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UPDATED STANDARDIZED CATCH RATES IN NUMBER AND WEIGHT FOR THE SWORDFISH (*XIPHIAS GLADIUS* L.) FROM THE SPANISH LONGLINE FLEET IN THE MEDITERRANEAN SEA, 1988-1997

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SUMMARY

A General Linear Modeling (GLM) approach to analysis of variance was used to examine logged catch rates (in number and weight) from 12,835 trips carried out by the Spanish surface longline fleet targeting swordfish in the Mediterranean from 1988 to 1997.

RÉSUMÉ

La technique du modèle linéaire généralisé (GLM) a servi à examiner le taux de capture (numérique et en poids) de 12.835 sorties de la flottille palangrière espagnole ciblant l'espadon dans la partie occidentale de la Méditerranée de 1988 à 1997.

RESUMEN

Se llevó a cabo un análisis mediante técnicas de Modelo Lineal Generalizado (GLM) de las tasas de captura (en número y peso) de 12.835 mareas realizadas por la flota española de palangre de pez espada en el Mediterráneo occidental, para el período 1988-1997.

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MATERIAL AND METHODS

BASIC DATA

Records used in the analysis are from the Spanish longline activity in the Mediterranean Sea from 1988 to 1997. As in previously developed analyses (Mejuto & de la Serna, 1994), data are records per trip obtained by the Spanish Oceanography Institute (IEO) at the most important landing ports of the Spanish Mediterranean fleet.

Records were estructured as follows: vessel code, date of landing, landing in number, landing in kg round weight, number of sampled fishes, catch by LJFL (5 cm interval), quadrant, area (5 x 5 degrees), number of sets, hooks by set and type of bait.

Following traditional criteria, nominal effort by trip was defined as number of hooks (in thousands of hooks), calculated from the number of sets carried out and the mean number of hooks per set.

MODEL AND SPECIFICATIONS

Three previosly defined areas (Mejuto and de la Serna, 1994) were used. Temporal definition corresponded to the following "quarters":

quarter 1 = January, February, March
quarter 2 = April, May, June
quarter 3 = July, August, September
quarter 4 = October, November, December

The basic multiplicative model (Gavaris 1980, 1988) was defined as:

$$Ln(CPUE) = \mu + Y_i + Q_j + A_k + Q_j * A_k + e_{ijk}$$

μ = overall mean
Y_i = natural logarithm of the effect year i
Q_j = natural logarithm of the effect quarter j
A_k = natural logarithm of the effect area k
e_{ijk} = natural logarithm of the normally distributed error term

RESULTS AND DISCUSSION

Table I shows the number of observations per year/area/quarter used in the GLM analysis. A total of 12,835 trips were used. The number of observations per cell (spatial- temporal) may be considered satisfactory.

Table II is the summary of the ANOVA results for the final model. It is provided the number of observations, R^2, mean square error, F statistics, etc. The three considered factors; year, quarter and area as well as the interactions between quarter and area were statistically significant at the 1% level. The variability rate explained by the model (R^2) was 11.2 for CPUE in number and 11.9 for CPUE in weight.

Standardized residuals patterns for CPUE in number and weight by year (*Figure 1*) seems to be as expected. Annual relative abundance indices with 95 % upper and lower confidence limits (*Table III, Figure 2*) were obtained from marginal means adjusted for the GLM statistically significant terms.

LITERATURE CITED

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ICCAT Col. Vol. Sci. Pap. Vol XLIV(I): 124- 129.

Table I.- Number of observations by year/area/quarter for GLM analysis.

YEAR 1988

AREA frequency	QUARTER 1	2	3	4	Total
2	1	43	79	49	172
3	33	60	69	49	211
5	4	28	177	18	227
Total	38	131	325	116	610

YEAR 1989

AREA frequency	QUARTER 1	2	3	4	Total
2	37	140	223	114	514
3	38	77	100	43	258
5	5	2	162	27	196
Total	80	219	485	184	968

YEAR 1990

AREA frequency	QUARTER 1	2	3	4	Total
2	54	117	224	114	509
3	40	54	150	71	315
5	0	12	285	69	366
Total	94	183	659	254	1190

YEAR 1991

AREA frequency	QUARTER 1	2	3	4	Total
2	35	109	162	4	310
3	45	76	101	115	337
5	2	0	146	74	222
Total	82	185	409	193	869

YEAR 1992

AREA frequency	QUARTER 1	2	3	4	Total
2	21	80	358	131	590
3	55	54	188	147	444
5	0	10	95	17	122
Total	76	144	641	295	1156

