# An update of CPUE standardization of southern bluefin tuna caught by Taiwanese longline fishery *

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## Abstract

The CPUE of southern bluefin tuna caught by Taiwanese longline fishery during the period of 1996-2005 was standardized using generalized linear model. Besides the update of CPUE standardization of SBT for the entire CCSBT statistical areas, this report also provide standardized CPUE for the main fishing areas and the main fishing seasons. The standardized CPUE roughly follow the trends of nominal CPUE. High CPUE in 2004 and 2005 might be resulted from decreased effort for SBT and stable catch of SBT. As the results, the standardized CPUE revealed a relatively stable trend than nominal CPUE.

## Introduction

Taiwanese tuna longline fishery caught the southern bluefin tuna (SBT) as a bycatch to albacore fishery in the past. In recent years, some vessels with super cold freezers started to target on the species seasonally. The two main fishing seasons are June-September in the central Indian Ocean and October-next February in the southwestern Indian Ocean. Low percentage of SBT was caught in other months (Anon, 2006). The fishing seasons were different from other fleets and the fishing grounds were also a little different from the CCSBT statistical areas and concentrated on some specific regions (hotspots). Therefore, besides the update of CPUE standardization of SBT caught by Taiwanese longline fishery during 1996-2005 for the entire CCSBT statistical areas, this report also provide standardized CPUE for the main fishing areas and the main fishing seasons.

* A working document for CCSBT CPUE Modelling workshop, 21-25 May 2007, Shimizu, Japan.
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## Materials and methods

Since 1996, Taiwanese fishery statistics system has much more improvement for collecting SBT data (Chang, 1998; Anon, 2006). CCSBT SAG7 also suggested that the CPUE of SBT caught by Taiwanese longline fishery could be analyzed for the time series after early 1990s. Thus the catch and effort used in the report were based on the data from the CCSBT data base for 1996-2002 and the revised data of logbook provided by Overseas Fisheries Development Council of Taiwan for 2002-2005. The data including number of hooks, catch in number of SBT and catch in weight of SBT were monthly aggregated by 5x5 degree and were also split up into 15 sub areas based on the SBT statistical areas (Fig. 1). The data in the north of 20S were excluded for analyses based on the north boundary for Taiwanese SBT fishery.

The 1x1 degree aggregated sea surface temperature (SST) data during 1982 to 2005 were collected from Jet Propulsion Laboratory, California Institute of Technology, NASA (NASA/JPL PO.DAAC). The SST data were aggregated to be 5x5 degree format for combining with catch and effort data.

The generalized linear model (GLM) was applied to standardize the CPUE of SBT caught by Taiwanese longline fishery. The effects included in the models were year, month, area, SST and theirs interactions. The effect of SST was treated as continuous variable and other effects were treated as class variables. The year effect of year was not included in the interaction terms (Hinton and Maunder, 2003).

$$\log(CPUE + c) = Y + M + A + SST + \text{interactions} + \varepsilon$$

where c is the constant value (i.e. 10% of the average nominal CPUE);
Y is the year effect;
M is the month effect;
A is the area effect;
SST is the SST effect;
$\varepsilon$ is the error term and ($\varepsilon \sim N(0,\sigma^2)$).

The estimation of the log-transformed model was based on the Gaussian PDF and the identity as the link function. The Akaike's Information Criterion (AIC) is used to select among alternative models of which the one with the lowest value of AIC is selected as the final model. The standardized results were computed from the adjusted means (least square means) of the estimates of the year effects. The analyses were conducted using R version 2.5.0 (The R Development Core Team, 2007).

Based on the fishing pattern of Taiwanese SBT fishery (Anon, 2006; Wang et al., 2006), three cases of the fishing area and fishing season were selected for

standardizing CPUE, with the consideration of fishery aggregation:
Case 1: the analyses for area 2, 8, 9, 10, 14 and 15 and for entire year.
Case 2: the analyses for area 2, 8, 9 and 14 and for the months excluded March, April and May.
Case 3: the analyses for two main fishing areas (30E-60E and 35S-45S; 60E-110E and 20S-40S) and for the months excluded March, April and May. The fishing areas were redefined to two categories.

Case 1 was made for entire fishing area and fishing season of Taiwanese SBT fishery and Case 2 and 3 were made for main fishing area and fishing season.

