Evaluation of the effects of the operation of the Delta Cross Channel and proposed Through Delta Facility on the survival of yearling fall-run Chinook salmon migrating through the Central Delta.

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BACKGROUND

Project Purpose

The purpose of this project was to determine if there were differences in the survival of juvenile Chinook salmon (Oncorhynchus tshawytscha) migrating through the central Delta due to the operation of the Delta Cross Channel gates. This information will be used to help evaluate the potential effects on juvenile salmon survival of two North Delta conveyance alternatives being considered by California Bay-Delta Water Authority (previously CALFED – a consortium of State and Federal agencies with management and regulatory responsibility in the Delta.) The two alternatives are the re-operation of the Delta Cross Channel (DCC) gates and/or a new Through-Delta Facility (TDF).

When the DCC gates are open an increased amount of Sacramento River flow enters the central Delta. In addition, a new TDF would add up to 4,000 cfs of Sacramento River flow into the central Delta/ Mokelumne River system. Changes in flows (both direction and volume), channel capacity and configuration in the central Delta; and, any coincidental increase in exports at the Central Valley Project (CVP) and State Water Project (SWP) pumps due to a new facility or re-operation of the DCC gates may affect the survival of Mokelumne River salmon migrating through the central Delta. The information resulting from this project in assessing the status of the DCC gates on survival could also be used to assess the TDF if it was assumed that the central Delta flow with the DCC gates open would approximate the increased flow conditions with a TDF facility when the DCC gates are closed.

This experiment was conducted during October of 2002, with yearling hatchery salmon from Mokelumne River Hatchery. Since closure of the DCC is mandated for winter run salmon protection, between February 1 and May 20, the fall period was a time when the DCC gates could be opened and closed within a relative short time period. In addition, yearling salmon migrate downstream through the central Delta via the Mokelumne River during the October through January period.

Original Study Design

The original study design utilized four sets of marked juvenile salmon to be released on the Mokelumne River, upstream of the North and South Fork splits (Bean Farm) and at Jersey Point (in the western Delta) (Figure 1). The object was to measure survival of these salmon between the upstream site (Bean Farm) and Jersey Point, with the Delta cross channel gates open and

closed, during both spring and neap tides during October of 2002. Survival would be estimated using recoveries of the marked fish as they migrate downstream past Chipps Island. The null hypothesis was: There is no difference in survival with the gates open or closed on spring or neap tides.

Two weeks prior to releasing the marked fish, members of Central Valley Operations and CALFED Operations Group determined closing the gates during the first release on the neap tide as planned would further degrade water quality to unacceptable levels in the Delta. Thus the gates were not closed for the first set of releases and the experimental design of this part of the project was modified.

Modified Study Design

The projection was for the DCC gates to be open for at least the following two weeks, thus the upstream release site was changed from the Mokelumne River (Bean Farm) just upstream of the North and South Fork split, to releases in each of the Forks, with half the release group going in at each Fork. The null hypothesis was then changed to: There is no difference in survival estimates to Chipps Island between yearling, fall-run Chinook salmon released in the North or South Forks when the DCC is open.

During the second half of the experiment, the gates were to be closed for the first release and opened for second, with both releases occurring at the original site (Bean Farm), upstream of the splits on the Mokelumne River. The null hypothesis tested for these releases was: There is no difference in the survival estimates to Chipps Island between yearling fall-run Chinook salmon released on the Mokelumne River (Bean Farm) with the gates opened or closed.

For this part of the experiment the DCC gates were closed between October 16 and October 19. However, during opening on October 19, one gate (south) fell closed and remained closed until repairs were completed on November 12, 2002. Thus there was no data gathered for this part of the experiment with both gates open. The flow entering the DCC is similar between the one gate open (almost 90%) and both gates open (Jon Burau, personal communication).

