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Bag and Size Limit Analyses for Red Drum in Northern and Southern Regions of the U.S. Atlantic

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Executive Summary

Assessments of the Atlantic red drum for the northern (North Carolina and north) and southern (South Carolina through east coast of Florida) regions along the U. S. Atlantic coast were recently completed. The joint Red Drum Technical Committee (SAFMC/ASMFC) selected the most appropriate catch matrix (incorporating an assumption on size of recreationally-released fish), selectivity of age 3 relative to age 2, and virtual population analysis (FADAPT). Given gear- and age-specific estimates of fishing mortality (F) for the 1992-1998 period, analyses were made of potential gains in escapement through age 4 and static spawning potential ratio (SPR) from further reductions in fishing mortality due to changes in slot and bag limits. Savings from bag limits were calculated given a particular slot size for the recreational fishery, with no savings for the commercial fisheries in the northern region due to their being managed primarily through a quota. Relative changes in catch-at-age estimates were used to adjust age-specific F and hence calculated escapement through age 4 and static SPR. Adjustment was made with the recreational savings to account for release mortality (10%, as in the stock assessment). Alternate runs for the northern region commercial fishery considered 25% release mortality for lengths outside the slot (instead of 0% for the base run), and 0% vs. 10% gain or loss across legal sizes in F. These results are summarized for ranges of bag limits with increasing minimum size limit (for fixed maximum size), and with decreasing maximum size limit (for fixed minimum size limit). For the southern region, a bag limit of one-fish per angler trip would be required to attain the stated target of 40% static SPR if the current slot limit were not changed. However, for the northern region, a bag limit of one-fish per angler trip appears to be insufficient to attain the stated target of 40% static SPR while maintaining the current slot limit.

TABLE OF CONTENTS

INTRODUCTION

The status of Atlantic red drum (both northern and southern regions) was recently analyzed at the request of the South Atlantic Fishery Management Council (SAFMC) (Vaughan and Carmichael, 2000). Early assessments treated the Atlantic red drum as a single stock along the U. S. Atlantic coast (Vaughan and Helser, 1990; Vaughan, 1992). More recent assessments of the Atlantic red drum stock (Vaughan, 1993, 1996; Vaughan and Carmichael, 2000) have divided this stock into a northern region (U. S. coastal waters of states from North Carolina and north), and a southern region (U. S. coastal waters from South Carolina through the east coast of Florida). A major difference between these two regions is a significant commercial fishery in the northern region (primarily in North Carolina, but to a much lesser extent in Virginia since 1992).

These assessments considered only subadult red drum (ages 1-5). Removing the effect of emigration offshore as an apparent source of fishing mortality has been a major concern. This is important for red drum because of their unique migration pattern, in which the adults are subject to greatly reduced fishing mortality. Three additional concerns were addressed in Vaughan and Carmichael (2000): (1) size distribution of recreational catch-and-release fish; (2) effects of slot limits introduced in 1992 on the selectivity of age 3 relative to age 2 (Table 1); and (3) use of calibrated virtual population analysis (VPA) approaches in addition to the separable VPA used previously.

Recommendations of the Red Drum Assessment Group (RDAG) (technical committee of the SAFMC) from the latest stock assessment were provided to the SAFMC (see Appendix A in Vaughan and Carmichael, 2000). The RDAG selected the preferred catch matrix ("DELTA" approach for treating size frequency of recreational catch and release red drum) and virtual population analysis approach (FADAPT) as most appropriate from Vaughan and Carmichael (2000). "Best" estimates of equilibrium spawning potential ratio (static SPR) and escapement through age 4 relative to the condition of no fishing were obtained from specific selectivity assumptions based on the RDAG recommendations. The selectivity of age 3 relative to age 2 assumed for the northern region was 0.70 and for the southern region was 0.87. The Atlantic coast red drum stock is overfished, with best estimates of static SPR at 18% for the northern region and 15% for the southern region. In addition, estimates of escapement were estimated at 18% for the northern region and 17% for the southern region. The estimates of static SPR and escapement for the northern region are considered overestimates by the RDAG because of unaccounted discard mortality from commercial fisheries.

The SAFMC defined 40% static SPR as its target level and 30% SPR as its threshold for overfishing (Appendix A in Vaughan and Carmichael, 2000). Management actions were initiated in 1992 through the Atlantic States Marine Fisheries Commission (ASMFC) to raise static SPR for Atlantic red drum from the very low levels estimated for 1986-1991 (~1%; Vaughan, 1993) to above 10% (McGurrin, 1991). These management actions in place for 1992-1998 are summarized in Table 1. Florida already had in place a one-fish bag limit with an 18"-27" total length (TL) slot limit. In 1992, Georgia and South Carolina introduced a five-fish bag limit and 14"-27" TL slot limit; while North Carolina, Virginia, and Maryland introduced a five-fish bag limit and 18"-27" TL slot limit, but with 1 fish allowed over 27" TL.

In this study, we estimated potential improvements in escapement and static SPR from stricter bag and size limits, based on conditions prevalent in each region during 1992-1998. Estimation of escapement and static SPR was based on adjustments to fishing mortality rates from Vaughan and Carmichael (2000; as recommended by the RDAG). We refer to "savings" as the proportion of fish that would not have been landed in the historical data base if a given management option were in place at that time. Gains from size limits (minimum and maximum) were determined based on savings by one-inch TL increments, and translated to savings by age based on age-length keys. Savings from the recreational component were adjusted for release mortality, while savings from the commercial component (northern region) were not adjusted due to lack of information on current catch-and-discard rates.

METHODS

Data for these analyses are from Vaughan and Carmichael (2000) for the period 1992-1998, during which there was approximately constant management for each region. The general approach described here was to determine savings on the basis of one-inch TL increments from more severe size and bag limits. The size-based savings were converted to age-based savings using age-length keys. Age-based savings were then used to modify age-specific estimates of fishing mortality rates (*F*) from Vaughan and Carmichael (2000), which were then used for estimation of escapement and static SPR for each region.

Data used for these calculations included: (1) age-specific estimates of fishing mortality rate (*F*) by region; (2) catch in numbers at age by fishery, gear, and region; (3) length frequency data by fishery, gear, and region; (4) catch per angler-trip from the recreational fishery by region; and (5) age-length keys by region. Detailed catch at age data permitted decomposition of age-specific *F* into that associated with each fishery and gear by region. Savings from bag and size regulations were calculated by TL increment (one-inch), and subsequently converted to relative savings by age using pooled age-length data for each region (Vaughan and Carmichael, 2000). Savings by age were used to determine age-specific estimates of *F* for different combinations of bag and size regulations. As in Vaughan and Carmichael (2000), estimates of *F* for ages 1-4 and natural mortality (*M*) on subadults were used to estimate escapement through age 4 (i.e., to age 5); while estimates of *F* for ages 1-5, *M* for subadults and adults, growth, sex ratios and maturity from the stock assessment were used for estimating static SPR.

Decomposition of Age-Specific *F*

All analyses were performed separately by region, and for each region estimates of age-specific *F* were averaged for the period 1992-1997. Values of *F* for 1998 were not used in this averaging because of concerns about retrospective bias in the most recent year (Vaughan and Carmichael, 2000). As noted above, age-specific instantaneous fishing mortality rate, *F*, was obtained for each region from the recommended approach in Vaughan and Carmichael (2000; see Appendix A for recommendations by RDAG).

Decomposition of *F* for the recreational fishery was into retained fish, either available for measurement (type A) or not available for measurement (type B1), and caught and released fish (type B2) (Essig et al., 1991). Type B2 fish were separated from type A and type B1 fish because savings associated with increasing constraints on bag and size limits will accrue to the type A and type B1 fish (formerly retained but now to be released), and not to the type B2 fish (never retained). Decomposition of F into commercial fishery gears included gillnet, haul seine, poundnet, trawl, and line gears. Estimates of F at age ($F_{j,g}$) associated with each of these gears (g) was based on the proportion of catch in numbers at age j for that type or gear ($C_{j,g}$) as used in developing the catch matrix:

$$F_{j,g} = \frac{C_{j,g}}{\sum_{g} C_{j,g}} \cdot F_j \,. \tag{1}$$

For the southern region, age-specific estimates of F were from the FADAPT VPA applied to the DELTA catch matrix with a selectivity of $F_3 = 0.87{*}F_2$. These values of F were then averaged over the period 1992-1997 (Table 2). Based on the mean catch in numbers at age (ages 1-5) for the 1992-1998 period, the age-specific estimates of F were decomposed into three components (recreational A+B1, recreational B2, and residual commercial lines) based on Eq. (1) (Table 2). Only three components were needed, because there were very few commercial landings. Essentially all landings were from the recreational fishery (99.8%), with some residual landings identified as commercial "line" gears.

