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SUMMARY

Swordfish sex ratio at size was examined for differences among areas, years, and quarters. Statistically significant differences were observed in all effects. The fishing area factor had substantially (roughly 10X) greater impact on observed sex ratio at size than year or quarter. The statistical significance of the year and quarter factors were considered to be reflective of the high sensitivity of the test statistic to small differences in observed sex ratios given the relatively large sample sizes analyzed.

The estimated age structure for the catch by sex of the U.S. catch was examined using the sex-specific growth equations of Ehrhardt *et al* (SCRS/95/99) and contrasted with the catch at age calculated with the ICCAT growth curve developed at the 1988 SCRS Swordfish Workshop. The total catch at age estimated with sex-specific growth curves showed a shift in the age composition to older ages and a much more even distribution of catches across ages.

RESUMÉ

Le sex-ratio par taille de l'espadon a été examiné à la recherche de différences entre secteurs, années et trimestres. Des différences significatives du point de vue statistique ont été observées pour tous les facteurs. Le facteur zone avait un impact beaucoup plus important (10X environ) sur le sex ratio par taille observé que le facteur trimestre. La signification statistique des facteurs année et trimestre a été jugée refléter la grande sensibilité des statistiques testées aux légères différences des sex ratio observés du fait de la taille relativement importante des échantillons analysés.

La structure démographique estimée pour la capture par sexe de la prise américaine a été examinée au moyen de l'équation de croissance spécifique du sexe de Ehrhardt *et al.* (SCRS/95/99) ; elle contrastait avec la prise par âge calculée avec la courbe de croissance de l'ICCAT élaborée lors des journées d'étude SCRS de 1988 sur l'espadon. La prise totale par âge estimée avec des courbes de croissance spécifiques du sexe montraient un déplacement de la structure démographique vers les âges plus avancés et une distribution beaucoup plus régulière des prises sur tous les âges.

RESUMEN

La proporción de sexos por clases de talla de pez espada se examinó para hallar diferencias entre áreas, años y trimestres. Se observaron significativas diferencias estadísticas en todos los efectos. El factor del área de pesca tuvo sustancialmente (aproximadamente 10X) un mayor impacto sobre la proporción por sexos por clases de talla que el año o trimestre. Se consideró que la importancia estadística de los factores año y trimestre reflejaba la alta sensibilidad de la estadística de prueba a las pequeñas diferencias en proporción por sexos observada dada la relativamente amplia muestra de tallas analizada.

La estructura por edad estimada para la captura por sexo de la captura de Estados Unidos fue examinada empleando las ecuaciones de crecimiento específicas del sexo de Ehrhardt *et al.* (SCRS/95/99) y contrastada con la captura por clases de edad calculada con la curva de crecimiento de ICCAT desarrollada en las Jornadas de Trabajo sobre Pez Espada, SCRS 1988. La captura total por clases de edad estimada con curvas de crecimiento específicas del sexo mostraron un cambio en la composición por edad a edades más viejas y a una distribución mucho más pareja de las capturas a lo largo de las edades.

Introduction

Male and female swordfish in the Atlantic grow at different rates (Berkley and Houde 1983, Ehrhardt 1992, Ehrhardt et al. SCRS/95/98). As a result of those growth rate differences, possible differences in mortality rates by size, and possible behavioral differences between the sexes, catches of Atlantic swordfish consist of a broad range of sex ratios at size (Hoey 1991, Mejuto et al. 1991, Mejuto et al. 1995, Lee and Arocha 1993, Arocha and Lee 1993, 1995, Alio et al. 1993, Arocha and Marciano 1994). To date the SCRS has not been able to analyze swordfish catch at age by sex, because of the absence of sufficient information on catch at size by sex. For several years scientists from several ICCAT member nations have collected information on swordfish sex ratio at size from their fisheries (Hoey 1991, Lee 1991, Lee et al. 1994, Mejuto et al. 1991, de la Serna et al. 1992). In 1994 the SCRS recommended that swordfish catch at size for the Atlantic Ocean be estimated by sex (Anon 1995).

