STANDARDIZED CPUE BY AGE FOR NORTH ATLANTIC SWORDFISH CAUGHT BY JAPANESE LONGLINE FISHERY

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SUMMARY

Two kinds of age-specific CPUE were standardized for north Atlantic swordfish *(Xiphias gladius)* caught by the Japanese longline fishery using General Linear Model (GLM). One was fit to the data which were processed using the age-slicing technique with the Gompertz growth equation (ICCAT 1989), and the other was fit to that with the Ehrhardt sex-specific growth equation (Ehrhardt 1995) and sex ratio information (Mejuto and de la Serna 1996).

RÉSUMÉ

On a standardisé, au moyen du modèle linéaire généralisé (GLM), deux types de CPUE spécifique de l'âge de l'espadon *(Xiphias gladius)* de l'Atlantique Nord capturé par les palangriers japonais. L'une d'entre elles a été ajustée à des données traitées par la technique de découpage des âges avec l'équation de Gompertz (ICCAT, 1989), et l'autre a été ajustée à la CPUE élaborée à partir de l'équation de croissance spécifique du sexe d'Ehrhardt (Ehrhardt, 1995) et des informations sur le sex-ratio (Mejuto et de la Serna, 1996).

RESUMEN

Se normalizaron dos clases de CPUE específicas de la edad para el pez espada *(Xiphias gladius)* del Atlántico norte, capturado por la pesquería palangrera de Japón, mediante técnicas del Modelo Lineal Generalizado (GLM). Una se ajustó a los datos que fueron procesados usando la técnica de separación de edades con la ecuación de crecimiento Gompertz (ICCAT 1989), y la otra se ajustó con la ecuación de crecimiento específica de la edad de Ehrhardt (Ehrhardt, 1995) e información sobre proporción de sexos (Mejuto y Serna, 1996).

Introduction

Current swordfish stock assessment for north Atlantic is base on age-structured method including Virtual Population Analysis (VPA), which needs indices of abundance for its calibration. For north Atlantic swordfish caught by Japanese longline fishery, however, the CPUE standardization have been carried out for age-combined data only one age group (5+). In this study, the catch in number data was specified into several age groups, and then age-specific CPUE were standardized using General Linear Model (GLM).

Materials and methods

1. Basic data

In this study, two kinds of age-specific catch-and-effort data were provided for the standardization of swordfish CPUE. One was made using age slicing with sex combined growth curve and includes age 1 to age 5+ for the period 1978-1995 (Gompertz data set), another was made using sex ratio information and age slicing with the different growth curves for female and male, and includes age 1 to age 10+ (Ehrhardt data set). The catch-and-effort data (C/E) originally used were obtained from the Japanese longline fishery statistics based on the logbooks and compiled at the National Research Institute of Far Seas Fisheries. It is the same data set as the Task II

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but additionally includes gear configuration information i.e., number of hooks per basket, for 1978-1995, with the preliminary data in 1995. The catch of swordfish was expressed in number of fish. The catch in the C/E was broken down into the catch by length class using the length frequency which was calculated from the Japanese catch at size data. The catch by length class in the C/E was divided into those for female and male based on the sex ratio data which was reported by Mejuto and Serna (1996). Each catch by length class of the C/E was separately altered to catch by age using age slicing technique with Ehrhardt growth equation (Ehrhardt 1995), and then pool the catches together for both sexes in the same age. While, the catch by length class in the C/E were also altered to catch by age using age slicing with Gompertz growth equation (ICCAT 1989) without considering sex specification. CPUE was defined as the number of catch of swordfish per 1,000 hooks. Observations with less than 3,000 hooks were excluded from this analysis.

