CPUE analysis for southern bluefin tuna caught by Taiwanese longline fleet

Sheng-Ping Wang[1], Shu-Ting Chang[2], Shiu-Ling Lin[3]

1. National Taiwan Ocean University, Taiwan
2. Overseas Fisheries Development Council, Taiwan
3. Fisheries Agency, Council of Agriculture, Executive Yuan, Taiwan

ABSTRACT

This study attempts to select Taiwanese longline vessels which deployed more effort for catching southern bluefin tuna. Comparing to the amounts of catch and effort of all active longline vessels authorized to seasonally target SBT operating in the southern area of 20°S of the Indian Ocean, the results of vessel selections can exclude about 13.5-39.4% of efforts and keep about 78.1-96.1% of SBT catches. Nominal and standardized CPUE trends are generally similar among different vessel selection cases for fishing area of 20°S-40°S and east of 50°E, while CPUE trend of all SBT vessels is obviously distinct from those of selected vessels for fishing area of 20°S-45°S and 20°E-50°E.

INTRODUCTION

Southern bluefin tuna (SBT) (*Thunnus maccoyii*) was by-catch of Taiwanese tuna longline fleet targeting albacore in the past, but after the fishing vessels equipped with deep-frozen freezers, some fishing vessels operating in the Indian Ocean started targeting SBT seasonally since 1990s. However, large amount of vessels may not deploy their fishing effort for catching SBT even for vessels authorized to seasonally target SBT. This study attempts to extract the catch and effort data from the selected vessels which seasonally targeted SBT and deployed more effort for catching SBT. In addition, CPUE standardization of selected vessels are also performed to explore the trend of relative abundance index of SBT caught by Taiwanese longline fleet.

MATERIALS AND METHODS

Catch and Effort data

In this study, daily set-by-set catch and effort data (logbook) with 5x5 degree fishing location grids of Taiwanese active longline vessels authorized to seasonally target SBT operating in the southern area of 20°S of the Indian Ocean in the period of 2002-2010 are provided by Overseas Fisheries Development Council of Taiwan (OFDC).

Definition of fishing areas

Based on the catch and CPUE distribution of southern bluefin tuna caught by Taiwanese longline fleets (Anon, 2012), the fishing ground could be roughly divided into two areas: one is around the waters of the southern central Indian Ocean (Area1, in the area of 20°S-40°S and east of 50°E), and the other one is around the southeastern waters off South Africa (Area 2, in the area of 20°S-45°S and 20°E-50°E) (Fig. 1)

Vessel selection

In Taiwanese National Report and previous Taiwanese SBT CPUE analyses, the trend of SBT CPUE series were generally calculated based on the data from active longline vessels authorized to seasonally target SBT. In this study, the annual proportion of SBT catch to main species (albacore, bigeye tuan, yellowfin tuna, swordfish and SBT) are adopted as the criteria to select vessels and catch and effort data of these vessels are used to analyze CPUE trend. In order to compare the influence of vessel selection on CPUE calculation, various vessel selection cases are conducted:

All SBT vessel: The data of all active longline vessels authorized to seasonally target SBT operating in the southern area of 20°S of the Indian Ocean are used to analyze CPUE trend.

Case 10%-30%: The vessels, whose annual SBT catch proportion is less than 10, 20 and 30 percentiles of the annual SBT catch proportion of all SBT vessels, are excluded. The data of remaining vessels are used to analyze CPUE trend.

