# 2.8 Analysis of length-weight data from commercial sampling in 2016

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## Abstract

In 2016, International Pacific Halibut Commission (IPHC) port samplers weighed Pacific halibut in all staffed ports as part of standard random sampling procedures. Modelling of the length-net weight relationship showed strong evidence that estimated relationships from the observed weights fit the data better than the standard IPHC relationship for all regulatory areas, with the standard relationship overestimating expected weight in each case. As a result, we estimate positive biases in the 2016 mean net weight of commercial Pacific halibut calculated from the standard relationship ranging from 2% (Area 3B) to 11% (Area 4B). The proportion of the Pacific halibut weight removed as head varies across the coast and among individual plants, with Pacific halibut in some areas having mean head proportions above 0.13 in 2016, with individual plant means of up to 0.16. Head proportions were closest to assumed values in Area 2B.

## Introduction

As part of an ongoing study, International Pacific Halibut Commission (IPHC) port samplers are collecting data for use in estimating the relationship between fork length and net weight, including the estimation of adjustments necessary to convert gross weight (head-on, unwashed) to net weight (head-off, washed). The IPHC's standard length to net weight relationship is currently used in all IPHC work to convert length to net weight of Pacific halibut. The parameters of this relationship were estimated in 1926 based on a relatively small sample of Pacific halibut (454 fish) collected off Masset in Area 2B. Using 1989 data, Clark (1992) re-estimated the relationship's parameters and found good agreement with the earlier curve, and no changes to the standard IPHC relationship were made. It has always been recognized that such a calculated relationship will not be consistently accurate when computing total or mean weights from small numbers of Pacific halibut, but it has also been assumed that predictions should be accurate when data come from larger samples of fish (Clark 1992). However, when Courcelles (2012) estimated the relationship from data collected in 2011, she found significant differences between her estimated curve and that derived from the 1989 data, although inference was limited to a relatively small part of Area 3A and to the time of the setline survey. The primary goal of this project is to collect data coastwide, throughout the season, in order to examine the potential for bias in estimates of weights obtained from the standard length to net weight relationship.

The current relationship between fork length and net weight includes adjustments for the weight of the head, and of ice and slime (I/S): gross landed weight (gutted, with head, ice and slime) is assumed to include a proportion of 0.12 head weight and 0.02 ice and slime, which combine to give a multiplier of 0.8624 to convert gross to net weight. Clark (1992) noted that subsequent studies showed the head weighed less than 0.12 of gross weight, but that the adjustment factor worked well anyway, possibly because of additional shrinkage of fish after being weighed at sea (as they were in the 1926 study in which the relationship was estimated). In practice, combined deductions

of 0.12 in Areas 2A and 2B, and 0.118 in Alaska, are applied to commercial landings at the plants to convert from gross to net weight. These both include the 0.02 deduction for ice and slime assumed in the IPHC length-net weight relationship, but use 0.1 as the proportion for the head. This head deduction has been required as part of IPHC regulations since 2008 (Leaman and Gilroy 2008, Gilroy et al. 2008). The way the two deductions are combined differs among areas. In Areas 2A and 2B, these deductions are simply added (0.1+0.02=0.12), while in Alaska, the corresponding multipliers (1 minus the deduction) are multiplied (0.9×0.02), leading to a multiplier of 0.882, and a deduction of 0.118. Although the difference is minor, the latter is preferable because it accounts for ice and slime on the head. As a secondary goal of this project, samplers are also collecting data to provide direct estimates of adjustment factors to compare with the currently assumed values, and to assess variability in the weight of heads and ice and slime.

In 2016, Pacific halibut weight data were collected from all ports staffed with IPHC samplers throughout the fishing season, with the weighing of Pacific halibut integrated into the sampling of Pacific halibut for length and age data. This was the first year fish were weighed in St Paul, and the first year weight sampling was part of the standard length and age data collection in Dutch Harbor, allowing us to get representative samples in 2016 of Pacific halibut harvested in Areas 4A, 4B and 4CDE. In Area 2A, Pacific halibut landed in Bellingham were weighed, along with Pacific halibut landed during derby openings in Newport and tribal landings in La Push. Pacific halibut sampled in these fisheries for length and age collection will consistently be weighed in 2017.

