Apportionment and regulatory area harvest calculations

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Abstract

Setline survey weight per unit effort (WPUE) is used to apportion the estimated 2014 exploitable biomass from the coastwide stock assessment among regulatory areas. We review the survey timing and hook competition standardisations applied to WPUE, and present updated estimates of the bottom area of each regulatory area used in apportionment calculations. The effects of the 2013 survey expansion in Area 2A and the consequent increase in bottom area for Area 2A on apportionment are described. Total Constant Exploitation Yield (TCEY) is derived by applying area-specific harvest rates to the estimate of exploitable biomass in each regulatory area. Fishery Constant Exploitation Yield (FCEY) is then calculated by subtracting other removals (O26) from the TCEY. These calculations have been adjusted for this year to reflect the pending Catch Sharing Plan in Areas 2C and 3A, and therefore FCEYs and other removals are not directly comparable with analyses from previous years (guided recreational and commercial wastage are now included in the FCEY). Summary tables of these results are presented for the Blue Line from the 2013 stock assessment decision table (24.5 M lb FCEY, 36.4 M lb total mortality), consistent with the current harvest policy, as well as higher and lower alternatives (30 and 40 M lb total mortality). An apportionment table reflecting the *status quo* removals estimated for 2013 is also presented. The results of this analysis indicate that a reduction from 2013 harvest levels would be necessary in order to adhere to the current harvest policy.

Introduction

Since 2007, the IPHC has used the setline survey mean weight per unit effort (WPUE) index of density weighted by bottom area to apportion estimated exploitable biomass among regulatory areas. This method was reviewed by the IPHC's Scientific Review Board (SRB) during August, 2013 (Cox et al. 2014). Two adjustments to the raw WPUE index are made in order to account for important factors known to influence survey catch rates of halibut. Adjustments for survey timing and hook competition are intended to improve standardisation of the WPUE index by accounting for differences among regulatory areas in the timing of the survey relative to the fishery, and in the degree of competition with halibut for baits.

In this report, we briefly describe the two adjustments we make to the survey index, and the three-year reverse weighting applied to produce the WPUE index used for apportionment. The effects of these modifications to the raw index are shown, and the resulting estimates of the proportion of survey biomass (the biomass sampled by the survey) in each area are presented. These proportions are then applied to the coastwide estimates of Exploitable biomass (EBio) from the 2013 stock assessment to produce apportionment-based estimates of EBio for each regulatory area.

In 2013, we revised all estimates of bottom area using the method presented in Webster and Williams (2013). In addition, the setline survey in Area 2A was expanded to include stations south to 40° N, and the bottom area of Area 2A was increased to include the region between 40° N and 42° N, the previous southern limit of Area 2A as used in apportionment calculations. Here we

describe the effect of the expansion on apportionment. The Area 2A survey expansion and revised Area 2A WPUE calculations are described in detail in Webster et al. (2014).

Application of the current harvest policy to these apportionment-based estimates of EBio produces area-specific Total Constant Exploitation Yield (TCEY) values consistent with the "Blue Line" results in the stock assessment decision table (Stewart et al. 2014). Fishery Constant Exploitation Yield (FCEY) is then calculated by subtracting other removals (O26, by area and source) from the TCEY. Several alternative harvest levels are also reported.

Bottom area revision

Bottom area is defined to be the area of the Earth's surface between the 0 and 400 fathom contours, and is used to weight the WPUE density index values for each regulatory area for apportionment calculations. In 2013, Area 2A was expanded south to 40° N, and the bottom area re-estimated to include the additional area between 40° N and 42° N. The algorithm used to estimate the bottom area of the expanded Area 2A differed from that used in previous years (Hare 2010) and was described in Webster and Williams (2013). To ensure that bottom area estimates are calculated consistently, we revised the estimates for all regulatory areas, and the component regions of Area 4CDE. The revised estimates are in Table 1.

Survey timing

The amount of commercial catch taken prior to the IPHC setline survey varies with both regulatory area and time (Webster 2009). In areas where removals are greater early in the season, expected survey WPUE will be lower on average than in areas where removals occur later in the fishing season. Concern about the effect of removals on survey WPUE is particularly strong in Area 2A, where typically over 80% of the removals is taken prior to the mean survey date, much higher than all other areas (Webster 2009, Webster and Hare 2010). Our approach, detailed in Webster and Hare (2010), is to standardise WPUE to its expected value if 50% of all O32 removals had been taken prior to the mean date of the setline survey in each area.

No change to the survey timing methodology has been made for 2013; however, all data inputs for calculating the adjustment have been updated, including revisions to 2012 and earlier data made during 2013.

Hook competition

The fraction of baits that remain on the survey gear on retrieval within each regulatory area is used to compute an adjustment factor for hook competition (Clark, 2008, Webster et al. 2011). If a smaller than average proportion of baits are returned, an area's WPUE index is adjusted upwards because higher competition for baits in that area would have had a negative effective on the halibut catch and therefore on that area's WPUE. Conversely, an area with more than the average rate of baits returned will have its WPUE index adjusted downwards. This approach is intended to avoid the situation where differences in abundance of non-target species among regulatory areas would create bias in the observed WPUE index of density. Methods for calculating the hook adjustments followed those used in previous years (Clark 2008, Webster and Stewart 2013).

Three-year weighting

In addition to the two adjustments, WPUE for apportionment is also smoothed using a 75:20:5 reverse weighted averaging of the current and previous two year's adjusted WPUE values for each area derived from a Kalman filter-type analysis of survey data (Webster 2011). This weighting is intended to improve precision of the WPUE estimates, without introducing significant bias from including past observations.

