Updated Passage Estimates for the Pilot Station Sonar Project, 1995–2015

by

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and

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October 2017

Alaska Department of Fish and Game

Divisions of Sport Fish and Commercial Fisheries
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#### Weights and measures (metric)
- centimeter cm
- decimeter 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 ft³/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.
- compass directions: east E, north N, south S, west W
- copyright ©
- District of Columbia et alii (and others) e.g.
- et cetera (and so forth) etc.
- Federal Information Code FIC
- id est (that is) i.e.
- latitude or longitude lat or long
- monetary symbols (U.S.) S, $, €
- months (tables and figures): first three letters Jan., Feb., Dec.
- registered trademark trademark ®
- trademark ™
- United States (adjective) U.S.
- United States of America (noun) U.S.A
- United States Code U.S.C.
- United States Code 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, $\chi^2$, etc.) CI
- confidence interval
- correlation coefficient (multiple) $R$
- correlation coefficient (simple) $r$
- covariance $\text{cov}$
- degree (angular) °
- degrees of freedom df
- expected value $E$
- greater than $>$
- greater than or equal to $\geq$
- harvest per unit effort HPUE
- less than $<$
- less than or equal to $\leq$
- logarithm (natural) $\ln$
- logarithm (base 10) $\log$
- logarithm (specify base) $\log_b$, etc.
- minute (angular) '
- not significant NS
- null hypothesis $H_0$
- percent %
- probability $P$
- probability of a type I error (rejection of the null hypothesis when true) $\alpha$
- probability of a type II error (acceptance of the null hypothesis when false) $\beta$
- second (angular) "
- standard deviation SD
- standard error SE
- variance
- population Var
- sample var
UPDATED PASSAGE ESTIMATES FOR THE PILOT STATION SONAR PROJECT, 1995–2015

by
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ABSTRACT
Methodology used to apportion sonar counts to species at the Pilot Station sonar project was modified to limit the influence of fish with very low probability of capture. In addition, net selectivity parameters were recomputed using test gillnet data from 1990 to 2015, prior parameters only used data from 2000 to 2009. The code used to generate estimates was changed to reflect the modified methodology and the updated parameters were used to update daily estimates of fish passage by species from 1995 to 2015.

Key words sonar, dual-frequency identification sonar, DIDSON, net selectivity, Yukon River

INTRODUCTION
The Pilot Station sonar project, located on the Yukon River at river km 197 near the community of Pilot Station, is the most complex and comprehensive fish passage counting project in Alaska. The project was initiated in the 1980s and since 1995 the project has estimated passages of Chinook salmon (*Oncorhynchus tshawytscha*), summer and fall chum salmon (*O. keta*), coho salmon (*O. kisutch*), pink salmon (*O. gorbuscha*), humpback whitefish (*Coregonus pidschian*), broad whitefish (*C. nasus*), sheefish (*Stenodus leucichthys*), and cisco (*Coregonus* spp).

The sonar project consists of 2 processes: (1) estimating total fish passage (*N*), and (2) estimating species proportion (*ps*). Then, passage of fish by species (*Ns*) is estimated by multiplying the 2 components (i.e., *Ns* = *N*·*ps*). The first step involves estimating total fish passage by counting migrating fish detected using split-beam and imaging sonar, and the second step estimates the relative proportion of each species from the catches of drift gillnets. Although the accuracy of enumerating total passage has been improved by advancement of sonar technologies, estimating species proportions remain very difficult because fishing gear is selective to fish of particular morphologies and behaviors, in other words, every fish has different probability of capture. To compensate for the differential probability of capture, the Pilot Station sonar program employs gillnets of varying mesh sizes (2.75 to 8.5 inches) and fishing occurs at multiple stations along the river. Probability of capture is adjusted by net selectivity for each species (for details see Maxwell et al 1997; Carol and McIntosh 2008; Lozori and McIntosh 2014).

Since initiation of the project, statistical methods for estimating species apportionment have been reviewed and revised several times (see Methods for details), mostly to improve passage estimates of Chinook salmon. Since its inception, Chinook salmon passages by Pilot Station sonar have been considered an underestimate. Chinook salmon estimates at Pilot Station were lower than those estimated by a radiotelemetry mark–recapture study conducted approximately 90 miles upstream of Pilot Station during 2000–2004 (Spencer et al. 2009) as well as those estimated by genetic mark–recapture during 2005–2010 (Hamazaki and Decovich 2014). There are undoubtedly some fish that pass beyond the counting range of the sonar, but this number is probably low based on the distribution of targets observed at the site (Schumann and McIntosh 2017) and would not explain the discrepancy given the low proportion of Chinook salmon that would be applied to these missed counts. A more reasonable explanation is error or bias in species apportionment due to non-representative sampling or problems with the selectivity model. On occasion, it has been observed that least and Bering cisco (*C. sardinella* and *C. laurettae*) have received very high weighting that in many cases appear to inflate the cisco estimates at the expense of salmon estimates. For this reason, we believe that part of the underestimation was due to the relative shape of net selectivity curves between Chinook salmon and other species migrating concurrently (Figure 1). The selectivity parameters for cisco in particular produce narrow curves resulting in low probability of capture (and hence high
weighting) for fish that deviate even slightly from the mode. This prompted us to review and revise species apportionment methodologies. Additionally, historical changes in species apportionment methodologies have not been well documented. This report documents the changes made to the selectivity parameters, the methodology used to revise the historical estimates, and a summary of the revised estimates.

**OBJECTIVES**

- Document changes to the net selectivity parameters used at the Pilot Station sonar project.
- Document methodology used to revise historical estimates.
- Present a summary of the revised historical estimates for the Pilot Station sonar project.

**METHODS**

**HISTORICAL CHANGES OF SPECIES APPORTIONMENT METHODOLOGY**

In the Pilot Station sonar project, species proportion \( p_l \) at a fishing zone of a period is calculated by summing catch per unit effort (CPUE) of each length \( l \) of a species \( i \) across all mesh sizes, divided by CPUE of all species and all lengths:

\[
\hat{p}_l = \frac{\sum_i CPUE_{il}}{\sum_{i,l} CPUE_{il}}. \tag{1}
\]

Historical changes on species apportionment methodology occurred regarding species-length specific CPUE calculation and estimation of net-selectivity (Table 1).

From 1995 to 1999, CPUE was calculated by each mesh and length and then summed across meshes by length:

\[
CPUE_{il} = \sum_m c_{ilm} s_{ilm} f_m, \tag{2}
\]

where \( c_{ilm} \) is the number of a species \( i \) of a length \( l \) caught by gillnet of a mesh size \( m \); \( s_{ilm} \) is the net selectivity (ranging 0 to 1.0), and \( f_m \) is a fishing effort of the gillnet mesh size \( m \) deployed. To prevent overinflating CPUE, fish with selectivity values less than 0.1 were censored from CPUE calculation (i.e., \( c_{ilm} = 0 \) when \( s_{ilm} < 0.1 \)).

In 2000, CPUE calculation was modified to:

\[
CPUE_{uil} = \frac{\sum_m c_{ilm}}{\sum_m s_{ilm} f_m}. \tag{3}
\]

In this equation, catch of a species \( i \) of each length \( l \) caught by gillnet of a mesh size \( m \) \( (c_{ilm}) \) was summed across all mesh sizes, and then divided by product of net selectivity \( (s_{ilm}) \), and fishing effort of the gillnet \( (f_m) \) summed across all mesh sizes. This eliminated over inflation of catches of low net selectivity, and thus, minimum cut-off net selectivity was eliminated. In 2005, minimum selectivity criteria were reinstated along with new selectivity function. Catches and selectivity less than 0.01 were censored (i.e., \( s_{ilm} = 0 \) and \( c_{ilm} = 0 \) when \( s_{ilm} < 0.01 \)).
Estimation of Net Selectivity

From 1995 to 2004, a modified form of Schunte and Sibert’s (1983) equation was used and net selectivity parameters were estimated using all available (1990–1995) data in 1996. It is unknown how often the parameters were updated for estimation of subsequent years:

\[ s_j(l) = \exp\left(-\alpha\left(\frac{l_{m_j}}{\sigma} - \tau\right)\right) \cdot \left(1 - \beta\right)^{1 - y_j} \cdot \left(1 - \min\left(1, \beta \exp\left(-\alpha\left(\frac{l_{m_j}}{\sigma} - \tau\right)\right)\right)^{1 - y_j}\right). \]  \hspace{1cm} (4)

Net selectivity was originally estimated for 5 salmon species (Chinook, summer chum, fall chum, coho, and pink salmon), large whitefish (Broad, Humpback whitefish), cisco, and other miscellaneous species.

In 2005, the net selectivity model was revised to the Pearson model with the addition of a tangling parameter for fish caught in small mesh size (Bromaghin 2004, 2005):

\[ s_j(l) = \left[1 + \left(\frac{\lambda}{2\theta}\right)^2\right]^{\theta/2} \cdot \left[1 + \left(\frac{l - \frac{\alpha l}{\beta}}{\sigma}\right)^2\right]^{-\theta} \exp\left[ -\lambda \left(\tan^{-1}\left(\frac{l - \frac{\alpha l}{\beta}}{\sigma}\right) + \tan^{-1}\left(\frac{\lambda}{2\theta}\right)\right)\right]. \]  \hspace{1cm} (5)

Net selectivity was estimated using 2000–2009 test fishery data to reflect possible net selectivity change associated with morphological change over time.

Proposed Revision 2016

The major revision implemented was to raise the minimum net selectivity to 0.1 and not censor catches (i.e., \( s_{ILM} = 0.1 \) when \( s_{ILM} < 0.1 \)). This minimum threshold approach will include all captured fish in the estimation process while preventing outliers from disproportionally affecting the estimates. We also revised estimation of net selectivity parameters using all historical data (1990–2015) because limiting datasets increases fluctuations in net selectivity estimates. With the large dataset, we were also able to estimate net selectivity of sheefish.

Estimation of 2005 Total Sonar

Prior to 2005, the project operated dual-beam or split-beam sonar only. In 2005, DIDSON (dual-frequency identification sonar) passage counting was introduced on the left bank for the first time on June 19, about 3 weeks after split-beam sonar counting was started. It was at about this time the left bank profile changed considerably. What was once a gradual slope (approximately 2°) was becoming a cut bank (approximately 10° slope), making it difficult to fully insonify the water column with the narrow split-beam transducers. It was believed the wider beam of the DIDSON would provide better coverage, particularly in the nearshore. For most years prior to 2005, the slope was gradual and we do not believe compromised in this way, therefore estimates from prior years were not adjusted. As expected, the DIDSON tended to count more fish than split-beam for the first 20 m of the left-bank. Thus, during the periods when both sonars were operated, DIDSON counts were used for the first 20 m, unless split-beam counts were higher – which would have occurred in the rare event the DIDSON was improperly aimed.
For the first 20 m counts during the period of June 1–June 18 when the DIDSON was not installed, we estimated DIDSON equivalent counts using a regression as:

$$\hat{N}_{D,d} = \alpha N_{S,d},$$

where $N_{S,d}$ is counts of the first 20 m of left bank by split-beam.

Parameter $\alpha$ was estimated using data from June 19 to July 7. Data from later in the season was not used because the relationship changed as the season progressed and the water level decreased.

**ESTIMATION OF PASSAGE BY SPECIES**

Though passages of whitefish have been estimated separately, their passages have been combined as other species. This revision reports run size and trend of whitefish species for the first time.

**COMPARISON WITH OTHER INDICATORS OF RUN ABUNDANCE**

Unfortunately, for most species passing the sonar site, there are few estimates of run abundance that can be used to ground truth the sonar estimates. For Chinook salmon, a mark–recapture project was operated from 2000 to 2004 (Spencer et al. 2009) and the Eagle sonar project started providing estimates in 2005, which, when combined with harvest and estimates of genetic stock identification, provides an estimate of total abundance (Hamazaki and Decovich 2014). The Alaska Department of Fish and Game (ADF&G) also produces an estimate of the drainagewide run of fall chum salmon using escapement estimates on tributaries and historical relationships (Fleischman and Borba 2009; Estensen et al. 2017). All of these independent estimates have sources bias and uncertainty complicating direct comparison; however, they are the best alternative estimates available. The old and new Pilot Station estimates of Chinook and fall chum salmon passage were compared with these other estimates of run size to determine whether the previously observed biases were lessened.

**RESULTS**

Sample sizes for the selectivity parameters generated were 14,213 Chinook salmon, 85,669 summer chum salmon, 43,813 fall chum salmon, 22,390 coho salmon, 13,448 pink salmon, 2,798 broad whitefish, 8,830 humpback whitefish, 12,360 cisco, 3,490 sheefish, and 2,892 others. In general, the new selectivity parameters (Table 2) were similar to those generated in 2010 using the 2000–2009 data (Table 3), the exceptions are broad whitefish and cisco for which the new curves are slightly broader (Appendix B1). The new sheefish curves appear narrower, but that is only compared to the previous others category to which sheefish were previously grouped.

The revised estimates were generally higher for Chinook, summer chum, fall chum, coho, and pink salmon with reductions in the other species (Tables 4–13). On average, Chinook salmon passage increased by 35,000 (ranging from 4,116 in 1997 to 99,299 in 2005), which corresponds to an increase of 26%. Direction of revised summer chum salmon passage was variable. Though it increased by about 53,000 on average, it ranged from -56,524 in 1997 to 183,886 in 2008. Generally, revised passage was lower before 2005. On the other hand, fall chum passage size increased consistently, with average of 69,000 (2,295 in 1998 to 173,675 in 2006) or 12% on average. Coho salmon increased by 21,000 on average (9,459 in 1998 to 51,250 in 2014) or 16%
on average. The largest increase was pink salmon with average increase of 46,000 or increase of 81%. Those revised changes, however, did not alter overall historical abundance trends.

The effect on individual species within the other grouping (cisco, sheefish, etc.) cannot be easily determined because they were previously grouped and sheefish did not have separate parameters prior to generating these new parameters. Updated daily passage estimates by species can be obtained from the ADF&G, Division of Commercial Fisheries, Arctic-Yukon-Kuskokwim database management system (AYKDBMS)\(^1\).