2. Standardization

In order to standardize CPUE of swordfish, log-normal error structure was assumed. GLM procedures of SAS package (Ver. 6.11) was used in the present analysis. Year, season, subarea and gear configuration were incorporated as main effects. Quarter was used for fishing season and five subareas were defined as shown in Fig. 1. The gear configuration were categorized to four levels (3-7, 8-11, 12-15 and 16-20 hooks between float). The GLM used were :

$$\ln(CPUE+constant)=\mu+Y+Q+A+G+Q*A+Q*G+A*G+e$$

where μ : overall mean; Y : effect of year; Q : effect of quarter; A : effect of subarea; G : effect of gear; A*Q : interaction between A and Q; Q*G : interaction between Q and G; A*G : interaction between A and G; e : error term

In order to include observations with no catch of swordfish, the natural logarithm of (CPUE+constant) was used. The constants, 0.01, 0.02, 0.02, 0.005 and 0.003 for the age 1 to age 5+ groups for Gompertz data set, 0.001, 0.004, 0.008, 0.01, 0.01, 0.008, 0.005, 0.003, 0.002 and 0.005 for the age 1 to age 10+ groups for Ehrhardt data set were selected as 0.1*mean CPUE of swordfish, respectively. The 0.1*mean CPUE as the constant was recommended in Bluefin Species Group (ICCAT, 1996). The combination of interaction terms used were based on Nakano (1993).

Results and Discussion

The ANOVA results for the GLM are shown in Table 1 and 2. In most cases, F values in ANOVA tables were highly significant. The Gear effects were not significant, however, for the age 2 to age 5+ groups for Gompertz data set, and for the age 2 group for Ehrhardt data set. The R-squares were between 0.30 and 0.36 for Gompertz data set, between 0.29 and 0.44 for Ehrhardt data set. The distribution of the standardized residuals is shown in Fig. 2. Those appear roughly to be normal in all cases.

The standardized CPUEs for Gompertz and Ehrhardt data sets are shown in Figs. 3 and 4 with 95% confidence limits. The relative strong year class, 1987 year class was distinguished in CPUE trend from age 2 to age 4, though the change of CPUE by year (year effect) was more significant than difference of year class strength (year class effect). And the standardized CPUEs of same age group between both data sets also showed very similar pattern. For Gompertz data set, the standardized CPUEs showed slight decline trend for the age 2 to age 4 groups, whereas it showed relatively steeper decline for the age 5+ group. For Ehrhardt data set, the standardized CPUEs showed slight decline trend in all cases, and varied for the age 2 to age 6 groups compared with for the older age groups.

Reference

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Mejuto, J. and J. M. 1996. Serna Preparation of data from the Spanish surface longline fleet: creation of basic files to carry out ICCAT and GLM's by sex. ICCAT working document SCRS/96/136.

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Table. 1 ANOVA for the GLM fit to the catch and effort data which was processed using age slicing with sex combined Gompertz growth equation for the age 1 to age 5+ groups.

Age 1

Source	DF	SS	Mean Sq.	F Value	Pr > F
Model	60	7556.47	125.94	83.00	0.0001
Error	8673	13160.43	1.52		
Corr. Tot.	8733	20716.90			

R-Square	C.V.	Root MSE
0.364	-22.44	1.23

Source	DF	Type III SS	Mean Sq.	F Value	Pr > F
Y	17	1942.13	114.24	75.29	0.0001
Q	3	1338.65	446.22	294.07	0.0001
A	4	136.90	34.23	22.56	0.0001
G	3	32.68	10.89	7.18	0.0001
Q*A	12	204.50	17.04	11.23	0.0001
Q*G	9	103.71	11.52	7.59	0.0001
A*G	12	36.23	3.02	1.99	0.0213

Age 2

Source	DF	SS	Mean Sq.	F Value	Pr > F
Model	60	3944.60	65.74	69.44	0.0001
Error	8673	8211.14	0.95		
Corr. Tot.	8733	12155.75			

R-Square	C.V.	Root MSE
0.325	-29.99	0.97

Source	DF	Type III SS	Mean Sq.	F Value	Pr > F
Y	17	904.85	53.23	56.22	0.0001
Q	3	554.77	184.92	195.32	0.0001
A	4	279.45	69.86	73.79	0.0001
G	3	4.94	1.65	1.74	0.1568
Q*A	12	167.02	13.92	14.70	0.0001
Q*G	9	25.45	2.83	2.99	0.0015
A*G	12	67.69	5.64	5.96	0.0001

Age 3

Source	DF	SS	Mean Sq.	F Value	Pr > F
Model	60	3598.11	59.97	61.92	0.0001
Error	8673	8400.09	0.97		
Corr. Tot.	8733	11998.20			

