Northeast Fisheries Science Center Reference Document 12-04

Albatross-Bigelow Survey Data Calibration for American Lobsters

by Larry D. Jacobson and Timothy J. Miller
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US DEPARTMENT OF COMMERCE
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ABSTRACT

The *Research Vessel Henry B. Bigelow* (including a new survey bottom trawl and survey protocols) replaced the *NOAA Research Vessel Albatross IV* during 2009 for use in conducting Northeast Fisheries Science Center (NEFSC) spring and fall bottom trawl surveys. Paired tow calibration studies were carried out using both vessels during 2008. The vessel calibration experiment data and a beta-binomial model were used to estimate length based calibration factors that convert American lobster catches by the Bigelow into equivalent catches by the Albatross. Calibration factors for lobster were estimated so that the Bigelow catch for a particular size and station divided by the calibration factor estimates the equivalent catch by the Albatross. A total of 2,314 lobsters were taken by one or both research vessels at 201 out of 636 experimental stations. The Bigelow caught 64% more (N=1,481) lobsters than the Albatross (N= 833). Lobsters were taken by both vessels at 87 stations lobsters, the Albatross caught lobsters but the Bigelow did not at 36 stations, and the Bigelow caught lobsters but the Albatross did not at 78 stations. The Bigelow consistently caught higher numbers of lobsters < 10 cm carapace length (CL) and higher proportions of total catch for lobsters < 9 cm CL. At least 30 lobsters were taken in each 1 cm size group between 3 and 16 cm CL but sample sizes were lower at smaller and larger sizes. Calibration factors were $\rho = \frac{C_{Bigelow}}{C_{Albatross}} > 5$ for lobsters smaller than about 5.5 cm CL and ranged from about 1.2 to 4.8 for larger lobsters. CVs for calibration coefficients were less than 0.2 for lobsters 5-17 cm CL but increased to 0.48 at the smallest size and to 0.62 at the largest size. Considering the magnitude and variance of the estimates, calibration coefficients for lobsters 5+ cm (the size range currently used in stock assessments) are precise enough for use in providing management advice. A lookup table with calibration factors and CVs for lobsters in Bigelow bottom trawl survey catches is provided.

INTRODUCTION

The Northeast Fisheries Science Center (NEFSC) began using the new *NOAA Research Vessel Henry B. Bigelow* (Bigelow), a new four-seam survey bottom trawl with Patriot doors, and new operational protocols for bottom trawls surveys beginning in the spring of 2009 (NEFSC Vessel Calibration Working Group 2007; Miller et al. 2010). Prior surveys were carried out mainly by the *NOAA Research Vessel Albatross IV* (Albatross) using a standard Yankee No. 36 survey bottom trawl with Polyvalent doors according to original survey protocols.

This analysis uses data from Bigelow-Albatross calibration experiment data to estimate length-based calibration coefficients for American lobster. The calibration coefficients can be used to convert Bigelow catches to Albatross equivalents (or vice-versa) by length. Differences in area and volume swept between the two vessels are ignored (Miller et al. 2010) because the goal is to convert Bigelow catch per tow to equivalent Albatross catch per tow, not to compute densities (numbers caught per area or volume swept). However, the coefficients estimated here will require further modification if Bigelow towing protocols are modified in future so that the area or volume swept per tow is different than in the calibration study. Statistical methods for lobster are slight modifications of methods used previously for finfish. Lobster length is measured as carapace length (cm).

Miller et al. (2010) estimated calibration coefficients for total lobster catch without considering length. However, preliminary analyses showed that calibration factors for lobsters depend on length. Length-based calibration factors are important if size-selectivity patterns and size composition data (expressed as proportions) differ when the two vessels fish at the same time and in the same area. Under these conditions, predictions of total numbers per tow for Bigelow catches expressed as Albatross equivalents will be biased if calibration factors do not account for size.

MATERIALS AND METHODS

Miller et al. (2010) define the calibration coefficient for lobster length L (ρ_L) as the ratio of expected catches by the Bigelow (B_L) and Albatross (A_L) so that $A_L = B_L/\rho_L$ where A_L is equivalent Albatross catch, B_L is observed Bigelow catch and ρ_L is the calibration coefficient. This study uses the same definitions and methodologies.

NEFSC carried out paired tow Bigelow-Albatross calibration experiments (636 stations) during 2008 during June-July and the spring and fall bottom trawl surveys. Both vessels used their own standard gear and protocols. Additional gear performance data (i.e. sensor measurements of net opening, door spread and wing spread) were collected by the Bigelow. Sensor data, differences in net dimensions and tow distance and area swept are not used in calculations for this analysis, however, because the purpose was to derive calibration factors that would convert catches from standard Bigelow tows to catches from standard Albatross tows. Miller et al. (2010) calculate calibration factors for catch weight and mean weights also but these variables are not important for lobster and were ignored in this analysis. Seasonal differences in calibration factors were very small based on preliminary analysis and are ignored here.

