AN AGE-SPECIFIC CPUE FOR CANADIAN SWORDFISH LONGLINE, 1988-1993

SCRS/1994/111

Col.Vol.Sci.Pap. ICCAT, 44 (3) : 135-142 (1995)

Stone, H., J.M. Porter

Department of Fisheries and Oceans, Biological Station, St. Andrews, New Brunswick, Canada E0G 2X0

SUMMARY

An age-specific index of relative abundance is calculated for north Atlantic swordfish caught by longline in the Canadian fishery from 1988 to 1993. Standardized catch rates for ages ranging from 2 to 5+ were estimated using a multiplicative model. The variability in predicted CPUE explained by the model ranged from 16 to 36%.

RESUME

Un indice d'abondance relative spécifique de l'âge est calculé pour l'espadon de l'Atlantique Nord capturé à la palangre par le Canada entre 1988 et 1993. Les taux de capture standardisés pour les âges 2 à 5 + ont été estimés en utilisant un modèle multiplicatif. La variabilité dans la CPUE prévue expliquée par le modèle oscillait entre 16% à 36%.

RESUMEN

Se calcula un índice de abundancia relativa específico de la edad para el pez espada del Atlántico norte capturado con palangre en la pesquería de Canadá desde 1988 a 1993. Se estimaron las tasas de captura estandarizadas para edades comprendidas entre 2 a 5+ empleando un modelo multiplicativo. La variabilidad en la CPUE predicha explicada por el modelo osciló entre 16 y 36%.

Introduction

The purpose of this analysis is to provide age-specific indices of abundance for swordfish from the Canadian longline fishery from 1988 to 1993 for use by the SCRS in stock assessments. Age-specific, standardized CPUE indices for north Atlantic swordfish from Spanish (Mejuto 1994), Japanese (Nakano 1994) and U.S. (Scott and Bertolino 1994) commercial longline fisheries have been used by ICCAT to tune age-structured sequential population analysis (VPA). This manuscript is the first to provide standardized catch rates for the Canadian longline fishery, which operates from Georges Bank to the Grand Banks (Fig. 1) when swordfish migrate into Canadian waters. A multiplicative model approach (Gavaris 1980, 1988) is used to standardize Canadian catch per unit effort data for ages 2, 3, 4, and 5+.

Materials and Methods

Catch and effort database

Log records (catch and effort data) from the Canadian swordfish longline fishery are available from 1962 to 1993, though size samples (dressed weight) exist only for 1988 to 1993. Consequently, the analyses was restricted to this six year period.

Information on catch, effort, fishing location and date originated from commercial log records submitted to the Department of Fisheries and Oceans by fishermen. Set-by-set catch (number of swordfish) and effort (number of hooks) data were edited and condensed to the trip level to provide total number of fish and total number of hooks per trip. Two geographical areas of fishing were used for classification, defined as ICCAT Areas 2 (Georges Bank, western and central Scotian Shelf) and 14 (eastern Scotian Shelf, Grand Banks and Flemish Cap), falling west and east of the 60° W line of longitude, respectively (Fig. 1). A total of 563 trips with catch and effort information, cross-classified by year (1988-1993), area (2, 14) and month (May-November) were used in these analyses (Table 1). Coverage by the effort data during these years generally represents less than 50% of the landings for that year (Table 1). The annual pattern of abundance between areas 2 and 14 is believed to be similar, though the seasonal patterns differ. While only 10% of the Canadian catch is from area 14, both areas are retained for the analysis (Appendix 1). Months were combined at the beginning (i.e. May-June for Area 2; May-July for Area 14) and end (i.e. October-November, Areas 2 & 14) of the fishing season to increase the number of observations.

Individual dressed weights of swordfish, obtained from swordfish buyers, were converted to lower-jaw-fork-length and aggregated by 2 cm intervals into length frequencies for each year, area and month (similar to ICCAT Task II procedures). Length frequencies were converted to age frequencies (ages 1, 2, 3, 4 and 5+) for each analytical stratum (i.e. year, area and month) using age-length keys developed from the ICCAT Gompertz growth model and age slicing method used by the 1992 SCRS Swordfish Species Group (Anon. 1987, 1989). Data substitutions were made for strata with missing age frequency samples. Since there were very few age 1 fish in the samples for area 14, this age group was not included in the analysis. The proportions at age for each analytical stratum were then used to partition the trip data set to obtain age-specific catches for use in the multiplicative model.

