Hierarchical analysis of blacknose, sandbar, and dusky shark CPUE indices (SEDAR 21–AW–01)

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1 Introduction

Indices of abundance for SEDAR 21 encompass a wide range of gears, levels of spatial coverage, and a combination of fishery dependent and independent indices. In a recent review of SEDAR 21's data workshop (DW) report for sandbar, dusky, and blacknose sharks, Robin Cook (the Center for Independent Experts [CIE] reviewer) stressed that it was important to determine whether CPUE indices generated for these stocks were truly measuring changes in relative abundance rather than some other artifact (e.g., localized abundance trends, changes in spatial distribution, etc.). He suggested using factor analysis as a potential method for comparing similarities of trends among various indices.

The object of this working paper is to use a related approach - hierarchical analysis - to accomplish the same goal. The approach used here is the one described by Conn (2010), which assumes that each index is attempting to estimate relative abundance, but is subject to both sampling and process error. Sampling error is assumed to be captured by the standardization procedures used to generate abundance indices (i.e., via the CV's reported along withe each index in the DW report). However, each index is assumed to also be subject to process variation, which describes the degree to which a given index measures 'artifacts' above and beyond relative abundance in the population (in practice, process variance will also reflect differences in selectivity among the various indices).

2 Methods

Let indices of abundance be given as $\mathbf{U_i}$, where index i is composed of $\{U_{it}\}$ for $t \in \{t_{i1}, \ldots, t_{iT}\}$, where t is a time subscript and T gives the ending year of the study. If $\boldsymbol{\mu} = \mu_1, \mu_2, \ldots, \mu_T$ represent a scaled abundance time series, where annual changes in μ_t are reflective of changes of abundance at the population scale (that is, $\mu_t = cN_t$ for some unknown constant c), then lognormal process and sampling error yield the model

$$\log(U_{it}) \sim \text{Normal}(\log(\mu_t) + \log(q_i'), (\sigma_{it}^p)^2 + (\sigma_{it}^s)^2),$$

where q_i' gives a scaling coefficient for index i (relative to μ), σ_{it}^p gives process standard deviation (SD), and σ_{it}^s gives sampling standard deviation (Conn 2010). In this case, note that the relation $\sigma_{it}^s = \sqrt{\log([CV(U_{it})]^2 + 1)}$ can be used to convert index CVs into index SDs.

The model as described above is ill defined, as there is nothing constraining the μ_t values. Since they are only required to be proportional to true abundance, I imposed the constraint as in Conn (2010); namely, that the mean of $\ln(\mu_t)$ equal ln(100). This constraint is arbitrary but not capricious; other constraints could have been used with equal effectiveness, and would be expected to yield similar results as far as *relative* abundance.

I gathered relative abundance indices from the SEDAR 21 DW report to use for analysis. I only included indices recommended for the 'base run' of the assessment model, and elected to use indices that reflected relative abundance of adults (juvenile abundance indices were omitted because the selectivity process was substantially different). Each index was standardized to it's mean prior to analysis. Separate analyses were conducted for dusky, sandbar, south Atlantic blacknose, and Gulf of Mexico blacknose (blacknose being split into two stocks). Standardized indices and CVs for each analysis are provided in Tables 1-4. Each analysis was conducted in a Bayesian framework, using the same set of prior distributions and MCMC configuration as described by Conn (2010). Computation was performed using WinBUGS software (Lunn et al. 2000).

In addition to model fitting, I also calculated inverse variance weights for each index for all stocks under consideration. These weights are calculated as $w_i = \frac{1}{((\sigma^s_{it})^2 + (\sigma^p_i)^2)}$, and then renormalized so that the weights sum to one. These weights are intended as possible selectivity weights in the case that the combined index is considered for use in a sensitivity run.

3 Results

A table including hierarchical index values and associated CVs for each stock is provided in Table 5.

3.1 Dusky shark

For dusky shark, hierarchical analysis suggested that relative abundance decreased from the mid-1970s until the late 1990s or early 2000s, and that there has been an uptick in recent years (Fig. 1). The model also suggested that the bottom longline observer program (BLLOP) and large pelagic survey (LPS) had the lowest level of process error (these levels were consistent with process CVs on the order of 0.1) (Fig. 2). By contrast, the other indices had process CVs ranging from around 1.7 (VIMS) to 6.0 (Northeast longline survey). These estimates suggest that the VIMS, NE longline, and SEPLOP indices are substantially more imprecise at measuring population abundance than the sampling error CVs reported along with indices indicate (at least for dusky shark). Inverse variance selectivity weightings were esetimated at 0.043 (VIMS), 0.043 (Northeast Longline), 0.322 (BLLOP), 0.071 (SEPLOP), and 0.520 (LPS).

3.2 Sandbar shark

Similar to dusky, relative abundance of sandbar sharks was estimated to have decreased up until early 2000s, followed by an increase in more recent years (Fig.

