Appendix I. 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 <- 1.1415926
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 <- 1.1415926
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
######################################################################################
}
```

Appendix II. Appendix Figures.

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.

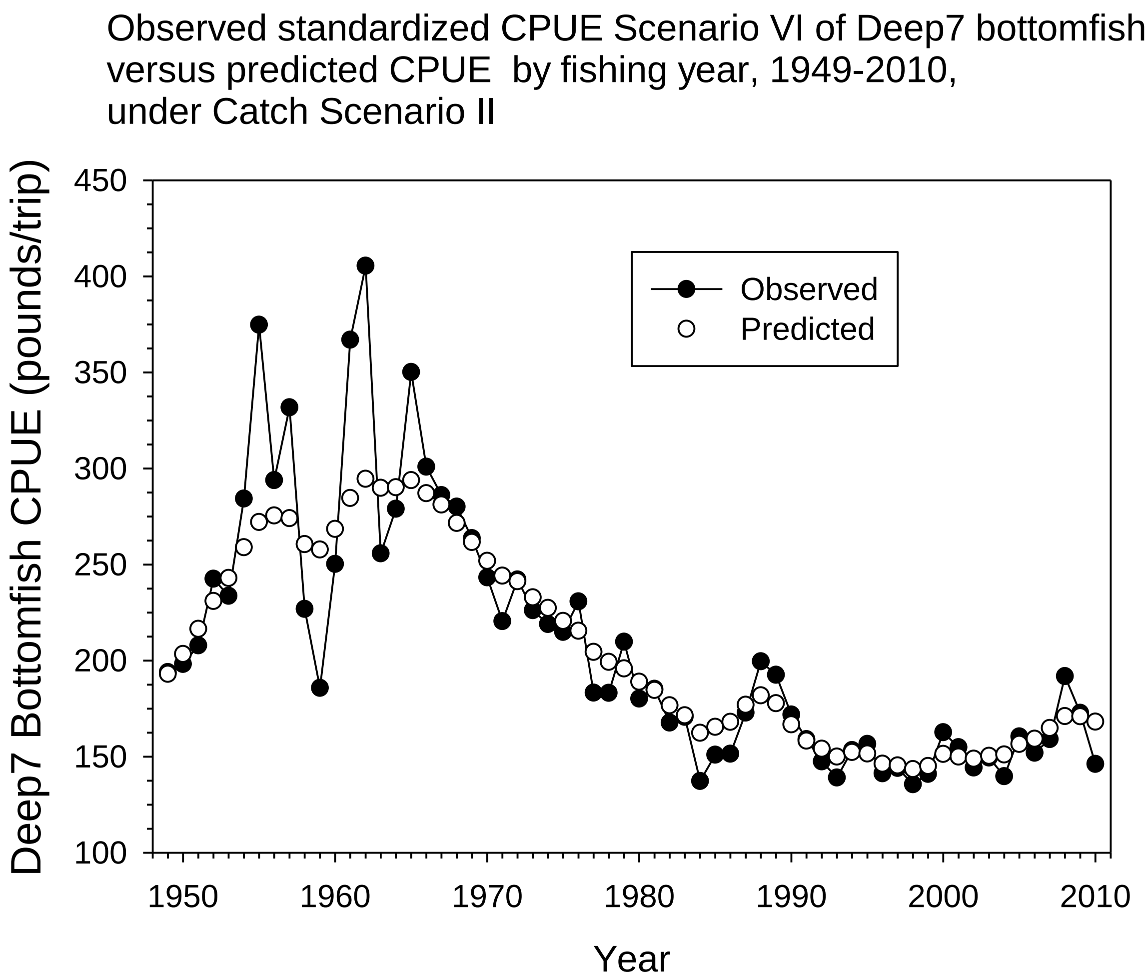


Figure A.1.2. Results of the catch Scenario II CPUE Scenario Ib production model fit to the observed standardized bottomfish CPUE for the main Hawaiian Islands along with standardized log-scale CPUE residuals and P-values for linear regression hypothesis tests of whether standardized residuals have a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

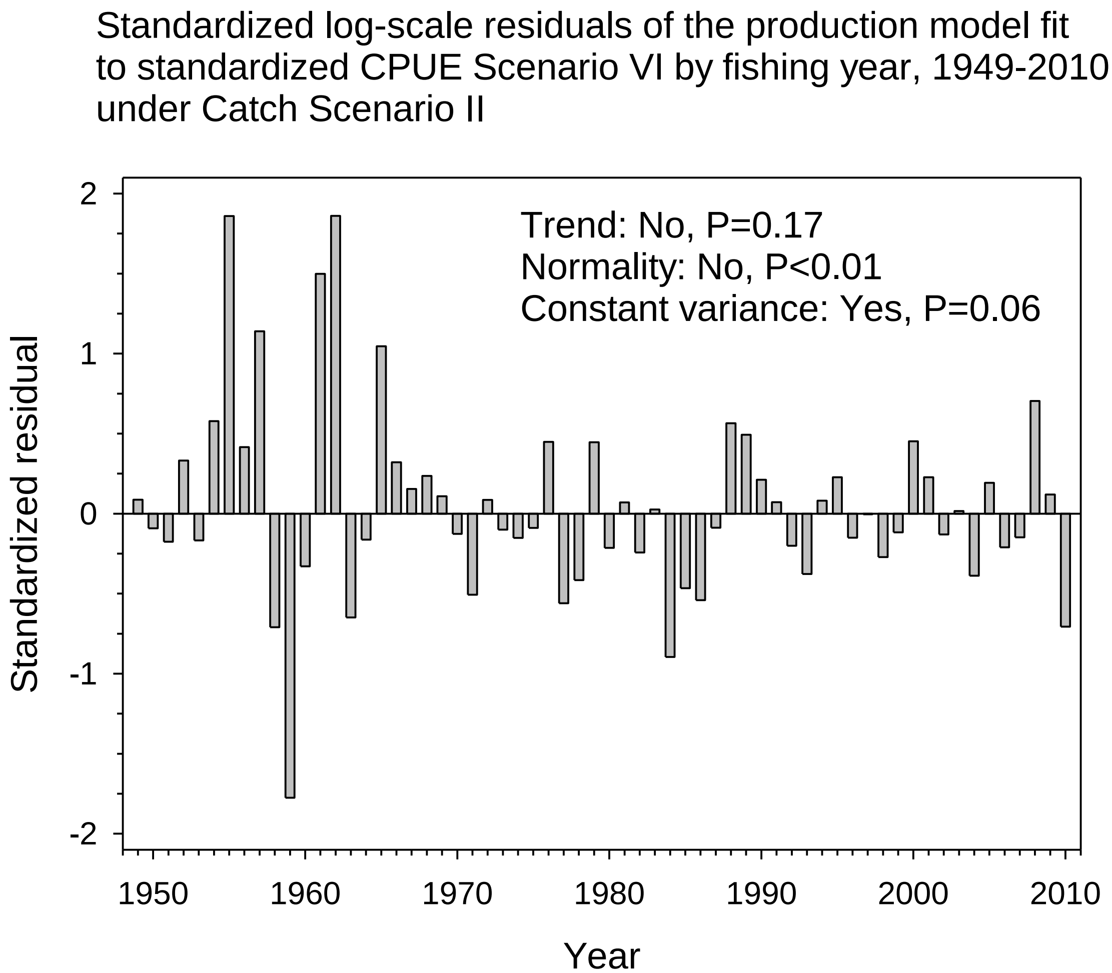


Figure A.2.1. Results of the catch Scenario II CPUE Scenario IV production model fit to the observed standardized bottomfish CPUE for the main Hawaiian Islands along with CPUE residuals.

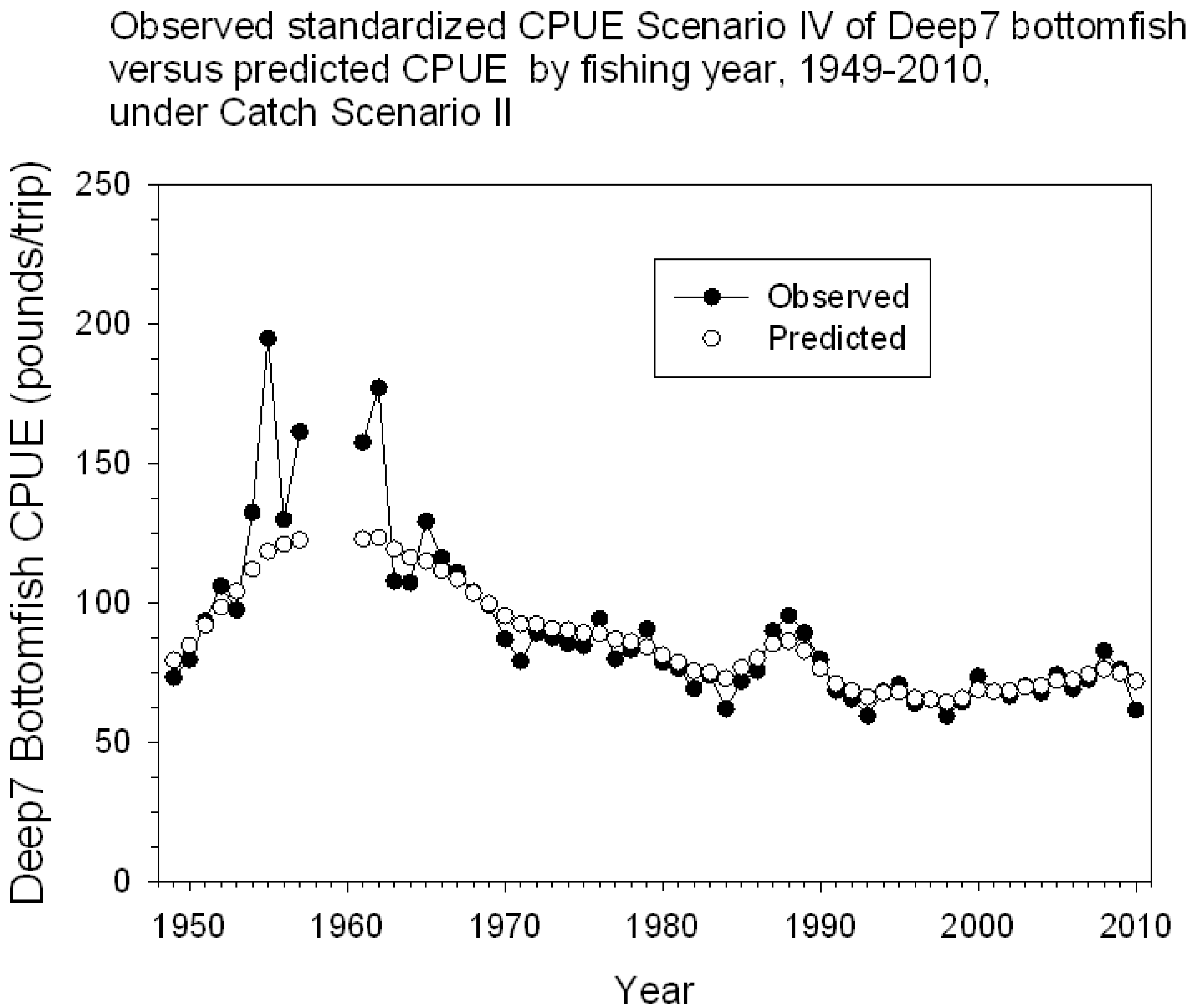


Figure A.2.2. Results of the catch Scenario II CPUE Scenario II production model fit to the observed standardized bottomfish CPUE for the main Hawaiian Islands along with standardized log-scale CPUE residuals and P-values for linear regression hypothesis tests of whether standardized residuals have a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

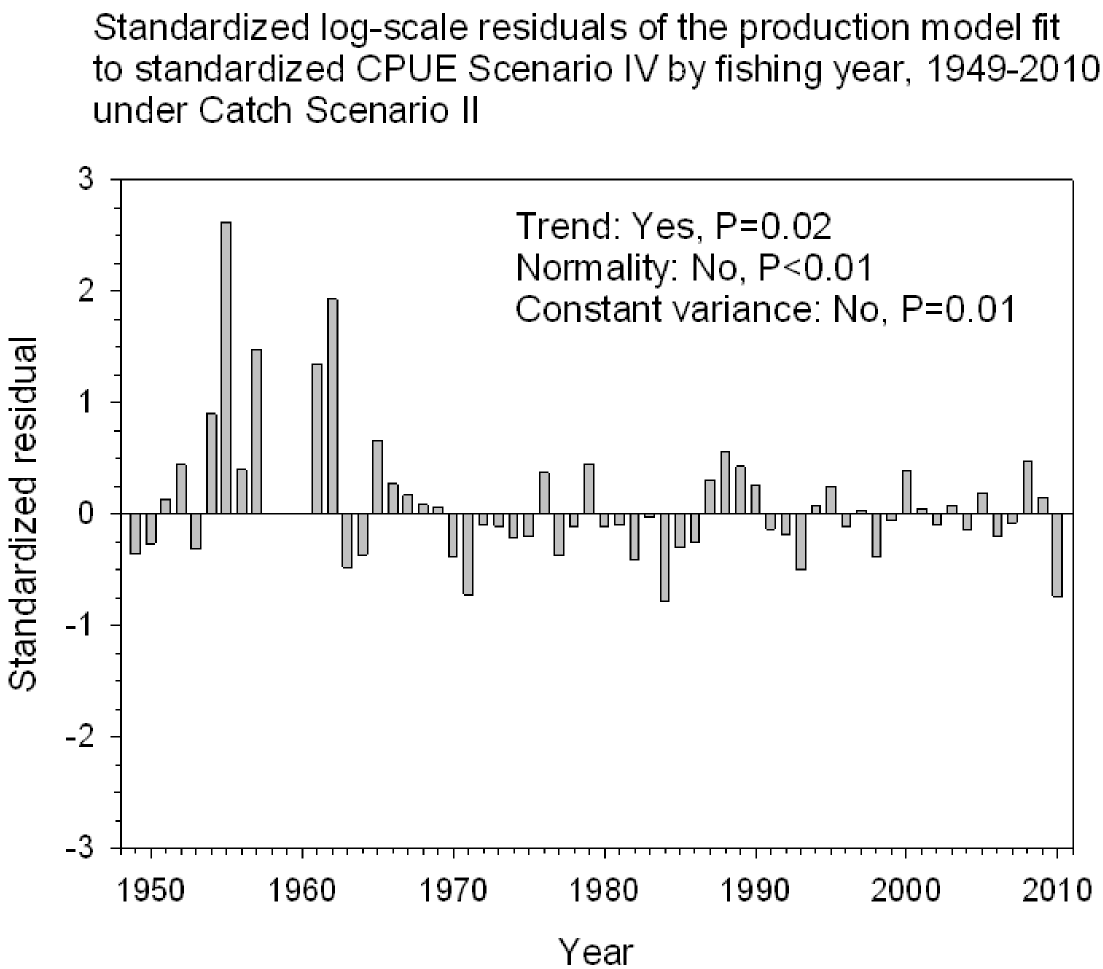


Figure A.3.1. Results of the catch Scenario II CPUE ScenarioV production model fit to the observed standardized bottomfish CPUE for the main Hawaiian Islands along with CPUE residuals.

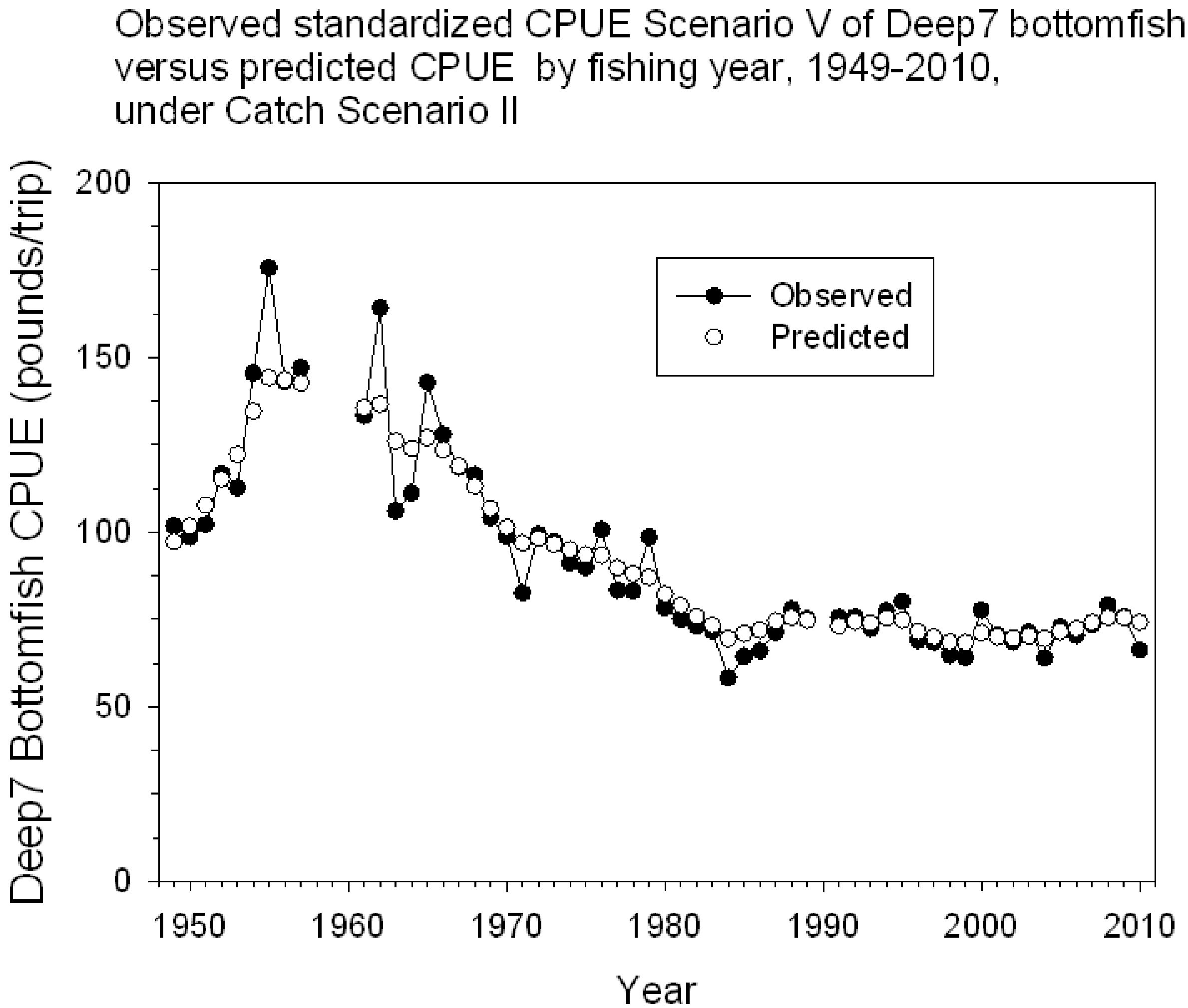


Figure A.3.2. Results of the catch Scenario II CPUE Scenario V production model fit to the observed standardized bottomfish CPUE for the main Hawaiian Islands along with standardized log-scale CPUE residuals and P-values for linear regression hypothesis tests of whether standardized residuals have a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

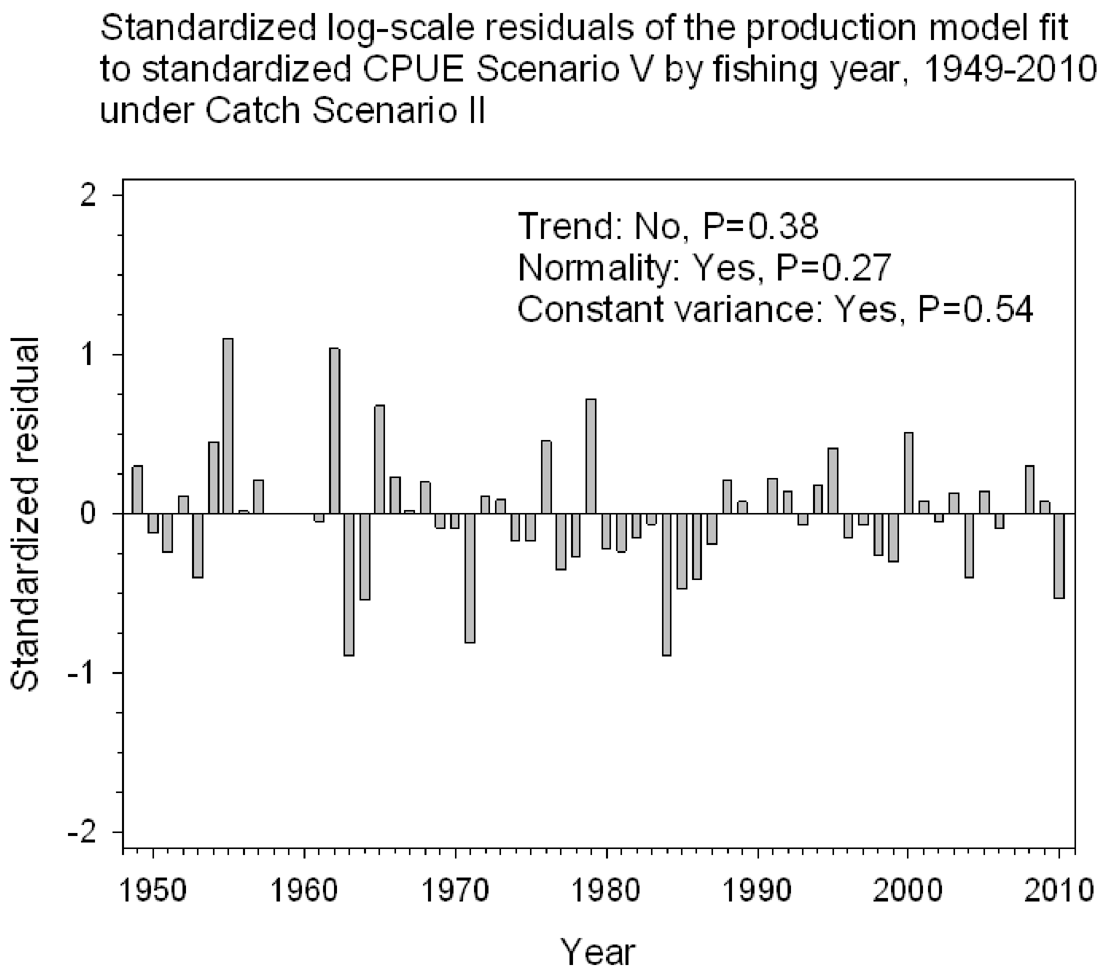


Figure A.4.1. Results of the catch Scenario I CPUE Scenario I production model fit to the observed standardized bottomfish CPUE for the main Hawaiian Islands along with CPUE residuals.

