SCRS/2006/081:
Large Pelagics Survey Bluefin Tuna Length Validation Assessment

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Background

The Large Pelagics Intercept Survey (LPIS) collects length data on recreationally landed Atlantic bluefin tuna (ABT). The LPIS Procedures Manual (prior to 2005) specified that interviewers should measure and record the straight fork length (SFL) of ABTs, not the curved fork length (CFL) that is used to define size classes for management purposes. Recently, some members of the recreational and commercial fishing industry have questioned whether or not this procedure has been consistently followed in the field. Some individuals have reported seeing LPIS interviewers measuring CFLs of landed bluefin tuna. Therefore, they have raised a concern that the interviewers may actually have been recording CFLs rather than SFLs. The curved fork length of a given fish is greater than its straight fork length by some small factor (typically between 1-5%). If such errors have occurred, then LPIS estimates of landed weight of bluefin tuna by size category would most likely be positively biased since length data are converted to weights for landings estimates.

This evaluation was conducted to: 1) determine the extent to which CFLs were mistakenly recorded, and the extent to which such errors may have biased the overall ABT landed weight estimate, and 2) investigate the effects that biased measurements could potentially have had on prior stock assessments. The approach taken for the first part was to compare LPIS length measurements with measurements from other data sources for individual fish for which the length was recorded also. Two additional sources of ABT length data – the Maryland ABT Catch Card Program and the NMFS Automated Landings Report System (ALRS) were examined. For both the Maryland Catch Card Program and the ALRS, anglers are asked to report the size of landed ABT as CFLs. The approach taken for the second part of this evaluation was to simulate a scenario in which all LPIS length measurements since 1993 were assumed to be erroneously recorded CFLs rather than SFLs.

LPIS and Maryland Catch Card Comparison

Data from 2002-2004 were used to compare catch card length measurements with LPIS measurements. The first step was to visually match records representing individual fish, between the LPIS and Maryland catch card datasets. Common variables used to determine if records matched were date landed, HMS permit number, and vessel name. It was determined that a total of 373 ABT measured in the LPIS were also reported on Maryland catch cards for the years 2002-2004 (Table 1). LPIS lengths, which are recorded in millimeters, were converted to inches to match catch card lengths. The plot of LPIS recorded lengths versus Maryland catch card reported lengths is shown below (Figure 1) for the three years combined.

Table 1. Number of ABT reported through the Maryland catch card program, the number of ABT measured by the Large Pelagic Intercept Survey (in Maryland), and matches between the two datasets, 2002-04.

Year	MD Catch Cards	LPIS Measured	Number Matched	Percent Matched
2002	2327	175	131	74.9
2003	2244	227	163	71.8
2004	3548	84	79	94.1
All	8119	486	373	76.7

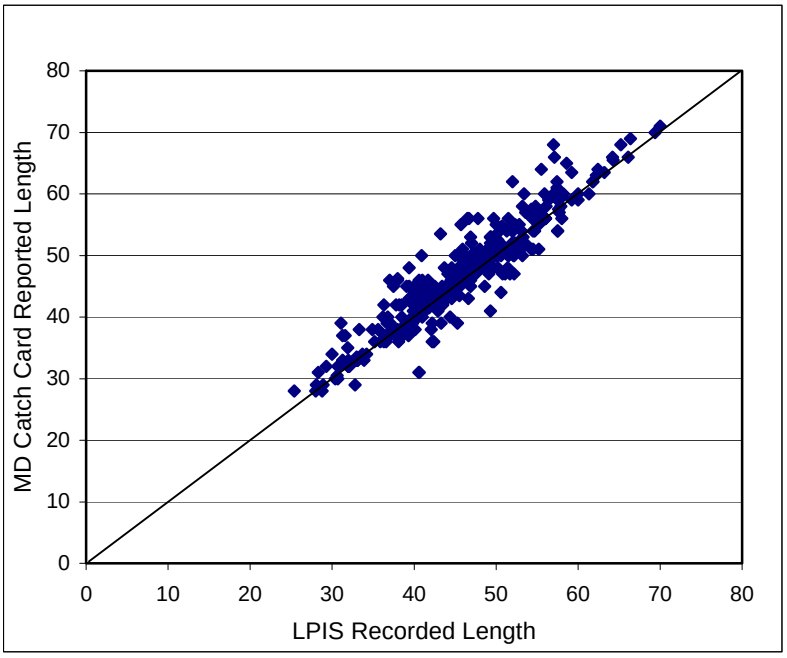

Figure 1. Plot of LPIS recorded lengths (in inches) versus reported Maryland catch card lengths, 2002-04.

The straight line represents a slope of 1 going through the origin. If both lengths were measured and recorded as required for each program, it would be expected that 1) most of the data points would fall above the line since straight fork lengths (LPIS) are smaller than CFLs (MD catch cards), and 2) the absolute difference between straight and curved length measurements (taken on the same fish) should increase with fish size (i.e., as the girth of the fish increases). Based on the above graph it is clear that for many individual fish the relationship between LPIS and catch card length measurements does not exactly match the expected relationship between straight and curved length measurements. Plotting these pairs by individual years also suggests there are differences between years in terms of length validation results. In particular, a greater proportion of data points are on or below the line in 2003 compared to 2002 or 2004 (Figures 2, 3 and 4).

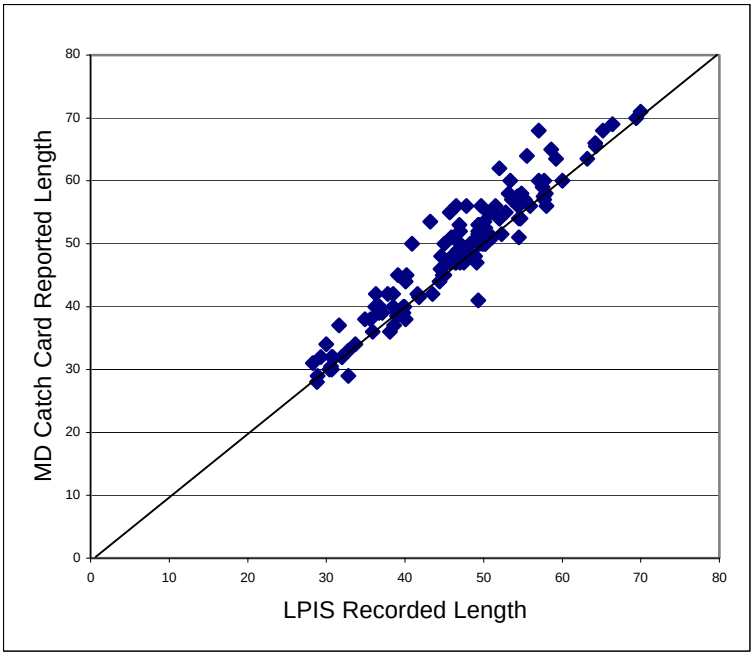

Figure 2. Plot of LPIS recorded lengths (in inches) versus reported Maryland catch card lengths, 2002.

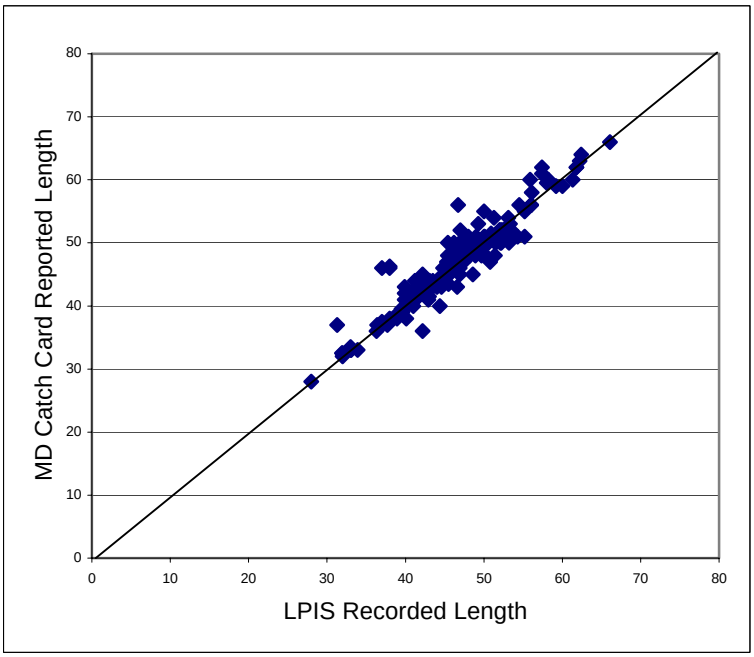

Figure 3. Plot of LPIS recorded lengths (in inches) versus reported Maryland catch card lengths, 2003.

