S E D A R

Southeast Data, Assessment, and Review

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History of Assessments of the Atlantic Menhaden Stock along the U.S. Atlantic Coast

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Assessment History

There is a long history of analyses on the Atlantic menhaden population. 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 1940, and detailed biostatistical sampling began in 1955). The first quantitative analysis appears to be that of Henry (1971) to address the significant decline in the menhaden stock during the 1960s. Henry suggests that "(O)f major importance to the proper management of any fishery is the ability to estimate the strength of the year class, before it enters the fishery." He notes that several large year classes are apparent in the catch data during the 1950s, including the "superabundant 1958 year class". But "(w)hen the 1958 year class virtually disappeared from the catch in 1963 and there were no subsequent strong year classes, it is not surprising that the landings declined." Schaaf and Hunstman (1972) conducted a more detailed analysis of the catch-at-age data to obtain estimate of age and year specific fishing mortality rates, and explore yield-per-recruit and stock recruitment relationships. Dryfoos et al. (1973) conduct a detailed analysis of the Atlantic menhaden population based on tag returns from a large tagging study. Various population-level analyses were conducted during the 1970s , building on the work of Schaaf and Huntsman (1972). Most notably was an investigation of the effects of Ekman transport on menhaden recruitment (Nelson et al. 1977, Schaaf 1979). In the early 1980s, a stochastic population model was developed under contract with NMFS to investigate among other things migration, density-dependent growth and harvesting strategies (Reish et al. 1985; Ruppert et al. 1985).

Two formal stock assessments were completed during the 1980s. The first (Ahrenholz et al. 1987) included data through 1979, and the second (Vaughan and Smith 1988) included data through 1984. 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. Surplus production models, spawner-recruit relationships, and yield-per-recruit analyses were then developed from the VPA output. A similar set of analyses was later conducted to address the developing Internal Waters Processing agreement with Russian factory ships in Maine (Vaughan 1990). Stock assessment results were summarized in a special menhaden issue of Marine Fisheries Review (Vaughan and Merriner 1991).

Further updates of Atlantic menhaden assessments were conducted during preparation of the revised fishery management plan for Atlantic menhaden (AMAC 1992). Annual assessments were conducted by Dr. Douglas Vaughan for the ASMFC Atlantic Menhaden Advisory Committee (AMAC) from 1993-2002. These annual reports were initially limited to estimation of the trigger variables developed for the revised fishery management plan, but expanded beginning in 1998 to include additional analyses. A detailed retrospective analysis was conducted on these annual assessments (through 1996) by Cadrin and Vaughan (1997). This analysis of historical retrospective patterns has been recently updated for assessments through

2006 as a brief report (dated March 10, 2009) by Dr. Douglas Vaughan to the ASMFC Assessment Science Committee. Uncertainty and risk analyses of these assessments were explored by Vaughan (1993) and Vaughan et al (2002).

As noted above, assessment methods used the "untuned" VPA method of Murphy (1995) as the primary assessment methodology through 2002. This method was accepted by a formal peer review in 1998 (ASMFC 1999a, 1999b). Amendment 1 to the Atlantic Menhaden Fishery Management Plan (Atlantic Menhaden Plan Development Team 2001) was issued in 2001. Among other changes, this amendment dropped the six triggers from the 1992 revision (AMAC 1992) and replaced them with two benchmarks that conformed to the 1998 revision to the Magnuson-Stevens Fishery Conservation and Management Act (Restrepo et al. 1998). Concurrently, new statistical assessment methods were introduced in 2001 and explored further in 2002 in parallel to the "untuned" VPA approach. Indices of juvenile abundance, and an "adult" abundance index (menhaden landings per poundnet license from the Potomac River Fishery Commission, PRFC) were developed for the statistical model, which then went through a formal peer review in 2003 (ASMFC 2004a, 2004b).

The most recently completed assessment of the status of the Atlantic menhaden stock was an update of the 2003 peer-reviewed assessment, and it included data through 2005 (ASMFC 2006). Data included abundance indices, recorded landings, and samples of annual size and age compositions from the landings. Six state juvenile abundance seine indices were developed; five of which were used in the 2003 peer-reviewed or benchmark assessment (ASMFC 2004a). The new seine index (New Jersey) was only used in an alternate model run. The pound net index from the PRFC was improved to better reflect fishing effort (from number of licenses which has been fixed at 100 licenses since 1994 to number of days fished). Landings and catch-in-numbers-at-age data were updated from the reduction and bait fisheries. A new vector of natural mortality at age was obtained from the recently peer-reviewed MSVPA-X model (NEFSC 2006a, 2006b) to replace the vector used in the benchmark assessment.

The statistical model from the benchmark assessment was applied to these updated data. A base assessment model run was developed and sensitivity model runs were made to evaluate performance of the assessment model to these updated data. Because unrealistically high levels of adult natural mortality were estimated when the new M-at-age vector from the recent MSVPA-X base run was used, the AW scaled this vector so that adult natural mortality matched historical tagging results ($M_{\text{adult}} = 0.5$). This was in keeping with the peer-reviewed results which found that adult M from the peer-reviewed assessment (0.55) was reasonable because it provided an estimate of adult M similar to the historical adult M obtained from tagging (Reish et al. 1985).

Status of stock was based on the terminal year (2005) estimate relative to its corresponding limit (or threshold). 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 56% of its limit (and 91% of its target). Correspondingly, the terminal year estimate of population fecundity was

estimated at 158% of its fecundity target (and 317% of its limit). Hence, the stock was not considered to be overfished, nor was overfishing occurring.

Updating 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). Amendment 1 to the Atlantic Menhaden Fishery Management Plan (Atlantic Menhaden Plan Development Team 2001) dropped the six triggers from the 1992 revision (AMAC 1992) and replaced them with two benchmark (management) variables that conformed to the 1998 revision to the Magnuson-Stevens Fishery Conservation and Management Act (Restrepo et al. 1998). So, 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 historically as catch-weighted age-specific F for ages 2 and older; this was changed to N-weighted in the 2003 peer-reviewed assessment.

- Spawning Stock Biomass (SSB) – calculated as the weight of mature females in the population. Initially, all females age 3 and older were assumed mature, and younger fish were assumed immature. This was modified in 2003 to reflect some age 2 may be mature (11.8%), and most, but not all age 3 mature (84.6%).

