

CATCH, FISHING EFFORT AND CATCH PER UNIT EFFORT OF TAIWANESE LONGLINE FISHERY FOR BLUE MARLIN AND WHITE MARLIN IN THE ATLANTIC

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ABSTRACT

*Catch, fishing effort and catch per unit effort of white marlin (*Tetrapturus albidus*) and blue marlin (*Makaira nigricans*) are verified and updated to 1998 for Taiwanese longline fishery. The nominal CPUE of white marlin and blue marlin were standardized by general linear model with Year, Quarter and Area factors, and with Quarter:Area interactions for two time periods (1968-1980 and 1981-1998). These analyses were done for the total Atlantic and separately using south and north Atlantic CPUE data. The results show similar decreasing tendencies in standardized CPUE from 1968 to 1992 for white marlin and from 1968 to 1989 for blue marlin, which then increase to the level of the early 1970s and become stable from 1990 onwards.*

RESUMEN

*Se comprueban y actualizan hasta 1998 los datos de captura, esfuerzo de pesca y captura por unidad de esfuerzo de aguja blanca (*Tetrapturus albidus*) y aguja azul (*Makaira nigricans*) correspondientes a la pesquería palangrera de Taipei Chino. La CPUE nominal de la aguja blanca y la aguja azul se estandarizaron por medio del modelo lineal generalizado, con los factores Año, Trimestre y Zona e interacciones Zona/Trimestre durante dos periodos (1968-1980 y 1981-1998). Estos análisis se llevaron a cabo para el conjunto del Atlántico y por separado, usando los datos de CPUE del Atlántico norte y Atlántico sur. Los resultados muestran tendencias descendentes similares en la CPUE estandarizada para la aguja blanca, de 1968 a 1992 y para la aguja azul, de 1968 a 1998, que posteriormente se elevan hasta el nivel de principios de la década de los 70 y se estabilizan a partir de 1990.*

RÉSUMÉ

*Les données de capture, d'effort de pêche et de capture par unité d'effort concernant le makaire blanc (*Tetrapturus albidus*) et le makaire bleu (*Makaira nigricans*) ont été vérifiées et actualisées jusqu'en 1998 pour ce qui est de la pêche palangrière du Taiwan. Les CPUE nominales du makaire blanc et du makaire bleu ont été standardisées par un modèle linéaire généralisé assorti des facteurs Année, Trimestre et Zone, et des interactions Trimestre:Zone pour deux périodes temporelles (1968-1980 et 1981-1998). Ces analyses ont été effectuées pour l'ensemble de l'Atlantique et séparément à l'aide des données de CPUE de l'Atlantique nord et sud. Les résultats indiquent des tendances à la baisse similaires de la CPUE standardisée de 1968 à 1992 pour le makaire blanc, et de 1968 à 1989 pour le makaire bleu, qui augmentent ensuite pour atteindre le niveau du début des années 1970 et se stabilisent à partir de 1990.*

KEYWORDS

Tuna fisheries, High seas fisheries, longlining, By catch, Logbooks, Fish catch statistics, Catch/effort, Multivariate analysis, Abundance

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INTRODUCTION

Taiwan is one of the major nations using longline gear fishing for tunas and tuna-like species in the Atlantic. In addition, tunas such as albacore, bigeye tuna, and yellowfin tuna are the target species, and the billfishes - swordfish, white marlin, blue marlin and sailfish - are caught incidentally by Taiwanese fishermen.

The Taiwanese longline fishery initiated in 1913 and operated in the waters off Taiwan, and extended into the Atlantic about 1962. The dominant species for the Taiwanese longline fishery in the Atlantic were albacore from the 1970s and then bigeye tuna starting in the early 1990s. This indicates that a transformation in the fishing pattern occurred at the end of the 1980's (Hsu and Chern 1996). This transformation resulted in increasing catch of tropical tunas along with an increase of swordfish and billfish catches (in particular, white marlin and blue marlin). The causes of the increased billfish catches were not verified. However, the amounts harvested annually are significant among longline fishing nations in the Atlantic. Therefore, Taiwanese fishing activities including number of vessels, fishing patterns and fishing grounds, catch, effort, catch per unit effort are important for billfish species assessment. Hence, a review of Taiwanese billfish catches in the Atlantic and the standardized catch per unit effort have been reported previously (Hsu 1998) during the Third Billfish Workshop (Miami, FL, USA, July 11-20, 1996).

In this document, an update of standardized catch per unit effort series for blue and white marlin based on the Taiwanese longline fishery operating in the Atlantic are provided using a general linear model (GLM).

MATERIALS AND METHODS

Basic data

The landings for white marlin (Fig. 1) and blue marlin (Fig. 2) are compiled by similar procedures to those of Hsu (1998), from sources of Fisheries Yearbooks of the Taiwan Area (Anonymous, 1966a-1999a), Annual Catch Statistics of Taiwanese Tuna Longline Fishery (Anonymous, 1967b-1993b), and the tuna longline logbooks which are submitted by captains of longline fleets and collected by the Department of Fisheries, Kaohsiung Municipal Government. Logbooks are the main source used to compile the catch. Catches of the two species, white marlin and blue marlin, are verified and provided by Oversea Fisheries Development Council (OFDC) from 1994 to 1999; the 1999 catch is preliminary.

Detailed data compilation of Taiwanese distant-water longline fishery was described in Hsu and Lin (1996), which includes raw data used, process of compilation and debugging.

Standardized abundance indices

In using the GLM as the standardization method, the single factors, year, quarter, and area were used with a quarter*area interaction to adjust the nominal catch per unit effort of white marlin and blue marlin. Thus, the GLM model used was:

$$\log(\text{CPUE} + 10\% \text{ of grand mean}) = u + \text{Year effect} + \text{Quarter effect} + \text{Area effect} + \text{Quarter*Area interaction} + \text{error},$$

where CPUE is in number of billfish caught per 1000 hooks, u is the overall mean, and the error term is assumed to be normally distributed with mean 0 and standard deviation σ . The F-test was used on all effects and interactions to determine the significance of the contribution of each factor to the model.

