CPUE standardization of blue marlin (Makaira mazara) caught by Taiwanese longline fishery in the Indian Ocean

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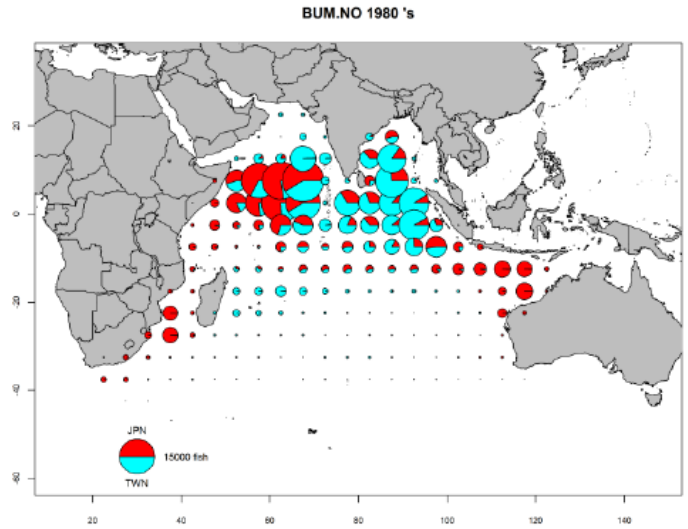
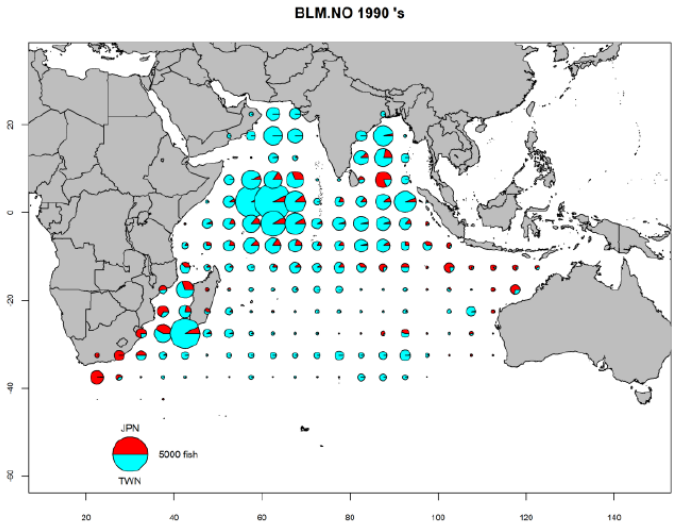
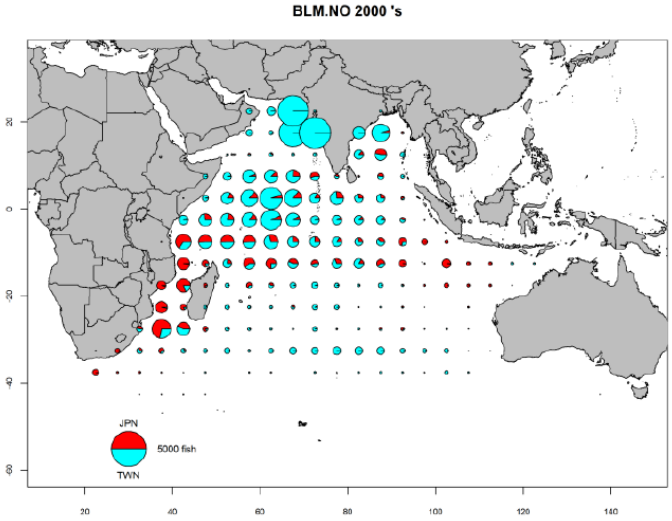
Definition of fishing area