For the northern region, age-specific estimates of F were from the FADAPT VPA applied to the DELTA catch matrix with a selectivity of $F_3 = 0.70{*}F_2$. The northern region was treated similarly to the southern region [using Eq. (1)] with the difference being that the age-specific estimates of F were decomposed into additional commercial gear types, including gillnet, haul seine, poundnet, and trawls (Table 2). Of the various commercial gears during the 1992-1998 period, gillnets contributed the greatest landings, averaging 139,800 pounds (77.8% of commercial landings), haul seines were next with 23,300 pounds (13.0%), poundnets with 11,200 pounds (6.2%), trawls with 2,800 pounds (1.5%), and miscellaneous "lines" with 2,600 pounds (1.4%). The annual average commercial landings (total of 179,700 pounds) compare to an average recreational landings (A+B1) of 283,200 pounds for the same period. For both regions, analyses associated with commercial "lines" were pooled with recreational type A+B1 fish to simplify the analyses, assumed similarity of gears, and because of the small level of landings from this commercial gear.

Length Frequency Distributions

Length frequency distributions by one-inch increment i and gear g ($L_{i,g}$) were obtained from Vaughan and Carmichael (2000), pooled across years 1992-1998 (Table 3). These distributions were available for recreational types A+B1 and B2 and, in the northern region only, for four commercial gears (gillnet, haul seine, poundnet, and trawl). The distributions represent the proportion of catch in numbers in each one-inch TL increment from 7" through 41" (the latter being a plus group).

Sample sizes from the recreational component (Type A) and gillnet and haul seine were generally sufficient for the period 1992-1998 (Table 3), while sample sizes from the poundnet and trawl gears were insufficient (Vaughan and Carmichael, 2000). Because mean landings during 1992-1998 for the trawl and poundnet gears represent about 2.5% of the total landings, biases in these length distributions are unlikely to have much effect on our analyses. The difference in size selectivity of the recreational length frequencies results from the differences in slot limits between the southern and northern regions (Fig. 1). Differences can also be seen among the commercial gears for the northern region (Fig. 2).

Catch Frequency Distributions

Bag limit savings were calculated from historical catch per angler-trip by reducing the number caught to that bag limit. The total numbers caught with and without that bag limit were then compared. The difference between the two numbers divided by the total without the new bag limit represents the savings from the new bag limit relative to historical conditions. At the same time, changes in slot limits will also produce savings. However, these savings were considered separately in our analysis, so bag limit savings were estimated conditioned on the corresponding slot limit.

Catch frequency data were obtained from recreational intercept data on catches per angler-trip in each region during 1992-1998. Some adjustments were necessary because of two situations: (1) some trips represented multiple anglers, and (2) all retained fish were not measured. For multiple anglers with more anglers then fish, 1 fish was assigned per angler up to the number of fish caught (i.e., for 10 fish and 12 anglers, there were then 10 angler trips with 1 fish for each). For multiple anglers with more fish than anglers, the number of fish was divided by the number of anglers and rounded to an integer as needed (i.e., 6 fish caught by 3 anglers would be 3 angler-trips with 2 fish per angler trip). Unmeasured type A fish and all type B2 fish were assigned to TLs in 1-inch increments proportional to measured type A fish. If no measured type A fish were available for a trip, the trip was deleted from this analysis.

Frequency of catch-per-angler trip from the recreational data base suggested most anglers during 1992-1998 caught only one red drum (60.5% in the southern region and 72.2% in the northern region) (Fig. 3). Sample size for the southern region was 1,769 angler trips, with 36 of them in excess of 5 fish (with one angler trip reporting 16 fish). Sample size for the northern region included 846 angler trips, with 2 of them reporting 6 fish.

Savings from bag limits were calculated from recreational data on type A and B1 fish with associated data on catch-per-angler trip and size of fish. For the period 1992-1998, sample size was 3,244 fish for the southern region and 1,304 fish for the northern region. Because minimum size limit was generally different between the regions, the range of values for the minimum size limit was different between the two regions (Table 1). The number of red drum caught and retained for different bag limits was calculated with slot limits varying in two ways. For the southern region, the minimum size limit was allowed to vary between 14" to 20" TL in one-inch increments with a fixed maximum size limit of 27" (Table 4a). The second method allowed the maximum size limit to vary between 21" and 27" TL in one-inch increments with a fixed minimum size limit of 14" (Table 4b). The northern region was treated in a similar manner with the exception that the minimum size limit was varied between 18" and 24" TL for fixed maximum size limit of 27" (Table 5a), and the minimum size limit was fixed at 18" TL while the maximum size limit was allowed to vary (Table 5b). Savings from the bag limits was calculated separately relative to the slot limit imposed. For example, a one-fish bag limit for the southern region with a 14"-27" TL slot limit (see Table 4a) would produce an unadjusted savings of 46.8% of number of fish caught in excess of 14" [100(1516/2848)] from the management conditions in place during 1992-1998. There were 2,848 fish that would have been retained with the 14"-27" TL slot limit, of which 1,516 fish would have been retained with the one-fish bag limit.

Age Length Keys

Age-length keys were used to transform size-specific information into age-specific information. Age-length keys ($A_{i,j}$, where i = 7" to 41" TL and j = age 1 to 6+) were developed from the pooled age and length data for the 1992-1998 period for each region from data in Vaughan and Carmichael (2000). Data for the southern region included information from South Carolina (94%), Georgia (5%) and the east coast of Florida (1%). Sample size for the age-length key for the southern region (n = 29,347) was high, and generally had more than 10 fish per one-inch increment (Table 6a). Only at the largest sizes in the key (38-40 inches) were there any concerns about inadequacy of sample size (assignment to age 5 or age 6+). Data for the northern region included information from North Carolina (99%) and Virginia (1%). Sample size for the northern region was considerably less (n = 3,150) than from the southern region, but still appears to be adequate for most one-inch increments (Table 6b).

Calculating Savings

Our approach for calculating savings from modifications to bag and size limits was to specify savings in one-inch TL interval. The cross product of the length frequency ($L_{i,g}$) and age columns from the age-length key ($A_{i,j}$) for each one-inch TL increment provides an index of catch at age. (This index would equal the catch in numbers at age for that gear if multiplied by the total number caught by that gear.) A corresponding index of the catch saved at age by the bag-size regulation can be calculated from the cross product of the length frequency ($L_{i,g}$), corresponding age column ($A_{i,j}$), and proportion saved for each one-inch TL increments ($S_{i,g}$). The ratio of these values by age provides the basis for modifying age-specific estimates of *F* to reflect the new bag-size regulation for that gear.

Expressed mathematically, we have defined $L_{i,g}$ as the proportion of sampled fish in one-inch TL increment i from gear g:

$$\sum_i L_{i,g} = 1 , \qquad (2)$$

and $A_{i,j}$ equals the proportion of fish of age j in TL increments i such that for all increments i:

$$\sum_j A_{i,j} = 1 . \qquad (3)$$

Hence, an index of the catch at age j by gear g ($I_{j,g}$) is given by:

$$I_{j,g} = \sum_i L_{i,g} \cdot A_{i,j} . \tag{4}$$

If we define size-specific savings for each TL increment i and gear g ($S_{i,g}$), then an index of saved catch for age j from gear g is given by:

$$I^*_{j,g} = \sum_i L_{i,g} \cdot A_{i,j} \cdot S_{i,g} . \tag{5}$$

Multiplying this index by the release survival $\delta_{i,g}$, where $1\text{-}\delta_{i,g}$ equals the release mortality that can be size and gear dependent, allows for adjusting (reducing) savings in catch for those fish caught and released, but that subsequently die. Allowing for release mortality across sizes and gear, an adjusted index of saved catch for age j from gear g (${}_aI^*_{j,g}$) is given by:

$${}_aI^*_{j,g} = \sum_i \delta_{i,g} \cdot L_{i,g} \cdot A_{i,j} \cdot S_{i,g} . \tag{6}$$

The ratio ${}_aI^*_{j,g}/I_{j,g}$ represents the adjusted savings in catch for age j from gear g. Adjusted age- and gear-specific F ($F^*_{j,g}$) is calculated by multiplying age- and gear-specific F ($F_{j,g}$) by one minus the adjusted savings for use in subsequent population models; e.g.,

$$F^*_{j,g} = \left(1 - \frac{{}_aI^*_{j,g}}{I_{j,g}}\right) \cdot F_{j,g} . \tag{7}$$

For recreational release (B2) fish there are no savings in F from changing bag and size limits, so

$$F^*_{j,B2} = F_{j,B2} . \tag{8}$$

Age-specific F at age (F^*_j) that reflects savings from bag and size limits across all gears is obtained by summing over these gears:

$$F^*_j = \sum_g F^*_{j,g} . \tag{9}$$

Developing the savings vector ($S_{i,g}$) for the recreational fishery is fairly straight forward. We assume 100% compliance with the size and bag restrictions. For TLs outside the slot limit, no retained catches would be permitted, and savings would be the release survival associated with that gear for type A+B1 and zero for type B2 fish. For type A+B1 fish, we used a release mortality of 10% (as in Vaughan and Carmichael, 2000). Hence, savings for fish outside the slot would be 0.9 (or 90%). Savings for fish within the slot are due to the bag limit. Thus, release survival multiplied by savings from the bag limit associated with a given slot limit (e.g., 0.9 times bag limit savings) gives savings for these sizes.