Area was classified according to fishing effort distributions (Fig. 3) and nominal catch per unit effort of white marlin (Fig. 4) and blue marlin (Fig. 5), indicating where the heavy fishing effort is employed, and where billfish CPUE is highest. The goal of the area classification is to attempt to eliminate as much noise as possible other than abundance itself. The final sub-area stratification is given in Fig. 6.

For the analysis of Taiwanese data, two time frames were defined according to the attributes of the data. One is from 1968 to 1980, with 5x5 degree-square aggregated catch and fishing effort data. The other is from 1981 to 1998, using daily logbook data. Quarter was assigned as the calendar quarter of the year. Observations having daily fishing effort smaller than 3000 hooks were excluded from the analysis following the reasoning of Uosaki (1998) and Uozumi (1998). However, observations with zero catch were retained in the analysis.

RESULTS AND DISCUSSION

Catch, effort and nominal catch per unit effort

Fishing effort, catch, mean weight and nominal CPUE for white marlin and blue marlin are given in Tables 1 and 3 respectively. White marlin (Tables 1 and 2), and blue marlin (Tables 3 and 4) were analyzed for the total Atlantic and also separately as north and south Atlantic stocks (separated at 5°N latitude).

The catches of white marlin indicate that there are two high-catch periods from 1969 to 1976, and from 1987 to 1995, which then decline from the historically-high level (Fig. 1). Those catches almost come from the south Atlantic (Table 2) where conventional longline Taiwanese vessels operated to target albacore (in particular since 1987). The increasing catch may relate to the albacore targeted by Taiwanese longline fleets. A similar situation occurs for blue marlin (Fig. 2 and Table 4).

Abundance indices

Nominal and adjusted catch per unit effort in the total Atlantic are given in Tables 1 and 3 for white marlin and blue marlin respectively, and also by sub-areas (Tables 2 and 4 for white marlin and blue marlin respectively) from 1968 to 1998. The standardized CPUE trends with 95% confidence intervals for 1968-1994 are given in Table 1 for white marlin and in Table 3 for blue marlin.

Adjusted catch per unit effort was standardized by the GLM method with year, quarter, and area factors, and quarter*area interaction as ICCAT species working groups used in previous assessments.

The significance tests of standardized catch per unit effort on the time frame 1968-1980 are given in Tables 5 and 7, and for 1981-1998 they are given in Tables 6 and 8 for white marlin and blue marlin, respectively. Model fits to white marlin and blue marlin in the total Atlantic and blue marlin in the north Atlantic were not significant. All effects and interactions were included in estimating yearly standardized catch per unit effort. The models explained 37% and 48% of the variation in CPUE for white marlin and blue marlin, respectively for the total Atlantic.

The adjusted catch per unit effort trend of white marlin for the Taiwanese longline fishery shows great fluctuation from 1968 to 1994 for the total Atlantic and north Atlantic series. In contrast, the south Atlantic series (Figure 7) showed a decreasing trend from 1968 to 1977, was relatively flat through 1986, and then fluctuated through 1994. The blue marlin index showed a decreasing trend from 1968 to 1975, was relatively flat from the late 1970s through the 1980s, and then increased through 1994 for the total Atlantic series (Figure 8). Trends for the north and south series (Figures 9 and 10) were similar to the total Atlantic results.

The Taiwanese distant-water tuna longline fishery catches billfishes incidentally in the Atlantic. However, targeting is suspected for Taiwanese longline fleets operating joint venture in the waters off Brazil during the period from 1990 to 1992. This may be one of the possible reasons for the increasing billfish catch during the 1990s. There were between several and 20 or more Taiwanese conventional longline vessels operating in the southeastern and northeastern waters off Brazil, especially in the southeastern waters during the period 1990 to 1992. Those vessels were joint ventures with Brazil, and targeted mainly albacore. Whether or not targeting on either swordfish or billfishes is suspected, the amounts of swordfish and billfish catches were highly significant. It is obvious that the billfish catches in Fisheries Yearbooks, Taiwan Area, increased during the mentioned period, and it did in Brazil-Taiwan statistics (Hsu 1998). However, to investigate the catches, the Taiwan Fishery Authority has regulated the catches of white marlin and blue marlin under the level of 550 t annually to reflect their by-catch status.

The 1967 Task II data were not included during standardization of catch per unit effort series because of the low coverage of 5x5 square blocks in Task II, which also pertained only to the last half of that year (from July to December). Therefore, the adjusted catch per unit effort in 1967 may not represent the abundance index appropriately. Thus, only the data from 1968 to 1998 were used for the standardization purpose. Further, complete 1999 data were not available. However, the standardized 1998 index may be carried over to 1999 if needed because the fishing pattern of the Taiwanese longline fishery in the Atlantic was similar.

Finally, the standardized catch per unit effort of white marlin (Figs. 7 and 8; Tables 1 and 2) and blue marlin (Figs. 9 and 10, Tables 3 and 4) were illustrated and tabulated. Those trends show similarly decreasing tendency from 1968 to 1992 for white marlin and to 1989 for blue marlin, increasing to the level of early 1970s and stable trend from 1990 afterward.

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Table 1. The catches, fishing effort, nominal catch per unit of effort (CPUE) and adjusted catch per unit of effort of white marlin by Taiwanese longline fishery in the whole Atlantic from 1967 to 1999. The CPUE was adjusted by GLM with year, quarter, area factors and quarter*area interaction as described in the text. '*' indicates a suspected figure.