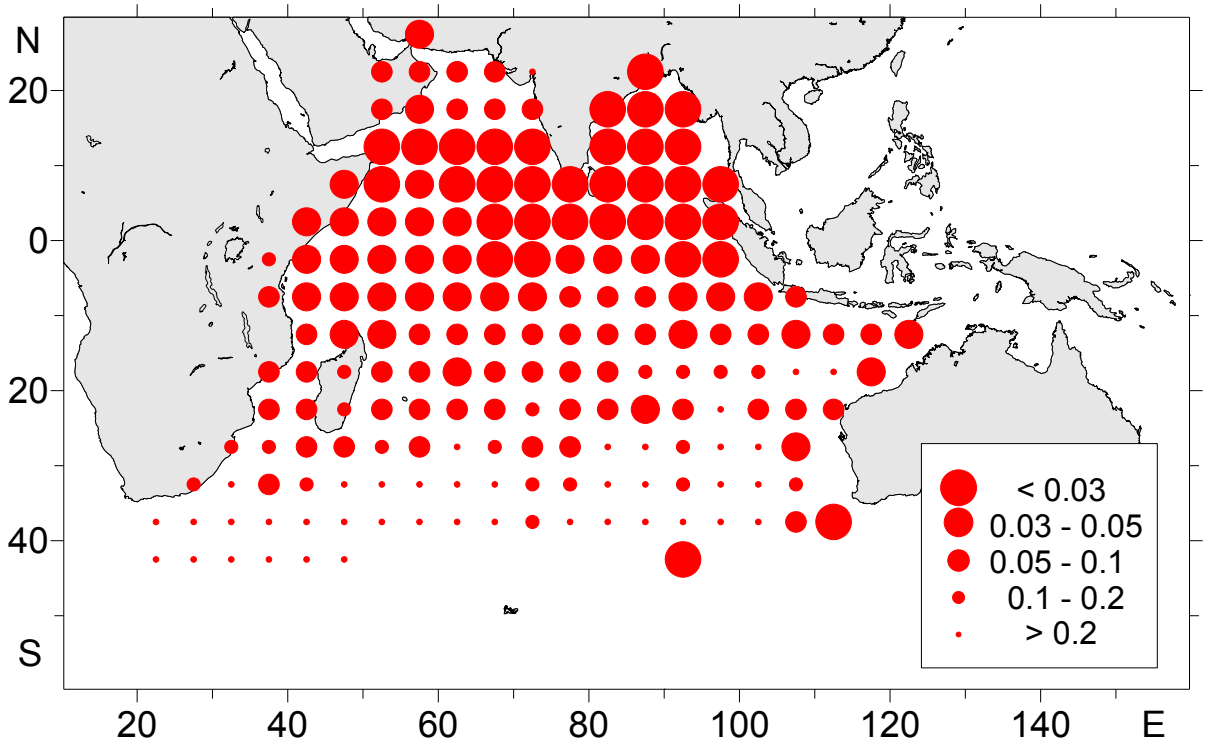






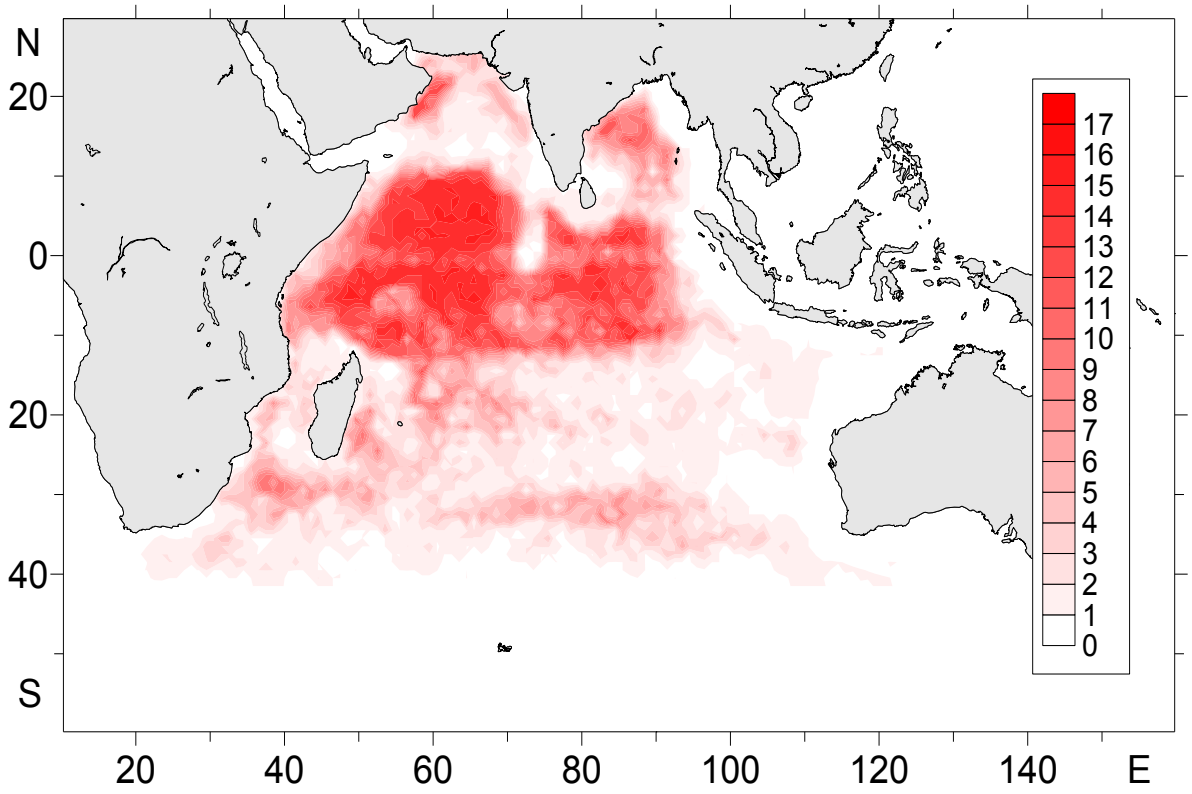
Definition of fishing area

- CPUE distribution of Taiwanese LL fleet



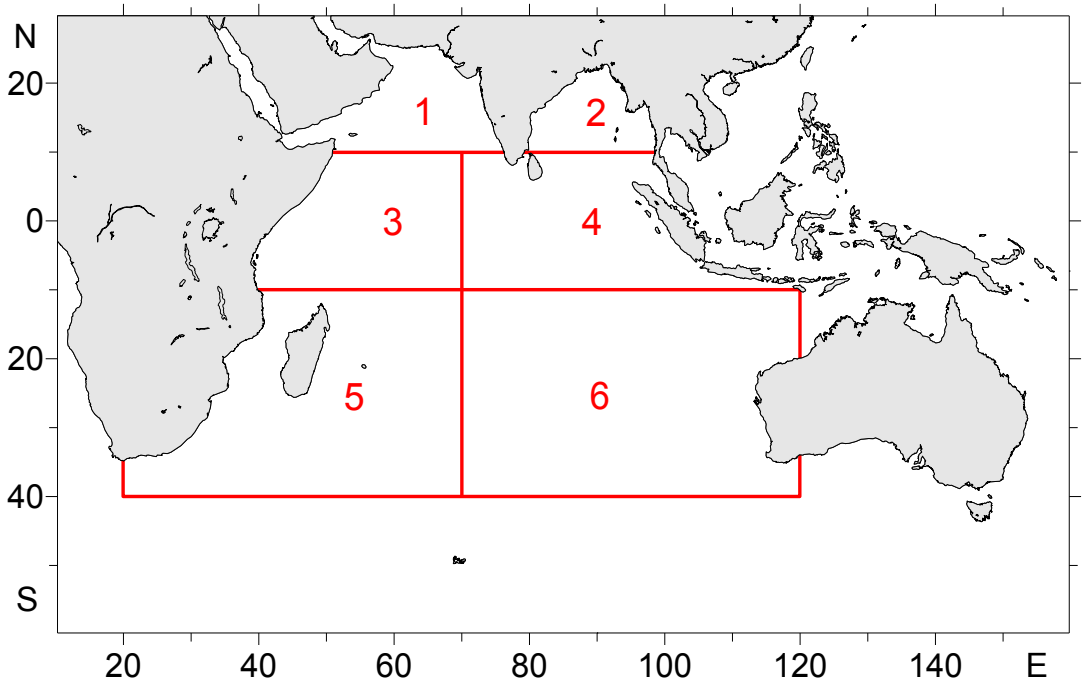
Definition of fishing area

- Distribution of number of years of catching BUM by Taiwanese LL fleet



Definition of fishing area

