PRELIMINARY ESTIMATES OF BLUE AND MAKO SHARKS BYCATCH AND CPUE OF TAIWANESE LONGLINE FISHERY IN THE ATLANTIC OCEAN

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SUMMARY

This report was based on observers' records of Taiwanese tuna longline fishing fleets operating in the Atlantic Ocean from 2002-2006. According to shark bycatch rate, five areas namely, A (5ºN-15ºS), B (15ºS-50ºS, west to 20ºW), C (15ºS-50ºS, 20ºW-20ºE), D (5ºN-20ºN) and E (north of 20ºN), were categorized. The shark catch data reported by observers were used to adjust the historical shark catch in Task I and to estimate blue shark and mako shark catches of Taiwanese longline fishery in the Atlantic Ocean. The shark bycatch in tropical area (areas A and D), is higher than that in temperate area (areas B, C, and E). The blue shark, and mako shark are the dominant species of shark bycatch in all areas. Shark bycatch in weight ranged from 1601 tons (1984) to 12872 tons (1996) in South Atlantic Ocean, and ranged from 196 tons (1989) to 3066 tons (1994) in North Atlantic Ocean. Blue shark bycatch in weight peaked in 1996 of 11628 tons in South Atlantic Ocean and 1994 of 2684 tons in North Atlantic Ocean. The results in this study are preliminary and further investigation is needed.

Introduction

Taiwanese longline fishery has operated in the Atlantic Ocean since the late 1960's. However, the by-catch of Taiwanese tuna longline fleets has never been reported until 1981 because of its low economic value compared with tunas and species-specific data were not available until 2003 because shark catch was recorded as "sharks" before then. The category "sharks" on the logbook has been further separated into four sub-categories namely the blue shark, *Prionace glauca*, mako shark, *Isurus* spp., silky shark, *Carcharihnus falciformis*, and others since 2003. As Taiwanese longline fishery has widely covered the Atlantic Ocean especially the South Atlantic, our fishery statistics must be one of the most valuable information, which describes population status of pelagic sharks. The observer program for far sea fishery is necessary to obtain detailed data for more comprehensive stock assessment and management studies. To fulfill the obligations of a far sea fishing nation, the pilot observer program was initiated by the scientist in 1999 and launched by Taiwanese Fisheries Agency in 2001. Since FAO and international environmental groups paid much attention to the conservation of elasmobranchs in recent years, it is useful to examine recent trend of sharks by logbook of tuna fisheries. However, standardization on Taiwanese catch rate on sharks is not straightforward because the data have confounded with many factors, such as under-reporting and target-shifting effects. Joung et al. (2004) and Liu et al. (2005) have estimated shark bycatch and CPUE of blue shark for Taiwanese longline fishery in the South Atlantic Ocean. However, their estimates were based on a limited observer's records from 1999 to 2002. The number of observers in Taiwanese longline fishing fleets increased in recent years and the coverage rate reached to 100% of bigeye tuna fishing fleets in 2006. The increasing observations enable us to get a better estimation of shark bycatch. Thus, the objective of this study is to update the historical catch data of sharks in Task I and to estimate the catches of blue and mako sharks based on observers' records.

Materials and Methods

The logbook data of Taiwanese longline fishery from 1981 to 2006 provided by the Overseas

Fisheries Development Council of the Republic of China was used in this study. These logbook data contain basic information on fishing time, area, number of hooks and catches of 14 species including major tunas, billfishes and sharks. Species-specific catch data including tunas, billfishes, and sharks from observers' records in 2002-2006 were used to estimate the catch ratio of sharks to tunas and the proportion of blue and mako shark in shark catch of Taiwanese longline fishery in the Atlantic Ocean. A total of 20021 thousand hooks reported by 68 observers on 107 trips were observed.

The Atlantic Ocean was stratified as 5 areas namely A (5ºN-15ºS), B (15ºS-50ºS, west to 20ºW), C (15ºS-50ºS, 20ºW-20ºE), D (5ºN-20ºN) and E (north of 20ºN) based on the distribution of shark bycatch rate recorded by observers during the period of 2002-2006 (Fig. 1). Because areas A and D are the tropical waters, the bigeye tuna (BYT) and yellow fin tuna (YFT) are the major target species and swordfish (SWO) is the major bycatch species. The averaged proportion of shark catch (both in number) to the total catch of BYT, YFT, and SWO reported by observers from 2002 to 2006 was used to adjust the historical shark catch data on set basis for 1981-2006. For each set, the shark catch was not adjusted if no bigeye tuna was recorded. In areas B, C and E, the ratio between sharks and albacore (ALB) was used to adjust historical shark catch data on set basis. For each set, the shark catch was not adjusted if no albacore was recorded. As the weight records were incomplete and might be biased, the catch in weight of blue, mako, and other sharks were estimated using the multiplication of mean weight of each species category and its corresponding catch in number. Total shark catch in weight was the sum of above three species categories. The mean weights of blue and mako sharks used in this study was 41.1 kg, and 63.0 kg, respectively (Huang, 2006; Chang, 2006). For other sharks, the mean weight was assumed to be 30 kg. Annual Task I shark catch data were obtained by using the adjusted shark catch in weight reported in logbook divided by coverage rate.

