ISC/14/PBFWG-1/03

Preliminary Population Dynamics Model for the Updated Stock Assessment of Pacific Bluefin Tuna

Hiromu Fukuda[1], Isana Tsuruoka[1], Yaoki Tei[1],
Kazuhiro Oshima[1], Hitoshi Honda[1] and Yukio Takeuchi[1]

[1.] National Research Institute of Far Seas Fisheries, 5-7-1, Shimizu-orido,
Shizuoka 424-8633, JAPAN

Corresponding author: fukudahiromu@fra.affrc.go.jp

Feb. 2014

Working document submitted to the ISC Pacific bluefin tuna Working Group, International Scientific Committee for Tuna and Tuna-Like Species in the North Pacific Ocean (ISC), 17-22 February 2014, La Jolla, San Diego, California, USA. **Document not to be cited without author's permission.**

The original version of this document used a CPUE time series with an error (ISC/14/PBFWG-1/07 appendix). Consequently, the results estimated in this document were slightly different from the stock assessment report 2014, which shows the corrected results.

Abstract

The model diagnostics and population dynamics results for the provisional updated stock assessment model are provided. The provisional model likely converges to a global minimum, with total negative log likelihood of 2411. Most of the parameters are estimated well by the updated model and not drastically changed from the last stock assessment held at 2012. However, a bootstrap analysis and retrospective analysis show the uncertainty of the terminal year's spawning stock biomass (SSB) and recruitment. The trend of SSB of the updated stock assessment model is similar with that of the last stock assessment. The highest SSB is occurred in 1961 (139,746 tons) and the second highest peak is in 1995 (86,601 tons). After the 1995, SSB is continuously declined until 2011 (25,114 tons) and the SSB of the terminal year (2012) is 26,270 tons. The recruitments after 2008 are lower for the updated stock assessment than those of the last stock assessment. The estimated recruitment of 2011 and 2012 are lower than the historical average and the average recruitment of most recent 5 years (2008-2012) is also lower than the historical average. The current level of fishing mortality ($F_{2009\text{-}2011}$) was estimated to be higher than all listed BRPs (F_{max}, $F_{0.1}$, F_{med}, F_{loss} and $F_{10\%\text{-}40\%}$) except F_{loss}.

1 Introduction

The latest full stock assessment was conducted by ISC Pacific Bluefin Tuna Working Group (PBFWG) in 2012 at Hawaii with the fishery data from 1952 to 2010 (Anon. 2012). At that time, there were 20 trial runs, which considered the possible uncertainties of input data and method to weight the data, as well as method to estimate selectivities. All these trial runs commonly depicted large long-term fluctuations in spawning stock biomass (SSB) and a highly depleted stock that has been declining for over a decade. Model estimates of current biomass are at or near the lowest level. In addition to these stock assessment results, newly available fishery data (CPUE and catch of 2011) suggested the potential risk of further declining of the SSB in recent years. Under these circumstances, PBFWG proposed to conduct an updated stock assessment with the additional two years fishery data to closely track the stock status by modeling the most recent data and to pay close attention to recruitment trends (Anon. 2013a). This proposal was approved in the 13th ISC plenary (Anon. 2013b).

For this updated stock assessment, the PBFWG members provided all required fishery data (Catch, CPUE, and size composition) of recent two years (Oshima et al., 2014), and updated the stock assessment model mostly in accordance with the original work plan (Fukuda et al., 2014). In this document, we provide the diagnostics of the provisional updated stock assessment model, and the results of a model run.

2 Diagnostics of Provisional Model

2.1 Model Convergence Diagnostics

The provisional model updated by Fukuda et al. (2014) converges with maximum gradient of 1.1×10^{-4} and total negative log likelihood of 2411. The jitter runs of 100 times showed that the model likely converges to a global minimum, with no evidence of further improvements to the total likelihood (Fig. 1).

2.2 Bootstrap Analysis

A bootstrap analysis of 300 times replicated are conducted. The estimated 90% confidence interval (CI) of SSB is wide from 1950's to 1960's and becomes narrow in 1970's onward (Fig. 2a). The point estimates of SSB tended to be higher than the median of bootstrap analysis though, all of point estimates were in 90% CI.

The estimated 90% CI of the recruitment was narrow throughout the assessment period and some of the point estimates were out of 90% CI (Fig. 2b). The estimated CI of recruitments is especially narrow in recent 20 years though, the CI of only terminal year (2012) is expanded.

2.3 Retrospective analysis

Retrospective analysis is conducted to assess the consistency of stock assessment results by sequentially eliminating data (Catch, CPUE, and size composition) from the terminal year while using the same model configuration. The results show a tendency of under-estimation in the SSB for recent 3 terminal years (2009, 2010, 2011) and over-estimation in the terminal year of 2007 and 2008. The SSB between 1993 and 2002 has a tendency of under-estimation except one-year-dropped model (Fig. 3a).

The recruitments of the terminal year show a tendency of over-estimation in 2009, 2010, and 2011, and a tendency of under-estimation in 2007 and 2008. In addition to those, the recruitments of the year classes from 2000 to 2004 tended to be overestimated (Fig. 3b).

2.4 Likelihood Profile regarding to log R0

The negative log likelihood values calculated in each fixed R0 value ranged from 9.2 to 9.9 are plotted in Figure 4. These plots indicate that the most influential component to the log R0 is the recruitment deviates penalty and this was also found in the previous stock assessment (Teo and Piner, 2013). Among available CPUEs, S1, S3 S5, and S9 are influential. Among the available size compositions, F2, F5, and F12 which caught juvenile PBFT strongly influence on the low side of R0, and some of the Set-net Fleets (F7 and F9) influence high side of R0. Note that some of the components have a one-way decreasing slope to the low side (CPUE of S1 and size composition of F7) or to the high side (size compositions of F2, F5, and F8) without having a minimum values of the negative log likelihood within a given range of R0.

3 Preliminary Population Dynamics of Updated Stock Assessment

3.1 Parameters estimated

Standard deviations of the estimated main recruitment deviations are smaller in 1990's and 2000's than the others (Fig. 5). This indicates that there are well informative data to estimate recruitments during this period. Newly estimated main recruitment deviations in this updated stock assessment are of 2010 and 2011, and those are within the input recruitment variability ($\sigma R = 0.6$).

Most of the selectivity parameters are not drastically changed in this update from the last assessment and relatively well estimated (Fig. 6). For Fleet1, the selectivity of the late period (after 1993) has been changed from the last stock assessment, the early period (1952-1992), on the other hand, is not changed. At the last stock assessment, the descending width parameter and the position of the last bin parameter of Fleet 1 were not well estimated especially in the late period (CV = 36 and 505%, respectively) due to the lack of information for the estimations (Anon. 2012). Thus, the estimated selectivity parameters of the late period of Fleet 1 might not be robust to the adding the information by the data update. In the updated model, a tail of the selectivity curve of high side is shifted to the bigger size in the late period of Fleet 1.

The selectivity parameters for the Taiwan longline fishery (Fleet 11), which was assumed to have an asymptotic selectivity, are not changed from the last stock assessment and are well estimated. Both the estimated length at 50% selectivity and width of 95% selectivity had small CVs (1 and 11%, respectively).

The selectivity for the Japanese others fishery (Fleet 14) is also estimated to be asymptotic (in an initial run), although the selectivity was assumed to be dome-shaped (using 5 parameters). The selectivity for Fleet 14 is not changed from the last stock assessment.

All other selectivity curves are estimated to be dome-shaped and are not changed from the last stock assessment except Fleet 3. Both the early and late period, the descending width parameters of Fleet 3 are estimated to be smaller than the last stock assessment and the selectivity curves are tended to extend to the bigger size.

3.2 Fit to the Abundance Index

The abundance trends in most of the abundance indices were well represented by the model (Fig. 7). The Japanese troll index (S5) and both Japanese longline indices before 1993 (S2 and S3) were fit very well (root mean square error [rmse] = 0.22 for S5 and 0.21 for the rest of three). However, the fit for Japanese longline index for 1993-2010 (S1) and the Taiwan longline index for 1998-2010 (S9), are relatively poorer (rmse = 0.52 and 0.41 respectively) and become worse from the last stock assessment (0.46 and 0.35, respectively). The expected Taiwanese CPUE tends to be lower than the input values, on the other hand, the expected Japanese longline CPUE tends to be higher than the input values in recent years.

3.3 Fit to Size Composition Data

Pearson residuals of the model fit to the quarterly size composition data are shown in Figure 8.

3.4 Spawning Stock Biomass and Recruitment

Estimated SSB by the updated stock assessment model are slightly higher than those of the last stock assessment in two periods of 1950-1970 and after 1990 (Fig. 9). Estimated R0 by the updated stock assessment is 9.62 and is lower than that of the last stock assessment (9.64). The trend of SSB of the updated stock assessment model is similar with that of the last stock assessment. The highest SSB is occurred in 1961 (139,746 tons) and the second highest peak is in 1995 (86,601 tons). After the 1995, SSB is continuously declined until 2011 (25,114 tons) and the SSB of the terminal year (2012) is 26,270 tons.

Recruitments estimated by the updated stock assessment model are similar with those of the last stock assessment before 2007 (Fig. 9). However, as noted in 2.3, the recruitments after 2008 are lower than those of the last stock assessment. Note that the estimated recruitment of 2011 and 2012 are lower than the historical average and the average recruitment of most recent 5 years (2008-2012) is also lower than the historical average.

