SCIENTIFIC COMMITTEE
NINTH REGULAR SESSION

6-14 August 2013
Pohnpei, Federated States of Micronesia

Update on the estimation of the species composition of the catch by purse seiners in the Western and Central Pacific Ocean, with responses to recent independent reviews

WCPFC-SC9-2013/ ST-WP-03

Tim Lawson[1]

[1] Secretariat of the Pacific Community (SPC), Ocean Fisheries Programme (OFP), Noumea, New Caledonia

UPDATE ON THE ESTIMATION OF THE SPECIES COMPOSITION OF THE CATCH BY PURSE SEINERS IN THE WESTERN AND CENTRAL PACIFIC OCEAN, WITH RESPONSES TO RECENT INDEPENDENT REVIEWS

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

Abstract

This paper (i) updates the estimation of selectivity bias with recent paired sampling data; (ii) presents the results of simulations of brailing and sampling, and compares two approaches to the analysis of the paired samples; (iii) further develops the models used to estimate the species composition by including the proportion of skipjack determined from catch and effort logsheets as a covariate; and (iv) presents the results of an exploratory analysis of the use of pooled observer data to estimate the species composition. References are made to recent independent reviews of Lawson (2012) and responses to the reviews are presented.

Introduction

The estimation of the species composition of catches by purse seiners in the Western and Central Pacific Ocean is problematic because (a) catches are misreported on logsheets; (b) information on unloadings to canneries or during transshipment is unavailable; (c) port sampling during transshipment is biased because of well mixing and other factors; and (d) grab samples taken by observers at sea are subject to selectivity bias (Lawson 2009, Hampton & Williams 2011). The SPC Oceanic Fisheries Programme (OFP) has recently developed an observer sampling protocol — the spill sample — that avoids the selectivity bias (Lawson 2008). Paired grab and spill samples have been collected [1] and used to estimate the selectivity bias and correct the historical grab samples (Lawson 2012). This paper (i) updates the estimation of selectivity bias with recent paired sampling data; (ii) presents the results of simulations of brailing and sampling, and compares two approaches to the analysis of the paired samples; (iii) further develops the models used to estimate the species composition by including the proportion of skipjack determined from catch and effort logsheets as a covariate; and (iv) presents the results of an exploratory analysis of the use of pooled observer data to estimate the species composition.

References are made to reviews of Lawson (2012) by Cordue (2012), Powers (2012) and McArdle (2013), and comments on the reviews are presented.

[1] The collection of paired grab and spill samples has been financed by the WCPFC under Project 60, "The Collection and Evaluation of Purse-Seine Species Composition Data", since 2009, and also by the New Zealand Aid Programme, "Pacific Economic Growth Observer Programme", since 2011.

For this study, lengths (cm) were converted to weights (kg) using the length-weight parameters below:

Species	a	b
Skipjack	0.8639E-05	3.2174
Yellowfin	2.5120E-05	2.9396
Bigeye	1.9729E-05	3.0247

Paired grab samples and spill samples, 2008–2013

Prior to 2008, it had been known that the species composition of the catch determined from grab samples collected by observers onboard purse seiners were biased, such that the proportion of skipjack was generally under-estimated and the proportion of yellowfin over-estimated. The protocol followed by observers when taking grab samples is to randomly select five fish per brail as the fish are transferred from the pursed net in the ocean to the holding wells on the wet deck. The cause of the bias was thought to be a tendency on the part of observers to non-randomly select fish; therefore, a new sampling protocol was developed to avoid this selectivity bias. The protocol for a spill sample is to spill the fish directly from the brail into a bin, such that the observer does not select the fish. A typical bin holds from about 100 to 400 fish depending on the size of the fish. Since a spill sample is much larger than a grab sample, and thus takes more time, spill samples are usually taken from every tenth brail. The starting brail for a given set is rotated to avoid possible effects of layering of fish by size (Lawson 2012); thus, brail #1 is chosen as the first brail sampled from set #1, brail #2 as the first brail sampled from set #2, etc.

Paired grab and spill samples have been collected since 2008. At the time of writing (August 2013), paired sampling data are available covering 575 sets collected during 41 trips (Table 1), a considerable increase from the 348 sets examined in Lawson (2012).

Table 1. Date, location, catch and number of sets sampled for trips during which paired grab and spill samples were collected

Trip #	Date		Latitude		Longitude		Sampled Catch (Tonnes)	Number of Sets					
	Min	Max	Min	Max	Min	Max		Total	Anchored FADs	Drifting FADs	Logs	Unassoc	Other
1	09-Jun-08	30-Jun-08	04S	00N	143E	149E	580	13	10	1	0	0	2
2	21-Jun-08	08-Aug-08	03S	00N	141E	150E	1,172	31	30	0	1	0	0
3	14-Jul-08	09-Aug-08	03S	02S	141E	146E	616	15	9	4	1	0	1
4	03-May-09	05-Jun-09	04S	02S	148E	151E	467	14	12	0	1	1	0
5	04-May-09	04-Jun-09	02S	01S	143E	146E	256	9	8	0	0	0	1
6	04-Jun-09	19-Jul-09	05S	02S	142E	151E	613	23	20	1	2	0	0
7	15-Jun-09	18-Jul-09	04S	01S	144E	148E	335	13	9	0	4	0	0
8	16-Jun-09	26-Jul-09	05S	02S	142E	150E	352	22	17	0	5	0	0
9	22-Aug-09	10-Sep-09	04S	04S	150E	151E	317	16	10	1	4	0	1
10	27-Sep-09	10-Oct-09	05S	02S	143E	150E	518	10	7	0	3	0	0
11	09-Oct-09	21-Oct-09	02S	02S	143E	144E	541	8	4	0	4	0	0
12	03-Nov-09	01-Dec-09	03S	01S	143E	146E	514	15	12	0	3	0	0
13	11-Nov-09	04-Dec-09	03S	02S	143E	146E	353	13	13	0	0	0	0
14	13-Nov-09	07-Dec-09	03S	02S	142E	142E	460	15	15	0	0	0	0
15	19-Mar-10	16-Apr-10	04S	00N	146E	165E	749	20	0	10	0	9	1
16	30-Apr-10	07-May-10	00N	01N	152E	154E	343	8	0	7	0	1	0
17	10-Dec-10	06-Jan-11	06S	01S	152E	160E	866	21	0	2	0	16	3
18	20-Aug-11	23-Aug-11	03S	03S	143E	143E	45	3	3	0	0	0	0
19	28-Nov-11	12-Dec-11	09S	08S	158E	159E	240	10	10	0	0	0	0
20	19-Jan-12	21-Feb-12	08S	02N	145E	162E	811	16	0	1	0	15	0
21	07-Feb-12	18-Feb-12	01N	02N	144E	150E	1,036	12	0	0	0	12	0
22	09-Mar-12	13-Apr-12	00N	02N	144E	155E	1,047	22	0	0	3	19	0
23	11-Mar-12	19-Apr-12	06S	02N	148E	161E	911	13	0	3	0	9	1
24	21-Mar-12	08-Apr-12	06S	05N	154E	159E	883	15	0	14	0	1	0
25	15-Apr-12	10-May-12	03S	08N	154E	174E	764	17	0	13	1	1	2
26	25-May-12	01-Jul-12	11S	07S	179W	168W	1,080	31	0	29	1	1	0
27	09-Aug-12	16-Aug-12	03S	01S	175E	179E	167	10	0	0	0	10	0
28	29-Aug-12	08-Sep-12	09S	07S	157E	157E	399	9	8	0	1	0	0
29	05-Sep-12	01-Oct-12	02S	04N	153E	173E	692	12	0	0	2	10	0
30	17-Sep-12	24-Sep-12	10S	09S	157E	161E	388	9	8	1	0	0	0
31	19-Sep-12	20-Sep-12	03N	04N	156E	156E	299	2	0	0	0	2	0
32	23-Sep-12	04-Oct-12	02S	04N	155E	173E	759	9	0	2	0	7	0
33	27-Sep-12	12-Oct-12	04S	03N	155E	173E	910	13	4	1	0	8	0
34	28-Sep-12	11-Oct-12	09S	07S	157E	159E	420	11	11	0	0	0	0
35	14-Oct-12	29-Oct-12	03S	00N	172E	176E	652	9	0	6	1	2	0
36	18-Oct-12	26-Oct-12	10S	08S	157E	158E	197	7	5	1	1	0	0
37	03-Nov-12	20-Nov-12	11S	08S	156E	160E	460	16	16	0	0	0	0
38	23-Nov-12	13-Dec-12	07S	01N	159E	174E	395	11	0	10	1	0	0
39	24-Nov-12	10-Dec-12	09S	08S	156E	159E	345	15	12	2	0	1	0
40	04-Jan-13	24-Jan-13	12S	09S	156E	166E	960	20	0	2	0	18	0
41	07-Jan-13	23-Jan-13	10S	09S	154E	167E	609	17	0	0	1	15	1
						Total	23,520	575	253	111	40	158	13

The location of the paired samples is shown in Figure 1. During 2008–2011, the samples were taken primarily in the waters of Papua New Guinea, whereas during 2012 and 2013, the samples also covered other parts of the region.

Figure 1. Location of sets from which paired spill and grab samples were collected, 2008–2013

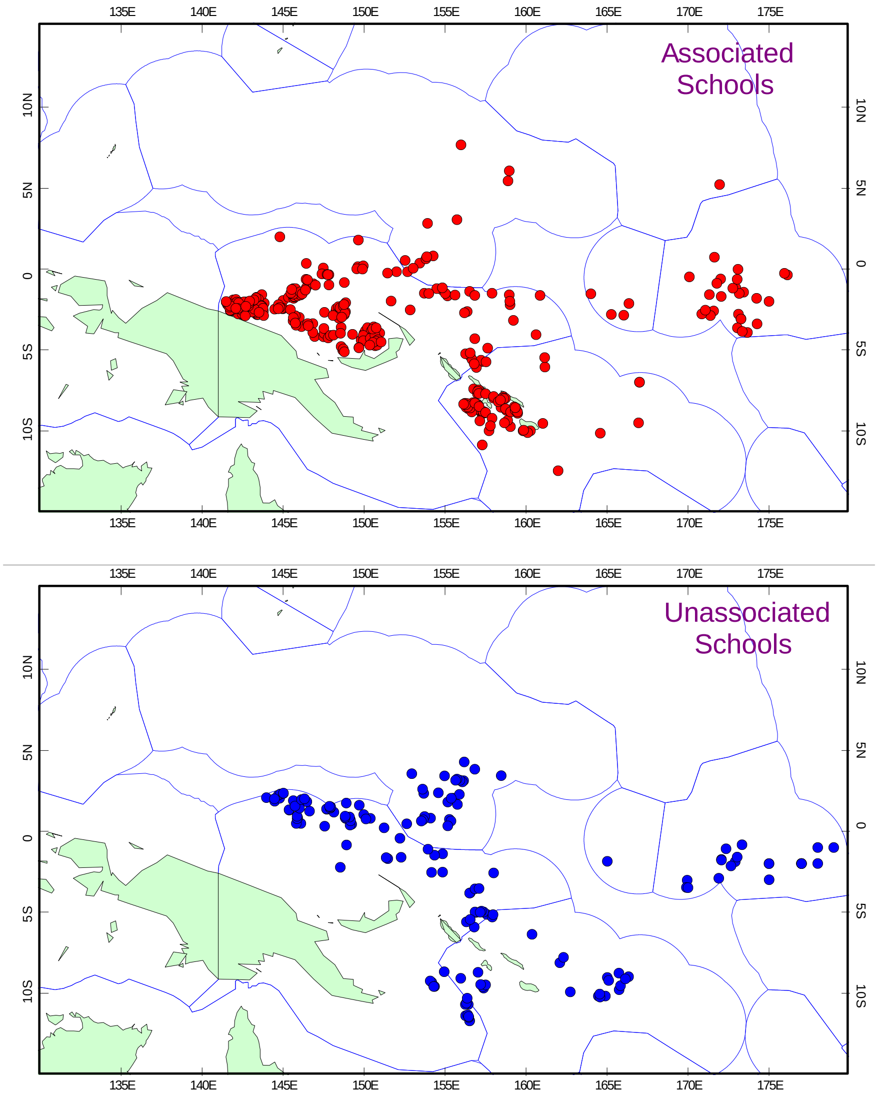
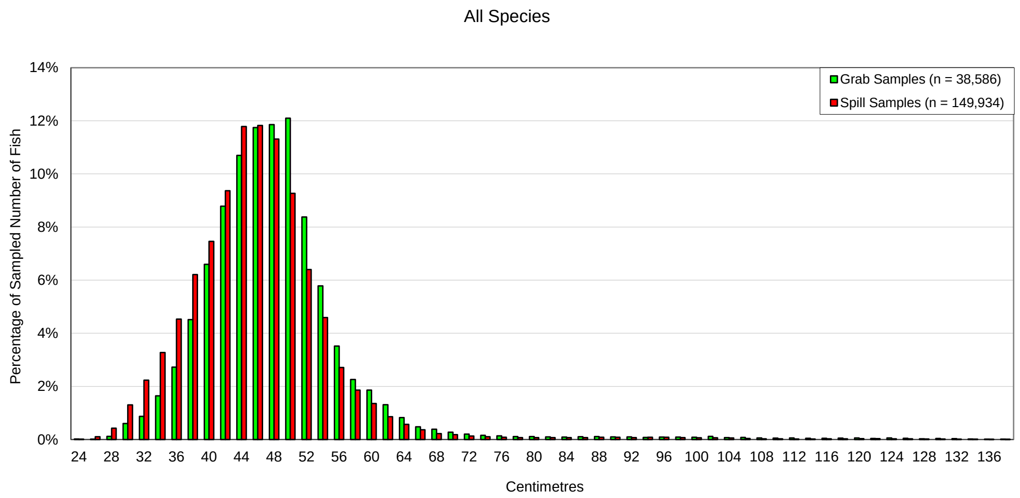


Figure 2 presents length frequencies (in terms of numbers of fish, rather than weight) determined from all 575 sets; the length frequencies for each set have been raised by the set weight. The length frequency at the top of Figure 2 is for skipjack, yellowfin and bigeye combined, and shows that for lengths less than 48 cm, there are greater proportions of fish in the spill samples than in the grab samples and vice versa for fish greater than or equal to 48 cm. Assuming that length frequencies determined from spill samples are unbiased, this is a clear indication of a size selection bias in the grab samples. The same pattern is observed in the length frequencies for each species separately, although the length at which the change occurs differs slightly. For bigeye, the pattern is somewhat less distinct because of the smaller number of fish in the samples. For all fish greater than about 70 cm, the pattern is indistinct for the same reason.

