AYKSSI paper-Hypothesis #5: Ocean Bycatch/Ecosystem Overfishing – Fishery caused mortality or changes in Bering Sea ecosystem structure and function have contributed to the decline of AYK-region Chinook salmon stocks.

Diana L. Stram, North Pacific Fishery Management Council and James N. Ianelli, Alaska Fisheries Science Center, NOAA.

**Note that per request this paper only addresses the 'ocean bycatch' component of this hypothesis**

## Introduction

The North Pacific Fishery Management Council (NPFMC or Council) is one of eight regional councils established by the Magnuson Fishery Conservation and Management Act in 1976 to oversee management of the nation's fisheries. With jurisdiction over the million square mile Exclusive Economic Zone (EEZ) off Alaska, the Council has primary responsibility for groundfish management in the Gulf of Alaska (GOA) and Bering Sea and Aleutian Islands (BSAI), including cod, pollock, flatfish, mackerel, sablefish, and rockfish species harvested mainly by trawlers, hook and line longliners and pot fishermen.

While the State of Alaska has management authority for salmon stocks, the NPFMC is responsible for managing the bycatch of salmon species in the groundfish fisheries. Of groundfish fisheries in the Bering Sea, the walleye pollock fishery is responsible for the majority of the salmon taken as bycatch. Chinook and chum salmon are the main species taken incidentally (<0.1% of the salmon bycatch is made up of other species). Consequently, the Council has enacted management measures to minimize the bycatch of Chinook and chum salmon in the pollock fishery since the mid-1990s. Early management measures focused on large scale area closures in the Bering Sea based on historic spatial concentrations of bycatch. These areas would close during times of high bycatch. In 2011 the Council's new management program for Chinook salmon went into effect. This program imposes a strict limit on Chinook salmon bycatch in the pollock fishery. The limits are apportioned by season and fishery sector which if reached would prohibit further pollock fishing for those vessels. Additional measures are being considered currently for chum salmon bycatch by the Council.

Chinook salmon bycatch in the EBS pollock fishery occurs in both the winter (A) and summer (B) seasons (Table 1) while chum salmon bycatch occurs only in the B season (Table 2).

Table 1 Chinook salmon bycatch from the pollock fishery, 1991-2012 by season.

| Year | A-season | B-Season | Total |
|---|---|---|---|
| 1991 | 38,791 | 2,114 | 40,906 |
| 1992 | 25,691 | 10,259 | 35,950 |
| 1993 | 17,264 | 21,252 | 38,516 |
| 1994 | 28,451 | 4,686 | 33,136 |
| 1995 | 10,579 | 4,405 | 14,984 |
| 1996 | 36,068 | 19,554 | 55,623 |
| 1997 | 10,935 | 33,973 | 44,909 |
| 1998 | 15,193 | 36,130 | 51,322 |
| 1999 | 6,352 | 5,627 | 11,978 |
| 2000 | 3,422 | 1,539 | 4,961 |
| 2001 | 18,484 | 14,961 | 33,444 |
| 2002 | 21,794 | 12,701 | 34,495 |
| 2003 | 32,609 | 12,977 | 45,586 |
| 2004 | 23,104 | 28,595 | 51,699 |
| 2005 | 27,285 | 40,050 | 67,335 |
| 2006 | 58,287 | 24,306 | 82,592 |
| 2007 | 69,139 | 52,350 | 121,488 |
| 2008 | 16,574 | 4,842 | 21,415 |
| 2009 | 9,683 | 2,718 | 12,401 |
| 2010 | 7,624 | 2,067 | 9,692 |
| 2011 | 7,136 | 18,363 | 25,499 |
| 2012 | 7,773 | 3,577 | 11,350 |

Table 2 Non-Chinook (chum) salmon mortality in BSAI pollock directed fisheries 1991-2012.

| Year | Total |
|---|---|
| 1991 | 28,951 |
| 1992 | 40,274 |
| 1993 | 242,191 |
| 1994 | 92,672 |
| 1995 | 19,264 |
| 1996 | 77,236 |
| 1997 | 65,988 |
| 1998 | 64,042 |
| 1999 | 45,172 |
| 2000 | 58,571 |
| 2001 | 57,007 |
| 2002 | 80,782 |
| 2003 | 189,185 |
| 2004 | 440,468 |
| 2005 | 704,552 |
| 2006 | 309,630 |
| 2007 | 93,783 |
| 2008 | 15,267 |
| 2009 | 46,127 |
| 2010 | 13,222 |
| 2011 | 191,445 |
| 2012 | 22,213 |

## Evidence for/against hypothesis

In conjunction with the Council's decision on a new management program for Chinook salmon bycatch in the EBS pollock fishery a comprehensive analysis (an environmental impact statement or EIS) as required under the National Environmental Policy Act (NEPA) was prepared to assist the policy makers with the impacts of their alternatives management decisions on the environment. This Chinook FEIS (NPFMC/NMFS 2009) evaluated, to the extent possible, proposed hypotheses for bycatch fluctuations, the impact of current levels of bycatch to western Alaskan rivers as well as the potential impact of the proposed management measures. Information below summarizes some of the methods employed and analysis completed in 2009 to facilitate management decisions. Following this an updated (through A-season 2012) analysis is provided using a simplified assumption to estimate the adult equivalent (AEQ) returns to western Alaska.

### Why have bycatch levels fluctuated?

In conjunction with the FEIS analysis, potential changes in fishing patterns or practices that could contribute to increased bycatch in some years was investigated. Tow duration based on NMFS observer data indicated that a measure of total hours fishing increased by about 20% in 2006 and 2007. This compares with a nearly three-fold increase in the levels of Chinook bycatch (Figure 1). This suggests that other factors may affect bycatch levels. Increased numbers of Chinook found on the pollock fishing grounds due to run-sizes or environmental conditions clearly affects the magnitude of bycatch. Changes in fishing gear depth were examined to be similar through this period. Anecdotally, trawl gear (dimensions, net material etc.) has changed over time but information on this is unavailable for analysis. Seasonally, for the period 1991-2007 February averages to be the highest month of bycatch in the pollock fishery even though the average tow duration is relative low whereas October tends to be the second-highest month when bycatch occurs and is also when the average tow duration is the highest (Figure 2). Over time, tow duration in October has steadily increased (Figure 3).

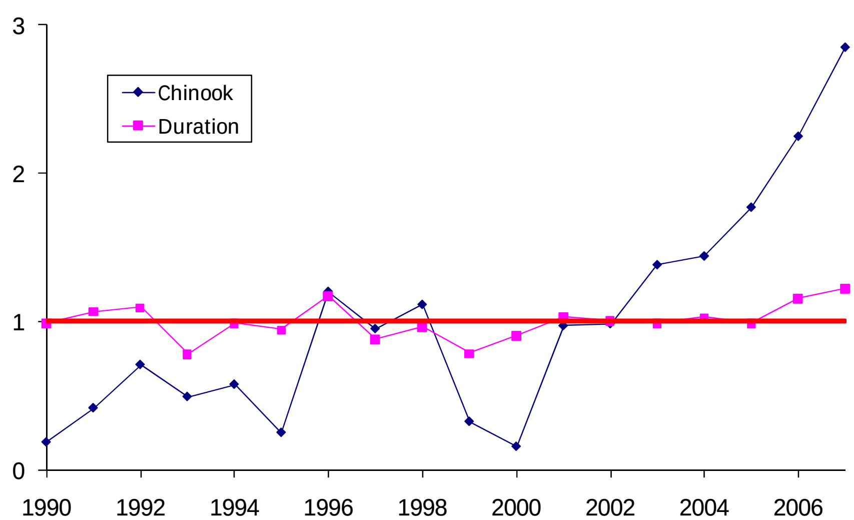


Figure 1. Standardized (to have mean values of 1) relative Chinook catch and pollock fishing effort (annual total hours spent towing).

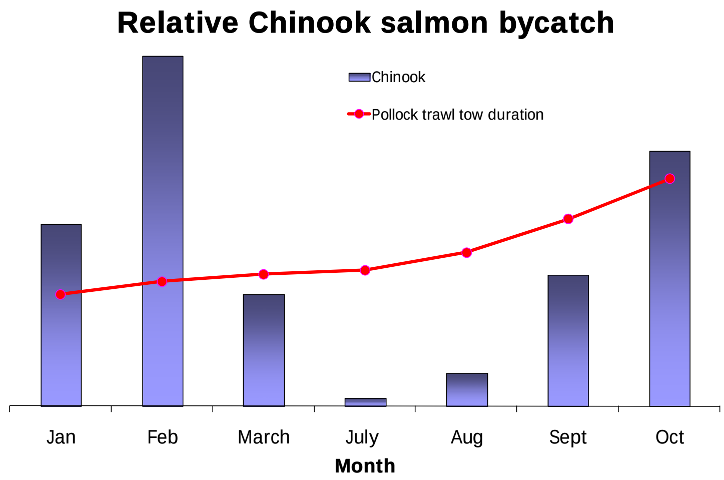


Figure 2. Average relative Chinook bycatch (columns) and tow duration (marked line) by month based on NMFS observer data, 1991-2007.

