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Evaluation of a New Technique to Remove Debris from Holding Tanks at the Tracy Fish Collection Facility

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14. ABSTRACT
Debris in holding tanks at the Tracy Fish Collection Facility (TFCF; Byron, California) interferes with fish salvage operations and may damage fish. A new debris removal technique was evaluated with the two most common types of debris at the TFCF: green and woody. The technique, called the Holding Tank Screen Lift (HTSL), required momentarily lifting the screens (approximately 1 s) situated in the center of the holding tanks to allow debris passage underneath. The procedure added, on average, 4.4 min and 4.6 min to the fish-count and haul-out processes, respectively. On average, 49 percent of green debris and 81 percent of woody debris were removed by completing the HTSL. Fish loss was 31 percent and 1 percent when the HTSL was used to remove green and woody debris, respectively. Due to loss of fish when using the HTSL, it will be necessary to sort through all debris removed during fish-counts and load all debris removed during haul-outs into the fish-haul truck. The HTSL is still useful at high debris loads because it can prevent filling of the fish-count station or clogging of the fish-count and haul-out bucket discharges during sample release, which likely promotes fish survival during the salvage process. The HTSL should be implemented during fish-counts when there is ≥ 8 kg of green debris or ≥ 26 kg of woody debris and during haul-outs when there is ≥ 90 kg of green debris or when amounts of woody debris are causing complications when loading the fish-haul truck.

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TFCF, holding tank screen, fish-count, haul-out, Brazilian elodea, *Egeria densa*, woody debris, green debris, fish salvage

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Evaluation of a New Technique to Remove Debris from Holding Tanks at the Tracy Fish Collection Facility

Tracy Series Volume 50

by

Brandon J. Wu[1] and Brent B. Bridges[1]

[1] Bureau of Reclamation
Tracy Fish Collection Facility; TO-417
16650 Kelso Road
Byron, CA 94514-1909

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Donald E. Portz, Ph.D.
U.S. Department of the Interior – Bureau of Reclamation
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Fisheries and Wildlife Resources Group, 86-68290
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Fish photography by René Reyes, Tracy Fish Collection Facility, Tracy, California. Design by Doug Craft.

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EXECUTIVE SUMMARY

The Tracy Fish Collection Facility (TFCF; Byron, California) functions to remove fish from Sacramento-San Joaquin Delta (Delta) water prior to export through the C.W. “Bill” Jones Pumping Plant (JPP) and Delta Mendota Canal (Arthur *et al.* 1996). Salvaged fish are held in 6-m diameter x 5-m deep concrete holding tanks for 8–14 h before being loaded into trucks, using a 1544-L bucket, for transport to the confluence of the Delta (haul-out). Fish salvage is typically estimated from a 30-min sample (fish-count) performed every 2 h. Debris accumulation in holding tanks interferes with fish salvage operations (Churchwell *et al.* 2005) and may damage fish (Karp and Lyons 2007).

A new technique to remove debris from holding tanks at the TFCF was evaluated. The method, called the Holding Tank Screen Lift (HTSL), involved lifting the screens situated in the center of the holding tanks for approximately 1 s to allow debris passage underneath. This method was evaluated with the two most common types of debris encountered at the TFCF: green and woody. The HTSL resulted in the collection of two samples: Sample #1 was composed of debris and fish that passed under the screen; Sample #2 consisted of debris and fish that remained in the holding tank. Ideally, Sample #1 would contain as much debris as possible and no fish, while Sample #2 would contain all of the fish with minimal debris.

The HTSL was evaluated in terms of its effectiveness at retaining fish while removing debris to keep mechanical salvage equipment functional. The average fish-count station capacities for green and woody debris were 8 kg and 26 kg, respectively. The fish-count bucket discharge clogged during sample release when there was 21 kg of green or 58 kg of woody debris. The haul-out bucket discharge clogged when there was 90 kg of green debris, although it did not clog up to the maximum amount of woody debris tested (91 kg). The HTSL added, on average, 4.4 min and 4.6 min to the fish-count and haul-out processes, respectively. On average, 49 percent of green debris and 81 percent of woody debris were removed in Sample #1. Fish loss in Sample #1 was 31 percent and 1 percent when the HTSL was used to remove green and woody debris, respectively.

It was initially intended that all debris removed from the holding tank would be immediately disposed of without additional processing. Despite this, due to loss of fish in Sample #1 when using the HTSL, it will be necessary to sort through all debris removed during fish-counts and load all debris removed during haul-outs into the fish-haul truck so that no fish are uncounted or discarded. The HTSL is still useful at high debris loads because it can prevent filling of the fish-count station or clogging of the fish-count and haul-out bucket discharge pipes during sample release, which likely promotes overall fish survival during the salvage process.

Debris loads in the holding tank may be estimated visually, or from processing of previous fish-counts or haul-outs, to determine if filling of the fish-count station or clogging of the fish-count or haul-out bucket discharges is likely to occur. During fish-counts, the HTSL should be used when there is ≥ 8 kg of green debris or ≥ 26 kg of woody debris to prevent filling the fish-count station and when there is ≥ 21 kg of green debris or ≥ 58 kg of woody debris to prevent the fish-count bucket discharge from clogging. During haul-outs, the process should be implemented when there is ≥ 90 kg of green debris or when amounts of woody debris are causing complications when loading the fish-haul truck.

INTRODUCTION

The Tracy Fish Collection Facility (TFCF; Byron, California) functions to remove fish from Sacramento-San Joaquin Delta (Delta) water prior to export through the C.W. "Bill" Jones Pumping Plant (JPP) and Delta Mendota Canal (Arthur *et al.* 1996). Salvaged fish are held (8–14 h) in flow-through, concrete holding tanks (6-m diameter x 5-m deep) with slightly conical bottoms (Sutphin *et al*. 2007). Each tank is designed to drain through a cylindrical, woven wire mesh holding tank screen (2-m diameter x 5-m deep, 4-mm maximum square openings) centered over the tank drain (Reclamation 1956; Figure 1). Salvage at the TFCF is estimated every 2 h by counting all fish in a 30-min sample (fish-count). To remove fish from the tank, a bucket is lowered into the drain pit and the screen is lifted. A 343-L fish-count bucket (Figure 2) is used to transfer fish from holding tanks to the 23-L fish-count station (Figure 3) where fish are separated from debris, identified, counted and measured. A 1544-L haul-out bucket (Figure 4) is used to transfer fish from holding tanks to the fish-haul truck. Fish are then transported for release at the confluence of the Delta, beyond the immediate influence of the JPP, in a process known as the "haul-out." Debris accumulation in holding tanks at the TFCF interferes with fish salvage operations (Churchwell *et al.* 2005) and may damage fish (Karp and Lyons 2007).