## Results and discussion

Fig. 2 shows the geographic distribution of CPUE of SBT caught by Taiwanese longline fishery during the period of 1996 to 2005. Except few data points, most observations presented in the area 2, 8, 9, 10, 14 and 15 (Case 1) and high CPUEs occurred in area 2, 8, 9 and 14 (Case 2). Particularly, high CPUEs concentrated in the area of 30E-60E and 35S-45S and the area of 60E-110E and 20S-40S (Case 3).

The results of stepwise analyses indicated that all main effects and interactions were statistically significant and they improved the explanations of variance for all three cases (results were not shown). Thus the selected final models are represented as follows:

$$\log(CPUE + c) = Y + M + A + SST + M * A + M * SST + A * SST$$

Table 1 shows the analysis of variance (ANOVA) of GLM model for three cases. Fig. 3 and Fig. 4 show the distribution of the standardized residuals and the normal probability plot for three models and do not appear to differ much from those expected under the normal distribution.

Fig. 5 shows the nominal and the standardized CPUE of SBT caught by Taiwanese longline fishery. The CPUEs for two periods (1996-2002 and 2002-2005) were merged by scaling them to the value for 2002. The trends of the standardized CPUE roughly followed those of the nominal CPUE for all three cases. The nominal and the standardized CPUEs both revealed relatively stable patterns before 2003. The nominal CPUE in 2004 and 2005 were obviously higher than those before 2003. Based on the information about fishing activity of Taiwanese longline fleets, the number of vessels registered for SBT decreased substantially from in 2004 and 2005. The number of SBT vessels decreased from 97 in 2003 to 57 in 2004 and 36 in 2005.

In recent years, some SBT vessels changed their fishing ground for other species. However, remaining SBT vessels still caught SBT until the quota being reached. Therefore, the decreased effort for SBT and stable catch of SBT could result in the high catch rate in these two years. Especially for 2004, the number of SBT vessels in 2004 decreased to about 40% of that in 2003 but the catch of SBT in 2004 were more that that in 2003. This might lead to higher nominal CPUE in 2004. For all three cases, however, the standardized CPUE for the period of 1996-2005 revealed a relatively stable trend than nominal CPUE.

## Reference

Anon. (2006). Review of Taiwanese SBT Fishery of 2004/2005. CCSBT-ESC/0609/SBT.

Chang, S. K. (1998). Rebuilding and overview of historical size frequency of southern bluefin tuna, Thunnus maccoyii, caught by Taiwan longliners. CCSBT-SC/9807/33. 14 pp.

Hinton, M. G., and M. N. Maunder (2003). Methods for standardizing CPUE and how to select among them. ICCAT SCRS/2003/034, 11 pp.

Wang. S. P., S. K. Chang., and S. L. Lin (2006). CPUE standardization of southern bluefin tuna caught by Taiwanese longline fishery. CCSBT-ESC/0609/46.

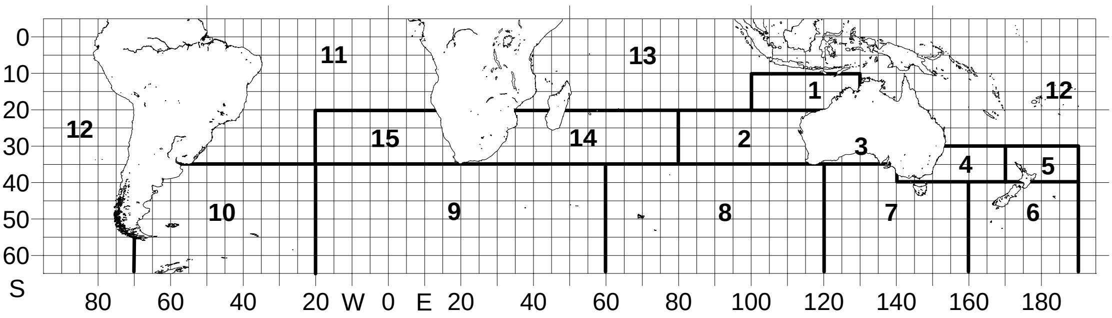



Fig. 1. Statistical area for southern bluefin tuna.