Model and specifications

The multiplicative model (Gavaris 1980, 1988) used to standardize the catch rates of swordfish (ages 2, 3, 4 and 5+) was solved using standard linear regression techniques after ln transformation of nominal CPUE data (number of fish per 1000 hooks). 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. To minimize the standard error of the CPUE estimate, standards were defined as area=2 (Scotian Shelf) and month=8 (August), when sample sizes (number of trips) were highest. Observations with CPUE=0 were omitted by excluding the age 1 group from the analysis. All analyses were conducted using the APL workspace "STNDR_V2".

Initially, a model based on three main effects (Year, Area, Month) and an interaction term (Area*Month) was examined, since previous experience (i.e. Mejuto 1994, Nakano 1994, Scott and Bertolino 1994) has shown that these factors account for most of the variation in CPUE in swordfish longline fisheries:

$$\ln(CPUE_{ijk}) = \mu + Year_i + Area_j + Month_k + Area_k * Month_j + \varepsilon_{ijk} \quad (1)$$

Since an interaction term used in such a model is difficult to interpret, a composite term for area and month was used. In this case, instead of an interaction term, a single composite main effect was modelled which combined Area and Month main effects, and Area*Month interaction into one term:

$$\ln(CPUE_{ijk}) = \mu + Year_i + [\, Area_j \,\&\, Month_k \,] + \varepsilon_{ijk} \quad (2)$$

where: $[\, Area_k \,\&\, Month_j \,]$ = composite effect of Area, Month and Area*Month.

The Area & Month composite variable contained codes representing each area-month combination. This treatment gives the same r^2 as when equation (1) is applied, but the sources of variation from the ANOVA are more easily interpreted.

To examine the effect of switching from rope to monofilament backline in the Canadian fishery during 1990 and 1991, a "Gear" category was added to the Composite Model as a main effect:

$$\ln(CPUE_{ijkl}) = \mu + Year_i + [\, Area_k \,\&\, Month_j \,] + Gear_l + \varepsilon_{ijkl} \quad (3)$$

where: Gear = rope or monofilament backline.

Results and Discussion

Analysis of variance (ANOVA) results for the Composite Model are given by age group in Tables 2-5. In all cases, the overall regression and individual main effects were significant ($P < 0.05$) and the model explained between 16 and 36 % (multiple r^2) of the variability in the data, depending on the age group modelled. For each age group, no trends were apparent in the pattern of residuals and partial probability plots indicate that residuals were normally distributed (Fig. 2).

Fishing with rope or monofilament backline did not appear to have any effect on CPUE. The main effect of Gear in the Composite Model was not significant for any of the age groups ($P>0.05$) and accounted for only a fraction more of the observed variability in the data than the original Composite Model without this effect (Tables 6a-d). This term was removed from the Composite Model since it did not improve the estimate of CPUE.

Estimates of standardized catch rates were highest and most variable for all ages in 1990 (Fig. 3). Trends in CPUE for age 2 swordfish were quite variable, reaching peaks in 1990 and 1992, but declining in 1993. The age 3, 4 and 5+ fish all had similar patterns in CPUE, showing a general increase in abundance from 1988 to 1990, followed by a gradual decline to 1992. For ages 4 and 5+, this decline continued to 1993; in contrast, CPUE increased slightly in 1993 for age 3 fish.

The results do not clearly indicate that the index is reflective of swordfish abundance, however, there is a peak in age 2 fish in 1992, which may also be detected in age 3 fish in 1993 (Fig. 3). This trend could be confirmed with additional years of data.

The following improvements and refinements might be explored to improve the model:

1) Modification of Area Specification: Split the areas at 55° W to separate the Canadian fishing zone into Scotian Shelf and Georges Bank vs the Grand Banks. The present split at 60° W (using ICCAT boundaries) includes some Scotian Shelf fish with the Grand Banks fish. The latter are known to be larger than Scotian Shelf fish.

2) Extend the Time Series: Further explore the size substitutions prior to 1988; if the substitutions are appropriate for the catch-at-age, they should be appropriate for an age-specific CPUE. The time series could then be extended back to 1978.

