Fish Tracking Methods to Evaluate Fish Protection at the CVP and SWP Exports

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This paper describes how fish tracking calculations can be used to evaluate the likely fish benefits of various gates, fish screens or fish deterrence facilities designed to shift the routes and survival of migrating fish in the Delta. Fish benefits can be estimated for existing or proposed fish protection facilities that would reduce the number of Sacramento River fish diverted to: 1) Delta Cross Channel and Georgian Slough, 2) Threemile Slough, 3) Old River and Middle River, 4) Clifton Court Forebay (SWP exports) or 5) DMC Intake (CVP exports). Results from several acoustic tagging and tracking studies of Chinook juveniles in the Sacramento River and in the SJR have been used to identify fish route selection and survival in the Delta channels. Similar tracking and survival evaluations for San Joaquin River (SJR) steelhead were made as part of the six-year study effort required by NMFS BO RPA Action IV.2.2). Previous studies at the head of Old River (HOR) and at Georgiana Slough have indicated that the migrating juvenile fish are generally diverted with the diversion flow (along hydraulic streamlines); although some Delta channel junctions have strong tidal flows (i.e., reversing directions), the fraction of the fish diverted was similar to the fraction of net flow diverted. A working hypothesis is that each diversion from the Sacramento River reduces the survival of the migrating fish reaching Delta outflow at Chipps Island, and diversions to the SJR increases the fraction of the migrating fish that are diverted into Old and Middle River and subsequently salvaged, lost to predation, or pass through the louvers (fish deflection facilities) to the CVP and SWP exports. An experiment to reduce Chinook and steelhead entrainment (loss) by pumping exclusively at the CVP Tracy Jones Pumping Plant is suggested; the effectiveness of this strategy to reduce salmonid take could be evaluated using these daily fish tracking methods.

1.1 Adaptive Management Experiment to Reduce CVP/SWP Fish Losses

An adaptive management experiment is suggested to test the hypothesis that fish take (loss) of Chinook salmon and steelhead could be substantially reduced by pumping all south Delta exports at the CVP Tracy Jones Pumping Plant rather than the normal pumping of 50% of south Delta exports at the CVP Jones pumping plant and 50% at the SWP Banks pumping plant. Because the estimated loss for each fish "counted" at the CVP fish facility is about 3, while the estimated loss for each fish "counted" at the SWP fish facility is about 17 (because of much higher assumed predation in Clifton Court Forebay), shifting all pumping to the CVP Jones pumping plant will likely increase the fish salvage (counts) but reduce the fish loss (take). This pumping strategy would likely protect (increase fish salvage, reduce fish loss) for all other Delta fish, including splittail, which spawn in high numbers in years with higher San Joaquin River flows in February and March (like 2017). The daily fish tracking methods that could be used to evaluate the Mossdale Trawl data and CVP/SWP salvage records will be described, after the hypothesis for this adaptive management experiment is explained.

Adaptive Management Premise: All Delta exports during the April-May period with out-migrating SJR Chinook smolts and steelhead (and splittail in high runoff years) should be pumped at the CVP Jones Pumping Plant, because the salvage efficiency at the Tracy Fish Collection Facility is much higher than the salvage efficiency at the SWP Skinner Fish Facility, because the measured predation in Clifton Court Forebay is very high, especially during low pumping rates in April and May.

All exports should be shifted to the CVP Jones pumping plant (5,000 cfs capacity) unless the allowable pumping is greater than 5,000 cfs. When all pumping is at the CVP Jones pumping plant, the SWP water needed for the South Bay Aqueduct could be transferred to the California Aqueduct (i.e., Bethany Forebay) through the CA/DMC Intertie pumping plant (completed in 2012 with a capacity of about 450 cfs). This would maximize the salvage of older juvenile Chinook (estimated as 60% at the CVP fish facility, 20% at the SWP fish facility) and minimize the loss of winter-run fish (estimated as 40% at the CVP fish facility, 80% at the SWP fish facility).

For example, if the CVP pumps were exporting 5,000 cfs (10 taf/day) during the limited OMR flow period, and the CVP salvage "count" of older juvenile Chinook was 10 fish/day, the expanded salvage would be 40 fish/day and the daily loss would be estimated as 27 fish (0.68 x salvage). Therefore, the estimated fish density in Old River (at the CVP fish facility) would be 6.7 fish/taf (67 fish/10 taf), the salvage density would be 4.0 fish/taf and the salvage loss density would be 2.7 fish/taf. The daily salvage loss density of 2.7 fish/taf would be similar to the minimum salvage loss density trigger of 2.5 fish/taf in the RPA. If this average fish density in Old River persisted for a month, the CVP pumps would export 300 taf during the month, the monthly salvage would be 1,200 fish and the cumulative loss of older juvenile Chinook would be 810 fish for the month.

By contrast, if the SWP pumps were exporting 5,000 cfs (10 taf/day) during the limited OMR flow period, and the fish density in Old River (at the CCF intake) was 6.7 fish/taf (estimated from the CVP salvage counts), the SWP salvage "count" of older juvenile Chinook would be about 1.3 taf/taf (20% of fish density) or 13 fish per day, and the salvage loss density would be about 5.4 fish/taf (80% of fish density) or 54 fish per day, because the CCF predation and louver loss is assumed to be very high (2 times the CVP loss). If this fish density persisted for a month, the monthly SWP salvage would be 390 fish (about one third of the CVP salvage), and the cumulative loss would be 1,620 fish (about twice the CVP loss). For WY 2011, WY 2012 and WY 2013 the CVP pumping was reduced to less than its permitted capacity (4,600 cfs) from February through June; the calculated cumulative loss of older juvenile Chinook, steelhead, delta smelt and longfin smelt could have been reduced by shifting as much of the SWP pumping as possible to the CVP pumping plant (4,600 cfs).

The fish-tracking analysis for adaptive management of the CVP and SWP exports would use daily estimated fish density in the Delta channels, based on measured salvage (averaged over a few days) or the estimated migration density in the river flow and the estimated fraction of the inflow water reaching the exports. The migrating fish density in the rivers can be calculated from the number of migrating fish (fish/day) and the river flows (taf/day).

Migrating Fish Density (fish/taf) = Number of fish / River flow (taf)

For example, if 50 fish were estimated in the SJR from the Mossdale Trawl, with a flow of 1,000 cfs (2 taf/day), the SJR fish density would be 25 fish/taf. The water and fish diversions at each channel junction and at each pumping plant could be estimated (as fish counts and fish density); the fish density will decrease if the fish fraction is lower than the water fraction at a specific channel junction. For example, the BAFF in Georgiana Slough would not change the water diversion, but might reduce the number of fish diverted, and thereby reduce the fish density. For the water and fish reaching the exports, the estimated salvage and loss fractions for each fish facility could be compared to determine the reduction in loss if all of the water was pumped at the CVP pumping plant.

1.1.1 Reduce Pumping Only as Needed to Reduce the Cumulative Loss (Take Limit)

The current RPA actions assume that reduced pumping will reduce the salvage loss, because the fish density in the south Delta was assumed to remain constant. The benefits from reduced pumping are assumed to be proportional to the reduced pumping flow; reducing the pumping from 5,000 cfs to 4,000 cfs was assumed to save 20% of the salvage loss. An alternative conceptual model for the salvage loss density might be that fish have moved into the south Delta channels independent of the exports or OMR reverse flow (e.g., searching for rearing habitat). In this case the south Delta fish density might decrease with higher pumping, because more water would enter the south Delta (Old and Middle River channels) with the same number of fish. If this alternative conceptual model for south Delta fish density was more accurate (i.e., density = constant number of fish/ exports), the fish benefits of the OMR restrictions for older juvenile Chinook would be less effective than assumed in NMFS RPA Action IV.3.2. This alternative conceptual model might apply to delta smelt; once adults enter the south Delta channels, the maximum fish density would be established, and additional pumping would reduce the fish density by removing fish from the south Delta channels. It might be beneficial to pump at a relatively high level to remove the majority of the adult delta smelt from the south Delta prior to their spawning (because the survival of juveniles is low).

1.2 Daily Fish Tracking Methods

Because the Delta inflows and exports can vary dramatically from day-to-day with major storm runoff events, and because the migration of fish is often triggered by these higher flow events, a daily analysis of the fish movement patterns in the Delta channels is necessary to accurately evaluate the fractions of the Sacramento River or San Joaquin River fish that likely move towards the CVP and SWP fish facilities and south Delta pumping plants (i.e., exports) and likely are salvaged (i.e., returned to the western Delta) or entrained (i.e., incidental take). While the water movement patterns can be measured with tidal flow meters, the fish movement and survival patterns are more difficult to evaluate. This paper describes an initial approach for evaluating the movement of migrating fish in the Delta, which begins with estimates of the daily water movement and assumes that fish are moving with the water at each channel junction. The results of acoustic tagging experiments (i.e., tracking) can be incorporated to identify fish selection fractions (i.e., preference or avoidance) for each channel junction. The survival fractions of fish in each pathway segment are needed to fully evaluate the likely benefits of fish deterrence systems (BAFF, FFGS or physical fish screens). The likely movement patterns for water and fish will be described and evaluated for recent years (2011-2013) using the daily flow records in DAYFLOW, to demonstrate the proposed daily fish tracking methods.

Sacramento River and San Joaquin River inflows to the Delta diverge at several channel junctions and may eventually reach the CVP and SWP export pump intakes or flow past Chipps Island to Suisun Bay and the ocean. The inflows from smaller rivers, such as the Cosumnes, Mokelumne, and Calaveras can be tracked in the same way during periods of higher flows (with river spawning). Tracking water from a river inflow through the Delta channel network involves calculating the fluctuating tidal flows at each junction, which are controlled by the channel geometry (cross-sections) and tidal elevation differences. Although the flow splits at tidal junctions might be different for upstream (i.e., flood-tide) and downstream (i.e., ebb-tide) flows, each flow diversion can be generally summarized with a daily "flow-split" relationship, with the diversion flow estimated with an algebraic function of the river or upstream channel flow.

Fish migrating in each river can be tracked through the Delta channels in a similar way, using the flow-split relationships as the initial estimates of the "fish-split" (i.e., route selection) through the Delta channels (i.e., pathways). The tracking of migrating fish through the Delta channel pathways also requires estimates of the daily number of fish entering the Delta from a specific river or habitat (e.g., splittail spawning). Because each fish species (or Chinook salmon run) have distinct seasonal spawning periods, each fish species or run enters the Delta with a specific seasonal pattern, although the daily migration abundance may also respond to storm events or other environmental conditions (e.g., turbidity or temperature). Additional parameters needed for fish tracking are the fish movement rate (travel time) and survival for each pathway segment (channels between junctions). The water travel time (channel volume/flow) was used as the initial estimate for the fish movement time, although fish may be rearing along the pathway (movement slower than water) or swimming with the ebb-tides (movement faster than water). Acoustic tagging experiments can be used to determine the fish splits (i.e., water fraction x fish preference) at channel junctions and the travel time and survival in each channel segment (between hydrophones).

Daily fish-tracking (i.e., fish movement and survival) is the overall framework for considering the specific effects of Delta operations (e.g., DCC closure, exports and outflow) on the overall survival of fish migrating through the Delta channels from the Sacramento River or the San Joaquin River. Some protections for these fish are already provided by the CVP and SWP fish salvage facilities; additional protections are provided by the DCC gate closures and minimum Delta outflows required by the Bay-Delta WQCP objectives (D-1641). Increased protections are also provided by the NMFS RPA Actions that may close the DCC or reduce exports in response to monitored fish catch in the river trawls (at Sacramento and Mossdale), Delta trawls (at Chipps Island) or at the CVP and SWP salvage facilities (near Tracy). Fish tracking is proposed as a quantitative framework for estimating fish protection benefits.

The fractions of the migrating fish in the Sacramento or San Joaquin Rivers that are caught in the Rotary Screw Traps (RSTs) or trawls used to monitor fish abundance in the rivers are very small (<0.1%), making it difficult to accurately estimate the timing and abundance of the migrating fish. Although the CVP and SWP salvage facilities count a much higher fraction (25%) of the fish separated at the primary louvers, salvage counts of steelhead, winter-run and spring-run juveniles are often zero for many days during the migration period. In addition, uncertain louver efficiencies and predation effects make it difficult to accurately estimate the loss of fish to entrainment (i.e., ESA loss). The increased fish protections from RPA Actions that reduce pumping can be estimated using the measured salvage (or salvage loss estimates), but the daily protection will depend on the measured salvage; no benefits can be calculated for days with no measured salvage. The use of daily fish counts (catch) as triggers for closing the DCC or for reducing exports (i.e., reverse OMR flow) may be logical (i.e., provide more protection when there are more fish to protect) but these daily triggers may be difficult to implement, because of the high variability in the daily river catch or in the daily CVP and SWP salvage counts for rare fish. This paper describes how fish tracking analysis could be used to estimate the additional fish protection likely provided by the NMFS Delta Actions (IV) compared with the existing protection under D-1641 objectives for DCC closure, minimum outflow and maximum exports as well as from the CVP and SWP salvage facilities.

1.2.1 Fish Benefits from Closing DCC or Installing a BAFF in Georgiana Slough

The fish-tracking methods can be used to calculate the effects of closing the DCC on fish survival. Closing the DCC will reduce the fraction of migrating Sacramento River fish that are diverted to the SJR, and will reduce the fraction of the Sacramento fish that reach the CVP and SWP exports (fish salvage facilities). The fish benefits from closing the DCC are based on the results of CWT and acoustic tag studies, which indicate that measured Chinook and steelhead survival of fish diverted to the DCC and Georgian Slough and migrating in the Mokelumne River channels and SJR channels to Chipps Island has generally been about half of the survival of fish remaining in the Sacramento River. Closing the DCC would therefore likely increase the survival of Sacramento River fish reaching Chipps Island. The fish-tracking calculation of the benefits would be:

Survival Benefit from DCC closure = reduction in % water diverted x increase in % survival

For example, if the DCC closure reduced the diversion of Sacramento River by 25%, and the survival of fish remaining in the Sacramento River was 40% more than the survival for fish diverted to the SJR (e.g., survival increased from 40% to 80%), the estimated fish population benefit would be 10% higher survival (i.e., 0.25 x 0.4 = 0.1).

This same calculation method could be used to estimate the additional benefits of a non-physical fish barrier or a wedge-wire fish screen in Georgiana Slough; if 20% of the Sacramento River water was diverted (with DCC closed) and a fish barrier would reduce the fish diverted by 10% of the population, from 20% to 10% (deflecting 50% of the fish that would have been diverted into Georgiana Slough), the fish population benefit would be 4% higher survival (i.e., 0.1 x 0.4 = 0.04). This benefit would be added to the 10% higher survival from closing the DCC. A fish barrier or fish screen would reduce the migrating fish density in Georgiana Slough and in the SJR, and would likely reduce the fraction of fish reaching the fish salvage facilities (exports). The reduction in the fish density (estimated from salvage density) would likely be proportional to the fish barrier exclusion; 50% fish exclusion would likely reduce the salvage density by 50%. The following sections describe and show examples of the water movement and fish-tracking analysis for WY 2011-2013.

1.3 Water Year 2011 Delta Flows

1.3.1 Delta Inflows and Water Movement in WY 2011

Figure 1 shows the daily patterns of total Delta inflows, San Joaquin River inflows, Delta outflows and CVP and SWP exports for WY 2011. The CVP and SWP exports were about 10,000 cfs for most of WY 2011 because of high inflows; exports were reduced to about 5,000 cfs in April and May as part of the VAMP (SJR pulse flows and export reductions) and the NFMS BiOp RPA Action IV. 2.1 (reduces export pumping to a specified fraction of the SJR inflow). The SJR inflow was similar or higher than the exports from January through June, suggesting that most of the water being exported at the CVP and SWP pumping plants was from the SJR inflow, and most of the fish being salvaged or entrained at the CVP and SWP fish facilities were likely SJR-origin fish. More of the Sacramento-origin fish would likely have been salvaged or entrained in October-December, and in August-September, when the CVP and SWP exports were higher than the SJR inflow. Tracking the origin of the water reaching the CVP and SWP

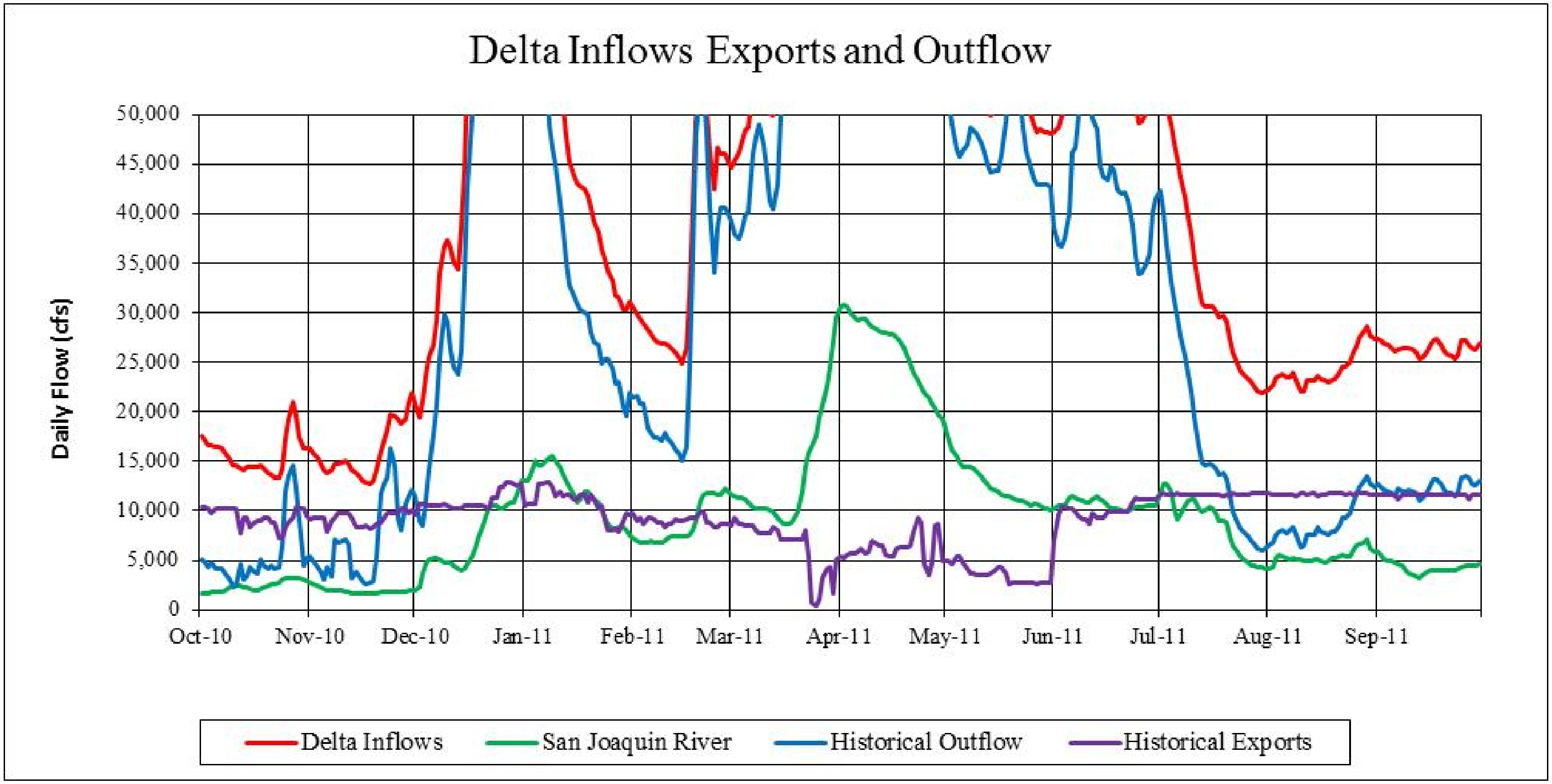

Figure 1. Daily Patterns of Total Delta Inflow, San Joaquin River Inflow, Delta Outflow and CVP and SWP Export for WY 2011. The CVP and SWP exports were about 10,000 cfs for most of WY 2011 because of high inflows; exports were reduced to about 5,000 cfs in April and May as part of the VAMP (SJR pulse flows and export reductions) and the NFMS BiOp RPA IV. 2.1 (reduces export pumping to a specified fraction of the SJR inflow). The SJR inflow was similar or higher than the exports from January through June, suggesting that most of the fish being salvaged or entrained at the CVP and SWP export pumps were SJR-origin fish. More of the Sacramento-origin fish would likely have been salvaged or entrained from October-December, and in August-September, when the CVP and SWP exports were higher than the SJR inflow. Tracking the origin of the water reaching the CVP and SWP exports is the first step in tracking fish from the SJR and Sacramento Rivers, although fish from each river may be found throughout the Delta or in CVP and SWP salvage regardless of the dominant source of water.

exports is the first step in tracking fish from the SJR and Sacramento Rivers, although some fish from both rivers may reach the CVP and SWP pumps (salvage facilities) regardless of the SJR inflows and exports.

