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Using scenario-based population dynamics modeling to prioritize those parameters in Gulf of Mexico red snapper stock assessment where uncertainty should be taken into account

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Executive Summary

1. A scenario-based age structured population dynamics model of Gulf of Mexico *Lutjanus campechanus* was constructed to help prioritize those parameters where uncertainty should be taken into account in the upcoming stock assessment. It is acknowledged that there are many simplifying approximations utilized in this model that will impact the models results and make them different from those obtained in the 1999 assessment. While the details of the results might be different from the 1999 assessment, the age structured model applied still captures many of the key features of the population dynamics, fishery and bycatch and is applied not as an alternative stock assessment but instead as a gaming tool to evaluate the direction and relative magnitude of impacts on model outputs of various changes in assumptions and model inputs.
2. The fish killed by shrimp trawl bycatch, commercial and recreational fishing were modelled using the commercial catch data, recreational catch data and annual shrimp bycatch estimates reported in Schirripa and Legault (1999). Unlike the 1999 assessment, this model projected the population from the year 1880, when the first records of catches are reported in Schirripa and Legault (1999). Shrimp bycatch is assumed to start occurring in 1946 and the values in unreported years are assumed to be the mean for the reported years.
3. Fishery selectivity at age for the retained catch was modelled to be stationary over time. The selectivity at age for the recreational and the aggregated commercial fleets was approximated by using the partial fishing mortality rate (F) values at age based on results in the 1999 stock assessment. Discard selectivity at age for the recreational fleet and commercial fleets were modelled separately also using partial F values for discards also based on data and results in the 1999 assessment.
4. To compute maximum sustainable yield (MSY) and MSY-related reference points, the 1999 assessment utilized a linked selectivity function that incorporated all sources of estimated fishing and discard mortality from the years 1995-1997. While this appears to be reasonable, the computation of MSY is not straightforward. For example, it is questionable whether discards should be counted as part of the MSY and the biomass at MSY (B_{MSY}) should include discardable fish. This may produce MSY reference points that are difficult to interpret because yield is typically interpreted as landed fish, not the sum of landed and discarded fish. Unavoidable discard could arguably be interpreted as a form of mortality akin to predation. This could still be taken into account in the computation of MSY but perhaps should not be counted as part of B_{MSY}. Moreover, the use of a selectivity pattern that is known to be no longer valid, due to recent changes in shrimp bycatch selectivity, make the use of the 1995-1997 linked selectivity function questionable. This modelling work undertaken explores some alternative MSY definitions. It is found that values for MSY reference points are highly sensitive to the manner in which MSY is defined and computed. It is thus recommended that some attention be given to how MSY reference points should be defined in the first place when there is unavoidable bycatch of the target species.
5. The model was run from 1880 to the present using the 1999 base case parameter values for steepness (h), average unfished recruitment and natural mortality but starkly different estimates of 1998 stock status were obtained. If steepness is 0.95 and unfished average recruitment (R_0) is 245 million, then the computed current abundance is hardly depleted at all, which we know not to be the case. It is only using smaller values for h and R_0 that high values for F in the 1990s can result.
6. When higher values for the rate of natural mortality at age 0 and age 1 (M_0, M_1) were applied, the estimates of R_0 increased markedly, and the estimates of F from recreational and commercial fishing also increased substantially.
7. In conclusion, the gaming model indicated that current estimates of h and R_0 are inconsistent with historic catches, and changes in input values for M_0, M_1, steepness, and the manner in which MSY is calculated can produce wildly different estimates of stock status.

Introduction

Many of the inputs to the 1999 Gulf of Mexico *Lutjanus campechanus* stock assessment model remained fixed yet little no account of potential uncertainties in these inputs was given. Some of these parameters included the rate of natural mortality at age, and the “linked” vulnerability at age function used in computing MSY. In this note, I briefly outline some ongoing work to build and run a scenario-based age structured population dynamics model of Gulf of Mexico *Lutjanus campechanus*. This model (termed “gaming model”) is being constructed to help identify modelling assumptions and those parameters where uncertainty should be further taken into account in the upcoming stock assessment.