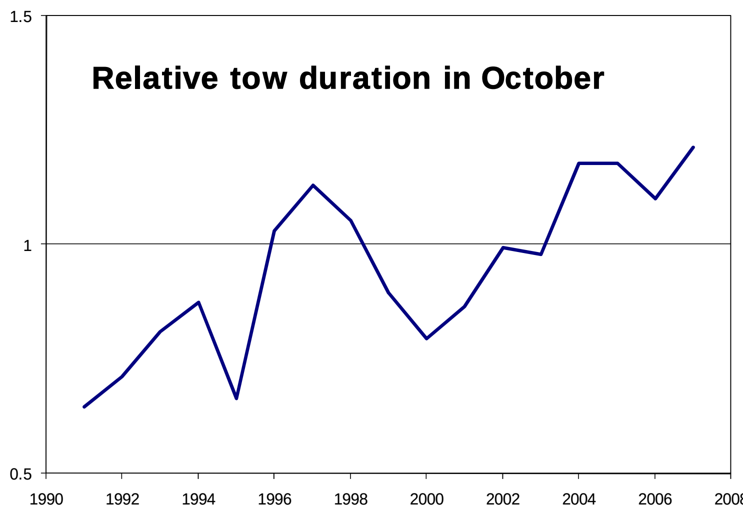


Figure 3. Average relative tow duration (scaled to have mean value of 1.0) for October based on NMFS observer data, 1991-2007.

## AEQ analysis of Chinook bycatch

An adult equivalency model was developed for use in the FEIS (NPFMC/NMFS 2009). To understand impacts on Chinook populations, a method was developed to estimate how the different bycatch numbers would propagate to adult equivalent spawning salmon. Estimating the adult equivalent bycatch is necessary because not all salmon caught as bycatch in the pollock fishery would otherwise have survived to return to their spawning streams. Currently, accurate in-season Chinook salmon abundance levels are unavailable. Therefore, the analysis relied on analyses of historical data. Developing regulations designed to reduce the impact of bycatch requires methods that appropriately assess the impact of bycatch on the various salmon populations. A stochastic "adult equivalence" model was developed, which accounts for sources of uncertainty. The model is an extension of Witherell et al.'s (2002) evaluation, and relaxes a number of that study's assumptions.

Adult-equivalency (AEQ) of the bycatch was estimated to translate how different management cap levels may affect Chinook salmon stocks. This is distinguished from the annual bycatch numbers that are recorded by observers each year for management purposes. The AEQ bycatch applies the extensive observer datasets on the length frequencies of Chinook salmon found as bycatch and converts these to the ages of the bycaught salmon, appropriately accounting for the time of year that catch occurred. Coupled with information on the proportion of salmon that return to different river systems at various ages, the bycatch-at-age data is used to pro-rate, for any given year, how bycatch affects future potential spawning runs of salmon.

Evaluating impacts to specific stocks was done by using historical scale-pattern analysis (Myers et al.1984, Myers and Rogers 1988, Myers et al. 2003) and preliminary genetics studies from samples collected in 2005, 2006 and 2007 (Seeb et al. 2008). While sample collection issues exist and different methodologies were employed (scale pattern analyses and genetic analyses), these stock estimates nonetheless provide similar overall proportions of between 54-60% for western Alaska. The consistency of these results from these different methodologies lends credibility to this general estimate. Where possible, historical run sizes were contrasted with AEQ mortality arising from the observed pollock fishery Chinook bycatch to river of origin. Additional information on the methodology for the AEQ analysis is available in Chapter 3 of the FEIS (NPFMC/NMFS 2009).

One issue that should be highlighted in estimating the AEQ to regions of origin was in equating the actual bycatch levels to the samples collected opportunistically for genetics between 2005 to 2007. The Seeb et al. (2008) study analyzed samples taken from the bycatch during the 2005 B season, both A and B seasons during 2006, and a sample from an excluder test fishery during the 2007 A season. Where possible, the genetics samples from the bycatch were segregated by major groundfish bycatch regions. Effectively, this entailed a single region for the entire fishery during winter (which is typically concentrated in space to the region east of 170°W) and two regions during the summer, a NW region (west of 170°W) and a southeast region (east of 170°W). The genetic sampling distribution varies considerably by season and region compared to the level of bycatch.

The samples used in the Seeb et al. (2008) analysis were obtained opportunistically for a study to evaluate using scales and other tissues as collected by the NMFS observer program for genetic sampling. Unfortunately, during this study, the collected samples failed to cover the bycatch in groundfish fisheries in a comprehensive manner. For example, in 2005 most sampling was completed prior to the month (October) when most of the bycatch occurred (Figure 4). To account for these sampling issues we computed a weighted average of the samples over years within regions and seasons. The 2005 B-season stock composition results were given one third of the weight since sampling effort was low during October of that year (relative to the bycatch) while the 2006 B-season stock composition data was given two-thirds of the weight in simulating stock apportionments. For the A season, the 2007 data (collected from a limited number of tows) were given one fifth the weight while the 2006 was weighted 4 times that value.

Once these mean stock composition estimates (and associated uncertainties) were obtained, it was necessary to apply the stratum-specific stock composition levels (Table 3) to the stratum specific bycatch totals to arrive at an annual stock-specific bycatch level for application in the model (Figure 5). An important feature of this analysis is that the bycatch amounts by location and season were used explicitly for the estimates of the relative contribution of bycatch from different salmon regions. This is also an important distinction from previous studies (e.g., Myers et al, 2003) which assumed that the stock identification samples were proportional to the season and area specific bycatch over all years.

For the purposes of assigning the bycatch to region of origin, the level of uncertainty is important to characterize. While there are many approaches to implement assignment uncertainty, the method chosen here assumes that the stratified stock composition estimates are unbiased and that the assignment uncertainty based on a classification algorithm (Seeb et al. 2008) adequately represents the uncertainty (i.e., the estimates and their standard errors are used to propagate this component of uncertainty). Inter-annual variability is introduced two ways: (1) by accounting for inter-annual variability in bycatch among strata; and (2) by using the point estimates (and errors) from the data over the different years (2005-2007) while weighting appropriately for the sampling intensity. The procedure for introducing variability in regional stock assignments of bycatch followed a Monte Carlo procedure with the point estimates and their variances used to simulate beta distributed random variables (which have the desirable property of being bounded by 0.0 and 1.0) and applied to the catch weightings (for the summer/fall (B) season) where areas are disaggregated. Areas were combined for the winter fishery since the period of bycatch by the fishery is shorter and from a more restricted area.

Application of GSI to estimate the composition of the bycatch by reporting region suggests that, if the goal is to provide estimates on the stock composition of the bycatch, there is a need to adjust for the magnitude of bycatch occurring within substrata (e.g., east and west of 170°W during the B season, top panels of Fig. 5). Applying the stock composition results presented in over different years and weighted by catch gives stratified proportions that have similar characteristics to the raw genetics data (Table 4). Importantly, these stratified stock composition estimates can be applied to bycatch levels in other years which will result in overall annual differences in bycatch proportions by salmon stock region. These simulations can be characterized graphically in a way that shows the covariance structure among regional stock composition estimates. This application extrapolates beyond the current analysis of these genetic data however and additional investigation of the temporal variation in stock composition is recommended.

The preliminary stock composition estimates for this more recent study based on the genetics are shown broken out by regions, year and season for the 9 stock units identified (Table 3). Accounting for sampling variability, the mean stock compositions by strata, and mean apportionments of the bycatch to stock (region) of origins by area and season of the pollock fishery are shown in Table 4.

While stock units differ from previous studies in levels of aggregation, results for western Alaskan aggregate river systems (e.g., AYK region) are similar to the scale-pattern study presented by Myers and Rogers (1988) and Myers et al. (2003; Table 5). The three studies indicate similarities in overall estimates of stock composition by river system even though aggregation levels, years of samples, and methodologies differ (Table 5). However, comparisons of stock composition estimates from other areas are more variable. For example the contribution from Cook Inlet stocks ranges from 4%-31% amongst studies while Russian stocks vary from 2%-14% (Table 5). There is particular variation amongst the two scale patterns studies (Myers and Rogers 1988 and Myers et al. 2003) for these other stocks. Impacts were characterized in aggregate Coastal western Alaska grouping (which includes the lower Yukon, Kuskokwim and other minor stocks) as well as by individual river system.