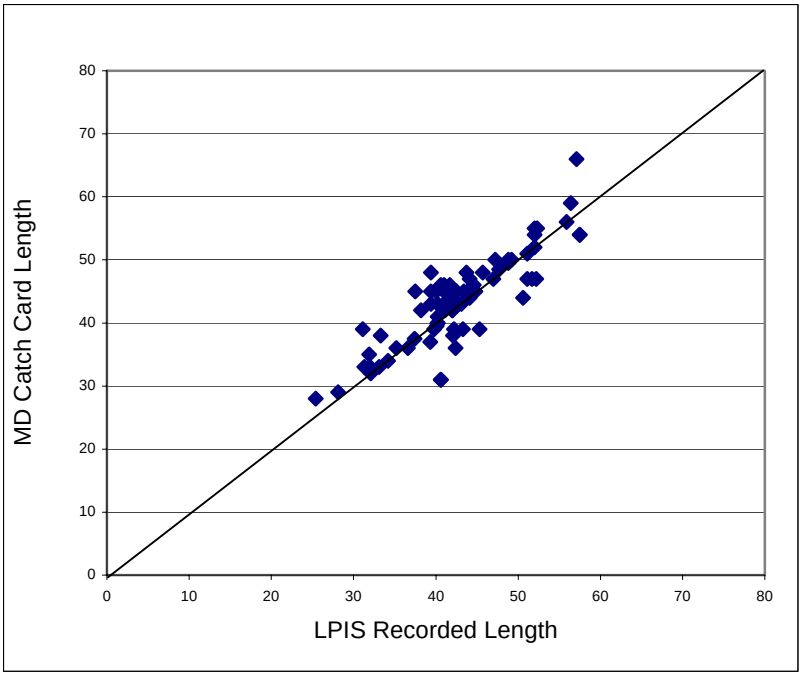

Figure 4. Plot of LPIS recorded lengths (in inches) versus reported Maryland catch card lengths, 2004.

A paired comparisons analysis was conducted to measure the mean difference in lengths recorded by LPIS interviewers and HMS anglers on Maryland catch cards for the same fish. Paired comparisons t-tests were run to determine if the mean difference (measured in inches as catch card length minus LPIS length) was significantly different from zero (Table 2).

Table 2. Pairwise comparison t-tests of the mean difference between Maryland catch card (curved fork) lengths and LPIS (straight fork) lengths (note: difference = catch card length – LPIS length)

Year	N	Mean Difference (inches)	Std. Error	t value	Prob. > | t |
2002	131	1.9137	0.259	7.39	<0.0001
2003	163	0.394	0.174	2.26	0.0251
2004	79	0.776	0.407	1.91	0.0604
All years combined	373	1.009	0.150	6.70	<0.0001

With all years combined, the mean difference (catch card length minus LPIS length) was about one inch. Mean difference varied greatly by year suggesting that the length measurement error rate (either as reported on catch cards or recorded by LPIS interviewers) was also variable from year to year during 2002-2004. Analysis of variance (ANOVA) confirmed significant differences in the mean difference between 2002 and 2003-2004 (2003 and 2004 were not significantly different at alpha = 0.05).

The mean difference (catch card length minus LPIS length) was positive and significantly different from zero for all years combined and for 2002 and 2003 individually (at the 0.05 significance level). For 2004 this mean difference was not significantly different from zero at the 0.05 level but was significant at the 0.10 level (p=0.06). While these pairwise t-tests indicate that the mean catch card lengths are significantly greater than the mean LPIS lengths (as would be expected), they provide no indication of how the magnitude of this difference compares to expected mean differences based on the true, unbiased relationship between ABT curved and straight fork lengths. Therefore, the next step was to compare these differences with expected differences based on the relationship between ABT curved fork and straight fork lengths over an equivalent range of fish sizes.

Two data sources which contained both curved and straight fork lengths for ABT were used to calculate a linear regression of these two variables: 1) 1996-2000 Large Pelagics Biological Survey (LPBS) data, and 2) 2005 LPIS data. ABT greater than 73 inches CFL were not used in this analysis since these landings are considered as part of the commercial catch and were not part of the length validation study. The regression line was forced through the origin (i.e., intercept = 0) to assure that a zero value for curved fork length would correspond to a zero value for straight fork length. The following equation, based on all years 1996-2000 (LPBS) and 2005 (LPIS) combined, describes the relationship between ABT straight fork length and curved fork length (both in inches):

Straight fork length = 0.9728 X curved fork length ($r^2 = 0.999$; $p < 0.001$; n=1,308)

Using these regression parameters a predicted straight fork length was calculated for each of the 373 (presumed) curved fork lengths in the 2002-2004 catch card datasets. Table 3 shows results of the pairwise comparison t-tests for the mean of the difference between LPIS measured lengths and the predicted straight fork lengths based on the regression formula above. LPIS measured lengths exceeded the predicted straight fork lengths by a mean difference of 0.264 inches for all years pooled (2002-2004) and this difference was not significantly different from zero at the 0.05 level (p=0.073). The standard error for this difference was 0.146 which translates into an approximate 95% confidence interval around this mean difference ranging from -0.025 to 0.554 inches. The difference between LPIS length and predicted SFL (based on catch card lengths) for individual observations with all years (2002-2004) combined is shown in Figure 5. The difference between LPIS measured length and predicted SFL expressed as a percent difference is shown in Table 4.

Investigation of the difference between observed (measured) and predicted lengths by year revealed appreciable differences between years (Figures 6-8). The mean difference was negative (i.e., predicted lengths were greater than LPIS measured lengths) for 2002 comparisons. This negative mean difference could not be explained by LPIS interviewers accidentally recording curved instead of straight lengths. This difference was significantly different from zero at the 0.05 level. The mean difference for the 2004 data comparisons was positive (0.408 inches) but was not significantly different from zero at the 0.05 level (p = 0.317). The mean difference for the 2003 data comparisons was both positive (0.886 inches) and highly significant. The results of this analysis suggest that if LPIS interviewers were recording curved lengths instead of straight lengths this problem was more prevalent in 2003 than either 2002 or 2004.

Table 3. Pairwise comparison t-tests of the mean difference between LPIS measured lengths and predicted straight fork lengths based on MD catch card lengths (note: difference = LPIS measured length – predicted straight fork length).

Year	N	Mean Difference (inches)	Variance	Std. Error	t value	Prob. > | t |
2002	131	-0.597	8.182	0.250	-2.37	0.019
2003	163	0.886	4.798	0.172	5.16	<0.0001
2004	79	0.408	12.617	0.400	1.02	0.317
All years combined	373	0.264	8.023	0.146	1.80	0.073

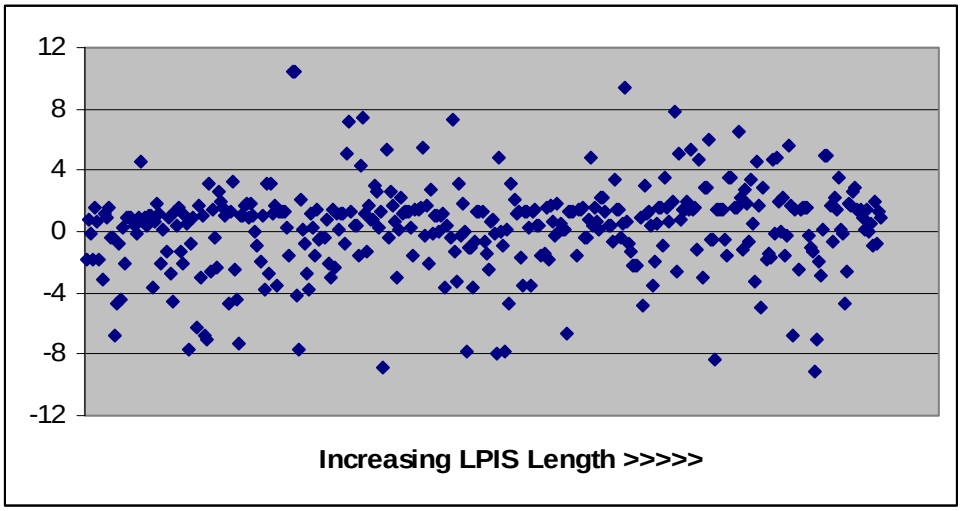

Figure 5. Difference between LPIS measured length and predicted SFL (based on MD catch card lengths) in inches for individual observations with all years (2002-2004) combined.

