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STANDARDIZED CATCH RATES FOR SWORDFISH *(XIPHIAS GLADIUS)* FROM THE U.S. LONGLINE FLEET THROUGH 1993

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SUMMARY

Swordfish catch, size and effort data collected from the U.S. longline fleet operating over a wide geographical range of the western north Atlantic Ocean were used to develop age-specific indices of abundance of north Atlantic swordfish. Standardized catch rates were estimated using the Generalized Linear Modeling approach.

RESUMÉ

Des données de capture, de taille et d'effort collectées sur l'espadon auprès de la flottille palangrière des Etats-Unis qui pêche dans une ample zone géographique de l'Atlantique nord-ouest ont été employées pour élaborer des indices d'abondance spécifiques de l'âge pour l'espadon nord-atlantique. Le taux standardisé de capture a été estimé au moyen du modèle linéaire généralisé.

RESUMEN

Se emplearon datos de captura, talla y esfuerzo de pez espada de la flota de palangre de Estados Unidos que faena en un amplio rango geográfico en el Océano Atlántico oeste norte, para desarrollar índices de abundancia específicos de la edad de pez espada en el Atlántico norte. Las tasas de captura estandarizadas se estimaron utilizando el enfoque de Modelo Lineal Generalizado.

Introduction

Information on the relative abundance of swordfish age classes is necessary to tune age-sequenced analyses (VPA). Data collected from the US longline fleet has been previously used to develop standardized catch per unit effort (CPUE) indices of abundance. This report documents the analytical methods applied to the available US longline fleet data through 1994 and presents age-and size-specific, standardized CPUE indices for use in tuning swordfish VPAs, updating the material presented in Scott *et.al.* (1993, 1994). Swordfish catch, size and effort data collected from the US longline fleet operating over a wide geographical range of the western north Atlantic Ocean were used to develop age-specific indicies of abundance of north Atlantic swordfish. Standardized catch rates were estimated using the General Linear Modeling (GLM) approach.

Methods

Hoey and Bertolino (1988) described the available catch and effort data for swordfish from the US longline fishery. Hoey *et. al.* (1989), Scott and Bertolino (1991,1994) and Scott *et. al.* (1992, 1993) described the GLM method of analysis employed for indexing swordfish abundance from those data. The present analysis is an application of the GLM techniques to updated catch and effort data (through 1994) from the US longline fleet. Age-specific indices of abundance (ages 1, 2, 3, 4, and 5^+ groupings) are developed after ageing the swordfish catch using the age slicing method applying the ICCAT Gompertz growth model for pooled sexes in the fashion described by Nelson *et. al.* (1990) and as used by the 1992-94 SCRS swordfish species groups. Alternative methods could be employed, but the purpose of this paper is to present the abundance index information in a fashion that is consistent with previous studies and to allow some evaluation of the most recent catch rate data in view of recent regulatory measures.

For the present analysis, the analytical data base on US longline catch and effort for 1981 through 1994 was reviewed and updated based on fishermen's reports and/or interviews received since the previous update. A total of 5288 vessel trips, representing 123 different vessels from which at least two years catch and effort observations were available were used for analysis (Table 1). This represents an approximately 13% increase in observations compared to the 1994 analysis (Scott and Bertolino 1994). As described in Hoey *et.al.* (1989), Nelson *et.al.* (1990), Scott and Bertolino (1991, 1994), and Scott *et.al.* (1992, 1993), the available catch and effort data were cross classified by year, calendar quarter, area of fishing, size of set, proportion of total catch comprised of swordfish, operation style, and age class. Nominal CPUE values were calculated as fish caught per thousand hooks set. Average nominal values from the updated data set by year, age, and fishing area, are shown in Table 2.

Implementation of US regulations, which are in conformity with the ICCAT recommendations for conservation of swordfish and limit the allowable landings of swordfish by US fishermen, resulted in changes in both the type of data obtained and the manner in which the US data are obtained for analysis. Three regulatory effects in particular, are of importance to the present analysis. The first is implementation of the ICCAT recommended minimum size of 25 kg whole weight. The second is implementation of additional reporting requirements wherein US fishermen are required to report both their daily fishing effort and the individual sizes for all swordfish landed. Prior to implementation of these regulations, reporting of fish sizes was voluntary and incomplete for many vessels. The third is a restriction on the total allowable harvest level by US fishermen since 1991 (4,173 mt in 1991 and 4,561 mt in 1992, 1993, and 1994).

