Skate Length-based Calibration Report

by

Skate Plan Development Team

March 16, 2011

Introduction

In 2009, the *NOAA SHIP Henry B. Bigelow* replaced the *R/V Albatross IV* as the primary vessel for conducting spring and fall annual bottom trawl surveys for the Northeast Fisheries Science Center (NEFSC). There are many differences in the vessel operation, gear, and towing procedures between the new and old research platforms (NEFSC Vessel Calibration Working Group 2007). To merge survey information collected in 2009 onward with that collected previously, we need to be able to transform indices (perhaps at size and age) of abundance from the *Henry B. Bigelow* into those that would have been observed had the *Albatross IV* still been in service. The general method for merging information from these two time series is to calibrate the new information to that of the old (e.g., Pelletier 1998, Lewy et al. 2004, Cadigan and Dowden 2010). Specifically we need to predict the relative abundance that would have been observed by the *Albatross IV* ($\hat{R}_A$) using the relative abundance from the *Henry B. Bigelow* (R_B) and a "calibration factor" (ρ),

$$\hat{R}_A = \rho R_B . \tag{1}$$

To provide information from which to estimate calibration factors for a broad range of species, 636 paired tows were conducted with the two vessels during 2008. Paired tows occurred at many stations in both the spring and fall surveys. Paired tows were also conducted during the summer and fall at non-random stations to augment the number of non-zero observations for some species. Protocols for the paired tows are described in NEFSC Vessel Calibration Working Group (2007).

The methodology for estimating the calibration factors was proposed by the NEFSC and reviewed by a panel of independent scientists in 2009. The reviewers considered calibration factors that could potentially be specific to either the spring or fall survey (Miller et al. 2010). They recommended using a calibration factor estimator based on a beta-binomial model for the data collected at each station for most species, but also recommended using a ratio-type estimator under certain circumstances and not attempting to estimate calibration factors for species that were not well sampled.

Since the review, it has become apparent that accounting for size of individuals can be necessary for many species. When there are different selectivity patterns for the two vessels, the ratio of the fractions of available fish taken by the two gears varies with size. Under these circumstances, the estimated calibration factor that ignores size reflects an average ratio weighted across sizes where the weights of each size class are at least in part related to the number of individuals at that size available to the two gears and the number of stations where individuals at that size were caught. Applying calibration factors that ignore size effects to surveys conducted in subsequent years when the size composition is unchanged should not produce biased predictions (eq. 1). However, when the size composition changes, the frequency of individuals and number of stations where individuals are observed at each size changes and the implicit weighting across size classes used to obtain the estimated calibration factor will not apply to the new data. Consequently, the predictions from the constant calibration factor of the numbers per tow that would have been caught by the *Albatross IV* will be biased.

Length-based calibration has been performed for groundfish (cod, haddock, and yellowtail flounder through TRAC and silver, offshore, and red hakes during SARC 51) and invertebrate species (loligo during SARC 51) (Brooks et al. 2010, NEFSC 2011). For those length-based calibrations, the same basic beta-binomial model from Miller et al. (2010) was assumed, but various functional forms were assumed for the relationship of length to the calibration factor. Since then, Miller (submitted) has explored two types of smoothers for this relationship and that of length to the beta-binomial dispersion parameter. These smoothers (orthogonal polynomials and thin-plate regression splines) allow much more flexibility than the functional forms previously considered for other species by Brooks et al. (2010) and NEFSC (2011).

Methods

Because the skate complex is managed as a whole and few positive observations for some skate species during the calibration experiment, numbers captured of all seven species were aggregated by vessel, station, and 1 cm length class for these analyses. Upon inspection of data and preliminary model fits, we determined that predicted relative catch efficiency at the largest size classes was both highly uncertain and sensitive to changes in proportions captured by each vessel between length classes despite few observations. As such, we decided to pool observations at length classes greater than 94 cm as 107 cm which is the average length of fish observed in these length classes.