The modified investigation examined survival of hatchery-produced yearling fall-run Chinook salmon released in the North and South Forks of the Mokelumne River when the DCC was open and upstream of the Forks with the gates both closed and one open. The North Fork releases were made at Eagle Tree, about 2.25 miles downstream of the flow split on the North Fork. The South Fork releases were made at Beaver Slough. The group released above the split was released in the Southeast corner of McCormick Williamson Tract – Bean Farm, about 4 miles upstream of the flow split. Additional releases were made at Jersey Point each week (Figure 1).

The comparison of survival indices or recovery rates to Chipps Island of an upstream group relative to its downstream group (Jersey Point) was used to correct for gear efficiency differences at Chipps Island between release sets to obtain absolute or standardized estimates of survival. These standardized estimates of survival or differential recovery rates allow for more valid comparisons of survival between the normalized upstream groups. It was assumed that it

would take roughly one week for the upstream group to reach the downstream location, thus the downstream groups were released 7 days after each upstream release group was made.

METHODS

Coded-Wire Tagged Salmon Releases

Hatchery-produced salmon from Mokelumne River Fish Hatchery (MRFH) were coded-wire tagged and released in the North (Eagle Tree) and South Forks (Beaver Slough) of the lower Mokelumne River and on the Mokelumne River upstream of the split (Bean Farm) and at Jersey Point. Most of the upstream groups contained two separate tag codes, with the exception of the second North Fork and South Fork releases, which only had one tag group. Only one tag group was used for each Jersey Point release, with 25,000 released per group compared to the 50,000 – 100,000 per group released for upstream groups. Upstream groups were released in up to four separate trips over two days. All releases occurred between October 1 and October 30, 2002 (Appendix 1).

Tagging

Tagging of the 500,000 salmon was conducted at the MRFH by Big Eagle and Associates, Inc., in July of 2002. The number of fish successfully coded wire tagged was evaluated using a magnetic detector to distinguish tagged from untagged fish processed during tagging and again prior to release. The total number in each coded wire tag release group was calculated based on the actual number of fish tagged adjusted for post tagging mortality during rearing and transport, tag retention, and recognizable adipose fin clip. A sub-sample of 200 fish per group (25,000 to 50,000) was used to verify tag retention and clips, and to obtain length and weight measurements. Length and weight data were collected to provide length frequency distributions and condition factors.

The tag codes were verified by collecting 10 – 25 fish from each group at the time of release. These fish were then brought back to the lab to determine if the tag code in each fish was the same as noted on the planting receipt completed by the hatchery.

Water Temperature Monitoring

Water temperature was monitored at the release sites and in the transport truck on the release day using a hand-held thermometer. Water temperatures were also monitored at each release site for several weeks after release using individual computerized temperature recorders (e.g., Onset Stowaway Temperature Monitoring/Data Loggers).

Recovery

The marked fish were recovered in fishery sampling at Chipps Island, at the CVP and SWP Fish Facilities, and other non-related fishery sampling in the Delta and on the Mokelumne River. Additional recoveries will also be made in the ocean commercial and recreational fisheries in future years (1-4) as the yearlings reach adulthood.

Trawling at Chipps Island as part of this experiment was conducted for an additional 27 days between October 3 and November 14. This augmented sampling conducted 3 days a week for the Interagency Ecological Program of the Sacramento-San Joaquin Estuary (IEP). These combined efforts resulted in sampling seven days a week to increase marked fish recoveries. Ten, 20-minute tows were conducted at Chipps Island each sample day. After November 14, trawling was resumed to three times a week until early December when daily sampling resumed for an unrelated mark and recapture experiment.

The net used at Chipps Island is towed at the surface. The trawl net has a mouth opening of 10 feet deep and 30 feet wide with the total length of 82 feet. Aluminum hydrofoils were used on the top bridles and steel depressors, along with a weighted lead line on the bottom of the net, to keep the mouth of the net open. The net has variable mesh starting with 4-inch mesh at the mouth and ending with a ¼ inch cod end. To sample across the channel, trawling at Chipps Island was conducted in three lanes: the north, the south and the middle. Each lane was sampled three times per day, with one lane (chosen at random) sampled four times.