Seven geographical areas of fishing were used for classification as defined in Hoey *et.al.* (1990), Scott and Bertolino (1991, 1994) and Scott *et.al.* (1992, 1993). The areas used for classification were: Caribbean (CAR), Gulf of Mexico (GOM), Florida east coast (FEC), South Atlantic Bight (SAB), mid-Atlantic Bight (MAB), New England coastal (NEC) and northeast distant waters (NED). Four set size classifiers were used: 1, <100 hooks/set; 2, 100-299 hooks/set; 3, 300-499 hooks/set; and 4, ≥ 500 hooks/set. Set size was assumed to control for changes in gear deployment hypothesized to affect CPUE. The levels used in classification approximated the quartiles in the data set. Four levels of the proportion swordfish in the total catch were used corresponding to the quartiles into which the proportion of swordfish fell (*i.e.* $\leq 25\%$, $>25\text{-}\leq 50\%$, $>50\text{-}\leq 75\%$, and $>75\%$). The percentage swordfish classifier was assumed to control for effects on swordfish CPUE through the diversification of the US longline fleet into a mixed species fishery and associated targeting on different species.

Nominal CPUE data were normalized through the natural log transform. Based on the results of Scott *et.al.* (1992) and the recommendation of the 1991 SCRS (SCRS Swordfish Assessment Group 1992), zero CPUE information was incorporated into the analyses by adding the zero CPUE effort uniformly across all other observations in the same analytical stratum.

Based on the 1991 SCRS recommendations (SCRS Swordfish Assessment Group, 1992), and those of Scott *et.al.* (1992) only models were fit to the data for which Least Square Means (LSM) for each year effect were estimable. In this analysis, due to the nature of the missing information, only main effect models resulted in estimable year effect LSMs. The final models fit to the CPUE data included main effects for year, calendar quarter, area, set size, operation style, and proportion swordfish. Standards were defined as the earliest year, and the highest classification level for all other main effects.

Results and Discussion

Analysis of variance (ANOVA) results for the models fit to the CPUE data are shown in Table 3. In all cases, the resulting F-statistic was highly significant. For the age-slicing method the main effect models fit explained between 50 and 65% of the variability in the observed data, depending on the age grouping modelled.

Indices of age-specific abundance, based on the yearly LSM estimates from the models fit are also presented in Tables 4 along with their 95% confidence regions (back transformed to arithmetic scale including the logrithmic bias correction). Graphically, these data are presented in Figure 1. As observed in prior GLM analyses of these data, the LSM estimates are sufficiently precise to allow discrimination of trend in the data for some ages.

Because the landing and sale of fish smaller the minimum size was restricted from 1991-present, catch rates estimated from landings data are underestimates of the actual catch rates. For this reason, estimates of standardized catch rates for fish aged 1 and 2 were only computed through 1990.

References

Hoey, J.J. and A. Bertolino. 1988. Review of the U.S. fishery for swordfish, 1978 to 1986. ICCAT - Col. Vol. Sci. Pap., Vol. XXVII:256-266.

Hoey, J. R. Conser, and E. Duffie. 1989. Catch per unit effort information from the U.S. swordfish fishery. ICCAT - Col. Vol. Sci. Pap., Vol. XXXIX:195-249.

Nelson, W.R., B.E. Brown, R.J. Conser, J.J. Hoey, S. Nichols, J.E. Powers, M.P. Sissenwine, S.C. Turner, and D.S. Vaughn. 1990. Report of the NMFS swordfish stock assessment workshop (March 20-24, 1989). ICCAT - Col. Vol. Sci. Pap., Vol. XXXII(2):287-352.

Scott, G.P. and A. Bertolino. 1991. Standardized catch rates for swordfish (*Xiphias gladius*) from the U.S. longline fleet through 1990. ICCAT - Col. Vol. Sci. Pap., Vol. XXXV(2):397-404.

Scott, G.P. and A. Bertolino. 1994. Standardized catch rates for swordfish (*Xiphias gladius*) from the U.S. longline fleet through 1993. ICCAT - Col. Vol. Sci. Pap., Vol. XLIV(3):yyy-zzz.

