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Trends in Red Grouper Mortality Rates Estimated from Tag Recaptures (1990-2006)

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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. This paper presents preliminary analyses of the MML data with the intent to foster further discussion during the upcoming SEDAR 12 data workshop.

Data

The tagging database contains over 16,000 records of red grouper tagging events during the period October 1990 through June 2006 (see Schirripa and Burns 1998 and Wilson and Burns 1996 for more details about the MML tagging program and database). There were 1200 records which contained information for both the date of tagging and date of recapture, excluding fish tagged and recaptured on the same day and fish that were not reported to be released in fair or better condition.

Multiple tagging and recapture of individual red grouper occurred relatively frequently in the database. 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.

Estimation

The Porch (1998) method of estimating annual mortality rates from tagging data is based upon the probability of a tagged fish being recaptured after a certain time at large:

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

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 chronic tag loss, including natural and fishing mortality, tag shedding, 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.

The method is implemented by parameterizing Z as the sum of F and a generic loss rate parameter L (which implicitly includes natural mortality, tag shedding and emigration). In practice, however, F and L will be highly correlated (i.e., difficult to distinguish) unless the data encompass a prolonged period with no fishing. Accordingly, only the composite parameter Z is uniquely estimated and one must fix L to some constant in order to obtain unique estimates of F.

The estimate of Z is generally insensitive to the assumed value of L (provided of course the value of L supplied is not too large).

The program TAP2 allows Z to vary across multiple intervals, but assumes Z is constant within the intervals. The time intervals used in the program were calendar years, except that Z was assumed constant for 1990 and 1991 (owing to sparse sampling in 1990) and for 2005 and 2006 (date were available only up until June of 2006).

Results and Discussion

The use of all the red grouper data available in the MML tagging database produced Z point estimates of 1.1 to 4.2 (Figure 1). 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. Subtracting an assumed value of L from each Z produces an index of F (Table 1).

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. To illustrate this, a second run was made which did not use records of recaptures within 30 of days of release. Removing these quick recaptures attempts to reduce the impact of "hot spots" and "fishing for tags." The resulting estimates of Z estimates are much lower for all years, but the overall trends are relatively unchanged (Figure 1 and Table 1).

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.

Previous assessments converted the estimates of F into a relative abundance index by solving the catch equation for numbers of fish (where the catches were the MRFSS estimates of the number of fish released alive and the tag loss rate L was assumed equal to the assumed natural mortality rate of 0.2 yr^{-1}). This conversion approach makes the implicit assumptions that tag shedding is negligible. However, SEFSC (2001) found the relative abundance index to be relatively insensitive to the assumed levels of L (Figure 2). No doubt the relative index would be more sensitive to systematic changes in the level of mixing or tag shedding, but this is akin to asserting that CPUE indices are sensitive to systematic changes in factors not included in the standardization process. In principle, a more appropriate use of the loss rate estimates would be to treat them as an index of relative mortality rate in the manner of Porch 2001, but there was insufficient time during the last assessment to incorporate that approach into the assessment model.