Figure 2. Length frequencies in terms of number of fish, determined from paired grab samples and spill samples



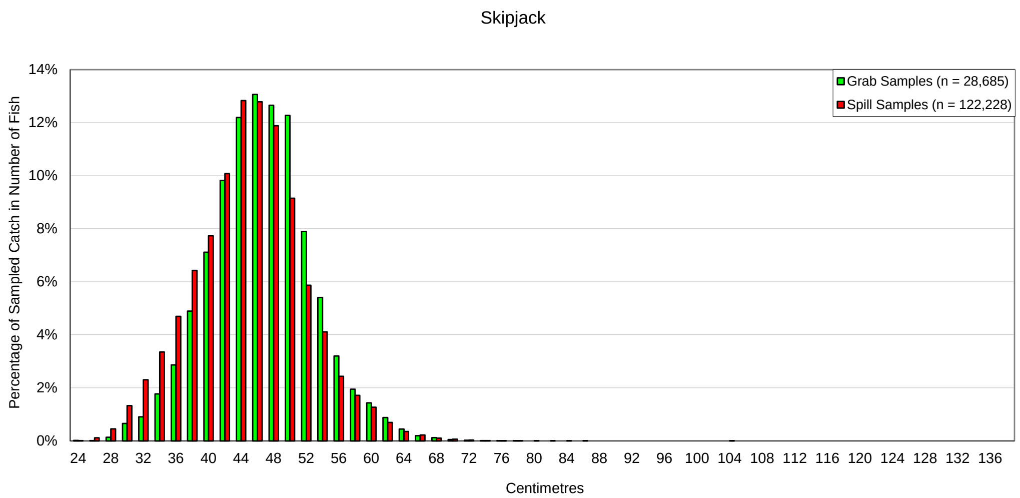
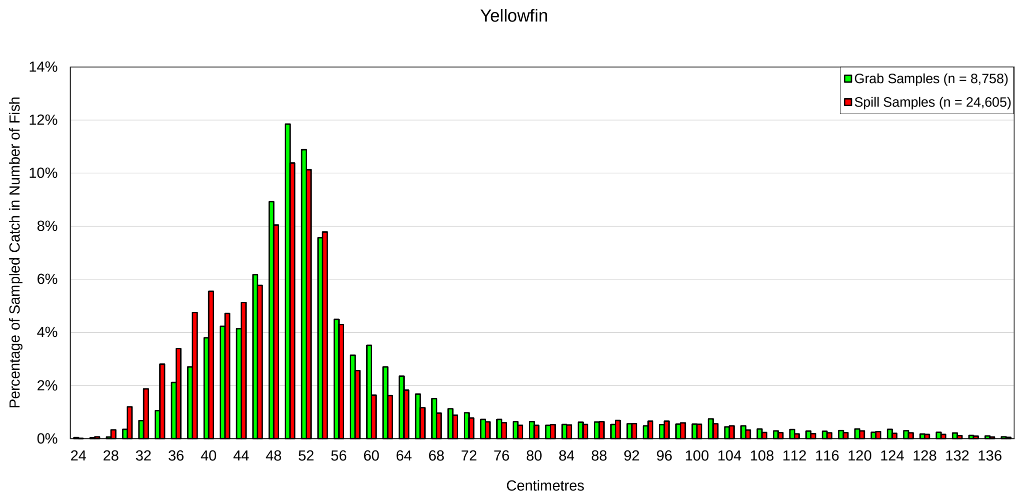
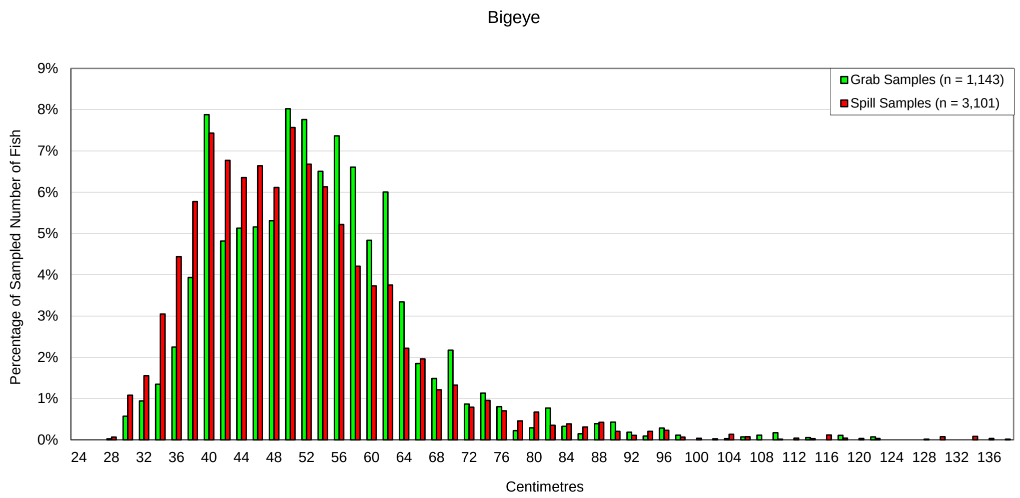


Figure 2 (continued)





Estimation of the selectivity bias in grab samples

Lawson (2009) formulated a method for estimating the selectivity bias in grab samples that is based on the observation that the probability of selecting a fish in a grab sample increases with the size of the fish. The objective of the method is to quantify this relationship, using the paired grab and spill samples; the relationship can then be used to correct for the bias in historical grab samples.

Consider a set in which all the fish are of the same length group *j*. The probability, *p*, of grabbing a fish in the set is the ratio of the number of fish in the grab samples taken from the set, *n*, and the total number of fish in the set, *N*.

$$p = \frac{n}{N} \tag{1}$$

The number of fish in the grab samples is determined by the number of fish grabbed per brail, *G*, the total weight of the set, *W*, and the weight of the fish in each of the brails, *B*. The total number of fish in the set is the ratio of the set weight, *W*, and the weight of individual fish of length *j*, w_j . We have

$$p = \frac{G \cdot \frac{W}{B}}{\frac{W}{w_j}} \tag{2}$$

$$= \frac{G}{B} \cdot w_j \tag{3}$$

Note that the probability, *p*, does not depend on the set weight; this is because the grab sample protocol is to always take *G* fish per brail. If the number of fish grabbed per brail and the weight of fish in each brail do not change among sets or trips, the probability of a fish being grabbed depends only on the weight of individual fish of length *j*, w_j . Furthermore, the relationship between the probability of a fish being grabbed and the length *j* of a fish is given by

$$p = \frac{G}{B} \cdot a \cdot j^b \tag{4}$$

where *a* and *b* are the length-weight parameters. That is, we should expect to see a nonlinear relationship between the probability of a fish being grabbed and the length of a fish.

Lawson (2009) used the term *availability* for the probability of a fish being grabbed from among fish of the same length interval. We have

$$n_{jk} = N_{jk} \cdot A_j \tag{5}$$

$$= \frac{W_k \cdot T_{jk}}{\overline{w}_j} \cdot A_j \tag{6}$$

where n_{jk} is the number of fish in length interval *j* selected by a grab sampler from set k ; N_{jk} is the "true" number of fish in length interval *j* in set k ; A_j is the *availability,* i.e., the probability that a grab sampler will select a fish from among those of length interval j ; W_k is the total weight of set k ; T_{jk} is the "true" proportion of fish of length interval *j* in set *k*, in terms of weight, determined from the spill sample taken from set k ; and $\overline{w}_j$ is the average weight of fish of length interval j .

Note that we assume that the *availability* for length interval *j* is constant over all sets. This does *not* mean that the probability of grabbing a fish of length *j* from among all fish in a set, including those not of length *j*, is constant, but only that the probability of grabbing a fish from among those of length *j* is constant. The objective of the analysis is to quantify the relationship between *availability* and length so that we can use that relationship to correct the historical grab samples. Since there are no spill samples for the historical grab samples, the relationship between *availability* and length must be independent of set.

An artefact of estimating the selectivity bias for length intervals is that the length frequencies estimated from grab samples corrected for selectivity bias (Lawson 2011) are discontinuous at the boundaries of each interval. To allow for smoother length frequencies, the selectivity bias was estimated with a cubic spline.

Estimates of the parameters of the splines were obtained using the following relationship for data grouped by set and length interval, which is derived from equation (2):

$$\frac{n_{jk}}{\frac{W_k \cdot T_{jk}}{\overline{w}_j}} = A_j + \varepsilon \qquad (7)$$

$$A_j = f\left(\overline{L}_{jk}, \beta\right) \qquad (8)$$

where the left-hand side of equation (3) is determined for strata of length interval *j* in set *k* from the data, the function *f* is a cubic spline, $\overline{L}_{jk}$ is the average length in the stratum, and β is the vector of parameters to be estimated. The left-hand side of equation (3) is simply the number of fish in length interval *j* in the grab sample from set k, n_{jk}, divided by the “true” number of fish in length interval j in set k; that is, the *availability*. The length of the vector β is equal to the degrees of freedom of the spline, which determines the complexity of the relationship between *availability* and length; the complexity increases with the degrees of freedom. Note that the T_{jk}, the “true” proportions of fish of length interval *j* in set *k*, determined from the spill sample, is itself a random variable; the error term, ε, is assumed to account for this and all noise in the data.

In his review, Cordue apparently misconstrued *availability* to be the probability of grabbing a fish of length *j* from among all fish in set, including those not of length *j*. He also claimed that there was a mathematical error in equation (6), but this is because he misinterpreted the denominator to be the mean weight of fish in the set, rather than the mean weight of fish in length interval *j*. [2]

Nevertheless, Cordue makes a valid point when he notes that measures of the probability of a fish being grabbed depend on the sample size. In regard to estimates of *availability* determined from paired samples, the sample size, although fixed at five fish per brail, may vary due to the brail capacity differing among vessels and due to differences in their degree of fullness. Observers are

[2] McArdle notes Cordue’s error and comments, “I believe here he failed to see the model clearly.”

trained to grab five fish per brail, but they sometimes take fewer fish per brail, sometimes more. However, in the analysis presented herein, these departures from the ideal are considered to simply be noise in the data. It will be shown in Figures 3 and 4 that there is a great deal of noise in the paired sampling data, but also that there is a strong signal concerning the relationship between *availability* and the length of a fish.

The model was fit to length intervals of 0–34 cm, 35–39 cm, 40–44 cm, 45–49 cm, 50–54 cm, 55–59 cm, 60–64 cm, 65–69 cm, 70–74 cm, 75–79 cm, 80–89 cm, 90–99 cm, 100–109 cm and ≥ 110 cm. The model was fit with values of the degrees of freedom ranging from 3 to 20; the model that minimised the Bayesian Information Criterion (BIC, Schwarz 1978) had 3 degrees of freedom and explained 22.5% of the deviance. Fitted *availability* is plotted against observed *availability* in Figure 3. The horizontal striations correspond to the length intervals, with the lowest band corresponding to the smallest length interval. Note that for all length intervals, there is a wide distribution of observed *availability*, although the distributions become more concentrated towards lower values of *availability* as the lengths of fish in the interval get smaller.

Figure 3. Observed vs fitted values of *availability*

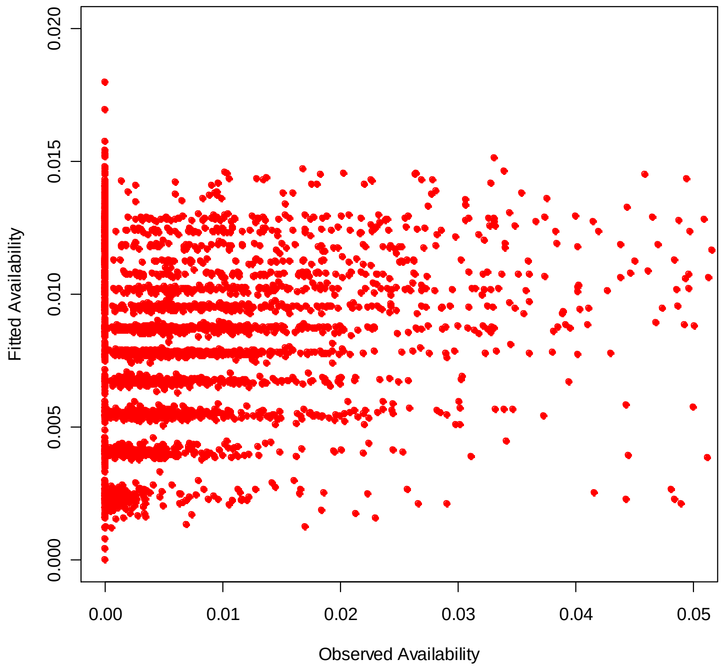
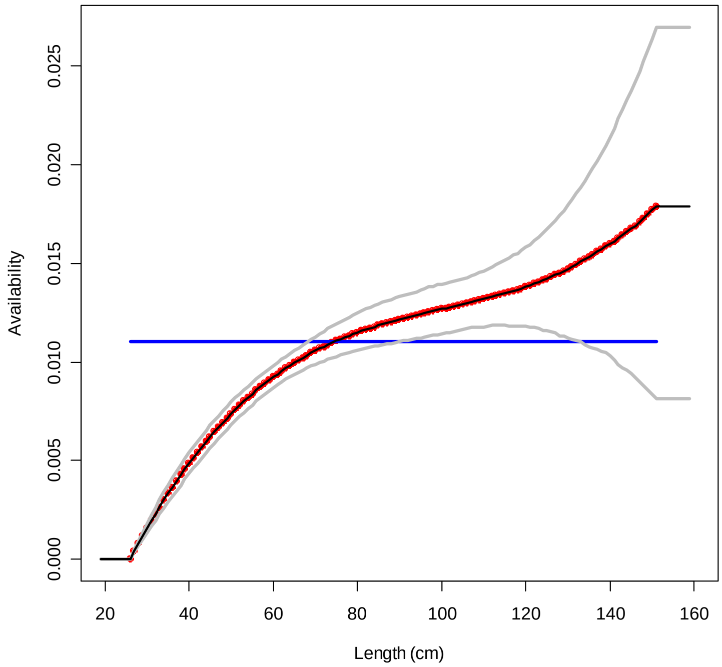


Figure 4 shows the fitted values (red dots) together with predicted values (black line) and upper and lower 95% confidence regions (grey lines). The fitted and predicted values of *availability* increase monotonically with length, increasing rapidly for smaller lengths, then less rapidly from about 60 cm to 100 cm, then somewhat more rapidly for larger lengths. The confidence regions are narrow for smaller fish, but increase progressively; the confidence regions for fish greater than about 110 cm are wide, which reflects the relative lack of data for large fish. The blue line in Figure 5 represents the average *availability*, 1.104%, which is reached at 75 cm. Figure 4 is similar to the figure in Lawson (2012), which was fit to paired samples taken from 348 sets.

