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Stock Assessment Update for the Main Hawaiian Islands Deep7 Bottomfish Complex through 2013 with Projected Annual Catch Limits through 2016

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National Marine Fisheries Service
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U.S. Department of Commerce

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ABSTRACT

A stock assessment update of the main Hawaiian Islands Deep7 bottomfish complex was conducted through fishing year 2013. This update used the previous benchmark assessment data analysis, modeling, and stock projection approaches with one major improvement in CPUE standardization. This update was conducted using up-to-date re-audited bottomfish catch and effort data from Hawaii state commercial catch reports for the years 1948-2013. Unreported catch was estimated and included in the model using the previous methods. Standardized catch-per-unit effort (CPUE) for the Deep7 bottomfish was estimated using catch and effort data from the deep-water bottomfish handline fishery. Model selection techniques were applied to select the best structural form to standardize CPUE. An important improvement to this stock assessment model is the inclusion of information on individual fishermen's skill, or license effect, to standardize CPUE from 1994-2013; this resulted in a significant increase in the explanatory power of the CPUE standardization model but did not have a substantial effect on the estimated trend in CPUE. CPUE in the model was split into two time series (1949-1993, and 1994-2013) in order to accommodate the inclusion of license effect which could only be tracked starting in 1994 when licenses became uniquely assigned to a fisher/vessel through time. A Bayesian production model was used to estimate time series of Deep7 bottomfish exploitable biomasses and harvest rates and was also used to conduct stochastic short-term projections of future catches, stock status conditions, and associated risks of overfishing in 2015-2016. These projections explicitly included uncertainty in the distribution of estimated bottomfish biomass in 2014 and population dynamics parameters. Results of the catch and CPUE analyses, production modeling, and stock projections are summarized and are used to characterize uncertainty of Deep7 ACLs for fishing years 2015-2016 assuming alternative commercial catch amounts in 2014. Overall, the Deep7 complex in the main Hawaiian Islands is not currently experiencing overfishing and is not currently depleted relative to the best available information on biological reference points, but the probability of the stock being overfished in 2013 is 45%.

INTRODUCTION

The Hawaii Deep7 bottomfish complex is a U.S. fishery management unit comprised of six species of snappers and a grouper inhabiting waters of the Hawaiian Archipelago (Table 1, Figure 1). The federal fisheries management regime includes three fishing zones: the main Hawaiian Islands (MHI) Zone, and two zones in the Northwestern Hawaiian Islands, the Mau Zone and the Hoomalu Zone. All Deep7 bottomfish fishing currently takes place in the MHI zone due to the closure of the Northwestern Hawaiian Islands under Presidential Proclamation 8031[1]. The Deep7 bottomfish complex includes a subset of seven species, the “Deep 7” (Table 1), that are the focus of this assessment and that have been a focus of fishery management measures in the main Hawaiian Islands since the archipelagic bottomfish stock was determined to be experiencing overfishing on an archipelagic basis in 2005 (Moffitt et al., 2006).

Hawaii bottomfish were targeted by native Hawaiians using deep handlines from canoes for hundreds of years before the advent of the modern fishery after World War II. The modern fishery employs similar handline gear, albeit with braided synthetic line, along with power reels to haul back gear, fish finders to locate schools of fish, and global positioning systems (GPS) and other navigational aids to find fishing grounds. Although the efficiency of the modern fishery has likely improved through time (Moffitt et al., 2011), the current Hawaii bottomfish fishery still uses traditional deep handline capture methods for commercial and recreational harvest.

Bottomfish restricted fishing areas (BRFAs) were imposed in Hawaii state waters in 1998 and revised in 2006 to conserve fishery resources. Current BRFAs cover potentially consequential areas of bottomfish habitat in comparison to areas considered to be essential fish habitat (EFH) and habitat areas of particular concern (HAPC), although BRFAs are on the order of several percent of total possible bottomfish essential fish habitat, given uncertainties in habitat classification (Table 2).

Previous Benchmark Stock Assessment in 2011

The previous assessment of Hawaii Deep7 bottomfish complex stocks in the main Hawaiian Islands through 2010 used similar commercial fishery data as in the 2008 update but included a modified treatment of unreported catch and a revised CPUE standardization. The baseline model was a biomass production model with model structure similar to the 2008 update. The treatment of the assessment data and the production model was modified to improve the approximation of bottomfish population dynamics based on recommendations from the Western Pacific Stock Assessment Review [WPSAR] report (Stokes, 2009) as well as new research information on the expected life span of opakapaka, a key bottomfish species (Andrews et al. 2011, Andrews et al. 2012).

The WPSAR recommendations for immediate consideration in the bottomfish stock assessment were (Stokes, 2009, see pp. 17-18):

1. Comprehensively explore MHI CPUE data and qualitative information in close collaboration with HDAR and fishers throughout the process. Develop credible CPUE standardization, including if appropriate alternative indices.
2. Attempt to reconstruct noncommercial catch histories, possibly in the same collaborative process used for (1).
3. Consider using meta-data to develop informative prior on Rmax. Develop prior for Binit in collaborative process above (1).
4. Assess MHI as single stock to develop population benchmarks and management parameters. Ensure appropriate sensitivity testing to CPUE uncertainty.

The 2011 bottomfish stock assessment was developed to address each of the WPSAR review recommendations within the constraints of available data and the time required to generate the assessment for subsequent fishery management purposes.

The first WPSAR recommendation was addressed by modifying the treatment of CPUE standardization. In particular, three alternative scenarios of changes in fishing power of bottomfish fishing vessels were developed. These alternatives included: (i) the baseline scenario (also labeled CPUE Scenario I) which assumed that there was a negligible change in bottomfish fishing power through time as was assumed in the WPRFMC SSC's production model analysis of the 2008 bottomfish assessment data (WPRFMC SSC 2009, unpubl.); (ii) a scenario that assumed a moderate change in fishing power, on the order of a 10% increase over roughly 60 years, had occurred (CPUE Scenario II); and (iii) a scenario that assumed a substantial change in fishing power, on the order of a 70% increase over 60 years, had occurred (CPUE Scenario III) as was assumed in both the 2005 bottomfish assessment (Moffitt et al., 2006) and the 2008 bottomfish assessment update (Brodziak et al., 2009).

In addition to the three primary CPUE scenarios, two alternative modeling approaches were also investigated to estimate standardized CPUE in order to address concerns about the potential influence of model structure and the treatment of zero-reported catch trips in the HDAR reports database. In particular, we evaluated whether using different statistical models to standardize CPUE would produce results that differed substantially from the baseline scenario. Details of the alternative scenarios and analyses were provided in the 2011 assessment section on CPUE standardization (Brodziak et al. 2011).

The second WPSAR recommendation was addressed by developing estimates of unreported Hawaii bottomfish catch. One baseline scenario of estimates of unreported catch used for the stock status determination assumed the ratio of unreported to reported catch was 1.08 on average, and three alternative scenarios of unreported catch were also developed to characterize the uncertainty in the available information about unreported catch. These estimates were based, in part, on published information about estimates of unreported bottomfish catch from Zeller et al. (2008) and Hamm and Lum (1992), as well as using other sources of data (Martell et al., 2011; Lamson et al., 2007; Courtney and Brodziak, 2011). Details of these analyses and the baseline and three alternative scenarios were provided in the 2011 assessment section on fishery catch and the estimation of unreported catch (Brodziak et al. 2011).

The third WPSAR recommendation was addressed by applying the assessment model to estimate the biomass and harvest rates of the set of Deep7 bottomfish species rather than all of the primary bottomfish species as in the 2005 assessment. In this context, the Deep7 bottomfish were a subset of the primary bottomfish, which were also a subset of the full set of all bottomfish management unit species (BMUS) included in the fishery management plan http://www.wpcouncil.org/bottomfish/Bottomfish%20FMP.html). The changes to assess only the Deep7 species was made because the Deep7 species have similar life histories and distributions, and were the focus of management efforts by the WPRFMC, using TAC regulation and closed seasons (WPRFMC, 2007). In contrast, in the bottomfish assessments prior to 2011, several productive shallow-water bottomfish species were included in the set of species modeled. In this context, it was judged that modeling Deep7 species as a biologically and ecologically related complex would provide a much better approximation of their population dynamics, would be more consistent with the fishery management approach being applied to the Hawaii bottomfish, and would provide a more accurate estimate of the probable levels of intrinsic growth rate and associated levels of sustainable harvest. As a result, prior distributions of parameters in the stock assessment model were revised to incorporate new research information on the life span of opakapaka, a primary Deep7 bottomfish, based on bomb radiocarbon and lead radium dating (Andrews et al. 2011, Andrews et al. 2012). These modifications and analyses were described in sections of the 2011 assessment (Brodziak et al. 2011) on fishery catch, CPUE standardization, and production modeling.

The fourth WPSAR recommendation was addressed by assessing the Deep7 bottomfish in the main Hawaiian Islands as a single unit stock. As a result, the putative archipelagic stock, which is comprised of all bottomfish in the MHI and Northwestern Hawaiian Islands, is not assessed in this document. To do this, the assessment data and production model were revised to focus solely on the status and management parameters of the Deep7 complex in the MHI in the current assessment, including explicit treatment of uncertainty about the CPUE estimates. In the 2011 assessment, both parametric and model uncertainty in the assessment results under the alternative fishing power and unreported catch scenarios were characterized to the extent practicable with the available data and resources (Brodziak et al. 2011).

Current Assessment Update through 2013

The current Deep7 bottomfish stock assessment update through 2013 uses the same analytical approaches and assessment methodology as in the 2011 assessment. The 2014 update includes an improved CPUE standardization analysis of data from 1994 to 2013 when Hawaii state commercial logbooks included consistent commercial marine license information to estimate fishery license/vessel effects. The inclusion of the license effect improved the explanatory power of the CPUE standardization by over 200% since 1994 and the resulting standardized CPUE was included in the updated production model analysis of the Deep7 bottomfish complex. Overall, results of the assessment update through 2013, and the stock projections produced using the assessment update were similar to the 2011 stock assessment.

MATERIALS AND METHODS

Here we provide basic information on the Deep7 bottomfish fishery system, including information on bottomfish fishery economics, bottomfish life history characteristics, bottomfish fishery-dependent data, commercial fishery CPUE standardization and results, and production model assumptions and structure that were used to estimate biomass and fishing mortality for the Deep7 bottomfish 2010 stock assessment in the main Hawaiian Islands.

Bottomfish Fishery Economics

Economic information on the Deep7 bottomfish fishery was collected from the Hawaii state fishery reporting system. Information on the number of commercial marine license holders participating in the MHI Deep7 bottomfish fishery indicates an increase in participation since 2002 (Table 3.1). Inflation-adjusted ex-vessel revenues have fluctuated around $1.5 million USD since 2002 (Table 3.1). Average prices for Deep7 bottomfish commercial catches have fluctuated around $6.80/pound (Table 3.2). Total bottomfish revenues in 2012 increased by about ½ million USD since 2002, primarily due to increased revenues from non-Deep7 bottomfish landings (Table 3.2). This shift to non-Deep7 landings and revenues is apparent in the percent of total revenues derived from the sale of Deep7 bottomfish which decreased from about 92% in 2002 to about 65% in 2012 (Table 3.3). The Gini coefficient for bottomfish revenue by vessel indicates there is a relatively high concentration of revenues for the top-revenue generating vessels (Table 3.3) and this is consistent with survey-based information on the higher frequency of highliner vessels relative to part-time fishery participants (Hospital and Beavers 2013). The season length for the Deep7 fishery was reduced during the period 2008-2010 to achieve reductions in fishing mortality and this reduction affected realized fishery catches and revenues (Table 3.3).

Bottomfish Life History Characteristics

The Hawaii bottomfish complex is comprised of shallow-water jacks and snappers, and deepwater snappers and a grouper (i.e., the Deep7 bottomfish, Table 1). A separate subunit of seamount groundfish (armorheads and alfonsins) is not found in the main Hawaiian Islands. The ecological niches occupied by the shallow-water and deepwater components of the bottomfish complex differ substantially. In assessments of this complex prior to 2011, several of the shallow-water and all of the deepwater bottomfish were combined for production model analyses; these are the primary bottomfish species (Table 1). In the 2011 assessment and this 2014 update, production model analyses are used to assess the status of the set of deepwater bottomfish species because these species are the focus of management regulations, which have included seasonal fishery closures and annual total allowable catch limits.

There is limited quantitative information on the life history parameters of the Deep7 bottomfish, and in particular, the early life stages and juvenile characteristics of Hawaii bottomfish are not yet well-described. Adult's essential fish habitat includes deep-water habitats of roughly 100-400 m depth in the main Hawaiian Islands, although some species (e.g., opakapaka) shoal to mid-water depths to feed.

Age determination for the Hawaiian snapper, or opakapaka (*Pristipomoides filamentosus*), has been challenging because their otoliths lack well-developed annual growth zones. Early growth has been well documented, and validated otolith growth rates were successfully developed for the first few years of growth using daily increments (Ralston and Miyamoto, 1983; Radtke, 1987). However, recent research on ageing of opakapaka (Table 1), based on bomb C-14 radiocarbon and lead radium dating of archival otolith samples shows that this species has a life span on the order of 40 years (Andrews et al. 2011, Andrews et al. 2012). Recent ageing research conducted since the 2011 assessment using bomb C-14 ageing of three Deep7 species indicates that potential lifespans are on the order of 50 years at 91 cm fork length (FL) for hapuupuu, 49 years at 79 cm FL for onaga, and 39 years at 43 cm FL for gindai (Table 1). Overall, the new information on maximal observed ages of Deep7 bottomfish in the main Hawaiian Islands is very consistent with biological assumptions about the prior mean value of intrinsic growth rate for the bottomfish complex. As a result, the same prior assumptions about the intrinsic growth parameter from the 2011 assessment were used in this assessment update.

Information on the expected natural mortality rate of opakapaka from the research thesis of Martinez-Andrade (2003) was used for the Deep7 bottomfish complex in the main Hawaiian Islands. The natural mortality rate estimate of M=0.25 for opakapa was assumed to be representative of the Deep7 bottomfish complex, noting that opakapaka is the most numerically abundant species in the complex and has historically accounted for the highest proportion of reported landings. This natural mortality estimate was about 15% lower than the value of M=0.30 used in the 2011 benchmark assessment. In particular, for the purposes of determining a minimum stock size threshold (B_{MSST}) of $B_{MSST} = (1 - M) \cdot B_{MSY}$, which is part of the bottomfish complex fishery management plan (FMP), the natural mortality rate value of M=0.25 was considered to be the best available scientific information for this stock assessment update in light of the new information on potential bottomfish lifespan and this value was used for calculating the B_{MSST} =0.75*B_{MSY} of the complex.

Fishing Year

The 2014 assessment update uses the same annual time period for reporting bottomfish catch as in the 2011 assessment. Catch and CPUE information is based on the fishing year from July 1st of the previous year through June 30th of the current year, i.e. the 2014 fishing year occurs from July 1, 2013 – June 30, 2014. This fishing year time period coincides with the State of Hawaii's fiscal year and commercial marine license period but differs somewhat from the definition of fishing year in the bottomfish FMP (which extends from September 1st of the previous year through August 31st of the current year). The fishing year time period also closely corresponds to the annual biological cycle of the Deep7 snapper and grouper bottomfish complex which spawn in late spring to early summer. Estimates of annual production biomass starting in July coincide with the settlement of juvenile bottomfish through midsummer. More importantly, the commercial fishery catch of Deep7 bottomfish is typically highest during the winter months when there is strong market demand for red snapper during New Year holidays.

Fishery Catch

Reported Commercial Catch of Bottomfish

Reported fishery catch data for the 2014 assessment update included commercial bottomfish catch and effort data extracted from about 4.6 million HDAR commercial trip catch reports submitted by commercial fishermen during 1948-2014 (K. Lowe, PIFSC, pers. comm.). Bottomfish catch data from these trip reports were assigned to the main Hawaiian Islands and the Northwestern Hawaiian Islands fishing zones, based on the reported HDAR fishing area in the trip reports (Figure 1). Only data for the main Hawaiian Islands are used in this assessment. Some bottomfish trip reports reported an unknown fishing area, and the minor catch amounts from these trip reports were prorated to fishing areas based on the Deep7 catch proportion by zone in each fishing year. The reported catch of Deep7 bottomfish in the main Hawaiian Islands was tabulated by fishing year during 1949-2013 for use in the current stock assessment (Table 4).

Estimates of Unreported Bottomfish Catch

Estimates of unreported Deep7 bottomfish catch were based on estimated ratios of unreported to reported catch summarized by Courtney and Brodziak (2011) and Brodziak et al. (2011). These estimates of unreported catch were included in the current stock assessment to account for the effects of total fishery removals on the complex, as recommended by Stokes (2009). The general approach for estimating unreported catch (C_U) was the same as in the 2011 benchmark assessment. We used all available relevant information to estimate the ratio of unreported to reported bottomfish catch (U) in the main Hawaiian Islands, noting that there is no directed long-term monitoring program in place for quantifying the amount of unreported catches of bottomfish in the main Hawaiian Islands. In general, unreported bottomfish catch was estimated from reported catch (C_R) and annual estimates of the ratio of unreported to reported catch U as $C_U = U^* C_R$.

As in the 2011 assessment, the magnitude of the unreported catch ratio U was estimated for each Deep7 species by fishing year to account for annual variation in the species composition of the reported Deep7 bottomfish catch (Courtney and Brodziak, 2011, Brodziak et al 2011). The unreported catch ratios by species were estimated based on information in Hamm and Lum (1992), Martell et al. (2011), and Lamson et al. (2007). The resulting estimates of the unreported catch ratio U (Table 5) indicated that unreported catch was slightly larger in magnitude to the reported commercial catch (Tables 4 and 5). The recent survey of bottomfish fishers conducted by Hospital and Beavers (2013) confirmed this magnitude of unreported bottomfish catch. Overall, the average unreported to reported catch ratio during 2008-2013 used in the 2011 and

2014 assessments was U = 1.08 and the magnitude of the recent average unreported catch was on the order of about 240 thousand pounds. The model included a +/- 20% range of uncertainty around the estimated unreported catch values (Brodziak et al. 2011).

The total catch of Deep7 bottomfish in the main Hawaiian Islands was comprised of the combined reported and unreported catch data (Table 6). Reported catches of Deep7 bottomfish in the main Hawaiian Islands were also apportioned to summary island groups based on the fishing area reported in the trip catch reports (Tables 7.1 and 7.2). In this summary, any minor catches with unknown fishing area were prorated to island group based on the annual proportions of reported catch by known area (Table 7.2).

Standardized Commercial Fishery Catch-Per-Unit Effort

Estimation of standardized commercial fishery CPUE for Deep7 bottomfish was revised in this assessment update from the 2011 assessment to include information about commercial marine license effects and individual fishermen's skill during 1994-2013 when such information was recorded in the Hawaii state logbook information. Otherwise, the CPUE standardization approach was the same as the analytical approach used in the 2011 assessment.

Fishery Data Filtering for CPUE Analyses

The same fishery logbook data filtering procedures from the previous 2011 stock assessment (Brodziak et al. 2011) were used in the 2014 update to calculate standardized CPUE. In brief, Deep7 bottomfish catch per single-day trip reports were summarized for directed deep handline trips in the MHI. Commercial trip reports were audited to remove duplicate records and also records that were missing fishing date, CML number, or fishing area. Only commercial trip reports that reported using deep handline fishing gear were selected for Deep7 bottomfish CPUE analyses because this gear was the predominant fishing gear used to capture Deep7 bottomfish, accounting for over 97% of commercial Deep7 bottomfish landings by weight during 1949-2013.

Commercial fishery CPUE data were filtered to remove uninformative trip reports, based on the recommendations of the bottomfish CPUE standardization workshop held in 2008 (Moffitt et al., 2011). In particular, CPUE data for trip reports that reported catches of over 1500 pounds of primary bottomfish per day were excluded because these reports were multiday trip reports and were extremely unlikely to represent single-day trip operations. In addition, all CPUE data reported during FY 1958-1960 were excluded from the CPUE standardization analyses because nominal CPUE was anomalously low during these years as determined by the WPSAR panel (Stokes, 2009). Further examination suggested that these 3 years contained substantially more aggregated catch records than other years in which catches from several single-day trips were aggregated and reported in a combined trip report record (Brodziak et al. 2011). Last, the cutoff fraction of percent Deep7 bottomfish catch per trip report was set to the value (17%) used in the 2011 benchmark stock assessment (Brodziak et al. 2011).

