6.0 LOWER YUBA RIVER REGIONAL INTERACTIONS

This Interim Report addresses lower Yuba River anadromous salmonid population dynamics, and the relationship and role of the lower Yuba River with respect to the ESU/DPS and contribution to recovery. The first part of this chapter focuses on lower Yuba River anadromous salmonid population abundance and productivity in comparison with the Central Valley and Sacramento Valley rivers in general, and the lower Feather River in particular. Comparative trend analyses are presented, and discussion is provided regarding performance expressions of the local populations relative to the regional populations. In particular, data evaluations and discussions address the manner in which lower Yuba River salmonid population structure, dynamics, and trends relate to Feather River populations, and the mechanisms (e.g., attraction flows) influencing local population responses and interactions.

6.1 COMPARISON OF ANNUAL YUBA RIVER SPRING-RUN CHINOOK SALMON RUN SIZES TO THE SACRAMENTO RIVER SYSTEM

The annual run sizes of spring-run Chinook salmon in-river spawners in the Sacramento River mainstem and its tributaries including Battle, Clear, Cottonwood, Antelope, Mill, Thomas, Deer, Big Chico and Butte creeks are reported in GrandTab. It is recognized that spawning escapement survey methods vary among rivers and streams of the Central Valley and, consequently, the numbers reported in GrandTab are not equally reliable among watersheds. For example, the spawning stock escapement estimates reported for Butte Creek are based on snorkel surveys, by contrast to carcass surveys employed on many other systems. It has been suggested that the spawning stock escapement estimates reported for Butte Creek could be significantly underestimated (T. McReynolds, CDFW, pers. comm. 2013).

Although GrandTab does report the annual run sizes of spring-run Chinook salmon returning to the Feather River Fish Hatchery (FRFH), it does not report the annual run sizes of in-river spring-run Chinook salmon spawners in the lower Feather River. In addition, the numbers reported in GrandTab significantly underestimate the spring-run Chinook salmon population abundance in the lower Feather River, because those numbers do not represent the fish that were tagged during the spring-run phenotypic period or the numbers in the river in that did not return to the FRFH, but simply represent the number of fish that were tagged during the spring and then re-entered the FRFH. All other Chinook salmon in the lower Feather River are reported as fall-run Chinook salmon in GrandTab. Nor does GrandTab report the annual run sizes of spring-run Chinook salmon spawners in the lower Yuba River – rather, all Chinook salmon spawning in the lower Yuba River are reported as fall-run Chinook salmon.

For the following analysis, the Chinook salmon reported by GrandTab as lower Feather River fall-run Chinook salmon in-river spawners were apportioned into lower Feather River spring-run Chinook salmon using the annual proportions of spring-run Chinook salmon with respect to all of the Chinook salmon that returned to the FRFH, and the result was added to the spring-run
Chinook salmon in-river spawners of the Sacramento River system. With the limitations on the veracity of spring-run Chinook salmon annual estimates in the Sacramento River system in mind, evaluation of the relative contribution of the lower Yuba River to the Sacramento River system annual spring-run Chinook salmon returns was undertaken. It is recognized that the following evaluations provide a rough indication of the lower Yuba River’s contribution to Sacramento Valley populations.

To compare the annual run sizes of phenotypic spring-run Chinook salmon in the lower Yuba River to those in the rest of the Sacramento River system (excluding the FRFH), the following information was used: (1) the run sizes of lower Yuba River Chinook salmon in-river spawners for the period 2004-2011, reported in Yuba River Chinook salmon escapement surveys; (2) the Schaefer mark-recovery escapements for the lower Yuba River upstream and downstream of Daguerre Point Dam, obtained during the 8 most recent carcass surveys conducted in the lower Yuba River; and (3) the annual percentage of phenotypic spring-run Chinook salmon (relative to all Chinook salmon) passing upstream of Daguerre Point Dam (previously described). These data sources (Table 6-1) were utilized to generate an 8-year time series of estimated lower Yuba River phenotypic spring-run Chinook salmon in-river spawners, based on GrandTab data, in order to obtain an equitable basis of comparison with the Sacramento River system.

Table 6-1. Data utilized to generate the time series of phenotypic spring-run Chinook salmon in-river spawners for the lower Yuba River for the years 2004 through 2011.

<table>
<thead>
<tr>
<th>Year</th>
<th>Lower Yuba River Chinook Salmon Escapement Estimates (Carcass Surveys)</th>
<th>Passage Upstream DPD (VAKI RiverWatcher)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lower Yuba River Chinook Salmon Escapement Estimates (Carcass Surveys)</td>
<td>Passage Upstream DPD (VAKI RiverWatcher)</td>
</tr>
<tr>
<td></td>
<td>(No.of Fish)</td>
<td>(No.of Fish)</td>
</tr>
<tr>
<td>2004</td>
<td>14,586</td>
<td>9,477</td>
</tr>
<tr>
<td>2005</td>
<td>17,630</td>
<td>12,316</td>
</tr>
<tr>
<td>2006</td>
<td>8,231</td>
<td>5,423</td>
</tr>
<tr>
<td>2007</td>
<td>2,604</td>
<td>---</td>
</tr>
<tr>
<td>2008</td>
<td>3,508</td>
<td>3,360</td>
</tr>
<tr>
<td>2009</td>
<td>4,795</td>
<td>4,020</td>
</tr>
<tr>
<td>2010</td>
<td>13,097</td>
<td>9,781</td>
</tr>
<tr>
<td>2011</td>
<td>9,183</td>
<td>7,785</td>
</tr>
</tbody>
</table>

(1) Because in 2007 not enough carcasses were collected to Schaefer escapement estimates by reach, the 2007 percentage upstream of Daguerre Point Dam was calculated as the average of the 2008 and 2008 percentages.

The estimated run sizes of the resulting 8-year time series of lower Yuba River phenotypic spring-run Chinook salmon were then compared to the corresponding series of spring-run Chinook salmon in-river spawners reported by GrandTab for the Sacramento River system to: (1) assess the contribution of lower Yuba River phenotypic spring-run Chinook salmon to the Sacramento River system spring-run Chinook salmon in-river spawners; and (2) evaluate their respective temporal trends.

