2.5.1.2.7.4.2.1 Survival by Route

There are four major migratory routes that fish can access from the north Delta to rear and migrate through; Sutter Slough, Steamboat Slough, Georgiana Slough and mainstem Sacaramento River, all were examined individually in the model (Perry 2017 model). These four migratory routes comprise the overall through-Delta survival probability. Results for the distributaries Sutter and Steamboat Slough were combined together as these routes merge in the western Delta and funnel into the Cache Slough. Sutter and Steamboat Slough have monthly and yearly variation in survival and entrainment probabilities but whether results are combined together or given separately, these two distributaries exhibit survival similar to the mainstem Sacramento migratory route. Therefore they are considered high survival routes in comparison to the Central Delta routes of Georgina Slough and the Delta Cross Channel (DCC). DCC was not included in this analysis as it is closed during most of the peak salmonid migratory activity.

Figure 4 shows daily boxplots of survival differences between the NAA and the PA for the mainstem Sacramento River, Sutter and Steamboat Slough and Georgiana Slough. Overall results show that in the mainstem Sacramento River, survival probabilities are reduced under the PA for at least 75% of the years for all months with the exception of April where survival differences are lower and median survival is reduced by -0.04% (Figure 4 top panel).

In the Sutter and Steamboat Slough migratory routes, survival is reduced under the PA for at least 75% of the years for all months with the exception of April where the survival difference is lower than the other months and median survival is reduced by -0.06% (Figure 4 middle panel).

In Georgiana Slough, survival is reduced under the PA for at least 75% of the years for all months with the exception of May where the survival difference is lower than the other months and median survival is reduced by -0.04% (Figure 4 bottom panel).

