Projections of Pacific halibut coastwide exploitable biomass using different methods and assumptions

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Abstract

At the request of industry, the IPHC has reported five-year projections of Pacific halibut exploitable biomass following the last year of annual stock assessments since 2005. Uncertainty included in the projections has included stochastic variability around future recruitment based on recruitment estimates from 1996-2007. In addition, previous biomass projections have included the effect of different harvest rates. This document presents projections under alternative assumptions, including changes in size-at-age, downward revisions of previous cohort strength estimated in subsequent stock assessments, uncertainty around the numbers at age at the start of the projection period, and different realized harvest rate levels. The status quo method results in projected exploitable biomass (EBio) increases between 60% and 70% over the 2011 estimated EBio by the end of the five-year projection under a realized harvest target rate equal to the target of 0.2, depending on the recruitment level. Alternative EBio projections assuming either declining size-at-age or downward revision of past cohort strength, such as those observed at least since the 2006 stock assessment; result in more modest increases (18% and 23%) of EBio during the five-year projection period. The combined effect of declining size-at-age and downward revisions of estimates of previous cohort strength results in a 5-year projected EBio decline of 12% assuming average recruitment (based on estimates from 1996-2007), the target harvest rate, and no uncertainty in the initial numbers at age. A 5-year projected decline of 31% from the 2011 EBio results when incorporating an observed pattern of downward revisions of the projected initial numbers at age and average recruitment. Results presented in this work are based on population numbers estimated from the stock assessment conducted at the end of 2010 for illustration of methods and assumptions; a similar analysis will be conducted for the 2011 cycle.

Introduction

Prior to 2005, the IPHC staff had not presented biomass projections due to its belief that the projections were not necessarily reliable and subject to realized harvest rates. In 2005, the staff did present biomass projections in as part of the harvest policy analysis (Clark and Hare 2005). The six-year projections of biomass (exploitable and spawning) were done in conjunction with an analysis of harvest rates. At the request of industry, the IPHC staff began providing five-year biomass projections following the annual stock assessments since 2005 (Hare and Clark, 2006, 2007, 2008; Hare 2010, 2011). Area-specific projections were based on closed-area assessments for 2005 and 2006 (Hare and Clark, 2006, 2007), and coastwide projections have been based on a coastwide assessment conducted since 2006 (Hare 2011). The status quo methodology for projections operates upon several premises. First, the projections start with the estimated numbers at age in the last year of the assessment, projecting those numbers forward assuming that size-at-age will be the same as during the last year of the assessment. The status quo methodology also assumes that the numbers at age at the start of the projections are accurately estimated (i.e., that they have no bias). A further assumption is that the ongoing pattern of downwards revisions of previous cohort strength will not continue to occur during the projection period. The final assumption is that the future realized harvest rate will be equal to the target harvest rate. In summary, the status quo projection method assumes that population processes (i.e., size-at-age, gear selectivity, natural and fishing mortality, etc.) are stationary. It also assumes that the population estimates dependent upon these population processes (i.e., estimates of past cohort strength, initial numbers at the start of projections, exploitation rate, etc.) are accurately (i.e., no bias) captured by the stock assessment model. That is, the status quo method assumes that the current population processes and estimates will not be revised. However, observed trends in population estimates bring into question the plausibility of some of the above assumptions and projections under alternative assumptions are a prudent consideration.

Changes in size-at-age

Age and size data collected since the 1920s shows large changes in size-at-age of Pacific halibut (Clark et al. 1999). Since the 1980s, the overall changes show a general decline in size-at-age across ages, sexes, and areas. This decline may potentially affect halibut length and weight relationships at age, calculated by a time invariant weight-at-length curve (Clark 1992). The decline in halibut length-at-age results in a reduction of the fraction at age selected to the commercial gear, given that commercial selectivity has been assumed to be determined by halibut length and modeled as a function of only length since 2003 (Hare 2011, Clark and Hare 2006).

