A REVIEW OF CATCH, FISHING EFFORT AND CATCH PER UNIT OF EFFORT OF TAIWANESE LONGLINE FISHERY FOR BILLFISHES IN THE ATLANTIC

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SUMMARY

The preparation of Task I (landings), Task II, and catch per unit of effort (CPUE) data were verified by using all possible data sources, including Fisheries Yearbooks, Taiwan Area, Annual Catch Statistics of Taiwanese Tuna Longline Fishery, and logbooks submitted by fishing fleets in the Atlantic for white marlin, blue marlin, and sailfish.

The nominal CPUE of white marlin and blue marlin were standardized by general linear model with year, quarter and area factors and year-quarter and quarter-area interactions for Task II 5x5 square data from 1968 to 1994. The time series results of adjusted CPUE of these two species were used as abundance indices. The 1967 Task II data were available only for the last half year. Hence, the adjusted CPUE may not be adequate for use in assessment. Also, the 1995 Task II data were not available at the time of writing. Therefore, the 1995 abundance index is provisionally assumed to have the same value as 1994.

RÉSUMÉ

Ce document a été préparé pour les Troisièmes Journées d'Etudes sur les Istiophoridés. Les données Tâche I (débarquements), Tâche II et les données de CPUE ont été vérifiées grâce à différentes sources d'informations, notamment les Fisheries Yearbooks, Taiwan Area, *les statistiques annuelles de capture de la pêcheries palangrière taïwanaise de thonidés et les carnets de pêche présentés par les flottilles qui visent le makaire bleu, le makaire blanc et le voilier dans l'Atlantique.*

Les captures nominales par unité d'effort des makaires bleus et blancs ont été standardisées avec le Modèle Linéaire Généralisé par année, trimestre, facteurs zone et interactions année-trimestre et année-zone pour les données Tâche II, par carrés de 5°, entre 1968 et 1994. Les résultats des séries temporelles des donnés ajustées de CPUE pour ces deux espèces ont été utilisés en tant qu'indices d'abondance. Il est possible que l'ajustement des CPUE n'ait pas été réalisé de façon adéquate car les données Tâche II de 1967 ne couvrent que la seconde moitié de l'année. En raison de la non disponibilité des données Tâche II de 1995, on a supposé provisoirement que l'indice d'abondance de 1995 était le même que celui de 1994.

RESUMEN

La preparación de la Tarea I (desembarques), Tarea II y captura por unidad de esfuerzo se verificó utilizando posibles fuentes de datos, que incluían Anuarios de Estadísticas de Pesca, Area de Taiwan, Estadísticas de Capturas Anuales de la pesquería de palangre de Taiwan dirigida a los túnidos, y cuadernos de pesca presentados por flotas pesqueras para aguja blanca, aguja azul y pez vela en el Atlántico.

Se estandarizó la captura nominal por unidad de esfuerzo de aguja blanca y aguja azul mediante el modelo lineal generalizado con interacciones de año, trimestre, factores de área, año-área, y trimestre-área para los datos de bloques de 5°x5° de la Tarea II desde 1968 a 1994. Los resultados de las series temporales del esfuerzo ajustado de captura por unidad de esfuerzo de esas dos especies se utilizaron como índices de abundancia. Debido a la disponibilidad de los datos de la Tarea II de 1967, que abarca los datos de la última mitad del año, podría no ser adecuado ajustar en la evaluación la captura por unidad de esfuerzo, y como no se dispone de datos de la Tarea II 1995 hasta este momento, el índice de abundancia de 1995 podría asumirse provisionalmente como un valor similar al de 1994.

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1. INTRODUCTION

Taiwan is one of the major nations using longline gear to fish for tunas and tuna-like species in the Atlantic Ocean. 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 incidently by Taiwanese fishermen. Taiwanese longliners catch billfishes as a by-catch, the amounts harvested annually being significant among longline fishing nations in the Atlantic. Therefore, Taiwanese fishing activities including number of vessels, fishing patterns and fishing grounds, catch, effort, and catch per unit of effort are important for billfish species assessment.

Taiwanese longline fishery began in 1913 and operated in the waters off Taiwan, and extended into the Atlantic about 1962. In order to meet fishing activity requirements, many foreign ports located close to the important fishing grounds have been used as base for replenishing supplies, effecting repairs, and transshipping fish from longliners since 1954. Those bases include Trinidad, Las Palmas, and Saint Martin in the northern Atlantic, and Montevideo and Cape Town in the southern Atlantic. The dominant species for the Taiwanese longline fishery in the Atlantic were albacore from the 1970's and then bigeye tuna in the early 1990's. 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 increased catches of tropical tunas along with an increase in catches of swordfish and billfishes (in particular, white marlin and blue marlin). The causes of the increased billfish catches are unknown, aside from the Taiwanese longliners operating in joint venture with Brazil, which target billfishes in the northeastern and southeastern waters off Brazil.

Although Taiwan has a long time-series of 5x5 degree square data (Task II in the ICCAT data base), a detailed verification of that database, necessary for assessment purpose, has not previously been carried out. This document aims at verifying billfish catch data (Task I and Task II) for the Taiwanese longline fleets operating in the Atlantic, and standardizing the CPUE using monthly 5x5 degree square data (Task II) to obtain adjusted Taiwanese longline abundance indices.

2. MATERIAL AND METHOD

2.1 Preparation of Task I data

The landing data are classified as Task I, and three sources were used to estimate total landings for white marlin, blue marlin, and sailfish. These sources are: (a) Fisheries Yearbooks, Taiwan Area (Anonymous, 1966a-1993a); (b) Annual Catch Statistics of Taiwanese Tuna Longline Fishery (Anonymous, 1967b-1993b); and (c) the tuna longline logbooks which are submitted by captains of longline fleets and collected by the Department of Fisheries, Kaohsiung Municipal Government. The logbooks are the main source of data used to compile the catch statistics.