- Recruits to Age 1 – directly estimated as number of age 1 fish in the population at the start of the fishing year (March 1 for Atlantic menhaden).

As already noted, a consistent assessment methodology was applied from 1990 through 2002, and this approach was accepted by a formal peer review in 1998 (ASMFC 1999a, 1999b). This consistent approach included the following:

- "Untuned" VPA method of Murphy (1965)
- Catch at age matrix based on reduction fishery only (through 2000)
- Constant natural mortality (M = 0.45)
- Knife-edge maturity beginning with age 3

Two types of comparisons have been developed for the annual estimates of management variables. First, the time series of estimated values are overlayed for each of the management variables (Figures 1a, 2a, and 3a). These plots include annual assessments with terminal years

1990, 1992-2001, with the exception of fishing mortality in 1990. Second, proportional deviations were developed between the time series with terminal year 2000 and earlier terminal years (Figures 1b, 2b, and 3b). Note that bait landings were included in assessments beginning with 2001 (terminal year 2000). The primary effect of adding bait landings was to decrease estimates of F and increase estimates of SSB and R_1. The selectivity of bait landings tends towards larger, older fish.

Concurrent with the "untuned" VPAs, the new statistical catch-at-age ("forward projecting") assessment model was introduced in 2001 and explored further in 2002. These analyses appeared as appendices to the 2001 and 2002 assessment reports. Results from the two assessment methods are compared in the next series of figures (Figures 4-6) for each of the three management variables.

In preparation for a formal peer review in 2003 (ASMFC 2004a, 2004b), several additional changes were made during the data workshop. Conversion of bait landings to catch at age were further refined. The concept of age-varying *M* was introduced based on the multi-species VPA under development by ASMFC, and later peer reviewed (NEFSC 2006a, 2006b). The maturity schedule was modified, reflecting that some age 2 and most, but not all, age 3 were mature. A coastwide index of juvenile abundance and "adult" index from PRFC were developed for use in "tuning". The most recent assessment was the update assessment conducted in 2006 with additional data through 2005 (ASMFC 2006). The last series of figures (Figures 7-9) compare these three management variables between the peer-reviewed and updated assessments.

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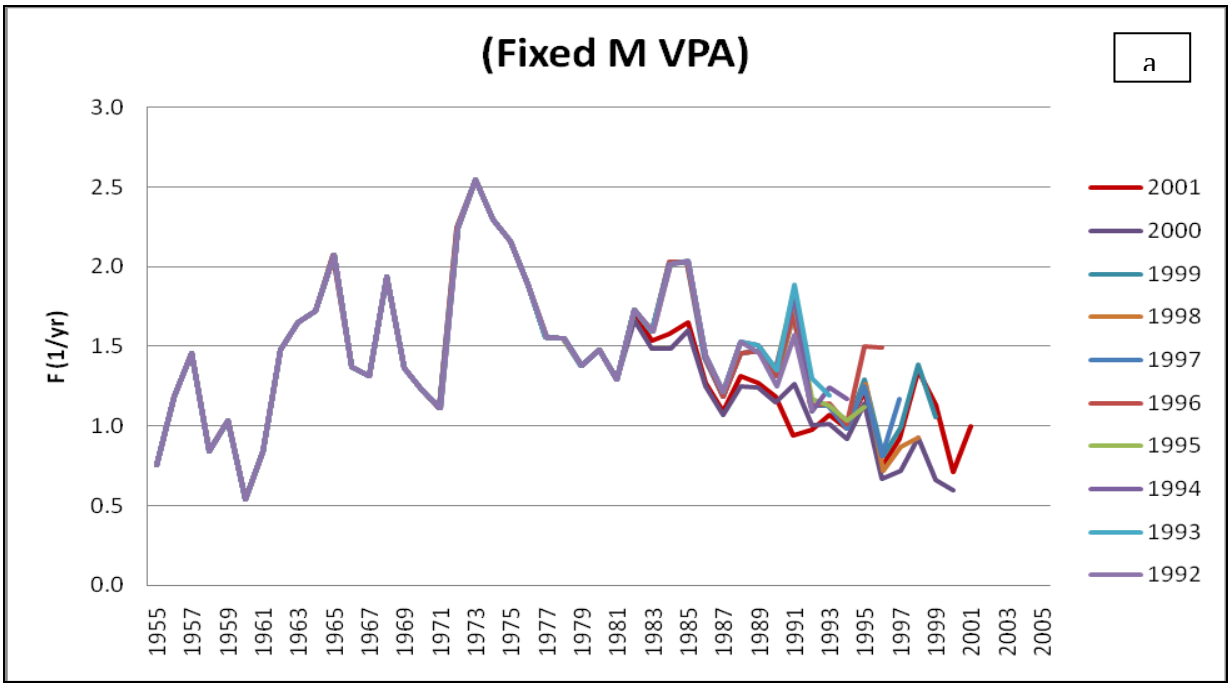
Figure 1. VPA historical retrospective on fishing mortality (F), both as (a) fishing mortality F for terminal years 1992-2001, and (b) as proportional deviations from terminal year 2000 (1992-1999).