Recoveries of marked fish were also made in sampling at the CVP and SWP fish facilities. Sampling at the salvage facilities was conducted approximately every two hours. The number of minutes sampled during the two-hour period was used to expand the number of marked salmon collected in the sampling. This estimate is called expanded salvage and it represents all the marked fish that went through the salvage process. Only the marked salmon recovered in the sampling were actually sacrificed for tag decoding. The salvaged fish are trucked to locations in the western Delta. Theoretically, some marked fish passing or recovered at Chipps Island could have gone through the salvage process but were not collected in the sampling.

Additional special studies or predator control activities were conducted at the CVP and SWP fish salvage facilities during this experiment. Marked fish from this experiment were recovered in some of this sampling and are reported in this report. Since the sampling was not systematic or done in previous years, recoveries have not been expanded or included in the salvage estimates.

Other recoveries of the marked fish were made in beach seining in the Delta as part of the IEP juvenile fishes monitoring program, and in electrofishing surveys and rotary screw trapping on the Mokelume River as part of East Bay Municipal Districts Fishery Monitoring Program.

Juvenile Chinook salmon with an adipose fin clip (which identify CWT salmon) caught at Chipps Island, in the SWP/CVP fish salvage operations or other sampling were sacrificed, labeled, and frozen pending CWT processing. Coded-wire tag processing was done by USFWS (Stockton) for fish recovered as part of the 2002 study.

Coded wire tag processing entailed dissecting each tagged fish to obtain the one millimeter

cylindrical tag embedded in the fishes snout. Tags are then placed under a dissecting microscope and the numbers are read and recorded into the database. Tags were read twice with any discrepancies resolved by a third reader. All tags have been archived for future reference.

Coded wire tagged fish recovered in the trawling at Chipps Island were used to generate survival indices, estimates and differential recovery rates and to estimate the period of migration for each group. Measurements of survival were used to compare between groups and statistically test the null hypotheses. The duration of migration (days) for each release group was calculated as the number of days between release and the date of last recapture for each release group at Chipps Island.

ENVIRONMENTAL CONDITIONS

Flows and Exports

Mean daily flows or exports between the date of release for each group, and the last date of recapture at Chipps Island was used to characterize the environmental conditions experienced by each CWT group is summarized in Table 1. The daily hydrologic data was obtained from the California Department of Water Resources (DWR) for Delta outflow, Sacramento River flow, San Joaquin River flow, Mokelumne River flow, CVP exports, and SWP exports. During the period of migration Delta outflow ranged from an average of 4,145 to 7,545 cfs. Sacramento River flow averages ranged from 9,953 to 11,088 cfs. San Joaquin River flows ranged from 1,407 to 1,848 cfs. Mokelumne River flows ranged from 152 to 211 cfs. CVP exports ranged from 1,382 to 2,799 cfs, while SWP exports ranged from 2,936 to 4,278 cfs. These combined export levels (4300 cfs – 7000 cfs) would be considered in the mid-range as high exports are around 11,000 to 12,000 cfs.

During the October to December period, Sacramento River flow remained relatively constant until early December. Most of the experimental fish had migrated to Chipps Island by early November (Figure 2). San Joaquin River flow showed a pattern of increasing discharge during late October, followed by a general pattern of recession during November through mid-December (Figure 2). Delta outflow was relatively stable between October and mid-December with a short pulsed increase in mid-November (Figure 3). Mokelumne River flow (Figure 3) remained relatively constant throughout the October to December period with the exception of a high peak in early November. SWP and CVP exports during the October -- December are shown in Figure 4. SWP exports were characterized by relatively high variability throughout the period. CVP exports were also variable, particularly during the period from late October through mid-November.

The Delta Cross Channel Gate Operation

The Delta Cross Channel Gates were open between October 1 and October 16. The gates were closed on October 16 and remained closed until October 19, when as they were being opened the number 2 gate fell into a closed position. The gates remained partially closed until the gate was repaired on November 12. Both gates remained open until they were closed on December 3.

