Z6070

Trends in Red Grouper Mortality Rates Estimated from Tagging Data

C.M. Legault[1], K.M. Burns[2], V.R. Restrepo[3], C.E. Porch[1], M.J. Schirripa[1], G. Scott[1]

[1] National Marine Fisheries Service
Southeast Fisheries Science Center
Sustainable Fisheries Division
75 Virginia Beach Drive
Miami, FL 33149

[2] Mote Marine Laboratory
1600 Ken Thompson Parkway
Sarasota, FL 34236

[3] University of Miami
Rosenstiel School of Marine and Atmospheric Science
Division of Marine Biology and Fisheries
4600 Rickenbacker Causeway
Miami, FL 33149

June 17, 1999

Sustainable Fisheries Division Contribution No. SFD-98/99-57

The Mote Marine Laboratory (MML) tagging database provided red grouper tag recapture information used in an algorithm developed by Porch (1998) to estimate annual mortality rates. This method allows for the random timing of tagging events during a year and does not require the total number of tags released to be known. These conditions are particularly suited for the MML tagging program which utilizes recreational, charter, headboat and commercial fishing operations to both release tagged fish and report recaptures of the tagged fish. The method, as all other tagging methods, requires that tagged fish mix with the untagged fish such that the tagged population is representative of the total population. Sensitivity analyses are conducted by truncating the database to examine this assumption.

Data

The tagging database contains over 5,000 records of red grouper tagging events during the period October 1990 through April 1999, see Schirripa and Burns (1998) and Wilson and Burns (1996) for more details about the MML tagging program and database. There were 627 records which contained information for both the date of tagging and date of recapture, excluding fish tagged and recaptured on the same day. The annual tagging and recaptures totals of red grouper show peaks in the early and late part of the time series with relatively few tagging events in the years 1994 through 1996 due to limited funding (Table 1).

Red grouper size at tagging ranged from 8 to 27.5 inches with most (95%) of the tagged fish less than 20 inches (the regulated minimum size). Size at recapture ranged from 8 to 29 inches with 80% of the recaptured fish less than 20 inches. Two records did not contain size at tagging information and six records did not contain size at recapture information. The 619 records that contained both size at tagging and size at recapture showed growth ranging from -3 to 11 inches with 75% of the records less than 2 inches (Figure 1). The 13 negative growth records can most likely be attributed to measurement error while the remaining records with minimal growth can be attributed to the usually short amount of time between tagging and recapture. The number of days at large (date of recapture minus date of tagging) ranged from 1 to 1,799 (almost five years) with 90% of the fish less than one year at large. Combining the growth and days at large produced positive growth rates of 0.37 to 169 inches per year, with 61% less than 5 inches per year and 18% greater than 10 inches per year (Figure 2). The extreme growth rates, for example 3.25 inches in seven days, can most likely be attributed to fishers not wanting to report keeping a fish below the minimum size regulation.

Multiple tagging and recapture of individual red grouper occurred relatively frequently in the database, 433 records were of single tag recapture events while 83 fish produced 194 multiple tag recapture events. The multiple tag recapture events were only recorded from successive taggings and treated as independent events. For example, if a fish was tagged originally in 1992 and recaptured in both 1993 and 1994 then only two tag recapture events were recorded, 1992 to 1993 and 1993 to 1994, but not the 1992 to 1994 record. Inclusion of the 1992 to 1994 event in this example would bias the results by double counting that fish. Multiple recaptures could happen quickly, as evidenced by one red grouper which was recaptured five times within a one month period.

