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FURTHER ANALYSIS OF THE PROPORTION OF BIGEYE IN 'YELLOWFIN PLUS BIGEYE' CAUGHT BY PURSE SEINERS IN THE WCPFC STATISTICAL AREA

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TIMOTHY LAWSON[1]

[1] Oceanic Fisheries Programme, Secretariat of the Pacific Community, Noumea, New Caledonia

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Timothy Lawson
Oceanic Fisheries Programme
Secretariat of the Pacific Community
Noumea, New Caledonia

Introduction

Catches of bigeye tuna (*Thunnus obesus*) taken by purse seiners fishing in the WCPFC Statistical Area (Figure 1) are usually recorded on catch and effort logsheets and reports of unloadings as yellowfin (*Thunnus albacares*), since juvenile bigeye and yellowfin are difficult to distinguish. As a result, estimates of annual catches of bigeye must be adjusted to account for the bias introduced by the mid-identification of bigeye as yellowfin.

Lawson (2003, 2005) examined the relationship between the proportion of bigeye in catches of yellowfin and bigeye combined ('yellowfin plus bigeye') and several variables, including calendar year, quarter, MULTIFAN bigeye area, fishing entity (or 'flag') and school association, using observer data in regression trees and analyses of variance (ANOVA). Based on the results, the SPC Oceanic Fisheries Programme (OFP) has adjusted annual catch estimates and aggregated catch and effort data with an an analysis of variance including year and school association.

This study updates the analysis of variance with more recent observer data and examines the effect of latitude and longitude on estimates of the proportion of bigeye in 'yellowfin plus bigeye' and annual catches of bigeye. The number of observed purse-seine sets used in the analyses are summarised by year and flag, and year and school association, in Tables 1 and 2. Useable data covering 5,304 observed sets were available for analysis in this study (April 2007).

Data transforms

Lawson (2003, 2005) applied an arcsine–square root transform to the proportions of bigeye in 'yellowfin plus bigeye' determined from the observer data to improve normality and homoscedasticity (Snedecor & Cochran 1989). To examine the effect of transforms, analyses of variance were applied to data with (i) an arcsin-square root transform, (ii) a logit transform and (iii) not transformed, and predicitons of the proportion of bigeye in 'yellowfin plus bigeye' were compared to average annual values, by school association, determined from the observer data. If the transform does not introduce a bias in the predicted proportions, then the predicted proportions should lie in the vicinity of the averages determined from the observer data. The results (Figure 2) indicate that the use of the logit transform or no transform results in a negative and positive bias respectively. Predictions from the arcsin-square root transform lies in the vicinity of the annual averages, but exhibit less variability (which is to be expected, since the predictions do not include the effect of interactions between year and school association). While a more rigorous study based on sub-sampling could be conducted, this simple analysis supports the use of the arcsin-square root transform.

Analysis of variance with year and school association

The observer data were stratified by year, quarter, MULTIFAN bigeye region, school association and flag. For each stratum, the observed proportion of bigeye in 'yellowfin plus bigeye' was calculated as the ratio of the sum of the weights of bigeye sampled from all sets to the sum of the weights of yellowfin and bigeye sampled from all sets. The analysis was also conducted with the observed proportion calculated as the average proportion per set weighted by the catch of 'yellowfin plus bigeye' per set; while differences in the results were negligible, this method is not preferred because of possible bias in the relative proportions of skipjack and 'yellowfin plus bigeye' determined from observer data (Lawson & Williams, 2005).

Predictions of the proportion of bigeye in 'yellowfin plus bigeye' from the analysis of variance with more recent observer data are compared to the results from the same analysis conducted with the observer data that were available in May 2006 in Figure 3. The major differences are for 2005, for which additional observer data covering 49 sets are available; the additional data cover the fleets of Chinese Taipei (22 sets), Papua New Guinea (14 sets) and Japan (13 sets). With the additional data available in April 2007, the estimated proportion of bigeye in 'yellowfin plus bigeye' in 2005 appears to decline relative to 2004. Figure 3 suggests that this declining trend continued in 2006; however, the results for 2006 are based on only 29 sets and may change as additional data collected by national and sub-regional observer programmes are compiled by the OFP.

Catches of bigeye in the WCPFC Statistical Area during 1995–2005 (Figure 4) were estimated by applying the predictions to aggregated catch data which have not already been adjusted prior to being provided to the OFP and for which observer data are available. Table 3 summarises the amounts of 'yellowfin plus bigeye' that were adjusted, by year; the average annual proportion was 68.0%. Fleets for which catches have already been adjusted include the offshore and distant-water fleets of Japan, and the Spanish fleet. Fleets for which no observer data are available include the coastal fleet of Japan and the domestic fleets of Indonesia and the Philippines.

The trend in the estimates of annual catches based on the analysis of data available in April 2007 are similar to the trend in estimates based on the analysis of data available in May 2006, although the estimate for 2005 that is based on the more recent data is somewhat lower than that based on data available in May 2006.

Effect of latitude and longitude

Figure 5 shows the geographic distribution of catches of 'yellowfin plus bigeye' from 1995 to 2005. The distribution of the catch by geographic area and school association has varied considerably among years.