We considered the same classes of smoothers as Miller (submitted). However, we also considered effects of season (spring or fall survey or non-survey stations) region(north or south, Table 1). We also were interested in determining whether there were further differences by depth strata (shallow and deep depth categories in Table 2), but there was insufficient information for some subsets to fit corresponding models. We first determined the best smoother to use for the relationship of length to relative catch efficiency and the dispersion parameter. Then we assessed whether models where these relationships differed by season and region were necessary. We evaluated relative goodness of fit of all models using Akaike Information Criteria corrected for small sample size bias (AIC_c; Hurvich and Tsai 1989).

All models were fitted in the R statistical programming environment (R Development Core Team 2010). For models where orthogonal polynomials and thin-plate regression splines were assumed, we used the gamlsss, gamlss.add and mgcv packages (Rigby and Stasinopoulos 2005, Stasinopoulos and Rigby 2007). For models where the orthogonal polynomials are assumed and the form of the dispersion parameter is based on the assumption that the mean catches by both vessels arise from a gamma distribution, programmed likelihoods were maximized using the optim function provided in R.

Ultimately, we calibrated mean numbers-at-length per tow for spring and fall bottom trawl surveys conducted in 2009 and 2010 and multiplied estimated mean weights-at-length from fitted length-weight models to obtain mean biomass per tow in Albatross IV units,

$$\hat{B}_A = \sum_{l=1}^{L} \frac{N_{B,l}}{\hat{\rho}(L_l)} \overline{w}(L_l). \tag{2}$$

Stuff about length-weight relationship estimation.

Results and Discussion

The models where the form of the beta-binomial dispersion parameter is based on a gamma assumption on the mean catches made by each vessel performed very poorly compared to other models and are not considered further. Among the other classes of beta-binomial models we considered, the model that assumed a thin-plate regression spline smoother for both the relative catch efficiency and dispersion parameter performed marginally better than the (Table 3). Further allowing the smoother of length to differ by season and region provided the best overall fit with regard to AIC$_C$.

Important to note, that when the data are broken down into small subsets for prediction (e.g., by region and season), the limits of the range of sizes available in the subsets can be narrower than the range of the entire data set. As such, the ability to predict lengths at the ends of the range will be compromised.

References

Brooks, E. N., Miller, T. J., Legault, C. M., O'Brien, L., Clark, K. J., Gavaris, S., and Van Eekhaute, L. 2010. Determining length-based calibration factors for cod, haddock, and yellowtail flounder. TRAC Ref. Doc. 2010/08.

Cadigan, N. G. and Dowden, J. J. 2010. Statistical inference about relative efficiency from paired-tow survey calibration data. Fish. Bull. 108: 15-29.

Hurvich, C. M. and Tsai, C.-L. 1989. Regression and time series model selection in small samples. Biometrika 76: 297-307.

Lewy, P., Nielsen, J. R., and Hovgård, H. 2004. Survey gear calibration independent of spatial fish distribution. Can. J. Fish. Aquat. Sci. 61: 636-647.

Miller, T. J. Submitted. A hierarchical model for relative catch efficiency from gear selectivity and calibration studies.

Miller, T. J., Das, C., Miller, A. S., Lucey, S. M., Legault, C. M., Brown, R. W., and Rago, P. J. 2010. Estimation of *Albatross IV* to *Henry B. Bigelow* calibration factors. NEFSC Ref. Doc. 10-05.

NEFSC. 2011. 51st Northeast regional stock assessment workshop (51st SAW) assessment report. NEFSC Ref. Doc. 11-01.

NEFSC Vessel Calibration Working Group. 2007. Proposed vessel calibration for NOAA Ship *Henry B. Bigelow*. NEFSC Ref. Doc. 07-12. 26p.

Pelletier, D. 1998. Intercalibration of research survey vessels in fisheries: a review and an application. Can. J. Fish. Aquat. Sci. 55: 2672-2690.

R Development Core Team. 2010. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria, ISBN 3-900051-07-0.

Rigby, R. A. and Stasinopoulos, D. M. 2005. Generalized additive models for location, scale, and shape (with discussion). Applied Statistics 54: 507-554.

Stasinopoulos, D. M. and Rigby, R. A. 2007. Generalized additive models for location, scale and shape (GAMLSS) in R. Journal of Statistical Software 23: 1-46.

Table 1. NEFSC survey strata in north and south regions used in length-based calibration analyses.