Downward revisions of past cohort strength

The halibut stock assessment estimates coastwide recruitment as numbers of age eight halibut in the year of the assessment (Hare 2011). Each year since the 2006 assessment (the first year of the coastwide assessment) initial recruitment estimates have been revised downwards in subsequent years, at least for year classes where at least five subsequent estimates are available. The most recent recruitment estimates are expected to be more variable (not only for halibut, but also for stock assessments in general) since the assessment model has had only a few years to gauge their numbers and their selectivity is small. Consequently, the most recent recruitment estimates are not used in calculations such as the estimation of reference points in halibut management (Clark and Hare 2006). On the other hand, the earliest estimates of recruitment have a relatively small effect on recent and future population numbers since those year classes constitute a small fraction currently in the population. The downward revisions of year classes between 1988 and 1993 are smaller than the revisions after 1994 (Fig. 5). A range of ages between 12 and 17 have a relatively large contribution to exploitable biomass and yield in 2010 as expected in a simple yield per recruit analysis. The 12-17 age range corresponds to year classes between 1994 and 1999. The downward revisions of recruitment estimates from 1994-1999 range between 5% (1994) and 8% per year (1998), with an average of 6% per year. It is important to note that downward recruitment revisions of past year classes results in population reductions through the estimated population numbers at age corresponding to the affected year classes for subsequent years.

Retrospective down revisions of the biomass of the year used to set catches

The coastwide assessment of Pacific halibut has been showing a retrospective pattern by which previously estimates of exploitable biomass are estimated to be smaller in subsequent assessments since at least since 2004 (Valero 2012). The magnitude of the retrospective pattern for the last year estimated EBio by the assessment has resulted in annual downward revisions of the initial EBio estimate of 14% in 2008, 15% in 2009, and 18% in 2010. As an example, the beginning of the year 2010 exploitable biomass (EBio) was estimated to be 334 M lb in the 2009 stock assessment. The 2010 yield calculations were based on the 334 M lb estimate of EBio. However, the original 2010 estimate of 334 M lb was revised down to 275 M lb (a decline of 18%) in the 2011 stock assessment. The status quo projection methods used to date rely on initial numbers corresponding to the first year after the assessment. Effectively, the initial numbers of the projection period are not directly estimated by the assessment but are calculated from the last estimated numbers. For a given assessment year, the numbers at the beginning of the following year are computed from estimates up to the year of the assessment. Numbers at the beginning of the year following the assessment are calculated using the last year values of size-at-age, gear selectivity, natural mortality, etc. As an example, the beginning of the year 2011 exploitable biomass, which is the basis for the 2011 yield calculations, is computed from the 2010 stock assessment using data through the end of 2010.

Objectives

The purpose of this work is to present projections under alternative assumptions to those used for the status quo projections. The alternative assumptions include: 1) changes in size-at-age, 2) downward revisions of previous cohort strength, 3) uncertainty around the numbers at age at the start of the projections, and 4) different harvest rate levels. Alternative assumptions are based on observed trends in population estimates from successive halibut assessments, namely a long-term declining trend in size-at-age, downward revisions of past cohort strengths and retrospective downward revisions of the biomass estimates in the year used to set catches and to initialize the projections. Part of this work was presented during the Public Session of the 2011 IPHC Annual Meeting (Valero 2011). Results presented in this work are based on the 2010 estimated population numbers for illustration of methods and assumptions, biomass projections for the 2011 cycle are reported as part of the 2011 harvest policy update (Valero 2012).

Materials and methods

The initial population numbers for the projections are the sex and age specific 2010 stock assessment estimates of halibut at the beginning of 2011 (Hare 2011), except where indicated. A constant natural mortality rate of 0.15 is used for all of the projections, the same value used in the rest of the Pacific halibut modeling work. Future recruitment is based on past halibut recruitment estimated by the 2011 stock assessment for the 1988 to 2003 year classes. Five scenarios are computed:

1) status quo (SQ),
2) reduced recruitment estimates (R_R),
3) reduced size-at-age (R_S),
4) reduced recruitment estimates and reduced size-at-age ($R_{R,S}$) and
5) reduced recruitment estimates, reduced size-at-age and reduced numbers at the start of the projections ($R_{R,S,N}$).

Salient features of each scenario are described below.

Status quo method (SQ)

Status quo projections follow the basic procedure and assumptions as the currently used method (Hare and Clark 2006, Hare 2011), namely:

1) Size-at-age is assumed to remain the same as that estimated for the last year of the assessment.
2) A constant realized harvest rate equal to the target harvest rate (HR=0.2).
3) The initial population numbers are projected without error.
4) There are no downward revisions of previous recruitment estimates.

Uncertainty in future recruitment is incorporated by using either the minimum, average or maximum recruitment estimates from the 2011 assessment (Hare 2011). In addition, the average recruitment scenario is projected under alternative harvest rates between 0.2 to 0.5.

Reduced recruitment estimates (R_R)

This alternative assumes that the observed pattern of downward revisions of past cohort strength will continue during the projection time. Cohorts (1994 to 1999) corresponding to the ages (12 to 17) that currently contribute to most of the yield have been consistently estimated to be weaker than estimates from previous assessment years, ranging from a 5% to 8% annual downward revision for the past five years (Fig. 5). Under this projection method, the numbers-at-age decrease during the projection period at 6% per year, the average observed downward revision across years and cohorts.