Table 3. ADF&G preliminary estimates of stock composition based on genetic samples stratified by year, season, and region (SE=east of 170°W, NW=west of 170°W). Standard errors of the estimates are shown in parentheses and were used to evaluate uncertainty of stock composition. Source: Seeb et al. 2008.

| Year / Season / Area | PNW | Coast W AK | Cook Inlet | Middle Yukon | N AK Penin | Russia | TBR | Upper Yukon | Other |
|---|---|---|---|---|---|---|---|---|---|
| 2005 B SE | 45.3% | 34.2% | 5.3% | 0.2% | 8.8% | 0.6% | 3.3% | 0.0% | 2.4% |
| N = 313 | (0.032) | (0.032) | (0.019) | (0.003) | (0.021) | (0.005) | (0.016) | (0.001) | (0.015) |
| 2005 B NW | 6.5% | 70.9% | 2.2% | 4.7% | 6.7% | 2.0% | 3.5% | 2.8% | 0.7% |
| N = 543 | (0.012) | (0.047) | (0.011) | (0.013) | (0.042) | (0.007) | (0.012) | (0.009) | (0.008) |
| 2006 B SE | 38.4% | 37.2% | 7.5% | 0.2% | 7.0% | 0.6% | 4.3% | 0.1% | 4.7% |
| N = 309 | (0.029) | (0.032) | (0.020) | (0.004) | (0.019) | (0.005) | (0.017) | (0.002) | (0.020) |
| 2006 B NW | 6.4% | 67.3% | 3.0% | 8.0% | 2.1% | 3.3% | 0.5% | 8.0% | 1.4% |
| N = 296 | (0.016) | (0.035) | (0.020) | (0.020) | (0.016) | (0.013) | (0.007) | (0.019) | (0.014) |
| 2006 A All | 22.9% | 38.2% | 0.2% | 1.1% | 31.2% | 1.1% | 1.1% | 2.3% | 1.9% |
| N = 902 | (0.015) | (0.038) | (0.004) | (0.005) | (0.039) | (0.004) | (0.007) | (0.006) | (0.011) |
| 2007 A All | 9.4% | 75.2% | 0.1% | 0.5% | 12.0% | 0.2% | 0.1% | 0.1% | 2.4% |
| N = 380 | (0.016) | (0.031) | (0.004) | (0.005) | (0.025) | (0.003) | (0.002) | (0.003) | (0.014) |

Table 4. Mean values of catch-weighted stratified proportions of stock composition based on genetic sampling by season, and region (SE=east of 170°W, NW=west of 170°W). Standard errors of the estimates (in parentheses) were derived from 200 simulations based on the estimates from Table and weighting annual results as explained in the text.

| Season / Area | PNW | Coast W AK | Cook Inlet | Middle Yukon | N AK Penin | Russia | TBR | Upper Yukon | Other |
|---|---|---|---|---|---|---|---|---|---|
| B SE | 45.0% | 34.7% | 5.1% | 0.1% | 8.6% | 0.6% | 3.4% | 0.0% | 2.4% |
| | (0.025) | (0.024) | (0.017) | (0.002) | (0.016) | (0.004) | (0.014) | (0.001) | (0.014) |
| B NW | 6.4% | 68.9% | 2.6% | 6.6% | 4.4% | 2.7% | 1.8% | 5.6% | 1.0% |
| | (0.010) | (0.023) | (0.012) | (0.011) | (0.019) | (0.007) | (0.006) | (0.012) | (0.008) |
| A All | 12.1% | 67.7% | 0.1% | 0.6% | 16.0% | 0.4% | 0.2% | 0.6% | 2.3% |
| | (0.012) | (0.021) | (0.003) | (0.004) | (0.019) | (0.002) | (0.002) | (0.003) | (0.010) |

Table 5. Comparison of stock composition estimates for three different studies on Chinook bycatch samples taken from trawl fisheries in the eastern Bering Sea.

<table>
<tr><td>Study</td><td colspan="4">Myers and Rogers (1988)</td><td colspan="3">Myers et al (2003)</td><td colspan="3">Seeb et al. 2008</td></tr>
<tr><td>Years sampled</td><td colspan="4">1979-1982</td><td colspan="3">1997-1999</td><td colspan="3">2005-2007[1]</td></tr>
<tr><td rowspan="15">Stocks and estimated aggregate % composition in bycatch<br><br>Smaller scale breakouts (where available) listed to the right (with associated % contrib. of aggregate below)</td><td rowspan="3">Western AK</td><td colspan="3">60%</td><td colspan="3">56%</td><td colspan="3" rowspan="3"></td></tr>
<tr><td>Yukon</td><td>Bristol Bay</td><td>Kusko-kwim</td><td>Yukon</td><td>Bristol Bay</td><td>Kusko-kwim</td></tr>
<tr><td>17%</td><td>29%</td><td>24%</td><td>40%</td><td>34%</td><td>26%</td></tr>
<tr><td rowspan="3">Coastal WAK (also includes Norton Sound)</td><td colspan="3" rowspan="3"></td><td colspan="3" rowspan="3"></td><td colspan="3">48%</td></tr>
<tr><td>Lower Yukon</td><td>Kusko-kwim</td><td>Bristol Bay</td></tr>
<tr><td>Na</td><td>Na</td><td>Na</td></tr>
<tr><td>Middle Yukon</td><td colspan="3"></td><td colspan="3"></td><td colspan="3">3%</td></tr>
<tr><td>Upper Yukon</td><td colspan="3"></td><td colspan="3"></td><td colspan="3">3%</td></tr>
<tr><td>NAK Penin</td><td colspan="3"></td><td colspan="3"></td><td colspan="3">13%</td></tr>
<tr><td>Cook Inlet</td><td colspan="3">17%</td><td colspan="3">31%</td><td colspan="3">4%</td></tr>
<tr><td>SEAK/Can</td><td colspan="3">9%</td><td colspan="3">8%</td><td colspan="3"></td></tr>
<tr><td>TBR</td><td colspan="3"></td><td colspan="3"></td><td colspan="3">2%</td></tr>
<tr><td>PNW[2]</td><td colspan="3"></td><td colspan="3"></td><td colspan="3">23%</td></tr>
<tr><td>Russia</td><td colspan="3">14%</td><td colspan="3">5%</td><td colspan="3">2%</td></tr>
<tr><td>Other[3]</td><td colspan="3"></td><td colspan="3"></td><td colspan="3">3%</td></tr>
</table>

[1]note for purposes of comparison, only 2006 stock composition estimates *averaged annually and across regions* are shown here.

[2]PNW is an aggregate of 54 stocks from British Columbia, Washington, Oregon and California. For a full list of stocks included see Table 3-7 of FEIS (NPFMC/NMFS 2009).

[3]'other' is comprised of minor components after aggregation to major river systems as described in Table 3-7 of FEIS (NPFMC/NMFS 2009).

