

EVALUATION OF CANADIAN SAMPLING PROGRAM FOR BLUEFIN TUNA, RESULTS OF NATAL ORIGIN STUDIES 2011-2012 AND ASSESSMENT OF LENGTH-WEIGHT CONVERSIONS

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SUMMARY

Results from the first two years of a three year long program of biological sampling of bluefin tuna caught in Canadian waters are presented. Approximately 20% of the landings by number were sampled, and the sampling effort appeared to follow the general spatial and temporal pattern of the fishery. Results of natal origin determinations generally support earlier studies showing that the Canadian catch is supported almost exclusively by western origin fish, but with some added finer-scale differences that require further evaluation. The process of obtaining size information from the fishery is also reviewed, and it is concluded that existing practices could be revised to avoid introducing biases from weight-length conversions.

RÉSUMÉ

Le présent document décrit les résultats des deux premières années d'un programme d'échantillonnage biologique du thon rouge sur trois ans capturé dans les eaux canadiennes. Environ 20% des débarquements en nombre ont été échantillonnés et l'effort d'échantillonnage semblait suivre le schéma spatio-temporel général de la pêche. En règle générale, les résultats de la détermination de l'origine natale appuient des études antérieures qui montraient que la prise canadienne est constituée presque exclusivement de poissons originaires de l'Ouest, avec toutefois des différences ajoutées à échelle plus réduite nécessitant une évaluation plus poussée. Le processus d'obtention des informations de taille de la pêche fait également l'objet d'un examen et l'on conclut que les pratiques existantes pourraient être révisées pour éviter d'introduire des biais issus de la conversion poids-longueur.

RESUMEN

Se presentan los resultados de los dos primeros años de un programa de tres años de muestreo biológico de atún rojo capturado en aguas canadienses. Se muestreó aproximadamente el 20% de los desembarques por número y el esfuerzo de muestreo parecía seguir el patrón espacial y temporal general de la pesquería. Los resultados de las determinaciones del origen natal respaldan de forma general estudios anteriores que demostraban que la captura canadiense se compone casi exclusivamente de peces originarios del oeste, pero con algunas diferencias añadidas en una escala más fina que requieren una mayor consideración. Se revisa también el proceso de obtener información sobre tallas en la pesquería y se concluye que las prácticas existentes podrían revisarse para evitar introducir sesgos a través de las conversiones talla-peso.

KEYWORDS

Otolith, Natal Origin, Sampling, Bluefin tuna, Monthly conversions

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1. Introduction

Key biological and ecological processes such as growth and stock mixing are important factors for reliable stock assessments of bluefin tuna. As a result, ICCAT has initiated a 6 year long Atlantic wide program (Grande Bluefin Year program or GBYP) intended to provide improved knowledge of stock mixing, biological characteristics (e.g. catch at age) and new analytical methods which would improve the stock assessment.

Past studies, conducted by Canada and the US, have improved our knowledge of natal origin and growth of bluefin tuna, however efforts were directed towards archived historic material which may not reflect the current situation (Rooker et al. 2008, Neilson and Campana 2008, Schloesser et al. 2010, Secor et al. *in Press*). As part of the Grande Bluefin Year Program, Canada initiated a biological sampling program aimed at providing critical information on the stock origin and age of the Canadian catch. This program supported initially for a three-year period (2011 to 2013) was designed to sample the commercial catch and reflect the spatial and temporal distribution of the fishery.

The GBYP also aims at improving the quality of Task II data for the bluefin tuna assessment. Currently, Canada derives catch at length size composition from measured weights using monthly conversion factors (described in more detail later). Quantifying and controlling the potential bias introduced by this process may improve Task II data quality or lead to alternative methods in the future.

The objectives of this paper therefore are (1) to evaluate the Canadian biological sampling program, in terms of sampling distribution in relation to landings by area, time and size (2) to present initial results of natal origin of the Canadian catch of bluefin tuna and (3) to assess the length-weight conversions in relation to bias introduced in the Task II submission.

2. Methods

2.1. Biological Sampling

Commercially caught bluefin tuna were sampled from two main fishing regions (Gulf of St Lawrence and Maritime) during the 2011-2012 fishing season (**Figure 1**). Bluefin tuna heads (labeled with a unique commercial tag number) were stockpiled by fishermen and co-ops, and then sampled by a field technician. Sampling consisted of extracting sagittal otoliths from Atlantic bluefin tuna heads and taking snout length measurements (**Figure 2**).

The commercial tag number was linked to commercial databases to obtain catch (e.g. location) and size information. In some cases, the curved fork length of the fish was not reported in commercial databases or the label with the commercial tag number was lost. In these instances, we used monthly length-weight conversion (ICCAT 2006) and snout length conversion (Secor et al. *in Press*) to calculate curved fork length.

The representativeness of the sampling program was evaluated by comparing sampling distribution to landings by area, time and size. Only measured curved fork lengths were used for length frequency distribution of landings.

2.2. Natal origin

A total of 359 bluefin tuna otolith (*sagittae*), collected in 2011 (n = 305) and 2012 (n = 54) from the Canadian Atlantic zone have been processed and analyzed to date for natal origin. An additional 250 samples were collected in 2012, but have not yet been analyzed. A single otolith (right or left) from each sample was embedded in resin and a 2.0 mm thick section was cut from the centre containing the juvenile portion of the otolith. A template from measured juvenile otolith sections was used to identify the first annulus, which increased the consistency of sampling (Rooker et al. 2008). Carbonate material was milled from the identified region using a New Wave Micromill©. Samples were analyzed for $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ ($\pm 0.1\text{‰}$ and $\pm 0.6\text{‰}$ respectively for $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$) at the University of Arizona Environmental Isotope Laboratory. Classification of the samples from each region/area into western and eastern origin was performed using the conditional maximum likelihood estimate procedure HISEA (Millar 1990; <http://www.stat.auckland.ac.nz/~millar/mixedstock/code.html>). For further information on processing of otolith and data analysis see Schloesser et al. (2010) and Secor et al. (*in Press*).

A resurgence of Atlantic bluefin tuna was noted in the Baie des Chaleurs area (**Figure 1**) during the 2011-2012 fishing season. Identifying the provenance of this resurgence is important from a stock mixing standpoint and samples from that area are planned for the 2013 fishery. As a preliminary exercise, we analyzed historical samples (n=10) collected in Caraquet and Miscou (1975-1977, **Figure 1**). Otolith $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ from historical samples were corrected for the Suess Effect prior to analysis (Schloesser et al. 2009).

2.3. Length-Weight conversion factors

2.3.1. Commercial Catch Sampling

Size data for the Canadian Bluefin fishery comes in four forms: hail-in weight (estimated by fisherman), logbook weights (weighed by fisherman and confirmed by certified dockside monitor), slip sheet (weighed and measured by dockside monitor at landing) and tally sheet weight (weighed and measured by dockside monitor at landing). Of the three regions encompassed by the Canadian bluefin tuna fishery, only the Maritime region has a tally sheet sampling program. The Gulf of St. Lawrence and Newfoundland regions all provide log information, with measurements which have been confirmed by dockside monitors (a blend of logbooks and slips). Ideally, this system results in individual size information for 100% of the bluefin tuna landed, but in some years this can be as low as 97%.

The tally sheet sampling program was initiated in 2002 and provides measurements of catches in the Maritime region. The individual fish are dressed at sea (gutted, head and tail off) and weighed by the dockside monitor at landing. A portion of the catch is measured for dressed length (head and tail cut off); subsequently, curved fork length is derived from dressed length using ICCAT conversion factors (ICCAT 2006). Since 2009, over 70% of the Maritime catch has been measured for length (**Table 1**), though some known unit and measurement errors continue to affect a small portion of the data. Despite the increasing availability of measured individual lengths, catch size composition for ICCAT Task II submissions continues to be based on measured weights obtained by dockside monitors converted to a curved fork length using monthly length-weight relationships (ICCAT 2006).

