SCTB16 Working Paper

SWG–6

ANALYSIS OF THE PROPORTION OF BIGEYE IN 'YELLOWFIN PLUS BIGEYE' CAUGHT BY PURSE SEINERS IN THE WESTERN AND CENTRAL PACIFIC OCEAN, BASED ON OBSERVER DATA

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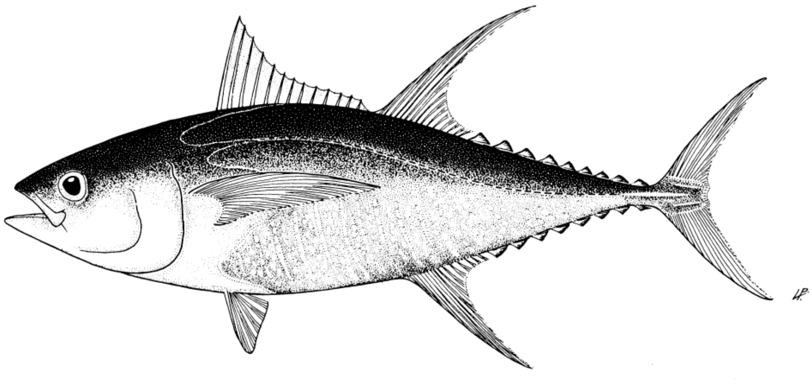

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INTRODUCTION

Catches of bigeye tuna (*Thunnus obesus*) taken by purse seiners fishing in the Western and Central Pacific Ocean (WCPO) are usually recorded on catch and effort logsheets as yellowfin (*Thunnus albacares*), since juvenile bigeye and yellowfin are difficult to distinguish. Furthermore, the prices paid by canneries for bigeye and yellowfin are usually the same; hence, there is no incentive to record the catches and landings of the two species separately.

Species composition samples that are collected by port samplers and observers can be used to correct the bias introduced by the mis-identification of bigeye as yellowfin. In this study, observer data held by the SPC Oceanic Fisheries Programme (OFP) are used to analyse the proportion of bigeye in the combined catch of yellowfin and bigeye ('yellowfin plus bigeye').

Bigelow (2001) conducted a similar analysis; however, a subsequent examination of the quality of the data suggested that many were unreliable (Lawson 2002a). In consequence, the quality of observer data held by the OFP for 1998–2001 was evaluated. Observer data for other years will be evaluated in due course.

This study examines the relationship between the proportion of bigeye in yellowfin plus bigeye and several variables, including calendar year, quarter, geographic area, fishing entity (or 'flag') and school association. Various analysis of variance (anova) models are used to derive input data for the MULTIFAN-CL assessment of bigeye (Hampton 2002). The proportion of bigeye in yellowfin plus bigeye may be related to the size of fish; however, since the available size sampling data may not be sufficient to enable purse-seine catches to be partitioned into size groups, the analyses were conducted both by excluding and including size group as an independent variable.

SOURCE OF DATA

At the time of writing, the OFP held species composition data for 4,078 purse-seine sets sampled from 1993 to 2002 by observers from SPC and the national observer programmes of SPC member countries and territories. For the purposes of the present analysis, the data were screened in the following order:

- All samples were taken within the MULTIFAN-CL Bigeye Areas 2 and 3 (Figure 1), except for 5 samples from Area 4 and 49 samples from Area 5. Since there was insufficient data to examine the proportion of bigeye in yellowfin plus bigeye in Areas 4 and 5, and also because the MULTIFAN-CL analysis restricted purse seine to Areas 2 and 3, the present study was therefore restricted to Areas 2 and 3. As a result, the 54 samples that were not from Areas 2 and 3 were not used.
- There were 706 samples for which the school association was unknown. Since including a school association category of 'unknown' in the analysis would almost certainly decrease the information content of the data, in regard to school association, these samples were not used.
- There were 208 samples from 'skunk sets', which were defined as those for which the catch was less than or equal to 2.5 tonnes. Since these samples may not have been representative of the entire school, they were not used.
- There were 764 sets for which no yellowfin or bigeye were sampled; therefore, these samples were not used.

- There were 430 sets for which the total number of bigeye and yellowfin sampled was less than 10; these small samples were not used since several resulted in estimates of the proportion of bigeye in yellowfin plus bigeye that were considered to be outliers.
- There were 401 samples that were not used because the species composition samples were evaluated to be of poor quality.
- Finally, there were 7 samples from years other than 1998–2001. Since these samples were insufficient to examine the proportion of bigeye in yellowfin plus bigeye in other years, they were not used.

Summaries of the number of the remaining 1,508 samples, by year and school association, by year and quarter, by year and bigeye area, and by year and flag, are presented in Tables 1–4 respectively.

ANALYSIS OF VARIANCE AMONG SAMPLES

The variance of the proportion of bigeye in yellowfin plus bigeye among samples was examined. The independent variables were all categorical, with four categories of year (1998–2001), four categories of quarter (January-March, April-June, July-September, October-December), two categories of area (Bigeye Areas 2 and 3), and three categories of school association (drifting log, drifting FAD, and unassociated or feeding on baitfish). Separate categories of flag were included for the major fleets (Japan, Korea, Taiwan and the United States), while all other flags were included in a combined category. The dependent variable was the proportion of bigeye in yellowfin plus bigeye, measured in weight (rather than numbers of fish), for each sample, where the weights of bigeye and yellowfin in the sample were determined from lengths using length-weight parameters $2.34684 \cdot 10^{-5}$ and 2.975750 for bigeye, and $1.90800 \cdot 10^{-5}$ and 2.977619 for yellowfin.

Several models were examined by analysis of variance. The models differed in the independent variables examined and by including or excluding second order effects. The following problems with the analysis of variation among samples became apparent.

First, since the samples were not independent[1], several first-order and second-order effects may have been identified as statistically significant when they were probably insignificant.

Second, since the number of samples and, hence, the number of degrees of freedom, was large, some effects were identified as statistically significant even though, quantitatively, the effects were insignificant.

Third, since the number of samples from the United States fleet accounted for 52.5 percent of the total, the results of the analyses of variance were strongly influenced by these samples.

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[1] The use of inferential statistics in data from experiments in which replicates are not statistically independent is termed *pseudoreplication* (Hulbert 1984). As a result of pseudoreplication, the variance in error terms used in statistical tests is under-estimated.

ANALYSIS OF VARIANCE AMONG STRATA

Replicates

In order deal with the problems noted above, the data were grouped into replicates for each strata of year – quarter – area – flag – school association, wherein each replicate represented the average proportion of bigeye in yellowfin plus bigeye determined from samples within the stratum. In order to further avoid outliers, only replicates that were based on at least five samples were included in the analysis.

There were a total of 67 replicates. The number of replicates, by category, is given below:

Year	Quarter	Area	Flag	School
1998: 26	qq1: 14	area_2: 23	JP : 5	FAD : 29
1999: 9	qq2: 23	area_3: 44	KR : 9	LOG : 16
2000: 14	qq3: 17		TW : 15	SCHOOL: 22
2001: 18	qq4: 13		US : 26	
			OTHER: 12	

Figures 2–6 show the distribution of the proportion of bigeye in yellowfin plus bigeye by variable. The proportions for all categories within each variable overlap to a large extent, except for school association, for which the proportions for school sets are much lower than those for log sets and FAD sets.

Regression tree

The data were first examined with binary recursive partitioning. The vertical distance between the nodes in the resulting regression tree (Figure 7) is proportional to the change in deviance and, hence, is a measure of the importance of the predictor. It can be seen that school association is by far the most important variable, followed to a lesser degree by flag and area. Figure 8 plots a complexity parameter table for the regression tree and indicates that the model should be pruned with a complexity parameter of 0.25. The resulting regression tree contained only three nodes, including the root node, one for school sets and one for FAD and log sets combined; all other variables were excluded from the pruned regression tree.

Anova #1

An analysis of variance was conducted with all first-order effects, after applying an arcsine–square root transformation to improve normality and homoscedasticity (Snedecor & Cochran 1989). However, interpretation of the results is complicated by the fact that the variables are unbalanced; that is, the number of replicates for a particular variable is not the same for each category of the other variables. When variables are unbalanced, the table of results of an analysis of variance should be interpreted as the effects of adding a variable to a model containing the variables above it. Therefore, the order in which the variables are listed in the table can affect the F values and the corresponding probablity levels. In order to minimise this problem, the residual sum of squares was determined after dropping each term from the model; the analysis of variance was then conducted with the results listed for variables in the order of their effect on the residual sum of squares.

The table below shows the effect of dropping each term from the analysis of variance with all first-order effects.

	Df	Sum of Sq	RSS
sch	2	2.474	3.454
flag	4	0.268	1.248
yy	3	0.212	1.192
area	1	0.090	1.070
qq	3	0.057	1.037

School association has the most important effect on the residual sum of squares, followed by flag, year, area and quarter, in that order. The results from the analysis of variance, with variables listed in order of their effect on the residual sum of squares, is given below. If variables with $p<0.001$ are considered strongly related to the proportion of bigeye in yellowfin plus bigeye and if variables with $0.001<p<0.01$ are considered weakly related, then school association and year are strongly-related variables and no other variables are statistically related.

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
sch	2	2.63403	1.31701	71.2169	9.992e-16
flag	4	0.26457	0.06614	3.5766	0.011790
yy	3	0.36896	0.12299	6.6504	0.000678
area	1	0.08764	0.08764	4.7389	0.033963
qq	3	0.05702	0.01901	1.0278	0.387776
Residuals	53	0.98013	0.01849		

The residuals from Anova #1 are plotted in Figures 9–13 against the variables. For most categories, the interquartile ranges are symetrically distributed about zero and the medians are close to zero; hence, the fit is relatively good.