Year	Fishing effort (1000hooks)	Catch (mt)	Mean Weight (kg)	Nominal CPUE (no./1000 hooks)	Adjusted CPUE (no./1000 hooks)	Lower CI of adjusted CPUE (no./1000 hooks)	Upper CI of adjusted CPUE (no./1000 hooks)
1967	3678	181	30.64	0.0710			
1968	56606	385	16.99	0.3142	0.16099	0.10211	0.24562
1969	72562	583	25.20	0.3188	0.18681	0.12629	0.27041
1970	70723	612	24.21	0.3020	0.11805	0.07652	0.17539
1971	102994	438	21.36	0.1754	0.12426	0.07984	0.18626
1972	98397	713	23.10	0.1117	0.10346	0.06324	0.16056
1973	108549	599	22.80	0.2418	0.12471	0.07888	0.18938
1974	98669	537	21.15	0.2572	0.15009	0.09902	0.22101
1975	90820	507	20.46	0.2728	0.11906	0.07484	0.18149
1976	110031	519	18.97	0.0713	0.01542	0.00144	0.03514
1977	142341	163	24.77	0.0221	0.00775	-0.00358	0.02351
1978	116006	277	25.73	0.0414	0.01027	-0.00220	0.02787
1979	84044	217	20.17	0.0494	0.04936	0.02233	0.08971
1980	87092	250	19.62	0.0996	0.05579	0.02807	0.09622
1981	104863	310	22.52	0.1224	0.04246	0.01850	0.07768
1982	134997	361	22.89	0.0652	0.02972	0.01062	0.05729
1983	96825	290	21.68	0.0657	0.03969	0.01693	0.07294
1984	99032	220	18.93	0.0636	0.02379	0.00604	0.04970
1985	172034	300	22.70	0.0598	0.02070	0.00263	0.04805
1986	256645	515	20.24	0.0992	0.04028	0.01700	0.07449
1987	220672	766	24.05	0.1443	0.05225	0.02404	0.09454
1988	155941	565	18.75	0.1758	0.02808	0.00521	0.06483
1989	144898	983	19.52	0.3474	0.06038	0.02532	0.11672
1990	199600	895	20.40	0.0950	0.01759	0.00159	0.04111
1991	165268	803	18.06	0.1915	-0.00683	-0.01470	0.00452
1992	185315	598	17.52	0.1292	0.00018	-0.01011	0.01521
1993	258161	616	22.58	0.1055	0.09319	0.05119	0.15627
1994	146607	1350	32.34	0.2847	0.14706	0.09336	0.22367
1995	142893	907	31.22	0.2033	0.05642	0.03014	0.09372
1996	80793	566	35.85	0.1954	0.10568	0.06586	0.16162
1997	78902	441	35.73	0.1564	0.07299	0.04295	0.11500
1998	231466	506	46.03	0.0475	0.02078	0.00422	0.04479
1999	212000	464	-	-	-	-	-

Table 2. The catches (mt), fishing effort (1000 hooks), nominal catch per unit of effort (CPUE, no./1000 hooks) and adjusted catch per unit of effort (no./1000 hooks) of white marlin by Taiwanese longline fishery in the north and south Atlantic from 1967 to 1999. The CPUE (no./1000 hooks) was adjusted by GLM with year, quarter, area factors and quarter*area interaction as described in the text.

Year	Catch (north)	Catch (south)	Effort (north)	Effort (south)	Nominal CPUE (north)	Nominal CPUE (south)	Adjusted CPUE (north)	Adjusted CPUE (south)
1967	47	134	1771	1907	0.0536	0.0871		
1968	58	327	16997	39610	0.2143	0.3570	0.09678	0.23747
1969	135	448	19792	52770	0.3231	0.3172	0.13496	0.24198
1970	104	508	28343	42380	0.1278	0.4184	0.11184	0.12434
1971	178	260	31562	71432	0.2633	0.1365	0.16131	0.10098
1972	244	469	20363	78034	0.2172	0.0841	0.11616	0.09217
1973	135	464	36491	72058	0.1854	0.2704	0.10761	0.14404
1974	252	285	33913	64756	0.3704	0.1978	0.21627	0.09857
1975	125	382	29894	60926	0.2207	0.2984	0.12621	0.10957
1976	142	377	25729	84302	0.0430	0.0799	0.00886	0.02521
1977	44	119	35488	106852	0.0130	0.0251	0.00263	0.01378
1978	79	198	18409	97597	0.0368	0.0423	0.00741	0.01371
1979	62	155	17737	66307	0.0660	0.0449	0.06814	0.03488
1980	105	145	19185	67907	0.2180	0.0661	0.07554	0.03870
1981	174	136	25276	79587	0.2896	0.0693	0.10724	0.02183
1982	134	227	39385	95612	0.1172	0.0438	0.06462	0.02424
1983	203	87	52030	44795	0.0880	0.0398	0.06846	0.03677
1984	96	124	65236	33796	0.0430	0.1033	0.03557	0.03959
1985	128	172	75683	96351	0.0689	0.0527	0.03894	0.02776
1986	319	196	120109	136536	0.1396	0.0637	0.08007	0.02444
1987	153	613	47611	173061	0.1537	0.1417	0.08879	0.03941
1988	0	565	10433	145507	0.0000	0.1884	0.00787	0.09381
1989	4	979	7029	137869	0.0046	0.3648	0.02513	0.11233
1990	85	810	29144	170456	0.0212	0.1076	0.04412	0.02398
1991	13	790	31773	133495	0.0059	0.2357	-0.00280	0.01476
1992	92	506	29726	155589	0.0262	0.1489	0.00847	0.01811
1993	123	493	56280	201881	0.1970	0.0800	0.16138	0.08036
1994	506	844	38944	107662	0.3194	0.2722	0.16311	0.15685
1995	241	666	32847	110046	0.2266	0.1963	0.07214	0.06842
1996	122	444	19874	60919	0.1511	0.2099	0.09633	0.14427
1997	80	361	15997	62905	0.1361	0.1616	0.08826	0.08530
1998	105	401	44663	186803	0.0468	0.0477	0.03693	0.03189
1999	96	368	40790	171460	-	-	-	-

Table 3. The catches, fishing effort, nominal catch per unit of effort (CPUE) and adjusted catch per unit of effort of blue marlin by Taiwanese longline fishery in the total Atlantic from 1967 to 1994. The CPUE was adjusted by GLM with year, quarter, area factors and quarter-area interaction as described in the text. '*' denotes a suspected figures; and '**' denotes a previous year mean weight was used in the estimation of adjusted CPUE in weight.