For the southern region, the estimates of age-specific *F* were decomposed into essentially two components (both recreational): A+B1 and B2. Because type B2 fish were not retained in the first place, estimates of *F* associated with type B2 were not modified by changes to bag and size limits [Eq. (8)]. Age-specific estimates of *F* associated with A+B1 catch were modified by the savings for each one-inch TL increment. The example savings vector given in Table 7 (second column under Recreational/Southern) portrays a slot limit of 18"-27" with a one-fish bag limit. Values for one-inch increments less than or equal to 17" TL and greater than or equal to 27" are represented by 1, suggesting complete savings. The savings from the slot limit (18" up to but not including 27") is given as 0.331 (from Table 4a). In Eq. (7) $\delta_{\mathrm{i,A+B1}}$ is replaced by 0.9 for all i, implying a release mortality of 10%, the value used in the stock assessment for type B2 red drum (Vaughan and Carmichael, 2000). Age-specific *F* for recreational A+B1 was then adjusted by 1 minus the ratio of adjusted index of saved fish to index of caught fish [Eq. (7)]. Age- and gear-specific adjusted estimates of *F* were combined as in Eq. (9). These adjusted estimates of age-specific *F* were calculated for a range of bag limits with either increasing minimum size limits (Table 8a) and decreasing maximum size limits (Table 8b).

The situation becomes more complicated for the northern region because of commercial gears. No data was available for the stock assessment on at-sea discarding of red drum (Vaughan and Carmichael, 2000). Further, the commercial fishery was managed by quota and size limit only during 1992-1998, there were no mesh-size restrictions on gear used for red drum in this region. North Carolina had a 250,000 pound quota on commercial red drum landings during 1992-1998, which was approached in 1993 and 1995, and exceeded significantly in 1998

(301,800 pounds).

Calculations for the recreational component (including commercial lines) remained the same for this region as for the southern region. For our base analyses of the northern region, size based savings for the four commercial gears was simplified by assuming 100% savings for fish caught outside the slot limit and no savings for fish within the slot limit (see column under Base in Table 7). Adjusted estimates of age-specific F were made for a range of bag limits with either increasing minimum size limits (Table 9a) or decreasing maximum size limits (Table 9b).

To display the sensitivity of the analyses for the northern region commercial fisheries, additional savings vectors were considered (Table 7). As an alternative to the base condition, we assumed 75% survival of fish outside the slot sizes (Alternate A). This approach assumes some mesh selectivity (e.g., gillnet) both above and below the legal sizes, but with no change in mortality assumed on the legal sizes. Two additional alternatives were considered that incorporated either a 10% increase (Alternate B) or a 10% decrease (Alternate C) in size-specific F for the legal sizes.

Escapement and Static SPR

Two approaches have been considered to determine management benchmarks for Atlantic red drum in recent assessments (Vaughan, 1993, 1996; Vaughan and Carmichael, 2000). Life history parameters used for these approaches were from Vaughan and Carmichael (2000). Escapement is a measure of relative survival to a fixed age that has been considered for red drum on both the U.S. Gulf and Atlantic coasts (McGurrin, 1991, Gulf of Mexico Spawning Potential Ratio Management Strategy Committee, 1996). Only estimates of natural and fishing mortality prior to that fixed age are needed to estimate escapement. In Vaughan and Carmichael (2000), escapement or relative survival from age 1 through age 4 (expressed as percentage) was calculated as follows:

$$Escapement = 100 \cdot \frac{\prod_{j=1}^{4} \exp(-M - F_j)}{\prod_{j=1}^{4} \exp(-M)}, \quad (10)$$

where M is natural mortality for subadults (constant across ages 1-4), and F_j are estimated fishing mortality rates for ages 1-4. The denominator reduces to exp(-4M). When multiplied by 100, escapement represents the percent of recruits to age 1 that survive through age 4 relative to the condition of no fishing ($F = 0$ for all ages).

However, the primary approach for measuring exploitation intensity on red drum is referred to as static or equilibrium spawning potential ratio (SPR) (Gabriel et al., 1989, Gulf of Mexico SPR Management Strategy Committee, 1996). This approach calculates the spawning stock biomass (or other measures of reproductive strength) under fishing and non-fishing conditions. Life history parameters needed include natural mortality for subadults and adults, parameters from the growth equation and weight-length relationship ($W = aL^b$), sex ratios and maturity schedules. Static SPR expressed as a percentage is given by:

$$Static\_SPR = 100 \cdot \frac{\sum_j s_j \cdot m_j \cdot w_j \cdot \prod_{i=1}^{j} \exp(-M_i - F_i)}{\sum_j s_j \cdot m_j \cdot w_j \cdot \prod_{i=1}^{j} \exp(-M_i)}, \qquad (11)$$

where M and F are needed for ages j equal to 1 through 60 (natural mortality rate for subadults was constant for ages 1-5 and for adults was constant for ages 6-60), proportion female (s_j) and maturity of females (m_j) were used to determine proportion of mature females for ages 1-60, and weight for ages 1-60 (w_j) was determine first from length at age and then corresponding weight from length. As in past assessments (e.g., Vaughan, 1993, 1996; Vaughan and Carmichael, 2000), F for ages 6 through 60 was assumed 0, which may lead to overestimation of static SPR.

Life history parameters by region for estimating escapement and static SPR were obtained from Vaughan and Carmichael (2000). The estimate of natural mortality for subadults (Table 10) combined with age-specific estimates of F were used to estimate escapement [Eq. (10)]. The additional information on adult natural mortality, growth rate in length and weight, sex ratios, and maturity schedule (Table 10) combined with age-specific estimates of F were used to estimate static SPR [Eq. (11)].

RESULTS

Southern Region

A bag limit of one-fish per angler trip would be required to attain the stated target of 40% static SPR if the current slot limit is not changed. Increasing minimum size limit above 14" TL while maintaining the maximum size limit of 27" TL does not appear sufficient to attain the stated target level with bag limits greater than 1 fish (Table 11a). However, if the minimum size limit were maintained at 14" while the maximum size limit were reduced from the current level of 27" TL (Table 11b), then higher bag limits could be allowed (e.g., a 3-fish bag limit and 14" to 24" TL slot limit) while attaining the stated target level.

Northern Region

With base (optimistic) savings vector for commercial gears, the stated target level can only be attained by increasing the minimum size limit to at least 21" TL while maintaining the maximum size limit at 27" TL (Table 12a), or decreasing maximum size limit to at least 24" TL while maintaining minimum size limit at 18" TL (Table 12b). Only small gains were noted from decreased bag limits. For the additional commercial savings vectors, the most severe assumption (pessimistic) is given by Alternate B, suggesting at least a 22" TL minimum size limit may be necessary with a 27" TL maximum size limit (Table 13). These analyses for the northern region assume that the commercial gears will maintain the status quo in terms of total harvest, or quota, and the only regulatory change imposed will be the slot limit requirements.

DISCUSSION AND CONCLUSIONS

As described in Vaughan and Carmichael (2000), numerous assumptions were necessary to conduct the assessment. An approach was developed in that assessment for estimating the size of released recreational fish, which became numerous during the period 1992-1998 for both regions. Additionally, estimation of the selectivity of age 3 relative to age 2 was necessary in conducting the tuned virtual population analysis (FADAPT). Obviously, estimation of escapement and static SPR depend in part on the age-specific estimates of F obtained from the stock assessment (Vaughan and Carmichael, 2000).

The northern region provides additional difficulties because of the commercial fishery component. Lack of data on at-sea discards precluded the addition of this component of fishing mortality in the stock assessment. This resulted in difficulty in fully integrating the potential commercial savings from size limits, and potential redirection of effort within the legal slot limit. Data needed to analyze commercial gains from trip limits would require detailed sampling of individual trips, primarily from gillnets and haul seines, to characterize size of fish and quantity in a manner comparable to the recreational data set used to analyze bag limits. In fact, North Carolina has recently implemented a trip limit on commercial gears, but the gains from this management action are presently uncertain.

