S E D A R

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SEDAR 18-DW07
Life-History Based Estimates of Natural Mortality for U.S. South Atlantic Red Drum

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Abstract: Natural mortality is one of the hardest parameters of a stock assessment to determine. A variety of life history approaches have been explored during past SEDAR data workshops, and some of these methods are summarized in this section. In preparation for the SEDAR 18 Data Workshop, estimates of M (fixed and age-varying) are made from growth parameters available from the latest South Atlantic red drum stock assessment (**Vaughan and Carmichael 2000**). It is expected that these will be updated by the Life History Working Group during the SEDAR 18 for inclusion in the Data Workshop Report as section 2.4.

2.4 Natural Mortality

2.4.1 Life-History Based Approaches (not including tagging approaches)

Natural mortality is one of the hardest parameters of a stock assessment to determine. Methods that relate life history traits with natural mortality were reviewed in **Vetter (1987)**. Subsequently additional methods have been developed. A variety of these methods have been explored during past SEDAR data workshops, and some of these methods are summarized in this section.

Because the US south Atlantic population has been split into two regions/stocks for recent assessments (**Vaughan 1996, Vaughan and Carmichael 2000**), separate estimates are provided for these two regions/stocks. Further, two forms of the von Bertalanffy growth equation have been considered for red drum (both for the South Atlantic and Gulf of Mexico). These forms included the standard 3-parameter von Bertalanffy growth curve, and the "linear" 4-parameter von Bertalanffy growth curve (developed by Geaghan at LSU and referenced in **Hoese et al. 1991**). The latter form is referred to as "linear" because the expression for L_∞ is modeled as a linear equation ($L_\infty = b_0 + b_1$*Age). If b_1 is not significantly different from 0, then this model reduces to the standard von Bertalanffy growth curve. For this report, growth in total length (**Figure 2.4.1**) is developed from the parameter estimates from **Vaughan and Carmichael (2000)**.

In preparation for the SEDAR 18 Data Workshop, analyses presented below are based on growth parameters available from the latest South Atlantic red drum stock assessment (**Vaughan and Carmichael 2000**). It is expected that these will be updated by the Life History Working Group during the SEDAR 18 Data Workshop.

2.4.1.1 *Age-Constant M Approaches*

In this section, we will describe various methods for determining an age-constant M based on life history characteristics, including maximum age (t_{max}), von Bertalanffy parameters (L_∞, k), and average water temperature (T^oC). Only parameters from the standard von Bertalanffy growth equation will be used in this section. The following approaches have been implemented (and summarized in **Table 2.4.1**):

Source	Equation
Alverson and Carney (1975)	$M = 3k/(\exp(0.38*t_{max}*k)-1)$
Hoenig (1983; F ~ 0)	$M \sim \exp(1.46 - 1.01*\ln(t_{max}))$
Jensen (1996)	$M = 1.5*k$
Pauly (1980)	$M = \exp(-0.0152+0.6543*\ln(k)-0.279*\ln(L_{\infty}, cm) +0.4634*\ln(T^{o}C))$
"Rule of thumb" (**Hewitt & Hoenig 2007**)	$M = 3/t_{max}$

Average water temperature (T) used for this exercise was 19^{o}C taken from **Williams et al. (1973**; referenced in **Ross et al. 1995**). **Quinn and Deriso (1999)** have converted Pauly's equation from base 10 to natural logarithms as presented above. The "rule of thumb" method has a long history in fisheries science, but it is difficult to pin down its source. I have referenced **Hewitt and Hoenig (2004)**, who recently compare this approach to that of **Hoenig (1983)**. Note that the **Hoenig (1983)** method provides an estimate of Z. It is only when fishing mortality can be assumed small (F ~ 0) that this becomes an estimate of M, otherwise it is an upper bound on M.