North	South
01190-01300	01010-01180
01330-01400	01610-01760
01351	03010-03460
03560	07510-07520
03590-03610	08500-08510
03640-03660	

Table 2. NEFSC survey strata in shallow and deep depth areas we were to consider in length-based calibration analyses.

Shallow	Deep
01010-01020	01030-01040
01050-01060	01070-01080
01090-01100	01110-01120
01130	01140-01150
01160	01170-01180
01190-01210	01220
01230	01240
01250-01260	01270-01300
01330	01340
01390-01400	01351
01610-01620	01360-01380
01650-01660	01630-01640
01690-17000	01670-01680
01730-01740	01710-01720
07510-07520	01750-01760
08500	08510

Table 3. Model type (thin-plate regression spline, SP, orthogonal polynomial, OP), numbers relative catch efficiency, dispersion, and total degrees of freedom, dispersion covariates, and log-likelihood for best performing models based on AIC_C.

Rank	Model Type	# ρ df	# ϕ length parameters	ϕ Covariates	# Total parameters	-LL	AIC_C	$\Delta(AIC_C)$
1	SP(Season,Region)	37.02	5	SF	46.02	-7359.32	14811.18	0.00
2	SP(Season)	15.56	4	SF	23.56	-7423.64	14894.53	83.36
3	SP	6.80	1	SF	8.80	-7522.98	15063.58	252.40
4	OP	9	1	SF	11	-7520.85	15063.73	252.55
5	OP	10	1	SF	12	-7520.35	15064.74	253.57
6	OP	9	2	SF	12	-7520.49	15065.01	253.83
7	SP	6.54	10.24	SF	16.78	-7515.75	15065.14	253.96
8	SP	6.81	1	SF, SA	9.81	-7522.88	15065.42	254.24
9	OP	9	1	SF, SA	12	-7520.76	15065.56	254.38
10	OP	10	2	SF	13	-7520.00	15066.04	254.87
11	OP	9	7	SF	17	-7516.00	15066.07	254.90
12	OP	11	1	SF	13	-7520.24	15066.51	255.34

Figure 1. Randomized quantile residuals of the best performing model (as measured by AICc, see Table 1) for Acadian redfish in relation to the predicted number captured by the *Henry B. Bigelow* (left), the total number of fish captured at a station (middle), and their normal quantiles (right).

