Matrix of Triggers for Delta Cross Channel Gate Operations
April 1 through November 15, 2014

The triggers outlined in this matrix provide direction and a method which strives to balance water quality objectives while protecting fisheries resources. This document addresses April 1 through November 15, 2014 Delta Cross Channel (DCC) gate operations while operating under the Drought Operations Plan. There is a reasonable potential that water quality will be affected by a continuation of the drought into early water year (WY) 2015, therefore the Drought Operations Plan proposes modifications to water quality criteria to achieve the aforementioned balance. The triggers are arranged in an upstream to downstream manner, but all triggers are independent of one another and do not need to occur sequentially.

Two to three separate catch indices, specific to species or age-classes, will be calculated at each monitoring location, as specified below. Exceedance of any catch index, at any location, will require implementation of the action specified for trigger exceedance at that monitoring location depending on the date. If multiple trigger thresholds are exceeded, the action most protective for fish shall be implemented.

Trigger calculated based on:	**Knights Landing Catch Index (KLCI)[f]**	**Sacramento Trawl Catch Index (STCI) [f]**	**Sacramento Beach Seine Index (SBCI)[f]**
Winter-run trigger: "Older juveniles" and winter-run-sized hatchery Chinook[a]	Yes	Yes	Yes
Spring-run trigger: Young-of-year spring-run-sized Chinook, both natural-origin and hatchery[b]	Yes	Yes	Yes
Steelhead trigger: Natural origin steelhead[c]	No	Yes	Yes

<u>Water Year 2014 -</u>April 1-May 20

Tisdale Catch Index (TCI) Rotary Screw Trap (RST) Alert

Catch @ RST	Water Quality Concern Levels Exceeded[e]	Action to be Taken at DCC Gates[d]
Any catch of fish	independent of WQ	No Action

Wilkins Slough flow increase Alert

Flow Increase	Water Quality Concern Levels Exceeded[e]	Action to be Taken at DCC Gates[d]
Flow increase over base flow by 45% within a 5-day time period, calculated using daily flow averages.	independent of WQ	No Action

Knights Landing Catch Index (KLCI) RST[f]

Catch @ RST	Water Quality Concern Levels Exceeded[e]	Action to be Taken at DCC Gates[d] Closures to occur within 24 hours of trigger being met and NMFS providing notification or data are disseminated by fisheries agencies.
N/A	N	Closed
< 3 fish per trap day	Y	Open
≥ 3 fish per trap day	Y	Closed until 3 consecutive days of catch < 3 fish per trap day; then open gates

Sacramento Beach Seine Catch Index (SBCI)[f]

Catch per day: standardized beach seines	Water Quality Concern Levels Exceeded[e]	Action to be Taken at DCC Gates[d] Closures to occur within 24 hours of trigger being met and NMFS providing notification or data are disseminated by fisheries agencies.
<1 per day	N	Closed
<1 per day	Y	Open
≥ 1 per day	N	Closed
≥ 1per day	Y	Diurnal Operations[g] until catch <1 fish per day for three consecutive days; then open gates.

Sacramento Trawl Catch Index (STCI) [f]

Catch per day : standardized trawl	Water Quality Concern Levels Exceeded[e]	Action to be Taken at DCC Gates[d] Closures to occur within 24 hours of trigger being met and NMFS providing notification or data are disseminated by fisheries agencies.
<1 per day	Y	Open
<3 per day	N	Closed
1 ≤ X ≤3 per day	Y	Diurnal Operations[g] Diurnal Operations until catch <1 fish per day for three consecutive days; then open gates.
3< X < 5 per day	Y	Closed until 3 consecutive days of daily catch <3 fish per day; then operate diurnally until catch <1 fish per day, then open gates (see above)
≥ 3 per day	N	Closed
≥ 5 per day	N	Closed
≥ 5 per day	Y	Closed until catch per day is < 5 fish

Water Year 2014 - May 21 – June 15

Date	Action Trigger	Action Response
May 16-Jun 15	D-1641 gate operations criteria	DCC gates may be closed for up to 14 days during the period, per 2006 WQCP, if RTDOT determines it is necessary.

