Analysis of Catch-per-Set Information from the Area B Purse Seine Individual-Transferable-Quota Fisheries

Final Report for the Southern Endowment Fund

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By

Jim Cave

Executive Summary

The focus of this Southern Endowment Fund project was the analysis of the relationship between existing catch-per-set (C/Set) data from Canadian purse seine ITQ fisheries (Area "B") and sockeye and pink salmon abundance and test fishing indices for the years 2010-2014. Because these data are limited by the occurrence of ITQ fisheries and the fact that Fraser pink salmon only return in odd- years, only two years were available for analysis of sockeye (2010, and 2014) and pink (2011 and 2013) relationships.

Findings

1. **In 2014, no relationships were found between CPUE data collected in-season from purse seine ITQ fisheries and test fishing CPUE data or sockeye abundance in the same area.** The relationships between ln-transformed Area 12-13 ITQ C/Set indices (Catch-by-individual-set information reported by fishers (FRITQ) or collected by J.O. Thomas observers (JOTITQ) and ln-transformed purse seine test fishing C/Set data or ln-transformed salmon abundance in the same area were not significant. In all cases, sample sizes were small on individual days of observation.
2. **By comparison, there is a significant relationship between the CPUE data of the purse seine test fishery and the sockeye abundance in the same area in 2014.** The relationship between ln-transformed Summer-run C/Set data from Areas 12 and 13 purse seine test fisheries and corresponding ln-transformed daily sockeye abundance for 2014 were significant (R^2=0.48 and 0.31 for Area 12 and 13 respectively) except when limiting the Area 12-3 test fishery data to include only those observations taken during the ITQ fishing period.
3. **By comparison with 2. above, when CPUE data was derived from "Log-book records" for 2010 and 2014 reported by fishers and available for analyses post-season (LBITQ), significant relationships were found between ITQ CPUE data and test fishing CPUE data and sockeye abundance in the same area.** All of the relationships between ln-transformed ITQ C/Set indices and ln-transformed purse seine test fishing C/Set data and ln-transformed sockeye abundance (Areas 12 and 13) were significant. Sample sizes were larger on individual days of observation.
4. **The correlation between CPUE and sockeye abundance in the same area was greater for the LBITQ records than for the test fishery data.** The coefficients of determination are larger for the correlation between ln-transformed Summer-run ITQ C/Set indices and ln-transformed Summer-run abundance (R^2=0.61, 0.65, and 0.55 for Area 12, upper and lower Area 13 respectively) than for the correlation between ln-transformed Summer-run C/Set data from purse seine test fisheries and ln-transformed Summer-run

abundance, especially when restricting the data to the same days (R^2=0.38, and 0.49 for Area 12 and Area 13 respectively, when restricting the data to the same dates).

5. **LBITQ C/Set data were found to be non-interchangeable with test fishing C/set for Area 12.** Analyses of covariance (ANCOVA) indicated a significant main effect of origin of C/Set for the Area 12-3 for 2010 and 2014 on the response of ln-transformed Summer-run C/Set on ln-transformed Summer-run Abundance. However, a similar test was not found to be significant for the lower Area 13 comparison.
6. **The LBITQ catch data are not entirely independent from the reconstructed marine abundance based on Mission escapement and commercial catch.** The LBITQ catches for 2014 represent 14%, 10% and 5% of the reconstructed Summer-run abundance in Area 12-3, Upper Area 13 and Lower Area 13 respectively. For 2010, the LBITQ catches represent 9%, 6% and 3% of the reconstructed Summer-run abundance in Area 12-3, Upper Area 13 and Lower Area 13 respectively. This will result in some positive bias or optimistic fit of the regression. By comparison, the C/Set data of the purse seine test fishery is completely independent of the corresponding reconstructed abundance in the same area.
7. **The relationship between ln-transformed Area 20 JOTITQ C/set and ln-transformed Area 20 purse seine test fishing C/Set for 2010 was not significant.** No further conclusions can be drawn from this as the sample size and number of years of information limits further analysis.
8. **The relationship between ln-transformed Area B FRITQ C/Set for Area 12-3 and ln-transformed pink C/Set from the Area 12-3 purse seine test fishery for 2011 was not significant.** No further conclusions can be drawn from this as the sample size and number of years of information limits further analysis.
9. **For 2011 and 2013, the pink salmon ITQ CPUE data at the mouth of the Fraser River correlates with the abundance at Mission but the utility of the relationship for fisheries management is sensitive to assumptions of travel speed.** The relationship between ln-transformed ITQ C/Set in Area 29 (JOTITQ and LBITQ records) and ln-transformed pink salmon abundance at Mission was examined assuming different travel times (3, 4, 5 and 6 days). The best relationship between ln-transformed ITQ C/Set in Areas 29 and ln-Mission abundance assumed a 5 day travel time for 2011 and a 3 day travel time for 2013.
10. The special case situation in Area 29 where ITQ Seiners have fished on delaying Fraser River sockeye (2010, 2014) was not examined as there were insufficient JOTITQ observations available for 2010. Due to time constraints, the LBITQ records were not analysed but may prove useful to examine in the future.

11. Although it was a goal of this project, I was unable to explore evidence for density dependence catchability in the ITQ fishery with the available information as only two years of observations on relatively high abundance were available in Areas 12-13.

12. At present, data limitations (years of observation) preclude the examination of the possible inclusion of the above results into a more thorough retrospective analysis of run-size estimation using ITQ time series.

Conclusions and Recommendations

1. "Catch-by-individual-set" data reported in-season by fishers (FRITQ) in 2014 do not provide sufficient statistical power to be used for run size estimation. By contrast, the C/Set information from log-book records may have utility in future run size models.
2. Do the above outlined results meet the Technical Criteria outlined in the Kowal Memo? All results are "Given the Data." For the ITQ sockeye fishery in Areas 12 and 13, only 2 years of data have been thoroughly evaluated. Conservation concerns resulted in near complete closures in other years. This severely limits the utility of the ITQ fishery because:
    a. Relationships using ITQ C/Set information cannot be established across the complete range of run-sizes.
    b. Run-size within the current year cannot be assessed with an ITQ based run-size model unless there is an ITQ fishery.

    Therefore the requirement of a "Minimum level of harvest" (Kowal 2002 memo) for run-size estimation is not met on all years.
3. Is the requirement that "harvest rate be independent of abundance" met? This is tricky and cannot currently be assessed. Caution is warranted as Individual Transferable Quotas are based on run-size estimates. This suggests the possibility of "Management Circularity" in which a management decision could influence the outcome from a run-size model. This possibility should be carefully considered if run-size models based on ITQ C/Set are to be considered in the future.
4. The assessments of the ITQ sockeye fishery in Area 12 and 13 support the following recommendation: **All Area B licensed vessels fishing in Area 12-13, 20 and 29 for either Fraser River sockeye or pink salmon report by electronic means complete log-book data, including locations (latitude and longitude from on-board GPS) by the end of the fishing day and this be instituted by 2017 and for future years as a condition of licence.** Achieving this recommendation is critical if ITQ information is to be utilized in run-size models. This is a relaxed version of the recommendation made at the Fraser Panel meeting (May 2016) that required catch-by-set information. DFO should consult with "Area B" to determine how best to bring this into effect.

5. Approaches towards using new information for run-size models should be conservative, given the investment in the "years of observation", important analyses and the "effect of error" of run-size models on fishery management. **I recommend that the Fraser River Panel draft policy that ensures future commitment to run-size models and the data required for their successful implementation.**

Introduction

In the 2015 request for proposals by the Southern Endowment Fund, the Fraser River Panel stated the following priority: "Identification of opportunities for more effective use of data from commercial and other fisheries in assessments of Fraser Sockeye run-size." The Fraser Panel wanted to explore the use of catch information from commercial fisheries, and in particular the Canadian purse seine "Individual Transferable Quota" (ITQ) fishery within run-size models for Fraser River sockeye and pink salmon in much the same manner as purse seine test fishing data. As current run-size models are highly reliant on test fishing information, the Panel was concerned that the information contained in commercial catches were currently ignored for run size estimation and deriving TAC. I submitted a proposal to the Southern Endowment Fund to analyse of catch-per-set Information from the Area B Purse Seine "Individual-Transferable-Quota" (ITQ) fisheries, which was accepted for funding, February 2016.

PSC staff have indicated that catch or CPUE data from smaller-scale daily "assessment" fisheries could be integrated into Bayesian time density models similar to the format in which test fishing data are currently integrated (Kowal 2002). ITQ fisheries may fit these criteria; however the conduct of these fisheries would have to meet important assumptions implicit in models for the estimation of run-size. First, a minimum level of harvest rate would be required for an assessment fishery to provide information on all levels of run-size and independent of conservation concerns. Second, effort and vessel power should be non-selective, stable over time and with density and operated systematically over time and space (i.e. at the same location over the course of the entire migration) (Kowal 2002). Finally, a set of data over a number of years would be required to understand the underlying relationships with abundance and the associated uncertainty.

The focus of this Southern Endowment Fund project was the analysis of the relationship between sockeye and pink salmon abundance and existing catch by set data from Canadian purse seine ITQ fisheries (Area "B") for the years 2010-2014:

1. Obtain catch data-by-set and location from individual Area B purse seiners in fishing locations were obtained and compare with indices of Fraser River sockeye and pink salmon abundance.
2. Examine the special case situation in Area 29 where ITQ Seiners have fished on delaying Fraser River sockeye (2010, 2014) and pink salmon (2013).
3. Explore evidence for density dependence catchability in the ITQ fishery dynamics.
4. In consultation with PSC Staff, incorporate the above (if useful) within a Bayesian hierarchical methodology.
5. Review compliance with the requirements identified in the Kowal Letter to the Fraser River Panel (2002) and also with the Run-size estimation workshop (2003).

6. Develop a plan for additional sampling opportunities for the Panel's consideration for implementation in future years.

Background

Assessments for Fraser River sockeye are directed towards the estimation of the abundance, timing and the route-of-migration (proportion of the run through Johnstone Strait and Juan de Fuca Strait) of the component stocks or management groups of Fraser River sockeye (PSC 1995). Four main programs provide information for this purpose: 1) The Mission Hydroacoustics program provides real-time estimates of the passage of sockeye upstream. 2) Estimates of catch are provided by the Department of Fisheries and Oceans (Canada), the Northwest Indian Fisheries Commission (NWIFC) and Washington Department of Fish and Wildlife (WDFW). 3) The Test Fishing program provides index data on abundance in the form of daily Catch-per-unit-effort (CPUE) data in the approach areas of Juan de Fuca Strait and Johnstone Strait. 4) The stock identification program provides estimates of the component sockeye stock contributions in catch, test fishing CPUE and estimates of upstream passage of sockeye at Mission.

Assessments for Fraser River pink are similar to sockeye but differ in two key areas. First, while the hydroacoustic program is able to provide in-season estimates of pink salmon abundance, the delay in the migration of pink salmon does not allow these data to be used for in-season assessment. [1] As a result, in-season estimates of Fraser River pink abundance are derived entirely from test fishing CPUE and stock ID information (Grant et al., 2014). Second, the estimates of stock proportions are used primarily to separate the Fraser River stock contribution from Canada non-Fraser and United States origin pink salmon.

Catch and effort information from Canadian commercial purse seine fisheries in Area 20 and Areas 12-13 were once used in important run-size models for Fraser River sockeye and pink salmon (Pacific Salmon Commission 1995). These models were underpinned with a high overall exploitation rate which provided for reasonable precision, systematic sampling and updating requirements for management of fisheries (Figures 1A and 1B).. The R^2 of model fits ranged from 0.839-0.995 for the dominant stocks Chilko, Late Stuart, Quesnel, Adams, and Stellako (see Pacific Salmon Commission 1995, page 116 for details). However, despite the relatively high precision and accuracy, the deviation of the "Adams 94" observation from the prediction

[1] Beginning with the 2009 return year, hydroacoustic estimates of escapement were included in the estimates of total abundance of adults, as there are currently no programs to assess spawner abundance of pink salmon in the Fraser River. From 1995-2007, the estimates of total return are derived entirely from expansion of purse seine test fishing information (Grant, 2013).

was the subject of detailed analytical assessments undertaken for the 1994 Fraser River Sockeye Review Board Inquiry (1995).