Apportionment results

The expansion of Area 2A southwards has led to an increase in this area's share of the coastwide exploitable biomass (Table 2): without the expansion, Area 2A would have had around 2.1% of the biomass at the start of 2014, but with the additional of the area off northern California, this has increased to 2.4%. This has had only minor effects on other area's apportionment values, because Area 2A contains a relatively small fraction of the stock and the effect of the increase is distributed across all other areas. This is the only Regulatory Area that had potential halibut habitat in the 0-400 fm depth range that was not already included in the spatial expansions.

Revisions to the estimation of WPUE in Area 4CDE (Webster 2014) have generally led to a reduction in historical the WPUE time series. In 2012, we estimated the share of biomass in Area 4CDE to be 10.6% at the start of 2013 (Webster and Stewart 2013), which has been revised to 10.0% in this year's calculations. Even with these revisions, the 2014 share is again estimated to be 10.6% (Table 2), due to WPUE declining less in Area 4CDE than the coastwide average.

Estimates of the percentage of over 32 inch (O32) removals taken prior to the mean survey date are shown in Figure 1. Area 2A has consistently had a high proportion of removals taken prior to the mean survey date, and the corresponding adjustment factors show that the only appreciable effect of the survey timing adjustment has been a relative increase in Area 2A's WPUE in most years (Fig. 2). We note that as harvest rates have been reduced over recent years, the impact of the survey timing adjustment on WPUE has decreased. Nevertheless, the timing adjustment for Area 2A in 2013 led to a 12% increase in WPUE relative to unadjusted WPUE, and therefore the effect of accounting for survey timing remains significant for that area.

Rates of bait returns are historically much higher in western areas on average (Fig. 3), implying that competition with halibut for the baits is lower in those areas. Area 2A has typically had the lowest rates of returned baits. In 2013, fewer baits were returned last year in Area 2B, while Areas 2C and Area 3A higher rates of returned baits than in 2012. This led to a positive adjustment in Area 2B, a smaller positive adjusted in Area 2C, and a slight negative adjustment in Area 3A (Fig. 4). The adjustment for Area 3B was also up from 2012, while other areas had adjustments for competition that were similar to last year's.

The effect of the adjustments and the three-year weighted averaging on WPUE for each area is shown in Figure 5. The adjusted, three-year weighted averaged WPUE values are weighted by bottom area in the 0-400 fathom range to produce a survey biomass index for each area. The proportion of this survey biomass index in each area (Table 2) is then used for subsequent apportionment among regulatory areas of total coastwide EBio estimated from the stock assessment.

Based on a full recalculation of apportionment for recent years, and using the 2013 stock assessment estimates of total coastwide EBio, the time-series of apportionment-based EBio estimates shows some clear trends. EBio is estimated to have declined sharply in central and western areas (Areas 3 and 4) in the early part of the time series, but the declines have slowed in

recent years (Fig. 6). Historically estimated rates of exploitation were highest in Area 2 (Fig. 7), and this is where the greatest response to reduced harvest rates can be seen, with strong increases in 2013 following generally increasing trends in recent years (Fig. 6). The trends in Areas 2B and 2C are consistent with observed WPUE in both the survey and commercial fishery catch rates (Stewart et al. 2014).

Yield calculations

Total and fishery yield calculations were performed using methods consistent with recent analyses. This process begins with the estimated 2013 coastwide exploitable biomass from the stock assessment. Based on results of the survey apportionment calculations described above, the estimated proportions from 2013 are used to infer the distribution of the EBio among areas at the beginning of 2013 (Fig. 8). The differences from last year's results reflect the reduction in the estimated coastwide exploitable biomass, as well as a change in the apportionment results (Fig. 9).

The current harvest policy uses different target exploitation rates by regulatory area. These rates are 21.5% for Areas 2A, 2B, 2C, and 3A and 16.125% for Areas 3B, 4A, 4B, and 4CDE. Based on the observed distribution of biomass in 2013, application of these target rates results in an effective coastwide harvest rate of 19.7%. The coastwide TCEY is therefore 33.49 M lb, based on the coastwide EBio estimate of 170.29 M lb.

In order to obtain the FCEY, the "other removals" (O26) in each area are subtracted from the TCEY. This calculation assumes that the values of bycatch, subsistence and personal use, and unguided recreational removals for 2014 remain constant at 2013 levels, with the exception of commercial wastage, which was scaled proportional to the change in TCEY. For the 2014 calculations, the allocation between guided recreational and commercial fishery removals is applied in Areas 2C and 3A, consistent with the pending Catch Sharing Plan (CSP). The CSP also includes O26 commercial wastage in the FCEY (rather than the other removals) for Areas 2C and 3A. These changes make previous years' tables not directly comparable with the results documented here. U26 removals are separated by regulatory area and source in Table 3. These removals are accounted for in the stock assessment dynamics but, consistent with the harvest policy, are not included directly in the yield analysis. The 2013 O26 removals included in the apportionment calculations are reported in Table 4, and 2013 fishery removals (for comparison) in Table 5.

The FCEY for 2013, consistent with the current harvest policy, corresponds to the Blue Line results from the stock assessment decision table (Stewart et al. 2014). These area-specific values are reported in Table 6. For alternative levels of coastwide harvest, the total CEY is adjusted in proportion to the apportionment results across all areas.

For comparison, the results of the apportionment calculations from 2012 are repeated here (Table 7). The total estimated exploitable biomass in the 2012 and 2013 analyses, as well as the changes in area-specific distribution, are presented in Figures 8 and 9.

Results for alternate rows from the decision table with 30 and 40 M lb of total mortality are presented in Tables 8 and 9. A *status quo* table representing 2014 O26 removals at the same level estimated for 2013 is reported in Table 10. Also presented for comparative purposes is the results consistent with the final adopted catch levels for 2013 (Table 11). Because the survey expansion conducted in Area 2A added new spatial area that was not previously included in apportionment calculations, a table reporting the Blue Line results excluding the new surveyed area is presented in Table 12.