3) Improvement of Substitutions: Between 1978 and 1988, Canadian catches were sized using USA Grand Banks samples. Other area-specific substitutions may be available

which have not previously been used. Prior to the court decision for the Canada/USA line (October, 1985), US vessels were fishing side-by-side with Canadian vessels on Georges Bank and the Scotian Shelf. Therefore, swordfish size samples should be available for Georges Bank and the Scotian Shelf for 1978-1985.

4) Inclusion of USA Effort Data: Use the USA Grand Banks, and Georges Bank and Scotian Shelf effort data in this index for all years. This would then represent the northern summer-autumn feeding range of the northwest Atlantic swordfish population.

Acknowledgements

We wish to thank S. Gavaris and A. Hanke for their many helpful suggestions and assistance in setting up the multiplicative model.

Literature cited

Anon. 1987. Report of the swordfish assessment workshop. Int. Comm. Conserv. Atl. Tunas Col. Vol. Sci. Pap. 26: 339-395.

Anon. 1989. Second ICCAT swordfish workshop. Int. Comm. Conserv. Atl. Tunas Col. Vol. Sci. Pap. 29: 71-83, 135-136.

Gavaris, S. 1980. Use of a multiplicative model to estimate catch rate and effort from commercial data. Can. J. Fish. Aquat. Sci. 37: 2272-2275.

Gavaris, S. 1988. Abundance indices from commercial fishing. p. 3-13 *In*: D. Rivard (ed) Collected papers on stock assessment methods. CAFSAC Res. Doc. 88/61. 167 p.

Mejuto, J. 1994. Standardized indices of abundance at age for swordfish (*Xiphias gladius*) from the Spanish longline fleet in the Atlantic, 1983-92. Int. Comm. Conserv. Atl. Tunas Col. Vol. Sci. Pap. 42(1): 328-334.

Nakano, H. 1994. An update of Japanese longline standardized CPUE for the Atlantic swordfish. Int. Comm. Conserv. Atl. Tunas Col. Vol. Sci. Pap. 42(1): 281-284.

Scott, G.P. and A.R. Bertolino. 1994. Standardized catch rates for swordfish (*Xiphias gladius*) from the U.S. longline fleet through 1992. Int. Comm. Conserv. Atl. Tunas Col. Vol. Sci. Pap. 42(1): 303-308.

Table 1. Summary statistics for Canadian swordfish longline trips by year, ICCAT Area, and month used in the CPUE analysis. Canadian annual landings are shown for comparison.

Year	ICCAT area	Month	No.of Trips	No.of fish	Biomass (t)	Landings (t)
1988	2	7	2	84	5.6	
1988	2	8	9	869	42.5	
1988	2	9	9	739	33.5	
1988	2	10	6	347	19.2	
1988	2	11	1	77	3.8	
1988	**2**	**all**	**27**	**2116**	**104.6**	**811.3**
1988	14	7	1	61	4.2	
1988	14	8	2	487	26.8	
1988	14	9	6	936	46.9	
1988	**14**	**all**	**9**	**1484**	**77.8**	**62.6**
1989	2	7	8	318	19.7	
1989	2	8	17	1172	61.9	
1989	2	9	6	552	32.9	
1989	2	10	5	276	15.5	
1989	2	11	1	3	0.1	
1989	**2**	**all**	**37**	**2321**	**130.1**	**942.0**
1989	14	8	4	785	41.5	
1989	14	9	2	710	36.2	
1989	14	10	1	268	15.4	
1989	**14**	**all**	**7**	**1763**	**93.1**	**155.0**
1990	2	7	5	250	13.0	
1990	2	8	18	2039	120.3	
1990	2	9	9	1403	82.2	
1990	2	10	4	411	30.2	
1990	**2**	**all**	**36**	**4103**	**245.7**	**618.5**
1990	14	7	2	84	3.1	
1990	14	8	1	218	14.0	
1990	14	9	4	964	64.5	
1990	14	10	1	181	16.8	
1990	14	11	1	53	3.1	
1990	**14**	**all**	**9**	**1500**	**101.4**	**200.7**
1991	2	6	8	688	42.5	
1991	2	7	21	1241	77.0	
1991	2	8	33	2438	155.0	
1991	2	9	34	2704	183.2	
1991	2	10	14	1105	79.8	
1991	2	11	1	27	1.2	
1991	**2**	**all**	**111**	**8203**	**538.8**	**881.2**
1991	14	8	4	745	35.5	
1991	14	9	2	241	14.8	
1991	**14**	**all**	**6**	**986**	**50.3**	**72.2**
1992	2	6	15	767	46.0	
1992	2	7	23	1207	78.0	
1992	2	8	28	1935	108.7	
1992	2	9	19	2189	134.6	
1992	2	10	8	544	36.4	
1992	**2**	**all**	**93**	**6642**	**403.7**	**1430.3**
1992	14	8	2	544	30.9	
1992	14	9	7	1336	71.1	
1992	14	10	2	438	29.0	
1992	**14**	**all**	**11**	**2318**	**131.0**	**55.6**
1993	2	5	4	114	6.1	
1993	2	6	22	630	33.4	
1993	2	7	51	2619	145.0	
1993	2	8	53	4553	258.2	
1993	2	9	31	2869	178.1	
1993	2	10	18	1148	77.7	
1993	2	11	2	137	18.1	
1993	**2**	**all**	**181**	**12070**	**716.7**	**2051.1**
1993	14	6	2	154	6.3	
1993	14	7	5	866	39.9	
1993	14	8	11	1450	86.8	
1993	14	9	8	947	68.6	
1993	14	10	8	1045	65.3	
1993	14	11	2	159	6.9	
1993	**14**	**all**	**36**	**4621**	**273.8**	**154.4**