The GLM including main effects of year (Y), quarter (Q), area (A) and interactions under the assumption of lognormal error structure was used for standardization of nominal CPUE:

$$\ln(CPUE_{ijk} + const) = \mu + Y_i + Q_j + A_k + (interactions) + \varepsilon_{ijk} \quad (1981\text{-}1994)$$

where CPUE is nominal cpue (catch in number per 1000 hooks, in year i, quarter j, area k), const is 0.05, μ is overall men, Y_i is effect of year i, Q_j is effect of quarter j, A_k is effect of area k, interactions are any combination of two way interaction, and ε_{ijk} is the error term.

The gear configuration (regular vs deep longline) is defined by number of hooks per basket (NHB): regular longline if NHB $\leqq$11 and deep longline if NHB $\geqq$12. However, NHB information was available since 1995 and this effect was added in the GLM model as:

$$\ln(CPUE_{ijk} + const) = \mu + Y_i + Q_j + A_k + G_l + (interactions) + \varepsilon_{ijkl} \quad (1995\text{-}2006)$$

where G_l is the gear configure effect.

Results and Discussion

According to the observers' records, the seasonal proportion of sharks to the total catch in number of BYT, YFT, and SWO in area A were 26.84%, 83.03%, 38.62% and 14.37%, respectively (Table 1). Blue shark occupied 97.17%, 91.09%, 86.74% and 88.50% of sharks catch in number, respectively (Table 2). And, mako sharks occupied 1.73%, 1.34%, 2.62% and 6.18% of sharks catch in number, respectively. In area B, the proportion of sharks to the total catch of ALB was 19.49% in number (Table 1). Blue shark and mako sharks occupied 92.55%

and 7.36% of sharks catch in number, respectively (Table 2). While in areas C, D, and E, sharks comprised 0.51%, 22.71%, and 4.83% of ALB or (BYT+YFT+SWO) catch (Table 1) and blue shark was the dominant species (Table 2).

Estimated shark bycatch in number ranged from 1984 of 38111 to 1996 of 309048 in South Atlantic Ocean (Table 3), and ranged from 1989 of 4801 to 1994 of 74544 in North Atlantic Ocean (Table 4). Similar trend was found for the blue shark in South and North Atlantic Ocean, its catch in number ranged from 34996 in 1984 to 282918 in 1996 and ranged from 4024 in 1989 to 65293 in 1994, respectively (Tables 3,4). Shark bycatch in weight ranged from 1601 tons (1984) to 12872 tons (1996) in South Atlantic Ocean (Table 5), and ranged from 196 tons (1989) to 3066 tons (1994)in North Atlantic Ocean (Table 6). Blue shark bycatch in weight peaked in 1996 of 11628 tons in South Atlantic Ocean (Table 5) and 1994 of 2684 tons in North Atlantic Ocean (Table 6). Nakano (2001) documented that the blue shark in the South Atlantic Ocean has an increasing trend in the period of 1993-2000. However, such trend can not be found from our estimation in this study.

In this study, seasonal variation of shark bycatch rate was found in area A. The highest shark bycatch rate was found in second quarter followed by third quarter in area A. This finding suggested that sharks especially the blue shark might have seasonal migration behavior. However, due to the constraint of sample size, seasonal information was not available in the other areas (B-E). Castro and Mejuto (1995) documented that female blue shark may have a west-east migration to give birth along the Atlantic equatorial line. Mature individuals migrate from the temperate waters to tropical waters for partuation and come back after this activity in the South Atlantic Ocean (Lessa et al. 2004). Whether the high catch rate of blue shark in second and third quarter was related to reproductive behavior needed more data to verify in the future.

