# Hierarchical analysis of U.S. Atlantic and Gulf of Mexico scalloped hammerhead recruitment indices

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**SEDAR 77 ASSESSMENT WORKSHOP DOCUMENT**

# Hierarchical analysis of U.S. Atlantic and Gulf of Mexico scalloped hammerhead recruitment indices

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***Summary***

This document details the hierarchical trends for U.S. Atlantic, Gulf of Mexico (GOM), and combined scalloped hammerhead indices of abundance recommended for use during the SEDAR 77 Data Workshop as recruitment indices. Recommended recruitment indices were the indices developed using only young-of-the-year data from the Cooperative Atlantic States Shark Pupping and Nursery (COASTPAN) longline and South Carolina Department of Natural Resources (SCDNR) COASTSPAN long and short gillnet surveys (SEDAR77-DW30, SEDAR77-DW31, and SEDAR77-DW32, respectively) in the Atlantic and from the Texas Parks and Wildlife Department and Gulf of Mexico Shark Pupping and Nursery (GULFSPAN) gillnet surveys (SEDAR77-DW16 and SEDAR77-DW17, respectively) in the GOM. The recommended indices (standardized to their means) and coefficients of variation were used in hierarchical analyses to estimate individual index process error, assuming a lognormal error structure, and hierarchical indices of abundance.

### ***Introduction***

Hierarchical analysis has been used in past shark SEDAR assessments to provide an overall abundance trend for multiple standardized indices of abundance. The standardization process is expected to capture the sampling error associated with each index of abundance, but does not account for the degree to which an index may measure 'artifacts' not related to the relative abundance of the entire population, referred to as process error (Conn 2010a, Conn 2010b). Process error can account for the variability in trends across multiple time series due to differences in catchability over time and space (Conn 2010b). The hierarchical method separates out the components of sampling and process error for each index and models the overall trend for all indices, while remaining robust to differences in trends of spatial mixing proportions and differing gear selectivities across surveys (Conn 2010b). This working paper details hierarchical analyses conducted to produce overall recruitment trends for the Atlantic, GOM and combined areas based on recruitment indices of abundance recommended by the SEDAR 77 Data Workshop.

### ***Data Analysis***

Recruitment indices recommended by the SEDAR 77 Data Workshop were the indices developed using only young-of-the-year data from the SCDNR COASTSPAN large and small gillnet surveys (SEDAR77-DW31 and SEDAR7-DW32, respectively) and the COASTSPAN longline survey (SEDAR77-DW30) in the Atlantic and the Texas Parks and Wildlife Department (SEDAR77-DW16) and GULFSPAN (SEDAR77-DW17) gillnet surveys in the GOM. These indices (standardized to their means) and coefficients of variation were incorporated into hierarchical analyses to produce estimates of individual index process error, assuming a lognormal error structure, and a hierarchical index of abundance with associated coefficients of variation and assessment model weights (based on the coefficients of variation). The relative abundance indices and CVs for each time series are provided in Table 1, excluding index values that did not produce a CV. The hierarchical analysis was conducted in a Bayesian framework using the same set of prior distributions (Figure 1) as described by Conn (2010b) and used for other shark species for stock assessment purposes (Conn 2010a). For each hierarchical index, inverse variance weights were produced for each index incorporated into the hierarchical analysis and were renormalized so that the weights for all indices summed to one. All analyses were conducted using the R programming environment (R Development Core Team 2021) in combination with WinBUGS software, version 1.4.3 (Lunn et al. 2000).

***Results***

The hierarchical index values and coefficients of variation are reported in Table 2 and the resulting inverse variance weights for each hierarchical index are reported in Table 3. The shorter time series in the Atlantic shows a slight decreasing trend overall, initially increasing to a peak in 2010, then decreasing until 2015, followed by a more subdued increase in recent years (Figure 2). In the GOM series there is an overall increasing trend, originally decreasing into the early 1990s and then increasing following implementation of the first shark fishery management plan (Figure 2). The combined index shows a similar trend to the GOM with a more subdued increase overall and reduced uncertainty where all indices overlap compared to the indices for the separate regions (Figure 2). There was little variation in process error across the individual surveys with all estimates under 1.0, regardless of region (Figure 3).