The following methodology was used to determine the landings of billfishes by the Taiwanese longline fishery in the Atlantic based on the above mentioned three sources; the product of the ratio (Atlantic catches for a species / total catch from all three Oceans recorded in the logbooks) and the distant-water catches for a species recorded in the Fisheries Yearbooks, Taiwan Area, if the latter figure is high, and using catch data from logbooks as Task I. This method was applied because: (1) catch figures calculated from the logbooks may not cover 100% of all catches, even when raised to the total fleet, and (2) data in the Fisheries Yearbooks, Taiwan Area, are mainly from reports of tuna exporters. This latter source does not cover 100% of the catch either, and therefore a greater figure was conservatively used for Task I until new information becomes available to update the databases.

Also, the Task I data of white marlin, blue marlin, and sailfish in 1995 in the Atlantic were raised from the summation of reports of tuna exporters and landings of distant-water longline vessels unloaded at Japanese market which were reported from Shin Nihon Kentei Kyokai (Hsu and Chern, 1996). The sources were used because the latter information mostly includes catches from longliners with super-cold freezers and the former from conventional longliners. The 1995 logbooks were not all available at the time of writing. Therefore, the breakdown of catch by area is not yet possible. As a result, the breakdown ratios for 1994 were used for 1995.

2.2 Preparation of Task II data

Task II data were based on logbooks submitted from captains, and collected by fishery managers, the specialists of the Department of Fisheries, Construction Bureau, Kaohsiung Municipal Government. The logbooks have been processed by the Institute of Oceanography, National Taiwan University for 1970 to 1994.

The logbooks include primarily the fishing activities, catch by species, effort and size measurement for the first 30 fish caught when the lines were lifted. Detailed Task II data processing of Taiwanese distant-water longline fishery was described in Hsu and Lin (1996), which includes raw data used, process of compilation and debugging.

2.3 Preparation of adjusted abundance indices

In using the GLM as the standardization method, the single factors, year, quarter, and area were used with year-quarter and quarter-area two-way interactions to adjust the nominal catch per unit of effort of white marlin and blue marlin.

The GLM model used is:

$$\log(\text{CPUE}+0.01) = u + \text{Year effect} + \text{Quarter effect} + \text{Area effect} + \text{Year*Quarter interaction} + \text{Quarter*Area interaction} + \text{error}$$

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

Area was classified as given in Figure 1 for white marlin and blue marlin. The area classification was according to the nominal CPUE and fishing effort distributions, indicating where the greatest fishing effort is employed, and where the effort directly targets these species. The goal of the area classification is to attempt to eliminate as much noise as possible, other than abundance itself.

3. RESULTS

3.1 Task I data

The Task I data are given in Tables 1, 2 and 3 for 1967 to 1994 for white marlin, blue marlin and sailfish, respectively. White marlin (Tables 1 and 4), and blue marlin (Tables 2 and 5) were separated into north and south Atlantic stocks, and sailfish (Tables 3 and 6) into west and east Atlantic stocks.

Only landings from 1962 to 1966 were available from Huang (1974). The 1962 to 1966 landings of billfishes by species are given in Table 7. The landings in Table 7 include the catch from three oceans, and are mainly from coastal and offshore waters off Taiwan. This is because the distant-water longline vessels from Taiwan exploiting tunas and tuna-like fish were mostly around the waters off Taiwan and the most westerly part of the Indian Ocean during the period from 1962 to 1966.

The 1995 landings of billfishes in the Atlantic were estimated as shown in Table 7 and are preliminary and conservative.

The catches of white marlin indicate that there are two high catch periods; from 1969 to 1976 and from 1987 to 1994. These catches, particularly the high catches taken in the period since 1987, mostly come from the south Atlantic where Taiwanese conventional longline vessels operated to target albacore. The increase in catch levels from 350 MT in 1977 to about the 800 MT level in 1986 may also relate to the albacore targeted by Taiwanese longline fleets. A similar situation occurs for blue marlin and sailfish.

3.2 Task II data

The results of Task II data were based on logbooks. The Task II database is the main source used to standardize CPUE and is compiled in monthly aggregated 5x5 degree squares.

Captains are asked to measure the first 30 fish from each single set. As billfishes were not targeted by the Taiwanese longline fleets, there were no size measurements of billfishes in the logbooks. Therefore, raising total catch in number to total catch in weight is difficult. However, captains' on-board estimates of round weight can be used to compare the accuracy of estimates of landings and logbooks. In this situation, we found some mean weights in some years were too small to apply for raising purposes. Consequently, a substitution of mean weight to estimate nominal CPUE and adjusted CPUE is used, e.g., Table 2.

The catch trends by species in the total Atlantic Ocean and with breakdown into suitable areas are shown in Figures 2 - 4 for white marlin, blue marlin and sailfish, respectively.

3.3 Abundance indices

Nominal and adjusted CPUE in the total Atlantic, and with breakdown into suitable areas, are given in Tables 1-6 for white marlin, blue marlin, and sailfish for 1967 to 1994. The standardized CPUE with 95% confidence interval for 1968-1994 are given for white marlin in Figures 5-7 and blue marlin in Figures 8-10.

Adjusted CPUE was standardized by GLM method with year, quarter, and area factors, and year*quarter and quarter*area interactions, as used by the ICCAT species working groups in assessments.

The significance tests of standardized CPUE for 1968-1994 are given in Tables 8 and 9 for white marlin and blue marlin, respectively. The test of year*quarter interaction for white marlin in the north Atlantic showed no significance. All effects and interactions were included in estimating yearly standardized CPUE. The adjusted CPUE explained 37% and 48% of abundance indices for white marlin and blue marlin respectively for the total Atlantic.

The adjusted CPUE trend of white marlin for the Taiwanese longline fishery shows great fluctuations 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 1970's through 1980's, and then increased through 1994 for the total Atlantic series (Figure 8). The north and south series (Figures 9 and 10) were similar to the total Atlantic results.

