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UPDATED STANDARDIZED CPUE INDICES FOR CANADIAN BLUEFIN TUNA FISHERIES BASED ON COMMERCIAL CATCH RATES*

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SUMMARY

Updated standardized relative abundance indices are presented for Canadian bluefin tuna fisheries in the Gulf of St. Lawrence (1981-2001) and off Southwest Nova Scotia (1988-2001) based on data from commercial log records. Methods used were as in the 1998 and 2000 Bluefin Tuna Stock Assessments. A delta lognormal-binomial model was used to standardize the Gulf of St. Lawrence series, which is characterized by high proportions of "0" catch trips and a Poisson loglinear model was used for the Southwest Nova Scotia data. In addition, alternate analyses (also presented in 2000) using step-wise regression to determine the most appropriate delta lognormal-binomial model specifications for standardizing CPUE series are presented for both series and are recommended for use in the 2002 stock assessment. CPUEs in the Gulf of St Lawrence have increased since 1997 so that the 1999-2001 values are higher than all but two years since 1985. On the other hand, catch rates for the year 2000 in Southwest Nova Scotia were the lowest of the time series, with recent years generally similar to the mid- to late 1990s.

RÉSUMÉ

Le présent document fournit une actualisation des indices standardisés de l'abondance relative pour les pêcheries de thon rouge canadiennes dans le Golfe du St Laurent (1981-2001) et au large du sud-ouest de la Nouvelle-Ecosse (1988-2001) en se fondant sur les carnets de bord commerciaux. Les méthodes utilisées étaient semblables à celles employées lors des évaluations du stock de thon rouge de 1998 et 2000. Un modèle delta lognormal-binomial a été utilisé pour standardiser la série du Golfe du St Laurent, qui se caractérise par de fortes proportions de sorties avec des prises « 0 », tandis qu'un modèle loglinéaire Poisson a été employé pour les données du sud-ouest de la Nouvelle-Ecosse. En outre, des analyses alternatives (également présentées en 2000) ayant recours à une régression pas à pas pour déterminer les spécifications les plus appropriées du modèle delta lognormal-binomial pour la standardisation de la série de CPUE sont présentées pour les deux séries et l'on recommande leur application à l'évaluation du stock de 2002. Les CPUE dans le Golfe du St Laurent augmentent depuis 1997 de telle manière que les valeurs de 1999-2001 sont les plus fortes depuis 1985, sauf pour deux années. D'autre part, les taux de capture pour 2000 dans le sud-ouest de la Nouvelle-Ecosse étaient les plus faibles de la série temporelle, les dernières années étant généralement similaires à la période allant du milieu à la fin des années 90.

RESUMEN

Se presentan índices estandarizados de abundancia relativa actualizados para las pesquerías canadienses de atún rojo en el Golfo de San Lorenzo (1981-2001) y en las aguas al suroeste de Nueva Escocia (1988-2001) basados en los datos de los registros de los cuadernos de pesca comerciales. Se utilizaron los mismos métodos que en las evaluaciones del stock de atún rojo de 1998 y 2000. Se utilizó un modelo delta-lognormal binomial para estandarizar las series del Golfo de San Lorenzo, que se caracterizan por una alta proporción de mareas con capturas "0"; para los datos del Suroeste de Nueva Escocia se utilizó un modelo loglineal de Poisson.

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Además, se presentan para ambas series análisis alternativos (que también se presentaron en 2000) que utilizan una regresión por fases para determinar las especificaciones del modelo delta-lognormal binomial más apropiadas para estandarizar las series de CPUE, y se recomiendan para su utilización en la evaluación de stock de 2002. Las CPUEs en el Golfo de San Lorenzo se han incrementado desde 1997, de modo que los valores de 1999-2001 son superiores a todos los demás desde 1985, con la excepción de dos años. Por otro lado, las tasas de captura para el año 2000 en el Suroeste de Nueva Escocia son las más bajas de la serie temporal, y en los años recientes fueron en general similares a las de mediados y finales de los noventa.

1. INTRODUCTION

Cooke and Lankester (1996) and Cooke (1997) suggested procedures for standardizing CPUE indices that can take account of process-related variability and lack of independence between observations in catch rate time series through the application of a random effects modeling method. Incorporation of this added variability is useful in application of variance weighting approaches in the stock assessment modeling methods. The SCRS has recommended the application of variance weighting procedures in bluefin assessments, using variance determined externally to the stock assessment model as an objective way of incorporating uncertainty about and inferring relative weights of the tuning index patterns into the assessment procedure. At the 1998 bluefin assessment meeting, additional analyses of the Canadian catch rate data (Stone and Porter 1999) were conducted at the working meeting to apply random effects models to account for correlation between observations in these time series. For future assessments, it was recommended that application of the random effects approach be implemented across all the time series used for indexing abundance or that other appropriate methods be applied to incorporate variability resulting from significant year interactions in the standardization procedures applied.

This manuscript updates (by two years: 2000 and 2001) the previous standardized Canadian series for bluefin tuna fisheries in the Gulf of St. Lawrence (age 13+, 1981-99) and off Southwest Nova Scotia (ages 7-13, 1988-99) developed by Stone *et al.* (2001) using the random effects modeling method developed at the 1998 Working Group meeting (Anon. 1999). In addition, alternate analyses using step-wise regression to determine the most appropriate delta lognormal-binomial model specifications are presented for both series (as was done in Stone *et al.* 2001). The 2000 Bluefin Tuna Working Group did not determine which method was superior and both methods are again presented in 2002 with our recommendation for the Working Group. Both series encompass the complete range of sizes of bluefin tuna found in Canadian waters and include new observations from the 2000 and 2001 fishing seasons with information from different fleet sectors, gear types and areas fished.