WY 2015 - October 1 – November 15

Date	Action Trigger	Action Responses
October 1 – November 15	Water quality concern levels[e] are met and either the KLCI or either of the SCIs are greater than 3 fish per day but less than or equal to 5 fish per day	Within 24 hours of trigger exceedance, DCC gates are closed. Gates will remain closed for 3 days.
	Water quality concern levels[e] are met and either the KLCI or either of the SCIs are greater than 5 fish per day.	Within 24 hours of trigger exceedance, DCC gates are closed and kept closed until catch indices are less than 3 fish per day at both the Knights Landing and Sacramento monitoring sites.
	The KLCI or either of the SCIs triggers are met but water quality concern levels are not met[e]	DOSS review monitoring data and makes recommendation to NMFS and WOMT per procedures in Action IV.5.

Footnotes:

a) Catch of older juvenile Chinook salmon and hatchery-produced Winter-run-sized Chinook will be the basis for one trigger criterion. The use of older juveniles is consistent with the triggers used in the Long Term Operations of the State Water Project and Central Valley Project biological opinion (NMFS June 4, 2009), reasonable and prudent alternative Action IV.2.3 Old and Middle River flow management. Older juvenile Chinook salmon are unclipped Chinook that are larger than the minimum Winter-run size criteria of the size at date river model for Chinook salmon. Older juveniles will include Winter-run Chinook salmon and older fish such as yearling Spring-run Chinook salmon and yearling Late Fall/Fall-run Chinook salmon as part of the catch considered for triggers. In addition, the work group decided to include hatchery Winter-run Chinook salmon as part of this trigger criterion. Hatchery-produced Winter-run-sized Chinook salmon will be distinguished by their missing adipose fin and their classification as winter-run based on the size-at-date table. While the CWTs will be verified as soon as possible, clipped fish will be included in the trigger calculation based on size-based, not CWT-confirmed, run assignment. At this time, no releases of hatchery-produced Chinook salmon should overlap with the sizes of the Living Stone National Fish Hatchery (LSNFH) Winter-run production release. Current hatchery produced Late Fall-run Chinook salmon from the Coleman National Fish Hatchery (CNFH) are considerably larger than the Winter-run production fish, thus there should be no mistaking one group of fish for the other. The average fork length at the time of release was 95mm; ad-clipped fish falling within the Winter-run size criteria of the size at date river model for Chinook salmon will be assumed to be hatchery Winter-run.

b) Natural origin (adipose fin present) Spring-run Chinook young-of-year (*not* yearlings) and hatchery origin (adipose fin absent) spring-run Chinook young-of-year identified using the size at date river model will be the basis for another trigger criterion until such time as the first release of hatchery Fall-run occurs (not expected until April 2014), after which time differentiation of natural origin Spring-run from unclipped hatchery Fall-run and hatchery origin spring-run from clipped hatchery-origin Fall-run becomes unreliable due to size overlap of the two runs.

In regards to young of the year Spring-run Chinook salmon, it is difficult to adequately distinguish between wild Spring-run and wild Fall-run Chinook salmon due to the overlap of the sizes of the fish emigrating downstream and the emergence timing of the fish from the spawning areas upstream of the monitoring efforts. Young of the year wild Spring-run are only slightly larger than the wild Fall-run Chinook salmon that are emerging from the gravel just a few weeks behind the wild Spring-run fish in streams and watersheds where they co-occur. For wild fish, this difference in the date of emergence from the gravel should allow for run discrimination based on size at date, assuming that ambient rearing conditions are similar for both groups of fish. However, run discrimination solely by length is further complicated by the large releases (tens of millions) of hatchery produced Fall-run Chinook salmon in river, typically in early April, that overlap with young-of-the-year Spring-run emigration. Seventy-five percent of the Fall-run hatchery release is not adipose fin clipped, and their larger sizes due to hatchery production techniques would overlap and swamp any wild produced Spring-run Chinook salmon production in the river, making the ability to distinguish runs by size at date unreliable. The DCC group believes that triggers using wild Spring-run Chinook salmon within the appropriate length at date size criteria can be implemented if the captures of these fish occur prior to the release of any hatchery produced fall run Chinook salmon. Furthermore, if hatchery production Fall-run Chinook salmon are trucked downstream to the Delta or bays, below the monitoring stations used in the Sacramento region beach seines and trawl, then the integrity of the size at date discrimination should still remain valid. It is not expected that hatchery produced Fall-run Chinook would subsequently ascend the Sacramento River from their downstream release locations and be present in the reaches where the monitoring efforts used in the DCC triggers are being conducted.

