The Role of Fishery Catch in Fishery Stock Assessments

Issues associated with how changes to historical recreational catch and effort data influence derivation of biological reference points in benchmark stock assessments

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Introduction

Fishery catch data play a crucial role in fish stock assessment models. It is one of three cornerstones of complete stock assessments. The other two are fish abundance data and fish biology data. There always is sampling uncertainty in each of these sources and the assessment result will reflect that imprecision. This is normal and expected; we can never expect to achieve perfect precision. However, where there is bias in a data input, then the assessment result will be biased as well. Sometimes when there are multiple data sources the bias in a particular data source can be detected as a discrepancy in the assessment model. Unfortunately, we rarely have enough high precision data to allow for such bias detection, so the biased input plays through to produce some degree of bias in the assessment result.

Changes in recreational catch estimates due to the improved MRIP procedures represent a possible case of both bias and imprecision relative to the previous estimates. If all the new catch values were higher or lower than the previous catch values, then this would be a clear case of a bias and the results from assessments with the MRIP catch data would shift to some degree relative to the previous assessments. Fortunately, a widespread shift in the catch estimates does not appear to have happened. However, individual updated catch estimates do change relative to the previous estimates. Although these changes are generally no larger than expected given the degree of imprecision in each estimate, the actual estimates that would go into an assessment model are changed so could have an effect on assessment results.

In this presentation, two phenomena will be explored. One will be the effect of a shift in catch estimates on the results of a simple assessment model. The other will be the influence of catch imprecision on the imprecision of the assessment result. The results will be discussed in terms of biological reference points.

How assessment models use catch data

Fish stock assessments have multiple goals. One is to determine if a fish stock is experiencing excessive fishing mortality (fraction caught each year), known as overfishing. Another is to determine if the stock has been reduced to low abundance, known as overfished or depleted. A third is to forecast a level of fishing mortality rate that would be sustainable and to combine this rate with a forecast of fish abundance to determine a level of future catch that would implement the sustainable harvest policy.

Assessment as Time Series: The first step of the assessment model is to use available catch, abundance and biology data to calibrate a population model. This is done as a time series of estimates of annual stock abundance, productivity (recruitment) and fishing mortality. It is not a snapshot using only the most recent data. By looking at the entire time series of data, the model gets information about the stock from the changes that have occurred. In particular, the model gets calibrated by the degree to which the abundance index has changed during periods in which catch has been high versus changes that occur when catch is lower. Thus, having access to long time series of data that contain contrast is important to good assessment results.

Biological Reference Points: The second step of the assessment process is to calculate biological reference points. The most important of these reference points are: (1) the annual fishing mortality rate, F_{lim}, beyond which overfishing would be occurring; and (2) the stock abundance level, B_{lim}, below which the stock is considered to be overfished. Where the stock assessment has been able to analyze the stock over a wide range of conditions, then it is sometime possible to estimate what F rate would produce maximum sustainable yield (MSY) and then to set F_{lim} equal to F_{msy} and to set B_{lim} equal to some fraction of Bmsy. However in most cases, direct estimation of MSY related BRPs is too imprecise to be useful so proxies are used. A common proxy is based on spawning biomass per recruit (SPR) because this can be based only on life history characteristics and fishery age-selectivity, both of which are easier to estimate than MSY. An example of a SPR proxy would be to fish at a rate such that 35% of the unfished spawning biomass per recruit would be preserved, e.g. "escape" the fishery. This typically would be termed $F_{35\%}$. A recap of how BRPs are related from assessment models is as follows:

- In simple, biomass-dynamics models, the model is defined in terms of MSY related quantities, so MSY output is obtained directly
- In more complex, age-structured models the model is focused on estimating the recruitment and subsequent mortality of each yearclass that enters the stock and on estimating the age-selectivity of the fisheries. A separate step is needed to estimate the BRPs.
  - Where the spawner-recruitment output from the assessment have enough contrast, then direct estimation of MSY is possible
  - Otherwise, proxies like $F_{35\%}$ are estimated to create the BRPs
- In the most complete models, termed integrated analysis, the spawner-recruitment curve is included as an integral part of the age-structured model so that direct estimation of MSY related quantities again becomes feasible.