4. DISCUSSION

All species of billfishes are caught incidently by the Taiwanese distant-water tuna longline fishery in the Atlantic Ocean. However, targeting is suspected for Taiwanese longline fleets operating joint ventures in the waters off Brazil during the period from 1990 to 1992. Gillnet, longline, and harpoon are the major gears used in targeting billfishes in the coastal and offshore waters off Taiwan.

There is a difference in billfish catch composition among oceans. In the Atlantic, the majority of billfish catches are white marlin and blue marlin, with some sailfish. A very minor catch reported in the logbooks might come from the waters between the Indian Ocean and south Atlantic. As there are no separate categories in the logbooks of Taiwanese longline fishery for *Istiophorus platypterus* and *I. albicans*, Taiwanese fishermen always fill in the catches of these species together. This results in confusion between the species and makes it difficult to separate the catch accurately. Also, the market price of these two species is similar in Taiwan. The species classification and separation of statistics becomes much more difficult. Hence, these species are still combined when compiling the "other billfishes" group.

To update the Task I data, the greater value between those in the Fisheries Yearbooks, Taiwan Area and in logbooks was adopted as Task I data. This occurred mostly for the data before 1980 because the logbooks were not available. Both of those estimates seemed to be conservative because neither represents 100% recovery from raw data sources. However, Task I estimated from logbooks seemed to be much more reasonable from 1981 onwards due to the availability of logbooks.

The 1967 Task II data were not included in standardizing CPUE series because the coverage of 5x5 square blocks in Task II was very low and covered only the last half of the year (from July to December). Therefore, the adjusted CPUE in 1967 may not represent the abundance index appropriately. Thus, only the series from 1968 to 1994 was used for standardization purposes. Furthermore, the 1995 index was not available. However, the standardized 1994 index may be taken for the 1995 index if necessary because the fishing pattern of the Taiwanese longline fishery in the Atlantic was similar in 1995 to that of 1994.

There were up to 20 or more Taiwanese conventional longline fleets operating in the southeastern and northeastern waters off Brazil, especially in the southeastern waters during the period 1990 to 1992. These fleets operated in joint ventures with Brazil, and mainly targeted albacore. Whether or not either swordfish or billfishes were targeted, 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 aforementioned period (Tables 1-3, and Figures 2,4 and 6), and this is also reflected in the Brazil-Taiwan statistics. There may be a double-counting problem between the two nations, but taking the estimates of Task I in Tables 1-3 may be the best choice for the present until the problem can be resolved.

As already mentioned in this document, white marlin, blue marlin, and sailfish are by-catch species for the Taiwanese longline fishery in the Atlantic Ocean, and the slight increase in catches may relate either to the albacore catch in the south or to the suspected double-counting with the Brazilian joint venture. The problem should be resolved in the near future.

5. LITERATURE CITED

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Table 1. The catches, fishing effort, nominal catch per unit effort (CPUE) and adjusted catch per unit effort of white marlin by Taiwanese longline fishery in the whole Atlantic from 1967 to 1994. The CPUE wasadjusted by GLM with year, quarter, area factors and year*quarter and quarter*area interactions as described in the text. '*' denotes a suspected figure.

Year	Fishing effort (1000hooks)	Catch (mt)	Mean Weight (kg)	Nomial CPUE (no./1000 hooks)	Adjusted CPUE (no./1000 hooks)	Adjusted CPUE (kg/1000 hooks)
1967	3678	181	30.64	0.0710		
1968	56606	385	16.99	0.3142	0.0424	0.7204
1969	72562	583	25.20	0.3188	0.0500	1.2600.
1970	70723	612	24.21	0.3020	0.0400	0.9684
1971	102994	438	21.36	0.1754	0.0505	1.0787
1972	98397	713	23.10	0.1117	0.0382	0.8824
1973	108549	599	22.80	0.2418	0.0432	0.9850
1974	98669	537	21.15	0.2572	0.0541	1.1442
1975	90820	507	20.46	0.2728	0.0410	0.8389
1976	110031	519	18.97	0.0713	0.0189	0.3585
1977	142341	163	24.77	0.0221	0.0125	0.3096
1978	116006	277	25.73	0.0414	0.0199	0.5120
1979	84044	217	20.17	0.0494	0.0164	0.3308
1980	87092	250	19.62	0.0996	0.0303	0.5945
1981	104863	310	22.52	0.1224	0.0333	0.7499
1982	134997	361	22.89	0.0652	0.0239	0.5471
1983	96825	290	21.68	0.0657	0.0271	0.5875
1984	99032	220	18.93	0.0636	0.0205	0.3881
1985	172034	300	22.70	0.0598	0.0231	0.5244
1986	256645	515	20.24	0.0992	0.0302	0.6112
1987	220672	766	24.05	0.1443	0.0398	0.9572
1988	155941	565	18.75	0.1758	0.0411	0.7706
1989	144898	983	19.52	0.3474	0.0302	0.5895
1990	199600	895	20.40	0.0950	0.0149	0.3040
1991	165268	803	18.06	0.1915	0.0200	0.3612
1992	185315	598	17.52	0.1292	0.0142	0.2488
1993	258161	616	22.58	0.1055	0.0351	0.7926
1994	46173*	852	24.03	0.0597	0.0259	0.6224

