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Catch and catch per unit effort of silky sharks in the Western and Central Pacific Ocean

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Summary
This paper is a supporting document of the updated silky shark assessment presented to SC9. We examine available Catch Per Unit Effort (CPUE) and catch series for silky shark (*Carcharhinus falciformis*) for the western central Pacific Ocean (WCPO). We describe eight CPUE series and four catch series with greater detail provided on new series that were not included in the 2012 assessment.

Five CPUE series from the 2012 assessment have been replaced for the 2013 assessment. The series based on bycatch in tuna-target longline fisheries, has been replaced with a series that does not include any Hawaiian data (due to concerns over unbalance introduced by it). The purse seine CPUE series from the 2012 assessment have been replaced with new series that incorporate the generic reported shark catches in the early years. This is because the reporting to species increased over time and almost all sharks reported to the species level from purse seining were silky sharks. Two CPUE series available in 2012, but not included in that assessment, are now included and these relate to the Japanese Research and Training Vessel (RTV) analysis and the analysis of the Hawaiian observer data.

Four catch series are considered, the estimates from Lawson and Rice used in the 2012 assessment are supplemented with updated catch estimates based on fin trade work. The 2013 assessment uses two fin-trade based estimates constructed using different assumptions.

1 Introduction
The objectives of this information paper are to review multiple time series of standardized CPUE used as indices of abundance in the updated silky shark stock assessment (Rice and Harley 2013). The sections of this report include a) alternative indices of abundance used, b) presentation of the standardized CPUE trends for silky sharks from purse seine and longline fisheries, c)comparison of alternative catch estimates, and d) model diagnostics (Annex 1). For an overview of GLM analyses, and a summary of the exploratory data analysis of silky shark CPUE and catch in the WCPO the reader is referred to Rice (2012a; 2012b).

2 CPUE abundance indices
Longline indices considered in the 2013 assessment are provided in Table 1 and we describe each in turn in the sections below.

Table 1: Summary of all CPUE series used in the 2013 assessment.

Index #	Series	Index Source	Years	Area	Gear Type
1	Hawaiian longline bycatch index	Walsh & Clarke (WCPFC-SC7-2011 / EB-WP-03)	2001 -2010	Hawaii (mainly 0?- 10? N and 170?W -150?W	Longline
2	Japanese Research and Training Vessel	Clarke et al. (WCPFC-SC7-2011/EB-WP-02)	1993-2008	Region 4	Longline
3	Longline bycatch (- no US)	This paper (new analysis)	1996-2009	WCPO (not US possessions)	Longline
4	Longline target	Rice (WCPFC-SC8-2012/SA-IP-11)	1995-2009	Mainly PNG and Solomon Is.	Longline
5	Unassociated purse seine (catch per set)	This paper (new analysis)	1996-2009	WCPO	Purse Seine
6	Associated purse seine (catch per set)	This paper (new analysis)	1996-2009	WCPO	Purse Seine
7	Unassociated purse seine (catch per MT of tuna)	This paper (new analysis)	1996-2009	WCPO	Purse Seine
8	Associated purse seine (catch per MT of tuna)	This paper (new analysis)	1996-2009	WCPO	Purse Seine

SERIES 1: *Hawaiian longline bycatch index*

This index comes from Walsh and Clarke (2011) which analysed the NOAA Fisheries Pacific Islands Regional Observer Program (PIROP) data from the Hawaii-based pelagic longline fishery over the years 1995–2010, though the analysis for silky shark was limited to 2000–2010 because sample sizes were considered too small in the earlier years. There are options to use two different series based on the statistical model used, but the series are very similar. We used the delta-lognormal series in the 2013 assessment.

We note the interannual variability in this series is likely too high to reflect changes in abundance and therefore we conclude that this series is subject to high observation error and/or high process error (i.e., there are factors that influence catchability strongly from year to year that are not included in the analysis).

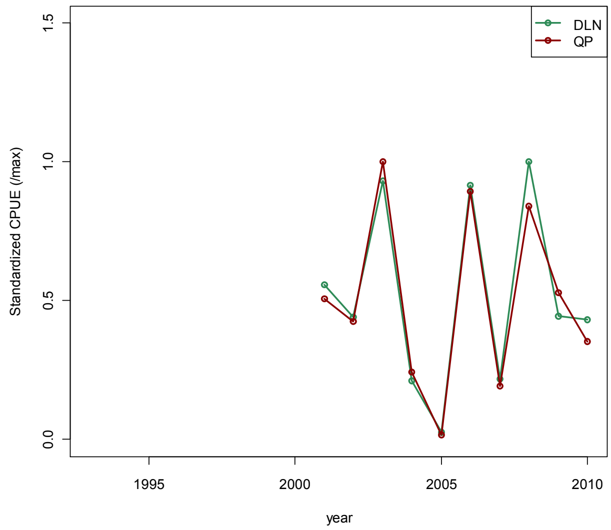


Figure 1: Silky shark longline CPUE for Hawaiian longline bycatch index (Series 1).

SERIES 2: *Japanese Research and Training Vessel*

This index is based on the paper "Analysis of North Pacific Shark Data from Japanese Commercial Longline and Research/Training Vessel Records" **(**Clarke et al. 2011). The series covers 1993 to 2008, and the data covers the region south and southwest of the Hawaiian island (see paper for details). This series provides an independent assessment of silky shark trends to that provided by the Hawaiian and SPC data holdings. Gulland's indices calculated with these data indicated no change over time with respect to areas of highest catch rates which is a good property for a CPUE series.

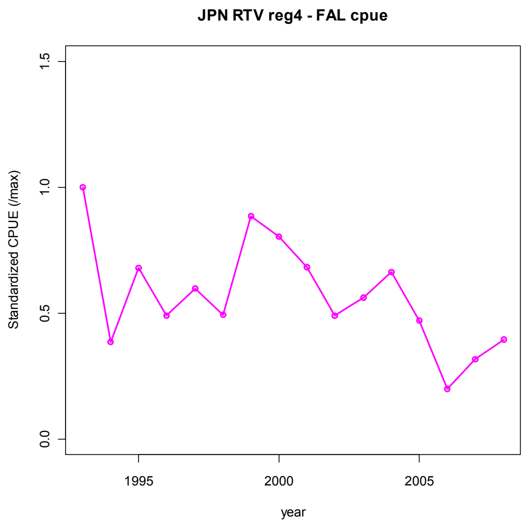


Figure 2: Silky shark CPUE trend from Japanese Research and Training vessels in region 4 (Series 2).

SERIES 3: Longline bycatch (no USA observer data)

This index is based on recent (post-SC8) analysis of the SPC held observer data - excluding the US data. The resulting index is based on analysis of data from throughout the WCPO and covers the years 1995-2009. This analysis was requested as an investigation into the effect of absence of US data since 2004. Initial fits of the SPC data holdings without the USA data resulted in models that did not converge when using the zero-inflated negative binomial (ZINB) model (which was the model used in the 2012 assessment), therefore an alternative delta lognormal (DLN) model was fit to the SPC data holdings with and without the USA data. Without the USA data, the DLN model for silky shark did not converge with the year 1995 in the analysis, so this year was dropped from the model, thus the model for the SPC observer data without the USA data runs from 1996-2009.

It is important to note that a comparison of the DLN and ZINB that includes the US data (Figure 3) indicates that the standardization method does impact on the resulting trend. However, a comparison of the DLN models with and without the US data did not show a large impact of the 'imbalance' in that data set (Figure 4). It is the red line in that figure (without USA) that is proposed as Series 3. See Annex 1 for further details regarding this analysis.