Anova #2

A second analysis of variance was conducted with the significant effects from Anova #1, i.e. school association and year. The results below indicate that in the absence of other effects, school association is strongly related and year is weakly related.

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
sch	2	2.63403	1.31701	56.2767	1.41e-14
yy	3	0.33076	0.11025	4.7112	0.005057
Residuals	61	1.42755	0.02340		

Anova #3

A third analysis of variance was conducted with first-order and second-order effects of school association and year. The results below indicate that in the presence of second-order effects, school association is strongly related, while no other effects are related.

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
sch	2	2.63403	1.31701	57.6758	7e-07
yy	3	0.33076	0.11025	4.8283	0.01982
sch:yy	5	0.22159	0.04432	1.9409	0.16081
sch:flag	12	0.41871	0.03489	1.5280	0.23680
sch:qq	9	0.16955	0.01884	0.8250	0.60623
sch:area	3	0.11000	0.03667	1.6058	0.23982
yy:flag	10	0.10931	0.01093	0.4787	0.87400
yy:qq	8	0.10045	0.01256	0.5499	0.79859
yy:area	2	0.02392	0.01196	0.5238	0.60522
Residuals	12	0.27402	0.02283		

Anova #4

Since year was only weakly related in Anova #2, a fourth analysis of variance was conducted with the first-order effect of school association only. The results are given below.

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
sch	2	2.63403	1.31701	47.937	1.892e-13
Residuals	64	1.75831	0.02747		

The predicted proportions of bigeye in yellowfin plus bigeye for the model containing only school association are 0.229 for FAD sets, 0.246 for log sets and 0.007 for school sets.

Anova #5

Since the predicted proportions for FAD and log sets in Anova #4 are similar, the analysis was repeated with FAD and log sets combined into a single category of associated sets. The results are given below.

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
sch	1	2.62627	2.62627	113.36	9.992e-16
Residuals	63	1.45952	0.02317		

The predicted proportions in Anova #5 are 0.237 for associated sets and 0.007 for school sets. The standard errors of the estimates are 0.020 and 0.134 respectively. The model explains 64.3 percent of the variance among replicates.

The residuals from Anova #5 are plotted against the variables in Figures 14–18. For several categories, the interquartile ranges are not symetrically distributed about zero and the medians are not close to zero; hence, the lack of fit is moderate.

Size Group

The proportion of bigeye in yellowfin plus bigeye may be related to the size of fish, with the proportion greater for smaller fish. In order to incorporate size group into the analysis, the samples were modified by splitting each sample into sub-samples of fish larger and smaller than 9 kg. The weight (kg) of each fish was estimated from the length (cm) using the length-weight parameters given above. Prior to screening, there were 5,077 sub-samples; after screening, there were 1,713 sub-samples.

The sub-samples were grouped into replicates for strata of year – quarter – area – flag – school association – size group, wherein each replicate represented the average proportion of bigeye in yellowfin plus bigeye determined from the sub-samples within the stratum. There were a total of 85 replicates. The number of replicates, by category, is given below:

Year	Quarter	Area	Flag	School	Size
1998: 31	qq1: 18	area_2: 29	JP : 5	FAD : 38	LARGE: 38
1999: 11	qq2: 29	area_3: 56	KR : 9	LOG : 23	SMALL: 47
2000: 18	qq3: 20		TW : 14	SCHOOL: 24	
2001: 25	qq4: 18		US : 19		
			OTHER: 38		

Figure 19 shows the distribution of the proportion of bigeye in yellowfin plus bigeye by size group. The proportions for large fish are clearly lower than for small fish.

The regression tree (Figure 20) indicates that school association is still the most important predictor, although quarter and size group were included in addition to flag and area, which were also included in the regression tree determined from data that did not include size group (Figure 7). A plot of the complexity parameter table indicated that the model should be pruned with a complexity parameter of 0.21. Similar to the results for the analysis that did not include size group, the resulting pruned regression tree contained only three nodes, including the root node, one for school sets and one for FAD and log sets combined; all other variables were excluded from the pruned regression tree.

An analysis of variance was conducted with all first-order effects. The results below, listed in the order of the effect of the variable on the residual sum of squares, indicate that school association and year are strongly related, while flag and size are weakly related.

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
sch	2	3.1652	1.5826	58.6356	1.110e-15
flag	4	0.5341	0.1335	4.9474	0.0014312
yy	3	0.5366	0.1789	6.6274	0.0005263
qq	3	0.2597	0.0866	3.2068	0.0282770
size	1	0.2183	0.2183	8.0878	0.0058377
area	1	0.0907	0.0907	3.3619	0.0709737
Residuals	70	1.8893	0.0270		

Another analysis of variance was then conducted with the first-order effects of the strongly- and weakly-related variables, i.e. school association, flag, year and size group. The results below indicate that school association is strongly related, while year and flag are weakly related, and size is unrelated.

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
sch	2	3.1652	1.5826	51.7606	8.66e-15
flag	4	0.5341	0.1335	4.3674	0.003170
yy	3	0.5366	0.1789	5.8504	0.001215
size	1	0.1954	0.1954	6.3922	0.013595
Residuals	74	2.2625	0.0306		

Since there is a strong relationship between size and school association, such that the average size of fish in associated schools is smaller than in unassociated schools, the effect of switching the order in which school association and size appear in the model was examined. The results below indicate that when size appears as the first variable in the model, size, school association and flag are strongly related, while year is unrelated.

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
size	1	2.00529	2.00529	65.5860	8.435e-12
flag	4	0.66432	0.16608	5.4319	0.0006858
yy	3	0.15970	0.05323	1.7410	0.1659793
sch	2	1.60204	0.80102	26.1986	2.496e-09
Residuals	74	2.26255	0.03057		

DISCUSSION

The results from Anovas #1 to #5 are consistent with those from the pruned regression tree. Both indicate that school association is the variable most strongly related to the proportion of bigeye in yellowfin plus bigeye. Year is strongly or weakly related, depending on the other variables that are included in the model.

While school association may be sufficient to predict the proportion of bigeye in yellowfin plus bigeye for the stratification used in the MULTIFAN-CL analysis, the prediction suffers from moderate lack of fit. This suggests that the MULTIFAN-CL assessment should perhaps be conducted on input data based on both Anova #1, which includes all variables, and on input data based on Anova #5, which includes only school association. The impact of varying the input data on the assessment should then be evaluated.

The statistical significance of the variables depends on the order in which they appear in the model. The fact that significance is unstable in this regard suggests that, if possible, sampling should be stratified on the basis of school association, year and flag. Quarter was neither strongly nor weakly related in any of the anovas; hence, stratifying by quarter may not be necessary. Size group is unrelated when school association is the first variable in the model, which suggests that if sampling is stratified by school association, then stratifying by size group may not be necessary.

On the basis of the analysis of observer data for 1998–2001 in Anova #5, the proportions of bigeye in yellowfin plus bigeye that are caught in associated and unassociated sets are, on average, 23.7 percent and 0.7 percent respectively.

Crone & Coan (2002) estimated the species composition of the United States purse-seine catch during 1997–2001 using port sampling data collected by the National Marine Fisheries Service. Their results, which are summarised in Table 5, indicate that the proportions of bigeye in yellowfin plus bigeye for associated and unassociated sets are, on average, 32.0 percent and 1.4 percent respectively.

The results from the observer data covering all fleets during 1998–2001 and the port sampling data covering the United States fleet during 1997–2001 are consistent. However, it should be noted that Crone & Coan (2002) did not consider non-sampling errors, such as the accuracy of species identification and errors related to well-mixing and the non-random selection of fish. In this regard, the NMFS port sampling programme is currently under review (Clarke, pers. comm.).

The results for associated sets based on the observer data for 1998–2001 for all fleets and the port sampling data for 1997–2001 for the United States fleet are considerably different from those based on port sampling data for the United States fleet for 1988–1995. The average values of the proportion for associated and unassociated sets, based on the port sampling data for 1988–1995, is 13.2 percent and 0.7 percent respectively (Lawson 2002b). The proportion for associated sets, based on port sampling data for the United States fleet, increased to 40.7 percent in 1996 (Coan, pers. comm.), which is the year that the United States fleet began setting on drifting FADs. Crone & Coan (2002) did not consider samples from sets on drifting FADs separately from sets on logs. However, the observer data for 1998–2001 indicate that the proportions of bigeye in yellowfin plus bigeye for log sets and FAD sets for the United States fleet are similar, 23.6 percent and 27.5 percent respectively.

The reason for the large difference in the average proportion of bigeye in yellowfin plus bigeye for associated sets, between 1988–1995 and 1996–2001, for the United States fleet, remains to be determined. It is possible that the difference is due to a change in environmental or biological factors that favoured an increase in bigeye, relative to yellowfin, in associated schools. However, it is doubtful that an environmental factor was directly involved, since the latter period, i.e. 1996–2001, includes both an El Niño event, during 1997–1998, and a La Niña event, during 1999–2001. On the other hand, the difference may well be related to the recruitment of bigeye, which, according to the MULTIFAN-CL assessment, increased during the mid-1990s from relatively stable levels (Hampton 2002).