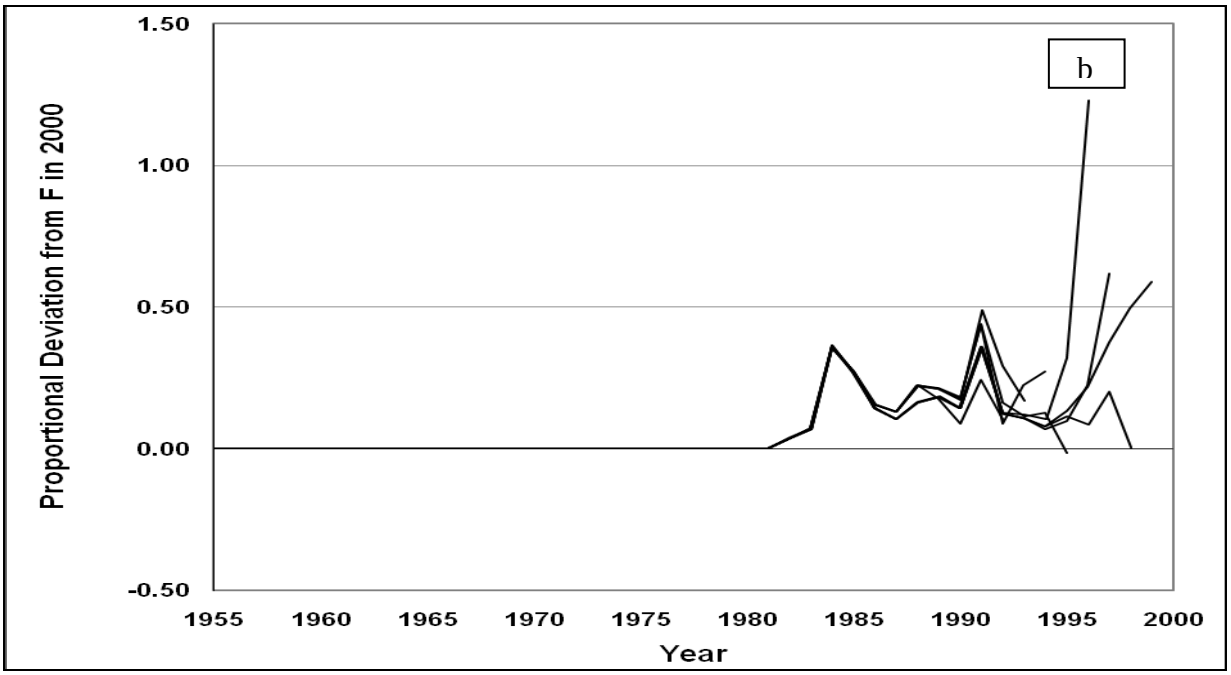
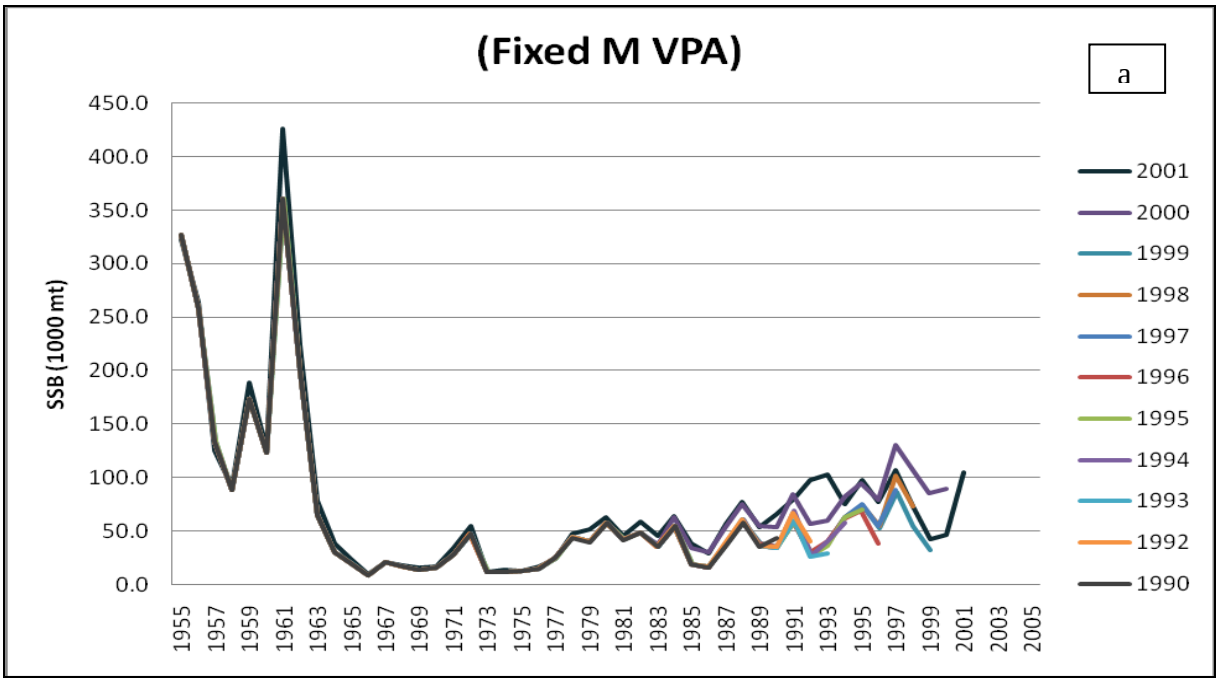


Figure 2. VPA historical retrospective on spawning stock biomass (SSB), both as (a) SSB for terminal years 1990, 1992-2001, and (b) as proportional deviations from terminal year 2000 (1992-1999).



