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ANNUAL ESTIMATES OF PURSE SEINE CATCHES BY SPECIES BASED ON ALTERNATIVE DATA SOURCES AND A REVIEW OF CURRENT PURSE-SEINE CATCH ESTIMATION ISSUES AND FUTURE PLANS

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John Hampton[1] and Peter Williams[1]

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

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ABSTRACT

The current paper responds to two requests from SC10 regarding the provision of purse seine catch by species estimates using several approaches, and to update the plan for the improvement of the availability and use of purse seine catch composition data.

Purse seine catch by species were estimated using four methods – uncorrected logsheets (Method 1), preserving the logsheet estimate of skipjack catch and using observer grab sampling data to determine the catches of yellowfin and bigeye tuna (Method 2), the current method based on estimation of the three species using observer grab sampling data corrected for selectivity bias (Method 3) and the current method but using uncorrected grab sampling data (Method 4). We show that the greatest impact on the species catch estimates has resulted from no longer assuming, as was done pre-2008, that the logsheet-declared skipjack catches are accurate. Using observer-based grab sampling as the basis for disaggregating the catch into the three species, the overall bigeye catch is increased by 252%, the skipjack catch reduced by 13% and the yellowfin catch increased by 36%. By contrast, the correction of the grab sampling data for selectivity bias resulted in relatively small incremental changes – a reduction of overall bigeye catch by 7%, and increase in skipjack catch of 3% and a reduction in yellowfin catch of 7%.

The two main questions that need further consideration are: (i) is spill sampling the method of choice for observer-based catch sampling?; and (ii) are corrected grab samples a reasonable proxy for spill samples? On the basis of the limited trials so far carried out, whereby the different sampling protocols have been compared to accurate species catches obtained at unloading, it is concluded that spill sampling is likely to consistently provide the most accurate estimates of species composition, and presumably size composition as well. It is therefore the current method of choice, although further such comparisons would be useful. On the basis of the paired sampling trips conducted thus far, it was found that for all data combined, the corrected grab samples provide species composition estimates for skipjack and yellowfin within 2% of the spill-sample-based estimates. For bigeye, the corrected grab samples overestimate the catch by 11% compared to the spill-sample-based estimates. This indicates that corrected grab samples may be considered adequate for the purpose of estimating highly aggregated catches. However, the variability of the estimates at the trip level and at the set level (particularly) is high, and corrected grab sampling is probably not adequate if accurate and precise catch estimates are ever required for management purposes at these levels. A number of future avenues of work are suggested to further refine estimates of purse seine species catches.

1. INTRODUCTION

The Scientific Committee at its 10th session (SC10) requested that (paragraph 100c, SC10 Report):

> *The Scientific Services Provider provide to SC11 annual estimates of purse-seine catch based on: a) logbook reported species composition, b) observer grab samples (previous approach), and c) observer grab samples corrected for selectivity bias from spill sampling. Catch series from any variants on these should also be included. This will allow the SC to follow changes in purse-seine catch estimates from historical methods. The work should also include any guidance on the implications of future estimates if only grab sampling occurs, e.g., can the selectivity bias correction be used into the future.*

SC10 also requested that (paragraph 100a, SC10 Report):

> *The Scientific Services Provider update the Plan for the Improvement of the Availability and Use of Purse-seine Catch Composition Data set out in SC8-WCPFC8-08 for consideration by SC11 and TCC11, noting the need for the Commission to adopt an integrated approach to improving purse-seine species composition data, including both scientific and compliance aspects. The update should take into account the outcomes of the work undertaken in Project 60, including the information in SC10-ST-WP-02.*

This paper responds to both of those requests, which are overlapping to an extent. Purse seine catches by species are presented in section 2 for the three methodologies noted above. In addition, we present estimates that are based on uncorrected grab samples, but where observer-based species composition is applied to all three tuna species. This method represents an intermediate step between the 'previous approach' (b), in which uncorrected grab sample data was applied only to yellowfin and bigeye, and the current approach (c) where grab sample data corrected for selectivity bias are applied to the three species.

In section 3, we summarise the various issues related to the estimation of purse seine catch by species, the current state of play and a recommended plan for where to from here.