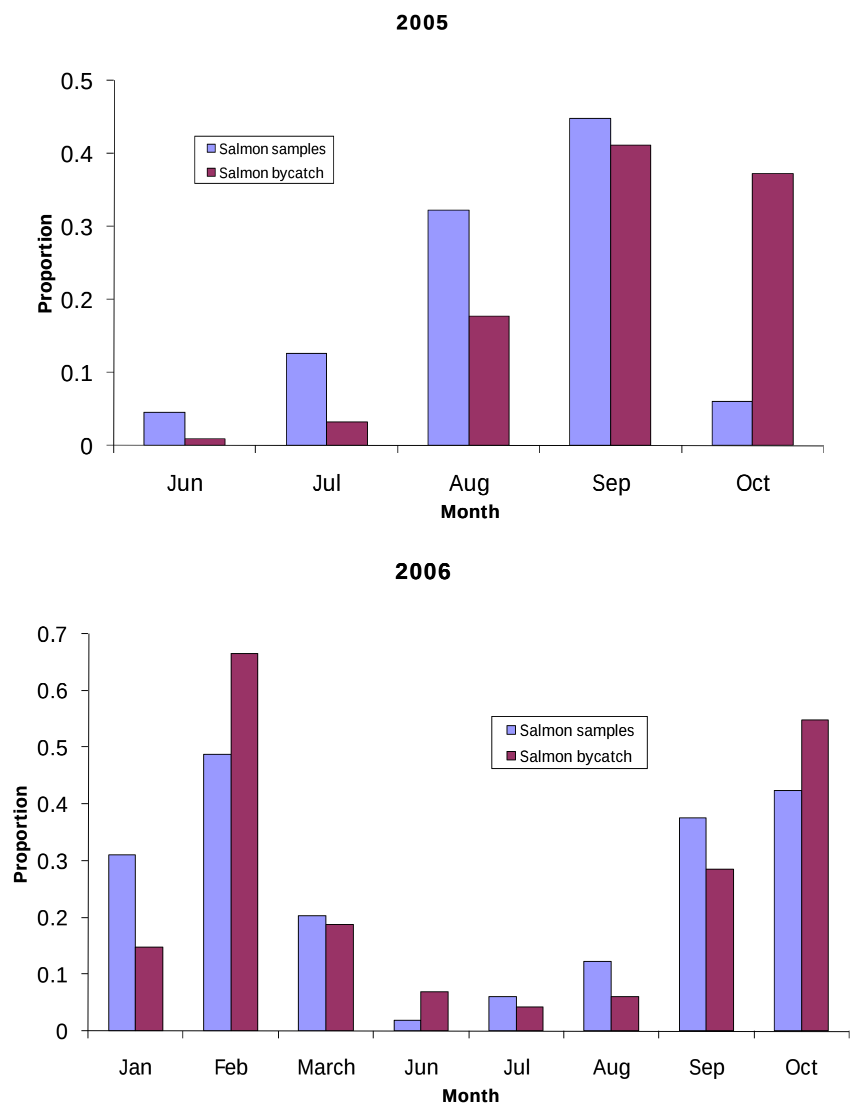


Figure 4. Proportion of Chinook salmon samples collected for genetics compared to the proportion of bycatch by month for 2005 B-season only (top panel) and 2006 A and B season combined (bottom panel).

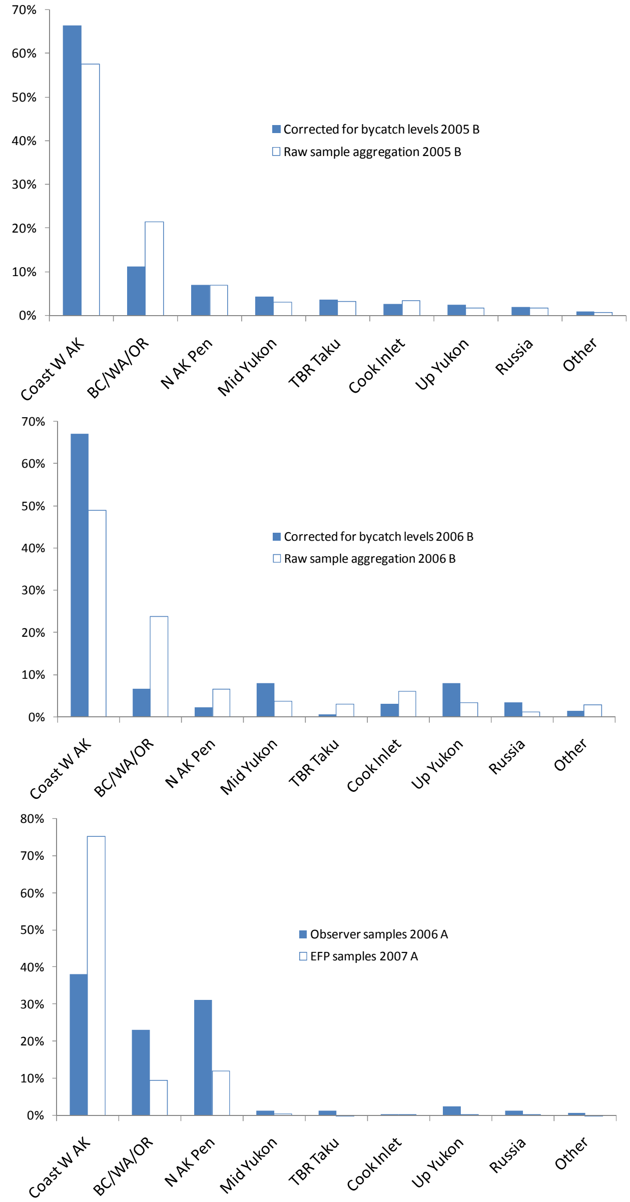


Figure 5. Chinook salmon bycatch results by reporting region for 2005 B season (top), 2006 B season (middle), and the 2006 and (partial sample) of 2007 A seasons (bottom). The top two panels include uncorrected results where bycatch differences between regions (east and west of 170°W) are ignored (empty columns).

## AEQ results and estimated proportions to western Alaska

The pattern of bycatch relative to AEQ is variable. In some years, the bycatch records may be below the actual AEQ, due to the lagged impact of previous years catches. For example, in 2000, as shown in Figure 6, actual bycatch is below the predicted AEQ bycatch. This is because 1996-1998, the actual bycatch was high. The impacts from those high bycatch years show up in the AEQ bycatch for subsequent years. Some of the Chinook salmon caught as bycatch in those years would not have returned to their river of origin in the year of bycatch. Based on their age and maturity, they might have returned up to one to four years later. Some proportion of the bycatch would not have returned in any year due to ocean mortality.


Figure 6. Time series of Chinook actual and adult equivalent bycatch from the pollock fishery, 1991-2007 (2008 raw annual bycatch also indicated separately). The dotted lines represent the uncertainty of the AEQ estimate, due to the combined variability of ocean mortality, maturation rate, and age composition of bycatch estimates.

Historical estimates of AEQ are shown for the aggregate coastal western Alaska stocks (Figure 7; which includes the lower Yukon River, Kuskokwim, Bristol Bay and other components). Note that indicating historical AEQ removals by region implies that the relative distribution of salmon bycatch occurring in space and time would be the same as what was observed during the genetics sampling years (2005-2007). As described previously, the relative intensity of inter-annual patterns of pollock fishing areas and seasons affects the relative contribution of various stocks by year in the bycatch (Figure 8). As the proportion of fishing in the NW region of the EBS increases, the proportional contribution of Upper Yukon Chinook in the bycatch increases. Likewise the relative proportional increase in fishing in the SE results in an increase in the bycatch of Chinook stocks from the Pacific Northwest.

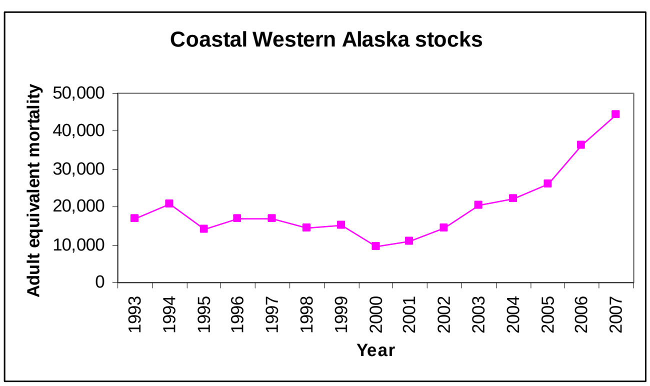


Figure 7. Annual estimated pollock fishery adult equivalent removals on stocks from the Coastal western Alaska returns, 1993-2007.

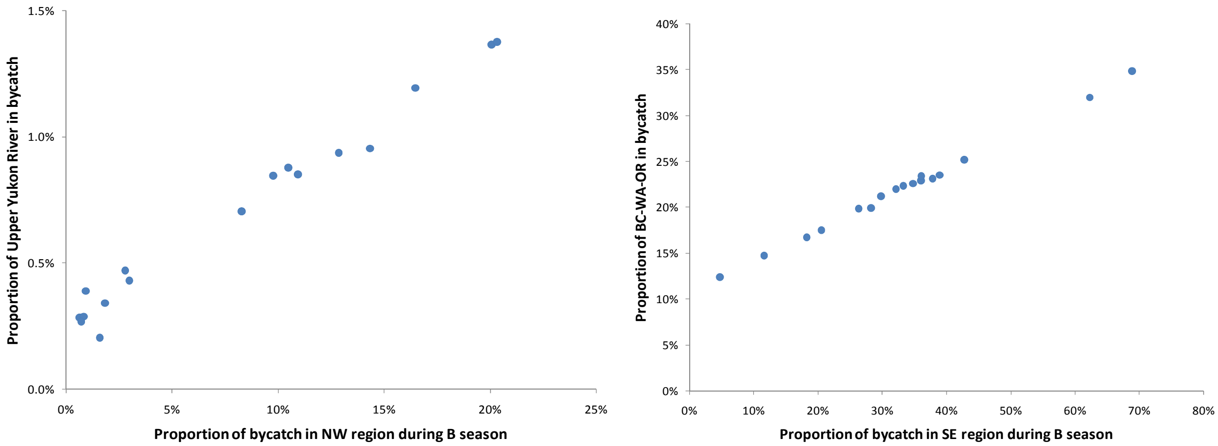


Figure 8. Illustration of how the overall proportion of Upper Yukon River relates to the bycatch proportion that occurs in the NW region (west of 170°W; top panel) and how the proportion of the BC-WA-OR (PNW) relates to the SE region (east of 170°W; bottom panel) during the summer-fall pollock fishery, 1991-2007.

