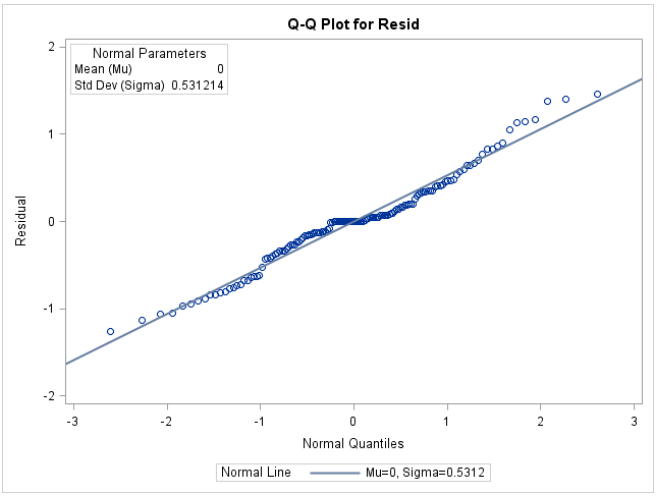



Figure 4. UNC scalloped hammerhead nominal (obcpue) and estimated (estcpue) indices with 95% confidence limits (LCI0, UCI0).