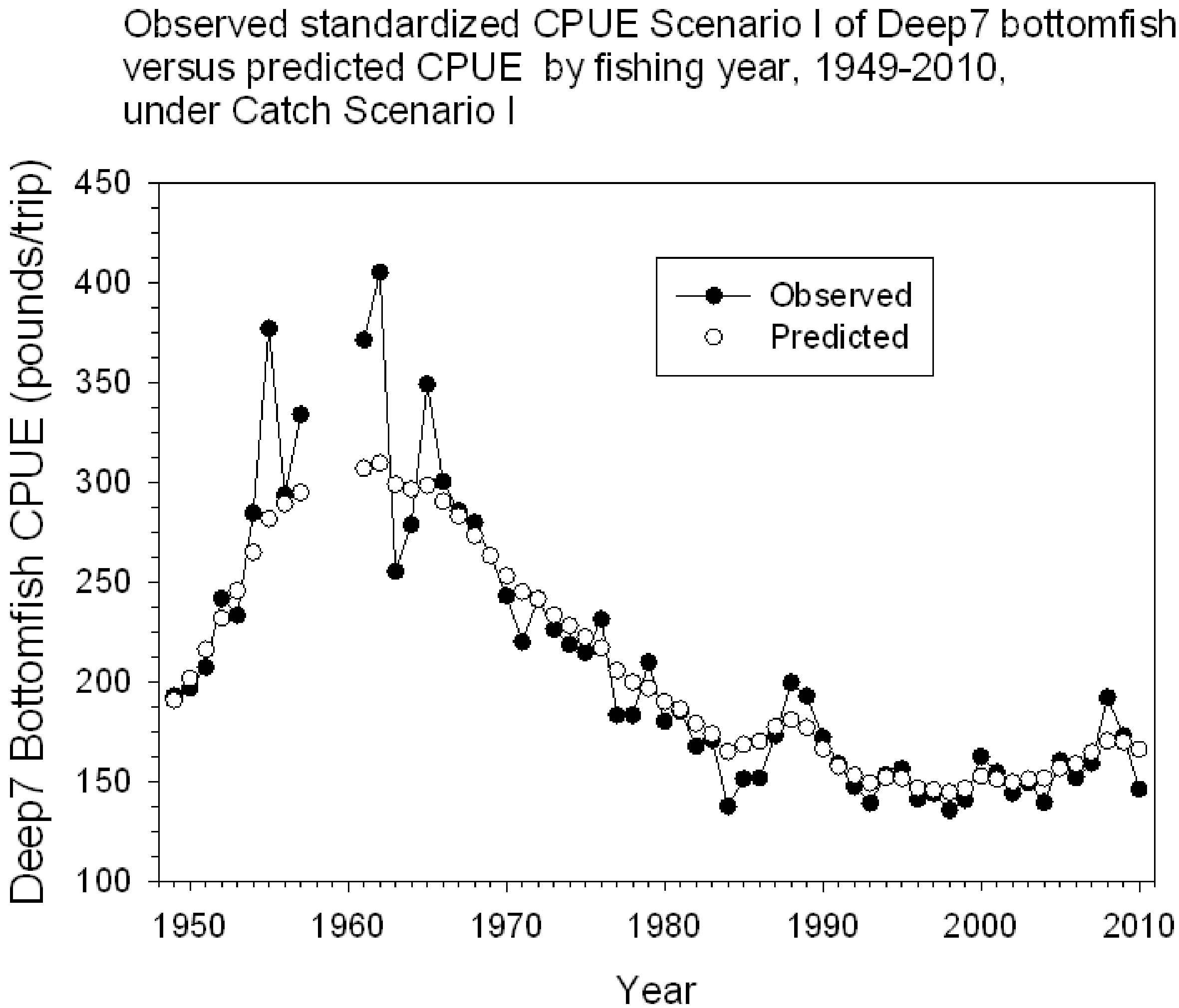


Figure A.4.2. Results of the catch Scenario I CPUE Scenario I production model fit to the observed standardized bottomfish CPUE for the main Hawaiian Islands along with standardized log-scale CPUE residuals and P-values for linear regression hypothesis tests of whether standardized residuals have a time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

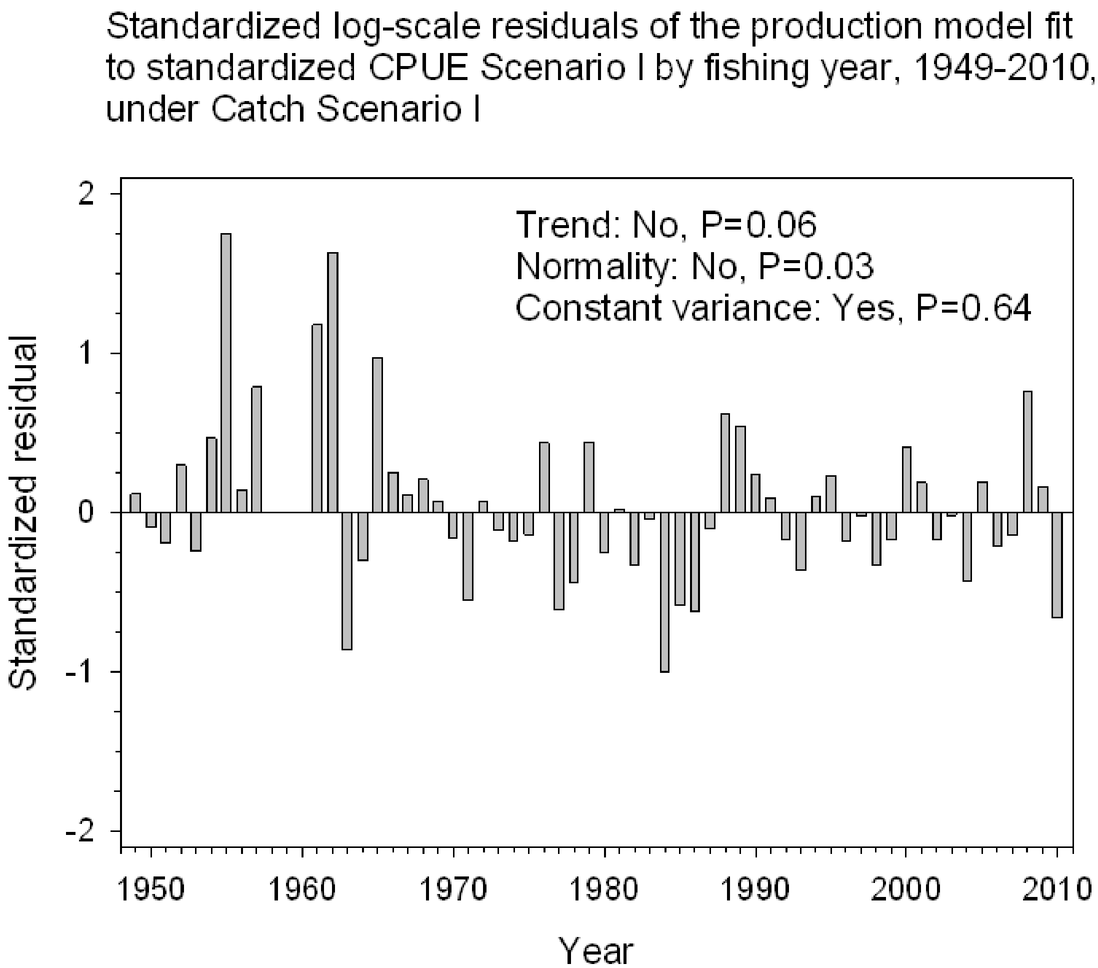


Figure A.5.1. Results of the catch Scenario I CPUE Scenario II production model fit to the observed standardized bottomfish CPUE for the main Hawaiian Islands along with CPUE residuals.

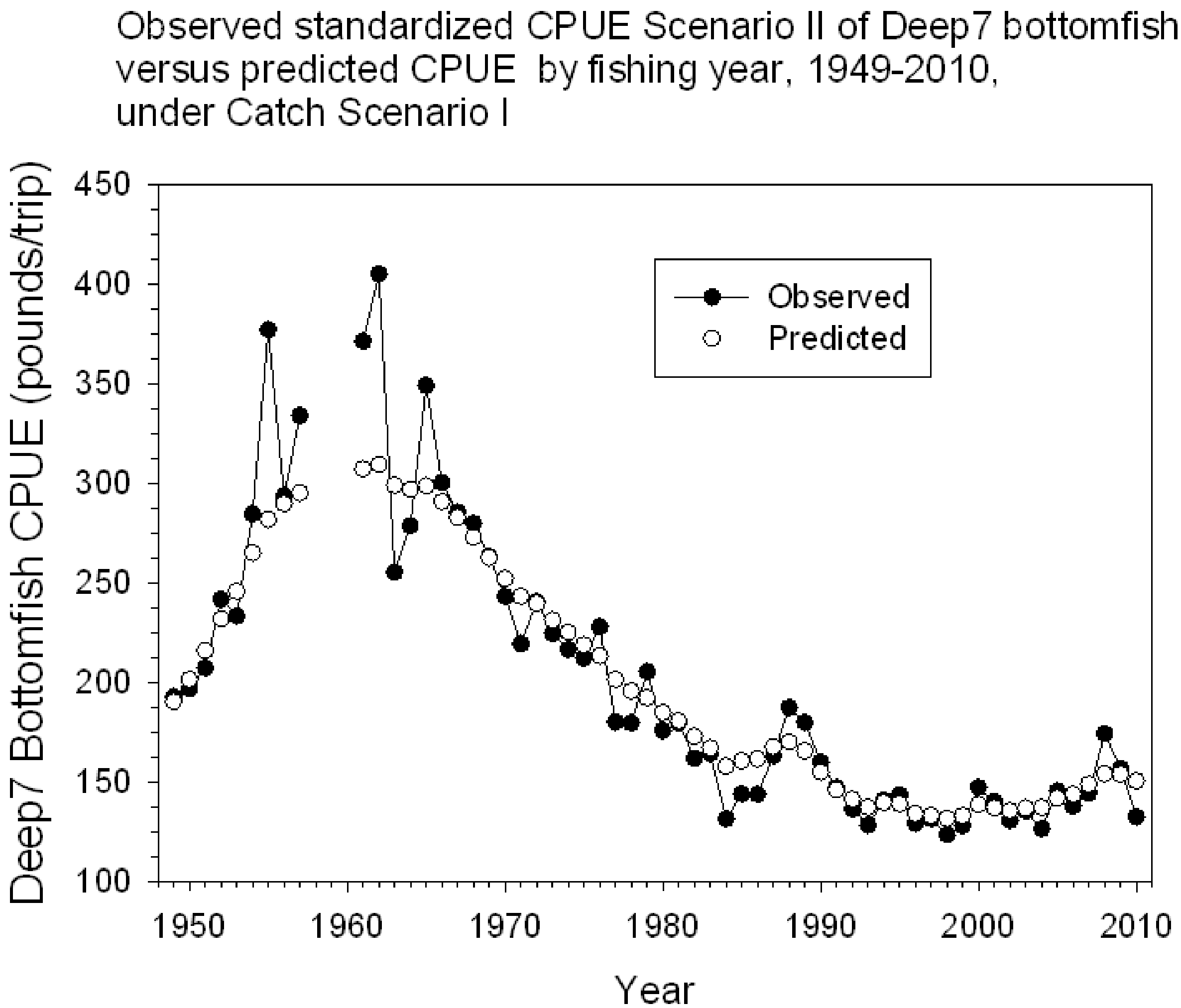


Figure A.5.2. Results of the catch Scenario I CPUE Scenario II production model fit to the observed standardized bottomfish CPUE for the main Hawaiian Islands along with standardized log-scale CPUE residuals and P-values for linear regression hypothesis tests of whether standardized residuals have a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

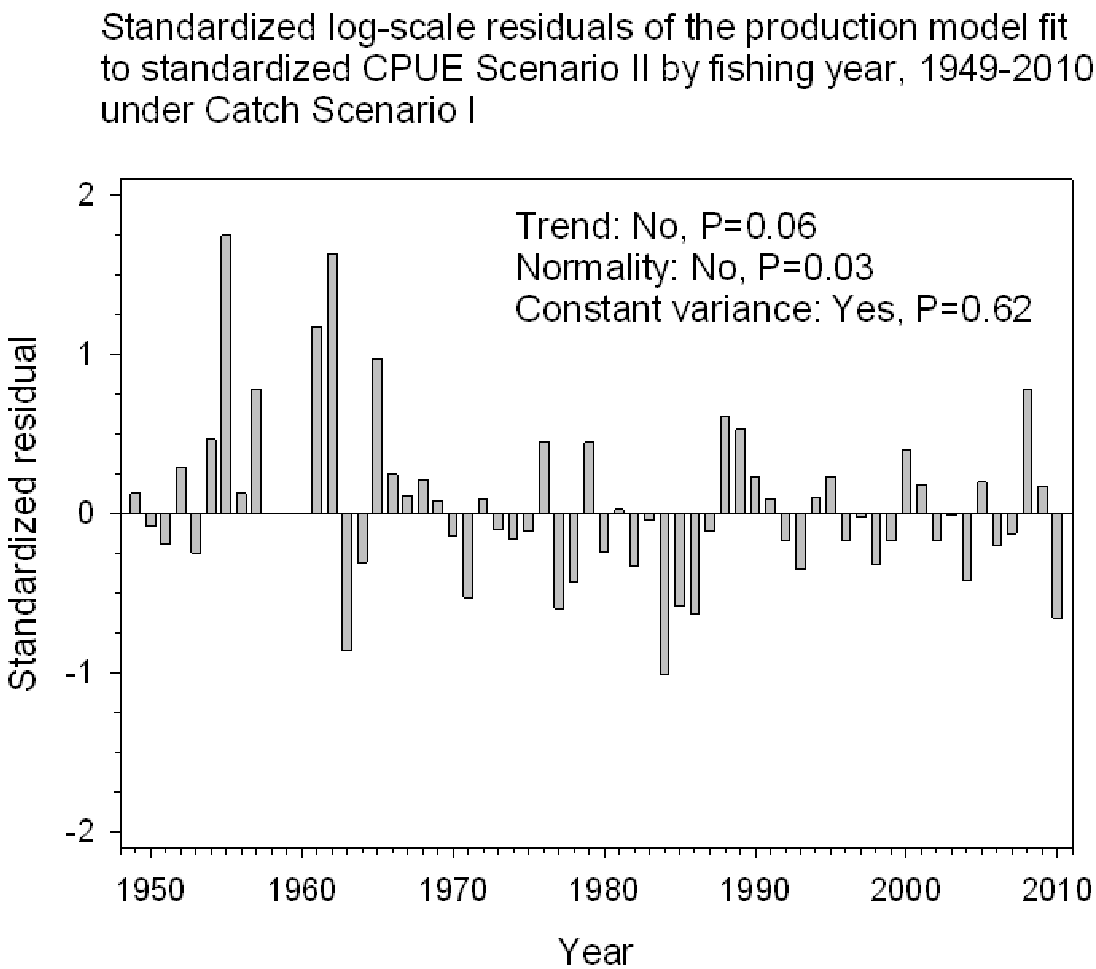


Figure A.6.1. Results of the catch Scenario I CPUE Scenario III production model fit to the observed standardized bottomfish CPUE for the main Hawaiian Islands along with CPUE residuals.

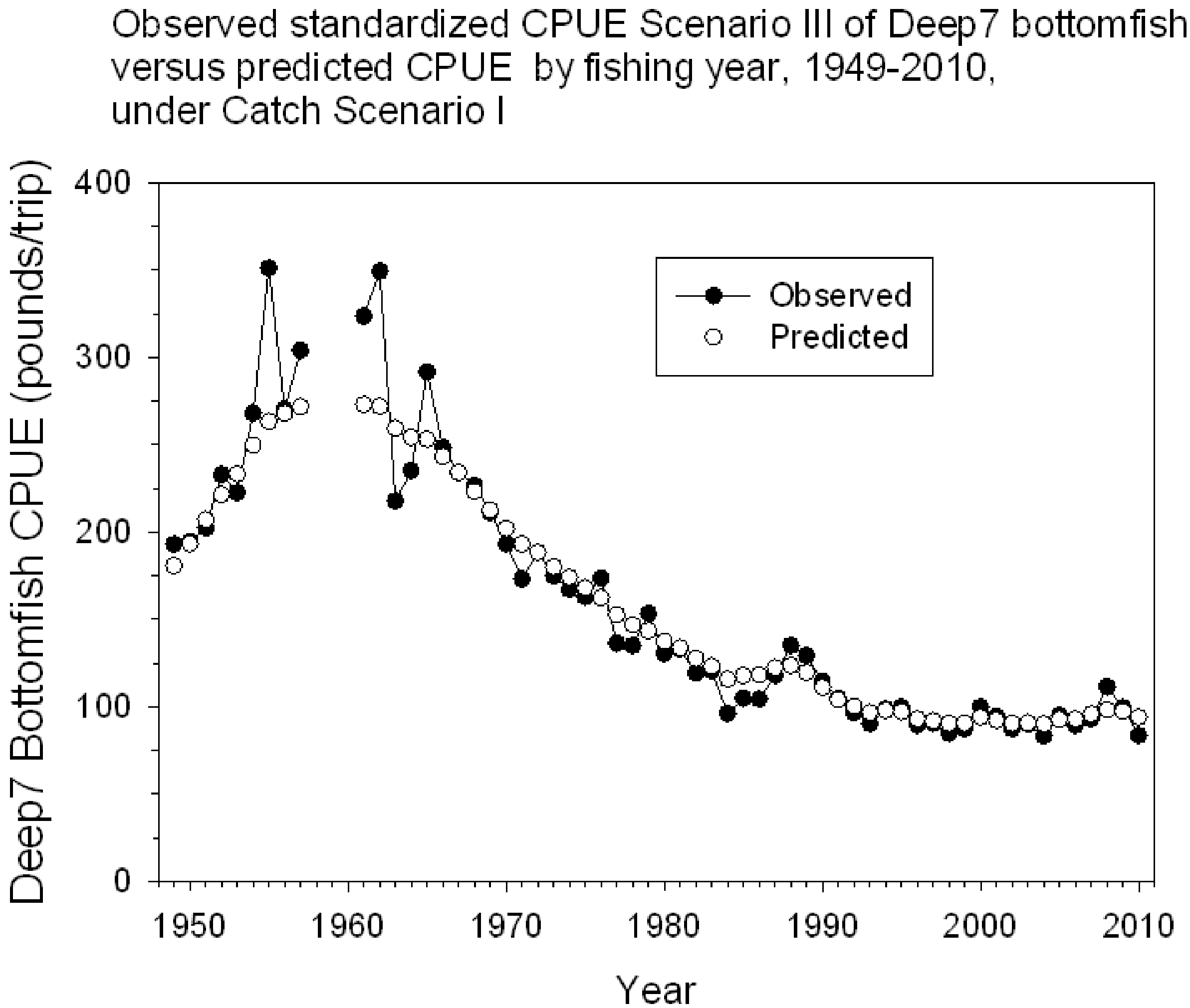


Figure A.6.2. Results of the catch Scenario I CPUE Scenario III production model fit to the observed standardized bottomfish CPUE for the main Hawaiian Islands along with standardized log-scale CPUE residuals and P-values for linear regression hypothesis tests of whether standardized residuals have a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

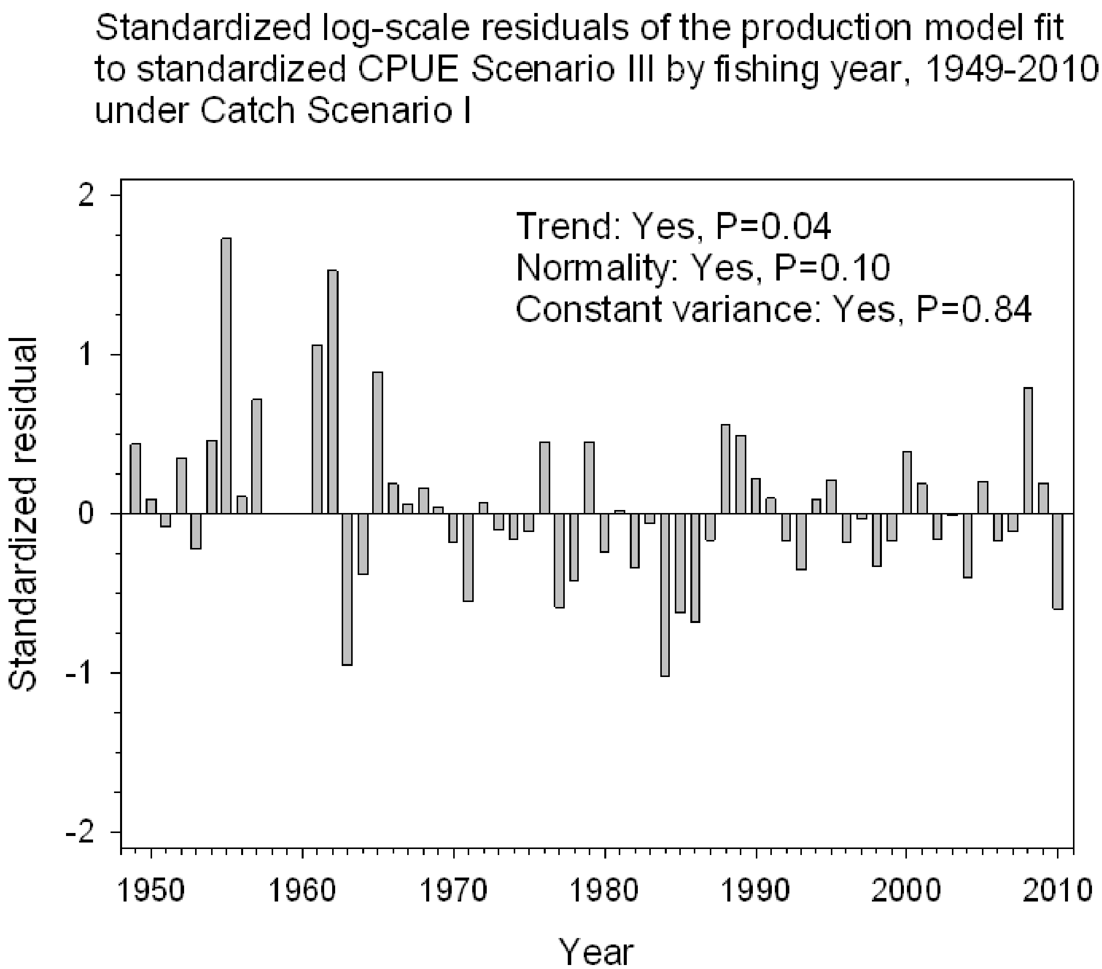


Figure A.7.1. Results of the catch Scenario III CPUE Scenario I production model fit to the observed standardized bottomfish CPUE for the main Hawaiian Islands along with CPUE residuals.