CPUE standardization

Based on the catch and effort data from selected vessels, general linear model (GLM) is applied to standardize the CPUE of SBT caught by Taiwanese longline fleet. The effects included in the models were year, quarter, fishing area, albacore and bigeye tuna CPUE and their interactions. However, interactions with the year effect would lead to problems for the year effect as an index of abundance (Hinton and Maunder, 2004; Maunder and Punt, 2004) and thus this study include only interaction related to the year effect, i.e. the interaction between year and area, for further the area-specific CPUE standardization. The GLM is

$$\ln(CPUE + c) = \mu + Y + Q + A + ALB + BET + Y \times A + Q \times A + Q \times ALB \\ + Q \times BET + A \times ALB + A \times BET + ALB \times BET + \varepsilon$$

where	*CPUE*	is the nominal CPUE of SBT (catch in number/1,000 hooks),
	c	is the constant value (i.e. 10% of the average nominal CPUE),
	μ	is the intercept,
	Y	is the year effect,
	Q	is the quarter effect,
	A	is the fishing area effect,
	ALB	is the albacore CPUE effect,
	BET	is the bigeye tuna CPUE effect,
	ε	is the error term, $\varepsilon \sim N(0, \sigma^2)$.

The quarter effect is classified into three categories (1: Jun-September; 2: October-next February; 3: other months). The ALB and BET effects are also classified into three categories (BET: 1: CPUE < 1.736; 2: 1.736 ≤ CPUE ≤ 4.644; 3: CPUE > 4.644. ALB: 1: CPUE < 1.270; 2: 1.270 ≤ CPUE ≤ 9.643; 3: CPUE > 9.643) based on the relationship between number of hooks between basket and ALB/BET CPUE (S. P. Wang, unpublished data). The area-specific standardized CPUE trends are estimated based on the exponentiations of the adjust means of the interaction between year and area effects (Butterworth, 1996; Maunder and Punt, 2004).

RESULTS AND DISCUSSIONS

Vessel selection

Table 1 shows the amount of selected vessels for various cases. The amount and percentage of exclusion of number of vessels increase when raising the vessel selection criterion. Generally, Cases 10%-30% can exclude about 10-30% of number of vessels from all SBT vessels (Tables 1 and 2).

Comparing to the case of all SBT vessels, the efforts (number of hooks) are substantially excluded for other vessel selection cases (Table 3). Comparatively, relative few amounts of SBT catch are excluded for all vessel selection cases (Table 4). Only about 3.9% of SBT catch are excluded when 13.5% of efforts are excluded. Even though about 39.4% of efforts are excluded, about 21.9% of SBT catch are excluded. The results of vessel selections can exclude larger amount of effort and keep about 78.1-96.1% of SBT catch. The results imply that large amount of efforts of active longline vessels authorized to seasonally target SBT operating in the southern area of 20°S of the Indian Ocean did not deploy efforts for catching SBT. Therefore, the data extract from selected vessels would be more representative for further CPUE analysis.

Trend of CPUE

Fig. 2 shows the area-specific nominal CPUE calculated based on the data of selected vessels for various cases. CPUEs of selected vessels are generally higher than those of all SBT vessels since large amount of effort are excluded. For Area 1, CPUE trends of selected vessels are similar to that of all SBT vessels. For Area 2, however, CPUE trend of all SBT vessels is somewhat different with those of selected vessels, especially for 2002-2003. In 2002, the SBT catch proportions of vessels operating in Area 2 were relatively lower than those in Area 1 and thus no SBT catch record is retained by vessel selections. Area-specific vessel selection might be helpful to reduce this problem.

Based on the GLM analysis, all of main effects and their interactions are statistically significant (Appendix). Fig. 3 shows the area-specific standardized CPUE estimated based on the data from different vessel selection cases. The values of standardized CPUE were scaled by historical average for each case. For Area 1, CPUE trends of selected vessels are generally similar to that of all SBT vessels. For Area 2, CPUE trend of all SBT vessels is obviously distinct from those of selected vessels, especially for early years. CPUE trend of all SBT vessels reveal a slightly increasing pattern since 2006, while CPUE trends of selected vessels generally decrease in the same period of time.