3.5 Fishing Mortality

Fishing mortality at age is summarized in Figure 10 and Table 1. The age specific geometric mean annual fishing mortalities of 2009-2011 (F2009-2011) decrease from those of 2007-2009 (F2007-2009) for the most of ages except age 2 and 3. Although the fishing mortalities for age 7+ are lower in F2009-2011 than those of F2002-2004, the fishing mortality for between age 0 and 7 are still higher in F2009-2011 than those of F2002-2004. Even in the year 2011 when the WCPFC and IATTC implemented their management for PBF, the fishing mortality for between age 0 and 7 show similar with F2002-2004 or 10-70% higher values than those of F2002-2004 (Table 1).

The age-specific fishing mortalities are summarized by the fishing gear in Figure 11. For all ages, there is not clear trend in the age-specific fishing mortality from 2000 to 2011. For age 2 and 3, rapid increasing of F are confirmed in 2012 though, it needs to be consider the uncertainty of terminal year.

3.6 Biological Reference Points

The ratio of the suite of candidate F–based biological reference points (F_{max}, $F_{0.1}$, F_{med}, F_{loss} and $F_{10\%\text{-}40\%}$) to $F_{2002\text{-}2004}$ (reference year of current WCPFC management measure), $F_{2007\text{-}2009}$, and $F_{2009\text{-}2011}$ (current F) are shown in Table 2. The current level of F is estimated to be higher than all listed BRPs except F_{loss}.

4 Discussion

Based on the comparison of the results between the updated stock assessment and the last stock assessment at Hawaii 2012, most of parameters are not changed by the update of the fishery data. Clear differences in the parameter estimations are found only in the selectivity curves of Fleet 1 and 3 (See 3.1), and the recruitment deviation in the recent several years. About the recruitment, the uncertainties in the recent years are confirmed by the bootstrap analysis (2.2) and the retrospective analysis (2.3). Especially, the retrospective analysis shows a tendency of the over-estimation in the recent terminal years (2009-2011). These results address a warning when we judge the recent recruitment trend from the updated stock assessment.

The estimated SSB between 1995 and 2012 are slightly larger in the updated stock assessment model than the last stock assessment. This difference seems to be brought by the update of CPUEs. The Japanese longline CPUE and Taiwanese longline CPUE, which are the abundance indices of matured fish, have different trend in the recent few years; Taiwanese longline CPUE increased after 2009, on the other hand, Japanese longline CPUE basically decreased after 2006 (Fig. 7). This difference in the trend of CPUEs might be caused by the difference in the selectivity of those Fleets; Taiwanese longline generally caught a larger PBF than the Japanese longline. Given updated data including those CPUEs, however, the updated assessment model could not fit well to those longline CPUE data especially in recent years (See 3.2). The higher estimated SSB trend than the last stock assessment might be influenced by the updated data of Taiwan CPUE, which has an increasing trend of matured fish in the recent years.

5 References

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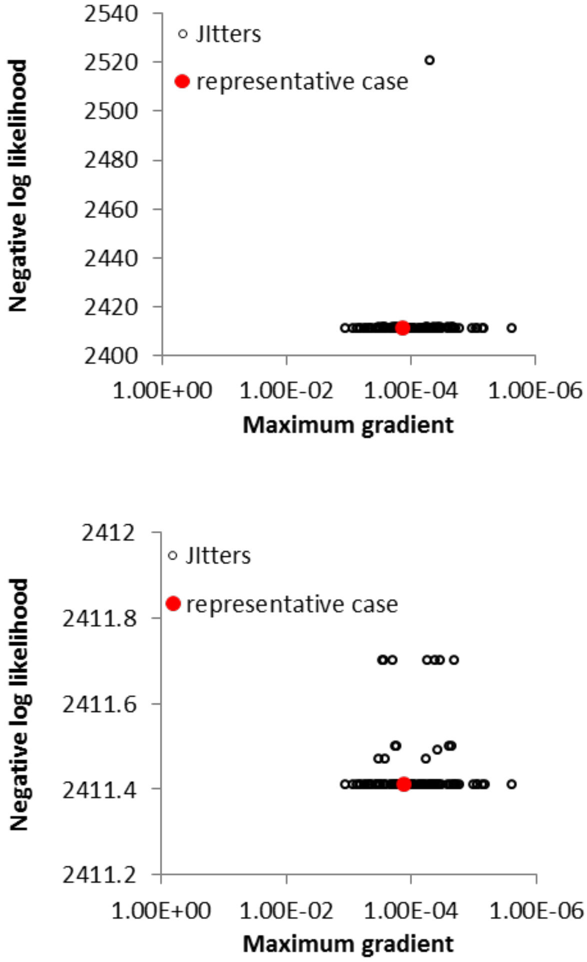


Fig. 1 plot of negative log likelihood and the maximum gradient.

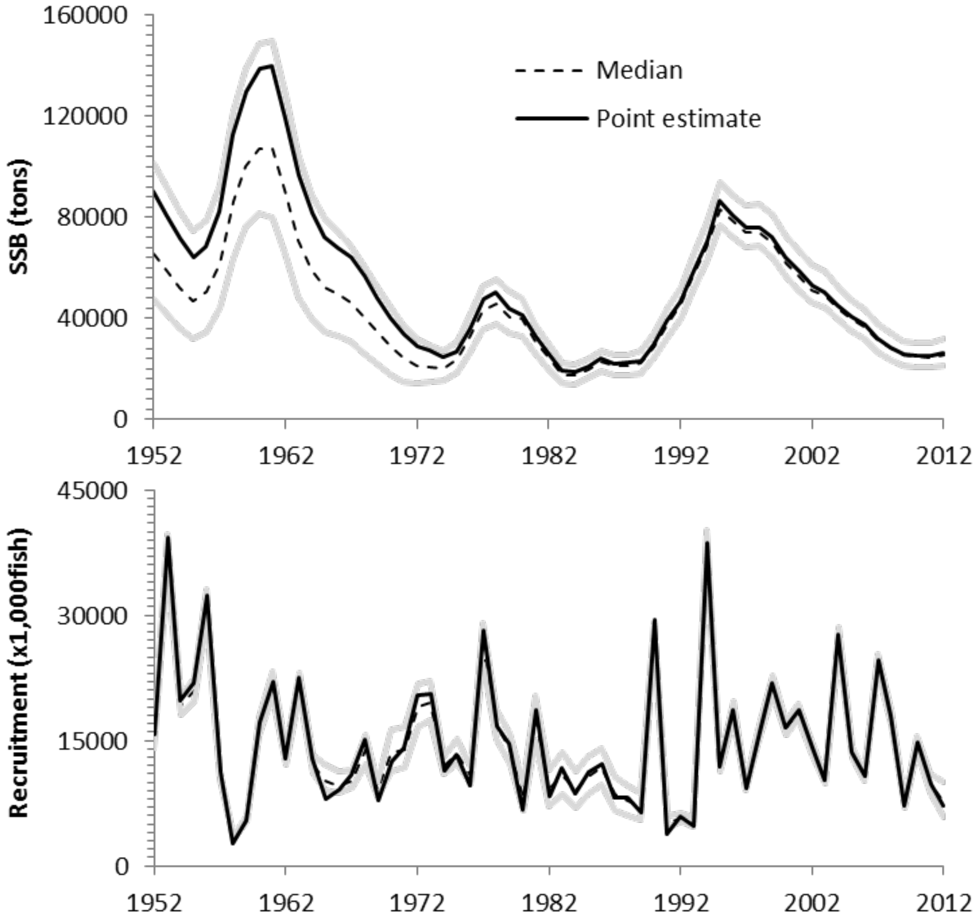


Fig. 2 Estimates of Spawning Stock Biomass and Recruitment from the Updated stock assessment model. Broken lines indicate 90% confidence intervals estimated by the 300 times replicates bootstrap analysis.

