# Catch curves from two periods in the black grouper fishery.

Robert G. Muller
Florida Fish and Wildlife Conservation Commission
Fish and Wildlife Research Institute
St. Petersburg, FL

## Introduction

Catch curves generate estimates of total mortality assuming that the stock is in equilibrium; i.e., recruitment, fishing mortality, and selectivity across included ages have remained constant for at least as many years as there are selected ages (Ricker 1975). Realizing that these assumptions are not met, separate catch curves were developed for the two periods with different regulations: 1992-1998 and 1999-2008. In 1999, the minimum size was increased from 20 inches to 24 inches and in the South Atlantic, the longline fishery was prohibited from landing black grouper. Years earlier than 1992 were excluded because there was only one fish sampled from the longline fishery prior to 1992. The main rationale for calculating catch curves is to provide a context for other assessment models. Also, estimates of total mortality can be used as an upper limit on natural mortality values.

## Methods

Ages derived from otoliths from these two time periods were tallied by fishery: headboat, general recreational fishing (NMFS Marine Recreational Fisheries Statistics Survey, MRFSS), commercial hook-and-line including bandit boats and other commercial gears such as traps and diving, and longline. The longline fishery caught significantly older fish (Kolmogorov-Smirnov Two-sample test, maximum difference = 0.41, test statistic = 0.11, $df$ = 178, 1127, $P < 0.05$) than the other fisheries that operate closer to shore and rarely encounter older fish. For example, Manooch and Mason(1987) sampled 303 specimens of black grouper from the headboat fishery in south Florida and found a maximum age of 14 years, while the maximum age observed in the recent period in the longline fishery was 33 years. With the low number of age samples each year, the annual longline lengths from NMFS' Trip Interview Program were converted to ages with growth curves. Although some years within the periods had to be grouped, ten, almost annual, von Bertalanffy growth curves were developed for the longline fishery.

The calculation of total mortality from a catch curve is straightforward. Two synthetic cohorts (Quinn and Deriso 1999) were constructed by calculating the number of fish by age from the longline fishery for 1992-98 and for 1999-2008. The ages included in the analyses were the ages older than the modal age in the catches because the modal age may not be fully recruited. Because a few fish were

large relative to the L∞ values, there were fish whose calculated age reached 40 years exceeding the oldest age observed in the fishery (33 year).

The Chapman-Robson method (1960) was used because the estimates of annual survival are unbiased although lower than those calculated by regression (Murphy 1997). The equation for the annual survival, *S*, is:

$$S = \frac{T}{\Sigma N + T - 1} \quad (1)$$

where *T = N1 + 2N2 + 3N3 +* … and *ΣN = N0 + N1 + N2 +* ….The sampling variance of *S* is

$$Var(S) = S(S - \frac{T-1}{\Sigma N + T - 2}) . \quad (2)$$

Total mortality, *Z*, is calculated from annual survival as *Z = -ln(S).* Similarly, the confidence interval for total mortality is

$$-\ln(S + 1.96\sqrt{Var(S)}) \le Z \le -\ln(S - 1.96\sqrt{Var(S)}) . \quad (3)$$

**Results**

The number of aged fish by fishery is shown in Table 1 and the proportion of fish by age for the longline fishery is shown in Figure 1. Selectivity in the longline fishery was evident by the absence of fish younger than three years old and the presence of age-30 fish in both time periods. The numbers of fish by age from the length samples are shown in Table 2.

The total mortality rates of these synthetic cohorts were 0.15 per year (0.14-0.17 per year 95% confidence interval) for the 1992-98 period and 0.18 per year (0.17-0.18 per year 95% confidence interval) for the 1999-08 period (Table 3).

**Discussion**

Because the fisheries for black grouper operate in different areas and the sizes of fish differ also, it was thought that fish from the longline fishery would be more representative of the population age structure because the longline fishery caught fish from age-4 sub-adults to 30 year old fish. The data were divided into two time periods because of changes in regulations. While the assumptions of constant recruitment, mortality, and selectivity were unlikely to be met, it was thought that by choosing periods with the similar regulations, some of the variability would be reduced.

The low total mortality values appear reasonable considering that the longline fishery catches older fish. The higher total mortality in the later period may not be real but rather a reflection of an increase in younger fish (Figure 1) given the larger minimum size.

