Adjusting IPHC setline survey WPUE for survey timing, hook competition and station depth

Raymond A. Webster and Steven R. Hare

Abstract

Methods are presented to adjust the survey WPUE index for three factors: timing of the setline survey relative to total removals, competition for baits on the survey, and the mismatch between station and actual bottom depth distribution. These individual adjustment factors may be further combined, though not always in a simple multiplicative manner.

Introduction

With staff recommending the use of setline survey WPUE (weight per unit effort) for biomass apportionment among regulatory areas, there has been much attention given to the validity of survey WPUE as an index of biomass. To address some concerns on area differences in catchability and survey station distribution, staff has respectively proposed adjustments for hook selectively (Clark 2008a, Hare and Clark 2009) and for bottom depth strata (Clark 2008b, Hare and Clark 2009). As well as reviewing these adjustments, this paper presents a new proposed adjustment for the timing of the setline survey, and examines how these adjustments can be combined to refine the computation of biomass apportionment from setline survey WPUE data.

The amount of commercial catch taken prior to the IPHC setline survey varies with both regulatory area and time (Webster 2009). It is plausible that survey WPUE is affected by the proportion of removals taken prior to the survey, as exploitable biomass is decreased by commercial and sport fishing and other forms of removals, leaving fewer fish for the survey to catch. In areas where removals are greater early in the season, we might expect survey WPUE to be lower on average than in areas where removals are spread evenly across the fishing season. In IPHC Staff (2009), we looked at the relationship between survey WPUE and proportion of commercial catch taken prior to the median survey date, but found no obvious patterns. The data, however, were highly variable, and it was not possible to conclude that no relationships exist. Concern about the effect of commercial catch in particular on survey WPUE is strong in Area 2A, where typically over 80% of the catch is taken prior to the mean survey date, much higher than all other areas (Webster 2009). In this report we take a different approach, and calculate survey WPUE values adjusted for the proportion of halibut removals taken prior to the mean survey date.

Survey timing adjustment

Survey WPUE of halibut over 32 inches in length (“O32”, previously termed “legal-sized”) is used as an index of exploitable biomass. WPUE is a function of both fish density (or abundance) and catchability, and how good an index of halibut biomass it provides depends on how catchability varies among regulatory areas, and on whether catchability varies with density. Here we will make the following assumptions:

1. Mean survey catchability is the same across all regulatory areas, and does not vary during the survey period.

2. The relationship between WPUE and exploitable biomass is linear.
3. Factors other than fishery removals that affect exploitable biomass during the fishing season do so on average in the same way as commercial removals.

While the first assumption is the subject of ongoing discussion, at present there is no compelling evidence to the contrary. The second assumption depends on catchability not being a function of density in the range of densities encountered by the survey. If halibut biomass is high and fish density around survey stations is therefore also high on average, it is possible that the survey lines approach saturation, that is, the halibut catch approaches the maximum possible catch. In this case, the WPUE index can be insensitive to changes in halibut biomass so that large changes in biomass lead to relatively small changes in WPUE. While this may be true in some years at a few high-density survey stations, over an entire region this is not thought to be a concern at recent levels of halibut biomass.

Were we to compute the adjustment based solely on commercial catch data, we would also require the assumption that temporal patterns of other removals, including sport catch and bycatch, are the same as those of commercial removals. As bycatch is a result of catch in other fisheries, some of which have seasons that do not coincide with the halibut season, the timing of these removals is not the same as targeted removals by the commercial halibut fleet. Similarly, the sport fishing season does not necessarily match the commercial fishery in terms of relative removals throughout the fishing season. For these reasons, we include recent data on sport catch timing in Areas 2A, 2C, and 3A in our calculations. Similar data for Area 2B are not available. For now, removals due to bycatch and personal use are assumed to be evenly distributed across the calendar year. Finally, we also include O32 wastage from the commercial fishery, which is assumed to follow the same temporal patterns as commercial removals. The sum of these different forms of catches is hereafter referred to as “total removals”.

Exploitable biomass in any region will change due to migration into and out of the region, individual halibut growth, and recruitment of previously U32 (under 32 inches, previously termed “sublegal-sized”) fish into the exploitable populations. Data on migration from PIT tagging and other studies do not provide sufficient information to account for migration effects in these adjustments, and this remains a limitation of the survey timing adjustment.

Making the above assumptions, exploitable biomass at any date will be a function of harvest rate and proportion of total removals taken prior to that date. For year *i* and area *j*, let p_{ij} be the proportion of total removals taken prior to a specified date. Then

$$Ebio_{ij}\left(p_{ij}\right) = Ebio_{ij}\left(0\right)\left(1 - HR_{ij}\, p_{ij}\right)$$

where $Ebio_{ij}\left(0\right)$ is the exploitable biomass prior to the start of the fishing season and HR_{ij} is the realised harvest rate of area *j* in year *i*. If the date is such that 50% of the total removals has already been taken, we have:

$$Ebio_{ij}\left(0.5\right) = Ebio_{ij}\left(0\right)\left(1 - HR_{ij}\, 0.5\right)$$

Thus Ebio at $p_{ij} = 0.5$ can be written as

$$Ebio_{ij}\left(0.5\right) = Ebio_{ij}\left(p_{ij}\right)\frac{\left(1 - HR_{ij}\,0.5\right)}{\left(1 - HR_{ij}\,p_{ij}\right)}$$

Given assumptions (1) and (2), this relationship will also hold for setline survey WPUE:

$$WPUE_{ij}\left(0.5\right) = WPUE_{ij}\left(p_{ij}\right)\frac{\left(1 - HR_{ij}\,0.5\right)}{\left(1 - HR_{ij}\,p_{ij}\right)} \qquad (1)$$

If p_{ij} is the proportion of the total removals taken prior to the mean survey date for area *j* in year *i*, this gives us a simple method of adjusting survey WPUE to the value we would expect if 50% of the removals had been taken prior to this date. The terms involving the harvest rate of the right hand side of Equation (1) can be thought of as the survey timing adjustment factor, which we denote by f_{ij}^{ST}, giving us

$$WPUE_{ij}\left(0.5\right) = WPUE_{ij}\left(p_{ij}\right) f_{ij}^{ST}$$

If more than 50% of the removals occur before mean survey date, f_{ij}^{ST} will be greater than 1, and the adjusted WPUE will be greater than the raw survey WPUE to account for the fewer fish that were available for the survey to sample. If less than 50% of the removals are taken prior to the survey, f_{ij}^{ST} will be less than zero, and the survey WPUE will be adjusted downwards. The magnitude of the timing adjustment will depend greatly on the realised harvest rate. If the harvest rate is very low, f_{ij}^{ST} will be close to one regardless of the proportion of removals taken prior to the survey date. That is, if only a small fraction of the exploitable biomass is harvested in a year, survey WPUE will not be greatly affected by the small amount of removals taken prior to the survey sets. On the other hand, if harvest rates are high, as they are estimated to have been in Area 2 in recent years, then a relatively large amount of biomass is taken prior to the survey, and the timing adjustment will have a greater effect.

Slightly complicating calculations is that harvest rates are computed from WPUEs from the previous years. Within our calculations of the timing adjustments, we compute harvest rates from the most recent year's data only as follows:

$$HR_{ij} = \frac{R_j}{Ebio_j}, \quad Ebio_{ij} = p^e{}_j\, Ebio_{i,coast}$$

where R_{ij} is the total removals in year *i* for area *j*, $Ebio_{i,coast}$ is the coastwide stock assessment estimate of exploitable biomass at the start of year *i*, and $p^e{}_j$ is an estimate of the proportion of the coastwide stock in area *j* at the start of year *i*.

