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An Evaluation of North Pacific Groundfish Observer Program. Methods of Haul Weight Estimation

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U.S. DEPARTMENT OF COMMERCE
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INTRODUCTION

The National Marine Fisheries Service (NMFS) North Pacific Groundfish Observer Program places observers on commercial fishing vessels to collect data essential to the management and assessment of the North Pacific groundfish fisheries. Key objectives of their work are to estimate haul weight and catch composition on each vessel that they monitor. These data are incorporated into NMFS estimates of the total annual removals of fish, shellfish, and other species, and into weekly harvest estimates generated for in-season fishery management

NMFS estimates of total annual removals and in-season weekly fishery harvests for offshore-processors are based on a blend of observer data and industry production data. Each of the two data sources provides a weekly estimate of catch by species for each processor: observers provide data from which overall total catch and speciescomposition estimates are derived; processors provide data on the production of fish products which are converted to round weight by NMFS, with processor-estimated discards added. Each week, the data from all offshore-processors are blended in a manner which selects between the observer data and the production data on a processor-by-processor basis. The selected data source is used by NMFS to compile weekly catch estimates. Compiled over the year, these blend estimates become the annual record of catch. The blend model is weighted toward selection of the observer data when it is available. Thus, weekly and annual catch estimates are dependent on observer data and the derivation of that data warrants examination.

Haul weight estimates obtained by observers are essential to the overall estimation of catch by species on trawl vessels. Catch composition sampling provides estimates of the proportion of each species in a haul. The proportion by species is multiplied by the haul weight to estimate catch (i.e., weight) by species. Bias in haul weight estimation will also bias the estimates of catch by species. For example, if the haul weight estimate is 10% too high, then the estimate of catch by species might also be 10% too high.

Estimates of haul weight by observers currently depend upon two components: independent observer catch estimates for observed hauls and vessel catch estimates for unobserved hauls. Observers on catcher-processor trawl vessels typically estimate the weight of between 50% and 70% of the hauls made while aboard vessels. For unobserved hauls, the observer is dependent on vessel personnel to provide estimates of catch weights. Observer and vessel catch weight estimates can be biased. Both methods deserve examination to determine if resultant estimates are unbiased.

The accuracy of vessel personnel's haul weight estimates is difficult to evaluate. Prior to 1995, vessel-dependent data were recorded such that they can not be readily segregated from the independent observer estimates. This issue will best be addressed when data from the 1995 season becomes available. At that time it will be possible to directly compare ship's haul weight estimates with observer's estimates.

The independent observer estimates are more readily examined because observer data are collected systematically using prescribed methods. In training, observers are taught two methods of estimating haul weight on trawlers--codend and bin volumetric estimates. Each method estimates the volume of fish and applies a density factor to that volume to calculate the weight.

Using the codend method, observers measure the dimensions of a codend after it is brought onboard to determine the volume of fish in the net. Typically, this is done using pre-determined marks on the trawl deck, a measuring stick, and a tape measure. Once measurements are obtained, the observer applies a formula for the volumetric solid which best approximates the codend shape. Formulas are available for rectangular, ellipsoidal, semi-ellipsoidal, and cylindrical solids. Depending upon the fullness of the codend, position of straps and bands, packing of the fish, and the shape of fish at the fore end, observers must make some judgments regarding the average height, width, and length of the portion of the net containing fish. Large codends will often be greater than 2 m in height or width, creating some difficulties in measuring these parameters. On many vessels the codends are immediately dumped into fish bins, and the time available to measure a codend may be insufficient.

On some vessels, observers can use fish bins (bin volume method) to estimate catch weights. These bins hold fish after they are dumped from the codend, but before processing occurs. Typically, observers measure the bins prior to the start of fishing and use these measurements throughout the cruise. Vessels which participate in the Community Development Quota Program have markings certified by engineers on their bins. Bin heights may be marked on the sides where an observer can view inside to determine the level of fish, or observers use reference points such as bin boards. Despite these markings, the observer may need to judge the average height of fish, as the catch typically is at an uneven level in the bins. The observer estimates the average level and uses calculated bin volume or the volume from bins which have been certified to determine the volume of the catch.

The fish density applied to volumetric estimates of catch is usually estimated in situ by weighing a number of sampling baskets, or other containers, of unsorted catch and using the volume of the measuring container to calculate the density. The volume of a full sampling basket is relatively small at 0.055 m^3. In contrast, the volume of a bin or codend is far greater and can exceed 100 m^3. Densities are calculated regularly and applied to sampled hauls with a similar species mix. Currently, a NMFS-prescribed density of 0.93 t/m^3 (t = metric ton) is applied to hauls that are greater than 95% walleye pollock (Theragra chalcouramma). This prescribed density was determined using historical Observer Program data and represents an average of many in situ density measurements calculated by observers using standard observer sampling fish baskets.

This paper describes fieldwork conducted aboard the FT Alaska Ocean designed to evaluate volumetric haul estimation procedures used by observers. The Alaska Ocean was suited to this type of work as it is outfitted with a Marel flow scale system. Using this scale, observer estimates using the two volumetric methods could be compared against a scale-derived value for the haul weight. The objective was to evaluate the bias and precision of the volumetric methods of haul weight estimation. Following sections of this paper describe the sampling procedures used, present and discuss the results, and provide recommendations for additional fieldwork and potential changes in methods that would improve observer haul weight estimates.

METHODS

The project was carried out on the FT Alaska Ocean, a 115 m (376 ft) factory trawler owned and operated by Alaska Ocean Seafoods, Incorporated. The Alaska Ocean has three 95 metric ton (t) capacity fish bins and uses a net with a codend capacity of approximately 200 t. The vessel was chosen as a platform for this work because a motion-compensating in-line flow scale (Marel Flow Scale type M2000-B0l, P1900/450) is used to weigh the retained catch as fish are moved from the fish bins to the processing area via conveyer belts.

Normal operating procedures on the Alaska Ocean made it possible to routinely obtain codend estimates- for the entire haul and bin volume estimates and scale weights for individual bins. A large codend (>100 t) would be dumped into two bins, but fish from separate hauls were not mixed in the bins. Fish were always processed one bin at a time, so Marel flow scale readings could be obtained for individual bins, and bin totals could be summed to represent a particular haul.