Fishery CPUE Standardization and Catchability Time Periods

In the 2014 assessment update, two time periods for CPUE standardization were used to include the best available information on fishery effective effort. These time periods were: 1949-1993 and 1994-2013. The latter time period was used to include license/vessel effects in the CPUE standardization and also to represent probable changes in the effective effort of the fishing fleet that targets Deep7 bottomfish with the advent of GPS and other high-accuracy location-reporting technology. This split of the CPUE data analyses was also done to address the WPSAR recommendation that the assessment include appropriate testing of CPUE uncertainty (Stokes, 2009). For the 1949-1993 time period, the CPUE standardization model from the 2011 assessment was compared to an alternative similar model using AIC for model selection. For the 1994-2013 time period, four alternative CPUE standardization models were considered and AIC was used to select among these alternatives. , CPUE standardization analyses with two time periods (1949-1993 and 1994-2013) were used in the 2014 assessment update.

CPUE Standardization Model Selection

In the 2011 assessment, Deep7 bottomfish CPUE in the main Hawaiian Islands was standardized using a multiplicative loglinear model (Gavaris, 1980; Kimura, 1981) with fixed effects of year, fishing area (Figure 2), and season, as well as area by season interactions (Brodziak et al. 2011). In this assessment update, the same analysis approach was applied for the 1949-1993 time period and this analysis produced nearly identical results (Tables 8 and 9.1) as the 2011 analysis and explained the same amount of CPUE variation (R^2 = 24%). Several other factors were explored in the 2011 assessment and not included in the CPUE standardization because of poor CPUE fits as measured by AIC values; such factors were also not included in this assessment update. For 1994-2013, we applied model selection techniques to evaluate four alternative models that were variants of the 2011 standardization model that either included or did not include commercial marine license and interaction effects (Table 8). The results of the comparisons of CPUE standardization models for 1994-2013 indicate that the best fitting model by far included year, area, season, and commercial marine license effects (Tables 8 and 9.2). This model explained more than twice the amount of CPUE variation (R^2 = 53%) as the alternative models, which indicated that the commercial marine license effect provided a substantial amount of explanatory power for the magnitude of Deep7 bottomfish CPUE. This was consistent with the findings of the fishery survey conducted by Hospital and Beavers (2013) as well as other information sources that the fisher skill effect is very important for explaining catch rates in the main Hawaiian Islands bottomfish fishery.

As a result, two time series of standardized CPUE data for Deep7 bottomfish in the main Hawaiian Islands are used in the 2014 assessment update (Table 10); one for 1949-1993 using the same analytic approach as in the 2011 assessment and one for 1994-2013 using an improved analytic approach that incorporates fishing license/vessel effects. For comparison, we also calculated standardized CPUE using a single 1949-2013 time period and the same model as in the 2011 assessment (Table 10). In this comparison, we found that the two-period and single period CPUE values were highly significantly correlated ($P<0.01$) for 1949-1993 ($\rho>0.99$) and for 1994-2013 ($\rho=0.87$).

Assessment Model

Same Model as in 2011 Benchmark Assessment

As noted above, the 2011 stock assessment modeling approach is also used in the current assessment. In particular, a Bayesian generalized surplus production model was fit to the catch and standardized CPUE time series. The 2014 model differs from the 2011 model only in that it includes two time periods for the CPUE observation fitting with both of these time periods fitted separately with different catchability coefficients and observation error variances. The model linked the two CPUE time series through continuous estimates of biomass and harvest rate, and the estimate of a single set of reference points. In brief, the production model structure and assumptions from the 2011 assessment are reviewed below. Further details can be found in Brodziak et al. (2011).

Biomass Dynamics Model

The biomass dynamics model for the Deep7 bottomfish complex in the MHI is formulated as a Bayesian-state space production model. This model includes explicit observation and process error terms that have been commonly used for fitting production models with relative abundance indices (Meyer and Millar, 1999; Brodziak 2001; McAllister et al., 2001; Punt, 2003; Brodziak and Ishimura, 2011). The exploitable biomass time series comprise the unobserved state variables and these annual biomasses are estimated by fitting model predictions to the observed relative abundance indices (i.e., CPUE) and catches using the observation error likelihood function and prior distributions for the model parameters (θ). In particular, the observation error likelihood measures the discrepancy between observed and predicted CPUE, while the prior distributions represent the relative degree of belief about the probable values of model parameters.

The process dynamics represent the temporal fluctuations in exploitable bottomfish biomass due to density-dependent population processes (e.g., growth) and fishery catches. The generalized production model is a power function model with an annual time step. Under this 3-parameter model, exploitable biomass in time period T (B_T) depends only on previous values of exploitable biomass (B_{T-1}), catch (C_{T-1}), intrinsic growth rate (R), carrying capacity (K), and production shape parameter (M) for $T = 2,\ldots, N$.

(1) $$B_T = B_{T-1} + R \cdot B_{T-1}\left(1-\left(\frac{B_{T-1}}{K}\right)^M\right) - C_{T-1}$$

The production model shape parameter M determines where surplus production peaks as biomass varies as a fraction of carrying capacity (Figure 3). If the shape parameter is less than unity ($0 < M < 1$), then surplus production peaks when biomass is below ½ of K (i.e., a right-skewed production curve). If the shape parameter M is greater than unity ($M > 1$), then biomass production is highest when biomass is above ½ of K (i.e., a left-skewed production curve). If the shape parameter is identically unity ($M = 1$), then the production model is identical to a discrete-time Schaefer production model where maximum surplus production occurs when biomass is equal to ½ of K. In practice, estimates of the shape parameter M for Deep7 biomass production in the MHI tend to be around $M = 2$ indicating a relatively lower productivity stock.

For computations, the production model is expressed in terms of the proportion (P) of carrying capacity (i.e., setting $P = B/K$) to improve the efficiency of the Markov Chain Monte Carlo algorithm to estimate parameters (e.g., Meyer and Millar, 1999). Given this, the process dynamics for the temporal changes in the proportion of carrying capacity with lognormal errors are

(2)
$$P_1 = \eta_1$$
$$P_T = \left(P_{T-1} + R \cdot P_{T-1}\left(1 - P_{T-1}^{M}\right) - \frac{C_{T-1}}{K} \right) \cdot \eta_T, \; for T > 1$$

These coupled equations set the prior distribution for the proportion of carrying capacity, $p(P_T)$, in each time period T, conditioned on the proportion in the previous period.

Observation Error Model

The observation error model relates the observed fishery CPUE to the exploitable biomass of the bottomfish complex for each CPUE standardization time period, i.e. 1949-1993 and 1994-2013. It is assumed that the standardized fishery CPUE index (I) in each time period is proportional to biomass with time period specific catchability coefficient q

(3)
$$I_T = qB_T = qKP_T$$

The observed CPUE dynamics are subject to natural sampling variation which is assumed to be lognormally distributed. The observation errors are distributed as $\nu_T = e^{\varepsilon_T}$ where the ε_T are independent and identically distributed normal random variables with zero mean and weighted variance $(W_T \cdot \tau)^2$ with standard deviation τ and weighting factor W_T. The weighting factors (W_T) of the annual CPUE variance terms reflect the relative uncertainty of the value of the CPUE index in year T and are scaled using the coefficient of variation (CV) of the difference between the observed and predicted log-transformed biomass indices (Brodziak and Ishimura, 2011). In particular, the annual weighting factors are calculated from the relative coefficients of variation of each annual CPUE index and the minimum observed CV of CPUE (min(CV[CPUE])) as $W_T =$

CV[CPUE$_T$]/min(CV[CPUE]). These weighting factors are derived from the annual standard error of standardized CPUE (Table 10).

Given the lognormal observation errors, the observation equations for each annual period indexed by $T = 1,\ldots, N$ are

$$(4) \qquad I_T = qKP_T \cdot \nu_T$$

The joint distribution of the error terms over the two CPUE standardization periods defines the observation error likelihood function $p(I_T|\theta)$ for the Deep7 bottomfish CPUE indices through time.

Prior Distributions

Prior distributions are employed to represent existing knowledge and beliefs about the likely values of model parameters in the exact same manner as the 2011 assessment (Table 11). In particular, the carrying capacity parameter, the intrinsic growth rate parameter, the production shape parameter, the catchability parameter, the process and observation error variance parameters, and the initial biomass as a proportion of carrying capacity parameters each have prior distributions as described in Brodziak et al. (2011). Unobserved biomass states are also assigned the same priors as in the 2011 assessment and are expressed as the proportion of carrying capacity, conditioned on the previous proportion, and the catchability parameter (Table 11).

Posterior Distribution

Independent samples from the joint posterior distribution of the production model parameters are numerically simulated to estimate model parameters and make inferences. In comparison to the 2011 benchmark stock assessment, the only change in the 2014 model is that there are two time period of CPUE observations, 1949-1993 and 1994-2013, and two associated catchability parameters, q_1 and q_2, and observation error variances, τ_1 and τ_2.The joint posterior distribution of model parameters, $p(\theta|D)$, is proportional to the product of the priors and the joint likelihood of the CPUE data given the catch and CPUE data D

$$(5) \qquad \begin{aligned} p(\theta \mid D) \propto\ & p(K)\, p(R)\, p(M)\, p(Q_1)\, p(Q_2)\, p(\sigma^2)\, p(\tau_1^2)\, p(\tau_2^2) \cdot \\ & \prod_{T=1}^{N} p(C_T \mid \theta) \prod_{T=1}^{N} p(P_T) \prod_{T=1}^{N_1} p(I_T \mid \theta) \prod_{T=N_1+1}^{N} p(I_T \mid \theta) \end{aligned}$$

We use a numerical Markov Chain Monte Carlo (MCMC) simulation to generate sequences of estimates from the posterior distribution or model solution. Parameter estimation for multiparameter and nonlinear Bayesian models like the bottomfish production model is typically based on simulating a large number of independent samples from the posterior distribution (Gelman et al., 1995). In this case, MCMC simulation (Gilks et al., 1996) is applied to numerically generate samples from the posterior distribution. The WinBUGS software (Lunn et al., 2000; Spiegelhalter et al., 2003) and R Language (R Development Core Team, 2009) using the R2WinBUGS package (Sturtz et al., 2005) were applied to program the production model, to set the initial conditions, to perform the MCMC calculations, to generate model diagnostics, and to summarize the assessment model results.

Production model results include the stock status of the Deep7 bottomfish complex in the main Hawaiian Islands relative to maximum sustainable yield (MSY) based reference points. Time series of the relative harvest rate (e.g., in 2007 the relative harvest rate is the ratio H_{2007}/H_{MSY}) and relative biomass (e.g., the ratio B_{2007}/B_{MSY}) are calculated for MHI Deep7 bottomfish using the ratio of mean values from the joint posterior distribution of model parameters. Probabilities of overfishing and becoming overfished are calculated based on an overfishing definition of $H>H_{MSY}$, and an overfished definition of $B<0.75*B_{MSY}$.

Convergence Diagnostics

MCMC simulations are conducted in an identical manner for the baseline assessment model and all sensitivity analyses described below. Two chains of 110,000 samples are simulated from the posterior distribution in each model run. The first 10,000 samples of each simulated chain are excluded from the estimation process. The 10,000 sample burn-in period removes dependence of the MCMC chains on the initial conditions. Next, each chain is thinned by 4 to reduce autocorrelation, e.g., every fourth sample from the posterior distribution is stored and used for inference. As a result, a total of 50,000 samples from the posterior distribution are available to summarize model results.

Convergence of the simulated MCMC chains to the posterior distribution is confirmed using the Geweke convergence diagnostic (Geweke et al., 1992), the Gelman and Rubin diagnostic (Gelman and Rubin, 1992; Brooks et al., 1998) and the Heidelberger and Welch stationarity and half-width diagnostics (Heidelberger and Welch, 1992). These diagnostic tests are implemented in the R Language (R Development Core Team, 2009) using the CODA software package (Best et al., 1996; Plummer et al., 2006). The set of convergence diagnostics are monitored for key model parameters (intrinsic growth rate, carrying capacity, production function shape parameter, catchability coefficient, MSY-parameters, and error variances) to verify convergence of the MCMC chains to the posterior distribution (e.g., Ntzoufras, 2009).

Model Diagnostics

Residuals from the baseline model fit to CPUE by time period are used to measure the goodness of fit of the production model. These log-scale observation errors ε_T of observed minus predicted Deep7 bottomfish CPUE are

(6) $$\varepsilon_T = \log(I_T) - \log(QKP_T)$$

Any nonrandom pattern in the CPUE residuals would suggest that the observed CPUE may not conform to one or more model assumptions. The RMSE of the CPUE fit provides a simple diagnostic of the model goodness of fit with lower RMSE indicating a better fit.

Comparisons of the prior distributions and estimated posterior distributions are made to show whether the observed catch and standardized CPUE data are informative for estimating model parameters. This comparison includes the priors and posteriors for the following model parameters: carrying capacity, production shape, intrinsic growth rate, initial proportion of carrying capacity, observation error variance, process error variance, catchability parameters, BMSY, MSY, and HMSY.

Sensitivity Analyses

Sensitivity analyses are conducted to evaluate how model results would be affected if different assumptions are made regarding the mean value of key prior distributions. These sensitivity analyses are conducted to confirm the expected results from the more extensive sensitivity analyses conducted in the 2011 stock assessment (Brodziak et al. 2011). The sensitivity of the production model results to the prior mean for intrinsic growth rate is evaluated by fitting the model using two different prior means for R. In this case, the prior mean for R is reduced by 25% and increased by 25%. Similarly, the sensitivity of the production model results to the prior mean for carrying capacity is evaluated by fitting the model when the prior means for K, M, and P_1 are reduced by 25% and increased by 25%.

Annual Catch Limit Projections for 2015-2016

Stock Projections

Stock projections are conducted to provide information on the risk that the Deep7 bottomfish complex would experience overfishing or become overfished under alternative annual catch limits in fishing years 2015 and 2016. The stock projections start with estimates of exploitable bottomfish biomass and all other model parameters taken directly from the joint posterior distribution in the 2014 base case model. We use a grid of possible annual catch limits for the commercial fishery to approximate the effects of different commercial harvest amounts on the resource. This grid consists of commercial catches of 0, 2, 4, …, up to 1000 in units of thousands of pounds, i.e., the grid ranges from no commercial catch to 1,000,000 pounds of commercial catch. Simulations are conducted for each commercial catch value in the grid; each simulation consists of 41,000 MCMC samples with 1,000 discarded for burn-in and a sampling rate of 1 in 4 values. Unreported catch in the projections is treated as a random variable using the same approach as used in the base case model. That is, each simulated unreported catch is sampled from a uniform distribution centered at its expected value from the unreported catch ratio and commercial catch with a range of -20% to +20%.

As in the 2011 stock assessment, estimated posterior distributions of bottomfish production model parameters in 2013 are projected forward for fishing years 2014-2016 to estimate future probable stock status under alternative future realized annual catch limits for the commercial fishery. In particular, we calculate the probability of overfishing, P*, under alternative future catches. These stock projections account for uncertainty in the distribution of estimates of model parameters in the estimation of P* for use in determining the overfishing level and setting annual catch limits (ACLs) or annual catch targets (ACTs) based on projected catch levels, noting that if there is no adjustment in the risk of overfishing due to catch or management uncertainty then the ACL is the same as the ACT.

The stock projections are conducted assuming the ACLs in fishing years 2015 and 2016 are equal as assumed in the 2011 stock assessment projections. The amount of the 2014 annual catch limit of 346,000 pounds of commercial Deep7 Hawaii bottomfish that is expected to be caught in fishing year 2014 is projected at several different values ranging from 70% to 94% of the commercial ACL set by the WPRFMC. These assumed 2014 catches are 244, 276, 310, and 325 thousand pounds corresponding to percentages of 70%, 80%, 90%, and 94% of the 2014 ACL being caught. It should be noted that in-season summaries of HDAR catch reports indicate that about 83% of the 2014 ACL had been caught between September 1, 2013 and June 27, 2014. By projecting a range of 2014 commercial catches, the effects of different amounts of annual catch of commercial Deep7 Hawaii bottomfish in fishing year 2014 are examined. This provides a characterization of the effects of the as-yet not completed Deep7 bottomfish harvest in fishing year 2014.

RESULTS

In this section, production model outcomes are described. The results include: model diagnostics, exploitable biomass and fishing mortality estimates to assess stock status, sensitivity analyses, and projection analyses.

Convergence Diagnostics

Convergence diagnostics indicated the MCMC simulation to estimate the posterior distribution of production model parameters converged. In particular, none of the Geweke diagnostics were greater than 2 standard deviations. The Gelman and Rubin potential scale reduction factors were equal to unity for parameters confirming convergence to the posterior distribution. The Heidelberger and Welch stationarity and half-width diagnostic tests were also passed by all of the parameters at a confidence level of $\alpha = 0.05$. Overall, the convergence diagnostics and relatively low autocorrelations supported the convergence of the 2014 assessment model.

Model Diagnostics

Model residuals indicated that the production model provided a good fit to the standardized CPUE observations during both the 1949-1993 (Figures 4.1 and 4.2) and 1994-2013 (Figures 5.1 and 5.2) time periods. Model residuals did not exhibit significant trends in either time period and also conformed to error distribution assumptions (Figures 4.2 and 5.2).

Stock Status

Production model estimates indicated that HMSY was about 6.6% and that BMSY was about 13.5 million pounds of exploitable Deep7 bottomfish biomass with an associated maximum sustainable yield of roughly 415 thousand pounds (Table 11). Estimates of production model parameters were also compared to the results of a simple update of the 2011 assessment using the single time series CPUE (Table 10). Overall, the comparison indicated that the results were similar and that there was a slightly lower HMSY and higher BMSY using the single time series of CPUE (Table 11).

Based on the 2014 assessment update for Deep7 bottomfish (Table 11), the mean estimates of the MSY-based biological reference points of maximum sustainable yield (MSY ± one standard error, expressed in units of reported catch), the harvest rate to produce MSY (H_{MSY} ± one standard error), and the exploitable biomass to produce MSY (B_{MSY} ± one standard error), were:

1) MSY = 415,000 pounds (± 164,000 pounds)
2) H_{MSY} = 6.6% (± 2.4%)
3) B_{MSY} = 13.5 million pounds (± 3.9 million pounds).

In comparison to the 2011 assessment, the 2014 assessment estimates of maximum sustained yield MSY =415,000 pounds and B_{MSY}=13.5 million pounds were 0.5% and 7% lower than the 2011 estimates (Brodziak et al. 2011), respectively, while the 2014 assessment estimate of the harvest rate to produce MSY H_{MSY}=6.6% was 7% higher than the 2011 estimate. Overall, 2014 assessment estimates of exploitable biomass by year were moderately lower than the 2011 assessment estimates although the time trends were very similar and there was no statistically significant difference between the 2014 and 2011 estimates. Similarly, 2014 assessment estimates of harvest rates by year were moderately higher than 2011 assessment estimates but had a very similar trend and differences were not statistically significant.

Estimates of the exploitable biomass of the Deep7 bottomfish complex exhibited a long-term decline from high values in the 1960s-1970s to lower values around B_{MSY} in the early 1990s (Table 12 and Figure 6). Exploitable biomass fluctuated around B_{MSY} in the late-1980s and has been below B_{MSY} since the mid-1990s. Harvest rates were relatively low in the 1960s to mid-1970s, increased to peak in 1989, and steadily declined to the mid-2000s (Table 12 and Figure 7). Harvest rates declined from about twice H_{MSY} in the late-1980s to range from about 60% to 110% of H_{MSY} since 2001.

The 2014 assessment results for the main Hawaiian Islands Deep7 bottomfish complex indicate that the stock was not depleted in 2013 (B_{2013}/B_{MSY}=0.86, Table 12 and Figure 6) but that there was a relatively high risk (45% probability) that the stock complex was overfished (Table 12 and Figure 6). The 2014 assessment results also indicate that the stock complex was not experiencing overfishing (H_{2013}/H_{MSY}=0.77, Table 12 and Figures 7 and 8). In fishing year 2013, there was a 45% probability that exploitable biomass was below the limit of 0.75*B_{MSY} and a 31% chance that the harvest rate exceeded H_{MSY}. As a result, the Deep7 bottomfish stock complex was categorized as not being overfished and not experiencing overfishing in 2013. It is important to note that, while the probability that the stock complex is in an overfished condition has decreased slightly from 47% to 45% in recent years, the probability the stock complex was overfished in 2013 is 45%.

