

# Updated 2021 assessments and initial projections of the west coast rock lobster resource

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**KEY WORDS:** West Coast rock lobster; *Jasus lalandii*; stock assessment; resource projections

## Summary

The 2020 assessments and deterministic projections for the five super-areas for the west coast rock lobster resource are updated to 2021, using basically the same approach as in 2019 and 2020. The update takes account of a further year's catch, resource monitoring and somatic growth data, and incorporates revisions made in 2021 of estimates of past poaching levels and of models for somatic growth. Stochastic projections are calculated on an identical basis to that used in 2019. Projection results are appreciably worse than in 2019: even under zero future legal catches (i.e. closure of the legal fishery), the resource cannot regain its 2006 level by 2025. The primary reason is the poorer recruitment to A8+ since the turn of the century that is now indicated (given the further data now available) compared to 2019.

## Background

Updated 2021 assessment results for west coast rock lobster, *Jasus lalandii*, for each super-area are reported here. These assessments use the 2019 (and 2020) assessment methodology (Johnston and Butterworth 2019, 2020), and updated CPUE, FIMS, somatic growth and poaching data. The 2020 assessments used data up to and including 2020, whereas the 2021 assessments have one further year of data.

For each assessment a value for  $\sigma_R = 1.0$  is assumed for recruitment estimation. For A7 the 2009-2019 TRAP CPUE data are up-weighted by a factor of 10 in the likelihood to provide better fits to these data.

## Poaching

FISHERIES/2021/JUL/SWGTT/WCRL?? outlines a suggested new approach to combining the TRAFFIC and Compliance poaching index inputs to form an aggregated trend of overall poaching. Poaching trends for the weighting scenario of  $w_1=1$ ,  $w_2=5$  and  $w_3=0.5$  are used for these assessments.

## Model scenarios

A number of different models are run, for which different assumptions apply to the estimate of recent local sale, the baseline or sensitivity compliance trend for the South, and updated somatic growth analyses (here examined for A8+ only).



*Total local sales estimate for 2020 (L(2020))*

Two extreme options are examined: L(2020)=850mt and L(2020)=200mt. Note that it is assumed that 30% of L(2020) is taken in the North, and 70% taken in the South (A8+).

*BS and SEN compliance trend*

Recent analyses of the compliance trend (where effort is taken into account) produced two options for the South (A8+). The BC analysis includes all data, whereas the sensitivity (SEN) excludes possible outliers. See FISHERIES/2021/AUG/SWG/WCRL17 for details.

*Somatic growth rate series*

Recent analyses of the somatic growth rate FISHERIES/2021/JUL/SWG/WCRL13 suggests that the preferred somatic growth analyses which does not have year-area interactions should be used as the BC somatic growth for west coast rock lobster (Table 8 of FISHERIES/2021/JUL/SWGTT/WCRL13). Sensitivity for which year-area interactions are included (Table 8 of FISHERIES/2021/JUL/SWGTT/WCRL13) is examined here for super-area A8+ (as has been carried out in past analyses).

**Projections**

The stochastic simulations for future recruitment are based on the same method as described in FISHERIES/2019/AUG/SWG/WCRL16 and in the Appendix. 100 simulations are run, with the median, 5<sup>th</sup> and 95<sup>th</sup> percentiles of the B75m trajectories recorded.

Projections are reported for constant future annual legal catches (CC) by all sectors of either:

- 1) Future (2021+) CC = zero, which gives the maximum recovery possible under current poaching levels.
- 2) Future (2021+) CC = 837 mt (the current TAC).

**Results**

Detailed updated super-area assessment results are reported in Tables 1a-e and Figures 1-3. Table 2a compares the recent **total** biomass estimates for the 2019, 2020 and 2021 assessments and Table 2b compares the super-area and total 2018 biomass estimates (mt) for the 2020 and 2021 assessments.

Figure 4 compares the **total** estimated resource biomass in absolute terms and relative to 2006 for the 2019, 2020 and 2020 BC assessments.

### *Projections*

Statistics of B75m(2025/2006) and B75m(2025/2020) for CC=0 MT and CC=837 mt are reported for each super-area and the Total resource in Tables 3a and 3b. Results are also presented for a range of model options.

Trajectories of B75m (mt) and B75m/2006 are shown in Figures 5 and 6 for the five super-areas and for the resource as a whole.

Figure 7 Compares the total resource biomass trajectories between the 2019 and 2021 BC projections under a Zero CC. Figure 8 compares the Total B75m/2006 trajectories under a CC=837mt situation for the 2019, 2020 and 2021 baseline assessments.

Figure 9a compares the A8+ recruitment trends between 2019 and 2021 assessments to show the differences, and Figure 9b compares the poaching trends assumed in 2019 (LS=700 mt) versus 2021 (LS=850 mt).

## **Discussion**

### *Updated assessments*

The 2021 updated assessments show similar fits to the data and parameter estimates as the 2020 assessments (Tables 1a-e, Figures 1-4). It is notable, however, that in absolute terms the biomass for the 2021 assessment is higher than for the preceding ones for recent years. It is evident that the changed approach for somatic growth estimation is the main cause of this, as is indicated (given this change) by the different trends for recruitment in Figure 1a<sub>ii</sub> and absolute biomass in Figure 3b for Area 8+. The 2021 assessment shows a notable increase in overall biomass over the last two seasons – this being driven by the trend estimated in A8+.

Table 2c compares the B75m(2018/2006) and B75m(2020/2006) estimates for A8+ for a range of model scenarios that examine alternate compliance trends and somatic growth trends (as well as the LS 850mt and LS 200mt possibilities). These results are evidently somewhat insensitive to these different assumptions for the 2018 value, but become highly sensitive to the compliance and particularly the somatic growth rate sensitivity, though not to the value for local poaching in 2020, for the 2020 value.

### *Projections*

Projections are more negative than in 2019. While for the 2019 results, the total biomass could readily exceed the 2006 level by 2025 under zero catch, for the 2021 assessments the total biomass remains well below the 2006 level at that time (Table 3 and Figure 7). Naturally these results are lower still if the current TAC is continued.

The primary reason for this is evident from Figure 9a: recruitment to super-area A8+ is now estimated (given the further data now available) to have been appreciably lower since the turn of the century than was the case two years ago.

## References

Johnston, S.J. and Butterworth, D.S. 2019. Comparison between methods of estimating historical and future recruitment for the west coast rock lobster super-areas. FISHERIES/2019/AUG/WCRL/15.

Johnston, S.J. and Butterworth, D.S. 2021. Updated 2020 assessments and deterministic projections for west coast rock lobster. FISHERIES/2021/JUN/WCRL/04.

Table 1a: **A8+** results for the two different poaching scenarios ( $L(2020)=850\text{mt}$  or  $200\text{mt}$ ). The **BC compliance** trend is also assumed for the poaching scenario. The values in parentheses next to the  $-\ln L$  values are the associated  $\sigma$  values for the fit to those data. The comparative 2020 assessment results are also provided (shaded columns). Note that here and in the tables that follow,  $-\ln L$  values are not comparable between 2020 and 2021 because the 2020 data set is larger including data from an extra year.

	2020		2021	
	LS 400	LS 700	BC compliance	
	LS 200	LS 850		
-lnL total (T=D+R)	-51.539	-53.592	-33.154	-35.864
-lnL from data (D)	-54.539	-56.274	-35.095	-36.225
R penalties (R)	2.768	2.681	1.939	2.361
Trap CPUE $-\ln L$ ( $\sigma$ )	-40.312 (0.185)	-40.377 (0.185)	-33.017 (0.236)	-33.103 (0.255)
Hoop CPUE $-\ln L$ ( $\sigma$ )	-41.401 (0.173)	-41.737 (0.171)	-37.298 (0.203)	-37.708 (0.200)
FIMS CPUE $-\ln L$ ( $\sigma$ )	-13.402 (0.376)	-15.173 (0.353)	-9.046 (0.437)	-8.933 (0.441)
R_2004	0.454	0.541	0.356	0.371
R_2007	0.491	0.578	0.337	0.369
R_2010	0.410	0.441	0.425	0.430
$\bar{x}$	0.534	0.544	0.547	0.577
B75m(2006) (B75m(2006)/K)	9272 (0.041)	9460 (0.043)	13122 (0.061)	12231 (0.061)
B75m(2019) (B75m(2019)/K)	5503 (0.025)	5571 (0.025)	7087 (0.033)	6814 (0.033)
B75m(2020) (B75m(2020)/K)	-	-	7558 (0.035)	7204 (0.034)
B75m(2020)/B75m(2026)	-	-	0.576	0.589
	nn.for a820b.res	nn.for a820.res	nn.for a8b.res	nn.for a8a.res

Table 1b: **A8+** results for the two different poaching scenarios ( $L(2020)=850\text{mt}$  or  $200\text{mt}$ ). The **SEN compliance** trend is also assumed for the poaching scenario.

	2020		2021	
	LS 400	LS 700	SEN compliance	
	LS 200	LS 850		
-lnL total (T=D+R)	-51.539	-53.592	-33.924	-36.149
-lnL from data (D)	-54.539	-56.274	-35.843	-38.051
R penalties (R)	2.768	2.681	1.919	1.902
Trap CPUE $-\ln L$ ( $\sigma$ )	-40.312 (0.185)	-40.377 (0.185)	-33.412 (0.233)	-35.231 (0.222)
Hoop CPUE $-\ln L$ ( $\sigma$ )	-41.401 (0.173)	-41.737 (0.171)	-36.385 (0.208)	-36.974 (0.204)
FIMS CPUE $-\ln L$ ( $\sigma$ )	-13.402 (0.376)	-15.173 (0.353)	-9.477 (0.432)	-10.336 (0.419)
R_2004	0.454	0.541	0.384	0.481
R_2007	0.491	0.578	0.425	0.297
R_2010	0.410	0.441	0.442	0.410
$\bar{x}$	0.534	0.544	0.610	0.552
B75m(2006) (B75m(2006)/K)	9272 (0.041)	9460 (0.043)	12683 (0.066)	12923 (0.060)
B75m(2019) (B75m(2019)/K)	5503 (0.025)	5571 (0.025)	6418 (0.034)	6456 (0.030)
B75m(2020) (B75m(2020)/K)	-	-	7030 (0.037)	6662 (0.031)
B75m(2020)/B75m(2026)	-	-	0.554	0.516
	nn.for a820b.res	nn.for a820.res	nn.for a8d.res	nn.for a8c.res

Table 1c: **A8+** results for two different **somatic growth** series. Results are for the poaching scenario  $L(2020)=850\text{mt}$  and the BC compliance trend.

	<b>2021 LS 850</b>	
	<b>BC somatic growth</b>	<b>Alternate somatic growth</b>
-lnL total (T=D+R)	-35.864	-44.052
-lnL from data (D)	-36.225	-46.742
R penalties (R)	2.361	2.690
Trap CPUE -lnL ( $\sigma$ )	-33.103 (0.255)	-37.878 (0.206)
Hoop CPUE -lnL ( $\sigma$ )	-37.708 (0.200)	-41.185 (0.181)
FIMS CPUE -lnL ( $\sigma$ )	-8.933 (0.441)	-8.688 (0.444)
R_2004	0.371	0.354
R_2007	0.369	0.266
R_2010	0.430	0.425
$\bar{x}$	0.577	0.524
B75m(2006) (B75m(2006)/K)	12231 (0.061)	9487 (0.047)
B75m(2019) (B75m(2019)/K)	6814 (0.033)	4873 (0.023)
B75m(2020) (B75m(2020)/K)	7204 (0.034)	4632 (0.022)
B75m(2020)/B75m(2006)	0.589	0.488
	nn.for a8a.res	nn.for a8e.res

Table 1b: **A7** results for  $L(2020)=850\text{mt}$  and  $200\text{mt}$ . The values in parentheses next to the  $-\ln L$  values are the associated  $\sigma$  values for the fit to those data. The comparative 2020 assessment results are also provided (shaded column).