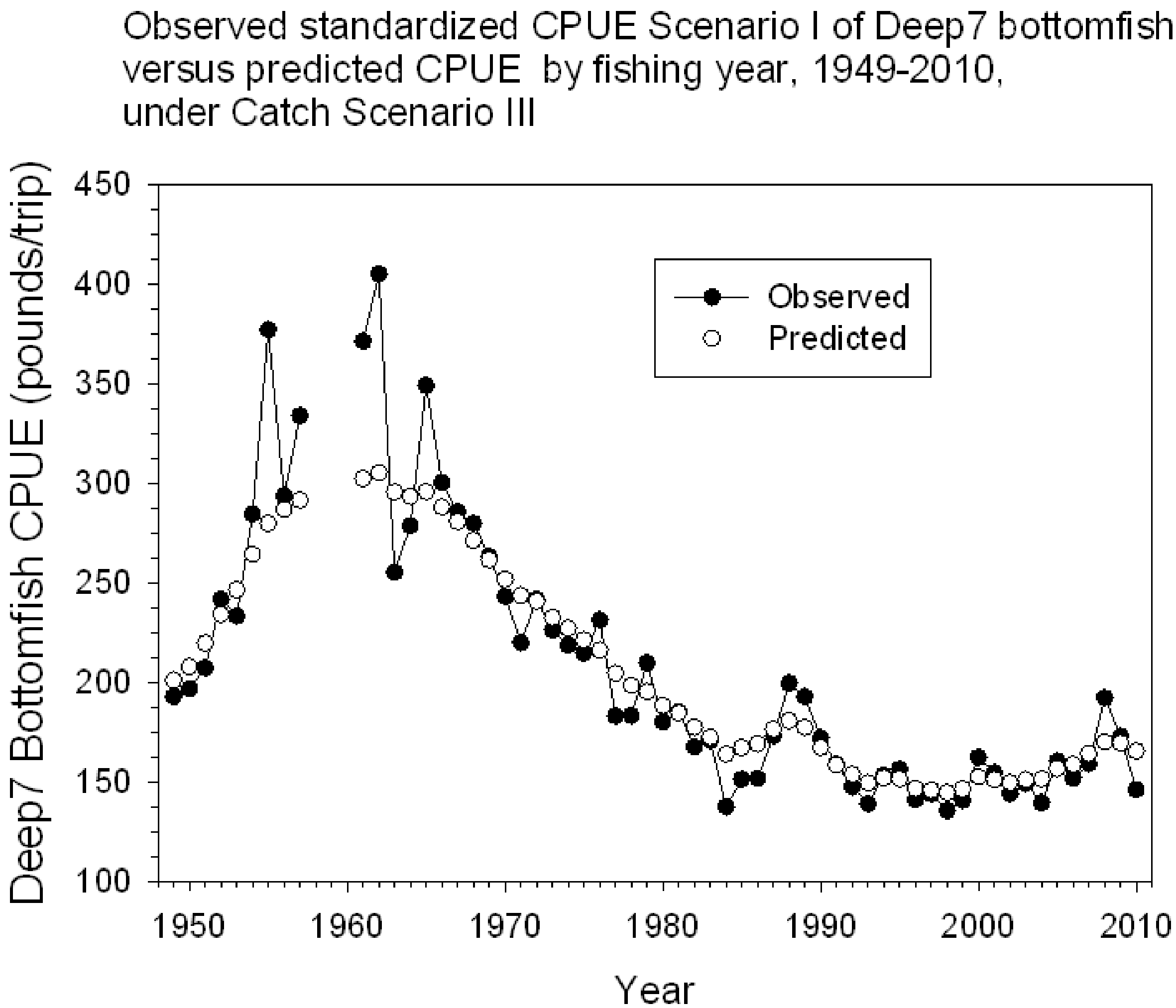


Figure A.7.2. Results of the catch Scenario III CPUE Scenario I production model fit to the observed standardized bottomfish CPUE for the main Hawaiian Islands along with standardized log-scale CPUE residuals and P-values for linear regression hypothesis tests of whether standardized residuals have a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

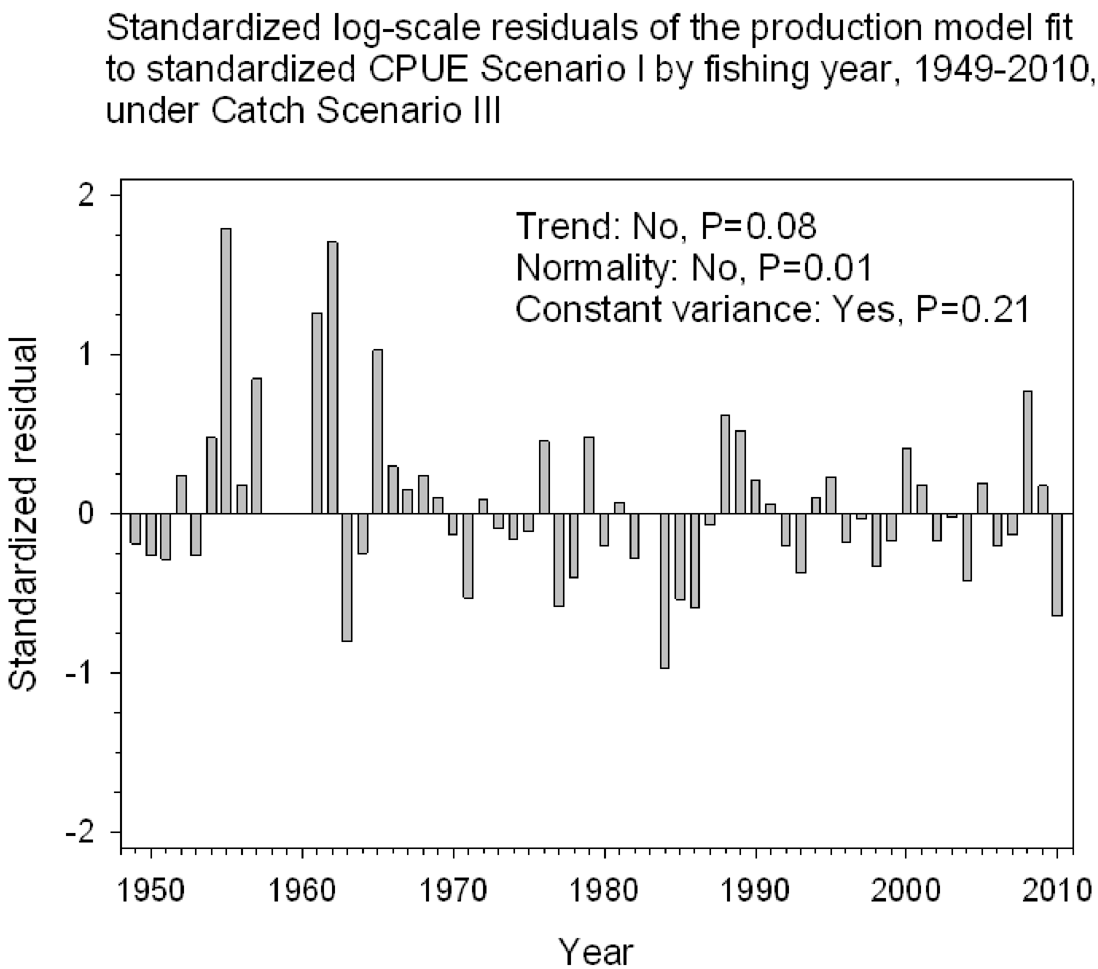


Figure A.8.1. Results of the catch Scenario III CPUE Scenario II production model fit to the observed standardized bottomfish CPUE for the main Hawaiian Islands along with CPUE residuals.

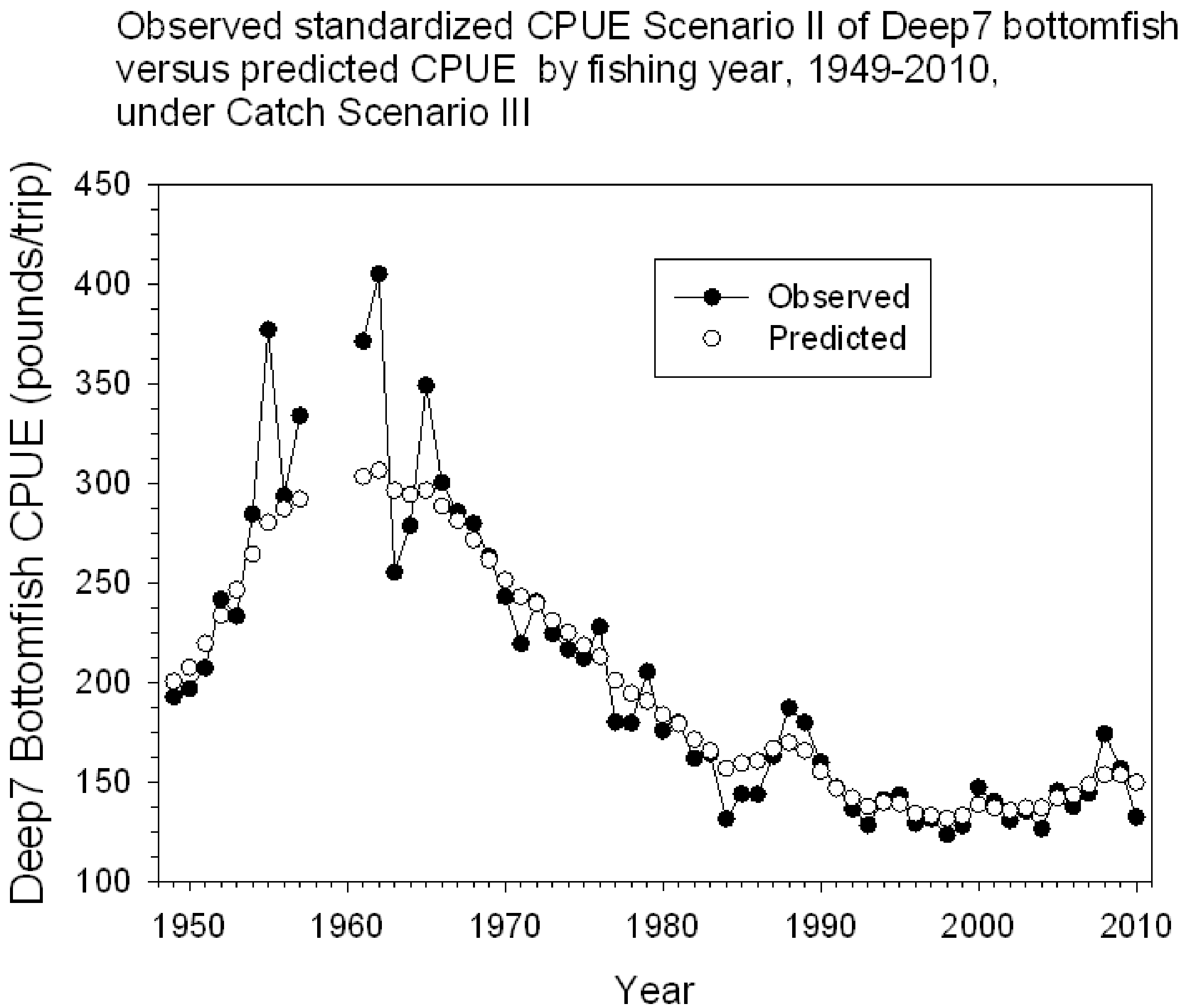


Figure A.8.2. Results of the catch Scenario III CPUE Scenario II production model fit to the observed standardized bottomfish CPUE for the main Hawaiian Islands along with standardized log-scale CPUE residuals and P-values for linear regression hypothesis tests of whether standardized residuals have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

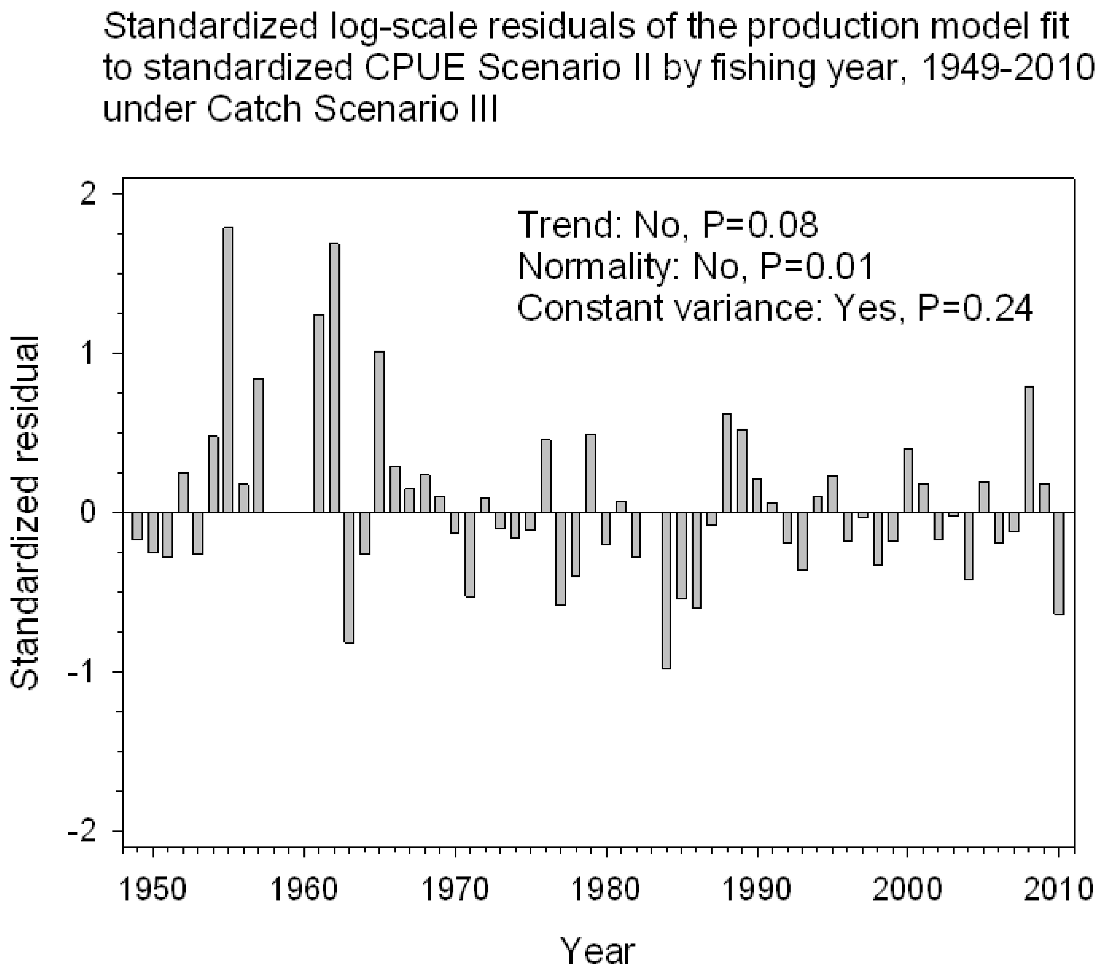


Figure A.9.1. Results of the catch Scenario III CPUE Scenario III production model fit to the observed standardized bottomfish CPUE for the main Hawaiian Islands along with CPUE residuals.

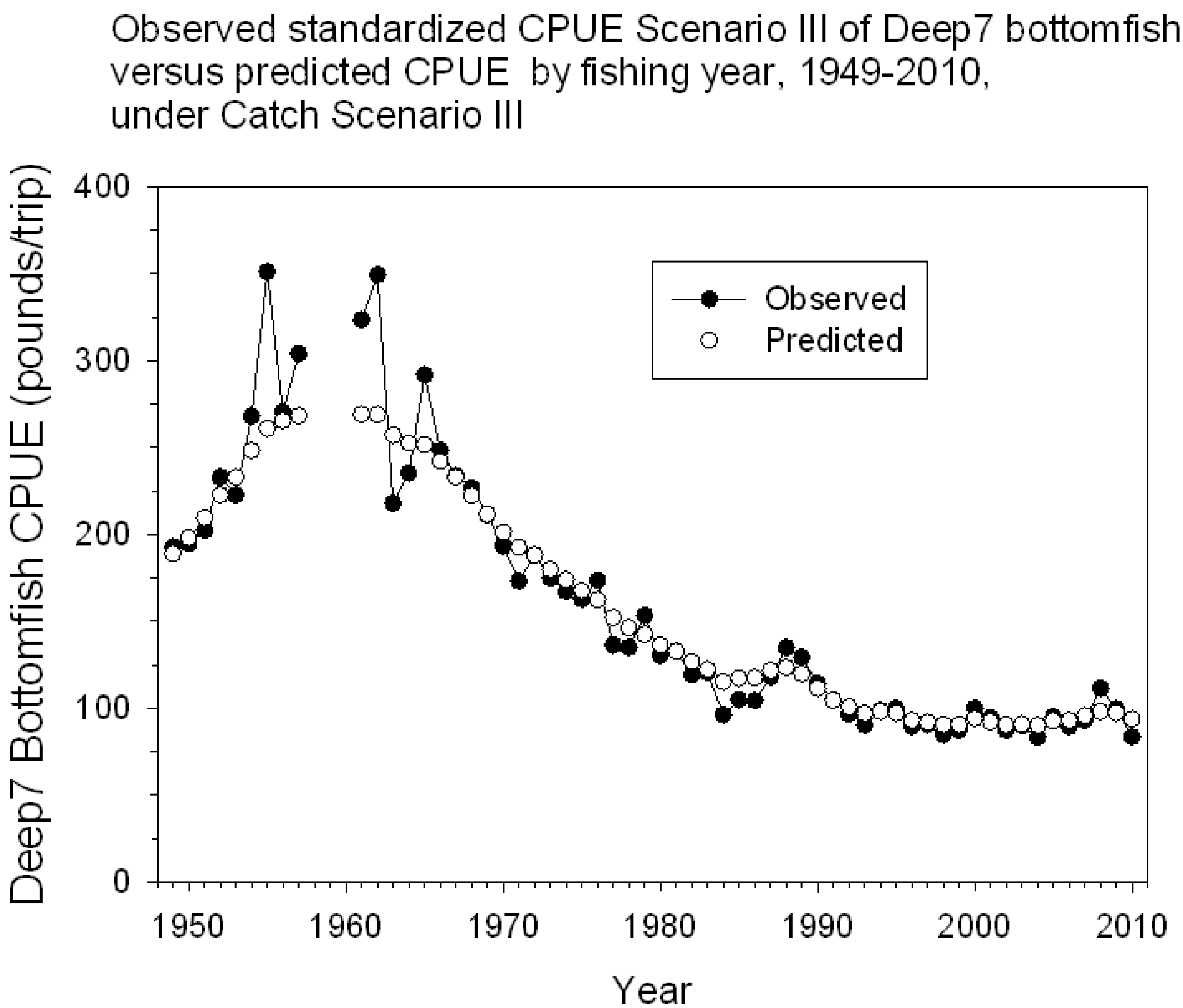


Figure A.9.2. Results of the catch Scenario III CPUE Scenario III production model fit to the observed standardized bottomfish CPUE for the main Hawaiian Islands along with standardized log-scale CPUE residuals and P-values for linear regression hypothesis tests of whether standardized residuals have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

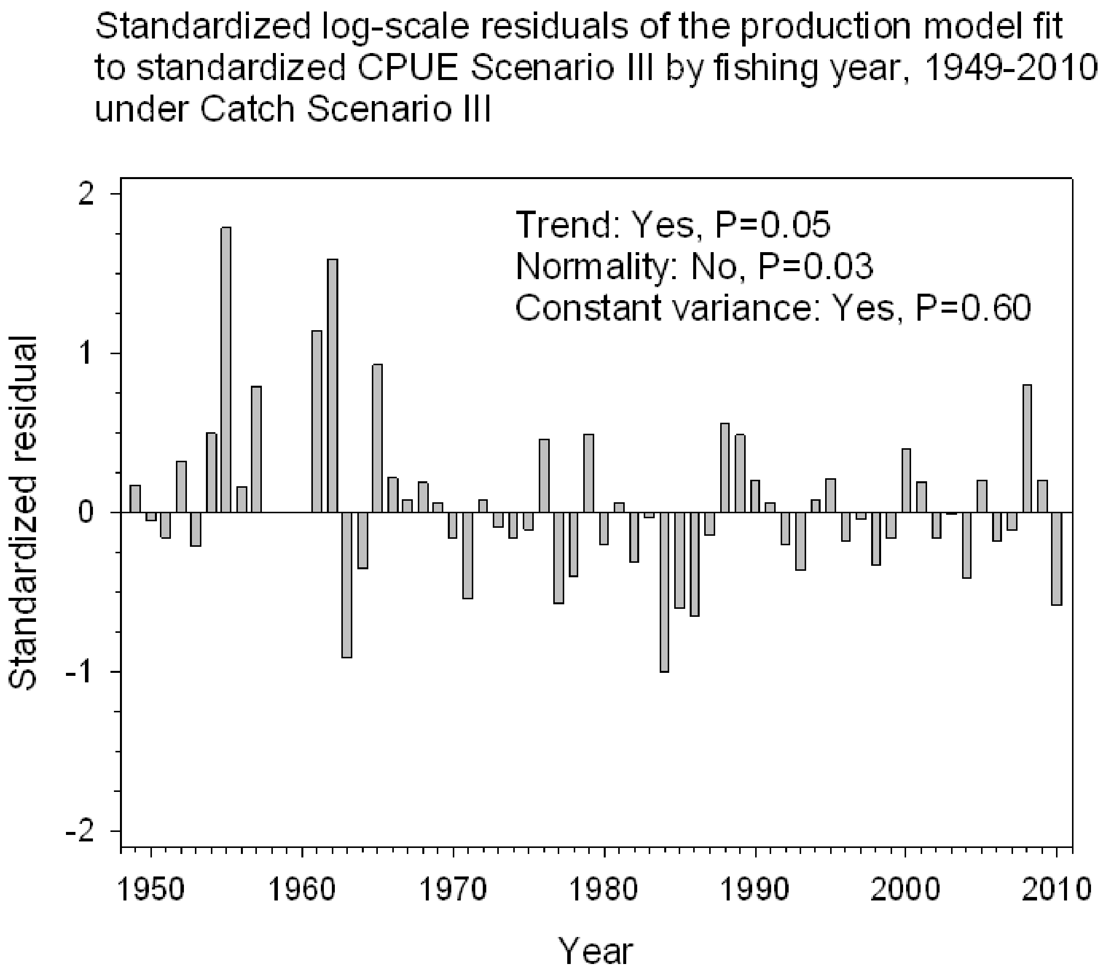


Figure A.10.1. Results of the catch Scenario IV CPUE Scenario I production model fit to the observed standardized bottomfish CPUE for the main Hawaiian Islands along with CPUE residuals.