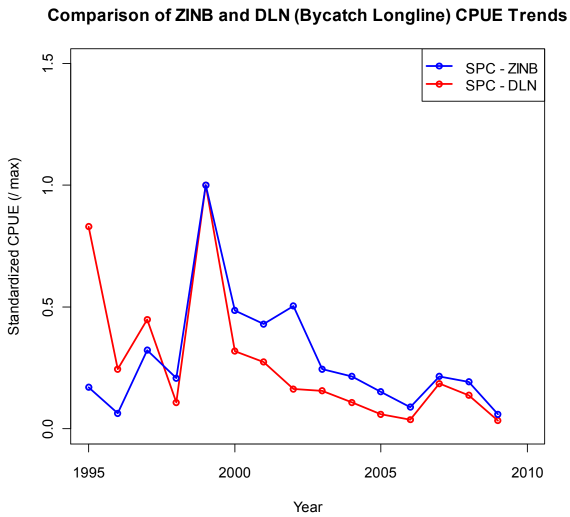


Figure 3: **A comparison of the silky shark longline CPUE trend for based on SPC data holdings. The blue line (ZINB) was used as the reference case CPUE in the 2012 assessment. The red line is identical to the blue line in Figure 4.**

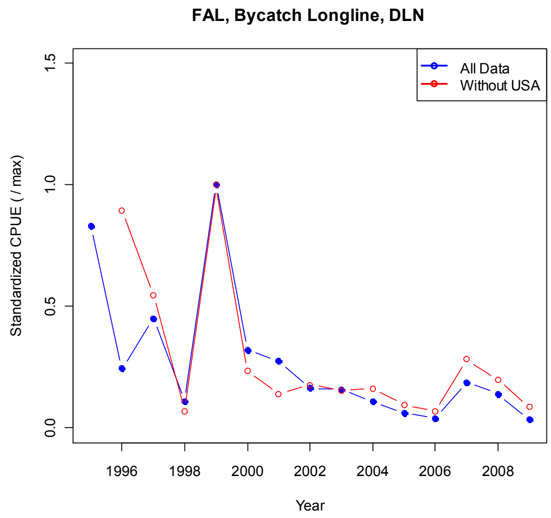


Figure 4: Silky shark longline CPUE trends without USA data (red line; Series 3) and with all data (blue line).

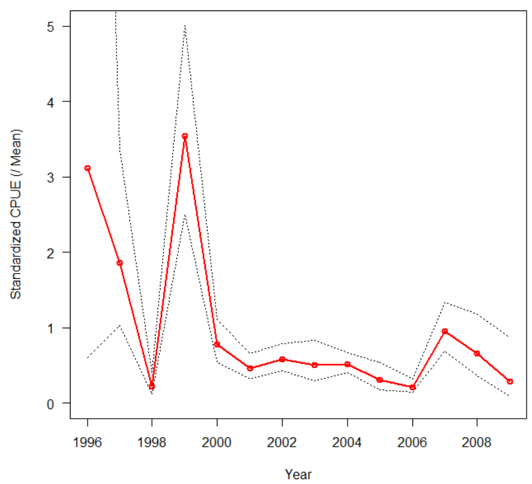


Figure 5 : Longline bycatch (Series 3) alone with 95% confidence intervals (dotted black lines), standardized to the mean of the series.

SERIES 4: *Target longline CPUE series (as used in the 2012 assessment)*

The target longline CPUE trend from the previous assessment (Rice 2012b) is presented with a rug plot to highlight the relative data deficiencies at the start and final year of the series (Figure 6). The target longline series is representative of the shark targeting fishery operating in and around the Solomon Islands and Papua New Guinea, and is the most spatially restrictive series considered in the updated assessment.

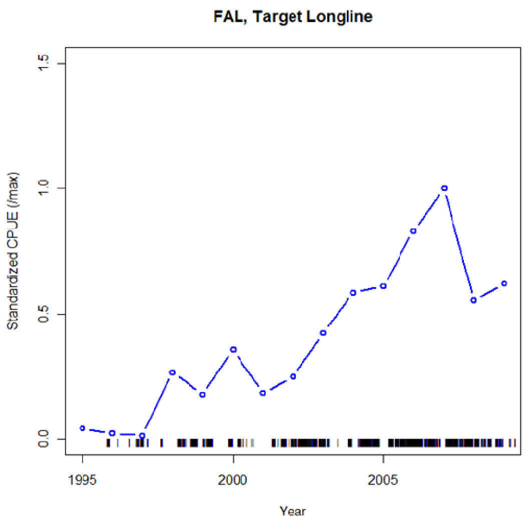
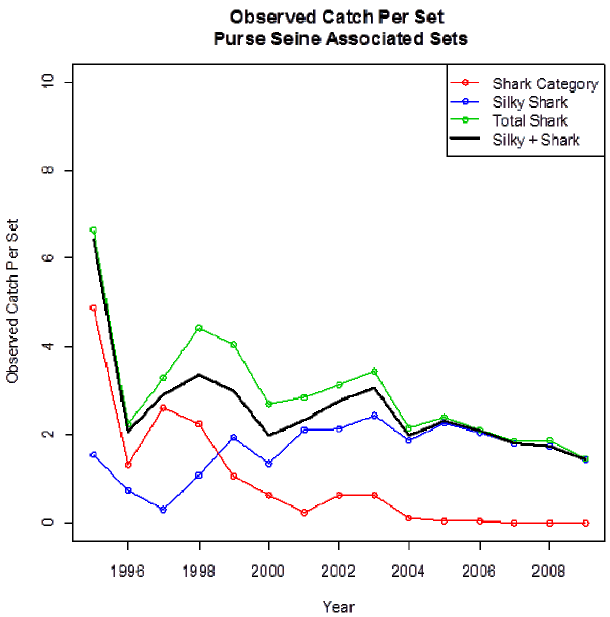


Figure 6: Series the FAL target longline CPUE trend based on SPC data holdings with rug plot showing the distribution of data underlying the analysis.

SERIES 5-8: Purse Seine – New analysis based on SPC observer data holdings

These trends are based on recent analysis of the SPC held observed data. In the associated and unassociated purse seine trends in Rice (2012b), which were standardized for operational effects only, no attempt was made to account for changes in reporting practices by observers. The main motivation for undertaking an updated analysis of the purse seine catch rates is to account for the change in reporting by species since the mid 1990's. Reporting of silky sharks to species began in the 1990's but was not fully implemented until some later time. The following figure shows that in both the associated and unassociated sets the nominal catch per set of the generic 'shark' category has declined to near zero in recent years while the nominal catch rate for silky sharks has increased as the generic shark trend decreased.



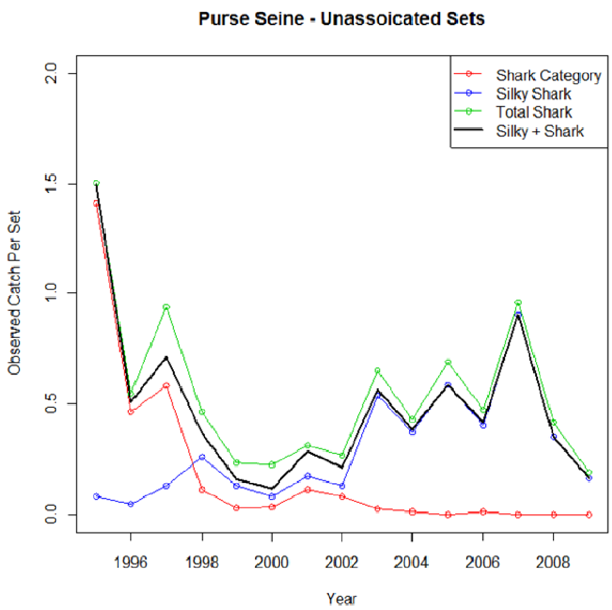


Figure 7: Nominal observed catch per set in the purse seine fishery for the generic shark (red line), silky shark (blue line), total shark (green line) , and 'silky + generic shark' (black line) . Associated sets are depicted in the left hand panel and unassociated sets in the right hand panel, note that the y-axis differs in the two panels.