3). Process errors were estimated to be lowest for the BLLOP, VIMS survey, and southeast bottom longline survey (Fig. 4), where process CV was close to 0.1. In contrast, process variation was estimated to be highest for the northeast longline suvey and South Carolina Coastspan survey (these process SDs translated into process CVs in the 2.0-3.0 range). Inverse variance selectivity weights were estimated as 0.207 (Southeast bottom longline), 0.101 (Coastspan age 1+), 0.140 (VIMS), 0.033 (Northeast longline), 0.027 (South Carolina coastspan), 0.087 (Red Drum), 0.271 (BLLOP), 0.052 (SEPLOP), and 0.082 (LPS).

3.3 GOM blacknose shark

For GOM blacknose shark, hierarchical analysis indicated that relative abundance increased over the duration for which indices were available (Fig. 5). However, the longest running index only went back to 1987, so it is difficult to infer from these data how more recent relative abundance compares to relative abundance at the time when other stocks seem to have been depleted (e.g. 1970s and early-mid 1980s).

In this case, the model seemed to key in on the fishery independent series (with the exception of the Dauphin lab survey (Fig. 6). In particular, the Dauphin and BLLOP surveys had higher estimated process errors than the other surveys (for reference, a value of process SD 0f 1.0 is approximately equal to a process CV of 1.7).

Inverse variance selectivity weights were estimated as 0.113 (SEAMAP summer), 0.113 (SEAMAP fall), 0.225 (Panama City gillnet), 0.367 (Southeast bottom longline), 0.096 (Mote), 0.044 (Dauphin Island survey), and 0.041 (BLLOP).

3.4 South Atlantic blacknose shark

For SA blacknose shark, hierarchical analysis revealed a pattern very similar to dusky and sandbar shark, with declines from the beginning of the time series (1972) up until the early to mid 2000's and an uptick in recent years (Fig. 7). In this case, the model seemed to have a rather poor view of the southeast bottom longline survey, with process variance quite high with SD = 4.5 (Fig. 8). This is likely a function of two factors: (1) the index exhibited wild swings in relative abundance from year to year which couldn't be explained by sampling error alone, and (2) the general pattern of large increase throughout the time series wasn't reconcilable with the other CPUE series.

Inverse variance selectivity weights were estimated as 0.004 (Southeast bottom longline), 0.286 (SC red drum), 0.186 (UNC), 0.102 (GA red drum), 0.057 (BLLOP), 0.198 (DGOP), and 0.167 (CFL).

4 Discussion

This analysis provided evidence that there is a good deal of process variation that is not accounted for by just modeling sampling error alone. For some indices, process variation was estimated to be relatively minor (with CVs on the order of 0.1). However, for others, it was quite high (process error CVs of 2 or greater). Thus, it appears that it would be a good idea to account for the fact that some indices appear to be modeling 'other stuff' than relative abundance. One way to do this would be to model 'additional variance' for indices within assessment models (sensu Geromont and Butterworth 2001). For instance, this can be done using the age structured catch-free model developed by Porch et al. (2006), which has been suggested for use with dusky sharks.

There was relatively little consistency between surveys with regard to whether they resulted in estimates of process variance that were large or small. For example, the model suggested that the BLLOP survey did a good job (low process error) at indexing dusky and sandbar shark, but a relatively poor job for blacknose. Similarly, the southeast bottom longline index was estimated to perform reasonably for sandbar and GOM blacknose, but extremely poorly with regard to SA blacknose. Such seeming discrepancies may be do in part to differences in life history, spatial distribution, etc. between stocks but may also be do in part to inherent conflicts between indices that are difficult to explain.

References

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Lunn, D., A. Thomas, N. Best, and D. Spiegelhalter. 2000. WinBUGS – a Bayesian modelling framework: concepts, structure, and extensibility. Statistics and Computing **10**:325–337.

Porch, C. E., A. Eklund, and G. P. Scott. 2006. A catch-free stock assessment model with application to goliath grouper (Epinephelus itajara) off southern Florida. Fishery Bulletin **104**:89–101.

Figure 1: Relative abundance of dusky sharks as estimated via hierarchical analysis using data from all CPUE indices recommended for the 'base' stock assessment model. The black line represents the posterior mean, while dashed lines represent 95% credible intervals. The time series were standardized to have a mean of 1.0 prior to plotting.