Table 2. The catches, fishing effort, nominal catch per unit effort (CPUE) and adjusted catch per unit effort of blue marlin by Taiwanese longline fishery in the whole Atlantic from 1967 to 1994. The CPUE was adjusted by GLM with year, quarter, area factors and time-area interactions 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)	Adjusted CPUE (kg/1000 hooks)
1967	3678	291	70.98	0.2477		
1968	56606	803	76.39	0.1859	0.1166	3.4288
1969	72562	1364	76.23	0.1861	0.1036	3.0401
1970	70723	929	85.11	0.1338	0.0637	2.0870
1971	102994	935	71.49	0.1271	0.0539	1.4833
1972	98397	928	88.73	0.0540	0.0332	1.1340
1973	108549	692	68.96	0.0604	0.0359	0.9530
1974	98669	552	59.07	0.0584	0.0314	0.7140
1975	90820	527	62.98	0.0291	0.0211	0.5116
1976	110031	409	16.79**	0.0481	0.0432	1.0473**
1977	142341	171	83.41	0.0138	0.0812	0.5844
1978	116006	258	85.42	0.0082	0.0201	0.6609
1979	84044	190	63.50	0.0146	0.0159	0.3887
1980	87092	289	47.65	0.0381	0.0278	0.5099
1981	104863	202	67.11	0.0253	0.0244	0.6303
1982	134997	250	58.81	0.0189	0.0255	0.5773
1983	96825	172	59.14	0.0156	0.0198	0.4508
1984	99032	172	55.32	0.0227	0.0193	0.4110
1985	172034	313	59.56	0.0177	0.0194	0.4448
1986	256645	215	53.43	0.0157	0.0186	0.3826
1987	220672	317	66.74	0.0215	0.0206	0.5292
1988	155941	292	57.25	0.0250	0.0246	0.5421
1989	144898	473	53.03	0.0451	0.0264	0.5389
1990	199600	1704	62.73	0.0510	0.0278	0.6713
1991	165268	1672	55.27	0.0620	0.0344	0.7319
1992	185315	824	69.14	0.0353	0.0371	0.9874
1993	258161	685	53.37	0.0498	0.0349	0.7170
1994	46173*	444	71.19	0.0394	0.0299	0.8194

Table 3. The catches, fishing effort, nominal catch per unit effort (CPUE) and adjusted catch per unit effort of sailfish by Taiwanese longline fishery in the whole Atlantic from 1967 to 1994. The CPUE was adjusted by GLM with year, quarter, area factors and year*quarter and quarter*area interactions as described in the text. "*" denotes a suspected figure.

Year	Fishing effort (1000hooks)	Catch (mt)	Mean Weight (kg)	Nomial CPUE (no./1000 hooks)	Adjusted CPUE (no./1000 hooks)	Adjusted CPUE (kg/1000 hooks)
1967	3678	177	15.37	0.0655	0.0818	1.2573
1968	56606	632	15.17	0.7362	0.6340	9.6178
1969	72562	674	21.84	0.4255	0.3280	7.1635
1970	70723	577	21.85	0.3731	0.3544	7.7436
1971	102994	872	15.69	0.5399	0.5870	9.2100
1972	98397	802	14.46	0.4619	0.3710	5.3647
1973	108549	598	17.12	0.1742	0.1763	3.0183
1974	98669	270	15.89	0.1721	0.1776	2.8221
1975	90820	148	17.01	0.0961	0.0964	1.6398
1976	110031	394	18.94	0.1891	0.2530	4.7918
1977	142341	64	20.26	0.0162	0.0153	0.3100
1978	116006	64	20.06	0.0274	0.0363	0.7282
1979	84044	37	23.56	0.0083	0.0278	0.6550
1980	87092	41	14.35	0.0325	0.0627	0.8997
1981	104863	93	14.77	0.0605	0.1362	2.0117
1982	134997	28	15.37	0.0136	0.0287	0.4411
1983	96825	51	18.73	0.0284	0.0469	0.8784
1984	99032	53	23.95	0.0223	0.0327	0.7832
1985	172034	41	24.79	0.0096	0.0122	0.3024
1986	256645	65	15.23	0.0165	0.0264	0.4021
1987	220672	31	13.14	0.0107	0.0183	0.2405
1988	155941	300	15.90	0.1151	0.0976	1.5518
1989	144898	178	17.22	0.0713	0.0613	1.0556
1990	199600	96	20.43	0.0185	0.0276	0.5639
1991	165268	73	17.51	0.0162	0.0179	0.3134
1992	185315	33	15.76	0.0049	0.0049	0.0772
1993	258161	643	24.73	0.1007	0.1175	2.9058
1994	46173*	195	18.70	0.0468	0.0627	1.1725

Table 4. The catches (mt), fishing effort (1000 hooks), nominal catch per unit effort (CPUE) and adjusted catch per unit effort of white 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 year*quarter and quarter*area interactions 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	0.0054	0.0707
1969	135	448	19792	52770	0.3231	0.3172	0.0135	0.0499
1970	104	508	28343	42380	0.1278	0.4184	0.0082	0.0466
1971	178	260	31562	71432	0.2633	0.1365	0.0225	0.0433
1972	244	469	20363	78034	0.2172	0.0841	0.0201	0.0306
1973	135	464	36491	72058	0.1854	0.2704	0.0188	0.0371
1974	252	285	33913	64756	0.3704	0.1978	0.0488	0.0322
1975	125	382	29894	60926	0.2207	0.2984	0.0195	0.0319
1976	142	377	25729	84302	0.0430	0.0799	0.0046	0.0181
1977	44	119	35488	106852	0.0130	0.0251	0.0027	0.0120
1978	79	198	18409	97597	0.0368	0.0423	0.0063	0.0168
1979	62	155	17737	66307	0.0660	0.0449	0.0027	0.0180
1980	105	145	19185	67907	0.2180	0.0661	0.0283	0.0195
1981	174	136	25276	79587	0.2896	0.0693	0.0339	0.0213
1982	134	227	39385	95612	0.1172	0.0438	0.0153	0.0179
1983	203	87	52030	44795	0.0880	0.0398	0.0206	0.0173
1984	96	124	65236	33796	0.0430	0.1033	0.0080	0.0228
1985	128	172	75683	96351	0.0689	0.0527	0.0108	0.0207
1986	319	196	120109	136536	0.1396	0.0637	0.0181	0.0208
1987	153	613	47611	173061	0.1537	0.1417	0.0232	0.0316
1988	0	565	10433	145507	0.0000	0.1884	0.0015	0.0530
1989	4	979	7029	137869	0.0046	0.3648	0.0022	0.0306
1990	85	810	29144	170456	0.0212	0.1076	0.0027	0.0147
1991	13	790	31773	133495	0.0059	0.2357	0.0000	0.0285
1992	92	506	29726	155589	0.0262	0.1489	0.0049	0.0130
1993	123	493	56280	201881	0.1970	0.0800	0.0320	0.0230
1994	172	680	8114	38059	0.0490	0.0620	0.0062	0.0259