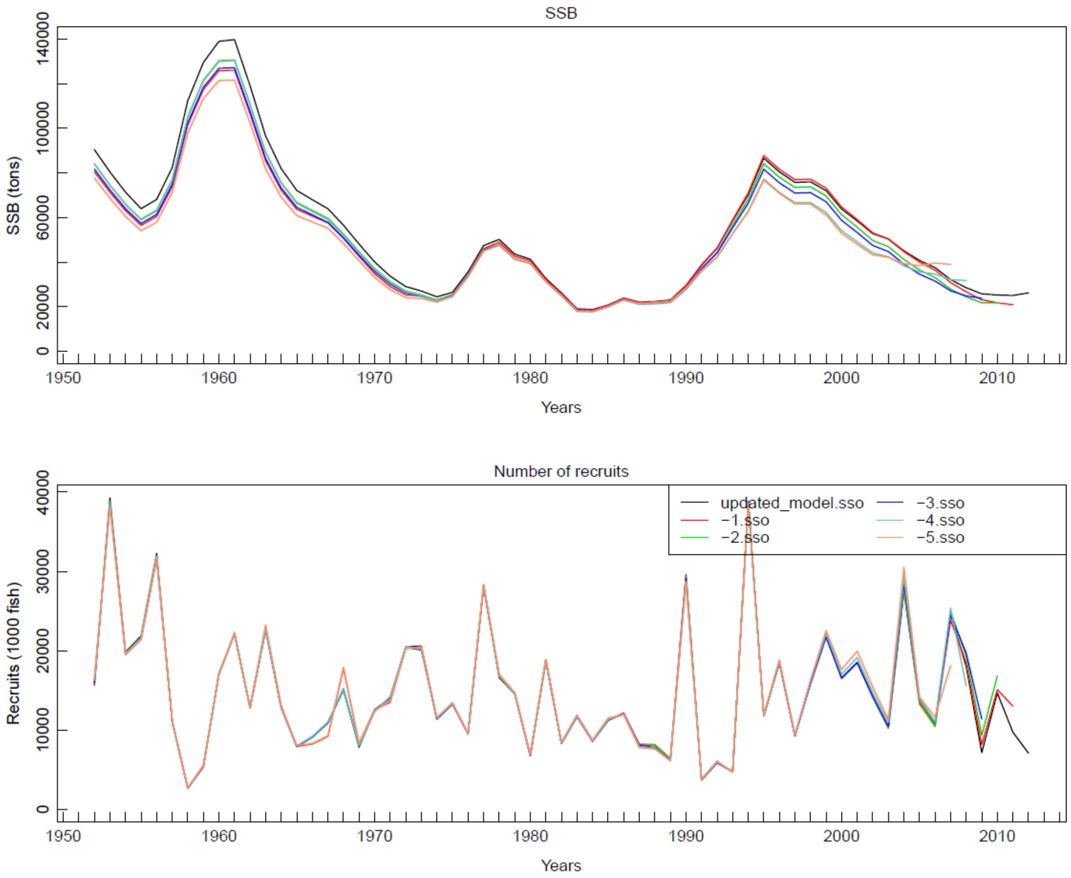


Fig. 3 Plot of Retrospective analysis for SSB and Recruitment for the updated stock assessment model and the 1-5 years data dropping model.

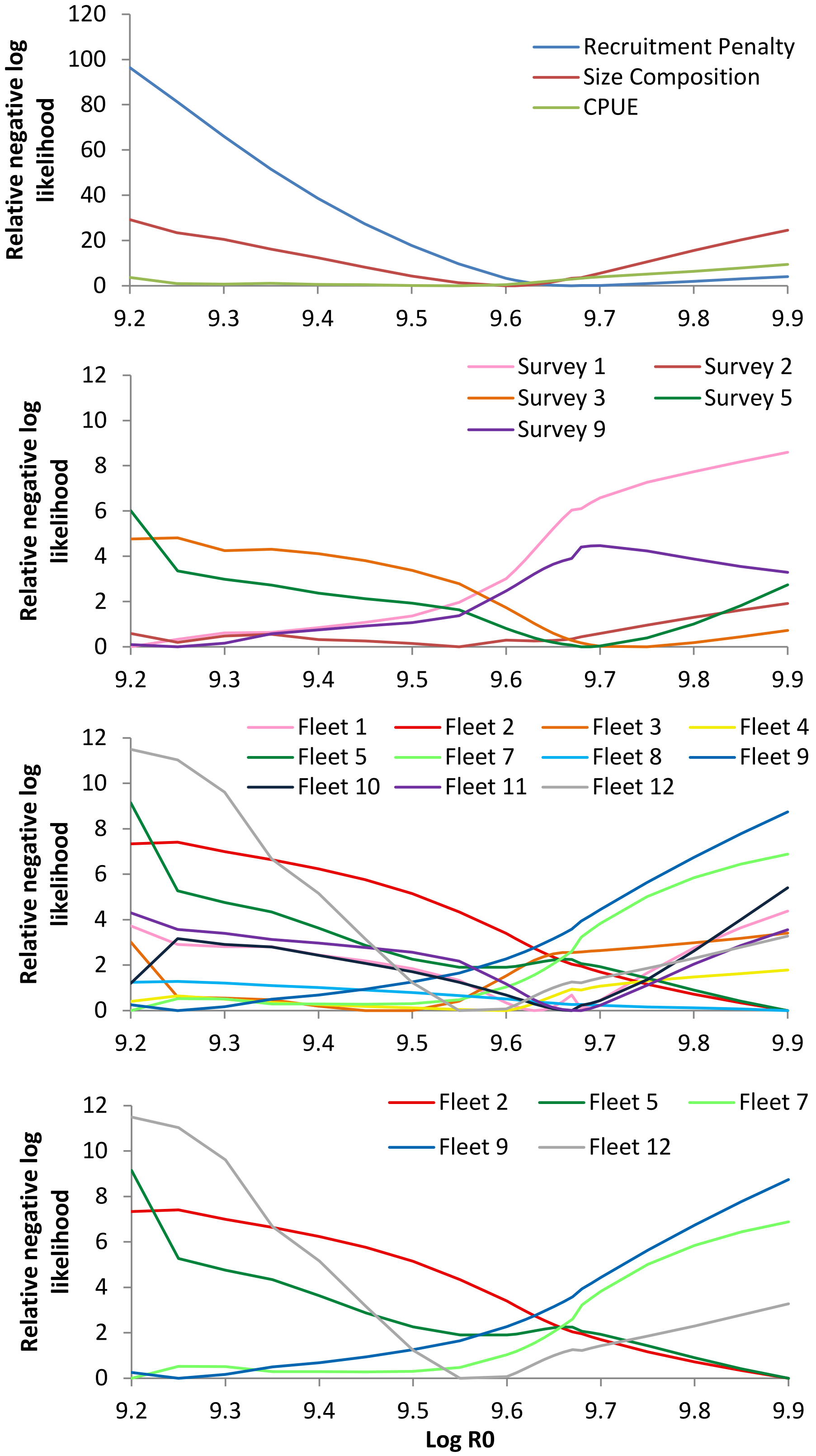


Fig. 4 Plot of likelihood profiles for the updated stock assessment model.

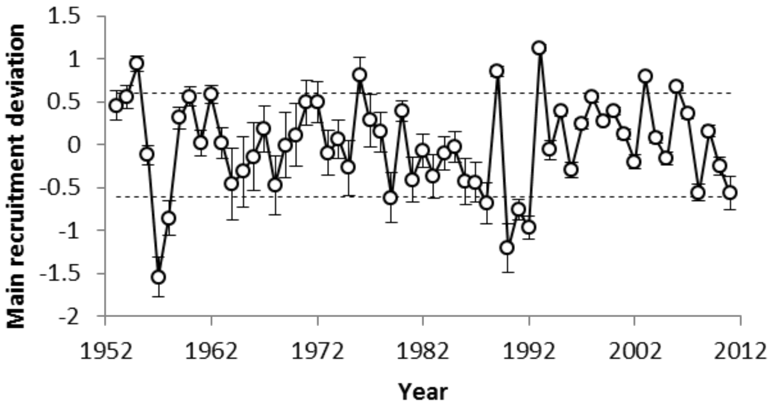


Fig. 5 Estimated recruitment deviations. The vertical bars indicate the standard deviations and the broken lines indicate the input recruitment variability (0.6).

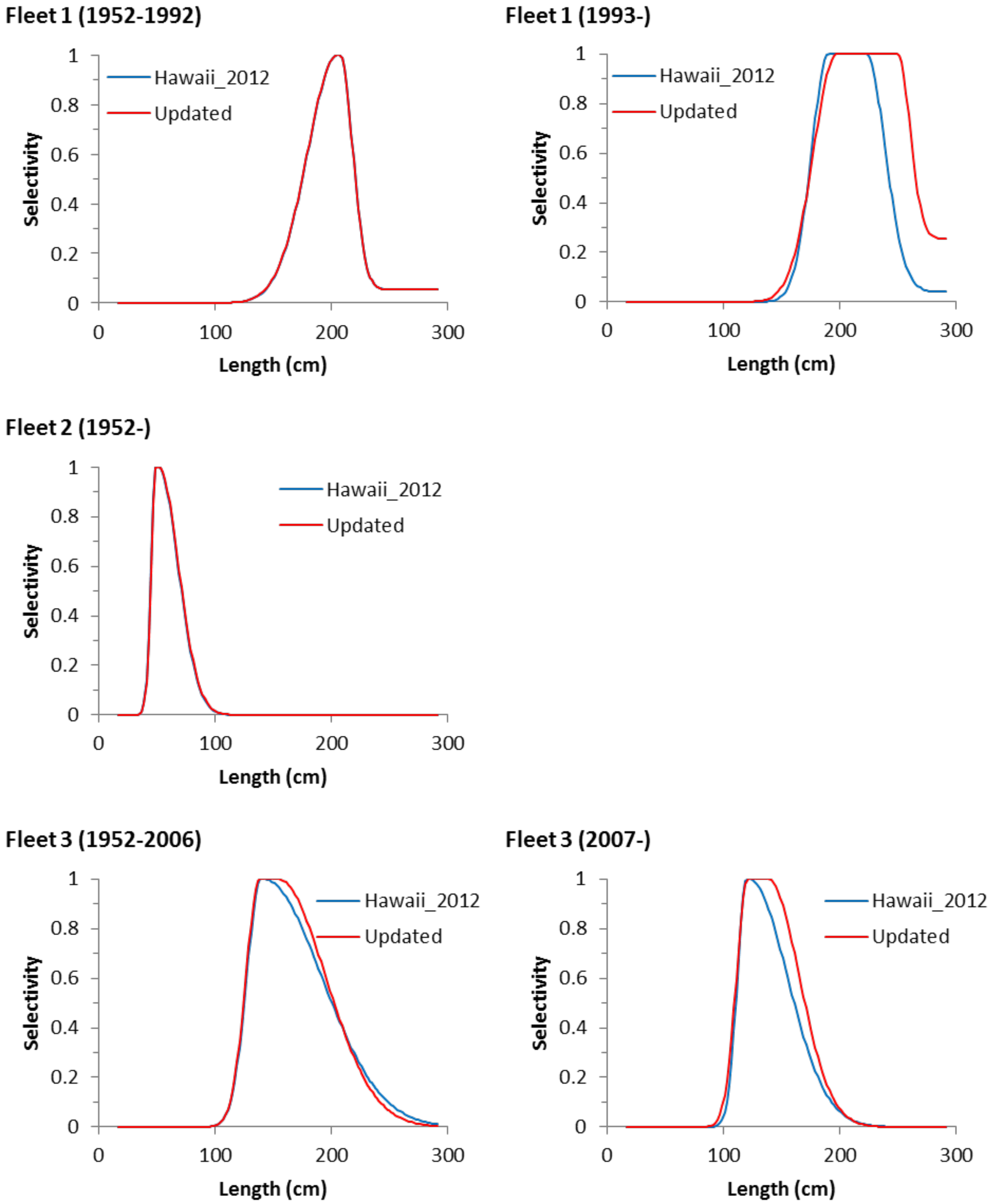


Fig. 6 Estimated length-based selectivity curves by fleet from the Last stock assessment (Hawaii 2012; blue), and the updated stock assessment model (Updated; red).

