South Atlantic U.S. Atlantic red snapper (*Lutjanus campechanus*) catch curve analysis

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SEDAR41-AW08

Submitted: 17 November 2015

Please cite this document as:

Sustainable Fisheries Branch – National Marine Fisheries Service. 2015. South Atlantic U.S. red snapper (*Lutjanus campechanus*) catch curve analysis. SEDAR41-AW08. SEDAR, North Charleston, SC. 20 pp.

Notice on SEDAR Working Papers

South Atlantic U.S. red snapper (*Lutjanus campechanus*) catch curve analysis

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18 November 2015

Introduction

The plot of catch (or abundance or proportion) at age is termed a catch curve. Analysis of catch curves provides a simple means of estimating total mortality rate (Z). Rarely is catch curve analysis alone used for management measures, as its simplifying assumptions are quite strong and rarely if ever met, but instead it serves as a method to understand results from more detailed models. Because catch curves rely on age data, they can reveal issues surrounding the observed age samples. The application of catch curve analysis in this report is primarily for diagnostic purposes.

The two most popular methods for estimating Z from catch curves are regression-based estimators (Quinn and Deriso, 1999) and the Chapman Robson estimator (Chapman and Robson, 1960; Robson and Chapman, 1961). Perhaps the strongest assumption behind these methods is that the population is in steady state, i.e., that the age structure is stable through time as a consequence of constant recruitment and constant mortality. Both methods also assume that ageing error is negligible and that fish older than some known age are equally vulnerable to sampling. Performance of the two methods will vary across data sets, but the Chapman Robson estimator has been found in some cases to be more robust to violations of assumptions (Murphy, 1997; Dunn et al., 2002).

Methods

Regression estimator

Regression estimators use linear regression to fit the log-transformed numbers or proportions-at-age, under the common assumption of exponential population decay. Thus, the estimated slope from this regression gives an estimate of Z. The regression can be performed by either tracking a cohort through time or to a single year of data (i.e., a synthetic cohort). In this report, regression estimators rely on synthetic cohorts, constructed from proportions of catch at age (although results are identical if based on absolute numbers rather than proportions).

One issue that arises with limited sampling data is the presence of zeros. Because the regression analysis involves log-transformed data, zeros must either be removed prior to fitting the linear model or treated with a small, additive constant. Both approaches were examined in this study. In cases where a constant was added to zero data, the constant was assumed to be 0.001.

Chapman-Robson estimator

The ChapmanRobson estimator is based on mean age (a) above the recruitment age and the sample size (n).

This estimator is considered a minimum variance unbiased estimator (Chapman and Robson, 1960).

Point estimate (aggregated)

The method employs a forward projecting cohort analysis using only age composition data. Parameters being estimated include logistic selectivity, a single value for mortality (Z), and annual relative (scaleless) estimates of recruitment (R). The model iteratively adjusts the values for selectivity, Z and R until the predicted age composition matrix matches the observed matrix. The model is structured with exponential mortality and assumes Z is constant across all years of data. The model is advantageous because it should reduce bias affects normally associated with catch curve analysis due to selectivity and fluctuating year-class strength.

Additional details

Both estimators were applied to landings at age data from the commercial fleet (handline), recreational fleets (headboat and MRIP) and the fisheries independent data. Synthetic cohorts were included if they met a minimum sample size criterion of 30 fish.

Both estimators require specifying the age at which all fish are vulnerable to capture. Although this age is typically unknown a priori, examination of the data can indicate an appropriate starting age for the analyses, typically the modal age or the modal age plus one. After visual inspection of age compositions, the starting age and terminal age was determined for each fleet. As these analyses rely only on landings data, vulnerable but discarded fish were not included here.

Results and discussion

Point estimates of total mortality rates suggest that Z generally ranges between 0.25 and 1.25, but with wide confidence intervals and with some point estimates well above or below that range for various fleets (Figure 1- Figure 8). Assuming a constant natural mortality of M=0.12, which corresponds to the point estimate recommended by the DW life history working group, fully selected fishing mortality rates could be expected on the range of [0.13, 1.13]. As this approximation is only a rough guideline, annual values outside that range should not be surprising.

Figure 9 and Table 1 illustrate higher Z values in the headboat fleet in time periods before the 2010 closure. During the closure, Z estimates among fleets were relatively similar.

Literature cited

Chapman, DG and DS Robson. 1960. The analysis of a catch curve. Biometrics 16:354−368.

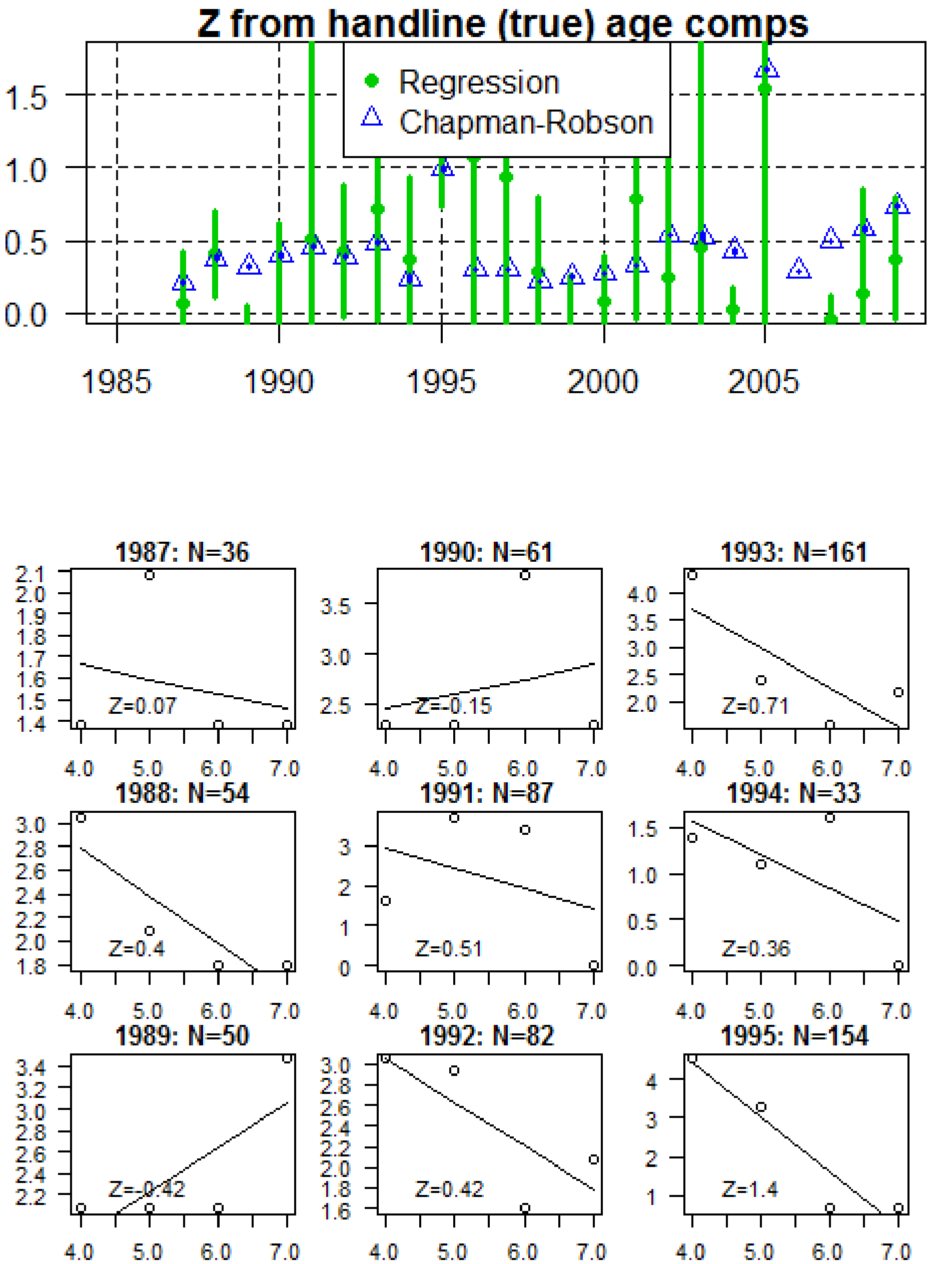
Dunn, A, RICC Francis, and IJ Doonan. 1992. Comparison of the Chapman−Robson and regression estimators of Z fro mcatch-curve data when non-sampling stochastic error is present. Fish. Res. 59:149−159.