R-Square	C.V.	Root MSE
0.300	-40.88	0.98

Source	DF	Type III SS	Mean Sq.	F Value	Pr > F
Y	17	363.48	21.38	22.08	0.0001
Q	3	50.61	16.87	17.42	0.0001
A	4	536.64	134.16	138.52	0.0001
G	3	1.92	0.64	0.66	0.5758
Q*A	12	222.99	18.58	19.19	0.0001
Q*G	9	68.19	7.58	7.82	0.0001
A*G	12	102.30	8.52	8.80	0.0001

Age 4

Source	DF	SS	Mean Sq.	F Value	Pr > F
Model	60	4188.72	69.81	73.55	0.0001
Error	8673	8232.61	0.95		
Corr. Tot.	8733	12421.34			

R-Square	C.V.	Root MSE
0.337	-40.90	0.97

Source	DF	Type III SS	Mean Sq.	F Value	Pr > F
Y	17	537.80	31.64	33.33	0.0001
Q	3	71.47	23.82	25.10	0.0001
A	4	627.70	156.92	165.32	0.0001
G	3	3.86	1.29	1.36	0.2545
Q*A	12	219.73	18.31	19.29	0.0001
Q*G	9	64.84	7.20	7.59	0.0001
A*G	12	112.13	9.34	9.84	0.0001

Age 5+

Source	DF	SS	Mean Sq.	F Value	Pr > F
Model	60	3391.27	56.52	70.80	0.0001
Error	8673	6923.67	0.80		
Corr. Tot.	8733	10314.94			

R-Square	C.V.	Root MSE
0.329	-45.40	0.89

Source	DF	Type III SS	Mean Sq.	F Value	Pr > F
Y	17	710.41	41.79	52.35	0.0001
Q	3	94.47	31.49	39.44	0.0001
A	4	488.43	122.11	152.96	0.0001
G	3	5.71	1.90	2.38	0.0673
Q*A	12	186.21	15.52	19.44	0.0001
Q*G	9	41.50	4.61	5.78	0.0001
A*G	12	85.33	7.11	8.91	0.0001

Table. 2 ANOVA for the GLM fit to the catch and effort data which was processed using age slicing with Ehrhardt growth equation by sex for the age 1 to age 10+ groups.

Age 1

Source	DF	SS	Mean Sq.	F Value	Pr > F
Model	52	3738.93	71.90	45.73	0.0001
Error	5042	7927.19	1.57		
Corr. Tot.	5094	11666.12			

R-Square	C.V.	Root MSE
0.320	-23.08	1.25

Source	DF	Type III SS	Mean Sq.	F Value	Pr > F
Y	9	1112.74	123.64	78.64	0.0001
Q	3	679.50	226.50	144.06	0.0001
A	4	106.40	26.60	16.92	0.0001
G	3	8.39	2.80	1.78	0.1490
Q*A	12	122.71	10.23	6.50	0.0001
Q*G	9	31.49	3.50	2.23	0.0179
A*G	12	65.05	5.42	3.45	0.0001

Age 2

Source	DF	SS	Mean Sq.	F Value	Pr > F
Model	52	2192.26	42.16	40.12	0.0001
Error	5042	5298.35	1.05		
Corr. Tot.	5094	7490.61			

R-Square	C.V.	Root MSE
0.293	-27.50	1.03

Source	DF	Type III SS	Mean Sq.	F Value	Pr > F
Y	9	664.42	73.82	70.25	0.0001
Q	3	157.83	52.61	50.06	0.0001
A	4	215.58	53.89	51.29	0.0001
G	3	14.51	4.84	4.60	0.0032
Q*A	12	104.25	8.69	8.27	0.0001
Q*G	9	17.85	1.98	1.89	0.0492
A*G	12	84.59	7.05	6.71	0.0001

Age 3

Source	DF	SS	Mean Sq.	F Value	Pr > F
Model	52	1735.04	33.37	41.94	0.0001
Error	5042	4011.42	0.80		
Corr. Tot.	5094	5746.47			

R-Square	C.V.	Root MSE
0.302	-30.17	0.89

Source	DF	Type III SS	Mean Sq.	F Value	Pr > F
Y	9	266.55	29.62	37.22	0.0001
Q	3	25.20	8.40	10.56	0.0001
A	4	251.08	62.77	78.90	0.0001
G	3	9.36	3.12	3.92	0.0083
Q*A	12	78.85	6.57	8.26	0.0001
Q*G	9	19.99	2.22	2.79	0.0029
A*G	12	70.57	5.88	7.39	0.0001