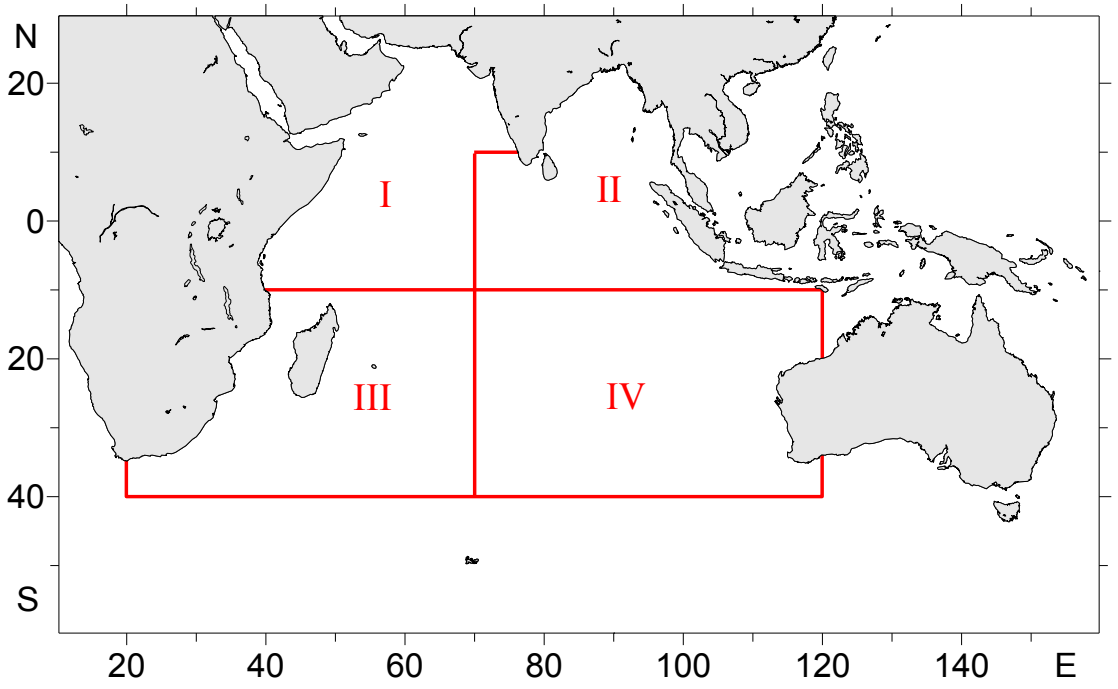
- 6 areas



Area 1	Area 2	Area 3	Area 4	Area 5	Area 6
0.083	0.040	0.132	0.167	0.253	0.326

Definition of fishing area

- 4 areas



Area I	Area II	Area III	Area IV
0.215	0.207	0.253	0.326

GLM analysis

- 6 areas + data set of 1995-2009 (1x1 grid)
  - Too many missing data before early 1990s