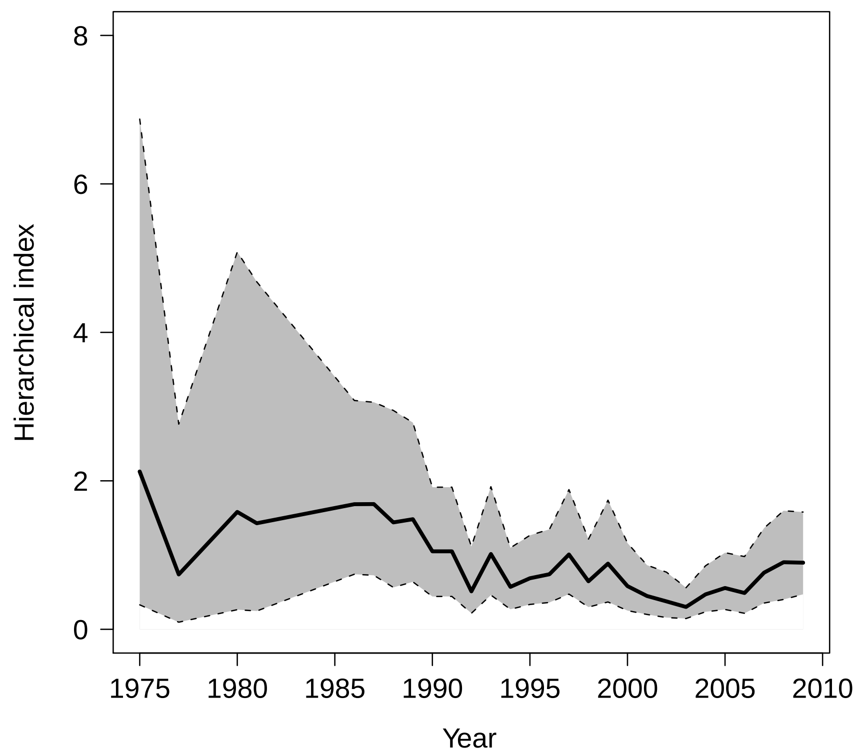


Figure 2: Process standard deviation as estimated for each 'base run' dusky CPUE series.

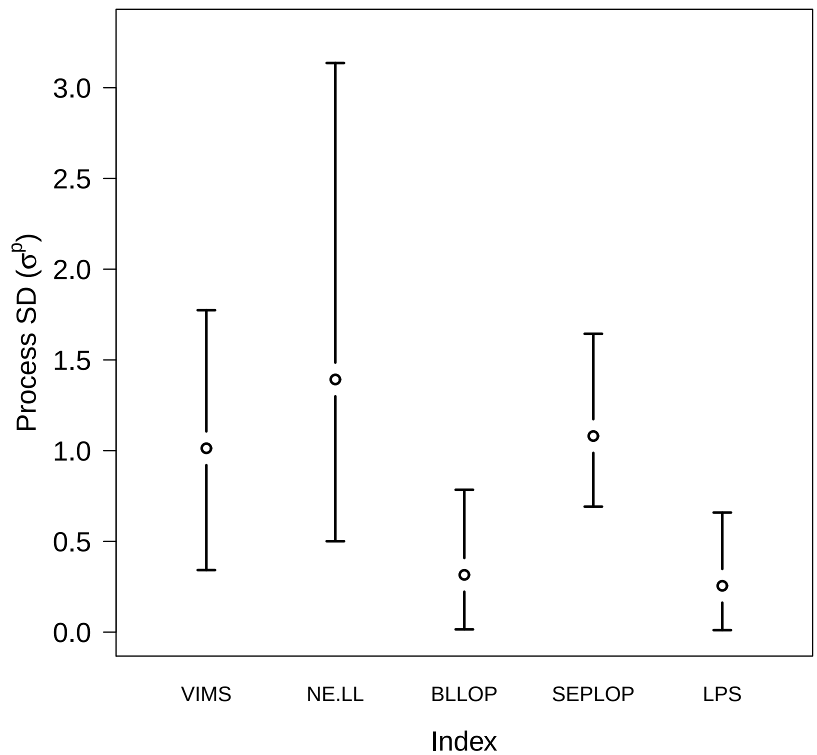


Figure 3: Relative abundance of sandbar sharks as estimated via hierarchical analysis using data from all CPUE indices recommended for the 'base' stock assessment model. The black line represents the posterior mean, while dashed lines represent 95% credible intervals. The time series were standardized to have a mean of 1.0 prior to plotting.

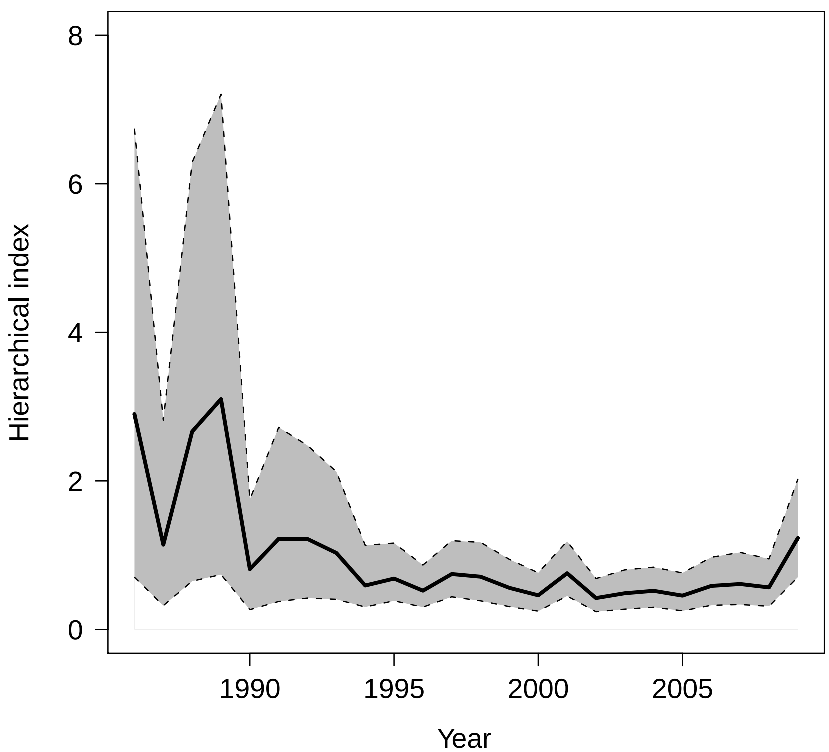


Figure 4: Process standard deviation as estimated for each 'base run' Sandbar CPUE series.