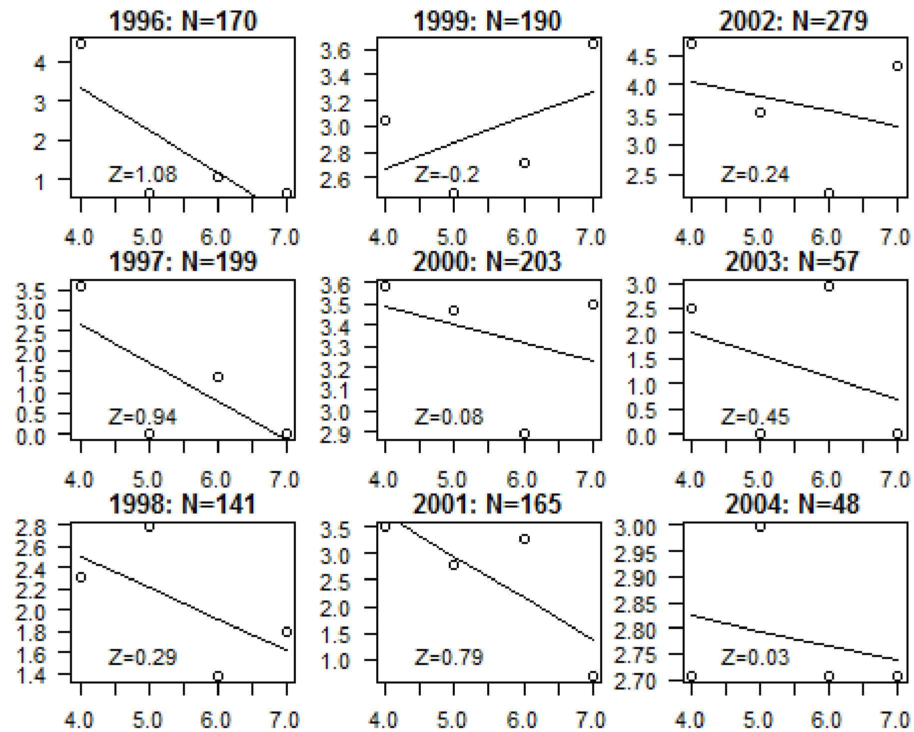
Murphy, MD. 1997. Bias in Chapman−Robson and least-squares estimators of mortality rates for steady-state populations. Fish. Bull. 95:863−868.

Quinn, TJ II and RB Deriso. 1999. Quantitative Fish Dynamics. Oxford University Press.

Robson, DS and DG Chapman. 1961. Catch curves and mortality rates. Trans. Am. Fish. Soc. 90:181−189.

Figure 1. Red snapper: Total mortality estimates (Z) from catch curve data from the commercial handline fleet. Analyses were conducted by year (i.e. using true cohorts). Vertical lines represent 95% confidence intervals. Annual regression estimates are below.




1996: N=170
Z=1.08
1999: N=190
Z=-0.2
2002: N=279
Z=0.24
1997: N=199
Z=0.94
2000: N=203
Z=0.08
2003: N=57
Z=0.45
1998: N=141
Z=0.29
2001: N=165
Z=0.79
2004: N=48
Z=0.03