Hatchery origin Spring-run will also be included in the trigger criteria prior to any hatchery Fall-run release. For the past few years Feather River Fish Hatchery has released a portion of Spring-run production (all fish are clipped) into the Feather River and upstream of the confluence with the Sacramento River. Similar to hatchery origin Winter-run, these fish are distinguishable by their missing adipose fin and fork lengths and at the time of release are not expected to overlap with other production releases that have occurred to date. An in-river release may not be possible this year if conditions in the river deteriorate due to drought but providing protection for these fish if conditions allow is crucial.

c) Natural origin (adipose fin present) steelhead will also be used as the basis for a trigger criterion but only for the Sacramento Catch Indices (trawl and beach seines). Initially, the group did not come to a consensus regarding the use of steelhead as a potential trigger in the RST catches, beach seines or river trawls. Steelhead are considerably rarer than Chinook in the RST, trawl, or beach seine catches. Although any steelhead (with or without adipose fin) captured in the Tisdale or Knights Landing RSTs are assumed to be part of the California Central Valley steelhead DPS (because natural origin fish and hatchery fish from both hatcheries upstream of those sampling locations, Coleman National Fish Hatchery (CNFH) and the Feather River Fish Hatchery (FRFH), are considered to be part of the protected DPS), clipped steelhead captured below the confluence of the American River cannot be considered wholly fish from the protected DPS due to the potential input of fish from the Nimbus Fish Hatchery (NFH; *not* considered to be part of the protected DPS). All wild fish (intact adipose fin) are considered to be part of the

protected DPS, and because all hatchery-produced steelhead are clipped, a trigger based on natural origin, unclipped, steelhead will include only fish that are part of the protected DPS. Given the unpredictability of steelhead downstream emigration, the group decided that only the Sacramento beach seine and trawl monitoring sites near the DCC gate location, and *not* the KLCI, should be used as indicators of steelhead being present in the vicinity of the gates and thus be vulnerable to entrainment into the DCC junction when gates are open. Capture of any wild steelhead in these beach seines or in the Sacramento River trawl will serve as a trigger for gate closures, using the same index thresholds as used for Chinook salmon.

d) The actions pertaining to the different sampling metrics are designed to protect both downstream migrating juvenile Chinook salmon and also those that may be rearing or holding in the Sacramento River near the DCC. With unidirectional river flow, catch data from Tisdale and Knights Landing provides an early warning of emigrating salmonids entering the Delta. Data from both the Sacramento River beach seine and trawl monitoring programs serves to further refine locational information on emigrating salmonids as well as provide information on salmonids rearing in the proximity of the DCC gates. The Tisdale and Knights Landing data provides information from discrete locations within the Sacramento River at the location of the RSTs. In comparison, the Sacramento River Trawl and the Sacramento River Beach Seines provides information from a broader suite of locations within the Sacramento River including mid-channel and river margin habitats that may harbor different life history strategies for juvenile salmonids (rearing versus emigration). In a 2012 NMFS Southwest Fisheries Science Center study using acoustically-tagged Winter-run Chinook hatchery smolts; the approximate travel time from the Knights Landing area to Georgiana Slough, which is downstream of the DCC, was approximately 2.5 days (unpublished data). Data from the aforementioned study and previous acoustic-tagged salmonid studies indicate that movement through the Delta is rapid. As such, the three-day closure period was deemed a reasonable balance between fisheries protection and providing operational flexibility for the operation of the DCC gates to ameliorate water quality issues in the central and southern Delta.