2. PURSE SEINE CATCH ESTIMATES

Purse seine catch estimates for 1967 – 2014 for the tropical purse seine fishery (20°N – 20°S) in the WCPFC Convention Area, excluding the domestic purse seine fisheries of Indonesia, Philippines and Vietnam, have been derived according to the following methods:

Method 1: Unadjusted logsheet data. Total catches are disaggregated by species according to the species catch proportions in logsheet data, stratified by year, month, flag, one-degree square and set type (the so-called 'S_BEST' stratification). This method has never been used by SPC for any analytical purpose.

Method 2: YFT-BET adjusted: Total catches are disaggregated into skipjack and yellowfin+bigeye according to the unadjusted logsheet data with the same S_BEST stratification as above. The yellowfin+bigeye component is then split into separate yellowfin and bigeye tuna components using uncorrected observer grab sampling data in an analysis of variance (ANOVA) or General Additive Model (GAM) procedure (Lawson 2007). Versions of this method were used by SPC to estimate purse seine species composition prior to 2008. These estimates were used in stock assessments and other analytical work conducted prior to 2008.

Method 3: Full species adjustment using observer sampling data corrected for grab sample selection bias: Total catches are disaggregated into skipjack, yellowfin and bigeye using the method described as "Case D" in Lawson (2013). The features of this method are:

- Proportions of skipjack, yellowfin and bigeye tuna are estimated directly from pooled observer data (that has been corrected for grab sample bias using estimates obtained from paired spill sampling and grab sampling experiments), stratified by year, quarter, five-degree square and school association, where the coverage of observer data (total catch compared to observed catch) in individual strata is >20%. The percentage of total strata meeting this criteria is close to 100% since 2010, when observer coverage increased dramatically (Lawson 2013, Table 6). These observer data are then applied to produce catch estimates in the S_BEST stratification.

- For strata not meeting the 20% observer coverage criteria, the species composition is estimated using a series of General Linear Models (GLMs).The GLMs estimate species composition from observer data that are corrected for grab sample bias using correction factors estimated from paired spill sampling and grab sampling experiments. The models have the following features:
    - For the period **1967-1995**, covariates of *quarter*, a two-dimensional spline of latitude and longitude, *lat_lon* and vessel *flag* are used in models fit separately to data for associated and unassociated sets. The model for associated sets additionally includes a categorical variable for *associated set sub-type* (anchored FADs, drifting FADs, logs, other). The unadjusted proportions of skipjack tuna obtained from logsheet data are used as a covariate in the model. Note that this model has no year effect, due to the paucity of observer data during this period.
    - For the period **1996-2001**, a *year* effect is added as a categorical variable.
    - For the period **2002-present**, the model also includes interaction terms for *year* and *quarter,* and *year* and *geographical areas* defined to be east and west of 170°E.

  The series of GLMs therefore consist of 18 discrete models defined by three time periods, two types of data (associated and unassociated sets) and three species. The models are then use to produce catch estimates in the S_BEST stratification for strata not covered by the direct estimates from observer data as described above.

These are the estimates currently used for routine analytical work by the OFP, including stock assessments.

Method 4: Full species adjustment using uncorrected observer data: This method is identical to method 3, except that we use observer grab sampling data that have not been corrected for grab sample selection bias. This method is not used for any analytical purpose, but has been included here to isolate the effects of full (SKJ/YFT/BET) species adjustment using the observer data and grab sample bias correction.

Note that none of the above methods are applied to the purse seine catches of Japan, because the National Research Institute of Far Seas Fisheries has implemented a port monitoring programme to accurately estimate the species composition of the Japanese purse seine fleet. These estimates are incorporated into the overall catch estimates reported here for each of the above methods. Previously, the species composition of vessels from Ecuador, El Salvador and Spain were estimated from logsheet data. However, observer data are now used to estimate the species composition for these fleets also, to be consistent for all fleets where alternative estimates of species composition are not available, or yet to be reviewed by the Commission.

