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Stock Assessment of the Main Hawaiian Islands Deep7 Bottomfish Complex Through 2010

Jon Brodziak, Dean Courtney, Lyn Wagatsuma, Joseph O'Malley, Hui-Hua Lee, William Walsh, Allen Andrews, Robert Humphreys, and Gerard DiNardo

Pacific Islands Fisheries Science Center
National Marine Fisheries Service
National Oceanic and Atmospheric Administration
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For further information direct inquiries to

Chief, Scientific Information Services
Pacific Islands Fisheries Science Center
National Marine Fisheries Service
National Oceanic and Atmospheric Administration
U.S. Department of Commerce
2570 Dole Street
Honolulu, Hawaii 96822-2396

Phone: 808-983-5386
Fax: 808-983-2902

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Pacific Islands Fisheries Science Center
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Jon Brodziak,[1] Dean Courtney,[1] Lyn Wagatsuma,[2]
Joseph O'Malley,[2] Hui-Hua Lee,[2] William Walsh,[2]
Allen Andrews,[1] Robert Humphreys,[1] and Gerard DiNardo[1]

[1]Pacific Islands Fisheries Science Center
National Marine Fisheries Service
2570 Dole Street
Honolulu, Hawaii 96822-2396

[2]Joint Institute for Marine and Atmospheric Research
University of Hawaii
1000 Pope Road
Honolulu, Hawaii 96822

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ABSTRACT

A stock assessment of the main Hawaiian Islands “Deep7” bottomfish complex was conducted through fishing year 2010, including projections to determine total allowable commercial catches (TACs) and their probabilities of overfishing. This assessment was conducted using re-audited bottomfish catch and effort data from commercial catch reports for the years 1948-2010. Standardized catch-per-unit effort (CPUE) for the Deep7 bottomfish was estimated using catch and effort data from the handline fishery. Model selection techniques were applied to choose the structural form to standardize CPUE. Recommendations of the Western Pacific Stock Assessment Review panel concerning the 2008 stock assessment were addressed in this assessment. The recommendations that were directly addressed in this assessment were: (i) develop credible standardized CPUE time series; (ii) construct noncommercial bottomfish catch histories; (iii) develop an informative prior for intrinsic growth rate using metadata or other analyses; and, (iv) assess the main Hawaiian Islands bottomfish complex as a single stock unit and ensure appropriate testing of CPUE uncertainty through sensitivity analyses. A Bayesian production model was used to estimate time series of Deep7 bottomfish exploitable biomasses and harvest rates under alternative scenarios of unreported catch and standardized CPUE. This model was also used to conduct stochastic short-term projections of future catches and associated risks of overfishing. These projections explicitly included uncertainty in the posterior distribution of estimated bottomfish biomass in 2010 and population dynamics parameters. Results of the catch and CPUE analyses, production modeling, and projections are summarized. Decision tables are provided to address uncertainty about the effects of selecting commercial fishery Deep7 TACs for fishing years 2012-2013 under alternative CPUE scenarios.

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1. INTRODUCTION

The Hawaii bottomfish complex is a U.S. fishery management unit comprised primarily of several species of snappers and jacks and a grouper inhabiting waters of the Hawaiian Archipelago (Table 1, Fig. 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 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 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 GPS units 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.

1.1 Previous Assessment in 2005

A previous assessment of the Hawaii bottomfish complex was conducted in 2005 using fishery data through calendar year 2004 (Moffitt et al., 2006). This assessment included surplus production model analyses of bottomfish catch and catch-per-unit effort data for the three fishing zones (Fig. 1). In these analyses, bottomfish CPUE was assumed to be proportional to relative abundance in each zone. Catchability of bottomfish in the MHI zone was assumed to be time varying and increasing through the assessment time horizon. Observed CPUE in the MHI was adjusted by an estimated catchability multiplier in four time periods to account for changes in catchability. Predicted CPUE was fitted to observed CPUE using nonlinear least squares to estimate model parameters. Biological reference points to achieve maximum sustainable yield (MSY) were estimated for each fishing zone. Stock status of the MHI bottomfish was assessed for calendar years 1948-2004, while status of the Mau and Hoomalu Zones was assessed for 1988-2004, the latter being the period in which the fishery was most active and for which reliable data were available. The status of the archipelagic management unit was assessed based on a weighted average of the stock status of the three zones, where the weights were the fraction of total bottomfish habitat by zone. Assessment results indicated that the archipelagic management unit was not depleted but was experiencing overfishing in 2004. Fishing mortality for the archipelagic bottomfish management unit was estimated to be 24% above the overfishing threshold. As a result, management measures were crafted to reduce fishing mortality on MHI bottomfish where overfishing was occurring; these included fishery closures and total allowable commercial catch limits (TACs). Analyses of bottomfish total allowable catch limits were conducted by the PIFSC in 2007-2008 to address the issue of

[1] http://www.papahanaumokuakea.gov/about/faq.html

overfishing on the archipelagic management unit and the MHI bottomfish stock, and these led to new TACs.

1.2 Previous Assessment Update in 2008

The next assessment was conducted in 2008 as an update to the 2005 assessment using fishery data through 2007. In this context, the updated assessment used the same data sources as the preceding assessment and also used a modeling approach that was very similar or identical to that used in the preceding assessment. However, the updated assessment addressed two concerns about the 2005 bottomfish assessment. The first concern was that the bottomfish catch and effort data from the MHI during the early portion of the time series may have contained multiday trips with larger catches than the single-day trips used to compute a standardized catch-per-unit effort time series. The presence of multiday bottomfish trips in the 1950s and 1960s could skew the average MHI CPUE to higher values than were representative of the single-day trips used to calculate the standard CPUE time series. This would lead to an overestimate of bottomfish relative abundance in the 1950s-1960s when MHI CPUE was used as an abundance index in the surplus production model. Thus, an intensive effort was made to re-audit the MHI catch and effort data to eliminate multiday trip records, using criteria developed from interviews with long-time bottomfish fishermen. The second concern about the 2005 bottomfish assessment was that it employed a least-squares estimation and modeling approach that provided no direct measure of the variability of parameter estimates for conducting risk analyses. To address this concern, a Bayesian surplus production modeling approach was applied in the 2008 update to estimate bottomfish biomass and fishing mortality rates, assuming similar model structure and assumptions to the 2005 assessment.

Data for the updated assessment included re-audited bottomfish catch and effort data from Hawaii Division of Aquatic Resources (HDAR) commercial catch reports for 1948-2007. A revised bottomfish catch-per-unit effort data set was constructed using the re-audited catch and effort data. The CPUE filtering approach used in the previous bottomfish assessment was applied to the revised CPUE data set to obtain the status quo CPUE series used in the previous assessment (Moffitt et al., 2006). A statistical log-linear model described by Gavaris (1980) was applied to develop a spatially standardized CPUE series for the main Hawaiian Islands. This series included fishing year, month, and fishing area as predictors of bottomfish CPUE on directed fishing trips (> 50% bottomfish catch by weight). Each of the predictors had a significant ($P < 0.0001$) influence on observed CPUE by trip. A Bayesian production model was used to estimate bottomfish biomass and harvest rate time series (Brodziak, 2007). This model was also used to conduct short-term projections of future catches and associated risks of overfishing. These projections explicitly included uncertainty in the posterior distribution of estimated bottomfish biomass in 2007 and population dynamics parameters. The production model was fit to catch and standardized CPUE data for each of the three Hawaiian fishing zones: the main Hawaiian Islands Zone, the Mau Zone, and the Hoomalu Zone. The production model fitting incorporated uninformative priors for carrying capacity, process error, observation error, and catchability parameters and an informative prior for intrinsic growth rate. The mean of the prior for intrinsic growth rate was equal to the estimate of the parameter used in the previous bottomfish assessment (Moffitt et al., 2006). Methods and results of the catch and CPUE analyses, production modeling analyses, and stochastic projection analyses for estimating 2009 TACs and associated probabilities of overfishing are described later in this document.

1.3 Current Assessment through 2010

The current assessment of Hawaii Deep7 bottomfish stocks in the main Hawaiian Islands through 2010 uses similar commercial fishery data as in the 2008 update but includes a modified treatment of unreported catch and a revised CPUE standardization. The baseline model is a biomass production model with similar model structure 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 (A. Andrews, PIFSC, unpubl. 2010 research).

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 current 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 are provided in the section on CPUE standardization below.

The second WPSAR recommendation was addressed by developing estimates of unreported Hawaii bottomfish catch. One baseline scenario of estimates of unreported catch was used for the stock status determination, 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 are provided in the section on fishery catch and the estimation of unreported catch below.

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 the set of primary bottomfish species assessed in the 2005 assessment. In this context, the Deep7 bottomfish were a subset of the primary bottomfish, which were also a subset of the complete set of bottomfish management unit species (BMUS) included in the fishery management plan http://www.wpcouncil.org/bottomfish/Bottomfish%20FMP.html). The change to assess only the Deep7 species was made because the Deep7 species have similar life histories, distribution, and are the focus of current management efforts by the WPRFMC, using TAC regulation and closed seasons (WPRFMC, 2007). In contrast, in the previous bottomfish assessments, several productive shallow-water bottomfish species were included in the set of species modeled. In this context, it was believed that choosing to model the 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 currently 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 rate. In addition, 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 (A. Andrews, PIFSC, unpubl. data). These modifications and analyses are described below in sections 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 current 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.

2. MATERIALS AND METHODS

In this section, information on 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 Hawaii bottomfish 2010 stock assessment is described.

2.1 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 previous assessments of this complex, 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 this assessment, 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, including 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. Adults tend to inhabit deep waters of roughly 100-400 m depth in the main Hawaiian Islands, although some species (e.g., opakapaka) may shoal to mid-water depths to feed.

Age determination for the Hawaiian snapper, or opakapaka (*Pristipomoides filamentosus*), has been an ongoing problem 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). Growth rates have been refined with the use of smaller age classes (DeMartini, et al. 1994), but the determination of age for the largest and oldest adults is still in question based on traditional otolith ageing techniques. Previous research on the growth of opakapaka, the most abundant Deep7 species, indicated substantial variation in growth and a wide range of estimates of expected size at age (Fig. 2) and an estimated maximum age of 18 years (Ralston and Miyamoto, 1983).

Recent research on ageing of opakapaka, based on bomb radiocarbon and lead radium dating of archival otolith samples (A. Andrews, PIFSC, unpubl. data), indicated that this species has a life span on the order of 40 years (Fig. 3). This suggests that the adult natural mortality rate of opakapaka, the key Deep7 species, is on the order of $M = 0.1$. This implies a relatively slow population turnover rate and indicated that the assumed mean value for the prior distribution of intrinsic growth rate of roughly r = 0.45 used in the 2008 assessment update (Brodziak et al., 2009) was very likely too high for the Deep7 complex.

Musick (1999) and Musick et al. (2000) described a qualitative approach for determining the likely productivities and intrinsic growth rates of fish species that may be at risk from anthropogenic stressors. Their approach uses life history characteristics to evaluate productivity in the absence of direct estimates of productivity. We used the approach described in Musick (1999) and Musick et al. (2000) along with life history information to categorize the Deep7 bottomfish species into low, medium, and high productivity categories (Table 2). The resulting categorization suggested that the overall productivity of the set of Deep7 bottomfish was likely to be low. This information was used to set the prior distribution of intrinsic growth rate for the production model analyses of Deep7 bottomfish as in Musick (1999) where a probable range of intrinsic rates of R = 0.05 to R = 0.15 was recommended for fishes that had low productivities, consistent with Andrews' research.

2.2 Fishing Year

For the current assessment, the annual time period for reporting bottomfish catch and CPUE is the fishing year from July 1 of the previous year through June 30 of the current year. Note that this definition of fishing year is coincident with the State of Hawaii's fiscal year and differs from the definition of fishing year in the bottomfish fishery management plan (which extends from September 1 of the previous year through August 31 of the current year). The timing of the fishing year also corresponds to the annual biological cycle of the deepwater snapper and grouper bottomfish complex in which spawning occurs in late spring to early summer. Thus, estimates of annual production biomass starting in July coincided with the settlement of juvenile bottomfish through midsummer. In addition, 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's and other holidays. The use of calendar year in the 2005 assessment split the Deep7 bottomfish season into two separate years. In the current assessment, the use of fishing year incorporates the primary bottomfish season into one annual assessment time period that roughly corresponds to the fishery management year ending on August 31.

2.3 Fishery Catch

2.3.1. Reported Commercial Catch of Bottomfish

Reported fishery catch data for the 2010 assessment included commercial bottomfish catch and effort data extracted from over 4 million HDAR commercial trip catch reports submitted by commercial fishermen during 1948-2010 (D. Hamm, 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 (Fig. 1). Some bottomfish trip reports had an unknown area, and the minor catch amounts from the trip reports with missing area were apportioned to fishing zone 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 1949-2010 for use in the current stock assessment (Table 3 and Figs. 4.1 and 4.2).

The reported catch of primary bottomfish species was also summarized by fishing year (Fig. 4.1) for estimating total primary bottomfish catch. This summary consisted of all reported bottomfish landings, excluding the catches of kahala (*Seriola dumerili*) and taape (*Lutjanus kasmira*) as in the previous assessment (Table 1). Reported commercial catches of primary bottomfish by trip were assigned to fishing year (the fishing year extends from July 1 of the previous year to June 30 of this year). This definition of fishing year corresponds to the fiscal year basis on which commercial fishing licenses are allocated by the State of Hawaii and also includes the entire winter fishery season, when bottomfish catches typically are highest in a single year.

2.3.2 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). These estimates of unreported catch were included in the current stock assessment to improve the approximation of the effects of fishery removals on the complex. This was consistent with the WPSAR recommendation to incorporate unreported and/or recreational catches in the stock assessment (Stokes, 2009). The general approach for estimating unreported catch (C_U) was to use all available relevant information to estimate the ratio of unreported to reported bottomfish catch (U) in the main Hawaiian Islands. In this context, it is important to note 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, although it is possible the Hawaii Marine Recreational Fishing Survey (HMRFS, http://hawaii.gov/dlnr/dar/hmrfs.html) program may provide some information in the future. In the meantime, relevant information and estimates of the ratio of unreported to reported bottomfish catches were gathered from a variety of sources. In all cases, unreported bottomfish catch was estimated from reported catch (C_R) and the ratio of unreported to reported catch U as $C_U = U^* C_R$.

There was one baseline scenario for unreported catch estimates and there were three alternative scenarios of unreported catch developed from the available information. Together, the baseline scenario and three alternative scenarios were labeled in order of magnitude from the highest estimates (Scenario I) to the lowest estimates (Scenario IV) of unreported catch. Information used for the development of Scenario I and the baseline Scenario II was described in Courtney and Brodziak (2011). Scenario III was developed from information presented in Lamson et al. (2007). Scenario IV was developed from the 2005 Hawaii bottomfish stock assessment, and this scenario represents a continuation of the treatment of unreported catch as being negligible. A description of the baseline scenarios and the three alternative scenarios along with an indication of the recent magnitude of unreported to reported catch follows.

Catch Scenario I--Under this scenario, annual amounts of unreported bottomfish catch were estimated using 5-year averages of the ratios of unreported to reported catches for the combined Deep7 bottomfish species (see Courtney and Brodziak, 2011). These estimates were similar in magnitude to those reported in Zeller et al. (2008) and Martell et al. (2011). The resulting estimates of the unreported catch ratio U (Tables 4.1 and A1) indicated that unreported catch was more than twofold greater than reported Deep7 bottomfish catch (Table 5). The average unreported to reported catch ratio during 2008-2010 was U = 2.50 under Scenario I, and the magnitude of the recent average unreported catch was about 550 thousand pounds (Fig. 4.3).

Baseline Catch Scenario II--Catch Scenario II was the Baseline Catch Scenario for the stock assessment because it was catch data used to estimate stock status. This scenario incorporates what was considered to be the best available information to estimate unreported to reported catch ratios for individual Deep7 bottomfish species (Fig. 4.4). Under the baseline scenario, the unreported catch ratio U was estimated for individual Deep7 species by fishing year to account for annual variation in the species composition of the reported Deep7 bottomfish catch (Courtney and Brodziak, 2011). The unreported catch ratios by species were estimated based on data in Hamm and Lum (1992), Martell et al. (2011), and Lamson et al. (2007). The resulting estimates of the unreported catch ratio U (Table 4.2 and Appendix Table A2) indicated that unreported catch was roughly equal in magnitude to the reported commercial catch (Tables 3, 4.2, and 5). Under the baseline scenario, the average unreported to reported catch ratio during 2008-2010 was U = 1.08 and the magnitude of the recent average unreported catch was about 240 thousand pounds (Fig. 4.3).

Catch Scenario III--Under Catch Scenario III, the unreported catch ratio for Deep7 bottomfish was assumed to equal the aggregate Deep7 bottomfish ratio of U = 0.20 reported in Lamson et al. (2007). As a result, estimates of unreported catches under this scenario were one-fifth of the magnitude of reported commercial catches (Table 4.3). The average unreported to reported catch ratio during 2008-2010 was U = 0.20 under Scenario III, and the magnitude of the recent average unreported catch was about 40 thousand pounds (Table 5 and Fig. 4.3).

Catch Scenario IV--Under Catch Scenario IV, it was assumed that unreported bottomfish catches were negligible in comparison to reported commercial catches (Table 3). As a result, unreported catch for Catch Scenario IV was treated in the same manner as in the 2005 assessment and the 2008 assessment update. As a result, the unreported catch ratio was U = 0 and the recent average unreported catch was 0 pounds (Table 5).

Estimates of the unreported catch of primary bottomfish were also developed for each of the four scenarios (Table 6). Based on this analysis, the resulting estimates of the recent average unreported catch ratio were similar to those for the Deep7 bottomfish, with the exception of Scenario II for which the average estimate of U during 2008-2010 was U = 1.83.

2.3.3 Estimates of Total Bottomfish Catch

Estimates of the total Deep7 bottomfish catch under each unreported catch scenario were summarized (Table 5). For comparison with previous assessments, estimates of the total catch of primary bottomfish under each unreported catch scenario were also summarized (Table 6). Estimates of reported commercial catches of Deep7 bottomfish were also summarized by island group (or county) in the main Hawaiian Islands for the potential application of allocating total allowable commercial bottomfish catches by island (Tables 7.1 and 7.2).

Uncertainty in the amount of unreported bottomfish catch was not directly estimable but was judged to be more substantial than that associated with reported commercial fishery catch. To account for uncertainty in estimates of unreported bottomfish catch, it was assumed that there was an independent error distribution for each annual estimate of unreported catch under the Baseline Scenario I and Alternative Scenarios II and III for fitting parameters of the production model used in the stock assessment. This error distribution is described in further detail in the section on the production model prior distributions. Under Scenario IV, it was assumed that the unreported catch was negligible, and there was no annual catch error distribution used to fit the assessment model.

2.4 Standardized Commercial Fishery Catch-Per-Unit Effort

Estimation of standardized commercial fishery CPUE for Deep7 bottomfish was revised in this assessment from the 2008 assessment update to address the relevant WPSAR recommendations. To this end, the primary WPSAR recommendations were: (i) to exclude the 1958-1960 CPUE observations from the standardization analyses because these years appeared to have anomalously low values of annual nominal CPUE; (ii) to adjust observed fishery CPUE to account for increases in fishing power, if appropriate, prior to standardizing CPUE in a model-based analysis; and (iii) to ensure appropriate sensitivity testing to uncertainty in CPUE standardization.

2.4.1 Fishery Data Filtering for CPUE Analyses

Deep7 and primary bottomfish catch per single-day trip reports were calculated for directed deep handline trips in the MHI. These trip reports included information on fishing date, commercial marine license, area fished, and fishing gear code during FY 1949-2010. Commercial trip reports were audited to remove records that were missing either fishing date, CML number, or fishing area. 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. Deep handline gear accounted for over 97% of commercial Deep7 bottomfish landings by weight during 1949-2010. Note that the removal of records for CPUE analyses did not affect the amount of bottomfish catch used in the assessment. This filtering was only used to select the bottomfish trip reports that were relevant and informative for analyzing relative abundance trends.

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 extremely unlikely to represent single-day trip operations. In addition, observed CPUE data reported during FY 1958-1960 were excluded from the CPUE standardization analyses because nominal CPUE was anomalously low during these years as recommended by the WPSAR panel (Stokes, 2009). Further investigations on the nature of the anomalous 1958-1960 data were conducted for this assessment and the results 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 single trip report record.

The fraction of bottomfish of the total catch weight captured per single-day trip was used as a filter to select directed bottomfish trips in the 2005 assessment and 2008 assessment updates. In the 2005 assessment, directed deep handline trips that captured a cutoff fraction of 90% or more bottomfish catch by weight were assumed to represent directed trips and were included in the CPUE standardization analysis. In the 2008 assessment update, the cutoff fraction was decreased to 50% or more bottomfish by weight. This change was made to increase the sample size and to improve spatial coverage of the deep handline trips for CPUE standardization analyses. While the choice of 50% was considered to be reasonable, it could be viewed as ad hoc choice and for this reason, an objective approach to selecting a cutoff fraction of bottomfish was developed for the current assessment.

In the current assessment, the cutoff fraction of percent Deep7 bottomfish catch per trip report was selected to satisfy two goals. The first goal was to maximize the total amount of bottomfish catch weight and sale value represented by the set of deep handline trips selected at the cutoff fraction. The second goal was to simultaneously minimize the variability of the mean catch weight and mean sale value per trip report. In this case, the goal was to minimize the number of single-day trips that split their fishing effort to target both bottomfish and pelagic species, and spent more effort focusing on catching pelagic species than bottomfish. It was common practice to spend some time fishing for pelagic fishes on a single-day trip that captured bottomfish, e.g., trolling for pelagic fish on the way to a bottomfish fishing hot spot.

To describe the selection of the cutoff fraction in the current assessment, some notation needs to be introduced. If the cutoff fraction of bottomfish for including a given trip in the set of trips used for standardization is denoted as “x”, then the proportion of the total Deep7 bottomfish catch weight captured using the cutoff “x” to select trips is denoted as $P_W(x)$ (Fig. 5.1). Similarly, the proportion of total bottomfish catch value using the cutoff “x” ($P_V(x)$) gives a measure of the total fishery value accounted for by the set of trips selected with cutoff “x” (Fig. 5.1).

The variation in mean bottomfish catch weight and value per trip also provided an indicator of the relative targeting of bottomfish over a selected set of trips. The amount of variability in bottomfish catch weight can be indexed by the relative coefficient of variation (CV) of bottomfish catch denoted as $relCV_W(x)$ for a given cutoff fraction “x”. The relative CV of bottomfish catch weight was $relCV_W(x) = 1 - CV(C_W(x))/maxCV(C_W(x))$, where $CV(C_W(x))$ is the coefficient of variation of the mean bottomfish catch weight per trip as a function of using cutoff “x”, and maxCV is the maximum CV over all possible values of “x” (Fig. 5.2). In this case, a more precise mean catch weight is represented by a higher value of $relCV_W(x)$. Thus, the relative CV provided a measure of how variable bottomfish catch weight was given a chosen cutoff fraction.

Similarly, one can use the relative coefficient of variation of Deep7 bottomfish catch value per trip as an indicator of the relative targeting of bottomfish for value per trip. In this case, the quantity $relCV_V(x) = 1 - CV(C_V(x))/maxCV(C_V(x))$, where $CV(C_V(x))$ was the coefficient of variation of the bottomfish sale value per trip as a function of using cutoff “x”, provided a measure of the variability in mean sale value (Fig. 5.2).

Given these indicators of relative catch and targeting of bottomfish, we defined an objective function (F) to be maximized that combined these four variables as $F(x) = P_W(x) + P_V(x) + relCV_W(x) + relCV_V(x)$ to select the cutoff fraction “x” of bottomfish for including trips in the CPUE standardization analyses (Fig. 5.3). The value of x that maximized F(x) was numerically determined over the grid of possible values of “x” ranging from 0 to 1, with a step size of 0.01 for both Deep7 and primary bottomfish (Fig. 5.3). The cutoff fraction “x” for Deep7 bottomfish that maximized the objective function F was x = 0.17. Using this cutoff accounted for roughly 90% of the deep handline trips (Fig. 5.4). For comparison, the cutoff “x” using the set of primary bottomfish that maximized the objective function F was x = 0.29. Overall, the cutoff fraction of x = 0.17 was used to select the set of directed Deep7 bottomfish day trips, using deep handline gear for the CPUE standardization analyses because this value maximized the chosen objective function.

The relative importance of the selection of a cutoff fraction “x” on trends in nominal CPUE of Deep7 bottomfish was also investigated. Trends in nominal Deep7 bottomfish CPUE using the optimal cutoff fraction of x = 0.17 for directed Deep7 bottomfish trips were compared to nominal CPUE using arbitrarily selected cutoff fractions of x = 0.1, 0.3, 0.5, 0.7, and 0.9 (Fig. 6). This was done to provide an idea of how sensitive trends in nominal CPUE were to the choice of a cutoff fraction. The results of this comparison showed that the trends in nominal CPUE using alternative cutoff fractions were very similar and significantly positively correlated (Fig. 6). In fact, all pairs of the alternative nominal CPUE time series were significantly positively correlated ($P < 0.0001$) with Pearson correlation coefficients ranging from $\rho = 0.92$ to $\rho = 1.00$. Thus, the trends in nominal CPUE of Deep7 bottomfish were robust to the procedure used to select a cutoff fraction.

2.4.2. Fishing Power Scenarios

In the current assessment, one baseline and two alternative CPUE standardization scenarios were developed to represent a range of possible changes in the fishing power of the fishing fleet that targets Deep7 bottomfish for commercial catch. This was done to address the WPSAR recommendation that the assessment include appropriate testing of CPUE uncertainty (Stokes, 2009).

For comparison, it is notable that in the 2008 assessment update (Brodziak et al., 2009), a single scenario for changes in Deep7 bottomfish fishing power was assumed for the stock assessment model (Fig. 7.1). This single scenario was based on the fishing power change coefficients assumed for the 2005 bottomfish stock assessment model (Moffitt et al., 2006) in which it was estimated that the bottomfish stock of the entire Hawaiian Archipelago was experiencing overfishing. Under this scenario, it was assumed that fishing power for bottomfish had increased at an average rate of approximately 1% per year since the 1950s. These putative changes were thought to be primarily due to improvements in fishing technology including the use of fish finders, GPS units, and more reliable fishing equipment (Fig. 7.1, Moffitt et al., 2011). Subsequent to the 2008 assessment update, the WPRFMC SSC developed an alternative assessment analysis that assumed that changes in bottomfish fishing power were negligible through time (Fig. 7.1). This assumption was also used in the current stock assessment and was incorporated into the baseline CPUE scenario (CPUE Scenario I) in contrast to the two alternative fishing power change scenarios considered below that represented moderate and substantial changes in fishing power through time (i.e., CPUE Scenarios II and III).

Overall, one baseline CPUE scenario and two alternative CPUE scenarios were developed to represent changes in fishing power of bottomfish fishing vessels in the current assessment. These were the following:

Baseline CPUE Scenario I--CPUE Scenario I was the baseline scenario used for stock assessment and status determination. This scenario was considered to represent the best scientific information about the efficiency of the Deep7 bottomfish fishing fleet through time because it did not include ad hoc assumptions about changes in fishing power for the deep handline fishery that has traditionally harvested the Deep7 bottomfish complex in the main Hawaiian Islands. Under this baseline scenario, it was assumed that there were negligible changes in bottomfish fishing power through time due to the maintenance of traditional deep handline fishing practices and to the inherent variability in the deep handline capture process (Fig. 7.2). This scenario was the same as that which was assumed for the post hoc modeling analysis of the 2008 bottomfish assessment data (WPRFMC SSC 2009, unpubl.). It was recognized during the WPSAR panel review that the previous assessment assumption of a change in fishing power on the order of a 1% increase per year was ad hoc and could not be quantitatively supported by the available information on the bottomfish fishery. This, combined with the fact that the WPRFMC SSC chose to not use the 1% increase per year assumption, supported the use of CPUE Scenario I as the baseline index of relative stock abundance.

CPUE Scenario II--Under this scenario, a moderate increase in bottomfish fishing power through time occurred. In particular, it was assumed that there were four decadal changes in fishing power during 1949-2010 and that the rate of increase in fishing power changed through time (Fig. 7.2). In particular, it was assumed that: (i) there was no change in fishing power during 1949-1970; (ii) fishing power increased at a rate of 0.25 percent per year during 1971-1980; fishing power increased at a rate of 0.5 percent per year during 1981-1990; (iii) fishing power increased at a rate of 0.25 percent per year during 1991-2000; and (iv) fishing power did not change during 2001-2010. The timing of the assumed changes in fishing power were based on the information on the bottomfish fishery collected during interviews with fishermen and the subsequent bottomfish CPUE standardization workshop (Moffitt et al., 2011). In particular, there were some changes in fishing technology that could have improved fishing power in the 1970s. These changes were suggested to have accelerated during the 1980s and then decreased during the 1990s, as participation in the bottomfish fishery declined. The assumption that there were negligible changes in bottomfish fishing power during the 2000s was based on the combined effects of ongoing attritional losses of experienced bottomfish fishermen from the fishery along with the potential negative impacts of bottomfish restricted fishing area closed areas and also some seasonal closures on fishing success. Scenario II was included to provide what was considered to be a more realistic appraisal of the temporal pattern of changes in fishing power for the Deep7 bottomfish fishing fleet through time than what was used in the

2005 assessment, although it was also recognized that the scale of the assumed changes in fishing power were ad hoc.

CPUE Scenario III--Under this scenario, fishing power for the bottomfish fleet was expected to have increased substantially since 1950 as was assumed in the 2005 assessment. In particular, it was assumed that an average annual increase in fishing power of roughly 1.2% per year had occurred since the 1950s (Fig. 7.2). This scenario was very similar to that which was assumed in the 2005 bottomfish assessment (Moffitt et al., 2006) and was subsequently used in the 2008 bottomfish assessment update (Brodziak et al., 2009). In particular, the only difference was that the changes in fishing power were assumed to occur in a stepwise manner during blocks of years in the 2005 assessment, while the changes in fishing power under CPUE Scenario III were assumed to occur each year. Scenario III was included in the modeling analyses to show what the stock assessment results would have been if the assumption of about a 1% change in fishing power per year had been continued in the current assessment.

Under CPUE Scenarios II and III, fishing power increased in each year. The annual incremental changes in fishing power (δ_T) were applied to adjust observed CPUE prior to fitting a CPUE standardization model, as recommended by the WPSAR panel (Stokes, 2009). In particular, this a prior adjustment was logically equivalent to the use of so-called “offset” adjustments in fitting the CPUE standardization model to the observed but not adjusted observed CPUE. For this analysis, the adjusted CPUE in a given year T ($CPUE_{ADJ,\ T}$) was computed from observed CPUE ($CPUE_{OBS,T}$) as $CPUE_{ADJ,T} = CPUE_{OBS,T}/(1 + \sum_{i=1}^{T} \delta_i)$. Given these annual adjustments, values of observed CPUE adjusted for changes in fishing power were used to standardize CPUE under CPUE Scenarios II and III (Fig. 7.2).

2.4.3 CPUE Standardization Model Selection

For the current assessment, Deep7 bottomfish CPUE in the main Hawaiian Islands was standardized using a multiplicative loglinear model (Gavaris, 1980; Kimura, 1981). This generalized linear model (GLM) was applied to the re-audited HDAR data to estimate standardized CPUE. In this analysis, the statistical significance of the available predictors and their possible interactions was explicitly evaluated and used to calculate the standardized CPUE from the estimated coefficients of the selected GLM.

Two potential predictors of bottomfish CPUE were consistently recorded in the HDAR data during 1949-2010; these were the fishing area and the month fished for each trip. In the context of CPUE standardization, each of these factors had some effect on bottomfish CPUE that varied on an annual basis because of changes in the spatial pattern of fishing effort and distribution of fish. The area factor represented potential differences in the spatial distribution of bottomfish and their catchability. The month factor represented potential differences in the seasonal distribution of bottomfish and associated catchability. Overall, the goal of the standardization analysis was to remove the impact of the spatial and seasonal factors on the annual relative abundance of bottomfish.

We evaluated alternative CPUE standardization models under CPUE Scenario I using either month or quarter to represent the seasonal effect and using either the reported HDAR fishing area (Fig. 8) or the island group corresponding to the reported HDAR fishing area to represent the spatial effect. In this case, the island groups of HDAR fishing areas were defined as: (i) fishing areas 100 to 128 for Hawaii; (ii) fishing areas 300-333 for Maui, Molokai, and Lanai; (iii) fishing areas 400-429 for Oahu; and fishing areas 500-528 for Kauai. This led to a set of 16 potential CPUE standardization models accounting for potential first-order interactions among the predictive factors of fishing year, seasonal predictor, and spatial predictor (Table 8). Each GLM provided a predictive model of log-transformed observed CPUE under CPUE Scenario I with linear predictors consisting of fishing year, seasonal effect, spatial effect, and first order interactions. The loglinear model also assumed an additive normal zero-mean, constant-variance error term for log-scale CPUE, as described in the previous assessment update (Brodziak et al., 2009).

Of the 16 alternative GLM fits to the observed CPUE data, 14 were highly statistically significant ($P < 0.0001$). This high level of significance was largely as a result of the high number of CPUE observations ($n \approx 150,000$) included in the analysis. Two of the GLM fits did not iteratively converge because of the large number of parameters involving interactions between year and area effects (i.e., models Std8 and Std14, Table 8).

We used model selection techniques to choose a best-fitting model for CPUE standardization. Model selection among the alternative CPUE standardization models was performed using Akaike's information criterion (AIC = Deviance +2*number of model parameters) to judge the relative goodness of fit of the alternative models for fixed data (Burnham and Anderson, 2002). The best-fitting model was labeled "Std6" (Table 8) and had the minimum AIC value. The best-fitting model included CPUE predictors of fishing year, area, quarter, and area by quarter interaction terms (Table 8). The relative difference among AIC values for the best-fitting and alternative models was substantial with differences in AIC values in excess of 200 units ($\Delta AIC > 200$). These large differences in AIC values indicated that the best-fitting model, which included predictors of fishing year, area, quarter, and area by quarter interaction terms, represented a substantial improvement over the alternative models. A comparison of the relative likelihoods and associated model probabilities (Table 8) indicated that there would be no benefit in applying model averaging to combine the results of several models that provided similar fits to the data based on AIC differences (e.g., Burnham and Anderson, 2002). As a result, the single best-fitting CPUE standardization model was used for assessment model fitting and inference.

The best-fitting CPUE standardization model explained approximately 24% of the deviance associated with the observed CPUE data (Table 9). The most important predictor of CPUE was the area effect (Fig. 9.1) followed by the fishing year, or time trend effect (Table 9, Appendix Table A3, and Fig. 9.2). The GLM structure for the best-fitting model was also used to standardize the observed and adjusted CPUE under both CPUE Scenarios II and III (Fig. 9.2). Results of the CPUE standardization for the Baseline CPUE Scenario I and Alternative CPUE Scenarios II and III were summarized for use in the production model analyses to estimate Deep7 bottomfish exploitable biomass, harvest rate, and stock status (Table 10 and Fig. 9.2).

2.4.4. Sensitivity Analyses of CPUE Standardization to Zero-Catch Trips

It was noted in the 2008 stock assessment update that a change in the apparent reporting of zero-catch trips (trip reports with zero reported catch) occurred in the HDAR bottomfish logbook data records during the late-1980s. This change was further investigated in the current assessment to quantify whether it had an impact on standardized CPUE. In this case, two alternative modeling approaches for handling zero-catch trips were applied as sensitivity analyses to estimate standardized CPUE in order to quantify the potential influence of model structure and the handling of zero-catch trips on the results of the CPUE standardization.

2.4.5 Empirical Patterns in the Fraction of Zero-Catch Bottomfish Trips

The number of HDAR trip reports using deep handline bottomfish trips with zero catch was summarized by calendar year (Fig. 10, top panel). Very few (< 0.5%) zero catch trips were reported from 1948 to 1956. The exception was 1953 when 4% of the trips reported zero catch. From 1957 to 1982, no trips reported zero catch and from 1983 to 1988, very few zero-catch trips were reported (< 0.1%). This abruptly changed in 1989 and all years during 1989-2010 reported zero-catch trips (annual percentage of trips ranged from 1 to 3.8%). The number of reported zero-catch trips prior to 1989 was statistically different from the number reported post-1989 ($Z = -2.22$, $P = 0.03$). From 1948 to 2010, a total of 1% of all deep handline trips reported zero catch.

The number of licenses reporting zero-catch trips from 1993 to present was examined by island (Fig. 11, top panel). Generally, Hawaii Island had the greatest number of licenses reporting zero catch followed by Maui Nui complex (Maui, Molokai, and Lanai), Oahu, Kauai, and finally NWHI. The only notable trend was an increase in the number of licenses reporting zero catch on Hawaii Island. The number of licenses steadily rose from 16 in 2004 to 32 in 2008 then subsequently fell to 17 in 2010.

The number of HDAR catch reports from trips with zero catch was also summarized by fishing year (July 1 of the prior year until June 30 of the fishing year) (Fig. 10, bottom panel). The same temporal pattern as calendar year was exhibited. There were very few reported zero-catch trips, a spike in 1953, no zero-catch trips reported from 1957 to 1982, very few trips reported zero catch from 1983 to 1988, then a sudden increase in the percentage of zero-catch trips from 1989 to 2011. There was also a statistical significant difference in the number of reported zero catches between pre-1989 and post-1989 ($Z = -2.42$, $P = 0.02$). From 1948 to 2011, roughly 1% of all trips reported zero catch.

The number of licenses reporting zero-catch trips by fishing year also followed the same general pattern as by calendar year (Fig. 11, bottom panel). However, the Hawaii Island increase was more abrupt (16 in 2007, 32 in 2008) relative to the calendar year increase.

Overall the zero-catch analyses indicated a step change in the proportion of zero-catch trips beginning in 1989. This change in the reporting of zero-catch trips coincided with changes in HDAR staffing and the treatment of catch report data records (R. Kokubun, HDAR, pers. comm.). As a result, it appeared that the change in the proportion of zeros in the catch reports did not reflect actual changes in fishing practices but instead reflected changes in data reporting and record keeping. It also appeared that there was some spatial variation in the number of commercial licenses that reported zero-catch trips among island groups in the Hawaiian Archipelago, with Hawaii Island having more zero-catch trip reports.

2.4.6 Alternative CPUE Standardization Analyses

Three alternative CPUE standardization analyses were conducted for Deep7 bottomfish to help ensure that the uncertainty regarding the data and structural assumptions of the standardization model were addressed as recommended by the WPSAR panel (Stokes, 2009). Each of these sensitivity analyses was based on the observed and unadjusted Deep7 single-trip handline data used under CPUE Scenario I.

The first sensitivity analysis was to investigate the effect of including CPUE data from 1958 to 1960 in the CPUE standardization analyses. This analysis used the best-fitting GLM (Table 8) to fit standardized CPUE to the observed data including the 1958-1960 CPUE data. Results indicated that the model with the augmented data produced a similar statistical fit with nearly identical estimates of standardized CPUE in comparable years (Table 11). This sensitivity analysis scenario was also denoted as CPUE Scenario Ib in some subsequent analyses of its impact on the production model used for the stock assessment.

The second sensitivity analysis was to investigate whether using an alternative approach to handling zero-catch trips would impact the CPUE standardization. In this analysis, a delta-GLM approach was applied to estimate standardized CPUE for Deep7 bottomfish (Piner and Lee, 2011). Under this approach, separate predictive models were developed for the proportion of positive Deep7 bottomfish catches and the positive CPUE distribution using the entire single-trip Deep7 bottomfish handline gear data set. The results of this analysis had a similar pattern to the baseline CPUE standardization but had a different estimated scale of mean catch per trip (Table 11). This CPUE standardization was also denoted as CPUE Scenario IV in some subsequent analyses of its impact on the production model used for the stock assessment.

The third sensitivity analysis also investigated whether using an alternative approach to handling zero-catch trips would impact the CPUE standardization. In this analysis, a quasi-likelihood Poisson-GLM approach was used to estimate standardized CPUE. In this case, separate Poisson-GLM models were estimated using data prior to and subsequent to 1990, and resulting estimates of standardized CPUE were predicted. This analysis produced results that had a similar pattern to the baseline standardized CPUE standardization but had a lower estimated mean standardized catch per trip (Table 11). This CPUE standardization was also denoted as CPUE Scenario V in some subsequent analyses of its impact on the production model used for the stock assessment.

Results of the three sensitivity analyses were contrasted with estimates of standardized CPUE under the baseline CPUE Scenario I and alternative CPUE Scenarios II and III through correlation analyses. Pearson correlations among the various series (Table 12) indicated that the estimates of standardized CPUE under CPUE Scenarios I, II, III, IV, V, and Ib were all very highly significantly correlated with pair wise positive correlations ranging from $\rho = 0.93$ to $\rho =$

1.00. Of these, it was notable that the standardized CPUE estimates from CPUE Scenario IV had the lowest set of positive correlations in comparison with estimates under the other scenarios. In addition, estimates of standardized CPUE under Scenario III exhibited a different trend than estimates under Scenarios I and II since the 1980s. This difference in trend was due to the substantial changes in fishing power assumed under Scenario III.

2.4.7 Association between Standardized CPUE and Indices of Environmental Forcing

Analyses to investigate possible associations between Deep7 bottomfish CPUE and indices of environmental forcing were also conducted (Lee and Brodziak, 2011). The indices of environmental forcing included three important determinants of ocean productivity in the Hawaiian Archipelago: the Southern Oscillation Index (SOI), the Pacific Decadal Oscillation Index (PDO), and sea surface height anomalies in the main Hawaiian Islands (see Table 1 in Lee and Brodziak (2011)). This set of analyses was based on the recommendation of the WPSAR panel to continue to investigate possible effects of environmental forcing on stock productivity (Stokes, 2009) as well as the findings of Brodziak (2007) which indicated a significant negative association existed between sea surface height indices and fitted CPUE residuals in the bottomfish stock assessment model.

Correlation analyses between CPUE for Deep7 bottomfish and the environmental indices showed that CPUE was significantly negatively correlated with the Pacific decadal oscillation ($\rho = -0.461$, $P < 0.05$) accounting for autocorrelation (see for example, Kope and Botsford, 1990). The cross-correlation between CPUE and the 1-year lag PDO also indicated that there was a negative association between CPUE and the 1-year lagged PDO. Overall, these analyses provided support to the hypothesis that either the productivity or the depth distribution and associated catchability of Deep7 bottomfish resources in the main Hawaiian Islands was subject to low frequency forcing by the Pacific Decadal Oscillation.

2.4.8 Catch and CPUE Scenarios for Baseline Model and for Sensitivity Analyses

The Deep7 bottomfish stock assessment model for status determination was applied to the baseline catch and CPUE scenarios; these were also labeled Catch Scenario II and CPUE Scenario I. In addition, there were a total of 11 combinations of catch and CPUE scenarios used for sensitivity analyses (Table 13 and Fig. 12). These combinations represented the possible alternative combinations of the four catch scenarios and three CPUE scenarios.

3. ASSESSMENT MODEL

In this assessment, the stock status of the Deep7 bottomfish complex in the main Hawaiian Islands was directly estimated. In comparison, for the previous assessment of the Hawaiian bottomfish complex conducted in 2005 and the 2008 assessment update, the status of the primary bottomfish complex in each fishing zone of the Hawaiian Archipelago was assessed using a Schaefer surplus production model (Moffitt et al., 2006; Brodziak et al., 2009), then the status of the assumed archipelagic stock was assessed by assuming that the intrinsic growth rate of Hawaii bottomfish was equal across zones and that the relative amount of bottomfish habitat in each zone was proportional to the linear extent of its 100-fathom contour. Since the 2005 assessment, the Northwestern Hawaiian Islands has been designated as an area where commercial fishing is prohibited. One ramification of the closure of the NWHI is that there will be no bottomfish harvests in the Mau and Hoomalu fishing zones. As a result, the focus of this stock assessment was on the fishery, population dynamics, and stock status of the Deep7 bottomfish complex of the main Hawaiian Islands.

3.1 Biomass Dynamics Model

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

The process dynamics represented the temporal fluctuations in exploitable bottomfish biomass due to density-dependent population processes (e.g., growth) and fishery harvests. The production dynamics of biomass were based on a power function model with an annual time step. Under this 3-parameter model, current exploitable biomass (B_T) depended on the previous exploitable biomass (B_{T-1}), previous catch (C_{T-1}), intrinsic growth rate (R), carrying capacity (K), and a 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 determined where surplus production peaked as biomass varied as a fraction of carrying capacity (Fig. 13). If the shape parameter was less than unity (0 < M < 1), then surplus production peaked when biomass was below ½ of K (i.e., a right-skewed production curve). If the shape parameter M was greater than unity (M > 1), then biomass production was highest when biomass was above ½ of K (i.e., a left-skewed production curve). If the shape parameter was identically unity (M = 1), then the production model was identical to a discrete-time Schaefer production model where maximum surplus production occurred when biomass was equal to ½ of M. In practice, estimates of the shape parameter M for Deep7 biomass production in the MHI tended to be greater than unity.

We expressed the production model 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 (see Meyer and Millar, 1999). Given this parameterization, the process dynamics for the temporal changes in the proportion of carrying capacity were

$$(2) \qquad P_T = P_{T-1} + R \cdot P_{T-1}\left(1 - P_{T-1}^{M}\right) - \frac{C_{T-1}}{K}$$

The values of exploitable biomass and harvest rate that maximized biomass production were relevant as biological reference points for fishery management and also for estimating the maximum sustainable yield (MSY) of the Deep7 Hawaii bottomfish complex. For the current stock assessment model, the exploitable biomass that was required to produce MSY (BMSY) was

$$(3) \qquad B_{MSY} = K \cdot \left(M + 1\right)^{\frac{-1}{M}}$$

The corresponding harvest rate that was required to produce MSY (HMSY) was

$$(4) \qquad H_{MSY} = R\left(1 - \frac{1}{M+1}\right)$$

Last, the estimate of maximum sustainable yield (MSY) for the Deep7 Hawaii bottomfish complex was

$$(5) \qquad MSY = R\left(1 - \frac{1}{M+1}\right) \cdot K\left(M + 1\right)^{\frac{-1}{M}}$$

As a result, the use of the production model led to direct estimates of MSY-based biological reference points for determining stock status of Deep7 Hawaii bottomfish under the U.S. Sustainable Fisheries Act (DOC, 2007).

The process error model related the dynamics of exploitable biomass to natural variability in demographic and environmental processes affecting the bottomfish complex. The deterministic process dynamics (Equation 2) were subject to natural variation as a result of fluctuations in life history parameters, trophic interactions, environmental conditions and other factors. In this case, the process error represented the joint effects of a large number of random multiplicative events which combined to form a multiplicative lognormal process under the Central Limit Theorem. As a result, the process error terms were set to be independent and lognormally distributed random variables $\eta_T = e^{U_T}$ where the U_T were normal random variables with mean 0 and variance σ^2.

Given the process errors, the state equations defined the stochastic process dynamics by relating the unobserved biomass states to the observed catches and the estimated population dynamics parameters. Given the multiplicative lognormal process errors, the state equations for the initial time period ($T = 1$) and subsequent periods ($T > 1$) were

$$(6)\qquad \begin{aligned} P_1 &= \eta_1 \\ P_T &= \left(P_{T-1} + R \cdot P_{T-1}\left(1 - P_{T-1}^S\right) - \frac{C_{T-1}}{K} \right) \cdot \eta_T \quad for\ T > 1 \end{aligned}$$

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

3.2 Observation Error Model

The observation error model related the observed fishery CPUE to the exploitable biomass of the bottomfish complex under each scenario. It was assumed that the standardized fishery CPUE index (I) was proportional to biomass with catchability coefficient Q

$$(7)\qquad I_T = QB_T = QKP_T$$

The observed CPUE dynamics were subject to natural sampling variation which was assumed to be lognormally distributed. The observation errors were 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 reflected the relative uncertainty of the value of the CPUE index in year T and were scaled using the coefficient of variation (CV) of the difference between the observed and predicted log-transformed biomass indices (Maunder and Starr, 2003; Brodziak and Ishimura, 2011). In particular, the annual weighting factors were 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 listed under the column “relative CVs” in the tabulation of baseline and alternative estimates of standardized CPUE (Tables 10 and 11).

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

$$(8)\qquad I_T = QKP_T \cdot \nu_T$$

This specified the general form of the observation error likelihood function $p(I_T|\theta)$ for the Deep7 bottomfish CPUE index through time.

3.3 Prior Distributions

We used a Bayesian estimation approach to estimate production model parameters. Prior distributions were employed to represent existing knowledge and beliefs about the likely values of model parameters. 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 had prior distributions. Unobserved biomass states were also assigned priors and were expressed as the proportion of carrying capacity, conditioned on the previous proportion, and the catchability parameter.

The choice of input catch data scenario influenced the fitting and numerical convergence of the Bayesian Markov Chain Monte Carlo (MCMC) simulations under different prior distributions. In particular, under the high catch Scenarios (Catch Scenario I and Baseline Catch Scenario II), it was necessary to assign different parameters for some prior distributions than under the lower catch scenarios (Catch Scenarios III and IV). This was due to the different scales of exploitable bottomfish biomass that were implied under the high and low catch scenarios. As a result, some prior distributions included values for both high and low catch scenarios. Regardless, the convergence of the MCMC simulations was assessed using standard diagnostic tests in all cases.

3.4 Prior for Carrying Capacity

The prior distribution for the carrying capacity $p(K)$ was a moderately informative lognormal distribution with mean $\left(\mu_K\right)$ and variance $\left(\sigma_K^2\right)$ parameters.

$$(9) \qquad p(K) = \frac{1}{\sqrt{2\pi}K\sigma_K}\exp\left(-\frac{\left(\log K-\mu_K\right)^2}{2\sigma_K^2}\right)$$

The prior mean for K was set based on the 2008 assessment update in which the product of the r and K parameters was roughly 1.8 million pounds (Brodziak et al., 2009). Assuming that the product r and K would be similar in the current assessment and observing that the mean of the intrinsic growth rate prior was r = 0.1 in the current assessment, the mean value of K was set to be 1.8/0.1 = 18.0 million pounds for the Baseline Catch Scenario II and Catch Scenario I. Under the low catch scenarios, the prior mean was set to be 9.0 million pounds to reflect the fact that the scaling of bottomfish biomass would be lower given that the catch removals were lower. Overall, the prior mean of K was chosen to reflect the magnitude of exploitable biomass likely needed to support the estimated time series of fishery catches under each scenario. Under the High Catch Scenarios I and II, the variance parameter was set to achieve a coefficient of variation (CV) for K of 50%, that is $CV[K] = \left(\exp\left(\sigma_K^2\right)-1\right)^{\frac{1}{2}} = 0.5$ while under the Low Catch Scenarios III and IV, the variance was chosen to set the CV of K to be 25%. Thus, the prior for carrying capacity was moderately informative (CV of 25%) for the expected value of K.

3.5 Prior for Intrinsic Growth Rate

The prior distribution for intrinsic growth rate $p(R)$ was a moderately informative lognormal distribution with mean $\left(\mu_R\right)$ and variance $\left(\sigma_R^2\right)$ parameters set to achieve a CV for R of 25% under both high and low catch scenarios.

$$(10) \quad p(R) = \frac{1}{\sqrt{2\pi} R \sigma_R} \exp\left(-\frac{\left(\log R - \mu_R\right)^2}{2\sigma_R^2} \right)$$

The mean of the intrinsic growth rate parameter was set to be $\mu_R = 0.10$ for the baseline and each alternative catch scenario. This mean value was chosen to reflect the expectation of low productivity of Deep7 bottomfish. The specific choice of $\mu_R = 0.10$ was based on the recommendations of Musick (1999) and Musick et al. (2000) and was consistent with the new information on the expected life span of the primary Deep7 species opakapaka. In particular, the probable range of R values of 0.05-0.15 recommended by Musick (1999) was represented with a prior mean of R = 0.10 with a CV of 25% which produces a 95% confidence interval that approximates the suggested range.

3.6 Prior for Production Shape Parameter

The prior distribution for the production function shape parameter $p(M)$ was a moderately informative gamma distribution with scale parameter λ and shape parameter k:

$$(11) \quad p(M) = \frac{\lambda^k M^{k-1} \exp\left(-\lambda M\right)}{\Gamma\left(k\right)}$$

The values of the scale and shape parameters were set to $\lambda = k = 0.5$. This choice of parameters set the mean of $p(M)$ to be $\mu_M = 1$, which corresponded to the value of M for the Schaefer production model. The choice of k = 0.5 also implied that the CV of the shape parameter prior was about 140%. In effect, the shape parameter prior was centered on the symmetric Schaefer production model as the default (Fig. 13) with sufficient flexibility to fit an asymmetrical production function.

3.7 Prior for Catchability

The prior for bottomfish fishery catchability p(q) was chosen to be an uninformative uniform distribution on the interval $[10^{-5}, 10^{5}]$. This diffuse prior was chosen to allow the data and model structure to completely determine the distribution of fishery catchability estimates.

3.8 Prior for Unreported Catch Error

An uninformative prior was used for the unreported catch error. The estimates of unreported catch under Catch Scenarios I, II, and III were assumed to be observed with a prior error distribution $p(C_T)$ for fitting the production model to the observed fishery data. It was assumed that the error in unreported catch was uniformly distributed about the point estimate with a ±20% error. For example, if the estimate of unreported catch was 100 thousand pounds in a given year, then the prior distribution of unreported catch with error was uniformly distributed between 80 and 100 thousand pounds, i.e., $C_U \sim$ Uniform[80, 120]. This catch error prior was chosen to propagate uncertainty in the estimation of unreported catch into the estimation of sustainable harvest rates and biomasses. Effects of the choice of 20% on model results were assessed through sensitivity analyses. Last, we note that analyses of Catch Scenario IV were not affected by the catch error prior because unreported catches were negligible under this scenario.

3.9 Priors for Error Variances

Priors for the process error variance $p(\sigma^2)$ and observation error variance $p(\tau^2)$ were chosen to be moderately informative inverse-gamma distributions with scale parameter $\lambda>0$ and shape parameter $k>0$:

$$p\left(\sigma^2\right) = \frac{\lambda^k \left(\sigma^2\right)^{-k-1} \exp\left(\frac{-\lambda}{\sigma^2}\right)}{\Gamma\left(k\right)} \tag{12}$$

The inverse-gamma distribution is a useful choice for priors that describe model variances (Congdon, 2001). For the process error variance prior, the scale parameter was set to $\lambda = 0.1$ and the shape parameter was $k = 0.2$. For this choice of parameters, the expected value of the inverse-gamma distribution is not defined, and the mode for σ^2 denoted as $\text{MODE}[\sigma^2] = 1/12 \approx 0.083$ provides an alternative measure of the central tendency of the distribution. For the observation error variance prior, the scale parameter was set to $\lambda = 1$ and the shape parameter was $k = 0.2$. The mode for τ^2 with this choice of parameters was $\text{MODE}[\tau^2] = 10/12 \approx 0.83$. The ratio of the modes of the observation error prior to the process error prior was $\text{MODE}[\tau^2]/\text{MODE}[\sigma^2] = 10$. Thus, the central tendency of the observation error variance prior was assumed to be about tenfold greater than the process error variance prior. The choice of the process error prior matched the expected scaling of process errors which were on the order of 0.1 for the state equations describing changes in the proportion of carrying capacity (Equation 6). Similarly, the choice of the observation error prior matched the expected scaling of observation errors which were on the order of 1 to 10 for the observation equations (Equation 8) describing the model fit to observed CPUE.

3.10 Priors for Proportions of Carrying Capacity

Prior distributions for the time series of biomass in proportion to carrying capacity, $p(P_T)$, were determined by examining the model fits to the CPUE data under high and low catch scenarios. The prior mean for the initial proportion of carrying capacity in the main Hawaiian Islands in 1949 (P_1) was set to equal the posterior mean $P_1^* = 0.53$ for the High Catch Scenarios I and II. The posterior mean of $P_1^* = 0.53$ was based on choosing the minimum root-mean square error of the fit to Baseline CPUE Scenario I for alternative models with prior mean values of P_1 ranging from 0.1 to 1.0 (Figs. 14.1 and 14.2). A similar approach was used to set P_1 for the Low Catch Scenarios III and IV. In this case, P_1 was set to equal the posterior mean $P_1^*=0.62$ for the Low Catch Scenarios III and IV based on the minimum root-mean square error of the fit to Baseline CPUE Scenario I over alternative models with prior mean values of P_1 from 0.1 to 1.0 (Figs. 15.1 and 15.2). The coefficient of variation of the lognormal distribution of P_1 was set to be 20% for both high and low catch scenarios. This choice of CV implied that probable values of P_1 ranged from roughly 0.3 to 0.7 for the baseline assessment model. Prior mean values for the proportion of carrying capacity in other years T, where T > 1949, were set to be 0.6 or 0.5.

3.11 Production Model Structure

Goodness-of-fit criteria were used to guide choices about the final structure of the prior distributions and their parameter values. We investigated one initial production model configuration that used a multilevel prior distribution for the intrinsic growth rate parameter R as recommended by the WPSAR 2009 review panel. This multiple-R model included annual values of intrinsic growth rate in year t (R_t) that were lognormally distributed and included a hyperprior for the overall time series mean value of R that was normally distributed (Appendix Table A4). This hierarchical setup for a time-varying intrinsic growth rate parameter was similar to the modeling analyses described in Jiao et al. (2009). This formulation of the production model also included a normally distributed prior for carrying capacity K (Appendix Table A4). The multiple-R model produced annual estimates of intrinsic growth rate R that exhibited some time trend to explain the relatively higher rates of bottomfish catches during the late-1950s to early-1960s and during the 1980s.

We compared the goodness-of-fit values of the deviance information criterion (Spiegelhalter et al., 2002 [DIC]) for the multiple-R model and the baseline assessment model used for the current assessment. In this context the baseline model included a single R parameter for all years with a lognormal prior and also included a lognormal prior for K (Appendix Table A5). Thus, the baseline model differed from the multilevel-R model in two ways; the baseline model had a single R parameter and had a lognormal prior for K. We found that the values of DIC for the baseline model were consistently lower than those for the multilevel R model under each catch and CPUE scenario (Table 14). In particular, under the Baseline Catch Scenario II and CPUE Scenario I, the baseline model value of DIC was 14.6 units lower than that of the multiple-R model. The fact that this difference was greater than 3 indicated that the baseline model produced a substantially better fit to the data (Spiegelhalter et al., 2002). Similarly, the baseline model produced substantially better fits under Catch Scenarios S1, S2, and S4 for all CPUE scenarios (Table 14). In contrast, there was no substantial difference between the baseline and multiple-R models under Catch Scenario S3 for all CPUE scenarios. Given this pattern, the baseline model was judged to provide a better fit to the catch and CPUE data than the multilevel R model.

Another structural choice for the baseline model was choosing between using a normal versus a lognormal distribution for the prior of the carrying capacity parameter K. In this case, the symmetric normal distribution was found to be susceptible to numerical overflow when the MCMC simulations produced infrequent large jumps in the Gibbs sampling process. This instability led to the selection of a lognormal prior for carrying capacity (Appendix Table A5) although it is notable that the choice of a normal distribution produced similar estimates of exploitable biomass and harvest rates.

3.12 Posterior Distribution

The posterior distribution of the production model was numerically sampled to estimate model parameters and make inferences about them. The posterior distribution, $p(\theta|D)$, was proportional to the product of the priors and the likelihood of the CPUE data given the catch and CPUE data D

(13)

$$p(\theta \mid D) \propto p(K)\,p(R)\,p(M)\,p(Q)\,p(\sigma^2)\,p(\tau^2)\prod_{T=1}^{N} p(C_T \mid \theta)\prod_{T=1}^{N} p(P_T)\prod_{T=1}^{N} p(I_T \mid \theta)$$

There was no analytic solution to determine parameter estimates of the production model, and we used a numerical simulation to generate sequences of estimates from the posterior distribution or model solution.

Parameter estimation for complex Bayesian nonlinear 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, Markov Chain Monte Carlo (MCMC) simulation (Gilks et al., 1996) was applied to numerically generate samples from the posterior distribution. The WINBUGS software (Lunn et al., 2000; Spiegelhalter et al., 2003) was used 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 (Appendix Table A5). The baseline production model was configured to fit the Baseline Catch Scenario II and Baseline CPUE Scenario I to estimate model parameters and stock status for the Deep7 Hawaii bottomfish complex.

Production model results included the stock status of the Deep7 bottomfish complex in the main Hawaiian Islands relative to MSY 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}) were calculated for the MHI using the mean values from the joint posterior distribution of model parameters (Appendix Table A5).

3.13 Convergence Diagnostics

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

Convergence of the simulated MCMC chains to the posterior distribution was 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 were 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 were 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. Monte Carlo errors, which measured the variation of the mean of each parameter due to the MCMC simulation, were also calculated and compared to the posterior standard deviation of the key model parameters. In this case, the existence of small Monte Carlo errors, on the order of a few percent of the posterior standard deviation, provided an empirical check that parameter variability due to the MCMC simulations was relatively low (e.g., Ntzoufras, 2009).

3.14 Model Diagnostics

Residuals from the baseline model fit to CPUE were 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 were

(14) $$\varepsilon_T = \log\left(I_T\right) - \log\left(QKP_T\right)$$

Nonrandom patterns in the CPUE residuals suggested that the observed CPUE may not have conformed to one or more model assumptions. The RMSE of the CPUE fit provided 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 were made to show whether the observed catch and standardized CPUE data were informative for estimating model parameters. This comparison included 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, catch distribution in 2010, BMSY, MSY, HMSY, and proportion of carrying capacity that would produce MSY.

3.15 Total Allowable Catch Projections for 2012-2013

3.15.1 Projection Model Assumptions

Estimated posterior distributions of assessment model parameters in 2010 were projected forward for fishing years 2011-2013 to estimate probable stock status (e.g., the probability of overfishing P*) under alternative future catches. As a result, the projection results accounted for uncertainty in the distribution of estimates of model parameters. Projections were conducted for a set of alternative values of total allowable commercial catches in 2012-2013 to estimate the probability of overfishing in 2012 and other stock status measures as a function of the 2012 TAC.

The projections were conducted assuming the TACs in fishing years 2012 and 2013 were equal, that is, $TAC_{2012} = TAC_{2013}$. The amount of commercial Deep7 Hawaii bottomfish catch in fishing year 2011 was also assumed to equal the commercial TAC set by the WPRFMC in 2011, which was TAC_{2011} = 254 thousand pounds. This value of TAC_{2011} was used to estimate the harvest rate in fishing year 2011 for each of the TAC alternatives.

Catch errors for unreported catch were also included in the projections. The catch error distribution used for the projected unreported catch in 2011-2013 was the same as that assumed under the given catch scenario. For example, under Catch Scenarios I, II, and III there was a uniform catch error distribution of ±20% assumed but no catch error was assumed under Catch Scenario IV.

The projection results were used to compute the 2-year constant commercial Deep7 TACs in the main Hawaiian Islands for 2012-2013 that would produce probabilities of overfishing ranging from 0% to 90% and above by 5% intervals. To do this, we calculated the effects of alternative TACs using a numerical grid of 2-year TACs ranging from 1 to 1001 thousand pounds of Deep7 reported commercial catch in steps of 2 thousand pounds (Appendix Table A5) and then used the closest calculated grid value to approximate the TACs corresponding to each 5% probability increment.

3.16 Sensitivity Analyses

A suite of sensitivity analyses were conducted to evaluate how the baseline model results would be affected if different assumptions were made regarding the appropriate catch or CPUE scenario or if different assumptions were made about the prior distributions.

3.16.1 Sensitivity to Alternative Catch and CPUE Scenarios

The sensitivity of model results to the choice of catch scenario and CPUE scenario was evaluated by fitting the production model using the alternative catch and CPUE scenarios with all other input data and assumptions remaining the same. This sensitivity analysis addressed the question of how model results under the Baseline Catch Scenario II and Baseline CPUE Scenario I would change if alternative catch or CPUE scenarios were used.

3.16.2 Sensitivity to Alternative Error Distribution for Unreported Catch

The sensitivity of baseline model results to the assumed amount of error in the estimation of unreported catch was evaluated. The effect of decreasing the error distribution of unreported catch to ±1% and increasing the error distribution of unreported catch to ±50% were evaluated by changing the width of the interval of uniform distribution of catch errors to [0.99, 1.01] and [0.50, 1.50] from the baseline interval of [0.80, 1.20]. The sensitivity of model results to directional biases in the unreported catch error was also evaluated. The effects of a 30% decrease in average catch error was assessed by changing the interval of catch errors to be [0.65, 1.05], while the effects of a 30% increase in average catch error was evaluated by setting the catch error interval to be [0.95, 1.35].

3.16.3 Sensitivity to Alternative Prior Distribution for Carrying Capacity

The sensitivity of baseline model results to the prior mean for carrying capacity was evaluated by fitting the model using two different prior means for K. For these analyses, the prior mean for K was reduced by 50% and increased by 100%. This sensitivity analysis addressed whether the choice of a prior mean had a strong influence on model results. An additional sensitivity analysis showed the effects on biomass and harvest rate estimates by varying the prior mean for K from $\mu_K = 9.0$ million pounds to $\mu_K = 27.0$ million pounds in increments of 3.0 million pounds.

3.16.4 Sensitivity to Alternative Prior Distribution for Intrinsic Growth Rate

The sensitivity of baseline model results to the prior mean for intrinsic growth rate was also evaluated by fitting the model using two different prior means for R. In this case, the prior mean for R was reduced by 50% and increased by 100%. This sensitivity analysis addressed whether the choice of a prior mean for R = 0.10 had a strong influence on model results. An additional sensitivity analysis showed the effects on biomass and harvest rate estimates by varying the prior mean for R from $\mu_R = 0.04$ to $\mu_R = 0.16$ in increments of 0.02.

3.16.5 Sensitivity to Alternative Prior Distribution for Production Model Shape Parameter

The sensitivity of baseline model results to the prior mean for the production model shape parameter M was evaluated. This sensitivity analysis showed the effects on biomass and harvest rate estimates by varying the prior mean for M from $\mu_M = 0.4$ to $\mu_M = 1.6$ in increments of 0.2.

3.16.6 Sensitivity to Alternative Prior Distribution for Initial Proportion of Carrying Capacity

The sensitivity of baseline model results to the prior mean for the initial proportion of carrying capacity in 1949 was evaluated by fitting the model using two different prior means for P[1]. As with the analyses for K and R, the prior mean for the initial proportion of carrying capacity was reduced by 50% and increased by 100%. This sensitivity analysis addressed whether the choice of a prior mean for P[1] had a strong influence on model results. An additional sensitivity analysis showed the effects on biomass and harvest rate estimates by varying the prior mean for P[1] from $\mu_{P1} = 0.25$ to $\mu_{P1} = 1.05$ in increments of 0.1.

3.16.7 Sensitivity to Proportion of 2011 TAC Assumed Caught

The sensitivity of baseline model projection results to the proportion of the 2011 Deep7 TAC that was caught was also evaluated by fitting the model using two different assumptions for this proportion, which was set to be 1 (or 100% of the 2011 TAC) in the baseline projections. For these analyses, the value of the proportion of the 2011 TAC was reduced by 20% and increased by 20%. This sensitivity analysis addressed whether the choice of the proportion of the 2011 TAC that was caught had a strong influence on model projection results.

3.16.8 Sensitivity to Alternative Prior Distribution for Observation Error Variance

The sensitivity of baseline model results to the prior mode for the observation error variance was evaluated. This sensitivity analysis showed the effects on biomass and harvest rate estimates by varying the prior mode for τ^2 over five orders of magnitude from $\eta_{\tau 2} = 0.000833$ to $\eta_{\tau 2} = 83.3$ in multiples of 10.

3.16.9 Sensitivity to Alternative Prior Distribution for Process Error Variance

The sensitivity of baseline model results to the prior mode for the process error variance was evaluated. This sensitivity analysis showed the effects on biomass and harvest rate estimates by varying the prior mode for σ^2 over five orders of magnitude from $\eta_{\sigma 2} = 0.0000833$ to $\eta_{\sigma 2} = 8.33$ in multiples of 10.

3.16.10 Sensitivity to Choice of Uniform Prior for Observation and Process Error Variances

The sensitivity of baseline model results to the choice of a probability distribution for the prior of the observation and process error variances was evaluated. This sensitivity analysis showed the effects of choosing a uniform prior instead of an inverse-gamma prior on model estimates of biomass, biomass status, probability that biomass is below BMSY, harvest rate, harvest rate status, and probability that harvest rates exceeds HMSY.

3.16.11 Sensitivity to Choice of Hypothetical Scenario Weights for Model Averaging

The sensitivity of baseline model results to the choice of catch and CPUE scenarios was investigated using model averaging over alternative scenarios. In this case, if one assumed that each alternative catch and CPUE scenarios could be assigned a subjective probability of being true, then the set of modeling results could be averaged based on the assigned probabilities. These scenario-averaged projection results might differ markedly from those under the baseline assessment scenario (Table 15.1). Thus, a model averaging approach provided a sensitivity analysis to the binary choice of selecting one baseline stock assessment scenario in contrast to a probabilistic interpretation of the alternative assessment scenarios (see for example, Brodziak and Piner, 2010). To do this, we assigned hypothetical subjective probabilities to the alternative catch and CPUE scenarios (Table 15.2). For the catch scenarios, a high degree of relative belief (80% relative probability of being true) was placed in Catch Scenario II because it applied what was judged to be the best and most comprehensive set of quantitative data to estimate unreported catches and also provided the best set of model fits to the CPUE time series. In comparison, Catch Scenarios I and IV were considered be very unlikely (5% relative probability of being true) while Catch Scenario III was considered to be much less likely than Scenario II (10% relative probability of being true but more likely than Scenarios I and IV. For CPUE, a similar high degree of belief was assigned to CPUE Scenarios I (50%) and II (40%) because it seemed unlikely that the efficiency of traditional fishing methods had increased at a rate of more than 1% per year since the 1950s.

3.17 Retrospective Analyses

Retrospective analyses were conducted to measure the effect of excluding successive years of data at the end of the assessment time series on model estimates of biomass and exploitation rate. This sensitivity analysis was conducted by successively deleting the catch and CPUE data for years 2010 to 2005 in 1 year increments, refitting the baseline assessment model, and summarizing the results.

3.18 Decision Table Analyses

Decision tables were constructed to show the impacts of setting a TAC under an assumed model catch and CPUE scenario when an alternative model catch and CPUE scenarios were actually the true state of nature (see for example, Hilborn and Peterman, 1996). To do this, projection model results were tabulated for the TACs that would produce a low risk of overfishing with a probability of overfishing of P* = 0.25 and also for the TACs that would produce a high risk of overfishing of P* = 0.50. The value of P* = 0.25 was chosen to highlight the effect of reducing P* by 50% from the high risk of overfishing scenario in which P*=0.50. These tables were intended to show the consequences and the relative risk of choosing alternative TACs in 2012 when there was uncertainty about the correct CPUE scenario, i.e., the estimated relative abundance index that provided the best approximation of the true state of nature.

4. RESULTS

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

4.1 Convergence Diagnostics

Convergence diagnostics indicated that it was very likely that the MCMC simulation converged under all catch and CPUE scenarios. In particular, the Geweke diagnostics were computed for 10 primary model parameters and two MCMC chains under all twelve combinations of Catch Scenarios I, II, III, and IV and CPUE Scenarios I, II, and III. The maximum number of Geweke diagnostic values for a given scenario that were greater than 2 standard deviations was 1 out of 20 values and occurred under Catch Scenario II with CPUE Scenarios II and III and also Catch Scenario III with CPUE Scenario I. Thus, the Geweke diagnostics conformed to expectations and did not indicate a lack of convergence. The Gelman and Rubin potential scale reduction factor was equal to unity for all twelve models confirming convergence to the posterior distribution. The Heidelberger and Welch stationarity and half-width diagnostic tests were also passed by all of the models at a confidence level of $\alpha = 0.05$. Overall, the residual and convergence diagnostics supported the convergence of the baseline assessment model and indicated that the alternative models used for sensitivity analyses also converged.

4.2 Model Diagnostics

In terms of the statistical fit to the standardized CPUE indices, the Baseline Catch Scenario II produced the lowest root mean square error (RMSE) for any given CPUE scenario. That is, under CPUE Scenario I, the lowest RMSE value was RMSE = 41.14 under Catch Scenario II (Tables 16.1 to 16.4). Similarly, under CPUE Scenario II, the lowest RMSE value among catch scenarios was RMSE = 40.45 under Catch Scenario II. Last, the lowest RMSE value under CPUE Scenario III was RMSE=34.12 under Catch Scenario II. Overall, this goodness-of-fit comparison indicated that Catch Scenario II was most consistent with the alternative CPUE scenarios under different assumptions about changes in fishing power or the structural form of the CPUE standardization model.

Model residuals indicated that the production model developed in this assessment provided a good fit to the Baseline Catch Scenario II under Alternative CPUE Scenarios I, II, and III (Figs. 16 to 18). Sensitivity analyses with alternative catch and CPUE scenarios also indicated reasonable diagnostic fits to the CPUE data (Appendix Figs. A1.1 to A12.2).

Comparisons of assumed prior distributions and estimated posterior distributions showed that the observed data were more informative for some model parameters than others (Fig. 19). The amount of information was indicated by the relative change in the mean value of the assumed prior distribution.

For the carrying capacity parameter (Fig. 19.1) the posterior mean (27.3) was 52% greater than the prior mean (18.0) indicating that the data were informative for K. The same was true for the production model shape parameter M (Fig. 19.2) which had a posterior mean of 1.84 in comparison to a prior mean of 1.00 (+84%). In contrast, the posterior mean of intrinsic growth rate R (0.11) was only 7% greater than the prior mean (0.10), suggesting that there was limited information for estimating R in the data (Fig. 19.3) Similarly, the data did not appear to be informative for the initial proportion of carrying capacity parameter P[1] (Fig. 19.4) because the posterior mean (0.59) was only 11% different from the prior mean (0.53). Of these four parameters, the priors for K and M were assigned substantial variability thus making them more vague, while the priors for R and P[1] were chosen using auxiliary information to set the prior mean close to the expected posterior mean resulting from the MCMC simulations.

The prior and posterior means were substantially different for the observation and process error variances (Figs. 19.5 and 19.6) as well as for the catchability parameter Q (Fig. 19.7). In these three cases, the posterior mean was about 99% below the prior mean. The priors for these parameters were selected to have relatively high variances and hence were relatively uninformative about the estimated parameter values.

There was apparently no information in the observed data to alter the mean of the prior distribution of bottomfish catch in 2010 (Fig. 19.8). In this case, the mean of the uniform prior (0.441) was equal to the mean of the posterior distribution.

The observed data were highly informative for the MSY-based parameters BMSY, HMSY, and MSY (Figs. 19.9 to 19.12), although the prior distributions of these parameters were not formally selected but instead were derived from the priors of R, K, and M. The posterior means for BMSY (14.6), HMSY (0.06), and MSY (0.868) were 73%, 74%, and 158% higher than the respective prior means. In contrast, the posterior mean of the proportion of carrying capacity to produce MSY (0.55) was only 17% higher than the prior mean. Overall, the observed data appeared to contain enough information to adjust the implied prior estimates of MSY-related parameters.

4.3 Stock Status

Bottomfish biomass, harvest rate estimates, and MSY-based reference points from the baseline production model (Catch Scenario II and CPUE Scenario I) and alternative sensitivity runs were summarized (Tables 16.1 to 16.4, Tables 17.1 to 17.3, Tables 18 to 18.3, Figs. 20 to 22, and Appendix Figs. A13 to A21).

Under the baseline stock assessment model scenario for Deep7 bottomfish (Table 16.1), 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:

(i) MSY = 417 thousand pounds (± 163 thousand pounds)
(ii) H_{MSY} = 6.1% (± 2.2%)
(iii) B_{MSY} = 14.6 million pounds (± 4.33 million pounds).

The range of estimated mean values of MSY-based biological reference points amongst the catch and CPUE scenarios was substantial, however (Tables 16.1 to 16.4), ranging from 299 to 422 thousand pounds for MSY expressed in units of reported catch, harvest rates to produce MSY from H_{MSY} = 5.3% to 6.7%, and exploitable biomasses to produce MSY from B_{MSY} = 5.33 to 19.88 million pounds.

Estimates of biological reference points for bottomfish differed from the estimates from the previous assessments (Moffitt et al., 2006; Brodziak et al., 2009) because the assessment model was fit to Deep7 bottomfish fishery data instead of all primary bottomfish fishery data, the

Baseline Catch Scenario II included unreported catch, and the baseline model was fit to a different CPUE scenario.

Bottomfish biomass exhibited a long-term decline from high values in the 1960s-1970s to lower values around B_{MSY} since the mid-1990s (Fig. 20.1). Biomass in the MHI Zone fluctuated around B_{MSY} in the late-1980s and is currently near B_{MSY} since 2008. Harvest rates were relatively low in the 1960s to mid-1970s, increased to peak in 1989, and have declined gradually since then (Fig. 20.2). Harvest rates declined from about twice H_{MSY} in the late-1980s to range from 50% to 85% of H_{MSY} since 2001.

Baseline model results for the main Hawaiian Islands Deep7 bottomfish stock indicated that the stock was not depleted (B_{2010}/B_{MSY}=0.92, Table 17.1 and Fig. 20) and that the stock was not experiencing overfishing (H_{2010}/H_{MSY}=0.58, Table 17.1 and Fig. 20). In fishing year 2010, there was an 84% probability that exploitable biomass exceeded the limit of 0.7*B_{MSY} and a 13% chance that the harvest rate exceeded H_{MSY}. As a result, the Deep7 bottomfish stock complex would be categorized as not being overfished and not experiencing overfishing in 2010 given the baseline assessment scenario results.

Under alternative assumptions about the correct assessment scenario, the stock status of Deep7 bottomfish would be similar to the baseline determination if it were true that there had been a moderate increase in fishing power in the bottomfish fishery through time (e.g., ~ 10% increase in fishing power under CPUE Scenario II, Table 17.2 and Fig. 21). In contrast, the status determination would differ from the baseline scenario with overfishing and stock depletion occurring if it were true that there had been a marked increase in bottomfish fishing power through time (e.g., ~ 70% increase in fishing power under CPUE Scenario III, Table 17.3 and Fig. 22). Thus, the Deep7 bottomfish stock status determination in 2010 was sensitive to whether there was a substantial increase in fishing power in the bottomfish fishery through time. Overall, it was not expected that there was a substantial increase (on the order of 70%) in bottomfish fishing power through time because the current fishery employs deep handline fishing gear that is similar to what was used at the beginning of the assessment time period and also because there is considerable inherent variability in fishery catches at expected fishing hot spots due to variability in environmental factors influencing Deep7 bottomfish feeding patterns, such as changes in ocean currents and the distribution of prey resources (see for example, Moffitt et al., 2011). Other sensitivity analyses showed the effects of choosing alternative hypotheses of catch scenario and CPUE scenario on status determination results for Deep7 Hawaii bottomfish in 2010 (Figs. 23.1 and 23.2).

4.4 Projections

Under the constant 2-year TAC projection scenarios evaluated, projected probabilities of overfishing, relative biomasses, and probabilities of depletion of Deep7 bottomfish (Table 19.1) showed the distribution of outcomes that would likely occur if constant TACs were applied in the MHI during 2012-2013. Results of the stochastic projections indicated that the Deep7 TAC in 2012 that would produce approximately 20% chance of overfishing in 2012 (i.e., exceeding H_{MSY}) was 255 thousand pounds, roughly equal to the 2011 TAC under the baseline model

(Table 19.1 and Fig. 24). For comparison, the smallest Deep7 TAC that would lead to a roughly 40% chance of overfishing was 341 thousand pounds. Total allowable commercial catches of Deep7 bottomfish in 2012 ranging from 147 to 383 thousand pounds corresponded to risks of overfishing ranging from 5% to 50%. The Deep7 TAC to achieve a low risk of overfishing (25%) in 2012 was estimated to be $TAC_{25\%}$ = 277 thousand pounds and the Deep7 TAC to achieve a high risk of overfishing (50%) in 2008 was estimated to be $TAC_{50\%}$ = 383 thousand pounds.

Sensitivity analyses of a similar projection model suggested that the estimates of overfishing risk would be sensitive to the estimates of biomass and intrinsic growth rate (Brodziak, 2008). In contrast, estimates of overfishing risk were unlikely to be sensitive to the estimate of carrying capacity, the assumed Deep7 bottomfish catch in 2011 (assumed to be equal to the TAC of 254 thousand pounds), and the coefficients of variation of these model parameters. Results of the sensitivity analyses for Catch Scenario II indicated that estimates of biomass would be lower and estimates of harvest rate would be higher if CPUE Scenarios II or III were more representative of the directed bottomfish fishery (Tables 19.2 and 19.3, Figs. 25 and 26). Results of the sensitivity analyses using Catch Scenario IV showed that biomasses would be lower with higher levels of depletion than under Catch Scenario II (Tables 20.1 to 20.3 and Appendix Figs. A31 to A33). Similarly, estimates of harvest rate and the risk of overfishing would be higher under Catch Scenario IV in comparison to the baseline model.

4.5 Sensitivity Analyses

Results of the sensitivity analyses for halving and doubling the prior means of key parameters under the Baseline Catch Scenario II and CPUE Scenario I showed the effects of changing the error distribution for unreported catch, prior mean for carrying capacity, prior mean for intrinsic growth rate, prior mean for the proportion of carrying capacity in 1949, and the proportion of the 2011 Deep7 total allowable catch that was captured showed that estimates of total allowable commercial catch and stock status indicators for Deep7 bottomfish were sensitive to a few parameters (Table 21). In general, the baseline model results were not sensitive to changes in the catch error distribution, the prior mean for carrying capacity, the proportion of the 2011 TAC assumed to be caught, or increasing the prior mean of the proportion of carrying capacity in 1949. In contrast, results were sensitive to decreasing the prior mean of the proportion of carrying capacity in 1949 or changing the prior mean for the intrinsic growth rate.

4.5.1 Sensitivity to Alternative Catch and CPUE Scenarios

Sensitivity analyses showed the effects of alternative choices of catch scenario and CPUE scenario on projection results (Appendix Figs. A22 to A30). In general, projected TACs at a given overfishing level P* were higher under Catch Scenarios I and II in comparison to Catch Scenarios III and IV. Similarly, projected TACs at a given overfishing level P* were higher under CPUE Scenarios I and II in comparison to CPUE Scenario III.

4.5.2 Sensitivity to Alternative Error Distribution for Unreported Catch

Model results were not sensitive to the assumed error distribution for unreported catch (Table 21). Modifying the catch error distribution by increasing or decreasing the bounds or by biasing the central tendency of the distribution by 30% would alter the estimate of the TAC to produce a 25% chance of overfishing by less than 5% from the baseline estimate, for example.

4.5.3 Sensitivity to Alternative Prior Distribution for Carrying Capacity

Model results were moderately sensitive to the assumed prior mean for carrying capacity (Fig. 27). The sensitivity analyses showed that the estimates of exploitable biomass are scaled with the prior mean for K. Assuming a higher prior mean leads to higher estimates of mean exploitable biomass (Fig. 27.1). A tripling of the prior mean for K from 9.0 million pounds to 27 million pounds leads to a 52% increase in the estimate of mean exploitable biomass from 10.88 million pounds to 16.58 million pounds. Increasing the prior mean for K also leads to a decrease in the estimate of mean harvest rate (Fig. 27.2). Increasing the prior mean for K by 300% leads to a 31% reduction in mean harvest rate from H = 0.045 to H = 0.031. Note that the baseline model used a prior mean of K = 18.0 million pounds.

4.5.4 Sensitivity to Alternative Prior Distribution for Intrinsic Growth Rate

Model results were moderately sensitive to the assumed prior mean for intrinsic growth rate (Fig. 28). The sensitivity analyses showed that the estimates of exploitable biomass are scaled with the prior mean for R. Assuming a higher prior mean for R leads to lower estimates of mean exploitable biomass (Fig. 28.1). A quadrupling of the prior mean for R from R = 0.04 to R = 0.16 leads to a 27% decrease in the estimate of mean exploitable biomass from 17.19 million pounds to 12.61 million pounds. Increasing the prior mean for R also leads to an increase in the estimate of mean harvest rate (Fig. 28.2) and increasing the prior mean for R by 300% leads to a 41% increase in mean harvest rate. Note that the baseline model used a prior mean of R = 0.10.

4.5.5 Sensitivity to Alternative Prior Distribution for Production Model Shape Parameter

Model results were not sensitive to the assumed prior mean for the production model shape parameter (Fig. 29). The sensitivity analyses showed that the estimates of exploitable biomass are scaled with the prior mean for M. Assuming a higher prior mean for M leads to lower estimates of mean exploitable biomass (Fig. 29.1). A quadrupling of the prior mean for M from M = 0.4 to M = 1.6 leads to a 9% decrease in the estimate of mean exploitable biomass from 14.86 million pounds to 13.52 million pounds. Increasing the prior mean for M also leads to an increase in the estimate of mean harvest rate (Fig. 29.2) and increasing the prior mean for M by 300% from M = 0.4 to M = 1.6 leads to a 9% increase in mean harvest rate. Note that the baseline model used a prior mean of M = 1.0.

4.5.6 Sensitivity to Alternative Prior Distribution for Initial Proportion of Carrying Capacity

Model results were moderately sensitive to the assumed prior for the initial proportion of carrying capacity P[1] (Fig. 30). The sensitivity analyses showed that the estimates of exploitable biomass are scaled with the prior mean for P[1]]. Assuming a higher prior mean leads to higher estimates of mean exploitable biomass (Fig. 30.1). A 320% increase of the prior mean for P[1] from 0.25 to 1.05 leads to a 75% increase in the estimate of mean exploitable biomass from 10.85 million pounds to 18.96 million pounds. Increasing the prior mean for P[1] leads to a decrease in the estimate of mean harvest rate (Fig. 30.2). Increasing the prior mean for P[1] by 320% leads to a 39% reduction in mean harvest rate from H = 0.046 to H = 0.028. Note that the baseline model used a prior mean of P[1] = 0.53.

4.5.7 Sensitivity to Proportion of 2011 TAC Assumed Caught

Model results were not sensitive to the proportion of the 2011 TAC that was assumed to be caught (Table 21). Modifying the proportion caught to be 80% or 120% of the 2011 TAC would alter the estimate of the TAC to produce a 25% chance of overfishing by less than 3% from the baseline estimate, for example.

4.5.8 Sensitivity to Alternative Prior Distribution for Observation Error Variance

Model results were moderately sensitive to the assumed prior mode for the observation error variance (Fig. 31). The sensitivity analyses showed that assuming a higher prior mode for τ^2 leads to higher estimates of mean exploitable biomass (Fig. 31.1). A 100,000-fold increase of the prior mode for τ^2 from $\tau^2 = 0.000833$ to $\tau^2 = 83.3$ leads to a 43% increase in the estimate of mean exploitable biomass from 12.55 million pounds to 17.93 million pounds. Increasing the prior mode for τ^2 also leads to an increase in the estimate of mean harvest rate (Fig. 31.2) and increasing the prior mean for τ^2 from $\tau^2 = 0.000833$ to $\tau^2 = 83.3$ leads to a 38% increase in mean harvest rate. Note that the baseline model used a prior mode of $\tau^2 = 0.833$.

4.5.9 Sensitivity to Alternative Prior Distribution for Process Error Variance

Model results were moderately sensitive to the assumed prior mode for the observation error variance (Fig. 32). The sensitivity analyses showed that assuming a higher prior mode for σ^2 leads to lower estimates of mean exploitable biomass (Fig. 32.1). A 100,000-fold increase of the prior mode for σ^2 from $\sigma^2 = 0.0000833$ to $\sigma^2 = 8.33$ leads to a 39% decrease in the estimate of mean exploitable biomass from 16.62 million pounds to 10.18 million pounds. Increasing the prior mode for τ^2 leads to an increase in the estimate of mean harvest rate (Fig. 32.2) and increasing the prior mean for σ^2 from $\sigma^2 = 0.0000833$ to $\sigma^2 = 8.33$ leads to a 107% increase in mean harvest rate. Note that the baseline model used a prior mode of $\sigma^2 = 0.0833$.

4.5.10 Sensitivity to Choice of Uniform Prior for Observation and Process Error Variances

The sensitivity of baseline model results to the choice of a probability distribution for the prior of the observation and process error variances showed that using a uniform prior produced more variable results (Fig. 33). Time series of estimates of mean biomass (Fig. 33.1), mean relative biomass (Fig. 33.2), and the probability that biomass was below BMSY (Fig. 33.3) using the uniform prior exhibited high frequency variation in comparison to the smoother estimates using the gamma prior. Regardless, the estimates of biomass-related results were significantly positively correlated (ρ) for the two choices of prior. Similar results were observed for the time series of estimates of mean harvest rate (Fig. 33.4), mean relative harvest rate (Fig. 33.5), and the probability that harvest rate was greater than HMSY (Fig. 33.6). This sensitivity analysis showed that assuming a uniform prior instead of an inverse-gamma prior would lead to (i) more variable estimates of biomass, biomass status, probability that biomass is below BMSY, harvest rate, harvest rate status, and probability that harvest rates exceeds HMSY and (ii) estimates that were highly positively correlated with estimates based on an inverse-gamma prior. Thus, the baseline model results were robust with respect to the choice of the form of the prior probability distribution for the observation and process error variances.

4.5.11 Sensitivity to Choice of Hypothetical Scenario Weights for Model Averaging

The results of averaging the projection results across scenarios under the hypothetical set of scenario probabilities produced moderately lower TACs (Table 22 and Fig. 34) at a given probability of overfishing P* than the baseline stock assessment scenario. Assuming the alternative assessment scenario weights gave lower TACs for probabilities of overfishing of P* = 0.25 (TAC = 230 thousand pounds) and of P* = 0.5 (TAC = 339 thousand pounds) than under the baseline stock assessment scenario (Table 19.1).

4.6 Retrospective Analyses

Retrospective analyses of the estimated time series of mean exploitable biomass and mean harvest rate indicated that these key model outputs did not exhibit a retrospective pattern (Fig. 35). As a result, the baseline model would be considered to be robust with respect to retrospective uncertainty. This also indicated that the projections to estimate TACs that produced chosen risks of overfishing would also not be expected to exhibit retrospective bias.

4.7 Decision Table Analyses

The decision table showing consequences of setting TACs for Deep7 bottomfish (thousand pounds) to produce a low probability of overfishing of P* = 0.25 (Table 23.1) in fishing year 2012 under CPUE Scenarios I, II, and III versus the true state of nature showed that setting a TAC in the range of 250-275 thousand pounds would produce a low-moderate risk of overfishing in 2012 if CPUE Scenario I or II were true and would produce a higher risk of overfishing and stock depletion if CPUE Scenario III were true (P* = 0.67). In contrast, setting a TAC of around 160 thousand pounds would produce very low risks of overfishing if CPUE Scenarios II or III were true but would risk a substantial loss in fishery yield.

The decision table showing consequences of setting TACs for Deep7 bottomfish (thousand pounds) to produce a high probability of overfishing of P* = 0.50 (Table 23.2) in fishing year 2012 under CPUE Scenarios I, II, and III versus the true state of nature showed that setting a TAC in the range of 340-380 thousand pounds would produce a high-very high risk of overfishing if CPUE Scenarios II or III were true. In contrast, setting a TAC of about 225 thousand pounds would produce low risks of overfishing if CPUE Scenarios I or II were true at the risk of some loss in fishery yield.

In addition, results of sensitivity analyses of the effects of alternative catch and CPUE Scenarios on assessment and projection results (see Appendix Figs. A1.1 to A33) can be used to quantify the trade-offs of selecting a desired probability of overfishing in 2012 under alternative model scenarios.

5. SUMMARY

Under the baseline assessment scenario, stock assessment results for the Deep7 bottomfish complex in the main Hawaiian Islands indicate with high probabilities that the stock is not overfished and that overfishing is not occurring. Setting a Deep7 bottomfish commercial TAC in the range of 250-275 thousand pounds would produce a low-moderate risk of overfishing in 2012 if changes in the fishing power of the bottomfish fleet were moderate through time under CPUE Scenarios I or II. Sensitivity analyses indicated that these projection results are sensitive to whether or not changes in fishing power on the order of an increase of 1% per year are appropriate (e.g., CPUE Scenario III) for analyzing the directed deep handline bottomfish fishery. The decision tables presented in this document highlight some of the conservation and utilization trade-offs that may occur if alternative scenarios provide a more accurate representation of true state of nature of the bottomfish fishery and Deep7 bottomfish population dynamics than the baseline model.

The primary differences between the results of this and previous bottomfish assessments were: (i) the stock assessment was conducted for the main Hawaiian Islands Deep7 bottomfish complex because these species are ecologically similar, have similar life history patterns, and are currently the focus of TAC-based management measures; (ii) ad hoc fishing power adjustments to compute standardized CPUE were not assumed in the baseline production model for use in stock status determination; (iii) estimates of unreported Deep7 bottomfish catches using the best available data were explicitly included in the stock assessment to characterize the impacts of total fishery removals; (iv) the main Hawaiian Islands Deep7 bottomfish complex was assessed as a unit stock; and (v) a more synoptic and explicit treatment of the effects of uncertainty in bottomfish CPUE on stock status and management advice for TAC determination was provided.