2.4.1.2 Age-Varying M Approaches

There are several approaches that provide age-varying estimates of M (**Peterson and Wroblewski 1984, Boudreau and Dickie 1989, Lorenzen 1996**). These methods use an inverse relationship between size and natural mortality (M). The method of **Peterson and Wroblewski (1984)** recently was used to describe natural mortality for young-of-year Atlantic menhaden (**Heimbuch et al. 2007**), but requires dry weight as its independent variable, which is not readily available, and is not pursued further in this report. The method of Boudreau and Dickie has been applied in several assessments, notably for red drum in **Vaughan and Carmichael (2000)**. However, the method of Lorenzen has gained favor in recent years, especially in the SEDAR arena (e.g., reference SEDAR 10, 15, 17). When applying the method of **Lorenzen (1996)**, estimates of M are scaled such that cumulative survival from age 1 to the maximum age is equal to 1.5%. This cumulative survival value comes from the fixed M method of **Hoenig (1983)** as described in **Hewitt and Hoenig (2004).**

Both unscaled and scaled estimates of M based on the approaches of **Boudreau and Dickie (1989)** and on **Lorenzen (1996)** have been developed from von Bertalanffy parameters using both the standard 3-parameter von Bertalanffy growth equations and the "linear" or 4-parameter von Bertalanffy growth equations for the two regions. Subsequently, the age-varying estimates of M are averaged over the subadult (1-5) and adult (6+) ages (**Table 2.4.2**). The unscaled and scaled estimates of M from the Lorenzen approach are compared across regions and forms of the von Bertalanffy curves in **Figures 2.4.2** and **2.4.3**, respectively.

2.4.1.3 *Topics of Discussion for the Life History Working Group*

During the course of the SEDAR 18 Data Workshop, the Life History Working Group should discuss the following topics and arrive at recommendations to forward to the SEDAR 18 Assessment Workshop:

1) What is maximum age of red drum in the US south Atlantic? Should we consider different values for the North and South regions separately?

2) What is average water temperature for use in Pauly approach? [**Ross et al. (1995)** used values from **Williams et al. 1973**.]

3) Which of the age-constant M approaches makes the most sense? Some of these approaches will yield unrealistic estimates (either too large or too small).

4) Does it make more sense to use age-varying estimates of M, recognizing higher natural mortality for the youngest ages?

5) To scale or not to scale: should the cumulative natural mortality over ages (age 1 to maximum age) be scaled to the equivalent mortality from a constant age approach (e.g., to Hoenig estimates as in recent SEDARs)? Should we favor the method of **Lorenzen (1996)**?

6) Should we average age-specific natural mortality over subadult ages (1-5) and adult ages (6+) as was done in **Vaughan and Carmichael (2000)**? How should we deal with age 0 (Sept – Dec of year hatched), or do we need to?

7) Can we recommend a range of natural mortality for use in the stock assessment sensitivity runs?

My expectation is that calculations for natural mortality will be reworked during the SEDAR 18 Data Workshop for inclusion into the S18 DW report as Section 2.4.

2.4.2 References

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Table 2.4.1. US South Atlantic red drum age-constant natural mortality rates. M: Natural mortality, k: Von Bertalanffy growth parameter, T: temperature (°C), L_∞: Von Bertalanffy asymptotic length (mm), maximum age: t_{max} = **62** for both regions. Average water temperature = **19**° C (Williams et al. 1973 as used in Ross et al. 1995).

Life History Approach	**Parameters**	**North Region**	**South Region**
		L_∞ = 120.4 cm, k =0.15	L_∞ = 106.2 cm, k= 0.24
Alverson & Carney	k, t_{max}	0.014	0.003
Hoenig	t_{max}	0.067	0.067
Jensen	k	0.225	0.360
Pauly	k, L_∞, T ^{o}C	0.293	0.412
Rule of thumb	t_{max}	0.048	0.048

Table 2.4.2. US South Atlantic red drum age-varying natural mortality rates averaged over subadult (ages 1-5) and adult (ages 6+) ages. Age-varying estimates are based on two approaches (Boudreau & Dickie and Lorenzen), two regions (North and South), and two forms of the von Bertalanffy growth equation (Standard and Linear). Age-specific estimates of natural mortality have been scaled to cumulative survival of 1.5% at maximum observed age.