Table 2. ANOVA results from Composite Model for Canadian swordfish longline CPUE, age 2.

REGRESSION OF MULTIPLICATIVE MODEL

MULTIPLE R............. 0.561
MULTIPLE R SQUARED..... 0.315

ANALYSIS OF VARIANCE

SOURCE OF VARIATION	DF	SUMS OF SQUARES	MEAN SQUARES	F-VALUE
INTERCEPT	1	2.887E2	2.887E2	
REGRESSION	13	6.709E1	5.161E0	19.413
YEAR	5	4.140E1	8.279E0	31.140
AREA&MONTH	8	2.606E1	3.258E0	12.254
RESIDUALS	549	1.460E2	2.659E-1	
TOTAL	563	5.017E2		

REGRESSION COEFFICIENTS

CATEGORY	VARIABLE	COEFFICIENT	STD. ERROR	NO. OBS.
88	INTERCEPT	0.676	0.118	563
1				
89	1	-0.039	0.117	44
90	2	0.434	0.116	45
91	3	-0.425	0.100	117
92	4	0.288	0.102	104
93	5	-0.176	0.095	217
2	6	-0.210	0.089	110
3	7	0.109	0.086	158
4	8	0.416	0.090	108
5	9	0.072	0.101	60
6	10	0.341	0.181	10
7	11	0.521	0.130	24
8	12	0.075	0.123	29
9	13	0.073	0.153	15

PREDICTED CATCH RATE

YEAR	LN TRANSFORM MEAN	LN TRANSFORM S.E.	RETRANSFORMED MEAN	RETRANSFORMED S.E.
88	0.7858	0.0090	2.495	0.236
89	0.7471	0.0070	2.403	0.201
90	1.2202	0.0069	3.857	0.319
91	0.3612	0.0036	1.636	0.098
92	1.0733	0.0039	3.335	0.207
93	0.6094	0.0026	2.099	0.107

Table 3. ANOVA results from Composite Model for Canadian swordfish longline CPUE, age 3.

REGRESSION OF MULTIPLICATIVE MODEL

MULTIPLE R............. 0.404
MULTIPLE R SQUARED..... 0.163

ANALYSIS OF VARIANCE

SOURCE OF VARIATION	DF	SUMS OF SQUARES	MEAN SQUARES	F-VALUE
INTERCEPT	1	3.296E2	3.296E2	
REGRESSION	13	2.805E1	2.158E0	8.248
YEAR	5	4.620E0	9.239E-1	3.532
AREA&MONTH	8	2.255E1	2.819E0	10.775
RESIDUALS	549	1.436E2	2.616E-1	
TOTAL	563	5.013E2		

REGRESSION COEFFICIENTS

CATEGORY	VARIABLE	COEFFICIENT	STD. ERROR	NO. OBS.
88	INTERCEPT	0.539	0.117	563
1				
89	1	0.050	0.116	44
90	2	0.337	0.115	45
91	3	0.202	0.099	117
92	4	0.047	0.101	104
93	5	0.068	0.094	217
2	6	-0.038	0.088	110
3	7	0.188	0.085	158
4	8	0.226	0.090	108
5	9	-0.247	0.100	60
6	10	0.233	0.179	10
7	11	0.598	0.129	24
8	12	0.478	0.122	29
9	13	0.087	0.152	15