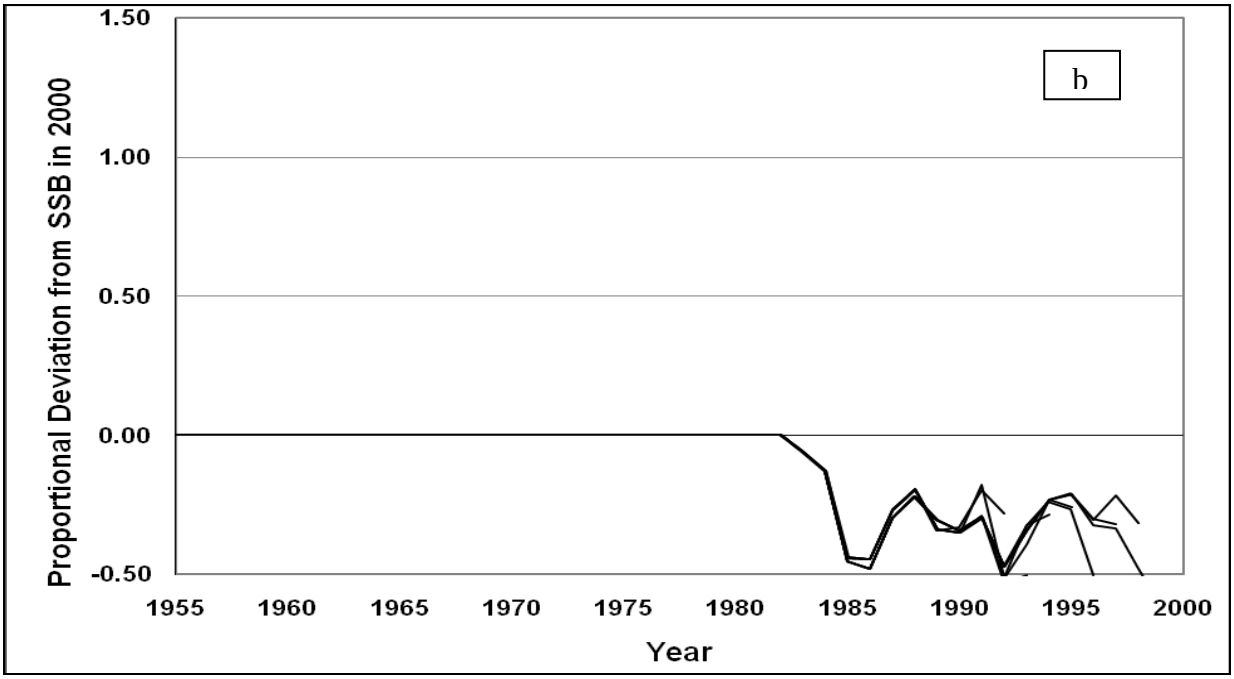


Figure 3. VPA historical retrospective on recruits to age 1 (R_1), both as (a) R_1 for terminal years 1990, 1992-2001, and (b) as proportional deviations from terminal year 2000 (1992-1999).

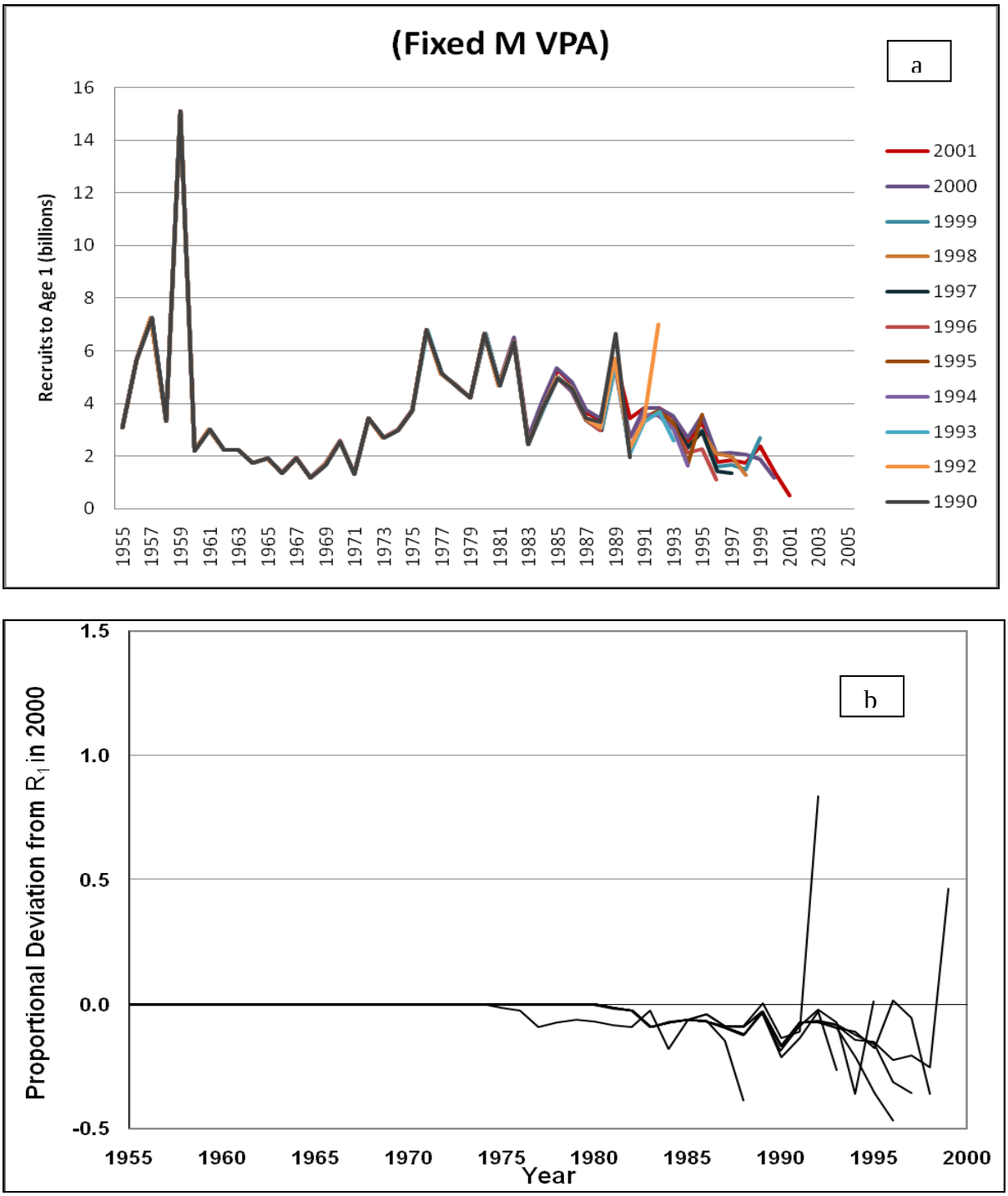
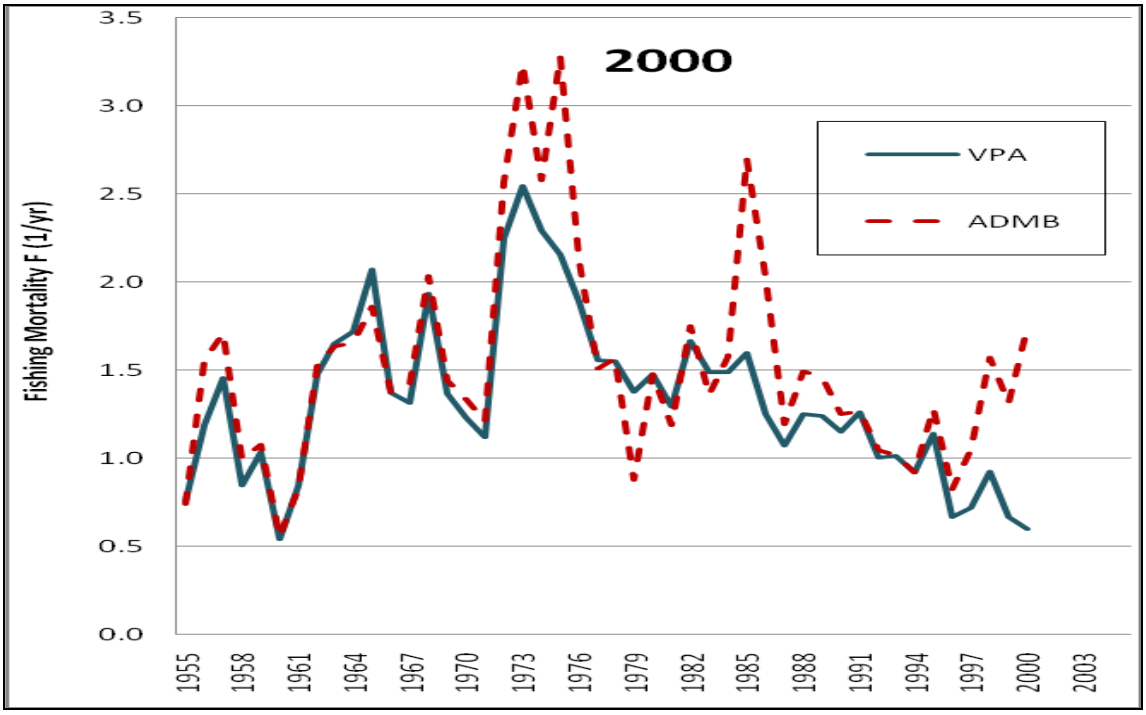