1.1 Description of the fisheries and selection of catch rate series

Canadian bluefin tuna fisheries currently operate in several geographic areas off the Atlantic coast from July to November when bluefin tuna have migrated into Canadian waters (Fig. 1). The main commercial fisheries occur off the coast of Nova Scotia (Hell Hole rod and reel/tended line, Bay of Fundy harpoon, St. Margaret's Bay trap, Canso rod and reel, and Halifax rod and reel/tended line), in the southern Gulf of St. Lawrence (tended line/rod and reel) and sporadically along western edge and central region of the Grand Banks (tended line/rod and reel). Generally, locations of bluefin tuna captured within these areas have been consistent over the past two years, and are comparable to those reported by Stone and Porter (1999) and Stone *et al.* (2001) for 1994 through 1999. Since the inception of the Hell Hole fishery in 1988, catches from the Hell Hole have predominated the Canadian fishery, with the exception of 2000 when the Gulf of St. Lawrence surpassed the Hell Hole in importance (Fig. 1, NAT/02/01). However, in 2001, the trend was again similar to the 1990s.

Only the Gulf of St. Lawrence and Southwest Nova Scotia (Hell Hole and Bay of Fundy) fisheries were considered for analyses as they provide adequate time series (Stone *et al*. 2001). There are no effort data available for the St. Margaret's Bay trap fishery, the Newfoundland tended line/rod and reel fishery tends to be highly variable due to its association with closures in groundfish fishery. The coastal Halifax and Canso fisheries are still fairly recent and were not evaluated for this update, however, the time series for these fisheries may be long enough to evaluate their performance as separate indices for a future assessment.

As in previous years, the average weight of bluefin tuna captured in the Gulf of St. Lawrence was higher than those from fisheries along the Atlantic coast of Nova Scotia, all of which appear to be comprised of different subgroups of variable-sized fish (Fig. 2). Bluefin captured off Southwest Nova Scotia (Hell Hole, Bay of Fundy) continue to be smallest overall, with slightly larger fish captured off Halifax and Canso. The major fisheries (e.g., Gulf of St. Lawrence, Hell Hole, Bay of Fundy) have shown a general trend of declining mean weight over the past five years. Several factors may be responsible for the observed decrease in size, including warmer water temperatures in recent years (which may allow more smaller fish to enter Canadian waters), a shift in fishing activity to the months of September and October (when more small fish are present due to seasonal warming of water temperatures), and to market conditions which favour smaller sized fish.

Two separate standardized indices were developed based on (1) the spatial distribution of catches, (2) differences in the size of fish captured, and (3) patterns of nominal CPUE: Gulf of St. Lawrence tended line/rod and reel (1981-2001), and Southwest Nova Scotia tended line/harpoon/rod and reel (=Hell Hole plus Bay of Fundy, 1988-2001). Using the von Bertalanffy growth parameters calculated by Turner (1994), the Southwest Nova Scotia fisheries capture bluefin tuna aged 7-13 and the Gulf of St. Lawrence fishery captures bluefin tuna aged 13+. These two series encompass the overall size/age range of tuna captured in the Canadian fishery and represent about two thirds of the Canadian landings.

2. METHODS

2.1 Catch and effort data

In Canada, submission of log records for the bluefin tuna fishery was initially done on a voluntary basis, although since 1994 it has been mandatory. While log record coverage has varied over the years, it has been assumed that what is available is representative of the fishery. The computerized log records provide detailed information on catch (number and weight of tuna), effort (hours fished), date, gear type, home port (fleet) and catch location (latitude and longitude). These data were edited and condensed to the trip level to provide total number of fish and total number of hours fished per trip by area, fleet, month and gear type. Catch per hour was the unit measure of effort selected for all fisheries used in the standardized series. This measure is most appropriate when effective fishing time during a day is generally limited to a period of time influenced by the tidal cycle and when trips occur over more than one day (i.e., Hell Hole). Standardized CPUE was calculated as the number of tuna captured per trip divided by total hours fished per trip. For the delta model formulations the nominal CPUE for both the Gulf of St Lawrence and Southwest Nova Scotia was scaled by a factor of 100.

2.1.1 Gulf of St. Lawrence Series

The Gulf of St. Lawrence standardized index was based on catch and effort data for vessels with 10+ trips per year and included observations for 21 years (1981-2001), three months (August, September, October), two fleets (Prince Edward Island and Gulf Nova Scotia) and two gear types (tended line, rod and reel) (n= 53,630 trips). The 10+ trip threshold restricts the analysis to full time, experienced fishermen that fish the main months of the fishery (August-October). While the Prince Edward Island fleet has more observations and higher catch rates than the Gulf Nova Scotia fleet, both fleets have similar trends in nominal CPUE across gear types (Stone *et al.* 2001). Trips with CPUE=0 were included in the series and represented over 90% of the observations, therefore, the data used in these analyses are binomially distributed, with catch observations of zero or one (Fig. 3; Stone *et al.* 2001).

2.1.2 Southwest Nova Scotia Series

Catch and effort data aggregated by trip from the Hell Hole (1988-2001) and Bay of Fundy (1992-2001) areas were combined and used in the development of a standardized CPUE series for Southwest Nova Scotia (see Stone *et al.* 2001). Catch data for this series essentially followed a Poisson distribution; trips with catch=0 were included in the series and represented 24% of the observations while the remaining 76% consisted of trips with catches ranging from 1 to 22 fish (Fig. 3). The data set used for CPUE standardization included observations for 14 years (1988-2001), two areas (Hell Hole, Bay of Fundy), five fleet sectors (Nova Scotia, Prince Edward Island, Quebec, Gulf Nova Scotia, Gulf New Brunswick), three gear types (rod and reel, tended line, harpoon), and three months (August, September, October) (*n*=4,131 trips). The present analyses include additional observations for rod and reel trips in the Hell Hole back to 1996 when this gear was first used in addition to tended line. Over the past four years, the use of rod and reel gear has become increasingly popular (Stone *et al.* 2001). Nominal catch rate trends for rod and reel are similar to the other gears fished off Southwest Nova Scotia as are trends among the various fleets over the time series (Stone *et al.* 2001).