Because the bag limit was generally five red drum during this period for both regions (with the exception of Florida in the southern region), it was not possible to analyze the consequences of increasing bag size above this value, only bag limits at or below five red drum could be considered. A similar constraint was extant for slot limits with 14" to 27" TL for the southern region (again with the exception of Florida with an 18" to 27" TL slot limit) and 18" to 27" TL for the northern region. Since a portion of the southern region (Florida) was more restrictive Table 1), analyses increasing restrictions on bag and size limits for this region assume there is no relaxation of the bag and size limits within Florida. Hence, the potential savings would be overestimated if the Florida regulations were relaxed. For the northern region, there was a five-fish bag and 18" TL minimum size, but with the allowance of one-fish over the maximum size of 27" TL; therefore, there was no true slot limit. In both regions, there were several cases of non-compliance with the regulations. Hence, gains are noted in each region from a five-fish bag limit and regional slot limit (Table 11a and 12a). No attempt is made to analyze future non-compliance with the regulations. In conclusion, significant gains in estimates of the benchmarks based on escapement and static SPR have been reached from the management measures put in place early in 1992. However, more restrictions will be needed, if the SAFMC stated goal of 40% static SPR is to be reached.

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Table 1. State-specific management regulations in effect during 1992-1998. Size limits are TLs in inches (modified from Appendix A in Vaughan and Carmichael, 2000). Limited to states with significant annual landings.

State	Size Limit Minimum	Size Limit Maximum	Bag Limit	Notes
Florida	18	27	1	No sale[b]
Georgia	14	27	5	
South Carolina	14	27	5	No sale[b]
North Carolina	18	27[a]	5	Quota[c]
Virginia	18	27[a]	5	No quota[d]
Maryland	18	27[a]	5	

[a] One fish over 27" TL allowed.
[b] Gamefish status.
[c] Commercial quota of 250,000 lbs.
[d] Commercial fishery subject to same bag and size limits as recreational fishery.

Table 2. Estimates of instantaneous fishing mortality rate for Atlantic red drum from Vaughan and Carmichael (2000) using FADAPT on DELTA catch matrix with selectivity of $F_3 = 0.87*F_2$ for the southern region and $F_3 = 0.7*F_2$ for the northern region. Age-specific estimates of F are decomposed by fishery and gear based on catch in numbers at age.

		Recreational		Commercial				
Age	F (1/yr)	A+B1	B2	Gillnet	Haulseine	Poundnet	Trawl	Line
				Southern region				
1	0.141	0.069	0.072	0.000	0.000	0.000	0.000	0.000
2	0.459	0.336	0.122	0.000	0.000	0.000	0.000	0.001
3	0.584	0.576	0.006	0.000	0.000	0.000	0.000	0.002
4	0.592	0.584	0.006	0.000	0.000	0.000	0.000	0.002
5	0.361	0.348	0.012	0.000	0.000	0.000	0.000	0.001
				Northern region				
1	0.243	0.062	0.125	0.028	0.019	0.008	0.000	0.001
2	0.920	0.472	0.064	0.306	0.054	0.018	0.002	0.004
3	0.525	0.288	0.004	0.187	0.017	0.020	0.005	0.004
4	0.058	0.040	0.004	0.009	0.001	0.002	0.000	0.001
5	0.009	0.007	0.001	0.000	0.000	0.000	0.000	0.000

Table 3. Frequency of Atlantic red drum sampling by one inch TL intervals from recreational by region (type A) and North Carolina commercial sampling by gear, 1992-1998.

TL interval (inches)	Recreational		Commercial			
	Southern	Northern	Gillnet	Haulseine	Poundnet	Trawl
7	0.001	0.002	0.000	0.000	0.000	0.000
8	0.001	0.003	0.000	0.001	0.000	0.000
9	0.000	0.003	0.000	0.001	0.000	0.000
10	0.002	0.003	0.000	0.004	0.000	0.012
11	0.005	0.002	0.000	0.000	0.000	0.012
12	0.003	0.002	0.001	0.003	0.005	0.025
13	0.050	0.005	0.001	0.006	0.000	0.012
14	0.159	0.010	0.001	0.005	0.005	0.012
15	0.156	0.011	0.001	0.001	0.005	0.000
16	0.118	0.011	0.003	0.001	0.010	0.000
17	0.076	0.023	0.042	0.023	0.025	0.000
18	0.047	0.064	0.128	0.250	0.036	0.000
19	0.031	0.058	0.200	0.166	0.020	0.000
20	0.032	0.052	0.178	0.071	0.015	0.000
21	0.046	0.086	0.086	0.057	0.005	0.037
22	0.044	0.121	0.050	0.142	0.051	0.000
23	0.042	0.145	0.099	0.094	0.117	0.112
24	0.037	0.139	0.076	0.116	0.147	0.186
25	0.034	0.088	0.051	0.044	0.254	0.224
26	0.040	0.051	0.055	0.009	0.203	0.168
27	0.035	0.035	0.021	0.001	0.066	0.149
28	0.020	0.018	0.004	0.000	0.005	0.000
29	0.008	0.005	0.001	0.000	0.005	0.000
30	0.008	0.002	0.000	0.000	0.000	0.000
31	0.001	0.004	0.001	0.000	0.005	0.000
32	0.000	0.005	0.001	0.005	0.010	0.006
33	0.002	0.004	0.000	0.000	0.000	0.000
34	0.001	0.007	0.000	0.000	0.000	0.000
35	0.000	0.002	0.000	0.000	0.000	0.000
36	0.001	0.002	0.000	0.000	0.000	0.006
37	0.001	0.000	0.000	0.000	0.000	0.006
38	0.000	0.004	0.000	0.000	0.000	0.025
39	0.000	0.005	0.000	0.000	0.005	0.000
40	0.000	0.002	0.000	0.000	0.000	0.000
41+	0.000	0.026	0.000	0.000	0.005	0.006
Sample size:	2403	1216	12614	8074	197	161

Table 4a. Number of southern region Atlantic red drum that would have been caught and retained (A+B1) from recreational fishery and savings accrued for range of slot sizes with increasing minimum size limit, 1992-1998. Note that No slot and No bag represent underlying conditions for 1992-1998; e.g., legally there was a 5 fish bag limit, minimum size limit of 14" TL, and maximum size limit for South Carolina and Georgia. Florida has had the same slot limit but with a 1 fish bag limit.

Bag limit	No slot	Increasing minimum size limit (maximum size = 27")						
		14"	15"	16"	17"	18"	19"	20"
				Number caught/retained if slot/bag limits in place				
1	1770	1516	1344	1126	928	783	694	629
2	2468	2127	1828	1466	1186	973	849	765
3	2820	2453	2083	1620	1309	1066	927	830
4	3037	2656	2237	1721	1377	1115	967	864
5	3164	2772	2319	1780	1414	1149	995	889
No bag	3244	2848	2356	1809	1443	1171	1017	911
				Proportion saved by bag relative to slot limit (unadjusted for release mortality)				
1	0.454	0.468	0.430	0.378	0.357	0.331	0.318	0.310
2	0.239	0.253	0.224	0.190	0.178	0.169	0.165	0.160
3	0.131	0.139	0.116	0.104	0.093	0.090	0.088	0.089
4	0.064	0.067	0.051	0.049	0.046	0.048	0.049	0.052
5	0.025	0.027	0.016	0.016	0.020	0.019	0.022	0.024

Table 4b. Number of southern region Atlantic red drum that would have been caught and retained (A+B1) from recreational fishery and savings accrued for range of slot sizes with decreasing maximum size limit, 1992-1998. Note that No slot and No bag represent underlying conditions for 1992-1998; e.g., legally there was a 5 fish bag limit, minimum size limit of 14" TL, and maximum size limit for South Carolina and Georgia. Florida has had the same slot limit but with a 1 fish bag limit.

Bag limit	No slot	Decreasing maximum size limit (minimum size = 14")						
		21"	22"	23"	24"	25"	26"	27"
	Number caught/retained if slot/bag limits in place							
1	1770	1081	1161	1238	1317	1386	1443	1516
2	2468	1542	1640	1747	1862	1946	2030	2127
3	2820	1781	1896	2025	2157	2255	2351	2453
4	3037	1920	2038	2185	2325	2447	2550	2656
5	3164	1994	2116	2272	2415	2549	2658	2772
No bag	3244	2050	2172	2330	2473	2613	2723	2848
	Proportion saved by bag relative to slot limit (unadjusted for release mortality)							
1	0.454	0.473	0.465	0.469	0.467	0.470	0.470	0.468
2	0.239	0.248	0.245	0.250	0.247	0.255	0.254	0.253
3	0.131	0.131	0.127	0.131	0.128	0.137	0.137	0.139
4	0.064	0.063	0.062	0.062	0.060	0.064	0.064	0.067
5	0.025	0.027	0.026	0.025	0.023	0.024	0.024	0.027

Table 5a. Number of northern region Atlantic red drum that would have been caught and retained (A+B1) from recreational fishery and savings accrued for range of slot sizes with increasing minimum size limit, 1992-1998. Note that No slot and No bag represent underlying conditions for 1992-1998; e.g., legally there was a 5 fish bag limit and minimum size limit of 18" TL for North Carolina and Virginia. One fish was allowed over the maximum size limit of 27", so a true slot limit was not in place.