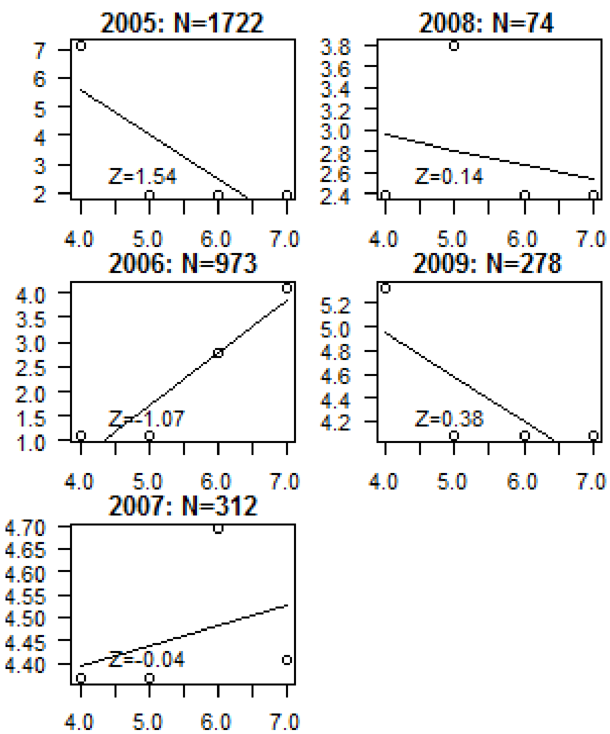
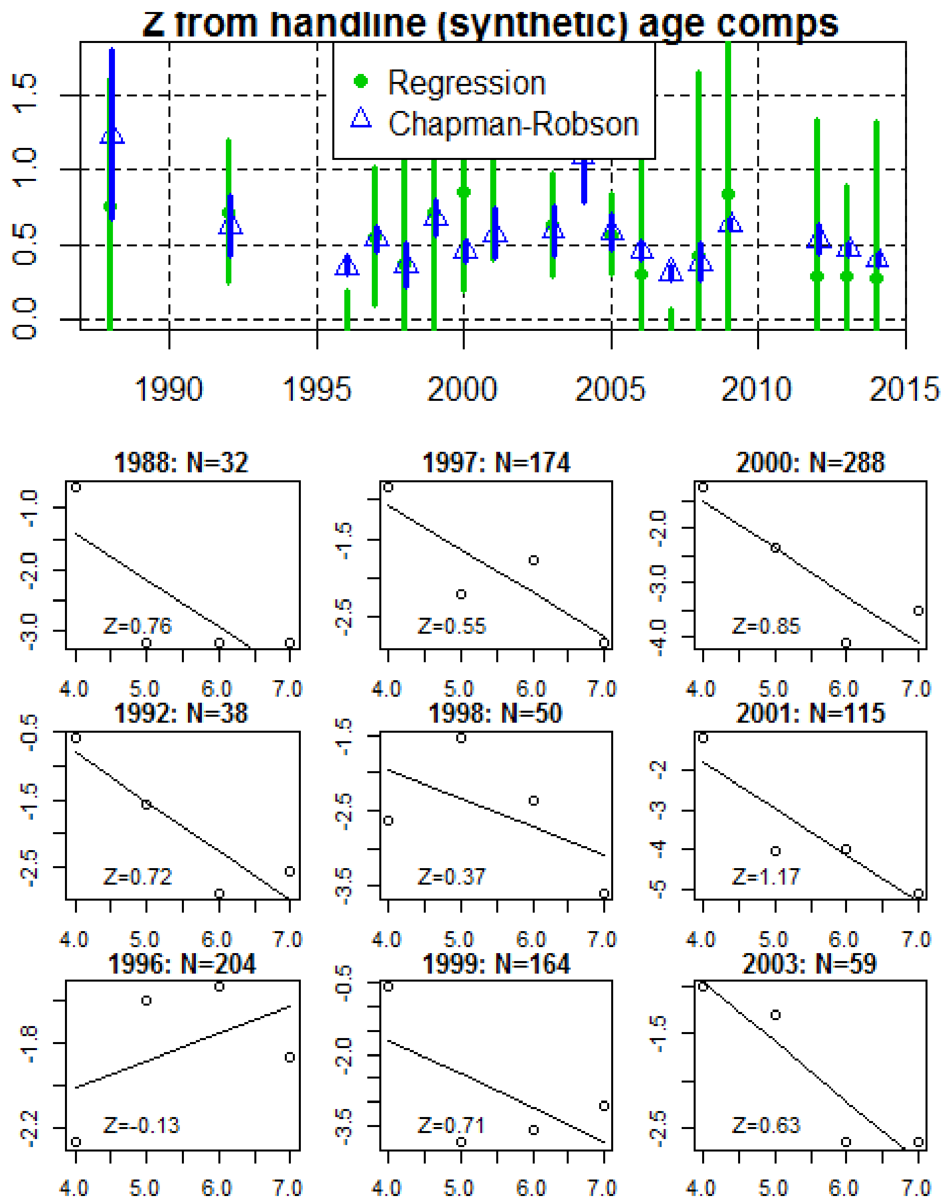

2005: N=1722
Z=1.54
2008: N=74
Z=0.14
2006: N=973
Z=-1.07
2009: N=278
Z=0.38
2007: N=312
Z=-0.04

Figure 2. Red snapper: Total mortality estimates (Z) from catch curve data from the commercial handline fleet. Analyses were conducted by year (i.e. using synthetic cohorts). Vertical lines represent 95% confidence intervals. Annual regression estimates are below.



