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Does the Queets Exploitation Rate Indicator Stock Represent the Distribution of Fishery Impacts of Washington Coastal Chinook Salmon Stocks in Pacific Salmon Treaty Fisheries?

by

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September 2016

Alaska Department of Fish and Game **Divisions of Sport Fish and Commercial Fisheries**

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Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
milliliter	mL
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
nautical mile	nmi
ounce	oz
pound	lb
quart	qt
yard	yd

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
degrees kelvin	K
hour	h
minute	min
second	s

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity (negative log of)	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

Alaska Administrative Code	AAC
all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.
all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.
at	@
compass directions:	
east	E
north	N
south	S
west	W
copyright	©
corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
District of Columbia	D.C.
et alii (and others)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.
Federal Information Code	FIC
id est (that is)	i.e.
latitude or longitude	lat or long
monetary symbols (U.S.)	$, ¢
months (tables and figures): first three letters	Jan,...,Dec
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S.C.	United States Code
U.S. state	use two-letter abbreviations (e.g., AK, WA)

Mathematics, statistics

all standard mathematical signs, symbols and abbreviations	
alternate hypothesis	H_A
base of natural logarithm	*e*
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	(F, t, χ^2, etc.)
confidence interval	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	*E*
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	$log_{2,}$ etc.
minute (angular)	'
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
variance	
population	Var
sample	var

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ABSTRACT

The Chinook Technical Committee (CTC) of the Pacific Salmon Commission (PSC) uses coded-wire tagged (CWT) hatchery-origin Chinook salmon as surrogates to estimate harvest and exploitation rates exerted on natural spawning populations. The Queets (QUE) exploitation rate indicator stock is used by the CTC to represent four natural-origin fall Chinook salmon stocks along the Washington Coast—Queets, Quillayute, Hoh, and Grays Harbor and to represent the distribution of fishing impacts on the overall Washington Coastal fall stock group. No formal evaluations on whether QUE hatchery-origin fish adequately represent harvests and exploitation rates of natural stocks have occurred. Although there is insufficient information available to test the applicability to represent natural-origin fish, there are other CWT release-groups from hatcheries along Washington Coast to make comparisons. We apply a new method to test representativeness of the QUE exploitation rate indicator stock with data from PSC aggregate abundance based management (AABM) troll fisheries in Southeast Alaska and Northern British Columbia. The methodology is based upon modified tag ratios, which standardize the probability of a fish having a CWT, and modified contributions, which should not expect differences between hatcheries. Five separate brood year and stock combinations were analyzed using a two-way ANOVA; in each analysis we found a significant difference between stocks with p-values <0.001. QUE was always significantly different from the other Washington Coast stocks. The difference of QUE to other stocks was >0 in all analyses, indicating that QUE over-represents fishery impacts in the AABM troll fisheries. Given that hatchery releases from Strait of Juan de Fuca and Willapa Bay regions represent nearly three quarters of the annual Washington Coast hatchery production, the inability of QUE to represent all Washington Coastal fall hatchery production is cause for reevaluation of the assumptions for use of this exploitation indicator stock in estimation of fishery impacts.

Key words Chinook salmon, Washington Coast, Queets, coded-wire tags, exploitation rate, indicator stocks, Pacific Salmon Treaty.

INTRODUCTION

Washington Coastal fall natural stocks tracked by the Chinook Technical Committee (CTC) of the Pacific Salmon Commission (PSC) include Chinook salmon from the Hoko, Quillayute, Hoh, and Queets rivers, and from Grays Harbor. Washington Coast origin Chinook salmon are an important component of Chapter Three of the Pacific Salmon Treaty (PST). These fall stocks are highly migratory with a northerly oceanic distribution, and are therefore significant contributors to several fisheries in the PST area. The Southeast Alaska aggregate abundance based management (AABM), Northern British Columbia AABM, and Washington coastal terminal fisheries are the primary harvest sectors for Washington Coastal fall stocks. The CTC conducts annual analyses using coded-wire tagged (CWT) data to determine stock specific exploitation rates in these fisheries.

Exploitation rate indicator stocks are CWT hatchery release-groups used as proxies to estimate harvest and exploitation rates for neighboring stocks—the *indicator stock* concept. The CTC assumes that exploitation rate indicator stocks experience the same harvest and maturation rates as the stock groups they represent, but more often than not this assumption is not validated. Indicator stocks are used in a cohort analysis, a procedure that reconstructs the cohort size and exploitation history of a given stock and brood year (BY) using CWT release and recovery data (TCCHINOOK (88)-02). The analysis provides stock-specific estimates of BY total, age- and fishery-specific exploitation rates, maturation rates, survival indices, annual distributions of fishery mortalities, and fishery indices. Estimates of age- and fishery-specific exploitation and maturation rates from the cohort analysis are combined with data on catches, escapements, incidental mortalities, and stock enhancement to complete an annual calibration of the PSC Chinook Model. Output from the model and related statistics are used to judge compliance of fisheries under the PST.

Chinook stocks of the Washington Coast originate from four regions—Strait of Juan de Fuca, Northern Washington Coast, Grays Harbor, and Willapa Bay (Table 1, Figure 1). There are numerous hatcheries in the Washington Coast area, multiple CWT hatchery release-groups, and the coverage of hatchery release-groups varies by region (Table 1). Each CWT stock in Table 1 is distinguishable by unique CWTs and clipped adipose fins (CWT+Ad) and has extensive historical tagging and recovery coverage. The CTC primarily uses hatchery release-groups from the Queets (QUE), and to a lesser extent Hoko (HOK) and Tsoo-Yess (SOO), as indicator stocks of the Washington Coast. The rationale behind the use of QUE, HOK, and SOO is predicated on data availability; these three stocks have the longest historical time series of release and catch data (TCCHINOOK 15-(01) V1). The PSC Chinook Model uses QUE as the sole indicator stock to represent both hatchery and natural stocks originating from the Washington Coast.

OBJECTIVES

The Queets exploitation rate indicator stock is used by the CTC to represent four natural-origin Chinook stocks along the Washington Coast and to represent the distribution of fishing impacts on the overall Washington Coastal fall stock group. No formal evaluations on whether tagged Queets hatchery-origin fish adequately represent the harvests and exploitation rates of the natural stocks that they are assumed to represent has occurred. Although insufficient information is available to test whether QUE represents the distribution of natural-origin fish, there are other CWT release-groups from hatcheries along the Washington Coast that can be used to verify whether the Queets exploitation rate indicator stock is sufficiently representative of the other Washington Coastal stocks to be suitable for PST purposes. The objective of this study is to test the representativeness of the QUE exploitation rate indicator stock by comparing the ocean distribution of fishing impacts with other Washington Coastal hatchery releases using data from the PSC AABM troll fisheries in Southeast Alaska and Northern British Columbia.

METHODS

MODIFIED CONTRIBUTION METHOD

The *modified contribution* method can be used to evaluate one or more indicator stocks across brood years, fisheries, and ages; and most importantly can be applied to compare CWT indicator stocks releasing different numbers of fish—as is often the case. The indicator stock assumption, which says that an indicator stock represents the same natural mortality, vulnerability, exploitation rates, and distributions as other stocks it was assumed to represent, is difficult to evaluate because there are rarely multiple indicator stocks from the same region to compare against. Given that there are two or more indicator stocks, the intuitive means to compare them would be compare brood year exploitation patterns, but this approach is limited to only the special case that each indicator stock releases the same number of fish annually (i.e. differences of harvest contributions would then be a function of differential mortality, vulnerability, exploitation rates, or distribution). The *modified contribution* method relaxes the requirement of equal release sizes so that brood year exploitation rates can be freely compared.

The following definitions of CWT hatchery stock, CWT hatchery stock group, *modified tag ratio,* and *modified contribution* are used in this analysis. A CWT hatchery stock is a series of CWT tag code release-groups from a single hatchery. A CWT hatchery stock group is a group of CWT hatchery stocks. Both CWT hatchery stocks and the CWT hatchery stock group were indexed by brood year. The *modified tag ratio*, which standardizes the probability of a fish having a CWT from a single CWT hatchery stock across the CWT hatchery stock group, within a brood year, is the sum of all fish released in a CWT hatchery stock group divided by the number of fish released for each CWT hatchery stock:

$$\theta_{i,by} = \frac{\sum_i R_{i,by}}{R_{i,by}} \qquad \text{(Eq. 1)}$$

where $R_{i,by}$ is the number of salmon released from a CWT hatchery stock *i* in brood year *by*. The *modified tag ratio* has a few notable properties. If the number of CWT hatchery stocks in a CWT hatchery stock group is 1, then the *modified tag ratio* is 1. If all CWT hatchery stocks' release sizes are the same, the *modified tag ratio* is a scalar and can be ignored. Large differences between CWT hatchery stock release sizes yield larger *modified tag ratios*. The estimated *modified contribution* of stock *i* in fishery ***j*** is calculated by normal means as the number of CWTs recovered in fishery stratum *j* multiplied by the *modified tag ratio* and expanded for sampling rates and head and tag loss (Bernard and Clark, 1996):

$$\hat{r}_{i,j} = \frac{m_{i,j} * \theta_j}{\varphi_i \lambda_i} \qquad \text{(Eq. 2)}$$

where $m_{i,j}$ is the number of CWTs recovered from stock *i* in fishery *j*, φ_j is the sampling expansion for fishery j, and λ_j is the expansion for head and tag loss in fishery j. Note that subscript *by* was dropped in Eq. 2 to simplify the equation at no cost to generality. The estimated total *modified contribution* of stock *i* in one or more fisheries *j* is calculated as:

$$\hat{T}_i = \sum_i \hat{r}_{i,j} \qquad \text{(Eq. 3)}$$

where $\widehat{T}_i$ is computed annually for each stock. Each brood is vulnerable to a fishery at one or more ages, so the total *modified contribution* is indexed by age. The estimated brood year total *modified contribution* of stock *i* is the sum harvest across ages vulnerable:

$$\widehat{by}T_i = \sum_a \hat{T}_{i,a} \qquad \text{(Eq. 4)}$$

where age ***a*** ranges from 2 to 8; however, since 99% of fish harvested in the AABM troll fisheries are ages 3 to 6, all other ages are ignored.. The brood year total *modified contribution* is the catch of stock *i* across multiple calendar years.