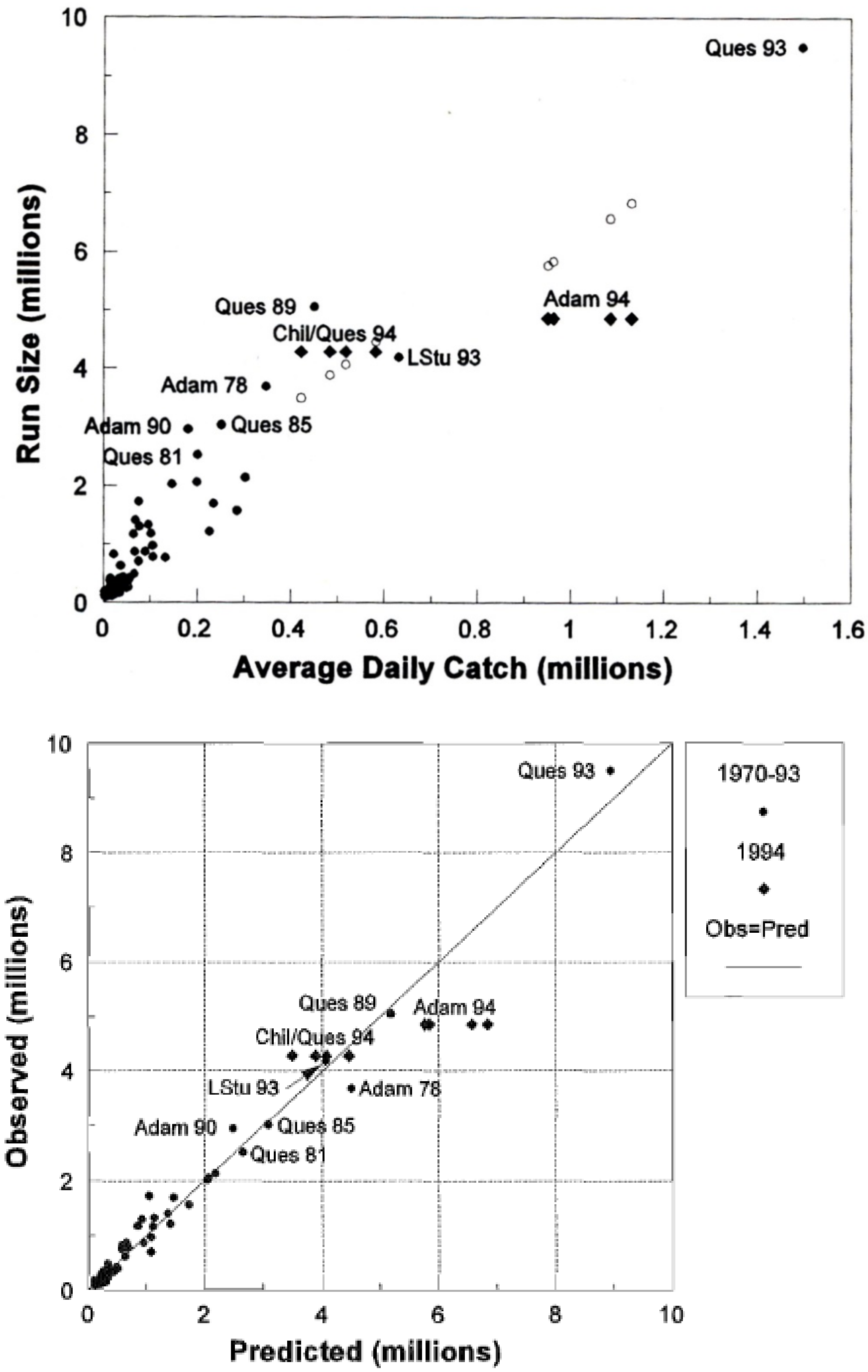


Figure 1A: Observed run size versus average daily catch during the peak-week purse seine fisheries in Johnstone Strait from commercial purse seine models for Johnstone Strait, 1970-1994. **Figure 1B:** The observed versus predicted run-size estimates for the same time series indicating the precision and accuracy about the 1:1 line. The largest historical runs are identified by stock and year, as are the estimates derived from the different in-season and post-season catch and SID estimates for Adams and Chilko/Quesnel groups in 1994. (PSC, 1995).

For the first 10 years of the Pacific Salmon Treaty (1985-1994), combined annual exploitation rates for purse seine fisheries (Area 20, Area 12-13) on Fraser River sockeye averaged 24% (Figure 2). Since that period, a combination of factors contributed to a decline in the associated purse seine exploitation rates which effectively crippled purse seine catch and effort based run-size models. First, fleet size in Areas 12-13 and 20 declined from over 450 vessels fishing during peak weeks in 1993-1994 to 330 licensed purse seine vessels in 1999, and to 131 licensed vessels in 2014 (Source: Pieter Van Will, DFO). This decline in licensed purse seine vessels was due to a combination of Area licencing which was instituted in 1996 and fleet buy-backs which began in 2000. Second, the proportion of the Total Return assigned to TAC declined during this period, as a result of increases in spawning escapement targets, the institution of "Management Adjustments" or MAs, and finally conservation concerns as a result of drastic declines in run-size (Cohen 2012).

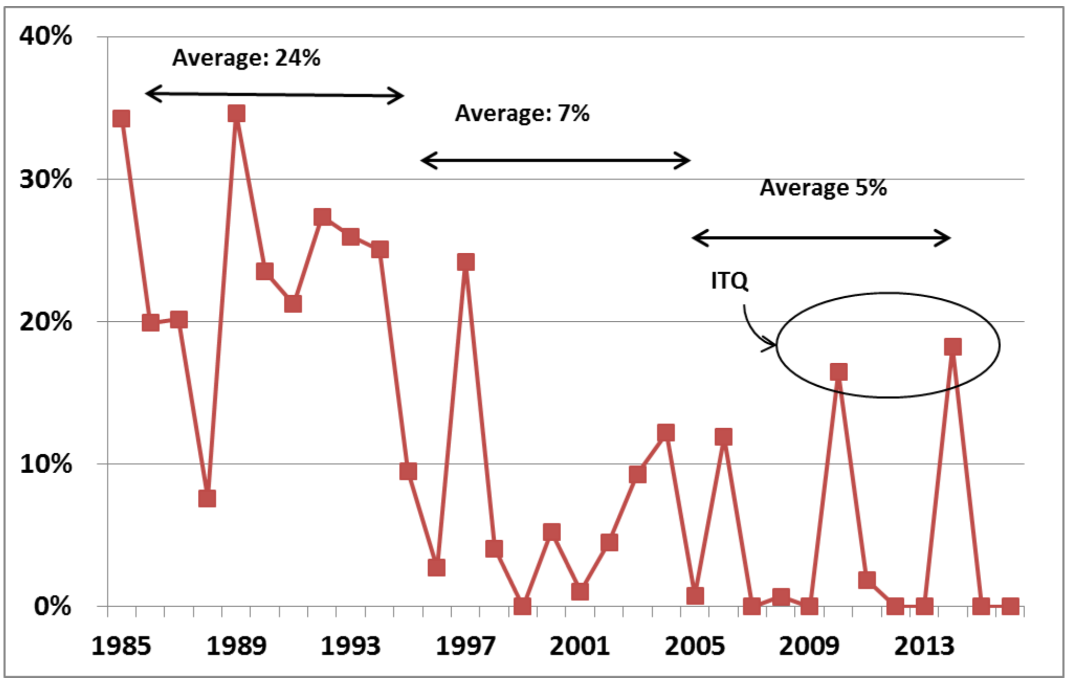


Figure 2: Annual exploitation rate (total catch divided by total return) for combined for purse seines (Area 20, Area 12-13) on Fraser River sockeye. First period 1985 (inception of the Pacific Salmon Treaty) to 1994: Average 24%, maximum purse seine vessel licenses 454. Second period 1995-2004: Average 7%, 330 purse seine vessels licensed to fish in Areas 12-13 and 20 in 1999. Third period 2005 to 2014: Average 5%, 131 Area B licenses. 2015-2016: Average 0%. Note: ITQ fisheries effectively begin 2010. Source: Pacific Salmon Commission.

The 10-year average annual purse seine exploitation rates (combined Area 12-13, and 20) declined from 24% (1985-1994), to 7% (1995-2004), to 5% (2005-2014) and to 0% (2015-2016, Figure 2). During 10 of the past 18 years (1999-2016), Area B was either closed completely or exploitation rates were below 1% (1999, 2001, 2005, 2007-2009, 2012-13, 2015-16). Finally, changes in fishery management resulted in entirely different relationships between abundance and catch and effort. As a result of these factors, “stand alone” run-size models using data from purse seine fisheries could no longer be used for fisheries management.

The “Normal Time Density Model”, formerly described as the Cumulative Normal Model (PSC, 1995) is now the primary run-size model for Fraser River sockeye. The method first involves reconstructing the daily abundance of the run, by accumulating catch in the migratory areas and escapement at Mission. Purse seine and gillnet test fisheries provide index information on the abundance on route to Mission prior to the assessment of upstream abundance (Pacific Salmon Commission 2005). Time series of reconstructed marine abundances based on CPUE data from marine test fishery and in-river hydro-acoustic data are fit to the model. A Bayesian version of the Normal Time Density Model was developed in 2008 and is now the principal method for the estimation of run-size and timing. This model allows the incorporation of the pre-season forecast of run size, timing and spread of the run within the assessment.

To conclude, in-season estimates of commercial catch and effort of Fraser River sockeye and pink salmon have been discontinued for use in stand-alone run-size models, except where appropriate in reconstructed abundance of summer-run sockeye. As outlined above, the purpose of this project is to assess whether catch-by-set data from Canadian purse seine ITQ fisheries (Area “B”) are related with daily estimates of abundance and whether they can be integrated in the current run-size models.

Data and Methods

Area B vessel masters in Areas 12, 13, 20 and 29, are required to provide daily catch reports by cell phone, land line or satellite phone to the salmon catch monitoring service provider or directly to DFO by E-log as a condition of licence, although specific details varied somewhat from year to year (Anon, 2015). In addition, vessel masters were to complete a logbook or E-log entry for each day of fishing. On completion of a fishing set, vessel masters of Area B licenced vessels fishing in Area 20, were required to report to the at-sea observer the set number for the current day's fishing, time the set was made, set location (grid area) and the number of all species of fish caught and retained or released. All landings were to be verified at designated landing sites. These data were entered in the Fisheries and Oceans Catch Monitoring system.

The initial analyses of this project were based on catch-by-individual-set information reported by fishermen which were obtained from Department of Fisheries and Oceans (DFO) Fishery Operations System (FOS) for 2011, 2013 and 2014 for Areas 12 and 13; 2010 for Area 20 and 2010, 2011, 2013 and 2014 for Area 29 (Table 1). In addition, JO Thomas observer data were also provided by DFO FOS. In May 2016 analyses of these data were presented to the

Fraser River Panel, at which time a request was made to report on analyses of the complete logbook information, greatly extending the initial scope of the project. Therefore three different data sources are evaluated in this study:

1) Data voluntarily reported in-season by individual fishermen (FRITQ)
2) Data collected in-season through observers of JO Thomas (JOTITQ)
3) Logbook data obtained post-season from DFO (LBITQ).

Sufficient numbers of observations were available to examine records for Areas 12-3, Upper Area 13 (Area 13 subareas above Chatham Point) and Lower Area 13 (Area 13 subareas below Chatham Point). For these subareas, only those records with the entire fishing day taking place within that subarea were included. Those cases where catches had been taken in multiple subareas were excluded as insufficient information was available within the record to partition the catch across subareas. Also, records were also excluded if the number of sets were not recorded or there was "0" catch for the target species as a "data quality" issue is indicated for these observations.

There are two possible approaches to calculate C/Set (CPUE) from the complete log-book data. The first approach is to sum all catches and all sets for all boats for the day and calculate the C/Set accordingly. This gives non-equal weight to outliers: vessels that have a large number of sets or alternatively very large catch. The second approach is to take the average of the C/Sets across the boats for each day. This was the approach taken in this report as it gives equal weight to each vessel. Summer-run stock proportions were applied to the ITQ CPUE data to allow for representative comparisons with daily Summer-run abundance.

Reconstructed estimates of Summer-run abundance for Area 12-3 and Area 13 for 2010 and 2014 were obtained from the Pacific Salmon Commission. The methodology involves backing up estimates of daily Summer-run sockeye abundance at Mission in time through the fishing areas and summing Summer-run catch, with appropriate timing lags (Pacific Salmon Commission 1995). The estimated proportion of the terminal (Area 29) abundance projected to have arrived from Johnstone Strait is used to scale the terminal abundance profile from Johnstone Straits. For 2014 the proportion of sockeye traveling that route exceeded 95% for most of August. This provided for a high degree of confidence in the daily reconstructed Summer-run abundance through Areas 12-13, ideal for comparisons with information from the Area B ITQ fishery and abundance as well as with indices from the test fisheries. Observations of abundance are log-normally distributed; therefore the natural-log transform (ln) was applied to the dependent and independent variables.

Area B ITQ fisheries for pink salmon in Area 29 first took place in 2011 and in 2013. JOTITQ and LBITQ information was available for analysis for both years. The relationship between ln-transformed ITQ C/Set in Areas 29 and ln-transformed Mission abundance was examined with 3, 4, 5 and 6 day off-sets in timing to travel times of pink salmon from Area 29 subareas 1-6 to Mission. The independent variable in these analyses was Mission abundance. Although the reconstruction of catches onto the Mission abundance with offsets for timing was considered, the management goal of the unique projection of Mission abundance was felt to be a cleaner and more defensible analysis as the dependent variable and covariates are completely independent from each other.

The coefficients of determination (R^2) are provided as an indication of the correlation in log-space. Significance was determined using the F-test (a priori α=0.05). Analyses of Covariance (ANCOVA) for unbalanced experimental designs (Winer, 1971) were used to examine the significance of main effects (for example origin of C/Set data, Year) with regard to the response variable (Y) after the appropriate linear adjustments of covariates (X). Caution is warranted when interpreting the resulting R^2 which is in log-space. Because of the need to log-transform the data prior to doing implementing a linear regression analysis, the R^2 in log-space will likely be greater than, and is not comparable with the R^2 of the non-transformed data.