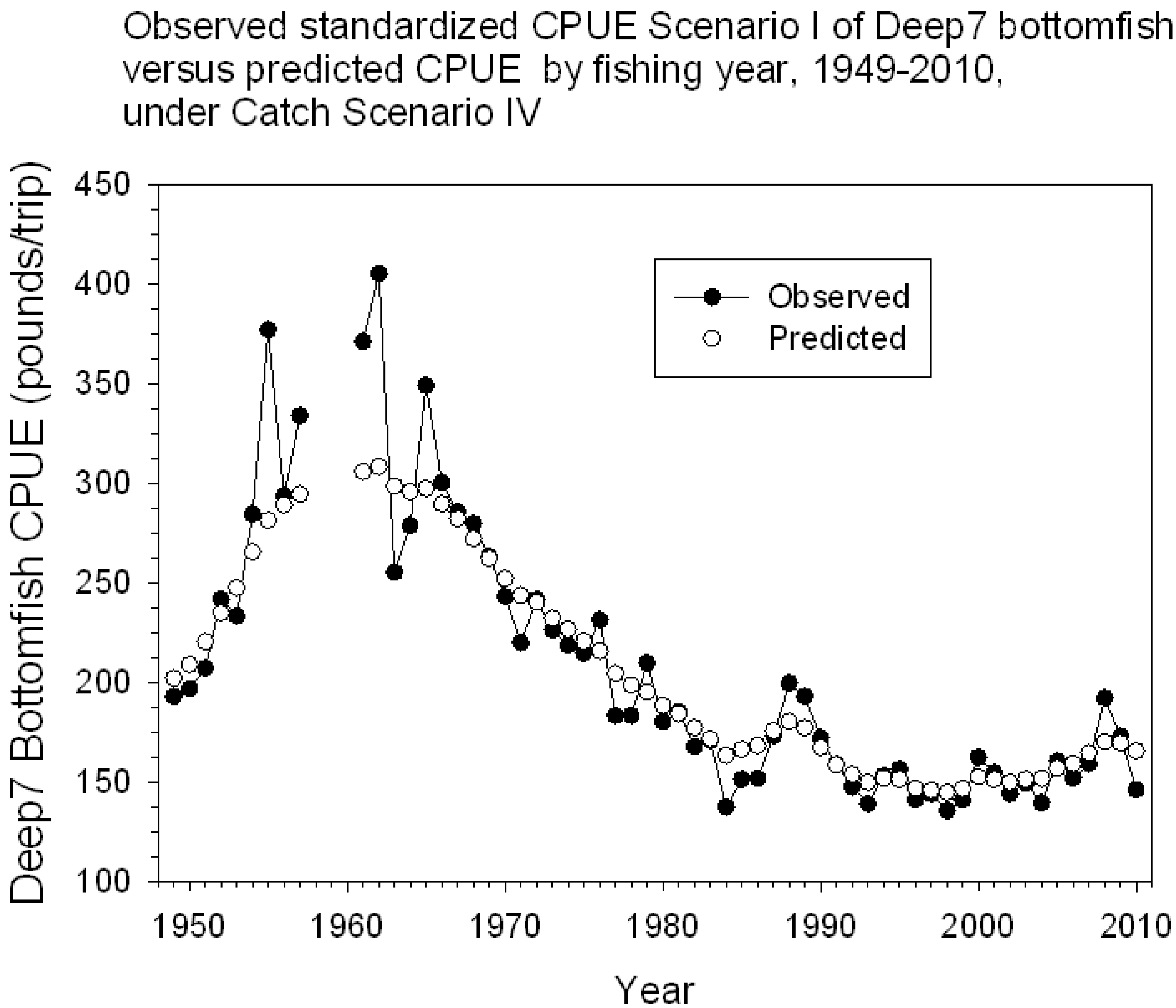


Figure A.10.2. Results of the catch Scenario IV CPUE Scenario I production model fit to the observed standardized bottomfish CPUE for the main Hawaiian Islands along with standardized log-scale CPUE residuals and P-values for linear regression hypothesis tests of whether standardized residuals have a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

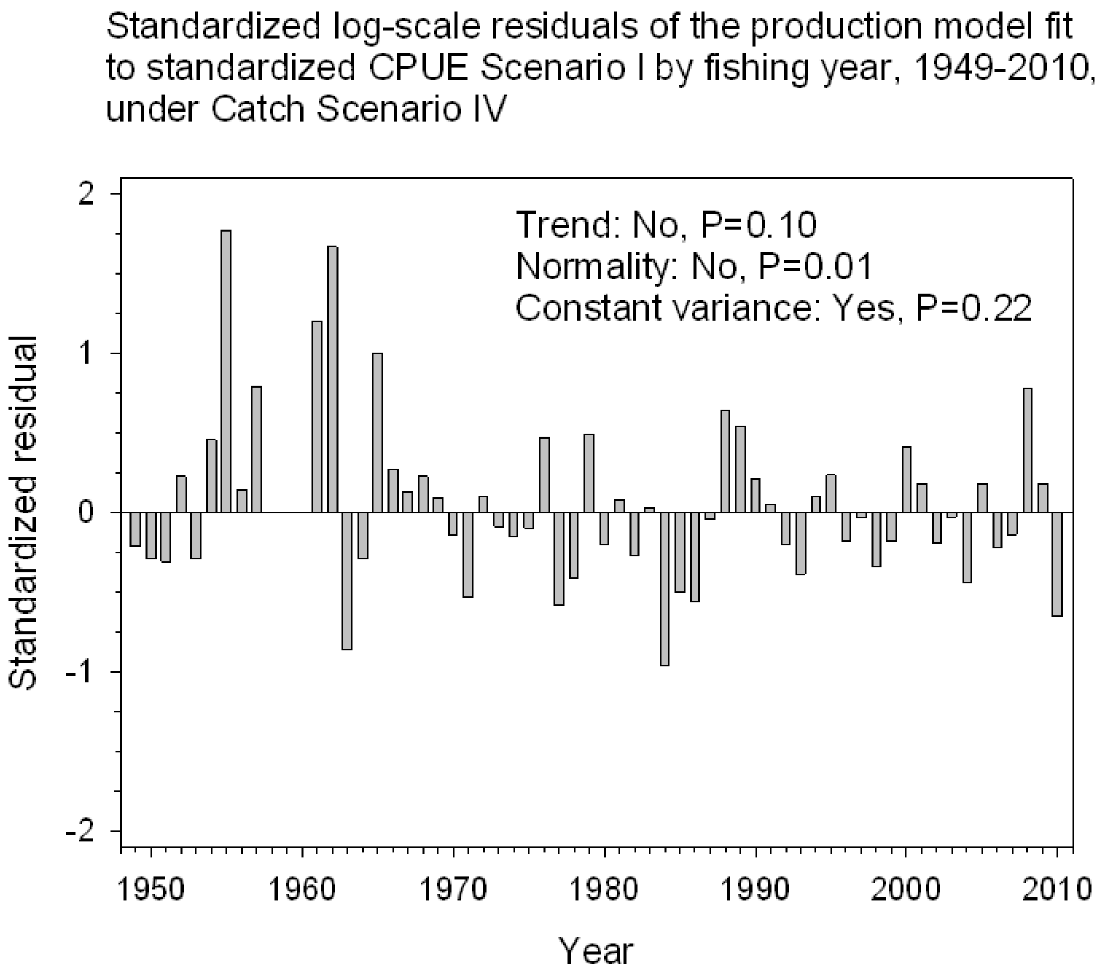


Figure A.11.1. Results of the catch Scenario IV CPUE Scenario II production model fit to the observed standardized bottomfish CPUE for the main Hawaiian Islands along with CPUE residuals.

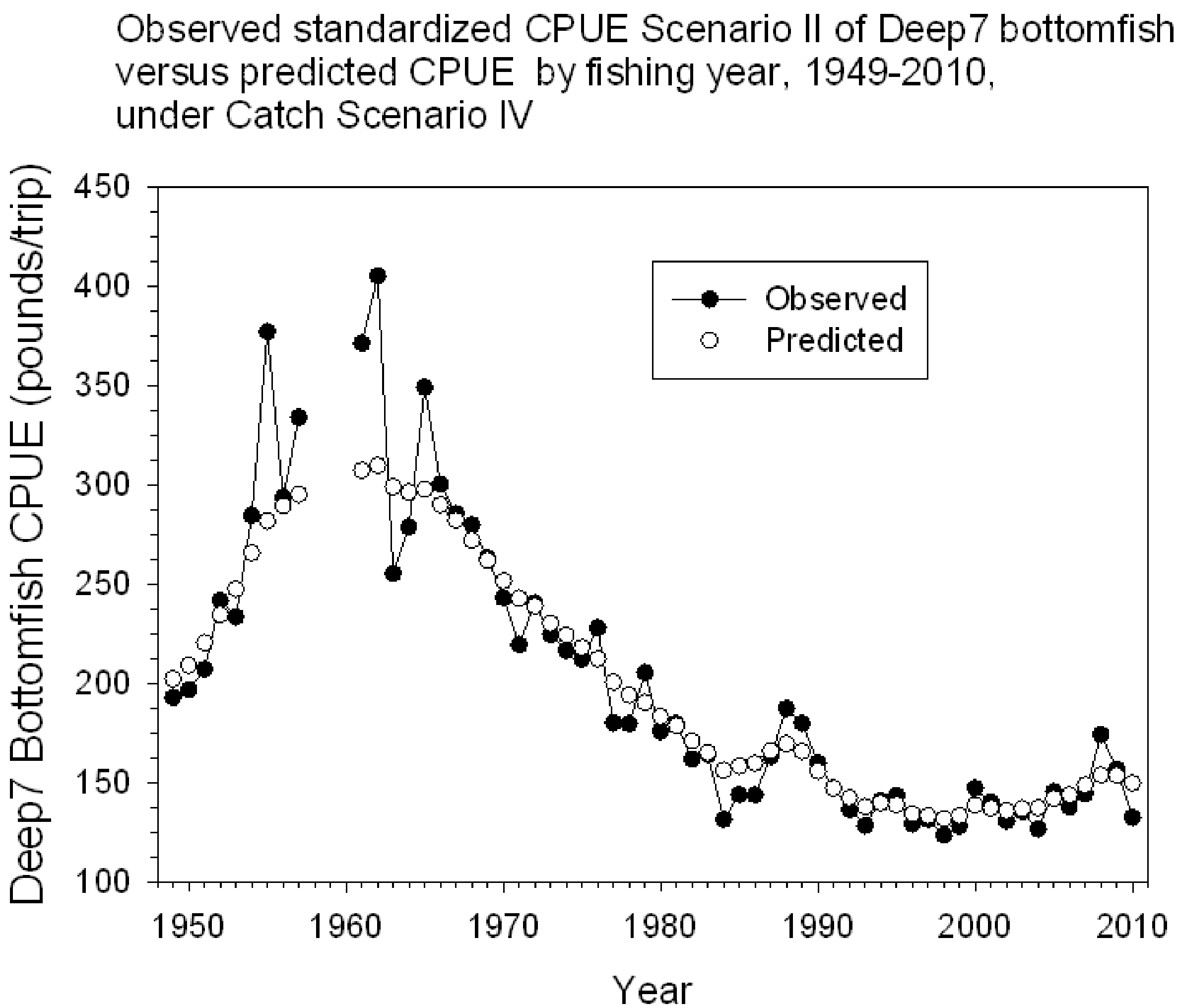


Figure A.11.2. Results of the catch Scenario IV CPUE Scenario II production model fit to the observed standardized bottomfish CPUE for the main Hawaiian Islands along with standardized log-scale CPUE residuals and P-values for linear regression hypothesis tests of whether standardized residuals have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

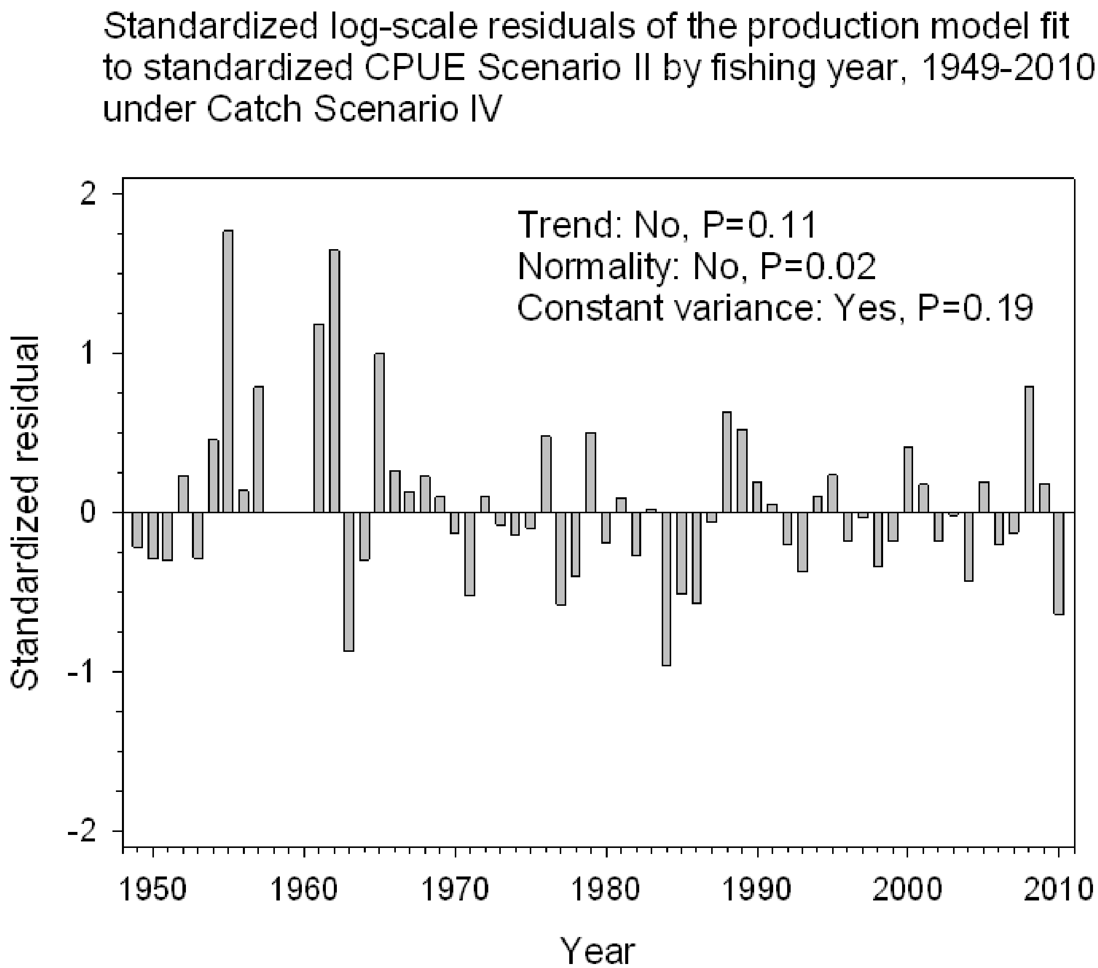


Figure A.12.1. Results of the catch Scenario IV CPUE Scenario III production model fit to the observed standardized bottomfish CPUE for the main Hawaiian Islands along with CPUE residuals.