Scott, G.P., V.R. Restrepo, and A.R. Bertolino. 1992. Standardized catch rates for swordfish (*Xiphias gladius*) from the US longline fleet through 1990. ICCAT - Coll. Vol. Sci. Pap., Vol. XXXIX(2):554-571.

Scott, G.P., V.R. Restrepo, and A.R. Bertolino. 1993. Standardized catch rates for swordfish (*Xiphias gladius*) from the US longline fleet through 1991. ICCAT - Coll. Vol. Sci. Pap., Vol. XL(1):458-467.

SCRS Swordfish Assessment Group. 1992. Reference paper on 1991 swordfish stock assessments. ICCAT - Coll. Vol. Sci. Pap. XXXIX(2):397-476.

Table 1. Trip data with swordfish size, catch, and effort information available for analysis from the US longline fleet, 1981-1993.

	Year														
AREA	81	82	83	84	85	86	87	88	89	90	91	92	93	94	Total
CAR	0	0	0	0	10	39	88	150	63	49	59	51	72	95	676
GOM	0	1	7	5	36	39	75	64	78	58	48	81	60	56	608
FEC	26	28	26	76	60	100	278	361	208	136	181	250	208	265	2203
SAB	3	10	18	4	4	18	31	55	28	52	21	62	65	63	434
MAB	9	43	57	51	31	67	99	44	34	63	77	82	94	74	825
NEC	2	13	18	18	12	15	28	5	10	12	4	45	48	19	249
NED	3	6	9	13	19	18	27	41	30	23	26	32	30	24	301
Total	43	101	135	167	172	296	626	720	451	393	416	603	577	596	5288

Table 2. Nominal average swordfish CPUE (fish/1000 hooks) by area and age based on the SCRS 1992 ageing method from the US Longline fishery.

		Age				
AREA	YR	1	2	3	4	5+
CAR	85	1.42	2.44	6.95	11.03	12.89
CAR	86	1.80	8.43	12.23	15.06	13.80
CAR	87	1.81	7.50	9.46	8.37	8.18
CAR	88	2.14	7.97	10.81	7.13	5.90
CAR	89	0.54	4.97	9.66	7.92	8.70
CAR	90	0.91	4.62	7.37	5.97	6.71
CAR	91	0.17	2.57	8.36	9.20	11.16
CAR	92	0.01	1.11	4.92	5.64	7.26
CAR	93	0.08	1.45	5.49	4.88	8.40
CAR	94	0.11	2.83	7.86	6.41	5.12
GOM	82	0.00	8.60	7.37	2.46	7.37
GOM	83	5.58	10.91	13.42	6.35	8.20
GOM	84	4.67	20.14	8.77	5.11	4.39
GOM	85	3.33	6.76	5.01	2.73	2.21
GOM	86	3.96	4.30	1.73	0.62	0.60
GOM	87	0.46	2.04	1.51	0.58	0.73
GOM	88	2.74	4.00	2.68	1.56	1.59
GOM	89	2.52	9.67	5.01	2.11	2.84
GOM	90	2.80	5.50	5.06	2.05	2.59
GOM	91	0.78	3.48	2.87	1.70	2.07
GOM	92	0.01	0.77	2.32	1.15	1.06
GOM	93	0.00	0.79	3.23	1.54	0.98
GOM	94	0.01	0.50	2.07	1.15	0.55
FEC	81	4.19	8.22	8.43	6.00	14.52
FEC	82	0.86	4.70	9.06	9.38	17.44
FEC	83	2.96	4.34	5.58	5.86	8.78
FEC	84	3.28	7.53	6.69	4.16	5.90
FEC	85	1.98	4.11	5.62	4.29	6.56
FEC	86	8.08	11.24	6.47	3.04	3.10
FEC	87	4.16	11.14	7.98	3.63	3.41
FEC	88	4.57	10.02	8.92	4.01	3.55
FEC	89	3.30	11.35	6.99	3.64	3.92
FEC	90	5.00	10.89	8.26	3.42	3.16
FEC	91	0.45	9.20	9.88	4.97	3.81
FEC	92	0.09	3.25	7.83	3.52	3.52
FEC	93	0.01	2.45	7.14	3.40	3.60
FEC	94	0.01	1.96	7.79	4.00	3.04
SAB	81	6.97	21.78	49.16	13.95	18.33
SAB	82	4.08	15.45	15.88	8.28	11.59
SAB	83	8.90	19.64	11.50	4.47	10.32
SAB	84	1.94	8.91	10.42	2.39	5.26
SAB	85	7.12	10.71	11.95	5.19	3.47
SAB	86	15.84	27.44	10.86	1.96	1.48
SAB	87	9.30	38.46	17.58	4.33	2.20
SAB	88	6.41	17.52	14.99	4.61	2.67
SAB	89	3.43	16.36	7.98	2.88	1.62
SAB	90	4.39	13.14	11.73	3.11	2.34
SAB	91	0.14	8.01	8.30	2.62	2.77
SAB	92	0.00	4.28	14.60	4.91	1.96
SAB	93	0.00	2.11	10.26	3.29	1.93
SAB	94	0.00	2.90	10.74	3.32	1.94