The 2005 expansion of split-beam estimates for 0–20 m (Table 14) using paired split-beam/DIDSON data resulted a significant positive relationship with DIDSON estimates 25.171 times the split-beam (Table 15). Expanding the split-beam estimates for June 1–18 by this relationship increased Chinook salmon estimates by 71,138, summer chum salmon estimates by 186,052, cisco by 14,671, humpback whitefish by 1,389, broad whitefish by 10,259, and sheefish by 36,836 (Table 16).

**DISCUSSION**

The combination of updated selectivity parameters and minimum selectivity threshold affected all species to varying degrees. The estimates for all salmon species increased but the combined others decreased. The salmon species least affected was summer chum which only increased 2.69% on average whereas the salmon species most affected was pink salmon at 80.68% (Tables 4–13). It should be noted that the average percent increase in pink salmon is inflated in even years when the run sizes are very small, and a small increase results in a large percentage gain. Others decreased by 31.19% on average (Table 13). Although the historical estimates for others are not broken out by species, it stands to reason the largest change was in cisco because the parameters for that species changed more dramatically than any of the others, as evidenced in the curves (Appendix C1). Specifically, the new parameters result in a much broader curve for cisco, the effect of which is that small deviations from peak efficiency will not result in large changes to selectivity; in other words, the new parameters for cisco are less sensitive to small differences in length than the old parameters were.

Overall, the updated selectivity parameters and minimum selectivity value used in estimation appears to improve the passage estimates at the Pilot Station sonar project. The concern about 1 or 2 fish disproportionally affecting estimates, particularly when in the presence of salmon, appears to be alleviated. The spikes in the daily estimates of others are much reduced, as evidenced in the 2015 field season (Figure 2). Additionally, the new estimates of Chinook and fall chum salmon are much closer to independent estimates of run size. On average, the previous estimates of Chinook salmon were 80% of the mark–recapture estimates, whereas the new estimates are 101% (Table 17). Likewise, the previous estimates of fall chum were 83% of the reconstructed run above Pilot Station whereas the new estimates are 92% (Table 18). Given the improvement in the comparisons of Chinook and fall chum salmon to independent run estimates, these changes should be incorporated into the project methodology going forward.

**ACKNOWLEDGEMENTS**

We would like to thank the crews at the Pilot Station sonar project for collecting the data used to generate the passage estimates.

REFERENCES CITED


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<td><strong>Minimum selectivity</strong></td>
<td>0.1</td>
<td>None</td>
<td>0.01</td>
<td>0.01</td>
<td>0.1</td>
</tr>
<tr>
<td><strong>Catches of minimum selectivity</strong></td>
<td>Remove</td>
<td>NA</td>
<td>Remove</td>
<td>Remove</td>
<td>Change to 0.1</td>
</tr>
<tr>
<td><strong>Species apportionment formula</strong></td>
<td>Eq (2)</td>
<td>Eq (3)</td>
<td>Eq (3)</td>
<td>Eq (3)</td>
<td>Eq (3)</td>
</tr>
</tbody>
</table>

### Table 2.–New net selectivity parameters derived from test fishery data, 1990–2015.

<table>
<thead>
<tr>
<th>Species</th>
<th>Tau</th>
<th>Sigma</th>
<th>Theta</th>
<th>Lambda</th>
<th>Tangle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chinook</td>
<td>1.902078925</td>
<td>0.186802768</td>
<td>0.660152352</td>
<td>-0.746205354</td>
<td>0.000000000</td>
</tr>
<tr>
<td>Jack</td>
<td>1.902078925</td>
<td>0.186802768</td>
<td>0.660152352</td>
<td>-0.746205354</td>
<td>0.000000000</td>
</tr>
<tr>
<td>Chum</td>
<td>2.043533171</td>
<td>0.16348896</td>
<td>0.771205361</td>
<td>0.003003834</td>
<td>0.042598264</td>
</tr>
<tr>
<td>Fall Chum</td>
<td>1.889853171</td>
<td>0.351076269</td>
<td>2.437277643</td>
<td>-2.657357848</td>
<td>0.055488254</td>
</tr>
<tr>
<td>Coho</td>
<td>1.942331380</td>
<td>0.277217781</td>
<td>0.831494925</td>
<td>-1.555468800</td>
<td>0.058675124</td>
</tr>
<tr>
<td>Pink</td>
<td>2.050473071</td>
<td>0.140560927</td>
<td>1.682653781</td>
<td>4.999993900</td>
<td>0.095370569</td>
</tr>
<tr>
<td>Broad Whitefish</td>
<td>1.799596516</td>
<td>0.192226804</td>
<td>0.924401709</td>
<td>-1.734789466</td>
<td>0.036245892</td>
</tr>
<tr>
<td>Humpback Whitefish</td>
<td>1.899857017</td>
<td>0.243394240</td>
<td>1.096037183</td>
<td>-1.998617643</td>
<td>0.030946407</td>
</tr>
<tr>
<td>Cisco</td>
<td>2.172545305</td>
<td>0.523398220</td>
<td>3.052048956</td>
<td>-2.754044551</td>
<td>0.016236055</td>
</tr>
<tr>
<td>Sheefish</td>
<td>2.113091700</td>
<td>0.193596124</td>
<td>0.755242549</td>
<td>-1.632169044</td>
<td>0.000000000</td>
</tr>
<tr>
<td>Other</td>
<td>2.265164567</td>
<td>0.325796239</td>
<td>0.860665310</td>
<td>-1.474167113</td>
<td>0.000000000</td>
</tr>
</tbody>
</table>
Table 3.–Original selectivity parameters used from 2009 to 2015 derived from 2000 to 2009 test fishery data.

<table>
<thead>
<tr>
<th>Species</th>
<th>Tau</th>
<th>Sigma</th>
<th>Theta</th>
<th>Lambda</th>
<th>Tangle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chinook</td>
<td>1.9008</td>
<td>0.2050</td>
<td>0.5923</td>
<td>-0.4334</td>
<td>0.023940</td>
</tr>
<tr>
<td>Jack</td>
<td>1.9008</td>
<td>0.2050</td>
<td>0.5923</td>
<td>-0.4334</td>
<td>0.023940</td>
</tr>
<tr>
<td>Chum</td>
<td>1.9699</td>
<td>0.1543</td>
<td>0.7504</td>
<td>-0.4841</td>
<td>0.000000</td>
</tr>
<tr>
<td>Fall Chum</td>
<td>1.8632</td>
<td>0.2330</td>
<td>1.1954</td>
<td>-1.4361</td>
<td>0.030340</td>
</tr>
<tr>
<td>Coho</td>
<td>1.9827</td>
<td>0.3269</td>
<td>0.8686</td>
<td>-1.4557</td>
<td>0.118500</td>
</tr>
<tr>
<td>Pink</td>
<td>1.9805</td>
<td>0.2598</td>
<td>1.5542</td>
<td>1.2820</td>
<td>0.164900</td>
</tr>
<tr>
<td>Broad Whitefish</td>
<td>1.7774</td>
<td>0.2205</td>
<td>1.4018</td>
<td>-1.9341</td>
<td>0.098090</td>
</tr>
<tr>
<td>Humpback Whitefish</td>
<td>1.9021</td>
<td>0.2320</td>
<td>1.1103</td>
<td>-2.0546</td>
<td>0.064150</td>
</tr>
<tr>
<td>Cisco</td>
<td>2.0830</td>
<td>0.2223</td>
<td>1.8771</td>
<td>-1.6381</td>
<td>0.180900</td>
</tr>
<tr>
<td>Other</td>
<td>2.2604</td>
<td>0.3642</td>
<td>0.9881</td>
<td>-2.2990</td>
<td>0.000000</td>
</tr>
</tbody>
</table>

Table 4.–Yearly Chinook salmon estimates with 90% confidence bounds.

<table>
<thead>
<tr>
<th>Year</th>
<th>Previous estimates</th>
<th>New estimates</th>
<th>Variance</th>
<th>SE</th>
<th>CV</th>
<th>Lower 90%</th>
<th>Upper 90%</th>
<th>Percent change</th>
</tr>
</thead>
<tbody>
<tr>
<td>1995</td>
<td>162,945</td>
<td>221,357</td>
<td>335,360,998</td>
<td>18,312.864</td>
<td>0.083</td>
<td>191,232</td>
<td>251,482</td>
<td>35.85%</td>
</tr>
<tr>
<td>1997</td>
<td>195,647</td>
<td>199,763</td>
<td>421,691,184</td>
<td>20,535.121</td>
<td>0.103</td>
<td>165,983</td>
<td>233,543</td>
<td>21.09%</td>
</tr>
<tr>
<td>1998</td>
<td>87,852</td>
<td>199,763</td>
<td>421,691,184</td>
<td>51,703.042</td>
<td>0.479</td>
<td>165,983</td>
<td>233,543</td>
<td>21.09%</td>
</tr>
<tr>
<td>1999</td>
<td>144,723</td>
<td>108,038</td>
<td>2,673,204,552</td>
<td>51,703.042</td>
<td>0.479</td>
<td>165,983</td>
<td>233,543</td>
<td>21.09%</td>
</tr>
<tr>
<td>2000</td>
<td>44,428</td>
<td>54,560</td>
<td>43,569,911</td>
<td>6,600.751</td>
<td>0.121</td>
<td>43,702</td>
<td>65,418</td>
<td>22.81%</td>
</tr>
<tr>
<td>2001</td>
<td>99,403</td>
<td>121,089</td>
<td>82,925,356</td>
<td>9,106.336</td>
<td>0.075</td>
<td>106,109</td>
<td>136,069</td>
<td>21.82%</td>
</tr>
<tr>
<td>2002</td>
<td>123,213</td>
<td>151,713</td>
<td>590,411,360</td>
<td>24,298.382</td>
<td>0.160</td>
<td>201,067</td>
<td>256,459</td>
<td>35.04%</td>
</tr>
<tr>
<td>2003</td>
<td>268,537</td>
<td>318,088</td>
<td>301,327,397</td>
<td>17,358.784</td>
<td>0.055</td>
<td>289,533</td>
<td>346,643</td>
<td>18.45%</td>
</tr>
<tr>
<td>2004</td>
<td>156,606</td>
<td>200,761</td>
<td>147,510,216</td>
<td>12,143,788</td>
<td>0.060</td>
<td>180,782</td>
<td>220,740</td>
<td>28.19%</td>
</tr>
<tr>
<td>2005</td>
<td>168,409</td>
<td>268,537</td>
<td>665,991,904</td>
<td>25,806,819</td>
<td>0.100</td>
<td>216,746</td>
<td>301,667</td>
<td>62.10%</td>
</tr>
<tr>
<td>2006</td>
<td>179,430</td>
<td>268,537</td>
<td>301,327,397</td>
<td>17,358,784</td>
<td>0.055</td>
<td>289,533</td>
<td>346,643</td>
<td>18.45%</td>
</tr>
<tr>
<td>2007</td>
<td>125,553</td>
<td>151,713</td>
<td>590,411,360</td>
<td>24,298,382</td>
<td>0.160</td>
<td>201,067</td>
<td>256,459</td>
<td>35.04%</td>
</tr>
<tr>
<td>2008</td>
<td>130,643</td>
<td>175,046</td>
<td>168,712,439</td>
<td>12,988,935</td>
<td>0.074</td>
<td>153,679</td>
<td>196,413</td>
<td>33.99%</td>
</tr>
<tr>
<td>2009</td>
<td>144,049</td>
<td>177,796</td>
<td>252,322,169</td>
<td>15,884,652</td>
<td>0.089</td>
<td>151,666</td>
<td>203,926</td>
<td>33.43%</td>
</tr>
<tr>
<td>2010</td>
<td>120,175</td>
<td>145,088</td>
<td>8,033,173,505</td>
<td>89,627,973</td>
<td>0.618</td>
<td>-2,350</td>
<td>292,526</td>
<td>20.73%</td>
</tr>
<tr>
<td>2011</td>
<td>123,369</td>
<td>148,797</td>
<td>150,398,891</td>
<td>12,263,723</td>
<td>0.082</td>
<td>128,623</td>
<td>168,971</td>
<td>20.61%</td>
</tr>
<tr>
<td>2012</td>
<td>106,731</td>
<td>127,555</td>
<td>128,570,238</td>
<td>11,338,882</td>
<td>0.089</td>
<td>108,903</td>
<td>146,207</td>
<td>19.51%</td>
</tr>
<tr>
<td>2013</td>
<td>114,424</td>
<td>136,805</td>
<td>400,021,291</td>
<td>20,000,532</td>
<td>0.146</td>
<td>103,904</td>
<td>169,706</td>
<td>19.56%</td>
</tr>
<tr>
<td>2014</td>
<td>137,755</td>
<td>163,895</td>
<td>129,716,149</td>
<td>11,389,300</td>
<td>0.069</td>
<td>145,160</td>
<td>182,630</td>
<td>19.98%</td>
</tr>
<tr>
<td>2015</td>
<td>115,907</td>
<td>146,859</td>
<td>354,178,375</td>
<td>18,819,627</td>
<td>0.128</td>
<td>115,901</td>
<td>177,817</td>
<td>26.70%</td>
</tr>
</tbody>
</table>

Average 25.94%
Table 5.—Yearly summer chum salmon estimates with 90% confidence bounds.