Figure 2 shows the daily patterns of SJR inflow, head of Old River flow and CVP and SWP exports with the estimated fraction of SJR water diverted to the head of Old River and in the CVP and SWP exports for WY 2011. The SJR inflow was similar or higher than the exports from January through June, suggesting that most of the water exported at the CVP and SWP pumps was from the SJR inflow. About 50% or more of the SJR flow was diverted at the head of Old River (brown dashed line, right-hand scale) to the CVP and SWP exports, while the remainder of the SJR flow would likely have been diverted into Turner Cut and Middle River as part of any reversed OMR flow needed to supply the exports. Only during periods when the SJR flow was greater than the CVP and SWP exports (e.g., March, April and May) did some of the SJR inflow and SJR-origin fish escape salvage or entrainment in the CVP and exports (green dashed line, right-hand scale). About 25% of the SJR water and SJR-origin fish were likely salvaged or entrained in April and May, while nearly 100% of the SJR water and fish were likely salvaged or entrained in the other months. For this high flow year, about 25% of the SJR fish may have escaped salvage or entrainment in March, and about 75% of the SJR fish may have escaped salvage or entrainment in April and May.

Figure 3 shows the daily patterns of river inflows and CVP and SWP exports with estimated fractions of Sacramento River flow diverted to the Delta Cross Channel and Georgiana Slough and in the CVP and SWP exports for WY 2011. Because the DCC and Georgiana Slough diversions increase with Sacramento River flow, generally about 40% of the Sacramento River water was diverted when the DCC was open (i.e., October-November, July-September), and about 15% was diverted when the DCC was closed (pink dashed line, right-hand scale). The fraction of the Sacramento River flow that remained in the Sacramento River was therefore increased by 25% when the DCC was closed; this was the purpose for NMFS RPA IV.1.2 (increased DCC closure). However, because of the high SJR flows in 2011, very little of the Sacramento River water diverted to Georgiana Slough from mid-December to mid-July reached the CVP and SWP export pumps, and few Sacramento River fish likely reached salvage or entrainment (blue dashed line, right-hand scale). The fraction of Sacramento River water (and fish) reaching the CVP and SWP exports was likely about 50% in October and November, and about 40% in August and September of WY 2011.

1.3.2 Effects of the NMFS RPA Actions on Exports and Fish Protection in WY 2011

The NMFS RPA Action IV.3 imposes a maximum export of 6,000 cfs or 4,000 cfs for 3 days if the older juvenile Chinook salvage loss density was greater than 8 fish/taf or 15 fish/taf, respectively, in November or December; this trigger was not exceeded in WY 2011. The NMFS RPA Action IV.2.3 imposes a maximum reversed OMR flow of -5,000 cfs from January 1 through June 15, or until the daily average Mossdale temperature reaches 22 C (71.6 F) for 7 days (assumed maximum temperature for migrating Chinook survival). Depending on the daily salvage of older juveniles (potentially winter-run or spring-run), the DOSS technical working group can recommend that the exports be reduced to maintain a maximum reversed OMR flow of -3,500 cfs (about 1,500 cfs less exports) or -2,500 cfs (about 2,500 cfs less exports) for at least 5-days. These export reductions are relaxed if the salvage loss density is less than the trigger for three days. The additional fish protection achieved with Action IV.2.3 (from a maximum reversed OMR flow of -5,000 cfs) can be calculated from the measured daily salvage losses and the exports and other Delta flows.

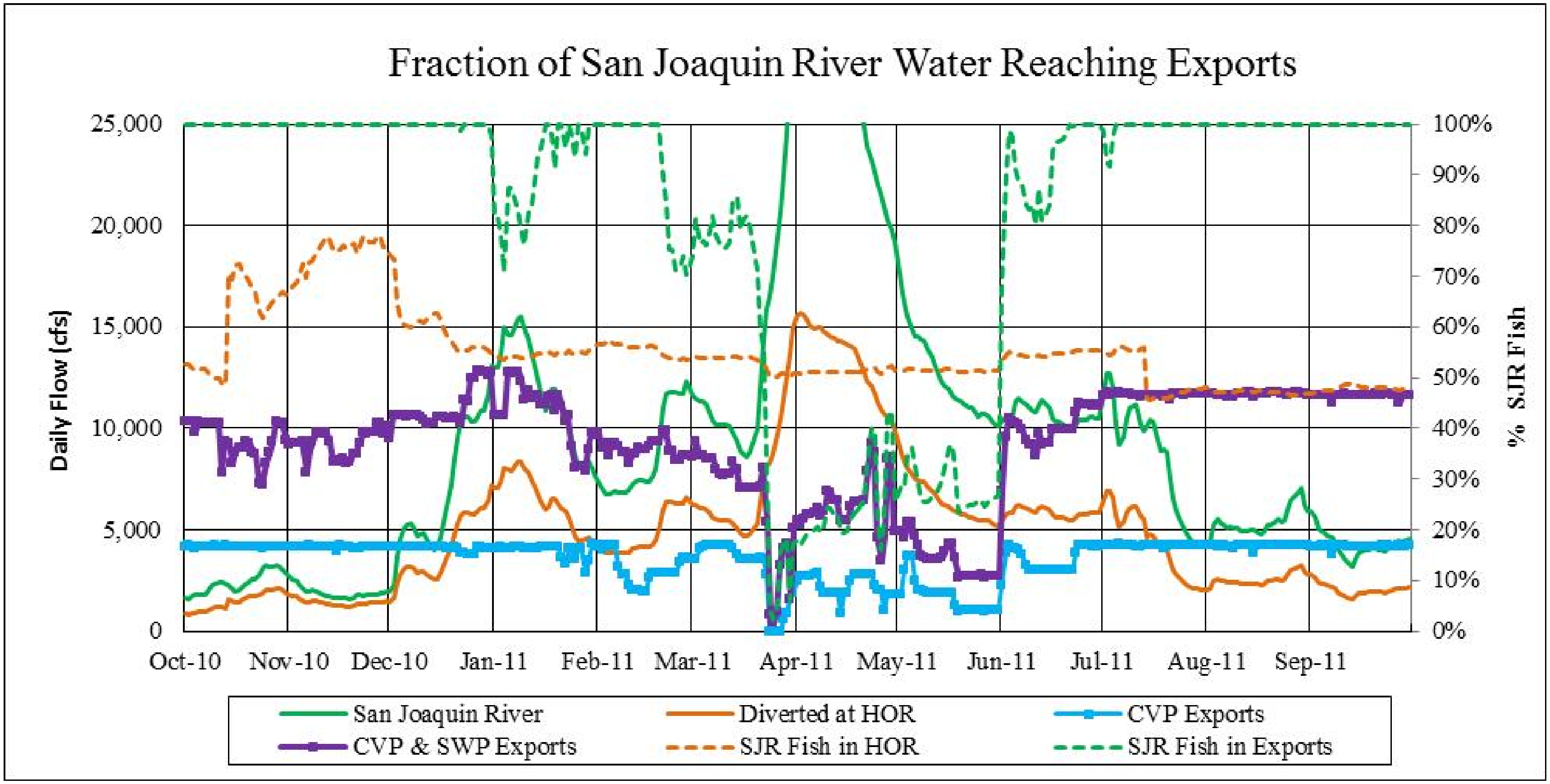

Figure 2. Daily Patterns of SJR Inflow, head of Old River flow and Exports with Estimated Fraction of SJR Fish Diverted to the head of Old River and in CVP and SWP exports for WY 2011. The SJR inflow was similar or higher than the exports from January through June, suggesting that most of the fish being salvaged or entrained at the CVP and SWP export pumps were SJR-origin fish. About 50% or more of the SJR flow was diverted at the head of Old River (brown dashed line, right-hand scale) to the CVP and SWP exports, while the remainder of the SJR flow would have been diverted into Turner Cut as part of any reversed OMR flow needed to supply the exports. Only during periods when the SJR flow was greater than the CVP and SWP exports (e.g., March, April and May) did any of the SJR-origin fish escape salvage or entrainment in the CVP and exports (green dashed line, right-hand scale). About 25% of the SJR-origin fish were salvaged or entrained in April and May, while nearly 100% were salvaged or entrained in the other months.

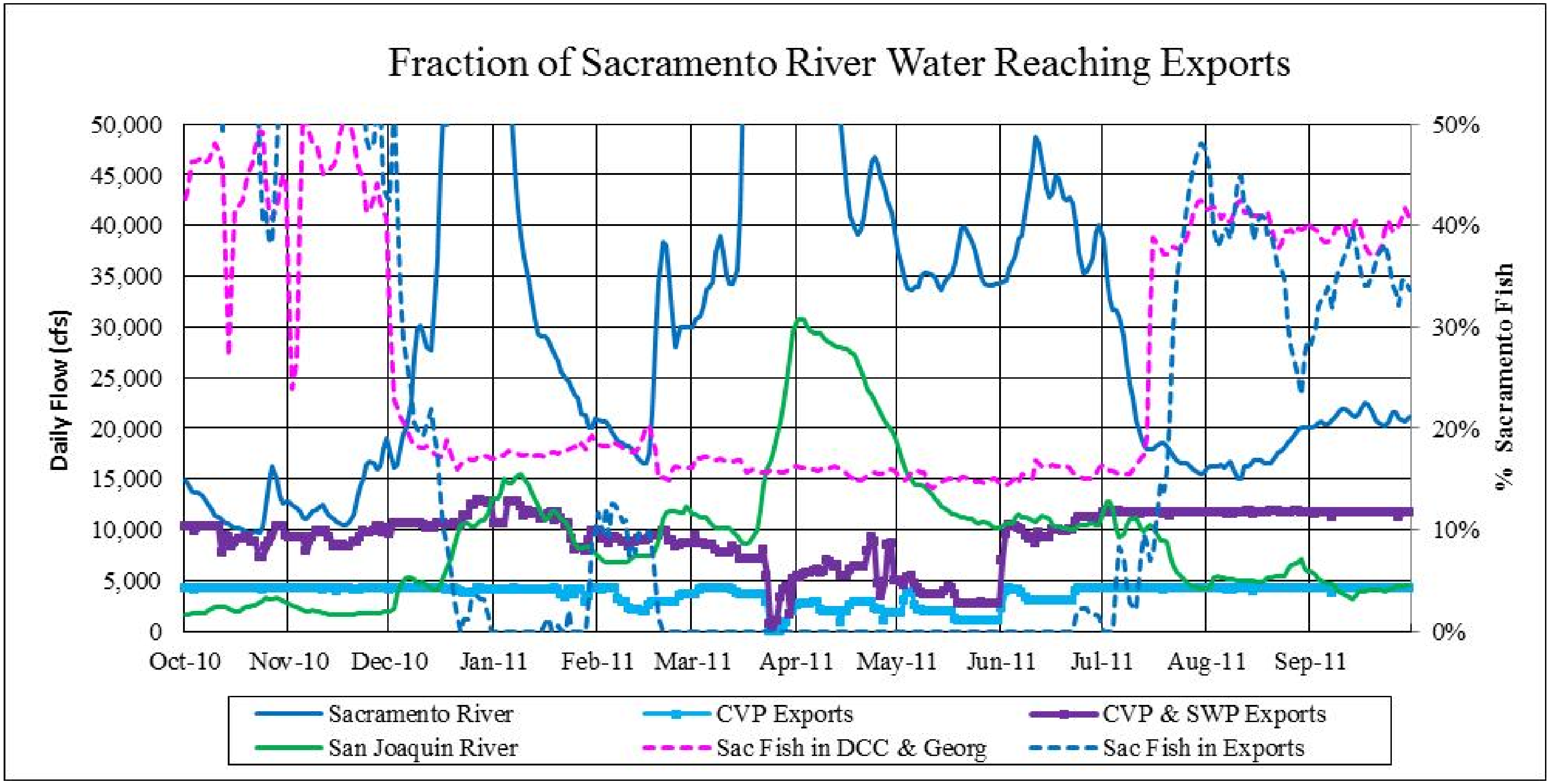

Figure 3. Daily Patterns of River Inflows and CVP and SWP Exports with Estimated Fraction of Sacramento River Fish Diverted to the Delta Cross Channel and Georgiana Slough and in the CVP and SWP Exports for WY 2011. Because the DCC and Georgiana Slough diversions increase with Sacramento River flow, generally about 40% of the Sacramento River fish are diverted when the DCC is open (i.e., October-November, July-September), and about 15% are diverted when the DCC is closed (pink dashed line, right-hand scale). The fraction of the Sacramento River fish that remain in the Sacramento River was increased by 25% when the DCC was closed; this is the purpose for NMFS RPA IV.1.2. However, because of the high SJR flows in 2011, very little of the Sacramento River water diverted to Georgiana Slough from mid-December to mid-July reached the CVP and SWP salvage or entrainment (blue dashed line, right-hand scale).

Figure 4 shows the daily patterns of CVP and SWP exports (purple dots) and reversed OMR flows with maximum reversed OMR flow restrictions (red line) in January-mid June and the export/SJR inflow ratio limits on exports (0.25 for wet years) on exports for April and May (green dots) for WY 2011. The Export/SJR ratio limits in April and May are not applied when SJR flow is >20,000 cfs, and the SJR flows were greater than 20,000 cfs until May. The total SWP and CVP water deliveries are also shown (gold line) to indicate when San Luis Reservoir storage was filled in mid-March. The export reduction of about 2,000 cfs for 4 days in early January was apparently DWR reducing SWP exports in order to reduce the reversed OMR flow to -5,000 cfs; there were no fish loss density triggers during this first week of the reverse OMR limits. There were several periods when reductions from the maximum reversed OMR flow of -5,000 cfs were requested by DOSS; a restriction to -3,500 cfs in the fourth week of January and a restriction to -2,500 cfs from the end of February through mid-March may have caused some reduction in exports. But because the reversed OMR flows were already reduced to less than 2,500 cfs in late February, the export reductions (purple dots) from these DOSS-requested restrictions on reverse OMR flows and fish benefits from these export reductions were likely small (in this wet year). For example, there were no reductions in exports and therefore no fish benefits from the DOSS-requested reduction in reverse OMR flow (to -3,500 cfs) in the second week of April, because the OMR flows were positive.

Because 2011 was a high flow year, there were relatively small reductions in exports caused by the NMFS RPA Actions compared to D-1641 objectives for required Delta outflow and E/I ratios. As indicated in Figure 4, the daily pattern of CVP and SWP exports was about 10,000 cfs for most of the year; and restrictions on exports in January-June caused by NMFS RPA Action IV.2.3 (OMR flows) were moderate. For example, assuming that exports in February-March could have remained at 10,000 cfs under D-1641 (i.e., no outflow or E/I limitations), the exports might have been about 150 taf more. However, because San Luis Reservoir filled on March 15, the exports in April would not likely have been higher, and the exports in May and June were limited by the SJR inflow ratio, not by fish triggers that reduced the OMR flows.

In most other years, the NMFS RPA Action IV.2.3 maximum reversed OMR flow limit (i.e., -5,000 cfs) from January 1 to June 15 is a strong restriction on exports, because this OMR limit reduces export pumping to less than half of the permitted capacity (i.e., 11,280 cf). The CVP and SWP salvage loss density triggers (fish/taf) for chinook and steelhead caused DOSS to request OMR restrictions of 1,500 cfs for about 5 days in January and OMR restrictions of 2,500 cfs for about 20 days in February-March (See Figure 4); therefore the possible increases in exports with a fish protection device (BAFF) in Georgiana Slough that might have reduced the salvage loss density by 50% (to less than the trigger loss density) could have been about 115 taf; however, these reductions in the revered OMR flow limits did not likely restrict total exports in 2011. Because historical exports were high (6,679 taf) in WY 2011, there were not likely any water supply reductions caused by the salvage loss density fish trigger reductions in reverse OMR flow that were recommended by DOSS in January-March of WY 2011.