Nominal catch per set for the 'generic shark', and total shark is highest in 1995 (the first year of major drifting FAD use) for both the associated sets and unassociated sets. This may be due to high initial abundance, smaller sample sizes or many other factors. In addition to the nominal catch per set trend, standardized CPUE trends for the 'silky + shark' catch were produced via GLM analysis for the associated and unassociated purse seine fisheries. Catch per MT of tuna (skipjack+yellowfin+bigeye) was modelled under the hypothesis that the shark catch was proportional to the catch of tuna, as an alternative shark catch per set was also modelled (Figure 8), deviance tables and diagnostic plots are in Annex 1.

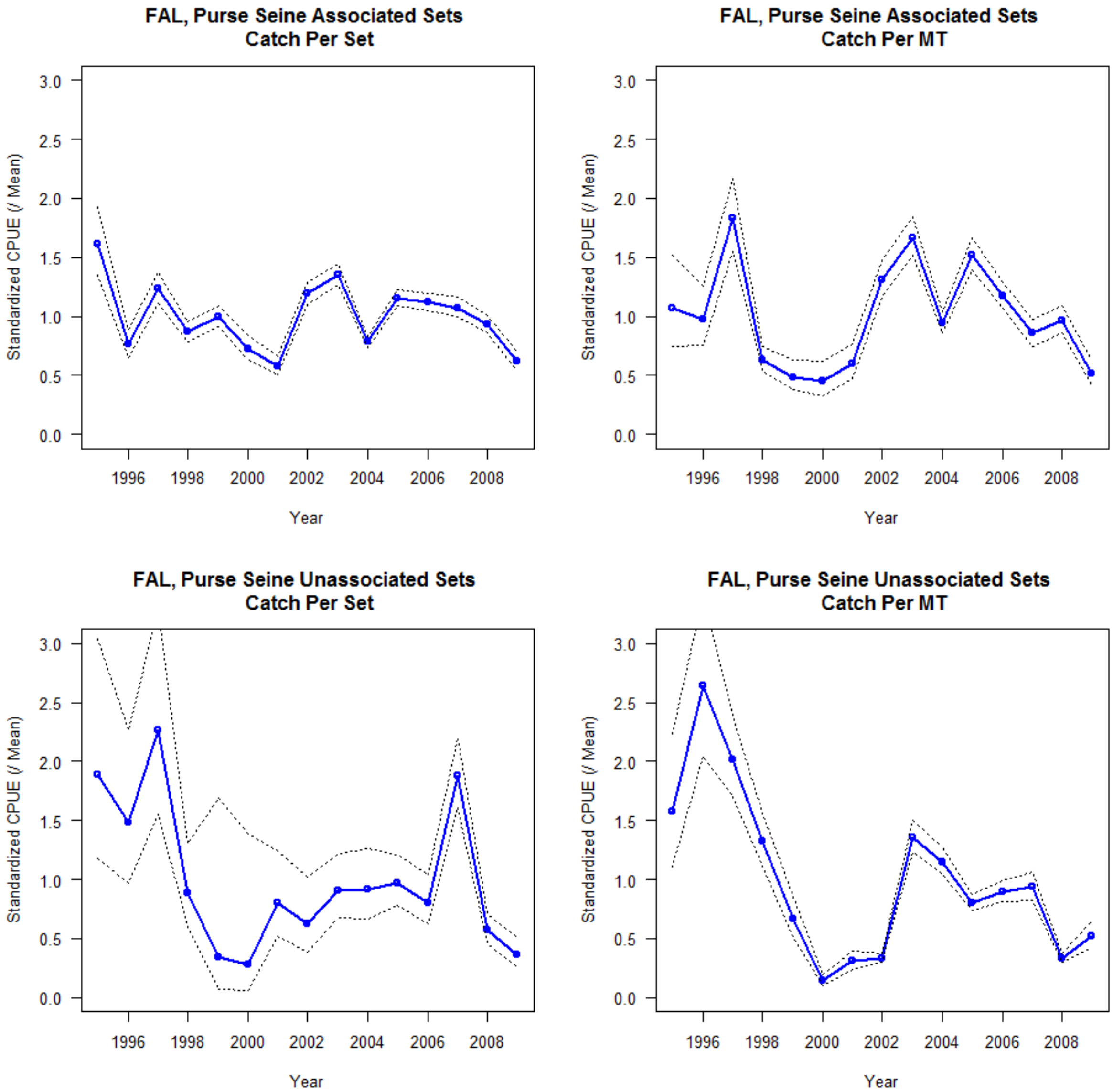


Figure 8: Series 5 (top left hand panel) and Series 6 (bottom left hand panel), Series 7 (top right hand panel) and Series 8 (bottom right hand panel). FAL Purse seine Catch rate trends for associated sets and unassociated sets by catch per set (left hand side) and catch per MT of tuna (right hand side).

At the request of the pre-assessment workshop (OFP, 2013) we examined a further set of purse seine abundance indices that instead of using MT of tuna caught instead used MT of skipjack tuna caught – where the skipjack catch was scaled by the skipjack stock assessment estimate of skipjack biomass, e.g. number of silky sharks per MT of skipjack catch per MT of skipjack biomass. This analysis failed abysmally due to the high number of sets with little or no skipjack catch. The models either could not converge or had very large spikes in some years. No further details of this analysis are provided here.

3 Catch estimates

Estimation of unobserved shark bycatch by pelagic longline and purse seine fisheries is difficult for multiple reasons, including 1) available data are sparse and often unrepresentative, 2) when reported, catch data are likely to be biased by underreporting, and non-reporting of discards (Camhi 2008) and 3) sharks are usually taken as bycatch which may be reported as 'total sharks', if reported at all (Camhi et al. 2008; Pikitch et al. 2008). For example; significant under- and non-reporting of blue shark (*Prionace glauca*) in the Hawaii longline fishery have been documented (Walsh et al. 2002) despite some of the best monitoring circumstances (Walsh et al. 2005).

Estimates of catches from Lawson (2011) (Figure 9) serve as the base-case catch series in this silky shark assessment. The annual catch estimates from all fisheries were expressed in numbers of fish. Following the methods in Lawson (2011), an alternative catch history was developed based on the SPC held observer data to explore the effect of different trends and magnitudes in the catch histories (Rice 2012a). Because these two catch trends used similar methods and different subsets of the same dataset, two estimates from Clarke (2009) were used, with values updated to 2009. These catch estimates were based on trade data extrapolated using various fishery indices such as tuna catch and area (Clarke 2005).

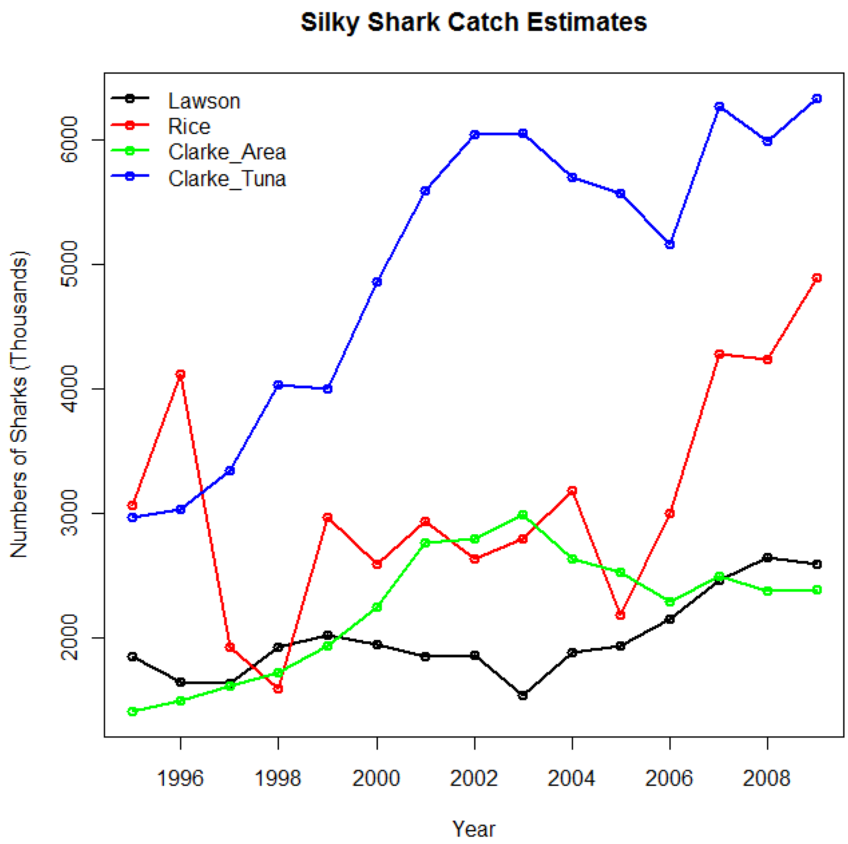


Figure 9: Silky shark catch estimates from the WCPO based on four different estimation methods