Figure 1.—Flow-through, open-end, conical-bottom, concrete holding tank at the Tracy Fish Collection Facility.

Figure 2.—Fish-count bucket (343-L) used to transfer fish from holding tanks to the fish-count station during salvage counts at the Tracy Fish Collection Facility.

Figure 3.—Fish-count station (23-L) where salvage samples are processed every 2 h at the Tracy Fish Collection Facility.

Figure 4.—Haul-out bucket (1544-L) used to transfer fish from holding tanks to the fish-haul truck during the haul-out process at the Tracy Fish Collection Facility.

Debris likely impacts fish survival and the accuracy of salvage estimates when it fills the fish-count station or clogs the discharge pipes of the fish-count or haul-out bucket during sample release. When fish are mixed with large amounts of debris during salvage operations, time spent out of water is likely increased and oxygen uptake across the gills may be reduced, both of which could possibly increase stress and eventually lead to mortality. Excessive amounts of debris also exposes fish to abrasive materials that can cause injury (Karp and Lyons 2007) and complicate fish-count and haul-out procedures by requiring additional time and labor to remove debris by hand (J. Imai 2009, personal communication). Large amounts of debris in the fish-count station make it difficult to find fish, which potentially reduces the accuracy of fish salvage estimates. During periods of excessive debris loads, the standard 30-min sampling time is often reduced (J. Imai 2014, personal communication) which may also reduce the accuracy of salvage estimates.

Debris includes a variety of material such as Asian clam (*Corbicula fluminea*) shells, sand, peat fibers, aquatic vegetation such as Brazilian elodea (*Egeria densa*), water hyacinth (*Eichornia crassipes*) and curly-leaved pondweed (*Potamogeton crispus*), woody material and human litter (Karp and Lyons 2007). The quantity and type of debris that accumulates in holding tanks varies seasonally and with pumping rate at the JPP. Between January and April, woody debris (sticks, culms from riparian plants, and bark) is often the dominant debris collected; Brazilian elodea becomes more prevalent during summer months and dominates debris loads from June to December (Boutwell and Sisneros 2007).

A simple debris-removal technique was developed and tested by lifting the holding tank screen momentarily (approximately 1 s) to allow debris concentrated at the base to pass under the screen and into the fish-count or haul-out bucket for removal (Holding Tank Screen Lift; HTSL). Two samples were collected from the HTSL: Sample #1 was composed of debris and fish that passed under the screen during the HTSL; Sample #2 consisted of debris and fish that remained in the holding tank after the HTSL was completed. Ideally, Sample #1 would contain most of the debris and no fish, while Sample #2 would contain all of the fish with minimal debris. Absolute separation of fish and debris would allow for the disposal of Sample #1 without additional processing. The effectiveness of the HTSL at removing debris and retaining fish was evaluated with the two most common types of debris encountered at the TFCF: green debris (Figure 5), that consisted almost entirely of Brazilian elodea, and woody debris (Figure 6), that consisted mostly of sticks, twigs, roots, bark, seeds and peat.

Figure 5.—Example of green debris encountered during the salvage process at the Tracy Fish Collection Facility. Green debris consisted almost entirely of Brazilian elodea during the Holding Tank Screen Lift evaluation.

The goal of this study was to evaluate the HTSL method for removing debris from the holding tanks and demonstrate that the technique could improve the overall salvage process at the TFCF. There were four main objectives of this study:
1) determine amounts (kg) of green and woody debris that fill the fish-count station and clog the fish-count and haul-out bucket discharge pipes during sample

Figure 6.—Example of woody debris encountered during the salvage process at the Tracy Fish Collection Facility. Woody debris consisted mostly of sticks, twigs, roots, bark, seeds and peat during the Holding Tank Screen Lift evaluation.

release 2) estimate minimum time costs to perform the HTSL during the fish-count and haul-out processes, 3) assess the effectiveness of the HTSL at removing each type of debris, including the determination of maximum debris loads at which performing the HTSL is beneficial (prevents filling of the fish-count station or clogging of the fish-count and haul-out bucket discharges), and 4) determine the effectiveness of the HTSL at retaining salvaged fish for each debris type.

METHODS

Fish-Count Station, Fish-Count Bucket and Haul-Out Bucket Filling/Clogging Evaluations

Fish-Count Station

The amount of green or woody debris required to fill the fish-count station (48-cm diameter x 24-cm deep) was determined by adding each type of debris into the count station until it was flush with the top. Debris was weighed (kg) using a polyethylene basket (48-cm top diameter, 37-cm bottom diameter, 37-cm height, 8-mm x 14-mm mesh; Memphis Net & Twine Co., Memphis, Tennessee) and a digital bench scale (Model BW-30, CAS-USA Corp., East Rutherford, New Jersey). All weights were obtained from debris with excess water removed. The average amount of debris to fill the fish-count station was determined for each debris type (n = 3). These values were used as reference points when evaluating the effectiveness of the HTSL at removing debris and represented minimum debris loads at which performing the HTSL would likely be beneficial to the salvage process.

Fish-Count and Haul-Out Buckets

The amounts of green or woody debris that clogged the discharge pipes of the fish-count and haul-out buckets during sample release were determined by adding known amounts of damp debris into each bucket, filling the buckets with water, and observing if the buckets clogged during release of the sample into a 2002-L fiberglass trough (356-cm long x 74-cm wide x 76-cm deep). If the buckets did not clog, the amount of debris added was doubled and tested until clogging occurred. When the buckets clogged, the amount tested was reduced by 50 percent of the difference between the amount found to clog the bucket and the highest amount that did not clog the bucket. This process was followed until the lowest amount of debris that clogged each bucket three consecutive times was determined. Debris was only used for three replicates until it was disposed of and new debris was gathered for use. These values were used as reference points when evaluating the effectiveness of the HTSL at removing debris.