Age 4

Source	DF	SS	Mean Sq.	F Value	Pr > F
Model	52	2031.10	39.06	53.54	0.0001
Error	5042	3678.16	0.73		
Corr. Tot.	5094	5709.26			

R-Square	C.V.	Root MSE
0.356	-31.56	0.85

Source	DF	Type III SS	Mean Sq.	F Value	Pr > F
Y	9	152.36	16.93	23.21	0.0001
Q	3	7.99	2.66	3.65	0.0121
A	4	347.96	86.99	119.24	0.0001
G	3	10.84	3.61	4.95	0.0020
Q*A	12	69.78	5.81	7.97	0.0001
Q*G	9	29.56	3.28	4.50	0.0001
A*G	12	68.02	5.67	7.77	0.0001

Age 5

Source	DF	SS	Mean Sq.	F Value	Pr > F
Model	52	2629.98	50.58	70.45	0.0001
Error	5042	3619.79	0.72		
Corr. Tot.	5094	6249.76			

R-Square	C.V.	Root MSE
0.421	-31.25	0.85

Source	DF	Type III SS	Mean Sq.	F Value	Pr > F
Y	9	326.11	36.23	50.47	0.0001
Q	3	17.11	5.70	7.95	0.0001
A	4	439.83	109.96	153.16	0.0001
G	3	7.01	2.34	3.25	0.0208
Q*A	12	73.52	6.13	8.53	0.0001
Q*G	9	32.66	3.63	5.06	0.0001
A*G	12	57.56	4.80	6.68	0.0001

Age 6

Source	DF	SS	Mean Sq.	F Value	Pr > F
Model	52	2762.45	53.12	76.63	0.0001
Error	5042	3495.34	0.69		
Corr. Tot.	5094	6257.78			

R-Square	C.V.	Root MSE
0.441	-28.12	0.83

Source	DF	Type III SS	Mean Sq.	F Value	Pr > F
Y	9	215.65	23.96	34.56	0.0001
Q	3	29.92	9.97	14.38	0.0001
A	4	461.22	115.31	166.33	0.0001
G	3	7.47	2.49	3.59	0.0130
Q*A	12	85.10	7.09	10.23	0.0001
Q*G	9	26.93	2.99	4.32	0.0001
A*G	12	57.18	4.76	6.87	0.0001

(continued)

Age 7

Source	DF	SS	Mean Sq.	F Value	Pr > F
Model	52	2561.51	49.26	70.01	0.0001
Error	5042	3547.50	0.70		
Corr. Tot.	5094	6109.01			

R-Square	C.V.	Root MSE
0.419	-24.43	0.84

Source	DF	Type III SS	Mean Sq.	F Value	Pr > F
Y	9	139.00	15.44	21.95	0.0001
Q	3	18.42	6.14	8.73	0.0001
A	4	420.38	105.10	149.37	0.0001
G	3	7.91	2.64	3.75	0.0106
Q*A	12	95.87	7.99	11.35	0.0001
Q*G	9	21.30	2.37	3.36	0.0004
A*G	12	61.73	5.14	7.31	0.0001

Age 8

Source	DF	SS	Mean Sq.	F Value	Pr > F
Model	52	2621.24	50.41	70.67	0.0001
Error	5042	3596.20	0.71		
Corr. Tot.	5094	6217.44			

R-Square	C.V.	Root MSE
0.421	-21.22	0.84

Source	DF	Type III SS	Mean Sq.	F Value	Pr > F
Y	9	340.97	37.89	53.12	0.0001
Q	3	26.48	8.83	12.37	0.0001
A	4	398.74	99.68	139.76	0.0001
G	3	11.40	3.80	5.33	0.0012
Q*A	12	103.76	8.65	12.12	0.0001
Q*G	9	25.26	2.81	3.93	0.0001
A*G	12	60.41	5.03	7.06	0.0001

Age 9

Source	DF	SS	Mean Sq.	F Value	Pr > F
Model	52	2283.82	43.92	63.42	0.0001
Error	5042	3491.65	0.69		
Corr. Tot.	5094	5775.46			