Table 4. Mean LPIS measured length, mean difference between LPIS measured length and predicted SFL based on MD catch card lengths, and percent difference.

Year	Mean LPIS Measured Length (inches)	Mean Difference Between LPIS and Predicted	Percent Difference
2002	46.51	-0.597	-1.28 %
2003	46.69	0.886	1.90 %
2004	42.76	0.408	0.95%
All years combined	45.79	0.264	0.58 %

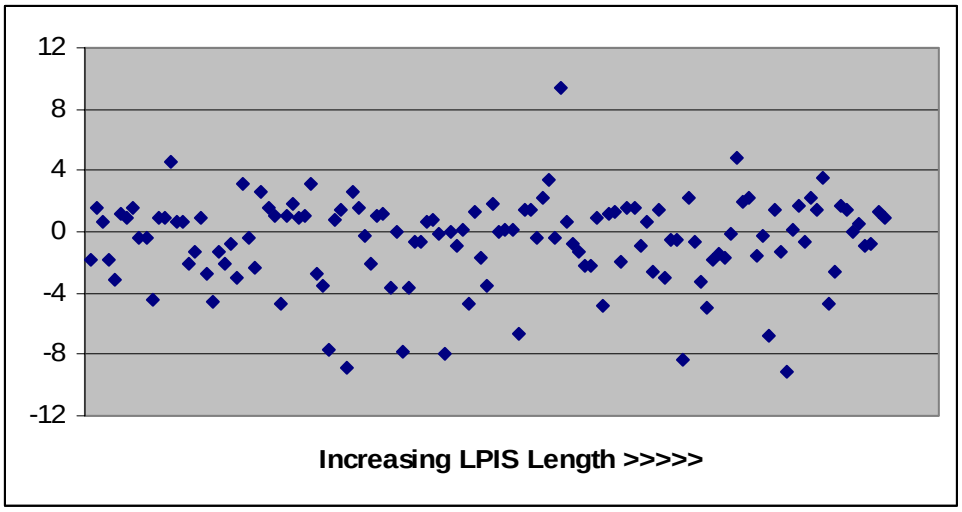

Figure 6. Difference between 2002 LPIS measured length and predicted SFL (based on MD catch card lengths) in inches for individual observations.

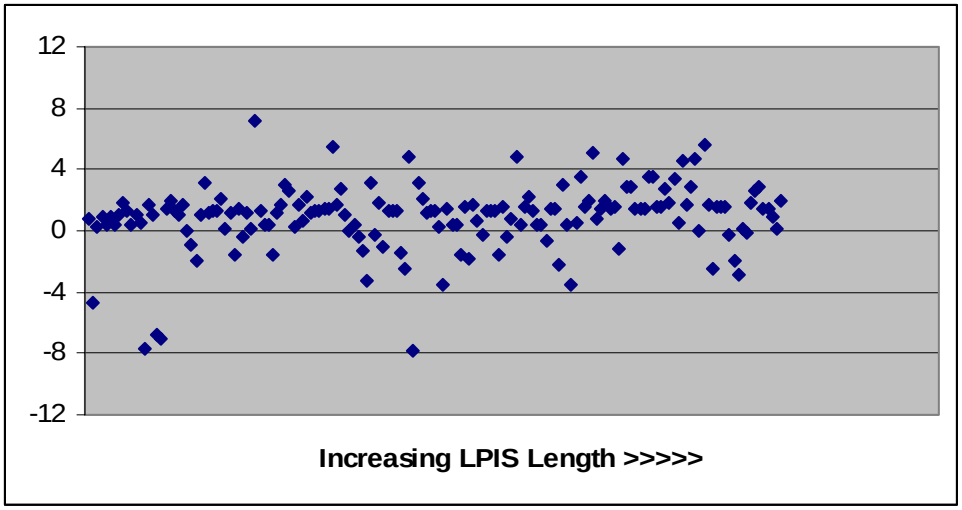

Figure 7. Difference between 2003 LPIS measured length and predicted SFL (based on MD catch card lengths) in inches for individual observations.

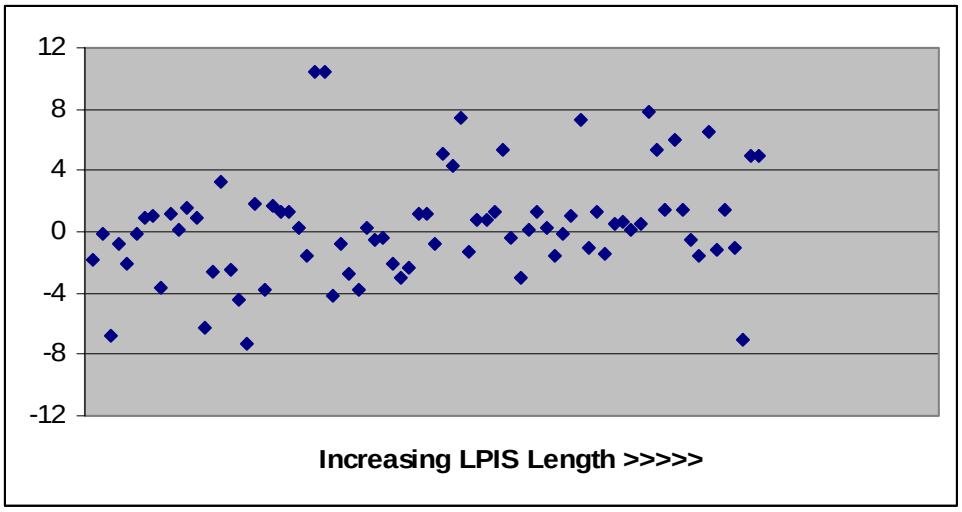

Figure 8. Difference between 2004 LPIS measured length and predicted SFL (based on MD catch card lengths) in inches for individual observations.

To further test the validity of LPIS lengths, the relationship between LPIS (presumed) straight fork lengths and Maryland catch card curved fork lengths, 2002-2004, was compared to the relationship between straight fork lengths and curved fork lengths from the combined LPBS (1996-2000) and LPIS (2005) datasets. The comparison was made using an F-test to formally test for a difference between the slope parameter from a linear regression of LPIS measured lengths on Maryland catch card lengths and the slope parameter from a linear regression of straight lengths on curved lengths from the LPBS/LPIS combined datasets. Both linear regressions were forced through the origin. The slope of the fitted regression equation of straight fork length on curved fork length from the LPBS and 2005 LPIS datasets was 0.9728 ($r^2 = 0.999$; $p < 0.001$; n=1,308). The 95% confidence interval around this slope parameter ranged from 0.9716 (lower bound) to 0.9740 (upper bound). The slope of the fitted regression equation of LPIS measured lengths on Maryland catch card lengths for all years combined was 0.9758 ($r^2 = 0.996$; $p < 0.0001$; n= 373). The difference between these slope parameters was not statistically significant (Prob. > F = 0.332) (Table 5). Slope parameters for individual years 2002 and 2003 were significantly different from 0.9782 (2004 was not significantly different). However, for 2002 the difference was in the opposite direction from what would be expected if LPIS interviewers were substituting curved fork lengths for straight fork lengths. Therefore, this difference could not be explained by LPIS interviewers accidentally recording curved instead of straight lengths. The difference in slopes for the 2003 data comparison were highly significant and in the direction one would expect if LPIS interviewers were substituting curved fork lengths for straight fork lengths. These results suggest that if LPIS interviewers were recording curved lengths instead of straight lengths this problem was more prevalent in 2003 than either 2002 or 2004.