Time Cost to Complete the Holding Tank Screen Lift

The HTSL was combined with fish salvage activities that occur at the TFCF. Additional time was necessary when using the HTSL because two samples were collected instead of one. The minimum time costs (not including time to fill and empty buckets or process fish) to perform the HTSL during fish-counts and haul-outs were approximated using the time needed to move each bucket with an overhead hoist.

Fish-Counts

Holding tank #2 was chosen as a starting point for time trials with the fish-count bucket since fish-counts typically start at this location. The time it took to hoist the empty fish-count bucket from holding tank #2 drain pit to the fish-count station (seated on the fish-count station) and back to holding tank #2 drain pit was recorded (n = 6; Figure 7).

Haul-Outs

Holding tank #3 was chosen for time trails with the haul-out bucket since salvaged fish are primarily removed from this tank prior to being loaded into the

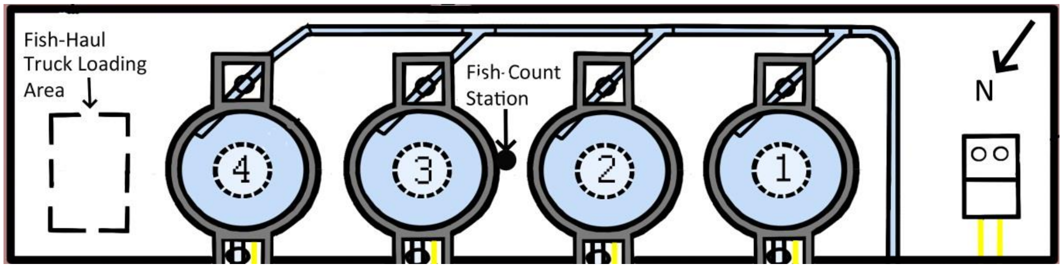

Figure 7.—Schematic of the holding tank building at the Tracy Fish Collection Facility showing numbering of holding tanks as well as locations of the fish-count station and fish-haul truck loading area.

fish-haul truck. The time it took to hoist the empty haul-out bucket from holding tank #3 drain pit to the fish-haul truck (seated on the front top hatch of the truck) and back to holding tank #3 drain pit was recorded (n = 6).

Effectiveness of Holding Tank Screen Lift at Removing Debris and Retaining Fish

Green and woody debris have unique characteristics and enter the facility under specific hydraulic and seasonal conditions. Generally, the facility is inundated with one type of debris at a time; consequently, testing the HTSL method focused on each individual type of debris. Debris did not always enter holding tanks in large amounts; therefore, a combination of naturally entrained and artificially introduced debris was used in replicates. Introduced debris was collected from the holding tanks, secondary channel and trash rack, and held in water prior to testing.

Fish seldom entered the facility in large numbers and it was necessary to add 20 fish of 4 species directly into the holding tank prior to many of the replicates. The four species that were added included Chinook salmon (*Oncorhynchus tshawytscha*), Sacramento splittail (*Pogonichthys macrolepidotus*), threadfin shad (*Dorosoma petenense*), and white catfish (*Ameiurus catus*). Chinook salmon were obtained from the Nimbus Fish Hatchery (Gold River, California), while Sacramento splittail, threadfin shad and white catfish were collected from TFCF salvage. The upper caudal fin was clipped on all fish that were added to the holding tank to differentiate them from wild fish. Various wild fish species, including American shad (*Alosa sapidissima*), bluegill (*Lepomis macrochirus)*, channel catfish (*Ictalurus punctatus*), Chinook salmon, common carp (*Cyprinus carpio)*, largemouth bass (*Micropterus salmoides)*, prickly sculpin (*Cottus asper*), Sacramento splittail, threadfin shad and white catfish, were also entrained during the replicates.

The HTSL was completed after a 10–30-min collection of water, debris and fish (n = 38 for green debris, n = 40 for woody debris). When the supplementation of debris and/or fish was needed, as determined by previous replicates and facility fish-counts, additions were made at the beginning of each replicate to allow debris and/or fish time to disperse in the holding tank. The swirling action of the water forced debris against the center screen; therefore, flow conditions were tested under normal operations (0.2-0.3 m^3/s). After each collection period, the holding tank was drained to a depth of 60-cm and either the fish-count or haul-out bucket, depending on the debris load, was inserted into the drain pit in the center of the screen. In general, the haul-out bucket was used when green and woody debris loads exceeded 60 kg. The holding tank screen was lifted twice, with durations of approximately 1 s per lift. After the first lift, water was allowed to drain down to the bottom level of the fish-count or haul-out bucket screen before performing the second lift. This was done to ensure that there was enough of a differential across the screen to draw in water and debris during the second lift. The first bucket lifted out of the drain pit was referred to as Sample #1, and it was processed in either the fish-count station or fiberglass trough. Debris was transferred to a polyethylene basket and weighed, to the nearest g, with the digital bench scale previously described, while fish were identified to species, measured (mm FL) and released into an additional holding tank. After Sample #1 was processed, the bucket was re-lowered into the holding tank drain pit to collect remaining fish and debris from the collection period (referred to as Sample #2). Both samples were processed in the same manner. The amounts of debris and fish in each sample were compared to the total amounts of debris and fish from both samples combined to calculate HTSL effectiveness at removing debris and retaining fish. The average effectiveness of the HTSL at removing debris was used, along with fish-count station filling capacities and fish-count and haul-out bucket clogging thresholds, to estimate the maximum loads of each debris type that the HTSL prevents from filling the fish-count station or clogging the discharge pipes of the fish-count or haul-out buckets during sample release. The numbers of fish in each sample were used to estimate retention efficiency for all fish combined, as well as individual species.