Figure 4. Relationship between *availability* and length determined in the current study from 575 paired samples



The estimates of *availability* can be used to approximately correct the species composition for an individual set determined from the grab samples as follows:

$$\widehat{P}_{ik} \approx \frac{\sum_j \frac{W_{ijk}}{A_j}}{\sum_i \sum_j \frac{W_{ijk}}{A_j}} \qquad (9)$$

$$W_{ijk} = W_k \cdot \frac{\sum_l a_i \cdot L_{ijkl}^{b_i}}{\sum_i \sum_j \sum_l a_i \cdot L_{ijkl}^{b_i}} \qquad (10)$$

where $\widehat{P}_{ik}$ is the estimated proportion of species i in set k ; W_{ijk} is the weight of fish of species i and length interval j, raised by the set weight W_k , that were selected by the grab sampler from set

k ; L_{ijkl} is the length of fish *l* in the category of species *i* and length interval *j* in the sample taken from set k ; and a_i and b_i are the weight-length parameters for species *i* (Lawson 2009).

Bias in the species composition estimated approximately by equation (11) is expected, since the probability of grabbing a small fish in the presence of larger fish will be greater than its *availability*, just as the probability of grabbing a large fish in the presence of smaller fish will be lower that its *availability*. This will result in an upward bias in the proportion of skipjack and a downward bias in the proportion of yellowfin. The extent of the bias for a given set will depend partly on the range of the sizes, with bias increasing with the range. It will be shown in the next section that the bias determined from simulated sampling of the sets from which the paired samples were taken is small.

Simulations of availability and correction factors

Correction factors

The initial formulation of the model of *availability* was presented in Lawson (2009), together with an alternate method based on the ratio of the proportion (in terms of weight) at each length interval determined from the grab samples to that determined from the spill samples. For a particular length, if the proportion in the length frequency determined from the grab samples is greater than the proportion determined from the spill samples, then the ratio will be greater than one; if smaller, then the ratio will be less than one. These ratios were termed *empirical factors* in Lawson (2009), as distinct from the model-based *availability*; they will be referred to here as *correction factors*.

If w_{ij} is the sum of the weight of fish of species *i* and length interval *j* in a grab sample, then the corrected proportion of species i , P_i' , in a grab sample using the weight-based *correction factors* is given by

$$P_i' = \frac{\sum_j w_{ij} \cdot f_{ij}}{\sum_i \sum_j w_{ij} \cdot f_{ij}} \qquad (11)$$

$$f_{ij} = \frac{P_{ij}^S}{P_{ij}^G} \qquad (12)$$

$$P_{ij}^S = \frac{\sum_k w_{ijk}^S}{\sum_{ijk} w_{ijk}^S} \qquad (13)$$

$$P_{ij}^G = \frac{\sum_k w_{ijk}^G}{\sum_{ijk} w_{ijk}^G} \qquad (14)$$

where f_{ij} is the correction factor for fish of species *i* and length interval *j*, and P_{ij}^{S} and P_{ij}^{G} are the uncorrected proportions of fish of species *i* and length interval *j* in spill samples and grab samples respectively. P_{ij}^{S} and P_{ij}^{G} are determined by summing the weights of fish, w_{ijk}^{S} and w_{ijk}^{G}, where the subscript *k* refers to the set from which a paired sample was taken.

The analyses in Lawson (2009) were based on paired samples collected during only four trips, with all sets on associated schools. The corrections of the grab samples using the weight-based *factors* gave reasonable results; however, as more paired sampling data were collected, including those taken from sets on unassociated schools, subsequent analyses indicated that the method was strongly biased and the method was no longer applied.

Cordue rejected the method based on *availability* and developed two methods based on multinomial distributions, one complex, the other simple. McArdle examined the simple method. In contrast to *availability*, which is used to correct individual sets, the numbers-based *correction factors* in the method developed by Cordue are applied to low-resolution strata. Thus, McArdle estimated the correction factors from the 394 paired samples that had been collected at that time and used them to correct the grab samples, which he grouped by school association (associated schools and unassociated schools). The formulae for estimating the species composition using correction factors, based on McArdle's implementation, are given in the Appendix. McArdle's conclusion, after comparing the resulting species composition to those based on *availability*, is that (1) both methods "produce plausible corrected values" and (2) "[w]ithout a simulation it is impossible to see which is the more reliable." Simulations were therefore conducted to compare the methods.

Simulations of availability and correction factors

The procedure for simulating (a) the brailing and sampling of fish, (b) analysing the simulated paired samples with *availability* and *correction factors*, (c) correcting the grab samples and (d) estimating the species composition of the sets with the corrected grab samples, is outlined below. At the time the simulations were conducted, there were data for 575 sets from which paired samples were taken. Ideally, simulating the sampling of all 575 sets should give an indication of the reliability of the methods corresponding to the number of paired samples that have been collected to date. The procedure outlined below can be considered the Base Case scenario; modifications to the Base Case will be examined in due course.

1. The simulated fish in each of the paired sampling sets are generated by applying the species and size composition of the spill sample to the set weight for each set. Thus, the true number of fish in each set, and the species and length of each fish, are known. The total number of simulated fish in the 575 sets is 9,794,005.

2. The simulated brailing and sampling of the sets, and the analyses, are repeated for a fixed number of replicates. At the completion of the replicates, the average and standard deviation of the species compositions determined from the corrected grab samples will be calculated.

3.1 For each replicate, each of the sets is brailed and sampled. When brailed, each fish is randomly selected from the set until a standard brail is filled; the average brail size of the 575 sets, 3.208 tonnes, was used as the standard.

3.2 For each brail, a grab sample of five fish is taken. To simulate the bias in the grab samples, the probability of a fish being grabbed size is calculated as a function of the size of the fish:

$$p = \frac{w_i}{\sum_i w_i} \tag{15}$$

where p is the probability of a fish being grabbed from the remaining fish in the brail, w_i is the weight of the i[th] fish remaining in the brail, and $\sum_i w_i$ is the sum of the weights of the fish remaining in the brail. That is, the probability of a fish being grabbed depends on all of the other fish remaining in the brail.

3.3 For every tenth brail, starting with the first brail, a spill sample is taken after the grab sample. Each fish remaining in the brail is randomly selected until a standard spill sample bin is filled; the average spill sample size of 725 kg was used as the standard.

4. After all sets have been completely brailed and sampled, the spill and grab samples are analysed to determine the relationship between (a) *availability* and length, and (b) the *correction factor* and length. The grab samples are then corrected and the species composition is determined from the corrected grab samples, using each of the two methods.

5. After all replicates in the simulation have been completed, the mean and standard deviation of the species composition are determined, for each of the two methods, and compared to the true species composition.

Note that in the Base Case, (i) the brail capacity is fixed, (ii) all brails are full, (iii) all grab samples are of five fish, (iv) the spill sample size is fixed, and (v) there is no layering of fish by species or size in the sets or brails.

Availability and *correction factors* were estimated for fourteen length groups of 0–34 cm, 35–39 cm, 40–44 cm, 45–49 cm, 50–54 cm, 55–59 cm, 60–64 cm, 65–69 cm, 70–74 cm, 75–79 cm, 80–89 cm, 90–99 cm, 100–109 cm and ≥ 110 cm. In the Base Case, the estimates of *availability* were for strata of length group only, and not for strata of species – length group. The estimates of the *correction factors* were for strata of school association (associated and unassociated), species and length interval.

Upon implementation of the simulations, it became apparent that they were computationally intensive, particularly for sets in excess of 20,000 fish. It was therefore decided to limit the simulations to 50 replicates of the 426 sets with less than 20,000 fish. These sets still contain a broad range of species and size compositions, with 308 sets on associated schools ranging from 3.6 tonnes to 89.4 tonnes and 118 sets on unassociated schools ranging from 6.2 to 89.6 tonnes. The results of the simulations are presented in Table 2 and explained below.

Table 2. Results of simulations for the base case

#	Method	Associated Schools			Unassociated Schools			All Schools		
		Skipjack	Yellowfin	Bigeye	Skipjack	Yellowfin	Bigeye	Skipjack	Yellowfin	Bigeye
1	True value	0.5591	0.3917	0.0493	0.5623	0.4276	0.0101	0.5601	0.4033	0.0366
2	Grab samples	0.3913	0.5446	0.0641	0.4691	0.5191	0.0118	0.4165	0.5363	0.0472
3	Spill samples	0.5607	0.3901	0.0491	0.5636	0.4261	0.0103	0.5617	0.4018	0.0366
4	Availability	0.6022	0.3513	0.0466	0.5706	0.4190	0.0104	0.5920	0.3732	0.0348
5	Correction factors	0.6296	0.3245	0.0460	0.8785	0.1139	0.0076	0.7102	0.2562	0.0335

<u>True value</u>

Row #1 in Table 2 gives the true value of the species composition of the 426 sets combined.

<u>Grab samples</u>

Row #2 gives the species compositions determined from the uncorrected grab samples. As expected due to the bias in the grab samples, the proportion of skipjack is under-estimated and the proportion of yellowfin is over-estimated.

<u>Spill samples</u>

Row #3 gives the species compositions determined from the spill samples. Also as expected, the species compositions are unbiased.

<u>Availability</u>

For associated and unassociated schools combined, row #4 indicates that for the grab samples corrected with *availability*, there is a small bias for skipjack and yellowfin, +3% and –3% respectively, while the proportions of bigeye are unbiased. The biases for associated schools are slightly greater than for unassociated schools

<u>Correction factors</u>

For associated and unassociated schools combined, row #5 indicates that for the species compositions estimated using *correction factors*, there is considerable bias for skipjack and yellowfin, +15% and –15% respectively, while the proportions of bigeye are unbiased. The biases for associated schools are +7% and –7% for skipjack and yellowfin, while for unassociated schools, the biases are +32% and –31%.

The analysis of the simulated samples with *correction factors* was repeated with all fish greater than 80 cm grouped together in a single length interval, but with no improvement. The manner of calculating the weight of individual fish within each stratum of species and length interval was modified, from using a fixed length for each length interval to using the average weight of fish in the grab samples in the stratum, with no improvement. The *correction factors* were also applied to each set individually, as in the estimation with *availability*, with only minor improvements.

<u>Future simulations</u>

The simulation model used to examine the Base Case will be a useful template to examine the various issues of concern. In the Base Case, the standard deviations of the estimates of the proportions of skipjack and yellowfin, for both *availability* and *correction factors*, were small, less than 1%, which suggests that fewer replicates are required in the simulations.

Future simulations should allow for noise in the samples due to variation in the brail capacity, the fullness of brails and spill sample sizes, and departures from the grab sample protocol of five fish per brail.

The effect of layering by species and size in the set and brail could also be examined. Lawson (2012) examined the average level of layering in sets; this analysis could be extended to look at the variance in layering between sets, with the results used in the simulations.

Measures to estimate the precision of the estimates of the species composition determined from the corrected grab samples, such as bootstrapping, could be considered.

Simulations would be useful in examining refinements to the method using *availability* that are directed to reducing the relatively small bias.

The bias in the Base Case using *correction factors* is large, particularly for unassociated schools. It would be of interest to further examine the *correction factors* with the simulation model, if only to better understand why the method fails.

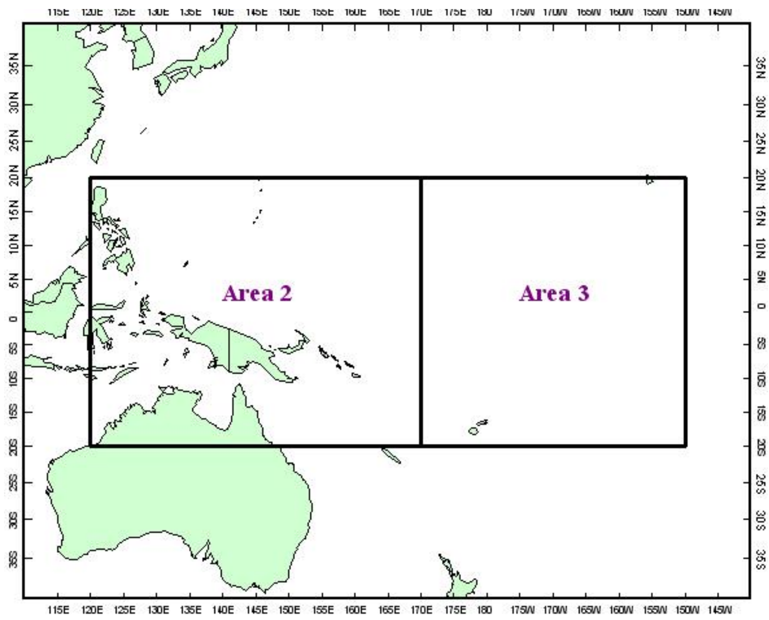
Inclusion of the proportion of skipjack determined from catch and effort logsheets as a covariate in models of species composition

Lawson (2012) examined three sets of models of purse-seine species composition. In Case A, three types of model were used. The models used to estimate the species composition for 1967–1995 had covariates of *quarter*, *area* and *school association*, all of which were categorical, and their first order interactions; the models used to estimate the species composition for 1996–2001 had covariates of *year*, *quarter*, *area* and *school association*, without their interactions; while the models used to estimate the species composition for 2002–2011 had covariates of *year*, *quarter*, *area* and *school association*, with their interactions. The *area* covariate had only two values, representing MFCL Skipjack Areas 2 and 3 (Figure 5); hence, the models of Case A were considered 'low resolution'. With three types of model and three species — skipjack, yellowfin and bigeye — the observer data were fit to nine models.