To estimate the proportion of the stock in each area in each year, the past three years' survey WPUEs were weighted by bottom area. The use of the three most recent years' data was to reduce the effect of random variation in any single year's WPUE. When computing adjusted WPUEs, we will instead compute all quantities using data from the previous year only, and then do the averaging at the very end. This simplifies matters when we consider combining a survey timing adjustment with other adjustments (see below). Thus, to estimate $p^e{}_j$, we use the following:

$$p^e{}_{ij} = \frac{W_j WPUE_{i-1,j}}{\sum_{j=1}^{J} \left\{ W_j WPUE_{i-1,j} \right\}}$$

where W_j is the bottom area of regulatory area *j*, and *J* is the number of areas included in the calculation. The current year's adjusted WPUE depends on last year's WPUE through the harvest rate, and so the adjustments must be made one year at a time.

The current survey design began in 1998, which is where we begin our survey timing adjustment calculations. No survey was done in Area 2A in 1998 and 2000, nor in Area 4CDE in 1998 and 1999, and we assign a value of $p^e{}_{ij} = 0.5$ in these cases. There is no annual setline survey in Area 4E, so the timing adjustment for combined Area 4CDE is based on the dates of the survey sets in Areas 4C and 4D only.

Information on sport catch taken prior to the survey is available for Areas 2A, 2C, and 3A. At present, we only use data from 2006-09, and use the 2006-09 mean of the proportion of catch taken prior to the mean survey data for earlier years. The handling of other removals was discussed above.

Hook adjustment (review)

In the IPHC setline survey, a standard number of skates each containing 100 baited hooks, is set and left to soak for a minimum of 5 hours. The capture of O32 halibut per skate represents the WPUE index used to estimate trends in Ebio. However, other animals compete for the baits, and the density and effectiveness of these other predators varies across areas. To the extent that the rate of removal of baits by other predators reduces the availability of the baits to halibut, the setline catchability of halibut may be affected. An analytical method for determining the level of hook comprtition and a correction factor was developed by Clark (2007). In essence, the removal of baits is modeled in a manner similar to the Baranov catch equation:

$$B_i = F_i \cdot B_0 \cdot \left(1 - \exp\left(-Z \cdot T\right)\right) / Z$$

where F_i is the instantaneous rate of bait removal by predator *i*, B_0 is the initial number of baited hooks, and $Z = \sum_i F_j$ is the sum of the instantaneous rates applied by all bait takers.

Under the assumption that catch of halibut is proportional to the density of halibut times the average number of baits available we have:

$$C_h = k \cdot B_h = k \cdot F_h \cdot B_0 \cdot \left(1 - \exp\left(-Z\right)\right) / Z = k' \cdot D_h \cdot B_0 \cdot \left(1 - \exp\left(-Z\right)\right) / Z$$

where k and k' are constants of proportionality, B_h is baits taken by halibut, F_h is the instantaneous rate of halibut catch, D_h is the density of halibut, and B_0 is the initial number of baits available.. In this equation, $\left(1 - \exp\left(-Z\right)\right)$ is the fraction of baits removed by all takers during the active period, and $\left(1-\exp(-Z)\right)/Z$ is the average number of baits remaining over the course of the active period as a proportion of the initial number. If this term is the same in all areas, then the effect of hook competition on survey catchability is not a factor that would affect comparisons of WPUE across areas. Otherwise survey WPUE does not index density consistently across areas due to hook competition. Figure 1 illustrates hook occupancy (i.e., proportion of baits taken by predator) over the period 2007-2009. This figure shows relative catch (in numbers) of halibut across areas but also numbers of other important predators. Where hooks are empty, the presumption is that an unknown predator removed the bait; the identity is unimportant in this context. The important number, however, is the number of baits remaining. It is this amount, and assuming an instantaneous rate of removal, that determines average number of baits available to halibut. Areas where the number of baits remaining is higher than the Coastwide average have higher catchability while areas with fewer average baits remaining have lower catchability. A hook competition correction factor is computed by dividing the coastwide value of average baits (1-exp(-*Z*))/*Z*) by the area-specific value of average baits. Thus, lower catchability will result in a correction factor greater than 1 (survey WPUE is increased) while higher catchability has the opposite result. Table 1 lists the fraction of baits returned by regulatory area over the period 1998-2009; this value is all that is required to compute Z (*Z* = -ln(fraction baits returned)) and, therefore, the hook adjustment factor.

With the partition of Area 4CDE into Area 4D edge, Area 4 islands (Area 4I) and Areas 4S and 4N (Hare et al. 2010), a combined hook adjustment for Area 4CDE must be computed by combining the data from all four subareas. We do this by calculating the weighted averaged of the subarea adjustment factors, where the weights are the bottom areas multiplied by the setline WPUEs. This combined adjustment is then applied to the combined Area 4CDE setline WPUE, computed as the weighted average of the subarea WPUEs, where this time the weights are simply the bottom areas. Hook adjustments are only available when a setline survey is conducted, and in our calculations we assume an adjustment factor of 1 (no adjustment) when no survey was conducted.

Bottom depth stratification (review)

The IPHC survey stations are set on a 10nmi grid between the depths of 20 and 275 fathoms. Ideally, such an arrangement should lead to stations having the same physical and oceanic characteristics as the entire bottom area within each regulatory area. As WPUE is affected by myriad factors that vary with depth, a simple mean WPUE computed from all stations should be the same as one computed from a depth weighted WPUE. Figure 2 illustrates how closely survey station depths relate to the cumulative bottom depth distribution. With the exception of Area 4B where survey stations are disproportionally deep, station depth distribution closely matches bottom depth distribution (strata). Minor differences are also noted in Area 2C, which has a slight surplus of deep stations and Area 4A which has a slight surplus of shallow stations. Survey stations were stratified by depth interval and mean WPUE values were computed for each interval. These depth-stratified WPUEs were weighted by the fraction of bottom area in each strata to compute a depth stratified mean WPUE (Fig. 3):

$$DWPUE_{i,j} = \sum_{i=1}^{n} \left(BottomArea_{s,i,j} * WPUE_{s,i,j} \right)$$

where s indexes the bottom area strata as a fraction of the total bottom area in year i and area j.

In computing the stratified means, it was necessary to find strata such that adequate numbers of stations contributed to the mean calculation, otherwise a biased computation could occur from undue influence of a small number of stations. The depth intervals were chosen such that 10 stations were included in each depth stratum. The resultant depth stratified means are very close to the simple survey means. The largest differences are in Areas 4B and 4D but the difference is not statistically meaningful either annually or over the long-term. Depth adjustments for combined Area 4CDE are computed using the method described for the hook adjustment above.

Results

Survey timing adjustment only

Table 2 shows the proportions of commercial catch taken prior to the mean survey date. In previous reports we used the median survey date, but this led to misleading proportions in some areas and years when the survey dates were not close to contiguous (i.e., there were large gaps in an area's survey period). In Table 3 we show estimates of the proportion of sport catch taken prior to the median survey date. Combined removals taken prior to the mean survey dates are given in Table 4. In our analyses, proportions of sport catch taken prior to the survey for years not listed in Table 3 are taken to be the averages in the final column of Table 3.

Apportionment of exploitable biomass among regulatory areas has been done by averaging the bottom-area weighted WPUEs from the last three years. We present the results of applying this weighting to survey timing adjusted WPUEs in Table 5. Figure 4 shows how much each of the adjusted apportionments differs from an apportionment based on unadjusted WPUE.

Other and combined adjustments

Apportionments calculated using hook and depth adjustments are given in Tables 6 and 7 respectively. Comparisons with an apportionment based on unadjusted WPUEs are made in Figures 5 and 6.

The survey timing adjustment to a year's WPUE depends on realised harvest rates computed from an apportionment based on the previous year's adjusted WPUE. If the hook or depth adjustments are combined with the timing adjustment, they are applied first to the raw survey WPUEs, so that the timing adjustment for any year is calculated using realised harvest rates estimated after application of these adjustments to the previous year's WPUE data. Tables 8-11 give apportionments based on combinations of adjusted to setline WPUE, and Figures 7-10 show the corresponding comparisons with apportionments based on unadjusted WPUE.