Figure 4. Comparison of fishing mortality, F, from "untuned" VPA with preliminary statistical catch model for terminal years (a) 2000 and (b) 2001.



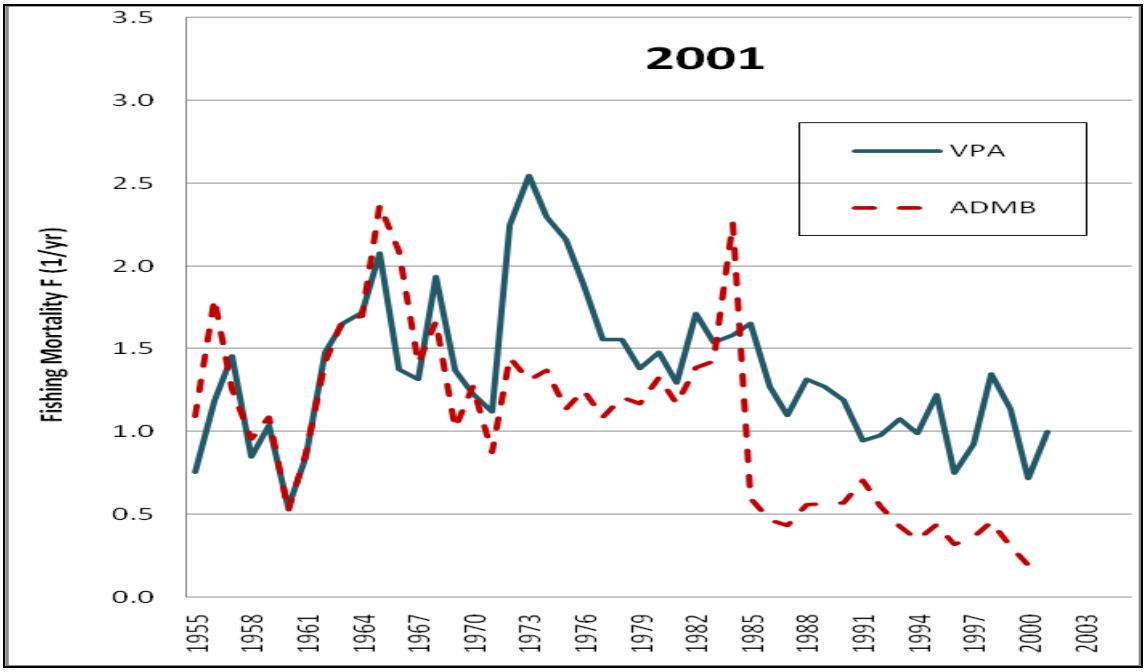
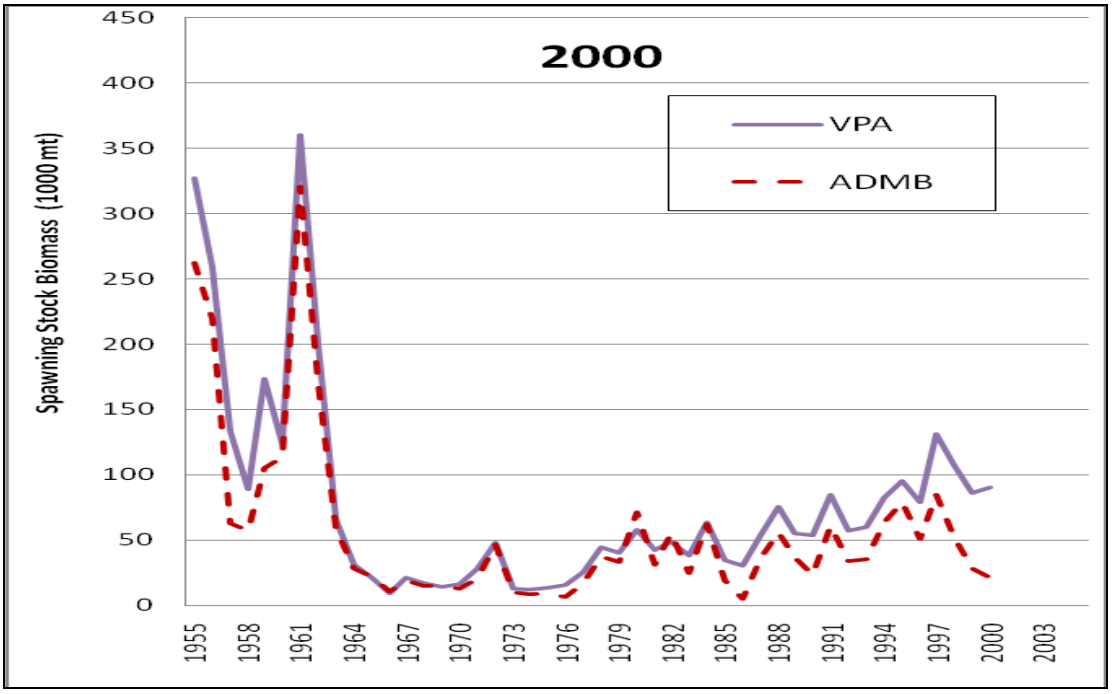


Figure 5. Comparison of spawning stock biomass, SSB, from "untuned" VPA with preliminary statistical catch model for terminal years (a) 2000 and (b) 2001.