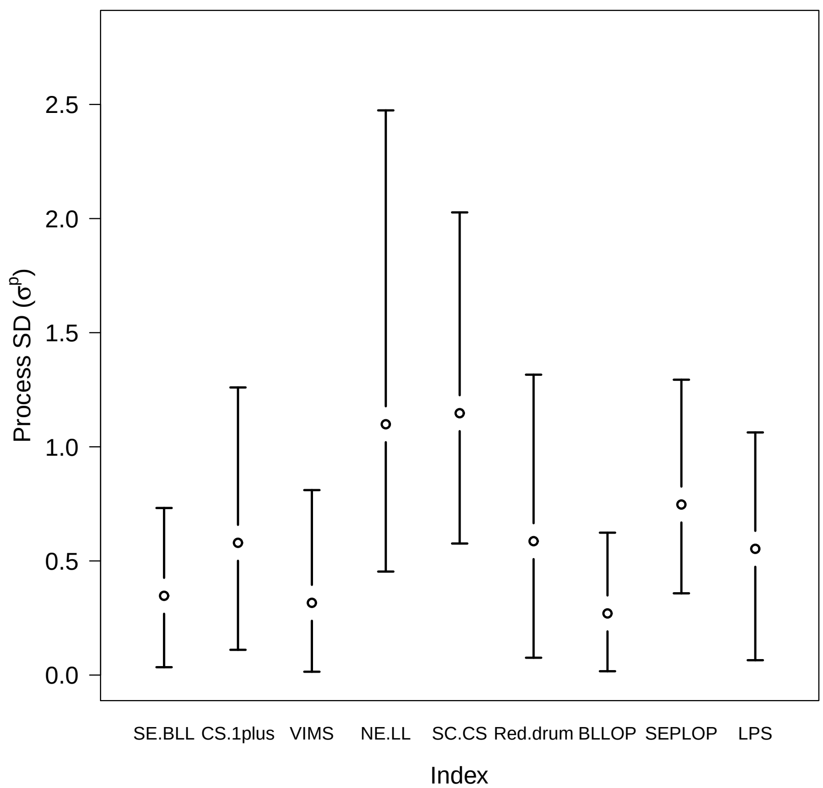


Figure 5: Relative abundance of GOM blacknose sharks as estimated via hierarchical analysis using data from all CPUE indices recommended for the 'base' stock assessment model. The black line represents the posterior mean, while dashed lines represent 95% credible intervals. The time series was standardized to have a mean of 1.0 prior to plotting.

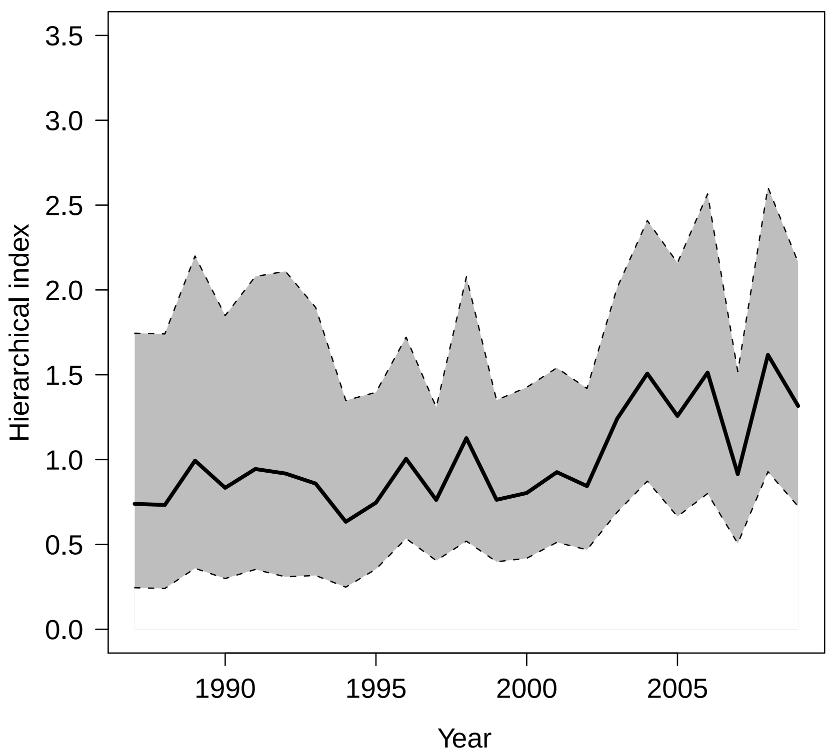


Figure 6: Process standard deviation as estimated for each 'base run' GOM blacknose CPUE series.