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ANNEX 1 DIAGNOSTIC PLOTS AND DEVIANCE TABLES FOR GLM STANDARDIZATION OF CPUE DATA

STANDARDIZATION OF SPC HELD LONGLINE OBSERVER DATA, EXCLUDING US POSSESSIONS (Series 3)

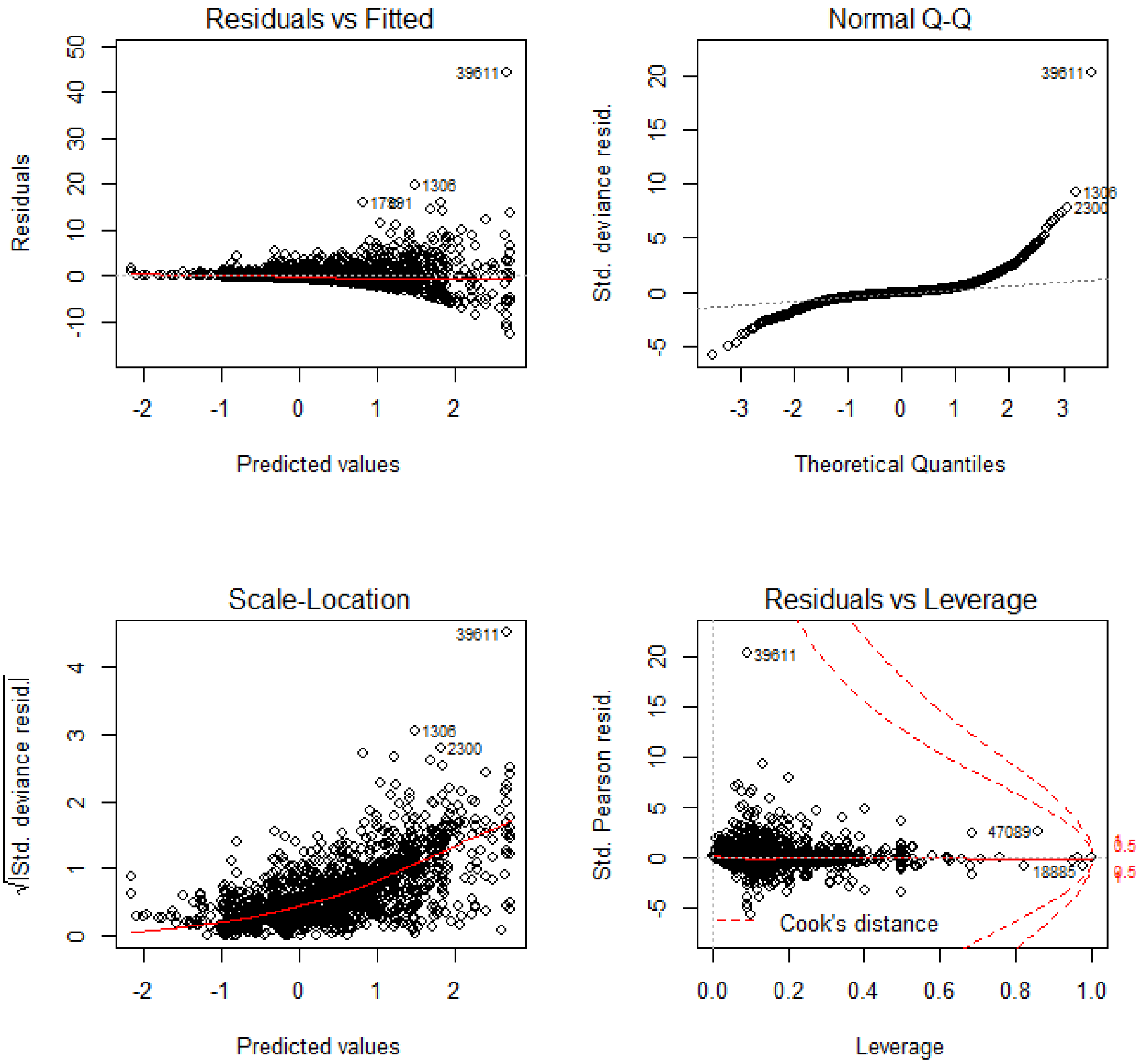
Table A1. Deviance table for Silky Shark CPUE standardization based on observed longline vessels, excluding US possessions, Lognormal error

	Df	Deviance	Resid. Df	Resid. Dev
NULL			2491	22228
+yy	14	2083	2477	20145
+hk_bt_flt	25	3427	2452	16718
+TIMECAT	5	566	2447	16152
+vesselname	261	4693	2186	11459
+ez_id	11	31	2175	11428