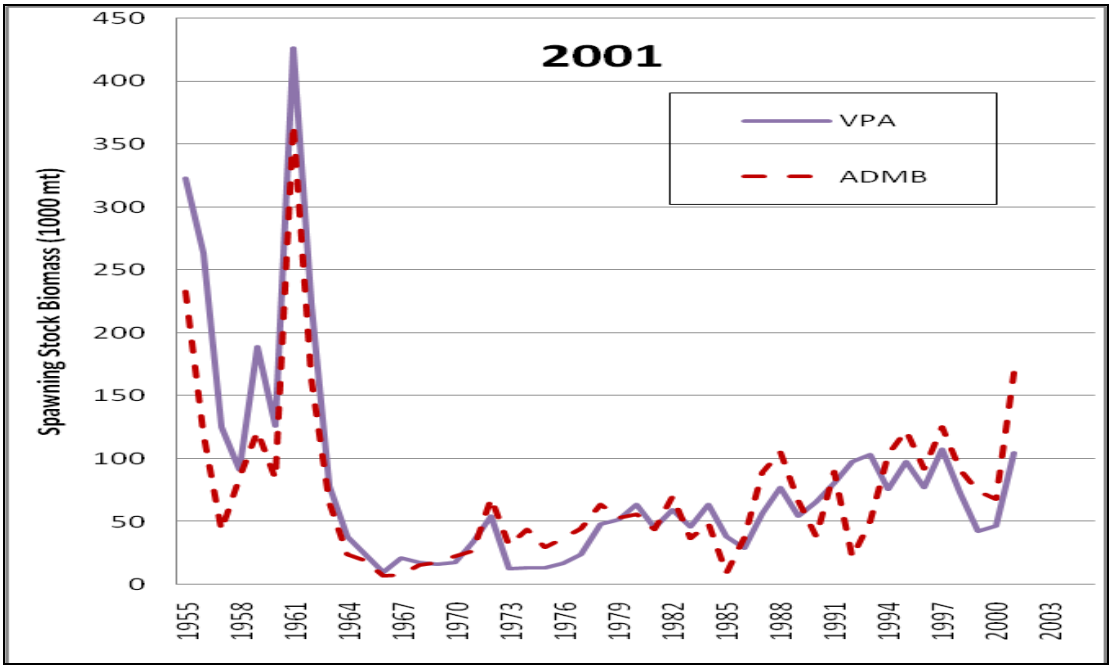
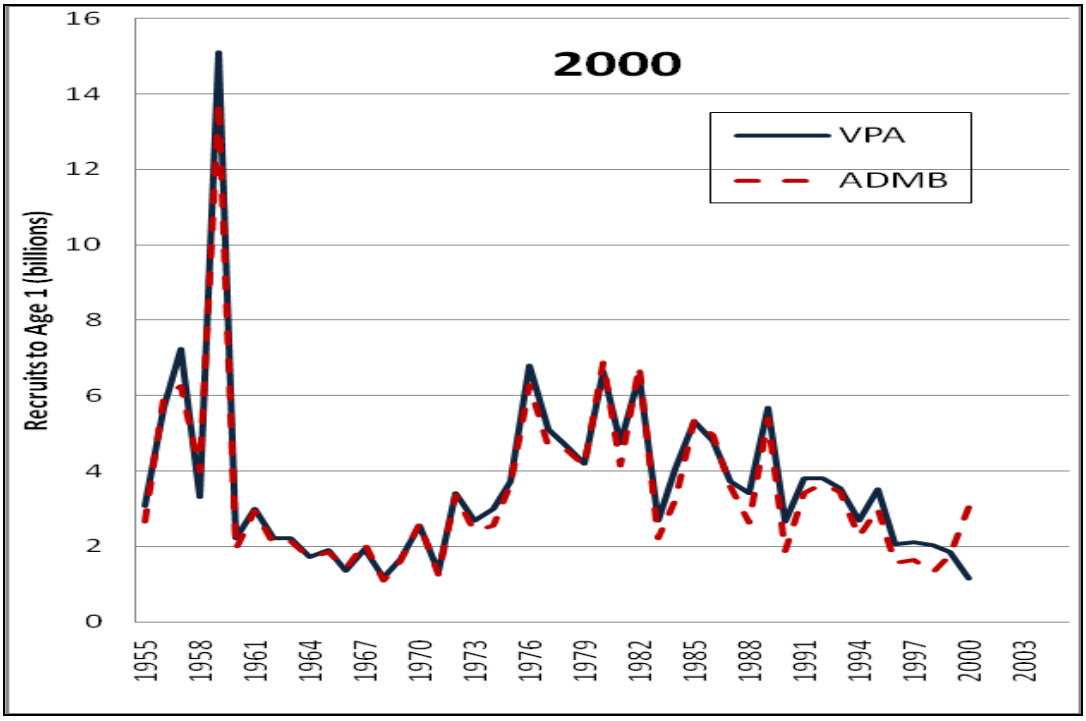


Figure 6. Comparison of recruits to age 1, R_1, from "untuned" VPA with preliminary statistical catch model for terminal years (a) 2000 and (b) 2001.