Table 1: Data provided by Department of Fisheries and Oceans (DFO) Fishery Operations System (FOS)

Year	Area	Sub Areas	Start Date	# of Sets	# Days	Source	Comments
2010	Area 20	N/A	08-Aug	228	13	JOTITQ[2]	Relationships with TF C/Set,
2010	Area 12	12-3	06-Aug	1180	26	LBITQ[3]	Relationships with TF C/Set, Summer Reconstructed abundance
2010	Area 13	Above CP[1]	06-Aug	1023	26	LBITQ[3]	" " " " " "
2010	Area 13	Below CP[1]	06-Aug	280	19	LBITQ[3]	" " " " " "
2011	Area 12	12-3	17-Aug	183	?	JOTITQ[2]	Pinks. Relationships with TF C/Set
2011	Area 29	N/A	04-Sep	149	12	JOTITQ[2]	Pinks. Relationships with Mission Upstream
2013	Area 29	N/A	01-Sep	240	12	JOTITQ[2]	" " " " "
2011	Area 29	N/A	04-Sep	149	12	LBITQ[3]	" " " " "
2013	Area 29	N/A	01-Sep	240	12	LBITQ[3]	" " " " "
2014	Area 12	12-3	06-Aug	40	4	JOTITQ[2]	Relationships with TF C/Set, Summer Reconstructed abundance
2014	Area 12	12-3	06-Aug	114	13	FRITQ[4]	" " " " " "
2014	Area 12	12-3	06-Aug	1360	26	LBITQ[3]	" " " " " "
2014	Area 13	Above CP[1]	06-Aug	56	9	FRITQ[4]	" " " " " "
2014	Area 13	Below CP[1]	06-Aug	30	6	FRITQ[4]	" " " " " "
2014	Area 13	Above CP[1]	06-Aug	553	25	LBITQ[3]	" " " " " "
2014	Area 13	Below CP[1]	06-Aug	337	21	LBITQ[3]	" " " " " "

[1] CP: Chatham Point

[2] JOTITQ: J.O. Thomas Observer recorded "Encounters-at-Sea" Catch-by-Set information

[3] LBITQ: Complete Log-book records by fisher and day.

[4] FRITQ: Fisher reported Catch-by-Set information

Results

1. **Analysis of Area B ITQ Catch-by-Set Information for Area 12-13 available in-season for 2014**

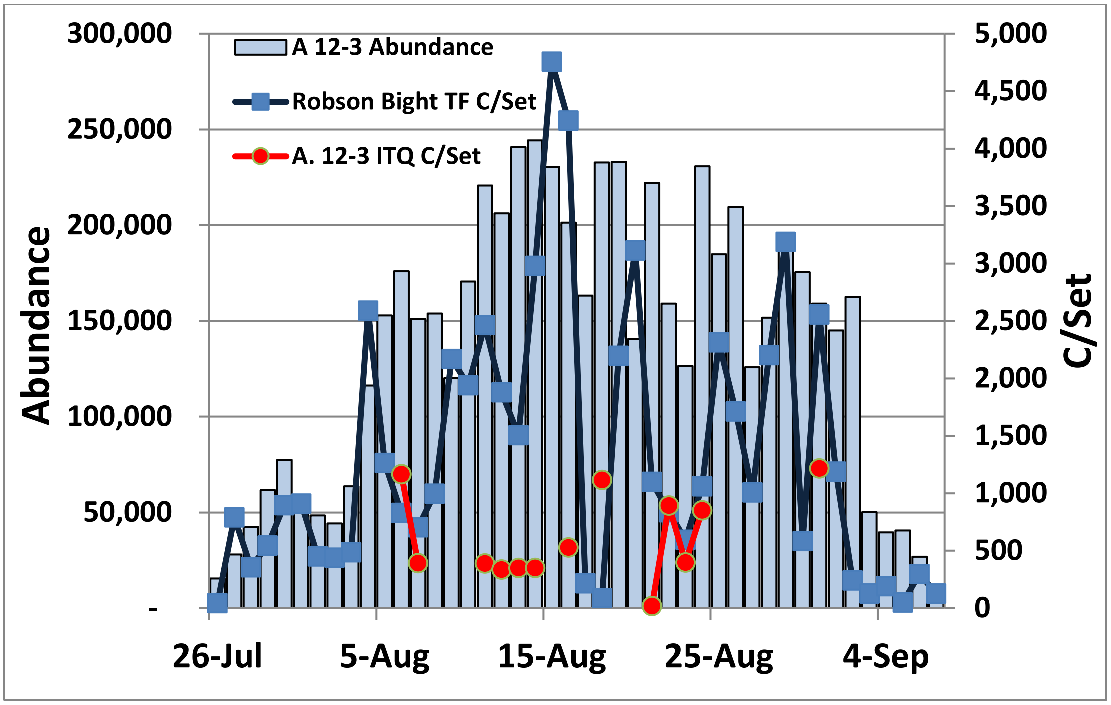
In 2014, "catch-by-individual-set" information was reported by some fishermen (FRITQ) to the Department of Fisheries and Oceans (DFO) for 2014 for Areas 12 and 13. In addition, JO Thomas observers also collected "catch-by-individual-set" data (JOTITQ). Data were summarized by sub-area and day and analysed using linear least squares regression analysis on the ln-transformed data and the following time-series were analysed:

- The relationships between ITQ C/Set data and test fishing CPUE data for Area 12-3 and Area 13 (Table 2),
- The relationship between ITQ C/Set data and the daily reconstructed summer-run abundance entering lower Area 13, Upper Area 13 and Area 12-3loglog (Table 3).

None of the relationships between ln-transformed ITQ C/Set indices and ln-transformed purse seine test fishing C/Set data (Areas 12 and 13) were significant (Table 2). In all cases, the sample size was small because of the limited individual days available for comparison, ranging from n= 5-12.

Time series plots of Summer-run abundance and Summer-run indices of C/Set by day demonstrate the intra-annual variation in correspondence between these two measures (Figures 3-4). None of the relationships between ln-transformed ITQ C/Set indices (FRITQ and JOTITQ) and ln-transformed daily Summer-run abundance were significant (Table 4). By comparison, the relationship between ln-transformed purse seine test fishing C/Set data (Areas 12 and 13) and ln-transformed daily Summer-run abundance were significant except for the case of the Area 12-3 test fishery when the observations were restricted for the ITQ period only (Table 4). Overall, the correlation with summer run abundance was greater for the Area 12-3 test fishery data (R^2=0.48) than for the Area 13 test fishery data (R^2=0.31).

There are two issues with these ITQ records. First, after summarizing the information by day, the number of observations is limited and the interpretation of the day-to-day fluctuations and relationships in C/Set and abundance are challenging. Second, because these data rely on voluntary reporting by fishermen or reporting by on-the-grounds observers, the number of observations (sets) is small on most days likely increasing the variability in C/Set. As a consequence, these observations may not be entirely representative of either the overall C/Set of the ITQ fishery as a whole or the abundance on any given day.



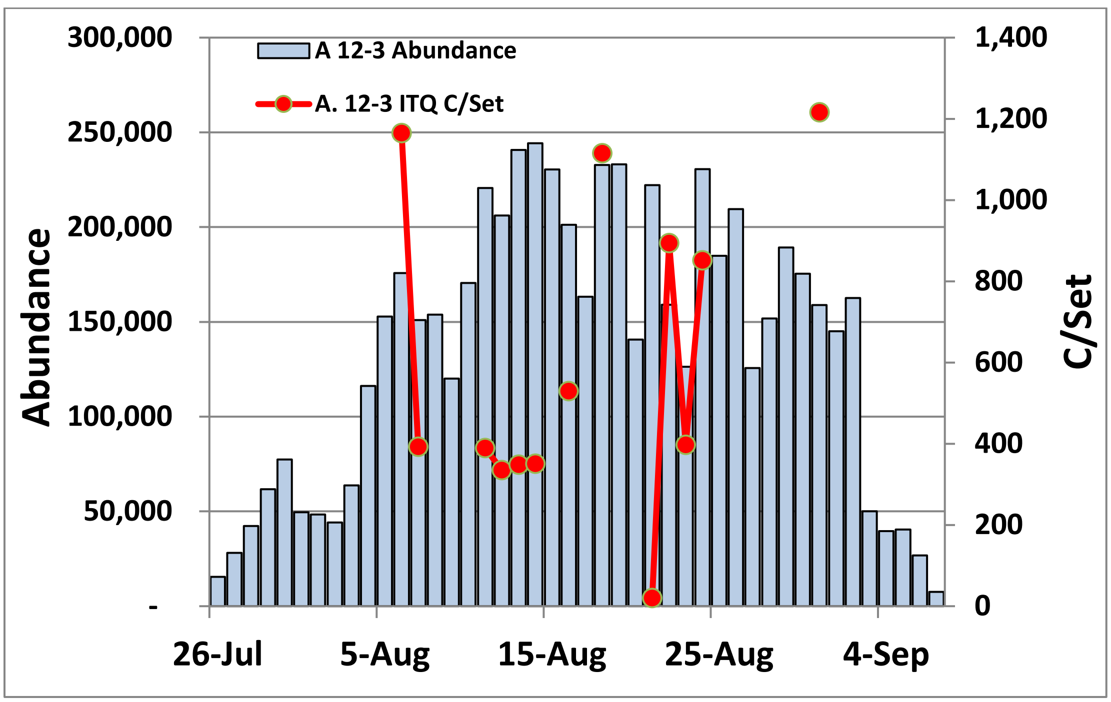
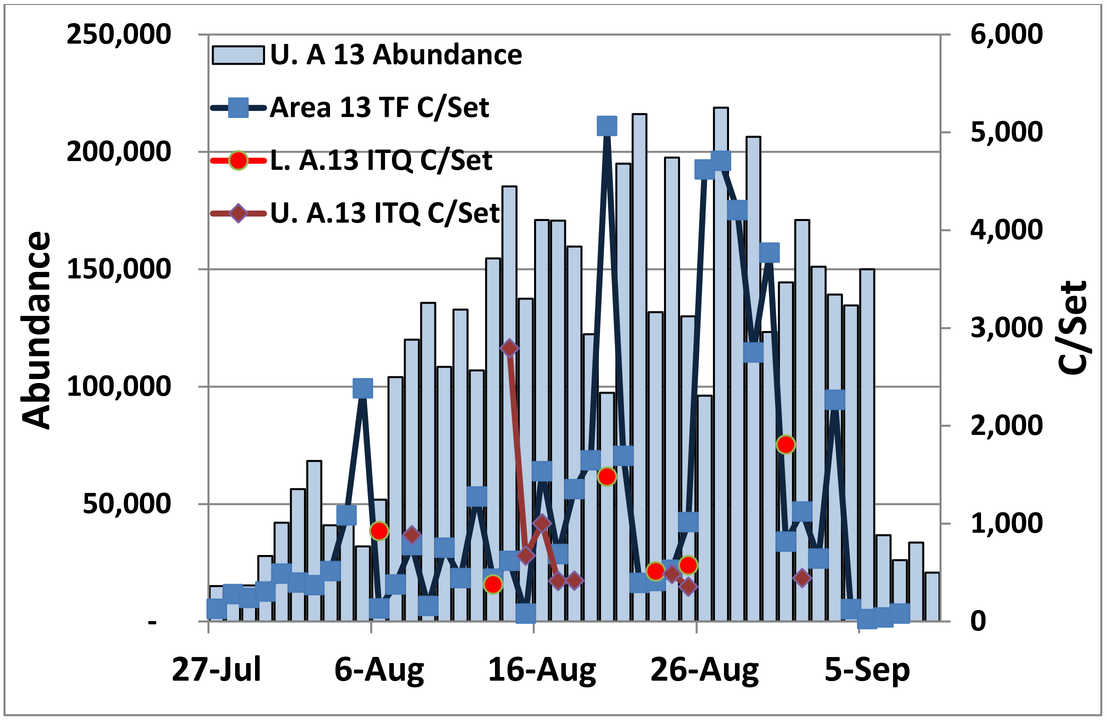


Figure 3A (top): Time series plots of reconstructed Summer-run abundance in Area 12-3 and C/Set in the Area 12-3 test fishery and C/Set from the Area 12-3 ITQ fishery (summarized from the FRITQ records). Figure 3B (bottom): same plot with the test fishery data removed allowing for a re-scaling of the FRITQ C/Set.



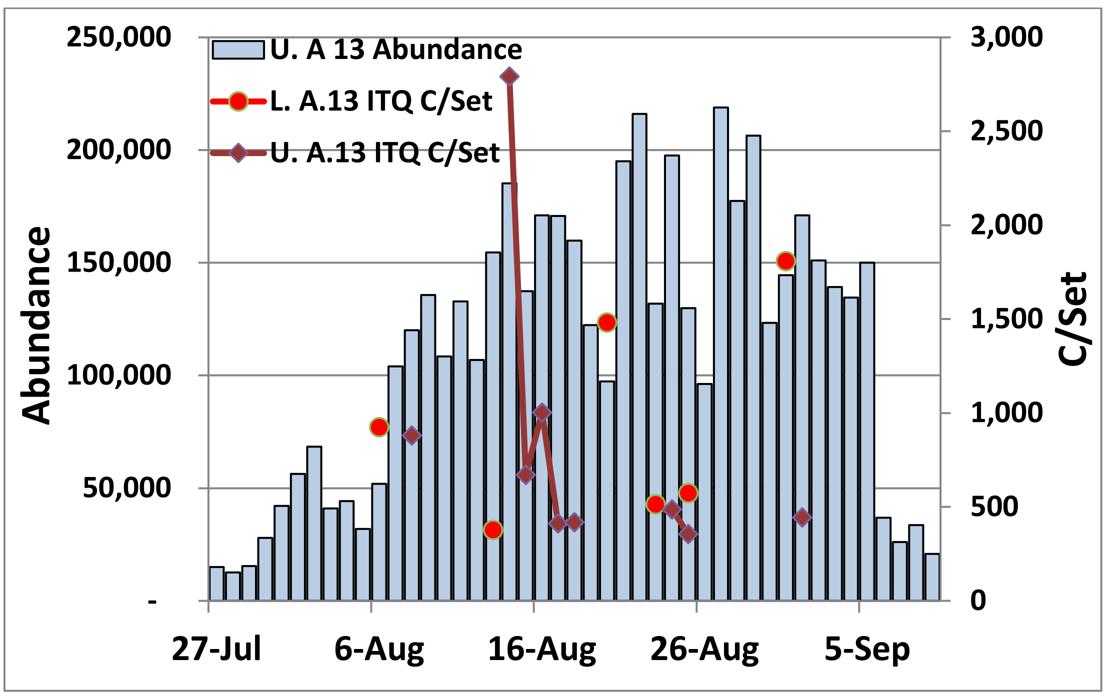


Figure 4A (top): Time series plots of reconstructed Summer-run abundance in Area 13 and C/Set in the Area 13 test fishery and C/Set from the Area 13 ITQ fishery (summarized from the FRITQ records). Upper (U) is above Chatham Point (Lower Johnstone Strait) and Lower (L) is below Chatham Point (Discovery Passage). Figure 4B (bottom): same plot with the test fishery data removed allowing for a re-scaling of the FRITQ C/Set.