Based on simulation analysis for a range of finfish, ratio and beta-binomial models are recommended for estimating calibration factors (Miller et al. 2010). However, the beta-binomial approach is the preferred method for lobsters in this analysis because a ratio estimator is not easy to parameterize as a smooth function of size. Therefore, ratio estimates in one cm length groups are used only to illustrate lobster calibration data in plots.

The ratio estimator for a calibration factor is:

$$\rho_L = \frac{\sum B_L}{\sum A_L}$$

where A_L is total catch by the Albatross, B_L is the total catch of lobsters by the Bigelow, and the summation is over stations (Cochran 1977).

The beta-binomial model was fit by maximum likelihood using the gamlss library in the R statistical programming language (R Core Development Team 2011; Rigby and Stasinopoulos 2005). The model for one lobster taken at a single station by either vessel is:

$$P_L = \frac{e^{\eta_L}}{1 + e^{\eta_L}} + \varepsilon_L$$

where P_L is the probability that the lobster of length L was taken by the Bigelow, $g_L' = e^{\eta_L}/(1 + e^{\eta_L})$ is the inverse of the logit link function $g_L = \log[P_L/(1 - P_L)] = \log(\rho_L)$, the linear predictor is $\eta_L = \alpha + s(L)$, α is an estimated intercept parameter, and *s(L)* is an non-linear function estimated as a cubic spline (McCullagh and Nelder 1983, Wood 2006).

The prediction errors ε_L were assumed to be from a beta-binomial distribution with parameters P_L and σ. The beta-binomial distribution is appropriate if the distribution of individual lobsters caught by the Bigelow at one site is Bernoulli with parameter p_L and the distribution of p_L at different sites is beta with population mean P_L and shape parameter σ. The parameters P_L, σ, α and *s(L)* are estimated in the model. The shape parameter σ can be a constant or vary as a function of size or other covariate, i.e. $\log(\sigma_L) = \alpha + \beta L$.

Calibration factors from the GAM and beta-binomial models were calculated:

$$\rho_L = \frac{P_L}{1 - P_L}$$

Variances for P_L and $\log\left(\frac{P_L}{1-P_L}\right) = \log(\rho_L)$ were calculated by the modeling software. The delta method was used to calculate variances and coefficients of variation (CV) for calibration factors: [1]

$$Var[\rho_L] = \rho^2 Var[\log(\rho_L)]$$

Ninety-five percent confidence intervals for predicted proportions were calculated by back-transforming the 95% bounds for $\log(P_L)$.

RESULTS AND DISCUSSION

There were 201 out of 636 stations where a total of 2,314 lobsters were taken by one or both research vessels. The Bigelow caught 1,481 (64% more) lobsters in total whereas the Albatross caught 833 lobsters. Lobsters were taken by both vessels at 87 stations. The Albatross caught lobsters but the Bigelow did not at 36 stations. The Bigelow caught lobsters but the Albatross did not at 78 stations.

Size composition data show that the Bigelow caught higher numbers of lobsters, mainly at sizes smaller than 10 cm carapace length (CL). Bigelow proportions were higher at all sizes less than 9 cm CL (Figures 1-2). At least 30 lobsters were taken in each 1 cm size group between 3 and 16 cm CL but sample sizes were lower at smaller and larger sizes (Figure 3).

Seasonal differences were not considered in the final beta-binomial model because preliminary analysis showed that they were very small. A likelihood ratio test (p=e^{-7}) and residual analysis showed that the spline term *s(L)* in the linear predictor (with about five

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[1] Another approach gives almost the save variances. If ρ_L is lognormal with log scale variance $s^2_{\eta_L}$, then $CV_{\rho_L} = \sqrt{e^{s^2_{\eta_L}} - 1}$ and $s^2_{\rho_L} = \rho_L CV_{\rho_L}$.

effective parameters to estimate) was superior to the simple linear term βL with only one estimated parameter. Preliminary analysis also showed that a beta-binomial model with σ as a linear function of size may be better in a statistical sense than the model with constant σ (p=0.07 and lower AIC) but the two models gave almost the same predicted values. The simpler model was used to estimate calibration factors because variance was reduced at the cost of little or no bias. All terms in the linear predictor of the final beta-binomial model for lobster calibration data were highly significant ($p \leq 10^{-5}$ for σ and $p \leq 10^{-19}$ for other parameters.

For convenience in use elsewhere, a lookup table was calculated by fitting the ancillary GAM models ρ~s(L) and cv~s(L) to estimates from the final beta-binomial model (R^2=100%). The fitted models were used to predict calibration factors and CVs for lobsters between 2.9 and 26 cm CW in steps of 0.1 cm for inclusion in the table (Table 1). The lookup table can be used in future for lobster calibration work without invoking the original models, etc.

Considering the magnitude and variance of the estimates, calibration coefficients for lobsters 5+ cm (the size range currently used in stock assessments, ASMFC 2009) appear useful for providing management advice. Calibration factors were large (ρ>5) for lobsters smaller than about 5.4 cm and ranged from 1.184 to 4.8 at larger sizes (Table 1 and Figure 4). CVs were less than 0.2 for lobsters between 5 and 17 cm CL but increased to 0.62 at the largest size and to 0.48 at the smallest size (Table 1 and Figure 5).