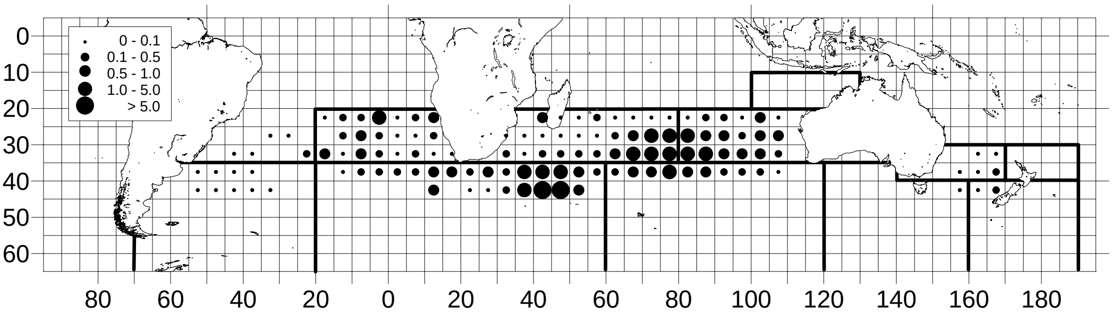
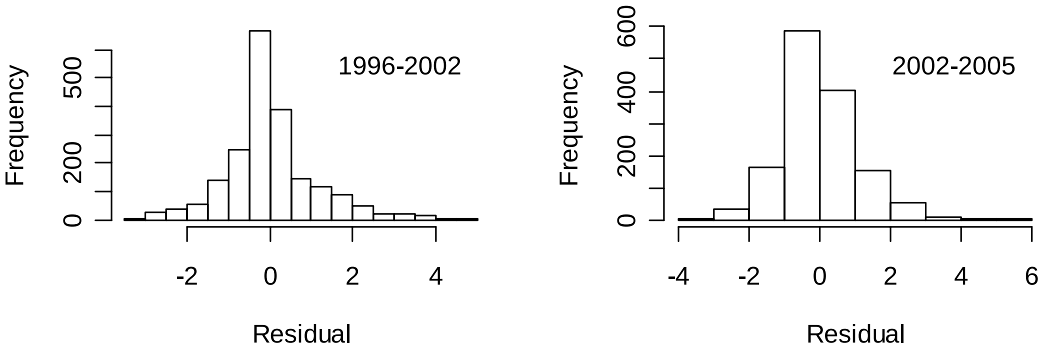



Fig. 2. CPUE distribution of southern bluefin tuna caught by Taiwanese longline fishery during 1996-2005.