Taiwanese longline fishery in the Atlantic Ocean mainly targeted on albacore in the 1970's and 1980's and shifted to bigeye tuna since 1990's. In this study, the catches of sharks and blue shark increased remarkably both in number and weight since 1990 which was corresponded to the time of target-shift of Taiwanese longline fishery. The major fishing ground of bigeye tuna was in tropical waters where higher shark bycatch occurred (areas A and D). Thus, it was suggested that the target-shifting might be a significant factor which affected the shark bycatch of Taiwanese tuna longline fishery.

Nominal CPUE of sharks in South Atlantic Ocean showed a few years of unusually high catch rates (1990, 1992 and 1996). This high variability was greatly reduced in the CPUE standardization. Standardized CPUE and relative CPUE series of all sharks combined caught by Taiwanese longline fishery showed a stable trend although slightly high values were found in 1995 and 1996. Similar trend was also found for blue shark (Figs. 2, 3). The nominal CPUE of sharks in North Atlantic Ocean also showed the high variability. More specifically, the time series from 2004 to 2006. Standardized CPUE and relative CPUE series of sharks and blue sharks peaked in 1990 and 1992. However, the stable trend was found for mako sharks (Figs. 4, 5).

The stable trend suggested that the blue shark stock in the South Atlantic Ocean seems at the level of optimum utilization. Nakano (2001) documented that the blue shark in the South Atlantic Ocean has an increasing trend in the period of 1993-2000. He standardized the blue shark CPUE based on three reporting levels and no significant difference was found among levels (Nakano 2001). The trends for the blue shark series obtained in this study are consistent with those of Japanese longline (2007 SCRS report). According to Nakano's (2001) report, although no comparison on standardized CPUE between different reporting levels was made in this study, we believe the results obtained in this study can represent the stock status of blue shark in the Atlantic Ocean.

The estimations of historical shark bycatch in this report were based on observers' records from 2002-2006. However, many factors may affect the standardization of CPUE trend. In addition to the temporal and spatial effects, environmental factors are important which may affect the representation of standardized CPUE of pelagic fish i.e., swordfish and blue shark in North Pacific (Bigelow et al. 1999), and bigeye tuna in Indian Ocean (Okamoto et al. 2001). In this report, environmental effects were not included in the model for standardization. Although the gear configuration (deep vs regular longline) has been taken into account in our analysis for the data since 1995, it will be preferable to develop a model incorporated with environmental effects in the future. Consequently, the results in this report are preliminary and further investigation is needed.