1.3.3 CVP and SWP Salvage Loss Density Fish Triggers in WY 2011

Figure 5 shows the daily CVP and SWP salvage loss and loss density (fish/taf) estimates for "older juveniles", with lengths greater than the daily minimum winter-run lengths for WY 2011. The NMFS OMR triggers for WY 2011 are indicated on the salvage loss density (fish/taf) graph. Because the WY 2011 winter-run Juvenile Production Estimate (JPE) of winter-run entering the Delta was 332,000 juveniles, the first salvage loss density trigger (2% of JPE/2,000) was 3.3 fish/taf and the second salvage loss density trigger (2% of JPE/1,000) was 6.6 fish/taf. The total salvage loss of older unmarked juveniles

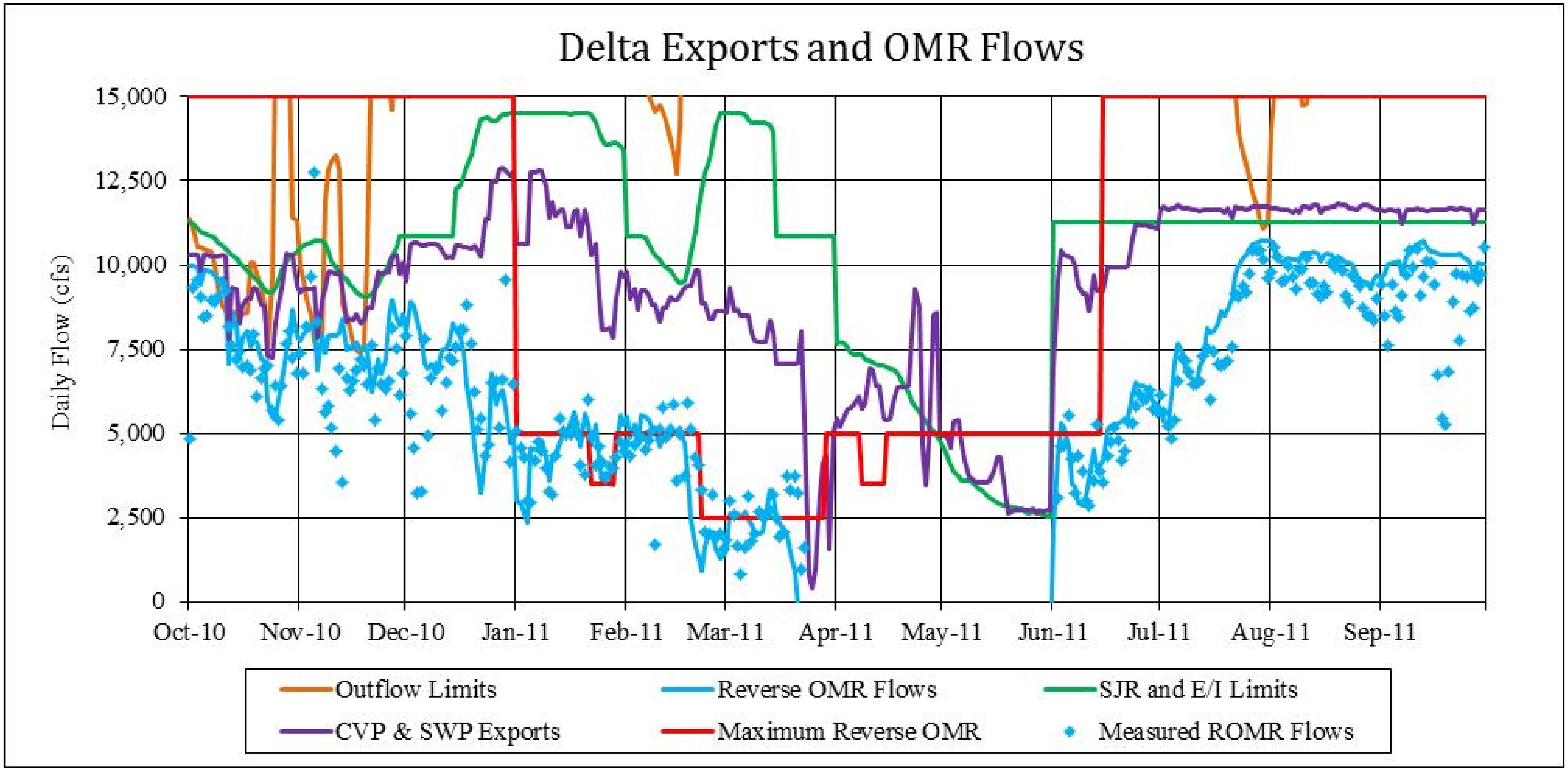

Figure 4. Daily Patterns of CVP and SWP Exports and Reversed OMR Flows with Maximum Reversed OMR Flow Restrictions (red line) and Export/SJR Inflow Ratio Limits (0.25 for wet years) on Exports (green line) for WY 2011. The SJR E/I limits in April were not applied because SJR inflow was greater than 20,000 cfs. The CVP and SWP exports for June 1-15 were restricted to the SJR Inflow by NMFS RPA Action IV.2.2 for 6-year steelhead study. The export reduction of about 2,000 cfs for 4 days in early January was DWR reducing SWP exports to meet the -5000 cfs OMR requirement. Several reductions in the maximum reversed OMR flow from -5,000 cfs were requested by DOSS; a restriction to -3,500 cfs in the fourth week of January and a restriction to -2,500 cfs from the end of February through mid-March caused a reduction if exports.

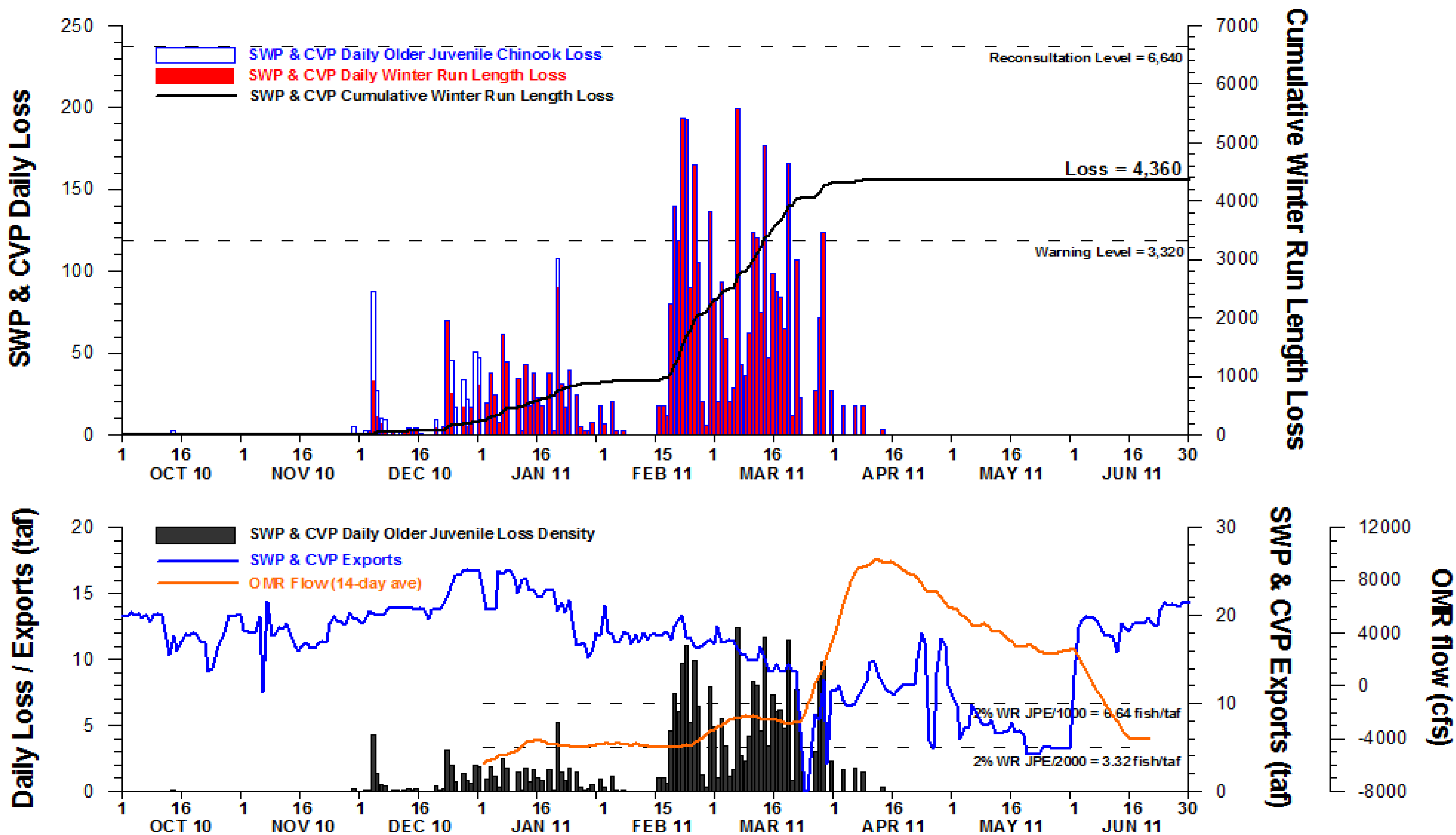

Figure 5. Daily loss and loss density of wild (non-clipped) winter-run length and older juvenile Chinook at the Delta fish facilities for WY 2011 (Source DWR 2011 Salmonid and Green Sturgeon Incidental Take Report, Figure 2). The daily loss density exceeded the triggers in February and March, causing DOSS to request reversed OMR flows of -3500 cfs and -2,500 cfs during this period. The cumulative loss for older Juvenile Chinook was 4,360, which was about 65% of the incidental take limit of 6,640 (2% of JPE expected to reach the Delta).

in WY 2011 was about 4,360 (assumed to be winter-run), which was about 66% of the (2% JPE) incidental take limit (6,640 fish). The first period of higher salvage was from mid-December through January, corresponding to higher Sacramento River flows, with daily salvage loss estimates generally less than 50 fish/day; with full exports of about 10,000 cfs (20 taf/day) the combined CVP and SWP salvage loss density was generally less than 2.5 taf/taf (i.e., 50 fish / 20 taf). The second period of higher salvage was mid-February through March, again corresponding to higher Sacramento River and SJR flows. The salvage loss was higher (50-200 fish/day) and the salvage loss density was generally 2.5 fish/taf to 10 fish/taf. Many of these days had salvage loss density values that exceeded the 3.3 fish/taf and 6.6 fish/taf triggers, so that the maximum allowed reverse OMR flows were reduced from -5,000 cfs to -3,500 cfs or -2,500 cfs for much of this period (Figure 4). As written, the RPA Action IV.3.2 requires as least 5-days of reduced exports if the salvage loss density is greater than the trigger for a single day; while relaxation of the action requires 3 days with salvage loss densities of less than the trigger.

The NMFS RPA Action IV.2.3 uses the CVP and SWP salvage loss estimates for Coleman hatchery (CWT) releases of late-fall run and the Livingston Stone hatchery (CWT) release of winter-run fish, as surrogates for natural spring-run Chinook loss at the CVP and SWP exports. The goal is to reduce the entrainment loss to less tahn1% of these migrating fish. For WY 2011, the first release of 778,000 late-fall run Chinook was made on December 9, 2010; a few of these fish were recovered at the CVP and SWP facilities between December 20, 2010 and March 29, 2011, and the total estimated salvage loss was 2,331 fish (0.30%). The second release of 76,000 late-fall run Chinook was made on December 21, 2010; a few of these fish were recovered between December 22, 2010 (tag error?) and March 11, 2011, and the total estimated salvage loss was 116 fish (0.15%). The third release of 158,000 late-fall run Chinook was made on January 14, 2011; a few of these fish were recovered between January 25, 2011 and February 6, 2011, and the total estimated salvage loss was 63 fish (0.04%). The release of 124,000 Livingston Stone hatchery winter-run fish was made on February 3, 2011 and none of these CWT fish were recovered at the CVP or SWP fish facilities. Therefore, in WY 2011, the relatively high pumping in December-March when these fish likely migrated through the Delta did not approach the designated take limits of 1% of the released fish. CVP and SWP pumping could likely have been sustained at 10,000 cfs through this period without causing the 1% incidental take limits to be exceeded.

1.3.4 Calculating Fish Benefits from Reduced Exports in WY 2011

The overall goal for the NMFS RPA Action IV.2.3 is to reduce the cumulative loss of winter-run and other older juvenile Chinook to less than 2% of the JPE for winter-run juveniles entering the Delta , and to reduce the loss of hatchery releases of late-fall run and winter-run and steelhead to less than 1% of the upstream river releases. The 1% of the hatchery release limit is similar to the 2% of the JPE limit if 50% of the hatchery juveniles are assumed to reach the Delta. [Although the 2013 LSNFH limits was set at 1% of the 50% of the hatchery releases assumed to enter the Delta]. The salvage loss density triggers were developed to reduce pumping during periods of higher juvenile abundance (i.e., peak migration). Although the Sacramento River Rotary Screw Traps and trawls are used to indicate the movement of fish, the fraction of the river that is sampled is quite small (<.001) so the catch fluctuates widely from day to day, with many days of no catch of older juveniles in the December-March migration period. Perhaps a review of the cumulative salvage loss for winter-run (% JPE) and the number (percentage) of hatchery fish (CWT) that are recovered at the salvage facilities should be conducted, as the basis for developing an alternative approach to the salvage loss goals. The daily salvage loss density values may be too highly variable to serve as the primary trigger for export reductions.

For WY 2011, the cumulative CVP and SWP salvage loss of older juvenile Chinook was estimated to be 4,360 fish, while the incidental take limit was estimated to be 6,640 fish (2% of JPE). If the daily fish density pattern was assumed to be independent of export pumping (i.e., pumping will not change the fish density in Old River), the export pumping could have been about 50% more during the four month period when older juveniles were salvaged (e.g., mid-December to mid-April) without exceeding the take limit for winter-run (older juvenile Chinook). But as already discussed, the combined CVP and SWP exports were near the permitted capacity (11,280 cfs) or near the maximum allowable pumping under D-1641 objectives (E/I limits, X2 outflow requirements) for much of this period in WY 2011. Therefore, because pumping was high but the cumulative loss remained less than the 2% JPE take limit, NMFS RPA Action IV.3.2 (reverse OMR flow limits) was not likely needed for WY 2011, and the salvage loss density triggers that allowed DOSS to request export reductions of 1,500 cfs or 2,500 cfs for several days did not likely reduce the cumulative loss by very many fish.

The likely fish benefits can be calculated for periods when the reverse OMR flow limits were reduced from -5,000 cfs to -2,500 cfs. For example, if the daily salvage loss was about 100 fish with combined pumping of 5,000 cfs (10 taf/day), the cumulative winter run Chinook take limit for WY 2011 (6,640 fish) would have been reached in 60 days, if the salvage loss remained at 100 fish per day (10 fish/taf). Reducing the export pumping from 5,000 cfs to 2,500 cfs when the salvage loss was 100 fish/day would reduce the daily salvage loss by 50 fish, saving 250 fish during a five-day period, but also reducing the exports by 25 taf during the five days. The salvage loss density measured during each period of reduced exports can be used to provide an estimate of the reduced salvage loss. As described above, the amount of reduced pumping during a trigger period may not always be 1,500 cfs or 2,500 cfs, if one of the D-1641 objectives would have limited the exports to less than 5,000 cfs (10 taf/day).

1.4 Water Year 2012 Delta Flows

1.4.1 Delta Inflows and Water Movement in WY 2012

Figure 6 shows the daily patterns of total Delta inflows, San Joaquin River inflows, Delta outflows and CVP and SWP exports for WY 2012. The CVP and SWP exports (purple line) were about 10,000 cfs for parts of October-December and most of July-September, but were less than 5,000 cfs for most of the January-June period because of NFMS RPA Action IV. 2.3 (limits reverse OMR flow to -5,000 cfs) and NMFS RPA Action IV.2.1 (reduces export pumping to a specified fraction of the SJR inflow). The SJR inflow was quite low throughout the year, and exports were generally limited to the SJR inflow in April and May. All of the SJR water and migrating SJR fish were likely salvaged or entrained at the CVP and SWP pumps. More of the Sacramento River water and Sacramento-origin migrating fish would likely have been salvaged or entrained in October-January and in July-September, when the CVP and SWP exports were much higher than the SJR inflow. Tracking the origin of the water reaching the CVP and SWP exports is the first step in tracking fish from the SJR and Sacramento Rivers, although some fish from both rivers may reach the CVP and SWP pumps regardless of the SJR inflows and exports.