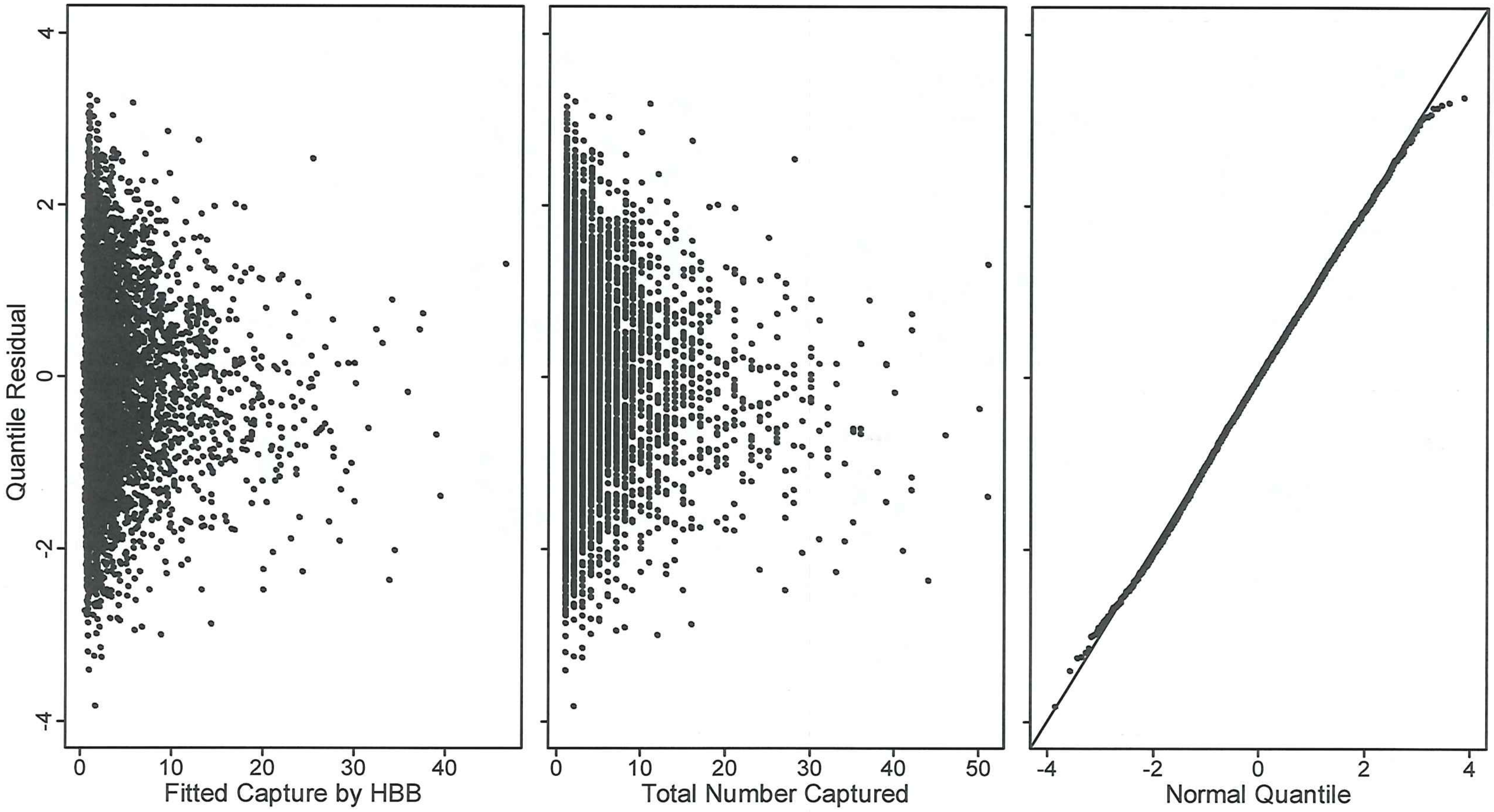
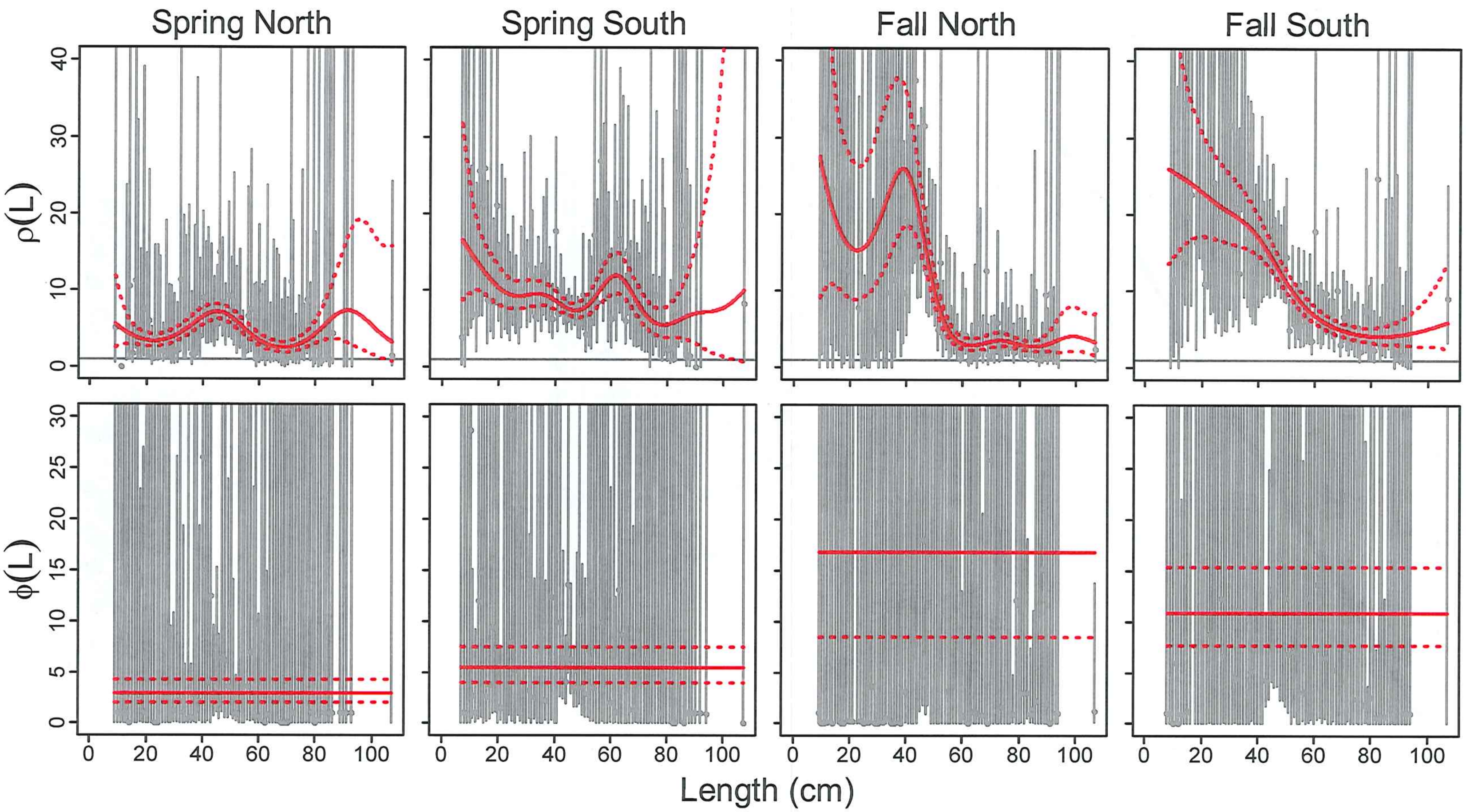