Methods

The Porch (1998) method of estimating annual mortality rates from tagging data is based upon the probability of a tagged fish being recaptured assuming M and reporting rates are constant over time:

$$p(recapture) = \frac{F_w e^{-\sum_{i=\alpha}^{w-1} Z_i \Delta_i - Z_w (t_w - d_w)}}{\sum_{i=\alpha}^{I} \frac{F_i}{Z_i}(1 - e^{-Z_i \Delta_i}) e^{-\sum_{j=\alpha}^{i-1} Z_j \Delta_j}}$$

t_α	time (date) animal was tagged
t_w	time (date) animal was recaptured
α	discrete time interval during which the animal was tagged
w	discrete time interval during which the animal was recaptured
d_i	time (date) at start of i'th interval, except $d_\alpha = t_\alpha$
Δ_i	time spent in each interval (d_{i+1}-d_i)
I	last interval for which data are available
F	fishing mortality rate
Z	all sources of tag loss, includes natural and fishing mortality, tag shedding, non reported recaptures, emigration, etc.

This leads to the negative log-likelihood function which is minimized to determine the F for each time interval

$$-\sum_{k=1}^{n} \{\log F_{w,k} - \sum_{i=\alpha_k}^{w_k-1} Z_i \Delta_i - Z_{w,k}(t_{w,k} - d_{w,k}) - \log(\sum_{i=\alpha_k}^{I} \frac{F_i}{Z_i}(1 - e^{-Z_i \Delta_i}) e^{-\sum_{j=\alpha}^{i-1} Z_j \Delta_j})\}$$

where n is the number of tag-recapture events.

This method in practice cannot distinguish between sources of tag loss. The method estimates the total tag losses (Z) for each time period and subtracts an assumed natural mortality rate (M), scaled for the length of the time period, to produce annual mortality rates (Z*). These Z* values contain the effects of tag shedding, emigration from the study area, non reported recaptures, etc. If all factors other than annual fishing mortality rates can be assumed constant during the study period, then the relative change in the annual Z* estimates from this method can be used as an index of the relative changes of annual F in the fishery. The index reported here is formed by dividing each annual Z* estimate by the average of all estimates such that the index is centered about 1.0. This standardization allows for easy comparison of values estimated from different subsets of the database. The natural mortality rate was set at 0.2 for these analyses.

The program TAP2, kindly provided by C. Porch (NMFS, SEFSC, Miami), allows for two methods of estimating these time period specific Z* rates. Each Z* can be estimated independently or through a Bayesian random walk. In the case of the random walk, the amount of change allowed in Z* between successive time intervals is determined by a user supplied value (σ) which causes changes larger than e^{σ} to be unlikely. The discrete time intervals used in the program were calendar years, except 1990 and 1991 tagging events were grouped together, as were the 1998 and 1999 tagging events. This grouping was required because of the limited amount of time and data available from 1990 and 1999 (see Table 1). The results presented are all annual values.

Results and Discussion

Using all the red grouper data available in the MML tagging database produced Z* point estimates of 1.1 to 4.5 with a large increase in the final two years (Figure 3). Note, these Z* values incorporate many factors besides just fishing mortality and should not be interpreted as the actual fishing mortality rate in the fishery. Dividing each Z* by the average produces the index (Table 2). Using the Bayesian random walk instead of estimating each annual value separately leads to smoother trends in Z*, with the smoothness dependent upon the value of sigma (Figure 4 and Table 2). The smoothness of the Bayesian random walk estimates under low sigmas is due to the limited amount of data during the 1994 to 1996 period. The low sigma random walks fill in these years with interpolated Z* levels, while the high sigma random walks follows more closely the independent estimates for these years. Thus, although the limited amount of data during this period corresponds to relatively low Z* values for the years 1994 to 1996, these years can be assumed to follow a smooth trend in fishing mortality such that there is not a large break in the time series. However, the coefficients of variation for the random walk process with low sigmas are noticeably smaller than when all years are estimated independently (Table 2). This reduction in uncertainty is due to the additional assumption that only a limited amount of change in Z* is allowed from one year to the next. The low level of uncertainty associated with the low sigma random walk estimates would cause these values to be relatively important if used as a tuning index for a sequential population analysis.