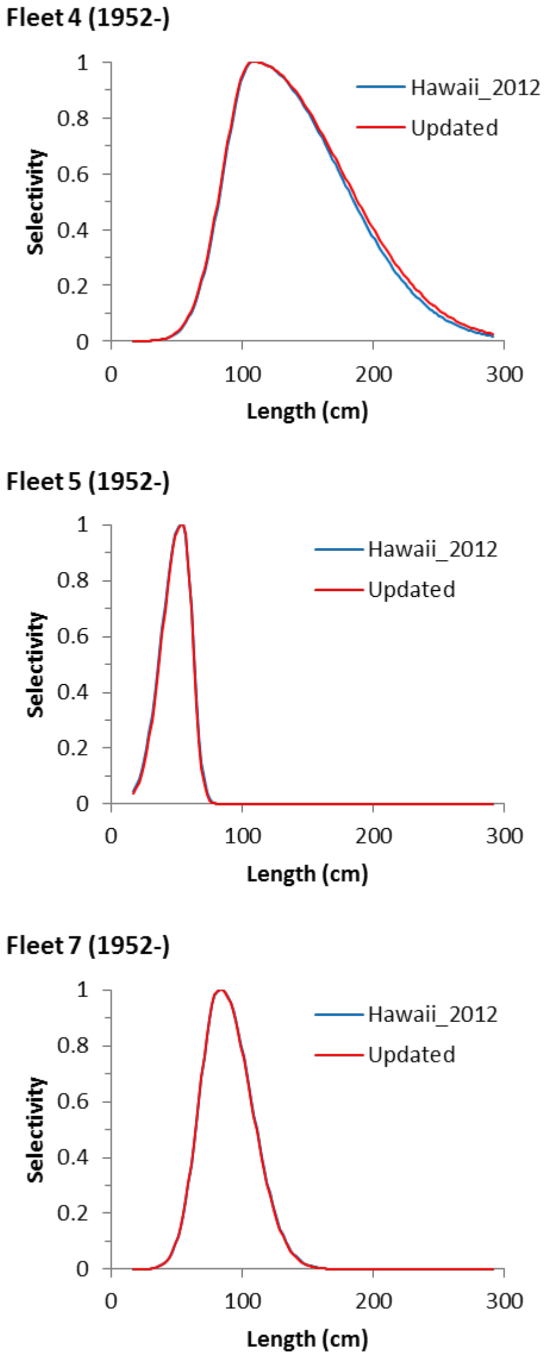
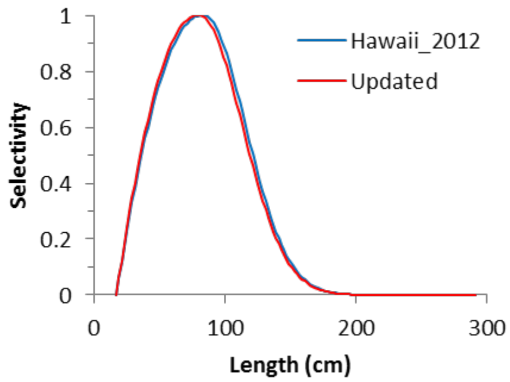
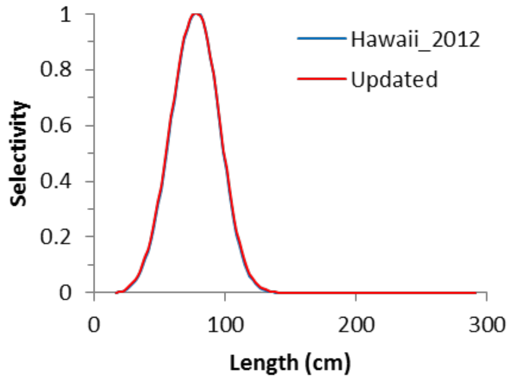


Fig. 6 Continued.

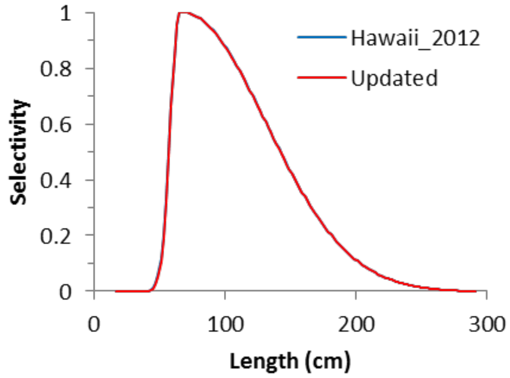
Fleet 8 (1952-)



Fleet 9 (1952-)



Fleet 10 (1952-)



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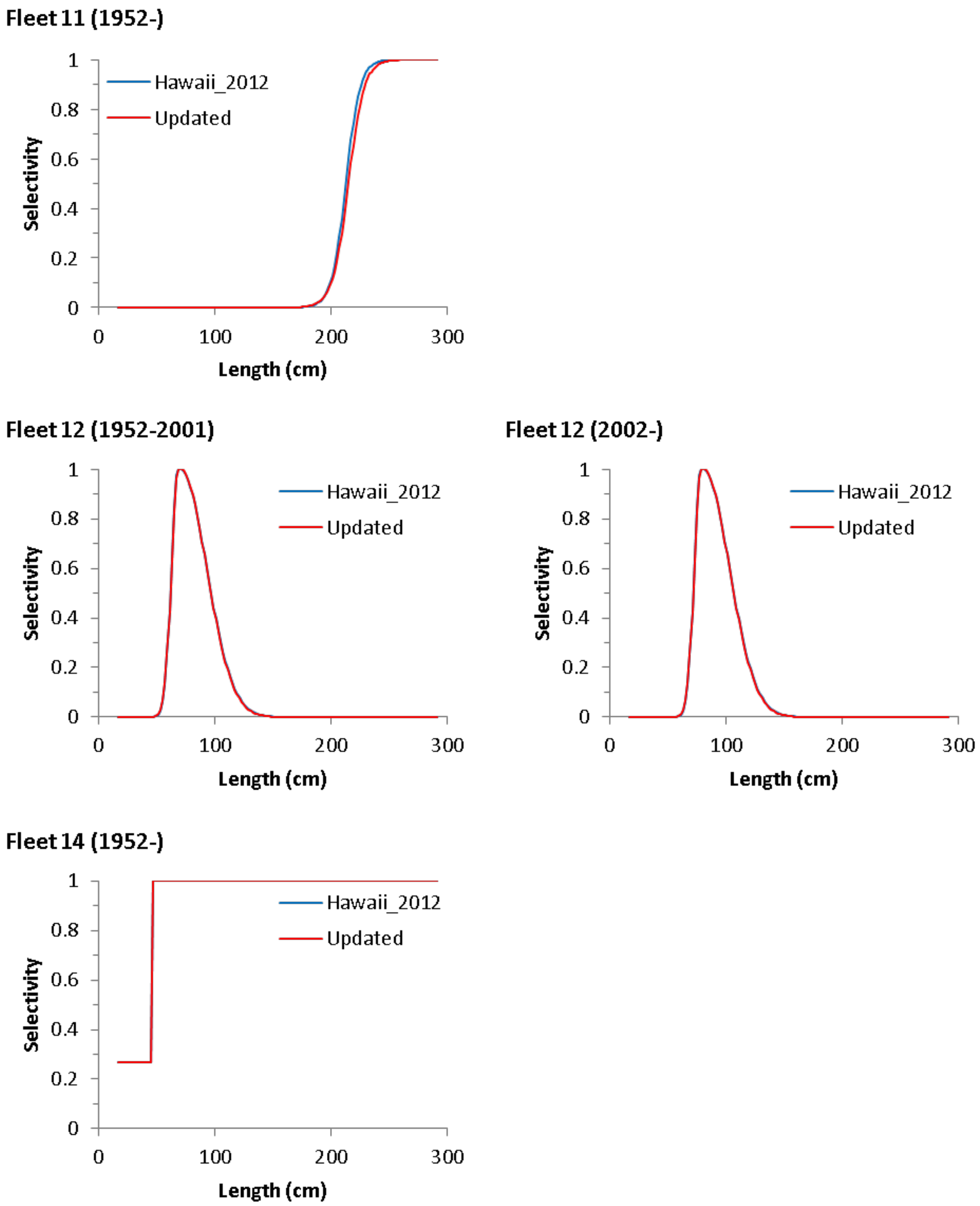