The effect of latitude and longitude on the proportion of bigeye in 'yellowfin plus bigeye' was examined with a general additive model (GAM) including year and school association as factors, and latitude and longitude smoothed with cubic splines. The observer data were stratified by year, school association, latitude (2° intervals) and longitude (5° intervals) and, for each stratum, the observed proportion of bigeye in 'yellowfin plus bigeye' was calculated as the ratio of the sum of the weights of bigeye sampled from all sets to the sum of the weights of yellowfin and bigeye sampled from all sets. An arcsin-square root transform was applied. The degrees of freedom for latitude and longitude were selected by comparing the Bayesian information criterion (BIC).

A GAM including year and school as factors, and latitude and longitude smoothed with a two-dimensional spline (instead of two separate one-dimensional splines) was also considered, but the two-dimensional spline did not improve the fit and so this model was not examined further.

Catches of bigeye for each stratum of year and school association in the 'yellowfin plus bigeye' catch data that require adjustment were estimated by (i) taking 1000 samples from the joint posterior distribution of the GAM parameter estimates, (ii) applying each of the 1000 sets of GAM parameters to the 'yellowfin plus bigeye' catch data for which adjustment is required (stratified by year, school association, 2° intervals of latitude and 5° intervals of longitude) to predict 1000 values of the catch for each stratum of year, school association, latitude and longitude, (iii) summing the catch estimates across latitude and longitude within each stratum of year and school association, for each of the 1000 sets, and (iv) calculating the median of the 1000 values of the bigeye catch within each stratum of year and school association. The proportions of bigeye in 'yellowfin plus bigeye', by year and school, were estimated as the ratio of the estimate of the catch of bigeye to the catch of 'yellowfin plus bigeye' for the stratum of year and school. Confidence regions were determined from the 2.5% and 97.5% quantiles of the 1000 values of the catch of bigeye.

A similar method was used to estimate the proportions of bigeye in 'yellowfin plus bigeye' by school and latitude, and by school and longitude.

Total annual catches of bigeye in the WCPFC Statistical Area were determined by summing the catches estimated with the GAM across school associations, and adding the result to the estimates of bigeye catches that did not require adjustment. Confidence regions for the total annual catches were determined from the confidence regions for each stratum of year and school.

Figure 6 compares the estimates of the proportion of bigeye in 'yellowfin plus bigeye' determined from the ANOVA with year and school association, and from the GAM with year, school association, latitude and longitude; estimates from the GAM for 2006 are not shown since the catch data required in step (ii) above were not yet complete at the time of the analysis. While the trends are almost identicial, the estimates from the GAM are generally lower than the estimates from the ANOVA when the school type was fished further to the west and higher when fished further to the east (Figure 5).

The effect of longitude is clear in Figure 7, which presents the estimates of the proportion of bigeye in 'yellowfin plus bigeye' determined from the GAM, by school and latitude and by school and longitude. For all school associations, values peak at the equator and decline with higher latitudes, and generally increase from western to eastern longitudes.

Figure 8 compares estimates of the annual catches of bigeye in the WCPFC Statistical Area determined from the ANOVA and the GAM. Consistent with Figure 7, the estimates of the total bigeye catch determined from the GAM are generally less than those from the ANOVA for those years when fishing was further to the west and greater when further to the east.