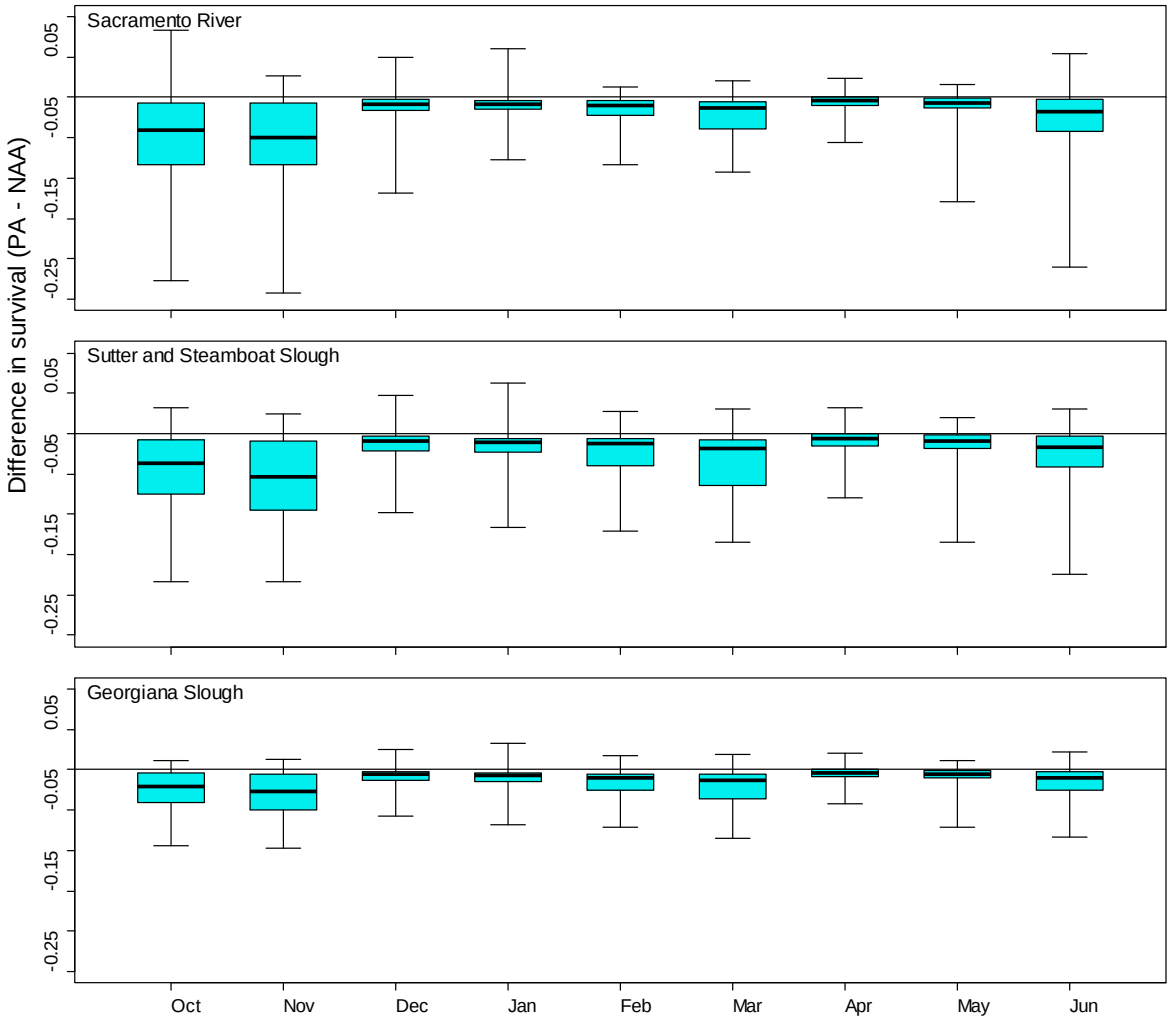

Figure 4. Boxplots of differences in through-Delta survival between the NAA and PA scenario for fish using different migration routes through the Delta. Each box plot represents the distribution of daily survival differences among years for a given month. The point in each box represents the median, the box hinges represent the 25th and 75th percentile, and the whiskers display the minimum and maximum.

The results of the survival by migratory route show trends similar to the overall through Delta survival results. All migratory routes in the north Delta are anticipated to result in reduced survival for juvenile salmonids under the PA. This finding is significant and is different from the results shown in the other flow survival model the Delta Passage Model (DPM) (Section 2.5.1.2.7.4.1 *Delta Passage Model*). The DPM results showed that smolts using the Georgiana Slough migratory route had higher survival under the PA. The likely reason for the different outcomes is the following; the Perry 2010 analysis modeled survival as a function of flow through a subset of the reaches used in the more recent (2017) analysis. In the 2010 analysis, there was no effect of flow on survival through the interior Delta from the confluence of the Mokelumne and San Joaquin to Chipps Island (Reach 8, Fig. 1 in summary methods section). The Perry 2017 model also saw no flow effect in Reach 8, so these findings are consistent between models. However, the 2017 analysis also included the reach from the entrance of Georgiana Slough to the confluence of the Mokelumne and San Joaquin (Reach 5, summary methods), which was not included in the 2010 analysis. It is in Reach 5 where a strong flow relationship exists (see Fig 3, summary methods), driving the flow-survival relationship for fish that enter Georgiana Slough (Fig 4, bottom panel, summary methods). Additionally, the DPM uses the export dependent relationship (Newman and Brandes 2010) as part of the model structure. This would influence survival on smolts entering the interior Delta from the Georgiana Slough. Since south Delta exports are generally lower under the PA, this would be a beneficial effect by reducing entrainment into the south Delta facilities and increasing probability of migratory success within this reach.

NMFS is using the Perry 2017 model (Perry and others 2017 (in prep)) as best available science and considers the benefits of reduced south Delta pumping and the inclusion of a HOR gate under the PA with several other methods (reference salvage stressor section and SalSim Section). Therefore the results that the migratory route of Georgiana Slough has a flow survival relationship will help guide the effects analysis. Additionally, there are life cycle models that consider the system in a more holistic way by considering effects on all life-stages and in key geographic areas including the north and south Delta along with the operational differences under the PA and NAA scenarios (Section 2.5.1.2.7.5 *Life Cycle Modeling*).

2.5.1.2.7.4.2.2 Winter-run Exposure and Risk

The Perry 2017 model comprehensively looks at factors that affect survival, such as travel time and migratory route taken to evaluate how changes in Delta inflow will affect smolt migratory success between the scenarios. Since results are segregated by month and then further by water year type we can thoroughly examine the exposure and risk associated with these changes for winter-run Chinook smolts.

The main migratory period for winter-run Chinook juveniles is November through April (Table 2-5, Section 2.5.1.2.7.2.3 *Winter-run Exposure and Risk*). Within this migratory window, November has the least protection and the largest survival reductions due to static Bypass rules that leave 7,000 cfs in river unless real time management operations are triggered. The remaining months fall under the December through April NDD Bypass operations where the largest survival reductions are expected to occur in March and the lowest survival reductions under the PA would occur in April (Figure 1).

