S E D A R

Southeast Data, Assessment, and Review

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History of Assessments of the Menhaden Stock along the U.S. Gulf of Mexico Coast

Prepared by
Douglas S. Vaughan
NOAA Fisheries
Beaufort, North Carolina
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SEDAR
The South Atlantic Fishery Management Council
4055 Faber Place #201
North Charleston, SC 29405
(843) 571-4366

Assessment History

Quantitative analyses seem to have begun in the early 1970s, as the time series of detailed data developed (accurate reduction landings have been recorded since 1946, and detailed biostatistical sampling began in 1964). The first quantitative analysis was that based on a Schaefer-type surplus production model using CPUE and effort data (Chapoton 1972). Schaaf (1975) updated this analysis and provides some cautionary comments on applying this model in a developing fishery. A further update of this analysis can be found in the original management plan for this stock (Christmas and Etzold 1977). Ahrenholz (1981) developed estimates of rates of exploitation, population movements and recruitment into the fishery from returns of tagged juveniles and adults. An important result from this study that has been used in subsequent assessment is the estimate for natural mortality (M = 1.1) based on tagged adults.

Two formal stock assessments were completed during the 1980s. First, Nelson and Ahrenholz (1986) included data through 1978, and the second, Vaughan (1987), included data through 1985. These assessments used an "untuned" virtual population analysis (VPA) approach based on the cohort-linked method described by Murphy (1965) to estimate age- and year-specific fishing mortality and population numbers from the catch-at-age matrix computed from the reduction fishery landings and biostatistical samples. Yield-per-recruit analyses, spawner-recruit relationships and surplus production models were then developed from the VPA output. Results of these two assessments appeared in revisions to the Fisheries Management Plan (Christmas et al. 1983, 1988). Stock assessment results were also summarized in the special menhaden issue of Marine Fisheries Review (Vaughan and Merriner 1991).

Two formal stock assessments were conducted during the 1990s (Vaughan et al. 1996, 2000) and results incorporated into further revisions to the Fisheries Management Plan (Leard et al., 1995, VanderKooy and Smith 2002). Vaughan et al. (1996) included fisheries data through 1992. In addition to applying the VPA approach of Murphy (1965), they also applied the separable VPA approach of Doubleday (1976). The separable VPA was fit to the full catch-at-age matrix (1964-2002) and discrete fits to two separate time periods (1964-1975, 1976-1992). Vaughan et al. (2000) continued these methods, applying the method of Murphy (1965) to the early time period (1964-1975) and updating the separable VPA to the later time period (1976-1997). As in the 1980s, results from the VPAs were used in developing, yield-per-recruit analyses, spawner-recruit relationships, and surplus production models. Vaughan et al. (2000) also began investigating the utility of juvenile abundance indices from Louisiana (trawl survey) and Texas (bag seine). They also updated the relationship between menhaden recruitment and Mississippi River flow reported by Govoni (1997).

As noted above, assessment methods used the "untuned" VPA method of Murphy (1995) and later separable VPA of Doubleday (1976) as the primary assessment methodology through 2000. The most recently completed assessment of the status of the gulf menhaden stock was Vaughan et al (2007). As before, data included abundance indices, recorded landings, and samples of

annual size and age compositions from the landings through 2004. Several important changes were made for this assessment. First, age-varying natural mortality was implemented based on the approach of Boudreau and Dickie (1989). Natural mortality was related inversely to the weight at age of gulf menhaden and scaled to M estimated by Ahrenholz (1981) for adult menhaden. Next, a statistical model similar to that currently used for Atlantic menhaden (ASMFC 2004) was applied to these data. Finally, the added flexibility of this approach further allowed three state juvenile abundance seine indices to be incorporated into this model. A base assessment model run was developed and sensitivity model runs were made to evaluate performance of the assessment model.