Literature Cited

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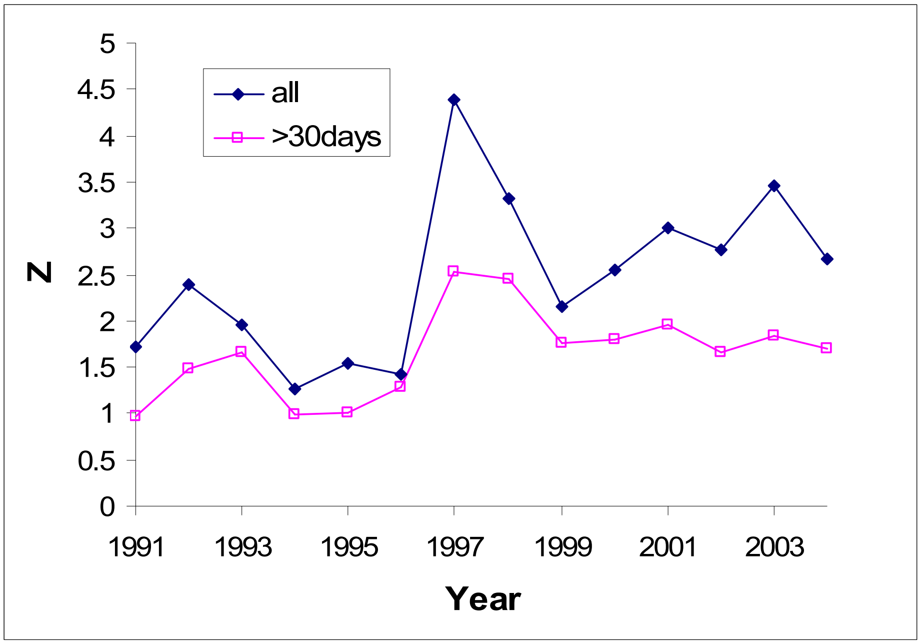
Table 1. Estimated red grouper fishing mortality indices under different assumed non-fishing loss rates (L) from different subsets of the Mote Marine Laboratory database (all=all records, >30 days=only recaptures of 30 or more days after tagging used).

	All			> 30 days		
Year	L=0.2	L=0.4	L=0.6	L=0.2	L=0.4	L=0.6
1991	1.5	1.3	1.2	0.8	0.6	0.5
1992	2.2	2.0	1.7	1.3	1.1	0.9
1993	1.8	1.5	1.3	1.5	1.2	1.0
1994	1.1	0.9	0.8	0.8	0.6	0.5
1995	1.3	1.1	1.0	0.8	0.6	0.5
1996	1.2	1.1	1.0	1.1	1.0	0.8
1997	4.2	3.9	3.7	2.3	2.1	1.9
1998	3.1	2.9	2.7	2.3	2.0	1.8
1999	2.0	1.8	1.6	1.6	1.3	1.1
2000	2.4	2.2	2.0	1.6	1.4	1.2
2001	2.8	2.6	2.4	1.8	1.5	1.3
2002	2.6	2.4	2.2	1.5	1.3	1.1
2003	3.2	3.0	2.8	1.6	1.4	1.2
2004	2.5	2.3	2.1	1.5	1.3	1.1



