# 2020 California Halibut Stock Assessment, Executive Summary

The California Department of Fish and Wildlife (CDFW) is embarking on an evaluation of its management of California halibut (*Paralichthys californicus*). The first step of the evaluation is to develop consensus on the status of the fishery both from the ecological perspective (health of the stock and fishery impacts to the ecosystem) as well as the societal perspective (economic performance and benefits to the fishing community). We will draw on stakeholder input and a suite of CDFW scientific endeavors to achieve this first step.

California halibut have been actively fished prior to the beginning of California landings records in 1916, and support one of the largest and most valuable finfish fisheries that is under state-only management. CDFW completed the first statewide peer-reviewed **stock assessment** of the California halibut fishery and resource in 2011. As part of the **2018 Master Plan for Fisheries (Master Plan)** implementation, CDFW amended the 2011 stock assessment in 2020 to follow up on peer review recommendations and incorporate additional data and information. Both assessments treat California halibut as two separate stocks— a northern and southern stock—separated at Point Conception and bounded by the borders with Oregon and Mexico. While there is some connectivity (movement of larvae and adults) between stocks, regional differences in the biology, history of fishery regulations, and availability of data support the treatment of California Halibut as two stocks. Results of the 2020 efforts were reviewed by a panel of stock assessment and found not to be inadequate for use in management for the northern stock and needing investigation of technical issues for the southern stock. The **California Halibut 2020 Stock Assessment Review Panel Report (Panel Report)** outlines recommendations for additional data collection, analysis, and model improvements, including reconstructing historical halibut landings to reflect an unfished or nearly unfished condition and initial population estimates. A key uncertainty for each region is the stock condition at the start of the modeling period (1980 for the north and 1971 for the south). While CDFW has commercial landings information as far back as 1916, there are issues with the data such as mixing of California and Pacific halibut and inclusion of California halibut caught off Mexico (Barsky 1990). These issues, as well as a lack of data on catch-at-age and catch-at-length prior to 1970, lead to the models being initialized well into the exploitation history. CDFW is working to exploring these recommendations and improve the stock assessment over time to better understand the health of the resource.

An attempt was made to correct the older landings data to remove Pacific halibut and Mexican catches and despite uncertainty, the data do provide helpful context. Peak statewide landings in 1917 may have been as high as 3.5 million pounds whereas in 2019 they were less than 720,000 pounds (Figure 1). Landings separated by region since 1930 show that the majority came from southern California until the 1960s. Landings are now consistently higher in northern California and were substantially so during some years in the 1990s and 2000s. While landings of species with a long exploitation history can be sustainable at substantially lower levels than early, peak catches, the magnitude of the difference informs our understanding of fishery and other impacts. Regional shifts may be the result of a combination of regulatory and environmental forces that are difficult to disentangle. These are issues we hope to address with continued effort to improve the stock assessment. Below we outline the key features of both models, features that differ, their current results, sensitivity analyses, and next steps.