YEAR 1993

AREA frequency	QUARTER 1	2	3	4	Total
2	163	218	541	254	1176
3	51	38	85	85	259
5	5	19	74	18	116
Total	219	275	700	357	1551

YEAR 1994

AREA frequency	QUARTER 1	2	3	4	Total
2	196	195	596	328	1315
3	56	54	169	129	408
5	0	7	136	32	175
Total	252	256	901	489	1898

YEAR 1995

AREA frequency	QUARTER 1	2	3	4	Total
2	124	236	566	343	1269
3	60	39	202	180	481
5	39	2	93	108	242
Total	223	277	861	631	1992

YEAR 1996

AREA frequency	QUARTER 1	2	3	4	Total
2	158	149	382	197	886
3	73	27	208	140	448
5	13	0	100	46	159
Total	244	176	690	383	1493

YEAR 1997

AREA frequency	QUARTER 1	2	3	4	Total
2	81	110	427	219	837
3	48	12	65	18	143
5	4	0	72	55	131
Total	133	122	564	292	1111

Table II.- Spanish Mediterranean Longline. Swordfish. CPUE in number and weight. General Linear Models Procedure. Results of ANOVA.

Class	Levels	Values
YEAR	10	1988 1989 1990 1991 1992 1993 1994 1995 1996 1997
QUARTER	4	1 2 3 4
AREA	3	2 3 5

Number of observations in data set = 12834

Dependent Variable: LnCPUE (in number)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	21	52684.47760	2508.78465	5127.81	0.0
Error	12813	6268.77066	0.48925		
Uncorrected Total	12834	58953.24826			

R-Square	C.V.	Root MSE	LnCPUE Mean
0.112077	34.78496	0.699465	2.01082487

Source	DF	Type I SS	Mean Square	F Value	Pr > F
YEAR	9	302.67302	33.63034	68.74	0.0001
QUARTER	3	403.15952	134.38651	274.68	0.0001
AREA	2	26.79343	13.39671	27.38	0.0001
QUARTER*AREA	6	58.64206	9.77368	19.98	0.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
YEAR	9	265.11031	29.45670	60.21	0.0001
QUARTER	3	107.39502	35.79834	73.17	0.0001
AREA	2	29.28723	14.64361	29.93	0.0001
QUARTER*AREA	6	58.64206	9.77368	19.98	0.0001

Parameter		Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT		1.713417754 B	42.44	0.0	0.04036937
YEAR					
	1988	0.562428858 B	15.56	0.0001	0.03614959
	1989	0.184590610 B	5.95	0.0001	0.03104584
	1990	0.407250831 B	13.74	0.0001	0.02963294
	1991	0.075304974 B	2.34	0.0191	0.03212121
	1992	0.143396432 B	4.83	0.0001	0.02971464
	1993	0.189344716 B	6.86	0.0001	0.02759418
	1994	0.290434155 B	10.95	0.0001	0.02652121
	1995	0.258388859 B	9.81	0.0001	0.02633538
	1996	0.002079260 B	0.07	0.9406	0.02790255
	1997	0.000000000 B	.	.	.
QUARTER					
	1	0.296944458 B	3.30	0.0010	0.08993452
	2	0.114546583 B	1.32	0.1858	0.08656715
	3	0.290996405 B	7.16	0.0001	0.04063517
	4	0.000000000 B	.	.	.
AREA					
	2	0.031237516 B	0.80	0.4250	0.03915272
	3	0.319610122 B	7.53	0.0001	0.04244041
	5	0.000000000 B	.	.	.

Table II (cont.).

Parameter	Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
QUARTER*AREA				
1 2	-0.444411644 B	-4.71	0.0001	0.09444580
1 3	-0.726734409 B	-7.41	0.0001	0.09803041
1 5	0.000000000 B	.	.	.
2 2	-0.403970073 B	-4.49	0.0001	0.08999992
2 3	-0.702686875 B	-7.41	0.0001	0.09479911
2 5	0.000000000 B	.	.	.
3 2	-0.115163538 B	-2.54	0.0110	0.04529305
3 3	-0.348147283 B	-6.91	0.0001	0.05038264
3 5	0.000000000 B	.	.	.
4 2	0.000000000 B	.	.	.
4 3	0.000000000 B	.	.	.
4 5	0.000000000 B	.	.	.

NOTE: The X'X matrix has been found to be singular and a generalized inverse was used to solve the normal equations. Estimates followed by the letter 'B' are biased, and are not unique estimators of the parameters.