Generally, nominal and standardized CPUE trends are similar among different vessel selection cases for both areas (Figs 2 and 3). CCSBT (2007) also indicated that the approach of sub-setting the fleet to a set of core vessels may provide more robust indices. In order to avoid the bias on CPUE calculation, relevant CPUE analyses should be perform based on the catch and effort data of selected Taiwanese longline vessels.

REFERENCE

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Table 1. Number of selected vessels for various cases.

Year	ALL SBT vessel	Case 10%	Case 20%	Case 30%
2002	21	19	17	15
2003	72	63	56	49
2004	77	70	62	54
2005	47	43	38	33
2006	33	29	26	23
2007	27	25	22	19
2008	35	32	28	25
2009	34	31	28	24
2010	65	60	53	47

Table 2. Percentage of exclusion of number of vessels for various cases comparing to the case that all SBT vessels are selected.

Year	Case 10%	Case 20%	Case 30%
2002	9.5	19.1	28.6
2003	12.5	22.2	31.9
2004	9.1	19.5	29.9
2005	8.5	19.2	29.8
2006	12.1	21.2	30.3
2007	7.4	18.5	29.6
2008	8.6	20.0	28.6
2009	8.8	17.7	29.4
2010	7.7	18.5	27.7
Overall	9.5	19.7	29.7

Table 3. Percentage of exclusion of effort (number of hooks) for various cases comparing to the case that all vessels are selected.

Year	Case 10%	Case 20%	Case 30%
2002	8.8	24.3	40.0
2003	19.5	36.3	50.3
2004	22.6	42.2	53.1
2005	11.6	29.5	48.1
2006	12.6	24.8	34.0
2007	8.5	17.1	30.4
2008	12.6	25.0	31.3
2009	13.5	25.2	37.1
2010	7.8	19.5	29.8
Overall	13.5	27.6	39.4

Table 4. Percentage of exclusion of catch (number of fishes) using different criteria comparing to the case that all vessels are selected.

Year	Case 10%	Case 20%	Case 30%
2002	4.6	13.3	26.0
2003	4.3	14.4	25.5
2004	7.5	17.4	27.2
2005	4.6	13.2	25.7
2006	3.1	12.2	24.5
2007	0.3	3.3	15.2
2008	3.0	12.1	20.1
2009	1.5	6.3	14.3
2010	6.0	12.1	20.7
Overall	3.9	11.6	21.9