$$\text{Model 1}: \log(CPUE + c) = \mu + Y + Q + A + Y \times A + \varepsilon$$

$$\text{Model 2}: \log(CPUE + c) = \mu + Y + Q + A + Y \times A + V + \varepsilon$$

$$\text{Model 3}: \log(CPUE + c) = \mu + Y + Q + A + Y \times A + NHBF + \varepsilon$$

$$\text{Model 4}: \log(CPUE + c) = \mu + Y + Q + A + Y \times A + ENV1 + \varepsilon$$

$$\text{Model 5}: \log(CPUE + c) = \mu + Y + Q + A + Y \times A + ENV2 + \varepsilon$$

$$\text{Model 6}: \log(CPUE + c) = \mu + Y + Q + A + Y \times A + V + NHBF + ENV1 + ENV2 + Q \times A + Q \times NHBF + A \times NHBF + \varepsilon$$

GLM analysis

- 4 areas + data set of 1980-2009 (5x5 grid)

$$\text{Model 1}: \log(CPUE + c) = \mu + Y + Q + A + Y \times A + \varepsilon$$

$$\text{Model 2}: \log(CPUE + c) = \mu + Y + Q + A + Y \times A + V + \varepsilon$$

$$\text{Model 3}: \log(CPUE + c) = \mu + Y + Q + A + Y \times A + ALB + BET + YFT + \varepsilon$$

$$\text{Model 4}: \log(CPUE + c) = \mu + Y + Q + A + Y \times A + ENV1 + \varepsilon$$

$$\text{Model 5}: \log(CPUE + c) = \mu + Y + Q + A + Y \times A + ENV2 + \varepsilon$$

$$\text{Model 6}: \log(CPUE + c) = \mu + Y + Q + A + Y \times A + V + ALB + BET + YFT + ENV1 + ENV2 + Q \times A + Q \times ALB + Q \times BET + Q \times YFT + A \times ALB + A \times BET + A \times YFT + ALB \times BET + ALB \times YFT + \varepsilon$$

GLM analysis

- 4 areas + data set of 1995-2009 (1x1 grid)

$$\text{Model 1}: \log(CPUE + c) = \mu + Y + Q + A + Y \times A + \varepsilon$$

$$\text{Model 2}: \log(CPUE + c) = \mu + Y + Q + A + Y \times A + V + \varepsilon$$

$$\text{Model 3}: \log(CPUE + c) = \mu + Y + Q + A + Y \times A + NHBF + \varepsilon$$

$$\text{Model 4}: \log(CPUE + c) = \mu + Y + Q + A + Y \times A + ENV1 + \varepsilon$$

$$\text{Model 5}: \log(CPUE + c) = \mu + Y + Q + A + Y \times A + ENV2 + \varepsilon$$

$$\text{Model 6}: \log(CPUE + c) = \mu + Y + Q + A + Y \times A + V + NHBF + ENV1 + ENV2 + Q \times A + Q \times NHBF + A \times NHBF + \varepsilon$$

GLM analysis

- Model selection (6 areas + data set of 1995-2009 (1x1 grid))

	Model	Model DF	AIC	BIC	R2(%)	ΔR2(%)	ΔAIC	ΔBIC
	1	92	352590	353600	6.1			
	2	487	323458	328806	12.5	6.3	-29132	-24794
	3	94	351629	352661	6.3	0.2	-961	-939
ENV1	4	95	352596	353639	6.2	0.0	6	39
	5	98	350088	351165	6.7	0.5	-2501	-2435
	6	503	320381	325904	13.1	7.0	-32209	-27695

GLM analysis

- Model selection (4 areas + data set of 1980-2009 (5x5 grid))