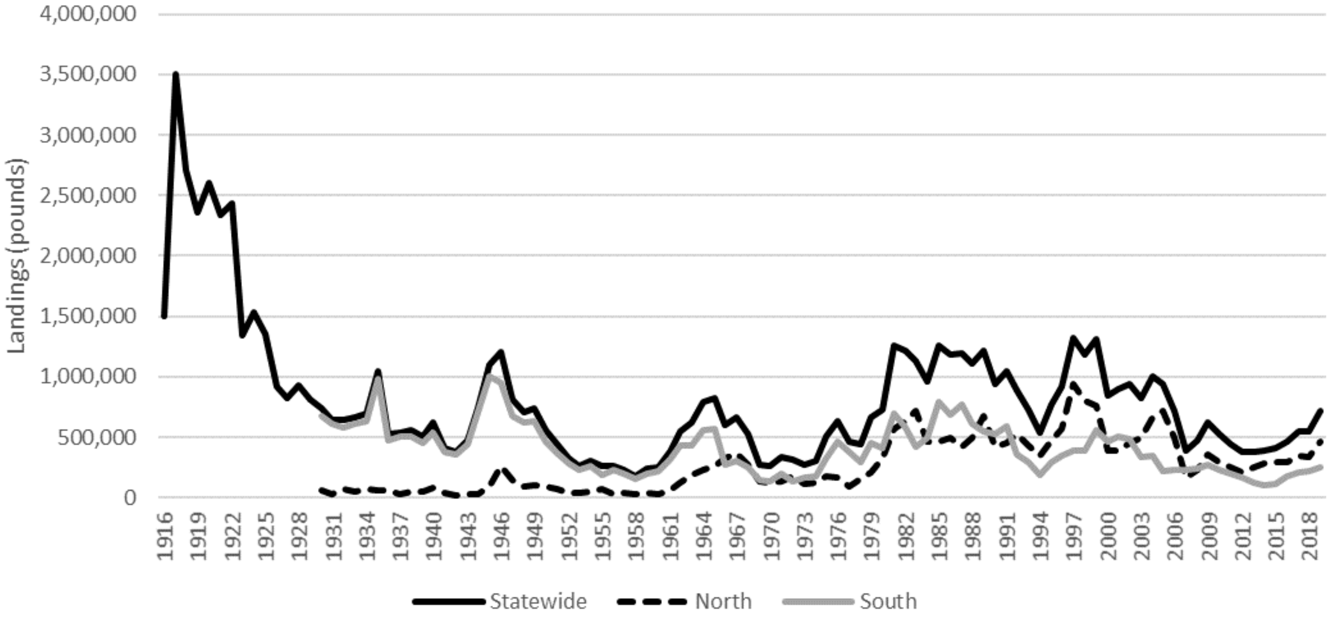

Figure 1. Preliminary reconstruction of historical California halibut landings statewide and by regions split at Point Conception.

## Features common to both models

Assessments were performed in Stock Synthesis (ver. 3.3.14) using a sex-specific, age- and length-structured statistical catch-at-age model with different natural mortality rates, growth, and selectivity parameters for males and females. The models were fit to indices of relative abundance calculated from standardized Commercial Passenger Fishing Vessels (CPFV) logbook data and standardized trawl logbook data, as well as length composition data from both recreational and commercial fisheries and age composition data from the commercial fisheries. Five fleets were modeled: three commercial and two recreational. These were commercial trawl, gillnet, and hook and line fleets as well as recreational CPFV and all other recreational take. Some of the selectivity parameters were estimated for females in each fishery, and male selectivity was fixed as an offset from females. Growth parameters were estimated externally and fixed within the models, and steepness of the stock-recruitment curve (h) was fixed at 0.9 based on expert judgement which is supported by likelihood profiling. Unfished equilibrium recruitment ($R_0$) and natural mortality (M) for each sex were estimated within the models. The models include population age bins ranging from 0 to 40 years, after which point any older predicted ages are lumped into the 40-year-old bin as a ‘plus group’. There were no age observations greater than 40. Indeed, halibut aged as more than 20 years are extremely rare.  The population and data length bins range from 10 to 140 cm in 1-cm increments, again with the max end of that range acting as a ‘plus group’.

## Southern model

### *Unique features*

Initial efforts to respond to the 2020 peer review focused on the southern model because 1) it showed greater stability across alternative model structures and had fewer technical issues compared with the northern model and 2) there is more concern over southern stock status. The current model estimates a total of 92 parameters. These include $R_0$, female and male natural mortality, 45 recruitment deviations, parameters describing the initial age composition, initial fishing mortality for each fleet, catchability for each abundance index, and selectivity parameters. During the peer review process, initial fishing mortality was estimated based on initial equilibrium catch for each fleet then fixed in subsequent model runs. The method for derivation of these initial equilibrium catches was unclear and this is particularly problematic because initial equilibrium catch represented a large component of the total likelihood. Therefore, in subsequent work responding to reviewer comments we used the initial equilibrium catches presented in the pre-review model as a prior and allowed initial fishing mortality to be estimated. Below we present results of sensitivity tests on the impact of variation in initial equilibrium catch.

Several other adjustments were made in response to the 2020 scientific peer review panel's recommendations. First, the method for model tuning was adjusted. Data weights for length and age composition of each fleet were calculated using the Francis et al. (2011) method and these point estimates were applied to all fleets for two iterations. Second, the pre-review southern model included an abundance index based on samples of larval California halibut collected in California Cooperative Oceanic and Fisheries Investigations (CalCOFI) samples. Procedures used in development of that index were unclear and therefore fitting of the model to the index and estimation of survey catchability were turned off. Finally, an error that omitted some recent gillnet landings was corrected.