		Age				
AREA	YR	1	2	3	4	5+
MAB	81	4.56	11.57	18.68	9.87	19.49
MAB	82	9.66	16.02	7.39	6.23	14.05
MAB	83	3.88	12.59	6.78	3.05	6.52
MAB	84	3.90	6.88	6.10	3.45	4.40
MAB	85	7.49	11.41	4.75	2.51	4.33
MAB	86	5.07	11.03	6.79	2.56	3.15
MAB	87	2.46	7.40	4.89	2.56	2.90
MAB	88	3.40	5.54	4.04	1.79	1.97
MAB	89	1.76	5.14	3.03	1.79	1.83
MAB	90	3.55	4.01	3.12	1.30	1.93
MAB	91	0.06	0.79	1.64	1.04	1.33
MAB	92	0.03	0.49	1.22	0.63	0.92
MAB	93	0.02	0.45	1.65	0.66	0.90
MAB	94	0.01	0.67	1.03	0.46	0.81
NEC	81	1.35	3.64	2.95	2.05	3.37
NEC	82	5.40	5.55	5.73	6.35	8.59
NEC	83	1.72	5.41	3.32	2.60	5.31
NEC	84	0.57	5.10	7.40	5.34	9.73
NEC	85	2.73	6.83	8.62	6.20	6.94
NEC	86	2.94	7.87	6.73	3.74	5.11
NEC	87	2.52	6.32	5.51	2.45	3.62
NEC	88	0.69	3.41	4.57	2.01	2.15
NEC	89	5.14	10.84	5.73	2.29	3.01
NEC	90	4.24	5.16	5.48	2.42	2.52
NEC	91	0.00	0.53	4.52	4.34	4.21
NEC	92	0.00	0.42	1.62	0.64	1.05
NEC	93	0.00	0.32	1.27	0.87	0.79
NEC	94	0.00	0.65	1.16	0.57	0.71
NED	81	0.02	0.27	1.46	3.28	5.74
NED	82	0.02	0.56	5.13	6.38	8.40
NED	83	0.08	1.62	3.89	7.18	12.21
NED	84	0.71	4.60	11.69	11.66	15.19
NED	85	1.53	8.03	23.81	23.82	24.14
NED	86	2.19	9.82	11.56	11.88	13.04
NED	87	3.20	9.83	11.87	7.90	9.74
NED	88	2.16	16.46	17.27	9.80	8.39
NED	89	2.54	12.08	16.40	7.86	6.15
NED	90	1.67	8.86	17.51	10.05	6.48
NED	91	0.02	2.72	13.56	9.61	7.36
NED	92	0.00	2.65	9.94	7.12	5.99
NED	93	0.07	3.03	11.26	6.69	5.23
NED	94	0.00	2.42	10.41	6.40	4.25

Table 3. US LL swordfish CPUE ANOVA results, using distributed effort method.