Recall that the *modified tag ratio* standardizes the probability of a fish having a CWT within a CWT hatchery stock group by weighting each CWT hatchery stock by the number of fish released against the total number of fish released by the entire CWT hatchery stock group. Hence, two CWT hatchery stocks that release the same number of fish would have the same probability of capture and therefore the same *modified tag ratio* and if CWT hatchery stock 1 released more fish than CWT hatchery stock 2, CWT hatchery stock 1 would a higher probability of capture and therefore a smaller *modified tag ratio*. Thus, in both cases from the aforementioned example, we'd expect that the sum *modified contribution* of each CWT hatchery stock would be equal under the null hypothesis that there was no difference, which is equivalent to the indicator stock assumption.

An appropriate model to compare the brood year total *modified contributions* and control for variability between broods is a two-way analysis of variance (ANOVA). The log-linear model is written as:

$$\log(byT_{i,by}) = \mu + \alpha_i + \rho_{by} + e_{i,by} \qquad \text{(Eq. 5)}$$

$$i = 1, 2, ..., n; by = 1, 2 ..., t$$

where μ is the general mean, α_i is the stock effect, ρ_{by} is the brood year effect, and $e_{i,by}$ is the random errors; note $e_{i,by}$~N(0, σ^2). Equation 5 can be used to compare brood year total *modified contributions* of any number of stock and brood years, though the choice of n and t will determine the degrees of freedom available to test hypotheses. No interaction term was included because there was not sufficient number of replicate hatchery release-groups.

There are three hypotheses of interest: 1) differences between stocks, 2) difference between QUE and other stocks, and 3) all pairwise differences between stocks. The latter two hypotheses are *post hoc* tests, and where appropriate, used adjusted p-values (Bretz et al. 2016). The first hypothesis tests for differences among stocks, $H_0: \alpha_1 = \cdots = \alpha_n$ vs $H_a: \alpha_i \neq \alpha_k$. Hypothesis 1 was calculated using the traditional F test in a two-way ANOVA and was computed in R (Experimental design book, R core team, 2016). If the first hypothesis was not significantly different, no further hypotheses were tested. The second hypothesis tests for a difference between QUE and all other stocks, $H_0: C = \alpha_{QUE} - \frac{1}{n}(\alpha_i + \cdots + \alpha_n) = 0$ vs $H_a: C = \alpha_{QUE} - \frac{1}{n}(\alpha_i + \cdots + \alpha_n) \neq 0$, where α_{QUE} was the mean of QUE and $\frac{1}{n}(\alpha_i + \cdots + \alpha_n)$ was the average of the means of the other stocks. If $C = 0$, it indicates that there was no difference between QUE and the average of the other stocks. If $C > 0$, it indicates that QUE on average was exploited at a higher rate than the average of the other stocks and similarly if $C < 0$, it indicates that QUE on average was exploited at a lower rate than the average of the other stocks. The third hypothesis tests for differences between all stocks, $H_0: C = \alpha_i - \alpha_j = 0$ vs $H_a: C = \alpha_i - \alpha_j \neq 0$, for all $i \neq j$, resulting in *n(n-1)/2* comparisons. Conducting statistical tests of all pairwise differences increases the chances of making a Type-I error, so hypothesis three was applied once. The interpretation of C in hypothesis 3 is similar to that of hypothesis 2: $C = 0$ implies no difference between stock *i* and stock *j*, $C > 0$ implies that stock *i* was exploited at a higher rate than stock *j*, and $C < 0$ implies that stock *i* was exploited at a lower rate than stock *j*. Hypotheses 2 and 3 were computed using the multcomp package in R (Hothorn et al. 2008).

The feasibility of the *modified contribution* method was evaluated by comparing hatchery release-groups released at the NOAA research hatchery at Little Port Walter in Alaska and is discussed in Appendix A. A test of robustness of the *modified contribution* method to removal of a highly influential stock (QUE) is presented in Appendix C.

DATA

The eight hatchery stocks used in the analysis are, from north to south: Hoko Falls (HOK), Salmon River (QUE), Makah (SOO), Quinault Lake (QNT), Quinault (QN2), Humptulips (HUM), Naselle (NAS), and Forks Creek (FCH) (Table 1). Values of $R_{i,by}$, $m_{i,j}$, φ_j, and λ_j were retrieved online from the Regional Mark Information System (RMIS) database (http://www.rmpc.org). Data from RMIS were loaded into the CTC's CAS database in order to relate CWT recoveries to the standard fishery definitions used by the CTC. The number of Washington Coast CWT hatchery release-groups varied by stock and brood year (Appendix D). Across brood years, QUE hatchery release-groups were the most consistent, with regular releases since brood year 1985. Hatchery release-groups from SOO, QNT, QN2, and HOK were a little less consistent, with nearly continuous releases since brood year 1985. Hatchery release-groups from FCH, HUM, and NAS were the least consistent. Nearly 90% of the hatchery release-groups were comprised of 100,000 or more fish with an average of 175,000 fish per hatchery release-group. Hatchery release-groups from QNT were the smallest, with four release-groups less than 50,000. The CWT tag codes used in this analysis are available upon request.

Five separate brood year and stock combinations were selected to compare a maximal number of hatchery release-groups, within the constraints of the brood year data available (Table 3). Breaks in the brood year time series were present in most of the analyses; however, the existence of breaks does not prevent application of the *modified contribution* method. Data after brood year 2009 were not considered in this analysis because catch information for these brood years was not complete.

Each brood year and stock combination examined compares a unique set of stocks. *Analysis 1* compared the three CWT indicator stocks from the Washington Coastal stock aggregate that the CTC regularly reports (TCCHINOOK 15-(01) V1). *Analysis 2* compared CWT hatchery stocks across the entire Washington Coast aggregate. *Analysis 3* was the same as *Analysis 1* except that it included a stock from Willapa Bay, FCH. *Analysis 4* was similar to *Analysis 3*, but it included two stocks near QUE – QN2, QNT. *Analysis 5* compared only stocks from North Washington Coast.

RESULTS

Modified tag ratios and brood year total modified contributions were calculated for the five stock and brood year combinations. QUE often had the greatest modified contribution, whereas SOO often had the smallest (Figure 3). Error bars in Figure 3 show the standard error of modified contributions for Analyses 1–5; as expected, analyses with more years of data have smaller standard errors. Although not depicted in Figure 3, stocks with higher modified contributions tended to have greater variability, which was as expected for log-normally distributed data. Scatterplots of the log modified contribution for Analyses 1–5 can be found in Appendix A. Under the null hypothesis, expected values should fall on the 1:1 line in each scatterplot, which provides a visual means to compare pairwise differences between hatchery release-groups. Scatterplots for each analysis highlighted differences among most of the stocks in the analysis. Analyses with more brood years in the comparison— 1, 3, and 5— indicated that QUE had consistently greater modified contributions than other stocks, with the exception of QNT.

Two-way ANOVAs were calculated for the five stock and brood year combinations (Table 4). All analyses were significant, $p < 0.001$. In all of the analyses, the stock effect was significant, $p < 0.001$, indicating that in each analysis at least two stocks were significantly different. The brood year effect was significant in all of the analyses, $p < 0.05$.

Comparisons show that QUE was significantly different from the other stocks in all analyses, $p < 0.05$ (Table 5). The difference of QUE to the average of the other stocks was greater than 0 in all comparisons. Pairwise comparisons of the Northern Washington Coast stocks were significant in 5 of the 6 comparisons, $p < 0.001$ (Table 6). An additional analysis was conducted to determine if the presence of QUE in the analyses was driving the significance of the stock effect; results were robust to the removal of QUE (Appendix C).

DISCUSSION

The analysis clearly indicates that the QUE indicator stock does not share the same ocean distribution of fishing impacts as the other Washington Coastal hatchery releases. Differences in the contributions to fisheries between stocks were significant in all comparisons, indicating that QUE may not represent all stocks along the Washington coast and may not represent stocks in the same geographic area such as Makah (SOO), Quinault Lake (QNT), or Quinault (QN2). QUE consistently over-represented fishery impacts in SEAK and NBC AABM troll fisheries relative to other Washington Coastal stocks it is assumed to represent. Given that hatchery releases from the Strait of Juan de Fuca and Willapa Bay regions combined represent nearly three quarters of the annual Washington Coast hatchery production, the inability of QUE to represent all Washington Coastal fall hatchery production is cause for a serious reevaluation of the assumptions for use of this exploitation indicator stock in estimation of fishery impacts. This apparent bias also has implications for the validity of management objectives of Washington Coast stocks, since many of the production models for these stocks are based on run reconstructions of ocean impacts from QUE recovery data.

These results also bring into question the scientific rigor of current assessments of natural-origin Washington Coast stocks. The validity of QUE (or any of the other hatchery stocks) as a surrogate for natural-origin stocks has never been evaluated to verify that exploitation rate of hatchery-origin indicator stocks adequately represent the harvests and exploitation rates of natural stocks. Although only part of the exploitation history of these stocks, the pattern of AABM fishery contributions differs from other Washington Coast hatchery releases across all analyses conducted herein, raising questions regarding the true exploitation rate and distribution of total mortalities of all natural-origin stocks along the Washington coast.

The use of QUE as the sole Washington Coast exploitation indicator stock by the CTC is problematic and rife with implications for the management and evaluation of fisheries under the Pacific Salmon Treaty (PST). The CTC uses data from recoveries of QUE releases to generate estimates of age- and fishery-specific exploitation and maturation rates from cohort analysis combined with data on catches, escapements, incidental mortalities, and stock enhancement to complete an annual calibration of the PSC Chinook Model. Output from the model and related statistics are used to set harvest limits for AABM fisheries and used to evaluate compliance of all fisheries under the PST. Consequently, all CTC analyses that use QUE as the sole indicator stock of the Washington Coast stock aggregate should be interpreted with caution until the validity of this approach is evaluated.