## Methods

As in last year's report (Webster et al. 2016), we assess the current standard IPHC length to net weight relationship by first comparing the fit of this relationship to the data in each regulatory area with the fit of a model estimated from the data. For estimating the relationship between fork length and net weight, only head-on fish (with the same standard head and I/S deductions assumed in the standard IPHC relationship, 0.12 and 0.02 respectively) are used to ensure a consistent comparison due to the high spatial variability in the proportion of the weight removed when cutting heads (see below). Function parameters are estimated by fitting linear models (on the log scale) using least squares. Let $L$ be the fork length of a Pacific halibut in centimetres, and $W$ be its net weight in pounds. The standard IPHC length-net weight relationship is

$$W = 6.921\times10^{-6}L^{3.24} \tag{1}$$

More generally, the relationship between length and weight is assumed to have the following form

$$W = \alpha L^{\beta}$$

While this can be fitted as a non-linear model, it is somewhat easier to linearise the equation by taking logs of both sides, giving

$$\log(W) = a + \beta\log(L)$$

where $a = \log(\alpha)$. For the standard IPHC model, $a$ = −11.88. Now suppose we have $N$ Pacific halibut in our sample, and each is indexed by $i$, $i$ = 1, …, $N$. Then the model we actually fit is

$$\log(W_i) = a + \beta \log(L_i) + \varepsilon_i \quad (1)$$

where $\varepsilon_i \sim N(0, \sigma^2)$. For the standard IPHC model, the parameters are fixed at the standard values, and the fit of this model is compared with the model with the parameters estimated from the data. The two models are compared for each regulatory area using $F$-tests.

With large sample sizes in each area in 2016, the statistical tests comparing the two models have very high power to detect a difference, even if the difference is small. In order to understand whether such differences are meaningful, we also compare the mean net weight for each regulatory area obtained using the IPHC length-weight function with the mean calculated from the directly-measured head-on weights with standard head and I/S deductions applied. This provides a way of assessing the practical effect of any bias in the standard length-net weight relationship.

## Results

### Data summary

As of 15 November 2016, the IPHC database had records of weights of 11,392 Pacific halibut measured in 2016, compared with 13,378 Pacific halibut weighed in all of 2015. Pacific halibut sampled from catch landed at ports from Area 2B north were weighed throughout the commercial season (Table 1), with over 90% of sampled Pacific halibut weighed from Area 2B to Area 4B. A much smaller proportion of sampled Pacific halibut from Area 2A (0.37) were weighed, as weighing was concentrated in Bellingham, and (during derby openings) in Newport, while much of the length sampling is done at tribal ports without access to an IPHC scale for weighing. The proportion of samples weighed in Area 2C was somewhat lower than 1 in May and June, due to less than 100% weighing in Sitka (Table 2), although overall, sampling rates for weights improved greatly in this area over 2015, when 0.78 of the sampled catch was weighed (Webster et al. 2016). The biggest improvement in sample sizes came in western areas (Areas 4A, 4B and 4CDE) due to the integration of weighing into the standard sampling procedures in Dutch Harbor, and the availability of a scale in St Paul (although it arrived late, leading to sample proportions much less than 1; Table 2). We will be working with port sampling staff to help understand the cause of lower sampling rates in other ports. With high sampling rates throughout the season (Table 1) and across ports (Table 2), the samples obtained are likely representative of landed Pacific halibut in all areas except Area 2A.

### The length-net weight relationship

Models were fitted to data from all regulatory areas. For all areas, there was very strong evidence that the standard IPHC length-net weight equation provided a poorer fit to the data than a model with estimated parameters ($F$-test, $p<0.001$ in all cases). Figure 1 plots the observed data and the fitted relationships from the two models for each area. For all areas, the relationship estimated from the data predicts lower weights for a given length than the standard relationship, although the two curves are close in Area 3B, the only area with no statistical evidence of a difference in 2015

(Webster et al. 2016). As a result, the standard relationship produces positively biased estimates of net weight (Table 3), with the degree of bias varying by area. Areas 3A (+8.6%) and 4B (+11.4%) show the greatest degree of bias, while Area 3B shows the least (+2.3%).

### Head weights

Head weights can be estimated when fish are weighed twice, head-on followed by head-off (with both weights obtained from either washed or unwashed Pacific halibut). Coastwide, the database has records of 1296 Pacific halibut that were weighed both head-on and head-off with both measurements taken either before or after washing. An additional 450 Pacific halibut were weighed head-on unwashed and then head-off washed, providing combined head plus I/S weights. No Pacific halibut weights allowing direct measurement of I/S weight were obtained (weighed washed and unwashed, with either both weights head-on or head-off). Not all ports have plants that head Pacific halibut, and thus samplers did not get information on head weights from Juneau, Homer, Dutch Harbor or St Paul in 2016.