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Table 1. Estimated bottom areas of IPHC regulatory areas. All areas are calculated between the 0 and 400 fathom contours unless stated otherwise.

Area	Bottom Area (nmi²)
Area 2A	16 679
Area 2B	29 916
Area 2C	14 329
Area 3A	49 297
Area 3B	30 361
Area 4A	20 224
Area 4B	19 730
Area 4CDE total	218 694
Area 4N	50 991
Area 4S (0-75 fathoms)	150 284
Area 4IC	2 069
Area 4ID	1 530
Area 4CDE Edge (75-400 fathoms)	13 820

Table 2. Estimated percentages of the coastwide exploitable biomass in each regulatory area by year. Values were calculated using the adjusted WPUE with the three year weighted averaging described in the text. In some years, row totals do not sum exactly to 100% because of rounding. For comparison, 2013 apportionment using the Area 2A bottom area north of 42° N is included in the final row.

Year	2A	2B	2C	3A	3B	4A	4B	4CDE
1999	1.5	4.7	6.3	23.9	31.8	11.1	7.5	13.2
2000	1.6	5.5	6.8	26.8	29.0	12.0	6.7	11.7
2001	2.3	7.0	7.7	32.2	24.3	9.1	5.8	11.6
2002	1.6	8.2	9.0	36.9	21.3	8.0	4.4	10.6
2003	1.4	6.2	9.1	38.2	23.0	7.2	3.6	11.3
2004	1.6	6.7	6.7	42.0	21.9	7.0	3.1	11.0
2005	2.5	7.2	8.1	45.4	18.4	6.3	3.5	8.7
2006	1.5	7.4	7.8	42.6	20.3	6.1	4.5	9.8
2007	1.4	7.2	8.2	43.4	20.7	5.0	5.1	8.9
2008	1.8	8.6	7.3	41.3	19.6	6.8	6.0	8.7
2009	1.2	10.8	7.3	35.7	20.4	7.7	6.3	10.6
2010	2.8	13.4	7.9	34.5	18.4	6.9	5.1	11.0
2011	2.8	13.6	10.5	35.9	16.1	5.8	5.5	9.9
2012	2.4	13.4	12.3	37.3	14.3	6.7	3.6	10.0
2013	**2.4**	**15.6**	**14.9**	**32.9**	**13.6**	**5.7**	**4.2**	**10.6**
2013 (2A >42° N)	2.1	15.7	15.0	33.0	13.6	5.7	4.3	10.6

Table 3. Removals of U26 halibut (M net lb) in 2013 that are included in the stock assessment (total coastwide) but, consistent with current harvest policy, not in the apportionment calculations.

	2A	2B	2C	3A	3B	4A	4B	4CDE	Total
Bycatch	0.01	0.04	0.00	0.51	0.26	0.47	0.13	1.42	2.83
Wastage	0.00	0.01	0.01	0.03	0.06	0.01	0.00	0.01	0.12
Total	0.01	0.04	0.01	0.54	0.32	0.48	0.14	1.42	2.95

Table 4. "Other removals" (026; M net lb) observed in 2013. Note that these differ from the values deducted from the TCEY in apportionment calculations due to the scaling of commercial fishery wastage relative to 2013 values. NAs indicate removals that are included in the FCEY for that regulatory area. Sport removals in 2C and 3A include only unguided estimates, consistent with the CSP.

	2A	2B	2C	3A	3B	4A	4B	4CDE	Total
Bycatch	0.12	0.19	0.01	0.93	0.62	0.63	0.32	2.23	5.05
Wastage	0.03	0.20	NA	NA	0.35	0.07	0.03	0.05	0.73
Sport	NA	NA	0.90	1.44	0.02	0.03	0.00	0.00	2.39
Personal/subsistence	NA	0.41	0.40	0.25	0.02	0.01	0.00	0.03	1.11
Total	0.15	0.79	1.31	2.63	1.00	0.73	0.36	2.31	9.28

Table 5. Fishery removals (026; M net lb) observed in 2013. Note that in 2C and 3A sport removals include only guided estimates, and commercial wastage is included in the FCEY, consistent with the CSP.

	2A	2B	2C	3A	3B	4A	4B	4CDE	Total
Sport	0.45	0.83	0.72	2.27	NA	NA	NA	NA	4.27
Personal/subsistence	0.03	NA	NA	NA	NA	NA	NA	NA	0.03
Commercial wastage	NA	NA	0.08	0.49	NA	NA	NA	NA	0.57
Commercial	0.54	5.92	3.04	11.05	4.12	1.23	1.24	1.78	28.91
Total	1.02	6.75	3.84	13.81	4.12	1.23	1.24	1.78	33.78

Table 6. Blue Line removals, based on applying the current harvest policy to the results of the apportionment calculations. All biomass values are reported in millions of net pounds.

	2A	2B	2C	3A	3B	4A	4B	4CDE	Total
Exploitable biomass	4.03	26.64	25.44	56.07	23.14	9.69	7.23	18.06	170.29
Percent of total	2.4%	15.6%	14.9%	32.9%	13.6%	5.7%	4.2%	10.6%	100.0%
Harvest rate	21.5%	21.5%	21.5%	21.5%	16.1%	16.1%	16.1%	16.1%	19.7%
Total CEY	0.87	5.73	5.47	12.05	3.73	1.56	1.17	**2.91**	33.49
Other removals (O26) 26)	0.14	0.74	1.31	2.63	0.90	0.71	0.34	**2.27**	9.04
Fishery CEY	0.72	4.98	4.16*	9.43*	2.84	0.85	0.82	**0.64**	24.45

*For comparison with analyses from previous years, the breakdown of the FCEY is as follows: 2C = 3.32 directed fishery landings + 0.08 commercial wastage + 0.76 guided recreational; 3A = 7.32 directed fishery landings + 0.33 commercial wastage + 1.78 guided recreational

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Table 7. Blue line results from the 2012 apportionment and harvest policy calculations (Table 11, Webster and Stewart; 2013). All biomass values are reported in millions of net pounds.