Calibrated fall survey data for 2009-2010 (Figures 6-7) show how survey data, particularly for small lobsters, collected by the Bigelow are adjusted downward when converted to Albatross equivalents.

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Table 1. Size-based calibration coefficients and CVs from the final beta-binomial model for American lobsters.

CL (cm)	ρ	CV	CL (cm)	ρ	CV	CL (cm)	ρ	CV	CL (cm)	ρ	CV	CL (cm)	ρ	CV	CL (cm)	ρ	CV
2.6	17.272	0.48	6.1	3.784	0.13	9.6	1.450	0.07	13.1	1.185	0.08	16.6	1.237	0.18	20.1	1.564	0.52
2.7	16.735	0.47	6.2	3.640	0.12	9.7	1.443	0.07	13.2	1.186	0.08	16.7	1.247	0.18	20.2	1.562	0.53
2.8	16.198	0.45	6.3	3.504	0.12	9.8	1.436	0.07	13.3	1.188	0.09	16.8	1.259	0.19	20.3	1.559	0.54
2.9	15.661	0.44	6.4	3.376	0.12	9.9	1.431	0.07	13.4	1.191	0.09	16.9	1.271	0.19	20.4	1.556	0.56
3	15.127	0.43	6.5	3.255	0.11	10	1.426	0.07	13.5	1.195	0.09	17	1.285	0.20	20.5	1.552	0.57
3.1	14.594	0.41	6.6	3.141	0.11	10.1	1.422	0.07	13.6	1.198	0.09	17.1	1.299	0.20	20.6	1.548	0.58
3.2	14.065	0.40	6.7	3.032	0.11	10.2	1.418	0.07	13.7	1.202	0.09	17.2	1.314	0.21	20.7	1.544	0.60
3.3	13.539	0.38	6.8	2.928	0.11	10.3	1.413	0.07	13.8	1.206	0.09	17.3	1.329	0.22	20.8	1.540	0.61
3.4	13.018	0.37	6.9	2.828	0.10	10.4	1.409	0.07	13.9	1.210	0.10	17.4	1.345	0.23	20.9	1.536	0.62
3.5	12.502	0.36	7	2.733	0.10	10.5	1.403	0.07	14	1.213	0.10	17.5	1.360	0.23			
3.6	11.994	0.34	7.1	2.641	0.10	10.6	1.397	0.07	14.1	1.216	0.10	17.6	1.376	0.24			
3.7	11.493	0.33	7.2	2.553	0.10	10.7	1.390	0.07	14.2	1.218	0.10	17.7	1.391	0.25			
3.8	11.002	0.32	7.3	2.468	0.10	10.8	1.383	0.07	14.3	1.220	0.10	17.8	1.407	0.26			
3.9	10.521	0.30	7.4	2.386	0.09	10.9	1.374	0.07	14.4	1.221	0.11	17.9	1.422	0.27			
4	10.051	0.29	7.5	2.308	0.09	11	1.364	0.07	14.5	1.222	0.11	18	1.436	0.28			
4.1	9.594	0.28	7.6	2.233	0.09	11.1	1.354	0.07	14.6	1.221	0.11	18.1	1.450	0.28			
4.2	9.151	0.27	7.7	2.160	0.09	11.2	1.343	0.07	14.7	1.220	0.11	18.2	1.463	0.29			
4.3	8.722	0.26	7.8	2.091	0.09	11.3	1.331	0.07	14.8	1.219	0.12	18.3	1.476	0.30			
4.4	8.309	0.25	7.9	2.026	0.09	11.4	1.319	0.07	14.9	1.217	0.12	18.4	1.487	0.31			
4.5	7.911	0.24	8	1.963	0.09	11.5	1.306	0.07	15	1.214	0.12	18.5	1.499	0.32			
4.6	7.530	0.23	8.1	1.905	0.08	11.6	1.293	0.07	15.1	1.212	0.12	18.6	1.509	0.34			
4.7	7.167	0.22	8.2	1.849	0.08	11.7	1.280	0.07	15.2	1.209	0.13	18.7	1.519	0.35			
4.8	6.821	0.21	8.3	1.798	0.08	11.8	1.267	0.07	15.3	1.206	0.13	18.8	1.528	0.36			
4.9	6.492	0.20	8.4	1.750	0.08	11.9	1.255	0.07	15.4	1.203	0.13	18.9	1.536	0.37			
5	6.181	0.19	8.5	1.706	0.08	12	1.243	0.07	15.5	1.201	0.13	19	1.543	0.38			
5.1	5.887	0.18	8.6	1.666	0.08	12.1	1.232	0.07	15.6	1.199	0.14	19.1	1.549	0.39			
5.2	5.611	0.17	8.7	1.629	0.08	12.2	1.222	0.07	15.7	1.198	0.14	19.2	1.555	0.40			
5.3	5.351	0.17	8.8	1.597	0.08	12.3	1.213	0.08	15.8	1.198	0.14	19.3	1.559	0.42			
5.4	5.107	0.16	8.9	1.568	0.08	12.4	1.205	0.08	15.9	1.199	0.15	19.4	1.563	0.43			
5.5	4.878	0.16	9	1.542	0.07	12.5	1.199	0.08	16	1.200	0.15	19.5	1.565	0.44			
5.6	4.664	0.15	9.1	1.520	0.07	12.6	1.193	0.08	16.1	1.203	0.15	19.6	1.567	0.45			
5.7	4.464	0.14	9.2	1.501	0.07	12.7	1.189	0.08	16.2	1.207	0.16	19.7	1.568	0.47			
5.8	4.276	0.14	9.3	1.485	0.07	12.8	1.186	0.08	16.3	1.213	0.16	19.8	1.568	0.48			
5.9	4.101	0.13	9.4	1.471	0.07	12.9	1.185	0.08	16.4	1.219	0.17	19.9	1.567	0.49			
6	3.938	0.13	9.5	1.460	0.07	13	1.184	0.08	16.5	1.227	0.17	20	1.566	0.50			