In the aft section of the Alaska Ocean, adjustable openings at the base of the bins allow fish to flow onto conveyer belts which carry the fish from starboard to port. The fish next travel up an incline, forward 2 m, and then back across the vessel from the port to starboard sides. There are three discard stations along this port to starboard portion where crew members remove bycatch (all non-target species and undersized or damaged fish of the target species). At each discard station, bycatch is dropped onto a discard belt that runs below the primary conveyer to a discard chute. The retained catch (i.e., catch that is not discarded) is carried via conveyer across the Marel flow scale and on into the processing factory.

Because sorting takes place before fish cross the Marel flow scale, discards for each sampled codend or bin were weighed by an observer. For this purpose, Alaska Fisheries Science Center (AFSC) staff acting as second observers were deployed on the vessel, for the 1994 "B" season pollock fishery (16 August to 21 September) and during the October 1994 Pacific whiting (Merluccius productus) fishery (1 October to 5 October). The primary observer followed the normal observer sampling regime, while the second observer was dedicated to this special project and collected and weighed all the discards for the sampled hauls using a 100 kg platform scale. The discard weights (typically less than 2% of the total catch) obtained using the platform scale were added to the Marel flow scale weights to obtain a total weight estimate for a particular bin, henceforth referred to as the scale weight. The scale weight from each bin could then be compared with a bin volume density-based weight estimate. The comparison of codend volume estimates to scale-derived weights for larger hauls (greater than one bin) required weighing discards from more than one bin. This type of comparison was difficult to achieve regularly. Some hauls selected for this project were abandoned because the bycatch rate was too high for the second observer to weigh all the discards.

Scale Weights

The Marel scale is a motion-compensating type in-line scale. The unit integrates a weighing assembly (load cells and weighing plate) with measurement of the belt travel speed to record a cumulative weight of product. The weighing operation was designed to compensate for vessel motion using two load cells: the first is mounted beneath the weighing plate and senses the weight of material passing across it on the belt while the second load cell is fitted with a known weight. The M2000 Indicator component of the flow scale reads the signal from each load cell and uses the difference between apparent weight and known weight on the second cell to calculate a correct weight of material for the first cell.

The Marel scale was calibrated regularly with a 10 kg test weight and was further checked using known weights of fish, as determined on the platform scale. This test usually consisted of weighing a basket of approximately 50 kg of fish, and placing them on or sending them across the Marel flow scale. Platform and flow scale readings differed by less than 5% and were usually within 2%. Early in the study a larger quantity (560 kg) of fish were weighed using the platform scale and then sent across the flow scale. Scale readings were within 5 kg (0.89%). Thus, no substantial differences were found between the Marel scale weight and those obtained using the platform scale.

Determining the accuracy and precision of the Marel flow scale was beyond the scope of this project. Comprehensive work on scale performance under actual commercial (at-sea) conditions has not been fully explored, and the Marel motion-compensating flow scale has not been subjected to scale certification tests or procedures. However, for the purpose of this study, we treat the scale-derived weights as a measure of actual catch weights so that we can contrast the two volumetric-based methods.

Volumetric Estimates

We wanted to compare the two volumetric methods against a "known" weight to 1) delineate the accuracy and precision of each method, and 2) examine each method for indications of potential bias. The methods employed to determine volumetric estimates of catch for this study followed those of the Observer Program, as described earlier and in a Observer Program field manual (Teig et al. 1994). With both methods, observers first determine the volume of the catch, and then apply a density factor to this volume.

The fish bins on the *Alaska Ocean* were suitable for volumetric catch estimates. The bins were roughly rectangular, with some floor irregularity, and heights were marked clearly along the sides 'and back. The height of fish could be seen easily through either a viewing portal or by raising bin boards. The first AFSC staff member on the vessel measured the bin dimensions and produced a table that converted the depth of fish in the bin to a volume estimate. This table was used by all subsequent observers. Bin measurements were checked against ship drawings, measurements made by earlier observers, and measurements of the bins made when the vessel returned to port.

Observers could feasibly weigh only a limited amount. of discard (bycatch) using the platform scale. Therefore, only hauls of greater than 95% pollock were sampled for this project, to which the NMFS-prescribed 0.93 t/m^3 density was applied. Observers-did not calculate in situ densities during the pollock fishery. No in situ pollock density estimates based on basket weight were calculated during this project. During the whiting fishery, density was calculated in situ using fish in the standard 0.055 m^3 sampling baskets.

Analytical Approach

Volumetric-derived catch weight estimates depend upon two components: calculated volume and fish density. Therefore, in analyzing these data, questions about the bias of the volumetric component can not be addressed separately from questions about the appropriate density for fish in the bins or in a codend. For this reason, our analysis examined the relationship between the volume estimate (in m^3) obtained with standard observer-methods and the scale weights (Marel flow scale + discard). A linear regression model was used to explore the nature of that relationship. For each type of estimate (pollock bin, pollock codend, whiting bin, and whiting codend), we tested whether the relationship between volume and weight had a zero y-intercept, and whether there was any curvature in the relationship. The presence of either a non-zero y-intercept or curvature in the relationship between volume and weight would indicate that the density of fish changes with the weight of fish in the codend or bin. This would also suggest that the use of a single density value to convert volume to weight across a range of volumes is inappropriate.

An estimate of the appropriate codend or bin in situ density (t/m^3) is the slope of a zero-intercept linear regression (Neter et al. 1985),

$$y_i = \beta x_i + \varepsilon_i ,$$

where y_i = weight of haul i (t),
x_i = volume of haul i (m^3),
β = density (t/m^3),
and ε_i = the measurement error of haul i.

RESULTS

During the 1994 walleye pollock "B" season, observers collected 13 codend and 35 bin estimates that could be compared with scale weights (Marel scale weights + weighed discard) (Table 1) In the Pacific whiting fishery, 6 codend and 12 bin estimates were made (-Table 2). Codend volumes used in this study ranged between 22.4 and 218.3 m^3, single bin volumes ranged between 17.6 and 106.0 m^3. Deviations of the volumetric estimated pollock catch weights (using the prescribed density) from the scale weights ranged from 39.59 t to -22.78 t for codends and from 10.32 t to -10.64 t for bins, with an apparent bias among bin volumetric estimates (Fig. 1).