The Gulf of St. Lawrence region also has dockside monitors over-seeing the landing of the fish, but the fish are generally landed round. The weight is confirmed by the monitor in the logbook during landing and recorded in the slip. Although the length is measured for 90% of the catch in the Gulf of St. Lawrence, there have been some suspected inconsistencies of straight length measurements being recorded as curved fork length, as well as suspected misidentified units of measurement. As these issues are still being resolved, size data for Task II submissions continue to be based on weights converted to curved fork lengths.

For fish landed in Newfoundland, the weight is the only measurement verified by the dockside monitor. Although fork and dressed lengths are reported, this information often comes from estimates and has limited data quality checks. As a result, Task II catch size composition data from Newfoundland are based on weights converted to curved fork lengths.

2.3.2. Evaluation of Length-Weight conversions

Commercial catch data from the Gulf of St. Lawrence (2004-2012) and Maritime regions (2003-2012) having both measured and recorded weight and length, were used to assess the appropriateness of monthly length-weight conversion factors provided by ICCAT (ICCAT 2006). In each region, monthly length-weight conversions were used to convert round weight to curved fork length (CFL). The differences between measured and converted CFL were tested for significant deviations from zero within monthly and annual strata. The influence of area was also assessed after stratifying the data into NAFO areas (**Figure 3**). Tests for normality of the paired differences indicated that they were not normally distributed provoking bootstrap testing of the trends and biases in the data. The distribution of the bootstrap sample mean differences was based on 1000 re-samples and 95% confidence intervals were bias corrected (Canty and Ripley 2012, Davidson and Hinkley 1997). The conversion of curved fork length to round weight using monthly length-weight conversions was evaluated using identical methods.

2.3.3. Task II submissions

Canadian Task II submissions of weights converted to curved fork lengths also undergo a scaling exercise to ensure that calculated weights by gear, month and area strata equal the Canadian commercial landings of bluefin tuna in those strata. Ideally, the sampled size data is assigned to the correct strata, however each year a small portion of the sample data is identified with incorrect strata causing the sample weight to be greater or less than

the total caught weight. This issue is addressed by scaling the number of the fish at each length frequency in a given strata by the ratio of the total commercial weight to the sampled weight for that strata.

The effect of the current method of Task II submissions was estimated using Maritime commercial catch data. To estimate the bias of using weight sample to generate length frequency distributions, individual measured weights were converted to lengths using monthly conversion factors (ICCAT 2006), and the frequency distribution of the generated lengths was compared to the known measured lengths for the dataset. Consequently, only data with reliable length measurements were used in this estimation, amounting to 70% of the sampled catch in the Maritime.

The expected bias resulting from Task II submissions based on 70% sampling² compared with 100% sampling was also evaluated using the Maritime dataset. The known measured lengths were re-sampled to generate length distributions based on 70% of the data. The resulting distribution was raised to the level of the catch and compared to the true length distribution. The re-sampling was done by omitting data from single ports rather than randomly across all ports. This reflects how the data omissions occur in practice, where only certain ports fail to measure the length of the catch.

3. Results and Discussion

A total of 603 Atlantic bluefin tuna were sampled from the Gulf of St Lawrence (GSL) and Maritime regions during the 2011 and 2012 fishing seasons. The number of samples decreased slightly from 2011 ($n = 309$) to 2012 ($n = 294$), but there was an increase in areas sampled within each region (**Figure 1**). This area trend is likely to continue with increasing awareness of the biological sampling program. The monthly distribution of samples was approximately proportional to the commercial landings, indicating representative coverage of the fishing season (**Figure 4**).

Overall, approximately 20% of the total commercial landings by number were sampled each year. The proportion of total landings sampled was higher in the Gulf of St Lawrence (~12%) compared to the Maritime (~7%) (**Figure 5**). This difference in coverage is likely due to fish being dressed at sea in the Maritime region, reducing the likelihood of the head being brought back to port. There was a decrease in the proportion of catch sampled from 2011 to 2012 (**Figure 5**), but this trend resulted from an increase in the total number of tuna landed in 2011 ($n = 1517$) relative to 2012 ($n = 1659$) and not from a significant decrease in the number sampled (2011 $n = 309$ and 2012 $n = 294$).

Samples collected covered the length frequency range of landings by region and year (**Figure 6**), with the exception of the Maritime region in 2012 where sampling was biased towards fish with a curved fork length (CFL) less than 235 cm. In 2012, the length frequency distribution of landings was bimodal, with an emergence of a high number of younger fish (200-225 cm). This bimodal distribution is unusual and is consistent with individuals from the 1999-2003 year class (9-13 years old), according to the Restrepo et al. (2010) growth curve. The opportunistic nature of the sampling in both regions captured this influx of younger fish, which may be important from a stock mixing standpoint (**Figure 6**). Furthermore, ageing of samples may provide increased accuracy to year class assignment of these younger fish. It should be noted that there was no coverage in the Newfoundland region (**Figure 5**), which has had an increase in the number of landings in recent years (**Figure 7**).

The initial natal origin analyses of Canadian biological samples indicated that 99.9% of fish in the Gulf of St. Lawrence were of western origin, compared with 85.0% of Maritime fish (**Table 2, Figure 8**). The predominance of western fish in all areas of the Gulf of St. Lawrence conforms to previously reported natal origin of fish in this region (Rooker et al. 2008, Schloesser et al. 2010). Similarly, estimates of natal origin of fish in the St Margaret's Bay region (90% $\pm$ 11 western) were slightly lower but comparable to those reported by Schloesser et al. (2010) (99% western origin). The Wedgeport area showed higher occurrence of western origin fish (96% western) than the overall Maritime region (85% western). However, the occurrence of western/eastern fish in the Canso area was high (64.5% western-35.5% eastern) and similar to those reported in the Mid Atlantic Bight for giant bluefin tuna (64.9% western-35.1% eastern) (Rooker et al. 2008). However, it should be noted that Canso's natal origin results are based on a relatively small sample size ($n = 52$) (Note: An additional 33 samples collected from Canso in 2012 are yet to be analyzed).

² This is the current proportion of catch with reliable length measurements (excludes absent lengths and those with suspected unit or measurement errors).

³ NAFO: Northwest Atlantic Fisheries Organization.

The goodness of fit of measured curved fork lengths to estimates of curved fork length based on ICCAT conversions of weight was evaluated for both the Maritime and GSL regions (**Figure 9**). The results showed that most of the data followed a 1:1 linear relationship except for a proportion of 4W fish in the Maritime and 4TG fish in the GSL. The conversions generally overestimate the length in 4W but, as the monthly plots indicate, this is only true for September to November, while in May the conversion underestimates the length. Interestingly, over the years the number of 4W fish that do not fit the linear relationship has decreased. In contrast, conversions for fish in 4TG only overestimate length, with no evident underestimation (**Figure 9**). Similarly to the Maritime, this overestimation occurs in September-October, but appears to be a distinctive feature of 2012. The loess lines fit to the data show no distinct patterns in either the monthly or annual plots of the residuals (**Figure 10**); however bootstrap testing indicated that estimated curved fork length significantly underestimates actual measured length of bluefin tuna (**Figure 11**). Furthermore, this underestimation of length appears to increase monthly and yearly in both regions, except for October in the Maritime region. The trending in the bias associated with using the ICCAT conversions indicates that any bias introduced into the catch at age table could be becoming progressively worse and that the monthly length-weight conversion factors require periodic validation and updating or perhaps should incorporate regional variation.

The goodness of fit of the measured round weight to estimates of round weight based on ICCAT conversions of length was similar to the measured and estimated curved fork length fit described above. However, the loess lines showed a strong pattern in the residuals that related to fish length both in the total population and by month. The trend was to underestimate weights for small fish and increasingly over estimate weights as the fish become larger. The variation in the differences was large for small fish and decreased for larger fish (**Figure 12**). The bootstrap statistics indicated that estimated round weight significantly over-estimated actual measured weight of bluefin tuna. This overestimation of length appears to increase monthly and yearly in both regions, except for October in the Maritimes (**Figure 13**). These results indicate that using monthly conversion factors to convert curved fork length to round weight would introduce a bias dependent upon the size of the fish.

It should be noted that there was a distinct difference in the fit of data between regions. For instance, the measured and estimated weight/length from the Gulf of St. Lawrence data showed a tighter fit to the linear relationship, as compared to the Maritime data (**Figure 9, 10**).

