

Options for modifying the Area 2A setline survey

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Introduction

During the 2009 Biomass Apportionment Workshop, IPHC staff were asked if we were to design the survey for apportionment purposes only, would the design be different from the current survey design? Indeed, there is one good reason why we might wish to design the survey differently, and that is to achieve relatively equally precise estimates of biomass proportions in each regulatory area. If an area's share of the biomass is imprecisely estimated, the estimate will be more greatly affected by random variation in the data than if its share is precisely estimated. This can lead to a biomass proportion for that area that differs from its "true" share of the coastwide biomass, (the theoretical share it would have received based on the average CPUE from an infinite number of surveys in a year).

The current survey design has excellent spatial coverage, but in smaller regulatory areas, the 10 nautical mile grid means that sample sizes are relatively low. This is not a problem when estimating biomass on a coastwide basis in the Stock Assessment, but when closed area assessments were done, there were often insufficient data to fit separate assessment models for smaller areas like Area 2A and Area 4CDE. Similarly, when using setline CPUE for apportionment of coastwide biomass among areas, ideally all proportions would be precisely estimated. Instead, mean CPUE is estimated with low precision in Area 2A and (to a lesser degree) in parts of Area 4 (Hare and Clark 2009, page 164). While the absolute effect on areas shares of biomass might be small, in smaller areas that difference can be a large fraction of the local biomass.

The problem is particularly acute in Area 2A, which has a very patchy distribution of halibut, leading to lower precision than other areas with comparable sample size. Table 1 gives the range of sample sizes and sample coefficients of variation (CVs) for each regulatory area over the last several years (Area 4C is omitted from the comparison because its survey only began in 2006). Except for Area 2A and Area 4D in one year (2004, when there were 48 stations compared to 58 today), CVs are always below 20%. Thus, Area 2A is an area of particular concern, with its highly imprecise estimates of mean CPUE likely leading to estimates of its share of total coastwide biomass that are further from its "true" share than other areas. All CVs are computed assuming a simple random sample of stations in each area. The survey is a systematic sample, and because of spatial dependence, the CVs are likely to be understated to some degree. This is not of concern in this report, as our focus is on comparisons among areas and among sampling alternatives for Area 2A, and we do not expect the comparisons to be affected by this assumption.

This report presents for discussion an approach to reducing sampling variation in Area 2A in order that its share of biomass with estimated with relative precision comparable to other areas. At present, the results should not be considered as IPHC staff recommendations for a redesign of the setline survey in Area 2A since we are also working with other agencies concerning augmentation of the Area 2A survey for data collection on species under management by those agencies.

Methods

For the reasons discussed above, were we to redesign the survey to improve the precision of the survey CPUE, we might allocate greater effort to small regulatory areas than does the current design. In some areas, we may be able to make better use of our resources by considering designs that improve the efficiency of the CPUE estimator subject to cost constraints. One way to do this is to use a stratified design with an optimal allocation. This is likely to be particularly useful in Area 2A, which has a few distinct areas of relatively high halibut density among a region of generally low density, and was identified above as the area of greatest concern. While it may be possible to consider habitat variables as the basis of strata definitions (e.g., depth strata) one simple approach is to use statistical areas within a regulatory area as strata. Area 2A has seven of these, with two (areas 10 and 50) having higher CPUE on average in recent years. Assuming the cost of a survey set is always the same (including sailing time), we can compute optimal sample sizes per stratum based on estimates of stratum variances from recent survey data using the Neyman allocation. The number of stations allocated to stratum h is given by

$$n_h = n \frac{N_h s_h}{\sum_{i=1}^L N_i s_i}$$

where n is the total number of stations to be sampled, N_h is the population size in stratum h , s_h is an estimate of the stratum standard deviation, and L is the number of strata. Here the “population” is the set of locations of all potential survey stations, so for N_h we should use the bottom area of stratum h . For this report, we substitute the number of stations in the current survey grid, which is approximately proportional to the bottom area.