Winter-run Chinook primarily enter the Delta during November and December at mean sizes of 63mm and 75mm respectively (Table 2-5, Section 2.5.1.2.7.2.3 *Winter-run Exposure and Risk*).

Although peak entrance into the Delta for juveniles is November and December, out migration activity observed at Chipps Island during those months averages less than 1% of the population sampled (Table 2-5, Section 2.5.1.2.7.2.3 *Winter-run Exposure and Risk*). Winter run Chinook can spend months in freshwater before out-migrating en masse where on average 66% of the annual population exits Chipps Island during the month of March at a mean size of 111mm (Table 2-5, Section 2.5.1.2.7.2.3 *Winter-run Exposure and Risk*). The long term monitoring data reveals that winter-run Chinook spend considerable time growing and rearing in and upstream of the Delta based on average timing and size patterns of entrance and exit from the Delta (Table 2-5, Section 2.5.1.2.7.2.3 *Winter-run Exposure and Risk*).

To best apply the Perry 2017 model to winter-run, we restrict the survival differences between scenarios to smolt sized fish over 70 mm. The entrainment and flow survival models (Perry et al 2016 (in review), Perry and others 2017 (in prep) are based off of acoustic tag data of smolt sized fish exhibiting migratory behavior. This results in the core migratory window for winter-run Chinook smolts being December through April. Although November is an important migratory month especially in wetter years, winter run Chinook tend to be under 70 mm and will most likely rear and remain in the Delta for several weeks/months. Since all life-stages of winter-run must be protected in their critical habitat, PA operations have been developed to manage diversions in a more protective manner should winter run sized fish be detected in October and November. Changes in hydrology (flow timing and quantity) under the PA will be experienced by the smaller juveniles as well and implications for rearing habitat and shelter are evaluated in Section 2.5.2 *Effects to Critical Habitat*.

Migratory patterns for winter-run Chinook into the Delta have been found to be hydrology driven and influenced by upstream flow pulses (del Rosario et al 2013). We use water year type characterization to help understand which months during drier or wetter year types will increase the exposure and risk of winter-run Chinook to diversion effects of the PA in the north Delta. Since migration stimulus for winter-run juveniles is a flow pulse that can potentially happen in any water year type, the water year characterizations are just an approximation of what is likely to occur in wetter versus drier year type hydrology.

During wetter year hydrology (wet and above normal water year types), winter-run Chinook smolts will begin entering the Delta in November (Figure 1-4, Section 2.5.1.2.7.2.3 *Winter-run Exposure and Risk*) and will experience the largest survival reductions during this month unless real time operations (RTO) diversion restrictions are applied. This is expected to affect 5% of the smolt population during these year types. If RTO are enacted, the survival reductions for approximately 5% of the population will likely range from a 0.3% to 10.1% reduction in over 75% of years. For the remaining 25% of years there could be a survival reduction of 0.9% to an increase in survival under the PA of 2.5% (Table 3 above). If winter-run go undetected, the full range of survival reduction under the PA of 23% could be experienced.

During December, approximately 25% of winter run Chinook smolts could be exposed to reduced survival due to reduced flows in migratory corridors in wetter years (Table 1-4, Section 2.5.1.2.7.2.3 *Winter-run Exposure and Risk*). Survival reductions under the PA for 75% of the years range from 0.2 to 8.5%. For the remaining 25% of years there would be a survival reduction of 0.05% to 3.8% increase in survival under the PA (Figure 2).

In January, approximately 9% of winter run Chinook smolts could be exposed to reduced survival due to reduced flows in migratory corridors in wetter years (Table 1-4, Section

2.5.1.2.7.2.3 *Winter-run Exposure and Risk*). Survival reductions under the PA for 75% of the years range from 0.5 to 7.7%. For the remaining 25% of years there would be a survival reduction of 0.07% to 2.9% increase in survival under the PA (Figure 2).

In February, approximately 22% of winter run Chinook smolts could be exposed to reduced survival due to reduced flows in migratory corridors in wetter years (Table 1-4, Section 2.5.1.2.7.2.3 *Winter-run Exposure and Risk*). Survival reductions under the PA for 75% of the years range from 0.5 to 10%. For the remaining 25% of years there would be a survival reduction of 0.06% to 2.1% increase in survival under the PA (Figure 2).