The pollock volume and weight data were collected by two different AFSC staff members acting as secondary observers. The first observer was on the Alaska Ocean from 16 August to 3 September, the second observer from 6 to 23 September. The data was first tested for between-observer differences. Bin weights were regressed on bin volumes with the observer as covariate with two factor levels. A test for differences in y-intercepts between observers was not significant (P = 0.40). A test for differences in slopes was also not significant (P = 0.43). Codend weights were regressed on the codend volumes and the same statistical tests were conducted. Again, neither the test for differences in y-intercepts between observers (P = 0.17) nor the tests for differences in slopes (P = 0.15) were significant. Based on these results, we combined the data for the two observers in all subsequent analyses. Since both observers used the same bin and codend measurements to determine volume, the high level of agreement is not surprising. A potentially important source of between-observer differences is error in the measurement of bin or codend dimensions. This would bias all of the observer's haul weight estimates. However, these results suggest that observer volume estimates are consistent; different, observers would independently produce. similar weight estimates.

A second series of statistical tests was used to examine whether the relationship between volume and weight is linear and if it passes through the origin. A single density value might not be appropriate to convert a volumetric estimate to a haul. weight over a wide range of volumes. For example, a large haul in a codend or a bin might compress the fish, increasing the in situ density. Two tests were performed for each data set: a test for a zero y-intercept and a test for a quadratic term in the regression. The purpose of the first test was to determine whether the weight estimate would go to zero as the volume goes to zero. The purpose of the second test was to determine whether there is any curvature in the relationship between volume and weight. For the pollock bin volume data set, the test for a non-zero y-intercept was significant (P = 0.04), but an additional test for a quadratic term was not significant (P = 0.21). For the pollock codend data set, the test for a non-zero y-intercept again was significant (P = 0.01) and the test for an additional quadratic term was not (P = 0.15). These results indicate that the apparent density of pollock declines linearly with increasing haul size (Fig. 2). This result is opposite to the deviation from a constant density relationship that would occur if fish were being compressed in a large haul, where the apparent density would increase with haul size. The possible explanations for this are 1) the observers tended to underestimate the volume of small hauls relative to large hauls or 2) changes in density between large and small hauls. The estimated y-intercept was larger for the codend volume estimates: therefore, this tendency was greater for codends than it was for bins (Fig. 3). However, the overall effect of this tendency was small.

The volume and weight data collected during the whiting fishery showed a similar pattern to the pollock data. For the whiting bin weight-volume regression, the y-intercept was significant (P = 0.011, but an additional quadratic term was not significant (P = 0.34) (Fig. 4). For the whiting codend data set, neither the y-intercept nor quadratic coefficient in the regression of haul weight on volume were significant (y-intercept

P = 0.30, quadratic P = 0.23) . The whiting codend sample size (n = 6) was too small to adequately test for a significant departure from a zero y-intercept linear relationship. The direction of departure was the same as with the pollock codend data sets, where smaller hauls had a higher apparent density than the larger hauls (Fig. 5).

The zero y-intercept linear regression estimates of fish density (Table 3) show some differences from the nominal values of fish density obtained from basket sampling. For pollock, a t-test (Weisberg 1985) indicated that the in situ bin density estimate of 1.02 t/m^3 was significantly larger than the NMFS-prescribed value of 0.93 t/m^3 ($P < 0.001$). However, the codend in situ density estimate of 0.93 t/m^3 was not significantly different than the nominal value (P = 0.945). The lower estimated in situ density for codends probably does not indicate that fish are packed less tightly in codends than in fish bins, though this is one possible interpretation. -A more likely explanation is that codend volumes are consistently overestimated, producing a lower apparent density.

For Pacific whiting, a standard NMFS fish density was not used, and observers estimated fish density daily with basket samples. An average of fish densities from four vessels fishing in the same area as the Alaska Ocean was 0.90 t/m^3. The in situ bin density estimate of 0.89 t/m^3 was not significantly different than the basket sample estimate (P = 0.801). The in situ codend density of 0.91 t/m^3 also was not significantly different than the basket sample estimate (P = 0.727).

Although the data showed statistically significant departures from a constant density, the percent difference is fairly small over the range of haul weights typically observed (Fig. 2). For the bin volume data, the difference was 4% for bin weights between 40 and 60 t, and less than 1% for bin weights in the 80-110 t range. For the pollock codend data the departure from a constant density was larger. The difference was 22% for haul weights between 40 and 60 t, and 2% for haul weights between 175 and 200 t (Fig. 3). For the whiting bin volume data, the difference is 16% for bin weights in the 20-30 t range and less than 1% for bin weights in the 40-60 t range (Fig. 4). There were too few whiting codend estimates (n = 6) to make a meaningful comparison between the constant density estimates and the linear regression predictions (Fig. 5).

An additional aspect to be considered when comparing the bin volume estimates with the codend estimates is their relative precision. The estimated weights for the bin volume method tended to have smaller deviations than the codend method (Figs. 2-5). An F-test (Rosner 1982) for the ratio of mean square errors (MSES) for the bin volume and codend constant density regressions was highly significant for both the pollock and the whiting data (pollock: $P < 0.001$, whiting: $P= 0.025$). This is a strong indication that the bin volume method is more precise than the codend method.

Using the constant density estimate for pollock and a pollock bin volume of 50 m^3 the 80% confidence interval for a new haul weight is plus or minus 12% of the predicted haul weight. For a codend volume of 50 m^3, the 80% confidence interval is plus or minus 42% of the predicted value. For a pollock bin volume of 100 m^3, an 80% confidence interval to predict a new haul weight is plus or minus 6%, while for a codend volume of 100 m^3, the 80% confidence interval is plus or minus 21%. With these 80% confidence intervals, we would be 80% sure that the true haul weight is between 96 and 109 t for a bin volume of 100 m^3, while for a codend volume of 100 m^3, we would be 80% sure that true haul weight is between 73 and 113 t. An 80% confidence interval is 'reported for haul weight because in our judgment this is an appropriate level of accuracy to compare different methods of monitoring catches on fishing vessels at sea. The 95% confidence interval used in scientific work is too high a standard of accuracy.