Sensitivity Analyses

Results of the sensitivity analyses for the prior means of intrinsic growth rate, carrying capacity, initial proportion of carrying capacity, and production model shape parameters showed that most quantities of interest were not sensitive to a ±25% change in the mean (Table 13). Overall, the results appeared to be most sensitive to a change in the prior mean of the initial proportion of carrying capacity in 1949 and least sensitive to change in the prior mean of the production shape parameter.

Stock Projections

Under the constant 2-year ACL stochastic projection scenarios evaluated, projected probabilities of overfishing, biomasses, harvest rates, and probabilities of depletion of Deep7 bottomfish showed the distribution of outcomes that would likely occur if alternative annual catch limits were set and realized in the main Hawaiian Islands during 2015-2016 (Table 14 and Figures 9, 10, 11, and 12). Results of the stochastic projections indicated that the Deep7 ACL in 2015 that would produce approximately 50% chance of overfishing in 2015 (i.e., H_{2015} exceeding H_{MSY}) ranged from 312,000 to 316,000 pounds depending on the amount of 2014 commercial catch; these values are close to the 2012-2013 ACTs of 325,000 pounds (Table 15 and Figure 9). For comparison, the smallest Deep7 2015 ACL for commercial catch that would lead to a roughly 41% chance of overfishing was either 266,000 or 264,000 pounds depending on the amount of 2014 commercial catch (Table 15 and Figure 9). Annual catch limits for commercial catches of Deep7 bottomfish in 2015 ranging from 116,000 to 382,000 pounds corresponded to risks of overfishing ranging from 10% to 60%. In 2015, the Deep7 annual catch limit to achieve a low risk of overfishing (P*=25%) in 2015 was estimated to be $ACL_{25\%}$ = 190,000 or 186,000 pounds depending on the amount of 2014 commercial catch and the Deep7 ACL to achieve a high risk of overfishing (50%) was estimated to be $ACL_{50\%}$ = 316,000 or 312,000 pounds depending on the amount of 2014 commercial catch. A 2015 ACL of 346,000 pounds would result in a 55% to 56% risk of overfishing depending on the amount of 2014 commercial catch. Sensitivity analyses of the projection results to the amount of 2014 commercial catch indicate that the projected outcomes were not sensitive to catches ranging from 244,000 to 325,000 pounds (Table 15 and Figure 12) corresponding to a range of 70% to 94% of the 2014 ACL.

SUMMARY

The 2014 Deep7 bottomfish stock assessment update includes new information on commercial marine license effects for standardizing CPUE since 1994. This new information for estimating the relative abundance trend of bottomfish was incorporated into the stock assessment and changed mean estimates of exploitable biomass, harvest rates and biological reference points for the Deep7 bottomfish complex in the main Hawaiian Islands in comparison to the 2011 stock assessment, although the differences are not significant. The Deep7 bottomfish stock complex in the main Hawaiian Islands was categorized as not being overfished and not experiencing overfishing in 2013. It is important to note that, while the probability that the stock complex is in an overfished condition has decreased slightly in recent years, it remains relatively high and the probability the stock complex was overfished in 2013 is 45%. The smallest Deep7 annual catch limit for commercial catch that would lead to a P*=41% chance of overfishing was about 266,000 or 264,000 pounds depending on the amount of 2014 commercial catch; this was approximately the risk of overfishing chosen for setting the ABC and ACL in 2012-2013. In comparison, the Deep7 ACL to achieve a high risk of overfishing (50%) in 2015 was estimated to be $ACL_{50\%}$ = 316,000 or 314,000 pounds depending on the amount of 2014 commercial catch; these values are just below the ACT in 2012-2013.

REFERENCES

Andrews, A. H., R. L. Humphreys, E. E. DeMartini, R. S. Nichols, and J. Brodziak. 2011. Bomb radiocarbon and lead-radium dating of opakapaka (*Pristipomoides filamentosus*). Pacific Islands Fish. Sci. Cent., Natl. Mar. Fish. Serv., NOAA, Honolulu, HI 96822-2396. Pacific Islands Fish. Sci. Cent. Admin. Rep. H-11-07, 58 p. + Appendices.

Andrews, A. H., R. L. Humphreys, E. E. DeMartini, R. S. Nichols, and J. Brodziak. 2012. Comprehensive validation of a long-lived life history for a deep-water snapper (*Pristipomoides filamentosus*) using bomb radiocarbon and lead-radium dating, with daily increment data. Can. J. Fish. Aquat. Sci. 69:1-20. doi:10.1139/f2012-109.

Best, N., M. Cowles, and K. Vines. 1996. CODA: Convergence diagnostics and output analysis software for Gibbs sampling output, Version 0.30. MRC Biostatistics Unit, Institute of Public Health, Cambridge, UK.

Brodziak, J., R. Moffitt, and G. DiNardo. 2009. Hawaiian bottomfish assessment update for 2008. Pacific Islands Fish. Sci. Cent., Natl. Mar. Fish. Ser., NOAA, Honolulu, HI 96822-2326. Pacific Islands Fish. Sci. Cent. Admin Rep. H-09-02, 93 p.

Brodziak, J., and G. Ishimura. 2011. Development of Bayesian production models for assessing the North Pacific swordfish population. Fish. Sci. 77:23-34.

Brodziak, J., D. Courtney, L. Wagatsuma, J. O'Malley, H. Lee, W. Walsh, A. Andrews, R. Humphreys, and G. DiNardo. 2011. Stock assessment of the main Hawaiian Islands Deep7 bottomfish complex through 2010. U.S. Dep. Commer., NOAA Tech. Memo., NOAA-TM-NMFS-PIFSC-29, 176 p. + Appendix.

Brooks, S. P., and A. Gelman. 1998. Alternative methods for monitoring convergence of iterative simulations. Journal of Computational and Graphical Statistics, 7:434–455.

Burnham, K., and D. Anderson. 2002. Model selection and multimodel inference, 2nd Ed. Springer Verlag, New York, 488 p.

Courtney, D. and J. Brodziak. 2011. Review of unreported to reported catch ratios for bottomfish resources in the main Hawaiian Islands. Pacific Islands Fish. Sci. Cent., Natl. Mar. Fish. Ser., NOAA, Honolulu, HI 96822-2396. Pacific Islands Fish. Sci. Cent. Internal Rep. IR-11-017, 45 p.

DeMartini, E., K. Landgraf, and S. Ralston.
1994. A recharacterization of the age-length and growth relationships of Hawaiian snapper, *Pristipomoides filamentosus*. U.S. Dept. Commer. NOAA Tech. Memo. NOAA-TM-NMFS-SWFSC-199, 14 p.

U.S. Department of Commerce [DOC].
2007. Magnuson-Stevens Fishery Conservation and Management Act as amended through January 12, 2007, Public Law 94-265. Available at http://www.nmfs.noaa.gov/msa2005/docs/MSA_amended_msa%20_20070112_FINAL.pdf.

Gavaris, S.
1980. Use of a multiplicative model to estimate catch rate and effort from commercial data. Can. J. Fish. Aquat. Sci. 37:2272-2275.

Gelman, A., and D. Rubin.
1992. Inference from iterative simulation using multiple sequences. Statistical Science 7:457-511.

Gelman, A., J. Carlin, H. Stern, and D. Rubin.
1995. Bayesian data analysis. Chapman and Hall, New York, NY, 526 p.

Geweke, J.
1992. Evaluating the accuracy of sampling-based approaches to calculating posterior moments. In Bernardo et al. [1992], p. 169-193.

Gilks, W. R., S. Richardson, and D. J. Spiegelhalter. [Eds.]
1996. Markov Chain Monte Carlo in Practice. Chapman and Hall, London. 486 p.

Hamm, D., and H. K. Lum.
1992. Preliminary results of the Hawaii small-boat fisheries survey. Honolulu Lab., Southwest Fish. Sci. Cent., Natl. Mar. Fish. Serv., NOAA, Honolulu, HI 96822-2396. Southwest Fish. Sci. Cent. Admin. Rep. H-92-08, 35 p.

Heidelberger, P. and P. Welch.
1992. Simulation run length control in the presence of an initial transient. Operations Research 31:1109-1144.

Hospital, J., and C. Beavers.
2013. Catch shares and the Main Hawaiian Islands bottomfish fishery: Linking fishery conditions and fisher perceptions. Marine Policy http://dx.doi.org/10.1016/j.marpol.2013.08.006.

Lamson, M. R., B. McNaughton, and C. J. Severance.
2007. Analysis and expansion of the 2005 Hawaii State/Western Pacific Regional Fishery Council Bottomfish Fishermen Survey. 16 p. Submitted to the Western Pacific Regional

Fishery Management Council on 29 May 2007 [A Draft Report Presented to the 95th SSC and Council Meetings of the WPFMC] Received from Personal Communication with Craig J. Severance (sevc@hawaii.edu) October 9, 2010

Lunn, D.J., A. Thomas, N. Best, and D. Spiegelhalter.
2000. WinBUGS -- a Bayesian modelling framework: concepts, structure, and extensibility. Statistics and Computing, 10:325--337.

Martell, S. J. D., J. Korman, M. Darcy, L. B. Christensen, and D. Zeller.
2011. Status and trends of the Hawaiian bottomfish stocks: 1948-2006. A report submitted under Contract No. JJ133F-06-SE-2510 September 2006. Pacific Islands Fish. Sci. Cent., Natl. Mar. Fish. Ser., NOAA, Honolulu, HI 96822-2396. Pacific Islands Fish. Sci. Cent. Admin. Rep. H-11-02C, 57 p.

Martinez-Andrade, F. 2003. A comparison of life histories and ecological aspects among snappers (Pisces: Lutjanidae). PhD Dissertation, Louisiana State University.

McAllister, M., E. Babcock, E. Pikitch, and M. Prager.
2001.Application of a non-equilibrium generalized production model to South and North Atlantic swordfish: Combining Bayesian and demographic methods for parameter estimation. 2000. Col. Vol. Sci. Pap. ICCAT, 51(5):1523-1550.

Meyer, R., and R. Millar.
1999. BUGS in Bayesian stock assessments. Can. J. Fish. Aquat. Sci. 56:1078–1086.

Moffitt, R., and F. Parrish.
1996. Habitat and life history of juvenile Hawaiian pink snapper, *Pristipomoides filamentosus*. Pacific Science 50: 371-381.

Moffitt, R., D. Kobyashi, and G. DiNardo.
2006. Status of the Hawaiian bottomfish stocks, 2004. Pacific Islands Fish. Sci. Cent., Natl. Mar. Fish. Ser., NOAA, Honolulu, HI 96822-2326. Pacific Islands Fish. Sci. Cent. Admin. Rep. H-06-01, 45 p.

Moffitt, R., G. DiNardo, J. Brodziak, K. Kawamoto, M. Quach, M. Pan, K. Brookins, C. Tam, and M. Mitsuyatsu.
2011. Bottomfish CPUE standardization workshop proceedings August 4-6, 2008. Pacific Islands Fish. Sci. Cent., Natl. Mar. Fish. Ser., NOAA, Honolulu, HI 96822-2396. Pacific Islands Fish. Sci. Cent. Internal Rep. IR-11-003, 17 p.

Musick, J.
1999. Criteria to define extinction risk in marine fishes: the American Fisheries Society Initiative. Fisheries 24(12):6-14.

Musick, J., M. Harbin, S. Berkeley, G. Burgess, A. Eklund, L. Findley, R. Gilmore, J. Golden, D. Ha, G. Huntsman, J. McGovern, S. Parker, S. Poss, E. Sala, T. Schmidt, G. Sedberry, H. Weeks, and S. Wright.
2000. Marine, estuarine, and diadromous fish stocks at risk of extinction in North America (Exclusive of Pacific Salmonids). Fisheries 25(11): 6-28.

Ntzoufras, I.
2009. Bayesian modeling using WinBUGS. John Wiley & Sons, Inc., Hoboken, New Jersey, 492 p.

Plummer, M., N. Best, K. Cowles, and K. Vines.
2006. "CODA: Convergence diagnosis and output analysis for MCMC", R News 6(1), 7-11, available at http://CRAN.R-project.org/doc/Rnews/Rnews_2006-1.pdf.

Punt, A.
2003. Extending production models to include process error in the population dynamics. Can. J. Fish. Aquat. Sci. 60:1217-1228.

R Development Core Team.
2009. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org.

Radtke, R.
1987. Age and growth information from the otoliths of the Hawaiian snapper, *Pristipomoides filamentosus*. Coral Reefs 6:19-25.

Ralston, S., and G. Miyamoto.
1983. Analyzing the width of daily otolith increments to age the Hawaiian snapper, *Pristipomoides filamentosus*. Fish. Bull. 81(3): 523-535.

Searle, S.
1987. Linear models for unbalanced data. John Wiley & Sons, New York, NY, 535 p.

Spiegelhalter, A., N. Best, B. Carlin, and A. van der Linde.
2002. Bayesian measures of model complexity and fit. J. R. Statist. Soc. B. 64:583-639.

Spiegelhalter, D., A. Thomas, N. Best, and D. Lunn.
2003. WinBUGS User Manual. Available at: http://www.mrc.bsu.carn.ac.uk/bugs/winbugs/manual14.pdf

Stokes, K.
2009. Report on the Western Pacific stock assessment review 1 Hawaii deep slope bottomfish. Center for Independent Experts, stokes.net.nz Ltd., Wellington 6035, New Zealand, 27 p.

Sturtz, S., Ligges, U., and Gelman, A.
2005. R2WinBUGS: A Package for Running WinBUGS from R. Journal of Statistical Software 12(3): 1-16.

Western Pacific Fishery Management Council [WPRFMC].
2007. Main Hawaiian Islands Bottomfish Seasonal Closure Announcement. Available at: http://www.wpcouncil.org/index.htm\

Zeller, D., M. Darcy, S. Booth, M. K. Lowe, and S. Martell.
2008. What about recreational catch? Potential impact on stock assessment for Hawaii bottomfish fisheries. Fisheries Research 91:88-97.

TABLES

Table 1.--List of species in the Hawaiian bottomfish management unit species complex. The current stock assessment provides an assessment of the status of the set of Deep7 bottomfish species; these seven species are used for reporting fishery catch and CPUE and are included in production model analyses in this assessment. The primary bottomfish species were assessed in the 2005 assessment and the 2008 assessment update and are listed for comparison (Moffitt et al., 2006; Brodziak et al. 2009).

Common name	Local name	Scientific name	Deep 7 species	Primary bottomfish species
Pink snapper	Opakapaka	*Pristipomoides filamentosus*	×	×
Longtail snapper	Onaga	*Etelis coruscans*	×	×
Squirrelfish snapper	Ehu	*Etelis carbunculus*	×	×
Sea bass	Hapuupuu	*Hyporthodus quernus*	×	×
Grey jobfish	Uku	*Aprion virescens*		×
Snapper	Gindai	*Pristipomoides zonatus*	×	×
Snapper	Kalekale	*Pristipomoides seiboldii*	×	×
Blue stripe snapper	Taape	*Lutjanus kasmira*		
Yellowtail snapper	Yellowtail kalekale	*Pristipomoides auricilla*		×
Silver jaw jobfish	Lehi	*Aphareus rutilans*	×	×
Amberjack	Kahala	*Seriola dumerili*		
Thick lipped trevally	Butaguchi	*Pseudocaranx dentex*		×
Giant trevally	White ulua	*Caranx ignobilis*		×
Black jack	Black ulua	*Caranx lugubris*		×

Table 2.--Habitat areas (km^2) for Deep7 bottomfish by island group in the main Hawaiian Islands. “EFH” is Essential Fish Habitat, “BRFA” is Bottomfish Restricted Fishing Area, and “HAPC” is Habitat Area of Particular Concern.

Island Group	EFH	non-EFH	BRFA	non-BRFA	HAPC	non-HAPC	Total Area
Hawaii	2206.6	71091.1	1079.0	72218.7	1016.6	72281.1	73297.8
Maui-Nui	5553.2	33589.2	541.3	38601.0	3774.7	35367.7	39142.4
Oahu	1429.8	37795.7	274.1	38951.3	587.0	38638.4	39225.4
Kauai	1422.1	52717.3	177.5	53961.9	708.5	53430.9	54139.4
Total	10611.7	195193.2	2072.0	203733.0	6086.8	199718.1	205804.9
Areas in square kilometers							

Table 3.1.--Time series of economic information for the Deep7 bottomfish complex in the main Hawaiian Islands during 2002-2012 including number of commercial marine licenses (CMLs) that report landings of Deep7 bottomfish, number of CMLs that reported sales of Deep7 bottomfish, number of vessels reporting landings of Deep7 bottomfish, the average number of trips per reporting vessel, the total ex-vessel revenue from sales of Deep7 bottomfish, and the total inflation-adjusted (expressed in 2012 USD) ex-vessel revenue from sales of Deep7 bottomfish.

Year (Prior to 2007 this is calendar year. Since 2007, this is fishing year from WPRFMC)	Number of commercial marine licenses (CML) that reported landings of Deep7 per year	Number of CML that reported landings of sold Deep7 per year	Number of vessels that reported landings of Deep7 per year	Average number of annual trips per reporting vessel	Total ex-vessel revenue from sale of Deep7 species (nominal $) per year	Total ex-vessel revenue from sale of Deep7 species adjusted for inflation (2012 $) per year
2002	384	339	551	5.4	$1,157,824	$1,573,305
2003	348	335	360	8.0	$1,220,325	$1,620,486
2004	358	350	392	7.0	$1,281,303	$1,647,005
2005	373	362	401	6.5	$1,278,913	$1,584,093
2006	332	326	376	6.3	$1,162,571	$1,360,219
2007	351	349	359	6.5	$1,182,015	$1,319,333
2008	476	468	490	6.7	$1,446,323	$1,548,052
2009	459	446	479	5.8	$1,244,382	$1,325,537
2010	471	446	489	7.0	$1,566,279	$1,633,624
2011	479	477	491	6.3	$1,463,915	$1,472,328
2012	458	424	465	6.4	$1,640,055	$1,640,055
Average 2002-2012	408	393	441	6.5	$1,331,264	$1,520,367

Table 3.2.--Time series of economic information for the Deep7 bottomfish complex in the main Hawaiian Islands during 2002-2012 including average price per pound, inflation-adjusted average price per pound (2012 $), total ex-vessel revenue from sales of non-Deep7 bottomfish, total inflation-adjusted ex-vessel revenue (2012 $), total revenue from sales of Deep7 bottomfish, and total inflation-adjusted revenue (2012 $) from sales of Deep7 bottomfish.

Year (Prior to 2007 this is calendar year. Since 2007, this is fishing year from WPRFMC)	Average price per pound (nominal $) of sold Deep7 per year	Average price per pound (nominal 2012 $) of sold Deep7 per year	Total ex-vessel revenue from sold non-Deep 7 species (nominal $) per year	Total ex-vessel revenue from sold non-Deep 7 species adjusted for inflation (2012 $) per year	Total bottomfish revenue (nominal $) per year	Total bottomfish revenue (2012 $) per year
2002	$5.15	$7.00	$96,320	$130,884	$1,254,144	$1,704,189
2003	$5.27	$7.00	$178,017	$236,391	$1,398,342	$1,856,877
2004	$5.61	$7.21	$226,089	$290,618	$1,507,392	$1,937,624
2005	$6.15	$7.62	$250,032	$309,696	$1,528,945	$1,893,789
2006	$6.22	$7.28	$253,946	$297,119	$1,416,517	$1,657,338
2007	$6.12	$6.83	$217,322	$242,569	$1,399,337	$1,561,902
2008	$5.65	$6.05	$367,163	$392,988	$1,813,486	$1,941,040
2009	$6.08	$6.48	$560,746	$597,316	$1,805,128	$1,922,854
2010	$5.91	$6.16	$486,609	$507,532	$2,052,888	$2,141,156
2011	$6.33	$6.37	$596,283	$599,710	$2,060,198	$2,072,038
2012	$6.83	$6.83	$872,750	$872,750	$2,512,805	$2,512,805
Average 2002-2012	$5.94	$6.80	$373,207	$407,052	$1,704,471	$1,927,419

Table 3.3.--Time series of economic information for the Deep7 bottomfish complex in the main Hawaiian Islands during 2002-2012 including the percent of total revenue from sales of Deep7 bottomfish, the Gini coefficient for individual vessel revenue per year, the total revenue for active vessels per year, the total inflation-adjusted revenue (2012 $) for active vessels per year, and the Deep7 bottomfish fishery season length (days) per year.