R-Square	C.V.	Root MSE
0.395	-18.70	0.83

Source	DF	Type III SS	Mean Sq.	F Value	Pr > F
Y	9	440.66	48.96	70.70	0.0001
Q	3	14.34	4.78	6.90	0.0001
A	4	351.41	87.85	126.86	0.0001
G	3	5.57	1.86	2.68	0.0453
Q*A	12	87.36	7.28	10.51	0.0001
Q*G	9	26.87	2.99	4.31	0.0001
A*G	12	52.07	4.34	6.27	0.0001

Age 10+

Source	DF	SS	Mean Sq.	F Value	Pr > F
Model	52	1929.85	37.11	48.28	0.0001
Error	5042	3875.45	0.77		
Corr. Tot.	5094	5805.30			

R-Square	C.V.	Root MSE
0.332	-25.73	0.88

Source	DF	Type III SS	Mean Sq.	F Value	Pr > F
Y	9	165.45	18.38	23.92	0.0001
Q	3	12.74	4.25	5.53	0.0009
A	4	352.96	88.24	114.80	0.0001
G	3	11.32	3.77	4.91	0.0021
Q*A	12	83.69	6.97	9.07	0.0001
Q*G	9	31.02	3.45	4.48	0.0001
A*G	12	66.67	5.56	7.23	0.0001

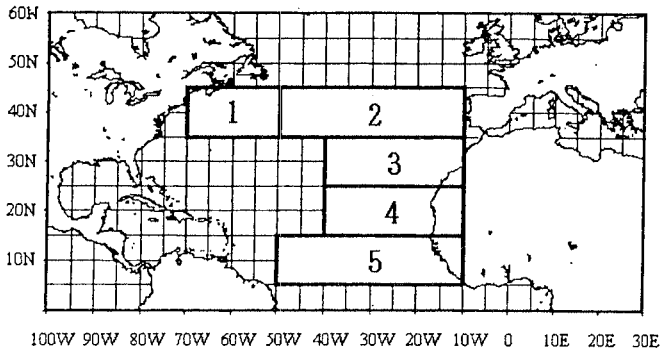

Fig. 1 Subarea used in standardization of CPUE for north Atlantic swordfish.