## Update to AEQ analysis

A short study extends the analysis provided in the FEIS (and summarized above) through to 2012, by relating season- and area-specific PSC totals with the estimates of impact on numbers of returning adult equivalent Chinook salmon. Without re-running the AEQ model, it is possible to derive a simple calibration using regression analysis against available data on the absolute PSC levels by season and region in order to predict the anticipated impact of bycatch on in-river runs.

Two pieces of information are required. First, a time series of AEQ estimates is needed, which take into account age structure of the PSC, where and when the PSC occurred, the maturation rates observed for Chinook salmon, and the available information on stock identification. These are taken from the FEIS, and provided in Table 6. Second, Chinook salmon PSC by the pollock fleet in the eastern Bering Sea, updated through A-season 2012 (i.e., the winter fishery), are in Table 7.

Since the AEQ model from the EIS clearly indicates a lag effect (e.g., Fig. 6), and given that genetic estimates of stock identification vary by bycatch locales, creating a simple proxy approach that retains these characteristics was desired. For example, let the AEQ ($y_t$) estimate in year $t$ be

$$y_t = \beta_0 + \beta_1 T_{t-1} + \beta_2 T_{t-2} + \beta_3 A_t + \beta_4 B_{t-1}^{SE} + \beta_5 B_{t-1}^{NW} \ldots$$

where $T_{t-1}$ is the total Chinook PSC in the previous year, $A_t$ is the PSC in the A-season in year $t$, $B_{t-1}^{NW}$ is the PSC in the NW region in the previous year's B-season and so on. The coefficients $\beta_i$ are parameters to be estimated. A variety of models were proposed and AIC (Akaike 1974) statistic was used as a model selection criteria.

A stepwise model selection procedure ("stepAIC", Crawley 2007) in R was used to select among diverse sets of models. For coastal western Alaska Chinook salmon stocks, the following model was selected:

```
lm(formula = AEQ ~ A_0 + A_1 + BNW_0 + BNW_1 + BSE_0 + BSE_1)
```

with coefficients and diagnostics:

```
Residuals:
    Min      1Q  Median      3Q     Max 
-1522.4  -497.6  -137.8   574.0  1455.7 

Coefficients:
              Estimate Std. Error t value Pr(>|t|)    
(Intercept) 5854.33118  589.69481   9.928 2.24e-05 ***
A_0            0.34787    0.02317  15.016 1.39e-06 ***
A_1            0.20676    0.03171   6.521 0.000328 ***
BNW_0          0.32788    0.10000   3.279 0.013506 *  
BNW_1          0.30027    0.10223   2.937 0.021804 *  
BSE_0         -0.13617    0.03739  -3.642 0.008263 ** 
BSE_1          0.10771    0.03604   2.989 0.020265 *  
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1 

Residual standard error: 1106 on 7 degrees of freedom
Multiple R-squared: 0.9931,   Adjusted R-squared: 0.9872 
F-statistic: 167.8 on 6 and 7 DF,  p-value: 3.346e-07
```

all indicating a reasonable fit (~99% of the variability explained).

In words, this model indicates that coastal western Alaska Chinook salmon AEQ in year *t* can be well approximated with Chinook salmon PSC records on A-season catches in years *t* and *t-1* (A_0 and A_1 in the notation above) together with the same statistics for B-season but stratified to be east and west of 170°W (i.e., columns 2, 4, and 5 of Table 7 with appropriate lags). Applying recent data allows one to estimate updated AEQ impacts for coastal western Alaska and for 2011 the impact ranged from 5.4 thousand to 11.5 thousand Chinook salmon (Fig. 9; Table 8).  Even though the 2012 A-season Chinook PSC presently was relatively low (less than 9,000 fish) due to the higher PSC in 2011 (25,510 fish) the impact (in AEQ –in rivers terms) has already reached 12.5 thousand Chinook salmon (with 95% prediction interval ranging from 9.5 to 15.4 thousand fish).

As noted in the FEIS (NPFMC/NMFS 2010), genetic delineation was plausible for the middle and upper Yukon Chinook runs.  The same model selection process resulted in a model that indicated for the Upper Yukon stock that the PSC in the current-year A season and regionally split B-seasons explained nearly 96% of the variability:

```
lm(formula = AEQ ~ A_0 + BNW_0 + BSE_0 + BSE_1)      Upper Yukon

Residuals:
    Min      1Q  Median      3Q     Max
-70.747 -15.037   1.346  20.120  49.114

Coefficients:
              Estimate Std. Error t value Pr(>|t|)
(Intercept) 61.8881130 18.7598286   3.299  0.00925 **
A_0          0.0028181  0.0006251   4.509  0.00147 **
BNW_0        0.0406229  0.0031203  13.019 3.83e-07 ***
BSE_0       -0.0034026  0.0011900  -2.859  0.01880 *
BSE_1        0.0034277  0.0010548   3.250  0.01000 *
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 36.44 on 9 degrees of freedom
Multiple R-squared: 0.9713,    Adjusted R-squared: 0.9586
F-statistic: 76.23 on 4 and 9 DF,  p-value: 6.143e-07
```

Projecting this model forward for the Upper Yukon indicates variability with the upper 95% confidence bands from 2008-2012 ranging from 180 fish to 387 fish (Fig. 10; Table 9).

For the middle Yukon region, the characteristic and selected model was very similar to results from the Upper Yukon:

```
lm(formula = AEQ ~ A_0 + BNW_0 + BSE_0 + BSE_1)      Middle Yukon

Residuals:
   Min     1Q Median     3Q    Max
-86.00 -14.69  -1.94  23.43  54.11

Coefficients:
              Estimate Std. Error t value Pr(>|t|)
(Intercept) 71.3855795 22.7854771   3.133  0.01206 *
A_0          0.0025905  0.0007592   3.412  0.00772 **
BNW_0        0.0493457  0.0037899  13.020 3.83e-07 ***
BSE_0       -0.0036238  0.0014453  -2.507  0.03346 *
BSE_1        0.0040784  0.0012812   3.183  0.01112 *
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 44.26 on 9 degrees of freedom
Multiple R-squared: 0.9697,    Adjusted R-squared: 0.9562
F-statistic: 71.95 on 4 and 9 DF,  p-value: 7.897e-07
```

Results for the middle Yukon show the upper 95% confidence bands from 2008-2012 ranging from 210 fish to 451 fish (Fig.11; Table 10).

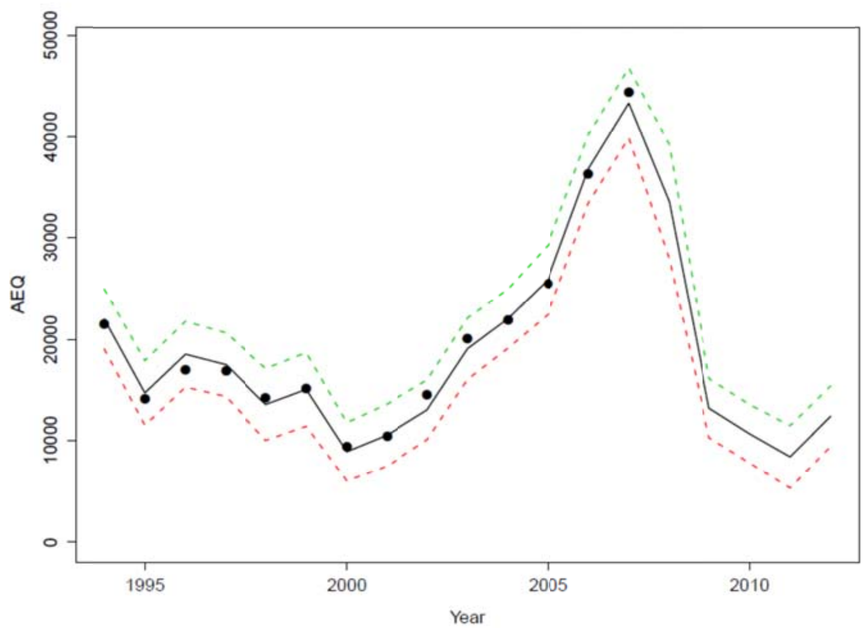


Figure 9. Estimated **coastal western Alaska** Chinook salmon adult equivalent mortality (AEQ; in numbers of fish) due to PSC in the eastern Bering Sea pollock fishery.