2.2 Models and specifications

2.2.1 Update of 1998 Assessment Series

The Canadian CPUE series have been updated using the model formulations chosen by the 1998 Bluefin Tuna Working Group (Anon. 1999) and were modeled using general linear mixed models (GLM's) with random effects terms to take account of correlation between observations within each series. The Gulf of St. Lawrence index was derived using a delta lognormal-binomial approach in which separate analyses were conducted on the proportion of fishing trips with positive catches and on trips with positive catches. The proportion of positive trips was modeled as a binomial distribution, while the mean catch rate of positive trips was modeled as a lognormal distribution. The logit function was used to link the linear factor component and the binomial error. Estimates for the proportion of successful trips and CPUE for trips with positive catch were based on a linear function of fixed factors and random effect interactions between the *year* term. For the Southwest Nova Scotia series, where there is a higher proportion of positive trips, a Poisson loglinear approach was used to model the number of bluefin caught with an offset of the log of fishing hours.

For the **updated Gulf of St. Lawrence standardized series**, the models (based on the 1998 bluefin tuna stock assessment session (Anon. 1999)) that were combined using the delta-binomial method with random effects to produce a single index included the following variables:

Proportion positive:

Fixed effects: year gear*fleet
Random effects: year*month

Positive catch rates:

Fixed effects: year fleet month
Random effects: year*month

For the **updated Southwest Nova Scotia standardized series**, the final model (based on the 1998 bluefin tuna stock assessment session (Anon. 1999)) included the following variables:

Poisson log-linear model:
Fixed effects: year month area fleet
Random effects: year*month year*area year*month*area

2.2.2 Alternate Analyses

Further, alternate analyses, proposed in 2000, using step-wise regression to determine the most appropriate delta lognormal-binomial model specifications have been updated. In the absence of rationale for the 1998 model formulation, these additional analyses were performed. For the Gulf of St. Lawrence, slightly different delta lognormal model formulations were used. For the Southwest Nova Scotia series, the Poisson loglinear model of the 1998 Working Group was compared to an alternative delta lognormal-binomial model that provided an adequate alternative, a reasonable fit to the data (given that 24% of the trips had zero catch), and trends similar to the nominal series. The authors recommend the use of these alternate models as the rationale for the selection of the model variables is well documented and defensible (Stone *et al.* 2001).

For the new delta lognormal-binomial models developed for the 2000 bluefin tuna assessment, a step-wise regression procedure was used to determine the set of systematic factors and interactions that significantly explained the observed variability (Table 1). The difference of deviance between two consecutive models follows a χ^2 (Chi-square) distribution. This statistic was used to test for the significance of an additional factor in the model. The number of additional parameters associated with the added factor minus one corresponds to the number of degrees of freedom in the χ^2 test (McCullagh and Nelder, 1989 pp 393). Final selection of explanatory factors was conditional on: a) the relative percent of deviance explained by adding the factor in evaluation (normally factors that explained more than 5 % were selected), b) the χ^2 test significance, and c) the type III test significance within the final specified model.

Once a set of fixed factors was specified, possible interactions were evaluated, in particular interactions between the *year* effect and other factors. Selection of the final mixed model was based on the Akaike's Information Criterion (AIC), the Schwarz's Bayesian Criterion (SBC), and a chi-square test of the difference between the –2 loglikelihood statistic of a successive model formulations (Littell *et al.* 1996) (Table 2). Relative indices for the delta model formulation were calculated as the product of the year effect least square means (LSMeans) from the binomial and the lognormal model components. The LSMeans estimates use a weighted factor of the proportional observed margins in the input data to account for the non-balance characteristics of the data. LSMeans of lognormal positive trips were bias corrected using Lo *et al.* (1992) algorithms. Analyses were done using the GLIMMIX and MIXED procedures from the SAS® statistical computer software (SAS Institute Inc. 1997).

For the **alternate Gulf of St. Lawrence standardized series**, the final models that were combined using the delta-binomial method with random effects to produce a single index included the following variables (see Fig. 4 for diagnostic plots):

Proportion positive:
Fixed effects: year gear fleet month
Random effects: year*gear year*month
Positive catch rates:
Fixed effects: year fleet month
Random effects: year*fleet year*month

For the **alternate Southwest Nova Scotia standardized series,** the final models that were combined using the delta-binomial method with random effects to produce a single index included the following variables (see Fig. 4 for diagnostic plots):

Proportion positive:
Fixed effects: year area fleet month
Random effects: year*area year*fleet year*month

Positive catch rates:
Fixed effects: year fleet month area gear
Random effects: year*fleet year*month

3. RESULTS AND DISCUSSION

Results are presented in Tables 3 and 4 and Figs. 5 and 6. While the authors recognize the requirement to provide an update from the 1998 and 2000 assessments, there is concern that the rationale for the choice of model by the 1998 Working Group was not well documented in Anon. (1999). The analyses using step-wise regression to select the model variables is an alternative that the authors recommend the Bluefin Tuna Species Group use in 2002.

The Gulf of St. Lawrence series, for each of the updated and alternate model formulations clearly shows an increase in relative abundance since 1997. This is consistent with the nominal data and observations of commercial fishers. On the other hand, the Hell Hole series has had a fairly stable trend through the mid- to late 1990s. While 2000 is the lowest value on record, 2001 is more consistent with levels generally seen in the 1990s.

The analyses for the Gulf of St. Lawrence and the Southwest Nova Scotia series show that there are significant year interactions in both the proportion positive trips and the mean catch rate of successful trips (see also deviance analyses in Table 1). This may occur because in some years, a particular fleet does not operate, and also the start and end months of the fishery can vary from year to year.

The standardized series for both the Gulf of St. Lawrence and Southwest Nova Scotia, using both the updated series and the alternate delta lognormal model formulation, follow the nominal series closely and overall trends are similar between the two models. (Tables 3, 4; Figs. 5, 6). Differences in main effects and interaction terms specified in the updated and alternate model formulations likely account for the observed differences in standardized CPUE and coefficients of variation. The alternate delta lognormal-binomial formulations have more random interaction terms included in the models, which explains why the CV's are higher compared with the updated model formulation.