The Schaefer mark-recovery escapement estimates for the lower Yuba River upstream of Daguerre Point Dam, relative to the escapement estimates for the whole lower Yuba River, were used to generate a series of eight percentages ($CHN_{DPD\%}$) representing the annual proportion of Chinook salmon spawning upstream of Daguerre Point Dam.
The annual estimates of spring-run Chinook salmon passing upstream of Daguerre Point Dam obtained from the Vaki Riverwatcher data, relative to the annual estimates of all Chinook salmon passing upstream of Daguerre Point Dam, were used to generate another series of percentages ($CHN_{SR,DPD\%}$) representing the annual proportion of phenotypic spring-run Chinook salmon passing upstream of Daguerre Point Dam.

Using the 2004-2011 run sizes of lower Yuba River spawners that were reported in GrandTab as fall-run Chinook spawners as the annual numbers of all Chinook salmon (i.e., spring-run and fall-run combined) that spawned in the lower Yuba River ($CHN$), the annual numbers of phenotypic spring-run Chinook salmon that spawned in the lower Yuba River ($CHNSR$) were calculated as:

$$CHNSR = CHN \cdot \frac{CHN_{DPD\%}}{100} \cdot \frac{CHN_{SR,DPD\%}}{100}.$$

The annual numbers of fall-run Chinook salmon that spawned in the lower Yuba River ($CHN_{FR}$) were also calculated for the 2004-2011 period using the related formula:

$$CHN_{FR} = CHN \cdot \left(1 - \frac{CHN_{DPD\%}}{100} \cdot \frac{CHN_{SR,DPD\%}}{100}\right).$$

Table 6-2 displays the results of the above calculations for the 2004-2011 run sizes of lower Yuba River Chinook salmon, and the spring-run and fall-run Chinook salmon in-river spawners reported by GrandTab for the Sacramento River system.

It is recognized that this approach to separate the annual GrandTab run sizes of lower Yuba River Chinook salmon spawners into spring-run and fall-run annual estimates is rather simplistic and results in crude estimates. The existence of unavoidable differences in accuracy and precision between the estimates generated from the carcass surveys and the VAKI Riverwatcher counts may affect the accuracy and precision of the resulting estimates of phenotypic spring-run Chinook salmon that spawn in the lower Yuba River. These estimates based on GrandTab data were developed only to obtain a more equitable basis of comparison with the Sacramento River system.
Table 6-2. Estimated number of phenotypic spring-run and fall-run Chinook salmon spawning in the lower Yuba River from 2004 through 2011, and corresponding spring-run and fall-run Chinook salmon spawners reported in GrandTab for Sacramento River system.

<table>
<thead>
<tr>
<th>Year</th>
<th>Yuba River Spring-run Chinook Salmon Spawners (No. of Fish)</th>
<th>Yuba River Fall-run Chinook Salmon Spawners (No. of Fish)</th>
<th>Sacramento River System (GrandTab)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Spring-run Chinook Salmon Spawners (No. of Fish)</td>
</tr>
<tr>
<td>2004</td>
<td>1,180</td>
<td>13,406</td>
<td>18,715</td>
</tr>
<tr>
<td>2005</td>
<td>3,889</td>
<td>13,741</td>
<td>17,959</td>
</tr>
<tr>
<td>2006</td>
<td>1,382</td>
<td>6,849</td>
<td>19,045</td>
</tr>
<tr>
<td>2007</td>
<td>562</td>
<td>2,042</td>
<td>14,602</td>
</tr>
<tr>
<td>2008</td>
<td>691</td>
<td>2,817</td>
<td>6,234</td>
</tr>
<tr>
<td>2009</td>
<td>540</td>
<td>4,255</td>
<td>3,250</td>
</tr>
<tr>
<td>2010</td>
<td>4,364</td>
<td>8,733</td>
<td>5,580</td>
</tr>
<tr>
<td>2011</td>
<td>1,159</td>
<td>8,024</td>
<td>5,756</td>
</tr>
</tbody>
</table>

Figure 6-1 displays the percent contribution of the estimated number of lower Yuba River phenotypic spring-run Chinook salmon to the total numbers of in-river spawning spring-run Chinook salmon in the Sacramento River system during the last eight years. The lowest contribution of lower Yuba River phenotypic spring-run Chinook salmon to the Sacramento River system occurred in 2007 (3.7%). The lower Yuba River percent contribution has increased since 2007, reaching its maximum during 2010 (43.9%), and decreasing to 16.8% in 2011.

Figure 6-2 illustrates the temporal trend in the estimated number of phenotypic spring-run Chinook salmon annually spawning in the lower Yuba River, compared to the total number of in-river spawning spring-run Chinook salmon in the Sacramento River system, excluding the lower Yuba River.
A statistical procedure was used to evaluate recent changes in the abundance of lower Yuba River and Sacramento River system in-river spawning populations of spring-run Chinook salmon. A full model was initially fitted to the 16 available data points (i.e., the natural logarithms of the 8 annual run sizes of lower Yuba River phenotypic spring-run Chinook salmon, and the 8 annual run sizes of Sacramento River system in-river spawning spring-run Chinook salmon) using a simple least-square approach. The analysis of the resulting fitted full model indicated that there was no need for the additional fitting of a reduced model, or for the use of the ANCOVA approach to test whether over the last 8 years the abundance of lower Yuba River and that of the Sacramento River system spring-run Chinook salmon were changing at statistically different rates.

The fit of the full model explained 77.12% of the variability present in the combined data sets of spring-run Chinook salmon run sizes ($Y_i$). The fitted full model had the following expression:

$$\ln(Y_i) = 493.190 - 434.413 \cdot I_i - 0.2411 \cdot Year_i + 0.2154 \cdot I_i \cdot Year_i$$

with error term $\varepsilon$ assumed to be normally distributed with mean 0 and estimated standard deviation of 0.676. The fit was statistically significant ($P = 0.0004$). The resulting lower Yuba River regression line was:

$$\ln(Y_i) = 58.777 - 0.0257 \cdot Year_i$$

that explained only about 0.61% of the variability present in the 8 years of lower Yuba River run sizes, with a negative slope that was not statistically significant ($P = 0.854$). By contrast, the

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**Figure 6-2. Temporal trends in the estimated number of spring-run Chinook salmon in the lower Yuba River (green circles and dashed line) and the total number of in-river spawning spring-run Chinook salmon in the Sacramento River system excluding the lower Yuba River (pink circles and dashed line) during 2004-2011.**
resulting Sacramento River system regression line was:

\[ \ln(Y_i) = 493.190 - 0.2411 \cdot \text{Year}_i \]

that explained about 71.92% of the variability present in the 8 years of Sacramento River system run sizes, with a negative slope that was highly statistically significant (\(P = 0.008\)).

