

DEVELOPMENT OF CANADIAN CPUE INDICES FOR BLUEFIN TUNA BASED ON COMMERCIAL CATCH RATES (REVISED)

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SUMMARY

Nominal and standardized abundance indices for giant bluefin tuna from Canadian tended line fisheries in the Hell Hole (1988-95) and Gulf of St. Lawrence (1984-95) were developed based on data from commercial log records. An update (1991-95) of the nominal Canadian tended line 13+ fish index (1981-1990) used in previous assessments is provided. A multiplicative model approach was used to standardize the two bluefin tuna catch rate series for the effects of year and month using different levels of data aggregation.

RÉSUMÉ

On a élaboré des indices nominaux et standardisés de l'abondance pour la pêche canadienne à la ligne surveillée ("tended line") dans la région du Hell Hole (1988-95) et dans le Golfe du Saint-Laurent (1984-95), d'après des données extraites de carnets de pêche commerciale. L'indice nominal de la pêche canadienne de poissons des âges 13+ à la ligne surveillée (1981-90), qui avait été utilisé dans les évaluations antérieures, a été actualisé. Une approche plurimodélisque a servi à standardiser les deux séries de taux de capture du thon rouge à la recherche des effets mois et année, au moyen de différents niveaux de regroupement des données.

RESUMEN

Se desarrollaron índices nominales y estandarizados de abundancia para atún rojo gigante de las pesquerías de barrilete ("tended line") de Canadá en Hell Hole (1988-95), y Gulf of St. Lawrence (1984-95), basados en datos de registros de cuadernos de pesca comerciales. Se facilita una actualización (1991-95) del índice de peces 13+ de barrilete (1981-1990) utilizado en evaluaciones previas. Se empleó un enfoque de modelo multiplicativo para estandarizar las dos series de tasas de captura de atún rojo a efectos de año y mes, aplicando diferentes niveles de agregación de datos.

Introduction

ICCAT has recommended an examination of Canadian bluefin tuna commercial catch rate data from all fisheries and the development of a standardized CPUE series for use in calibrating age-structured virtual population analysis (VPA) (Anon. 1995). Nominal catch rate data from 1981 to 1990 from the PEI tended line fishery are currently used in the VPA (Clay and Hurlbut 1989). Our objective is to develop new, standardized catch rate series for bluefin tuna in Canada generally, using the best information available. Catch rate data were examined from all of the Canadian bluefin fisheries (all gears and areas), however, the analyses concentrate on the tended line fisheries of the Gulf of St. Lawrence and the Hell Hole; fisheries which represent the majority of the landings and encompass the range of sizes of bluefin tuna found in Canadian waters.

This manuscript documents procedures used to select and standardize the two new catch rate series for Canada (Hell Hole ages 8-11, 1988-95, and Gulf of St. Lawrence age 13+, 1984-95, tended line for large fish) and provides an update (1991-95) of the nominal Canadian tended line large fish index (Anon. 1995).

Description of the fisheries

The Canadian bluefin tuna fishery currently operates in several geographic areas off the Atlantic coast from July to November when bluefin migrate into Canadian waters (Fig. 1). Since the late 1980's, the main commercial fisheries have included: Hell Hole tended line, Bay of Fundy harpoon, St. Margarets Bay trap, Gulf of St. Lawrence tended line/rod and reel, Chedabucto Bay rod and reel, and Grand Banks tended line/rod and reel. Bluefin tuna capture locations within these geographic areas (fisheries) have been highly variable during the time series for which data on fishing location is available (1988-95, Fig. 2). Most notable in recent years is: a) the expansion of catches from the Hell Hole to adjacent areas on Georges Bank, Browns Bank and the Scotian Shelf, b) the development of an electric harpoon fishery in the Bay of Fundy in 1991, c) an expanding rod and reel fishery in Chedabucto Bay (beginning in 1990), d) a general decline in catches from the Grand Banks region off Newfoundland associated with closures of the groundfish fishery, and e), a concentration of catches from the Gulf of St. Lawrence to the southern part of this region and higher catches in recent years (1995 catches approached levels not seen since the early 1980's).