In the future, it may be useful to conduct stock assessments for individual bottomfish species to better characterize their productivity. However, it should be recognized that such efforts will be constrained by available resources and the quality of biological and fishery data. If fishery-dependent and fishery-independent data collection systems for Hawaiian bottomfish were augmented, age- or length-structured assessment models could be more readily applied to assess individual bottomfish species. In this context, one priority should be to directly sample the recreational fishery to estimate total recreational catch as well as catch at length by species. Collection of bottomfish length composition and length-weight data from the Honolulu fish auction have been initiated by the PIFSC and will provide valuable information on commercial fishery catches. Such fishery-dependent data could be used to evaluate the catch at age by species given sufficient age-length keys and ongoing sampling effort. Some tag-recapture data of Deep7 bottomfish have been collected by HDAR. These tagging data were not available to the PIFSC for this bottomfish assessment but would likely improve the estimation of fishing mortality if they were available for use in future bottomfish stock assessments. Last, the development of a consistent fishery-independent survey of multispecies fishery resources in the main Hawaiian Islands would greatly enhance the capacity to accurately assess and to effectively manage the bottomfish stock complex.

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Table 1.--List of species in the Hawaiian bottomfish management unit species (BMUS) 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*	X	X
Longtail snapper	Onaga	*Etelis coruscans*	X	X
Squirrelfish snapper	Ehu	*Etelis carbunculus*	X	X
Sea bass	Hapuupuu	*Epinephelus quernus*	X	X
Grey jobfish	Uku	*Aprion virescens*		X
Snapper	Gindai	*Pristipomoides zonatus*	X	X
Snapper	Kalekale	*Pristipomoides seiboldii*	X	X
Blue stripe snapper	Taape	*Lutjanus kasmira*		
Yellowtail snapper	Yellowtail kalekale	*Pristipomoides auricilla*		X
Silver jaw jobfish	Lehi	*Aphareus rutilans*	X	X
Amberjack	Kahala	*Seriola dumerili*		
Thick lipped trevally	Butaguchi	*Pseudocaranx dentex*		X
Giant trevally	White ulua	*Caranx ignobilis*		X
Black jack	Black ulua	*Caranx lugubris*		X

Table 2.--Summary of life history parameters of Deep7 Hawaii bottomfish used to categorize the productivity of individual species and the Deep7 complex based on the approach described in Musick (1999).

Deep 7 Species	Productivity Category	Intrinsic Growth Rate r (y^{-1})	von Bertalanffy K (y^{-1})	Fecundity (y^{-1})	Age at Maturity T_{MAT} (y)	Expected Life Span T_{MAX} (y)
Hapuupuu *(Epinephelus quernus)*	Low	-	0.16-0.23 (Medium)	-	>7 y (Low)	11 y (Low)
Kalekale *(Pristipomoides seiboldii)*	Medium	-	0.12-0.33 (Medium)	-	-	7 y (Medium)
Opakapaka *(Pristipomoides filamentosus)*	Low	-	0.15-0.25 (Medium)	$\geq 10^5$ (High)	3.5 y (Medium)	~ 40 y (Low)
Ehu *(Etelis carbunculus)*	Low	-	0.06-0.19 (Low)	$\geq 10^5$ (High)	-	13 y (Low)
Onaga *(Etelis coruscans)*	Low	-	0.11-0.27 (Medium)	-	-	13 y (Low)
Lehi *(Aphareus rutilans)*	Medium	-	0.16 (Medium)	-	-	8 y (Medium)
Gindai *(Pristipomoides zonatus)*	Medium	-	0.23 (Medium)	-	-	-

Table 3.--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, 1949-2010.

Deep7 Bottomfish Reported Catch (1000 pounds) by Species, 1949-1979								
Fishing Year	Hapuupuu	Kalekale	Opakapaka	Ehu	Onaga	Lehi	Gindai	Total
1949	29.5	36.8	112.0	103.4	66.6	5.7	0.2	354.1
1950	18.6	29.2	113.7	75.3	61.2	4.6	0.8	303.4
1951	22.4	32.1	133.0	66.0	72.7	2.8	2.1	331.1
1952	32.6	45.7	139.7	54.4	45.6	9.6	2.9	330.4
1953	23.0	32.5	108.6	50.4	49.9	2.9	2.0	269.3
1954	16.7	40.2	104.0	40.8	65.5	3.9	1.9	272.9
1955	18.4	28.5	80.6	30.1	61.7	1.1	2.6	223.1
1956	27.3	32.4	110.2	40.1	69.4	3.8	3.7	287.0
1957	18.1	29.6	147.7	37.2	84.6	8.7	2.2	328.0
1958	20.9	17.5	93.9	26.8	52.2	2.4	2.0	215.8
1959	16.7	19.4	92.2	23.1	65.6	2.1	1.5	220.6
1960	12.9	19.3	70.6	19.4	39.4	1.6	1.2	164.4
1961	7.2	19.6	56.2	13.0	36.6	1.0	0.4	134.0
1962	10.5	17.6	84.6	16.4	51.1	1.8	0.8	182.8
1963	13.3	18.5	97.1	23.9	60.8	2.7	0.8	217.0
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	85.9	16.2	53.9	5.9	0.5	177.5
1970	19.9	5.1	69.7	15.9	43.5	2.7	1.4	158.2
1971	14.5	4.3	59.1	15.3	39.3	1.8	0.9	135.2
1972	18.0	8.2	118.7	21.4	58.9	4.4	1.2	230.9
1973	14.8	5.1	93.4	14.6	35.6	4.5	1.3	169.3
1974	14.6	4.9	135.2	21.1	43.6	4.9	1.5	225.8
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	84.8	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	7.8	146.0	22.5	53.0	12.1	2.9	273.8

Table 3.--Continued.

Deep7 Bottomfish Reported Catch (1000 pounds) by Species, 1980-2010								
Fishing Year	Hapuupuu	Kalekale	Opakapaka	Ehu	Onaga	Lehi	Gindai	Total
1980	17.7	7.0	151.1	17.0	31.3	17.8	2.4	244.4
1981	17.0	8.2	197.4	21.2	42.9	19.9	1.9	308.3
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
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	145.4	45.3	1.7	563.8
1990	14.2	15.5	210.4	37.6	141.5	34.9	2.8	456.9
1991	14.9	18.3	135.9	30.8	102.9	19.0	3.5	325.3
1992	15.3	28.0	173.1	31.9	91.8	17.3	5.1	362.5
1993	13.3	17.0	138.6	23.9	52.6	11.2	3.8	260.4
1994	10.4	17.9	173.7	23.2	68.5	11.6	4.0	309.3
1995	19.5	21.8	198.2	27.2	73.6	14.4	4.5	359.1
1996	10.3	20.3	145.8	29.1	69.6	10.4	3.2	288.8
1997	14.1	22.8	160.5	26.1	61.3	11.8	3.0	299.7
1998	12.7	24.4	149.7	26.4	70.8	9.4	3.4	296.8
1999	9.9	11.1	103.8	19.5	59.4	8.8	2.3	214.8
2000	13.1	15.9	167.0	26.7	72.6	11.2	3.2	309.7
2001	15.5	15.3	125.0	26.5	63.0	11.5	3.6	260.4
2002	9.0	10.3	105.1	17.0	60.0	11.7	2.4	215.6
2003	9.4	12.0	127.7	16.3	68.5	8.6	2.1	244.6
2004	7.9	8.0	88.0	19.2	76.0	4.9	2.1	206.1
2005	10.4	7.8	104.4	22.6	89.8	6.9	2.0	243.9
2006	7.3	5.5	76.0	18.9	74.5	6.3	1.6	190.0
2007	7.5	6.1	92.4	19.5	85.5	8.4	2.3	221.8
2008	6.6	5.5	96.2	18.2	55.7	11.0	2.8	196.2
2009	7.9	9.6	133.4	24.5	59.2	16.8	3.6	254.9
2010	8.2	8.2	106.4	24.2	57.6	6.1	2.7	213.3
Average 1949-2010	16.9	16.4	132.3	29.8	72.7	10.9	2.2	281.3
Average 1950-1959	21.5	30.7	112.4	44.4	62.8	4.2	2.2	278.2
Average 1960-1969	11.4	14.7	87.5	19.2	56.0	2.2	0.9	192.0
Average 1970-1979	21.6	6.8	110.5	23.6	55.1	6.6	1.6	225.7
Average 1980-1989	23.5	15.7	217.9	36.2	114.8	28.8	2.7	439.7
Average 1990-1999	13.4	19.7	159.0	27.6	79.2	14.9	3.6	317.3
Average 2000-2009	9.5	9.6	111.5	20.9	70.5	9.7	2.6	234.3
Average 2008-2010	7.5	7.8	112.0	22.3	57.5	11.3	3.1	221.5

Table 4.1.--Estimates of unreported Deep7 bottomfish catches (1000 pounds) under Alternative Catch Scenario I by fishing year, 1949-2010.

Scenario I Deep7 Bottomfish Unreported Catch (1000 pounds) by Species, 1949-2010								
Fishing Year	Hapuupuu	Kalekale	Opakapaka	Ehu	Onaga	Lehi	Gindai	Total
1949	67.1	83.5	254.1	234.6	151.1	12.9	0.5	803.8
1950	42.3	66.2	258.1	170.9	138.8	10.5	1.7	688.6
1951	50.9	72.8	302.0	149.8	165.0	6.4	4.7	751.6
1952	73.9	103.7	317.0	123.6	103.6	21.8	6.6	750.1
1953	52.3	73.8	246.4	114.4	113.3	6.6	4.5	611.3
1954	37.9	91.2	236.1	92.5	148.8	8.8	4.3	619.5
1955	41.7	64.8	183.0	68.4	140.1	2.6	6.0	506.5
1956	62.0	73.6	250.2	91.0	157.6	8.7	8.4	651.6
1957	41.1	67.1	335.2	84.4	192.0	19.9	5.0	744.7
1958	47.4	39.7	213.2	60.9	118.6	5.5	4.6	489.8
1959	38.0	44.1	209.2	52.4	149.0	4.8	3.4	500.8
1960	29.3	43.8	160.2	44.1	89.4	3.6	2.7	373.2
1961	16.3	44.5	127.6	29.5	83.1	2.2	0.9	304.2
1962	23.9	39.9	192.0	37.3	116.0	4.0	1.9	415.0
1963	30.1	42.0	220.4	54.3	138.0	6.1	1.8	492.5
1964	25.5	53.3	216.2	56.1	107.0	2.2	5.3	465.6
1965	29.3	33.5	241.4	48.8	157.1	2.9	2.2	515.1
1966	26.9	30.8	162.1	41.2	145.4	4.6	1.9	412.8
1967	28.1	21.8	279.2	41.8	155.4	5.4	1.7	533.4
1968	25.7	15.7	191.8	45.1	157.8	5.0	1.7	442.7
1969	24.7	9.4	195.1	36.7	122.4	13.4	1.1	402.9
1970	45.1	11.6	158.2	36.0	98.8	6.1	3.3	359.1
1971	32.9	9.8	134.2	34.7	89.1	4.1	2.0	306.9
1972	40.8	18.6	269.5	48.5	133.8	10.1	2.8	524.1
1973	33.7	11.6	211.9	33.1	80.9	10.3	2.9	384.2
1974	33.2	11.0	306.9	47.9	99.0	11.1	3.3	512.5
1975	52.7	13.5	263.7	49.8	102.3	19.0	3.2	504.2
1976	50.8	17.9	239.5	71.0	182.1	23.5	2.7	587.6
1977	69.1	19.5	241.4	81.5	192.4	16.5	3.5	624.0
1978	69.4	23.7	373.6	86.3	160.7	23.7	6.2	743.5
1979	75.7	19.9	374.1	57.6	135.9	31.1	7.4	701.6

Table 4.1.--Continued.

Scenario I Deep7 Bottomfish Unreported Catch (1000 pounds) by Species, 1949-2010								
Fishing Year	Hapuupuu	Kalekale	Opakapaka	Ehu	Onaga	Lehi	Gindai	Total
1980	48.0	19.1	409.1	46.0	84.9	48.3	6.5	661.8
1981	48.4	23.3	563.3	60.4	122.3	56.9	5.3	879.9
1982	65.0	24.2	533.2	73.3	197.8	89.9	4.8	988.3
1983	98.3	45.0	691.3	84.1	218.4	85.4	8.0	1230.5
1984	89.2	40.3	478.1	108.5	259.8	49.6	10.7	1036.1
1985	99.7	68.1	611.0	132.1	521.6	76.7	13.8	1522.9
1986	79.6	76.2	544.1	185.7	589.5	83.1	11.3	1569.6
1987	96.8	85.2	802.1	147.6	526.7	116.1	9.8	1784.4
1988	30.2	52.7	875.5	122.0	455.8	110.9	6.0	1653.0
1989	38.0	31.0	863.1	107.7	407.1	126.8	4.7	1578.6
1990	38.3	41.8	568.0	101.6	382.2	94.3	7.5	1233.7
1991	38.8	47.5	353.2	80.1	267.6	49.3	9.2	845.7
1992	38.1	70.1	432.8	79.8	229.5	43.1	12.8	906.3
1993	33.2	42.4	346.6	59.8	131.6	27.9	9.4	650.9
1994	25.9	44.7	434.3	58.1	171.1	29.1	9.9	773.2
1995	48.7	54.5	495.4	68.1	184.0	35.9	11.1	897.8
1996	25.8	50.7	364.5	72.8	174.1	26.0	8.0	721.9
1997	35.1	57.0	401.2	65.3	153.3	29.6	7.6	749.2
1998	31.7	61.1	374.2	65.9	177.1	23.5	8.4	741.9
1999	24.8	27.7	259.5	48.8	148.5	21.9	5.8	537.0
2000	32.9	39.7	417.6	66.8	181.6	28.0	7.9	774.4
2001	38.7	38.2	312.5	66.2	157.5	28.8	9.1	651.0
2002	22.6	25.7	262.9	42.4	150.0	29.3	6.1	539.0
2003	23.6	30.0	319.2	40.6	171.2	21.4	5.3	611.4
2004	19.8	20.1	220.1	48.0	189.9	12.3	5.2	515.3
2005	26.0	19.6	260.9	56.4	224.4	17.2	5.0	609.6
2006	18.1	13.8	190.0	47.2	186.2	15.8	4.0	475.0
2007	18.8	15.4	231.0	48.7	213.8	21.0	5.8	554.4
2008	16.4	13.8	240.5	45.6	139.4	27.6	7.1	490.4
2009	19.7	24.0	333.4	61.2	148.1	41.9	9.0	637.3
2010	20.5	20.4	265.9	60.5	143.9	15.3	6.9	533.3
Average 1949-2010	42.1	40.3	335.8	73.8	184.4	29.0	5.6	710.9
Average 1950-1959	48.7	69.7	255.0	100.8	142.7	9.6	4.9	631.5
Average 1960-1969	26.0	33.5	198.6	43.5	127.2	4.9	2.1	435.8
Average 1970-1979	50.3	15.7	257.3	54.6	127.5	15.5	3.7	524.8
Average 1980-1989	69.3	46.5	637.1	106.7	338.4	84.4	8.1	1290.5
Average 1990-1999	34.0	49.8	403.0	70.0	201.9	38.1	9.0	805.8
Average 2000-2009	23.7	24.0	278.8	52.3	176.2	24.3	6.5	585.8
Average 2008-2010	18.9	19.4	280.0	55.8	143.8	28.3	7.6	553.7

Table 4.2.--Baseline Catch Scenario II estimates of unreported Deep7 bottomfish catches (1000 pounds) by fishing year, 1949-2010.

Scenario II Deep7 Bottomfish Unreported Catch (1000 pounds) by Species, 1949-2010								
Fishing Year	Hapuupuu	Kalekale	Opakapaka	Ehu	Onaga	Lehi	Gindai	Total
1949	30.1	1.1	321.3	114.7	48.6	0.2	0.0	516.1
1950	19.0	0.9	326.3	83.6	44.7	0.2	0.1	474.7
1951	22.9	1.0	381.8	73.3	53.1	0.1	0.3	532.4
1952	33.2	1.4	400.8	60.4	33.3	0.4	0.4	530.0
1953	23.5	1.0	311.6	56.0	36.4	0.1	0.3	428.8
1954	17.0	1.2	298.5	45.2	47.8	0.2	0.3	410.2
1955	18.8	0.9	231.3	33.5	45.0	0.0	0.4	329.9
1956	27.9	1.0	316.3	44.5	50.7	0.2	0.6	441.0
1957	18.5	0.9	423.8	41.3	61.7	0.3	0.3	546.8
1958	21.3	0.5	269.6	29.8	38.1	0.1	0.3	359.7
1959	17.1	0.6	264.5	25.6	47.9	0.1	0.2	356.0
1960	13.1	0.6	202.5	21.6	28.7	0.1	0.2	266.8
1961	7.3	0.6	161.3	14.4	26.7	0.0	0.1	210.5
1962	10.7	0.5	242.7	18.2	37.3	0.1	0.1	309.7
1963	13.5	0.6	278.6	26.6	44.4	0.1	0.1	363.8
1964	11.5	0.7	273.3	27.4	34.4	0.0	0.3	347.7
1965	13.2	0.4	305.2	23.9	50.5	0.1	0.1	393.4
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	246.7	17.9	39.4	0.2	0.1	315.5
1970	20.2	0.2	200.0	17.6	31.8	0.1	0.2	270.1
1971	14.8	0.1	169.7	17.0	28.7	0.1	0.1	230.4
1972	18.3	0.2	340.7	23.7	43.0	0.2	0.2	426.4
1973	15.1	0.2	267.9	16.2	26.0	0.2	0.2	325.8
1974	14.9	0.1	388.1	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	415.1
1976	22.8	0.2	302.8	34.7	58.6	0.4	0.2	419.7
1977	31.1	0.3	305.2	39.9	61.9	0.3	0.2	438.8
1978	29.3	0.3	443.8	39.6	48.5	0.4	0.4	562.4
1979	30.1	0.2	419.1	25.0	38.7	0.5	0.4	514.0

Table 4.2.--Continued.

Scenario II Deep7 Bottomfish Unreported Catch (1000 pounds) by Species, 1949-2010								
Fishing Year	Hapuupuu	Kalekale	Opakapaka	Ehu	Onaga	Lehi	Gindai	Total
1980	18.1	0.2	433.5	18.9	22.9	0.7	0.4	494.6
1981	17.3	0.2	566.4	23.5	31.3	0.8	0.3	639.8
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
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	1049.7
1990	14.5	0.5	603.8	41.8	103.3	1.4	0.4	765.6
1991	15.2	0.5	389.9	34.2	75.1	0.8	0.5	516.3
1992	15.6	0.8	496.9	35.4	67.0	0.7	0.8	617.2
1993	13.5	0.5	397.9	26.6	38.4	0.4	0.6	477.9
1994	10.6	0.5	498.6	25.8	50.0	0.5	0.6	586.5
1995	19.9	0.7	568.7	30.2	53.7	0.6	0.7	674.5
1996	10.5	0.6	418.5	32.3	50.8	0.4	0.5	513.7
1997	14.3	0.7	460.6	29.0	44.8	0.5	0.5	550.3
1998	11.9	2.0	402.7	24.7	42.1	0.5	0.8	484.6
1999	8.4	1.4	260.7	15.0	27.2	0.6	0.8	314.0
2000	10.0	2.9	389.4	15.9	23.4	0.9	1.4	443.8
2001	10.5	3.5	269.0	11.2	11.7	1.0	1.9	308.8
2002	5.3	2.9	207.4	4.2	3.0	1.2	1.5	225.5
2003	5.6	3.4	251.9	4.1	3.4	0.9	1.3	270.4
2004	4.7	2.3	173.6	4.8	3.8	0.5	1.3	190.9
2005	6.1	2.2	205.9	5.6	4.4	0.7	1.2	226.2
2006	4.3	1.5	149.9	4.7	3.7	0.6	1.0	165.7
2007	4.5	1.7	182.3	4.9	4.2	0.9	1.4	199.8
2008	3.9	1.6	189.8	4.6	2.8	1.1	1.7	205.4
2009	4.7	2.7	263.1	6.1	2.9	1.7	2.2	283.4
2010	4.8	2.3	209.8	6.0	2.8	0.6	1.7	228.1
Average 1949-2010	16.5	0.9	362.4	29.9	44.8	0.5	0.5	455.5
Average 1950-1959	21.9	0.9	322.4	49.3	45.9	0.2	0.3	440.9
Average 1960-1969	11.7	0.4	251.1	21.3	40.9	0.1	0.1	325.6
Average 1970-1979	22.0	0.2	317.1	26.1	40.2	0.3	0.2	406.1
Average 1980-1989	24.0	0.5	625.2	40.2	83.8	1.2	0.4	775.3
Average 1990-1999	13.4	0.8	449.8	29.5	55.2	0.6	0.6	550.1
Average 2000-2009	6.0	2.5	228.2	6.6	6.3	1.0	1.5	252.0
Average 2008-2010	4.5	2.2	220.9	5.6	2.8	1.2	1.9	239.0

Table 4.3.--Estimates of unreported Deep7 bottomfish catches (1000 pounds) under Alternative Catch Scenario III by fishing year, 1949-2010.

Scenario III Deep7 Bottomfish Unreported Catch (1000 pounds) by Species, 1949-2010

Fishing Year	Hapuupuu	Kalekale	Opakapaka	Ehu	Onaga	Lehi	Gindai	Total
1949	5.9	7.4	22.4	20.7	13.3	1.1	0.0	70.8
1950	3.7	5.8	22.7	15.1	12.2	0.9	0.2	60.7
1951	4.5	6.4	26.6	13.2	14.5	0.6	0.4	66.2
1952	6.5	9.1	27.9	10.9	9.1	1.9	0.6	66.1
1953	4.6	6.5	21.7	10.1	10.0	0.6	0.4	53.9
1954	3.3	8.0	20.8	8.2	13.1	0.8	0.4	54.6
1955	3.7	5.7	16.1	6.0	12.3	0.2	0.5	44.6
1956	5.5	6.5	22.0	8.0	13.9	0.8	0.7	57.4
1957	3.6	5.9	29.5	7.4	16.9	1.7	0.4	65.6
1958	4.2	3.5	18.8	5.4	10.4	0.5	0.4	43.2
1959	3.3	3.9	18.4	4.6	13.1	0.4	0.3	44.1
1960	2.6	3.9	14.1	3.9	7.9	0.3	0.2	32.9
1961	1.4	3.9	11.2	2.6	7.3	0.2	0.1	26.8
1962	2.1	3.5	16.9	3.3	10.2	0.4	0.2	36.6
1963	2.7	3.7	19.4	4.8	12.2	0.5	0.2	43.4
1964	2.2	4.7	19.0	4.9	9.4	0.2	0.5	41.0
1965	2.6	3.0	21.3	4.3	13.8	0.3	0.2	45.4
1966	2.4	2.7	14.3	3.6	12.8	0.4	0.2	36.4
1967	2.5	1.9	24.6	3.7	13.7	0.5	0.2	47.0
1968	2.3	1.4	16.9	4.0	13.9	0.4	0.2	39.0
1969	2.2	0.8	17.2	3.2	10.8	1.2	0.1	35.5
1970	4.0	1.0	13.9	3.2	8.7	0.5	0.3	31.6
1971	2.9	0.9	11.8	3.1	7.9	0.4	0.2	27.0
1972	3.6	1.6	23.7	4.3	11.8	0.9	0.2	46.2
1973	3.0	1.0	18.7	2.9	7.1	0.9	0.3	33.9
1974	2.9	1.0	27.0	4.2	8.7	1.0	0.3	45.2
1975	4.6	1.2	23.2	4.4	9.0	1.7	0.3	44.4
1976	4.5	1.6	21.1	6.3	16.0	2.1	0.2	51.8
1977	6.1	1.7	21.3	7.2	17.0	1.5	0.3	55.0
1978	5.7	2.0	30.9	7.1	13.3	2.0	0.5	61.5
1979	5.9	1.6	29.2	4.5	10.6	2.4	0.6	54.8

Table 4.3.--Continued.

Scenario III Deep7 Bottomfish Unreported Catch (1000 pounds) by Species, 1949-2010								
Fishing Year	Hapuupuu	Kalekale	Opakapaka	Ehu	Onaga	Lehi	Gindai	Total
1980	3.5	1.4	30.2	3.4	6.3	3.6	0.5	48.9
1981	3.4	1.6	39.5	4.2	8.6	4.0	0.4	61.7
1982	4.3	1.6	35.5	4.9	13.2	6.0	0.3	65.9
1983	6.6	3.0	46.1	5.6	14.6	5.7	0.5	82.0
1984	5.9	2.7	31.9	7.2	17.3	3.3	0.7	69.1
1985	6.6	4.5	40.7	8.8	34.8	5.1	0.9	101.5
1986	5.3	5.1	36.3	12.4	39.3	5.5	0.8	104.6
1987	6.5	5.7	53.5	9.8	35.1	7.7	0.7	119.0
1988	2.1	3.6	60.4	8.4	31.4	7.6	0.4	114.0
1989	2.7	2.2	61.6	7.7	29.1	9.1	0.3	112.8
1990	2.8	3.1	42.1	7.5	28.3	7.0	0.6	91.4
1991	3.0	3.7	27.2	6.2	20.6	3.8	0.7	65.1
1992	3.1	5.6	34.6	6.4	18.4	3.5	1.0	72.5
1993	2.7	3.4	27.7	4.8	10.5	2.2	0.8	52.1
1994	2.1	3.6	34.7	4.6	13.7	2.3	0.8	61.9
1995	3.9	4.4	39.6	5.4	14.7	2.9	0.9	71.8
1996	2.1	4.1	29.2	5.8	13.9	2.1	0.6	57.8
1997	2.8	4.6	32.1	5.2	12.3	2.4	0.6	59.9
1998	2.5	4.9	29.9	5.3	14.2	1.9	0.7	59.4
1999	2.0	2.2	20.8	3.9	11.9	1.8	0.5	43.0
2000	2.6	3.2	33.4	5.3	14.5	2.2	0.6	61.9
2001	3.1	3.1	25.0	5.3	12.6	2.3	0.7	52.1
2002	1.8	2.1	21.0	3.4	12.0	2.3	0.5	43.1
2003	1.9	2.4	25.5	3.3	13.7	1.7	0.4	48.9
2004	1.6	1.6	17.6	3.8	15.2	1.0	0.4	41.2
2005	2.1	1.6	20.9	4.5	18.0	1.4	0.4	48.8
2006	1.5	1.1	15.2	3.8	14.9	1.3	0.3	38.0
2007	1.5	1.2	18.5	3.9	17.1	1.7	0.5	44.4
2008	1.3	1.1	19.2	3.6	11.1	2.2	0.6	39.2
2009	1.6	1.9	26.7	4.9	11.8	3.4	0.7	51.0
2010	1.6	1.6	21.3	4.8	11.5	1.2	0.5	42.7
Average 1949-2010	3.4	3.3	26.5	6.0	14.5	2.2	0.4	56.3
Average 1950-1959	4.3	6.1	22.5	8.9	12.6	0.8	0.4	55.6
Average 1960-1969	2.3	2.9	17.5	3.8	11.2	0.4	0.2	38.4
Average 1970-1979	4.3	1.4	22.1	4.7	11.0	1.3	0.3	45.1
Average 1980-1989	4.7	3.1	43.6	7.2	23.0	5.8	0.5	87.9
Average 1990-1999	2.7	3.9	31.8	5.5	15.8	3.0	0.7	63.5
Average 2000-2009	1.9	1.9	22.3	4.2	14.1	1.9	0.5	46.9
Average 2008-2010	1.5	1.6	22.4	4.5	11.5	2.3	0.6	44.3

Table 5.--Comparison of Baseline Catch Scenario I estimates of total catches (1000 pounds) of Deep7 bottomfish in the main Hawaiian Islands with alternative catch scenarios by fishing year, 1949-2010.

Estimated Total Catch of Deep7 Bottomfish (1000 pounds) Used in Assessment by Unreported Catch Scenario, 1949-2010

Fishing Year	Reported Catch (1000 pounds)	Unreported Catch Scenario I (1000 pounds)	Unreported Catch Scenario II (1000 pounds)	Unreported Catch Scenario III (1000 pounds)	Unreported Catch Scenario IV (1000 pounds)	Total Catch Used in Assessment Scenario I (1000 pounds)	Total Catch Used in Assessment Scenario II (1000 pounds)	Total Catch Used in Assessment Scenario III (1000 pounds)	Total Catch Used in Assessment Scenario IV (1000 pounds)
1949	354.1	803.8	516.1	70.8	0	1157.9	870.2	424.9	354.1
1950	303.4	688.6	474.7	60.7	0	992.0	778.0	364.0	303.4
1951	331.1	751.6	532.4	66.2	0	1082.7	863.4	397.3	331.1
1952	330.4	750.1	530.0	66.1	0	1080.5	860.4	396.5	330.4
1953	269.3	611.3	428.8	53.9	0	880.7	698.2	323.2	269.3
1954	272.9	619.5	410.2	54.6	0	892.4	683.1	327.5	272.9
1955	223.1	506.5	329.9	44.6	0	729.7	553.0	267.8	223.1
1956	287.0	651.6	441.0	57.4	0	938.6	728.0	344.4	287.0
1957	328.0	744.7	546.8	65.6	0	1072.7	874.9	393.7	328.0
1958	215.8	489.8	359.7	43.2	0	705.6	575.5	259.0	215.8
1959	220.6	500.8	356.0	44.1	0	721.5	576.6	264.8	220.6
1960	164.4	373.2	266.8	32.9	0	537.6	431.2	197.3	164.4
1961	134.0	304.2	210.5	26.8	0	438.2	344.5	160.8	134.0
1962	182.8	415.0	309.7	36.6	0	597.9	492.6	219.4	182.8
1963	217.0	492.5	363.8	43.4	0	709.5	580.8	260.4	217.0
1964	205.1	465.6	347.7	41.0	0	670.7	552.8	246.1	205.1
1965	226.9	515.1	393.4	45.4	0	742.1	620.3	272.3	226.9
1966	181.9	412.8	284.6	36.4	0	594.7	466.4	218.2	181.9
1967	235.0	533.4	436.5	47.0	0	768.3	671.5	282.0	235.0
1968	195.0	442.7	327.2	39.0	0	637.8	522.3	234.0	195.0
1969	177.5	402.9	315.5	35.5	0	580.4	493.0	213.0	177.5
1970	158.2	359.1	270.1	31.6	0	517.3	428.3	189.8	158.2
1971	135.2	306.9	230.4	27.0	0	442.1	365.6	162.2	135.2
1972	230.9	524.1	426.4	46.2	0	754.9	657.3	277.0	230.9
1973	169.3	384.2	325.8	33.9	0	553.5	495.0	203.1	169.3
1974	225.8	512.5	458.8	45.2	0	738.3	684.6	270.9	225.8
1975	222.1	504.2	415.1	44.4	0	726.3	637.2	266.5	222.1
1976	258.9	587.6	419.7	51.8	0	846.4	678.6	310.6	258.9
1977	274.9	624.0	438.8	55.0	0	898.9	713.7	329.9	274.9
1978	307.7	743.5	562.4	61.5	0	1051.2	870.1	369.3	307.7
1979	273.8	701.6	514.0	54.8	0	975.4	787.9	328.6	273.8

Table 5.--Continued.

Estimated Total Catch of Deep7 Bottomfish (1000 pounds) Used in Assessment by Unreported Catch Scenario, 1949-2010									
Fishing Year	Reported Catch (1000 pounds)	Unreported Catch Scenario I (1000 pounds)	Unreported Catch Scenario II (1000 pounds)	Unreported Catch Scenario III (1000 pounds)	Unreported Catch Scenario IV (1000 pounds)	Total Catch Used in Assessment Scenario I (1000 pounds)	Total Catch Used in Assessment Scenario II (1000 pounds)	Total Catch Used in Assessment Scenario III (1000 pounds)	Total Catch Used in Assessment Scenario IV (1000 pounds)
1980	244.4	661.8	494.6	48.9	0	906.2	739.0	293.3	244.4
1981	308.3	879.9	639.8	61.7	0	1188.2	948.1	370.0	308.3
1982	329.4	988.3	609.1	65.9	0	1317.7	938.6	395.3	329.4
1983	410.2	1230.5	781.0	82.0	0	1640.6	1191.1	492.2	410.2
1984	345.4	1036.1	592.6	69.1	0	1381.5	938.0	414.4	345.4
1985	507.6	1522.9	796.6	101.5	0	2030.6	1304.3	609.2	507.6
1986	523.2	1569.6	762.2	104.6	0	2092.8	1285.4	627.8	523.2
1987	594.8	1784.4	986.0	119.0	0	2379.2	1580.8	713.8	594.8
1988	570.0	1653.0	1040.9	114.0	0	2223.0	1610.9	684.0	570.0
1989	563.8	1578.6	1049.7	112.8	0	2142.3	1613.5	676.5	563.8
1990	456.9	1233.7	765.6	91.4	0	1690.6	1222.5	548.3	456.9
1991	325.3	845.7	516.3	65.1	0	1171.0	841.5	390.3	325.3
1992	362.5	906.3	617.2	72.5	0	1268.8	979.7	435.0	362.5
1993	260.4	650.9	477.9	52.1	0	911.2	738.2	312.4	260.4
1994	309.3	773.2	586.5	61.9	0	1082.4	895.8	371.1	309.3
1995	359.1	897.8	674.5	71.8	0	1256.9	1033.6	430.9	359.1
1996	288.8	721.9	513.7	57.8	0	1010.7	802.4	346.5	288.8
1997	299.7	749.2	550.3	59.9	0	1048.9	850.0	359.6	299.7
1998	296.8	741.9	484.6	59.4	0	1038.6	781.4	356.1	296.8
1999	214.8	537.0	314.0	43.0	0	751.8	528.8	257.8	214.8
2000	309.7	774.4	443.8	61.9	0	1084.1	753.5	371.7	309.7
2001	260.4	651.0	308.8	52.1	0	911.5	569.2	312.5	260.4
2002	215.6	539.0	225.5	43.1	0	754.5	441.1	258.7	215.6
2003	244.6	611.4	270.4	48.9	0	856.0	515.0	293.5	244.6
2004	206.1	515.3	190.9	41.2	0	721.4	397.0	247.3	206.1
2005	243.9	609.6	226.2	48.8	0	853.5	470.1	292.6	243.9
2006	190.0	475.0	165.7	38.0	0	665.0	355.7	228.0	190.0
2007	221.8	554.4	199.8	44.4	0	776.1	421.5	266.1	221.8
2008	196.2	490.4	205.4	39.2	0	686.6	401.6	235.4	196.2
2009	254.9	637.3	283.4	51.0	0	892.2	538.3	305.9	254.9
2010	213.3	533.3	228.1	42.7	0	746.7	441.5	256.0	213.3
Average 1949-2010	281.3	710.9	455.5	56.3	0.0	992.2	736.8	337.5	281.3
Average 1950-1959	278.2	631.5	440.9	55.6	0.0	909.6	719.1	333.8	278.2
Average 1960-1969	192.0	435.8	325.6	38.4	0.0	627.7	517.5	230.4	192.0
Average 1970-1979	225.7	524.8	406.1	45.1	0.0	750.4	631.8	270.8	225.7
Average 1980-1989	439.7	1290.5	775.3	87.9	0.0	1730.2	1215.0	527.6	439.7
Average 1990-1999	317.3	805.8	550.1	63.5	0.0	1123.1	867.4	380.8	317.3
Average 2000-2009	234.3	585.8	252.0	46.9	0.0	820.1	486.3	281.2	234.3
Average 2008-2010	221.5	553.7	239.0	44.3	0.0	775.2	460.4	265.8	221.5

Table 6.--Estimates of total catches (1000 pounds) of primary bottomfish in the main Hawaiian Islands under the Baseline Catch Scenario I and alternative catch scenarios by fishing year, 1949-2010.

Estimated Total Catch of Primary Bottomfish (1000 pounds) by Unreported Catch Scenario, 1949-2010									
Fishing Year	Reported Catch (1000 pounds)	Unreported Catch Scenario I (1000 pounds)	Unreported Catch Scenario II (1000 pounds)	Unreported Catch Scenario III (1000 pounds)	Unreported Catch Scenario IV (1000 pounds)	Total Catch Used in Assessment Scenario I (1000 pounds)	Total Catch Used in Assessment Scenario II (1000 pounds)	Total Catch Used in Assessment Scenario III (1000 pounds)	Total Catch Used in Assessment Scenario IV (1000 pounds)
1949	595.9	1352.6	1435.9	119.2	0	1948.5	2031.8	715.1	595.9
1950	492.1	1117.1	1169.9	98.4	0	1609.2	1662.0	590.5	492.1
1951	480.1	1089.9	1090.0	96.0	0	1570.0	1570.1	576.1	480.1
1952	473.1	1073.9	1066.8	94.6	0	1547.0	1539.9	567.7	473.1
1953	439.9	998.7	1024.3	88.0	0	1438.6	1464.2	527.9	439.9
1954	404.6	918.5	871.2	80.9	0	1323.2	1275.8	485.6	404.6
1955	342.5	777.4	712.6	68.5	0	1119.9	1055.1	411.0	342.5
1956	455.2	1033.2	1027.1	91.0	0	1488.4	1482.3	546.2	455.2
1957	478.8	1086.8	1039.1	95.8	0	1565.5	1517.9	574.5	478.8
1958	349.7	793.9	794.0	69.9	0	1143.6	1143.7	419.7	349.7
1959	342.5	777.5	755.1	68.5	0	1119.9	1097.6	411.0	342.5
1960	251.6	571.2	562.5	50.3	0	822.9	814.2	302.0	251.6
1961	219.9	499.3	505.9	44.0	0	719.2	725.8	263.9	219.9
1962	279.5	634.5	624.4	55.9	0	914.0	903.9	335.4	279.5
1963	336.3	763.4	757.9	67.3	0	1099.7	1094.2	403.6	336.3
1964	338.9	769.4	770.9	67.8	0	1108.3	1109.8	406.7	338.9
1965	358.5	813.8	833.7	71.7	0	1172.3	1192.2	430.2	358.5
1966	275.6	625.6	603.0	55.1	0	901.2	878.6	330.7	275.6
1967	370.4	840.8	904.4	74.1	0	1211.2	1274.8	444.5	370.4
1968	299.0	678.8	679.6	59.8	0	977.8	978.6	358.8	299.0
1969	299.4	679.6	744.9	59.9	0	979.0	1044.2	359.3	299.4
1970	258.7	587.2	612.4	51.7	0	845.9	871.1	310.4	258.7
1971	223.3	506.9	519.9	44.7	0	730.2	743.2	268.0	223.3
1972	328.2	744.9	744.4	65.6	0	1073.1	1072.6	393.8	328.2
1973	251.2	570.3	591.5	50.2	0	821.5	842.7	301.5	251.2
1974	352.8	800.9	869.2	70.6	0	1153.8	1222.0	423.4	352.8
1975	349.4	793.1	820.6	69.9	0	1142.5	1170.0	419.3	349.4
1976	404.1	917.3	921.1	80.8	0	1321.4	1325.2	484.9	404.1
1977	405.5	920.4	923.0	81.1	0	1325.9	1328.4	486.6	405.5
1978	473.3	1143.6	1097.1	94.7	0	1616.9	1570.4	568.0	473.3
1979	444.1	1137.7	1097.6	88.8	0	1581.8	1541.6	532.9	444.1

Table 6.--Continued.

Estimated Total Catch of Primary Bottomfish (1000 pounds) by Unreported Catch Scenario, 1949-2010									
Fishing Year	Reported Catch (1000 pounds)	Unreported Catch Scenario I (1000 pounds)	Unreported Catch Scenario II (1000 pounds)	Unreported Catch Scenario III (1000 pounds)	Unreported Catch Scenario IV (1000 pounds)	Total Catch Used in Assessment Scenario I (1000 pounds)	Total Catch Used in Assessment Scenario II (1000 pounds)	Total Catch Used in Assessment Scenario III (1000 pounds)	Total Catch Used in Assessment Scenario IV (1000 pounds)
1980	380.2	1029.6	964.3	76.0	0	1409.9	1344.6	456.3	380.2
1981	497.6	1420.1	1281.9	99.5	0	1917.7	1779.5	597.1	497.6
1982	504.3	1513.0	1182.3	100.9	0	2017.3	1686.6	605.2	504.3
1983	625.9	1877.8	1479.0	125.2	0	2503.7	2105.0	751.1	625.9
1984	610.1	1830.4	1415.7	122.0	0	2440.6	2025.9	732.2	610.1
1985	686.0	2057.9	1345.4	137.2	0	2743.8	2031.3	823.1	686.0
1986	661.7	1985.0	1188.5	132.3	0	2646.7	1850.2	794.0	661.7
1987	775.3	2325.9	1502.3	155.1	0	3101.2	2277.6	930.4	775.3
1988	846.7	2455.5	1829.5	169.3	0	3302.3	2676.2	1016.1	846.7
1989	1027.3	2876.4	2358.2	205.5	0	3903.7	3385.4	1232.7	1027.3
1990	695.8	1878.6	1484.7	139.2	0	2574.4	2180.4	834.9	695.8
1991	535.9	1393.3	1150.8	107.2	0	1929.2	1686.7	643.1	535.9
1992	522.9	1307.3	1111.4	104.6	0	1830.2	1634.3	627.5	522.9
1993	378.7	946.7	837.6	75.7	0	1325.4	1216.3	454.4	378.7
1994	426.7	1066.7	927.2	85.3	0	1493.3	1353.9	512.0	426.7
1995	483.0	1207.5	1040.6	96.6	0	1690.6	1523.6	579.6	483.0
1996	395.7	989.2	870.7	79.1	0	1384.8	1266.3	474.8	395.7
1997	417.3	1043.2	896.9	83.5	0	1460.5	1314.2	500.7	417.3
1998	403.7	1009.2	826.2	80.7	0	1412.9	1229.9	484.4	403.7
1999	329.8	824.5	646.5	66.0	0	1154.3	976.3	395.8	329.8
2000	429.8	1074.4	755.6	86.0	0	1504.2	1185.4	515.7	429.8
2001	362.4	906.0	612.8	72.5	0	1268.4	975.2	434.9	362.4
2002	306.5	766.4	493.6	61.3	0	1072.9	800.2	367.9	306.5
2003	307.2	768.0	496.5	61.4	0	1075.2	803.7	368.6	307.2
2004	281.8	704.5	463.4	56.4	0	986.3	745.2	338.2	281.8
2005	338.1	845.3	554.6	67.6	0	1183.4	892.7	405.7	338.1
2006	263.5	658.7	408.0	52.7	0	922.1	671.4	316.2	263.5
2007	310.9	777.2	613.1	62.2	0	1088.0	924.0	373.0	310.9
2008	301.4	753.6	599.7	60.3	0	1055.1	901.1	361.7	301.4
2009	351.0	877.6	590.5	70.2	0	1228.6	941.5	421.2	351.0
2010	339.6	849.1	618.8	67.9	0	1188.7	958.4	407.6	339.6
Average 1949-2010	422.1	1065.1	914.8	84.4	0.0	1487.2	1336.9	506.5	422.1
Average 1950-1959	425.8	966.7	955.0	85.2	0.0	1392.5	1380.9	511.0	425.8
Average 1960-1969	302.9	687.6	698.7	60.6	0.0	990.5	1001.6	363.5	302.9
Average 1970-1979	349.1	812.2	819.7	69.8	0.0	1161.3	1168.7	418.9	349.1
Average 1980-1989	661.5	1937.2	1454.7	132.3	0.0	2598.7	2116.2	793.8	661.5
Average 1990-1999	458.9	1166.6	979.3	91.8	0.0	1625.6	1438.2	550.7	458.9
Average 2000-2009	325.3	813.2	558.8	65.1	0.0	1138.4	884.1	390.3	325.3
Average 2008-2010	330.7	826.8	603.0	66.1	0.0	1157.5	933.7	396.8	330.7

Table 7.1.--Reported commercial catches (thousand pounds) of Deep7 bottomfish by Hawaiian Island group and fishing year, 1949-2010.

	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
1949	69.84	187.33	20.97	75.95	354.10
1950	69.70	159.42	17.29	56.94	303.36
1951	70.90	207.36	8.71	44.12	331.10
1952	37.67	215.20	36.83	40.73	330.43
1953	44.60	172.31	12.31	40.10	269.32
1954	55.58	188.62	7.74	20.98	272.92
1955	38.59	146.85	10.39	27.31	223.14
1956	55.23	177.78	14.43	39.59	287.03
1957	97.76	195.52	11.24	23.52	328.05
1958	43.97	135.17	15.14	21.51	215.79
1959	47.30	117.67	8.44	47.23	220.64
1960	27.36	125.14	2.43	9.47	164.40
1961	14.30	111.00	2.59	6.11	134.00
1962	23.70	135.43	4.28	19.44	182.84
1963	10.70	169.20	8.11	28.96	216.98
1964	16.88	144.40	6.47	37.36	205.12
1965	31.97	170.98	11.69	12.30	226.94
1966	17.08	152.65	5.55	6.60	181.87
1967	26.43	180.10	11.47	16.97	234.96
1968	18.75	157.41	11.59	7.30	195.04
1969	12.37	146.49	10.66	7.98	177.50
1970	13.35	122.15	5.24	17.46	158.20
1971	13.52	97.64	9.84	14.19	135.19
1972	48.59	151.68	19.61	10.99	230.87
1973	43.06	107.91	12.86	5.45	169.27
1974	60.36	141.76	20.93	2.72	225.77
1975	55.43	137.87	15.53	13.28	222.11
1976	64.37	153.80	24.33	16.36	258.85
1977	64.66	165.57	13.09	31.56	274.88
1978	80.20	174.92	28.01	24.60	307.74
1979	85.30	139.66	16.61	32.29	273.85

	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
1980	91.1	126.2	15.6	11.5	244.4
1981	105.8	172.3	21.8	8.3	308.3
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
1986	142.7	260.6	33.5	86.4	523.2
1987	133.5	312.5	52.9	95.9	594.8
1988	173.2	282.1	66.3	48.4	570.0
1989	160.8	291.9	71.2	40.0	563.8
1990	120.4	230.0	68.9	37.7	456.9
1991	69.0	189.5	26.7	40.0	325.3
1992	98.0	202.6	14.4	47.6	362.5
1993	60.5	142.6	33.5	23.7	260.4
1994	54.7	185.2	35.5	33.8	309.3
1995	66.2	208.5	38.2	46.1	359.1
1996	50.6	173.5	32.9	31.7	288.8
1997	66.1	168.5	40.4	24.7	299.7
1998	58.1	180.3	24.6	33.8	296.8
1999	42.8	130.8	25.5	15.7	214.8
2000	65.7	184.6	39.8	19.6	309.7
2001	60.6	149.6	21.7	28.5	260.4
2002	44.7	123.5	18.3	29.1	215.6
2003	43.1	136.0	31.8	33.6	244.6
2004	35.0	133.7	17.6	19.8	206.1
2005	31.6	155.8	18.6	37.8	243.9
2006	33.9	109.3	15.6	31.2	190.0
2007	51.2	119.0	19.9	31.6	221.8
2008	55.7	103.0	23.1	14.4	196.2
2009	85.5	138.8	15.7	14.9	254.9
2010	48.3	133.1	14.3	17.6	213.3
Average 2008-2010	63.2	125.0	17.7	15.6	221.5
Average 1949-2010	61.0	166.2	22.1	32.0	281.3
Average 1950-1959	56.1	171.6	14.3	36.2	278.2
Average 1960-1969	20.0	149.3	7.5	15.2	192.0
Average 1970-1979	52.9	139.3	16.6	16.9	225.7
Average 1980-1989	118.0	221.6	38.9	61.2	439.7
Average 1990-1999	68.6	181.2	34.1	33.5	317.3
Average 2000-2009	50.7	135.3	22.2	26.0	234.3

Table 7.2.--Annual proportion of reported commercial catches of Deep7 bottomfish by Hawaiian Island group and fishing year, 1949-2010.

	Main Hawaiian Island Group			
Fishing Year	Hawaii Proportion	Maui-Molokai-Lanai Proportion	Oahu Proportion	Kauai Proportion
1949	0.20	0.53	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	0.20	0.69	0.03	0.08
1955	0.17	0.66	0.05	0.12
1956	0.19	0.62	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
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	0.09	0.10
2005	0.13	0.64	0.08	0.15
2006	0.18	0.58	0.08	0.16
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
Average 2008-2010	0.28	0.56	0.08	0.07
Average 1949-2010	0.21	0.61	0.07	0.11
Average 1950-1959	0.20	0.62	0.05	0.13
Average 1960-1969	0.10	0.78	0.04	0.08
Average 1970-1979	0.22	0.63	0.07	0.07
Average 1980-1989	0.28	0.51	0.08	0.13
Average 1990-1999	0.21	0.58	0.11	0.10
Average 2000-2009	0.22	0.58	0.09	0.11

Table 8.--Model selection analysis for the generalized linear model (GLM) to standardize Deep7 bottomfish CPUE among 16 candidate models using Akaike's information criterion (AIC). The iterative parameter estimation algorithm did not converge for the Std8 and Std14 models.

Model Selection for Deep7 CPUE Standardization GLM									
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
Std1	Y+A+M	0.234	150535	1.161	152	22750.2	284.0	0.000	0.000
Std2	Y+A+M+A*M	0.248	150535	1.149	1039	22959.9	493.8	0.000	0.000
Std3	Y+I+M	0.146	150535	1.294	74	38900.1	16433.9	0.000	0.000
Std4	Y+A+Q	0.233	150535	1.162	144	22876.8	410.6	0.000	0.000
Std5	Y+I+Q	0.145	150535	1.295	66	39023.7	16557.5	0.000	0.000
Std6	Y+A+Q+A*Q	0.239	150535	1.155	387	22466.1	0.0	1.000	1.000
Std7	Y+I+Q+I*Q	0.147	150535	1.291	75	38599.2	16133.1	0.000	0.000
Std8	Y+A+M+Y*A	-	150535	-	4930	--- Did not converge ---			-
Std9	Y+I+M+Y*I	0.166	150535	1.264	251	35817.2	13351.0	0.000	0.000
Std10	Y+A+Q+Y*Q	0.237	150535	1.157	317	22599.6	133.5	0.000	0.000
Std11	Y+A+M+Y*M	0.243	150535	1.152	783	22827.4	361.3	0.000	0.000
Std12	Y+I+M+I*M	0.149	150535	1.289	107	38406.5	15940.3	0.000	0.000
Std13	Y+I+M+Y*M	0.156	150535	1.283	705	38864.8	16398.7	0.000	0.000
Std14	Y+A+Q+Y*A	-	150535	-	4922	--- Did not converge ---			-
Std15	Y+I+Q+Y*I	0.165	150535	1.266	243	35944.0	13477.8	0.000	0.000
Std16	Y+I+Q+Y*Q	0.150	150535	1.289	239	38682.1	16216.0	0.000	0.000

Table 9.--Analysis of variance table for the best-fitting GLM used to standardize Deep7 bottomfish CPUE.

ANOVA Table for model selected by AIC for Deep7 CPUE Standardization					
	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Pr > F
Model	386	54372.12	140.860	121.96	< 0.0001
Error	150148	173416.82	1.155		
Corrected Total	150534	227788.94			
R-Square =	0.239				
Effects	Degrees of Freedom	Type III Sum of Squares	Mean Square	F Value	Pr > F
Y(year)	59	6195.10	105.002	90.91	< 0.0001
A(area)	81	40691.43	502.363	434.96	< 0.0001
Q(quarter)	3	178.38	59.459	51.48	< 0.0001
A*Q	243	1317.10	5.420	4.69	< 0.0001

Table 10.--Estimates of standardized CPUE for Deep7 bottomfish by fishing power scenario for the Baseline CPUE Scenario I and Alternative CPUE Scenarios II and III.

Deep7 Bottomfish Standardized CPUE Time Series Scenarios										
	CPUE Scenario 1				CPUE Scenario 2			CPUE Scenario 3		
Fishing Year	Standardized CPUE (lbs/trip)	CV of Standardized CPUE	Relative CV of Standardized CPUE		Standardized CPUE (lbs/trip)	CV of Standardized CPUE	Relative CV of Standardized CPUE	Standardized CPUE (lbs/trip)	CV of Standardized CPUE	Relative CV of Standardized CPUE
1949	192.8	0.032	1.21		192.8	0.032	1.21	192.80	0.032	1.21
1950	196.9	0.033	1.23		196.9	0.033	1.23	194.46	0.033	1.23
1951	207.2	0.034	1.28		207.2	0.034	1.28	202.26	0.034	1.28
1952	241.6	0.038	1.42		241.6	0.038	1.42	232.96	0.038	1.42
1953	233.4	0.042	1.57		233.4	0.042	1.57	222.42	0.042	1.57
1954	284.5	0.043	1.62		284.5	0.043	1.62	268.05	0.043	1.62
1955	376.9	0.052	1.95		376.9	0.052	1.95	351.03	0.052	1.95
1956	293.7	0.046	1.73		293.7	0.046	1.73	270.44	0.046	1.73
1957	333.9	0.044	1.64		333.9	0.044	1.64	303.97	0.044	1.64
1958	-	-	-		-	-	-	-	-	-
1959	-	-	-		-	-	-	-	-	-
1960	-	-	-		-	-	-	-	-	-
1961	371.1	0.060	2.26		371.1	0.060	2.26	323.40	0.060	2.26
1962	405.1	0.052	1.96		405.1	0.052	1.96	349.27	0.052	1.96
1963	255.2	0.048	1.81		255.2	0.048	1.81	217.74	0.048	1.81
1964	278.6	0.047	1.77		278.6	0.047	1.77	235.22	0.047	1.77
1965	349.1	0.043	1.61		349.1	0.043	1.61	291.66	0.043	1.61
1966	300.3	0.044	1.65		300.3	0.044	1.65	248.36	0.044	1.65
1967	285.5	0.039	1.44		285.5	0.039	1.44	233.76	0.039	1.44
1968	279.8	0.042	1.56		279.8	0.042	1.56	226.76	0.042	1.56
1969	263.1	0.041	1.55		263.1	0.041	1.55	211.17	0.041	1.55
1970	243.0	0.042	1.57		243.0	0.042	1.57	193.13	0.042	1.57
1971	220.0	0.041	1.53		219.4	0.041	1.53	173.13	0.041	1.53
1972	241.5	0.036	1.33		240.3	0.036	1.33	188.25	0.036	1.33
1973	226.2	0.038	1.41		224.5	0.038	1.41	174.61	0.038	1.41
1974	218.6	0.034	1.28		216.5	0.034	1.28	167.20	0.034	1.28
1975	214.8	0.035	1.30		212.1	0.035	1.30	162.72	0.035	1.30
1976	231.3	0.034	1.29		227.8	0.034	1.29	173.61	0.034	1.29
1977	183.2	0.033	1.25		180.0	0.033	1.25	136.26	0.033	1.25
1978	183.3	0.032	1.21		179.7	0.032	1.21	135.10	0.032	1.21
1979	209.9	0.035	1.30		205.2	0.035	1.30	153.30	0.035	1.30
1980	180.2	0.031	1.17		175.8	0.031	1.17	130.42	0.031	1.17
1981	185.2	0.030	1.12		179.7	0.030	1.12	132.86	0.030	1.12
1982	167.6	0.030	1.11		161.9	0.030	1.11	119.20	0.030	1.11
1983	170.8	0.028	1.06		164.2	0.028	1.06	120.47	0.028	1.06
1984	137.5	0.029	1.08		131.5	0.029	1.08	96.10	0.029	1.08
1985	151.3	0.027	1.02		144.0	0.027	1.02	104.83	0.027	1.02
1986	151.7	0.027	1.01		143.7	0.027	1.01	104.28	0.027	1.01
1987	173.1	0.027	1.01		163.2	0.027	1.01	117.98	0.027	1.01
1988	199.7	0.027	1.00		187.3	0.027	1.00	134.95	0.027	1.00
1989	192.8	0.027	1.00		180.0	0.027	1.00	129.21	0.027	1.00
1990	172.0	0.027	1.02		159.9	0.027	1.02	114.37	0.027	1.02
1991	158.8	0.028	1.06		147.2	0.028	1.06	104.73	0.028	1.06
1992	147.5	0.028	1.05		136.4	0.028	1.05	96.46	0.028	1.05
1993	139.1	0.029	1.10		128.3	0.029	1.10	90.24	0.029	1.10
1994	153.2	0.029	1.08		141.0	0.029	1.08	98.65	0.029	1.08
1995	156.3	0.028	1.06		143.4	0.028	1.06	99.82	0.028	1.06
1996	141.1	0.029	1.07		129.2	0.029	1.07	89.40	0.029	1.07
1997	143.9	0.028	1.05		131.4	0.028	1.05	90.51	0.028	1.05
1998	135.6	0.028	1.06		123.5	0.028	1.06	84.59	0.028	1.06
1999	140.9	0.030	1.12		128.0	0.030	1.12	87.24	0.030	1.12
2000	162.4	0.029	1.07		147.2	0.029	1.07	99.78	0.029	1.07
2001	154.6	0.029	1.09		140.2	0.029	1.09	94.31	0.029	1.09
2002	144.0	0.030	1.14		130.5	0.030	1.14	87.18	0.030	1.14
2003	149.3	0.030	1.13		135.3	0.030	1.13	89.71	0.030	1.13
2004	139.6	0.031	1.16		126.5	0.031	1.16	83.25	0.031	1.16
2005	160.3	0.031	1.16		145.4	0.031	1.16	94.95	0.031	1.16
2006	151.9	0.032	1.21		137.7	0.032	1.21	89.29	0.032	1.21
2007	159.2	0.031	1.16		144.3	0.031	1.16	92.93	0.031	1.16
2008	192.2	0.032	1.21		174.2	0.032	1.21	111.36	0.032	1.21
2009	172.9	0.030	1.12		156.7	0.030	1.12	99.46	0.030	1.12
2010	146.0	0.031	1.16		132.4	0.031	1.16	83.43	0.031	1.16

Table 11.--Sensitivity analyses comparing estimates of standardized CPUE for Deep7 bottomfish under two alternative standardization models (Delta-GLM and Poisson-GLM) with estimates from the best-fitting CPUE standardization model with CPUE data for the anomalous year (1958-1960) included in the standardization analysis (i.e., CPUE Scenario Ib).

Alternative Deep7 Bottomfish Standardized CPUE Time Series Scenarios

	CPUE Scenario 1b			Delta-GLM CPUE			Poisson-GLM CPUE		
Fishing Year	Standardized CPUE (lbs/trip)	CV of Standardized CPUE (lb/trip)	Relative CV of Standardized CPUE	Standardized CPUE (lbs/trip)	CV of Standardized CPUE (lb/trip)	Relative CV of Standardized CPUE	Standardized CPUE (lbs/trip)	CV of Standardized CPUE (lb/trip)	Relative CV of Standardized CPUE
1949	193.9	0.032	1.21	73.2	0.030	1.50	101.80	-	1.00
1950	198.1	0.033	1.23	79.6	0.030	1.50	98.62	-	1.00
1951	207.9	0.034	1.28	93.3	0.030	1.50	102.23	-	1.00
1952	242.6	0.038	1.42	106.0	0.040	2.00	116.65	-	1.00
1953	233.6	0.042	1.57	97.2	0.040	2.00	112.57	-	1.00
1954	284.2	0.043	1.62	132.4	0.040	2.00	145.52	-	1.00
1955	374.8	0.052	1.95	194.8	0.050	2.50	175.70	-	1.00
1956	293.8	0.046	1.73	129.8	0.050	2.50	143.12	-	1.00
1957	331.8	0.044	1.64	161.3	0.050	2.50	147.01	-	1.00
1958	226.9	0.045	1.69	100.0	0.050	2.50	-	-	1.00
1959	185.8	0.047	1.74	66.3	0.040	2.00	-	-	1.00
1960	250.2	0.044	1.66	100.6	0.040	2.00	-	-	1.00
1961	367.0	0.060	2.26	157.4	0.060	3.00	133.29	-	1.00
1962	405.5	0.052	1.96	177.1	0.050	2.50	164.12	-	1.00
1963	255.7	0.048	1.81	107.7	0.050	2.50	106.03	-	1.00
1964	279.0	0.047	1.77	107.2	0.040	2.00	111.19	-	1.00
1965	350.2	0.043	1.61	129.2	0.040	2.00	142.87	-	1.00
1966	300.9	0.044	1.65	116.1	0.040	2.00	128.02	-	1.00
1967	286.1	0.039	1.44	110.7	0.030	1.50	118.57	-	1.00
1968	280.0	0.042	1.56	103.8	0.040	2.00	116.37	-	1.00
1969	263.7	0.041	1.55	99.1	0.040	2.00	104.17	-	1.00
1970	243.3	0.042	1.57	87.0	0.040	2.00	98.78	-	1.00
1971	220.5	0.041	1.53	79.1	0.030	1.50	82.53	-	1.00
1972	242.1	0.036	1.33	89.2	0.030	1.50	99.32	-	1.00
1973	226.2	0.038	1.41	87.5	0.030	1.50	97.22	-	1.00
1974	218.9	0.034	1.28	85.3	0.030	1.50	91.15	-	1.00
1975	214.8	0.035	1.30	84.6	0.030	1.50	89.75	-	1.00
1976	230.8	0.034	1.29	94.2	0.030	1.50	100.70	-	1.00
1977	183.2	0.033	1.25	79.8	0.030	1.50	83.33	-	1.00
1978	183.1	0.032	1.21	83.1	0.030	1.50	83.10	-	1.00
1979	209.7	0.035	1.30	90.5	0.030	1.50	98.55	-	1.00
1980	180.1	0.031	1.17	78.6	0.030	1.50	78.30	-	1.00
1981	185.2	0.030	1.12	76.4	0.020	1.00	74.90	-	1.00
1982	167.7	0.030	1.11	69.2	0.020	1.00	72.95	-	1.00
1983	170.6	0.028	1.06	74.0	0.020	1.00	71.68	-	1.00
1984	137.2	0.029	1.08	62.0	0.020	1.00	58.28	-	1.00
1985	151.0	0.027	1.02	71.8	0.020	1.00	64.36	-	1.00
1986	151.5	0.027	1.01	75.6	0.020	1.00	66.04	-	1.00
1987	172.9	0.027	1.01	89.8	0.020	1.00	71.23	-	1.00
1988	199.5	0.027	1.00	95.3	0.020	1.00	77.91	-	1.00
1989	192.6	0.027	1.00	89.2	0.020	1.00	75.16	-	1.00
1990	171.9	0.027	1.02	79.7	0.020	1.00	-	-	1.00
1991	159.0	0.028	1.06	68.5	0.020	1.00	75.49	-	1.00
1992	147.5	0.028	1.05	65.4	0.020	1.00	75.63	-	1.00
1993	139.1	0.029	1.10	59.5	0.020	1.00	72.38	-	1.00
1994	153.3	0.029	1.08	68.1	0.020	1.00	77.40	-	1.00
1995	156.5	0.028	1.06	70.7	0.020	1.00	80.10	-	1.00
1996	141.2	0.029	1.07	63.9	0.020	1.00	68.95	-	1.00
1997	144.1	0.028	1.05	65.2	0.020	1.00	68.51	-	1.00
1998	135.6	0.028	1.06	59.3	0.020	1.00	64.72	-	1.00
1999	140.9	0.030	1.12	64.4	0.020	1.00	64.15	-	1.00
2000	162.6	0.029	1.07	73.5	0.020	1.00	77.62	-	1.00
2001	154.8	0.029	1.09	68.2	0.020	1.00	70.49	-	1.00
2002	144.2	0.030	1.14	66.5	0.020	1.00	68.51	-	1.00
2003	149.5	0.030	1.13	70.2	0.020	1.00	71.37	-	1.00
2004	139.7	0.031	1.16	67.7	0.020	1.00	63.99	-	1.00
2005	160.5	0.031	1.16	74.1	0.020	1.00	72.72	-	1.00
2006	151.9	0.032	1.21	69.1	0.020	1.00	70.45	-	1.00
2007	159.1	0.031	1.16	72.5	0.020	1.00	73.41	-	1.00
2008	191.9	0.032	1.21	82.7	0.020	1.00	79.03	-	1.00
2009	172.8	0.030	1.12	76.2	0.020	1.00	75.70	-	1.00
2010	146.2	0.031	1.16	61.5	0.020	1.00	66.26	-	1.00

Table 12.--Pearson correlation coefficients (top row) for pairs of standardized CPUE estimates from the Baseline CPUE Scenario I (cpue1) and alternative CPUE scenarios (cpue2 to cpue1b) along with P-values for two-sided hypothesis test that the correlation is zero (middle row) and the sample size used for the correlation analysis (bottom row). All pairs of CPUE scenarios are significantly positively correlated (P <0.0001).

	cpue2	**cpue3**	**cpue4**	**cpue5**	**cpue1b**
cpue1	0.998	0.976	0.949	0.954	1.000
	7.909E-073	2.542E-039	2.967E-030	6.722E-031	1.461E-112
	59	59	59	58	59
cpue2		0.983	0.941	0.955	0.999
		1.983E-043	2.046E-028	3.356E-031	8.042E-074
		59	59	58	59
cpue3			0.933	0.972	0.976
			5.420E-027	6.096E-037	1.519E-039
			59	58	59
cpue4				0.939	0.946
				1.144E-027	6.129E-031
				58	62
cpue5					0.954
					4.352E-031
					58

Table 13.--Combinations of Deep7 bottomfish catch and CPUE scenarios used for stock status determination and sensitivity analyses. The baseline model used for stock status determination was Baseline Catch Scenario II and Baseline CPUE Scenario I. The Baseline Catch Scenario I row is outlined in boldface.

Catch Scenarios	Catch and CPUE Scenarios		
Catch Scenario I (S1)	S1 and C1	S1 and C2	S1 and C3
Catch Scenario II (S2)	S2 and C1	S2 and C2	S2 and C3
Catch Scenario III (S3)	S3 and C1	S3 and C2	S3 and C3
Catch Scenario IV (S4)	S4 and C1	S4 and C2	S4 and C3
CPUE Scenarios	CPUE Scenario I (C1)	CPUE Scenario II (C2)	CPUE Scenario III (C3)

Table 14.-- Comparison of fitted deviance information criterion (DIC) values for the baseline production model used for the current stock assessment with an alternative model formulation with annual parameters for the intrinsic growth rate (Multiple-R model). The comparison of the baseline and Multiple-R models fit to the Baseline Catch Scenario II and Baseline CPUE Scenario I (boldface) shows that the baseline model produces a substantially better fit to the data.

Baseline Model

DIC Values by Catch and CPUE Scenario

	CPUE Scenario					
Catch Scenario	CPUE1	CPUE2	CPUE3	CPUE1b	CPUE4	CPUE5
S1	612.5	607.2	576.2	644.2	519.4	489.0
S2	**607.6**	604.1	572.6	638.8	514.8	484.2
S3	618.1	613.2	581.7	650.6	525.8	497.8
S4	617.0	611.9	580.5	649.6	524.4	495.8

Multiple-R Model

DIC Values by Catch and CPUE Scenario

	CPUE Scenario					
Catch Scenario	CPUE1	CPUE2	CPUE3	CPUE1b	CPUE4	CPUE5
S1	625.3	620.5	590.7	657.4	532.7	506.7
S2	**622.2**	617.4	586.6	654.6	529.8	502.9
S3	619.1	615.8	583.5	651.6	526.4	499.0
S4	621.2	616.4	585.1	653.8	529.0	501.5

Comparison of Baseline and Multiple-R Models

Differences in DIC Values by Catch and CPUE Scenario

	CPUE Scenario					
Catch Scenario	CPUE1	CPUE2	CPUE3	CPUE1b	CPUE4	CPUE5
S1	12.8	13.3	14.5	13.2	13.3	17.7
S2	**14.6**	13.3	14.0	15.8	15.1	18.7
S3	1.0	2.6	1.8	1.0	0.7	1.3
S4	4.2	4.5	4.5	4.2	4.6	5.7

Table 15.1.--Summary of probabilities of alternative catch and CPUE scenarios when the baseline assessment model (Baseline Catch Scenario II and Baseline CPUE Scenario I) represents the true state of nature with absolute certainty.

Probabilities of Catch Scenarios P(S)	Joint Probabilities of Catch and CPUE Scenarios P(S)· P(C)		
Catch Scenario I P(S1) = 0	0	0	0
Catch Scenario II P(S2) = 1	1	0	0
Catch Scenario III P(S3) = 0	0	0	0
Catch Scenario IV P(S4) = 0	0	0	0
Probabilities of CPUE Scenarios P(C)	CPUE Scenario I P(C1) = 1	CPUE Scenario II P(C2) = 0	CPUE Scenario III P(C3) = 0

Table 15.2.--Summary of probabilities of alternative catch and CPUE scenarios under the hypothetical values described in the text assuming that the individual combinations of catch and CPUE scenarios represent the true state of nature with a relative degree of certainty.

Probabilities of Catch Scenarios P(S)	Joint Probabilities of Catch and CPUE Scenarios P(S)· P(C)		
Catch Scenario I P(S1) = 1/20	25/1000	20/1000	5/1000
Catch Scenario II P(S2) = 4/5	400/1000	320/1000	80/1000
Catch Scenario III P(S3) = 1/10	50/1000	40/1000	10/1000
Catch Scenario IV P(S4) = 1/20	25/1000	20/1000	5/1000
Probabilities of CPUE Scenarios P(C)	CPUE Scenario I P(C1) = 1/2	CPUE Scenario II P(C2) = 2/5	CPUE Scenario III P(C3) = 1/10

Table 16.1.--Mean parameter estimates for the Deep7 bottomfish stock complex based on production model analyses (mean estimate in boldface with estimated standard deviation immediately below) for the baseline model which is Catch Scenario II with CPUE Scenario I. Results of sensitivity analyses under Catch Scenario II and alternative CPUE Scenarios II and III as well as mean parameter estimates for the sensitivity analyses based on alternative CPUE standardization models from CPUE Scenarios IV and V are also listed below. Parameter estimates are labeled as: 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; $relH_{2010}$, the ratio of harvest rate in 2010 to HMSY; $relB_{2010}$, the ratio of exploitable biomass in 2010 to BMSY; r, the intrinsic growth rate per year; K, the carrying capacity (million pounds); M, the production model shape parameter, with M = 1 indicating a symmetric production function; and RMSE, the root mean squared error of the model fit to standardized CPUE under the given CPUE scenario. MSY-based reference points are calculated as average parameter values from MCMC simulations for a nonlinear model and, as a result, may not precisely satisfy E[HMSY]*E[BMSY] = E[MSY], where E[·] denotes the expected value operator.

MODEL SCENARIO	HMSY	BMSY	MSY for Total Catch	MSY for Reported Catch	PMSY	$relH_{2010}$	$relB_{2010}$	r	K	M	RMSE
Catch Scenario 2	**6.1%**	**14.59**	**0.868**	**0.417**	**0.578**	**0.58**	**0.92**	**0.107**	**27.24**	**1.85**	**41.14**
CPUE Scenario 1	2.2%	4.33	0.338	0.163	0.079			0.026	9.4	1.35	
Catch Scenario 2	**6.0%**	**14.55**	**0.846**	**0.407**	**0.544**	**0.66**	**0.84**	**0.106**	**27.37**	**1.79**	**40.45**
CPUE Scenario 2	2.2%	4.23	0.332	0.160	0.079			0.025	9.27	1.34	
Catch Scenario 2	**5.3%**	**15.87**	**0.805**	**0.387**	**0.520**	**0.96**	**0.60**	**0.104**	**31.34**	**1.46**	**34.12**
CPUE Scenario 3	2.1%	4.57	0.344	0.165	0.079			0.025	10.74	1.23	
Catch Scenario 2	**6.4%**	**14.19**	**0.877**	**0.422**	**0.556**	**0.57**	**0.96**	**0.108**	**26.14**	**1.98**	**21.33**
CPUE Scenario 4	2.3%	4.41	0.360	0.173	0.080			0.026	9.36	1.41	
Catch Scenario 2	**5.6%**	**15.43**	**0.828**	**0.398**	**0.529**	**0.64**	**0.88**	**0.105**	**29.95**	**1.55**	**18.8**
CPUE Scenario 5	2.1%	4.59	0.331	0.159	0.076			0.025	10.57	1.2	

Table 16.2.--Mean parameter estimates for the Deep7 bottomfish stock complex based on production model analyses (mean estimate in boldface with estimated standard deviation immediately below) for the sensitivity analyses under Catch Scenario I and Alternative CPUE Scenarios I, II, and III are listed below. Parameter estimates are labeled as: 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; $relH_{2010}$, the ratio of harvest rate in 2010 to HMSY; $relB_{2010}$, the ratio of exploitable biomass in 2010 to BMSY; r, the intrinsic growth rate per year; K, the carrying capacity (million pounds); M, the production model shape parameter, with M = 1 indicating a symmetric production function; and RMSE, the root mean squared error of the model fit to standardized CPUE under the given CPUE scenario.

MODEL SCENARIO	HMSY	BMSY	MSY for Total Catch	MSY for Reported Catch	PMSY	$relH_{2010}$	$relB_{2010}$	r	K	M	RMSE
Catch Scenario 1	**6.7%**	**18.04**	**1.177**	**0.336**	**0.564**	**0.73**	**0.92**	**0.110**	**32.63**	**2.09**	**41.54**
CPUE Scenario 1	2.2%	5.13	0.415	0.119	0.077			0.026	10.75	1.40	
Catch Scenario 1	**6.5%**	**18.22**	**1.155**	**0.330**	**0.559**	**0.80**	**0.84**	**0.109**	**33.32**	**2.01**	**40.92**
CPUE Scenario 2	2.2%	5.17	0.411	0.117	0.077			0.026	11.01	1.38	
Catch Scenario 1	**5.8%**	**19.88**	**1.114**	**0.318**	**0.535**	**1.17**	**0.60**	**0.107**	**38.03**	**1.65**	**34.51**
CPUE Scenario 3	2.2%	5.54	0.433	0.124	0.078			0.025	12.4	1.27	

Table 16.3.--Mean parameter estimates for the Deep7 bottomfish stock complex based on production model analyses (mean estimate in boldface with estimated standard deviation immediately below) for the sensitivity analyses under Catch Scenario III and alternative CPUE Scenarios I, II, and III are listed below. Parameter estimates are labeled as: 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; $relH_{2010}$, the ratio of harvest rate in 2010 to HMSY; $relB_{2010}$, the ratio of exploitable biomass in 2010 to BMSY; r, the intrinsic growth rate per year; K, the carrying capacity (million pounds); M, the production model shape parameter, with M = 1 indicating a symmetric production function; and RMSE, the root mean squared error of the model fit to standardized CPUE under the given CPUE scenario.

MODEL SCENARIO	HMSY	BMSY	MSY for Total Catch	MSY for Reported Catch	PMSY	$relH_{2010}$	$relB_{2010}$	r	K	M	RMSE
Catch Scenario 3	**6.6%**	**5.76**	**0.380**	**0.317**	**0.564**	**0.736**	**0.957**	**0.109**	**10.32**	**2.07**	**41.52**
CPUE Scenario 1	2.0%	1.21	0.132	0.110	0.074			0.026	2.22	1.35	
Catch Scenario 3	**6.5%**	**5.78**	**0.374**	**0.312**	**0.560**	**0.813**	**0.880**	**0.108**	**10.43**	**2.00**	**40.89**
CPUE Scenario 2	2.0%	1.21	0.131	0.109	0.074			0.025	2.2	1.34	
Catch Scenario 3	**6.1%**	**5.93**	**0.359**	**0.299**	**0.544**	**1.183**	**0.631**	**0.107**	**11.00**	**1.76**	**34.44**
CPUE Scenario 3	1.9%	1.22	0.131	0.109	0.074			0.025	2.3	1.27	

Table 16.4.--Mean parameter estimates for the Deep7 bottomfish stock complex based on production model analyses (mean estimate in boldface with estimated standard deviation immediately below) for the sensitivity analyses under Catch Scenario IV and Alternative CPUE Scenarios I, II, and III are listed below. Parameter estimates are labeled as: 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; $relH_{2010}$, the ratio of harvest rate in 2010 to HMSY; $relB_{2010}$, the ratio of exploitable biomass in 2010 to BMSY; r, the intrinsic growth rate per year; K, the carrying capacity (million pounds); M, the production model shape parameter, with M = 1 indicating a symmetric production function; and RMSE, the root mean squared error of the model fit to standardized CPUE under the given CPUE scenario.

MODEL SCENARIO	HMSY	BMSY	MSY for Reported Catch	PMSY	$relH_{2010}$	$relB_{2010}$	r	K	M	RMSE
Catch Scenario 4	**6.1%**	**5.35**	**0.325**	**0.548**	**0.711**	**0.974**	**0.106**	**9.85**	**1.82**	**41.27**
CPUE Scenario 1	2.0%	1.17	0.125	0.075			0.025	2.18	1.27	
Catch Scenario 4	**5.9%**	**5.33**	**0.316**	**0.543**	**0.798**	**0.888**	**0.105**	**9.92**	**1.75**	**40.60**
CPUE Scenario 2	2.0%	1.14	0.122	0.075			0.025	2.17	1.25	
Catch Scenario 4	**5.5%**	**5.44**	**0.300**	**0.528**	**1.174**	**0.640**	**0.104**	**10.41**	**1.54**	**34.18**
CPUE Scenario 3	1.9%	1.14	0.121	0.075			0.025	2.23	1.21	

Table 17.1.--Results of the baseline production model used for stock status determination under Baseline Catch Scenario II and Baseline CPUE Scenario I.

Year	Mean Biomass (B, klb)	Median Relative Biomass (B/BMSY)	Probability of Being Overfished	Mean Harvest Rate (H)	Median Relative Harvest Rate (H/HMSY)	Probability of Overfishing	Year	Mean Biomass (B, klb)	Median Relative Biomass (B/BMSY)	Probability of Being Overfished	Mean Harvest Rate (H)	Median Relative Harvest Rate (H/HMSY)	Probability of Overfishing
1949	15.85	1.06	0.02	0.06	1.00	0.51	1980	15.56	1.04	0.06	0.05	0.87	0.37
1950	16.74	1.12	0.02	0.05	0.85	0.33	1981	15.21	1.01	0.07	0.07	1.14	0.65
1951	17.89	1.19	0.01	0.05	0.88	0.38	1982	14.57	0.97	0.10	0.07	1.18	0.68
1952	19.18	1.27	0.01	0.05	0.82	0.31	1983	14.15	0.94	0.12	0.10	1.54	0.88
1953	20.34	1.35	0.01	0.04	0.63	0.14	1984	13.39	0.89	0.17	0.08	1.28	0.75
1954	21.91	1.45	0.00	0.04	0.57	0.10	1985	13.61	0.91	0.14	0.11	1.74	0.93
1955	23.31	1.54	0.00	0.03	0.44	0.04	1986	13.83	0.93	0.13	0.10	1.69	0.92
1956	23.95	1.58	0.00	0.03	0.56	0.09	1987	14.56	0.97	0.09	0.12	1.98	0.96
1957	24.48	1.61	0.00	0.04	0.66	0.16	1988	14.98	1.00	0.08	0.12	1.96	0.96
1958	24.42	1.59	0.00	0.03	0.44	0.05	1989	14.67	0.98	0.09	0.12	2.02	0.96
1959	24.67	1.61	0.00	0.03	0.43	0.05	1990	13.79	0.91	0.15	0.10	1.63	0.90
1960	24.96	1.63	0.00	0.02	0.32	0.02	1991	13.09	0.87	0.20	0.07	1.19	0.68
1961	25.43	1.66	0.00	0.02	0.25	0.02	1992	12.73	0.85	0.23	0.09	1.42	0.83
1962	25.63	1.68	0.00	0.02	0.35	0.03	1993	12.38	0.82	0.27	0.07	1.10	0.61
1963	24.79	1.63	0.00	0.03	0.43	0.04	1994	12.56	0.84	0.25	0.08	1.30	0.77
1964	24.57	1.62	0.00	0.03	0.41	0.04	1995	12.51	0.83	0.25	0.09	1.52	0.87
1965	24.68	1.63	0.00	0.03	0.46	0.05	1996	12.08	0.80	0.30	0.08	1.22	0.71
1966	24.00	1.59	0.00	0.02	0.36	0.03	1997	12.01	0.80	0.31	0.08	1.30	0.77
1967	23.36	1.55	0.00	0.03	0.53	0.08	1998	11.87	0.79	0.33	0.07	1.21	0.70
1968	22.50	1.49	0.00	0.03	0.43	0.04	1999	12.02	0.80	0.32	0.05	0.81	0.30
1969	21.68	1.44	0.01	0.03	0.42	0.04	2000	12.52	0.83	0.26	0.07	1.11	0.62
1970	20.87	1.39	0.01	0.02	0.38	0.03	2001	12.41	0.82	0.27	0.05	0.85	0.35
1971	20.19	1.34	0.01	0.02	0.33	0.03	2002	12.30	0.81	0.28	0.04	0.66	0.16
1972	19.88	1.33	0.01	0.04	0.61	0.13	2003	12.44	0.83	0.27	0.05	0.76	0.25
1973	19.20	1.28	0.02	0.03	0.47	0.06	2004	12.48	0.83	0.26	0.04	0.59	0.11
1974	18.72	1.25	0.02	0.04	0.67	0.17	2005	12.91	0.86	0.22	0.04	0.67	0.17
1975	18.20	1.21	0.02	0.04	0.64	0.15	2006	13.14	0.87	0.20	0.03	0.50	0.07
1976	17.76	1.18	0.02	0.04	0.70	0.20	2007	13.61	0.91	0.17	0.04	0.57	0.10
1977	16.87	1.12	0.04	0.05	0.78	0.27	2008	14.14	0.94	0.13	0.03	0.52	0.08
1978	16.40	1.09	0.04	0.06	0.97	0.48	2009	14.11	0.94	0.13	0.04	0.70	0.20
1979	16.13	1.07	0.05	0.06	0.90	0.40	2010	13.86	0.92	0.16	0.04	0.58	0.13

Table 17.2.--Results of production model sensitivity analysis under alternative Catch Scenario II and CPUE Scenario II.

Year	Mean Biomass (B, klb)	Median Relative Biomass (B/BMSY)	Probability of Being Overfished	Mean Harvest Rate (H)	Median Relative Harvest Rate (H/HMSY)	Probability of Overfishing	Year	Mean Biomass (B, klb)	Median Relative Biomass (B/BMSY)	Probability of Being Overfished	Mean Harvest Rate (H)	Median Relative Harvest Rate (H/HMSY)	Probability of Overfishing
1949	15.97	1.07	0.02	0.06	1.01	0.51	1980	15.28	1.02	0.08	0.05	0.90	0.40
1950	16.88	1.13	0.02	0.05	0.86	0.33	1981	14.88	1.00	0.09	0.07	1.19	0.69
1951	18.04	1.20	0.01	0.05	0.89	0.38	1982	14.18	0.95	0.12	0.07	1.23	0.72
1952	19.34	1.29	0.01	0.05	0.83	0.32	1983	13.70	0.92	0.14	0.10	1.62	0.91
1953	20.46	1.36	0.01	0.04	0.64	0.14	1984	12.91	0.86	0.20	0.08	1.35	0.80
1954	22.06	1.46	0.00	0.04	0.58	0.11	1985	13.08	0.88	0.18	0.11	1.84	0.95
1955	23.45	1.55	0.00	0.03	0.44	0.05	1986	13.23	0.89	0.17	0.11	1.80	0.95
1956	24.16	1.60	0.00	0.03	0.56	0.10	1987	13.86	0.93	0.13	0.13	2.11	0.98
1957	24.70	1.63	0.00	0.04	0.67	0.17	1988	14.18	0.95	0.11	0.13	2.10	0.98
1958	24.67	1.61	0.00	0.03	0.44	0.05	1989	13.83	0.92	0.14	0.13	2.18	0.98
1959	24.97	1.63	0.00	0.03	0.44	0.05	1990	12.93	0.86	0.21	0.11	1.77	0.94
1960	25.28	1.65	0.00	0.02	0.32	0.03	1991	12.24	0.81	0.29	0.08	1.29	0.76
1961	25.71	1.69	0.00	0.02	0.25	0.02	1992	11.86	0.79	0.32	0.09	1.54	0.88
1962	25.90	1.71	0.00	0.02	0.36	0.03	1993	11.51	0.77	0.37	0.07	1.20	0.70
1963	25.03	1.65	0.00	0.03	0.44	0.05	1994	11.65	0.78	0.35	0.09	1.43	0.84
1964	24.79	1.64	0.00	0.03	0.42	0.04	1995	11.57	0.77	0.36	0.10	1.67	0.92
1965	24.91	1.65	0.00	0.03	0.46	0.05	1996	11.15	0.74	0.42	0.08	1.35	0.79
1966	24.23	1.61	0.00	0.02	0.36	0.03	1997	11.05	0.74	0.43	0.09	1.44	0.84
1967	23.57	1.57	0.00	0.03	0.53	0.08	1998	10.90	0.73	0.46	0.08	1.34	0.79
1968	22.69	1.51	0.00	0.03	0.43	0.05	1999	10.99	0.73	0.44	0.05	0.90	0.40
1969	21.84	1.45	0.00	0.03	0.42	0.05	2000	11.43	0.76	0.38	0.07	1.23	0.72
1970	20.95	1.40	0.01	0.02	0.38	0.04	2001	11.32	0.75	0.40	0.06	0.94	0.44
1971	20.22	1.35	0.01	0.02	0.34	0.03	2002	11.23	0.75	0.41	0.04	0.74	0.22
1972	19.90	1.33	0.01	0.04	0.62	0.13	2003	11.35	0.76	0.39	0.05	0.85	0.34
1973	19.19	1.28	0.01	0.03	0.48	0.06	2004	11.38	0.76	0.39	0.04	0.65	0.15
1974	18.66	1.25	0.02	0.04	0.69	0.18	2005	11.79	0.79	0.34	0.05	0.75	0.23
1975	18.09	1.21	0.02	0.04	0.66	0.16	2006	11.98	0.80	0.32	0.03	0.56	0.09
1976	17.61	1.18	0.03	0.04	0.72	0.21	2007	12.40	0.83	0.27	0.04	0.64	0.14
1977	16.68	1.11	0.04	0.05	0.80	0.28	2008	12.88	0.86	0.22	0.04	0.58	0.11
1978	16.20	1.08	0.05	0.06	1.00	0.51	2009	12.87	0.86	0.22	0.05	0.78	0.27
1979	15.88	1.06	0.06	0.06	0.93	0.43	2010	12.63	0.84	0.26	0.04	0.65	0.17

Table 17.3.--Results of production model sensitivity analysis under alternative Catch Scenario II and CPUE Scenario III.

Year	Mean Biomass (B, klb)	Median Relative Biomass (B/BMSY)	Probability of Being Overfished	Mean Harvest Rate (H)	Median Relative Harvest Rate (H/HMSY)	Probability of Overfishing	Year	Mean Biomass (B, klb)	Median Relative Biomass (B/BMSY)	Probability of Being Overfished	Mean Harvest Rate (H)	Median Relative Harvest Rate (H/HMSY)	Probability of Overfishing
1949	18.89	1.17	0.01	0.05	0.97	0.46	1980	14.05	0.86	0.22	0.06	1.12	0.62
1950	20.08	1.24	0.01	0.04	0.82	0.29	1981	13.63	0.84	0.25	0.08	1.47	0.86
1951	21.42	1.32	0.01	0.05	0.86	0.34	1982	12.95	0.80	0.32	0.08	1.54	0.89
1952	22.86	1.40	0.00	0.04	0.80	0.29	1983	12.47	0.77	0.37	0.11	2.02	0.98
1953	24.08	1.47	0.00	0.03	0.62	0.14	1984	11.71	0.72	0.47	0.09	1.69	0.93
1954	25.74	1.57	0.00	0.03	0.57	0.11	1985	11.85	0.73	0.44	0.12	2.32	0.99
1955	27.15	1.66	0.00	0.02	0.44	0.06	1986	11.95	0.74	0.43	0.12	2.26	0.99
1956	27.68	1.69	0.00	0.03	0.56	0.11	1987	12.49	0.77	0.36	0.14	2.66	1.00
1957	28.09	1.71	0.00	0.04	0.67	0.18	1988	12.73	0.79	0.34	0.14	2.67	1.00
1958	27.89	1.68	0.00	0.02	0.45	0.06	1989	12.33	0.76	0.39	0.15	2.77	1.00
1959	27.94	1.68	0.00	0.02	0.45	0.06	1990	11.45	0.70	0.51	0.12	2.27	0.99
1960	28.01	1.69	0.00	0.02	0.33	0.04	1991	10.76	0.66	0.61	0.09	1.67	0.92
1961	28.18	1.71	0.00	0.01	0.26	0.03	1992	10.40	0.64	0.65	0.11	2.00	0.97
1962	28.04	1.71	0.00	0.02	0.38	0.05	1993	10.04	0.62	0.69	0.08	1.57	0.90
1963	26.79	1.63	0.00	0.02	0.46	0.07	1994	10.13	0.62	0.68	0.10	1.88	0.96
1964	26.25	1.61	0.00	0.02	0.45	0.06	1995	9.98	0.61	0.71	0.12	2.20	0.99
1965	26.06	1.59	0.00	0.03	0.51	0.08	1996	9.54	0.59	0.76	0.09	1.79	0.95
1966	25.04	1.54	0.00	0.02	0.40	0.05	1997	9.41	0.58	0.77	0.10	1.92	0.97
1967	24.11	1.48	0.00	0.03	0.59	0.13	1998	9.22	0.57	0.80	0.09	1.80	0.95
1968	22.93	1.41	0.01	0.03	0.49	0.08	1999	9.23	0.57	0.79	0.06	1.22	0.71
1969	21.82	1.34	0.01	0.03	0.48	0.08	2000	9.56	0.59	0.76	0.09	1.68	0.93
1970	20.74	1.27	0.02	0.02	0.44	0.06	2001	9.38	0.58	0.78	0.07	1.30	0.77
1971	19.84	1.22	0.03	0.02	0.39	0.05	2002	9.23	0.57	0.79	0.05	1.02	0.52
1972	19.34	1.19	0.03	0.04	0.73	0.22	2003	9.28	0.57	0.79	0.06	1.18	0.68
1973	18.50	1.14	0.04	0.03	0.57	0.12	2004	9.24	0.57	0.79	0.05	0.92	0.41
1974	17.86	1.10	0.05	0.04	0.82	0.31	2005	9.50	0.58	0.76	0.06	1.06	0.56
1975	17.19	1.06	0.07	0.04	0.79	0.28	2006	9.57	0.59	0.75	0.04	0.79	0.28
1976	16.61	1.02	0.09	0.05	0.87	0.36	2007	9.86	0.61	0.72	0.05	0.91	0.40
1977	15.63	0.96	0.13	0.05	0.97	0.47	2008	10.16	0.62	0.68	0.04	0.84	0.33
1978	15.08	0.93	0.16	0.06	1.23	0.71	2009	10.09	0.62	0.69	0.06	1.14	0.63
1979	14.68	0.90	0.18	0.06	1.14	0.64	2010	9.82	0.60	0.71	0.05	0.96	0.46

Table 18.1.--Results of production model sensitivity analysis under alternative Catch Scenario IV and CPUE Scenario I.