To examine the possibility that red grouper below the 20" minimum size experience a different mortality rate than those above the minimum size, only records with tagging size less than 20 inches were used. All years were estimated independently. The annual Z* estimates decreased slightly (average of 3%) but the pattern and uncertainty was nearly identical to that using all data. Since only 31 red grouper (5%) were tagged greater than 20" it would take an extreme difference in the mortality rates between sub-legal and legal sized red grouper to allow detection.

The behavior of red grouper poses a significant problem to tagging studies used to estimate fishing mortality rates. Red grouper do not move great distances for most of their lives, especially as juveniles. They are also territorial and will remain in one particular location for months or years. This behavior means that a particular red grouper can be caught repeatedly if fishers return to its home location, assuming the capture process does not kill the fish. Tagged fish would become relatively more abundant in "hot spots" where fishers regularly aggregated than in less frequently fished areas. Fishers could also go "fishing for tags" if they so desired given the behavior of red grouper. This could explain some of the "hook happy" fish in the database which were captured repeatedly in short periods of time. These short times at large between tagging and recapture explain the high values of Z* estimated by the model, even though the release mortality rate must be quite low to allow for so many multiple recaptures of individual fish.

Two separate approaches were taken to examine the breaking of the assumption that tagged fish are representative of untagged fish. The first approach did not use records less than 10, 20 or 30 of days at large. Removing quick recaptures attempts to reduce the impact of "hot spots" and "fishing for tags." These truncations of the database produced lower Z* estimates for all years, but had only minor impacts on the index trends (Figure 5 and Table 2). The second approach treated red grouper that were tagged multiple times as a different group than those only tagged and recaptured once. The multiple tagged fish were either not used at all in the model, or else were condensed into a single tag recapture record consisting of the first time tagged and the last time recaptured. Condensing the multiple tagged fish into a single record will *a priori* reduce the Z*, but this sensitivity test was done to examine if the trend over time is changed by removing the number of records associated with these "hook happy" fish. Both cases reduced the annual Z* estimates, but did not change the trend over time (Figure 6 and Table 2).

The relative Z* indices from all methods were similar with a low early period followed by larger values in recent years (Figure 7). The largest differences were seen by assuming a Bayesian random walk process with low sigmas for the Z* values, which resulted in smoother trends but with lower levels of uncertainty. The use of any of the cases where annual Z* values were estimated separately would most likely produce similar results in a tuned sequential population analysis. It should be noted that these indices probably do not show as much annual variation as the true changes in fishing mortality rates. This is because the factors in Z* other than F are assumed constant from year to year. If the amount of Z* due to these factors could be estimated and removed, the index would be more variable. For example, if Z* ranged from 1.0 to 2.0 but the non fishing mortality tag loss was 0.5 per year, the Z* index would have a two fold range while the F index would have a three fold range. A true natural mortality rate greater than the 0.2 value assumed would produce the same impact on the relationship between the Z* and true F changes.

The ability to extrapolate these indices to the entire population is still an open question given the behavior of red grouper and the fact that these data were collected with the a different purpose than estimating annual fishing mortality rates. Much of these data were collected to examine the impact of puncturing a fish to vent gases released by swim bladder rupture. Other researchers using this same database have seen indications that venting the fish causes decreased mortality in the short term but no significant differences in the long term (V. Restrepo, University of Miami, pers. comm.). Factors such as venting, depth, area, etc. could not be incorporated into this analysis and still produce annual F estimates. Any imbalance in the distribution of these factors over time could impact the trends estimated here.

Literature Cited

Porch, C. E. 1998. Estimating Atlantic bluefin tuna mortality from the release and recapture dates of recovered tags (preliminary results). ICCAT SCRS/98/65. 9 pp.

Schirripa, M.J. and K.M. Burns. 1998. Estimates of growth based on hard-part analyses and release-recapture for 3 reef fish species in the eastern Gulf of Mexico. Bull. Mar. Sci. 61: 581-591.

Wilson, Jr., R.R. and K.M. Burns. 1996. Potential survival of released groupers caught deeper than 40m based on shipboard and in-situ observations, and tag recapture data. Bull. Mar. Sci. 58: 234-247.