We recommend that additional hatchery exploitation stocks used to represent distribution and harvest of Washington Coast and Juan de Fuca Chinook stocks be established and that natural-origin CWT indicator stocks be established. This would facilitate tracking of natural-origin fish and allow carefully developed experiments to verify the assumption that hatchery-origin Chinook adequately represent their natural-origin counterparts. An option for further consideration until such time as natural origin Chinook are directly tagged is to use a blended approach to represent this stock group using a combination of all available CWT data.

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TABLES AND FIGURES

Table 1.–Washington Coast hatchery release-groups.

Washington Coast Region	Hatchery	CWT Stock Acronym
Strait of Juan de Fuca	Hoko Falls Hatchery	HOK
Northern Washington Coast	Salmon River Fish Culture Hatchery	QUE
	Makah National Fish Hatchery	SOO
	Quinault Lake Hatchery	QNT
	Quinault National Fish Hatchery	QN2
Grays Harbor	Humptulips Hatchery	HUM
Willapa Bay	Naselle Hatchery	NAS
	Forks Creek Hatchery	FCH

Table 2.–Overall Chinook salmon hatchery and CWT+Ad production from Washington Coast by Region, BY 1999–2014.

	CWT+Ad		All Releases	
Washington Coast Region	Average	SD	Average	SD
Strait of Juan de Fuca	225,040	111,870	3,495,831	1,071,048
Northern Washington Coast	746,674	130,271	3,356,982	834,733
Grays Harbor	99,255	159,473	715,269	270,072
Willapa Bay	301,353	218,168	7,105,935	1,359,107

Table 3.–Description of the stocks and brood year combinations investigated.

Analysis	Stocks	Brood Years
1	QUE, HOK, SOO	1985–1987, 1989–2009
2	QUE, HOK, SOO, QNT, QN2, FCH, HUM, NAS	2003–2006
3	QUE, HOK, SOO, FCH	1985–1987, 1998–1999, 2003–2009
4	QUE, HOK, SOO, QNT, QN2, FCH	2003–2009
5	QUE, SOO, QNT, QN2	1986–1987, 1989–2001, 2003–2009

Table 4.–ANOVA table for *Analyses 1–5*.

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F	Pr > F	
Analysis 1: QUE, HOK, SOO						
Brood year	23	45.338	1.971	2.636	0.003	**
Stock	2	67.263	33.631	44.972	<0.001	***
Error	46	34.400	0.748			
Analysis 2: QUE, HOK, SOO, QNT, QN2, FCH, HUM, NAS						
Brood year	3	12.957	4.319	5.099	0.008	**
Stock	7	57.818	8.260	9.752	<0.001	***
Error	21	17.786	0.847			
Analysis 3: QUE, HOK, SOO, FCH						
Brood year	11	25.983	2.362	2.841	0.010	**
Stock	3	47.969	15.990	19.229	<0.001	***
Error	33	27.441	0.832			
Analysis 4: QUE, HOK, SOO, QNT, QN2, FCH						
Brood year	6	17.100	2.850	3.137	0.017	*
Stock	5	58.178	11.636	12.808	<0.001	***
Error	30	27.255	0.909			
Analysis 5: QUE, SOO, QNT, QN2						
Brood year	21	54.184	2.580	3.913	<0.001	***
Stock	3	89.532	29.844	45.260	<0.001	***
Error	63	41.542	0.659			

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05

Table 5.–Tests of the hypothesis that QUE was not different from the other stocks: $H_0: C_i = 0$ vs $H_a: C_i \neq 0$ where contrast, $C_{,i}$, is defined separately for *Analyses 1–5*.

Analysis	Contrast	Estimate	Standard Error	t	Pr > F	
1	$C_1 = \alpha_{QUE} - \frac{1}{2}(\alpha_{HOK} + \alpha_{SOO})$	1.725	0.216	7.977	<0.001	***
2	$C_2 = \alpha_{QUE} - \frac{1}{7}(\alpha_{HOK} + \alpha_{QNT} + \alpha_{QN2} + \alpha_{SOO} + \alpha_{FCH} + \alpha_{HUM} + \alpha_{NAS})$	1.190	0.492	2.420	0.025	*
3	$C_3 = \alpha_{QUE} - \frac{1}{3}(\alpha_{HOK} + +\alpha_{SOO} + \alpha_{FCH})$	1.657	0.304	5.452	<0.001	***
4	$C_4 = \alpha_{QUE} - \frac{1}{5}(\alpha_{HOK} + \alpha_{QNT} + \alpha_{QN2} + \alpha_{SOO} + \alpha_{FCH})$	1.519	0.395	3.849	<0.001	***
5	$C_5 = \alpha_{QUE} - \frac{1}{3}(\alpha_{QNT} + \alpha_{QN2} + \alpha_{SOO})$	1.087	0.200	5.437	<0.001	***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05

Table 6.–Comparison of mean brood year total modified contributions of all hatchery release-groups from *Analysis 5*.

Contrast	Estimate	Standard Error	t	Pr > F	
QN2 - QUE = 0	-0.974	0.245	-3.980	0.001	**
QNT - QUE = 0	0.115	0.245	0.468	0.966	
SOO - QUE = 0	-2.401	0.245	-9.807	<0.001	***
QNT - QN2 = 0	1.089	0.245	4.448	<0.001	***
SOO - QN2 = 0	-1.427	0.245	-5.827	<0.001	***
SOO - QNT = 0	-2.516	0.245	-10.275	<0.001	***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05

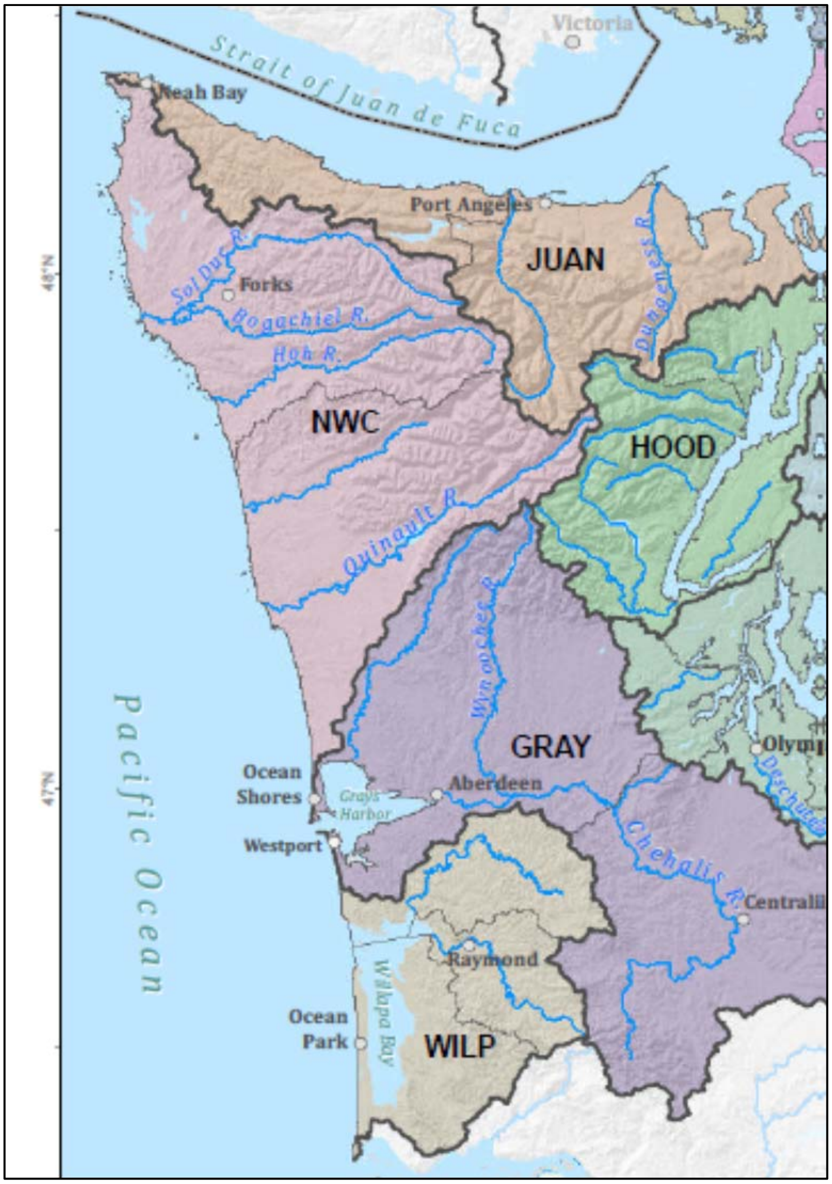


Figure 1.–Map showing Washington Coast regions (source: http://www.rmis.org/files/rmis_maps/RMIS_Atlas_Domain_WA.pdf).

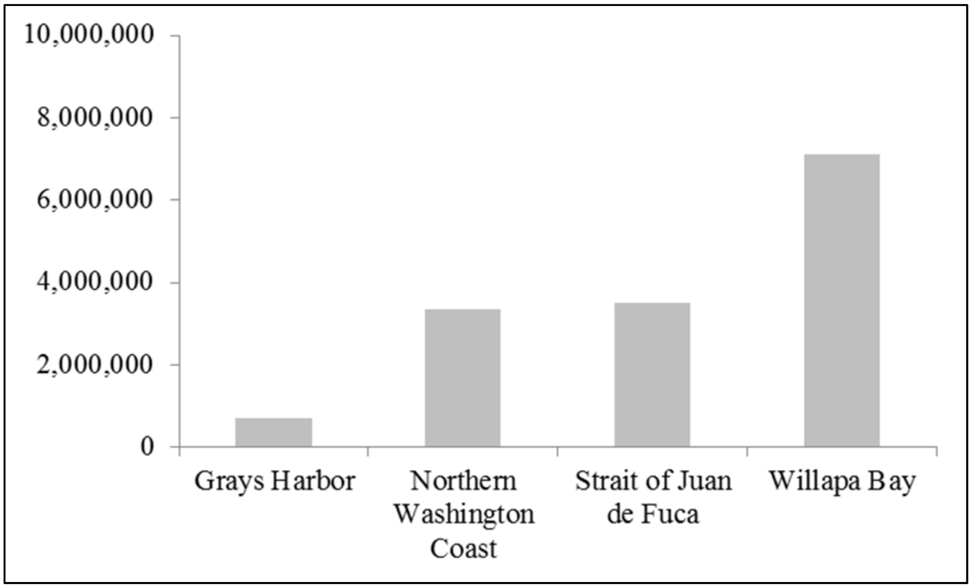


Figure 2.–Average annual hatchery production of Washington Coastal stocks by region, for brood years 1999–2014.