The gates were reopened on December 10 and closed again on December 16. Gates remained closed throughout December after the 16th.

RESULTS

Tagging

A large percentage of the fish were successfully tagged and clipped. The number of juvenile salmon successfully tagged ranged from 94 to 100 percent. The number successfully clipped ranged from 98 to 100 percent for the 12 separate groups.

The tag codes for all releases were verified, based on the reading of the 10-25 marked fish collected at each release. However, reports from observations at the hatchery indicate there was some low level mixing between groups. Some of these fish were observed jumping over the raceway walls and landing on the pavement (a few hundred by hatchery staff estimate). It is likely, then, that some fish also jumped into the adjacent rearing pond (S. Boyd, personal communication). If the mixing were limited to a few hundred fish, as estimated, which is a small percentage of our release group, our results would not be seriously compromised.

Fish used in this study were yearlings. Mean fork length for each group ranged between 160 and 178 millimeters. Mean weight ranged from 52 to 72 grams. Condition factors (length/weight) ranged from 0.00032 to 0.00041. Length and weight measurements from sub-samples of each group were taken usually within a few days of release with the exception of the last Jersey Point group, which was measured nine days prior to release.

Although fish health was not specifically assessed for these experimental groups it was noted by hatchery staff that the first group released at the North Fork Mokelumne on October 1 and 2 had a low incidence of Bacterial Kidney Disease (Bill Cox, personal communication). This incidence of disease could have affected this group's survival through the Delta relative to the other groups.

Water Temperature

The water temperature both in the hatchery truck and in the receiving waters was measured at the release site immediately prior to release. Water temperatures within the hatchery truck ranged from 55 to 60 F with receiving water temperatures at the time of release ranging from 58 to 68 F (Appendix 1).

Water temperature has been identified as a significant environmental factor affecting the survival of juvenile Chinook salmon migrating from the Sacramento, San Joaquin, and Mokelumne River systems during the spring period of juvenile smolt migration. Water temperatures during the late fall and winter period of yearling Chinook salmon migration are typically within the range considered to be suitable for salmonid migration. Results of water temperature monitoring at the release sites during the period after October 1, 2002 showed water temperatures were less than

68 F (20 C) (Figure 5). Water temperatures less than approximately 68 F (20 C) are generally considered to be within the range suitable for downstream-migrating salmonids. Results of 2002 temperature monitoring showed that temperature conditions were within the range considered to be suitable for juvenile salmonids and hence these results provide no indication that water temperature was a significant factor affecting salmonid survival during the studies.

Recovery of Marked Fish at Chipps Island and Measurements of Survival

Recoveries of marked fish from the releases made during October of 2002 were made at Chipps Island between October 6 and January 9. The pattern of recoveries for each upstream release group with its downstream group released at Jersey Point is shown in Appendix 2. Most recoveries from both groups occurred within a couple of weeks after release with only a few recoveries after that. In general, the upstream groups and the Jersey Point groups were recovered at Chipps Island over a similar time period. Sampling was 200 minutes per day, with the exception of a few days when sampling was disrupted due to weather. After November 14, sampling was reduced to 3 days per week and resumed daily starting December 5 (Appendix 2). The total number recovered at Chipps Island for each of the release groups is provided in Appendix 1. These recoveries are used to generate survival indices, survival estimates and differential recovery rates. These indices and estimates of survival are used to compare survival between groups. The differential recovery rates were also used to determine if any differences observed were statistically significant and to reject or not reject the null hypotheses of the experiments.

Survival indices

Survival indices were generated using the following formula:

$$S = \frac{\#\ \text{recovered}}{(\#\ \text{released} * \mu)}$$

where μ is the fraction of the channel width sampled * the percent of time sampled.
The fraction of space sampled is a constant and based on the net width (30 feet) divided by the channel width (3900 feet). The percent of time sampled is based on the number of minutes sampled divided by the number of minutes between the first and last day that the tag group was recovered (Appendix 1).