Table 1. *Red grouper tag-recapture records from the Mote Marine Laboratory tagging database. Data in 1990 are for months Ocotber to December only, while data in 1999 are for months January to April only.*

		recovered										
		90	91	92	93	94	95	96	97	98	99	total
	90	1	6	2	0	0	0	0	0	0	0	9
tagged	91		47	51	11	3	1	0	0	0	0	113
	92			126	46	8	2	1	1	0	0	184
	93				39	8	1	1	0	0	0	49
	94					13	6	5	1	0	0	25
	95						14	3	0	0	0	17
	96							2	1	0	0	3
	97								91	27	3	121
	98									93	11	104
	99										2	2
	total	1	53	179	96	32	24	12	94	120	16	627

Table 2. *Estimated red grouper fishing mortality indices from different subsets of the Mote Marine Laboratory database: all=all records, sig X=random walk with sigma of X, 20"=only fish less than 20 inches at tagging used, Y days=only recaptures of Y or more days after tagging used, single=only fish which were tagged and recaptured once, mult1=fish with multiple tag and recapture records condensed into single longest record.*

Fishing Mortality Rate Indices

Year	All	sig 0.1	sig 0.2	sig 0.3	sig 0.4	sig 0.5	20"	10days	20days	30days	single	mult1
91	0.726	0.841	0.790	0.766	0.751	0.742	0.680	0.700	0.565	0.580	0.850	0.866
92	1.064	0.889	0.918	0.961	0.990	1.009	1.066	0.976	0.879	0.895	0.881	0.957
93	0.796	0.847	0.784	0.773	0.773	0.776	0.823	0.839	0.931	1.025	0.828	0.837
94	0.516	0.844	0.705	0.634	0.595	0.572	0.488	0.497	0.508	0.590	0.586	0.637
95	0.667	0.929	0.809	0.738	0.700	0.680	0.653	0.586	0.604	0.619	0.655	0.750
96	0.634	1.066	1.024	0.962	0.906	0.859	0.648	0.653	0.756	0.878	0.749	0.777
97	2.052	1.275	1.501	1.657	1.762	1.833	2.060	2.095	2.088	1.819	1.876	1.637
98	1.545	1.310	1.468	1.510	1.524	1.529	1.581	1.654	1.669	1.594	1.576	1.538

Coefficient of Variation

Year	All	sig 0.1	sig 0.2	sig 0.3	sig 0.4	sig 0.5	20"	10days	20days	30days	single	mult1
91	14	8	10	12	13	13	16	15	18	19	15	14
92	8	6	10	13	14	14	8	9	10	11	10	9
93	11	6	9	11	12	12	11	11	12	12	13	12
94	19	6	10	13	15	17	20	20	21	21	20	19
95	22	6	11	15	18	20	22	25	26	28	24	23
96	30	6	11	16	19	22	30	32	32	32	30	30
97	11	6	11	15	18	20	11	11	12	15	15	13
98	12	6	10	12	14	14	12	12	14	17	15	14
n	627	627	627	627	627	627	596	559	478	414	433	516