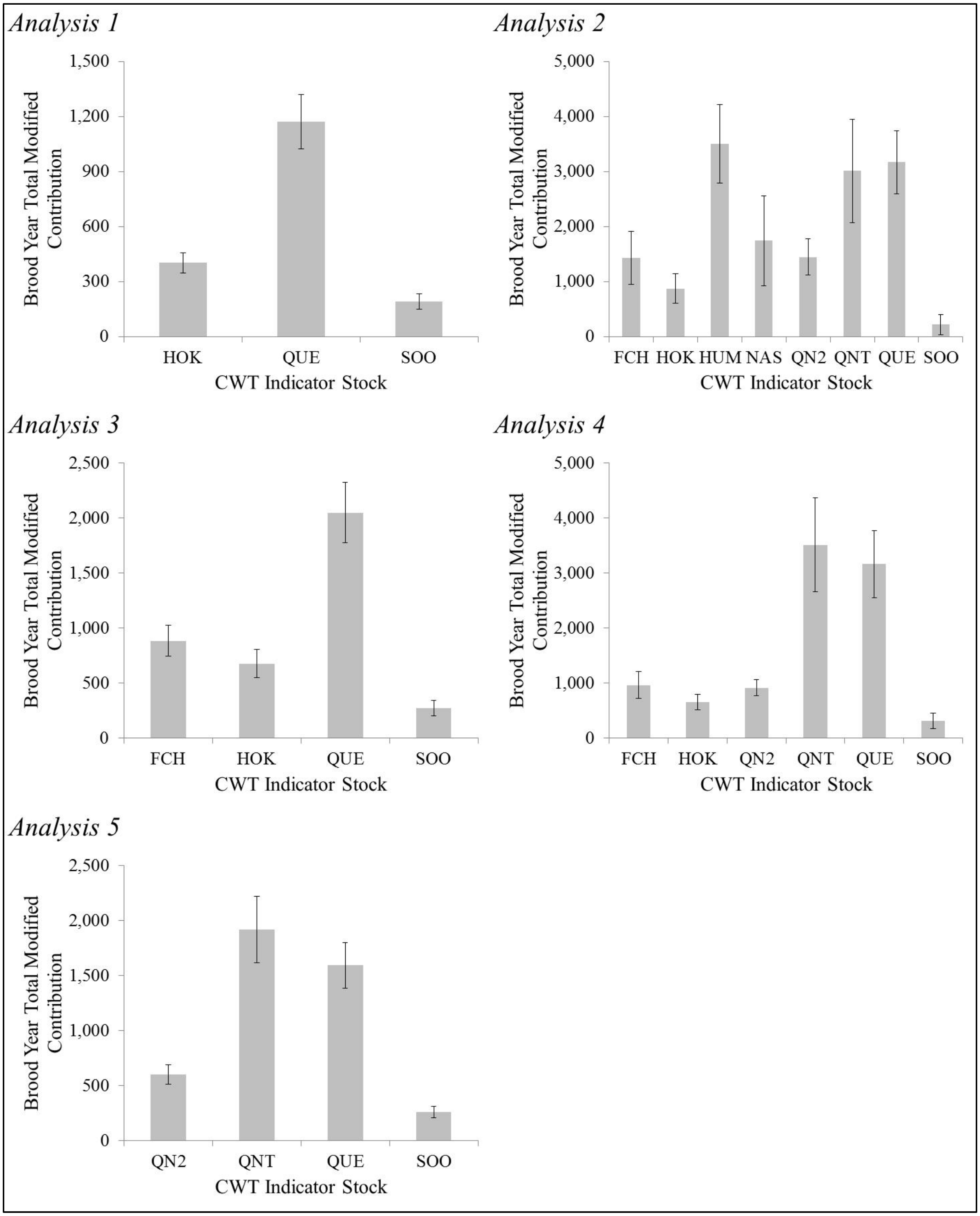
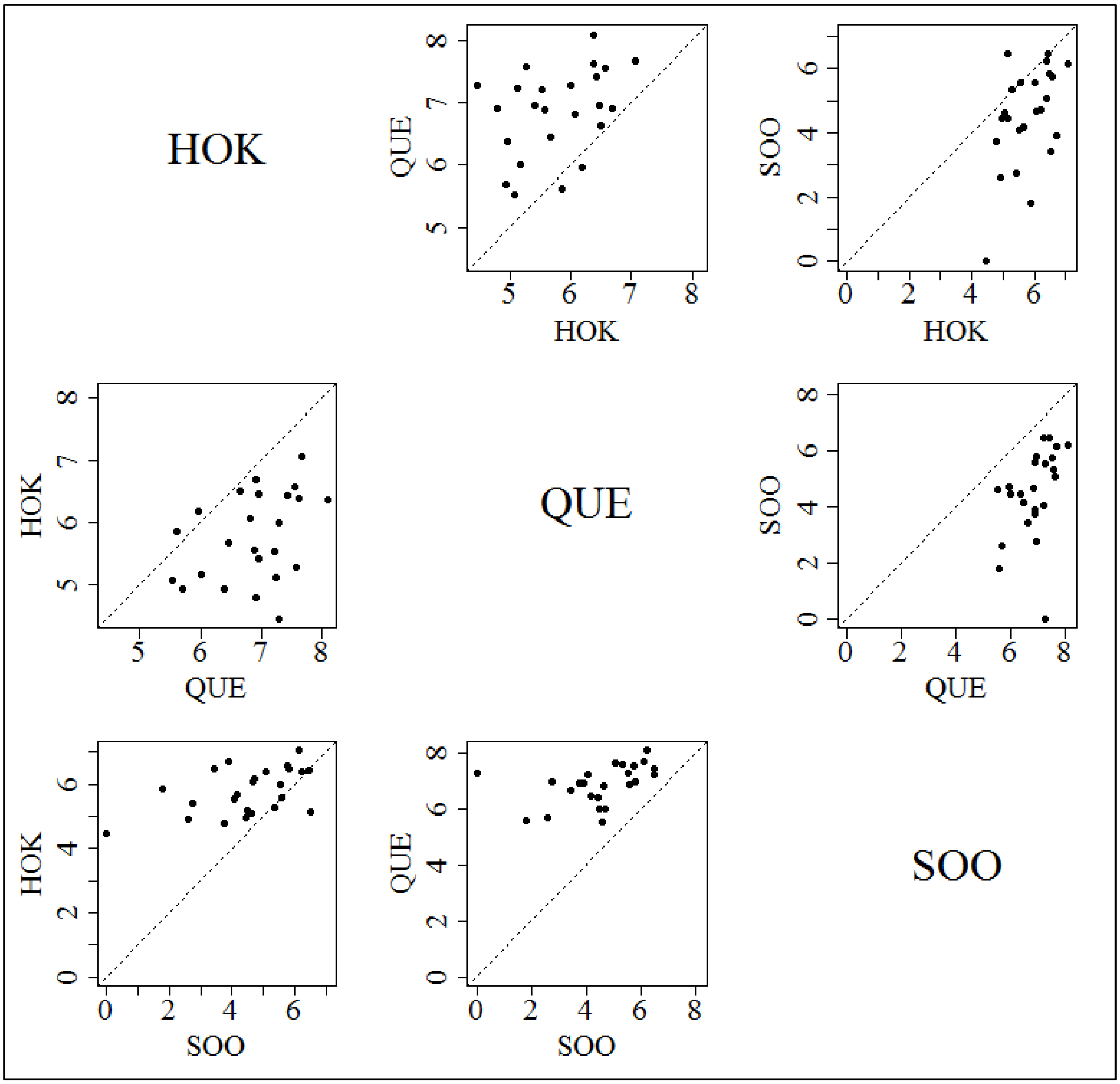