Canadian Task II catch length distributions are currently derived from measured weights using monthly length-weight conversion factors (ICCAT 2006). Given our findings above, the use of a conversion relationship is expected to introduce a bias into the Task II data which would shift the weight-derived size distribution away from the actual length distribution of the catch. When applied to annual Maritime Task II data with reliable length measurements, the differences between the measured and converted lengths for individual fish result in a positive bias (**Figure 14**), supporting the finding that length-weight conversion factors underestimate the actual length of the fish. However, when looking at the generated length distributions for the whole sample, the cumulative frequency of both the measured and the converted length types overlap for fish >200 cm in most years (**Figure 15**). Interestingly, prior to 2008 there was an obvious mismatch of the length frequencies for fish smaller than 200 cm, where converted lengths did not represent this size class well. In recent years, however, this disparity appears to have been remedied.

The effect of conversion bias on current Task II submissions results in apparently contradictory conclusions. A directional bias emerges (underestimation of fish lengths derived from weights) when analyzing the effect of conversions on individual fish, whereas the cumulative length frequency distribution generated for the whole stratum does not seem to reflect this magnitude of bias. An explanation is that, on a population basis, unusually heavy fish from 4W are counteracting the effect of the conversion bias; however, this possibility was not examined in detail in this analysis. Regardless of the cause, these divergent conclusions emphasize the need to further examine the current method of Task II submissions. Also, given the persistence of bias in length-weight conversions for individual fish, a possible solution may involve deriving new length-weight conversion relationships specific to the size class of fish found in Canadian waters.

An alternative approach for Task II data submissions would be to raise the length frequency distribution of measured lengths from a sample of the catch to the length distribution for the total catch. The bias introduced by this alternative approach is expected to be slight, given the present percentage of lengths reported (**Figure 16**). Currently, a large proportion (70%) of the annual catch data in the Maritime region has an associated measured length while the current weight-based approach offers 100% of the data with a reported weight.

4. Recommendations

In summary, the Canadian biological sampling program appears to have adequate coverage in relation to landings by area, timing and size. However, the lack of sampling in the Newfoundland region and distant areas where fish are appearing, or re-appearing (e.g. Baie des Chaleurs, Bonaventure Bay, Trinity Bay), should be addressed as it could contribute novel critical insights into stock mixing of Atlantic bluefin tuna.

The natal origin results indicate that eastern origin fish contribute to Canadian Maritime region fisheries. This was particularly true for the Canso area, but this result is primarily based on a single year's sample (2011). Furthermore, these results contrast previous studies which reported mainly western fish in Canadian waters (Rooker et al. 2008, Schloesser et al. 2010). This may reflect episodic eastern migrants in Canadian waters, highlighting the need for sustained sampling efforts. Future work should focus on analyses examining covariates of mixing such as size-class, region of harvest, and season.

The use of monthly conversion to estimate round weight significantly overestimated actual measured weight of bluefin tuna. Therefore, in the event that only curved fork length is reported, this conversion bias should be taken into account.

The use of monthly conversion factors to estimate curved fork length biases length downwards and this bias increases annually and by month for both regions. The bias could be as large as 8 cm in some months and years. These monthly length-weight conversion factors appear to work poorly on a proportion of Atlantic bluefin tuna caught in NAFO area 4W and 4TG. The effect of these biases on the Task II data and subsequent impact on the assessment of Bluefin tuna needs to be quantified and there should be periodic validation and updating of the conversion formula with consideration given to incorporating possible regional variation. The difference in the performance of length-weight conversion factors between regions requires that we examine the morphology of the fish and the monitoring within regions more formally, especially the 4W and 4TG sub-populations.

It is recommended that Canadian national scientists discuss this option with the Secretariat, to further evaluate its feasibility. A further option would be to develop new weight-length relationships that better reflect the observations from the Canadian fishery.

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Table 1. Number and proportion of fish landed and measured by Dockside Monitors in the Maritime region.

Year	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
N Landed	2,294	2,413	1,875	2,187	2,588	1,551	2,090	1,114	1,040	1,002	926
N Length	0	24	1,125	1,281	1,700	965	1,228	826	761	711	684
%	0%	<1%	60%	58%	66%	62%	59%	74%	73%	71%	74%

Table 2. Estimates of natal origin of Atlantic bluefin tuna sampled in the Gulf of St Lawrence (GSL), Maritime and St Margarets Bay (SMB) regions during the 2011 (n = 305) and 2012 (n = 54) fishing season. Historic samples were collected in the period of 1975-1977. CFL = curved fork length; MLE = maximum likelihood estimate of population compositions; SD = standard deviation.

Region	Area	N	CFL (cm)	Population	MLE %	MLE SD
GSL		191	186-313	West	100.0	0.2
				East	0.0	
	North Lake	80	197-307	West	100.0	0.0
				East	0.0	
	Port Hood	54	186-310	West	98.6	2.7
				East	1.4	
	Tignish	57	222-307	West	96.6	4.4
				East	3.4	
Maritime		151	127-300	West	85.0	5.4
				East	15.05	
	Wedgeport	99	149-300	West	96.0	4.2
				East	3.4	
	Canso	52	127-277	West	64.5	10.2
				East	35.5	
SMB		17	175-277	West	89.3	11.6
				East	10.7	
GSL Historic		10	274-297	West	100.0	0.0
				East	0.0	

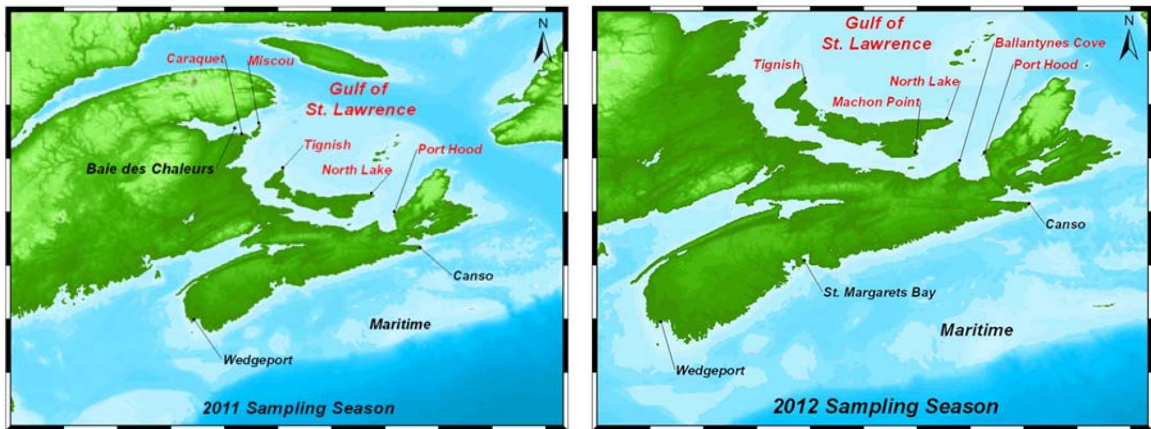


Figure 1. Areas sampled in the Gulf of St. Lawrence and Maritime region during the 2011-2012 fishing season. Note: 2011 Sampling map illustrates sampling location of historic samples.