DISCUSSION

Potential biases of varying magnitude exist for both the bin and codend volumetric methods used by observers for haul weight estimation. Two significant problems are apparent. First, both methods showed a decrease in apparent fish density as the haul size increased. This phenomenon would occur if the volumes of small hauls were consistently underestimated, or if the volumes of larger hauls were consistently overestimated. It is not possible from this study to determine which is occurring. While this phenomenon is slight, it is consistent for both pollock and whiting, and for both estimation methods. However, the bin volume method had smaller deviations from a constant density than the codend method.

A second potential problem is that the NMFS-prescribed pollock density values applied to volume estimates may be inappropriate and are causing a bias in the haul weights. This problem appears most severe for the pollock bin volume estimates. While there is apparent agreement between the codend density estimate from the <u>Alaska</u> <u>Ocean</u> sampling and nominal pollock density, this may be- due to opposing biases that cancel. The bin density estimate may bias the catch low while the codend estimates may bias the catch high. For Pacific whiting, both the' codend and bin density estimates corresponded well with the mean of the in situ basket sample estimates of fish density. The conclusion that the NMFS-prescribed pollock density value may be inappropriate is contingent on the accuracy of the Marel scale weights; a bias in scale weights would explain all or part of this apparent density bias.

Our results suggest that the current prescribed 0.93 t/m^3 density may not be a good approximation of the density of pollock in bins or codends under all conditions. The prescribed density value is based on historical data derived by the basket method and represents an average of many densities obtained by observers. Either the average gained from all in situ densities (across fishery seasons and catch proportions) should not be applied to specific cases; that is, hauls composed of greater than 95% pollock during the B season, or the in situ densities making up this average are themselves in error. The density measurements may bias the catch estimates such that the actual catch weight is underestimated. The data from the *Alaska Ocean* indicate that the estimates of pollock catch-weight using bin volumes and a density of 0.93 t/m^3 are 9% too low. A possible explanation for this density bias is that fish are not packed as tightly in a basket as they are in bins. In addition, the surface area to volume ratio decreases with size of the container used to estimate density. Thus, the effect of container size is much more important in a small basket compared with a bin, which tends to further reduce the estimated density.

Regardless of these biases, the codend method of volumetric-based catch estimation is significantly less precise than the bin volume method and shows a greater departure from a constant density across a wide range, of haul volumes.

RECOMMENDATIONS

Several recommendations follow as a result of this study which could reduce bias and increase precision in current observer haul weight estimation procedures.

1. Conduct fieldwork to evaluate Marel flow scale performance under field conditions. This would encompass work where a large quantity of fish can be weighed independently and then weighed by a flow scale.

Rationale--The accuracy and precision of motion-compensating flow scales has not been addressed in an experimental setting. Results of such work will provide guidance on the best way of improving precision in haul weight estimates. Further work may also identify the source of the discrepancy between the Marel scale weights and the volumetric estimates based on the NMFS-prescribed pollock density.

2. Conduct fieldwork to further evaluate volumetric-based haul weight estimation methods.

   Rationale--the existing methods to-determine codend or bin volume warrant review to identify potential improvements. Additional work would explore the relationship between density and volume (codend or bin size) by increasing the number of samples at various codend or bin volumes. Current procedures assume a constant density of fish regardless of volume. Results reported in this paper suggested that the assumption of constant density is questionable,

3. Prioritize fieldwork to further research the density variable used in volumetric catch estimation, expanding it beyond the pollock and whiting fisheries. Such fieldwork should address broader issues such as determining the most appropriate density sampling unit (size, shape, volume), use of an accurate weight scale to experimentally calculate codend or bin in situ densities, determining prescribed densities for specific fisheries, and developing a density table for use by observers which takes into account species

composition and other factors or developing an appropriate device for in situ density measurement by observers.

Rationale--The current method likely has a bias in the pollock or whiting fishery which may be present in other fisheries. Investigating options to resolution will help to determine what is needed to obtain in situ density measurements which are not biased. Current methods appear inadequate.

4. Direct observers to use codend estimates only when bin volume measurements are not possible.

   Rationale--This work demonstrates that codend estimates are less precise than bin volume estimates.

5. Pursue regulatory measures to either weigh catch at sea or provide marked, measured, lighted, and accessible bins for use by observers.

   Rationale--The proper approach would depend upon results of the work suggested thus far. Scaleswould provide a weight of catch. Alternatively, marked, measured, lighted, and accessible bins would increase the precision of catch estimates over codends, and provide for consistency in those estimates between different observers. Increased precision might also be gained through the use of bin indicators to determine the height of fish in a bin.

When available, analyze the 1995 data to determine if there are systematic differences between observer volumetric data and vessel estimates of catch.

Rationale--The current total catch estimates in the Observer Program database may contain a bias that affects current and historical catch estimates..

7. Develop analytical procedures to eliminate dependence on vessel estimates of catch.

Rationale--The current observer catch estimation relies on a combination of observer estimates mixed with vessel estimates. Expansion of catch data from observed to unobserved hauls should represent a consistent scientific approach to catch estimation rather than a mix of methodologies.

In addition to the above recommendations, the level of catch weight precision needed for management should be defined, and the most reliable and cost-effective means (volumetric estimates or direct weighing) of achieving this goal determined. Should the currently used pollock density be in error, once this is corrected the volumetric estimate method provides reasonably accurate, precise, and dependable haul weight estimates. Whether volumetric estimates will be outperformed by catch weight determination using at-sea weighing has yet to be determined. A critical factor in such a comparison is the overall reliability of each method. Reliability can be assessed through I) an analysis of the at-sea dependability and 2) a review of the amount of work needed to ensure either method's feasibility. The feasibility measures include regulatory action, observer training and workload, compliance monitoring, and enforcement.

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Table 1. Pollock "B" season (16 Aug.-21Sept., 1994) Marel scale weights, discard, codend and bin volume estimates using a density of 0.93.t/m^3 . W= whole haul sample, B = bin sample, Numbers 1, 2, 3 identify bins.