For both the Gulf of St. Lawrence and the Southwest Nova Scotia fisheries, the standardized CPUE series seem to track each other rather well over the past 6 years (1995-2001) suggesting an extrinsic factor influencing abundance (Figs. 5 and 6). The relative abundance of bluefin tuna is thought to be highly dependent on environmental conditions during the fishing season, throughout their geographic range and especially at the northern limit of their range (i.e., within the Canadian EEZ). The fact that recent trends in relative abundance are similar for these two geographically separate regions within the Canadian EEZ suggests that there may be some extrinsic environmental factors influencing the movement of separate age groups of bluefin tuna into these areas at the same time. In future, it would be worthwhile to conduct age-specific analyses.

4. CONCLUSIONS AND RECOMMENDATIONS

CPUE trends. CPUEs in the Gulf of St Lawrence have increased since 1997 so that the 1999-2001 values are higher than all but two years since 1985. On the other hand, catch rates for the year 2000 in Southwest Nova Scotia were the lowest of the time series, with 2001 generally similar to the mid- to late 1990s.

Model formulation. Both the updated series (based on the 1998 model formulation) and alternate standardized CPUE series (using step-wise regression to select the model formulation) for Gulf of St. Lawrence age 13+ and Southwest Nova Scotia age 7-13 are presented. While the authors recognize the requirement to provide an update from the 1998 and 2000 assessments, there is concern that the rationale for the choice of model by the 1998 Working Group was not well documented in Anon. (1999). The analyses using step-wise regression to select the model variables is an alternative that the authors recommend the Bluefin Tuna Species Group use for the 2002 stock assessment.

Stock-wide abundance? Given that the Gulf of St. Lawrence and Southwest Nova Scotia series represent different age groups with relatively little overlap and that they show similar trends in recent years, there is concern that they may not reflect trends in stock-wide abundance. In fact, many of the catch rate series which have been developed for west Atlantic bluefin tuna are based on catches from relatively small geographic areas and are assumed to represent the relative abundance of a group of ages for the entire west Atlantic stock. A recommendation for future research would be to calculate age-specific catch rates and examine all the series simultaneously to see if they track the abundance of separate cohorts. The objective would be to evaluate whether the catch rates used for the assessment are tracking only local abundance within smaller geographic areas or stock-wide abundance.

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Table 1. Summary of alternate analyses using step-wise regression analyses used for determining the most appropriate delta lognormal-binomial model specifications for standardizing CPUE series from: a) Gulf of St. Lawrence and b) Southwest Nova Scotia. Each table includes the deviance for the proportion of positive observations (i.e. positive trips/total trips) and the deviance for the positive catch rates. Shaded areas indicate factors selected for model formulations.

Canada Gulf of St Lawrence

Bluefin tuna

Model factors positive catch rates values	Degrees of freedom	Residual deviance	Change in deviance	% of total deviance	*p*
1	1	1582.0			
Year	20	1517.6	64.3	58.7%	< 0.001
Year Fleet	1	1510.5	7.1	6.5%	0.008
Year Fleet Month	2	1508.5	2.0	1.8%	0.372
Year Fleet Month Gear	1	1508.1	0.4	0.4%	0.515
Year Fleet Month Gear Year:Fleet	12	1496.1	12.0	11.0%	0.443
Year Fleet Month Gear Year:Fleet Year:Month	36	1472.3	23.8	21.7%	0.941

Model factors proportion positives	Degrees of freedom	Residual deviance	Change in deviance	% of total deviance	*p*
1	1	25818.6			
Year	20	24982.0	836.59	58.0%	< 0.001
Year Fleet	1	24844.8	137.19	9.5%	< 0.001
Year Fleet Month	2	24830.6	14.18	1.0%	< 0.001
Year Fleet Month Gear	1	24752.3	78.36	5.4%	< 0.001
Year Fleet Month Gear Year:Fleet	14	24672.1	80.23	5.6%	< 0.001
Year Fleet Month Gear Year:Fleet Year:Month	40	24458.5	213.59	14.8%	< 0.001
Year Fleet Month Gear Year:Fleet Year:Month Year:Gear	14	24376.2	82.25	5.7%	< 0.001

Canada Southwest Nova Scotia

Bluefin tuna

Model factors positive catch rates values	d.f.	Residual deviance	Change in deviance	% of total deviance	*p*
1	1	3047.1			
year	13	2179.9	867.3	78.1%	< 0.001
year area	1	2175.5	4.4	0.4%	0.037
year area gear	1	2175.5	0.1	0.0%	0.820
year area gear month	2	2175.2	0.3	0.0%	0.868
year area gear month fleet	4	2151.1	24.1	2.2%	< 0.001
year area gear month fleet year:area	9	2135.7	15.4	1.4%	0.081
year area gear month fleet year:area year:gear	5	2132.8	2.9	0.3%	0.713
year area gear month fleet year:area year:gear year:month	25	2032.9	99.9	9.0%	< 0.001
year area gear month fleet year:area year:gear year:month year:fleet	49	1936.1	96.8	8.7%	< 0.001

Model factors proportion positives	d.f.	Residual deviance	Change in deviance	% of total deviance	*p*
1	1	4495.9			
year	13	3661.1	834.77	55.5%	< 0.001
year area	1	3588.7	72.45	4.8%	< 0.001
year area gear	1	3581.9	6.72	0.4%	0.010
year area gear month	2	3365.2	216.74	14.4%	< 0.001
year area gear month fleet	4	3320.7	44.47	3.0%	< 0.001
year area gear month fleet year:area	9	3235.8	84.91	5.6%	< 0.001
year area gear month fleet year:area year:gear	5	3208.8	26.99	1.8%	< 0.001
year area gear month fleet year:area year:gear year:month	25	3110.4	98.48	6.5%	< 0.001
year area gear month fleet year:area year:gear year:month year:fleet	49	2991.2	119.19	7.9%	< 0.001

Table 2. Selection criteria for alternate delta lognormal-binomial mixed models used for the standardization of the a) Gulf of St. Lawrence and b) Southwest Nova Scotia catch rate series. Models with asterisks were chosen for CPUE standardization.