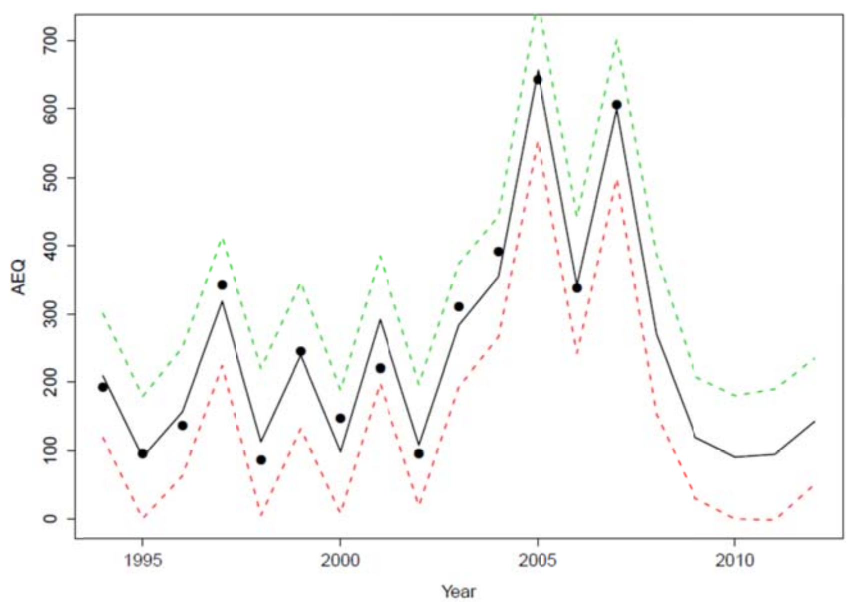


Figure 10. Estimated **Upper Yukon** Chinook salmon adult equivalent mortality (AEQ; in numbers of fish) due to PSC in the eastern Bering Sea pollock fishery.

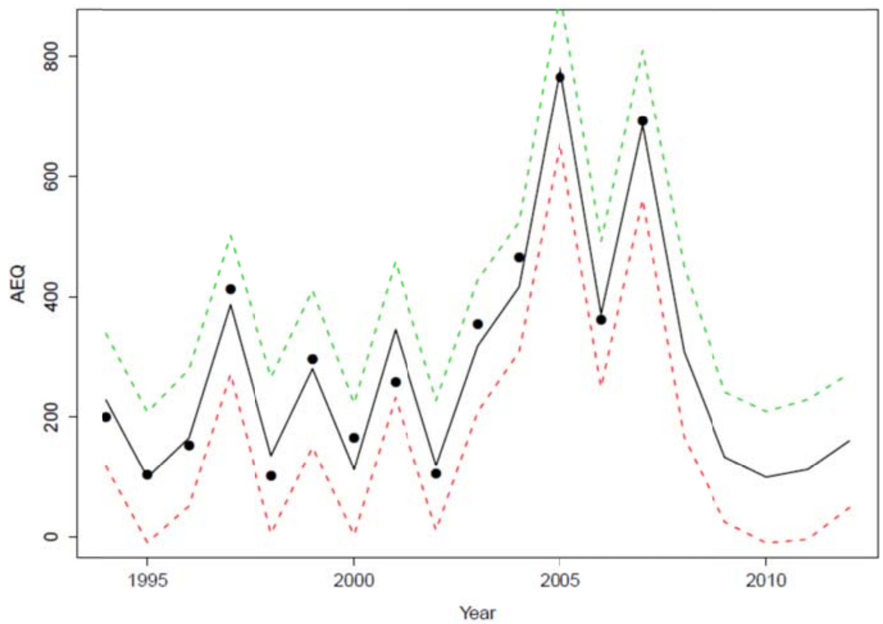


Figure 11. Estimated **Middle Yukon** Chinook salmon adult equivalent mortality (AEQ; in numbers of fish) due to PSC in the eastern Bering Sea pollock fishery.

Table 6. Median values of stochastic simulation results of AEQ Chinook mortality attributed to the pollock fishery by region, 1994-2007. These simulations include stochasticity in natural mortality (Model 2, CV=0.1), PSC age composition (via bootstrap samples), maturation rate (CV=0.1), and stock composition (as detailed above). **NOTE: these results are based on the assumption that the genetics findings from the 2005-2007 data represent the historical pattern of PSC stock composition (by strata).**

| | BC, WA, OR, and CA | Coastal W. AK | Cook Inlet | Middle Yukon | N. Alaska Peninsula | Other | Russia | Upper Yukon | TBR (SE) | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| 1994 | 5,198 | 21,518 | 242 | 201 | 4,898 | 714 | 147 | 194 | 198 | 33,310 |
| 1995 | 5,635 | 14,084 | 415 | 104 | 3,302 | 532 | 112 | 96 | 279 | 24,559 |
| 1996 | 6,974 | 17,025 | 520 | 154 | 3,939 | 632 | 142 | 137 | 364 | 29,886 |
| 1997 | 11,376 | 16,895 | 1,276 | 413 | 3,364 | 715 | 277 | 343 | 783 | 35,442 |
| 1998 | 10,967 | 14,218 | 1,110 | 103 | 3,382 | 696 | 165 | 87 | 711 | 31,439 |
| 1999 | 6,429 | 15,099 | 573 | 297 | 3,193 | 561 | 188 | 245 | 387 | 26,973 |
| 2000 | 2,815 | 9,383 | 219 | 167 | 2,106 | 330 | 99 | 147 | 152 | 15,418 |
| 2001 | 3,694 | 10,473 | 349 | 260 | 2,141 | 375 | 149 | 221 | 238 | 17,899 |
| 2002 | 6,236 | 14,516 | 509 | 106 | 3,467 | 609 | 117 | 96 | 341 | 25,997 |
| 2003 | 5,743 | 20,065 | 398 | 356 | 4,424 | 679 | 207 | 311 | 292 | 32,475 |
| 2004 | 10,164 | 21,904 | 1,018 | 466 | 4,592 | 859 | 305 | 393 | 685 | 40,386 |
| 2005 | 11,169 | 25,462 | 1,203 | 767 | 5,107 | 923 | 439 | 645 | 772 | 46,487 |
| 2006 | 12,719 | 36,337 | 892 | 363 | 8,355 | 1,348 | 290 | 339 | 633 | 61,275 |
| 2007 | 18,079 | 44,380 | 1,597 | 694 | 9,743 | 1,688 | 485 | 608 | 1,069 | 78,344 |

Table 7. Chinook salmon PSC from the eastern Bering Sea pollock fishery (all sectors including CDQ) by season and by region during the B-season, 1991-2012 (as of July 16, 2012). NW and SE regions encompass the area west and east of 170°W, respectively.

| Year | A-season | B-season | B-NW region | B-SE region | Total |
|---|---|---|---|---|---|
| 1991 | 36,838 | 2,215 | 366 | 1,849 | 39,053 |
| 1992 | 23,413 | 10,258 | 213 | 10,045 | 33,671 |
| 1993 | 15,415 | 21,204 | 7,344 | 13,860 | 36,619 |
| 1994 | 27,285 | 4,605 | 892 | 3,713 | 31,890 |
| 1995 | 8,982 | 4,421 | 112 | 4,309 | 13,403 |
| 1996 | 35,985 | 19,488 | 1,021 | 18,467 | 55,473 |
| 1997 | 10,347 | 33,974 | 6,358 | 27,616 | 44,321 |
| 1998 | 15,118 | 36,127 | 820 | 35,307 | 51,245 |
| 1999 | 6,351 | 5,626 | 1,309 | 4,317 | 11,977 |
| 2000 | 2,410 | 668 | 379 | 290 | 3,078 |
| 2001 | 8,571 | 10,477 | 5,460 | 5,018 | 19,049 |
| 2002 | 10,076 | 2,524 | 200 | 2,324 | 12,599 |
| 2003 | 30,805 | 12,016 | 3,802 | 8,214 | 42,821 |
| 2004 | 24,493 | 27,589 | 6,578 | 21,011 | 52,082 |
| 2005 | 28,581 | 38,277 | 13,021 | 25,256 | 66,858 |
| 2006 | 58,952 | 23,560 | 2,444 | 21,116 | 82,512 |
| 2007 | 70,879 | 51,480 | 10,033 | 41,447 | 122,359 |
| 2008 | 16,938 | 4,819 | 793 | 4,026 | 21,757 |
| 2009 | 9,514 | 2,708 | 582 | 2,126 | 12,222 |
| 2010 | 7,834 | 2,220 | 144 | 2,077 | 10,054 |
| 2011 | 7,147 | 18,363 | 1,531 | 16,832 | 25,510 |
| 2012 | 8,289 | 299 | 9 | 290 | 8,588 |