Ten HTSL replicates were completed in which an abundance (453–11,845) of fish (mostly Sacramento splittail and common carp) were collected in the fish-counts with woody debris (0.6–13 kg/sample). In addition, one replicate was completed during the haul-out process when there was woody debris and large numbers (695,883) of fish, which consisted almost entirely of Sacramento splittail and common carp (Appendix 1, Table A1-1). The same procedure as previously described was completed during these replicates to calculate the percent of fish lost and debris removed in Sample #1; however, the haul-out sample required a small modification to this approach. Since the haul-out sample contained many times more fish and debris than fish-count samples, there were too many fish in Sample #2 to hand count and keep alive; therefore, the number of fish in this sample was determined from the difference between the total number of fish estimated to be in the haul-out and the number of fish in Sample #1. All fish in Sample #2 were loaded directly into the fish-haul truck for release back to the Delta. Fish in Sample #1 were hand counted and debris weighed prior to disposal.

These replicates were included with all other woody debris replicates for analyses, although the haul-out replicate with 695,883 fish was not used when evaluating the retention efficiency of individual species due to the fact that only the total number of fish in Sample #2 was estimated and the number of individual species in Sample #2 was not determined.

Data Analysis

Average fish-count station filling capacities were reported for each type of debris. Amounts (kg) of each debris type that clogged the discharge pipes of the fish-count and haul-out buckets during sample release were provided and minimum time costs to perform the HTSL during the fish-count and haul-out processes were described as averages ± 95 percent confidence interval (CI).

Amounts of debris in the two samples during the HTSL evaluation were reported as mean percentages ± 95 percent CIs, while numbers of fish were reported as percentages of the combined total. Only fish species that were present in both green and woody debris replicates were used to evaluate the retention efficiency of individual species. Linear and curvilinear least squares regressions (Minitab version 15) were used to develop equations predicting debris weight (kg) in Samples #1 and #2 based on starting sample size and debris type. Linear regression was also used to determine if the percentage of fish collected in Sample #2 was influenced by the quantity of each type of debris in the holding tank. Ranges in amounts of green and woody debris in which performing the HTSL will likely benefit the salvage process at the TFCF were estimated based on filling capacities of the fish-count station, clogging values of the fish-count and haul-out buckets, and debris removal efficiency of the HTSL for each type of debris.

RESULTS AND DISCUSSION

Fish-Count Station, Fish-Count Bucket and Haul-Out Bucket Filling/Clogging Evaluations

Debris-specific filling capacities for the fish-count station and clogging values for each bucket are reported in Table 1. The maximum amount of woody debris tested with the haul-out bucket was limited by availability. Although amounts of debris that clog the discharge pipe of each bucket have been provided, debris used was typically uniform in size and shape; unusually shaped or large debris could clog bucket discharges at lower debris loads than expected. The filling capacities of the fish-count station represent the minimum green and woody debris loads at which performing the HTSL is likely beneficial to the salvage process and, along with clogging values of the fish-count and haul-out buckets, are general thresholds to stay under in order to reduce negative impacts on fish survival.

Table 1.—Filling capacity of fish-count station and clogging values of fish-count and haul-out buckets for green and woody debris

Station/Bucket	Green Debris Filling Capacity or Clogging Value (kg)	Woody Debris Filling Capacity or Clogging Value (kg)
Fish-Count Station (23-L)	8	26
Fish-Count Bucket (343-L)	21	58
Haul-Out Bucket (1544-L)	90	Undetermined, > 91 kg

Time Cost to Complete the Holding Tank Screen Lift

The average (± 95 percent CI) minimum time costs to perform the HTSL during the fish-count and haul-out processes were 4.4 ± 0.1 min and 4.6 ± 0.1 min, respectively. These times reflect the speed of the hoist and trolley motor only. The amounts of time necessary to fill and empty the contents of the buckets, as well as process fish, were not included in the analyses as they were likely dependent on sample size and individual performing the fish-count or haul-out.

Effectiveness of Holding Tank Screen Lift at Removing Debris and Retaining Fish

Debris injection tests demonstrated that there was less green and woody debris in holding tanks after performing the HTSL. On average ± 95 percent CI, 49 ± 7 percent of green debris and 81 ± 5 percent of woody debris were removed in Sample #1. Differences in these replicates were likely due to operator variability. It was not possible to lift the holding tank screen the same height and duration in each replicate. It is expected that operators will be more proficient at standardizing the method as they become more familiar with the technique.

The HTSL was less effective at removing green debris than woody debris because density and shape differences likely prevented green debris from settling in a pile at the base of the holding tanks screen, as was observed with woody debris. For example, Brazilian elodea tended to float away from the center screen during draining of the holding tank and frequently stuck to the ladder and holding tank screen. Green debris was also generally much longer than woody debris. This made it more likely to be pinched between the holding tank screen and the floor when the screen was momentarily lifted. These two characteristics of green debris (*e.g.*, lighter and longer) help explain why removal efficiency was not linearly related to debris abundance. The HTSL method removed approximately half of the green debris in the tank when there was ≤ 60 kg of debris present, but removal efficiency continued to decline as more debris was added. The amount of green debris removed in Sample #1 was dependent on the total amount of green debris in the holding tank (Regression, P = < 0.001), although the HTSL could only remove approximately 50 kg of green debris regardless of how much was in the tank (Figure 8).

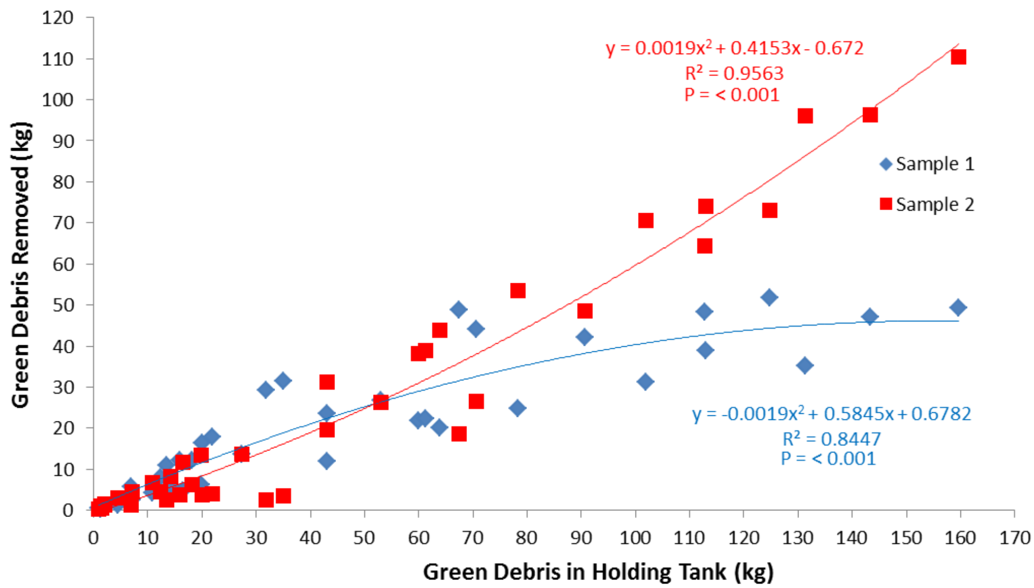

Figure 8.—Green debris in Sample #1 and #2 relative to the total amount of green debris in the holding tank (n = 38).