Year (Prior to 2007 this is calendar year. Since 2007, this is fishing year from WPRFMC)	Percent of total revenue from sale of Deep7 species per year	Gini coefficient for revenue of individual vessels per year	Total revenue per active vessel (nominal $) per year	Total revenue per active vessel 2012 $) per year	Season length (days) per year
2002	92%	0.78	$2,276	$3,093	365
2003	87%	0.79	$3,884	$5,158	365
2004	85%	0.77	$3,845	$4,943	366
2005	84%	0.77	$3,813	$4,723	365
2006	82%	0.78	$3,767	$4,408	365
2007	84%	0.69	$3,898	$4,351	198
2008	80%	0.73	$3,701	$3,961	233
2009	69%	0.72	$3,769	$4,014	231
2010	76%	0.71	$4,198	$4,379	192
2011	71%	0.76	$4,196	$4,220	366
2012	65%	0.72	$5,404	$5,404	365
Average 2002-2012	80%	0.75	$3,886	$4,423	310

Table 4.--Reported commercial catches (units are 1000 pounds) of Deep7 bottomfish in the main Hawaiian Islands as reported in the HDAR fishery logbook database by fishing year (July 1st - June 30th), 1949-2013.

Deep7 Bottomfish Reported Catch (1000 pounds) by Species, 1949-1985								
Fishing Year	Hapuupuu	Kalekale	Opakapaka	Ehu	Onaga	Lehi	Gindai	Total
1949	29.9	36.7	112.0	77.2	66.4	5.6	0.2	327.9
1950	18.6	29.2	113.7	75.3	61.2	4.6	0.8	303.4
1951	22.3	31.9	132.7	66.0	72.7	2.8	2.1	330.4
1952	32.6	45.7	139.7	54.4	45.6	9.6	2.9	330.4
1953	22.7	32.5	108.6	50.4	49.9	2.9	2.0	269.0
1954	16.7	40.1	99.1	39.8	65.5	3.9	1.9	266.9
1955	18.3	28.5	77.8	30.1	61.7	1.1	2.6	220.2
1956	28.2	33.0	112.5	40.2	70.2	3.8	3.6	291.5
1957	18.1	29.6	147.7	37.1	84.6	8.7	2.2	327.9
1958	20.9	17.5	93.9	26.8	52.2	2.4	2.0	215.8
1959	16.7	19.4	92.2	23.0	65.6	2.1	1.5	220.6
1960	12.8	19.3	70.6	19.4	39.2	1.6	1.2	164.1
1961	7.2	19.6	56.2	13.0	36.6	1.0	0.4	134.0
1962	10.5	17.6	84.5	16.4	51.1	1.8	0.8	182.8
1963	13.3	18.5	96.8	23.9	60.8	2.7	0.8	216.7
1964	11.2	23.5	95.2	24.7	47.1	1.0	2.3	205.1
1965	12.9	14.8	106.3	21.5	69.2	1.3	1.0	226.9
1966	11.9	13.6	71.4	18.1	64.1	2.0	0.8	181.9
1967	12.4	9.6	123.0	18.4	68.4	2.4	0.8	235.0
1968	11.3	6.9	84.5	19.9	69.5	2.2	0.8	195.0
1969	10.9	4.2	85.8	16.2	53.9	5.9	0.5	177.4
1970	19.8	5.1	69.5	15.9	43.5	2.7	1.4	158.0
1971	14.5	4.3	59.1	15.3	39.3	1.8	0.9	135.2
1972	17.9	8.2	118.7	21.4	58.9	4.4	1.2	230.8
1973	14.8	5.1	93.3	14.6	35.6	4.5	1.3	169.2
1974	14.6	4.9	135.2	21.1	43.6	4.9	1.5	225.7
1975	23.2	6.0	116.2	21.9	45.1	8.4	1.4	222.1
1976	22.4	7.9	105.5	31.3	80.2	10.3	1.2	258.9
1977	30.5	8.6	106.3	35.9	84.7	7.3	1.6	274.9
1978	28.7	9.8	154.6	35.7	66.5	9.8	2.6	307.7
1979	29.6	7.7	146.0	22.5	53.0	12.1	2.9	273.8
1980	17.7	7.0	151.0	17.0	31.3	17.8	2.4	244.3
1981	16.9	8.2	197.3	21.1	42.7	19.9	1.9	308.0
1982	21.7	8.1	177.7	24.4	65.9	30.0	1.6	329.4
1983	32.8	15.0	230.4	28.0	72.8	28.5	2.7	410.2
1984	29.7	13.4	159.4	36.2	86.6	16.5	3.6	345.4
1985	33.2	22.7	203.7	44.0	173.9	25.6	4.6	507.6

Table 4 (*continued*)

Deep7 Bottomfish Reported Catch (1000 pounds) by Species, 1986-2013								
Fishing Year	Hapuupuu	Kalekale	Opakapaka	Ehu	Onaga	Lehi	Gindai	Total
1986	26.5	25.4	181.4	61.9	196.5	27.7	3.8	523.2
1987	32.3	28.4	267.4	49.2	175.6	38.7	3.3	594.8
1988	10.4	18.2	301.9	42.1	157.2	38.2	2.1	570.0
1989	13.6	11.1	308.2	38.5	145.3	45.3	1.7	563.7
1990	14.2	15.5	210.3	37.6	141.5	34.9	2.8	456.8
1991	14.9	18.3	135.8	30.8	102.9	18.9	3.5	325.1
1992	15.3	28.0	173.1	31.9	91.8	17.2	5.1	362.4
1993	13.3	16.9	138.6	23.8	52.6	11.2	3.8	260.1
1994	10.4	17.9	173.6	23.2	68.4	11.6	4.0	309.1
1995	19.5	21.8	198.0	27.2	73.5	14.4	4.5	358.9
1996	10.3	20.3	145.8	29.1	69.6	10.4	3.2	288.7
1997	14.0	22.8	160.4	26.1	61.3	11.8	3.0	299.5
1998	12.7	24.4	149.6	26.4	70.8	9.4	3.4	296.6
1999	9.9	11.1	103.6	19.5	59.3	8.7	2.3	214.4
2000	13.1	15.9	165.9	26.7	72.1	11.1	3.2	308.0
2001	15.4	15.3	124.8	26.5	62.9	11.5	3.6	260.0
2002	9.0	10.3	103.5	16.9	59.6	10.8	2.4	212.4
2003	9.4	12.0	127.7	16.3	68.8	8.5	2.1	244.8
2004	7.9	8.0	87.2	19.2	75.7	4.9	2.1	205.0
2005	10.4	7.8	104.4	22.6	89.6	6.9	2.0	243.7
2006	7.2	5.2	72.1	18.7	74.1	6.3	1.6	185.3
2007	7.5	6.1	92.4	19.4	85.5	8.4	2.3	221.7
2008	6.6	5.5	96.2	18.2	55.7	11.0	2.8	196.0
2009	7.9	9.6	132.9	24.5	59.2	16.7	3.6	254.5
2010	8.2	8.2	105.4	24.7	57.9	6.1	2.8	213.4
2011	8.2	9.9	148.4	24.5	67.7	11.6	3.1	273.4
2012	9.1	11.3	105.1	25.7	52.6	7.9	3.7	215.3
2013	10.5	12.3	95.7	30.1	66.9	13.0	3.4	231.9
Average								
1949-2013	16.5	16.2	131.3	29.2	72.2	10.9	2.3	278.7
1950-1959	21.5	30.7	111.8	44.3	62.9	4.2	2.2	277.6
1960-1969	11.4	14.7	87.4	19.2	56.0	2.2	0.9	191.9
1970-1979	21.6	6.8	110.4	23.6	55.1	6.6	1.6	225.6
1980-1989	23.5	15.7	217.8	36.2	114.8	28.8	2.7	439.7
1990-1999	13.4	19.7	158.9	27.6	79.2	14.9	3.6	317.2
2000-2009	9.4	9.6	110.7	20.9	70.3	9.6	2.6	233.1
2010-2013	9.0	10.4	113.7	26.3	61.3	9.6	3.2	233.5

Table 5.--Estimates of unreported Deep7 bottomfish catches (1000 pounds) in the main Hawaiian Islands by fishing year (July 1st -June 30th), 1949-2013.

Deep7 Bottomfish Unreported Catch (1000 pounds) by Species, 1949-1985								
Fishing Year	Hapuupuu	Kalekale	Opakapaka	Ehu	Onaga	Lehi	Gindai	Total
1949	30.5	1.1	321.3	85.7	48.5	0.2	0.0	487.3
1950	19.0	0.9	326.3	83.6	44.7	0.2	0.1	474.7
1951	22.8	1.0	381.0	73.3	53.0	0.1	0.3	531.4
1952	33.2	1.4	400.8	60.4	33.3	0.4	0.4	529.9
1953	23.2	1.0	311.6	56.0	36.4	0.1	0.3	428.5
1954	17.0	1.2	284.4	44.2	47.8	0.2	0.3	395.0
1955	18.7	0.9	223.2	33.4	45.0	0.0	0.4	321.7
1956	28.8	1.0	322.8	44.6	51.2	0.2	0.5	449.2
1957	18.5	0.9	423.8	41.1	61.7	0.3	0.3	546.7
1958	21.3	0.5	269.5	29.8	38.1	0.1	0.3	359.6
1959	17.1	0.6	264.5	25.6	47.9	0.1	0.2	356.0
1960	13.0	0.6	202.5	21.6	28.6	0.1	0.2	266.6
1961	7.3	0.6	161.3	14.4	26.7	0.0	0.1	210.5
1962	10.7	0.5	242.6	18.2	37.3	0.1	0.1	309.6
1963	13.5	0.6	277.7	26.6	44.4	0.1	0.1	362.9
1964	11.5	0.7	273.3	27.4	34.4	0.0	0.3	347.7
1965	13.2	0.4	305.1	23.9	50.5	0.1	0.1	393.3
1966	12.1	0.4	204.9	20.1	46.8	0.1	0.1	284.6
1967	12.6	0.3	353.0	20.4	50.0	0.1	0.1	436.5
1968	11.5	0.2	242.5	22.1	50.7	0.1	0.1	327.2
1969	11.1	0.1	246.4	17.9	39.4	0.2	0.1	315.2
1970	20.2	0.2	199.4	17.6	31.8	0.1	0.2	269.5
1971	14.8	0.1	169.7	17.0	28.7	0.1	0.1	230.4
1972	18.3	0.2	340.6	23.7	43.0	0.2	0.2	426.3
1973	15.1	0.2	267.8	16.2	26.0	0.2	0.2	325.7
1974	14.9	0.1	388.0	23.4	31.8	0.2	0.2	458.8
1975	23.7	0.2	333.4	24.3	32.9	0.3	0.2	415.0
1976	22.8	0.2	302.8	34.7	58.6	0.4	0.2	419.7
1977	31.1	0.3	305.2	39.8	61.9	0.3	0.2	438.7
1978	29.3	0.3	443.8	39.6	48.5	0.4	0.4	562.4
1979	30.1	0.2	419.0	25.0	38.7	0.5	0.4	514.0
1980	18.1	0.2	433.4	18.9	22.9	0.7	0.4	494.5
1981	17.3	0.2	566.3	23.4	31.1	0.8	0.3	639.5
1982	22.1	0.2	510.1	27.1	48.1	1.2	0.2	609.1
1983	33.4	0.5	661.3	31.1	53.1	1.1	0.4	781.0
1984	30.3	0.4	457.3	40.1	63.2	0.7	0.5	592.6
1985	33.9	0.7	584.5	48.9	126.9	1.0	0.7	796.6

Table 5 (*continued*)

Deep7 Bottomfish Unreported Catch (1000 pounds) by Species, 1986-2013								
Fishing Year	Hapuupuu	Kalekale	Opakapaka	Ehu	Onaga	Lehi	Gindai	Total
1986	27.1	0.8	520.6	68.7	143.5	1.1	0.6	762.2
1987	32.9	0.9	767.4	54.6	128.2	1.5	0.5	986.0
1988	10.6	0.5	866.5	46.7	114.7	1.5	0.3	1040.9
1989	13.9	0.3	884.6	42.7	106.1	1.8	0.3	1049.6
1990	14.5	0.5	603.5	41.7	103.3	1.4	0.4	765.3
1991	15.2	0.5	389.7	34.2	75.1	0.8	0.5	516.0
1992	15.6	0.8	496.9	35.4	67.0	0.7	0.8	617.1
1993	13.5	0.5	397.8	26.5	38.4	0.4	0.6	477.7
1994	10.6	0.5	498.3	25.8	49.9	0.5	0.6	586.1
1995	19.9	0.7	568.4	30.2	53.7	0.6	0.7	674.0
1996	10.5	0.6	418.4	32.3	50.8	0.4	0.5	513.5
1997	14.3	0.7	460.3	29.0	44.8	0.5	0.5	549.9
1998	11.8	2.0	402.6	24.7	42.0	0.5	0.8	484.4
1999	8.4	1.4	260.1	15.0	27.2	0.6	0.8	313.4
2000	10.0	2.9	386.9	15.8	23.2	0.9	1.4	441.0
2001	10.4	3.5	268.5	11.2	11.7	1.0	1.9	308.2
2002	5.3	2.9	204.2	4.2	2.9	1.1	1.5	222.1
2003	5.6	3.4	251.9	4.1	3.4	0.9	1.3	270.5
2004	4.7	2.2	172.1	4.8	3.7	0.5	1.3	189.3
2005	6.1	2.2	205.9	5.6	4.4	0.7	1.2	226.2
2006	4.2	1.5	142.3	4.7	3.7	0.6	1.0	157.9
2007	4.4	1.7	182.3	4.9	4.2	0.9	1.4	199.8
2008	3.9	1.6	189.7	4.5	2.8	1.1	1.7	205.2
2009	4.7	2.7	262.1	6.1	2.9	1.7	2.2	282.5
2010	4.9	2.3	208.0	6.2	2.9	0.6	1.7	226.5
2011	4.8	2.8	292.8	6.1	3.3	1.2	1.9	313.0
2012	5.4	3.2	207.3	6.4	2.6	0.8	2.2	227.9
2013	6.2	3.5	188.8	7.5	3.3	1.3	2.1	212.7
Average								
1949-2013	16.0	1.0	355.7	28.3	42.8	0.6	0.6	445.0
1950-1959	21.9	0.9	320.8	49.2	45.9	0.2	0.3	439.3
1960-1969	11.7	0.4	250.9	21.3	40.9	0.1	0.1	325.4
1970-1979	22.0	0.2	317.0	26.1	40.2	0.3	0.2	406.1
1980-1989	24.0	0.5	625.2	40.2	83.8	1.2	0.4	775.2
1990-1999	13.4	0.8	449.6	29.5	55.2	0.6	0.6	549.8
2000-2009	5.9	2.4	226.6	6.6	6.3	0.9	1.5	250.3
2010-2013	5.3	2.9	224.2	6.6	3.0	1.0	2.0	245.0

Table 6.--Estimates of total Deep7 bottomfish reported and unreported catches (1000 pounds) in the main Hawaiian Islands used in the stock assessment by fishing year (July 1st -June 30th), 1949-2013.

Deep7 Bottomfish Total Catch (1000 pounds), 1949-2013							
Fishing Year	Reported Catch Total	Unreported Catch Estimate	Total Catch Estimate	Fishing Year	Reported Catch Total	Unreported Catch Estimate	Total Catch Estimate
1949	327.9	487.3	815.2	1986	523.2	762.2	1285.4
1950	303.4	474.7	778.0	1987	594.8	986.0	1580.7
1951	330.4	531.4	861.8	1988	570.0	1040.9	1610.9
1952	330.4	529.9	860.4	1989	563.7	1049.6	1613.3
1953	269.0	428.5	697.5	1990	456.8	765.3	1222.1
1954	266.9	395.0	662.0	1991	325.1	516.0	841.1
1955	220.2	321.7	541.8	1992	362.4	617.1	979.5
1956	291.5	449.2	740.7	1993	260.1	477.7	737.8
1957	327.9	546.7	874.7	1994	309.1	586.1	895.2
1958	215.8	359.6	575.4	1995	358.9	674.0	1032.9
1959	220.6	356.0	576.6	1996	288.7	513.5	802.2
1960	164.1	266.6	430.6	1997	299.5	549.9	849.4
1961	134.0	210.5	344.5	1998	296.6	484.4	781.0
1962	182.8	309.6	492.4	1999	214.4	313.4	527.9
1963	216.7	362.9	579.6	2000	308.0	441.0	749.0
1964	205.1	347.7	552.7	2001	260.0	308.2	568.2
1965	226.9	393.3	620.2	2002	212.4	222.1	434.5
1966	181.9	284.6	466.4	2003	244.8	270.5	515.4
1967	235.0	436.5	671.5	2004	205.0	189.3	394.3
1968	195.0	327.2	522.3	2005	243.7	226.2	470.0
1969	177.4	315.2	492.6	2006	185.3	157.9	343.2
1970	158.0	269.5	427.5	2007	221.7	199.8	421.5
1971	135.2	230.4	365.6	2008	196.0	205.2	401.2
1972	230.8	426.3	657.1	2009	254.5	282.5	537.0
1973	169.2	325.7	494.9	2010	213.4	226.5	439.9
1974	225.7	458.8	684.5	2011	273.4	313.0	586.4
1975	222.1	415.0	637.1	2012	215.3	227.9	443.3
1976	258.9	419.7	678.6	2013	231.9	212.7	444.6
1977	274.9	438.7	713.6	Average	Reported	Unreported	Total
1978	307.7	562.4	870.1	1949-2013	278.7	445.0	723.7
1979	273.8	514.0	787.8	1950-1959	277.6	439.3	716.9
1980	244.3	494.5	738.9	1960-1969	191.9	325.4	517.3
1981	308.0	639.5	947.4	1970-1979	225.6	406.1	631.7
1982	329.4	609.1	938.6	1980-1989	439.7	775.2	1214.9
1983	410.2	781.0	1191.1	1990-1999	317.2	549.8	866.9
1984	345.4	592.6	938.0	2000-2009	233.1	250.3	483.4
1985	507.6	796.6	1304.3	2010-2013	233.5	245.0	478.5

Table 7.1.--Reported commercial catches (thousands of pounds) of Deep7 bottomfish by Hawaiian Island group and by fishing year (July 1st -June 30th), 1949-2013, with partial years of data for 1948 and 2014.