Figure 7 shows the daily patterns of SJR Inflow, head of Old River flow and CVP and SWP exports with the estimated fraction of SJR water and fish diverted to the head of Old River and in the CVP and SWP exports for WY 2012. The SJR inflow was less than the exports for the entire year, except for April and May when exports were limited to the SJR inflow by NMFS Action IV.2.1 (as modified for the 2012 Joint Settlement Agreement). About 50% or more of the SJR flow was diverted at the head of Old River

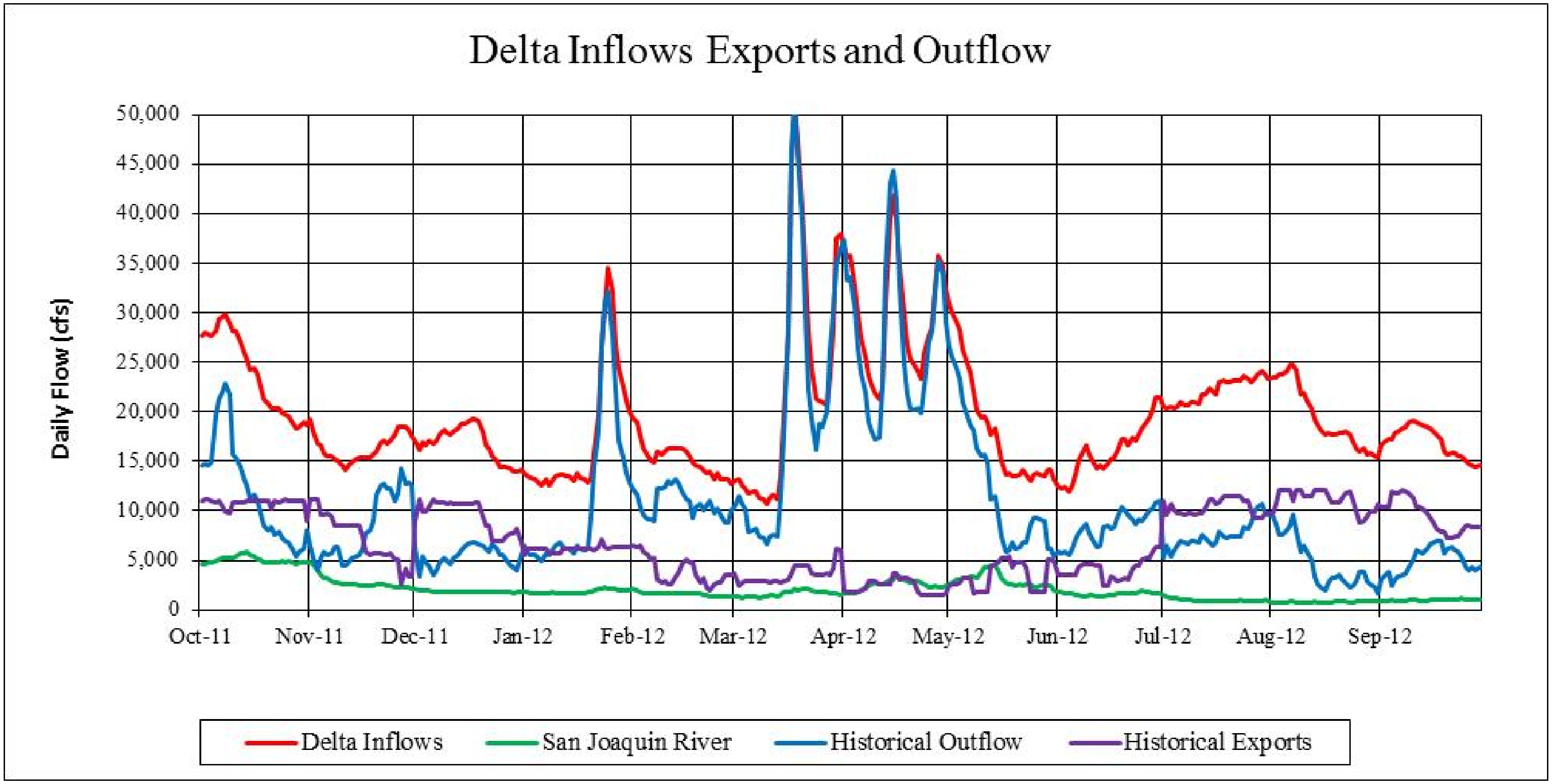

Figure 6. Daily Patterns of Total Delta Inflow, San Joaquin River Inflow, Delta Outflow and CVP and SWP Export for WY 2012. The CVP and SWP exports were about 10,000 cfs for parts of October-December and most of July-September, but were less than 5,000 cfs for most of the January-June period because of NFMS RPA Action IV. 2.3 (limits reverse OMR flow to -5,000 cfs and NMFS RPA Action IV.2.1 (reduces export pumping to a specified fraction of the SJR inflow). The SJR inflow was quite low throughout the year, and exports were limited to the SJR inflow in April and May. All of the SJR fish were likely salvaged or entrained at the CVP and SWP pumps. More of the Sacramento-origin fish would likely have been salvaged or entrained in October-January and in July-September, when the CVP and SWP exports were much higher than the SJR inflow.

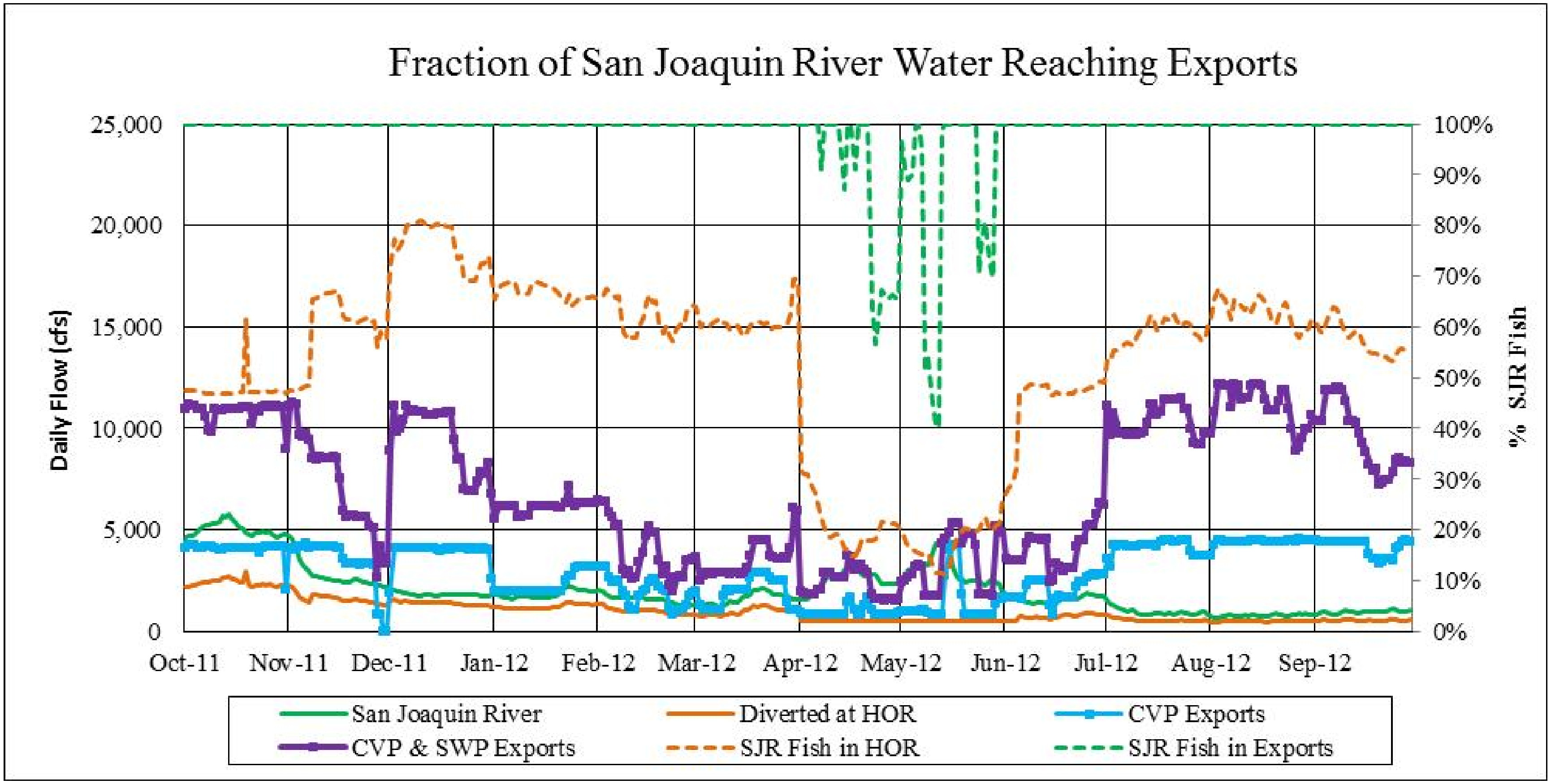

Figure 7. Daily Patterns of SJR Inflow, head of Old River flow and Exports with Estimated Fraction of SJR Fish Diverted to the head of Old River and in CVP and SWP exports for WY 2012. The SJR inflow was much less than the exports for the entire year, except for April and May when exports were limited to the sJR inflow by NMFS Action IV.2.1. About 50% or more of the SJR flow was diverted at the head of Old River (brown dashed line, right-hand scale) to the CVP and SWP exports, except in April and May when the Head of Old River fish protection barrier was installed, reducing the Old River flow to about 500 cfs. Only during periods when the SJR flow was greater than the CVP and SWP exports (e.g., a few weeks in April and May) did any of the SJR-origin fish escape salvage or entrainment in the CVP and exports (green dashed line, right-hand scale).

(brown dashed line, right-hand scale) to the CVP and SWP exports, except in April and May when the Head of Old River fish protection barrier was installed, reducing the Old River flow to about 500 cfs. Only during periods when the SJR flow was greater than the CVP and SWP exports (e.g., a few weeks in April and May) did any of the SJR water or SJR-origin fish escape salvage or entrainment in the CVP and SWP exports (green dashed line, right-hand scale).

Figure 8 shows the daily patterns of river inflows and CVP and SWP exports with estimated fractions of Sacramento River water diverted to the Delta Cross Channel and Georgiana Slough and reaching the CVP and SWP exports for WY 2012. Because the DCC and Georgiana Slough diversions increase with Sacramento River flow, generally about 45% of the Sacramento River water and fish were likely diverted when the DCC was open (i.e., October-November, July-September), and about 20% of the water and fish were likely diverted when the DCC was closed (pink dashed line, right-hand scale). The fraction of the Sacramento River water and fish that remained in the Sacramento River was increased by 25% when the DCC was closed. However, because of the low flows in 2012, a maximum of about 50% of the Sacramento River water and fish likely reached the CVP and SWP salvage or entrainment (blue dashed line, right-hand scale) in November-December and in July-September of 2012. Because of higher Sacramento River flow and lower exports in February-June, less than 20% of the Sacramento River water reached the CVP and SWP exports.

1.4.2 Effects of the NMFS RPA Actions on Exports and Fish Protection in WY 2012

The NMFS RPA Action IV.3 triggers for reduced exports in November or December were not exceeded in WY 2012. Figure 9 shows the daily patterns of combined exports (purple line) and reversed OMR flows (light blue line) with maximum reversed OMR limits (red line), SJR and E/I limits (green line) and outflow limits (brown line) for WY 2012. Exports were reduced in the first half of November and at the end of December because of minimum outflow requirements. Determining how much of a reduction in exports was caused by the -5,000 OMR limit (or by daily fish loss triggers) requires that other D-1641 objectives (minimum outflow, E/I, SJR) be tracked. Several reductions in the maximum reversed OMR flows were requested by DOSS during the February-May period. The export reductions in February were caused by the minimum outflow objective; the OMR restrictions to -2,500 cfs from the end of February through March were caused by daily fish loss density triggers, while the reductions in April and May were determined by the Joint Stipulation Agreement operations in conjunction with steelhead acoustic tag experiments, in lieu of the NMFS RPA Action IV.3.1 (exports equal to SJR inflow).

Comparison of the daily D-1641 export limits from required minimum outflow and the SJR inflow or E/I suggests that the exports (with OMR flow of -5,000 cfs) were reduced by about 2,500 cfs in January and by about 5,000 cfs in the second half of March and the first half of April, equivalent to about 450 taf. DOSS requested reductions in reverse OMR to -2,500 cfs from the end of February through most of March. The reduction in exports caused by daily salvage loss density triggers was estimated to be about 100 taf (20 days of -2,500 cfs) for WY 2012. Therefore, the possible increases in exports with a fish protection device (BAFF) in Georgiana Slough that might have reduced the salvage loss density by 50% (to less than the salvage loss density trigger) might have been about 100 taf for WY 2012. The restriction to OMR flow of -5,000 cfs would not have been relaxed with a BAFF in Georgiana Slough.

The exports in April and May would have been restricted to half of the SJR inflow in WY 2012 (SJR dry year) by the NMFS RPA Action IV.2.1. The D-1641 limits would have been exports equal to the SJR flow from April 15 to May 15. However, a Federal Court Joint Stipulation Agreement (JSA) modified these

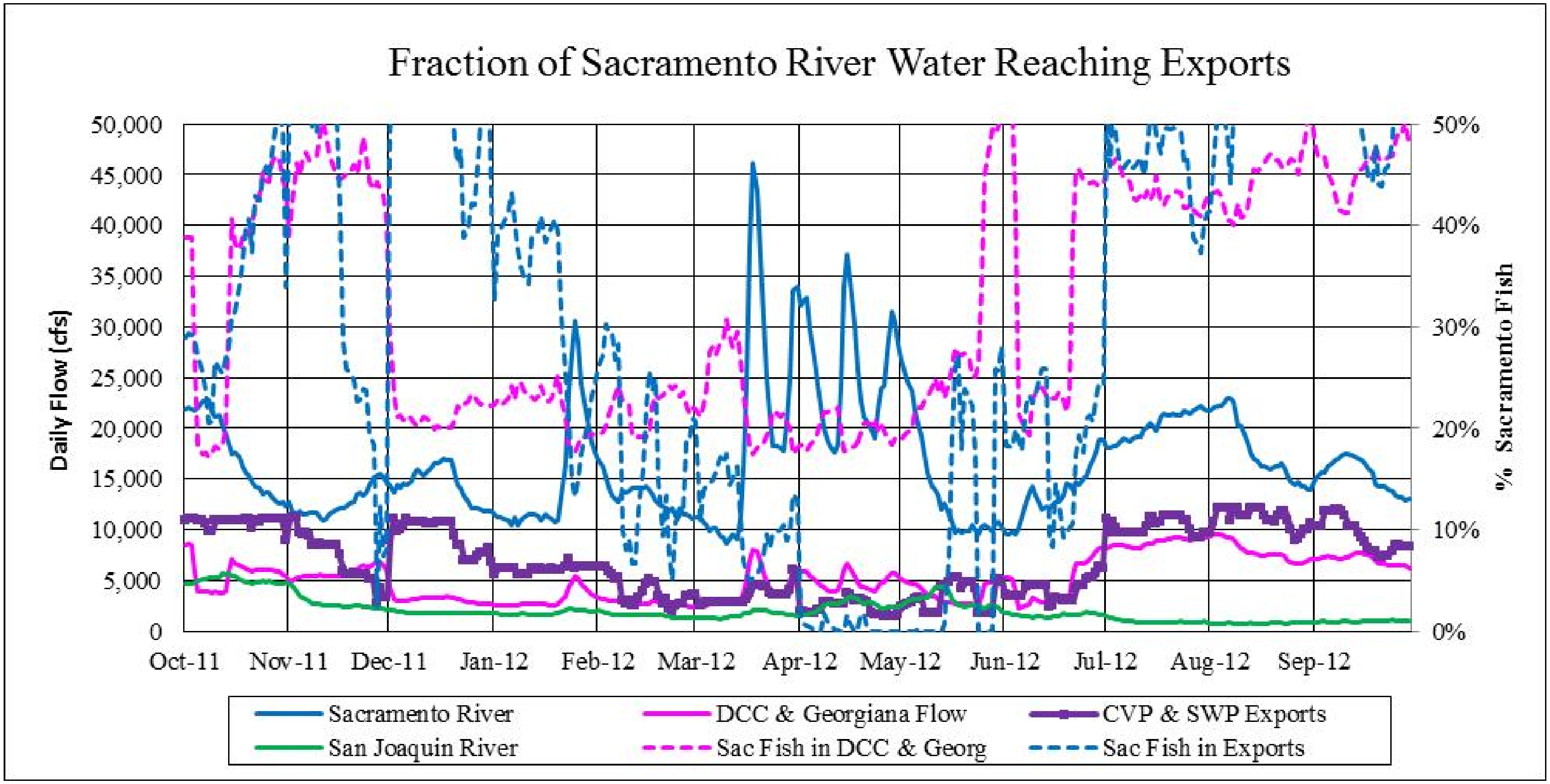

Figure 8. Daily Patterns of River Inflows and CVP and SWP Exports with Estimated Fraction of Sacramento River Fish Diverted to the Delta Cross Channel and Georgiana Slough and in the CVP and SWP Exports for WY 2012. Because the DCC and Georgiana Slough diversions increase with Sacramento River flow, generally about 45% of the Sacramento River fish were likely diverted when the DCC was open (i.e., October-November, July-September), and about 20% were likely diverted when the DCC was closed (pink dashed line, right-hand scale). The fraction of the Sacramento River fish that remained in the Sacramento River was increased by 25% when the DCC was closed; this is the purpose for NMFS RPA IV.1.2. However, because of the low flows in 2012, a maximum of about 50% of the Sacramento River water and fish likely reached the CVP and SWP salvage or entrainment (blue dashed line, right-hand scale) in November-December and in July-September of 2012.