Results

If we fix the number of stations at 84 for Area 2A, the Neyman allocation gives us the values in Table 2 for the five most recent years. Because of rounding, totals for some years do not sum to 84.

The biggest contributor to stratified variance is Area 50, with Area 10 also being important, and the optimal allocation tells us we should put most of our effort there. Using 2008 allocations as an example, the 2008 estimates of stratum variances would give us an overall SE for Area 2A of 3.43, compared with 5.49 using post-stratification on the current sample allocation, and 5.86 assuming simple random sampling. Thus, even if we keep the number of units fixed at 84 so that there is no cost increase in terms of additional stations, we can get big improvements in precision, leading in turn to more reliable apportionment. Note that the post-stratification, where we compute the stratified SE using the current design and statistical areas as strata, provides little improvement because high CPUE strata are not very homogenous: they have both high and low CPUE stations.

In some strata, the Neyman allocation assigns zero or close to zero stations, something that is undesirable, even if it minimises the standard error. The distribution of halibut is not fixed, and we need information from all parts of the regulatory area in order to monitor distributional changes.

Given that the current design has a minimum of three units per stratum, we could set this as the minimum in any modified design. If we wish to use no more than 84 stations, we could reduce the allocation to areas 10 and 50 with little cost to the overall SE. Table 3 gives examples of different allocations and the SE of the stratified sample mean from each.

For continuity with previous years' data, and to maintain the 10 nmi grid as the minimum spatial coverage, it may be more desirable to only increase station numbers per stratum. Under the average of the 2004-08 optimal allocations, only Areas 10 and 50 would have an increase in stations over the current design, and in the case of Area 10, the increase would only be a single station. Allocation method (7) in Table 3 keeps the current allocation in all areas, except for Area 50. In this area, the number of stations is multiplied by four, giving 52 stations, the same as the average of the 2004-08 optima. Method 7 leads to SEs and CVs at least as good as the optimal allocations (2). Thus under this allocation, we would maintain the current 10 nmi grid in all areas and use a 5 nmi grid in Area 50. This design entails a significant cost increase over the current design, with an additional 39 stations in Area 50. Some of these would be existing stations on a 2.5 nmi subgrid used for rockfish data for other agencies, but most would be completely new stations.

Figure 1 illustrates how a new design might look were we to use a 5 nmi grid in Area 50. The figure shows a total of 67 stations in Area 50 in the 20-275 fathom depth range used on the survey, including 54 potential new stations. Some of these potential stations are also on the 10 nmi grid, but have been excluded from the survey because of unsuitable habitat or because they are in shipping lanes. For the same reasons, other potential stations would also not be fished in the survey, and the total number of stations in Area 50 should end up being very close to the 52 suggested by our analysis.

Summary and Discussion

Area 2A is the only regulatory area for which the IPHC setline survey CPUE has a coefficient of variation greater than 20% with the current survey grid design, and in recent years the CV has averaged over 30%. With survey CPUE being used as the basis of biomass apportionment, this area's share is much more greatly affected by random sample variation than other areas, leading to annual estimates of its share of biomass that are less likely to reflect the actual share of biomass than other areas. By either optimally allocating sample effort to statistical areas, or quadrupling sample effort in statistical area 50 (where mean and variance are greatest), we can bring the CV for Area 2A under 20%, a level comparable with other areas. It is important to point out, however, that such an increase in station density in statistical area 50 would also increase the cost of conducting the survey substantially, perhaps prohibitively so from the perspective of the Commission's ability to fund such a modification.

It should be noted that current practice is for apportionment to be computed using averages of the three most recent years' worth of data. This is done in order to reduce large variation in area catch proportions from year to year, although at the expense of sensitivity to changes in biomass (estimates will be more stable with time, but with greater bias). It might be expected that using three years worth of data will lead to more precise CPUE means, hence more precise biomass proportions. However, the gain in precision is actually very small (Table 4) due to the strong temporal correlation between measurements on the same stations in consecutive years, i.e., very little is gained in terms of increased sample size. The conclusions from examining three-year averages would be the same as those above for data from a single year for Area 2A.