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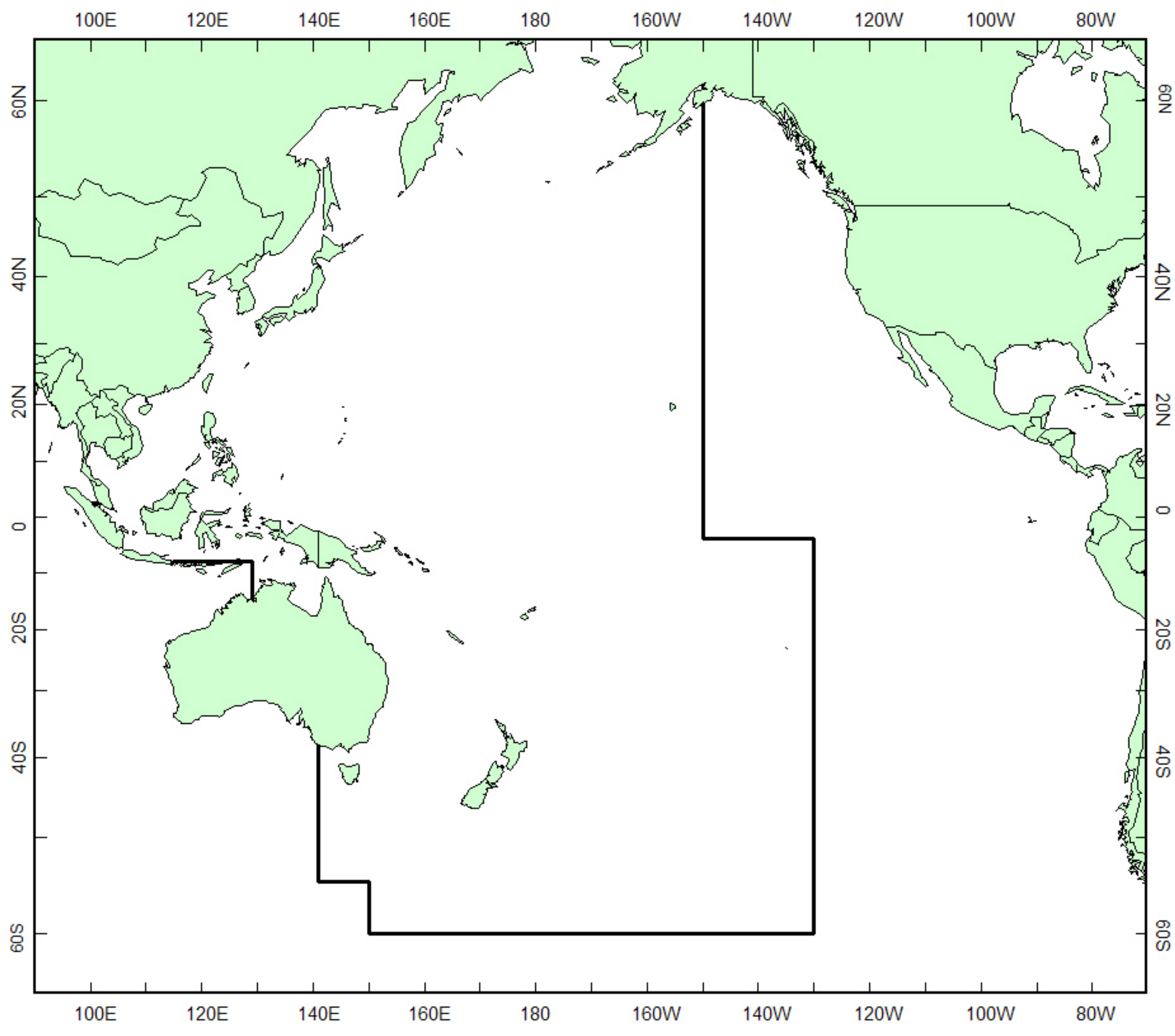
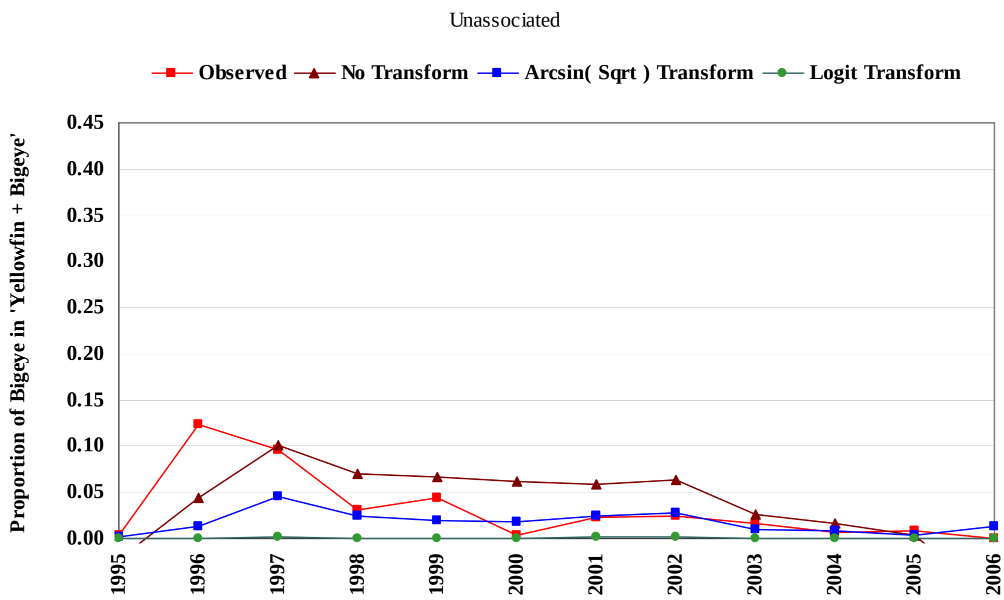


Figure 1. WCPFC Statistical Area

Figure 2. Comparison of proportions of bigeye in 'yellowfin plus bigeye' for unassociated schools predicted from analyses of variance with year and school association, for data with (i) an arcsin-square root transformation, (ii) a logit transformation and (iii) not transformed, and (iv) average proportions of bigeye in 'yellowfin plus bigeye' determined from the observer data