Bag Limit	No slot	Increasing minimum size limit (maximum size = 27") 18"	19"	20"	21"	22"	23"	24"
	Number caught/retained if slot/bag limits in place							
1	846	666	610	562	524	473	407	291
2	1081	860	786	724	676	603	495	335
3	1193	960	879	809	753	657	534	353
4	1264	1024	942	867	795	693	548	354
5	1302	1054	971	891	819	707	551	355
No bag	1304	1056	973	893	821	708	551	355
	Proportion saved by bag relative to slot limit (unadjusted for release mortality)							
1	0.351	0.369	0.373	0.371	0.362	0.332	0.261	0.180
2	0.171	0.186	0.192	0.189	0.177	0.148	0.102	0.056
3	0.085	0.091	0.097	0.094	0.083	0.072	0.031	0.006
4	0.031	0.030	0.032	0.029	0.032	0.021	0.005	0.003
5	0.002	0.002	0.002	0.002	0.002	0.001	0.000	0.000

Table 5b. Number of northern region Atlantic red drum that would have been caught and retained (A+B1) from recreational fishery and savings accrued for range of slot sizes with decreasing maximum size limit, 1992-1998. Note that No slot and No bag represent underlying conditions for 1992-1998; e.g., legally there was a 5 fish bag limit and minimum size limit of 18" TL for North Carolina and Virginia. One fish was allowed over the maximum size limit of 27", so a true slot limit was not in place.

Bag Limit	No slot	Decreasing maximum size limit (minimum size = 18")						
		21"	22"	23"	24"	25"	26"	27"
	Number caught/retained if slot/bag limits in place							
1	846	188	265	357	463	549	619	666
2	1081	225	321	452	603	713	805	860
3	1193	236	339	494	665	807	904	960
4	1264	237	342	506	686	856	965	1024
5	1302	237	342	506	693	875	990	1054
No bag	1304	237	342	506	694	877	992	1056
	Proportion saved by bag relative to slot limit (unadjusted for release mortality)							
1	0.351	0.207	0.225	0.294	0.333	0.374	0.376	0.369
2	0.171	0.051	0.061	0.107	0.131	0.187	0.189	0.186
3	0.085	0.004	0.009	0.024	0.042	0.080	0.089	0.091
4	0.031	0.000	0.000	0.000	0.012	0.024	0.027	0.030
5	0.002	0.000	0.000	0.000	0.001	0.002	0.002	0.002

Table 6a. Atlantic red drum age-length key for the southern region, 1992-1998 (n = 29,347).

TL	Sample size	Ages					
(in)	n	1	2	3	4	5	6+
7	37	0.892	0.108				
8	51	0.980	0.020				
9	231	0.996	0.004				
10	852	0.991	0.005	0.005			
11	800	0.996	0.003	0.001			
12	861	0.983	0.008	0.009			
13	1048	0.933	0.065	0.002			
14	1848	0.682	0.315	0.002	0.001		
15	2860	0.459	0.539	0.001	0.0		
16	2542	0.360	0.638	0.002	0.0		
17	1641	0.255	0.745	0.001	0.0		
18	792	0.106	0.888	0.005	0.001		
19	674	0.034	0.904	0.062	0.0		
20	763	0.004	0.769	0.227	0.0		
21	1152	0.006	0.601	0.392	0.001		
22	1613	0.001	0.460	0.534	0.005		
23	1789	0.002	0.373	0.605	0.020		0.001
24	1872	0.001	0.207	0.705	0.085	0.002	0.001
25	1573		0.126	0.670	0.196	0.008	0.0
26	1218		0.045	0.506	0.413	0.035	0.001
27	1155		0.010	0.349	0.539	0.099	0.003
28	1025		0.002	0.235	0.571	0.189	0.003
29	949		0.001	0.109	0.581	0.298	0.012
30	781		0.003	0.069	0.579	0.327	0.023
31	485		0.002	0.035	0.555	0.363	0.045
32	302			0.020	0.487	0.437	0.056
33	170			0.012	0.353	0.418	0.218
34	99			0.0	0.364	0.424	0.212
35	60			0.017	0.133	0.367	0.483
36	34				0.059	0.206	0.735
37	18				0.056	0.056	0.944
38	6					0.167	0.833
39	11					0.0	1.0
40	7					0.0	1.0
41+	28					0.036	0.964

Table 6b. Atlantic red drum age-length key for the northern region, 1992-1998 (n = 3,150).

TL	Sample size	Ages					
(in)	n	1	2	3	4	5	6+
7	2	1.0					
8	5	1.0					
9	26	1.0					
10	58	1.0					
11	51	0.980	0.020				
12	119	0.975	0.025				
13	158	0.949	0.051				
14	159	0.899	0.101				
15	180	0.850	0.150				
16	211	0.706	0.294				
17	158	0.557	0.443				
18	149	0.362	0.638				
19	72	0.194	0.792	0.014			
20	52	0.019	0.962	0.019			
21	80	0.013	0.975	0.013			
22	122	0.000	0.951	0.049			
23	205	0.005	0.898	0.098			
24	244		0.869	0.127	0.004		
25	194		0.706	0.273	0.021		
26	112		0.455	0.536	0.009		
27	80		0.200	0.763	0.038		
28	76		0.079	0.882	0.039		
29	45		0.089	0.822	0.089		
30	40		0.000	0.875	0.125		
31	24		0.042	0.542	0.417		
32	21			0.429	0.524	0.048	
33	17			0.412	0.588	0.000	
34	25			0.080	0.360	0.560	
35	13				0.154	0.462	0.385
36	16				0.125	0.500	0.375
37	20				0.050	0.250	0.700
38	20					0.100	0.900
39	27						1.0
40	39						1.0
41+	330						1.0

Table 7. Sample set up for proportional reduction in size-specific fishing mortality rate of Atlantic red drum (before adjustment for release mortality) by fishery by TL interval based on 18" to 27" slot limit with 1 fish bag limit. Various alternate approaches to the commercial gears in the northern region are defined below: Base, Alternate A, Alternate B and Alternate C. Age-length keys are then used to convert these to proportion reduction in age-specific fishing mortality rates by fishery and gear (and adjusted for release mortality in recreational fishery).

TL interval	Recreational		Commercial (Gill, Haul, Pound, Trawl)			
(inches)	Southern	Northern	Base	Alter. A	Alter. B	Alter. C
7	1	1	1	0.75	0.75	0.75
8	1	1	1	0.75	0.75	0.75
9	1	1	1	0.75	0.75	0.75
10	1	1	1	0.75	0.75	0.75
11	1	1	1	0.75	0.75	0.75
12	1	1	1	0.75	0.75	0.75
13	1	1	1	0.75	0.75	0.75
14	1	1	1	0.75	0.75	0.75
15	1	1	1	0.75	0.75	0.75
16	1	1	1	0.75	0.75	0.75
17	1	1	1	0.75	0.75	0.75
18	0.331	0.369	0	0	-0.1	0.1
19	0.331	0.369	0	0	-0.1	0.1
20	0.331	0.369	0	0	-0.1	0.1
21	0.331	0.369	0	0	-0.1	0.1
22	0.331	0.369	0	0	-0.1	0.1
23	0.331	0.369	0	0	-0.1	0.1
24	0.331	0.369	0	0	-0.1	0.1
25	0.331	0.369	0	0	-0.1	0.1
26	0.331	0.369	0	0	-0.1	0.1
27	1	1	1	0.75	0.75	0.75
28	1	1	1	0.75	0.75	0.75
29	1	1	1	0.75	0.75	0.75
30	1	1	1	0.75	0.75	0.75
31	1	1	1	0.75	0.75	0.75
32	1	1	1	0.75	0.75	0.75
33	1	1	1	0.75	0.75	0.75
34	1	1	1	0.75	0.75	0.75
35	1	1	1	0.75	0.75	0.75
36	1	1	1	0.75	0.75	0.75
37	1	1	1	0.75	0.75	0.75
38	1	1	1	0.75	0.75	0.75
39	1	1	1	0.75	0.75	0.75
40	1	1	1	0.75	0.75	0.75
41+	1	1	1	0.75	0.75	0.75

Table 8a. Adjusted estimates of age-specific *F* for increasing minimum size limit (maximum size of 27" TL) and varying bag limit for the southern region.