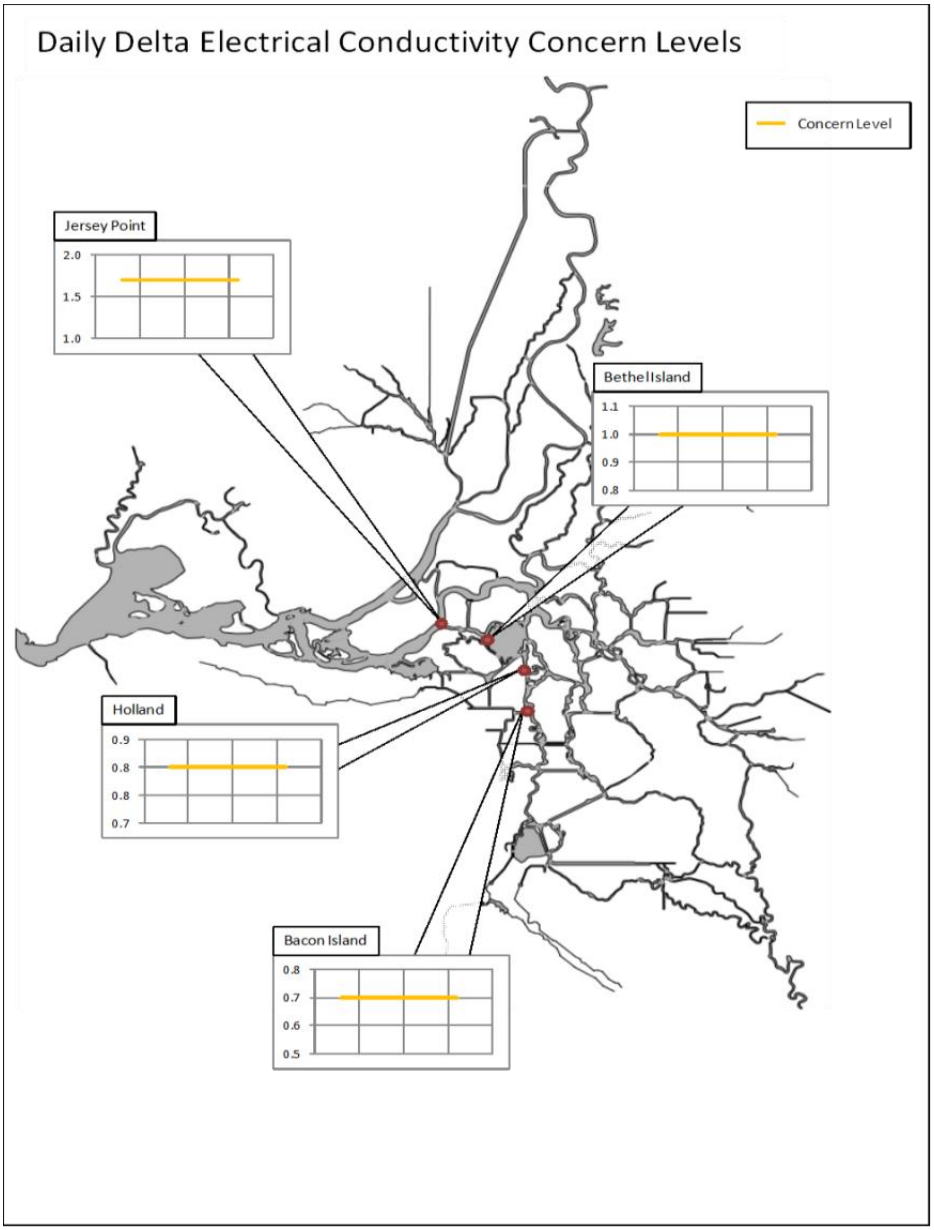
During periods when the DCC gates are closed, consideration should be given to returning the increased Sacramento Trawl and beach seine efforts to baseline levels. Historic baseline efforts are defined as follows. The Sherwood Harbor trawl will continue with sampling occurring 3 days per week through March 31st using a Kodiak trawl, then switching to a mid-water trawl on April 1st. The frequency of trawls will decrease in May and June to twice per a week, resuming to three days per week in July. Kodiak trawls will resume in October. The Lower Sacramento and North Delta beach seine sites will be sampled once per week year round. The special Sacramento region beach seine sites, which includes portions of the Lower Sacramento and North Delta seine routes will be sampled weekly after February 1st, and will continue to include the three additional sites (Sand Cove, Sherwood Harbor, and Miller Park) for the duration of the emergency drought response. Tisdale and Knights Landing RSTs will continue to sample daily with an elevated level of effort until listed species are no longer observed in the monitoring effort. The Projects must notify the Real Time Drought Operations Management Team that water quality concerns levels may be reached within 5-7 days so that monitoring efforts can be increased to daily sampling no less than 72 hours prior to DCC gate opening, depending on fisheries catch indices. Having a complete set of data that maintains the frequency of sampling effort will provide substantial benefits in any retrospective analysis of this data for future

operations of the DCC. If sampling effort is allowed to vary across time, then the analysis of fish presence and movement becomes much more difficult as "zero" could mean fish were either not present, or were missed on the off days that sampling did not occur. It should additionally be noted that determining where in the Sacramento River or Delta a majority of Winter-run and Spring-run out-migrating population is will be more difficult if sampling is discontinued.

e) The values for Jersey Point, Bethel Island, and Holland were adapted from the Chinook Salmon Decision Tree. Water Quality Concern Levels are exceeded when the electrical conductivity levels listed below are reached at one or more stations. The Chinook Salmon Decision Tree can be found at:
(https://www.usbr.gov/mp/cvo/OCAP/sep08_docs/Appendix_B.pdf).