Age Grouping	**Subadults (ages 1-5)**	**Adults (ages 6+)**
	Boudreau & Dickie (1989)	
North Region		
Standard VB	0.11	0.06
Linear VB	0.11	0.06
South Region		
Standard VB	0.15	0.10
Linear VB	0.15	0.10
	Lorenzen (1996)	
North Region		
Standard VB	0.10	0.06
Linear VB	0.10	0.06
South Region		
Standard VB	0.14	0.10
Linear VB	0.15	0.10

Figure 2.4.1 Comparison of total length at age for north and south regions from standard and "linear" von Bertalanffy growth curves as estimated in **Vaughan and Carmichael (2000)**.

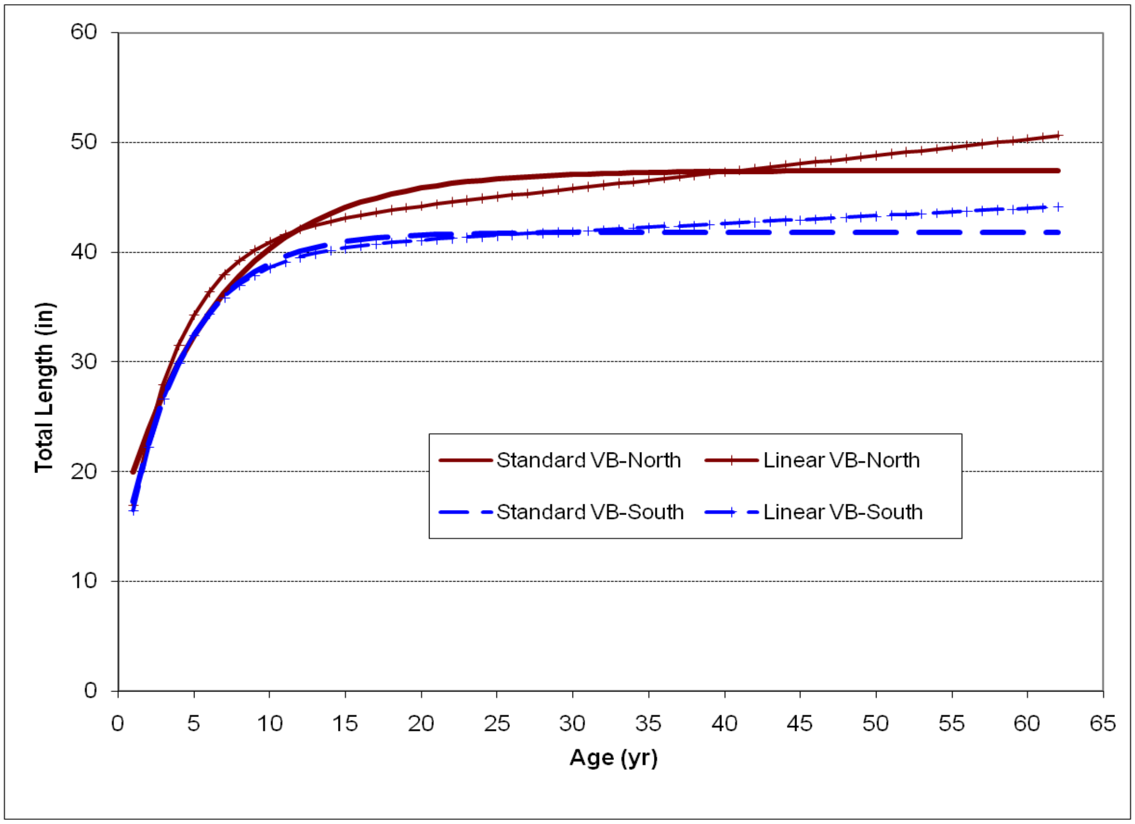

Figure 2.4.2 Comparison of unscaled estimates of age-varying M from the method of Lorenzen (1996) based on growth predicted by both the standard and "linear" forms of the von Bertalanffy growth equation (parameters from **Vaughan and Carmichael 2006**).