Reduced size-at-age (R_S)

This alternative assumes that size-at-age continues to decline during projection time at rates similar to those observed in the past. Size-at-age is reduced during the projections by the average sex and age specific declining rate observed between 2002 and 2010 (Fig. 4). The declining rate is estimated by a simple linear regression for each age and sex. Selectivity at age is recomputed for each year and sex to account for the effect of reducing size-at-age on the fixed selectivity at size (Fig. 4).

Reduced recruitment, size-at-age ($R_{R,S}$)

This alternative combines the previous two scenarios, assuming continuing downwards revisions of previous cohort strength in combination with declining size-at-age, modeled as described in the preceding scenarios.

Reduced recruitment, size-at-age and numbers ($R_{R,S,N}$)

This alternative assumes continuing downwards revisions of previous cohort strength and declining size-at-age, while starting projections at the downward revision of the estimated numbers at age. The beginning of the year 2011 numbers-at-age are revised down to account for recent downward revisions of the initial numbers-at-age for the projections, corresponding also to the first year after the assessment year and the numbers used to set catch limit recommendations for the following year. In this scenario the initial numbers at age (2011) were revised downwards 16%, the average of the downward revisions that occurred during 2008 (14%), 2009 (15%) and 2010 (18%).

Results

The status quo projection method results in EBio increases over a five-year projection period between 60% and 70% greater than the 2011 estimated EBio under a target harvest rate of 0.2, depending on the assumed recruitment level (Fig. 2). Status quo projections under higher harvest rates up to 0.5 also result in projected biomass increases during the next 5 years given average recruitment (Fig. 3). The effect of different harvest rate levels on projections is larger than the effect of different recruitment levels.

Alternative projection methods that assume either declining size-at-age (R_S) or continued downward revisions of past cohort estimated strength (R_R) result in 18% and 23% projected increases over the 2011 estimated EBio. The combined effect of declining size-at-age and revisions of cohort strength ($R_{R,S}$) results in an EBio decline of 12%, assuming average recruitment, the realized harvest rate equal to the target harvest rate, and no uncertainty on the initial numbers at age (Fig. 6). Projections incorporating continued declines of size-at-age, downward revisions of past cohort strength and downward revisions of the numbers at age at the start of the projections ($R_{R,S,N}$) result in a 5-year projected decline of 31% from the 2011 estimated EBio, assuming average recruitment (Fig. 6). The original estimate of 2011 EBio by the 2010 stock assessment was revised downwards by the 2011 stock assessment to within less than 4% of the level projected by the $R_{R,S,N}$ method at the end of 2010 (Fig. 6). The statistical, within- projection model uncertainty included in the status quo projections by way of the alternative future recruitment levels is much smaller than the potential structural, between-projection model uncertainties due to the alternative assumptions presented in this work.

Discussion

Projections of exploitable biomass over a 5-year period have been computed and presented since 2005 as part of the IPHC annual management cycle. The status quo method of doing the projections assumes that size-at-age and gear selectivity are stationary, and that the estimates of past cohort strength along with the initial numbers at the start of projections are accurately (no revisions or bias) captured by the stock assessment model. To date, exploitable biomass projections using the status quo method have performed poorly. Projected biomasses have been consistently higher than biomasses estimated in subsequent years. Furthermore, the general exploitable biomass trend has not been captured by the status quo projection method as past projections consistently indicated an increasing trend when subsequent revisions of past estimates show a consistent declining trend. Recommended catch limits are calculated on what could be called the first projection year, since it relies on projected size-at-age to update the last numbers estimated by the assessment. The status quo projections of EBio have been optimistic, resulting in recommended catch limits at higher levels than they should have been, in retrospect, given downward revisions of the EBio. The poor performance of biomass projections under the status quo method could be due to:

1) Consistent overestimation of EBio
2) Realized harvest rates that are higher than the target harvest rate, both from overestimation of EBio and departures between recommended and accepted catch limits, and application of harvest control rule adjustments such as the slow up fast down adjustment
3) Continued decline in size-at-age
4) Unaccounted mortality
5) Model misspecification

Examples of stock assessment model misspecification could include potential mistreatment of commercial and survey fishing gear selectivity type (currently fully specified by halibut size) or catchability (allowed to drift over time in both commercial and survey indices). An example of unaccounted mortality would be poor estimation of bycatch mortality in non-target fisheries, particularly in the Gulf of Alaska. The above mentioned, along with other potential processes, are not completely independent from each other and could act in combination to create the observed pattern, thus identifying the ultimate driving process/processes could prove difficult.