The purposes of this paper are (1) to examine the data collected by U.S and Venezuelan scientists on swordfish sex ratio at size to determine the most appropriate stratifications for developing catch at size by sex for the U.S. and (2) to develop that catch at size if possible and to examine the resulting estimates of U.S. catch at age for differences due to assigning age from a single growth curve for all fish and sex specific growth curves.

Materials and Methods

Observations of the numbers of swordfish by sex and size were examined for differences in areas, years and/or quarters using categorical data analysis with length intervals as a quantitative (continuous) covariate. Areas were defined as temperate, subtropical and tropical (Figure 1).

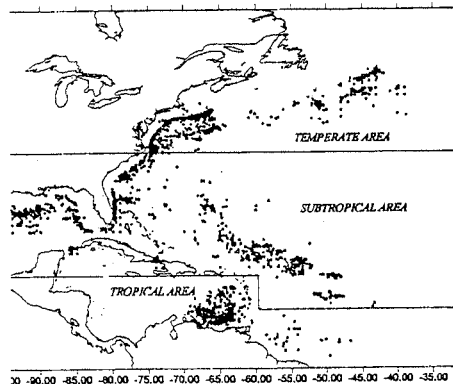


Figure 1. Map of the western North Atlantic showing areas used to stratify sex ratio data.

Quarters were defined as December-February, March-May, June-August and September-November to correspond as closely as possible to different phases in annual swordfish reproductive condition (Arocha and Lee SCRS/95/98). For analysis lengths from 100 cm to 200 cm length intervals of 10 cm were analyzed while for lengths of 80-99 cm and 200-239 cm length intervals of 20 cm were used. To analyze the observed numbers of swordfish at size by sex maximum likelihood statistics were used to evaluate the contribution to the total variance of the area, year and quarter effects.

The data used for analysis were restricted to area, year, and quarter strata with at least 100 observations. For all areas sizes were restricted to < 220 cm. For the temperate area no data from fish less than 110 cm or greater than 220 cm were included. For the subtropics the lower size limit was 80 cm and the upper was 220 cm. For the tropics the lower size limit was 80 cm and the upper was 189 cm.

The sex ratio at size data used for assigning sex to the catches was aggregated by 5 cm intervals. If no information on sex ratio was available for fish < 100 cm lfl, it was assumed that sex ratio was 1:1, and for fish > 219 cm it was assumed that 100% of the fish were females.

Sex specific catch at size was developed both for the U.S. landed catch (data in dressed weight) and for the 1991-1994 discarded catch (data in LJFL, Cramer et al. in press). For the catch at size of discarded swordfish the area of capture was unknown; those fish were assigned a subtropical sex ratio because that is where the most discards were reported (Cramer et al. in press).

To develop the catch at size by sex, adjustments were needed to account for differences in the geographic strata used in developing the catch at size (Figure 2) and for the sex ratio data (Figure 1). Portions of the two most southern areas used for the catch at size occurred in both the subtropical and tropical areas used for the sex ratio data. Swordfish logbook data were used to

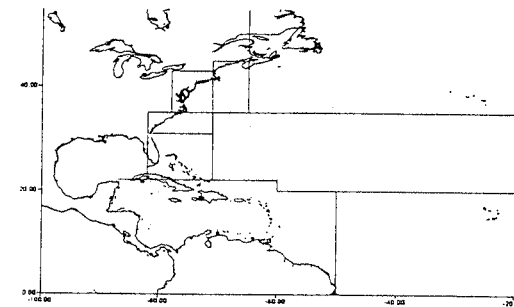


Figure 2. Geographic strata used in creating U.S. catch at size.

determine the fractions of the catches in each of those two catch at size areas to be assigned subtropics or tropic sex ratios at size.

The sex specific catch at size was created from the original catch at size by (1) multiplying the original catch at a size (such as 120 cm) by the proportion of females at that size in that area and then calculating the associated number of males.