**Figure 6-3** displays the antilogarithmic transformation of the lower Yuba River and Sacramento River system regression lines resulting from fitting the full model to the spring-run Chinook salmon run sizes. A statistically significant decline in abundance over the 8 years examined can be inferred only for the Sacramento River system run sizes. According to NMFS (2011a), recent anomalous conditions in the coastal ocean, and consecutive dry years affecting inland freshwater conditions, have contributed to statewide escapement declines in spring-run Chinook salmon.

By contrast, the lower Yuba River phenotypic spring-run Chinook salmon population over this time period is not exhibiting a statistically significant declining trend. Because of the GrandTab data limitations previously described, the preceding general trends may be appropriately represented, but actual abundance estimates need to be viewed with caution. In addition to the interpretive limitations of the Sacramento River system escapement estimates described above, any such trend analysis inherently assumes that lower Yuba River spring-run Chinook salmon represent an independent population, which does not appear to be the case (see Chapter 5). Rather, phenotypic spring-run Chinook salmon returning to the lower Yuba River represent a mixture of lower Yuba River and lower Feather River-origin fish. Hence, additional analyses are undertaken to further examine lower Feather-lower Yuba river interactions.

![Spring-run Chinook Salmon](image-url)

**Figure 6-3.** Temporal trends in the phenotypic spring-run Chinook salmon population in the lower Yuba River and in the Sacramento River system (excluding the lower Yuba River), from 2004 through 2011. Regression lines for each of the two distributions are included.
6.2 **COMPARISON OF ANNUAL YUBA RIVER SPRING-RUN CHINOOK SALMON RUN SIZES TO THE FEATHER RIVER RUN SIZES**

As previously mentioned, GrandTab does not report the annual run sizes of spring-run Chinook salmon in-river spawners in the Feather River. Instead, all Feather River Chinook salmon in-river spawners are reported as fall-run Chinook salmon. However, GrandTab does report the annual run sizes of spring-run and fall-run Chinook salmon returning to the FRFH. The FRFH implemented a methodology change in 2005 for distinguishing spring-run from fall-run Chinook salmon. Fish arriving during spring, prior to the spring-run spawning period, were tagged and returned to the river. The spring-run escapement to the FRFH was then estimated as the number of these tagged fish that subsequently returned to the hatchery during the spring-run spawning period. Again, as previously mentioned, this methodology results in an underestimation of spring-run Chinook salmon returning to the FRFH, but represents the best available information.

For the analyses in this and the following section, the Chinook salmon reported by GrandTab as lower Feather River fall-run Chinook salmon in-river spawners were apportioned into lower Feather River spring-run and fall-run Chinook salmon in-river spawners using the annual proportions of spring-run Chinook salmon with respect to all of the Chinook salmon that returned to the FRFH. **Table 6-3** provides the Feather River Chinook salmon escapement as originally reported in GrandTab, and the resulting estimated number of Feather River spring-run and fall-run Chinook salmon in-river spawning that is used in the trend analyses of this and following sections.

**Figure 6-4** compares the temporal trend of Feather River Chinook salmon in-river escapement reported in GrandTab (i.e., spring and fall runs combined) to the temporal trend of the combined spring-run and fall-run escapements to the hatchery. The light blue bars indicate the annual percent contribution of spring-run fish to the combined Chinook salmon escapement to the hatchery.

**Table 6-3.** Estimated number of Feather River spring-run and fall-run Chinook salmon in-river spawning from 2004 through 2011, and corresponding spring-run and fall-run Chinook salmon escapement as reported in GrandTab.

<table>
<thead>
<tr>
<th>Year</th>
<th>Estimated Feather River Chinook Salmon Spawners (No.of Fish)</th>
<th>Feather River Chinook Salmon Escapement Estimates (GrandTab)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fall-run</td>
<td>Spring-run</td>
</tr>
<tr>
<td></td>
<td>In-River Spawners (No.of Fish)</td>
<td>In-River Spawners (No.of Fish)</td>
</tr>
<tr>
<td>2004</td>
<td>45,226</td>
<td>8,945</td>
</tr>
<tr>
<td>2005</td>
<td>45,553</td>
<td>3,607</td>
</tr>
<tr>
<td>2006</td>
<td>66,136</td>
<td>10,278</td>
</tr>
<tr>
<td>2007</td>
<td>14,584</td>
<td>7,302</td>
</tr>
<tr>
<td>2008</td>
<td>4,501</td>
<td>1,438</td>
</tr>
<tr>
<td>2009</td>
<td>4,409</td>
<td>438</td>
</tr>
<tr>
<td>2010</td>
<td>41,465</td>
<td>3,449</td>
</tr>
<tr>
<td>2011</td>
<td>44,597</td>
<td>2,692</td>
</tr>
</tbody>
</table>
When both the spring- and fall-runs are combined, the annual in-river and hatchery escapements showed a strong and statistically significant correlation ($r = 0.752$, $P = 0.031$). In fact, the annual in-river and hatchery abundance estimates displayed similar temporal patterns, both showing a considerable decrease in abundance from 2006 with relatively low numbers exhibited during 2007, 2008 and 2009. Figure 6-4 displayed another noticeable pattern - during 2007 and 2008 the contributions of spring-run Chinook salmon hatchery escapement, with respect to the hatchery escapement of both runs combined, were 33.4% and 24.2%, roughly doubling the average annual percent contribution of 14.7%.

The natural logarithm of the estimated annual Feather River spring-run Chinook salmon in-river escapement was regressed against year, and the resulting estimated temporal trend was compared to that obtained for the lower Yuba River Chinook salmon in-river escapement.

The resulting Feather River regression line was:

$$\ln(Y_i) = 479.446 - 0.2348 \cdot Year_i$$

that explained 29.9% of the variability present in the 8 years of Feather River spring-run Chinook salmon sizes, with a negative slope that was not statistically significant ($P = 0.161$). **Figure 6-5** displays the spring-run Chinook salmon in-river spawners for the lower Yuba River and the Feather River, together with the antilogarithmic transformation of the Feather River and lower Yuba River regression lines displayed in the above equations.
An additional regression analysis was performed, in which the natural logarithm of the sum of the estimated annual Feather River spring-run Chinook salmon in-river and hatchery escapements (second and seventh columns in Table 6-3) was regressed against year. The resulting Feather River regression line was:

\[
\ln(Y_i) = 371.991 - 0.1810 \cdot Year_i
\]

that explained 34.6% of the variability present in the 8 years of Feather River run sizes, with a negative slope that was not statistically significant \((P = 0.125)\).