<table>
<thead>
<tr>
<th>Year</th>
<th>Previous estimates</th>
<th>New estimates</th>
<th>Variance</th>
<th>SE</th>
<th>CV</th>
<th>Lower 90%</th>
<th>Upper 90%</th>
<th>Percent change</th>
</tr>
</thead>
<tbody>
<tr>
<td>1995</td>
<td>3,556,445</td>
<td>3,620,102</td>
<td>3,980,940,938</td>
<td>63,094.698</td>
<td>0.017</td>
<td>3,516,311</td>
<td>3,723,893</td>
<td>1.79%</td>
</tr>
<tr>
<td>1997</td>
<td>1,415,641</td>
<td>1,359,117</td>
<td>1,569,122,001</td>
<td>39,612.145</td>
<td>0.029</td>
<td>1,293,955</td>
<td>1,424,279</td>
<td>-3.99%</td>
</tr>
<tr>
<td>1998</td>
<td>826,385</td>
<td>824,901</td>
<td>1,542,144,910</td>
<td>39,270.153</td>
<td>0.048</td>
<td>760,302</td>
<td>889,500</td>
<td>-0.18%</td>
</tr>
<tr>
<td>1999</td>
<td>973,708</td>
<td>969,459</td>
<td>2,236,895,659</td>
<td>47,295.831</td>
<td>0.049</td>
<td>891,657</td>
<td>1,047,261</td>
<td>-0.44%</td>
</tr>
<tr>
<td>2000</td>
<td>456,271</td>
<td>448,665</td>
<td>207,205,857</td>
<td>14,394.647</td>
<td>0.032</td>
<td>424,986</td>
<td>472,344</td>
<td>-1.67%</td>
</tr>
<tr>
<td>2001</td>
<td>441,450</td>
<td>442,546</td>
<td>216,182,048</td>
<td>14,703.131</td>
<td>0.033</td>
<td>418,359</td>
<td>466,733</td>
<td>0.25%</td>
</tr>
<tr>
<td>2002</td>
<td>1,088,463</td>
<td>1,097,769</td>
<td>964,836,766</td>
<td>31,061.822</td>
<td>0.028</td>
<td>1,046,672</td>
<td>1,148,866</td>
<td>0.85%</td>
</tr>
<tr>
<td>2003</td>
<td>1,168,518</td>
<td>1,183,009</td>
<td>1,359,288,137</td>
<td>36,868.525</td>
<td>0.031</td>
<td>1,122,360</td>
<td>1,243,658</td>
<td>1.24%</td>
</tr>
<tr>
<td>2004</td>
<td>1,357,826</td>
<td>1,344,213</td>
<td>921,883,525</td>
<td>30,362,535</td>
<td>0.023</td>
<td>1,294,267</td>
<td>1,394,159</td>
<td>-1.00%</td>
</tr>
<tr>
<td>2005</td>
<td>2,442,285</td>
<td>2,572,586</td>
<td>2,298,581,295</td>
<td>47,943,522</td>
<td>0.019</td>
<td>2,493,719</td>
<td>2,651,453</td>
<td>5.34%</td>
</tr>
<tr>
<td>2006</td>
<td>3,767,044</td>
<td>3,780,760</td>
<td>8,930,229,537</td>
<td>94,499,892</td>
<td>0.025</td>
<td>3,625,308</td>
<td>3,936,212</td>
<td>0.36%</td>
</tr>
<tr>
<td>2007</td>
<td>1,726,885</td>
<td>1,875,491</td>
<td>2,045,252,549</td>
<td>45,224,468</td>
<td>0.024</td>
<td>1,801,097</td>
<td>1,949,885</td>
<td>8.61%</td>
</tr>
<tr>
<td>2008</td>
<td>1,665,667</td>
<td>1,849,553</td>
<td>1,736,126,408</td>
<td>41,666,850</td>
<td>0.023</td>
<td>1,781,011</td>
<td>1,918,095</td>
<td>11.04%</td>
</tr>
<tr>
<td>2009</td>
<td>1,421,646</td>
<td>1,477,186</td>
<td>1,805,363,834</td>
<td>42,489,573</td>
<td>0.029</td>
<td>1,407,291</td>
<td>1,547,081</td>
<td>3.91%</td>
</tr>
<tr>
<td>2010</td>
<td>1,405,533</td>
<td>1,415,027</td>
<td>8,816,530,953</td>
<td>93,896,384</td>
<td>0.066</td>
<td>1,260,567</td>
<td>1,569,487</td>
<td>0.68%</td>
</tr>
<tr>
<td>2011</td>
<td>1,977,808</td>
<td>2,051,501</td>
<td>2,218,765,768</td>
<td>47,103,777</td>
<td>0.023</td>
<td>1,974,015</td>
<td>2,128,987</td>
<td>3.73%</td>
</tr>
<tr>
<td>2012</td>
<td>2,131,453</td>
<td>2,136,476</td>
<td>2,308,437,662</td>
<td>48,046,203</td>
<td>0.022</td>
<td>2,057,440</td>
<td>2,215,512</td>
<td>0.24%</td>
</tr>
<tr>
<td>2013</td>
<td>2,696,939</td>
<td>2,849,683</td>
<td>4,853,505,805</td>
<td>69,667,107</td>
<td>0.024</td>
<td>2,735,081</td>
<td>2,964,285</td>
<td>5.66%</td>
</tr>
<tr>
<td>2014</td>
<td>1,926,922</td>
<td>2,020,309</td>
<td>3,615,276,638</td>
<td>60,127,171</td>
<td>0.030</td>
<td>1,921,400</td>
<td>2,119,218</td>
<td>4.85%</td>
</tr>
<tr>
<td>2015</td>
<td>1,412,861</td>
<td>1,591,505</td>
<td>3,579,063,695</td>
<td>59,825,276</td>
<td>0.038</td>
<td>1,493,092</td>
<td>1,689,918</td>
<td>12.64%</td>
</tr>
</tbody>
</table>

Average 2.69%
Table 6.—Yearly fall chum salmon estimates with 90% confidence bounds.

<table>
<thead>
<tr>
<th>Year</th>
<th>Previous estimates</th>
<th>New estimates</th>
<th>Variance</th>
<th>SE</th>
<th>CV</th>
<th>Lower 90%</th>
<th>Upper 90%</th>
<th>Percent change</th>
</tr>
</thead>
<tbody>
<tr>
<td>1995</td>
<td>1,053,245</td>
<td>1,148,916</td>
<td>2,032,278,761</td>
<td>45,080.803</td>
<td>0.039</td>
<td>1,074,758</td>
<td>1,223,074</td>
<td>9.08%</td>
</tr>
<tr>
<td>1997</td>
<td>506,621</td>
<td>579,767</td>
<td>411,211,702</td>
<td>20,278.356</td>
<td>0.035</td>
<td>546,409</td>
<td>613,125</td>
<td>14.44%</td>
</tr>
<tr>
<td>1998</td>
<td>372,927</td>
<td>375,222</td>
<td>153,441,909</td>
<td>12,387.167</td>
<td>0.033</td>
<td>354,845</td>
<td>395,599</td>
<td>0.62%</td>
</tr>
<tr>
<td>1999</td>
<td>379,493</td>
<td>451,505</td>
<td>232,665,402</td>
<td>15,253,373</td>
<td>0.034</td>
<td>426,413</td>
<td>476,597</td>
<td>18.98%</td>
</tr>
<tr>
<td>2000</td>
<td>247,935</td>
<td>273,206</td>
<td>157,230,216</td>
<td>12,539.147</td>
<td>0.046</td>
<td>252,579</td>
<td>293,833</td>
<td>10.19%</td>
</tr>
<tr>
<td>2001</td>
<td>376,182</td>
<td>408,961</td>
<td>374,133,329</td>
<td>19,342.526</td>
<td>0.047</td>
<td>377,143</td>
<td>440,779</td>
<td>8.71%</td>
</tr>
<tr>
<td>2002</td>
<td>326,858</td>
<td>367,886</td>
<td>306,514,771</td>
<td>17,507.563</td>
<td>0.048</td>
<td>339,086</td>
<td>396,686</td>
<td>12.55%</td>
</tr>
<tr>
<td>2003</td>
<td>889,778</td>
<td>923,540</td>
<td>1,299,769,902</td>
<td>36,052.322</td>
<td>0.039</td>
<td>864,234</td>
<td>982,846</td>
<td>3.79%</td>
</tr>
<tr>
<td>2004</td>
<td>594,060</td>
<td>633,368</td>
<td>493,112,062</td>
<td>22,206.127</td>
<td>0.035</td>
<td>596,839</td>
<td>669,897</td>
<td>6.62%</td>
</tr>
<tr>
<td>2005</td>
<td>1,812,824</td>
<td>1,894,078</td>
<td>4,537,264,383</td>
<td>67,359.219</td>
<td>0.036</td>
<td>1,783,272</td>
<td>2,004,884</td>
<td>4.48%</td>
</tr>
<tr>
<td>2006</td>
<td>790,563</td>
<td>964,238</td>
<td>770,005,999</td>
<td>27,748.982</td>
<td>0.029</td>
<td>918,591</td>
<td>1,009,885</td>
<td>21.97%</td>
</tr>
<tr>
<td>2007</td>
<td>684,011</td>
<td>740,195</td>
<td>793,856,053</td>
<td>28,175.451</td>
<td>0.038</td>
<td>693,846</td>
<td>786,544</td>
<td>8.21%</td>
</tr>
<tr>
<td>2008</td>
<td>615,127</td>
<td>636,525</td>
<td>333,092,389</td>
<td>18,250.819</td>
<td>0.029</td>
<td>606,502</td>
<td>666,548</td>
<td>3.48%</td>
</tr>
<tr>
<td>2009</td>
<td>233,307</td>
<td>274,227</td>
<td>549,228,640</td>
<td>23,435.628</td>
<td>0.085</td>
<td>235,675</td>
<td>312,779</td>
<td>17.54%</td>
</tr>
<tr>
<td>2010</td>
<td>393,326</td>
<td>458,103</td>
<td>615,064,300</td>
<td>24,800.490</td>
<td>0.054</td>
<td>417,306</td>
<td>498,900</td>
<td>16.47%</td>
</tr>
<tr>
<td>2011</td>
<td>764,194</td>
<td>873,877</td>
<td>672,528,459</td>
<td>25,933.154</td>
<td>0.030</td>
<td>831,217</td>
<td>916,537</td>
<td>14.35%</td>
</tr>
<tr>
<td>2012</td>
<td>682,650</td>
<td>778,158</td>
<td>1,428,981,615</td>
<td>37,801.873</td>
<td>0.049</td>
<td>715,974</td>
<td>840,342</td>
<td>13.99%</td>
</tr>
<tr>
<td>2013</td>
<td>710,805</td>
<td>865,295</td>
<td>1,930,469,983</td>
<td>43,937.114</td>
<td>0.051</td>
<td>793,018</td>
<td>937,572</td>
<td>21.73%</td>
</tr>
<tr>
<td>2014</td>
<td>669,627</td>
<td>706,630</td>
<td>1,416,043,642</td>
<td>37,630.355</td>
<td>0.053</td>
<td>644,728</td>
<td>768,532</td>
<td>5.53%</td>
</tr>
<tr>
<td>2015</td>
<td>544,329</td>
<td>669,483</td>
<td>613,854,017</td>
<td>24,776.078</td>
<td>0.037</td>
<td>628,726</td>
<td>710,240</td>
<td>22.99%</td>
</tr>
</tbody>
</table>

Average 11.79%
Table 7.—Yearly coho salmon estimates with 90% confidence bounds.

<table>
<thead>
<tr>
<th>Year</th>
<th>Previous estimates</th>
<th>New estimates</th>
<th>Variance</th>
<th>SE</th>
<th>CV</th>
<th>Lower 90%</th>
<th>Upper 90%</th>
<th>Percent change</th>
</tr>
</thead>
<tbody>
<tr>
<td>1995</td>
<td>101,806</td>
<td>115,569</td>
<td>296,159,202</td>
<td>17,209.277</td>
<td>0.149</td>
<td>87,260</td>
<td>143,878</td>
<td>13.52%</td>
</tr>
<tr>
<td>1997</td>
<td>104,343</td>
<td>118,065</td>
<td>117,217,481</td>
<td>10,826.702</td>
<td>0.092</td>
<td>100,255</td>
<td>135,875</td>
<td>13.15%</td>
</tr>
<tr>
<td>1998</td>
<td>136,906</td>
<td>146,365</td>
<td>88,420,292</td>
<td>9,403.206</td>
<td>0.064</td>
<td>130,897</td>
<td>161,833</td>
<td>6.91%</td>
</tr>
<tr>
<td>1999</td>
<td>62,521</td>
<td>76,174</td>
<td>28,685,196</td>
<td>5,355.856</td>
<td>0.070</td>
<td>67,364</td>
<td>84,984</td>
<td>21.84%</td>
</tr>
<tr>
<td>2000</td>
<td>175,421</td>
<td>206,365</td>
<td>104,205,159</td>
<td>10,208.093</td>
<td>0.049</td>
<td>189,573</td>
<td>223,157</td>
<td>17.64%</td>
</tr>
<tr>
<td>2001</td>
<td>137,769</td>
<td>160,272</td>
<td>139,497,066</td>
<td>11,810.888</td>
<td>0.074</td>
<td>140,843</td>
<td>179,701</td>
<td>16.33%</td>
</tr>
<tr>
<td>2002</td>
<td>122,566</td>
<td>137,077</td>
<td>59,121,205</td>
<td>7,689.031</td>
<td>0.056</td>
<td>124,429</td>
<td>149,725</td>
<td>11.84%</td>
</tr>
<tr>
<td>2003</td>
<td>269,081</td>
<td>280,552</td>
<td>412,126,229</td>
<td>20,300.892</td>
<td>0.072</td>
<td>247,157</td>
<td>313,947</td>
<td>10.35%</td>
</tr>
<tr>
<td>2004</td>
<td>188,350</td>
<td>207,844</td>
<td>142,402,268</td>
<td>11,933.242</td>
<td>0.057</td>
<td>188,214</td>
<td>227,474</td>
<td>10.15%</td>
</tr>
<tr>
<td>2005</td>
<td>184,281</td>
<td>194,622</td>
<td>317,652,857</td>
<td>17,822.818</td>
<td>0.092</td>
<td>165,303</td>
<td>223,941</td>
<td>5.61%</td>
</tr>
<tr>
<td>2006</td>
<td>131,919</td>
<td>163,889</td>
<td>121,967,005</td>
<td>11,043.867</td>
<td>0.067</td>
<td>145,722</td>
<td>182,056</td>
<td>24.23%</td>
</tr>
<tr>
<td>2007</td>
<td>173,289</td>
<td>192,406</td>
<td>137,071,776</td>
<td>11,707.766</td>
<td>0.061</td>
<td>173,147</td>
<td>211,665</td>
<td>11.03%</td>
</tr>
<tr>
<td>2008</td>
<td>135,570</td>
<td>145,378</td>
<td>71,245,969</td>
<td>8,440.733</td>
<td>0.058</td>
<td>131,493</td>
<td>159,263</td>
<td>7.23%</td>
</tr>
<tr>
<td>2009</td>
<td>206,620</td>
<td>240,779</td>
<td>315,329,147</td>
<td>17,757.510</td>
<td>0.074</td>
<td>211,568</td>
<td>269,990</td>
<td>16.53%</td>
</tr>
<tr>
<td>2010</td>
<td>155,784</td>
<td>177,724</td>
<td>57,638,106</td>
<td>7,591.976</td>
<td>0.043</td>
<td>165,235</td>
<td>190,213</td>
<td>14.08%</td>
</tr>
<tr>
<td>2011</td>
<td>124,931</td>
<td>149,533</td>
<td>159,417,647</td>
<td>12,626.070</td>
<td>0.084</td>
<td>128,763</td>
<td>170,303</td>
<td>19.69%</td>
</tr>
<tr>
<td>2012</td>
<td>108,828</td>
<td>130,734</td>
<td>92,194,074</td>
<td>9,601.775</td>
<td>0.073</td>
<td>114,939</td>
<td>146,529</td>
<td>20.13%</td>
</tr>
<tr>
<td>2013</td>
<td>86,245</td>
<td>110,515</td>
<td>200,563,120</td>
<td>14,162.031</td>
<td>0.128</td>
<td>87,218</td>
<td>133,812</td>
<td>28.14%</td>
</tr>
<tr>
<td>2014</td>
<td>232,181</td>
<td>283,421</td>
<td>292,042,750</td>
<td>17,089.258</td>
<td>0.060</td>
<td>255,309</td>
<td>311,533</td>
<td>22.07%</td>
</tr>
<tr>
<td>2015</td>
<td>94,432</td>
<td>121,193</td>
<td>78,928,608</td>
<td>8,884.177</td>
<td>0.073</td>
<td>106,579</td>
<td>135,807</td>
<td>28.34%</td>
</tr>
</tbody>
</table>