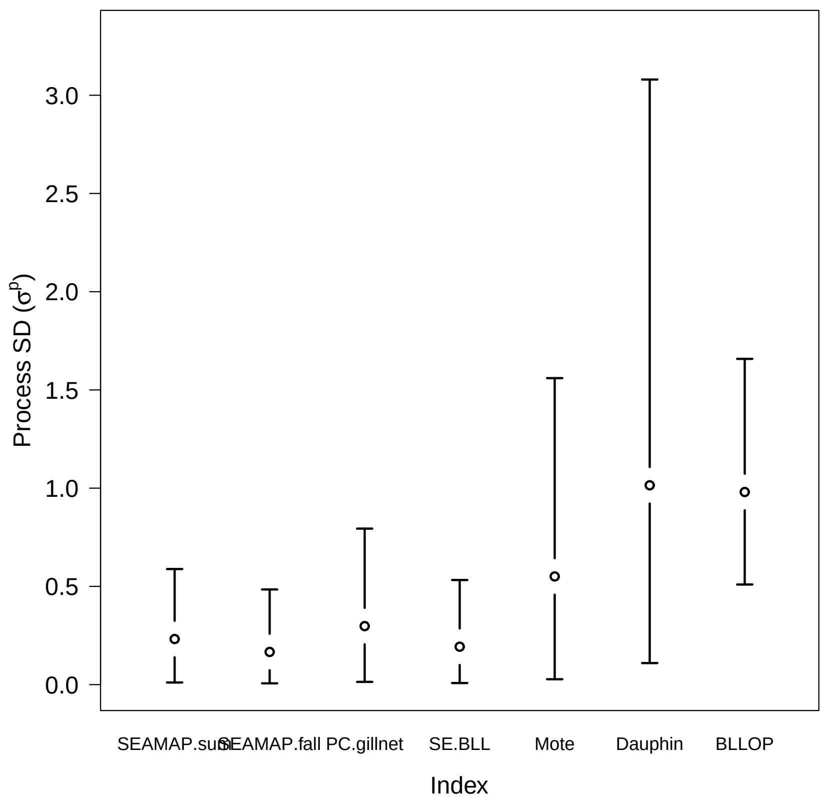


Figure 7: Relative abundance of SA blacknose sharks as estimated via hierarchical analysis using data from all CPUE indices recommended for the 'base' stock assessment model. The black line represents the posterior mean, while dashed lines represent 95% credible intervals. The time series was standardized to have a mean of 1.0 prior to plotting.

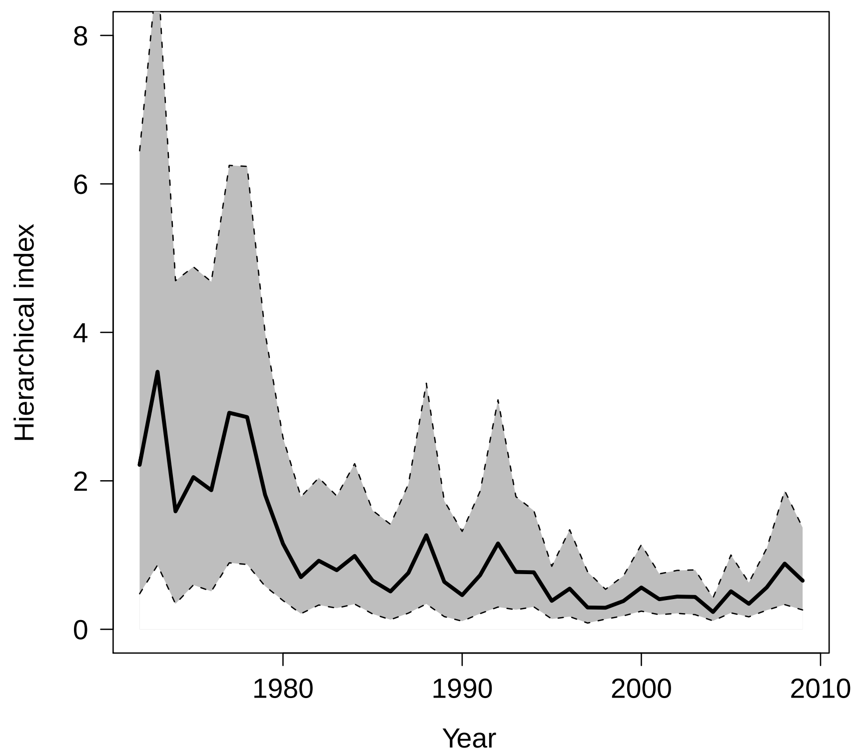
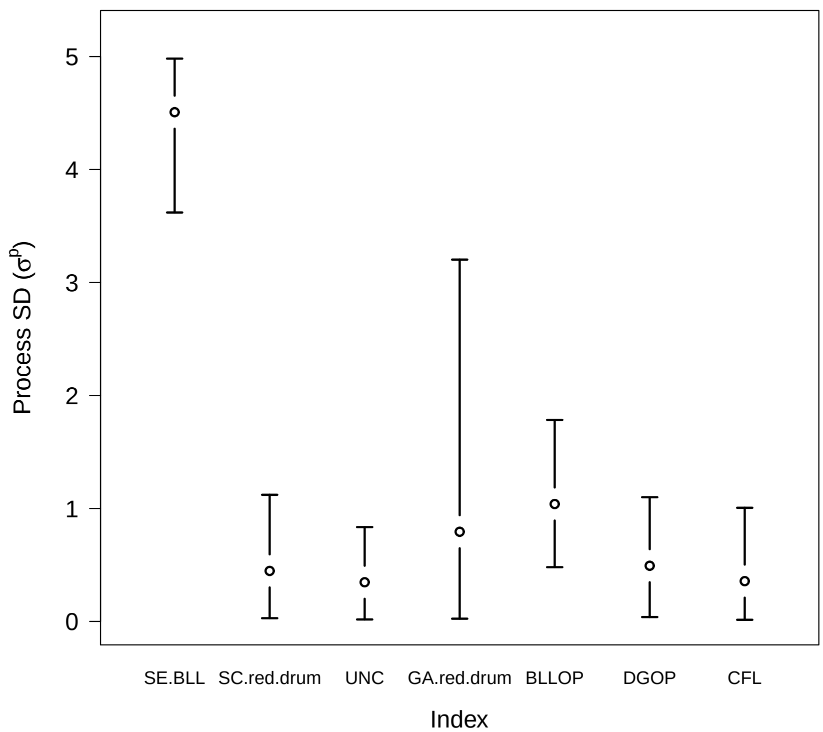