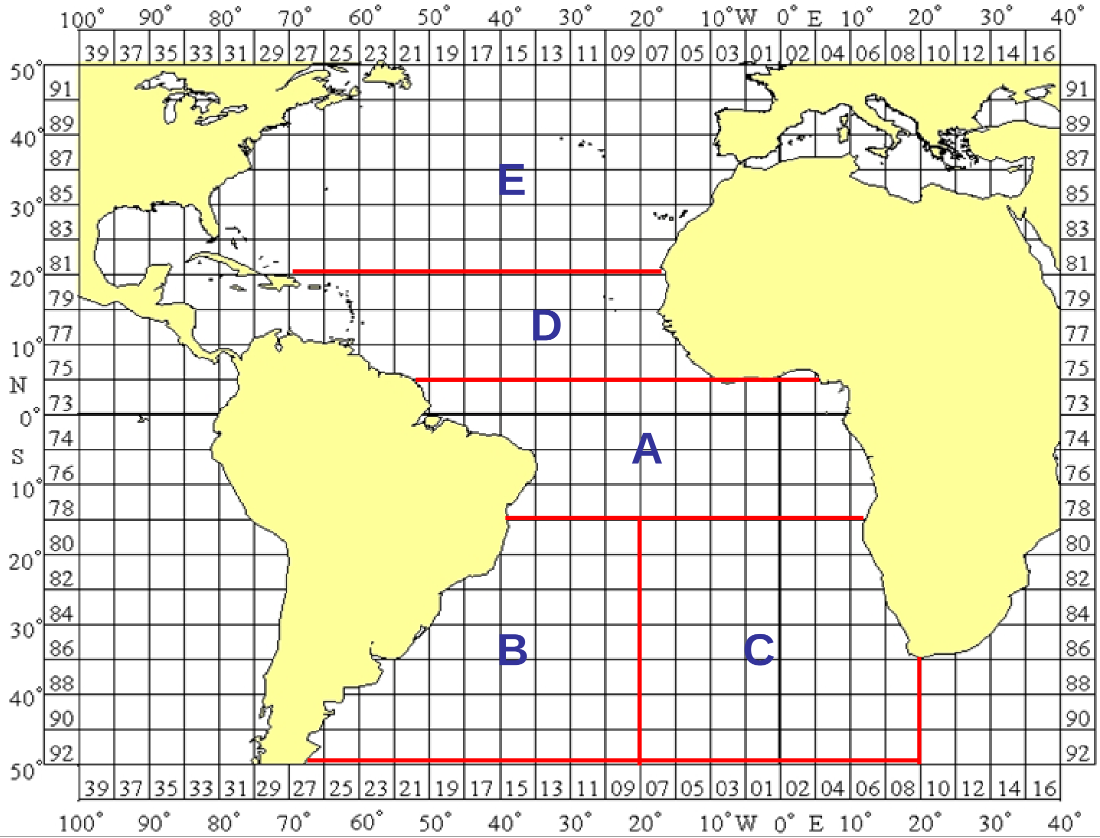

Figure 1. Area stratification used for the estimate of shark bycatch of Taiwanese longline fishery in Atlantic Ocean.

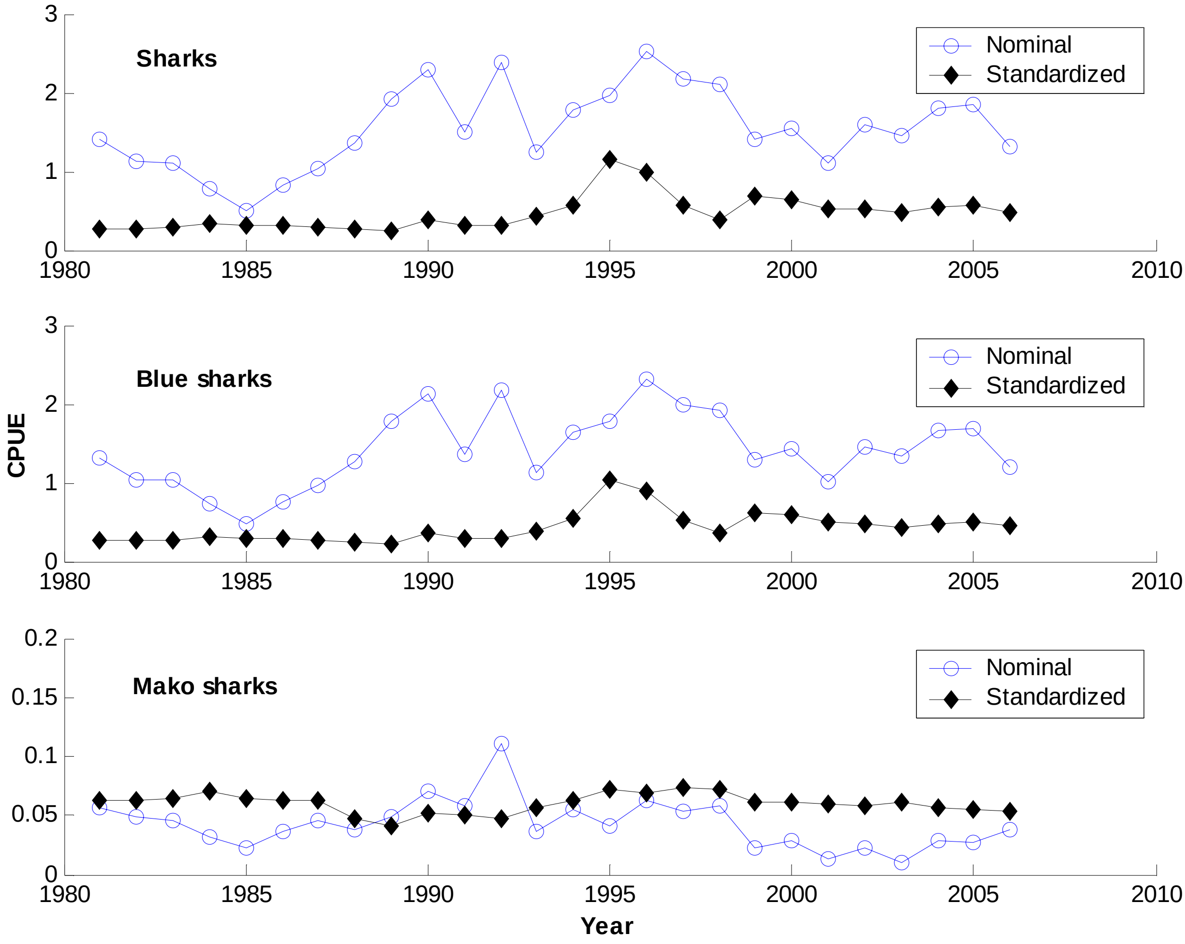

Figure 2. Nominal and standardized CPUEs of sharks estimated from observers' records of Taiwanese longline fishery in the South Atlantic Ocean (1981-2006).