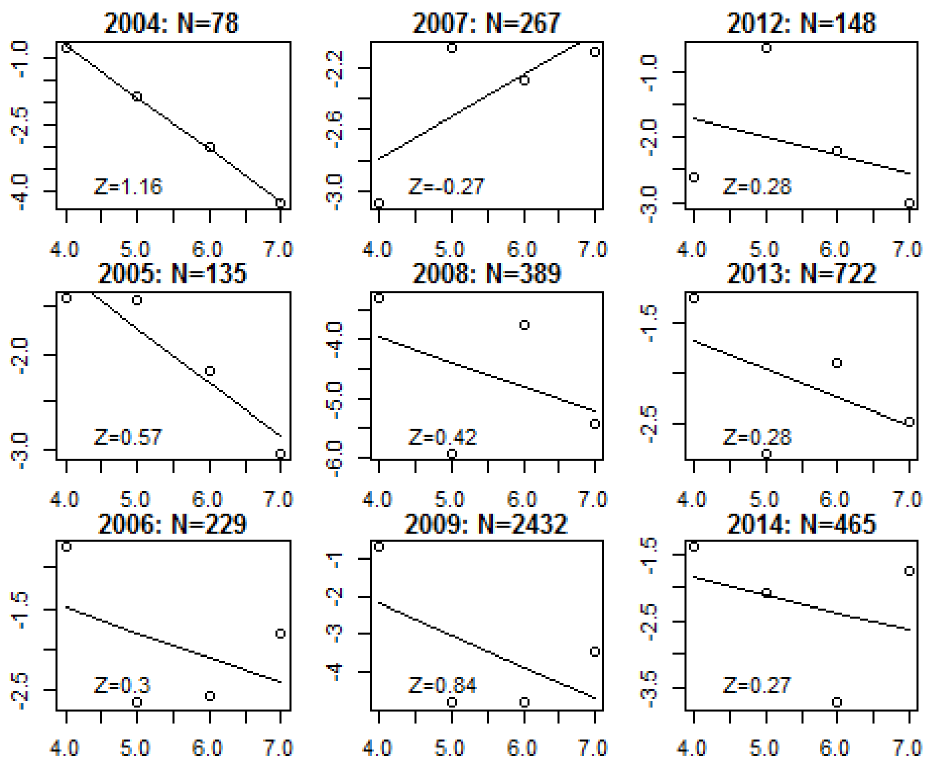
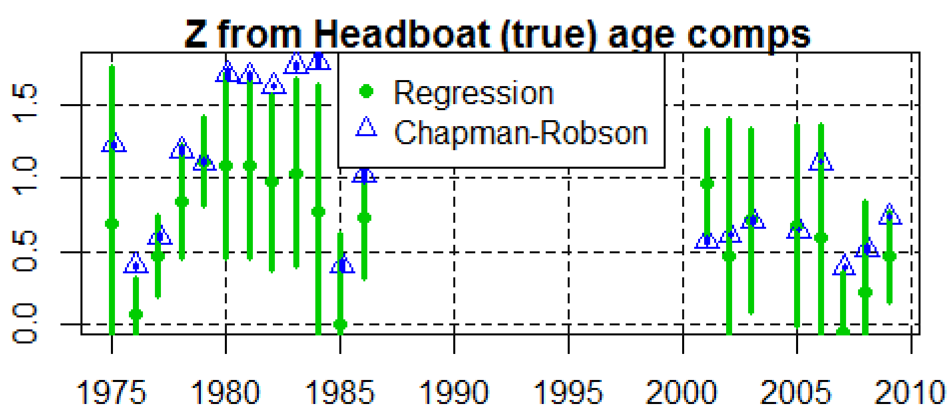
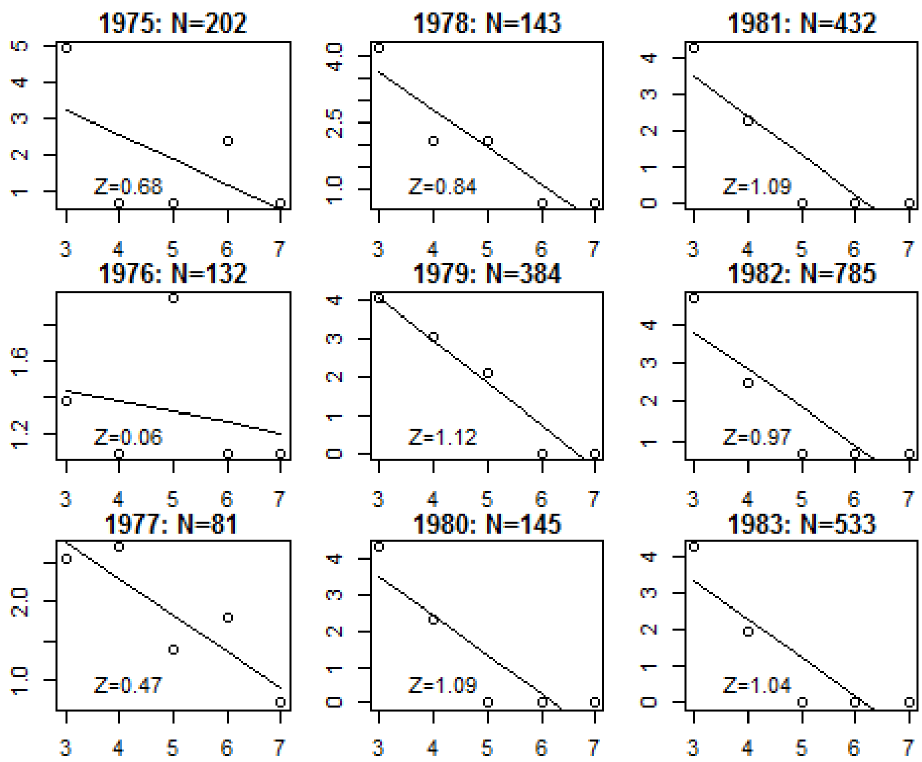
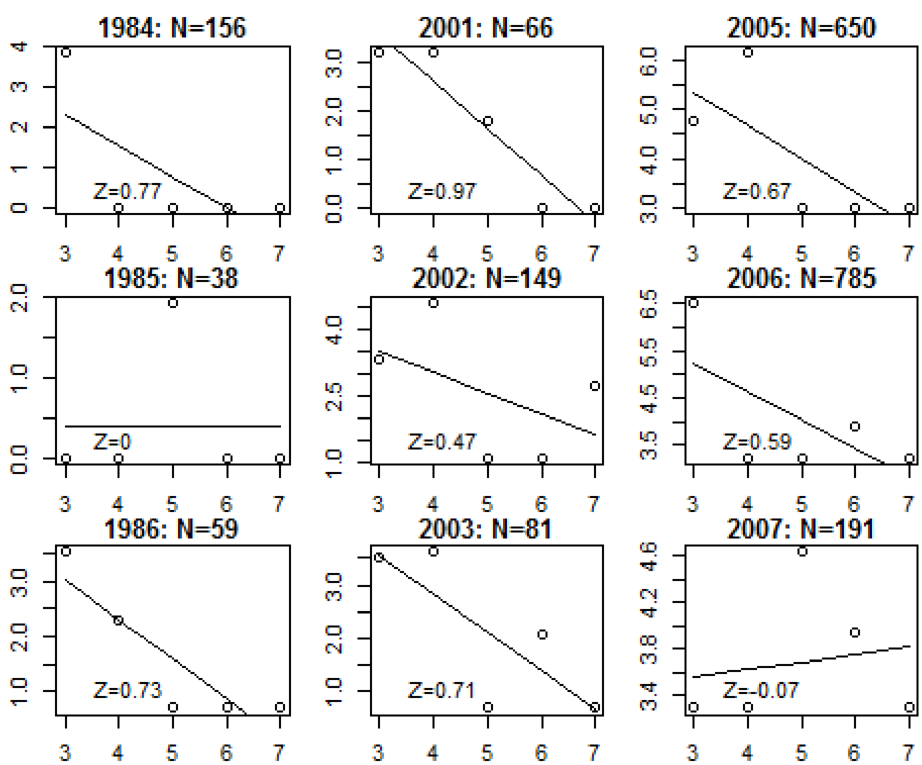


Figure 3. Red snapper: Total mortality estimates (Z) from catch curve data from the recreational headboat fleet. Analyses were conducted by year (i.e. using true cohorts). Vertical lines represent 95% confidence intervals. Annual regression estimates are below.




1975: N=202
Z=0.68
1978: N=143
Z=0.84
1981: N=432
Z=1.09
1976: N=132
Z=0.06
1979: N=384
Z=1.12
1982: N=785
Z=0.97
1977: N=81
Z=0.47
1980: N=145
Z=1.09
1983: N=533
Z=1.04


1984: N=156
Z=0.77
2001: N=66
Z=0.97
2005: N=650
Z=0.67
1985: N=38
Z=0
2002: N=149
Z=0.47
2006: N=785
Z=0.59
1986: N=59
Z=0.73
2003: N=81
Z=0.71
2007: N=191
Z=-0.07