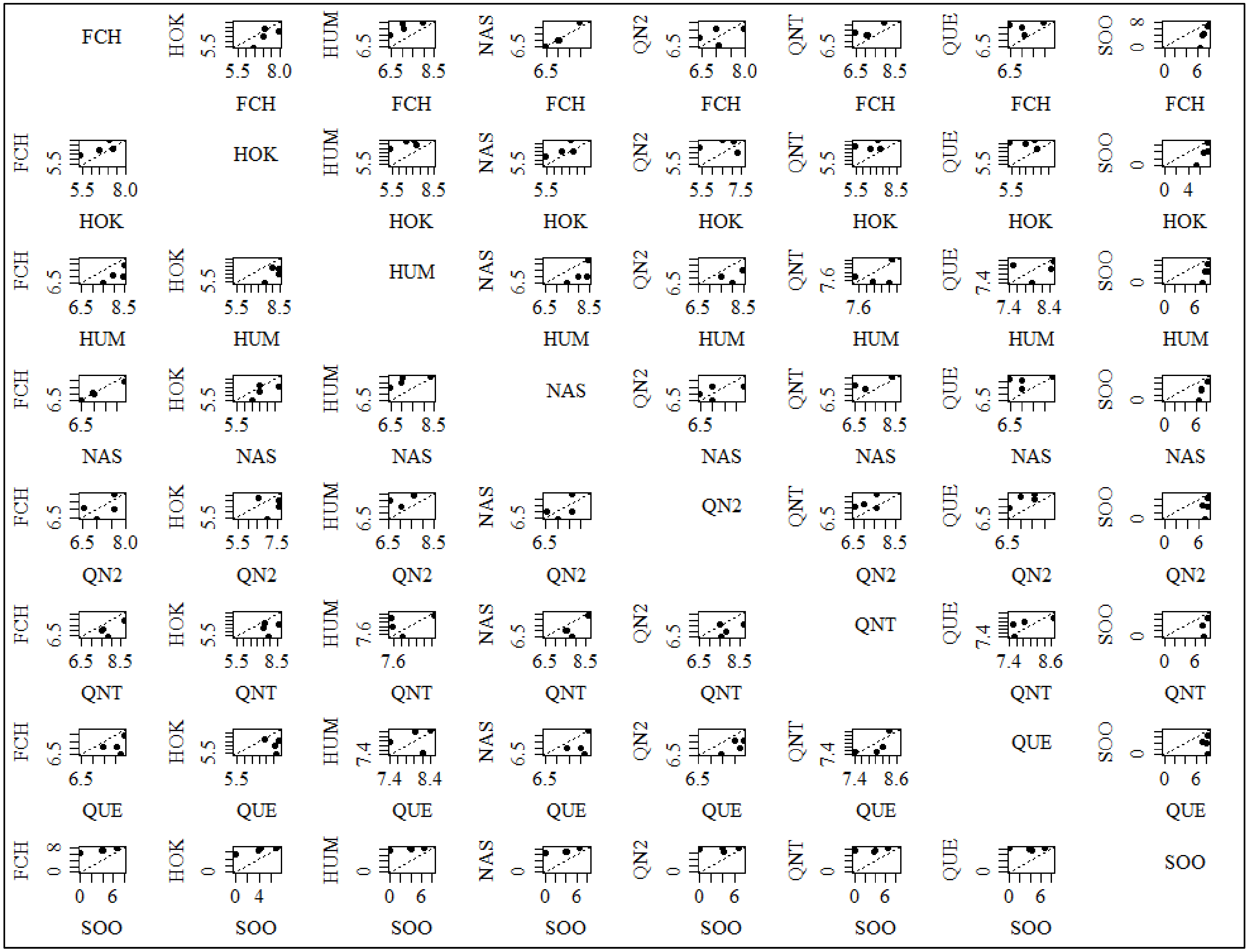
Figure 3.–Average brood year total modified contributions by stock for each of the stock and brood year combinations analyzed. Reported error bars (+/-1 standard error) show the variability between brood years.

APPENDIX A: BROOD YEAR TOTAL MODIFIED CONTRIBUTION SCATTERPLOTS

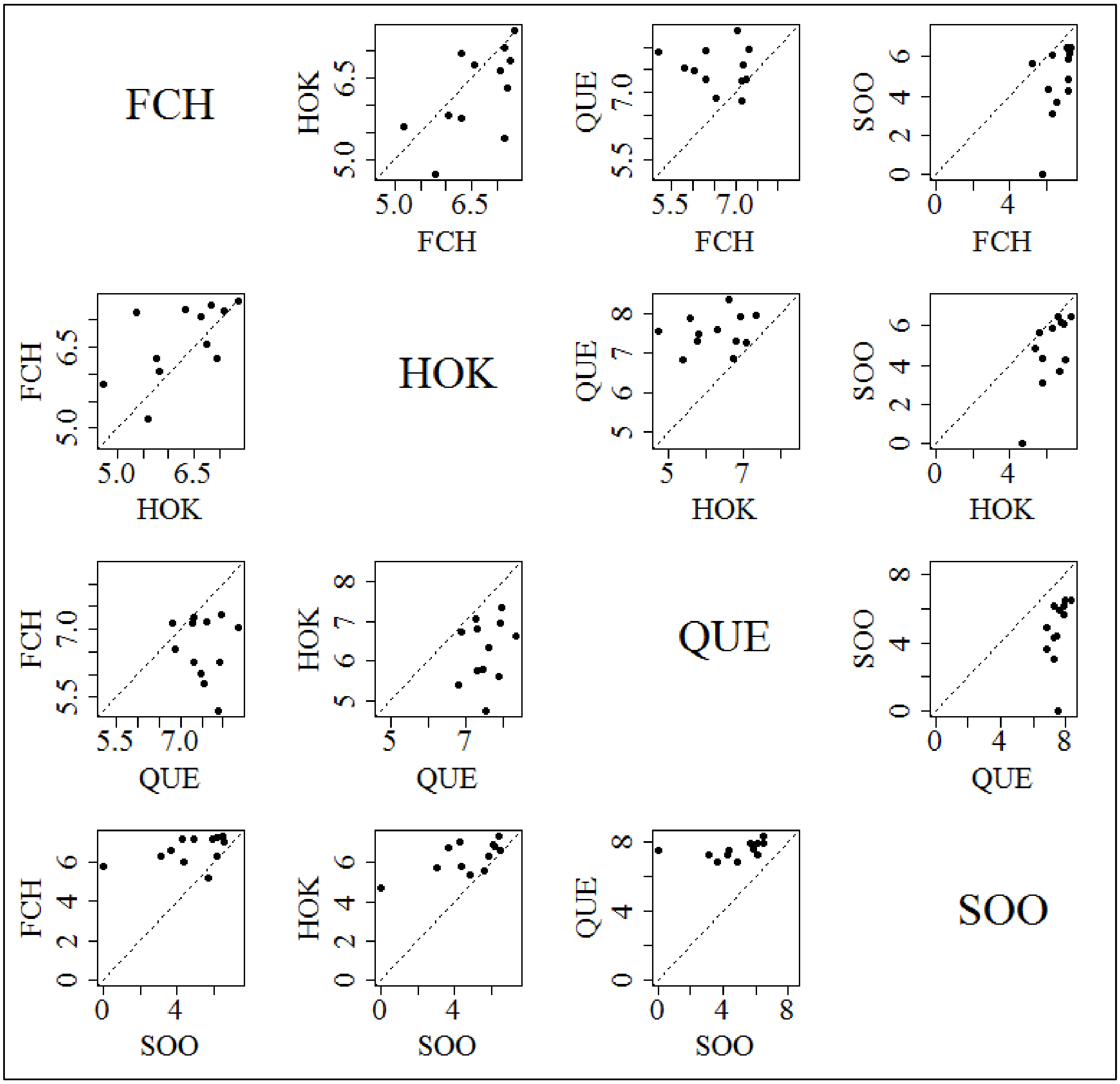
Appendix A.1.–Log brood year total modified contribution scatterplots for *Analysis 1*.



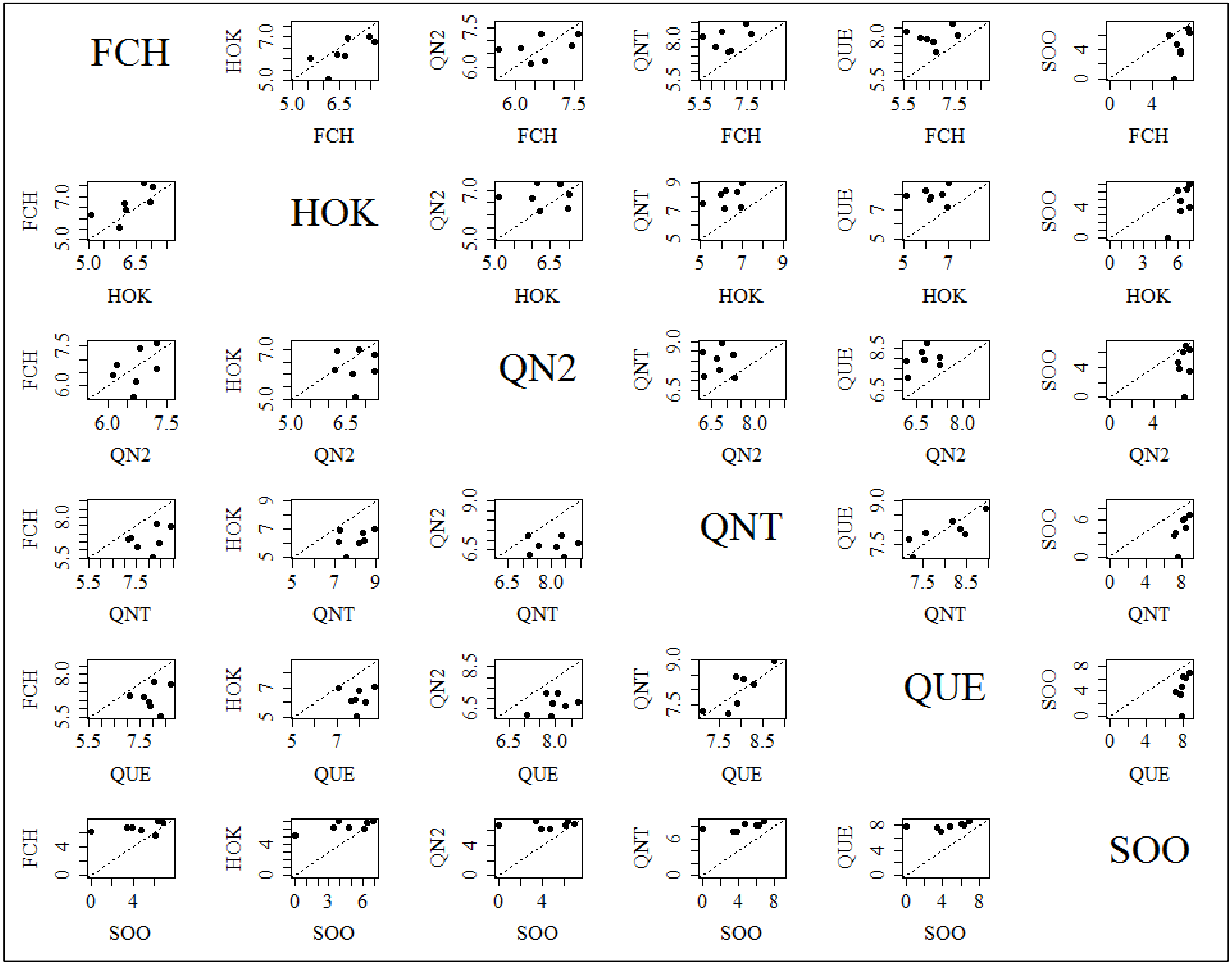
Appendix A.2.–Log brood year total modified contribution scatterplots for *Analysis 2*.