Table 2: Relationship between different commercial CPUE time series (Dependent Variable) and ln-Test Fishing CPUE time series in the same statistical area (both log-transformed)

Year	Test Fishing Area	Dependent Var. (Y) Summer Catch per set...	R^2	Slope	Int.	F	Deg F.	Significance
Individual ITQ Sets, as Identified….								
2014	Area 12	ln-A-12- FRITQ Catch-by-Set	0.0082	-0.0949	7.74	0.09	11	Not Sig.
2014	Area 12	ln-A-12-3 JOTITQ Catch-by-Set	0.0033	-0.0466	6.96	0.02	5	Not Sig.
2014	Area 13	ln-Upper A-13 FRITQ Catch-by-Set	0.2519	-0.2922	9.19	2.36	7	Not Sig.
2014	Area 13	ln-Lower A-13 FRITQ Catch-by-Set	0.3787	0.3401	4.97	2.44	4	Not Sig.

Table 3: Relationship between Dependent Variable (identified by model) and ln-transformed Summer-run Abundance.

Year	Dependent Var. (Y)	Slope	Int.	R^2	F	Deg F.	Significance
	Individual ITQ Sets, as Identified….						
2014	ln-Summer-run A-12-3 FRITQ Catch-by-Set	-1.1682	20.33	0.3033	0.63	11	Not Sig.
2014	ln-Summer-run A-12-3 JOTITQ Catch-by-Set	-0.2703	8.35	0.3640	2.18	5	Not Sig.
2014	ln-Summer-run Upper A-13 FRITQ Catch-by-Set	0.7090	-2.01	0.0336	0.24	7	Not Sig.
2014	ln-Summer-run Lower A-13 FRITQ Catch-by-Set	0.1969	4.36	0.0110	0.04	4	Not Sig.
2014	ln-Summer-run A-12-3 Seine Test Fishing C/Set	0.9653	-4.50	0.4823	40.06	43	Significant
2014	" " " " " ITQ Period	0.4567	1.69	0.0121	0.29	24	Not Sig.
2014	ln-Summer-run A-13 Seine Test Fishing C/Set	0.9428	-4.32	0.3112	18.52	41	Significant
2014	" " " " " ITQ Period	1.7955	-14.42	0.1789	5.23	24	Significant

2. **Analysis of complete log-book information for Area B ITQ Sockeye C/Set, Areas 12-13 available post-season for 2014.**

In May 2016 the analyses of the FRITQ and JOTITQ information were presented to the Fraser River Panel, at which time a request was made to report on analyses of the complete logbook information (LBITQ), extending the initial scope of the project. These data were subsequently provided by DFO from the Fishery Operations System (FOS) (Table 1). Data were summarized by sub-area and day and analysed using linear least squares regression analysis on the ln-transformed data and the following time-series were analysed:

- The relationships between ITQ CPUE data and test fishing CPUE data for Area 12-3 and Area 13 (Table 4).
- The relationship between ITQ CPUE data and the daily reconstructed summer-run abundance entering lower Area 13, Upper Area 13 and Area 12-3loglog (Table 5).

All of the relationships between ln-transformed LBITQ C/Set indices and ln-transformed purse seine test fishing C/Set data (Areas 12 and 13) were significant (Table 4). Sample sizes for comparison were larger for the LBITQ data than for the data that were reported voluntarily in-season in 2014 (FRITQ) or the data obtained from observers (JOTITQ).

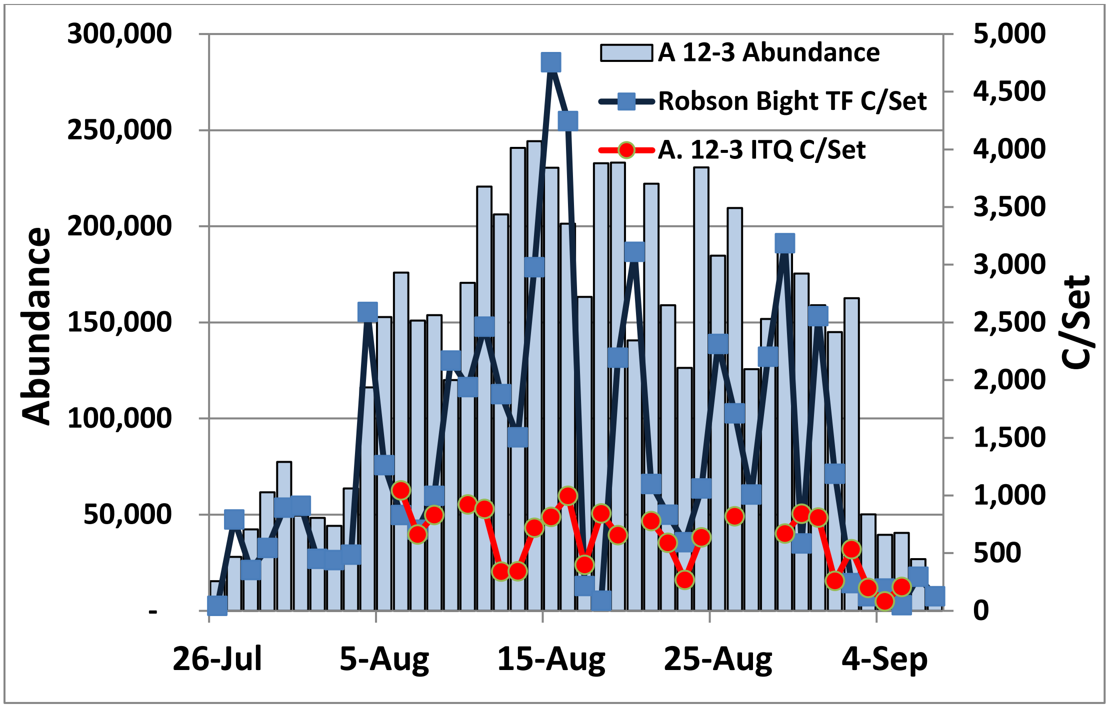
Time series plots of Summer-run abundance and Summer-run indices of LBITQ C/Set by day demonstrate the intra-annual variation in correspondence between these two measures (Figures 5-6). The relationships between ln-transformed ITQ C/Set indices and ln-transformed daily Summer-run abundance were significant (Table 5).

In contrast to the analyses of the FRITQ and JOTITQ information, there was a significant relationship between ln-transformed Summer-run LBITQ C/Set and log-transformed Summer-run abundance in for Area 12-3 and Area 13 below and above Chatham Point (Table 5, Figure 7). The relationship between ln-transformed Summer-run C/Set from the purse seine test fisheries and ln-transformed Summer-run abundance for both Area 12 and 13 were also significant and are shown in comparison with the LBITQ information (Table 5, Figure 7). The relationship between C/Set and abundance appears to be more precise for the LBITQ than for the test fishery with a tighter distribution of observations. However the condition of independence of the covariate from the dependent variable is not completely met with the LBITQ data, as the ITQ catches are also included in the abundance. In 2014, the ITQ catches represented 14%, 10% and 5% of the reconstructed Summer-run abundance in Area 12-3, Upper Area 13 and Lower Area 13 respectively. This will result in a positive bias or optimistic fit of the regression. By comparison, this conditional independence is completely met in the C/Set data in purse seine test fishery.

Analysis of covariance (ANCOVA) was used to test for a significant main effect of "origin of C/Set" (i.e. are the LBITQ and test fishery C/Set information different) on the response of ln-transformed C/Set on ln-transformed Abundance for Area 12-3. The test for homogeneity of slopes was rejected, indicating that the regression slopes are similar, given the data. The ANCOVA results were significant ($F=10.5$, $p<0.05$), indicating a significant main effect of origin of the C/Set data, with the purse seine test fishing C/Set data being greater for large abundance. This indicates that the LBITQ C/Set data are not interchangeable with test fishing indices of abundance.

Analysis of covariance (ANCOVA) was used to test for a significant main effect of "origin of C/Set" on the response of ln-transformed C/Set on ln-transformed Abundance for lower Area 13. The test for homogeneity of slopes was rejected, indicating that the regression slopes are similar, given the data. The ANCOVA results were not significant ($F=0.1$, $p>>0.05$), indicating no differences in the response of C/Set data, with abundance. This is intuitive, given the observations and regression lines shown in Figure 7b are virtually overlapped.

When compared with either the FRITQ or the JOTITQ information the increased number of sets and days of observation with the LBITQ data set demonstrate greater precision in CPUE data. As a consequence, the log-book observations appear to be more representative of both the overall catch and the abundance on any given day. In addition, the relationships between the LBITQ C/Set and abundance are more precise, although the condition of independence between the covariate and dependent variable is not completely met. These results support a recommendation that all Area B licensed vessels fishing in Areas 12-13 for either Fraser River sockeye or pink salmon report the complete log-book data, including locations (latitude and longitude from on-board GPS) by the end of the fishing day and this be instituted for 2017. This is a relaxed version of the recommendation made at the Fraser Panel meeting (May 2016) that required catch-by-set information.



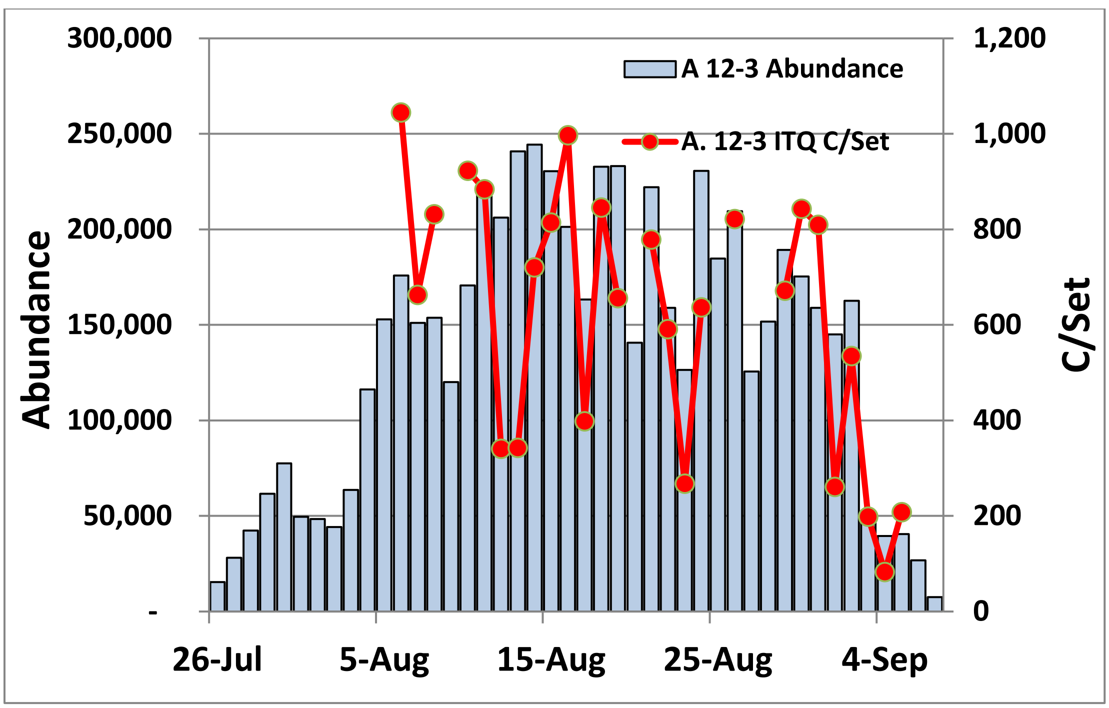
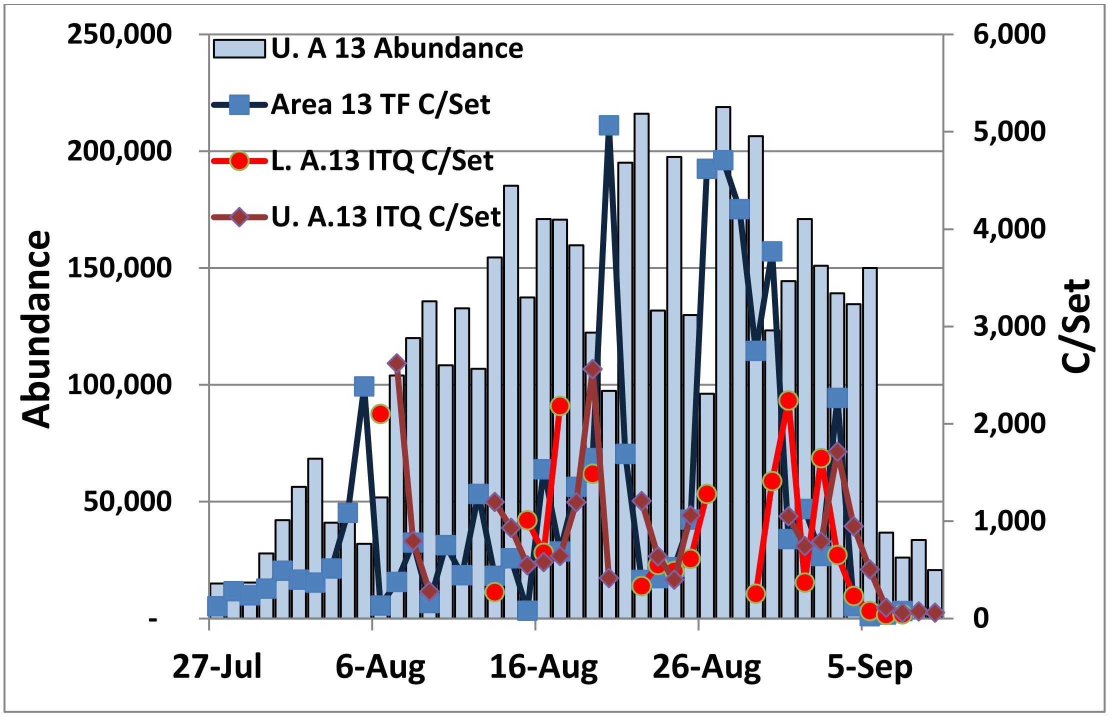


Figure 5A (top): Time series plots of reconstructed Summer-run abundance in Area 12-3 and C/Set in the Area 12-3 test fishery and C/Set from the Area 12-3 LBITQ fishery. Figure 5B (bottom): same plot with the test fishery data removed allowing for a re-scaling of the LBITQ C/Set.