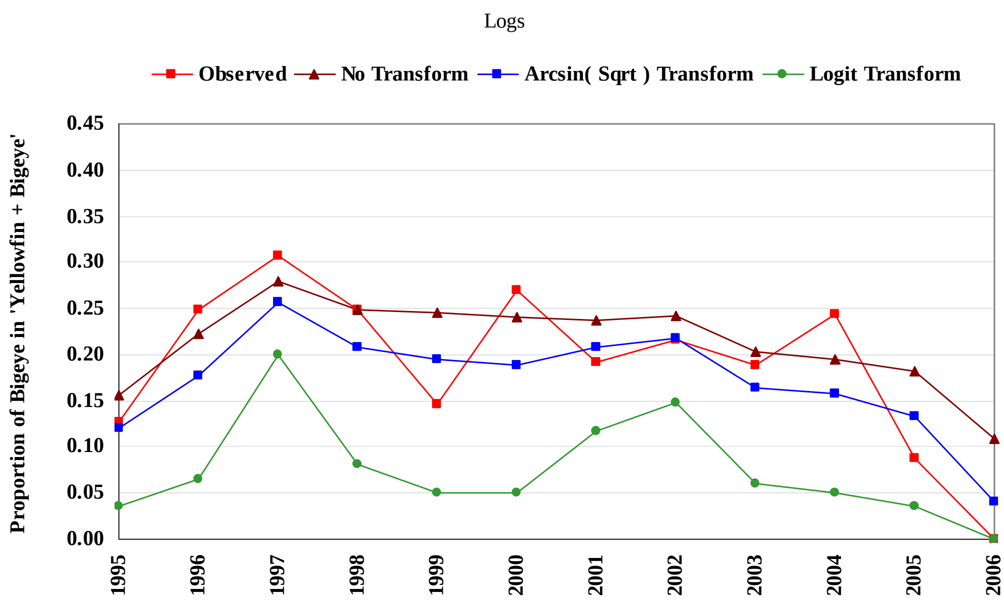
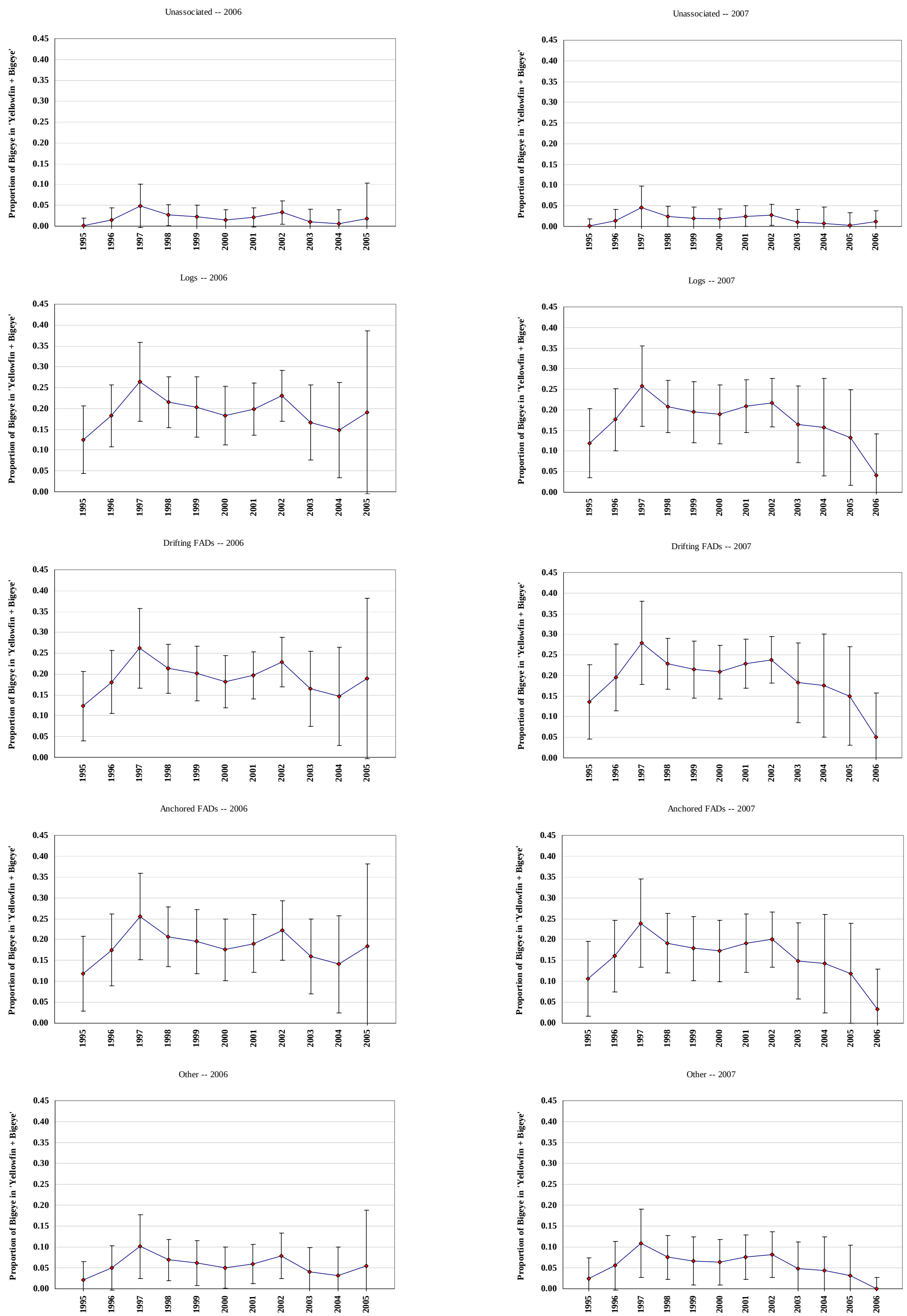


Figure 3. Predictions of the proportion of bigeye in ‘yellowfin plus bigeye’ based on observer data available in May 2006 and in April 2007, by school association