Status of stock based on the terminal year (2004) estimates relative to their corresponding limits (or threshold) was compared. These benchmarks corresponded to the approach used by ASMFC for Atlantic menhaden (ASMFC 2004). Benchmarks were estimated based on the results of the updated base run. The terminal year estimate of fishing mortality rate (F_{2+}) was estimated to be 75% of its limit (and 116% of its target). Correspondingly, the terminal year estimate of population fecundity was estimated at 93% of its fecundity target (and 186% of its limit). Hence, the stock was not considered to be overfished, nor was overfishing occurring.

Historical Retrospective

"Historical retrospective" can be investigated using annual stock assessments that have been conducted consistently over the years (Cadrin and Vaughan 1997). These analyses compare estimates of important management variables from the most recent assessment with contemporary estimates from prior stock assessments. In particular, Cadrin and Vaughan (1997) compared three management variables (or "triggers") in their analysis, including spawning stock biomass, recruitment to age 1, and maximum spawning potential (%MSP). For the purpose of this analysis, we have replaced %MSP with adult fishing mortality (F). The management variables analyzed in this report are:

- Fishing Mortality (F) – calculated unweighted age-specific F for ages 2 and older.
- Spawning Stock Biomass (SSB) – calculated as the weight of mature females in the population for ages 2 and older assuming a sex ratio of 1:1.
- Recruits to Age 1 – directly estimated as number of age 1 fish in the population at the start of the fishing year (January 1 for gulf menhaden).

The first two assessments (Nelson and Ahrenholz 1986; Vaughan 1987) used the Murphy (1965) approach to VPA. Catch in numbers at age were divided into four seasons, and the program was applied a cohort at a time. Subsequent assessments used the separable VPA approach developed by (Doubleday 1976). Because the SVPA program provided diagnostics suggesting the

separability assumption was poorly met prior to 1976, the results from the earlier Murphy VPA's were retained for 1964, and the SVPA was applied from 1976 through the terminal year for subsequent assessments (Vaughan et al. 1996, 2000). A forward-projecting age structured model was developed in ADMB to incorporate juvenile abundance index and age-varying natural mortality (Vaughan et al. 2007). A short report was prepared for GSMFC updating the SVPA applied to the period 1976-2004, and comparing results to the ADMB assessment. In summary, the following modifications have been made of these assessments:

- "Untuned" VPA methods applied:
  - Murphy (1965) approach: Nelson and Ahrenholz (1986), Vaughan (1987)
  - SVPA approach: Vaughan et al. (1996), Vaughan et al. (2000), GSMFC report
  - ADMB approach: Vaughan et al. (2007)
- Catch at age matrix based on reduction fishery only through 2000, small amount of bait landings added for 2007 assessments (Vaughan et al. 2007 and GSMFC report)
- Constant natural mortality (M = 1.1) for all ages and years, except in Vaughan et al. (2007)

Output from these historical analyses are compared as a series of figures (Fig. 1 – Fig. 3). Nomenclature for labeling the individual lines are as follows: Nelson and Ahrenholz (N&A_1986), Vaughan (V_1987), Vaughan et al (V_1996), Vaughan et al. (V_2000), GSMFC report (SVPA_2007), and Vaughan et al. (ADMB_2007).

Mean fishing mortality for ages 2 and older are compared in Figure 1. Murphy estimates of F showed occasional large peaks, while the separable assumption for SVPA tended to smooth these out. Ignoring these peaks, all assessments show similar patterns over years of overlap.

Spawning stock biomass (weight of mature females ages 2 and older) are compared in Figure 2. The ADMB provides higher estimates of recruitment compared to the SVPA approach, especially since the early 1990s. Patterns are similar among these assessments with the exception of the divergence of the ADMB approach beginning in the early 1990s.

Recruits to age 1 are compared in Figure 3. The ADMB provides higher estimates of recruitment compared to the SVPA approach, especially since the late 1980s. Patterns are similar among these assessments with the exception of the divergence of the ADMB approach beginning in the late 1980s.

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Figure 1. Historical retrospective on fishing mortality (F) from Nelson and Ahrenholz (N&A_1986), Vaughan (V_1987), Vaughan et al (V_1996), Vaughan et al. (V_2000), GSMFC report (SVPA_2007), and Vaughan et al. (ADMB_2007).