Dependent Variable: LnCPUE (in weight)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	21	282577.2356	13456.0588	26659.66	0.0
Error	12813	6467.1668	0.5047		
Uncorrected Total	12834	289044.4024			

R-Square	C.V.	Root MSE	LnCPUE Mean
0.119840	15.16428	0.710447	4.68500276

Source	DF	Type I SS	Mean Square	F Value	Pr > F
YEAR	9	250.5304	27.8367	55.15	0.0001
QUARTER	3	560.8555	186.9518	370.40	0.0001
AREA	2	41.1489	20.5745	40.76	0.0001
QUARTER*AREA	6	28.0152	4.6692	9.25	0.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
YEAR	9	281.26967	31.25219	61.92	0.0001
QUARTER	3	181.14307	60.38102	119.63	0.0001
AREA	2	31.57057	15.78528	31.27	0.0001
QUARTER*AREA	6	28.01517	4.66920	9.25	0.0001

Parameter		Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT		4.491715800 B	109.55	0.0	0.04100321
YEAR	1988	0.410957534 B	11.19	0.0001	0.03671717
	1989	0.090250369 B	2.86	0.0042	0.03153329
	1990	0.225424530 B	7.49	0.0001	0.03009820
	1991	-0.054228765 B	-1.66	0.0965	0.03262554
	1992	-0.210623483 B	-6.98	0.0001	0.03018119
	1993	0.118805477 B	4.24	0.0001	0.02802743
	1994	0.228277311 B	8.47	0.0001	0.02693762
	1995	0.157097258 B	5.87	0.0001	0.02674887
	1996	-0.035212087 B	-1.24	0.2141	0.02834064
	1997	0.000000000 B	.	.	.
QUARTER					
	1	0.191411755 B	2.10	0.0362	0.09134657
	2	-0.482485526 B	-5.49	0.0001	0.08792633
	3	0.169406640 B	4.10	0.0001	0.04127318
	4	0.000000000 B	.	.	.

Table II (cont.).

Parameter	Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
AREA				
2	0.217504503 B	5.47	0.0001	0.03976745
3	0.341416692 B	7.92	0.0001	0.04310676
5	0.000000000 B	.	.	.
QUARTER*AREA				
1 2	-0.562431969 B	-5.86	0.0001	0.09592869
1 3	-0.574797287 B	-5.77	0.0001	0.09956957
1 5	0.000000000 B	.	.	.
2 2	-0.120203573 B	-1.31	0.1886	0.09141300
2 3	-0.022211293 B	-0.23	0.8176	0.09628754
2 5	0.000000000 B	.	.	.
3 2	-0.172712735 B	-3.75	0.0002	0.04600419
3 3	-0.233858042 B	-4.57	0.0001	0.05117369
3 5	0.000000000 B	.	.	.
4 2	0.000000000 B	.	.	.
4 3	0.000000000 B	.	.	.
4 5	0.000000000 B	.	.	.

NOTE: The X'X matrix has been found to be singular and a generalized inverse was used to solve the normal equations. Estimates followed by the letter 'B' are biased, and are not unique estimators of the parameters.

Table III.- Least Squares Means. Relative CPUE in number and weight and upper and lower 95% confidence limits.

YEAR	LnCPUE LSMEAN	Std Err LSMEAN	UCPUEn	CPUEn	LCPUEn
1988	2.33999153	0.02961538	11.00639	10.38570	9.80002
1989	1.96215329	0.02456262	7.46778	7.11678	6.78227
1990	2.18481351	0.02256011	9.29323	8.89125	8.50667
1991	1.85286765	0.02588970	6.71233	6.38022	6.06454
1992	1.92095911	0.02296340	7.14370	6.82930	6.52874
1993	1.96690739	0.02046564	7.44267	7.15003	6.86890
1994	2.06799683	0.01916417	8.21320	7.91042	7.61880
1995	2.03595153	0.01826125	7.93998	7.66081	7.39147
1996	1.77964194	0.02061841	6.17350	5.92899	5.69417
1997	1.77756268	0.02357325	6.19687	5.91706	5.64989