Year	Fishing effort (1000hooks)	Catch (mt)	Mean Weight (kg)	Nomial CPUE (no./1000 hooks)	Adjusted CPUE (no./1000 hooks)	Lower CI of adjusted CPUE (no./1000 hooks)	Upper CI of adjusted CPUE (no./1000 hooks)
1967	3678	291	70.98	0.2477			
1968	56606	803	76.39	0.1859	0.14956	0.10846	0.20430
1969	72562	1364	76.23	0.1861	0.21423	0.16254	0.28091
1970	70723	929	85.11	0.1338	0.10381	0.07698	0.13843
1971	102994	935	71.49	0.1271	0.10302	0.07560	0.13867
1972	98397	928	88.73	0.0540	0.07153	0.05048	0.09928
1973	108549	692	68.96	0.0604	0.06071	0.04256	0.09928
1974	98669	552	59.07	0.0584	0.03764	0.02551	0.08453
1975	90820	527	62.98	0.0291	0.02536	0.01562	0.05335
1976	110031	409	16.79**	0.0481	0.01338	0.00649	0.03816
1977	142341	171	83.41	0.0138	0.00864	0.00309	0.02241
1978	116006	258	85.42	0.0082	0.00547	0.00047	0.01584
1979	84044	190	63.50	0.0146	0.01284	0.00515	0.01204
1980	87092	289	47.65	0.0381	0.03224	0.01995	0.02340
1981	104863	202	67.11	0.0253	0.03698	0.02312	0.05582
1982	134997	250	58.81	0.0189	0.02129	0.01197	0.03377
1983	96825	172	59.14	0.0156	0.02050	0.01112	0.03318
1984	99032	172	55.32	0.0227	0.02451	0.01409	0.03859
1985	172034	313	59.56	0.0177	0.01508	0.00647	0.02705
1986	256645	215	53.43	0.0157	0.01541	0.00724	0.02651
1987	220672	317	66.74	0.0215	0.01873	0.00930	0.03175
1988	155941	292	57.25	0.0250	0.02332	0.01111	0.04113
1989	144898	473	53.03	0.0451	0.02215	0.01030	0.03941
1990	199600	1704	62.73	0.0510	0.06163	0.04127	0.08928
1991	165268	1672	55.27	0.0620	0.0926	0.00299	0.01765
1992	185315	824	69.14	0.0353	0.01780	0.00913	0.02950
1993	258161	685	53.37	0.0498	0.05518	0.03563	0.08220
1994	146607	663	59.27	0.0763	0.08306	0.05878	0.1153
1995	142893	467	71.98	0.0454	0.06233	0.04339	0.08736
1996	80793	660	88.83	0.0920	0.06324	0.04457	0.08771
1997	78902	1478	89.48	0.2093	0.06710	0.04775	0.09235
1998	231466	578	81.01	0.0308	0.03682	0.02340	0.05486
1999	212000	486	-	-	-	-	-

Table 4. The catches (mt), fishing effort (1000 hooks), nominal catch per unit of effort (CPUE, no./1000hooks) and adjusted catch per unit of effort (no./1000 hooks) of blue marlin by Taiwanese longline fishery in the north and south Atlantic from 1967 to 1994. The CPUE (no./1000 hooks) was adjusted by GLM with year, quarter, area factors and quarter*area interaction as described in the text.

Year	Catch (north) (mt)	Catch (south) (mt)	Effort (north) /1000	Effort (south) /1000	Nomial CPUE (north)	Nomial CPUE (south)	Adjusted CPUE (north)	Adjusted CPUE (south)
1967	131	160	1771	1907	0.4872	0.0252		
1968	374	429	16997	39610	0.3202	0.1283	0.18887	0.12529
1969	348	1016	19792	52770	0.1856	0.1862	0.19655	0.23253
1970	369	560	28343	42380	0.1142	0.1469	0.10104	0.10669
1971	193	742	31562	71432	0.1053	0.1368	0.07810	0.12930
1972	300	628	20363	78034	0.0609	0.0522	0.06431	0.07913
1973	155	537	36491	72058	0.0513	0.0651	0.07138	0.05056
1974	183	369	33913	64756	0.0800	0.0471	0.03945	0.03539
1975	105	422	29894	60926	0.0369	0.0253	0.01989	0.03368
1976	169	240	25729	84302	0.0566	0.0455	0.00876	0.02019
1977	64	107	35488	106852	0.0239	0.0105	0.00902	0.00812
1978	81	177	18409	97597	0.0073	0.0083	0.00217	0.00984
1979	51	139	17737	66307	0.0162	0.0142	0.00629	0.02108
1980	160	129	19185	67907	0.1160	0.0161	0.04953	0.01858
1981	98	104	25276	79587	0.0430	0.0196	0.03392	0.05031
1982	100	150	39385	95612	0.0338	0.0128	0.01659	0.03313
1983	125	47	52030	44795	0.0190	0.0095	0.01602	0.03570
1984	102	70	65236	33796	0.0226	0.0228	0.01349	0.05319
1985	148	165	75683	96351	0.0220	0.0143	0.00843	0.03711
1986	117	98	120109	136536	0.0202	0.0118	0.00985	0.03451
1987	52	265	47611	173061	0.0204	0.0218	0.01023	0.04428
1988	26	266	10433	145507	0.0281	0.0248	0.01847	0.04508
1989	11	462	7029	137869	0.0048	0.0471	0.01015	0.05694
1990	937	767	29144	170456	0.1429	0.0351	0.08379	0.07174
1991	716	956	31773	133495	0.0882	0.0558	0.00566	0.02147
1992	336	488	29726	155589	0.0428	0.0338	0.00935	0.03554
1993	281	404	56280	201881	0.1528	0.0211	0.08443	0.05433
1994	180	483	38944	107662	0.0969	0.0689	0.06025	0.11899
1995	97	370	32847	110046	0.0415	0.0466	0.03882	0.11410
1996	148	512	19874	60919	0.0925	0.0918	0.04026	0.10059
1997	37	110	15997	62905	0.2454	0.2002	0.03959	0.10998
1998	80	498	44663	186803	0.0243	0.0324	0.01938	0.06094
1999	68	418	40790	171460	-	-	-	-