Figure 6-6 displays the phenotypic spring-run Chinook salmon in-river spawners for the lower Yuba River, and the combined in-river and hatchery spring-run Chinook salmon spawners for the Feather River, together with the antilogarithmic transformation of the Feather River and lower Yuba River regression lines displayed in the above equations. Examination of Figure 6-6 indicates that for several of the years, an inverse relationship was observed between the lower Feather and the lower Yuba River – in other words, relatively high phenotypic spring-run Chinook salmon abundance in the lower Yuba River occurred concurrently with relatively low spring-run Chinook salmon abundance in the Feather River. However, that trend was not consistently observed during all years.
Figure 6-6. Temporal trends in the number of the phenotypic spring-run Chinook salmon in-river spawners in the lower Yuba River, and in-river plus hatchery spawners in the Feather River, from 2004 through 2011. Regression lines for each of the two distributions are included.

6.3 COMPARISON OF ANNUAL YUBA RIVER FALL-RUN CHINOOK SALMON RUN SIZES TO THE SACRAMENTO RIVER SYSTEM

GrandTab reports the annual run sizes of fall-run Chinook salmon in-river spawners in the Sacramento River mainstem and its tributaries including Battle, Clear, Cottonwood, Cow, Bear, Mill, Deer, and Butte creeks, and the lower American River. As previously discussed, GrandTab reports all Chinook salmon spawning in the lower Yuba River and the lower Feather River as fall-run Chinook salmon. For the following analyses, the Chinook salmon reported by GrandTab as lower Feather River fall-run Chinook salmon in-river spawners were apportioned into lower Feather River fall-run Chinook salmon using the annual proportions of fall-run Chinook salmon with respect to all of the Chinook salmon that returned to the FRFH, and the result was added to the fall-run Chinook salmon in-river spawners of the Sacramento River system.

In the previous section, the procedure and formula used to evaluate the fall-run Chinook salmon spawning in the lower Yuba River were explained, and the resulting estimates were displayed in Table 6-2. The estimated numbers of lower Yuba River fall-run Chinook salmon spawners in Table 6-2 were used to evaluate their percent contribution to the in-river spawning population of fall-run Chinook salmon in the Sacramento River system (i.e., the fall-run Chinook salmon reported by GrandTab for the Sacramento River mainstem and tributaries plus the current estimates of lower Yuba River fall-run Chinook salmon spawners) during the period of 2004-2011.
Figure 6-7 displays the percent contribution of the estimated numbers of lower Yuba River phenotypic fall-run Chinook salmon to the in-river spawning fall-run Chinook salmon population in the Sacramento River system during the last eight years. The lowest contribution of lower Yuba River fall-run Chinook salmon to the Sacramento River system occurred in 2007 (2.6%). The lower Yuba River percent contribution has increased since 2007, reaching its maximum percent contribution during 2009 (13.2%), and decreasing to 5.1% in 2011.

Figure 6-8 illustrates the temporal trend in the estimated number of phenotypic fall-run Chinook salmon annually spawning in the lower Yuba River, compared to the temporal trend displayed by the in-river spawning population of fall-run Chinook salmon in the Sacramento River system, excluding the lower Yuba River. In spite of differences in magnitude, the time series of phenotypic fall-run Chinook salmon annually spawning in the lower Yuba River and the Sacramento River System display remarkably similar temporal patterns from 2004 through 2011.

The same statistical procedure used to evaluate recent changes in the abundance of lower Yuba River and Sacramento River system in-river spawning populations of spring-run Chinook salmon was used to evaluate the abundance trends of fall-run Chinook salmon in the lower Yuba River and Sacramento River system. The full model was initially fitted to the 16 available data points (i.e., the natural logarithms of the 8 annual run sizes of lower Yuba River fall-run Chinook salmon, and the 8 annual run sizes of Sacramento River system in-river spawning fall-run Chinook salmon) using a simple least-square approach. The analysis of the resulting fitted full model also indicated that there was no need for the additional fitting of a reduced model.

![Figure 6-7](image-url)  
Figure 6-7. Annual percent contribution of phenotypic fall-run Chinook salmon in the lower Yuba River (green bars) to the total in-river spawning fall-run Chinook salmon population in the Sacramento River system (pink circles and dashed line), during 2004-2011.
Figure 6-8. Temporal trends in the estimated numbers of lower Yuba River fall-run Chinook salmon and in-river spawning fall-run Chinook salmon in the Sacramento River system excluding the lower Yuba River during 2004-2011.

The fit of the full model explained 84.2% of the variability present in the combined data sets of fall-run Chinook salmon run sizes ($Y_i$). The fitted full model had the following expression:

$$\ln(Y_i) = 354.788 - 179.589 \cdot I_i - 0.1709 \cdot \text{Year}_i + 0.0880 \cdot I_i \cdot \text{Year}_i$$

with error term $\varepsilon$ assumed to be normally distributed with mean 0 and estimated standard deviation of 0.752. The fit was statistically significant ($P = 0.00004$). The resulting lower Yuba River regression line was:

$$\ln(Y_i) = 175.199 - 0.0829 \cdot \text{Year}_i$$

that explained only about 8.5% of the variability present in the 8 years of lower Yuba River run sizes, with a negative slope that was not statistically significant ($P = 0.485$). The resulting Sacramento River system regression line was:

$$\ln(Y_i) = 354.788 - 0.1709 \cdot \text{Year}_i$$

that explained about 25.1% of the variability present in the 8 years of Sacramento River system run sizes, with a negative slope that was not statistically significant ($P = 0.206$). Figure 6-9 displays the antilogarithmic transformation of the lower Yuba River and Sacramento River system regression lines resulting from fitting the full model to the fall-run Chinook salmon run sizes.
Figure 6-9. Temporal trends in the number of fall-run Chinook salmon in the lower Yuba River and in the Sacramento River system (excluding the lower Yuba River), from 2004 through 2011. Regression lines for each of the two distributions are included.

Results of the analyses indicate that although both the Sacramento River system and the lower Yuba River exhibit declining trends in annual fall-run Chinook salmon abundance, these trends are not statistically significant. Because of the GrandTab data limitations previously described, the preceding general trends may be appropriately represented, but actual abundance estimates need to be viewed with caution.