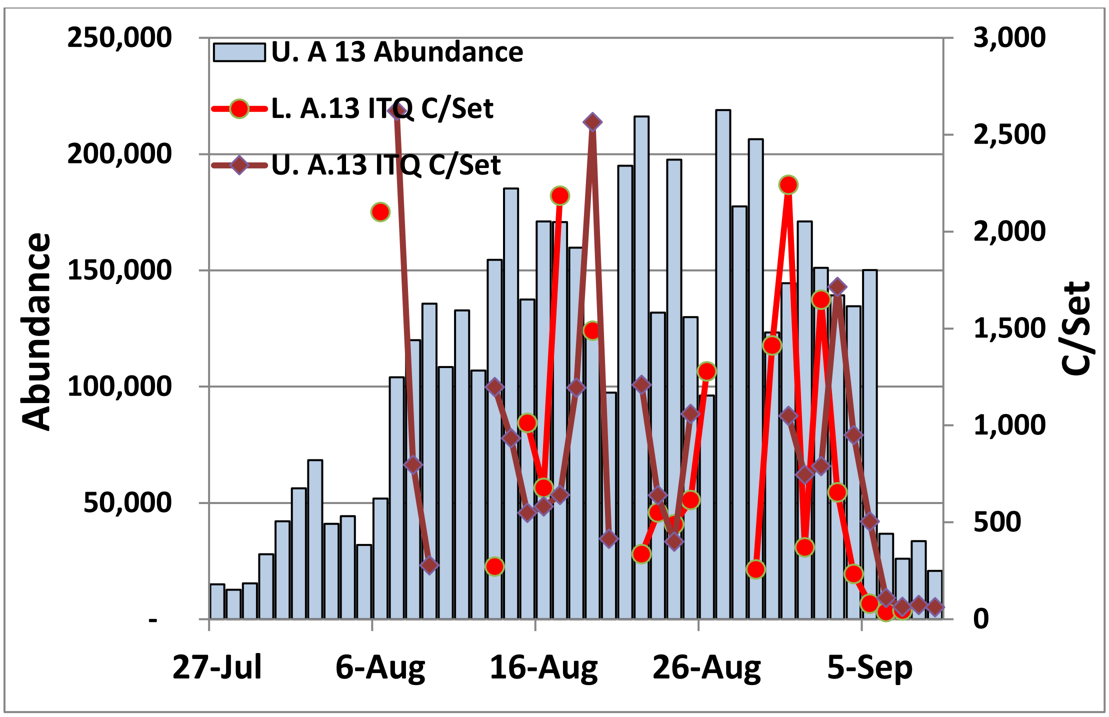
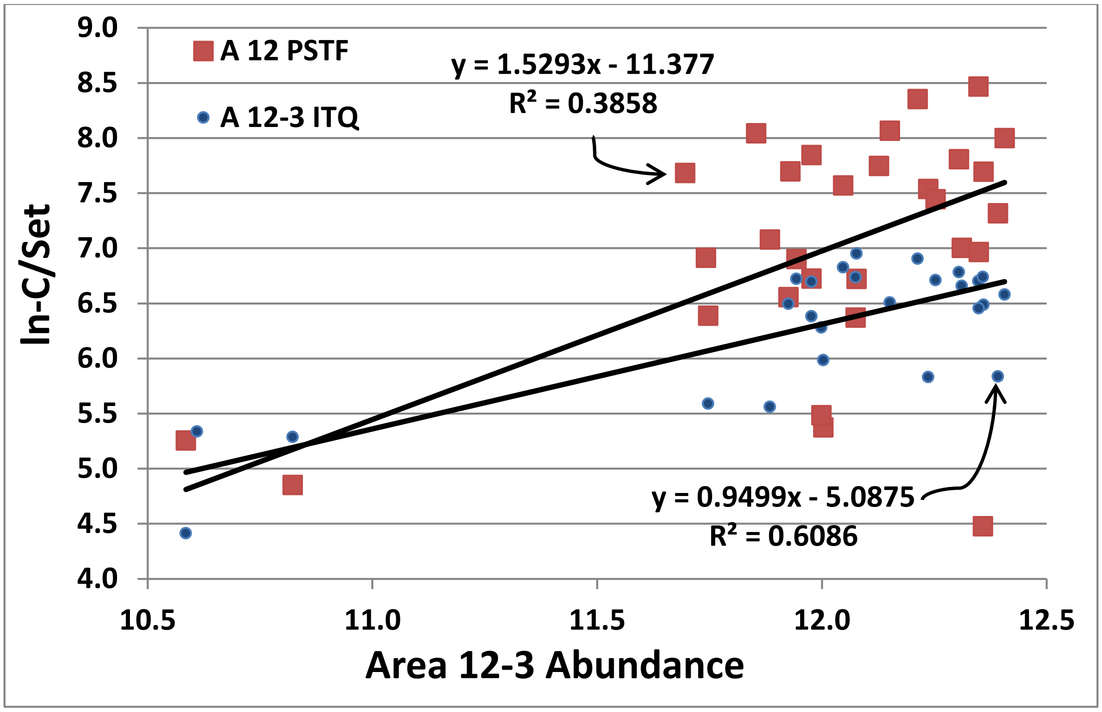


Figure 6A (top): Time series plots of reconstructed Summer-run abundance in Area 13 and C/Set in the Area 13 test fishery and C/Set from the Area 13 LBITQ fishery. Upper (U) is above Chatham Point (Lower Johnstone Strait) and Lower (L) is below Chatham Point (Discovery Passage). Figure 6B (bottom): same plot with the test fishery data removed allowing for a re-scaling of the LBITQ C/Set.



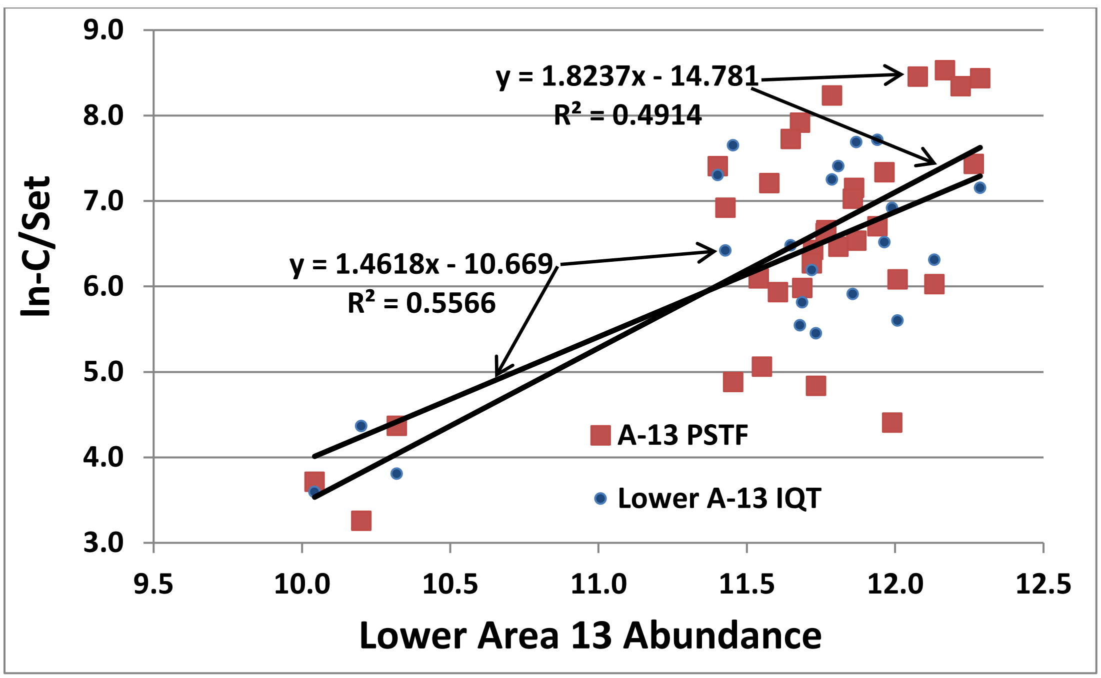


Figure 7a (top): Relationship between ln-Summer-run C/Set (LBITQ and Purse Seine Test Fisheries for Area 12-3) and ln-Summer-run abundance in Area 12-3. Figure 7b (bottom): Relationship between ln-Summer-run C/Set (LBITQ and Purse Seine Test Fisheries for Area 13 below Chatham Point) and ln-Summer-run abundance in Area 13 below Chatham Point. Note that the line for the ITQ fishery has lower values at the upper end of the reconstructed abundance on the graph.

Table 4: Relationship between Dependent Variable (identified by model) and ln-transformed Test Fishing Catch/Set

Year	Test Fishing Area	Dependent Var. (Y) Catch per set...	R^2	Slope	Int.	F	Deg F.	Significance
Complete logbook data by day, as Identified….								
2014	Area 12	ln-A-12-3 LBITQ Catch/Set	0.2487	0.2418	5.36	7.94	24	Significant
2014	Area 13	ln-Upper A-13 LBITQ Catch/Set	0.3542	0.3740	4.77	12.06	22	Significant
2014	Area 13	ln-Lower A-13 LBITQ Catch/Set	0.2815	0.4002	4.31	7.44	19	Significant

Table 5: Relationship between Dependent Variable (identified by model) and ln-transformed Summer-run Abundance.

Year	Dependent Var. (Y)	Slope	Int.	R^2	F	Deg F.	Significance
	Complete logbook data by day, as Identified….						
2014	ln-Summer-run A-12-3 LBITQ C/Set	0.9499	-5.09	0.6086	37.32	24	Significant
2014	ln-Summer-run Upper A-13 LBITQ C/Set	1.3251	-9.06	0.6522	43.12	23	Significant
2014	ln-Summer-run Lower A-13 LBITQ C/Set	1.4618	-10.67	0.5566	23.85	19	Significant
2014	ln-Summer-run A-12-3 Seine Test Fishing C/Set	0.9653	-4.50	0.4823	40.06	43	Significant
2014	" " " " " ITQ Period	1.5293	-11.38	0.3858	18.22	29	Significant
2014	ln-Summer-run A-13 Seine Test Fishing C/Set	0.9428	-4.32	0.3112	18.52	41	Significant
2014	" " " " " ITQ Period	1.8237	-14.78	0.4914	29.95	31	Significant

3. Analysis of complete log-book information for Area B ITQ Catch/Set, Areas 12-13 available post-season for 2010.

The data were provided by DFO from the Fishery Operations System (FOS) (Table 1) and were summarized by sub-area and day. The relationships between LBITQ C/Set and test fishing C/Set were examined for Area 12-3 and Area 13. Least squares regressions were computed on ln-transformed Area 12-3 ITQ catch/set (dependent variable) and ln-transformed Area 12 purse seine test fishing catch/set. The daily reconstructed summer-run abundance entering lower Area 13, Upper Area 13 and Area 12-3 were estimated and the ln-transformed estimates were used as the dependent variable in least squares regressions with ln-transformed C/set indices.

The relationship between ln-transformed LBITQ C/Set indices and ln-transformed purse seine test fishing C/Set data for was significant for Area 12 but not for either of the comparisons for Area 13 (Table 6).

Time series plots of Summer-run abundance and Summer-run indices of C/Set by day demonstrate the intra-annual variation in correspondence between these two measures (Figures 8-9). The LBITQ C/Set for Area 12 matches the first peak of Summer-run abundance but does not match the second peak (Figure 8). This could be due to error in the reconstructions due to some sort of "violation of the order of movement assumption" or to availability issues due to fine-scale temporal or spatial distribution of the fish. Also the Summer-run stock identification proportions that were applied to the C/Set data may also be biased low. There is evidence that this second peak is matched somewhat by the test fishery (Figure 8A) and also in Area 13 (Figure 9).