Table 5. Results of F-tests comparing the slope of the fitted regression equation of LPIS measured lengths on Maryland catch card lengths with the straight to curved fork length slope parameter of 0.9728.

Year	N	Estimated Slope	95% Confidence Limit Low Bound	Hi Bound	F Value	Prob. > F
2002	131	0.9577	0.9477	0.9676	9.07	0.003
2003	163	0.9904	0.9832	0.9976	23.36	<0.0001
2004	79	0.9786	0.9604	0.9967	0.40	0.531
All years combined	373	0.9758	0.9697	0.9819	0.94	0.332

Importantly, the results from comparing slopes mirror those found for the pairwise comparison t-tests of the mean difference between LPIS measured lengths and predicted straight fork lengths based on MD catch card lengths (see above). Both analyses suggest that if LPIS interviewers were recording curved lengths instead of straight lengths this problem was more prevalent in 2003 than either 2002 or 2004. With all three years combined neither test found a significant difference at the alpha = 0.05 level.

LPIS and NMFS Automated Landings Report System

Similar to the above analysis, ABT length measurements reported through the NMFS Automated Landings Report System (ALRS) were compared with LPIS measurements. Individual records from each dataset were visually matched using date of landing, HMS permit number and vessel name. Unlike the Maryland catch card program, the ALRS covers all LPIS states (except Maryland) and therefore may be a more appropriate comparison for assessing potential length measurement errors throughout the LPIS interviewing range. Maine data were not used since the Maine Department of Marine Resource conducts LPIS interviews, not the government contractor. New Hampshire was not included since no matches were found between LPIS and ALRS for the years 2002-2004.

After matching records it was determined that a total of 148 ABT that were measured in the LPIS were also reported via the ALRS for 2002-2004 (Table 6). Small sample sizes in most states (and overall) made it difficult to validate length measurements in any particular state. Since overall sample sizes in 2003 and 2004 were also very small, all three years were pooled for the analysis. LPIS lengths, which are recorded in millimeters, were converted to inches to match ALRS lengths. The plot of LPIS recorded lengths versus ALRS lengths is shown below for all three years combined (Figure 9).

The straight line represents a slope of one going through the origin. If both lengths were taken and reported as required for each program, it would be expected that 1) most of the data points would fall above the line since straight fork lengths (LPIS) are smaller than curved fork lengths (ALRS reports), and 2) the absolute difference between straight and curved length measurements (taken on the same fish) should increase with fish size (i.e., as the girth of the fish increases). Based on Figure 9 it is clear that, similar to the catch card comparison, for many individual fish

the relationship between LPIS and ALRS length measurements does not match the expected relationship between straight and curved length measurements.

Table 6. Number of records matched between ALRS and LPIS by state, 2002-04.

State	2002	2003	2004	All
MA	6	4	2	12
RI	3	15	1	19
CT	0	3	1	4
NY	1	3	1	5
NJ	5	1	0	6
DE	22	1	14	37
VA	44	11	10	65
All	81	38	29	148

A paired comparisons analysis was conducted to measure the mean difference in lengths recorded by LPIS interviewers and reported by HMS anglers through the ALRS for the same fish. Paired comparisons t-tests were run to determine if the mean difference (measured in inches as ALRS length minus LPIS length) was significantly different from zero (Table 7). With all years and states combined, the mean difference (ALRS minus LPIS length) was 0.205 inches and was not significantly different from zero.

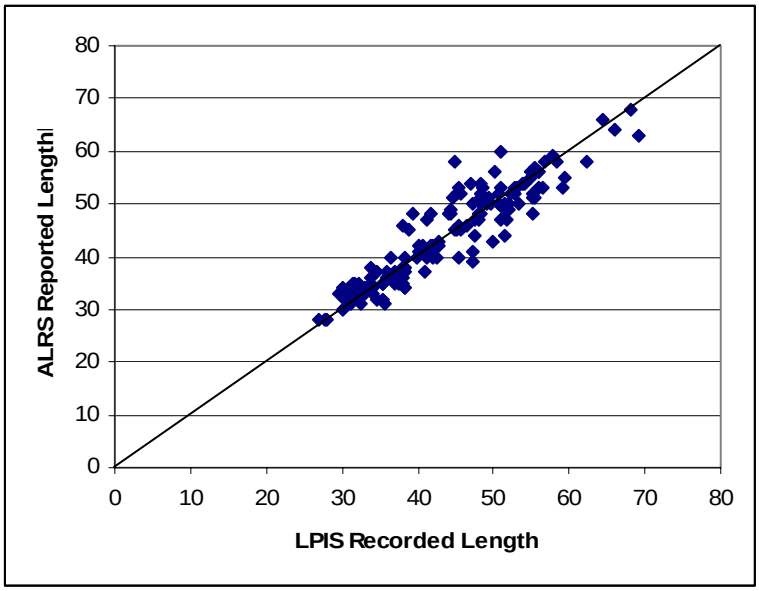

Figure 9. Plot of LPIS recorded lengths (in inches) versus reported ALRS lengths, 2002-2004.

Table 7. Pairwise comparison t-tests of the mean difference between ALRS (curved fork) lengths and LPIS (straight fork) lengths (note: difference = ALRS length – LPIS length).

Year	N	Mean Difference (inches)	Std. Error	t value	Prob. > | t |
2002-2004 combined	148	0.205	0.284	0.72	0.472

Similar to the catch card analysis, the straight fork length versus curved fork length regression (i.e., straight fork length = 0.9728 X curved fork length) was used to calculate a predicted straight fork length for each of the 148 (presumed) curved fork lengths in the 2002-2004 ALRS datasets. As mentioned above, for all states north of Delaware sample sizes were considered too small to analyze differences between predicted fork length and LPIS lengths on a state-by-state basis. Data from New Jersey through Massachusetts (n=46) were pooled for comparison with pooled data from Delaware and Virginia (n=102). No significant difference was detected in the mean difference between LPIS measured lengths and the predicted straight fork lengths between these two groups (NJ-MA = 0.708, DE/VA = 1.129, p = 0.491). This justified pooling all states in the analysis.

Results of the pairwise comparison t-tests for the mean of the difference between LPIS measured lengths and the predicted straight fork lengths with all years and states pooled are shown in Table 8. LPIS measured lengths exceeded the predicted fork lengths by a mean difference of 0.998 inches for all years and states pooled (2002-2004) and this difference was significantly different from zero. The standard error for this difference was 0.282 which translates into an approximate 95% confidence interval around this mean difference ranging from 0.441 to 1.555 inches. The difference between LPIS length and predicted SFL (based on ALRS lengths) for individual observations with all years (2002-2004) combined is shown in Figure 10. The difference between LPIS measured length and predicted SFL expressed as a percent difference is shown in Table 9.

Table 8. Pairwise comparison t-tests of the mean difference between LPIS measured lengths and predicted straight fork lengths based on ALRS reported lengths (note: difference = LPIS measured length – predicted straight fork length).