The timing adjustment has the greatest effect on Area 2A, which consistently has a large proportion of its removals taken prior to the survey date (Table 4), and has high estimated realised harvest rates (Hare 2010). Although Areas 4A, 4B and 4CDE have relatively few removals taken prior to the survey, the adjustments to the WPUEs are small due to low realised harvest rates in these area. In general, if harvest rates are low, the effect of a timing adjustment will be small, as whatever the survey timing, there is only a small decrease in exploitable biomass prior to the survey. Area 4CDE includes components for which no data were available to compute a survey timing adjustment, and these attenuate the downward adjustment this area would have received had we used only the available survey data from Areas 4D edge and 4I (see Hare et al., 2010).

Estimated shares of biomass in Areas 4CDE, 4B, and 2A are most affected by the hook adjustment, with the first two getting reduced shares due to the large number of returned baits, and Area 2A increased shares because of low bait returns. Depth adjustments are more modest, and as would be expected, tend to be greater in areas with fewer stations, particularly Area 4B and 2A, where there is a greater chance that the depth distribution of survey stations does not match an area's actual depth distribution. Combining adjustments leads to apportionment scenarios that are intermediate to those that result from single adjustments.

References

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Table 1. Average fraction of baits returned on the setline survey and year and area. 4S refers to the south Bering Sea shelf, 4I refers to the survey stations around the Pribilof Islands and St. Matthew, 4D refers to the 4D edge survey stations. NS means no survey was done in that area in that year. Total refers to the coastwide average.

Area	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Total	0.117	0.149	0.126	0.136	0.156	0.14	0.152	0.145	0.114	0.112	0.146	0.117
4S	NS	NS	NS	NS	NS	NS	NS	NS	0.132	NS	NS	NS
4I	NS	NS	NS	NS	NS	NS	NS	NS	0.145	0.235	0.139	0.181
4D	NS	NS	0.161	0.24	0.441	0.359	0.413	0.476	0.206	0.516	0.283	0.25
4B	0.095	0.194	0.282	0.316	0.35	0.417	0.315	0.362	0.295	0.214	0.257	0.347
4A	0.097	0.171	0.104	0.196	0.182	0.188	0.182	0.222	0.129	0.142	0.078	0.096
3B	0.119	0.061	0.071	0.172	0.158	0.091	0.109	0.227	0.105	0.125	0.065	0.045
3A	0.129	0.167	0.125	0.083	0.111	0.058	0.087	0.12	0.128	0.08	0.116	0.117
2C	0.096	0.149	0.129	0.125	0.134	0.118	0.246	0.135	0.134	0.098	0.097	0.125
2B	0.124	0.223	0.12	0.101	0.059	0.148	0.137	0.095	0.077	0.082	0.22	0.112
2A	NS	0.068	NS	0.03	0.158	0.062	0.068	0.018	0.107	0.109	0.06	0.047

Table 2. Percentage of commercial catch and wastage taken prior to the mean setline survey date. NS means no survey was done in that area in that year.

Area	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
4CDE	NS	NS	22	14	19	22	15	6	16	23	26	22
4B	17	29	41	43	48	40	50	28	52	71	34	31
4A	40	70	46	21	42	33	28	40	32	44	18	20
3B	41	55	49	40	55	59	53	48	56	48	39	43
3A	52	67	63	64	68	62	63	61	61	54	56	51
2C	57	63	58	53	66	68	65	64	60	60	57	56
2B	50	59	54	51	52	49	50	45	53	54	51	48
2A	NS	62	NS	85	86	90	86	81	88	91	96	99

Table 3. Percentage of sport catch taken prior to the mean setline survey date.

Area	2006	2007	2008	2009	Average
2A	83	67	74	84	77
2C	37	35	23	16	28
3A	39	34	39	37	38

Table 4. Percentage of O32 halibut removals taken prior to the mean setline survey date.[1] NS means no survey was done in that area in that year.

Area	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
4CDE	NS	NS	32	28	32	33	29	22	31	34	34	31
4B	19	31	42	44	48	40	51	30	52	70	36	34
4A	45	69	48	24	44	35	31	41	35	46	22	26
3B	42	55	49	41	55	59	53	48	56	49	40	44
3A	50	63	57	59	63	57	58	56	56	51	52	49
2C	52	57	52	48	59	60	57	57	54	52	48	46
2B	50	59	54	51	52	49	50	45	53	54	51	48
2A	NS	59	NS	72	76	80	77	76	82	78	84	84

[1]Includes commercial catch, wastage, sport catch in Areas 2A, 2C and 3A, bycatch and personal use.

Table 5. Percentage share of coastwide exploitable biomass based on an equal weighting of the three most recent WPUEs calculated by applying a survey timing adjustment only. Values are for the beginning of each year.

Area	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
4CDE	17.5	16.5	15.4	16.3	16.0	14.8	13.3	12.2	12.2	12.6
4B	8.1	8.0	7.2	6.2	5.0	4.8	5.1	6.0	7.2	8.1
4A	11.3	10.6	9.2	8.1	7.7	7.3	6.6	5.7	5.7	6.2
3B	24.2	24.0	22.2	21.7	20.5	20.1	19.2	19.7	18.7	17.5
3A	26.0	26.9	30.5	31.6	34.7	37.0	40.3	40.9	39.9	37.7
2C	6.5	6.9	7.9	8.6	8.5	8.2	7.6	7.8	7.4	7.3
2B	5.3	6.0	6.3	6.4	6.4	6.4	6.6	6.4	7.8	9.6
2A	1.0	1.2	1.2	1.2	1.1	1.2	1.2.	1.2	1.1	1.1

Table 6. Percentage share of coastwide exploitable biomass based on an equal weighting of the three most recent WPUEs calculated by applying a hook adjustment only. Values are for the beginning of each year.

Area	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
4CDE	17.0	15.7	13.9	14.0	13.2	12.8	12.3	11.5	11.1	11.1
4B	7.3	6.3	5.3	4.3	3.4	3.3	3.7	4.5	5.5	5.9
4A	11.3	10.0	9.0	7.3	7.0	6.5	6.2	5.4	6.2	6.8
3B	27.7	27.3	23.0	21.4	21.1	20.2	19.2	18.9	19.9	19.8
3A	24.4	26.8	32.4	36.0	39.2	41.6	42.8	43.1	41.1	38.9
2C	6.4	6.7	7.9	8.6	7.9	7.4	6.9	7.8	7.5	7.5
2B	4.8	5.7	7.1	7.1	7.0	6.6	7.3	7.3	7.7	9.0
2A	1.1	1.4	1.4	1.4	1.1	1.5	1.5	1.4	1.1	1.0

Table 7. Percentage share of coastwide exploitable biomass based on an equal weighting of the three most recent WPUEs calculated by applying a depth adjustment only. Values are for the beginning of each year.

Area	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
4CDE	17.4	16.4	15.1	16.2	15.8	14.7	13.3	12.3	12.1	12.4
4B	8.4	8.0	7.4	6.6	5.5	5.6	5.9	7.1	8.4	9.5
4A	11.8	11.1	9.9	8.9	8.7	8.2	7.1	6.1	6.1	6.8
3B	23.6	23.4	21.8	21.3	20.4	20.3	19.5	19.9	18.8	17.7
3A	25.3	26.1	29.4	30.2	33.0	35.2	38.5	39.2	38.3	35.9
2C	6.9	7.3	8.3	8.9	8.8	8.3	7.8	7.9	7.5	7.4
2B	5.6	6.3	7.0	6.8	6.7	6.7	6.8	6.5	7.9	9.6
2A	1.1	1.3	1.1	1.1	1.1	1.1	1.0	0.9	0.9	0.7

Table 8. Percentage share of coastwide exploitable biomass based on an equal weighting of the three most recent WPUEs calculated by applying timing and hook adjustments. Values are for the beginning of each year.