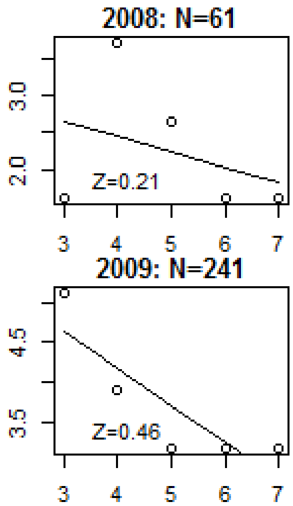
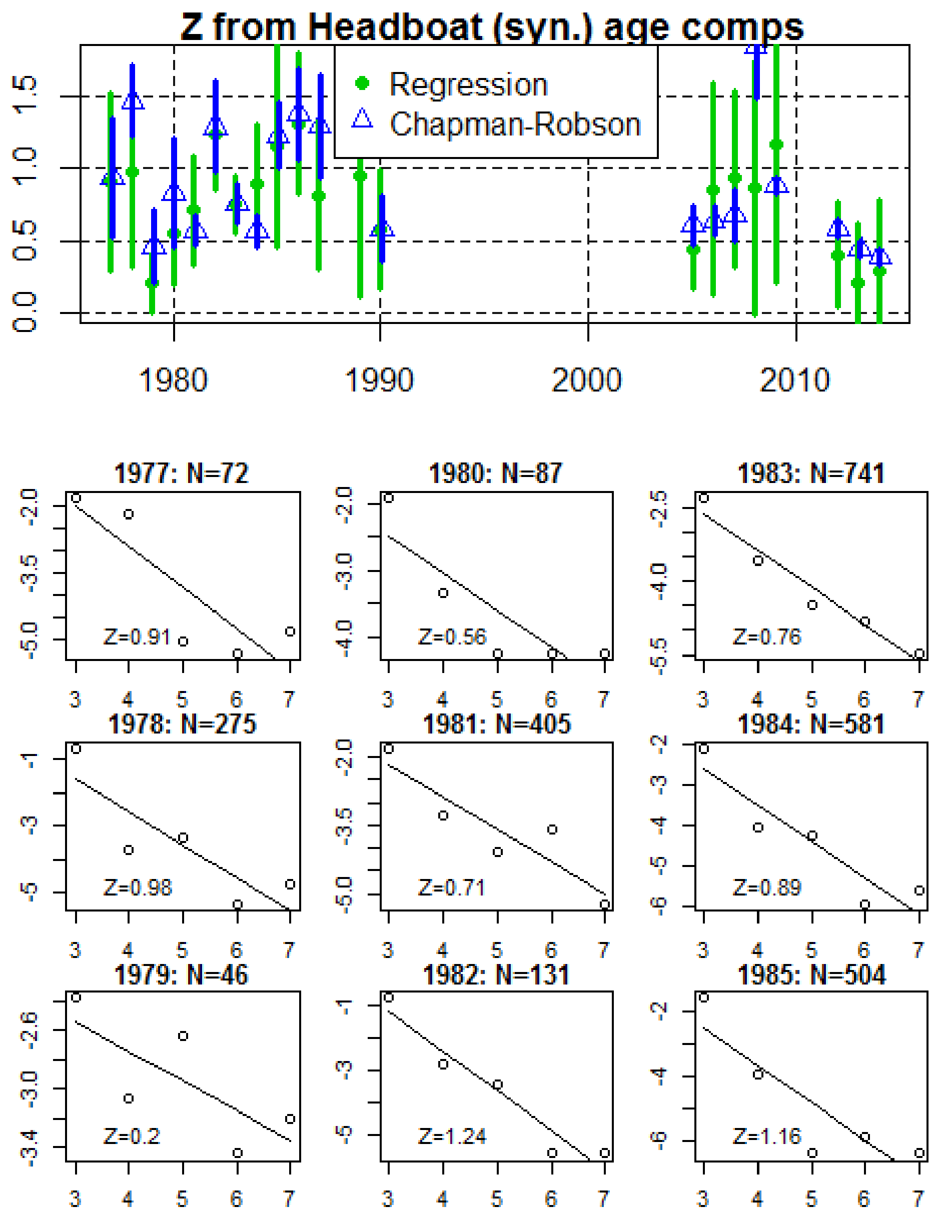

2008: N=61
3.0
2.0
Z=0.21
3
4
5
6
7
2009: N=241
4.5
3.5
Z=0.46
3
4
5
6
7

Figure 4. Red snapper: Total mortality estimates (Z) from catch curve data from the recreational headboat fleet. Analyses were conducted by year (i.e. using synthetic cohorts). Vertical lines represent 95% confidence intervals. Annual regression estimates are below.