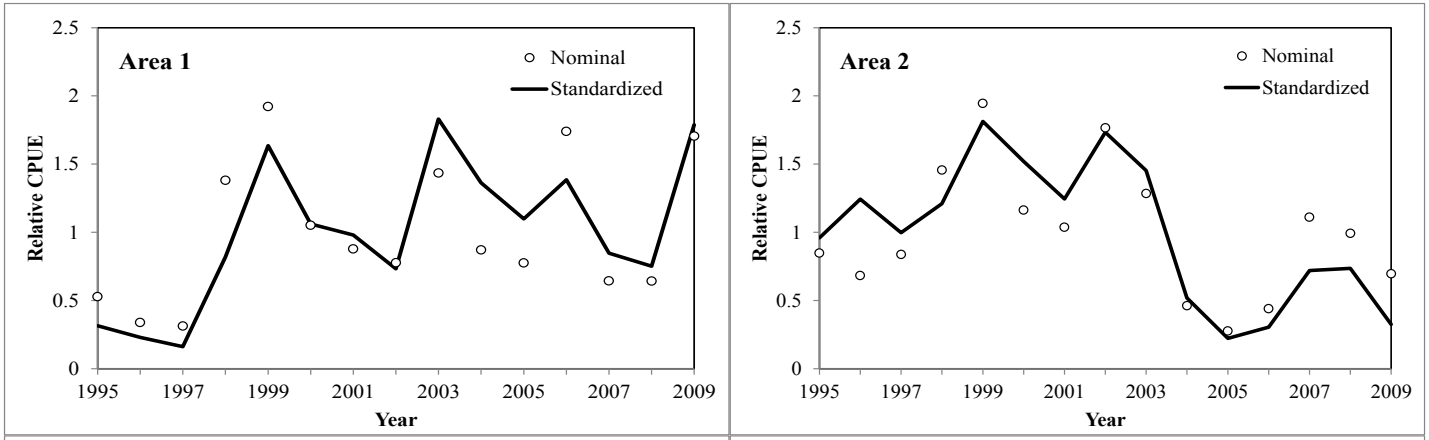
	Model	Model DF	AIC	BIC	R2(%)	ΔR2(%)	ΔAIC	ΔBIC
	1	122	598598	600010	9.5			
	2	869	547012	557067	15.5	6.0	-51586	-42943
	3	125	595687	597134	9.8	0.3	-2911	-2876
ENV1	4	124	598602	600037	9.5	0.0	4	27
	5	126	592761	594219	10.2	0.7	-5837	-5791
	6	896	536873	547239	16.6	7.1	-61726	-52771

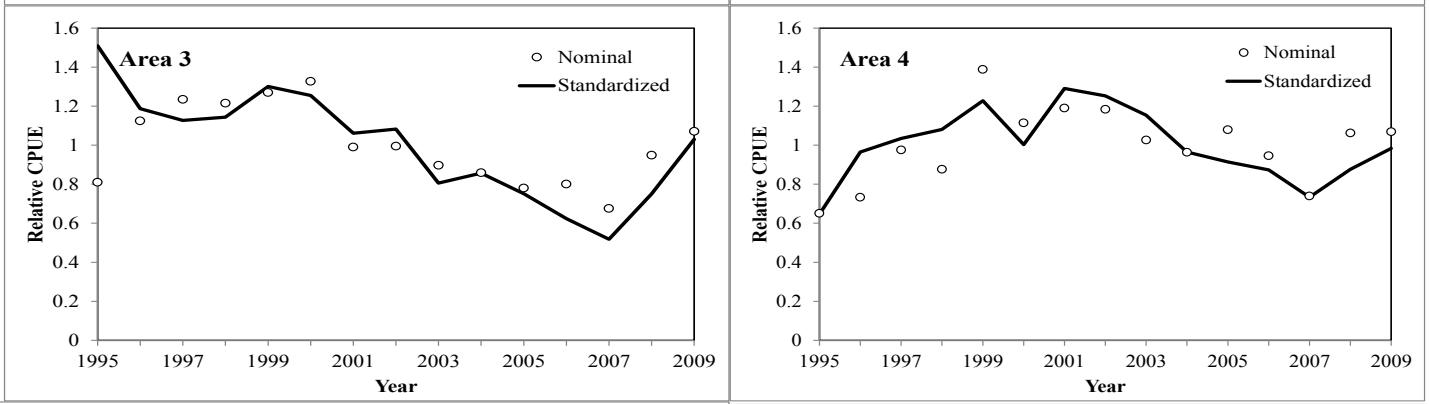
GLM analysis

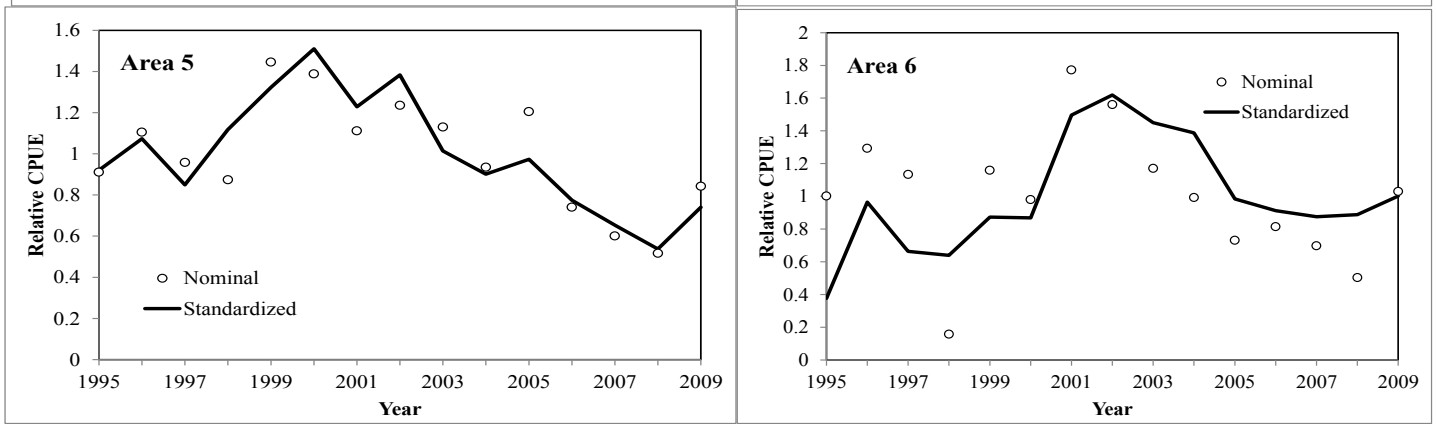
- Model selection (4 areas + data set of 1995-2009 (1x1 grid))