Table1

Station	Water Quality Concern Level
Jersey Point	1.8 mmhos/cm
Bethel Island	1.0 mmhos/cm
Holland	0.8 mmhos/cm
Bacon Island	0.7 mmhos/cm



f) The Knights Landing rotary screw trap (RST) data are standardized to the number of older juvenile Chinook salmon (defined as fish larger than the minimum size length for winter-run Chinook salmon at date, *i.e.*, >95mm and hatchery winter-run Chinook) captured in one trap day (24 hours). The number of older juvenile fish captured in each RST is enumerated, and then the cumulative number of fish is divided by the number of hours the two RSTs were operated between sampling days divided by 24. For example, if the two traps are fished for 2 days there is a maximum of 96 hours that the 2 traps could have been fished: (2 days x 24 hours per day x 2 traps = 96 hours total time fished). If 100 fish were caught between both traps, then the catch per trap day is: 100 ÷ (96 hours/ 24 hours per day) = 25 fish per trap day. In a similar fashion the catch from the Sacramento trawl (STCI) and Sacramento area beach seines (SBCI) are standardized to one catch day with 10 tows per sampling day for the trawl data and eight hauls per day for the beach seine data. Data used to calculate the indices will represent the most current

day of sampling, data from the Sacramento trawl and the Sacramento area beach seine Catch Indices sites will be reported on the day sampling occurs. Data collected from the Knights Landing RST, representing a 24 hour period, will include the previous daytime trap check (pm) and the current morning trap check (am).

g) Should diurnal operations[1] occur, operations of the gates will follow table 2 (DCC Gate Diurnal Operations):

Table 2: DCC Gate Diurnal Operations

Tidal Phase	Operational window. DCC gates will be closed during crepuscular periods and at night.
	Day is considered to be from sunrise to sunset (approximately 7am-7pm PST). Crepuscular periods are considered to be 1 hour after sunrise and 1 hour before sunset. Gate open window of operations for up to 6 hours within the daylight period.
Ebb Tide[2]	Period of operations for opening the DCC gates will occur during the ebb tidal phase during daylight periods. Periods of gate openings shall avoid the period of slack water surrounding the low tide and high tide changes (± 1 hour; bottom and top of the tides).
Slack[3]	Avoid the period of slack water surrounding the low tide and high tide changes (± 1 hour; bottom and top of the tides).
Flood Tide[4]	If Water Quality concern levels are being exceeded with DCC operations limited to the ebb tidal phase, the Real Time Drought Operations Team can request DCC operations to occur on the flood tide phase.

1 It has not been determined whether or not the necessary water quality benefits can be achieved through diurnal operations of the DCC gates. Additionally the design and wear of the gates may preclude successive openings and closings that may occur through diurnal operations.

2 This phase of the tide has been shown to create hydraulic conditions at junctions that enhance fish entrainment. Best to use period of the ebb tide with the strongest downstream flow. Avoid overlapping this phase of the tide with crepuscular period. Fish migratory movement is elevated during the crepuscular period.

3 Avoid the period of slack water surrounding the low tide and high tide changes (± 1 hour; bottom and top of the tides, as fish may be holding in the vicinity of the DCC and the increased movement by fish (milling behavior) will create conditions for greater exposure to entrainment.

4 This is a less optimal period of DCC gate operations for fish protection since flow convergence will occur with the water moving upstream on the flood tide meeting water still moving downstream at the beginning of the flood tide. This will send more water into an open DCC channel and extend the zone of entrainment across a significant proportion of the Sacramento River channel. If gates are opened 1 to 2 hours after flows change at the bottom of tide, there are likely fewer impacts due to opening during this period. Avoid crepuscular periods.

Biological Justification for Diurnal Delta Cross Channel Gate Operations.