### 6.4 Comparison of Annual Yuba River Fall-run Chinook Salmon Run Sizes to the Feather River Run Sizes

The natural logarithm of the estimated annual Feather River fall-run Chinook salmon in-river escapement (first column in Table 6-3) was regressed against year, and the resulting estimated temporal trend was compared to that obtained for the lower Yuba River Chinook salmon in-river escapement (second column in Table 6-2).

The resulting Feather River regression line was:

\[
\ln(Y_i) = 245.866 - 0.1175 \cdot \text{Year}_i
\]

that explained only 6.9% of the variability present in the 8 years of Feather River run sizes, with a negative slope that was not statistically significant \((P = 0.530)\). Figure 6-10 displays the fall-run Chinook salmon in-river spawners for the lower Yuba River and the Feather River, together with the antilogarithmic transformation of the Feather River and lower Yuba River regression lines displayed in the above equations.
An additional regression analysis was performed, in which the natural logarithm of the sum of the estimated annual Feather River fall-run Chinook salmon in-river and hatchery escapements (first and fifth columns in Table 6-3) was regressed against year. The resulting Feather River regression line was:

$$\ln(Y_i) = 138.411 - 0.0637 \cdot Year_i$$

that explained very little (3.3%) of the variability present in the 8 years of Feather River run sizes, with a negative slope that was not statistically significant ($P = 0.668$).

Figure 6-11 displays the phenotypic fall-run Chinook salmon in-river spawners for the lower Yuba River and the combined in-river and hatchery fall-run Chinook salmon spawners for the Feather River, together with the antilogarithmic transformation of the Feather River and lower Yuba River regression lines displayed in the above equations. Results of the analyses indicate that although both the lower Feather River and the lower Yuba River exhibit declining trends in annual fall-run Chinook salmon abundance, these trends are not statistically significant. However, specific abundances associated with these trends must be viewed with caution because of the GrandTab data limitations previously described.
Figure 6-11. Temporal trends of the numbers of fall-run Chinook salmon in-river spawners in the lower Yuba River, and in-river plus hatchery spawner populations in the Feather River, from 2004 through 2011. Regression lines for each of the two distributions are included.

6.5 RELATIONSHIPS BETWEEN SPRING-RUN CHINOOK SALMON STRAYING INTO THE LOWER YUBA RIVER AND ATTRACTION FLOWS AND WATER TEMPERATURES

The RMT recognizes that substantially higher amounts of straying of adipose fin-clipped Chinook salmon into the lower Yuba River occurs than that which was previously believed. Although no quantitative analyses or data were presented, NMFS (2007) stated that some hatchery fish stray into the lower Yuba River and that these fish likely come from the FRFH.

Some information indicating the extent to which adipose-clipped Chinook salmon originating from the FRFH return to the lower Yuba River is available from coded wire tag analysis. During the October through December 2010 carcass survey period in the lower Yuba River, the RMT collected heads from fresh Chinook salmon carcasses with adipose fin clips, and sent the heads to the CDFW coded wire tag (CWT) interpretive center. In April of 2011, the results of the interpretation of the CWTs became available. Of the 333 Chinook salmon heads sent to the CDFW interpretive center, 11 did not contain a CWT, 8 were fall-run Chinook salmon from the Coleman National Fish Hatchery, 2 were from the RST captured and tagged juveniles in the lower Yuba River, 1 was a naturally-spawned fall-run Chinook salmon from the Feather River, 1 was a fall-run Chinook salmon from the Mokelumne River Hatchery, and 310 were Chinook salmon from the FRFH (234 spring-run and 76 fall-run Chinook salmon). Thus, for all CWT hatchery-origin fish returning to the Yuba River from out-of-basin sources, 97% were from the FRFH. However, this information does not indicate the percentage of hatchery contribution from the FRFH to the phenotypic spring-run Chinook salmon run in the lower Yuba River, because,
among other reasons, all of these heads were collected during the fall and represent a mixture of phenotypic spring- and fall-run Chinook salmon spawning in the lower Yuba River.

Additional information that can be used to assess the amount of straying of FRFH Chinook salmon into the lower Yuba River is provided from Vaki Riverwatcher data collected from 2004 through 2011. The estimated numbers of adipose fin-clipped spring-run Chinook salmon that passed upstream of Daguerre Point Dam from 2004 through 2011 that were derived from the Vaki Riverwatcher data (according to the procedure previously described in Chapter 5) are an indicator of the minimum number of Chinook salmon of hatchery origin (most likely of FRFH origin) that strayed into the lower Yuba River.

To evaluate the influence of “attraction” flows and water temperatures on the straying of adipose fin-clipped adult phenotypic spring-run Chinook salmon into the lower Yuba River, variables related to flows and water temperatures in the lower Yuba River and the lower Feather River were developed and statistically related to the weekly proportions of adipose fin-clipped phenotypic spring-run Chinook salmon (relative to all spring-run Chinook salmon) passing upstream of Daguerre Point Dam during each of the 8 years when annual Vaki Riverwatcher counts at Daguerre Point Dam are available. Details of this evaluation are provided below.

6.5.1 GENERAL ASSESSMENT PROCEDURE

For the 2004-2011 annual phenotypic spring-run Chinook salmon adult immigration periods, the daily numbers of ad-clipped (i.e., \( n_{\text{Ad-clip}_w} \)) and not ad-clipped (i.e., \( n_{\text{Not Ad-clip}_w} \)) spring-run Chinook salmon that passed upstream of Daguerre Point Dam were combined into weekly proportions of ad-clipped fish (i.e., \( \pi_{\text{Ad-clip}_w} \)) using the formula:

\[
\pi_{\text{Ad-clip}_w} = \frac{\sum_{i=d}^{d+6} n_{\text{Ad-clip}_i}}{\sum_{i=d}^{d+6} \left( n_{\text{Ad-clip}_i} + n_{\text{Not Ad-clip}_i} \right)}. 
\]

The daily counts \( n_{\text{Ad-clip}_w} \) and \( n_{\text{Not Ad-clip}_w} \) used in the calculation of weekly proportions of ad-clipped fish produced 136 weekly proportions. The weekly proportions are computationally independent from each other (i.e., they do not share any daily counts). Each year, the first weekly proportion corresponds to the week that starts on the date of the first phenotypic spring-run count at Daguerre Point Dam, and the last weekly proportion corresponds to the last week ending prior to the annual demarcation date of phenotypic spring-run and fall-run Chinook salmon.