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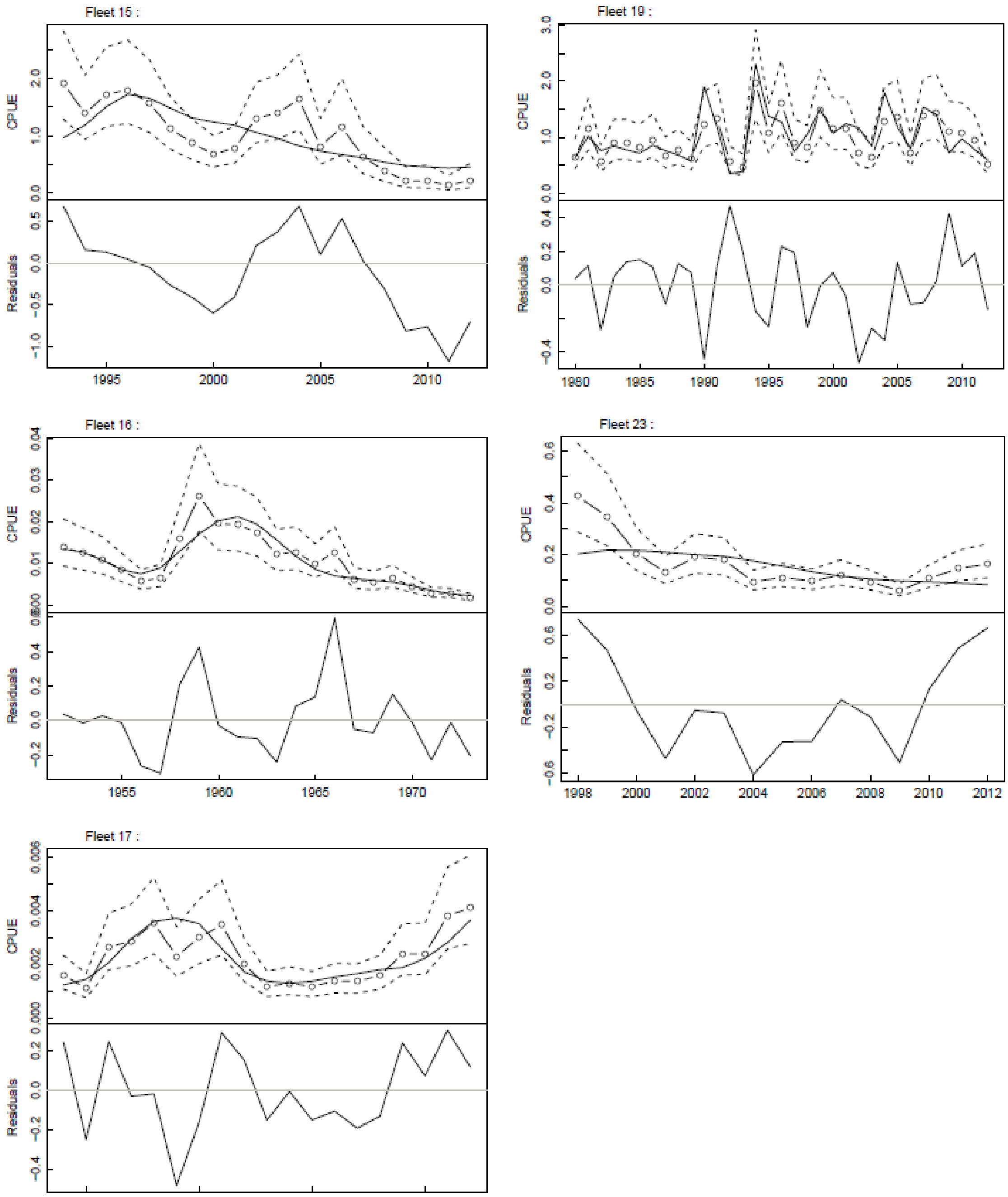


Fig. 7 Expected (line) and observed (line and circle) CPUEs, and log residuals (observed – expected) for the updated stock assessment model.

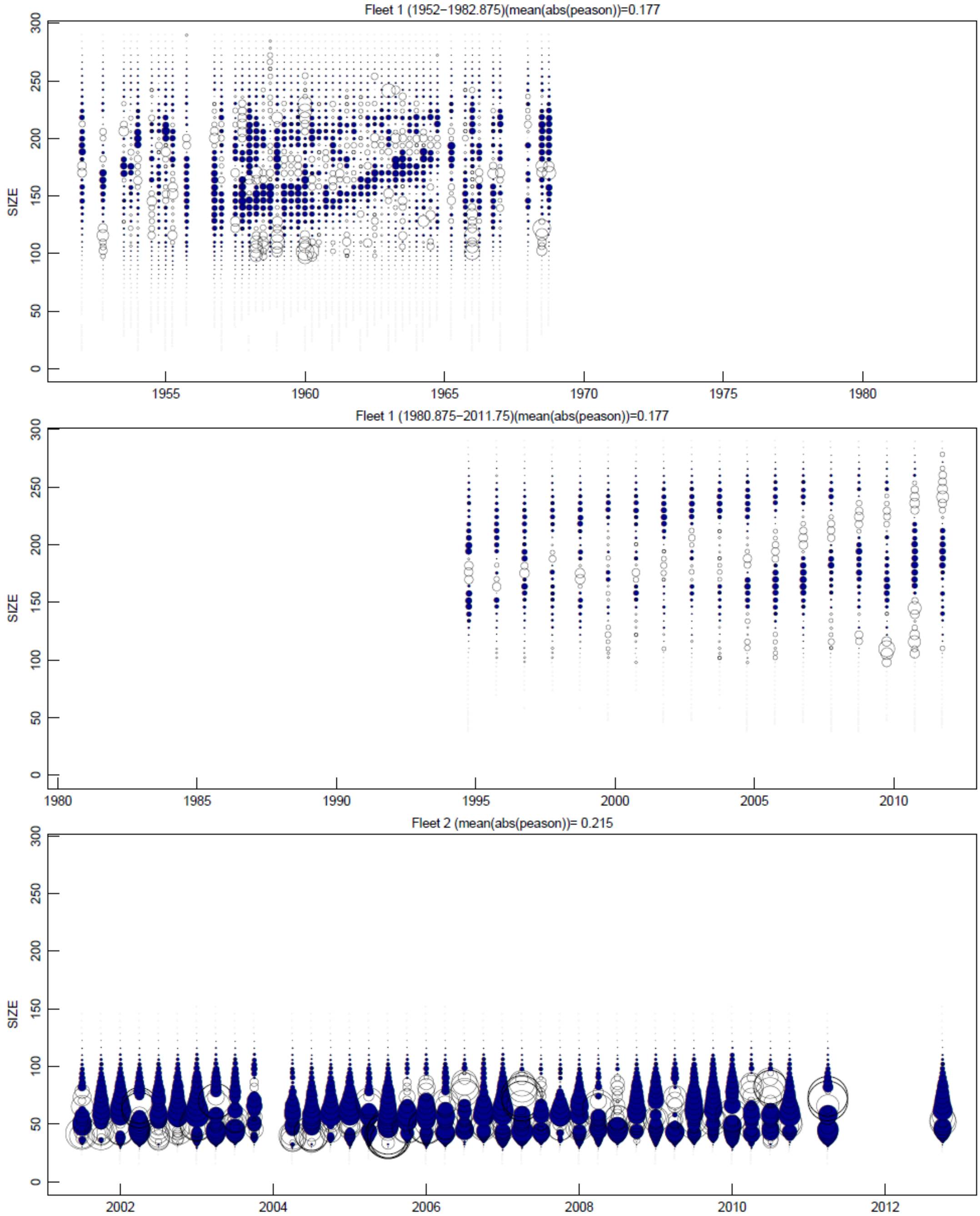
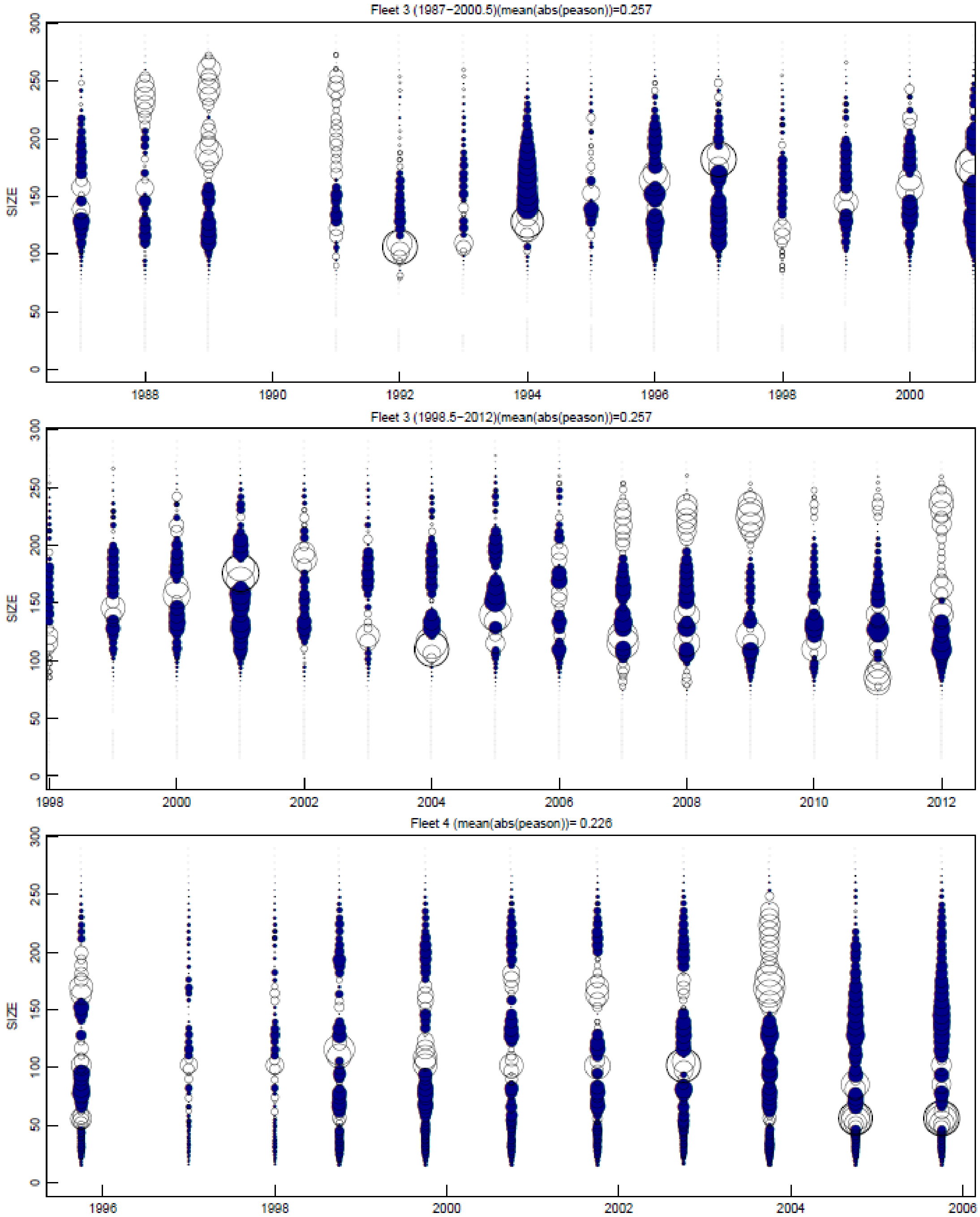