Average 15.65%
Table 8—Yearly pink salmon estimates with 90% confidence bounds.

<table>
<thead>
<tr>
<th>Year</th>
<th>Previous estimates</th>
<th>New estimates</th>
<th>Variance</th>
<th>SE</th>
<th>CV</th>
<th>Lower 90%</th>
<th>Upper 90%</th>
<th>Percent change</th>
</tr>
</thead>
<tbody>
<tr>
<td>1995</td>
<td>24,604</td>
<td>53,165</td>
<td>156,126,622</td>
<td>12,495.064</td>
<td>0.235</td>
<td>32,611</td>
<td>73,719</td>
<td>116.08%</td>
</tr>
<tr>
<td>1997</td>
<td>2,379</td>
<td>3,872</td>
<td>4,067,645</td>
<td>2,016.840</td>
<td>0.521</td>
<td>554</td>
<td>7,190</td>
<td>62.76%</td>
</tr>
<tr>
<td>1998</td>
<td>66,751</td>
<td>103,416</td>
<td>46,319,018</td>
<td>6,805.808</td>
<td>0.066</td>
<td>92,220</td>
<td>114,612</td>
<td>54.93%</td>
</tr>
<tr>
<td>1999</td>
<td>1,801</td>
<td>3,947</td>
<td>3,029,370</td>
<td>1,740.509</td>
<td>0.441</td>
<td>1,084</td>
<td>6,810</td>
<td>119.16%</td>
</tr>
<tr>
<td>2000</td>
<td>35,501</td>
<td>61,389</td>
<td>48,412,461</td>
<td>6,957.906</td>
<td>0.113</td>
<td>49,943</td>
<td>72,835</td>
<td>72.92%</td>
</tr>
<tr>
<td>2001</td>
<td>665</td>
<td>2,846</td>
<td>1,804,294</td>
<td>1,343.240</td>
<td>0.472</td>
<td>636</td>
<td>5,056</td>
<td>327.97%</td>
</tr>
<tr>
<td>2002</td>
<td>64,891</td>
<td>123,698</td>
<td>137,934,088</td>
<td>11,744.534</td>
<td>0.095</td>
<td>104,378</td>
<td>143,018</td>
<td>90.62%</td>
</tr>
<tr>
<td>2003</td>
<td>4,656</td>
<td>11,370</td>
<td>5,067,999</td>
<td>2,251.222</td>
<td>0.198</td>
<td>7,667</td>
<td>15,073</td>
<td>144.20%</td>
</tr>
<tr>
<td>2004</td>
<td>243,375</td>
<td>399,339</td>
<td>421,505,711</td>
<td>20,530.604</td>
<td>0.051</td>
<td>365,566</td>
<td>433,112</td>
<td>64.08%</td>
</tr>
<tr>
<td>2005</td>
<td>37,918</td>
<td>61,122</td>
<td>47,136,781</td>
<td>6,865.623</td>
<td>0.112</td>
<td>49,828</td>
<td>72,416</td>
<td>61.20%</td>
</tr>
<tr>
<td>2006</td>
<td>115,624</td>
<td>183,006</td>
<td>206,668,401</td>
<td>14,375.966</td>
<td>0.079</td>
<td>159,358</td>
<td>206,654</td>
<td>58.28%</td>
</tr>
<tr>
<td>2007</td>
<td>56,701</td>
<td>126,282</td>
<td>186,458,449</td>
<td>13,654.979</td>
<td>0.108</td>
<td>103,820</td>
<td>148,744</td>
<td>122.72%</td>
</tr>
<tr>
<td>2008</td>
<td>558,050</td>
<td>580,127</td>
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<td>52,427.383</td>
<td>0.090</td>
<td>493,884</td>
<td>666,370</td>
<td>3.96%</td>
</tr>
<tr>
<td>2009</td>
<td>23,679</td>
<td>34,529</td>
<td>58,639,966</td>
<td>7,657.674</td>
<td>0.222</td>
<td>21,932</td>
<td>47,126</td>
<td>45.82%</td>
</tr>
<tr>
<td>2010</td>
<td>747,297</td>
<td>917,731</td>
<td>2,346,365,450</td>
<td>48,439.297</td>
<td>0.053</td>
<td>838,048</td>
<td>997,414</td>
<td>22.81%</td>
</tr>
<tr>
<td>2011</td>
<td>6,526</td>
<td>9,754</td>
<td>3,287,470</td>
<td>1,813.138</td>
<td>0.186</td>
<td>6,771</td>
<td>12,737</td>
<td>49.46%</td>
</tr>
<tr>
<td>2012</td>
<td>365,124</td>
<td>420,344</td>
<td>1,322,507,140</td>
<td>36,366.291</td>
<td>0.087</td>
<td>360,521</td>
<td>480,167</td>
<td>15.12%</td>
</tr>
<tr>
<td>2013</td>
<td>3,557</td>
<td>6,126</td>
<td>15,589,093</td>
<td>3,948.303</td>
<td>0.645</td>
<td>-369</td>
<td>12,621</td>
<td>72.22%</td>
</tr>
<tr>
<td>2014</td>
<td>513,599</td>
<td>679,126</td>
<td>1,329,992,116</td>
<td>36,469.057</td>
<td>0.054</td>
<td>619,134</td>
<td>739,118</td>
<td>32.23%</td>
</tr>
<tr>
<td>2015</td>
<td>22,421</td>
<td>39,690</td>
<td>57,149,553</td>
<td>7,559.732</td>
<td>0.190</td>
<td>27,254</td>
<td>52,126</td>
<td>77.02%</td>
</tr>
</tbody>
</table>

Average 80.68%
Table 9.–Yearly cisco estimates with 90% confidence bounds.

<table>
<thead>
<tr>
<th>Year</th>
<th>New estimates</th>
<th>Variance</th>
<th>SE</th>
<th>CV</th>
<th>Lower 90%</th>
<th>Upper 90%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1995</td>
<td>309,786</td>
<td>683,028,437</td>
<td>26,134,813</td>
<td>0.084</td>
<td>266,794</td>
<td>352,778</td>
</tr>
<tr>
<td>1997</td>
<td>214,397</td>
<td>331,176,898</td>
<td>18,198,266</td>
<td>0.085</td>
<td>184,461</td>
<td>244,333</td>
</tr>
<tr>
<td>1998</td>
<td>118,820</td>
<td>131,186,612</td>
<td>11,453,672</td>
<td>0.096</td>
<td>99,979</td>
<td>137,661</td>
</tr>
<tr>
<td>1999</td>
<td>170,377</td>
<td>190,259,810</td>
<td>13,793,470</td>
<td>0.081</td>
<td>147,687</td>
<td>193,067</td>
</tr>
<tr>
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<td>12,472,964</td>
<td>0.074</td>
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<td>188,415</td>
</tr>
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<td>106,299,598</td>
<td>10,310,170</td>
<td>0.069</td>
<td>133,390</td>
<td>167,310</td>
</tr>
<tr>
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<td>329,785,662</td>
<td>18,160,002</td>
<td>0.087</td>
<td>178,357</td>
<td>238,103</td>
</tr>
<tr>
<td>2003</td>
<td>123,129</td>
<td>161,414,548</td>
<td>12,704,903</td>
<td>0.103</td>
<td>102,229</td>
<td>144,029</td>
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<tr>
<td>2004</td>
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<td>254,011,518</td>
<td>15,937,739</td>
<td>0.082</td>
<td>169,153</td>
<td>221,589</td>
</tr>
<tr>
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<td>225,649,516</td>
<td>15,021,635</td>
<td>0.072</td>
<td>184,798</td>
<td>234,219</td>
</tr>
<tr>
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<td>18,664,191</td>
<td>0.072</td>
<td>228,174</td>
<td>289,580</td>
</tr>
<tr>
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<td>25,002,274</td>
<td>0.078</td>
<td>280,369</td>
<td>362,627</td>
</tr>
<tr>
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<td>313,481,722</td>
<td>17,705,415</td>
<td>0.118</td>
<td>121,183</td>
<td>179,433</td>
</tr>
<tr>
<td>2009</td>
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<td>466,466,952</td>
<td>21,597,846</td>
<td>0.084</td>
<td>222,021</td>
<td>293,077</td>
</tr>
<tr>
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<td>1,467,745,258</td>
<td>38,311,164</td>
<td>0.137</td>
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<td>343,041</td>
</tr>
<tr>
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<td>16,564,103</td>
<td>0.068</td>
<td>215,702</td>
<td>270,198</td>
</tr>
<tr>
<td>2012</td>
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<td>203,242,564</td>
<td>14,256,317</td>
<td>0.070</td>
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<td>227,782</td>
</tr>
<tr>
<td>2013</td>
<td>383,326</td>
<td>777,472,498</td>
<td>27,883,194</td>
<td>0.073</td>
<td>337,458</td>
<td>429,194</td>
</tr>
<tr>
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Table 10.–Yearly humpback whitefish estimates with 90% confidence bounds.

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<th>Season total</th>
<th>Variance</th>
<th>SE</th>
<th>CV</th>
<th>Lower 90%</th>
<th>Upper 90%</th>
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<td>CV</td>
<td>Lower 90%</td>
<td>Upper 90%</td>
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Table 12.—Yearly sheefish estimates with 90% confidence bounds.

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<th>Year</th>
<th>Season total</th>
<th>Variance</th>
<th>SE</th>
<th>CV</th>
<th>Lower 90%</th>
<th>Upper 90%</th>
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Avg -31.19%
Table 14.—Paired HTI and DIDSON data for 0–20 m on the left bank of the Yukon River, 2005.

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<td>2,142.90</td>
<td>52,780.63</td>
</tr>
<tr>
<td>6/22/2005</td>
<td>3,410.45</td>
<td>112,217.49</td>
</tr>
<tr>
<td>6/23/2005</td>
<td>920.29</td>
<td>34,750.84</td>
</tr>
<tr>
<td>6/24/2005</td>
<td>462.19</td>
<td>19,296.00</td>
</tr>
<tr>
<td>6/25/2005</td>
<td>770.23</td>
<td>72,711.13</td>
</tr>
<tr>
<td>6/26/2005</td>
<td>548.38</td>
<td>48,888.09</td>
</tr>
<tr>
<td>6/27/2005</td>
<td>584.17</td>
<td>16,298.66</td>
</tr>
<tr>
<td>6/28/2005</td>
<td>824.33</td>
<td>13,922.96</td>
</tr>
<tr>
<td>6/29/2005</td>
<td>819.01</td>
<td>14,323.77</td>
</tr>
<tr>
<td>6/30/2005</td>
<td>517.68</td>
<td>10,738.11</td>
</tr>
<tr>
<td>7/1/2005</td>
<td>506.62</td>
<td>9,826.23</td>
</tr>
<tr>
<td>7/2/2005</td>
<td>275.14</td>
<td>5,142.84</td>
</tr>
<tr>
<td>7/3/2005</td>
<td>418.28</td>
<td>7,834.45</td>
</tr>
<tr>
<td>7/4/2005</td>
<td>1,520.65</td>
<td>13,447.19</td>
</tr>
<tr>
<td>7/5/2005</td>
<td>1,528.53</td>
<td>7,946.12</td>
</tr>
<tr>
<td>7/6/2005</td>
<td>1,016.37</td>
<td>15,324.90</td>
</tr>
<tr>
<td>7/7/2005</td>
<td>1,636.71</td>
<td>4,893.50</td>
</tr>
</tbody>
</table>
Table 15.—Regression summary for estimating DIDSON counts based on observed split-beam counts.

<table>
<thead>
<tr>
<th>Min</th>
<th>1Q</th>
<th>Median</th>
<th>3Q</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>-36305</td>
<td>6559</td>
<td>1783</td>
<td>8207</td>
<td>53323</td>
</tr>
</tbody>
</table>

Coefficients:

| Estimate | Std. Error | t value | Pr(>|t|) |
|----------|------------|---------|---------|
| Splitbeam | 25.171     | 3.886   | 6.478   | 0.0000043 *** |

Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 21250 on 18 degrees of freedom
Multiple R-squared:  0.6998, Adjusted R-squared: 0.6832
F-statistic: 41.97 on 1 and 18 DF,  p-value: 0.000004298
Table 16.—Additional sonar estimates by species for period before DIDSON was operational, 2005.