The catch estimates for each species derived using each of the four methods are shown in Figure 1 and in Table 1. The main point that emerges from these comparisons is that the substantial changes in estimated species composition that occurred in moving from Method 2 to Method 3 (or slight variants thereof) after 2008 were due mostly to the estimation of the species composition for the three species from the observer grab sampling data (cf Model 2 and Model 4) rather than because of the correction of the grab sampling data for selectivity bias. This is evident in the similar estimates of catches for all three species for Method 3 (with bias correction) and Method 4 (without bias correction) (Figure 1). For the period 1967-2014 aggregated, the change in catch estimates from the pre-2008 Method 2 to using uncorrected grab sampling (Method 4) is large: +252% (bigeye), -13% (skipjack) and +36% (yellowfin). Then, the use of the correction for selectivity bias changes the estimates from Method 4 to the current Method 3 only slightly by comparison, and in the reverse direction: -7% (bigeye), +3% (skipjack) and -7% (yellowfin).

3. SUMMARY OF ISSUES AND FUTURE PLAN

Since 2008, considerable progress has been made in refining estimates of purse seine catch by species. In particular, the greater availability and coverage of observer data has allowed better estimates of species composition that do not need to rely on what are now known to be biased estimates reported on purse seine logsheets. The current methodology only relies on the total catch declared on logsheets.

While good progress has been made, a number of issues remain to be addressed in future plans. These issues are summarised below.

3.1 Spill sampling – is it the sampling method of choice?

A number of trials have been undertaken to attempt to compare estimates of species composition based on spill sampling with the 'true' species composition, based on accurately sorted unloaded catches. This work has been undertaken as part of the SC's 'Project 60 – Collection and Evaluation of Purse-Seine Species Composition Data' and was reported in detail by Lawson (2014). Species composition estimates based on observer spill sampling and grab sampling were compared with unloadings data for two series of trips undertaken by Solomon Islands and Japanese purse seiners. It was concluded that (Lawson 2014) "*… for the Solomon Islands vessels, on average, the species compositions determined from the spill samples agree more closely with the cannery and container receipts than the logsheets and the grab samples. For the Japanese vessels, on average, the species compositions from each of the logsheets, grab samples, spill samples and market data are similar.*"

The conclusion thus far from this work therefore is that estimates of the species and size composition should if possible be based on spill samples collected by observers. However, comparisons of the grab samples corrected for selectivity bias with the unloadings (market) data were not made, so it is not clear if the corrected grab samples would have done almost as good a job as the spill samples for these trips. Also, the number of comparisons done to date is very limited, and should be expanded. An additional five paired sampling trips were conducted on PNG purse seiners in 2014; however at the time of writing, the port sampling data for these trips collected in Madang, PNG had only just been received and have not yet been analysed. This will be done as soon as possible, but it would be desirable to obtain data for additional trips where paired sampling can be conducted and accurate catches by species at unloading sites can be obtained.

3.2 Are corrected grab samples a reasonable proxy for spill samples?

Various comparisons of grab and spill sampling estimates from purse-seine trips on which paired grab and spill samples were collected by observers (Lawson 2009, 2010, 2012) and on the basis of a simulation study (Lawson 2013) have indicated that species and size compositions determined from spill samples are more accurate than those determined from grab samples, primarily because spill samples are not subject to the selectivity bias and the sample sizes are much larger. However, the question of whether the grab samples corrected for selectivity bias, as described by Lawson (2013), are consistent with spill-sample-based estimates has not previously been examined.

Since the report of Lawson (2013), at which point 41 paired sampling trips covering 575 purse seine sets had been undertaken, a further 11 trips (making 52 in total) have been undertaken, bringing the total number of sets covered by paired sampling to 752. We have estimated the species composition based on spill sampling, uncorrected grab sampling and corrected grab sampling for this data set overall, for each trip and for each set (Table 2). For the aggregate data set, there is a moderate difference in the species composition for spill sampling (0.709, 0.217, 0.074 for skipjack, yellowfin and bigeye, respectively) and grab sampling (0.662, 0.247, 0.091). When the grab sampling is corrected for selectivity bias, the estimates are very close to those from the spill samples (0.697, 0.221, 0.082). If we accept that the spill samples provide unbiased estimates of catch by species, the corrected grab samples would provide catch estimates that have relatively small bias of -1.8%, +1.9% and +11.5%, respectively. This compares to the bias in the estimates based on uncorrected grab samples of -6.7%, +14.1% and +23.0%, respectively for skipjack, yellowfin and bigeye. At least for this aggregate data set, correction for selectivity bias substantially improves the estimates of catches of all three species.