	2020	2021	2021
	LS=700	LS=200	LS=850
-lnL total (T=D+R)	148.715	129.710	130.115
-lnL from data (D)	143.7144	122.183	123.934
R penalties (R)	4.777	7.527	6.180
Trap CPUE $-\ln L$ ( $\sigma$ )	24.824 (1.028)	12.327 (0.466)	13.019 (0.476)
Hoop CPUE $-\ln L$ ( $\sigma$ )	-	-	-
FIMS CPUE $-\ln L$ ( $\sigma$ )	6.388 (0.775)	3.602 (0.693)	-4.158 (0.708)
R_2004	0.019	0.014	0.016
R_2007	0.018	0.012	0.013
R_2010	0.027	0.011	0.011
$\bar{x}$	0.049	0.022	0.026
B75m(2006) (B75m(2006)/K)	6507 (0.026)	3603 (0.012)	3767 (0.012)
B75m(2019) (B75m(2019)/K)	2930 (0.018)	1415 (0.004)	1570 (0.005)
B75m(2020) (B75m(2020)/K)	-	1273 (0.004)	1423 (0.005)
	N7.for A720.res	N7.for N7b.res	N7.for N7a.res



Table 1c: **A56** results for the  $L(2020)=850\text{mt}$  and 200mt poaching scenarios. The values in parentheses next to the  $-\ln L$  values are the associated  $\sigma$  values for the fit to those data. The comparative 2020 assessment results are also provided (shaded column).

	<b>2020</b>	<b>2021</b>	<b>2021</b>
	LS=700	LS=200	LS=850
-lnL total (T=D+R)	141.992	130.373	140.557
-lnL from data (D)	140.260	128.893	129.041
R penalties (R)	1.703	1.480	1.520
Trap CPUE $-\ln L$ ( $\sigma$ )	-	-	-
Hoop CPUE $-\ln L$ ( $\sigma$ )	6.204 (0.736)	-14.837 (0.363)	-15.551 (0.355)
FIMS CPUE $-\ln L$ ( $\sigma$ )	11.036 (1.002)	-11.467 (0.999)	11.497 (0.999)
R_2004	0.051	0.052	0.051
R_2007	0.056	0.050	0.053
R_2010	0.055	0.059	0.057
$\bar{x}$	0.054	0.062	0.062
B75m(2006) (B75m(2006)/K)	1750 (0.007)	1897 (0.008)	1841 (0.008)
B75m(2019) (B75m(2019)/K)	2820 (0.011)	3111 (0.013)	3078 (0.013)
B75m(2020) (B75m(2020)/K)	-	3283 (0.014)	3221 (0.014)
	nn.for a5620.res	nn.for a56b.res	nn.for a56a.res

Table 1d: **A34** results for the L(2020)=850mt and 200mt poaching scenarios. The values in parentheses next to the  $-\ln L$  values are the associated  $\sigma$  values for the fit to those data. The comparative 2020 assessment results are also provided (shaded column).

	2020	2021	2021
	LS=700	LS=200	LS=850
-lnL total (T=D+R)	149.145	154.958	154.978
-lnL from data (D)	147.472	152.716	152.930
R penalties (R)	1.672	2.242	2.048
Trap CPUE $-\ln L$ ( $\sigma$ )	-4.560 (0.512)	-5.742 (0.493)	-5.787 (0.493)
Hoop CPUE $-\ln L$ ( $\sigma$ )	-6.175 (0.506)	-4.881 (0.528)	-4.503 (0.533)
FIMS CPUE $-\ln L$ ( $\sigma$ )	23.604 (1.504)	24.420 (1.495)	24.445 (1.500)
R_2004	0.069	0.069	0.069
R_2007	0.072	0.076	0.071
R_2010	0.123	0.102	0.106
$\bar{x}$	0.085	0.083	0.091
B75m(2006) (B75m(2006)/K)	3593 (0.020)	3556 (0.022)	3748 (0.023)
B75m(2019) (B75m(2019)/K)	2598 (0.034)	2688 (0.017)	2734 (0.017)
B75m(2020) (B75m(2020)/K)	-	2826 (0.017)	2867 (0.017)
	nn.for a3420.res	nn.for a34b.res	nn.for a34a.res

Table 1e: **A12** results. The values in parentheses next to the  $-\ln L$  values are the associated  $\sigma$  values for the fit to those data. Note that the assumption made is that poaching in A12 is zero for all poaching scenarios. The comparative 2019 assessment results are also provided (shaded column).

	<b>2020</b>	<b>2021</b>
$-\ln L$ total (T=D+R)	-30.891	-29.028
$-\ln L$ from data (D)	-32.361	-30.710
R penalties (R)	1.470	1.682
Trap CPUE $-\ln L$ ( $\sigma$ )	-	-
Hoop CPUE $-\ln L$ ( $\sigma$ )	-41.883 (0.218)	-41.183 (0.227)
FIMS CPUE $-\ln L$ ( $\sigma$ )	-	-
R_2004	0.009	0.008
R_2007	0.023	0.005
R_2010	0.054	0.015
$\bar{x}$	0.035	0.023
B75m(2006) (B75m(2006)/K)	1206 (0.018)	575 (0.008)
B75m(2019) (B75m(2019)/K)	1576 (0.024)	794 (0.011)
B75m(2020) (B75m(2020)/K)	-	1260 (0.018)
	N12.for A1220.res	N12.for A12t.res

Table 2a: Comparison of recent **total** biomass estimates (in mt) for the 2019, 2020 and 2021 assessments.

	2019 LS=700	2020 LS=700	2021 LS=200	2021 LS=850
B75m(2018)	15 029	13 664	12 426	12 282
B75m(2018/2006)	0.694	0.607	0.546	0.542
B75m(2019)	-	15 427	15 095	14 991
B75m(2019/2006)	-	0.685	0.663	0.661
B75m(2020)	-	-	16 201	15 979
B75m(2020/2006)	-	-	0.712	0.705

Table 2b: Comparison of super-area and total 2018 biomass estimates (mt) for the 2020 and 2021 assessments.

	2020 assessment LS=700	2021 assessment LS=200	2021 assessment LS=850
A8+ B75m(2018)	4253	5185	4871
A7 B75m(2018)	2991	1456	1589
A56 B75m(2018)	2575	2706	2686
A34 B75m(2018)	2410	2330	2385
A12 B75m(2018)	1510	749	749
TOTAL B75m(2018)	13 664	12 426	12 282
A8+ B75m(2018/2006)	0.450	0.393	0.383
A7 B75m(2018/2006)	0.460	0.353	0.422
A56 B75m(2018/2006)	1.471	1.730	1.459
A34 B75m(2018/2006)	0.671	0.792	0.637
A12 B75m(2018/2006)	1.252	2.190	1.301
TOTAL B75m(2018/2006)	0.607	0.546	0.542
A8+ B75m(2020)	-	7558	7205
A7 B75m(2020)	-	1273	1423
A56 B75m(2020)	-	3283	3221
A34 B75m(2020)	-	2826	2868
A12 B75m(2020)	-	1260	1260
TOTAL B75m(2020)	-	16 201	15 978
A8+ B75m(2020/2006)	-	0.576	0.566
A7 B75m(2020/2006)	-	0.353	0.378
A56 B75m(2020/2006)	-	1.730	1.750
A34 B75m(2020/2006)	-	0.792	0.765
A12 B75m(2020/2006)	-	2.190	2.190
TOTAL B75m(2020/2006)	-	0.712	0.705

Table 2c: Comparison of super-area **A8+** B75m(2018/2006) and B75m(2020/2006) values for a range of model scenarios.

	<b>BC compliance</b>		<b>SEN compliance</b>		BC compliance
	<b>BC somatic growth</b>		BC somatic growth		<b>SEN somatic growth</b>
	L(2020)=200	L(2020)=850	L(2020)=200	L(2020)=850	L(2020)=850
B75m(2018/2006)	0.393	0.383	0.368	0.381	0.406
B75m(2020/2006)	0.576	0.566	0.359	0.373	0.488

Table 3a: B75m(2025/**2006**) for a range of future CC scenarios and assessment models.

		BC compliance BC somatic growth L(2020)=200mt	BC compliance BC somatic growth L(2020)=850mt	SEN compliance BC somatic growth L(2020)=200mt	SEN compliance BC somatic growth L(2020)=850mt	SEN compliance SEN somatic growth L(2020)=850mt
CC=0 mt	A12	1.377	1.377	1.377	1.377	1.377
	A34	0.966	0.875	0.966	0.875	0.875
	A56	2.127	1.980	2.127	1.980	1.980
	A7	0.268	0.217	0.268	0.217	0.217
	A8	0.742	0.610	0.725	0.538	0.607
	T	<b>0.833</b>	<b>0.719</b>	<b>0.826</b>	<b>0.677</b>	<b>0.735</b>
CC=837 mt	A12	1.246	1.246	1.246	1.246	1.246
	A34	0.948	0.855	0.948	0.855	0.855
	A56	2.015	1.865	2.015	1.865	1.865
	A7	0.175	0.132	0.175	0.132	0.132
	A8	0.716	0.584	0.698	0.513	0.570
	T	<b>0.789</b>	<b>0.675</b>	<b>0.780</b>	<b>0.634</b>	<b>0.683</b>

Table 3b: B75m(2025/**2020**) for a range of future CC scenarios and assessment models.

		BC compliance BC somatic growth L(2020)=200mt	BC compliance BC somatic growth L(2020)=850mt	SEN compliance BC somatic growth L(2020)=200mt	SEN compliance BC somatic growth L(2020)=850mt	SEN compliance SEN somatic growth L(2020)=850mt
CC=0 mt	A12	1.093	1.093	1.093	1.093	1.093
	A34	1.219	1.140	1.219	1.140	1.140
	A56	1.231	1.133	1.231	1.133	1.133
	A7	0.953	0.756	0.953	0.756	0.756
	A8	1.288	1.079	1.309	1.046	1.245
	T	<b>1.232</b>	<b>1.080</b>	<b>1.240</b>	<b>1.065</b>	<b>1.141</b>
CC=837 mt	A12	0.989	0.989	0.989	0.989	0.989
	A34	1.196	1.118	1.196	1.118	1.118
	A56	1.166	1.067	1.166	1.067	1.067
	A7	0.621	0.458	0.621	0.458	0.458
	A8	1.244	1.033	1.261	0.997	1.170
	T	<b>1.166</b>	<b>1.013</b>	<b>1.171</b>	<b>0.996</b>	<b>1.059</b>

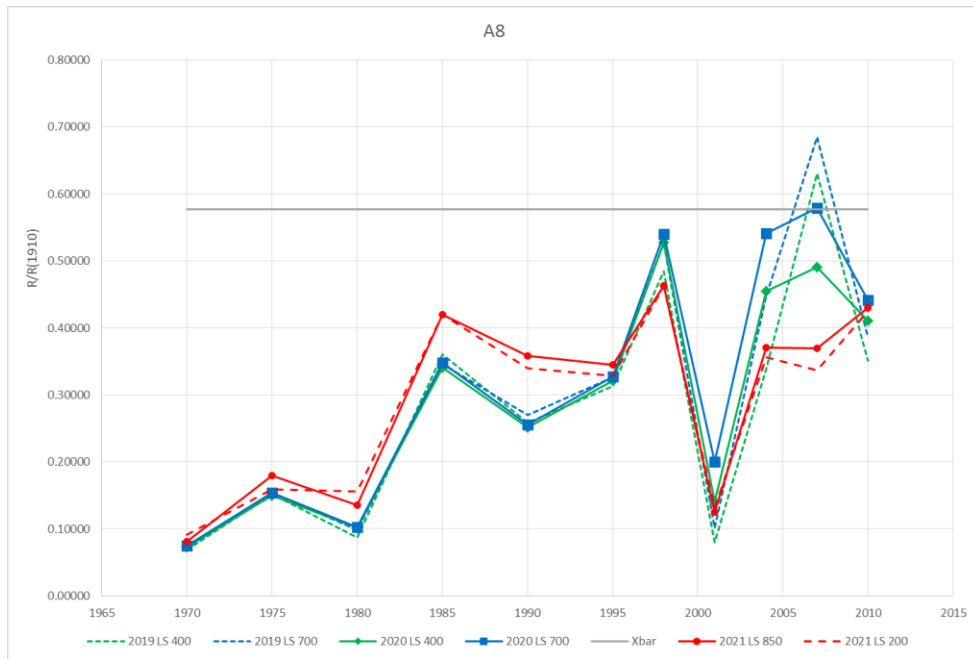


Figure 1ai: R estimates (relative to that in 1910) for **A8+**. Values are reported for the 2019, 2020 and updated 2021 assessments. The 2021 estimates assume the BC compliance trend. Xbar refers to the average  $R/R(2010)$  value about which the 1970-2010 recruitment estimates vary.