Fig. 8 Pearson residuals of model fits to size composition data for the update stock assessment model. Dark blue circles indicate negative residuals (observation value < expected value), while white circles indicate positive residuals (expected value > observation value).



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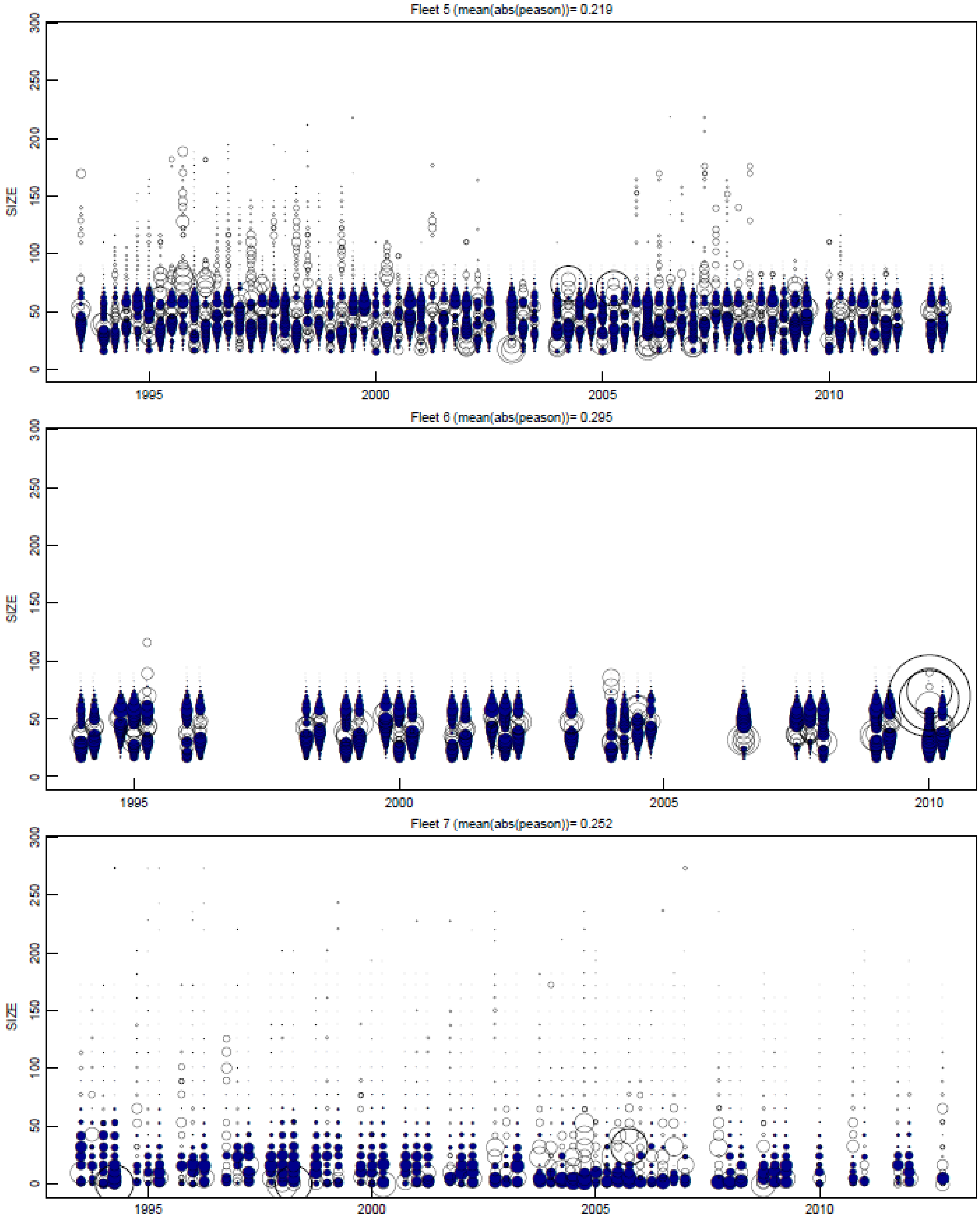

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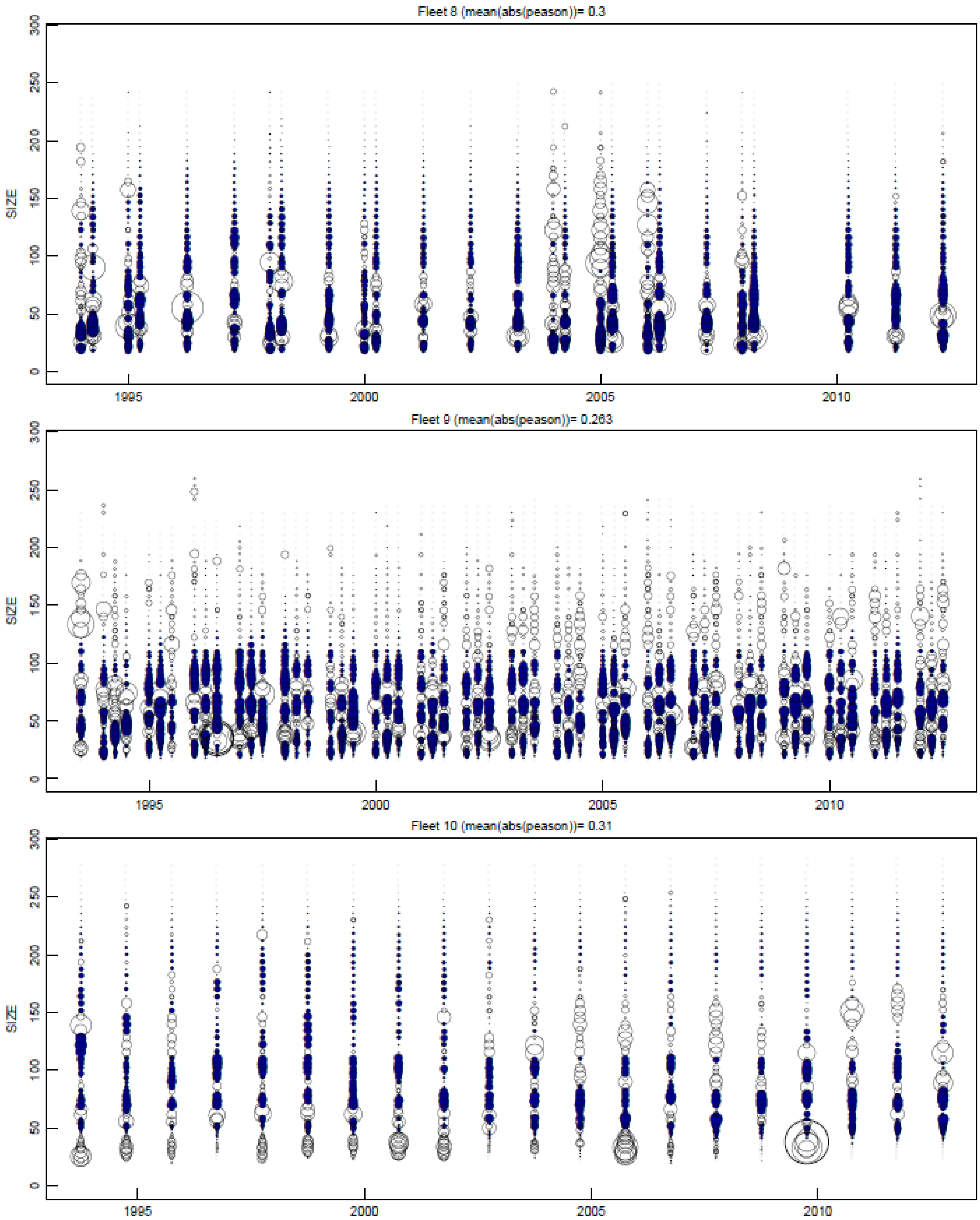