<table>
<thead>
<tr>
<th>Date</th>
<th>Chinook</th>
<th>Jack</th>
<th>Summer Chum</th>
<th>Fall Chum</th>
<th>Pink</th>
<th>Coho</th>
<th>Cisco</th>
<th>Humpback whitefish</th>
<th>Broad whitefish</th>
<th>Sheefish</th>
<th>Other</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>6/1/05</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>5,257</td>
<td>13,154</td>
<td>0</td>
<td>18,411</td>
</tr>
<tr>
<td>6/2/05</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2,259</td>
<td>5,652</td>
<td>0</td>
<td>7,910</td>
</tr>
<tr>
<td>6/3/05</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1,989</td>
<td>4,976</td>
<td>0</td>
<td>6,965</td>
</tr>
<tr>
<td>6/4/05</td>
<td>497</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2,351</td>
<td>402</td>
<td>338</td>
<td>0</td>
<td>5,077</td>
</tr>
<tr>
<td>6/5/05</td>
<td>946</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1,840</td>
<td>495</td>
<td>417</td>
<td>0</td>
<td>5,804</td>
</tr>
<tr>
<td>6/6/05</td>
<td>1,166</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2,269</td>
<td>495</td>
<td>417</td>
<td>0</td>
<td>7,157</td>
</tr>
<tr>
<td>6/7/05</td>
<td>2,592</td>
<td>876</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1,636</td>
<td>0</td>
<td>0</td>
<td>1,667</td>
<td>6,771</td>
</tr>
<tr>
<td>6/8/05</td>
<td>2,382</td>
<td>370</td>
<td>2,985</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2,025</td>
<td>0</td>
<td>0</td>
<td>1,136</td>
<td>8,899</td>
</tr>
<tr>
<td>6/9/05</td>
<td>2,475</td>
<td>484</td>
<td>4,276</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1,470</td>
<td>0</td>
<td>8,705</td>
</tr>
<tr>
<td>6/10/05</td>
<td>2,068</td>
<td>356</td>
<td>4,160</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>461</td>
<td>0</td>
<td>0</td>
<td>632</td>
<td>7,676</td>
</tr>
<tr>
<td>6/11/05</td>
<td>2,035</td>
<td>394</td>
<td>5,211</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2,522</td>
<td>493</td>
<td>0</td>
<td>679</td>
<td>11,333</td>
</tr>
<tr>
<td>6/12/05</td>
<td>7,295</td>
<td>292</td>
<td>8,747</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<td>0</td>
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<td>0</td>
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<td>16,334</td>
</tr>
<tr>
<td>6/13/05</td>
<td>3,674</td>
<td>990</td>
<td>16,788</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1,568</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>23,020</td>
</tr>
<tr>
<td>6/14/05</td>
<td>16,875</td>
<td>4,198</td>
<td>57,472</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>78,545</td>
</tr>
<tr>
<td>6/15/05</td>
<td>15,730</td>
<td>1,107</td>
<td>47,234</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>64,071</td>
</tr>
<tr>
<td>6/16/05</td>
<td>2,261</td>
<td>0</td>
<td>11,572</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>94</td>
<td>0</td>
<td>0</td>
<td>13,927</td>
</tr>
<tr>
<td>6/17/05</td>
<td>467</td>
<td>267</td>
<td>12,360</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>59</td>
<td>0</td>
<td>0</td>
<td>13,153</td>
</tr>
<tr>
<td>6/18/05</td>
<td>1,342</td>
<td>0</td>
<td>15,246</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>16,588</td>
</tr>
<tr>
<td>Total</td>
<td>61,805</td>
<td>9,333</td>
<td>186,052</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>14,671</td>
<td>1,389</td>
<td>10,259</td>
<td>36,836</td>
<td>320,346</td>
</tr>
</tbody>
</table>
Table 17.—Mark–recapture estimates of Chinook salmon with new and old Pilot Station sonar estimates.

<table>
<thead>
<tr>
<th>Year</th>
<th>Eagle sonar estimates</th>
<th>Canadian proportion</th>
<th>Canadian origin harvest</th>
<th>Mark–recapture</th>
<th>Old Chinook estimates</th>
<th>New Chinook estimates</th>
</tr>
</thead>
<tbody>
<tr>
<td>2002</td>
<td>202,678 (^a)</td>
<td></td>
<td></td>
<td>123,213</td>
<td>151,713</td>
<td></td>
</tr>
<tr>
<td>2003</td>
<td>309,887 (^a)</td>
<td></td>
<td></td>
<td>268,537</td>
<td>318,088</td>
<td></td>
</tr>
<tr>
<td>2004</td>
<td>229,739 (^b)</td>
<td></td>
<td></td>
<td>156,606</td>
<td>200,761</td>
<td></td>
</tr>
<tr>
<td>2005</td>
<td>255,121 (^b)</td>
<td></td>
<td></td>
<td>159,915</td>
<td>259,214</td>
<td></td>
</tr>
<tr>
<td>2006</td>
<td>237,678 (^b)</td>
<td></td>
<td></td>
<td>169,403</td>
<td>228,763</td>
<td></td>
</tr>
<tr>
<td>2007</td>
<td>185,548 (^b)</td>
<td></td>
<td></td>
<td>125,553</td>
<td>170,246</td>
<td></td>
</tr>
<tr>
<td>2008</td>
<td>157,746 (^b)</td>
<td></td>
<td></td>
<td>130,643</td>
<td>175,046</td>
<td></td>
</tr>
<tr>
<td>2009</td>
<td>222,402 (^b)</td>
<td></td>
<td></td>
<td>144,049</td>
<td>177,796</td>
<td></td>
</tr>
<tr>
<td>2010</td>
<td>128,859 (^b)</td>
<td></td>
<td></td>
<td>120,175</td>
<td>145,088</td>
<td></td>
</tr>
<tr>
<td>2011</td>
<td>191,155 (^b)</td>
<td></td>
<td></td>
<td>123,369</td>
<td>148,797</td>
<td></td>
</tr>
<tr>
<td>2012</td>
<td>34,844 0.435</td>
<td></td>
<td>10,700</td>
<td>104,819 (^c)</td>
<td>106,731</td>
<td>127,555</td>
</tr>
<tr>
<td>2013</td>
<td>31,140 0.520</td>
<td></td>
<td>10,700</td>
<td>80,462 (^c)</td>
<td>114,424</td>
<td>136,805</td>
</tr>
<tr>
<td>2014</td>
<td>64,564 0.500</td>
<td></td>
<td>5,000</td>
<td>139,128 (^c)</td>
<td>137,755</td>
<td>163,895</td>
</tr>
<tr>
<td>2015</td>
<td>83,246 0.426</td>
<td></td>
<td>5,000</td>
<td>206,956 (^c)</td>
<td>115,907</td>
<td>146,859</td>
</tr>
</tbody>
</table>

Average proportion of mark–recapture 0.8012 1.0117

Median proportion of mark–recapture 0.6972 0.9893

\(^a\) Radiotelemetry mark recapture estimate (Spencer et al. 2009).

\(^b\) Genetic mark–recapture estimate (Hamazaki and DeCovich 2014).

\(^c\) Eagle sonar plus estimated Canadian origin harvest divided by Pilot Station genetic proportion.
Table 18.–Reconstructed fall chum salmon run above Pilot Station with new and old Pilot Station sonar estimates.

<table>
<thead>
<tr>
<th>Year</th>
<th>Harvest below Pilot Station</th>
<th>Total run reconstruction</th>
<th>Reconstruction above Pilot</th>
<th>Old PS Fall chum</th>
<th>New fall chum estimates</th>
</tr>
</thead>
<tbody>
<tr>
<td>1995</td>
<td>177,183</td>
<td>1,613,147</td>
<td>1,435,964</td>
<td>1,053,245</td>
<td>1,148,916</td>
</tr>
<tr>
<td>1997</td>
<td>62,834</td>
<td>705,179</td>
<td>642,345</td>
<td>506,621</td>
<td>579,767</td>
</tr>
<tr>
<td>1998</td>
<td>6,424</td>
<td>350,923</td>
<td>344,499</td>
<td>372,927</td>
<td>375,222</td>
</tr>
<tr>
<td>1999</td>
<td>27,436</td>
<td>418,275</td>
<td>390,839</td>
<td>379,493</td>
<td>451,505</td>
</tr>
<tr>
<td>2000</td>
<td>6,293</td>
<td>252,153</td>
<td>245,860</td>
<td>247,935</td>
<td>273,206</td>
</tr>
<tr>
<td>2001</td>
<td>4,929</td>
<td>376,926</td>
<td>371,997</td>
<td>376,182</td>
<td>408,961</td>
</tr>
<tr>
<td>2002</td>
<td>2,818</td>
<td>424,085</td>
<td>421,267</td>
<td>326,858</td>
<td>367,886</td>
</tr>
<tr>
<td>2003</td>
<td>9,821</td>
<td>792,279</td>
<td>782,458</td>
<td>889,778</td>
<td>923,540</td>
</tr>
<tr>
<td>2004</td>
<td>4,303</td>
<td>653,396</td>
<td>649,093</td>
<td>594,060</td>
<td>633,368</td>
</tr>
<tr>
<td>2005</td>
<td>135,619</td>
<td>2,167,418</td>
<td>2,031,799</td>
<td>1,812,824</td>
<td>1,894,078</td>
</tr>
<tr>
<td>2006</td>
<td>148,273</td>
<td>1,194,186</td>
<td>1,045,913</td>
<td>790,563</td>
<td>964,238</td>
</tr>
<tr>
<td>2007</td>
<td>81,195</td>
<td>1,119,467</td>
<td>1,038,272</td>
<td>684,011</td>
<td>740,195</td>
</tr>
<tr>
<td>2008</td>
<td>113,431</td>
<td>822,504</td>
<td>709,073</td>
<td>615,127</td>
<td>636,525</td>
</tr>
<tr>
<td>2009</td>
<td>25,986</td>
<td>604,719</td>
<td>578,733</td>
<td>233,307</td>
<td>274,227</td>
</tr>
<tr>
<td>2010</td>
<td>2,888</td>
<td>569,905</td>
<td>567,017</td>
<td>393,326</td>
<td>458,103</td>
</tr>
<tr>
<td>2011</td>
<td>222,557</td>
<td>1,216,866</td>
<td>994,309</td>
<td>764,194</td>
<td>873,877</td>
</tr>
<tr>
<td>2012</td>
<td>279,381</td>
<td>1,080,189</td>
<td>800,808</td>
<td>682,650</td>
<td>778,158</td>
</tr>
<tr>
<td>2013</td>
<td>219,823</td>
<td>1,241,226</td>
<td>1,021,403</td>
<td>710,805</td>
<td>865,295</td>
</tr>
<tr>
<td>2014</td>
<td>119,352</td>
<td>960,063</td>
<td>840,711</td>
<td>669,627</td>
<td>706,630</td>
</tr>
<tr>
<td>2015</td>
<td>179,832</td>
<td>843,452</td>
<td>663,620</td>
<td>544,329</td>
<td>669,483</td>
</tr>
</tbody>
</table>

Average proportion of reconstruction above Pilot Station: 0.8314
Median proportion of reconstruction above Pilot Station: 0.8084
Figure 1.—Selectivity curves for Chinook, summer chum and coho salmon, cisco, and other species.

*Note:* Parameters derived from 2000 to 2009 test fish catches at the Pilot Station sonar project.
Figure 2.–Daily passage for other species using old and new selectivity parameters, Pilot Station, 2015.
APPENDIX A: CODE USED IN ESTIMATING NET SELECTIVITY PARAMETERS
Appendix A1.–Original SAS code for estimating net selectivity parameters.

******************************************************************************
******************************************************************************
**              **
**  FILE: Net-selectivity.sas                  **
**  TTITLE: Yukon River Pilot Station Net-Selectivity Parameter     **
**         Estimation Program          **
**  PLATFORM: SAS           **
**  DATE: Jan 27 2005           **
**  AUTHOR: TOSHIHIDE "HAMACHAN" HAMAZAKI                                **
**  UPDATED: 05/24/06 - B. McINTOSH            **
******************************************************************************
******************************************************************************;
******************************************************************************
THIS PROGRAM READS HISTORICAL PILOT STATION TEST-FISHERY CSV OUTPUT  *
DATA AND CONDUCT ESTIMATE PEARSON-T NET-SELECTIVITY MODEL PARAMETERS *
******************************************************************************;
******************************************************************************
* 1.0 READ TEST FISHERY DATA FROM ACCESS TEST-FISHERY EXPORTED TO CSV   *
******************************************************************************;
filename tfdat 'D:\Yukon Sonar 2006\SAS06\net_selectivity\fishdat90_05.dat';
******************************************************************************
data temp;
infile tfdat dlm =' ,';
informat dat dm2 dm3 dm4 dm5 mmddyy. startout fullout startin fullin dm1 time8.;
input id dat dm1 tfperiod zone $ bank $ mesh fathoms dm2 startout dm3 fullout
   dm4 startin dm5 fullin gmethod $ captain $ spcode length sex $;
method = upcase(substr(gmethod,2,1));
if method ne 'D' then delete;

/* This file input format is exactly the same as the Pilot Station Species */
Apportionment test fishery data input form */

drop id gmethod captain sex method dm1-dm5;
******************************************************************************
data correctd;
set temp;
year = year(dat);
month = month(dat);
day = day(dat);
bank = upcase(substr(bank,2,1));
zone = upcase(substr(zone,2,1));
* DEFINE ZONE VARIABLE;
if bank eq 'R' then
  lzone = 1;
else if bank eq 'L' and zone eq 'N' then
  lzone = 2;
else if bank = 'L' and zone eq 'F' then
  lzone = 3;
else
  lzone = .;