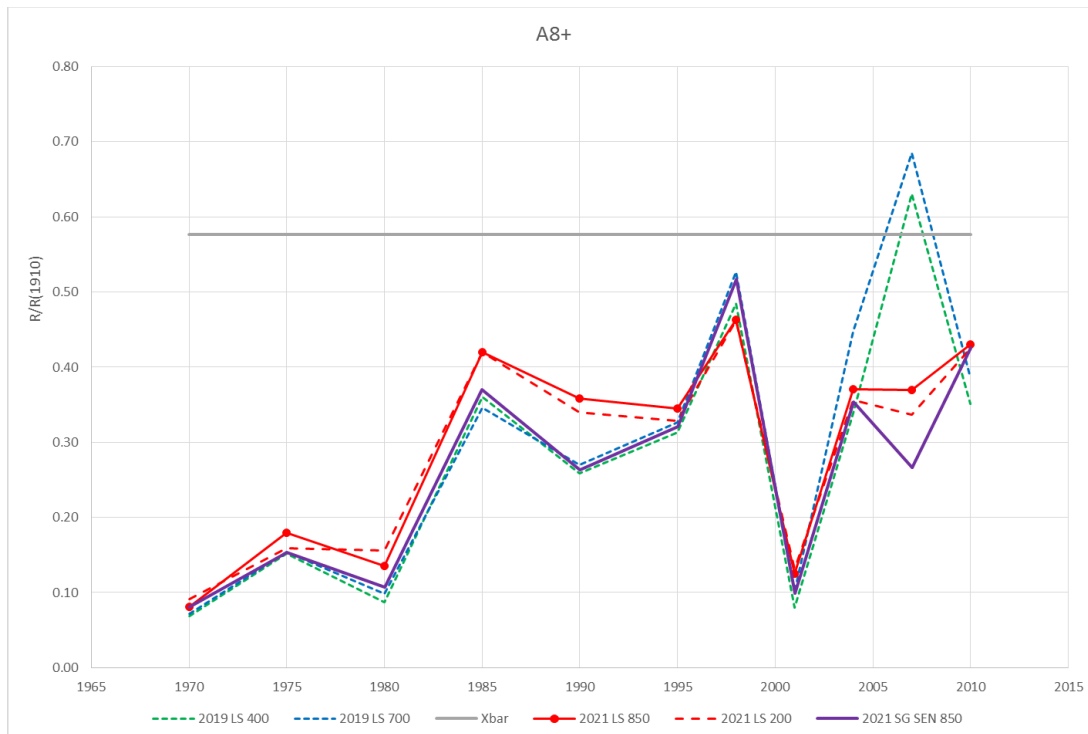


Figure 1aai: R estimates (relative to that in 1910) for **A8+**. Values are reported for the 2019 and updated 2021 assessments including the 2021 SG SEN model. The 2021 estimates assume the BC compliance trend. Xbar refers to the average  $R/R(2010)$  value about which the 1970-2010 recruitment estimates vary.

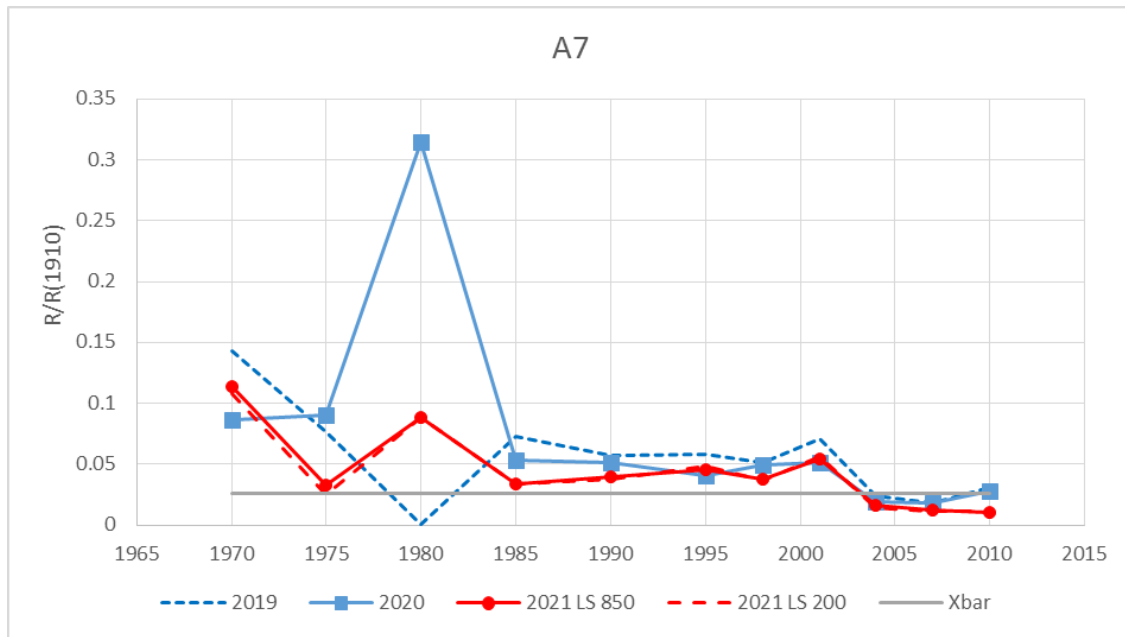


Figure 1b: R estimates (relative to that in 1910) for **A7**. Values are reported for the 2019, 2020 and updated 2021 assessments. Xbar refers to the average  $R/R(2010)$  value about which the 1970-2010 recruitment estimates vary.

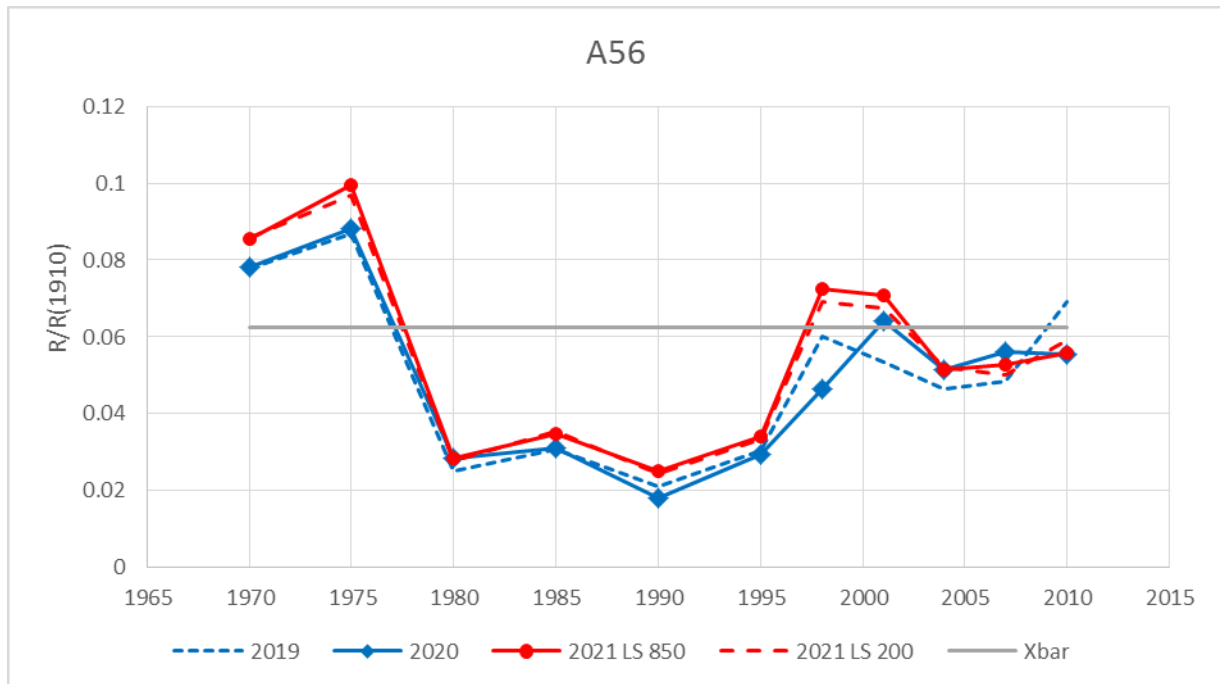


Figure 1c: R estimates (relative to that in 1910) for **A56**. Values are reported for the 2019, 2020 and updated 2021 assessments. Xbar refers to the average  $R/R(2010)$  value about which the 1970-2010 recruitment estimates vary.



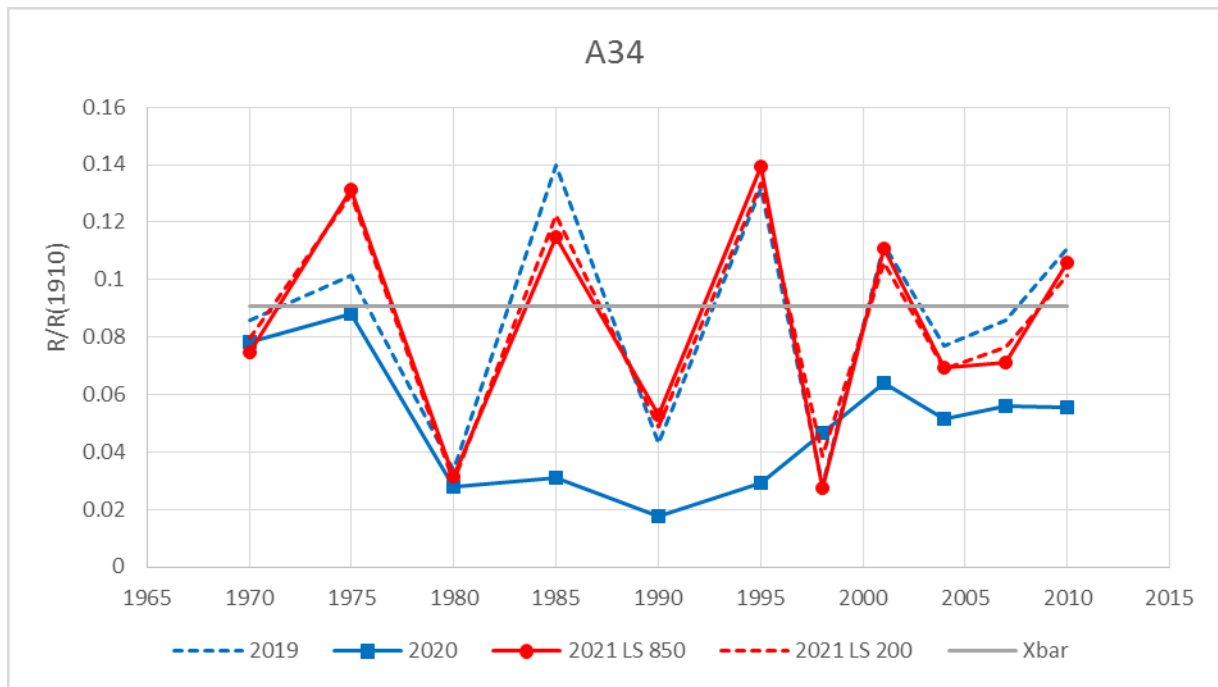


Figure 1d: R estimates (relative to that in 1910) for **A34**. Values are reported for the 2019, 2020 and updated 2021 assessments. Xbar refers to the average  $R/R(2010)$  value about which the 1970-2010 recruitment estimates vary.

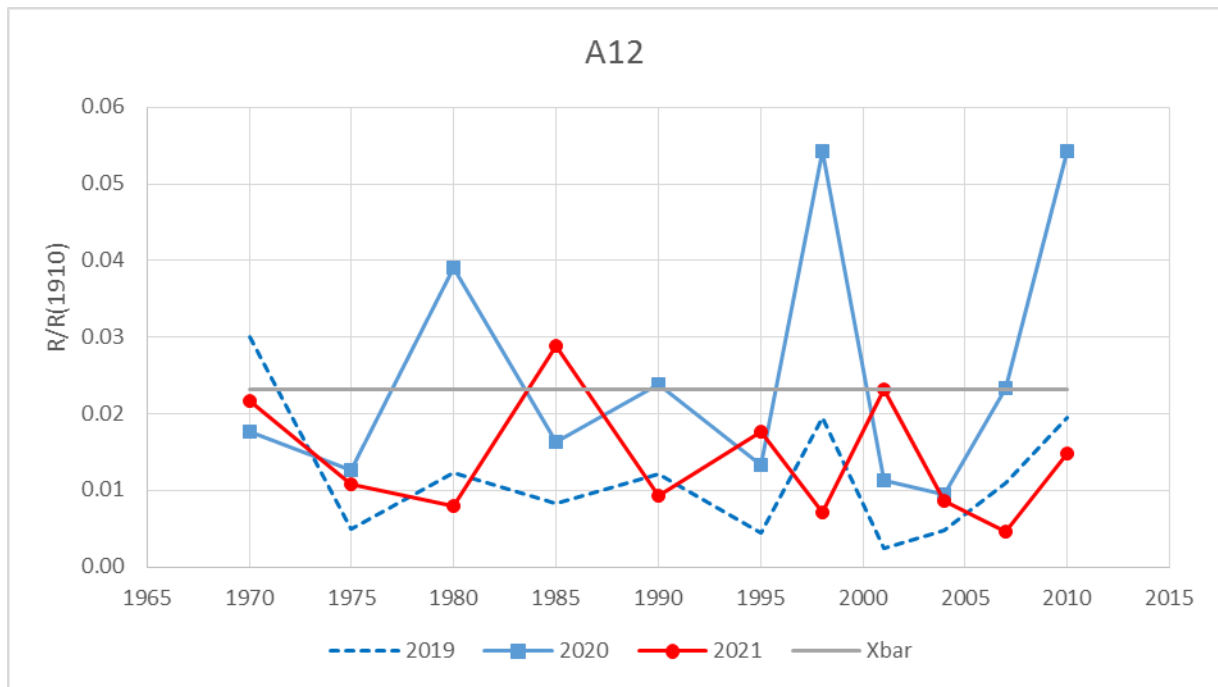


Figure 1e: R estimates (relative to that in 1910) for **A12** (no poaching is assumed to occur in A12). Values are reported for the 2019, 2020 and updated 2021 assessments. Xbar refers to the average  $R/R(2010)$  value about which the 1970-2010 recruitment estimates vary.