The relationship of the weekly proportion of adipose fin-clipped phenotypic spring-run Chinook salmon was modeled as a logistic response to variables developed to measure the weekly attraction influence of lower Yuba River flows (i.e., \( X_{Q_w} \)) and water temperatures (i.e., \( X_{WT_w} \)), relative to flows and water temperatures in the lower Feather River. Details on the computation
of these “attraction” variables are provided below. The modeled response of the weekly proportions $\pi_{\text{Ad-clip}_w}$ as a function of the attraction variables $X_{Q_w}$ and $X_{WT_w}$ has the expression:

$$
\pi_{\text{Ad-clip}_w} = \frac{\exp\left(\alpha + \beta_1 \times X_{Q_w} + \beta_2 \times X_{WT_w} + \beta_3 \times X_{Q_w} \times X_{WT_w}\right)}{1 + \exp\left(\alpha + \beta_1 \times X_{Q_w} + \beta_2 \times X_{WT_w} + \beta_3 \times X_{Q_w} \times X_{WT_w}\right)},
$$

(1)

where $X_{Q_w} \times X_{WT_w}$ represents the interaction between the weekly attraction influence of lower Yuba River flows relative to lower Feather River flows, and the weekly attraction influence of lower Yuba River water temperatures relative to lower Feather River water temperatures. The symbols $\alpha, \beta_1, \beta_2$ and $\beta_3$ are the response function parameters.

Prior to fitting the model, equation (1) was linearized using a logit transformation (the inverse of the sigmoidal logistic function). Through this logit transformation the modeled response (1) became:

$$
\text{logit}\left(\pi_{\text{Ad-Clip}_w}\right) = \ln\left(\frac{\pi_{\text{Ad-Clip}_w}}{1-\pi_{\text{Ad-Clip}_w}}\right) = \alpha + \beta_1 \times X_{Q_w} + \beta_2 \times X_{WT_w} + \beta_3 \times X_{Q_w} \times X_{WT_w}.
$$

(2)

Equation (2) was fitted to the data using a weighted least squares regression approach to handle the unequal variance of the error terms. The weekly weights were calculated using the formula:

$$
\text{Weight}_w = \left(\frac{n_{\text{Ad-clip}_w} + n_{\text{Not Ad-clip}_w}}{\pi_{\text{Ad-clip}_w} \times (1-\pi_{\text{Ad-clip}_w})}\right).
$$

Because the weekly proportions of ad-clipped fish should not take values of 0 or 1, cases where the observed $\pi_{\text{Ad-clip}_w} = 1$ were replaced by $\pi_{\text{Ad-clip}_w} = 1 - \left(1/2 \times \left(n_{\text{Ad-clip}_w} + n_{\text{Not Ad-clip}_w}\right)\right)$ prior to estimation (Neter et al. 1985). Similarly, cases where the observed $\pi_{\text{Ad-clip}_w} = 0$ were replaced by $\pi_{\text{Ad-clip}_w} = \sqrt{1/2} \times \left(n_{\text{Ad-clip}_w} + n_{\text{Not Ad-clip}_w}\right)$ prior to fitting equation (2).

**Attraction Flow Variables**

The values of the variables developed to measure the weekly attraction influence of lower Yuba River flows relative to lower Feather River flows (i.e., $X_{Q_w}$ in equations 1 and 2) were derived from daily flows (cfs) measured at the Marysville Gage (CDEC station “MRY”, USGS station 11421000) in the lower Yuba River, and at the Gridley Gage in the lower Feather River (CDEC station “GRL”, USGS station 11407150). The Marysville Gage is located approximately 6 miles...
upstream of the mouth of the lower Yuba River, and the Gridley Gage is located approximately
20 miles upstream of the Feather River confluence with the lower Yuba River.

The “attraction” flow variables consist of weekly attraction indices calculated as weekly
averages. Ten “attraction” flow variables were used in the analysis as the explanatory
variable $X_Q$ in equations 1 and 2. The only difference among these variables consists of the
week over which the attraction indices were averaged with respect to the week of the
corresponding weekly proportions $\pi_{\text{Ad-clip}_w}$.

For example, the first weekly attraction flow index variable (i.e., $AFI_0$) was computed as the
average of the daily ratios of Marysville flows ($Q_{\text{MRY}}$) to Gridley flows ($Q_{\text{GRL}}$) for the same
days used in computing the corresponding weekly proportion $\pi_{\text{Ad-clip}_w}$. Thus, $AFI_0$ was
computed as $\frac{1}{7} \sum_{i=d}^{d+6} \frac{Q_{\text{MRY}}}{Q_{\text{GRL}}}$, where $d$ is the first day in the week of the corresponding
weekly proportions $\pi_{\text{Ad-clip}_w}$. The second weekly attraction flow index variable (i.e., $AFI_7$) that
corresponds to the average of the daily ratios of Marysville and Gridley flows for the week prior
to the week of the corresponding weekly proportion $\pi_{\text{Ad-clip}_w}$ was then computed
as $\frac{1}{7} \sum_{i=d-7}^{d-1} \frac{Q_{\text{MRY}}}{Q_{\text{GRL}}}$. The remaining eight variables used in the analysis (i.e., $AFI_{14}$, $AFI_{21}$,
$AFI_{28}$, $AFI_{35}$, $AFI_{42}$, $AFI_{49}$, $AFI_{56}$ and $AFI_{63}$) correspond to weekly averages of the daily ratios of
Marysville and Gridley flows for two, three, four, five, six, seven, eight and nine weeks prior to
the week of the corresponding weekly proportion $\pi_{\text{Ad-clip}_w}$. These explanatory variables were
developed to represent differences in attraction to the lower Yuba River relative to the lower
Feather River for up to 9 weeks prior to phenotypic spring-run Chinook salmon passing
Daguerre Point Dam because of the extended holding periods exhibited by acoustically-tagged
spring-run Chinook salmon in the lower Yuba River prior to passing Daguerre Point Dam (see
Chapters 4 and 5).

Because weekly attraction flow indices are averages of flow ratios, they do not have units
associated with them. The $AFI_j$ can only take values greater than 0. $AFI_j$ values greater than 1
indicate that the lower Yuba River flows (at the Marysville Gage) were higher than the lower
Feather River flows (at the Gridley Gage). Similarly, $AFI_j$ values greater than 0 but smaller than
1 indicate that lower Yuba River flows for a specific week were less than the lower Feather
River flows.
**ATTRACTION WATER TEMPERATURE VARIABLES**

The values of the variables developed to measure the weekly attraction influence of lower Yuba River water temperatures relative to lower Feather River water temperatures (i.e., $X_{WT}$ in equations 1 and 2) were derived from average daily water temperatures ($^\circ$F) measured at the Marysville Gage in the lower Yuba River and at the Gridley Gage in the lower Feather River.