Year	Mean Biomass (B, klb)	Median Relative Biomass (B/BMSY)	Probability of Being Overfished	Mean Harvest Rate (H)	Median Relative Harvest Rate (H/HMSY)	Probability of Overfishing	Year	Mean Biomass (B, klb)	Median Relative Biomass (B/BMSY)	Probability of Being Overfished	Mean Harvest Rate (H)	Median Relative Harvest Rate (H/HMSY)	Probability of Overfishing
1949	6.47	1.19	0.01	0.06	0.96	0.46	1980	6.11	1.11	0.04	0.04	0.71	0.20
1950	6.73	1.23	0.01	0.05	0.80	0.27	1981	5.97	1.09	0.04	0.06	0.92	0.42
1951	7.12	1.30	0.01	0.05	0.83	0.31	1982	5.74	1.04	0.06	0.06	1.02	0.53
1952	7.59	1.38	0.00	0.05	0.78	0.26	1983	5.56	1.01	0.07	0.08	1.31	0.78
1953	8.01	1.45	0.00	0.04	0.60	0.11	1984	5.29	0.96	0.10	0.07	1.16	0.67
1954	8.59	1.55	0.00	0.03	0.57	0.09	1985	5.38	0.98	0.08	0.10	1.68	0.93
1955	9.10	1.64	0.00	0.03	0.44	0.04	1986	5.45	0.99	0.08	0.10	1.71	0.93
1956	9.35	1.68	0.00	0.03	0.55	0.08	1987	5.69	1.03	0.05	0.11	1.86	0.96
1957	9.53	1.71	0.00	0.04	0.62	0.12	1988	5.85	1.06	0.05	0.11	1.74	0.94
1958	9.48	1.69	0.00	0.03	0.41	0.04	1989	5.75	1.04	0.06	0.11	1.75	0.94
1959	9.60	1.70	0.00	0.03	0.41	0.04	1990	5.43	0.98	0.09	0.09	1.50	0.87
1960	9.71	1.72	0.00	0.02	0.30	0.02	1991	5.16	0.93	0.13	0.07	1.13	0.64
1961	9.89	1.76	0.00	0.02	0.24	0.02	1992	5.00	0.91	0.16	0.08	1.30	0.77
1962	9.97	1.79	0.00	0.02	0.33	0.02	1993	4.87	0.88	0.19	0.06	0.96	0.46
1963	9.66	1.73	0.00	0.02	0.40	0.04	1994	4.93	0.90	0.17	0.07	1.12	0.63
1964	9.57	1.72	0.00	0.02	0.38	0.03	1995	4.91	0.89	0.17	0.08	1.31	0.77
1965	9.63	1.73	0.00	0.03	0.42	0.04	1996	4.77	0.86	0.21	0.07	1.08	0.59
1966	9.38	1.69	0.00	0.02	0.35	0.03	1997	4.74	0.86	0.21	0.07	1.13	0.63
1967	9.14	1.65	0.00	0.03	0.46	0.05	1998	4.70	0.85	0.22	0.07	1.13	0.63
1968	8.82	1.59	0.00	0.02	0.39	0.03	1999	4.76	0.86	0.21	0.05	0.81	0.29
1969	8.50	1.53	0.00	0.02	0.37	0.03	2000	4.96	0.90	0.17	0.07	1.12	0.62
1970	8.17	1.48	0.00	0.02	0.35	0.03	2001	4.92	0.89	0.18	0.06	0.95	0.45
1971	7.90	1.43	0.00	0.02	0.31	0.02	2002	4.87	0.88	0.19	0.05	0.79	0.28
1972	7.78	1.41	0.00	0.03	0.53	0.08	2003	4.92	0.89	0.18	0.05	0.89	0.38
1973	7.53	1.37	0.01	0.02	0.40	0.04	2004	4.93	0.89	0.17	0.05	0.75	0.23
1974	7.35	1.33	0.01	0.03	0.55	0.08	2005	5.10	0.92	0.14	0.05	0.86	0.35
1975	7.15	1.30	0.01	0.03	0.56	0.09	2006	5.17	0.94	0.13	0.04	0.66	0.16
1976	7.00	1.27	0.01	0.04	0.66	0.16	2007	5.34	0.97	0.11	0.05	0.74	0.23
1977	6.63	1.20	0.02	0.05	0.74	0.22	2008	5.52	1.00	0.09	0.04	0.64	0.14
1978	6.44	1.17	0.03	0.05	0.85	0.35	2009	5.50	1.00	0.09	0.05	0.83	0.32
1979	6.33	1.15	0.03	0.05	0.77	0.26	2010	5.37	0.97	0.12	0.04	0.71	0.22

Table 18.2.--Results of production model sensitivity analysis under alternative Catch Scenario IV and CPUE Scenario II.

Year	Mean Biomass (B, klb)	Median Relative Biomass (B/BMSY)	Probability of Being Overfished	Mean Harvest Rate (H)	Median Relative Harvest Rate (H/HMSY)	Probability of Overfishing
1949	6.53	1.20	0.01	0.06	0.98	0.47
1950	6.79	1.24	0.01	0.05	0.81	0.27
1951	7.18	1.30	0.01	0.05	0.84	0.31
1952	7.65	1.39	0.00	0.05	0.79	0.26
1953	8.08	1.46	0.00	0.04	0.61	0.12
1954	8.68	1.57	0.00	0.03	0.58	0.10
1955	9.21	1.65	0.00	0.03	0.45	0.05
1956	9.45	1.70	0.00	0.03	0.56	0.09
1957	9.64	1.72	0.00	0.04	0.62	0.13
1958	9.62	1.71	0.00	0.03	0.41	0.04
1959	9.72	1.73	0.00	0.03	0.42	0.04
1960	9.84	1.75	0.00	0.02	0.31	0.02
1961	10.03	1.79	0.00	0.01	0.25	0.02
1962	10.11	1.81	0.00	0.02	0.33	0.03
1963	9.76	1.75	0.00	0.02	0.41	0.04
1964	9.68	1.74	0.00	0.02	0.39	0.03
1965	9.73	1.75	0.00	0.03	0.43	0.04
1966	9.48	1.71	0.00	0.02	0.35	0.03
1967	9.22	1.66	0.00	0.03	0.47	0.05
1968	8.89	1.60	0.00	0.02	0.40	0.04
1969	8.56	1.55	0.00	0.02	0.38	0.03
1970	8.22	1.49	0.00	0.02	0.35	0.03
1971	7.94	1.44	0.00	0.02	0.31	0.02
1972	7.82	1.42	0.00	0.03	0.54	0.08
1973	7.53	1.36	0.01	0.02	0.41	0.04
1974	7.34	1.33	0.01	0.03	0.56	0.09
1975	7.13	1.29	0.01	0.03	0.57	0.09
1976	6.95	1.26	0.01	0.04	0.68	0.17
1977	6.57	1.19	0.02	0.05	0.77	0.24
1978	6.36	1.15	0.03	0.05	0.89	0.37
1979	6.23	1.13	0.03	0.05	0.81	0.28
1980	6.00	1.09	0.04	0.04	0.75	0.22
1981	5.84	1.06	0.05	0.06	0.97	0.46
1982	5.59	1.02	0.07	0.06	1.08	0.58
1983	5.40	0.98	0.09	0.08	1.39	0.83
1984	5.10	0.93	0.13	0.07	1.23	0.73
1985	5.17	0.94	0.11	0.11	1.79	0.95
1986	5.22	0.95	0.10	0.11	1.83	0.96
1987	5.42	0.98	0.08	0.12	2.00	0.98
1988	5.55	1.01	0.07	0.11	1.88	0.96
1989	5.43	0.98	0.08	0.11	1.91	0.96
1990	5.11	0.92	0.13	0.10	1.64	0.92
1991	4.82	0.87	0.19	0.07	1.24	0.72
1992	4.66	0.84	0.23	0.09	1.43	0.84
1993	4.52	0.82	0.27	0.06	1.06	0.56
1994	4.58	0.83	0.25	0.07	1.24	0.73
1995	4.55	0.82	0.25	0.09	1.45	0.85
1996	4.40	0.80	0.30	0.07	1.20	0.69
1997	4.37	0.79	0.31	0.08	1.26	0.74
1998	4.32	0.78	0.33	0.08	1.26	0.74
1999	4.37	0.79	0.32	0.05	0.90	0.39
2000	4.54	0.82	0.26	0.07	1.25	0.74
2001	4.50	0.81	0.27	0.06	1.06	0.56
2002	4.45	0.81	0.29	0.05	0.89	0.37
2003	4.49	0.81	0.28	0.06	1.00	0.49
2004	4.50	0.81	0.27	0.05	0.84	0.32
2005	4.65	0.84	0.23	0.06	0.96	0.45
2006	4.71	0.85	0.22	0.04	0.74	0.22
2007	4.88	0.88	0.18	0.05	0.83	0.31
2008	5.04	0.91	0.15	0.04	0.71	0.20
2009	5.03	0.91	0.15	0.06	0.93	0.42
2010	4.90	0.89	0.19	0.05	0.80	0.29

Table 18.3.--Results of production model sensitivity analysis under alternative Catch Scenario IV and CPUE Scenario III.

Year	Mean Biomass (B, klb)	Median Relative Biomass (B/BMSY)	Probability of Being Overfished	Mean Harvest Rate (H)	Median Relative Harvest Rate (H/HMSY)	Probability of Overfishing
1949	7.19	1.30	0.00	0.05	0.95	0.43
1950	7.55	1.36	0.00	0.04	0.78	0.24
1951	7.99	1.43	0.00	0.04	0.81	0.28
1952	8.50	1.52	0.00	0.04	0.76	0.24
1953	8.91	1.59	0.00	0.03	0.59	0.11
1954	9.51	1.69	0.00	0.03	0.56	0.09
1955	10.00	1.77	0.00	0.02	0.44	0.05
1956	10.16	1.80	0.00	0.03	0.56	0.09
1957	10.27	1.82	0.00	0.04	0.63	0.14
1958	10.17	1.79	0.00	0.02	0.42	0.04
1959	10.19	1.79	0.00	0.02	0.43	0.05
1960	10.22	1.79	0.00	0.02	0.32	0.03
1961	10.30	1.81	0.00	0.01	0.26	0.02
1962	10.27	1.82	0.00	0.02	0.35	0.03
1963	9.82	1.74	0.00	0.02	0.43	0.05
1964	9.64	1.71	0.00	0.02	0.42	0.04
1965	9.58	1.70	0.00	0.03	0.46	0.06
1966	9.22	1.64	0.00	0.02	0.39	0.04
1967	8.87	1.58	0.00	0.03	0.52	0.08
1968	8.46	1.51	0.00	0.03	0.45	0.05
1969	8.05	1.44	0.01	0.02	0.43	0.05
1970	7.66	1.37	0.01	0.02	0.41	0.04
1971	7.33	1.31	0.01	0.02	0.36	0.03
1972	7.15	1.28	0.02	0.04	0.63	0.14
1973	6.84	1.22	0.02	0.03	0.49	0.06
1974	6.61	1.18	0.03	0.04	0.67	0.16
1975	6.38	1.14	0.04	0.04	0.68	0.17
1976	6.17	1.10	0.05	0.05	0.82	0.30
1977	5.79	1.04	0.07	0.05	0.93	0.42
1978	5.57	0.99	0.09	0.06	1.08	0.59
1979	5.43	0.97	0.11	0.05	0.99	0.49
1980	5.19	0.93	0.14	0.05	0.92	0.41
1981	5.04	0.90	0.17	0.07	1.19	0.70
1982	4.81	0.86	0.21	0.07	1.34	0.81
1983	4.63	0.83	0.26	0.10	1.73	0.95
1984	4.36	0.78	0.34	0.09	1.54	0.91
1985	4.42	0.79	0.32	0.12	2.23	0.99
1986	4.44	0.80	0.31	0.13	2.29	1.00
1987	4.60	0.83	0.26	0.14	2.51	1.00
1988	4.68	0.84	0.24	0.13	2.38	1.00
1989	4.55	0.81	0.28	0.13	2.42	1.00
1990	4.24	0.76	0.38	0.12	2.11	0.99
1991	3.98	0.71	0.47	0.09	1.60	0.92
1992	3.84	0.69	0.53	0.10	1.85	0.97
1993	3.70	0.66	0.58	0.08	1.38	0.83
1994	3.73	0.67	0.57	0.09	1.62	0.93
1995	3.70	0.66	0.58	0.11	1.90	0.97
1996	3.54	0.63	0.64	0.09	1.59	0.92
1997	3.50	0.63	0.66	0.09	1.67	0.94
1998	3.44	0.62	0.68	0.09	1.69	0.94
1999	3.46	0.62	0.67	0.07	1.22	0.72
2000	3.58	0.64	0.63	0.09	1.70	0.94
2001	3.51	0.63	0.65	0.08	1.45	0.87
2002	3.45	0.62	0.68	0.07	1.23	0.72
2003	3.46	0.62	0.67	0.08	1.38	0.83
2004	3.44	0.61	0.68	0.07	1.17	0.68
2005	3.53	0.63	0.65	0.08	1.35	0.81
2006	3.54	0.63	0.64	0.06	1.05	0.55
2007	3.64	0.65	0.60	0.07	1.19	0.69
2008	3.73	0.67	0.56	0.06	1.03	0.53
2009	3.70	0.66	0.57	0.08	1.35	0.80
2010	3.58	0.64	0.62	0.07	1.17	0.66

Table 19.1.--Projection results showing the total allowable commercial catches (1000 pounds) of Deep7 bottomfish in fishing years 2012 and 2013 that would produce probabilities of overfishing in 2012 of 0%, 5%, 10%, …, 50% and greater under Baseline Catch Scenario II and Baseline CPUE Scenario I.

Catch Scenario II and CPUE Scenario I				
Probability of Overfishing Deep7 Bottomfish in the Main Hawaiian Islands in Fishing Year 2012	Total Allowable Commercial Catch (1000 pounds) of Deep7 Bottomfish in Fishing Years 2012 and 2013	Probability of Overfishing Deep7 Bottomfish in the Main Hawaiian Islands in Fishing Year 2013	Median Ratio of Deep7 Bottomfish Exploitable Biomass in 2013 to BMSY	Probability That Deep7 Bottomfish Biomass in 2013 Is Greater Than the Minimum Stock Size Threshold (0.7*BMSY)
0	11	0	1.05	0.92
0.05	147	0.02	1.03	0.91
0.10	197	0.09	1.02	0.90
0.15	229	0.14	1.02	0.90
0.20	255	0.19	1.01	0.89
0.25	277	0.24	1.01	0.89
0.30	299	0.29	1.01	0.89
0.35	319	0.34	1.00	0.88
0.40	341	0.39	1.00	0.88
0.45	361	0.45	1.00	0.88
0.50	383	0.50	0.99	0.88
0.55	407	0.56	0.99	0.87
0.60	429	0.60	0.99	0.87
0.65	455	0.66	0.98	0.87
0.70	481	0.71	0.98	0.86
0.75	513	0.76	0.97	0.86
0.80	549	0.81	0.97	0.85
0.85	597	0.86	0.96	0.84
0.90	665	0.91	0.95	0.83
0.95	783	0.96	0.93	0.81
0.99	1001	0.99	0.90	0.77

Table 19.2.--Projection results showing the total allowable commercial catches (1000 pounds) of Deep7 bottomfish in fishing years 2012 and 2013 that would produce probabilities of overfishing in 2012 of 0%, 5%, 10%, …, 50% and greater under Baseline Catch Scenario II and alternative CPUE Scenario II.

Catch Scenario II and CPUE Scenario II				
Probability of Overfishing Deep7 Bottomfish in the Main Hawaiian Islands in Fishing Year 2012	Total Allowable Commercial Catch (1000 pounds) of Deep7 Bottomfish in Fishing Years 2012 and 2013	Probability of Overfishing Deep7 Bottomfish in the Main Hawaiian Islands in Fishing Year 2013	Median Ratio of Deep7 Bottomfish Exploitable Biomass in 2013 to BMSY	Probability That Deep7 Bottomfish Biomass in 2013 Is Greater Than the Minimum Stock Size Threshold (0.7*BMSY)
0	9	0	0.97	0.86
0.05	135	0.05	0.95	0.84
0.10	177	0.10	0.94	0.83
0.15	205	0.15	0.94	0.83
0.20	227	0.19	0.93	0.83
0.25	249	0.24	0.93	0.82
0.30	265	0.29	0.93	0.82
0.35	285	0.34	0.92	0.81
0.40	303	0.39	0.92	0.81
0.45	319	0.44	0.92	0.81
0.50	339	0.49	0.92	0.81
0.55	357	0.54	0.91	0.80
0.60	377	0.59	0.91	0.80
0.65	399	0.64	0.91	0.79
0.70	423	0.69	0.90	0.79
0.75	451	0.74	0.90	0.78
0.80	483	0.79	0.89	0.78
0.85	525	0.84	0.89	0.77
0.90	581	0.90	0.88	0.75
0.95	681	0.95	0.86	0.73
0.99	1001	0.99	0.82	0.66

Table 19.3.--Projection results showing the total allowable commercial catches (1000 pounds) of Deep7 bottomfish in fishing years 2012 and 2013 that would produce probabilities of overfishing in 2012 of 0%, 5%, 10%, …, 50% and greater under Baseline Catch Scenario II and alternative CPUE Scenario III.

Catch Scenario II and CPUE Scenario III				
Probability of Overfishing Deep7 Bottomfish in the Main Hawaiian Islands in Fishing Year 2012	Total Allowable Commercial Catch (1000 pounds) of Deep7 Bottomfish in Fishing Years 2012 and 2013	Probability of Overfishing Deep7 Bottomfish in the Main Hawaiian Islands in Fishing Year 2013	Median Ratio of Deep7 Bottomfish Exploitable Biomass in 2013 to BMSY	Probability That Deep7 Bottomfish Biomass in 2013 Is Greater Than the Minimum Stock Size Threshold (0.7*BMSY)
0	1	0	0.69	0.44
0.05	75	0.05	0.68	0.42
0.10	109	0.10	0.68	0.41
0.15	131	0.15	0.67	0.41
0.20	147	0.19	0.67	0.40
0.25	163	0.24	0.67	0.40
0.30	177	0.29	0.67	0.39
0.35	189	0.34	0.67	0.39
0.40	201	0.38	0.66	0.39
0.45	215	0.44	0.66	0.38
0.50	227	0.48	0.66	0.38
0.55	241	0.53	0.66	0.37
0.60	255	0.58	0.66	0.37
0.65	271	0.64	0.65	0.37
0.70	287	0.69	0.65	0.36
0.75	307	0.74	0.65	0.36
0.80	329	0.79	0.65	0.35
0.85	357	0.84	0.64	0.34
0.90	397	0.89	0.64	0.33
0.95	459	0.94	0.63	0.32
1.00	683	0.99	0.60	0.27

Table 20.1.--Sensitivity analysis for projection results showing the total allowable commercial catches (1000 pounds) of Deep7 bottomfish in fishing years 2012 and 2013 that would produce probabilities of overfishing in 2012 of 0%, 5%, 10%, …, 50% and greater under Alternative Catch Scenario IV and Alternative CPUE Scenario I.

Catch Scenario IV and CPUE Scenario I				
Probability of Overfishing Deep7 Bottomfish in the Main Hawaiian Islands in Fishing Year 2012	Total Allowable Commercial Catch (1000 pounds) of Deep7 Bottomfish in Fishing Years 2012 and 2013	Probability of Overfishing Deep7 Bottomfish in the Main Hawaiian Islands in Fishing Year 2013	Median Ratio of Deep7 Bottomfish Exploitable Biomass in 2013 to BMSY	Probability That Deep7 Bottomfish Biomass in 2013 Is Greater Than the Minimum Stock Size Threshold (0.7*BMSY)
0	13	0.01	1.08	0.94
0.05	125	0.05	1.06	0.93
0.10	163	0.10	1.06	0.92
0.15	191	0.15	1.05	0.92
0.20	211	0.20	1.05	0.91
0.25	231	0.25	1.04	0.91
0.30	247	0.30	1.04	0.91
0.35	265	0.35	1.04	0.91
0.40	281	0.40	1.03	0.91
0.45	297	0.46	1.03	0.90
0.50	313	0.51	1.03	0.90
0.55	331	0.56	1.02	0.90
0.60	351	0.61	1.02	0.89
0.65	371	0.66	1.01	0.89
0.70	393	0.72	1.01	0.89
0.75	417	0.76	1.01	0.88
0.80	447	0.82	1.00	0.88
0.85	483	0.86	0.99	0.87
0.90	533	0.91	0.98	0.86
0.95	617	0.96	0.97	0.85
1.00	885	1.00	0.91	0.79

Table 20.2.--Sensitivity analysis for projection results showing the total allowable commercial catches (1000 pounds) of Deep7 bottomfish in fishing years 2012 and 2013 that would produce probabilities of overfishing in 2012 of 0%, 5%, 10%, …, 50% and greater under Alternative Catch Scenario IV and alternative CPUE Scenario II.

Catch Scenario IV and CPUE Scenario II				
Probability of Overfishing Deep7 Bottomfish in the Main Hawaiian Islands in Fishing Year 2012	Total Allowable Commercial Catch (1000 pounds) of Deep7 Bottomfish in Fishing Years 2012 and 2013	Probability of Overfishing Deep7 Bottomfish in the Main Hawaiian Islands in Fishing Year 2013	Median Ratio of Deep7 Bottomfish Exploitable Biomass in 2013 to BMSY	Probability That Deep7 Bottomfish Biomass in 2013 Is Greater Than the Minimum Stock Size Threshold (0.7*BMSY)
0	9	0.01	1.00	0.88
0.05	109	0.05	0.98	0.87
0.10	143	0.10	0.98	0.86
0.15	165	0.14	0.97	0.85
0.20	185	0.20	0.97	0.85
0.25	201	0.24	0.96	0.85
0.30	217	0.29	0.96	0.84
0.35	233	0.35	0.96	0.84
0.40	245	0.39	0.96	0.84
0.45	261	0.44	0.95	0.83
0.50	275	0.49	0.95	0.83
0.55	291	0.54	0.95	0.83
0.60	307	0.59	0.94	0.82
0.65	325	0.64	0.94	0.82
0.70	345	0.69	0.94	0.81
0.75	367	0.75	0.93	0.81
0.80	393	0.80	0.93	0.80
0.85	425	0.85	0.92	0.80
0.90	471	0.90	0.91	0.79
0.95	547	0.95	0.90	0.77
1.00	781	1.00	0.85	0.70

Table 20.3.--Sensitivity analysis for projection results showing the total allowable commercial catches (1000 pounds) of Deep7 bottomfish in fishing years 2012 and 2013 that would produce probabilities of overfishing in 2012 of 0%, 5%, 10%, …, 50% and greater under Alternative Catch Scenario IV and Alternative CPUE Scenario III.

Catch Scenario IV and CPUE Scenario III				
Probability of Overfishing Deep7 Bottomfish in the Main Hawaiian Islands in Fishing Year 2012	Total Allowable Commercial Catch (1000 pounds) of Deep7 Bottomfish in Fishing Years 2012 and 2013	Probability of Overfishing Deep7 Bottomfish in the Main Hawaiian Islands in Fishing Year 2013	Median Ratio of Deep7 Bottomfish Exploitable Biomass in 2013 to BMSY	Probability That Deep7 Bottomfish Biomass in 2013 Is Greater Than the Minimum Stock Size Threshold (0.7*BMSY)
0	3	0	0.72	0.50
0.05	69	0.05	0.71	0.47
0.10	93	0.10	0.70	0.47
0.15	109	0.14	0.70	0.46
0.20	121	0.19	0.70	0.45
0.25	133	0.24	0.70	0.45
0.30	145	0.30	0.69	0.44
0.35	155	0.35	0.69	0.44
0.40	165	0.40	0.69	0.44
0.45	175	0.45	0.69	0.43
0.50	183	0.49	0.69	0.43
0.55	193	0.54	0.68	0.43
0.60	205	0.59	0.68	0.42
0.65	217	0.64	0.68	0.42
0.70	231	0.69	0.68	0.41
0.75	245	0.74	0.67	0.41
0.80	263	0.79	0.67	0.40
0.85	283	0.84	0.67	0.39
0.90	313	0.90	0.66	0.38
0.95	361	0.95	0.65	0.37
1.00	511	0.99	0.62	0.32

Table 21.--Results of sensitivity analyses under the Baseline Catch Scenario II and Baseline CPUE Scenario I for the effects of changing the error distribution for unreported catch, prior mean for carrying capacity, prior mean for intrinsic growth rate, prior mean for the proportion of carrying capacity in 1949, and the proportion of the 2011 Deep7 total allowable catch that was captured on estimates of total allowable commercial catch and stock status indicators for Deep7 bottomfish.

	Total Allowable Catches (1000 lbs) and Status Indicators for Deep7 Bottomfish					
Sensitivity Analysis	TAC to produce a 25% chance of overfishing in 2012	TAC to produce a 50% chance of overfishing in 2012	Median relative exploitable biomass in 2012 (B_{2013}/B_{MSY})	Median relative harvest rate in 2011 (H_{2013}/H_{MSY})	Probability that stock would be overfished in 2012	Probability that overfishing would occur in 2011
Baseline Model	277	383	0.97	0.69	0.12	0.20
Catch Error Set to 1%	277	376	0.97	0.68	0.11	0.19
Catch Error Set to 50%	275	383	0.99	0.67	0.11	0.20
Biased Catch Error Set to -30%	275	381	0.98	0.69	0.12	0.21
Biased Catch Error Set to +30%	289	393	0.98	0.67	0.11	0.18
Prior Mean of K Reduced by 50%	289	375	0.97	0.70	0.11	0.18
Prior Mean of K Increased by 100%	291	391	0.99	0.66	0.11	0.23
Prior Mean of R Reduced by 50%	161	231	0.87	1.09	0.24	0.57
Prior Mean of R Increased by 100%	391	518	1.16	0.50	0.03	0.07

Table 21.--Continued. Results of sensitivity analyses for the effects of changing the error distribution for unreported catch, prior mean for carrying capacity, prior mean for intrinsic growth rate, prior mean for the proportion of carrying capacity in 1949, and the proportion of the 2011 Deep7 total allowable catch that was captured.

	Total Allowable Catches (1000 lbs) and Status Indicators for Deep7 Bottomfish					
Sensitivity Analysis	TAC to produce a 25% chance of overfishing in 2012	TAC to produce a 50% chance of overfishing in 2012	Median relative exploitable biomass in 2012 (B_{2013}/B_{MSY})	Median relative harvest rate in 2011 (H_{2013}/H_{MSY})	Probability that stock would be overfished in 2012	Probability that overfishing would occur in 2011
Baseline Model	277	383	0.97	0.69	0.12	0.20
Prior Mean of Proportion of Carrying Capacity in 1949 Reduced by 50%	195	267	0.62	0.98	0.65	0.48
Prior Mean of Proportion of Carrying Capacity in 1949 Increased by 100%	277	421	1.34	0.63	0.01	0.23
120% of 2011 TAC Captured	277	381	0.96	0.82	0.13	0.33
80% of 2011 TAC Captured	283	387	0.97	0.55	0.11	0.11

Table 22.--Summary of the projected total allowable catches of Deep7 bottomfish (thousand lbs) in 2012 that would produce specified probabilities of overfishing P* ranging from 0% to 50% for scenario-averaged values along with the corresponding P* values under each scenario using the hypothetical scenario probabilities listed in Table 21.2.

	Probability of Deep7 Overfishing P* in 2012 Averaged Across Catch and CPUE Scenarios												
	Catch and CPUE Scenario	Catch I CPUE I	Catch I CPUE II	Catch I CPUE III	Catch II CPUE I	Catch II CPUE II	Catch II CPUE III	Catch III CPUE I	Catch III CPUE II	Catch III CPUE III	Catch IV CPUE I	Catch IV CPUE II	Catch IV CPUE III
	Scenario Probability	0.025	0.020	0.005	0.400	0.320	0.080	0.050	0.040	0.010	0.025	0.020	0.005
Deep7 Total Allowable Catch (thousand lbs)	Scenario-Averaged Value of P*	P* for Catch I CPUE I	P* for Catch I CPUE II	P* for Catch I CPUE III	P* for Catch II CPUE I	P* for Catch II CPUE II	P* for Catch II CPUE III	P* for Catch III CPUE I	P* for Catch III CPUE II	P* for Catch III CPUE III	P* for Catch IV CPUE I	P* for Catch IV CPUE II	P* for Catch IV CPUE III
9	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01
123	0.05	0.04	0.06	0.20	0.03	0.04	0.13	0.04	0.06	0.19	0.05	0.07	0.20
165	0.10	0.10	0.14	0.40	0.06	0.08	0.26	0.10	0.14	0.40	0.10	0.15	0.40
193	0.15	0.16	0.22	0.54	0.09	0.13	0.36	0.16	0.22	0.55	0.15	0.22	0.55
215	0.20	0.22	0.30	0.64	0.13	0.17	0.45	0.22	0.30	0.65	0.21	0.29	0.64
237	0.25	0.29	0.37	0.72	0.16	0.22	0.53	0.29	0.39	0.73	0.27	0.37	0.72
255	0.30	0.34	0.44	0.77	0.20	0.27	0.60	0.35	0.46	0.79	0.32	0.43	0.78
275	0.35	0.40	0.51	0.83	0.24	0.32	0.66	0.41	0.53	0.85	0.38	0.50	0.83
293	0.40	0.46	0.57	0.86	0.29	0.37	0.71	0.47	0.60	0.88	0.44	0.55	0.87
311	0.45	0.52	0.62	0.89	0.33	0.42	0.76	0.53	0.65	0.91	0.49	0.61	0.90
331	0.50	0.58	0.68	0.92	0.38	0.48	0.80	0.59	0.71	0.93	0.55	0.66	0.92
353	0.55	0.64	0.73	0.94	0.43	0.53	0.84	0.65	0.76	0.95	0.60	0.72	0.94
373	0.60	0.68	0.77	0.95	0.48	0.59	0.87	0.70	0.81	0.97	0.65	0.76	0.96
397	0.65	0.74	0.82	0.97	0.53	0.64	0.90	0.76	0.85	0.98	0.71	0.81	0.97
423	0.70	0.78	0.86	0.98	0.59	0.70	0.93	0.80	0.89	0.98	0.76	0.85	0.98
453	0.75	0.83	0.89	0.98	0.65	0.75	0.94	0.85	0.92	0.99	0.81	0.88	0.99
487	0.80	0.87	0.92	0.99	0.71	0.80	0.96	0.89	0.94	0.99	0.85	0.91	0.99
533	0.85	0.91	0.95	1.00	0.78	0.86	0.98	0.93	0.97	1.00	0.90	0.94	1.00
593	0.90	0.95	0.97	1.00	0.84	0.91	0.99	0.96	0.98	1.00	0.94	0.97	1.00
699	0.95	0.98	0.99	1.00	0.92	0.96	1.00	0.99	1.00	1.00	0.98	0.99	1.00
1001	0.99	1.00	1.00	1.00	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Table 23.1.--Decision table showing consequences of setting TACs for Deep7 bottomfish (1000 pounds) to produce a low probability of overfishing of P* = 0.25 in fishing year 2012 under CPUE Scenarios I, II, and III versus the true state of nature, along with the probabilities of overfishing in 2012 (row 1) and 2013 (row 2), relative exploitable biomasses in 2013 (row 3), and probabilities of depletion of Deep7 bottomfish (row 4) based on selected 2-year TAC alternatives in fishing years 2012-2013.

P* = 0.25	True State of Nature		
Model Catch and CPUE Scenario Used to Set TAC	Catch II CPUE I	Catch II CPUE II	Catch II CPUE III
Catch II CPUE I TAC = 277	$Pr(H_{2012}>H_{MSY}) = 0.25$ $Pr(H_{2013}>H_{MSY}) = 0.24$ $B_{2013}/B_{MSY} = 1.00$ $Pr(B_{2013}<0.7B_{MSY}) = 0.11$	$Pr(H_{2012}>H_{MSY}) = 0.33$ $Pr(H_{2013}>H_{MSY}) = 0.32$ $B_{2013}/B_{MSY} = 0.91$ $Pr(B_{2013}<0.7B_{MSY}) = 0.18$	$Pr(H_{2012}>H_{MSY}) = 0.67$ $Pr(H_{2013}>H_{MSY}) = 0.65$ $B_{2013}/B_{MSY} = 0.62$ $Pr(B_{2013}<0.7B_{MSY}) = 0.63$
Catch II CPUE II TAC = 249	$Pr(H_{2012}>H_{MSY}) = 0.19$ $Pr(H_{2013}>H_{MSY}) = 0.18$ $B_{2013}/B_{MSY} = 1.00$ $Pr(B_{2013}<0.7B_{MSY}) = 0.11$	$Pr(H_{2012}>H_{MSY}) = 0.25$ $Pr(H_{2013}>H_{MSY}) = 0.24$ $B_{2013}/B_{MSY} = 0.91$ $Pr(B_{2013}<0.7B_{MSY}) = 0.18$	$Pr(H_{2012}>H_{MSY}) = 0.58$ $Pr(H_{2013}>H_{MSY}) = 0.56$ $B_{2013}/B_{MSY} = 0.64$ $Pr(B_{2013}<0.7B_{MSY}) = 0.63$
Catch II CPUE III TAC = 163	$Pr(H_{2012}>H_{MSY}) = 0.06$ $Pr(H_{2013}>H_{MSY}) = 0.06$ $B_{2013}/B_{MSY} = 1.01$ $Pr(B_{2013}<0.7B_{MSY}) = 0.10$	$Pr(H_{2012}>H_{MSY}) = 0.08$ $Pr(H_{2013}>H_{MSY}) = 0.08$ $B_{2013}/B_{MSY} = 0.92$ $Pr(B_{2013}<0.7B_{MSY}) = 0.16$	$Pr(H_{2012}>H_{MSY}) = 0.25$ $Pr(H_{2013}>H_{MSY}) = 0.24$ $B_{2013}/B_{MSY} = 0.65$ $Pr(B_{2013}<0.7B_{MSY}) = 0.60$

Table 23.2.--Decision table showing consequences of setting TACs for Deep7 bottomfish (1000 pounds) to produce a high probability of overfishing of P* = 0.5 in fishing year 2012 under CPUE Scenarios I, II, and III versus the true state of nature, along with the probabilities of overfishing in 2012 (row 1) and 2013 (row 2), relative exploitable biomasses in 2013 (row 3), and probabilities of depletion of Deep7 bottomfish (row 4) based on selected 2-year TAC alternatives in fishing years 2012-2013.

P* = 0.5	True State of Nature		
Model Catch and CPUE Scenario Used to Set TAC	Catch II CPUE I	Catch II CPUE II	Catch II CPUE III
Catch II CPUE I TAC = 383	$Pr(H_{2012}>H_{MSY}) = 0.50$ $Pr(H_{2013}>H_{MSY}) = 0.50$ $B_{2013}/B_{MSY} = 0.98$ $Pr(B_{2013}<0.7B_{MSY}) = 0.12$	$Pr(H_{2012}>H_{MSY}) = 0.61$ $Pr(H_{2013}>H_{MSY}) = 0.60$ $B_{2013}/B_{MSY} = 0.89$ $Pr(B_{2013}<0.7B_{MSY}) = 0.20$	$Pr(H_{2012}>H_{MSY}) = 0.88$ $Pr(H_{2013}>H_{MSY}) = 0.88$ $B_{2013}/B_{MSY} = 0.62$ $Pr(B_{2013}<0.7B_{MSY}) = 0.66$
Catch II CPUE II TAC = 339	$Pr(H_{2012}>H_{MSY}) = 0.40$ $Pr(H_{2013}>H_{MSY}) = 0.39$ $B_{2013}/B_{MSY} = 0.99$ $Pr(B_{2013}<0.7B_{MSY}) = 0.12$	$Pr(H_{2012}>H_{MSY}) = 0.50$ $Pr(H_{2013}>H_{MSY}) = 0.49$ $B_{2013}/B_{MSY} = 0.90$ $Pr(B_{2013}<0.7B_{MSY}) = 0.19$	$Pr(H_{2012}>H_{MSY}) = 0.82$ $Pr(H_{2013}>H_{MSY}) = 0.81$ $B_{2013}/B_{MSY} = 0.62$ $Pr(B_{2013}<0.7B_{MSY}) = 0.65$
Catch II CPUE III TAC = 227	$Pr(H_{2012}>H_{MSY}) = 0.15$ $Pr(H_{2013}>H_{MSY}) = 0.14$ $B_{2013}/B_{MSY} = 1.00$ $Pr(B_{2013}<0.7B_{MSY}) = 0.10$	$Pr(H_{2012}>H_{MSY}) = 0.20$ $Pr(H_{2013}>H_{MSY}) = 0.19$ $B_{2013}/B_{MSY} = 0.91$ $Pr(B_{2013}<0.7B_{MSY}) = 0.17$	$Pr(H_{2012}>H_{MSY}) = 0.50$ $Pr(H_{2013}>H_{MSY}) = 0.48$ $B_{2013}/B_{MSY} = 0.64$ $Pr(B_{2013}<0.7B_{MSY}) = 0.62$

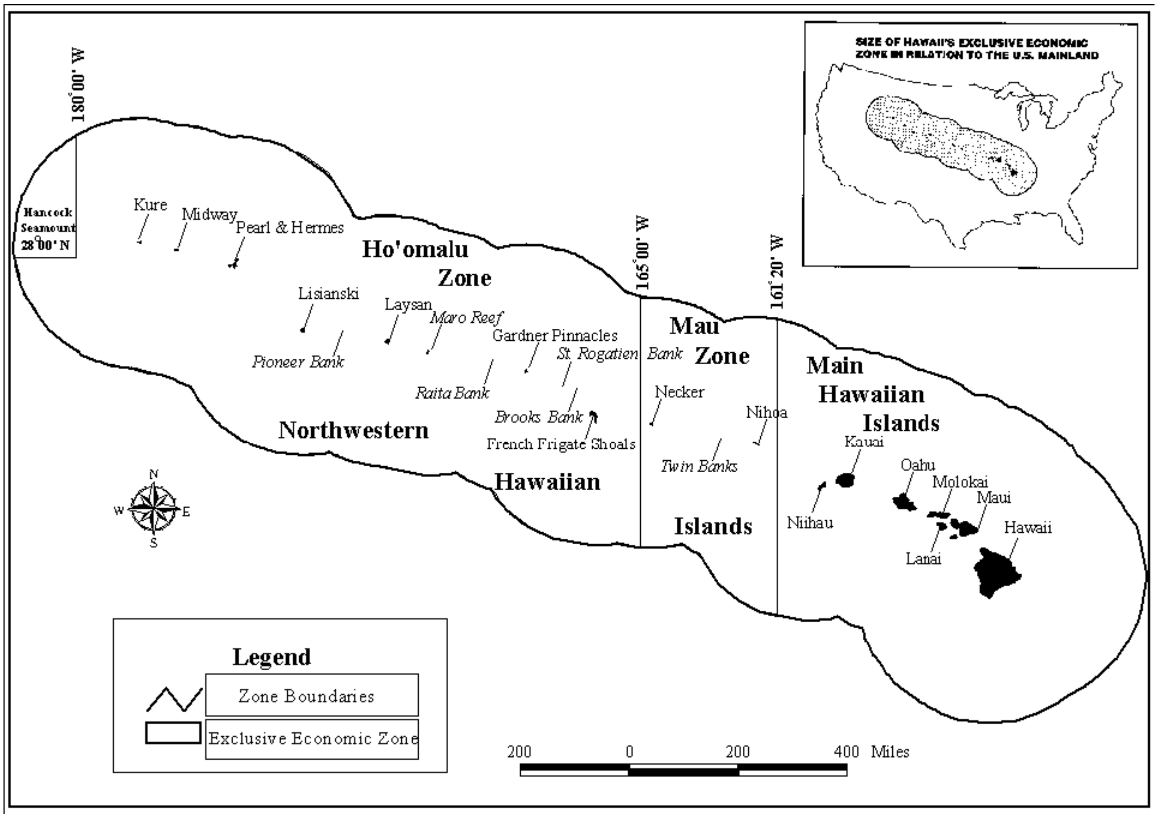


Figure 1.--Location of the three Hawaiian bottomfish fishing zones: the main Hawaiian Islands (MHI) Zone, the Mau Zone, and the Hoomalu Zone. Together, the Mau and Hoomalu Zones are known as the Northwestern Hawaiian Islands (NWHI). The current stock assessment is for the Deep7 bottomfish complex in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

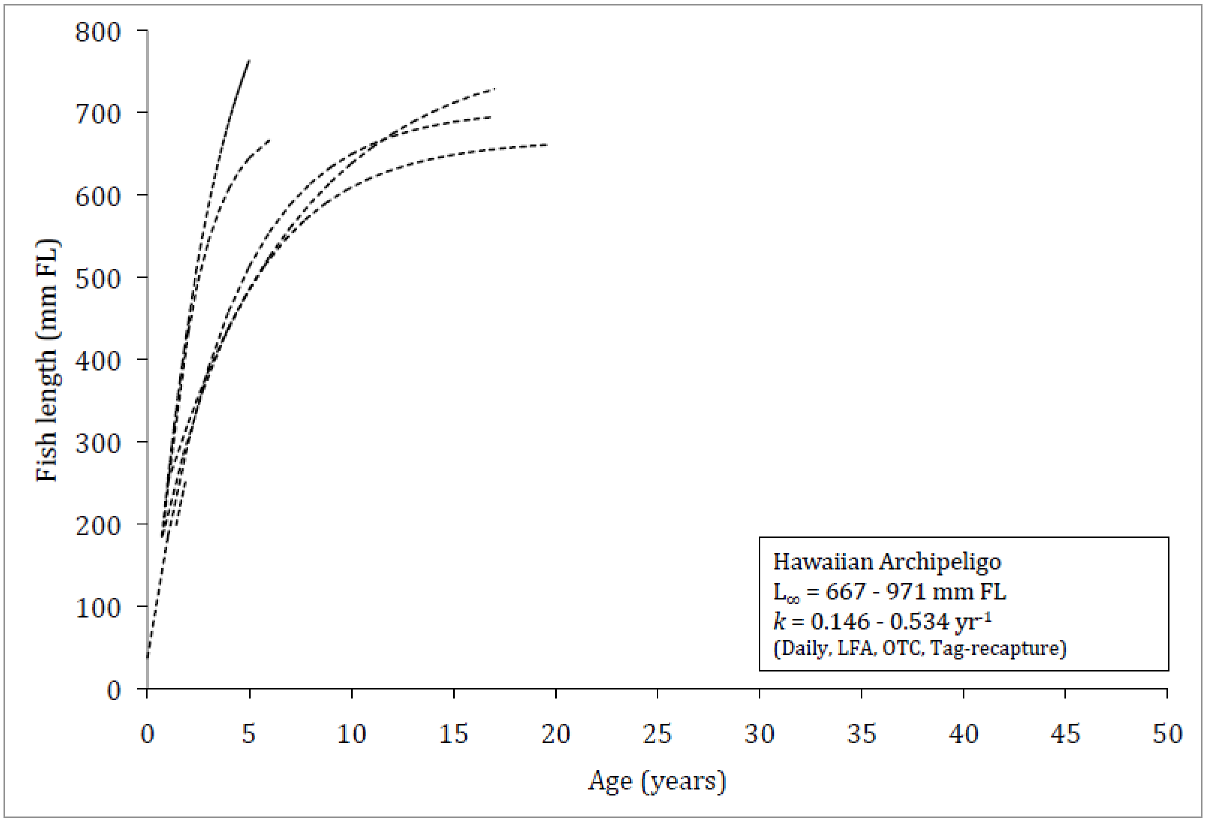


Figure 2.--Variation in growth curves showing estimates of expected size at age of the primary Deep7 bottomfish opakapaka (*Pristipomoides filamentosus*) in the Hawaiian Archipelago. Plotted von Bertalanffy growth curves were taken from a series of sources (Ralston and Miyamoto, 1983; Kikkawa, 1984; Radtke, 1987; DeMartini et al., 1994; Moffitt and Parrish, 1996; and D. Kobayahsi, PIFSC, unpubl. data).

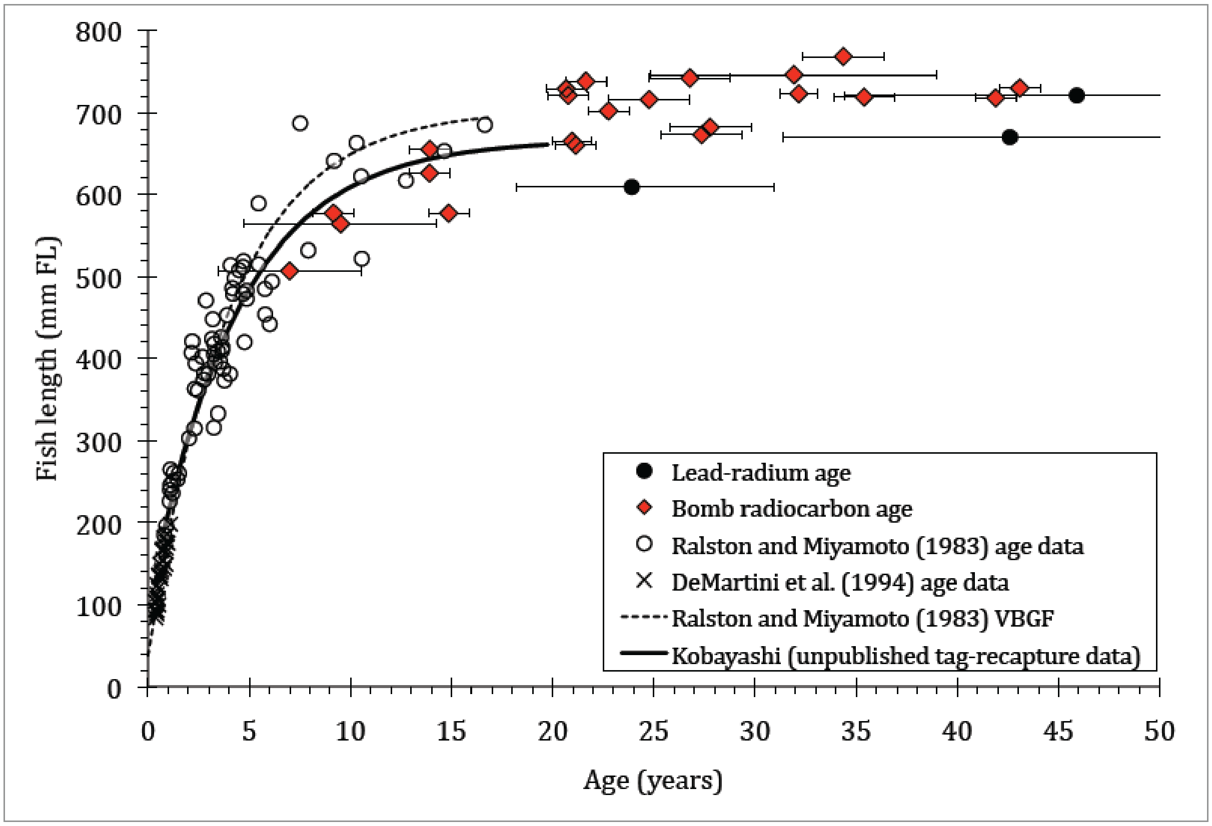


Figure 3.--Recent estimates of age at length from lead-radium and bomb radiocarbon dating for opakapaka (*Pristipomoides filamentosus*), plotted with age data and growth curves from daily growth increment analyses (Ralston and Miyamoto, 1983; DeMartini et al., 1994). The recent age determinations indicate opakapaka have a lifespan that can exceed 40 years, with one fish aged to be 43 years ± 1 year with bomb radiocarbon dating (A. Andrews, PIFSC, unpubl. data).

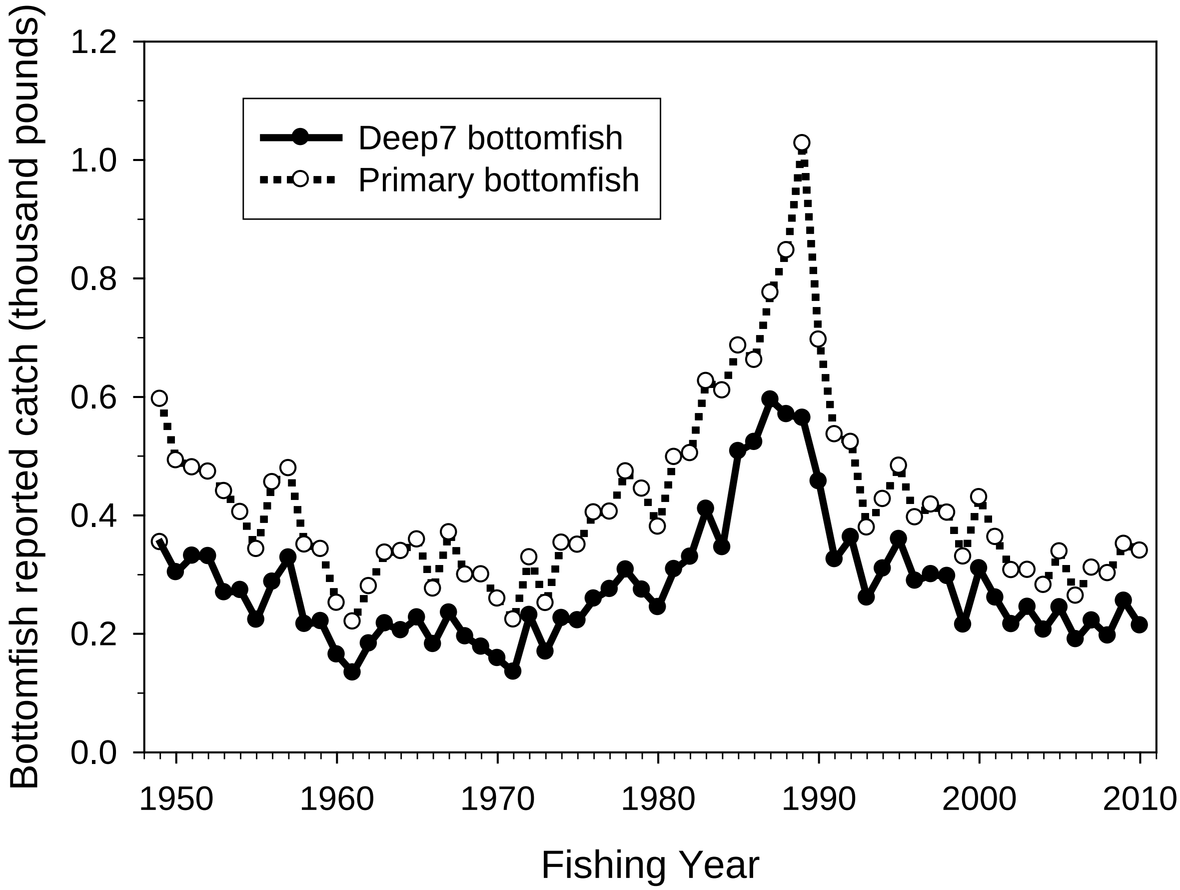


Figure 4.1.--Reported commercial catch of Deep7 and primary bottomfish in the main Hawaiian Islands by fishing year (July 1 previous year through June 30 current year) and species group.

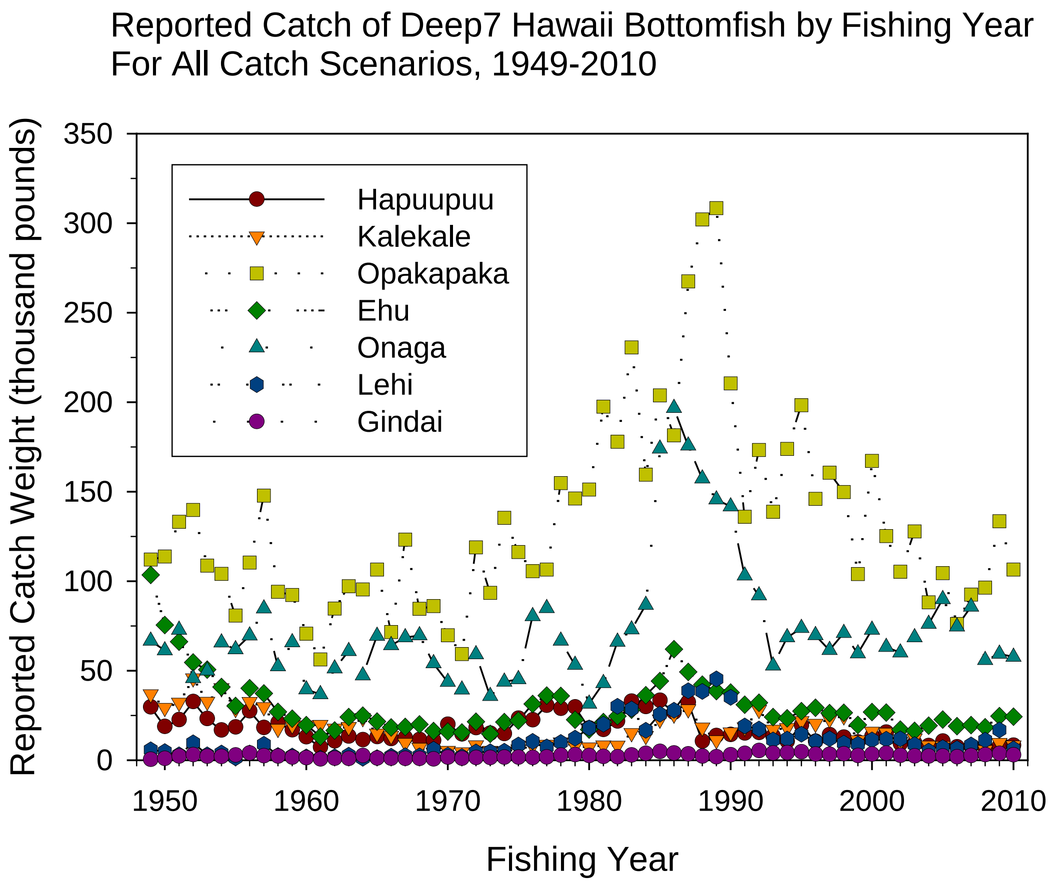


Figure 4.2.—Reported commercial catch of Deep7 in the main Hawaiian Islands by species and fishing year (July 1 previous year through June 30 current year).

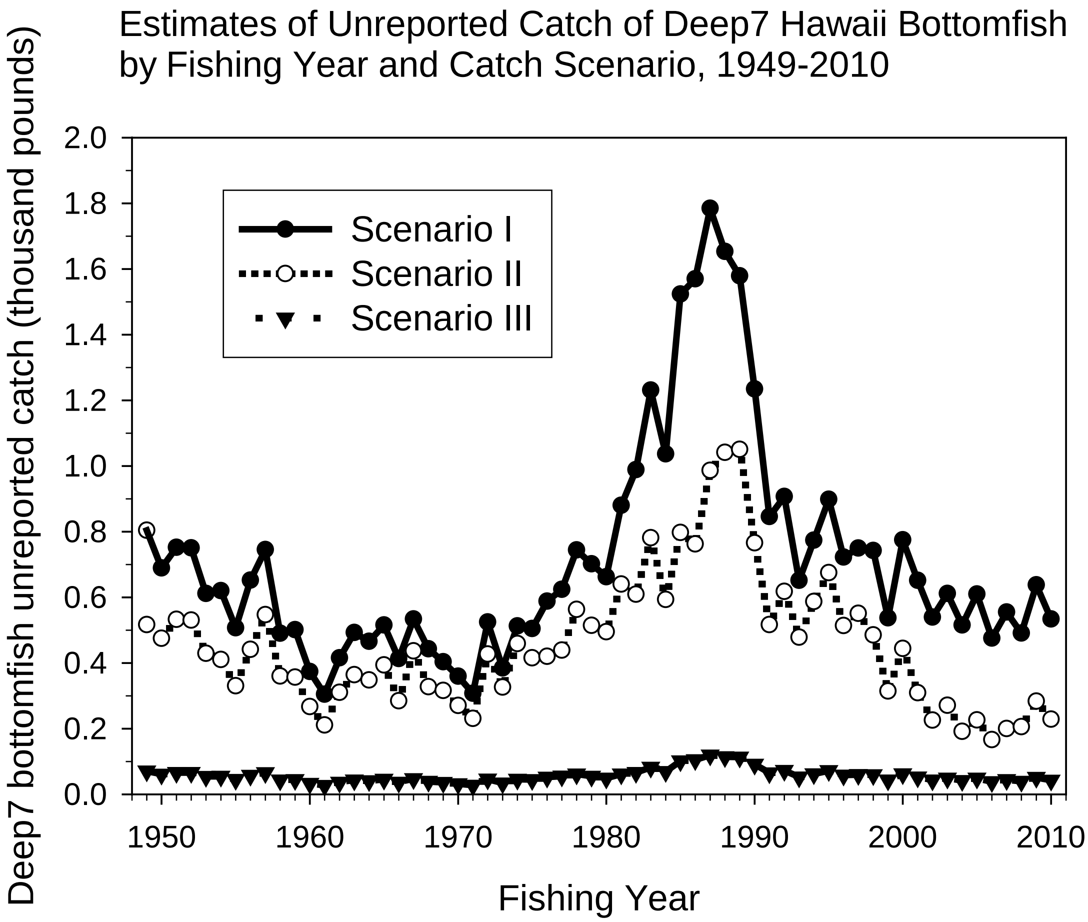


Figure 4.3.--Estimates of unreported catches of Deep7 bottomfish in the main Hawaiian Islands under Catch Scenarios I, II, and III (Catch Scenario IV includes no estimates of unreported catch) and by fishing year (July 1 previous year through June 30 current year).

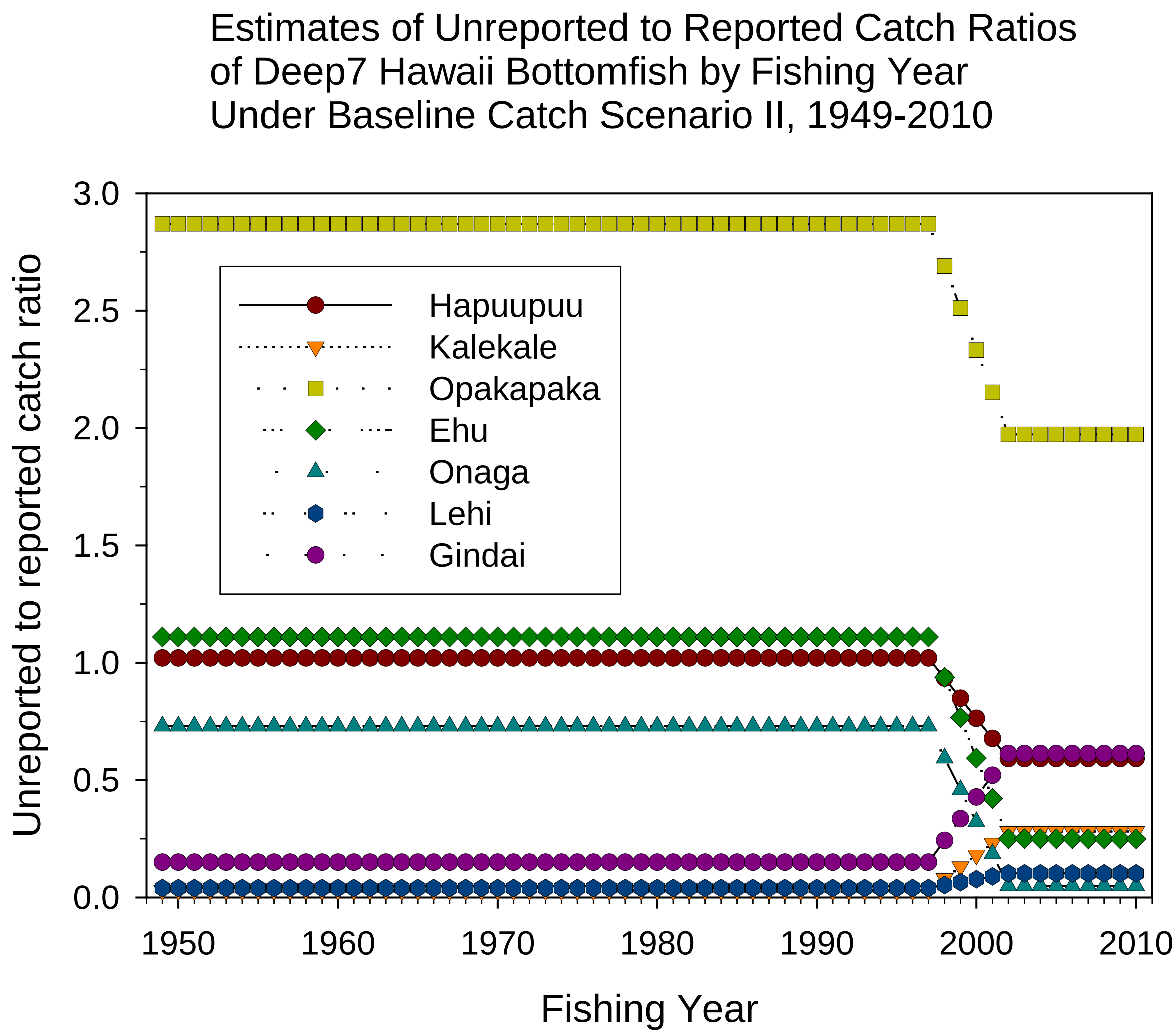


Figure 4.4.--Estimates of unreported to reported catch ratios (U) by species for Deep7 bottomfish in the main Hawaiian Islands under the Baseline Catch Scenario II and by fishing year (July 1 previous year through June 30 current year).

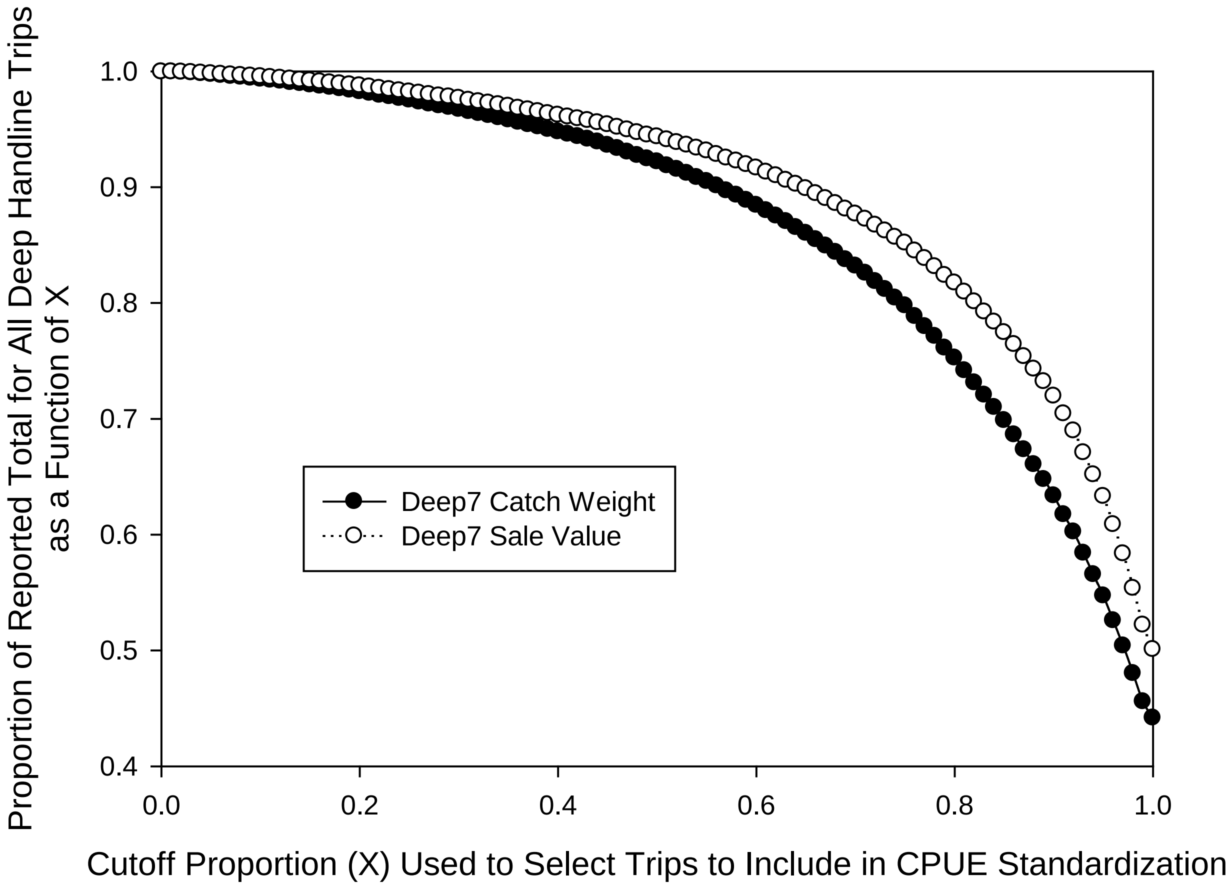


Figure 5.1.--Proportion of total Deep7 bottomfish reported catch weight and value that would be accounted for by the set of deep handline trips used to standardize CPUE as a function of the cutoff fraction of Deep7 bottomfish catch per trip used to select the set of trips.

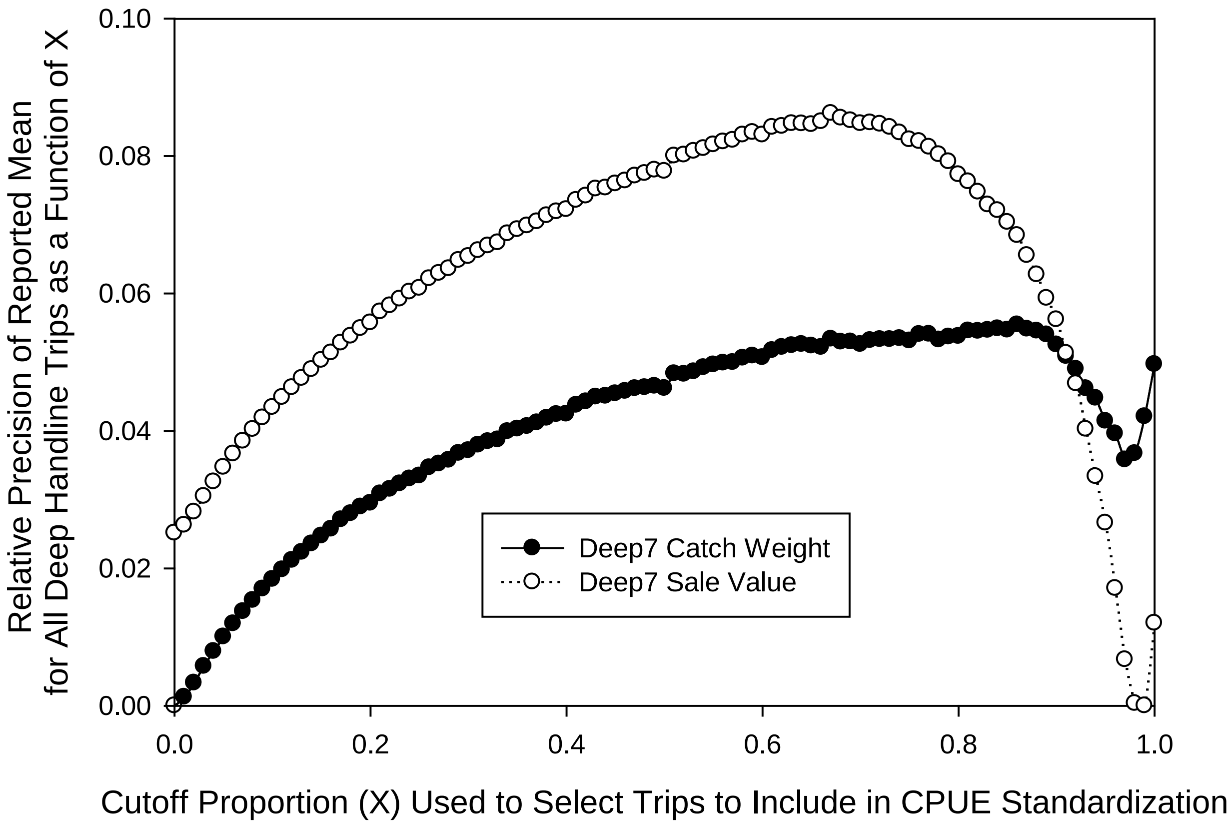


Figure 5.2.--Relative precision of mean Deep7 bottomfish reported catch weight and value for the set of deep handline trips used to standardize CPUE as a function of the cutoff fraction of Deep7 bottomfish catch per trip used to select the set of trips.

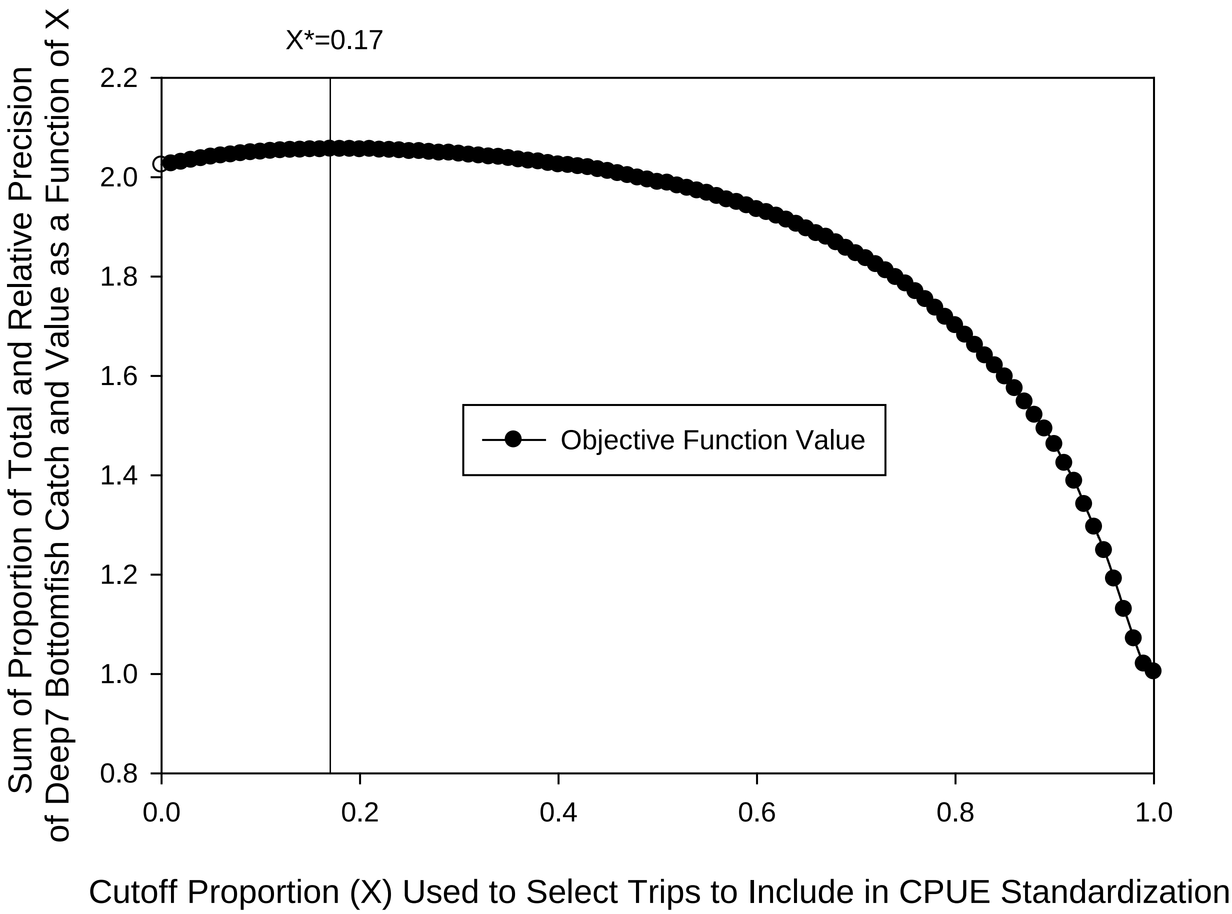


Figure 5.3.--Objective function value for the set of deep handline trips used to standardize CPUE as a function of the cutoff fraction of Deep7 bottomfish catch per trip used to select the set of trips.

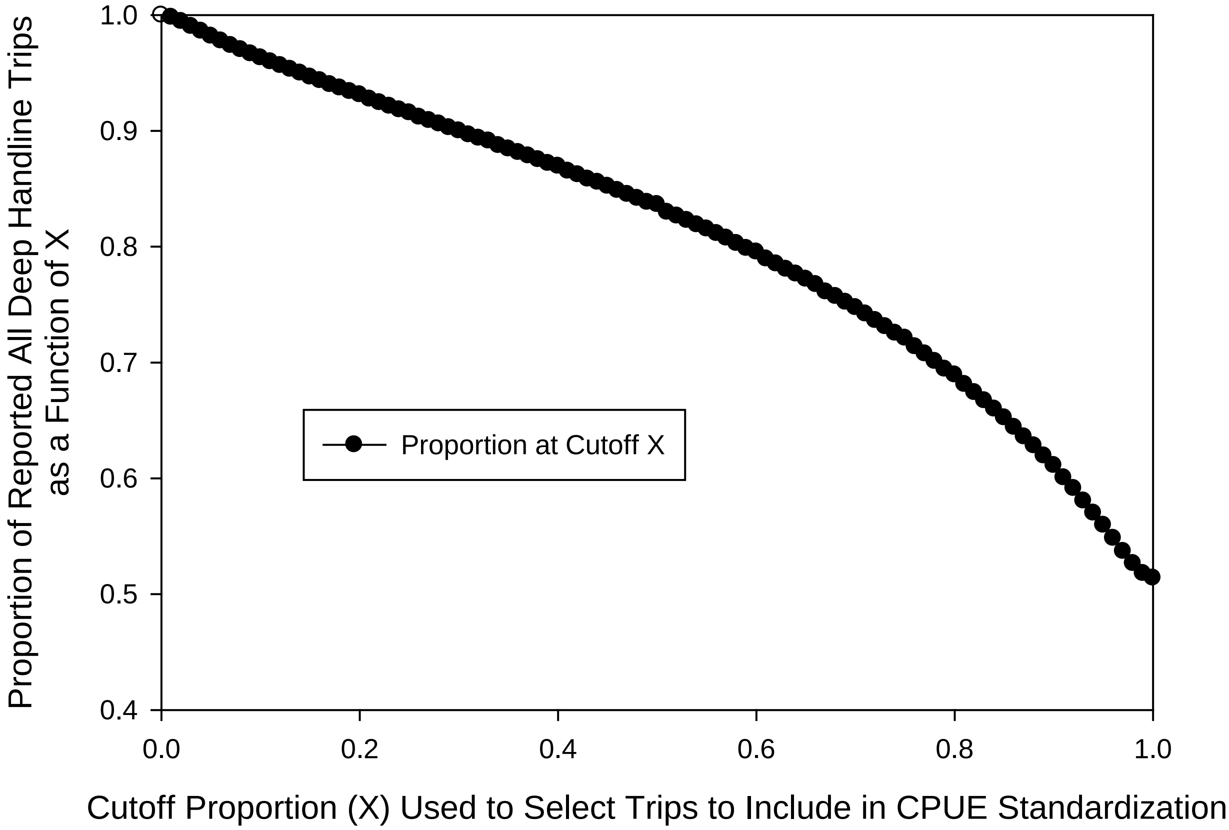


Figure 5.4.--Proportion of the total set of deep handline trips used to standardize CPUE as a function of the cutoff fraction of Deep7 bottomfish catch per trip used to select the set of trips.

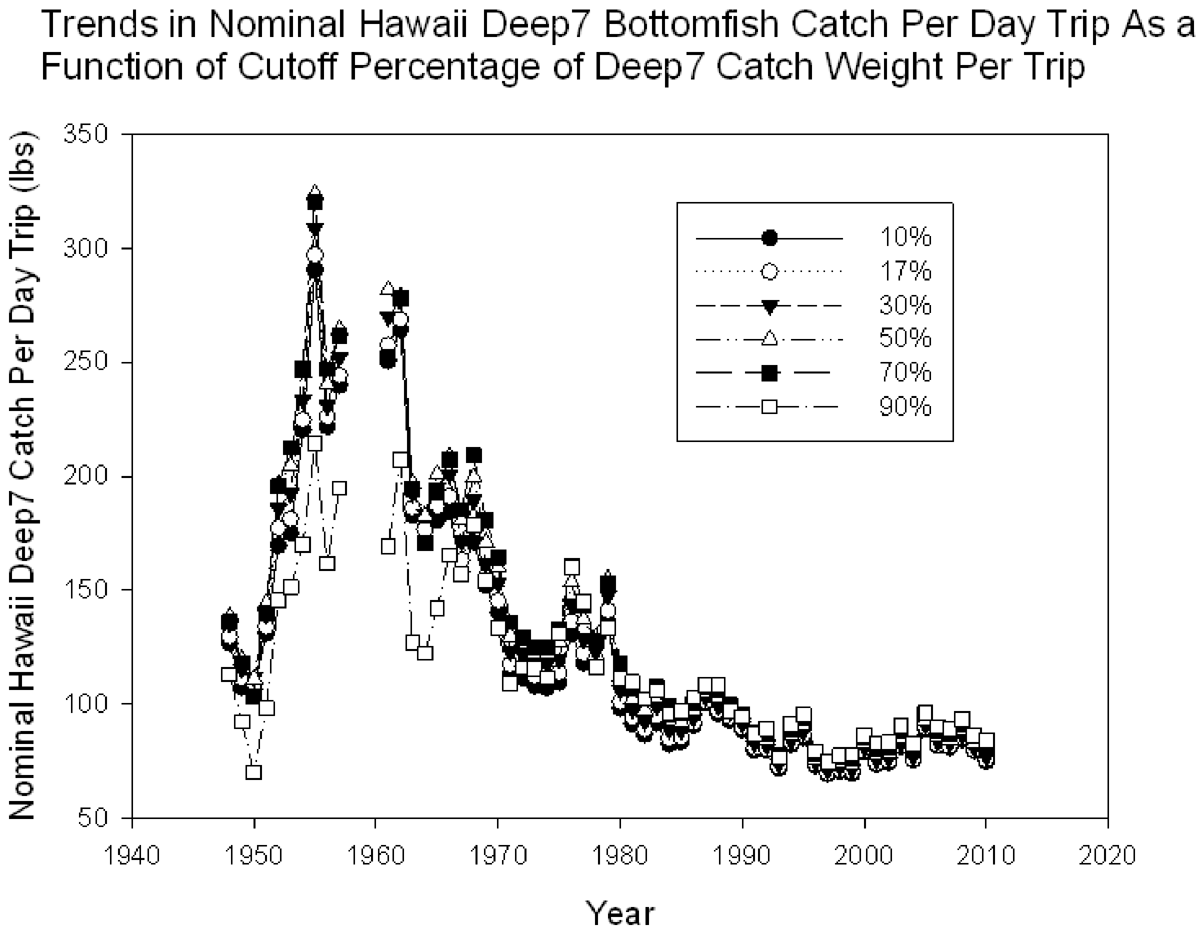


Figure 6.--Comparison of trends in nominal CPUE of Deep7 Hawaii bottomfish from day trips using deep handline gear for alternative cutoff fractions of minimum percentage of Deep7 bottomfish catch weight per trip used to define a set of directed trips.

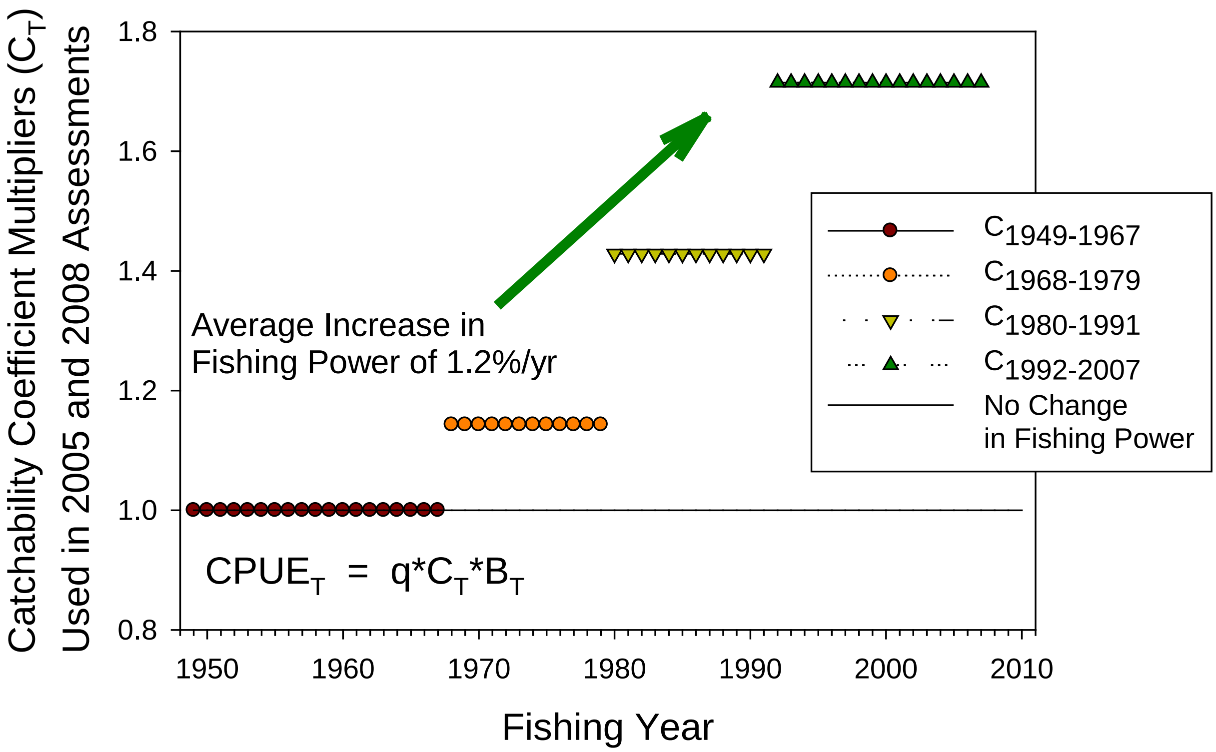


Figure 7.1.--Bottomfish CPUE adjustment coefficients used to account for putative increases in fishing technology in the directed deep handline fishery during 1949-2007 taken from the 2005 stock assessment (Moffitt et al., 2006). Standardized CPUE input to the assessment model was predicted as the product of the catchability parameter (q) for the standard time period (1980−1991) times the technology coefficient (C_T) times the model estimate of fishable biomass (B_T) in year T. The assumption that there was no change in fishing power (solid line) was part of the WPRFMC SSC's alternative analyses of data in the 2008 assessment update (Brodziak et al., 2009).

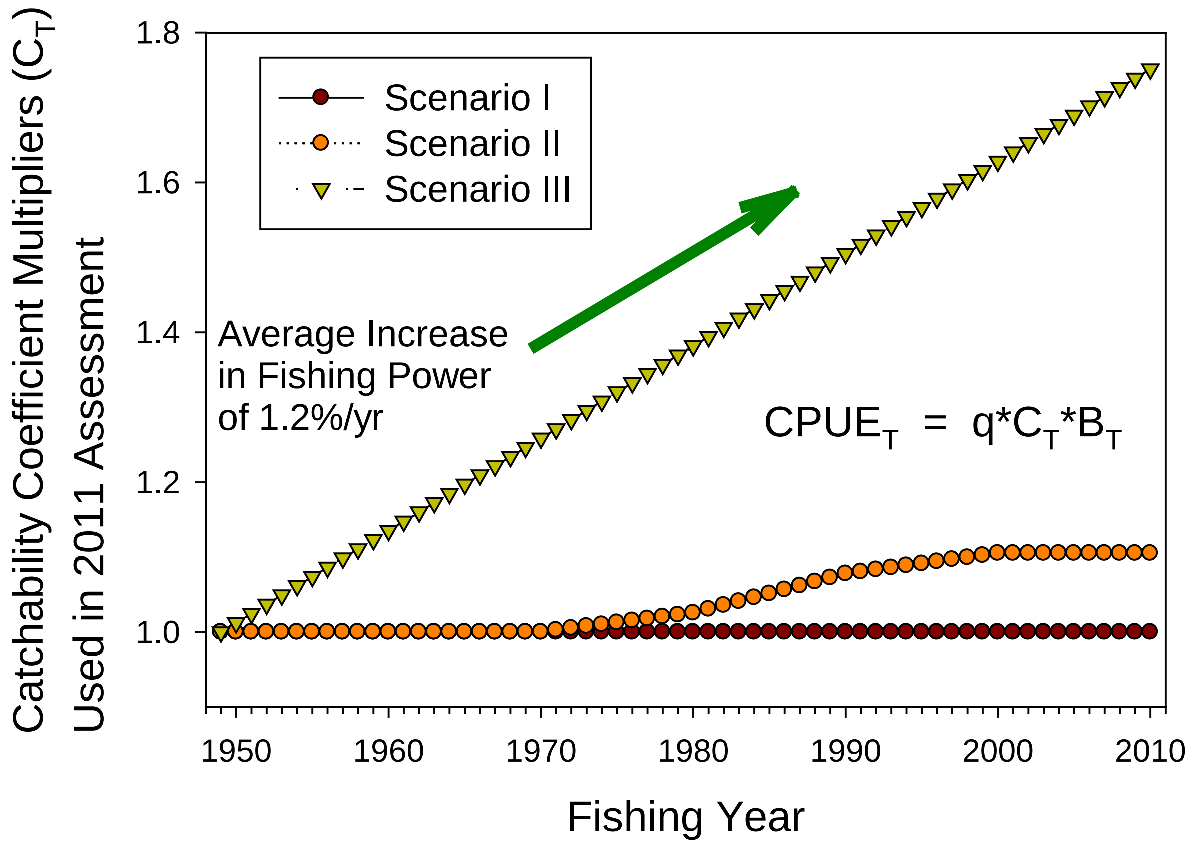


Figure 7.2.--Bottomfish CPUE adjustment coefficients to account for increases in Hawaiian bottomfish fishing technology during 1949−2007 (Scenario III) similar to those used in the 2005 stock assessment (Moffitt et al., 2006). Observed CPUE input to the assessment model was predicted as the product of the catchability parameter (q) for the standard time period (1980−1991) times the technology coefficient (C_T) times the model estimate of fishable biomass (B_T). The assumption that there was no fishing power change (Scenario I) was the baseline CPUE scenario used to model the relative abundance of Deep7 bottomfish in this assessment.

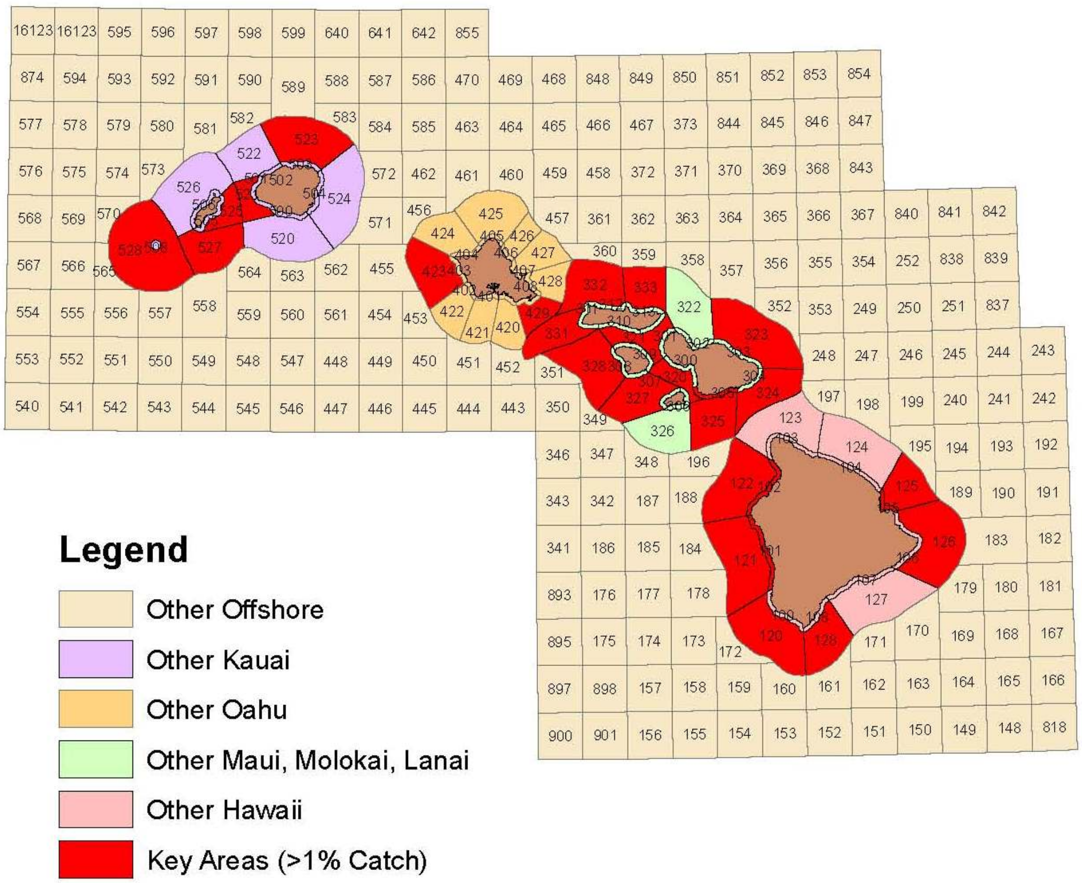


Figure 8.--Depiction of the general location of Hawaii Division of Aquatic Resources (HDAR) fishery reporting areas used to report bottomfish commercial fishery catch data in the main Hawaiian Islands.

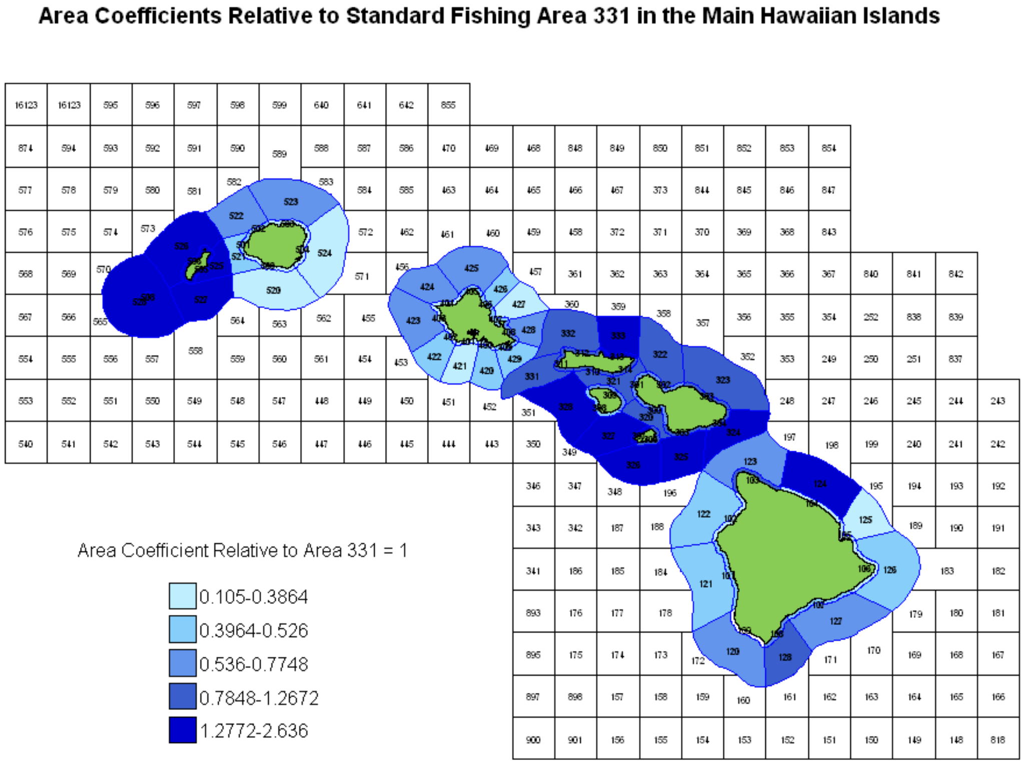


Figure 9.1.--Average relative abundance of Deep7 bottomfish by HDAR fishing area as estimated by the main effects area coefficients under the Baseline CPUE Scenario I for the directed Deep7 bottomfish handline fishery in the main Hawaiian Islands. Higher coefficient values indicate higher relative abundance in comparison to the standard fishing area 331 with coefficient equal to 1.

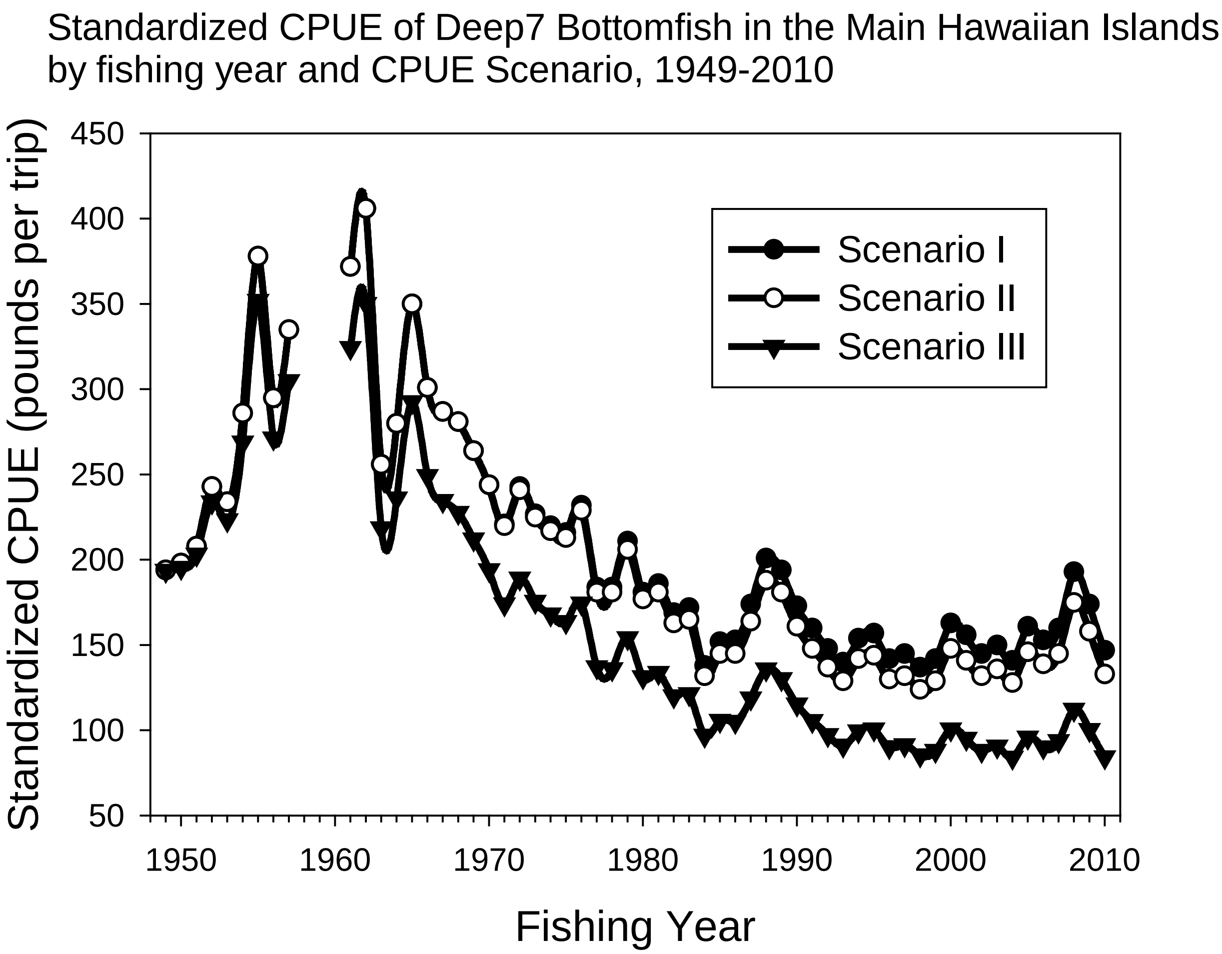


Figure 9.2.--Estimates of standardized CPUE for Deep7 bottomfish in the main Hawaiian Islands under Baseline CPUE Scenario I and Alternative CPUE Scenarios II and III.