Dependent Variable: Ln(age 1/1000 hooks)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	30	2363.02778401	78.76759280	81.81	0.0001
Error	1719	1655.04008952	0.96279237		
Corrected Total	1749	4018.06787353			

R-Square	C.V.	Root MSE	T2CPU1 Mean
0.588101	111.3423	0.98121984	0.88126386

Source	DF	Type III SS	Mean Square	F Value	Pr > F
YR	9	45.18955082	5.02106120	5.22	0.0001
QTR	3	1595.83390662	531.94463554	552.50	0.0001
AREA	6	106.30887077	17.71814513	18.40	0.0001
OP	6	100.56529703	16.76088284	17.41	0.0001
SZST	3	75.76043465	25.25347822	26.23	0.0001
TARG	3	76.96333367	25.65444456	26.65	0.0001

Dependent Variable: Ln(age 2/1000 hooks)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	30	1865.66349925	62.18878331	94.52	0.0001
Error	2820	1855.49446223	0.65797676		
Corrected Total	2850	3721.15796149			

R-Square	C.V.	Root MSE	T2CPU2 Mean
0.501366	44.96371	0.81115767	1.80402742

Source	DF	Type III SS	Mean Square	F Value	Pr > F
YR	9	108.68679414	12.07631046	18.35	0.0001
QTR	3	421.69576481	140.56525494	213.63	0.0001
AREA	6	96.88677373	16.14779562	24.54	0.0001
OP	6	114.08638140	19.01439690	28.90	0.0001
SZST	3	68.13427558	22.71142519	34.52	0.0001
TARG	3	290.77718228	96.92572743	147.31	0.0001

Dependent Variable: Ln(age 3/1000 hooks)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	34	3187.95481862	93.76337702	203.01	0.0001
Error	4201	1940.32190604	0.46187144		
Corrected Total	4235	5128.27672466			

R-Square	C.V.	Root MSE	T2CPU3 Mean
0.621643	41.40358	0.67961124	1.64143104

Source	DF	Type III SS	Mean Square	F Value	Pr > F
YR	13	49.23122660	3.78701743	8.20	0.0001
QTR	3	5.23986573	1.74662191	3.78	0.0101
AREA	6	191.05227299	31.84204550	68.94	0.0001
OP	6	69.72291362	11.62048560	25.16	0.0001
SZST	3	85.99113739	28.66371246	62.06	0.0001
TARG	3	564.86379295	188.28793098	407.66	0.0001

Dependent Variable: Ln(age 4/1000 hooks)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	34	2748.98820642	80.85259431	178.74	0.0001
Error	3713	1679.52997538	0.45233773		
Corrected Total	3747	4428.51818179			

R-Square	C.V.	Root MSE	T2CPU4 Mean
0.620747	61.88275	0.67256057	1.08683044

Source	DF	Type III SS	Mean Square	F Value	Pr > F
YR	13	74.41848583	5.72449891	12.66	0.0001
QTR	3	243.35426307	81.11808769	179.33	0.0001
AREA	6	374.09680010	62.34946668	137.84	0.0001
OP	6	49.56025061	8.26004177	18.26	0.0001
SZST	3	45.46044345	15.15348115	33.50	0.0001
TARG	3	302.45034324	100.81678108	222.88	0.0001

Table 3. (Continued)

Dependent Variable: Ln(age 5+/1000 hooks)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	34	2759.54502504	81.16308897	158.24	0.0001
Error	3730	1913.11859202	0.51290043		
Corrected Total	3764	4672.66361706			

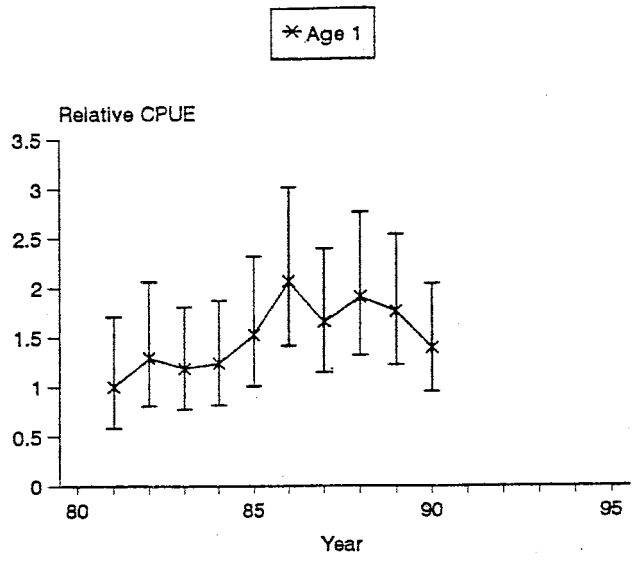
R-Square	C.V.	Root MSE	T2CP5P Mean
0.590572	65.98062	0.71617067	1.08542583