*Results*

The model converged, meaning the change in log likelihood met an acceptably low threshold. Initial fishing mortality estimates for the trawl and commercial hook and line fleets were close to their lower bounds but resulted in catch estimates in the first model year close to the expected values. Natural mortality estimates for each sex were higher than their priors. Fits to the abundance indices were good with the exception of not capturing a peak in the trawl index which conflicted with a low period in the CPFV index. There were also some problematic residual patterns in the composition data for the gillnet fleet. Despite these issues, initial fishing mortality for each fleet could be estimated and final stock status was not sensitive to estimation phases.

The southern stock is estimated to be at 23.5% of unfished biomass. For reference, this is just below the Pacific Fishery Management Council target for flatfish of 25% and well above the limit of 12.5% (Figure 2). This places the stock at approximately the same status as the beginning of the modeling period in 1971. Recruitment was estimated to be low (negative deviations) for most years since 1999 (Figure 3). We are not sharing stock biomass or target yield amounts in absolute terms currently due to the need to improve the model.

Initial fishing mortality (F), natural mortality (M), and the steepness of the stock recruitment curve (h) are all tightly linked with estimated unfished and current biomass as well as to each other. Given that in this case initial conditions are uncertain, and M and h are always difficult to estimate, we explored the sensitivity of results to variation in M and h. Male and female M were fixed at +/- 20% of the base value while h was set at 0.8, 0.9, and 1, resulting in 9 model runs. There are clear relationships between M, h, depletion ($B/B_0$) and $R_0$ as would be anticipated based upon theory. Current stock status improves as M increases. Future work to increase confidence in initial conditions may allow for greater confidence in M. We also allowed M to be estimated for values of h equal to 0.8, 0.9, and 1. The estimated M, initial F for each fleet and $B/B_0$ changed very little as h changed. Finally, we varied initial equilibrium catch +/- 40% of the base value. This impacted initial F estimates as expected but had minor impact on current depletion state.

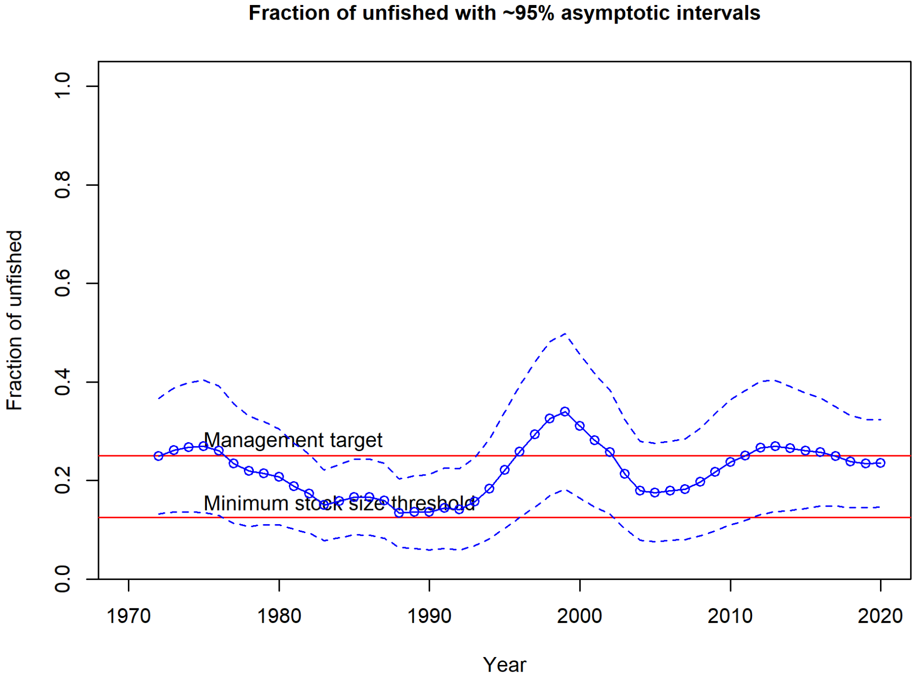

Figure 2. Time series of the southern stock status as indicated by estimated spawning biomass in a given year divided by unfished spawning biomass with 95% confidence intervals based on asymptotic variance estimates. For reference, the Pacific Fishery Management Council reference points for flatfish are a target at 25% and limit at 12.5%.