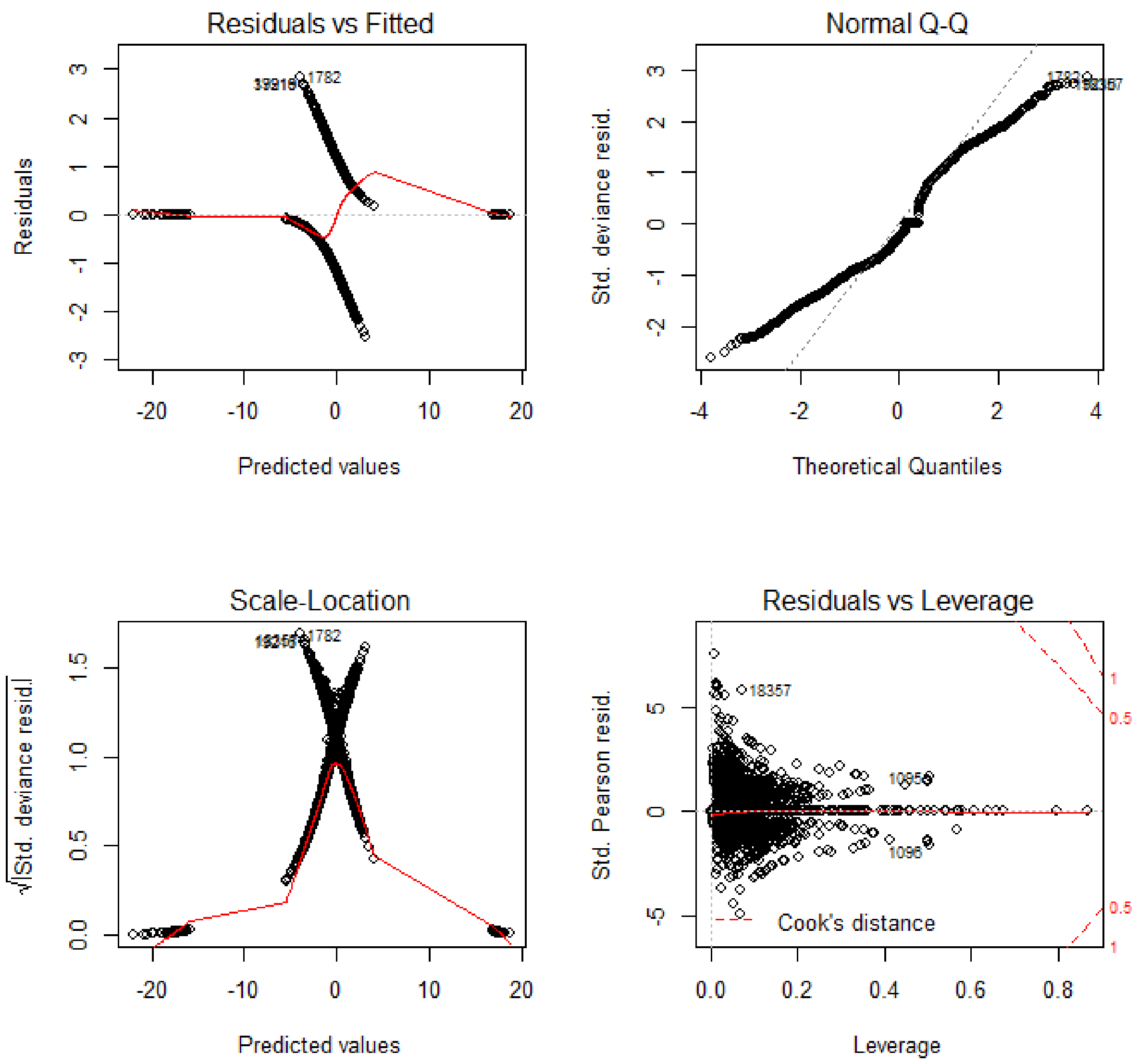
Binomial

	Df	Deviance	Resid. Df	Resid. Dev
NULL	NA	NA	6681	9249
+yy	13	411	6668	8838
+hk_bt_flt	25	655	6643	8184
+TIMECAT	5	66	6638	8118
+vesselname	332	1810	6306	6308
+ez_id	13	45	6293	6264

No US Data, Lognormal



No US Data, Binomial



PURSE SEINE – Associated -Catch /MT- (Series 5)

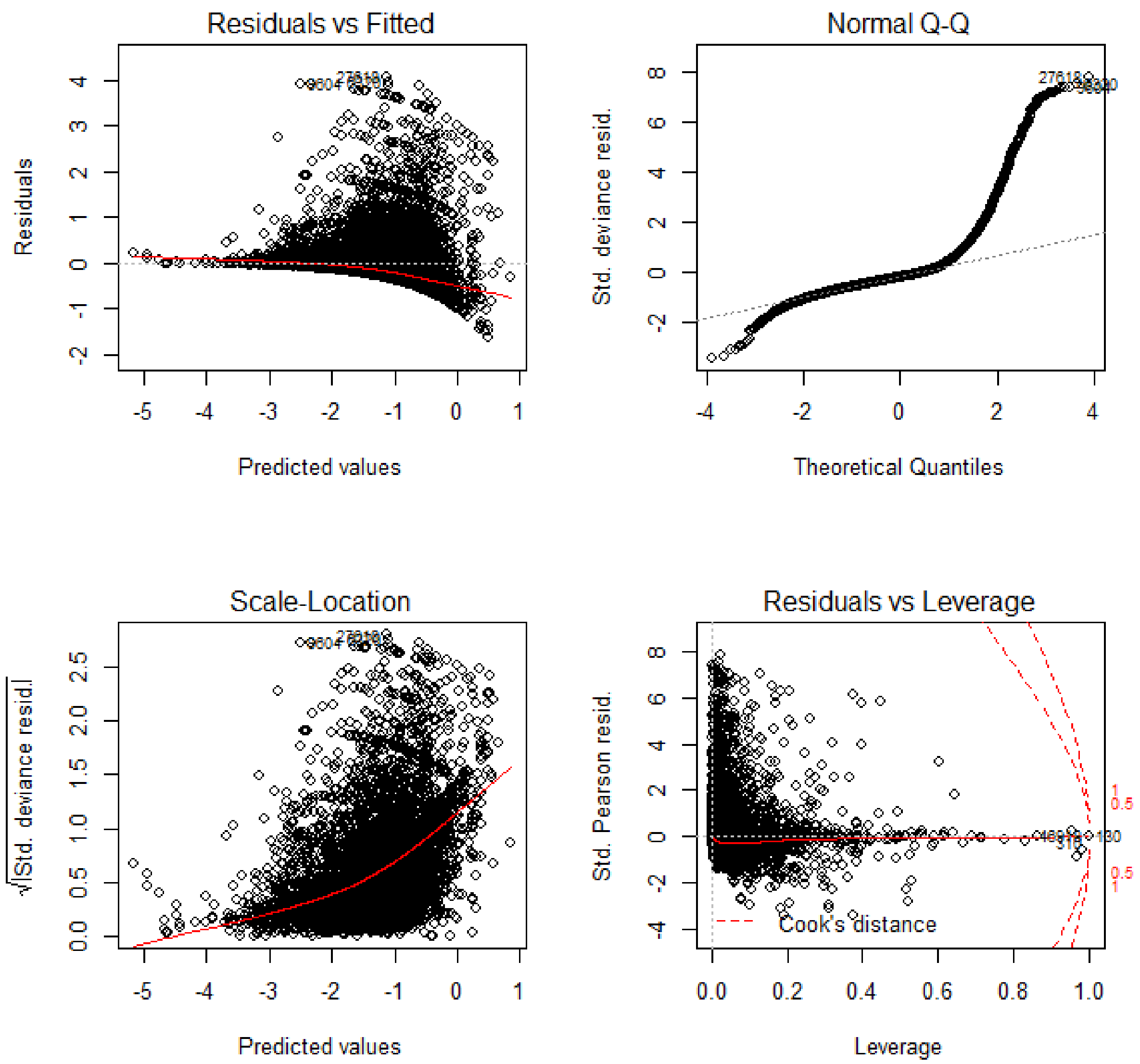
Table A3. Deviance table for Silky Shark CPUE standardization based on purse seine associated sets with the response = Catch/MT, Lognormal error.

	Df	Deviance	Resid. Df	Resid. Dev
NULL			10521	3186
+yy	14	43	10507	3143
+cell	65	31	10442	3112
+flag_id	13	16	10429	3096
+vesselname	337	255	10092	2840
+sch_id	4	32	10088	2808