The purpose of this work was to present alternative methods of projecting EBio under a range of assumptions, based on observed patterns, regarding the future dynamics of the population and revisions of previous estimates during the projection time. Weights or values representing the likelihood of the alternative projection methods are not presented. However, the alternative projection methods presented capture greater uncertainty in EBio projections when compared to the status quo projection method. The uncertainty among alternative projections methods is much larger than the recruitment level variability that has been previously incorporated in status quo projections. An increased emphasis on the understanding of current population trends and status as well the performance of past projections could improve the ability to produce more reliable EBio projections. It could also provide a more realistic evaluation of the effects of alternative management actions on potential future stock trends, stock status and the performance of the harvest strategy. Results presented in this work are based on the 2010 estimated population numbers for illustration of methods and assumptions, similar analysis are conducted for the 2011 cycle (Valero 2012).

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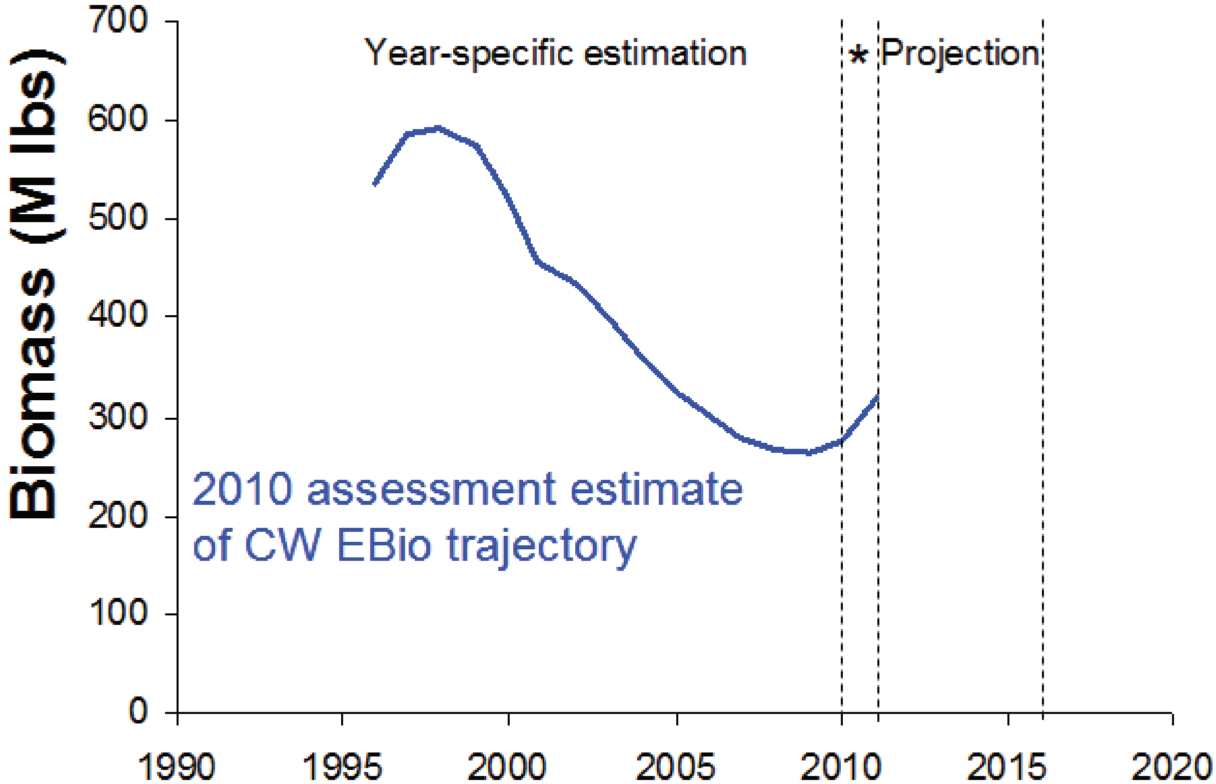

Figure 1. Coastwide (CW) exploitable biomass (EBio) trajectory as estimated by the 2010 Pacific halibut stock assessment. *The beginning of the year 2011 computed using 2010 size-at-age, selectivity, etc.

