IPHC STOCK ASSESSMENT -RETROSPECTIVE PATTERN OF PROJECTING BIOMASS ESTIMATES (2002-2011)

IPHC REPORT OF ASSESSMENT AND RESEARCH ACTIVITIES 2011

"**A retrospective pattern dating back at least to 2004 has continued to persist through 2011 and has resulted in stock assessment estimates of exploitable biomass (EBio) that show downwards revisions of biomass during successive years of up to 39% of the initial estimate.** Due to this retrospective pattern, coastwide realized harvest rates have been up to 62% higher than target harvest rates for some recent years. The performance of the harvest policy relative to reference points is also affected by the retrospective pattern. The revised female spawning biomass time trajectory is estimated to have dropped below the 30% (relative to unfished) threshold for five consecutive years (2005 to 2009).

"Downward revisions of original estimates for 2006, 2007, 2008, 2009 and 2010 EBio are on the order of 25% to 39% one to five years following the assessment year (Fig. 6)."

IPHC REPORT OF ASSESSMENT AND RESEARCH ACTIVITIES 2012

"The 2012 assessment indicated that the Pacific halibut stock has been declining continuously over much of the last decade as a result of decreasing size-at-age, as well as poor recruitment strengths. The population decline is estimated to have slowed and the stock trajectory is now relatively flat at 35% of the reference level, just above the harvest policy threshold (30%). **Despite reductions in harvest levels in 2011 and 2012, the assessment estimates that, in retrospect, harvest rates have been well above the coastwide targets implied by the current harvest policy.** The 2013 estimate of exploitable biomass is 186.49 million pounds, significantly smaller than the 2011 estimate of 260 million pounds.

The most pressing issue to resolve for 2012 was the pronounced retrospective pattern (Fig. 26) observed among recent Pacific halibut stock assessments (Clark and Hare 2006b, 2007, Hare and Clark 2008, Hare 2009, 2010, 2011). This retrospective pattern resulted in each stock assessment estimating a lower absolute stock level than the previous assessment, which can have strong potential implications for harvest policy (Valero 2011). However, it is difficult to correct adequately for such a bias when the cause is unknown.

The retrospective pattern was clearly evident within the 2011 model (the wobblesq configuration, on which most of the 2011 results were focused) when evaluated by sequentially removing the terminal year of data and re-estimating the time-series of spawning biomass (Fig. 27). As was documented in the 2011 assessment, the retrospective bias in stock size was a direct result of transient **overestimation of incoming year-class** strengths during the period for which they were relatively poorly informed by the data but contributing significantly to the spawning biomass.

AREA 4CDE HALIBUT BIOMASS ESTIMATES

YEAR	Biomass[1]	Biomass[2]	%Diff	4CDE FCEY
2002	66 Mlbs	57 Mlbs	**12%**	4.45 Mlbs
2003	74 Mlbs	52 Mlb	**30%**	4.45 Mlbs
2004	47 Mlbs	44 Mlbs	**6%**	3.79 Mlbs
2005	34 Mlbs	30 Mlbs	**11%**	3.99 Mlbs
2006	37 Mlbs	30 Mlbs	**19%**	3.55 Mlbs
2007	37 Mlbs	24 Mlbs	**35%**	4.10 Mlbs
2008	31 Mlbs	21 Mlbs	**32%**	3.89 Mlbs
2009	34 Mlbs	22 Mlbs	**35%**	3.46 Mlbs
2010	37 Mlbs	20 Mlbs	**46%**	3.58 Mlbs
2011	35 Mlbs	19 Mlbs	**46%**	3.72 Mlbs

Biomass[1]-Expoitable Biomass estimate from annual reports (2002-2011).
Biomass[2] –Exploitable Biomass estimate from 2014 assessment (retrospective analysis)
% Diff- between the overestimated biomass from the model compared to the retrospective analysis.
FCEY- the final harvest limit