Area	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
4CDE	16.8	15.4	13.6	13.6	12.8	12.4	11.8	11.0	10.8	10.8
4B	7.2	6.2	5.2	4.2	3.4	3.2	3.7	4.5	5.5	5.9
4A	11.3	10.0	8.9	7.1	6.8	6.3	6.0	5.3	5.9	6.5
3B	27.6	27.1	22.8	21.3	21.1	20.3	19.2	18.8	19.8	19.7
3A	24.7	27.3	32.9	36.5	39.6	42.0	43.3	43.4	41.4	39.2
2C	6.4	6.7	8.0	8.7	8.1	7.8	7.2	8.1	7.6	7.5
2B	4.9	5.8	7.2	7.1	7.0	6.5	7.2	7.3	7.8	9.1
2A	1.1	1.5	1.5	1.5	1.2	1.7	1.6	1.6	1.2	1.2

Table 9. Percentage share of coastwide exploitable biomass based on an equal weighting of the three most recent WPUEs calculated by applying timing and depth adjustments. Values are for the beginning of each year.

Area	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
4CDE	17.2	16.1	14.8	15.7	15.4	14.2	12.9	11.8	11.8	12.1
4B	8.3	7.9	7.3	6.5	5.4	5.4	5.8	7.1	8.4	9.5
4A	11.8	11.1	9.8	8.6	8.5	7.9	6.9	5.9	5.9	6.6
3B	23.5	23.2	2.6	21.3	20.4	20.3	19.4	19.8	18.7	17.5
3A	25.5	26.6	29.9	30.8	33.5	35.7	39.0	39.6	38.6	36.2
2C	6.9	7.3	8.4	9.0	9.0	8.6	8.6	8.2	7.6	7.4
2B	5.7	6.5	7.0	6.8	6.6	6.6	6.8	6.5	8.0	9.8
2A	1.2	1.3	1.2	1.2	1.2	1.2	1.2	1.1	1.1	0.9

Table 10. Percentage share of coastwide exploitable biomass based on an equal weighting of the three most recent WPUEs calculated by applying hook and depth adjustments. Values are for the beginning of each year.

Area	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
4CDE	16.7	15.3	13.4	13.5	12.8	12.3	11.9	11.2	10.8	10.7
4B	7.5	6.2	5.4	4.6	3.7	3.8	4.2	5.4	6.5	7.0
4A	11.7	10.5	9.6	7.8	7.7	7.1	6.5	5.6	6.3	7.2
3B	26.9	26.5	22.4	20.9	21.0	20.4	19.5	19.1	20.0	19.9
3A	24.0	26.5	31.7	35.1	37.9	40.2	41.6	41.8	39.9	37.5
2C	6.8	7.1	8.4	9.0	8.3	7.9	7.3	8.1	7.7	7.6
2B	5.2	6.2	7.9	7.7	7.3	6.8	7.5	7.5	7.9	9.2
2A	1.1	1.6	1.4	1.4	1.2	1.5	1.5	1.3	1.0	0.9

Table 11. Percentage share of coastwide exploitable biomass based on an equal weighting of the three most recent WPUEs calculated by applying a timing, hook and depth adjustments. Values are for the beginning of each year.

Area	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
4CDE	16.5	15.1	13.0	13.1	12.4	11.9	11.5	10.7	10.4	10.4
4B	7.4	6.1	5.3	4.5	3.7	3.6	4.1	5.3	6.5	7.0
4A	11.7	10.5	9.4	7.6	7.4	6.8	6.3	5.5	6.0	6.9
3B	26.8	26.3	22.2	20.9	21.1	20.5	19.5	19.0	19.9	19.8
3A	24.2	27.0	32.3	35.6	38.4	40.6	42.1	42.1	40.2	37.9
2C	6.9	7.2	8.4	9.2	8.5	8.2	7.6	8.4	7.8	7.6
2B	5.3	6.3	8.0	7.7	7.2	6.6	7.4	7.5	8.0	9.3
2A	**1.2**	**1.6**	**1.4**	**1.5**	**1.3**	**1.7**	**1.6**	**1.4**	**1.1**	**1.1**