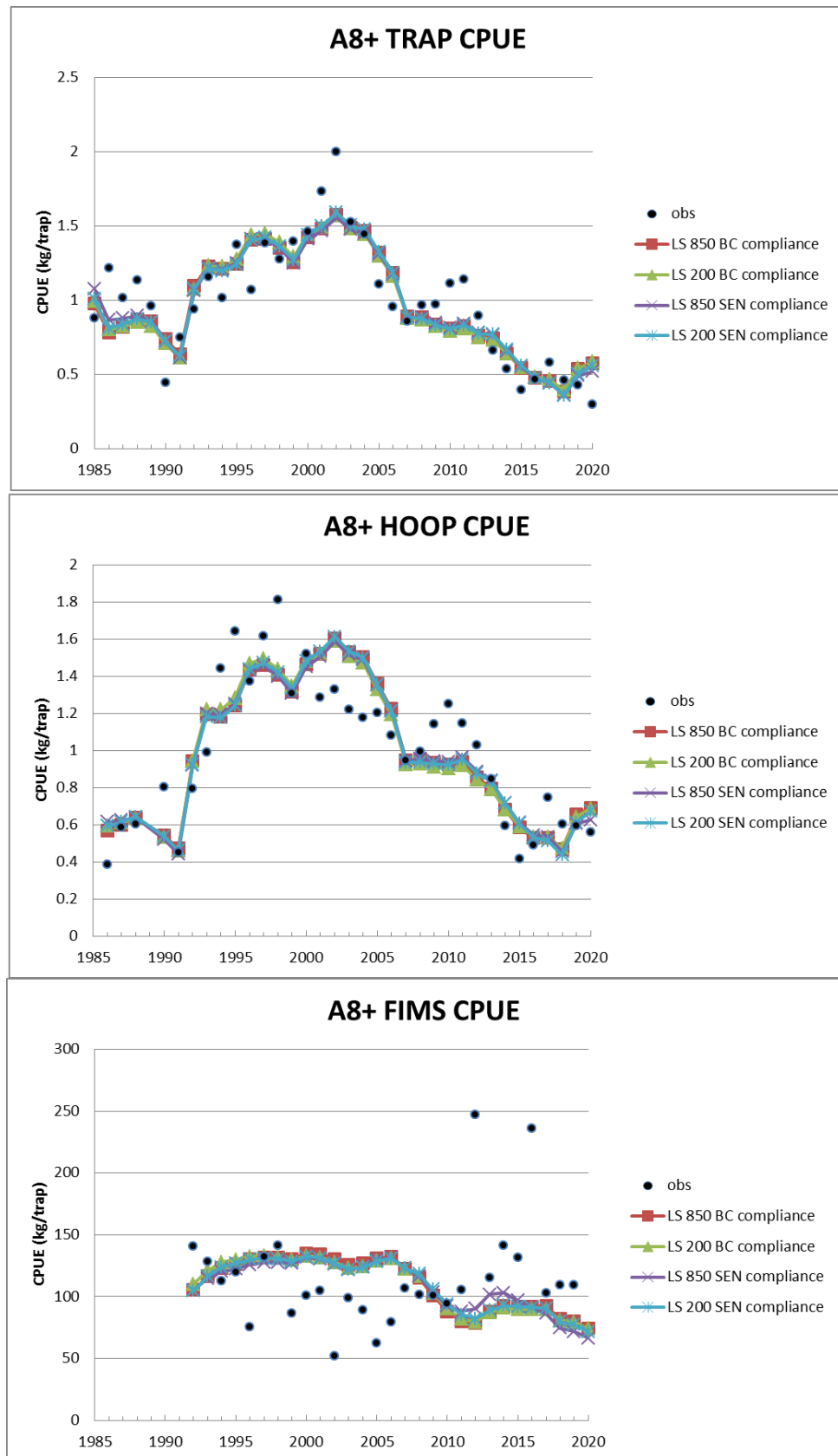


Figure 2ai: Comparison of fits to **A8+** CPUE and FIMS for the different 2021 assessments.

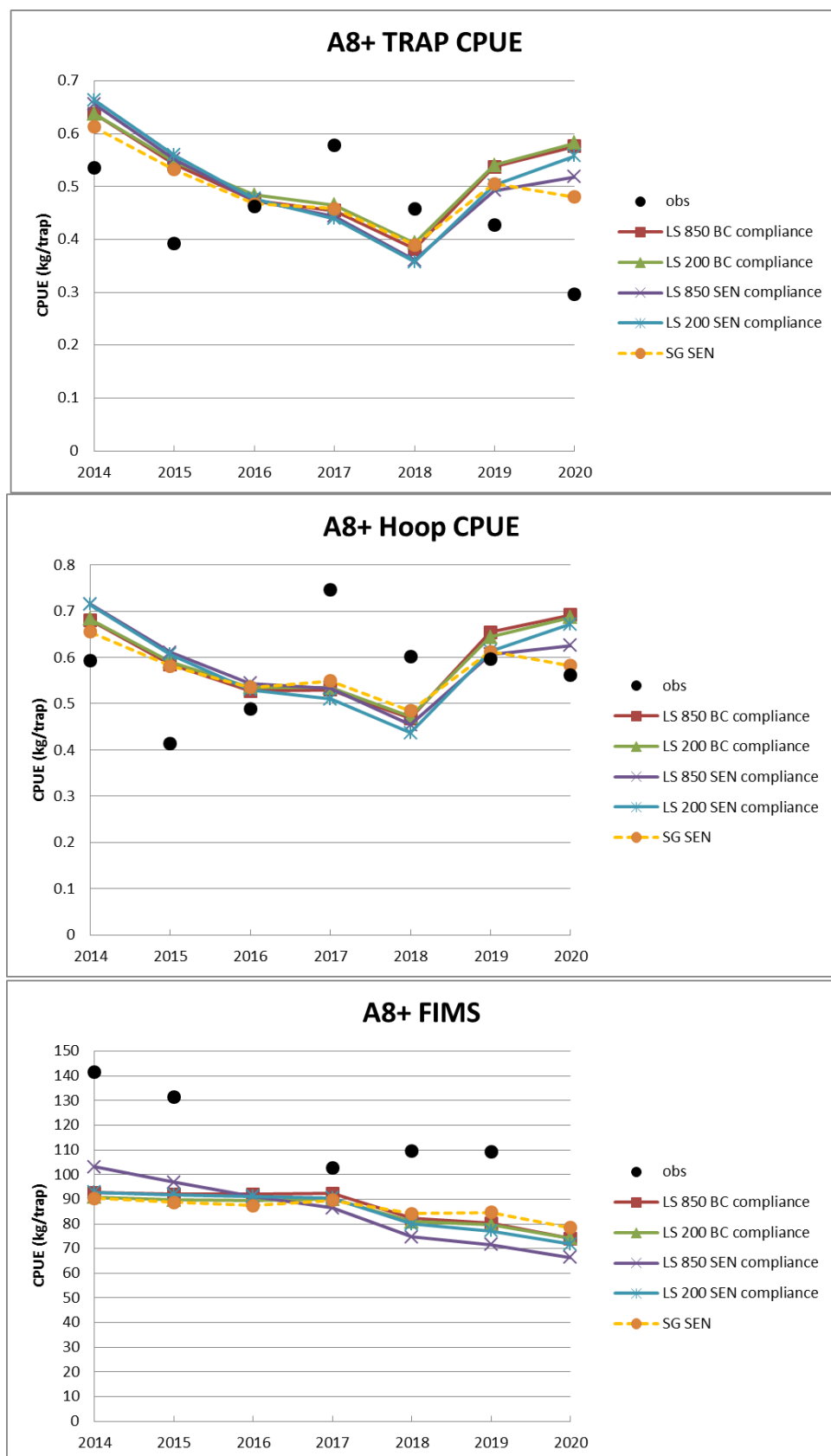


Figure 2ii: Comparison of fits to **A8+** CPUE and FIMS for 2014-2020 for the different 2021 assessments, including the SG SEN model.

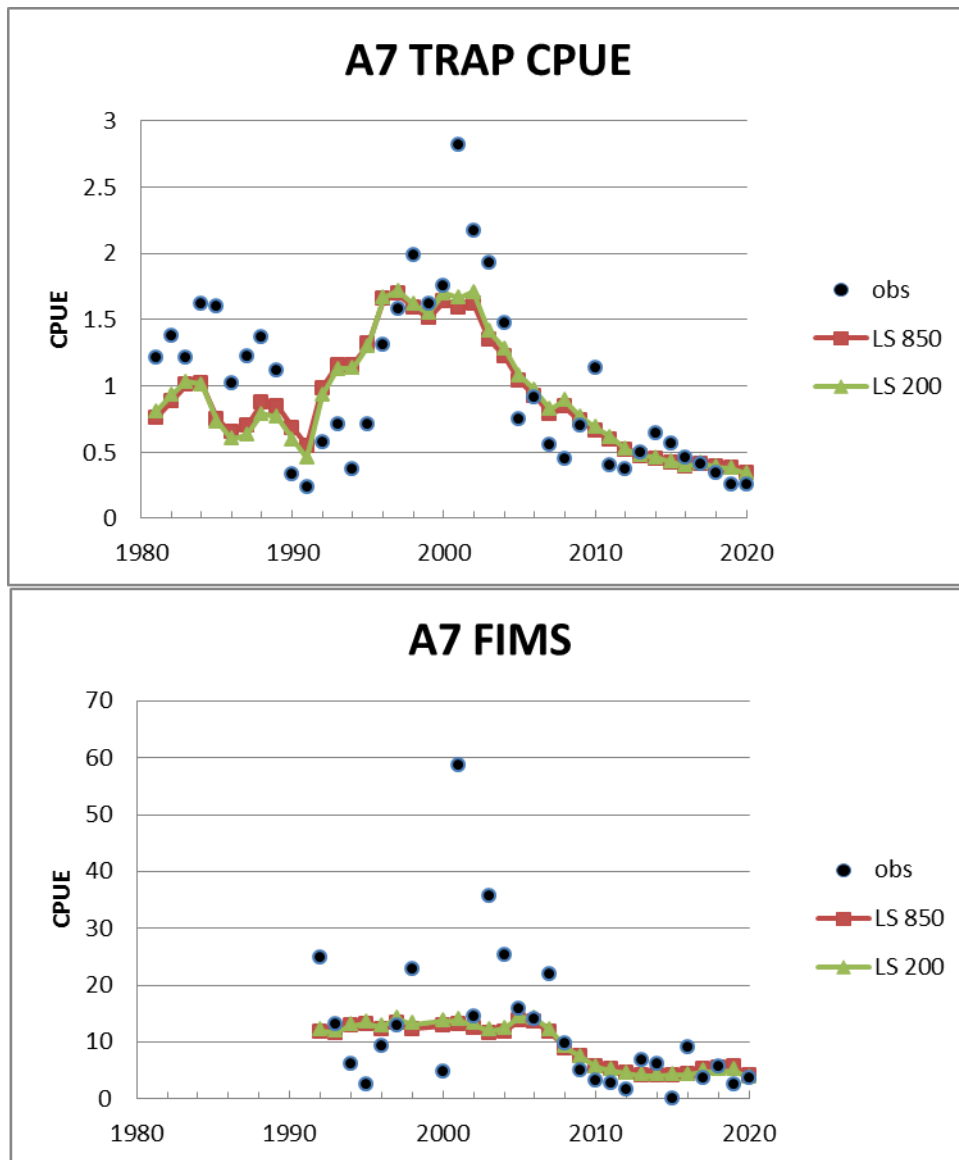


Figure 2b: Comparison of fits to **A7** CPUE and FIMS for the 2021 assessments.