It may be of interest to understand how the estimates of species composition based on spill and corrected grab sampling compare at finer resolution, e.g. trip and individual set. We have plotted the estimates of species composition for both methods at both resolutions in Figure 2. Unsurprisingly, variability is higher at the set level. It may be judged that the relationships are too variable to provide highly reliable estimates of species composition at the set level and even at the trip level. The CVs for the species composition of skipjack, yellowfin and bigeye, respectively are approximately 0.12, 0.25 and 0.80 at the trip level, and 0.17, 0.51 and 1.38 at the set level.

Our conclusion from the above is that grab samples corrected for selectivity bias may be sufficiently accurate at higher levels of aggregation, such as total catch estimates and 1° square and month (although the extent of paired sampling is probably insufficient to test this quantitatively at the moment), but is probably insufficient for higher levels of resolutions, such as trip or set.

3.3 Future plans

At this stage, it is suggested that this work could be progressed by the following activities:

- Analyse the spill and grab sampling data for the trips conducted on PNG purse seiners in 2014, and compare those results to the estimates of species composition obtained from intensive port sampling.
- Undertake additional observer sampling / unloading comparisons where it is possible to conduct paired sampling trials and obtain accurate estimates of catch by species for the same trips from unloadings.
- Extend the comparisons of grab- and spill-sampling-based species composition with accurate unloadings data to include the comparison of grab samples corrected for selectivity bias with the unloadings data.
- Where possible and logistically feasible, observer programmes should continue to undertake paired sampling trials on a limited basis (say 10 trips per year) to continue to refine estimates of selectivity bias and to support additional simulation modelling.

- Undertake additional simulation modelling to estimate precision and bias of using corrected spill sampling data as the basis for estimating purse seine species composition at various levels of resolution.
- While not mentioned in this paper, there is other work in progress to assess the accuracy of cannery records with respect to estimates of species composition at the trip level. If accurate data could be obtained from canneries, it would be an invaluable additional source of information for the estimation of species composition of the purse seine catch.

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Table 1. Purse seine catch estimates derived using the four different methods. See text for details.

	METHOD 1: UNADJUSTED LOGSHEET			METHOD 2: YFT-BET CORRECTION			METHOD 3: SKJ-YFT-BET CORRECTION, ADJ GRAB SAMPLING			METHOD 4: SKJ-YFT-BET CORRECTION, UNADJ GRAB SAMPLING		
Year	BET	SKJ	YFT	BET	SKJ	YFT	BET	SKJ	YFT	BET	SKJ	YFT
1967	-	34	33	-	34	33	1	40	26	1	38	28
1968	-	140	218	-	140	218	11	185	162	12	173	172
1969	-	77	3	-	77	3	4	61	15	5	58	17
1970	-	333	123	-	333	123	20	307	130	22	292	142
1971	35	667	192	35	667	192	44	593	257	50	558	286
1972	47	539	188	47	539	188	41	501	232	46	470	258
1973	166	1,602	504	166	1,602	504	60	1,545	668	68	1,466	738
1974	194	2,437	743	194	2,437	743	203	2,278	892	226	2,152	995
1975	141	4,583	1,664	141	4,583	1,664	411	4,402	1,575	458	4,162	1,769
1976	241	10,353	3,305	241	10,353	3,305	832	9,599	3,467	931	9,069	3,899
1977	153	13,434	4,956	153	13,434	4,956	895	12,434	5,214	997	11,720	5,825
1978	307	23,249	7,654	307	23,249	7,654	1,782	21,028	8,400	1,986	19,837	9,387
1979	403	24,875	10,671	403	24,875	10,671	1,937	23,587	10,426	2,132	22,246	11,571
1980	397	31,794	9,696	397	31,794	9,696	2,188	28,974	10,725	2,444	27,485	11,958
1981	1,037	55,069	40,856	1,037	55,069	40,856	7,793	60,218	28,951	8,402	56,273	32,287
1982	1,050	129,893	64,209	1,050	129,893	64,209	13,041	127,020	55,091	14,116	119,445	61,591
1983	1,425	250,073	92,451	1,425	250,073	92,451	18,754	233,200	91,994	20,236	221,384	102,327
1984	653	263,766	101,257	653	263,766	101,257	20,992	252,567	92,118	22,665	239,916	103,096
1985	2,003	231,858	74,101	2,003	231,858	74,101	15,923	212,675	79,364	17,511	201,949	88,503
1986	2,562	259,176	95,194	2,562	259,176	95,194	22,923	249,816	84,193	25,008	237,517	94,408
1987	1,629	266,272	149,724	1,629	266,272	149,724	27,818	263,797	126,010	29,969	248,382	139,275
1988	488	383,215	87,366	488	383,215	87,366	26,721	346,357	97,991	29,381	330,877	110,810
1989	1,538	383,548	154,950	1,538	383,524	154,939	27,917	361,565	150,520	30,473	342,429	167,099
1990	3,955	491,931	162,884	3,955	491,931	162,884	31,607	447,779	179,384	34,781	425,349	198,640
1991	2,756	617,003	213,618	2,756	617,003	213,618	33,346	589,525	210,506	36,546	564,201	232,630
1992	3,960	587,949	255,535	3,960	587,949	255,535	41,444	566,021	239,978	44,883	537,530	265,031
1993	2,139	481,149	240,125	6,789	481,149	235,476	32,295	488,214	202,903	34,991	466,343	222,079
1994	1,681	608,494	210,054	6,421	608,494	205,315	31,926	580,582	207,721	34,918	557,471	227,840
1995	952	585,891	171,132	5,954	585,891	166,130	28,441	550,481	179,054	31,326	528,495	198,155
1996	3,241	616,122	104,038	18,546	616,122	88,733	37,916	529,490	155,995	42,596	506,298	174,507
1997	12,042	477,390	249,521	52,423	477,390	209,140	69,824	399,599	269,529	74,198	377,662	287,093