* COMPUTE DRIFT TIME IN MINUTES AND EFFORT IN FATHOM HOURS;
if fullout lt startout then
  do;
    t1 = startout;
    t2 = fullout + 86400;
    t3 = startin + 86400;
    t4 = fullin + 86400;
  end;
else if startin lt fullout then
  do;
    t1 = startout;
    t2 = fullout;
    t3 = startin + 86400;
    t4 = fullin + 86400;
  end;
else if fullin lt startin then
  do;
    t1 = startout;
    t2 = fullout;
    t3 = startin;
    t4 = fullin;
  end;
else
  do;
    t1 = startout;
    t2 = fullout;
    t3 = startin;
    t4 = fullin;
  end;
  driftmin = (t3 + t4 - t1 - t2)/120;
  effort = fathoms*driftmin/60;
if (year(dat) = 1992 ) then delete;
/* Remove data from 1992 because it was an experimental year
   and often times drifts were not done at the present day sonar site */
format dat mmddyy8.;
drop fullout startin fullin driftmin t1-t4;

************************************************************************************
*  2.0 EXTRACT UNIQUE DRIFT NET COMBINATIONS (SUITESET) *
************************************************************************************
************************************************************************************
*  2.1 EXTRACT UNIQUE DRIFT SET PER DAY *
************************************************************************************
proc summary data=correctd nway;
class dat mesh;
var fathoms; *: USE AS A DUMMY VARIABLE;
  output out = mesh1 n=ndrfish;
/* ndrfish = number of drifts used for each mesh per day */
run;

**************************************************************************
*  2.2 INSERT DUMMY COUNT VARIABLE                                   *
*  This variable will be used to identify mesh used for each day       *
**************************************************************************;
data mesh1; set mesh1;
count = 1;

**************************************************************************
*  2.3 TRANSPOSE DATA AND INSERT DUMMY COUNT VARIABLE                 *
*  Add dummy variable count2                                          *
**************************************************************************;
proc transpose data=mesh1 out = mesh2;
  by dat;
  id mesh;
  var count;
run;
/* The transposed data show which net was used in each day by count.  
If the mesh was used, it is identified as 1 otherwise */
/* Each column represent mesh size */
/* Column name will be _2d75 _4 _5 _5d25 _5d5 _5d75 _6d5 _7d5 _8d5,
by way of SAS conversion from numerical to nominal data. For instance
mesh 2.75 is converted _2d75, 4.0 is converted to _4
Since this is a temporary file, don't bother to rename the column */
data mesh2; set mesh2;
count2=1;
/* This dummy variable will be used to count how many times a particular
mesh size combination was used. */

**************************************************************************
*  2.4 SUMMARIZE THE UNIQUE NET COMBINATION                          *
**************************************************************************;
proc sort data=mesh2;
  by _2d75 _4 _5 _5d25 _5d5 _5d75 _6d5 _7d5 _8d5;
proc means data=mesh2 sum noprint;
  by _2d75 _4 _5 _5d25 _5d5 _5d75 _6d5 _7d5 _8d5;
  var count2;
  output out = mesh3 n=numday;
run;
/* Make sure this class statment includes all mesh sizes used. This should
match with colum title of the mesh2 */
/*numday = number of days the particular mesh combination (suiteset) is used */

**************************************************************************
*  2.5 ASSIGN UNIQUE SUITESET MUNBER                                 *
**************************************************************************;
data suiteset (drop = _freq_ _type_);
  set mesh3;
suiteset = _n_;  
nummesh = sum(_2d75,_4,_5d25,_5d5,_5d75,_7d5,_8d5);  
id = sum(_2d75*100000000,_4*10000000,_5*1000000,_5d25*100000,_5d5*10000,_5d75*1000,  
_6d5*100,_7d5*10,_8d5);  
/* suiteset = particular mesh combination  
numesh = number of mesh used in each suiteset  
id = suiteset id number */

**************************************************************************
*  2.6  ASSOCIATE SUITESET DATA INTO TEST-FISH DATA  
**************************************************************************;
proc sort data = suiteset;  
by _2d75 _4 _5 _5d25 _5d5 _5d75 _6d5 _7d5 _8d5;  
proc sort data = mesh2;  
by _2d75 _4 _5 _5d25 _5d5 _5d75 _6d5 _7d5 _8d5;  
data allfish;  
merge mesh2 suiteset;  
by _2d75 _4 _5 _5d25 _5d5 _5d75 _6d5 _7d5 _8d5;  
proc sort data = allfish;  
by dat;  
proc sort data = correctd;  
by dat;  
data allfish;  
merge correctd allfish;  
by dat;  
run;

**************************************************************************
**************************************************************************
*  3.0: NET-SELECTIVITY CALCULATION PORTION  
**************************************************************************
**************************************************************************;
**************************************************************************
*  3.1    COMBINE SPECIES CLASS AND LENGTH CLASS  
**************************************************************************;
**************************************************************************
*     ORIGINAL SPECIES CODES         
*  1: CHINOOK SALMON   2: SOCKEYE SALMON      3: COHO SALMON   
*  4: PINK SALMON   5: SUMMER CHUM SALMON  6: FALL CHUM SALMON  
*  7: CISCO     8: BRD WHITEFISH   9: HMP WHITEFISH    
* 10: BURBOT    11: SHEEFISH   12: CHAR    
* 13: SMELT    14: PIKE    15: SUCKER  
* 16: OTHER            
**************************************************************************;
data spdata1;  
set allfish;  
if length = . or length = 0 then delete;   *: DELETE DATA WITH NO LENGTH INFO;  
if spcode >= 10 then spcode = 10;   *: COMBINE OTHER FISH;  
if spcode = 2 then spcode = 10;   *: COMBINE SOCKEYE TO OTHERS;  
*: CATEGORIZE FISH LENGTH (FOR CHINOOK AND OTHERS);  
if spcode = 1 then lencat = round(length,20);  
run;
*: CATEGORIZE FISH LENGTH (FOR COHO, PINK, CHUM);
if (2 <= spcode) then lencat = round(length,10);
/* lencat = length category by 20 mm increment for chinook,
and 10 mm increment for others*/

**************************************************************************
* REFINED SPECIES CODES                                                             *
* 1: CHINOOK SALMON      3: COHO SALMON   4: PINK SALMON  *
* 5: SUMMER CHUM SALMON   6: FALL CHUM SALMON  7: CISCO   *
* 8: BRD WHITEFISH       9: HMP WHITEFISH 10: OTHERS    *
**************************************************************************;

* DEFINE SPECIES NAMES;
if spcode = 1 then
  species = 'CHINOOK';
else if spcode = 3 then
  species = 'COHO';
else if spcode = 4 then
  species = 'PINK';
else if spcode = 5 then
  species = 'SCHUM';
else if spcode = 6 then
  species = 'FCHUM';
else if spcode = 7 then
  species = 'CISCO';
else if spcode = 8 then
  species = 'BRDWF';
else if spcode = 9 then
  species = 'HMPWF';
else
  species = 'OTHER';

**************************************************************************;
* 3.1 COMBINE CLASS AND LENGTH CLASS                          *
**************************************************************************;
proc summary data = spdata1 nway;
class species lencat;
var length;
output out = mlength mean(length)= mlength;
run;
/* mlength = mean lengtha at each length class */

proc sort data = spdata1;
by species lencat;
run;
/* add mlength to the data */
data spdata1;
  merge spdata1 mlength (drop = _type_ _freq_);
  by species lencat;
run;

**************************************************************************;
* 3.2 CALCULATE NUMBER OF FISH IN EACH LENCAT AND DRIFT            *
* PER DAY.                                                             *
**************************************************************************;
proc summary data = spdata1 nway;
class species year suiteset dat mesh mlength;
var effort;
output out = fish n(effort)=numfish;
/* numfish = number of fish captured */
/* data set fish contain number of fish for each lencat */
run;

**************************************************************************;
* 3.3   TRANSPOSE DATA          *
**************************************************************************;
proc sort data = fish;
    by species year suiteset dat mlength;
run;
proc transpose data = fish out=fish2;
    by species year suiteset dat mlength;
        id mesh;
    var numfish;
run;
/* Rename column into other name indicating mesh size */
data fish2;
    rename _2D75 = m275 _4 = m400 _5 = m500 _5D25 = m525 _5D5 = m550
        _5D75 = m575 _6D5 = m650 _7D5 = m750 _8D5 = m850;
set fish2;
proc sort data = fish2;
    by suiteset;
run;

**************************************************************************;
* 3.4   MERGE DATA WITH SUITESET DATA         *
*   AND DIFFERENTIATE MISSING AND REAL ZERO (0) DATAPoints   *
**************************************************************************;
data fish2;
    merge fish2 suiteset;
        by suiteset;
data fish2; set fish2;
    if (m275 = . and _2d75 = 1) then m275=0;
/* this indicate that net was used but the fish was not caght */
    if (m400 = . and _4 = 1) then m400=0;
    if (m500 = . and _5 = 1) then m500=0;
    if (m525 = . and _5d25 = 1) then m525=0;
    if (m550 = . and _5d5 = 1) then m550=0;
    if (m575 = . and _5d75 = 1) then m575=0;
    if (m650 = . and _6d5 = 1) then m650=0;
    if (m750 = . and _7d5 = 1) then m750=0;
    if (m850 = . and _8d5 = 1) then m850=0;
    drop _name_ _2d75 _4 _5 _5d25 _5d5 _5d75 _6d5 _7d5 _8d5 numday nummesh;
run;

**************************************************************************;
* 3.5   TRANSPOSE DATA BACK TO THE ORIGINAL FORM     *
*   REMOVE MISSING VALUE SECTION      *
**************************************************************************;
proc sort data=fish2;
    by species year suiteset dat mlength;
proc transpose data = fish2 out=fish3;
by species year suiteset dat mlength;
run;
/* convert nominal mesh size data to numerical one */
data fish3;
set fish3;
if _name_ = 'm275' then mesh=2.75;
if _name_ = 'm400' then mesh=4.0;
if _name_ = 'm500' then mesh=5.0;
if _name_ = 'm525' then mesh=5.25;
if _name_ = 'm550' then mesh=5.5;
if _name_ = 'm575' then mesh=5.75;
if _name_ = 'm650' then mesh=6.5;
if _name_ = 'm750' then mesh=7.5;
if _name_ = 'm850' then mesh=8.5;
if col1 = . then delete;
numfish = col1;
drop _name_ col1;
**************************************************************************
*  3.6   IDENTIFY UNIQUE SET OF EFFORT DATA         *
**************************************************************************;
proc summary data = spdata1 nway;
class year suiteset dat tfperiod startout mesh;
var effort;
output out = eff  min(effort)=effort;
run;
**************************************************************************
*  3.7   SUMMARIZE EFFORT DATA PER DATE        *
**************************************************************************;
proc summary data = eff nway;
class year suiteset dat mesh;
var effort;
output out = eff2  sum(effort)=effort;
run;
**************************************************************************
*  3.8   MERGE EFFORT DATA WITH NUMFISH DATA PER DATE       *
*   SPDATA2 IS THE REFINED ORIGINAL DATA FOR FURTHER ANALYSES   *
**************************************************************************;
proc sort data = fish3;
by year suiteset dat mesh;
proc sort data = eff2;
by year suiteset dat mesh;
data spdata2;
merge fish3 eff2;
by year suiteset dat mesh;
cpue = numfish/effort;
/* cpue = catch per effort unit */
lpr = mlength/(mesh*25.4*2);
/* lpr = ratio between fish length and mesh size in mm */
drop _type_ _freq_;
**************************************************************************
*  3.9 GET SUITESET MESH NUMBER DATA         *
*   AND ADD BACK TO THE DATA        *
**************************************************************************
data meshnum;
set suiteset;
keep id suiteset nummesh;
proc sort data = spdata2;
by suiteset;
proc sort data = meshnum;
by suiteset;
data spdata2;
merge spdata2(in=a) meshnum;
by suiteset;
if a;
proc sort data = spdata2; *: SPDATA2 IS A REFINED ORIGINAL DATA;
by species year id suiteset dat mlength mesh;
run;

* 3.10 CALCULATE CPUE BY ANNUAL
**************************************************************************;
* 3.11 SUMMARIZE DATA BY SPECIES SUITESET MESH MLENGTH
**************************************************************************;
proc summary data = spdata2 nway;
class species suiteset nummesh mlength mesh lpr;
var cpue;
output out = spdata3 sum(cpue)= ;
run;
/* spdata3 is summarized cpue per mesh & length*/
proc summary data = spdata2 nway;
class species suiteset nummesh mlength;
var cpue;
output out = temp2 sum(cpue)= sumcpue;
run;
/* temp2 is summarized cpue per mesh */

* 3.12 FIND NUMBER OF ZEROS IN EACH CATEGORY
**************************************************************************;
data temp21;
set spdata3;
if cpue =0;
proc summary data = temp21 nway;
class species suiteset mlength;
var cpue;
output out = temp21 n = n0;
/* n0: number of zero catches */
run;