	2A	2B	2C	3A	3B	4A	4B	4CDE	Total
Exploitable biomass	3.81	24.54	23.28	70.38	26.02	11.97	6.75	19.74	186.49
Percent of total	2.0%	13.2%	12.5%	37.7%	14.0%	6.4%	3.6%	10.6%	100.0%
Harvest rate	21.5%	21.5%	21.5%	21.5%	16.1%	16.1%	16.1%	16.1%	19.6%
Total CEY	0.82	5.28	5.00	15.13	4.20	1.93	1.09	3.18	36.63
Other removals (O26) 26)	0.11	0.69	2.03	5.89	1.46	1.08	0.47	2.33	14.08
Fishery CEY	0.71	4.58	2.97	9.24	2.73	0.85	0.62	0.85	22.55

Table 8. Apportionment results for the decision table row with 30 M lb total mortality. All biomass values are reported in millions of net pounds.

	2A	2B	2C	3A	3B	4A	4B	4CDE	Total
Exploitable biomass	4.03	26.64	25.44	56.07	23.14	9.69	7.23	18.06	170.29
Percent of total	2.4%	15.6%	14.9%	32.9%	13.6%	5.7%	4.2%	10.6%	100.0%
Harvest rate	17.5%	17.4%	17.4%	17.4%	13.1%	13.1%	13.1%	13.1%	15.9%
Total CEY	0.71	4.64	4.43	9.76	3.02	1.27	0.95	2.36	27.13
Other removals (O26) 26)	0.14	0.71	1.31	2.63	0.84	0.70	0.34	2.26	8.92
Fishery CEY	0.57	3.93	3.12	7.13	2.18	0.57	0.61	0.10	18.21

Table 9. Apportionment results for the decision making table row with 40 M lb total mortality. All biomass values are reported in millions of net pounds.

	2A	2B	2C	3A	3B	4A	4B	4CDE	Total
Exploitable biomass	4.03	26.64	25.44	56.07	23.14	9.69	7.23	18.06	170.29
Percent of total	2.4%	15.6%	14.9%	32.9%	13.6%	5.7%	4.2%	10.6%	100.0%
Harvest rate	23.8%	23.8%	23.8%	23.8%	17.9%	17.9%	17.8%	17.9%	21.8%
Total CEY	0.96	6.34	6.06	13.35	4.14	1.73	1.29	**3.22**	37.10
Other removals (O26) 26)	0.14	0.76	1.31	2.63	0.93	0.72	0.35	**2.28**	9.12
Fishery CEY	0.82	5.59	4.75	10.73	3.21	1.01	0.94	**0.94**	27.98

Table 10. Apportionment results for the *status quo* O26 removals estimated from 2013. All biomass values are reported in millions of net pounds.

	2A	2B	2C	3A	3B	4A	4B	4CDE	Total
Exploitable biomass	4.03	26.64	25.44	56.07	23.14	9.69	7.23	18.06	170.29
Percent of total	2.4%	15.6%	14.9%	32.9%	13.6%	5.7%	4.2%	10.6%	100.0%
Harvest rate	27.5%	29.2%	19.7%	30.4%	25.4%	25.1%	26.8%	23.7%	26.7%
Total CEY	1.11	7.77	5.02	17.06	5.87	2.43	1.93	**4.28**	45.48
Other removals (O26) 26)	0.15	0.80	1.31	2.63	1.06	0.76	0.36	**2.31**	9.38
Fishery CEY	0.96	6.98	3.71	14.43	4.81	1.67	1.57	**1.97**	36.10

Table 11. Apportionment results for the adopted catch levels in 2013. All biomass values are reported in millions of net pounds.

	2A	2B	2C	3A	3B	4A	4B	4CDE	Total
Exploitable biomass	3.81	24.54	23.28	70.38	26.02	11.97	6.75	19.74	186.49
Percent of total	2.0%	13.2%	12.5%	37.7%	14.0%	6.4%	3.6%	10.6%	100.0%
Harvest rate	29.0%	31.7%	21.6%	24.2%	22.6%	20.3%	28.6%	21.7%	24.4%
Total CEY	1.11	7.78	5.02	17.07	5.87	2.43	1.93	4.28	45.48
Other removals (O26) 26)	0.11	0.73	2.05	6.04	1.58	1.10	0.48	2.35	14.45
Fishery CEY	0.99	7.04	2.97	11.03	4.29	1.33	1.45	1.93	31.03

Table 12. Comparative results of application of the harvest policy (Blue Line) to apportionment results excluding the expanded survey area in 2A. All biomass values are reported in millions of net pounds.