***References***


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Lunn, DJ., Thomas, A., Best, N., and Spiegelhalter, D. 2000. WinBUGS - a Bayesian modelling framework: concepts, structure, and extensibility. Statistics and Computing, 10:325–337. URL https://www.mrc-bsu.cam.ac.uk/software/bugs/

R Development Core Team. 2021. R: A language and environment for statistical computing, reference index version 4.1.1. The R Foundation for Statistical Computing Platform: x86_64-w64-mingw32/x64 (64-bit), URL http://www.R-project.org.

Table 1. Relative abundance indices and coefficients of variation (CV) of scalloped hammerhead recruitment for use in hierarchical analysis, including the index name and SEDAR document number.

| | SEDAR 77 DW16 | | SEDAR 77 DW17 | | SEDAR 77 DW31 | | SEDAR 77 DW32 | | SEDAR77 DW30 | |
|---|---|---|---|---|---|---|---|---|---|---|
| YEAR | TX PWD Gillnet | CV | GULF Gillnet | CV | SC COAST Large Gillnet | CV | SC COAST Small Gillnet | CV | COAST Longline | CV |
| 1983 | 0.0004 | 0.912 | | | | | | | | |
| 1984 | | | | | | | | | | |
| 1985 | 0.0002 | | | | | | | | | |
| 1986 | 0.0003 | 0.732 | | | | | | | | |
| 1987 | | | | | | | | | | |
| 1988 | 0.0005 | 0.618 | | | | | | | | |
| 1989 | 0.0001 | | | | | | | | | |
| 1990 | 0.0009 | 0.603 | | | | | | | | |
| 1991 | 0.0005 | 0.749 | | | | | | | | |
| 1992 | | | | | | | | | | |
| 1993 | 0.0003 | 0.819 | | | | | | | | |
| 1994 | 0.0003 | 0.848 | | | | | | | | |
| 1995 | 0.0001 | 1.165 | | | | | | | | |
| 1996 | 0.0009 | 0.536 | 0.009 | 0.294 | | | | | | |
| 1997 | 0.0017 | 0.666 | 0.016 | 0.461 | | | | | | |
| 1998 | 0.0003 | 0.842 | 0.002 | 0.548 | | | | | | |
| 1999 | 0.0002 | 0.781 | 0.091 | 0.312 | | | | | | |
| 2000 | 0.0005 | 0.589 | 0.156 | 0.253 | | | | | | |
| 2001 | 0.0015 | 0.603 | 0.148 | 0.302 | 1.2498 | 0.4793 | | | | |
| 2002 | 0.0003 | 0.822 | 0.150 | 0.166 | 0.7881 | 0.5178 | | | | |
| 2003 | 0.0018 | 0.577 | 0.102 | 0.181 | 2.7417 | 0.4496 | | | | |
| 2004 | 0.0007 | 0.689 | 0.070 | 0.227 | 0.5413 | 1.4316 | | | | |
| 2005 | 0.0025 | 0.517 | 0.048 | 0.373 | 0.6254 | 0.5384 | | | 5.4638 | 0.5288 |
| 2006 | 0.0007 | 0.630 | 0.079 | 0.220 | 0.9807 | 1.0179 | | | 8.1187 | 0.4156 |
| 2007 | 0.0008 | 0.778 | 0.168 | 0.171 | 1.9521 | 0.5328 | 0.1709 | 0.4233 | 1.9764 | 1.1276 |
| 2008 | 0.0008 | 0.703 | 0.172 | 0.189 | 1.3839 | 0.7066 | 0.2857 | 0.5813 | 1.7300 | 1.1650 |
| 2009 | 0.0010 | 0.560 | 0.163 | 0.200 | 7.2980 | 1.3825 | | | 3.4816 | 0.6543 |
| 2010 | 0.0021 | 0.598 | 0.208 | 0.211 | 2.2974 | 0.8537 | 0.1135 | 0.5813 | 9.3760 | 0.3267 |
| 2011 | 0.0009 | 0.563 | 0.159 | 0.201 | 1.4874 | 0.5401 | 0.1129 | 0.3072 | 3.8756 | 0.3722 |
| 2012 | 0.0012 | 0.540 | 0.093 | 0.217 | 8.1799 | 0.5273 | 0.1155 | 0.3072 | 1.9065 | 0.4686 |
| 2013 | 0.0048 | 0.428 | 0.129 | 0.215 | 4.0580 | 0.4515 | 0.0897 | 0.4233 | 2.0521 | 0.4267 |
| 2014 | 0.0020 | 0.477 | 0.141 | 0.207 | 2.2039 | 0.6955 | | | 2.4430 | 0.5484 |
| 2015 | 0.0028 | 0.565 | 0.068 | 0.252 | 0.9686 | 0.6158 | 0.0199 | 0.5813 | 1.1579 | 0.5536 |
| 2016 | 0.0019 | 0.590 | 0.124 | 0.235 | 1.6754 | 0.5384 | 0.0978 | 0.3507 | 1.8986 | 0.4191 |
| 2017 | 0.0004 | 0.775 | 0.184 | 0.200 | 6.8082 | 0.3406 | | | 1.1227 | 0.5195 |
| 2018 | 0.0048 | 0.499 | 0.210 | 0.225 | 3.7252 | 0.5473 | | | 0.7381 | 0.5650 |
| 2019 | 0.0025 | 0.514 | 0.176 | 0.265 | 3.3050 | 0.4230 | 0.0208 | 0.5813 | 1.0289 | 1.1753 |