Table 5. The catches (mt), fishing effort (1000 hooks), nominal catch per unit effort (CPUE) and adjusted catch per unit effort 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 year*quarter and quarter*area interactions 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	131	160	1771	1907	0.4872	0.0252		
1968	374	429	16997	39610	0.3202	0.1283	0.1517	0.0929
1969	348	1016	19792	52770	0.1856	0.1862	0.1279	0.0944
1970	369	560	28343	42380	0.1142	0.1469	0.0649	0.0575
1971	193	742	31562	71432	0.1053	0.1368	0.0416	0.0643
1972	300	628	20363	78034	0.0609	0.0522	0.0395	0.0305
1973	155	537	36491	72058	0.0513	0.0651	0.0409	0.0341
1974	183	369	33913	64756	0.0800	0.0471	0.0411	0.0261
1975	105	422	29894	60926	0.0369	0.0253	0.0217	0.0213
1976	169	240	25729	84302	0.0566	0.0455	0.0553	0.0400
1977	64	107	35488	106852	0.0239	0.0105	0.0224	0.0160
1978	81	177	18409	97597	0.0073	0.0083	0.0187	0.0192
1979	51	139	17737	66307	0.0162	0.0142	0.0086	0.0194
1980	160	129	19185	67907	0.1160	0.0161	0.0401	0.0235
1981	98	104	25276	79587	0.0430	0.0196	0.0323	0.0213
1982	100	150	39385	95612	0.0338	0.0128	0.0311	0.0227
1983	125	47	52030	44795	0.0190	0.0095	0.0252	0.0172
1984	102	70	65236	33796	0.0226	0.0228	0.0200	0.0211
1985	148	165	75683	96351	0.0220	0.0143	0.0202	0.0199
1986	117	98	120109	136536	0.0202	0.0118	0.0211	0.0174
1987	52	265	47611	173061	0.0204	0.0218	0.0157	0.0216
1988	26	266	10433	145507	0.0281	0.0248	0.0284	0.0237
1989	11	462	7029	137869	0.0048	0.0471	0.0081	0.0272
1990	937	767	29144	170456	0.1429	0.0351	0.0725	0.0188
1991	716	956	31773	133495	0.0882	0.0558	0.0568	0.0296
1992	336	488	29726	155589	0.0428	0.0338	0.0512	0.0335
1993	281	404	56280	201881	0.1528	0.0211	0.0719	0.0249
1994	182	262	8114	38059	0.0677	0.0334	0.0456	0.0284

Table 6. The catches (mt), fishing effort (1000 hooks), nominal catch per unit effort (CPUE) and adjusted catch per unit effort of sailfish by Taiwanese longline fishery in the east and west Atlantic from 1967 to 1994. The CPUE (no./1000 hooks) was adjusted by GLM with year, quarter, area factors and year*quarter and quarter*area interactions as described in the text.

Year	Catch (west)	Catch (east)	Effort (west)	Effort (east)	Nominal CPUE (west)	Nominal CPUE (east)	Adjusted CPUE (west)	Adjusted CPUE (east)
1967	106	71	1771	1907	0.0869	0.0456	0.0690	0.0946
1968	75	557	12159	44447	0.5090	0.7984	0.9718	0.2963
1969	251	423	19363	53199	0.5837	0.3680	0.6390	0.0171
1970	281	296	26561	44162	0.3949	0.3600	0.5220	0.1869
1971	346	526	32395	70599	0.6592	0.4852	0.7283	0.4558
1972	17	785	32983	65414	0.1629	0.6127	0.6572	0.0849
1973	107	491	48144	60406	0.2066	0.1483	0.3265	0.0261
1974	171	99	57077	41592	0.2021	0.1308	0.2798	0.0755
1975	123	25	40373	50448	0.1829	0.0266	0.1879	0.0050
1976	177	217	52334	57697	0.2020	0.1774	0.3216	0.1845
1977	5	59	66870	75471	0.0306	0.0033	0.0306	0.0000
1978	57	7	50494	65512	0.0558	0.0054	0.0676	0.0050
1979	18	19	45313	38731	0.0137	0.0019	0.0555	0.0000
1980	36	5	46971	40120	0.0571	0.0036	0.0406	0.0849
1981	81	12	54268	50595	0.1027	0.0153	0.0502	0.2221
1982	22	6	63780	71216	0.0251	0.0032	0.0291	0.0283
1983	31	20	53841	42983	0.0332	0.0224	0.0599	0.0339
1984	45	8	62616	36416	0.0302	0.0086	0.0505	0.0149
1985	39	9	88536	83498	0.0158	0.0030	0.0244	0.0000
1986	64	1	143500	113145	0.0293	0.0003	0.0357	0.0171
1987	31	0	118794	101877	0.0199	0.0001	0.0196	0.0169
1988	300	0	83319	72622	0.2155	0.0001	0.1928	0.0025
1989	171	7	104952	39947	0.0966	0.0050	0.1226	0.0000
1990	83	13	136588	63012	0.0254	0.0035	0.0364	0.0169
1991	73	0	101157	64111	0.0258	0.0011	0.0358	0.0000
1992	33	0	137733	47582	0.0033	0.0094	0.0100	0.0000
1993	223	420	126851	131310	0.0650	0.1352	0.2156	0.0194
1994	95	100	191943	26979	0.0859	0.0190	0.0993	0.0261

Table 7. Annual landings (mt) of billfishes, by spceis, by Taiwan, from 1962-1966. (after Huang 1974).