Catch data will influence BRPs in a couple of ways. First, catch affects the assessment and the estimated degree of change in the stock over time, so direct estimates of MSY will be affected by changes in catch data. Second, the relative catch between fishing fleets can affect the overall age-selectivity of the combined fisheries' impact on the stock, so even quantities like $F_{35\%}$ can be affected.

Abundance data: Abundance data is nearly always available only as an abundance index. The fishery-independent surveys can rarely be calibrated directly into an estimate of the abundance of the fish stock. Counting out-of-sight fish in the 3D ocean is a lot harder than counting trees in the forest. There are factors, such as how fish interact with the sampling gear, that make such direct calibration infeasible in most cases. Fortunately, various advanced technologies are improving our ability to achieve this direct calibration. Currently, fishery-independent surveys focus on standardization of procedures so that the average catch rate will go up in down in direct proportion to the abundance of the fish stock. Then we rely on the assessment model to turn the information in these index changes into estimates of absolute fish abundance.

Because the abundance data is used only as an index, it is sometimes possible to calibrate a time series of fishery catch rates, even recreational catch rates, to be a proxy for a fishery-independent survey. When this is done, the basic data come from fishermen's logbooks or from observers and are in the form of something like: catch per tow, catch per hundred hooks fished, catch per hour fished, or some other measure of the encounter rate between fish and fishermen. The total effort by the fleet is not needed, instead the individual fishermen's logbooks are treated as if they were survey observations. Although statistical procedures are used to achieve some standardization of the extraneous factors that also may affect fishermen's catch rates, it is much more difficult to be confident that the fishery data cover the range of the stock and that the fishing techniques have remained highly stable over time. Thus, fishery-independent surveys are a preferred source of abundance data.

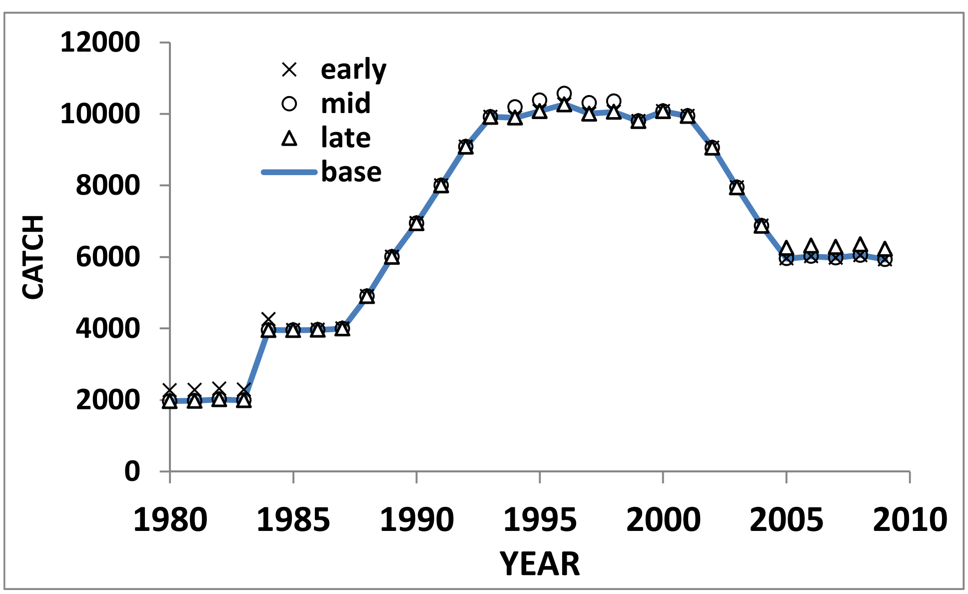
Catch data in assessments: Assessment models can infer stock abundance from changes in an abundance index because catch is treated as an absolute measure of catch. This is realistic for most commercial fisheries where landings receipts provide a census of the landings. Assessment models have built upon this census-like characteristic of commercial catch data; it's the place to stand when we exert the stock assessment lever. Historically, assessments for fisheries with well-sampled catch age composition have gone a step further and the Virtual Population Analysis technique treats the calculated catch-at-each-age as an absolute measure. However, there are many circumstances where the catch is not known with such high certainty. One is in multi-species fisheries where the species composition is based on a limited number of samples from mixed-species catches. Another is for the discarded catch where a limited number of observers observe discards from only a portion of the trips. The third is recreational fisheries where sampling, rather than census, procedures are used throughout the estimation process. As catch monitoring becomes more complete across all components of catch, it is important that assessment models evolve to more accurately account for the characteristics of this catch.