Unlike green debris, woody debris pieces were generally short and dense, sank to the bottom faster, and concentrated around the holding tank screen, resulting in greater debris removal in Sample #1. When performing the HTSL with woody debris, a maximum threshold of debris removed in Sample #1 was not encountered over the range of debris loads tested, as with green debris. Instead, removal efficiency was a constant fraction of the initial amount in the holding tank (Regression, P = < 0.001; Figure 9). This suggests that performing the HTSL with woody debris was equally effective over all debris loads tested and more predictable than with green debris. Despite this, bucket capacity will eventually limit the amount of woody debris that the HTSL is able to remove. Additional sampling is needed with extreme woody debris loads to determine the debris removal capacity of the fish-count and haul-out buckets.

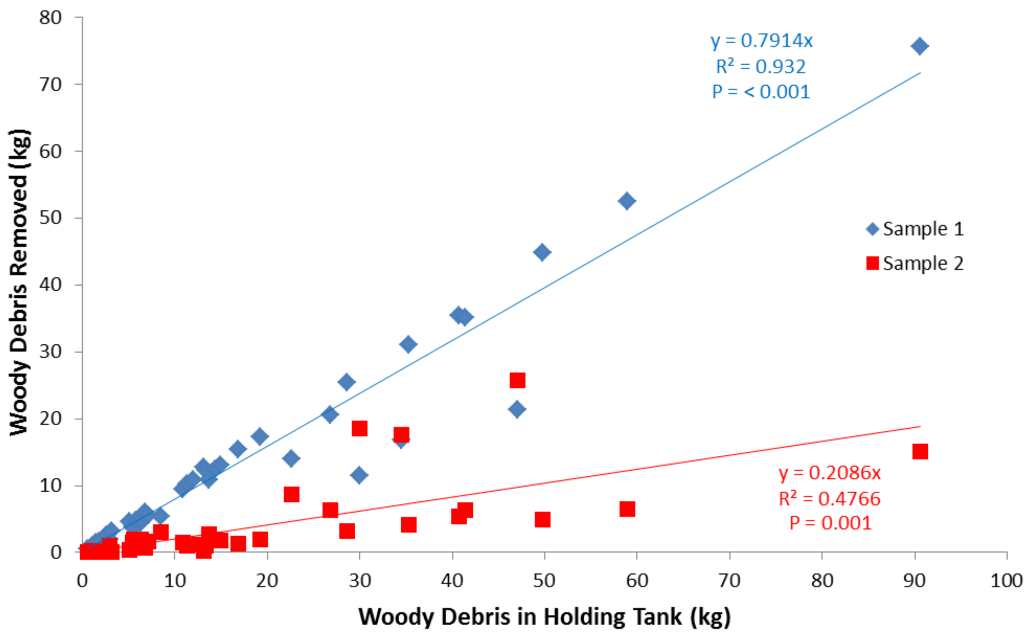

Figure 9.—Woody debris in Sample #1 and #2 relative to the total amount of woody debris in the holding tank (n = 40).

The HTSL prevented the fish-count station from filling when the tank had approximately 20 kg of green debris and 125 kg of woody debris, or less (Figures 10 and 11). The HTSL prevented the fish-count and haul-out bucket discharge pipes from clogging when there was up to 43 kg and 135 kg of green debris in the holding tank, respectively. This process prevented the fish-count and haul-out bucket discharge pipes from clogging with woody debris up to the maximum amount tested (91 kg); therefore, it was not possible to estimate ranges in woody debris loads in which performing the HTSL will likely benefit the salvage process by preventing clogging of the buckets.

When combining all fish species together (wild and artificially added), fish loss in Sample #1 was 31 percent and 1 percent when the HTSL was used with green and woody debris, respectively (Figure 12). However, these results were influenced by the most abundant species. In Figure 12, Sacramento splittail and common carp were largely responsible for woody debris results, while white catfish, Sacramento splittail, threadfin shad and Chinook salmon all had nearly equal representation in green debris replicates. The loss of fish in Sample #1 suggests it will not be reasonable to immediately dispose of debris removed in Sample #1 without additional processing.