The group survival index for the first North Fork groups released on October 1 and 2 was 0.59 (Table 2). The survival indices for the individual tag groups ranged between 0.77 and 0.56 (Appendix 1). This is higher than for the first South Fork groups, which had a group index of 0.41 (table 2) and individual tag code indices of 0.43 and 0.39 (Appendix 1).

A similar pattern was observed for the second set of releases in the North and South Forks. The second North Fork group had a survival index of 0.16 and the second South Fork group had an

index of 0.11 (Table 2). The DCC gates were open for both sets of releases in the North and South Fork.

The survival indices for the first set of releases made above the split (Bean Farm 1) with the gates closed indicated a higher survival rate (0.15) than for the second group (Bean Farm 2) released a week later (0.05) when one DCC gate was open (Table 2).

Survival indices at Jersey Point decreased through the four-week study with the first group surviving at a higher rate (1.37) than the second (1.05), third (0.65) or last group (0.24) (Table 2).

Survival estimates

Survival estimates (absolute survival) were calculated by dividing the survival index of the upstream group by the survival index of the downstream group (Jersey Point). These estimates provide a standardized survival rate between the two locations. The survival index of the downstream group is used to factor out potential differential gear efficiency at Chipps Island between releases and between years.

Absolute survival rates were 0.43 and 0.15 for the first and second North Fork releases and 0.30 and 0.10 for the first and second South Fork releases, respectively. Again, the first release groups survived at a higher rate than the second and the North Fork was consistently higher than the South Fork releases. The DCC gates were open during both tests.

Absolute survival rates for juvenile released above the Mokelumne River split (Bean Farm) were 0.23 for the first release with the gates closed for three days versus 0.21 for the second, when one gate was open.

Differential recovery rates

Differential recovery rates were also estimated for the paired groups. The recovery rate for any one group is the number recovered divided by the number released. The differential recovery rate is the recovery rate of one group relative to another. The use of differential recovery rates is similar to estimating survival but has been suggested by Ken Newman, a statistician previously at the University of Idaho and now at the University of Saint Andrews, (Scotland), as a way to compare survival between groups and test significant differences using confidence intervals. His methodology to estimate the differential recovery rate (maximum likelihood estimate), variance and standard errors using one recovery location is shown in Appendix 3. Even with this methodology, getting statistically significant results between test groups is always problematic with small sample sizes (recovery numbers). Thus we have reported both the 95 and 68% confidence intervals to see if statistical differences are observed at either level of statistical confidence.

In Figure 6 the differential recovery rates between the North (noted as downstream group in the Newman report) and South Fork (upstream group in the Newman report) groups is shown with

plus or minus 1 and 2 standard errors. Plus or minus one standard error is considered similar to 68% confidence level whereas plus or minus two standard errors is closer to the 95% confidence interval.

It was estimated for the first sets of releases, from these differential recovery rates, that juvenile salmon released on the North Fork survived 55% higher than those released in the South Fork. The second group of releases indicated a similar benefit of being released in the North Fork (48%). Estimates of standard errors and confidence intervals indicate that the differences were not significant at the 95% confidence level. Confidence intervals that include 1.0 would indicate no difference between the North and South Fork groups. The difference between the North and South Fork group was significantly different at the 68% level for the first group but not the second.

Differences in the differential recovery rates were also compared between the two groups of juveniles released above the split (Bean Farm) with the gates closed for three days versus one gate open. The differential recovery rate between the upstream and downstream group (Jersey Point) was estimated at 0.24 for the first group and 0.17 for the second group - a difference of 0.07. The variance of the first group was added to the variance of the second group to estimate the variance of the difference between the two Bean Farm groups. The standard error of the difference was calculated by taking the square root of the variance of the difference. From these calculations, it appears survival was not different between the two Bean Farm groups as the confidence limits of the difference included zero thus no statistical difference was detected at the 95% or 68% confidence levels (Figure 6).