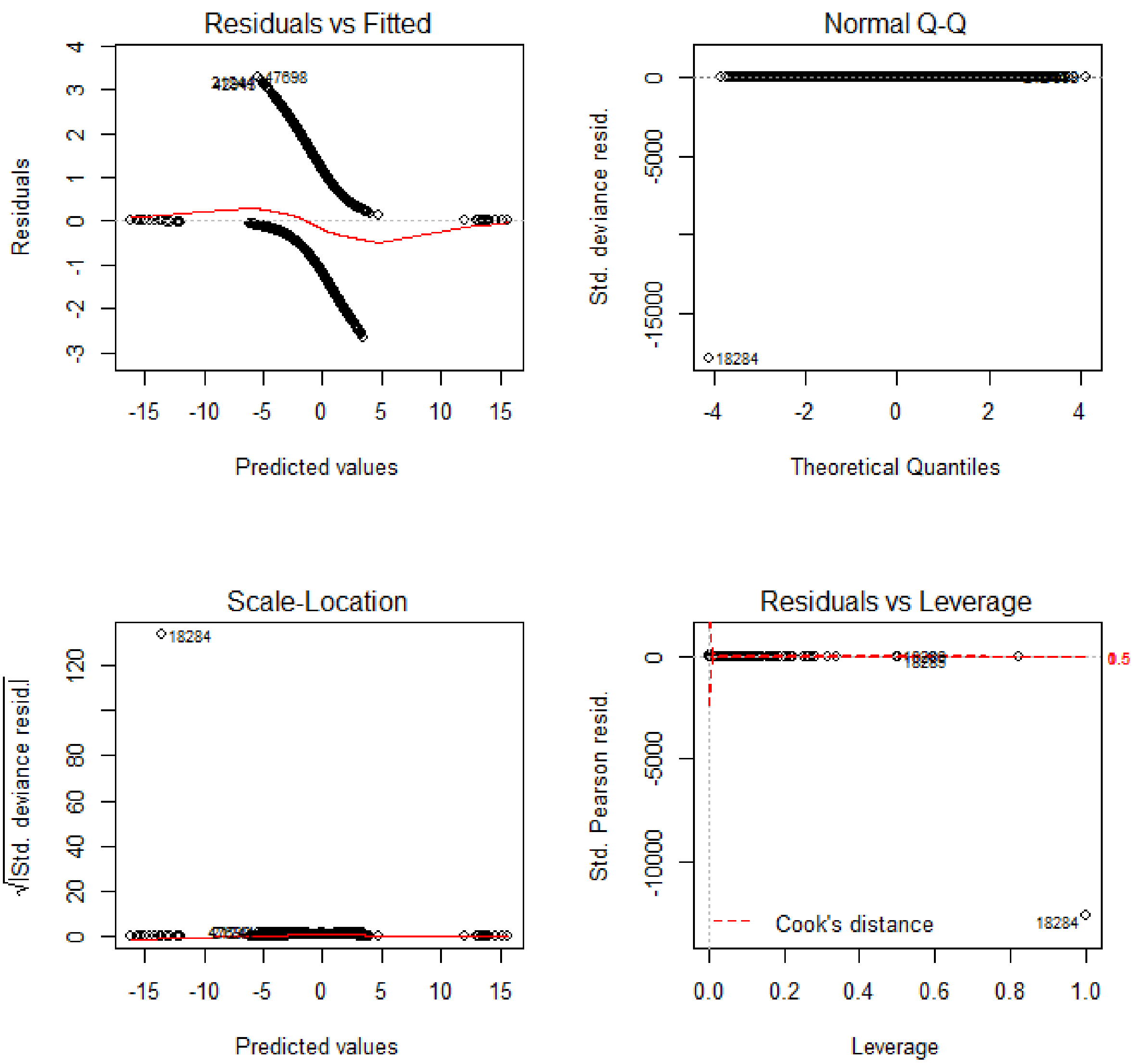
Associated - Catch/MT - Binomial

	Df	Deviance	Resid. Df	Resid. Dev
NULL			27225	40469
+yy	14	500	27211	39969
+cell	71	1015	27140	38954
+flag_id	13	410	27127	38544
+sch_id	4	539	27123	38005

Associated - Catch/MT - Lognormal



Associated - Catch/MT - Binomial



PURSE SEINE – Unassociated -Catch /MT- (Series 6)

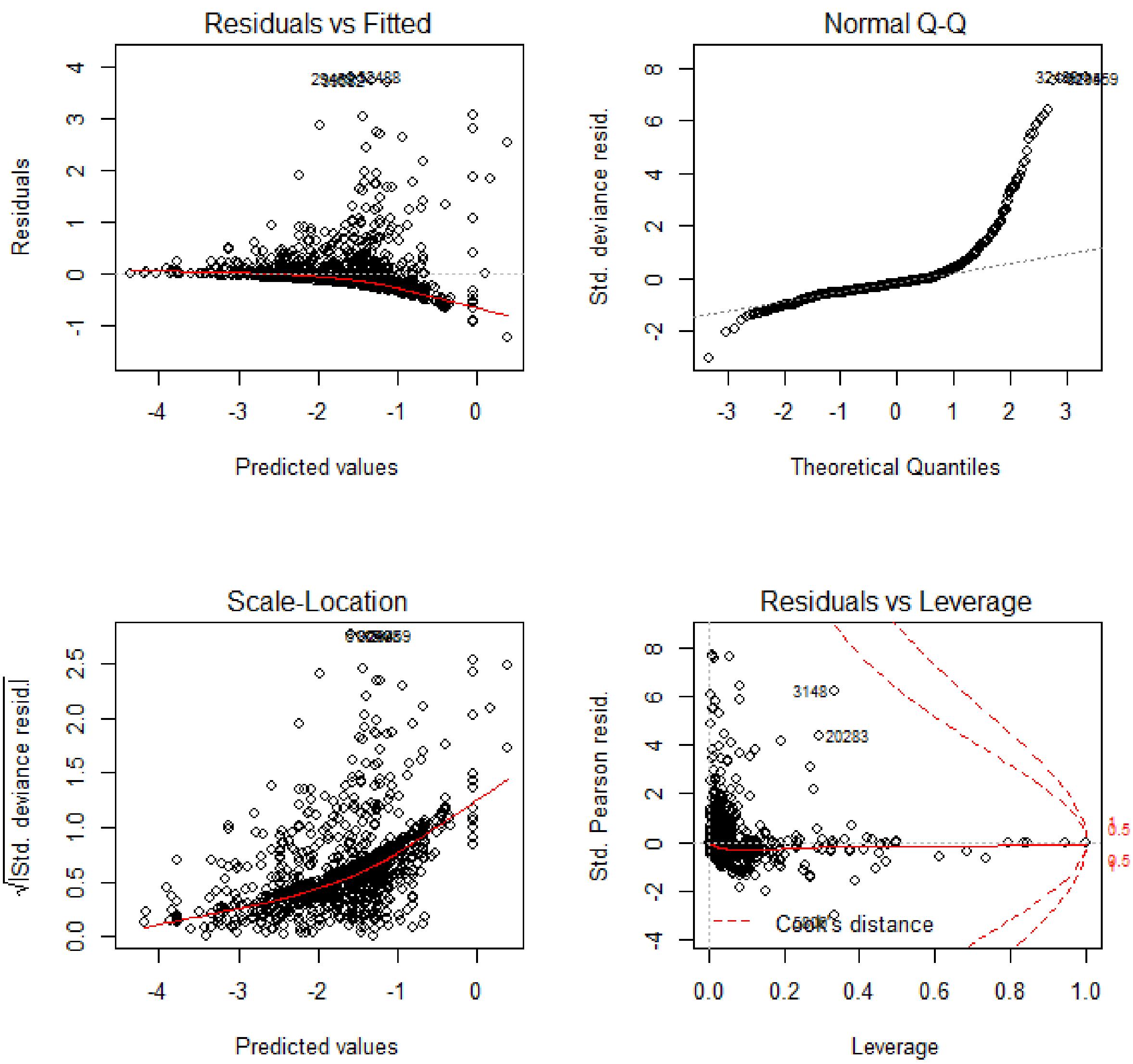
Table A2. Deviance table for Silky Shark CPUE standardization based on purse seine unassociated sets with the response = Catch/MT, Lognormal error

Predictor	Df	Deviance	Resid. Df	Resid. Dev
NULL			1177	294
+ yy	14	4	1163	290
+ cell	50	8	1113	282
+ flag_id	14	9	1099	273