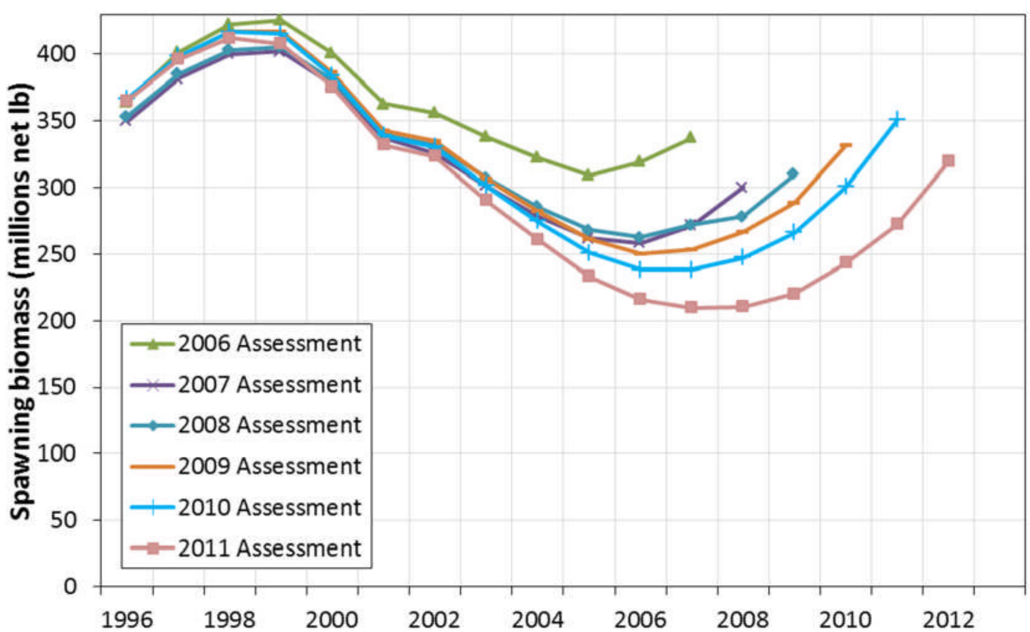


Figure 26. Retrospective analysis among recent stock assessments.

Harvest policy considerations on retrospective bias and biomass projections

Juan L. Valero Abstract (IPHC REPORT OF ASSESSMENT AND RESEARCH ACTIVITIES 2011)

Different methods for assessing stock trends and status as well as different harvest policy approaches have been used in the management of Pacific halibut. The current harvest policy relies on a constant target harvest rate of 0.215, except for areas of specific concern where the target harvest rate is 0.161. The target harvest rate is applied to a coastwide estimate of exploitable biomass that is partitioned by regulatory area based on IPHC survey weight-per-unit of effort. A retrospective pattern dating back at least to 2004 has continued to persist through 2011 and has resulted in stock assessment estimates of exploitable biomass (EBio) that show downwards revisions of biomass during successive years of up to 39% of the initial estimate. Due to this retrospective pattern, coastwide realized harvest rates have been up to 62% higher than target harvest rates for some recent years. The performance of the harvest policy relative to reference points is also affected by the retrospective pattern. The revised female spawning biomass time trajectory is estimated to have dropped below the 30% (relative to unfished) threshold for five consecutive years (2005 to 2009). Had the female spawning biomass been estimated below 30% at the time, a reduction in the target harvest rate to up to 0.14 would have been triggered following the current harvest control rule. Alternative ways are proposed to factor the retrospective issues in the harvest strategy. One way forward is to adjust the current target harvest rates downwards by a factor equal to the observed departure between original estimates of exploitable biomass and successive downwards revisions. Downward adjustment of current target harvest rates by 39% would result in revised target harvest rates of 0.131 (down from 0.215) for all of Area 2 and Area 3A and 0.098 (down from 0.161) for all of Area 4 and Area 3B. Another approach to addressing this retrospective pattern is to adjust target harvest rates based on departures between estimated realized harvest rates and target harvest rates. Downward adjustment of current target harvest rates would result in revised target harvest rates of 0.134 (down from 0.215) for all of Area 2 and Area 3A and 0.100 (down from 0.161) for all of Area 4 and Area 3B. Five-year biomass projections that incorporate continuing declines in size at age, downward revisions of recruitment estimates and adjusted initial conditions to take into account retrospective bias result in stable or decreasing EBio depending on harvest rate levels. Adjusting initial conditions for retrospective bias does result in SBio being below the 30% biomass reference point threshold at the start of the projections. Depending on the assumed realized harvest rate levels during the projection time SBio is expected to remain below or to be above the 30% reference biomass threshold by 2017.