Year	N	Mean Difference (inches)	Variance	Std. Error	t value	Prob. > | t |
2002-2004 combined	148	0.998	11.731	0.282	3.54	0.0005

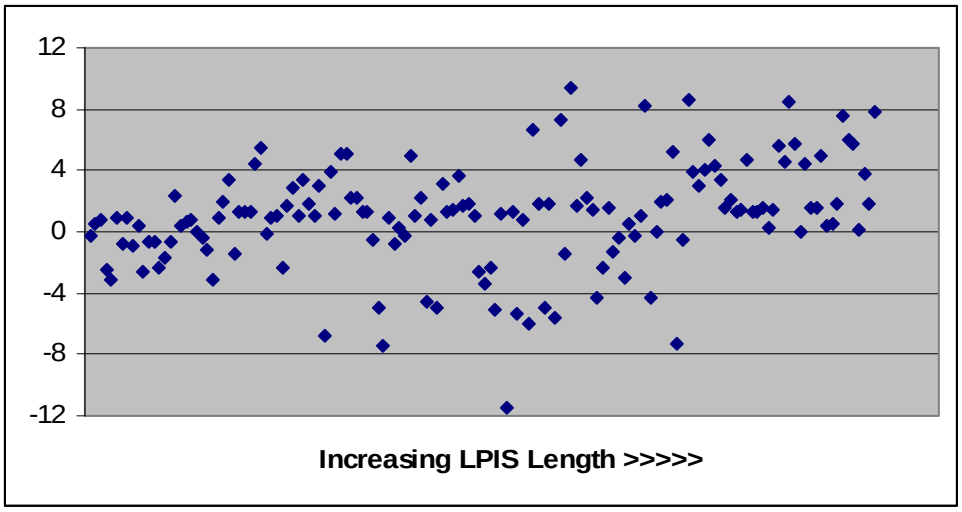

Figure 10. Difference between LPIS measured length and predicted SFL (based on ALRS reported lengths) in inches for individual observations with all years (2002-2004) combined.

Table 9. Mean LPIS measured length, mean difference between LPIS measured length and predicted straight fork length based on ALRS reported lengths, and percent difference.

Year	Mean LPIS Measured Length (inches)	Mean Difference Between LPIS and Predicted	Percent Difference
2002-2004 combined	44.00	0.998	2.27 %

To further test the validity of LPIS lengths, the relationship between LPIS (presumed) straight fork lengths and ALRS curved fork lengths, 2002-2004, was compared to the relationship between straight fork lengths and curved fork lengths from the combined LPBS (1996-2000) and LPIS (2005) datasets. The comparison was made using an F-test to formally test for a difference between the slope parameter from a linear regression of LPIS measured lengths on ALRS lengths and the slope parameter from a linear regression of straight lengths on curved lengths from the LPBS/LPIS combined datasets. Both linear regressions were forced through the origin. The slope of the fitted regression equation of straight fork length on curved fork length from the LPBS and 2005 LPIS datasets was 0.9728 ($r^2 = 0.999$; $p < 0.001$; n=1,308). The 95% confidence interval around this slope parameter ranged from 0.9716 (lower bound) to 0.9740 (upper bound). The slope of the fitted regression equation of LPIS measured lengths on ALRS lengths for all three years combined was 0.99934 ($r^2 = 0.994$; $p < 0.0001$; n= 148). The difference between these slope parameters was statistically significant (Prob. > F = 0.0013) (Table 10) and in the direction one would expect if LPIS interviewers were substituting curved fork lengths for straight fork lengths.

Table 10. Results of F-tests comparing the slope of the fitted regression equation of LPIS measured lengths on ALRS lengths with the straight to curved fork length slope parameter of 0.9728.

Year	N	Estimated Slope	95% Confidence Limit Low Bound	Hi Bound	F Value	Prob. > F
2002-2004 combined	148	0.9934	0.9810	1.0058	10.77	0.0013

Importantly, the results from comparing slopes mirror those found for the pairwise comparison t-tests of the mean difference between LPIS measured lengths and predicted straight fork lengths based on ALRS lengths (see above).

Level of Analysis

The analyses above suggest that temporal and geographic variation exist in terms of differences between LPIS length measurements and predicted SFLs (based on catch cards and ALRS). This raises the question as to what temporal/geographic scale should such differences, and potential length measurement error rates, be evaluated. Potential error rates could, theoretically, be calculated and applied for particular state/year strata combinations. However, from a practical standpoint this is difficult to justify statistically since sample sizes are very small within many of these strata. It may also be preferable to apply a uniform correction factor across the entire LPS area and time frame under consideration from a management perspective.

Since the LPIS-ALRS comparison did not cover Maine and New Hampshire and for several other states sample sizes were very small, the following assumption is made for the purpose of examining the implications of a potential length measurement error rate:

- The presumed overall LPIS-ALRS length measurement error rate represents a valid estimate of the error rate in Maine and New Hampshire as well as other states where sample sizes for this analysis were small.

To arrive at a single potential length measurement error rate for all LPS states (Maine through Virginia) and years, the overall length difference (LPIS versus predicted SFLs) from the LPIS-MD catch card comparison (which only covers ABT length measured in Maryland) was weighted and averaged with the LPIS-ALRS length difference. Weighting factors were based on total estimated ABT recreational landings (in numbers) from the 2002-2004 LPS (Table 11). ABT in the large medium and giant categories were not included in the weighting procedure since these are considered commercial and were not part of the length validation assessment.

Table 11. Total recreational bluefin tuna landings (young school, school, large school and small medium size classes) used for weighting of length measurement adjustment factors.

Geographic Area	Total ABT Landings 2002-2004 (numbers of fish)	Percent Weight
Maryland	13,087	27.6%
Maine through Virginia (excluding Maryland)	34,371	72.4%
Total	47,458	100%

LPIS measured lengths exceeded the predicted fork lengths based on the Maryland catch card data by a mean difference of 0.264 inches for all years pooled (2002-2004). LPIS measured lengths exceeded the predicted fork lengths based on the ALRS data by a mean difference of 0.998 inches for all years pooled (2002-2004). The weighted mean difference is calculated as follows:

Mean Difference (weighted) = (0.264 X 0.276) + (0.998 X 0.724) = 0.795 inches

The weighted mean LPIS length is calculated as follows:

Mean LPIS length (weighted) = (45.79 X 0.276) + (44.0 X .724) = 44.494 inches = 113.01 cm

Mean Predicted Straight Fork Length = 44.494 – 0.795 = 43.699 inches = 111.00 cm

The percent difference between the mean LPIS length and the predicted straight fork length is 1.779%.

Conversion to Weight-based Adjustment Factor

The next step was to convert from a length-based adjustment factor (0.795 inches per fish) to a weight-based adjustment factor. Data from the 1998-2000 Large Pelagics Biological Survey (LPBS) were used to compute a weight-length conversion formula. This represents the three most recent years of the LPBS data collection. After thorough error-checking and outlier reduction analysis, a total of 409 observations were available for the regression. ABT greater than 73 inches CFL were not used in this analysis since these landings are considered as part of the commercial catch and were not part of this length validation study. A simple linear regression was computed of the log of weight (kg) and the log of length (SFL cm):

- Log(weight kg) = m X log(SFL cm) + b
  (Where m = slope, and b = intercept)
- Log(weight kg) = 2.78986 X log(SFL cm) – 4.296
- Weight kg = 0.0000506 X (SFL cm) $^{2.790}$

Using this weight-length conversion formula, the estimated mean ABT weight based on the mean LPIS length measurement is:

- Weight kg = 0.0000506 X (113.01) $^{2.790}$ = 27.061 kg

The estimated mean ABT weight based on the mean predicted SFL is:

- Weight kg = 0.0000506 X (111.00) $^{2.790}$ = 25.740 kg

The percent difference between the estimated mean weight based on LPIS lengths and the estimated mean weight based on predicted SFL is 4.88%. It should be noted that this method could produce additional bias if the size distribution of the samples are in fact not representative of the actual catch.

Limiting Assumptions

It is important to identify the limiting assumptions of this evaluation, particularly if these results are to be used to make adjustments to historical landings data and/or for future ABT quota allocations. Failure to meet the assumptions would change the provisional results presented and could well invalidate the method described for estimating potential length measurement error rates.

1.A. Maryland catch card length measurements and LPIS length measurements were independent.

1.B. ALRS length measurements and LPIS length measurements were independent.