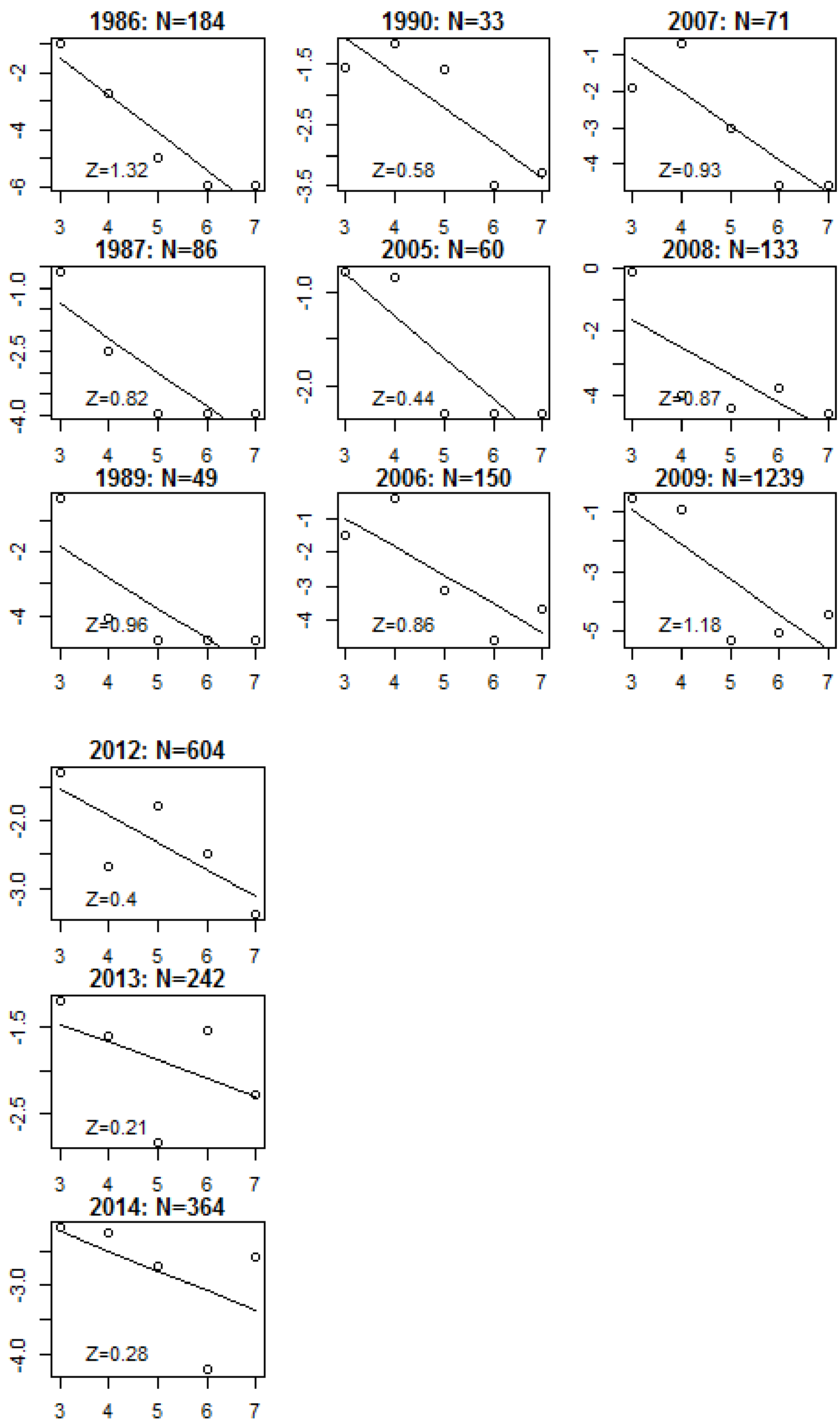
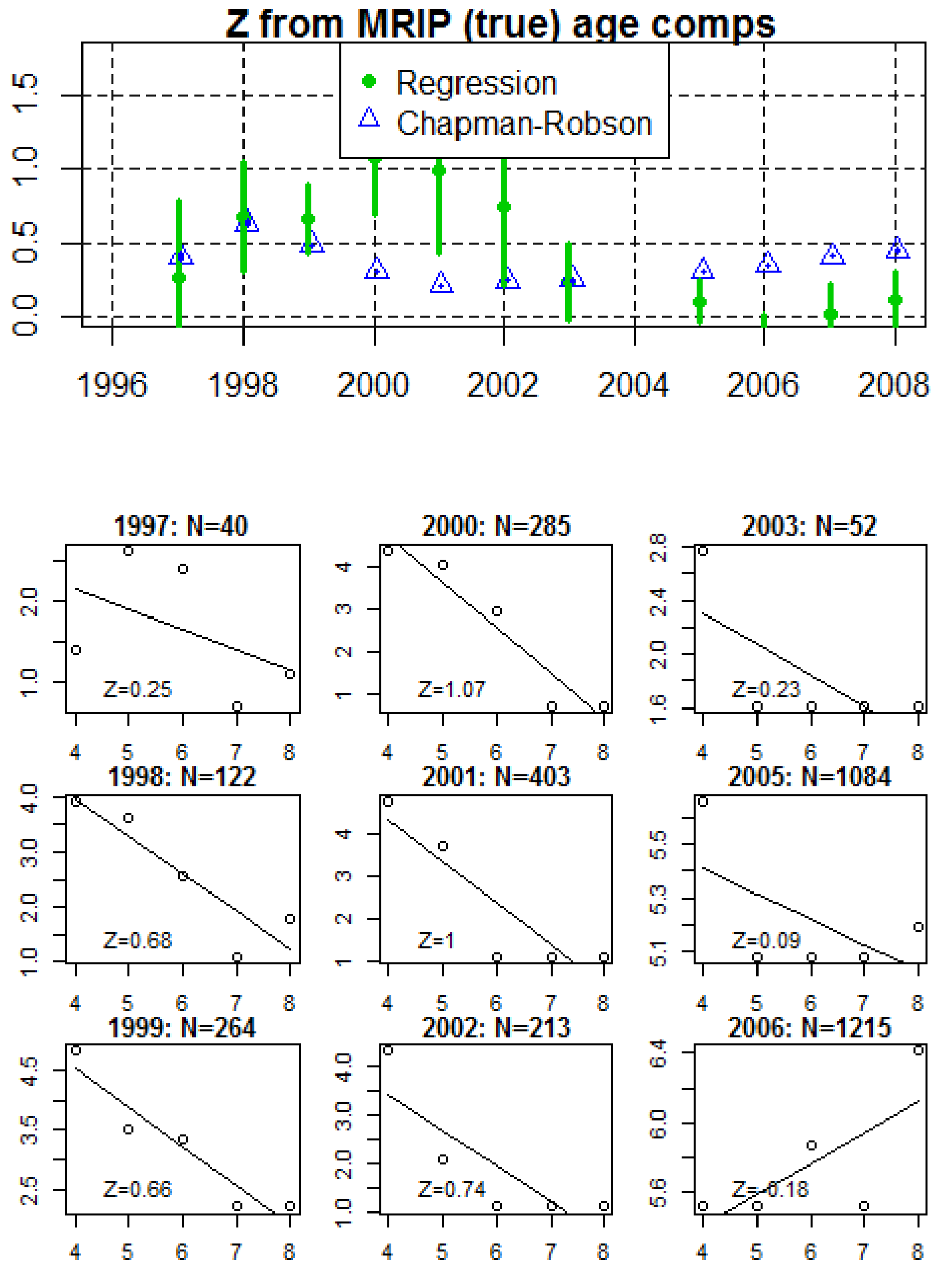

1986: N=184
Z=1.32
1990: N=33
Z=0.58
2007: N=71
Z=0.93
1987: N=86
Z=0.82
2005: N=60
Z=0.44
2008: N=133
Z=0.87
1989: N=49
Z=0.96
2006: N=150
Z=0.86
2009: N=1239
Z=1.18
2012: N=604
Z=0.4
2013: N=242
Z=0.21
2014: N=364
Z=0.28

Figure 5. Red snapper: Total mortality estimates (Z) from catch curve data from the recreational MRIP (private and charterboat combined) fleet. Analyses were conducted by year (i.e. using true cohorts). Vertical lines represent 95% confidence intervals. Annual regression estimates are below.



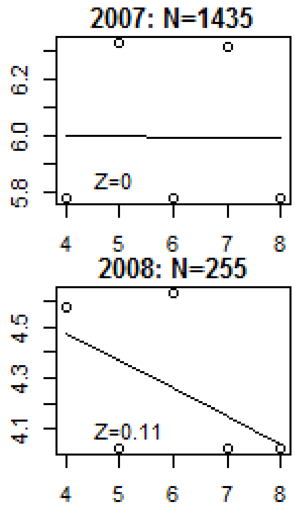
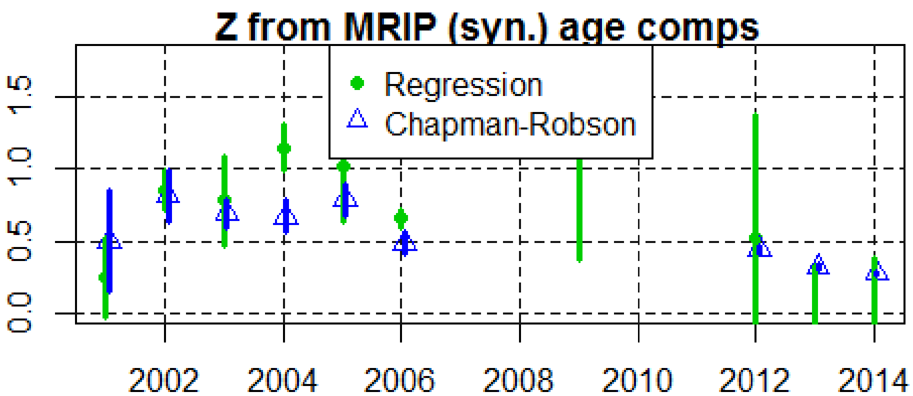
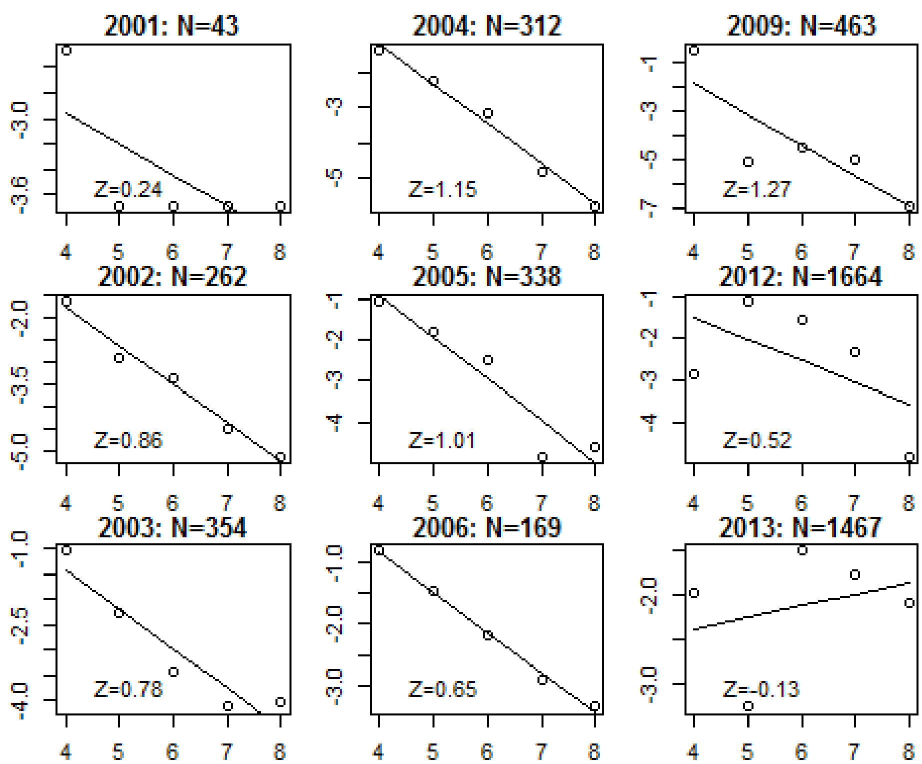