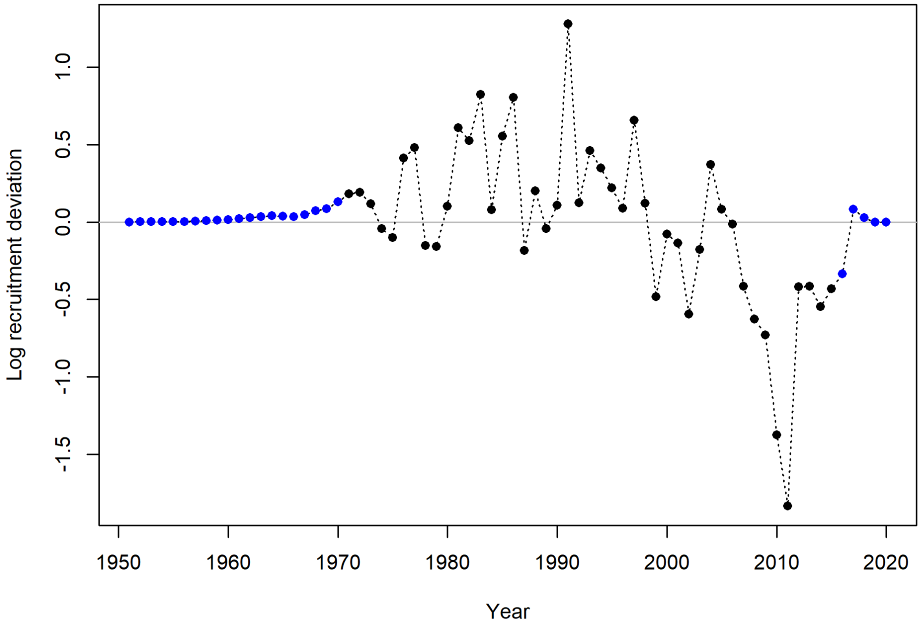

Figure 3. Southern stock recruitment deviations estimated by the model. Deviations from zero indicate recruitment higher or lower than expected by a Beverton-Holt stock recruitment relationship.

Northern model

*Unique features*

In addition to indices of abundance based on CPFV and trawl logbook data, the northern model was fit to a juvenile abundance index based on fishery independent research trawl survey data collected by CDFW's San Francisco Bay Study and the Interagency Ecological Program for the San Francisco Estuary. A total of 78 parameters were estimated including 10 selectivity parameters, $R_0$, sex-specific natural mortality, catchability for each of the three abundance indices, parameters associated with the initial age distribution, and recruitment deviations. Selectivity parameters were estimated across four of the five fleets using the double-normal option with a fixed retention curve, and a fixed male offset. The commercial bottom trawl, CPFV, and Rec-Other fleets had large enough composition sample sizes to allow the ascending limb, the peak, and the descending limb of the selectivity curve to be estimated. The gillnet fishery (discontinued in northern California since 2002) lacked compositional data entirely, so those values were fixed based on estimated values from the southern population. Many selectivity parameters for the commercial hook and line fishery tended to drift toward unrealistic values, regardless of starting values, so all but the descending limb parameter were fixed.

*Results*

The model successfully converged but was sensitive to estimation phases for key parameters and occasionally did not meet the gradient criteria when estimation phases were altered. Estimates of natural mortality increased only slightly from their priors. When allowed to be estimated, growth parameters were close to their externally estimated values. Estimated recruitment deviations were cyclical. Fits to the three indices of abundance were good except for failing to capture a few peaks. Initial Fs could not be estimated. When attempting to estimate, initial Fs hit upper boundaries while likelihood profiles over these parameters showed that the negative log likelihood was minimized at the smallest values. This contradictory result could not be resolved. Fixing initial Fs effectively predetermines the size of the population in the starting year and the choice of whether to estimate recruitment deviations prior to the start year greatly affected initial stock status. Stock status in the final year was sensitive to additive variance parameters for abundance indices suggesting data conflicts. Therefore, despite some sound results, the key output of the scale of population abundance at the model beginning and end points could not be resolved.

## Next steps

While the southern model results are more stable, both the southern and northern models require improvement prior to informing management. The primary task for both regions is to reduce the uncertainty associated with initial conditions. Staff are currently gathering the available information to reconstruct catches by region to allow for extension of the models farther back in the fishery exploitation history. For the southern model, staff will reconstruct the abundance index based on CalCOFI data to ensure it follows the best practices used in federal assessments then reintroduce it to the model tuning procedure. Addition of recent length composition data will allow for estimation of recent recruitment deviations.

## References

Barsky KC. 1990. History of the commercial California Halibut fishery. Calif. Fish Game Bull, 174:217-227.

Francis, R.C. and Hilborn, R. 2011. Data weighting in statistical fisheries stock assessment models. Canadian Journal of Fisheries and Aquatic Sciences **68**(6): 1124–1138. doi:10.1139/f2011-025