It is acknowledged that there are many simplifying approximations utilized in the current form of the gaming model that will impact the model’s results and make them different from those obtained in the 1999 assessment. While the details of the results might be different from the 1999 assessment, the age structured model applied still captures many of the key features of the population dynamics, fishery and bycatch and is applied not as an alternative stock assessment but instead as a gaming tool to evaluate the direction and relative magnitude of impacts on model outputs of various changes in modelling assumptions and model inputs.

This note reports on issues regarding the computation of MSY-related reference points in fisheries with large amounts of discarding, the potential inconsistency of current assumptions about stock-recruit parameters and historic records of catches, and implications of applying different values for the rate of natural mortality at age. Due to limitations of time in producing this note, only a basic description of the population dynamics model developed and qualitative results are reported.

Methods

Due to running out of time before the April 19-23 SEDAR workshop, the equations for the age-structured population dynamics model developed are not reported in this document. These will be detailed in a subsequent SEDAR workshop document in preparation for the August 2004 SEDAR workshop.

The model develop is age structured with a plus group at 15 years. However, the model is set up to allow the plus group to be changed easily to younger or older ages. The Beverton-Holt stock-recruit function is employed to predict age 0 recruits from the total number of eggs spawned, assuming a sex ratio of 50% females at age. The fish killed by commercial fishing were modelled using the catch data for the commercial fleets aggregated into single annual values. Recreational fishing mortality and shrimp bycatch mortality were modelled using recreational catch data and annual shrimp bycatch estimates reported in Schirripa and Legault (1999).

Unlike the 1999 assessment, this model projected the population from the year 1880, when the first records of catches are reported in Schirripa and Legault (1999). The many missing values in commercial catches in some of the periods before the 1940s are filled by filling the catch just prior to each segment of missing years. Shrimp bycatch of juvenile red snapper is assumed to start occurring in 1946 and the values in unreported years are assumed to be the mean for the reported years. When more time permits variations in these assumptions regarding missing and historic records can be varied to evaluate the impact on results of changes in these assumptions.

Fishery selectivity at age for the retained catch was modelled to be stationary over time. The selectivity at age for the recreational and commercial landings was approximated by using the 1998 partial fishing mortality rate (F) values at age for the recreational and the aggregated commercial fleets (Schirripa and Legault 1999). Discard selectivity at age for the recreational fleet and commercial fleets were modelled separately also using partial F values for discards also based on data and results in the 1999 assessment. These discards are modelled to have begun in 1985, after the first size based regulations were imposed in 1984.

Due to time limitations, the model was not fitted to catch-age data. However, the lognormal recruitment residuals from the 1999 assessment for the years 1984 to 1998 were re-computed and utilized in the gaming model to take into account the recent estimates of variations in cohort strength.

In some instances, the model was fitted to the SEAMAP and recreational indices and a penalty function was applied to make the fishing mortality rate in 1998 close to that in the 1999 stock assessment.

To compute maximum sustainable yield (MSY) and MSY-related reference points, the 1999 assessment utilized a linked selectivity function that incorporated all sources of estimated fishing and discard mortality from the years 1995-1997. While this appears to be reasonable, the computation of MSY is not straightforward. For example, it is questionable whether discards, especially those that are pre-recruits, such as those in the shrimp bycatch, should be counted as part of the MSY. It is also questionable whether the stock biomass that gives rise to MSY (B_{MSY}) should include parts of the population that are not considered to be recruited to the fishery. Such calculations may produce MSY reference points that are difficult to interpret. For example, yield is typically interpreted as landed fish that are marketable, not the sum of landed marketable fish and discarded fish. Unavoidable discard could arguably be interpreted as artificial mortality akin to predation but not normally as part of the yield. This is not to say that unavoidable discards should not be taken into account in the computation of MSY. Arguably, discards should still be taken into account in the computation of MSY, but only as an additional source of mortality. If it is unavoidable shrimp bycatch, then this bycatch mortality rate should not be made to vary with adjustments to the targeted fishing mortality rates, as it appears to in the 1999 stock assessment. Rather, it is argued here that the shrimp bycatch mortality rates at age should be made to be fixed at values deemed to be plausible for the near future. FMSY should then be found by adjusting the fishing mortality rate on the recruited population. If discards for the recreational and commercial fisheries are a function of recreational and commercial fishing effort, then only the recreational and commercial discards in the computation of MSY should be made to be directly linked to the fishing mortality rate targeted on the recruited population.