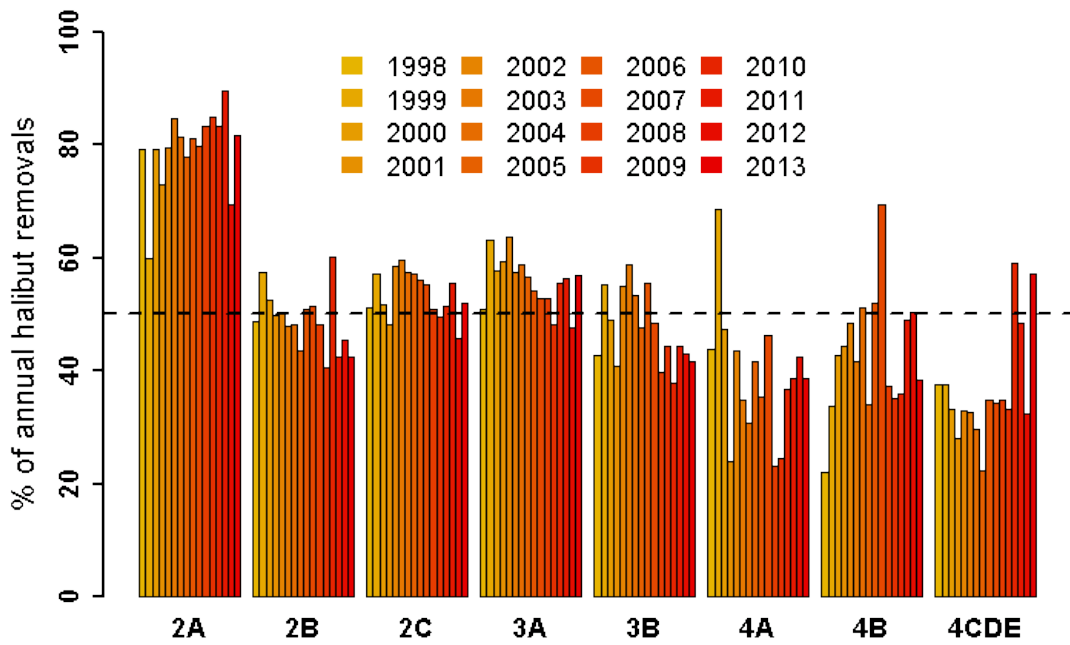|	2A	2B	2C	3A	3B	4A	4B	4CDE	Total
Exploitable biomass	3.54	26.72	25.51	56.23	23.21	9.72	7.25	18.12	170.29
Percent of total	2.1%	15.7%	15.0%	33.0%	13.6%	5.7%	4.3%	10.6%	100.0%
Harvest rate	21.5%	21.5%	21.5%	21.5%	16.1%	16.1%	16.1%	16.1%	19.7%
Total CEY	0.76	5.75	5.49	12.09	3.74	1.57	1.17	**2.92**	33.48
Other removals (O26) 26)	0.14	0.74	1.31	2.63	0.90	0.71	0.34	**2.27**	9.04
Fishery CEY	0.62	5.01	4.18	9.47	2.85	0.85	0.83	**0.65**	24.44