Chapman *et al*. (2013) described a series of experiments conducted on the Sacramento River in which hatchery produced late-fall Chinook salmon (*Oncorhynchus tshawytscha*) and steelhead trout (*O. mykiss*) were released in the upper Sacramento River and tracked as they migrated downstream through the San Francisco Bay estuary and into the Pacific Ocean through the Golden Gate. From 2007 to 2010, during the months of December and January, a total of 1,110 Late-fall Chinook salmon and 1,100 steelhead trout were released into the upper Sacramento River. In 2007 the release was made in Battle Creek. From 2008 to 2010, releases were made at three different sites: 1) Jellys Ferry; 2) Butte City; and 3) Hamilton City within the upper and middle sections of the Sacramento River. Fish were released just after twilight at each site. Fish were tracked through 420 monitors placed at 186 different locations within the Sacramento and San Joaquin river systems and Delta, the San Francisco estuary, and coastal waters outside the Golden Gate. Receivers were deployed to provide coverage across river channels as single, dual, and multiple arrays to ensure complete coverage of the channel width.

This study found that within the upper river section, late-fall Chinook salmon traveled almost exclusively at night with 90.6 percent of detections recorded at night between sunset and sunrise. As the Chinook salmon smolts moved downstream, the proportion of movement during diurnal periods progressively increased, although movements at night still remained significantly greater than diurnal movements. Within the upper river reaches there were no significant differences in the timing of fish movement during the night, in particular movements were not concentrated within crepuscular periods, but were distributed relatively evenly throughout the nocturnal period. Movement ceased relatively quickly after sunrise and began shortly after sunset (. In contrast, as fish moved downstream into the middle and lower reaches, salmon movement did not stop abruptly at sunrise, but instead detections gradually decreased as light increased.

Tagged hatchery steelhead migrated more uniformly throughout the day in all regions of the river, estuary, and ocean compared to yearling late-fall Chinook salmon smolts. Like the Chinook salmon smolts, the proportion of detected movement at night decreased as fish migrated downstream. In the upper river 63.0 percent of detections occurred at night compared 90.6 percent for salmon smolts in the same reaches. Once these steelhead reached the estuary, the detections of night time movements decreased to 40.9 percent compared to 57.0 percent for late-fall Chinook salmon. In the upper river, there was a significant preference for nighttime movement. In the lower river, where Knights Landing is located, there is no significant difference between night time and day time movement, however in the middle river, Delta, and estuary there were significant preferences for daytime migration.

Chapman *et al.* (2013) found that more than 50 percent of Chinook salmon travelled at night in all of the study reaches, while steelhead were more variable. Chinook salmon also moved more during the day when river flows were increasing, regardless of flow direction (important in the tidal Delta and estuarine environment). In the estuary, incoming flood tides between zero and a flow of approximately -3500 cfs increased daytime detections. Similarly, downstream flows of approximately 12,300 cfs elicited daytime movements of Chinook salmon. Steelhead responded in a more muted manner. Incoming tides did not appear to stimulate more daytime movements in the estuary. In the riverine reaches of the study area, steelhead daytime movement was more likely when flows were 25,000 cfs or greater. Thus, both Chinook salmon and steelhead

responded to increases in flow with increased daytime movements. However, Chinook salmon appear to be more sensitive to these higher flows, and also responded to the perceived higher flows of an incoming flood tide in the estuary.

The movement of both Chinook salmon smolts and steelhead were affected by increasing turbidity. In general, increasing turbidity reduced the percentage of nighttime movement, and stimulated daytime movement in fish. However, increasing turbidity is often associated with increasing flow and these two variables typically co-occur.

Plumb reported that in a U.S. Geological Survey (USGS) study the majority of acoustically tagged fish moving downstream past the location of the DCC did so at night. During the winter of 2008-2009 (November through March) 2,983 acoustically tagged Late-Fall Chinook salmon were released upriver from the DCC gate location. The release point was far enough upstream that fish were distributed in the river channel and were believed to be exhibiting normal migratory behavior and movements. Results indicated that 39 percent of the released fish (1,162 fish) were eventually detected in the vicinity of the DCC gates with approximately 5 percent of these detections believed to be fish within predators (154 fish). Of the arriving fish detected (1,008 fish), approximately 83 percent (840 fish) arrived at night, with the remainder (17 percent) arriving during the day (168 fish). Of the fish arriving at the DCC location (day and night), approximately 13 percent (143 fish) arrived when the gate was open. Of the 143 fish arriving at the gates when they were open, 20 percent (20 fish out of 100 fish) were entrained at night and 21 percent were entrained during the day (9 fish out of 43 fish). USGS performed an analysis of the data and calculated the joint probability of arriving at night and being subsequently entrained using different environmental covariates and determined that there was approximately a 19 percent chance of being entrained into the DCC at night. Conversely, the probability of being entrained during the day was approximately 6 percent. During the period of the study (November 2008 through March 2009), 73 percent of negative flood flows occurred during the day, and entrainment was more likely during these periods. Plumb *et al.* (2013 unpublished study) summarized that operation of the DCC gates during the day may allow for water diversion in to the interior Delta while minimizing the risk of entrainment of migrating Chinook salmon into the DCC.