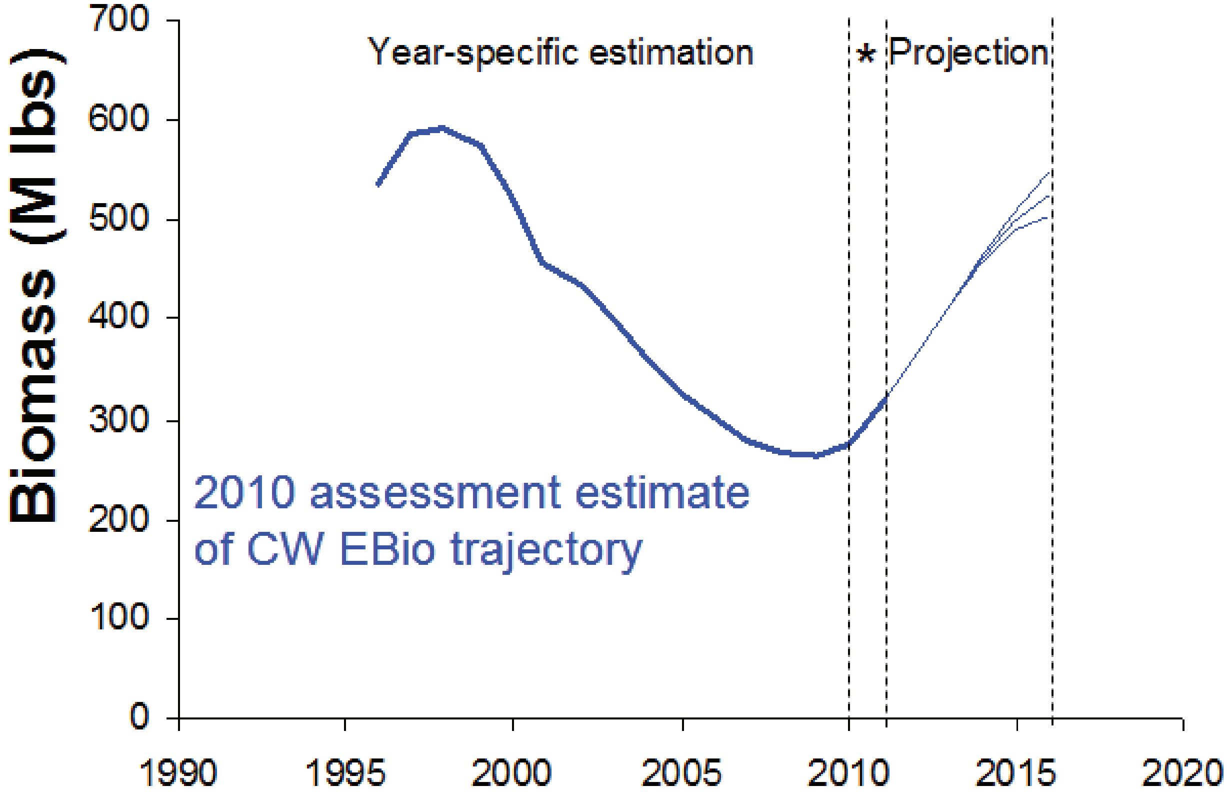

Figure 2. Coastwide (CW) exploitable biomass (EBio) trajectory as estimated by the 2010 Pacific halibut stock assessment and EBio five year status quo projections under average, minimum and maximum observed recruitment and a HR=0.2. *The beginning of the year 2011 computed using 2010 size-at-age, selectivity, etc.