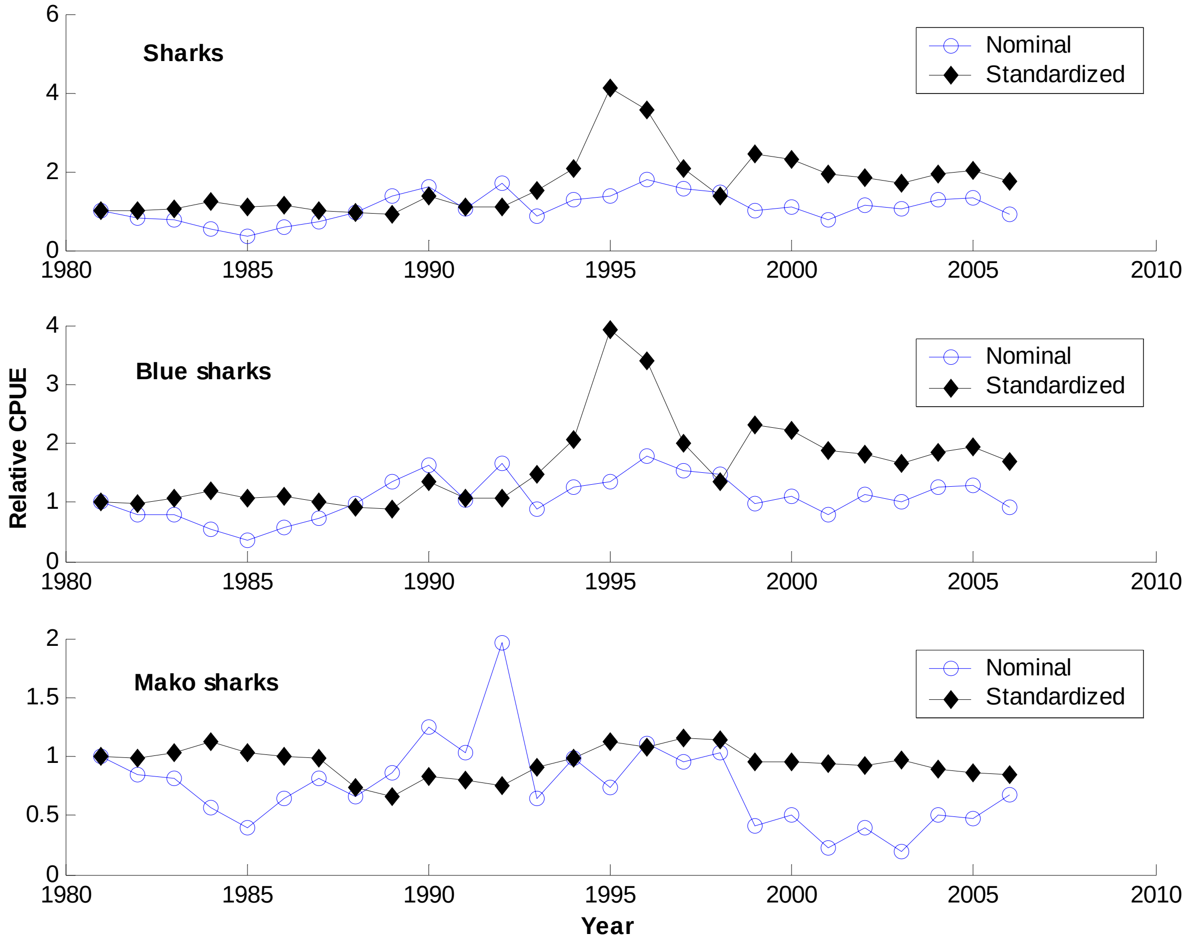

Figure 3. Nominal and standardized relative CPUEs of sharks estimated from observers' records of Taiwanese longline fishery in the South Atlantic Ocean (1981-2006).