The uncertainty expressed by the narrow confidence intervals is understated because those values do not include sampling errors, reporting issues, aging errors, etc. In addition, changing regulations such as different minimum sizes, restricting fishing in selected waters, and closed seasons preclude the stock achieving equilibrium. The mortality values from the two periods probably are not different if those other sources of error could be quantified.

As to putting natural mortality into a context, the Data Work shop recommended evaluating a range of natural values of 0.10–0.25 per year; however, the estimates of total mortality in the longline fishery were 0.15 per year and 0.18 per year. Because there is fishing mortality incorporated into the total mortality estimates, it would be reasonable to lower the upper end of the natural mortality range to, perhaps, the lower of the two values or 0.15 per year.

Selectivity is quite evident in the black grouper fishery, earlier estimates of total mortality for black grouper calculated with catch curves from headboat samples produced much higher total mortality values ($Z = 0.53$ per year for ages 7and older, Manooch and Mason 1987) and the oldest fish that they observed was 14 years. When total mortality was estimated using the numbers of fish at age from the headboat fishery for the 1999-08 time period, a similar value was obtained 0.56 per year and the oldest calculated age was 11 years (Table 3). The difference between the longline and headboat fisheries' analyses indicate that black grouper become less available to the headboat fishery as the fish become older.

## Literature Cited

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Manooch, C. S. III and D. L. Mason. 1987. Age and growth of the warsaw grouper and blak grouper from the southeast region of the united states. Northeast Gulf Science 9:65-75.

Murphy, M. D. 1997. Bias in Chapman-Robson and least-squares estimators of mortality rates for steady-state populations. Fishery Bulletin 95:863-868.

Quinn, T. J. II and R. B. Deriso. 1999. Quantitative fish dynamics. Oxford University Press. New York. 542 p.

Ricker, W. E. 1975. Computation and interpretation of biological statistics of fish populations. Bulletin of the Fisheries Research Board of Canada. Bulletin 191.