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The average weight of giant bluefin tuna captured in Canadian fisheries varies consistently among areas (Fig. 3, Table 1). The Gulf of St. Lawrence fishery captures mainly giants (425+ kg) that are over 13 years old. The Newfoundland and Chedabucto Bay fisheries capture slightly smaller (320 kg) and younger (age 12+) fish than those from the Gulf. Bluefin tuna captured in the Hell Hole and Bay of Fundy are the smallest (200 kg, ages 8-11). The increase in size of Hell Hole fish apparent in 1992 may represent an influx of larger fish or a change in harvesting practices. The fact that size remains relatively constant within areas suggests that fish of a particular size/age aggregate in certain areas and then move on to other locations as they increase in size.

Selection of catch rate series

Commercial log records in computerized format are available for rod and reel and/or tended line fisheries from the Grand Banks (1988-95), Hell Hole (1988-95), Gulf of St. Lawrence (1984-95), Chedabucto Bay (1990-95), and the harpoon fishery in the Bay of Fundy (1991-95). The St. Margarets Bay trap fishery was not considered in these analyses since there are no effort data available. With the exception of the Gulf of St. Lawrence tended line fishery which dates back to 1981, all time series begin when the fisheries first developed. In Canada, submission of log records for the bluefin tuna fishery was initially done on a voluntary basis, although in the past few years it has become mandatory. While log record coverage has varied over the years, it must be assumed that what is available is representative of the fishery. However, note our caution associated with this assumption (see below). The 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).

It is apparent from the spatial distribution of catches and differences in the size of fish captured that there are distinct aggregations of bluefin tuna in Canadian waters. These size-specific aggregations may consist of separate groups of fish which arrive at different times, have their own relative abundance and are mutually exclusive of each other. Based on these findings, it was decided that separate indices of abundance should be developed, and that they should cover enough years to provide a reasonable time series.

During a series of consultations with the Canadian bluefin tuna fishing industry, it was concluded that a meaningful index of relative abundance could be calculated from commercial catch rates so long as certain factors can be taken into account (i.e. gear, area, season). Based on these discussions and preliminary analyses of nominal catch rates, a series of "decision-making" steps were taken to determine which catch rate data sets most adequately represent the Canadian fishery. The two fisheries selected had the longest time series: the Hell Hole tended line for age 8-11 fish and Gulf of St. Lawrence tended line for age 13+ fish. The other series were not developed because either the time series was too short or trends were confounded with events in other fisheries. Using only these two data sets automatically standardizes for area (separate indices for Hell Hole and Gulf of St. Lawrence) and gear (tended line is most commonly used for both) and ensures that the size/age range of tuna captured is representative of the Canadian fishery (Table 1).

Methods

Catch and effort data

Computerized log record data are available for the entire Hell Hole tended line fishery time series (1988-95), and for all but the first three years of the Gulf of St. Lawrence tended line fishery (1984-95). Log record 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, month and fleet. Nominal CPUE was calculated as the number of tuna captured per trip divided by total hours fished per trip averaged over a month or year, and was scaled up by a factor of 100 for the Gulf of St. Lawrence data.

For the Hell Hole fishery, catch per hour is probably the best unit measure of effort because the effective fishing time during a day is generally limited to a period of time influenced by the tidal cycle. Furthermore, the present log record format provides information on catch per hour, but a measure such as catch per trip could only be extrapolated by adjusting for time spent steaming to and from the fishing grounds. Catch per trip has previously been used for the Gulf of St. Lawrence tended line index developed by Clay and Hurlbut (1989), where trips are only one day in duration, but this would be less useful for areas where trips might be two or more days in length (e.g. Hell Hole).

Although all fleets from the Canadian Atlantic provinces participate in the Hell Hole fishery, Nova Scotia vessels, because of their close proximity to the fishing grounds, have the greatest access to the fishery throughout the season and therefore the greatest number of trips. Consequently, the Nova Scotia fleet was selected as the principal fleet on which to base the Hell Hole index. Consultations with industry indicated that some of the Hell Hole trips with "no catch" may not have been reported in some years. Since the reported trips with no catch generally occurred at the beginning (July) and end (October) of the fishing season, these months were dropped from the data series. Observations with CPUE=0 were omitted from the series by excluding 17 of 613 trips (3%) from the analysis. The final data set used for CPUE standardization included observations for 8 years (1988-95) and two months (August, September) ($n=596$ trips, Table 2).