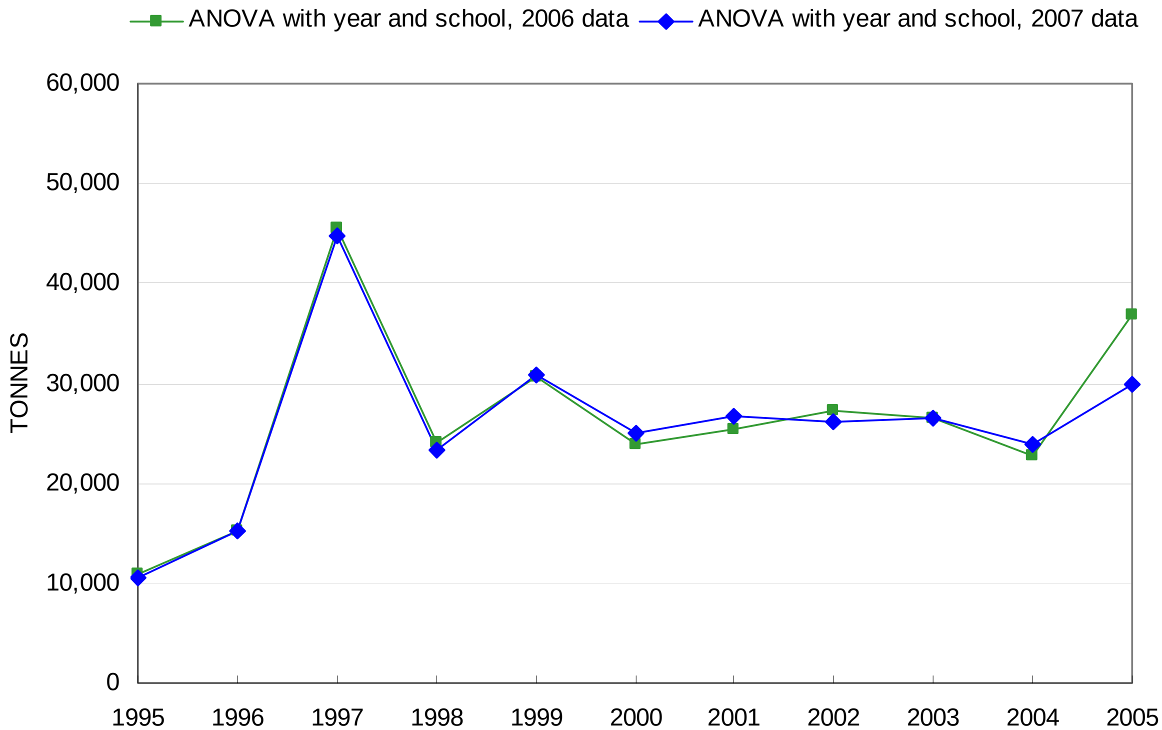


Figure 4. Catches of bigeye by purse seiners in the WCPFC Statistical Area estimated from analyses of variance with year and school association, based on observer data available in May 2006 and April 2007

Figure 5. Purse-seine catches of ‘yellowfin plus bigeye’, by school association, 1995–2005