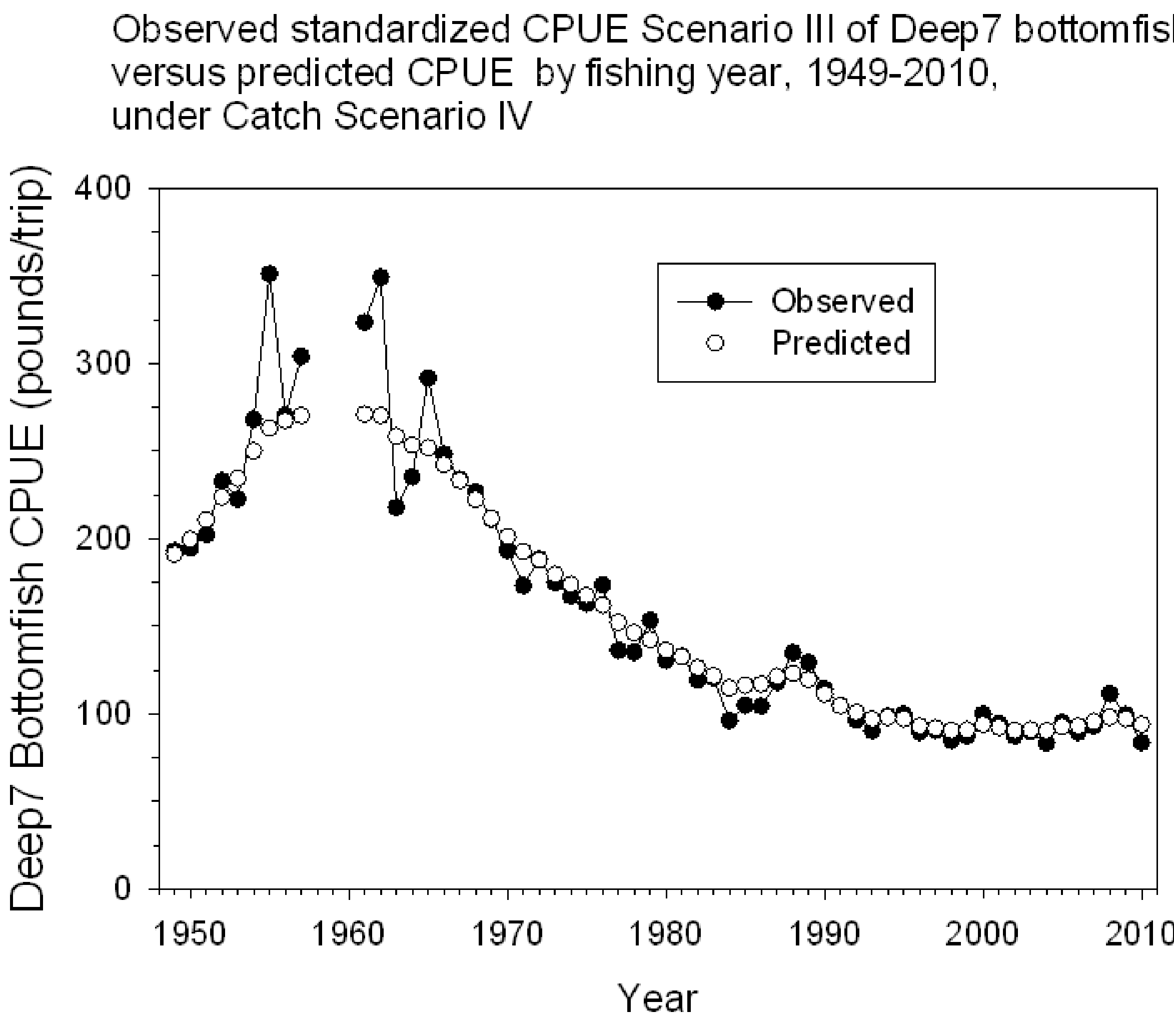


Figure A.12.2. Results of the catch Scenario IV CPUE Scenario III production model fit to the observed standardized bottomfish CPUE for the main Hawaiian Islands along with standardized log-scale CPUE residuals and P-values for linear regression hypothesis tests of whether standardized residuals have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

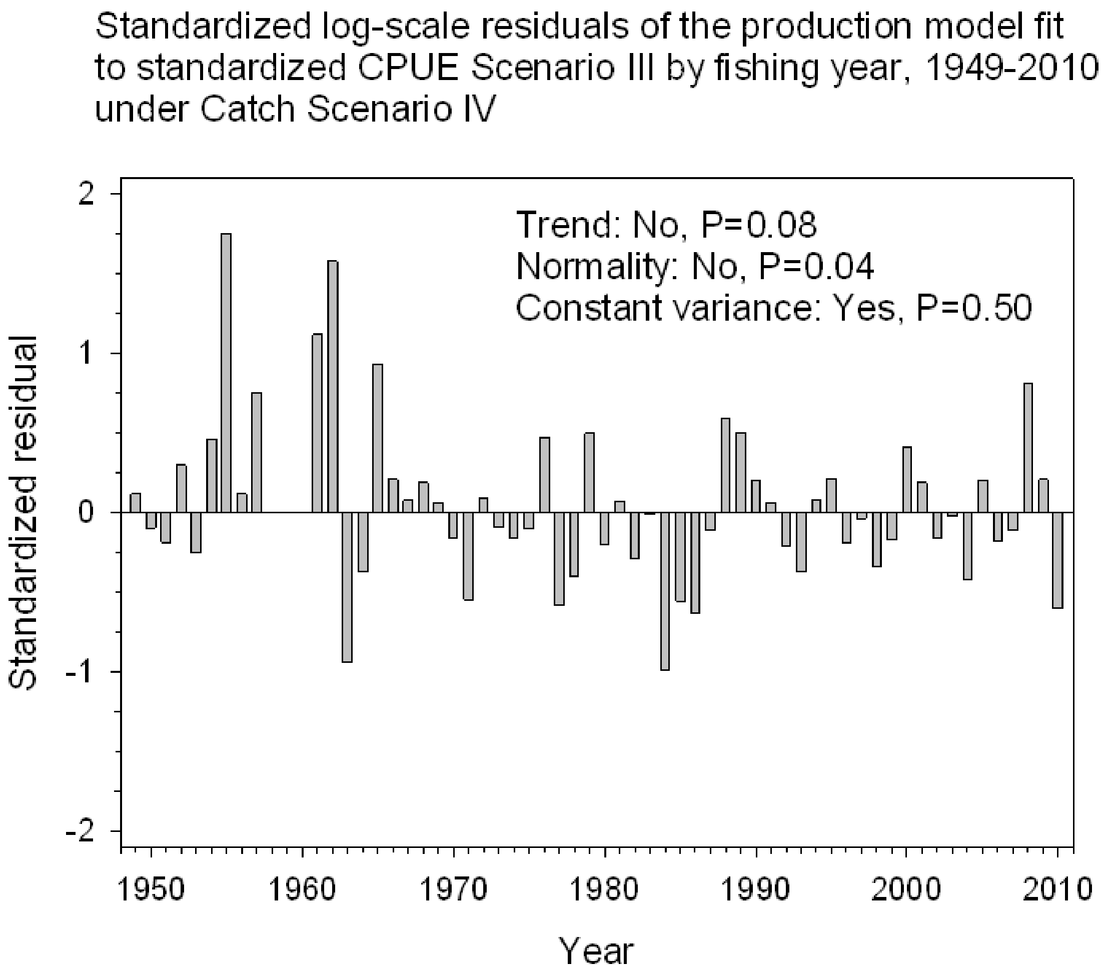
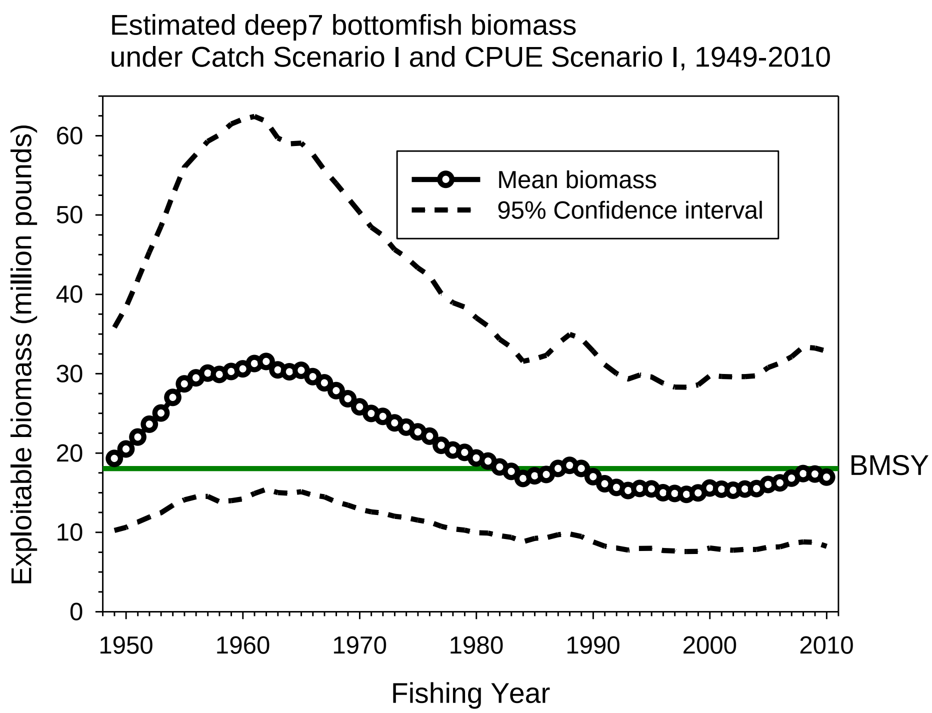


Figure A13. Sensitivity analyses of assessment results for exploitable biomass and harvest rate under catch Scenario I and CPUE Scenario I.



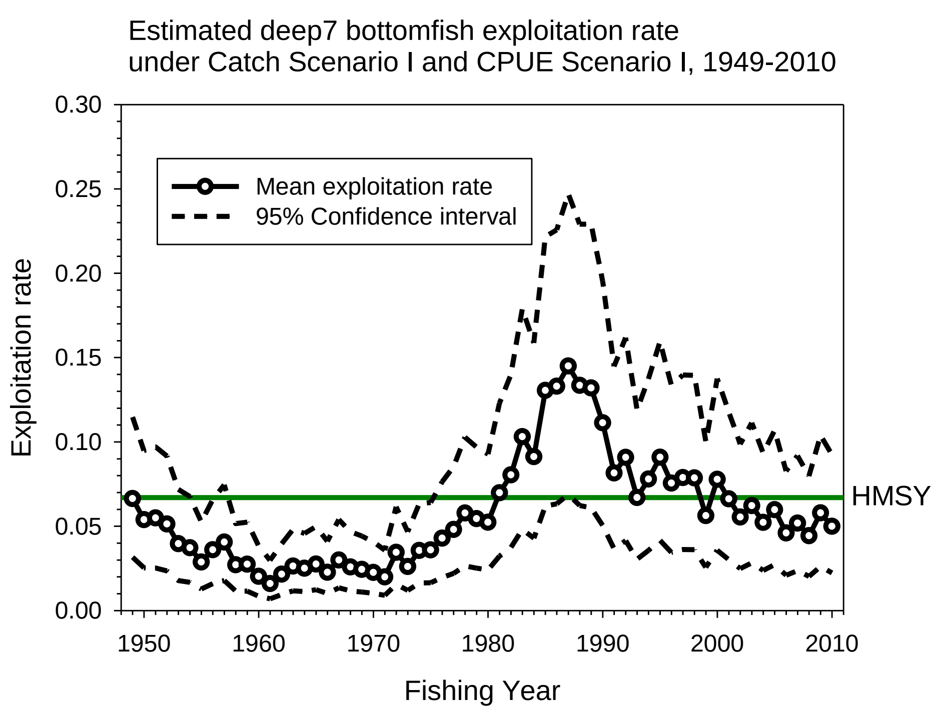
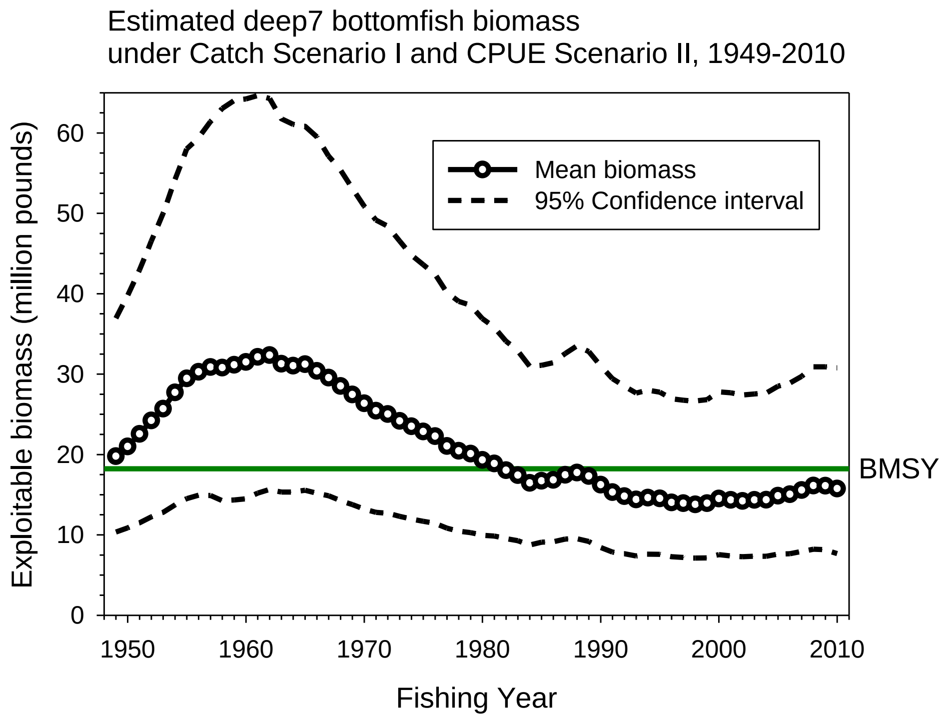


Figure A14. Sensitivity analyses of assessment results for exploitable biomass and harvest rate under catch Scenario I and CPUE Scenario II.



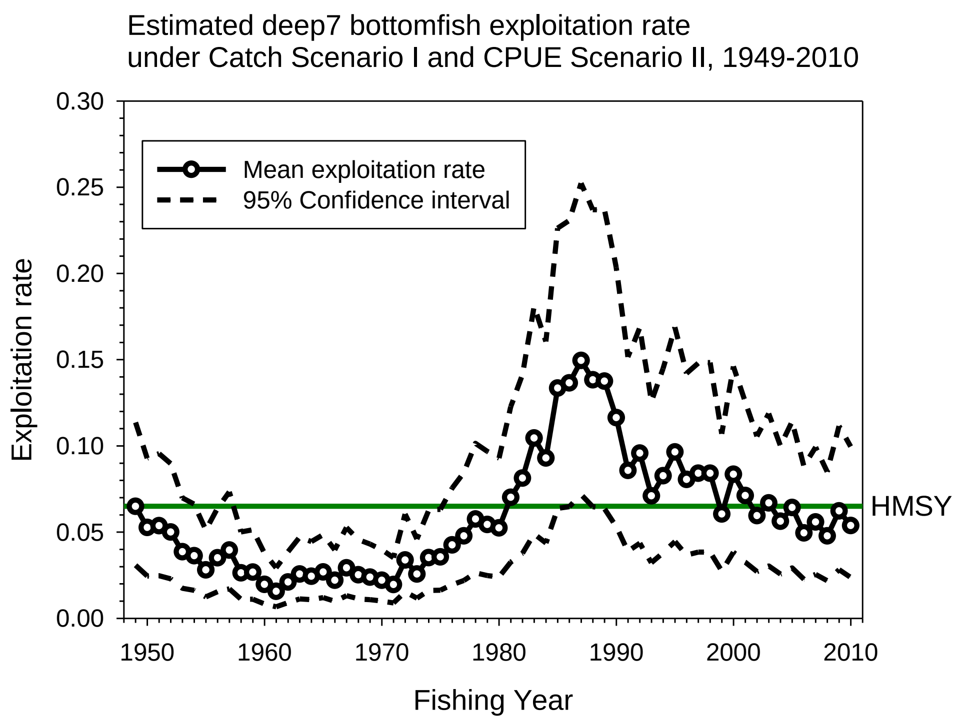
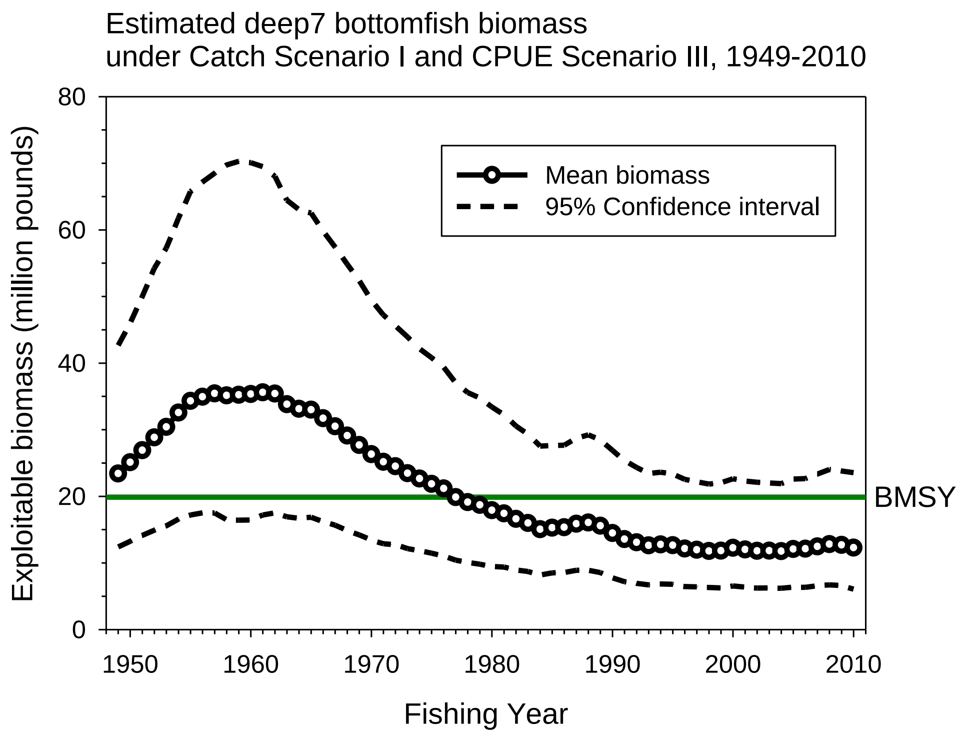


Figure A15. Sensitivity analyses of assessment results for exploitable biomass and harvest rate under catch Scenario I and CPUE Scenario III.



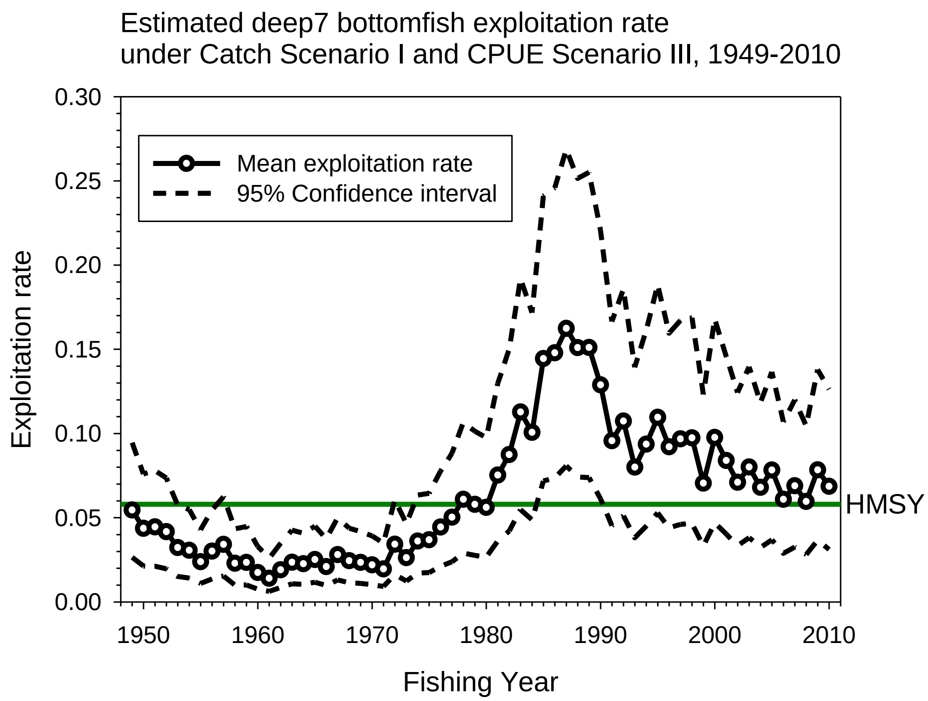
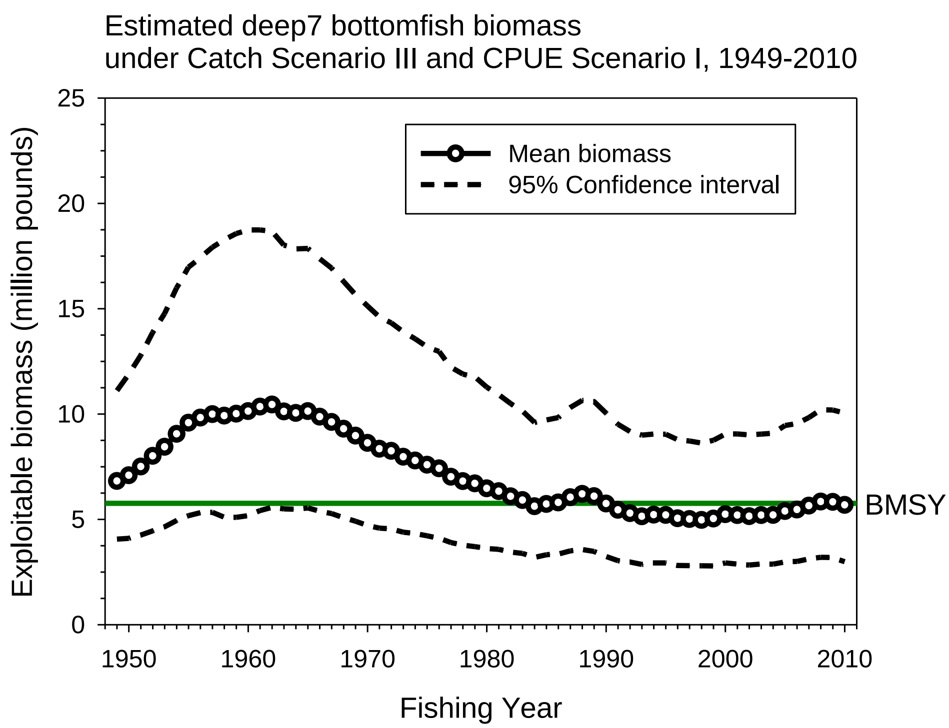


Figure A16. Sensitivity analyses of assessment results for exploitable biomass and harvest rate under catch Scenario III and CPUE Scenario I.



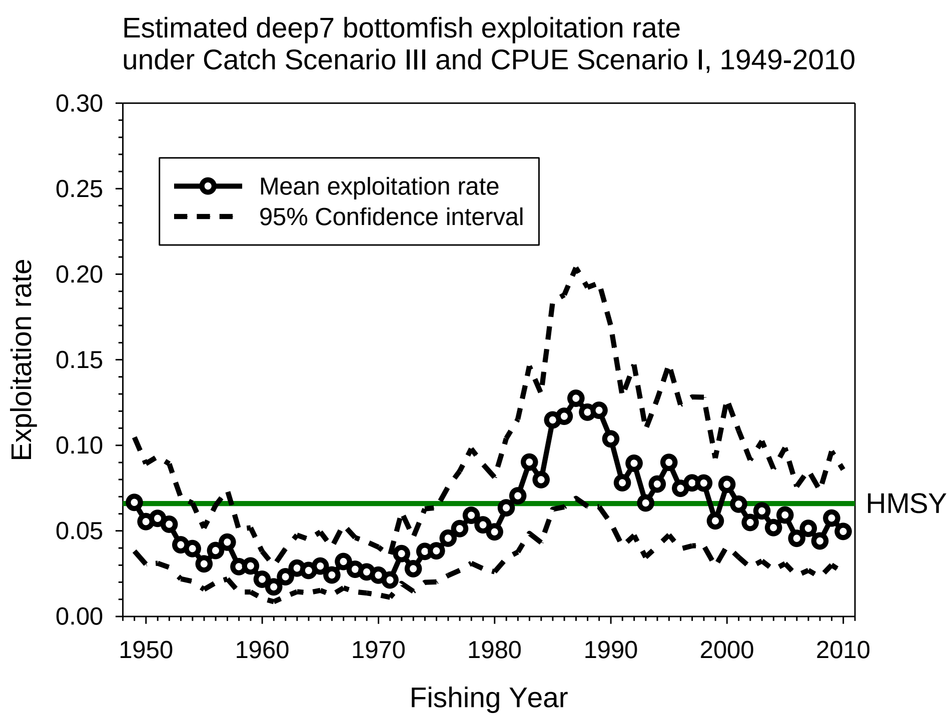
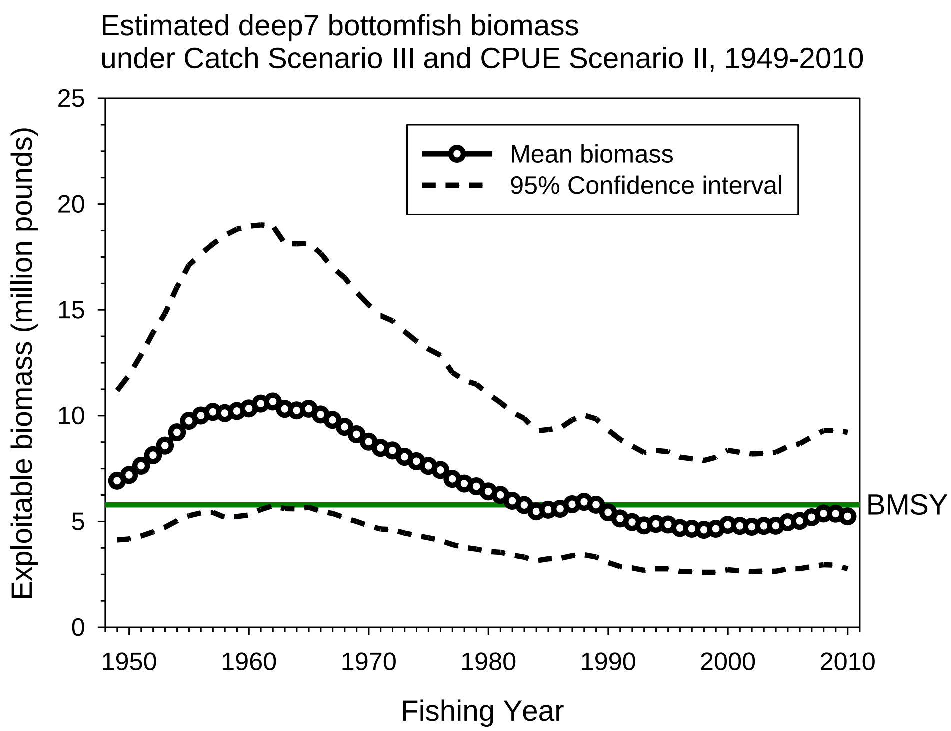


Figure A17. Sensitivity analyses of assessment results for exploitable biomass and harvest rate under catch Scenario III and CPUE Scenario II.