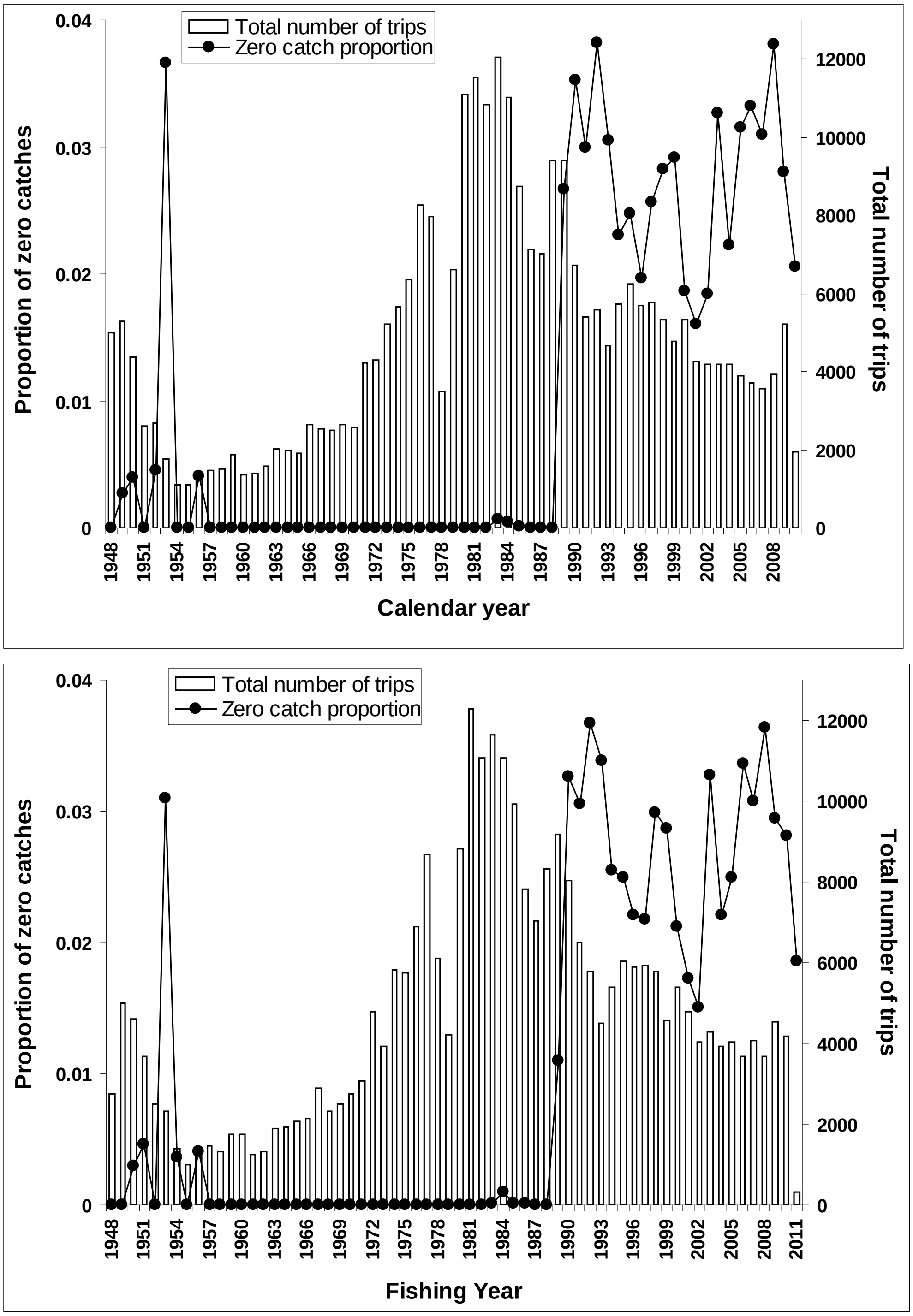


Figure 10.--HDAR logbook data showing the reported number of deep handline trips and proportion of trips with zero bottomfish catch by calendar year (top panel) and fishing year (bottom panel).

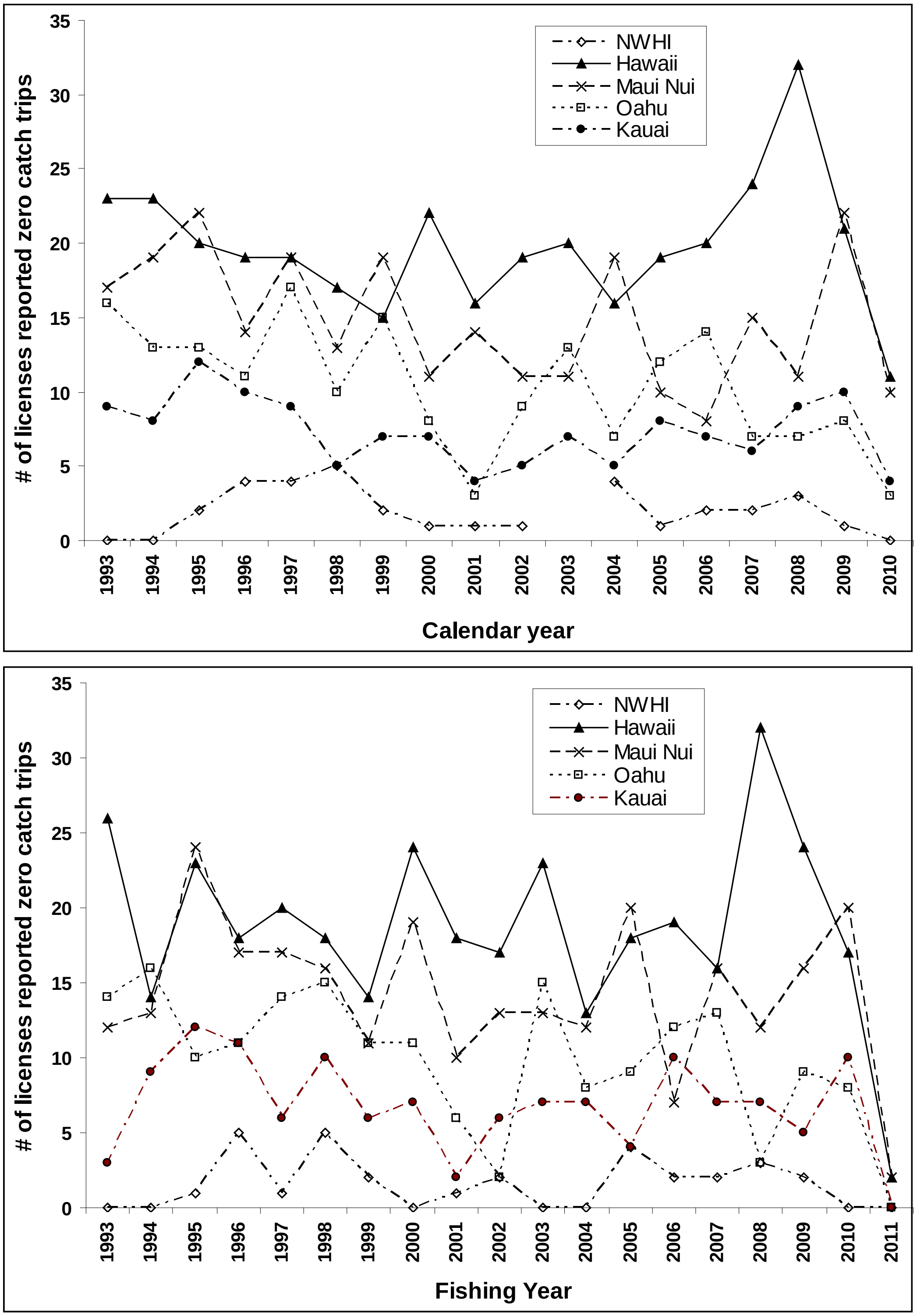


Figure 11.--HDAR logbook data showing the reported number of licenses with zero bottomfish catch trips by island and calendar year (top panel) and fishing year (bottom panel).

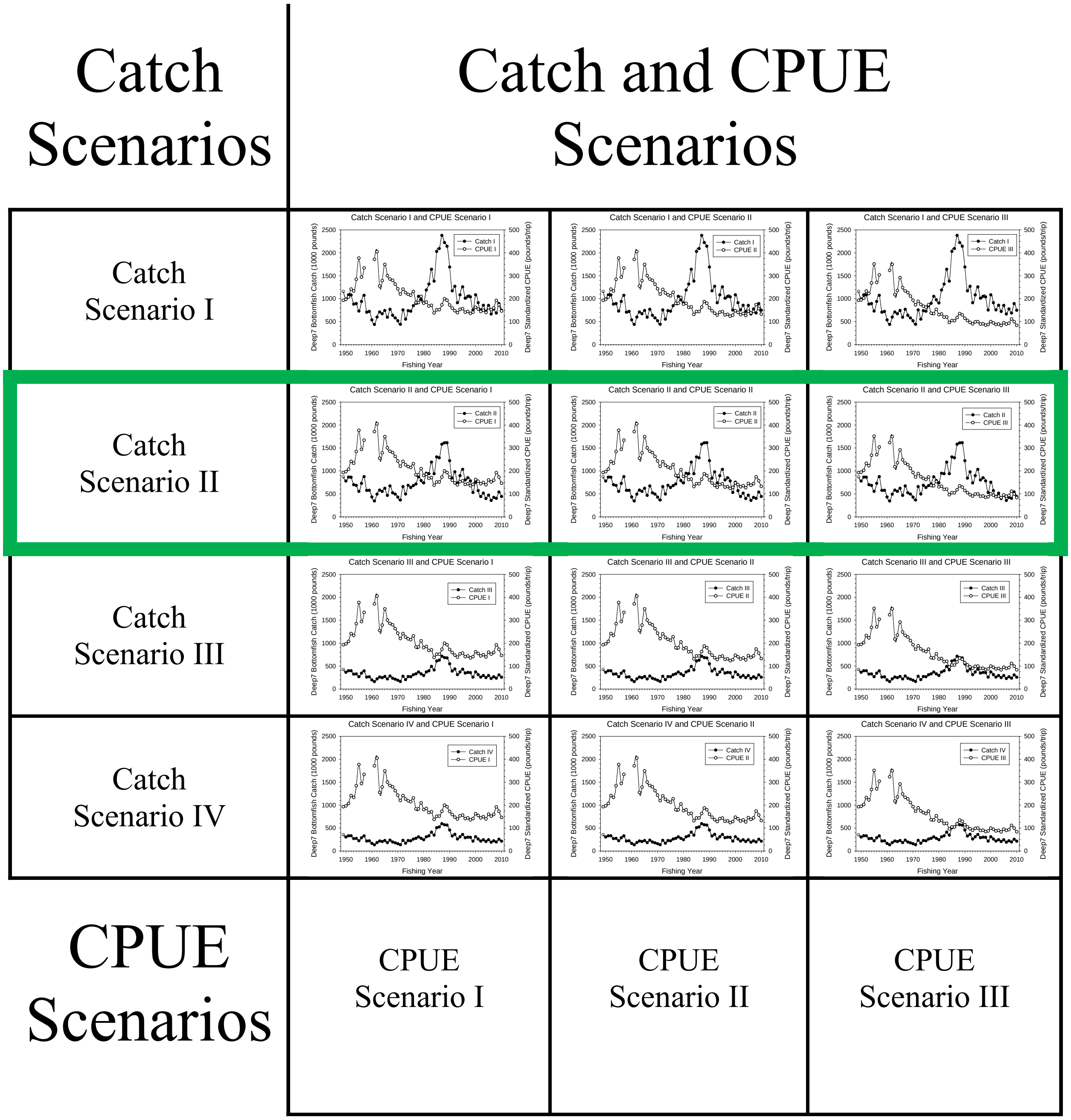


Figure 12.--Combinations of Deep7 bottomfish catch and CPUE scenarios for assessment.

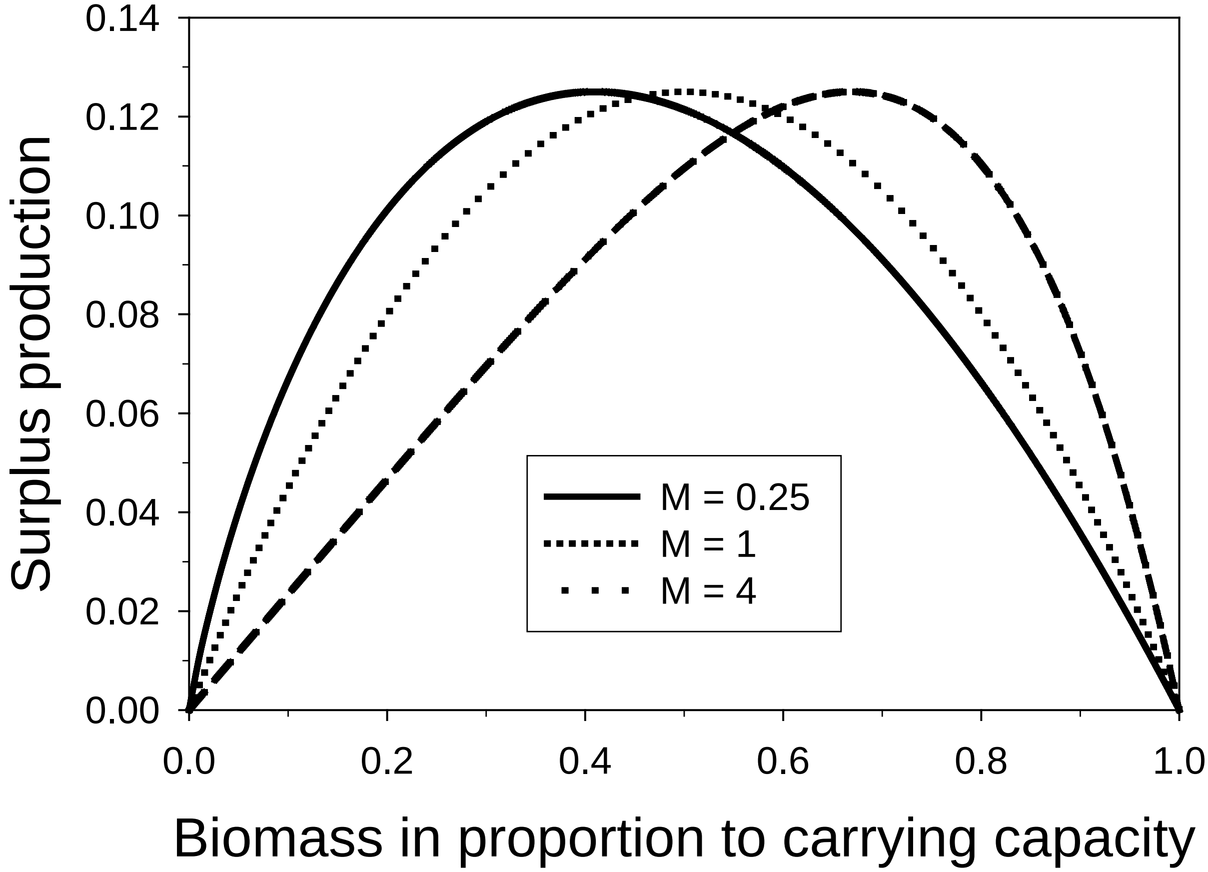


Figure 13.--Effect of shape parameter M on the relationship between surplus production and the biomass as a proportion of carrying capacity curve.

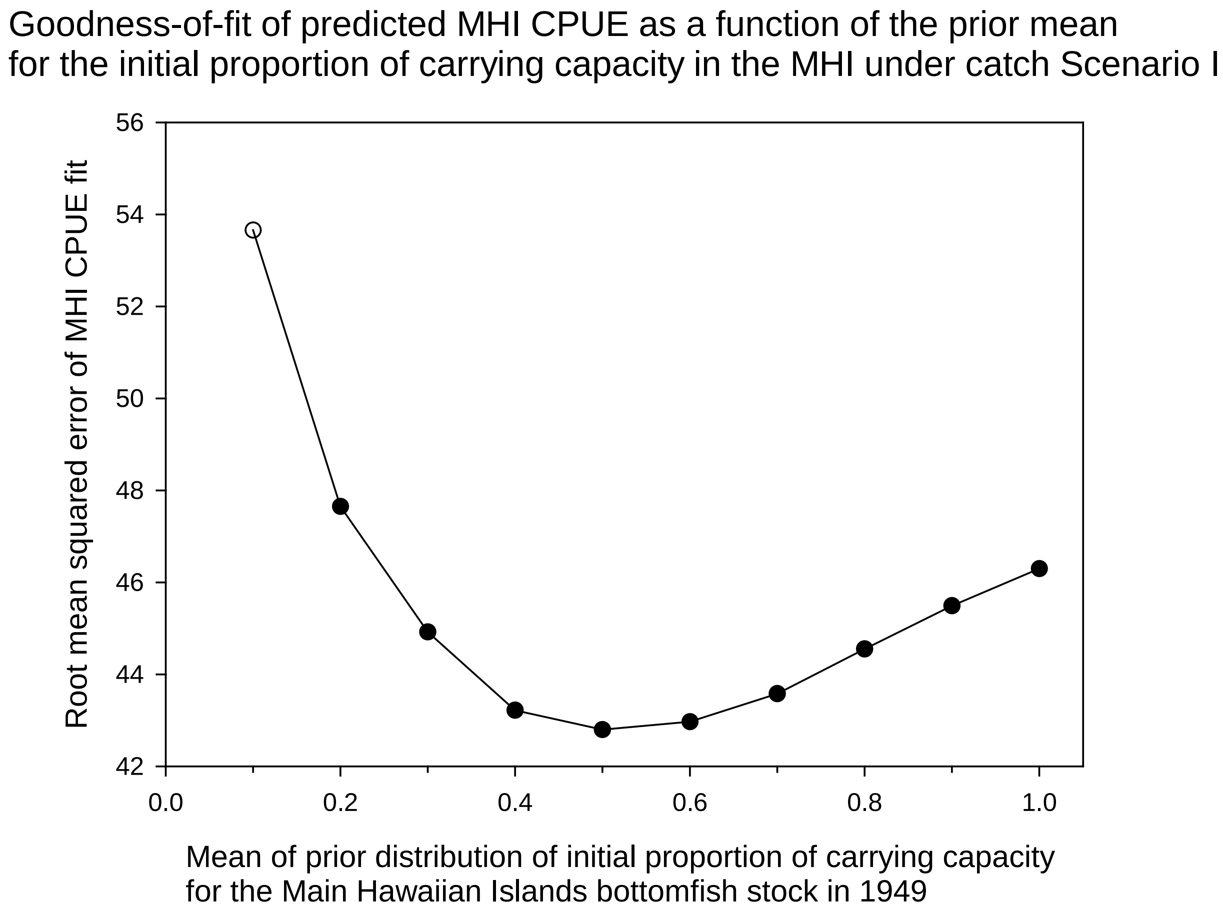


Figure 14.1.--Goodness-of-fit values for alternative choices for the mean of the prior distribution of the initial proportion of Deep7 bottomfish carrying capacity in the main Hawaiian Islands in 1949 under the Baseline Catch Scenario II and CPUE Scenario I.

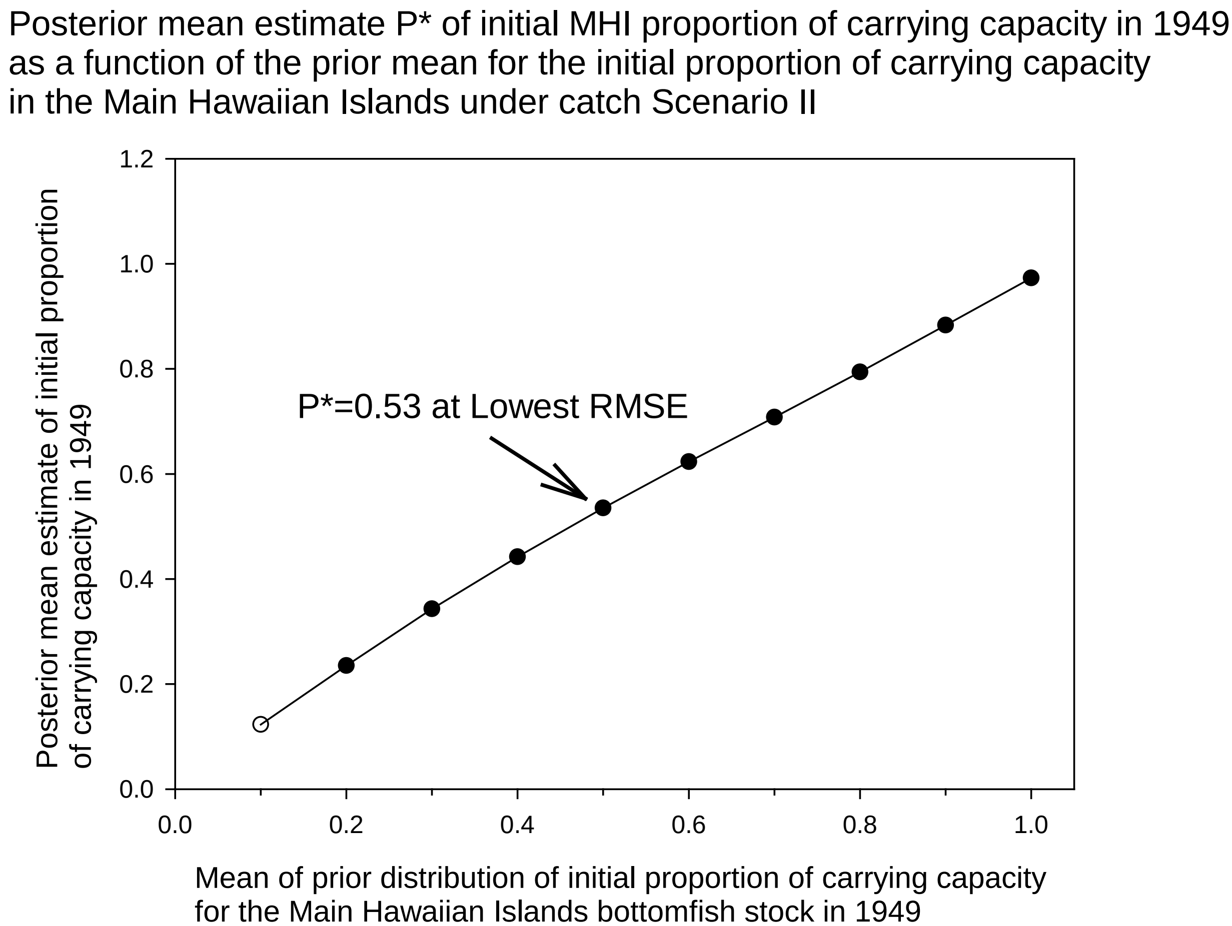


Figure 14.2.--Posterior distribution means under alternative choices for the mean of the prior distribution of the initial proportion of Deep7 bottomfish carrying capacity in the main Hawaiian Islands in 1949 under the Baseline Catch Scenario II and CPUE Scenario I.

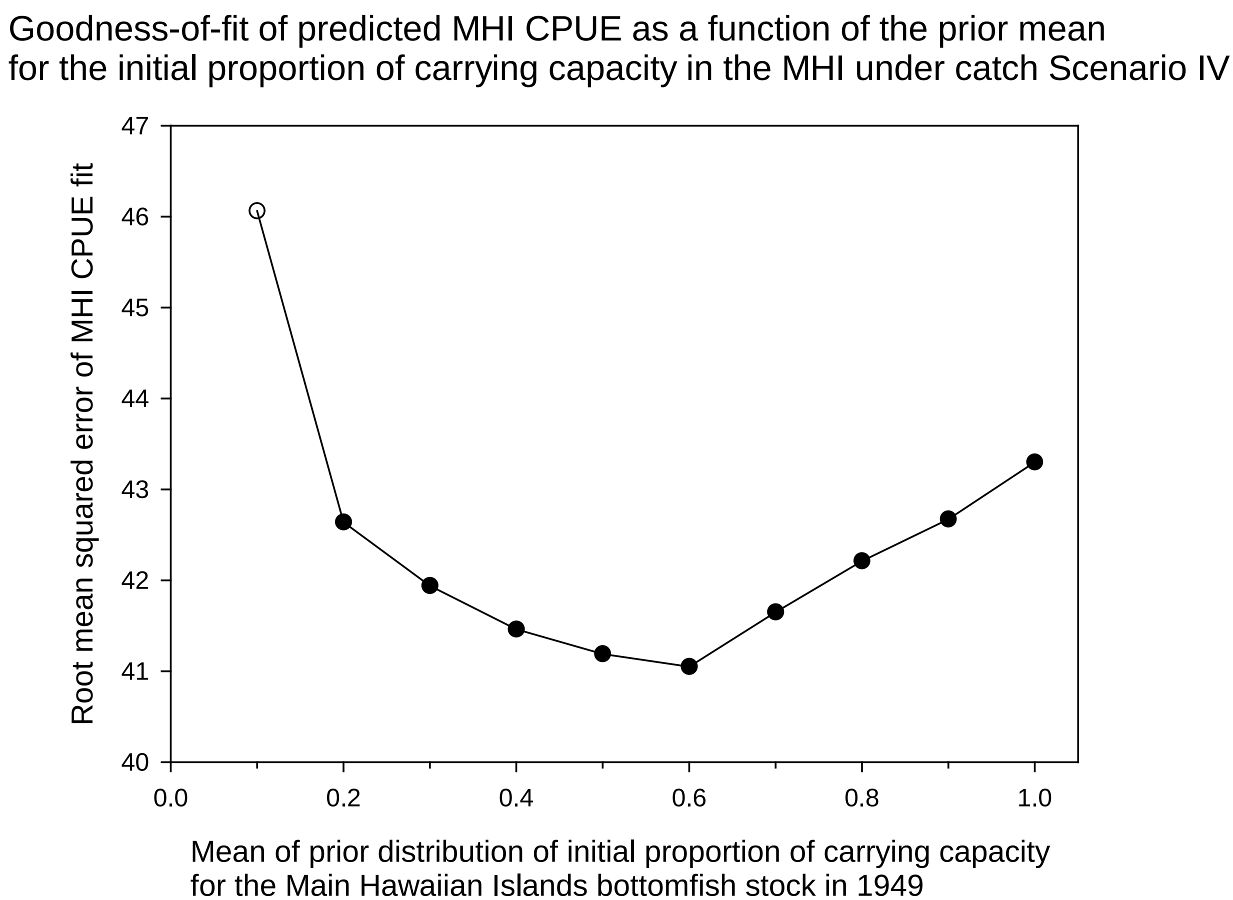


Figure 15.1.--Goodness-of-fit values for alternative choices for the mean of the prior distribution of the initial proportion of Deep7 bottomfish carrying capacity in the main Hawaiian Islands in 1949 under Catch Scenario IV and CPUE Scenario I.

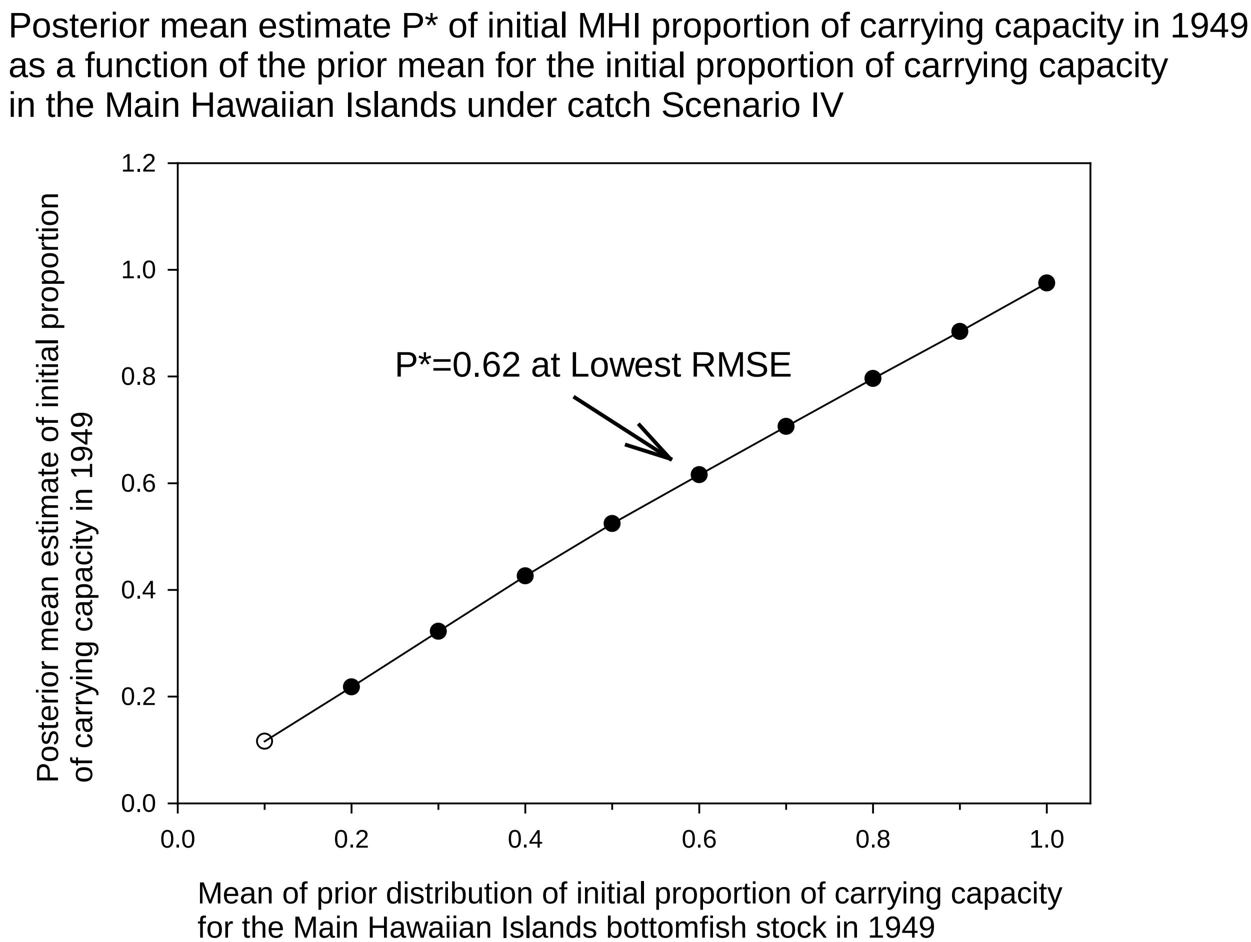


Figure 15.2.--Posterior distribution means under alternative choices for the mean of the prior distribution of the initial proportion of Deep7 bottomfish carrying capacity in the main Hawaiian Islands in 1949 under the Baseline Catch Scenario IV and CPUE Scenario I.

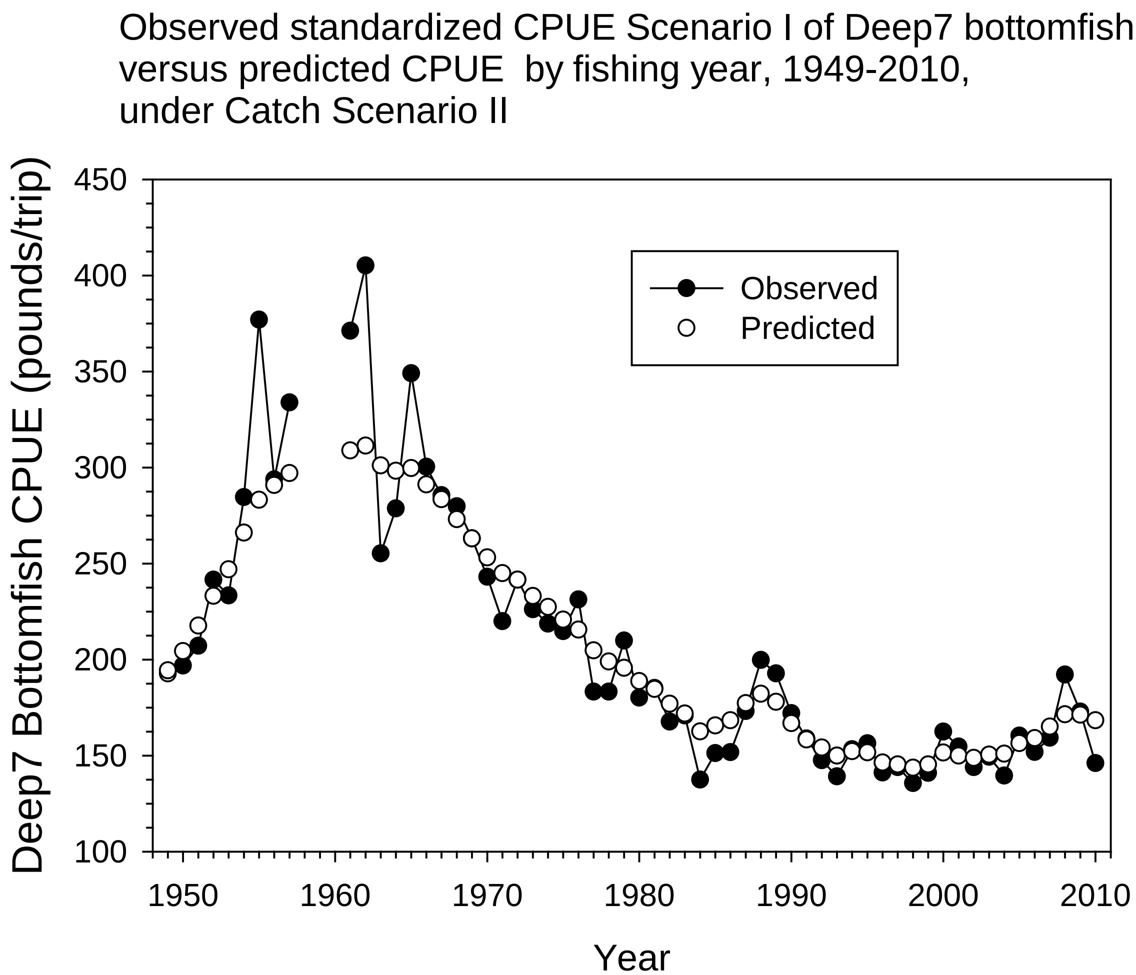


Figure 16.1.--Results of the Baseline Catch Scenario II and Baseline CPUE Scenario I production model fit to the observed standardized bottomfish CPUE for the main Hawaiian Islands along with CPUE residuals.

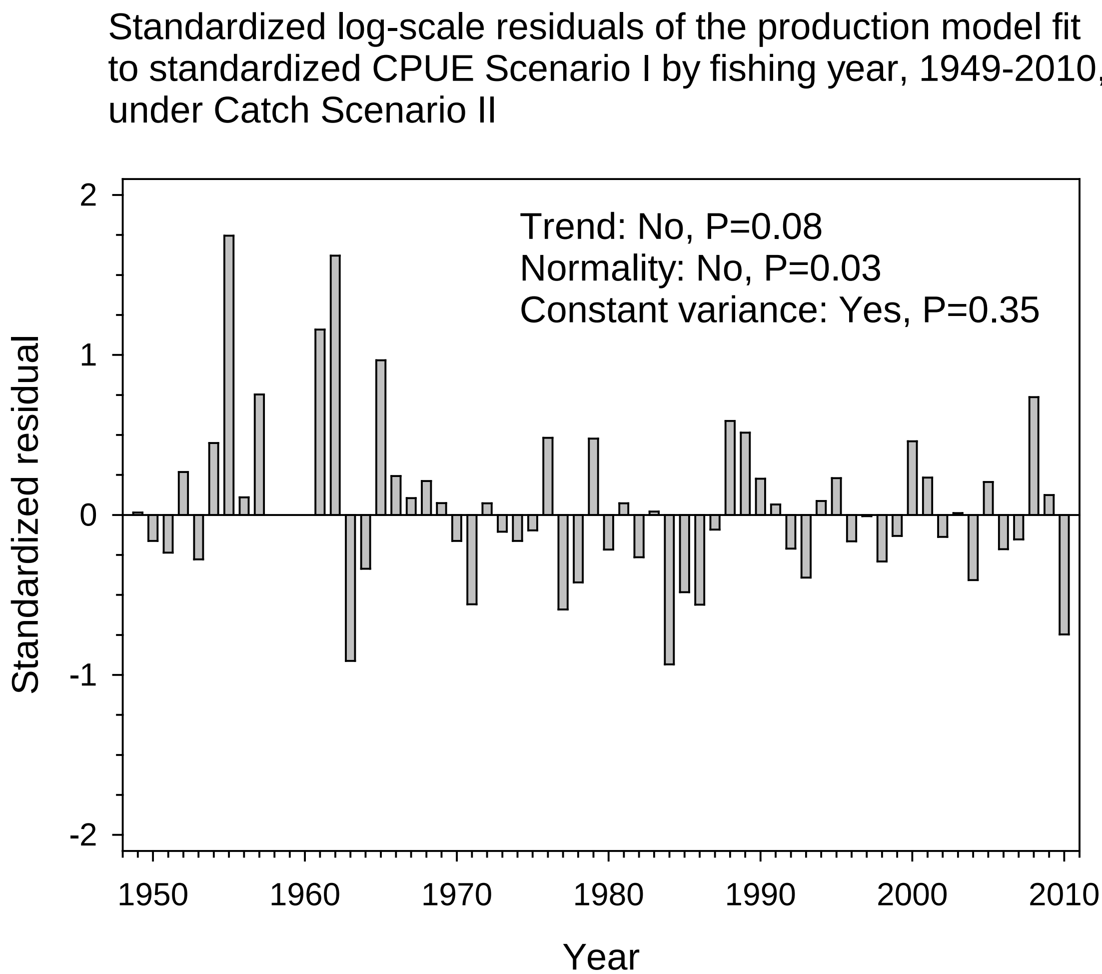


Figure 16.2.--Results of the Baseline Catch Scenario II and Baseline CPUE Scenario I production model fit to the observed standardized bottomfish CPUE for the main Hawaiian Islands along with standardized log-scale CPUE residuals and P-values for linear regression hypothesis tests of whether standardized residuals have a time trend, are normally distributed, and have constant variance.

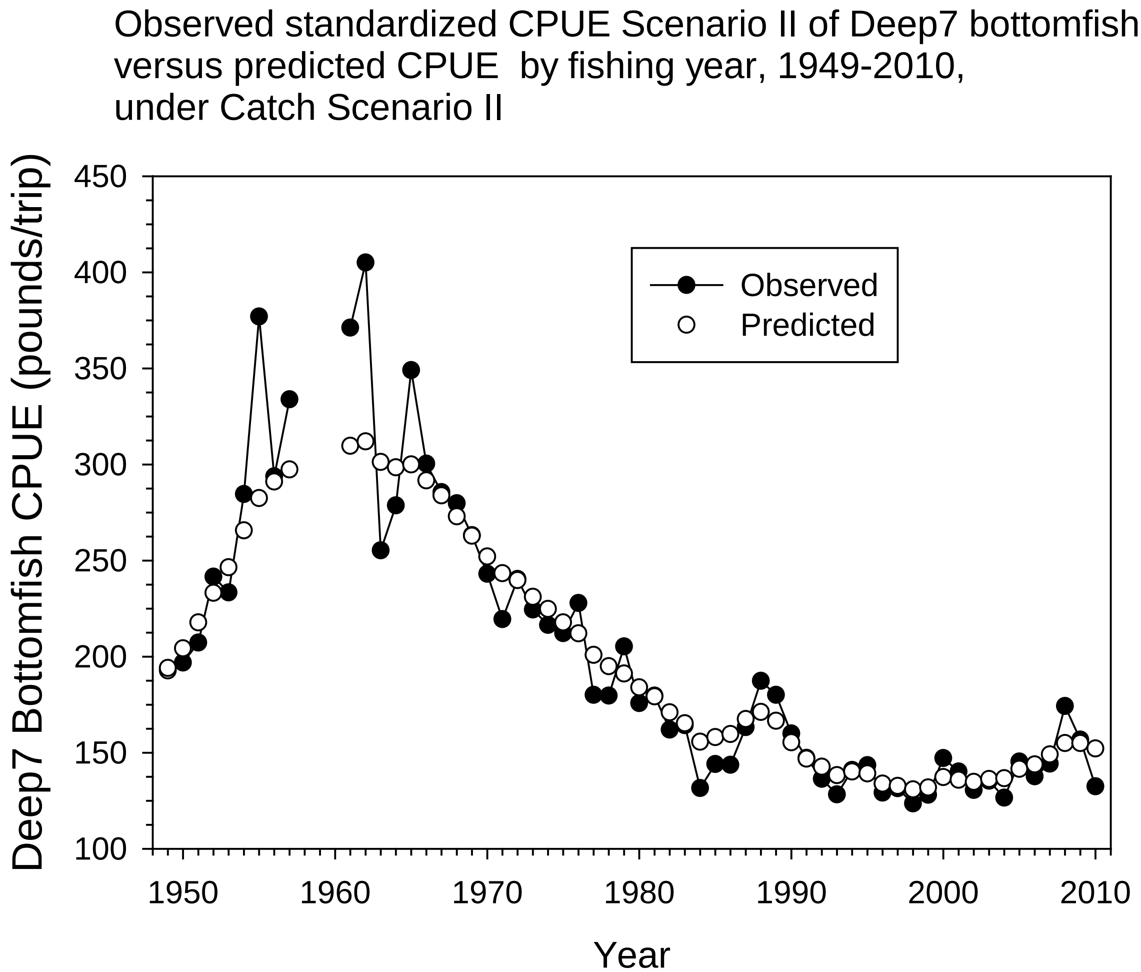


Figure 17.1.--Results of the alternative Catch Scenario II and CPUE Scenario II production model fit to the observed standardized bottomfish CPUE for the main Hawaiian Islands along with CPUE residuals.

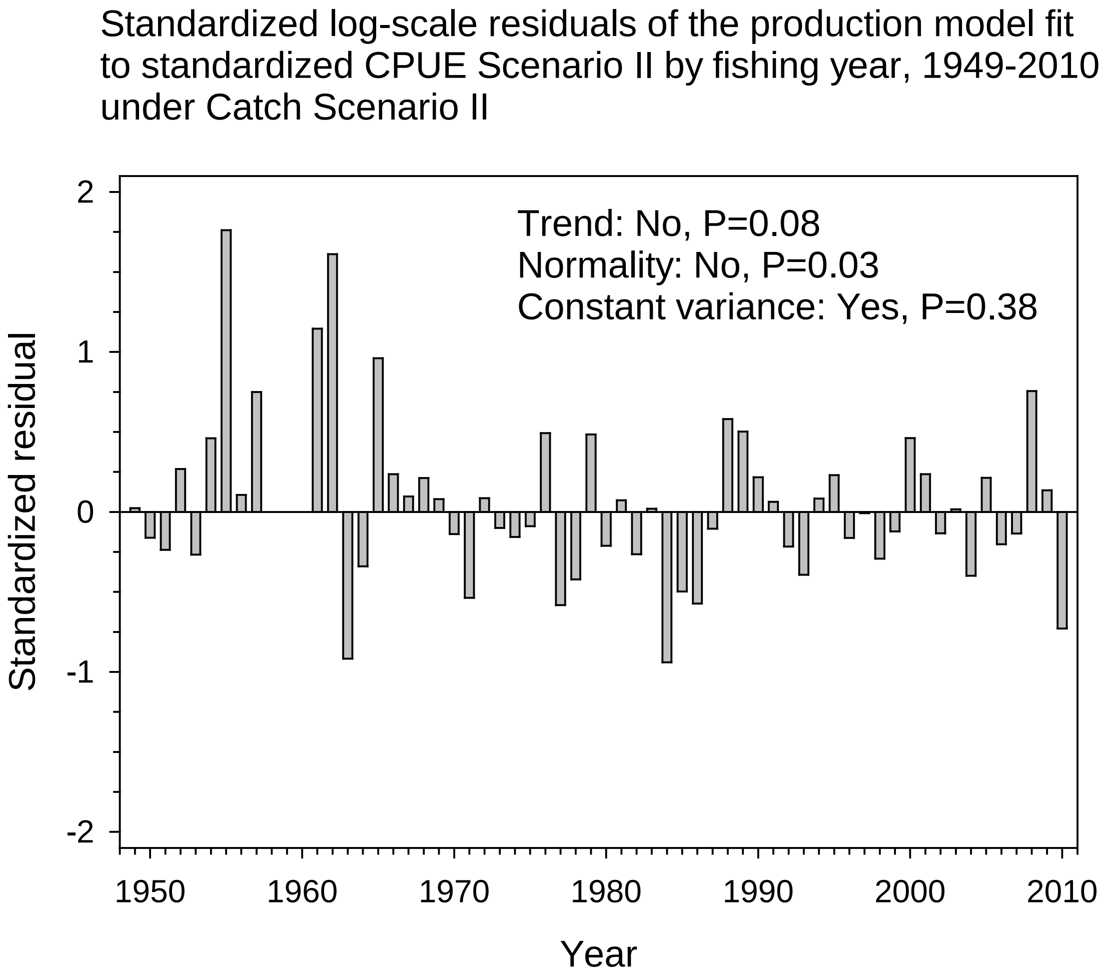


Figure 17.2.--Results of the alternative Catch Scenario II and CPUE Scenario II production model fit to the observed standardized bottomfish CPUE for the main Hawaiian Islands along with standardized log-scale CPUE residuals and P-values for linear regression hypothesis tests of whether standardized residuals have a time trend, are normally distributed, and have constant variance.

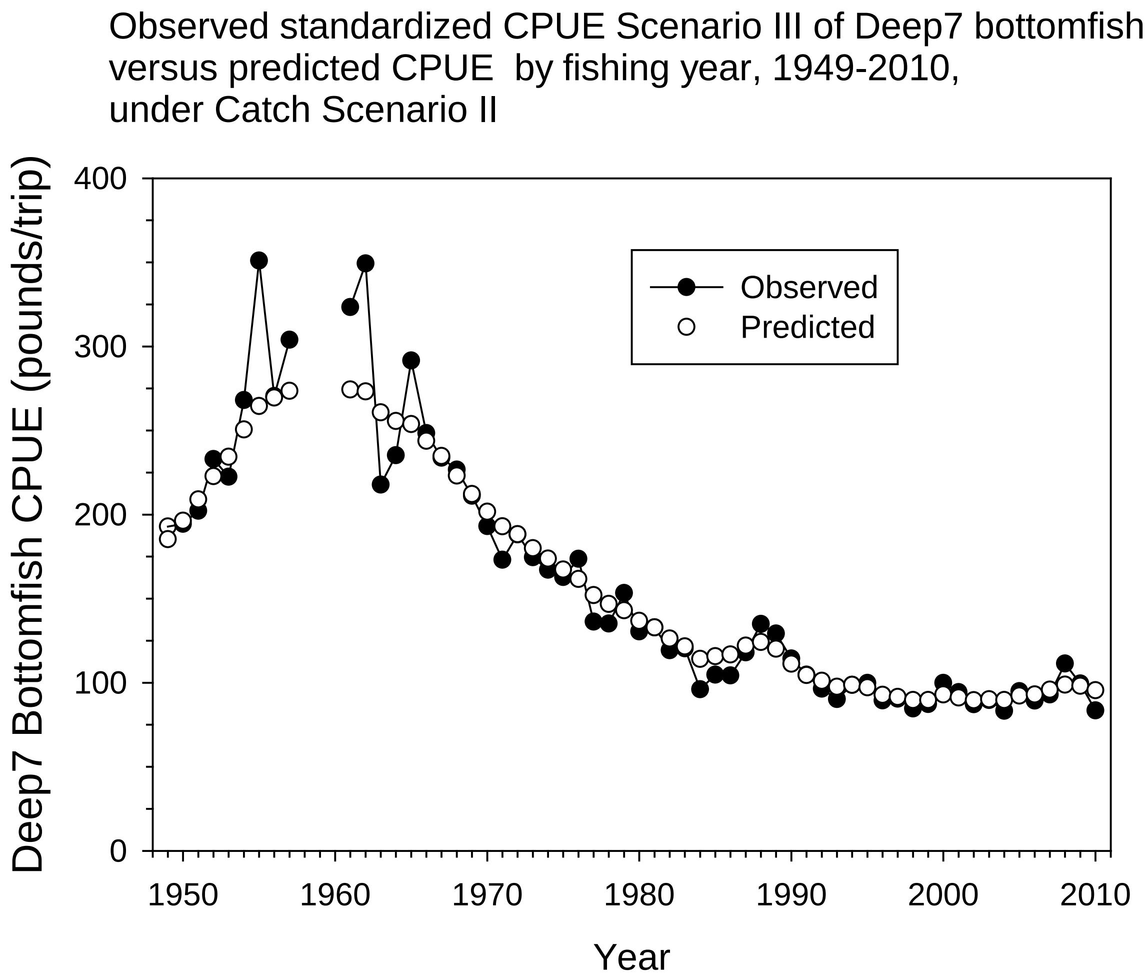


Figure 18.1.--Results of the Alternative Catch Scenario II and CPUE Scenario III production model fit to the observed standardized bottomfish CPUE for the main Hawaiian Islands along with CPUE residuals.

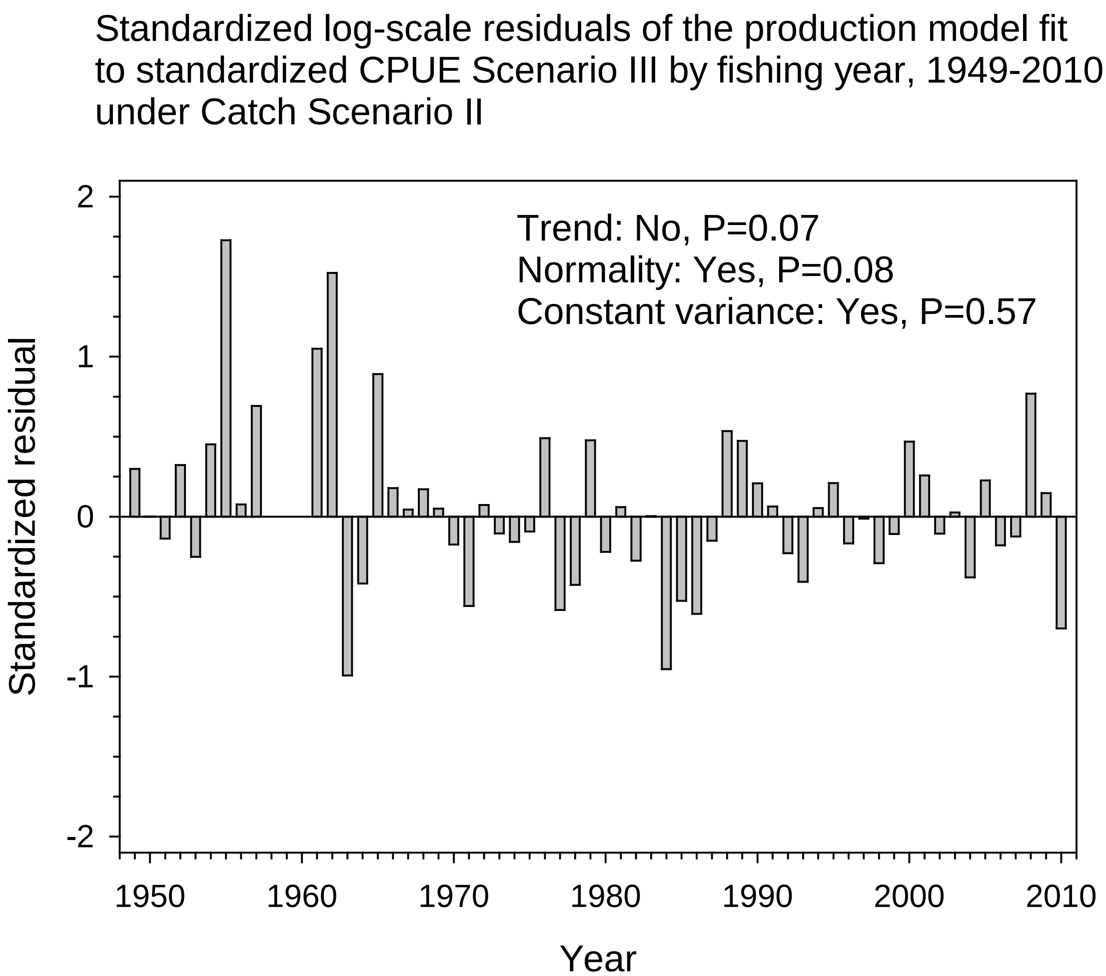
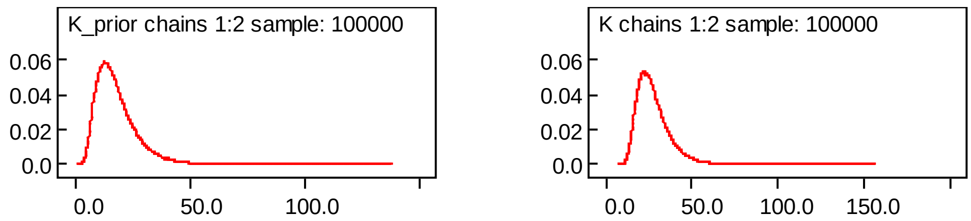
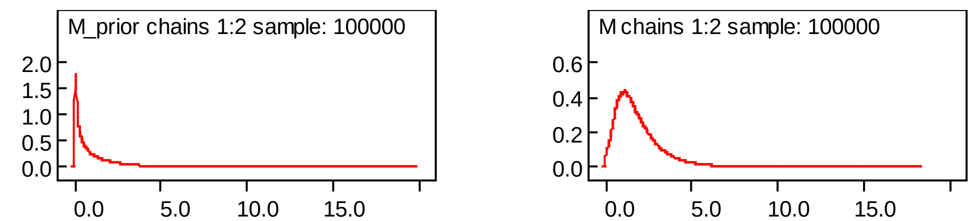


Figure 18.2.--Results of the Alternative Catch Scenario II and CPUE Scenario III production model fit to the observed standardized bottomfish CPUE for the main Hawaiian Islands along with standardized log-scale CPUE residuals and P-values for linear regression hypothesis tests of whether standardized residuals have a time trend, are normally distributed, and have constant variance.

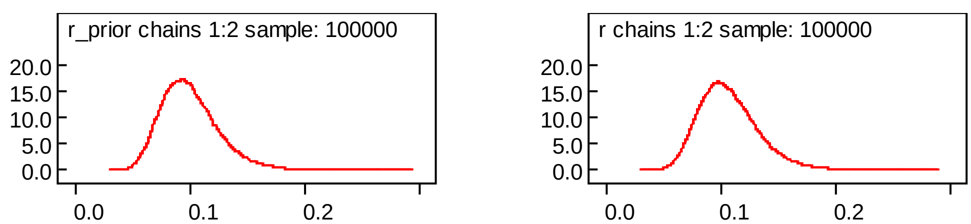
(19.1) Carrying capacity (K)



(19.2) Production shape parameter (M)



(19.3) Intrinsic growth rate (r)



(19.4) Initial proportion of carrying capacity (P[1])

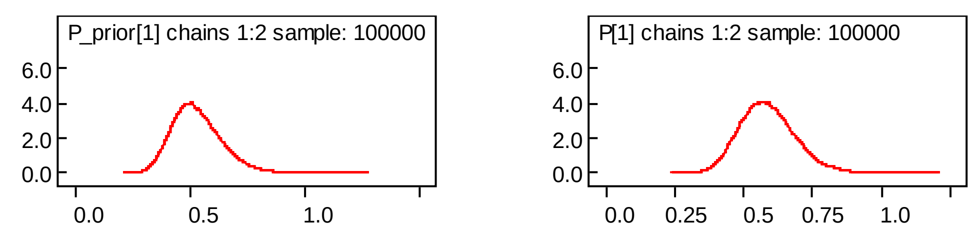
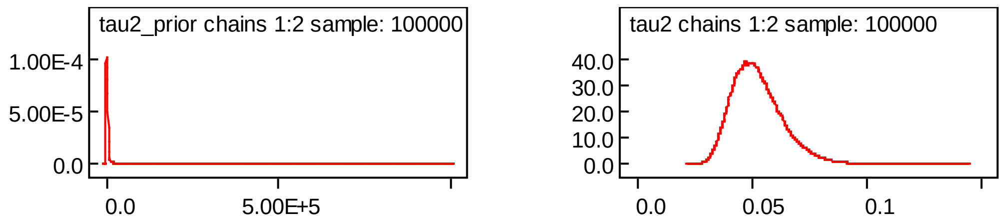
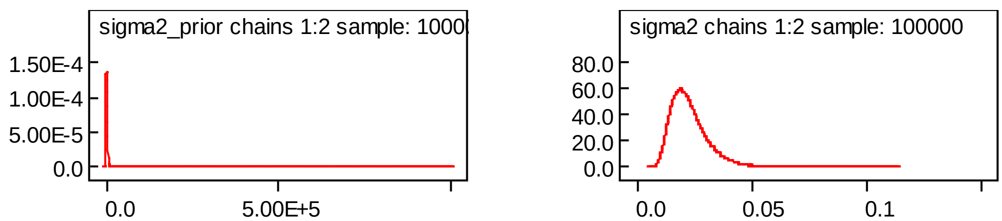


Figure 19.--Comparisons of assumed prior (left panel) and estimated posterior (right panel) distributions of (1) carrying capacity, (2) production shape, (3) intrinsic growth rate, (4) initial proportion of carrying capacity, (5) observation error variance, (6) process error variance, (7) catchability and (8) catch distribution in 2010 parameters along with implicit priors and estimated posterior distributions of (9) BMSY, (10) HMSY, (11) MSY, and (12) the proportion of carrying capacity to produce MSY for the baseline production model for Deep7 Hawaii bottomfish.

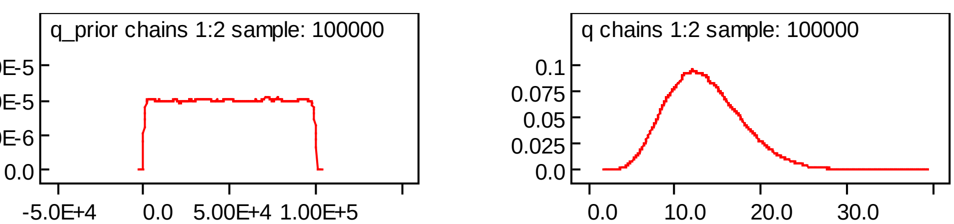
(19.5) Observation error variance (tau2)



(19.6) Process error variance (sigma2)



(19.7) Catchability parameter (q)



(19.8) Catch distribution in 2010 (Catch[62])

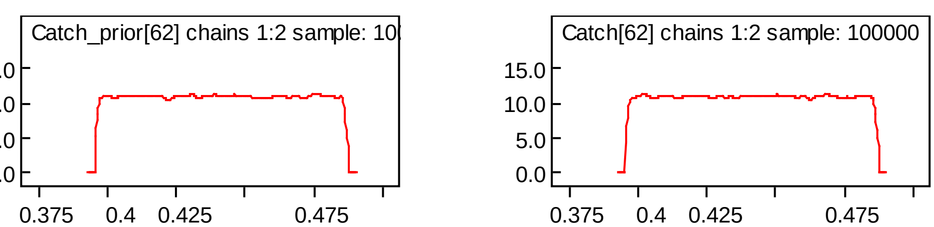
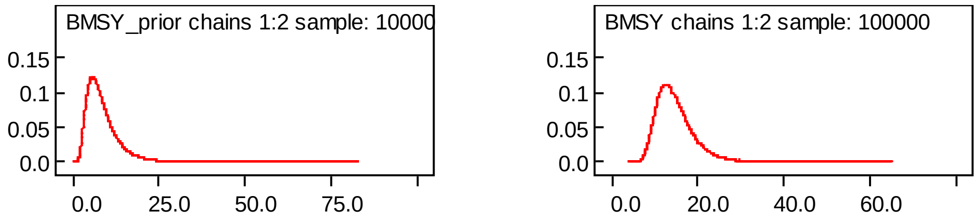
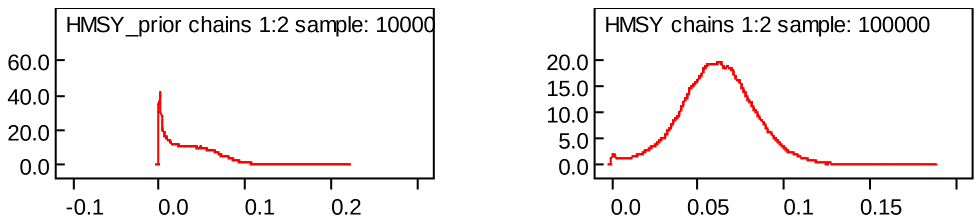


Figure 19.--Comparison of priors and posteriors for baseline model, continued.

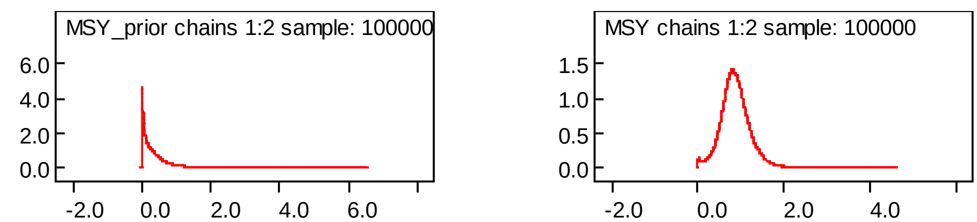
(19.9) Biomass to produce MSY (BMSY)



(19.10) Harvest rate to produce MSY (HMSY)



(19.11) Maximum sustainable yield (MSY)



(19.12) Proportion of carrying capacity to produce MSY (PMSY)

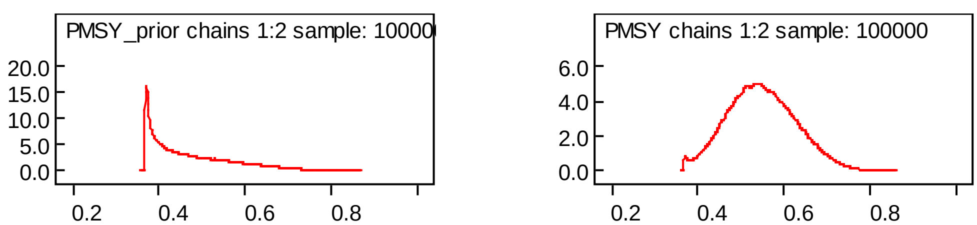


Figure 19.--Comparison of priors and posteriors for baseline model, continued.

(20.1)

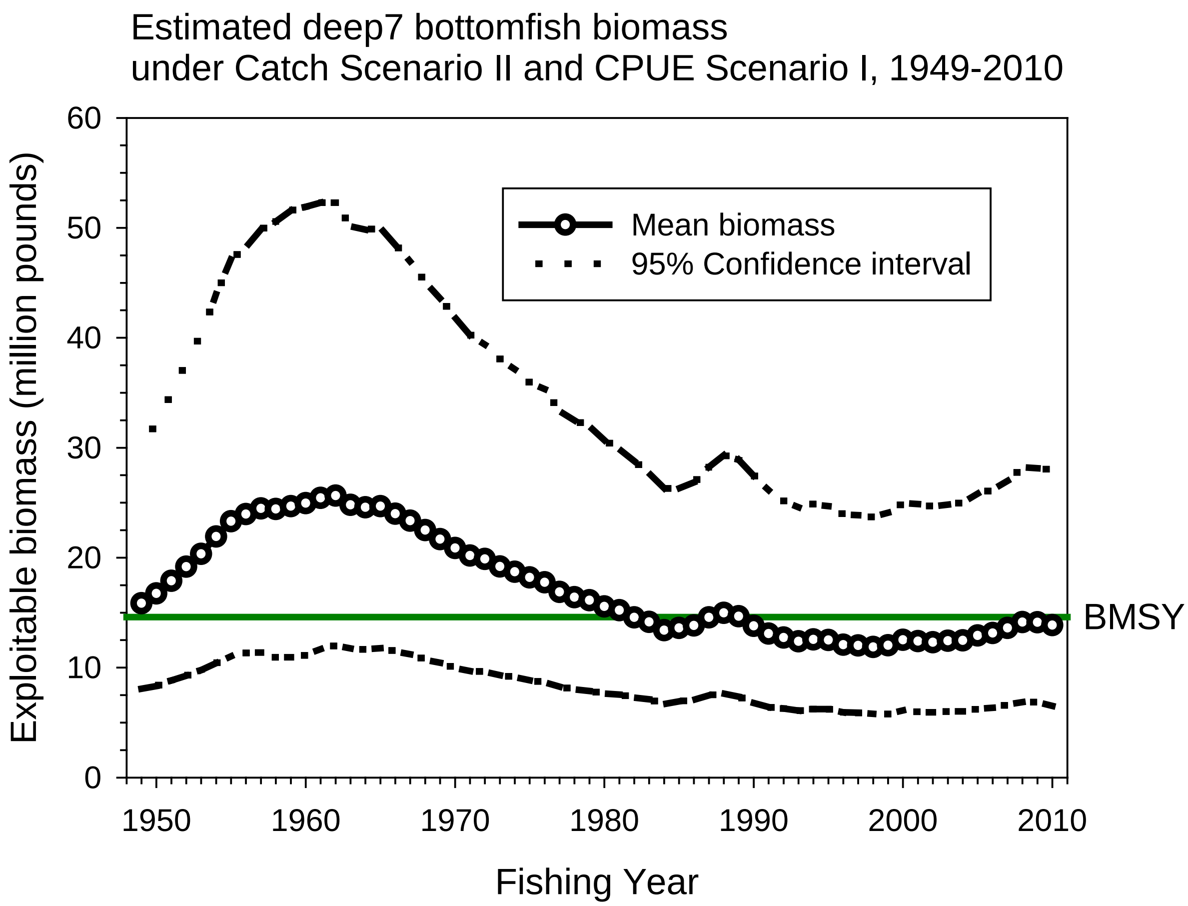


Figure 20.--Baseline model estimates of exploitable biomass (1), harvest rate (2), overfishing status in 2010 (3), depletion status in 2010 (4), and relative stock status as a Kobe plot (5) of Deep7 Hawaiian bottomfish under Catch Scenario II and CPUE Scenario I by fishing year, 1949-2010.

(20.2)

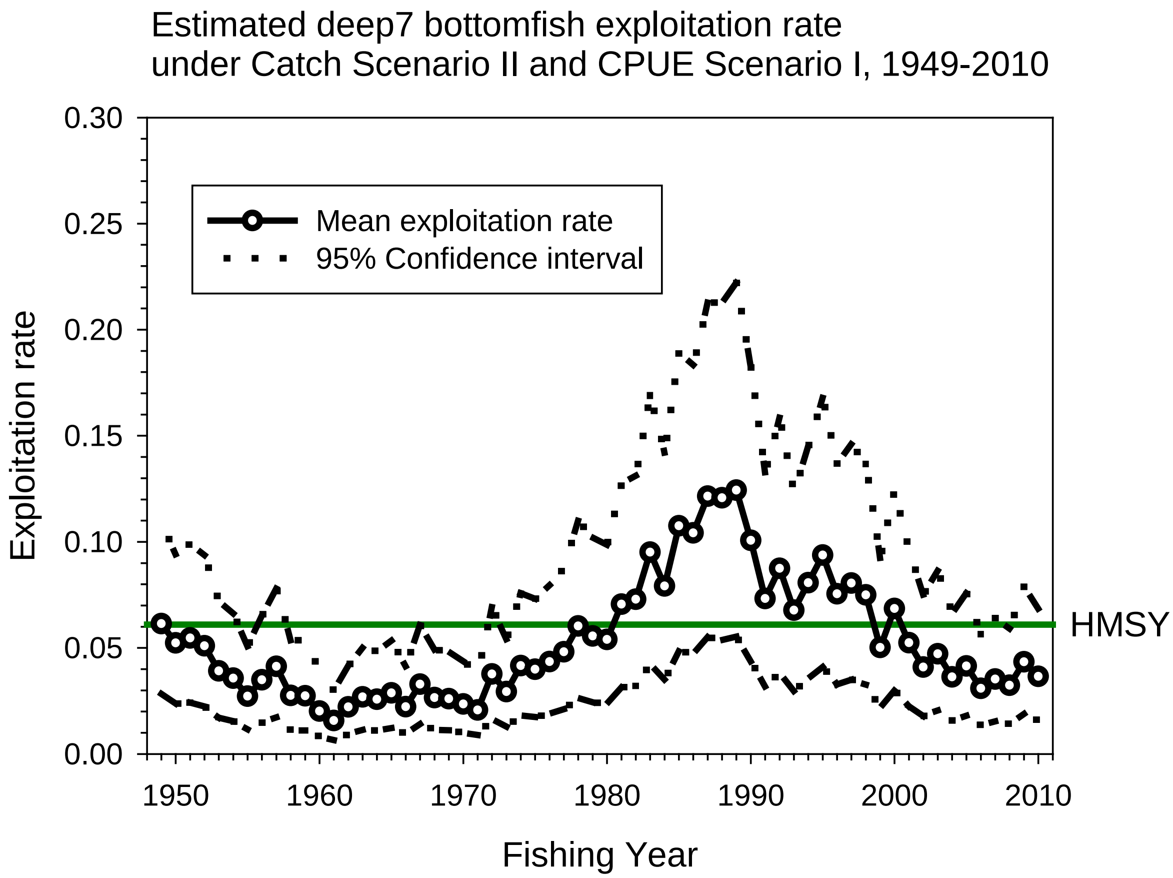


Figure 20.—Baseline model estimates of exploitable biomass, continued.

(20.3)

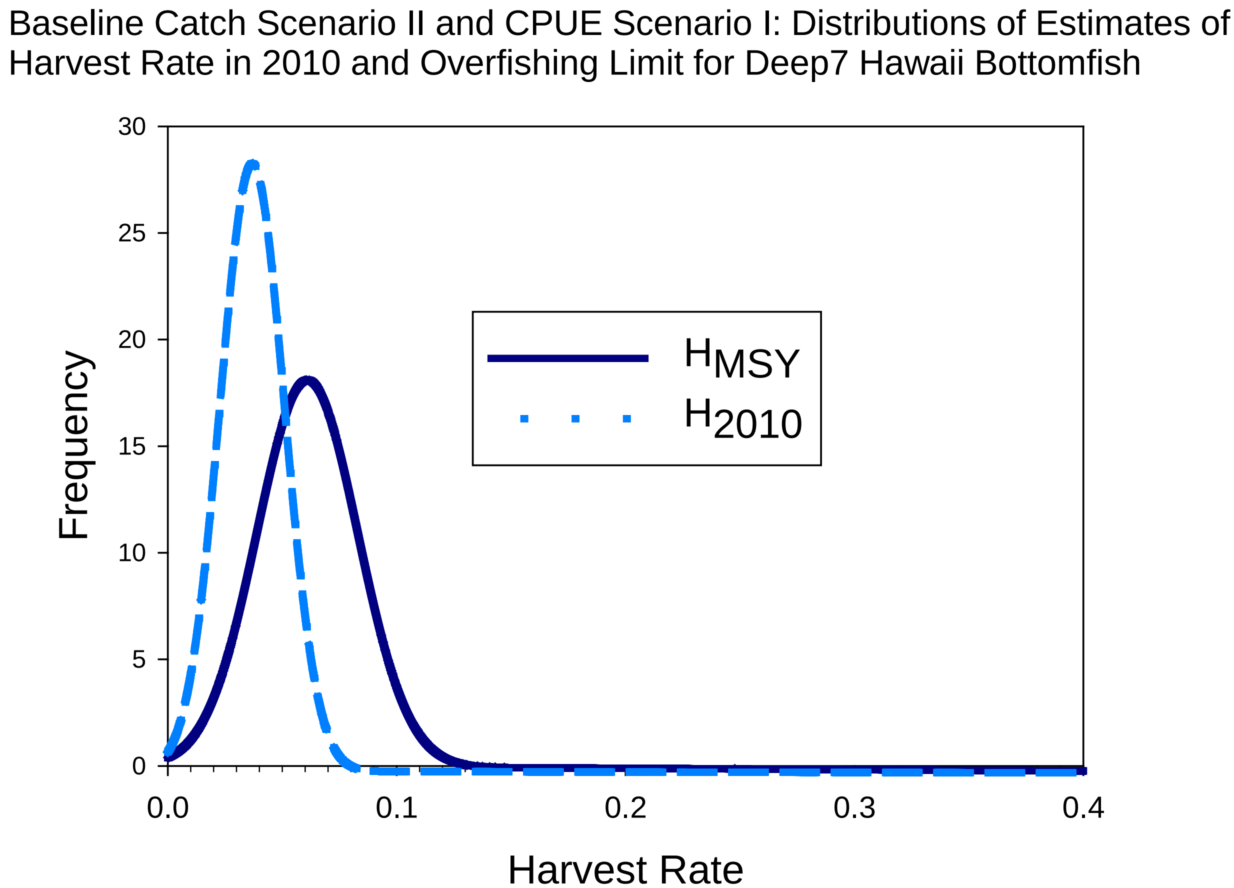


Figure 20.—Baseline model estimates of exploitable biomass, continued.

(20.4)

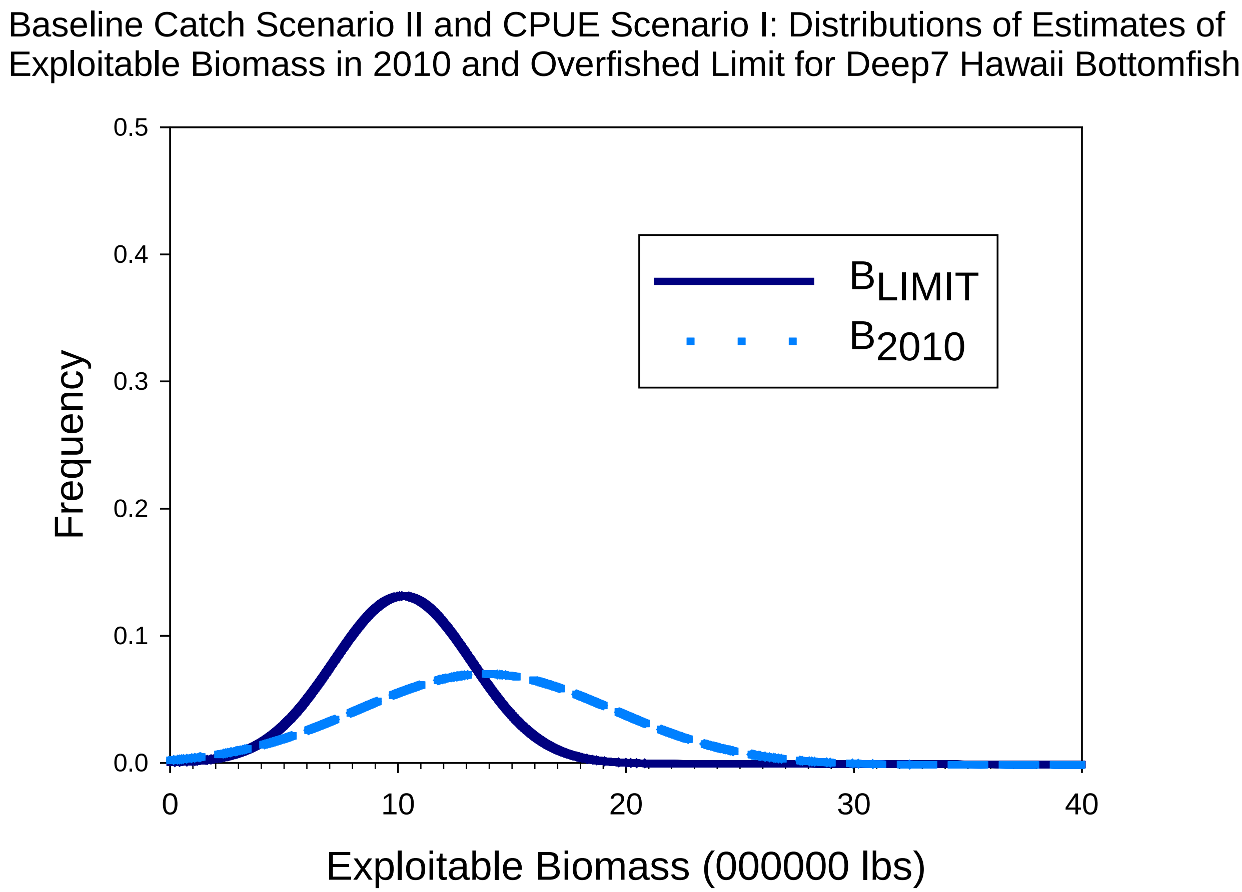


Figure 20.—Baseline model estimates of exploitable biomass, continued.

(20.5)

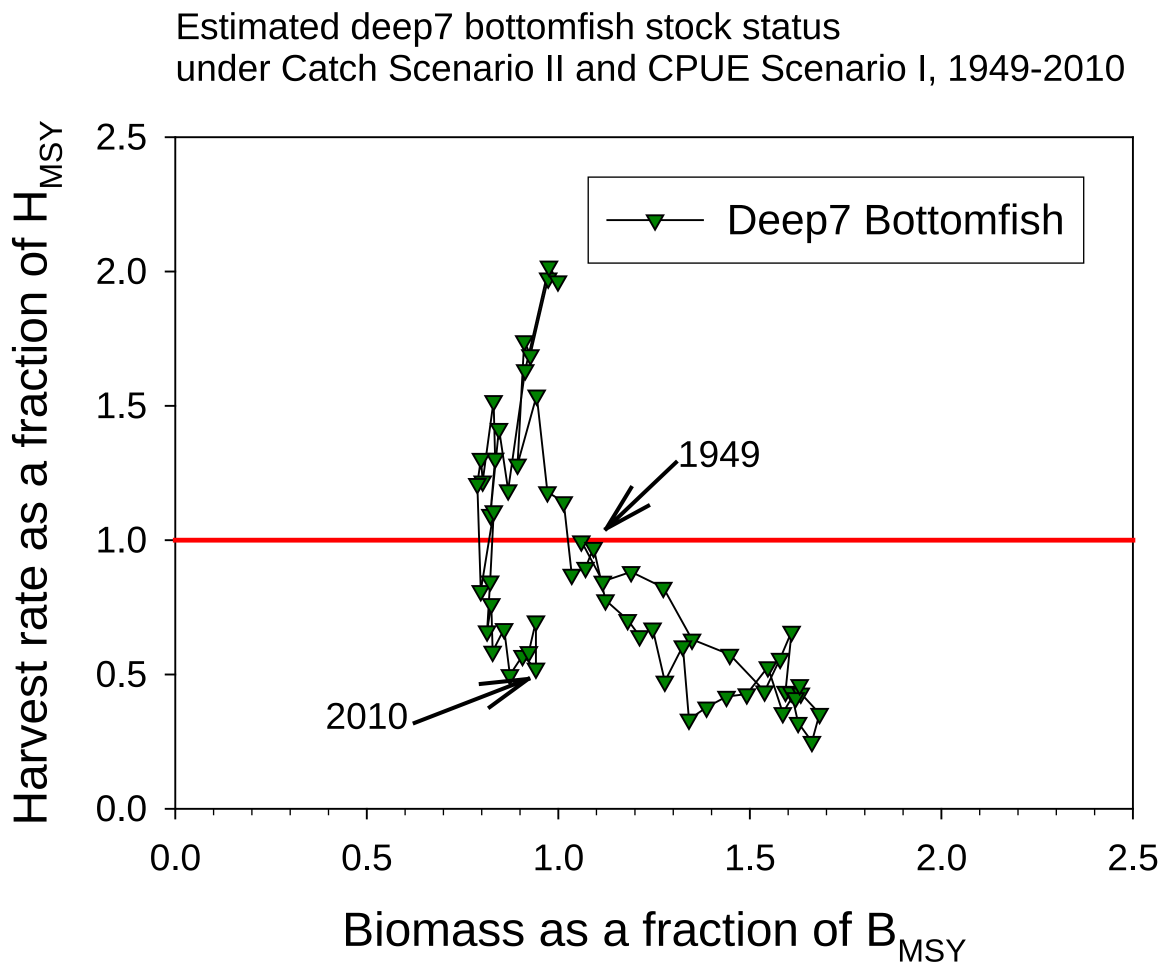


Figure 20.—Baseline model estimates of exploitable biomass, continued.

(21.1)

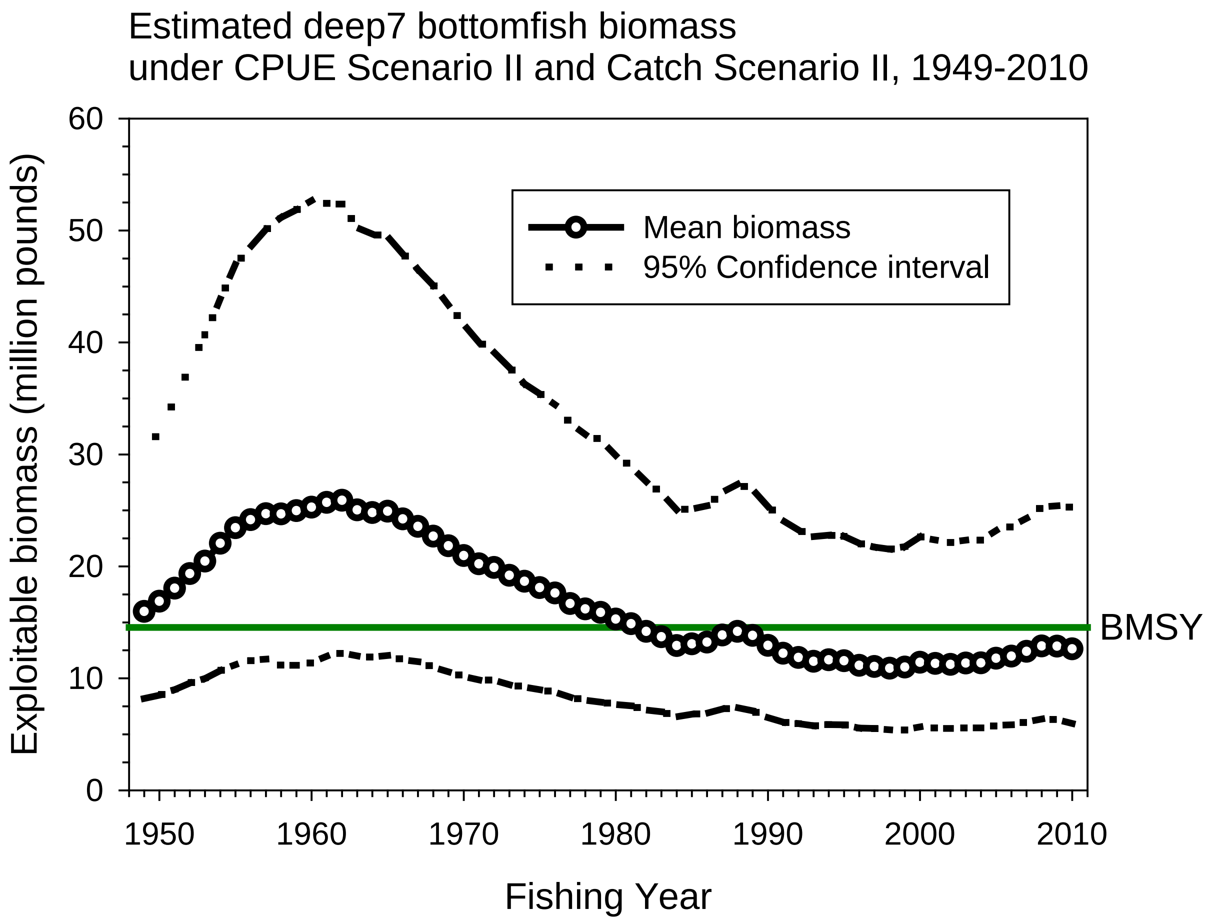


Figure 21.--Estimates of exploitable biomass (1), harvest rate (2), overfishing status in 2010 (3), depletion status in 2010 (4), and relative stock status as a Kobe plot (5) of Deep7 Hawaiian bottomfish under Catch Scenario II and CPUE Scenario II by fishing year, 1949-2010.

(21.2)

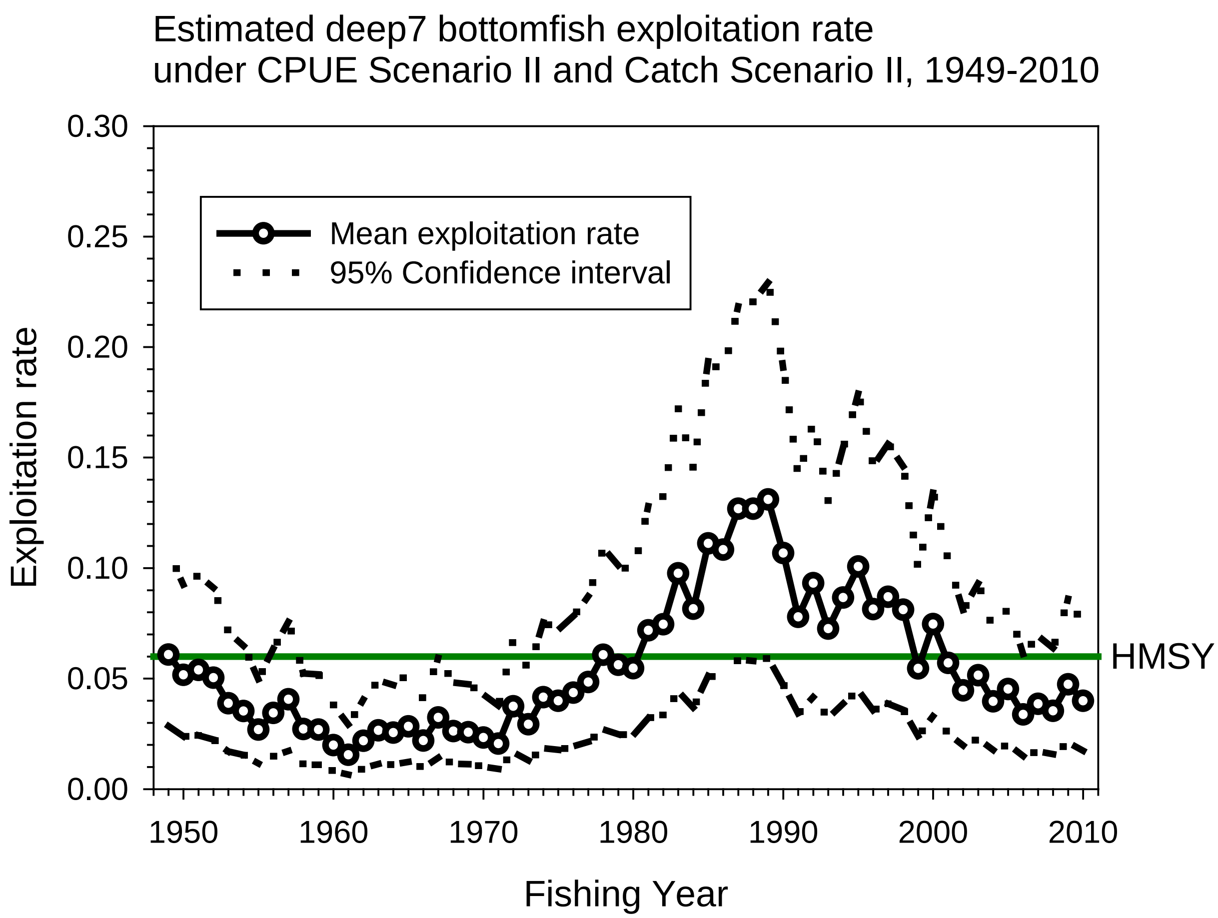


Figure 21.—Estimates of exploitable biomass, continued.

(21.3)

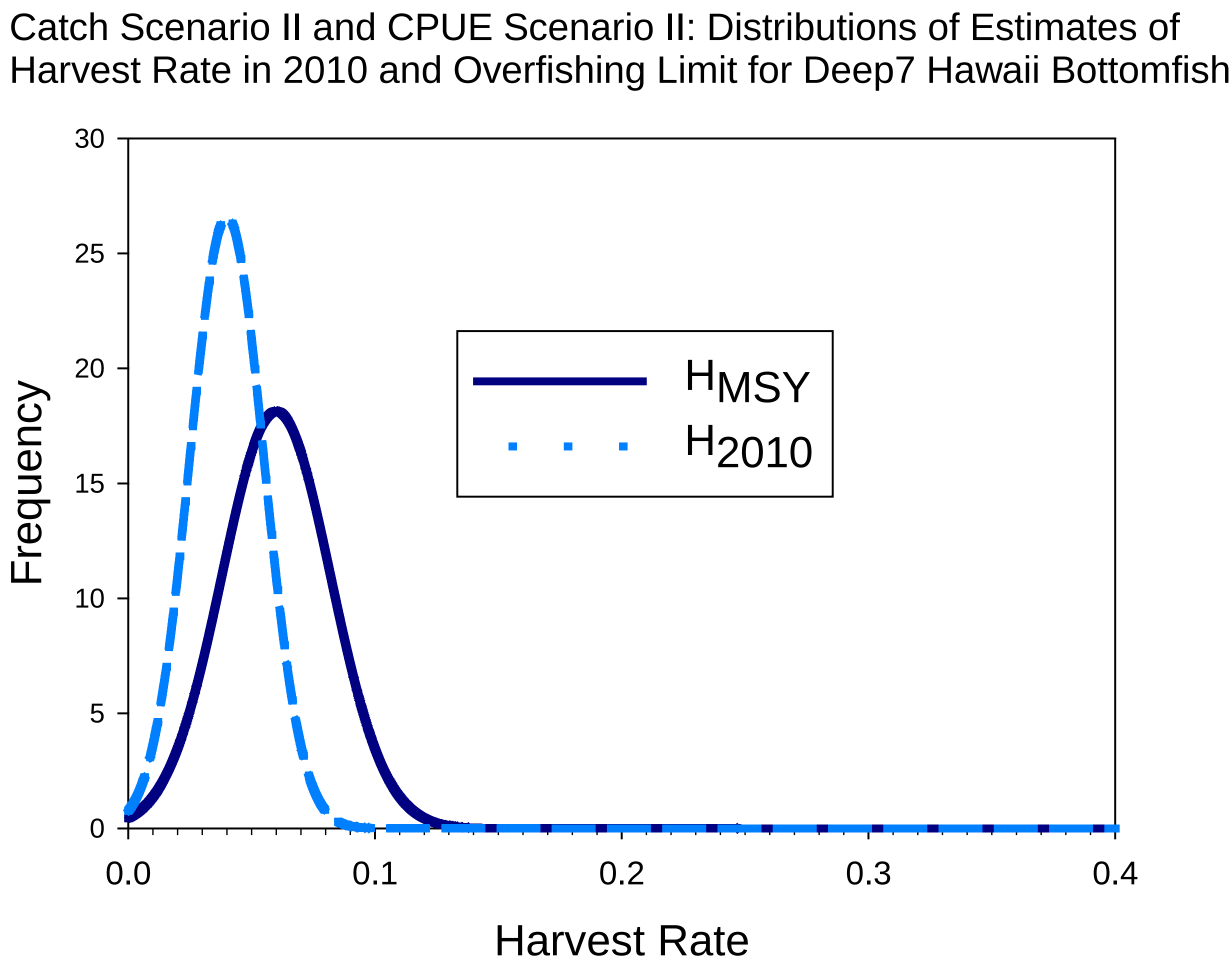


Figure 21.—Estimates of exploitable biomass, continued.