Likewise, it could be argued that the computation of B_{MSY} should include only the parts of the population that could be considered to be recruited to the targeted recreational and commercial fisheries. BMSY should not be computed to include also unrecruited parts of the population susceptible to other bycatch fisheries such as the shrimp trawl fishery.

Moreover, the use of a selectivity pattern that is known to be no longer valid, due to recent changes in shrimp bycatch selectivity, make the use of the 1995-1997 linked selectivity function questionable.

This modelling work undertaken begins to explore some alternative MSY definitions. The alternative approach described above was applied for the computation of MSY reference points in the gaming model reported in this paper.

Results and Discussion

It is found that values for MSY reference points are highly sensitive to the manner in which MSY is defined and computed. Using the base case value for R_0, and steepness of 0.95, and values for F_0 and F_1 similar to the mean estimates in 1995-1997 of Schirripa and Legault (1999), the value obtained for F_{MSY} (0.15 yr^{-1}) was not very different from that obtained in Schirripa and Legault (1999) (0.12yr^{-1}). However, the values for MSY and B_{MSY} were markedly lower than those obtained in Schirripa and Legault (1999) due presumably to not including in MSY and B_{MSY} the biomass of the unrecruited population. It is thus recommended that some further attention be given to how MSY reference points should be defined in the first place when there is unavoidable bycatch of the target species, particularly when this bycatch comes from the unrecruited parts of the population.

When the model was run from 1880 to the present using estimates of historic catches in Schirripa and Legault (1999), the 1999 base case parameter values for steepness (h), average unfished recruitment and natural mortality in (Schirripa and Legault 1999), estimates of 1998 stock status starkly different from those in Schirripa and Legault (1999) were obtained. If steepness is 0.95 and unfished average recruitment (R_0) is 245 million as in Schirripa and Legault (1999), then the computed current abundance is hardly depleted at all (e.g., at about 70% of unfished abundance), which we know not to be the case. It is only using much smaller values for h and/or R_0 that high values for F in the 1990s can result.

Trouble was experienced while fitting the model to data with the 1972 very high shrimp bycatch estimate. It was impossible to obtain fishing mortality rates for age 1 much higher than about 0.3 with this value included. To obtain results with similarly high fishing mortality rates in the 1990s the 1972 shrimpbycatch value was thus masked in further computations. When steepness was fixed at 0.95 and the model was fitted to the SEAMAP and recreational CPUE data and constrained to give a high value for F in 1998, R_0 became 69 million and the depletion dropped to 18% and the fishing mortality from recreational and commercial fishing (F_T) was 0.088. With steepness of 0.7, R_0 became 82 million and depletion dropped slightly to 16.7% and the F_T was 0.078.

When higher values for the rate of natural mortality at age 0 and age 1 (M_0, M_1) were applied, the estimates of R_0 increased markedly, and the estimates of F from recreational and commercial fishing also increased substantially. For example, with h at 0.7 and when the values for M_0 and M_1 were increased from 0.5 yr^{-1} and 0.3yr^{-1}, to 2 yr^{-1} and 1 yr^{-1}, then R0 became 375 million, depletion became 15%, and F_T became 0.19.

It is already well known that FMSY is highly sensitive to steepness. For example, when steepness at 0.95, and assuming shrimp bycatch will drop by 60%, F_{MSY} was 0.24. Dropping steepness to 0.7 resulted in F_{MSY} = 0.12.

In conclusion, the gaming model indicated that current estimates of h and R_0 are inconsistent with historic catches, and changes in input values for M_0, M_1, steepness, and the manner in which MSY is calculated can produce wildly different estimates of stock status.

References

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