Performance of target harvest rates relative to realized harvest rates

Current target rates have been determined by simulation modeling that incorporates uncertainty in density-dependent growth responses, future levels and distribution of recruitment among areas, stock and environmental relationships, and selectivity curves (Clark and Hare 2006). departures from the target harvest rates is the result of the misspecification of closed-area assessments Uncertainty in the annual stock assessment (other than random observation error on biomass estimates) was not incorporated in the simulations that form the basis of the current harvest strategy, nor has management uncertainty such as potential differences between recommended and established catch levels (Clark and Hare 2006). A recent review of the IPHC stock assessment and harvest policy (Francis 2008) pointed out that assuming that the realized harvest is the same as the target harvest could be a potential weakness of the current harvest policy. In response to the review, auto correlated errors in the assessment were included in the simulations and it was reported that the effect was relatively minor and that it was expected to result in a more frequent triggering of target harvest rate reduction (Hare and Clark 2008a). An example of realized harvest rate. In summary, area specific closed-area assessments were biased high because the main assumption, that of a closed population, was violated due to ongoing migration of halibut between areas. Misspecification in the closed-area stock assessments resulted in realized harvest rates, estimated by recent coastwide stock assessments with survey-partitioned biomass, as much as three times higher than the target in areas 2B and 2C and as low as half the target harvest rate for Area 4 during part of the last decade (Fig. 2). Estimated coastwide realized harvest rates have increased from a low of 0.14 in 1997, the earliest year estimated by the current stock assessment, to a high of 0.32 in 2007. Following the implementation of the coastwide assessment with survey-partitioned biomass realized harvest rates declined to 0.24, as estimated for 2011 by the assessment at the end of 2011.

An important caveat should be noted regarding the most recent estimates of realized harvest rates. It is common for most (if not all) age structured stock assessment models, to produce more uncertain estimates for the most recent year in comparison to estimates for previous years. There is greater uncertainty in the most recent stock assessment year because earlier years are informed by more years of data, allowing for better tracking of cohorts as they pass through the fishery, while the most recent annual estimates have much less data. Furthermore, each year the assessment estimates population quantities (biomass, numbers at age, etc.) not only for the latest year, but also for all previous years included in the model. The re-estimation of values by subsequent assessments can be random (reflecting mainly observation errors) or can show patterns of consistent, systemic downwards or upwards revisions of previous estimates. Such systematic revisions are termed retrospective patterns and the assessment model is said to have a retrospective problem (Legault 2009). The retrospective problem has been described as a systematic inconsistency among a series of estimates of population size, or related assessment variables, based on increasing periods of data (Mohn 1999). Retrospective patterns can arise for many reasons (NRC 1998, Legault 2009) including bias in the data (e.g., catch misreporting, unaccounted for mortality) or different types of model misspecification. Some types of model misspecification could be due to parameters that are assumed to be constant/variable in the analysis but are variable/constant, as well misspecification of commercial and/or survey catchability and/or selectivity (Parma 1993, Parma and Sullivan 1996). As reviewed by NRC (1998) and Legault (2009), early abundance estimates can be consistently biased (either upward or downward) with respect to corresponding estimates obtained in later assessments (e.g., some Northwest and Northeast groundfish stocks, Pacific halibut, North Sea sole). In some cases, such as with Pacific halibut, the retrospective pattern can change in direction, from underestimation to overestimation of biomass (Parma 1993). Risk associated with management actions when facing underestimation or overestimation of biomass are different depending on the emphasis of management goals. Consistent underestimation of biomass can lead to sub-optimal use of fishery resources (NRC 1998, Legault 2009). Extreme cases of consistent overestimation of stock abundance can have severe management consequences as illustrated by the collapse of the Newfoundland northern cod and management issues on the Georges Bank yellowtail flounder (Walters and Maguire 1996, Walters and Pearse 1996, Walters and Martel 2004, NRC 1998, Legault 2009).

The coastwide stock assessment of Pacific halibut has been showing a consistent retrospective pattern since at least 2004, by which previous estimates of exploitable biomass (Fig. 3) are estimated to be smaller in subsequent assessments (see Clark and Hare 2006, 2008; Hare 2011, 2012). A recent external review of the IPHC stock assessment and harvest policy reported that the main problem with the current assessment was the significant retrospective bias (Medley 2008). A concurrent external review (Francis 2008) stated that it can be difficult to decide whether a retrospective trend is of concern, indicating a serious flaw in the stock assessment model structure, or if the retrospective trend is the result of a random pattern of residuals around the observations. The probability of occurrence of a set of consecutive random observations can be calculated by assuming that for each year there is a 50% chance that the estimate of biomass from previous year's stock assessment is revised downward and then multiplying the combined probability for all years with the observed pattern. During the external reviews data were available through 2007 and the retrospective coastwide fits were only available for three years (2004, 2005 and 2006). By random chance alone the probability of observing a downward revision of the previous year's biomass estimates two years in a row, such as the pattern observed by the external reviewers, is 25%. By random change alone the probability of observing a downward revision of the previous year's biomass estimates five years in a row, such as the pattern observed in the stock assessments through 2008, is 3%. By random chance alone the probability of observing a downward revision of the previous year's biomass estimates eight years in a row, such as the pattern observed in the stock assessment through 2011, is 0.4%.