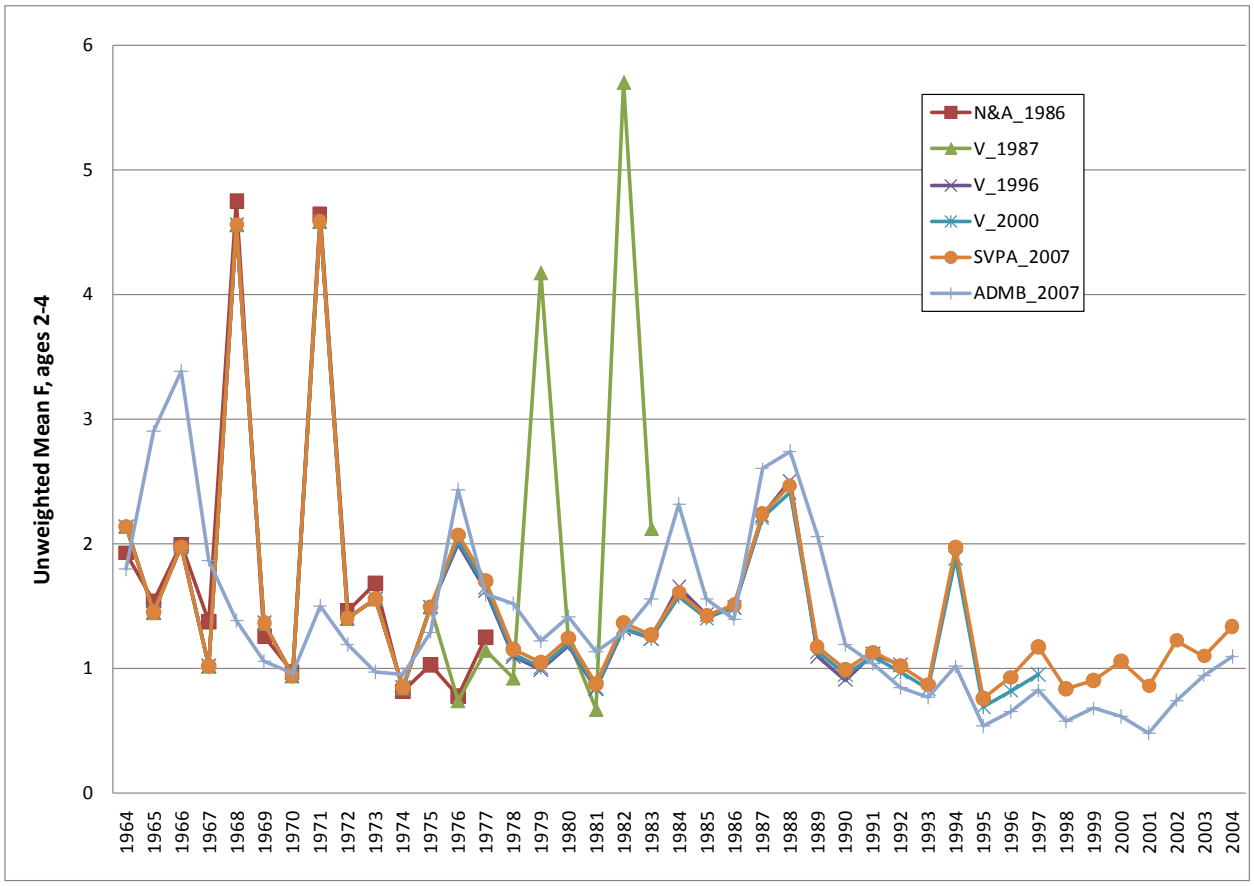

Figure 2. Historical retrospective on spawning stock biomass (SSB) from Nelson and Ahrenholz (N&A_1986), Vaughan (V_1987), Vaughan et al (V_1996), Vaughan et al. (V_2000), GSMFC report (SVPA_2007), and Vaughan et al. (ADMB_2007).