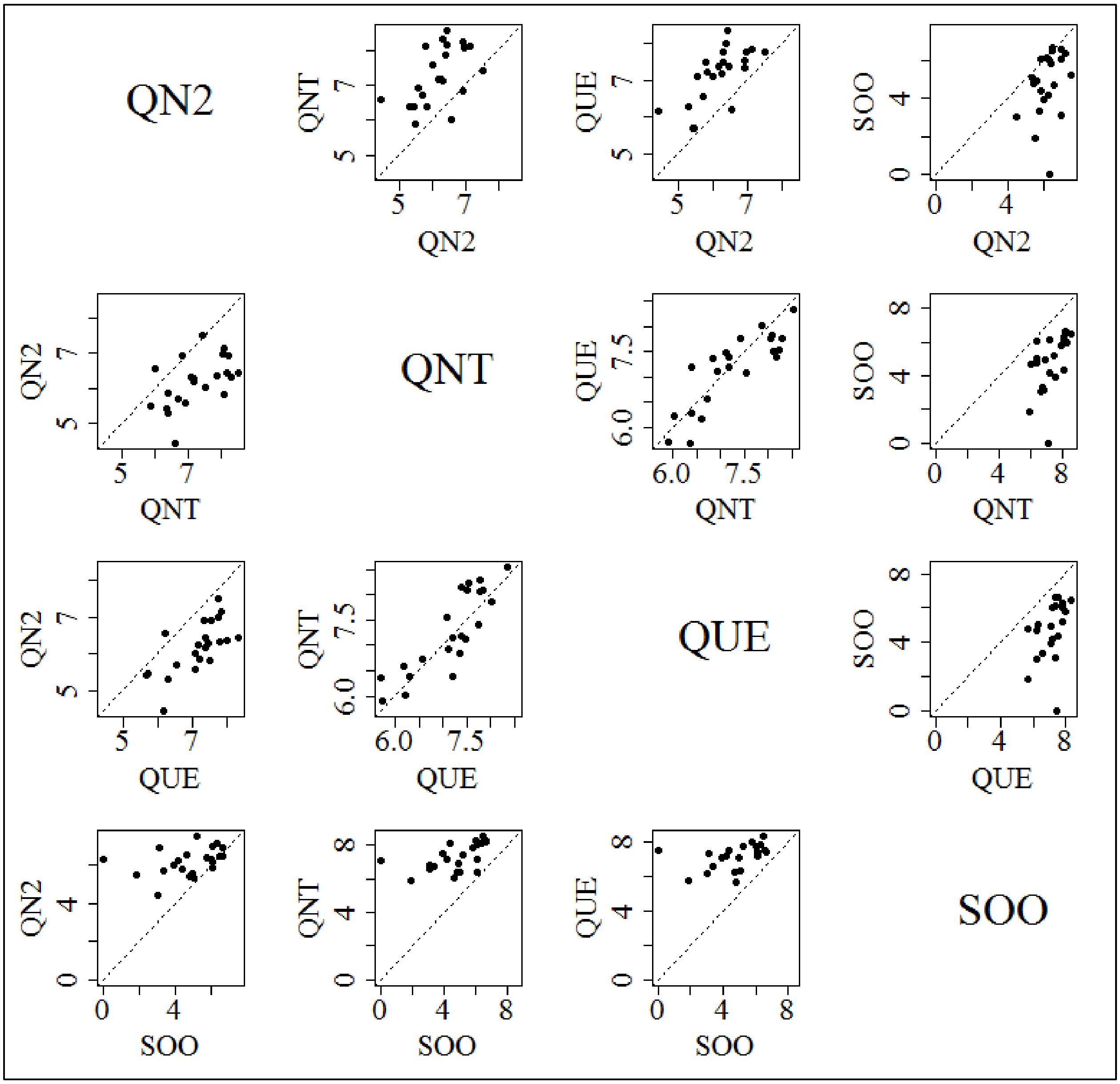
Appendix A.3.–Log brood year total modified contribution scatterplots for *Analysis 3*.



Appendix A.4.–Log brood year total modified contribution scatterplots for *Analysis 4*.



Appendix A.5.–Log brood year total modified contribution scatterplots for *Analysis 5*.



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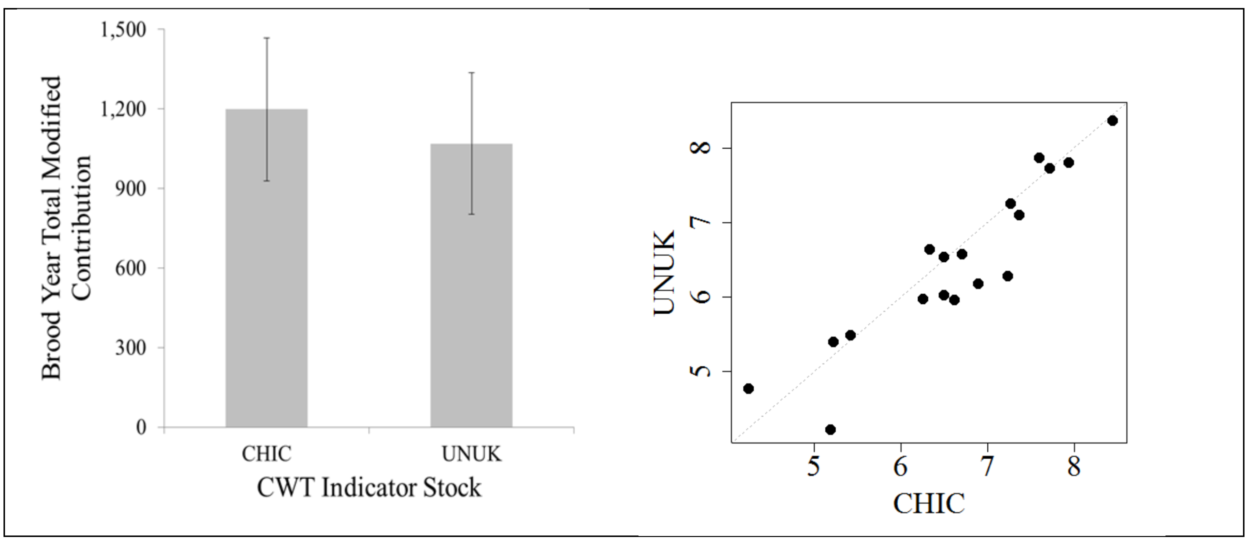
APPENDIX B: FEASIBILITY ANALYSIS OF THE *MODIFIED CONTRIBUTION* METHOD: LITTLE PORT WALTER

The efficacy of the *modified contribution* method was evaluated by comparing hatchery release-groups released at the NOAA research hatchery at Little Port Walter in Alaska. Beginning in the early 1980s, two separate broodstocks were collected from the Chickamin and Unuk rivers and reared at Little Port Walter. Concurrent hatchery releases-groups have since occurred from 1991–1999 and 2001–2011

Both the Chickamin and Unuk rivers are from the same region in Southeast Alaska and both stocks have similar distributions and life histories. Since both broodstocks are released from the same hatchery, are from the same region originally, have similar life histories, and similar distributions, it was expected that the *modified contribution* method would not detect a difference between the two stocks. Beginning in brood year 1991, hatchery release-groups of both broodstocks have been released concurrently with sufficient CWTs to facilitate a comparison between release-groups. *Modified contributions* were calculated using the SEAK AABM troll, net, and sport fisheries (Appendix E). The *modified contributions* of both broodstocks were similar across all brood years (Appendix B.1, left panel). Furthermore, the log *modified contributions* of each stock by brood year, when plotted against each other, fell almost exactly on the 1:1 line, which is what would be expected under the null hypothesis (Appendix B.1, right panel). Based on ANOVA results, the stock effect was not significant (Appendix B.2). The results of this analysis show that *modified contribution* method works as anticipated.

Appendix B.1.–Average brood year total modified contribution of Chickamin (CHIC) and Unuk (UNUK) broodstock (left panel). Log brood year total modified contribution scatterplot (right panel).



Appendix B.2.–ANOVA table for Little Port Walter analysis.

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F	Pr > F	
Brood year	17	39.115	2.301	25.238	<0.001	***
Stock	1	0.284	0.284	3.115	0.096	
Error	17	1.550	0.091			

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05

APPENDIX C: REMOVE QUEETS ANALYSIS

Tests of significance in two-way ANOVAs compare mean values across all groups and the inclusion of a group that is very different from all of the others could be the sole factor in observed significant differences. The stock effect was significant ($p<0.001$) in all five of our analyses, but we hypothesize that this conclusion could be the result of including data from QUE in all of the analyses. Our hypothesis is based on the following: visually, modified contributions of QUE were different than the modified contributions of the other stocks (Figure 3; Appendix A); and, QUE was significantly different than the other stocks (Table 5). To evaluate this possible explanation for the significant result, data from QUE releases were removed from each of the analyses and the modified tag ratios and modified contributions re-computed for each of the remaining stocks. The null hypothesis in this case would be that removal of QUE from the analyses will not affect the conclusions of a significant stock effect in all five analyses. Recall that the modified tag ratio is calculated as:

$$\theta_{i,by} = \frac{\sum_{i,by} R_i}{R_{i,by}}, \qquad \text{(Eq. C.1)}$$

where the omission of a stock from the analysis, given that $i \geq 2$, will only change the numerator, and thus not change the ratio of the *modified tag ratios* for any of the remaining stocks:

$$\frac{\theta_i}{\theta_j} = c; \;\; i \neq j, \qquad \text{(Eq. C.2)}$$

and it follows that the relationship of the modified contributions will also remain the same. Removal of a stock from the analysis was anticipated to have largely two different influences:

1. The removal of a stock(s) will result in a modified tag ratio that is strictly less than the previous tag ratio, with the opposite also being true, that the addition of a stock(s) will give a modified tag ratio that is strictly greater. Noting that larger tag ratios have greater uncertainty, and vice versa, the omission of a stock will only impact the uncertainty around the modified contribution estimate. However, because the sum modified contribution is log-transformed, some of the stock addition or removal effect is mitigated.
2. The removal of a stock(s) will decrease the degrees of freedom used to test the main stock effect by (n-1) and (n-1)*(t-1) degrees of freedom. Fewer stocks could mean less ability to detect differences, especially when t (the number of brood years) is small.