Catch at age was calculated using age slicing. For aging without regard to sex the growth curve in weight adopted by the SCRS in 1988 (Anon 1989) was used. Catch at age by sex was calculated using the growth curves of Ehrhardt et al. (SCRS/95/99).

Results

Proportion female at size is shown by area and quarter in Figure 3 and by area and year in Figure 4. In general those figures indicate that sex ratio at size appears to be relatively consistent across years. There is some indication that in the subtropics which are considered the spawning area the proportion of females is lower (males are relatively more abundant) in the 160-180 cm range in the first two quarters when most of the spawning is thought to occur (Arocha and Lee SCRS/95/98) than in the later part of the year; additional analysis of those patterns is needed.

A total of 9,752 sexed swordfish were used for the analysis. The number of observations analyzed are given in Table 1 by area, year and quarter.

Analysis of observations of the number of swordfish by sex and size using maximum likelihood statistics for differences in sex ratio at size indicated that area, year, quarter were all statistically significant (Table 2). The statistical significance was considered reflective of high sensitivity of the test statistics to the large sample sizes. The maximum likelihood score for area factor was about ten times large than for the year factor and the quarter factor. Therefore it was concluded that in development of the catch at size by sex, year and quarter effects contributed little to the observed sex ratio at size. and therefore the data might be aggregated by area across years. It was further assumed that the 1991-1994 data might be applied to all previous years (1978-1990); clearly the validity of this assumption was not testable with this sex ratio at size data.

The U.S. catch at age calculated using one growth curve for all fish is given in Table 3. The catch at age using sex specific growth curves is given in Table 4 for males, females and the reaggregated total. The reaggregated sex specific catch at age (CAA) showed decreases in the number of fish at ages 2-4 than the single growth curved CAA, and increases in both younger and older ages.

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Table 1. Number of observations of swordfish sex by area, year and quarter used for analysis after restrictions for small sample sizes were made.

YEAR	QUARTER				TOTAL
	1	2	3	4	
temperate					
91	0	244	514	273	1031
92	89	0	191	0	280
93	0	0	615	490	1105
94	151	0	149	0	300
Total	240	244	1469	763	2716
subtropics					
91	330	0	0	0	330
92	309	162	117	136	724
93	965	477	377	453	2272
94	541	232	330	351	1454
Total	2145	871	824	940	4780
tropics					
91	0	0	0	0	0
92	413	127	0	326	866
93	119	268	289	307	983
94	0	284	123	0	407
Total	532	679	412	633	2256

Table 2. Results of analysis of the effects of area, year and quarter on swordfish sex ratio at size.

CATMOD PROCEDURE

Response: SEX
 Weight Variable: COUNT
 Data Set: FROAQYLS

Response Levels (R)= 2
 Populations (S)= 334
 Total Frequency (N)= 9752
 Observations (Obs)= 648

RESPONSE PROFILES

Response SEX

1	female
2	male

MAXIMUM LIKELIHOOD ANALYSIS

Iteration	Sub Iteration	-2 Log Likelihood	Convergence Criterion	Parameter Estimates	
				1	2
0	0	12591.687	1.0000	0.6434	0.5114
1	0	12575.857	0.001257	0.9925	0.5460
2	0	12575.848	6.9458E-7	0.9986	0.5474
3	0	12575.848	4.678E-13	0.9986	0.5474

Iteration	Parameter Estimates				
	3	4	5	6	7
0	-0.5501	-0.0832	0.0662	0.1540	0.1945
1	-0.5692	-0.0595	0.0539	0.1531	0.2031
2	-0.5706	-0.0591	0.0537	0.1534	0.2037
3	-0.5706	-0.0591	0.0537	0.1534	0.2037

Iteration	Parameter Estimates		
	8	9	10
0	-0.0701	-0.0819	-0.006746
1	-0.0768	-0.0741	-0.009417
2	-0.0769	-0.0742	-0.009468
3	-0.0769	-0.0742	-0.009468