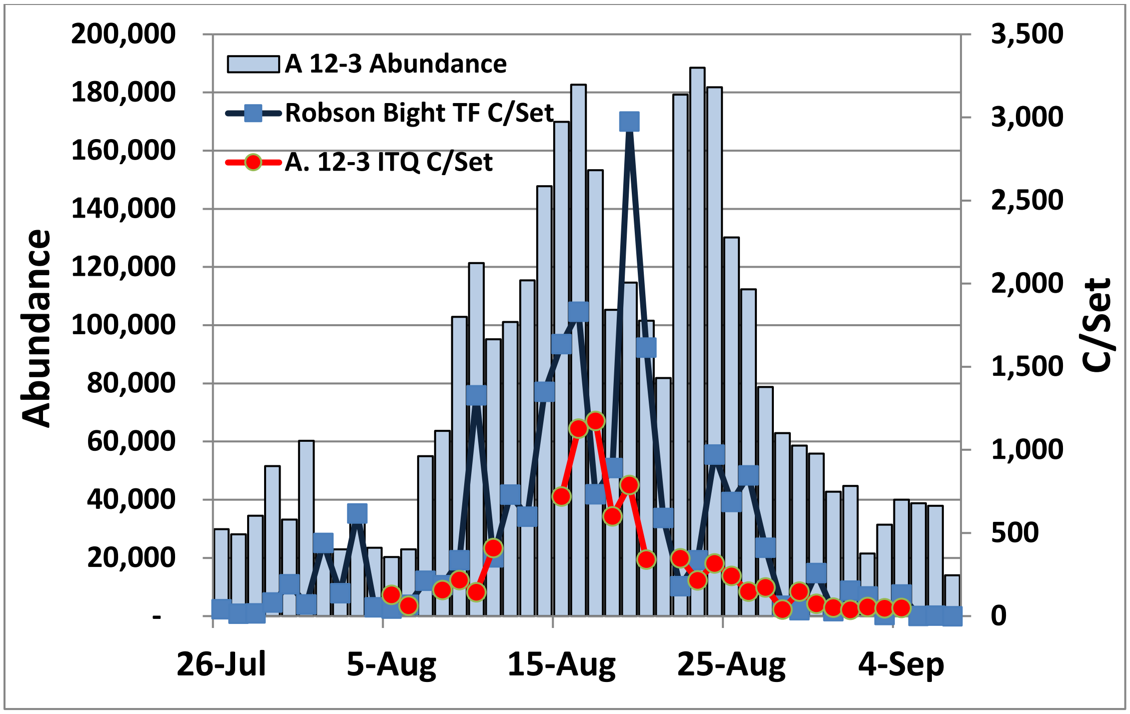
There was a significant relationship between ln-transformed Summer-run LBITQ C/Set for Area 12-3 and ln-transformed Summer-run abundance in Area 12-3 (Table 8, Figure 10a). The relationship between ln-Summer-run LBITQ C/Set Area 13 below Chatham Point and ln-Summer-run abundance in Area 13 below Chatham Point was also significant (Table 8, Figure 10b) as was the relationship between ln-Summer-run LBITQ C/Set Area 13 above Chatham Point and ln-Summer-run abundance in Area 13 above Chatham Point (Table 8). The relationships between ln-transformed Summer-run C/Set from the purse seine test fisheries and ln-transformed Summer-run abundance for both Area 12 and 13 were also significant and are shown in comparison with the complete logbook information (Table 8, Figure 10 a&b). The relationship between LBITQ C/Set and abundance for Area 12 appears to have approximately the same precision as the test fishery. Again, as was the case for 2014, the condition of independence of the covariate from the dependent variable is not completely met with the ITQ data as the ITQ catches are also included in the abundance. The ITQ catches represent 9%, 6% and 3% of the reconstructed Summer-run abundance in Area 12-3, Upper Area 13 and Lower Area 13 respectively. As was the case for 2014 this contributes to positive bias or optimistic fit of the regression. The condition of independence is completely met in the C/Set data in purse seine test fishery with respect to abundance.

Analysis of covariance (ANCOVA) was used to test for a significant main effect of “origin of C/Set” on the response of ln-transformed C/Set on ln-transformed Abundance for Area 12-3. The test for homogeneity of slopes was rejected, indicating that the regression slopes are similar, given the data. The ANCOVA results were just significant ($F=5.26$, $p<0.05$), indicating a significant main effect of origin of the C/Set data, with the purse seine test fishing C/Set data being greater for large abundance. This result could change with increased sample size.

Analysis of covariance (ANCOVA) was used to test for a significant main effect of “origin of C/Set” on the response of ln-transformed C/Set on ln-transformed Abundance for lower Area 13. The test for homogeneity of slopes was rejected, indicating that the regression slopes were similar, given the data. The ANCOVA results were not significant ($F=0.7$, $p>>0.05$), indicating no differences in the response of C/Set data, with abundance. This is intuitive, given the observations and regression lines shown in Figure 10 are virtually overlapped.

Analysis of covariance (ANCOVA) was used to test for a significant main effect of “year” on the response of ln-transformed LBITQ C/Set on ln-transformed Abundance, years 2014 and 2010, separately by area for Area 12-3, upper Area 13 and lower Area 13. The ANCOVA results were not significant for Area 12-3 and lower Area 13, indicating no significant differences between years. However The ANCOVA results were significant for Upper Area 13 ($F=5.45$, $p<0.05$), indicating significant between years. Inter-annual differences are frequently present for test fishing catchability so this result is not surprising.

The relationships between the LBITQ C/Set and abundance were found to be significant for all ITQ relationships and abundance although the condition of independence between the covariate and dependent variable is not completely met. As for 2014, the results support a modified recommendation that all Area B licensed vessels fishing in Area 12 for either Fraser River sockeye or pink salmon report the complete log-book data, including locations (latitude and longitude from on-board GPS) by the end of the fishing day and this be instituted by 2017.



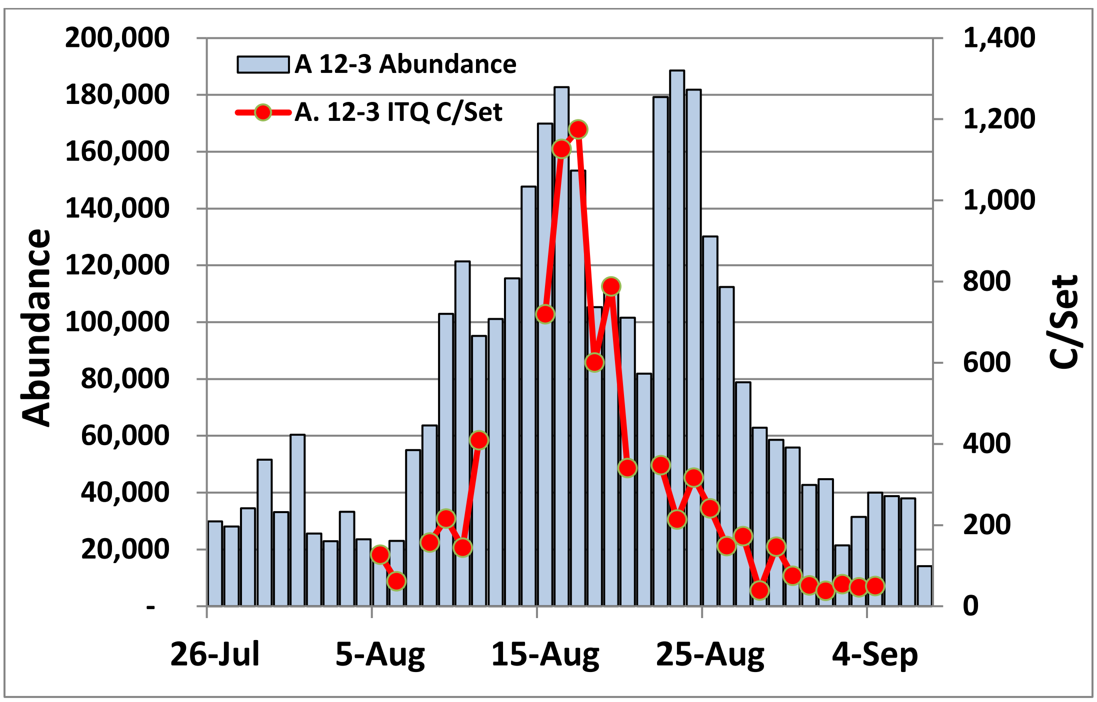
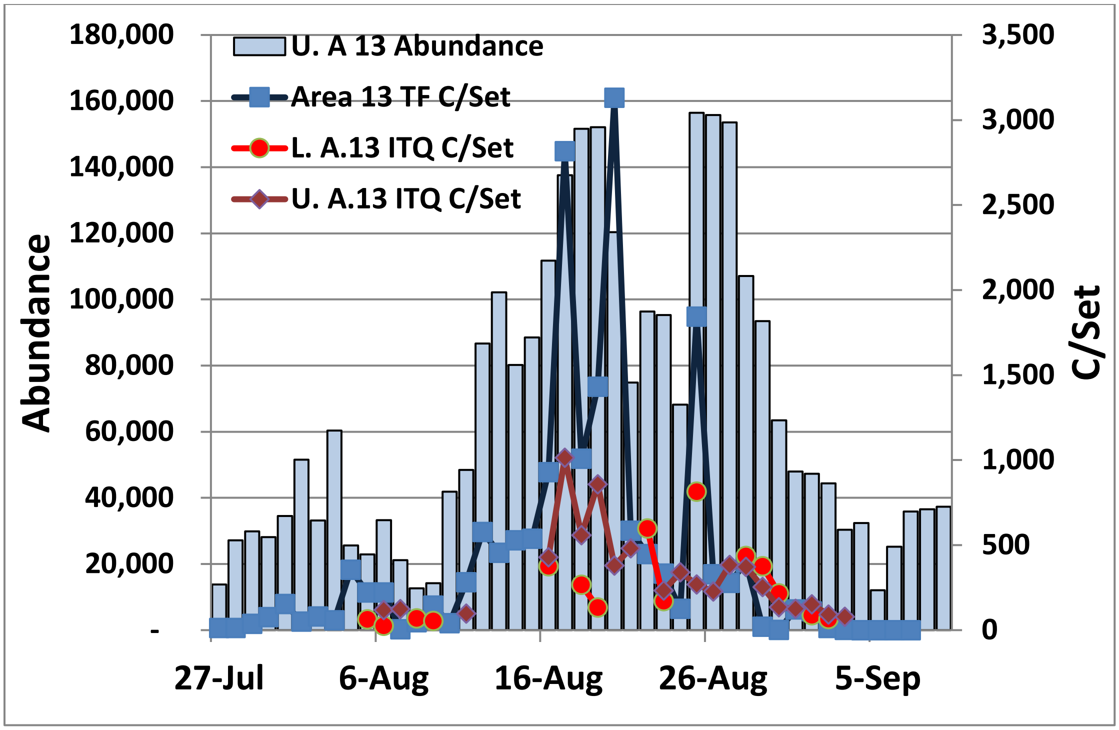


Figure 8A (top): Time series plots of reconstructed Summer-run abundance for 2010 in Area 12-3 and C/Set in the Area 12-3 test fishery and LBITQ C/Set from the Area 12-3 ITQ fishery. Figure 8B (bottom): same plot with the test fishery data removed allowing for a re-scaling of the LBITQ C/Set.



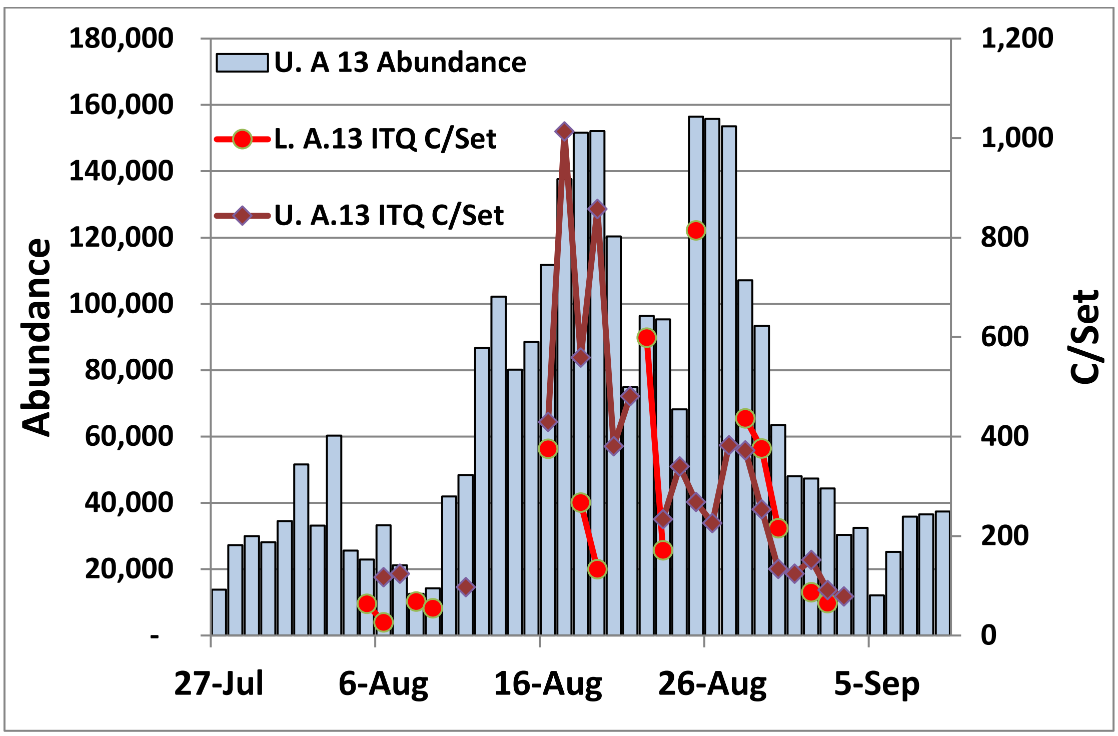
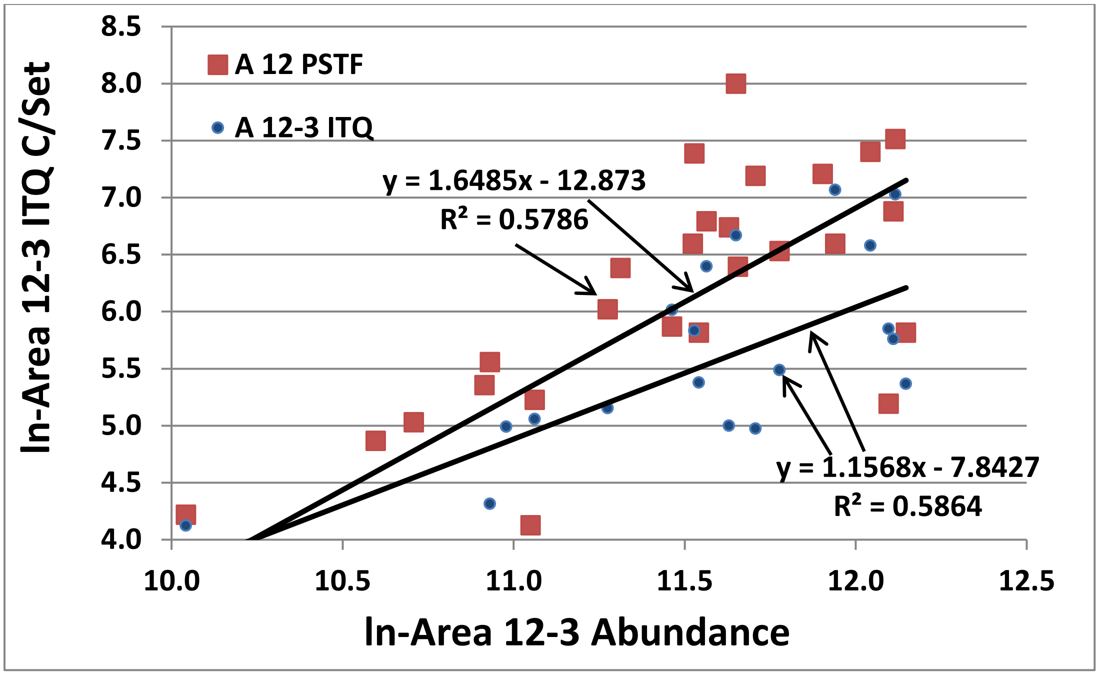