Canada Bluefin tuna

	Gulf St Lawrence Model	-2 REM Log likelihood	Akaike's Information Criterion	Schwartz's Bayesian Criterion	Likelihood Ratio Test	
	Proportion Positives					
	Year Fleet Month Gear	477.8	479.8	482.8		
	Year Fleet Month Gear *Year*Month*	469.8	473.8	478.1	8	0.0047
***	Year Fleet Month Gear *Year*Month Year*Gear*	446.1	452.1	458.6	23.7	0.0000
	Year Fleet Month Gear *Year*Month Year*Gear Year*Fleet*	445.9	453.9	462.5	0.2	0.6547
	Positive Catch					
	Year Fleet Month	7064.8	7066.8	7073		
	Year Fleet Month *Year*Fleet*	7059	7063	7066	5.8	0.0160
***	Year Fleet Month *Year*Fleet Year*Month*	7052	7058	7062.5	7	0.0082

	Southwest Nova Scotia	-2 REM Log likelihood	Akaike's Information Criterion	Schwartz's Bayesian Criterion	Likelihood Ratio Test	
	Proportion Positives					
	Year Month Area Fleet	819.9	821.9	825.1		
	Year Month Area Fleet *Year*Area*	810.8	814.8	817.1	9.1	0.0026
	Year Month Area Fleet *Year*Area Year*Month*	804.1	810.1	813.6	6.7	0.0096
***	Year Month Area Fleet *Year*Area Year*Month Year*Fleet*	800	808	812.7	4.1	0.0429
	Positive Catch					
	Year Month Area Gear Fleet	7846.5	7848.5	7854.5		
	Year Month Area Gear Fleet *Year*Month*	7763.6	7767.6	7771	82.9	0.0000
***	Year Month Area Gear Fleet *Year*Month Year*Fleet*	7728.8	7734.8	7740	34.8	0.0000

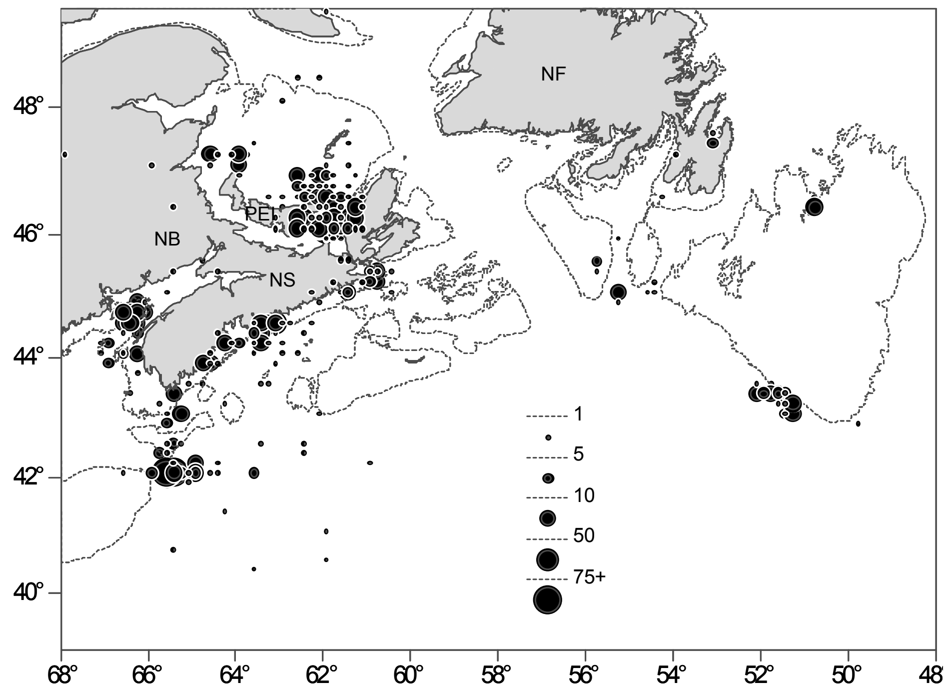
Table 3. Nominal and standardized (delta lognormal-binomial mixed model) CPUE series (tuna/100 hours) for the Canadian bluefin tuna tended line/rod and reel fishery in the Gulf of St. Lawrence based on catch and effort data from commercial log records for Prince Edward Island and Gulf Nova Scotia vessels with 10+ trips annually from August through October, 1981-2001. Standardized CPUE is presented for the updated (Anon. 1999) and alternate model formulations (Stone *et al.* 2001). (Nominal CPUE= number of tuna per 100 hours of fishing).

					Delta lgN pdated 1998 SA			Delta lgN Alternative		
Year	No of trips	No fish	Hours fished	Nominal CPUE	Index	SE	CV	Index	SE	CV
1981	1643	248	12347.8	1.952	1.680	0.380	0.226	1.715	0.739	0.431
1982	4122	303	28052	2.261	1.795	0.392	0.218	1.650	0.732	0.443
1983	4262	525	31267.5	3.368	2.423	0.475	0.196	2.487	1.045	0.420
1984	1362	152	11650.5	2.277	1.590	0.401	0.252	1.395	0.601	0.431
1985	1465	61	13185.5	0.661	0.503	0.166	0.330	0.532	0.274	0.515
1986	673	26	5775	0.870	0.638	0.279	0.438	0.670	0.364	0.543
1987	263	8	1615	0.456	0.360	0.260	0.722	0.390	0.296	0.757
1988	410	22	3276	0.945	0.704	0.332	0.472	0.747	0.439	0.588
1989	320	16	2821	0.978	0.679	0.364	0.537	0.744	0.467	0.627
1990	827	22	6334.6	0.592	0.432	0.204	0.471	0.424	0.244	0.577
1991	310	15	2074.5	0.975	0.707	0.377	0.534	0.776	0.479	0.617
1992	466	27	3122.5	1.129	0.848	0.370	0.436	0.810	0.440	0.543
1993	937	66	7806	1.130	0.842	0.257	0.305	0.955	0.389	0.408
1994	1494	39	12859	0.538	0.288	0.113	0.392	0.314	0.150	0.479
1995	2353	170	21906	1.633	1.122	0.258	0.229	1.184	0.429	0.363
1996	7018	213	56265.2	0.702	0.328	0.078	0.238	0.395	0.149	0.378
1997	6269	189	51176.3	0.750	0.354	0.085	0.239	0.398	0.154	0.386
1998	3954	224	33476.9	1.371	0.628	0.146	0.232	0.743	0.278	0.374
1999	3538	347	30816.6	2.120	0.897	0.205	0.229	1.046	0.388	0.371
2000	6543	506	58232.8	1.756	0.803	0.165	0.206	0.903	0.339	0.375
2001	5401	360	47603.2	1.722	0.766	0.168	0.220	1.004	0.394	0.392