Figure 8: Process standard deviation as estimated for each 'base run' SA blacknose CPUE series.



Year	VIMS	CV	NE.LL	CV	BLLOP	CV	SEPLOP	CV	LPS	CV
1975	4.15	0.52								
1976										
1977	0.19	1.92								
1978										
1979										
1980	2.21	0.54								
1981	1.76	0.52								
1982										
1983										
1984										
1985										
1986									2.17	0.12
1987									2.17	0.12
1988									1.84	0.30
1989									1.89	0.17
1990	0.06	2.54							1.43	0.15
1991	0.08	2.29							1.42	0.16
1992	0.02	5.18					4.10	0.27	0.45	0.29
1993	0.34	1.24					1.91	0.22	1.26	0.24
1994					0.68	0.39	3.10	0.22	0.54	0.38
1995	0.16	1.84			1.44	0.34	1.24	0.26	0.60	0.32
1996	0.50	0.86	0.08	0.75	1.23	0.34	1.22	0.29	0.99	0.41
1997					2.25	0.36	0.56	0.35	0.94	0.38
1998	0.17	1.53	0.35	0.53	1.35	0.38	1.45	0.30	0.51	0.49
1999	0.82	0.95			2.20	0.39	0.39	0.39	0.54	0.68
2000	1.23	0.68			0.74	0.66	0.82	0.31	0.51	0.53
2001	0.29	1.28	0.37	0.48	0.93	0.44	0.35	0.37	0.31	0.66
2002	0.94	0.95			0.28	0.51	0.17	0.89	0.65	0.61
2003	0.17	2.16			0.37	0.37	0.10	0.63	0.42	0.38
2004	0.97	0.71	1.08	0.31	0.41	0.38	0.56	0.31	0.61	0.34
2005	2.09	0.69			0.45	0.50	0.46	0.30	0.73	0.34
2006	2.69	0.50			0.57	0.55	0.82	0.28	0.34	0.46
2007	0.28	1.12	1.01	0.52	0.68	0.66	0.33	0.32	1.22	0.24
2008	0.12	2.04			0.95	0.62	0.23	0.42	1.48	0.21
2009	2.75	0.75	3.11	0.34	1.46	0.32	0.21	0.29	0.98	0.26

Table 1: Relative abundance indices and CVs for dusky sharks for use in hierarchical analysis. Each index was divided by its mean prior to analysis.