Year	Total	Swordfish	White marlin	Blue marlin	Black marlin	Saifish
1962	9027	774	761	1193	2567	3732
1963	10915	723	1188	1379	2656	4969
1964	9167	584	1000	1808	2563	3212
1965	8667	540	1001	2127	2323	2676
1966	10404	885	1191	2031	3163	3134
1995	2988	1872	490	500	66	60

Table 8. The ANOVA test of the GLM procedure for effect factors to adjusted white marlin in the Atlantic.

(1) Total Atlantic

Sources	DF	Sum of Square	Mean Square	F value	Pr >F
Model	159	13242.4450	83.2858	38.20	0.0001
Year	26	761.7201	29.2969	13.44	0.0001
Quarter	3	32.7649	10.9216	5.01	0.0018
Area	13	2125.0182	163.4629	74.98	0.0001
Year-Quarter	78	587.9680	7.5380	3.46	0.0001
Quater-area	39	2095.6417	53.7344	24.65	0.0001
Error	10214	22268.0858	2.1802		
Corrected total	10373	35510.5308			

R^2	C.V. (%)	Root MSE
0.3729	-43.469	1.4765

(2) North Atlantic

Sources	DF	Sum of Square	Mean Square	F value	Pr >F
Model	49	7929.6876	161.8304	25.45	0.0001
Year	26	1981.6282	76.2165	11.99	0.0001
Quarter	3	634.1341	211.3780	33.25	0.0001
Area	5	1458.9467	291.7893	45.89	0.0001
Quater-area	15	823.5636	54.9042	8.645	0.0001
Error	3441	21878.2180	6.3581		
Corrected total	3490	29807.9056			

R^2	C.V. (%)	Root MSE
0.2660	-54.462	2.5215

(3) South Atlantic

Sources	DF	Sum of Square	Mean Square	F value	Pr >F
Model	135	10109.2467	74.8833	40.46	0.0001
Year	26	537.2821	20.6647	11.16	0.0001
Quarter	3	339.0480	113.0160	61.06	0.0001
Area	7	1326.6142	189.5163	102.39	0.0001
Year-Quarter	78	507.7921	6.5102	3.52	0.0001
Quater-area	21	439.4812	20.9277	11.31	0.0001
Error	6677	12358.5817	1.8509		
Corrected total	6812	22467.8284			

R^2	C.V. (%)	Root MSE
0.4499	-39.1607	1.3605

Table 9. The ANOVA test of the GLM procedure for effect factors to adjusted blue marlin in the Atlantic.

(1) Total Atlantic

Sources	DF	Sum of Square	Mean Square	F value	Pr >F
Model	159	11864.9217	74.6221	59.27	0.0001
Year	26	1342.8760	51.6491	41.02	0.0001
Quarter	3	113.7495	37.9165	30.11	0.0001
Area	13	3127.7747	240.5981	191.09	0.0001
Year-Quarter	78	511.3923	6.5563	5.21	0.0001
Quater-area	39	1053.4155	27.0107	21.45	0.0001
Error	10214	12860.4788	1.2591		
Corrected total	10373	24725.4006			

R^2	C.V. (%)	Root MSE
0.4799	-31.3800	1.1221

(2) North Atlantic

Sources	DF	Sum of Square	Mean Square	F value	Pr >F
Model	127	4362.8538	34.3532	21.95	0.0001
Year	26	639.3456	24.5902	15.71	0.0001
Quarter	3	89.2216	29.7405	19.00	0.0001
Area	5	784.9710	156.9942	100.32	0.0001
Year-Quarter	78	367.4702	4.7112	3.01	0.0001
Quater-area	15	330.4191	22.0279	14.08	0.0001
Error	3433	5372.2497	1.5649		
Corrected total	3560	9735.1035			

R^2	C.V. (%)	Root MSE
0.4482	-37.6292	1.2510

(3) South Atlantic

Sources	DF	Sum of Square	Mean Square	F value	Pr >F
Model	135	7702.5535	57.0560	54.85	0.0001
Year	26	781.0808	30.0416	28.88	0.0001
Quarter	3	147.0032	49.0011	47.11	0.0001
Area	7	1877.8658	268.2665	257.91	0.0001
Year-Quarter	78	521.5733	6.6868	6.43	0.0001
Quater-area	21	273.0518	13.0025	12.50	0.0001
Error	6677	6944.9981	1.0401		
Corrected total	6812	14647.5516			

R^2	C.V. (%)	Root MSE
0.5259	-27.5102	1.0199

Table 10. The ANOVA test of the GLM procedure for effect factors to adjusted sailfish in the Atlantic.

Sources	DF	Sum of Square	Mean Square	F value	Pr >F
Model	61	10.6959	0.1753	6.40	0.0001
Year	27	6.2759	0.2324	8.48	0.0001
Quarter	3	0.1889	0.0630	2030	0.0797
Area	1	1.1196	1.1196	40.85	0.0001
Year-Area	27	2.2502	0.0833	3.04	0.0001
Quater-area	3	0.8613	0.2871	10.48	0.0001
Error	161	4.3850	0.0274		
Corrected total	222	15.0809			