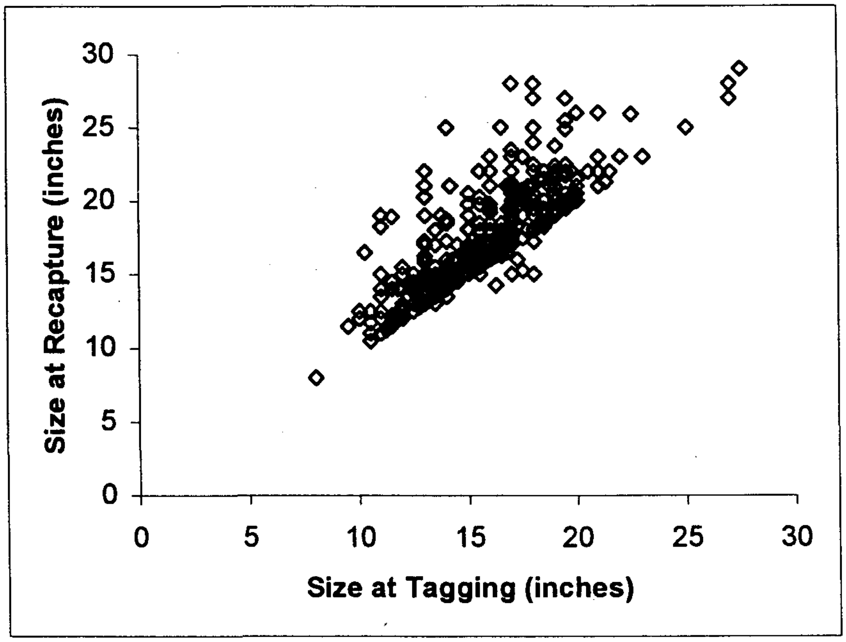

***Figure 1**. Red grouper sizes in Mote Marine Laboratory tagging database.*

***Figure 2**. Red grouper growth rates (positive values only) in Mote Marine Laboratory tagging database. One value not shown (17.25 inches, 169 inches/year).*

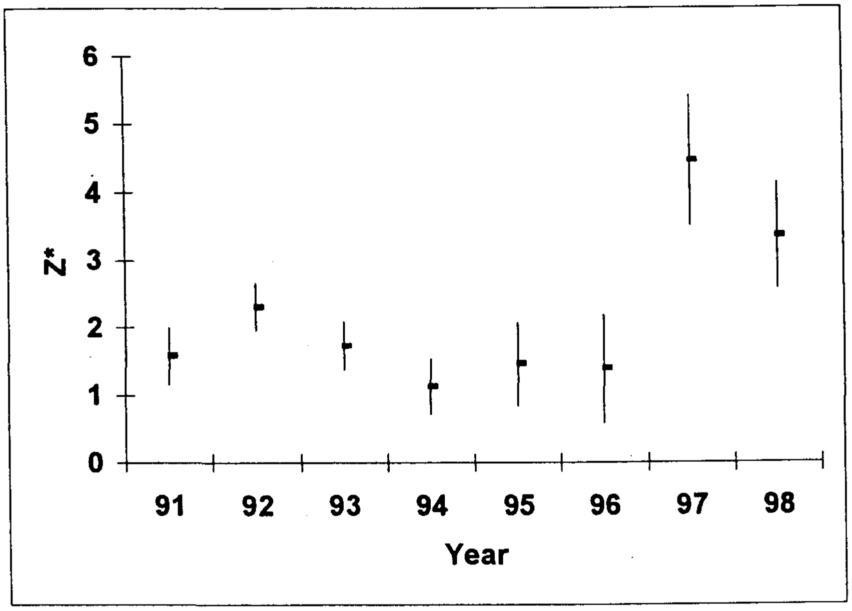

Figure 3. Red grouper Z estimated from all records in Mote Marine Laboratory tagging database. Horizontal line denotes point estimates, vertical lines denote approximate 95% confidence intervals.*