Table 8. **Coastal western Alaska** Chinook salmon PSC impact (in AEQ terms) from the eastern Bering Sea pollock fishery (all sectors including CDQ), 1994-2012 (as of July 16, 2012). Columns 3-5 contain predictions based on the linear model described in the text; bolded numbers are point estimates of impact due to PSC.

| Year | EIS AEQ Model | Linear Model Estimate | Lower CI | Upper CI |
|---|---|---|---|---|
| 1994 | 21,518 | 22,018 | 19,064 | 24,972 |
| 1995 | 14,084 | 14,738 | 11,558 | 17,918 |
| 1996 | 17,025 | 18,547 | 15,310 | 21,784 |
| 1997 | 16,895 | 17,514 | 14,379 | 20,649 |
| 1998 | 14,218 | 13,597 | 10,054 | 17,141 |
| 1999 | 15,099 | 15,080 | 11,452 | 18,707 |
| 2000 | 9,383 | 8,949 | 6,077 | 11,820 |
| 2001 | 10,473 | 10,586 | 7,523 | 13,649 |
| 2002 | 14,516 | 13,060 | 10,118 | 16,002 |
| 2003 | 20,065 | 19,092 | 16,068 | 22,117 |
| 2004 | 21,904 | 22,066 | 19,160 | 24,973 |
| 2005 | 25,462 | 25,930 | 22,505 | 29,354 |
| 2006 | 36,337 | 36,827 | 33,451 | 40,203 |
| 2007 | 44,380 | 43,354 | 39,905 | 46,802 |
| 2008 | | **33,590** | 27,953 | 39,227 |
| 2009 | | **13,239** | 10,328 | 16,151 |
| 2010 | | **10,715** | 7,833 | 13,597 |
| 2011 | | **8,437** | 5,365 | 11,509 |
| 2012 | | **12,452** | 9,470 | 15,434 |

Table 9. **Upper Yukon** Chinook salmon PSC impact (in AEQ terms) from the eastern Bering Sea pollock fishery (all sectors including CDQ), 1994-2012 (as of July 16, 2012). Columns 3-5 contain predictions based on the linear model described in the text; bolded numbers are point estimates of impact due to PSC.

| Year | EIS AEQ Model | Linear Model Estimate | Lower CI | Upper CI |
|---|---|---|---|---|
| 1994 | 194 | 210 | 119 | 301 |
| 1995 | 96 | 90 | 0 | 179 |
| 1996 | 137 | 157 | 63 | 251 |
| 1997 | 343 | 319 | 224 | 413 |
| 1998 | 87 | 112 | 5 | 220 |
| 1999 | 245 | 239 | 132 | 347 |
| 2000 | 147 | 98 | 7 | 188 |
| 2001 | 221 | 292 | 199 | 385 |
| 2002 | 96 | 108 | 18 | 197 |
| 2003 | 311 | 283 | 193 | 373 |
| 2004 | 393 | 355 | 266 | 444 |
| 2005 | 645 | 657 | 554 | 761 |
| 2006 | 339 | 342 | 242 | 442 |
| 2007 | 608 | 601 | 499 | 703 |
| 2008 | | **270** | 153 | 387 |
| 2009 | | **119** | 30 | 208 |
| 2010 | | **90** | 0 | 180 |
| 2011 | | **94** | 0 | 190 |
| 2012 | | **142** | 50 | 234 |

Table 10. **Middle Yukon** Chinook salmon PSC impact (in AEQ terms) from the eastern Bering Sea pollock fishery (all sectors including CDQ), 1994-2012 (as of July 16, 2012). Columns 3-5 contain predictions based on the linear model described in the text; bolded numbers are point estimates of impact due to PSC.

| Year | EIS AEQ Model | Linear Model Estimate | Lower CI | Upper CI |
|---|---|---|---|---|
| 1994 | 201 | 229 | 119 | 340 |
| 1995 | 104 | 100 | 0 | 209 |
| 1996 | 154 | 166 | 52 | 280 |
| 1997 | 413 | 387 | 272 | 502 |
| 1998 | 103 | 136 | 5 | 266 |
| 1999 | 297 | 281 | 150 | 411 |
| 2000 | 167 | 113 | 3 | 223 |
| 2001 | 260 | 346 | 233 | 459 |
| 2002 | 106 | 119 | 11 | 228 |
| 2003 | 356 | 318 | 209 | 428 |
| 2004 | 466 | 417 | 309 | 525 |
| 2005 | 767 | 782 | 656 | 908 |
| 2006 | 363 | 371 | 250 | 493 |
| 2007 | 694 | 686 | 562 | 810 |
| 2008 | | **309** | 167 | 451 |
| 2009 | | **133** | 25 | 242 |
| 2010 | | **100** | 0 | 210 |
| 2011 | | **113** | 0 | 230 |
| 2012 | | **161** | 49 | 273 |

The combined 2011 Alaska harvests of Chinook salmon are reported at 468,000 fish (Eggers and Carroll 2012). For western Alaska region, the combined run sizes are on the order of 500-800 thousand fish whereas for the Upper Yukon, the run sizes average around 75-100 thousand fish. In comparison, recent estimates of PSC impacts are on the order of 10 – 15 thousand Chinook for all of coastal western Alaska and in the 100-500 fish range for the middle and Upper Yukon.

## Overview of Council action –Amendment 91

The Council took final action on Amendment 91, Chinook salmon PSC management measures in the Bering Sea pollock fishery in April 2009. NMFS approved regulations implementing Amendment 91 on August 30, 2010 (72 FR 53026), and the fishery has been operating under the requirements since January 2011. Amendment 91 established two Chinook salmon PSC limits (60,000 Chinook salmon and 47,591 Chinook salmon) for the Bering Sea pollock fishery. For each PSC limit, NMFS issues A season and B season Chinook salmon PSC allocations to the catcher/ processor sector, the mothership sector, the inshore cooperatives, and the CDQ groups. When a PSC allocation is reached, the affected sector, inshore cooperative, or CDQ group is required to stop fishing for pollock for the remainder of the season even if its pollock allocation had not been fully harvested.

NMFS issues transferable allocations of the 60,000 Chinook salmon PSC limit to those sectors that participate in an incentive plan agreement (IPA) and remain in compliance with the performance standard. Sector and cooperative allocations would be reduced if members of the sector or cooperative decided not to participate in an IPA. Vessels and CDQ groups that do not participate in an IPA fish under a restricted opt-out allocation of Chinook salmon. If a whole sector does not participate in an IPA, all members of that sector would fish under the opt-out allocation.

The IPA component was designed as an innovative approach for fishery participants to design industry agreements with incentives for each vessel to avoid Chinook salmon bycatch at all times and thus reduce bycatch below the PSC limits. To ensure participants develop effective IPAs, the final rule required that participants submit annual reports to the Council that evaluate whether the IPA is effective at providing incentives for vessels to avoid Chinook salmon at all times while fishing for pollock. The sector-level performance standard ensures that the IPA is effective and that sectors cannot fully harvest the Chinook salmon PSC allocations under the 60,000 Chinook salmon PSC limit in most years. Each year, each sector is issued an annual threshold amount that represents that sector's portion of 47,591 Chinook salmon. For a sector to continue to receive Chinook salmon PSC allocations under the 60,000 Chinook salmon PSC limit, that sector must not exceed its annual threshold amount three times within 7 consecutive years. If a sector fails this performance standard, it will permanently be allocated a portion of the 47,591 Chinook salmon PSC limit. Under Amendment 91, NMFS would issue transferable allocations of the 47,591 Chinook salmon PSC limit to all sectors, cooperatives, and CDQ groups if no IPA is approved, or to the sectors that exceed the performance standard.

This program was implemented in January 2011, thus the fishery has operated under the new program for one year. The first annual reports by the industry to the Council were provided in April 2012.

## Status of 2011-12 first two years of implementation

2011 was the first year of implementation under the new program for Chinook bycatch management. The industry began with a voluntary stand down in late January to avoid Chinook. Incidental catch of Chinook salmon by the pollock fishery participants in the 2011 indicated that pollock fishery participants remained well below their limits and with catch much lower than in the recent five years. Total 2011 A-season PSC was 7,136 fish. This compares to Chinook salmon PSC ranging from 7,624 fish in the A season of 2010 to 69,139 fish in the A season of 2007. In the B-season incidental catch of Chinook salmon by the pollock fishery was also well below the seasonal PSC limits with a total B-season bycatch of 18,363. This is higher than B-season PSC in the previous 3 years but is substantially less than the B-season of 2007 where 25,499 fish were taken. The overall 2011 total Chinook PSC was 25,499. While this amount is higher than the recent years (driven by the increase in the B-season) this was nonetheless well below both the overall PSC limit under Amendment 91 as well as the (lower) performance standard established under that management program. In contrast, in 2012, the A-season PSC was 7,773 fish while B-season catch was substantially lower at 3,577.