* 3.13 CALCULATE LPR, TYPE B SELECTIVITY VALUE (SELECTS)
* AND NUMBER OF NON-ZEROS TO CALCULATE THE SELECTS
**************************************************************************;
proc sort data = spdata3;
by species suiteset mlength;
data spdata3;
merge spdata3 temp2 temp21;
by species suiteset mlength;
selects = cpue/sumcpue;
/* selects = empirical net-selectivity */
if n0 = . then n0 = 0;
nonzero = nummesh - n0;
drop _type_ _freq_ n0;
run;
/
******************************************************************************
* 3.14 OUTPUT FILES FOR SELECTIVITY FUNCTION CALCULATION *
******************************************************************************;
filename lpr 'e:\Projects\Net_Selectivity\Pilot_Station\tfishdata\lpr.dat';
data asciiout; set temp2;
file lpr;
put species suiteset lencat numfish efforts lpr select;
run;
*/
******************************************************************************
* 3.15 FINAL TABLE REFORMAT FOR NETSELECTIVITY PARAMETER ESTIMATION *
******************************************************************************;
proc sort data = spdata3;
by species suiteset mlength;
proc transpose data = spdata3 out=tempt;
var lpr;
by species suiteset mlength;
id mesh;
data tempt;
set tempt;
rename _2D75 = m275 _4 = m400 _5 = m500 _5D25 = m525 _5D5 = m550
_5D75 = m575 _6D5 = m650 _7D5 = m750 _8D5 = m850;
data spdata3;
merge spdata3 tempt;
by species suiteset mlength;
drop _type_ _freq_;
******************************************************************************
******************************************************************************
** 4.0 NET SELECTIVITY ANALYSES **
** Parameter Estimation: Pearson T model **
******************************************************************************;
data spdata4;
set spdata3;
proc sort;
by species;
******************************************************************************
* 4.1 Maximum likelihood estimation *
******************************************************************************;
/* proc nlmixed is used to do a maximum likelihood estimation of netselectivity
parameters */
proc nlmixed data=spdata4 tech= dbldog;
   by species;
   title 'Gillnet Selectivity: Person T';
   parms  tau = 2 sigma = .5 theta = 1 lamda = -1 w = 0.15;
   bounds 0<tau<3, 0<sigma<5, 0<theta<10, -3<lamda<5, 0<= w <=0.5;
/* original, default values:
   parms  tau = 2 sigma = 1 theta = 4 lamda = 0 w = 0.15;
   bounds 0<tau<3, 0<sigma<5, 0<theta<10, -3<lamda<5, 0<= w <=0.5;*/
/* parms = initial value for maximum likelihood estimation */
/* bounds = possible range each parameter can take */
/* Maximum likelihood parameter estimation is often influenced by initial parameter
   value and parameter bounds. When estimates do not seem right, tweak values of
   parms and bounds */
   dum1 = lamda/(2.0*theta);
   dum2 = ((lpr - sigma*dum1 - tau)/sigma);
   dum3 = (1 + dum1)**2;
   g = dum3*(1 + (((lpr - sigma*dum1 - tau)/sigma)**2))**(-theta) -
   exp(-lamda*(atan((lpr - sigma*dum1 - tau)/sigma) + atan(dum1)));
   g275 = dum3*(1 + (((m275 - sigma*dum1 - tau)/sigma)**2))**(-theta) -
   exp(-lamda*(atan((m275 - sigma*dum1 - tau)/sigma) + atan(dum1)));
   g400 = dum3*(1 + (((m400 - sigma*dum1 - tau)/sigma)**2))**(-theta) -
   exp(-lamda*(atan((m400 - sigma*dum1 - tau)/sigma) + atan(dum1)));
   g500 = dum3*(1 + (((m500 - sigma*dum1 - tau)/sigma)**2))**(-theta) -
   exp(-lamda*(atan((m500 - sigma*dum1 - tau)/sigma) + atan(dum1)));
   g525 = dum3*(1 + (((m525 - sigma*dum1 - tau)/sigma)**2))**(-theta) -
   exp(-lamda*(atan((m525 - sigma*dum1 - tau)/sigma) + atan(dum1)));
   g550 = dum3*(1 + (((m550 - sigma*dum1 - tau)/sigma)**2))**(-theta) -
   exp(-lamda*(atan((m550 - sigma*dum1 - tau)/sigma) + atan(dum1)));
   g575 = dum3*(1 + (((m575 - sigma*dum1 - tau)/sigma)**2))**(-theta) -
   exp(-lamda*(atan((m575 - sigma*dum1 - tau)/sigma) + atan(dum1)));
   g650 = dum3*(1 + (((m650 - sigma*dum1 - tau)/sigma)**2))**(-theta) -
   exp(-lamda*(atan((m650 - sigma*dum1 - tau)/sigma) + atan(dum1)));
   g750 = dum3*(1 + (((m750 - sigma*dum1 - tau)/sigma)**2))**(-theta) -
   exp(-lamda*(atan((m750 - sigma*dum1 - tau)/sigma) + atan(dum1)));
   g850 = dum3*(1 + (((m850 - sigma*dum1 - tau)/sigma)**2))**(-theta) -
   exp(-lamda*(atan((m850 - sigma*dum1 - tau)/sigma) + atan(dum1)));
   f = max(sign(tau-lpr)*g,g,min(w,sign(lpr-tau)*w));
   f275 = max(sign(tau-m275)*g275,g275,min(w,sign(m275-tau)*w));
   f400 = max(sign(tau-m400)*g400,g400,min(w,sign(m400-tau)*w));
   f500 = max(sign(tau-m500)*g500,g500,min(w,sign(m500-tau)*w));
   f525 = max(sign(tau-m525)*g525,g525,min(w,sign(m525-tau)*w));
   f550 = max(sign(tau-m550)*g550,g550,min(w,sign(m550-tau)*w));
   f575 = max(sign(tau-m575)*g575,g575,min(w,sign(m575-tau)*w));
   f650 = max(sign(tau-m650)*g650,g650,min(w,sign(m650-tau)*w));
   f750 = max(sign(tau-m750)*g750,g750,min(w,sign(m750-tau)*w));
   f850 = max(sign(tau-m850)*g850,g850,min(w,sign(m850-tau)*w));
   sums = sum(f275,f400,f500,f525,f550,f575,f650,f750,f850)-(9-nummesh)*w;
   phi = f/sums;
   ll = cpue*log(phi);
   id f sums phi;
model selects ~ general(ll);
predict phi out = resid;
/* resid is used for diagnosis */
run;

**************************************************************************
* 4.2 MODEL PARAMETER DIAGNOSIS  *
**************************************************************************;
data resid;
  set resid;
  if selects > 0 then do;
    ll = cpue*log(phi);
    cl = cpue*log(selects);
  end;
  resid = phi*sumcpue - cpue;
  v = selects*sums;
data temp;
  set resid;
  if nonzero > 1;
  proc summary data = temp nway;
    class species;
    var ll cl;
    output out = temp sum =;
  data temp;
  set temp;
  d = 2*(cl-ll);
/* d = deviance: The smaller deviance the better model */
  proc print data = temp;
run;

**************************************************************************
* 4.3 MODEL PARAMETER DIAGNOSIS SCATTER PLOT         *
**************************************************************************;
goptions reset=global gunit=pct border cback=white
  colors=(black blue green red)
  ftitle=swissb ftext=swiss htitle=6 htext=4;
symbol1
  color=black value = dot;
symbol2
  color=blue value = dot;
symbol3
  color=red value = dot;
proc gplot data=resid;
  bubble v*lpr = cpue;
  plot v*lpr f*lpr /overlay;
  by species;
run;
/* Look at the graph if the line (model) is going through center of
clouds */
quit;
Appendix A2—R code used to generate new selectivity parameters.

```r
# Net Selectivity parameter estimates R code
#
# Developed by: Toshihide Hamachan Hamazaki
# Modified by: Carl Thomas Pfisterer 11/3/2015
#
library(gplots)
library(data.table)
library(stringr)
rm(list=ls(all=TRUE))
source '~/Documents/RWork/TestFishQuery.R')  # Needed for functions to query database for test fish data

# This first section contains all the functions used to process the data and for the selectivity
# model. The section after the functions are the commands to read and process the data, optimize
# selectivity parameters, and produce the plots.
#
# FUNCTIONS

dataclean<-function(tfdata){
# convert time factor to numeric and calculate effort
t1 <- as.numeric(strptime(tfdata$startin,format="%H:%M:%S")
t2 <- as.numeric(strptime(tfdata$startout,format="%H:%M:%S")
t3 <- as.numeric(strptime(tfdata$fullin,format="%H:%M:%S")
t4 <- as.numeric(strptime(tfdata$fullout,format="%H:%M:%S")
# Calculate minutes nets are in the water: t5 is soak time.
t5 <- (t1-t4)/2+(t3-t2)/2
# Special conversion case when netting goes to next day
# Add effort data to the file: Effort is calculated as soak time*net fathom
# Remove unnecessary data
# Keep only drift data
# Keep only columns necessary
```
tfdata <- tfdata[\c("date","period","zone","bank","mesh","startout","species","length","sex","effort")\]
tfdata
}

netsuite <- function(data){
  tp1 = unique(data.frame(date=data$date,mesh=data$mesh));
  # Add dummy variable
  tp1$d = 1;
  # Transpose data to give each net fished each day
  tp2 = reshape(tp1,idvar="date",timevar="mesh",direction='wide');
  # Extract unique net combination used: all used nets are 2.75, 4.0, 5.25, 5.5, 5.75, 6.5, 7.5, 8.5
  suiteset = unique(tp2[,2:length(tp2)])
  # Calculate total number of meshizes used (nnets)
  suiteset$nnets <- rowSums(suiteset,na.rm = TRUE)
  # Assign a unique netset combination number (netset)
  suiteset$netset <- 1:length(suiteset$d.2.75)
  # Merge netset combination number
  tp2 = merge(tp2,suiteset,by=names(tp2)[2:length(names(tp2))])
  # Keep only variables necessary
  # suiteset <- suiteset[c('date','nnets','netset')]
  # Convert date variable, so that it can be joined
  tp2$date <- as.POSIXct(tp2$date)
  data$date <- as.POSIXct(data$date)
  # Merge nnets and netset to each date
  data <- merge(data,tp2, by='date')

  list(data=data,suiteset=suiteset)
}

binlengths = function(data){
data$lencat = ifelse(data$species=='Chinook',round(data$length/20+0.0001)*20,round(data$length/10+0.0001)*10)
  # create temporal data without zero catch info
  spdata1 <- data[which(data$length != 0),]
  attach(spdata1)
  mlength <- aggregate(length, by = list(species, lencat), FUN = "mean")
  names(mlength) <- c('species','lencat','mlength')
  spdata1 <- merge(spdata1,mlength, by = c('species','lencat'))
  detach()

  spdata1
}

numfishbyspecies = function(data){
  # Returns the number of fish by species
numfishbyspecies = function(data, suiteset) {
    # transpose catch data to get how many fish caught by species
    # calculate the number of fish caught by day and mesh
    fish1 <- aggregate(sex~species+date+netset+mesh+mlength, data = data, FUN = 'length')
    fish2 <- reshape(fish1, idvar = c('species', 'date', 'netset', 'mlength'), timevar = 'mesh', direction = 'wide')
    # merge to netset
    fish2 <- merge(fish2, suiteset, by = 'netset')
    fish2 = fish2[, c(1:4, length(fish2), (order(names(fish2)[5:(length(fish2)-1)])+4))]  # Reorder columns and sort by mesh size
    # add zero to fish without
    numNets = (length(fish2)-1 - 4)/2;  # Determine the number of mesh sizes present
    for(i in 1:numNets) {  # Loop through each mesh size
        index1 = i + 5;
        index2 = numNets + i + 5;
        name = paste('m', substr(names(fish2)[index1], 3, 20), sep = '.
        fish2[, (length(fish2)+1)] = ifelse(is.na(fish2[, index2]) & fish2[, index1] == 1, 0, fish2[, index2])
        names(fish2)[length(fish2)] = paste('m', substr(names(fish2)[index1], 3, 20), sep = '.
    }
    # Keep only variables necessary
    fish2 = fish2[, c(3,2,1,5,4, (numNets*2+6):(length(fish2)))]
    # Change to the long form.
    fish3 <- reshape(fish2, idvar = c('species', 'date', 'netset', 'mlength'), varying =
        list(names(fish2)[6:length(fish2)]), timevar = 'mesh', times = as.numeric(substr(names(fish2)[6:length(fish2)], 3, 20)),
        direction = 'long', v.name = 'nfish')
    # Delete row name
    row.names(fish3) <- NULL
    # Remove nfish = na: nfish = NA means that the net set was not used on the day of fishing.
    fish3 <- fish3[which(fish3$nfish != 'NA'),]
    fish3$date = as.POSIXct(fish3$date);
}

#########################################################################
## computeuniqueeffort()  
#########################################################################

computeuniqueeffort = function(data) {
    # Extract unique effort data
    eff <- aggregate(effort ~ date + netset + period + startout + mesh, data = data, FUN = "min")
    # Add names to the eff data
    names(eff) <- c('date', 'netset', 'period', 'startout', 'mesh', 'effort')
    # Summarize to
    eff2 <- aggregate(effort ~ date + netset + mesh, data = eff, FUN = "sum")
    names(eff2) <- c('date', 'netset', 'mesh', 'effort')
    eff2 <- eff2[order(eff2$date, eff2$mesh), ]
    eff2$date <- as.POSIXct(eff2$date)
}

#########################################################################
## summarizedata()  
#########################################################################

summarizedata = function(data) {
    # Combines cpue by species, length, and net suite and computes empirical net selectivity
    summarizedata = function(data) {
    # Summarize cpue by combining by species, length, suiteset meshsize

mlcpue <- aggregate(cpue~species+netset+nnets+mesh+mlength+lpr, data=data, FUN = 'sum')
# Summarize cpue by combining by species, length, suiteset
lcpue <- aggregate(cpue~species+netset+nnets+mlength, data=data, FUN = 'sum')
names(lcpue)[length(names(lcpue))] <- 'Scpue'
# Calculate the number of zero catch days for
n0 <- mlcpue[which(mlcpue$cpue == 0),]

n.0 <- aggregate(cpue~species+netset+nnets+mlength, data=data, FUN = 'length')
# Merge the 2 data to calculate empirical net selectivity
names(n.0)[length(names(n.0))] <- 'n0'
# Merger
spdata3 <- merge(mlcpue, lcpue, by=c('species','netset','nnets','mlength'))
spdata3$Scpue <- spdata3$cpue/spdata3$Scpue
spdata3 <- merge(spdata3, n.0, by = c('species','netset','nnets','mlength'))
spdata3$nonzero <- spdata3$nnets - spdata3$n0