Changes in gear technology may also have been responsible. The possibility that when the fleet switched to setting on schools associated with FADs, deeper nets (which catch more bigeye) were used, was considered. However, this explanation is not supported by information collected by observers (Table 6). Furthermore, anecdotal evidence indicates that the United States fleet increased the depth of nets in the early 1990s, rather than in 1996 and subsequent years (Itano, pers. comm.). Another possibility is that light boats, which aggregate baitfish that may attract bigeye to the surface, may have been introduced in 1996, in conjunction with the switch to FADs (Fukofuka, pers. comm.), although this cannot be confirmed with the information currently available.

The difference might also be due to an improvement in the identification of bigeye by port samplers in 1996, when there were more sets on associated schools and bigeye were sampled more frequently, although there is no evidence to support this explanation.

It is important to determine the causes of the increase in the proportion of bigeye in yellowfin plus bigeye for associated schools, from 1988–1995 to 1996–2001, since this will affect how bigeye and yellowfin catch estimates are adjusted. In particular, it needs to be determined whether the port sampling data covering the United States fleet during 1988–1995 are representative of other fleets. If so, then port sampling data for 1988–1995 can be used to adjust catch estimates for other fleets for those years (see Data Sets #1 and #4 below). If not, then the observer data for 1998–2001 should be used (see Data Sets #2 and #3 below).

The port sampling data for 1988–1995 are probably representative of other fleets if the increase in the proportion during 1996 is primarily due to an increase in the recruitment of bigeye. If the increase is primarily due to an increase in the accuracy in the identification of bigeye by port samplers, then they are not representative of either the United States fleet or other fleets. If the increase is due primarily to technological changes, then it will be appropriate to adjust catch estimates for other fleets using the port sampling data for 1996–1997 only if they underwent the same technological changes as the United States fleet.

INPUT DATA FOR MULTIFAN-CL

Four sets of input data to MULTIFAN-CL were derived, based on the following criteria:

Data set #1: Port sampling data, 1988–1995

These data were used in Hampton (2002). Bigeye catch estimates were adjusted primarily on the basis of port sampling data for 1988–1995 for the United States fleet. For 1988–1995, annual values of the proportion of bigeye in yellowfin plus bigeye were used. For 1967–1987 and 1996–2001, average values for 1988–1995, for associated and unassociated schools, i.e. 13.2 percent and 0.7 percent respectively, were used.

Data set #2: Observer data, 1998–2001, all variables

For 1967–1997, bigeye catch estimates were adjusted on the basis of an analysis of variance that included school association, flag, area and quarter. For 1998–2001, bigeye catch estimates were adjusted on the basis of an analysis of variance including school association, flag, year, area and quarter. School association was stratified into ‘associated’ and ‘unassociated’ categories.

Data set #3: Observer data, 1998–2001, school association only

Bigeye catch estimates for all years were adjusted on the basis of an analysis of variance including school association only. School association was stratified into ‘associated’ and ‘unassociated’ categories. The values of the porportion of bigeye in yellowfin plus bigeye, for associated and unassociated schools, were 23.7 percent and 0.7 percent respectively.

Data set #4: Port sampling data, 1988–1995, and observer data, 1998–2001, all variables

This data set is a combination of data set #1, for 1967–1995, and data set #2, for 1996–2001. It assumes that the port sampling data for the United States fleet, 1988–1995, are accurate and representative of other fleets and earlier years, and that the proportion of bigeye in yellowfin plus bigeye, particularly from associated sets, increased in 1996. It also assumes that the observer data for 1998–2001 are representative of all fleets during 1996–1997; this assumption could be validated if information regarding the timing of changes to the depth of nets was available for each of the fleets.

Comparison of annual catches

The time series of estimates of annual bigeye catches determined from data sets #1, #2 and #3 are presented in Figure 21. (Data set #4, which is not shown, is a combination of data set #1 for 1967–1995 and data set #2 for 1996–2001.) The sum of bigeye catches for 1967–2001 from data sets #2, #3 and #4 are 50.5 percent, 74.4 percent and 18.8 percent greater than for data set #1, respectively.

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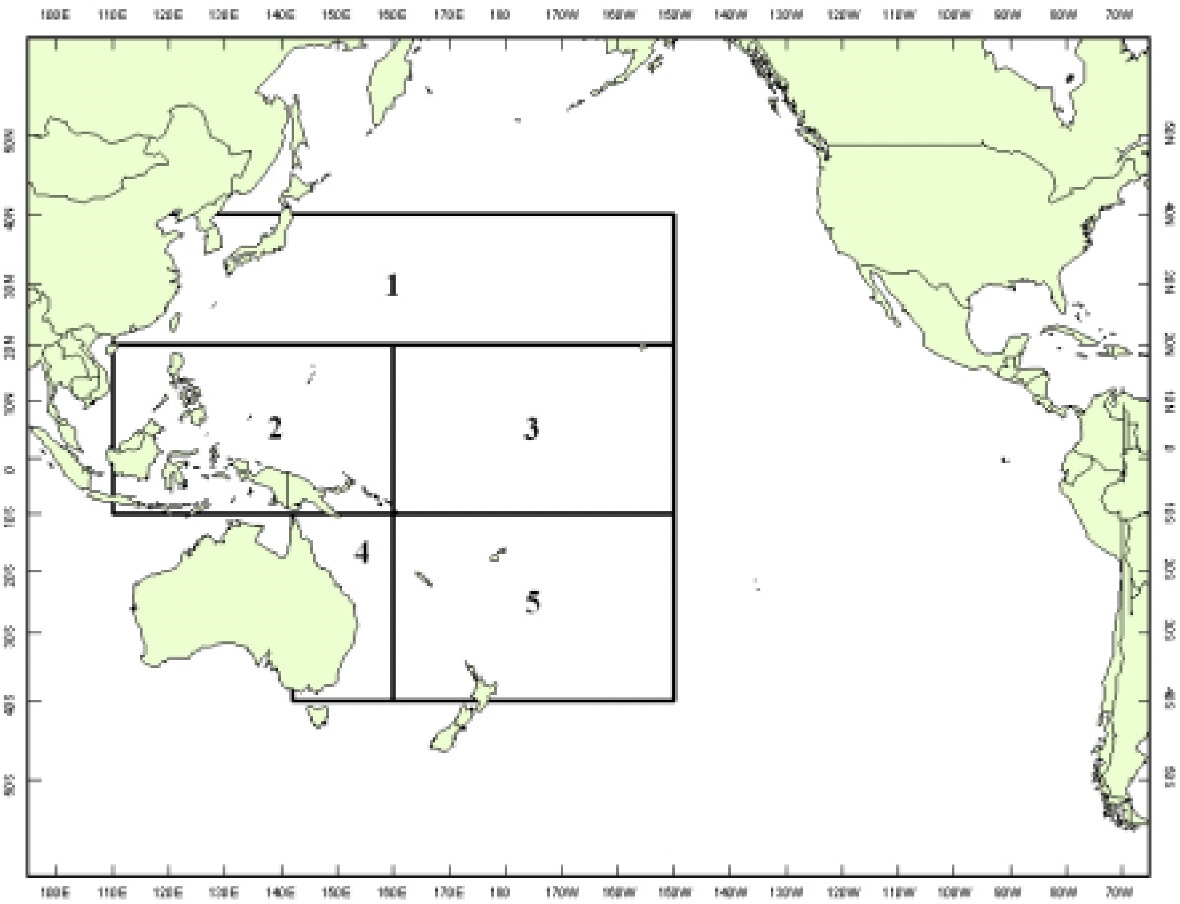

Figure 1. Areas used in the MULTIFAN-CL assessment of bigeye (Hampton 2002)

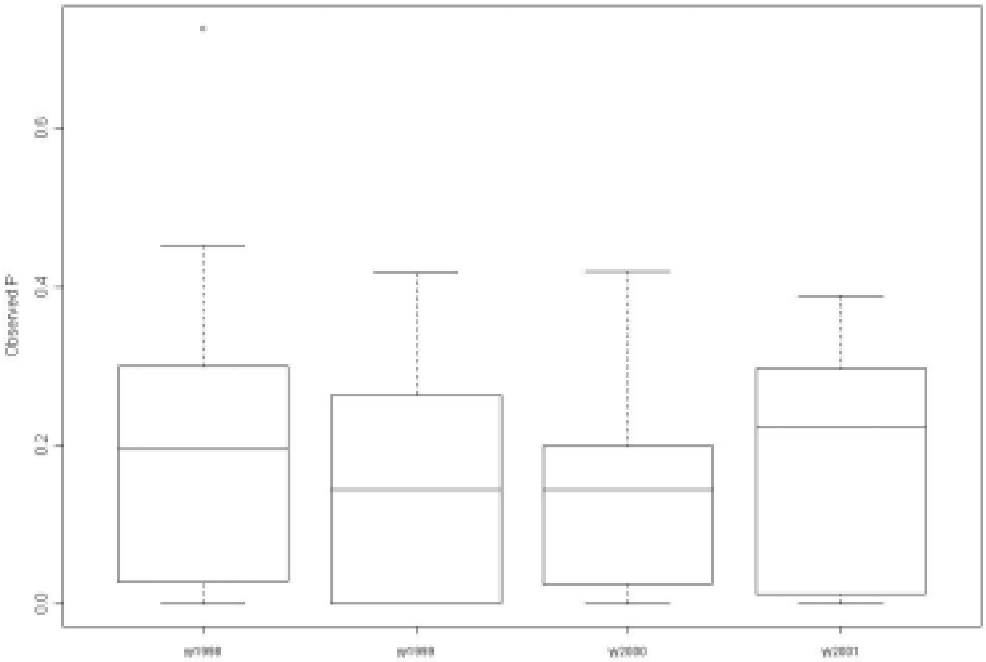

Figure 2. Distribution of the proportion of bigeye in yellowfin plus bigeye, by year.
Boxplots show the median, the interquartile range, the minimum
and maximum within 1.5 * IQR, and outliers.