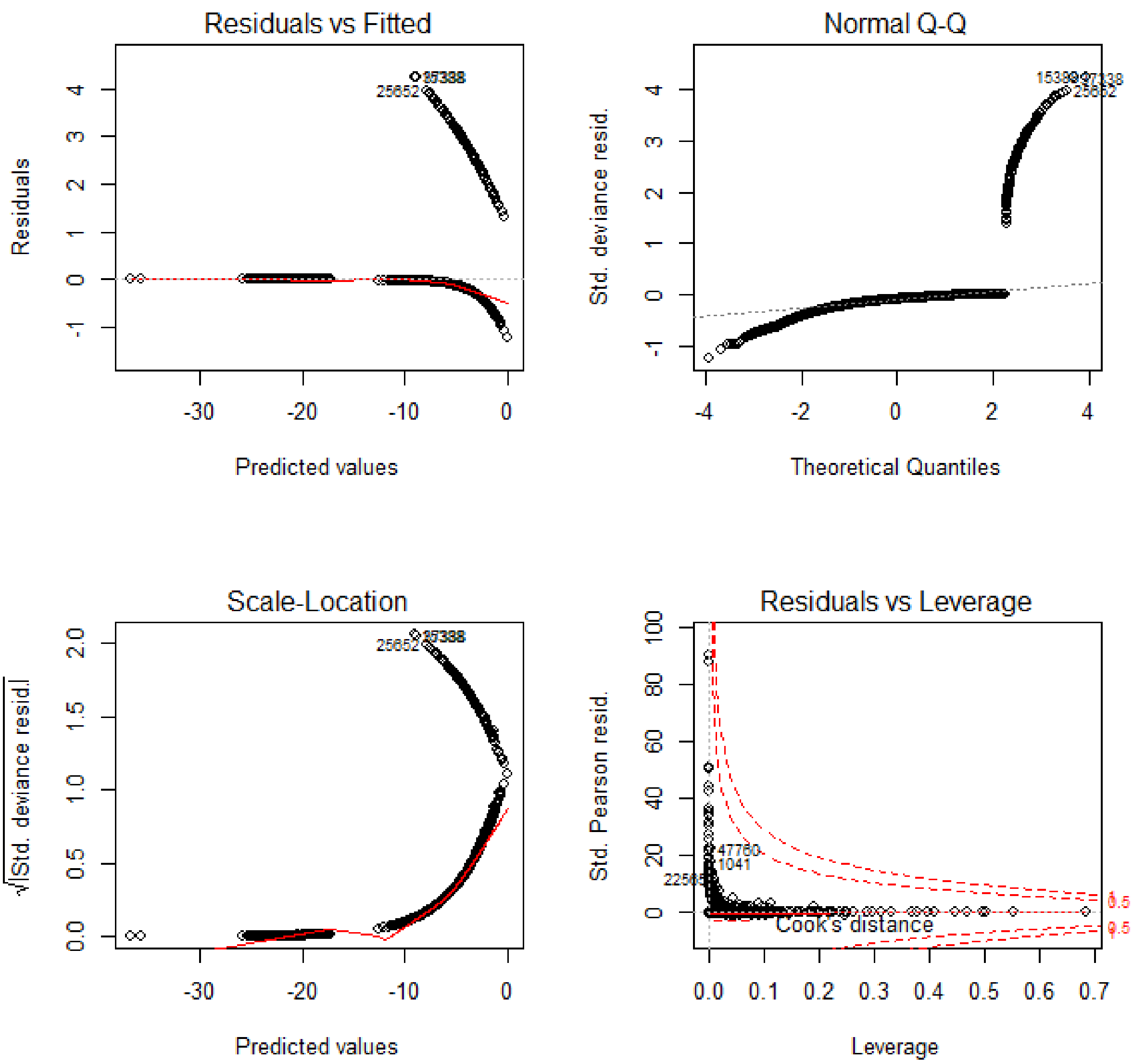
Unassociated - Catch/MT - Binomial

	Df	Deviance	Resid. Df	Resid. Dev
NULL			13022	1744
+yy	14	110	13008	1634
+cell	66	123	12942	1511
+flag_id	14	10	12928	1502

Unassociated - Catch/MT - Lognormal



Unassociated - Catch/MT - Binomial



ASSOCIATED SETS CATCH /SET (**Series 7**)

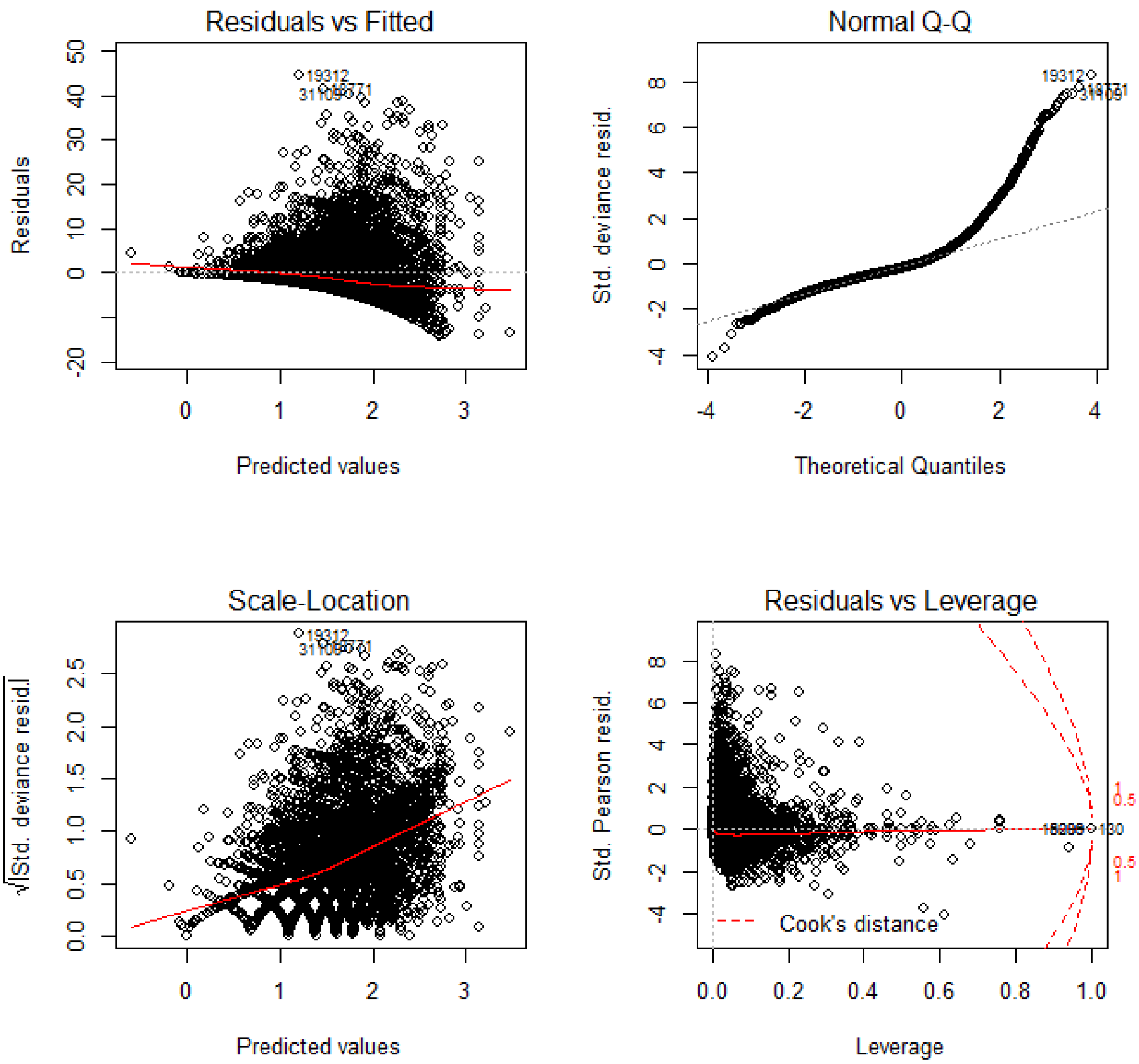
Table A5. Deviance table for Silky Shark CPUE standardization based on purse seine associated sets with the reponse = Catch/Set - lognormal error.