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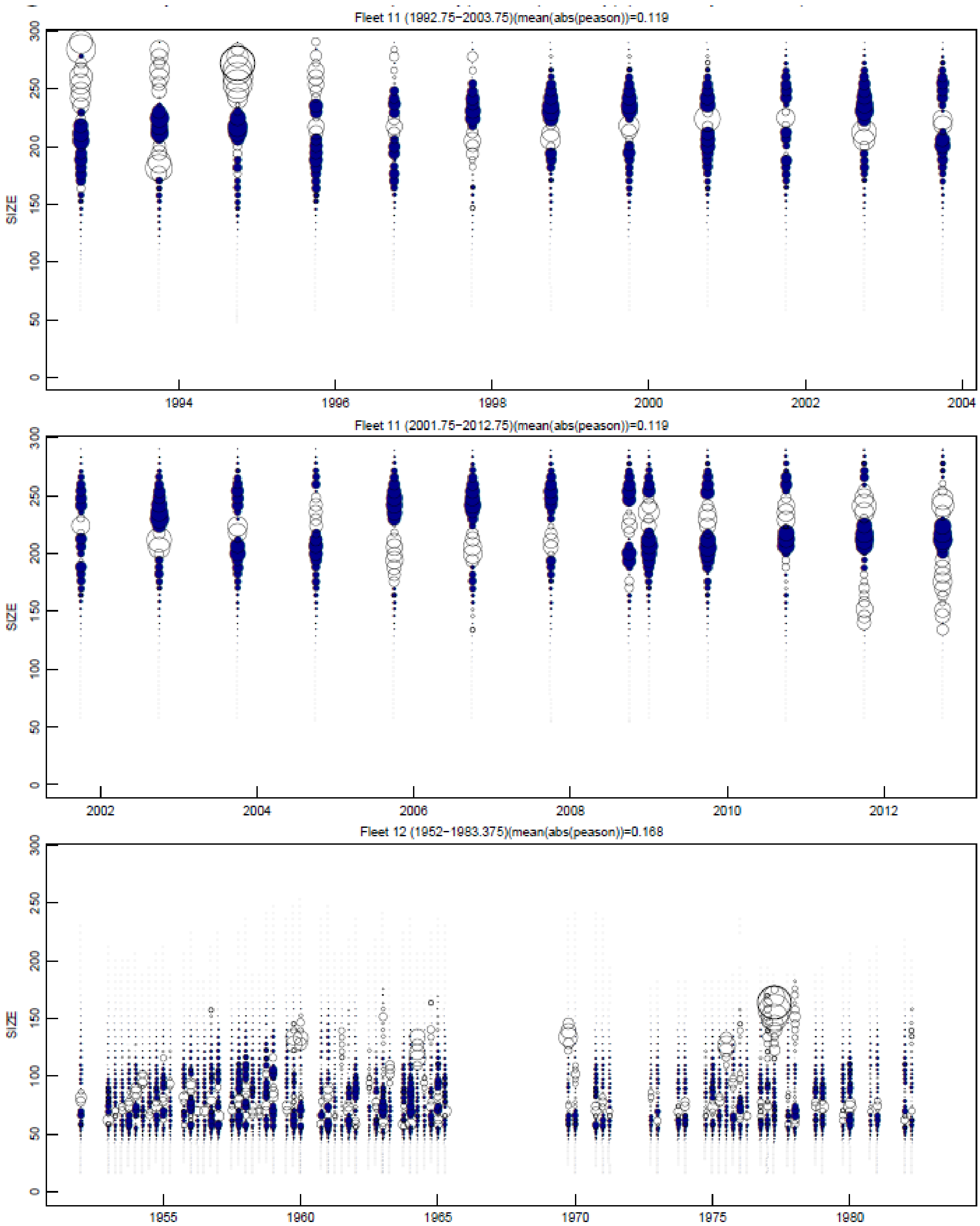

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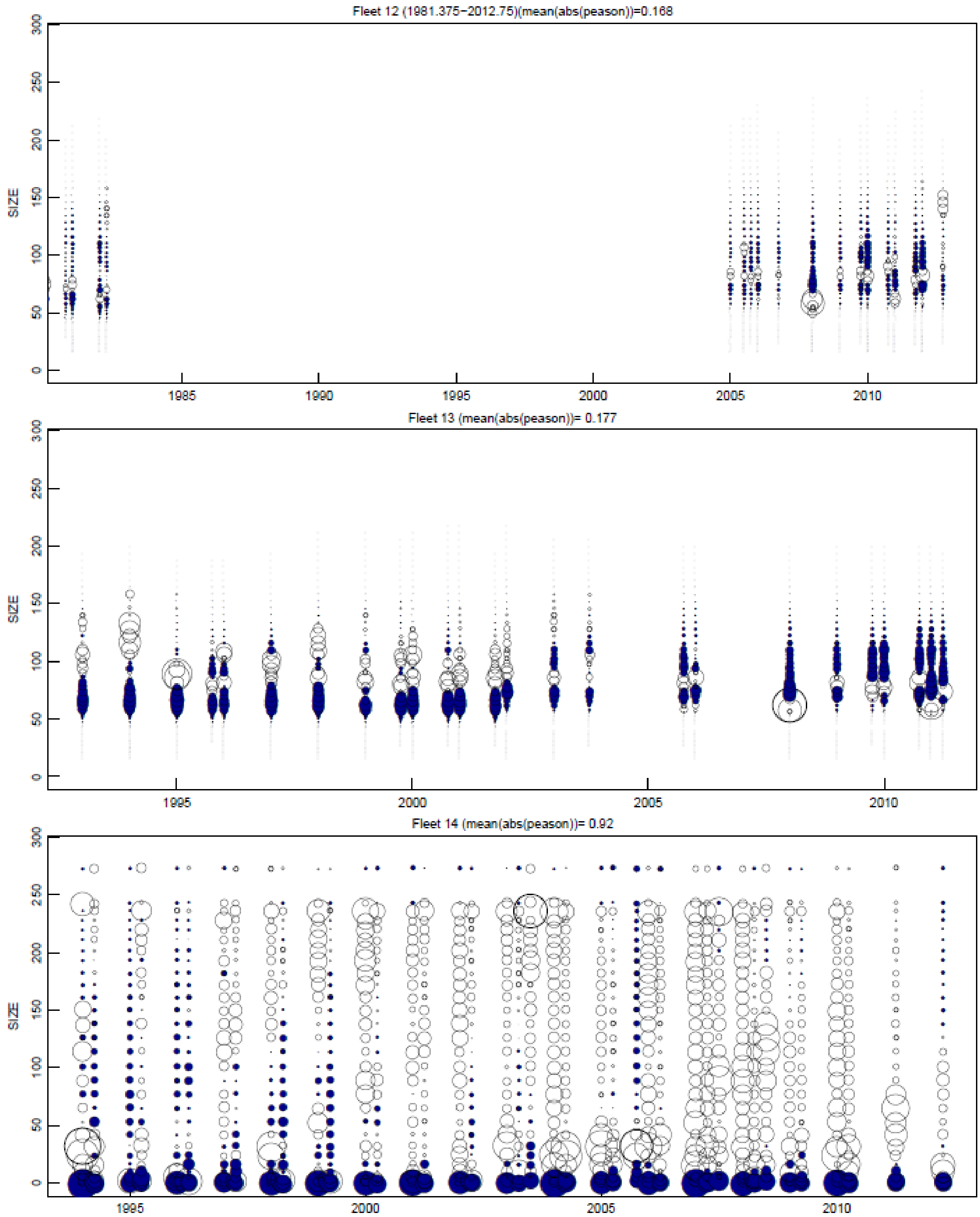

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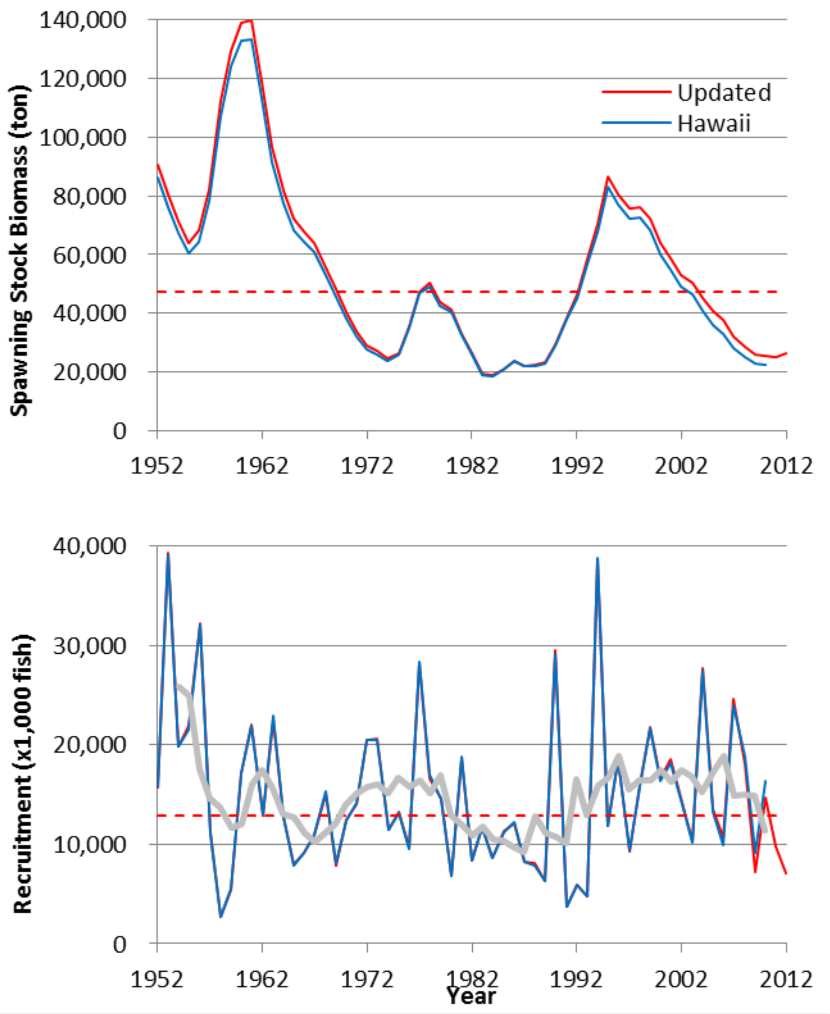