The mean proportion of a Pacific halibut's weight accounted for by the head is given in the first two columns of Table 4, by regulatory area and year. For samples from all areas, except Area 2B, mean head proportions are greater than the nominal value of 0.1. These can be attributed to differences among the way Pacific halibut are processed at plants in different ports. Closer inspection of the data showed variation in averages among ports, and some variability among plants within each port. The largest estimate of mean head proportion in a single plant was 0.16 (head only) in 2016. Plants in certain western ports tended to produce larger head proportions leading to the highest estimates of head proportion in Area 3B. Overall, mean head proportions are generally similar between the two years.

Data on combined head plus I/S weights tell much the same story (Table 4, final two columns), with measured values of head plus I/S typically much larger than the assumed value. Differences between 2015 and 2016 may be due to the lack of head-off weight data from Dutch Harbor in 2016, which also resulted in no estimates for Pacific halibut caught in Areas 4A and 4B this year.

## Discussion

Data collected in 2016 show evidence that the IPHC standard length-net weight relationship produces positively biased estimates of net weight averaged over the commercial season in all regulatory areas. In terms of annual mean net weight in 2016, biases ranged from +2% to +11%. For the four areas with high sample sizes in 2015 (Areas 2B, 2C, 3A and 3B), estimates of bias in 2016 were similar (Areas 2B and 2C) or higher (Areas 3A and 3B) than in 2015 (Webster et al. 2016). As we noted in last year's report, mean weight changes from year to year, so it is expected that the amount of bias in a regulatory area's estimated mean weight will also vary annually. To avoid bias in calculations that depend on commercial weight data, it is preferable to use observed head-on weights (converted to net weight using a standard multiplier) from the commercial weight sampling instead of weights estimated from the standard length-weight relationship. The estimate of bias for Area 2A should be interpreted cautiously, given that catch taken early in the season is under-represented in our samples. The scope of weighing Pacific halibut in Area 2A will be expanded in coming years.

The results of this work have important implications for the estimation of weight-per-unit-effort (WPUE) from the IPHC's fishery-independent setline survey. While the stock assessment

uses numbers-per-unit-effort in its modelling, the apportionment of biomass among regulatory areas is based on WPUE (Webster and Stewart 2016), with all weights of setline survey caught Pacific halibut estimated using the standard length to net weight relationship. Any systematic bias in that relationship will affect the apportionment estimates. For example, if mean WPUE from Area 4B is overestimated by a greater amount than other areas (as implied by results in Table 3), the proportion of the coastwide biomass in Area 4B will also be overestimated. Direct measurement of setline survey-caught Pacific halibut weights at the dock would ensure that WPUE estimates are not affected by inherent biases in the standard length-net weight relationship.

Head proportions (with or without ice and slime) were typically above average in all areas, with the exception being Area 2B. As we noted last year (Webster et al. 2016), cutting larger heads than the assumed value on average has management implications, potentially allowing more individual Pacific halibut to be harvested within the catch limits. With data from both 2015 and 2016 showing head proportions larger than assumed values in all areas except Area 2B, the IPHC staff has made a regulatory proposal for all commercial Pacific halibut to be weighed head-on at the dock and this value recorded in the reporting system. If this proposal is adopted, net weight of landings can be computed by applying standard multipliers to head-on weight, and sampling for head weights by IPHC port sampling staff may be discontinued. There is still a need for ice and slime estimates, as some plants weigh washed Pacific halibut, while others weigh unwashed Pacific halibut, and adjustments have to be made to the weights of the latter. To date, IPHC samplers have been unable to obtain weights from any fish either head-on washed and head-on unwashed, or head-off washed and head-off unwashed, so no direct estimates of the ice and slime adjustment are available from this project.

## References

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**Table 1. Sample sizes of weighed Pacific halibut (with proportion of sampled fish weighed) by month and regulatory area in 2016[1].**