In Case B, two types of model were used. The models used to estimate the species composition for 1967–1995 had covariates of *quarter,* a two-dimensional spline of latitude and longitude, *lat_lon*, and vessel *flag*; the models used to estimate the species composition for 1996–2011 had covariates of *year*, *quarter*, *lat_lon* and *flag*. The models were fit with data covering associated schools and unassociated schools separately, so there was no covariate for associated and unassociated schools; however, the model for associated schools included a categorical covariate for *associated school sub-type* (anchored FADs, drifting FADs, logs, 'other'). Since geographic area was parameterised as a continuous latitude–longitude surface, the models of Case B were considered 'high resolution'. With two types of model, two types of observer data (covering associated schools and unassociated schools) and three species, the observer data were fit to twelve models.

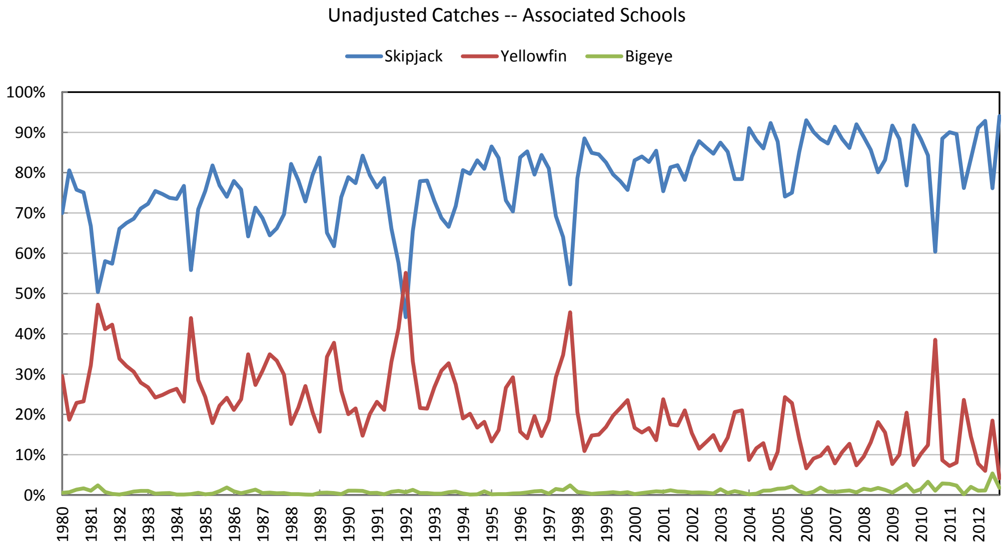
Case C was similar to Case B, except three models were used, for 1967–1995, 1996–2001 and 2002–2011 respectively; the models for 2002–2011 included interaction terms for *year* and *quarter*, and *year* and MFCL Skipjack Area. With three types of model, two types of data (associated schools and unassociated schools) and three species, the observer data were fit to eighteen models.

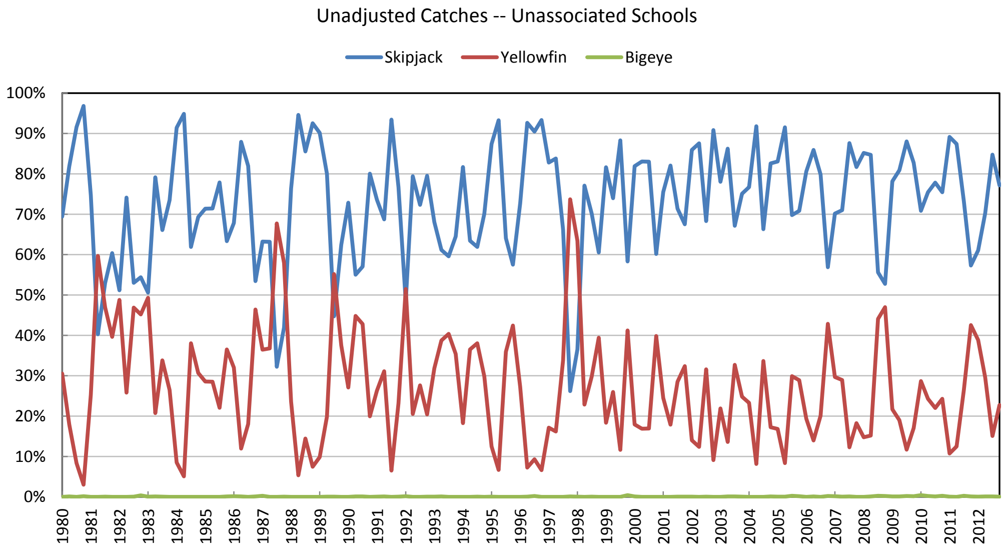
Figure 5. MFCL Skipjack Areas 2 and 3



In each of Cases A, B and C, the models for the period 1967–1995 did not include the *year* covariate; the deviance explained by the models were much less than those that included the *year* covariate (see, e.g., Lawson 2011, Table 4). Therefore consideration was given to the means by which estimates of the species composition for this period, during which observer data were not being collected, might be improved. While the catches reported on catch and effort logsheets are known to be mis-reported — with catches of skipjack over-estimated, catches of yellowfin under-estimated and negligible catches of bigeye — they still contain at least *some* information on the species composition. For example, Figure 6 presents the species composition of quarterly catches in MFCL Skipjack Areas 2 and 3, 1980–2012, that were determined from catches reported on logsheets. The proportion of skipjack is generally high, yellowfin low and bigeye negligible, as expected, but there is also considerable temporal variation in the proportions.

Figure 6. Purse-seine species compositions of catches in MFCL Skipjack Areas 2 and 3 determined from catches reported on logsheets





It was therefore considered reasonable to include the proportion of skipjack determined from logsheets as a covariate in the models of species composition. Since the proportion of bigeye reported on logsheets is negligible, the proportion of yellowfin is the complement of the proportion of skipjack; the proportion of skipjack therefore captures all of the information on the species composition that is contained in the logsheet data.

The replicates of observer data used to fit the models of the species composition in Lawson (2012) were defined as strata of *trip – school association*; the response variables were the proportion of each species determined from the sum of the observed catches by species for the trip and school association, wherein the catches by species for each set were the product of the species composition determined from the samples and the set weight. In the current analyses, with data covering 2012 and 2013, there were a total of 6,589 strata of observed *trip – school association*. Purse-seine trips typically take place over parts of two to three months; the year and month assigned to each stratum of *trip – school association* was the month for which the number of days in the stratum on which at least one set was made was greatest. The *latitude* and *longitude* assigned to each stratum was the average latitude and longitude of the location of sets in the stratum, weighted by the catch. For strata of *trip – associated schools*, the *school association* assigned to the stratum — logs, anchored FADs, drifting FADs or 'other' — was the school association for which the total catch in the stratum was greatest. For simplicity, a value of 13 degrees of freedom was used to determine the basis values of the *lat_lon* spline in each model of Cases B and C. When fitting the models, each stratum was weighted by the number of sets in the stratum.

The same models and replicates as those used in Case C were used in the current analysis, except that the *unadjusted proportion of skipjack* (determined from logsheets) was excluded as a covariate in Case C1 and included in Case C2. For each replicate, the *unadjusted proportion of skipjack* was determined for the stratum of year – quarter – 2° x 2° grid – school association (associated or unassociated); vessel flag was not considered in the stratification. For 239 out of 6,770 replicates (3.5%) for which the stratum was not found in the logsheet data, the *unadjusted proportion of skipjack* was determined for the larger stratum of year – quarter – school association. For 5 out of 6,770 replicates (0.07%) for which the larger stratum was not found, the average unadjusted proportions of skipjack by for associated schools and unassociated schools were used.

Table 3 compares the deviance explained in each of the 18 models of Cases C1 and C2. The top two rows of Table 3 show that including the unadjusted proportion of skipjack in the model without the year covariate considerably improves the fit; the middle two rows show that including the unadjusted proportion of skipjack in the model with the year covariate, but without the year interactions, somewhat improves the fit; while the bottom two rows show that including the unadjusted proportion of skipjack in the model with the year covariate and with the year interactions, only slightly improves the fit.

Table 4 shows the deviance explained by each of the covariates separately. For both associated and unassociated schools, the deviance explained by the *unadjusted proportion of skipjack* is high for skipjack and yellowfin and negligible for bigeye.

Table 3. Comparison of the deviance explained in the models with and without the unadjusted proportion of skipjack from logsheets

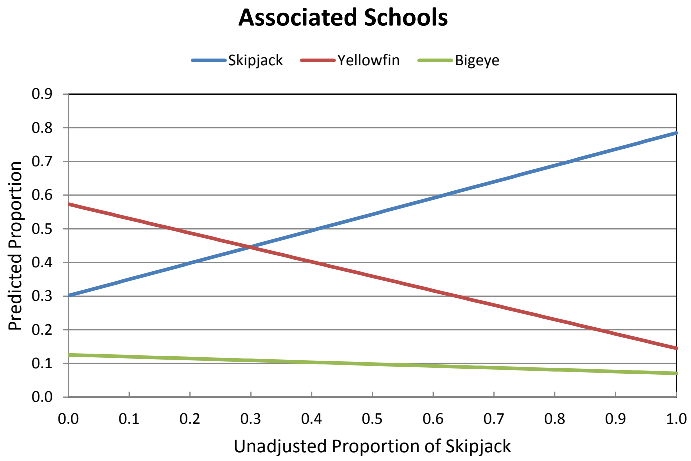
Covariates Included in the Models			School Association					
Year	Year Interactions	Unadjusted Proportion of Skipjack	Associated			Unassociated		
			Skipjack	Yellowfin	Bigeye	Skipjack	Yellowfin	Bigeye
No	No	No	21.0%	29.4%	10.7%	20.8%	20.9%	1.8%
No	No	Yes	29.4%	36.9%	11.3%	35.6%	35.8%	1.9%
Yes	No	No	30.5%	36.2%	16.6%	25.5%	25.7%	2.4%
Yes	No	Yes	35.6%	41.0%	16.8%	37.8%	38.0%	2.5%
Yes	Yes	No	35.5%	40.3%	22.4%	36.5%	36.5%	4.2%
Yes	Yes	Yes	39.1%	43.8%	22.5%	42.1%	42.2%	4.2%

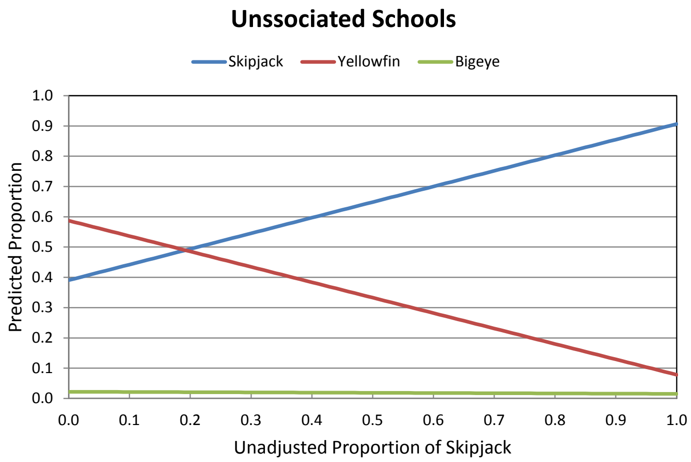
Table 4. Deviance explained by each covariate separately

Covariate	School Association					
	Associated			Unassociated		
	Skipjack	Yellowfin	Bigeye	Skipjack	Yellowfin	Bigeye
Year	15.4%	14.0%	6.1%	3.6%	3.8%	0.6%
Quarter	6.3%	6.4%	0.4%	1.6%	1.5%	0.2%
Year – Quarter Interaction	21.7%	20.4%	11.7%	16.3%	16.2%	1.9%
Latitude x Longitude	13.6%	21.2%	6.1%	17.4%	17.5%	0.5%
Flag	11.0%	17.0%	6.2%	9.1%	9.3%	1.1%
MFCL Area – Year Interaction	19.2%	18.8%	8.9%	7.2%	7.3%	1.0%
School Association Sub-Type	9.8%	15.1%	2.1%			
Unadjusted Proportion of Skipjack	23.8%	28.6%	0.1%	30.3%	30.5%	0.3%

Figure 7 shows the effect of the *unadjusted proportion of skipjack* on predictions of the species composition. For associated schools, the effect on the proportion of bigeye is relatively constant, about 10%, though declining slightly with an increase in the unadjusted proportion of skipjack, while for unassociated schools, the effect is negligible. For both associated and unassociated schools, the effects on the proportions of skipjack and yellowfin are complements, less the effect on bigeye For simplicity, the covariate was parameterised as linear; a more complex parameterisation would probably not greatly enhance the results.

Figure 7. Effect of the *unadjusted proportion of skipjack* on predictions of the species composition



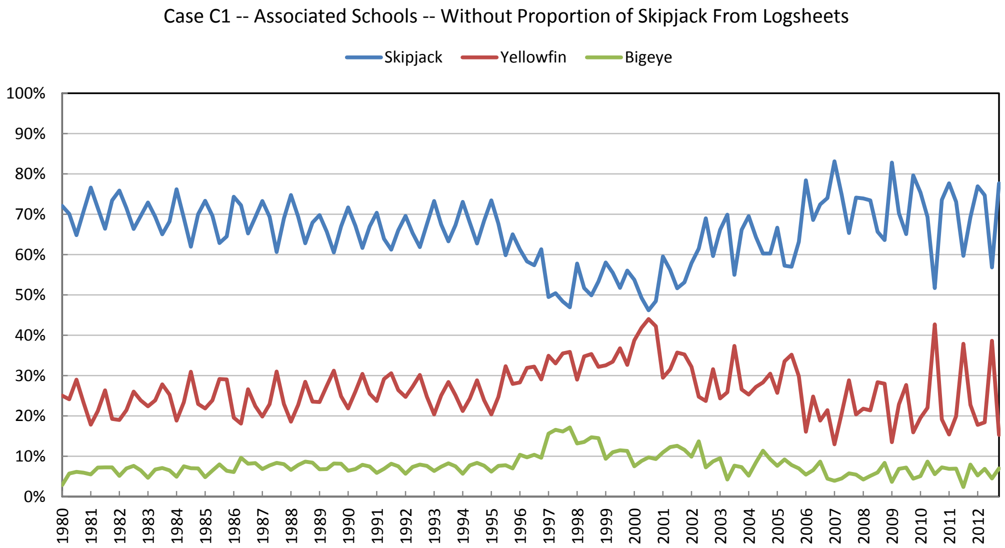


Following the procedure of Lawson (2012), the models in Case C1 and C2 were used to predict the species composition for the catch data in the OFP database, 's_best', which are stratified by year, month, 1° x 1°, school association and vessel flag; the species composition was predicted for a total of 232,869 strata. For each stratum, the *unadjusted proportion of skipjack* was used as a covariate for the prediction.