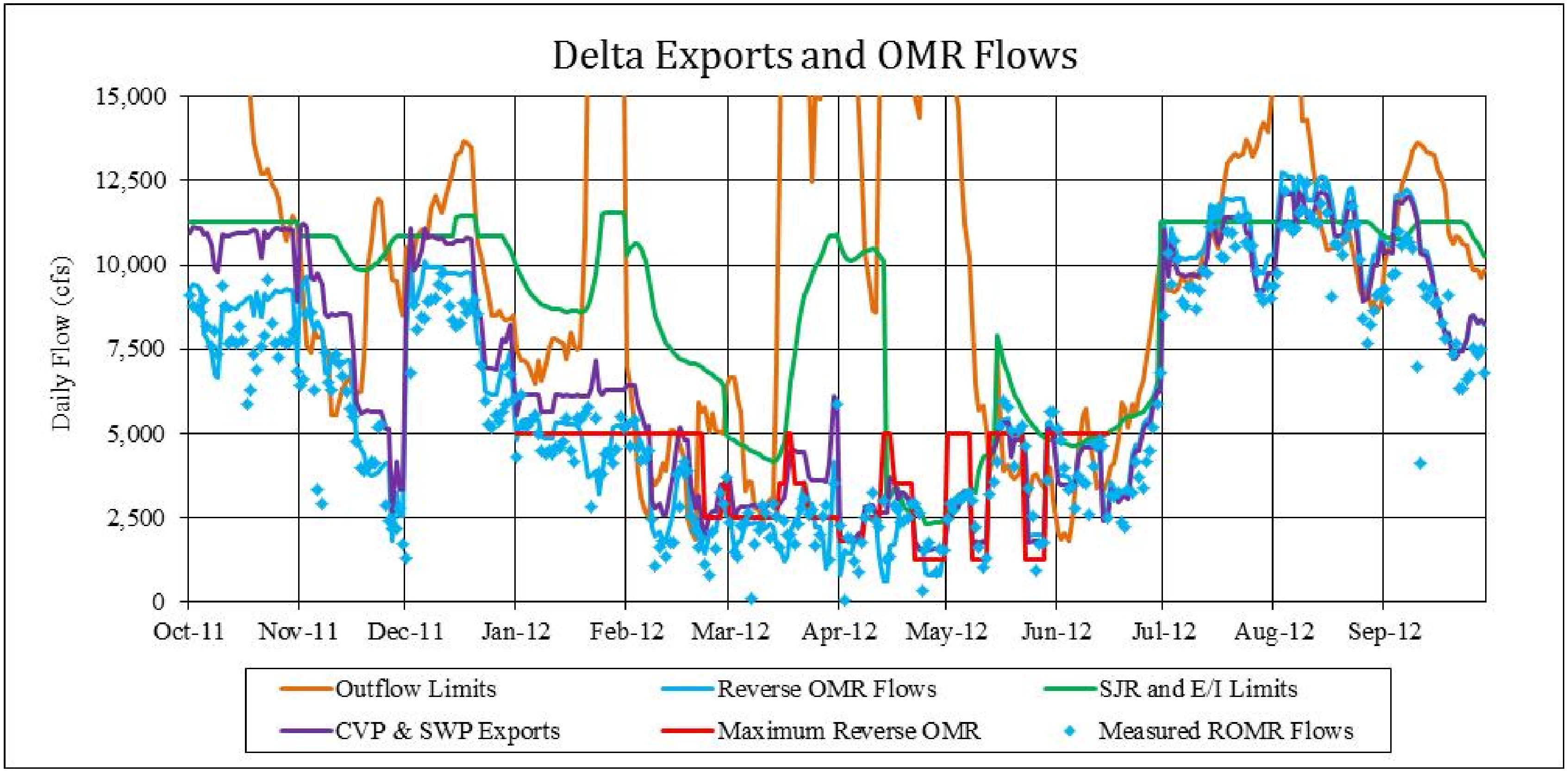

Figure 9. Daily Patterns of Combined Exports and Reversed OMR Flows with Maximum Reversed OMR Flow Restrictions (red line), SJR and E/I Limits (green line) and Outflow Limits on Exports for WY 2012. Exports were reduced in the first half of November and at the end of December because of minimum outflow requirements. Determining how much of a reduction in exports was caused by the -5,000 OMR limit (or by s daily fish loss triggers) requires that other D-1641 objectives (minimum outflow, E/I, SJR) be tracked. Several reductions in the maximum reversed OMR flows were requested by DOSS during the February-May period. The export reductions in February were caused by the minimum outflow objective; the OMR restrictions to -2,500 cfs from the end of February through March were caused by daily fish loss density triggers, while the reductions in April and May were determined by the Joint Stipulation Agreement operations in conjunction with steelhead acoustic tag experiments, in lieu of the NMFS RPA Action IV.3.1 (exports equal to SJR inflow).

normal requirements to allow acoustic tag tracking experiments of steelhead in 2012 with a range of reverse OMR flows (exports) of -1,250 cfs to -5,000 cfs in April and May. The April-May operations allowed considerably more exports (352 taf) than would have been allowed with the exports equal to the maximum of half the SJR inflow or 1,500 cfs (218 taf).

1.4.3 CVP and SWP Salvage Loss Density Fish Triggers in WY 2012

Figure 10 shows the daily CVP and SWP salvage loss (fish) and salvage loss density (fish/taf) estimates for "older juveniles", with lengths greater than the daily minimum winter-run lengths for WY 2012. The NMFS OMR triggers for WY 2012 are indicated on the salvage loss density (fish/taf) graph. Because the WY 2012 winter-run Juvenile Production Estimate (JPE) of fish entering the Delta was 162,000 juveniles, the first loss trigger (2% of JPE/2,000) was less than the minimum allowed trigger, so the daily loss density triggers were 2.5 fish/taf and 5.0 fish/taf. The total salvage loss of older juveniles in WY 2012 was 2,079 (assumed to be winter-run), which was about 65% of the 2% JPE take limit (3,240 fish). The period of higher salvage loss, from mid-February through March, had daily salvage loss estimates of less than 10 fish/day to more than 200 fish/day; because the exports were about 2,500 cfs (5 taf/day) the combined CVP and SWP salvage loss density ranged from less than 2 taf/taf to more than 40 fish/taf (on two days).

If the daily fish density pattern were assumed to be independent of export pumping, the export pumping could have been about 50% more during the 1.5-month period when older juveniles were salvaged (e.g., mid-February through March) without exceeding the take limit for winter run. These same assumptions suggest that if the pumping had been twice as great during February and March, the salvage loss could have been about twice as high (4,000 fish), and could have exceeded the 2% JPE take limit (3,240 fish). If CVP and SWP export pumping actually draws more fish into the south Delta channels (i.e., reverse Old and Middle River flows), so that the salvage loss density remains constant with higher (or lower) pumping, then the RPA Action IV.3.2 might have reduced the loss of older juvenile Chinook in proportion to the reduced pumping.

The NMFS RPA Action IV.2.3 uses the CVP and SWP salvage loss estimates for Coleman hatchery (CWT) releases of late-fall run and the Livingston Stone hatchery (CWT) release of winter-run fish, as surrogates for natural spring-run Chinook loss at the CVP and SWP exports. For WY 2012, the first release of 62,000 late-fall run Chinook was made on December 23, 2011; a few fish were recovered between January 18 and 31, 2012 and the total estimated salvage loss was 3 fish (0.005%). The second release of 80,000 late-fall run Chinook was made on January 13, 2012; a few of these fish were recovered between January 31 and February 18, 2012, and the total estimated salvage loss was 52 fish (0.064%). The third release of about 20,000 late-fall run Chinook was made on January 20, 2012; a few of these fish were recovered between January 30 and March 31, 2012, and the total estimated salvage loss was 101 fish (0.5%). The release of 185,000 Livingston Stone hatchery winter-run fish was made on February 9, 2012 and 1 of these fish was recovered at the SWP fish facilities, for a total salvage loss of 17 fish (0.018%). Therefore, in WY 2012, the CVP and SWP pumping could likely have been sustained at 10,000 cfs through this period (December-March) without exceeding the 1% incidental take limits.

The likely fish benefits can be calculated for periods when the reverse OMR flow limits were reduced from -5,000 cfs to -2,500 cfs. For example, if the daily salvage loss was about 100 fish with combined pumping of 5,000 cfs (10 taf/day), the cumulative winter run Chinook take limit for WY 2012 (3,240 fish) would have been reached in 30 days, if the salvage loss remained at 100 fish per day (10 fish/taf).

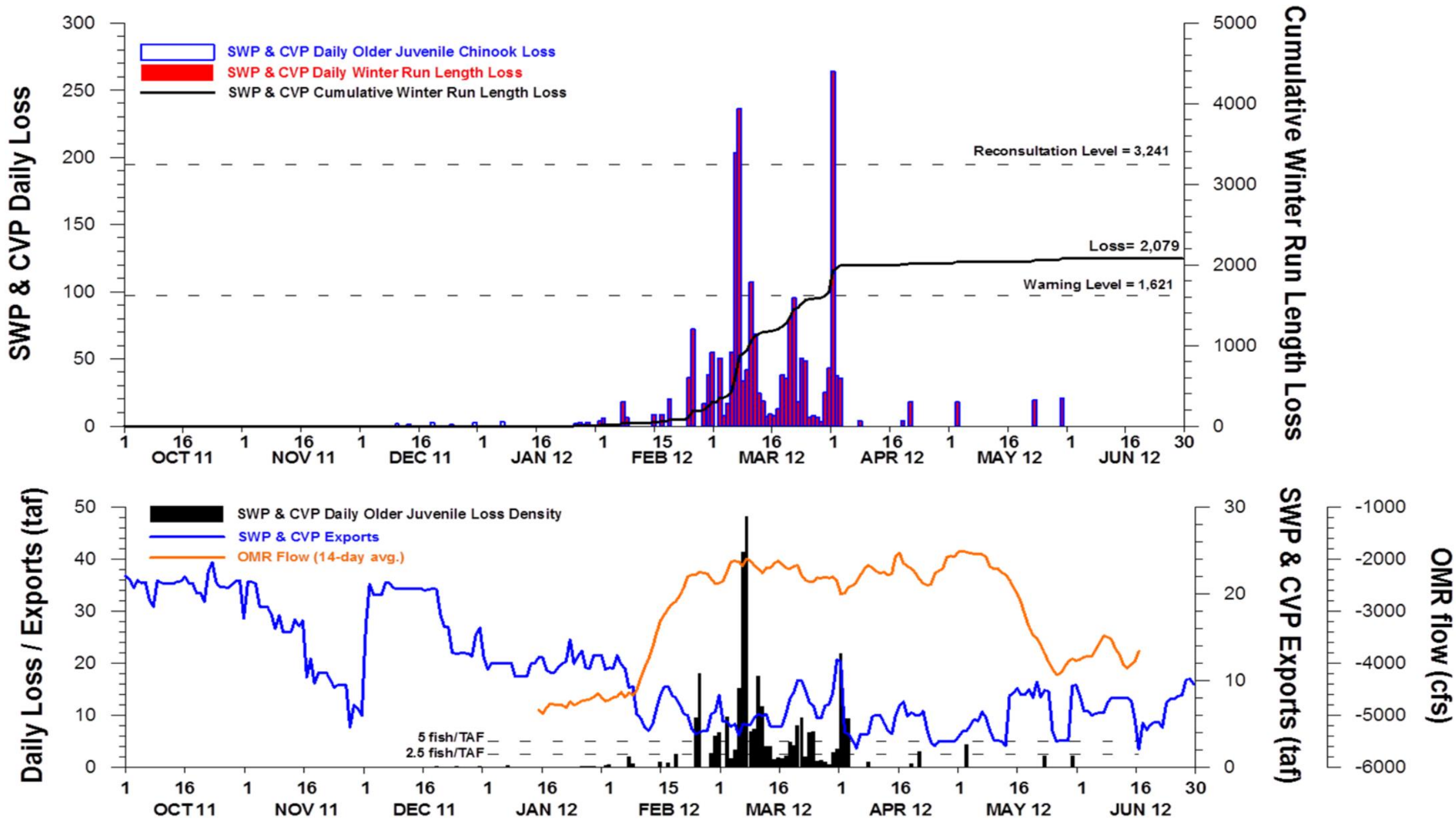

Figure 10. Daily CVP and SWP salvage loss and salvage loss density of wild (non-clipped) winter-run length and older juvenile Chinook at the Delta fish facilities for WY 2012. (Source DWR 2012 Salmonid and Green Sturgeon Incidental Take Report, Figure 3). The daily loss density exceeded the triggers in March, causing DOSS to request reversed OMR flows of -3500 cfs and -2,500 cfs during this period. The cumulative loss for older Juvenile Chinook was 2,079, which was about 65% of the incidental take limit of 3,241 (2% of JPE expected to reach the Delta).

Reducing the export pumping from 5,000 cfs to 2,500 cfs when the salvage loss was 100 fish/day would reduce the daily salvage loss by 50 fish, saving 250 fish during a five-day period, but also reducing the exports by 25 taf during the five days. The salvage loss density measured during each period of reduced exports can be used to provide an estimate of the reduced salvage loss. As described above, the amount of reduced pumping during a trigger period may not always be 1,500 cfs or 2,500 cfs, if one of the D-1641 objectives would have limited the exports to less than 5,000 cfs (10 taf/day).

1.5 Water Year 2013 Delta Flows

1.5.1 Delta Inflows and Water Movement in WY 2013

Figure 11 shows the daily patterns of total Delta inflows, San Joaquin River inflows, Delta outflows and CVP and SWP exports for WY 2012. The CVP and SWP exports (purple line) were about 10,000 cfs for parts of October-December and most of July-September, but were less than 5,000 cfs for most of the January-June period because of NFMS RPA Action IV. 2.3 (limits reverse OMR flow to -5,000 cfs) and NMFS RPA Action IV.2.1 (reduces export pumping to a specified fraction of the SJR inflow). The SJR inflow was quite low throughout the year, and exports were generally limited to the SJR inflow in April and May. All of the SJR water and migrating SJR fish were likely salvaged or entrained at the CVP and SWP pumps. More of the Sacramento River water and Sacramento-origin migrating fish would likely have been salvaged or entrained in October-January and in July-September, when the CVP and SWP exports were much higher than the SJR inflow. Tracking the origin of the water reaching the CVP and SWP exports is the first step in tracking fish from the SJR and Sacramento Rivers, although some fish from both rivers may reach the CVP and SWP pumps regardless of the SJR inflows and exports.

Figure 12 shows the daily patterns of SJR inflow, head of Old River flow and exports with estimated fraction of SJR water diverted to the head of Old River and in CVP and SWP exports for WY 2013. The SJR inflow was much less than the exports for the entire year, except for April and May when exports were limited to the SJR inflow by NMFS Action IV.2.1. About 50% or more of the SJR flow was diverted at the head of Old River (brown dashed line, right-hand scale) to the CVP and SWP exports, except in April and May when the Head of Old River fish protection barrier was installed, reducing the Old River flow to about 500 cfs. Only during periods when the SJR flow was greater than the CVP and SWP exports (e.g., a couple of weeks in April and May) did any of the SJR water or SJR-origin fish escape salvage or entrainment in the CVP and exports (green dashed line, right-hand scale).

Figure 13 shows the daily patterns of river inflows and CVP and SWP exports with estimated fraction of Sacramento River fish diverted to the delta cross channel and Georgiana Slough and in the exports for WY 2013. Because the DCC and Georgiana Slough diversions increase with Sacramento River flow, generally about 45% of the Sacramento River fish were likely diverted when the DCC was open (i.e., October-November, July-September), and about 20% were likely diverted when the DCC was closed (pink dashed line, right-hand scale). However, because of the low flows in 2013, a maximum of about 50% of the Sacramento River water likely reached the CVP and SWP pumps (blue dashed line, right-hand scale) in November-December and in July-September of 2013. Estimating the fraction of the Sacramento River fish that might have reached the exports is more difficult, because the fish preferences and survivals are generally uncertain.

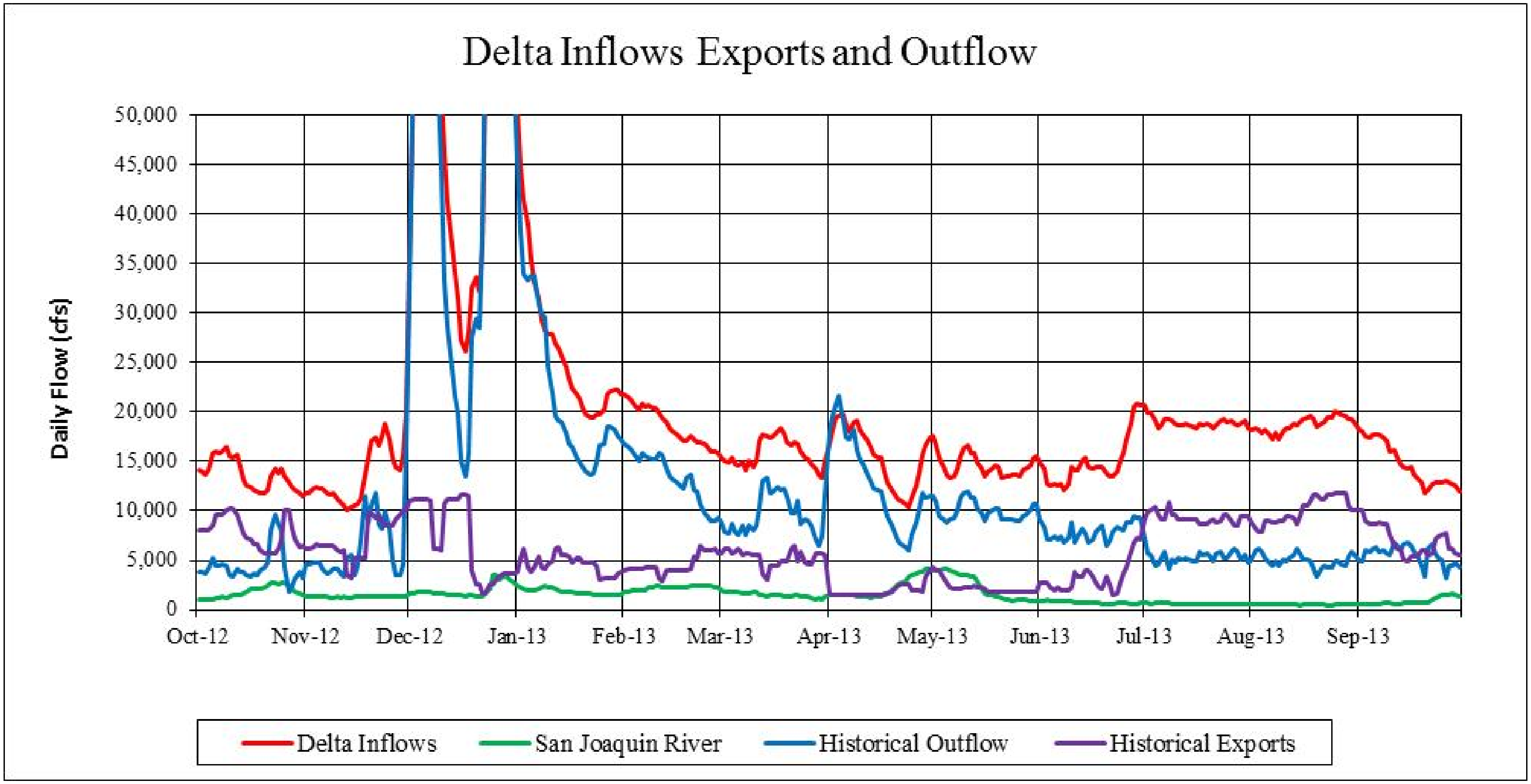

Figure 11. Daily Patterns of Total Delta Inflow, San Joaquin River Inflow, Delta Outflow and CVP and SWP Export for WY 2013. The CVP and SWP exports were about 10,000 cfs for parts of October-December and most of July-September, but were about 5,000 cfs for most of the January-March period because of NFMS RPA Action IV. 2.3 limits reverse OMR flow, and were about 1,500 fs in April and May because of NMFS RPA Action IV.2.1 that reduces export pumping to a specified fraction of the SJR inflow (with minimum of 1,500 cfs). All of the SJR water and SJR fish were likely salvaged or entrained at the CVP and SWP pumps. More of the Sacramento-origin fish would likely have been salvaged or entrained in October-January and in July-September, when the CVP and SWP exports were much higher than the SJR inflow.