Date	Haul number	B/W	Marel wt. (t)	Discard wt. (t)	Total haul wt. (t)	Codend vol. (m^3)	Codend wt. est. (t)	Bin volume (m^3)	Bin volume wt. est. (t)
16-Aug	6	W	165.355	0.576	165.931	189.198	175.954	---	---
17-Aug	11	W	184.999	0.325	185.324	177.375	164.959	---	---
17-Aug	12	B-1	30.956	0.228	31.184	---	---	27.526	25.599
19-Aug	20	B-2	96.691	0.317	97.008	---	---	89.519	83.253
19-Aug	21	B-1	78.675	0.713	79.388	---	---	77.302	71.891
20-Aug	23	B-2	53.479	0.714	54.193	---	---	52.879	49.178
21-Aug	31	B-3	91.631	0.223	91.854	---	---	90.252	83.934
22-Aug	34	B-2	96.069	0.188	96.257	---	---	91.937	85.502
23-Aug	35	B3	68.844	0.595	69.439	---	---	65.021	60.469
23-Aug	36	B-1	65.349	0.287	65.636	---	---	57.318	53.306
24-Aug	39	B-3	89.962	0.763	90.725	---	---	94.394	87.787
24-Aug	43	B-3	93.403	0.154	93.557	---	---	91.381	84.985
26-Aug	51	B-2	92.977	0.096	93.073	---	---	90.078	83.772
26-Aug	51	W	193.196	1.097	194.293	213.259	198.331	---	---
28-Aug	60	B-1	92.675	0.496	93.171	---	---	97.286	90.476
29-Aug	63	W	136.378	0.341	136.719	148.653	138.247	---	---
31-Aug	71	W	192.673	0.127	192.800	201.455	187.353	---	---
1-Sep	75	B-2	95.251	0.137	95.388	---	---	90.078	83.772
3-Sep	84	B-3	91.150	1.232	92.382	---	---	87.048	80.955
6-Sep	102	W-3	38.710	0.534	39.244	28.737	26.725	41.945	39.009
7-Sep	105	B-1	77.541	2.251	79.792	---	---	77.303	71.892
8-Sep	111	W-1	93.008	0.537	93.545	85.761	79.758	91.819	85.392
11-Sep	119	W-3	36.613	0.610	37.223	33.368	31.032	29.621	27.547
11-Sep	120	W-1	32.394	1.223	33.617	22.372	20.806	34.003	31.623
11-Sep	121	B-3	84.706	1.916	86.622	---	---	87.239	81.132
12-Sep	124	B-1	89.685	0.752	90.437	---	---	87.664	81.528
12-Sep	124	B-2	85.097	3.178	88.275	---	---	93.053	86.539
12-Sep	124	W	174.782	3.930	178.712	218.301	203.020	---	---
12-Sep	125	B-3	80.351	0.895	81.246	---	---	87.239	81.132
13-Sep	129	B-1	89.326	0.530	89.856	---	---	90.995	84.625
14-Sep	133	B-3	93.612	1.765	95.377	---	---	105.693	98.294
15-Sep	137	B-3	56.888	1.582	58.470	---	---	57.352	53.337
15-Sep	138	W-1	61.409	2.309	63.718	40.935	38.070	62.869	58.469
16-Sep	145	B-3	91.561	1.028	92.589	---	---	87.239	81.132
17-Sep	148	B-1	96.098	2.205	98.303	---	---	87.664	81.528
18-Sep	151	B-3	91.939	1.152	93.091	---	---	87.239	81.132
19-Sep	155	B-3	93.415	1.130	94.545	---	---	87.239	81.132
20-Sep	161	B-2	42.642	0.503	43.145	---	---	42.371	39.405
20-Sep	162	W-1	22.936	1.084	24.020	24.152	22.461	16.886	15.704
21-Sep	165	W-1	91.011	3.167	94.178	89.659	83.383	85.074	79.119
23-Sep	175	B-3	91.147	1.476	92.623	---	---	90.629	84.285

Table 2. Pacific whiting Oct. opening (1-5 Oct., 1,994) Marel scale weights, discard, codend and bin volume estimates using a density of 0.90 t/m^3. W= whole haul sample, B= bin sample, Numbers 1, 2, 3 identify bins.

Date	Haul number	B/W	Marel wt. (t)	Discard wt. (t)	Total haul wt. (t)	Codend vol. (m^3)	Codend wt. est. (t)	Bin volume (m^3)	Bin volume wt. est. (t)
1-Oct	3	B-2	22.660	1.409	24.069	---	---	18.673	16.806
1-Oct	4	B-2	55.027	0.329	55.356	---	---	54.729	49.256
1-Oct	4	B-3	51.004	0.246	51.250	---	---	55.680	50.112
1-Oct	4	W	106.031	0.575	106.606	113.774	102.397	---	---
2-Oct	8	B-2	29.956	0.297	30.253	---	---	31.394	28.255
2-Oct	8	B-3	51.402	0.868	52.270	---	---	60.350	54.315
2-Oct	8	W	81.358	1.165	82.523	89.606	80.646	---	---
3-Oct	14	B-2	28.256	0.111	28.367	---	---	28.181	25.363
3-Oct	14	B-3	55.606	0.797	56.403	---	---	67.355	60.619
3-Oct	14	W	83.862	0.908	84.770	75.398	67.858	---	---
4-Oct	22	B-2	55.786	0.130	55.916	---	---	60.955	54.860
4-Oct	22	B-3	58.919	0.434	59.353	---	---	70.857	63.772
4-Oct	22	W	114.705	0.564	115.269	134.126	120.713	---	---
5-Oct	28	W-3	48.498	0.295	48.793	52.543	47.289	55.680	50.112
5-Oct	30	B-2	19.890	0.068	19.958	---	---	19.811	17.830
5-Oct	30	B-3	63.374	0.235	63.609	---	---	73.192	65.873
5-Oct	30	W	83.264	0.303	83.567	98.713	88.842	---	---

Table 3. Zero y-intercept linear regression estimates of fish density.