Year	SE.BLL	CV	CS.1plus	CV	VIMS	CV	NE.LL	CV	SC.CS	CV	Red.drum	CV	BLLOP	CV	SEPLOP	CV	LPS	CV
1986																	3.48	0.15
1987																	1.02	0.21
1988																	3.19	0.20
1989																	3.78	0.12
1990					0.51	0.60											1.24	0.18
1991					0.71	0.63											2.08	0.17
1992					0.30	0.90									3.33	0.32	1.62	0.18
1993					0.96	0.59									2.63	0.21	0.83	0.55
1994													0.62	0.17	1.86	0.23	0.51	0.47
1995	1.85	0.26			1.13	0.29							0.66	0.14	1.50	0.29	0.44	0.57
1996	0.97	0.34			1.13	0.37	0.14	0.37					0.57	0.15	1.22	0.38	0.54	0.59
1997	1.47	0.27			1.05	0.37							0.91	0.18	1.24	0.34	0.62	0.47
1998					1.71	0.31	0.83	0.27	0.70	0.70	0.55	0.46	1.00	0.19	0.88	0.52	0.17	0.98
1999	0.46	0.27			1.35	0.53			0.61	0.64	2.33	0.35	0.74	0.21	1.12	0.41	0.24	0.84
2000	1.08	0.18			1.28	0.37			0.10	0.92	0.23	0.55	0.44	0.31	0.41	0.46	0.29	0.86
2001	1.02	0.25	1.34	0.23	1.41	0.34	0.41	0.27	0.05	0.85	1.37	0.47	1.26	0.20	0.48	0.48	1.22	0.65
2002	0.80	0.22	0.46	0.41	0.76	0.52			0.22	0.86	0.90	0.40	0.52	0.40	0.03	1.97	0.42	0.76
2003	0.98	0.25	1.27	0.24	0.65	0.61			0.31	0.73	0.60	0.36	0.75	0.37	0.03	1.97	0.19	0.59
2004	0.77	0.26	1.26	0.27	0.87	0.46	0.32	0.35	1.75	0.36	1.32	0.29	0.58	0.38	0.55	0.35	0.11	0.66
2005	0.35	0.59	1.31	0.26	0.56	0.49			1.06	0.26	0.61	0.42	0.76	0.42	0.20	0.48	0.47	0.46
2006	0.45	0.36	0.68	0.31	1.38	0.29			1.78	0.23	1.09	0.26	1.07	0.40	0.88	0.43	0.15	0.79
2007	0.97	0.39	0.71	0.29	0.40	0.65	1.41	0.30	2.02	0.32			1.42	0.41	0.55	0.37	0.33	0.44
2008	0.84	0.32	0.22	0.49	1.23	0.33			2.01	0.38			1.06	0.43	0.54	0.28	0.39	0.44
2009	1.99	0.21	1.75	0.19	1.62	0.36	2.89	0.21	1.37	0.37			3.63	0.37	0.55	0.28	0.64	0.39

Table 2: Relative abundance indices and CVs for sandbar sharks for use in hierarchical analysis. Each index was divided by its mean prior to analysis.

Year	SEAMAP.sum	CV	SEAMAP.fall	CV	PC.gillnet	CV	SE.BLL	CV	Mote	CV	Dauphin	CV	BLLOP	CV
1987	0.53	0.78	0.77	0.92										
1988	0.55	0.84	0.70	0.89										
1989	1.26	0.61	0.61	0.89										
1990	0.48	0.82	1.05	0.67										
1991	0.82	0.70	0.99	0.69										
1992	0.60	0.84	1.12	0.76										
1993	1.11	0.66	0.55	0.75										
1994	0.65	0.69	0.83	0.69									0.08	0.77
1995	0.56	0.91	1.70	0.62			0.50	0.43					0.24	0.60
1996	0.91	0.67	0.94	0.77	0.96	0.31	1.14	0.41					0.16	0.74
1997	0.95	0.73	0.88	0.79	0.55	0.43	0.77	0.32					0.19	0.78
1998	0.77	0.74	0.91	0.73	1.39	0.31							0.32	0.61
1999	0.57	0.85	1.22	0.69			0.63	0.26					0.80	0.62
2000	0.96	0.64	1.05	0.73			0.66	0.26						
2001	2.01	0.65	0.68	0.80	0.84	0.43	0.86	0.24					0.12	0.74
2002	0.82	0.73	0.82	0.75	0.81	0.36	0.67	0.27					1.56	0.42
2003	1.48	0.59	1.10	0.58	0.66	0.36	1.64	0.21	0.40	0.65			0.97	0.40
2004	1.10	0.63	0.86	0.81	1.61	0.36	1.54	0.22	1.27	0.37			1.45	0.43
2005	1.20	0.74	1.20	0.57	1.24	0.36	0.50	0.79	1.06	0.33			2.98	0.43
2006	0.97	0.68	0.77	0.77			1.68	0.28	0.74	0.62	1.92	0.25	2.96	0.41
2007	0.81	0.74	1.38	0.74	0.42	0.43	0.71	0.31	1.16	0.33	0.99	0.31	1.51	0.46
2008	1.23	0.60	1.73	0.47	2.02	0.31	1.18	0.33	2.12	0.37	0.76	0.37	1.28	0.53
2009	2.65	0.29	1.16	0.62	0.47	0.58	1.52	0.25	0.26	0.87	0.33	0.56	0.39	0.56

Table 3: Relative abundance indices and CVs for GOM blacknose sharks for use in hierarchical analysis. Each index was divided by its mean prior to analysis.