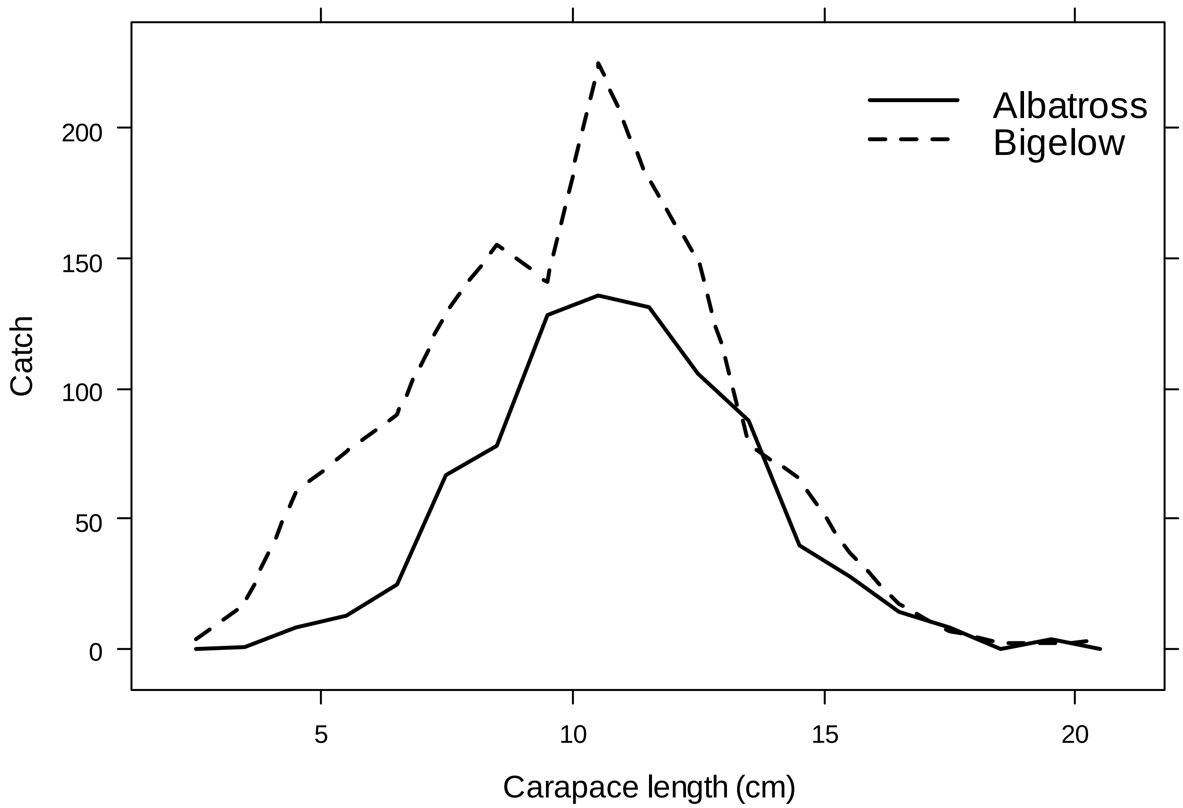

Figure 1. Mean catch in numbers per tow at size (1 cm size groups, seasons combined) for lobsters in NEFSC calibration experiments.