Duration of migration

The duration of migration was similar for yearling Chinook salmon released on the North Fork Mokelumne River, which were 58 and 60 days, respectively, for the October 1 and October 8 releases. Results of the South Fork releases showed that the duration of migration was substantially shorter for the October 1 release (24 days) when compared to the October 8 release (68 days)(Table 1). However, most recoveries from all releases were made within a couple of weeks of release indicating no real difference in duration of migration between the two groups (Appendix 2).

The duration of migration for the yearling salmon released on October 16 at the Bean Farm when the Delta Cross Channel gates were closed for three days was 46 days. The first fish was recovered 6 days after release (Appendix 1 and 3). The migration duration was greater for the October 24 and 25 releases, when one Cross Channel gate was open, with the first fish recovered 10 days after release and the last fish recovered 77 days after release (Appendix 1).

Other recovery locations

Marked fish were also recovered at the State and Federal Fish Facilities. Less than 150 marked fish from any of the marked groups were estimated to have passed through the State and Federal

Fish Facilities (expanded salvage). The estimate of expanded salvage was low and generally similar between upstream groups (Appendix 1). The greatest relative salvage was from the first Bean Farm release made on October 16 and 17th and may be a function of the higher survival index for the group relative to the second Bean Farm group and the 3 day closure of the DCC gates. Potentially the higher survival allowed the first group released at the Bean Farm to be salvaged at higher numbers than the second Bean Farm group because a larger number survived to be salvaged. The DCC gates were open for the two North and South Fork releases and may account for the lower fish facility recoveries for those groups compared to the first Bean Farm release when the gates were closed for 3 days.

Yearling Chinook salmon released on the North Fork Mokelumne River were reported in both the CVP and SWP fish salvage operations while, yearling Chinook salmon released on the South Fork Mokelumne River were only reported in CVP salvage. Potentially those migrating down the South Fork arrived in the South Delta via a different route than those released on the North Fork that made them more vulnerable to the CVP export facility than the SWP.

A few additional fish were recovered as part of the predation control activities or special studies at the two project fish facilities. The timing of the unexpanded recoveries from all sources of fish facility recoveries is shown in Appendix 2. Only 4 fish were recovered in the predator control or special studies at the fish facilities from the releases made at Jersey Point.

A few recoveries were also made in other non-related fish sampling in the Delta and Mokelumne River. Five tagged fish were recovered downstream of the release sites during beach seining in the Delta (B&W Marina and Terminous) (Table 3 and Figure 7). Additional tagged fish were recovered on the Mokelumne River in the screw trap at Woodbridge Dam, in electrofishing surveys at the confluence of the Consumnes and Mokelumne Rivers and near the Camanche Reservoir, which are upstream of the release locations (Table 3 and Figure 7).

DISCUSSION

While statistically we could not reject the null hypotheses of either of these paired experiments at the 95% confidence level, juveniles released on the North Fork appeared to consistently survive at a higher rate than those released on the South Fork with the gates opened. Survival through the Delta did not appear different for juveniles released above the split when the Delta Cross Channel gates were fully closed for three days, than when one gate was open.

Comparison with past studies

The results of the fall 2002 Study can be compared to similar experiments in the North and South Forks of the Mokelumne River conducted in the springs of 2002 and 2001 and to other paired releases in prior years.