Figure 1. Estimated percentage of O32 halibut removals taken prior to the mean setline survey date, by area and year. **Includes commercial catch, wastage, sport catch in Areas 2A, 2B, 2C, and 3A, bycatch, personal use, and survey and other research catch.**
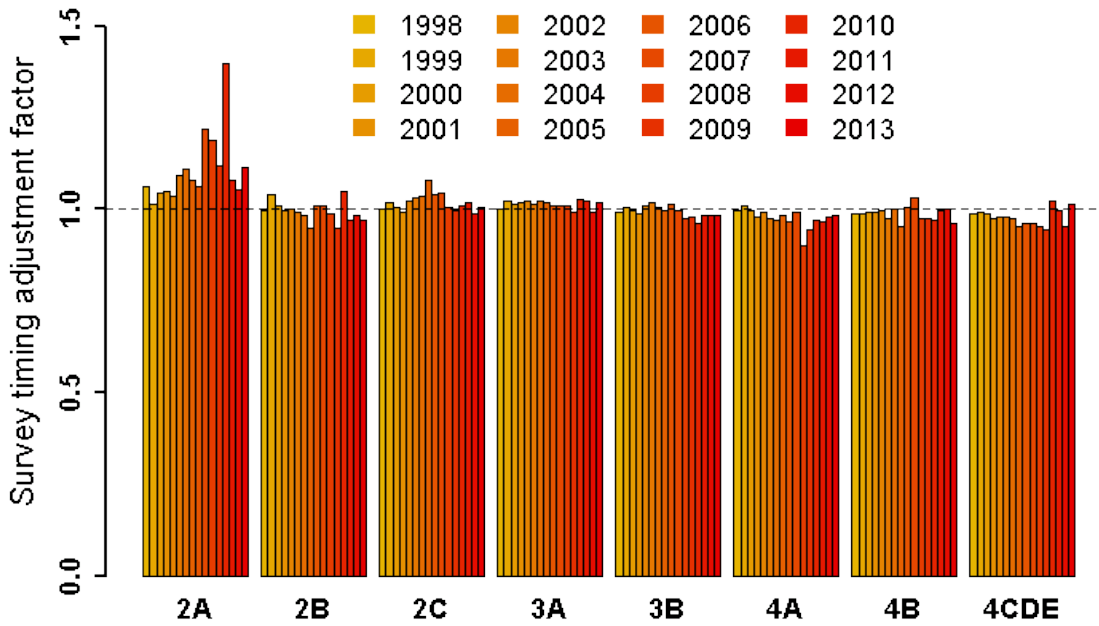
Figure 2. **Survey timing adjustment factors that are applied to setline survey WPUE for biomass apportionment, by area and year.**
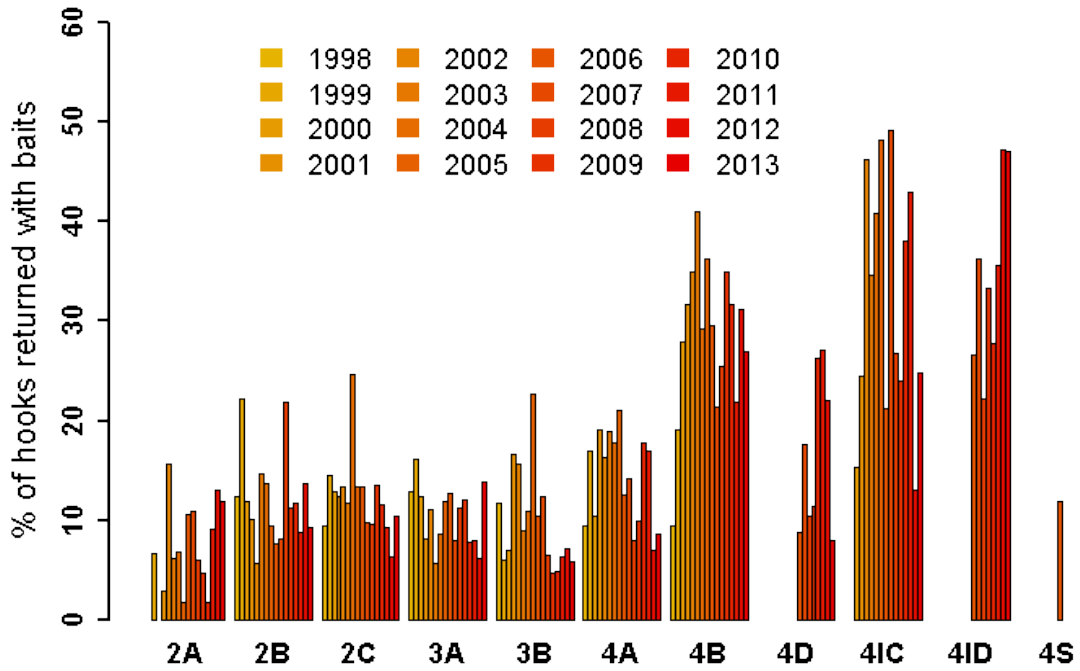
Figure 3. Percentage of setline survey hooks returned with baits by area and year. Area 4S is the southern portion of the eastern Bering Sea, surveyed in 2006 only, while Areas 4ID and 4IC are the island portions (St Matthew, Pribilofs) of Areas 4D and 4C respectively. Here Area 4D means the Area 4CDE Edge.