1998	4,988	738,713	247,225	24,713	738,713	227,499	64,241	564,417	362,267	69,686	535,542	385,697
1999	7,543	664,455	191,834	23,724	664,455	175,653	61,726	520,423	281,682	69,787	485,712	308,332
2000	9,531	727,996	169,246	16,035	727,968	162,705	38,088	583,510	285,110	39,599	557,491	309,618
2001	9,110	691,178	201,033	20,988	691,178	189,155	45,092	588,789	267,441	46,863	564,170	290,289
2002	7,181	886,976	152,049	24,264	886,976	134,966	54,662	764,720	226,825	59,232	737,493	249,482
2003	8,758	794,381	185,778	18,431	794,381	176,105	35,350	688,055	265,512	37,590	662,223	289,104
2004	9,347	913,902	134,619	20,523	913,902	123,443	61,719	733,032	263,117	66,805	695,833	295,230
2005	13,325	954,937	217,018	30,103	954,937	200,241	47,585	835,547	302,148	49,354	805,487	330,440
2006	11,990	1,036,405	170,484	22,671	1,036,405	159,803	48,331	935,318	235,230	52,062	907,216	259,602
2007	15,196	1,144,212	191,994	23,123	1,144,212	184,067	41,859	1,041,219	268,322	45,667	1,014,840	290,895
2008	25,858	1,069,513	299,518	31,401	1,069,513	293,975	49,105	986,541	359,244	51,861	963,768	379,261
2009	20,922	1,310,105	190,622	28,622	1,310,105	182,921	51,296	1,198,984	271,370	53,649	1,174,995	293,005
2010	23,672	1,186,791	273,392	32,023	1,186,791	265,042	50,437	1,117,064	316,355	50,838	1,115,408	317,610
2011	33,214	1,165,168	213,951	39,054	1,165,168	208,111	70,534	1,062,902	278,898	71,099	1,061,090	280,144
2012	26,753	1,326,488	287,095	42,152	1,326,488	271,696	60,891	1,261,939	317,506	61,426	1,259,930	318,980
2013	33,264	1,330,587	224,961	42,319	1,330,587	215,906	68,077	1,227,481	293,254	68,866	1,224,659	295,286
2014	28,500	1,459,049	265,532	40,388	1,459,049	253,645	63,320	1,364,920	324,842	65,478	1,348,872	338,732

Table 2. Estimates of species composition from 52 purse seine trips on which paired grab and spill sampling was conducted.