Figure 8 presents the species compositions of quarterly catches in MFCL Skipjack Areas 2 and 3, 1980–2012, that were adjusted with the models of Cases C1 and C2. Note that for 1967–1995, the models do not include the *year* covariate; for 1996–2001, the models include the *year* covariate but not the year interactions; and for 2002–2011, the models include the *year* covariate and *year* interactions. For the period 1967–1995, inclusion of the *unadjusted proportion of skipjack* in Case C2 results in greater volatility in the species composition; the spikes correspond closely to those in the species composition determined only from the logsheet data (Figure 6). For the period 1996–2001, the differences between Cases C1 and C2 are relatively small, while for the period 2002–2012, they are minor. These results are consistent with the deviance explained by the models

(Table 3). The *unadjusted proportion of skipjack* thus appears to contribute additional information on the species composition of the catch primarily in the absence of a *year* covariate and its interactions.

Figure 8. Purse-seine species compositions of catches in MFCL Skipjack Areas 2 and 3 that were adjusted with the models of Cases C1 and C2



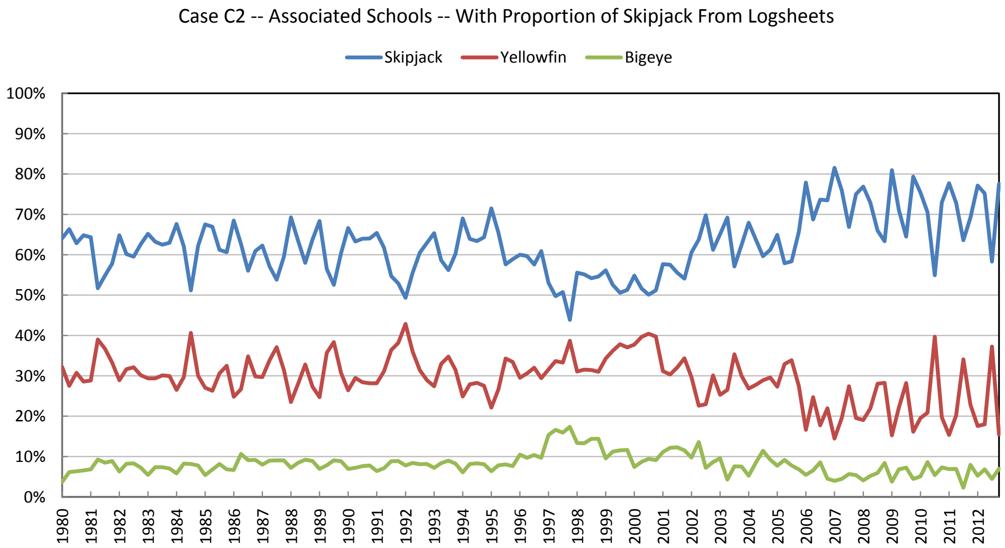
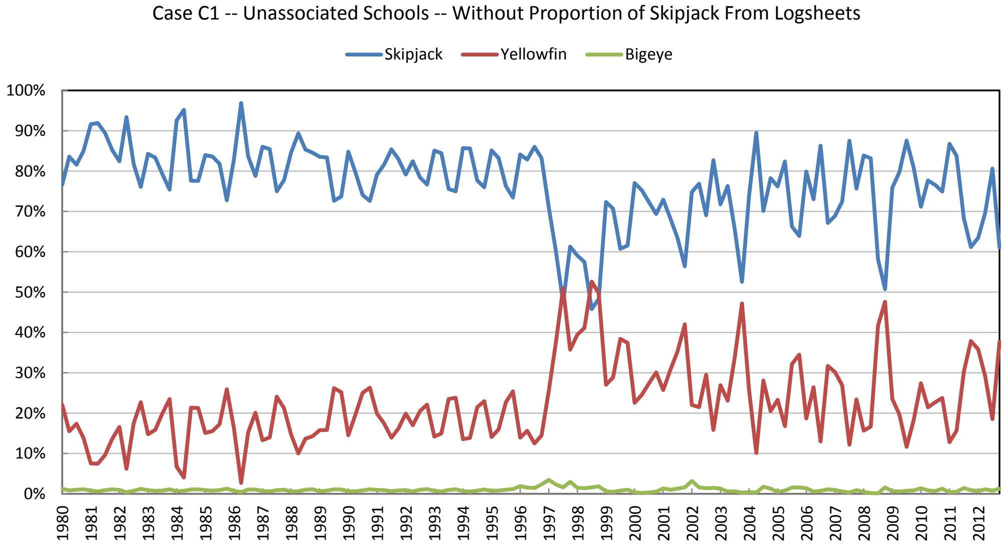


Figure 8 (continued)



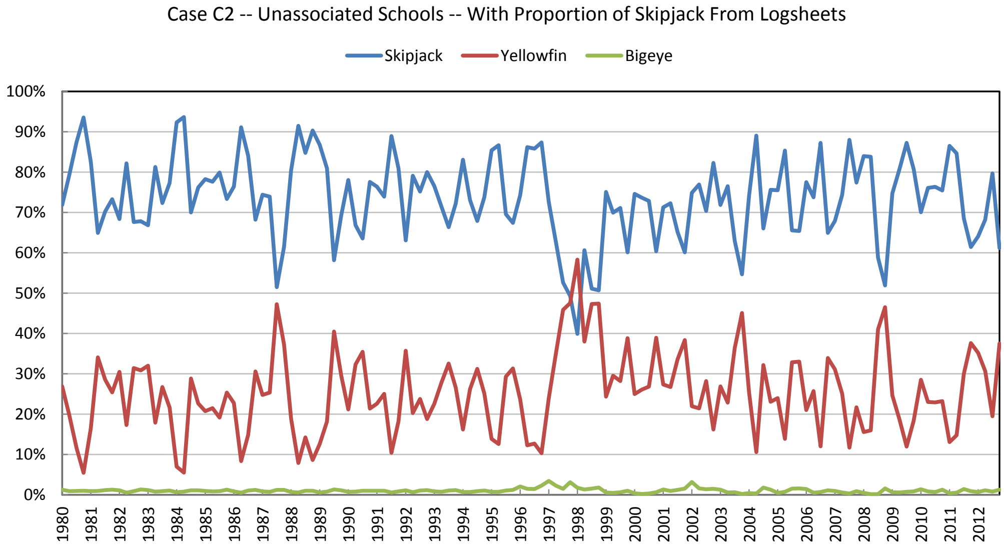
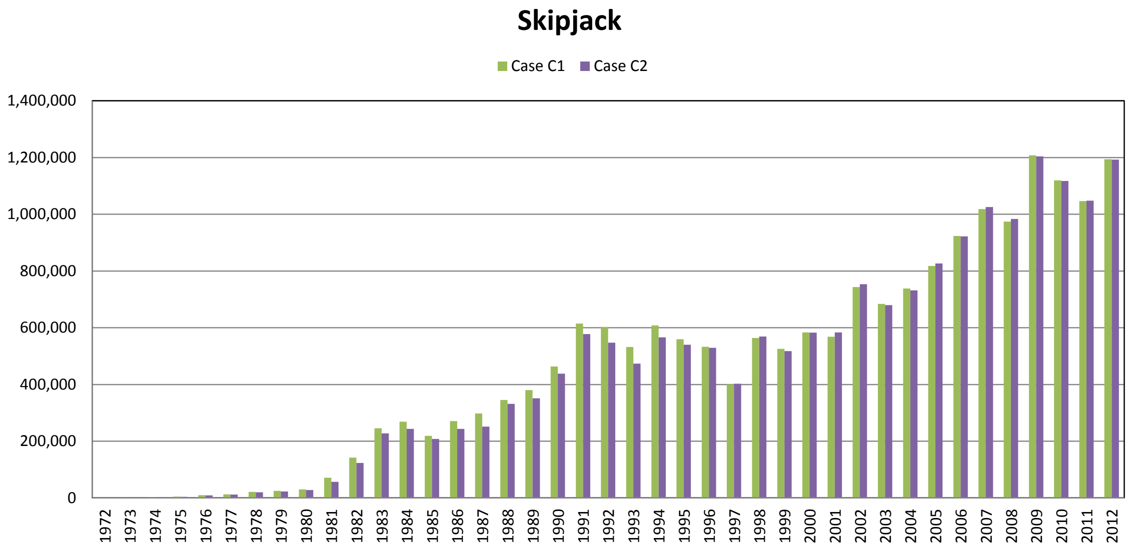
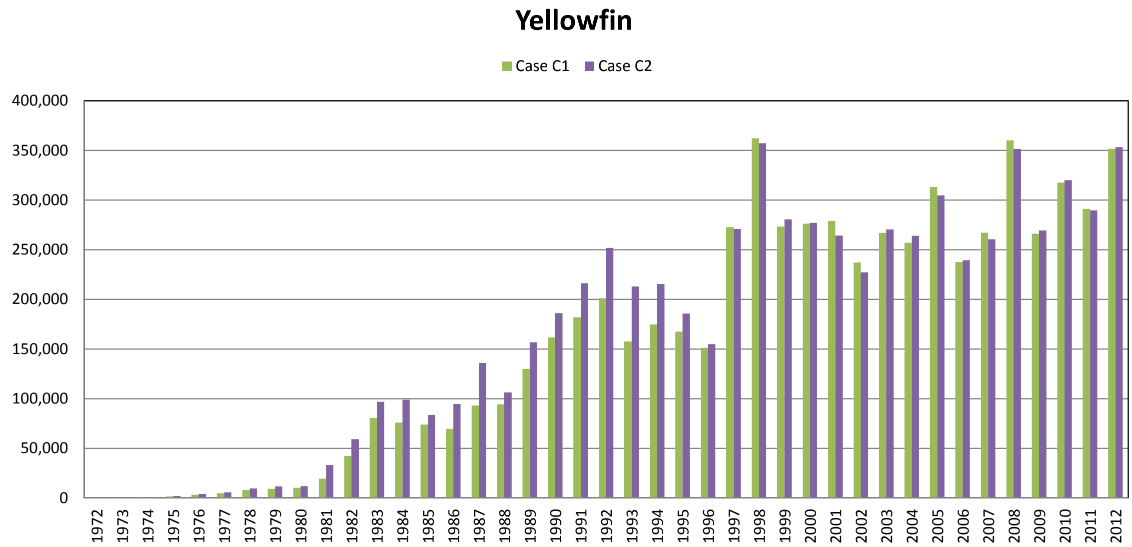
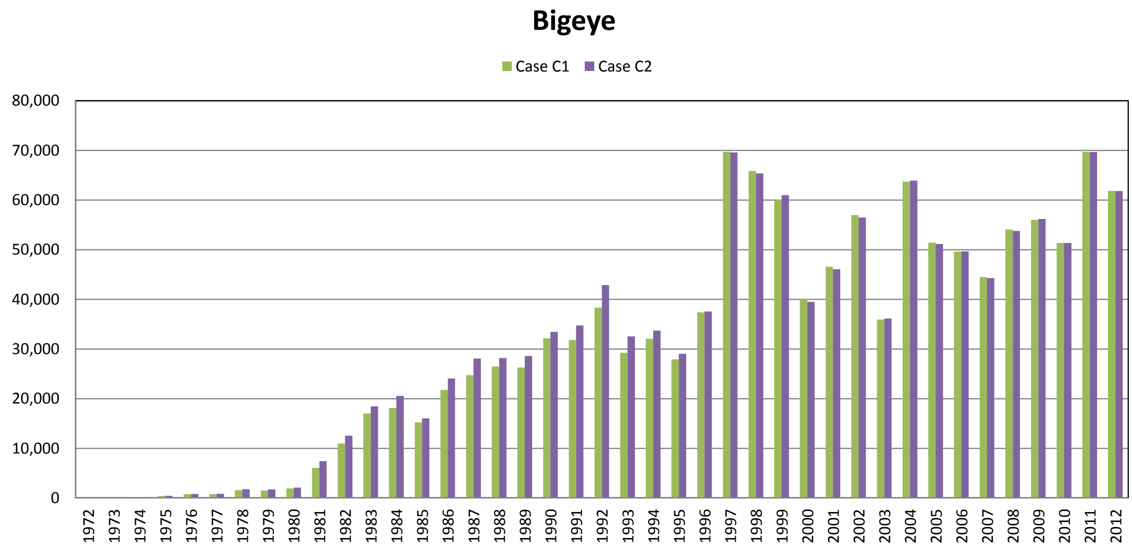


Figure 9 shows that the annual catch estimates for Skipjack Areas 2 and 3 determined from the species composition predicted for Cases C1 and C2. For the period 1972–1995, the estimates for Case C2 show smaller catches of skipjack and larger catches of yellowfin and bigeye than Case C1. For the period 1996–2011, the *unadjusted proportion of skipjack* has less of an effect and the catch estimates in Cases C1 and C2 are similar.

Figure 9. Annual purse-seine catches in MFCL Skipjack Areas 2 and 3 determined from species compositions estimated for Cases C1 and C2







Estimation of the species composition from pooled observer data

Observer coverage of the purse-seine catch in MFCL Skipjack Areas 2 and 3 are presented in Table 5. Coverage remained low until 2010, when, as a result of WCPFC Conservation and Management Measure 2008–01, the target coverage was increased to 100% as of January 1, 2010. Table 5 represents the observer data that have been received at SPC and that have been screened for data quality; the levels of coverage for 2010 and 2011, 47.8% and 46.8% respectively, are much higher than in previous years. (The level of coverage for 2012 will increase as more data are provided to SPC.)