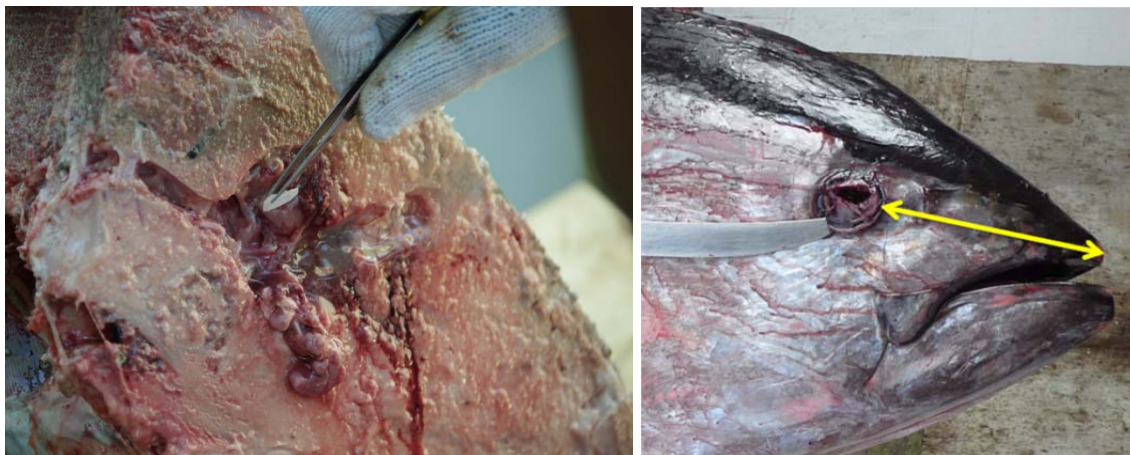


Figure 2. Photograph showing the extraction of a sagittal otolith from a bluefin tuna head and illustrating the snout length measurement (snout length are taken with a flexible measuring tape from the tip of the upper jaw to the most anterior edge of the orbit).

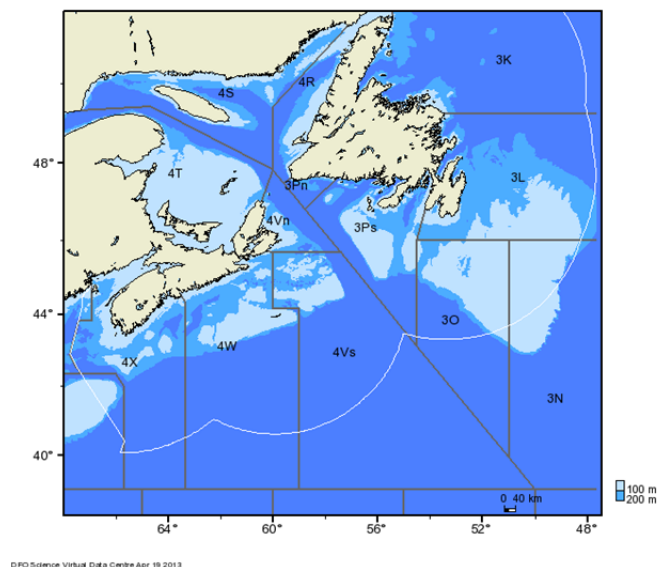


Figure 3. Map showing the major NAFO areas in the Gulf of St. Lawrence, Maritime and Newfoundland regions.

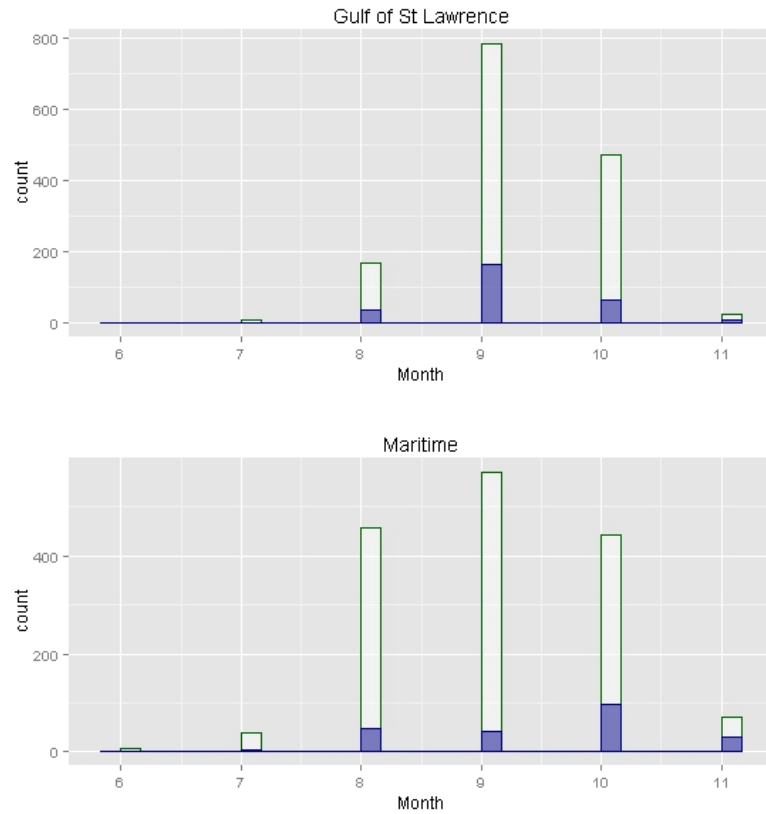


Figure 4. Superimposed monthly distribution of landings (green) and samples (blue) in the Gulf of St Lawrence and Maritime region for 2011 and 2012.

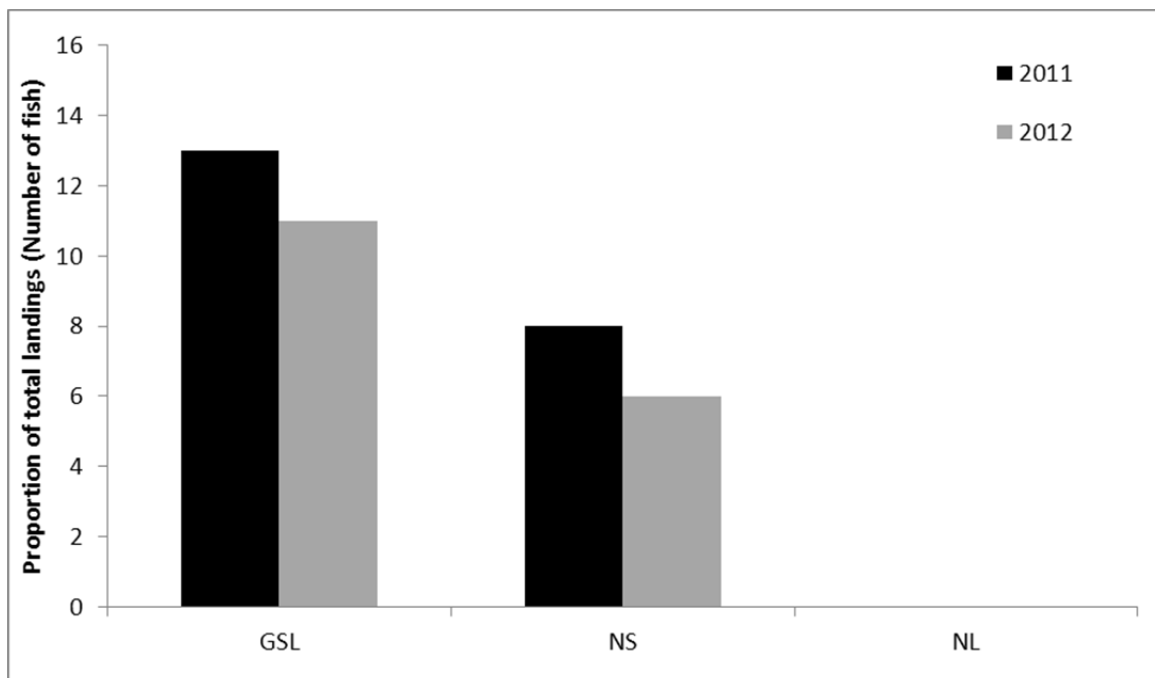


Figure 5. Proportion by number of the bluefin tuna sampled from total landings by region in 2011 and 2012. GSL = Gulf of St. Lawrence, NS = Maritime and NL = Newfoundland. Fork Length were binned by 5cm interval.