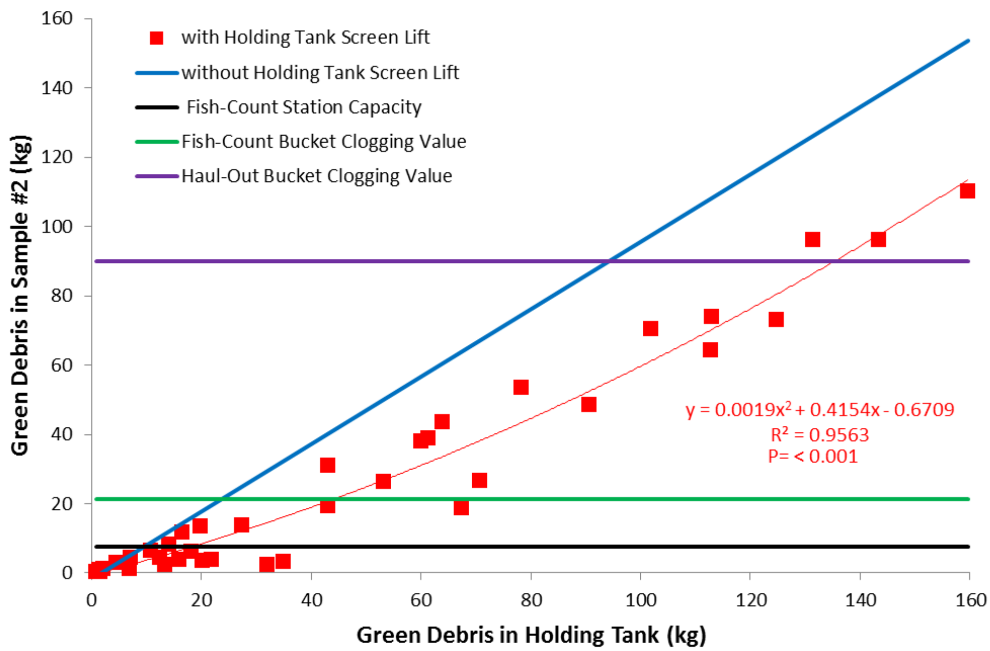

Figure 10.—Green debris in Sample #2 relative to the total amount of green debris in the holding tank. The blue line (without Holding Tank Screen Lift) is for reference to illustrate how much debris would be in the sample if not removed. The black, green and purple horizontal lines are referencing the clogging values of the fish-count station, fish-count bucket and haul-out bucket, respectively.

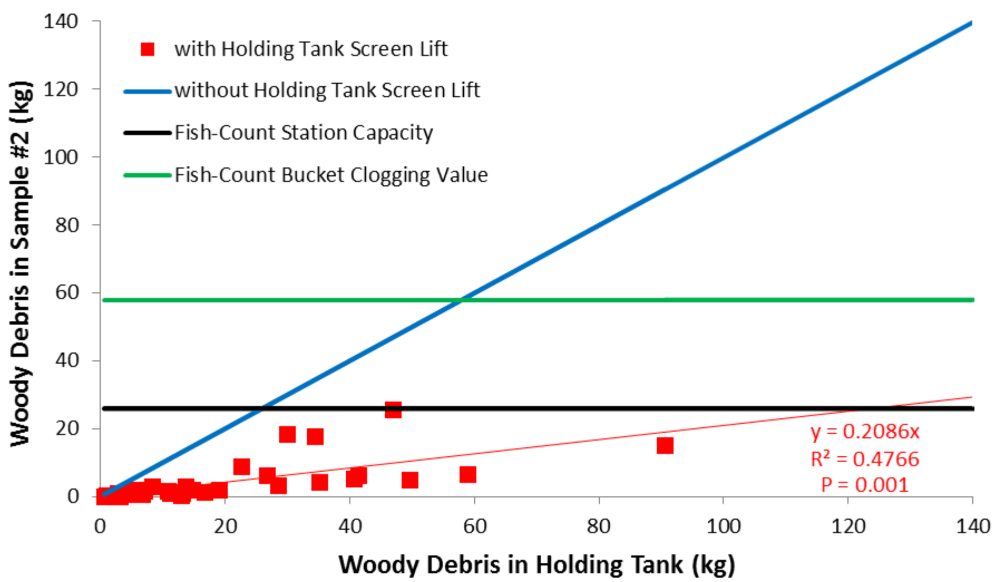

Figure 11.—Woody debris in Sample #2 relative to the total amount of woody debris in the holding tank. The blue line (without Holding Tank Screen Lift) is for reference to illustrate how much debris would be in the sample if not removed. The black and green horizontal lines are referencing the clogging values of the fish-count station and fish-count bucket, respectively.

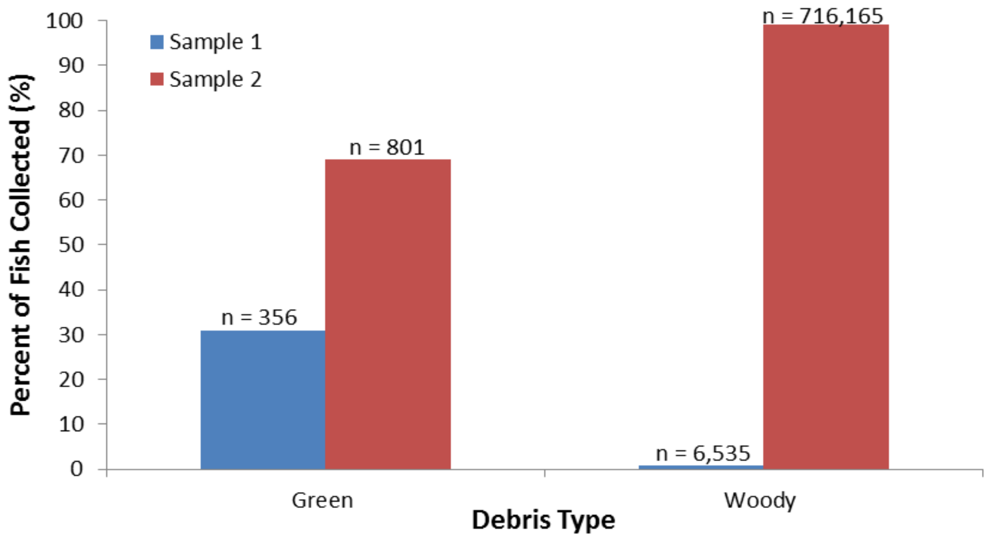

Figure 12.—Percentage of all fish combined in each sample for each debris type when using the Holding Tank Screen Lift. The number of fish collected in each sample for each debris type is represented by “n”.

The percentage of fish recovered in Sample #2 was generally not influenced by quantity of debris in the holding tank for both debris types. However, percentage of fish collected in Sample #2 during green debris replicates was more dependent on amount of debris in the holding tank (Regression, P = 0.094; Figure 13) than during woody debris replicates (Regression, P = 0.698; Figure 14). If the 2 extreme values above 70 kg of green debris were removed from Figure 13, there would be an inverse relationship between recovered fish and debris load. This trend should be further evaluated.

While the majority of fish remained in the holding tank after the HTSL was completed, variation in percent fish loss in Sample #1 was high between fish species and debris type (Figures 15 and 16). This suggests the loss of fish may be dependent on species, as well as type of debris in the holding tank, when using the HTSL. The relatively high loss of Chinook salmon with both debris types (approximately 45–56 percent) further supports that the immediate disposal of Sample #1, and fish contained therein, would not be appropriate due to the possible loss of fish, including threatened or endangered species.