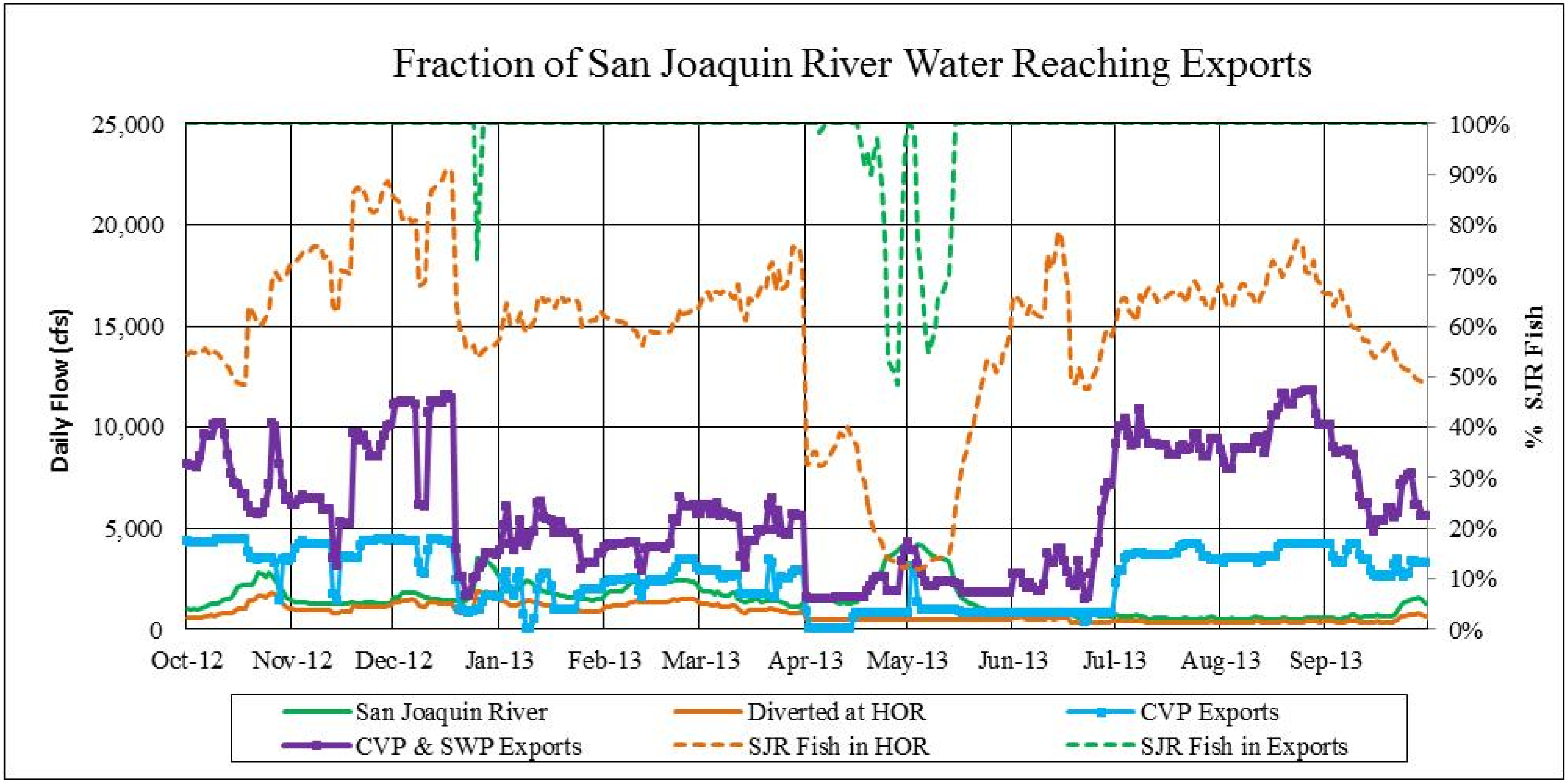

Figure 12. Daily Patterns of SJR Inflow, head of Old River flow and Exports with Estimated Fraction of SJR Fish Diverted to the head of Old River and in CVP and SWP exports for WY 2013. The SJR inflow was much less than the exports for the entire year, except for April and May when exports were limited to the SJR inflow by NMFS Action IV.2.1. About 50% or more of the SJR flow was diverted at the head of Old River (brown dashed line, right-hand scale) to the CVP and SWP exports, except in April and May when the Head of Old River fish protection barrier was installed, reducing the Old River flow to about 500 cfs. Only during periods when the SJR flow was greater than the CVP and SWP exports (e.g., a couple of weeks in April and May) did any of the SJR water or SJR-origin fish escape salvage or entrainment in the CVP and exports (green dashed line, right-hand scale).

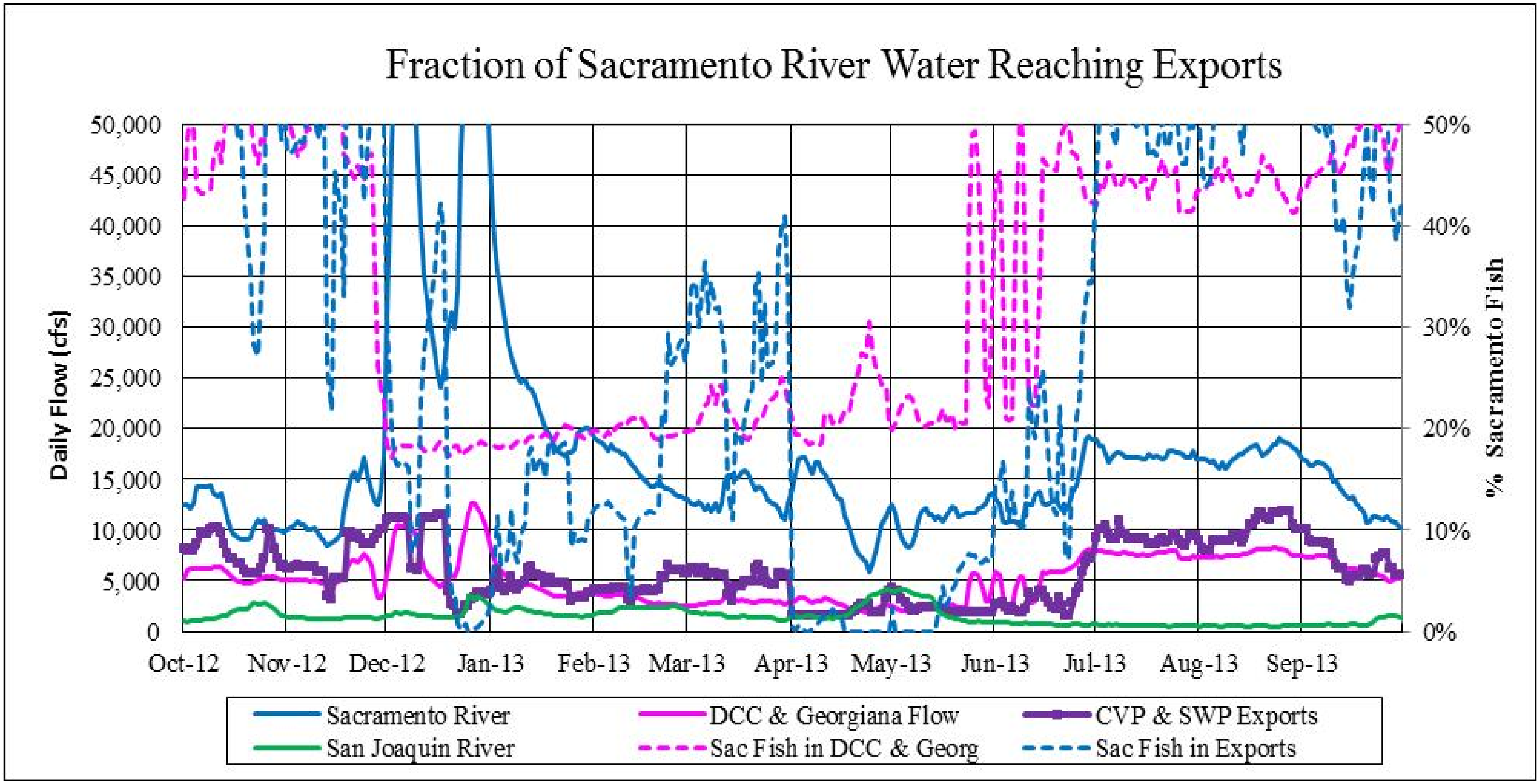

Figure 13. Daily Patterns of River Inflows and CVP and SWP Exports with Estimated Fraction of Sacramento River Fish Diverted to the Delta Cross Channel and Georgiana Slough and in the CVP and SWP Exports for WY 2013. Because the DCC and Georgiana Slough diversions increase with Sacramento River flow, generally about 45% of the Sacramento River fish were likely diverted when the DCC was open (i.e., October-November, July-September), and about 20% were likely diverted when the DCC was closed (pink dashed line, right-hand scale). However, because of the low flows in 2013, a maximum of about 50% of the Sacramento River water likely reached the CVP and SWP pumps (blue dashed line, right-hand scale) in November-December and in July-September of 2013. Estimating the fraction of the Sacramento River fish that might have reached the exports is more difficult, because the fish preferences and survivals are generally uncertain.

1.5.2 Effects of the NMFS RPA Actions on Exports and Fish Protection in WY 2013

Figure 14 shows the daily patterns of combined exports (purple line) and reversed OMR flows with OMR flow limits (red line), SJR and E/I limits (green line) and outflow limits (brown line) on exports for WY 2013. Determining how much of a reduction in exports was caused by the -5,000 OMR limit requires that other D-1641 objectives be tracked. Several reductions in the maximum reversed OMR flows were requested by the Smelt Work Group (SWG) and DOSS in December-May. The D-1641 required outflow and the E/I and SJR export limits controlled the historical exports in October and November, and in June-September of 2013. Exports would likely have remained at capacity in December and January (during the major inflow period for 2013) except for the reverse OMR flow limit of 5,000 cfs, and the SWG and DOSS restrictions based on salvage loss density triggers. The reductions for fish protection reduced the pumping by about 8,000 cfs in the second half of December (240 taf) and by about 6,000 cfs (360 taf) in January. Exports would have followed the E/I limits and outflow limits from February-May, with an average of about 5,000 cfs. But actual OMR restrictions by SWG and DOSS reduced pumping to an average of about 3,500 cfs for these four months, further reducing pumping by about 400 taf.

1.5.3 CVP and SWP Salvage Loss Density Fish Triggers in WY 2013

Figure 15 shows the daily CVP and SWP salvage loss and salvage loss density of wild (non-clipped) winter-run length and older juvenile Chinook at the Delta fish facilities for WY 2013. The daily loss density exceeded the older juvenile Chinook triggers in early December, causing DOSS to request 3-days of reduced exports of 6,000 cfs (12 taf/day). The SWG requested many reductions in reverse OMR flows from mid-December through March. The DOSS older juvenile Chinook triggers (Figure 15) and steelhead triggers (not shown) were also exceeded several times in 2013, but the SWG reductions in reverse OMR were often lower than the DOSS requests.

The cumulative loss for older Juvenile Chinook was 731, which was much less than the incidental take limit of 10,656 (2% of JPE expected to reach the Delta). Non-clipped steelhead were also monitored at SWP and CVP salvage, and salvage loss triggers were exceeded on 18 days during the late-March through May migration period. The total steelhead salvage was 800 fish, considerably less than the 3,000 incidental take limit. If the daily fish density pattern were assumed to be independent of export pumping, the export pumping could have been at full capacity (11,280 cfs) during December and March when older juveniles were salvaged without exceeding the take limit for winter run.

The NMFS RPA Action IV.2.3 uses the CVP and SWP salvage loss estimates for Coleman hatchery (CWT) releases of late-fall run and the Livingston Stone hatchery (CWT) release of winter-run fish, as surrogates for natural spring-run Chinook loss at the CVP and SWP exports. For WY 2013, the first release of 73,000 late-fall run Chinook was made on December 18, 2012; a few fish were recovered in January and the total salvage loss was 75 fish (0.1%). The second release of 70,000 late-fall run Chinook was made on January 8, 2013; a few of these fish were recovered between mid-January and March and the total salvage loss was 139 fish (0.2%). The third release of about 80,000 late-fall run Chinook was made on January 25, 2013; a few of these fish were recovered and the total salvage loss was 24 fish (0.03%). The release of 182,000 Livingston Stone hatchery winter-run fish was made on February 7, 2012 and about half (96,500) were expected to reach the Delta; 1 of these fish was recovered at the SWP fish facilities for a total salvage loss of 9 fish (0.5%). Therefore, in WY 2013, the CVP and SWP pumping could likely have been sustained at full capacity (11,280 cfs) through this period (December-March) without exceeding any of the 1% incidental take limits.

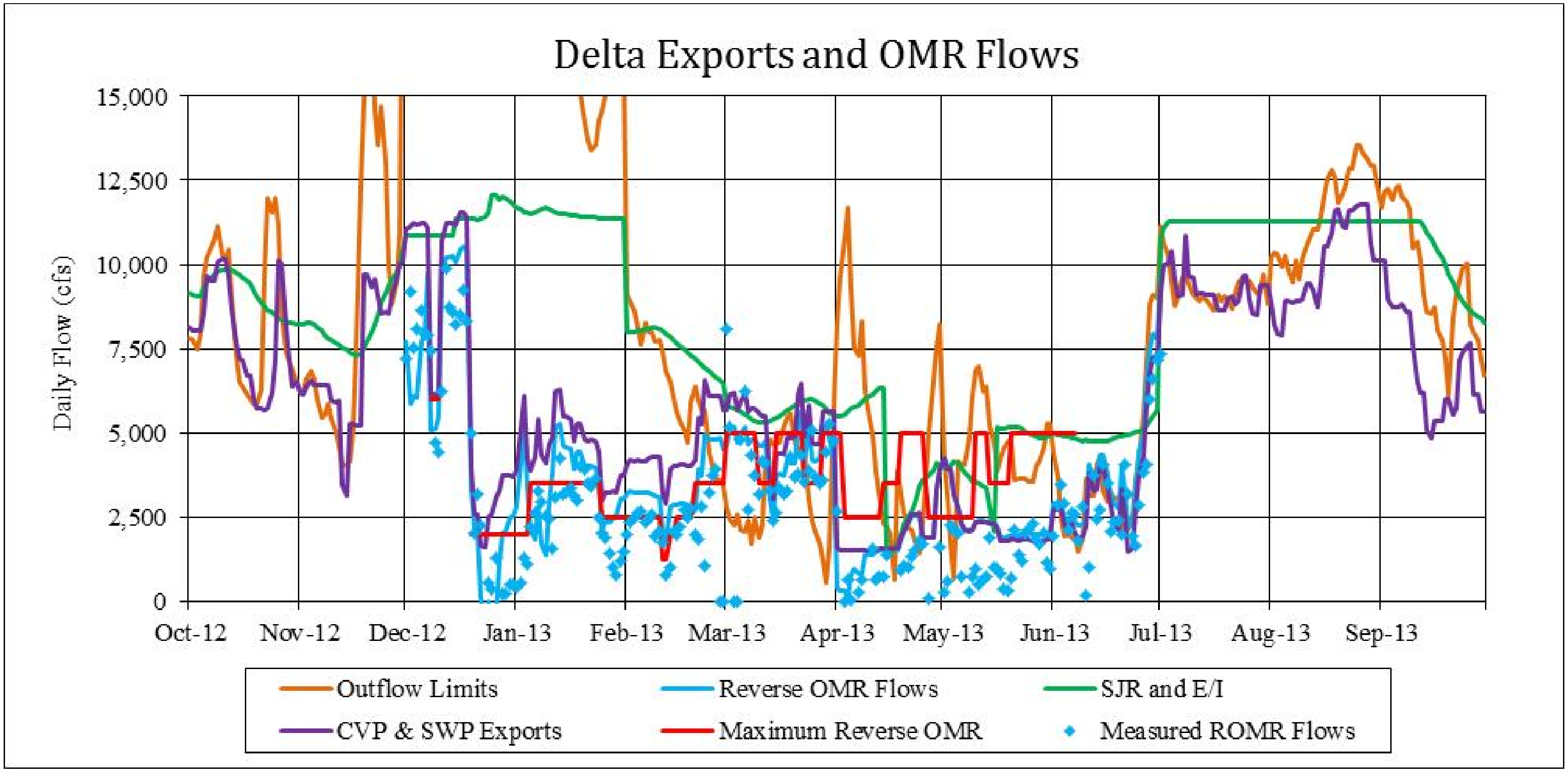

Figure 14. Daily Patterns of Combined Exports (purple line) and Reversed OMR Flows with OMR Flow Limits (red line), Export/ Inflow Limits (green line) and Outflow Limits (brown line) on Exports for WY 2013. Determining how much of a reduction in exports was caused by the -5,000 OMR limit requires that other D-1641 objectives be tracked. Several reductions in the maximum reversed OMR flows were requested by SWG and DOSS in December-May. The required outflow and the E/I and SJR export limits controlled the historical exports in October and November, and in June-September of 2013. Exports would have remained at capacity in December and January (during the major inflow) except for the SWG and DOSS restrictions. The reductions for fish protection reduced the pumping by about 240 taf in December and by 400 taf in January. Exports would have followed the E/I or outflow limits from February-May, with an average of about 5,000 cfs. But actual OMR restrictions by SWG and DOSS reduced pumping to an average of about 3,500 cfs for these four months, reducing pumping by about 400 taf.