Table 5. ANOVA results for the factors in the GLM procedure for adjusted catch per unit of effort for white marlin in the Atlantic, 1968-1980.

(1) Total Atlantic					
Sources	DF	Sum of Square	Mean Square	F value	Pr >F
Model	51	4578728	8.9779	9.51	0.0001
Year	12	134.5806	11.2151	11.87	0.0001
Quarter	3	1.6928	0.5643	0.60	0.6171
Area	9	125.6934	13.9659	14.79	0.0001
Quarter-area	27	138.3005	5.1222	5.42	0.0001
Error	362	341.9222	0.9445		
Corrected total	413	799.7951			

R ²	C.V. (%)	Root MSE
0.5725	-44.2076	0.9719

(2) North Atlantic					
Sources	DF	Sum of Square	Mean Square	F value	Pr >F
Model	31	220.9476	7.1273	6.33	0.0001
Year	12	79.3242	6.6103	5.87	0.0001
Quarter	3	29.4360	9.8120	8.71	0.0001
Area	4	42.8664	10.7166	9.51	0.0001
Quarter-area	12	33.7689	2.8141	2.50	0.0048
Error	175	197.1132	1.1264		
Corrected total	206	418.0608			

R ²	C.V. (%)	Root MSE
0.5285	-48.7896	1.0613

(3) South Atlantic					
Sources	DF	Sum of Square	Mean Square	F value	Pr >F
Model	31	252.4035	8.1420	11.10	0.0001
Year	12	69.9865	5.8322	7.95	0.0001
Quarter	3	27.8093	9.2698	12.64	0.0001
Area	4	75.7306	18.9327	25.82	0.0001
Quarter-area	12	44.5340	3.7112	5.06	0.0001
Error	175	128.3183	0.7332		
Corrected total	206	280.7218			

R ²	C.V. (%)	Root MSE
0.6630	-38.5569	0.8563

Table 6. ANOVA results for the factors in the GLM procedure for adjusted catch per unit of effort for white marlin in the Atlantic, 1981-1998.

(1) Total Atlantic					
Sources	DF	Sum of Square	Mean Square	F value	Pr >F
Model	56	438.8705	7.8370	7.04	0.0001
Year	17	128.7696	7.5747	6.81	0.0001
Quarter	3	7.3463	2.4488	2.20	0.0871
Area	9	211.9647	23.5516	21.17	0.0001
Quarter-area	27	78.5987	2.9111	2.62	0.0001
Error	492	547.3389	1.1125		
Corrected total	548	986.2094			

R ²	C.V. (%)	Root MSE
0.4450	-39.6872	1.0547

(2) North Atlantic					
Sources	DF	Sum of Square	Mean Square	F value	Pr >F
Model	36	199.1861	5.5329	4.31	0.0001
Year	17	86.5608	5.0918	3.97	0.0001
Quarter	3	7.4633	2.4878	1.94	0.1239
Area	4	79.6601	19.9150	15.53	0.0001
Quarter-area	12	23.3548	1.9462	1.52	0.1186
Error	229	293.6380	1.2823		
Corrected total	265	492.8241			

R ²	C.V. (%)	Root MSE
0.4042	-43.8818	1.1324

(3) South Atlantic					
Sources	DF	Sum of Square	Mean Square	F value	Pr >F
Model	36	288.1117	8.0031	9.62	0.0001
Year	17	86.7808	5.1048	6.14	0.0001
Quarter	3	24.8601	8.2867	9.96	0.0001
Area	4	118.8026	29.7006	35.71	0.0001
Quarter-area	12	33.0466	2.7529	3.31	0.0002
Error	246	204.6246	0.8318		
Corrected total	282	492.7363			

R ²	C.V. (%)	Root MSE
0.5847	-33.3756	0.9120

Table 7 ANOVA results for the factors in the GIM procedure for adjusted catch per unit of effort for blue marlin in the Atlantic, 1968-1980.

(1) Total Atlantic

Sources	DF	Sum of Square	Mean Square	F value	Pr >F
Model	51	613.5362	12.0301	20.45	0.0001
Year	12	221.3072	18.4423	31.35	0.0001
Quarter	3	5.4758	1.8253	3.10	0.0267
Area	9	227.4461	25.2718	42.96	0.0001
Quarter-area	27	83.7882	3.1032	5.28	0.0001
Error	362	212.9302			
Corrected total	413	826.4664			

R ²	C.V. (%)	Root MSE
0.7424	-27.3527	0.7669

(2) North Atlantic

Sources	DF	Sum of Square	Mean Square	F value	Pr >F
Model	31	302.9902	9.7739	15.59	0.0001
Year	12	121.1708	10.0976	16.10	0.0001
Quarter	3	17.8062	5.9254	9.47	0.0001
Area	4	103.3224	25.8306	41.20	0.0001
Quarter-area	12	20.5776	1.7148	2.73	0.0002
Error	175	109.7260	0.6270		
Corrected total	206	412.7162			

R ²	C.V. (%)	Root MSE
0.7341	-28.6170	0.7918

(3) South Atlantic

Sources	DF	Sum of Square	Mean Square	F value	Pr >F
Model	31	321.7399	10.3787	19.69	0.0001
Year	12	110.1262	9.1772	17.41	0.0001
Quarter	3	18.7823	6.2608	11.88	0.0001
Area	4	112.3644	28.0911	53.29	0.0001
Quarter-area	12	28.1493	2.3458	4.45	0.0001
Error	175	92.2503	0.5271		
Corrected total	206	413.9902			

R ²	C.V. (%)	Root MSE
0.7772	-25.5485	0.7260

Table 8 ANOVA results for the factors in the GIM procedure for adjusted catch per unit of effort for blue marlin in the Atlantic, 1981-1998.