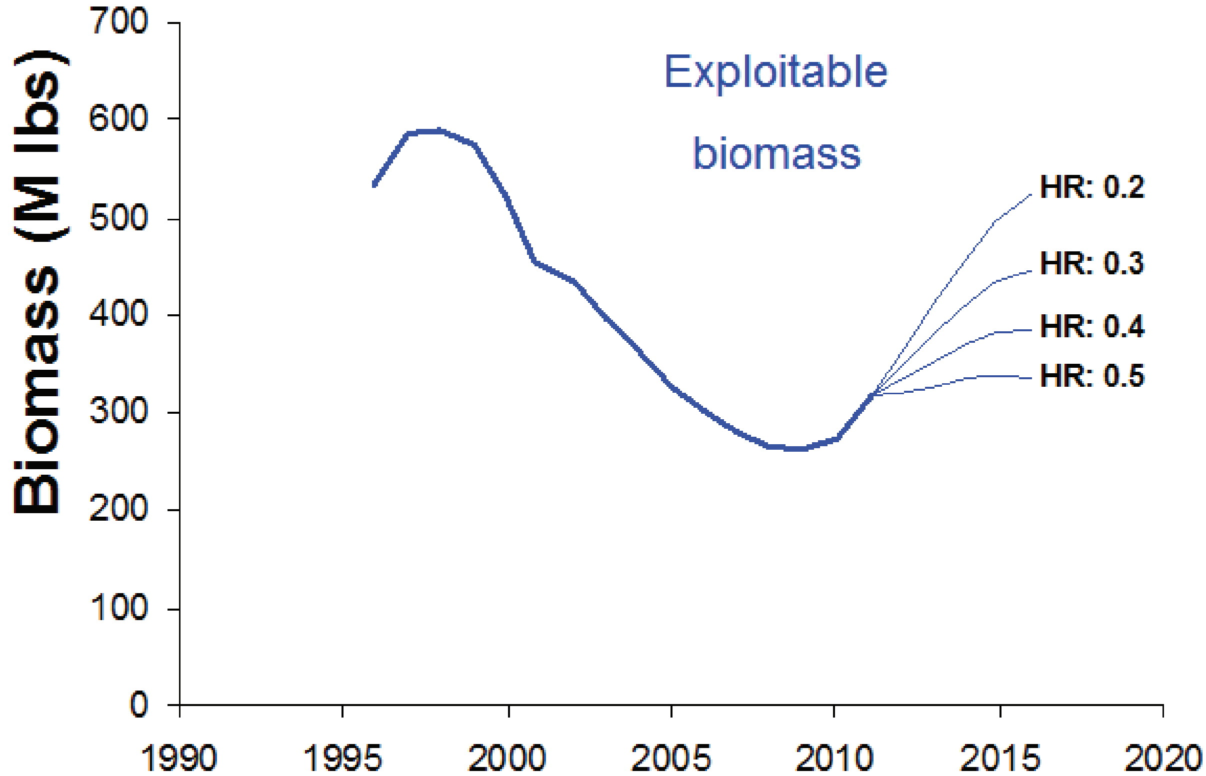

Figure 3. Coastwide (CW) exploitable biomass (EBio) trajectory as estimated by the 2010 Pacific halibut stock assessment and five-year projections under different harvest rates (HR) and average recruitment level.