**Table 1.** Number of ages by fishery and period.

| Period | Age (yr) | Headboat | Recreational | Other gears | Hook-and-line | Longline | Total |
|---|---|---|---|---|---|---|---|
| 1992-98 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 2 | 1 | 0 | 0 | 2 | 0 | 3 |
| | 3 | 1 | 1 | 1 | 5 | 0 | 8 |
| | 4 | 3 | 2 | 0 | 5 | 1 | 11 |
| | 5 | 3 | 1 | 0 | 3 | 8 | 15 |
| | 6 | 4 | 0 | 1 | 4 | 25 | 34 |
| | 7 | 3 | 0 | 0 | 4 | 17 | 24 |
| | 8 | 1 | 0 | 1 | 1 | 21 | 24 |
| | 9 | 0 | 0 | 0 | 0 | 24 | 24 |
| | 10 | 1 | 0 | 0 | 3 | 15 | 19 |
| | 11 | 0 | 0 | 1 | 0 | 15 | 16 |
| | 12 | 2 | 0 | 0 | 1 | 19 | 22 |
| | 13 | 0 | 0 | 0 | 2 | 6 | 8 |
| | 14 | 0 | 0 | 0 | 0 | 8 | 8 |
| | 15 | 0 | 0 | 0 | 0 | 7 | 7 |
| | 16 | 0 | 0 | 0 | 0 | 4 | 4 |
| | 17 | 0 | 0 | 0 | 0 | 1 | 1 |
| | 18 | 0 | 0 | 0 | 0 | 8 | 8 |
| | 19 | 1 | 0 | 0 | 0 | 4 | 5 |
| | 20 | 0 | 0 | 0 | 0 | 3 | 3 |
| | 21 | 0 | 0 | 0 | 0 | 13 | 13 |
| | 22 | 1 | 0 | 0 | 0 | 6 | 7 |
| | 23 | 0 | 0 | 0 | 1 | 3 | 4 |
| | 24 | 0 | 0 | 1 | 0 | 1 | 2 |
| | 25 | 0 | 0 | 0 | 0 | 2 | 2 |
| | 26 | 0 | 0 | 0 | 0 | 4 | 4 |
| | 27 | 0 | 0 | 1 | 0 | 4 | 5 |
| | 28 | 0 | 0 | 0 | 0 | 3 | 3 |
| | 29 | 0 | 0 | 0 | 0 | 1 | 1 |
| | 30 | 0 | 0 | 0 | 0 | 2 | 2 |
| | 31 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 32 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 33 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Subtotal | 21 | 4 | 6 | 31 | 225 | 287 |
| 1999-08 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 2 | 0 | 3 | 0 | 3 | 0 | 6 |
| | 3 | 1 | 9 | 6 | 10 | 2 | 28 |
| | 4 | 5 | 16 | 4 | 32 | 31 | 88 |
| | 5 | 2 | 15 | 4 | 26 | 68 | 115 |
| | 6 | 0 | 8 | 0 | 23 | 117 | 148 |
| | 7 | 3 | 2 | 3 | 16 | 143 | 167 |
| | 8 | 0 | 3 | 0 | 13 | 155 | 171 |
| | 9 | 0 | 0 | 0 | 8 | 87 | 95 |
| | 10 | 1 | 0 | 0 | 3 | 86 | 90 |
| | 11 | 0 | 0 | 0 | 2 | 40 | 42 |
| | 12 | 0 | 0 | 0 | 2 | 34 | 36 |
| | 13 | 0 | 0 | 0 | 1 | 27 | 28 |
| | 14 | 0 | 0 | 0 | 2 | 26 | 28 |
| | 15 | 0 | 0 | 0 | 1 | 8 | 9 |
| | 16 | 0 | 0 | 0 | 2 | 10 | 12 |
| | 17 | 0 | 0 | 0 | 0 | 9 | 9 |
| | 18 | 0 | 0 | 0 | 2 | 5 | 7 |
| | 19 | 0 | 0 | 0 | 0 | 8 | 8 |
| | 20 | 0 | 0 | 0 | 0 | 6 | 6 |
| | 21 | 0 | 0 | 0 | 1 | 2 | 3 |
| | 22 | 0 | 0 | 0 | 0 | 7 | 7 |
| | 23 | 0 | 0 | 0 | 0 | 4 | 4 |
| | 24 | 0 | 0 | 0 | 0 | 4 | 4 |
| | 25 | 0 | 0 | 0 | 0 | 4 | 4 |
| | 26 | 0 | 0 | 0 | 0 | 6 | 6 |
| | 27 | 0 | 0 | 0 | 0 | 6 | 6 |
| | 28 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 29 | 0 | 0 | 0 | 0 | 2 | 2 |
| | 30 | 0 | 0 | 0 | 0 | 1 | 1 |
| | 31 | 0 | 0 | 0 | 0 | 1 | 1 |
| | 32 | 0 | 0 | 0 | 0 | 2 | 2 |
| | 33 | 0 | 0 | 0 | 0 | 1 | 1 |
| | Subtotal | 12 | 56 | 17 | 147 | 902 | 1134 |
| | Total | 33 | 60 | 23 | 178 | 1127 | 1421 |

**Table 2.** The numbers of fish by age from the longline and headboat fisheries in the two time periods. Note that the oldest observed fish was 33 years old while the calculated values extend to age-40.

| | Fishery and time periods | | | |
|---|---|---|---|---|
| | Longline | | Headboat | |
| | 1992-98 | 1999-08 | 1992-98 | 1999-08 |
| Age (yr) | Number | Number | Ave Num | Ave Num |
| 1 | 1 | 4 | 3 | 1 |
| 2 | 5 | 14 | 22 | 5 |
| 3 | 8 | 70 | 32 | 18 |
| 4 | 21 | 200 | 29 | 23 |
| 5 | 52 | 375 | 26 | 14 |
| 6 | 84 | 450 | 19 | 11 |
| 7 | 91 | 407 | 8 | 6 |
| 8 | 53 | 358 | 2 | 1 |
| 9 | 59 | 255 | 2 | 1 |
| 10 | 57 | 216 | 0 | 1 |
| 11 | 44 | 144 | 0 | 2 |
| 12 | 35 | 135 | 0 | 0 |
| 13 | 31 | 94 | 0 | 0 |
| 14 | 19 | 68 | 0 | 0 |
| 15 | 16 | 46 | 0 | 0 |
| 16 | 18 | 44 | 0 | 0 |
| 17 | 21 | 50 | 0 | 0 |
| 18 | 13 | 40 | 0 | 0 |
| 19 | 10 | 29 | 0 | 0 |
| 20 | 13 | 26 | 0 | 0 |
| 21 | 11 | 23 | 0 | 0 |
| 22 | 6 | 15 | 0 | 0 |
| 23 | 6 | 12 | 0 | 0 |
| 24 | 11 | 15 | 0 | 0 |
| 25 | 5 | 11 | 0 | 0 |
| 26 | 2 | 6 | 0 | 0 |
| 27 | 4 | 10 | 0 | 0 |
| 28 | 3 | 3 | 0 | 0 |
| 29 | 1 | 4 | 0 | 0 |
| 30 | 3 | 1 | 0 | 0 |
| 31 | 2 | 4 | 0 | 0 |
| 32 | 0 | 0 | 0 | 0 |
| 33 | 4 | 3 | 0 | 0 |
| 34 | 0 | 2 | 0 | 0 |
| 35 | 1 | 1 | 0 | 0 |
| 36 | 3 | 0 | 0 | 0 |
| 37 | 0 | 2 | 0 | 0 |
| 38 | 1 | 0 | 0 | 0 |
| 39 | 0 | 2 | 0 | 0 |
| 40 | 2 | 5 | 0 | 0 |