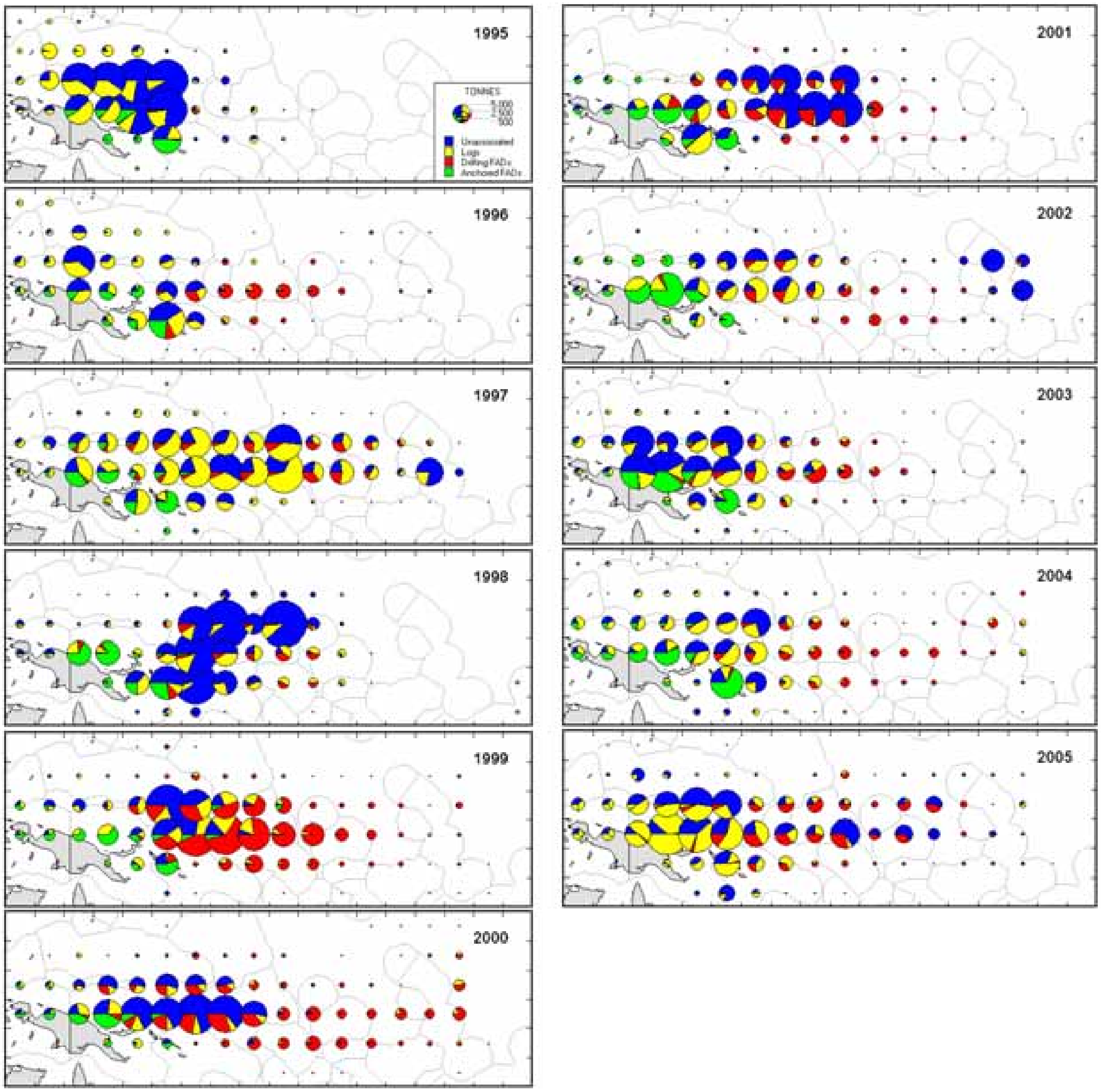


Figure 6. Estimates of the proportion of bigeye in 'yellowfin plus bigeye' determined from an analysis of variance with year and school association, and a general additive model with year, school association, latitude and longitude