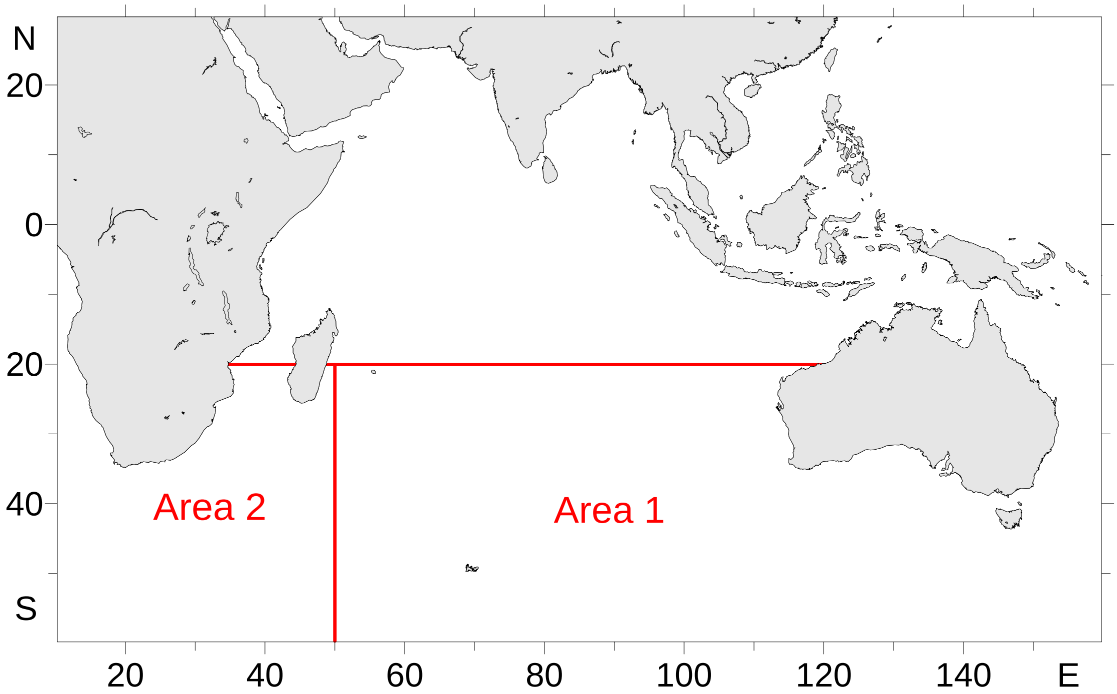
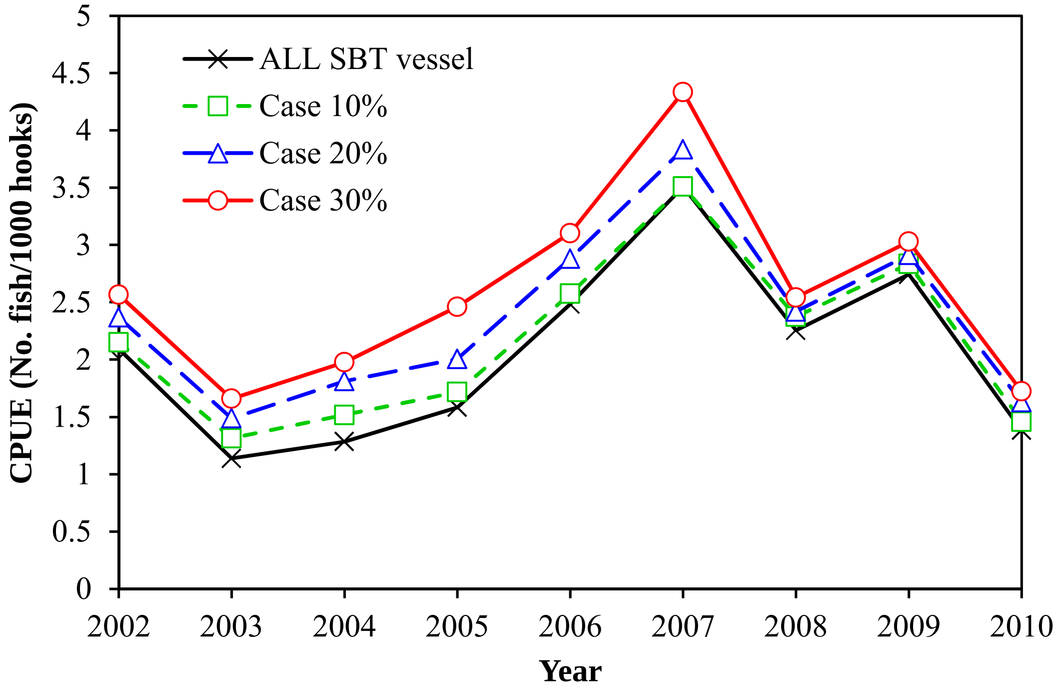


Fig 1. The definition of two fishing grounds of southern bluefin tuna for Taiwanese fleets operated in the Indian Ocean.