Species	Estimation method	Density (t/m^3)	df	RSE	95% CI		R-sq
					Lower	Upper	
Pollock	Bin vol.	1.02	34	4.79	1.003	1.045	0.96
Pollock	Codend vol.	0.93	12	14.37	0.869	0.996	0.95
Whiting	Bin vol.	0.89	11	3.78	0.850	0.940	0.94
Whiting	Codend vol.	0.91	5	8.45	0.822	1.004	0.87

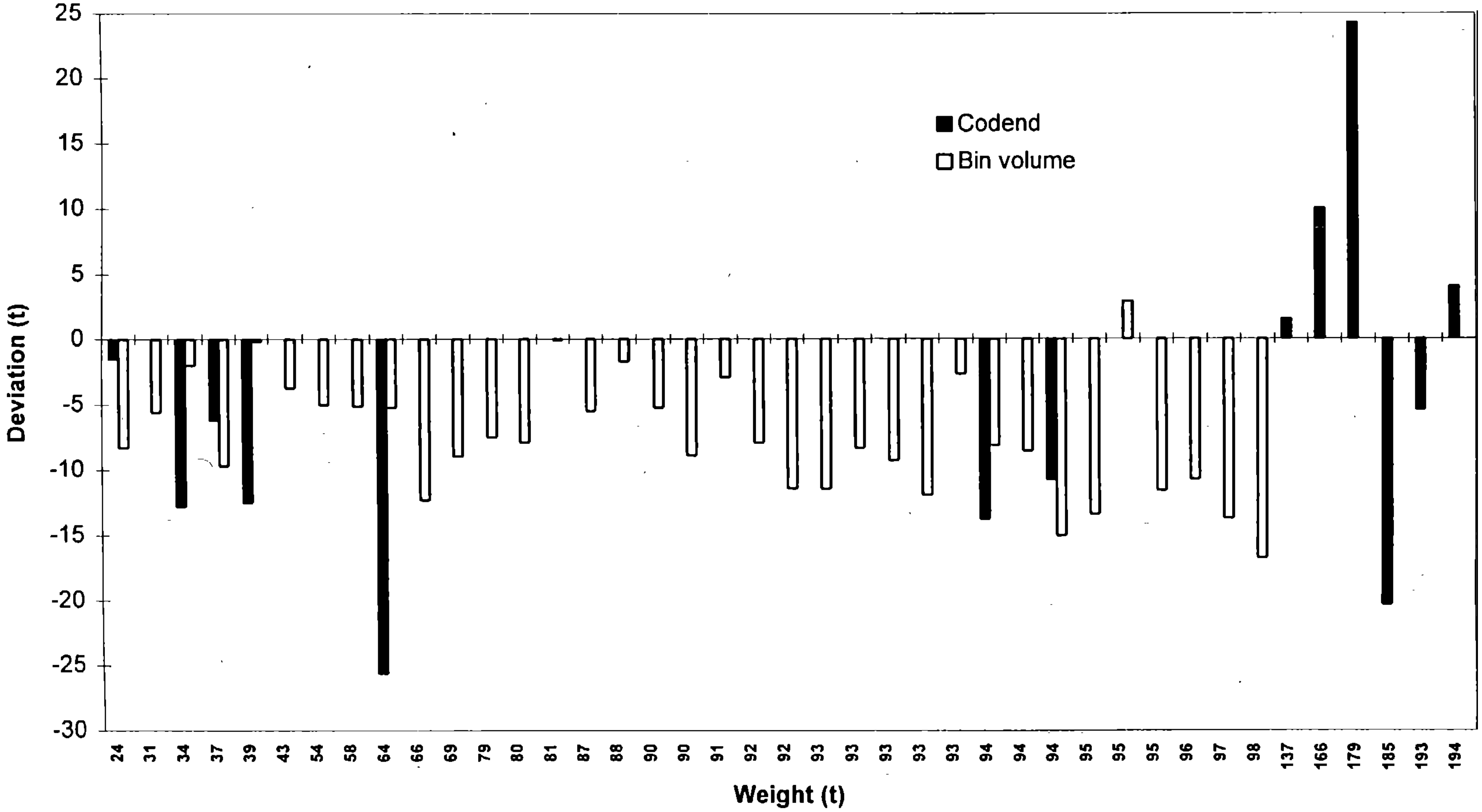

Figure 1. Codend and bin volume estimated haul weight deviations from the scale-derived haul weights for pollock. Haul weights were estimated using the NMFS-prescribed density of 0.93 t/m^3. The numbers along the bottom axis are the scale-derived haul weights, and are arranged in ascending order.