	Main Hawaiian Island Group				
Fishing Year	Hawaii Reported Catch	Maui-Molokai-Lanai Reported Catch	Oahu Reported Catch	Kauai Reported Catch	Total Reported Catch By Island Group
1948*	27.0	88.9	23.8	41.7	181.5
1949	63.1	176.2	20.7	67.8	327.9
1950	69.7	159.4	17.3	56.9	303.4
1951	68.0	200.3	8.4	42.5	319.2
1952	34.3	196.2	33.6	37.1	301.2
1953	43.0	166.3	11.9	38.6	259.8
1954	55.2	181.6	7.7	20.8	265.3
1955	38.2	144.3	10.4	27.3	220.2
1956	54.7	169.7	14.4	37.8	276.6
1957	94.6	189.4	10.9	22.8	317.7
1958	43.0	132.2	14.8	21.0	211.0
1959	43.7	108.8	7.8	43.7	204.0
1960	27.3	124.4	2.4	9.4	163.5
1961	13.8	106.9	2.5	5.9	129.0
1962	23.7	135.4	4.3	19.4	182.8
1963	10.4	164.1	7.9	28.1	210.5
1964	16.5	141.9	6.4	36.7	201.5
1965	31.6	169.0	11.6	12.2	224.4
1966	17.1	152.6	5.5	6.6	181.9
1967	26.0	177.3	11.3	16.7	231.3
1968	18.7	157.4	11.6	7.3	195.0
1969	12.4	146.4	10.7	8.0	177.4
1970	13.3	121.9	5.2	17.5	158.0
1971	13.5	97.6	9.8	14.2	135.2
1972	48.0	150.0	19.4	10.9	228.3
1973	43.1	107.9	12.9	5.4	169.2
1974	60.3	141.8	20.9	2.7	225.7
1975	55.4	137.9	15.5	13.3	222.1
1976	64.4	153.8	24.3	16.4	258.9
1977	64.7	165.5	13.1	31.6	274.9
1978	80.2	174.9	28.0	24.6	307.7
1979	85.3	139.7	16.6	32.3	273.8
1980	91.1	126.1	15.6	11.5	244.3
1981	105.5	172.3	21.8	8.3	308.0
1982	89.5	186.9	32.1	20.9	329.4
1983	111.9	192.3	25.5	80.4	410.2
1984	78.2	174.6	22.1	70.5	345.4
1985	93.7	216.5	48.2	149.3	507.6

	Main Hawaiian Island Group				
Fishing Year	Hawaii Reported Catch	Maui-Molokai-Lanai Reported Catch	Oahu Reported Catch	Kauai Reported Catch	Total Reported Catch By Island Group
1986	142.7	260.6	33.5	86.4	523.2
1987	133.5	312.5	52.9	95.9	594.8
1988	172.8	281.4	66.2	48.3	568.7
1989	160.7	291.9	71.1	40.0	563.7
1990	120.3	230.0	68.9	37.7	456.8
1991	68.9	189.5	26.6	40.0	325.1
1992	98.0	202.5	14.4	47.6	362.4
1993	60.3	142.6	33.5	23.7	260.1
1994	54.6	185.2	35.4	33.8	309.0
1995	66.1	208.4	38.2	46.1	358.9
1996	50.5	173.5	32.9	31.7	288.7
1997	66.0	168.4	40.3	24.7	299.5
1998	58.1	180.2	24.6	33.8	296.6
1999	42.8	130.8	25.2	15.7	214.4
2000	65.7	183.4	39.3	19.6	308.0
2001	60.5	149.4	21.6	28.5	260.0
2002	44.2	121.3	17.9	29.0	212.4
2003	43.0	136.3	31.8	33.6	244.8
2004	34.9	133.6	16.7	19.8	205.0
2005	31.6	155.7	18.6	37.8	243.7
2006	33.9	107.7	12.4	31.2	185.3
2007	51.2	119.0	19.9	31.6	221.7
2008	55.5	103.0	23.1	14.4	196.0
2009	85.4	138.5	15.7	14.9	254.5
2010	48.5	133.7	14.2	17.6	213.9
2011	45.0	173.6	24.4	30.4	273.4
2012	46.8	136.4	9.4	22.7	215.3
2013	52.7	151.4	11.7	16.2	231.9
2014*	43.5	99.1	9.8	12.4	164.8
Average					
2010-2013	48.2	148.8	14.9	21.7	233.6
1949-2013	60.0	164.0	21.6	31.2	276.8
1950-1959	54.4	164.8	13.7	34.9	267.8
1960-1969	19.7	147.5	7.4	15.0	189.7
1970-1979	52.8	139.1	16.6	16.9	225.4
1980-1989	118.0	221.5	38.9	61.2	439.5
1990-1999	68.6	181.1	34.0	33.5	317.2
2000-2009	50.6	134.8	21.7	26.0	233.1

Table 7.2.--Annual proportion of reported commercial catches (thousands of pounds) of Deep7 bottomfish by Hawaiian Island group and by fishing year (July 1st -June 30th), 1949-2013, with partial years of data for 1948 and 2014.

	Main Hawaiian Island Group			
Fishing Year	Hawaii Proportion	Maui-Molokai-Lanai Proportion	Oahu Proportion	Kauai Proportion
1948*	0.15	0.49	0.13	0.23
1949	0.19	0.54	0.06	0.21
1950	0.23	0.53	0.06	0.19
1951	0.21	0.63	0.03	0.13
1952	0.11	0.65	0.11	0.12
1953	0.17	0.64	0.05	0.15
1954	0.21	0.68	0.03	0.08
1955	0.17	0.66	0.05	0.12
1956	0.20	0.61	0.05	0.14
1957	0.30	0.60	0.03	0.07
1958	0.20	0.63	0.07	0.10
1959	0.21	0.53	0.04	0.21
1960	0.17	0.76	0.01	0.06
1961	0.11	0.83	0.02	0.05
1962	0.13	0.74	0.02	0.11
1963	0.05	0.78	0.04	0.13
1964	0.08	0.70	0.03	0.18
1965	0.14	0.75	0.05	0.05
1966	0.09	0.84	0.03	0.04
1967	0.11	0.77	0.05	0.07
1968	0.10	0.81	0.06	0.04
1969	0.07	0.83	0.06	0.04
1970	0.08	0.77	0.03	0.11
1971	0.10	0.72	0.07	0.10
1972	0.21	0.66	0.08	0.05
1973	0.25	0.64	0.08	0.03
1974	0.27	0.63	0.09	0.01
1975	0.25	0.62	0.07	0.06
1976	0.25	0.59	0.09	0.06
1977	0.24	0.60	0.05	0.11
1978	0.26	0.57	0.09	0.08
1979	0.31	0.51	0.06	0.12
1980	0.37	0.52	0.06	0.05
1981	0.34	0.56	0.07	0.03
1982	0.27	0.57	0.10	0.06
1983	0.27	0.47	0.06	0.20
1984	0.23	0.51	0.06	0.20
1985	0.18	0.43	0.09	0.29

	Main Hawaiian Island Group			
Fishing Year	Hawaii Proportion	Maui-Molokai-Lanai Proportion	Oahu Proportion	Kauai Proportion
1986	0.27	0.50	0.06	0.17
1987	0.22	0.53	0.09	0.16
1988	0.30	0.49	0.12	0.08
1989	0.29	0.52	0.13	0.07
1990	0.26	0.50	0.15	0.08
1991	0.21	0.58	0.08	0.12
1992	0.27	0.56	0.04	0.13
1993	0.23	0.55	0.13	0.09
1994	0.18	0.60	0.11	0.11
1995	0.18	0.58	0.11	0.13
1996	0.18	0.60	0.11	0.11
1997	0.22	0.56	0.13	0.08
1998	0.20	0.61	0.08	0.11
1999	0.20	0.61	0.12	0.07
2000	0.21	0.60	0.13	0.06
2001	0.23	0.57	0.08	0.11
2002	0.21	0.57	0.08	0.14
2003	0.18	0.56	0.13	0.14
2004	0.17	0.65	0.08	0.10
2005	0.13	0.64	0.08	0.15
2006	0.18	0.58	0.07	0.17
2007	0.23	0.54	0.09	0.14
2008	0.28	0.53	0.12	0.07
2009	0.34	0.54	0.06	0.06
2010	0.23	0.62	0.07	0.08
2011	0.16	0.63	0.09	0.11
2012	0.22	0.63	0.04	0.11
2013	0.23	0.65	0.05	0.07
2014*	0.26	0.60	0.06	0.08
Average				
2010-2013	0.21	0.64	0.06	0.09
1949-2013	0.21	0.61	0.07	0.11
1950-1959	0.20	0.62	0.05	0.13
1960-1969	0.10	0.78	0.04	0.08
1970-1979	0.22	0.63	0.07	0.07
1980-1989	0.28	0.51	0.08	0.13
1990-1999	0.21	0.58	0.11	0.10
2000-2009	0.22	0.58	0.09	0.11

Table 8.--Model selection analyses for the generalized linear model (GLM) to standardize Deep7 bottomfish CPUE during 1949-1993 and 1994-2013 using Akaike's information criterion (AIC). For the 1949-1993 time period, the best-fitting GLM (Base_1949-1993) had the same structure (Year, Area, Quarter, and Area*Quarter effects) as in the previous assessment. For the 1994-2013 time period, the best-fitting GLM (Base_1994-2013_CML) included a Hawaii commercial marine license effect and did not include an Area*Quarter effect. The iteratively reweighted least squares estimation algorithm did not converge for the GLM parameters including both commercial marine license and Area*Quarter effects.

GLM Selection for Deep7 Main Hawaiian Islands Bottomfish CPUE Standardizations, 1949-1993 and 1994-2013									
Model Name	Structure of CPUE Predictor	R-square	Number of Data Points	Mean Square Error	Number of Parameters	AIC Value	ΔAIC	Model Relative Likelihood	Model Probability
Base_1949-1993	**Y+A+Q+A*Q**	**0.239**	**95905**	**1.209**	**369**	**18900.5**	**0.0**	**1.00**	**1.00**
Base_1949-1993_wo_AQ	Y+A+Q	0.231	95905	1.218	126	19189.1	288.6	0.00	0.00
Model Name	Structure of CPUE Predictor	R-square	Number of Data Points	Mean Square Error	Number of Parameters	AIC Value	ΔAIC	Model Relative Likelihood	Model Probability
Base_1994-2013_CML	**Y+A+Q+L**	**0.534**	**63636**	**0.651**	**2086**	**-23103.4**	**0.0**	**1.00**	**1.00**
Base_1994-2013_AQ_CML	Y+A+Q+A*Q+L	*Did not converge*	63636		2329				
Base_1994-2013_AQ	Y+A+Q+A*Q	0.244	63636	1.029	346	2516.8	25620.2	0.00	0.00
Base_1994-2013_wo_AQ	Y+A+Q	0.233	63636	1.039	103	2632.7	25736.1	0.00	0.00

Table 9.1.--Analysis of deviance table for the best-fitting GLM used to standardize Deep7 bottomfish CPUE during 1949-1993.

CPUE Standardization for 1949-1993					
	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Pr > F
Model	369	36288.022	98.342	81.37	< 0.0001
Error	95536	115457.082	1.209		
Corrected Total	95905	151745.104			
R-Square =	0.239				
Effects	Degrees of Freedom	Type III Sum of Squares	Mean Square	F Value	Pr > F
Y(year)	42	4118.523	98.060	81.14	< 0.0001
A(area)	81	26479.943	326.913	270.51	< 0.0001
Q(quarter)	3	68.195	22.732	18.81	< 0.0001
A*Q(area-quarter interaction)	243	1226.161	5.046	4.18	< 0.0001

Table 9.2.--Analysis of deviance table for the best-fitting GLM used to standardize Deep7 bottomfish CPUE during 1994-2013.

CPUE Standardization for 1994-2013					
	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Pr > F
Model	2086	46005.456	22.054	33.86	< 0.0001
Error	61550	40094.533	0.651		
Corrected Total	63636	86099.989			
R-Square =	0.534				
Effects	Degrees of Freedom	Type III Sum of Squares	Mean Square	F Value	Pr > F
Y(year)	19	234.493	12.342	18.95	< 0.0001
A(area)	81	1022.561	12.624	19.38	< 0.0001
Q(quarter)	3	362.524	120.841	185.51	< 0.0001
L(license)	1983	25908.310	13.065	20.06	< 0.0001

Table 10.--Estimates of standardized CPUE for Deep7 bottomfish in the main Hawaiian Islands during 1949-1993 and during 1994-2013 used in the baseline assessment model. The single time-series estimate of standardized Deep7 CPUE during 1949-2013 and nominal Deep7 CPUE are included for comparison.

Fishing Year	Two-Series MHI Deep7 Bottomfish Standardized CPUE (lbs/trip) from 2014 Assessment	Standardized CPUE Two Standard Error Offset (2σ, lbs/trip)	Single-Series MHI Deep7 Bottomfish Standardized CPUE (lbs/trip) from 2014 Assessment	Standardized CPUE Two Standard Error Offset (2σ, lbs/trip)	Nominal Deep7 Bottomfish Deep Handline CPUE Used in CPUE Standardization (lbs/trip)	Nominal CPUE Two Standard Error Offset (2σ, lbs/trip)
1949	188.6	12.6	179.1	11.6	106.8	9.2
1950	208.3	14.1	195.3	12.8	108.7	7.6
1951	214.4	15.1	205.4	14.0	134.4	9.2
1952	251.2	19.6	240.7	18.3	177.4	13.1
1953	240.7	20.8	232.9	19.6	180.9	15.5
1954	289.3	25.8	277.7	24.1	218.9	19.8
1955	366.6	39.3	365.7	38.1	292.1	28.0
1956	307.7	29.3	295.9	27.4	226.1	21.8
1957	340.5	30.7	334.8	29.3	244.3	19.0
1958						
1959						
1960						
1961	376.8	46.7	371.5	44.8	257.4	28.8
1962	421.6	45.3	404.7	42.3	268.7	23.3
1963	261.8	26.1	253.0	24.5	185.7	18.0
1964	289.1	28.0	277.4	26.2	176.7	16.7
1965	361.5	32.1	343.9	29.6	186.7	14.9
1966	307.6	27.9	299.1	26.3	191.1	16.3
1967	296.3	23.5	284.2	21.9	163.3	12.0
1968	283.2	24.4	280.3	23.4	178.5	15.3
1969	266.7	22.7	262.0	21.6	155.8	12.7
1970	248.6	21.4	241.2	20.2	145.1	13.3
1971	224.5	18.9	218.7	17.9	117.5	10.2
1972	247.8	18.1	239.6	17.0	116.4	8.8
1973	233.8	18.2	225.4	17.0	112.3	9.0
1974	224.9	15.8	218.4	14.9	112.6	7.4
1975	220.9	15.7	214.1	14.9	113.8	8.2
1976	237.1	16.7	231.0	15.9	136.4	9.6
1977	189.5	12.9	182.4	12.1	122.3	8.2
1978	189.2	12.6	183.0	11.9	119.5	7.6
1979	217.3	15.5	209.2	14.5	141.2	10.2
1980	184.9	11.9	179.7	11.3	101.1	6.1
1981	189.6	11.6	184.6	11.0	94.2	4.3
1982	172.3	10.5	167.0	9.9	89.1	4.5
1983	177.5	10.3	170.0	9.6	94.7	4.5
1984	141.5	8.4	137.2	7.9	85.2	4.5
1985	155.9	8.7	150.7	8.2	85.5	3.3
1986	156.6	8.7	151.2	8.2	92	4.1
1987	179.0	10.0	172.8	9.4	101.5	3.5
1988	206.8	11.4	199.1	10.7	97.2	2.9
1989	197.7	10.9	192.4	10.3	94.4	3.1
1990	177.0	9.9	171.6	9.4	89.8	3.3
1991	164.8	9.6	158.3	9.0	80.9	3.1
1992	154.1	8.9	146.2	8.2	80.4	3.3
1993	111.6	6.7	138.0	8.1	72.6	3.3

Table 10 (continued)

Fishing Year	Two-Series MHI Deep7 Bottomfish Standardized CPUE (lbs/trip) from 2014 Assessment	Standardized CPUE Two Standard Error Offset (2σ, lbs/trip)	Single-Series MHI Deep7 Bottomfish Standardized CPUE (lbs/trip) from 2014 Assessment	Standardized CPUE Two Standard Error Offset (2σ, lbs/trip)	Nominal Deep7 Bottomfish Deep Handline CPUE Used in CPUE Standardization (lbs/trip)	Nominal CPUE Two Standard Error Offset (2σ, lbs/trip)
1994	103.0	5.0	152.3	8.8	83.1	3.5
1995	109.4	5.2	155.2	8.8	86.3	3.9
1996	98.5	4.7	140.1	8.0	73.7	2.9
1997	98.9	4.6	142.9	8.0	70	2.5
1998	92.8	4.3	134.4	7.6	71.3	2.7
1999	97.9	4.8	139.7	8.4	70.4	2.7
2000	111.6	5.2	160.5	9.2	79.5	3.1
2001	103.8	4.9	153.2	8.9	74	2.9
2002	93.1	4.5	142.3	8.7	74.6	3.9
2003	95.7	4.6	148.8	9.0	82.2	3.9
2004	90.5	4.5	138.1	8.5	76.1	3.3
2005	100.2	4.9	159.4	9.9	90.3	4.1
2006	100.5	5.1	149.7	9.6	82.2	4.1
2007	105.1	5.1	158.9	9.8	82.2	4.1
2008	120.6	6.1	191.5	12.3	85.4	3.7
2009	111.6	5.2	171.6	10.3	80	3.1
2010	97.1	4.6	144.6	8.9	75.3	3.5
2011	107.0	4.8	155.8	9.2	80	3.1
2012	103.4	4.6	147.7	8.9	72.2	3.1
2013	107.4	4.8	146.7	8.9	77.6	3.3

Table 11.--Assumed prior distributions and mean parameter estimates for the Deep7 bottomfish stock complex based on the 2014 base case assessment production model results (mean estimate in boldface with estimated standard deviation immediately below) along with a comparison of results if the 2011 stock assessment was a strict update. Assumed priors are the same as used in the 2011 assessment. Parameter estimates are labeled as: r, the intrinsic growth rate per year; K, the carrying capacity (million pounds); M, the production model shape parameter; P_1, the proportion of biomass to K in 1949; q, the catchability coefficient; τ^2, observation error variance; σ^2, process error variance; C_T, the error in unreported catch estimates; HMSY, the exploitation rate (% of annual exploitable biomass harvested) to produce MSY; BMSY, the exploitable biomass (million pounds) to produce MSY; MSY for total catch, the estimate of MSY as the sum of reported and unreported catch (million pounds); MSY for reported catch, the estimate of MSY as reported catch only (million pounds); PMSY, the proportion of carrying capacity to produce MSY; H_{2010}, the harvest rate in 2010; B_{2010}, the exploitable biomass in 2010; H_{2013}, the harvest rate in 2013; B_{2013}, the exploitable biomass in 2013. "Base Case 2014 Assessment" indicates the 2014 base case assessment that includes commercial marine licenses for CPUE standardization and two time periods for CPUE (1949-1993 and 1994-2013), and "Updated Base Case 2011 Assessment" indicates model results that use the 2011 base case CPUE assumption of only one time period for CPUE from 1949-2013 and exclude commercial marine licenses for CPUE standardization.

Assumed Priors	r	K	M	P_1	$q_{1949-1993}$	$q_{1994-2013}$	$\tau^2_{1949-1993}$	$\tau^2_{1994-2013}$	σ^2	C_T
Distribution	Lognormal	Lognormal	Gamma	Lognormal	Uniform	Uniform	Inverse-gamma	Inverse-gamma	Inverse-gamma	Uniform
Mean	0.1	18.0 million lbs	1	0.53	$[10^{-5}, 10^{5}]$	$[10^{-5}, 10^{5}]$	0.83	0.83	0.083	Unreported catch
CV	25%	50%	140%	20%	NA	NA				20%

Deep 7 MHI Bottomfish Assessment	r	K	M	P_1	$q_{1949-1993}$	$q_{1994-2013}$	$\tau^2_{1949-1993}$	$\tau^2_{1994-2013}$	σ^2
Base Case	**0.110**	**24.600**	**2.06**	**0.58**	**15.3**	**11.9**	**0.072**	**0.146**	**0.026**
2014 Assessment	0.027	8.266	1.48	0.10	4.6	5.7	0.018	0.055	0.010
Updated Base Case	**0.106**	**27.360**	**1.76**	**0.58**	**13.0**		**0.050**		**0.022**
2011 Assessment	0.025	9.378	1.28	0.1	4.3		0.010		0.008

(continued next page)

Table 11 (continued)

Deep 7 MHI Bottomfish Assessment	HMSY	BMSY	MSY for Total Catch	MSY for Reported Catch	PMSY	H_{2010}	B_{2010}	H_{2013}	B_{2013}
Base Case	**6.6%**	**13.460**	**0.863**	**0.415**	**0.56**	**5.0%**	**11.320**	**5.1%**	**11.630**
2014 Assessment	2.4%	3.903	0.342	0.164	0.08	2.6%	6.428	2.9%	6.745
Updated Base Case	**6.0%**	**14.510**	**0.839**	**0.404**	**0.54**	**3.7%**	**13.470**	**3.8%**	**13.340**
2011 Assessment	2.1%	4.267	0.324	0.156	0.08	1.3%	5.333	1.4%	5.397

Table 12.--Estimates of exploitable biomass and harvest rate time series of Deep7 bottomfish in the main Hawaiian Islands and stock status information by fishing year, 1949-2013. Overfished is defined as $B<0.75*B_{MSY}$, and overfishing is defined as $H>H_{MSY}$.