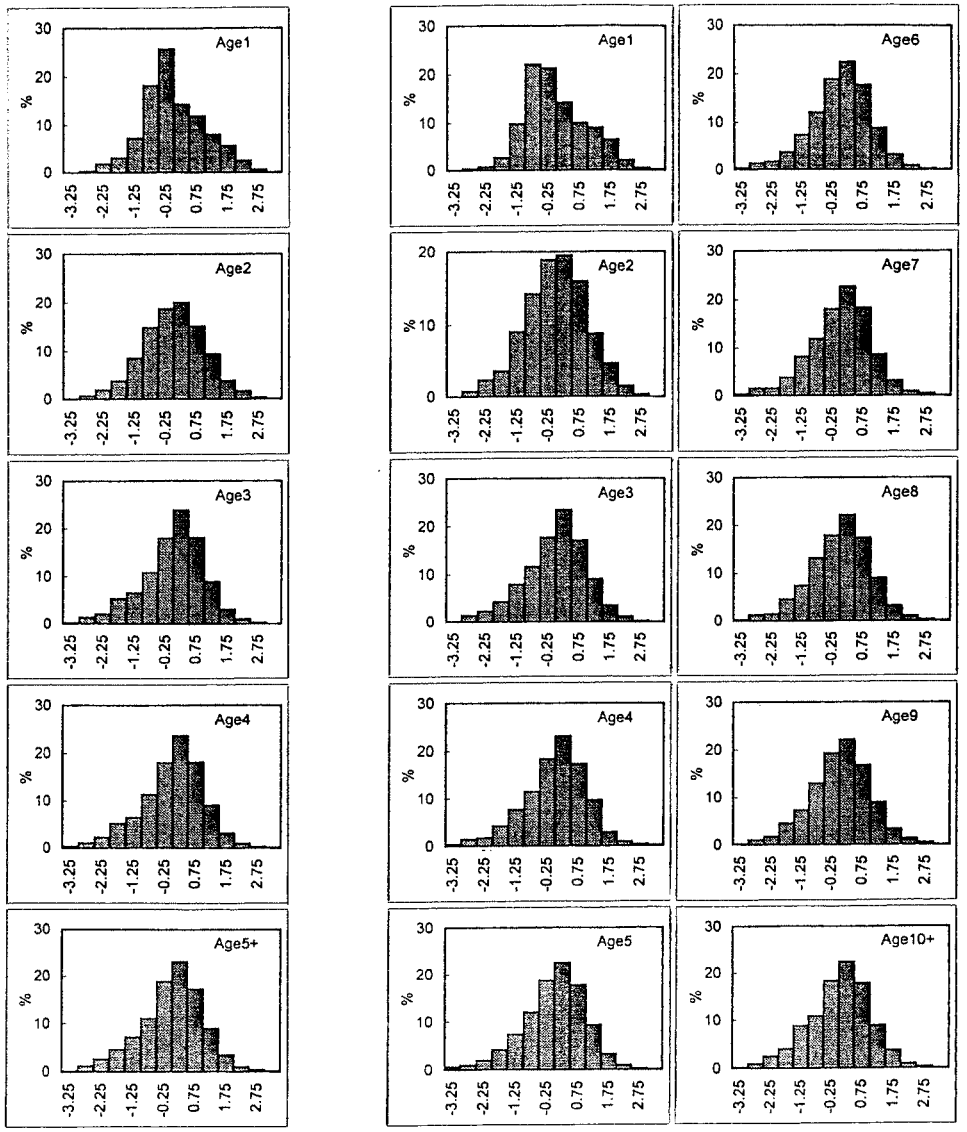

Fig. 2 Distributions of standarzized residual of the GLM fit to the catch and effort data which was processed using age slicing with sex-combimed Gompertz growth equation for the age 1 to age 5+ groups (left), and that with Ehrhardt growth equation by sex for the age 1 to age 10+ groups (right).

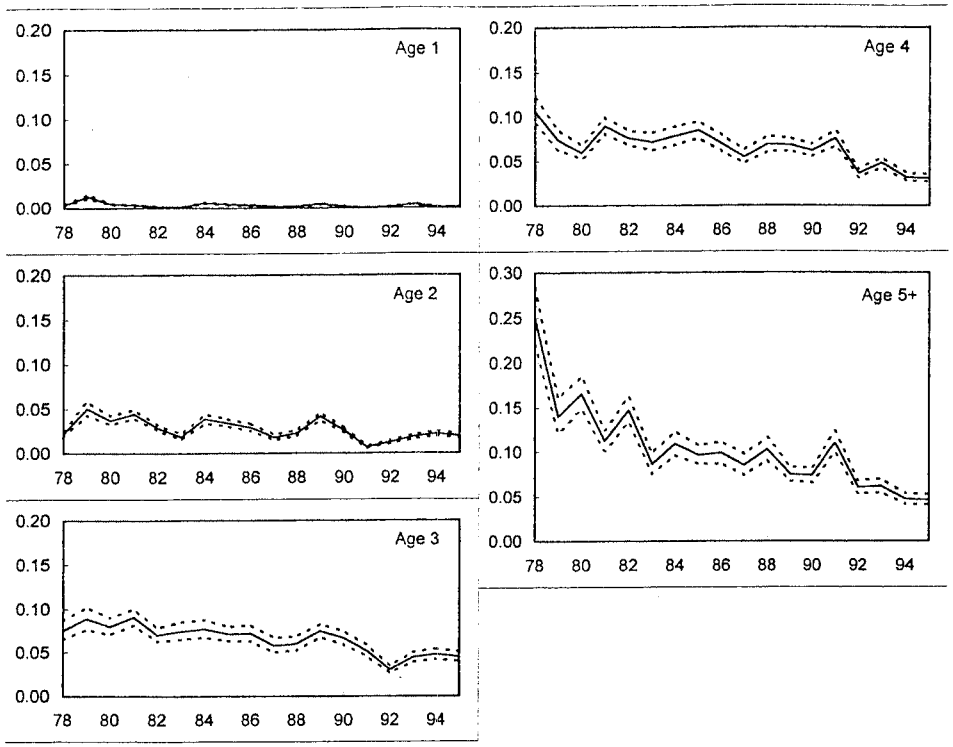

Fig. 3 Standardized CPUE of north Atlantic swordfish for the age 1 to age 5+ for the GLM fit to the catch and effort data which was proccessed using age slicing with sex-combined Gompertz growth equation. Dotted line shows 95% upper and lower confidance limits.