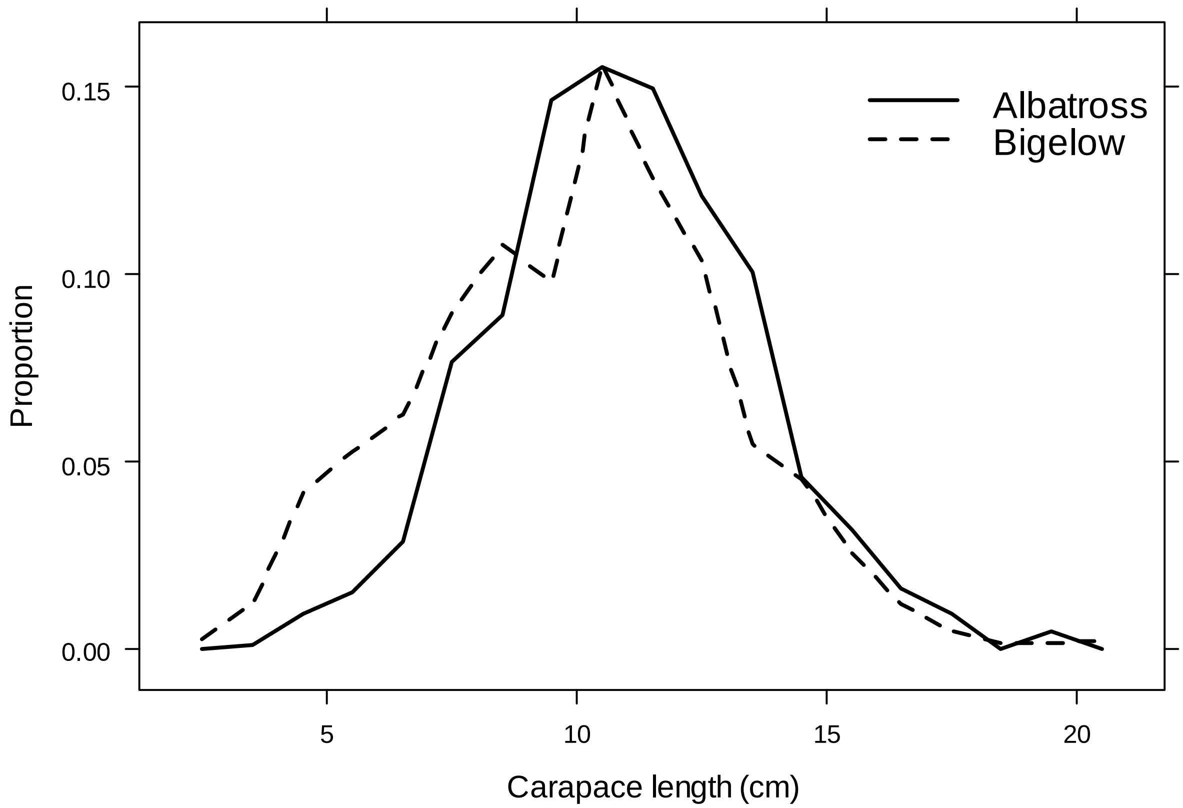

Figure 2. Proportions of total catch at size (1 cm size groups, seasons combined) for lobsters in NEFSC calibration experiments.