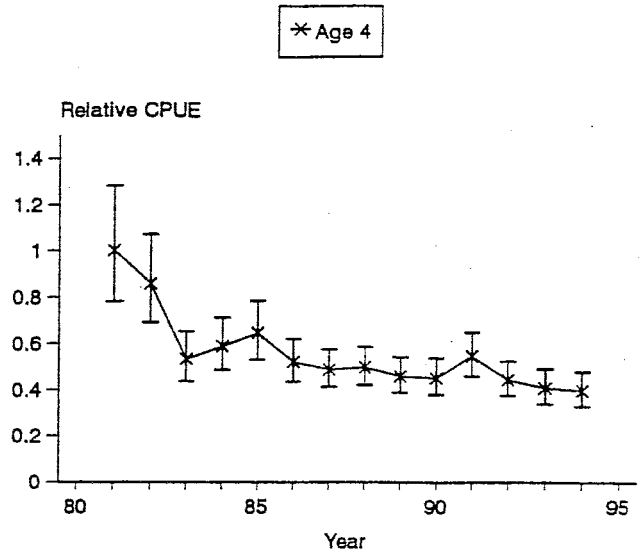
Source	DF	Type III SS	Mean Square	F Value	Pr > F
YR	13	367.28816844	28.25293603	55.08	0.0001
QTR	3	255.52883484	85.17627828	166.07	0.0001
AREA	6	334.61436551	55.76906092	108.73	0.0001
OP	6	40.62529722	6.77088287	13.20	0.0001
SZST	3	54.32593638	18.10864546	35.31	0.0001
TARG	3	235.54273643	78.51424548	153.08	0.0001

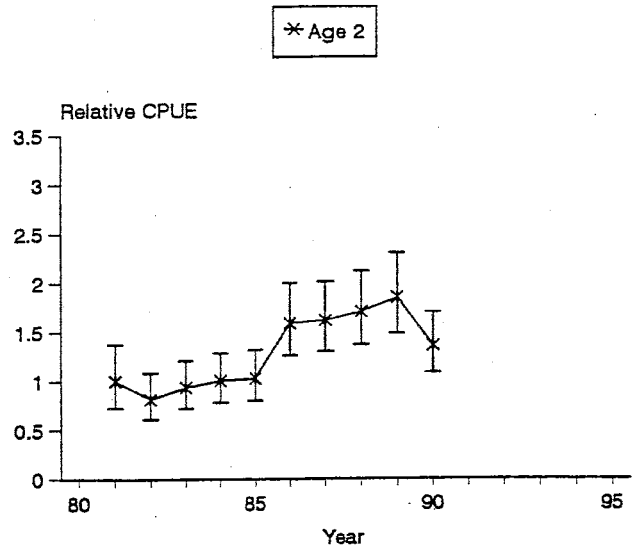
Table 4. Annual, standardized age-specific CPUE from the distributed effort method, expressed relative (REL column) to the 1981 mean, with approximate upper and lower 95% confidence intervals (UREL and LREL).