We briefly mentioned the possibility of using depth or some other habitat gradient to determine strata for optimal allocation. Depth alone is unlikely to provide any improvement, as both high and low density strata include a range of depths. The drawback of using statistical areas is that statistical area 50 in Area 2A is relatively inhomogeneous, with some stations with high CPUE and most with low CPUE (Fig. 1). A design that puts more effort only in the high density areas will be more efficient, although we would advise against using density itself to define strata since high and low density areas are likely to change with time. Alternative strata definitions could be investigated if it is decided that a re-design of the Area 2A survey is to proceed, although at this point such alternatives are not obvious.

Reference

Hare, S.R. and Clark, W.G. 2009. Assessment of the Pacific halibut stock at the end of 2008. Int. Pac. Halibut Comm. Report of Assessment and Research Activities 2008: 137-201.

Table 1. Mean and range of coefficients of variation of mean CPUE for each regulatory area from 2001-08.

Area	Stations (2001-08)	Mean CV (2001-08)	CV range (2001-08)
2A	84	33%	27-40%
2B	169-170	8%	7-9%
2C	107-110	7%	6-8%
3A	366-374	5%	4-5%
3B	210-231	4%	4-5%
4A	107-114	12%	10-14%
4B	86-89	10%	9-13%
4D	48-58	17%	14-23%

Table 2. Comparison of current Area 2A station allocation among statistical areas to calculated optimal allocations for 2004-08.

Year	Statistical Area						
	8	9	10	20	30	40	50
Current design	3	9	15	17	14	13	13
2004	0	1	21	4	2	10	45
2005	0	3	6	8	3	5	59
2006	0	4	22	5	4	1	47
2007	0	3	10	3	1	6	62
2008	0	1	24	5	1	5	48
Mean 2004-08	0	2	16	5	2	5	52

Table 3. Comparison of alternative methods for allocating sampling effort to statistical area in Area 2A.

Sample allocation method	Stratified SE and CV by year									
	2004		2005		2006		2007		2008	
	SE	CV	SE	CV	SE	CV	SE	CV	SE	CV
1. Post-stratification with current allocation	7.27	27%	8.63	31%	4.61	28%	6.94	37%	5.49	30%
2. Optimal allocation for each year	4.77	18%	4.73	17%	3.04	19%	3.66	20%	3.43	19%
3. 2008 optimal allocation	4.93	18%	5.34	19%	3.42	22%	4.05	22%	3.43	19%
4. Average of 2004-08 optimal allocations	4.95	18%	4.99	18%	3.18	20%	3.81	20%	3.53	19%
5. #4 with minimum of 3 stations per stratum	5.03	19%	5.06	18%	3.20	20%	3.89	21%	3.61	20%
6. #4 with no fewer stations per stratum than current allocation	4.50	17%	4.52	16%	2.90	18%	3.63	19%	3.37	18%
7. Current allocation with four times the stations in Area 50	4.59	17%	4.53	16%	2.90	18%	3.65	19%	3.44	19%

Table 4. Mean and range of coefficients of variation of three-year average CPUE values for each regulatory area based on data from 2001-08. Here we averaged the station CPUEs for each area over the three years up to and including the year of interest, beginning in 2003 (average of 2001-03). The coefficient of variation is calculated as the CV of the three-year individual station averages. The narrower CV range compared with one year values is in part due to the smaller CV, but also partly due to the inclusion of fewer years worth of data.