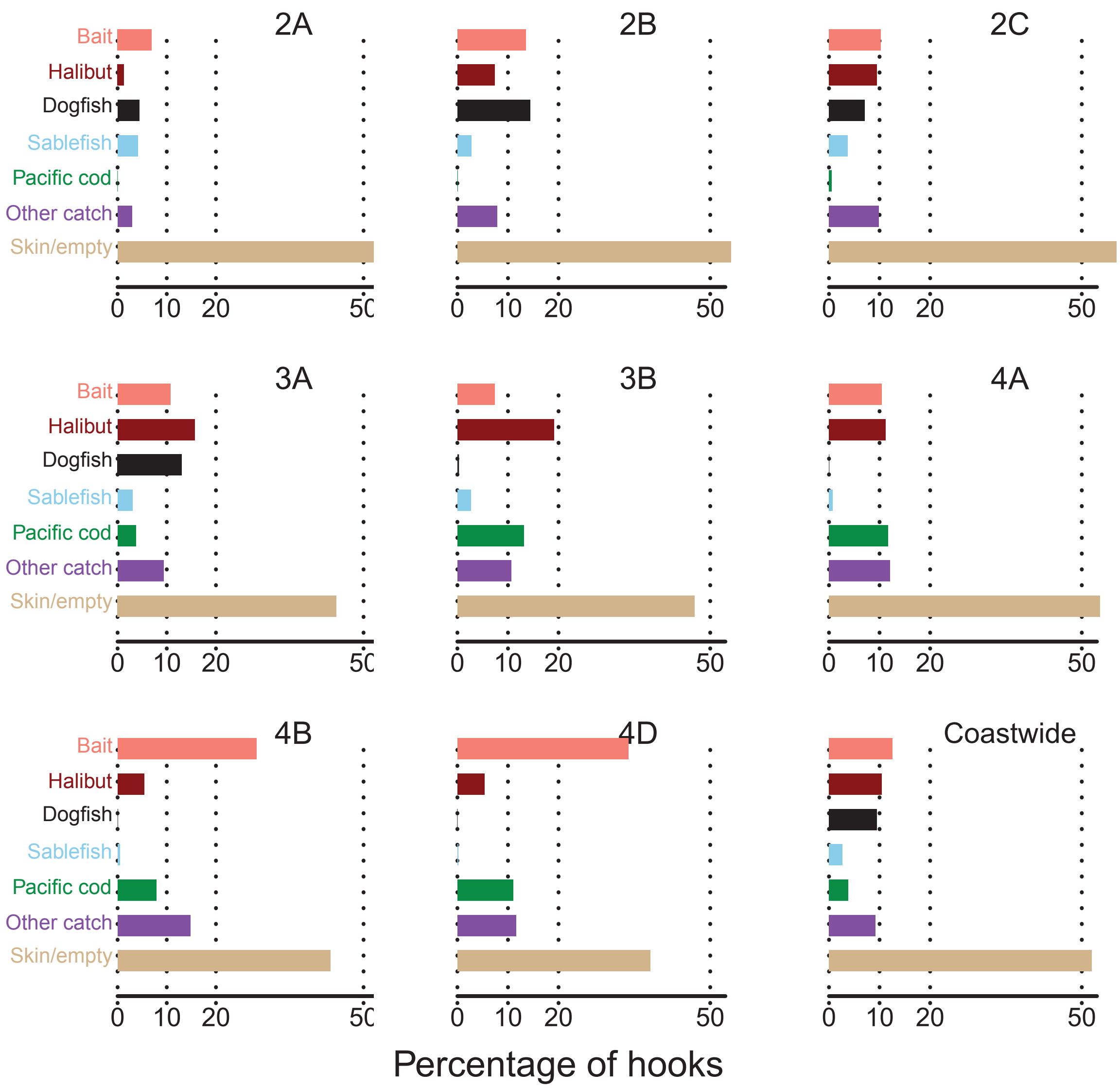

Figure 1. Hook occupancy by regulatory area, 2007-2009 data combined

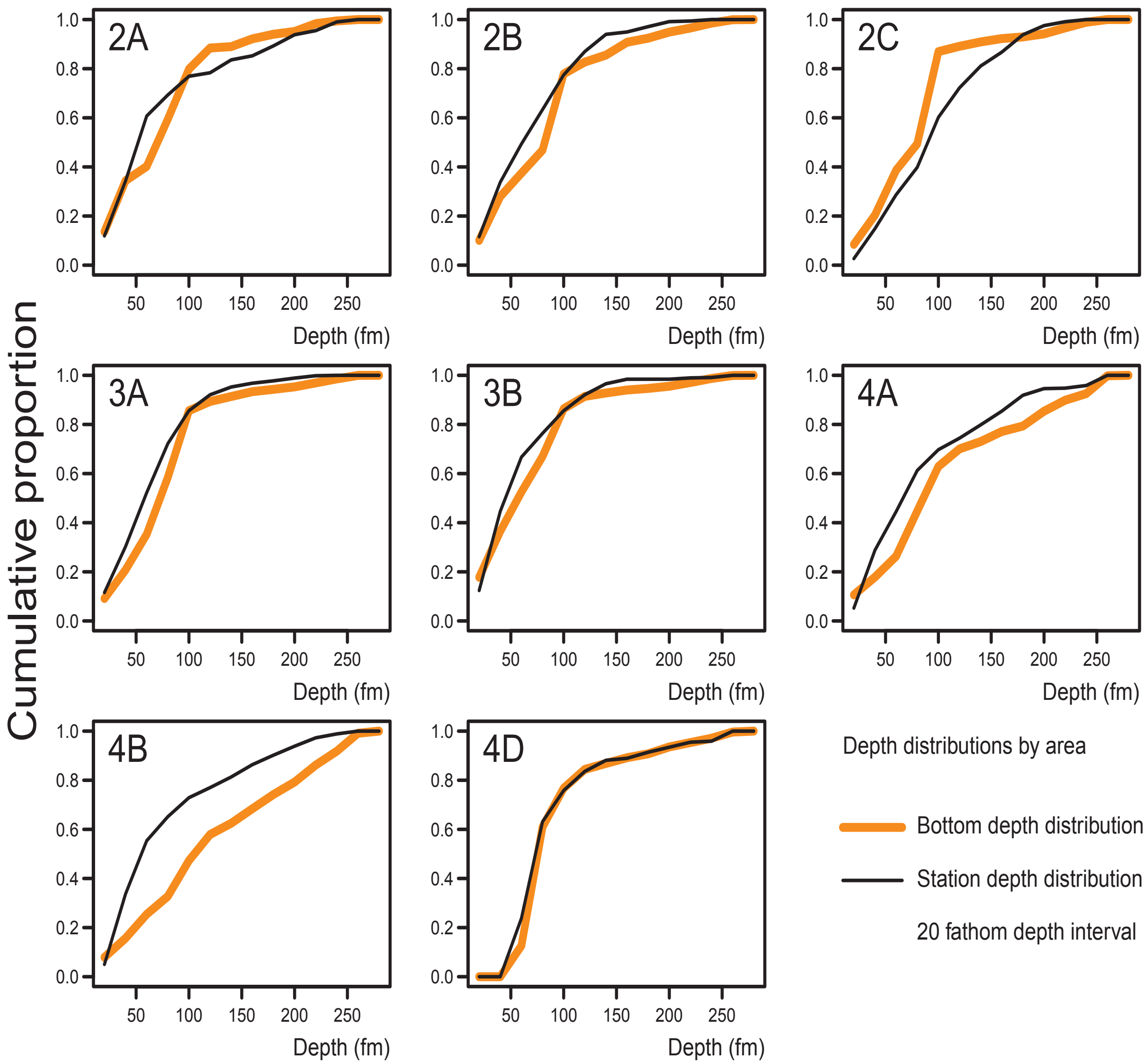

Figure 2. Cumulative distributions of bottom depth and survey station depth by regulatory area.

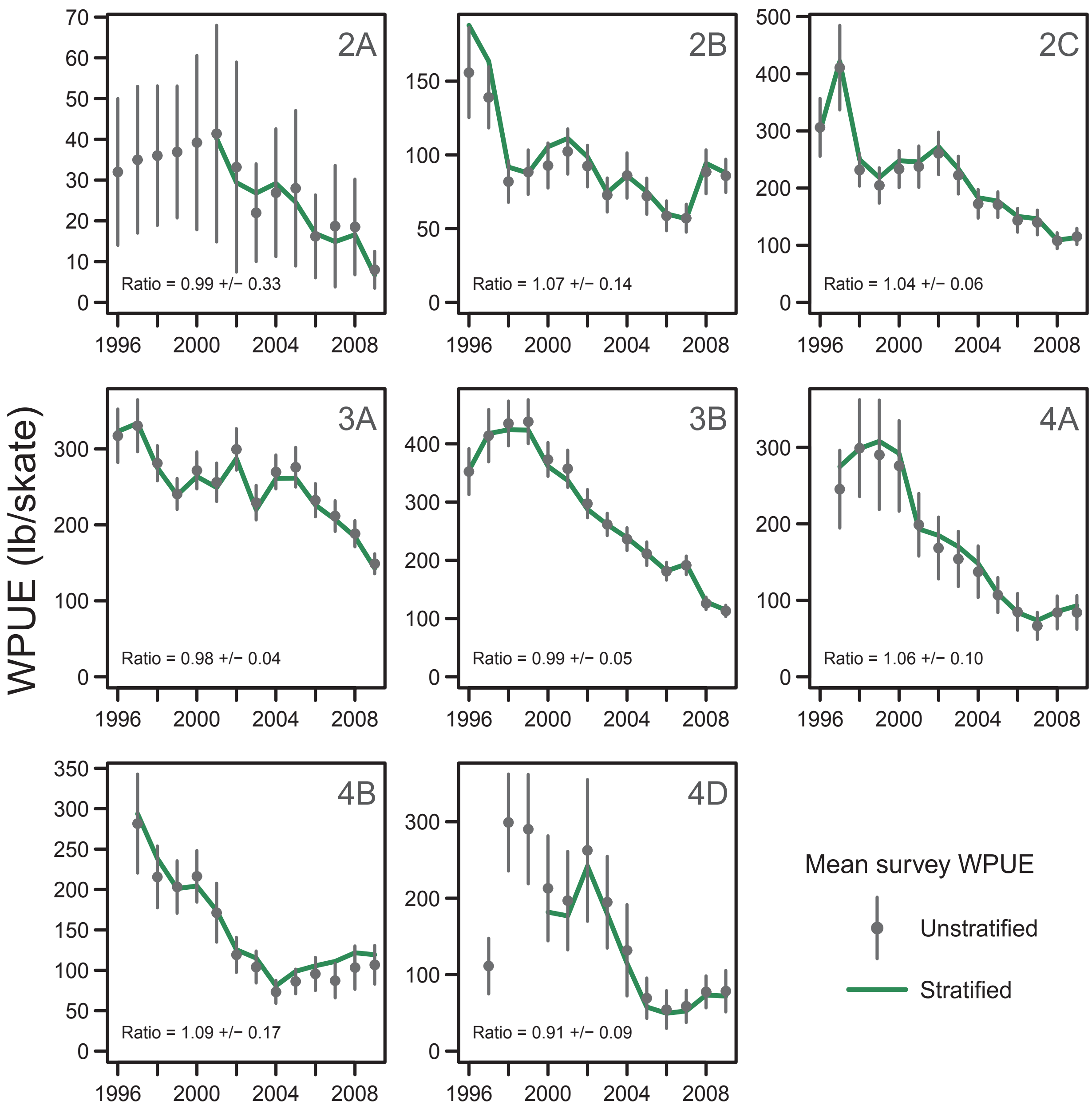

Figure 3. Survey WPUE plotted as simple mean (unstratified, gray dots) and depth-stratified WPUE (green line). The error bars are +/- two standard errors of the mean for the un-stratified mean.