Stock assessment documents noted the retrospective pattern in the coastwide assessment since 2007, when it was stated that the stock assessment "had not tracked very well for the last few years" (Clark and Hare 2008). Subsequent stock assessment documents described the retrospective pattern as relatively small or modest and that the trend of successively lowering all earlier EBio estimates had greatly tapered off, along with a consideration that the retrospective behavior did not weaken the assessment in any way (Hare and Clark 2009, Hare 2010, 2011).

There are alternative approaches to quantify and analyze retrospective bias in stock assessment models (Legault 2009). One approach is the within-model retrospective analysis, done by sequentially removing one year (or different set of years) of data from the latest assessment. This approach is mostly used to diagnose potential sources of retrospective bias. Another approach is the historical retrospective analysis, using the actual annual assessment estimates at the time each assessment was done. This report focuses on historical retrospective analysis and the range of years used reflect the availability of historical annual coastwide stock assessments (2006 to 2011). The historical retrospective analysis is most useful when comparing the performance of management actions and harvest strategy in the face of retrospective revisions of the actual management quantities as originally estimated in each assessment year, rather than those estimated by sequential removal of data if using the within-model retrospective approach.

Inspection of the successive historical estimates of exploitable biomass (Fig. 3, Top), spawning biomass (Fig. 3, Bottom) and total biomass (Fig. 4) extracted from published stock assessments documents shows ongoing retrospective patterns. The magnitude of the retrospective pattern for the last year of the stock assessment's estimated EBio has resulted in downward revisions of the initial EBio estimate of 14% in 2008, 15% in 2009, 18% in 2010 and 25% in 2011 in the first year following the assessment. As an example, the 2009 stock assessment estimated the 2010 EBio at the beginning of the year to be 334 M lb. Therefore, the 2010 yield calculations were based on this 334 M lb estimate of EBio. However, the 2009 stock assessment estimate of EBio in 2010, 334 M lb, was revised down to 275 M lb (a decline of 18%) in the 2011 stock assessment. Yield calculations ultimately consist of multiplying target harvest rates times the estimated EBio for the year following the assessment. The 2010 catch has already been taken and is therefore fixed, even if the originally estimated EBio is revised downwards in future assessments. Continual downward revisions of EBio result in a consistent, ongoing upwards revision of realized harvest rates. This retrospective pattern affects the performance of biomass projections conducted following past (Fig. 3) and recent (Valero 2011, 2012) assessments. Biomass projections conducted in the recent past consistently indicated a quick turnaround of ongoing biomass declines and a fast biomass increase, only to be revised downwards and estimated to continue the declining trend by subsequent assessments.

The performance of the harvest policy relative to reference points is also affected by the retrospective pattern. For example, Hare (2011) notes that the revised female spawning biomass time trajectory seems to have dropped slightly below the spawning biomass (SBio) threshold (30% relative to unfished). Given the retrospective bias and resulting overestimation of spawning biomass estimates the revised spawning biomass trajectory is estimated to have been below the 30% threshold during five consecutive years, 2005 to 2009. Had the female spawning biomass been estimated below 30% at the time, a reduction in the target harvest rate would have been triggered during 2005-2009 following the current harvest control rule (Fig. 5). These target harvest rate reductions (Fig. 5) should have been between 0.186 for 2005 and 0.14 for 2007 (Fig. 5).