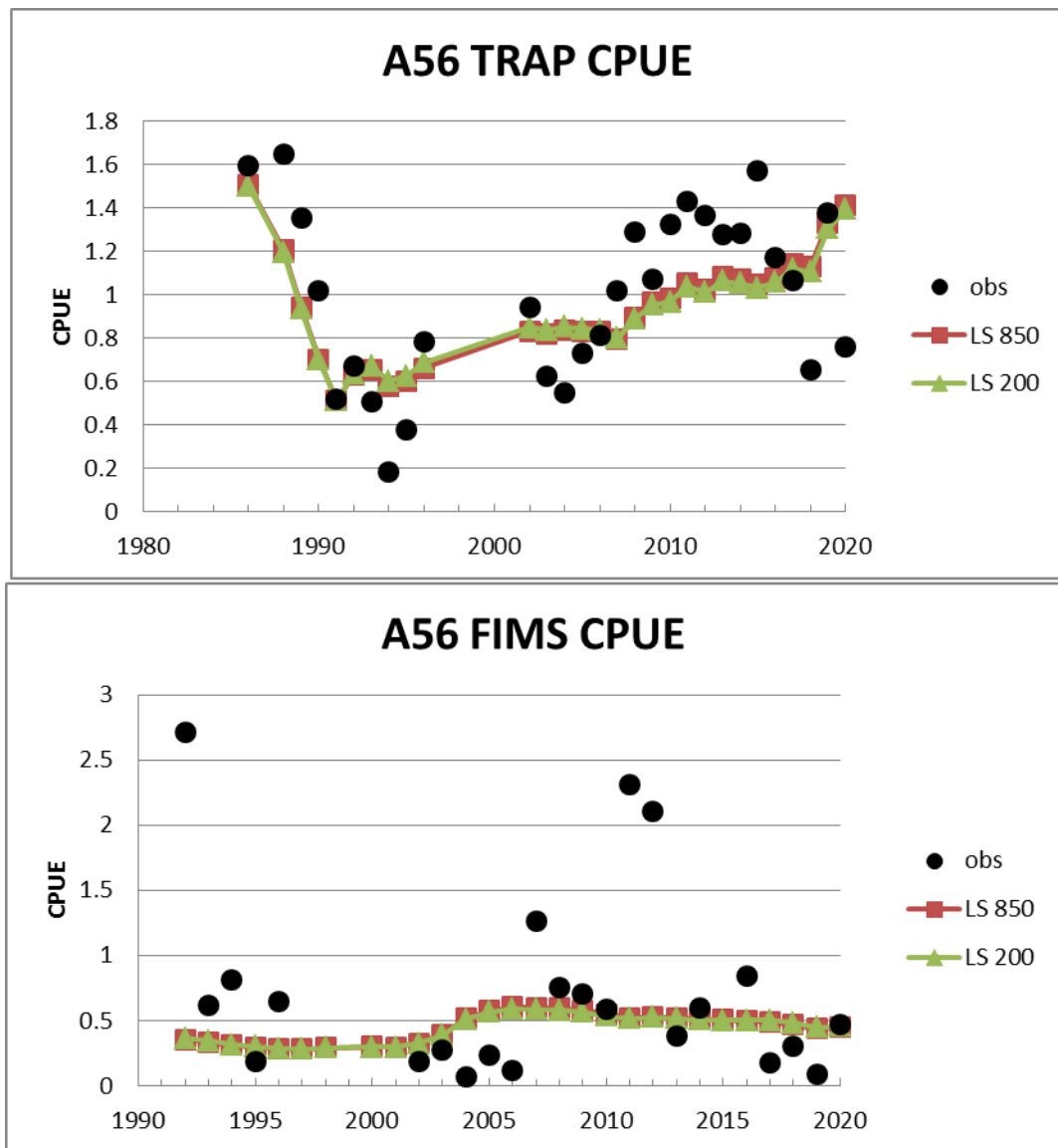


Figure 2c: Comparison of fits to **A56** CPUE and FIMS for the 2021 assessments.

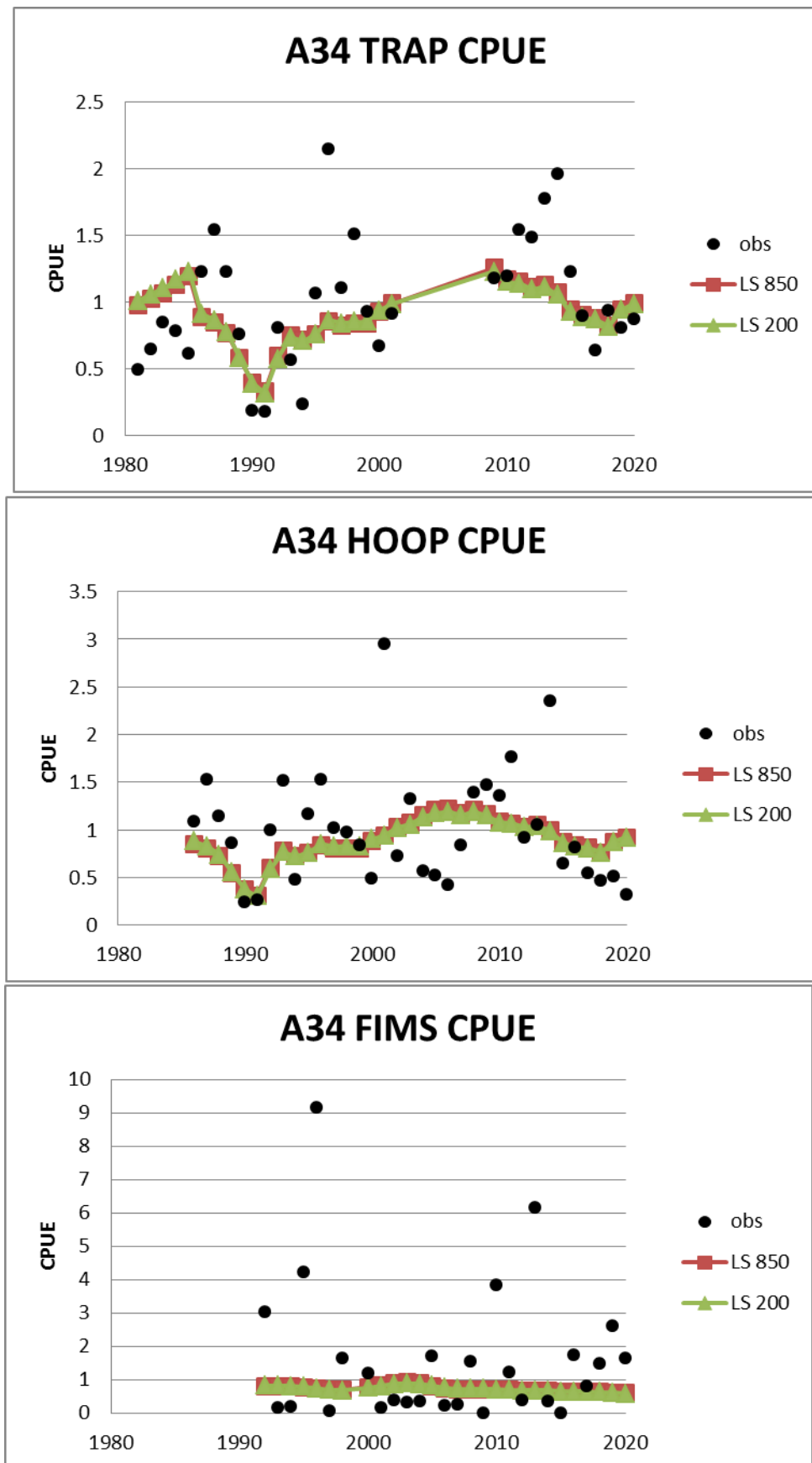


Figure 2d: Comparison of fits to **A34** CPUE and FIMS for the 2021 assessments.

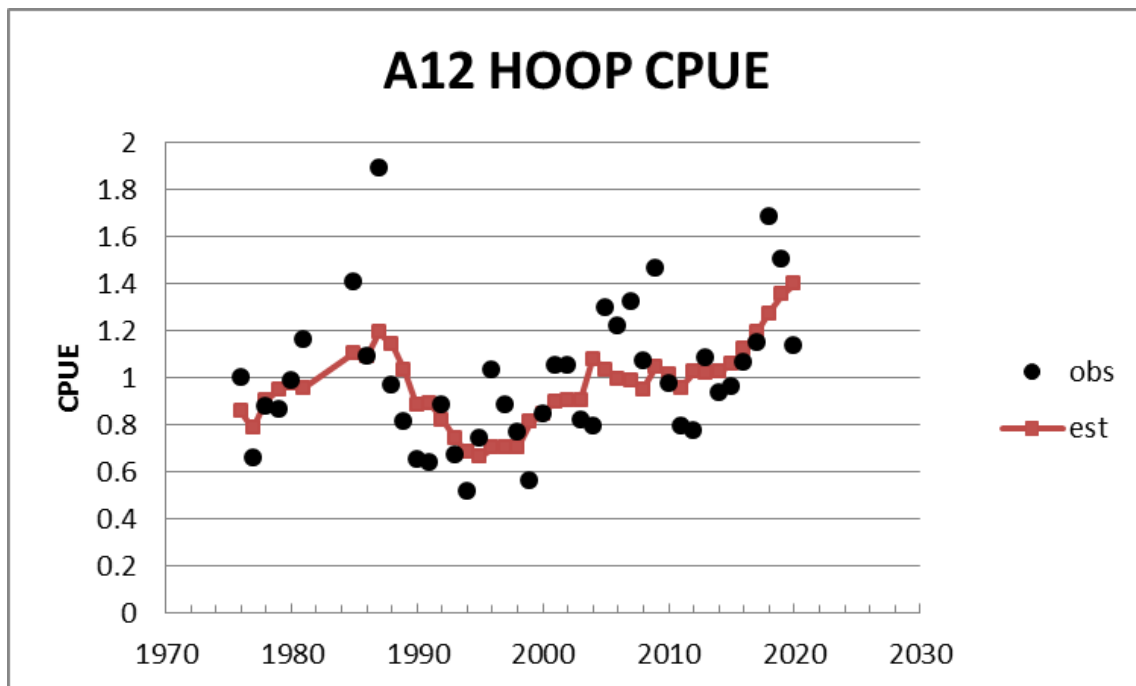


Figure 2e: Comparison of fits to **A12** CPUE for the 2020 assessment (no poaching is assumed to occur in A12).