Springs of 2002 and 2001

In April of 2002, marked juvenile salmon were released in the South Fork (at New Hope) and North Fork (Eagle Tree) Mokelumne River with the DCC gates closed prior to and during the Vernalis Adaptive Management Plan (VAMP) (Figure 8). During VAMP exports were reduced to approximately 1500 cfs from roughly 7500 cfs (San Joaquin River Group Authority, 2002). Marked fish were recovered at both Chipps Island and Antioch during the spring experiment. Comparison of survival indices and estimates indicated that the North and South Fork groups appeared to survive at similar levels under the two export conditions (Table 4). Testing significant differences between groups using the combined differential recovery rates indicated that the North Fork group survived at a higher rate than the New Hope group (at the 68% confidence interval) during the pre-VAMP (higher export) period (Figure 9). The combined differential recovery rate uses the sum of recoveries at both Chipps Island and Antioch. Using recoveries at both locations changes the methodology used for estimating variances, standard errors and confidence intervals (Appendix 4). Using Chipps Island recoveries alone, the estimate was greater for New Hope than the North Fork, but the difference was not significant at either confidence interval (Figure 9). Why there would be differences between using the recoveries from both Chipps Island and Antioch versus Chipps Island alone is uncertain, although recovery numbers are generally low and the differences may be due to the inherent variability in recovery.

The most interesting aspect of the 2002 spring data was that smolts released at Jersey Point appeared to survive at almost twice the rate during VAMP (low exports) than they did prior to VAMP (higher exports)(Table 4). We saw a similar level of variability within the Jersey Point groups for the fall experiment with survival indices substantially lower for each release throughout the month (Appendix 1). An unbiased control group to standardize gear efficiency is important in evaluating the survival ratios and differential recovery rates. Why survival or recovery rates for fish released at Jersey Point would be so different within one to two weeks of each other is unclear. If exports are affecting the survival of juvenile salmon released at Jersey Point, then our concept of using that release site as a control is flawed. It will be possible to check whether the survival of the four Jersey Point groups was different when comparing the ocean recovery rates in future years.

A similar experiment on the North and South Fork Mokelumne was also conducted in the spring of 2001. Releases were made on the South Fork at Beaver Slough (as was done in the fall of 2002) and New Hope (as was done in the spring of 2002), on the North Fork (at Eagle Tree) and at Jersey Point (Figure 8). The DCC gates were closed and exports were low (~1500 cfs) during these experiments. Recoveries were made at both Chipps Island and Antioch. Survival indices were higher for the North Fork releases than for either of the South Fork releases. Using the combined differential recovery rates to test for significant differences, the North Fork group appeared to survive at a significantly higher (68% level) rate than the New Hope release (Figure 9). The differential recovery rate of the North Fork group was also significantly higher than either group released on the South Fork at the 68% confidence level using only Chipps Island recoveries (Figure 9). The 68% confidence level is significant if it does not include zero.

Springs of 1984, 1985 and 1986

Paired releases of coded wire tagged smolts have been released into the North Fork and South Fork (New Hope) Mokelumne Rivers in past years. While the North Fork release location (Guisti's) was somewhat different than those used in 2001 and 2002, it still may be useful to compare results. In 1984, 1985 and 1986 releases of Feather River hatchery stock (and in one instance Coleman National Fish Hatchery stock) were released during the months of May or June. The cross channel gates were open for two of these experiments. In 1985, the gates were closed for the first two days and open thereafter. Results indicated from both trawling at Chipps Island and from ocean recovery information, that smolts in 1985 and 1986 appeared to survive at a higher rate when released in the North Fork as compared to the South Fork Mokelumne River (Table 5). Those released in 1984 appeared to be in anomaly such that survival appeared to be higher for the South Fork release than for the North Fork (Table 5).

Summary

Thus in most cases it appears that survival in the North Fork is generally higher than that on the South Fork. These results appear to be reasonable based on our understanding of the flow differences in the North and South Forks of the Mokelumne. Flows are much greater in the North Fork than the South Fork under either gate position (Figure 10). When the gates are open, the flow on the North Fork is unidirectional (all positive flows) while the flow on the South Fork is mostly bi-directional regardless of gate operations (J. Burau, personal communication)(Figure 11). Perhaps survival is higher on the North Fork because the flow is higher and when the gates are closed the flow is also unidirectional. The additional flow and a unidirectional flow may result in less residence time in the North Fork for juvenile salmon that could lead to higher survival.