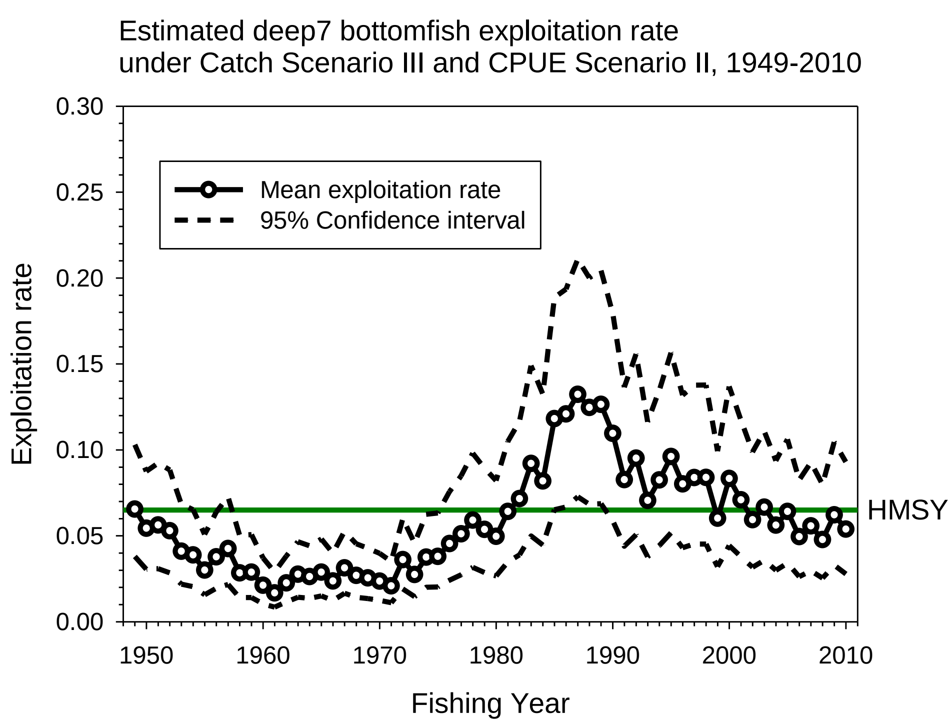
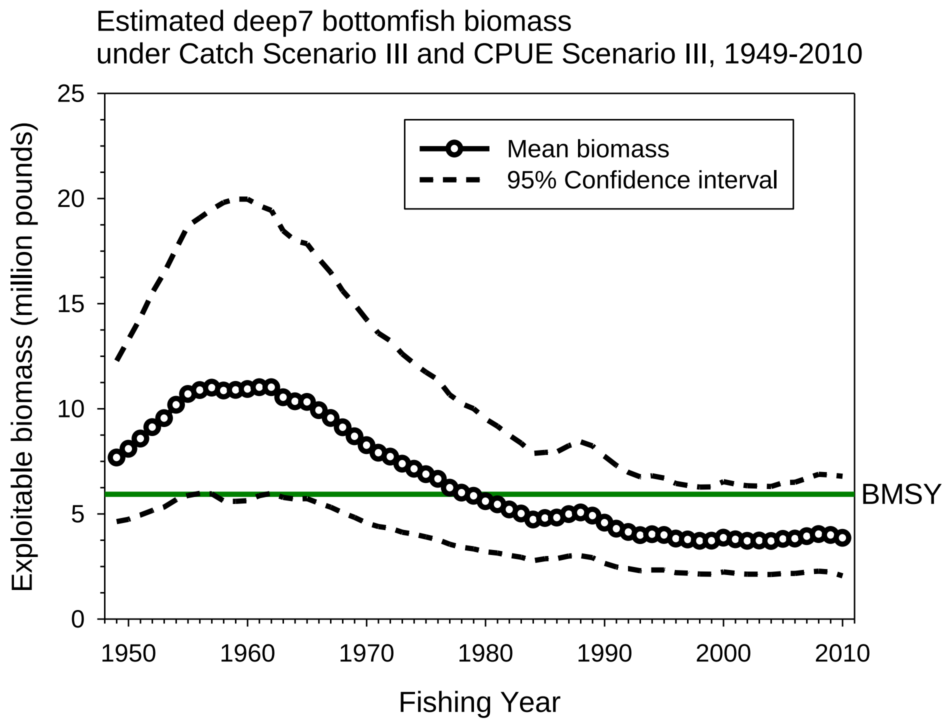


Figure A18. Sensitivity analyses of assessment results for exploitable biomass and harvest rate under catch Scenario III and CPUE Scenario III.



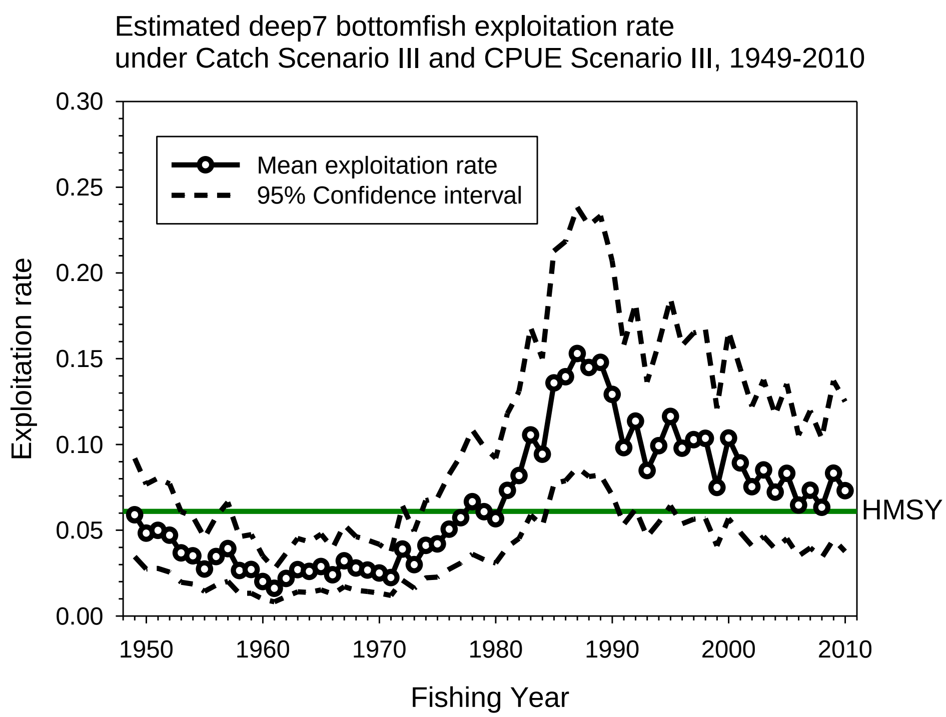
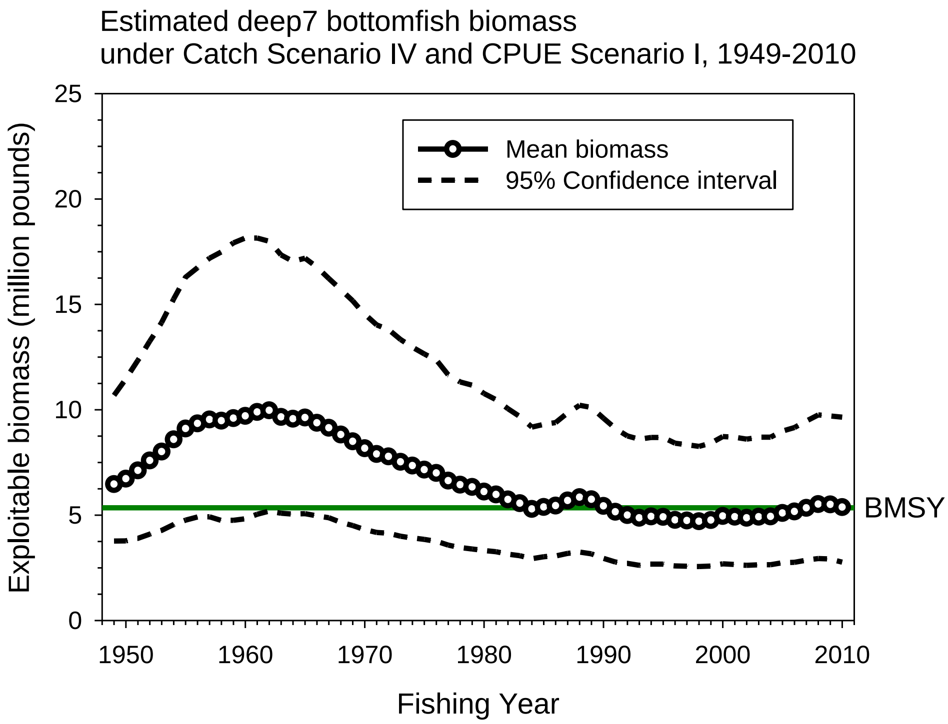


Figure A19. Sensitivity analyses of assessment results for exploitable biomass and harvest rate under catch Scenario IV and CPUE Scenario I.



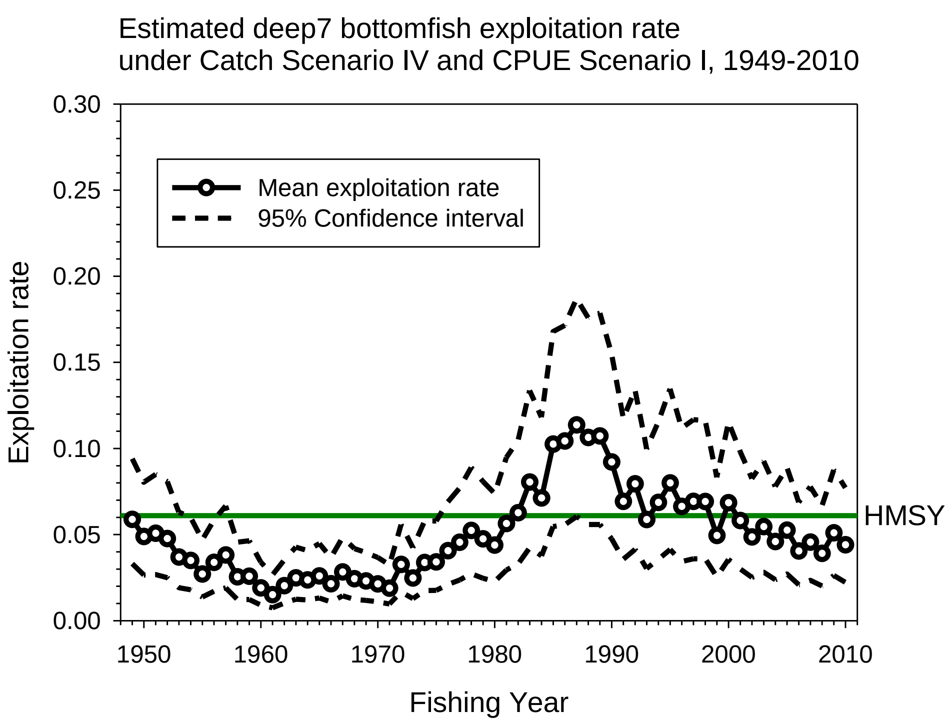
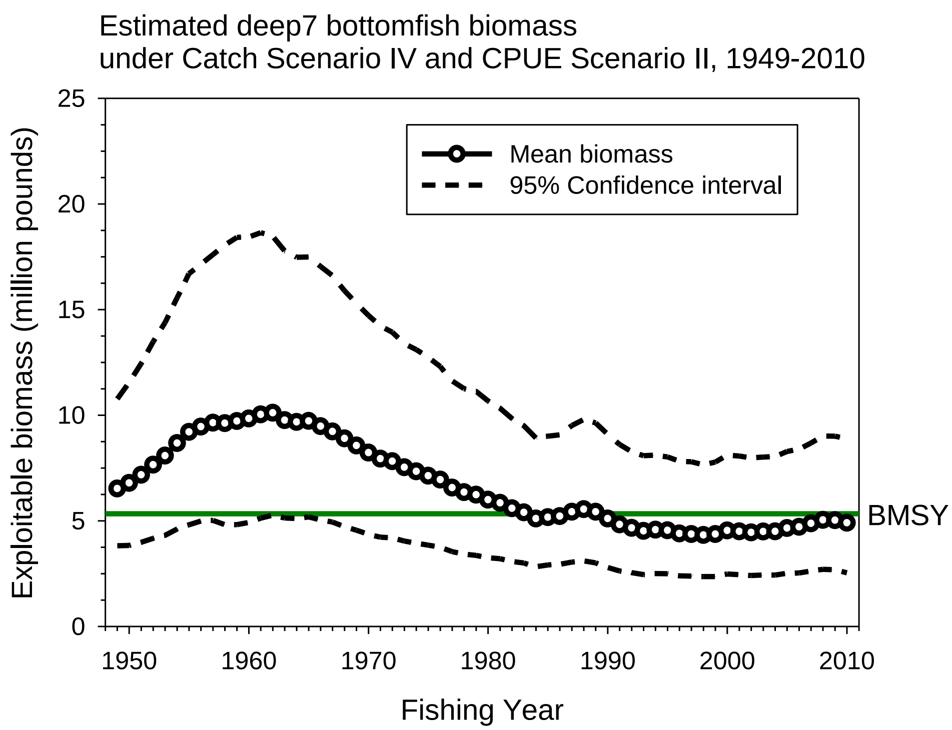


Figure A20. Sensitivity analyses of assessment results for exploitable biomass and harvest rate under catch Scenario IV and CPUE Scenario II.



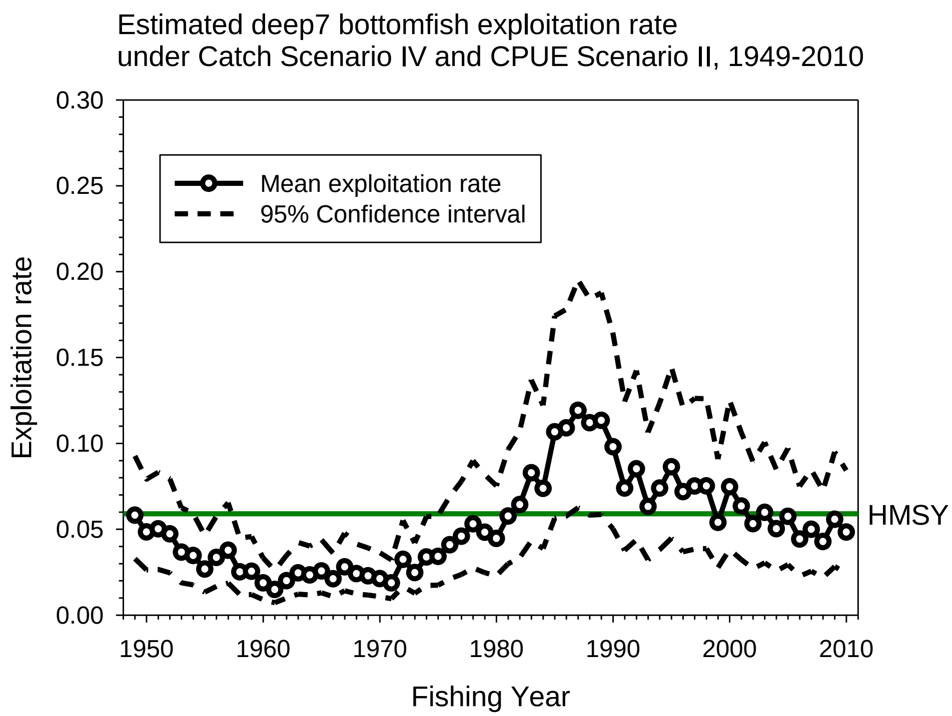
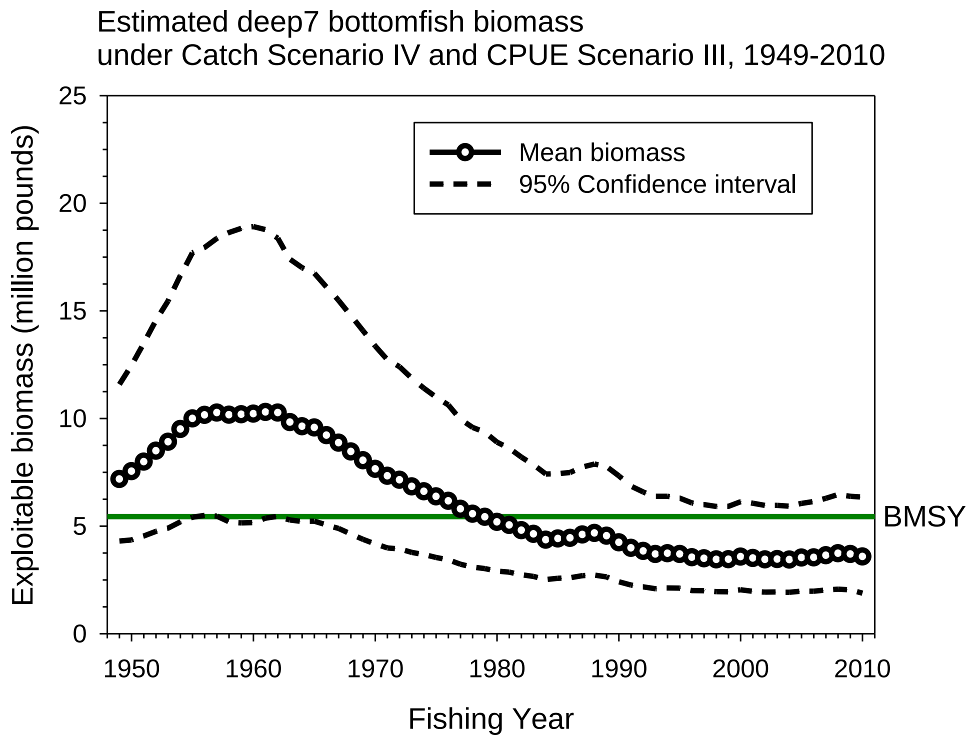


Figure A21. Sensitivity analyses of assessment results for exploitable biomass and harvest rate under catch Scenario IV and CPUE Scenario III.



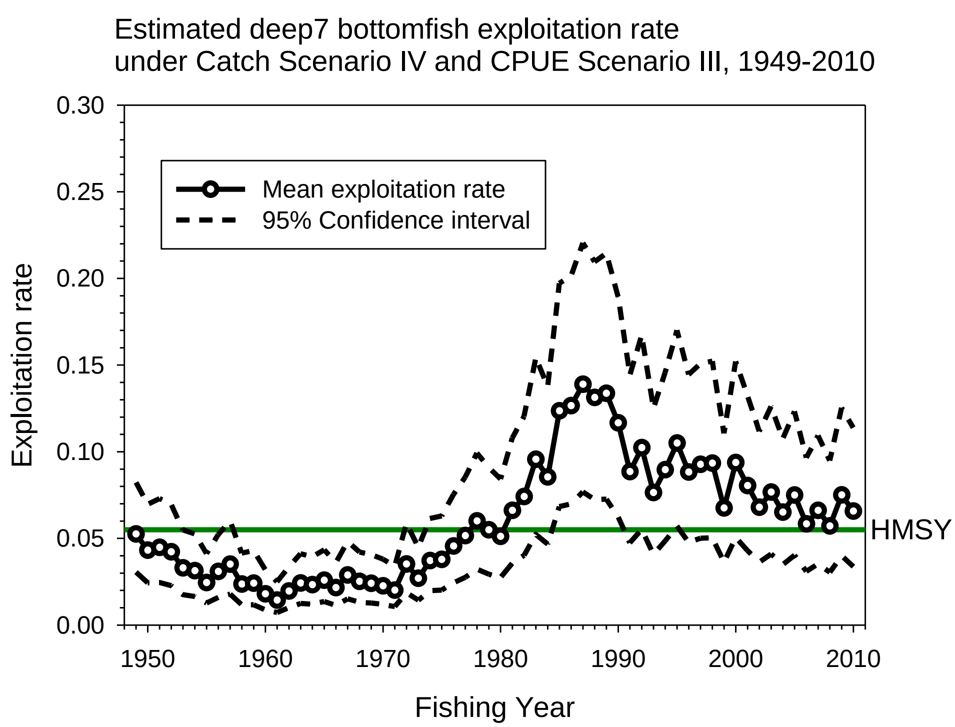


Figure A22. Sensitivity analyses of projection results for estimates of total allowable catches of Deep7 Hawaiian bottomfish for fishing years 2012-2013 that would produce a range of probabilities of overfishing in 2012 from 0% to 50% and greater under baseline catch Scenario I and CPUE Scenario I.