Method	Species composition		
	SKJ	YFT	BET
Spill sampling	0.709	0.217	0.074
Grab sampling	0.662	0.247	0.091
Grab sampling corrected	0.697	0.221	0.082

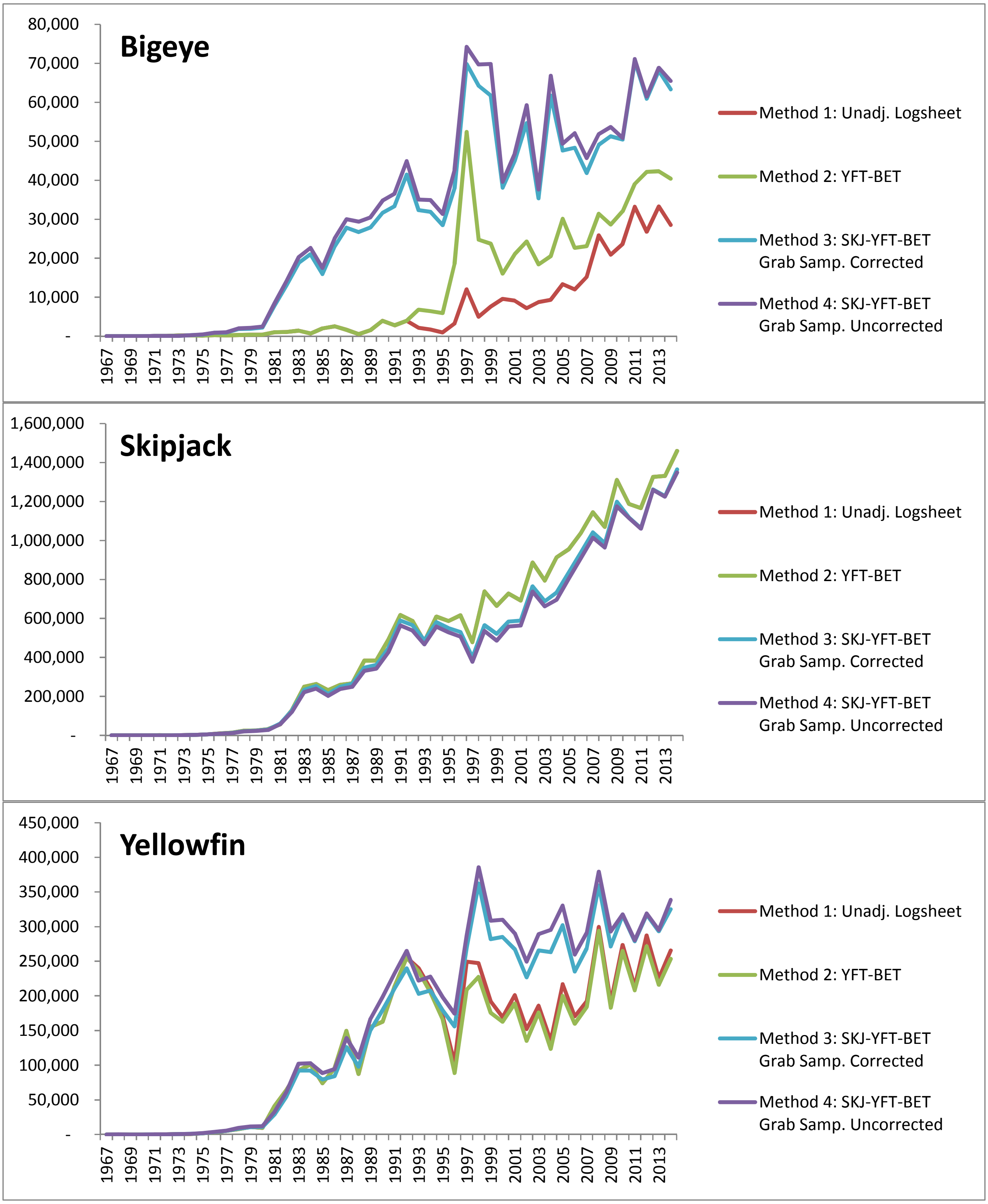

Figure 1. Purse seine catch estimates for bigeye, skipjack and yellowfin tuna, derived using the four methods described in the text. Note that for skipjack, the Method 1 and Method 2 catches are identical.