Fig. 9 Spawning Stock Biomass and Recruitment estimated by the updated stock assessment (red) and the last stock assessment (blue). The red dashed line of SSB indicates historical median SSB estimated by the updated stock assessment. The red dashed line of recruitment indicates historical average recruitment estimated by the updated stock assessment. The gray bold line of recruitment is 5-years running average value of the recruitment estimated by the updated stock assessment.

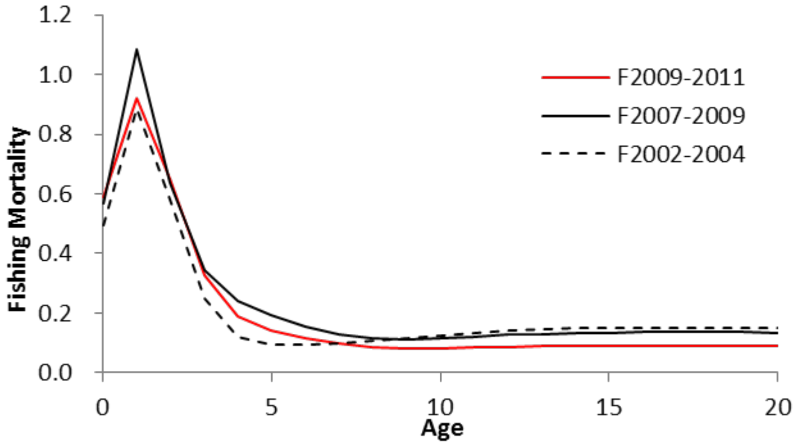

Fig. 10 Geometric mean annual age-specific fishing mortalities for 2002-2004 (broken line), 2007-2009 (solid line) and 2009-2011 (red line).

Table 1 Geometric mean annual age-specific fishing mortalities for 2002-2004 (broken line), 2007-2009 (solid line) and 2009-2011 and annual age-specific fishing mortality for 2009, 2010 and 2011. The ratio of annual age-specific mortality of 2009, 2010, and 2011 for the $F_{2002\text{-}2004}$ are showed by percentages.

age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
$F_{2002-2004}$	0.50	0.89	0.58	0.25	0.12	0.09	0.10	0.10	0.10	0.11	0.12	0.13	0.14	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
$F_{2007-2009}$	0.57	1.09	0.64	0.34	0.24	0.19	0.16	0.13	0.11	0.11	0.11	0.12	0.13	0.13	0.13	0.13	0.14	0.14	0.14	0.14	0.13
$F_{2009-2011}$	0.59	0.92	0.65	0.33	0.19	0.14	0.11	0.10	0.09	0.08	0.08	0.08	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
F_{2009}	0.64	1.06	0.53	0.27	0.19	0.16	0.13	0.11	0.10	0.09	0.09	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
$F_{2009}/F_{2002-2004}$	129%	120%	91%	107%	161%	167%	137%	111%	94%	83%	76%	72%	70%	69%	69%	69%	68%	68%	68%	68%	68%
F_{2010}	0.66	0.73	0.77	0.39	0.18	0.12	0.10	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.09	0.09	0.09	0.08	0.08	0.08
$F_{2010}/F_{2002-2004}$	133%	83%	131%	154%	148%	126%	101%	84%	73%	66%	62%	59%	58%	57%	57%	56%	56%	56%	56%	56%	56%
F_{2011}	0.48	1.00	0.67	0.34	0.20	0.15	0.12	0.10	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
$F_{2011}/F_{2002-2004}$	98%	113%	115%	135%	169%	162%	126%	97%	80%	69%	62%	59%	57%	56%	55%	55%	55%	55%	55%	55%	54%

Table 2 Ratio of candidate F based biological reference points to the fishing mortality (F) of each year for the updated stock assessment. If the ratio is larger than 1.0, the estimated F is higher than the biological reference point.

	F_{max}	$F_{0.1}$	F_{med}	F_{loss}	$F_{10\%}$	$F_{20\%}$	$F_{30\%}$	$F_{40\%}$
$F_{2002\text{-}2004}$	1.71	2.45	1.09	0.85	1.16	1.68	2.26	2.99
$F_{2007\text{-}2009}$	2.09	2.97	1.39	1.08	1.49	2.14	2.88	3.79
$F_{2009\text{-}2011}$	1.79	2.54	1.23	0.96	1.32	1.90	2.55	3.35

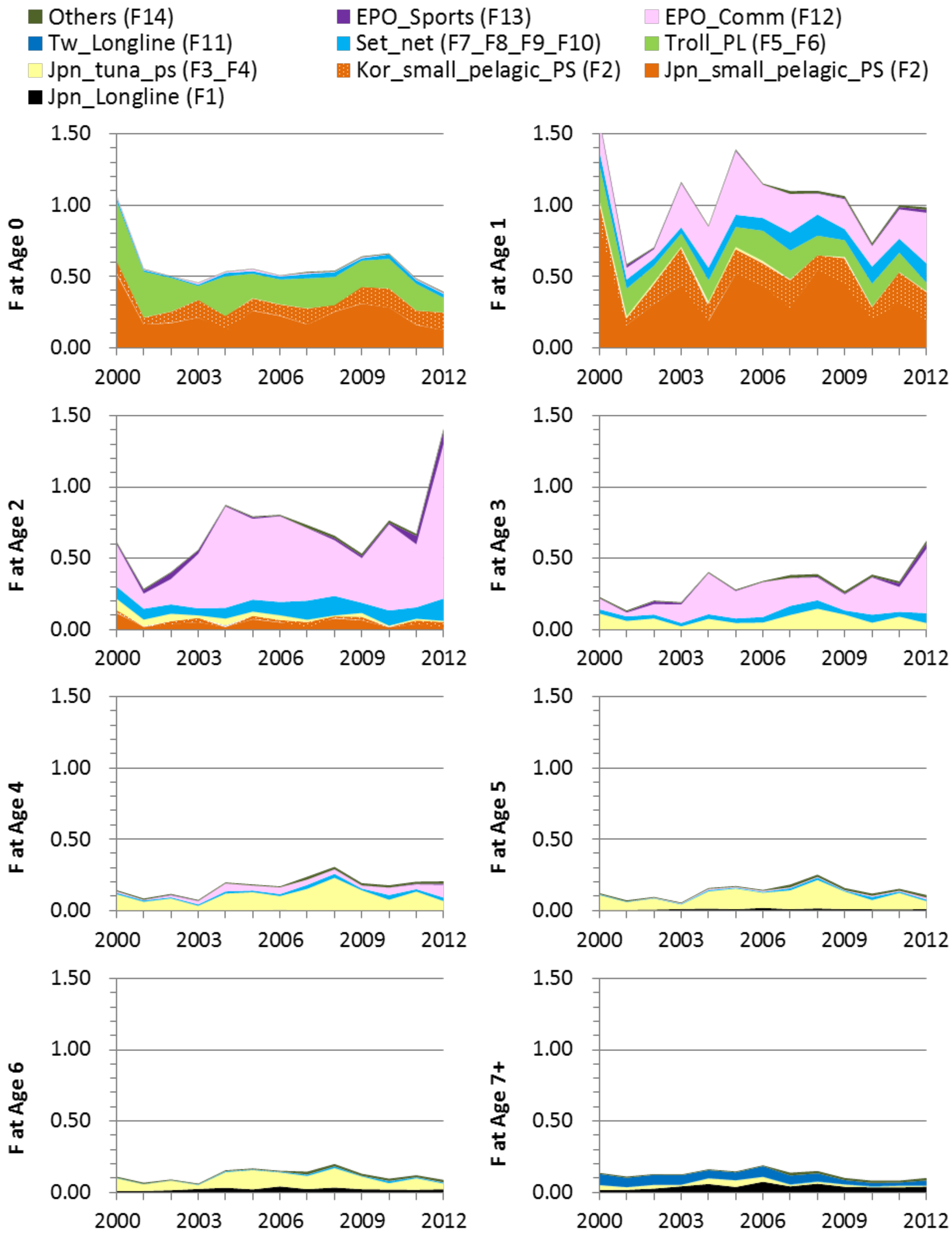

Fig. 11 Estimated annual fishing mortality by gear in each age from 2000 to 2012. The Fishing mortality of Fleet 2 (small pelagic purse seine) is divided into two gears (Japanese PS and Korean PS) in accordance with the contributions of catch in each country.