(A) Area1



(B) Area 2

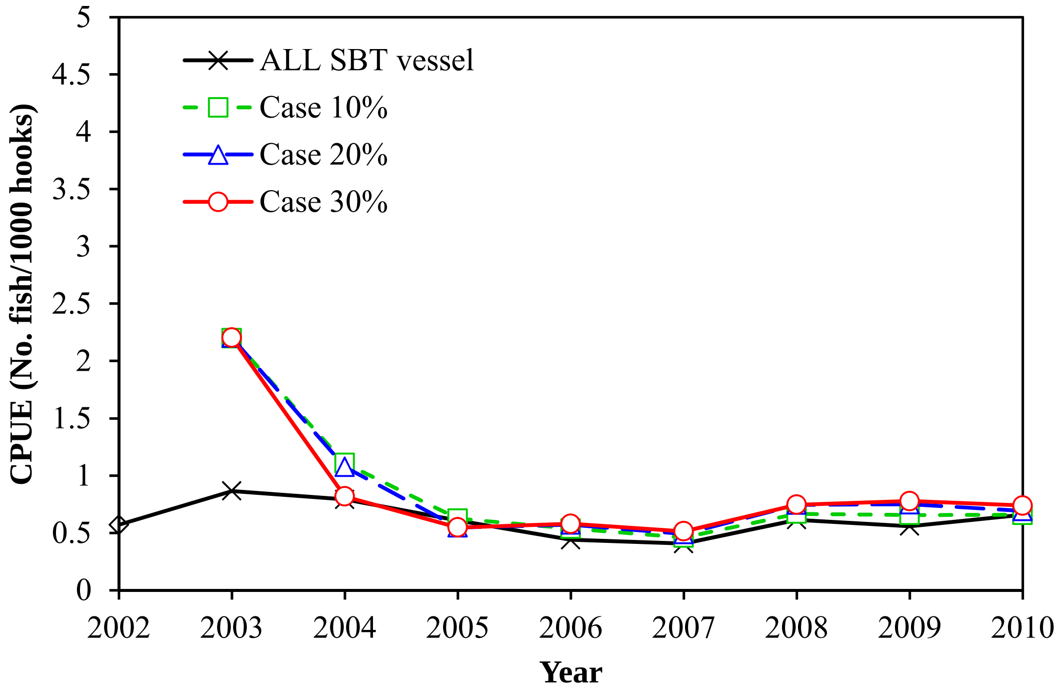
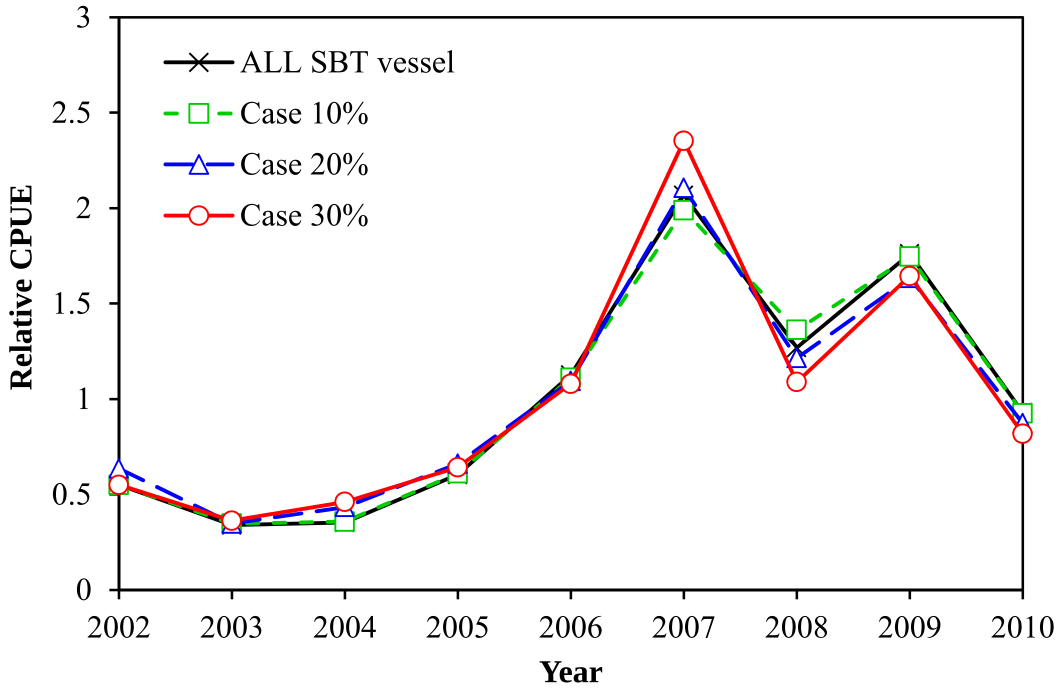


Fig. 2. Nominal CPUE of southern bluefin tuna calculated based on the data of vessels selected using different criteria.