Case 1




Case 2

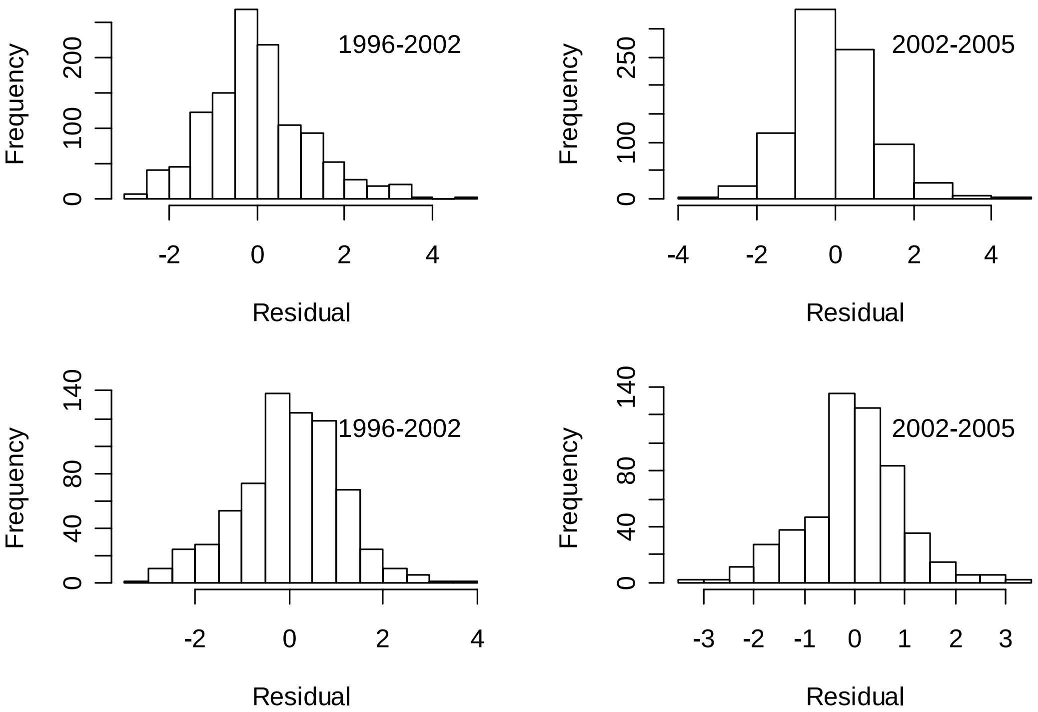
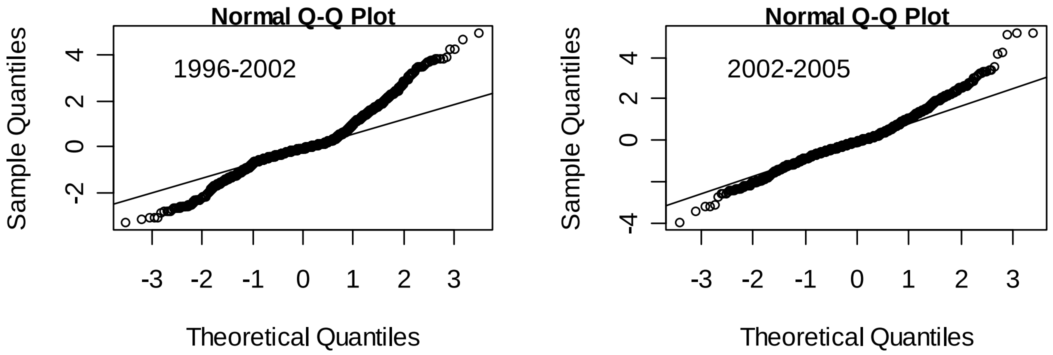
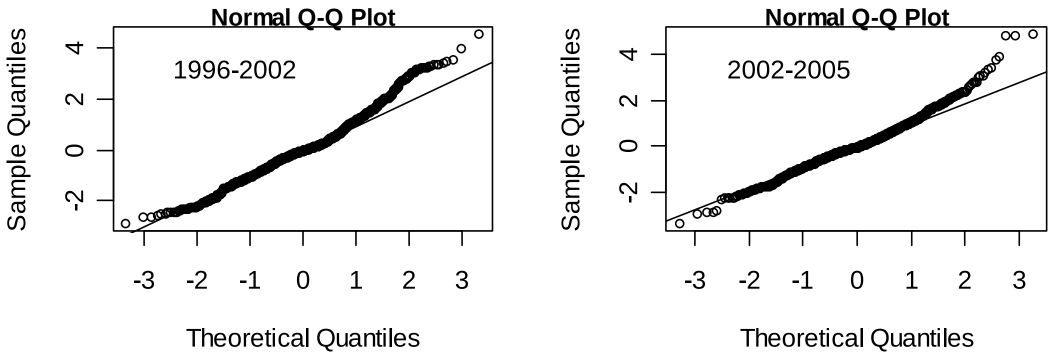



Fig. 3. The distribution for the standardized residuals for three cases.

Case 1




Case 2




Case 3

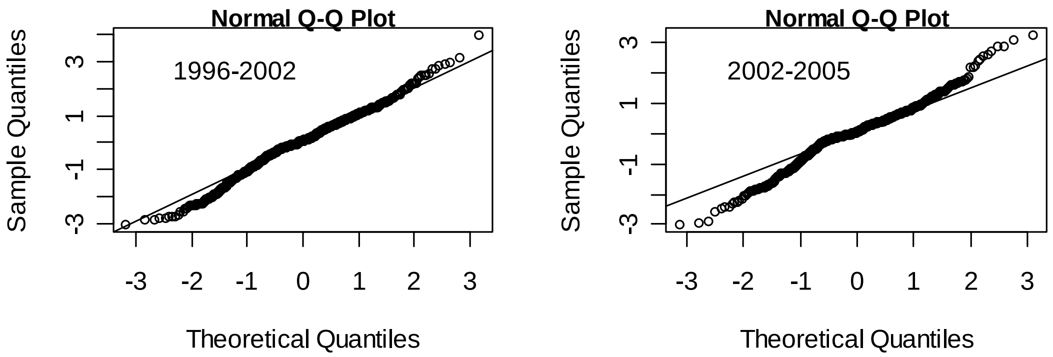



Fig. 4. The normal probability plots for the standardized residuals for three cases.