After removing data from QUE and re-running the analyses, we found that the removal of QUE did not change the main conclusion – the stock effect remained significant in all five analyses (Appendix C.1). We could not reject the null hypothesis that removal of QUE would not affect the conclusions. These results show that the conclusions gained from the comparisons are valid for all stocks and are robust to the influence of data from QUE.

Appendix C.1.–ANOVA table for *Analyses 1–5* with QUE removed.

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F	Pr > F	
Analysis 1: QUE, HOK, SOO						
Brood year	23	47.396	2.061	2.341	0.023	*
Stock	1	18.967	18.967	21.550	<0.001	***
Error	23	20.243	0.880			
Analysis 2: QUE, HOK, SOO, QNT, QN2, FCH, HUM, NAS						
Brood year	3	13.873	4.625	5.455	0.008	**
Stock	6	52.078	8.680	10.239	<0.001	***
Error	18	15.259	0.848			
Analysis 3: QUE, HOK, SOO, FCH						
Brood year	11	30.841	2.804	3.253	0.009	**
Stock	2	22.644	11.322	13.138	<0.001	***
Error	22	18.959	0.862			
Analysis 4: QUE, HOK, SOO, QNT, QN2, FCH						
Brood year	6	17.406	2.901	2.903	0.028	*
Stock	4	44.035	11.009	11.018	<0.001	***
Error	24	23.980	0.999			
Analysis 5: QUE, SOO, QNT, QN2						
Brood year	21	48.484	2.309	2.708	0.003	**
Stock	2	70.038	35.019	41.077	<0.001	***
Error	42	35.806	0.853			

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05

APPENDIX D: HATCHERY RELEASE-GROUPS, MODIFIED TAG RATIOS, AND MODIFIED CONTRIBUTIONS

Appendix D.1.–Number of Ad+CWTs fish released by hatchery and brood year.

Brood	Stock								
Year	FCH	HOK	HUM	NAS	QN2	QNT	QUE	SOO	Total
1985	208,302	123,563	215,738	202,924	201,209		117,674	137,990	1,207,400
1986	211,092	144,482	201,468		200,006	99,925	199,013	127,387	1,183,373
1987	207,950	199,740	209,254		193,395	151,701	101,914	203,819	1,267,773
1988			206,735		161,118	147,936	132,135		647,924
1989		110,572	203,892		187,402	143,129	120,787	93,972	859,754
1990		164,815	207,589		193,235	137,094	164,504	173,677	1,040,914
1991		182,308			158,079	92,806	168,795	248,384	850,372
1992		177,056			189,731	94,130	165,014	126,876	752,807
1993		202,858			180,775	122,109	170,604	261,790	938,136
1994		144,132			197,922	137,487	80,019	271,025	830,585
1995		199,041			182,411	130,440	209,929	223,712	945,533
1996		81,578			184,158	137,991	206,522	105,907	716,156
1997		200,516			188,538	144,675	200,731	240,765	975,225
1998	242,011	178,002			193,421	126,044	175,687	187,220	1,102,385
1999	204,257	141,633			207,247	42,378	179,685	258,306	1,033,506
2000		136,880			196,903	36,091	186,609	245,710	802,193
2001		157,639			191,935	39,888	204,251	259,391	853,104
2002		203,669					181,046	250,529	635,244
2003	192,238	260,590	196,605	198,318	182,936	31,661	206,096	228,862	1,497,306
2004	194,111	211,296	180,029	198,220	176,487	173,153	170,652	230,523	1,534,471
2005	202,922	67,347	236,285	198,596	206,823	184,372	194,075	252,446	1,542,866
2006	199,782	78,892	198,689	209,561	97,044	215,153	201,780	194,614	1,395,515
2007	201,838	210,854			189,570	205,869	186,540	252,628	1,247,299
2008	197,835	67,479			197,512	157,773	218,187	238,849	1,077,635
2009	198,941	155,144		101,863	176,530	200,838	214,648	242,077	1,290,041

Appendix D.2.–Number of Ad+CWTs released and modified tag ratios for *Analysis 1*.

	Ad+CWTs Released			Modified Tag Ratio		
Brood year	HOK	QUE	SOO	HOK	QUE	SOO
1985	123,563	117,674	137,990	3.07	3.22	2.75
1986	144,482	199,013	127,387	3.26	2.37	3.70
1987	199,740	101,914	203,819	2.53	4.96	2.48
1989	110,572	120,787	93,972	2.94	2.69	3.46
1990	164,815	164,504	173,677	3.05	3.06	2.90
1991	182,308	168,795	248,384	3.29	3.55	2.41
1992	177,056	165,014	126,876	2.65	2.84	3.70
1993	202,858	170,604	261,790	3.13	3.72	2.43
1994	144,132	80,019	271,025	3.44	6.19	1.83
1995	199,041	209,929	223,712	3.18	3.01	2.83
1996	81,578	206,522	105,907	4.83	1.91	3.72
1997	200,516	200,731	240,765	3.20	3.20	2.67
1998	178,002	175,687	187,220	3.04	3.08	2.89
1999	141,633	179,685	258,306	4.09	3.23	2.24
2000	136,880	186,609	245,710	4.16	3.05	2.32
2001	157,639	204,251	259,391	3.94	3.04	2.40
2002	203,669	181,046	250,529	3.12	3.51	2.54
2003	260,590	206,096	228,862	2.67	3.37	3.04
2004	211,296	170,652	230,523	2.90	3.59	2.66
2005	67,347	194,075	252,446	7.63	2.65	2.04
2006	78,892	201,780	194,614	6.02	2.36	2.44
2007	210,854	186,540	252,628	3.08	3.48	2.57
2008	67,479	218,187	238,849	7.77	2.40	2.20
2009	155,144	214,648	242,077	3.94	2.85	2.53
2010	178,081	161,952	252,961	3.33	3.66	2.34
2011	247,131	194,550	205,444	2.62	3.33	3.15
2012	263,519	196,583	199,639	2.50	3.36	3.30

Appendix D.3.–Number of Ad+CWTs released and modified tag ratios for *Analysis 2*.

Brood year	Ad+CWTs Released							
	HOK	QUE	SOO	QNT	QN2	FCH	HUM	NAS
2003	260,590	206,096	228,862	31,661	182,936	192,238	196,605	198,318
2004	211,296	170,652	230,523	173,153	176,487	194,111	180,029	198,220
2005	67,347	194,075	252,446	184,372	206,823	202,922	236,285	198,596
2006	78,892	201,780	194,614	215,153	97,044	199,782	198,689	209,561

Brood year	Modified Tag Ratio							
	HOK	QUE	SOO	QNT	QN2	FCH	HUM	NAS
2003	5.75	7.27	6.54	47.29	8.18	7.79	7.62	7.55
2004	7.26	8.99	6.66	8.86	8.69	7.91	8.52	7.74
2005	22.91	7.95	6.11	8.37	7.46	7.60	6.53	7.77
2006	17.69	6.92	7.17	6.49	14.38	6.99	7.02	6.66

Appendix D.4.–Number of Ad+CWTs released and modified tag ratios for *Analysis 3*.

Brood	Ad+CWTs Released					Modified Tag Ratio				
year	HOK	QUE	SOO	QNT	FCH	HOK	QUE	SOO	QNT	FCH
1985	123,563	117,674	137,990	208,302	215,738	6.50	6.83	5.82	3.86	3.72
1986	144,482	199,013	127,387	211,092	201,468	6.11	4.44	6.94	4.19	4.39
1987	199,740	101,914	203,819	207,950	209,254	4.62	9.05	4.53	4.44	4.41
2003	260,590	206,096	228,862	31,661	192,238	3.53	4.46	4.02	29.04	4.78
2004	211,296	170,652	230,523	173,153	194,111	4.64	5.74	4.25	5.66	5.05
2005	67,347	194,075	252,446	184,372	202,922	13.38	4.64	3.57	4.89	4.44
2006	78,892	201,780	194,614	215,153	199,782	11.28	4.41	4.57	4.14	4.46
2007	210,854	186,540	252,628	205,869	201,838	5.02	5.67	4.19	5.14	5.24
2008	67,479	218,187	238,849	157,773	197,835	13.04	4.03	3.68	5.58	4.45
2009	155,144	214,648	242,077	200,838	198,941	6.52	4.71	4.18	5.04	5.09
2010	178,081	161,952	252,961	218,016	194,364	5.65	6.21	3.97	4.61	5.17
2011	247,131	194,550	205,444	212,609	201,823	4.30	5.46	5.17	4.99	5.26
2012	263,519	196,583	199,639	198,230	199,030	4.01	5.38	5.29	5.33	5.31

Appendix D.5.–Number of Ad+CWTs released and modified tag ratios for *Analysis 4*.

Brood	Ad+CWTs Released						Modified Tag Ratio					
year	HOK	QUE	SOO	QNT	QN2	FCH	HOK	QUE	SOO	QNT	QN2	FCH
2003	260,590	206,096	228,862	31,661	182,936	192238	4.23	5.35	4.82	34.82	6.03	5.73
2004	211,296	170,652	230,523	173,153	176,487	194111	5.47	6.78	5.02	6.68	6.55	5.96
2005	67,347	194,075	252,446	184,372	206,823	202922	16.45	5.71	4.39	6.01	5.36	5.46
2006	78,892	201,780	194,614	215,153	97,044	199782	12.51	4.89	5.07	4.59	10.17	4.94
2007	210,854	186,540	252,628	205,869	189,570	201838	5.92	6.69	4.94	6.06	6.58	6.18
2008	67,479	218,187	238,849	157,773	197,512	197835	15.97	4.94	4.51	6.83	5.46	5.45
2009	155,144	214,648	242,077	200,838	176,530	198941	7.66	5.54	4.91	5.92	6.73	5.97

Appendix D.6.–Number of Ad+CWTs released and modified tag ratios for *Analysis 5*.