The Canadian tended line index for large fish (age 13+) in the Gulf of St. Lawrence developed by Clay and Hurlbut (1989) uses number of fish/day (=fish/trip) and is based on Prince Edward Island (PEI) vessels which have made 10+ trips in a given year for the period 1981-1990. The 10+ trip threshold restricts the analysis to full time, experienced fishermen that fish the entire season (July-November). The PEI fleet was originally selected for this index because it has consistently made more trips than any of the other fleets operating in this region. In the transfer of mandate of bluefin tuna in Canada, some of the Clay and Hurlbut data were missing or incomplete. Further, the data were limited in scope (i.e. no information on trip number, position etc.). Accordingly, original log records were recoded and computerized for a new analysis. The importance of the 1981-1983 data was not recognized at the time data from original logs were entered for the PEI series. This will be rectified in the future so that the series includes data from the beginning of the tended line fishery in PEI and covers the period of substantial change in catch rates in the early 1980's. The Clay and Hurlbut index has been recalculated and compares closely

with the original nominal index for 1984-90. Therefore, this index was updated (1991-95) and compared with a "new" nominal catch rate series based on number of fish per 100 hours for PEI vessels with 10+ trips during August, September and October, when most fishing trips occur. This new data set was used for CPUE standardization and included observations for 12 years (1984-95) and three months (August, September, October) and is based on PEI vessels with 10+ trips per year ($n=8341$ trips, Table 3).

Model and specifications

The multiplicative model (Gavaris 1980, 1988) used to standardize the catch rates of bluefin tuna from the Hell Hole and Gulf of St. Lawrence, was solved using standard linear regression techniques after \ln transformation of nominal CPUE data expressed as number of fish per hour (Hell Hole) or number of fish per 100 hours (Gulf of St. Lawrence). Estimated mean CPUE values and associated standard errors were then retransformed to arithmetic scale, with logarithmic bias correction. The model required a standard for each main effect upon which all other mean CPUE values were scaled. Standards were defined as month=8 for the Hell Hole and month=9 for the Gulf of St. Lawrence, when catch rates were highest, respectively. All analyses were conducted using the APL workspace "STNDR_V2".

Since there is a very high proportion of unsuccessful trips in the Gulf of St. Lawrence fishery, (i.e. > 88% each year), application of the model to single trip data would have resulted in residual distributions which are highly skewed. Therefore, two data sets with aggregated observations were created to minimize the proportion of catch rate values of zero while retaining catch rate information. Each of these were evaluated through separate model runs. Individual trip observations in the first series were aggregated by vessel and month to generate a data set based on total catch and effort for each vessel by month within year ($n=801$ observations). Individual trip records in the second data series were aggregated by month, yielding a new data base of catch and effort observations summarized by month and year ($n=36$ observations). Observations with zero catch represented 73% and 11% of the records in the new data sets, respectively. It was necessary to add a constant to each observation prior to analysis to permit taking the logs of all catch rate values, including nominal catch rates of zero. A constant of 0.001 was chosen since it was slightly less than the lowest annual mean nominal CPUE observed. The effect of adding a smaller constant (i.e. in the order of 10% of the mean (0.0006)) was examined but resulted in rather large values for the retransformed means.

A model based on two main effects (Year, Month) was examined since other factors (Gear, Area, Captain's Experience) have already been taken into account:

$$\ln(\text{CPUE}_{ij}) = \mu + \text{Year}_i + \text{Month}_j + \epsilon_{ij}$$

For each run, residual patterns were examined for outliers and partial probability plots of residuals were examined for normality.

Results and Discussion

Hell Hole Index

Nominal catch rates for the Hell Hole tended line series (fish per hour) exhibit a typical pattern which could be interpreted as a "learning curve" from 1988-90, followed by a "fishing-up" effect through to 1993, with a subsequent increase in 1994, followed by a slight decline in 1995 (Table 2, Fig. 4a). ANOVA results from the multiplicative model indicate that the overall regression and year effect was significant ($P < 0.05$), but the month effect was not ($P > 0.05$) (Table 4). No trends were apparent in the pattern of residuals and their distribution was normal. The model explained 16% (multiple r^2) of the variability in the data, which is essentially attributed to the year effect, given that gear and area are taken into account outside the model. The relatively low r^2 indicates that catch rates are highly variable in this fishery largely due to chance or to factors which are not accounted for (e.g. environment). Standardized catch rates are very similar to the nominal series (Fig. 4a). Since the month effect is not significant, either series could be used for VPA calibration.