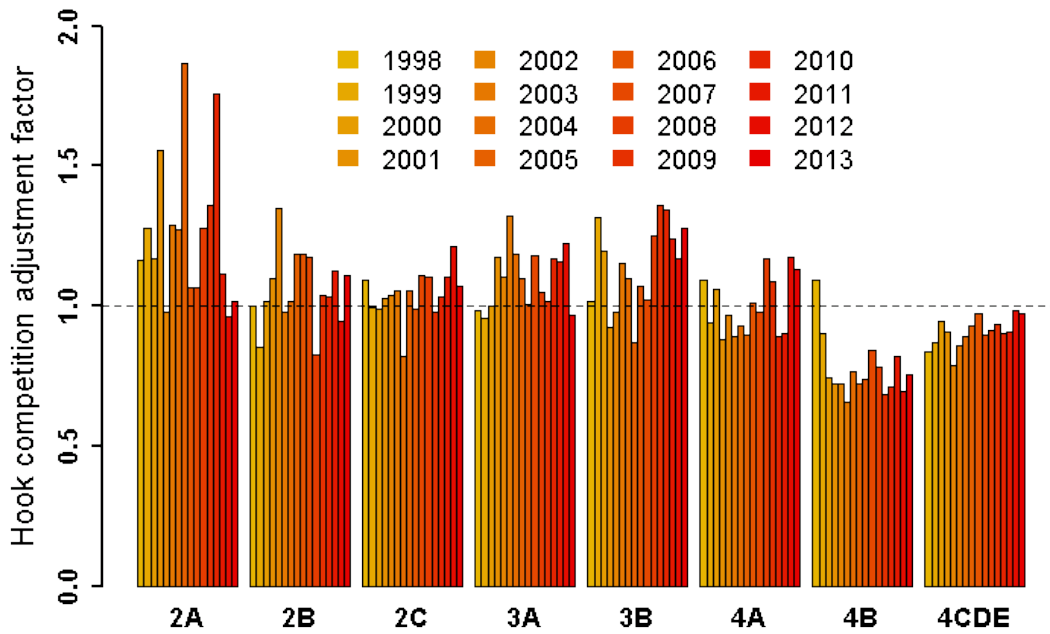
Figure 4. Hook competition adjustment factors that are applied to setline survey WPUE for biomass apportionment.
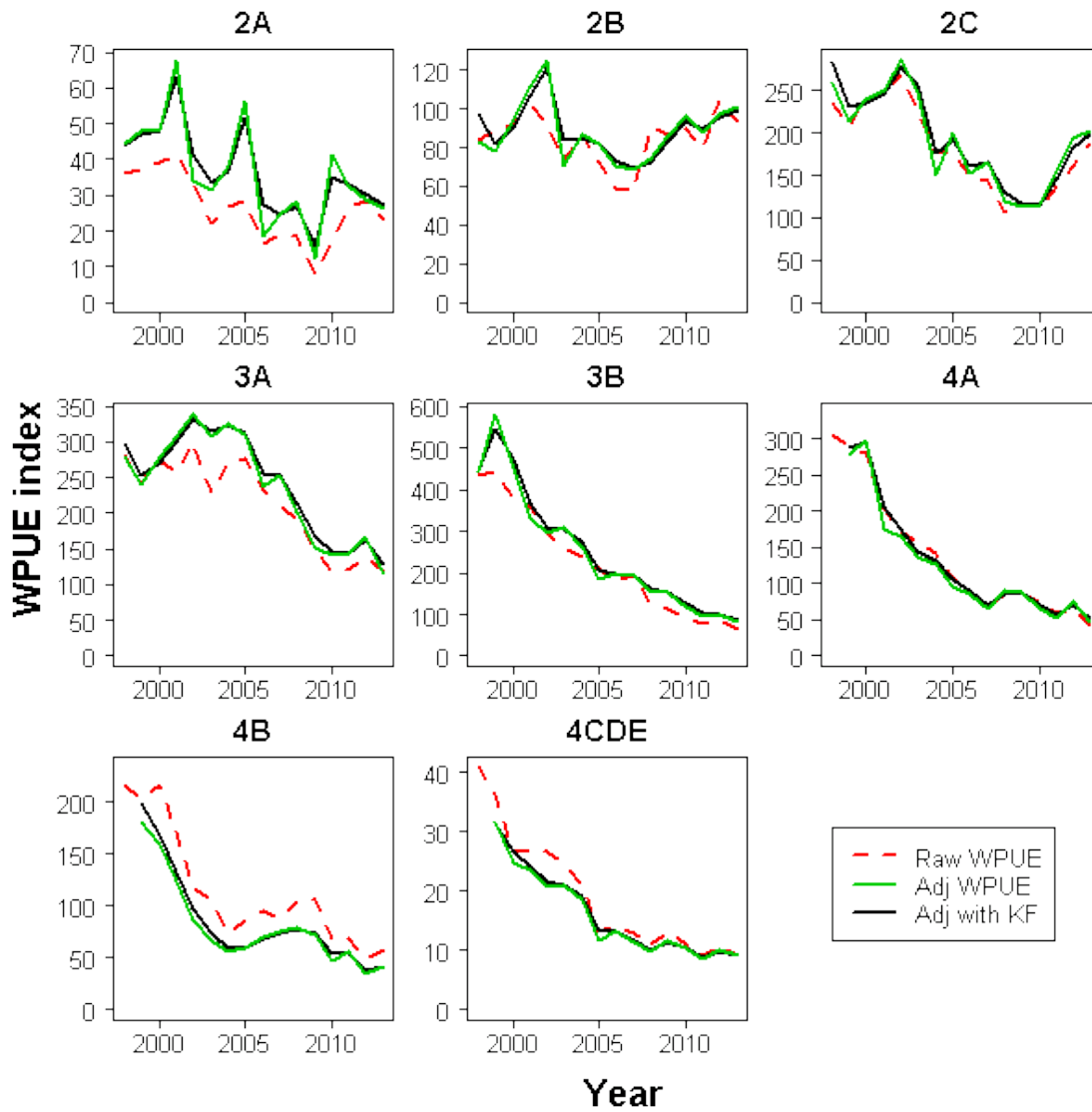
Figure 5. Comparison of survey WPUE without adjustments (Raw WPUE), with both timing and hook competition adjustments applied (Adj WPUE), and with adjustments and a 75:20:5 weighting of the three most recent years' values (Adj with KF).
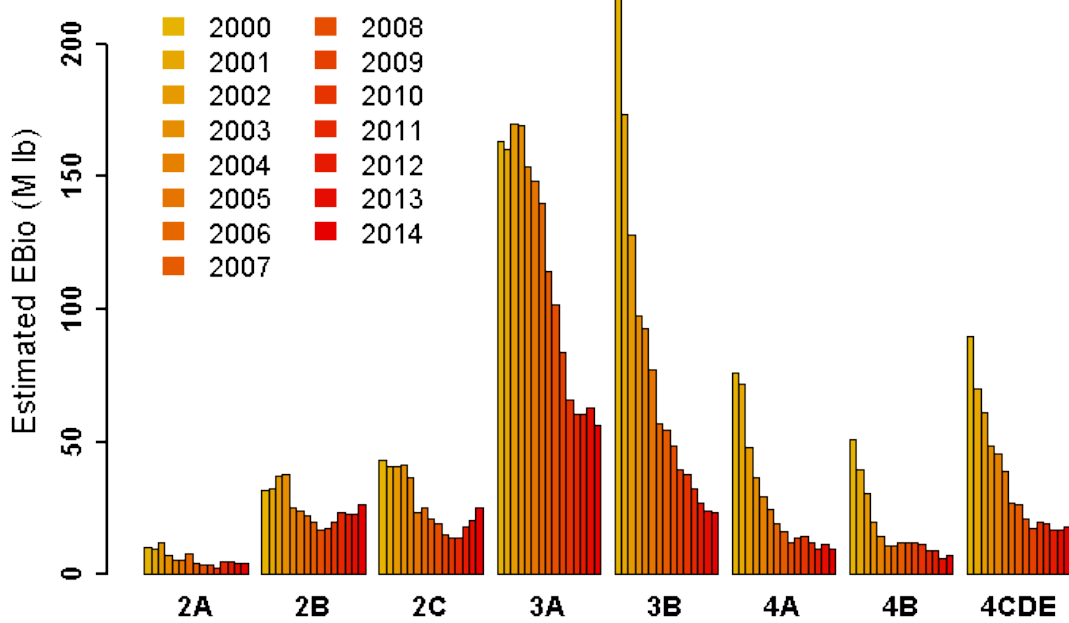
Figure 6. Apportionment-based exploitable biomass estimates by year and area, calculated by applying the proportions in Table 2 to the 2013 stock assessment estimates of coastwide Ebio.
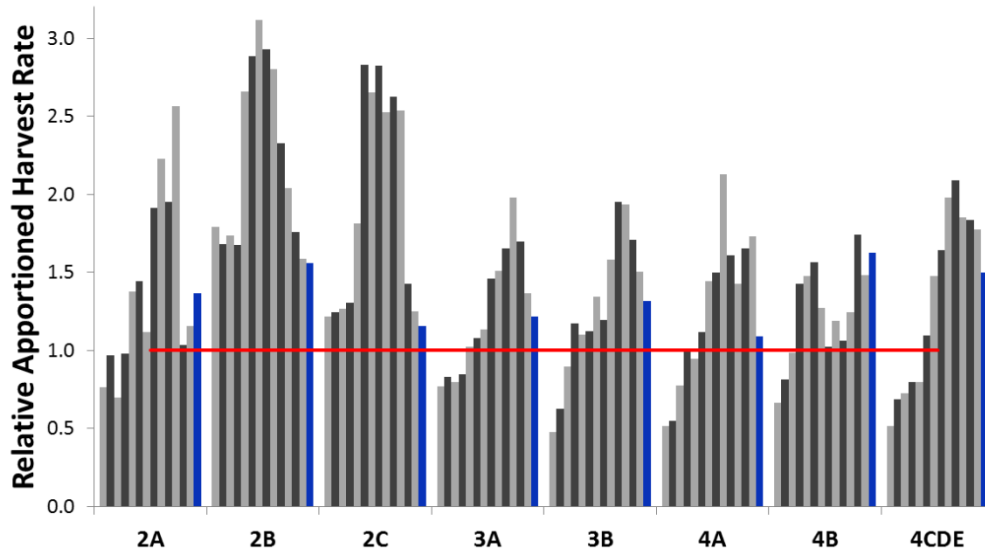