(1) Total Atlantic

Sources	DF	Sum of Square	Mean Square	F value	Pr >F
Model	56	379.3962	6.7749	9.62	0.0001
Year	17	96.4730	5.6749	8.06	0.0001
Quarter	3	2.8449	0.9483	1.35	0.2587
Area	9	158.1803	17.5756	24.95	0.0001
Quarter-area	27	76.7587	2.8429	4.04	0.0001
Error	492	346.5839	0.7044		
Corrected total	548	725.9801			

R ²	C.V. (%)	Root MSE
0.5226	-27.8631	0.8393

(2) North Atlantic

Sources	DF	Sum of Square	Mean Square	F value	Pr >F
Model	36	262.1989	7.2833	5.90	0.0001
Year	17	80.8947	4.7585	3.85	0.0001
Quarter	3	7.2888	2.4296	1.97	0.1195
Area	4	92.5526	23.1381	18.74	0.0001
Quarter-area	12	42.99348	3.5779	2.90	0.0009
Error	229	282.6842	1.2344		
Corrected total	265	544.8832			

R ²	C.V. (%)	Root MSE
0.4812	-32.7932	1.1110

(3) South Atlantic

Sources	DF	Sum of Square	Mean Square	F value	Pr >F
Model	36	51.6574	1.4349	9.09	0.0001
Year	17	11.9225	0.7014	4.44	0.0001
Quarter	3	3.4590	1.1530	7.30	0.0001
Area	4	21.8583	5.4646	34.61	0.0001
Quarter-area	12	7.5210	0.6267	3.97	0.0001
Error	246	38.8386	0.1579		
Corrected total	282	90.4960			

R ²	C.V. (%)	Root MSE
0.5708	-19.9840	0.3973

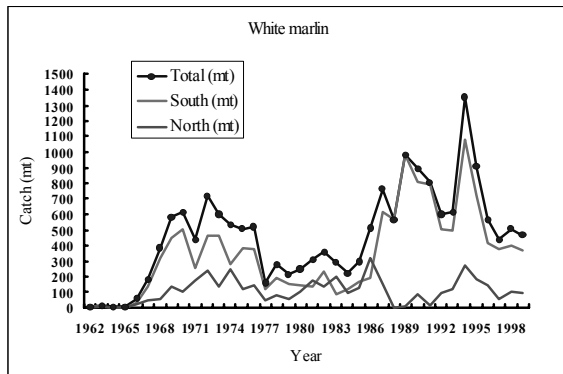


Figure 1 Annual catches of white marlin by Taiwanese longline fleets in the Atlantic. Catches are separated into assumed north and south Atlantic stocks at 5°N and total Atlantic.

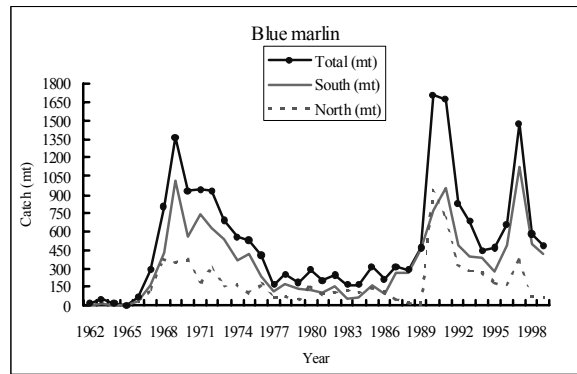


Figure 2 Annual catches of blue marlin by Taiwanese longline fleets in the Atlantic. Catches are separated into assumed north and south Atlantic stocks at 5°N and total Atlantic.