## Council consideration of chum measures and impacts on Chinook

The Council is now considering additional management measures targeted at chum salmon bycatch reduction on the EBS pollock fishery. As with the measures considered for Chinook, the Council is considering a combination of hard cap limits and area closures as well as conferring primary management responsibility to the industry to manage a rolling hotspot program as is done currently. Measures under consideration are intended to target proving protection for WAK chum stocks by focusing on June and July measures when genetic information has indicated there is a higher proportion of WAK bound chum on the fishing grounds (Kondzela et al. 2012; Gray et al, 2011, Gray et al., 2010). However, policy decisions for alternative management measures for chum must also consider the potential impact on the catch of Chinook salmon as a result of imposing additional management measures on the same pollock fishery. The pollock fishery catches both chum and Chinook salmon PSC in the B-season. The timing of this catch is dissimilar amongst the two species, with Chinook salmon caught in the latter part of the B season and chum salmon caught throughout the B season (Figure 12). Current analysis of the impact of various chum management measures under consideration show that chum measures appear to result in more fishing later in the year and thus will result in more Chinook bycatch. A revised industry-initiated and managed rolling hot-spot program is under consideration which attempts to address the balance between prioritization of Chinook and chum avoidance measures in the same season. The Council will review a draft analysis in December 2012. Final action by the Council is likely in April 2013 with any regulations to implement a new program likely by 2015.

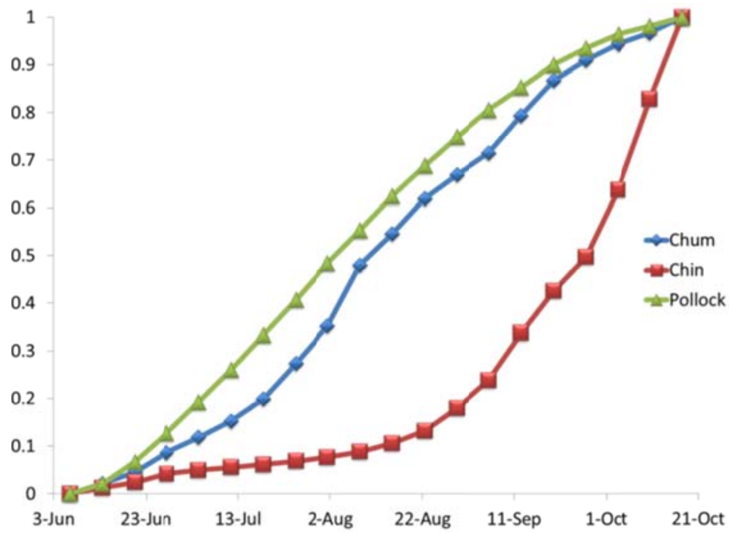


Figure 12. Mean relative values of pollock catch (triangles) compared with catch of chum (diamonds) and Chinook (squares) salmon species in the pollock fishery during the B-season.

## Research Recommendation

Several recommendations for additional analyses to assist management are provided below based on experiences with analyzing these data for impact analyses as well as new genetics information.

1. AEQ/genetics analysis of bycatch on recent genetics data: To date the only AEQ and genetics evaluations on EBS bycatch that have been conducted have been done so in conjunction with Council analyses of modifying management measures. As a result of Amendment 91 annual reports of genetics of proportions from bycatch in the groundfish fisheries are being provided, however absent a Council decision to conduct an analysis of modifying management measures, no additional updated analysis of bycatch AEQ and genetic stock of origin is anticipated. Ideally an annual or periodic update to the Council on the genetic analysis of the bycatch (specifically in the EBS pollock fishery) would be advisable.
2. Spatial analysis of genetics for potential consistency over time: In evaluating appropriate management measures to reduce WAK bound Chinook (and chum) salmon additional analyses on the spatial consistency over time on a small a scale as possible would be extremely useful.
3. Evaluation of bycatch of Chinook in other EBS fisheries outside of pollock: Currently management measures are targeted at the EBS pollock fishery as this comprises the majority of the bycatch of both salmon species. Recent genetic stock composition proportions however include bycatch from other groundfish fisheries. To the extent that these fisheries bycatch could be examined separately for spatial and temporal consistency in genetic stock proportions this may give an indication of other fisheries contribution to bycatch impacts. Potentially should information indicate that fisheries outside of the EBS pollock fishery contribute less bycatch annually but a disproportionate impact consistently on some stocks (e.g. Upper Yukon Chinook) this would be informative for future management actions on other groundfish fisheries.

## References:

Akaike, H. 1974. A new look at the statistical model identification. IEEE Transactions on Automatic Control 19 (6): 716–723.

Crawley, M.J. 2007. *The R Book.* Wiley. 945p.

Eggers, D.M. and A.M. Carroll. 2012. Run forecasts and harvest projections for 2012 Alaska salmon fisheries and review of the 2011 season. Alaska Department of Fish and Game, Special Publication No. 12-01, Anchorage.

Gray, A. K.,W. T. McCraney, C. T. Marvin, C. M. Kondzela, H. T. Nguyen and J. R. Guyon. 2011. Genetic stock composition analysis of chum salmon bycatch samples from the 2008 Bering Sea groundfish fisheries, 29 p. NTIS No. PB2011-110765.

Gray, A. K.,W. T. McCraney, C. T. Marvin, C. M. Kondzela, H. T. Nguyen and J. R. Guyon. 2011. Genetic stock composition analysis of chum salmon bycatch samples from the 2007 Bering Sea groundfish fisheries, 29 p. NTIS No. PB2011-110764.

Guthrie, C. M. III, H. T. Ngyen, and J. R. Guyon. 2012. Genetic stock composition analysis of chinook salmon bycatch samples from the 2010 Bering Sea trawl fisheries, U.S Dep Commer., NOAA Tech. Memo. NMFS-AFSC-232.

Marvin, C. T., S. L. Wildes, C. M. Kondzela, H. T. Nguyen, and J. R. Guyon. 2011. Genetic stock composition analysis of chum salmon bycatch samples from the 2006 Bering Sea groundfish fisheries, 29 p. NTIS No. PB2011-108416.

Myers, K.W., R.V. Walker, J.L. Armstrong, and N.D. Davis. 2003. Estimates of the bycatch of Yukon River Chinook salmon in U.S. groundfish fisheries in the eastern Bering Sea, 1997-1999. Final Report to the Yukon River Drainage Fisheries Association, Contr. No. 04-001. SAFS-UW-0312, School of Aquatic and Fishery Sciences, University of Washington, Seattle. 59 p.

Myers, K.W., and D.E. Rogers. 1988. Stock origins of Chinook salmon in incidental catches by groundfish fisheries in the eastern Bering Sea. North American Journal of Fisheries Management 8:162-171.

Myers, K.W., D.E. Rogers, C.K. Harris, C.M. Knudsen, R.V. Walker, and N.D. Davis. 1984. Origins of Chinook salmon in the area of the Japanese mothership and landbased driftnet salmon fisheries in 1975-1981. International North Pacific Fisheries Commission Document, Fisheries Research Institute, University of Washington, Seattle. 204 p.

North Pacific Fishery Management Council (NPFMC)/National Marine Fisheries Service (NMFS) 2009. Bering Sea Chinook Salmon Bycatch Management Final Environmental Impact Statement. NOAA/NMFS Alaska Region. Juneau, AK.

Seeb, J.E,. S. Abe, S. Sato, S. Urawa, N. Varnavskaya, N. Klovatch, E.V. Farley, C. Guthries, B. Templin, C. Habicht, J.M. Murphy, L.W. Seeb. 2008. The Use of Genetic Stock Identification to Determine the Distribution, Migration, Early Marine Survival, and Relative Stock Abundance of Sockeye, Chum, and Chinook Salmon in the Bering Sea. Poster presentation at the North Pacific Anadromous Fish Commission International Symposium on Bering-Aleutian Salmon International Surveys (BASIS): Climate Change, Production Trends, and Carrying Capacity of Pacific Salmon in the Bering Sea and Adjacent Waters. Seattle, Washington. November 23-25, 2008.

Stram, D. L., and J. N. Ianelli. 2009. Eastern Bering Sea pollock trawl fisheries: variation in salmon bycatch over time and space. *In* C. C. Krueger and C. E. Zimmerman, editors.

Pacific salmon: ecology and management of western Alaska's populations. American Fisheries Society, Symposium 70, Bethesda, Maryland.

Witherell, D.W., D. Ackley and C. Coon. 2002. An overview of salmon bycatch in Alaska groundfish fisheries. Alaska Fishery Research Bulletin (9)1:53-6.