**Table 3.** The ages included in the analyses, annual survival (S), the variance of annual survival, the total mortality per year, and the confidence limits of total mortality by fishery and period.

| Fishery | Period | Ages | Annual Survival (S) | Variance Survival | Total mortality (Z) per year | Total mortality Confidence interval Lower 95% | Upper 95% |
|---|---|---|---|---|---|---|---|
| Longline | 1992-98 | 8-40 | 0.86 | 3.807E-05 | 0.15 | 0.14 | 0.17 |
| | 1999-08 | 7-40 | 0.84 | 1.349E-05 | 0.18 | 0.17 | 0.18 |
| Headboat | 1992-98 | 4-9 | 0.58 | 1.209E-03 | 0.55 | 0.44 | 0.68 |
| | 1999-08 | 5-11 | 0.57 | 3.020E-03 | 0.56 | 0.38 | 0.76 |

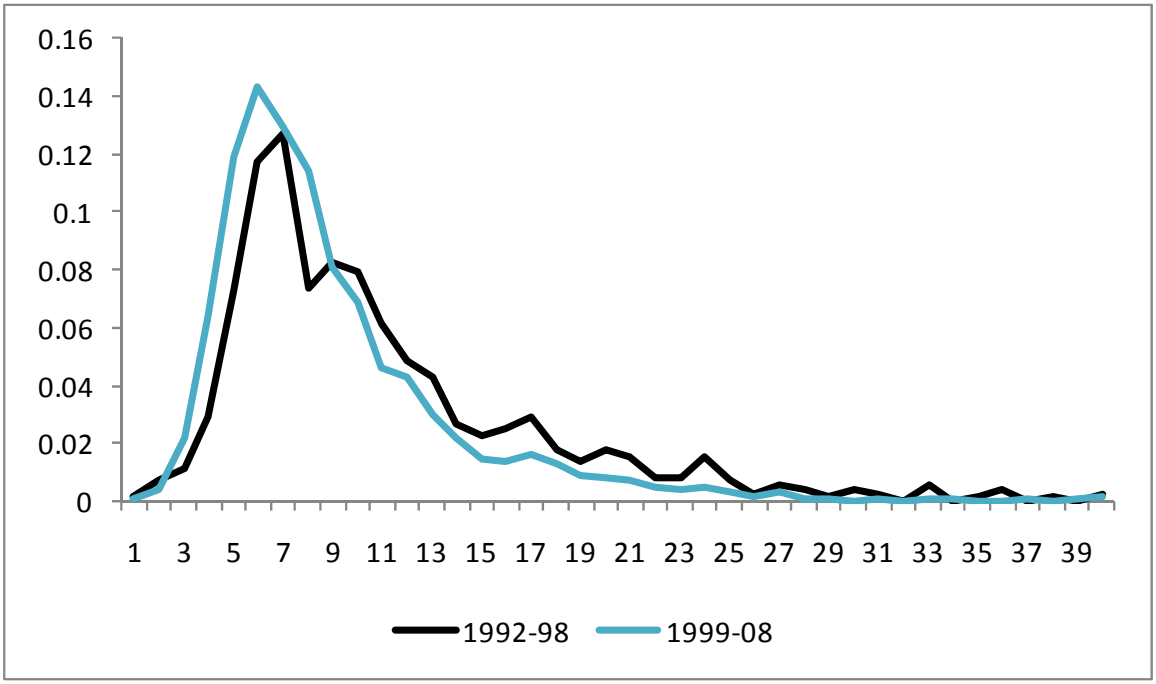


**Figure 1.** The proportion of fish by age from the longline fishery in two time periods.