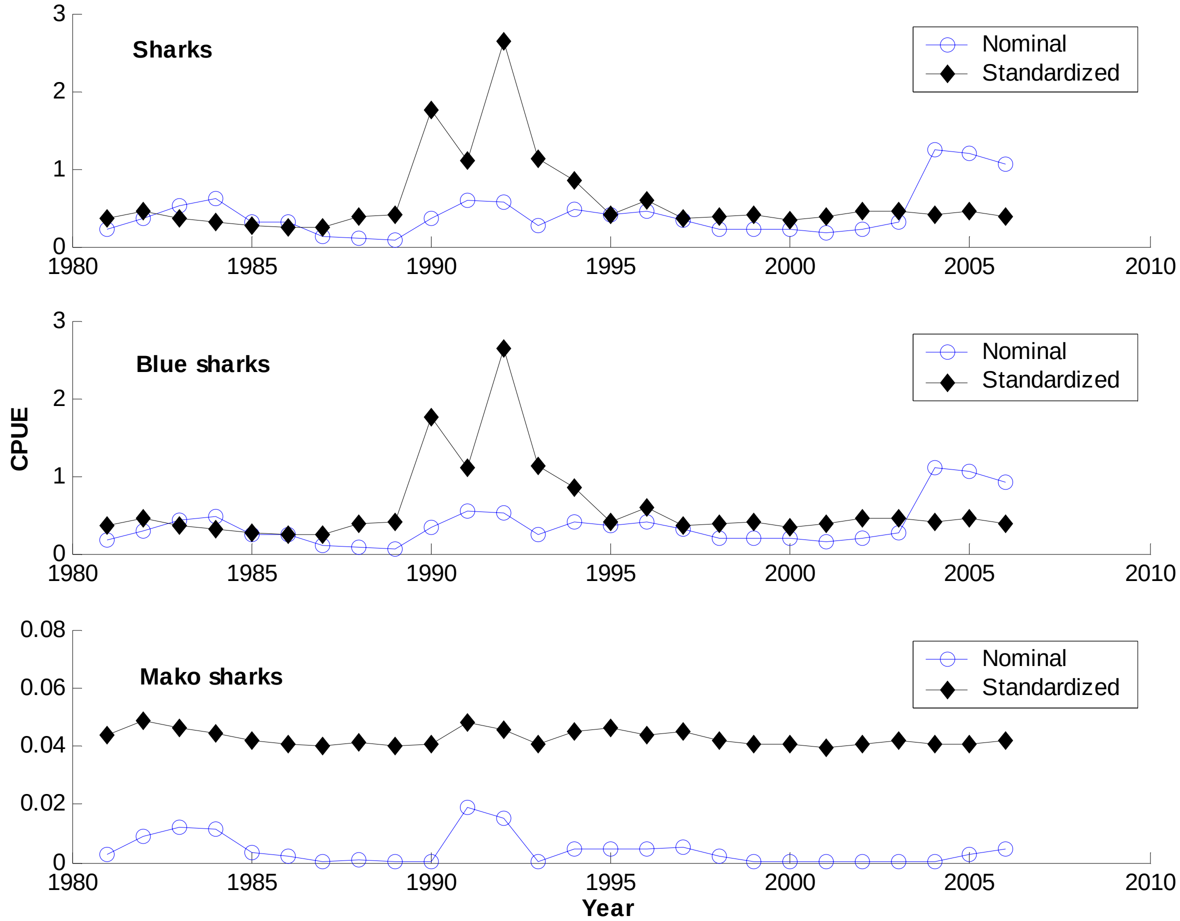

Figure 4. Nominal and standardized CPUEs of sharks estimated from observers' records of Taiwanese longline fishery in the North Atlantic Ocean (1981-2006).