# Summarize data by combining all by suiteset
# Add transpose data, so that which nets are used each day
spdata4 <- reshape(spdata3,idvar=c('species','netset','nnets','mlength'),drop=c('cpue','Scpue','select','n0','nonzero')
   ,timevar='mesh',direction='wide')
spdata4 <- merge(spdata3, spdata4, by = c('species','netset','nnets','mlength'))

likelihood <- function(par,likedat){
  tau <- par[1]
  sigma <- par[2]
  theta <- par[3]
  lamda <- par[4]
  tangle <- par[5]
  dm1 <- lamda/(2.0*theta)
  dm2 <- (likedat[,lpr] - sigma*dm1 - tau)/sigma
  dm3 <- (1 + dm1^2)^theta
  g <- dm3*((1+(((likedat[,lpr]-sigma*dm1 - tau)/sigma)^2))^(theta))*exp(-lamda*(atan((likedat[,lpr] - sigma*dm1 - tau)/sigma)+atan(dm1)))
  # Add tangle parameter
  f <- pmax((tau<likedat[,lpr])*tangle,g)
  matrixNames = colnames(likedat);
  for(i in 1:(length(matrixNames)-10)){
    g=dm3*((1+(((likedat[,matrixNames[i+10]]-sigma*dm1 - tau)/sigma)^2))^(theta))*exp(-lamda*(atan((likedat[,matrixNames[i+10]] - sigma*dm1 - tau)/sigma)+atan(dm1)))
    if(i==1){sumValue=pmax((tau<likedat[,matrixNames[i+10]])*tangle,g)}
    else{sumValue = sum(sumValue,pmax((tau<likedat[,matrixNames[i+10]])*tangle,g),na.rm=TRUE)}
  }
  loglink = -sum(likedat[,cpue]*log(f/sumValue));
  return(loglink)
}

###########################################################################
# select()
# Calculates the selectivity from known (or previously derived) parameter values
select <- function(par,lpr) {
  tau <- par[1]
  sigma <- par[2]
  theta <- par[3]
  lamda <- par[4]
  tangle <- par[5]
  dm1 <- lamda/(2.0*theta)
  dm2 <- (lpr - sigma*dm1 - tau)/sigma
  dm3 <- (1 + dm1^2)^theta
  g <- dm3*((1+(((lpr-sigma*dm1 - tau)/sigma)^2))^(-theta))*exp(-lamda*(atan((lpr - sigma*dm1 -
                                                                         tau)/sigma)+atan(dm1)))
  f <- pmax((tau<lpr)*tangle,g)
  return(f)
}

computeParameters = function(data,species){
  ### set initial values and bounds
  init <- c(2.0,0.2,0.6,-0.5,0.15)
  lb <- c(0.0,1.0,-4.0,0)
  ub <- c(3.0,1.5,20.0,5.0,1.0)
  nll <- optim(par=init,fn=likelihood,method="L-BFGS-B",lower=lb, upper = ub, likedat=data, hessian = T)
  min_NLL <- nll$value
  # Plot the data and curves
  lpr <- seq(0,8,by=0.05)
  lpr.r <- data[,'cpue']/20
  lpr.r = lpr.r/max(lpr.r)
  #symbols(data[,lpr], data[,select],circles=lpr.r,inches = TRUE,ylim=c(0,1),xlab='LPR',ylab='Net Selectivity',
  main = species);
  #ramp = rainbow(255,start=.7,end=.1)
  ramp = heat.colors(255)
  #colors = ramp[255*(lpr.r/max(lpr.r))]
  #colors = rgb(log10(lpr.r+1),0,log10(max(lpr.r+1)),maxColorValue=log10(max(lpr.r+1,na.rm=T)))
  #colors=rgb(0,0,0,lpr.r,maxColorValue=max(lpr.r,na.rm=T))
  plot(data[,lpr],data[,select],col=colors,ylim=c(0,1),xlab='LPR',ylab='Net Selectivity',main = species,bty='l');
  lines(lpr,select(nllSpar,lpr),col='black',lwd=2,lty='solid')
  legend('topright',c("New Parameters","Old Parameters"),col='black',lwd=2,lty=c("solid","dotted"),bty='n')
  nllSpar
}

oldParameters()
oldParameters = function(species){
#The following are the parameters using TF data 2000-2009 and were used in 2009-2015
  data = data.frame(
    Species = c("Chinook","Jack","Chum","Fall Chum","Coho","Pink","Broad Whitefish","Humpback "Whitefish","Cisco","Sheefish","Other"),
    TAU = c(1.9008,1.9008,1.96990,1.8632,1.9827,1.9805,1.7774,1.9021,2.083,2.2604,2.2604),
    SIGMA = c(0.205,0.205,0.1543,0.233,0.233,0.2598,0.2205,0.232,0.2223,0.3642,0.3642),
    THETA = c(0.5923,0.5923,0.7504,1.1954,0.8686,1.5542,1.40180,1.1103,1.8771,0.98810,0.98810),
    LAMDA = c(-0.4334,-0.4334,-0.4841,-1.43610,-1.4557,1.282,-1.9341,-2.0546,-1.6381,-2.299,-2.299),
    TANGLE = c(0.02394,0.02394,0.0,0.03034,0.1185,0.1649,0.09809,0.06415,0.18090,0,0)
  )
  parameters = as.vector(data[which(data$Species==species),-1],mode="numeric")
  parameters
}

empiricalSelectivity = function(data,species){
  for (s in species){
    increment=0.25
    d = data.matrix(data[which(data$Species==s & data$select>0),-1]);
    bins = seq(0,max(d[,"lpr"]),by= increment);
    meanSelect = 0;
    for (b in 1:(length(bins)-1)){
      meanSelect = c(meanSelect,mean(d[which(d[,"lpr"]>=bins[b] & d[,"lpr"]<bins[b+1]),"select"]))
    }
    d2=data.frame(lpr=bins,meanSelect=meanSelect)
    plot(d2$lpr,d2$meanSelect,type='l',bty='l',xlab="LPR",ylab="Mean Selectivity",ylim=c(0,1),main=paste(s,"Min=",round(min(d2$meanSelect,na.rm=TRUE),digits=4))
    points (d,'lpr',d['select'],col=rgb(0,0,0.4,maxColorValue=1))
    cat(s," Min Select=",round(min(d2$meanSelect,na.rm=TRUE),digits=4),"n")
    #cat(s,"n")
    #cat("lpr",bins)
    #cat("msel",meanSelect)
    #cat("n\n\n")
  }
}

empiricalSelectivityPoints = function(data,species,add=FALSE,col='blue'){
  for (s in species){
    increment=0.25
    d = data.matrix(data[which(data$Species==s & data$select>0),-1]);
    bins = seq(0,max(d[,"lpr"]),by= increment);
    if(add==FALSE){
      plot(d,['lpr'],d,['select'],col=col,type='p',bty='l',xlab="LPR",ylab="Selectivity",ylim=c(0,1),main="Empirical
    }
  }
Selectivity")
    }
    else{
        points (d[,1],d[,2],col=col)
    }
}

# ******************************** END OF FUNCTIONS **************************** #

startTime = proc.time();
allspecies = c("Chinook","Chum","Fall Chum","Coho","Pink","Broad Whitefish","Humpback Whitefish","Cisco","Sheefish","Other")
tfdata = testFishQuery(Year=1990:2015,Species='ALL',LowerMesh=2.5,Table="PSTFish");  #Query the database for all test fish records between 1995 and 2015
#tfdata = read.table('~/Documents/Work/Eagle/2013/Eagle Selectivity/Eagle_Testfish.csv',sep=',' ,header=T) #Read data from comma delimited text file
names(tfdata) = str_to_lower(names(tfdata)); #Convert column labels to lower case
wkdata = dataclean(tfdata);
wkdata = netsuite(wkdata);
suiteset = wkdata$suiteset;
wkdata = wkdata$sdata;
spdata2 = merge(numfishbyspecies(binlengths(wkdata),suiteset),computeuniqueeffort(binlengths(wkdata)),by=c('date', 'netset', 'mesh'))
spdata2$ctue = spdata2$nfish/spdata2$effort
spdata2$lpr = spdata2$mlength/(spdata2$mesh*25.4*2)
data = summarizedata(spdata2);
params = data.frame(Species=NA,TAU=NA,SIGMA=NA,THETA=NA,LAMDA=NA,TANGLE=NA)

#bg='transparent';fg='white'
bg='white';fg='black'
pdf("~/Desktop/Selectivity Plots.pdf",width=7,height=9.5)
par(col.axis=fg,col.lab=fg,col.main=fg,col.sub=fg,fg=fg,bg=bg,cex=1.0,mfrow=c(2,1),family='serif')
for (s in allspecies){
  if(s != "Other"){
    specData <- data.matrix(data[which(data$species == s),-1])
    cat("Processing Species:" ,s," n=",length(data[which(data$species==s),1]),  "n")
  }
  else{
    specData <- data.matrix(data[which(data$species == s) ,data$species == "Sockeye" | data$species == "Dolly Varden" | data$species == "Longnose Sucker") ,
    cat("Processing Species:" ,s," n=",length(data[which(data$species==s) ,| tfdata$species == "Sockeye" | tfdata$species == "Dolly Varden" | tfdata$species == "Longnose Sucker") ,  "n")
    params = rbind(params,c(s,computeParameters(specData,s)))
  }
}
dev.off()
params[-1,1] = str_to_upper(params[-1,1]); #Convert species names to uppercase to make it easier to add to netsel.dat text file
print(params[-1,])

df("~/Desktop/Empirical Selectivity Plots.pdf",width=8,height=6)
empiricalSelectivity(data,allspecies)
dev.off()
endTime = proc.time()
cat("n\n";"Time Elapsed=";endTime[3]-startTime[3])
APPENDIX B: TIMELINE OF PROJECT CHANGES
Appendix B1.—Timeline of project changes.

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Operated Bendix fan scan (300 kHz) and BioSonics single-beam sonar (420 kHz).</td>
</tr>
<tr>
<td></td>
<td>Direction of travel determined from slant of fish traces (transducers were aimed 45 deg downstream).</td>
</tr>
<tr>
<td>1985</td>
<td>BioSonics 420 kHz.</td>
</tr>
<tr>
<td></td>
<td>20 min sampling duration.</td>
</tr>
<tr>
<td></td>
<td>4 Mesh sizes utilized 101.6 mm (4.0 in), 139.7 mm (5.5 in), 162.0 mm (6.38 in), and 215.9 mm (8.5 in) 45.7 m (150 ft)</td>
</tr>
<tr>
<td></td>
<td>Report periods were 3-9 days to obtain minimum sample of 120 fish at each site.</td>
</tr>
<tr>
<td></td>
<td>Utilized a -32 dB detection threshold.</td>
</tr>
<tr>
<td></td>
<td>Transducers were aimed 15 deg downstream to determine direction of travel.</td>
</tr>
<tr>
<td></td>
<td>Counts within sectors were expanded for the proportion of the water column covered.</td>
</tr>
<tr>
<td></td>
<td>Sampled 4 strata, left bank nearshore, left bank offshore, right bank bottom, right bank surface. Left bank strata required 2 transducers deployed at different ranges.</td>
</tr>
<tr>
<td>1986</td>
<td>6 Mesh sizes utilized 101.6 mm (4.0 in), 127.0 mm (5.0 in), 139.7 mm (5.5 in), 165.1 mm (6.5 in), 190.5 mm (7.5 in), and 215.9 mm (8.5 in). All were 45.7 m (150 ft) long and 7.6 m (25 ft) deep.</td>
</tr>
<tr>
<td>1987</td>
<td>No substantial changes.</td>
</tr>
<tr>
<td>1988</td>
<td>Did not adjust catches for selectivity (this was 1988 only)</td>
</tr>
<tr>
<td>1990</td>
<td>Spatial expansion based on the proportion of the water column insonified was discontinued.</td>
</tr>
<tr>
<td></td>
<td>8.5” and 7.5” drifted twice per bank per period, other nets drifted once per bank.</td>
</tr>
</tbody>
</table>

-continued-
Stopped fishing 8.5" and 7.5" nets after July 25

Net selectivity methodology improved from previous, used McCombie and Fry method (1960) for Chinook and chum salmon and Holt (Peterson 1966) for coho salmon, pink salmon, and whitefish. Began computing sample variance for the estimates. SAS used to generate estimates.

1991 First year 70 mm (2.75 in) net fished.

1992 Project only operated a partial season and savings used to purchase 120kHz equipment.

1993 Sonar frequency changed from 420 kHz to 120 kHz to detect fish at greater ranges.

Individual sonar stratum were sampled in 15 min periods (was 20 min previously).

Sonar operated 24 hrs/day 4 times during the season.

No expansion for fish beyond the counting range using down looking fathometer. Log-normal curves used to describe selectivity.

1994 No substantial changes.

1995 Utilized a single stratum on the right bank

No longer used the angle of traces to distinguish downstream from upstream fish. All traces were considered upstream.

1996 Project did not produce estimates and operated for training purposes only.

1997 140 mm (5.5 in) mesh added in the fall when 7.5 in and 8.5 in discontinued.

1998 Sampled 3 sonar strata on right bank.

Dropped the 127.0 mm (5.0 in) and 165.1 mm (5.5 in) nets, used 133 mm (5.25 in).

-continued-
1999 In the fall season, dropped 215.0 mm (8.5 in) and 133 mm (5.25 in) nets and added 146 mm (5.75 in) and 127 mm (5.0 in).

2000 No substantial changes.

2001 Transitioned to HTI split-beam equipment. Frequency kept at 120 kHz and still marked fish using paper charts.

2002 No substantial changes.

2003 No substantial changes.

2004 Changed selectivity model to use Pearson-T curve.

2005 Incorporated the DIDSON into left bank sampling for the first 20m.

2006 No substantial changes.

2007 No substantial changes.

2008 No substantial changes.

2009 Transitioned from marking fish on paper charts to electronic echograms

2010 Tested 50 fathom nets during summer season. Alternated 25 fathom and 50 fathom by test fishing period.

2011 Preliminary testing of side-scan sonar for use offshore during periods of extreme turbidity.

2012 Dropped the 50 fathom nets and resumed normal test fishing operations.

-continued-
<table>
<thead>
<tr>
<th>Year</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013</td>
<td>No substantial changes.</td>
</tr>
<tr>
<td>2014</td>
<td>No substantial changes.</td>
</tr>
<tr>
<td>2015</td>
<td>No substantial changes.</td>
</tr>
<tr>
<td>2016</td>
<td>Switched from DIDSON to ARIS on the left bank sampling the entire stratum 3 (0-50 m). Updated selectivity parameters for all species and implemented a minimum selectivity threshold of 0.1.</td>
</tr>
</tbody>
</table>