Factoring retrospective issues in the harvest strategy

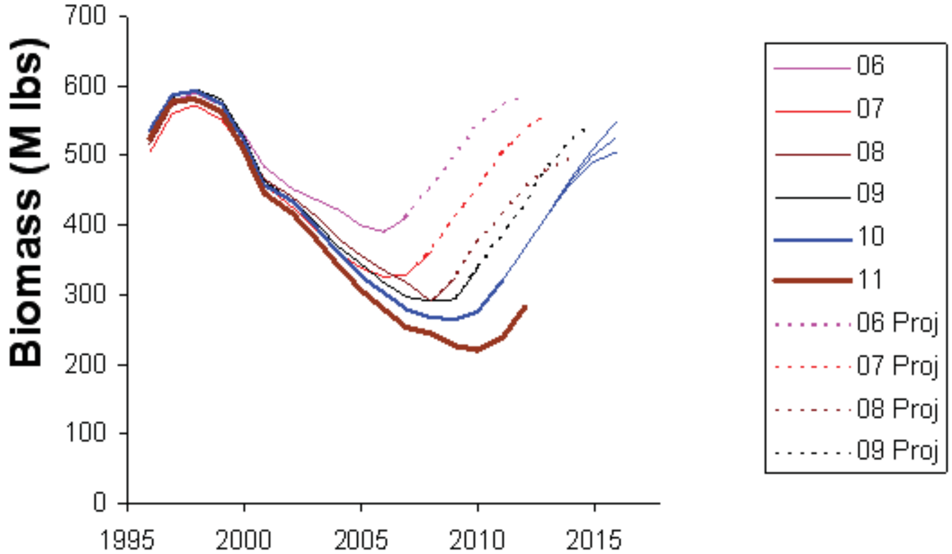
Consistent retrospective bias is indicative of problems in the specification of the stock assessment model (either the model itself or its use of available data). Therefore, conventional model-based measures of uncertainty of management parameters are not realistic because they are based on the structural assumptions of the model being correct (NRC 1998). Consistent retrospective bias can lead to biased management advice and could lead to continued overfishing of stocks, and loss of potential yield (Legault 2009). A direct approach to deal with retrospective biases is to identify the processes responsible for it and to address them in the stock assessment model structure and/or its use of available data. Identifying the ultimate driving process/processes of retrospective patterns has proven difficult for most stocks where it is present (NRC 1998, Mohn 1999, Legault 2009) and the provision of management advice in the intervening time can be challenging.

Alternative approaches to take into account retrospective issues in the provision of management advice have been developed in the fisheries context, including adjustment factors based on consistent past retrospective errors patterns applied to correct the estimates used for management (e.g., Showell and Bourbonnais 1994, NRC 1998, Haist 2008, Legault and Terceiro 2008). As an example, if original estimates of abundance were estimated to have been 40% above the subsequently revised estimates, current estimates could be adjusted downward by 40% to compensate, assuming that similar bias would also be present in the last year's estimate of abundance. Showell and Burbonnais (1994) applied this approach in the assessment of Scotian shelf silver hake populations and associated stock projections. Although ad hoc, downward adjustment of abundance estimates to account for retrospective patterns have been considered a sensible precautionary approach in cases of consistent overestimation of abundance (NRC 1998). Legault and Terceiro (2008) analyzed alternative approaches to adjusting projections for groundfish assessments, including reductions of fishing mortality and adjusting downwards the end of year/start of projection numbers produced by the assessment, these methods were considered appropriate to use for projections and were expected to minimize bias in the projections (Haist 2008). Accounting for downward revisions of past estimates has been incorporated into recent projections of coastwide biomass for Pacific halibut (Valero 2011, 2012). However, the impact of the retrospective pattern of persistent overestimation of EBio and resulting underestimation of realized harvest rates have not been incorporated into the IPHC harvest policy. A potential way forward is to adjust downwards current target harvest rates by a factor equal to the observed departure between original estimates of EBio and successive downwards revisions. Downward revisions of original estimates for 2006, 2007, 2008, 2009 and 2010 EBio are on the order of 25% to 39% one to five years following the assessment year (Fig. 6). However, for the available years, declining estimates of EBio have not stabilized and reductions in the estimates are still ongoing. As an example, an earlier version of this analysis used estimates up to the ones provided by the assessment at the end of 2010. The largest one year downward revision of EBio was 18%, and the largest cumulative downward revision was around 30%. Including the latest available assessment (at the end of 2011) brings the largest one year decline to 25% and a cumulative decline of almost 40% from earlier estimates. Therefore, a working value of at least 39% downwards adjustment to the target harvest rate seems appropriate. In view of the ongoing decline of EBio estimates since 2006, with no evidence of stabilization for the earliest estimates the downwards adjustment could be higher and the proposed adjustment should be viewed as being in the lower range of potential adjustments. Downward adjustment of current target harvest rates by 39% would result in revised target harvest rates of 0.131 (down from 0.215) for all of Area 2 and Area 3A and 0.098 (down from 0.161) for all of Area 4 and Area 3B.