Many assessment models are able to simultaneously account for the catch from several different fleets. Fleets are not kept separate because the impact of commercial fishing is different from the impact of recreational fishing; a dead fish is a dead fish. Rather, fleets are kept separate because catching a ton of large, old fish has a different impact from catching a ton of small, young fish. Because of the gears they use and the areas they fish, different fleets may target a different size/age range, thus have a differential impact on the stock. Keeping the fleets separate in the assessment model provides a quantification of these differences, and allows for more transparent treatment of the different levels of sampling applied to the various fleets.

Catch Bias Example

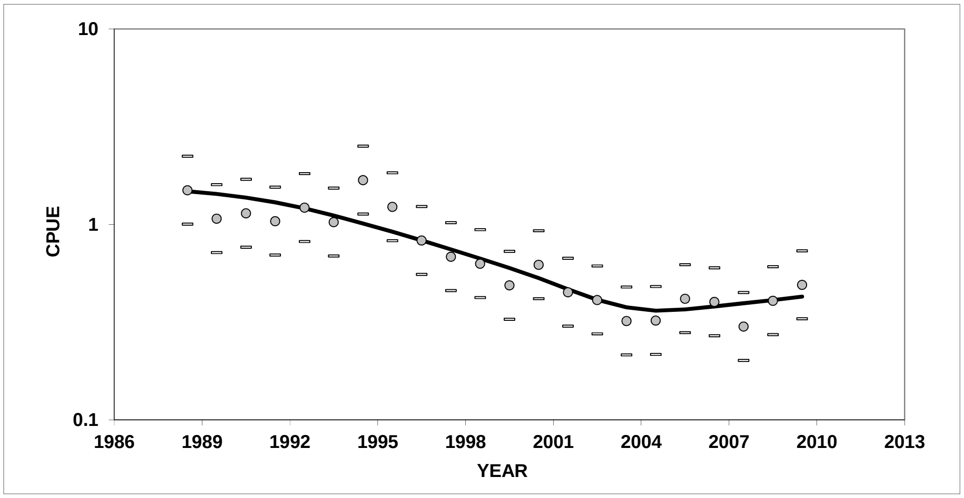
In this example, simulated data will be used to illustrate the impact of biased catch estimates. The assessment model is a simple age-structured production model implemented in the Stock Synthesis assessment framework. The data will be simply a time series of catch and a time series of an abundance index. Because this is an age-structured example and not a simpler biomass only model, some biological characteristics need to be assigned, so natural mortality was set at 0.2 yr-1, growth was set like a typical bottomfish, and selectivity to the fishery and the abundance index was set to fully select ages 1 and older, and maturity was set at a delayed level such that 50% maturity did not occur until age 7, so the stock is quite vulnerable to overfishing.