R^2	C.V. (%)	Root MSE	CPUE mean
0.7092	119.1074	0.1656	0.1390

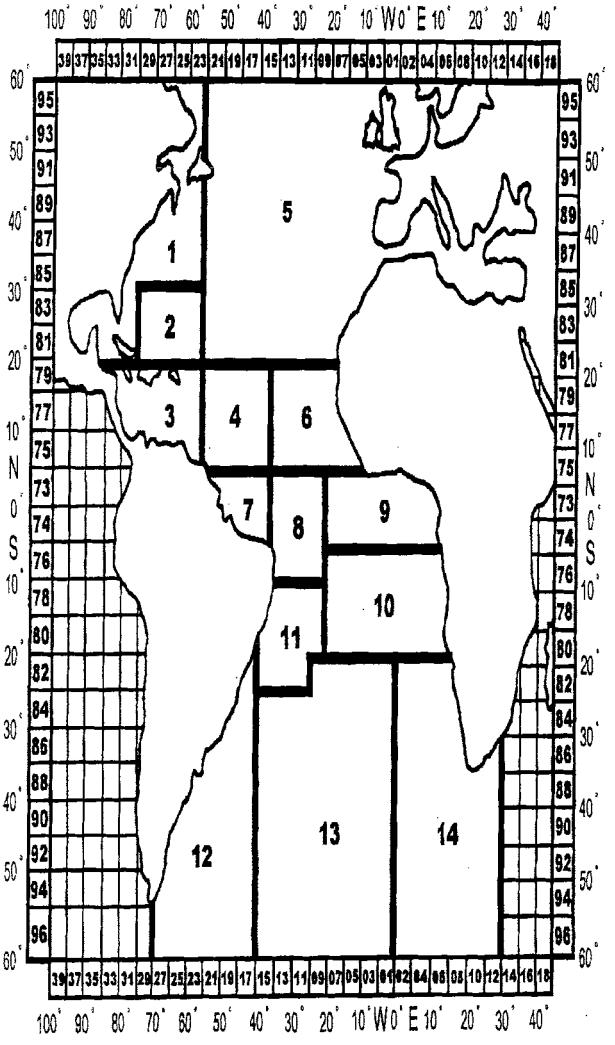

Fig. 1. Sub-areas used in the standardization of catch per unit effort for white marlin and blue marlin from 1986 to 1994.

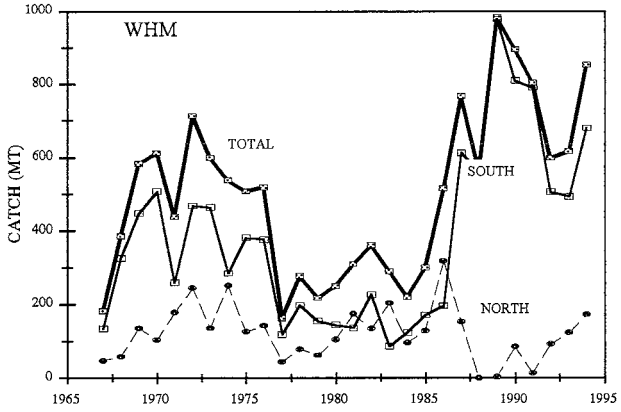

Fig. 2. Annual catches of white marlin by Taiwanese longline fleets in the Atlantic. Catches are separated into assumed north and south Atlantic stocks at 5° N.

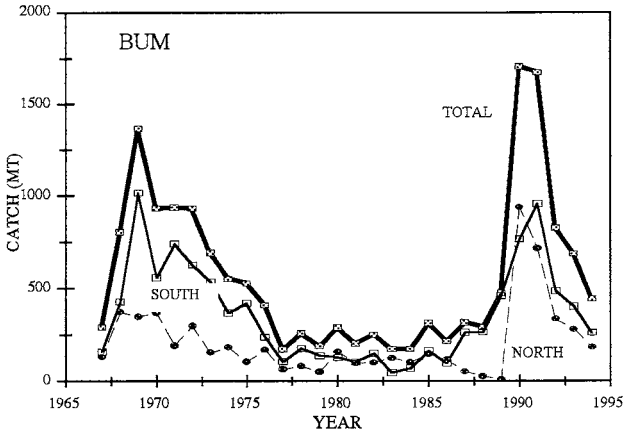

Fig. 3. Annual catches of blue marlin by Taiwanese longline fleets in the Atlantic. Catches are separated into assumed north and south Atlantic stocks at 5° N

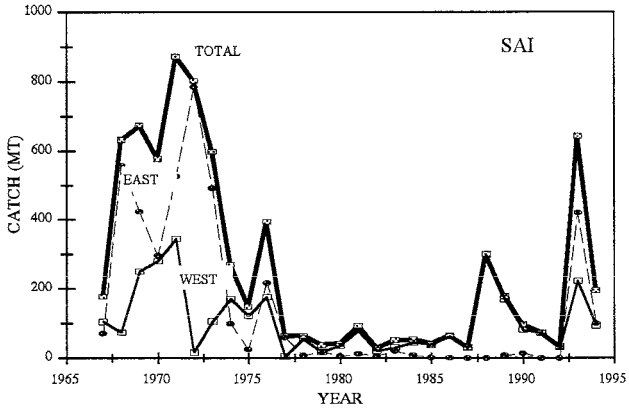

Fig. 4. Annual catches of sailfish by Taiwanese longline fleets in the Atlantic. Catches are separated into east and west Atlantic stocks at 30° W.

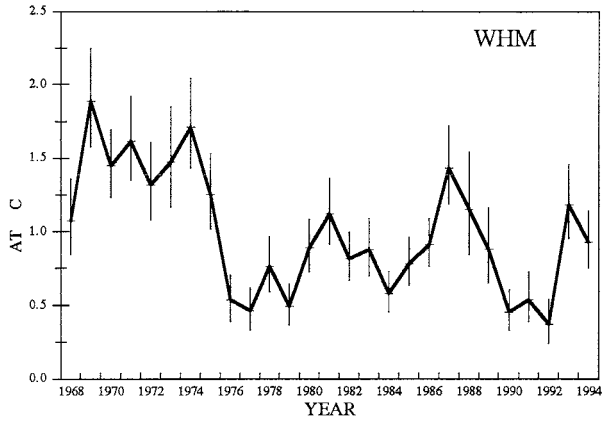

Fig. 5. Trends of adjusted catch per unit effort for Taiwanese longline fishery used as abundance index of white marlin in the total Atlantic from 1968 to 1994. The adjusted catch per unit effort with 95% confidence interval was standardized by GLM method with year, quarter, and area effects and year-quarter and quarter-area two-way interactions.