Table 4. Nominal and scaled to their mean standardized CPUE series for combined Canadian bluefin tuna fisheries in the Hell Hole (rod and reel/tended line) and Bay of Fundy (harpoon) based on catch and effort data from commercial log records for August through October, 1988-2001. Standardized CPUE is presented for the updated (Poisson, Anon. 1999) and alternate (Delta logN random, Stone *et al.* 2001) model formulations. (Nominal CPUE= number of tuna per hour of fishing).

					Delta lgN updated 1998 SA			Delta lgN Alternative		
Year	No of trips	No fish	Hours fished	Nominal CPUE	Index	SE	CV	Index	SE	CV
1988	40	230	845	0.42985	1.431	0.050	0.271	1.731	0.106	0.403
1989	214	1120	3158	0.57006	2.277	0.067	0.229	3.112	0.140	0.295
1990	168	871	2679	0.54993	1.952	0.057	0.227	2.030	0.090	0.292
1991	218	714	3451.5	0.32570	1.492	0.043	0.227	1.147	0.072	0.412
1992	232	857	4758.5	0.25442	1.286	0.032	0.196	1.117	0.049	0.288
1993	653	1042	11263.4	0.12776	0.563	0.012	0.171	0.341	0.023	0.452
1994	282	867	4992	0.24755	1.057	0.025	0.186	1.305	0.060	0.302
1995	330	1088	7533.6	0.21895	0.912	0.020	0.174	0.884	0.038	0.283
1996	373	675	10315	0.07290	0.339	0.008	0.191	0.300	0.020	0.447
1997	366	445	9616	0.05974	0.322	0.008	0.192	0.232	0.017	0.494
1998	350	845	8931	0.11952	0.498	0.012	0.185	0.324	0.021	0.434
1999	266	894	5653.2	0.19763	0.790	0.019	0.187	0.770	0.051	0.440
2000	280	347	7208.3	0.05450	0.275	0.007	0.213	0.148	0.012	0.551
2001	359	1027	9162.4	0.13333	0.807	0.018	0.177	0.559	0.031	0.363

2000 Fishery



2001 Fishery

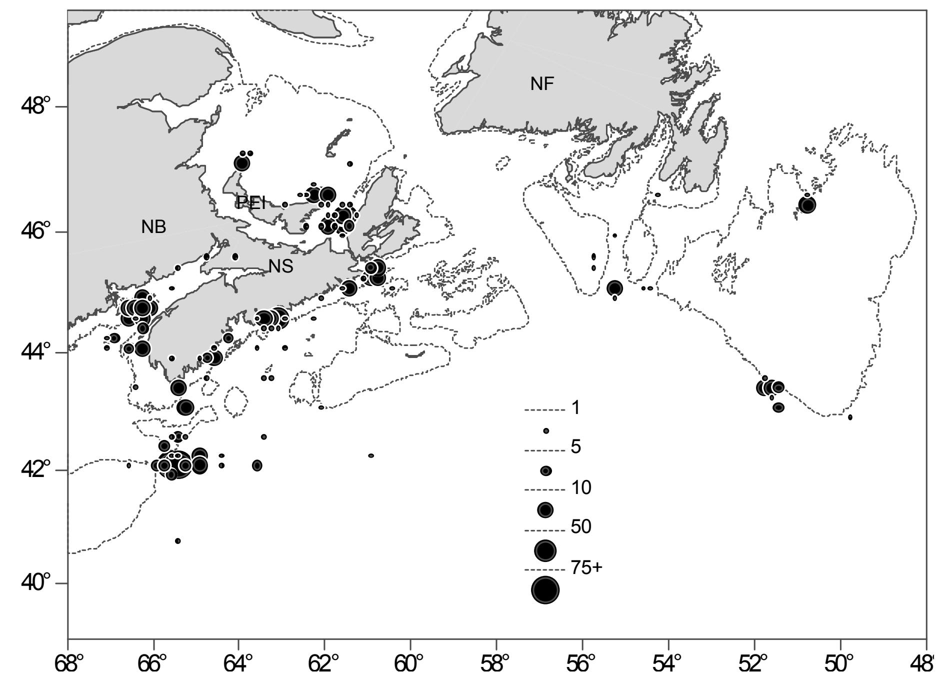


Figure 1. Canadian bluefin catch (numbers) from log record data aggregated by 10 minute rectangles for the 2000 and 2001 fisheries. St. Margarets Bay trap catches are not shown on this plot. (NS, Nova Scotia; NB, New Brunswick; PEI, Prince Edward Island; NF, Newfoundland).