Survival through the Mokelumne River Delta for fish released above the split did not appear different with the DCC gates closed for three days than with one gate open. This result seems inconsistent with the results of modeling conducted by Ken Newman. Using data from past releases at various locations on the North, South and lower Mokelumne River, he found that survival of fall run smolts released into the Mokelumne system during the spring, increased when the DCC gates were open (Newman, 2002). Again, this increase in survival could be due to the additional flow entering the North Fork when the DCC gates are open, if we assume most of the fish migrate down the North Fork.

In radio tagging work conducted between late March and early June of 1996 (with the gates closed), 80% of the 12 radio-tagged fish that moved downstream of the split migrated into the North Fork (D. Vogel, personal communication). If we assume that most of the fish went down the North Fork with either the gates open or closed, we would have anticipated the survival with one gate open to be greater than when both gates were closed. It's not clear why we were unable to detect a difference using either significance level. Perhaps in this case most of the fish migrated down the South Fork where the flow changes due to the closed cross channel gates are less apparent.

Experimental limitations and Recommendations

In theory, similar experiments in the future could be improved by increasing recovery numbers, reducing variability from other factors, using smaller fish and replication. Increasing recovery numbers either by increasing recapture effort or increasing release numbers is logistically difficult and expensive. The number of hatchery fish available for experiments is often limited and increasing sampling effort with the same vessel or additional vessel substantially increases the cost of the experiment.

Field experiments are especially difficult because flows, weather, fish size and a whole host of other conditions that may affect survival, but that we cannot control, may change during the time period of the experiment. As conditions change between test groups, additional noise in survival is produced making it difficult to detect the effect of the test variable.

Another aspect in implementing field experiments is that the test variables be manipulated based on the study design. In this particular experiment, the original study design was not followed because of the inability to close the gates due to poor water quality. One of the gates was broken during the later half of the experiment preventing a full open condition to be tested with releases above the split. In addition the gate closure was also only for 3 days, but the fish took a minimum 6 days to reach Chipps Island. For those fish that took longer to migrate, they may have been exposed to the one gate open condition.

It is also important that tag lots not be mixed at the hatchery. While the estimated mixing in this experiment was considered small and likely insignificant, such actions increase the noise associated with the experiment and limit our ability to see differences between groups.

In this fall experiment, some fish were recaptured upstream of the release locations. It is one of the assumptions of these experiments that juveniles will migrate downstream to the ocean after release. While the number migrating upstream may have been a small component of the group, we don't really know the magnitude and it does cause some level of concern. Using smaller fish for testing may alleviate this problem in the future, although there have been some instances where even smaller fish (smolts) have been recovered many miles upstream of where they have been released.

Probably the most important factor to consider in the future in these types of experiments is replication. The experiment or test conditions should be repeated within a year and between years to determine the consistency of the results. If results are consistent between and within years the confidence in determining if there are differences is increased even if variability is high.
While many factors detracted from this particular test, the data in conjunction with past and future data will be useful in assessing re-operating the DCC gates or a new Through Delta Facility.

Management Implications

The implications for re-operating the Delta cross channel or a new Through Delta Facility are not clear relative to how either would affect the survival through the Delta for salmon originating from the Mokelumne River. It is not clear that survival through the Delta is higher with the gates open, based on the results of this experiment.

It appears there is some difference between survival in the South and North Fork Mokelumne River. Survival appears to be higher in the North Fork, especially with the gates open, potentially due to the additional flow that enters the North Fork. With a new through Delta facility up to 4000 cfs is to be routed through the central Delta. If this additional flow enters the South Fork, survival may increase there, relative to the North Fork, with either the gates open or closed.

While there is still great uncertainty relative to the implications of re-operating the DCC or constructing a new Through Delta Facility, this data provides somewhat of a baseline of which to make future comparisons. Recoveries of the marked fish as adults in the ocean fishery will provide an additional and independent comparison of relative survival between groups and help confirm and solidify conclusions.

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