YEAR	LnCPUE LSMEAN	Std Err LSMEAN	UCPUEw	CPUEw	LCPUEw
1988	4.91804571	0.03008037	145.10471	136.79701	128.96494
1989	4.59733854	0.02494828	104.22462	99.25078	94.51430
1990	4.73251270	0.02291432	118.82922	113.61042	108.62083
1991	4.45285941	0.02629619	90.44534	85.90183	81.58657
1992	4.29646469	0.02332395	76.89583	73.45968	70.17708
1993	4.62589365	0.02078697	106.36240	102.11603	98.03918
1994	4.73536548	0.01946507	118.35712	113.92666	109.66205
1995	4.66418543	0.01854797	110.02542	106.09739	102.30959
1996	4.47187609	0.02094214	91.20794	87.53996	84.01949
1997	4.50708817	0.02394338	95.04057	90.68344	86.52607

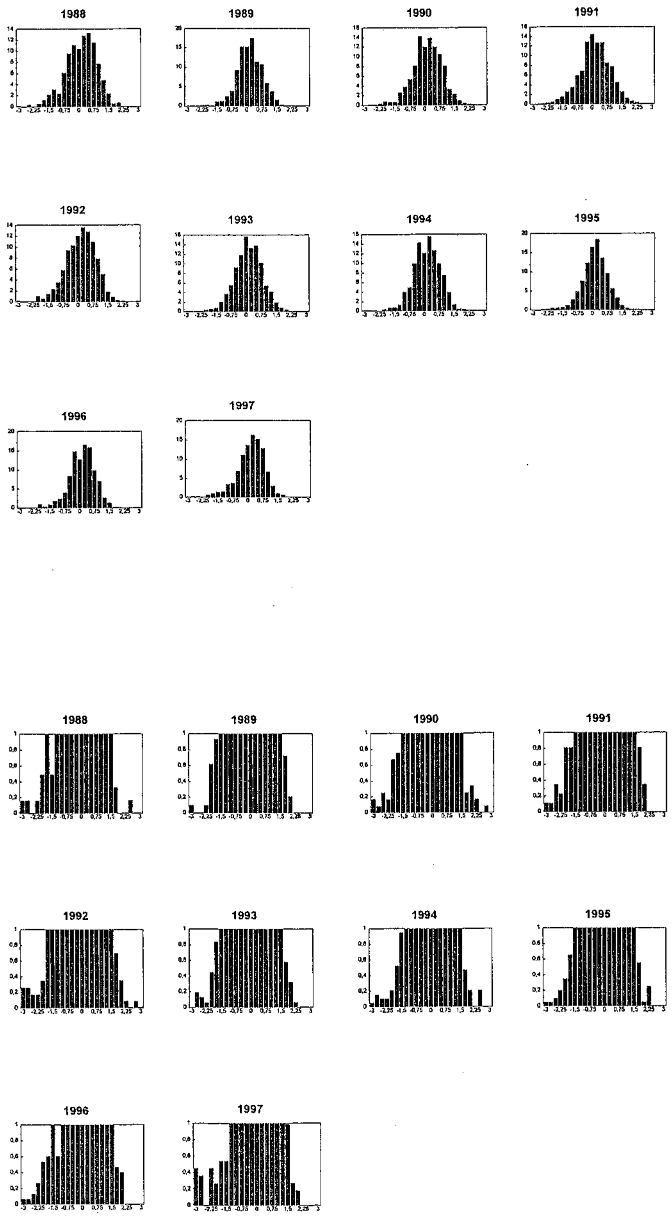

Figure 1.- Standardized residual patterns for CPUE in number and weight by year.

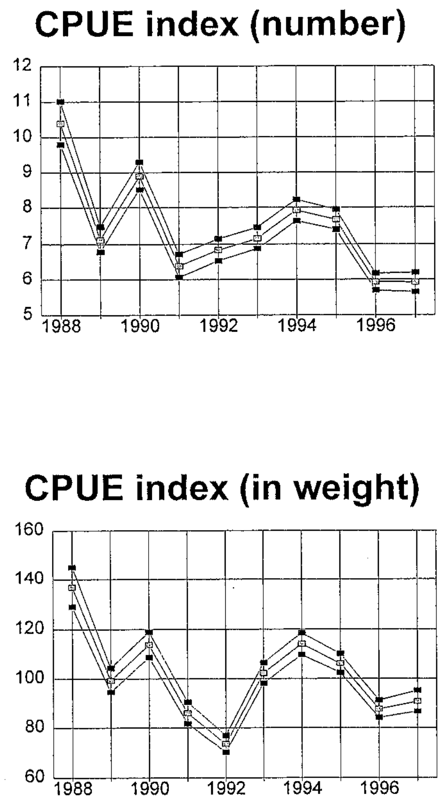

Figure 2.- Standardized CPUE index, in number of fish and kg round weight. Upper and lower 95% confidence limits.