Year	SE.BLL	CV	SC.red.drum	CV	UNC	CV	GA.red.drum	CV	BLLOP	CV	DGOP	CV	CFL	CV
1972					3.36	0.88								
1973					5.21	0.59								
1974					1.89	0.90								
1975					2.31	0.46								
1976					2.10	0.53								
1977					3.33	0.30								
1978					3.35	0.34								
1979					1.88	0.34								
1980					1.07	0.33								
1981					0.54	0.52								
1982					0.82	0.29								
1983					0.67	0.31								
1984					0.88	0.33								
1985					0.50	0.46								
1986					0.31	0.70								
1987					0.60	0.55								
1988					1.24	0.61								
1989					0.44	0.65								
1990					0.24	0.78								
1991					0.56	0.54								
1992					1.08	0.64								
1993					1.01	0.60					0.73	0.74		
1994					0.51	0.72			1.15	1.15	1.72	0.31		
1995	0.00	0.72			0.25	0.78			0.66	0.42	0.72	0.67		
1996	0.00	0.66			0.41	0.69			1.01	0.40				
1997	0.18	0.75			0.20	0.77			0.13	0.64				
1998			0.93	0.28	0.11	0.85			0.38	0.55	0.43	0.59	0.42	0.70
1999	2.77	0.60	1.27	0.41	0.13	1.01			2.17	0.57	0.56	0.27	0.44	0.70
2000	0.65	0.43	0.81	0.24	0.15	0.80			4.03	0.48	2.52	0.31	0.73	0.67
2001			0.77	0.35	0.24	0.84			2.51	0.81	1.08	0.28	0.37	0.68
2002	1.64	0.31	1.57	0.25	0.12	0.85			1.17	0.51	0.82	0.28	0.45	0.69
2003			1.64	0.21	0.08	1.15			0.09	1.02	0.84	0.36	0.76	0.69
2004	0.40	0.84	0.60	0.38	0.20	0.80			0.09	0.80	0.49	0.33	0.28	0.71
2005	0.00	0.83	0.67	0.53	0.22	0.86			0.60	0.56	2.26	0.35	0.90	0.71
2006	1.72	0.55	0.74	0.29	0.38	0.57			0.32	0.67	0.21	0.75	1.05	0.67
2007					0.89	0.47	0.52	0.54	1.21	1.01	0.63	0.75	0.56	0.72
2008	3.03	0.57			0.24	0.80	1.31	0.45	0.33	0.99			4.58	0.64
2009	0.61	1.16			0.48	0.72	1.17	0.48	0.15	0.99			1.46	0.67

Table 4: Relative abundance indices and CVs for SA blacknose sharks for use in hierarchical analysis. Each index was divided by its mean prior to analysis.

Year	Dusky	CV	Sandbar	CV	GOM.BN	CV	SA.BN	CV
1972							2.22	0.73
1973							3.47	0.62
1974							1.59	0.74
1975	2.13	0.87					2.05	0.55
1976	1.27	1.30					1.87	0.59
1977	0.74	1.06					2.92	0.48
1978	1.27	1.34					2.86	0.49
1979	1.27	1.32					1.81	0.50
1980	1.58	0.86					1.15	0.50
1981	1.43	0.88					0.70	0.61
1982	1.27	1.31					0.92	0.50
1983	1.26	1.29					0.80	0.51
1984	1.27	1.32					0.99	0.51
1985	1.26	1.27					0.66	0.58
1986	1.69	0.36	2.90	0.56			0.51	0.70
1987	1.69	0.36	1.14	0.58	0.74	0.54	0.76	0.62
1988	1.44	0.43	2.66	0.57	0.73	0.54	1.27	0.63
1989	1.48	0.38	3.10	0.56	0.99	0.49	0.64	0.66
1990	1.05	0.36	0.81	0.49	0.83	0.49	0.46	0.73
1991	1.05	0.36	1.22	0.51	0.94	0.48	0.73	0.61
1992	0.51	0.48	1.22	0.44	0.92	0.52	1.16	0.65
1993	1.01	0.38	1.03	0.44	0.86	0.48	0.77	0.52
1994	0.57	0.38	0.59	0.37	0.63	0.46	0.77	0.44
1995	0.69	0.35	0.69	0.29	0.75	0.36	0.38	0.49
1996	0.74	0.34	0.52	0.28	1.01	0.30	0.55	0.57
1997	1.01	0.37	0.75	0.26	0.76	0.30	0.29	0.63
1998	0.65	0.37	0.71	0.28	1.13	0.36	0.29	0.36
1999	0.88	0.40	0.56	0.29	0.76	0.33	0.38	0.37
2000	0.58	0.41	0.46	0.29	0.80	0.33	0.56	0.42
2001	0.45	0.39	0.76	0.25	0.93	0.29	0.41	0.35
2002	0.38	0.43	0.42	0.27	0.84	0.29	0.44	0.34
2003	0.30	0.36	0.49	0.28	1.24	0.27	0.44	0.36
2004	0.47	0.34	0.52	0.27	1.51	0.26	0.23	0.35
2005	0.56	0.36	0.46	0.29	1.26	0.30	0.51	0.40
2006	0.49	0.41	0.59	0.28	1.51	0.30	0.34	0.35
2007	0.76	0.34	0.61	0.29	0.91	0.28	0.56	0.38
2008	0.90	0.34	0.57	0.29	1.62	0.27	0.88	0.45
2009	0.90	0.32	1.23	0.28	1.32	0.28	0.66	0.44

Table 5: Hierarchical relative abundance indices for dusky, sandbar, GOM blacknose, and SA blacknose stocks as estimated by the posterior mean of the hierarchical analysis, together with associated estimates of coefficient of variation.