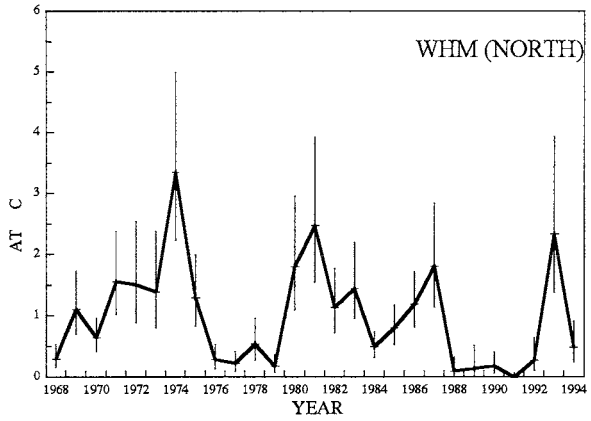

Fig. 6. Trends of adjusted catch per unit effort for the Taiwanese longline fishery used as abundance index of white marlin in the north Atlantic from 1968 to 1994. The adjusted catch per unit effort with 95% confidence interval was standardized by GLM method with year, quarter, and area effects and year-quarter and quarter-area two-way interactions.

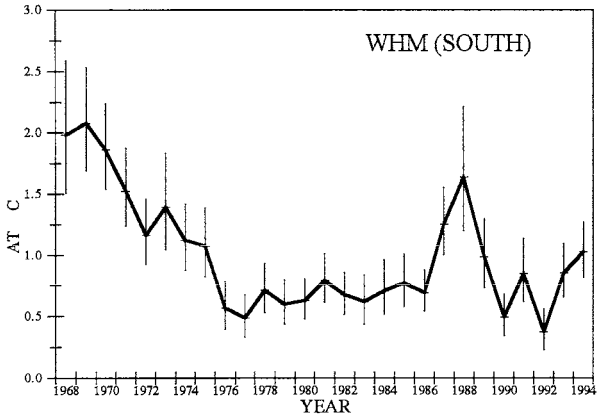

Fig. 7. Trends of adjusted catch per unit effort for the Taiwanese longline fishery used as abundance index of white marlin in the south Atlantic from 1968 to 1994. The adjusted catch per unit effort with 95% confidence interval was standardized by GLM method with year, quarter, and area effects and year-quarter and quarter-area two-way interactions.

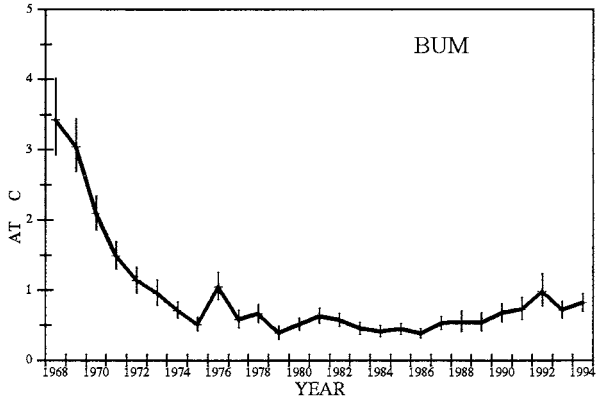

Fig.8. Trends of adjusted catch per unit effort for Taiwanese longline fishery used as abundance index of blue marlin in the total Atlantic from 1968 to 1994. The adjusted catch per unit effort with 95% confidence interval was standardized by GLM method with year, quarter, and area effects and year-quarter and quarter-area two-way interactions.

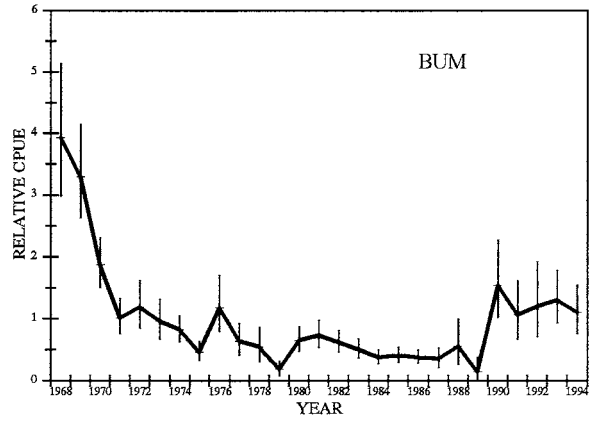

Fig.9. Trends of adjusted catch per unit effort for Taiwanese longline fishery used as abundance index of blue marlin in the north Atlantic from 1968 to 1994. The adjusted catch per unit effort with 95% confidence interval was standardized by GLM method with year, quarter, and area effects and year-quarter and quarter-area two-way interactions.

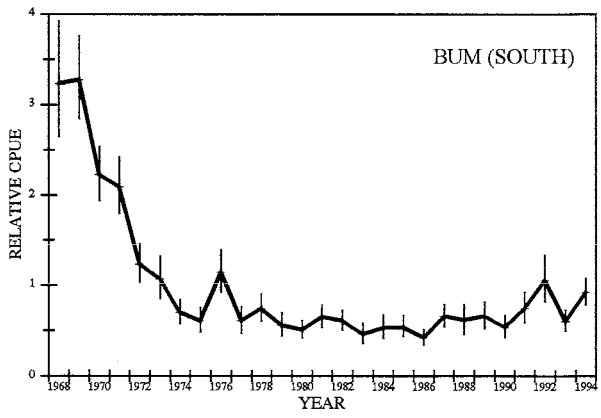

Fig.10. Trends of adjusted catch per unit effort for Taiwanese longline fishery used as abundance index of blue marlin in the south Atlantic from 1968 to 1994. The adjusted catch per unit effort with 95% confidence interval was standardized by GLM method with year, quarter, and area effects and year-quarter and quarter-area two-way interactions.