In addition to the base model run, three biased catch data time series were created. One added 300 mt per year for 5 years early in the time series (15% increase), a second added the same amount during the middle of the time series when the high catch (so only 3% increase) was causing the greatest stock decline, and a third added the extra catch late in the time series after the stock had stabilized at a moderate level of abundance. These catch time series are illustrated in Figure 1.

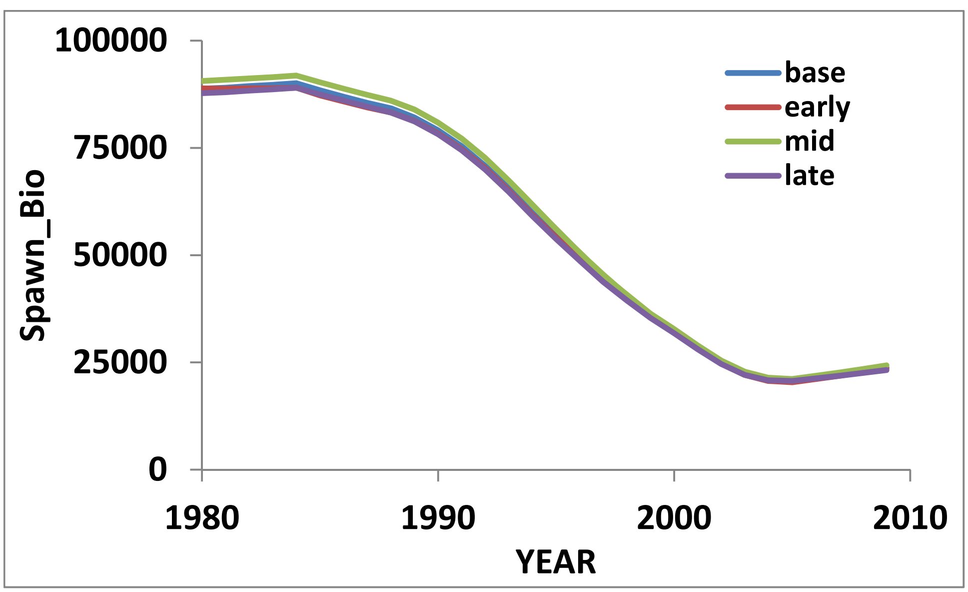


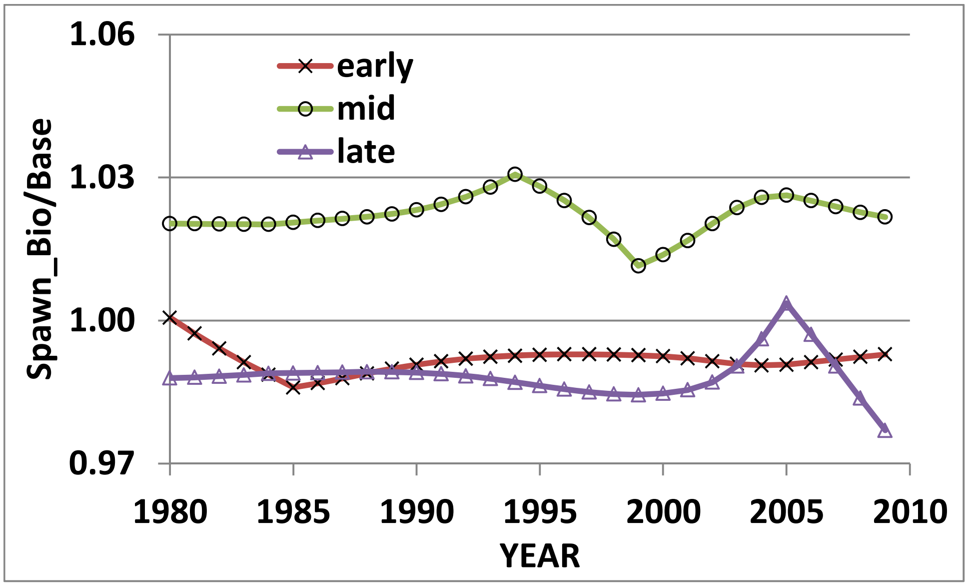
The abundance index was generated from the population model that had the base time series of catch. The abundance index starts in 1989, the year in which the catch started to increase.