Brood year	Ad+CWTs Released				Modified Tag Ratio			
	QUE	SOO	QNT	QN2	QUE	SOO	QNT	QN2
1986	199,013	127,387	99,925	200,006	3.15	4.92	6.27	3.13
1987	101,914	203,819	151,701	193,395	6.39	3.19	4.29	3.37
1989	120,787	93,972	143,129	187,402	4.51	5.80	3.81	2.91
1990	164,504	173,677	137,094	193,235	4.06	3.85	4.88	3.46
1991	168,795	248,384	92,806	158,079	3.96	2.69	7.20	4.23
1992	165,014	126,876	94,130	189,731	3.49	4.54	6.12	3.03
1993	170,604	261,790	122,109	180,775	4.31	2.81	6.02	4.07
1994	80,019	271,025	137,487	197,922	8.58	2.53	4.99	3.47
1995	209,929	223,712	130,440	182,411	3.56	3.34	5.72	4.09
1996	206,522	105,907	137,991	184,158	3.07	5.99	4.60	3.45
1997	200,731	240,765	144,675	188,538	3.86	3.22	5.35	4.11
1998	175,687	187,220	126,044	193,421	3.88	3.64	5.41	3.53
1999	179,685	258,306	42,378	207,247	3.83	2.66	16.23	3.32
2000	186,609	245,710	36,091	196,903	3.57	2.71	18.43	3.38
2001	204,251	259,391	39,888	191,935	3.40	2.68	17.44	3.62
2003	206,096	228,862	31,661	182,936	3.15	2.84	20.52	3.55
2004	170,652	230,523	173,153	176,487	4.40	3.26	4.34	4.25
2005	194,075	252,446	184,372	206,823	4.32	3.32	4.54	4.05
2006	201,780	194,614	215,153	97,044	3.51	3.64	3.29	7.30
2007	186,540	252,628	205,869	189,570	4.47	3.30	4.05	4.40
2008	218,187	238,849	157,773	197,512	3.72	3.40	5.15	4.11
2009	214,648	242,077	200,838	176,530	3.89	3.45	4.15	4.72

Appendix D.7.–Brood year total modified contribution estimates for *Analysis 1*.

Brood year	Stock		
	HOK	QUE	SOO
1985	139.80	587.40	84.10
1986	806.43	996.93	48.53
1987	643.67	1044.63	335.97
1989	259.71	968.02	266.33
1990	434.56	911.03	104.55
1991	349.25	269.95	4.97
1992	174.14	406.70	86.01
1993	594.20	2024.08	157.58
1994	481.87	388.62	109.35
1995	158.36	250.20	99.72
1996	137.26	295.98	12.54
1997	120.00	989.42	41.46
1998	715.66	1889.81	318.36
1999	1161.52	2117.14	464.74
2000	167.25	1379.10	652.99
2001	622.74	1676.58	648.42
2002	288.29	632.31	63.14
2003	662.56	762.79	29.78
2004	84.90	1445.47	0.00
2005	400.96	1447.36	257.84
2006	223.81	1048.16	14.68
2007	581.54	3259.10	505.35
2008	194.71	1947.62	207.52
2009	251.03	1343.44	57.58

Appendix D.8.–Brood year total modified contribution estimates for *Analysis 2*.

Brood year	Stock							
	FCH	HOK	HUM	NAS	QN2	QNT	QUE	SOO
2003	1178.21	1426.29	2872.61	1069.69	690.39	1909.17	1642.06	64.12
2004	622.77	212.71	1798.71	637.80	1110.12	2510.41	3621.45	0.00
2005	2827.50	1203.88	4836.60	4155.64	1971.64	5788.72	4345.62	774.16
2006	1104.71	657.14	4510.85	1099.71	2008.77	1838.89	3077.56	43.10

Appendix D.9.–Brood year total modified contribution estimates for *Analysis 3*.

Brood year	Stock			
	FCH	HOK	QUE	SOO
1985	1252.92	216.59	910.05	130.29
1986	1253.28	1167.95	1443.84	70.29
1987	1410.76	908.48	1474.39	474.18
1998	534.43	1035.86	2735.34	460.79
1999	1511.91	1570.83	2863.21	628.52
2003	698.59	845.68	973.61	38.02
2004	327.35	111.81	1903.59	0.00
2005	1313.61	559.30	2018.90	359.66
2006	534.39	317.89	1488.74	20.85
2007	1156.89	762.11	4271.08	662.26
2008	177.27	268.16	2682.22	285.80
2009	414.98	332.65	1780.25	76.30

Appendix D.10.–Brood year total modified contribution estimates for *Analysis 4*.

Brood year	Stock					
	FCH	HOK	QN2	QNT	QUE	SOO
2003	867.45	1050.10	508.30	1405.62	1208.95	47.20
2004	469.25	160.28	836.47	1891.59	2728.76	0.00
2005	2030.52	864.55	1415.90	4157.08	3120.74	555.95
2006	781.53	464.90	1421.12	1300.93	2177.24	30.49
2007	1693.92	1115.89	919.63	7621.12	6253.75	969.68
2008	264.46	400.05	777.87	3493.35	4001.47	426.36
2009	608.12	487.47	470.88	4685.61	2608.81	111.81

Appendix D.11.–Brood year total modified contribution estimates for *Analysis 5*.

Brood	Stock			
year	QN2	QNT	QUE	SOO
1986	523.22	1296.66	1326.04	64.56
1987	345.92	586.39	1345.03	432.58
1989	483.34	1301.61	1622.50	446.40
1990	259.95	1015.58	1210.81	138.95
1991	238.78	360.64	300.84	5.54
1992	705.14	410.36	499.33	105.60
1993	1821.04	1671.38	2342.79	182.39
1994	200.81	596.05	538.74	151.59
1995	224.43	582.93	295.21	117.66
1996	82.98	732.20	476.70	20.19
1997	411.56	1897.32	1193.92	50.04
1998	552.68	4012.52	2384.05	401.62
1999	1270.47	3240.45	2511.60	551.33
2000	634.18	3508.42	1611.97	763.25
2001	1015.65	3761.52	1876.78	725.84
2003	299.50	828.23	712.35	27.81
2004	543.18	1228.34	1771.97	0.00
2005	1070.52	3143.05	2359.50	420.34
2006	1019.98	933.72	1562.67	21.88
2007	615.36	5099.53	4184.58	648.85
2008	586.36	2633.29	3016.30	321.39
2009	330.56	3289.27	1831.37	78.49

APPENDIX E: FISHERY DEFINITIONS

Appendix E.1.–Description of the fisheries used in the Washington Coast Analyses.

Fishery	Description
NBC AABM Troll	North Fall Troll
	North Spring Troll
	North Summer Troll
SEAK AABM Troll	Alaska Early Winter North Inside Troll
	Alaska Early Winter North Outside Troll
	Alaska Early Winter South Inside Troll
	Alaska Fall North Inside Troll
	Alaska Fall North Outside Troll
	Alaska Fall South Inside Troll
	Alaska Fall South Outside Troll
	Alaska July North Inside Troll
	Alaska July North Outside Troll
	Alaska July South Inside Troll
	Alaska July South Outside Troll
	Alaska June North Inside Troll
	Alaska June North Outside Troll
	Alaska June South Inside Troll
	Alaska June South Outside Troll
	Alaska Late Winter North Inside Troll
	Alaska Late Winter North Outside Troll
	Alaska Late Winter South Inside Troll
	Alaska Late Winter South Outside Troll
	Alaska Spring North Inside Troll
	Alaska Spring North Outside Troll
	Alaska Spring South Inside Troll
	Alaska Spring South Outside Troll

Source: Fishery definitions used in the CTC's 2016 ERA (TCCHINOOK 16-03)

Appendix E.2.–Description of the fisheries used in the Little Port Walter analysis.

Fishery	Description
SEAK AABM Sport	Alaska Southeast Sport
SEAK AABM Troll	Alaska Early Winter North Inside Troll
	Alaska Early Winter North Outside Troll
	Alaska Early Winter South Inside Troll
	Alaska Fall North Inside Troll
	Alaska Fall North Outside Troll
	Alaska Fall South Inside Troll
	Alaska Fall South Outside Troll
	Alaska July North Inside Troll
	Alaska July North Outside Troll
	Alaska July South Inside Troll
	Alaska July South Outside Troll
	Alaska June North Inside Troll
	Alaska June North Outside Troll
	Alaska June South Inside Troll
	Alaska June South Outside Troll
	Alaska Late Winter North Inside Troll
	Alaska Late Winter North Outside Troll
	Alaska Late Winter South Inside Troll
	Alaska Late Winter South Outside Troll
	Alaska Spring North Inside Troll
	Alaska Spring North Outside Troll
	Alaska Spring South Inside Troll
	Alaska Spring South Outside Troll
SEAK AABM Net	Alaska District 101 And 102 Gillnet
	Alaska District 106 And 108 Gillnet
	Alaska District 111 Gillnet
	Alaska District 115 Gillnet
	Alaska Southeast Other Gillnet
	Alaska Southeast Set Gillnet
	Alaska District 101 & 102 Seine
	Alaska District 103 & 104 Seine
	Alaska District 105 106 & 107 Seine
	Alaska District 109 & 110 Seine
	Alaska District 111 Seine
	Alaska District 112 Seine
	Alaska District 113 Seine
	Alaska District 114 Seine
	Alaska Trap

Source: CTC's 2016 ERA

APPENDIX F: MODEL DIAGNOSTICS OF ANALYSES 1–5

Appendix F.1.–Residual vs fitted plots from each of the analyses. Panel A is the residual vs fitted plot from *Analysis 1*. Panel B is the residual vs fitted plot from *Analysis 2*. Panel C is the residual vs fitted plot from *Analysis 3*. Panel D is the residual vs fitted plot from *Analysis 4*. Panel E is the residual vs fitted plot from *Analysis 5*.