| Month | 2A | 2B | 2C | 3A | 3B | 4A | 4B | 4CDE |
|---|---|---|---|---|---|---|---|---|
| March | 44 (0.10) | 342 (1.00) | 484 (0.98) | 95 (1.00) | | | | |
| April | 8 (0.14) | 321 (1.00) | 465 (1.00) | 283 (1.00) | 189 (1.00) | | | |
| May | 10 (0.19) | 244 (1.00) | 227 (0.78) | 378 (1.00) | 222 (1.00) | 337 (1.00) | 210 (1.00) | 112 (0.67) |
| June | 68 (0.62) | 234 (1.00) | 83 (0.87) | 169 (1.00) | 312 (1.00) | 274 (1.00) | 173 (1.00) | 264 (1.00) |
| July | 138 (0.98) | 118 (1.00) | 29 (1.00) | 87 (0.98) | 173 (1.00) | 238 (1.00) | 358 (1.00) | 148 (0.61) |
| August | 7 (1.00) | 125 (1.00) | 170 (0.99) | 181 (0.96) | 243 (1.00) | 287 (0.92) | 298 (1.00) | 229 (1.00) |
| Sept. | 44 (1.00) | 262 (1.00) | 138 (0.95) | 146 (1.00) | 203 (0.80) | 323 (1.00) | 198 (1.00) | 327 (1.00) |
| October | 2 (1.00) | 92 (1.00) | 16 (1.00) | 79 (1.00) | 39 (1.00) | 78 (1.00) | 30 (1.00) | 146 (1.00) |
| Total | 321 (0.37) | 1738 (1.00) | 1612 (0.94) | 1418 (1.00) | 1381 (0.96) | 1537 (0.98) | 1267 (1.00) | 1226 (0.89) |

[1]Does not include length-weight data for samples not aged as of Nov 15 2016.

**Table 2. Sample sizes of weighed Pacific halibut (with proportion of sampled fish weighed) by port and regulatory area in 2016[1].**

| Port | 2A | 2B | 2C | 3A | 3B | 4A | 4B | 4CDE |
|---|---|---|---|---|---|---|---|---|
| Newport | 181 (0.80) | | | | | | | |
| La Push | 55 (0.98) | | | | | | | |
| Bellingham | 85 (0.48) | | 8 (0.89) | 87 (1.00) | | | | |
| Vancouver | | 105 (1.00) | | | | | | |
| Pt Hardy | | 530 (1.00) | | | | | | |
| Pr. Rupert | | 1103 (1.00) | | | | | | |
| Petersburg | | | 888 (1.00) | 41 (1.00) | | | | |
| Sitka | | | 421 (0.81) | 61 (0.90) | | | | |
| Juneau | | | 295 (1.00) | 83 (1.00) | | | | |
| Seward | | | | 392 (1.00) | 335 (0.87) | | | |
| Homer | | | | 434 (1.00) | 504 (1.00) | 141 (1.00) | | |
| Kodiak | | | | 320 (1.00) | 497 (1.00) | 184 (0.99) | 54 (1.00) | 153 (1.00) |
| Dutch Hbr | | | | | 45 (1.00) | 1212 (0.98) | 1213 (1.00) | 798 (0.93) |
| St Paul | | | | | | | | 275 (0.75) |

[1] Does not include length-weight data for samples not aged as of Nov 15 2016.

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**Table 3. Estimated annual mean weight of commercially-caught Pacific halibut by regulatory area, calculated from fork length using the standard length-weight relationship, and from directly measured weight data, with estimated bias in the standard relationship's estimators. The same Pacific halibut were used in both estimates.**

| Area | Estimated mean net weight (lb) | | Estimated bias in IPHC l-w curve estimator (%) |
|---|---|---|---|
| | IPHC l-w curve | Directly measured | |
| 2A | 20.3 | 19.6 | + 3.7 |
| 2B | 22.6 | 21.5 | + 5.0 |
| 2C | 29.8 | 28.8 | + 3.4 |
| 3A | 19.4 | 17.8 | + 8.6 |
| 3B | 21.7 | 21.2 | + 2.3 |
| 4A | 23.7 | 22.6 | + 4.7 |
| 4B | 22.7 | 20.4 | + 11.4 |
| 4CDE | 22.3 | 21.1 | + 5.6 |

**Table 4. Mean head weight, and mean head weight plus ice and slime, as proportions of gross weight (with sample sizes), by regulatory area and year.**

| | Head only | | Head plus ice and slime | |
|---|---|---|---|---|
| Assumed value | 0.1 | | 0.118 | |
| | **2015** | **2016** | **2015** | **2016** |
| 2B | 0.096 (212) | 0.096 (161) | | |
| 2C | 0.109 (885) | 0.116 (648) | 0.111 (142) | |
| 3A | 0.143 (330) | 0.124 (280) | 0.149 (105) | 0.091 (1) |
| 3B | 0.135 (258) | 0.132 (193) | 0.147 (166) | 0.150 (184) |
| 4A | 0.149 (133) | 0.133 (14) | 0.151 (107) | 0.136 (221) |
| 4B | | | 0.150 (145) | |
| 4CDE | | | 0.136 (50) | 0.108 (44) |
| Total | 0.120 (1818) | 0.118 (1296) | 0.141 (715) | 0.139 (450) |