(21.4)

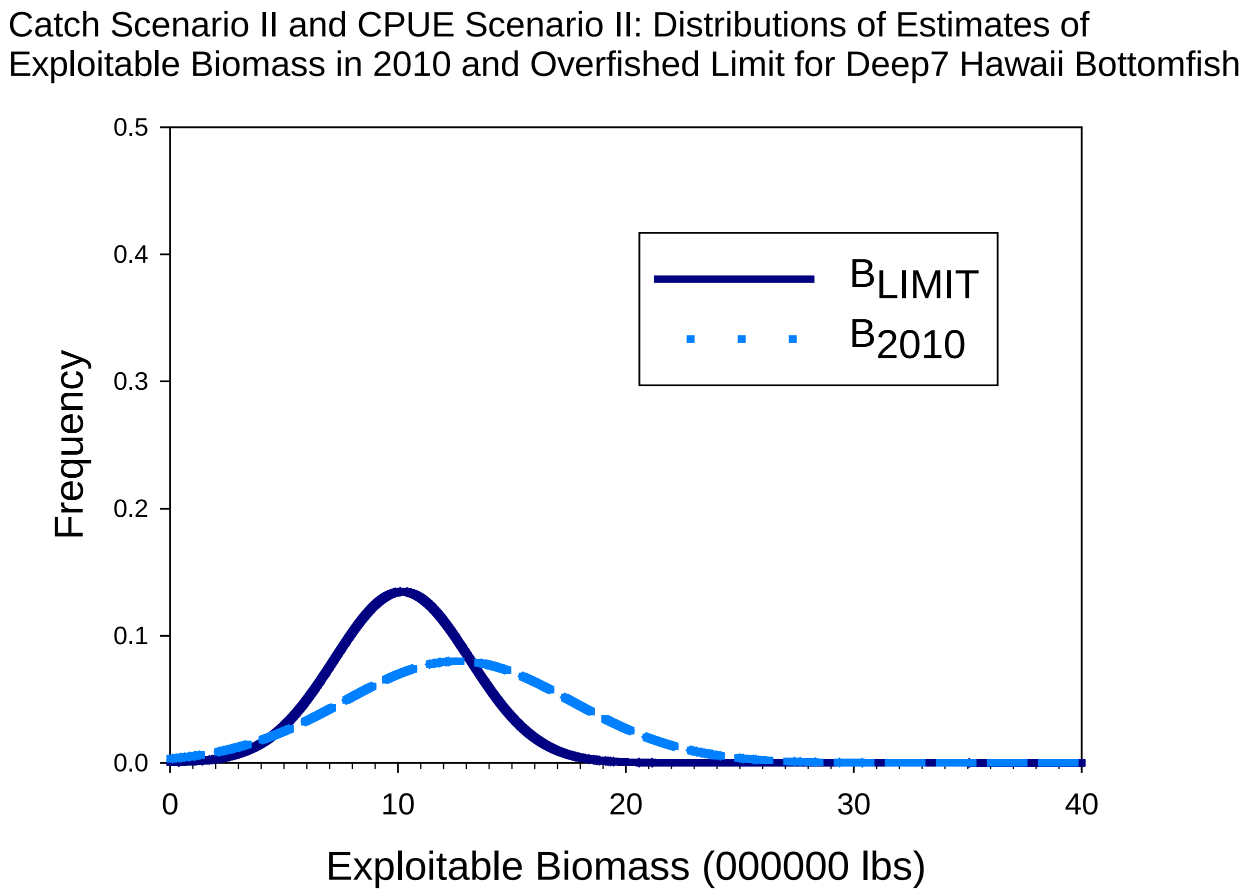


Figure 21.—Estimates of exploitable biomass, continued.

(21.5)

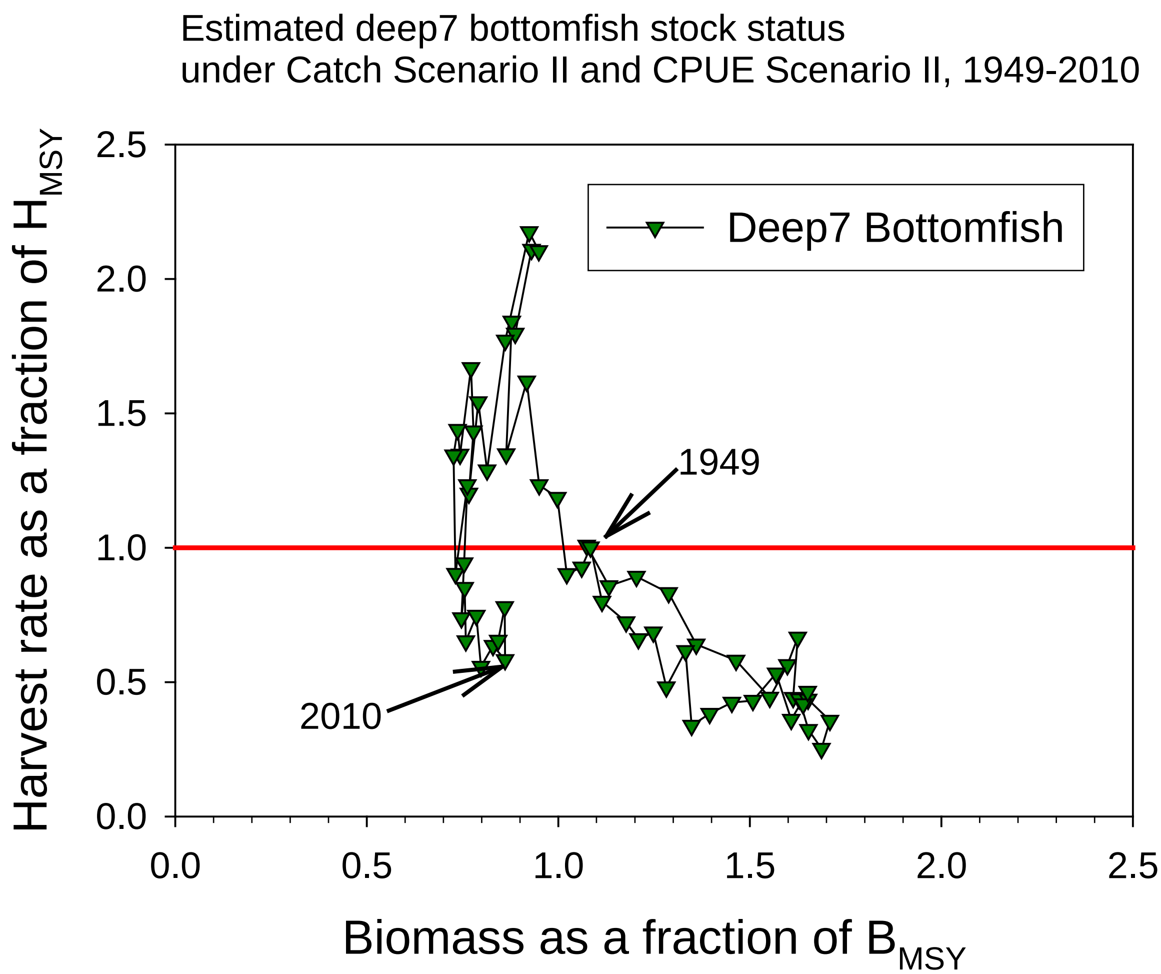


Figure 21.—Estimates of exploitable biomass, continued.

(22.1)

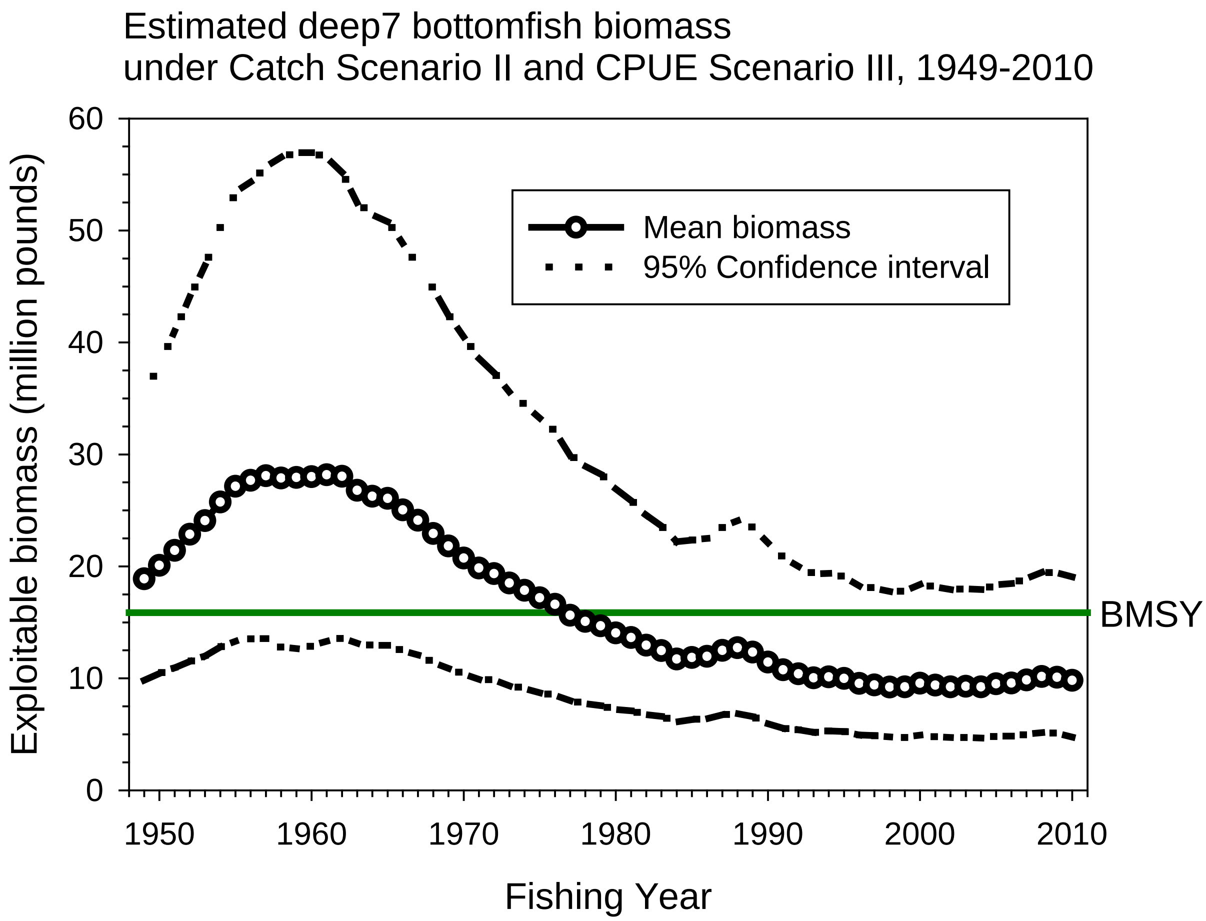


Figure 22.--Estimates of exploitable biomass (1), harvest rate (2), overfishing status in 2010 (3), depletion status in 2010 (4), and relative stock status as a Kobe plot (5) of Deep7 Hawaiian bottomfish under Catch Scenario II and CPUE Scenario III by fishing year, 1949-2010.

(22.2)

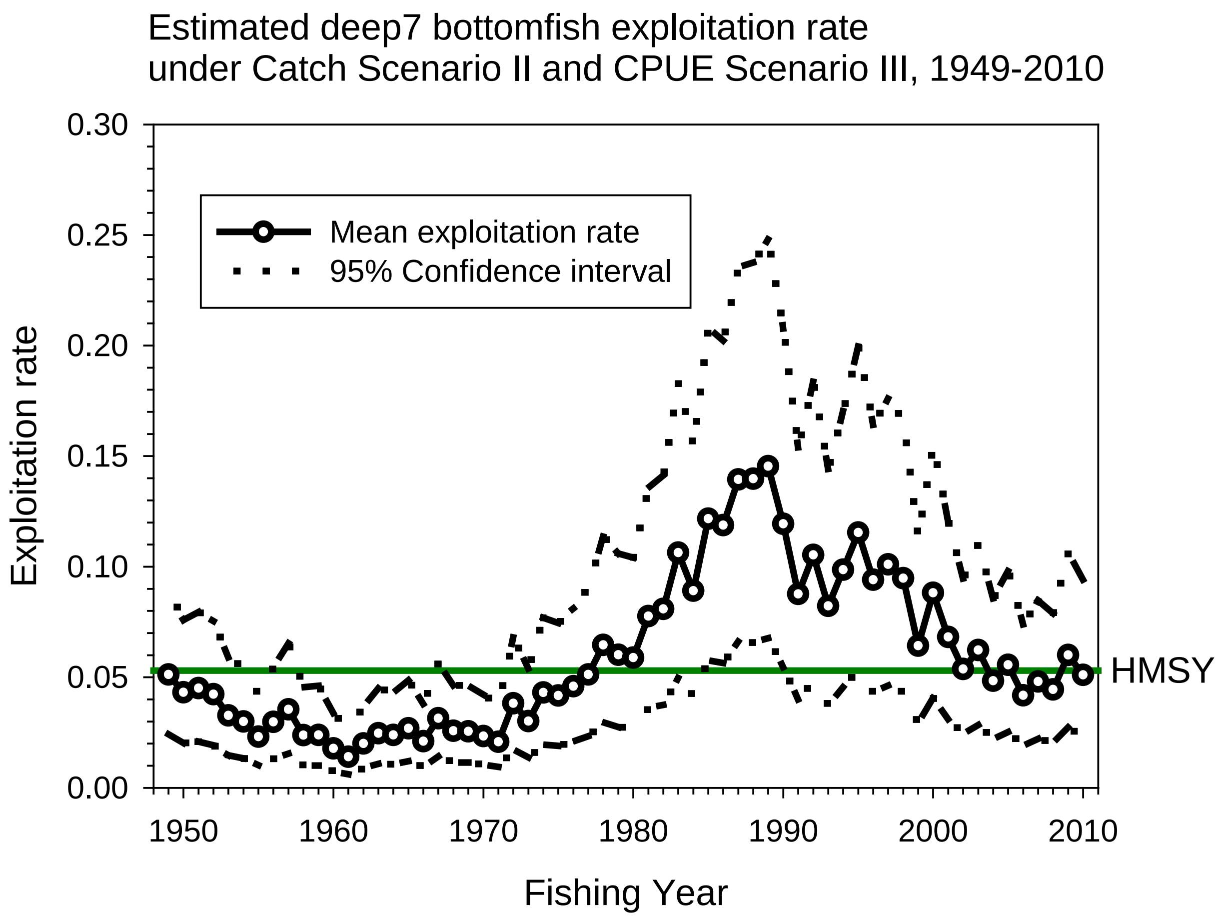


Figure 22.—Estimates of exploitable biomass, continued.

(22.3)

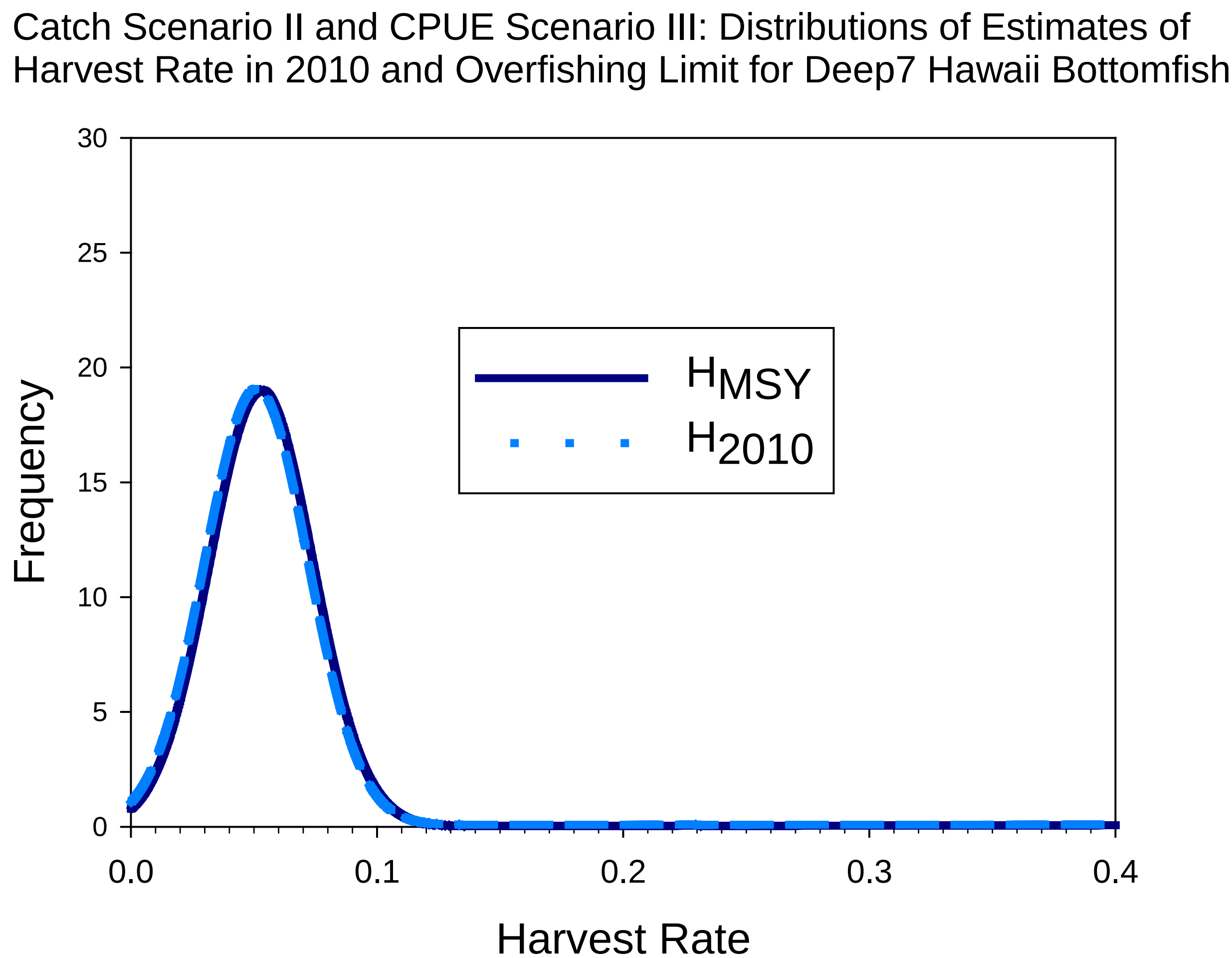


Figure 22.—Estimates of exploitable biomass, continued.

(22.4)

Catch Scenario II and CPUE Scenario III: Distributions of Estimates of Exploitable Biomass in 2010 and Overfished Limit for Deep7 Hawaii Bottomfish

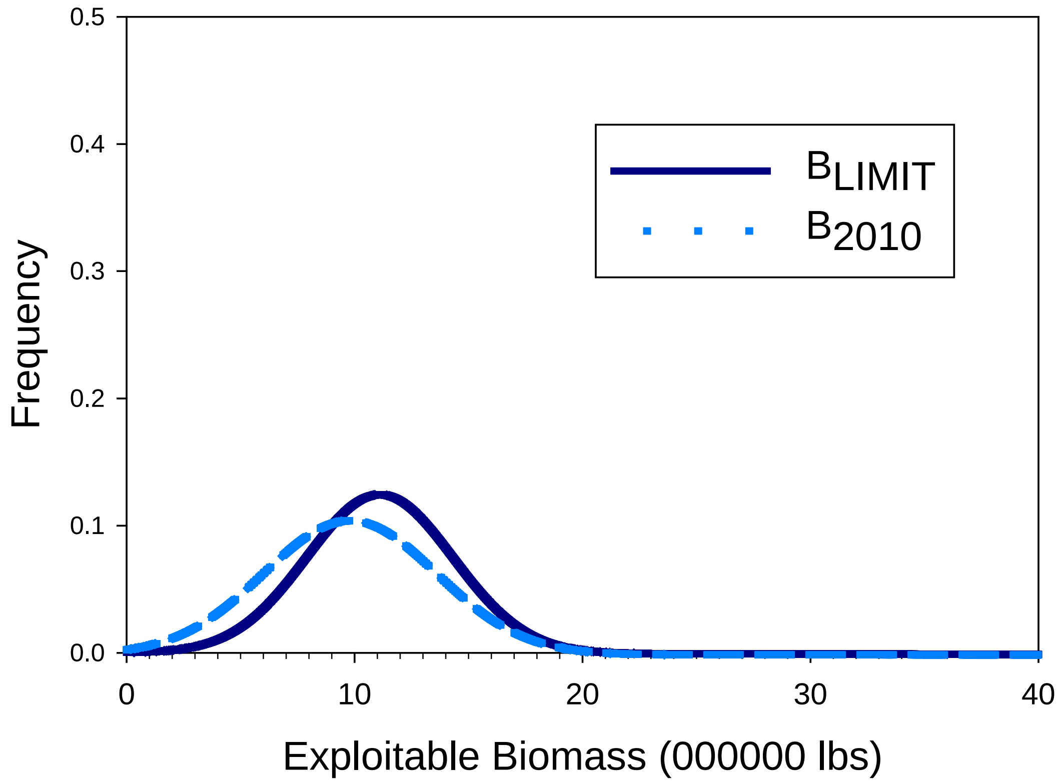


Figure 22.—Estimates of exploitable biomass, continued.

(22.5)

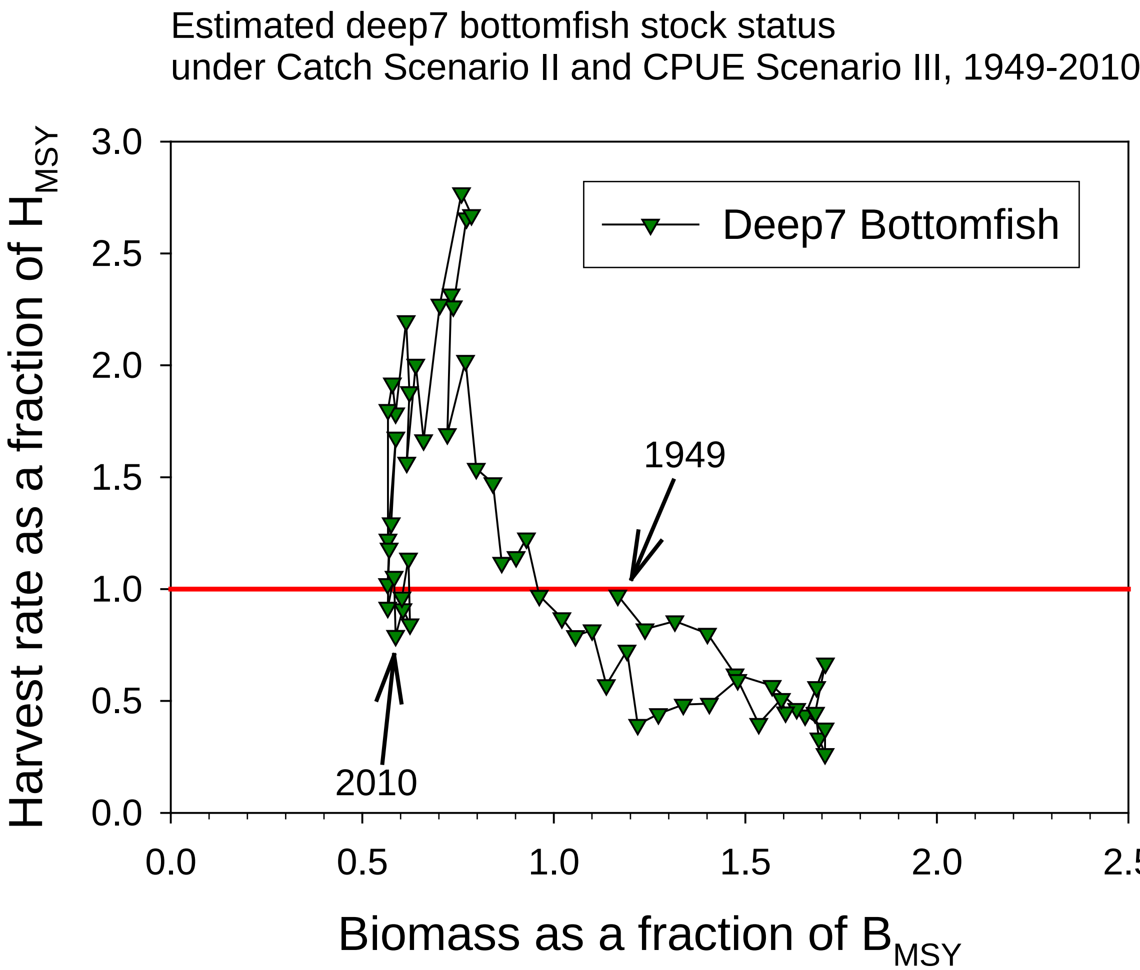


Figure 22.—Estimates of exploitable biomass, continued.

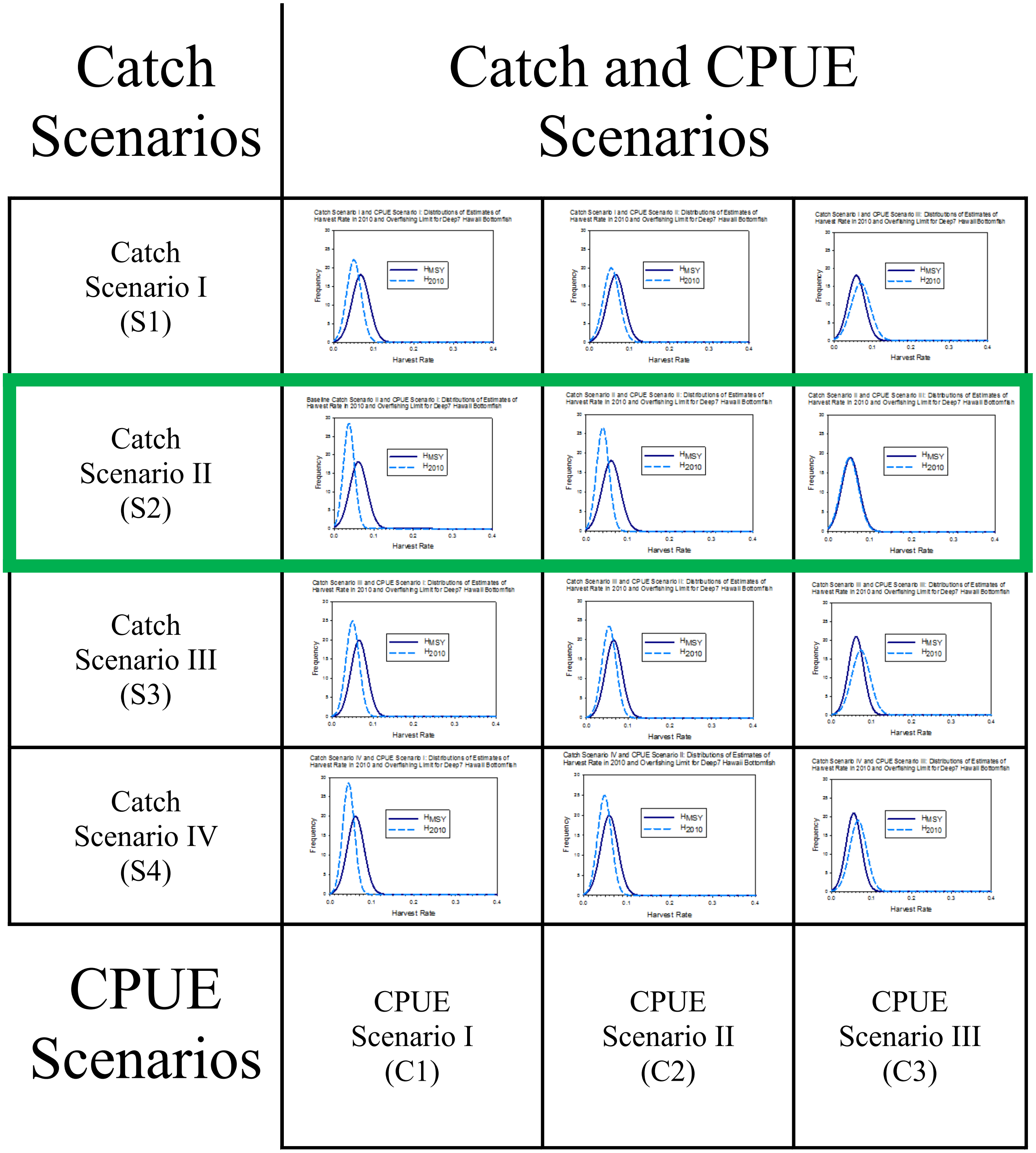


Figure 23.1.--Sensitivity analyses showing a comparison of overfishing status determinations of Deep7 Hawaii bottomfish in the main Hawaiian Islands under alternative assumptions about the appropriate catch and CPUE scenarios.

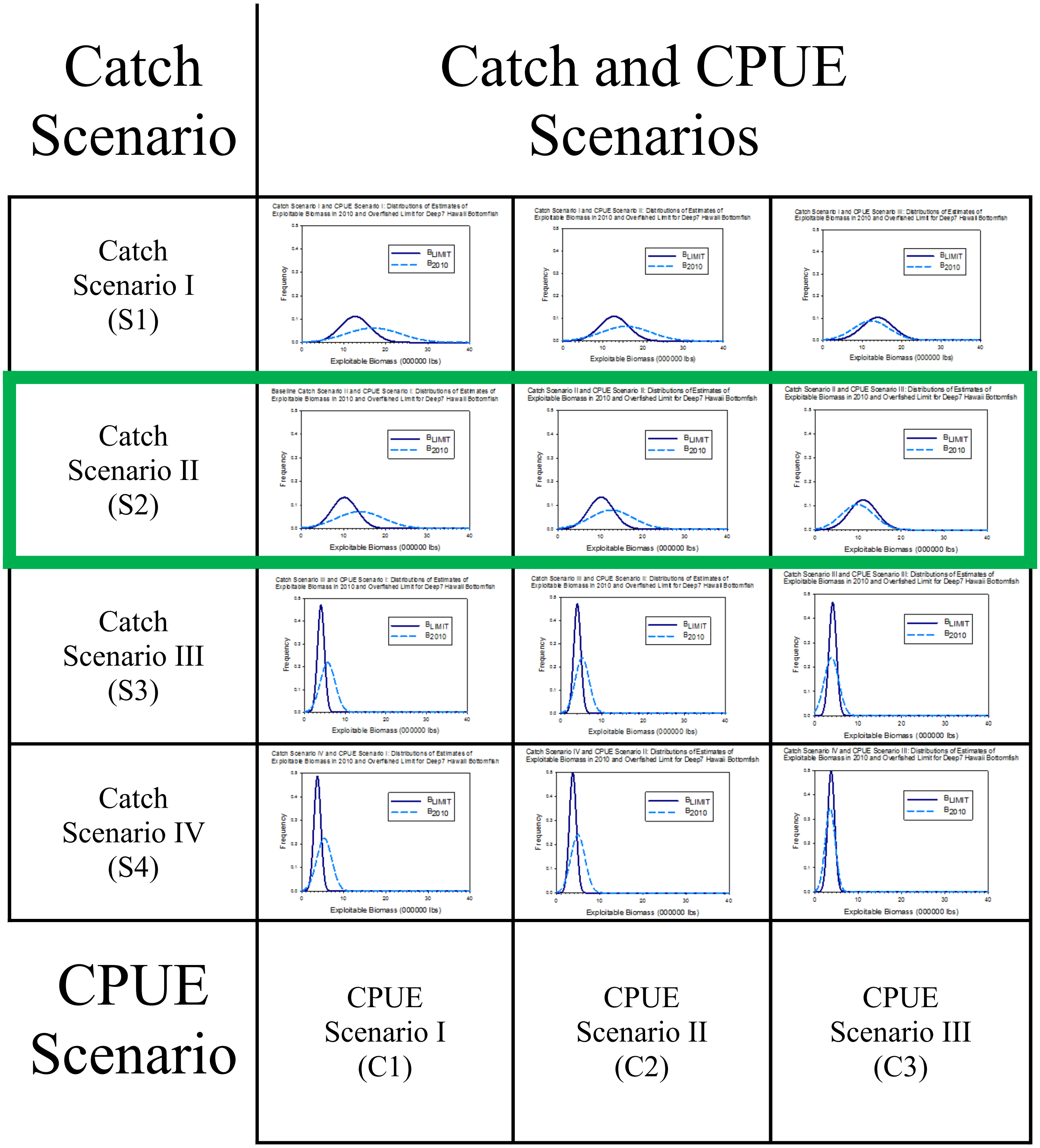


Figure 23.2.--Sensitivity analyses showing a comparison of status determinations of stock depletion of Deep7 Hawaii bottomfish in the main Hawaiian Islands under alternative assumptions about the appropriate catch and CPUE scenarios.

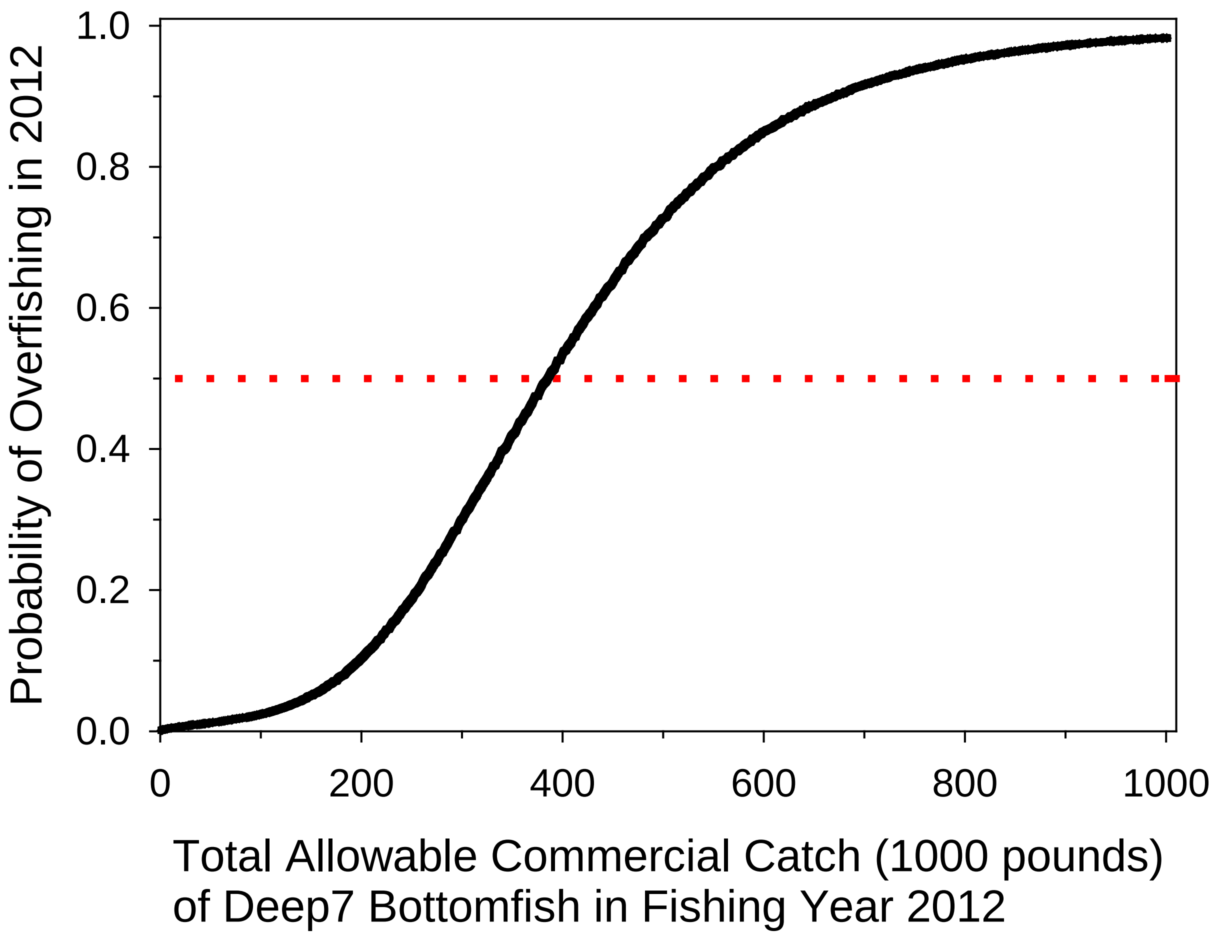


Figure 24.1.--Projection results for estimates of total allowable catches of Deep7 Hawaiian bottomfish for fishing years 2012-2013 that would produce a range of probabilities of overfishing in 2012 from 0% to 50% and greater under Baseline Catch Scenario II and Baseline CPUE Scenario I.

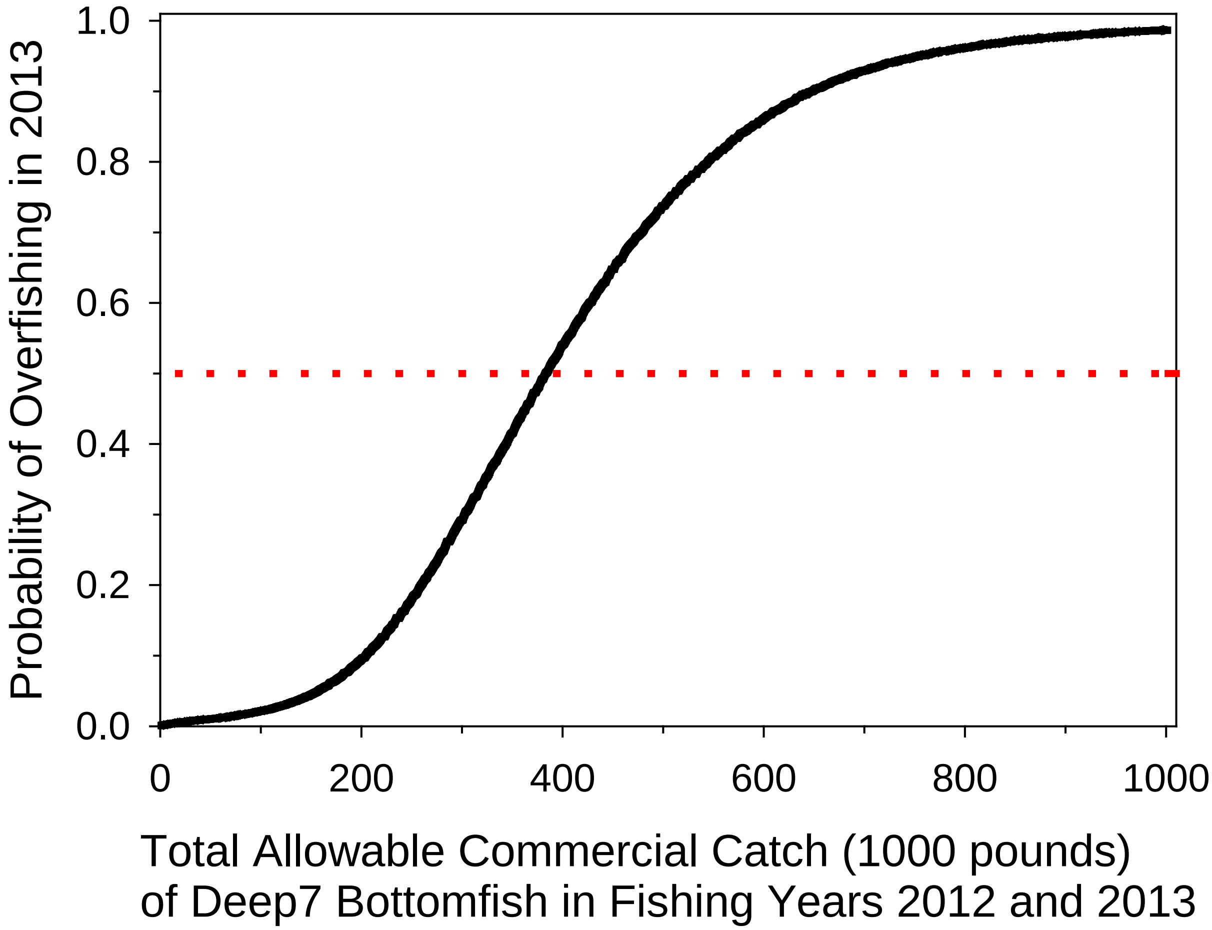


Figure 24.2.--Projection results for estimates of total allowable catches of Deep7 Hawaiian bottomfish for fishing years 2012-2013 that would produce a range of probabilities of overfishing in 2013 from 0% to 50% and greater under Baseline Catch Scenario II and Baseline CPUE Scenario I.

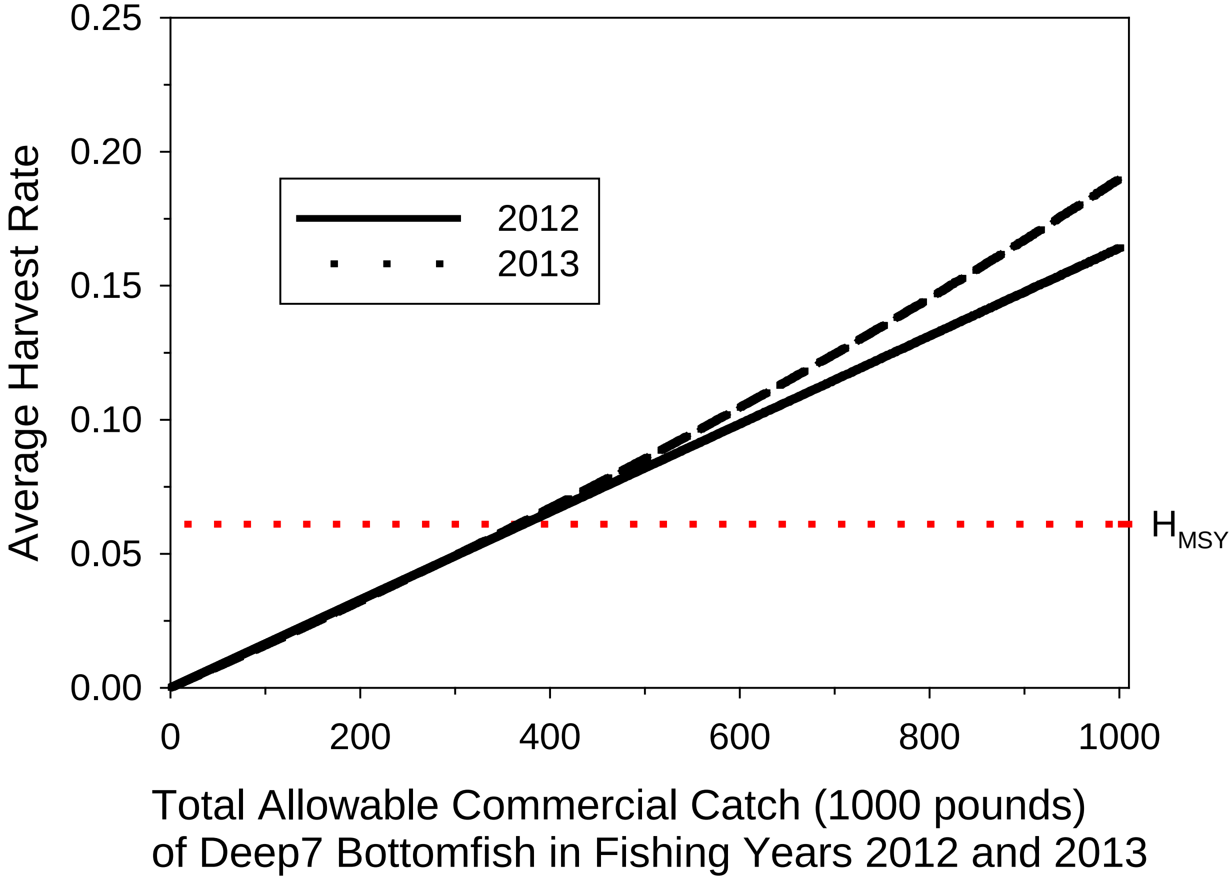


Figure 24.3.--Projection results showing estimates of average harvest rates of Deep7 Hawaiian bottomfish for fishing years 2012-2013 for alternative commercial TACs under Baseline Catch Scenario II and Baseline CPUE Scenario I.

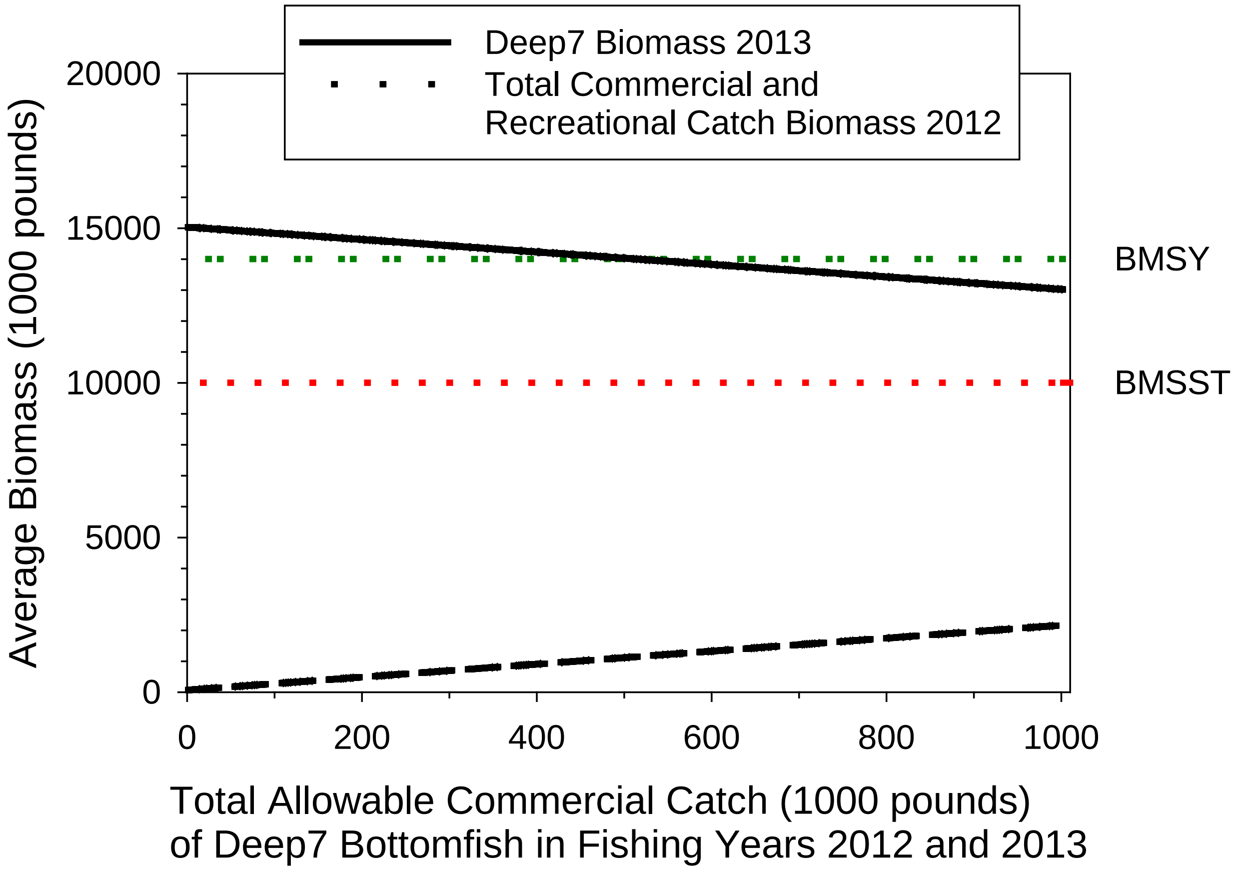


Figure 24.4.--Projection results showing estimates of average exploitable biomass of Deep7 Hawaiian bottomfish for fishing years 2012-2013 for alternative commercial TACs under Baseline Catch Scenario II and Baseline CPUE Scenario I.

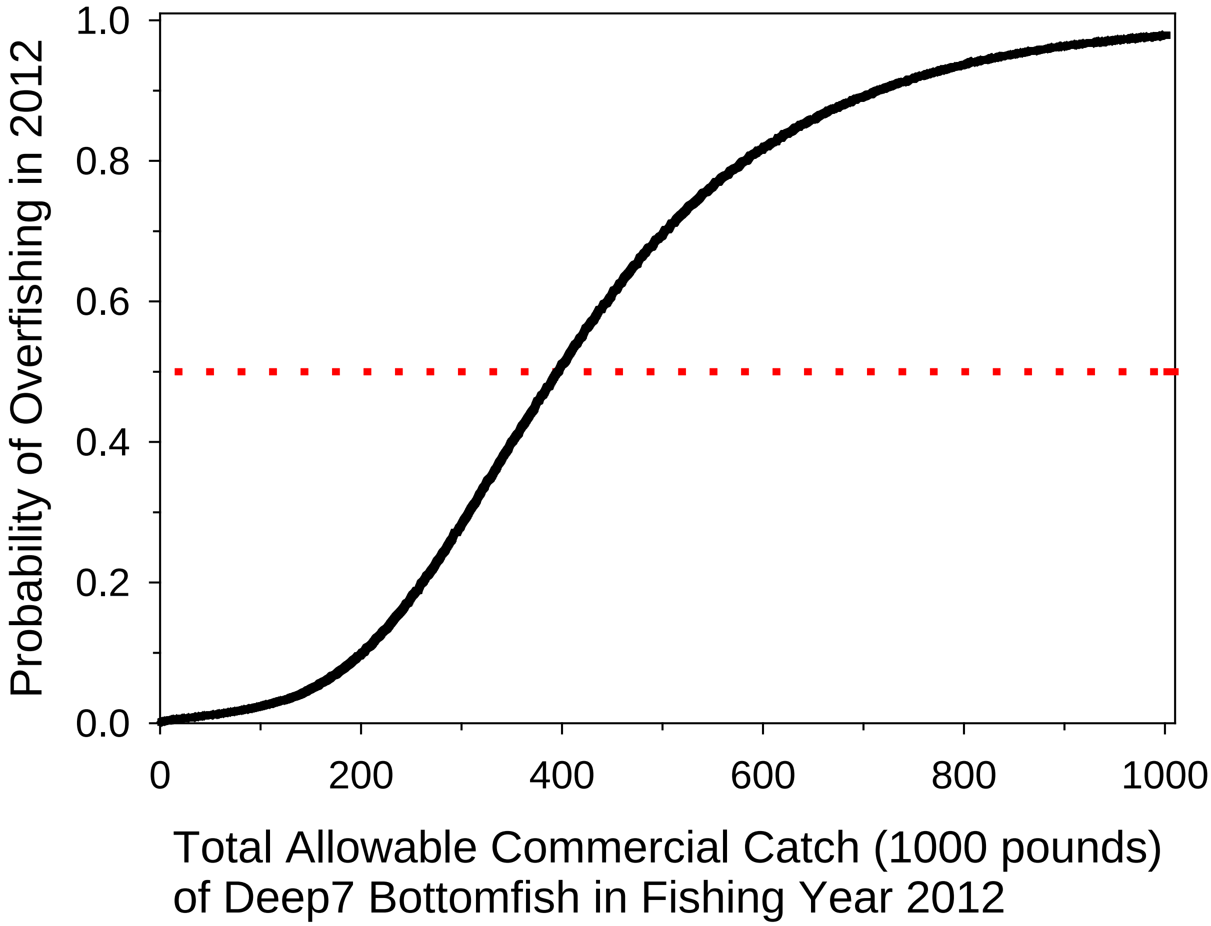


Figure 25.1.--Projection results for estimates of total allowable catches of Deep7 Hawaiian bottomfish for fishing years 2012-2013 that would produce a range of probabilities of overfishing in 2012 from 0% to 50% and greater under Catch Scenario II and CPUE Scenario II.

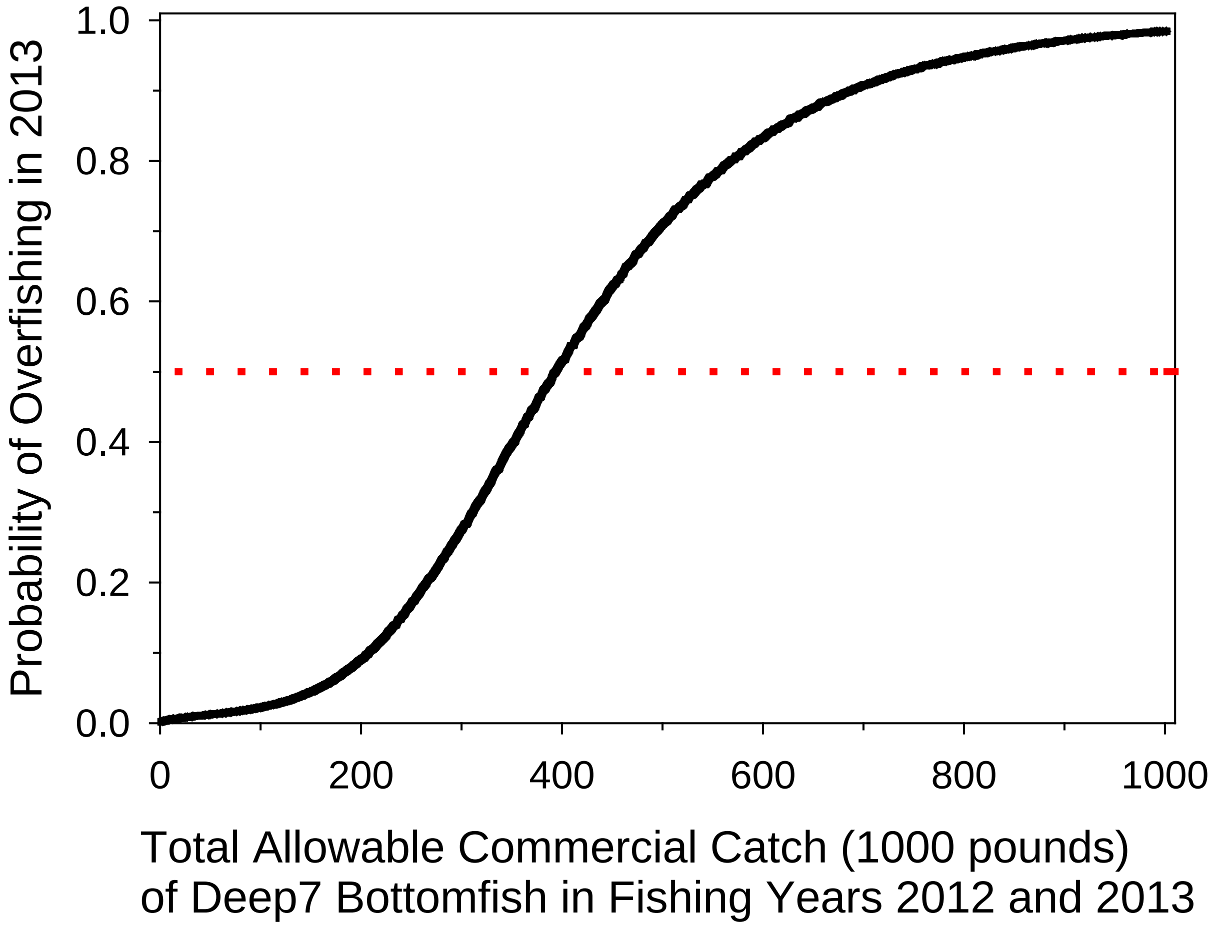


Figure 25.2.--Projection results for estimates of total allowable catches of Deep7 Hawaiian bottomfish for fishing years 2012-2013 that would produce a range of probabilities of overfishing in 2013 from 0% to 50% and greater under Catch Scenario II and CPUE Scenario II.

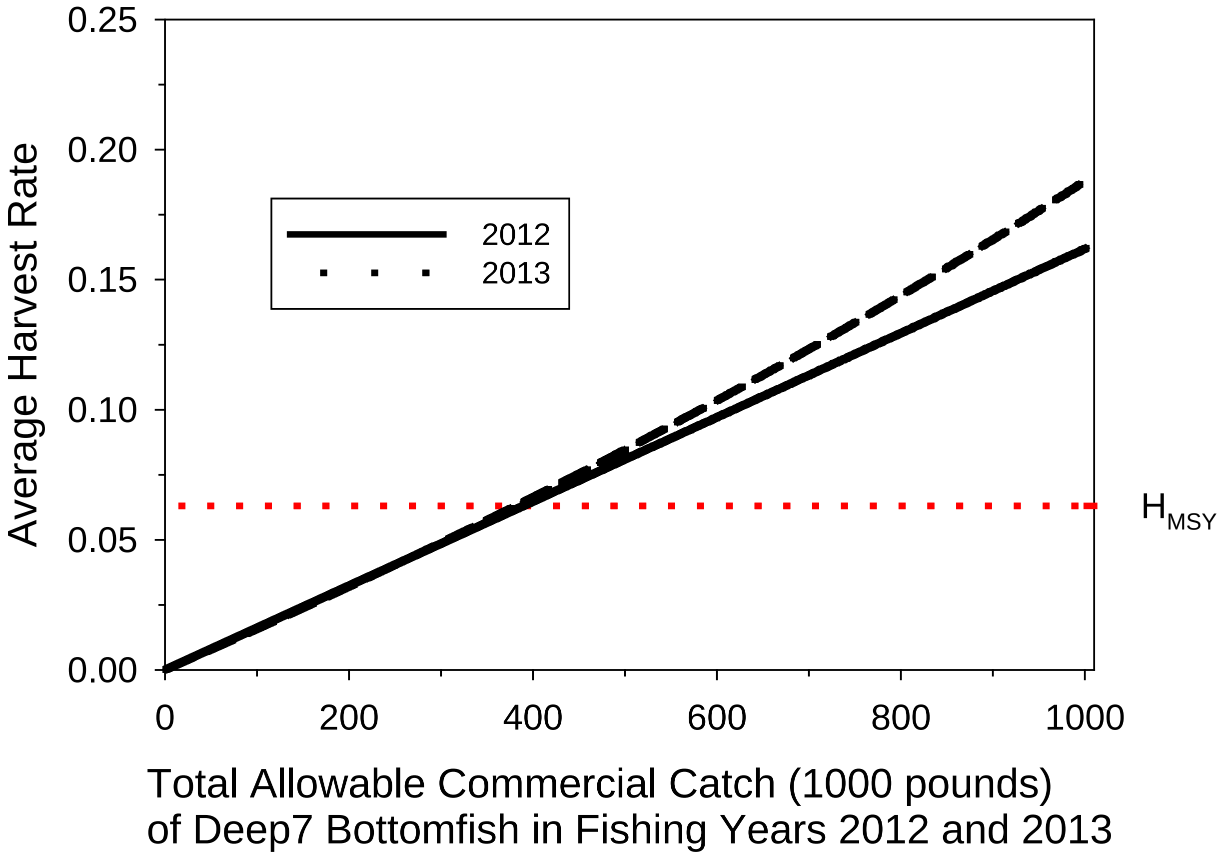


Figure 25.3.--Projection results showing estimates of average harvest rates of Deep7 Hawaiian bottomfish for fishing years 2012-2013 for alternative commercial TACs under Catch Scenario II and CPUE Scenario II.

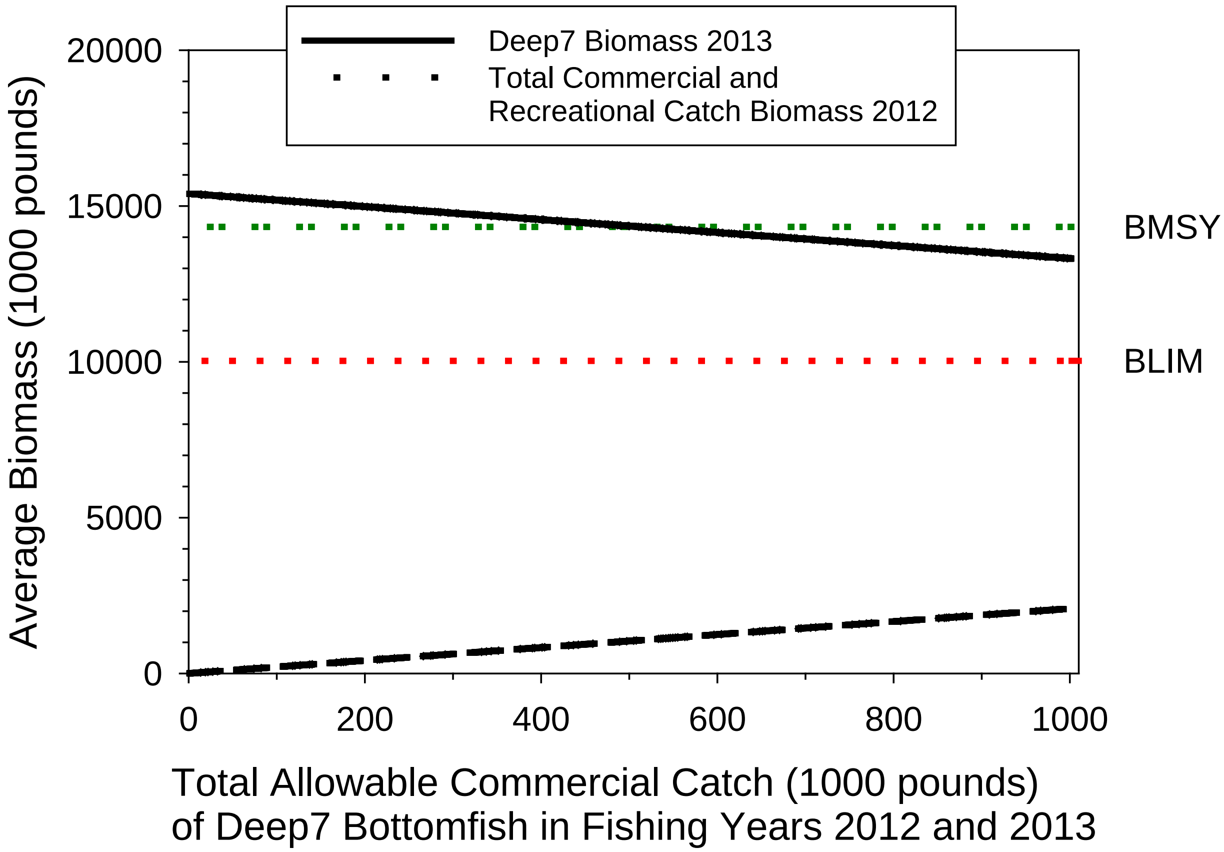


Figure 25.4.--Projection results showing estimates of average exploitable biomass of Deep7 Hawaiian bottomfish for fishing years 2012-2013 for alternative commercial TACs under Baseline Catch Scenario II and CPUE Scenario II.

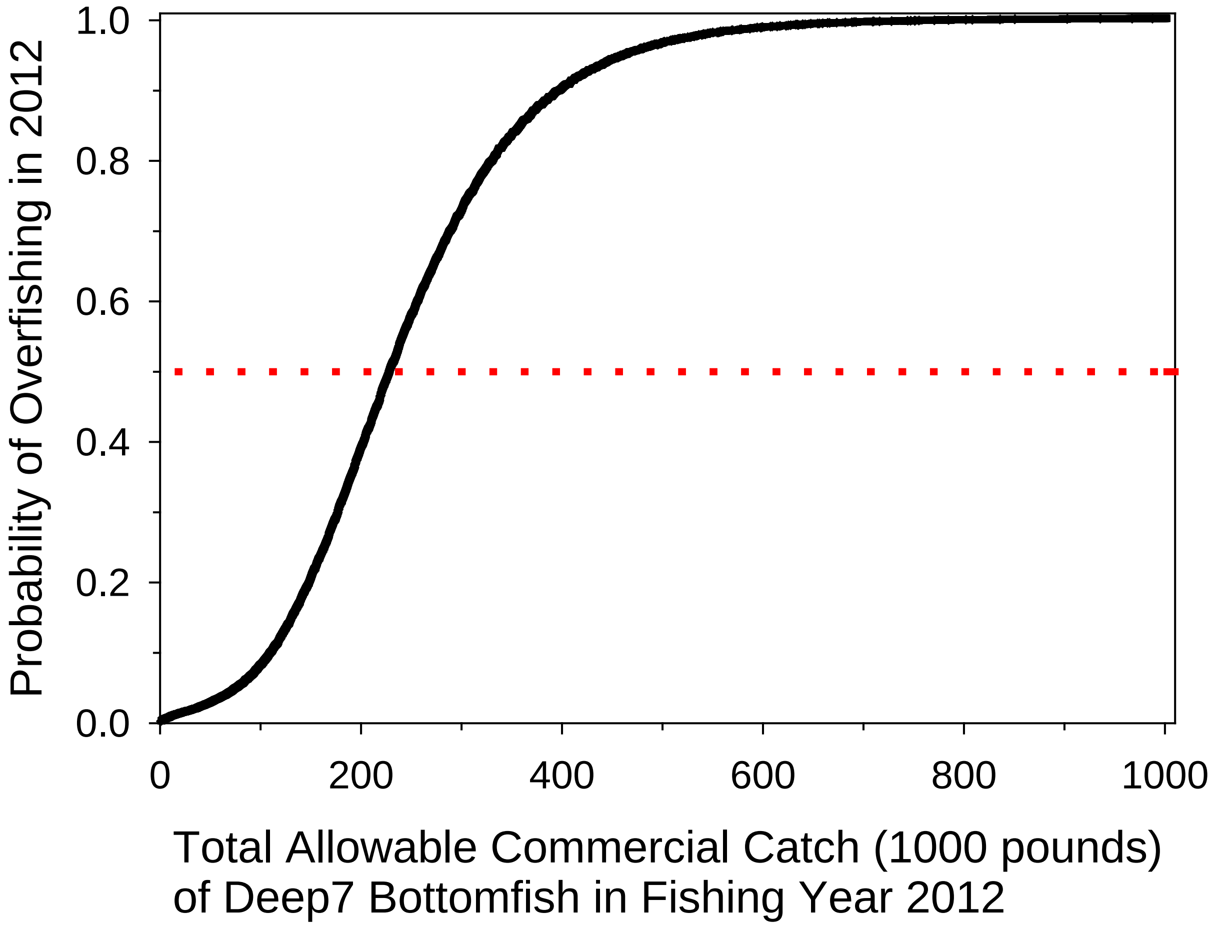


Figure 26.1.--Projection results for estimates of total allowable catches of Deep7 Hawaiian bottomfish for fishing years 2012-2013 that would produce a range of probabilities of overfishing in 2012 from 0% to 50% and greater under Catch Scenario II and CPUE Scenario III.

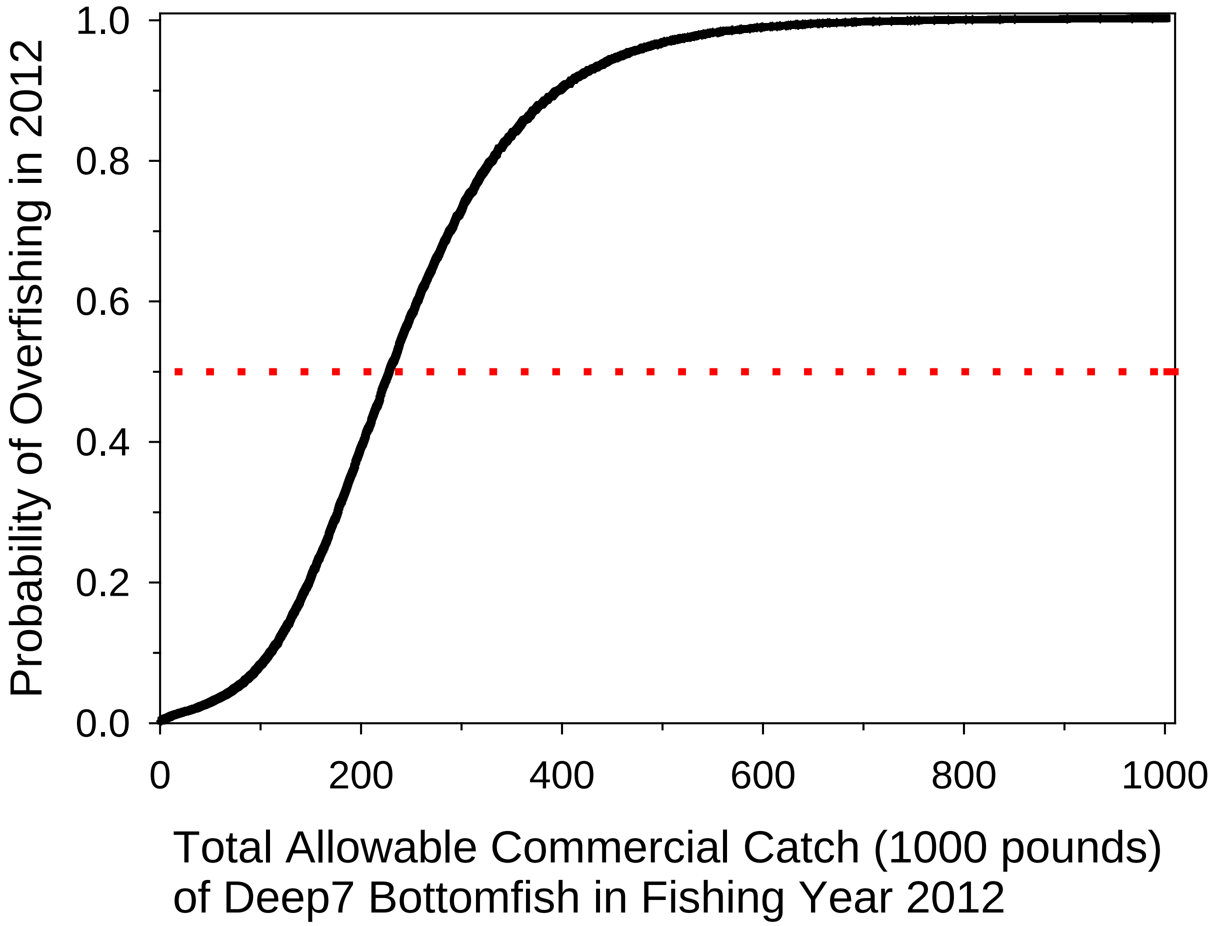


Figure 26.2.--Projection results for estimates of total allowable catches of Deep7 Hawaiian bottomfish for fishing years 2012-2013 that would produce a range of probabilities of overfishing in 2013 from 0% to 50% and greater under Catch Scenario II and CPUE Scenario III.

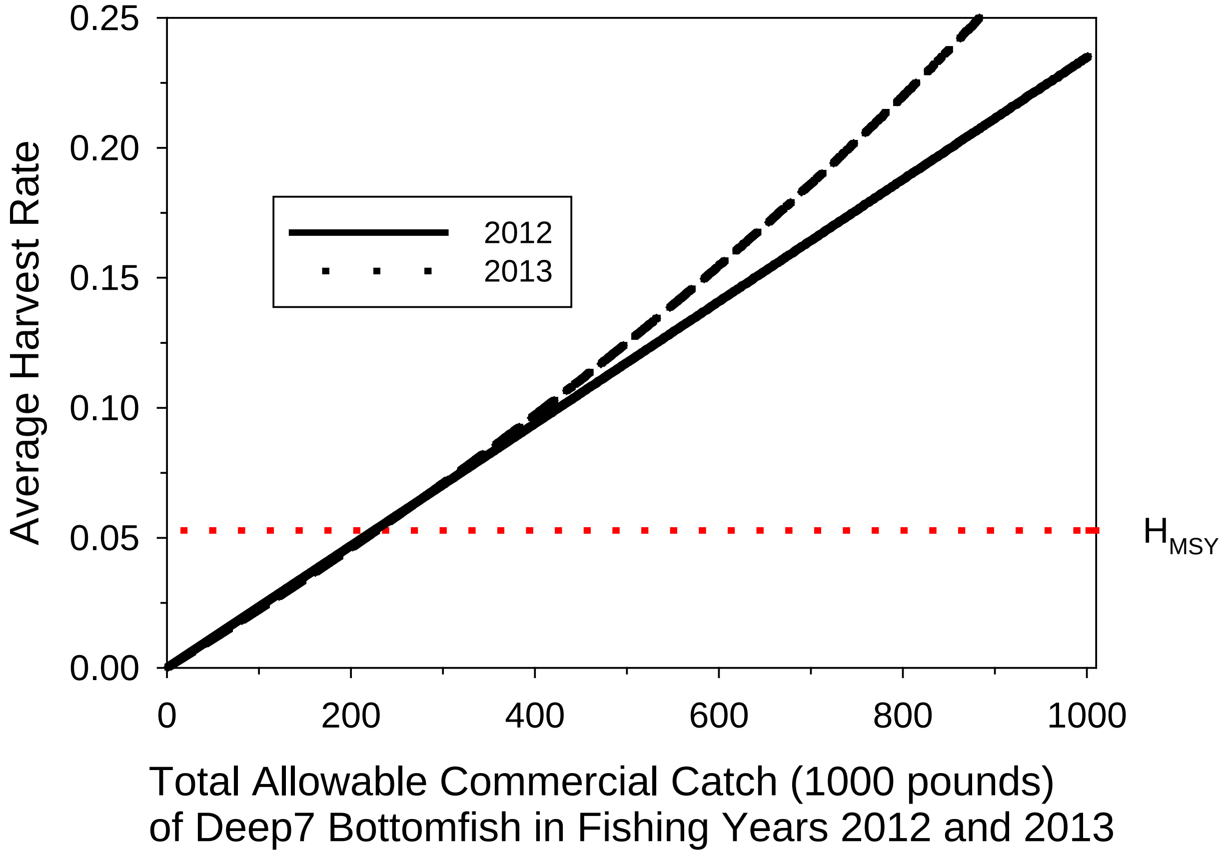


Figure 26.3.--Projection results showing estimates of average harvest rates of Deep7 Hawaiian bottomfish for fishing years 2012-2013 for alternative commercial TACs under Catch Scenario II and CPUE Scenario III.

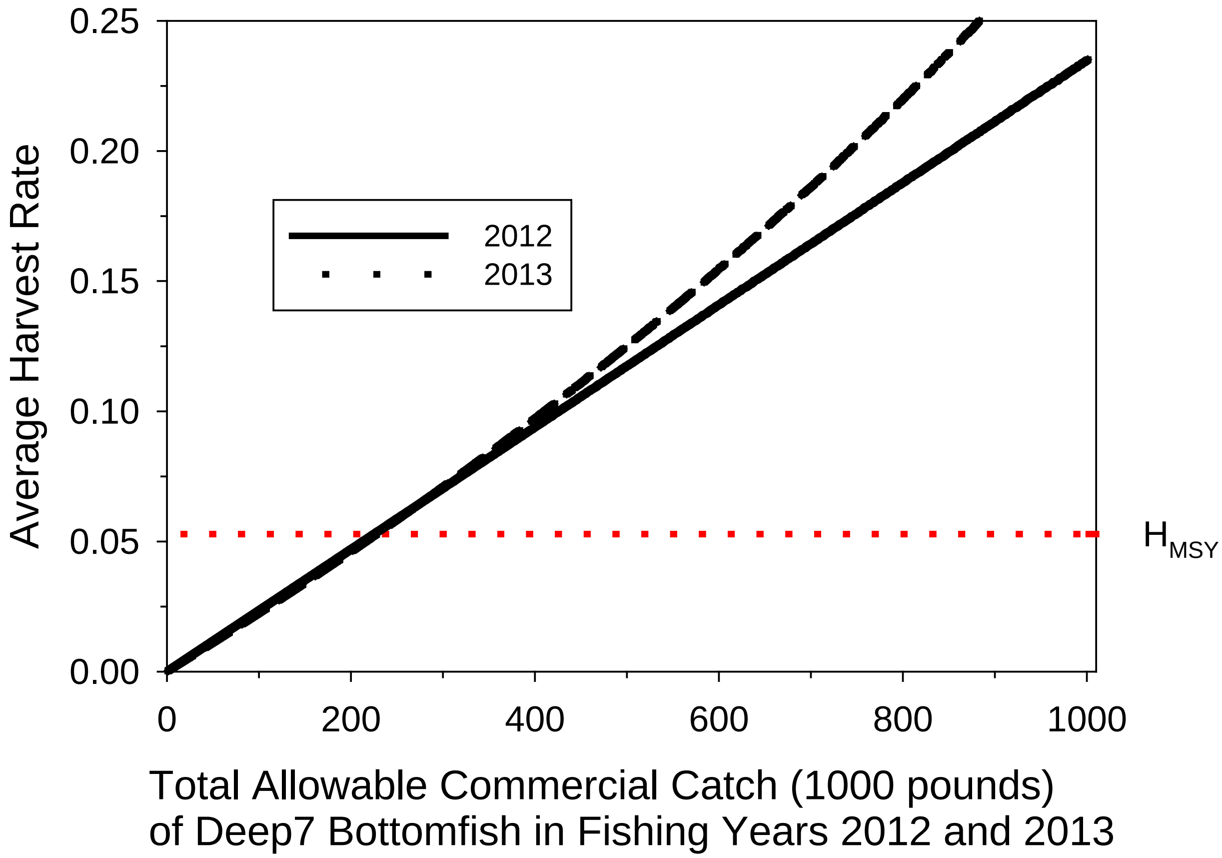


Figure 26.4.--Projection results showing estimates of average exploitable biomass of Deep7 Hawaiian bottomfish for fishing years 2012-2013 for alternative commercial TACs under baseline Catch Scenario II and CPUE Scenario III.

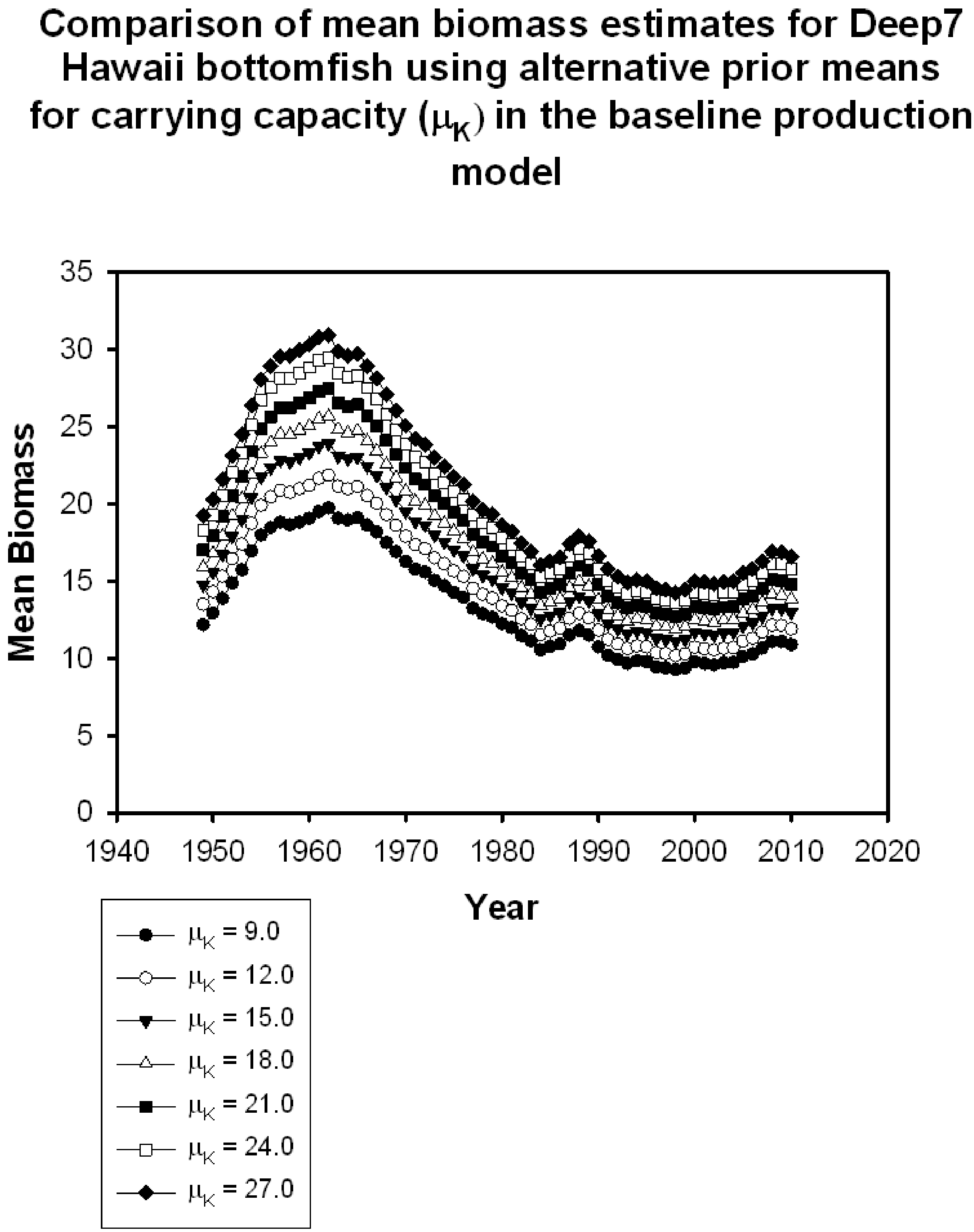


Figure 27.1.--Sensitivity analysis for prior mean of carrying capacity parameter.

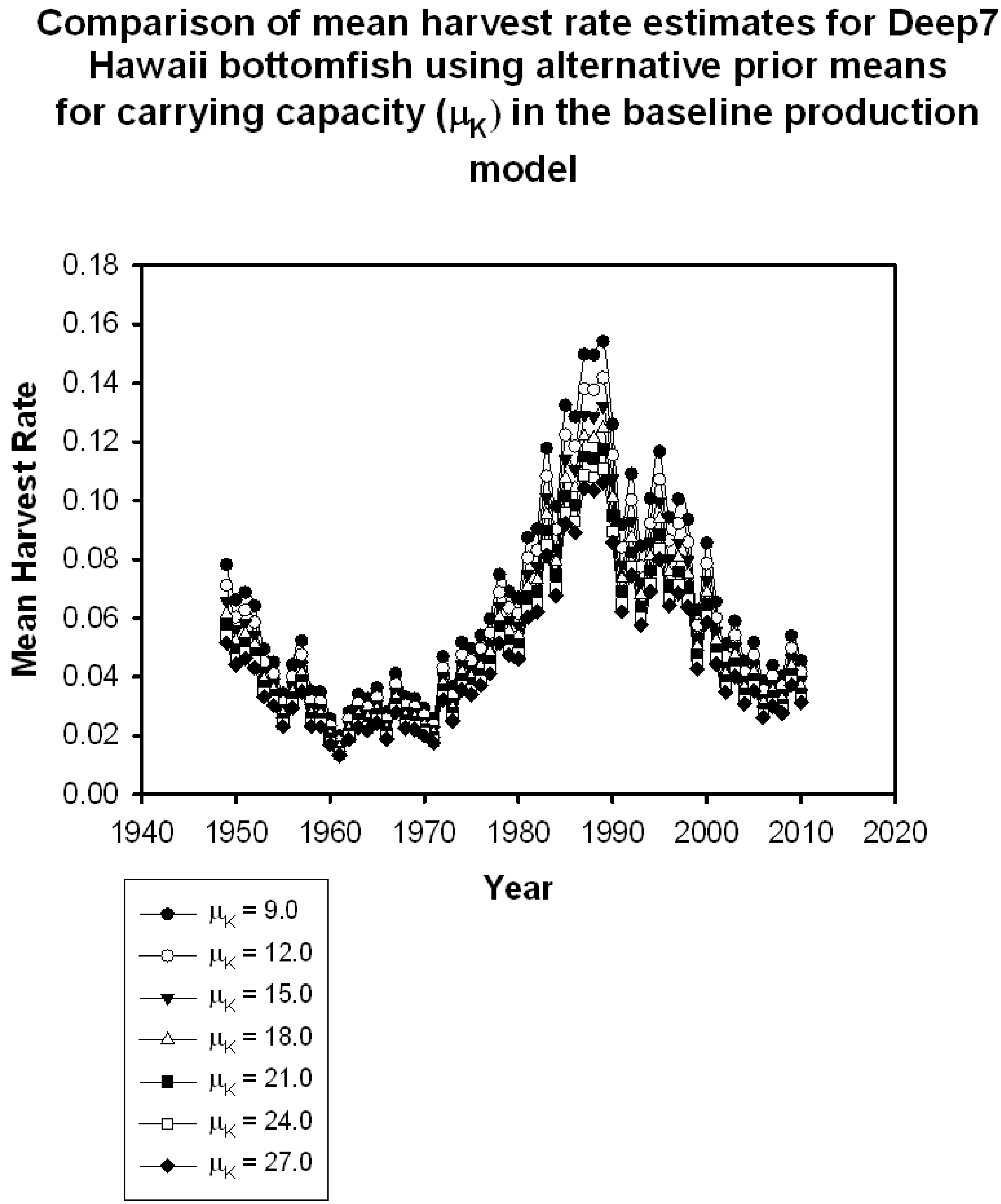


Figure 27.2.--Sensitivity analysis for prior mean of carrying capacity parameter.

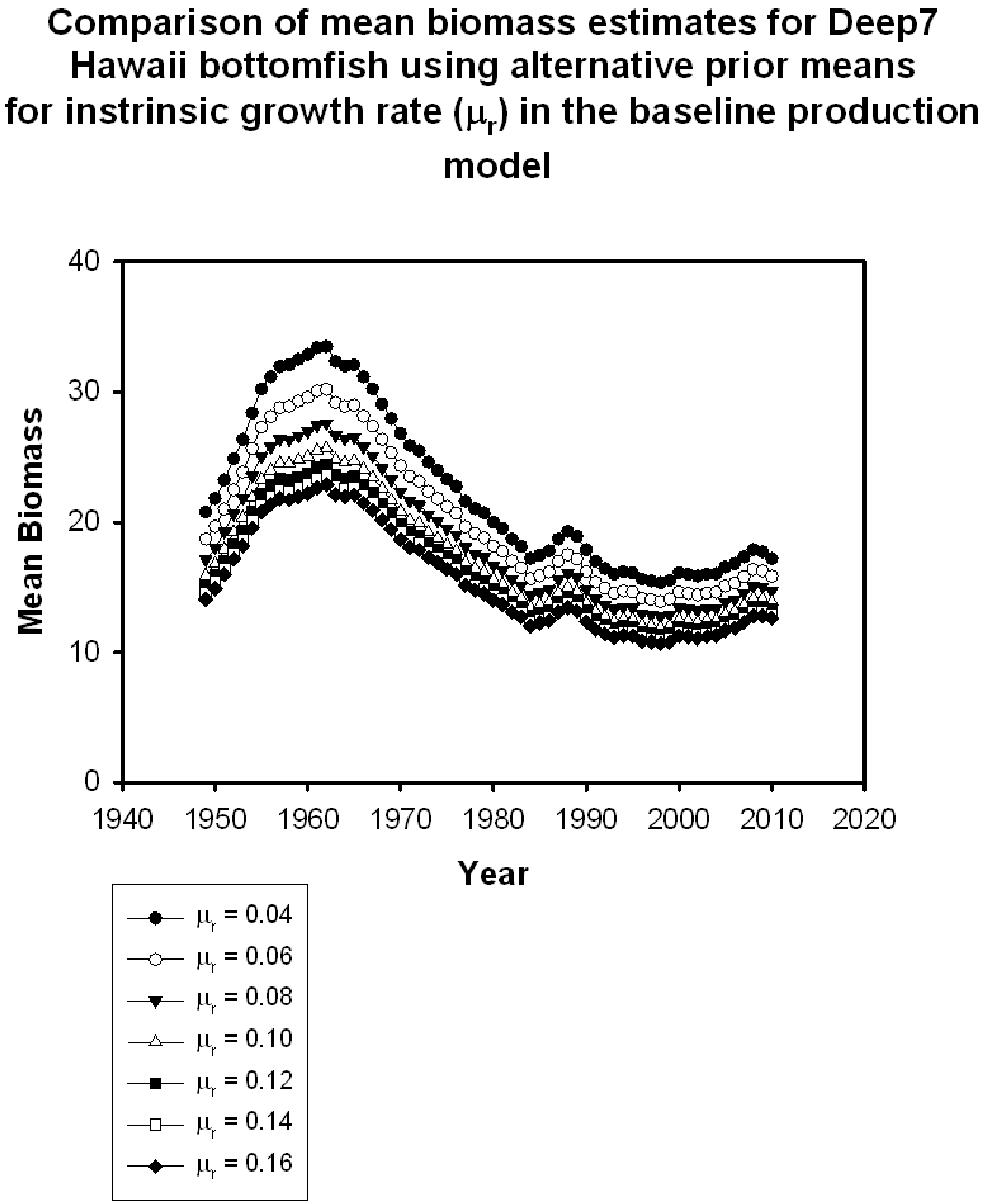


Figure 28.1.--Sensitivity analysis for prior mean of intrinsic growth rate parameter.

Comparison of mean harvest rate estimates for Deep7 Hawaii bottomfish using alternative prior means for instrinsic growth rate (μ_r) in the baseline production model

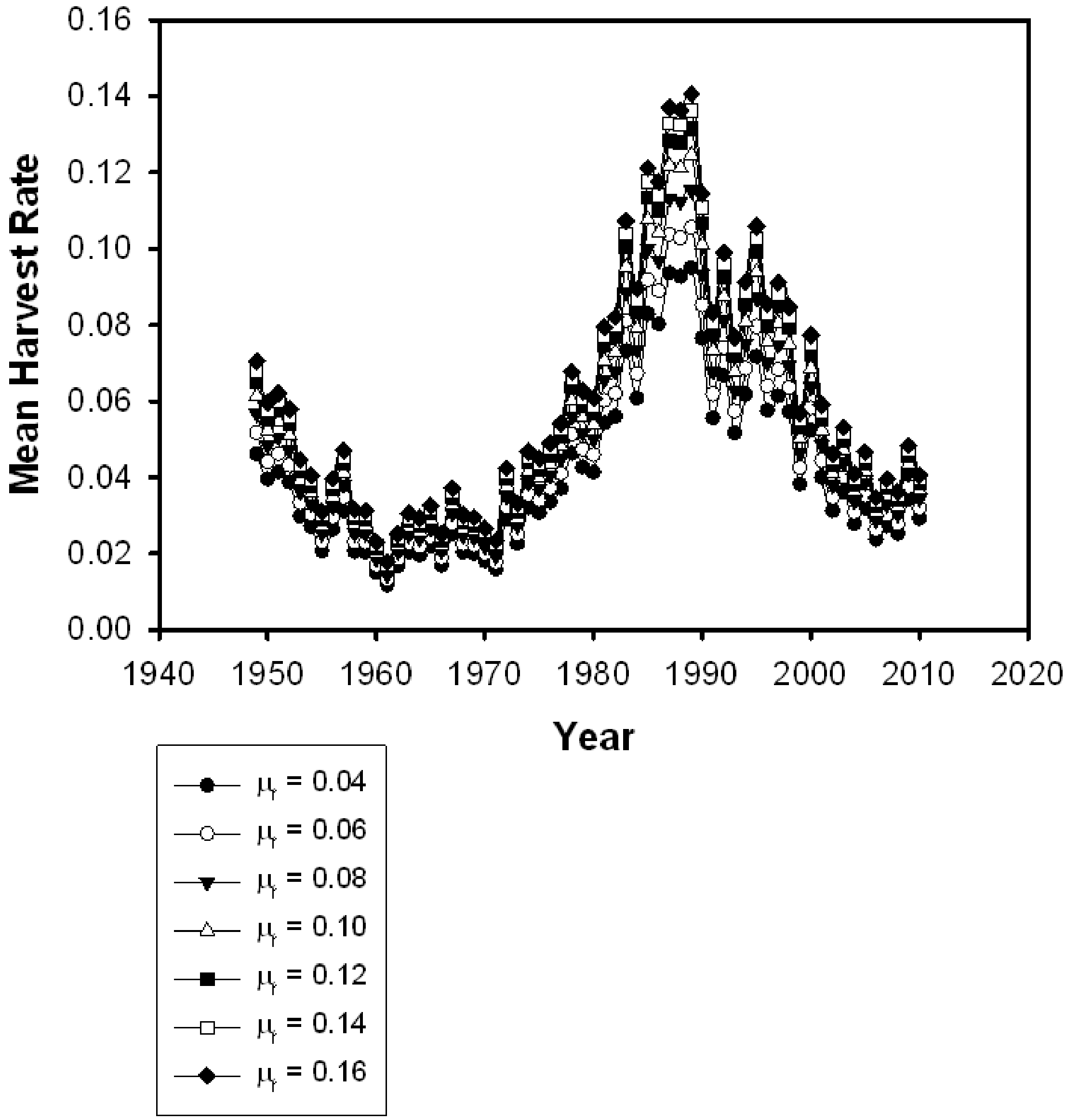


Figure 28.2.--Sensitivity analysis for prior mean of intrinsic growth rate parameter.