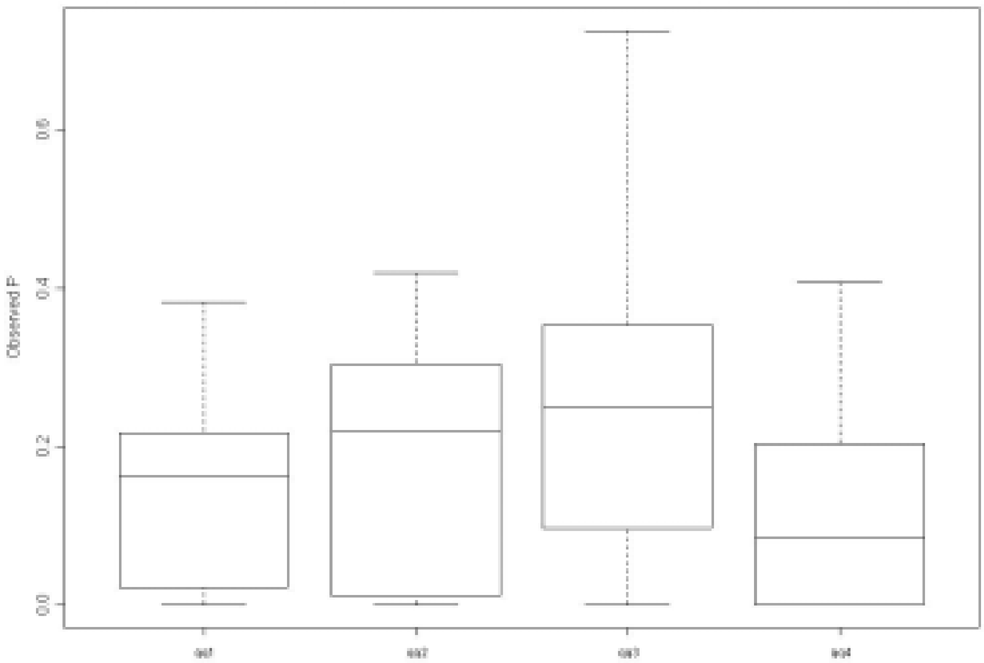

Figure 3. Distribution of the proportion of bigeye in ‘yellowfin plus bigeye’, by quarter

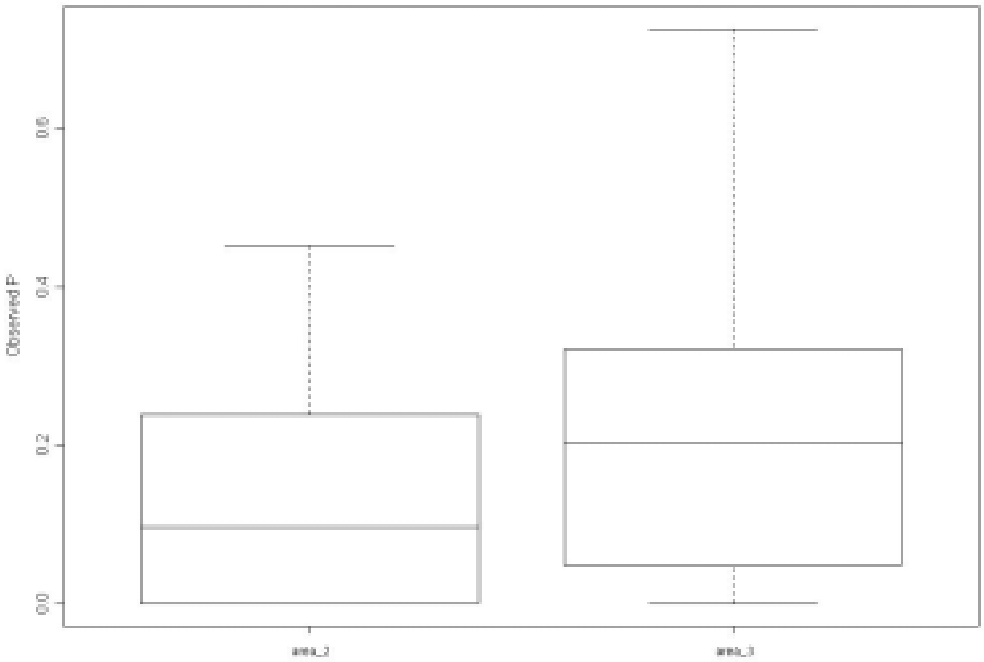

Figure 4. Distribution of the proportion of bigeye in yellowfin plus bigeye, by area

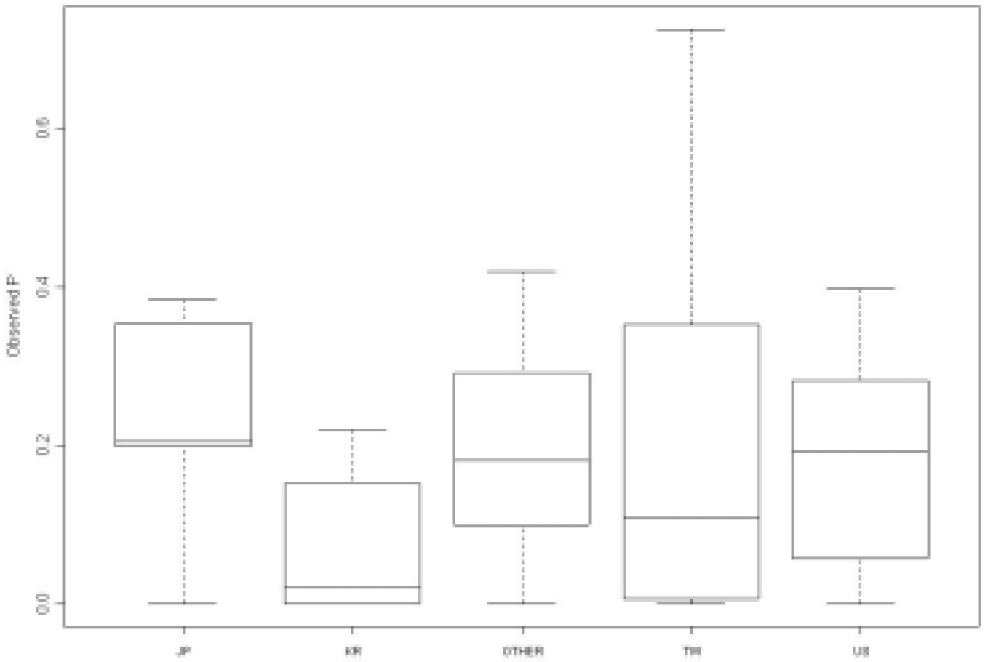

Figure 5. Distribution of the proportion of bigeye in yellowfin plus bigeye, by flag

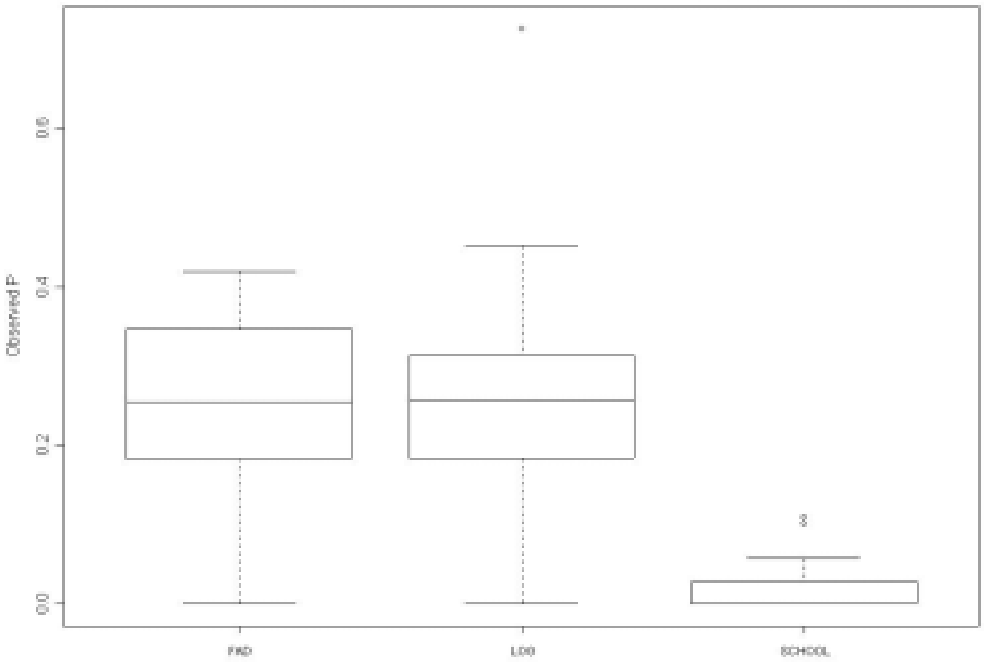

Figure 6. Distribution of the proportion of bigeye in yellowfin plus bigeye, by school association