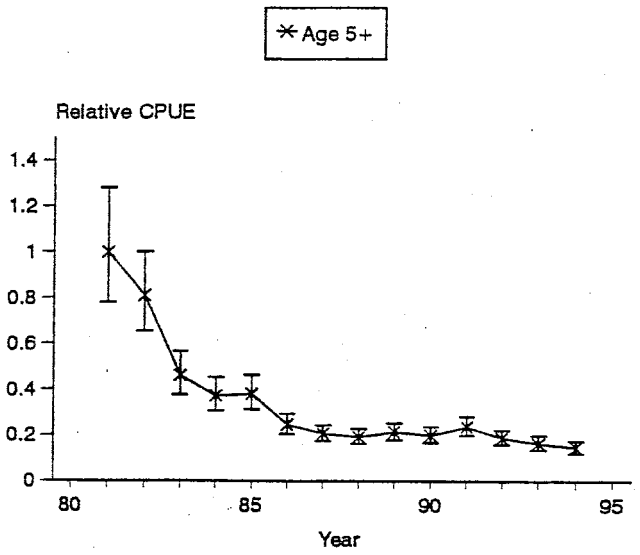
Yr	UREL	REL	LREL
Age 1:			
81	0.58501	1.00000	1.70938
82	0.80597	1.28964	2.06356
83	0.77396	1.18181	1.80458
84	0.81427	1.23448	1.87155
85	1.00438	1.52502	2.31554
86	1.41440	2.06350	3.01050
87	1.14422	1.65502	2.39385
88	1.31485	1.90351	2.75571
89	1.21851	1.75632	2.53150
90	0.94980	1.38953	2.03282
Age 2:			
81	0.72701	1.00000	1.37550
82	0.61155	0.81406	1.08364
83	0.72291	0.93508	1.20951
84	0.78266	1.00286	1.28502
85	0.79792	1.02648	1.32050
86	1.25951	1.58556	1.99601
87	1.29994	1.61711	2.01167
88	1.36710	1.70113	2.11678
89	1.48093	1.84678	2.30300
90	1.08477	1.35833	1.70088
Age 3:			
81	0.77732	1.00000	1.28647
82	0.62840	0.78145	0.97176
83	0.53124	0.64939	0.79383
84	0.66458	0.80453	0.97396
85	0.69936	0.85043	1.03413
86	0.72766	0.86830	1.03611
87	0.76656	0.90507	1.06861
88	0.80482	0.95004	1.12145
89	0.71833	0.84999	1.00580
90	0.74700	0.88740	1.05420
91	0.75995	0.90337	1.07385
92	0.64470	0.76209	0.90086
93	0.55129	0.66241	0.79594
94	0.55366	0.66635	0.80198

Yr	UREL	REL	LREL
Age 4:			
81	0.78039	1.00000	1.28141
82	0.69134	0.85956	1.06870
83	0.43571	0.53338	0.65294
84	0.48647	0.58927	0.71380
85	0.53230	0.64703	0.78648
86	0.43550	0.52064	0.62242
87	0.41277	0.48723	0.57514
88	0.41999	0.49567	0.58499
89	0.38679	0.45752	0.54118
90	0.37894	0.45094	0.53662
91	0.45979	0.54694	0.65062
92	0.37451	0.44304	0.52412
93	0.33837	0.40757	0.49092
94	0.32933	0.39712	0.47887
Age 5+:			
81	0.78174	1.00000	1.27920
82	0.65261	0.81133	1.00866
83	0.37713	0.46141	0.56453
84	0.30689	0.37272	0.45268
85	0.31294	0.38125	0.46447
86	0.20605	0.24651	0.29492
87	0.17520	0.20672	0.24391
88	0.16322	0.19238	0.22675
89	0.17947	0.21258	0.25181
90	0.16709	0.19859	0.23604
91	0.19896	0.23647	0.28104
92	0.15939	0.18811	0.22202
93	0.13640	0.16466	0.19877
94	0.12172	0.14655	0.17646









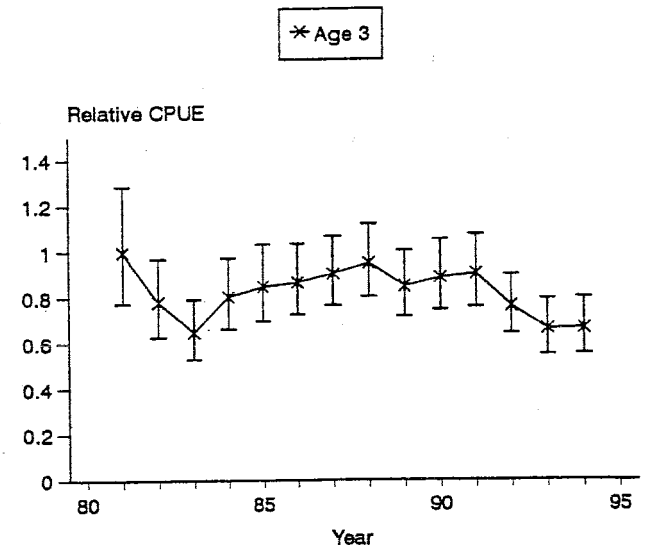


Figure 1. Standardized catch rate trajectories with associated approximate 95% confidence intervals for the age classes indicated.