PREDICTED CATCH RATE

YEAR	LN TRANSFORM MEAN	LN TRANSFORM S.E.	RETRANSFORMED MEAN	RETRANSFORMED S.E.
88	0.7264	0.0088	2.347	0.220
89	0.7764	0.0069	2.469	0.205
90	1.0633	0.0067	3.290	0.270
91	0.9289	0.0035	2.881	0.170
92	0.7734	0.0038	2.466	0.152
93	0.7942	0.0026	2.519	0.128

Table 4. ANOVA results from Composite Model for Canadian swordfish longline CPUE, age 4.

REGRESSION OF MULTIPLICATIVE MODEL

MULTIPLE R............. 0.514
MULTIPLE R SQUARED..... 0.264

ANALYSIS OF VARIANCE

SOURCE OF VARIATION	DF	SUMS OF SQUARES	MEAN SQUARES	F-VALUE
INTERCEPT	1	5.758E1	5.758E1	
REGRESSION	13	5.199E1	3.999E0	15.151
YEAR	5	2.249E1	4.497E0	17.037
AREA&MONTH	8	2.405E1	3.006E0	11.387
RESIDUALS	549	1.449E2	2.640E-1	
TOTAL	563	2.545E2		

REGRESSION COEFFICIENTS

CATEGORY	VARIABLE	COEFFICIENT	STD. ERROR	NO. OBS.
88	INTERCEPT	0.248	0.117	563
1				
89	1	-0.314	0.117	44
90	2	0.199	0.116	45
91	3	0.026	0.100	117
92	4	-0.107	0.101	104
93	5	-0.390	0.095	217
2	6	0.100	0.089	110
3	7	0.332	0.086	158
4	8	0.313	0.090	108
5	9	-0.051	0.101	60
6	10	0.085	0.180	10
7	11	0.591	0.129	24
8	12	0.806	0.123	29
9	13	0.353	0.153	15

PREDICTED CATCH RATE

YEAR	LN TRANSFORM MEAN	LN TRANSFORM S.E.	RETRANSFORMED MEAN	RETRANSFORMED S.E.
88	0.5805	0.0089	2.030	0.192
89	0.2667	0.0070	1.485	0.124
90	0.7799	0.0068	2.481	0.204
91	0.6063	0.0035	2.089	0.124
92	0.4732	0.0038	1.829	0.113
93	0.1905	0.0026	1.379	0.070

Table 5. ANOVA results from Composite Model for Canadian swordfish longline CPUE, age 5+.

REGRESSION OF MULTIPLICATIVE MODEL

MULTIPLE R............. 0.601
MULTIPLE R SQUARED..... 0.361

ANALYSIS OF VARIANCE

SOURCE OF VARIATION	DF	SUMS OF SQUARES	MEAN SQUARES	F-VALUE
INTERCEPT	1	3.186E2	3.186E2	
REGRESSION	13	8.685E1	6.680E0	23.853
YEAR	5	2.678E1	5.357E0	19.126
AREA&MONTH	8	5.288E1	6.610E0	23.603
RESIDUALS	549	1.538E2	2.801E-1	
TOTAL	563	5.592E2		

REGRESSION COEFFICIENTS

CATEGORY	VARIABLE	COEFFICIENT	STD. ERROR	NO. OBS.
88	INTERCEPT	-0.109	0.121	563
1				
89	1	0.097	0.120	44
90	2	0.793	0.119	45
91	3	0.498	0.103	117
92	4	0.365	0.104	104
93	5	0.130	0.098	217
2	6	0.233	0.091	110
3	7	0.635	0.088	158
4	8	0.776	0.093	108
5	9	0.760	0.104	60
6	10	-0.058	0.186	10
7	11	0.646	0.133	24
8	12	1.266	0.127	29
9	13	0.909	0.157	15

PREDICTED CATCH RATE

YEAR	LN TRANSFORM MEAN	LN TRANSFORM S.E.	RETRANSFORMED MEAN	RETRANSFORMED S.E.
88	0.5258	0.0095	1.937	0.188
89	0.6228	0.0074	2.137	0.183
90	1.3187	0.0072	4.286	0.364
91	1.0240	0.0037	3.198	0.196
92	0.8909	0.0041	2.799	0.179
93	0.6557	0.0028	2.214	0.116