One important assumption is that the two length measurements being compared are independent of one another. For many observations, the LPIS length measurement was identical to the length recorded by anglers on the catch cards or reported using ALRS. For several other matches the two lengths were close enough that they could be explained by angler rounding error on the catch cards or ALRS (i.e., LPIS lengths are recorded in millimeters while anglers typically round to the nearest inch or half-inch). Two possible explanations for identical (or nearly identical) LPIS and catch card lengths for the same fish are: 1) LPIS interviewers incorrectly recorded a curved length rather than a straight length, or 2) anglers were completing the catch cards using the measurements made by the LPIS interviewers, irregardless of whether these were curved or straight lengths. Only if we assume that the two length measurements were largely independent of one another can we reject the second explanation that anglers were recording catch card lengths based on information provided to them by LPIS interviewers. The assumption of independence is further complicated by the fact that LPIS interviewers from 2002-2004 were instructed, as a courtesy, to measure the curved fork length of a bluefin tuna if asked to do so by an interviewed captain or angler (even though they were only supposed to record the straight fork length on the standard data form).

2.A. Angler reported Maryland catch card lengths represent fairly accurate measurements of ABT curved fork lengths, and if there are sources of error associated with these measurements the error is random.

2.B. Angler reported ALRS lengths represent fairly accurate measurements of ABT curved fork lengths, and if there are sources of error associated with these measurements the error is random.

There is reason to believe that some anglers "ballpark" ABT length information on the catch cards or in reports to the ALRS. In addition, catch card lengths are generally reported in whole inch (or sometimes half-inch) increments and only rarely with a higher degree of precision. Thus, another necessary assumption is that any errors (rounding, digit-bias or otherwise) associated with angler self-reported lengths on catch cards (or to ALRS) are random and essentially cancel each other out (e.g., overestimations and underestimations occur with the same frequency). By contrast, if, for example, anglers more frequently overestimate rather than underestimate ABT lengths, such a bias could affect the validity of this analysis.

In 2005 LPIS interviewers recorded both straight fork lengths (SFLs) and curved fork lengths (CFLs) for bluefin tuna. LPIS interviewers will continue to collect both straight and curved lengths on ABT in future years to avoid any ambiguity regarding which lengths were actually measured in the field. This will also provide additional data for computing a straight to curved length ratio. LPIS 2005 curved length measurements were compared with Maryland 2005 catch card and ALRS 2005 curved length measurements to test the assumption that angler reported Maryland catch card lengths and ALRS lengths from 2002-2004 represent fairly accurate, unbiased measurements of ABT CFLs. The LPIS and catch card/ALRS datasets were visually matched to identify individual fish that had been measured and recorded by both an LPIS interviewer and an angler or captain. The method used to match records was identical to that used to match data from the 2002-2004 datasets.

A total of 126 ABT had CFLs recorded through both the Maryland catch card program and the LPIS. A pairwise t-test was used to compare differences between the CFLs recorded for the two data collection methods. The mean Maryland catch card CFL was 0.79 inches greater than the mean LPIS CFL. However, these means were not significantly different at the alpha=0.05 level ($df = 125$, $t = 1.97$, $p = 0.051$). These results suggest that the 2005 catch card lengths represent fairly accurate measurements of ABT CFLs, and if there are sources of error associated with these measurements the error is random. The fact that catch card lengths were larger, on average, than LPIS CFLs suggests that anglers have a tendency to round up to the nearest inch when reporting lengths on catch cards (LPIS interviewers record to the nearest millimeter). In 2005 only 14 ABT had CFLs both reported through the ALRS and recorded by LPIS interviewers. This sample size was deemed too small to perform any meaningful statistical analysis. Therefore, it was not possible to directly test the assumption that ALRS lengths represent fairly accurate, unbiased measurements of ABT CFLs.

The 2005 data provide tentative support for accepting the assumption that angler reported Maryland catch card lengths and ALRS lengths from 2002-2004 are unbiased, and if there are sources of error associated with these measurements the error is random. However, support for this assumption is predicated on acceptance of two additional limiting assumptions:

- Angler CFLs recorded on Maryland catch cards from 2002-2004 were at least as accurate as angler CFLs recorded on Maryland catch cards in 2005.
- Angler CFLs reported via ALRS are at least as accurate as CFLs recorded by Maryland anglers on catch cards.

If one assumes that the LPIS measurements were recorded accurately, irrespective of whether they were SFLs or CFLs, then an angler reported length should never be smaller than an LPIS length from the same fish, except for rounding differences. If, after correcting for rounding, an angler reported length (via ALRS or catch card) is still smaller than an LPIS length, the likeliest explanation is that the angler length is inaccurate. More than one-third (35%) of the 148 ALRS lengths were smaller than the LPIS length for the same fish even after accounting for rounding. By comparison, after accounting for rounding, only 20% of the self-recorded catch card curved lengths were actually smaller than the associated LPIS length. Therefore, these results suggest that ALRS lengths are not as accurate as Maryland catch card lengths.

3. The relationship between ABT curved and straight fork lengths, based on LPBS data from 1996-2000 and LPIS data from 2005, is a good fit for the 2002-2004 length measured ABT.

The relationship between straight and curved fork lengths may vary from year to year depending on a number of factors including average fish size, condition, and geographic and temporal distribution throughout the fishing season. Ideally, we would want to use data from the years in question (i.e., 2002-2004) to establish the curved-straight length relationship. However, since the LPBS was not conducted from 2002-2004, the regression was based on pooled data from the most recent five years of LPBS data, 1996-2000. LPBS data were combined with LPIS data from 2005, the first year that both curved and straight fork lengths were collected on the LPIS. The ratio of straight fork length to curved fork length computed from 2005 LPIS was nearly identical to the same ratio based on 1996-2000 Large Pelagics Biological Survey (LPBS) data. This provided support for the assumption that the ratio used for this assessment was a good fit for the 2002-2004 data.

4. The difference between the expected deviation and the mean sample deviation represents a measure of the relative frequency of curved lengths being incorrectly substituted for straight lengths in the LPIS data.

Estimation of an actual error rate (i.e., percent of curved lengths being incorrectly substituted for straight lengths in the LPIS data) from individual matched records would have been extremely sensitive to unknown measurement errors. Instead, this analysis focused on differences between mean sample lengths (LPIS lengths versus expected straight fork lengths). Therefore, another necessary assumption of this analysis is that the difference between these sample means represents a fairly accurate measure of this error rate.

Impact of Length Measurement Errors on ABT Stock Assessment

The approach taken for this component was to simulate a scenario in which all LPIS length measurements from 1993 on were assumed to be curved fork lengths rather than straight. The U.S. rod and reel caught ABT lengths less than 178 cm in the catch-at-length data used for the 2002 ICCAT ABT stock assessment were multiplied by an adjustment factor of 0.955 (the standard factor which has been used for previous conversions from curved to straight length) representing a 4.5% reduction. A new a catch-at-age matrix was created following the usual procedures. Finally, a virtual population analysis (VPA) was conducted, using the same inputs as were used for the 2002 ICCAT ABT stock assessment except for the changes to the catch-at-age matrix and corresponding weight-at-age. The VPA results were then compared to the results obtained from the 2002 stock assessment.

Changes to the VPA estimates of historical abundance and fishing mortality results appear to be minor, even given the assumption that all LPIS length measurements taken since 1993 were curved rather than straight. The largest differences appear in the recruitment trends (Table 12 and Figure 11), which are shown through 1998 since the last several years are not predicted well by the VPA. Only 1997 shows a difference greater than 6%. The differences in spawning stock biomass (SSB, Table 13 and Figure 12)) and fishing mortality (ages 8+, Table 14 and Figure 13) trends are even smaller. Changes to the VPA estimates are likely to be even smaller than estimated here since this analysis assumed a 4.5% reduction (SFL/CFL = 0.955) in LPIS lengths while the regression calculated from LPBS and 2005 LPIS data predicted only a 2.7% difference between SFL and CFL. It appears unlikely that any bias resulting from measurements of curved rather than straight lengths in the LPIS would have altered stock status evaluations. This is not surprising, since the VPA is based on estimates of catch in numbers of fish at age, a feature not very sensitive to the issues discussed above. More importantly, however, are the implications of assuming different average weight at age for future projections of TAC levels. NMFS will attempt to collect more ABT lengths and weights in 2006 to test the validity of the length-weight relationships used for stock assessment purposes.