Age (yr)	Increasing minimum size limit (maximum size = 27") 14"	15"	16"	17"	18"	19"	20"
				one-fish bag limit			
1	0.105	0.095	0.087	0.082	0.079	0.079	0.079
2	0.316	0.138	0.111	0.105	0.123	0.132	0.140
3	0.310	0.096	0.112	0.084	0.091	0.078	0.063
4	0.178	0.075	0.079	0.070	0.072	0.068	0.067
5	0.065	0.048	0.049	0.047	0.048	0.047	0.047
				2-fish bag limit			
1	0.116	0.101	0.090	0.083	0.080	0.079	0.079
2	0.380	0.362	0.325	0.284	0.253	0.230	0.214
3	0.409	0.422	0.437	0.442	0.446	0.447	0.444
4	0.224	0.229	0.236	0.239	0.240	0.241	0.242
5	0.073	0.074	0.075	0.075	0.075	0.076	0.076
				3-fish bag limit			
1	0.122	0.104	0.091	0.083	0.080	0.079	0.079
2	0.414	0.391	0.342	0.298	0.263	0.237	0.219
3	0.462	0.472	0.476	0.481	0.482	0.482	0.477
4	0.248	0.252	0.254	0.257	0.257	0.257	0.257
5	0.077	0.077	0.078	0.078	0.078	0.078	0.078
				4-fish bag limit			
1	0.125	0.105	0.092	0.084	0.080	0.079	0.079
2	0.436	0.408	0.354	0.305	0.268	0.240	0.222
3	0.495	0.502	0.502	0.503	0.502	0.500	0.493
4	0.263	0.266	0.266	0.267	0.266	0.265	0.265
5	0.079	0.080	0.080	0.080	0.080	0.080	0.080
				five-fish bag limit			
1	0.127	0.106	0.092	0.084	0.080	0.079	0.079
2	0.448	0.418	0.361	0.309	0.271	0.243	0.224
3	0.514	0.518	0.517	0.515	0.515	0.513	0.506
4	0.272	0.274	0.273	0.272	0.272	0.271	0.271
5	0.080	0.081	0.081	0.081	0.081	0.081	0.081

Table 8b. Adjusted estimates of age-specific *F* for decreasing maximum size limit (minimum size of 14" TL) and varying bag limit for the southern region.

Age (yr)	Decreasing maximum size limit (minimum size = 14") 21"	22"	23"	24"	25"	26"	27"
				one-fish bag limit			
1	0.105	0.105	0.105	0.105	0.105	0.105	01059
2	0.286	0.298	0.304	0.311	0.313	0.314	0.316
3	0.081	0.112	0.151	0.194	0.237	0.275	0.310
4	0.066	0.066	0.067	0.070	0.083	0.110	0.178
5	0.047	0.047	0.047	0.047	0.047	0.050	0.065
				2-fish bag limit			
1	0.116	0.116	0.116	0.116	0.116	0.116	0.116
2	0.342	0.357	0.366	0.375	0.376	0.379	0.380
3	0.088	0.131	0.186	0.247	0.307	0.361	0.409
4	0.066	0.066	0.068	0.072	0.090	0.128	0.224
5	0.047	0.047	0.047	0.047	0.047	0.052	0.073
				3-fish bag limit			
1	0.122	0.122	0.122	0.122	0.122	0.122	0.122
2	0.371	0.388	0.399	0.409	0.411	0.414	0.414
3	0.092	0.142	0.205	0.276	0.345	0.407	0.462
4	0.066	0.067	0.068	0.073	0.094	0.138	0.248
5	0.047	0.047	0.047	0.047	0.048	0.052	0.077
				4-fish bag limit			
1	0.126	0.126	0.126	0.126	0.126	0.126	01259
2	0.387	0.406	0.418	0.429	0.433	0.436	0.436
3	0.094	0.148	0.217	0.293	0.369	0.437	0.495
4	0.066	0.067	0.068	0.074	0.097	0.145	0.263
5	0.047	0.047	0.047	0.047	0.048	0.053	0.079
				five-fish bag limit			
1	0.127	0.128	0.128	0.128	0.128	0.128	0.127
2	0.396	0.415	0.429	0.440	0.445	0.448	0.448
3	0.095	0.151	0.223	0.301	0.382	0.452	0.514
4	0.066	0.067	0.068	0.075	0.098	0.148	0.272
5	0.047	0.047	0.047	0.047	0.048	0.053	0.080

Table 9a. Adjusted estimates of age-specific *F* for increasing minimum size limit (maximum size of 27" TL) and varying bag limit for the northern region.

Age (yr)	Increasing minimum size limit (maximum size = 27") 18"	19"	20"	21"	22"	23"	24"
				one-fish bag limit			
1	0.172	0.147	0.133	0.132	0.132	0.132	0.132
2	0.671	0.606	0.519	0.428	0.366	0.316	0.249
3	0.284	0.283	0.276	0.269	0.269	0.265	0.242
4	0.018	0.018	0.018	0.018	0.018	0.019	0.019
5	0.003	0.003	0.003	0.003	0.003	0.003	0.003
				2-fish bag limit			
1	0.172	0.147	0.133	0.132	0.132	0.132	0.132
2	0.726	0.655	0.563	0.468	0.396	0.335	0.259
3	0.304	0.303	0.296	0.289	0.289	0.281	0.253
4	0.019	0.019	0.019	0.019	0.019	0.020	0.020
5	0.003	0.003	0.003	0.003	0.003	0.003	0.003
				3-fish bag limit			
1	0.173	0.147	0.133	0.132	0.132	0.132	0.132
2	0.755	0.681	0.586	0.487	0.409	0.344	0.263
3	0.315	0.314	0.307	0.299	0.297	0.289	0.257
4	0.020	0.020	0.020	0.020	0.020	0.020	0.020
5	0.003	0.003	0.003	0.003	0.003	0.003	0.003
				4-fish bag limit			
1	0.173	0.148	0.133	0.132	0.132	0.132	0.132
2	0.773	0.698	0.602	0.498	0.417	0.347	0.263
3	0.321	0.321	0.314	0.305	0.302	0.291	0.258
4	0.020	0.020	0.020	0.020	0.020	0.020	0.020
5	0.003	0.003	0.003	0.003	0.003	0.003	0.003
				five-fish bag limit			
1	0.173	0.148	0.133	0.132	0.132	0.132	0.132
2	0.782	0.706	0.609	0.504	0.420	0.347	0.263
3	0.324	0.324	0.317	0.308	0.304	0.292	0.258
4	0.020	0.020	0.020	0.020	0.020	0.020	0.020
5	0.003	0.003	0.003	0.003	0.003	0.003	0.003

Table 9b. Adjusted estimates of age-specific *F* for increasing maximum size limit (minimum size of 18" TL) and varying bag limit for the northern region.

Age (yr)	Decreasing minimum size limit (minimum size = 27") 21"	22"	23"	24"	25"	26"	27"
				one-fish bag limit			
1	0.172	0.172	0.172	0.172	0.172	0.172	0.172
2	0.371	0.443	0.493	0.557	0.606	0.644	0.671
3	0.049	0.053	0.063	0.093	0.126	0.178	0.284
4	0.008	0.008	0.008	0.008	0.010	0.016	0.018
5	0.003	0.003	0.003	0.003	0.003	0.003	0.003
				2-fish bag limit			
1	0.172	0.172	0.172	0.173	0.172	0.172	0.172
2	0.385	0.465	0.527	0.602	0.654	0.696	0.726
3	0.050	0.053	0.065	0.097	0.132	0.189	0.304
4	0.008	0.008	0.008	0.008	0.010	0.016	0.019
5	0.003	0.003	0.003	0.003	0.003	0.003	0.003
				3-fish bag limit			
1	0.172	0.173	0.173	0.173	0.173	0.173	0.173
2	0.389	0.472	0.543	0.622	0.682	0.725	0.755
3	0.050	0.053	0.066	0.099	0.135	0.194	0.315
4	0.008	0.008	0.008	0.008	0.010	0.017	0.020
5	0.003	0.003	0.003	0.003	0.003	0.003	0.003
				4-fish bag limit			
1	0.172	0.173	0.173	0.173	0.173	0.173	0.173
2	0.389	0.474	0.547	0.628	0.696	0.742	0.773
3	0.050	0.054	0.066	0.100	0.137	0.198	0.321
4	0.008	0.008	0.008	0.008	0.010	0.017	0.020
5	0.003	0.003	0.003	0.003	0.003	0.003	0.003
				five-fish bag limit			
1	0.172	0.173	0.173	0.173	0.173	0.173	0.173
2	0.389	0.474	0.547	0.631	0.701	0.749	0.782
3	0.050	0.054	0.066	0.100	0.138	0.199	0.324
4	0.008	0.008	0.008	0.008	0.010	0.017	0.020
5	0.003	0.003	0.003	0.003	0.003	0.003	0.003

Table 10. Life history data for escapement and static spawner potential ratio (SPR) (Vaughan and Carmichael, 2000).