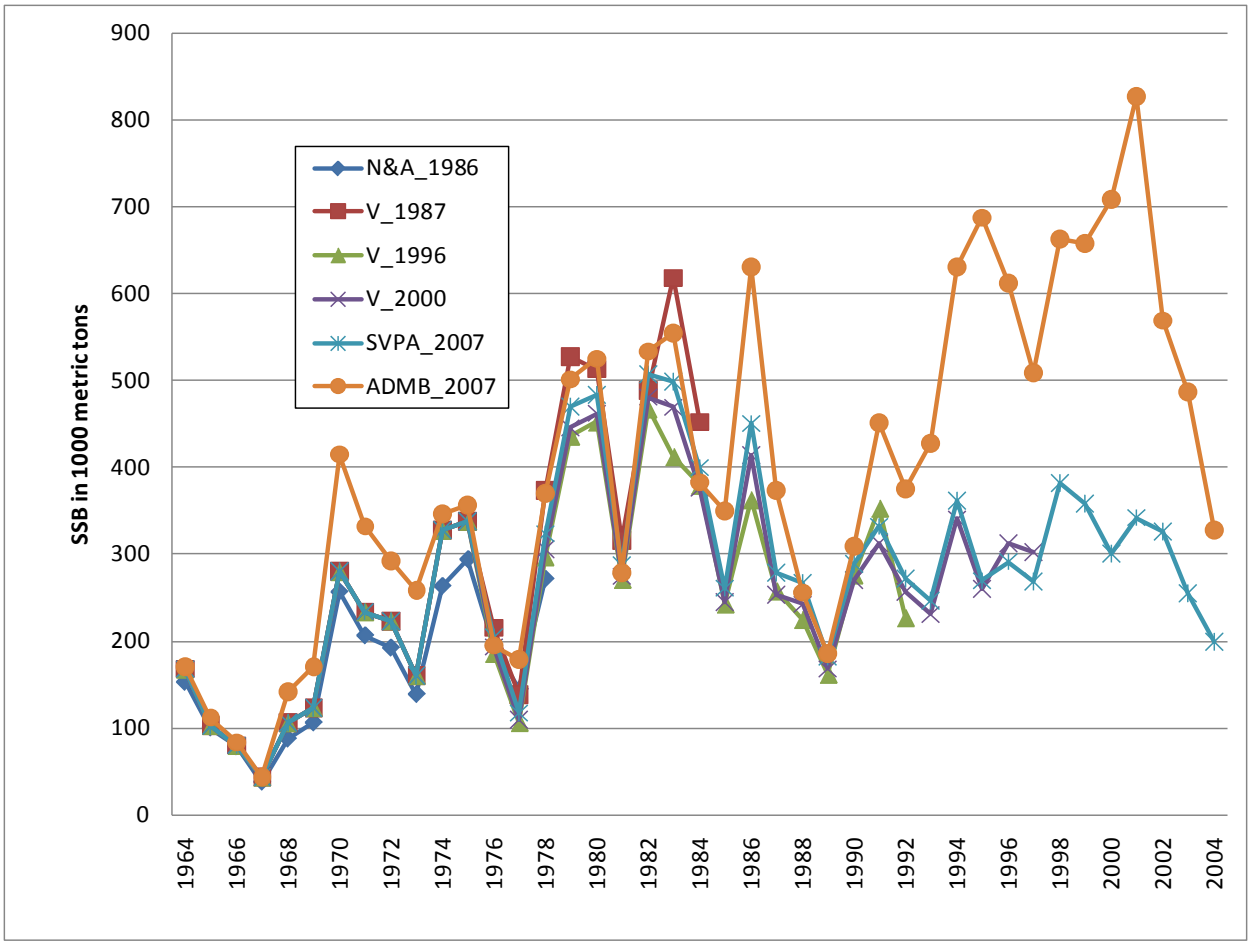

Figure 3. Historical retrospective on recruits to age 1 (R_1) from Nelson and Ahrenholz (N&A_1986), Vaughan (V_1987), Vaughan et al (V_1996), Vaughan et al. (V_2000), GSMFC report (SVPA_2007), and Vaughan et al. (ADMB_2007).