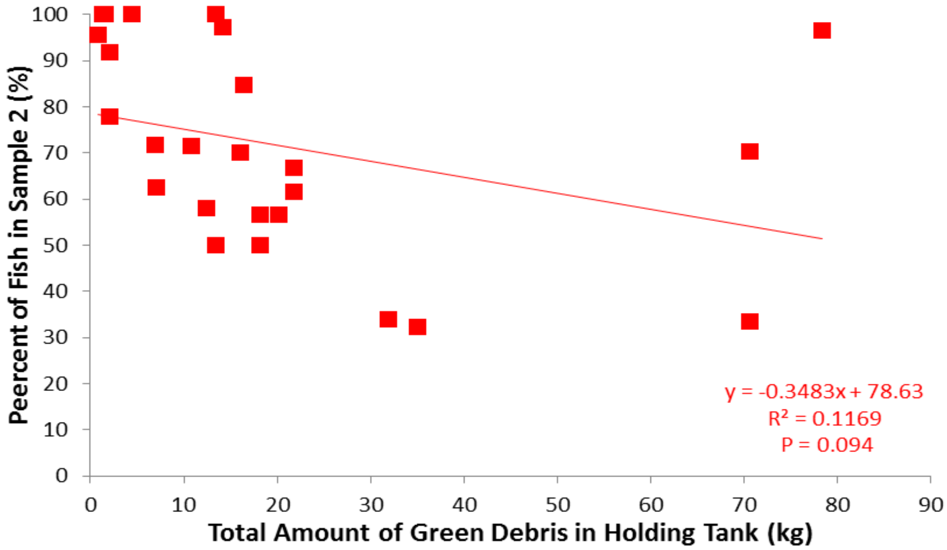

Figure 13.—Percentage of fish recovered in Sample #2 relative to the total amount of green debris in the holding tank.

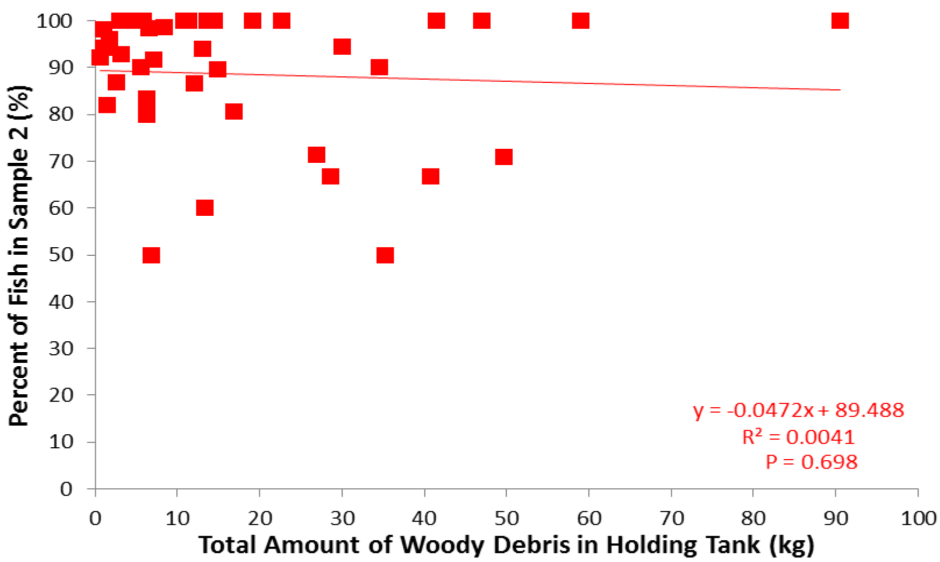

Figure 14.—Percentage of fish recovered in Sample #2 relative to the total amount of woody debris in the holding tank.

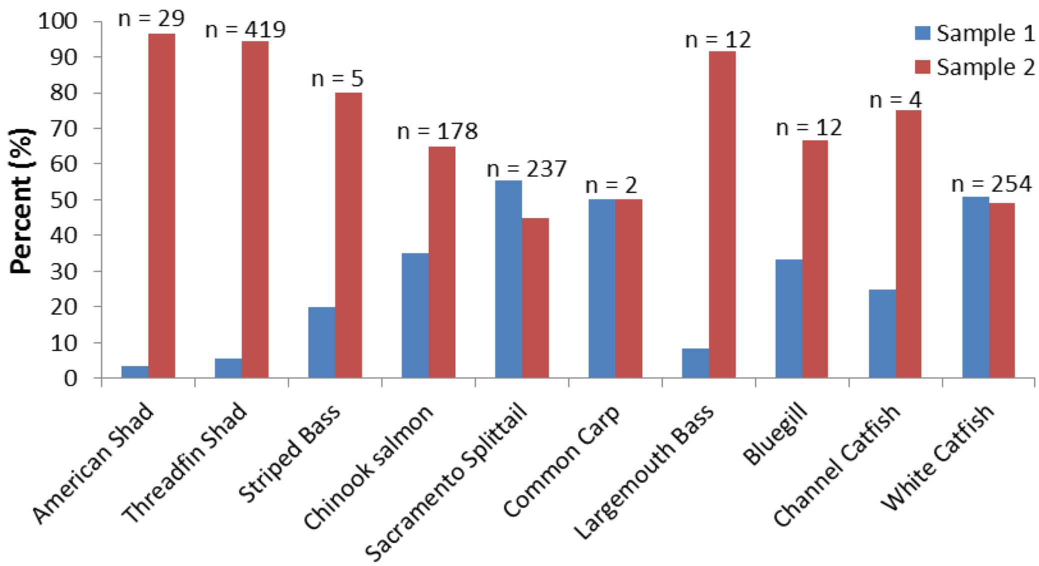

Figure 15.—Percentage of each fish species in Sample #1 and #2 for green debris samples. The total number of each species of fish observed during sampling is represented by "n".