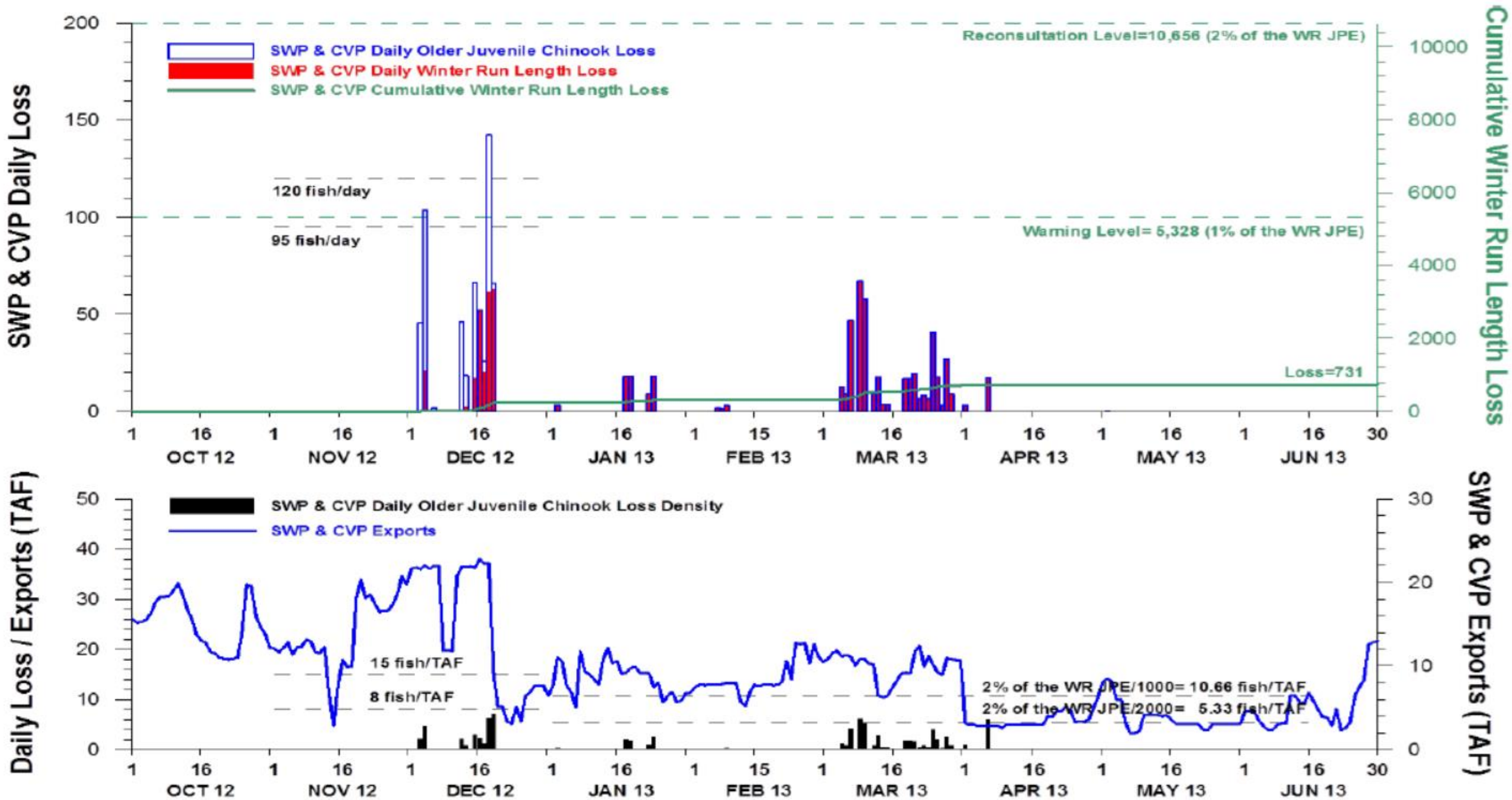

Figure 15. Daily CVP and SWP salvage loss and salvage loss density of wild (non-clipped) winter-run length and older juvenile Chinook at the Delta fish facilities for WY 2013. (Source DWR 2013 Salmonid and Green Sturgeon Incidental Take Report, Figure 3). The daily loss density exceeded the triggers in early December, causing DOSS to request 3-days of reduced exports of 6,000 cfs (12 taf/day). The SWG requested many reductions in reverse OMR flows from mid-December through March. The DOSS older juvenile Chinook and steelhead triggers were exceeded several times in 2013, but the SWG reductions were often lower than the DOSS requests. The cumulative loss for older Juvenile Chinook was 731, which was much less than the incidental take limit of 10,656 (2% of JPE expected to reach the Delta).

1.6 Using Daily Salvage Loss to Calculate Fish Benefits

As these three years show (by example), it is not easy to identify the fish benefits that the RPA actions might have produced, or to estimate the effects of increased or decreased exports on salvage loss density. Chapter 6 of the 2012 DOSS annual report describes this RPA analysis dilemma: "The ability to assess the effectiveness of these RPA actions in terms of biological responses to fish is constrained by a lack of tools and data such as routing models and specific reach survival estimates; however, we can compare on an annual basis fish losses at the CVP/SWP export facilities, survival of specific hatchery releases (*e.g*., spring-run surrogates), and routing of acoustically tagged fish to make some inferences about fish responses" (DOSS 2012 page 35). The conclusion of Chapter 6 states: "Given the tools and data available, DOSS was able to minimize losses of older juvenile Chinook and wild steelhead at the CVP/SWP export facilities. It is unknown how effective the RPA actions were in reducing losses and/or increasing juvenile survival through the Delta. DOSS was able to provide weekly advice to NMFS and WOMT because of implementation of the enhanced web-based monitoring system for reporting fish loss densities and CWT data in real time (*i.e.,* daily reporting). The RPA actions did reduce the number of other ESA-listed species (*e.g.*, delta smelt and longfin smelt) entrained at the CVP/SWP export facilities. Had the RPA actions not been taken, the losses at the facilities would have been higher. Whether the RPA had a quantifiable impact at the population level remains to be seen. As models are developed, these impacts can be better assessed." (DOSS 2012 page 40).

The Delta fish tracking methods assume that migrating fish generally "follow the water" through the Delta channels to the Chipps Island trawl (Delta outflow) or to the CVP and SWP fish salvage facilities (Delta exports). For fish reaching Delta outflow, the survival fraction can be calculated as the assumed survival for each pathway (channels) times the fraction of the fish using each pathway, compared to the number of migrating fish entering the Delta. For fish reaching the CVP and SWP salvage facilities, the survival through the Delta to the CCF gates or DMC intake can be calculated in a similar manner. The survival fraction at the fish salvage facilities is the expanded salvage (i.e., fish count times the fraction of time sampled) compared to the number of fish entering the Delta. The salvage loss at the SWP and CVP fish facilities can be calculated with assumed pre-screen predation losses and louver efficiency (percent diverted to bypass channels). The current method uses an assumed loss/salvage fraction that is related to the assumed predation and louver losses. The CVP fish facility is assumed to salvage 60% of the fish with a loss of 40%. The SWP fish facility with CCF predation is assumed to salvage only 20% of the fish with a loss of 80%. More fish would survive at the salvage facilities if the predation was reduced or if the louver efficiency could be increased.

One of the important elements for evaluating the RPA fish protection actions is to quantify (compare) the historical pumping (reduced by RPA Actions) with the (higher) pumping that would likely have occurred without the RPA Actions. As described in the previous sections reviewing the WY 2011-2013 RPA actions, it was somewhat difficult to identify the daily changes in pumping caused by the SWG or DOSS requests without an official accounting of the RPA restrictions and the otherwise allowable pumping with D-1641 objectives. If the pumping restrictions (and changes in other Delta flows) were identified during the DOSS, SWG, DCT and WOMT weekly data evaluation and operational decision process, the annual reviews of the effectiveness of the RPA actions would be much easier to accomplish. This accounting of fish protection actions might be provided by extending the daily record of Delta flows (DAYFLOW) to include daily values for each of the D-1641 objectives (e.g., daily E/I pumping limit, required Delta outflow). Data columns could be added for each of the outflow requirements (i.e. monthly average, X2 equivalent, salinity equivalent) and export limits for each D-1641 objective. For example, the minimum monthly average outflow and daily X2 (outflow equivalent) for each day could be calculated. Each of the NMFS RPA Actions as well as USFWS RPA Actions for delta smelt (e.g., OMR reductions, Fall X2) could also be included in this official record of "daily operating constraints". Without this daily accounting of each D-1641 rules and RPA actions, comparing the historical operations with alternative operations (e.g., eliminating one of the rules or actions) will remain a very difficult enterprise that will not be easily resolved (i.e., different estimates by different groups).

The weekly DOSS reports contain extensive discussions of the daily fish catch at the various river traps and trawls, as well as the daily CVP and SWP salvage and loss; the details of estimating daily salvage loss and salvage loss densities, deciding if triggers were exceeded, determining how soon exports could be reduced and determining if the OMR restrictions could be relaxed were quite involved. The use of fish catch as a trigger for closing the DCC or for reducing exports (i.e., reverse OMR flow) may be logical (i.e., provide more protection when there are more fish to protect) but these triggers may be difficult to implement, because of the variability in the daily river catch or in the daily CVP and SWP salvage counts. Fish-tracking methods can also be used to describe and understand the likely effects of CVP and SWP exports on fish entrainment losses, and provide a framework for evaluating the benefits achieved by the RPA actions.

Because there are no conditions in NMFS RPA Action IV.2.3 for allowing increased pumping (more than 5,000 cfs) during days with reduced salvage loss density during the January-June 15 OMR flow limit period, the annual export volume (water supply) is generally reduced whenever the salvage loss density triggers are exceeded and the 5-day reduction is requested by DOSS. Because the daily salvage loss is quite variable, reducing exports in response to a single day of high salvage loss may not be an efficient method for controlling (i.e., reducing) the cumulative loss of older juvenile Chinook. The difficulties in using daily salvage loss triggers to reduce exports to protect fish are increased by the delay of 2-3 days needed to report the salvage and obtain operational changes from Reclamation or SWP; the daily salvage density is often lower during the days when the pumping reductions were implemented. An alternative approach to adaptively manage the CVP and SWP exports might be developed, based on the historical salvage patterns for these older juvenile Chinook, as described in the last section of this report.

1.6.1 Salvage Loss Calculations

Salvage loss of fish each day is calculated by DFW using estimated fractions of the expanded salvage at each fish facility. The SWP fish facility was assumed to have a loss/salvage multiplier of 4.33, with each fish "sampled" at the SWP fish facility (sampling 25% of the time) assumed to represent 4 fish salvaged (i.e., expanded salvage) and the loss of 17 additional fish (from predation and passing through the louvers); therefore each fish "counted" at the SWP fish facility was assumed to represent 20 additional fish (+3 salvaged, 17 lost). The CVP fish facility was assumed to have a loss/salvage multiplier of 0.68, with each fish "sampled" assumed to represent 4 fish salvaged (25% sampling rate) and the loss of 2.7 additional fish; therefore each fish "counted" at the CVP fish facility was assumed to represent 6 additional fish (+3 salvaged, 3 lost). The daily salvage loss density estimates are sensitive to the number of fish counted at the CVP and SWP fish facilities. Assuming that the reverse OMR flow was -5,000 cfs, the combined pumping would also be about 5,000 cfs (10 taf/day). Therefore, one additional fish counted at the CVP fish facility would increase the combined loss density by 0.27 fish/taf (i.e., 2.7/10), while one additional fish counted at the SWP facility would increase the combined loss density by 1.7 fish/taf (i.e., 17/10).

It may be easier to consider the assumed fraction of the fish that are salvaged (survive); the CVP fish facility has an assumed salvage fraction of about 60% (40% loss) while the SWP fish facility with CCF has an assumed salvage fraction of about 20% (80% loss). The daily salvage loss therefore depends on the daily salvage counts for specific fish at the SWP and CVP fish facilities; there is no salvage loss calculated for days with no salvage counts for specific fish. However, as the graphs of daily fish loss indicate (Figures 5, 10 and 15) there are many days when no fish are counted, because the fish density is relatively low, and the possibility of missing fish in the 75% of each day when fish are not sampled is relatively high. A 7-day centered average of salvage might be used to estimate the general fish density during periods when some salvage fish are detected. Fish tracking methods can also be used to estimate the fish density expected at the salvage facilities, as an alternative to the measured daily or 7-day averaged salvage counts. Fish tracking methods can be used to provide estimates of the number of fish and fish density arriving at the CVP and SWP salvage facilities; these daily estimates of fish densities can then be used to calculate the effects of reduced pumping. Reduced pumping may shift the flows in various Delta channels and change the number of fish arriving at the salvage facilities, and the reduced pumping (taf/day) can be multiplied by the fish density to calculate the fish benefits (reduced loss).

Because incidental take of protected species or runs are currently estimated from the measured daily salvage “counts”, the effects of additional protection measures on the expected salvage “counts” should be considered. For example, a BAFF or rock barrier at the head of Old River may reduce the diversion of SJR fish to Old River, and may thereby reduce the measured salvage and calculated salvage loss of these fish. But this may not be an accurate index of additional fish protection for SJR Chinook and steelhead, because the survival of fish that remain in the SJR channel may be less than the survival of fish salvaged at the CVP fish facility (assumed to be 60%). The fish tracking framework would consider the expected reductions in the measured fish salvage “counts” at the CVP and SWP fish facilities, but would also calculate the overall survival of the SJR fish reaching the CVP and SWP salvage facilities and reaching Chipps Island. A reduction in the measured or calculated CVP or SWP salvage (or salvage loss) should not be assumed to be an equivalent fish survival benefit, expressed as a fraction of the migrating fish.

A similar problem with the current methods for salvage loss calculations was the installation of the travelling fish screens that were installed in the secondary louver channel of the CVP fish facility in 2014. These new screens (replacing louvers) likely increased the measured salvage by about 10% (because 10% of the acoustic tagged steelhead were “lost” through the secondary louvers in the 2013 study). The DFW calculated CVP salvage loss values likely increased by 10%, although the salvage/loss ratio should have been reduced (from 40%/60% = 0.67 to 30%/70% = 0.43) with the travelling screens. For every 10 fish entering the CVP fish facility, 1 more survives (and 1 fewer is lost). The next section describes an alternative method for calculating fish salvage density and fish salvage loss, using a Delta fish tracking framework to link the daily migrating fish with the water flows through the Delta channels and the survival of fish along each of these channels. The fish tracking framework allows the fraction of the migrating fish that reach Chipps Island, or reach the fish salvage facilities to be calculated, and allows the fish benefits from each RPA action to be separately evaluated.

1.6.2 Estimating Sacramento and San Joaquin River Daily Fish Densities

Because the measured salvage densities are often highly variable, with many days of zero salvage, the fish density in the south Delta channels are uncertain. Both the CVP and SWP salvage densities should be used (replicate samples), but the estimated number of migrating fish entering the Delta should also be used for calculating Delta fish benefits. The fish-tracking methods can be used to estimate the daily number of migrating fish and fish density in the Sacramento and San Joaquin Rivers.

Figure 16 shows the calculated Sacramento River daily fish density (fish/taf) for winter-run Chinook juveniles entering the Delta in November-March of WY 2011. The JPE for 2013 was 532,000 fish. The number of natural (river spawning) winter-run fish entering the Delta was 5,000 fish per day (150,000 per month) in November-January (red diamonds). The migrating juvenile fish were "diluted" by the high flows in December, reducing the fish density. The LSNFH hatchery release of 180,000 fish in early February was illustrated with two potential movement patterns. The blue boxes assumed that 5,000 fish per day arrived in the Delta) in February (140,000 fish, while the green triangles represent the February 7 release of 140,000 fish with a 10-day migration travel time (delay), with a 2.5% daily mortality and a 5% daily movement parameter assumed. These assumed parameters resulted in about 55% of the fish reaching the Delta (75,000 fish), with fish densities of 200 fish/taf in late February declining to less than 20 fish/taf at the end of March. The historical salvage of older juvenile fish (hatchery releases) was observed in December during the high runoff, and in March. As the CWT recoveries from the hatchery releases of late-fall run fish indicate, very few of these fish were observed in the CVP and SWP salvage. While the Sacramento River densities would be 100/taf with a river flow of 25,000 (50 taf/day) for 5,000 fish migrating per day, the salvage density appears to be less than 1%. IT appears that few of the migrating Chinook juveniles are diverted from the Sacramento River and from the San Joaquin River tidal channels, or a very large fraction of the juvenile Chinook are being lost to predation in these Delta Channels. More analysis of the acoustic tag studies will be needed to identify the fish diversion fractions at these channel junctions and the survival in these Delta channels.

Figure 17 shows the comparison of SJR at Mossdale fish density (fish /taf) with CVP and SWP salvage density (fish/taf) for WY 2005. The fish density was graphed with a logarithmic scale (left-hand side) because the migrating fall-run Chinook fish densities increased from about 10 fish/taf to about 1,000 fish/taf during April, May and June. These fish data were analyzed as part of an evaluation of the effectiveness of the Head of Old River barrier (VAMP) for Reclamation (Jones and Stokes 2007). The measured CVP and SWP salvage fish densities were similar to the SJR fish densities in April, but were less than 10% of the SJR fish densities in May and June. The Head of Old River temporary barrier was not installed in WY 2005 because of the relatively high SJR flows. Fish-tracking methods could be used to calculate the measured CVP and SWP salvage densities from the measured SJR fish densities and the flows, channel diversions and exports. The reduced fish densities in May and June might be explained by higher temperatures (e.g., higher predation, with lower survival) and by the reduced pumping (lower fish fraction diverted to salvage facilities). The patterns of migrating SJR fish densities for Chinook and splittail matched the CVP and SWP salvage densities surprisingly well for the years 1996-2005 that were evaluated.