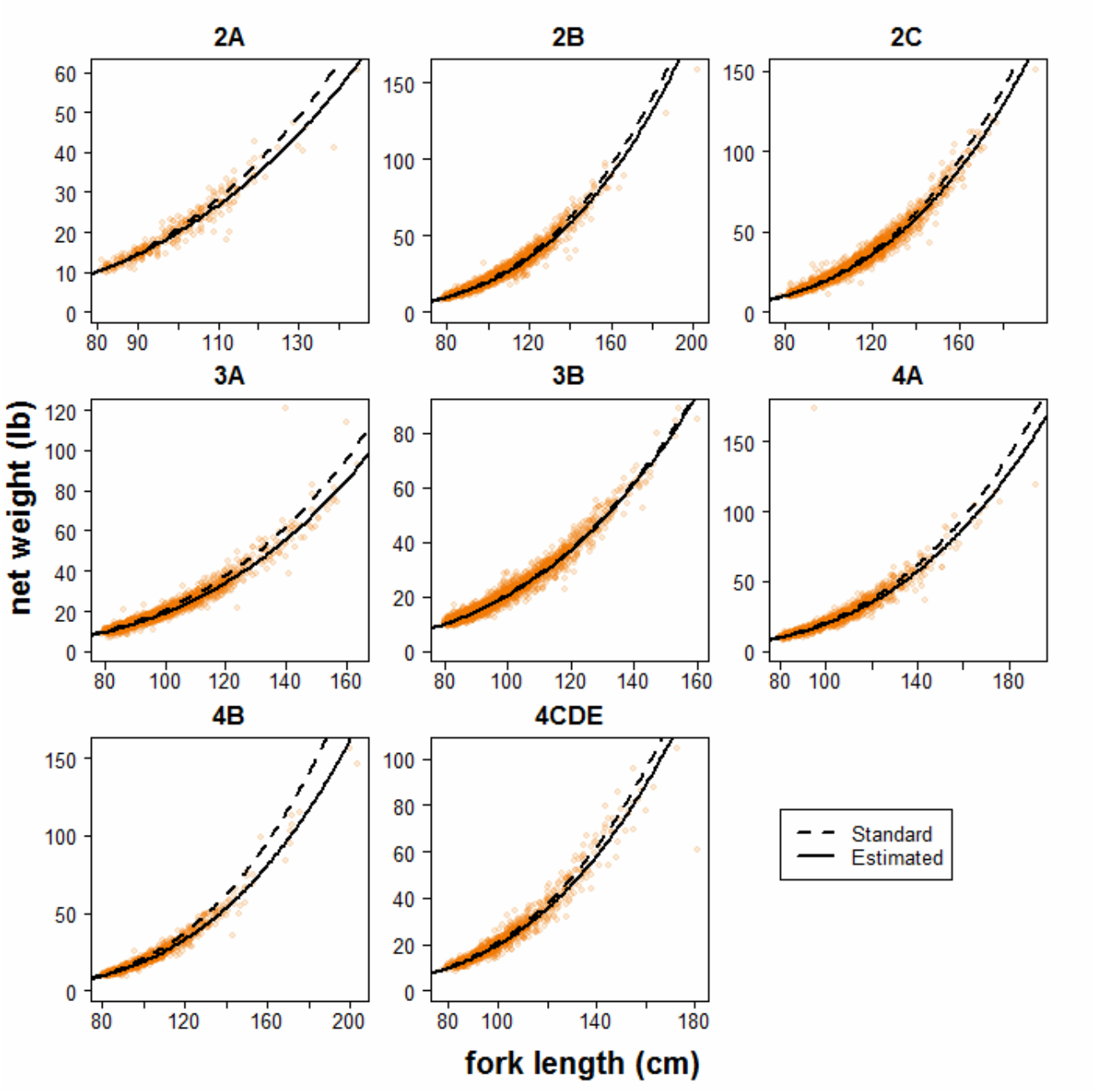


**Figure 1. Net weight (lb) plotted against fork length (cm) by area. Orange points show observed 2016 data by month are shown with coloured circles, while estimated relationships are shown with solid lines. The standard IPHC length-net weight relationship (dashed line) is included for comparison.**