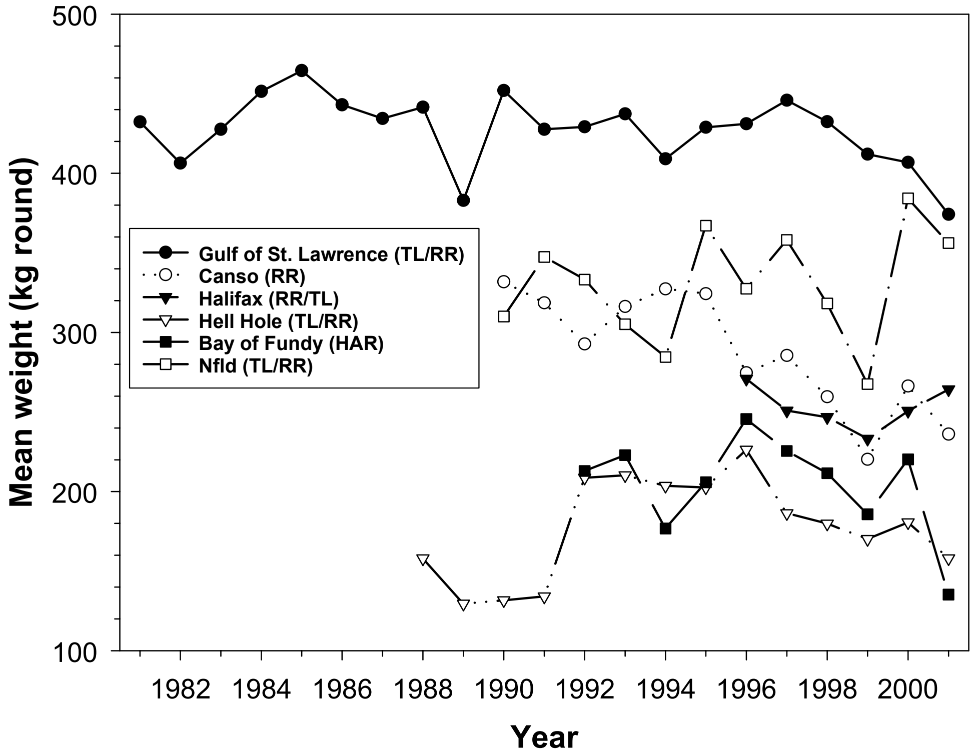


Figure 2. Analyses of mean weight (kg round) of bluefin tuna captured in Canadian fisheries by year, area and gear (TL, tended line; RR, rod and reel; HAR, harpoon).

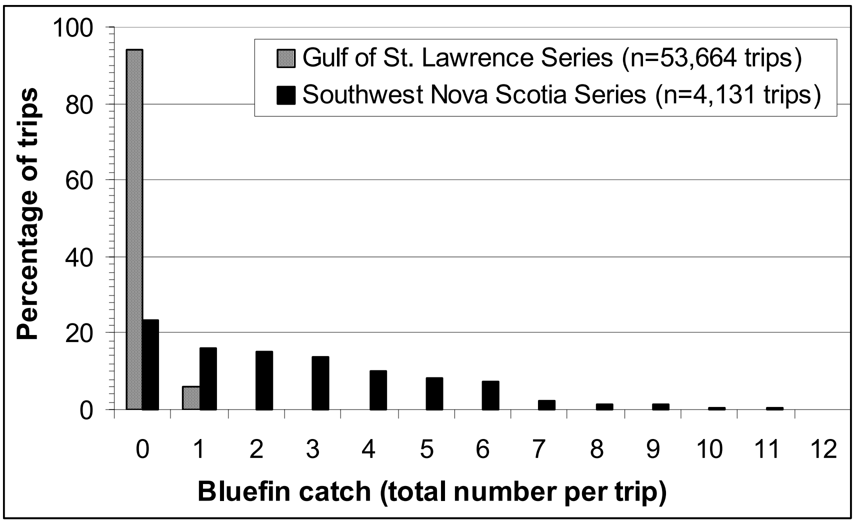


Figure 3. Frequency distributions (percent) of bluefin tuna catch per trip used in the development of CPUE indices for the Southwest Nova Scotia (Hell Hole and Bay of Fundy, 1988-2001) and Gulf of St. Lawrence (1981-2001) fisheries.