Year	Mean Exploitable Biomass (B, 1000,000 lbs)	Relative Mean Exploitable Biomass (B/BMSY)	Probability of Being Overfished	Mean Harvest Rate (H)	Relative Mean Harvest Rate (H/HMSY)	Probability of Overfishing
1949	14.090	1.05	0.07	6.4%	0.97	0.47
1950	15.090	1.12	0.05	5.8%	0.87	0.35
1951	16.120	1.20	0.03	6.0%	0.91	0.40
1952	17.190	1.28	0.02	5.6%	0.86	0.34
1953	18.100	1.34	0.02	4.4%	0.66	0.15
1954	19.320	1.44	0.01	3.9%	0.59	0.10
1955	20.460	1.52	0.01	3.0%	0.46	0.05
1956	21.160	1.57	0.01	4.0%	0.61	0.11
1957	21.540	1.60	0.01	4.7%	0.71	0.19
1958	21.480	1.60	0.01	3.1%	0.47	0.05
1959	21.760	1.62	0.01	3.1%	0.47	0.05
1960	22.000	1.63	0.01	2.3%	0.34	0.02
1961	22.400	1.66	0.01	1.8%	0.27	0.01
1962	22.680	1.68	0.00	2.5%	0.38	0.03
1963	22.030	1.64	0.00	3.0%	0.46	0.04
1964	21.840	1.62	0.00	2.9%	0.44	0.04
1965	21.920	1.63	0.00	3.2%	0.49	0.06
1966	21.340	1.59	0.01	2.5%	0.38	0.03
1967	20.860	1.55	0.01	3.7%	0.55	0.08
1968	20.060	1.49	0.01	3.0%	0.45	0.04
1969	19.370	1.44	0.01	2.9%	0.44	0.04
1970	18.690	1.39	0.02	2.6%	0.39	0.03
1971	18.190	1.35	0.02	2.3%	0.35	0.02
1972	17.970	1.34	0.02	4.1%	0.63	0.13
1973	17.390	1.29	0.03	3.2%	0.49	0.06
1974	16.970	1.26	0.03	4.6%	0.69	0.18
1975	16.470	1.22	0.04	4.4%	0.66	0.16
1976	16.080	1.19	0.05	4.8%	0.72	0.21
1977	15.350	1.14	0.07	5.2%	0.79	0.28
1978	14.960	1.11	0.08	6.6%	0.99	0.50
1979	14.660	1.09	0.10	6.1%	0.92	0.42
1980	14.130	1.05	0.12	5.9%	0.89	0.39
1981	13.830	1.03	0.13	7.7%	1.17	0.66

Table 12 (continued)

Year	Mean Exploitable Biomass (B, 1000,000 lbs)	Relative Mean Exploitable Biomass (B/BMSY)	Probability of Being Overfished	Mean Harvest Rate (H)	Relative Mean Harvest Rate (H/HMSY)	Probability of Overfishing
1982	13.260	0.99	0.17	7.9%	1.20	0.69
1983	12.920	0.96	0.19	10.3%	1.56	0.88
1984	12.260	0.91	0.25	8.5%	1.29	0.76
1985	12.490	0.93	0.22	11.6%	1.76	0.93
1986	12.630	0.94	0.20	11.3%	1.71	0.92
1987	13.200	0.98	0.15	13.3%	2.01	0.96
1988	13.450	1.00	0.14	13.3%	2.02	0.96
1989	13.060	0.97	0.18	13.8%	2.09	0.97
1990	12.220	0.91	0.26	11.3%	1.71	0.91
1991	11.560	0.86	0.34	8.2%	1.25	0.72
1992	11.070	0.82	0.40	10.0%	1.52	0.85
1993	10.490	0.78	0.50	8.1%	1.22	0.68
1994	10.700	0.79	0.49	9.8%	1.49	0.79
1995	10.750	0.80	0.50	11.5%	1.74	0.85
1996	10.510	0.78	0.53	9.4%	1.42	0.73
1997	10.470	0.78	0.54	10.1%	1.53	0.76
1998	10.330	0.77	0.56	9.6%	1.45	0.72
1999	10.370	0.77	0.56	6.5%	0.99	0.48
2000	10.630	0.79	0.53	9.0%	1.37	0.68
2001	10.430	0.77	0.55	7.0%	1.07	0.53
2002	10.330	0.77	0.56	5.5%	0.83	0.36
2003	10.420	0.77	0.55	6.4%	0.98	0.47
2004	10.450	0.78	0.55	4.9%	0.75	0.30
2005	10.710	0.80	0.53	5.7%	0.86	0.39
2006	10.880	0.81	0.52	4.1%	0.62	0.20
2007	11.200	0.83	0.50	4.9%	0.74	0.29
2008	11.450	0.85	0.47	4.6%	0.69	0.25
2009	11.480	0.85	0.47	6.1%	0.92	0.42
2010	11.320	0.84	0.48	5.0%	0.76	0.31
2011	11.430	0.85	0.47	6.7%	1.01	0.48
2012	11.430	0.85	0.47	5.1%	0.77	0.31
2013	11.630	0.86	0.45	5.1%	0.77	0.31

Table 13.--Sensitivity analyses for posterior estimates of production model parameters to a 25% increase (1.25*mean) and a 25% decrease (0.75*mean) in the mean values of the prior distributions for intrinsic growth rate (*r*), carrying capacity (*K*), initial proportion of carrying capacity in 1949 (P_1), and production model shape parameter (*M*).

Parameter	Base case		1.25**r*		0.75**r*		1.25**K*		0.75**K*	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
r	0.11	0.03	0.11	0.03	0.11	0.03	0.11	0.03	0.11	0.03
K	24.42	8.13	27.30	9.26	23.38	7.41	21.61	6.73	27.61	9.87
M	2.10	1.48	1.84	1.38	2.11	1.48	2.31	1.53	1.87	1.43
P_1	0.58	0.10	0.46	0.08	0.68	0.12	0.58	0.10	0.57	0.10
B_{MSY}	13.44	3.91	14.58	4.22	12.92	3.69	12.20	3.33	14.72	4.54
B1949	14.07	4.94	12.31	4.07	15.94	5.64	12.53	4.14	15.64	5.80
B1949/BMSY	1.05	0.24	0.85	0.19	1.24	0.30	1.04	0.23	1.07	0.25
B2013	11.87	6.76	10.73	6.13	12.54	7.11	10.40	5.73	12.65	7.67
B2013/BMSY	0.89	0.41	0.75	0.38	0.97	0.43	0.86	0.40	0.86	0.41
H_{MSY}	0.07	0.02	0.06	0.02	0.07	0.02	0.07	0.02	0.06	0.02
H1949	0.06	0.02	0.07	0.02	0.06	0.02	0.07	0.02	0.06	0.02
H1949/HMSY†	0.97		1.17		0.86		1.00		0.96	
H2013	0.05	0.03	0.05	0.03	0.05	0.03	0.06	0.03	0.05	0.03
H2013/HMSY†	0.69		0.82		0.65		0.73		0.72	
MSY	0.87	0.35	0.88	0.34	0.84	0.35	0.85	0.31	0.87	0.38

Parameter	Base case		1.25*P_1		0.75*P_1		1.25**M*		0.75**M*	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
r	0.11	0.03	0.08	0.02	0.14	0.03	0.11	0.03	0.11	0.03
K	24.97	8.13	27.16	8.77	22.57	7.87	25.29	8.38	24.37	8.21
M	1.97	1.42	2.20	1.60	1.93	1.34	1.79	1.24	2.30	1.67
P_1	0.58	0.10	0.58	0.10	0.58	0.10	0.58	0.10	0.58	0.10
B_{MSY}	13.55	3.76	15.08	4.37	12.21	3.63	13.49	3.86	13.62	3.98
B1949	14.27	4.89	15.56	5.19	12.99	4.78	14.47	5.01	14.00	4.90
B1949/BMSY	1.06	0.23	1.05	0.25	1.07	0.23	1.08	0.24	1.04	0.23
B2013	10.85	5.63	11.93	6.65	11.47	6.50	11.95	6.72	11.82	6.68
B2013/BMSY	0.80	0.33	0.80	0.38	0.94	0.42	0.89	0.41	0.87	0.40
H_{MSY}	0.06	0.02	0.05	0.02	0.08	0.03	0.06	0.02	0.07	0.02
H1949	0.06	0.02	0.06	0.02	0.07	0.02	0.06	0.02	0.06	0.02
H1949/HMSY†	0.99		1.12		0.89		0.99		0.96	
H2013	0.05	0.02	0.05	0.03	0.05	0.03	0.05	0.03	0.05	0.03
H2013/HMSY†	0.78		0.89		0.60		0.73		0.68	
MSY	0.84	0.31	0.76	0.33	0.94	0.36	0.83	0.34	0.90	0.35

Table 14.--Stochastic projection results showing the estimates of annual catch limits for commercial catches (1000 pounds) of Deep7 bottomfish in the main Hawaiian Islands in fishing years 2015 and 2016 that would produce probabilities of overfishing in 2015 of 0%, 5%, 10%, …, 50% and greater assuming that annual commercial catch in 2014 was 244,000 pounds, or 70% of the 2014 annual catch limit of 346,000 pounds, as well as mean projected harvest rates, exploitable biomasses, and probable stock status conditions. Overfished is defined as $B<0.75*B_{MSY}$, and overfishing is defined as $H>H_{MSY}$.

Probability of Overfishing Deep7 Bottomfish in the main Hawaiian Islands in Fishing Year 2015	Annual Catch Limit for Commercial Catch (1000 pounds) of Deep7 Bottomfish in Fishing Years 2015 and 2016	Expected Harvest Rate in 2015	Probability of Overfishing in 2016	Expected Harvest Rate in 2016	Mean Exploitable Biomass (1000,000 pounds) in 2016	Probability of being overfished in 2016
0.00	14	0.3%	0.00	0.3%	12.890	0.37
0.05	84	2.0%	0.05	1.9%	12.740	0.38
0.10	120	2.9%	0.10	2.8%	12.670	0.38
0.15	148	3.6%	0.15	3.5%	12.610	0.39
0.20	172	4.1%	0.19	4.1%	12.560	0.39
0.25	196	4.7%	0.24	4.7%	12.510	0.39
0.30	220	5.3%	0.29	5.3%	12.460	0.40
0.35	244	5.9%	0.34	6.0%	12.410	0.40
0.40	268	6.4%	0.39	6.6%	12.360	0.40
0.41	274	6.6%	0.40	6.8%	12.350	0.40
0.45	296	7.1%	0.45	7.4%	12.300	0.41
0.50	324	7.8%	0.50	8.2%	12.240	0.41

Table 15.--Stochastic stock projection results showing the estimates of annual catch limits for commercial catches (1000 pounds) of Deep7 bottomfish in the main Hawaiian Islands in fishing years 2015 and 2016 that would produce probabilities of overfishing in 2015 of 0%, 5%, 10%, …, 50% given that the annual 2014 commercial catch is 244, 276, 310, or 325 thousand pounds, or 70%, 80%, 90%, or 94% of the 2014 annual catch limit of 346,000 pounds. Overfished is defined as $B<0.75*B_{MSY}$, and overfishing is defined as $H>H_{MSY}$.

Probability of Overfishing Deep 7 Bottomfish in the main Hawaiian Islands in Fishing Year 2015	Annual Catch Limit for Commercial Catch (1000 pounds) of Deep 7 Bottomfish in Fishing Year 2015 if the 2014 Commercial Catch is 244,000 pounds	Annual Catch Limit for Commercial Catch (1000 pounds) of Deep 7 Bottomfish in Fishing Year 2015 if the 2014 Commercial Catch is 276,000 pounds	Annual Catch Limit for Commercial Catch (1000 pounds) of Deep 7 Bottomfish in Fishing Year 2015 if the 2014 Commercial Catch is 310,000 pounds	Annual Catch Limit for Commercial Catch (1000 pounds) of Deep 7 Bottomfish in Fishing Year 2015 if the 2014 Commercial Catch is 325,000 pounds
0.00	14	16	12	12
0.05	84	82	82	80
0.10	120	116	114	112
0.15	148	142	140	140
0.20	172	168	164	162
0.25	196	190	186	186
0.30	220	212	210	210
0.35	244	238	232	234
0.40	268	262	256	260
0.41	274	266	264	264
0.45	296	286	284	286
0.50	324	316	312	316

FIGURES

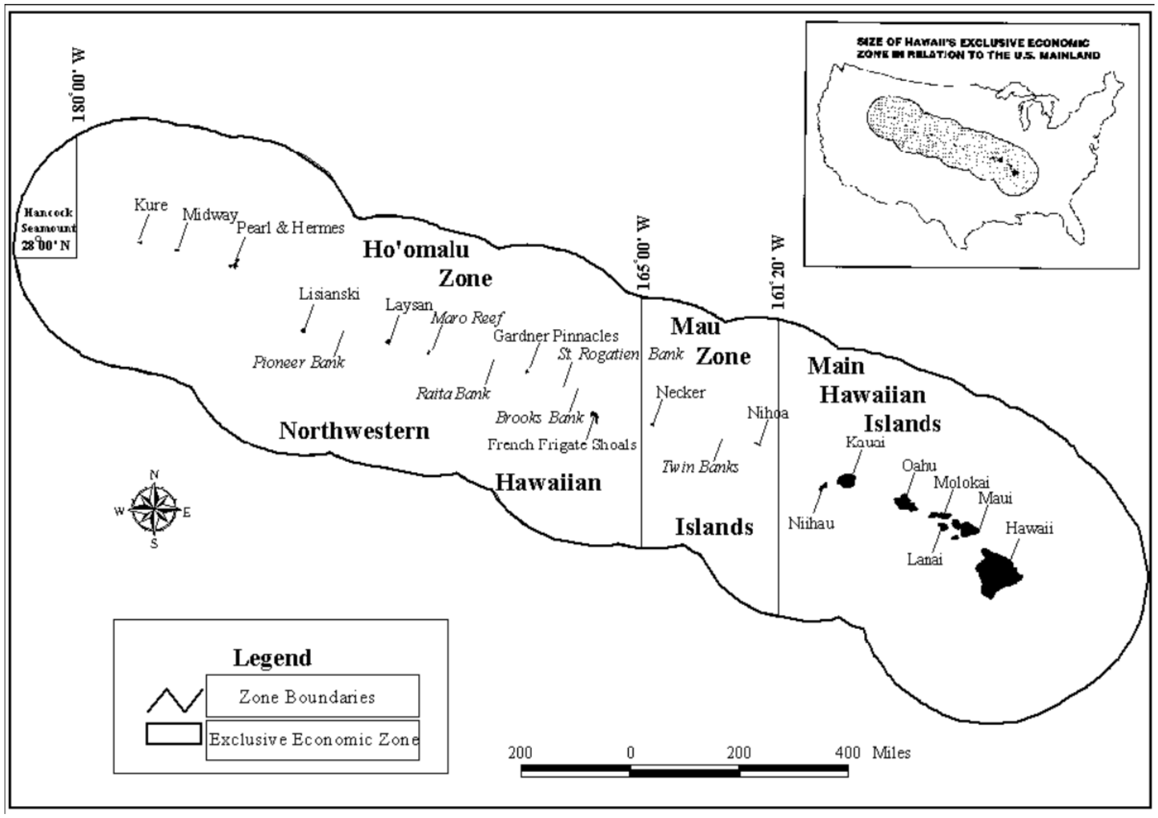

Figure 1.--Location of the three Hawaiian bottomfish fishing zones: the main Hawaiian Islands (MHI) Zone, the Mau Zone, and the Hoomalu Zone. Together, the Mau and Hoomalu Zones are known as the Northwestern Hawaiian Islands (NWHI). The current stock assessment is for the Deep7 bottomfish complex in the main Hawaiian Islands.

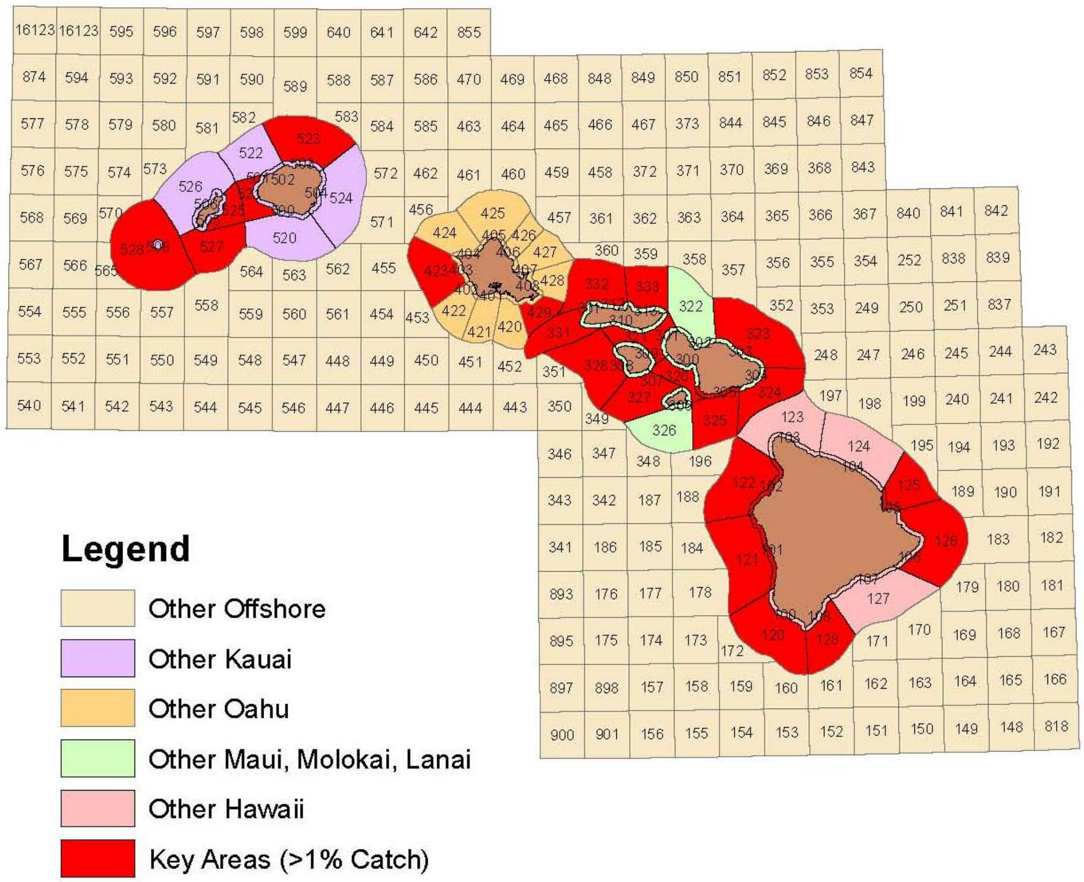

Figure 2.--Description of the Hawaii Division of Aquatic Resources (HDAR) fishery reporting areas used to report and characterize Deep7 bottomfish commercial fishery catch data in the main Hawaiian Islands.

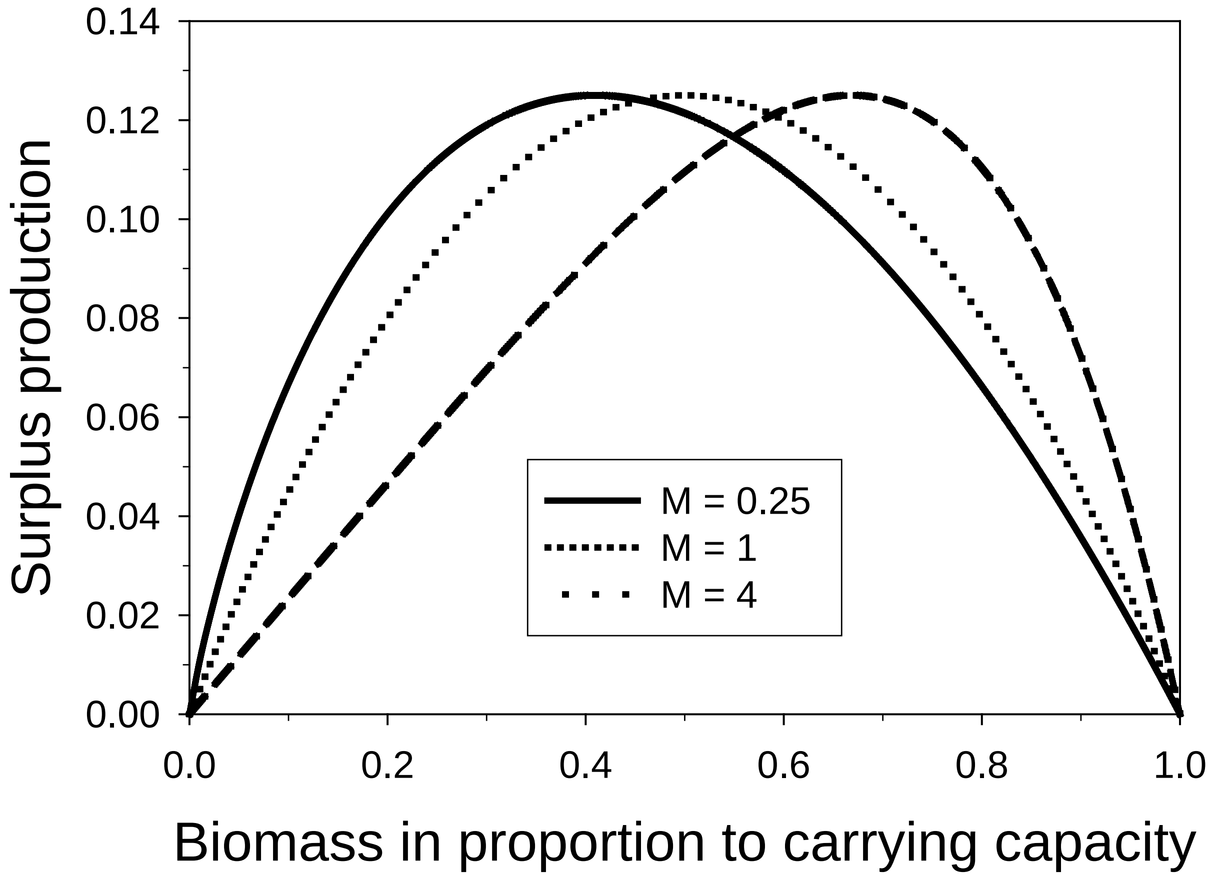

Figure 3.--Effects of alternative production model shape parameter values (*M*, not natural mortality) on the relationship between the surplus production of biomass and the exploitable biomass as a proportion of carrying capacity curve.