Table 6. ANOVA results from the Composite Model with gear as a main effect for Canadian swordfish longline CPUE for ages 2-5+.

a) AGE 2 SWORDFISH

REGRESSION OF MULTIPLICATIVE MODEL

MULTIPLE R............. 0.562
MULTIPLE R SQUARED..... 0.315

ANALYSIS OF VARIANCE

SOURCE OF VARIATION	DF	SUMS OF SQUARES	MEAN SQUARES	F-VALUE
INTERCEPT	1	2.158E4	2.158E4	
REGRESSION	14	6.719E1	4.799E0	18.030
YEAR	5	3.994E1	7.988E0	30.011
MONTH&AREA	8	2.600E1	3.250E0	12.211
GEAR	1	9.527E-2	9.527E-2	0.358
RESIDUALS	548	1.459E2	2.662E-1	
TOTAL	563	2.180E4		

b) AGE 3 SWORDFISH

REGRESSION OF MULTIPLICATIVE MODEL

MULTIPLE R............. 0.405
MULTIPLE R SQUARED..... 0.164

ANALYSIS OF VARIANCE

SOURCE OF VARIATION	DF	SUMS OF SQUARES	MEAN SQUARES	F-VALUE
INTERCEPT	1	2.124E4	2.124E4	
REGRESSION	14	2.810E1	2.007E0	7.661
YEAR	5	4.668E0	9.336E-1	3.563
AREA&MONTH	8	2.227E1	2.784E0	10.627
GEAR	1	4.933E-2	4.933E-2	0.188
RESIDUALS	548	1.436E2	2.620E-1	
TOTAL	563	2.141E4		

c) AGE 4 SWORDFISH

REGRESSION OF MULTIPLICATIVE MODEL

MULTIPLE R............. 0.514
MULTIPLE R SQUARED..... 0.265

ANALYSIS OF VARIANCE

SOURCE OF VARIATION	DF	SUMS OF SQUARES	MEAN SQUARES	F-VALUE
INTERCEPT	1	2.443E4	2.443E4	
REGRESSION	14	5.211E1	3.722E0	14.085
YEAR	5	2.174E1	4.347E0	16.451
AREA&MONTH	8	2.347E1	2.934E0	11.103
GEAR	1	1.149E-1	1.149E-1	0.435
RESIDUALS	548	1.448E2	2.642E-1	
TOTAL	563	2.463E4		

d) AGE 5+ SWORDFISH

REGRESSION OF MULTIPLICATIVE MODEL

MULTIPLE R............. 0.602
MULTIPLE R SQUARED..... 0.362

ANALYSIS OF VARIANCE

SOURCE OF VARIATION	DF	SUMS OF SQUARES	MEAN SQUARES	F-VALUE
INTERCEPT	1	2.133E4	2.133E4	
REGRESSION	14	8.713E1	6.224E0	22.223
YEAR	5	2.699E1	5.399E0	19.277
AREA&MONTH	8	5.172E1	6.465E0	23.085
GEAR	1	2.859E-1	2.859E-1	1.021
RESIDUALS	548	1.535E2	2.800E-1	
TOTAL	563	2.157E4		