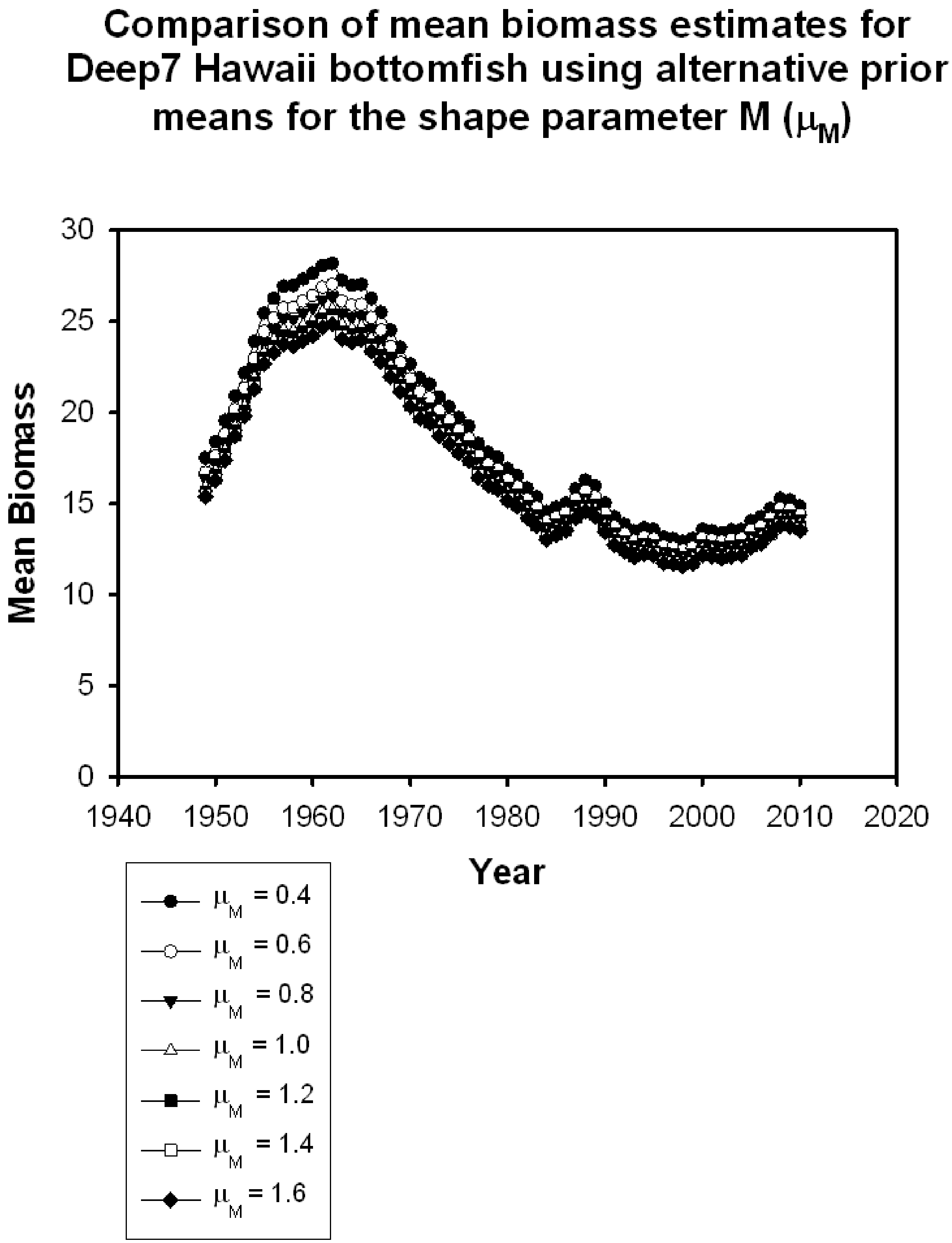


Figure 29.1.--Sensitivity analysis for prior mean of shape parameter.

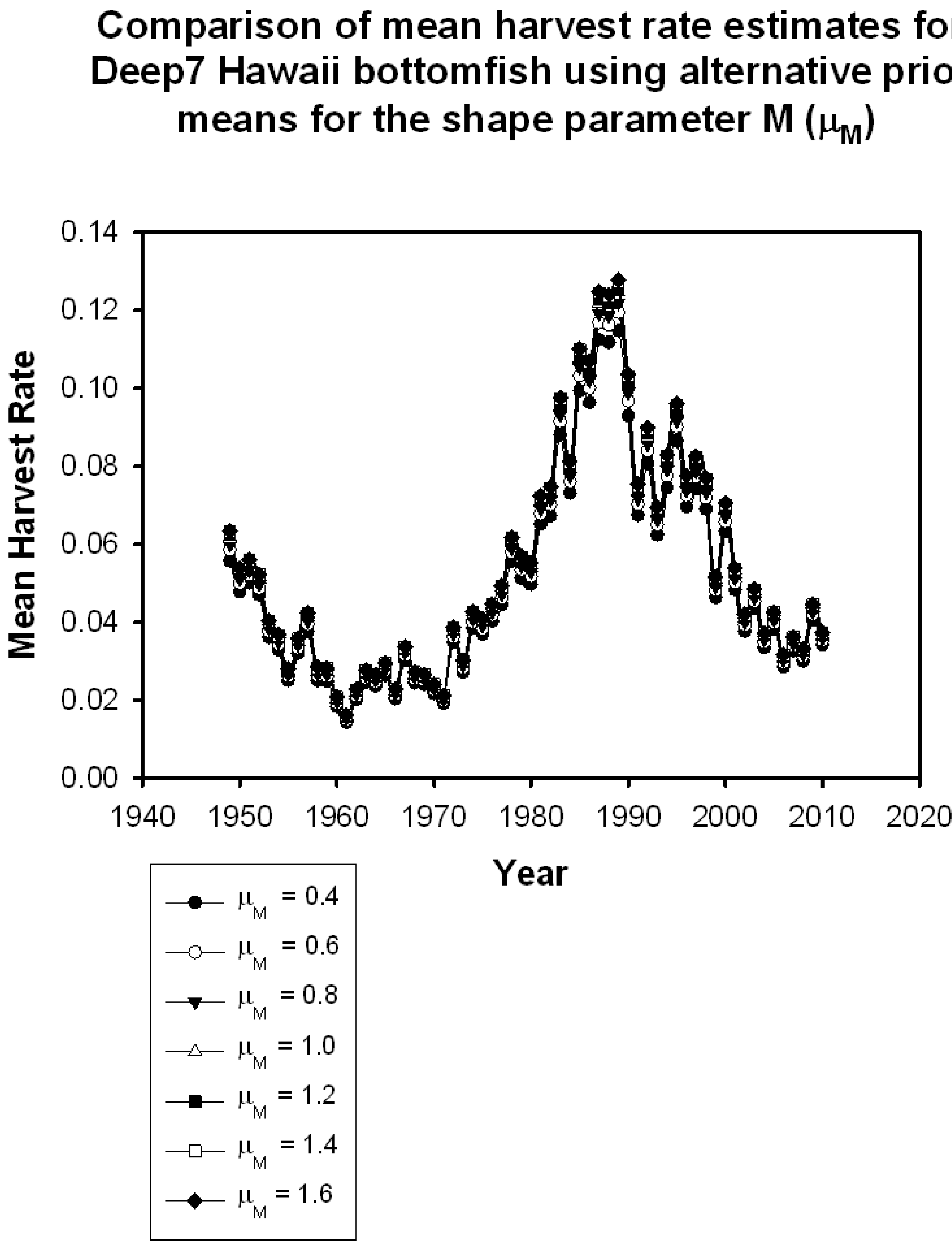


Figure 29.2.--Sensitivity analysis for prior mean of shape parameter.

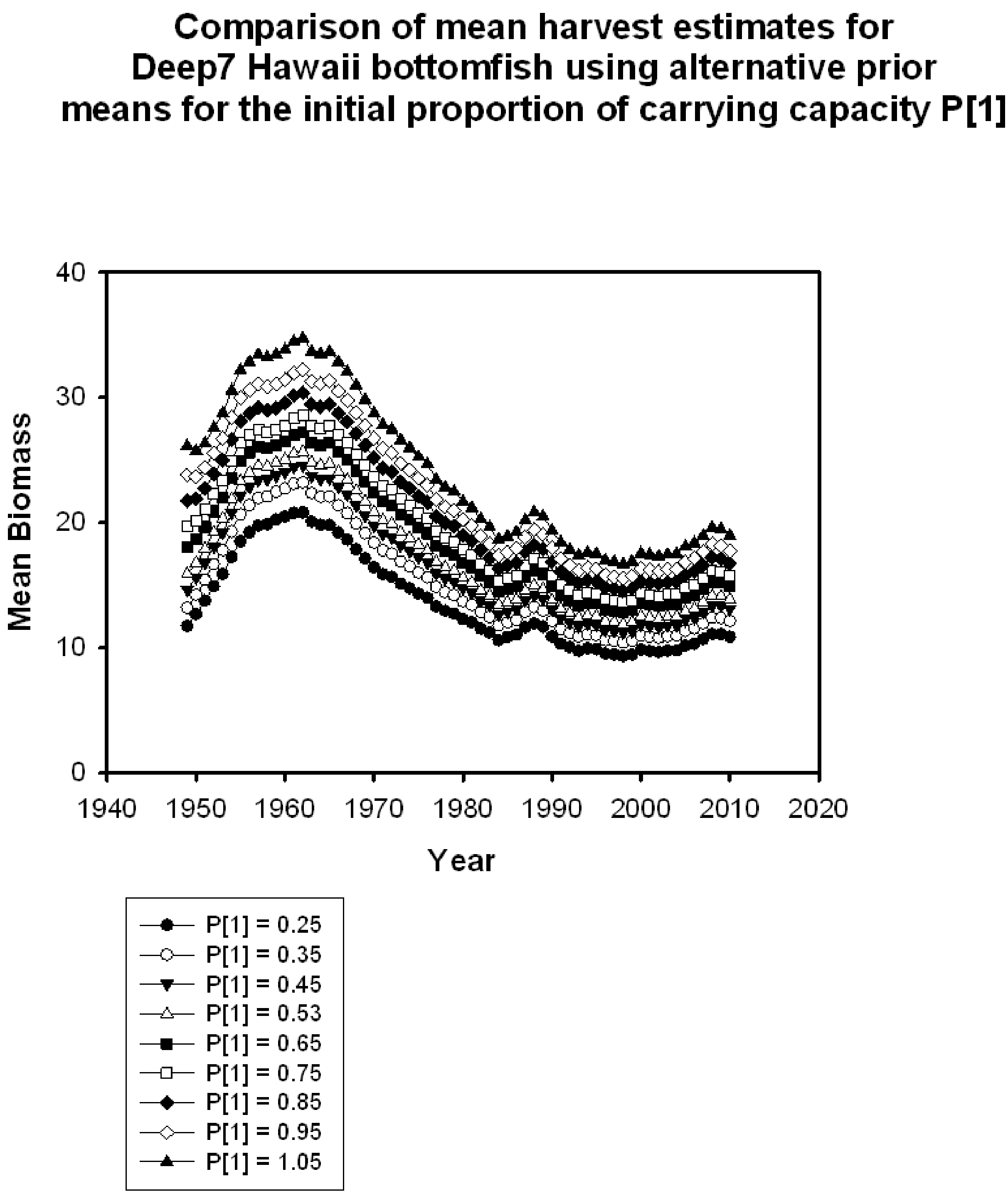


Figure 30.1.--Sensitivity analysis for prior mean of initial proportion of carrying capacity.

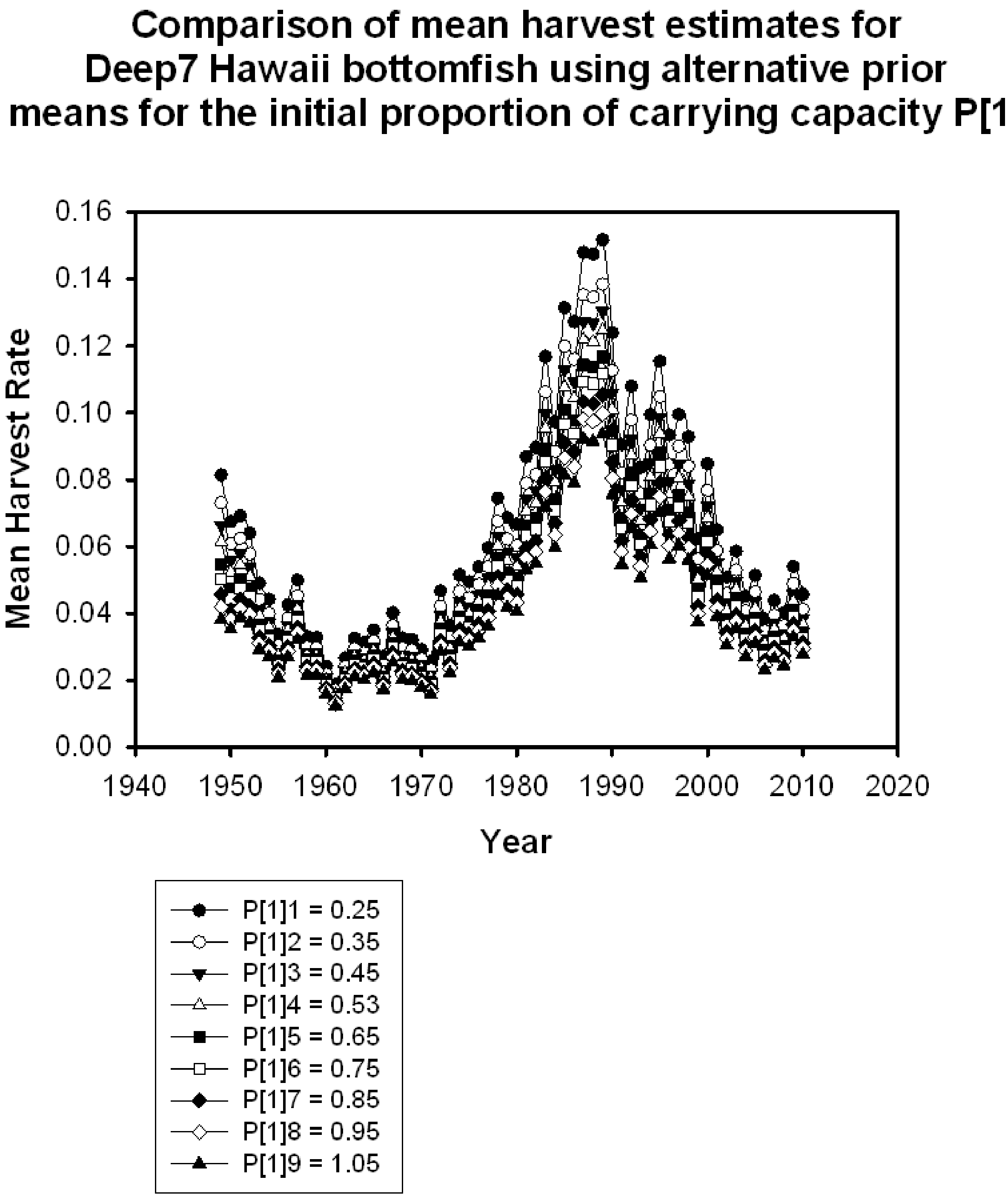


Figure 30.2.--Sensitivity analysis for prior mean of initial proportion of carrying capacity.

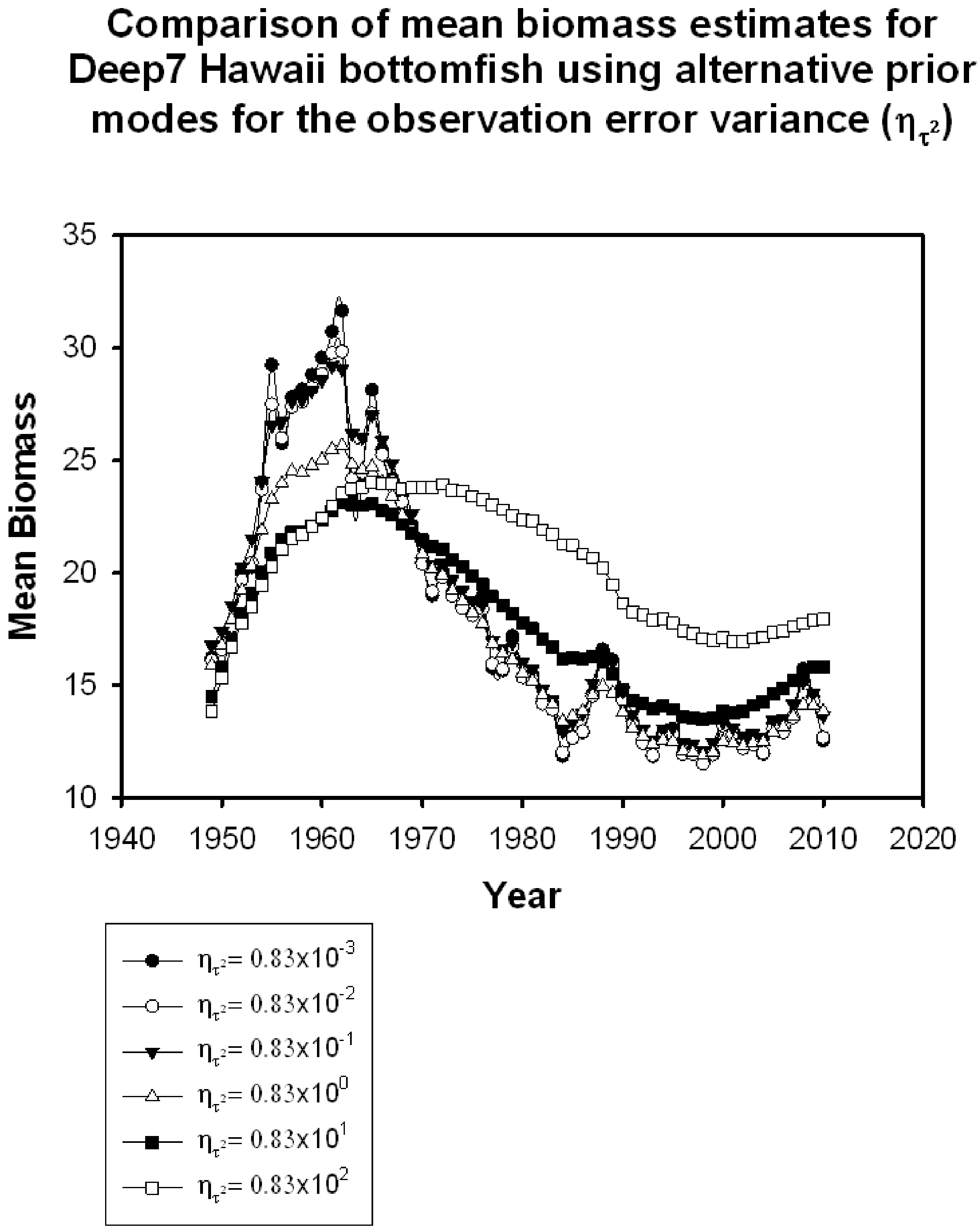


Figure 31.1.--Sensitivity analysis for prior mean of observation error variance.

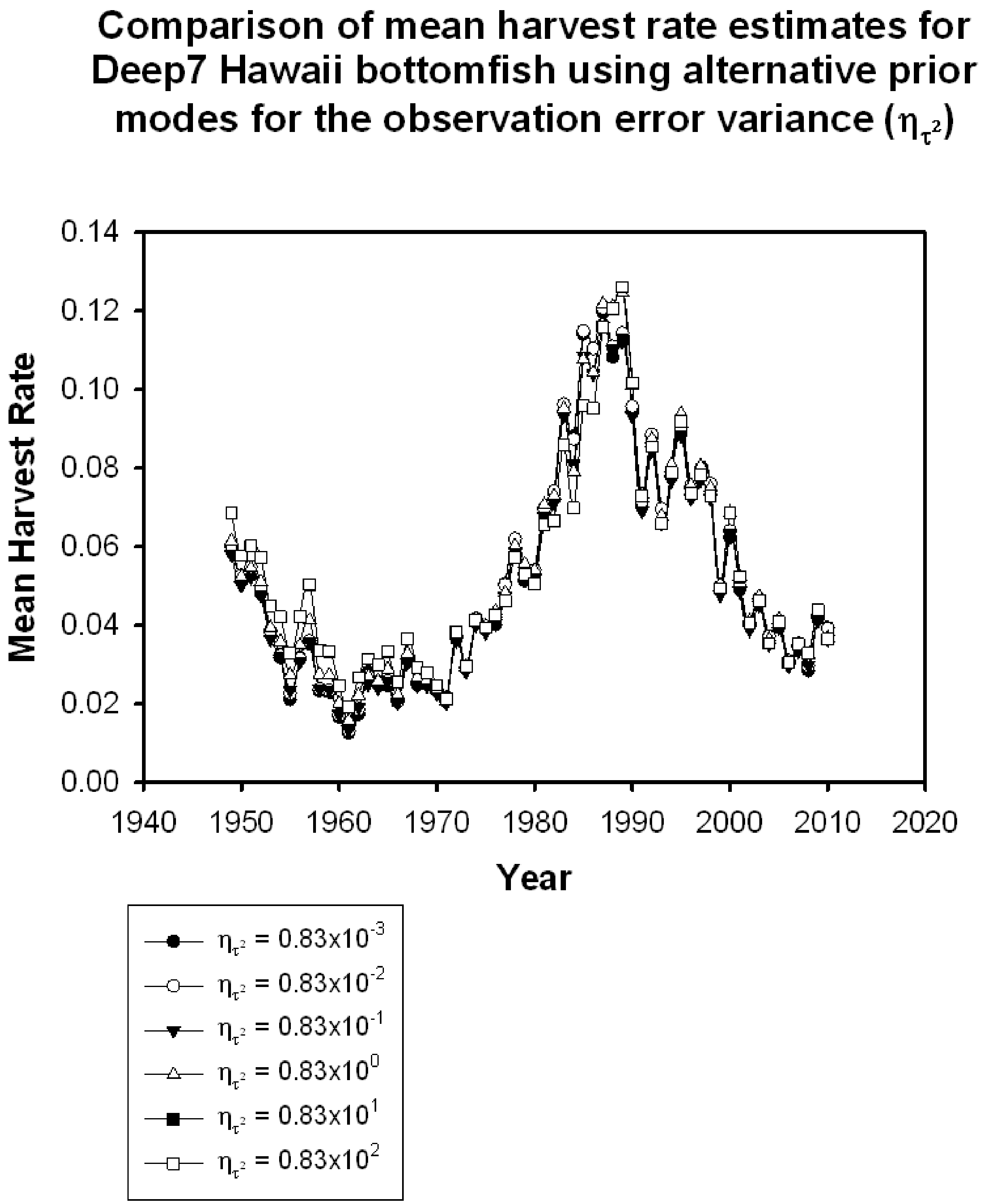


Figure 31.2.--Sensitivity analysis for prior mean of observation error variance.

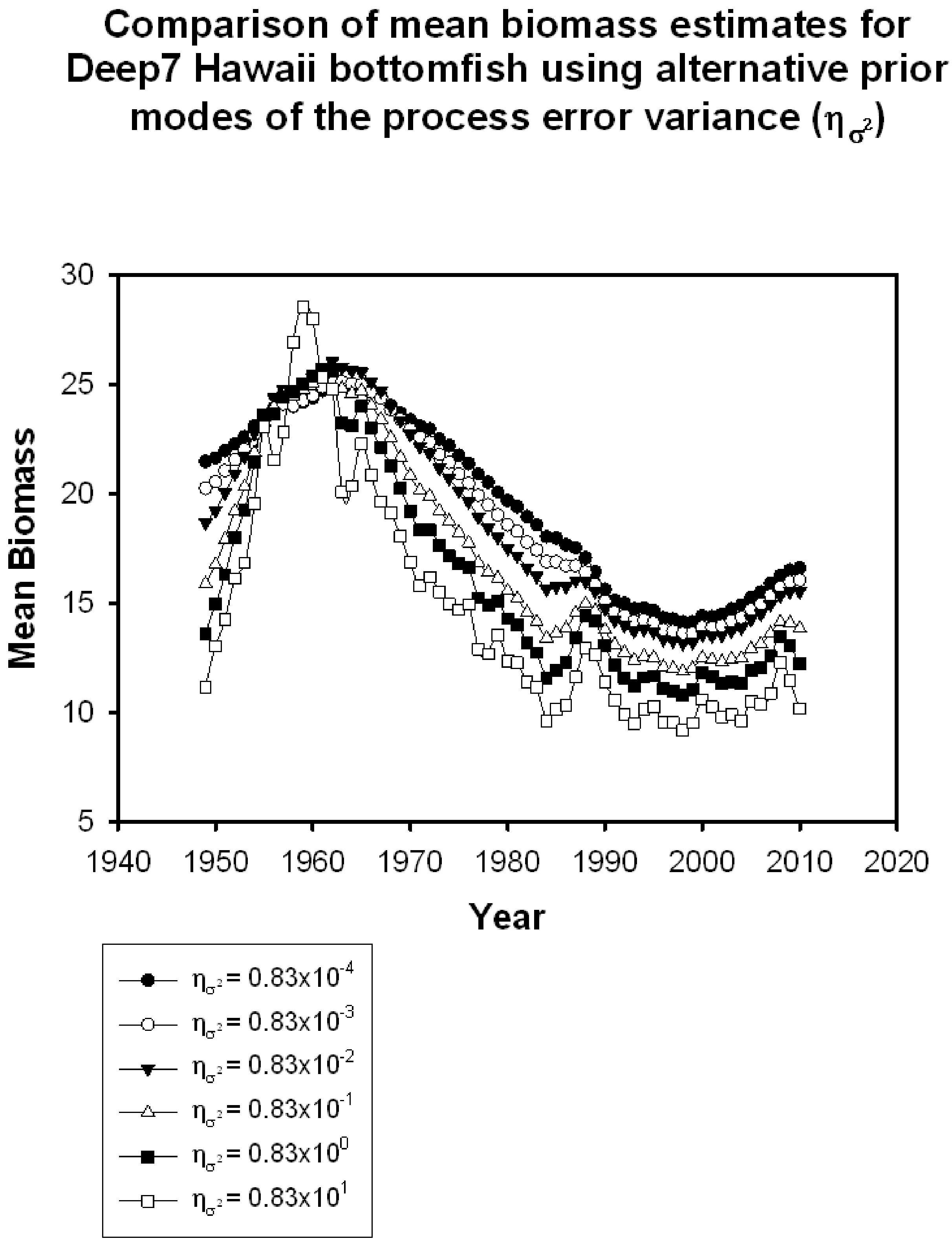


Figure 32.1.--Sensitivity analysis for prior mean of process error variance.

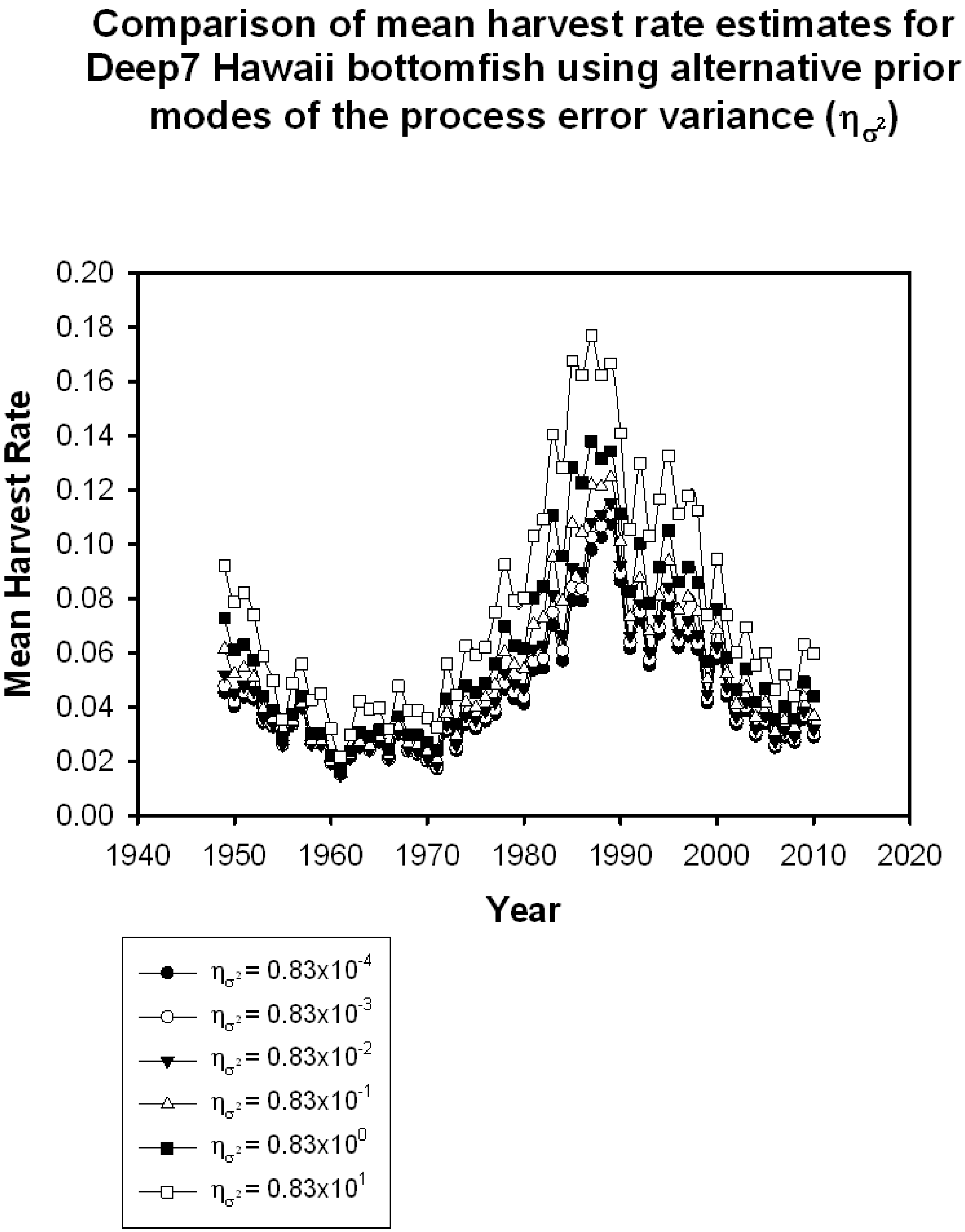


Figure 32.2.--Sensitivity analysis for prior mean of process error variance.

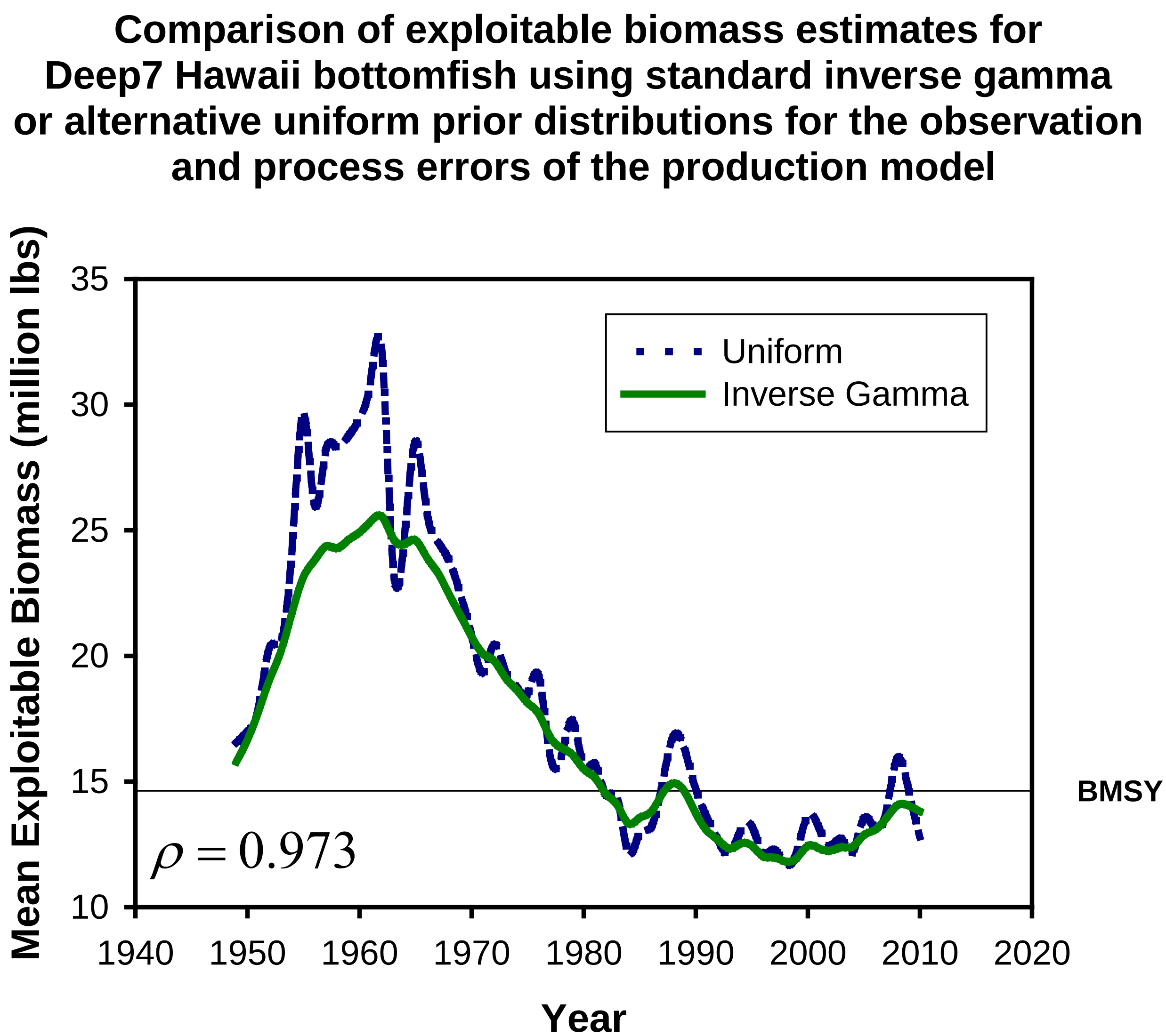


Figure 33.1.--Sensitivity analysis for distributional choice of prior for error variances.

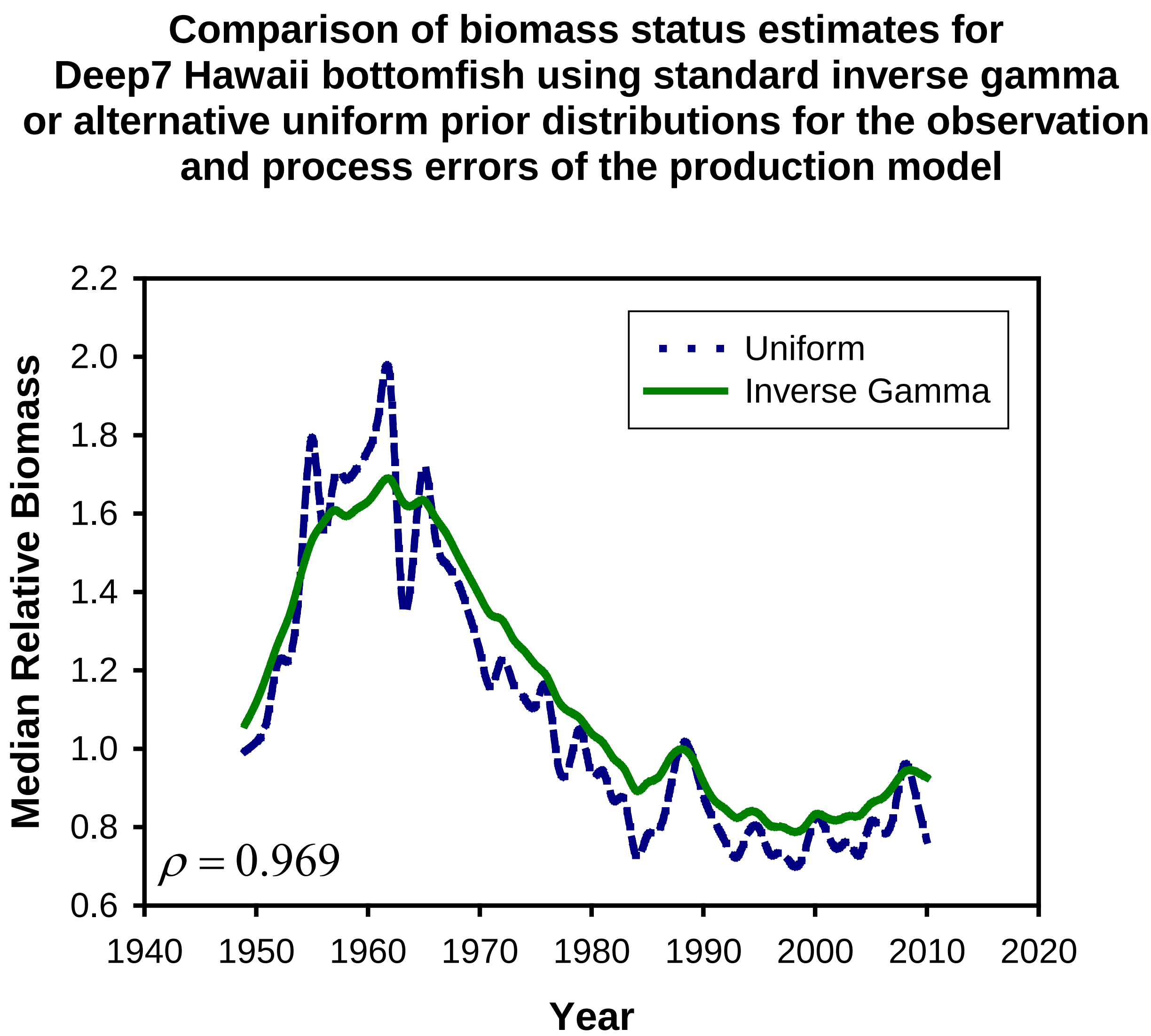


Figure 33.2.--Sensitivity analysis for distributional choice of prior for error variances.

Comparison of probability that biomass is below BMSY for Deep7 Hawaii bottomfish using standard inverse gamma or alternative uniform prior distributions for the observation and process errors of the production model

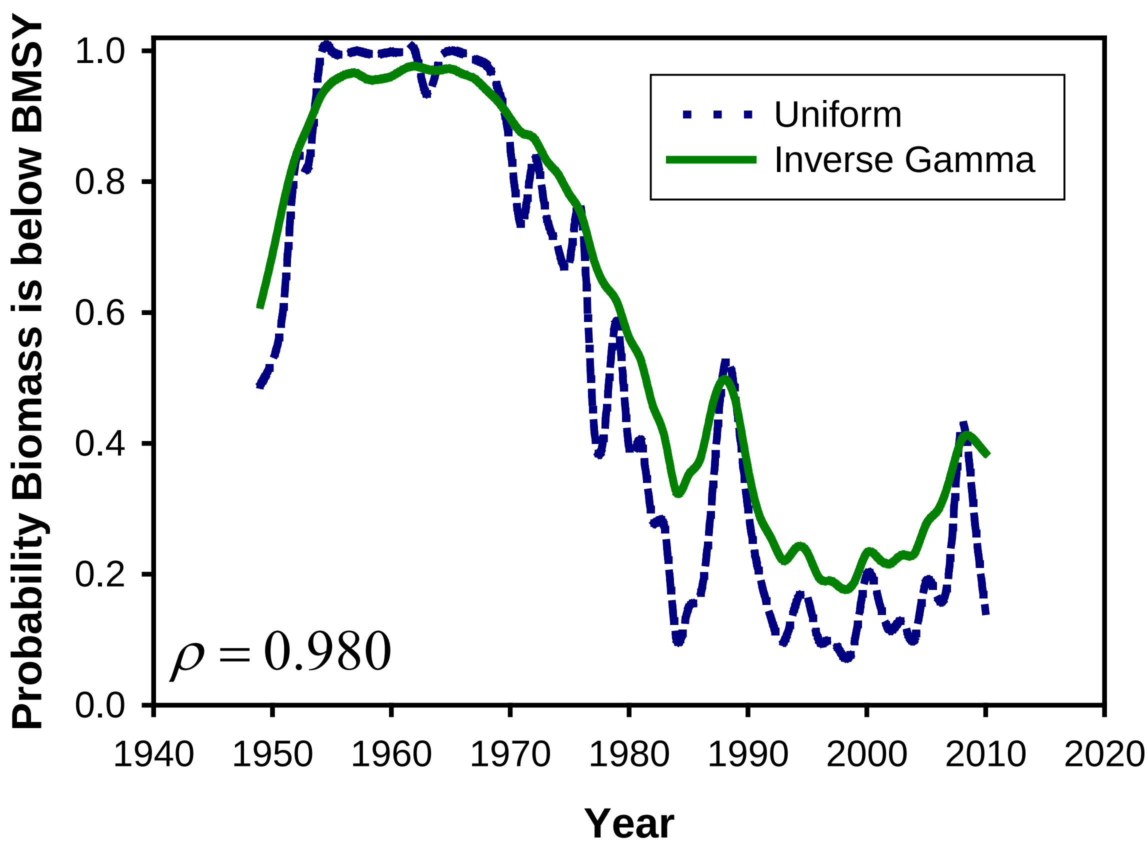


Figure 33.3.--Sensitivity analysis for distributional choice of prior for error variances.

Comparison of harvest rate estimates for Deep7 Hawaii bottomfish using standard inverse gamma or alternative uniform prior distributions for the observation and process errors of the production model

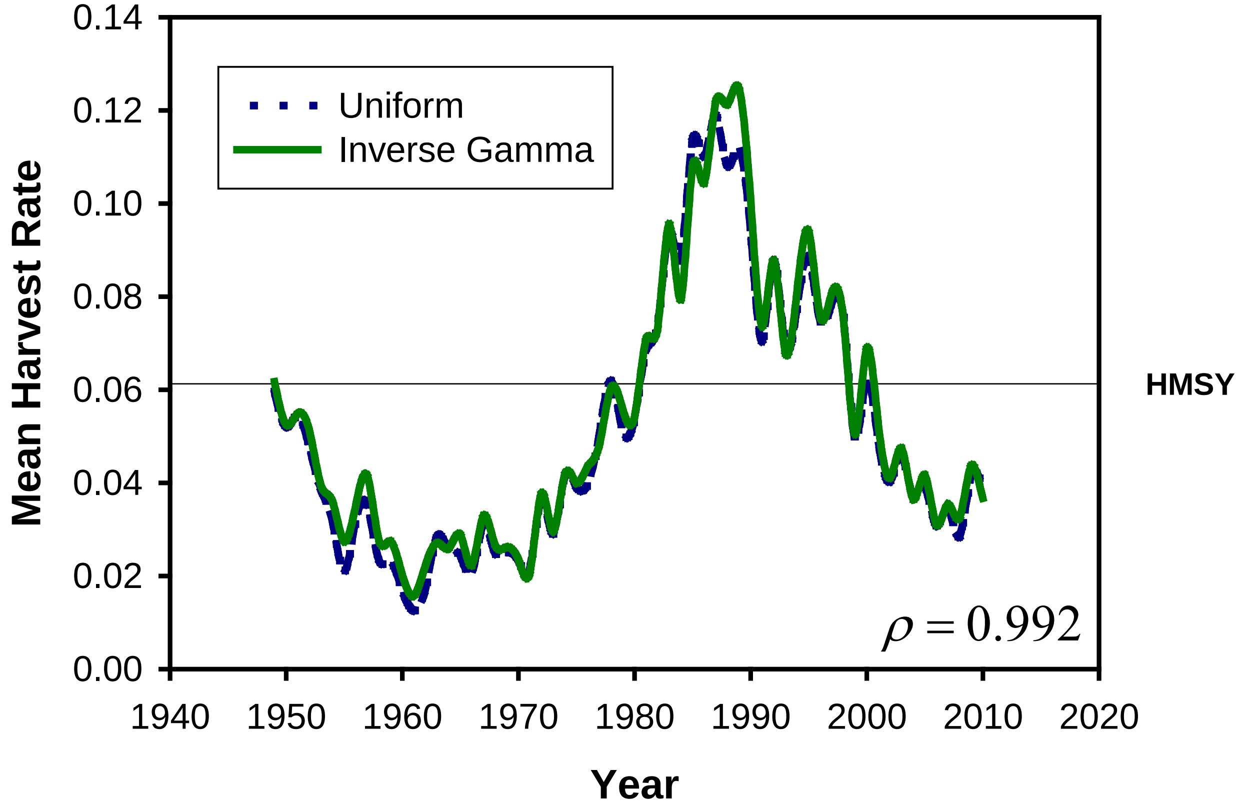


Figure 33.4.--Sensitivity analysis for distributional choice of prior for error variances.

Comparison of harvest rate status estimates for Deep7 Hawaii bottomfish using standard inverse gamma or alternative uniform prior distributions for the observation and process errors of the production model

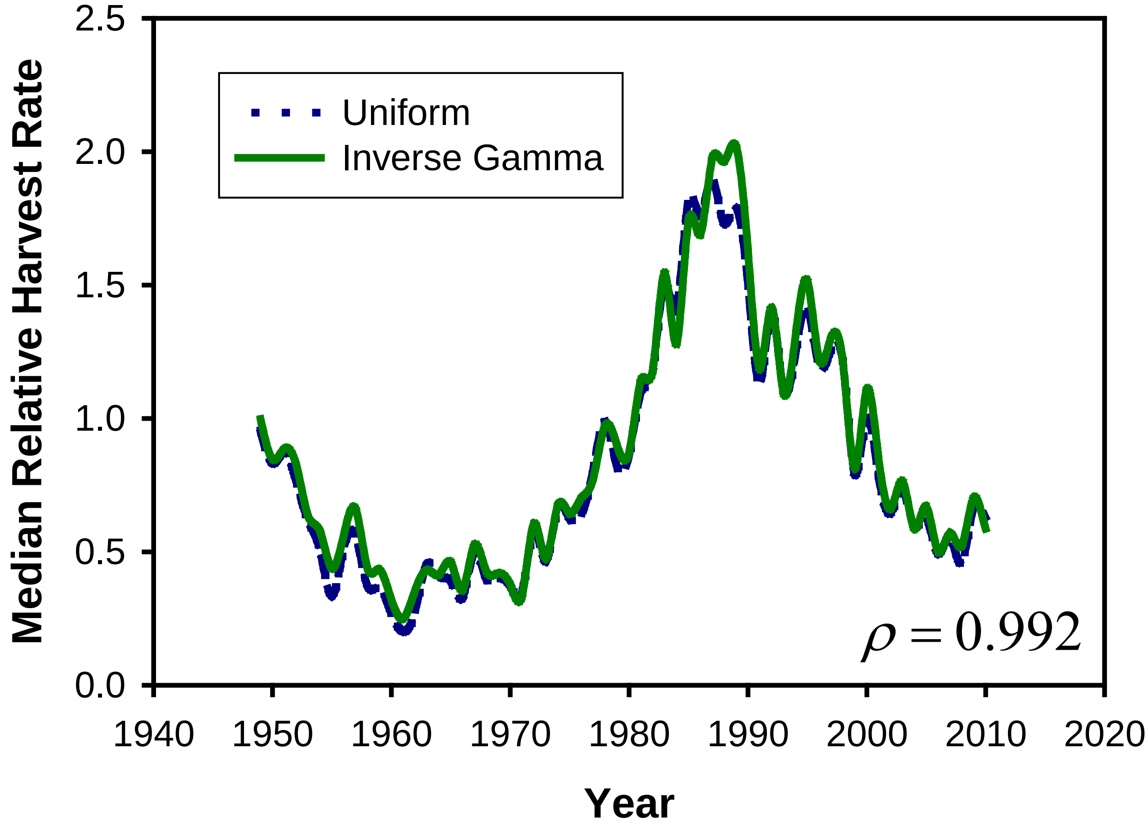


Figure 33.5.--Sensitivity analysis for distributional choice of prior for error variances.

Comparison of probability that harvest rate is above overfishing rate HMSY estimates for Deep7 Hawaii bottomfish using standard inverse gamma or alternative uniform prior distributions for the observation and process errors of the production model

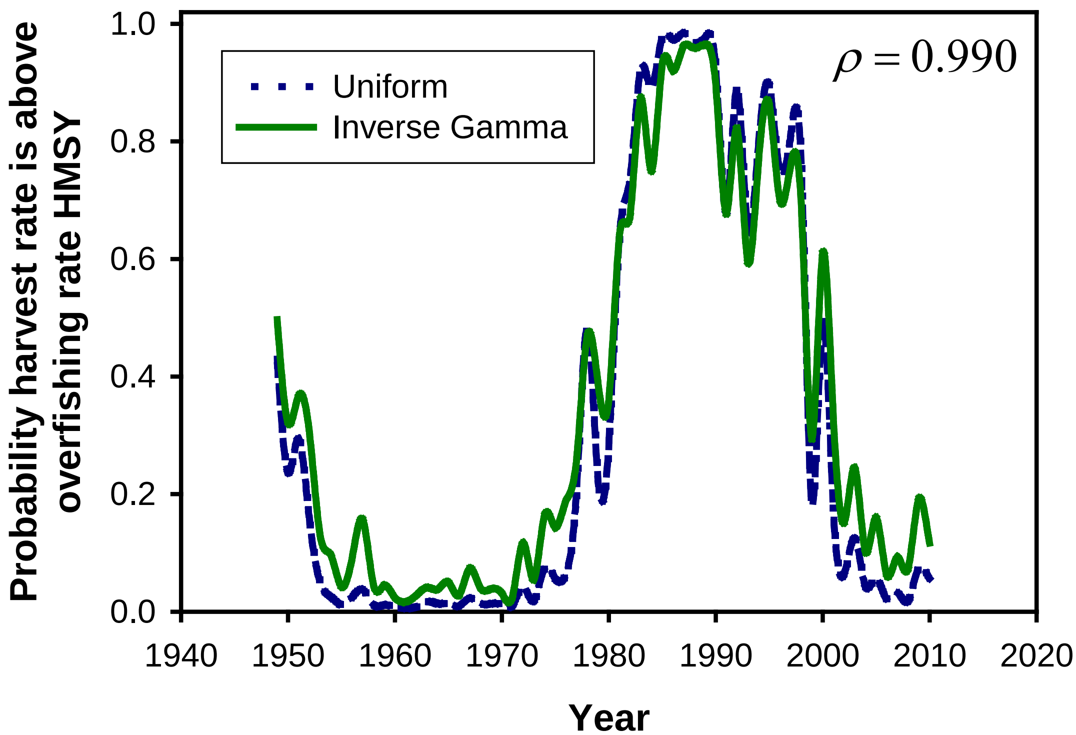


Figure 33.6.--Sensitivity analysis for distributional choice of prior for error variances.

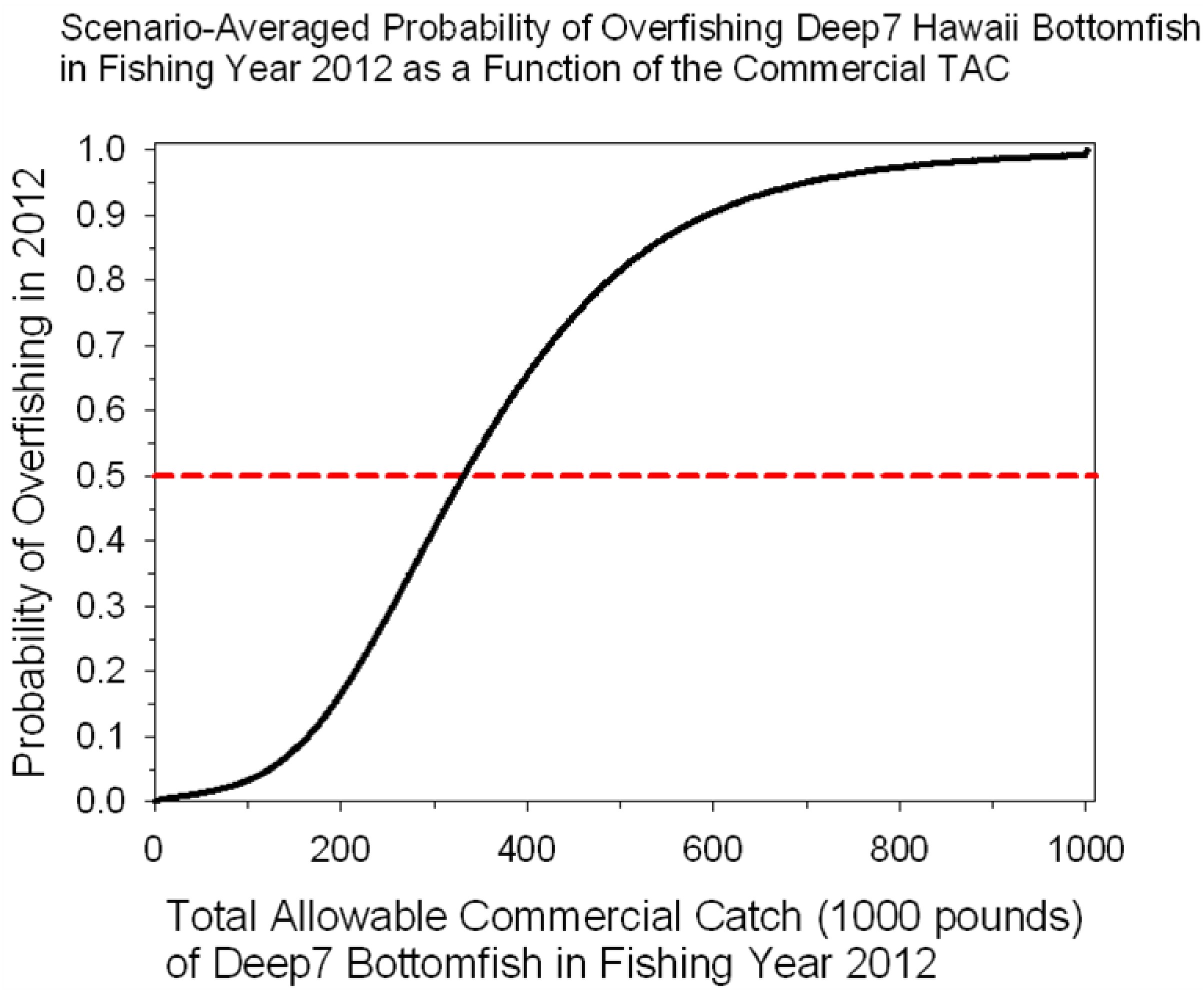


Figure 34.--Scenario-averaged projection results for estimates of total allowable catches of Deep7 Hawaiian bottomfish for fishing years 2012−2013 that would produce a range of probabilities of overfishing in 2012 from 0% to 50% and greater as a weighted average using the example set of hypothetical scenario probabilities.

Retrospective patterns in estimates of mean exploitable biomass of Deep7 Hawaii bottomfish using the baseline production model with different ending years for estimating model parameters ranging from 2005-2010.

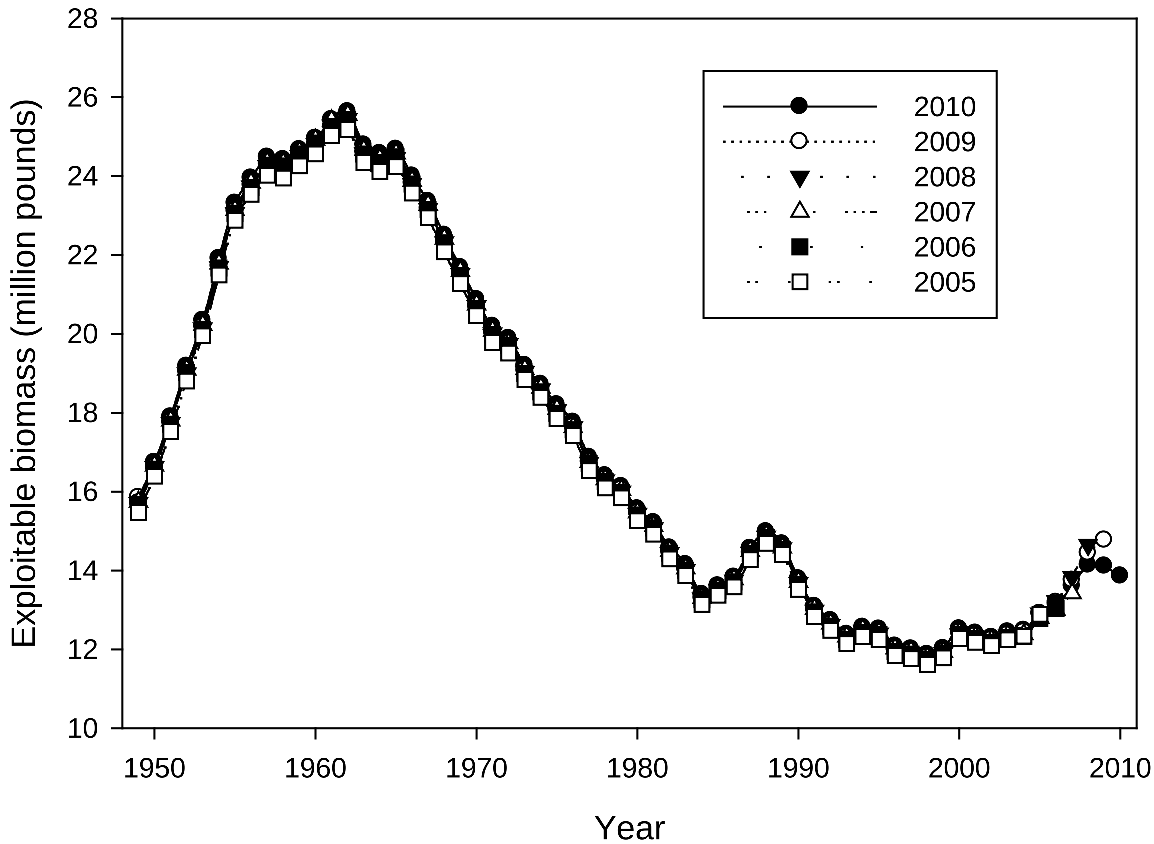


Figure 35.1.--Retrospective analysis for mean exploitable biomass.

Retrospective patterns in estimates of mean exploitable biomass of Deep7 Hawaii bottomfish using the baseline production model with different terminal years to input data and to estimate model parameters ranging from 2005-2010.

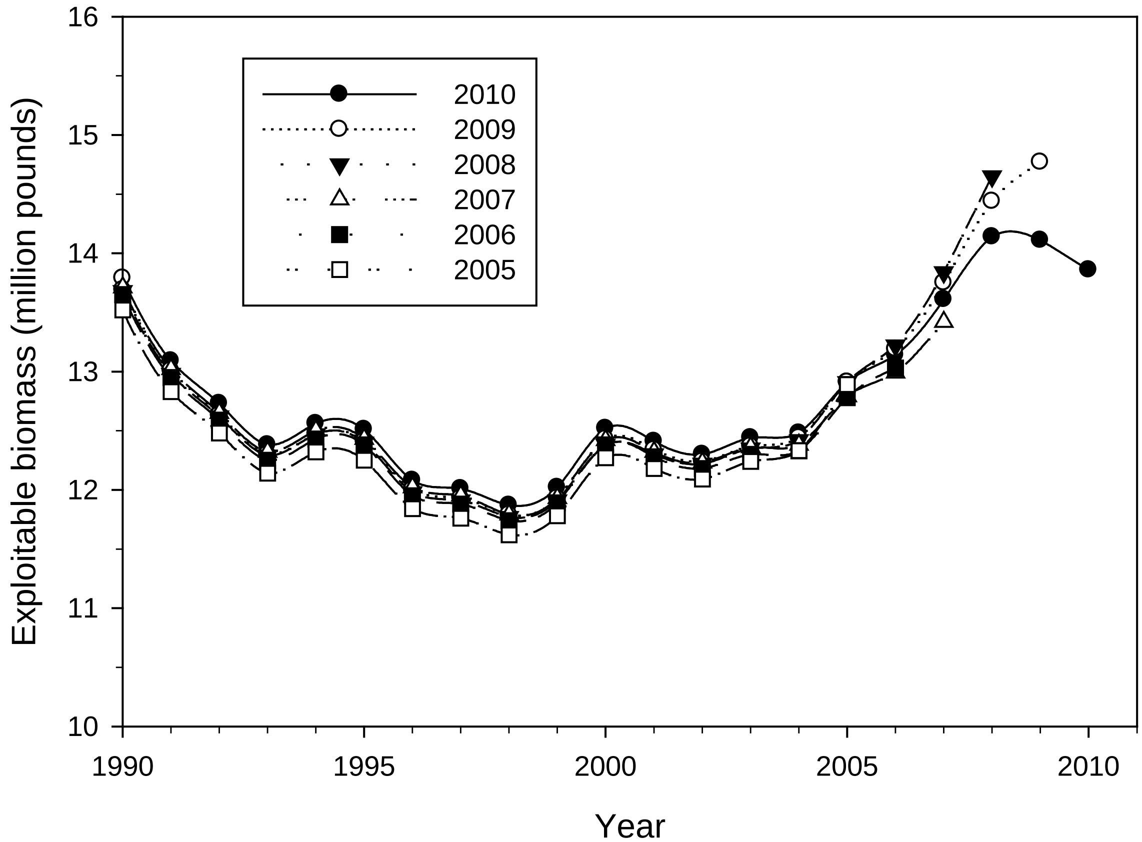


Figure 35.2.--Retrospective analysis for mean exploitable biomass.

Retrospective patterns in estimates of mean exploitation rate of Deep7 Hawaii bottomfish using the baseline production model with different ending years for estimating model parameters ranging from 2005-2010.

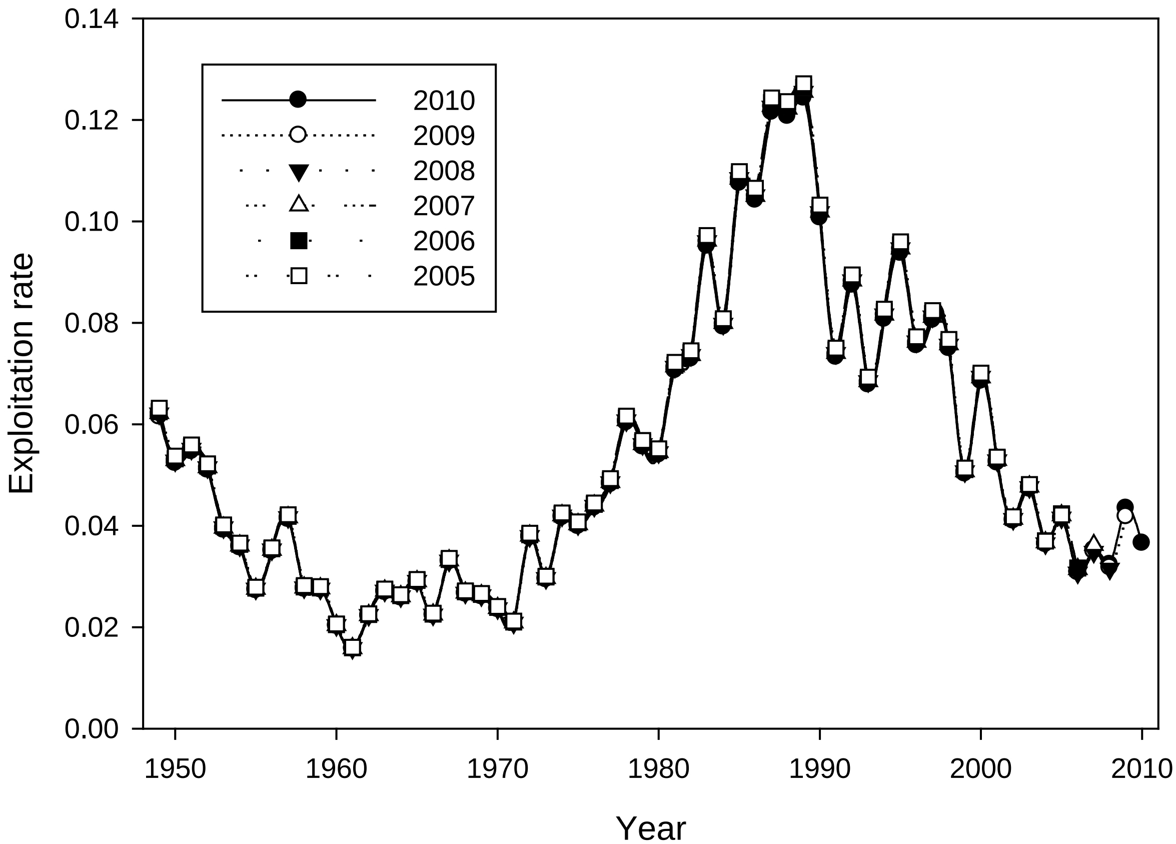


Figure 35.3.--Retrospective analysis for mean exploitation rate.

Retrospective patterns in estimates of mean exploitation rate of Deep7 Hawaii bottomfish using the baseline production model with different ending years for estimating model parameters ranging from 2005-2010.

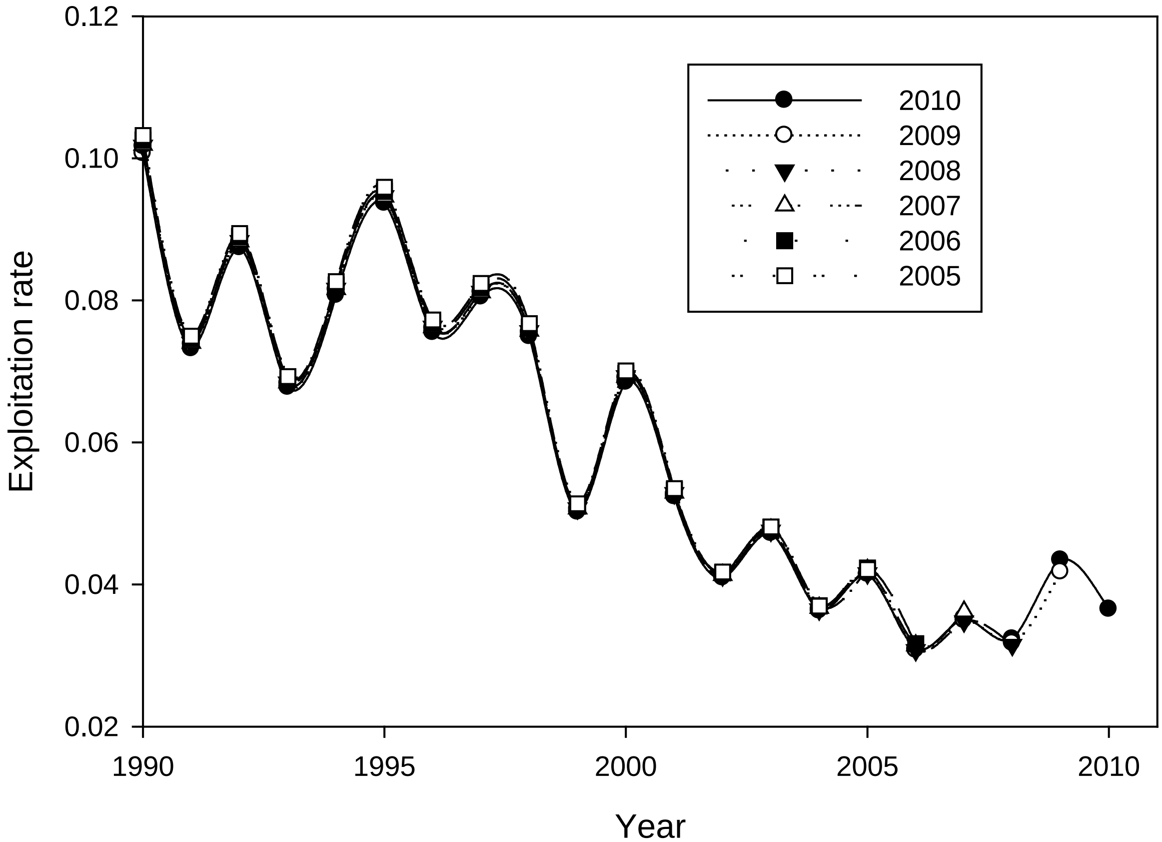


Figure 35.4.--Retrospective analysis for mean exploitation rate.

Appendix Tables and WINBUGS code

Table A1.--Unreported to reported catch ratios under Catch Scenario I.

Estimated Unreported Catch Ratios of the Deep7 Bottomfish							
Using Ratio Data from Martell et al. (2006) and Zeller et al. (2008)							
Fishing Year	Ratio of Total to Reported Commercial Catch	Ratio of Unreported to Reported Commercial Catch (U)	Smoothed 5-Year Ratio of Unreported to Commercial Catch	Fishing Year	Ratio of Total to Reported Commercial Catch	Ratio of Unreported to Reported Commercial Catch (U)	Smoothed 5-Year Ratio of Unreported to Commercial Catch
1948	3.27	2.27	2.27	1980	4	3	2.27
1949	3.27	2.27	2.27	1981	4	3	2.27
1950	3.27	2.27	2.27	1982	4	3	3.00
1951	3.27	2.27	2.27	1983	4	3	3.00
1952	3.27	2.27	2.27	1984	4	3	3.00
1953	3.27	2.27	2.27	1985	4	3	3.00
1954	3.27	2.27	2.27	1986	4	3	3.00
1955	3.27	2.27	2.27	1987	4	3	3.00
1956	3.27	2.27	2.27	1988	4	3	2.90
1957	3.27	2.27	2.27	1989	4	3	2.80
1958	3.27	2.27	2.27	1990	3.5	2.5	2.70
1959	3.27	2.27	2.27	1991	3.5	2.5	2.60
1960	3.27	2.27	2.27	1992	3.5	2.5	2.50
1961	3.27	2.27	2.27	1993	3.5	2.5	2.50
1962	3.27	2.27	2.27	1994	3.5	2.5	2.50
1963	3.27	2.27	2.27	1995	3.5	2.5	2.50
1964	3.27	2.27	2.27	1996	3.5	2.5	2.50
1965	3.27	2.27	2.27	1997	3.5	2.5	2.50
1966	3.27	2.27	2.27	1998	3.5	2.5	2.50
1967	3.27	2.27	2.27	1999	3.5	2.5	2.50
1968	3.27	2.27	2.27	2000	3.5	2.5	2.50
1969	3.27	2.27	2.27	2001	3.5	2.5	2.50
1970	3.27	2.27	2.27	2002	3.5	2.5	2.50
1971	3.27	2.27	2.27	2003	3.5	2.5	2.50
1972	3.27	2.27	2.27	2004	3.5	2.5	2.50
1973	3.27	2.27	2.27	2005	3.5	2.5	2.50
1974	3.27	2.27	2.27	2006	3.5	2.5	2.50
1975	3.27	2.27	2.27	2007	3.5	2.5	2.50
1976	3.27	2.27	2.27	2008	3.5	2.5	2.50
1977	3.27	2.27	2.27	2009	3.5	2.5	2.50
1978	3.27	2.27	2.27	2010	3.5	2.5	2.50
1979	3.27	2.27	2.27				

Table A2.--Unreported to reported catch ratios under Catch Scenario II.

Estimated Rec/Com Ratios of the Deep7 Bottomfish Species							
Using Smoothed Estimates from Hamm and Lum (1992), HMRFSS, and Lamson et al (2007)							
	Scenario 2: 5-Year Average Rec/Com Ratio by Species and Fishing Year						
Fishing Year	Hapuupuu	Kalekale	Opakapaka	Ehu	Onaga	Lehi	Gindai
1949	1.02	0.03	2.87	1.11	0.73	0.04	0.15
1950	1.02	0.03	2.87	1.11	0.73	0.04	0.15
1951	1.02	0.03	2.87	1.11	0.73	0.04	0.15
1952	1.02	0.03	2.87	1.11	0.73	0.04	0.15
1953	1.02	0.03	2.87	1.11	0.73	0.04	0.15
1954	1.02	0.03	2.87	1.11	0.73	0.04	0.15
1955	1.02	0.03	2.87	1.11	0.73	0.04	0.15
1956	1.02	0.03	2.87	1.11	0.73	0.04	0.15
1957	1.02	0.03	2.87	1.11	0.73	0.04	0.15
1958	1.02	0.03	2.87	1.11	0.73	0.04	0.15
1959	1.02	0.03	2.87	1.11	0.73	0.04	0.15
1960	1.02	0.03	2.87	1.11	0.73	0.04	0.15
1961	1.02	0.03	2.87	1.11	0.73	0.04	0.15
1962	1.02	0.03	2.87	1.11	0.73	0.04	0.15
1963	1.02	0.03	2.87	1.11	0.73	0.04	0.15
1964	1.02	0.03	2.87	1.11	0.73	0.04	0.15
1965	1.02	0.03	2.87	1.11	0.73	0.04	0.15
1966	1.02	0.03	2.87	1.11	0.73	0.04	0.15
1967	1.02	0.03	2.87	1.11	0.73	0.04	0.15
1968	1.02	0.03	2.87	1.11	0.73	0.04	0.15
1969	1.02	0.03	2.87	1.11	0.73	0.04	0.15
1970	1.02	0.03	2.87	1.11	0.73	0.04	0.15
1971	1.02	0.03	2.87	1.11	0.73	0.04	0.15
1972	1.02	0.03	2.87	1.11	0.73	0.04	0.15
1973	1.02	0.03	2.87	1.11	0.73	0.04	0.15
1974	1.02	0.03	2.87	1.11	0.73	0.04	0.15
1975	1.02	0.03	2.87	1.11	0.73	0.04	0.15
1976	1.02	0.03	2.87	1.11	0.73	0.04	0.15
1977	1.02	0.03	2.87	1.11	0.73	0.04	0.15
1978	1.02	0.03	2.87	1.11	0.73	0.04	0.15
1979	1.02	0.03	2.87	1.11	0.73	0.04	0.15
1980	1.02	0.03	2.87	1.11	0.73	0.04	0.15
1981	1.02	0.03	2.87	1.11	0.73	0.04	0.15
1982	1.02	0.03	2.87	1.11	0.73	0.04	0.15
1983	1.02	0.03	2.87	1.11	0.73	0.04	0.15
1984	1.02	0.03	2.87	1.11	0.73	0.04	0.15
1985	1.02	0.03	2.87	1.11	0.73	0.04	0.15
1986	1.02	0.03	2.87	1.11	0.73	0.04	0.15
1987	1.02	0.03	2.87	1.11	0.73	0.04	0.15
1988	1.02	0.03	2.87	1.11	0.73	0.04	0.15
1989	1.02	0.03	2.87	1.11	0.73	0.04	0.15
1990	1.02	0.03	2.87	1.11	0.73	0.04	0.15
1991	1.02	0.03	2.87	1.11	0.73	0.04	0.15
1992	1.02	0.03	2.87	1.11	0.73	0.04	0.15
1993	1.02	0.03	2.87	1.11	0.73	0.04	0.15
1994	1.02	0.03	2.87	1.11	0.73	0.04	0.15
1995	1.02	0.03	2.87	1.11	0.73	0.04	0.15
1996	1.02	0.03	2.87	1.11	0.73	0.04	0.15
1997	1.02	0.03	2.87	1.11	0.73	0.04	0.15
1998	0.93	0.08	2.69	0.94	0.59	0.05	0.24
1999	0.85	0.13	2.51	0.77	0.46	0.06	0.34
2000	0.76	0.18	2.33	0.59	0.32	0.08	0.43
2001	0.68	0.23	2.15	0.42	0.19	0.09	0.52
2002	0.59	0.28	1.97	0.25	0.05	0.10	0.61
2003	0.59	0.28	1.97	0.25	0.05	0.10	0.61
2004	0.59	0.28	1.97	0.25	0.05	0.10	0.61
2005	0.59	0.28	1.97	0.25	0.05	0.10	0.61
2006	0.59	0.28	1.97	0.25	0.05	0.10	0.61
2007	0.59	0.28	1.97	0.25	0.05	0.10	0.61
2008	0.59	0.28	1.97	0.25	0.05	0.10	0.61
2009	0.59	0.28	1.97	0.25	0.05	0.10	0.61
2010	0.59	0.28	1.97	0.25	0.05	0.10	0.61

Table A3.--Results of the multiplicative loglinear model (Gavaris, 1980) used to standardize Deep7 bottomfish CPUE for the main Hawaiian Islands. The CPUE predictors included fishing year (fishyear), quarter (qtr), and fishing area (area) and interactions between quarter and fishing area as predictors of bottomfish CPUE on directed fishing trips (defined as trips that had at least 17% bottomfish catch by weight). Estimates of log-scale parameter factor coefficients along with their standard errors and P-values were listed for each predictor. Inferences about the significance of predictors was judged using the Type III sums of squares which are appropriate for unbalanced data sets (e.g., Searle, 1987).

```
                                Deep7 CPUE standardization by fishing year                  1
                  logdeep7 = fishyear + area + qtr + area*qtr
                                                16:13 Thursday, November 4, 2010

                               The GLM Procedure

                            Class Level Information

Class        Levels  Values

fishyear         60  1948 1949 1950 1951 1952 1953 1954 1955 1956 1957 1961 1962
                     1963 1964 1965 1966 1967 1968 1969 1970 1971 1972 1973 1974
                     1975 1976 1977 1978 1979 1981 1982 1983 1984 1985 1986 1987
                     1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999
                     2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 91980

area             82  100 101 102 103 104 105 106 107 108 120 121 122 123 124 125
                     126 127 128 300 301 302 303 304 305 306 307 308 309 310 311
                     312 313 314 320 321 322 323 324 325 326 327 328 332 333 400
                     401 402 403 404 405 406 407 408 409 420 421 422 423 424 425
                     426 427 428 429 500 501 502 503 504 505 506 508 520 521 522
                     523 524 525 526 527 528 9331

qtr               4  1 2 3 4

                        Number of observations    150535
```

The GLM Procedure

Dependent Variable: logdeep7

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	386	54372.1175	140.8604	121.96	<.0001
Error	150148	173416.8241	1.1550		
Corrected Total	150534	227788.9416			

R-Square	Coeff Var	Root MSE	logdeep7 Mean
0.238695	27.63464	1.074697	3.888947

Source	DF	Type I SS	Mean Square	F Value	Pr > F
fishyear	59	8030.00015	136.10170	117.84	<.0001
area	81	44443.95976	548.69086	475.07	<.0001
qtr	3	581.05458	193.68486	167.70	<.0001
area*qtr	243	1317.10305	5.42018	4.69	<.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
fishyear	59	6195.10401	105.00176	90.91	<.0001
area	81	40691.43450	502.36339	434.96	<.0001
qtr	3	178.37549	59.45850	51.48	<.0001
area*qtr	243	1317.10305	5.42018	4.69	<.0001

Parameter		Estimate		Standard Error	t Value	Pr > |t|
Intercept		4.433804439	B	0.02665051	166.37	<.0001
fishyear	1948	0.328511362	B	0.03826807	8.58	<.0001
fishyear	1949	0.067900446	B	0.03232216	2.10	0.0357
fishyear	1950	0.088712584	B	0.03282813	2.70	0.0069
fishyear	1951	0.140161283	B	0.03424211	4.09	<.0001
fishyear	1952	0.293518901	B	0.03804880	7.71	<.0001
fishyear	1953	0.259205643	B	0.04212159	6.15	<.0001
fishyear	1954	0.457494365	B	0.04341470	10.54	<.0001
fishyear	1955	0.739144789	B	0.05223143	14.15	<.0001
fishyear	1956	0.489438899	B	0.04640792	10.55	<.0001
fishyear	1957	0.617447641	B	0.04389021	14.07	<.0001
fishyear	1961	0.724097950	B	0.06047528	11.97	<.0001
fishyear	1962	0.811256365	B	0.05236324	15.49	<.0001
fishyear	1963	0.349072678	B	0.04852754	7.19	<.0001
fishyear	1964	0.436676260	B	0.04726002	9.24	<.0001
fishyear	1965	0.661863961	B	0.04310051	15.36	<.0001

The GLM Procedure

Dependent Variable: logdeep7

Parameter		Estimate		Standard Error	t Value	Pr > |t|
fishyear	1966	0.511443268	B	0.04414938	11.58	<.0001
fishyear	1967	0.460749064	B	0.03861889	11.93	<.0001
fishyear	1968	0.440504704	B	0.04187675	10.52	<.0001
fishyear	1969	0.379145068	B	0.04137518	9.16	<.0001
fishyear	1970	0.299712500	B	0.04191223	7.15	<.0001
fishyear	1971	0.200059597	B	0.04093844	4.89	<.0001
fishyear	1972	0.293237402	B	0.03554863	8.25	<.0001
fishyear	1973	0.227670870	B	0.03784457	6.02	<.0001
fishyear	1974	0.193613709	B	0.03422371	5.66	<.0001
fishyear	1975	0.175841591	B	0.03478121	5.06	<.0001
fishyear	1976	0.249847530	B	0.03439333	7.26	<.0001
fishyear	1977	0.016799005	B	0.03333285	0.50	0.6143
fishyear	1978	0.017288600	B	0.03250623	0.53	0.5948
fishyear	1979	0.152775226	B	0.03466607	4.41	<.0001
fishyear	1981	0.027345080	B	0.02983635	0.92	0.3594
fishyear	1982	-0.072383769	B	0.02980424	-2.43	0.0152
fishyear	1983	-0.053136030	B	0.02833464	-1.88	0.0608
fishyear	1984	-0.270473242	B	0.02889424	-9.36	<.0001
fishyear	1985	-0.174965973	B	0.02722361	-6.43	<.0001
fishyear	1986	-0.171728375	B	0.02706428	-6.35	<.0001
fishyear	1987	-0.039906021	B	0.02713070	-1.47	0.1413
fishyear	1988	0.102782780	B	0.02686935	3.83	0.0001
fishyear	1989	0.067602894	B	0.02675265	2.53	0.0115
fishyear	1990	-0.046141420	B	0.02737829	-1.69	0.0919
fishyear	1991	-0.126006434	B	0.02844374	-4.43	<.0001
fishyear	1992	-0.200182988	B	0.02803793	-7.14	<.0001
fishyear	1993	-0.258831626	B	0.02935502	-8.82	<.0001
fishyear	1994	-0.161834210	B	0.02889905	-5.60	<.0001
fishyear	1995	-0.142073437	B	0.02847466	-4.99	<.0001
fishyear	1996	-0.244516702	B	0.02854464	-8.57	<.0001
fishyear	1997	-0.224439562	B	0.02817905	-7.96	<.0001
fishyear	1998	-0.284421404	B	0.02826354	-10.06	<.0001
fishyear	1999	-0.245865364	B	0.03008195	-8.17	<.0001
fishyear	2000	-0.103941441	B	0.02872770	-3.62	0.0003
fishyear	2001	-0.152782722	B	0.02923642	-5.23	<.0001
fishyear	2002	-0.223927470	B	0.03043059	-7.36	<.0001
fishyear	2003	-0.187904155	B	0.03024900	-6.21	<.0001
fishyear	2004	-0.255314569	B	0.03091874	-8.26	<.0001
fishyear	2005	-0.116480453	B	0.03104548	-3.75	0.0002
fishyear	2006	-0.170588133	B	0.03227083	-5.29	<.0001
fishyear	2007	-0.123504365	B	0.03093670	-3.99	<.0001
fishyear	2008	0.064593505	B	0.03231911	2.00	0.0457
fishyear	2009	-0.041333409	B	0.02997560	-1.38	0.1679
fishyear	2010	-0.209963825	B	0.03101774	-6.77	<.0001
fishyear	91980	0.000000000				

Table A4.--WINBUGS source code used to fit a multilevel R (intrinsic growth rate) assessment model under Catch Scenario II and CPUE Scenario I during 1949-2010.

```
###################################################################################
# deep7_s2_cpue1_model.txt
# MULTILEVEL-R Version
# Jon Brodziak, PIFSC, November 2010
# deep7_model analyzes MHI Deep7 catch & cpue data for 1949-2010 by fishing year
# Catch units are thousands of pounds
# CPUE units are pounds per trip
###################################################################################

model base_2010
{

PI <- 3.1415926
dim_model <- NPAR + N_TIME

###################################################################################
# PRIOR DISTRIBUTIONS
###################################################################################

# Normal prior for carrying capacity parameter, K
#(P1)##############################################################################
K_Prior_Stdev <- CV_K*K_Prior_Avg
K_Prior_Precision <- 1.0/pow(K_Prior_Stdev,2)
K ~ dnorm(K_Prior_Avg,K_Prior_Precision)

# Lognormal prior for intrinsic growth rate parameter, r
#(P2)##############################################################################
r_Hyperprior_Precision <- 1.0/pow(abs(Target_r_Prior_Avg)*CV_Hyper_r,2)
r_Prior_Precision <- 1.0/log(1.0+CV_r*CV_r)
r_Hyperprior_Avg <- log(Target_r_Prior_Avg) - (0.5/r_Prior_Precision)
r_Prior_Avg ~ dnorm(r_Hyperprior_Avg,r_Hyperprior_Precision)

# Gamma prior for production shape parameter, M
#(P3)##############################################################################
M ~ dgamma(0.5,0.5)

# Uniform prior for CPUE catchability coefficient
# within interval (0.0001,10000), q
#(P4)##############################################################################
q ~ dunif(0.00001,100000)

# Gamma prior for process error variance, sigma2
#(P5)##############################################################################
isigma2 ~ dgamma(proc_shape,proc_scale)I(0.000001,1000000)
sigma2 <- 1/isigma2

# Gamma prior for observation error variance, tau2
#(P6)##############################################################################
itau2   ~ dgamma(obs_shape,obs_scale)I(0.000001,1000000)
tau2   <- 1/itau2

# Lognormal priors for unobserved states, the time series of proportions of K, P[]
#(P7)##############################################################################
# MHI time catch series starts in FY1949 and ends in FY2010, n=62
P1_Prior_Precision <- 1.0/log(1.0+CV_P1*CV_P1)
P1_Prior_Avg <-log(Target_P1_Prior_Avg) - (0.5/P1_Prior_Precision)
P[1] ~ dlnorm(P1_Prior_Avg,P1_Prior_Precision) I(0.0001,10000)
r[1] ~ dlnorm(r_Prior_Avg,r_Prior_Precision)
lower[1] <- LB*Unreported_Catch[1] + Reported_Catch[1]
upper[1] <- UB*Unreported_Catch[1] + Reported_Catch[1]
Catch[1] ~ dunif(lower[1],upper[1])

# Process dynamics
for (i in 2:N_TIME) {
  Pmean[i] <- log(max(P[i-1] + r[i-1]*P[i-1]*(1-pow(P[i-1],M)) - Catch[i-1]/K,0.0001))
  P[i]  ~ dlnorm(Pmean[i],isigma2)I(0.0001,10000)
```

```
  r[i] ~ dlnorm(r_Prior_Avg,r_Prior_Precision)
  lower[i] <- LB*Unreported_Catch[i] + Reported_Catch[i]
  upper[i] <- UB*Unreported_Catch[i] + Reported_Catch[i]
  Catch[i] ~ dunif(lower[i],upper[i])
  }


##################################################################################
# SAMPLE LIKELIHOOD
##################################################################################

# MHI Bottomfish CPUE Likelihood 1949-1957 P[1:N1_CPUE]
#(L1)#############################################################################
for (i in 1:N1_CPUE) {
     CPUE_mean[i] <- log(q*K*P[i])
     Precision_CPUE[i] <- itau2/(rel_CV_CPUE[i]*rel_CV_CPUE[i])
     CPUE[i] ~ dlnorm(CPUE_mean[i],Precision_CPUE[i])
     LOG_RESID[i] <- log(CPUE[i]) - log(q*K*P[i])
     LOG.LIKE[i] <- 0.5*(log(Precision_CPUE[i])) - 0.5*log(2*PI) - log(CPUE[i]) +
                    - 0.5*Precision_CPUE[i]*pow((log(CPUE[i]) - CPUE_mean[i]),2)
     }
# MHI Bottomfish CPUE Likelihood 1961-2010 P[N1_CPUE+NMISS+1:N2_CPUE]
#(L2)#############################################################################
for (i in N1_CPUE+NMISS+1:N2_CPUE) {
     CPUE_mean[i] <- log(q*K*P[i])
     Precision_CPUE[i] <- itau2/(rel_CV_CPUE[i]*rel_CV_CPUE[i])
     CPUE[i] ~ dlnorm(CPUE_mean[i],Precision_CPUE[i])
     LOG_RESID[i] <- log(CPUE[i]) - log(q*K*P[i])
     LOG.LIKE[i] <- 0.5*(log(Precision_CPUE[i])) - 0.5*log(2*PI) - log(CPUE[i]) +
                    - 0.5*Precision_CPUE[i]*pow((log(CPUE[i]) - CPUE_mean[i]),2)
     }

# Compute LOG_RSS and LOG_RMSE for MHI CPUE
#(L3)#############################################################################
LOG_RSS <- inprod(LOG_RESID[1:N1_CPUE], LOG_RESID[1:N1_CPUE]) +
       inprod(LOG_RESID[N1_CPUE+NMISS+1:N2_CPUE], LOG_RESID[N1_CPUE+NMISS+1:N2_CPUE])
LOG_RMSE <- sqrt(LOG_RSS/(N2_CPUE-NMISS))
Deviance <- -2.0*sum( LOG.LIKE[1:N1_CPUE] ) - 2.0*sum( LOG.LIKE[N1_CPUE+NMISS+1:N2_CPUE] )
AIC <- Deviance + dim_model*2.0
BIC <- Deviance + dim_model*log((N2_CPUE-NMISS))

# Compute standardized log-scale residuals, predicted CPUE, and unscaled residuals
#(L4)#############################################################################
for (i in 1:N1_CPUE) {
     STD_LOG_RESID[i] <- LOG_RESID[i]/LOG_RMSE
     PRED_CPUE[i] <- exp(log(CPUE[i]) - LOG_RESID[i])
     RESID[i] <- CPUE[i] - PRED_CPUE[i]
     }
for (i in N1_CPUE+NMISS+1:N2_CPUE) {
     STD_LOG_RESID[i] <- LOG_RESID[i]/LOG_RMSE
     PRED_CPUE[i] <- exp(log(CPUE[i]) - LOG_RESID[i])
     RESID[i] <- CPUE[i] - PRED_CPUE[i]
     }

# Compute RSS and RMSE for MHI CPUE
#(L5)#############################################################################
RSS <- inprod(RESID[1:N1_CPUE], RESID[1:N1_CPUE]) +
       inprod(RESID[N1_CPUE+NMISS+1:N2_CPUE], RESID[N1_CPUE+NMISS+1:N2_CPUE])
RMSE <- sqrt(RSS/(N2_CPUE-NMISS))

##################################################################################
# STOCK ASSESSMENT ESTIMATES
##################################################################################

# Compute exploitation rate and biomass time series
#(A1)############################################################################
# MHI 1949-2010 P[1:N_TIME]
for (i in 1:N_TIME) {
     B[i] <- P[i]*K
     H[i] <- Catch[i]/B[i]
    }
```

```
# Compute average r
#(A2)###############################################################################
ravg <- mean(r[])

# Compute reference points
#(A3)###############################################################################
  BMSY <- K*pow(M+1.0,(-1.0/M))
  MSY <- ravg*BMSY*(1.0-(1.0/(M+1.0)))
  HMSY <- ravg*(1.0-(1.0/(M+1.0)))
  PMSY <- BMSY/K
  FMSY <- -log(1-HMSY)
  INDEXMSY <- q*BMSY


# Compute MHI 1949-2010 BSTATUS and HSTATUS
#(A4)###############################################################################
for (i in 1:N_TIME) {
     BSTATUS[i] <- B[i]/BMSY
     HSTATUS[i] <- H[i]/HMSY
     production[i] <- r[i]*B[i]*(1-pow((B[i]/K),M))
    }

# Compute probabilities of overfishing and overfished 1949-2010
#(A5)###############################################################################
for (i in 1:N_TIME) {
     pH[i] <- step(HSTATUS[i] - 1.0)
     pB[i] <- step(BSTATUS[i] - 1.0)
    }

# Projections
#(11)#################################################################################
P2011 <- max(P[N_TIME]+ravg*P[N_TIME]*(1-P[N_TIME])-Catch[N_TIME]/K,0.0001)
B2011 <- P2011*K
C2011 <- B2011*HPROJ
B2011_STAT <- B2011/BMSY
B2012 <-  B2011*(1.0+ravg*(1.0-(B2011/K))-HPROJ)
C2012 <- B2012*HPROJ
B2012_STAT <- B2012/BMSY
B2013 <-  B2012*(1.0+ravg*(1.0-(B2012/K))-HPROJ)
C2013 <- B2013*HPROJ
B2013_STAT <- B2013/BMSY

# END OF CODE
####################################################################################
}
```