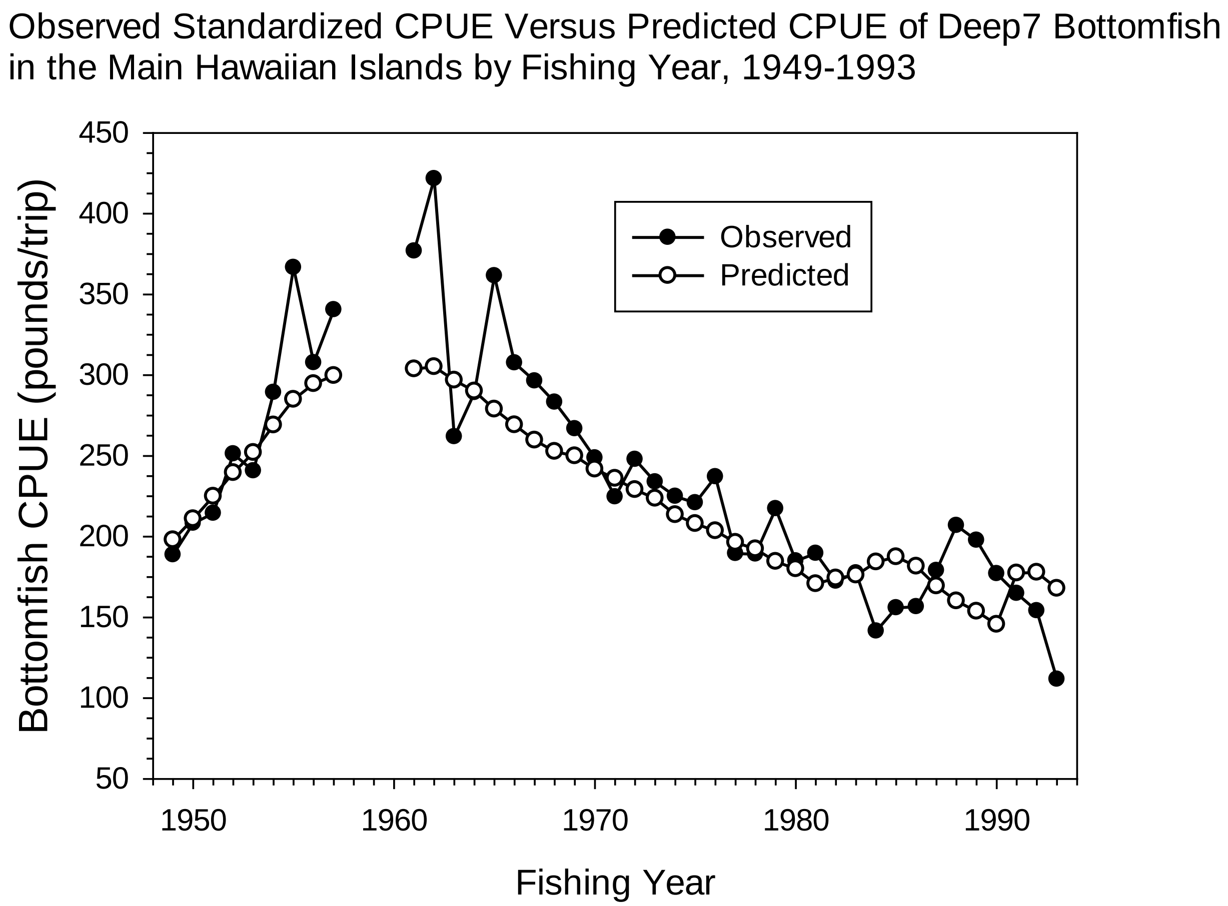

Figure 4.1.--Observed versus predicted CPUE of Deep7 bottomfish CPUE in the main Hawaiian Islands by fishing year during 1949-1993.

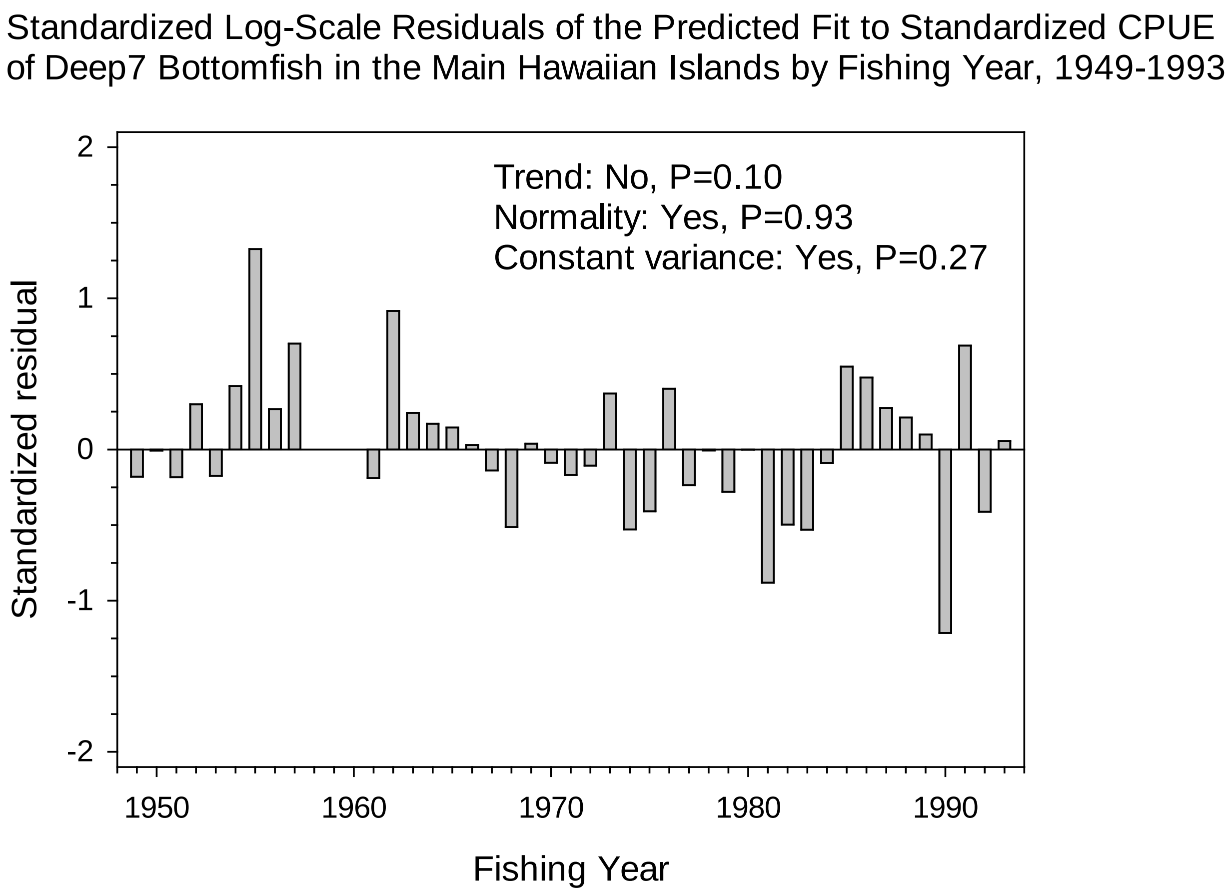

Figure 4.2.--Standardized residuals of observed versus predicted CPUE of Deep7 bottomfish CPUE in the main Hawaiian Islands by fishing year during 1949-1993 along with P-values for linear regression hypothesis tests of whether standardized residuals had a time trend, were normally distributed, and had constant variance.

Observed Standardized CPUE Versus Predicted CPUE of Deep7 Bottomfish in the Main Hawaiian Islands by Fishing Year, 1994-2013

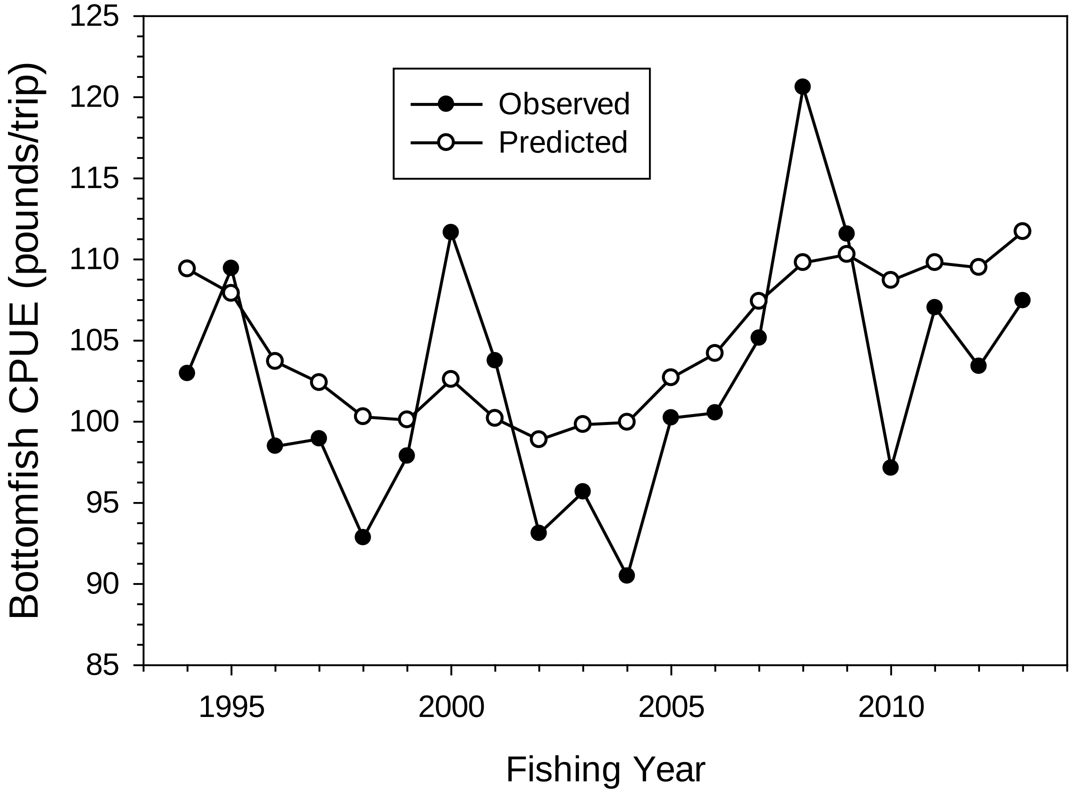

Figure 5.1.--Observed versus predicted CPUE of Deep7 bottomfish CPUE in the main Hawaiian Islands by fishing year during 1994-2013.

Standardized Log-Scale Residuals of the Predicted Fit to Standardized CPUE of Deep7 Bottomfish in the Main Hawaiian Islands by Fishing Year, 1994-2013

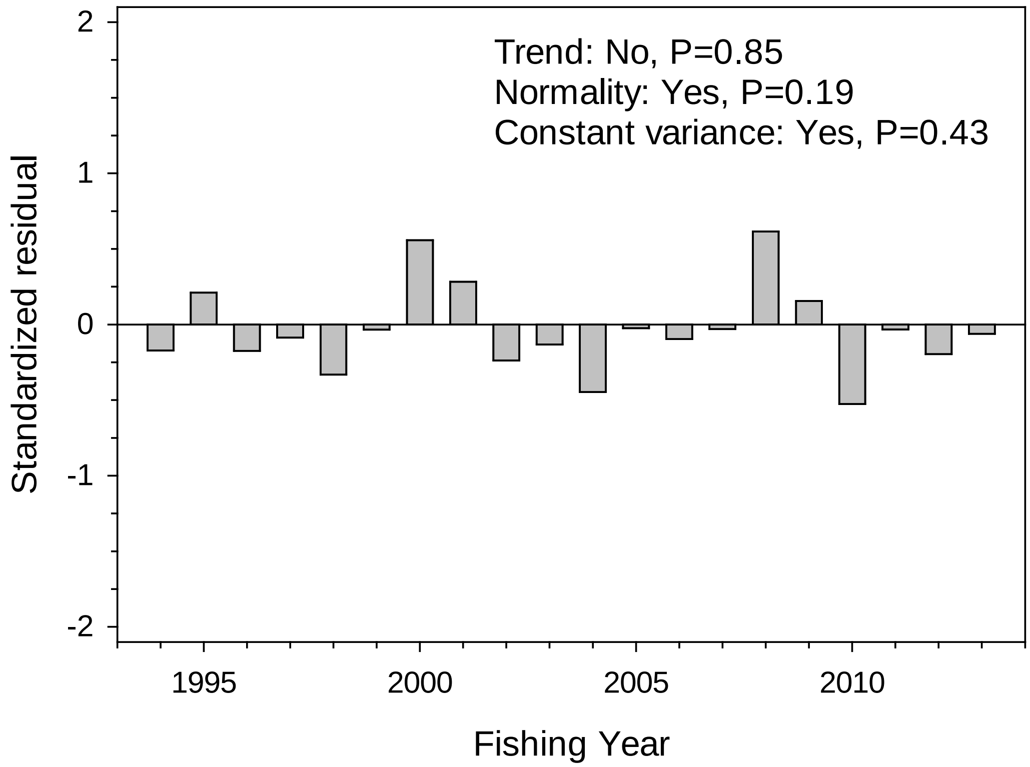

Figure 5.2.--Standardized residuals of observed versus predicted CPUE of Deep7 bottomfish CPUE in the main Hawaiian Islands by fishing year during 1994-2013 along with P-values for linear regression hypothesis tests of whether standardized residuals had a time trend, were normally distributed, and had constant variance.

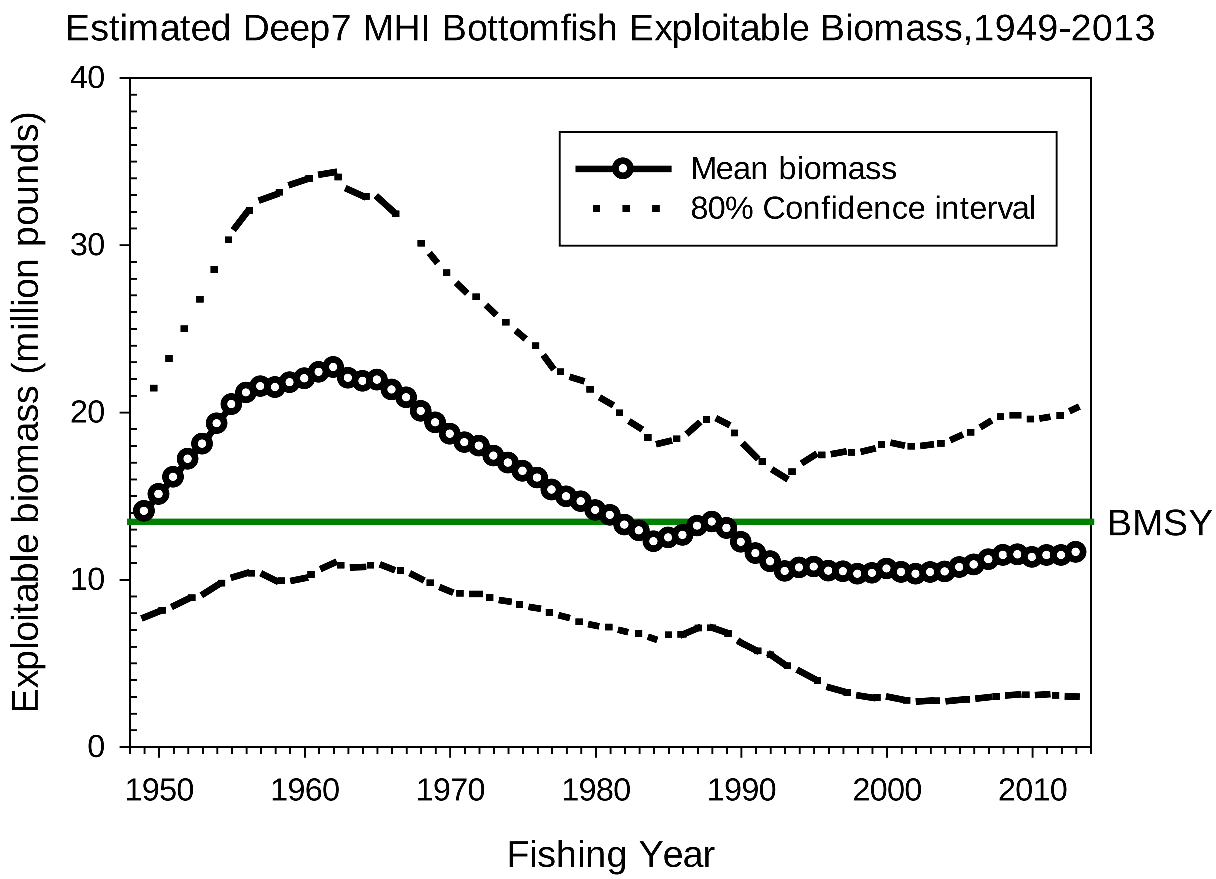

Figure 6. --Time series of estimates of exploitable biomass of Deep7 bottomfish in the main Hawaiian Islands along with associated 80% confidence intervals, 1949-2013.