Figure 2. Estimated relative catch efficiency (top) and dispersion parameter (bottom) by season and region (columns) from the best beta-binomial model where relative catch efficiency is modeled as a a penalized thin-plate regression spline smoother of length (solid red line) and from separate models fit to data in each length class (gray points). Dotted red lines and vertical gray lines represent approximate 95% confidence intervals. Horizontal gray line in top plots represents equal efficiency of the *Henry B. Bigelow* and *Albatross IV*.



Appendix

The constant model that ignores length is

$$\rho\left(l\right)=e^{\gamma}$$

and the logistic model is

$$\rho\left(l\right)=e^{\gamma}+\frac{e^{\alpha}}{1+e^{-(\beta_0+\beta_1 l)}}$$

which allows the lowest calibration factors to asymptote at a value greater than zero and the difference between the lowest and greatest values to be different than 1.

The double-logistic model is

$$\rho\left(l\right)=e^{\alpha}\left(e^{\gamma_1}+\frac{1-e^{\gamma_1}}{1+e^{-(\beta_0+e^{\beta_1}l)}}\right)\left(e^{\gamma_2}+\frac{1-e^{\gamma_2}}{1+e^{(\beta_2+e^{\beta_3}l)}}\right)$$

which allows the lowest calibration factors to asymptote at a value greater than zero at both small and large size classes and the difference between the lowest and greatest values to be greater than 1. In all models, the exponentiation of various parameters avoids boundary conditions during estimation. The parameters may differ for data obtained at spring or fall survey stations or the site-specific stations.

Letting the full set of calibration factor parameters be θ (which depends on the above models used), the beta-binomial likelihood we maximized is

$$L\left(\theta,\phi\right)=\prod_{i=1}^{S}\prod_{j=1}^{M}\frac{\mathrm{Beta}\left(a_j+N_{Bij},b_j+N_{Aij}\right)}{\mathrm{Beta}\left(a_j,b_j\right)}\binom{N_{Aij}+N_{Bij}}{N_{Bij}}$$

where $\mathrm{Beta}()$ is the beta function, and N_{Aij} and N_{Bij} are the numbers caught at station i in length class j by the Albatross IV and Bigelow, respectively. The likelihood is parameterized with parameters a and b which are functions of the calibration factor and dispersion parameter ϕ,

$$a_j=\rho\left(l_j\,|\,\theta\right)\phi$$

and

$$b_j=\phi/(1+\rho(l_j\,|\,\theta)).$$