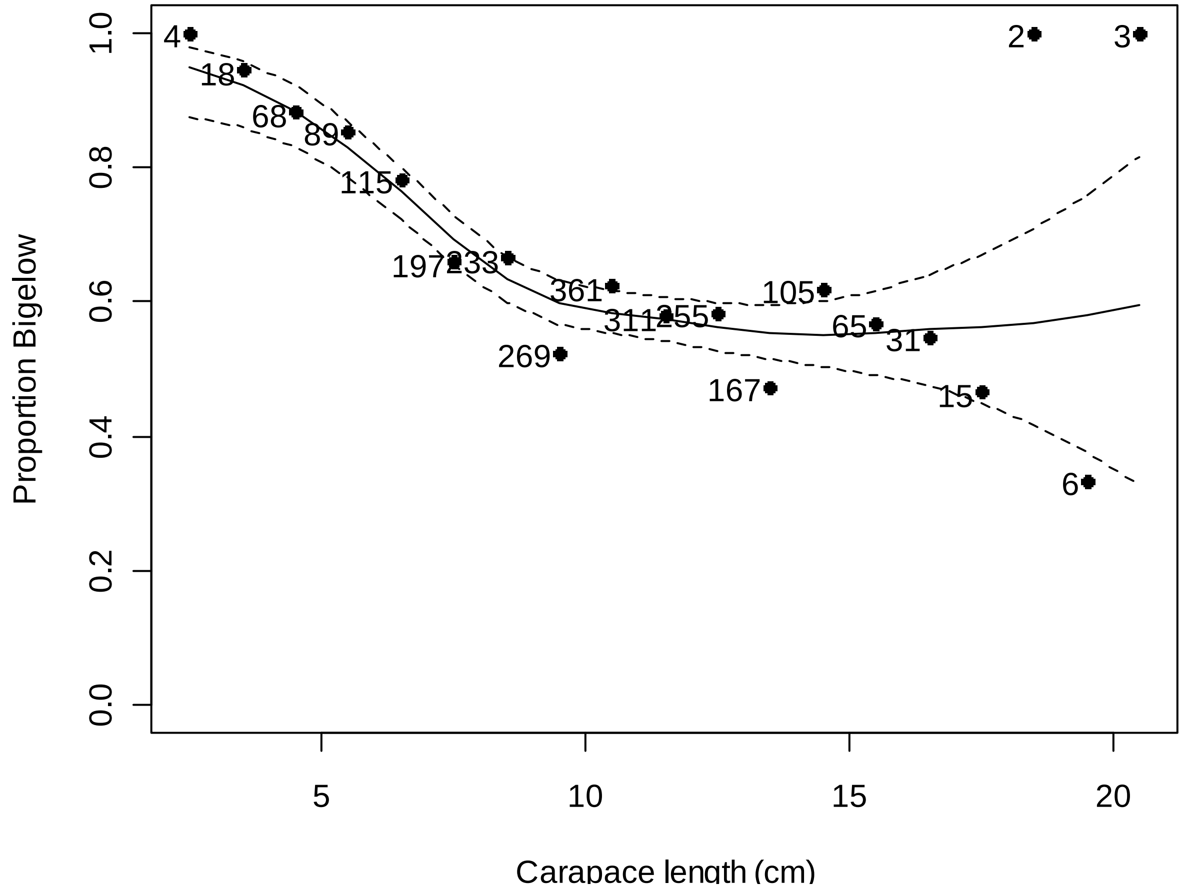

Figure 3. Final beta-binomial model fit to lobster calibration data. The smooth line is the fitted relationship and the dashed lines bracket a 95% confidence interval. Symbols show proportions of total catch by the Bigelow in 1 cm size groups. Numbers are the total number of lobsters in each size group. For example, there were a total of 68 lobsters at 4-5 cm CL in catches by both vessels.

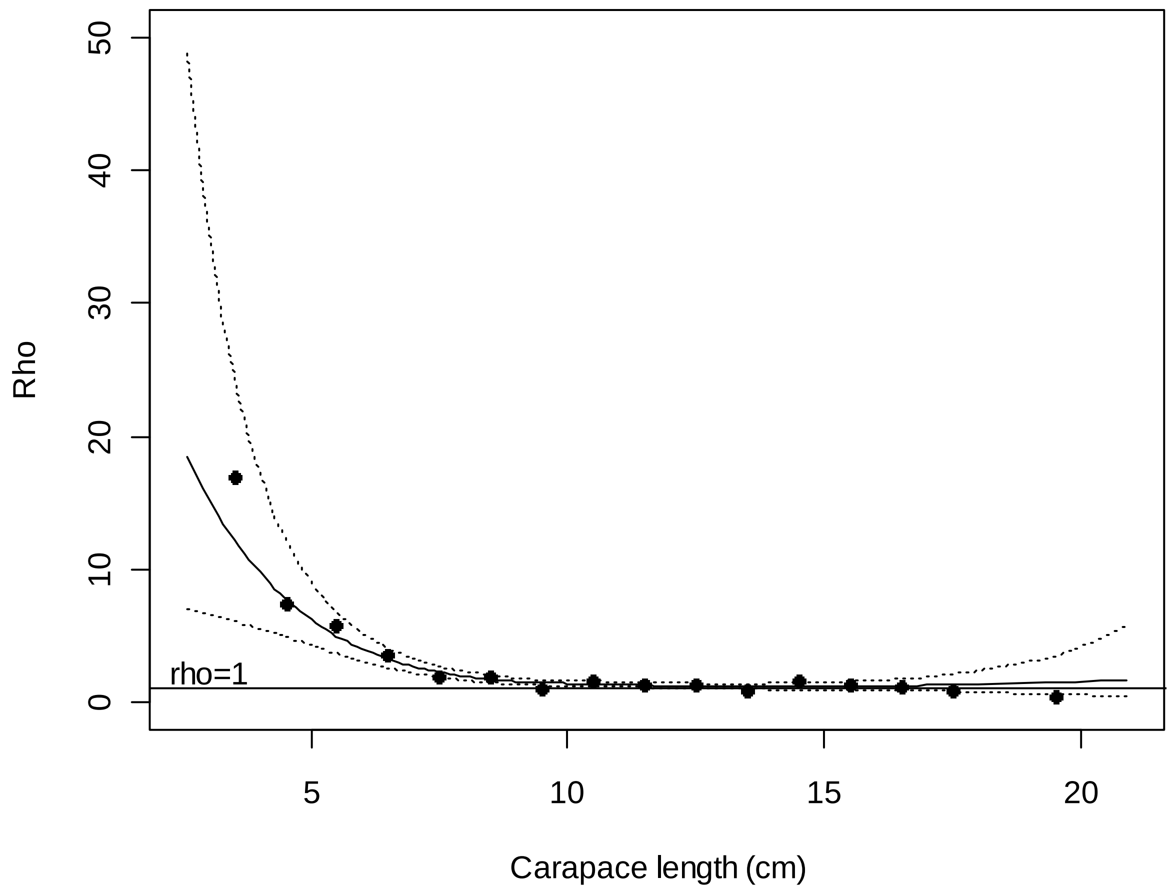

Figure 4. Calibration factors (ρ_L) from the final beta-binomial fit to lobster calibration data. The symbols show the ratio estimates $\frac{\sum B_L}{\sum A_L}$ that summarize data for each 1 cm size group. The dashed lines bracket a 95% confidence interval for beta-binomial estimates. The horizontal line at ρ=1 shows the calibration coefficient ρ_L=1 where Albatross and Bigelow proportions would both be 50%.