Consistent with the “attraction” flow variables previously discussed, the “attraction” water temperature variables consist of weekly attraction indices calculated as weekly averages of the ratios of daily lower Yuba River to lower Feather River water temperatures. Ten “attraction” water temperature variables were used in the analysis as the explanatory variable $X_{WT}$ in equations 1 and 2. The ten “attraction” water temperature variables used (i.e., $AWTI_0$, $AWTI_7$, $AWTI_{14}$, $AWTI_{21}$, $AWTI_{28}$, $AWTI_{35}$, $AWTI_{42}$, $AWTI_{49}$, $AWTI_{56}$ and $AWTI_{63}$) correspond to weekly averages of daily ratios of Marysville and Gridley water temperatures for the week of the corresponding weekly proportion $\pi_{\text{Ad-clip}_w}$ (i.e., $AWTI_0$) and for one, two, three, four, five, six, seven, eight and nine weeks prior to the week of the corresponding weekly proportion $\pi_{\text{Ad-clip}_w}$.

As with the weekly attraction flow indices, the weekly attraction water temperature indices are averages of water temperature ratios and therefore also do not have units associated with them. Similarly, the $AWTI_j$ can only take values greater than 0. $AWTI_j$ values greater than 1 indicate that the lower Yuba River water temperatures (at the Marysville Gage) were higher than the lower Feather River water temperatures (at the Gridley Gage). Similarly, $AWTI_j$ values greater than 0 but smaller than 1 indicate that the lower Yuba River water temperatures were less than the lower Feather River water temperatures.

**6.5.2 RELATIONSHIPS WITH ATTRACTION FLOW AND WATER TEMPERATURE INDICES**

Equation 2 was fitted ten times. In each case a particular attraction flow variable (i.e., $AFI_0$, $AFI_7$, $AFI_{14}$, $AFI_{21}$, $AFI_{28}$, $AFI_{35}$, $AFI_{42}$, $AFI_{49}$, $AFI_{56}$ and $AFI_{63}$) was combined with the attraction water temperature variable for the same week. The ten combinations of flow and water temperature explanatory variables provided statistically significant relationships with the proportion of adipose fin-clipped phenotypic spring-run Chinook salmon passing Daguerre Point Dam. However, the combination of $AFI_{28}$ and $AWTI_{28}$ produced the largest coefficient of determination ($R^2 = 0.72$). In other words, the combination of attraction flow and water temperature indices corresponding to the weekly averages of daily flow and water temperature ratios four weeks prior to the week of the corresponding weekly ad- clipped proportion passing Daguerre Point Dam explained 72.3 % of the data variability, the largest amount of explained data variability among the ten explanatory variable combinations that were analyzed.
The fitted logistic model is described by the following equation:

$$\pi_{\text{Ad-clip}_w} = \frac{\exp(3.96547-10.14229 \times AFI_{28} - 6.56692 \times AWTI_{28} + 12.16288 \times AFI_{28} \times AWTI_{28})}{1 + \exp(3.96547-10.14229 \times AFI_{28} - 6.56692 \times AWTI_{28} + 12.16288 \times AFI_{28} \times AWTI_{28})}.$$  

Results of the analysis suggest that there is a moderately strong ($R^2=0.72$) and highly significant ($P < 0.000001$) relationship between the percentage of adipose fin-clipped spring-run Chinook salmon contribution to the weekly spring-run Chinook salmon total counts at Daguerre Point Dam and the attraction flow and water temperature indices four weeks prior. The attraction flow index explained 20.4% of the data variability, the attraction water temperature index explained 27.5% of the variability, and the interaction term explained 24.4% of the variability in the proportion of adipose fin-clipped phenotypic spring-run Chinook salmon passing Daguerre Point Dam weekly. Figure 6-12 displays the 3-D response surface produced by the fitted logistic model.

![Figure 6-12. Relationship of the weekly percentage of adipose fin-clipped contribution to the weekly phenotypic spring-run Chinook salmon count at Daguerre Point Dam as function of the weekly attraction flow and water temperature indices calculated four weeks prior to the week of passage at Daguerre Point Dam.](image-url)
The analysis described above showed that an estimated 72% of the variation in the proportion of adipose fin-clipped phenotypic spring-run Chinook salmon passing upstream of Daguerre Point Dam can be accounted for by the ratio of lower Yuba River flow relative to lower Feather River flow, and the ratio of lower Yuba River water temperature relative to lower Feather River water temperature, four weeks prior to the time of passage at Daguerre Point Dam. In other words, the higher the Yuba River flows relative to Feather River flows, combined with the lower the Yuba River water temperatures relative to Feather River water temperatures, the higher the percentage of fin-clipped Chinook salmon passing upstream of Daguerre Point Dam four weeks later.

As described in Chapter 5, the acoustically-tagged phenotypic spring-run Chinook salmon spent variable and extended periods of time holding below Daguerre Point Dam after being tagged and prior to passing upstream of Daguerre Point Dam, with a range of 0 to 116 days. Based on all 67 acoustically-tagged spring-run Chinook salmon that passed upstream of Daguerre Point Dam, the average holding time before passing upstream of Daguerre Point Dam was about 50 days. For the phenotypic acoustically-tagged spring-run Chinook salmon that passed upstream of Daguerre Point Dam by the annual spring-run Chinook salmon demarcation date for each year, the average holding periods before passing upstream of Daguerre Point Dam were approximately 51, 41, and 57 days during 2009, 2010 and 2011, respectively. Therefore, it would be expected that attraction of adipose fin-clipped fish to the lower Yuba River associated with flows and water temperatures in the lower Yuba River relative to the lower Feather River would occur at least several weeks prior to passage of phenotypic spring-run Chinook salmon upstream of Daguerre Point Dam.