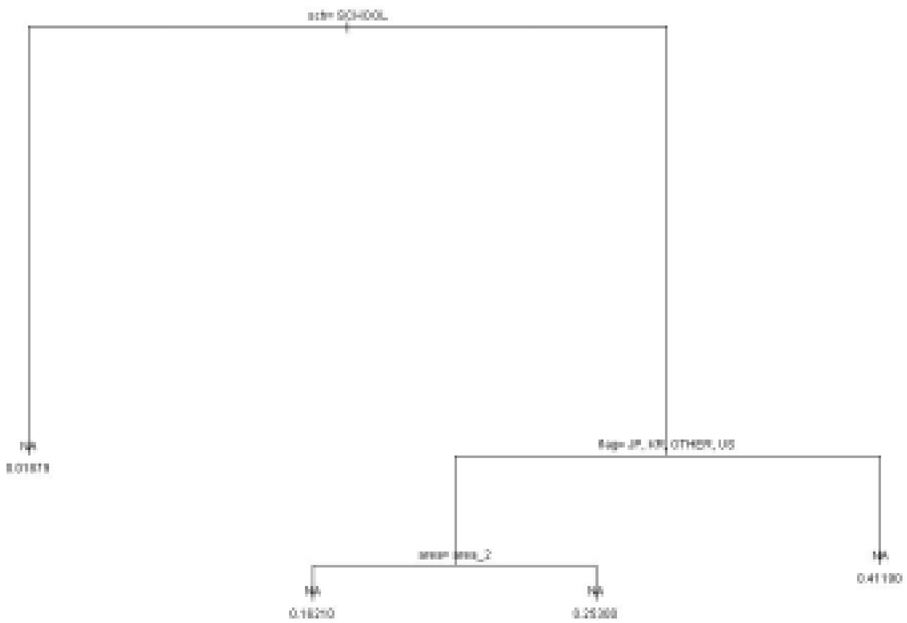

Figure 7. Regression tree for the proportion of bigeye in yellowfin plus bigeye

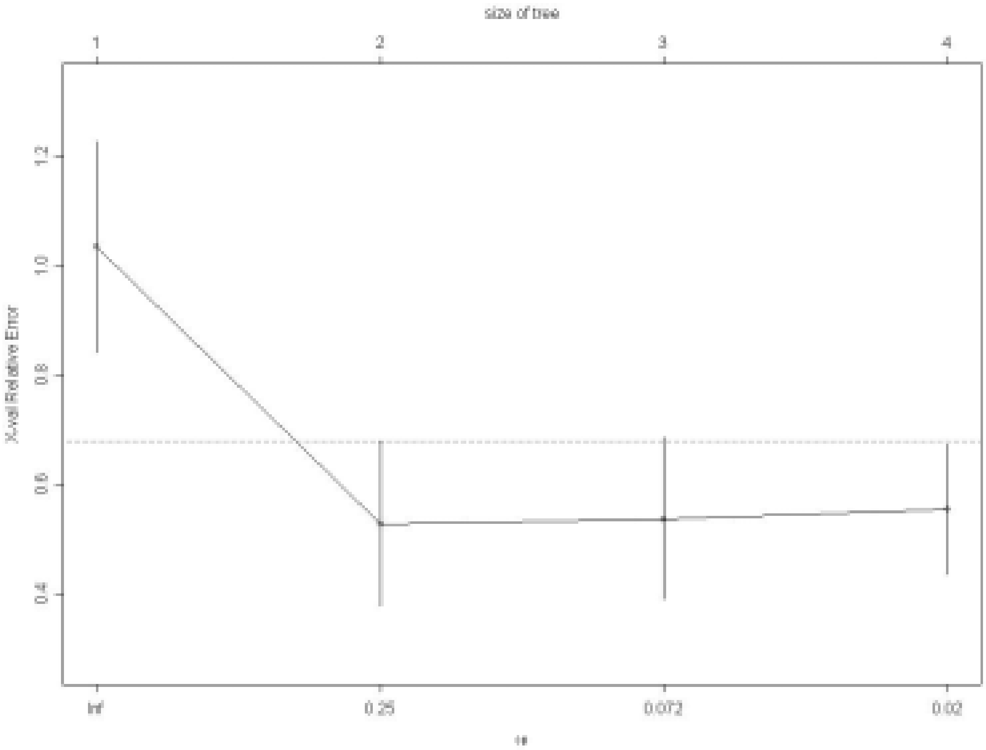

Figure 8. Complexity parameter plot for the regression tree in Figure 7

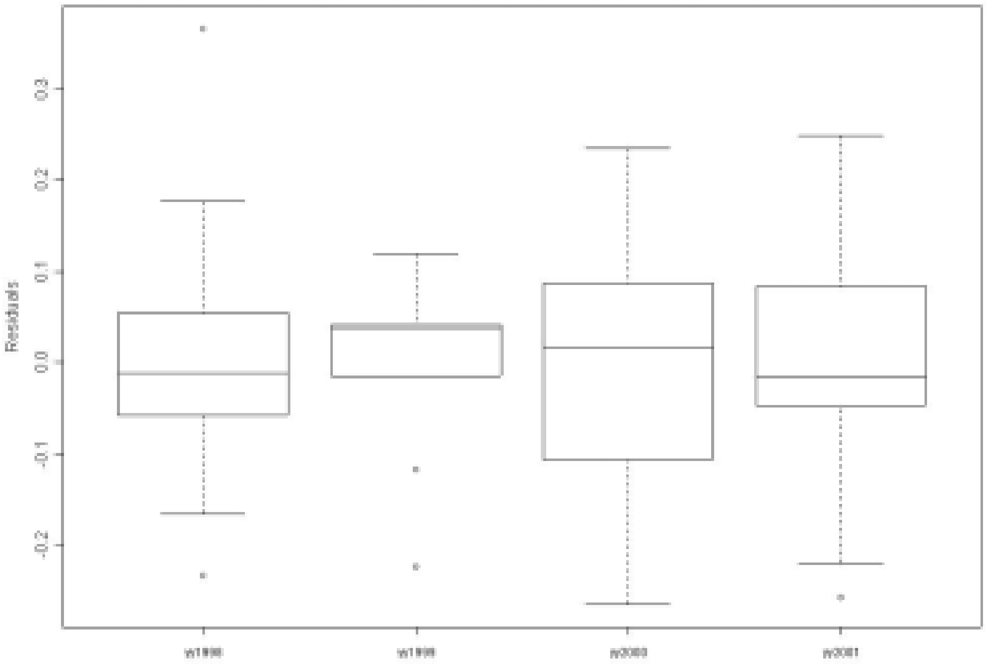

Figure 9. Residuals for Anova #1, by year

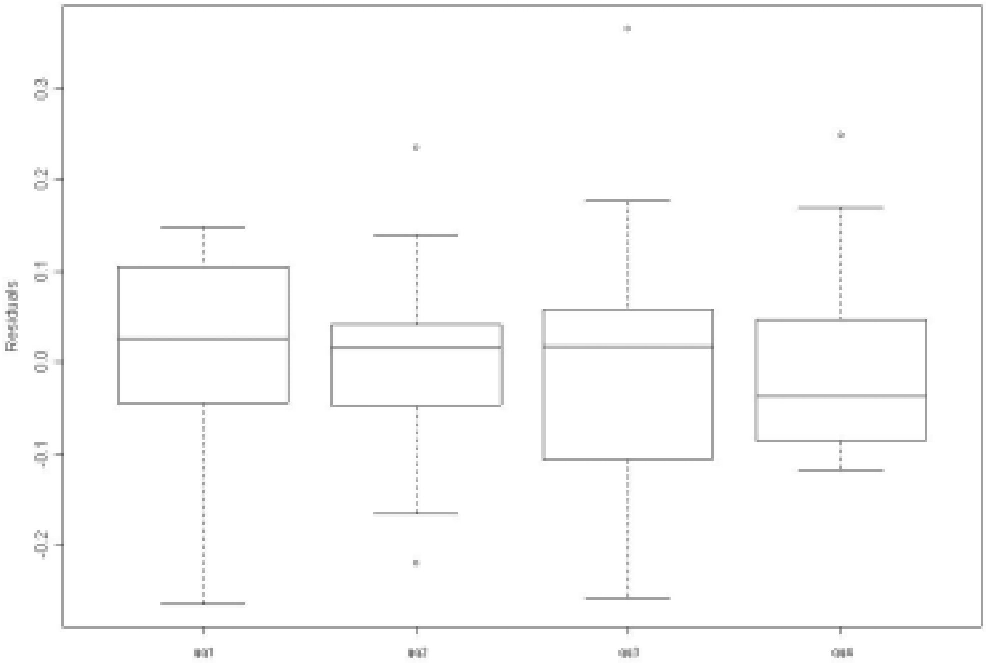

Figure 10. Residuals for Anova #1, by quarter