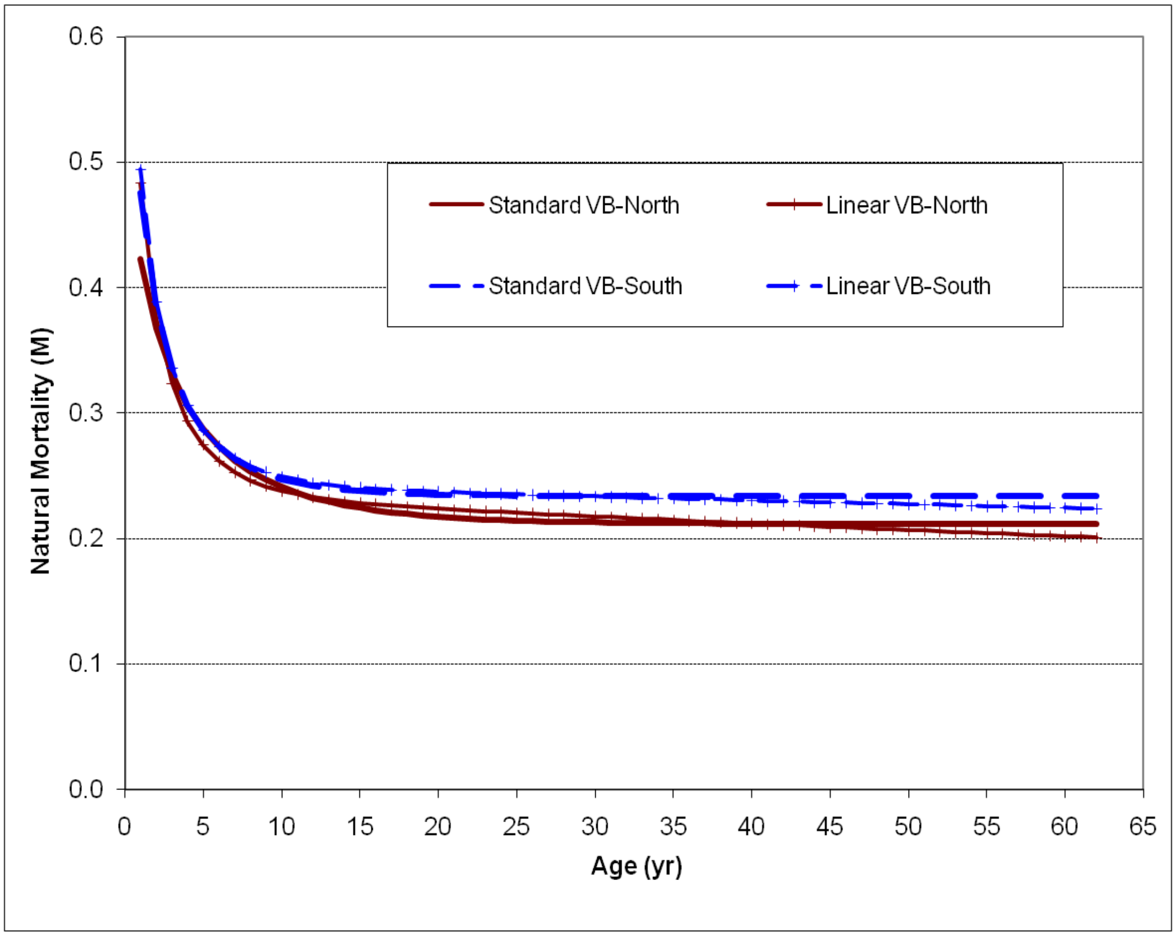

Figure 2.4.3 Comparison of scaled estimates of age-varying M from the method of Lorenzen (1996) based on growth predicted by both the standard and "linear" forms of the von Bertalanffy growth equation (parameters from **Vaughan and Carmichael 2006**).