Figure 9A (top): Time series plots of reconstructed Summer-run abundance for 2010 in Area 13 and C/Set in the Area 13 test fishery and C/Set from the Area 13 LBITQ fishery. Upper (U) is above Chatham Point (Lower Johnstone Strait) and Lower (L) is below Chatham Point (Discovery Passage). Figure 9B (bottom): same plot with the test fishery data removed allowing for a re-scaling of the LBITQ C/Set.



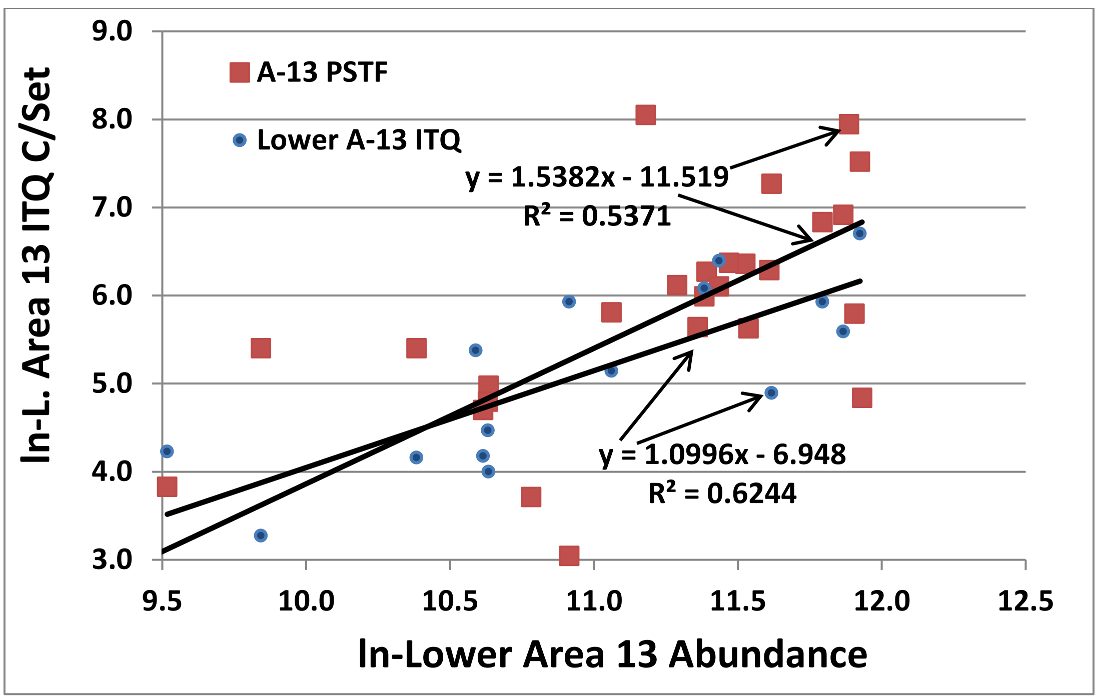


Figure 10a (top): Relationship between ln-Summer-run C/Set (LBITQ and Purse Seine Test Fisheries for Area 12-3) and ln-Summer-run abundance in Area 12-3 for 2010. Figure 10b (bottom): Relationship between ln-Summer-run C/Set (LBITQ and Purse Seine Test Fisheries for Area 13 below Chatham Point) and ln-Summer-run abundance in Area 13 below Chatham Point for 2010.

Table 6: 2010 Relationship between Dependent Variable (identified by model) and ln-transformed Test Fishing Catch/Set

Year	Test Fishing Area	Dependent Var. (Y) Catch per set...	R^2	Slope	Int.	F	Deg F.	Significance
Complete logbook data by day, as Identified….								
2010	Area 12	ln-A-12-3 LBITQ Catch/Set	0.6075	0.4556	3.88	32.50	21	Significant
2010	Area 13	ln-Upper A-13 LBITQ Catch/Set	0.0599	0.1069	6.93	1.21	19	Not Sig.
2010	Area 13	ln-Lower A-13 LBITQ Catch/Set	0.0171	0.1208	6.28	0.23	13	Not Sig.

Table 7: 2010 Relationship between Dependent Variable (identified by model) and ln-transformed Summer-run Abundance.

Year	Dependent Var. (Y)	Slope	Int.	R^2	F	Deg F.	Significance
	Complete logbook data by day, as Identified….						
2010	ln-Summer-run A-12-3 LBITQ C/Set	1.1529	-7.81	0.5867	34.07	24	Significant
2010	ln-Summer-run Upper A-13 LBITQ C/Set	0.9751	-5.46	0.6275	32.00	19	Significant
2010	ln-Summer-run Lower A-13 LBITQ C/Set	1.1321	-7.29	0.6393	23.04	13	Significant
2010	ln-Summer-run A-12-3 Seine Test Fishing C/Set	1.4821	-10.98	0.5337	46.93	41	Significant
2010	" " " " " ITQ Period	1.6708	-13.13	0.5782	39.76	29	Significant
2010	ln-Summer-run A-13 Seine Test Fishing C/Set	1.2558	-8.67	0.3497	18.29	34	Significant
2010	" " " " " ITQ Period	1.2256	-8.28	0.3279	12.69	26	Significant

4. Analysis of Area B ITQ Catch-by-Set Information for Area 20 for 2010

Catch-by-individual-set information reported by fishermen were obtained from the DFO Fishery Operations System (FOS) for 2010 for Area 20. The relationship between ln-transformed Area 20 ITQ C/set and ln-transformed Area 20 purse seine test fishing C/Set was examined for the period August 8-24, which included 228 ITQ sets over 13 days of fishing. The relationship was not significant (F= 0.11, $p<0.05$). Insufficient information is available for a proper evaluation of this ITQ fishery.

5. Analysis of Area B ITQ Pink C/Set Information for Area 12 and 13 for 2011

The relationship between ITQ pink C/Set in Areas 12-13 and abundance is beyond the scope of the current study because of the mixed stock composition in the catches and the uncertainly inherent in reconstructed pink salmon abundance for Fraser River pinks are highly uncertain. However comparisons can be made with the C/Set in the Areas 12 and 13 test fisheries as stock composition in the estimates would be similar in the covariates as they operate in the same locations. The relationship between ln-transformed Area B FRITQ C/Set for Area 12-3 and ln-transformed pink C/Set from the Area 12-3 purse seine test fishery for 2011 was not significant (R2 = 0.00; F = 0.02). There were no fishery openings for pink salmon for Area B ITQ in 2013 or 2015. Currently, there is insufficient justification to substitute ITQ C/Set in Areas 12-13 in run-size models using test fishing C/Set information without more years of observations.

6. Analysis of Area B ITQ Pink C/Set Information for Area 29 for 2011 and 2013

Area B ITQ fisheries for pink salmon in Area 29 first took place in 2011 and in 2013. The relationship between ln-transformed ITQ C/Set in Areas 29 and ln-transformed Mission abundance was examined with 3, 4, 5 and 6 day off-sets in timing to travel times of pink salmon from Area 29 subareas 1-6 to Mission. The independent variable in these analyses was Mission abundance: no attempt was made to reconstruct catches onto the Mission abundance with offsets for timing. Initial analyses focused on data collected by on-the-grounds observers JO Thomas (JOTITQ) from 2011 which were reported to the Fraser River Panel in May, 2016. Follow up analyses were on JOTITQ data for 2013 and LBITQ data for both 2011 and 2013. Unfortunately, there were no Area B Seine ITQ fisheries in Area 29 in 2015 because of the smaller return of Fraser River pink salmon which resulted in no available TAC for Canadian Commercial fisheries.

The best relationship between ln-transformed ITQ C/Set in Areas 29 and ln-Mission abundance for 2011 was for the 5-day timing offset for the JOTITQ (Figure 11; R^2 = 0.8469, F = 60.9) and the LBITQ (Figure 12; R^2 = 0.8308, F = 49.1 for 5-day off-set). Similar relationships for 2013 were more ambiguous and demonstrate poorer fits for the JOTITQ. The best relationship for JOTITQ for 2013 was for the 4-day timing offset R^2 = 0.5840, F = 14.0), however, the LBITQ for 2013 demonstrated that the best relationship was for the 3-day timing (R^2 = 0.7375, F = 22.5). The sensitivity of the correlationS depending on the assumption of travel speeds (for example the LBITQ R^2 = 0.7375 and R^2 = 0.3536 assuming 3 days migration in 2013 and 2011; **or** R^2 = 0.0984 and R^2 = 0.8308 assuming 5 days migration in 2013 and 2011), decreases the value of the data for in-season applications because travel times cannot be known a priori.

Analysis of covariance (ANCOVA) was used to test for a significant main effect of "Year" on the response of ln-transformed Area 29 ITQ C/Set (logbook information) with ln-transformed Mission Abundance at 3, 4 and 5 day timing off-sets, for "Years" 2011 and 2013. For all timing-offsets, the test for homogeneity indicated that the regression slopes are similar, given the data. The ANCOVA results were significant for all timing-offsets (3-day timing-offset: F=23.55, $p<0.05$; 4-day timing-offset: F=36.49, $p<0.05$; 5-day timing-offset: F=28.22, $p<0.05$), indicating a significant main effect of "Year", with the purse seine test fishing C/Set data being greater for all abundances in 2013, implying higher catchability. This result is consistent with other observations of interannual variability in catchability (PSC, 1995). It would therefore be better to estimate year specific in-season catchability estimates to predict pink salmon abundances at Mission than rely on historic catchability estimates.

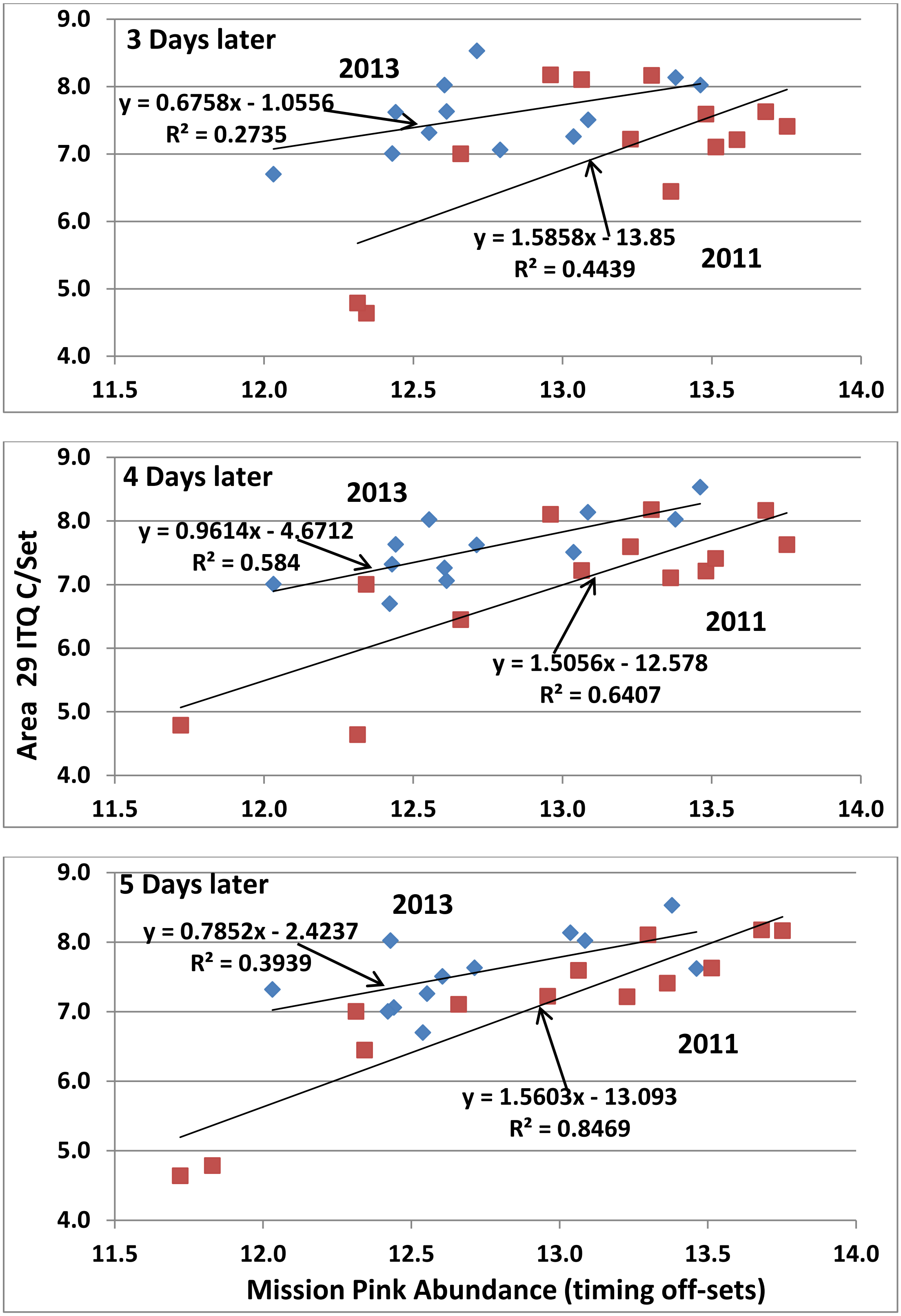


Figure 11. Relationship between ln-transformed JOITQ C/Set in Areas 29 and ln-transformed Mission pink abundance for 2011 and 2013 with 3-5 day timing offsets.