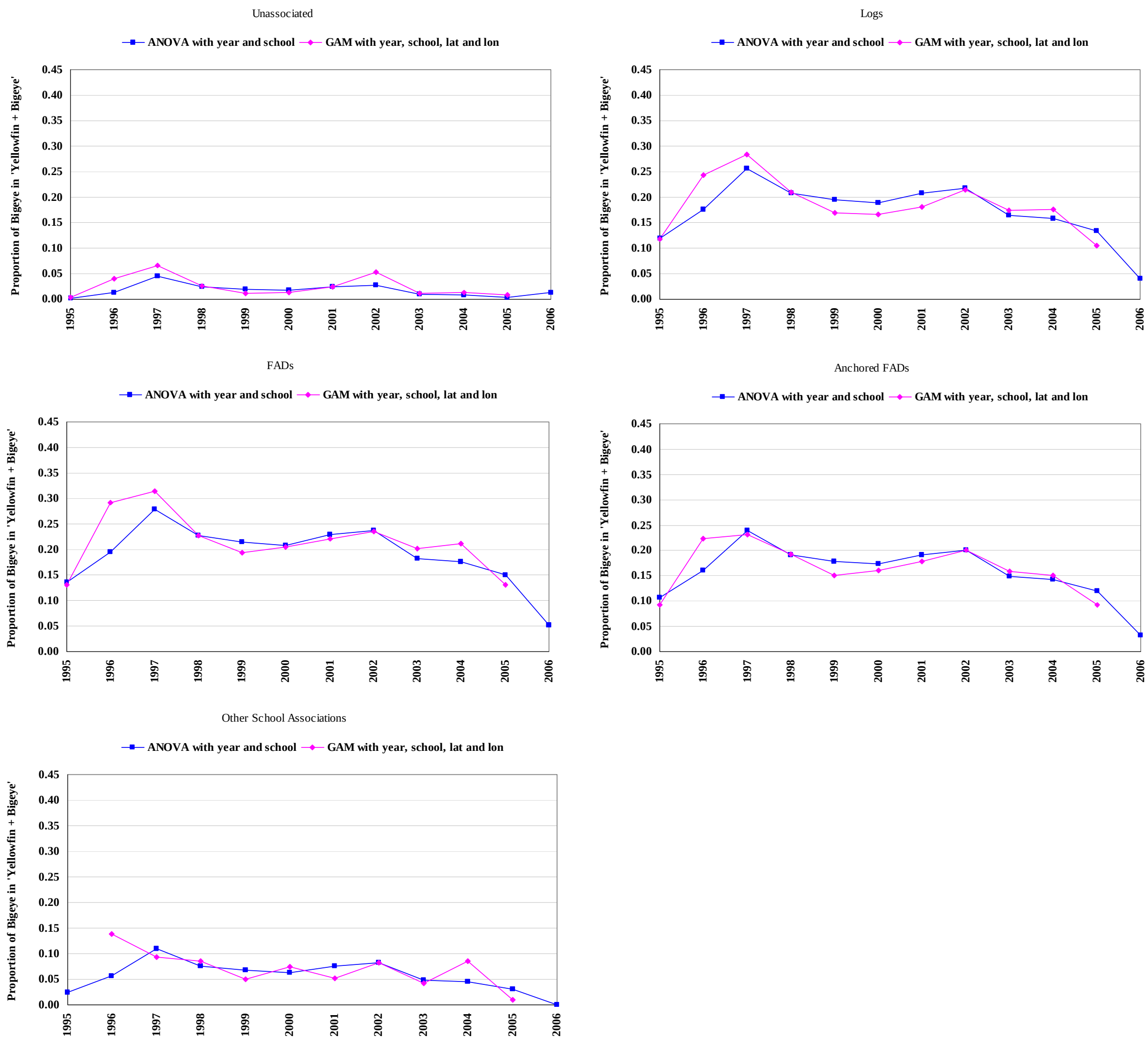
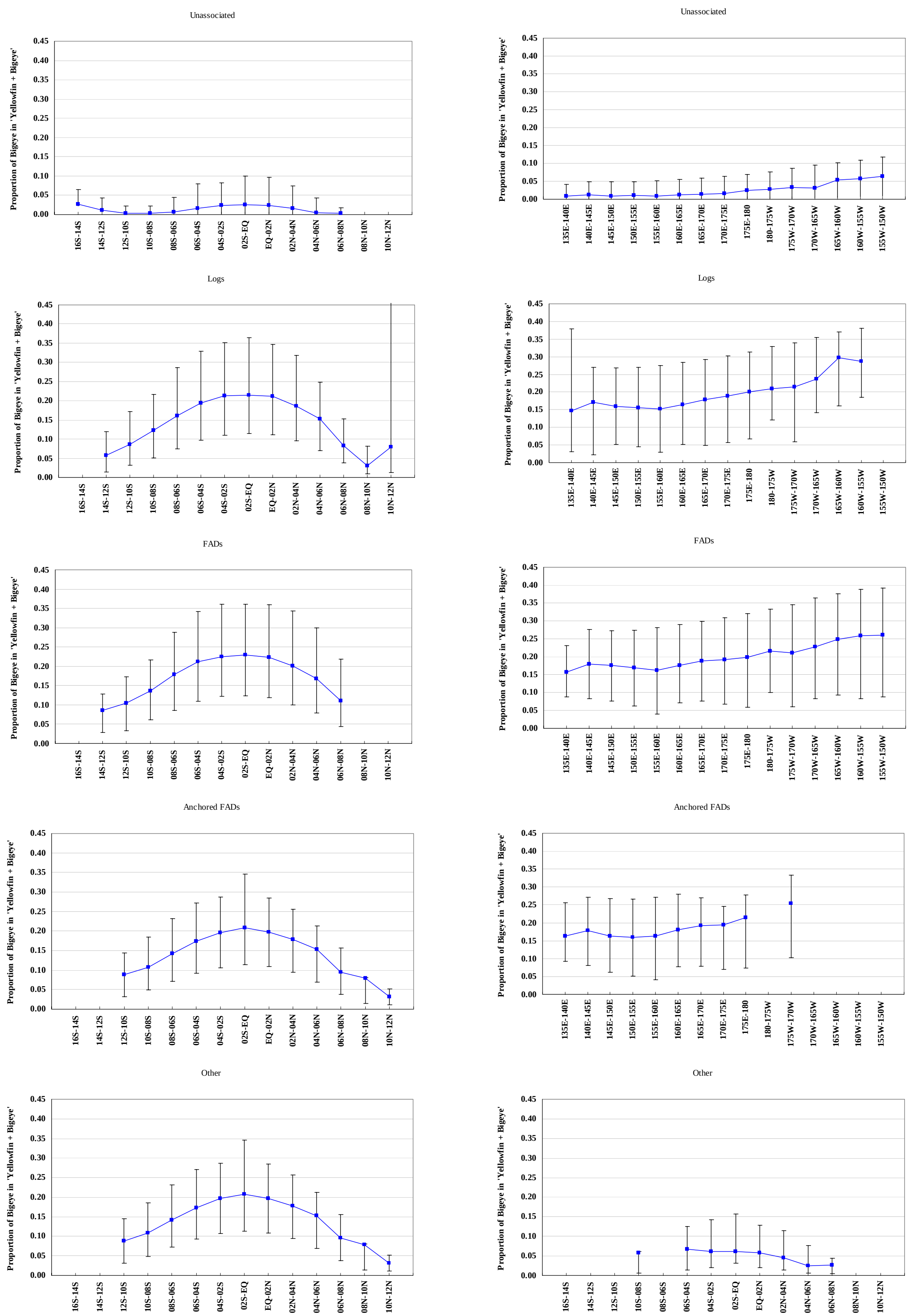


Figure 7. Proportion of bigeye in 'yellowfin plus bigeye' determined from a GAM with year, school association, latitude and longitude, by latitude and by longitude