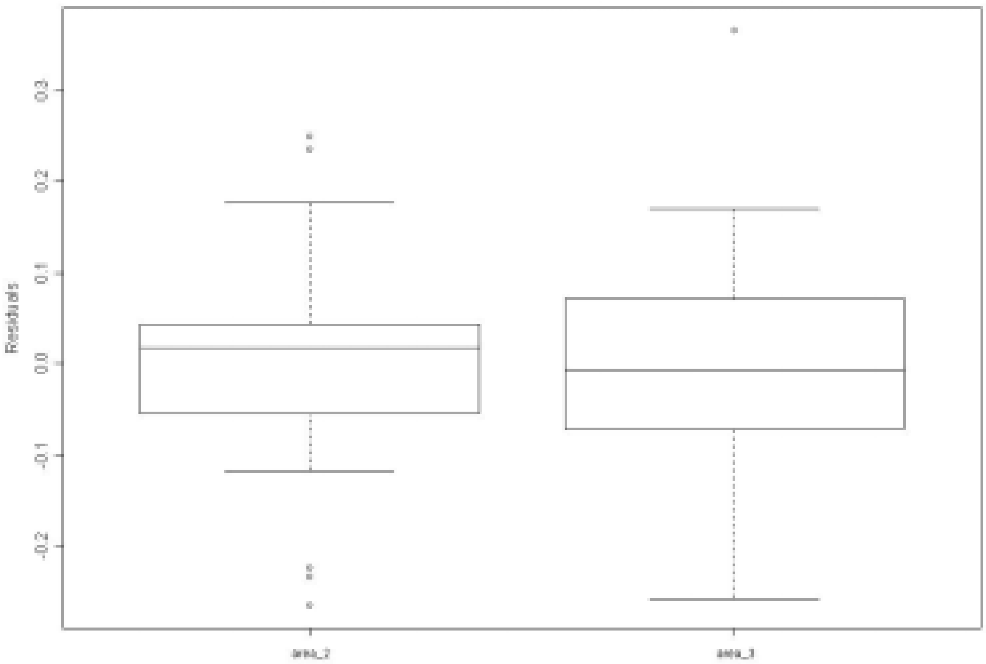

Figure 11. Residuals for Anova #1, by area

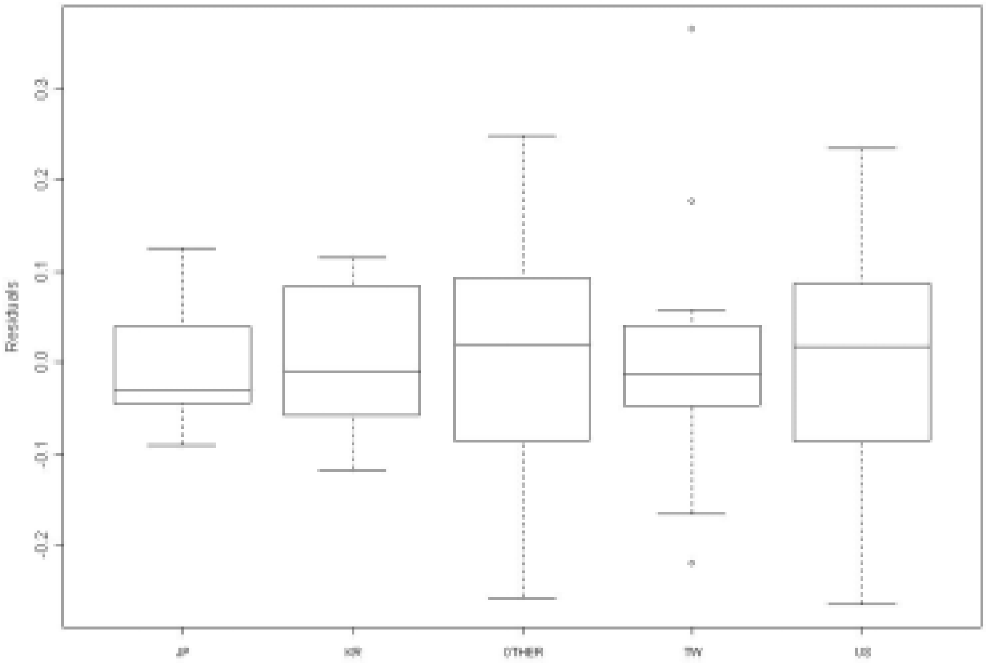

Figure 12. Residuals for Anova #1, by flag

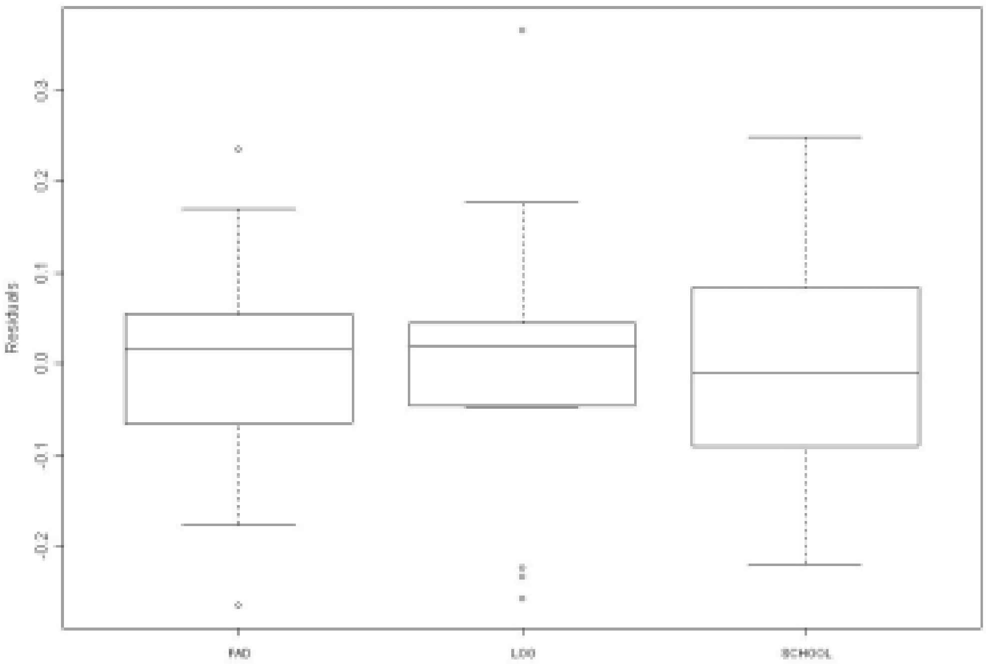

Figure 13. Residuals for Anova #1, by school association

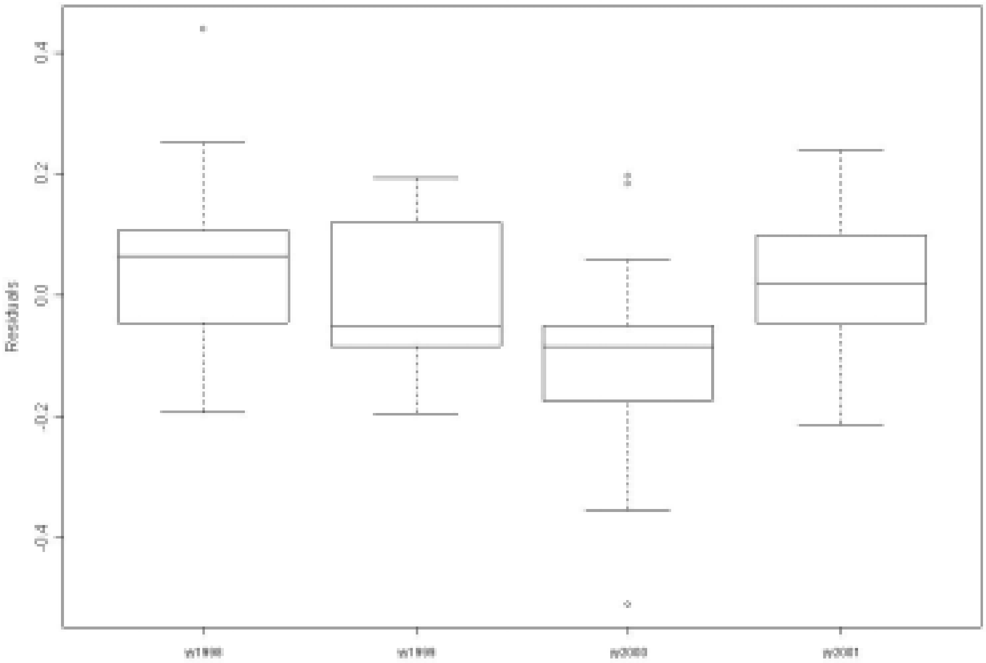

Figure 14. Residuals for Anova #5, by year

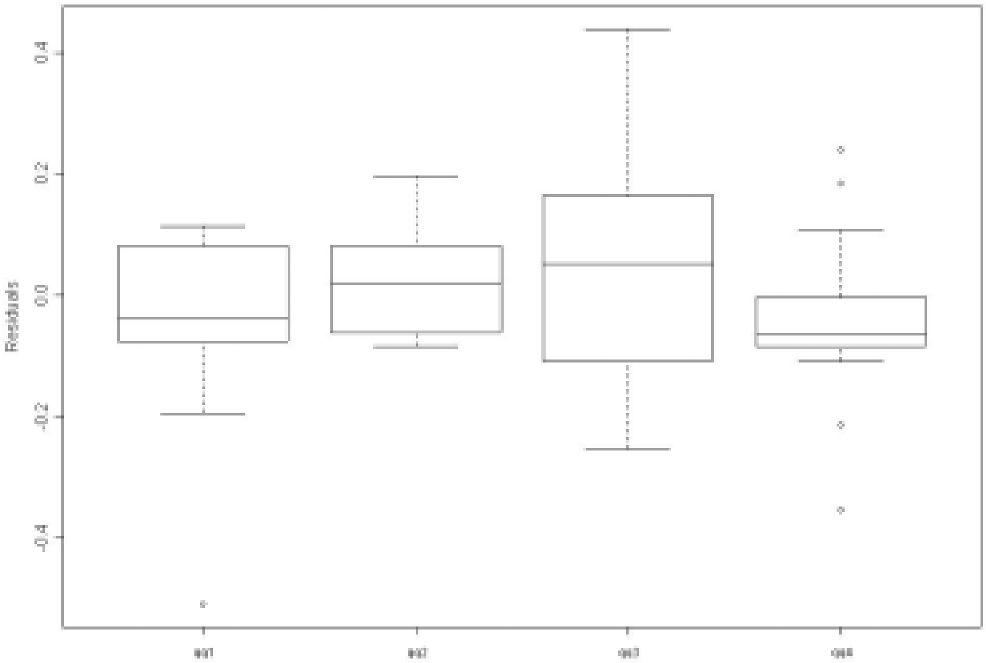

Figure 15. Residuals for Anova #5, by quarter