In March, approximately 30% of winter run Chinook smolts could be exposed to reduced survival due to reduced flows in migratory corridors in wetter years (Table 1-4 tt section). Survival reductions under the PA for 75% of the years range from 0.7 to 10.5%. For the remaining 25% of years there would be a survival reduction of 0.9% to 2.0% increase in survival under the PA (Figure 2).

In April, approximately 9% of winter run Chinook smolts could be exposed to reduced survival due to reduced flows in migratory corridors in wetter years (Table 1-4, Section 2.5.1.2.7.2.3 *Winter-run Exposure and Risk*). Survival reductions under the PA for 75% of the years range from 0.3 to 6.8%. For the remaining 25% of years there would be a survival reduction of 0.4% to 2.0% increase in survival under the PA (Figure 2).

Overall results show that March, which has the largest smolt (>70mm) entrance into the Delta in wetter years, coincides with when operations of the PA would cause the largest survival reductions. During wetter year hydrology, the risk of exposure is spread out over 6 months (November through April) which is in contrast to the exposure risk during drier year hydrology when the Delta migratory window is shortened to 3 or 4 months (January through April) (Figure 1-4 and 2-4 Section 2.5.1.2.7.2.3 *Winter-run Exposure and Risk*).

In drier year hydrology (below normal, dry and critical), winter-run Chinook enter the Delta after December and primarily in February (Figure 2-4, Section 2.5.1.2.7.2.3 *Winter-run Exposure and Risk*). During January, approximately 18% of winter-run Chinook could be exposed to reduced survival due to reduced flows in migratory corridors in drier years (Table 2-4 Section 2.5.1.2.7.2.3 *Winter-run Exposure and Risk*). Survival reductions under the PA for 75% of the years range from 0.4% to 9.6%. For the remaining 25% of years there would be a survival reduction of 0.4% to 6.0% increase in survival under the PA (Figure 2).

In February, approximately 50% of winter-run Chinook could be exposed to reduced survival due to reduced flows in migratory corridors in drier years (Table 2-4 Section 2.5.1.2.7.2.3 *Winter-run Exposure and Risk*). Survival reductions under the PA for 75% of the years range from 0.9% to 10.1%. For the remaining 25% of years there would be a survival reduction of 0.4% to a 0.5% increase in survival under the PA (Figure 2).

In March, approximately 30% of winter run Chinook could be exposed to reduced survival due to reduced flows in migratory corridors in drier years (Table 2-4, Section 2.5.1.2.7.2.3 *Winter-run Exposure and Risk*). Survival reductions under the PA for 75% of the years range from 0.2% to 11.2%. For the remaining 25% of years there would be a survival reduction of 1.7% to a 2.2% increase in survival under the PA (Figure 2).

In April, approximately 2% of winter run Chinook could be exposed to reduced survival due to reduced flows in migratory corridors in drier years (Table 2-4, Section 2.5.1.2.7.2.3 *Winter-run*

Exposure and Risk). Survival is quite similar under the scenarios for critical and dry water years ranging from a 3.9% reduction in survival to a 2.7% increase in survival under the PA. In below normal years, 75% of the time there would be a survival reduction from 0.1% to 5.5% under the PA and survival in the remaining 25% of years would be similar ranging from 0.1% reduction to 0.8% increase under the PA (Figure 2).

Overall, the winter run Chinook smolt (>70mm) population is concentrated in the Delta in February and March (approximately 80%) and the largest survival reductions under the PA occur during these months in drier water years (Figure 2-4, Section 2.5.1.2.7.2.3 *Winter-run Exposure and Risk*).

This analysis indicates that the PA increases mortality consistently (over 75% of the time) over the NAA scenario (Figures of all boxplots in this section). Additionally the extent of the survival reduction experienced during 75% of the time is larger (sometimes reaching 11%) during the core migratory months of December to April than the less common survival increases the PA occasionally has (sometimes reaching 6%). The NDD Bypass operations of the PA is an adverse effect on the majority of outmigrating winter run Chinook smolts. Although effects of the diversions vary from month to month and over water year types, the results show that the biggest reductions in survival under the PA occur when the majority of winter run Chinook smolts are migrating through the Delta.