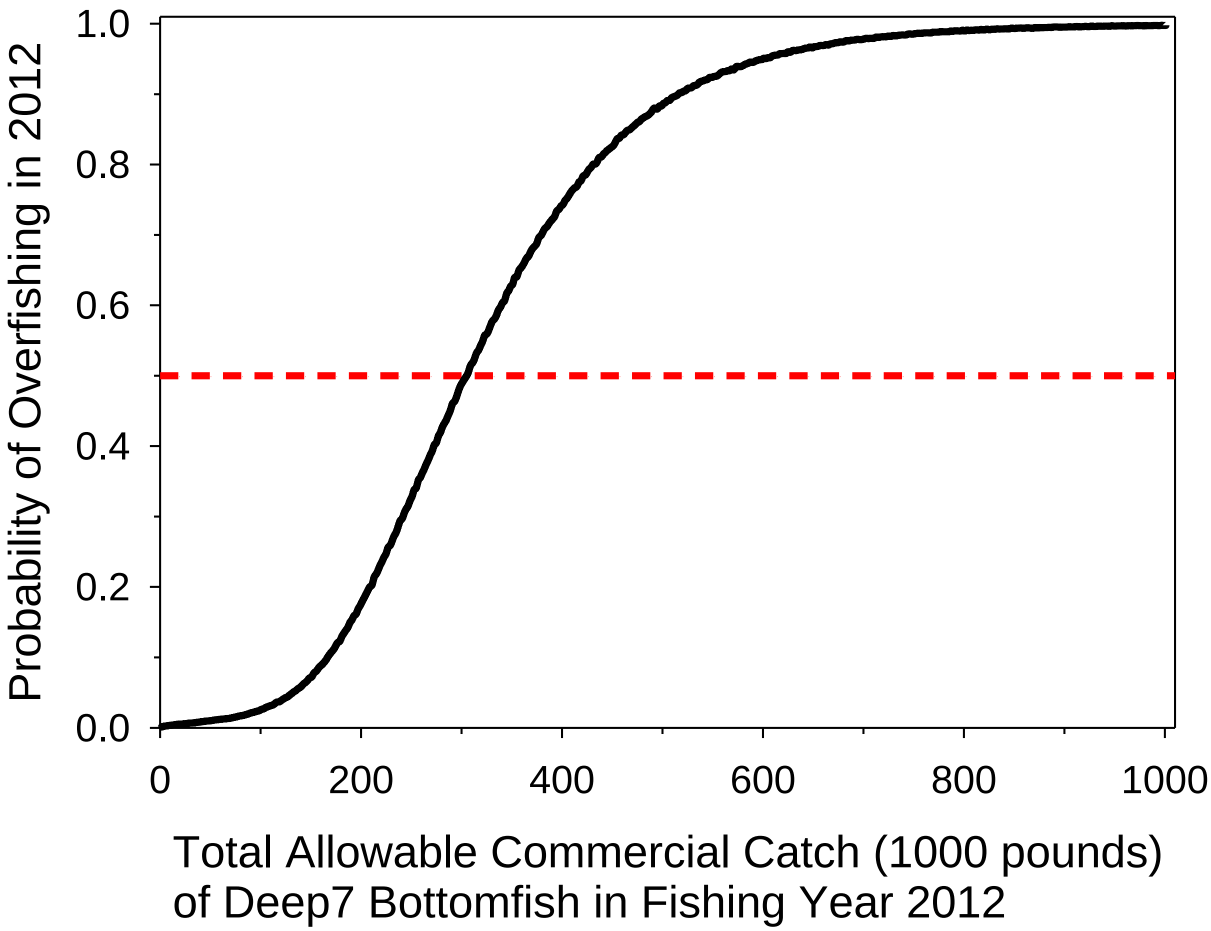


Figure A23. Sensitivity analyses of projection results for estimates of total allowable catches of Deep7 Hawaiian bottomfish for fishing years 2012-2013 that would produce a range of probabilities of overfishing in 2012 from 0% to 50% and greater under baseline catch Scenario I and CPUE Scenario II.

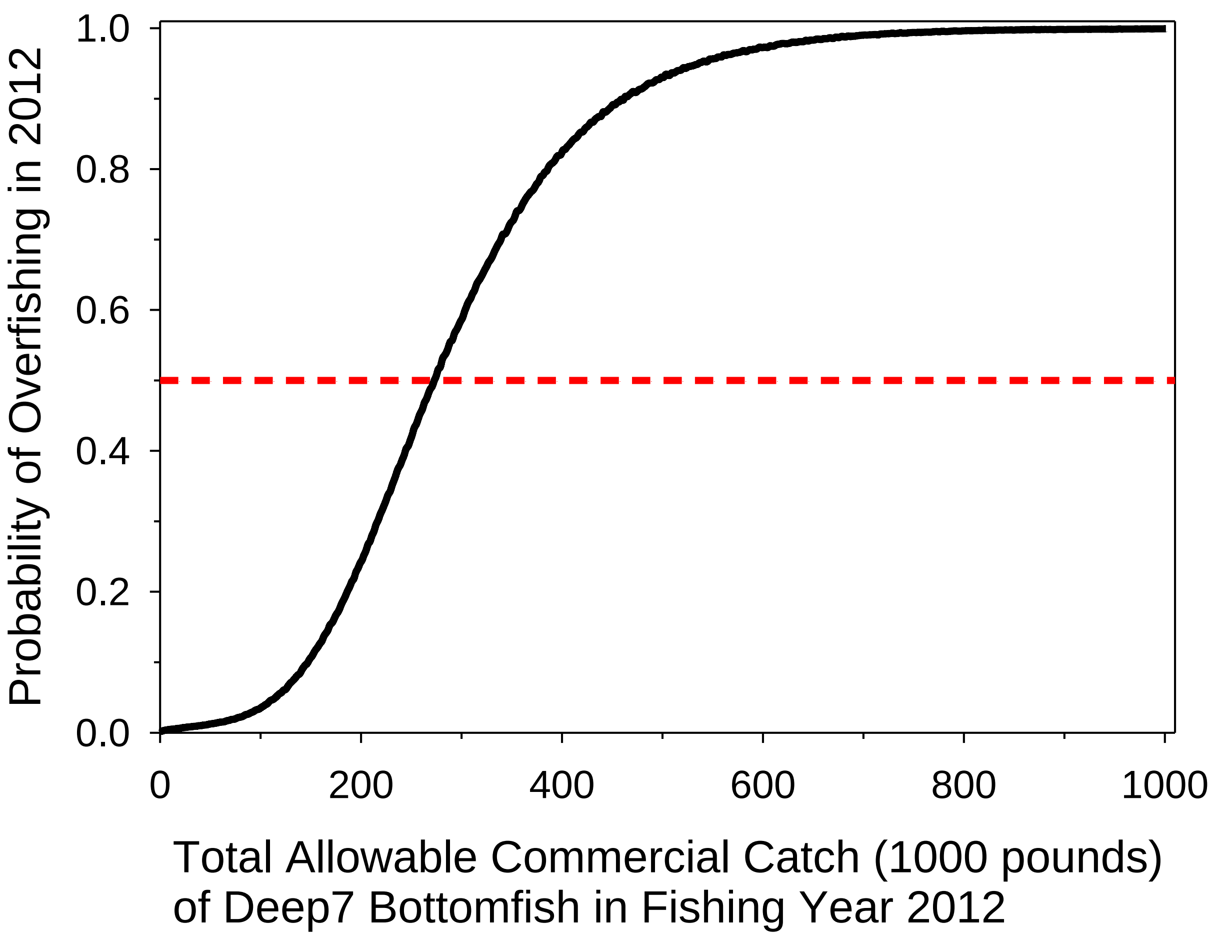


Figure A24. Sensitivity analyses of projection results for estimates of total allowable catches of Deep7 Hawaiian bottomfish for fishing years 2012-2013 that would produce a range of probabilities of overfishing in 2012 from 0% to 50% and greater under baseline catch Scenario I and CPUE Scenario III.

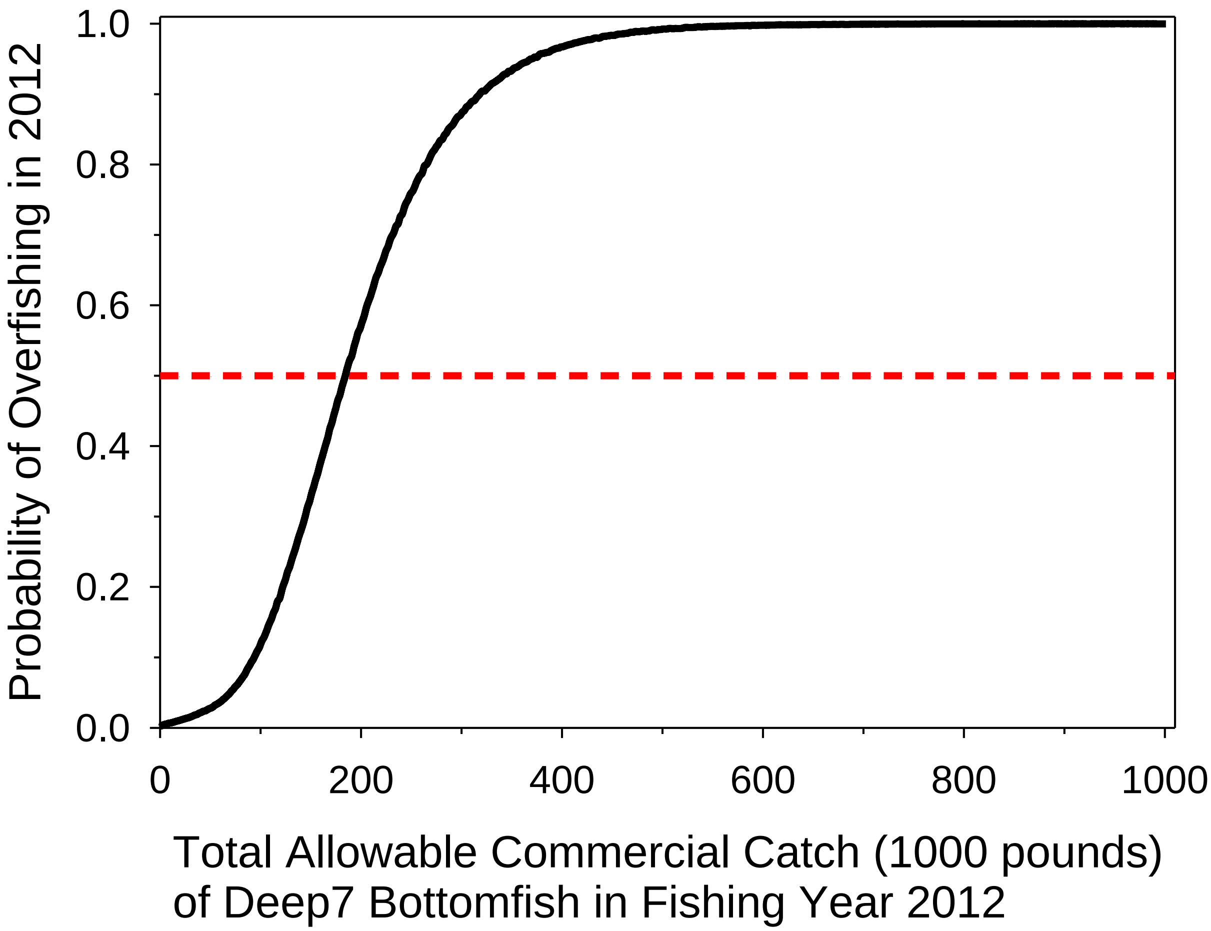


Figure A25. Sensitivity analyses of projection results for estimates of total allowable catches of Deep7 Hawaiian bottomfish for fishing years 2012-2013 that would produce a range of probabilities of overfishing in 2012 from 0% to 50% and greater under baseline catch Scenario II and CPUE Scenario IV.

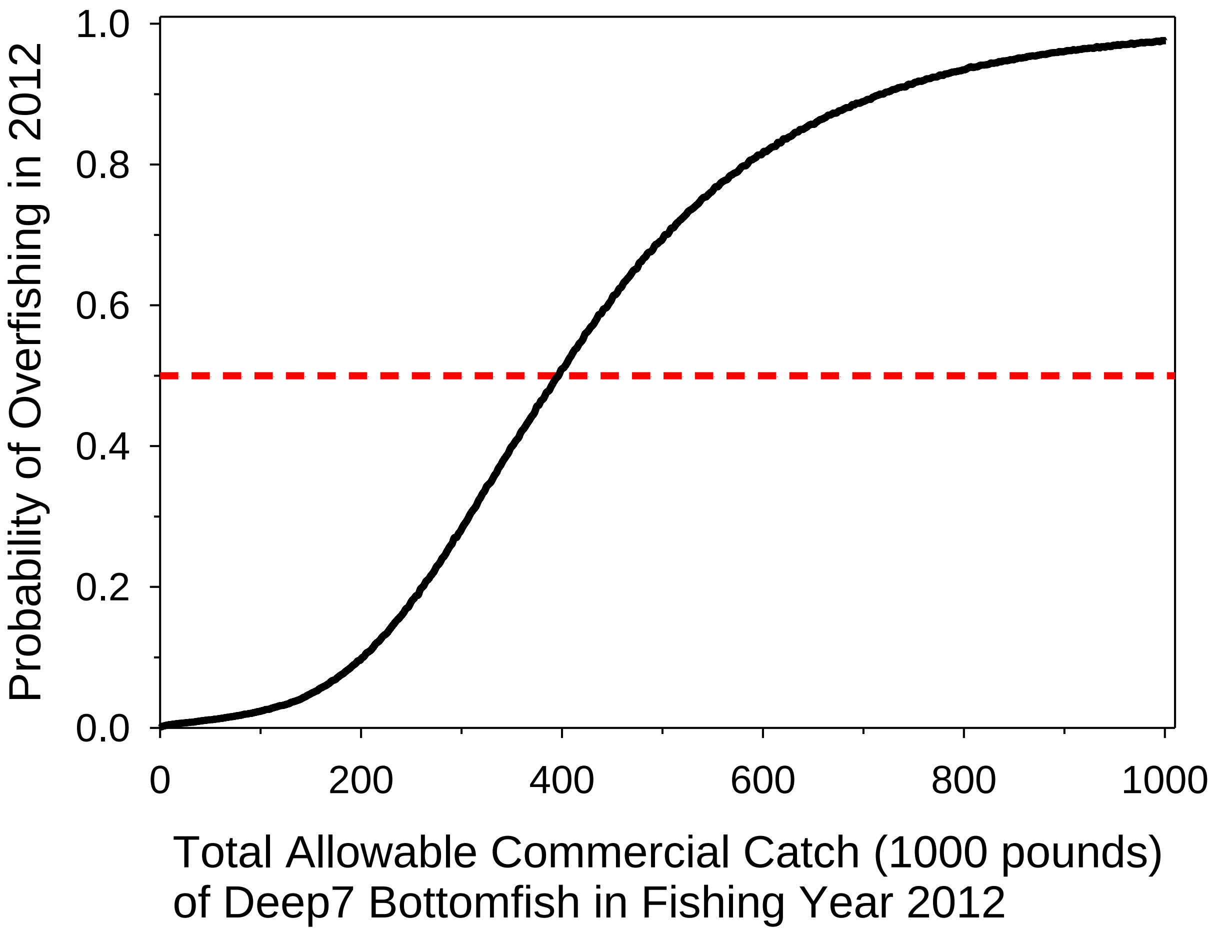


Figure A26. Sensitivity analyses of projection results for estimates of total allowable catches of Deep7 Hawaiian bottomfish for fishing years 2012-2013 that would produce a range of probabilities of overfishing in 2012 from 0% to 50% and greater under baseline catch Scenario II and CPUE Scenario V.

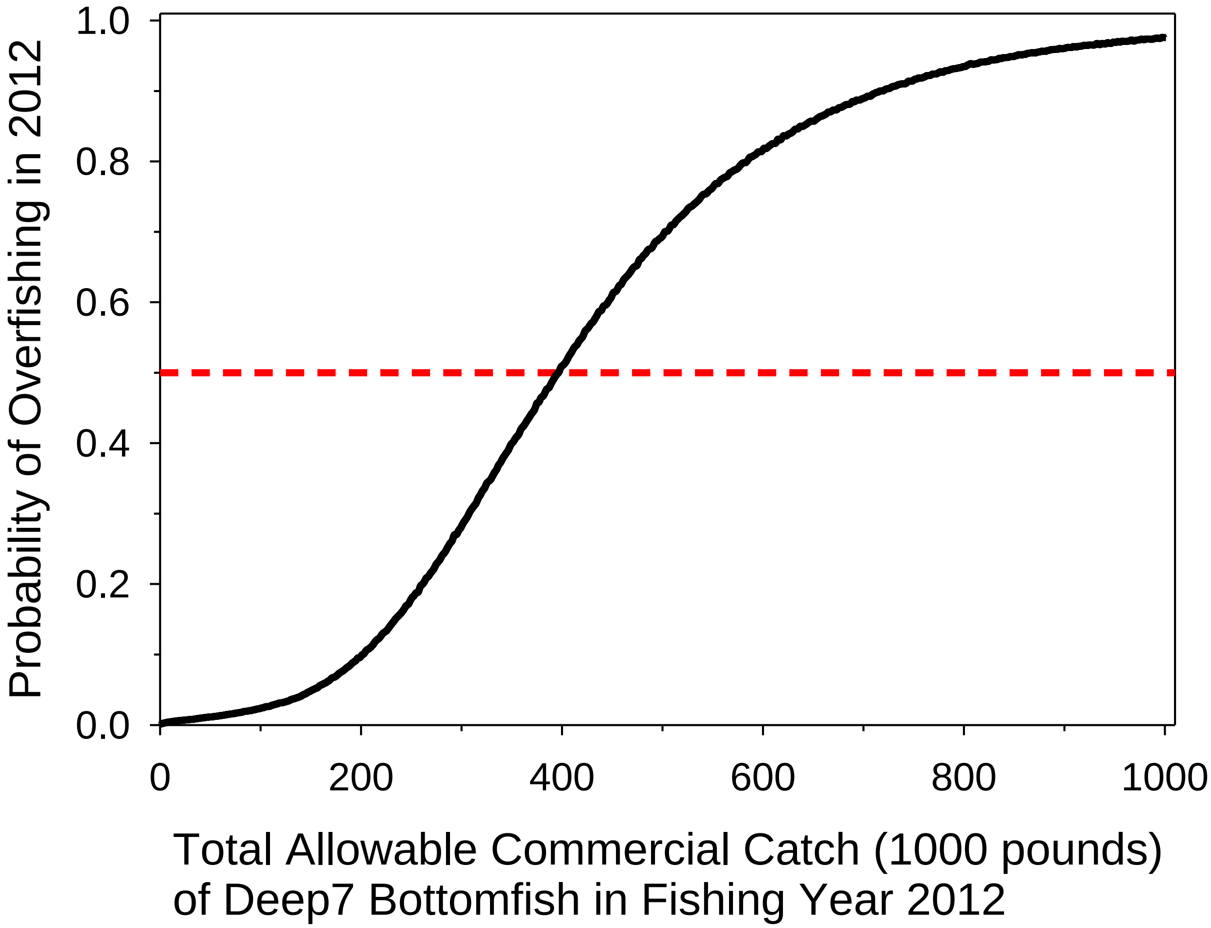


Figure A27. Sensitivity analyses of projection results for estimates of total allowable catches of Deep7 Hawaiian bottomfish for fishing years 2012-2013 that would produce a range of probabilities of overfishing in 2012 from 0% to 50% and greater under baseline catch Scenario II and CPUE Scenario Ib.