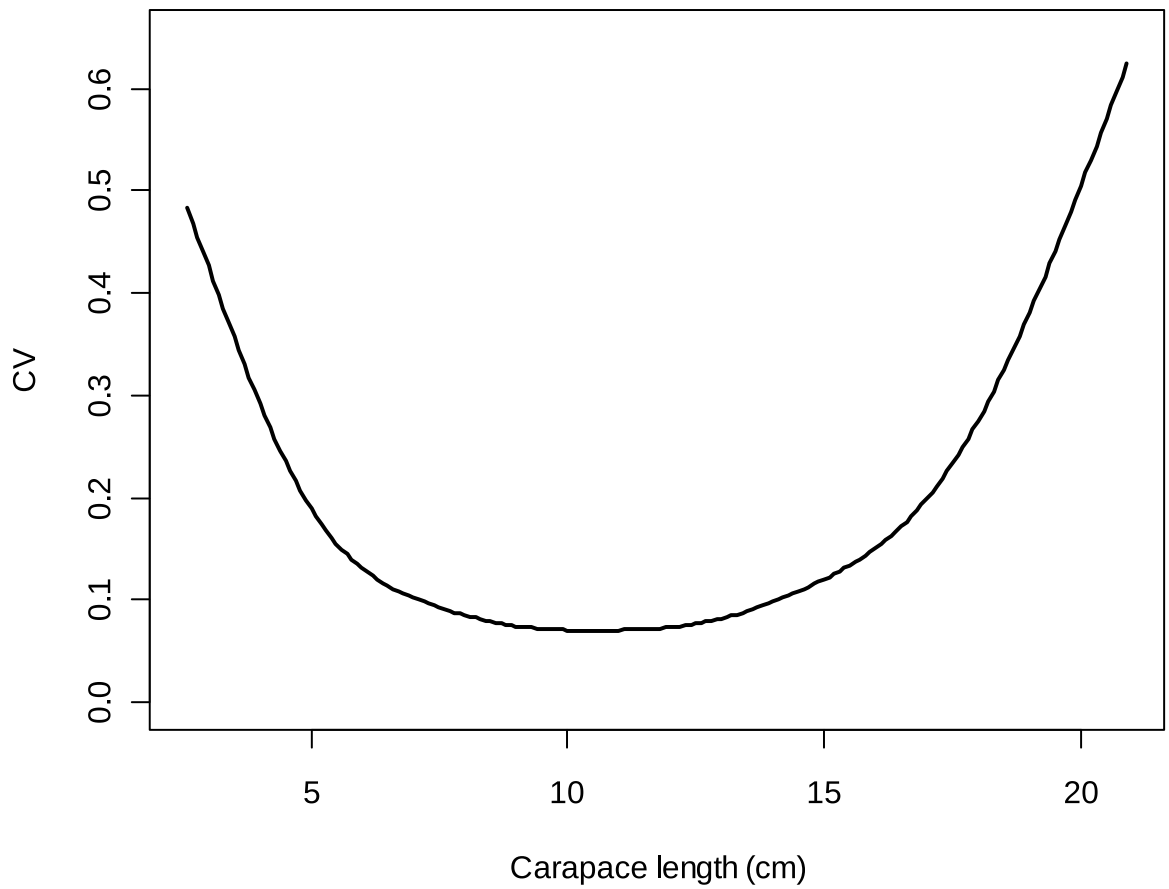

Figure 5. CVs for lobster calibration coefficients from the beta-binomial model.