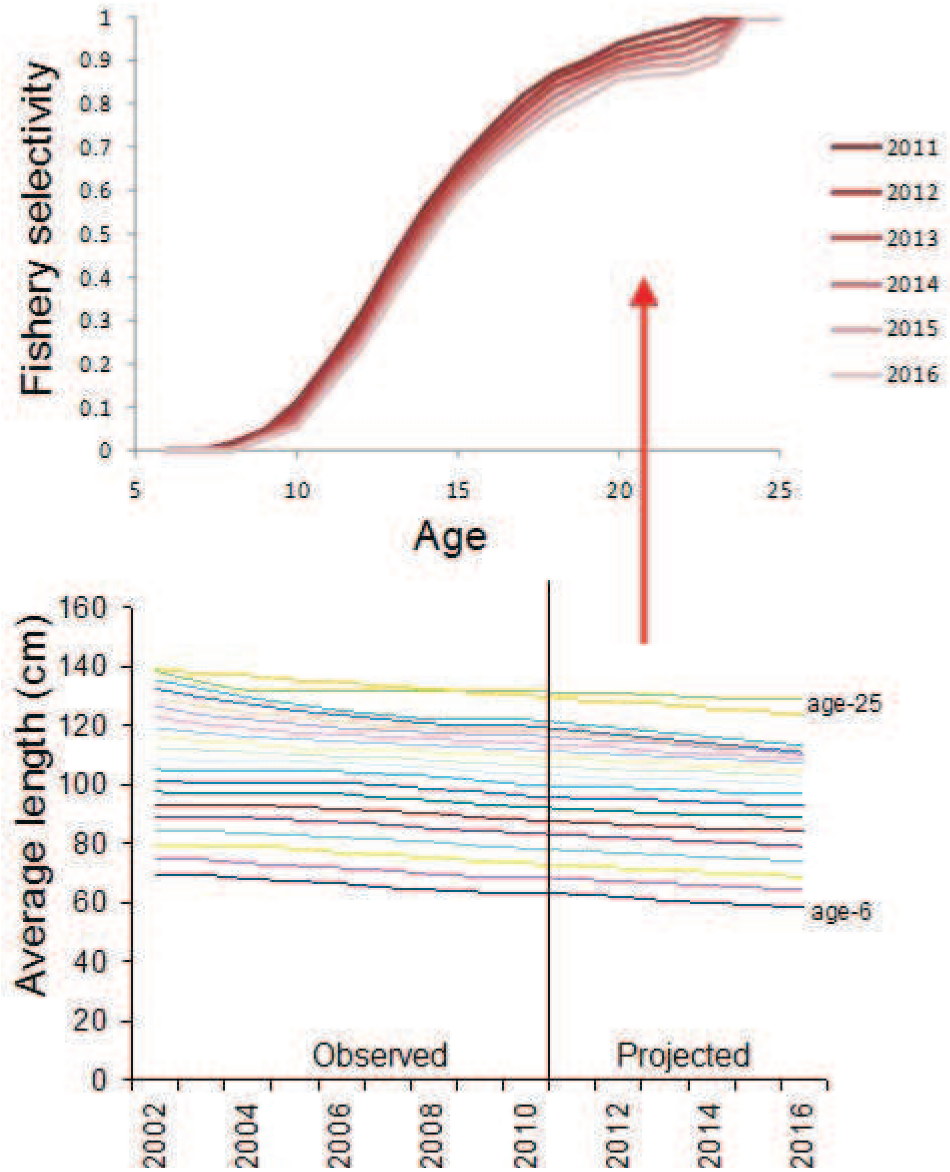

Figure 4. Observed coastwide size-at-age trajectories by age (only females shown) during 2002 and 2010. Size-at-age linearly projected for years 2012 to 2016. *The beginning of the year 2011 computed using 2010 size-at-age, selectivity, etc.