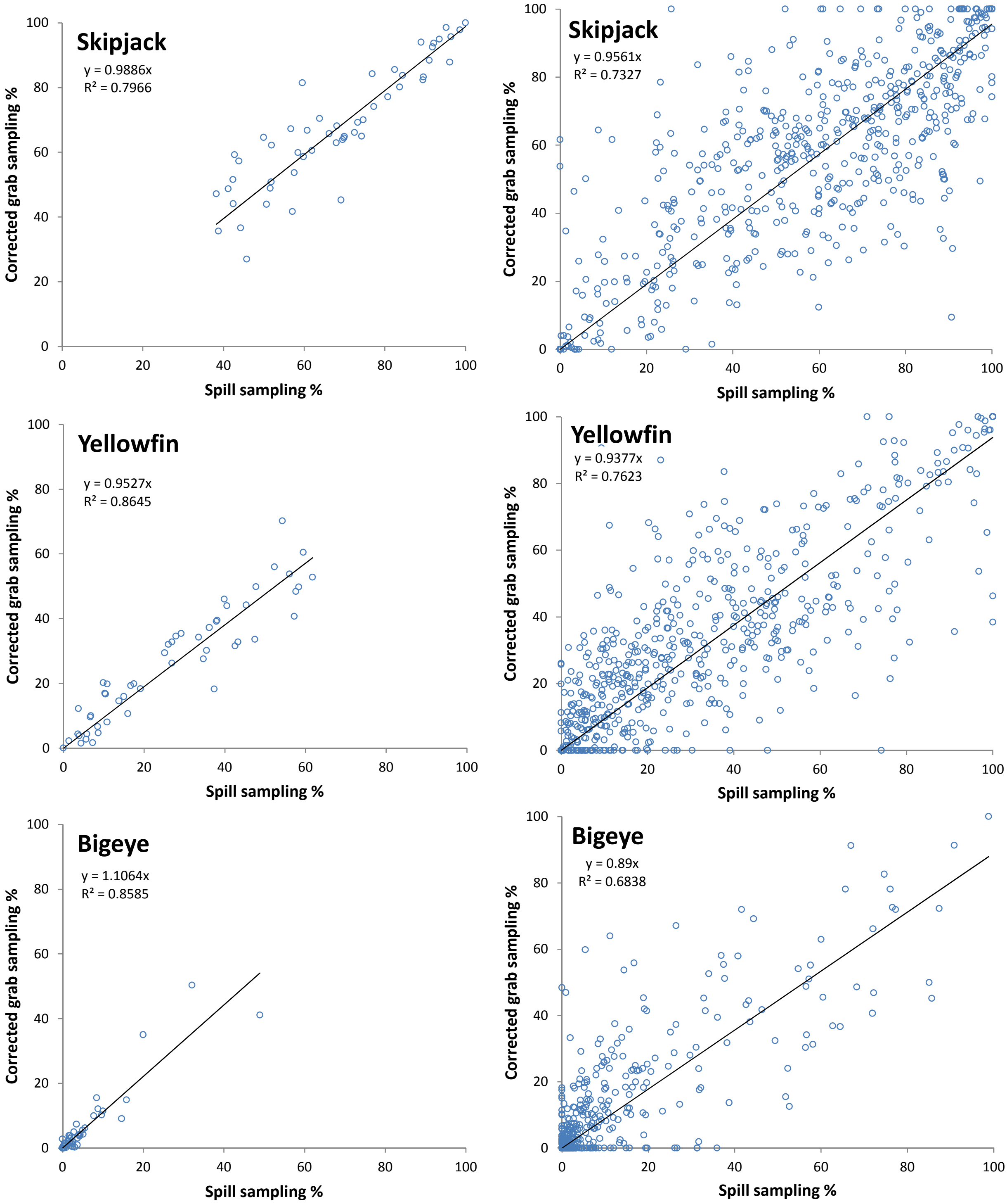

Figure 2. Species composition comparisons based on spill sampling and corrected grab sampling for trips (left hand side) and sets (right hand side) making up the paired sampling data set (52 trips, 752 sets).