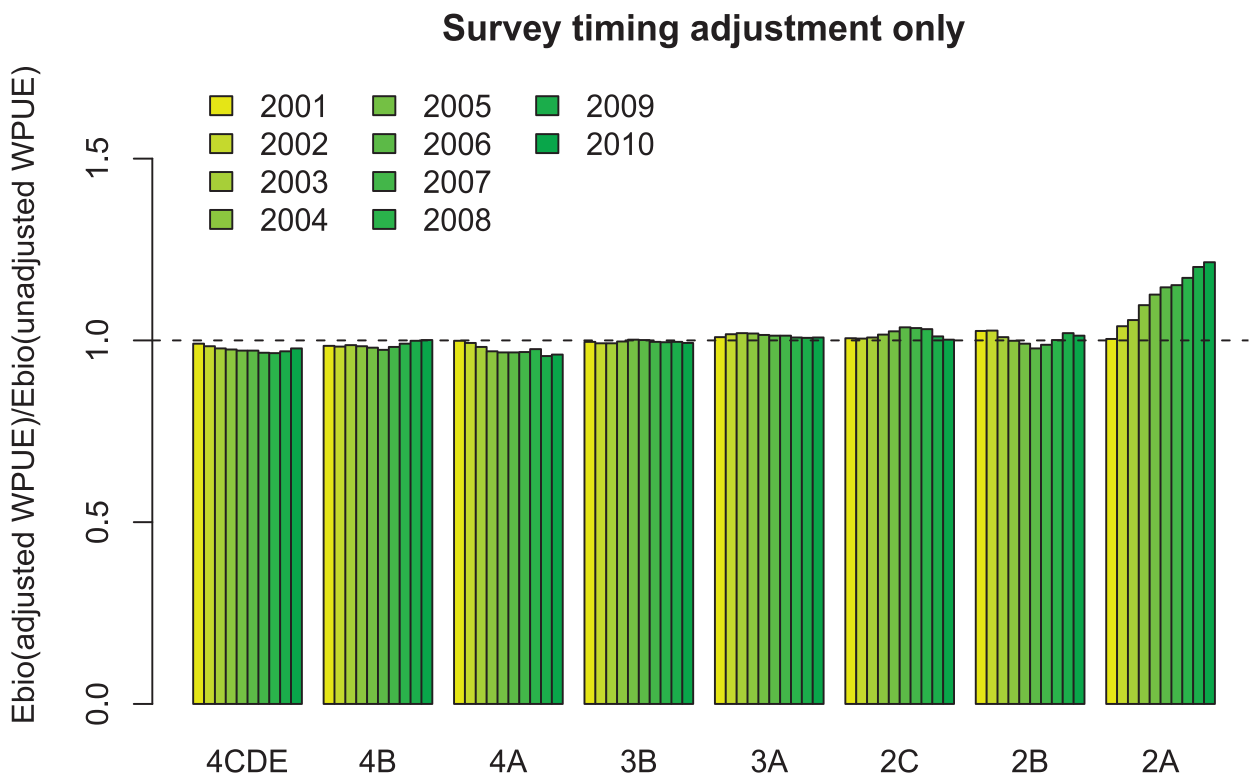

Figure 4. Ratios of exploitable biomass portions calculated using survey WPUEs adjusted for survey timing and unadjusted WPUEs.

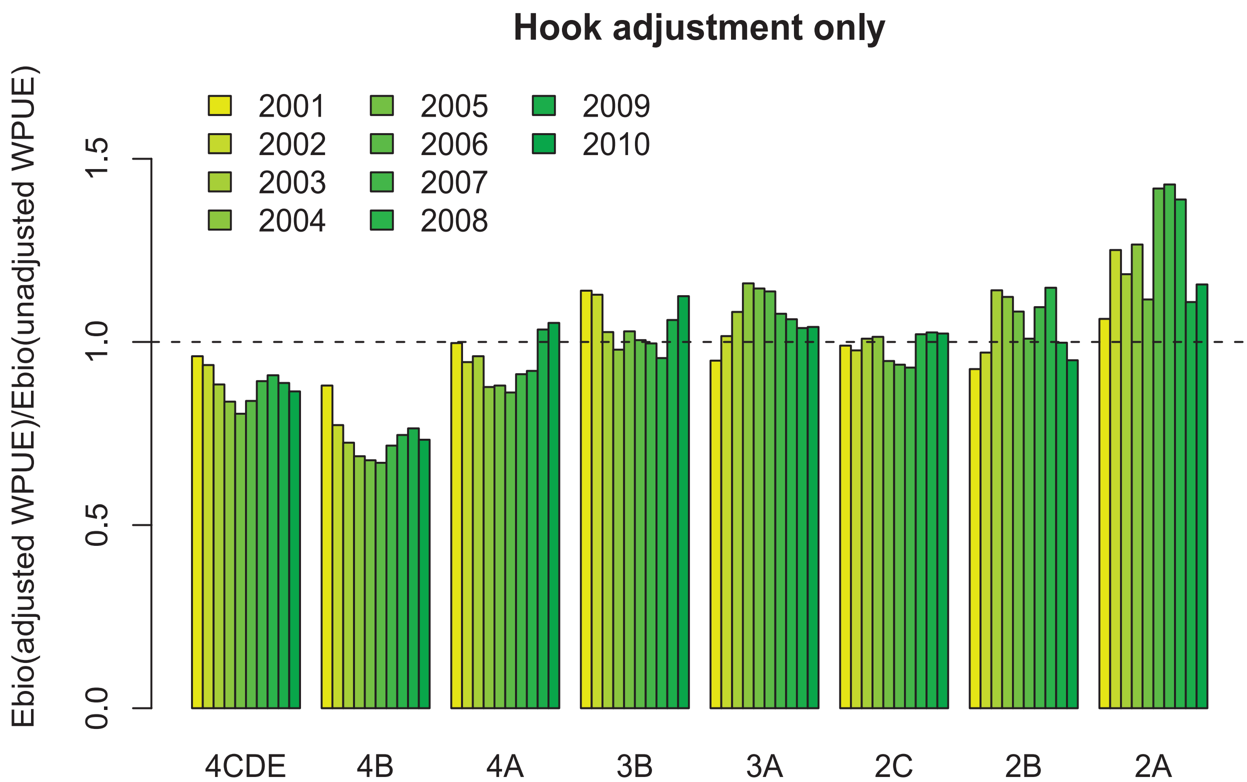

Figure 5. Ratios of exploitable biomass portions calculated using survey WPUEs adjusted for hook selectivity and unadjusted WPUEs.