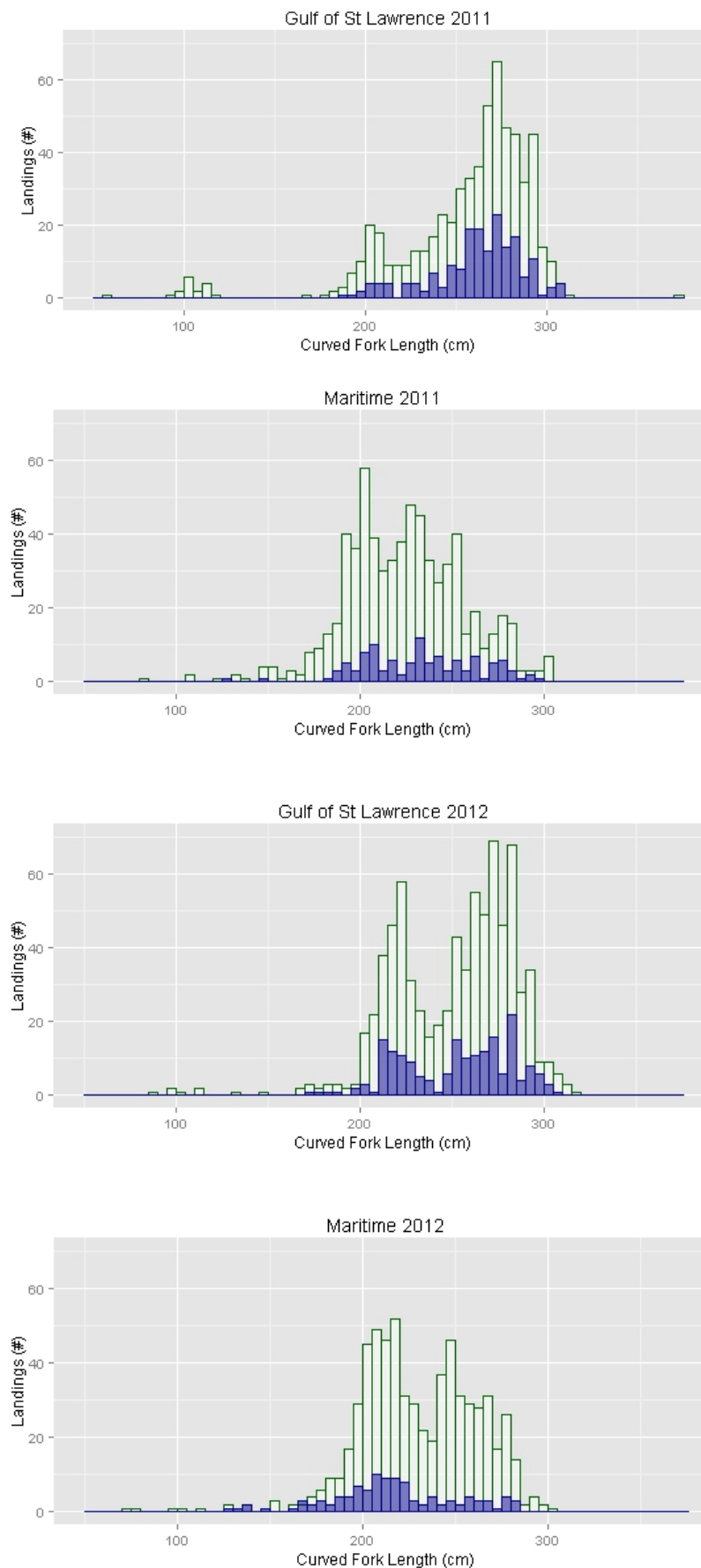


Figure 6. Superimposed length frequency of landings (green) and samples (blue) in the Gulf of St. Lawrence and Maritime regions. Note: Curved

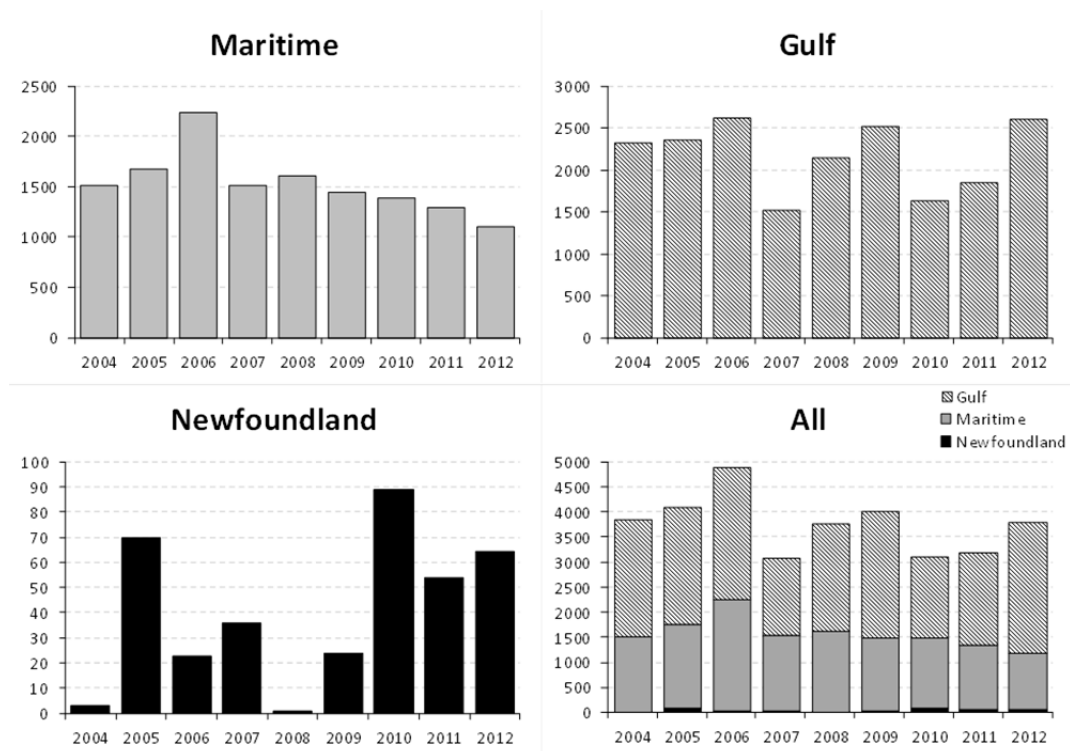


Figure 7. Annual number of western Atlantic bluefin tuna caught by the pelagic longline fleet and landed by region (Maritime, Gulf, Newfoundland) in Canadian waters. Bottom right plot shows combined catch (number of fish) for all three regions.

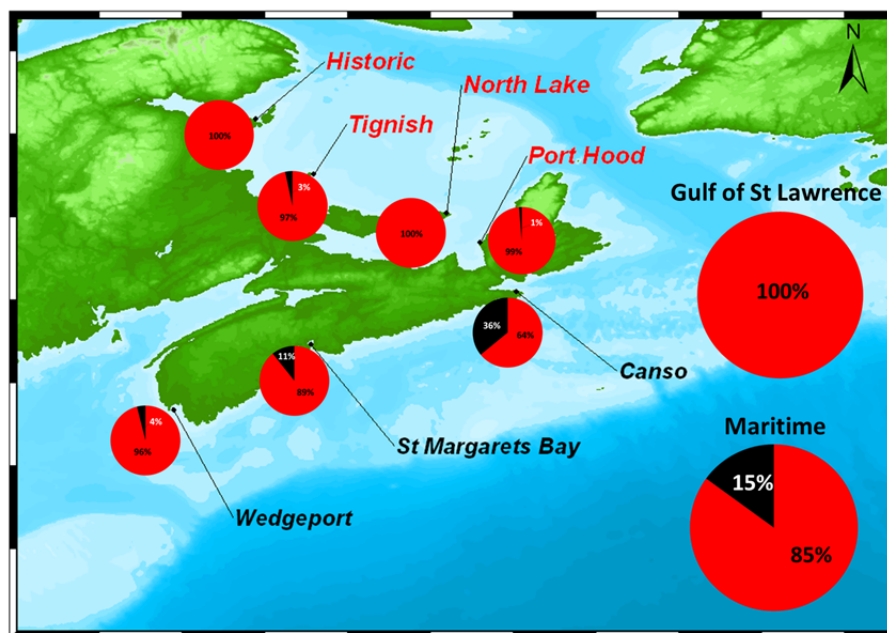


Figure 8. Estimates of natal origin of Atlantic bluefin tuna from the Gulf of St. Lawrence, Maritime and St Margarets Bay regions and associated sampling areas (red = western origin and black = eastern origin).