2007: N=1435
Z=0
5.8
6.0
6.2
4
5
6
7
8
2008: N=255
Z=0.11
4.1
4.3
4.5
4
5
6
7
8

Figure 6. Red snapper: Total mortality estimates (Z) from catch curve data from the recreational MRIP (private and charterboat combined) fleet. Analyses were conducted by year (i.e. using synthetic cohorts). Vertical lines represent 95% confidence intervals. Annual regression estimates are below.





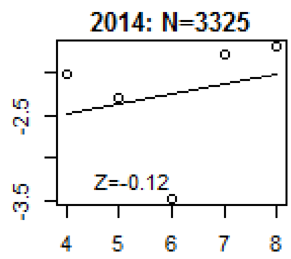
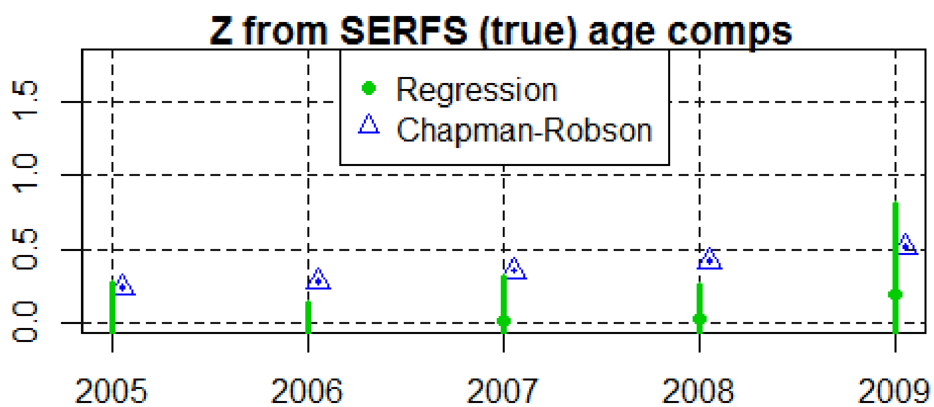


Figure 7. Red snapper: Total mortality estimates (Z) from catch curve data from the fishery independent survey (SERFS). Analyses were conducted by year (i.e. using true cohorts). Vertical lines represent 95% confidence intervals. Annual regression estimates are below.



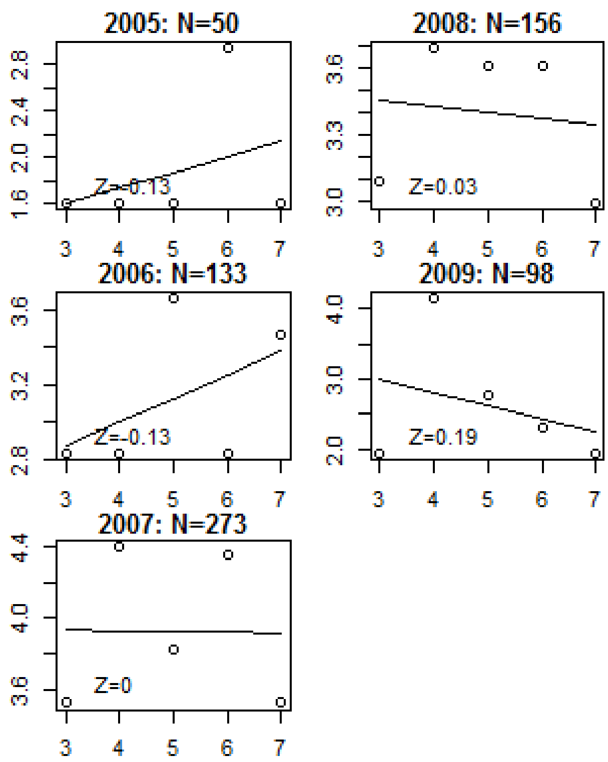
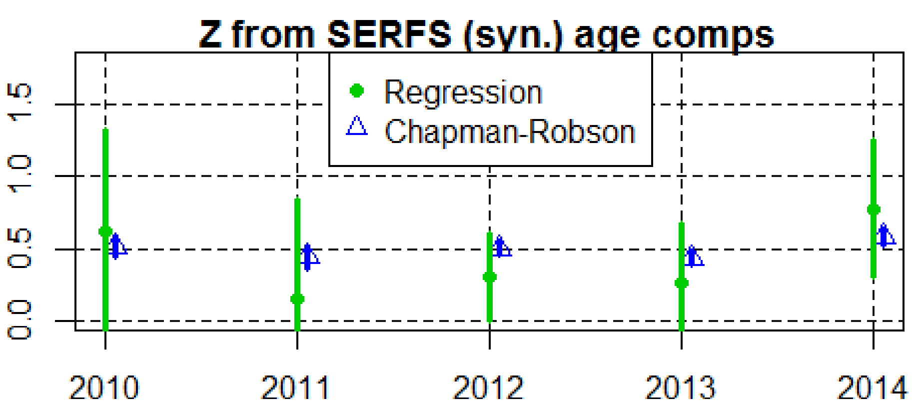
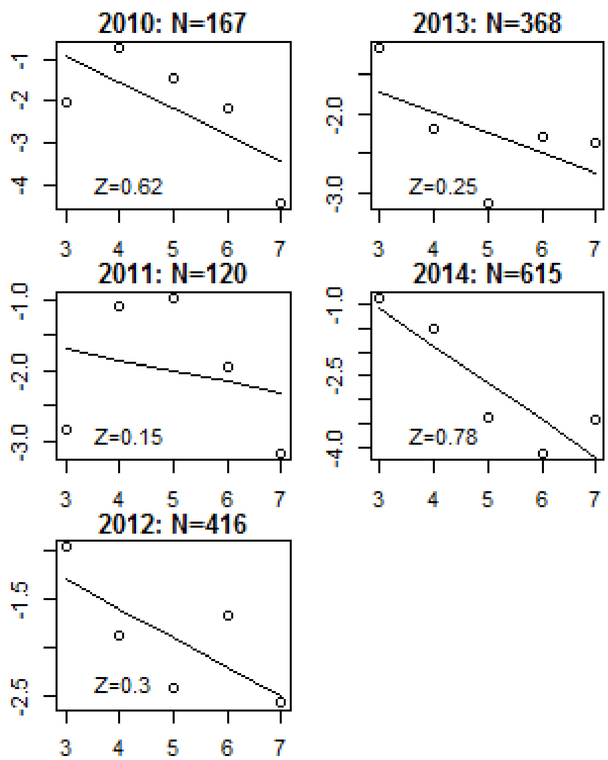