Table 12. Recruitment trends showing difference between 2002 stock assessment and adjusted assessment assuming all LPIS length were recorded as curved instead of straight.

year	2002 Assessment	Assuming Bias	% change	year	2002 Assessment	Assuming Bias	% change
1970	339984	339769	-0.1%	1985	74486	74586	0.1%
1971	266988	266725	-0.1%	1986	91726	91846	0.1%
1972	235103	234738	-0.2%	1987	68750	68343	-0.6%
1973	152763	151818	-0.6%	1988	91673	91897	0.2%
1974	487089	487139	0.0%	1989	50771	50151	-1.2%
1975	143588	143613	0.0%	1990	90988	89979	-1.1%
1976	136118	136154	0.0%	1991	80782	80304	-0.6%
1977	86557	86572	0.0%	1992	47480	46641	-1.8%
1978	55327	55335	0.0%	1993	46026	46978	2.1%
1979	81449	81500	0.1%	1994	24204	25586	5.7%
1980	67036	67087	0.1%	1995	143648	138895	-3.3%
1981	61460	61502	0.1%	1996	85494	80393	-6.0%
1982	57357	57423	0.1%	1997	56820	69636	22.6%
1983	96243	96319	0.1%	1998	150680	141872	-5.8%
1984	68343	68406	0.1%				

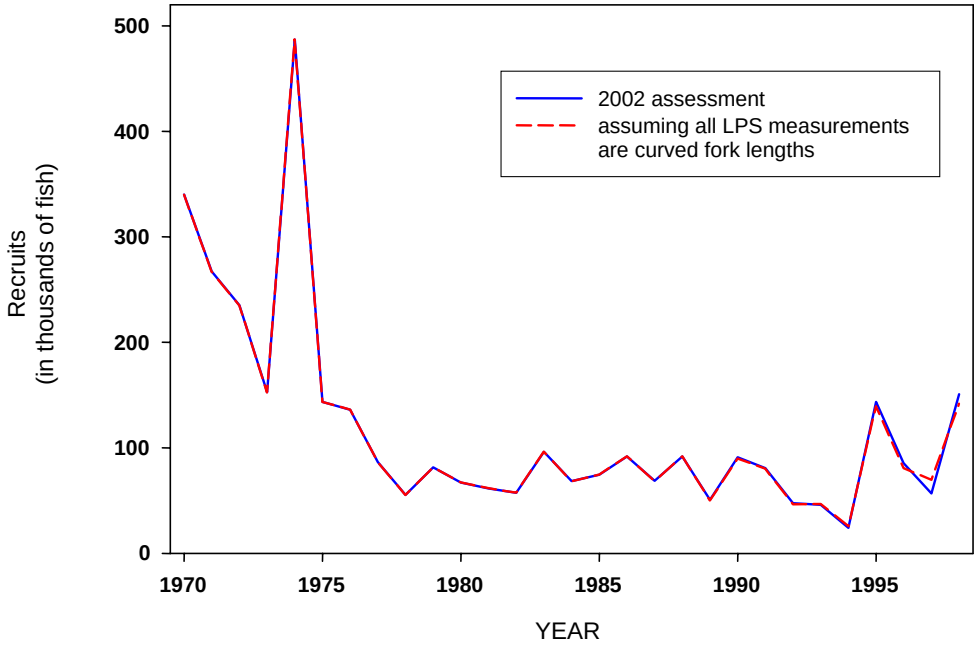

Figure 11. Plots of estimated ABT recruitment trends from the 2002 ICCAT stock assessment (solid line) and from a run assuming that all LPS measurements were curved fork lengths rather than straight (dashed line).

Table 13. Spawning stock biomass trends showing difference between 2002 stock assessment and adjusted assessment assuming all LPIS length were recorded as curved instead of straight.

Year	2002 Assessment	Assuming Bias	% change	year	2002 Assessment	Assuming Bias	% change
1970	50033	50932	1.8%	1986	11316	11354	0.3%
1971	45236	46075	1.9%	1987	10141	10176	0.3%
1972	45281	46165	2.0%	1988	9613	9648	0.4%
1973	43241	44028	1.8%	1989	8858	8893	0.4%
1974	44134	44837	1.6%	1990	8638	8675	0.4%
1975	37905	38446	1.4%	1991	7899	7936	0.5%
1976	36340	36751	1.1%	1992	7645	7684	0.5%
1977	31017	31373	1.1%	1993	8099	8143	0.5%
1978	28400	28700	1.1%	1994	8352	8399	0.6%
1979	22514	22736	1.0%	1995	8880	8935	0.6%
1980	21304	21446	0.7%	1996	8332	8390	0.7%
1981	18825	18932	0.6%	1997	8741	8809	0.8%
1982	17973	18027	0.3%	1998	8693	8770	0.9%
1983	17575	17626	0.3%	1999	7616	7701	1.1%
1984	14973	15017	0.3%	2000	6872	6970	1.4%
1985	11930	11968	0.3%	2001	5024	5124	2.0%

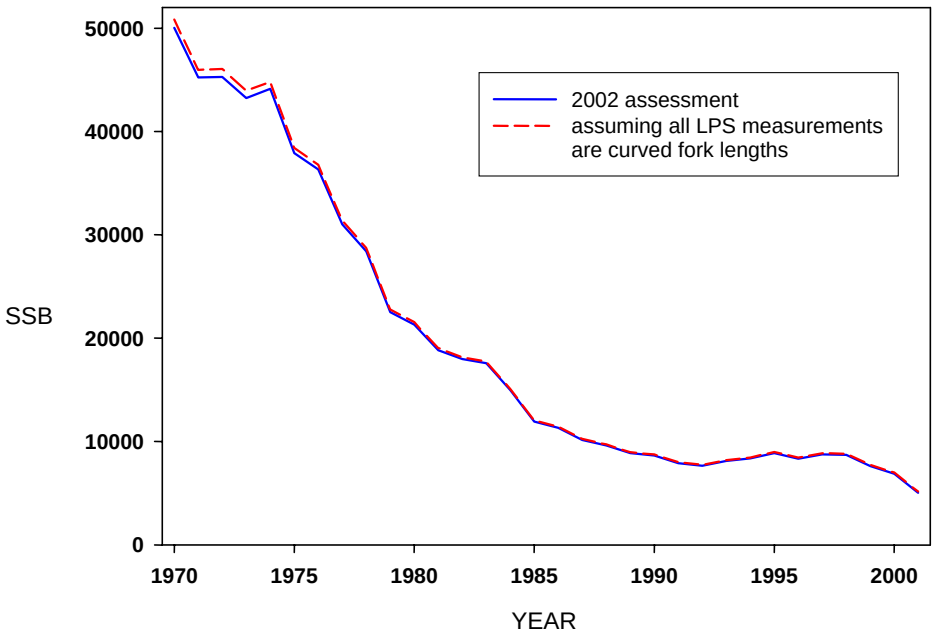

Figure 12. Plots of estimated ABT spawning stock biomass (SSB) trends from the 2002 ICCAT stock assessment (solid line) and from a run assuming that all LPS measurements were curved fork lengths rather than straight (dashed line).