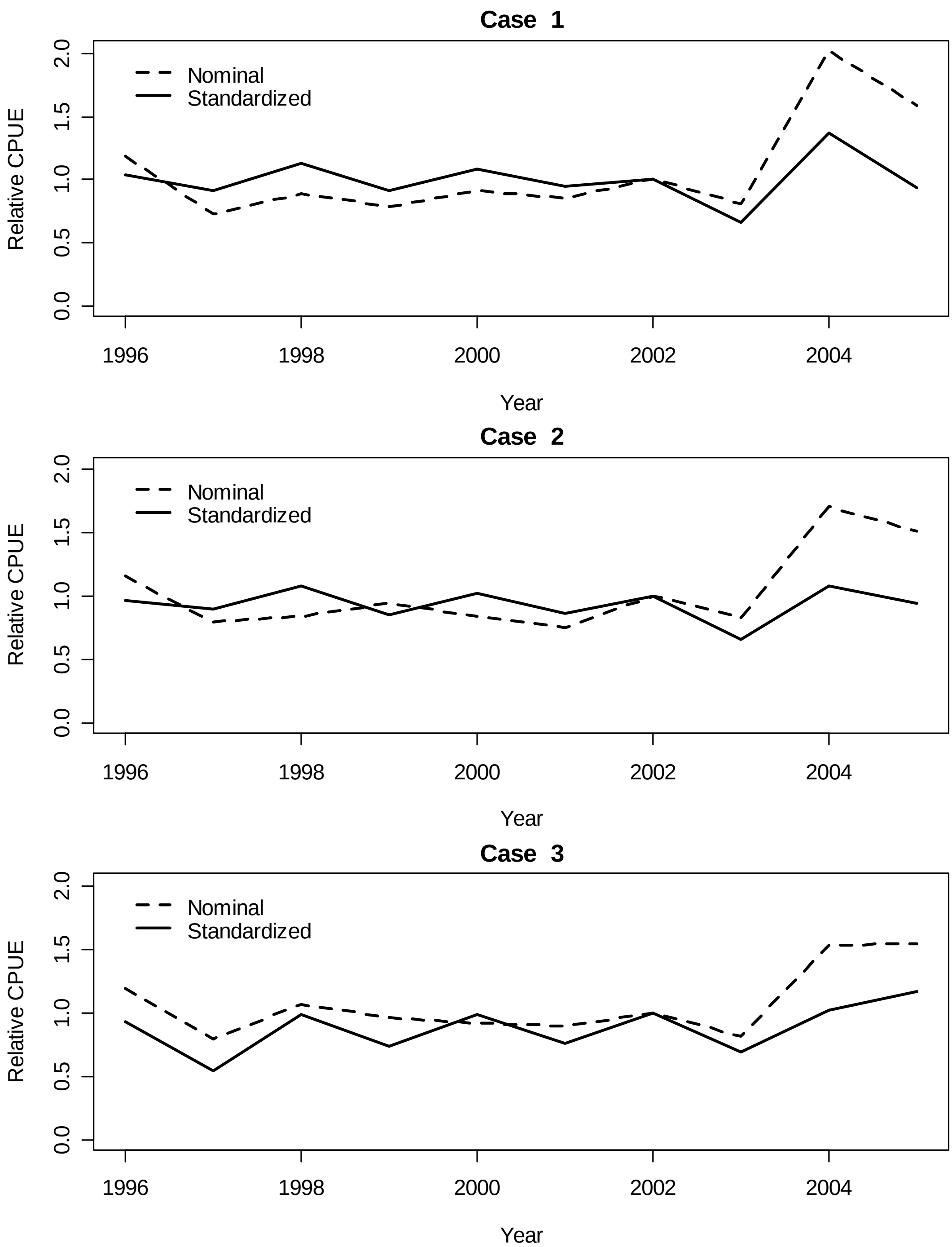



Fig. 5. Nominal and standardized CPUE of southern bluefin tuna caught by Taiwanese longline fishery for three cases.

Table 1. The analysis of variance of GLM model for three cases.

Case 1

1996-2002

| | Df | Sum Sq | Mean Sq | F value | Pr(>F) | |
|---|---|---|---|---|---|---|
| Y | 6 | 35.93 | 5.99 | 4.872 | 0.0000597 | *** |
| M | 11 | 354.19 | 32.2 | 26.1946 | < 2.2e-16 | *** |
| A | 5 | 395.61 | 79.12 | 64.3669 | < 2.2e-16 | *** |
| SST | 1 | 439.04 | 439.04 | 357.1698 | < 2.2e-16 | *** |
| M:A | 52 | 322.54 | 6.2 | 5.046 | < 2.2e-16 | *** |
| M:SST | 11 | 166.81 | 15.16 | 12.3367 | < 2.2e-16 | *** |
| A:SST | 5 | 33.94 | 6.79 | 5.5217 | 4.69E-05 | *** |