Figure 8. Red snapper: Total mortality estimates (Z) from catch curve data from the fishery independent survey (SERFS). Analyses were conducted by year (i.e. using synthetic cohorts). Vertical lines represent 95% confidence intervals.





2010: N=167
Z=0.62
2013: N=368
Z=0.25
2011: N=120
Z=0.15
2014: N=615
Z=0.78
2012: N=416
Z=0.3

Figure 9. Red snapper: Total mortality estimates (Z) from catch curve data and aggregate estimate for four time blocks and three fishery dependent fleets and SERFS. Analyses were conducted by year (i.e. using synthetic cohorts (syn), true cohorts (true) and aggregated estimator (agg) . The box plots illustrate the range of values for the synthetic (syn) and true estimates of Z. The aggregated estimate for each time block and fleet is represented by a black line.

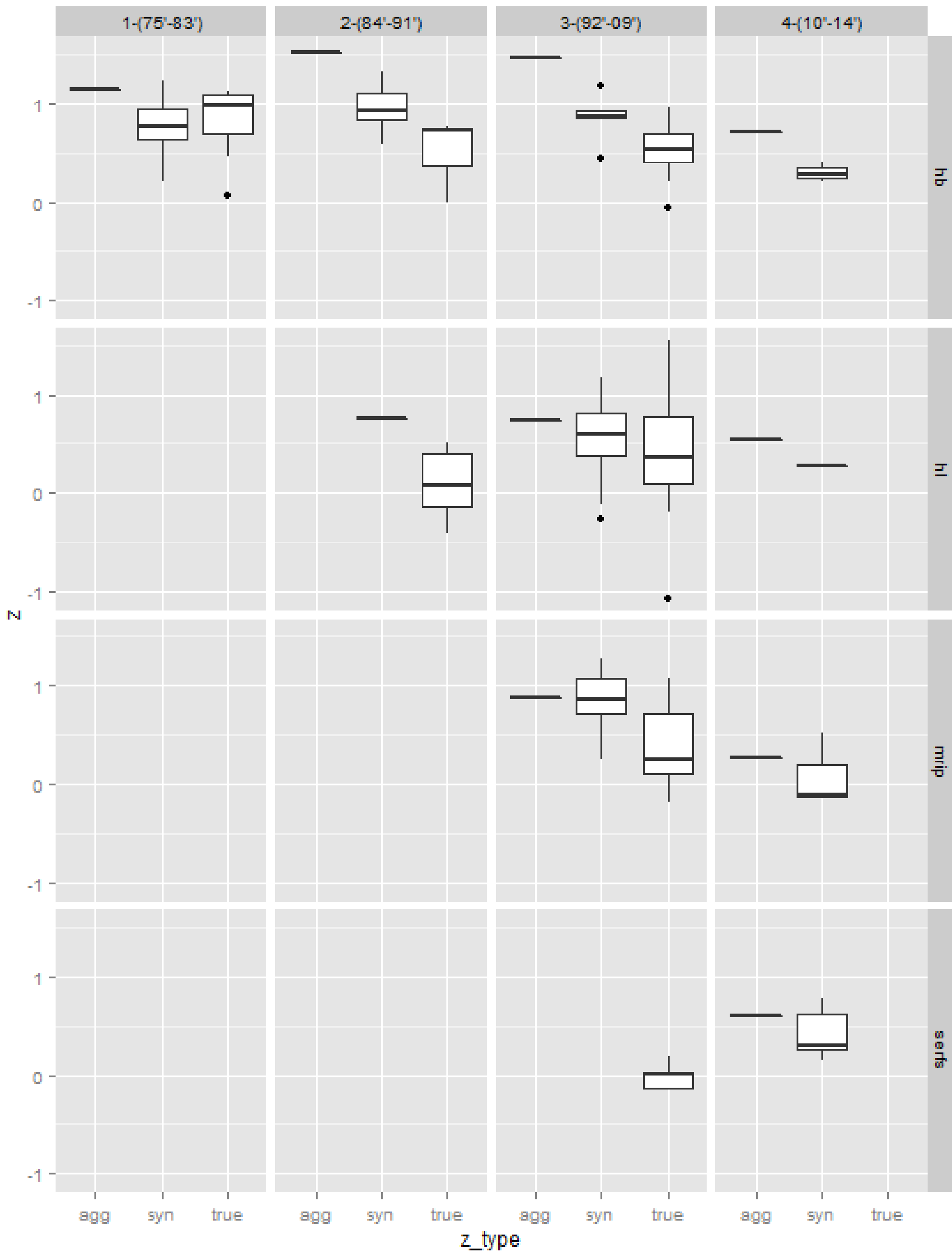


Table 1. Red snapper: Total mortality estimates (Z) from catch curve data and aggregate estimate for four time blocks and three fishery dependent fleets and SERFS. Analyses were conducted by year (i.e. using synthetic cohorts (syn), true cohorts (true) and an aggregated estimate (agg).

	Aggregated estimate including all ages				Mean of linear regression							
					synthetic				true			
Time period	**hb**	hl	mrip	serfs	hb	hl	mrip	serfs	hb	hl	mrip	serfs
1-(75'-83')	**1.14**				**0.76**				**0.82**			
2-(84'-91')	**1.52**				**0.95**	0.76			**0.50**	0.08		
3-(92'-09')	**1.47**	0.74	0.88		**0.86**	0.56	0.85		**0.50**	0.42	0.42	-0.01
4-(10'-14')	0.71	0.54	0.26	0.61	0.30	0.28	0.09	0.42				
Mean	1.21	0.64	0.57	0.61	0.77	0.53	0.62	0.42	0.64	0.35	0.42	-0.01