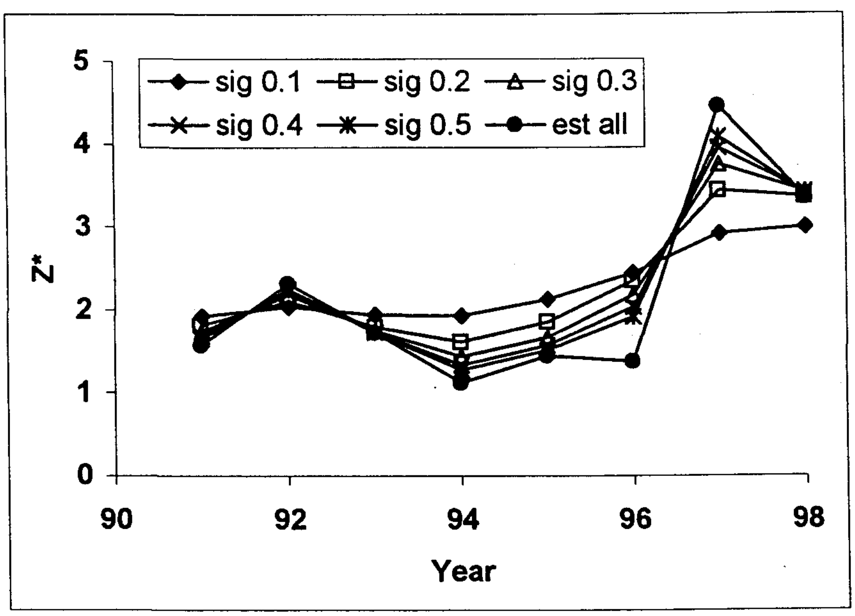

Figure 4. Red grouper Z point estimates from all records in Mote Marine Laboratory tagging database. Sig X denotes random walk process with assumed sigma of X, est all denotes annual values estimated independently.*

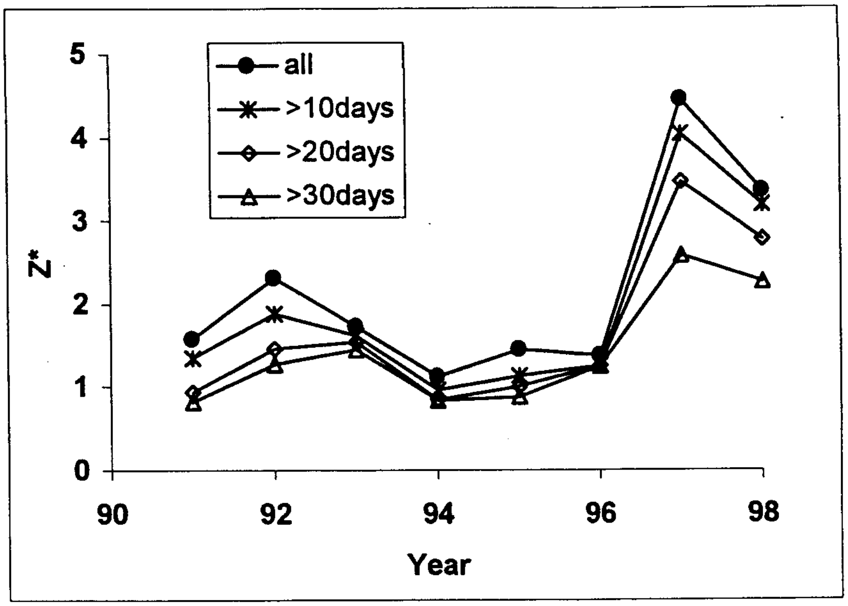

***Figure 5*..** *Red grouper Z* point estimates from Mote Marine Laboratory database. All denotes all records used in estimation, >X days denotes only recaptures more than X days after initial tagging used in estimation.*