	Model	Model DF	AIC	BIC	R2(%)	ΔR2(%)	ΔAIC	ΔBIC
	1	62	355986	356666	5.4			
	2	457	325458	330476	12.0	6.6	-30527	-26190
	3	64	355224	355927	5.6	0.2	-762	-740
ENV1	4	65	355800	356514	5.4	0.0	-185	-152
	5	66	353885	354610	5.9	0.5	-2101	-2057
	6	484	321797	327111	12.8	7.4	-34189	-29555

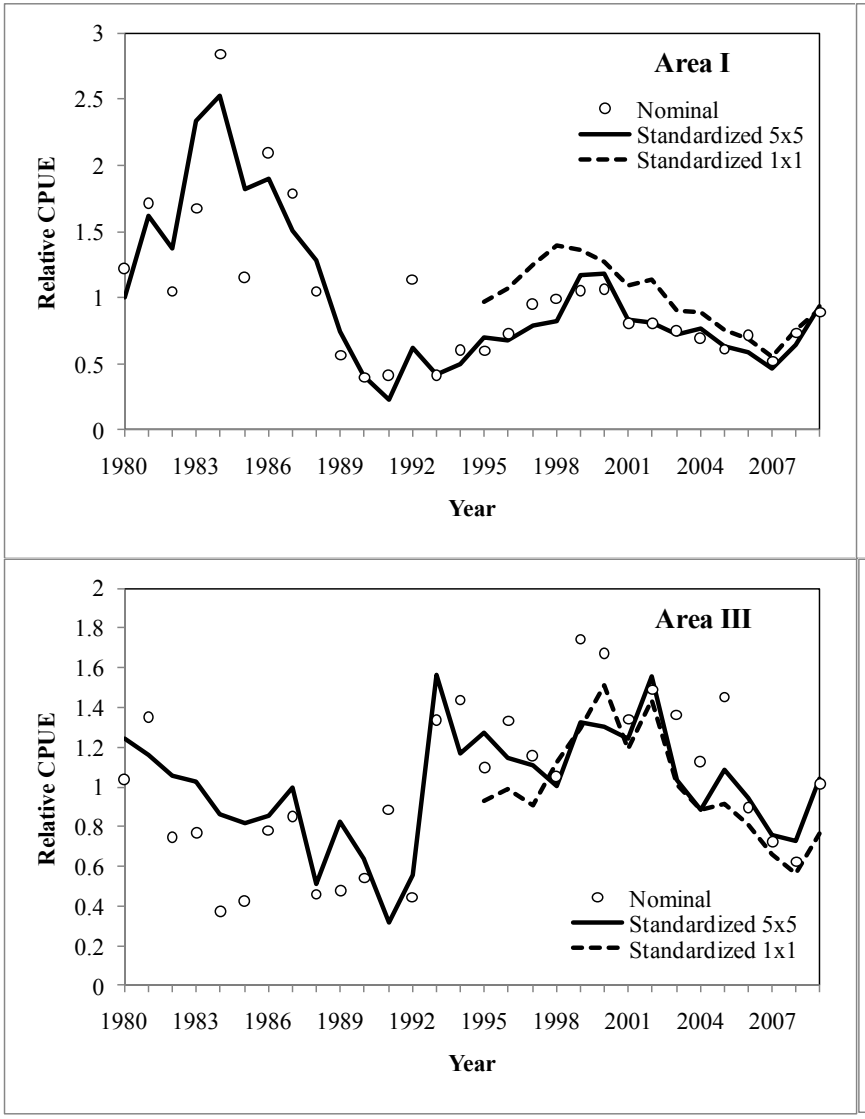
STD CPUE (6 areas + data set of 1995-2009)