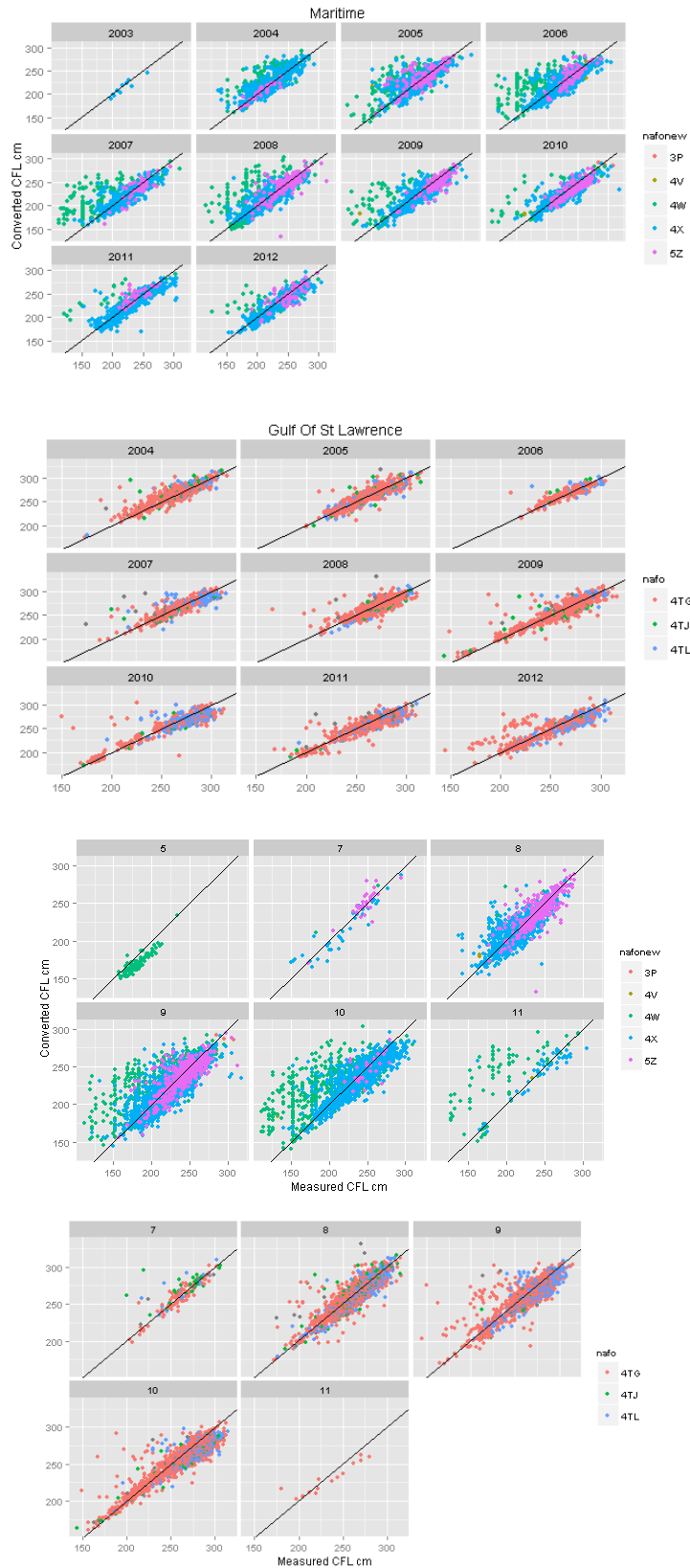


Figure 9. Measured vs. converted curved fork length by year (a) and month (b) for the Maritime and GSL regions. The line shows the expected 1:1 relationship. The converted curved fork length was derived from round weight using ICCAT monthly conversion factors (ICCAT 2006).

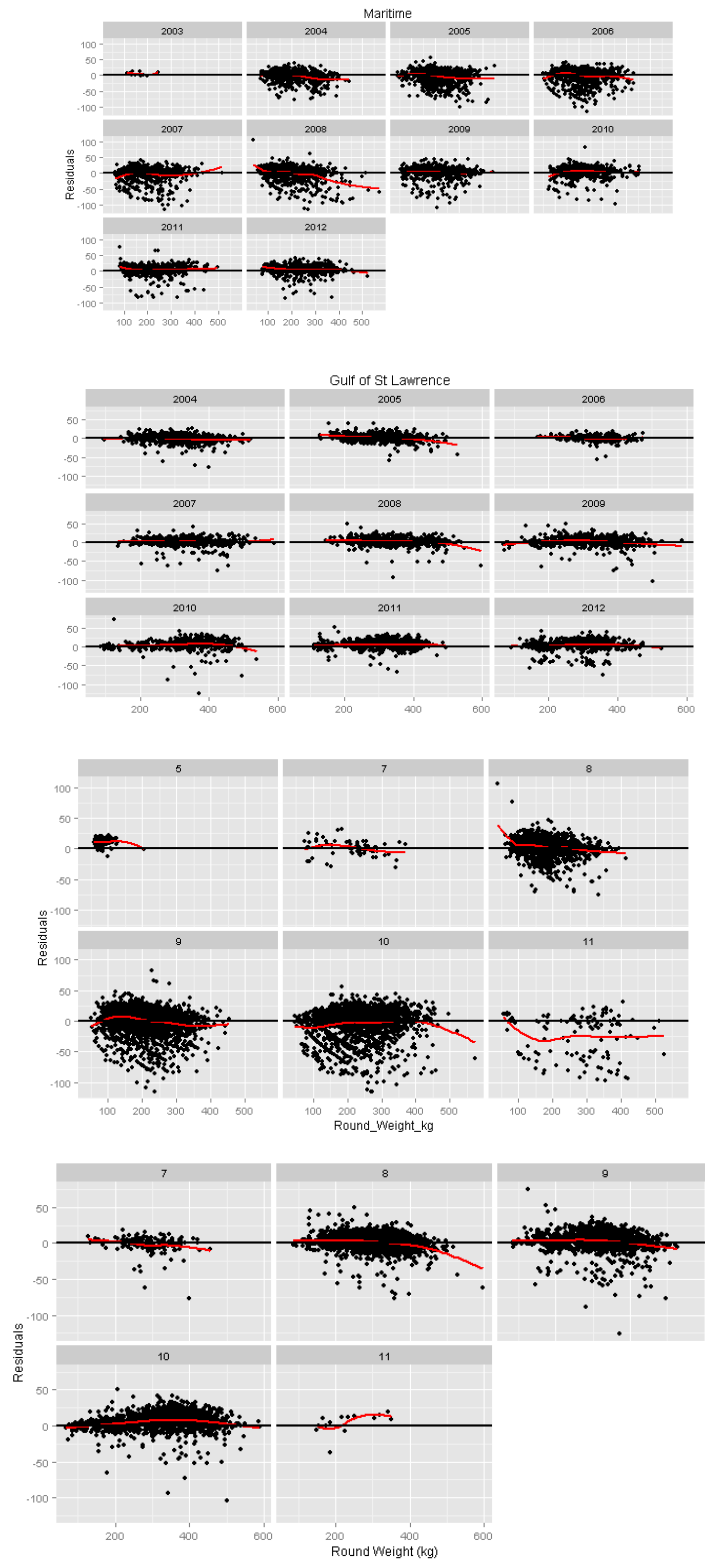


Figure 10. Residuals (measured – converted curved fork length) vs. round weight by year and month for the Maritime and GSL regions. The red line = loess smooth line ($\alpha=0.9$).