MAXIMUM LIKELIHOOD ANALYSIS OF VARIANCE TABLE

Source	DF	Chi-Square	Prob
INTERCEPT	1	69.09	0.0000
AREA	2	332.27	0.0000
YEAR	3	32.53	0.0000
QUARTER	3	28.77	0.0000
LEN_INT	1	134.32	0.0000
LIKELIHOOD RATIO	324	863.98	0.0000

ANALYSIS OF MAXIMUM LIKELIHOOD ESTIMATES

Effect	Parameter	Estimate	Standard Error	Chi-Square	Prob
INTERCEPT	1	0.9986	0.1201	69.09	0.0000
AREA	2	0.5474	0.0316	300.48	0.0000
	3	-0.5706	0.0430	175.92	0.0000
YEAR	4	-0.0591	0.0555	1.13	0.2870
	5	0.0537	0.0441	1.48	0.2232
	6	0.1534	0.0333	21.22	0.0000
QUARTER	7	0.2037	0.0381	28.60	0.0000
	8	-0.0769	0.0420	3.36	0.0668
	9	-0.0742	0.0397	3.50	0.0613
LEN_INT	10	-0.00947	0.000817	134.32	0.0000

Table 3. U.S. swordfish catch at age for 1978-1994 calculated using the ICCAT growth curve for both sexes.

AGE	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
0	59	486	1814	1028	3001	2074	3094	2789	3997	3181	8723	2961	5307	6458	6084	7579	4914
1	1760	4490	14502	6727	15365	15887	17894	18070	21600	32500	30812	38599	22091	20092	14501	15985	17105
2	6307	13716	25698	16536	19856	23284	29657	24879	37580	40639	56951	55023	46347	32315	34436	30958	31069
3	12787	13752	23339	18836	22977	17039	22519	24471	27923	30191	36592	37738	33163	29724	24818	27530	24921
4	11518	11392	15709	11513	15857	11878	13208	14981	18476	15241	18761	19007	16681	14412	13420	12980	11960
5	7579	8021	10354	7609	8876	8189	7595	8020	8567	7628	8678	9421	8678	7014	6811	6623	5279
6	4214	5419	6173	4834	5618	5221	4546	4153	4150	3849	4131	4856	4329	3590	3475	3462	2589
7	2541	3571	3569	3073	2908	3190	2423	2334	2137	1984	2122	2445	2210	1734	1865	1740	1509
8	1523	2156	2158	1935	2034	1987	1293	1400	1155	1138	1135	1360	1252	951	935	913	781
9	845	1352	1219	1231	1275	1261	749	858	760	644	741	852	746	558	555	544	474
10	670	937	822	836	783	774	480	499	467	470	494	511	451	340	348	322	276
11	458	776	611	550	522	542	336	342	262	271	339	345	287	228	240	189	202
12	388	545	380	385	331	311	185	217	211	211	195	236	197	164	185	104	131
13	237	354	260	255	254	205	139	155	127	107	126	122	133	132	95	96	78
14	224	262	160	179	166	160	91	102	93	95	94	86	99	67	56	58	51
15+	2117	2930	2199	2753	2783	2360	1674	1553	1276	1347	1177	1325	1156	1063	939	825	684
total	53226	70161	108969	78280	102605	94363	105884	104822	128782	139495	171072	174888	143126	118841	108763	109907	102023

Table 4a. U.S. swordfish catch at age for 1978-1994 calculated using sex specific growth curves from Ehrhardt et al.