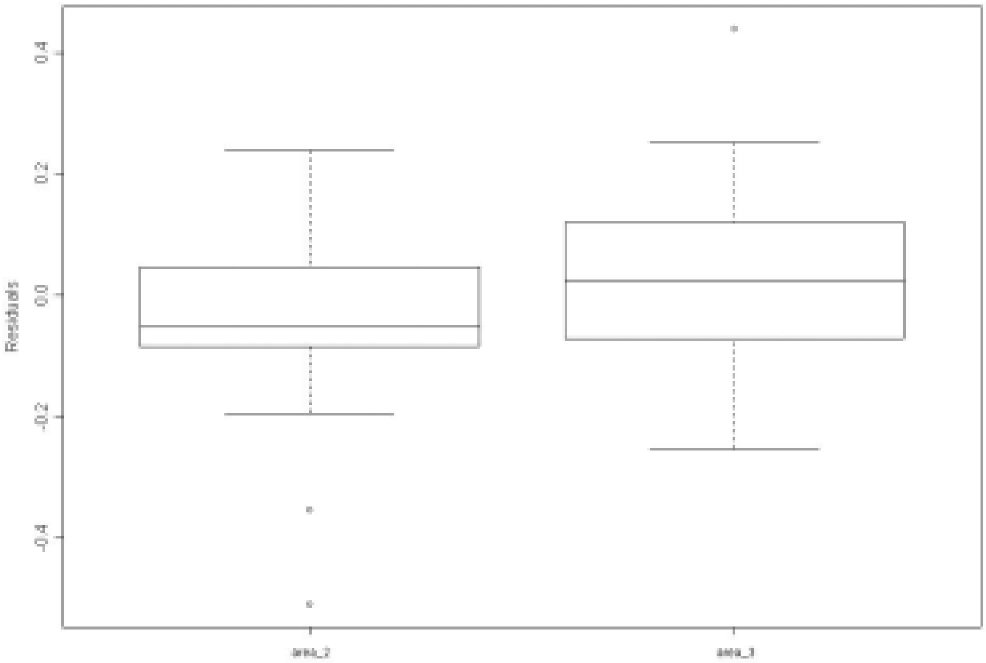

Figure 16. Residuals for Anova #5, by area

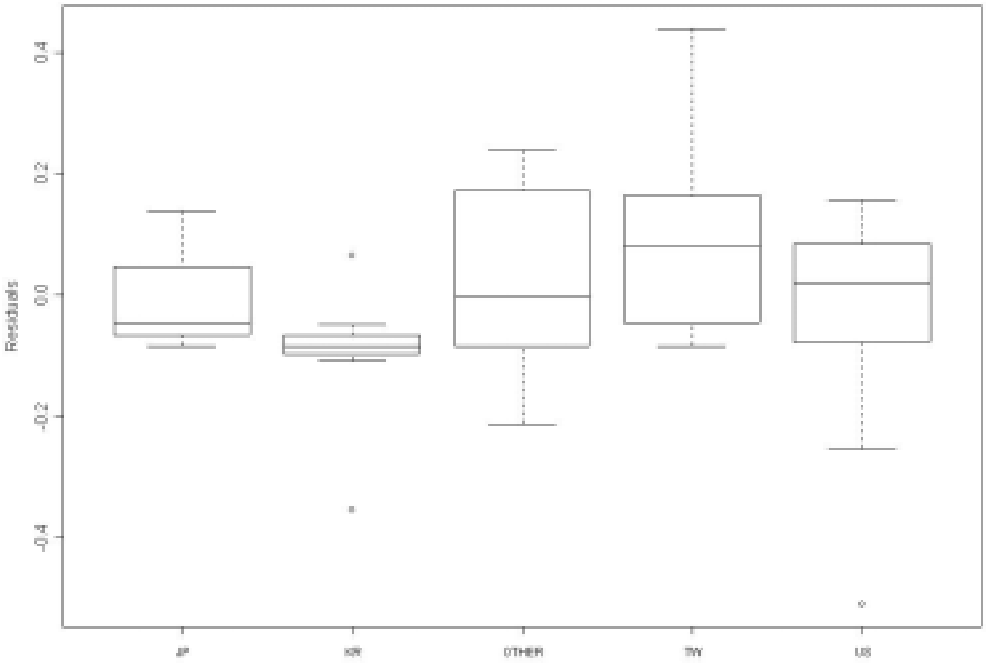

Figure 17. Residuals for Anova #5, by flag

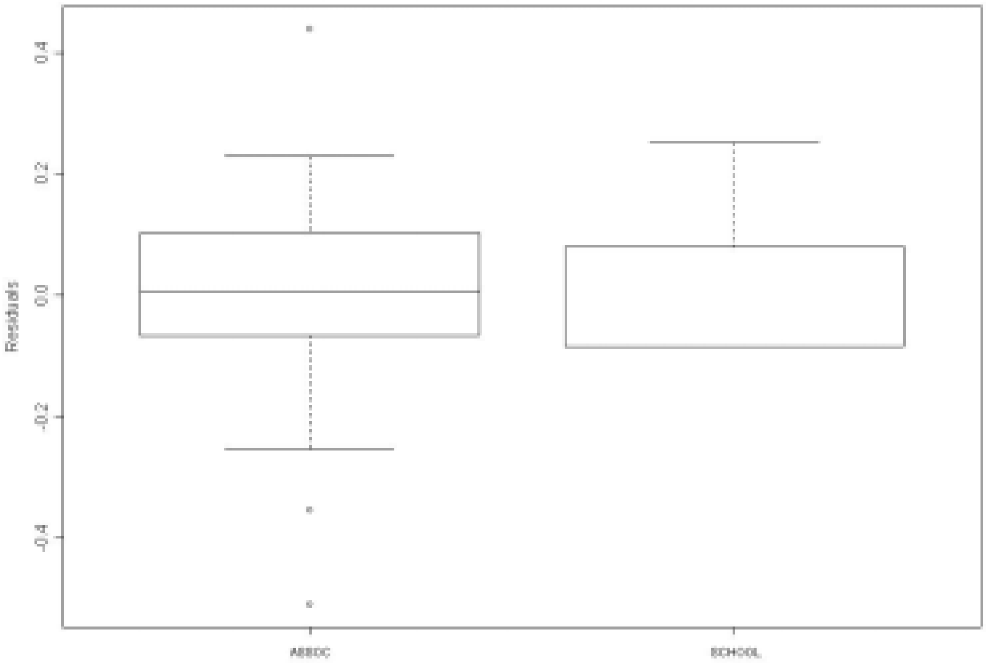

Figure 18. Residuals for Anova #5, by school association

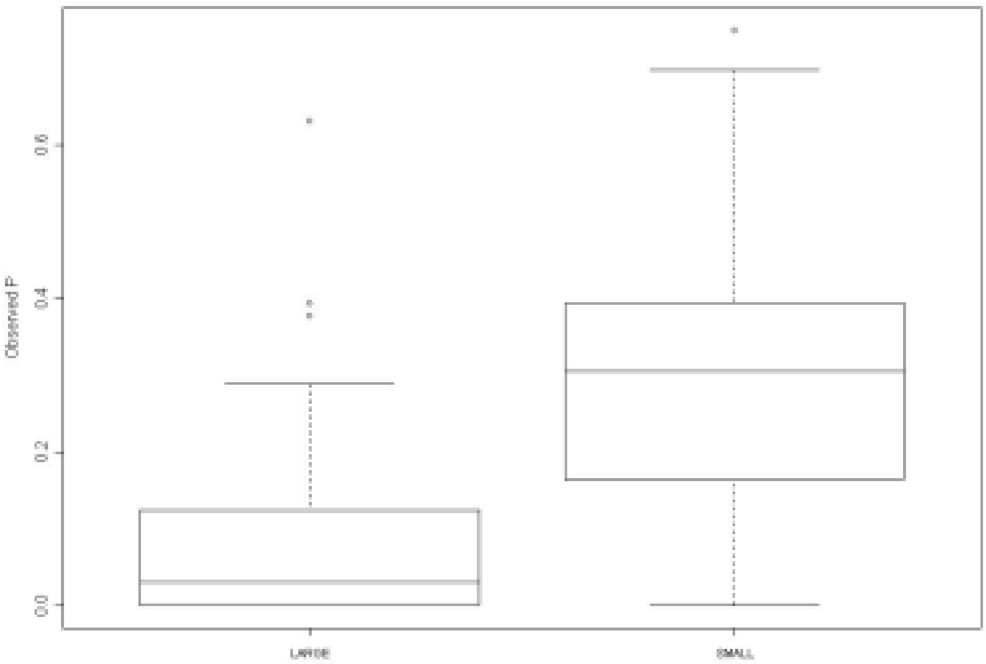

Figure 19. Distribution of the proportion of bigeye in yellowfin plus bigeye, by size group