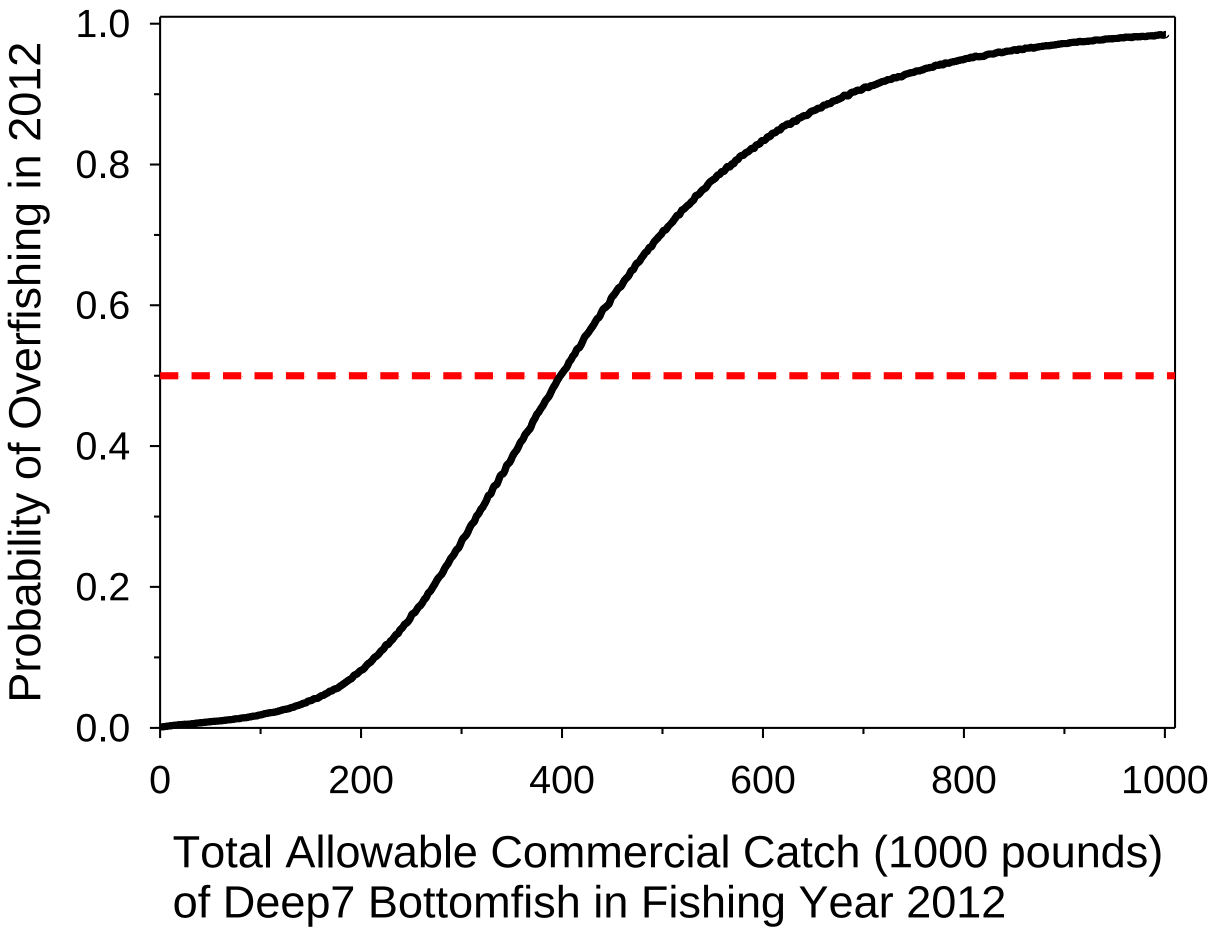


Figure A28. Sensitivity analyses of projection results for estimates of total allowable catches of Deep7 Hawaiian bottomfish for fishing years 2012-2013 that would produce a range of probabilities of overfishing in 2012 from 0% to 50% and greater under baseline catch Scenario III and CPUE Scenario I.

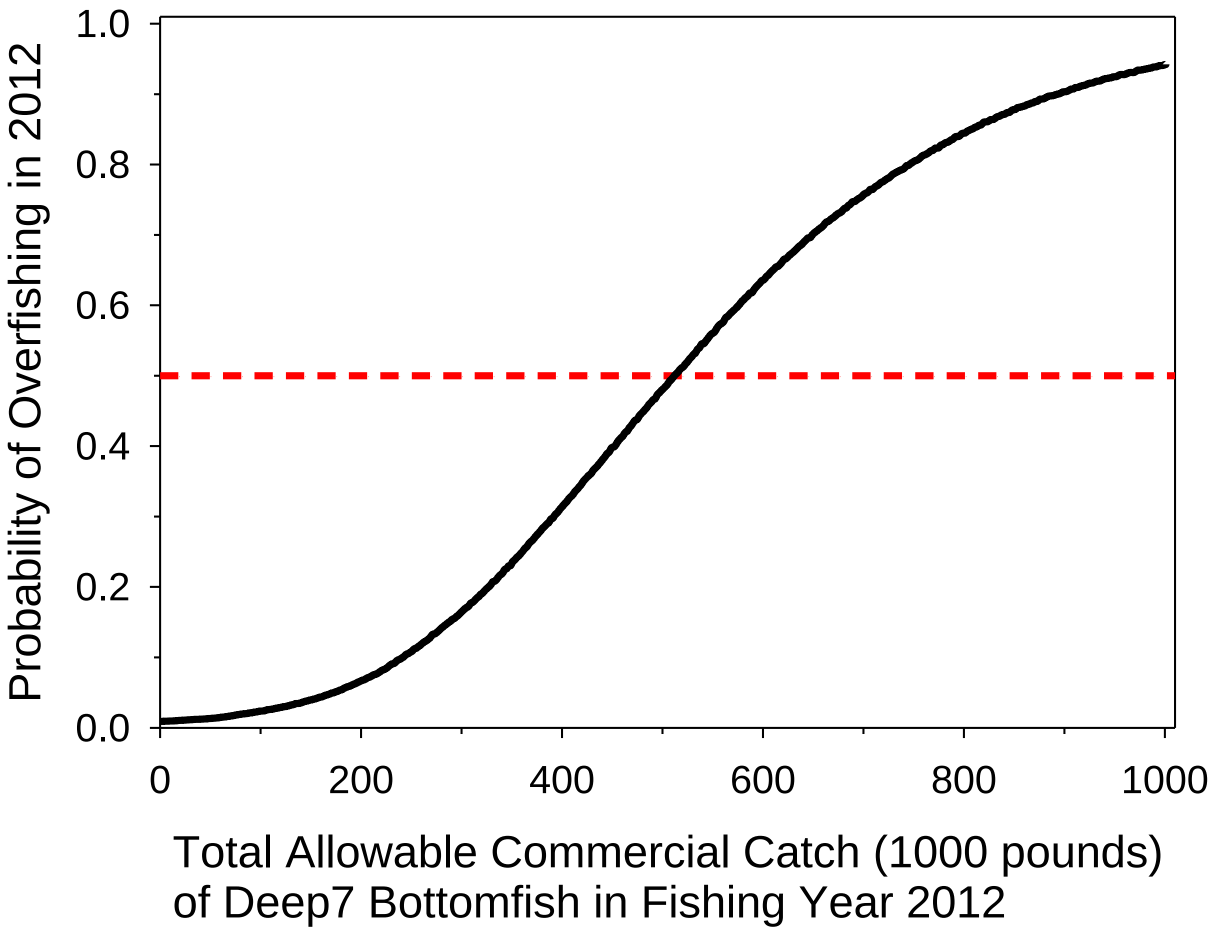


Figure A29. Sensitivity analyses of projection results for estimates of total allowable catches of Deep7 Hawaiian bottomfish for fishing years 2012-2013 that would produce a range of probabilities of overfishing in 2012 from 0% to 50% and greater under baseline catch Scenario III and CPUE Scenario II.

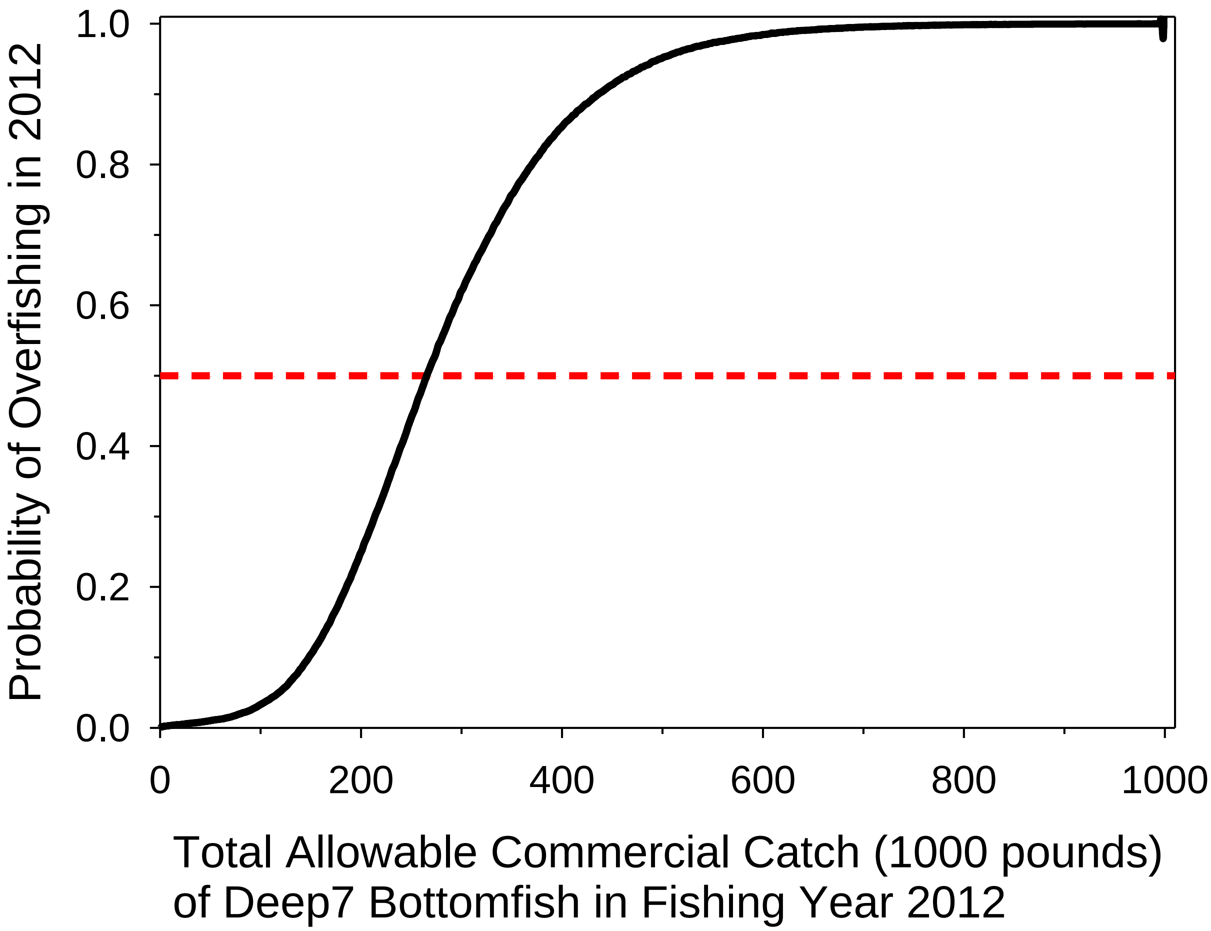


Figure A30. Sensitivity analyses of projection results for estimates of total allowable catches of Deep7 Hawaiian bottomfish for fishing years 2012-2013 that would produce a range of probabilities of overfishing in 2012 from 0% to 50% and greater under baseline catch Scenario III and CPUE Scenario III.

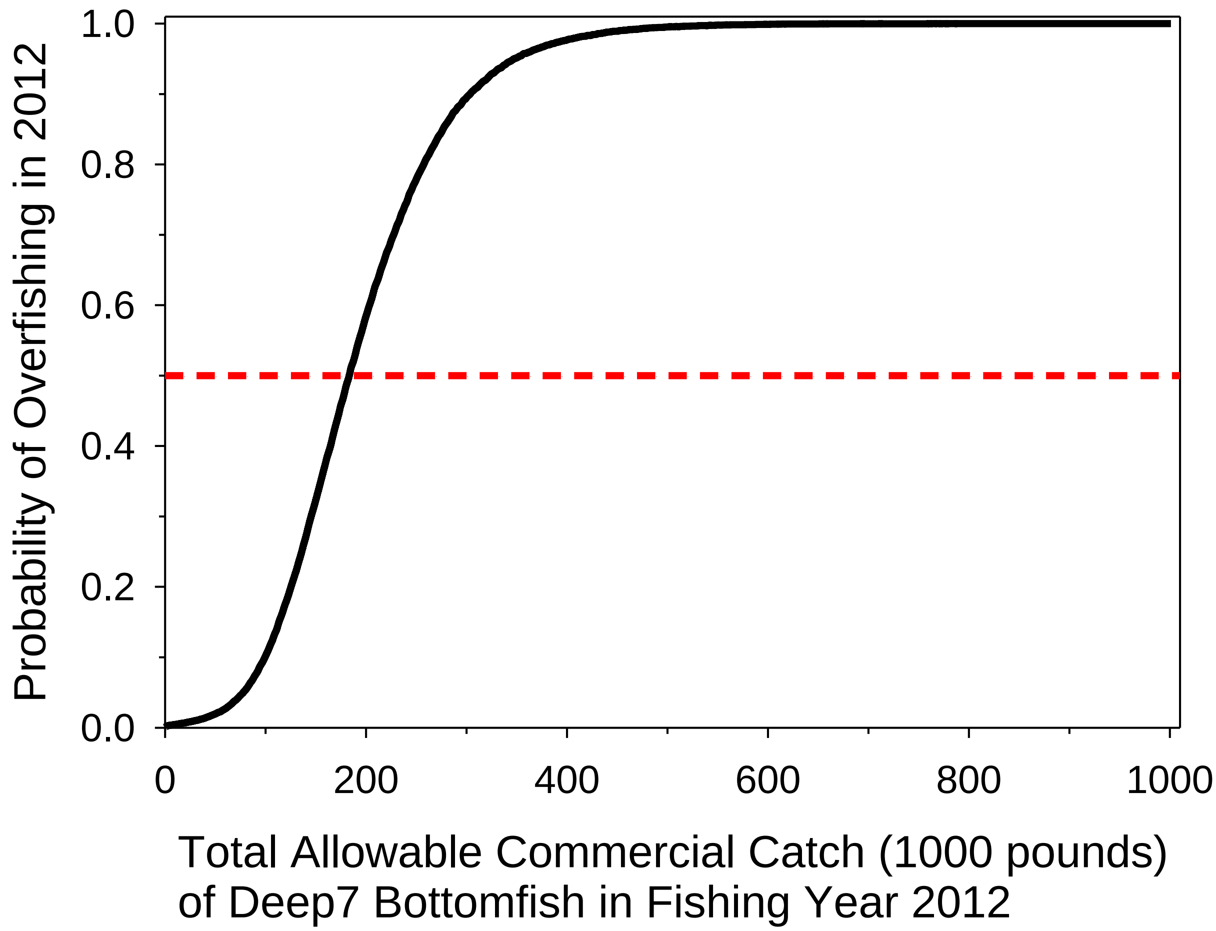


Figure A31. Sensitivity analyses of projection results for estimates of total allowable catches of Deep7 Hawaiian bottomfish for fishing years 2012-2013 that would produce a range of probabilities of overfishing in 2012 from 0% to 50% and greater under baseline catch Scenario IV and CPUE Scenario I.

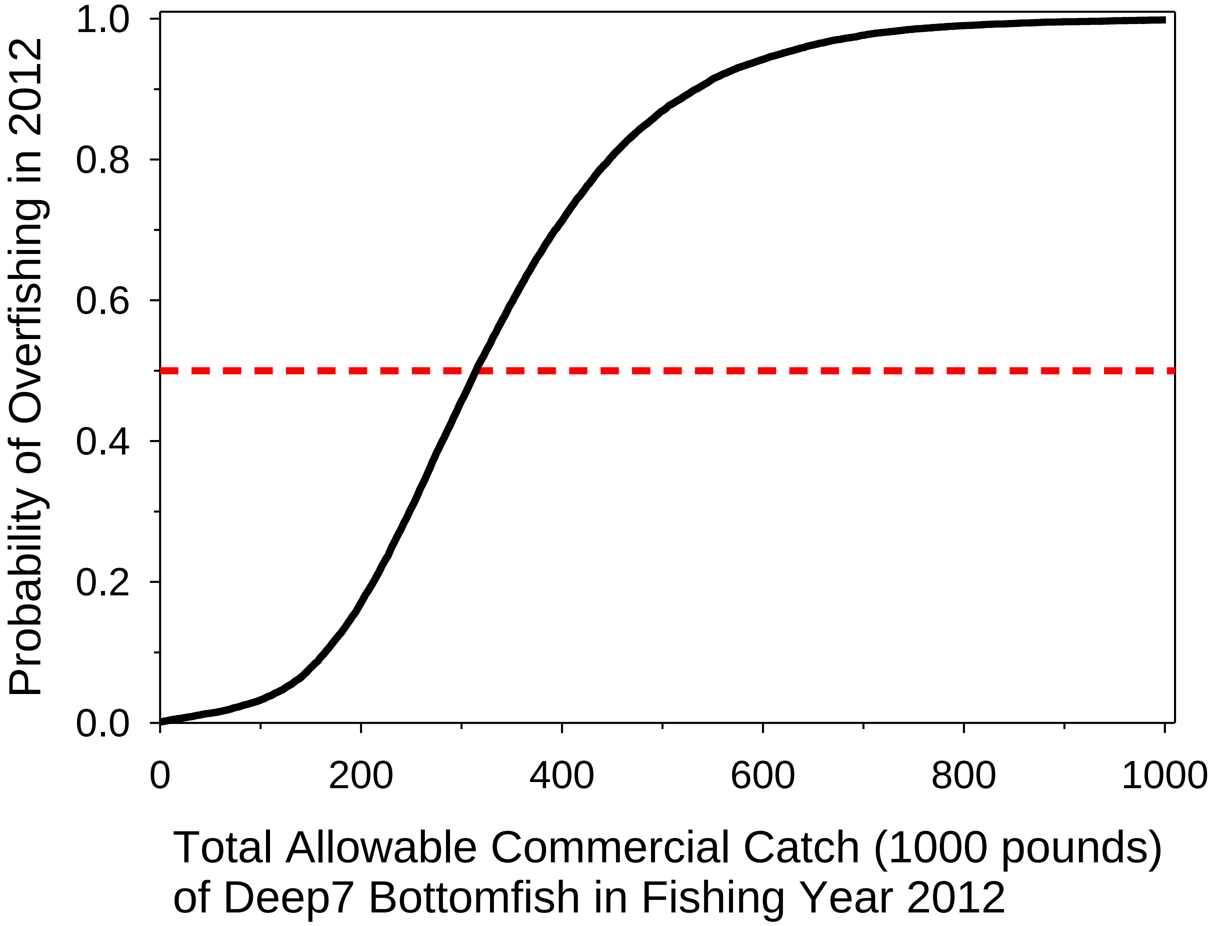


Figure A32. Sensitivity analyses of projection results for estimates of total allowable catches of Deep7 Hawaiian bottomfish for fishing years 2012-2013 that would produce a range of probabilities of overfishing in 2012 from 0% to 50% and greater under baseline catch Scenario IV and CPUE Scenario II.

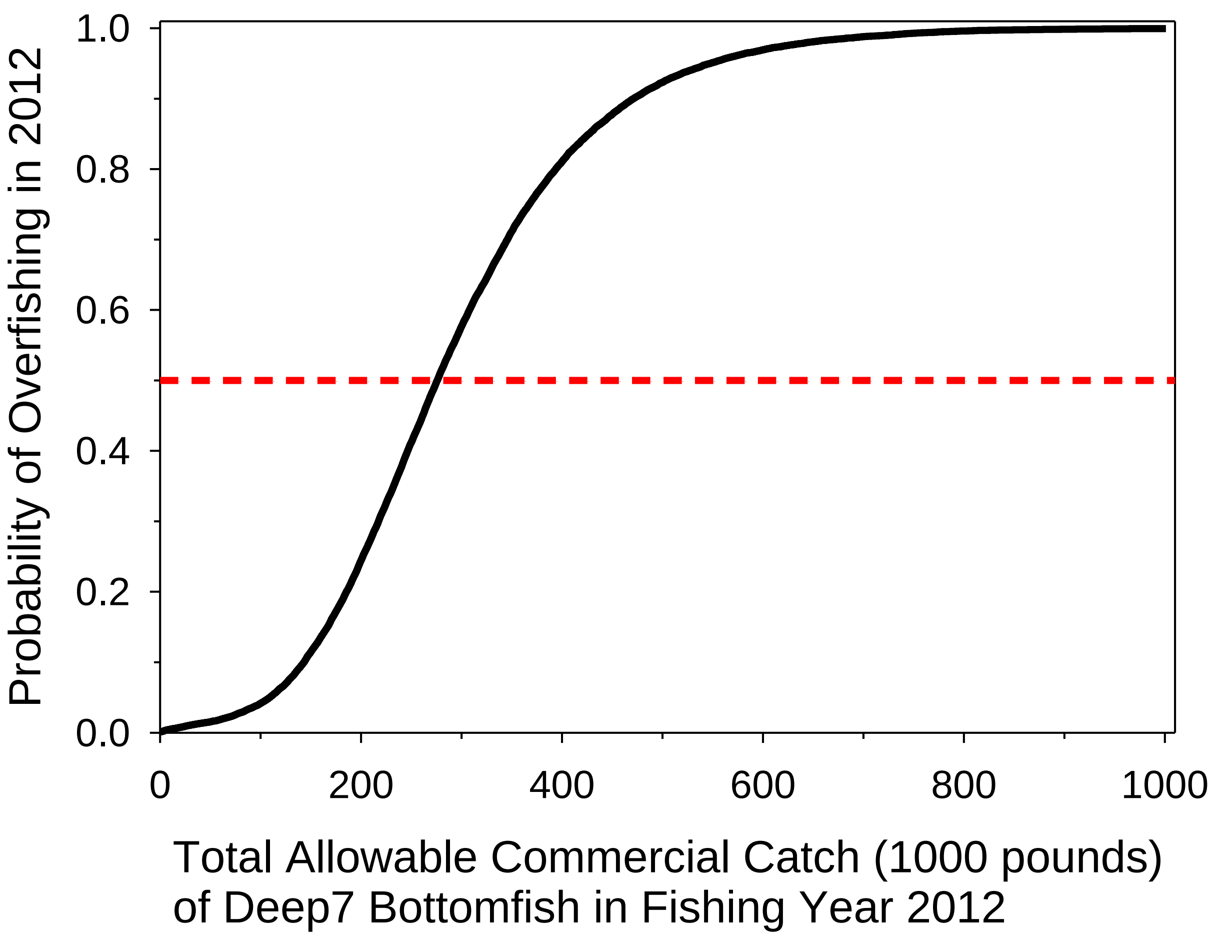


Figure A33. Sensitivity analyses of projection results for estimates of total allowable catches of Deep7 Hawaiian bottomfish for fishing years 2012-2013 that would produce a range of probabilities of overfishing in 2012 from 0% to 50% and greater under baseline catch Scenario IV and CPUE Scenario III.