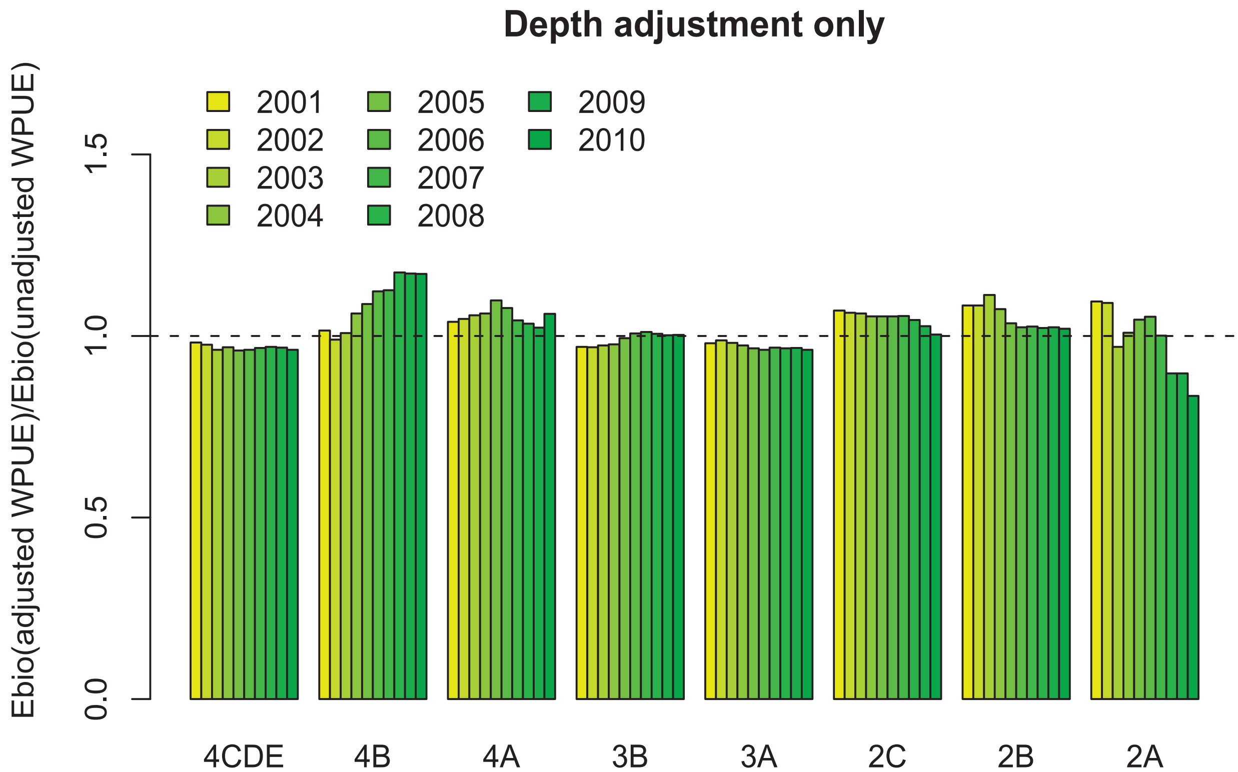

Figure 6. Ratios of exploitable biomass portions calculated using survey WPUEs adjusted for depth stratification and unadjusted WPUEs.

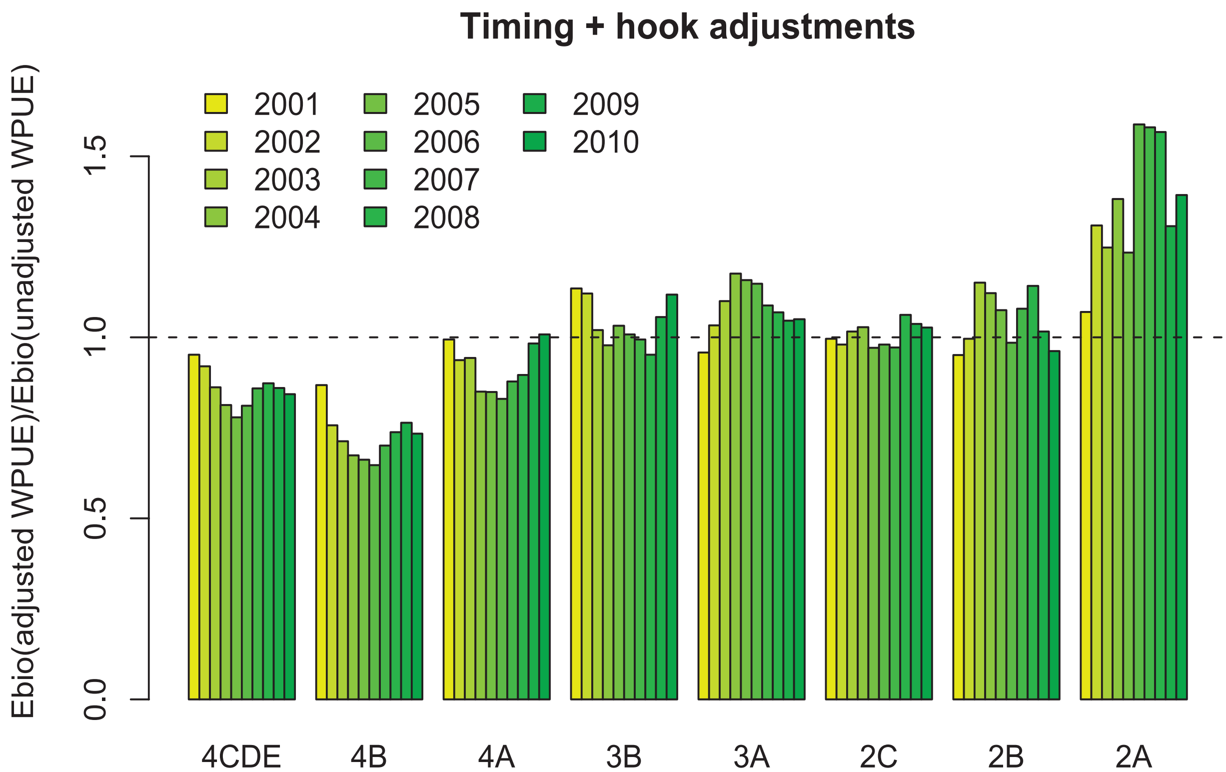

Figure 7. Ratios of exploitable biomass portions calculated using survey WPUEs adjusted for survey timing and hook selectivity and unadjusted WPUEs.