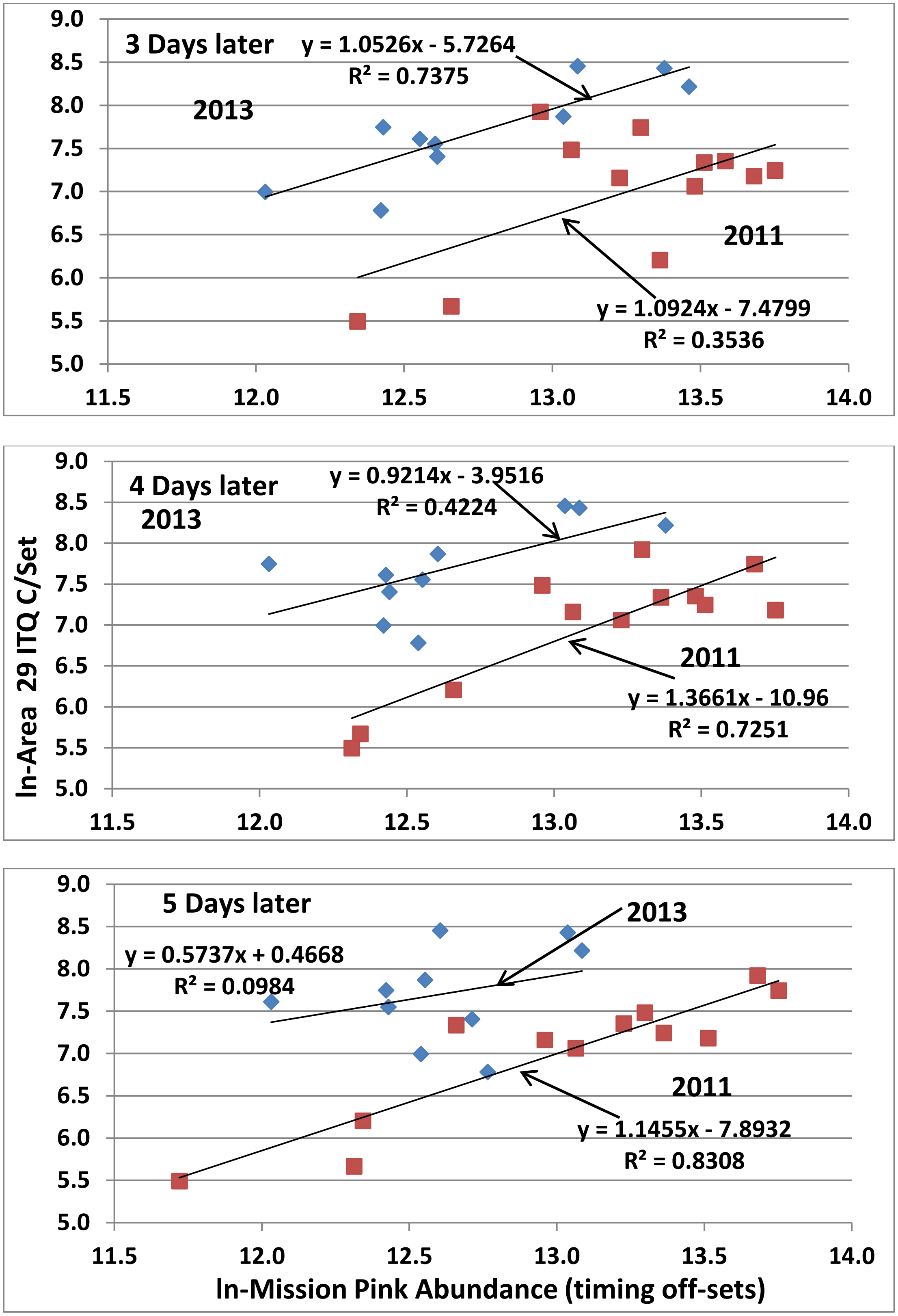


Figure 12. Relationship between ln-transformed LBITQ C/Set in Areas 29 and ln-transformed Mission pink abundance for 2011 and 2013 with 3-5 day timing offsets.

Discussion

The focus of this Southern Endowment Fund project was the analysis of the relationship between existing catch-per-set (C/Set) data from Canadian purse seine ITQ fisheries (Area "B") and sockeye and pink salmon abundance and test fishing indices for the years 2010-2014. Initially this was focused on "Catch-by-individual-set" information reported by fishers (FRITQ) or collected by J.O. Thomas observers (JOTITQ) and available in-season. The work was subsequently extended to include "Log-book records" (LBITQ) reported by fishers in 2010-2014 and available post-season.

"Catch-by-individual-set" information reported by fishers (FRITQ) in 2014 and similar individual set information collected by J.O. Thomas observers (JOTITQ) were examined for relationships with Area 12 and Area 13 test fishing indices and with salmon abundance, estimated to be in the area at time the catches were taken. None of the relationships between these indices and either purse seine test fishing indices or abundance were significant, indicating it would not be prudent to use either the FRITQ or JOTITQ information as surrogates for test fishing data in test fishing based run-size models. In all cases, the sample size (number of sets) was small when rolled up into the individual days for comparison.

"Log-book records" (LBITQ) reported by fishers in 2010 and 2014 were examined for relationships with Area 12 and Area 13 test fishing indices and also Summer-run abundance. All of the relationships between LBITQ C/Set indices and ln-transformed purse seine test fishing C/Set data were significant. Sample sizes were larger when rolled up into the individual days for comparison than commensurate FRITQ and JOTITQ information that was available in-season. The relationships between ITQ C/Set indices and ln-transformed daily summer run abundance were also all significant. The relationship between C/Set and abundance appears to be more precise than for the test fishery with a tighter distribution of observations. A series of ANCOVAs indicated significant differences between ITQ and purse seine test fisheries in the relationship between C/Set and abundance, indicating that the ITQ C/Set data are not interchangeable with test fishing C/set for 2010 and 2014 for Area 12 and a different catchability estimate would need to be used compared to the catchability currently used for test fisheries. However, a similar examination for Area 13 indicated no significant differences in the relationship between C/Set and abundance for the ITQ and test fishery information.

The condition of independence of the covariate from the dependent variable is not completely met with the ITQ data (Years 2014 and 2010), as the ITQ catches are also included in the abundance. The ITQ catches for 2014 represent 14%, 10% and 5% of the reconstructed Summer-run abundance in Area 12-3, Upper Area 13 and Lower Area 13 respectively. For 2010, the ITQ catches represent 9%, 6% and 3% of the reconstructed Summer-run abundance in Area 12-3, Upper Area 13 and Lower Area 13 respectively. This will result in a positive bias or optimistic fit of the regression. By comparison, this condition of independence is completely met in the C/Set data in purse seine test fishery.

Although it was a goal of this project, I was unable to explore evidence for density dependence catchability in the ITQ fishery with the available information as only two years of observations on relatively high abundance were available in Areas 12-13. This was also the case for pink salmon in Area 29. While I explored relationships between Summer-run ITQ C/Set and Summer-run abundance, Late-run stocks and also the presence of local pink salmon stocks contribute to density dependent effects within a fishery. Because of delay of Late-run stocks in the Strait of Georgia, reconstructed estimates of Late-run abundance are more difficult to estimate for Areas 12 and 13 (See for discussion, Pacific Salmon Commission 1995), although they are estimated from Area 12-13 test fisheries, albeit with some considerable uncertainty. Consequently more years of information are required, across difference levels of salmon abundance are required to adequately explore density dependence in the fishery. The use of natural log transforms on abundance and C/Set data do address non-linearity in these relationships, to the extent that the variables are log-normally distributed.

Because of the absence of information, little can be said at this time about the utility of ITQ C/Set data for the Area 20 on either sockeye or pink salmon fishery. Similarly, there is insufficient information to evaluate the ITQ C/Set data for pink salmon in Areas 12-13. In future there should be a focus towards collecting and analysing these data, should there be developments in these fisheries. If this is to be further explored for pink salmon in the migratory areas, stock ID information would be required to scale catch indices.

Significant relationships between ITQ C/Set for Area 29 (1-6) and Mission abundance with 3, 4, 5 and 6 day off-sets in to Mission interesting in their potential for use in run-size updates. The best relationship between ln-transformed ITQ C/Set in Areas 29 and ln-Mission abundance for 2011 was for the 5-day timing offset and for 2013 was for the 3-day timing offset, for both data sources. However, the implied variation in the timing off-sets between years, albeit for only 2 years, is concerning if these relationships are to be considered for management purposes. For example, assuming a 5 day travel time between the entrance to the river and Mission when it is actually 3 days would result in run-size estimates that would be biased “high”, particularly near the peak of the migration upstream. However, it may be useful in understanding the components of the run that delay or alternately migrate directly upstream. Also, it may be indicative of the relative availability of pink salmon to the fishery between years, with a greater C/Set demonstrated for a given abundance in 2013 than in 2011 (Figure 11). These inter-annual differences may be related to the distribution of pink salmon near the “drop-off” of the Fraser River delta, perhaps affected by tides, as well as possible interference by the distribution of commercial crab traps in the area.

At present, data limitations (years of observation) preclude the examination of the possible inclusion of these results into estimation more thorough retrospective analysis. Based on the available information "Catch-by-individual-set" data reported by fishers does not provide sufficient statistical power for use in Run-size models. By comparison, the C/Set information from log-book records may have utility in future run-size models. PSC Staff together with the Fraser River Panel Technical Committee (FRPTC) should continue to evaluate these fisheries in the future for possible integration in run-size models. Such integration is contingent on stability in the ITQ fishery, and in particular that inter and intra-annual variability in catchability and fleet dynamics are minimized.

The special case situation in Area 29 where ITQ seiners have fished on delaying Fraser River sockeye (2010, 2014) was not examined as there were insufficient JOTITQ observations available for 2010. Although LBITQ records later became available, due to time constraints, the data were not analysed but may prove useful to examine in the future. The inability to separate the delaying component from the actively migrating component within the C/Set data would likely cloud any direct relationship with Mission abundance. However these data may yet prove useful as an index of the abundance of Late-run sockeye delaying in the Strait of Georgia.

Do the above outlined results meet the Technical Criteria outlined in the Kowal 2002 Memo? All results summarized in this report are "Given the Data" in other words with the information available to-date. For the ITQ sockeye fishery in Areas 12 and 13, only 2 years of data have been thoroughly evaluated. Conservation concerns resulted in near complete fisheries closure of these fisheries in other years. This severely limits the utility of the ITQ fishery because:

a. Relationships using ITQ C/Set information cannot be established across the complete range of run-sizes.
b. Run-size within the current year cannot be assessed with an ITQ based run-size model unless there is an ITQ fishery.

Therefore the requirement of a "Minimum level of harvest" for run-size estimation is not met on all years.

Is the requirement that "harvest rate be independent of abundance" met? This is tricky and cannot currently be assessed. However, caution is warranted as "Individual Transferable Quotas" are based on run-size estimates. This suggests the possibility of "Management Circularity" in which a management decision could influence the outcome from a run-size model if that decision somehow affects effort or unit vessel fishing power. For example, the vessel master could adjust the intensity of the fishing operation depending on the size of the particular ITQ target for that day of fishing. The possibility of "Management circularity" should be carefully considered if run-size models based on ITQ C/Set are to be considered in the future.

The assessments of the ITQ sockeye fishery in Area 12 and 13 support the following recommendation: **All Area B licensed vessels fishing in Areas 12-13, 20 and 29 for either Fraser River sockeye or pink salmon report the complete log-book data, including locations (latitude and longitude from on-board GPS) by the end of the fishing day and that this be instituted by 2017 and for future years.** Achieving this recommendation is critical if ITQ information is to be utilized in run-size models. This is a relaxed version of the recommendation made at the Fraser Panel meeting (May 2016) that required catch-by-set information. At this time additional information from individual sets does not seem to improve run-size estimates and could meet with resistance from some vessel masters.

In conclusion, I wish to emphasis to the Fraser River Panel, approaches towards using new information in run-size models should be conservative, given the investment in the "years-of-observation" and important analyses as well as the "effect-of-error" of run-size models on fishery management. **The Fraser River Panel should draft policy that ensures future commitment to run-size models and the data required for their successful implementation**.

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