(SCRS/95/99).
Both sexes
summed.

both sexes combined																	
AGE	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
0	472	1728	5704	3351	8592	7697	9117	9674	12208	13841	20167	14305	13847	11771	10694	12291	9000
1	2940	8129	19344	9345	16777	19692	23090	20428	28570	37796	41686	50229	31035	26450	18785	19068	20741
2	6231	10792	20696	14897	16025	16419	21832	19379	26925	29833	40797	39197	34662	25623	29929	28025	27351
3	9109	8759	14724	11886	15056	10841	14872	16168	18707	19870	23688	24466	21377	19412	15975	17879	16430
4	8103	8100	11543	8584	12113	9303	10756	12216	15208	12896	15568	15235	13753	12236	10766	10654	10339
5	7314	7164	9262	6956	8888	7134	7503	8179	9378	8223	9567	9919	8891	7606	7040	6873	6052
6	5246	6471	7531	5516	6790	6170	5718	5515	5788	5349	6388	6939	6158	4999	4984	4929	3903
7	3543	5146	6031	4644	5032	4717	3988	3963	3896	3668	4113	4660	4004	3481	3434	3323	2687
8	2721	3752	4012	3533	3513	3477	2609	2708	2340	2297	2611	2928	2672	2084	2181	2119	1685
9	1620	2614	2633	2487	2512	2468	1650	1854	1634	1575	1791	1950	1726	1339	1336	1318	1113
10	1335	2114	1975	1753	1723	1626	1084	1135	1055	996	1180	1280	1123	942	923	802	711
11	1150	1536	1244	1251	1209	1105	750	764	698	716	725	788	745	642	556	549	469
12	741	909	959	897	912	798	523	517	453	472	485	542	437	391	392	317	279
13	481	651	611	660	563	551	406	390	347	371	387	432	386	359	318	278	245
14	330	498	296	336	322	264	245	230	181	186	181	196	163	161	162	172	125
15+	1312	2098	2425	2184	2618	2102	1742	1704	1395	1406	1559	1825	1596	1348	1287	1310	894
total													143126	118841	108763	109907	102023

Table 4b. U.S. swordfish catch at age for males in 1978-1994 calculated using a growth curve from Ehrhardt et al. (SCRS/95/99).

males																	
AGE	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
0	248	943	3267	1855	4705	4334	4972	5353	6495	7945	10623	8230	7328	5993	5222	6006	4603
1	1209	4110	9325	4735	7907	9335	10968	9600	12995	17565	18959	23825	14880	12790	8761	8833	9829
2	2054	5246	9547	7385	7059	7294	9546	8486	10477	12419	16625	16180	14805	11429	13655	13059	12481
3	2322	4112	7118	6408	6354	5120	6359	6908	7021	8159	10480	10775	10107	8604	7545	8580	7263
4	2149	3035	4701	4021	4370	3599	4001	4533	4924	5033	6236	6339	5723	5402	4640	4867	4454
5	1535	2058	3221	2501	2948	2168	2378	2682	3040	2870	3805	3841	3274	3012	2800	2848	2470
6	899	1206	1996	1466	1732	1316	1353	1475	1511	1533	2157	2263	1940	1653	1697	1691	1413
7	508	1044	1570	1045	1228	952	905	1104	1102	1018	1490	1513	1280	1180	1073	1107	851
8	423	632	974	690	825	612	587	713	675	672	894	924	849	703	746	767	500
9	260	481	638	507	529	447	424	464	448	487	619	604	567	473	451	455	372
10	192	319	469	335	355	325	282	284	286	274	345	426	336	301	294	302	217
11	133	215	321	237	258	224	175	218	210	195	250	264	236	201	189	226	139
12	81	163	257	178	199	142	133	148	144	136	176	220	154	135	144	124	97
13	129	173	279	198	195	202	163	167	166	166	223	223	207	181	182	158	134
14	65	113	138	114	117	95	98	99	83	74	87	103	97	83	83	97	65
15+	931	1657	2104	1690	2035	1717	1382	1343	1067	1128	1342	1552	1349	1153	1093	1125	776
total	13356	25596	45925	33364	40817	37881	43726	43597	50645	59676	74312	77284	63212	53294	48575	50247	45664

Table 4c. U.S. swordfish catch at age for females in 1978-1994 calculated using a growth curves from Elrhardt et al. (SCRS/93/99).