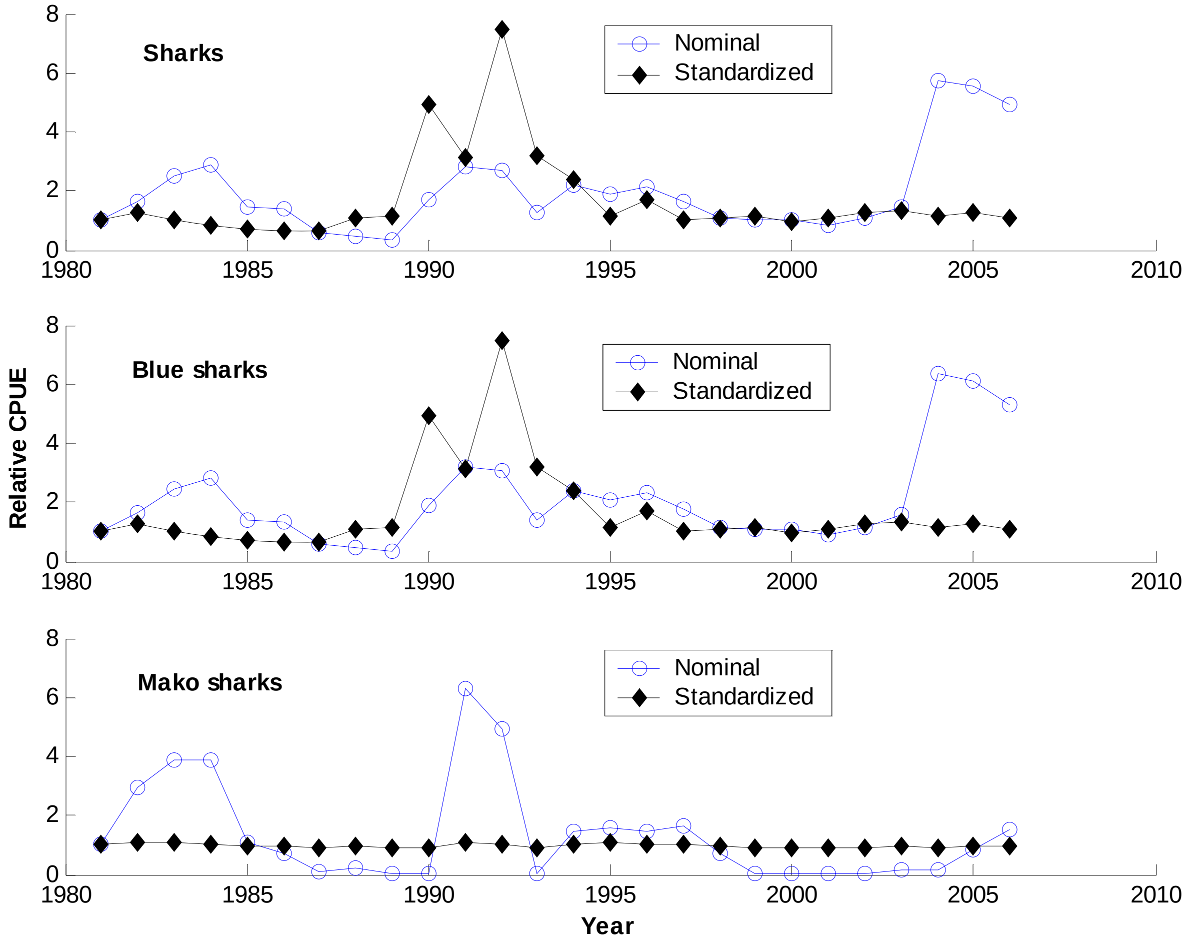

Figure 5. Nominal and standardized relative CPUEs of sharks estimated form observers' records of Taiwanese longline fishery in the North Atlantic Ocean (1981-2006).

Table 1. The proportions of shark to target species catch estimated from observers' records of Taiwanese tuna longline fishery in the Atlantic Ocean (2002-2006).

area		shark	blue shark	mako shark	other sharks	target species
A	quarter 1	26.84%	26.08%	0.46%	0.30%	BET_N+YFT_N+SWO_N
	quarter 2	83.03%	75.63%	1.11%	6.29%	
	quarter 3	38.62%	33.50%	1.01%	4.11%	
	quarter 4	14.37%	12.72%	0.89%	0.76%	
B		19.49%	18.04%	1.43%	0.02%	ALB_N
C		0.51%	0.38%	0.02%	0.11%	
D		22.71%	20.83%	0.94%	0.94%	BET_N+YFT_N+SWO_N
E		4.83%	3.96%	0.59%	0.28%	ALB_N

Table 2. The species composition of sharks estimated from observers' records of Taiwanese tuna longline fishery in the Atlantic Ocean (2002-2006).

area		blue shark	mako shark	other sharks
A	quarter 1	97.17%	1.73%	1.10%
	quarter 2	91.09%	1.34%	7.57%
	quarter 3	86.74%	2.62%	10.64%
	quarter 4	88.50%	6.18%	5.32%
B		92.55%	7.36%	0.09%
C		74.51%	3.64%	21.85%
D		91.72%	4.15%	4.13%
E		82.00%	12.17%	5.83%

Table 3. Annual shark bycatch in number of Taiwanese tuna longline fishery in the South Atlantic Ocean. SHK: Sharks, BLSHK: blue shark, MASHK: mako shark.