Table 2. Hierarchical index values and associated coefficients of variation (CV)

| | **Atlantic** | | **GOM** | | **Combined** | |
|---|---|---|---|---|---|---|
| **Year** | **Index** | **CV** | **Index** | **CV** | **Index** | **CV** |
| 1983 | | | 0.5827 | 0.7827 | 0.7018 | 0.8854 |
| 1984 | | | 1.2286 | 1.2877 | 1.3641 | 1.3273 |
| 1985 | | | 1.2254 | 1.2856 | 1.3596 | 1.3078 |
| 1986 | | | 0.4817 | 0.7216 | 0.6025 | 0.8446 |
| 1987 | | | 1.2251 | 1.3202 | 1.3562 | 1.3013 |
| 1988 | | | 0.5694 | 0.6903 | 0.7000 | 0.8249 |
| 1989 | | | 1.2264 | 1.3185 | 1.3542 | 1.2890 |
| 1990 | | | 0.8410 | 0.6494 | 0.9528 | 0.7873 |
| 1991 | | | 0.6259 | 0.7268 | 0.7429 | 0.8339 |
| 1992 | | | 1.2243 | 1.2901 | 1.3624 | 1.3159 |
| 1993 | | | 0.4788 | 0.7477 | 0.5997 | 0.8778 |
| 1994 | | | 0.4395 | 0.7761 | 0.5600 | 0.9885 |
| 1995 | | | 0.3255 | 0.8541 | 0.4251 | 0.9381 |
| 1996 | | | 0.4634 | 0.5783 | 0.2701 | 0.7174 |
| 1997 | | | 0.7304 | 0.6147 | 0.4684 | 0.6733 |
| 1998 | | | 0.1876 | 0.6919 | 0.1164 | 0.7751 |
| 1999 | | | 0.4752 | 0.5946 | 0.6482 | 0.5088 |
| 2000 | | | 0.7241 | 0.5573 | 1.0283 | 0.4898 |
| 2001 | 0.7474 | 0.8175 | 1.2393 | 0.5240 | 1.0379 | 0.4152 |
| 2002 | 0.5934 | 0.8827 | 0.7087 | 0.5870 | 0.8007 | 0.4526 |
| 2003 | 1.1687 | 0.7757 | 1.2227 | 0.5216 | 1.1518 | 0.4002 |
| 2004 | 0.6841 | 0.9789 | 0.7178 | 0.5404 | 0.6370 | 0.4475 |
| 2005 | 0.9005 | 0.6636 | 1.2463 | 0.5381 | 0.7621 | 0.4564 |
| 2006 | 1.5404 | 0.6157 | 0.7072 | 0.5334 | 0.9131 | 0.4356 |
| 2007 | 1.1401 | 0.4901 | 1.0186 | 0.5625 | 1.2854 | 0.3553 |
| 2008 | 1.2372 | 0.5457 | 0.9766 | 0.5548 | 1.2916 | 0.3805 |
| 2009 | 1.4898 | 0.6665 | 1.0150 | 0.5171 | 1.4087 | 0.4062 |
| 2010 | 1.6858 | 0.5017 | 1.6271 | 0.5200 | 1.7936 | 0.3640 |
| 2011 | 1.0402 | 0.4281 | 0.9869 | 0.5218 | 1.1850 | 0.3379 |
| 2012 | 1.2285 | 0.4922 | 0.9765 | 0.5025 | 1.3108 | 0.3707 |
| 2013 | 0.9827 | 0.4616 | 2.3478 | 0.4984 | 1.4948 | 0.3650 |
| 2014 | 0.9472 | 0.5903 | 1.4121 | 0.4886 | 1.2529 | 0.3739 |
| 2015 | 0.3761 | 0.5003 | 1.3800 | 0.5456 | 0.6482 | 0.3901 |
| 2016 | 0.8139 | 0.4350 | 1.3166 | 0.5194 | 1.0851 | 0.3436 |
| 2017 | 1.1404 | 0.6715 | 0.8068 | 0.5889 | 1.5044 | 0.3980 |
| 2018 | 0.7207 | 0.6659 | 2.5518 | 0.5004 | 1.6565 | 0.3909 |
| 2019 | 0.5629 | 0.5936 | 1.6869 | 0.5028 | 1.1678 | 0.3791 |