(A) Area 1



(B) Area 2

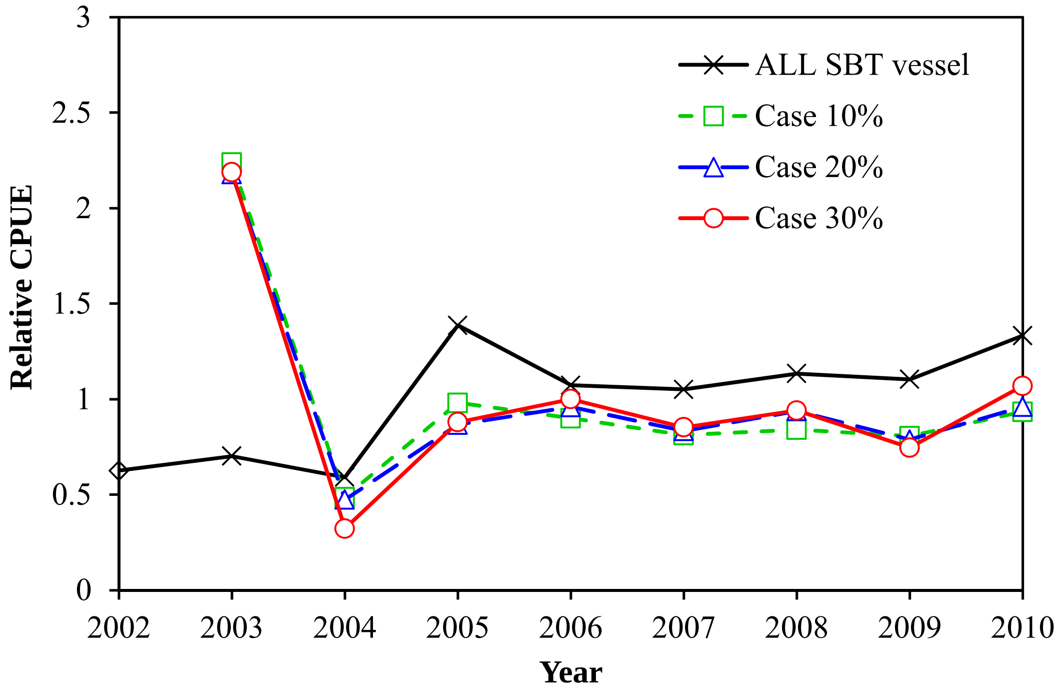


Fig. 3. Relative standardized CPUE of southern bluefin tuna estimated based on the data of vessels selected using different criteria. The values of CPUE were scaled by historical average for each case.

Appendix. ANOVA tables for vessels selection cases

(A) All SBT vessel

	Df	Deviance	Resid. Df	Resid. Dev	F	Pr(>F)
NULL			53185	140207		
Y	8	1351.3	53177	138855	102.9	< 2.2e-16 ***
Q	2	26220.7	53175	112635	7987.1	< 2.2e-16 ***
A	1	11390.8	53174	101244	6939.5	< 2.2e-16 ***
ALB	2	1431.5	53172	99812	436.1	< 2.2e-16 ***
BET	2	64.5	53170	99748	19.6	2.97E-09 ***
Y:A	8	1178.9	53162	98569	89.8	< 2.2e-16 ***
Q:A	2	7921.2	53160	90648	2412.9	< 2.2e-16 ***
Q:ALB	4	1695.0	53156	88953	258.2	< 2.2e-16 ***
Q:BET	4	237.9	53152	88715	36.2	< 2.2e-16 ***
A:ALB	2	1022.2	53150	87693	311.4	< 2.2e-16 ***
A:BET	2	47.0	53148	87646	14.3	6.00E-07 ***
ALB:BET	4	412.6	53144	87233	62.8	< 2.2e-16 ***