Table 14. Fishing mortality trends showing difference between 2002 stock assessment and adjusted assessment assuming all LPIS length were recorded as curved instead of straight.

year	2002 Assessment	Assuming Bias	% change	year	2002 Assessment	Assuming Bias	% change
1970	0.0177	0.0177	0.0%	1986	0.1333	0.1333	0.0%
1971	0.0780	0.0770	-1.3%	1987	0.1383	0.1380	-0.2%
1972	0.0353	0.0347	-1.9%	1988	0.1883	0.1880	-0.2%
1973	0.0443	0.0440	-0.8%	1989	0.2207	0.2197	-0.5%
1974	0.0607	0.0597	-1.6%	1990	0.2127	0.2120	-0.3%
1975	0.0640	0.0633	-1.0%	1991	0.2307	0.2300	-0.3%
1976	0.0820	0.0817	-0.4%	1992	0.2077	0.2067	-0.5%
1977	0.1007	0.1007	0.0%	1993	0.1893	0.1883	-0.5%
1978	0.0937	0.0940	0.4%	1994	0.1693	0.1683	-0.6%
1979	0.1133	0.1130	-0.3%	1995	0.1773	0.1760	-0.8%
1980	0.1657	0.1653	-0.2%	1996	0.1663	0.1653	-0.6%
1981	0.1997	0.1993	-0.2%	1997	0.1837	0.1827	-0.5%
1982	0.0647	0.0647	0.0%	1998	0.2407	0.2383	-1.0%
1983	0.1143	0.1143	0.0%	1999	0.2940	0.2910	-1.0%
1984	0.1187	0.1187	0.0%	2000	0.2763	0.2730	-1.2%
1985	0.1743	0.1743	0.0%	2001	0.4150	0.4070	-1.9%

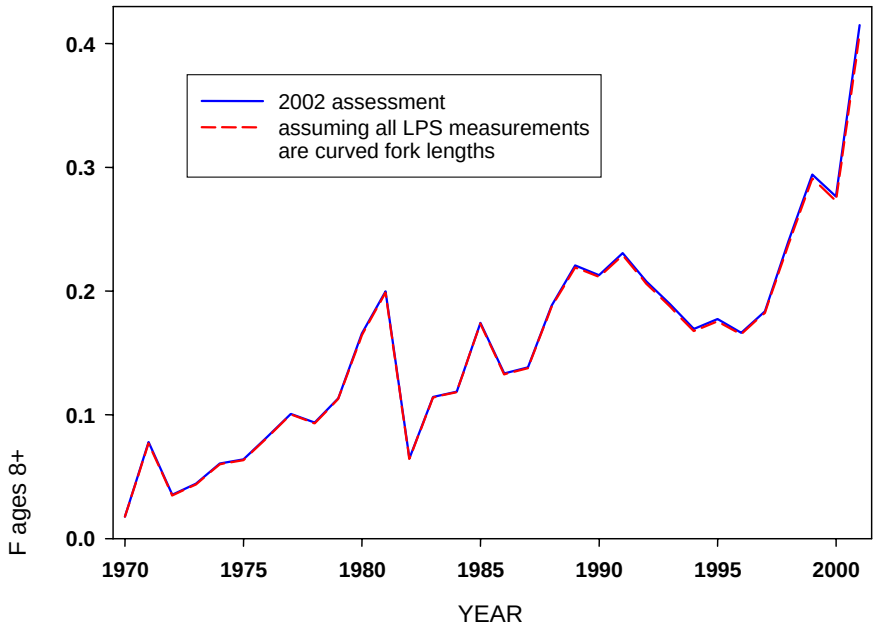

Figure 13. Plots of estimated ABT fishing mortality trends on ages 8 and above ($F_{ages\ 8+}$) from the 2002 ICCAT stock assessment (solid line) and from a run assuming that all LPS measurements were curved fork lengths rather than straight (dashed line).

Management Alternatives

Survey data errors are best addressed as close to the source (i.e., the interviewer) and collection date as possible. The above assessment highlights the difficulties associated with validating historical fisheries survey data collected up to three years ago by multiple interviewers. The LPIS contractor claims that their interviewers were measuring and recording ABT straight fork lengths. Some fishing industry members claim that curved fork lengths were being measured and recorded by LPIS interviewers. Management must decide if an adjustment to historical bluefin tuna landings data due to this potential measurement error is warranted at this time. Regardless of this decision, the straight length / curved length debate will not be an issue in future years (2005 and beyond) now that LPIS interviewers are instructed to collect both lengths on all ABT measured.

Several alternatives are available to management given the inherent and un-quantified uncertainty associated with these results. Management alternatives include the following:

Alternative #1: No action alternative.

If the limiting assumptions that this evaluation is predicated upon are not accepted then management may chose the no action alternative. That is, if there is reason to believe that any of the assumptions have been violated (e.g., that angler reported ABT lengths on catch cards or through ALRS are biased and/or that these lengths are not independent from matched LPIS lengths), any adjustment to historical ABT landings based on these results may be biased. Justification for supporting this alternative could be derived from the following findings: 1) inconsistent (even contradictory) results across years, 2) high variability in comparisons between angler lengths and interviewer lengths, 3) low sample sizes and limited coverage of the available data (across state/year/interviewer strata) to test for measurement bias, and 4) the likely violation of one or more of the limiting assumptions.

Both curved fork and straight fork lengths are difficult to measure accurately without proper training and equipment. Considering that for a given fish the difference between these two measures is proportionally small (less than 3% on average per fish) even a minor measurement bias could significantly alter the results of this evaluation. Testing the validity of angler recorded Maryland catch card lengths provided only marginal support for the assumption that these lengths are unbiased curved fork lengths. The validity of angler reported ALRS lengths could not be tested due to the small sample size. However, comparisons with LPIS measurements did suggest that ALRS reported lengths were not as accurate as catch card lengths. If this is the case, it is highly likely that the assumption that angler reported ALRS lengths represent unbiased curved fork lengths is violated.

Since the LPIS-ALRS length comparison analysis results were weighted more heavily than the LPIS-catch card comparison results (72.4% versus 27.6%), even a slight bias in the ALRS reported lengths could significantly impact the adjustment factor results. In addition, the LPIS-catch card results indicate no clear, consistent pattern regarding LPIS mis-measurements across years. When compared to MDCC predicted straight lengths, LPIS lengths were significantly

smaller in 2002, significantly larger in 2003, not significantly different in 2004, and not significantly different with all three years pooled.

The claims by some anglers and fishing industry representatives that they have observed curved lengths being recorded have been given strong credence. NMFS has expended considerable resources researching these claims and attempting to validate LPIS length measurements. If the no action alternative is chosen by management this should not be interpreted as a definitive conclusion that no biased measurements (CFLs rather than the expected SFLs) were taken by LPIS interviewers. Rather, selection of this alternative would indicate that the agency believes that available data and analyses are insufficient to determine to what extent curved lengths rather than straight may have been recorded, and how that rate may have varied across years and areas.

Alternative #2: Apply an adjustment factor of 4.88% to the ABT recreational landings weight (Maine through Virginia, fish less than 73 inches CFL) over the years 2002-2004.

Fishing industry member claims that LPIS interviewers were recording curved lengths instead of straight lengths are directed at the 2002-2004 LPS survey years. If all of the limiting assumptions (see above) associated with this analysis are accepted, management can apply an adjustment factor to correct for over-estimated landings weight estimates for these three years. The weight of 2002-2004 recreational landings of ABT (Maine through Virginia, fish less than 73 inches CFL) could be reduced by 4.88%.

The sensitivity analysis performed on the stock assessment shows that even if all LPIS lengths are treated as curved fork lengths, (either over all years or just 2002-2004), changes to the VPA results in terms of recruitment trends, fishing mortality and spawning stock biomass will be relatively minor. It is, therefore, unlikely that in hindsight this presumed bias would have resulted in any significant impacts on stock status evaluations.

Alternative #3: Apply an adjustment factor of 4.88% to the ABT recreational landings weight (Maine through Virginia, fish less than 73 inches CFL) over the years 1995-2004.

If all of the limiting assumptions associated with this analysis are accepted, management can apply an adjustment factor to correct for over-estimated landings weight for all LPS survey years during which CFLs may have been substituted for SFLs. That is, if LPIS interviewers were incorrectly recording CFLs from 2002-2004, one may presume that they were also erroneously recording CFLs in previous survey years. While the Large Pelagics Survey has been conducted since 1986, the use of curved fork lengths for management regulations began in 1995. Since straight fork lengths were used for management prior to 1995, it is presumed that if there was any confusion amongst LPIS interviewers regarding which length to record this confusion began in 1995.

Alternative #3 is riskier than alternative #2 because: 1) it requires the additional assumption that ABT length measurement error rates from 1995-2001 were similar to those from 2002-2004, and 2) if any of the original assumptions above turn out to be false, all LPS ABT landings weight data from 1995-2004 will be adjusted by an inaccurate correction factor, rather than just three years of data as would be the case with Alternative #2.