2002-2002

| | Df | Sum Sq | Mean Sq | F value | Pr(>F) | |
|---|---|---|---|---|---|---|
| Y | 3 | 90.17 | 30.06 | 24.1554 | 3.193E-15 | *** |
| M | 11 | 547.39 | 49.76 | 39.9904 | < 2.2e-16 | *** |
| A | 5 | 187.01 | 37.4 | 30.0579 | < 2.2e-16 | *** |
| SST | 1 | 312.07 | 312.07 | 250.7862 | < 2.2e-16 | *** |
| M:A | 46 | 165.84 | 3.61 | 2.8972 | 8.143E-10 | *** |
| M:SST | 11 | 93.27 | 8.48 | 6.8143 | 3.041E-11 | *** |
| A:SST | 5 | 17.26 | 3.45 | 2.7746 | 1.68E-02 | * |

Case2

1996-2002

| | Df | Sum Sq | Mean Sq | F value | Pr(>F) | |
|---|---|---|---|---|---|---|
| Y | 6 | 18.63 | 3.1 | 2.2317 | 0.03803 | * |
| M | 8 | 121.01 | 15.13 | 10.8744 | 7.715E-15 | *** |
| A | 3 | 176.52 | 58.84 | 42.2997 | < 2.2e-16 | *** |
| SST | 1 | 384.42 | 384.42 | 276.3523 | < 2.2e-16 | *** |
| M:A | 23 | 132.46 | 5.76 | 4.1402 | 3.013E-10 | *** |
| M:SST | 8 | 83.02 | 10.38 | 7.4601 | 1.009E-09 | *** |
| A:SST | 3 | 9.44 | 3.15 | 2.2614 | 1.97E-02 | * |

2002-2005

| | Df | Sum Sq | Mean Sq | F value | Pr(>F) | |
|---|---|---|---|---|---|---|
| Y | 3 | 39.8 | 13.27 | 10.5295 | 8.431E-07 | *** |
| M | 8 | 227.81 | 28.48 | 22.6009 | < 2.2e-16 | *** |
| A | 3 | 130.79 | 43.6 | 34.6022 | < 2.2e-16 | *** |
| SST | 1 | 273.13 | 273.13 | 216.7771 | < 2.2e-16 | *** |
| M:A | 21 | 71.1 | 3.39 | 2.6871 | 0.000066 | *** |
| M:SST | 8 | 61.32 | 7.67 | 6.0839 | 1.253E-07 | *** |
| A:SST | 3 | 16.99 | 5.66 | 4.4947 | 3.88E-03 | ** |

Table 1. (Continued).

Case 3

1996-2002

| | Df | Sum Sq | Mean Sq | F value | Pr(>F) | |
|---|---|---|---|---|---|---|
| Y | 6 | 29.34 | 4.89 | 3.936 | 0.0007126 | *** |
| M | 8 | 67.94 | 8.49 | 6.8365 | 1.215E-08 | *** |
| A | 1 | 54.82 | 54.82 | 44.1287 | 6.555E-11 | *** |
| SST | 1 | 199.68 | 199.68 | 160.7379 | < 2.2e-16 | *** |
| M:A | 8 | 106.97 | 13.37 | 10.7632 | 2.827E-14 | *** |
| M:SST | 8 | 48.37 | 6.05 | 4.8677 | 0.000007583 | *** |
| A:SST | 1 | 2.63 | 2.63 | 2.1164 | 1.46E-02 | * |

2002-2005

| | Df | Sum Sq | Mean Sq | F value | Pr(>F) | |
|---|---|---|---|---|---|---|
| Y | 3 | 23.94 | 7.98 | 7.7201 | 0.00004785 | *** |
| M | 8 | 225.04 | 28.13 | 27.2173 | < 2.2e-16 | *** |
| A | 3 | 24.29 | 8.1 | 7.8354 | 0.00004083 | *** |
| SST | 1 | 140.61 | 140.61 | 136.0533 | < 2.2e-16 | *** |
| M:A | 21 | 72.97 | 3.47 | 3.362 | 9.883E-07 | *** |
| M:SST | 8 | 42.39 | 5.3 | 5.1266 | 0.000003788 | *** |
| A:SST | 3 | 7.59 | 2.53 | 2.4468 | 4.31E-02 | * |