Gulf of St. Lawrence Indices

Gulf of St. Lawrence tended line nominal catch rates based on catch per day (ICCAT 13+ index) and catch per 100 hours (new index) generally track each other quite well, particularly during the period for which the large fish index was updated (1991-95). Catch rate trends are quite variable, showing a decline to 1985, a highly variable pattern through to 1990, followed by an increase to 1992. Catch rates then drop off in 1994, partly due to an early closure of the fishery in that year, then increase again slightly in 1995. Catches reported in 1995 (107 MT, $n=347$ fish) were at a level not seen since the early 1980's, however, the catch rates are still at low values. The ICCAT large fish index based on number of fish per day (1981-90, Anon. 1995) and the updated large fish index (1991-95, this paper) are given below:

Year	Trips (days)	Catch	CPUE
1981	1613	332	0.206
1982	1087	201	0.185
1983	2405	329	0.137
1984	1381	131	0.094
1985	66	3	0.045
1986	37	2	0.054
1987	281	10	0.035
1988	429	24	0.055
1989	296	12	0.040
1990	959	25	0.026
1991	296	14	0.047
1992	438	27	0.062
1993	720	36	0.050
1994	1081	24	0.022
1995	783	28	0.036

ANOVA results from the multiplicative model using the data series aggregated by vessel and month indicate that the overall regression and main effects (Year, Month) were significant ($P < 0.05$, Table 5), and that the model explained only 8% (multiple r^2) of the variability in the data. Partial probabilities of residuals indicate that they do not follow a normal distribution, and reflect the high proportion of CPUE values equal to zero. Standardized catch rates using data aggregated by vessel and month generally do not track the nominal series (fish/day and fish/100 hours) all that well (Fig. 4b).

ANOVA results using the data series aggregated by month indicate that the overall regression and main effects (Year, Month) were not significant ($P < 0.05$, Table 6) even though the model explained much more of the variability in the data (multiple $r^2 = 48\%$) than in the previous case. For this run, no trends were apparent in the pattern of residuals and their distribution was normal. Standardized catch rates based on data aggregated by month generally followed the nominal CPUE series (fish/trip and fish/100 hours) better than the standardized series aggregated by vessel and month (Fig. 4b), however, catch rates for 1989 and 1992 appear to be higher than expected in comparison with the nominal series. It is clear that before the standardized series can be used in VPA tuning, data from 1981-83 should be included. This series would then include data from the beginning of the PEI tended line fishery, and cover the period of substantial change in catch rates in the early 1980's.

CPUE trends for the Gulf of St. Lawrence appear to be similar to the US RR large fish index and are consistent with the age 10+ trends from the VPA (Anon. 1995). No direct comparison can be made between the trends of the Hell Hole 8-11 series, as the N-matrix from the 1994 assessment only goes to 10+. However, the small peak in numbers for ages 8 and 9 in 1990 from the VPA is evident in the CPUE series.

Conclusions

It is recommended that the nominal CPUE series for the Gulf of St. Lawrence be used for VPA tuning as this series includes data from the beginning of the fishery and is consistent with VPA trends. However, there should be caution in the use of these data because of missing trip information. The data set for the Hell Hole is more complete and we are more confident that it is representative of the fishery. It is unclear how consistent it is with VPA trends in the absence of an N-matrix that isolates ages 8-11, although it appears to reflect trends of the age 8 and 9 fish. In order to effectively use both of these Canadian indices, it is recommended that the VPA be taken out to age 13+, at least in a sensitivity run.

Data from 1981 to 1983 for PEI will be included in future analyses of the standardized series. To ensure that the data are complete for both the PEI and Hell Hole series, interviews with individual fishermen will be conducted during the winter so that effort from all trips is included. These individuals will be selected based on the following criterion: good record keepers - both personal and DFO logs, and active in the fishery. Results obtained from interviews with selected fishermen will be used in the development of a revised subset of the data for use in a

standardization procedure. Since the Gulf of St. Lawrence fishery is characterized by a high proportion of unsuccessful trips, the use of the Poisson, negative binomial and delta-lognormal models should be examined for standardizing these series, as recommended during the ICCAT Bluefin Tuna Methodology Session (April 1996, Madrid, Spain). Before this is done, the data series used in this analysis need to be adequately examined and revised.

Literature cited

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