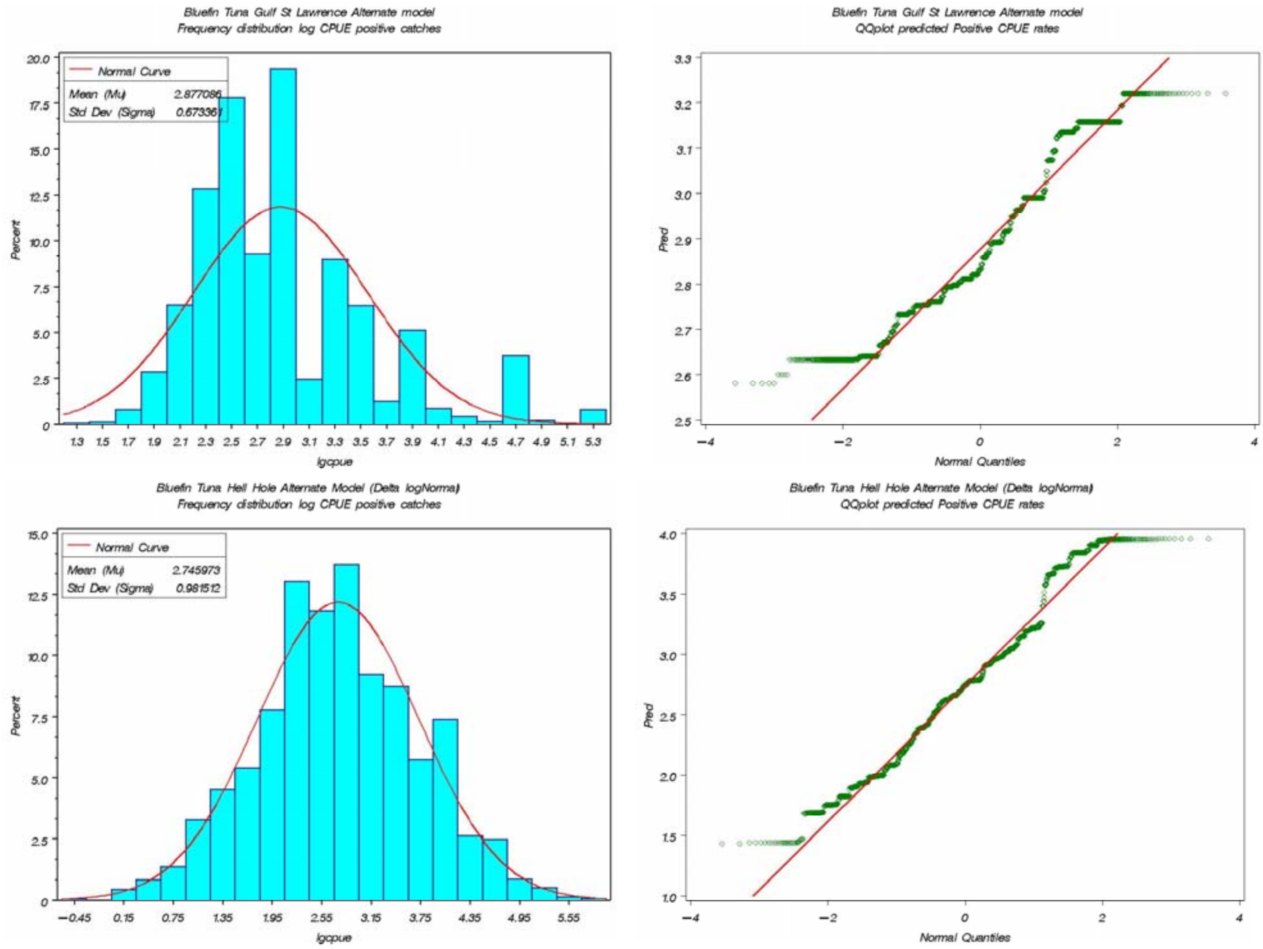


Figure 4. Diagnostic plots for the delta lognormal-binomial model formulation. The left panels show the frequency distribution of the log transformed nominal CPUE for positive trips for the Gulf of St Lawrence (upper) and Southwest Nova Scotia (lower) series. The right plots show the normalized cumulative residuals (or qq-plots) of the fit for the positive trips in the delta lognormal model component; the expected trend is a straight line.

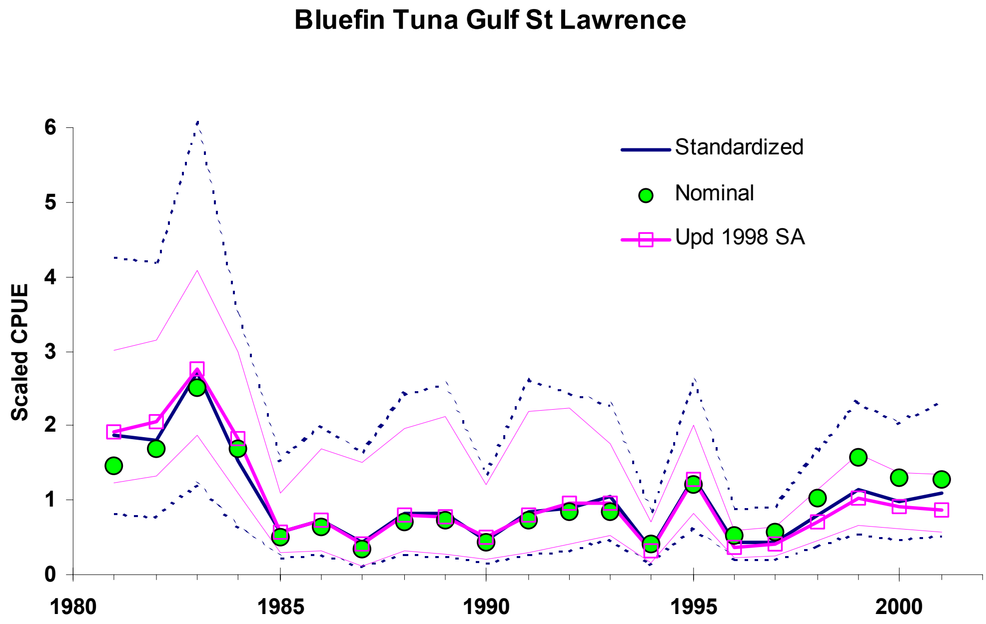


Figure 5. Comparison of standardized CPUE indices (Table 3) for the Gulf of St. Lawrence fishery from the updated 1998 stock assessment method and delta lognormal-binomial model formulations. Nominal catch rates are also shown. Series are scaled to their mean. Thin lines are the 95% CI.

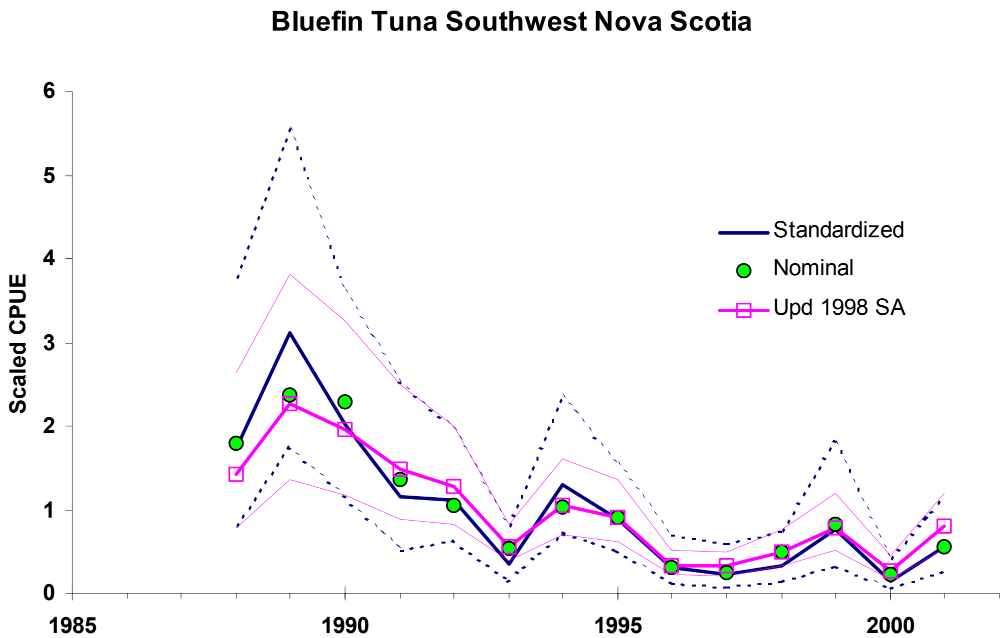


Figure 6. Comparison of standardized CPUE indices (Table 3) for the Southwest Nova Scotia fishery using the updated 1998 stock assessment method and delta lognormal-binomial model formulations. Nominal catch rates are also shown. Series are scaled to their mean. Thin lines are the 95% CI.