While the variation in the proportion of adipose fin-clipped phenotypic spring-run Chinook salmon passing Daguerre Point Dam was best explained with ratios of flows and water temperatures in the lower Yuba and Feather rivers 4 weeks prior to passage at Daguerre Point Dam, the acoustically-tagged individuals exhibited a somewhat longer duration of holding on average. However, due to the relatively small sample size of acoustically-tagged spring-run Chinook salmon (N=67), the short duration of the study, and based on the highly variable holding duration (i.e., 0-116 days), the average holding time calculated for the acoustically-tagged spring-run Chinook salmon is considered to be a general approximation of holding duration downstream of Daguerre Point Dam. Therefore, consideration of holding duration downstream of Daguerre Point Dam supports the observation that the ratios of flows and water temperatures in the lower Yuba River relative to the lower Feather River 4 weeks prior to passage of spring-run Chinook salmon at Daguerre Point Dam may be influencing the attraction of adipose fin-clipped spring-run Chinook salmon of FRFH-origin into the lower Yuba River.

To further demonstrate the role of flows and water temperatures in the lower Yuba and Feather rivers on adipose fin-clipped spring-run Chinook salmon entering the lower Yuba River, total and adipose fin-clipped spring-run Chinook salmon passage counts at Daguerre Point Dam were plotted with mean daily flows and water temperatures in the lower Yuba River (at the Marysville Gage) and lower Feather River (at the Gridley Gage) (Figure 6-13).
Figure 6-13. Daily number of Chinook salmon with adipose fin clips and without adipose fin clips that passed upstream of Daguerre Point Dam, and mean daily flows and temperatures at the Marysville Gage and Gridley Gage for 2004 and 2005. Vertical line represents the date of demarcation separating spring-run from fall-run Chinook salmon.
Figure 6-13. Continued (2006 and 2007).
Figure 6-13. Continued (2008 and 2009).
Figure 6-13. Continued (2010 and 2011).
Visual examination of Figure 6-13 indicates that flows in the lower Yuba and Feather rivers during the phenotypic spring-run Chinook salmon adult immigration period are highly variable within and among years. During the phenotypic spring-run Chinook salmon upstream migration period, as indicated by the number of individuals passing the Vaki Riverwatcher system at Daguerre Point Dam, lower Yuba River flows are often times substantially lower than those in the lower Feather River. Exceptions to that trend have been observed. For example, during 2005 lower Yuba River flows were greater than or approximately equal to lower Feather River flows from late March through mid-June, and relatively large numbers of adipose fin-clipped phenotypic spring-run Chinook salmon were observed passing the Vaki Riverwatchers from early June through July. Similarly, during 2009 lower Yuba River flows were higher than lower Feather River flows during the month of May, and an influx of fish and adipose fin-clipped Chinook salmon were observed during June. The most dramatic example of flows occurring one month prior to observed passage of Chinook salmon through Daguerre Point Dam, particularly adipose fin-clipped fish, can be observed during 2010 (Figure 6-13).

By contrast, water temperatures are often substantially lower in the lower Yuba River relative to water temperatures in the lower Feather River during most years. Water temperatures begin exhibiting substantial divergence between the lower Yuba River and the lower Feather River typically by early May, but can begin as early as early-April. Water temperatures remain highly divergent typically through mid-September. The maximum difference between lower Yuba and lower Feather River water temperatures generally occurs during June through August, with lower Yuba River water temperatures commonly 10 to 12 °F cooler than the lower Feather River.

6.6 CWT RECOVERIES IN THE LOWER YUBA RIVER

6.6.1 HATCHERY-ORIGIN SPRING-RUN CHINOOK SALMON CWT RECOVERIES IN THE LOWER YUBA RIVER

For the lower Yuba River, CWT-marked Chinook salmon recovery data are available for the period extending from 2000 through 2011. Annual recoveries of CWT-marked FRFH-origin spring-run Chinook salmon in the lower Yuba River for the period of 2000 through 2011 are presented in Table 6-4. A total of 497 CWT-marked FRFH spring-run Chinook salmon were recovered in the lower Yuba River during this period. Numbers of CWT recoveries peaked in 2005 and again in 2010 (Figure 6-14). Recoveries occurred both with individuals released into the San Francisco Bay and individuals released into the lower Feather River, although none of the 2004 stock released into the Sacramento River was recovered in the lower Yuba River. Overall return rates for hatchery spring-run Chinook salmon in the lower Yuba River were very low at 2.99 x 10^{-5} (0.003% of all Central Valley releases). Long-term San Francisco Bay releases and subsequent in-river recovery ratios were approximately 2.19 to 1. San Francisco Bay-released juvenile Chinook salmon had a disproportionately high return rate ($X^2 = 35.41, P < 0.001$). Although river releases began with brood year 2001, no recoveries of river-release brood year 2001 occurred in the lower Yuba River. Lower Feather River-released brood year 2002 appeared in the lower Yuba River during 2005.
Table 6-4. Annual Recoveries of CWT-marked FRFH-origin spring-run Chinook salmon in the lower Yuba River.

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6.6.2 CONTRIBUTION OF WILD-TAGGED YUBA RIVER CHINOOK SALMON TO THE LOWER YUBA RIVER POPULATION

Juvenile Chinook salmon captured by rotary screw trapping near Hallwood Boulevard in the lower Yuba River were coded wire tagged during 2003, 2004, 2005 and 2006. Because assignment of runs in the Yuba River utilizing Fisher-Greene tables has resulted in many CWT assignments being listed as “unknown run”, this analysis considers only the total numbers of CWT juvenile Chinook salmon released per brood year in the lower Yuba River, not differentiated by run-type. Tagging was high in brood years 2003 (n = 183,207), 2004 (n = 240,666) and 2006 (n = 241,148), but was low in 2005 (n = 43,729). All releases occurred in the lower Yuba River. Figure 6-15 shows recovery data for all known recoveries of Yuba River tagged and released Chinook salmon. From 2002 to present, only three fish have been recovered in the lower Yuba River. Recovery rates in the lower Yuba River were extremely low at \((4.21 \times 10^{-6})\) or approximately 0.0004%. One individual also was recovered in the Sacramento River at Red Bluff Diversion Dam. The other recoveries have been via ocean troll fishing (7 individuals), ocean sport fishing (2 individuals), and returns to the FRFH (4 individuals). Regardless of recovery location, these extremely low recovery rates of adults from naturally-produced juvenile Chinook salmon tagged and released in the lower Yuba River indicate potential overwhelming out-of-basin mortality influences.

Figure 6-14. Feather River Fish Hatchery-origin spring-run Chinook salmon CWT recoveries in the lower Yuba River, by release location (either the lower Feather River, or San Francisco Bay).
Figure 6-15. The number of juvenile Chinook salmon captured by RST, coded-wire tagged and released in the lower Yuba River.