Table 5. Observer coverage of the catch (tonnes) in MFCL Skipjack Areas 2 and 3

Year	Associated Sets			Unassociated Sets			Total		
	Observed Catch	Total Catch	%	Observed Catch	Total Catch	%	Observed Catch	Total Catch	%
1993	411	354,480	0.1%	515	364,751	0.1%	926	719,231	0.1%
1994	1,462	397,856	0.4%	1,379	417,175	0.3%	2,841	815,031	0.3%
1995	3,890	336,877	1.2%	1,381	417,945	0.3%	5,271	754,822	0.7%
1996	6,828	427,167	1.6%	4,540	294,635	1.5%	11,368	721,802	1.6%
1997	9,310	442,605	2.1%	2,490	300,576	0.8%	11,800	743,181	1.6%
1998	22,330	510,380	4.4%	14,878	481,426	3.1%	37,208	991,806	3.8%
1999	20,556	630,203	3.3%	6,100	228,760	2.7%	26,656	858,963	3.1%
2000	24,270	503,407	4.8%	9,412	396,196	2.4%	33,682	899,603	3.7%
2001	23,532	408,206	5.8%	16,062	485,277	3.3%	39,594	893,483	4.4%
2002	49,327	560,017	8.8%	19,413	477,570	4.1%	68,740	1,037,587	6.6%
2003	48,241	464,361	10.4%	21,752	522,270	4.2%	69,993	986,631	7.1%
2004	86,988	799,329	10.9%	17,419	260,065	6.7%	104,407	1,059,394	9.9%
2005	77,672	638,953	12.2%	39,956	543,588	7.4%	117,628	1,182,541	9.9%
2006	109,365	791,533	13.8%	35,243	419,306	8.4%	144,608	1,210,839	11.9%
2007	107,827	778,411	13.9%	63,280	551,844	11.5%	171,107	1,330,255	12.9%
2008	93,269	769,998	12.1%	65,292	618,638	10.6%	158,561	1,388,636	11.4%
2009	132,645	938,218	14.1%	78,141	591,809	13.2%	210,786	1,530,027	13.8%
2010	290,765	583,344	49.8%	420,362	905,354	46.4%	711,127	1,488,698	47.8%
2011	415,542	847,349	49.0%	242,238	559,600	43.3%	657,780	1,406,949	46.8%
2012	93,495	791,819	11.8%	83,612	816,195	10.2%	177,107	1,608,014	11.0%
Total	1,617,725	11,974,513	13.5%	1,143,465	9,652,980	11.8%	2,761,190	21,627,493	12.8%

In the past (e.g., Lawson 2012), the species composition has been estimated using General Linear Models fit to the historical grab samples, corrected for bias using *availability*. The rationale for using GLMs is that they are the best technique for dealing with low observer coverage rates; as explained in the preceding section, they have even been used to estimate the species composition in years for which there are no observer data. However, with the increased coverage in 2010 and 2011, the estimation of the species composition by pooling observer data, instead of using GLMs, was examined.

In an exploratory analysis, the corrected grab samples, 1993–2012, were pooled by strata of year–quarter, 5° latitude by 5° longitude, and school association. The catch covered by the observer data was then compared to the total catch in each stratum. Table 6 shows the total number of strata and the number of strata for which the coverage by the observer data was ≥ 20%, and the total catch and the catch in strata for which the coverage by the observer data was ≥ 20%. The coverage in terms of both the number of strata and the catch increase gradually from zero in 1993 to about 30% in 2009, then jump to almost complete coverage in 2010 and 2011.

Table 6. Observer coverage by strata of year–quarter, 5° by 5° longitude, and school association (see text)

Year	Strata			Catch		
	Total	≥ 20%	%	Total	≥ 20%	%
1993	302	0	0.0%	719,094	0	0.0%
1994	309	1	0.3%	815,013	153	0.0%
1995	237	1	0.4%	754,786	842	0.1%
1996	260	3	1.2%	560,270	1,071	0.2%
1997	299	5	1.7%	595,724	5,929	1.0%
1998	280	17	6.1%	820,097	21,886	2.7%
1999	293	15	5.1%	690,720	13,624	2.0%
2000	285	23	8.1%	713,667	32,043	4.5%
2001	296	37	12.5%	732,931	38,285	5.2%
2002	316	50	15.8%	867,170	101,880	11.7%
2003	258	42	16.3%	827,057	86,241	10.4%
2004	339	53	15.6%	895,839	133,844	14.9%
2005	329	66	20.1%	997,026	149,880	15.0%
2006	275	62	22.5%	1,011,098	199,602	19.7%
2007	292	64	21.9%	1,095,945	279,639	25.5%
2008	292	59	20.2%	1,114,137	228,981	20.6%
2009	329	85	25.8%	1,278,700	371,193	29.0%
2010	300	258	86.0%	1,233,061	1,202,863	97.6%
2011	309	258	83.5%	1,148,975	1,120,214	97.5%
2012	312	69	22.1%	1,196,775	183,353	15.3%
Total	5,912	1,168	19.8%	18,068,087	4,171,522	23.1%

Table 6 indicates that with a minimum level of observer coverage of at least 20% within a stratum, the species composition determined from the pooled observer data would cover 19.8% of all strata and 23.1% of the total catch, for all years combined, and almost complete coverage in the years for which the target observer coverage rate has been 100% (except for the most recent year). Adopting a minimum level of coverage of 20% would therefore imply that, going forward, GLMs would only be required for years prior to 2010 and the most recent year. This would certainly be a reasonable approach, but prior to adopting it, it would be of interest to compare the catches in those strata that meet the 20% minimum, based on the species composition determined from the pooled observer data and those determined from the GLMs (Figure 10). For skipjack, the relationship between the two sets of estimates is tight, with 98.9% of the variance explained by a regression. For yellowfin and bigeye, the relationship is less tight, with 90.4% and 85.2% of the variance explained, respectively.

Figure 10. Comparison of catches in strata, by species, determined from GLMs and pooled observer data (see text)

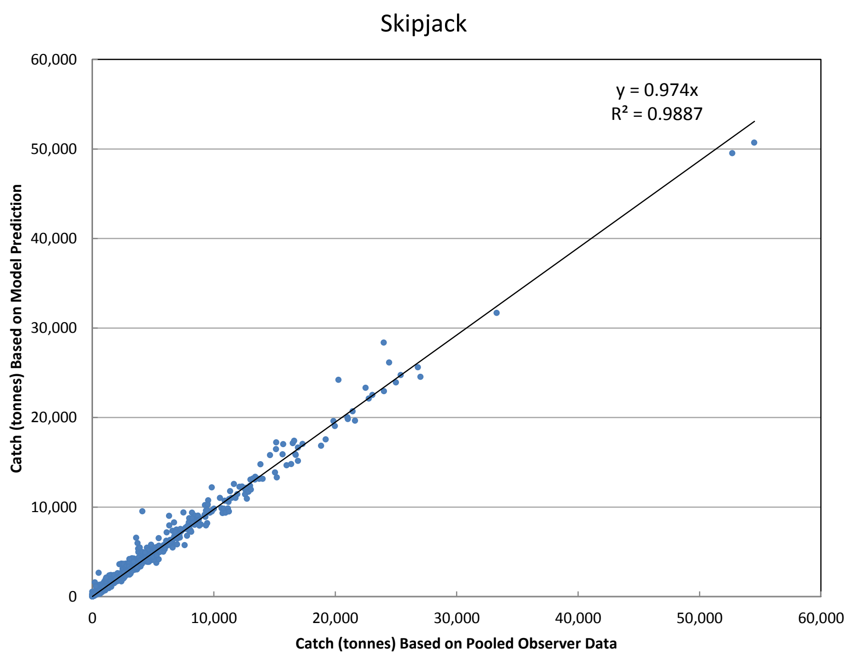
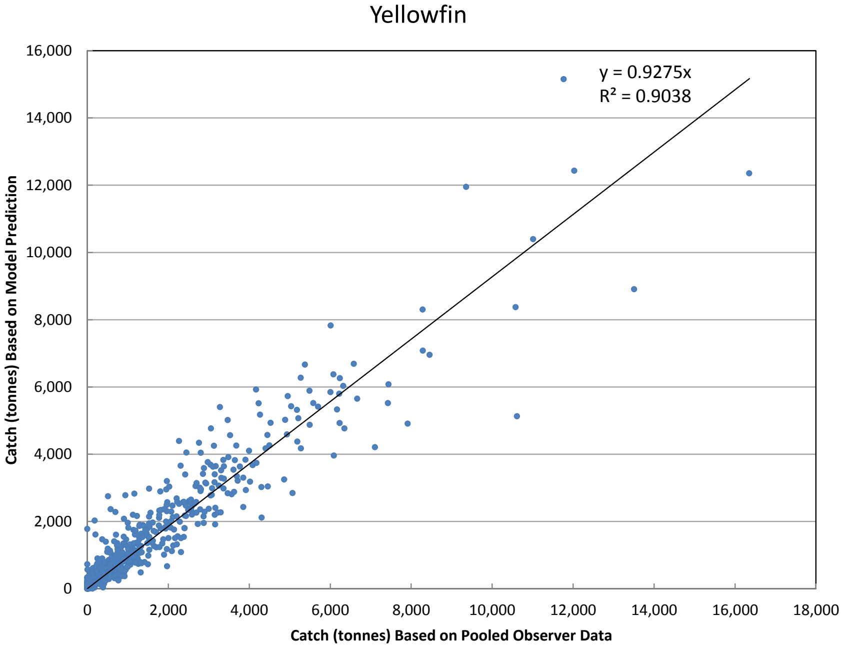
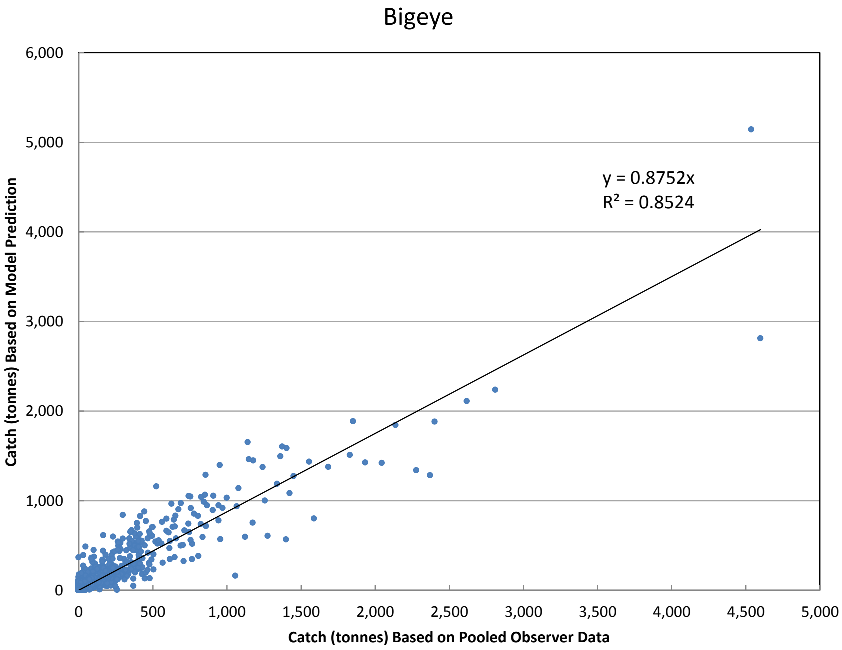


Figure 10 (continued)





While Figure 10 indicates that relationship between the species compositions determined from the GLMs and the pooled observer data is generally close, it would also be of interest to compare catch estimates in the MFCL Areas, by quarter and by school association, for 2010 and 2011, the years for which almost all strata meet the 20% minimum. Figure 11 compares the catch estimates using the GLMs (Case C2) and the pooled observer data (Case D). For skipjack, the catch estimates are almost identical for all quarters. For yellowfin, there is a noticeable difference for associated schools in the second quarter of 2011, while the other catches are in fairly close agreement. For bigeye in associated schools, there is noticeable difference of the first quarter of 2011, while for bigeye in associated schools, there are noticeable differences for four of the quarters, but the level of the catches (see the y–axis) is much lower than for associated schools.