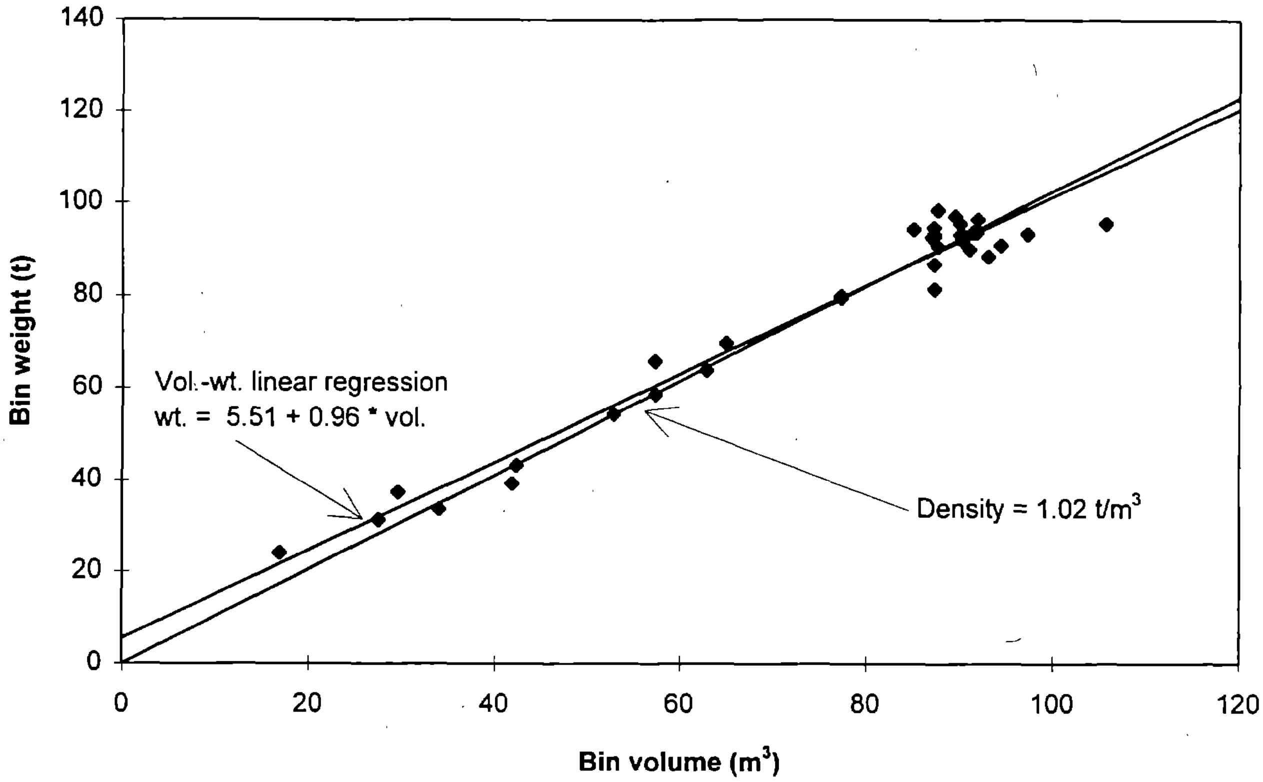

Figure 2. Haul weight in metric tons(t) (Marel scale weight + discard) versus bin volume (m^3) for sampled pollock hauls during the 1994 "B" season on the Alaska Ocean. Two regression lines are shown: 1) a zero y-intercept regression line to estimate a constant density and 2) a linear regression of weight on volume. The linear regression had a significant y-intercept (P = 0.04).

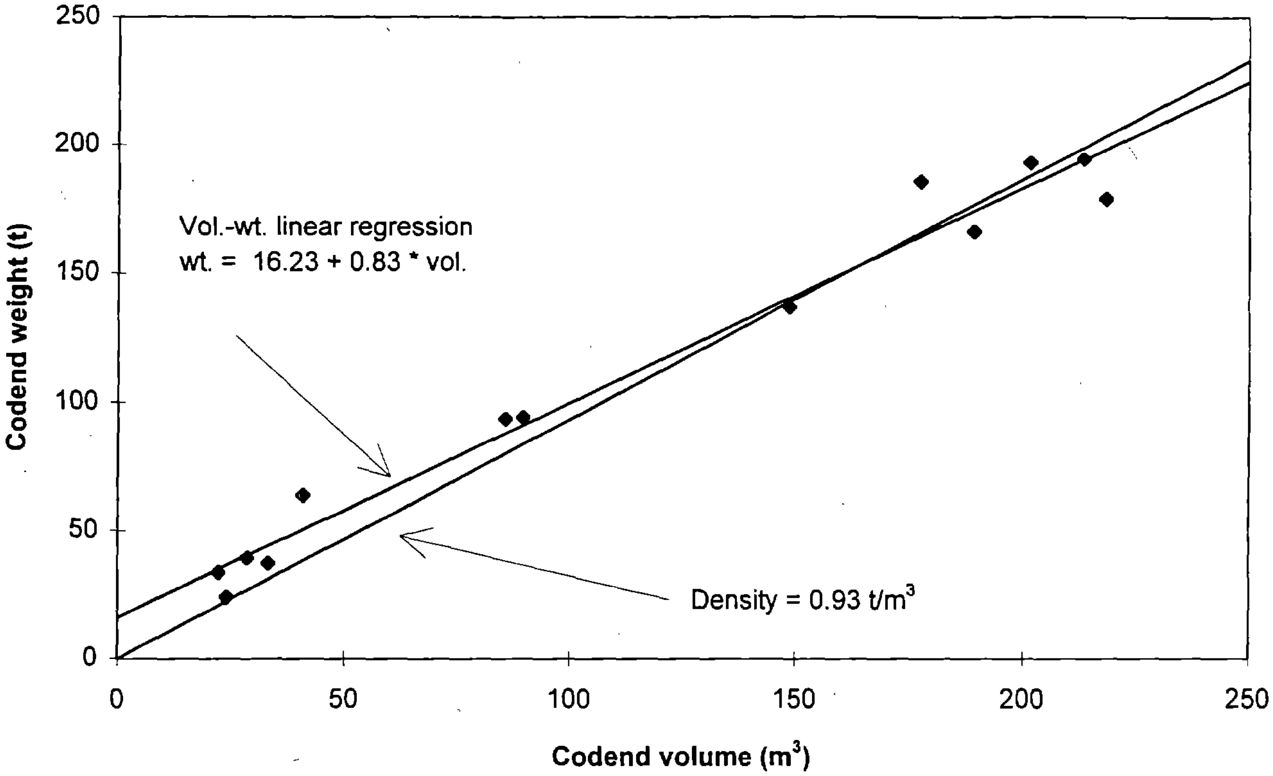

Figure 3. Haul weight in metric tons(t) (Marel scale weight + discard) versus codend volume (m^3) for sampled pollock hauls during the 1994 "B" season on the Alaska Ocean. Two regression lines are shown: 1) a zero y-intercept regression line to estimate a constant density and 2) a linear regression of weight on volume. The linear regression had a significant y-intercept (P = 0.01);