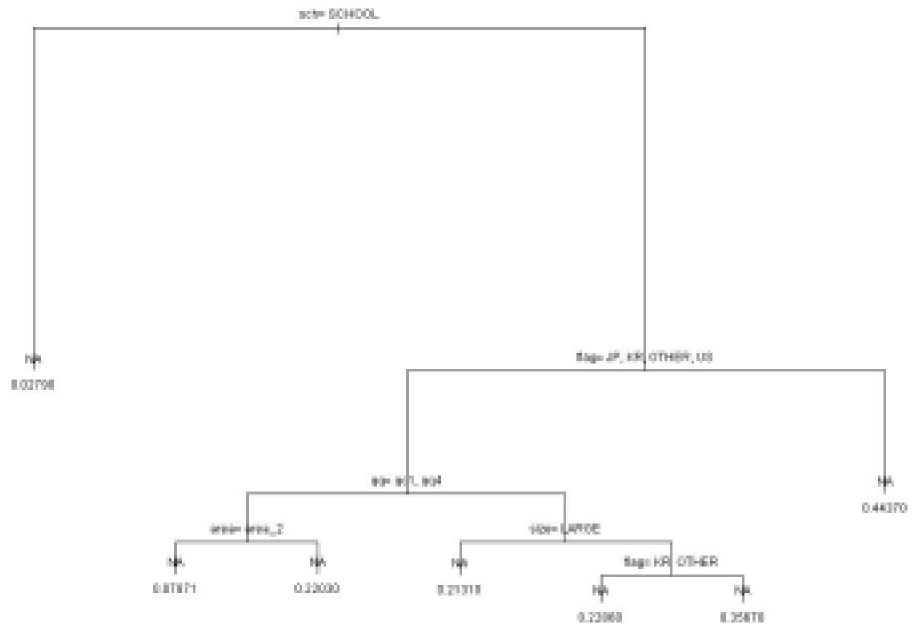

Figure 20. Regression tree for the proportion of bigeye in yellowfin plus bigeye, including size group

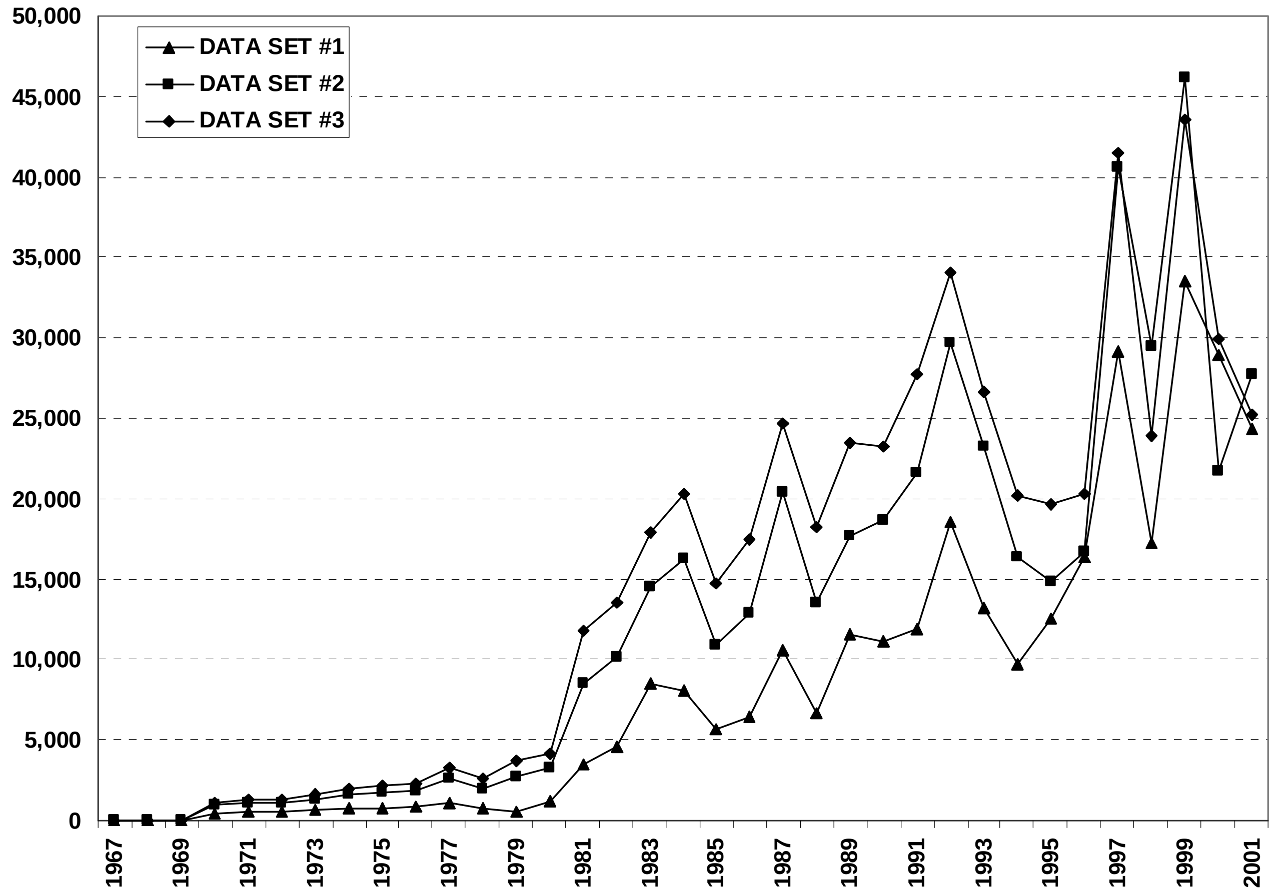

Figure 21. Estimates of bigeye catches (tonnes) in Areas 2 and 3. Data set #1 is based primarily on port sampling data for the United States fleet, 1988–1995. Data set #2 is based on an anova of observer data for all fleets, 1998–2001, with all variables. Data set #3 is based on an anova of observer data for all fleets, 1998–2001, with school association only.

Table 1. Number of species composition samples, containing yellowfin and bigeye, collected by observers from purse seiners, by year and school association. Key: LOG: Drifting log, debris or dead animal; FAD: Drifting raft, FAD or payao; SCHOOL: unassociated or feeding on baitfish.

YEAR	LOG	FAD	SCHOOL	TOTAL	%
1998	241	101	183	525	34.8
1999	20	226	36	282	18.7
2000	10	275	37	322	21.4
2001	57	222	100	379	25.1
TOTAL	328	824	356	1,508	100.0
%	21.8	54.6	23.6	100.0	

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

YEAR	Q1	Q2	Q3	Q4	TOTAL	%
1998	171	224	108	22	525	34.8
1999	41	106	111	24	282	18.7
2000	70	136	66	50	322	21.4
2001	76	102	133	68	379	25.1
TOTAL	358	568	418	164	1,508	100.0
%	23.7	37.7	27.7	10.9	100.0	

Table 3. Number of species composition samples, containing yellowfin and bigeye, collected by observers from purse seiners, by year and bigeye area (Figure 1)

YEAR	BET AREA		TOTAL	%
	2	3		
1998	82	443	525	34.8
1999	71	211	282	18.7
2000	95	227	322	21.4
2001	84	295	379	25.1
TOTAL	332	1,176	1,508	100.0
%	22.0	78.0	100.0	

Table 4. Number of species composition samples, containing yellowfin and bigeye, collected by observers from purse seiners, by year and fishing nation. Key: AU: Australia, FM: Federated States of Micronesia, JP: Japan, KR: Korea, PG: Papua New Guinea, PH: Philippines, SB: Solomon Islands, TW: Taiwan, US: United States of America, VU: Vanuatu.

YEAR	AU	FM	JP	KR	PG	PH	SB	TW	US	VU	TOTAL	%
1998	0	4	18	79	26	1	1	216	176	4	525	34.8
1999	0	0	0	21	11	0	8	28	204	10	282	18.7
2000	0	22	19	30	33	0	0	21	197	0	322	21.4
2001	11	21	38	20	0	31	0	44	214	0	379	25.1
TOTAL	11	47	75	150	70	32	9	309	791	14	1,508	100.0
%	0.7	3.1	5.0	9.9	4.6	2.1	0.6	20.5	52.5	0.9	100.0	

Table 5. Proportion of bigeye in yellowfin plus bigeye based on catches (tonnes) estimated from port sampling data covering the United States purse-seine fleet. (Based on Crone & Coan 2002, Table 1.)

YEAR	ASSOCIATED			UNASSOCIATED			TOTAL		
	YFT	BET	P	YFT	BET	P	YFT	BET	P
1997	27,774	9,908	0.263	56,441	653	0.011	84,215	10,561	0.111
1998	10,476	5,506	0.345	28,805	99	0.003	39,281	5,605	0.125
1999	39,700	21,559	0.352	1,568	80	0.049	41,268	21,639	0.344
2000	32,397	13,753	0.298	9,161	520	0.054	41,558	14,273	0.256
2001	10,907	6,438	0.371	14,039	190	0.013	24,946	6,628	0.210
TOTAL	121,254	57,164	0.320	110,014	1,542	0.014	231,268	58,706	0.202

Table 6. Average of the maximum net depth (metres) for United States purse seiners, determined from observer data

YEAR	VESSELS COVERED	TRIPS COVERED	MAX NET DEPTH
1994	14	14	287
1995	15	19	282
1996	24	26	278
1997	27	29	290
1998	33	33	243
1999	28	29	253
2000	21	24	231
2001	22	26	243
2002	6	6	231