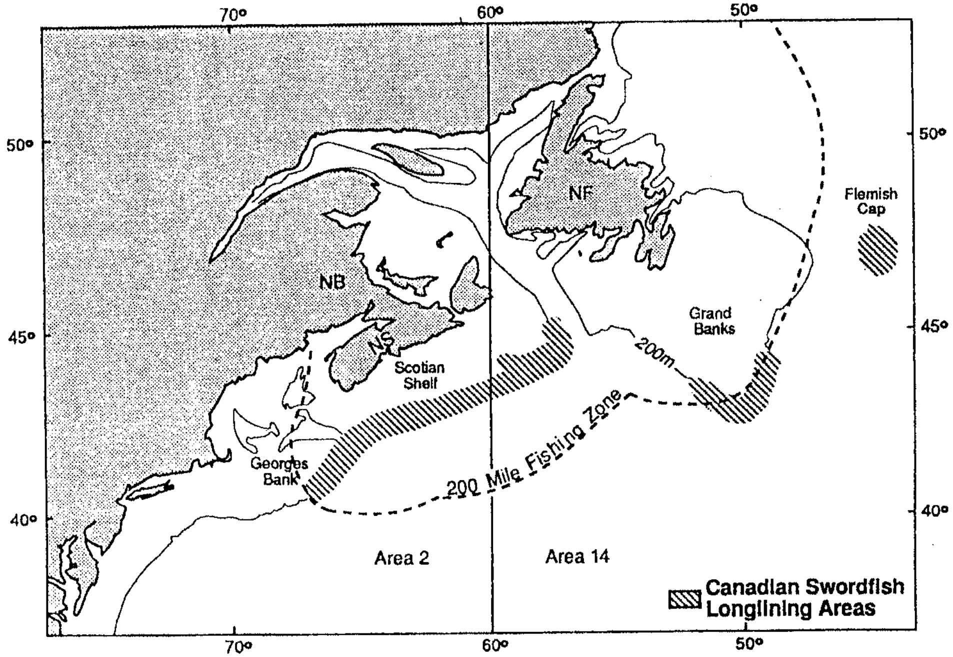


Figure 1. Geographic distribution of Canadian swordfish longlining areas within ICCAT Areas 2 and 14.

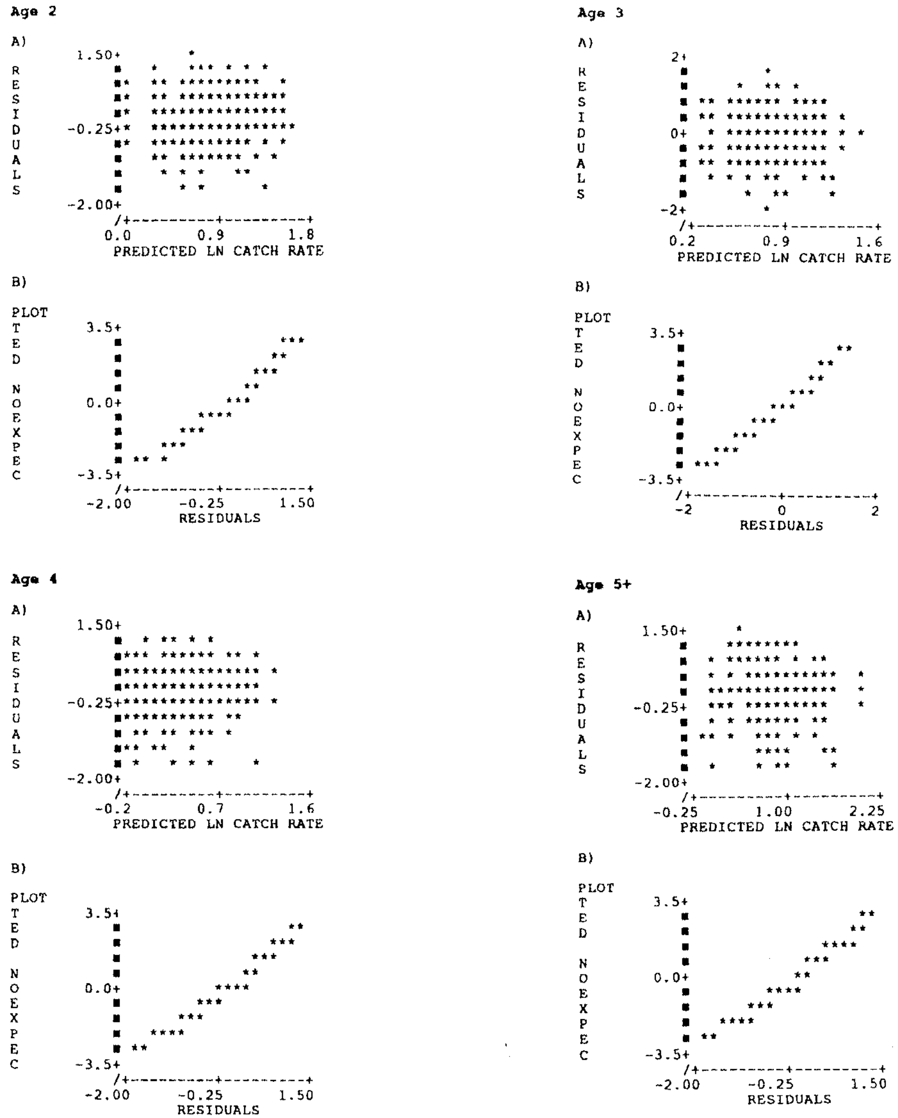


Figure 2. Plots by age group of: A) residuals from predicted catch rates (ln CPUE) and B) partial probabilities of residuals from Canadian swordfish longline data, 1988-93.