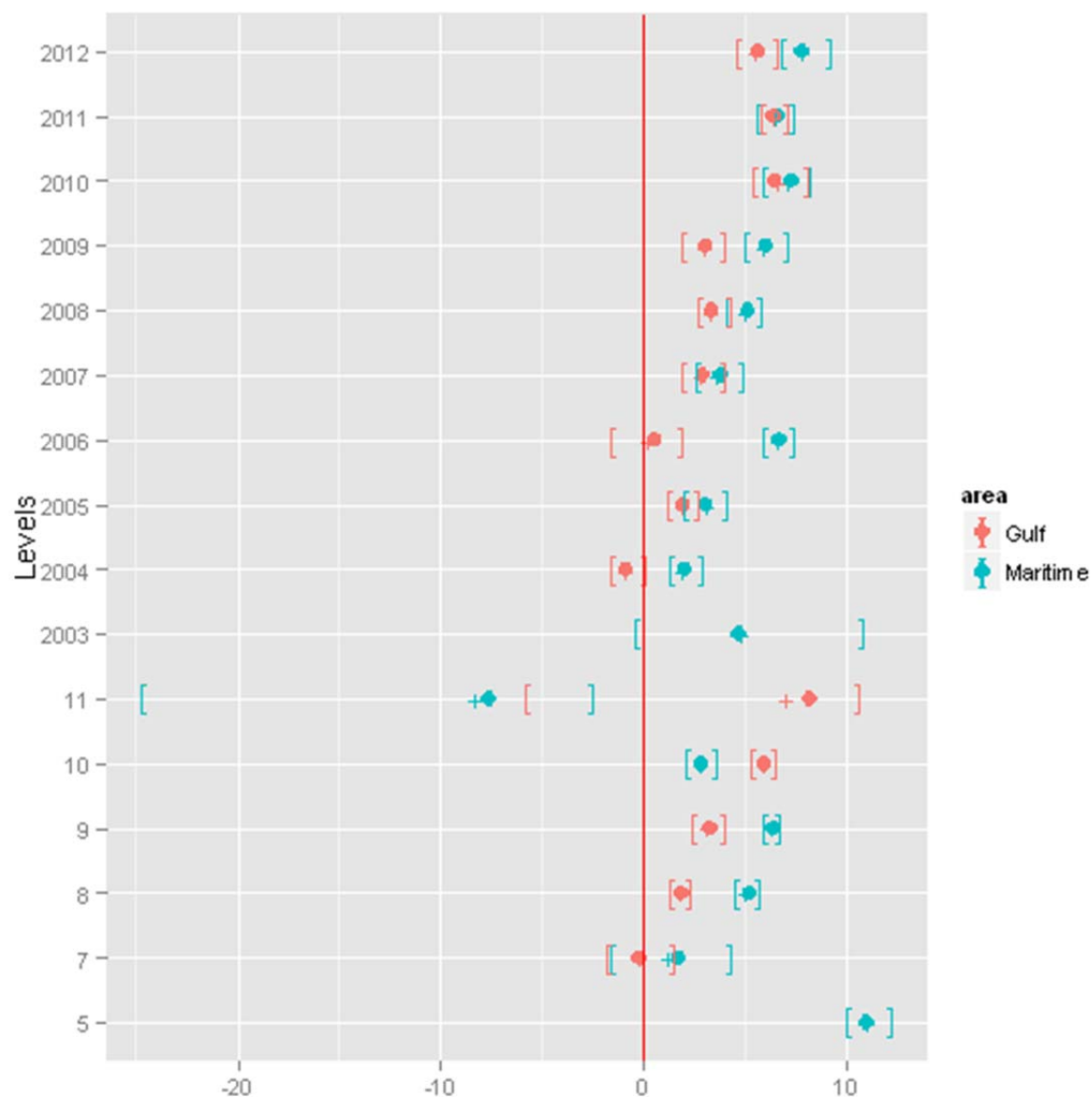


Figure 11. Average difference in measured and converted curved fork length by month and year in the Gulf of St. Lawrence (Gulf) and Maritime regions. The observed average difference is represented by a point, the average of 1000 bootstrap mean differences is represented by a cross and square brackets reflect the bias corrected 95% percentile confidence intervals.

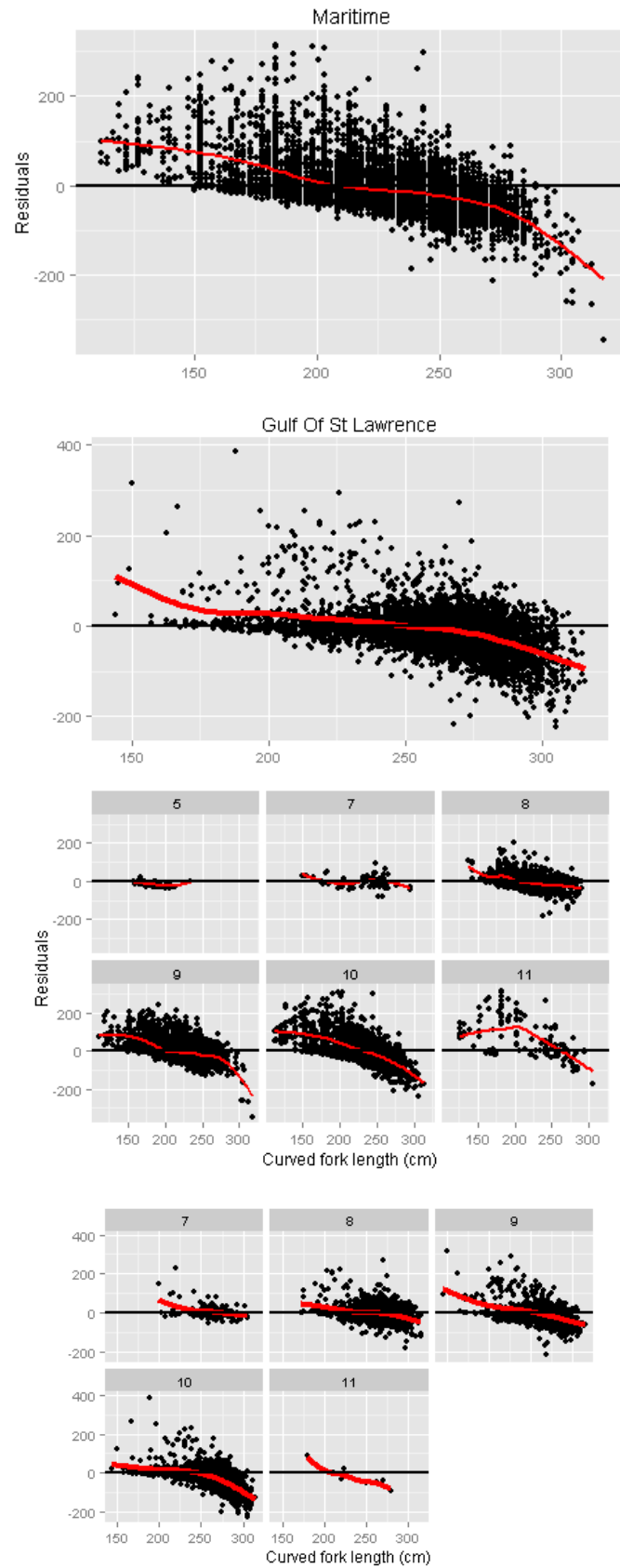


Figure 12. Residuals (measured – converted round weight) vs. curved fork length by year and month for the Maritime and GSL regions. The red line = loess smooth line($\alpha=0.9$).