Preliminary results from the 2012 Georgiana Slough non-physical barrier study (DWR 2013 draft) also help to illustrate the behavior of fish moving through this section of the river under different diel and flow conditions. Similar to the Plumb *et al*. 2013 and Chapman *et al.* (2013) studies, the majority of fish detected moving past the junctions of the DCC and Georgiana Slough channels with the main stem Sacramento occurred at night. In addition, data from tagged Late-Fall Chinook salmon passing through the Georgiana Slough junction indicate that greater numbers of fish passed through this study area at night than during the day. Furthermore, the passage of fish was also shown to be strongly influenced by tidal phase. During the night, more fish successfully passed the junction of the Georgiana Slough channel during a strong ebb phase than during the changing of the tide or a flood tide. During the changing of the tide from an outflowing tide to a flood tide, the flow of water increases into Georgiana Slough. It is during this transition that a converging flow situation sets up at the junction and 100 percent of the Sacramento River flow enters Georgiana Slough from both the upstream and downstream directions with little to no flow bypassing the junction. Under this specific scenario, all fish

present across the width of the Sacramento River channel are vulnerable to entrainment into the junction. This is particularly true during nocturnal periods when fish are more likely to be moving rather than holding and thus become vulnerable to entrainment as they encounter the junction reach. During the day, more fish are holding, and move less in the region of the junction, thus reducing their vulnerability to entrainment, although not being becoming completely immune to entrainment.).

Summary:
Chapman *et al*. (2013) illustrates how Chinook salmon smolts emigrate primarily at night in the upper reaches of the Sacramento River but progressively increase movements during daytime periods as fish emigrate downstream towards the Delta and San Francisco Bay. Daytime movement is also increased by increasing river flows and stronger flood tidal flows, as well as increased turbidity. Steelhead smolts are more balanced in their use of daytime and night time periods for movements in all river reaches in comparison to Chinook salmon. They are less sensitive to changes in flow and turbidity in comparison to Chinook salmon, but still respond in the same manner: more flow and/or turbidity reduce the proportion of nocturnal movement and increases daytime movement.

The USGS analysis of Chinook salmon at the DCC junction indicates that Chinook salmon predominately arrive at night and are more susceptible to entrainment at night than during the day based on the joint probabilities of arriving at the DCC junction at night and subsequently being entrained into the DCC junction.

The analyses conducted in support of the 2012 Georgiana Slough non-physical barrier (DWR 2013 draft) finds that fish move more at night past the Georgiana Slough junction than during the day based on the number of detections at the non-physical barrier acoustic receiver array and that the behavior of the fish in the junction is strongly dependent on tidal phase and position in the channel cross section at the time of encountering the junction. Fish are more likely to successfully move downstream on a strong ebb tide past the Georgiana Slough junction and avoid entrainment into the Georgiana Slough channel than when downstream flow is weaker and the tides are changing from ebb to flood. The period of time when fish are most vulnerable to entrainment into the Georgiana Slough channel is during the period when flows are reversing and essentially all of the flow in the Sacramento River channel is directed into the channel of Georgiana Slough (converging flows). As negative flows increase and the flood tide strengthens, the vulnerability of entrainment lessens and fish were found to "mill' in the vicinity of the junction or move back upstream, avoiding the region surrounding the junction.

If the DCC gates are to be operated (*i.e*., opened), then the option which minimizes the entrainment vulnerability to listed salmonids emigrating in the Sacramento River in the vicinity of the DCC gates would involve opening the gates on a diurnal cycle, and closing the gates during the night, thus avoiding the greater nocturnal presence of fish in the vicinity of the gates during fish movements. In addition, further reductions in entrainment vulnerability could be gained by operating the gates with recognition of the tidal phases in which the fish are more vulnerable to entrainment (*i.e*., periods of tidal transition from ebb to flood and when upstream and downstream flows result in converging flow phases entering the DCC channel).

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