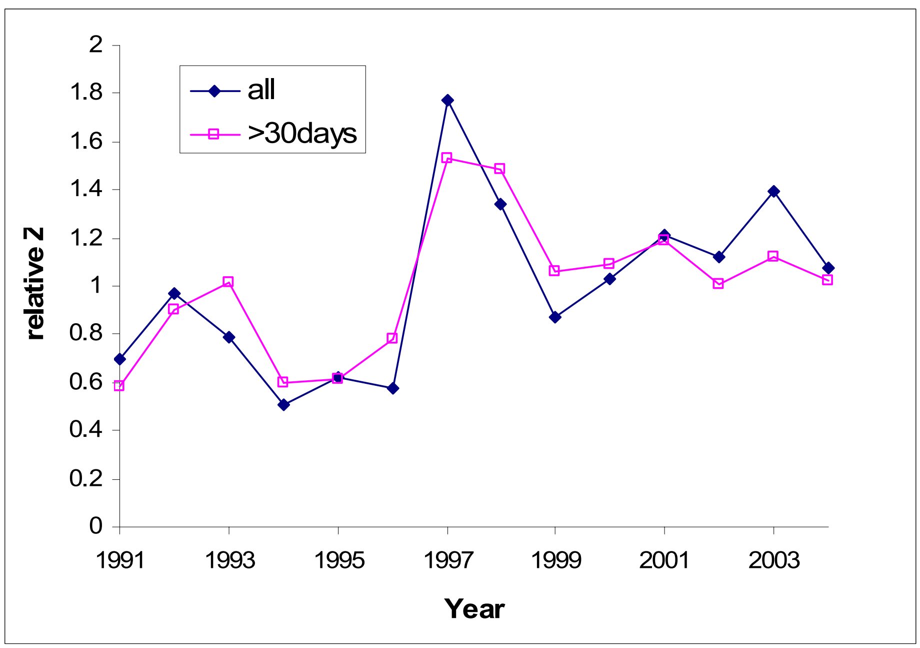


Figure 1. Red grouper Z point estimates from Mote Marine Laboratory database. All denotes all records used in estimation, *>30* days denotes only recaptures more than 30 days after initial tagging used in estimation. Top panel gives absolute values and bottom panel gives values relative to the overall mean for each series.

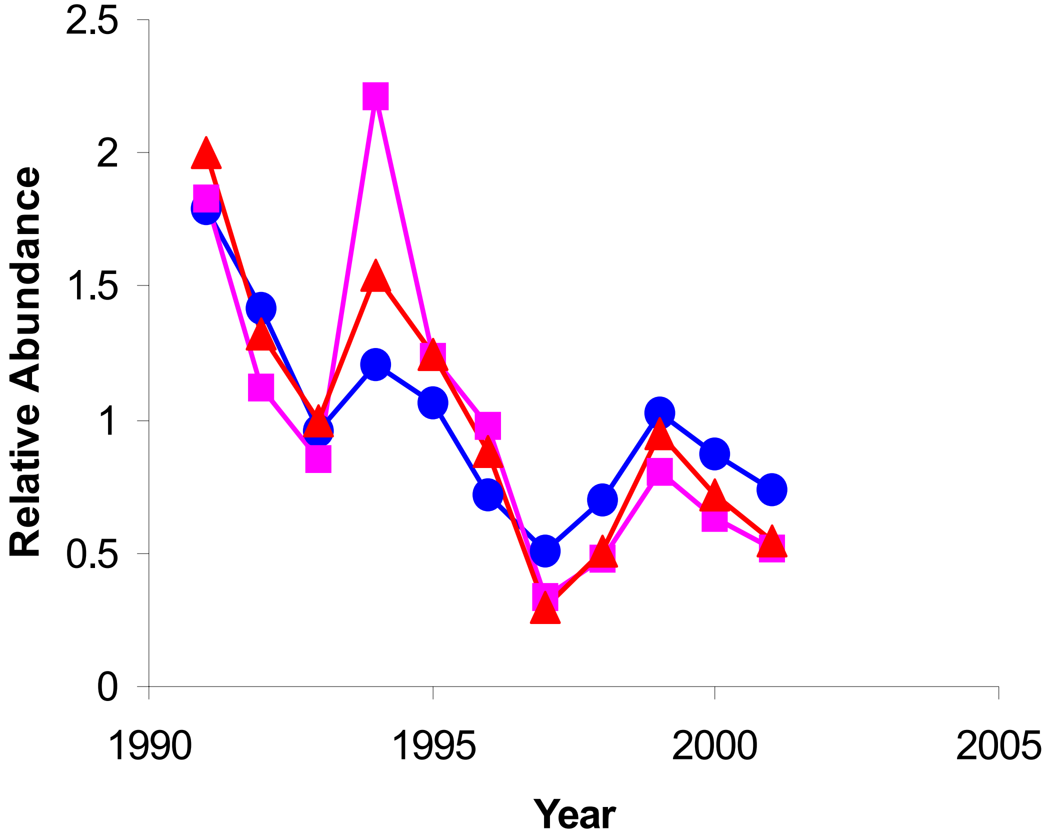


Figure 2. Relative indices of abundance assuming L=0.2 yr^{-1} and complete mixing of tags with resident population (circles), L=0.8 yr^{-1} and complete mixing (squares) and no tag shedding with little mixing such that the F on the tagged population is 10 time higher than the F on the untagged population (triangles). The major difference is in 1994, where the estimates of total loss rate were lowest (hence the effect of subtracting out the high L rate is proportionately the greatest). Reproduction of Figure 10 from SEFSC (2002).