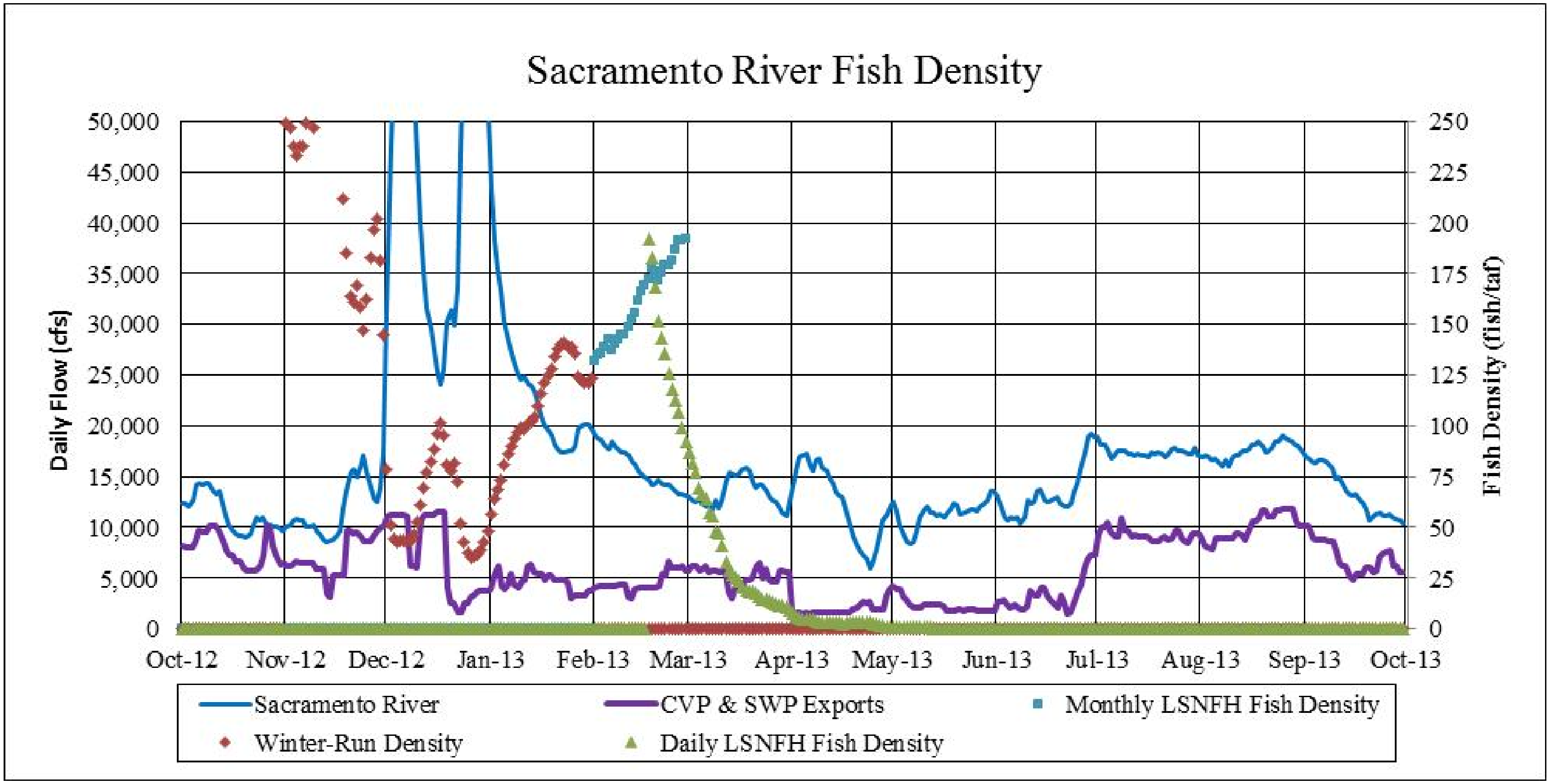

Figure 16. Calculated Sacramento River Daily Fish Density (fish/taf) Entering the Delta in November-March of WY 2011. Winter-run density for river spawning fish with 5,000 fish per day (150,000 per month) reaching the Delta in November-January (red diamonds) were "diluted" by the high flows in December. The LSNFH hatchery release in February was illustrated with two potential movement patterns. The blue boxes assumed that 5,000 fish per day arrived in the Delta (140,000 fish) while the green triangles represent the February 7 release with a 10-day migration travel time (delay) and with a 2.5% daily mortality and a 5% daily movement parameters. These assumed parameters resulted in about 55% of the fish reaching the Delta, with fish densities of 200 fish/taf declining to less than 20 fish/taf within a month of release.

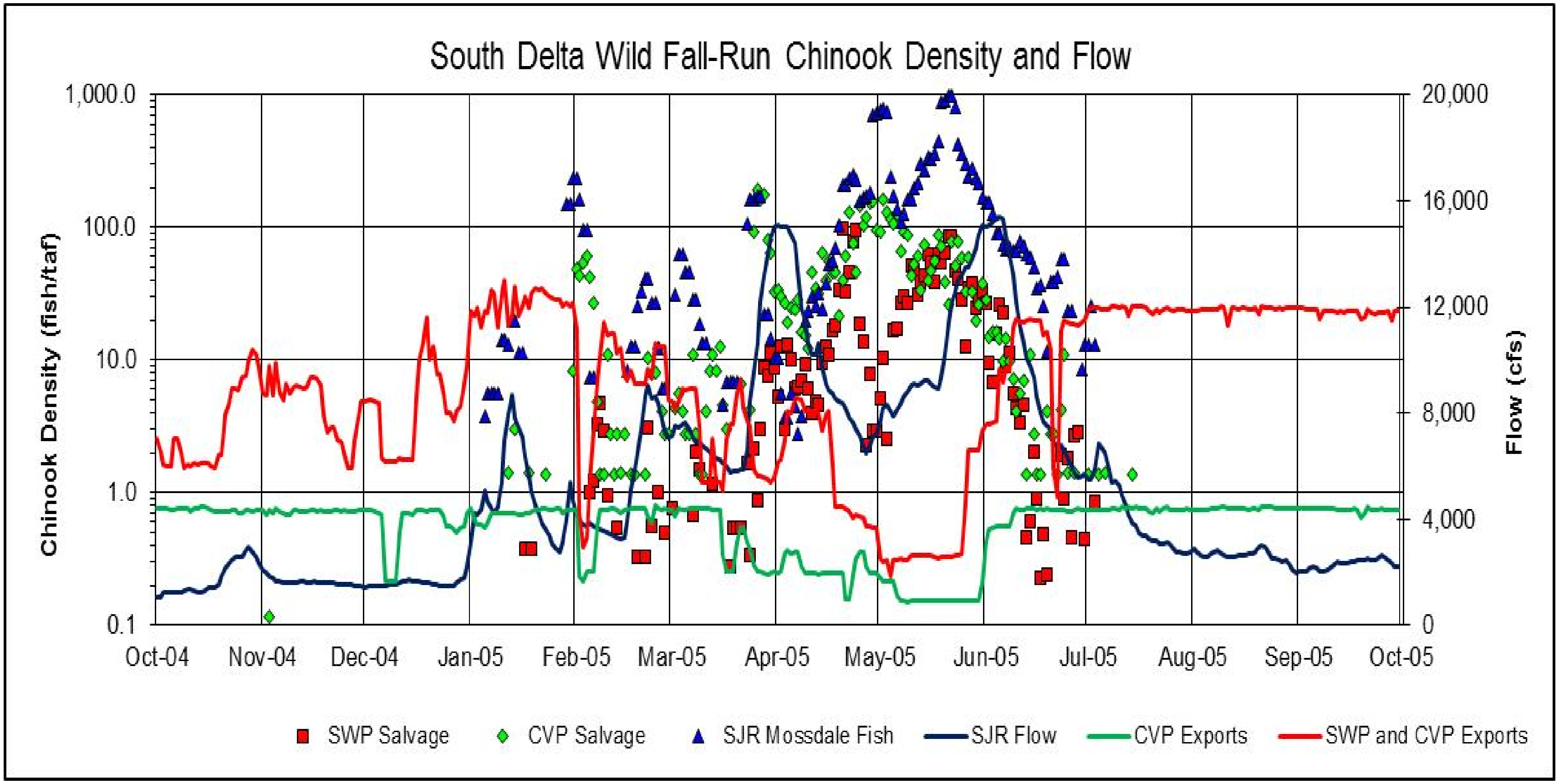

Figure 17. Comparison of SJR at Mossdale Fish Density (fish /taf) with CVP and SWP Salvage Density (fish/taf) for WY 2005. The fish density is graphed with a logarithmic scale (left-hand side) because the migrating fall-run Chinook fish density increases dramatically from less than 10/taf to 1,000 fish/taf during April, May and June. The measured CVP and SWP salvage fish densities were similar to the SJR fish density in April, but were less than 10% of the SJR fish density in May and June. The Head of Old River barrier was not installed in WY 2005 because of the high SJR flows. Fish-tracking methods might be used to calculate the measured salvage density from the measured SJR fish density and the flows and diversions and exports.

1.7 Alternative Approaches to Delta Fish Protection

This section describes the Delta fish-tracking framework that could be used to estimate the survival of migrating fish and also calculate the benefits of the USFWS or NMFS RPA fish protection actions. The Delta fish- tracking framework allows any combination of fish protection measures, with any historical pattern of daily Delta flows and exports to be properly compared and evaluated. Alternative approaches to adaptive management of the exports for fish protection are also described. Delta fish survival benefits are the combination of increased survival of migrating fish through the Delta channels and increased salvage survival for fish reaching the CVP and SWP salvage facilities. Closing the DCC is an example of a fish protection action that shifts the fraction of fish using the Sacramento River pathway, and also may reduce the fraction of Sacramento fish reaching the salvage facilities. Installing a rock barrier or BAFF at the head of Old River will reduce the fraction of SJR fish reaching the CVP and SWP fish facilities, but may also reduce the fraction of SJR fish reaching Chipps Island if salvage survival is higher than migration survival. Reducing the CVP and SWP pumping will likely reduce the number of fish entering the salvage facilities, and may reduce the fraction of Sacramento fish diverted into Old and Middle Rivers from the Mokelumne River. But reducing the SWP pumping may actually increase the daily salvage loss (because predation loss increases with fish travel time in CCF). ***Shifting pumping from SWP to CVP will reduce the salvage loss and increase the salvage survival, without changing the number of Sacramento fish reaching the exports.*** This recommended fish protection action will be effective for all juvenile fish.

The daily salvage loss (fish) and salvage loss density (fish/taf) indicate the pattern of fish abundance in south Delta water, which may depend on pumping (drawing or attracting fish into the south Delta channels) or may be independent of the amount of pumping, reflecting the migration of these juveniles through the Delta channels. The salvage density and salvage loss density provide the daily "concentration of fish" near the exports, independent of the daily pumping. The daily pumping (taf) times the daily salvage loss density (fish/taf) gives the daily loss, while the daily pumping times the salvage density (fish/taf) gives the daily salvage. There are three general methods for reducing the daily salvage loss; reduce the pumping, increase the salvage efficiency, or reduce the number of fish in the vicinity of the CVP and SWP fish facilities.

An alternative approach to protecting older juvenile Chinook and steelhead from salvage loss at the CVP and SWP pumping plants could be based on the cumulative salvage loss patterns from previous years, rather than the daily salvage loss triggers. Because the historical salvage loss density of older juvenile Chinook in December and January has been relatively low (<2.5 fish/taf, <50 fish/day at maximum pumping of 10,000 cfs), there is not likely any need to limit export pumping for older juvenile Chinook in December or January. For example, the cumulative loss at the end of January 2011 (Figure 5) was about 1,000 fish. The CVP and SWP pumping in February and March would not need to be restricted (by limits on reverse OMR flow) to less than the D-1641 E/I limit of 35% of inflow, unless the cumulative salvage loss for older juvenile Chinook was approaching 1% of JPE by the end of February, or 2% of JPE (take limit) by the end of March. ***The pumping would be restricted in February and March only if the projected cumulative salvage loss would be exceeded, assuming that the 7-day moving average of salvage loss density would persist through February and March.*** This recommended fish protection action that will be effective for older juvenile Chinook and steelhead:

For example, if 2% of JPE (take limit) was 6,000 fish, and the cumulative salvage loss at the end of February was 3,000 fish, and the 7-day moving average salvage loss density was 10 fish/taf, pumping for March would be restricted according to this equation:

Maximum Pumping (taf/day) = Remaining Loss (fish) / remaining days / loss density (fish/taf)

March Pumping (taf/day) = 3,000 / 30 days / 10 fish/taf = 10 taf/day = 5,000 cfs

For the example values given above, the March pumping would be limited to 5,000 cfs (10 taf/day). This equation could be checked each week during the months of February and March, so that if the fish density increased substantially during a week, subsequent pumping would be reduced; and if the fish density decreased during a week, the subsequent pumping could be increased. This would provide an adaptive framework for managing CVP and SWP exports to protect the older juvenile Chinook migrating through the Delta, without arbitrarily reducing exports based on the maximum reversed OMR flow of 5,000 cfs or based on a single day with salvage loss greater than the daily loss trigger. In most years, pumping could remain at the allowable pumping (with D-1641 objectives) without approaching the established take limits for older juveniles (winter-run) or hatchery released late-fall run (spring-run surrogates) or steelhead (cumulative salvage of 3,000 non-clipped fish per year).

1.7.1 Reduce the Fraction of Fish Diverted at the DCC and Georgiana Slough

The Delta fish-tracking method estimates the fraction of fish diverted to DCC and Georgiana Slough as the water fractions times a fish passage fraction:

Diverted Fish Fraction = Diverted Water Fraction x Fish Passage Fraction

For example, as described above in the introduction to fish-tracking methods, closing the DCC will reduce the Sacramento River water diversion fraction from about 50% to 25%, thereby reducing the water and fish diversions to the SJR channel. The fish density in the diverted water would be the same as the migrating fish density in the Sacramento River, but the fraction of fish remaining in the Sacramento River channel would be increased from 50% to 75%. If a fish screen or BAFF was installed in DCC or Georgiana Slough, the diverted water fraction would not change, but the fish diversion fraction and fish density would be reduced. A BAFF might have a fish passage fraction of 0.5, while a fish screen with openings for adult migrating Chinook and sturgeon and with boat passage facilities (e.g., gate or lock) might have a fish passage fraction of 0.1. The fish density in the diverted water would be reduced by the fish passage fraction.

The fish-tracking framework would calculate the fraction of these diverted fish that would also be diverted into Middle River or Old River, perhaps as a function of the diverted water fraction (reverse OMR flow). Because the goal for fish protection of migrating Sacramento River fish is to reduce the fish density in the vicinity of the CVP and SWP exports, separating of the fish from the diverted water will allow the greatest exports with a minimum of salvage loss. ***The diversion of Sacramento River fish at the DCC and Georgiana Slough should be reduced by constructing and testing a demonstration fish screen for the south gate of the DCC (3,000 cfs capacity)***. This recommended fish protection action will be effective for older juvenile Chinook and steelhead:

Opening the DCC (one gate) will increase the water diversion from the Sacramento River, but will reduce the water diversion to Georgiana Slough. The fish screen would be about 1,000 feet long and could be mounted on a double row of pilings with a working deck (pier) between the rows of pilings, between the

DCC and the Walnut Grove boat dock. The fish screen sections would be placed in about 25 feet of water, with a solid 5-ft wall at the bottom (to reduce sediment diversion) and at the top (to reduce screen effects on fish migrating near the surface). The effects of the fish screen on tidal hydraulics (e.g., water elevations and velocities in the DCC and in the Sacramento River) can be tested and evaluated; the DCC south gate can be opened and closed to measure the effects of the fish screen, and the north gate can be opened with the south gate closed to identify the effects of one DCC gate. A series of walls and baffles may be needed between the fish screen panels and the levee, to control the velocity distribution through the screens during both flood-tide (upstream) and ebb-tide (downstream) flows. Underwater cameras could be mounted on travelling racks to observe the behavior of fish in the vicinity of the screens, and determine any fish effects (e.g., screen impingement, predation) at the downstream end of the screen. If the demonstration fish screen proves effective, additional fish screen segments could be constructed for the north DCC gate and for Georgiana Slough.

1.7.2 Improve SWP Salvage Efficiency by Constructing a Salvage Corridor in CCF

The fish louvers at the SWP fish facility are similar to the original louvers at the CVP fish facility. Nevertheless, the salvage efficiency is much lower at the SWP facility (20% for SWP compared to 80% for CVP) because of very high assumed predation losses in CCF. A rock-wall levee could be constructed along the southern portion of CCF to directly connect the intake gates to the salvage facility (i.e., salvage corridor). The salvage corridor would allow water to flow directly from the CCF intake gates to the SWP fish facility trash rack and louvers. The transport time for pumping of 5,000 cfs would be less than 2 hours. This would greatly minimize the exposure of smaller fish to predation by striped bass, white catfish and other predators. The average travel time through CCF with pumping of 5,000 cfs is about 2.5 days. The predation loss during a 2-hour period in the salvage corridor would likely be less than 10% of the existing predation loss during a 2-3 day period inn CCF. The actual predation reduction benefits can be directly measured with this alternative fish protection facility. The rock-wall levee construction will allow water to move into and out of storage in the remainder of CCF (needed for tidal inflows and night-time pumping to minimize energy costs). A rock size of 4 to 6 inches will provide sufficient pore space to maintain the storage within an inch of the water level in the salvage corridor, while eliminating any fish movement out of the salvage corridor. ***Increase the Efficiency of the SWP Fish Facility by constructing a salvage corridor from the CCF gates to the fish facility trash rack along the southern shore of CCF.*** This recommended fish protection action will be effective for juvenile Chinook and steelhead, as well as adult and juvenile delta smelt and longfin smelt:

The salvage corridor will be designed to allow the predation reduction benefits to be directly measured. The salvage corridor levee will have a gate that can be closed at the CCF gates, to compare the salvage density with and without the salvage corridor. The salvage corridor gate would be opened for a 3-5 days and the fish salvage would be measured with the normal methods; the salvage corridor would then be closed for a 3-5 days so that the diversions to CCF and salvage for existing conditions would be measured and compared. The predation reduction benefits would be evaluated from the salvage ratio for each fish species during these alternating periods (treatment and control). The alternating measurement periods (salvage corridor open and closed) is needed because the fish abundance (i.e., fish concentration [fish/taf]) varies dramatically in the south Delta with migration events, spawning events, and seasonal habitat conditions. For example, if the measured salvage ratio with and without the salvage corridor was 0.5, then the salvage fraction for the SWP fish facility would be increased from 20% to 40%, and the salvage loss fraction would be reduced accordingly, from 80% to 60%. It is possible that a large portion of the predation loss occurs near the CCF intake gates, where a high abundance of predators may feed on the juvenile fish as they enter this turbulent eddy hole that has formed from the higher water velocities. The salvage corridor may eliminate this entrance eddy hole and the measured salvage ratio may be as low at 0.25. The testing and fish measurements (predator tracking) may indicate that a predator removal program should be included. A regular (weekly) trawling of the salvage corridor with a commercial fishing boat (barge) and appropriate nets might maintain a relatively low abundance of large predators within the 2.25-mile long salvage corridor.

The fish-tracking methods would be adjusted to reflect the much higher expected SWP salvage fraction, and the reduced salvage loss calculations. The construction costs for the CCF salvage corridor may be $75-100 million dollars, but this may provide a large enough fish benefit to convince USFWS and NMFS to allow the exports to increase to the E/I limit of 35%. Each month of pumping in the January-June period that could be increased by 2,500 cfs would provide 150 taf of additional exports. The estimated water value for an assumed price of $100/af would be about $15 million/month. The CCF salvage corridor would have a high fish protection benefit and may allow a substantial increase in SWP exports.