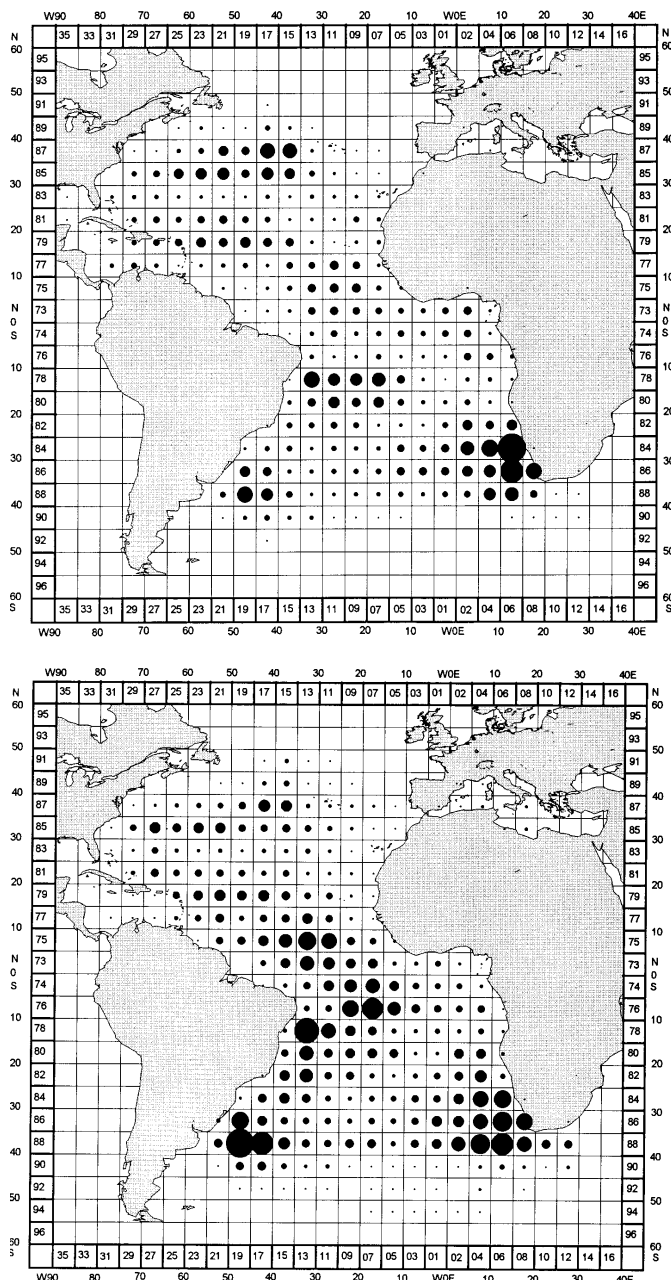


Figure 3. Effort distributions of Taiwanese longline fishery operating in the Atlantic Ocean. Data shown are aggregated from 1968-1980 (top) and from 1981-1998 (bottom)

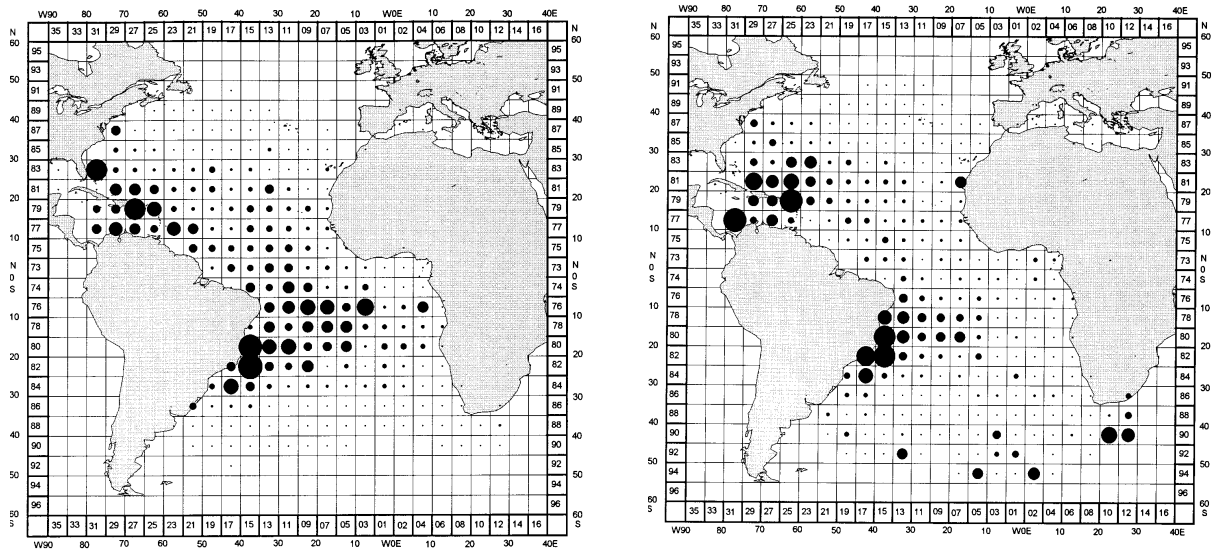


Figure 4. Nominal catch per unit of effort distribution of white marlin for Taiwanese longline fishery in the Atlantic. Data shown are aggregated from 1968 to 1980 (left) and from 1981 to 1998 (right).

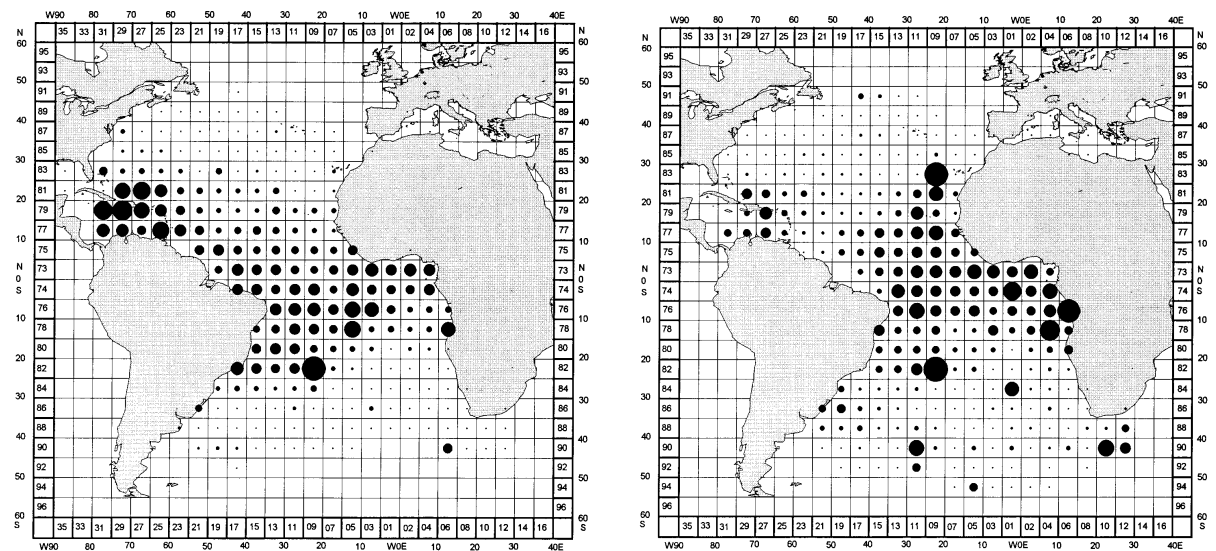


Figure 5. Nominal catch per unit of effort distribution of blue marlin for Taiwanese longline fishery in the Atlantic. Data shown are aggregated from 1968 to 1980 (left) and from 1981 to 1998 (right).