When the age-structured production model was fit to the base catch time series and the abundance index, the fit to the abundance index is shown in Figure 2.



So the question is, how different are the assessment results when using the three biased catch time series relative to the result from the base model? The estimated time series of spawning biomass are shown in Figure 3, which shows little difference because the catch bias is small, and then Figure 4 shows each alternative relative to the base result.





Results

- Each alternative produced basically the same time series of estimated spawning biomass because each was using the same abundance index and the bias in catch was rather small.
- Relative to the base case, the three alternatives each showed the greatest decline during the time period in which they were using biased catch data.
- Only the alternative with the positive catch bias in the middle of the time series showed a positive bias in estimated abundance. This is because the biased catch was occurring during the time period in which the abundance index was showing the greatest change.
- The least bias overall was when the catch offset occurred early, before the abundance index started in 1989.
- A more complete investigation would generate hundreds of abundance data sets for each of these alternatives and then look at the average of these results, rather than just the single result shown here. Nevertheless, the results of this simple test are logical and illustrative.
- The impact of the biased data sets on the MSY-based biological reference points is shown in Table 1.

	Base	**Early**	**Mid**	**Late**
SSB_unfished	**110561**	**110613**	**112528**	**109608**
steepness	**0.929**	**0.930**	**0.913**	**0.957**
SSB_MSY	**26004**	**25980**	**27245**	**24400**
SSB_MSY/SSB_u	**0.235**	**0.235**	**0.242**	**0.223**
SPR_MSY	**0.250**	**0.249**	**0.260**	**0.231**
F_MSY	**0.264**	**0.264**	**0.252**	**0.286**
MSY	**6821**	**6829**	**6833**	**6944**
OFL_2010	**3866**	**3845**	**3937**	**3774**

These results also are logical. For example, with the Late alternative, the use of biased high catches causes a higher steepness estimate in order to keep the recruitment high to offset the higher catches and still match the abundance time series. Because of this higher steepness, the stock is more resilient and the MSY is higher and the B_{msy} is lower.

Catch Imprecision Example

Using the base example, two configurations were investigated. Both used the identical catch time series, but one used a high catch precision (low standard error = 0.01), and the other used low catch precision (high standard error = 0.20). In both cases, the model was able to estimate annual F levels such that the catch was matched nearly exactly. This occurs because there are no other data in the model that are informative enough to lead to different F levels. The small difference between these two configurations is in the level of precision in the estimated spawning biomass, as shown by the coefficient of variation in the following table.

	catch_se=0.01	catch_se=0.20
CV_SpB_1980	17.0%	19.5%
CV_SpB_2009	14.2%	18.0%

Conclusion

Catch is an important input to stock assessment models and the absolute level of total catch has a scaling effect on the assessment result.

Recreational catch and commercial catch cumulatively affect the fish stock. Differential impact of recreational versus commercial catch only occurs if they have a different age-selection pattern.

When biological reference points are based on MSY quantities, then bias in catch will affect the assessment result which will then affect MSY and the biological reference points.

When biological reference points are based only on life history and fishery selectivity, then changes in the ratio of catch between fleets that catch older versus younger fish will affect the overall selection pattern and hence the biological reference points.

If an assessment model has used catches that are biased high during time periods of rapid stock decline and high data quality, then the stock abundance will also be biased high. However, if the assessment model has used catches that are biased high only late in the time series, then current stock abundance may be underestimated.

The results demonstrated here were for total catch biases that persisted for 5 years and were at a level of 3% to 15% of the actual total catch. If the bias was only for recreational catch that was small relative to commercial catch, or if the change in catch estimates was random from year-to-year (hence tending to average out), then less sensitivity in model results would occur.