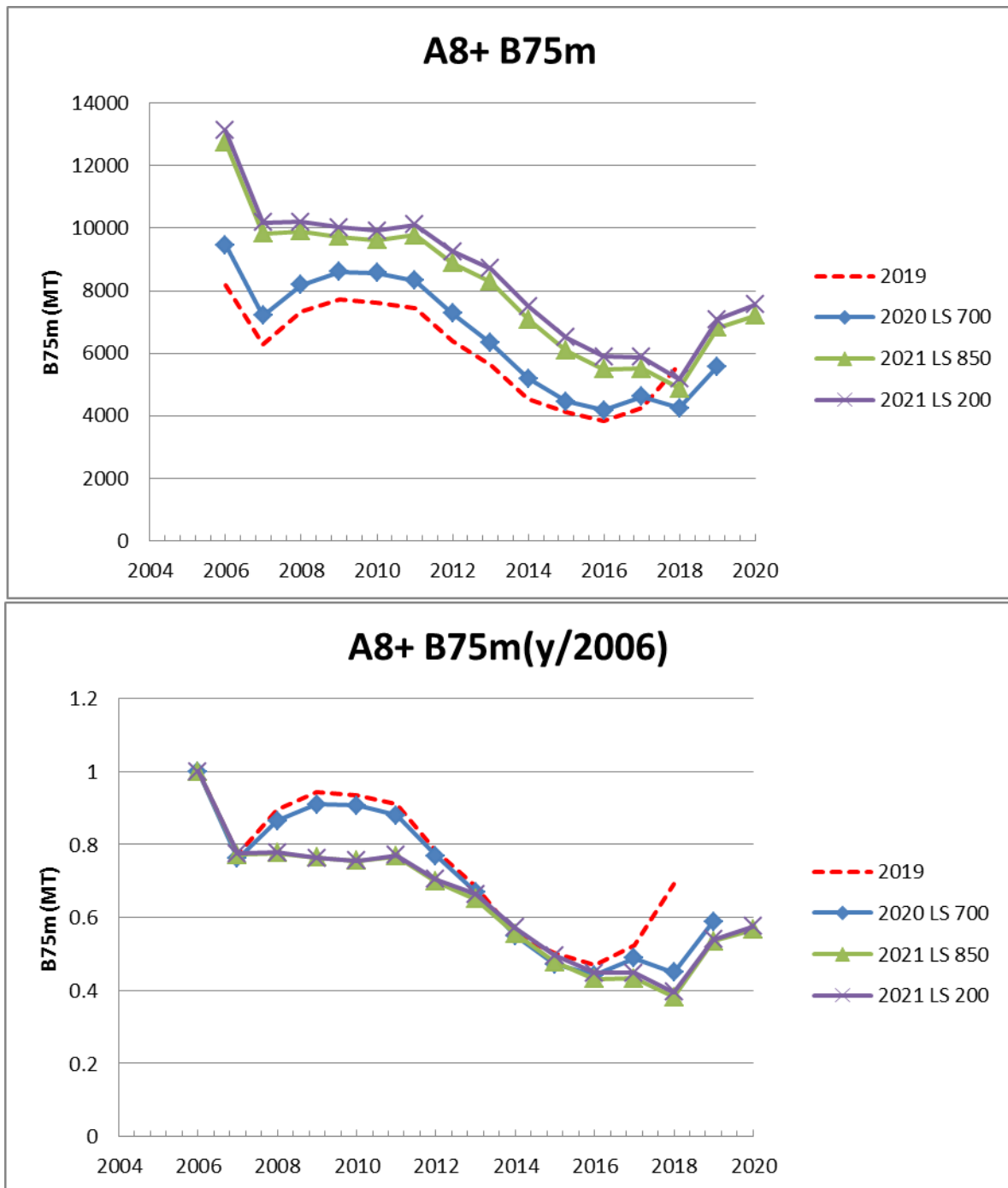


Figure 3a: Comparison of the 2019, 2020 and BC 2021 assessments **A8+ B75m** trajectories. The top plot shows absolute values with the bottom plot showing biomass relative to the 2006 levels.

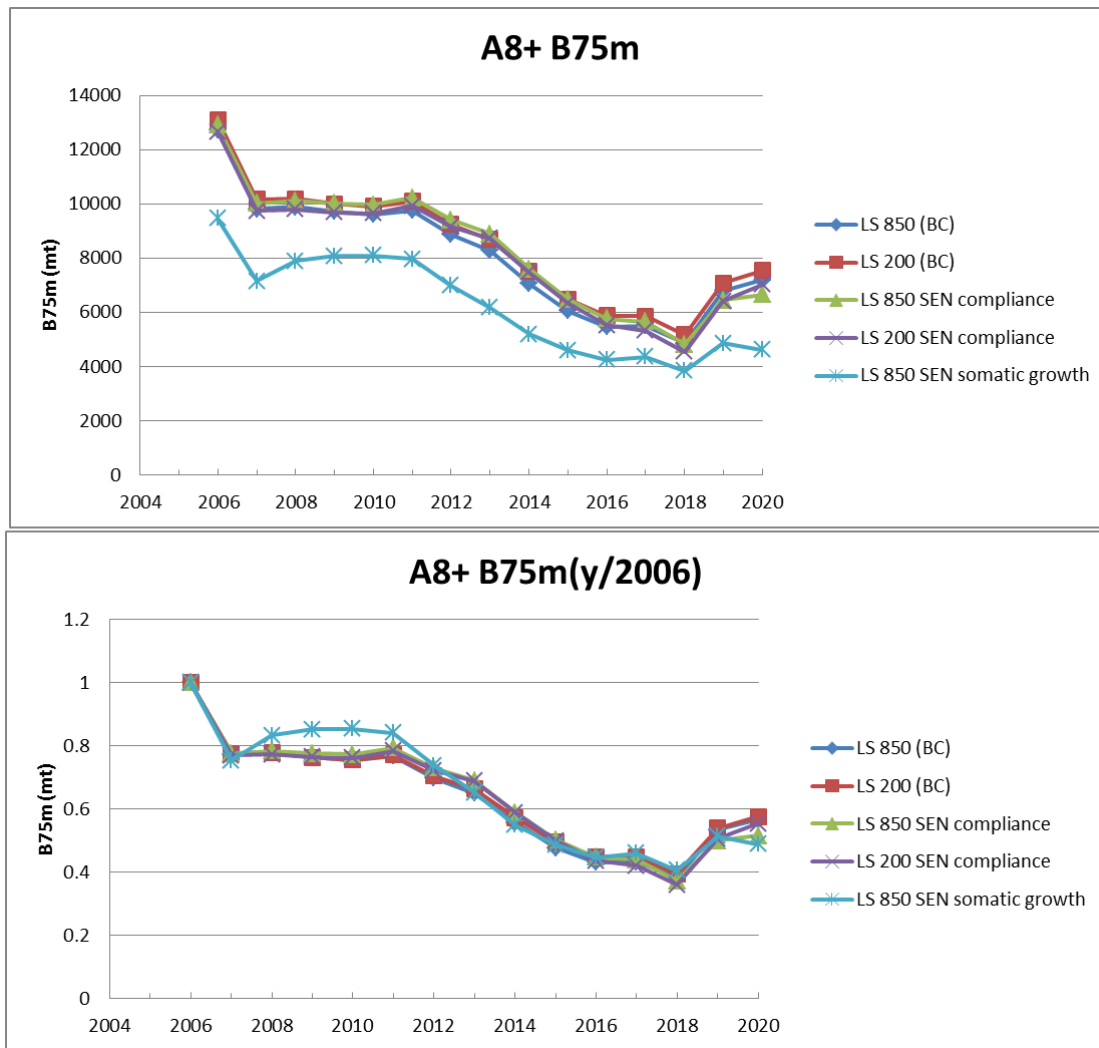


Figure 3b: Comparison of the 2021 assessments **A8+ B75m** trajectories. The top plot shows absolute values with the bottom plot showing biomass relative to the 2006 level.

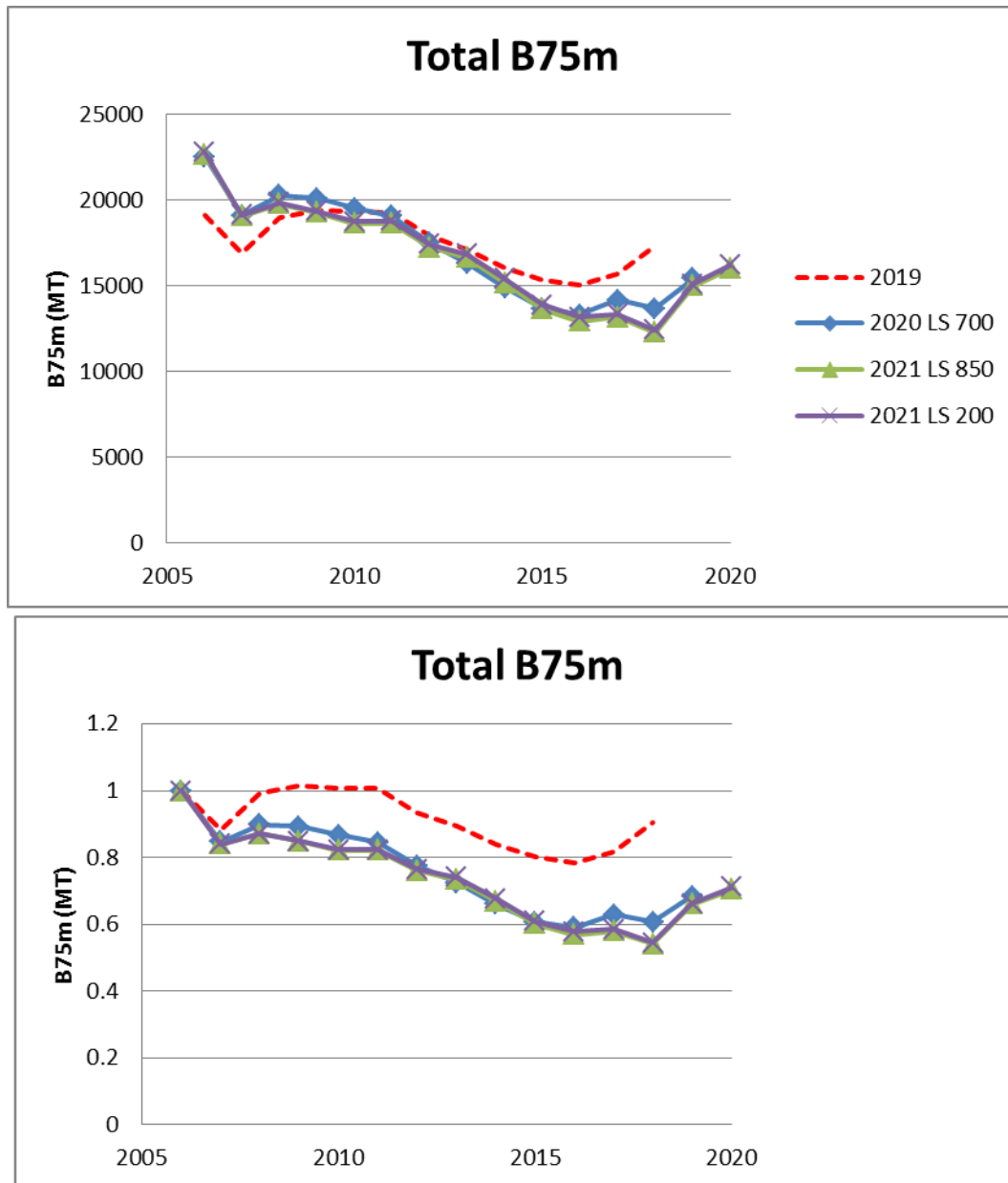


Figure 4: Comparison of the **total** estimated resource biomass in absolute terms (top plot) and relative to 2006 (bottom plot) for the 2019, 2020 and 2021 BC assessments.