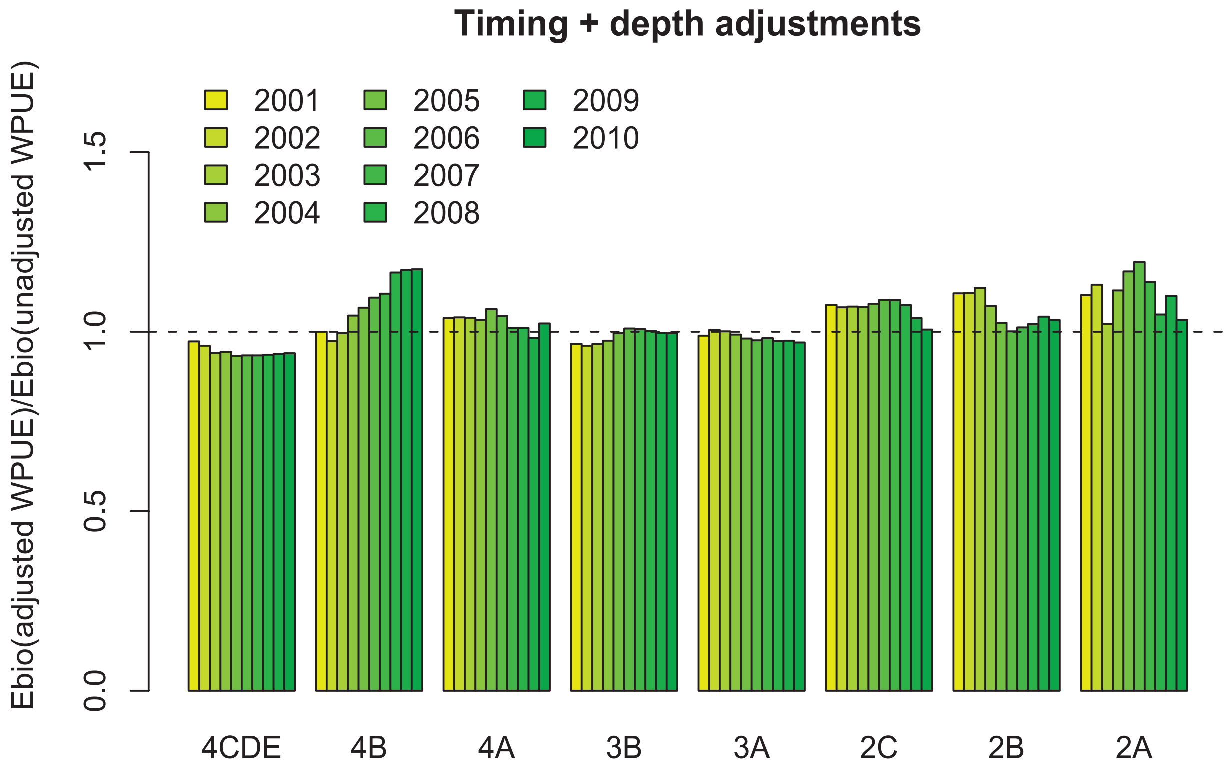

Figure 8. Ratios of exploitable biomass portions calculated using survey WPUEs adjusted for survey timing and depth stratification and unadjusted WPUEs.

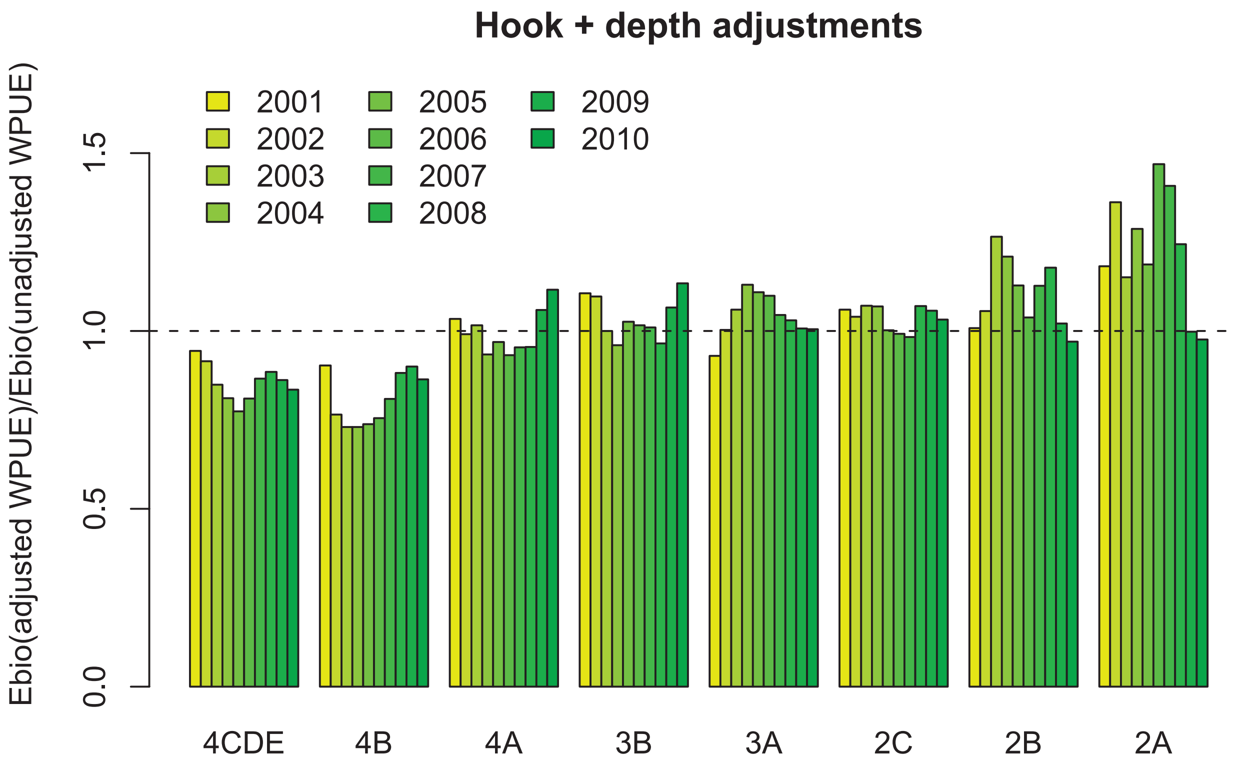

Figure 9. Ratios of exploitable biomass portions calculated using survey WPUEs adjusted for survey timing and unadjusted WPUEs.

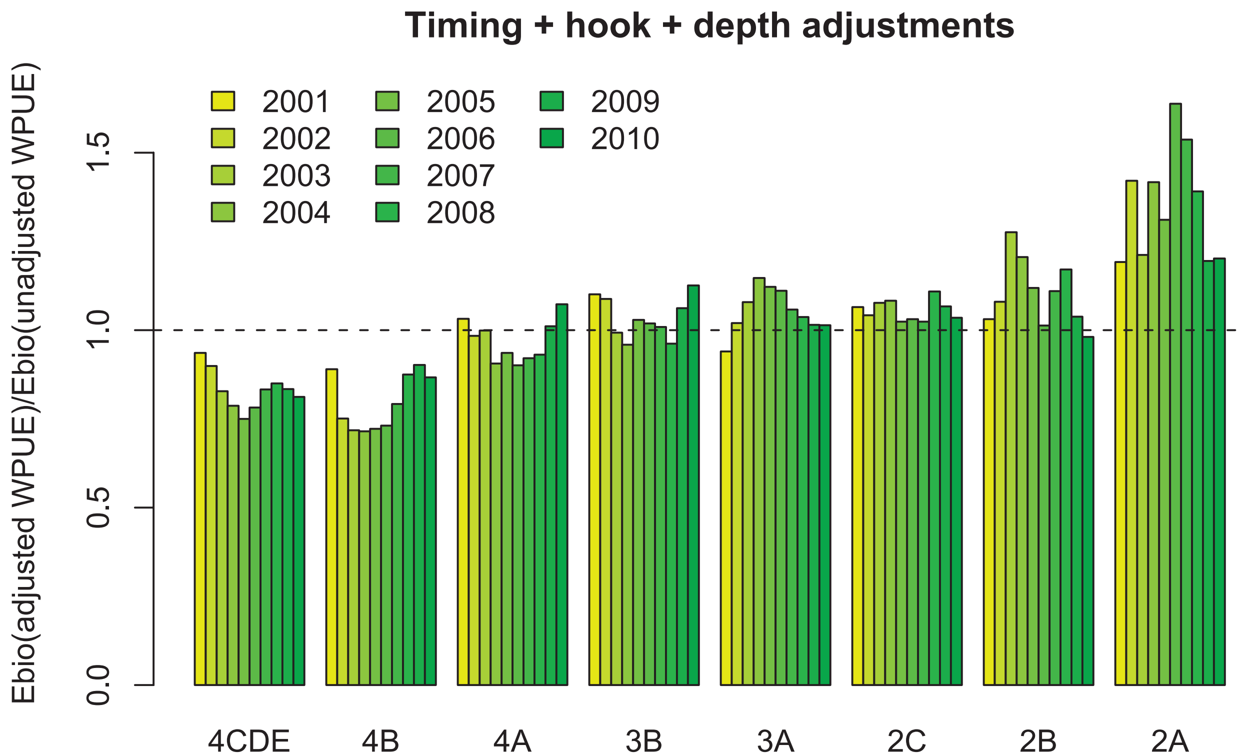

Figure 10. Ratios of exploitable biomass portions calculated using survey WPUEs adjusted for survey timing and unadjusted WPUEs.