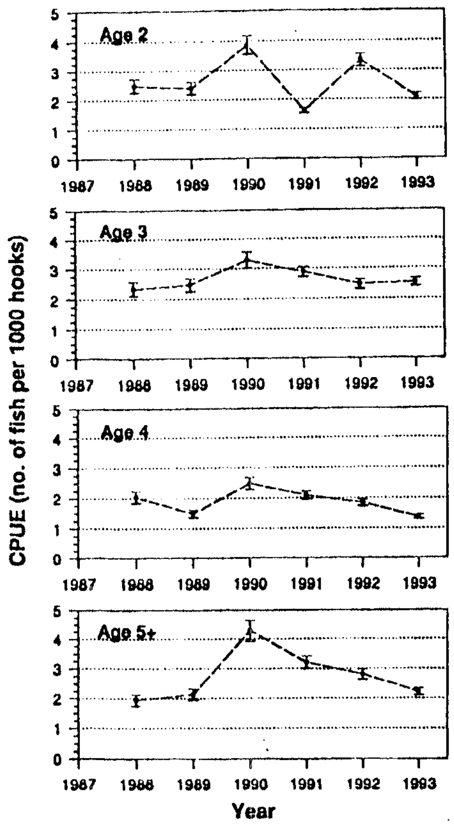


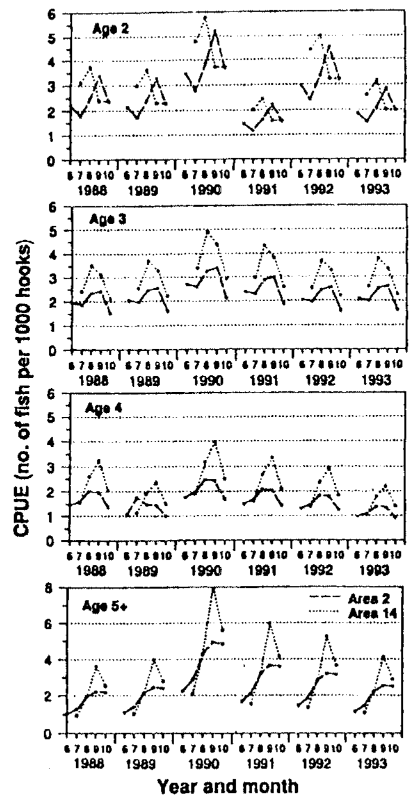
Figure 3. Standardized catch rates for swordfish (no. of fish per 1000 hooks) by age group for the Canadian longline fishery from 1988-1993. Vertical bars represent ± 1 standard error.

Appendix 1

The annual pattern of CPUE between areas 2 and 14 is considered to be similar and reflective of abundance, therefore, both areas were retained for the analysis. Although only 10% of the Canadian catch is from area 14, the seasonal pattern of CPUE is consistently different from area 2. The multiplicative model removes the seasonal difference in the pattern of CPUE between areas.

Monthly trends in CPUE for areas 2 and 14 were generated by running the Composite Model for each age group with different standards for the Area & Month composite term (Appendix Fig. 1). Differences between areas are apparent, with monthly catch rates from area 14 being consistently higher than area 2 for all age groups. Temporal shifts in peak catch rates occurred between areas but differed among age groups. For ages 2 and 3, the highest catch rates generally occurred during August in area 14 and in September for area 2. In contrast, for ages 4 and 5+, peak catch rates generally occurred during September in both areas.

Since swordfish exhibit temporal and spatial movement patterns in and out of the Canadian fishing zone during their summer feeding migration (Appendix Fig. 1), the composite term should help explain additional variability in the estimate of CPUE. Although swordfish captured in area 14 are generally larger (as indicated from Task II data) and catch rates higher than area 2, the number of trips to this region are low (i.e. 78 vs 485 in area 2 from 1988 to 1993) because of the distance to the fishing grounds and inclement weather conditions. It is recommended, however, that area 14 be included in the analysis since it is an important component of the Canadian fishery.



Appendix Fig.1 Standardized catch rates for age 2-5+ swordfish (no. of fish per 1000 hooks) by area and month for the Canadian longline fishery from 1988-1993.