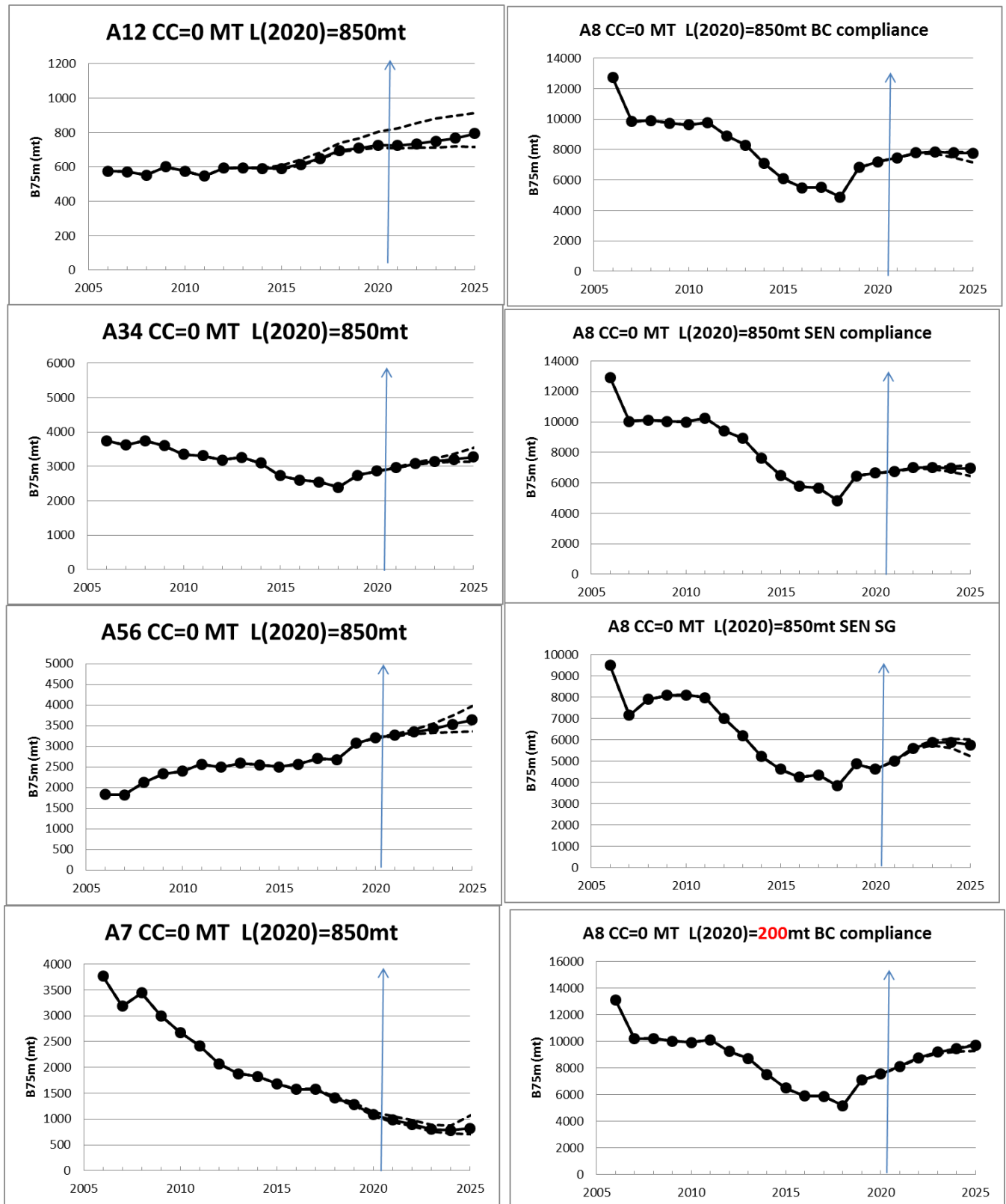


Figure 5a: **Super-area** B75m medians and 5<sup>th</sup> and 95<sup>th</sup> percentiles for CC=**Zero**. Results are for the L(2020)=850mt scenario for A12-A7 and A8+, as well as for the 200mt option for A8+. There are four different model options (RHS) for A8+.

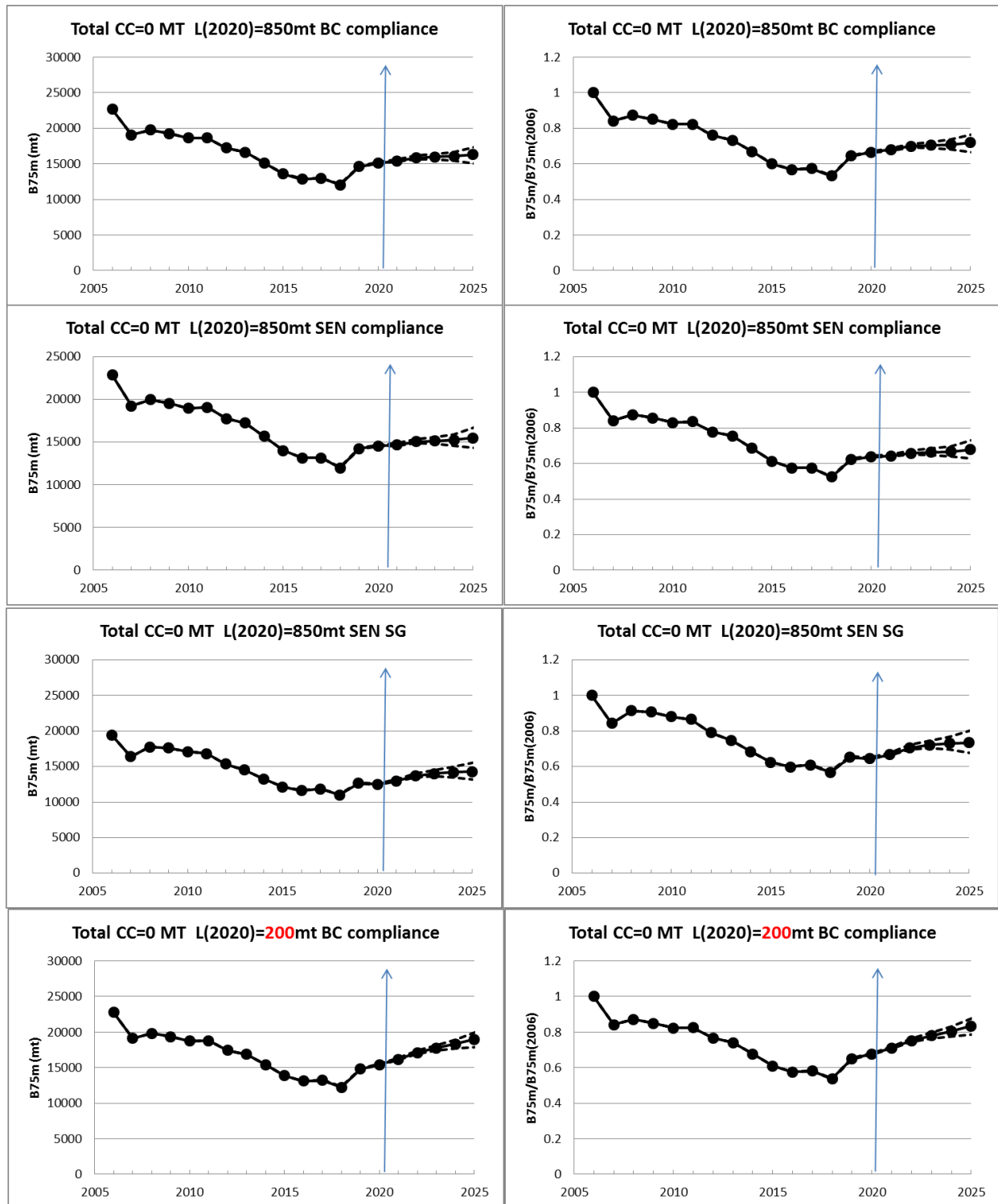


Figure 5b: **Total** B75m medians and 5<sup>th</sup> and 95<sup>th</sup> percentiles for CC=**Zero**. Results are for the L(2020)=850mt scenario (top 3 rows), as well as for the 200mt option (bottom row).

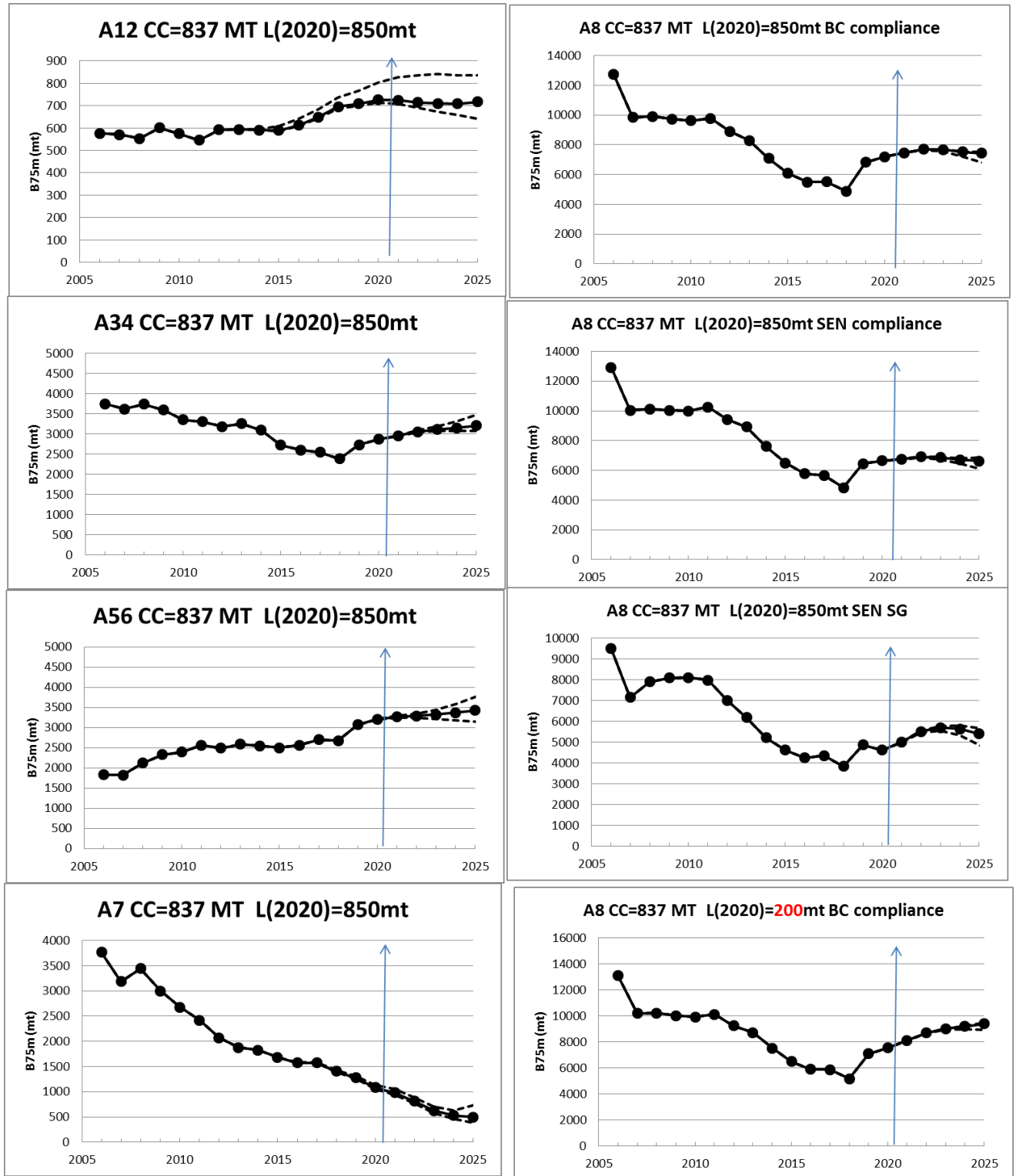


Figure 6a: **Super-area** B75m medians and 5<sup>th</sup> and 95<sup>th</sup> percentiles for CC=837 mt. Results are for the L(2020)=850mt scenario for A12-A7 and A8+, as well as for the 200mt option for A8+. There are four different model options (RHS) for A8+.

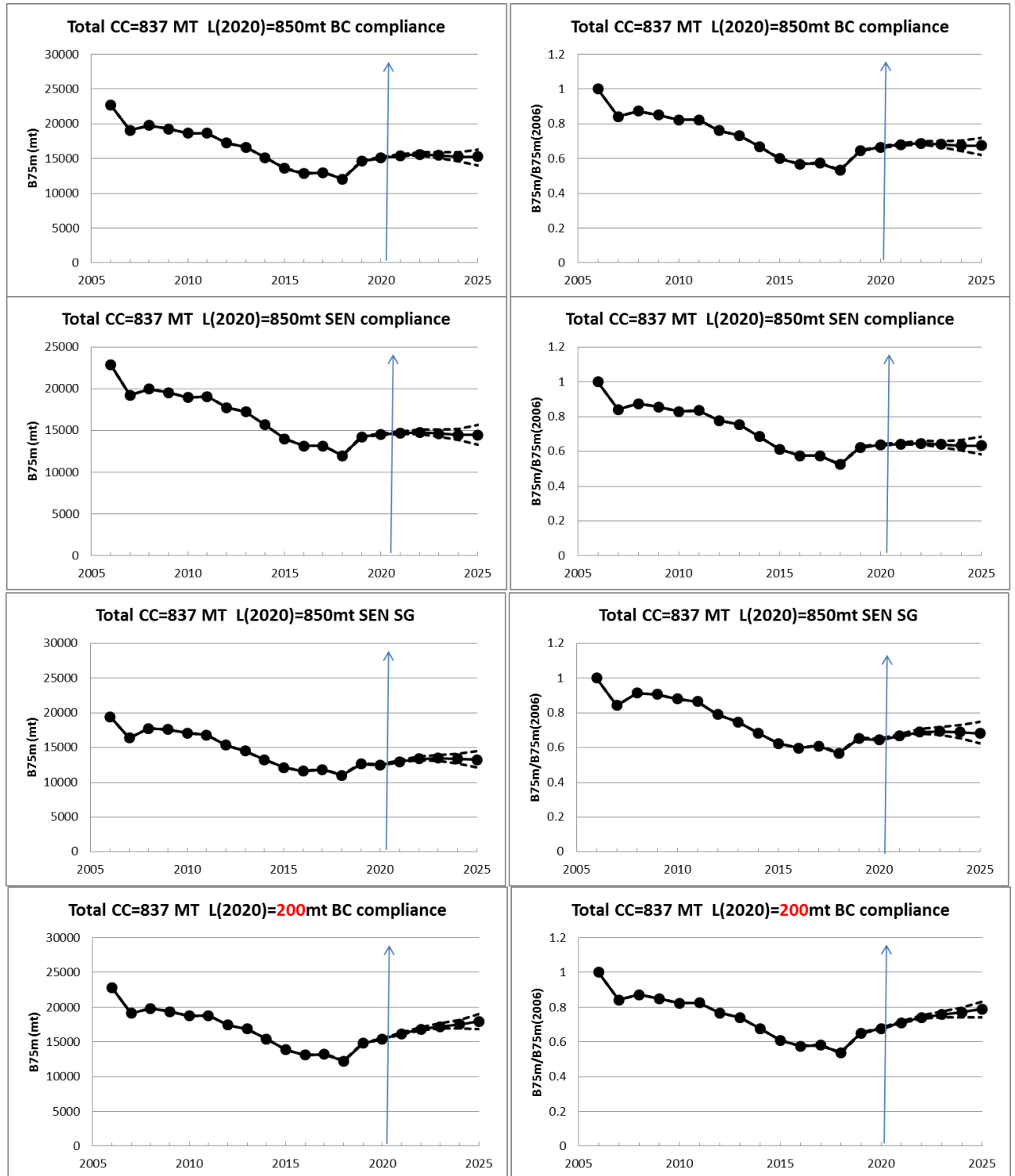


Figure 6b: **Total** B75m medians and 5<sup>th</sup> and 95<sup>th</sup> percentiles for CC=837 MT. Results are for the L(2020)=850mt scenario (top 3 rows) as well as the 200mt option (bottom row).