Parameter	Southern region	Northern region
Natural mortality (M):		
Subadult	0.23	0.20
Adult	0.13	0.12
'Linear' von Bertalanffy:		
b_0	39.76	41.32
b_1	0.069	0.145
k	0.284	0.285
L_∞	-0.398	-0.307
Weight-length:		
a	0.00115	0.00115
b	2.627	2.627
Sex ratios:		
Ages 1-2	0.50	0.50
Ages 3+	0.61	0.61
Maturity schedule:		
Age 1	0.0	0.0
Age 2	0.01	0.01
Age 3	0.58	0.58
Age 4	0.99	0.99
Ages 5+	1.0	1.0

Table 11a. Escapement and static SPR for range of bag limits with increasing minimum size limit for the southern region. (At or above target in bold)

Bag limit	Increasing minimum size limit (maximum size = 27") 14"	15"	16"	17"	18"	19"	20"
	Escapement through age 4						
1	**40.3**	**66.8**	**67.8**	**71.1**	**69.4**	**70.0**	**70.5**
2	32.3	32.8	33.7	35.1	36.1	36.9	37.6
3	28.8	29.6	31.3	32.7	33.9	34.8	35.6
4	26.7	27.8	29.7	31.4	32.8	33.8	34.7
5	25.6	26.8	28.9	30.7	32.1	33.1	34.0
	Static SPR						
1	**39.7**	**65.0**	**66.1**	**69.2**	**67.6**	**68.1**	**68.6**
2	32.1	32.6	33.5	34.9	36.0	36.8	37.4
3	28.7	29.5	31.2	32.7	33.9	34.8	35.6
4	26.8	27.8	29.8	31.4	32.8	33.9	34.7
5	25.7	26.9	28.9	30.8	32.1	33.2	34.0

Table 11b. Escapement and static SPR for range of bag limits with decreasing maximum size limit for the southern region. (At or above target in bold)

Bag limit	Decreasing minimum size limit (minimum size = 14")						
	21"	22"	23"	24"	25"	26"	27"
				Escapement through age 4			
1	**58.4**	**55.9**	**53.4**	**50.7**	**47.8**	**44.8**	**40.3**
2	**54.2**	**51.2**	**47.9**	**44.5**	**41.1**	37.4	32.3
3	**52.2**	**48.7**	**45.2**	**41.5**	37.8	33.9	28.8
4	**51.0**	47.4	43.7	39.8	35.9	31.9	26.7
5	**50.5**	46.7	42.8	38.9	34.9	30.9	25.6
				Static SPR			
1	**56.8**	**54.5**	**52.2**	**49.6**	**47.0**	**44.1**	**39.7**
2	**52.8**	**49.9**	**46.9**	**43.7**	**40.6**	37.1	32.1
3	**50.8**	**47.6**	**44.3**	**40.8**	37.4	33.8	28.7
4	**49.7**	**46.3**	**42.8**	39.2	35.6	31.8	26.8
5	**49.1**	**45.6**	**42.0**	38.3	34.6	30.8	25.7

Table 12a. Escapement and static SPR for range of bag limits with increasing minimum size limit and "base" commercial savings for the northern region. (At or above target in bold)

Bag limit	Increasing minimum size limit (maximum size = 27")						
	18"	19"	20"	21"	22"	23"	24"
				Escapement through age 4			
1	31.8	34.9	38.8	**42.9**	**45.6**	**48.1**	**52.6**
2	29.5	32.5	36.4	**40.3**	**43.3**	**46.4**	**51.5**
3	28.3	31.3	35.1	39.1	**42.4**	**45.6**	**51.1**
4	27.6	30.5	34.3	38.5	**41.9**	**45.4**	**51.0**
5	27.3	30.2	34.0	38.1	**41.6**	**45.3**	**51.0**
				Static SPR			
1	32.1	35.2	39.2	**43.2**	**46.0**	**48.5**	**53.0**
2	29.8	32.8	36.7	**40.7**	**43.8**	**46.8**	**51.9**
3	28.6	31.6	35.5	**39.5**	**42.8**	**46.0**	**51.5**
4	27.9	30.8	34.7	38.9	**42.3**	**45.8**	**51.4**
5	27.6	30.5	34.4	38.5	**42.1**	**45.8**	**51.4**

Table 12b. Escapement and static SPR for range of bag limits with decreasing maximum size limit and "base" commercial savings for the northern region. (At or above target in bold)

Bag limit	Decreasing maximum size limit (minimum size = 18")						
	21"	22"	23"	24"	25"	26"	27"
				Escapement through age 4			
1	**54.9**	**50.9**	**47.9**	**43.6**	**40.1**	36.4	31.8
2	**54.1**	**49.8**	**46.2**	**41.5**	38.0	34.2	29.5
3	**53.9**	**49.4**	**45.4**	**40.6**	36.8	33.0	28.3
4	**53.9**	**49.2**	**45.2**	**40.3**	36.2	32.3	27.6
5	**53.9**	**49.2**	**45.2**	**40.2**	36.0	32.1	27.3
				Static SPR			
1	**54.9**	**50.9**	**47.9**	**43.7**	**40.2**	36.6	32.1
2	**54.1**	**49.8**	**46.2**	**41.5**	38.1	34.4	29.8
3	**53.8**	**49.4**	**45.4**	**40.6**	36.9	33.2	28.6
4	**53.8**	**49.2**	**45.2**	**40.4**	36.3	32.5	27.9
5	**53.8**	**49.2**	**45.2**	**40.2**	36.1	32.2	27.6

Table 13. Sensitivity of static SPR to three alternate assumptions for commercial component savings for range of bag limits with increasing minimum size for northern region. All three alternates reduce *F* for nonlegal sizes by 25%. Alternate A assumes no change in *F* for legal sizes, Alternate B increases *F* by 10% for legal sizes, and Alternate C decreases *F* by 10% for legal sizes. (At or above target in bold)

Bag limit	Increasing minimum size limit (maximum size = 27")						
	18"	19"	20"	21"	22"	23"	24"
				Alternate A			
1	31.5	33.9	36.8	**39.9**	**42.0**	**44.0**	**47.3**
2	29.2	31.6	34.5	37.6	**40.0**	**42.4**	**46.3**
3	28.0	30.5	33.4	36.5	39.1	**41.7**	**45.9**
4	27.3	29.7	32.6	35.8	38.6	**41.5**	**45.9**
5	27.0	29.4	32.3	35.5	38.4	**41.5**	**45.9**
				Alternate B			
1	29.7	32.1	35.3	38.5	**40.7**	**42.7**	**46.3**
2	27.5	30.0	33.1	36.3	38.7	**41.3**	**45.4**
3	26.5	28.9	32.0	35.2	37.9	**40.7**	**44.9**
4	25.8	28.2	31.3	34.7	37.5	**40.4**	**44.9**
5	25.5	27.9	31.0	34.3	37.2	**40.3**	**44.9**
				Alternate C			
1	33.4	35.6	38.5	**41.3**	**43.4**	**45.1**	**48.3**
2	30.9	33.3	36.1	38.9	**41.2**	**43.6**	**47.2**
3	29.7	32.1	34.9	37.7	**40.4**	**42.9**	**46.8**
4	29.0	31.3	34.1	37.1	**39.9**	**42.7**	**46.8**
5	28.7	30.9	33.7	36.8	**39.7**	**42.6**	**46.8**