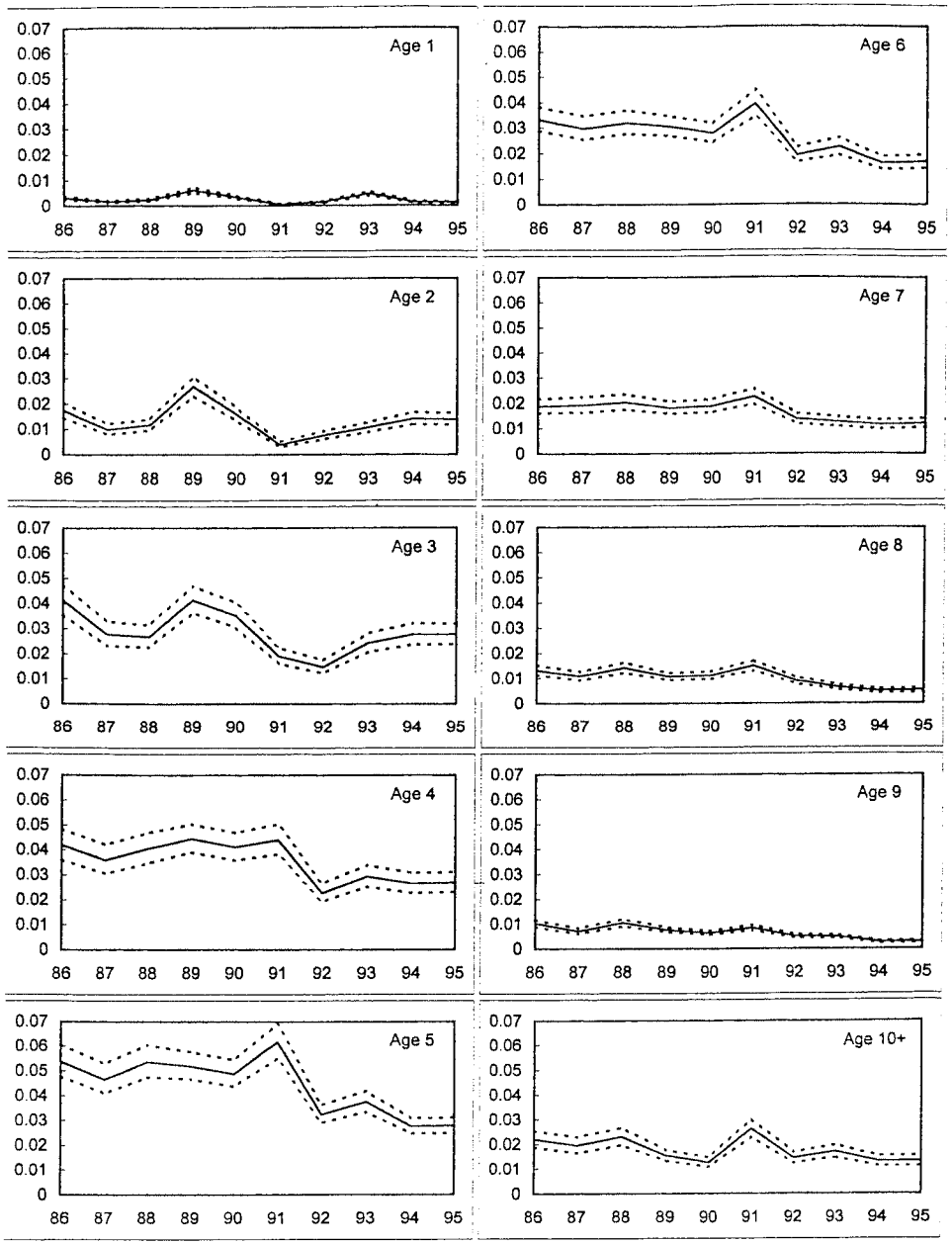

Fig. 4 Standardized CPUE of north Atlantic swordfish for the age 1 to age 5+ for the GLM fit to the catch and effort data which was proccessed using age slicing with Ehrhardt equation by sex. Dotted line shows 95% upper and lower confidance limits.