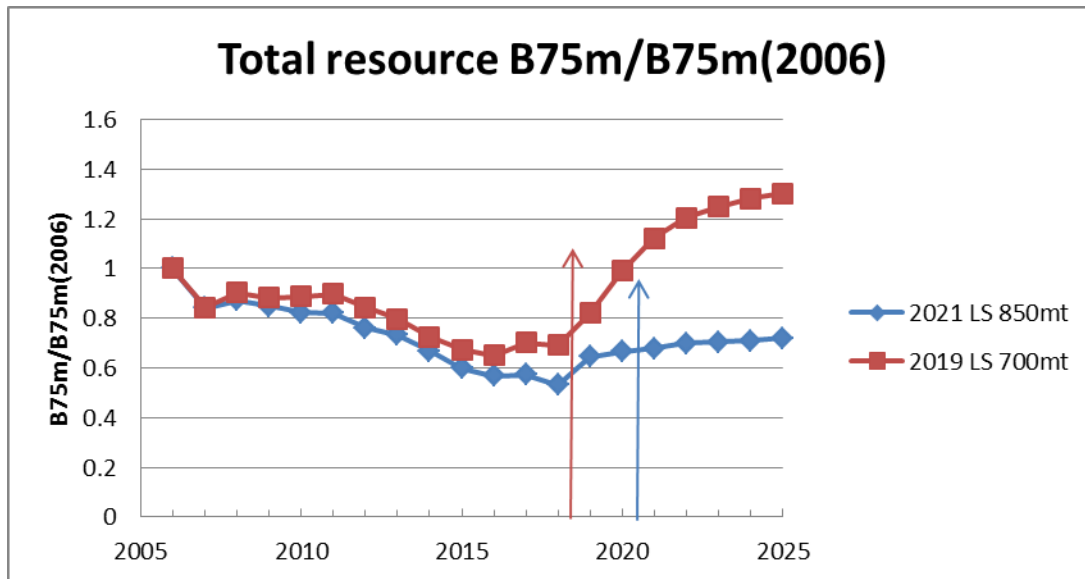


Figure 7: Comparison between the 2019 and 2021 BC projections under a **Zero** CC.

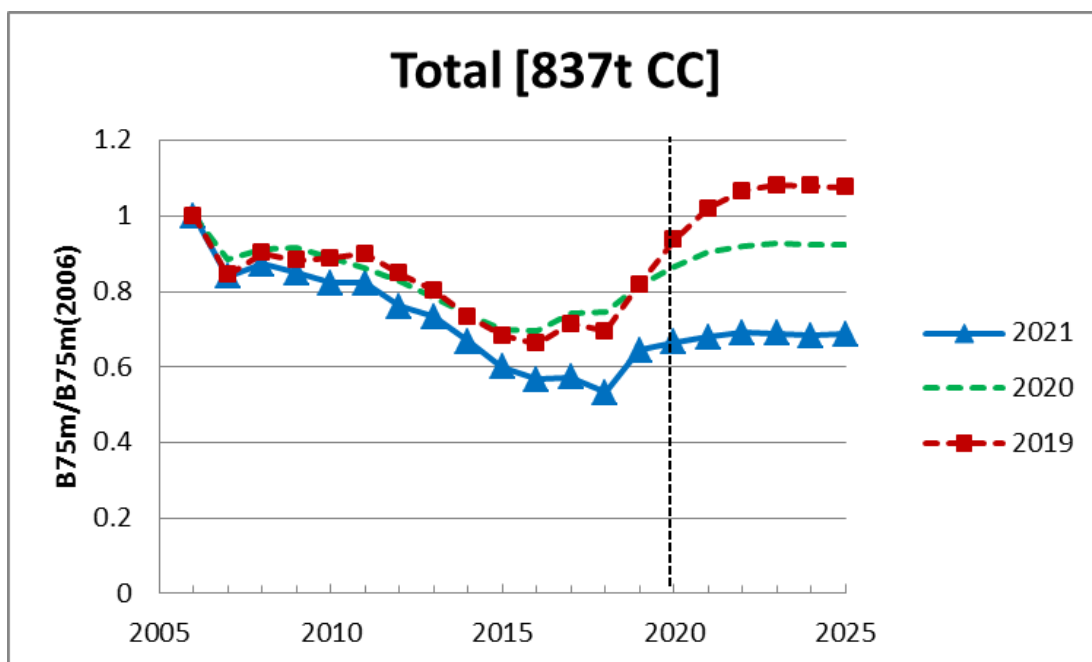


Figure 8: Total B75m trajectories under a CC=837mt for the 2019, 2020 and 2021 assessments.



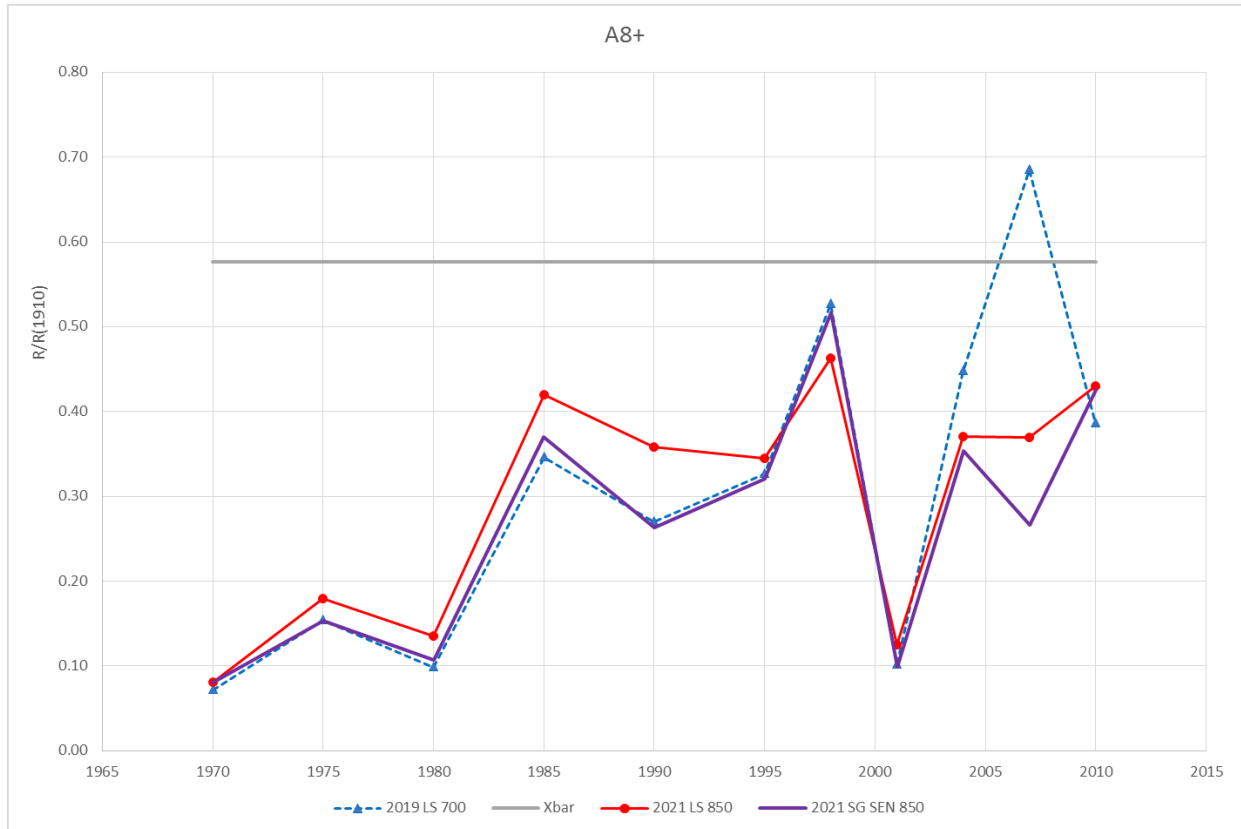


Figure 9a: Comparing A8+ recruitment trends for 2019 and 2021.

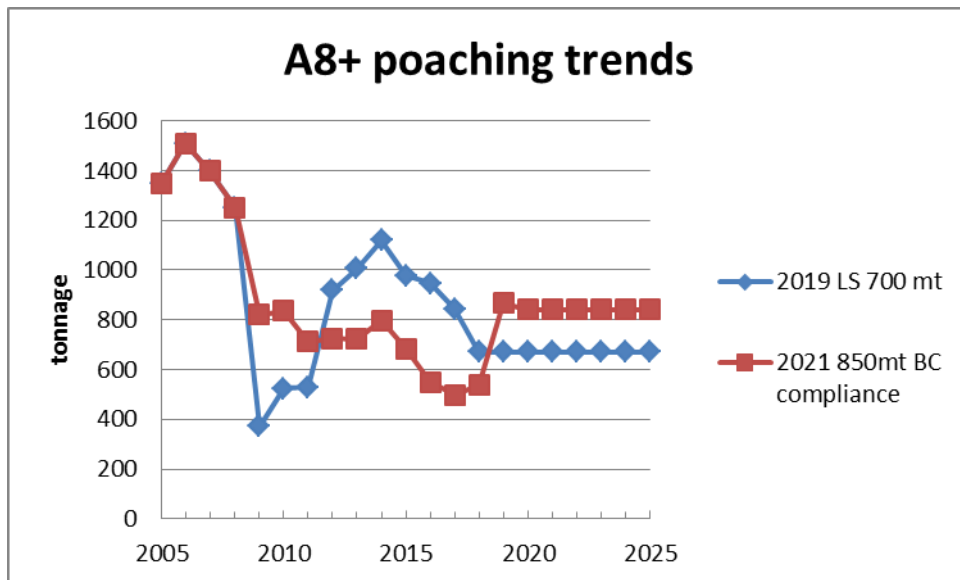


Figure 9b: Poaching trends for A8+ for 2019 and 2021.

## Appendix: Recruitment model

Estimate  $R_{1910}, x_{1920}, x_{1950}$  [3 estimable parameters]

Estimate  $\bar{x} = \sum_{y=1970}^{y=2010} (x_y) / 11$  [1 estimable parameter]

Estimate for  $y=1970 \dots 2010$ :  $x_y = \bar{x} e^{\varepsilon_y - \sigma_R^2/2}$  [11 estimable  $\varepsilon_y$  parameters]

Add to the  $-\ln L$  a penalty which is

$$\frac{1}{2\sigma_R^2} \sum_{y=1970}^{y=2010} \varepsilon_y^2$$

Note that estimating  $\bar{x}$  directly in this way takes account of the different precisions with which the individual recruitment values are estimated.

### Projections

Future recruitment values (i.e.  $R_{2015}$ ,  $R_{2020}$ ,  $R_{2025}$  and  $R_{2030}$ ) are drawn at random with replacement from the estimated  $R_{1970} \dots R_{2007}$  parameter estimates (i.e. **excluding  $R_{2010}$** ).