Table A5.--WINBUGS source code used to fit baseline assessment and projection model under Catch Scenario II and CPUE Scenario I during 1949-2010.

```
##########################################################################################
# deep7_s2_cpue1_proj
# Jon Brodziak, PIFSC, December 2010
# deep7_model analyzes MHI Deep7 catch & cpue data for 1949-2010 by fishing year
# Catch units are thousands of pounds
# CPUE units are pounds per trip
##########################################################################################

model deep7_s2_cpue1_proj
{

PI <- 3.1415926
dim_model <- NPAR + N_TIME

##########################################################################################
# PRIOR DISTRIBUTIONS
##########################################################################################

# Lognormal prior for carrying capacity parameter, K
#(P1)####################################################################################
K_Prior_Precision <- 1.0/log(1.0+CV_K*CV_K)
K_Prior_Avg <- log(Target_K_Prior_Avg) - (0.5/K_Prior_Precision)
K ~ dlnorm(K_Prior_Avg,K_Prior_Precision)I(0.001,200.0)

# Lognormal prior for intrinsic growth rate parameter, r
#(P2)####################################################################################
r_Prior_Precision <- 1.0/log(1.0+CV_r*CV_r)
r_Prior_Avg <- log(Target_r_Prior_Avg) - (0.5/r_Prior_Precision)
r ~ dlnorm(r_Prior_Avg,r_Prior_Precision)I(0.01,1.00)

# Gamma prior for production shape parameter, M
#(P3)####################################################################################
M ~ dgamma(0.5,0.5)

# Uniform prior for CPUE catchability coefficient
# within interval (0.0001,10000), q
#(P4)####################################################################################
q ~ dunif(0.00001,100000)

# Gamma prior for process error variance, sigma2
#(P5)####################################################################################
isigma2 ~ dgamma(proc_shape,proc_scale)I(0.000001,1000000)
sigma2 <- 1/isigma2

# Gamma prior for observation error variance, tau2
#(P6)####################################################################################
itau2   ~ dgamma(obs_shape,obs_scale)I(0.000001,1000000)
tau2   <- 1/itau2

# Lognormal priors for unobserved states, the time series of proportions of K, P[]
#(P7)####################################################################################
# MHI time catch series starts in FY1949 and ends in FY2010, n=62
P1_Prior_Precision <- 1.0/log(1.0+CV_P1*CV_P1)
P1_Prior_Avg <-log(Target_P1_Prior_Avg) - (0.5/P1_Prior_Precision)
P[1] ~ dlnorm(P1_Prior_Avg,P1_Prior_Precision) I(0.0001,10000)

lower[1] <- LB*Unreported_Catch[1] + Reported_Catch[1]
upper[1] <- UB*Unreported_Catch[1] + Reported_Catch[1]
Catch[1] ~ dunif(lower[1],upper[1])

# Process dynamics
for (i in 2:N_TIME) {
  Pmean[i] <- log(max(P[i-1] + r*P[i-1]*(1-pow(P[i-1],M)) - Catch[i-1]/K,0.0001))
  P[i]  ~ dlnorm(Pmean[i],isigma2)I(0.0001,10000)
  lower[i] <- LB*Unreported_Catch[i] + Reported_Catch[i]
  upper[i] <- UB*Unreported_Catch[i] + Reported_Catch[i]
```

```
  Catch[i] ~ dunif(lower[i],upper[i])
  }


################################################################################
# SAMPLE LIKELIHOOD
################################################################################

# MHI Bottomfish CPUE Likelihood 1949-1957 P[1:N1_CPUE]
#(L1)###########################################################################
for (i in 1:N1_CPUE) {
    CPUE_mean[i] <- log(q*K*P[i])
    Precision_CPUE[i] <- itau2/(rel_CV_CPUE[i]*rel_CV_CPUE[i])
    CPUE[i] ~ dlnorm(CPUE_mean[i],Precision_CPUE[i])
    LOG_RESID[i] <- log(CPUE[i]) - log(q*K*P[i])
    LOG.LIKE[i] <- 0.5*(log(Precision_CPUE[i])) - 0.5*log(2*PI) - log(CPUE[i]) +
                 - 0.5*Precision_CPUE[i]*pow((log(CPUE[i]) - CPUE_mean[i]),2)
    }
# MHI Bottomfish CPUE Likelihood 1961-2010 P[N1_CPUE+NMISS+1:N2_CPUE]
#(L2)###########################################################################
for (i in N1_CPUE+NMISS+1:N2_CPUE) {
    CPUE_mean[i] <- log(q*K*P[i])
    Precision_CPUE[i] <- itau2/(rel_CV_CPUE[i]*rel_CV_CPUE[i])
    CPUE[i] ~ dlnorm(CPUE_mean[i],Precision_CPUE[i])
    LOG_RESID[i] <- log(CPUE[i]) - log(q*K*P[i])
    LOG.LIKE[i] <- 0.5*(log(Precision_CPUE[i])) - 0.5*log(2*PI) - log(CPUE[i]) +
                 - 0.5*Precision_CPUE[i]*pow((log(CPUE[i]) - CPUE_mean[i]),2)
    }

# Compute LOG_RSS and LOG_RMSE for MHI CPUE
#(L3)###########################################################################
#LOG_RSS <- inprod(LOG_RESID[1:N1_CPUE], LOG_RESID[1:N1_CPUE]) +
#       inprod(LOG_RESID[N1_CPUE+NMISS+1:N2_CPUE], LOG_RESID[N1_CPUE+NMISS+1:N2_CPUE])
#LOG_RMSE <- sqrt(LOG_RSS/(N2_CPUE-NMISS))
#Deviance <- -2.0*sum( LOG.LIKE[1:N1_CPUE] ) - 2.0*sum( LOG.LIKE[N1_CPUE+NMISS+1:N2_CPUE] )
#AIC <- Deviance + dim_model*2.0
#BIC <- Deviance + dim_model*log((N2_CPUE-NMISS))
#
# Compute standardized log-scale residuals, predicted CPUE, and unscaled residuals
#(L4)###########################################################################
#for (i in 1:N1_CPUE) {
#     STD_LOG_RESID[i] <- LOG_RESID[i]/LOG_RMSE
#    PRED_CPUE[i] <- exp(log(CPUE[i]) - LOG_RESID[i])
#     RESID[i] <- CPUE[i] - PRED_CPUE[i]
#    }
#for (i in N1_CPUE+NMISS+1:N2_CPUE) {
#     STD_LOG_RESID[i] <- LOG_RESID[i]/LOG_RMSE
#     PRED_CPUE[i] <- exp(log(CPUE[i]) - LOG_RESID[i])
#     RESID[i] <- CPUE[i] - PRED_CPUE[i]
#     }
#
# Compute RSS and RMSE for MHI CPUE
#(L5)###########################################################################
#RSS <- inprod(RESID[1:N1_CPUE], RESID[1:N1_CPUE]) +
#       inprod(RESID[N1_CPUE+NMISS+1:N2_CPUE], RESID[N1_CPUE+NMISS+1:N2_CPUE])
#RMSE <- sqrt(RSS/(N2_CPUE-NMISS))
#
################################################################################
# STOCK ASSESSMENT ESTIMATES
################################################################################

# Compute exploitation rate and biomass time series
#(A1)##########################################################################
# MHI 1949-2010 P[1:N_TIME]
for (i in 1:N_TIME) {
    B[i] <- P[i]*K
    H[i] <- Catch[i]/B[i]
   }

# Compute reference points
```

```
#(A3)#############################################################################
  logBMSY <- log(K) - log(1.0+M)/M
  BMSY <- exp(logBMSY)
  MSY <- r*BMSY*(1.0-(1.0/(M+1.0)))
  HMSY <- r*(1.0-(1.0/(M+1.0)))
  PMSY <- BMSY/K
  FMSY <- -log(1-HMSY)
  INDEXMSY <- q*BMSY


# Compute MHI 1949-2010 BSTATUS and HSTATUS
#(A4)#############################################################################
for (i in 1:N_TIME) {
     BSTATUS[i] <- B[i]/BMSY
     HSTATUS[i] <- H[i]/HMSY
     production[i] <- r*B[i]*(1-pow((B[i]/K),M))
    }

# Compute probabilities of overfishing and overfished 1949-2010
#(A5)#############################################################################
for (i in 1:N_TIME) {
     pH[i] <- step(HSTATUS[i] - 1.0)
     pB[i] <- step(BSTATUS[i] - 0.7)
    }

# Projections
#(11)###############################################################################
############ Fishing Year 2011 Projection  ###############################################
proj_P[1] <- max(P[T] + r*P[T]*(1-pow(P[T],M)) - Catch[T]/K,0.0001)
B[T+1] <- proj_P[1]*K

RC[1] <- TAC_2011*prop_caught_2011
UC[1] <- UC_ratio*RC[1]

lower[T+1] <- proj_LB*UC[1] + RC[1]
upper[T+1] <- proj_UB*UC[1] + RC[1]

proj_C2011 ~ dunif(lower[T+1],upper[T+1])

H[T+1] <- proj_C2011/B[T+1]

BSTATUS[T+1] <- B[T+1]/BMSY
HSTATUS[T+1] <- H[T+1]/HMSY

pH[T+1] <- step(HSTATUS[T+1] - 1.0)
pB[T+1] <- step(BSTATUS[T+1] - 0.7)

############ Fishing Year 2012-2013 Projection #############################################
proj_lower <- proj_LB*UC_ratio
proj_upper <- proj_UB*UC_ratio

proj_P[2] <- max(proj_P[1] + r*proj_P[1]*(1-pow(proj_P[1],M)) - proj_C2011/K,0.0001)
B[T+2] <- proj_P[2]*K
BSTATUS[T+2] <- B[T+2]/BMSY
pB[T+2] <- step(BSTATUS[T+2] - 0.7)

for (j in 1:NTAC)
      {
      proj_TAC[j] <- start_TAC+mesh_TAC*(j-1)
      proj_UC_ratio1[j] ~ dunif(proj_lower,proj_upper)
      proj_UC1[j] <- proj_UC_ratio1[j]*proj_TAC[j]
      proj_C1[j] <- proj_TAC[j] + proj_UC1[j]
      proj_H1[j] <- proj_C1[j]/B[T+2]
      proj_HSTATUS1[j] <- proj_H1[j]/HMSY
      proj_pH1[j] <- step(proj_HSTATUS1[j] - 1.0)
      proj_B[j] <- K*max(proj_P[2] + r*proj_P[2]*(1-pow(proj_P[2],M)) - proj_C1[j]/K,0.0001)
      proj_BSTATUS[j] <- proj_B[j]/BMSY
      proj_pB[j] <- step(proj_BSTATUS[j] - 0.7)
      proj_UC_ratio2[j] ~ dunif(proj_lower,proj_upper)
      proj_UC2[j] <- proj_UC_ratio2[j]*proj_TAC[j]
```

```
    proj_C2[j] <- proj_TAC[j] + proj_UC2[j]
    proj_H2[j] <- proj_C2[j]/proj_B[j]
    proj_HSTATUS2[j] <- proj_H2[j]/HMSY
    proj_pH2[j] <- step(proj_HSTATUS2[j] - 1.0)
    }

# END OF CODE
########################################################################################
}
```

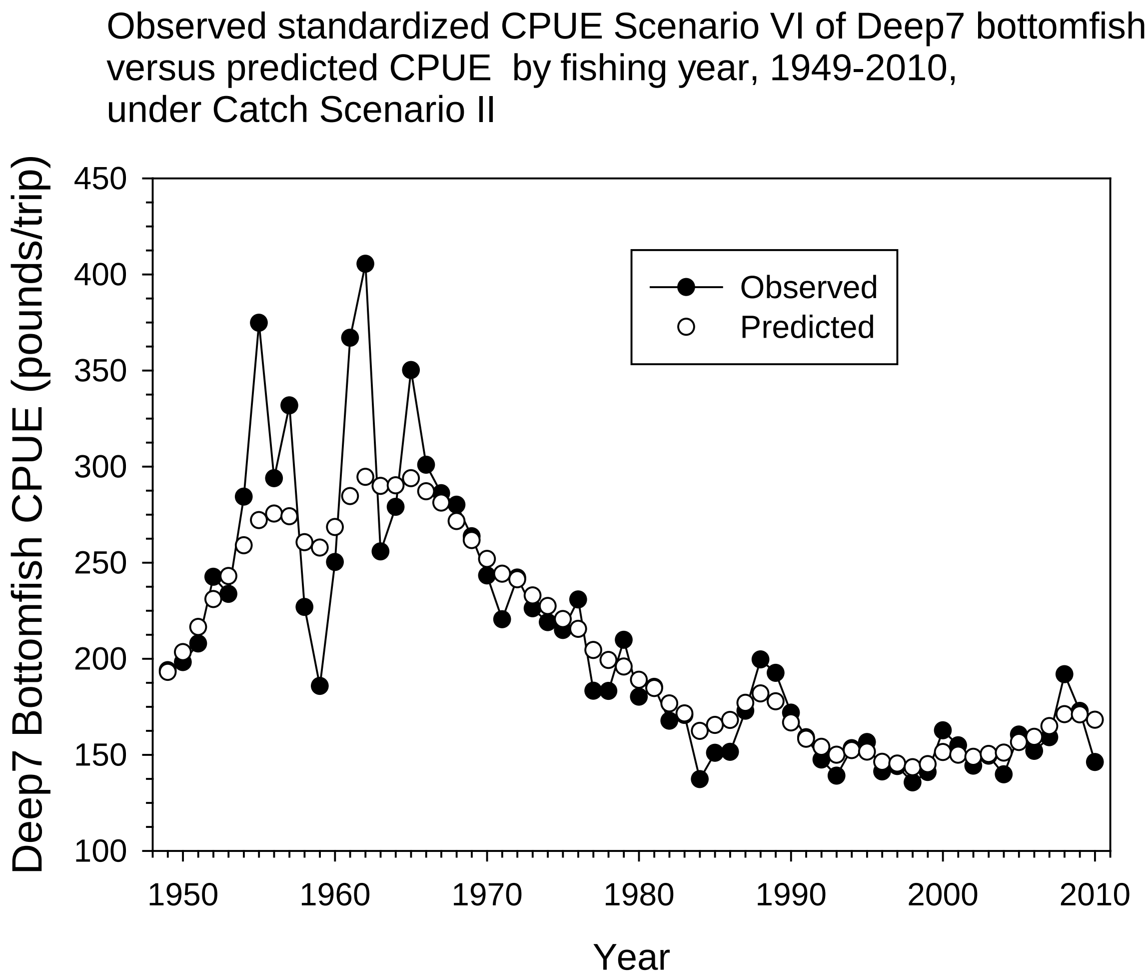


Figure A.1.1.--Results of the Catch Scenario II CPUE Scenario Ib production model fit to the observed standardized bottomfish CPUE for the main Hawaiian Islands along with CPUE residuals.

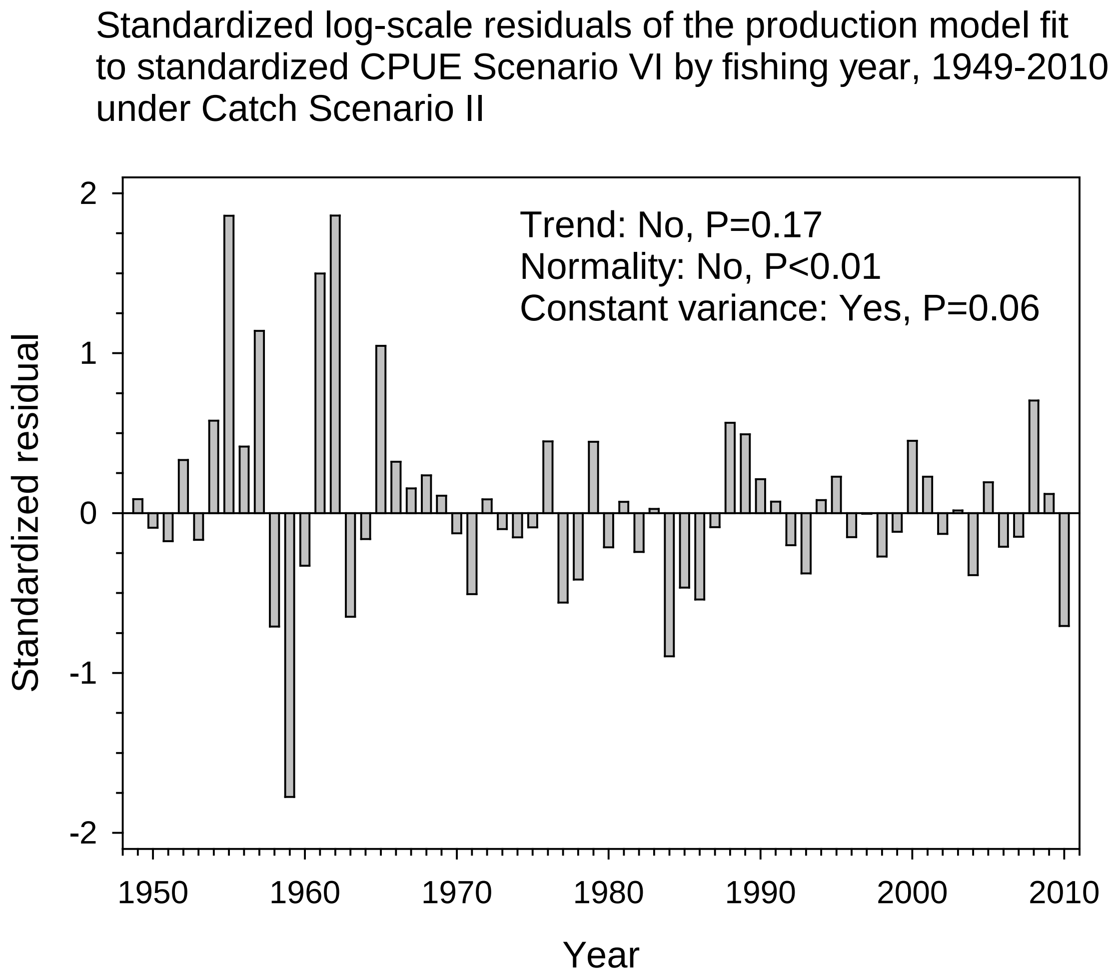


Figure A.1.2.--Results of the Catch Scenario II CPUE Scenario Ib production model fit to the observed standardized bottomfish CPUE for the main Hawaiian Islands along with standardized log-scale CPUE residuals and P-values for linear regression hypothesis tests of whether standardized residuals have a time trend, are normally distributed, and have constant variance.

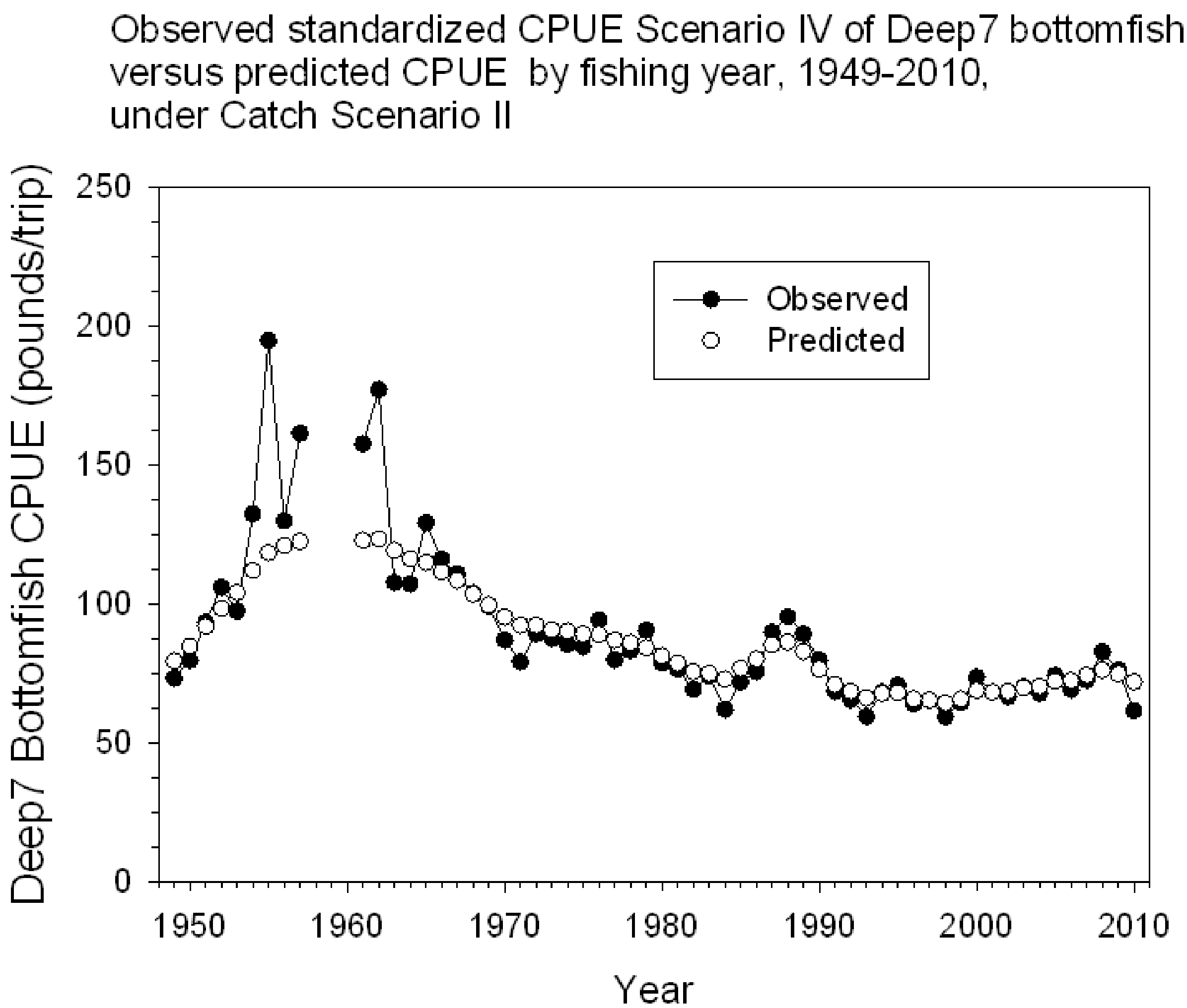


Figure A.2.1.--Results of the Catch Scenario II CPUE Scenario IV production model fit to the observed standardized bottomfish CPUE for the main Hawaiian Islands along with CPUE residuals.

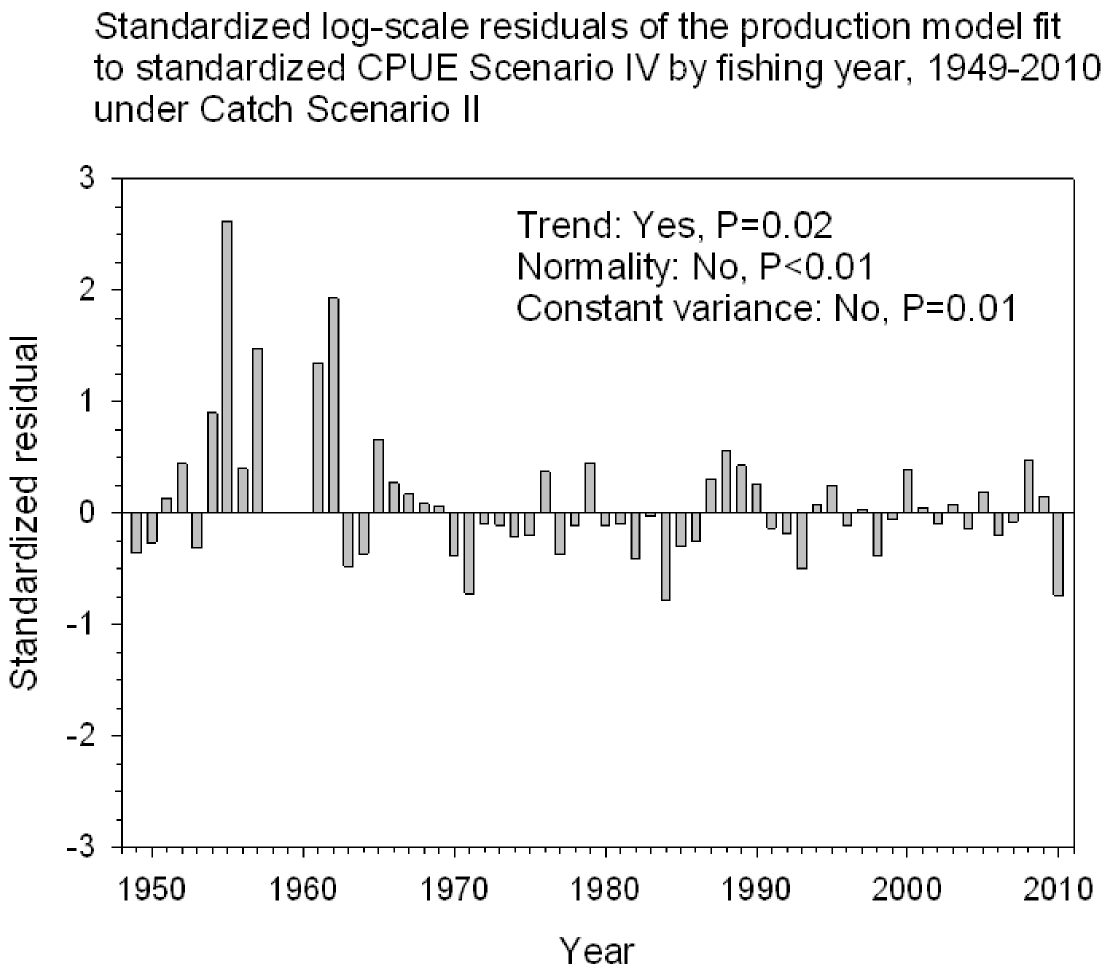


Figure A.2.2.--Results of the Catch Scenario II CPUE Scenario II production model fit to the observed standardized bottomfish CPUE for the main Hawaiian Islands along with standardized log-scale CPUE residuals and P-values for linear regression hypothesis tests of whether standardized residuals have a time trend, are normally distributed, and have constant variance.

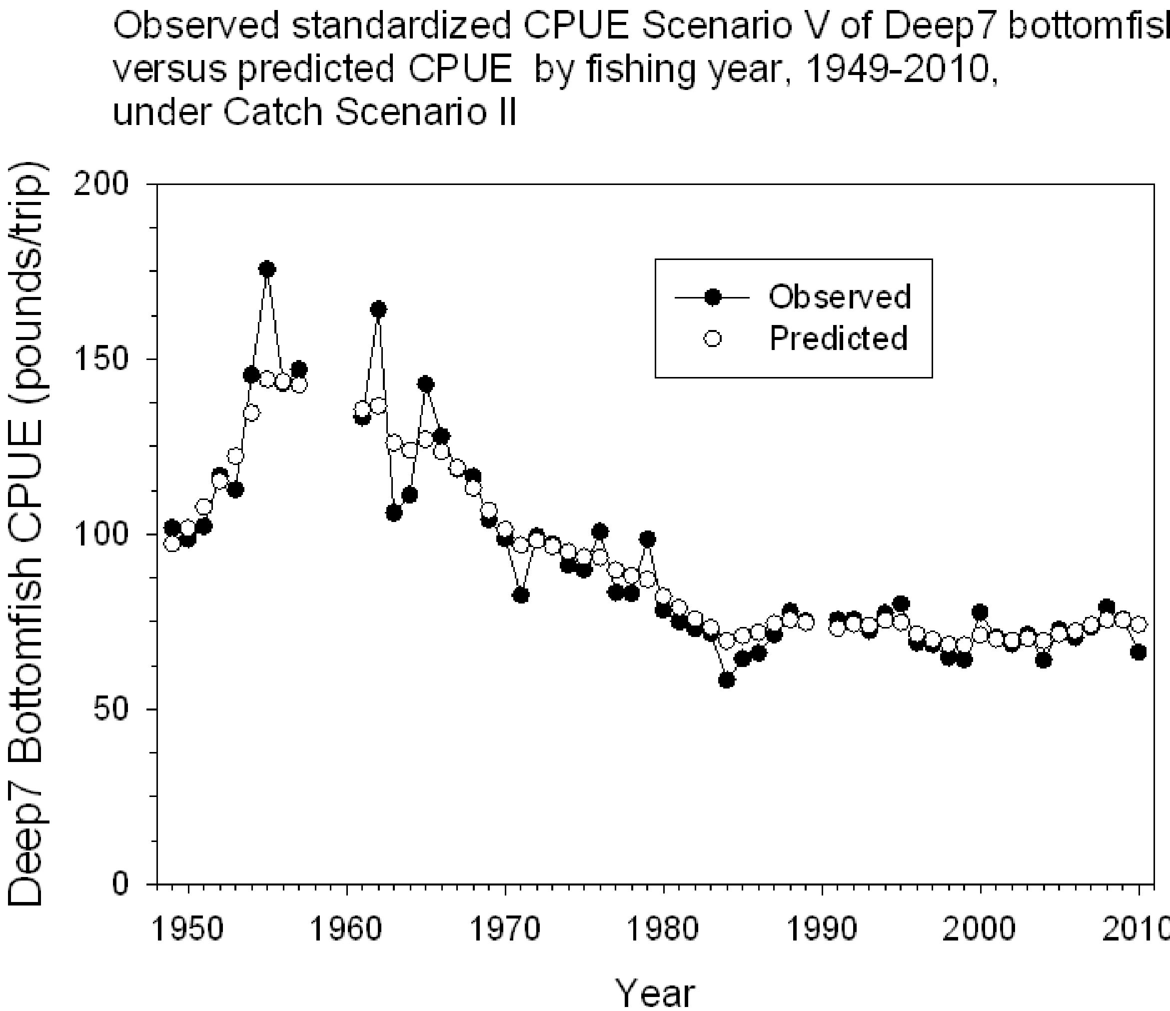


Figure A.3.1.--Results of the Catch Scenario II CPUE Scenario V production model fit to the observed standardized bottomfish CPUE for the main Hawaiian Islands along with CPUE residuals.

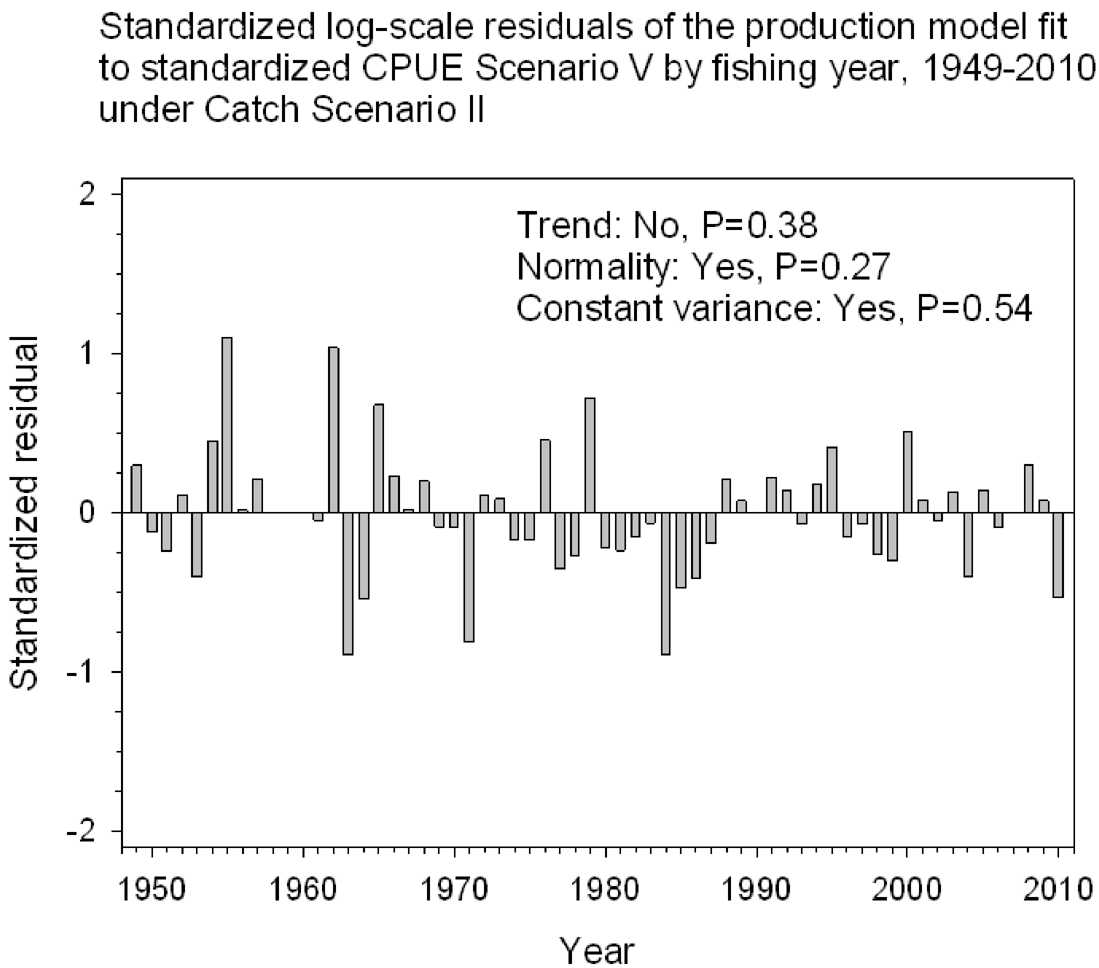


Figure A.3.2.--Results of the Catch Scenario II CPUE Scenario V production model fit to the observed standardized bottomfish CPUE for the main Hawaiian Islands along with standardized log-scale CPUE residuals and P-values for linear regression hypothesis tests of whether standardized residuals have a time trend, are normally distributed, and have constant variance.

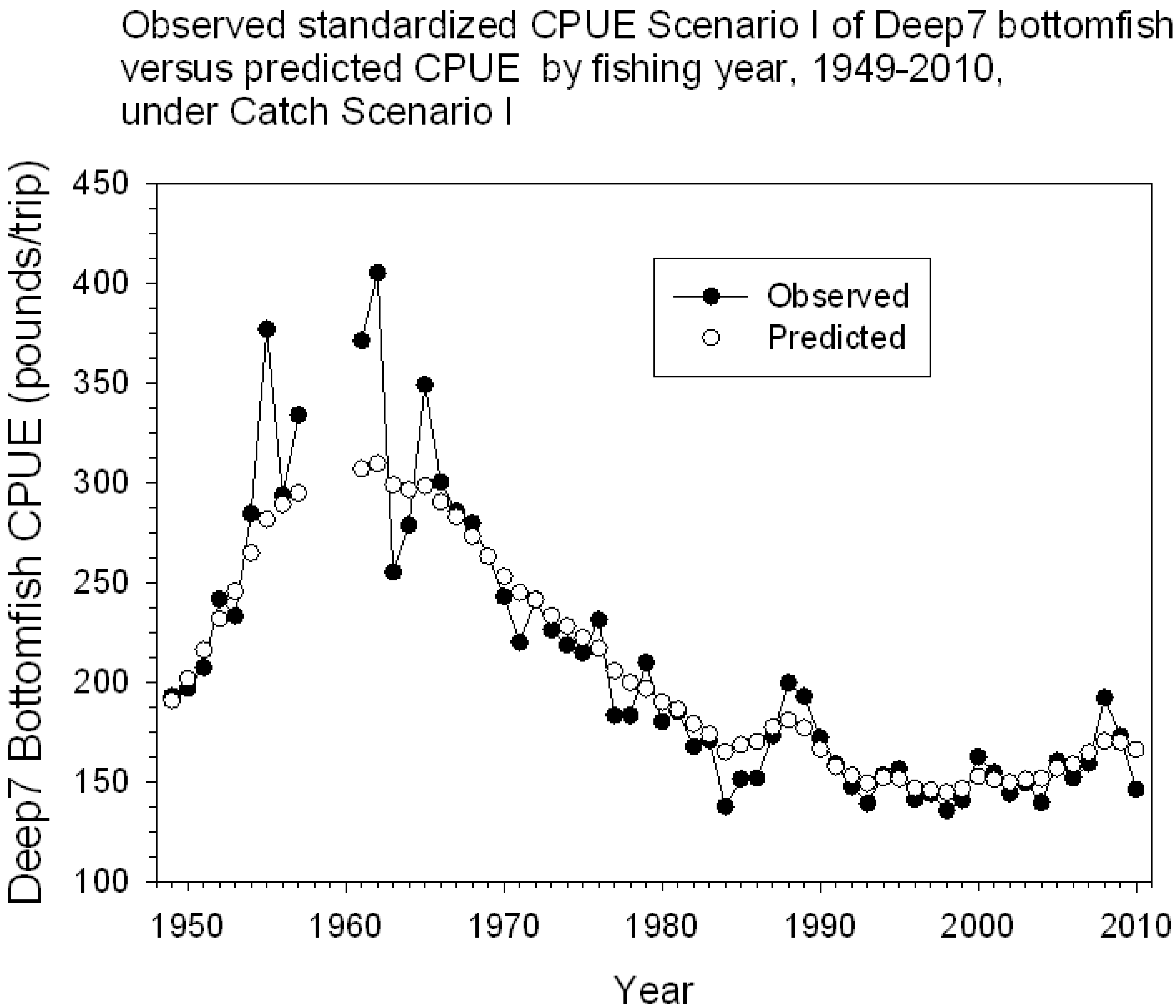


Figure A.4.1.--Results of the Catch Scenario I CPUE Scenario I production model fit to the observed standardized bottomfish CPUE for the main Hawaiian Islands along with CPUE residuals.

Standardized log-scale residuals of the production model fit to standardized CPUE Scenario I by fishing year, 1949-2010, under Catch Scenario I

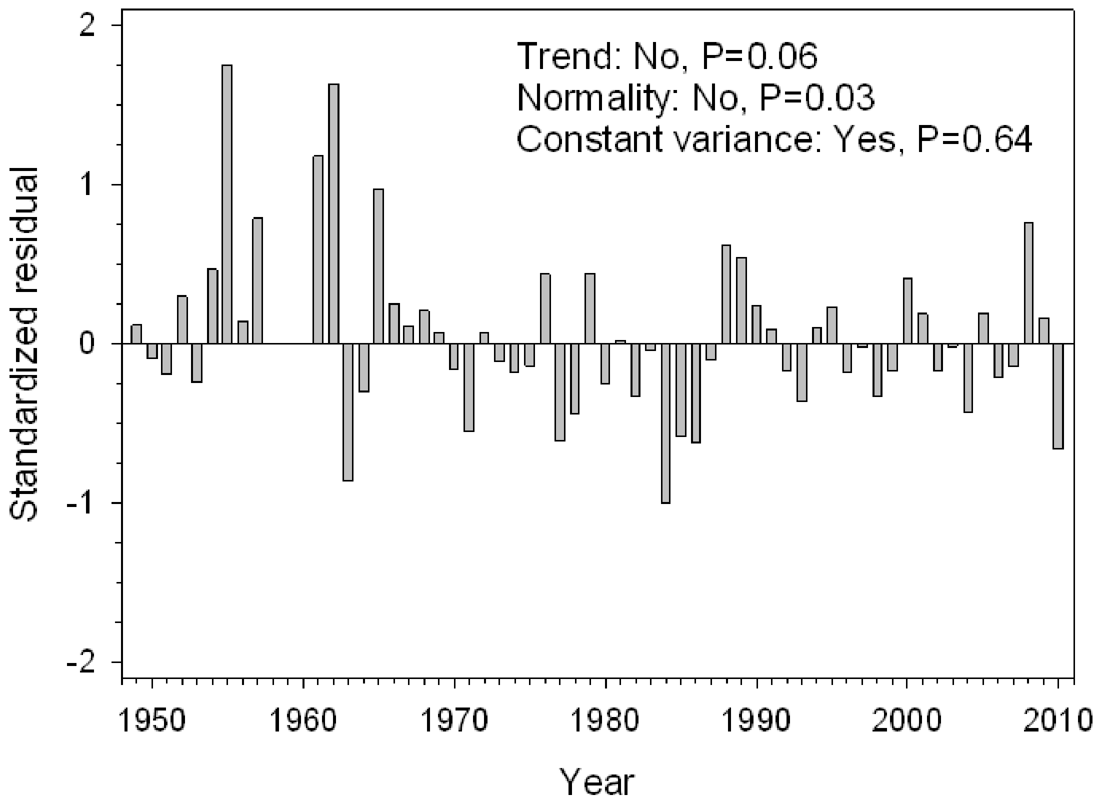


Figure A.4.2.--Results of the Catch Scenario I CPUE Scenario I production model fit to the observed standardized bottomfish CPUE for the main Hawaiian Islands along with standardized log-scale CPUE residuals and P-values for linear regression hypothesis tests of whether standardized residuals have a time trend, are normally distributed, and have constant variance.

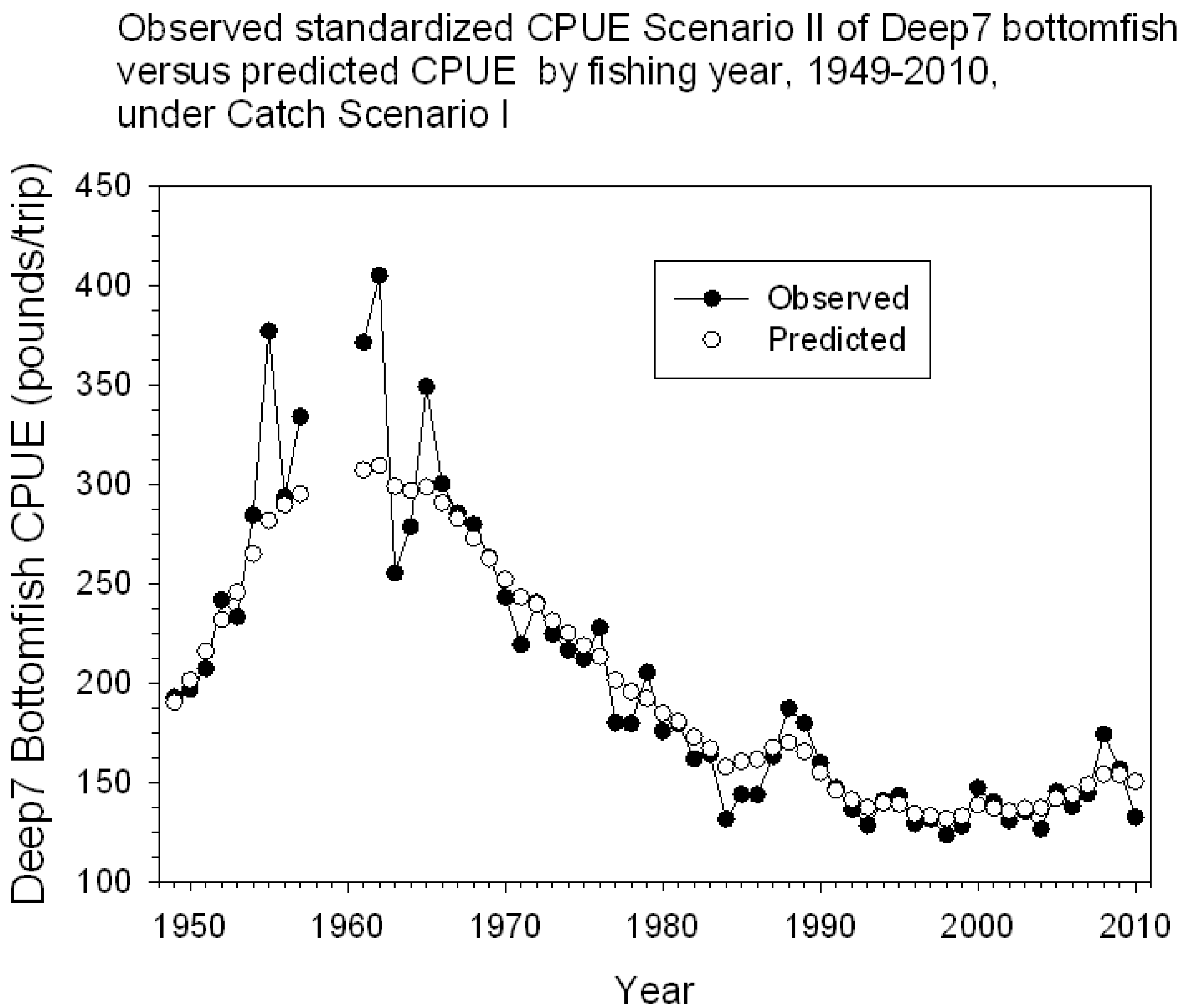


Figure A.5.1.--Results of the Catch Scenario I CPUE Scenario II production model fit to the observed standardized bottomfish CPUE for the main Hawaiian Islands along with CPUE residuals.

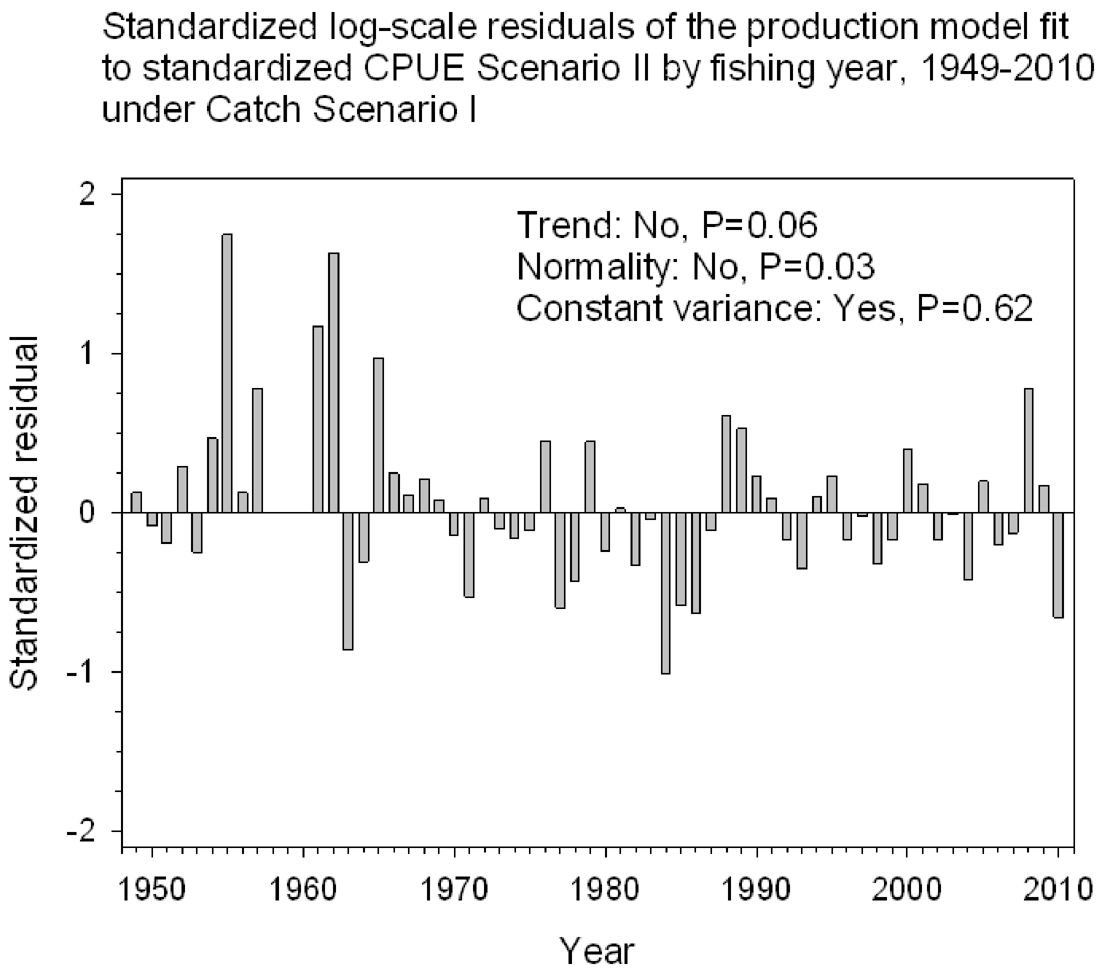


Figure A.5.2.--Results of the Catch Scenario I CPUE Scenario II production model fit to the observed standardized bottomfish CPUE for the main Hawaiian Islands along with standardized log-scale CPUE residuals and P-values for linear regression hypothesis tests of whether standardized residuals have a time trend, are normally distributed, and have constant variance.

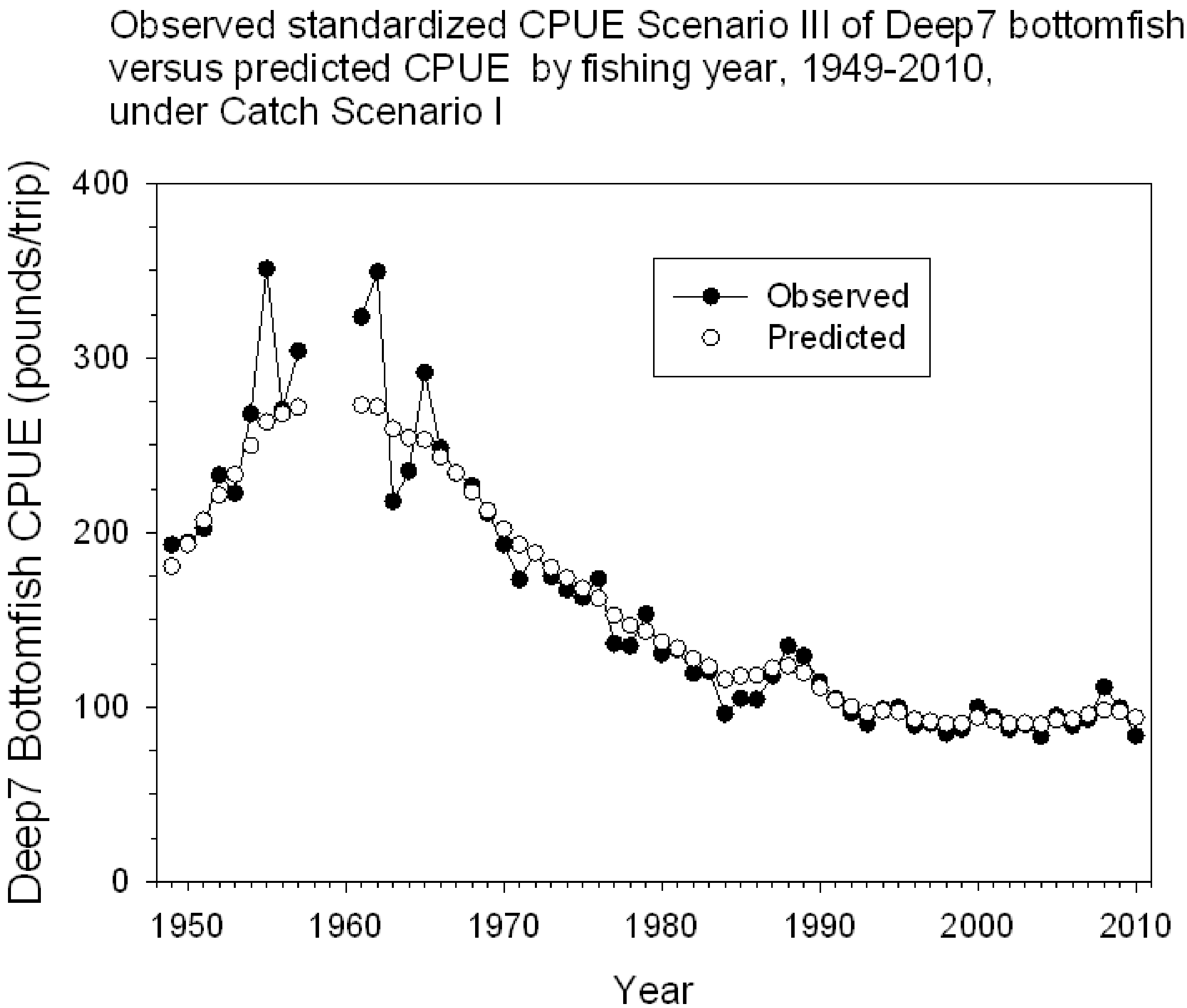


Figure A.6.1.--Results of the Catch Scenario I CPUE Scenario III production model fit to the observed standardized bottomfish CPUE for the main Hawaiian Islands along with CPUE residuals.

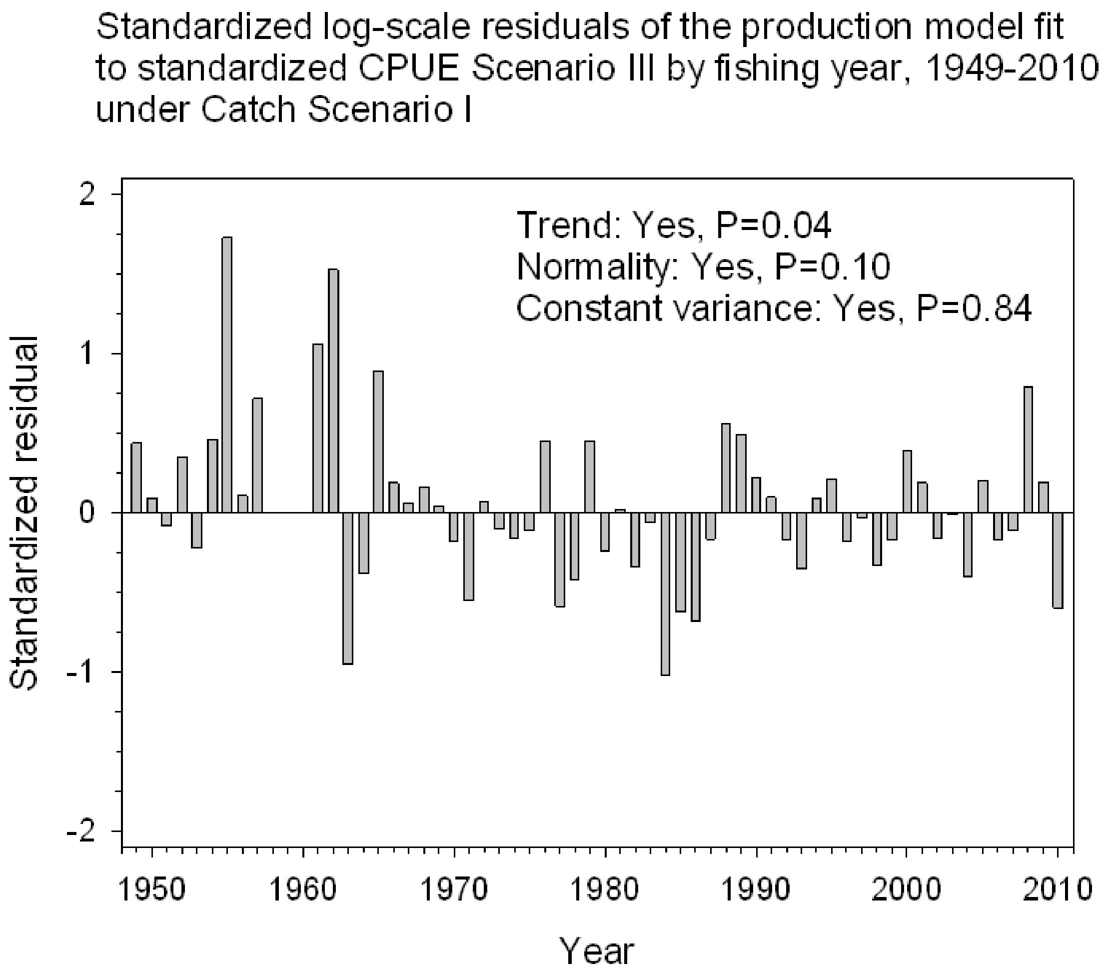


Figure A.6.2.--Results of the Catch Scenario I CPUE Scenario III production model fit to the observed standardized bottomfish CPUE for the main Hawaiian Islands along with standardized log-scale CPUE residuals and P-values for linear regression hypothesis tests of whether standardized residuals have a time trend, are normally distributed, and have constant variance.

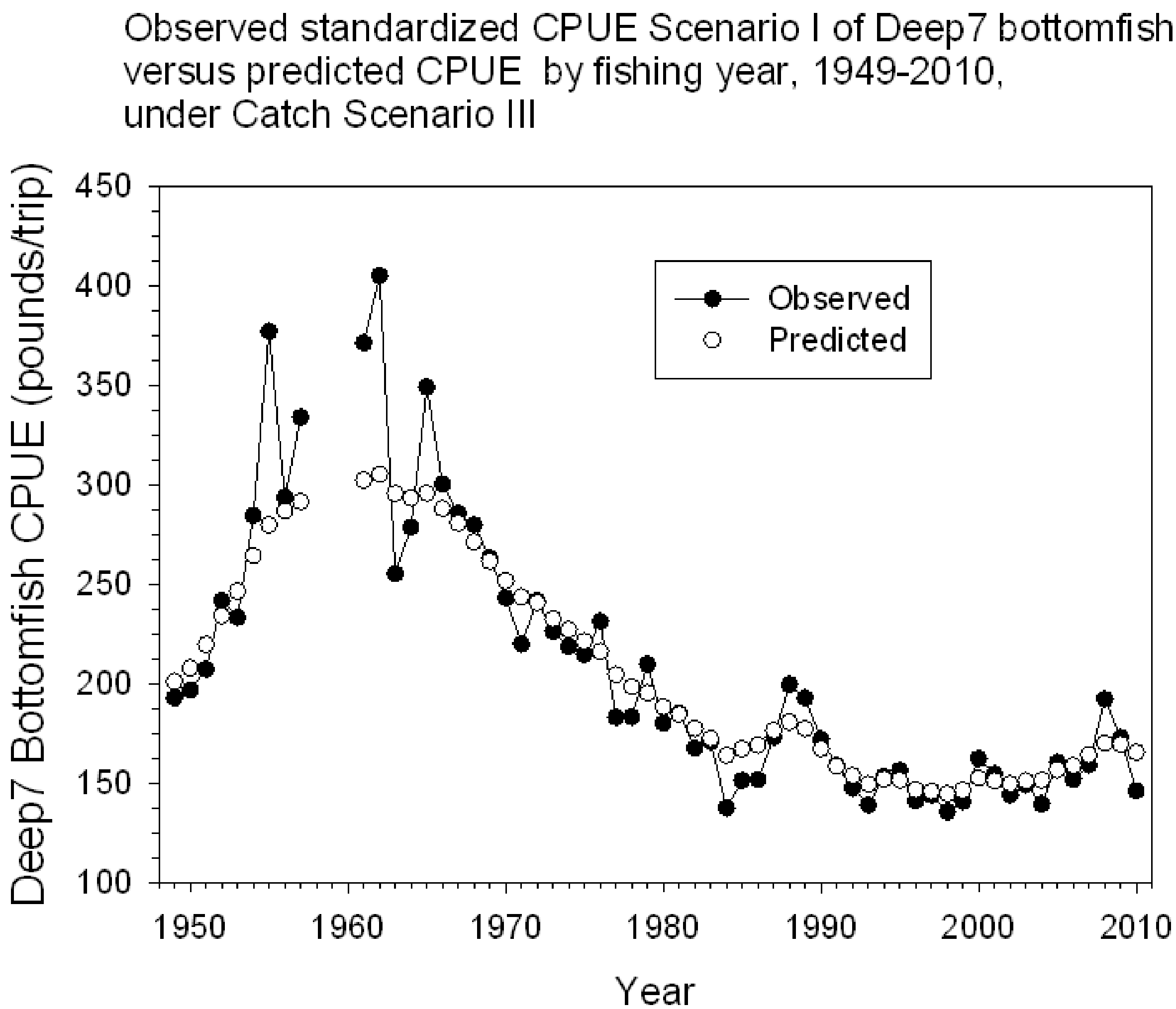


Figure A.7.1.--Results of the Catch Scenario III CPUE Scenario I production model fit to the observed standardized bottomfish CPUE for the main Hawaiian Islands along with CPUE residuals.

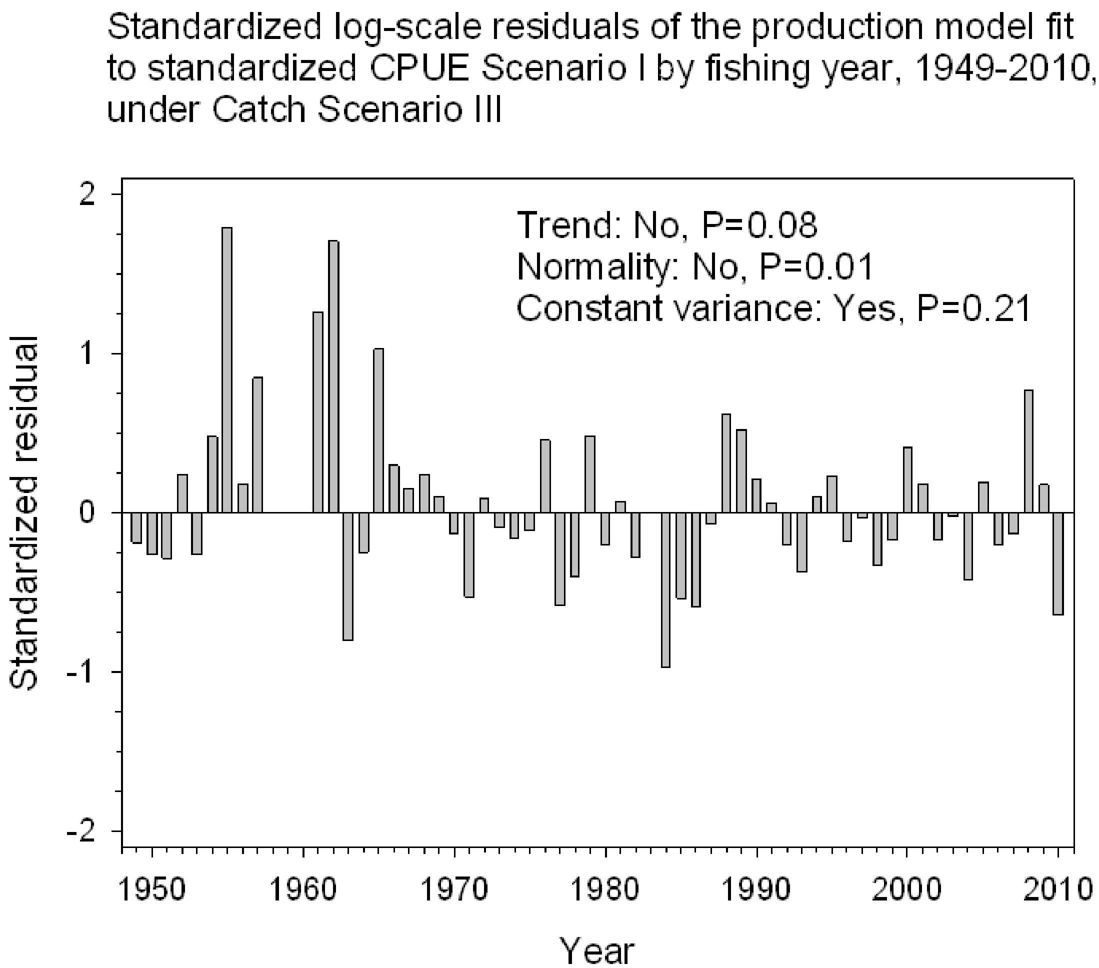


Figure A.7.2.--Results of the Catch Scenario III CPUE Scenario I production model fit to the observed standardized bottomfish CPUE for the main Hawaiian Islands along with standardized log-scale CPUE residuals and P-values for linear regression hypothesis tests of whether standardized residuals have a time trend, are normally distributed, and have constant variance.

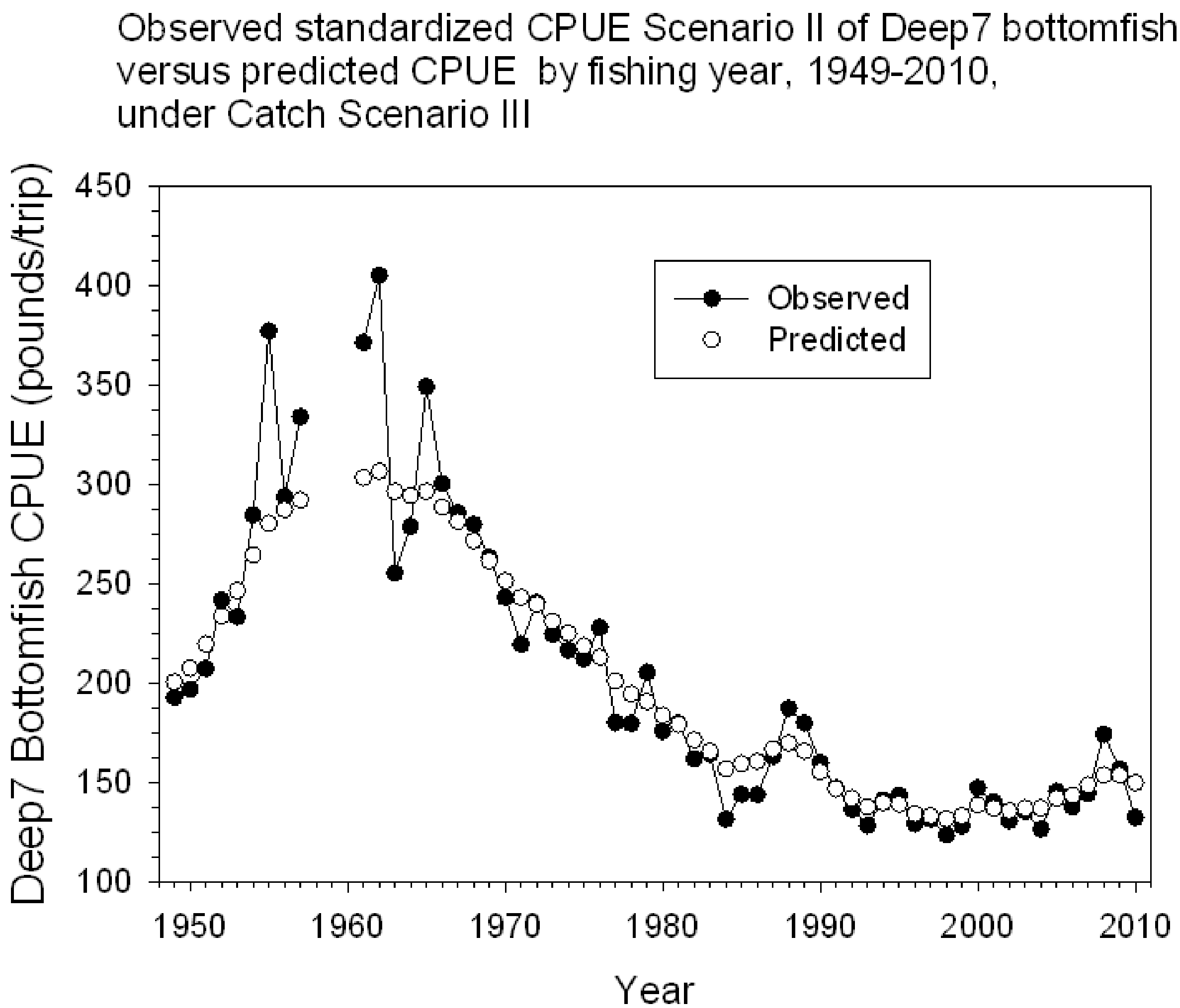


Figure A.8.1.--Results of the Catch Scenario III CPUE Scenario II production model fit to the observed standardized bottomfish CPUE for the main Hawaiian Islands along with CPUE residuals.

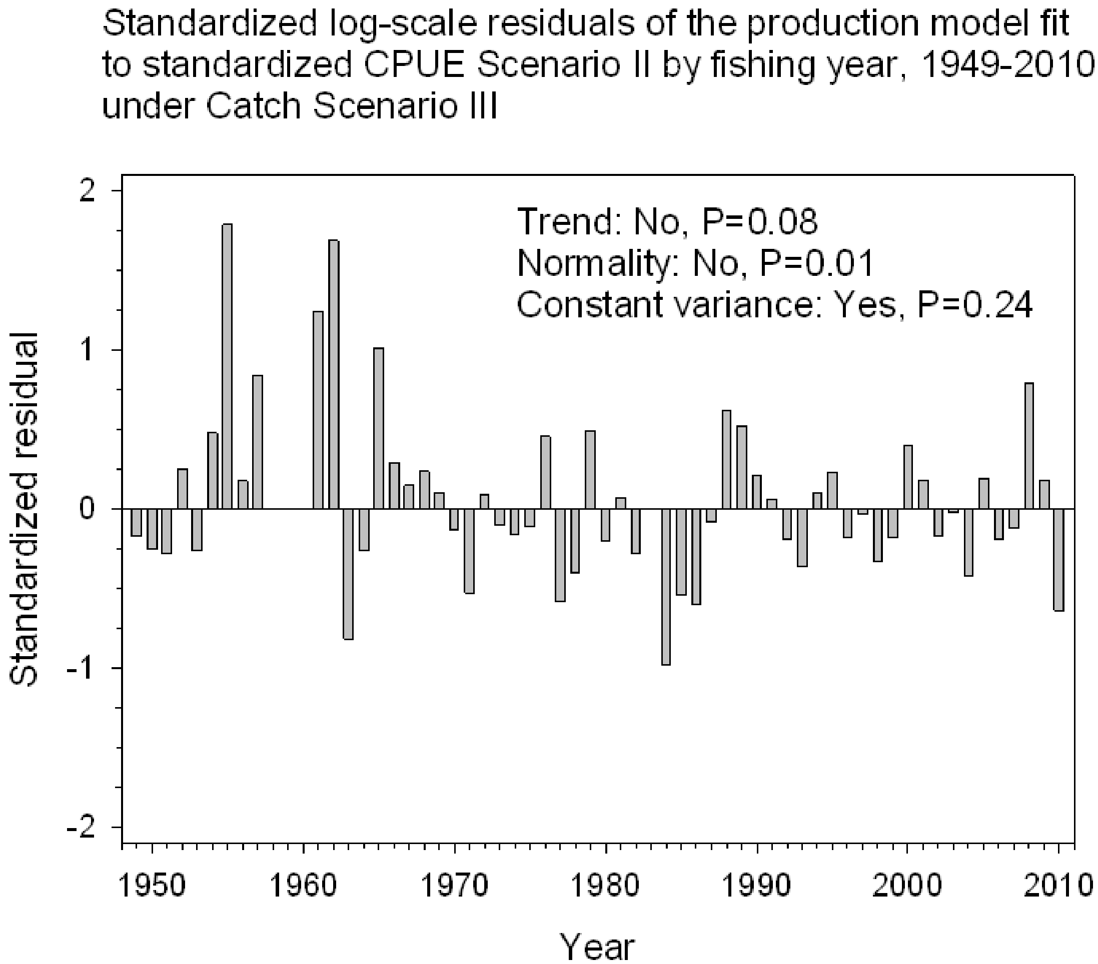


Figure A.8.2.--Results of the Catch Scenario III CPUE Scenario II production model fit to the observed standardized bottomfish CPUE for the main Hawaiian Islands along with standardized log-scale CPUE residuals and P-values for linear regression hypothesis tests of whether standardized residuals have a time trend, are normally distributed, and have constant variance.

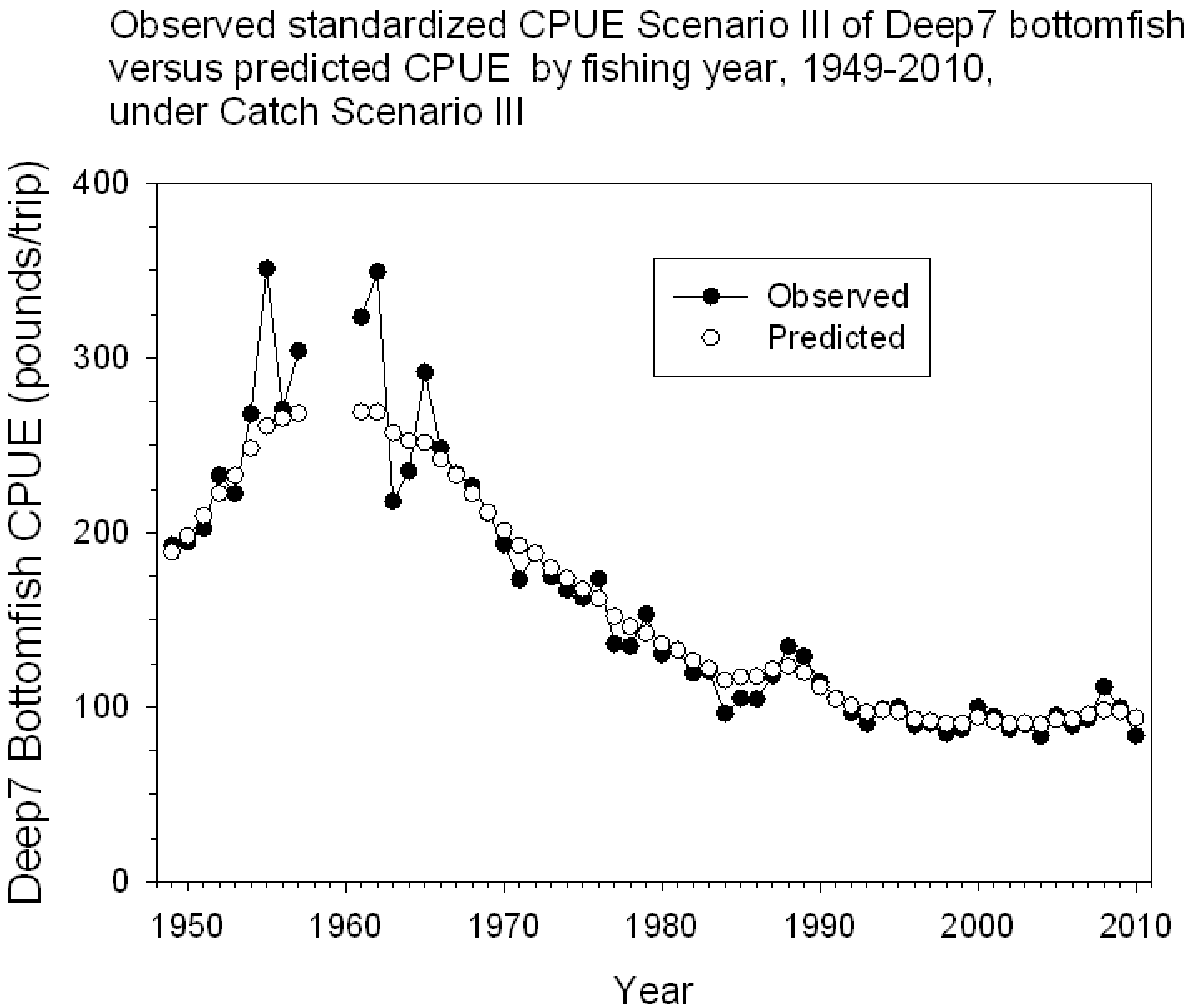


Figure A.9.1.--Results of the Catch Scenario III CPUE Scenario III production model fit to the observed standardized bottomfish CPUE for the main Hawaiian Islands along with CPUE residuals.

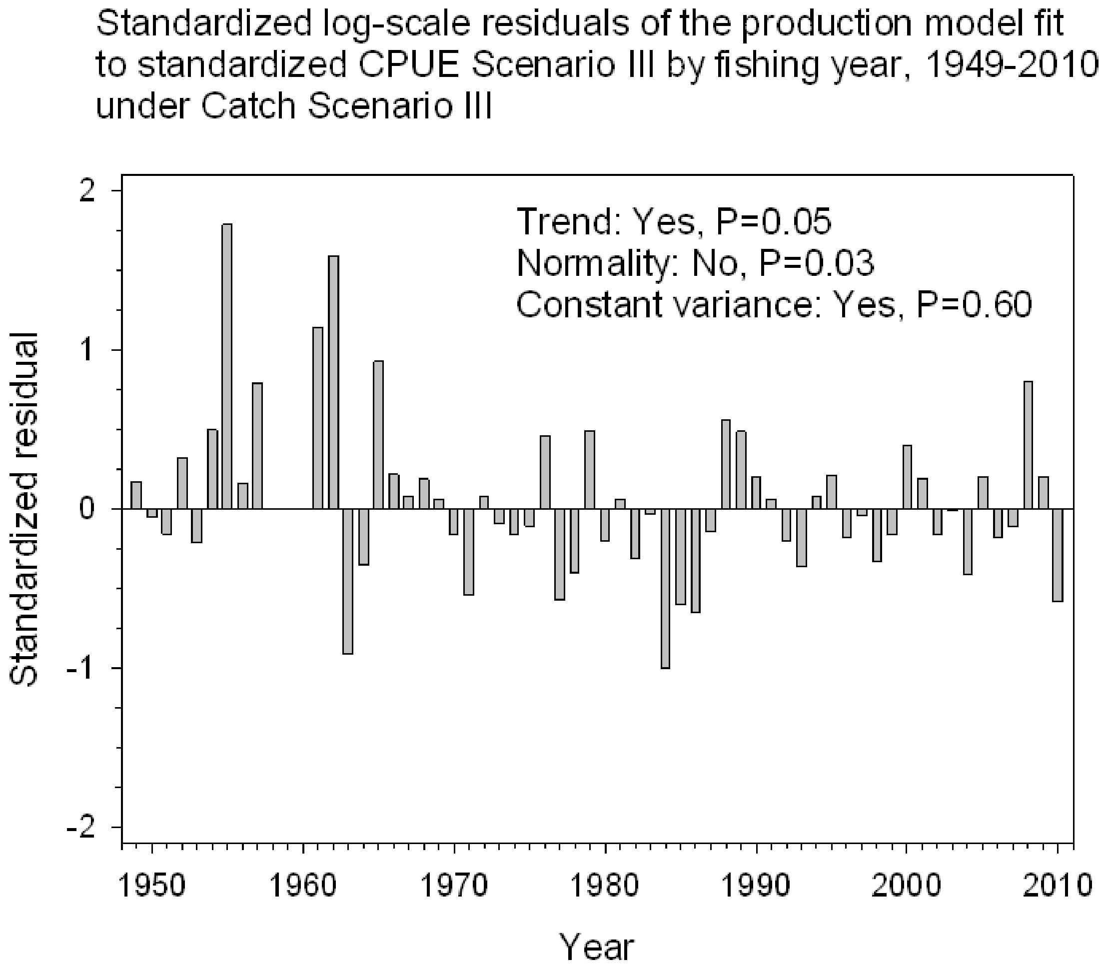


Figure A.9.2.--Results of the Catch Scenario III CPUE Scenario III production model fit to the observed standardized bottomfish CPUE for the main Hawaiian Islands along with standardized log-scale CPUE residuals and P-values for linear regression hypothesis tests of whether standardized residuals have a time trend, are normally distributed, and have constant variance.

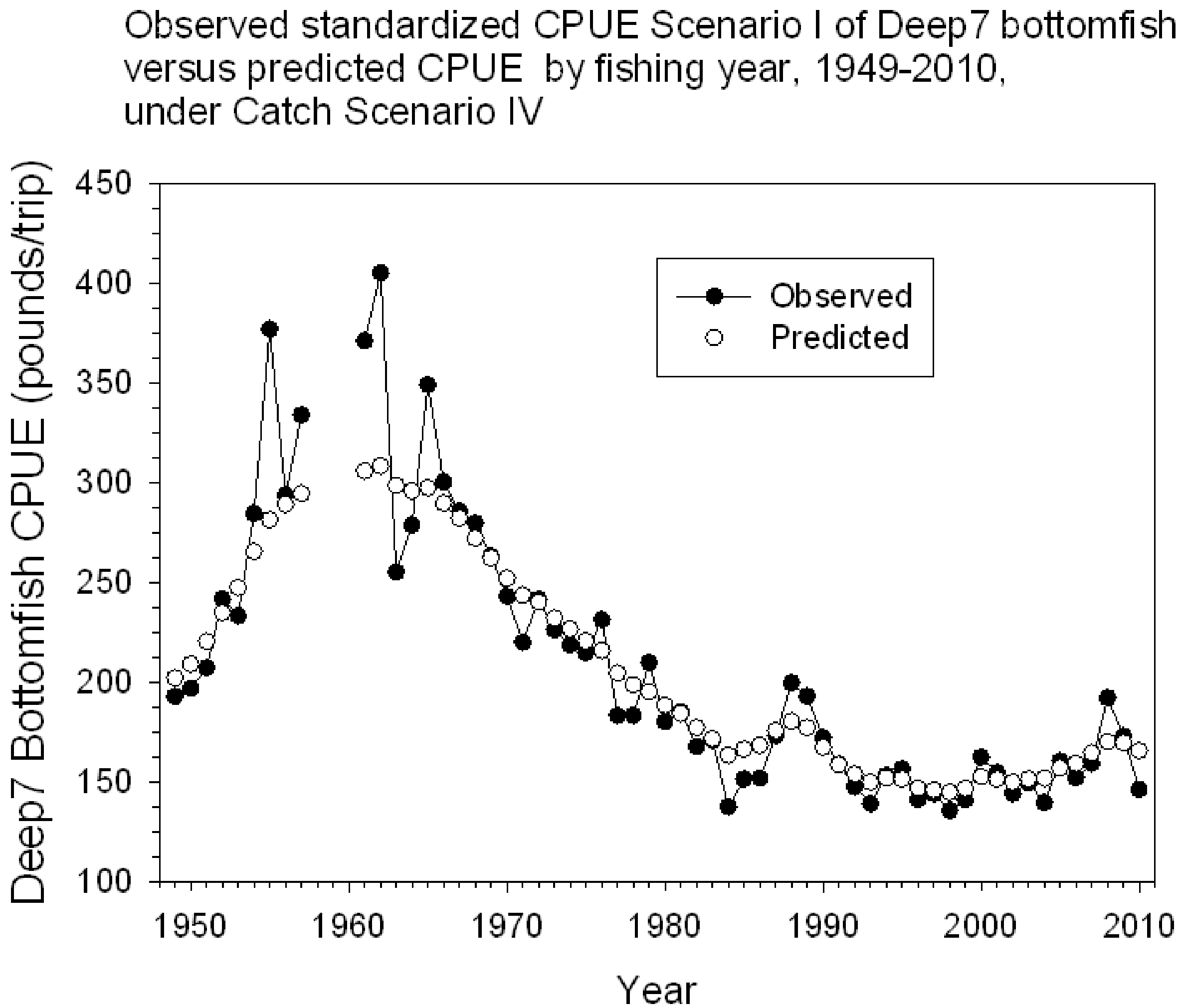


Figure A.10.1.--Results of the Catch Scenario IV CPUE Scenario I production model fit to the observed standardized bottomfish CPUE for the main Hawaiian Islands along with CPUE residuals.

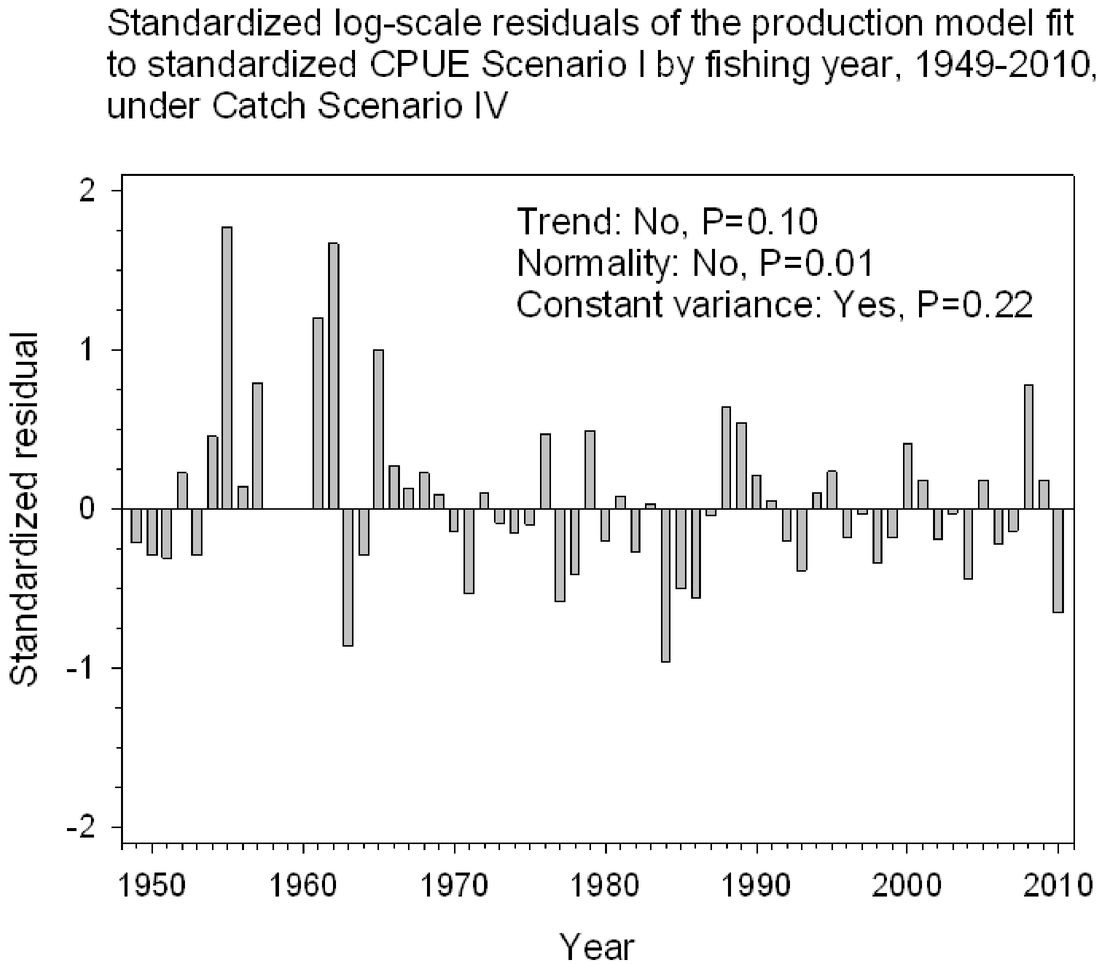


Figure A.10.2.--Results of the Catch Scenario IV CPUE Scenario I production model fit to the observed standardized bottomfish CPUE for the main Hawaiian Islands along with standardized log-scale CPUE residuals and P-values for linear regression hypothesis tests of whether standardized residuals have a time trend, are normally distributed, and have constant variance.

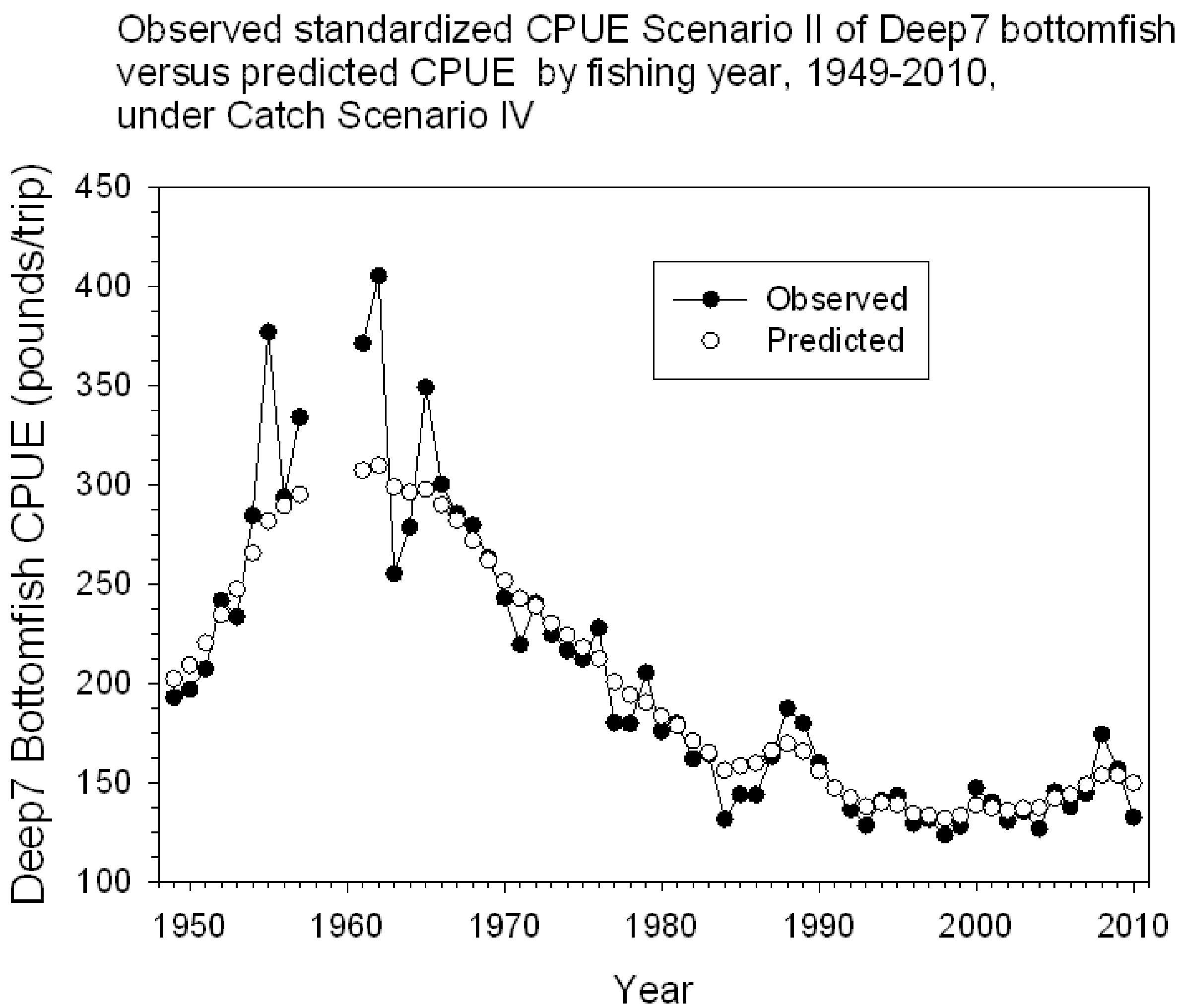


Figure A.11.1.--Results of the Catch Scenario IV CPUE Scenario II production model fit to the observed standardized bottomfish CPUE for the main Hawaiian Islands along with CPUE residuals.

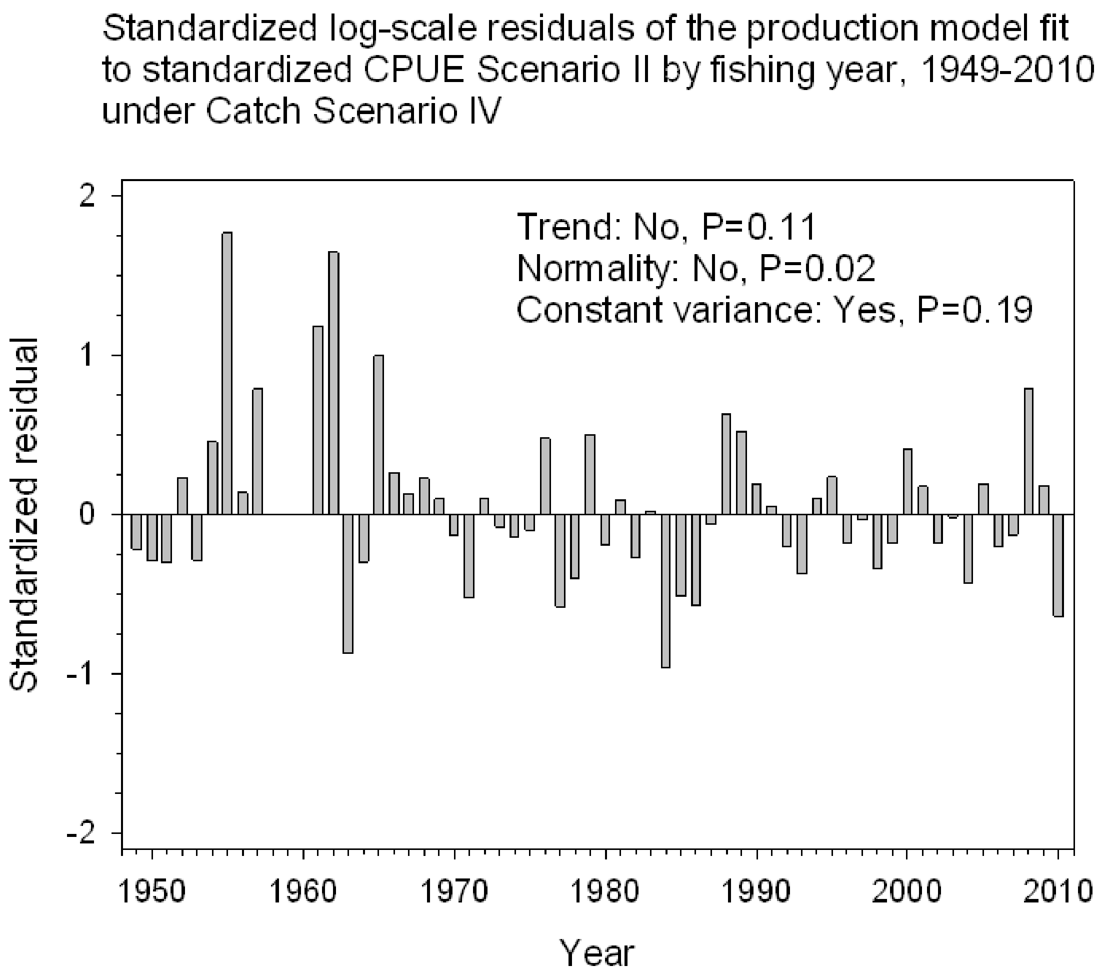


Figure A.11.2.--Results of the Catch Scenario IV CPUE Scenario II production model fit to the observed standardized bottomfish CPUE for the main Hawaiian Islands along with standardized log-scale CPUE residuals and P-values for linear regression hypothesis tests of whether standardized residuals have a time trend, are normally distributed, and have constant variance.