(B) Case 10%

	Df	Deviance	Resid. Df	Resid. Dev	F	Pr(>F)
NULL			45975	126221		
Y	8	1551.2	45967	124670	113.9	< 2.2e-16 ***
Q	2	23841.6	45965	100828	7002.7	< 2.2e-16 ***
A	1	9967.3	45964	90861	5855.2	< 2.2e-16 ***
ALB	2	1146.5	45962	89714	336.8	< 2.2e-16 ***
BET	2	34.6	45960	89680	10.2	3.89E-05 ***
Y:A	8	946.6	45952	88733	69.5	< 2.2e-16 ***
Q:A	2	7051.7	45950	81681	2071.2	< 2.2e-16 ***
Q:ALB	4	1861.1	45946	79820	273.3	< 2.2e-16 ***
Q:BET	4	345.8	45942	79475	50.8	< 2.2e-16 ***
A:ALB	2	866.0	45940	78609	254.4	< 2.2e-16 ***
A:BET	2	46.9	45938	78562	13.8	1.04E-06 ***
ALB:BET	4	367.8	45934	78194	54.0	< 2.2e-16 ***

(C) Case 20%

	Df	Deviance	Resid. Df	Resid. Dev	F	Pr(>F)
NULL			38584	109199		
Y	8	2876.7	38576	106322	208.3	< 2.2e-16 ***
Q	2	19808.9	38574	86513	5737.4	< 2.2e-16 ***
A	1	10147.4	38573	76366	5878.1	< 2.2e-16 ***
ALB	2	567.7	38571	75798	164.4	< 2.2e-16 ***
BET	2	20.0	38569	75778	5.8	0.003057 **
Y:A	8	662.7	38561	75116	48.0	< 2.2e-16 ***
Q:A	2	5750.9	38559	69365	1665.7	< 2.2e-16 ***
Q:ALB	4	1687.6	38555	67677	244.4	< 2.2e-16 ***
Q:BET	4	273.0	38551	67404	39.5	< 2.2e-16 ***
A:ALB	2	571.0	38549	66833	165.4	< 2.2e-16 ***
A:BET	2	44.7	38547	66789	12.9	2.40E-06 ***
ALB:BET	4	252.2	38543	66536	36.5	< 2.2e-16 ***

(D) Case 30%

	Df	Deviance	Resid. Df	Resid. Dev	F	Pr(>F)
NULL			32402	93392		
Y	8	4022.5	32394	89370	292.9	< 2.2e-16 ***
Q	2	15342.0	32392	74028	4468.2	< 2.2e-16 ***
A	1	10410.8	32391	63617	6064.1	< 2.2e-16 ***
ALB	2	254.0	32389	63363	74.0	< 2.2e-16 ***
BET	2	9.8	32387	63353	2.9	0.0468357 *
Y:A	8	721.5	32379	62632	52.5	< 2.2e-16 ***
Q:A	2	4592.7	32377	58039	1337.6	< 2.2e-16 ***
Q:ALB	4	1508.2	32373	56531	219.6	< 2.2e-16 ***
Q:BET	4	333.8	32369	56197	48.6	< 2.2e-16 ***
A:ALB	2	438.5	32367	55758	127.7	< 2.2e-16 ***
A:BET	2	28.0	32365	55730	8.2	0.0002865 ***
ALB:BET	4	173.2	32361	55557	25.2	< 2.2e-16 ***