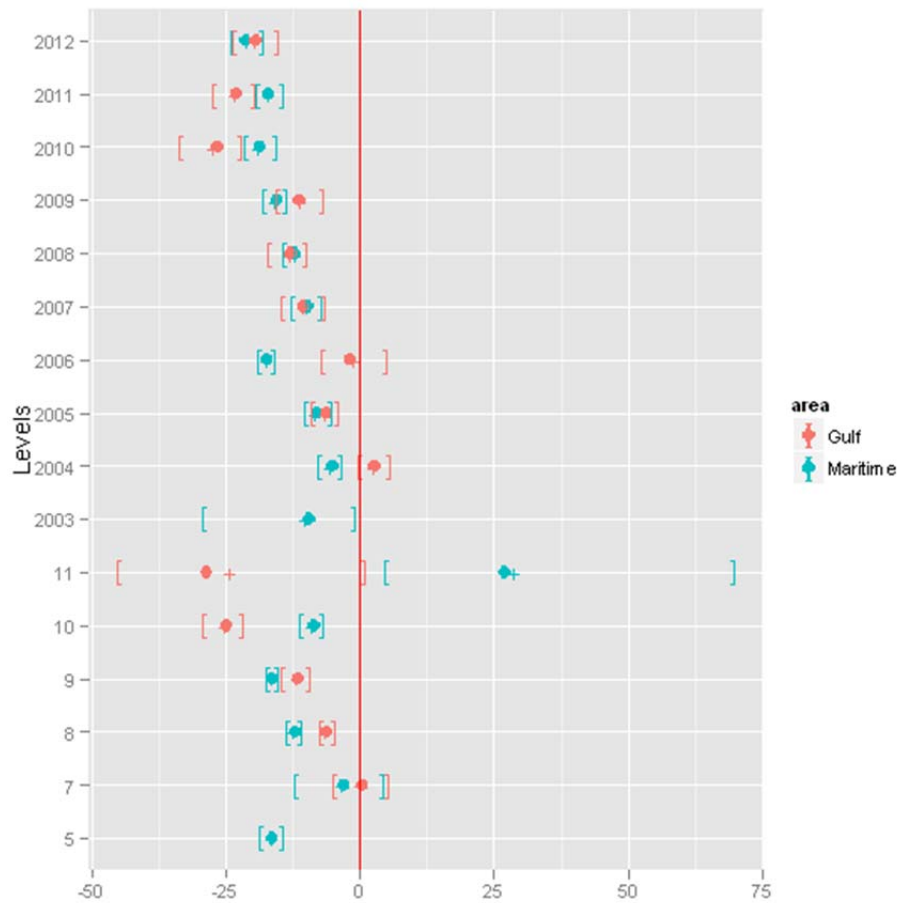


Figure 13. Average difference in measured and converted round weight by month and year in the Gulf of St. Lawrence (Gulf) and Maritime regions. The observed average difference is represented by a point, the average of 1000 bootstrap mean differences is represented by a cross and square brackets reflect the bias corrected 95% percentile confidence intervals.

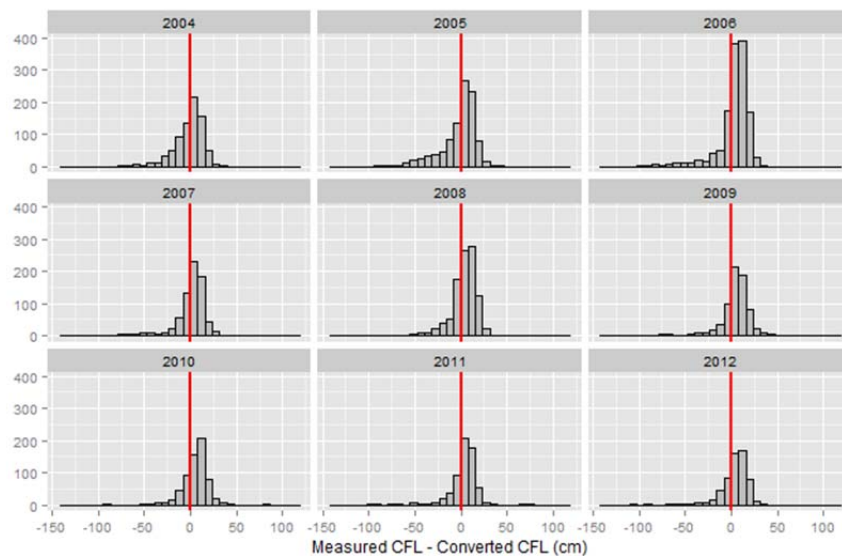


Figure 14. Annual distribution of differences between measured and converted CFL for individual fish in the Maritime region. Data have been limited to fish with reliable length measurements. Red line marks no difference between measured and converted lengths, and is used as a reference.

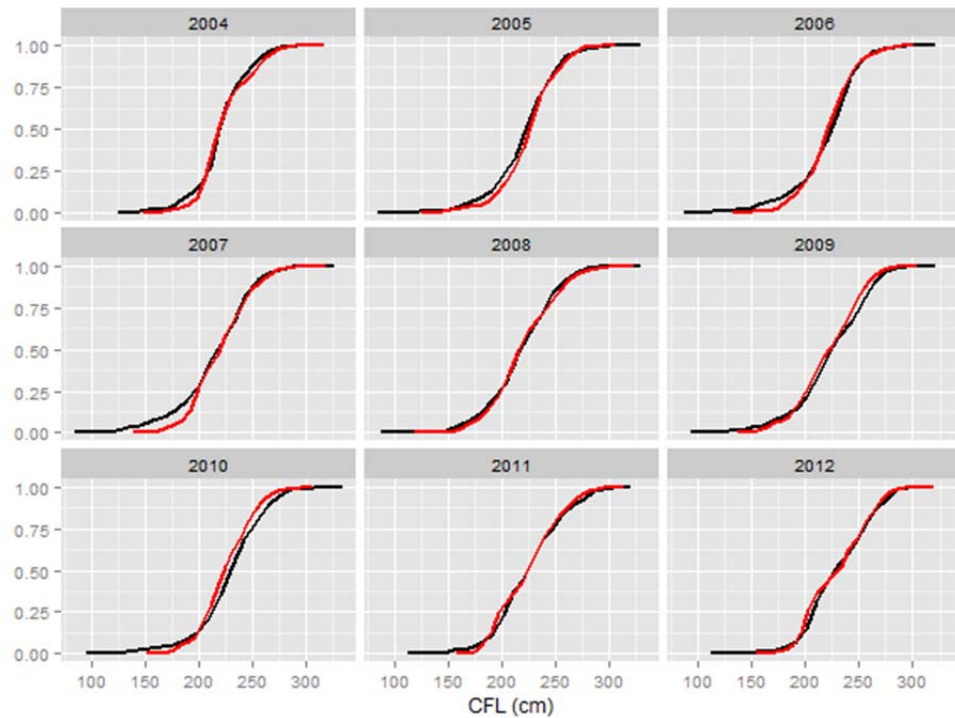


Figure 15. Cumulative frequency distribution of annual catch data from the Maritime. Black line indicates distribution for actual measured lengths; red line indicates distribution of lengths converted from measured weights.

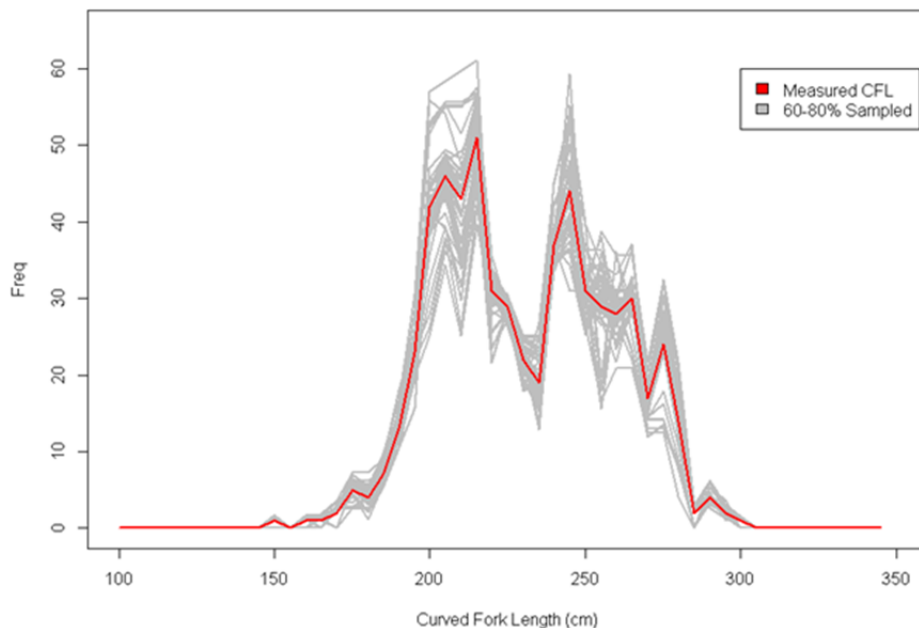


Figure 16. Estimated effect of using a sample of measured lengths to infer the size composition of the 2012 commercial catch in the Maritime region. The samples are comprised of non-random, port-based sampling of 60-80% of the catch and are intended to mimic the current length sampling process of the Canadian dockside monitoring program. The red line indicates actual size frequency distribution of the catch; grey lines indicate replicate raised length frequency distributions based on scenarios of 60% – 80% length sampling of the catch.