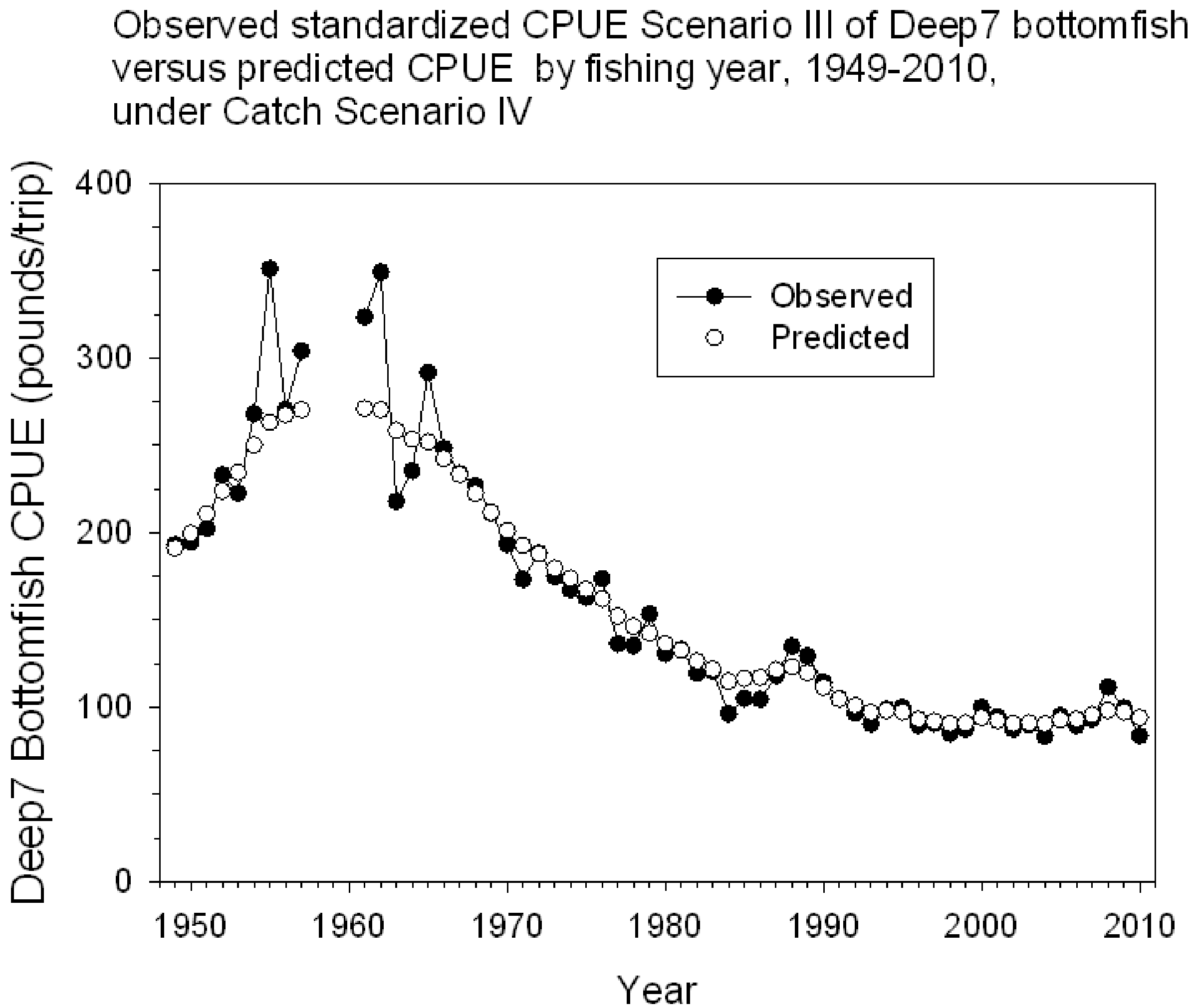


Figure A.12.1.--Results of the Catch Scenario IV CPUE Scenario III production model fit to the observed standardized bottomfish CPUE for the main Hawaiian Islands along with CPUE residuals.

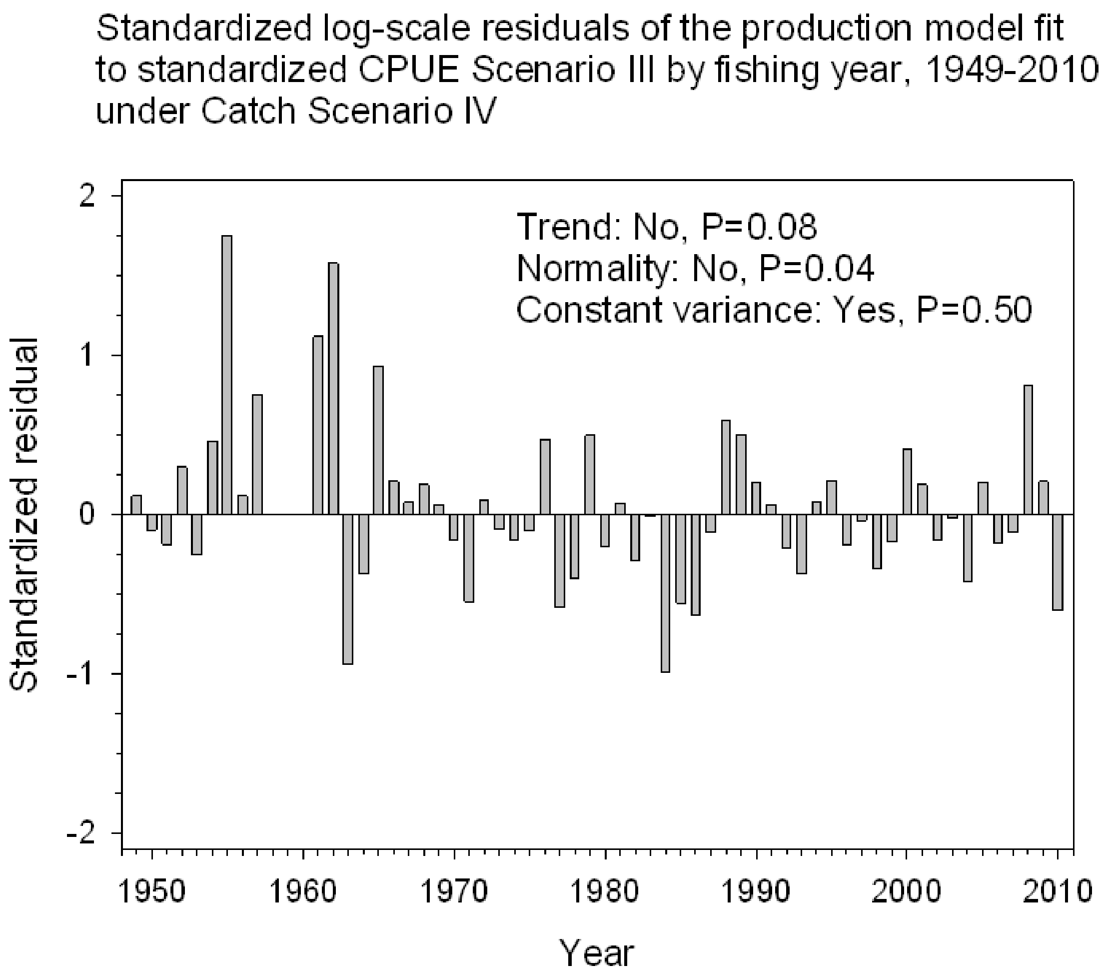
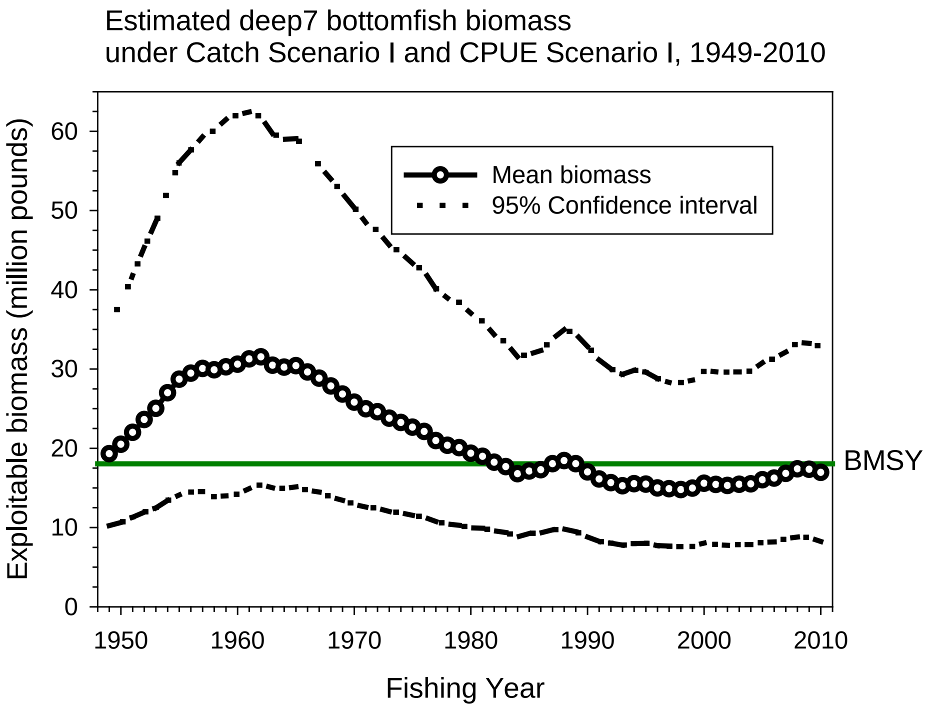


Figure A.12.2.--Results of the Catch Scenario IV CPUE Scenario III production model fit to the observed standardized bottomfish CPUE for the main Hawaiian Islands along with standardized log-scale CPUE residuals and P-values for linear regression hypothesis tests of whether standardized residuals have a time trend, are normally distributed, and have constant variance.



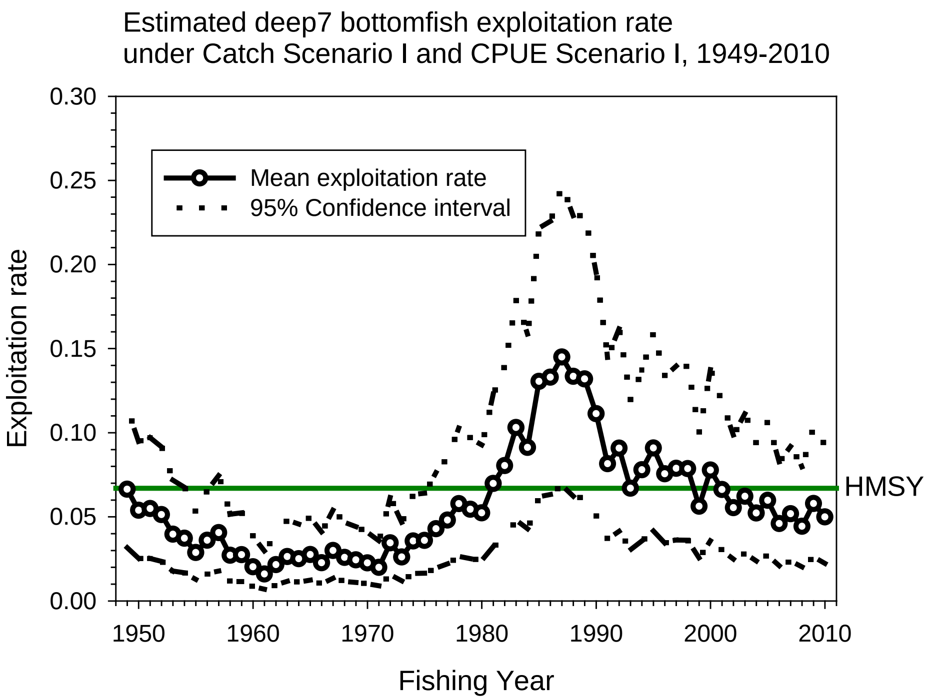
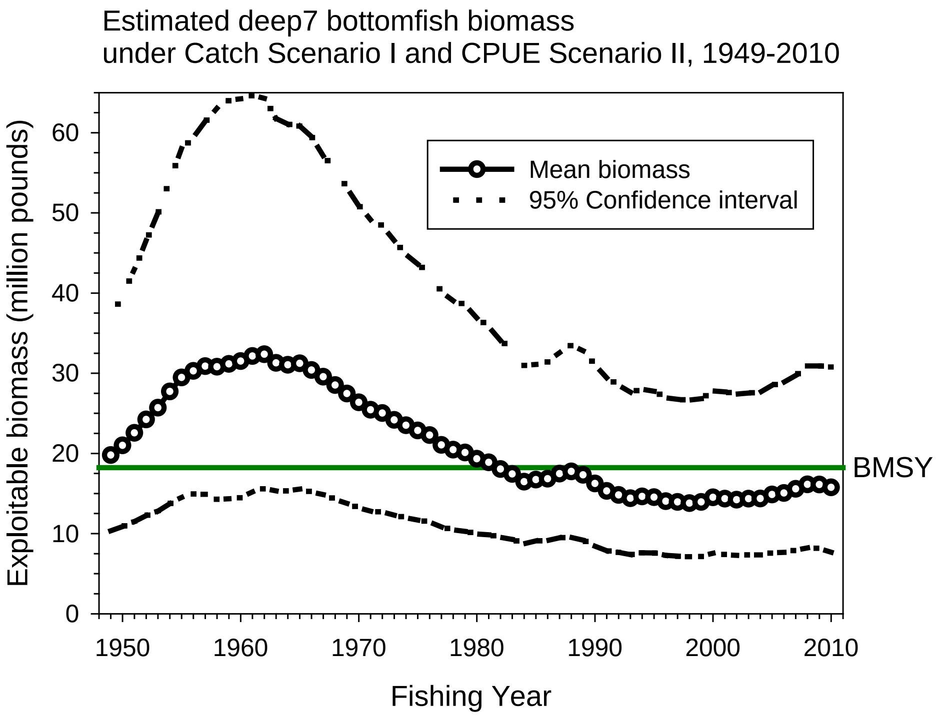


Figure A13.--Sensitivity analyses of assessment results for exploitable biomass and harvest rate under Catch Scenario I and CPUE Scenario I.



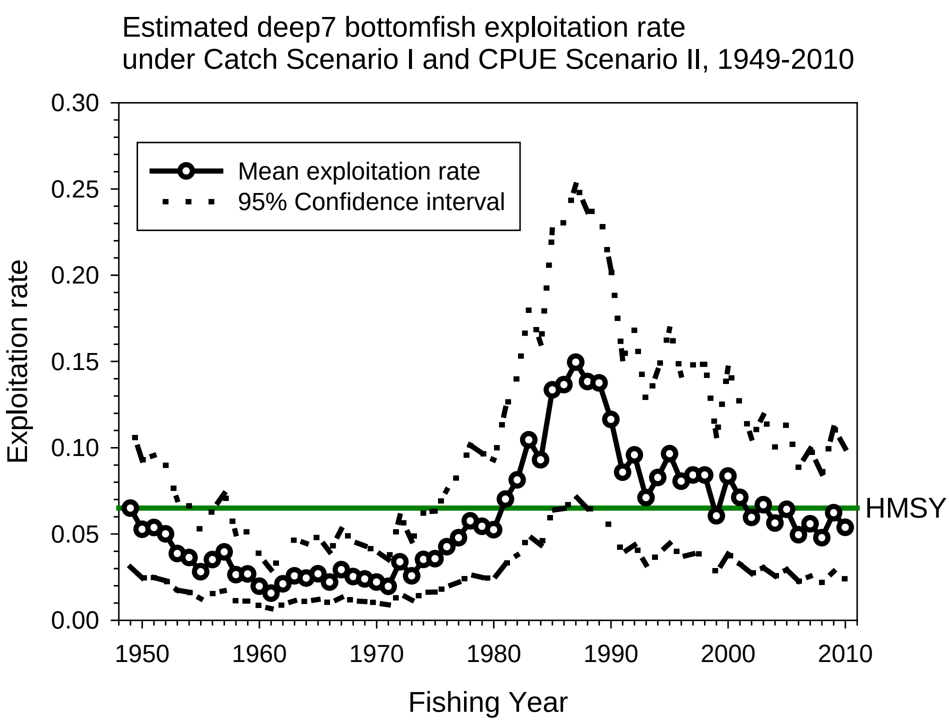


Figure A14.--Sensitivity analyses of assessment results for exploitable biomass and harvest rate under Catch Scenario I and CPUE Scenario II.

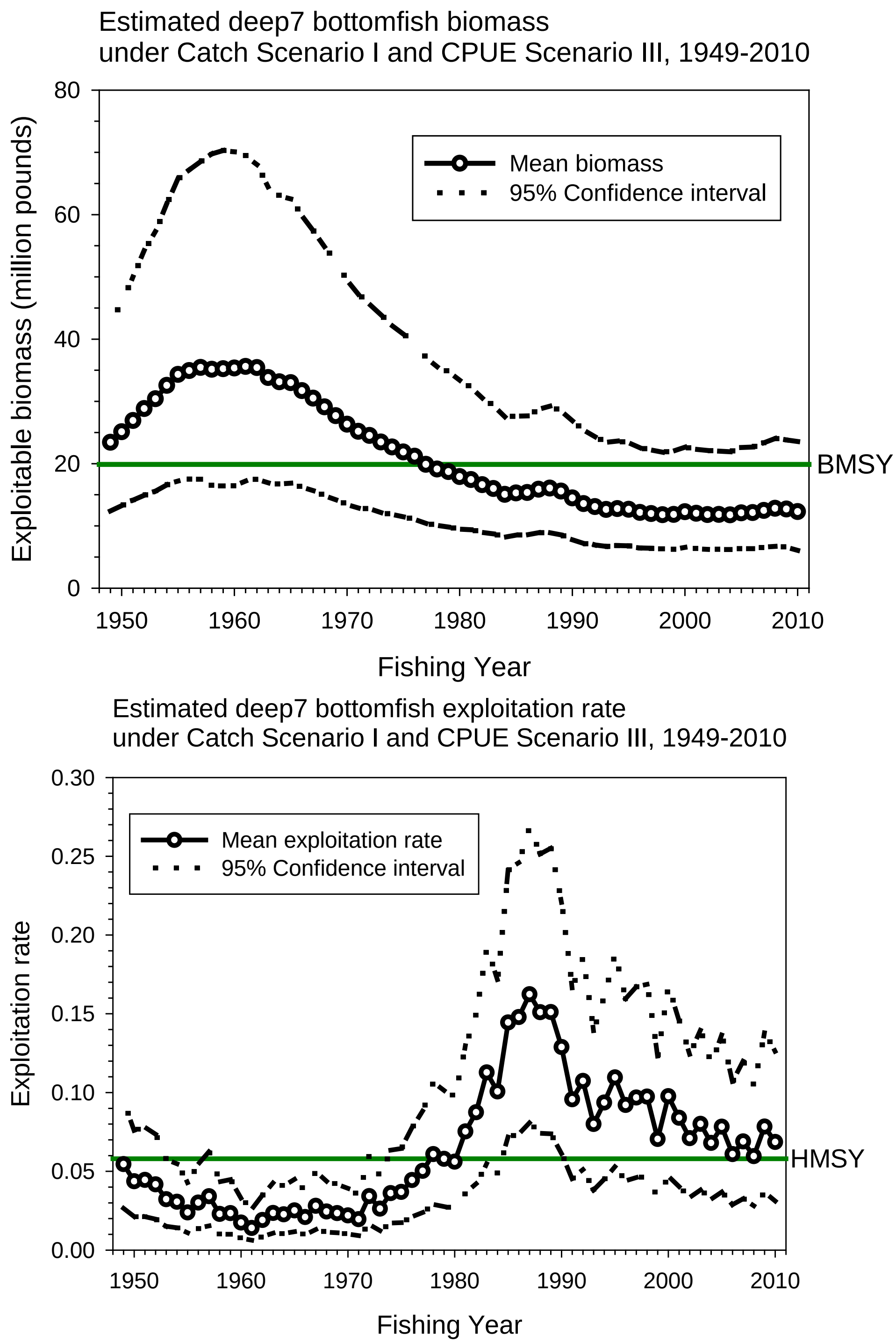
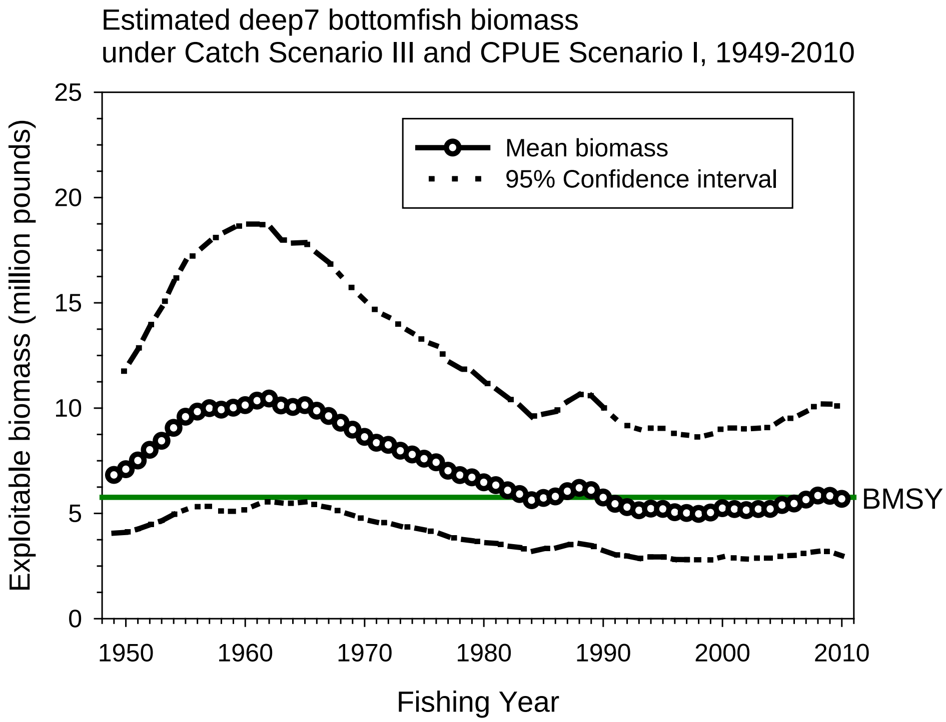


Figure A15.--Sensitivity analyses of assessment results for exploitable biomass and harvest rate under Catch Scenario I and CPUE Scenario III.



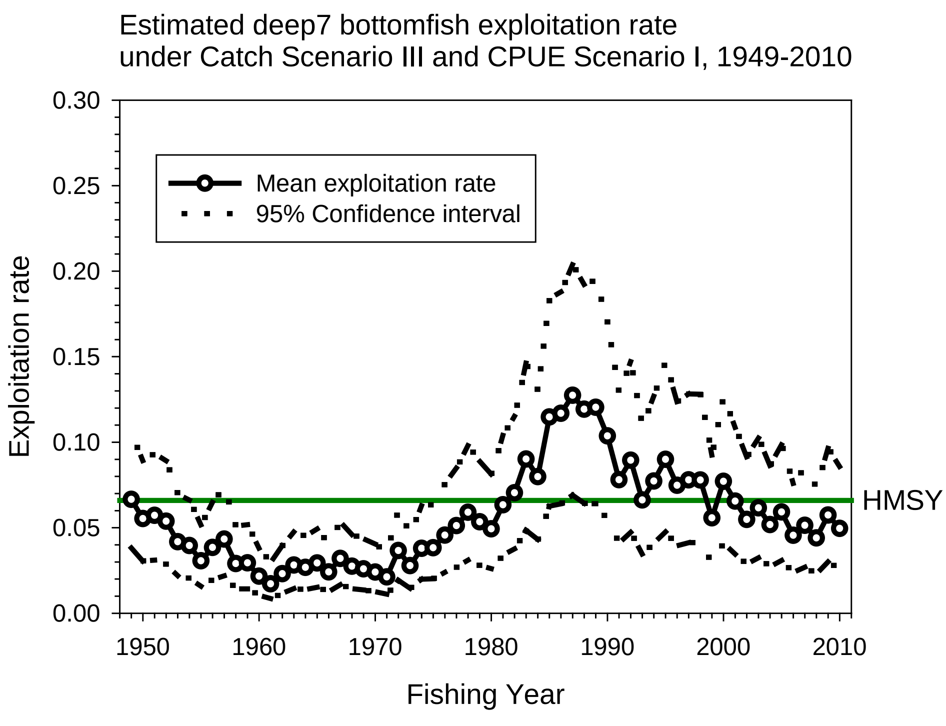


Figure A16.--Sensitivity analyses of assessment results for exploitable biomass and harvest rate under Catch Scenario III and CPUE Scenario I.

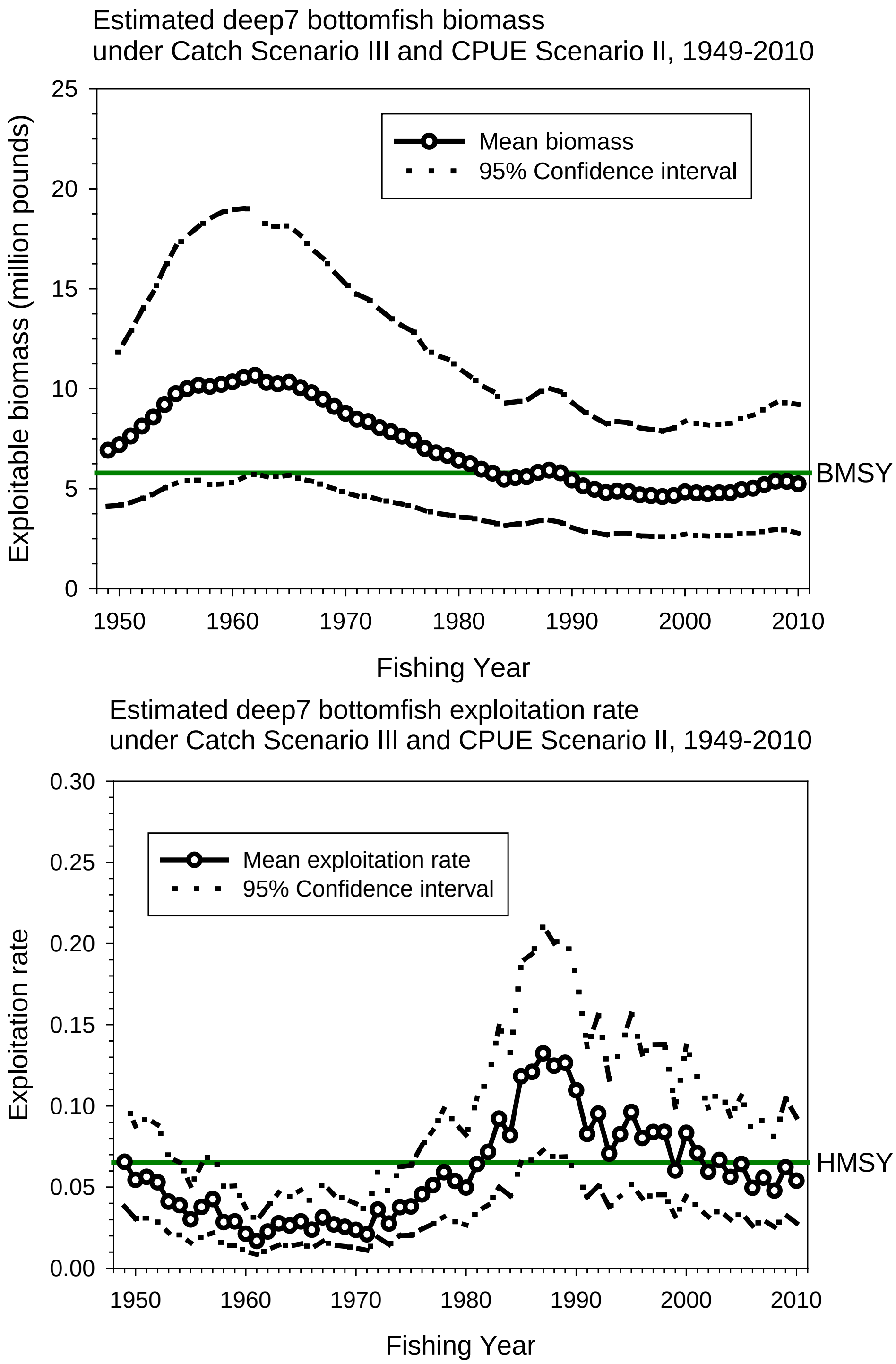
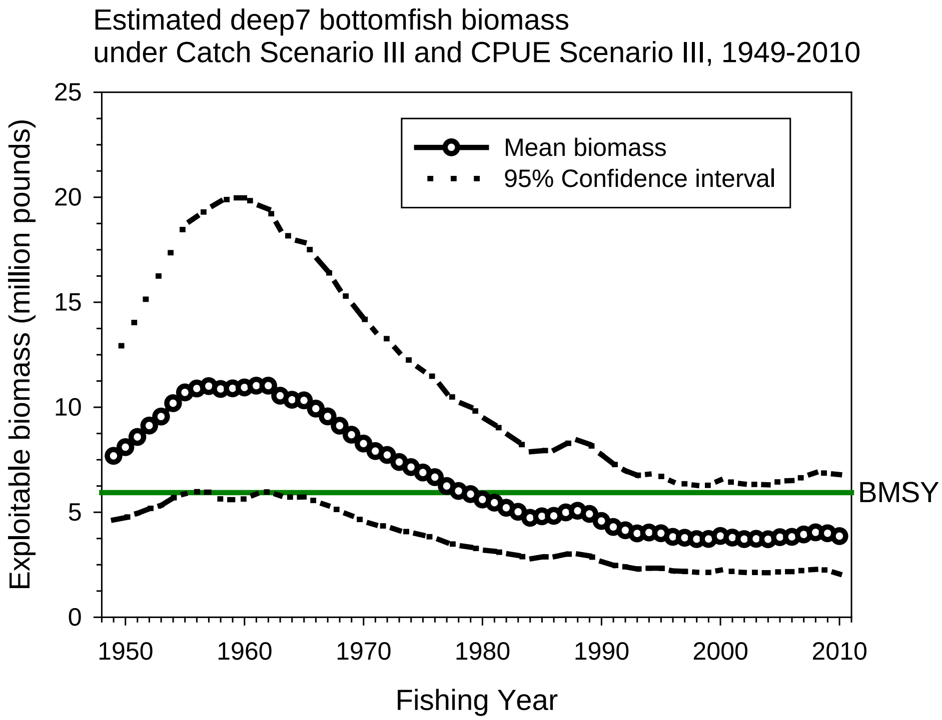


Figure A17.--Sensitivity analyses of assessment results for exploitable biomass and harvest rate under Catch Scenario III and CPUE Scenario II.



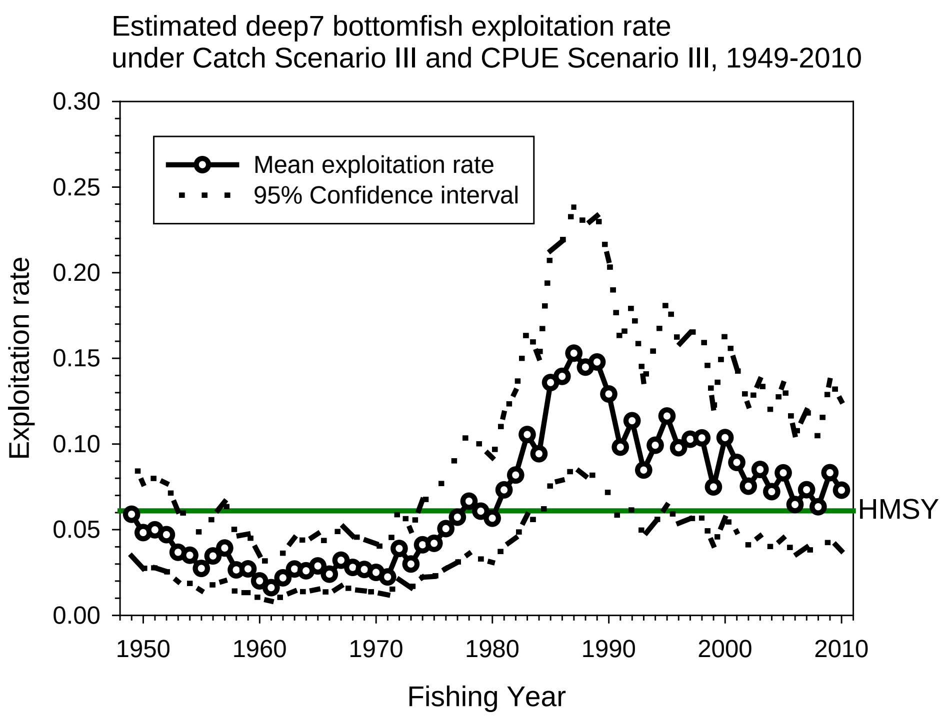
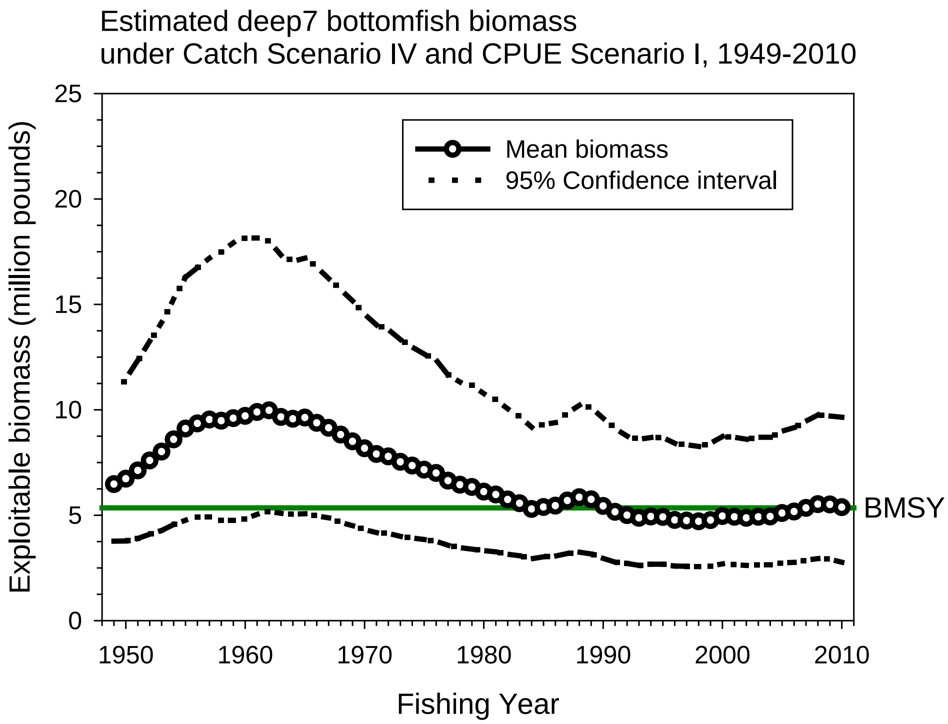


Figure A18.--Sensitivity analyses of assessment results for exploitable biomass and harvest rate under Catch Scenario III and CPUE Scenario III.



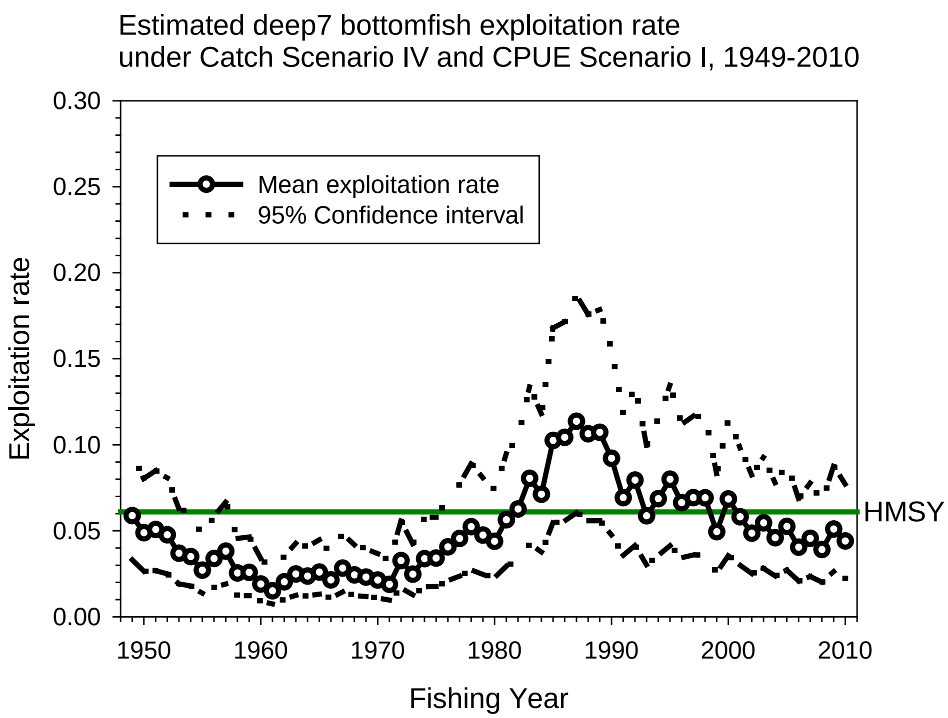
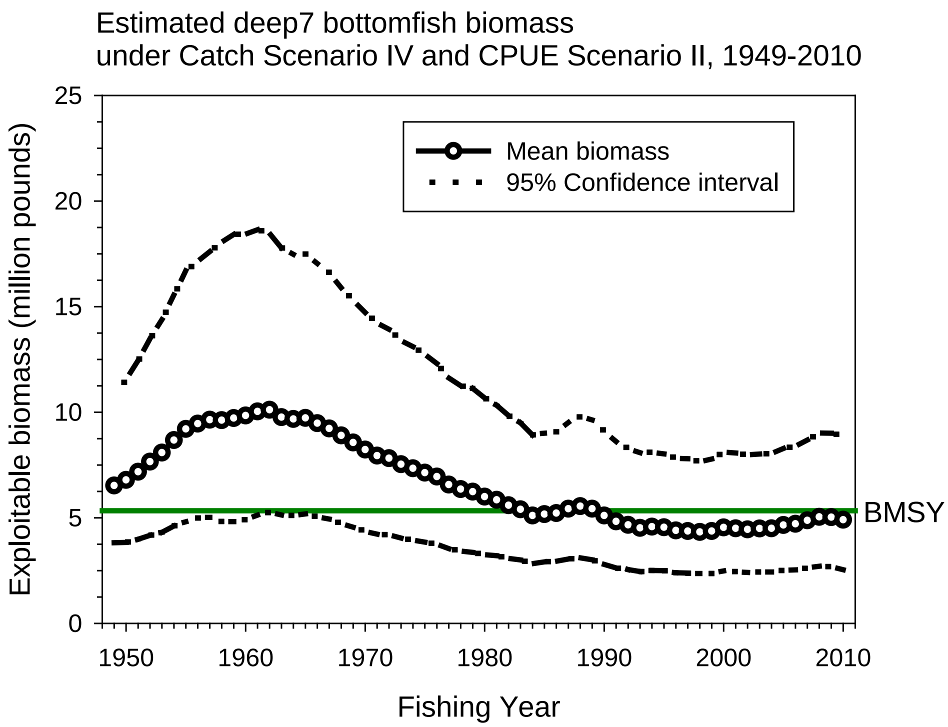


Figure A19.--Sensitivity analyses of assessment results for exploitable biomass and harvest rate under Catch Scenario IV and CPUE Scenario I.



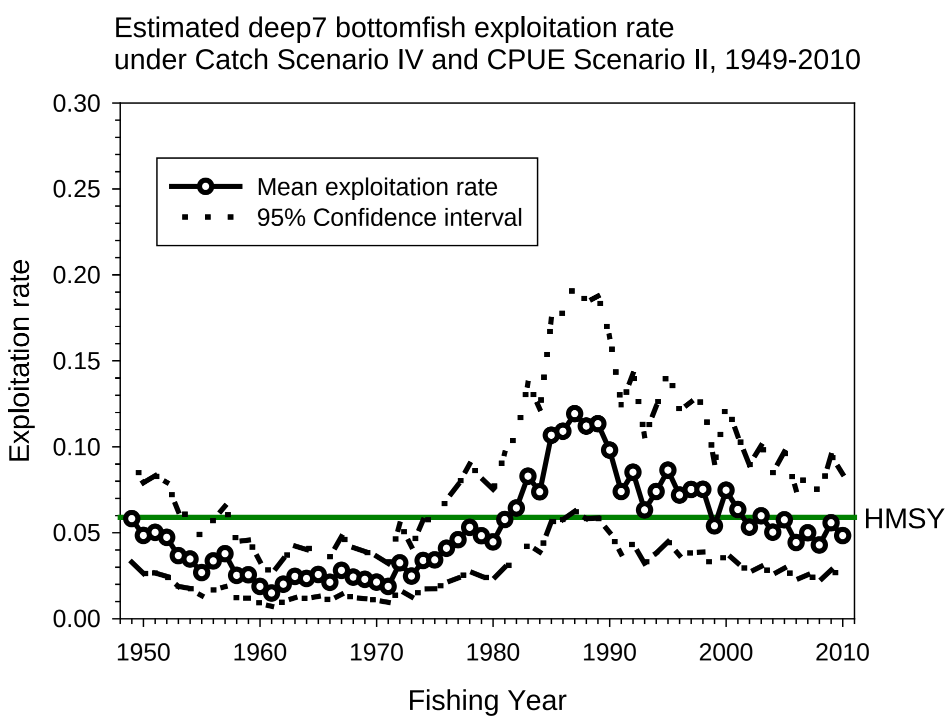
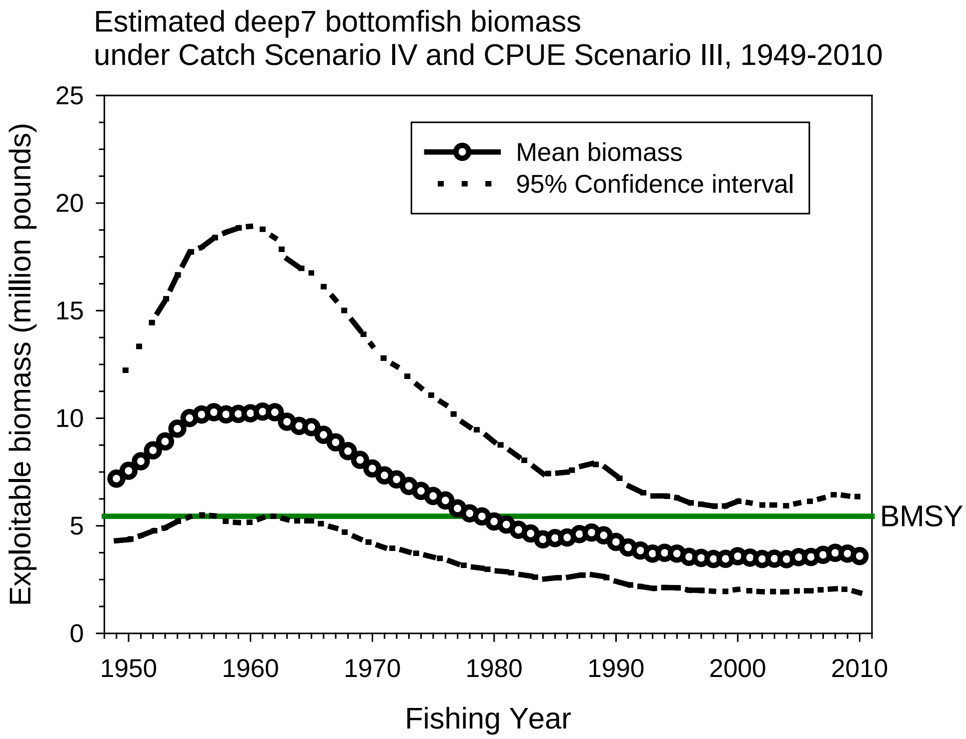


Figure A20.--Sensitivity analyses of assessment results for exploitable biomass and harvest rate under Catch Scenario IV and CPUE Scenario II.



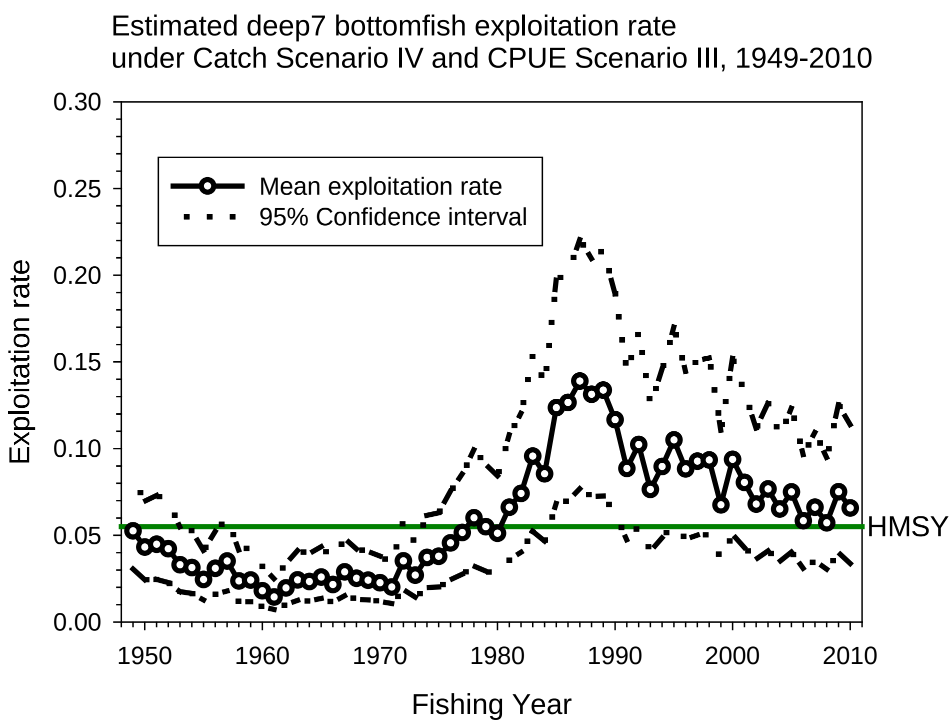


Figure A21.--Sensitivity analyses of assessment results for exploitable biomass and harvest rate under Catch Scenario IV and CPUE Scenario III.

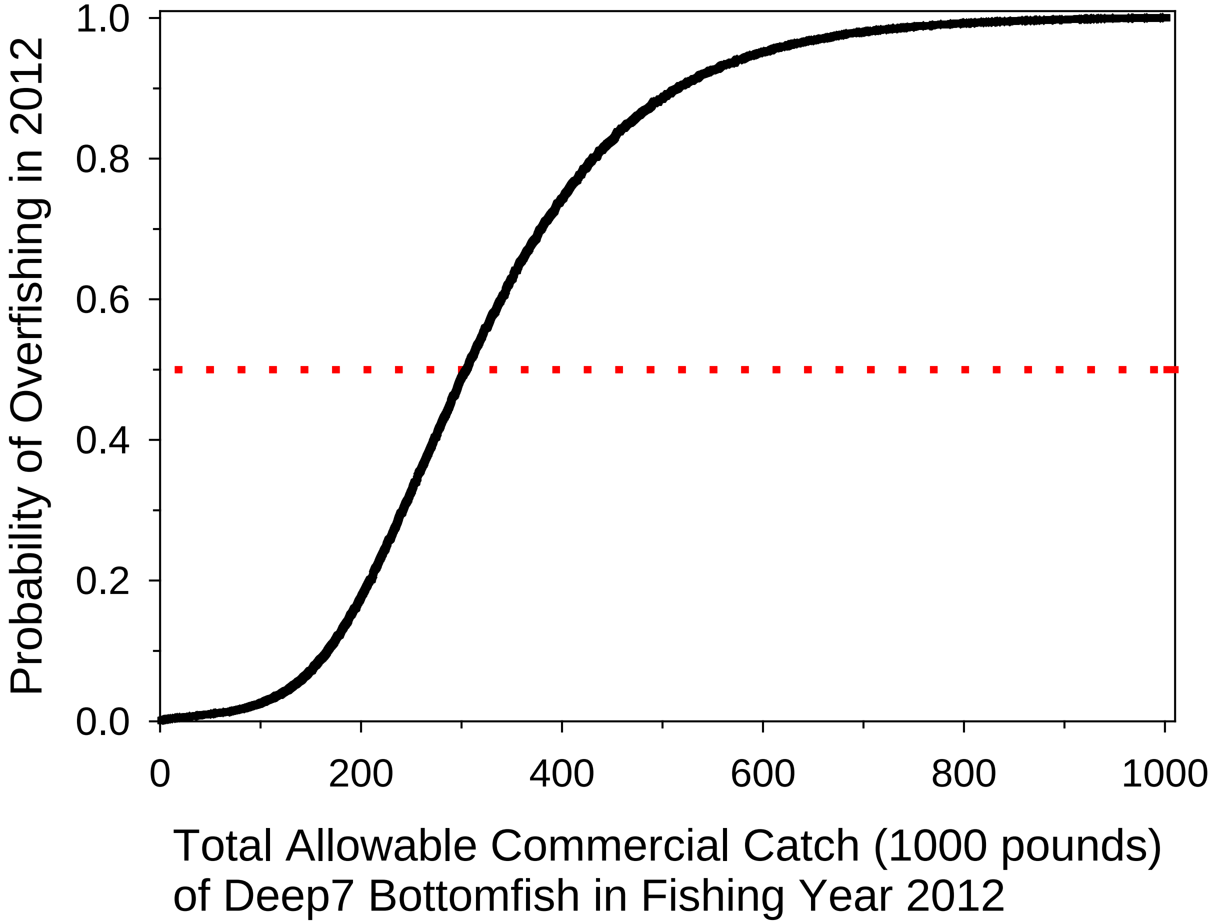


Figure A22.--Sensitivity analyses of projection results for estimates of total allowable catches of Deep7 Hawaiian bottomfish for fishing years 2012−2013 that would produce a range of probabilities of overfishing in 2012 from 0% to 50% and greater under Baseline Catch Scenario I and CPUE Scenario I.

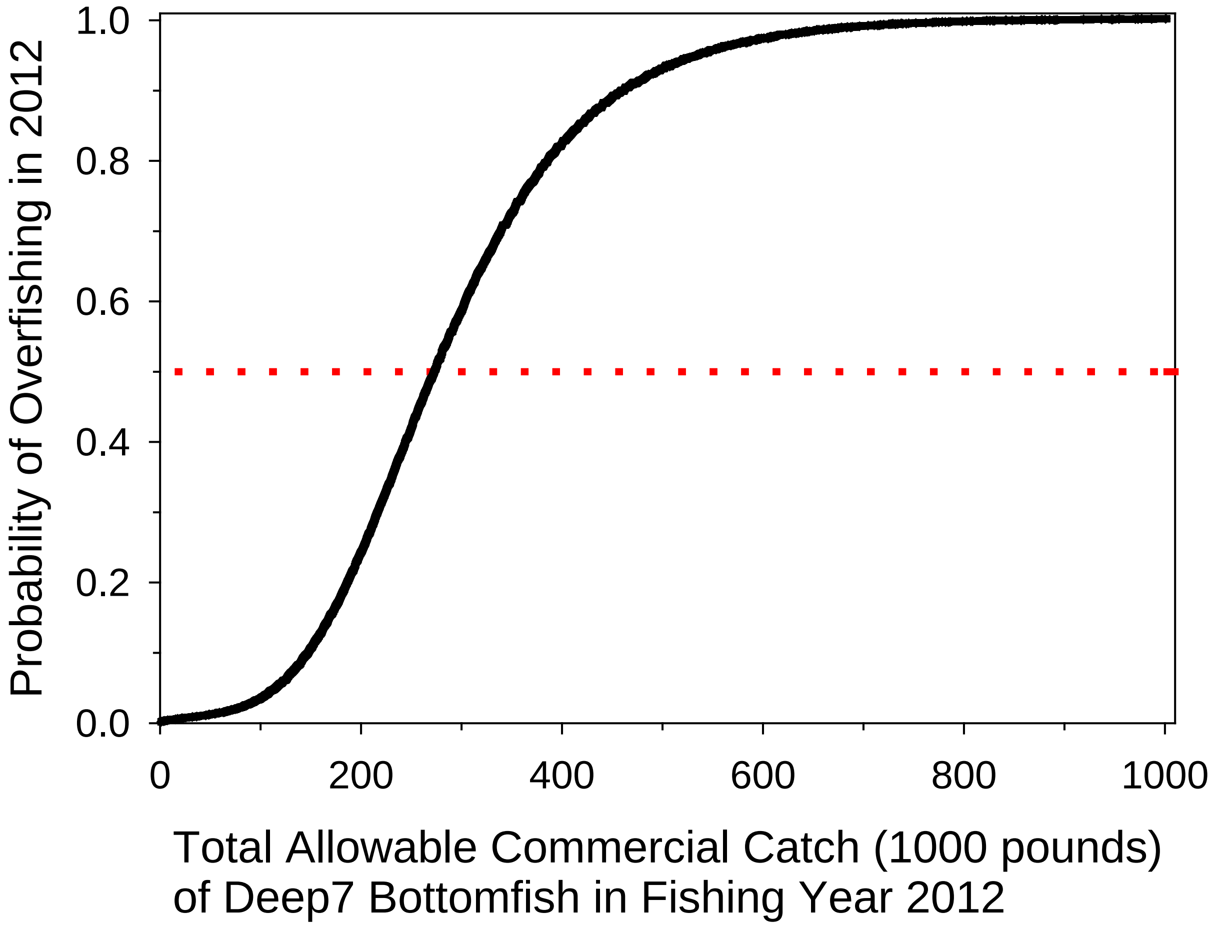


Figure A23.--Sensitivity analyses of projection results for estimates of total allowable catches of Deep7 Hawaiian bottomfish for fishing years 2012–2013 that would produce a range of probabilities of overfishing in 2012 from 0% to 50% and greater under Baseline Catch Scenario I and CPUE Scenario II.

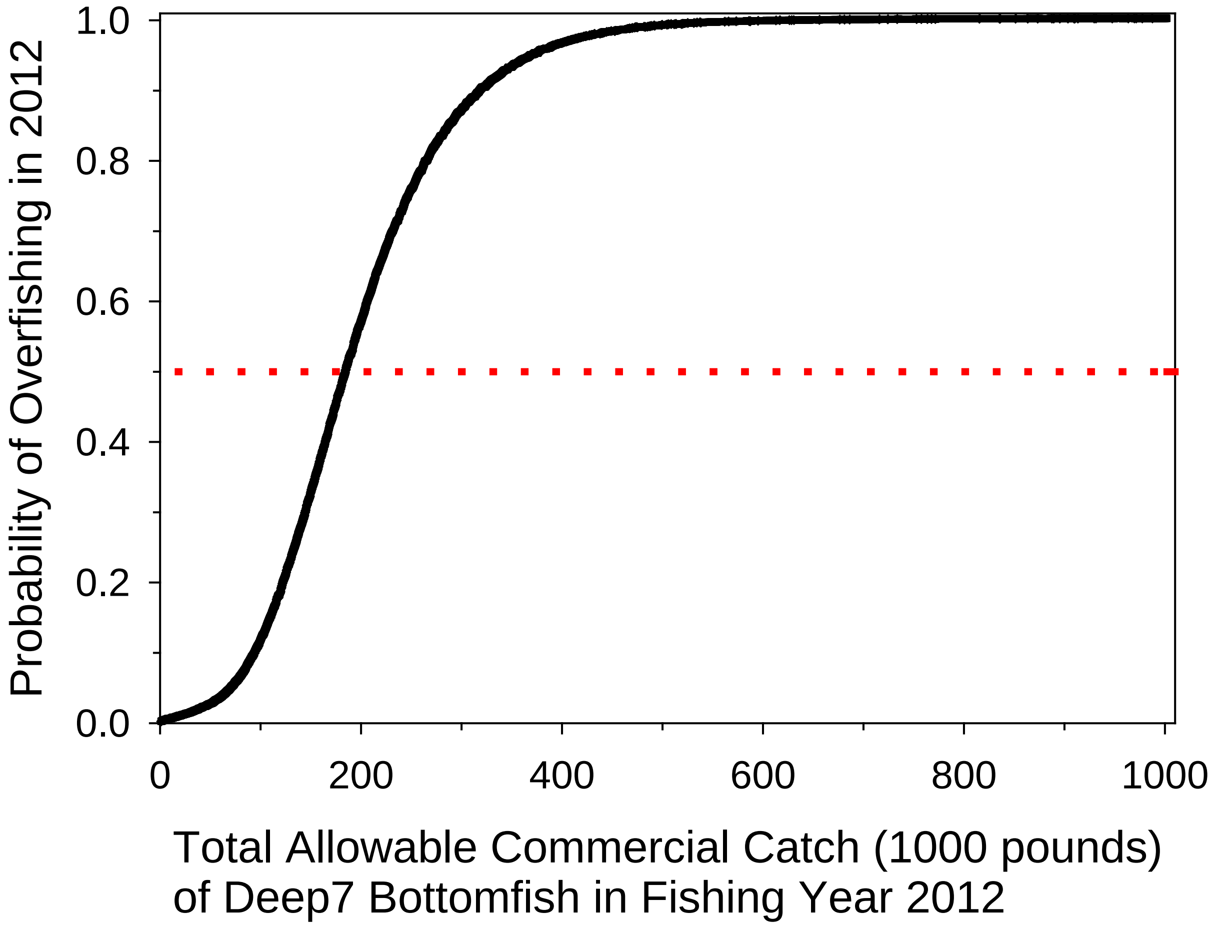


Figure A24.--Sensitivity analyses of projection results for estimates of total allowable catches of Deep7 Hawaiian bottomfish for fishing years 2012–2013 that would produce a range of probabilities of overfishing in 2012 from 0% to 50% and greater under Baseline Catch Scenario I and CPUE Scenario III.

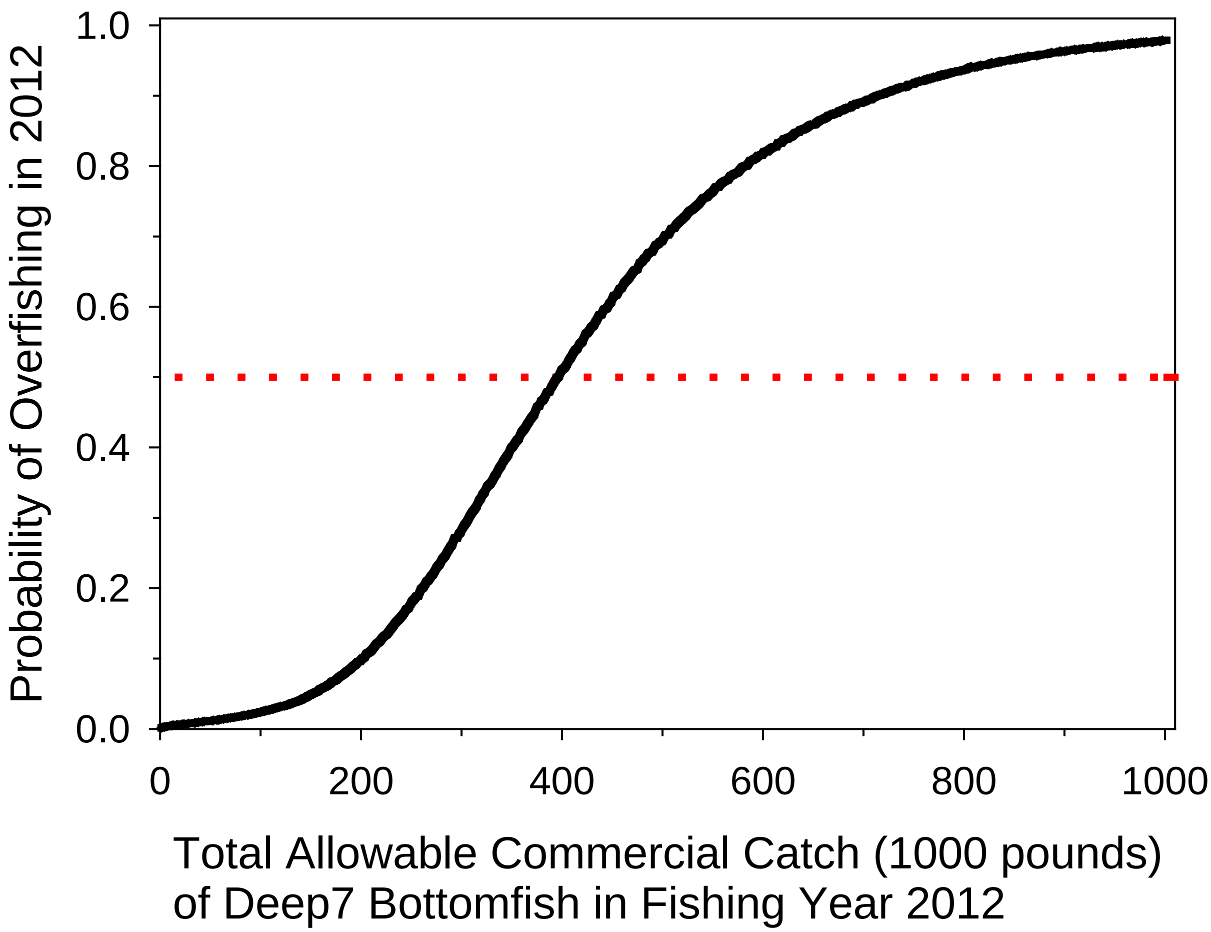


Figure A25.--Sensitivity analyses of projection results for estimates of total allowable catches of Deep7 Hawaiian bottomfish for fishing years 2012−2013 that would produce a range of probabilities of overfishing in 2012 from 0% to 50% and greater under Baseline Catch Scenario II and CPUE Scenario IV.

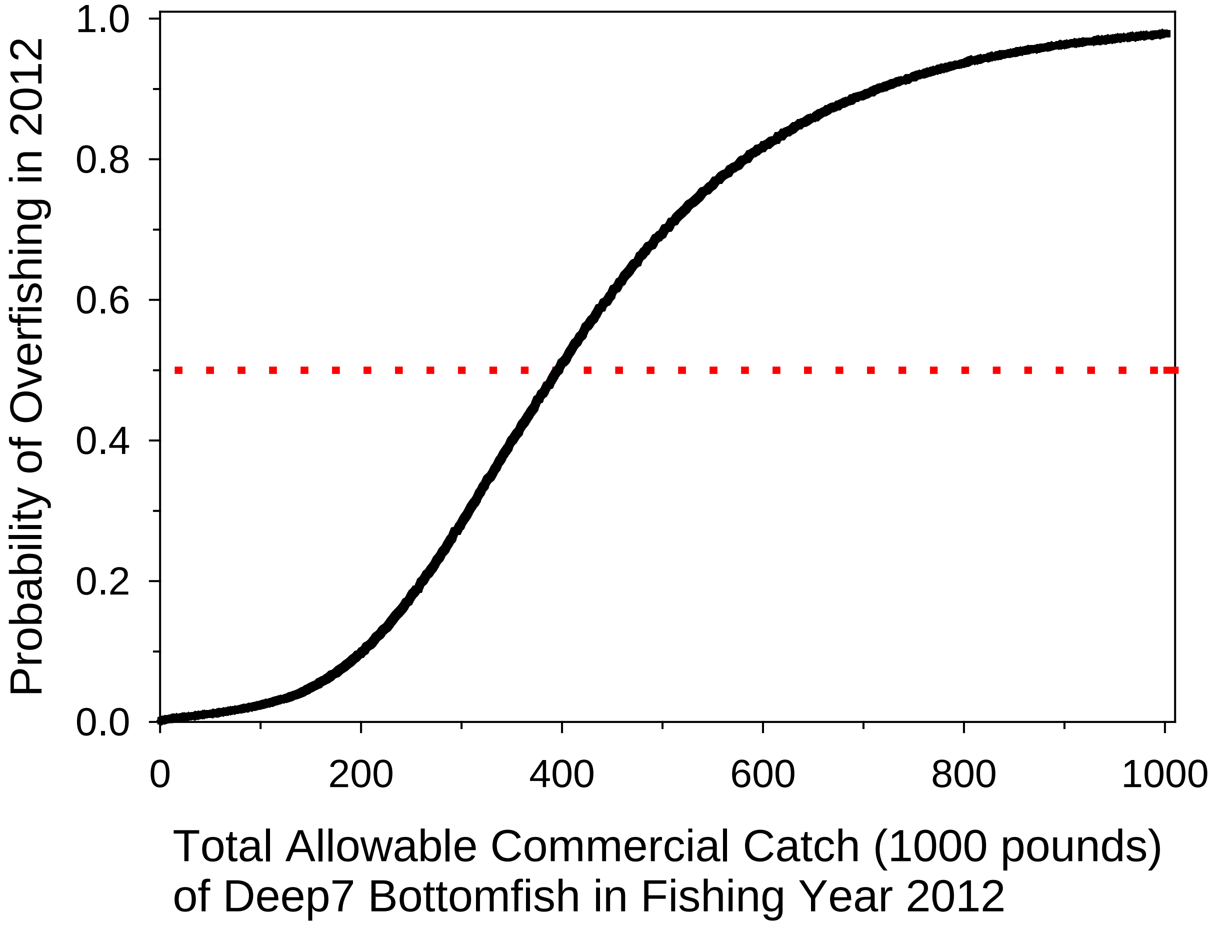


Figure A26.--Sensitivity analyses of projection results for estimates of total allowable catches of Deep7 Hawaiian bottomfish for fishing years 2012–2013 that would produce a range of probabilities of overfishing in 2012 from 0% to 50% and greater under Baseline Catch Scenario II and CPUE Scenario V.

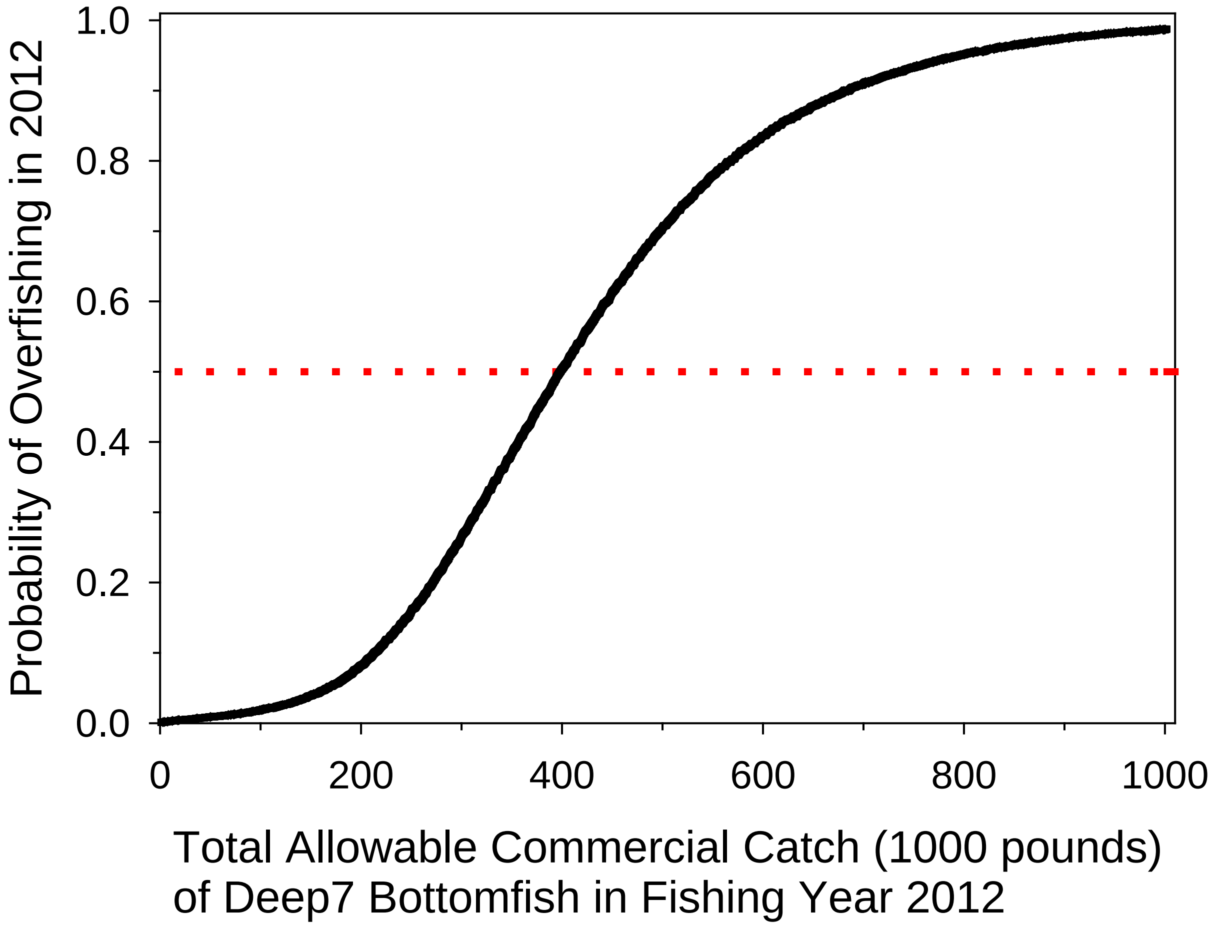


Figure A27.--Sensitivity analyses of projection results for estimates of total allowable catches of Deep7 Hawaiian bottomfish for fishing years 2012−2013 that would produce a range of probabilities of overfishing in 2012 from 0% to 50% and greater under Baseline Catch Scenario II and CPUE Scenario Ib.

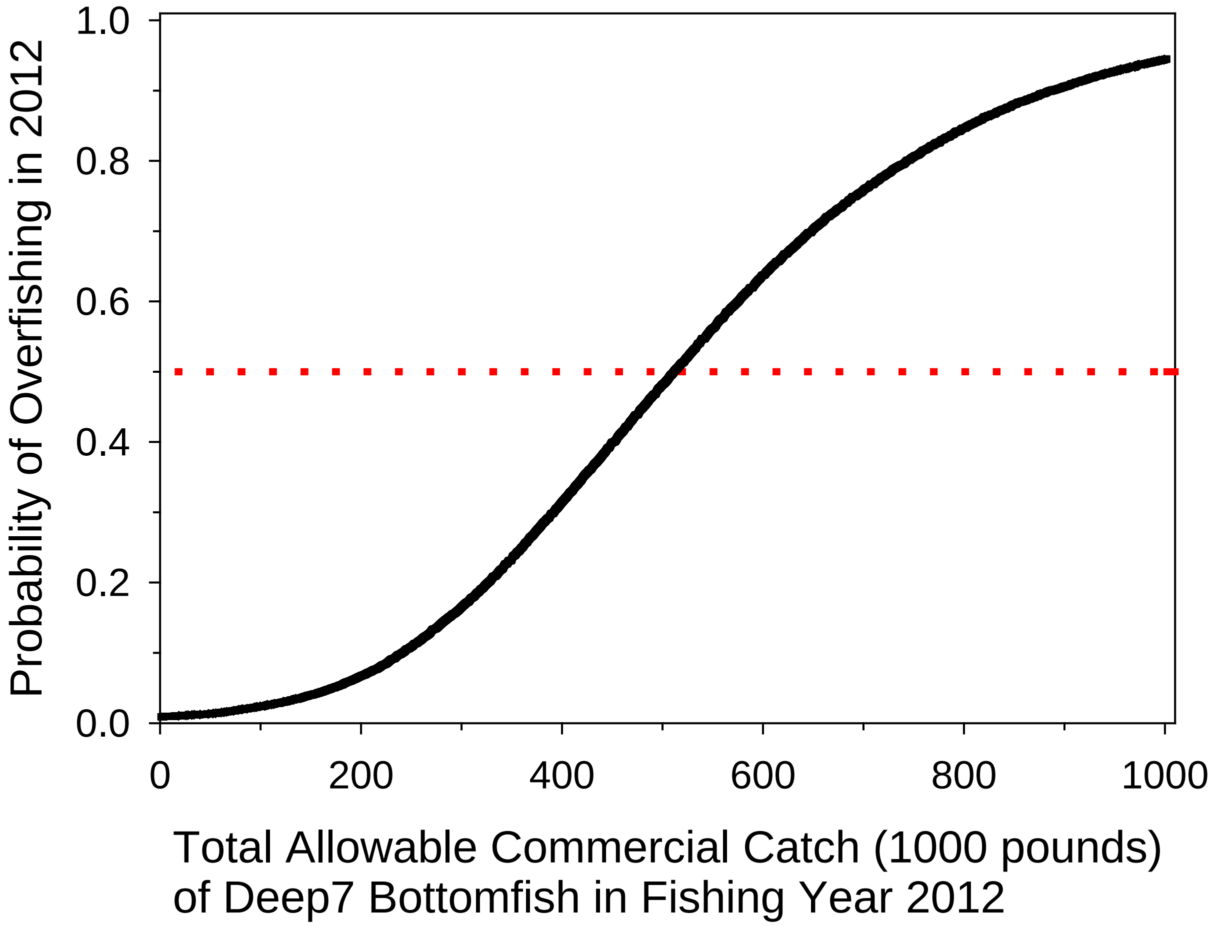


Figure A28.--Sensitivity analyses of projection results for estimates of total allowable catches of Deep7 Hawaiian bottomfish for fishing years 2012−2013 that would produce a range of probabilities of overfishing in 2012 from 0% to 50% and greater under Baseline Catch Scenario III and CPUE Scenario I.

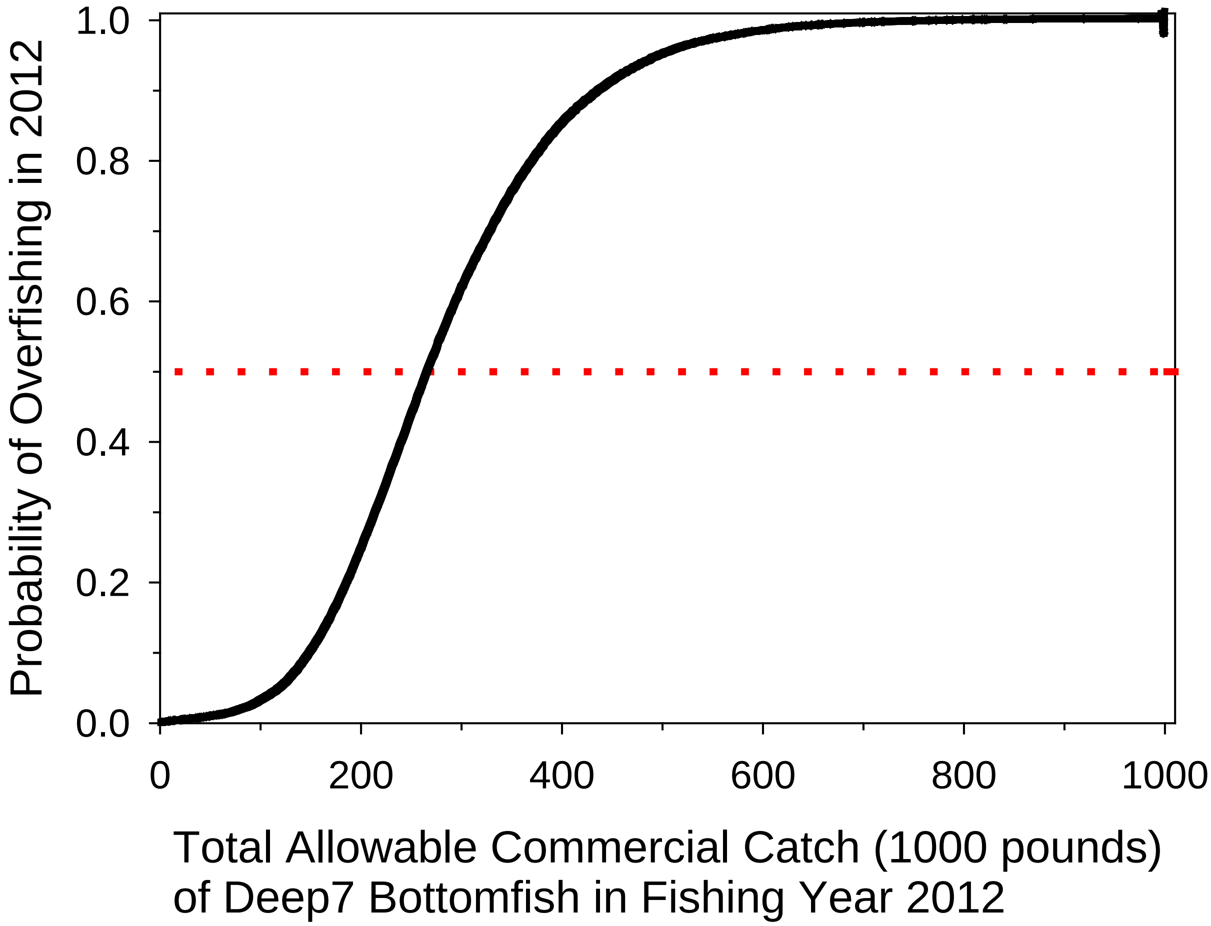


Figure A29.--Sensitivity analyses of projection results for estimates of total allowable catches of Deep7 Hawaiian bottomfish for fishing years 2012−2013 that would produce a range of probabilities of overfishing in 2012 from 0% to 50% and greater under Baseline Catch Scenario III and CPUE Scenario II.

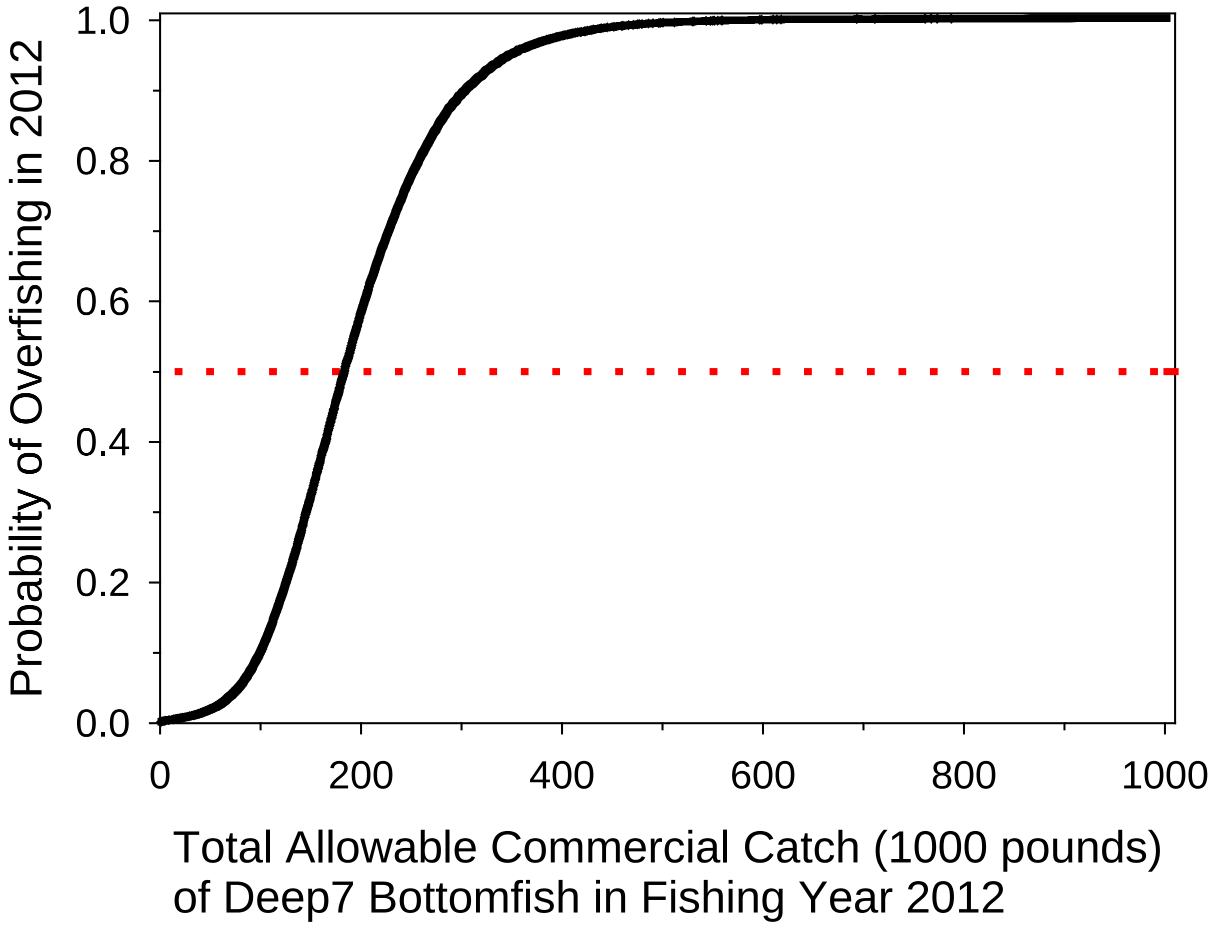


Figure A30.--Sensitivity analyses of projection results for estimates of total allowable catches of Deep7 Hawaiian bottomfish for fishing years 2012–2013 that would produce a range of probabilities of overfishing in 2012 from 0% to 50% and greater under Baseline Catch Scenario III and CPUE Scenario III.

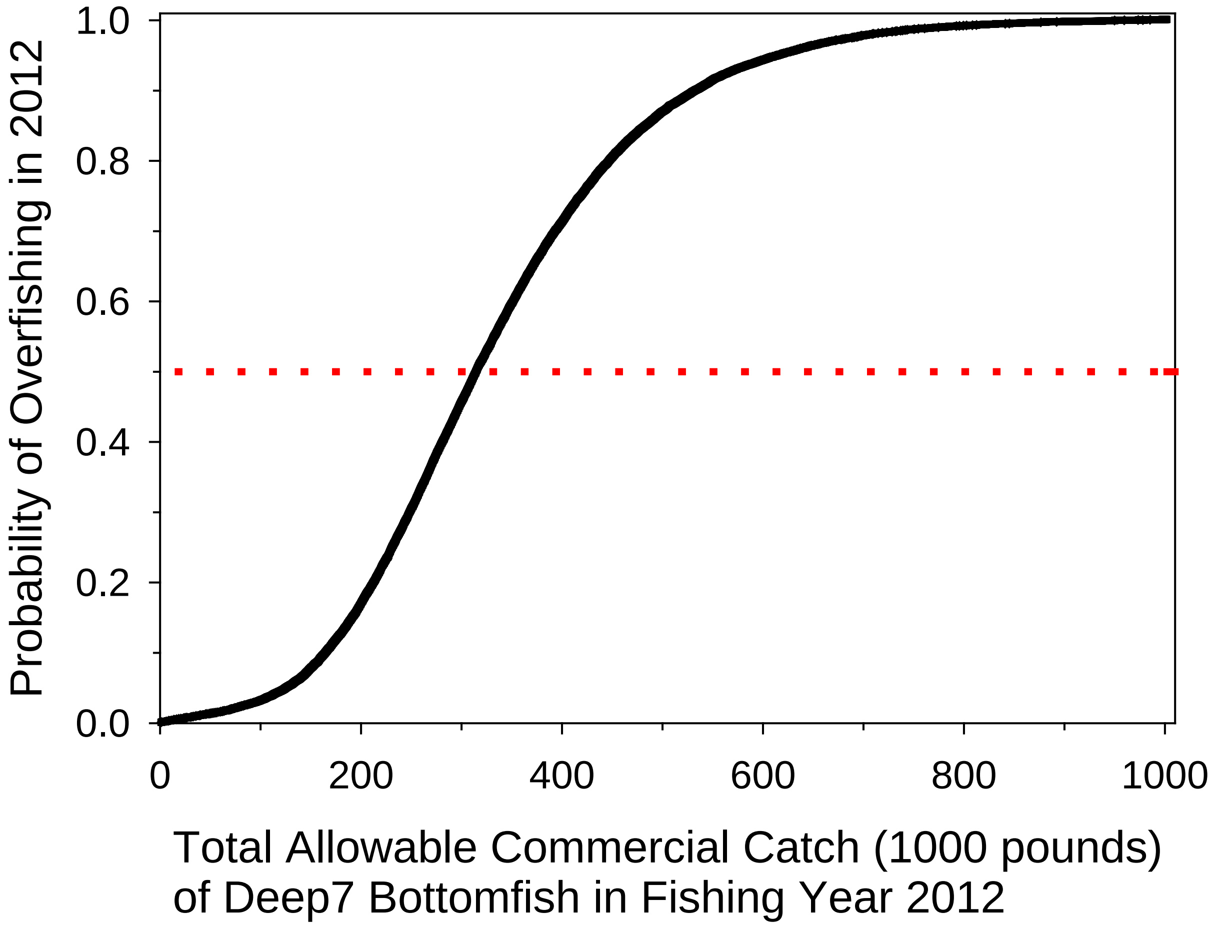


Figure A31.--Sensitivity analyses of projection results for estimates of total allowable catches of Deep7 Hawaiian bottomfish for fishing years 2012−2013 that would produce a range of probabilities of overfishing in 2012 from 0% to 50% and greater under Baseline Catch Scenario IV and CPUE Scenario I.

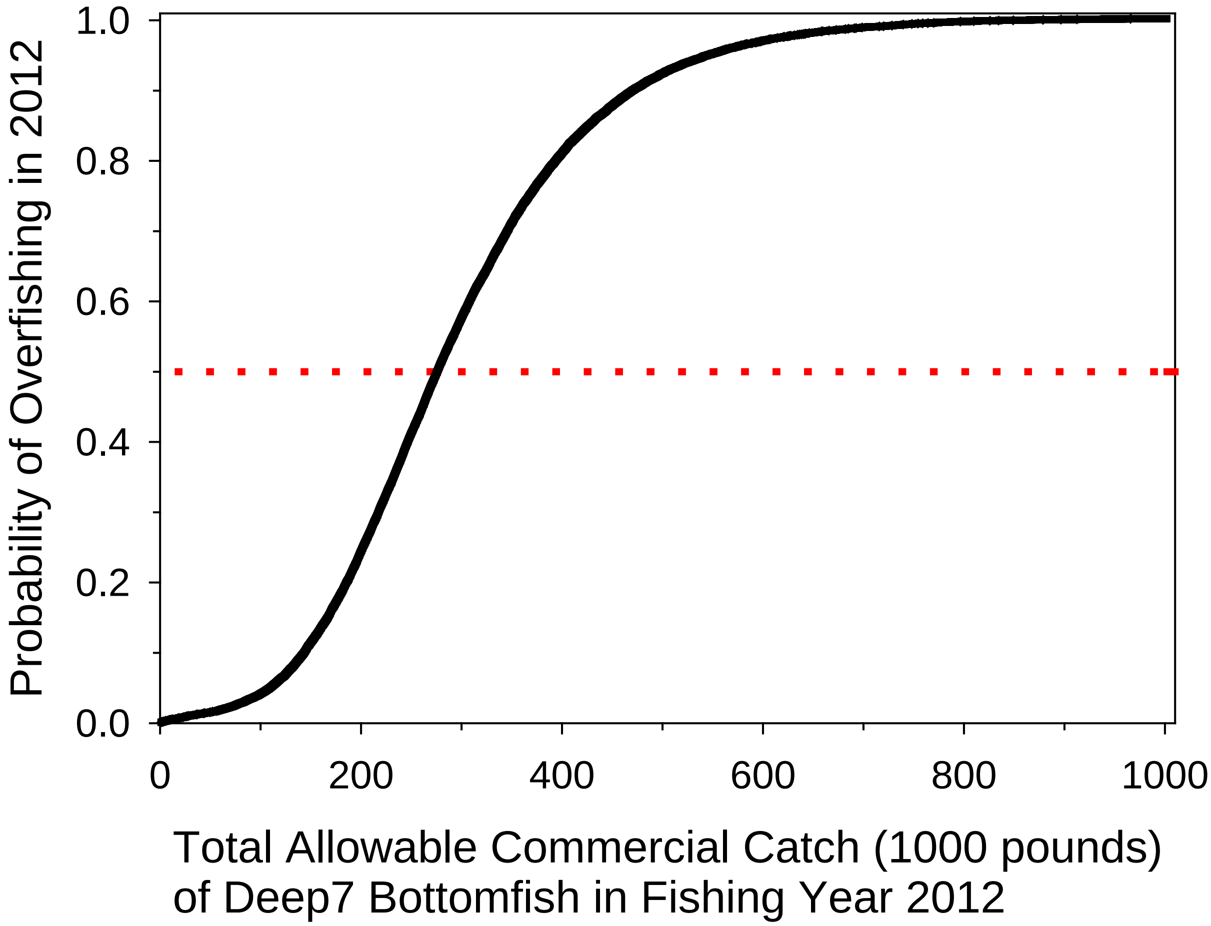


Figure A32.--Sensitivity analyses of projection results for estimates of total allowable catches of Deep7 Hawaiian bottomfish for fishing years 2012−2013 that would produce a range of probabilities of overfishing in 2012 from 0% to 50% and greater under Baseline Catch Scenario IV and CPUE Scenario II.

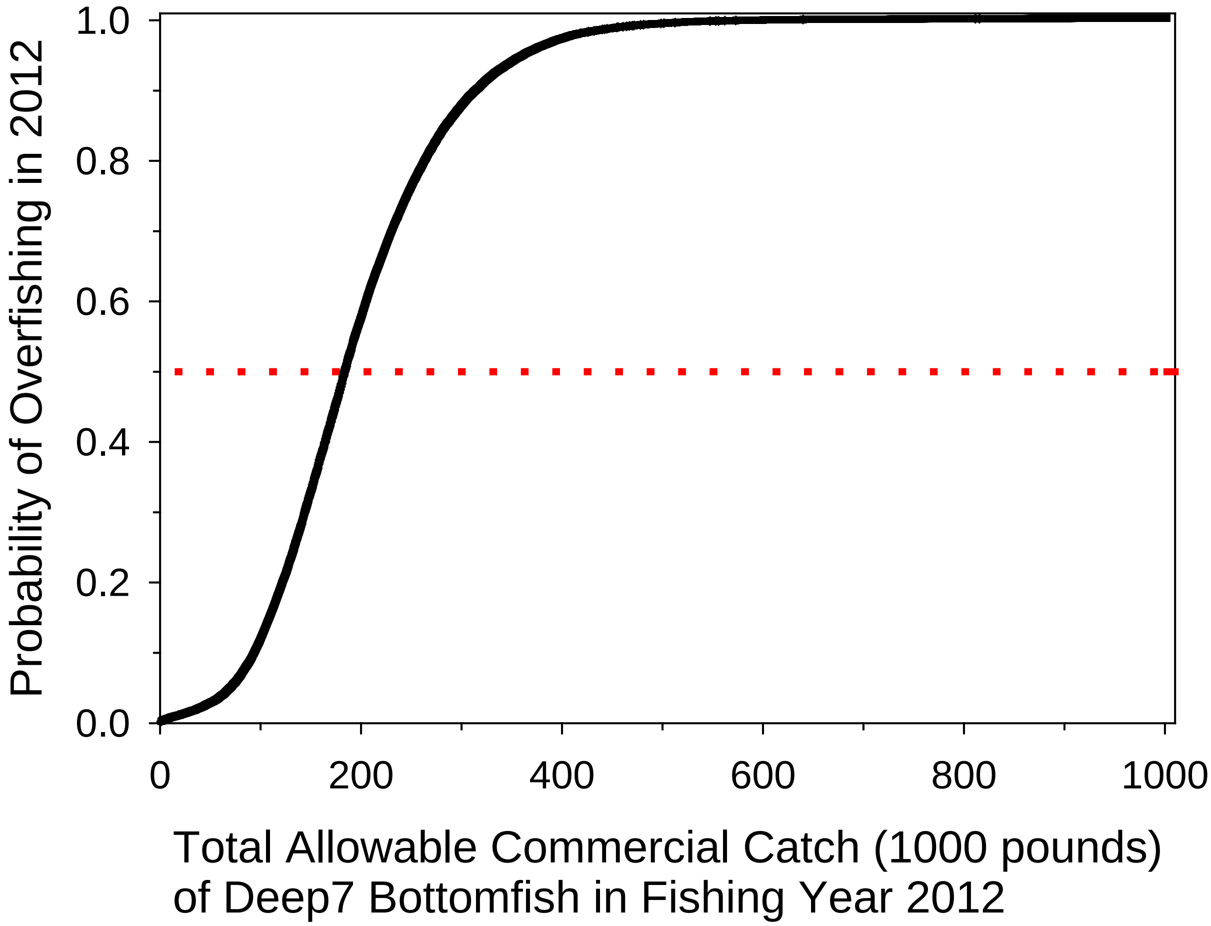


Figure A33.--Sensitivity analyses of projection results for estimates of total allowable catches of Deep7 Hawaiian bottomfish for fishing years 2012−2013 that would produce a range of probabilities of overfishing in 2012 from 0% to 50% and greater under Baseline Catch Scenario IV and CPUE Scenario III.

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