AGE	females												
	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	
0	183	746	2436	1496	3888	3363	4144	4320	5713	5896	9544	6075	
1	1641	3979	10020	4610	8870	10357	12123	10828	15575	20231	22727	26403	
2	4176	5546	11149	7512	8966	9125	12286	10892	16447	17414	24171	23017	
3	6787	4647	7606	5478	8702	5721	8513	9260	11686	11711	13387	13691	
4	6554	5125	6842	4563	7743	5704	6754	7662	10284	7863	9332	8897	
5	5759	5106	6041	4654	5939	4966	5125	5498	6338	5353	5762	6077	
6	4347	4755	5535	4050	5017	4854	4366	4040	4277	3816	4231	4676	
7	2955	4113	4461	3599	3804	3764	3082	2860	2794	2650	2623	3147	
8	2798	3150	3038	2844	2688	2865	2022	1994	1665	1625	1717	2035	
9	1560	2133	1994	1980	1982	2021	1226	1390	1186	1088	1172	1345	
10	1143	1795	1506	1418	1368	1301	802	852	769	722	835	854	
11	997	1370	923	1013	951	881	575	546	488	522	475	523	
12	660	795	683	719	713	656	390	369	309	336	309	322	
13	331	488	332	462	368	349	243	225	180	205	164	208	
14	265	375	158	222	205	169	147	132	98	112	93	92	
15+	381	442	321	495	583	385	360	361	329	277	217	273	
total	39840	44565	63044	44916	61788	56481	62159	61226	78137	79819	96761	97605	

AGE	females				
	1990	1991	1992	1993	1994
0	6519	5777	5472	6285	4397
1	16205	13660	10024	10235	10912
2	19778	14194	16274	14966	14669
3	11770	10808	8432	9298	9187
4	8030	6831	6125	5787	5885
5	5617	4594	4240	4025	3582
6	4219	3347	3287	3238	2490
7	2724	2301	2361	2216	1836
8	1823	1382	1435	1352	1185
9	1159	866	887	863	741
10	736	641	628	499	495
11	508	440	367	323	309
12	284	256	248	193	182
13	178	178	136	119	110
14	66	77	79	74	60
15+	247	195	194	184	118
total	79914	65547	60188	59660	56359

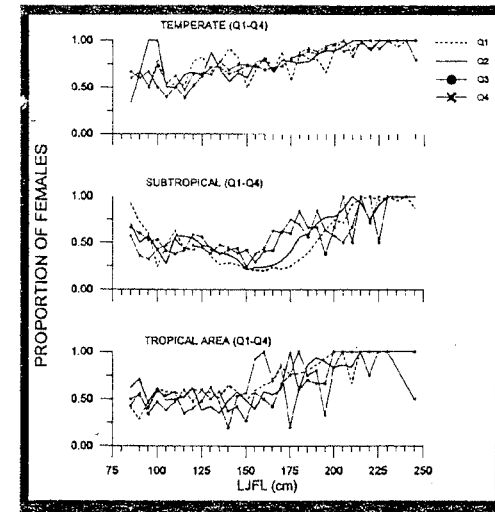


Figure 3. Proportion of female swordfish at size by area and quarter for 1991-1994.

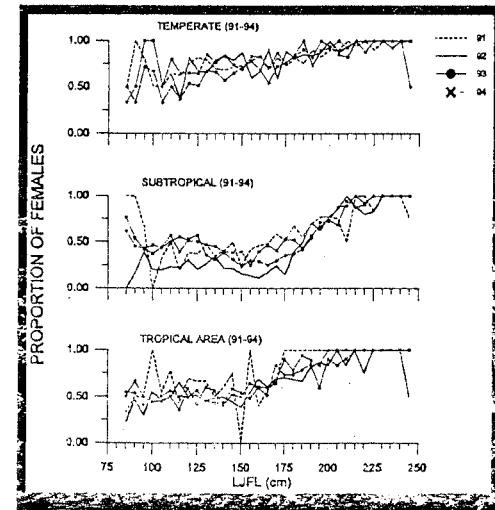


Figure 4. Proportion of female swordfish at size by area and year.