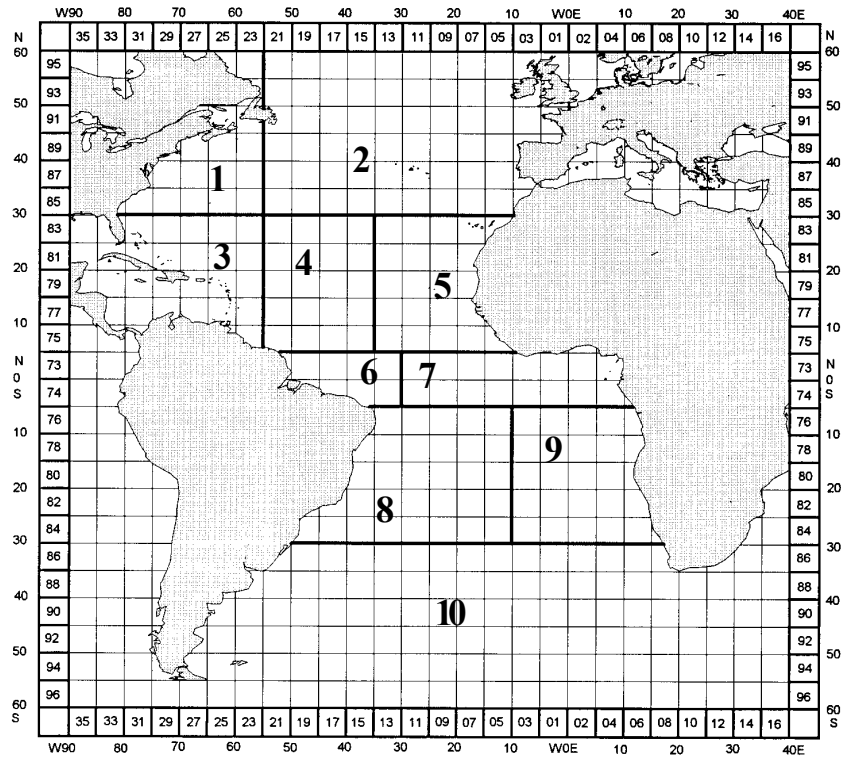


Figure 6. Area division used for general linear model analysis on the standardization of catch per unit of effort of white marlin and blue marlin by Taiwanese longline fishery in the Atlantic.

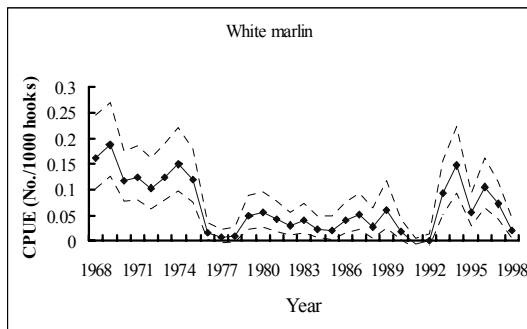


Figure 7. Standardized CPUE for white marlin in the total Atlantic by Taiwanese longline fishery, where dash lines show the lower and upper 95% confidence limit.

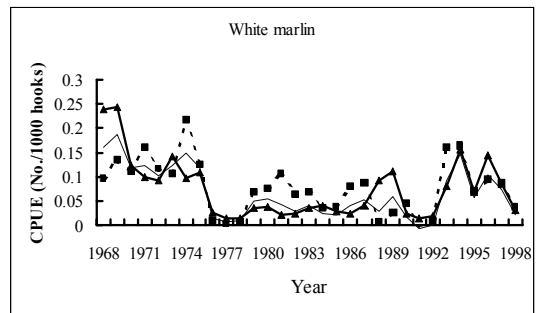


Figure 8. Standardized CPUE of white marlin in the total (thin line), north (squared) and south (triangle) Atlantic for Taiwanese longline fishery.

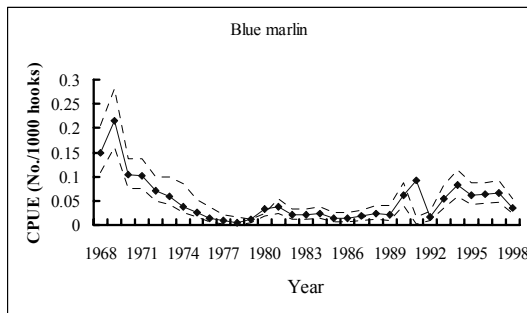


Figure 9. Standardized CPUE for blue marlin in the total Atlantic by Taiwanese longline fishery, where dash lines show the lower and upper 95% confidence limit.

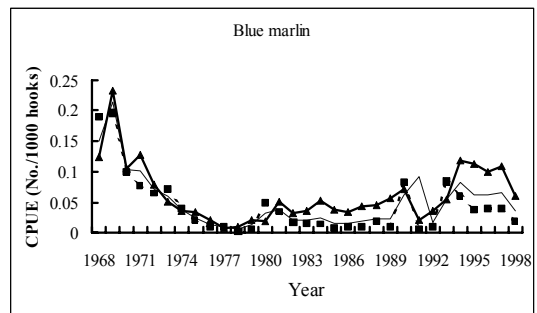


Figure 10. Standardized CPUE of blue marlin in the total (thin line), north (squared) and south (triangle) Atlantic for Taiwanese longline fishery.