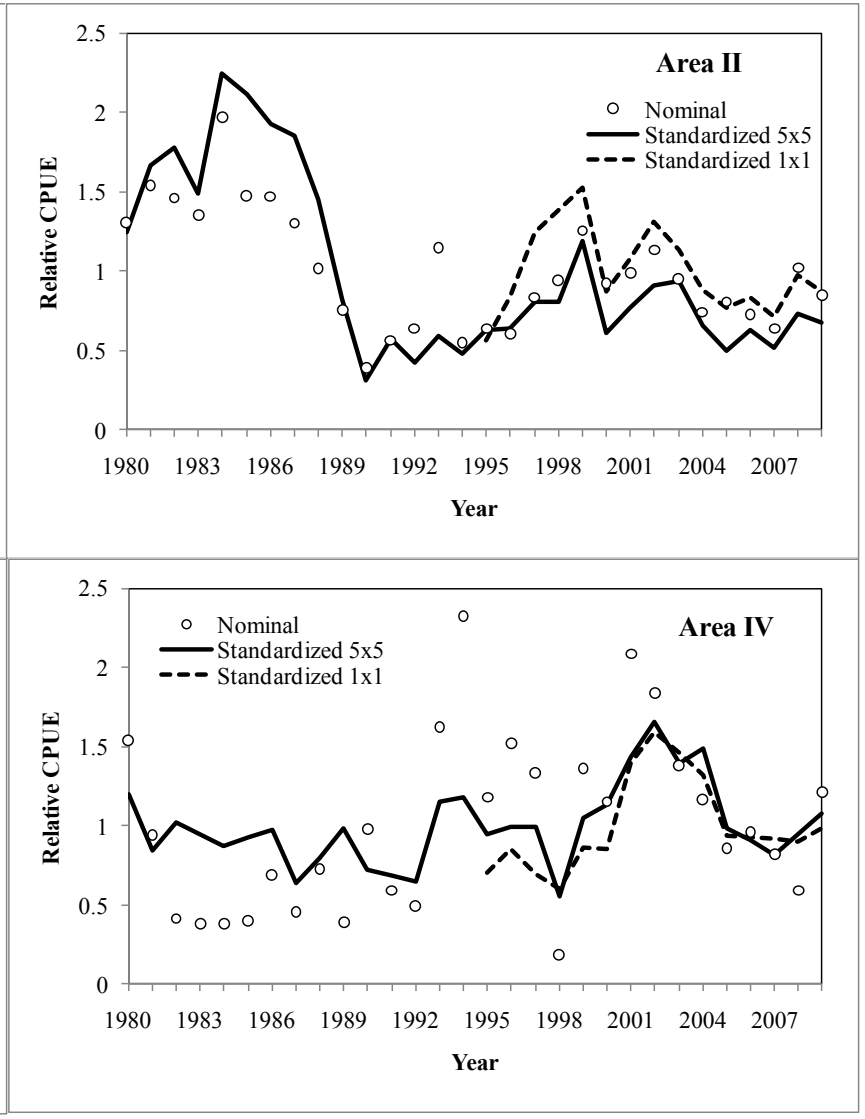




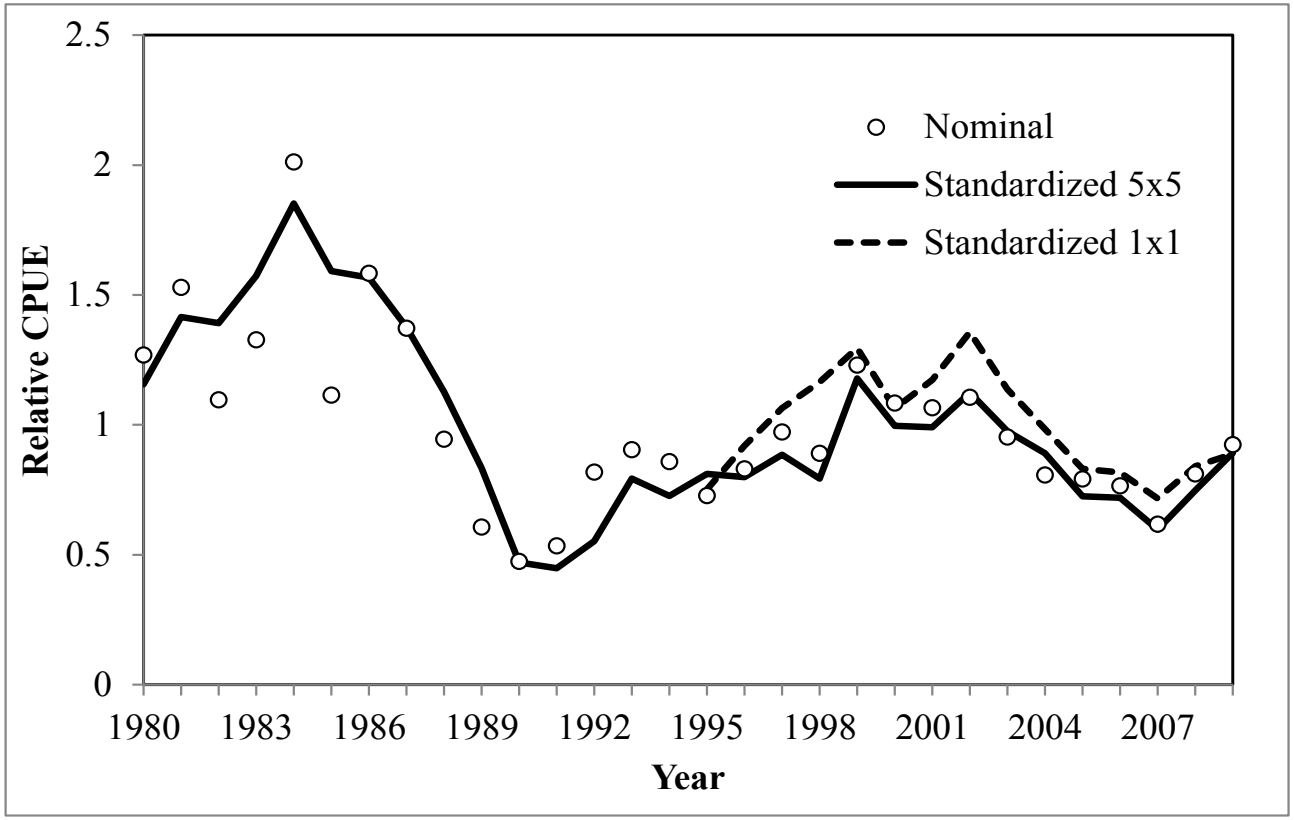


STD CPUE (6 areas + data set of 1980-2009 & 1995-2009)