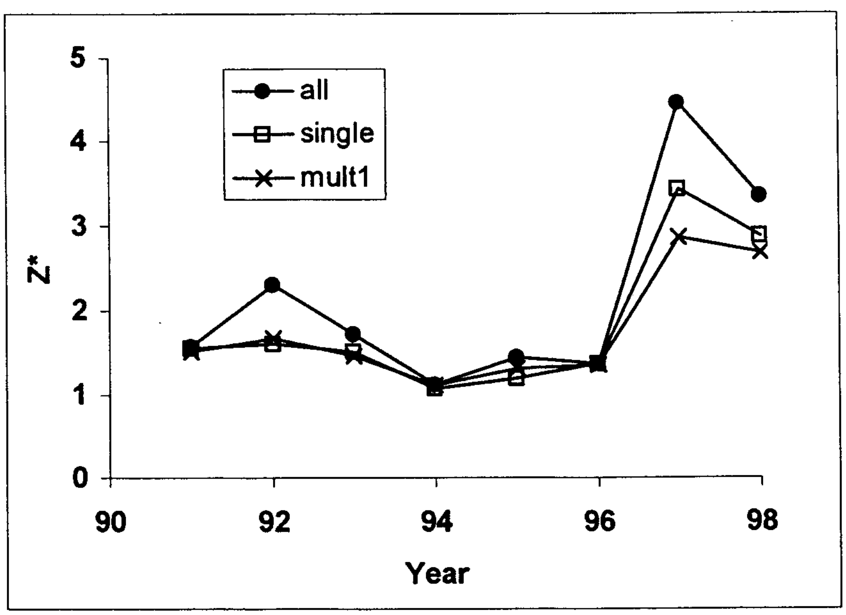

Figure 6. *Red grouper Z* point estimates from Mote Marine Laboratory tagging database. All denotes all records, single denotes only fish that were recaptured once, and mult1 denotes fish recaptured multiple times condensed into a single record, used in estimation.*

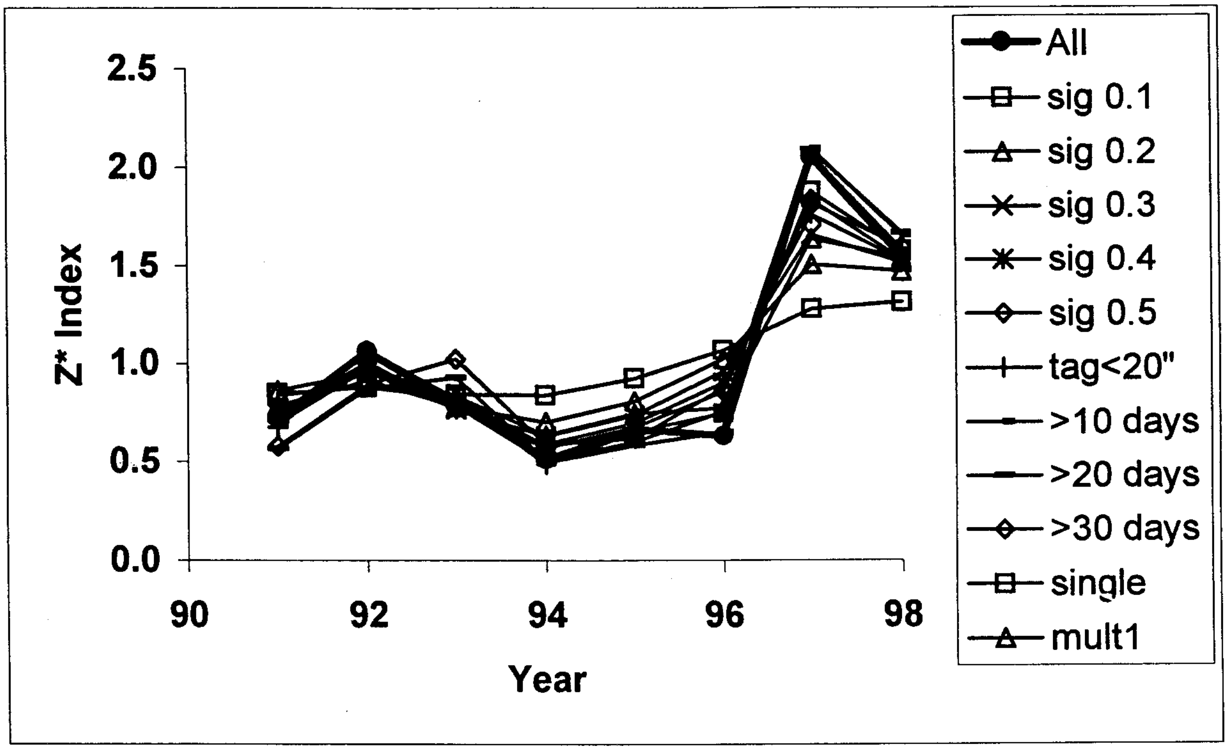

***Figure** 7. All red grouper Z* indices plotted on same scale. Legend entries as defined in previous figures.*