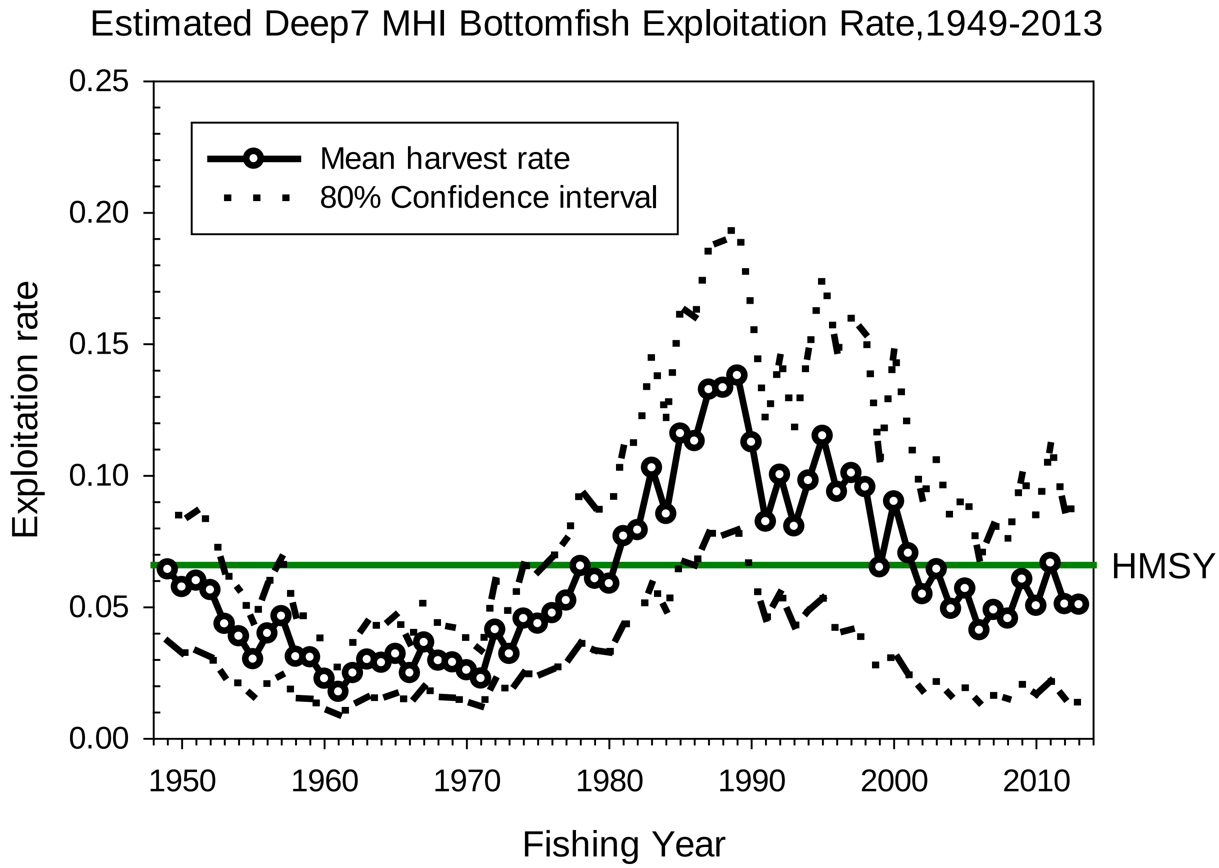

Figure 7.--Time series of estimates of exploitation rates of Deep7 bottomfish in the main Hawaiian Islands along with associated 80% confidence intervals, 1949-2013.

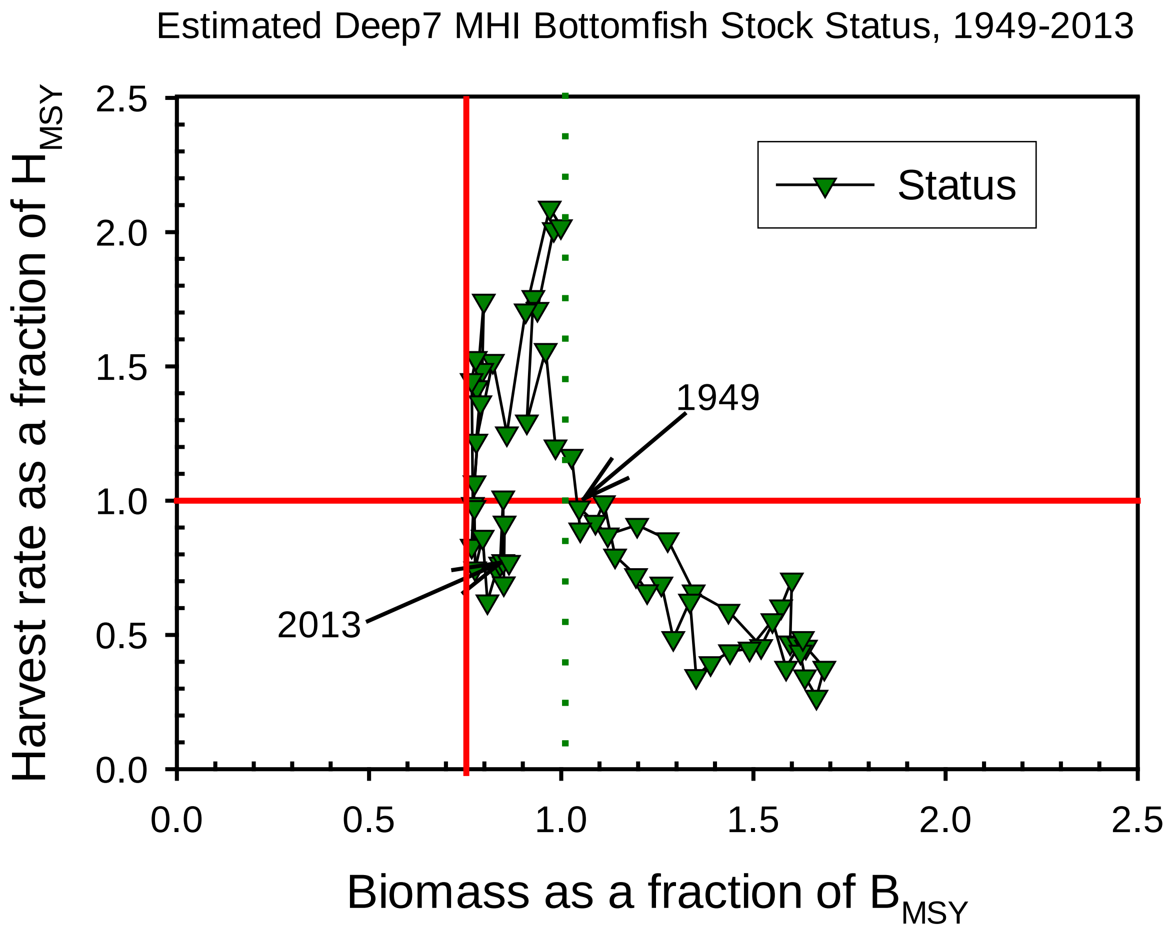

Figure 8. --Time series of estimates of stock status of Deep7 bottomfish in the main Hawaiian Islands relative to the overfishing harvest rate (H_{MSY}, solid red horizontal line), the exploitable biomass to produce maximum sustainable yield (B_{MSY}, dashed green vertical line), and the minimum stock size threshold ($0.75*B_{MSY}$, solid red vertical line), 1949-2013.

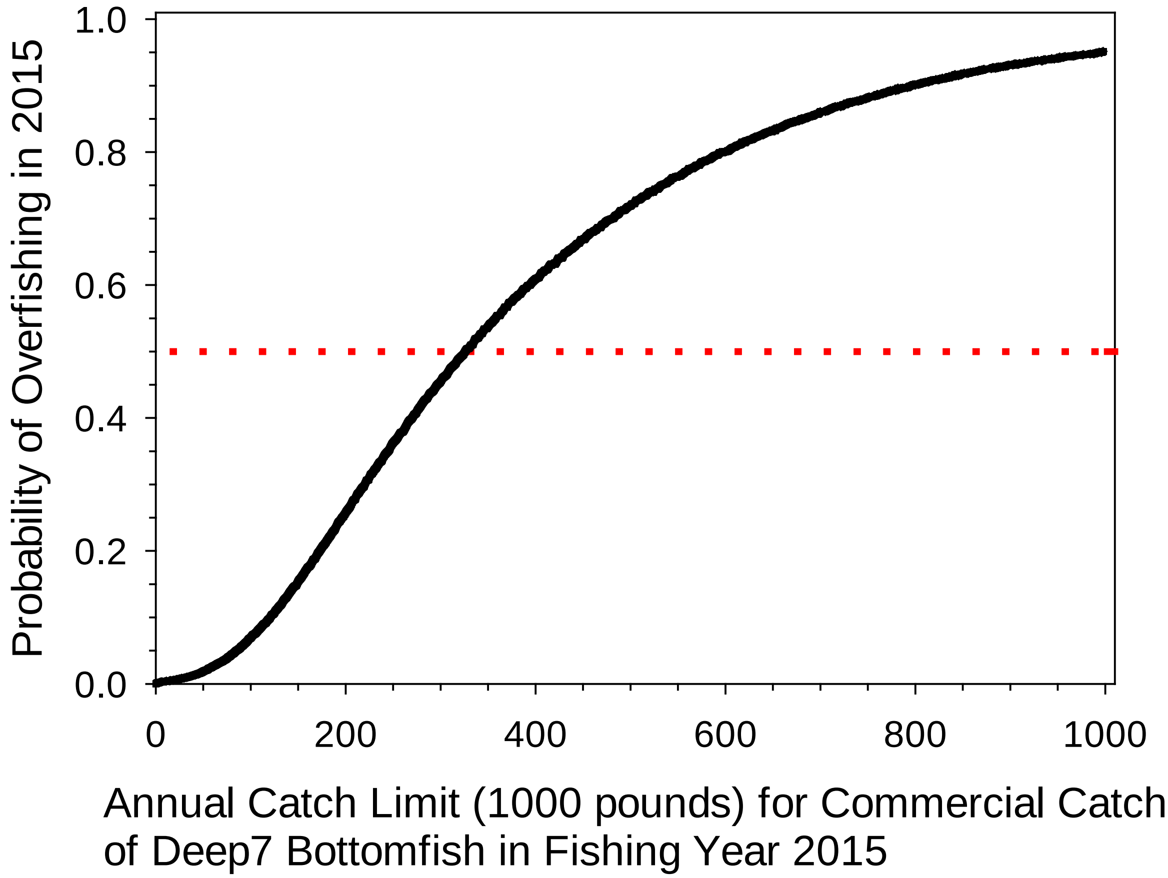

Figure 9.--Stochastic projection results for estimates of annual catch limits of commercial catches of Deep7 Hawaiian bottomfish for fishing years 2015-2016 that would produce a range of probabilities of overfishing (defined as $H>H_{MSY}$) in 2015 from 0% to 50% and greater, assuming that the total annual 2014 commercial catch was 244,000 pounds, or 70% of the 2014 annual catch limit.

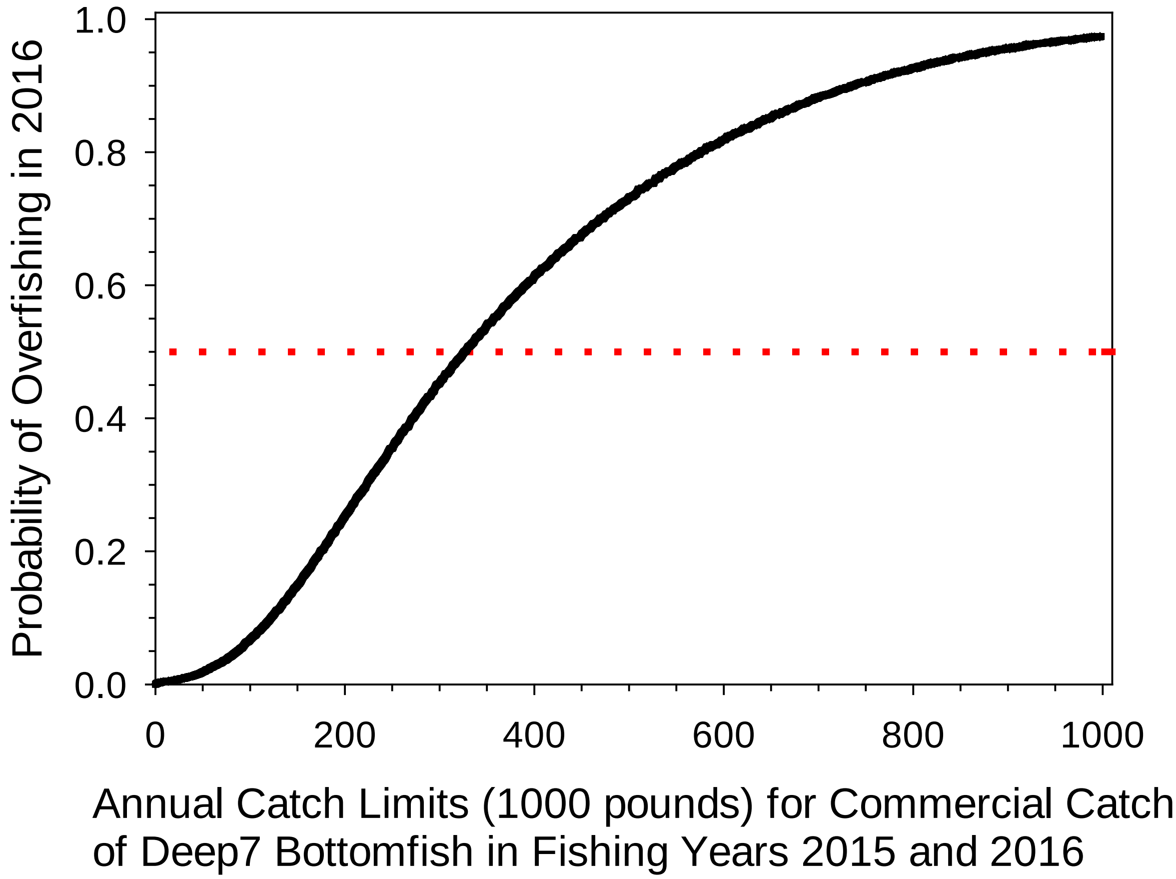

Figure 10.--Stochastic projection results for estimates of annual catch limits of Deep7 Hawaiian bottomfish for fishing years 2015-2016 that would produce a range of probabilities of overfishing (defined as $H>H_{MSY}$) in 2016 from 0% to 50% and greater, assuming that the total annual 2014 commercial catch was 244,000 pounds, or 70% of the 2014 annual catch limit.

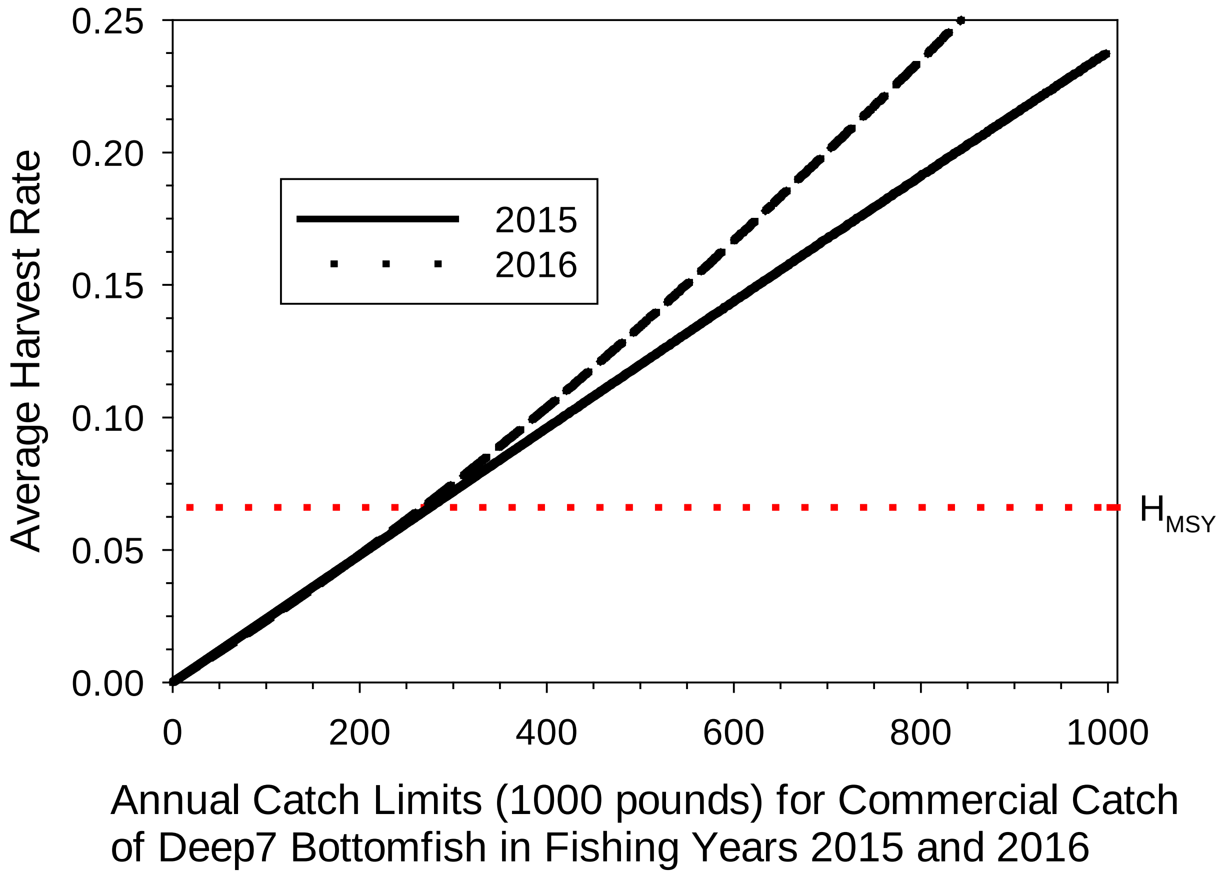

Figure 11.--Stochastic projection results showing estimates of average harvest rates of Deep7 Bottomfish in the main Hawaiian Islands for alternative annual catch limits for fishing years 2015-2016, assuming that the total annual 2014 commercial catch was 244,000 pounds, or 70% of the 2014 annual catch limit.

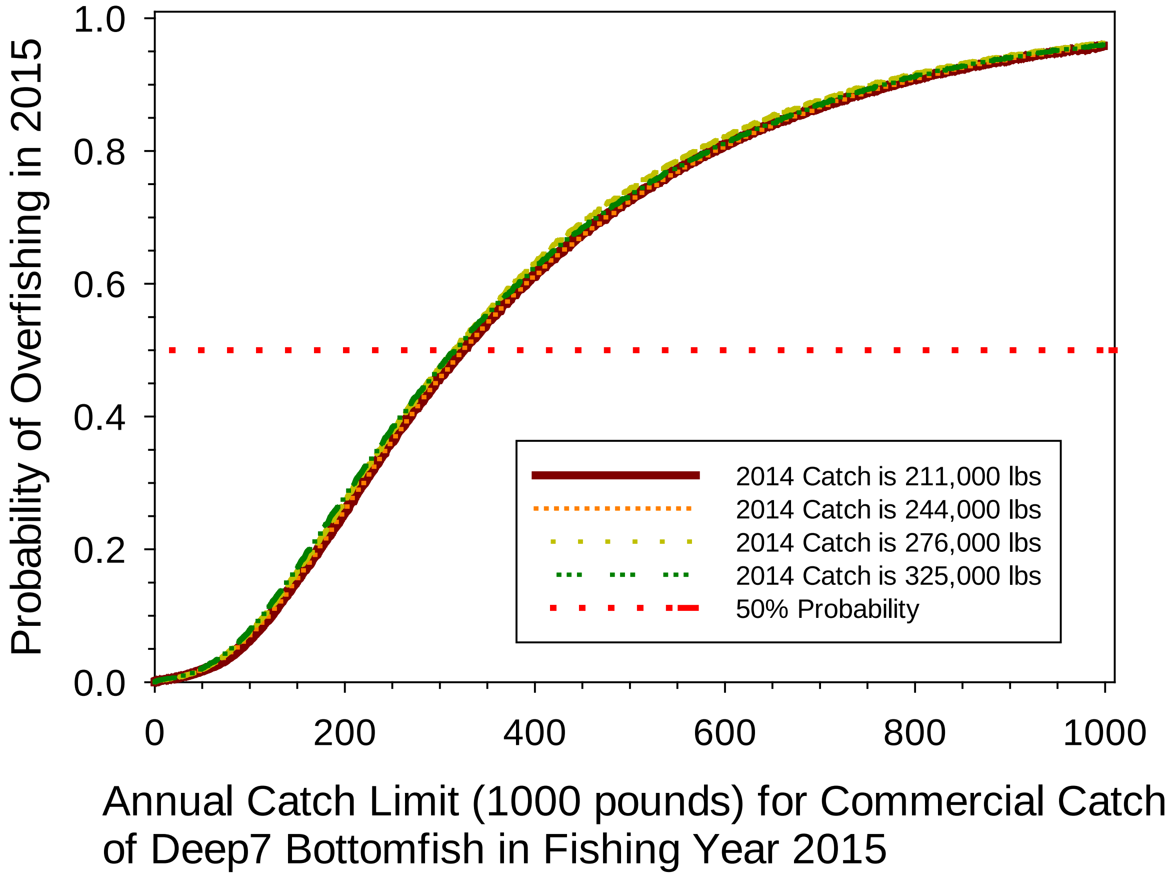

Figure 12.--Stochastic projection results showing the estimates of annual catch limits of Deep7 Hawaiian bottomfish for fishing years 2015-2016 that would produce a range of probabilities of overfishing (defined as $H > H_{MSY}$) in 2015 from 0% to 50% and greater if the total annual 2014 commercial catch was 211, 244, 276, or 325 thousand pounds, equivalent to 61%, 70%, 80%, and 94% of the 2014 annual catch limit.

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