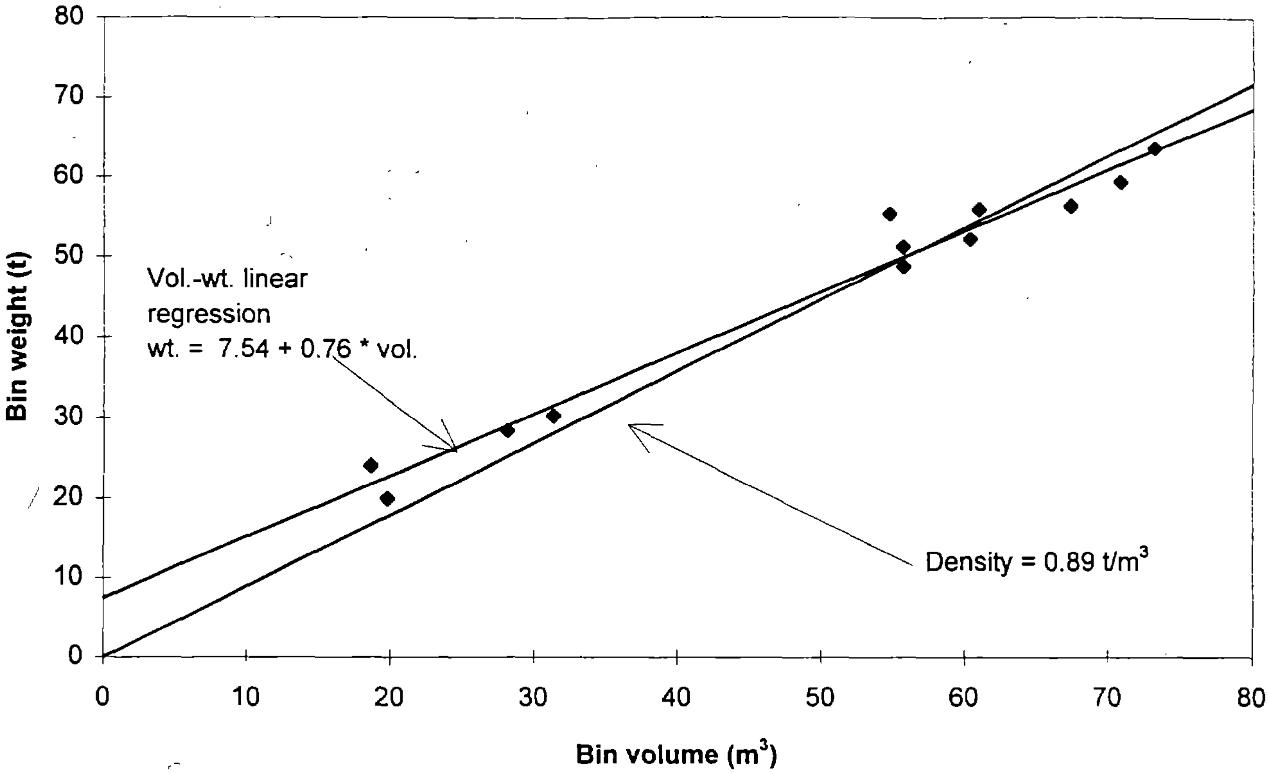

Figure 4. Haul weight in metric tons (t) (Marel scale weight + discard) versus bin volume (m^3) for sampled whiting hauls during the 1994 October whiting opening on the Alaska Ocean. Two regression lines are shown: 1) a zero y-intercept regression line to estimate a constant density and 2) a linear regression of weight on volume. The linear regression had a significant y-intercept (P = 0.01).

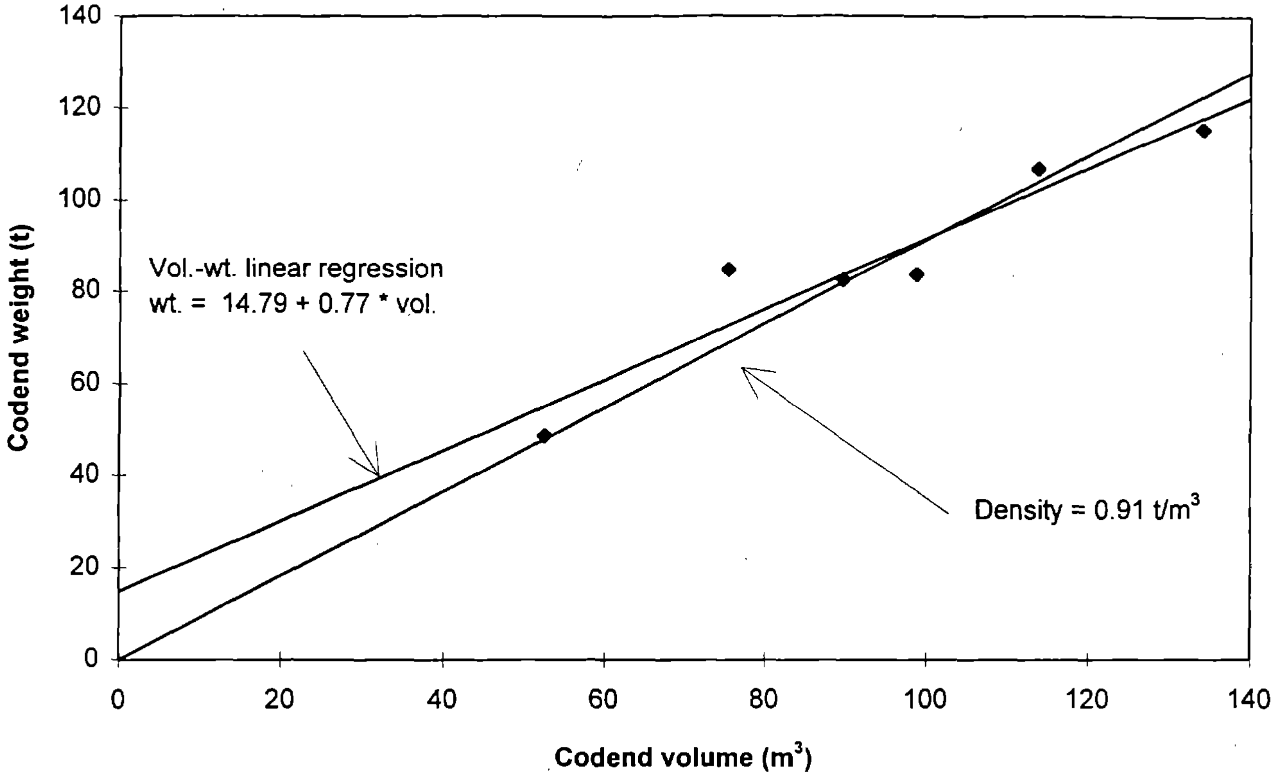

Figure 5. Haul weight (t) (Marel scale weight + discard) versus codend volume (m^3) for sampled whiting hauls during the 1994 October whiting opening on the <u>Alaska Ocean</u>. Two regression lines are shown: 1) a zero y-intercept regression line to estimate a constant density and 2) a linear regression of weight on volume. The y-intercept for the linear regression was not significant (P = 0.30).

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