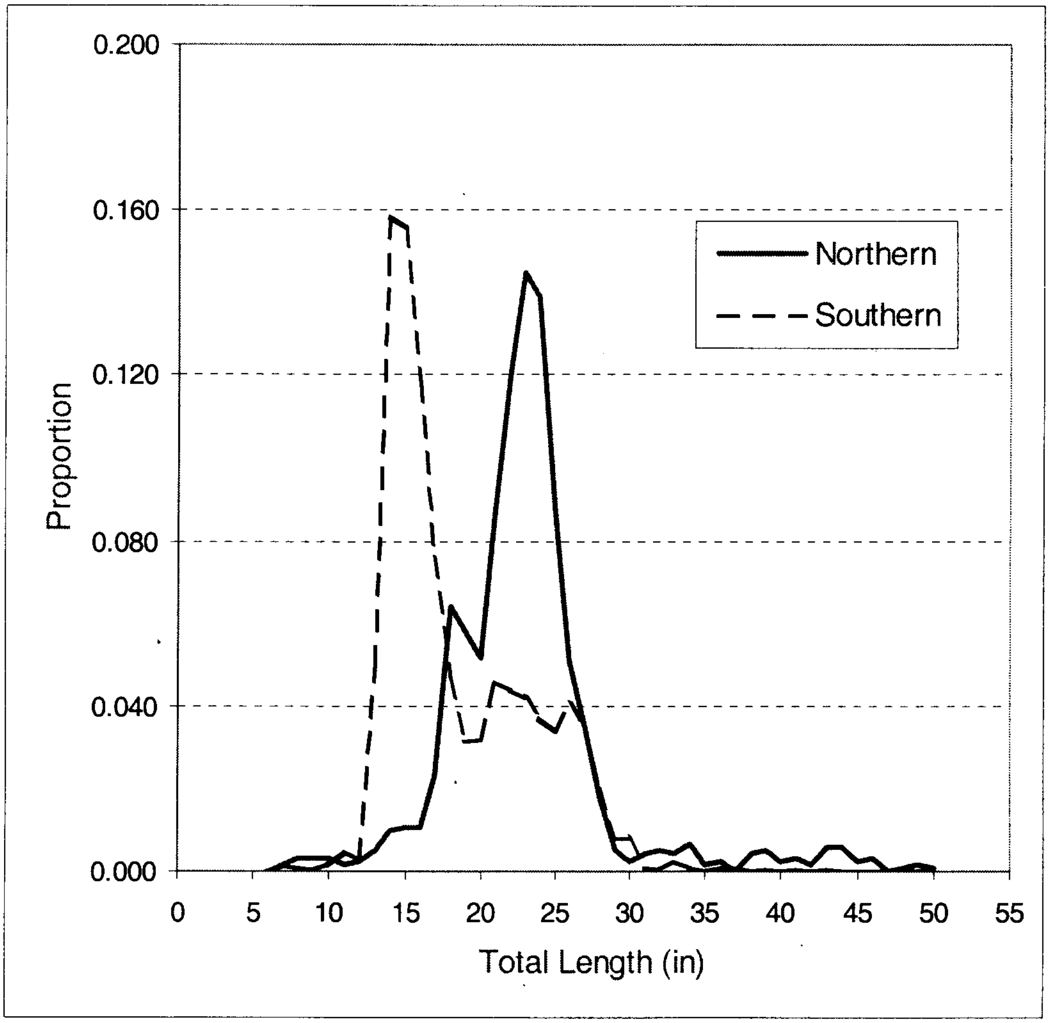

Figure 1. Comparison of Atlantic red drum length frequency distributions for recreational landings from the northern and southern regions, 1992-1998.

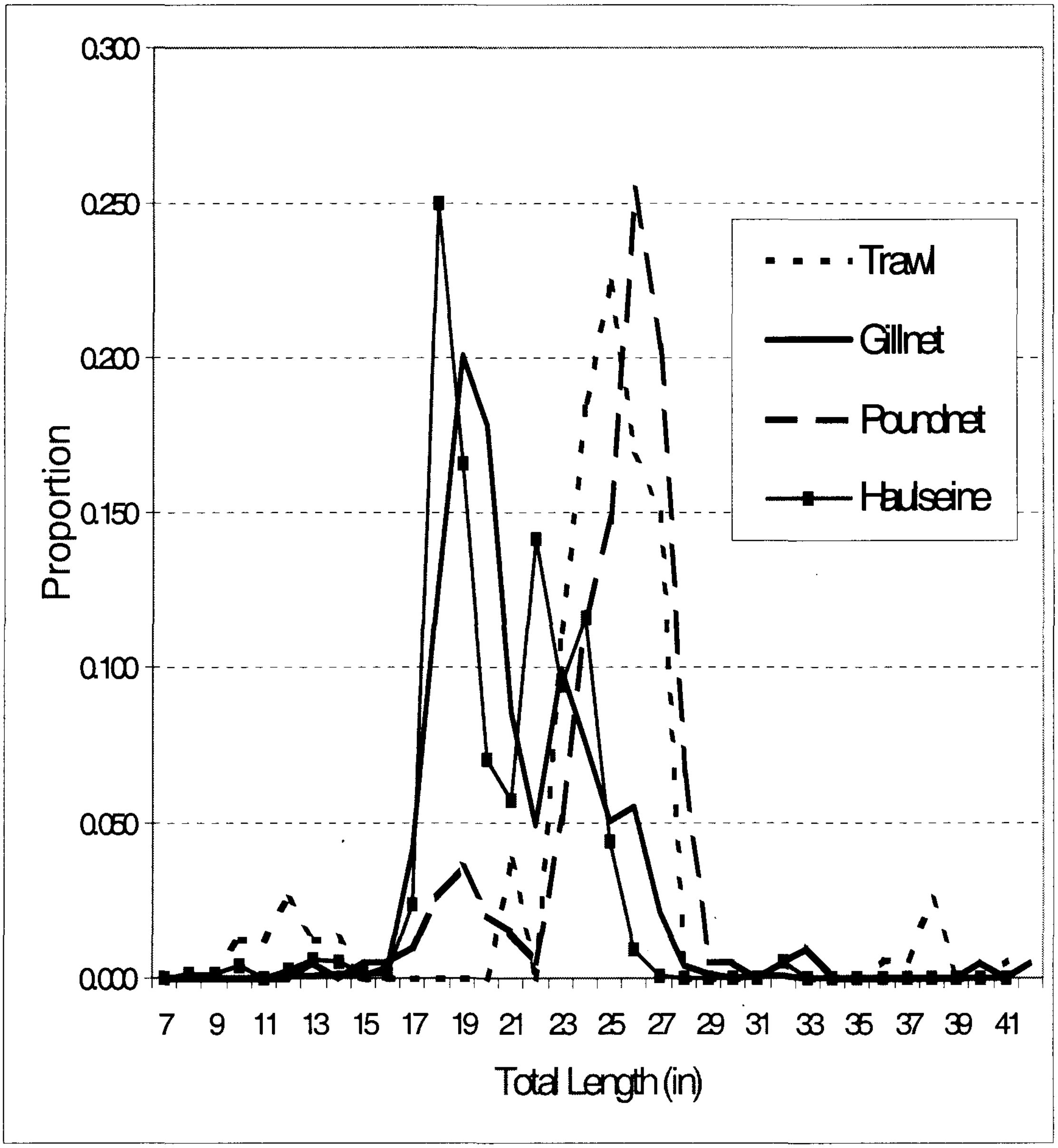

Figure 2. Comparison by gear of Atlantic red drum length frequency distributions for commercial landings from the northern region, 1992-1998.

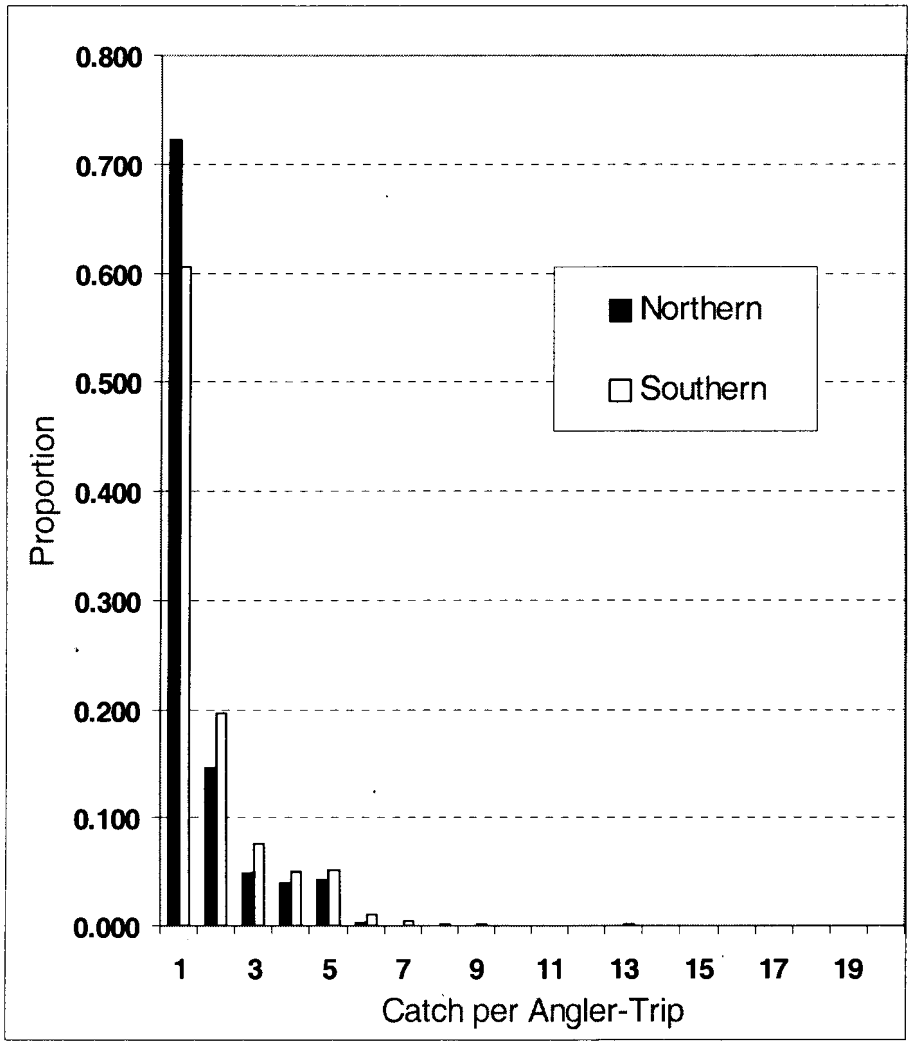

Figure 3. Comparison of catch of Atlantic red drum per angler-trip for southern and northern regions, 1992-1998.