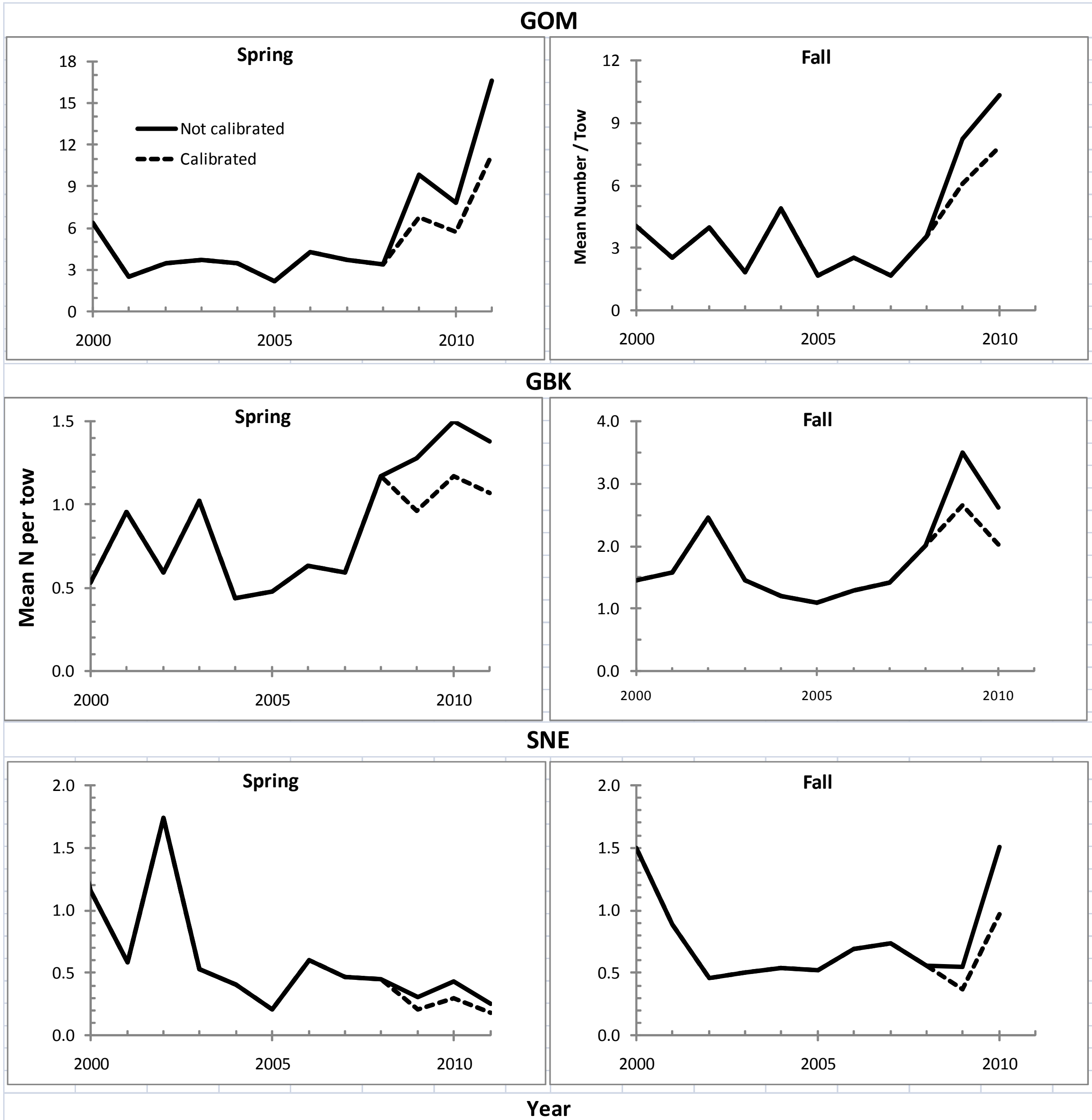

Figure 6. Trends in mean number of lobsters per tow (50+ mm CL) during 2000-2010 (fall) or 2000-2011 (spring) surveys with and without calibrating data collected by the *NOAA Research Vessel Bigelow II,* beginning in 2009.

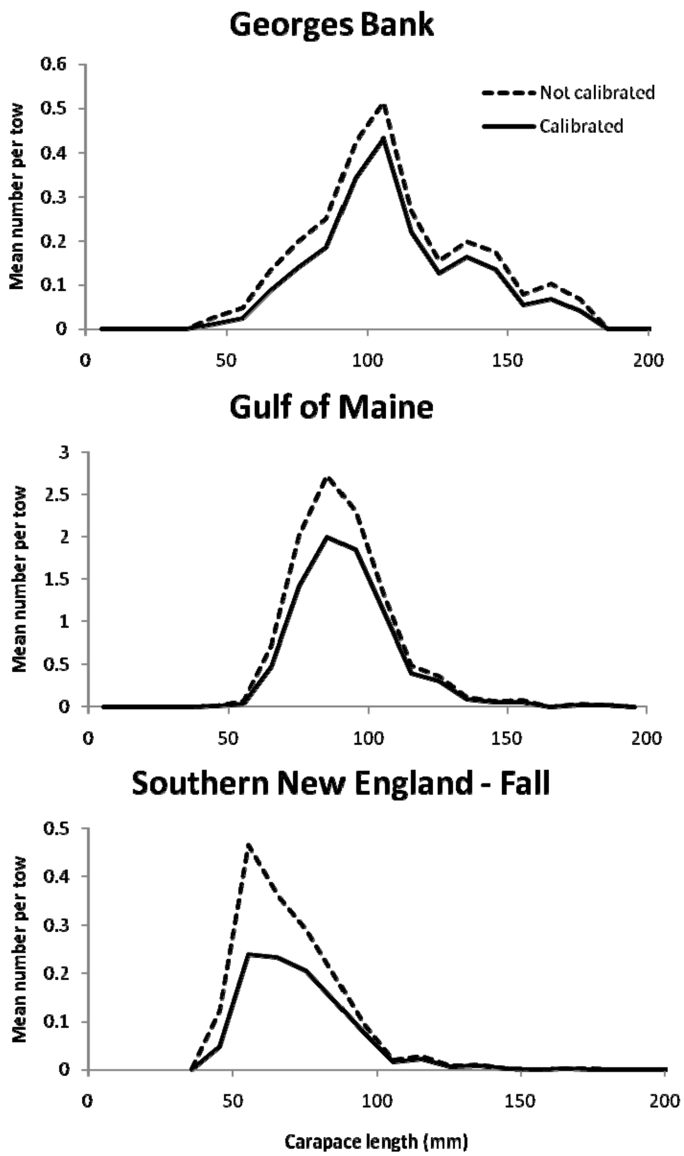

Figure 7. Size composition data for lobsters in the 2010 NEFSC fall survey. The dash line shows uncalibrated Bigelow data and the solid line is calibrated Bigelow data.

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