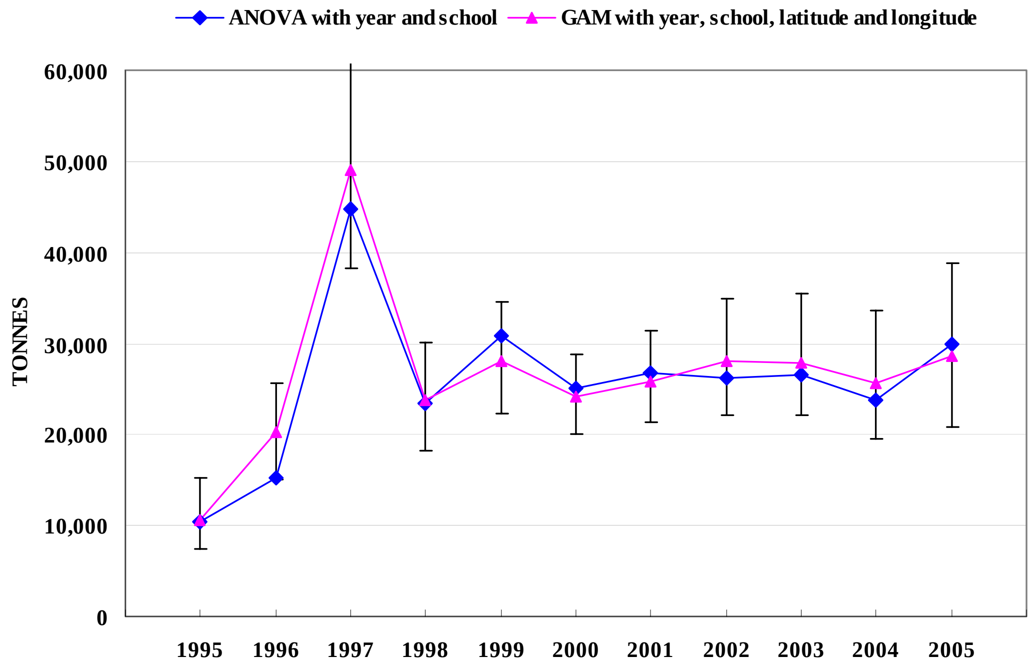


Figure 8. Estimates of the catch of bigeye by purse seiners in the WCPFC Statistical Area determined from an ANOVA with year and school association, and a GAM with year, school association, latitude and longitude. The confidence regions are for the GAM-based estimates.

Table 1. Number of species composition samples, containing yellowfin and bigeye, collected by observers from purse seiners, by year and fishing entity. Key: FM = Federated States of Micronesia, JP = Japan, KI = Kiribati; KR = Republic of Korea, MH = Marshall Islands, PG = Papua New Guinea, PH = Philippines, SB = Solomon Islands, TW = Chinese Taipei, US = United States of America, VU = Vanuatu.

Year	FM	JP	KI	KR	MH	PG	PH	SB	TW	US	VU	Total	%
1995	17	12	0	8	0	8	0	0	30	0	0	75	1.4
1996	8	10	0	58	0	7	17	0	143	0	8	251	4.7
1997	0	22	0	35	0	31	43	0	108	3	24	266	5.0
1998	4	30	0	119	0	72	0	23	285	156	8	697	13.1
1999	0	13	5	52	0	43	14	70	40	263	6	506	9.5
2000	38	33	6	45	0	82	0	15	58	314	0	591	11.1
2001	51	44	0	24	21	66	41	9	95	438	0	789	14.9
2002	44	28	7	10	1	701	361	172	85	198	0	1,607	30.3
2003	0	0	0	8	0	80	73	31	2	62	0	256	4.8
2004	0	0	0	0	0	90	0	0	48	0	0	138	2.6
2005	0	13	0	0	0	14	0	0	72	0	0	99	1.9
2006	0	0	0	8	0	5	0	0	16	0	0	29	0.5
Total	162	205	18	367	22	1,199	549	320	982	1,434	46	5,304	100.0
%	3.1	3.9	0.3	6.9	0.4	22.6	10.4	6.0	18.5	27.0	0.9	100.0	

Table 2. Number of species composition samples, containing yellowfin and bigeye, collected by observers from purse seiners, by year and school association

Year	Log	Drifting FAD	Anchored FAD	Other Associated	Unassociated	Total	%
1995	43	8	1	11	12	75	1.4
1996	166	21	11	10	43	251	4.7
1997	123	62	31	12	38	266	5.0
1998	267	126	71	34	199	697	13.1
1999	26	300	108	7	65	506	9.5
2000	26	432	44	13	76	591	11.1
2001	92	434	82	15	166	789	14.9
2002	311	255	890	21	130	1,607	30.3
2003	64	22	137	9	24	256	4.8
2004	36	7	83	3	9	138	2.6
2005	26	30	0	2	41	99	1.9
2006	4	18	0	0	7	29	0.5
Total	1,184	1,715	1,458	137	810	5,304	100.0
%	22.3	32.3	27.5	2.6	15.3	100.0	

Table 3. Amounts of 'yellowfin plus bigeye' that were adjusted and not adjusted in the estimation of annual catches of bigeye

Year	Adjusted		Unadjusted		Total
	Tonnes	%	Tonnes	%	
1995	131,268	65.6%	68,884	34.4%	200,152
1996	86,221	63.8%	48,878	36.2%	135,099
1997	202,644	69.3%	89,924	30.7%	292,568
1998	215,599	76.1%	67,709	23.9%	283,308
1999	158,319	66.6%	79,370	33.4%	237,689
2000	142,101	64.7%	77,467	35.3%	219,568
2001	171,336	70.5%	71,622	29.5%	242,958
2002	137,227	64.6%	75,273	35.4%	212,500
2003	166,197	68.1%	77,895	31.9%	244,092
2004	116,384	60.7%	75,347	39.3%	191,731
2005	200,878	71.1%	81,762	28.9%	282,640
Average	157,107	68.0%	74,012	32.0%	231,119