Figure 11. Comparison of catches in MFCL Areas, by species, determined from GLMs (Case C2) and pooled observer data (Case D)

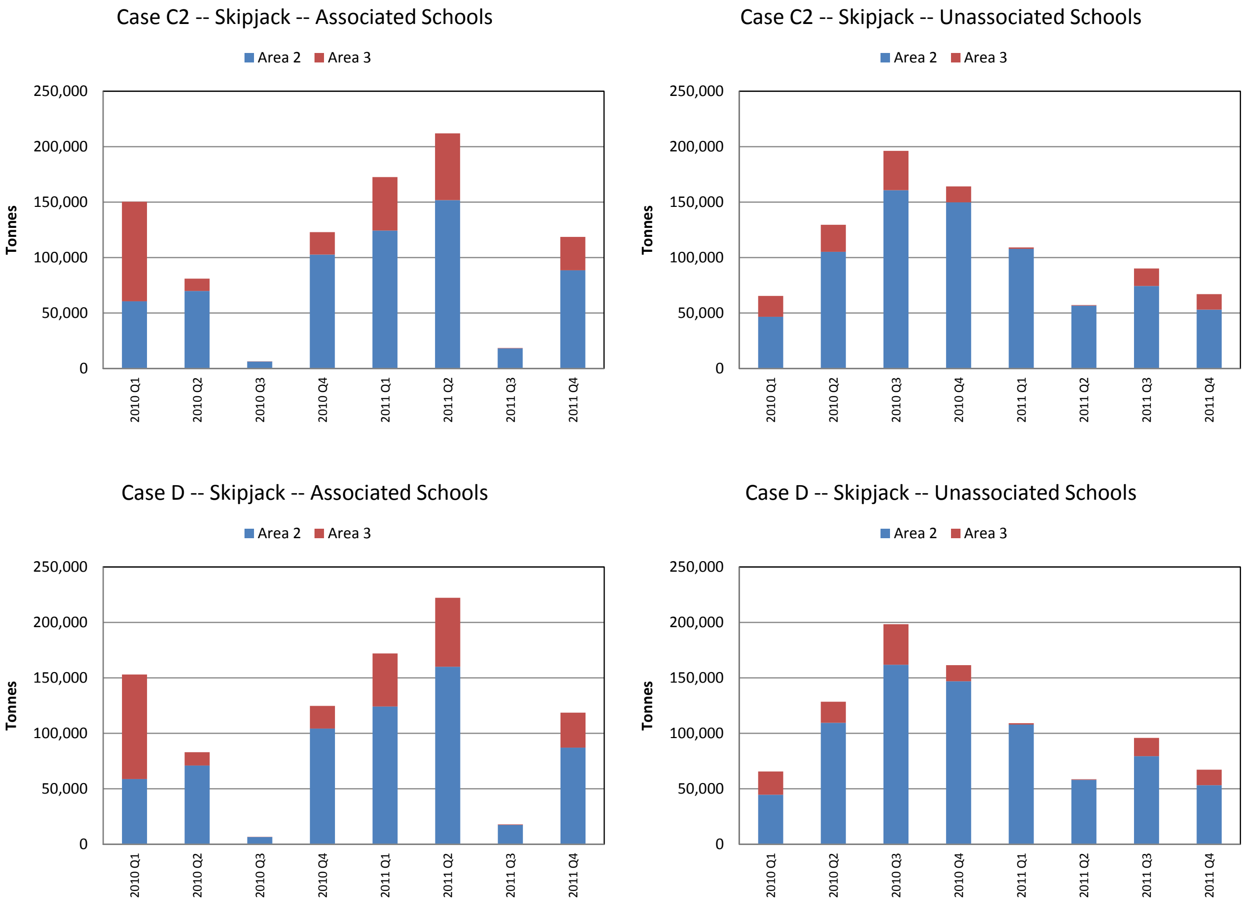
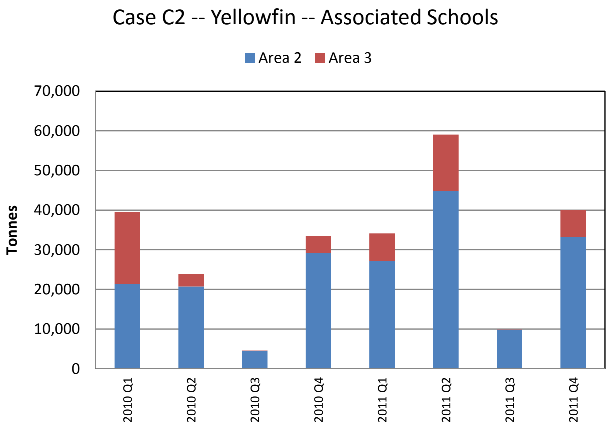
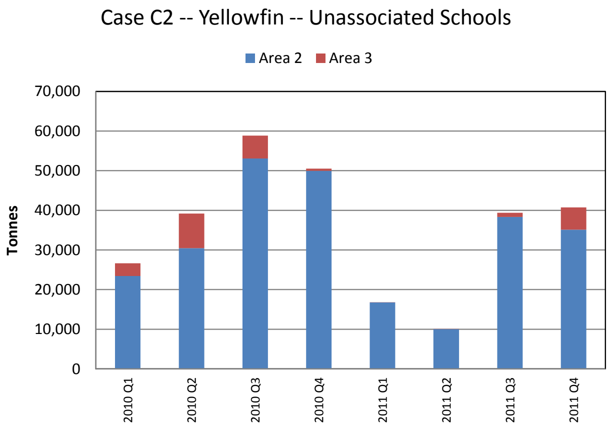
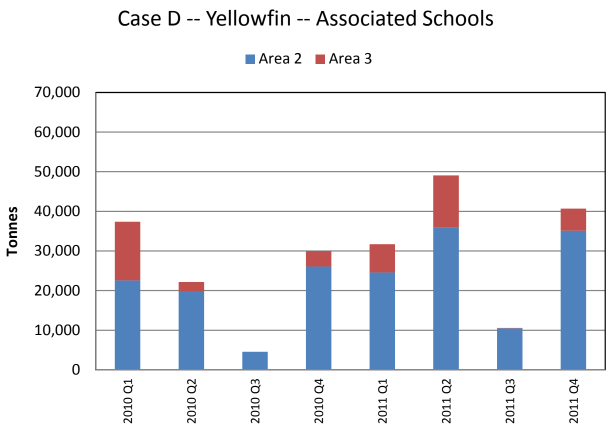


Figure 11 (continued)







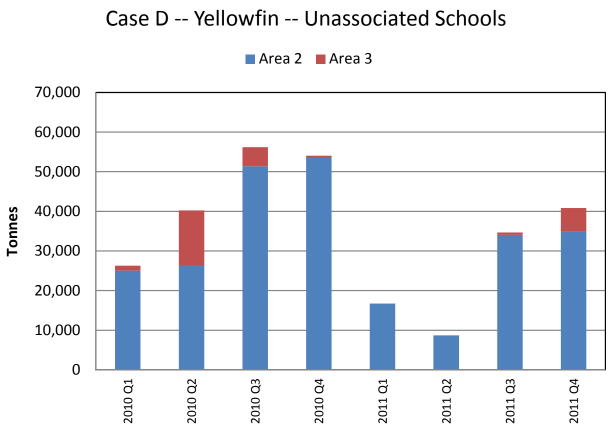
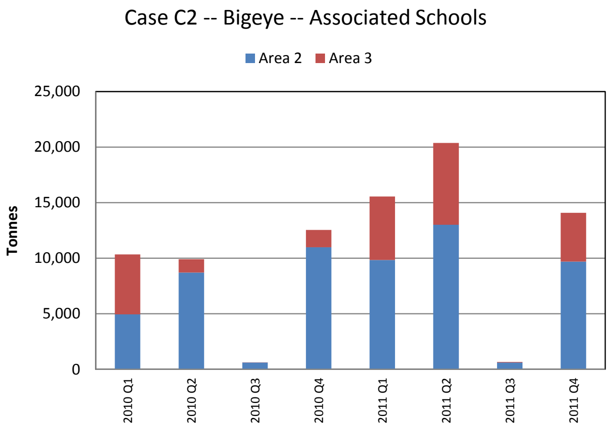
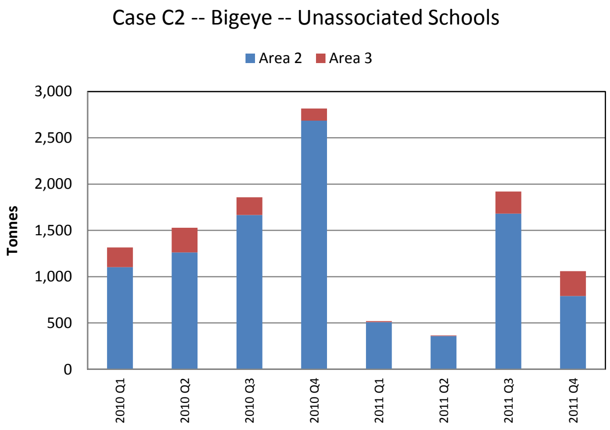
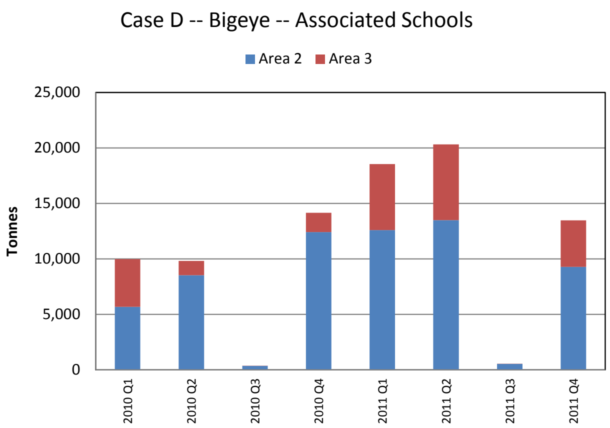
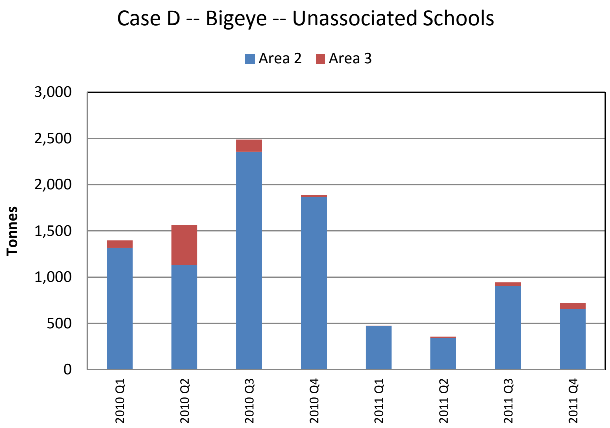


Figure 11 (continued)



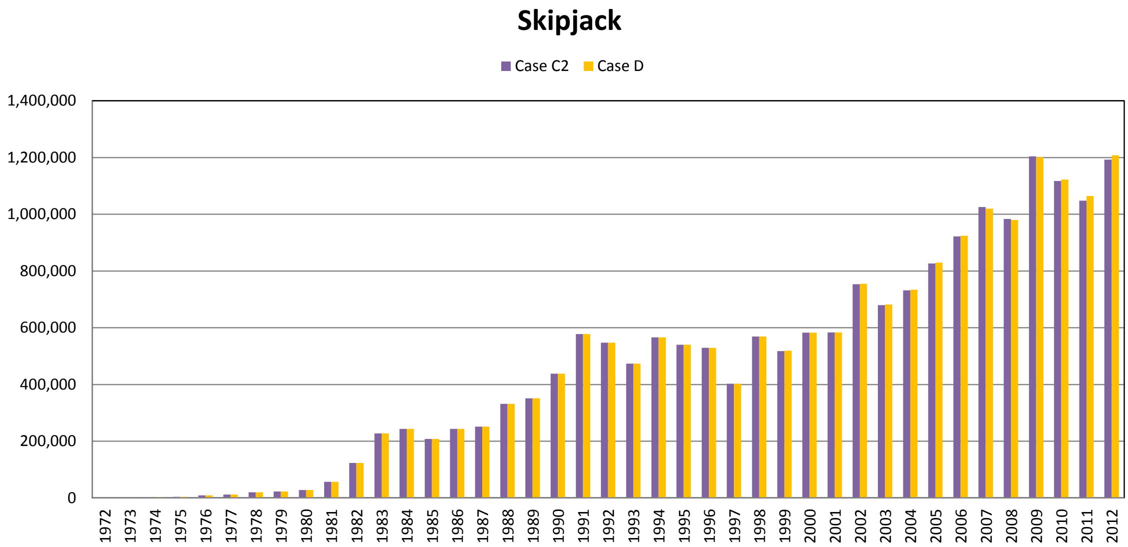


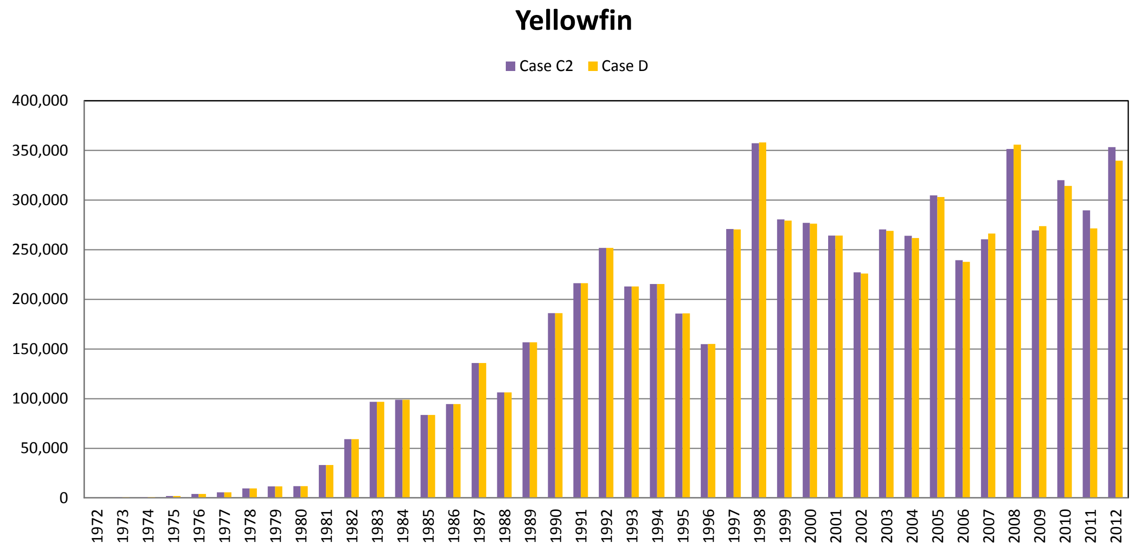


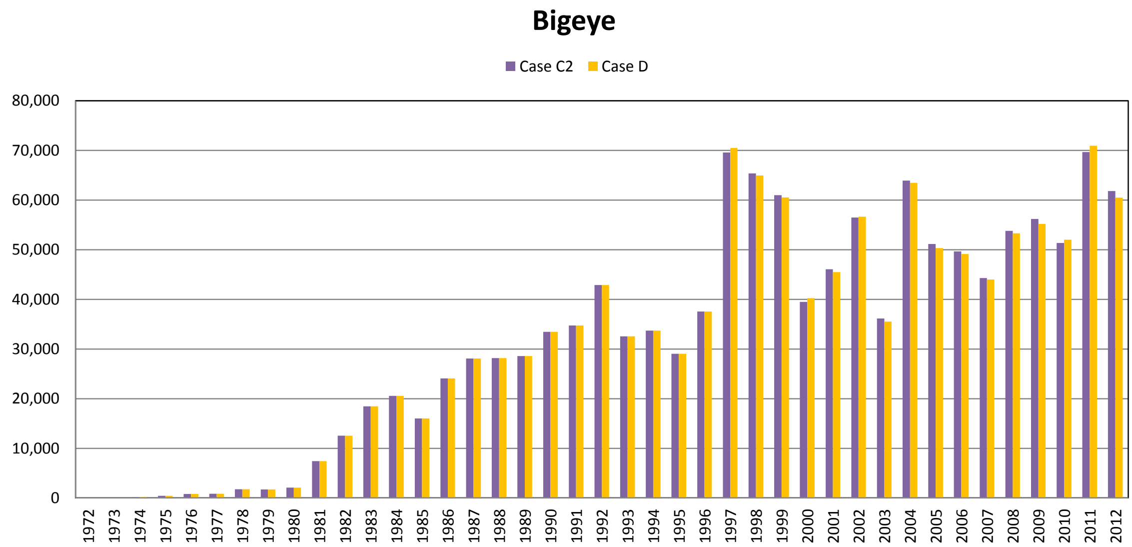


Annual catch estimates for the WCPFC Statistical Area, based on the pooled observer data for those strata that meet the 20% minimum, and GLMs for all other strata, are presented in Figure 12. The most noticeable difference is for yellowfin in 2011, for which the annual catch based on the pooled observer data is somewhat less than the estimate based on GLMs. Otherwise, the differences are minor.