Figure 7. Hindcast relative harvest rates based on the estimate of coastwide exploitable biomass from the 2012 stock assessment and recalculated apportionment for 2000-2013 (bars in chronological order from left to right within each Area). Horizontal line indicates area-specific harvest rates equal to the targets, based on the current harvest policy.
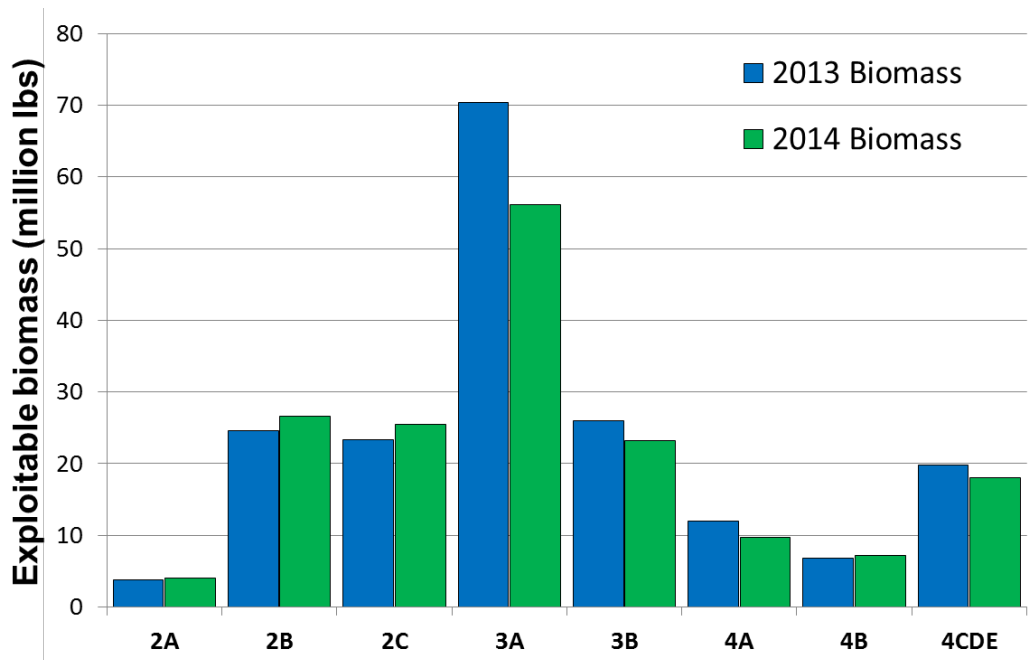
Figure 8. Distribution of coastwide exploitable biomass estimated from the 2012 apportionment process (2013; left bar for each area) and 2013 analysis (2014; right bar for each area).
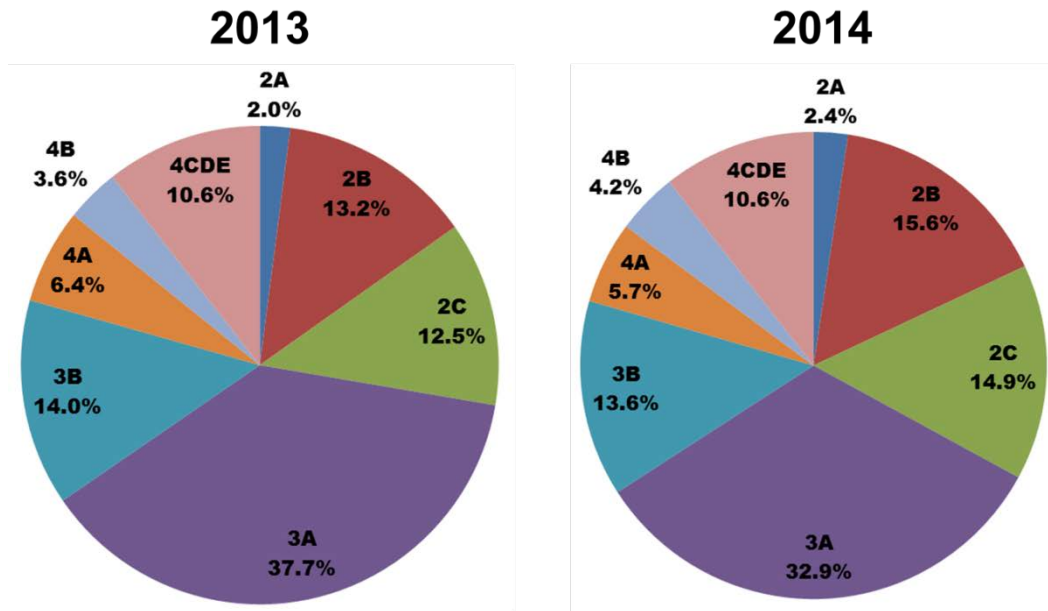
Figure 9. Relative distribution of coastwide exploitable biomass estimated from last year's apportionment process (2013) and the 2013 analysis (2014).