Another approach is to adjust target harvest rates based on departures between estimated realized harvest rates and target harvest rates. This attempts to capture not only departures due to retrospective problems but also due to implementation error of the target harvest rate due, for example, to departures between recommended and accepted catch limits, application of harvest control rule adjustments such as the recently modified Slow Up-Fast Down. Realized harvest rates from the coastwide assessment with survey partitioned biomass have been estimated around 0.30- 0.32 (excluding the most recent estimates of realized harvest rates since the most recent estimates are the most uncertain) (Fig. 7). Similarly to the non-converged declines in original Ebio estimates, it can be expected that some of the realized harvest rate estimates will continue to be revised upwards. Therefore, a working value of 0.32 seems appropriate. This would imply realized harvest rates 62% higher than the target. Downward adjustment of current target harvest rates by 50% would result in revised target harvest rates of 0.143 (down from 0.215) for all of Area 2 and Area 3A and 0.107 (down from 0.161) for all of Area 4 and Area 3B.

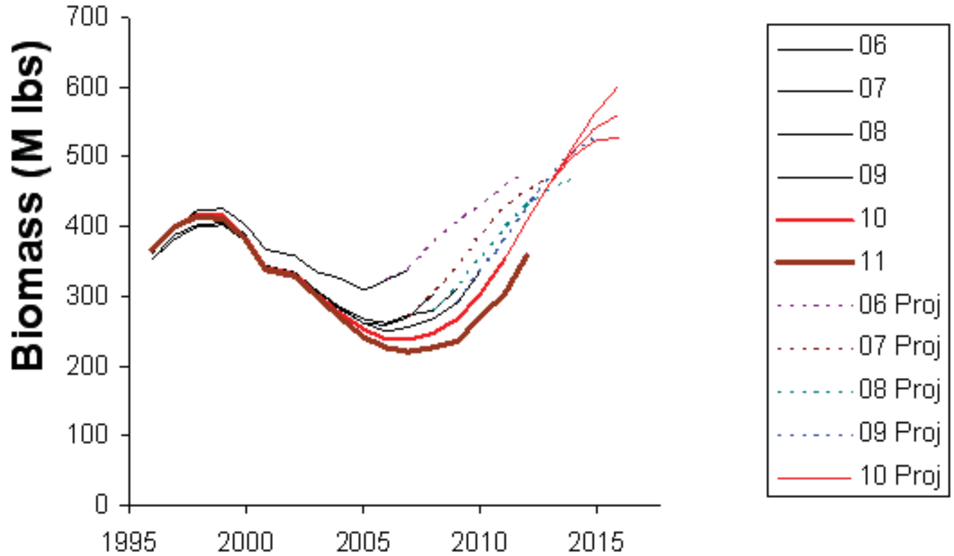
It is important to keep in mind that these potential modifications to the target harvest rate are not a reduction of the originally intended target harvest rates determined by the simulation work (Clark and Hare 2006, originally 0.2, revised recently to 0.215). Instead, these are adjustments to take into account factors, such as retrospective issues and implementation errors that were not included in the original development of those target harvest rates. If the observed patterns leading to the consistent departure between realized and target rates as well as the ongoing downwards revision of EBio continues, then applying the adjustments is expected to reduce the magnitude of departures between realized and target harvest rates. On the other hand, if the observed retrospective patterns and departures between realized and target rates disappear or changes, then the proposed adjustments could be removed (Table 1). Potential outcomes under different decisions regarding adjusting or not current target rates are illustrated in Table 1. The axis of potential future states that we have no control on are listed as hypothesis on the future retrospective behavior of population estimates. The expected outcomes from making a particular decision under the different hypothesis are yield, conservation risk and potential realizations of harvest rates. For example: if the decision is to adjust target harvest rates and overestimation continues (with associated decline in biomass), the potential outcome is to have lower yields in both short and long terms, but with the expectation of reducing differences between realized and target harvest rates. On the other hand, if the decision is to continue to use status quo target harvest rates and overestimation continues, the outcome expected is the continuation of realized harvest rates higher than target harvest rates. Adjusting target harvest rates in the event of a change in retrospective downwards revision of biomass is expected to result in foregone yield in the short term. However, such change in the retrospective pattern would be expected to result in a re-evaluation of adjustments and eventual return to unadjusted target harvest rates.

EBio



Biomass (M lbs)
0
100
200
300
400
500
600
700
1995
2000
2005
2010
2015
06
07
08
09
10
11
06 Proj
07 Proj
08 Proj
09 Proj

SBio



Biomass (M lbs)
0
100
200
300
400
500
600
700
1995
2000
2005
2010
2015
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