Figure 12. Annual purse-seine catches in MFCL Skipjack Areas 2 and 3 determined from species compositions estimated for Cases C2 and D







In this exploratory analysis, the definition of a stratum and the minimum level of coverage were fixed arbitrarily. Future analyses should examine the effect of varying both. The use of pooled observer data in post-stratification should also be examined; however, it is not expected that post-stratification will be more useful than GLMs in the early years in the time series (Table 5) because the observer coverage rates are so low.

Responses to recommendations of the reviewers

The recommendations of each of the reviewers are listed below; these are followed by comments on each of the main subject areas.

Patrick Cordue

1. A simulation model should be developed for testing alternative observer sampling designs with a view to implementing a design based on spill sampling.
2. Given guidance on the required levels of precision for bigeye, details that need to be worked out include: how to stratify within sets; how to stratify in time and space (extra sampling effort may be needed for bigeye, i.e., more than one observer on some vessels in some seasons/regions); what average size of spill samples/frequency of brail sampling is best; how best to achieve a random/uniform distribution of selected brails; how best to scale set-level estimates to stratum wide estimates.
3. The documentation of the design should include a full set of equations (and simulation results if needed) which show that estimators of length frequencies and catch by species are (almost) unbiased for individual sets and for strata.
4. Historical data need to be reanalysed to produce defensible estimates of catch histories and length frequencies for use in stock assessment and for other purposes: suitable post-stratification should be determined by model-based and descriptive analysis of the uncorrected grab-sample estimates at the set level; paired grab and spill sample data should be used to correct aggregated species length distributions and hence to corrected estimates of catch and length frequency in years with good observer coverage (uncertainty should be estimated by bootstrapping); historical catches in years with little or no observer coverage should be estimated using appropriate stratification (on explanatory variables available in logbooks) and substitution of species-mix estimates from the same stratum type using the average from years that are likely to have had similar species mix (temporal trends in species mix within strata need to be carefully examined).

Joseph Powers

1. There is a need to move away from the model based estimation procedure toward the experimental design based multinomial estimation.
2. There is a need for developing a purse seine set-simulation template to be used to examine the robustness of estimation to bias and variance and to evaluate alternative sampling protocols.
3. The impact of layering in the brail needs to be evaluated through simulation and experimental sequential sampling of brails.
4. Mixed sampling protocols and associated estimation procedures should be developed to encompass the cost efficiency of grab type samples and the less biased but more difficult spill samples.

Brian McArdle

1. The multinomial approach should be employed. Personally I have a feeling the modelling approach of Lawson might have some advantages if combined with a multinomial model. Basically the problems presented by the data seem to require exploitation of every opportunity to improve the quality of the predictions (smoothing, covariates, strata). Evidence for their utility would be from simulation.
2. However the model is developed, it is clear that robust and appropriate measures of the quality of the estimates must be put in place, validated by simulation.
3. A comprehensive multipurpose simulation program is therefore essential.
4. The available data should be examined to establish what stratification is necessary and simulation studies performed to see if useful results can then be achieved.
5. The same analysis should estimate parameters so that the simulation can reproduce realistic scenarios.
6. At the design stage of the simulation, information essential for the useful implementation of the full simulation should be identified and if not yet available then, where possible, data should be collected. For example: the true magnitude of the layering effect in brails.
7. The simulation should be used to compare the proposed models to test the precision of the estimates and proposed measures of reliability.
8. Only then can sensible, defensible, correction of the historical grab sample data be performed.
9. The simulation can then be used to investigate different sampling strategies to establish an optimised successor to the current system.

The recommendations by the reviewers can be grouped into the following subject areas:

Simulation model

A simulation model has been developed and has already proved useful for comparing methods of analysing the paired samples in a Base Case. That analysis will be continued and other issues will be examined with the simulation model in due course.

Multinomial approach

The reviewers prefer a multinomial approach to the method of *availability*; however, it is somewhat doubtful that they had a good understanding of the latter. Perhaps if they had been aware of the improvements in the estimates in purse-seine catches since Lawson (2009), they would have asked why *availability* works as well as it does, instead of simply dismissing the method. As mentioned above, Lawson (2009) developed a method similar to Cordue's simple multinomial method, but subsequently abandoned it when it resulted in catch estimates that were clearly unreasonable. The simulations in the Base Case reported here support that conclusion. It would perhaps be of interest to further examine the simple multinomial approach with the simulation model, if only to determine under which conditions it works, if any, and, when it fails, to better understand why.

Simulations can also be used to look at methods to reduce the bias in the species compositions determined from grab samples corrected with *availability*.

Layering

The reviewers were concerned with layering by species and size and the effect it might have on the sampling of individual sets; however, it should be noted that the objective of sampling is *not* to estimate the species composition of individual sets. Rather, the objective is to estimate the species compositions for aggregations of sets; for example, a vessel–trip or strata of time – area – school association. Layering should not be considered a major problem unless it is shown to occur on average.

Lawson (2012) examined the changes in relative weights of fish in the ten sequential quantiles of grab samples taken from each of 13,826 sets. For both associated and unassociated sets, the relative weight tends to decline from the beginning of brailing to the end of brailing; for associated schools, the relative weight declines from about +2% of the average weight of fish per set at the beginning of brailing to about –2% at the end, while for unassociated schools, the decline is somewhat less. This level of layering is small, but simulations will be useful to determine the effect that it has on estimates of the species composition. The data examined in Lawson (2012) will also be useful to examine the variability in layering between sets, which could also be incorporated into the simulations. Bigeye may float to the surface of sets and the presence of bigeye in the early brails could also be examined.

When discussing layering, it is typically suggested that data should be collected to examine layering in detail, through some form of intensive or "super" sampling. Super-sampling has been conducted in tuna fisheries in other ocean areas. However, the super-sampling is usually done for only a small number of sets or wells and because the sample size is so small, it is impossible to determine whether the sets or wells chosen for super-sampling are representative. Such data collection was suggested by the reviewers in this case, perhaps because they did not fully appreciate the approach taken by Lawson (2012), wherein layering within thousands of sets was examined.

Sampling design and sampling protocol

The reviewers identified a need to examine various aspects of the sampling design, from how to best sample the fishery in terms of time period, geographic area, school association, vessel flag, and perhaps other factors, to the protocol for sampling individual sets.

Regard the sampling design, at present, with 100% coverage under CMM 2008–01, the sampling design is for observers to sample all sets during all trips. That being the case, there is currently no need for a sampling design. A sampling design will only be required if and when the Regional Observer Programme decides to reduce the coverage of samples from 100%.

Regarding the sampling of individual sets, simulations will be useful to examine the effects of layering. Spill samples taken from every tenth brail, with relatively large bins, has been shown to be practical onboard the vessels, but the reviewers were concerned that the spill samples should be taken more often. In that regard, recent experiments using a smaller bin, but taking samples every fourth to sixth brail, have shown promise; these results are discussed in *Report on Project 60: Collection and Evaluation of Purse-Seine Species Composition Data.*

Pooling and post-stratification

The reviewers did not have time to fully consider the use of GLMs, fitted to historical grab samples corrected with *availability*, to estimate the species composition, as presented in Lawson (2012). Nevertheless, they recommended that there be a move away from GLMs towards pooling the observer data, with post-stratification. In the exploratory analysis presented here, pooling of the data has been shown to be a reasonable alternative to GLMs for strata of quarter – 5° x 5° – school association that have at least 20% coverage by the observer data, which includes almost all strata for years for which there has been 100% observer coverage. For years prior to 2010, pooling with post-stratification will be explored, using regression trees and perhaps other techniques, to identify the best post-stratification.

However, it should be noted that the degree of similarity between the catch estimates for 2010 and 2011 determined from the GLMs and pooling — as illustrated here in Figures 10–12 — indicates that the GLMs are efficient in extracting the signal from the observer data. For years for which the level of observer coverage is very low (1993–2001), it is doubtful that post-stratification will improve on the GLMs, but this should be confirmed. For years for which the coverage is low (2002–2009), a problem is that the observer data are not usually representative.

For years for which there are no observer coverage (1967–1992) or low coverage, the technique introduced here of using the proportion of skipjack reported on logsheets as a covariate in the GLMs has resulted in improvements. The GLMs might be further improved, particularly in regard to the use of interaction terms, through simulations. It would also be useful to reformulate the GLMs in terms of a Dirichlet distribution.

References

Cordue, P. 2012. Review of species and size composition estimation for the western and central Pacific purse seine fishery. Center for Independent Experts. National Marine Fisheries Service, Honolulu.

Hampton, J. & P. Williams. 2011. Misreporting of purse seine catches of skipjack and yellowfin-bigeye on logsheets. Working Papers ST–WP–02. Seventh Regular Session of the Scientific Committee of the Western and Central Pacific Fisheries Commission, 9–17 August 2011, Pohnpei, Federated States of Micronesia. Oceanic Fisheries Programme, Secretariat of the Pacific Community, Noumea, New Caledonia.

Lawson, T.A. 2008. Factors affecting the use of species composition data collected by observers and port samplers from purse seiners in the Western and Central Pacific Ocean. Working Paper SC4–ST–WP3. Fourth Regular Session of the Scientific Committee of the Western and Central Pacific Fisheries Commission, 11–22 August 2008, Port Moresby, Papua New Guinea. Oceanic Fisheries Programme, Secretariat of the Pacific Community, Noumea, New Caledonia

Lawson, T.A. 2009. Selectivity bias in grab samples and other factors affecting the analysis of species composition data collected by observers on purse seiners in the Western and Central Pacific Ocean. Working Paper SC5–ST–WP–03. Fifth Regular Session of the Scientific Committee of the Western and Central Pacific Fisheries Commission, 10–21 August 2009, Port Vila, Vanuatu. Oceanic Fisheries Programme, Secretariat of the Pacific Community, Noumea, New Caledonia.

Lawson, T.A. 2011. Purse-Seine length frequencies corrected for selectivity bias in grab samples collected by observers. Working Paper SC7–ST–IP–02. Seventh Regular Session of the Scientific Committee of the Western and Central Pacific Fisheries Commission, 9–17 August 2011, Pohnpei, Federated States of Micronesia. Oceanic Fisheries Programme, Secretariat of the Pacific Community, Noumea, New Caledonia.

Lawson, T.A. 2012. 03 Estimation of the species composition of the catch by purse seiners in the Western and Central Pacific Ocean using grab samples and spill samples collected by observers. Working Paper SC8–ST–WP–03. Eighth Regular Session of the Scientific Committee of the Western and Central Pacific Fisheries Commission, 7–15 August 2012, Busan, Korea. Oceanic Fisheries Programme, Secretariat of the Pacific Community, Noumea, New Caledonia.

McArdle, B. 2013. Report of a consultancy to improve the estimation of species and size composition of the Western and Central Pacific purse seine fishery from observer based sampling of the catch. Oceanic Fisheries Programme, Secretariat of the Pacific Community, Noumea, New Caledonia.

Powers, J. 2012. Review of SPC Estimation of Species and Size Composition of the Western and Central Pacific Purse Seine Fishery from Observer-based Sampling of the Catch. Center for Independent Experts. National Marine Fisheries Service, Honolulu.

Schwarz, G.E. 1978. Estimating the dimension of a model. Annals of Statistics 6 (2): 461–464.

Appendix. Formulae for estimating the species composition with *correction factors*

For school association *h*, the proportion by species *i* of the total catch from the sets for which the grab samples were taken, p_{hi}, is given by:

$$p_{hi} = \frac{W_{hi}}{\sum_i W_{hi}} \tag{16}$$

$$W_{hi} = \sum_j N'_{hij} \cdot \overline{w}_{ij} \tag{17}$$

$$N'_{hij} = N_h^* \cdot P'_{hij} \tag{18}$$

$$N_h^* = \frac{W_h^* \cdot 1000}{\sum_{ij} P'_{hij} \cdot \overline{w}_{ij}} \tag{19}$$

$$W_h^* = \sum_k W_{hk} \tag{20}$$

$$P'_{hij} = \frac{P_{hij} \cdot f_{hij}}{\sum_{ij} P_{hij} \cdot f_{hij}} \tag{21}$$

$$P_{hij} = \frac{N_{hij}}{\sum_{ij} N_{hij}} \tag{22}$$

$$N_{hij} = \sum_k N_{hijk} \tag{23}$$

$$N_{hijk} = N_{hk} \cdot P_{hijk} \tag{24}$$

$$N_{hk} = \frac{W_{hk} \cdot 1000}{\sum_{ij} P_{hijk} \cdot \overline{w}_{ij}} \tag{25}$$

$$P_{hijk} = \frac{n^G{}_{hijk}}{\sum_k n^G{}_{hijk}} \tag{26}$$

$$f_{hij} = \frac{P_{hij}^S}{P_{hij}^G} \tag{27}$$

$$P_{hij}^{S} = \frac{\sum_{k} n_{hijk}^{S}}{\sum_{hijk} n_{hijk}^{S}} \tag{28}$$

$$P_{hij}^{G} = \frac{\sum_{k} n_{hijk}^{G}}{\sum_{hijk} n_{hijk}^{G}} \tag{29}$$

where n_{hijk}^{S} and n_{hijk}^{G} are the number of fish in the spill and grab sample, respectively, from school association *h*, species *i*, length interval *j* and set *k* ; W_{hk} is the weight of set *k* in school assocation *h*, in tonnes; and $\overline{w}_{ij}$ is the average weight of a fish of species *i* and length interval *j* , in kilograms.