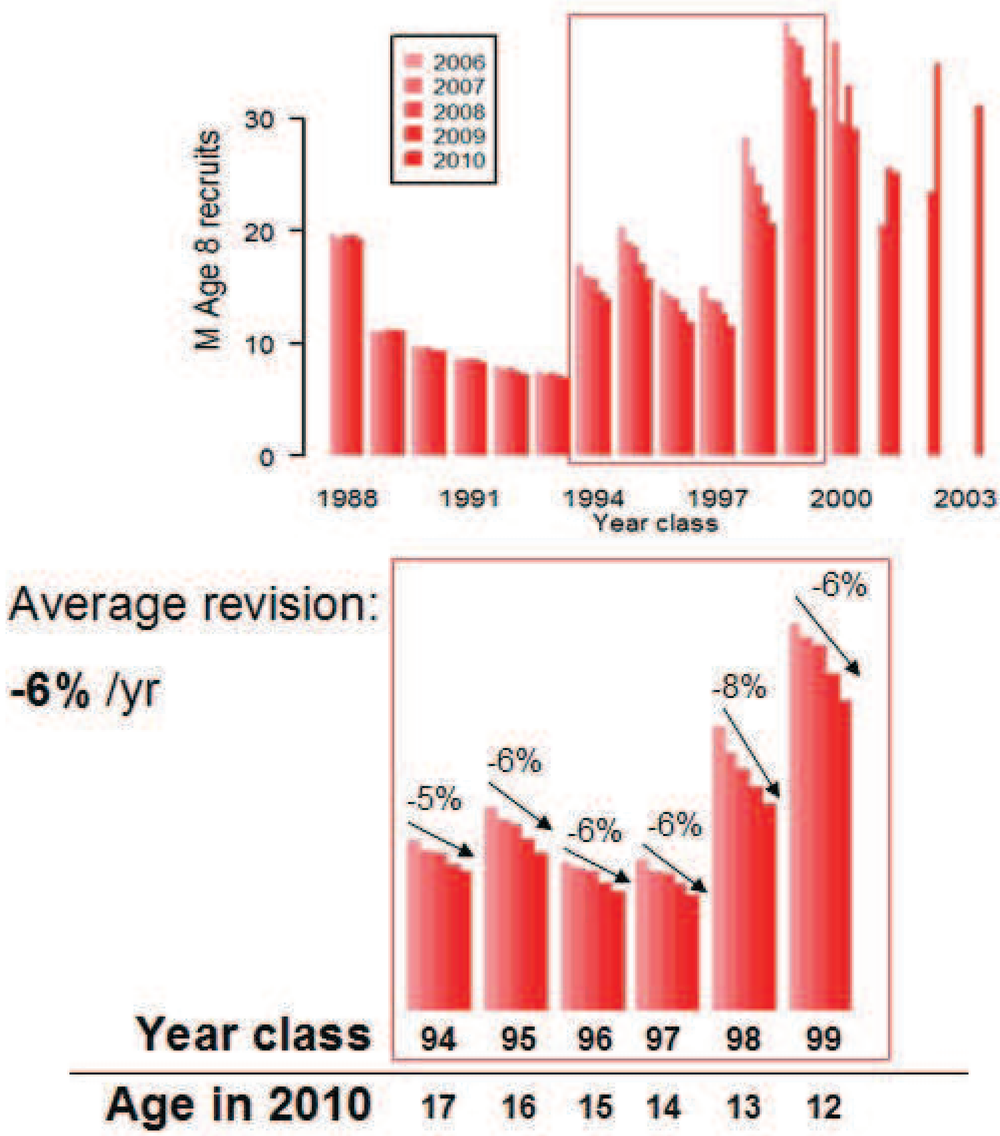

Figure 5. Downward revisions of halibut recruitment estimates (Millions of age 8 fish). Average percentage annual decline for cohorts 1994 to 1999 shown in bottom panel. Modified from Hare (2011).

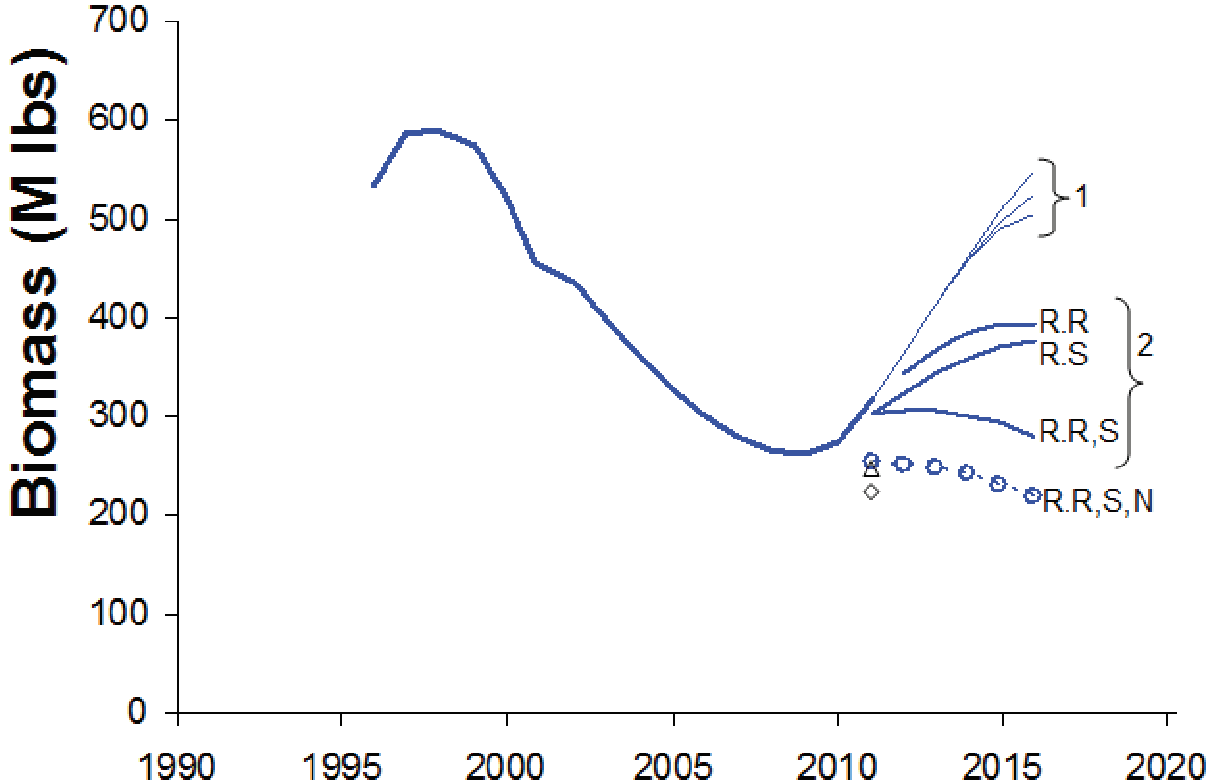

Figure 6. Coastwide (CW) exploitable biomass (EBio) trajectory as estimated by the 2010 Pacific halibut stock assessment and EBio five year alternative projections. Status quo projections under average, minimum and maximum observed recruitment and a HR=0.2. Alternative projections show only for average recruitment and HR=0.2. The beginning of the year 2011 computed using 2010 size-at-age, selectivity, etc. The triangle and romboid are updated 2011 EBio estimates from the 2011 assessment Trendless and WobbleSQ fits respectively (data from Hare 2012).