Year	SHK_N	BLSHK_N	MASHK_N
1981	80,371	74,154	3,231
1982	84,044	77,540	3,553
1983	58,880	54,379	2,401
1984	38,111	34,996	1,568
1985	44,404	40,532	1,927
1986	99,019	90,812	4,434
1987	112,579	103,640	5,030
1988	105,064	97,134	2,860
1989	140,553	129,870	3,597
1990	231,557	214,062	7,472
1991	188,584	171,923	7,620
1992	271,225	248,590	13,373
1993	155,095	140,921	4,199
1994	230,029	210,122	6,263
1995	209,342	189,396	4,417
1996	309,048	282,918	7,848
1997	253,942	232,545	6,289
1998	233,694	213,414	6,683
1999	223,218	204,133	4,206
2000	240,254	220,529	4,929
2001	160,767	147,464	1,574
2002	224,160	205,487	3,734
2003	190,579	175,860	2,600
2004	159,720	146,103	2,709
2005	134,132	122,740	2,010
2006	64,521	59,208	1,907

Table 4. Annual shark bycatch in number of Taiwanese tuna longline fishery in the North Atlantic Ocean . SHK: Sharks, BLSHK: blue shark, MASHK: mako shark.

Year	SHK_N	BLSHK_N	MASHK_N
1981	12,141	9,824	173
1982	26,473	21,415	659
1983	28,112	22,367	620
1984	29,737	23,589	569
1985	26,634	21,120	282
1986	36,737	28,577	274
1987	13,812	10,709	26
1988	7,538	6,026	54
1989	4,801	4,024	8
1990	31,627	28,561	7
1991	71,262	65,089	2,278
1992	53,790	49,274	1,395
1993	39,239	34,738	13
1994	74,544	65,293	557
1995	43,092	38,182	501
1996	54,452	48,759	539
1997	40,444	35,991	584
1998	25,349	21,730	258
1999	33,352	28,648	23
2000	32,729	28,158	19
2001	25,650	22,054	3
2002	31,166	26,964	22
2003	40,450	35,253	104
2004	37,497	33,520	16
2005	23,476	20,855	51
2006	10,152	8,855	47

Table 5. Annual shark bycatch in weight (kg) of Taiwanese tuna longline fishery in the South Atlantic Ocean. SHK: Sharks, BLSHK: blue shark, MASHK: mako shark.

Year	SHK_W	BLSHK_W	MASHK_W
1981	3,375,419	3,047,716	203,565
1982	3,533,586	3,186,874	223,841
1983	2,473,588	2,234,982	151,259
1984	1,601,385	1,438,338	98,783
1985	1,868,120	1,665,869	121,420
1986	4,168,903	3,732,370	279,341
1987	4,739,471	4,259,612	316,895
1988	4,381,058	3,992,206	180,166
1989	5,855,514	5,337,651	226,583
1990	9,682,875	8,797,963	470,706
1991	7,920,893	7,066,054	480,070
1992	11,446,723	10,217,048	842,498
1993	6,465,157	5,791,842	264,539
1994	9,590,495	8,636,003	394,574
1995	8,695,089	7,784,166	278,276
1996	12,871,917	11,627,916	494,415
1997	10,572,953	9,557,608	396,231
1998	9,750,904	8,771,296	421,014
1999	9,261,498	8,389,864	264,971
2000	9,978,928	9,063,756	310,531
2001	6,635,037	6,060,779	99,180
2002	9,289,165	8,445,500	235,271
2003	7,884,822	7,227,839	163,800
2004	6,619,609	6,004,853	170,651
2005	5,552,627	5,044,613	126,636
2006	2,693,795	2,433,464	120,142

Table 6. Annual shark bycatch in weight (kg) of Taiwanese tuna longline fishery in the North Atlantic Ocean. SHK: Sharks, BLSHK: blue shark, MASHK: mako shark.

Year	SHK_W	BLSHK_W	MASHK_W
1981	499,253	403,750	10,910
1982	1,096,727	880,139	41,491
1983	1,161,086	919,276	39,047
1984	1,225,383	969,513	35,836
1985	1,090,623	868,025	17,754
1986	1,498,375	1,174,526	17,262
1987	560,755	440,143	1,633
1988	308,090	247,667	3,432
1989	196,146	165,380	507
1990	1,296,753	1,173,844	413
1991	2,979,144	2,675,165	143,542
1992	2,241,079	2,025,177	87,866
1993	1,607,345	1,427,713	817
1994	3,066,130	2,683,524	35,085
1995	1,778,175	1,569,264	31,584
1996	2,245,476	2,004,007	33,942
1997	1,672,151	1,479,235	36,813
1998	1,043,315	893,110	16,266
1999	1,364,049	1,177,426	1,444
2000	1,338,592	1,157,274	1,207
2001	1,048,681	906,439	158
2002	1,275,246	1,108,239	1,410
2003	1,657,955	1,448,903	6,581
2004	1,536,892	1,377,673	1,030
2005	962,990	857,146	3,206
2006	416,697	363,920	2,976

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