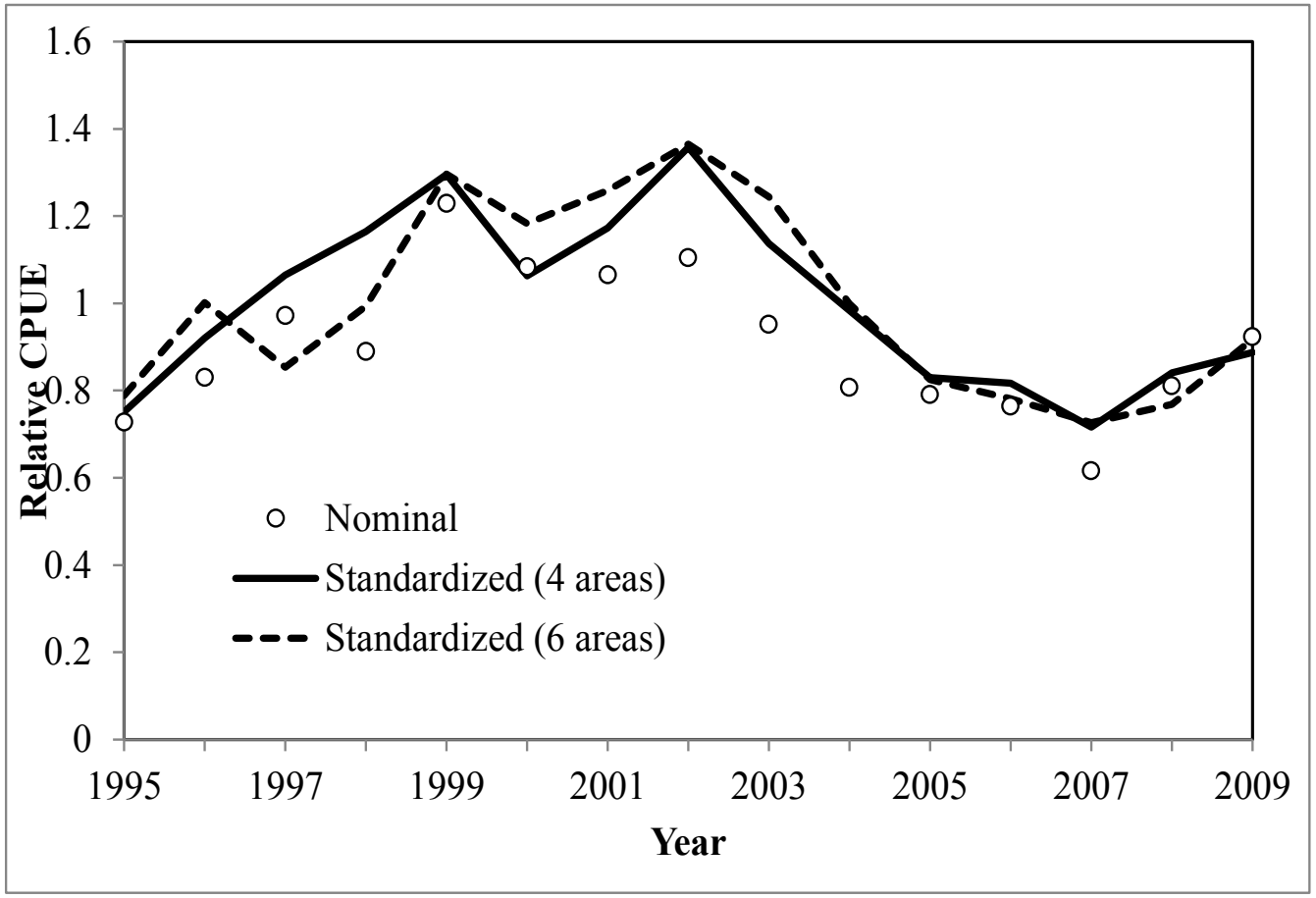




STD CPUE (6 areas + data set of 1980-2009 & 1995-2009)



STD CPUE (data set of 1995-2009 + 6 & 4 areas)



Because blue marlin is bycatch of Taiwan longline fleet, the proportion of 0 catch of blue marlin is very high and this might lead to the estimation problem when using GLM.

Therefore, alternative analysis approach could be used for further CPUE standardization, such as two-step delta-lognormal approach