Area	Stations (2001-08)	Mean CV (2003-08)	CV range (2003-08)
2A	84	29%	27-32%
2B	169-170	7%	6-7%
2C	107-110	6%	6.0-6.4%
3A	366-374	4%	4.0-4.3%
3B	210-231	3%	3.1-3.5%
4A	107-114	10%	10-12%
4B	86-89	8%	7-10%
4D	48-58	16%	14-17%

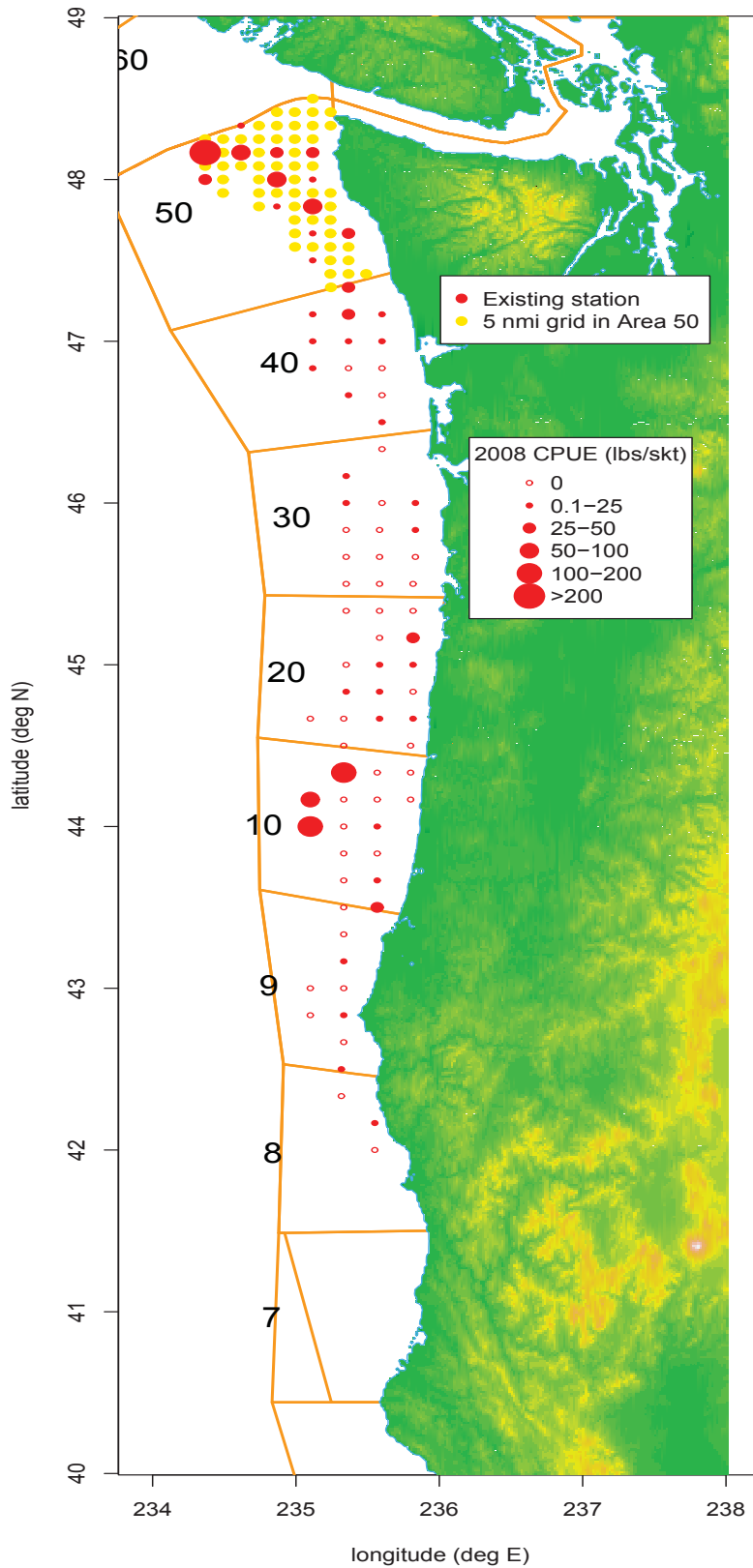


Figure 1. Current Area 2A survey design (with symbols showing 2008 CPUE) and potential new 5 nmi grid survey stations in statistical area 50.