Table 3. Inverse variance weights for the individual indices of abundance included in the develop of the three hierarchical indices

| Hierarchical Index | SC COAST Large Gillnet | SC COAST Small Gillnet | COAST Longline | TX PWD Gillnet | GULF Gillnet |
|---|---|---|---|---|---|
| Atlantic | 0.2341956 | 0.4636430 | 0.3021605 | | |
| GOM | | | | 0.6276011 | 0.3723989 |
| Combined | 0.1365222 | 0.3579566 | 0.2022996 | 0.1881566 | 0.1150651 |

Figure 1. Prior distributions (log space) with implied priors (real space)

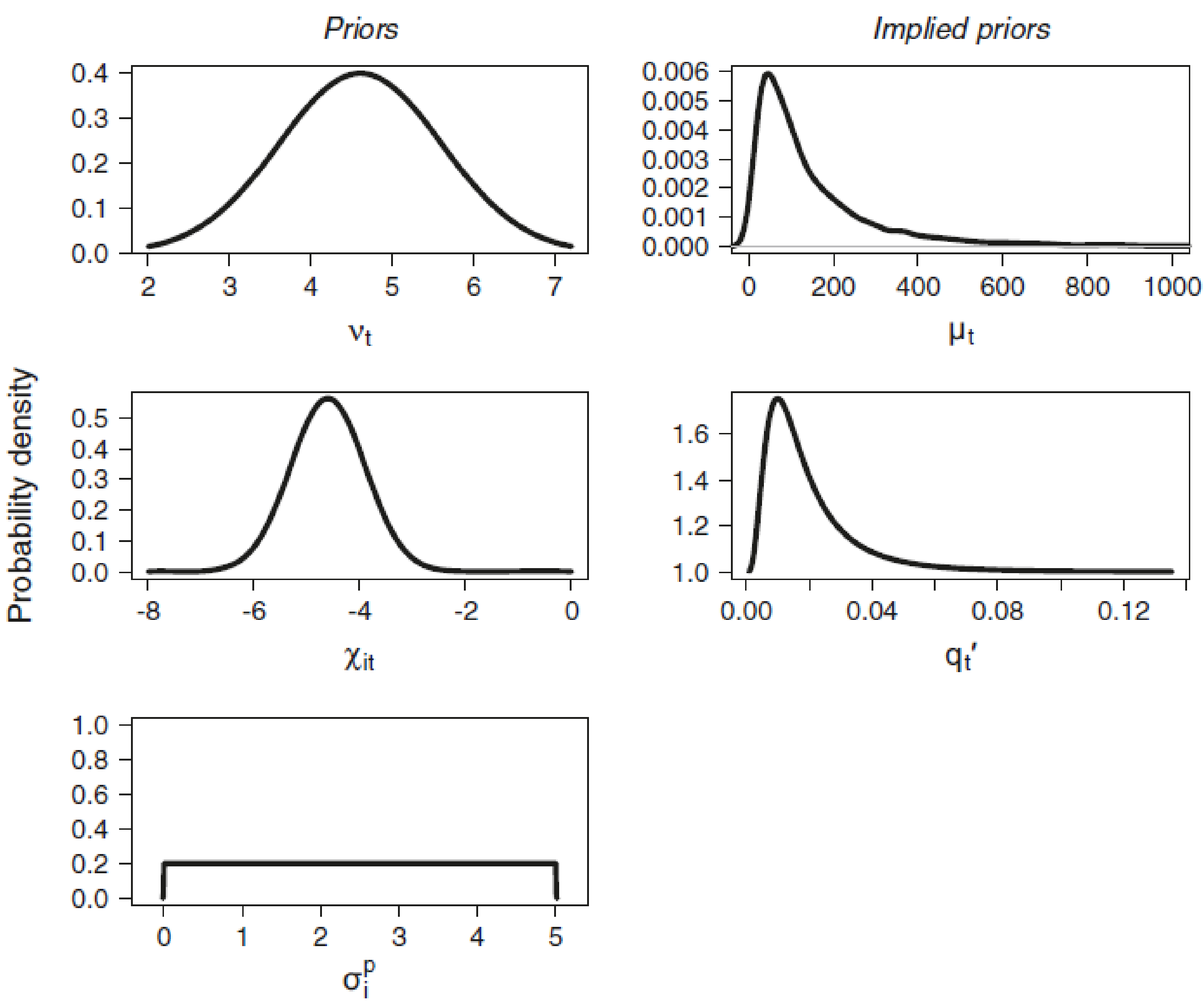

Figure 2. Hierarchical index for Atlantic, Combined, and GOM scalloped hammerhead recruitment indices.

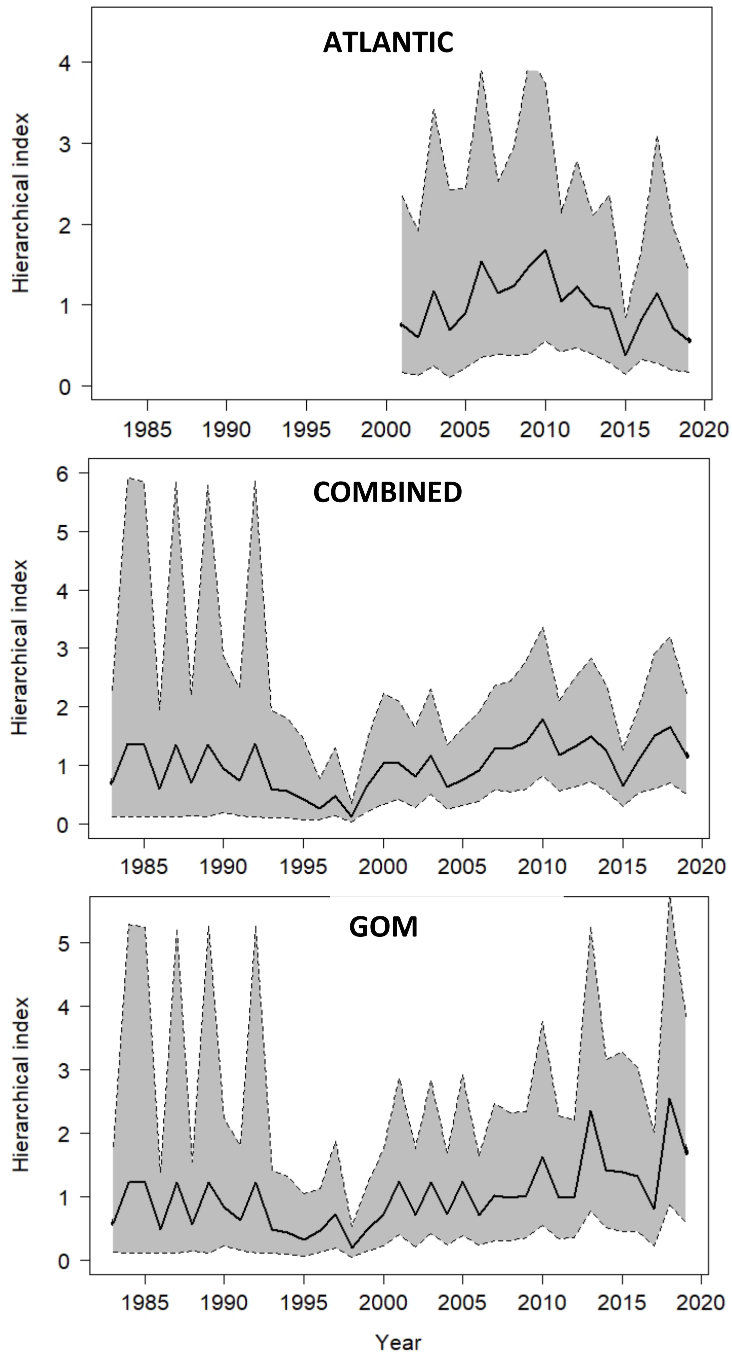

Figure 3. Process standard deviations for the indices used to develop the Atlantic, Combined, and GOM recruitment hierarchical index.