	Df	Deviance	Resid. Df	Resid. Dev
NULL	NA	NA	10521	368745
+yy	14	8285	10507	360460
+cell	65	10267	10442	350193
+flag_id	13	6643	10429	343551
+vesselname	337	39480	10092	304070
+sch_id	4	5794	10088	298276

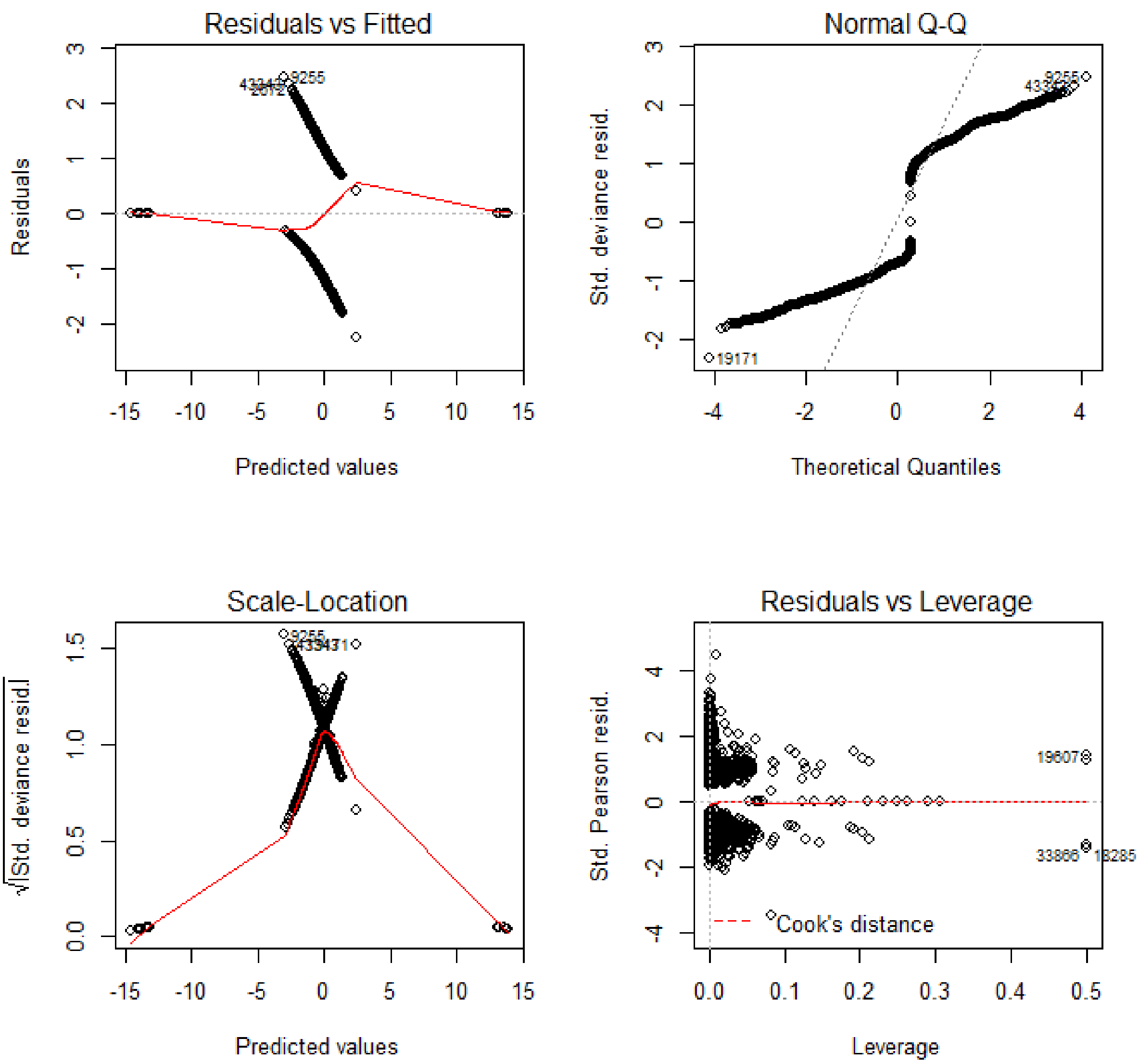
Associated - Catch/Set - Binomial

	Df	Deviance	Resid. Df	Resid. Dev
NULL	NA	NA	27225	36327
+yy	14	295	27211	36032
+cell	71	1284	27140	34748
+flag_id	13	282	27127	34466
+sch_id	4	526	27123	33940

Associated - Catch/Set - Lognormal



Associated - Catch/Set - Binomial



UNASSOCIATED PURSE SEINE- CATCH /SET (Series 8)

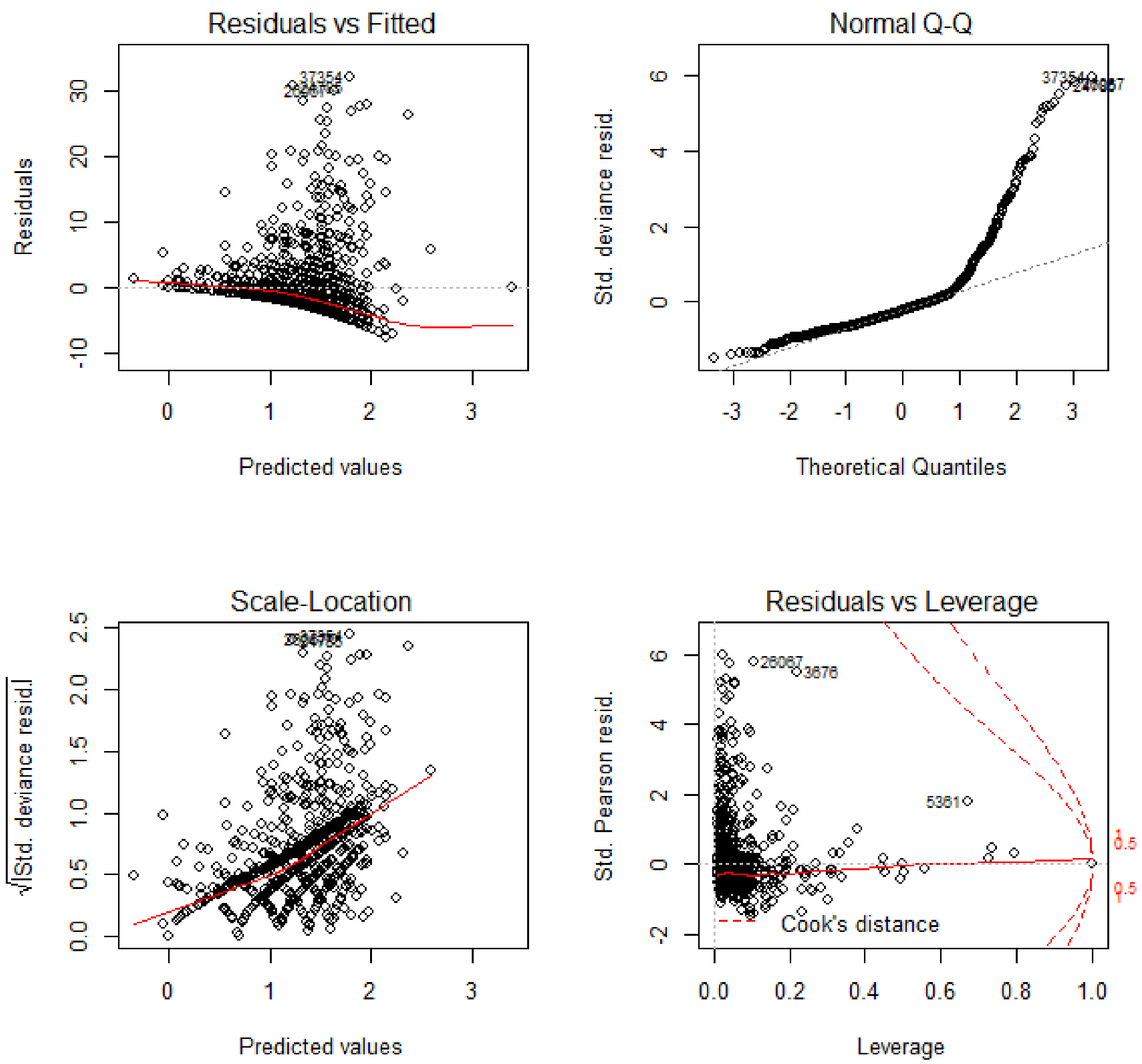
Table A4. Deviance table for Silky Shark CPUE standardization based on purse seine unassociated sets with the response = Catch/Set, lognormal error.

	Df	Deviance	Resid. Df	Resid. Dev
NULL			1177	35587
+yy	14	869	1163	34718
+cell	50	2198	1113	32520
+flag_id	14	219	1099	32301

Unassociated - Catch/Set - Binomial

	Df	Deviance	Resid. Df	Resid. Dev
NULL			13022	7907
+yy	14	224	13008	7683
+cell	66	445	12942	7238
+flag_id	14	121	12928	7117

Unassociated - Catch/Set - Lognormal



Unassociated - Catch/Set - Binomial