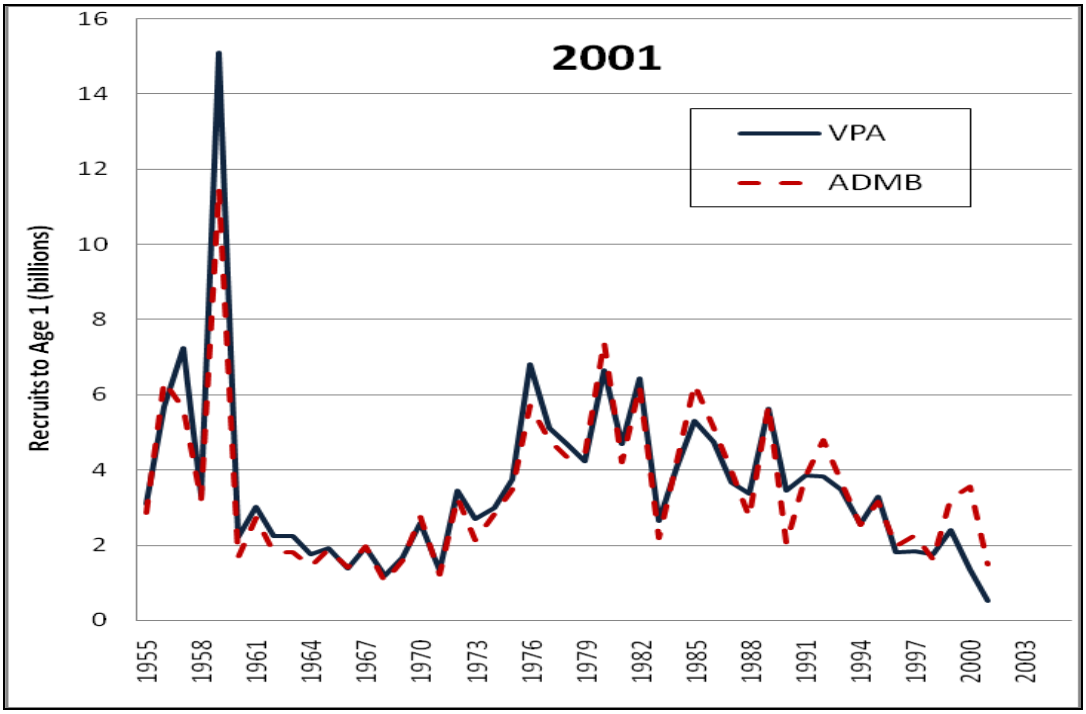


Figure 7. Comparison of fishing mortality, F, from statistical catch model for peer review (2003) and update (2006).

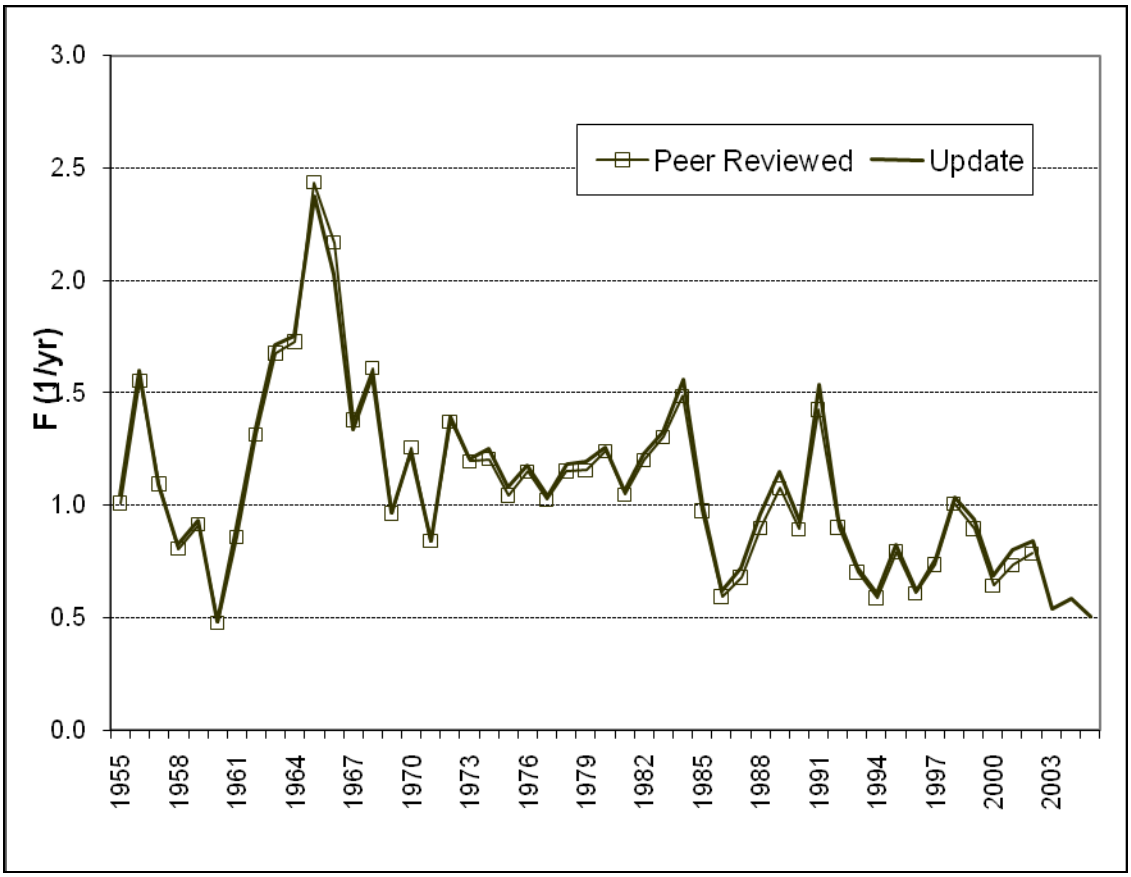


Figure 8. Comparison of spawning stock biomass, SSB, from statistical catch model for peer review (2003) and update (2006).

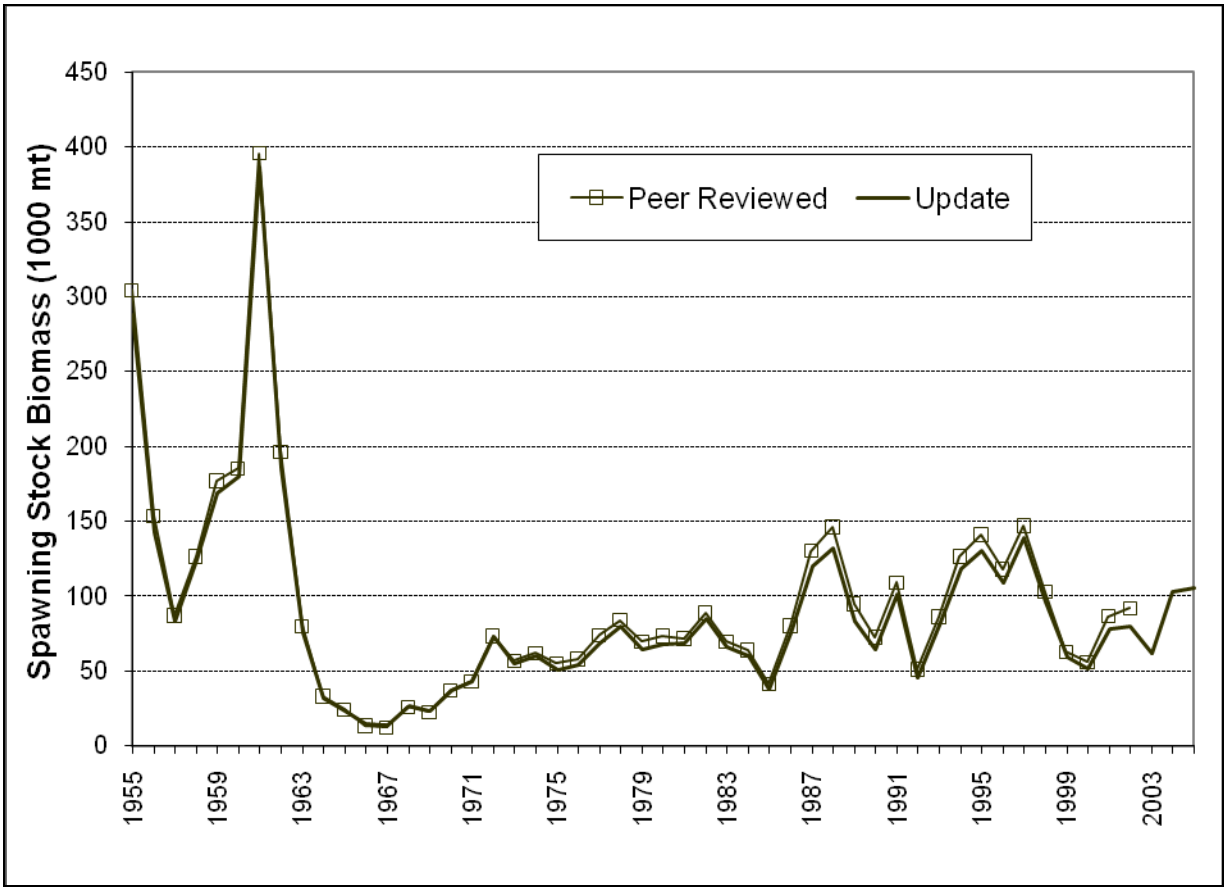
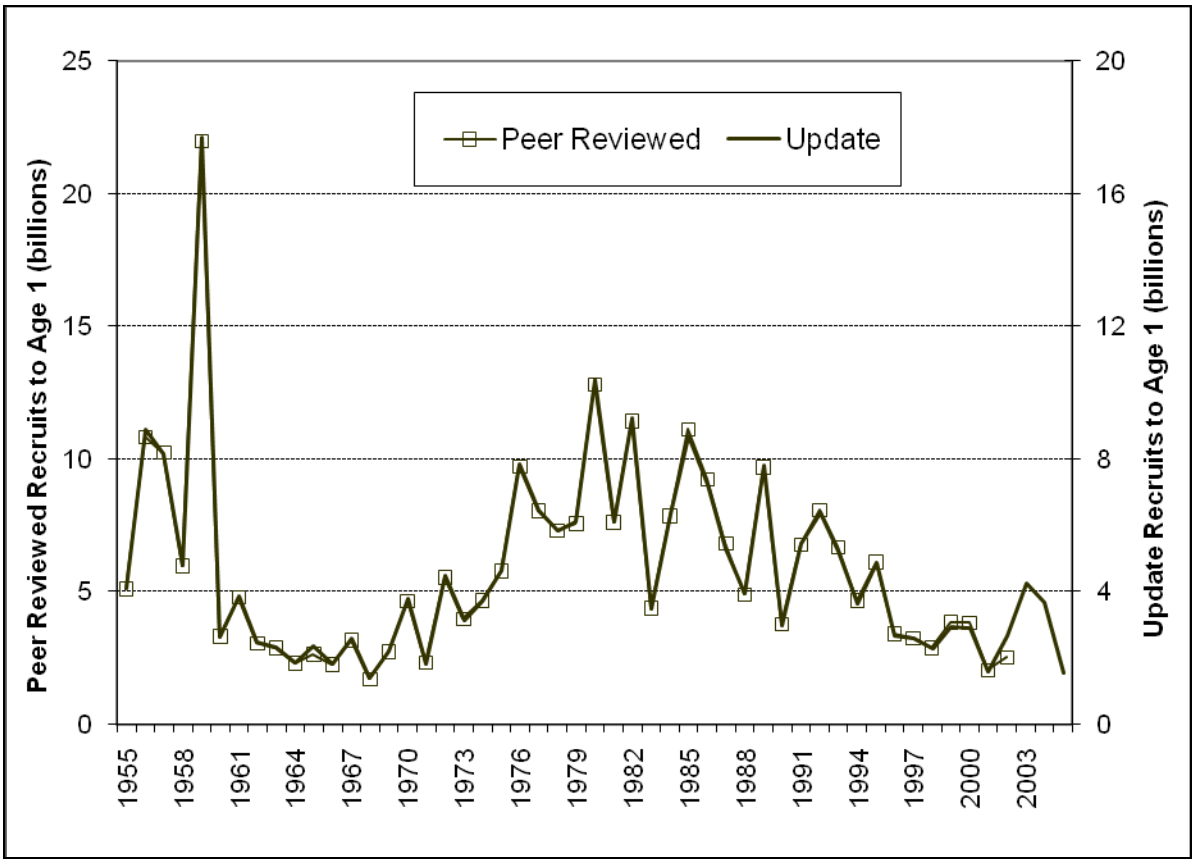



Figure 9. Comparison of recruits to age 1, R_1, from statistical catch model for peer review (2003) and update (2006).