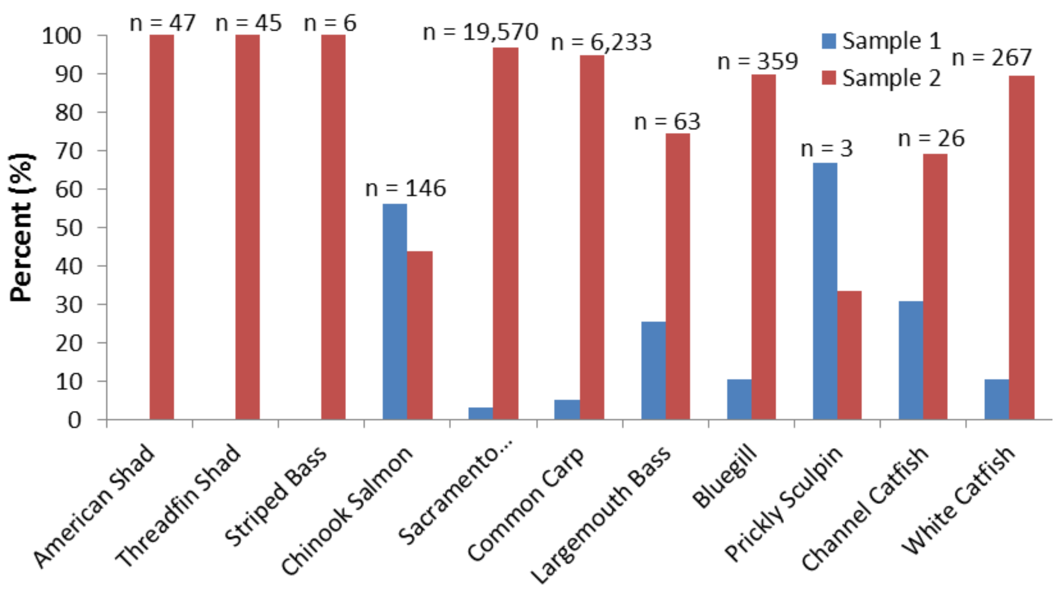

Figure 16.—Percentage of each fish species in Sample #1 and #2 for woody debris samples. The total number of each species of fish observed during sampling is represented by "n".

CONCLUSION

The HTSL is successful because it produces two samples with manageable debris loads in each and can prevent filling of the fish-count station or clogging of the fish-count and haul-out bucket discharge pipes during sample release, which likely promotes overall fish survival during the salvage process. Although this technique adds at least 4 min to the fish-count and haul-out processes, it removes debris from the tank in Sample #1 and retains most of the fish in the holding tank to be collected in Sample #2. Initially, it was intended that all debris removed from the holding tank in Sample #1 would be immediately disposed of without additional processing. However, the HTSL seldom resulted in perfect separation of debris and fish; therefore, it will likely be necessary to process both samples during fish-counts and load both samples into the fish-haul truck during haul-outs so that no fish are uncounted or discarded. Due to this, additional fish processing time will likely be needed during fish-counts. The only additional time anticipated during haul-outs is the time necessary to fill and empty the contents of the haul-out bucket.

It is recognized that amounts of debris removed in Sample #1 may be great enough to fill the fish-count station or clog the fish-count or haul-out bucket discharge pipes, likely compromising survival of fish contained in the sample. Despite this, results indicate that a minority of fish are lost and collected in Sample #1 when using the HTSL, suggesting the advantage of dividing the fish-count into two samples is that one may contain a few damaged fish with debris that is removed from the holding tank, while the other may contain most of the healthy fish with a reduced debris load. In addition, this technique offers an alternative way to cope with debris in the holding tanks besides reducing the fish-count period, which likely decreases the accuracy of fish salvage estimates. This technique is not perfect, but it provides a low-cost solution (no new equipment or installations are required) to processing a fish-count or haul-out that is inundated with debris.

Debris loads in the holding tank may be estimated visually, or from processing of previous fish-counts or haul-outs, to determine if filling of the fish-count station or clogging of the fish-count or haul-out bucket discharge pipes is likely to occur. Knowing the approximate amount of debris in the holding tank, fish-count station capacity, clogging thresholds for each of the buckets, and the HTSL debris removal efficiency for each debris type, it is possible to estimate when to use the HTSL.

The HTSL should be incorporated during fish-counts when there is ≥ 8 kg of green debris or ≥ 26 kg of woody debris estimated to be in the tank. The HTSL should be performed when there is 8–20 kg of green debris or 26–135 kg of woody debris to prevent the fish-count station from filling. When 21–43 kg of green debris or ≥ 58 kg of woody debris is present in a fish-count sample, the HTSL should be completed to prevent the fish-count bucket discharge pipe from clogging during sample release. During fish-counts in which there is > 43 kg of green debris, or when ≥ 58 kg of woody debris remains in the holding tank after completing the HTSL, it will likely be necessary to perform the HTSL additional times to eventually attain debris loads that do not clog the discharge pipe of the fish-count bucket when releasing the sample containing the majority of fish. It should be emphasized that, although the HTSL can reduce debris loads to levels that do not clog the fish-count bucket discharge, amounts of debris left in the holding tank may still fill the fish-count station unless the HTSL is performed until there is < 8 kg of green debris or < 26 kg of woody debris remaining. Filling of the fish-count station could also be avoided by releasing fish-count samples with ≥ 8 kg of green debris or ≥ 26 kg of woody debris into the previously described 2002-L fiberglass trough instead of the fish-count station.

During haul-outs, the HTSL should be performed when ≥ 90 kg of green debris is estimated to be in the tank to prevent clogging the haul-out bucket discharge pipe. Results suggest the HTSL prevents the haul-out bucket discharge from clogging when there is up to 135 kg of green debris. During haul-outs in which there is > 135 kg of green debris, the HTSL may need to be repeated to prevent clogging the bucket discharge during loading of the fish-haul truck. It is recommended that the HTSL be completed during haul-outs whenever woody debris loads in the holding tank are causing complications when loading the fish-haul truck.

When debris loads in the fish-haul truck are problematic at the release site, such as clogging of the truck outlet or site release pipe, the disposal of Sample #1 should be considered as it likely benefits the majority of fish during transport and release. The effectiveness of disposing Sample #1 to reduce overall debris load in the truck was demonstrated in 2006 when an estimated 690,447 fish (99 percent), which consisted almost entirely of Sacramento splittail and common carp, were placed in the fish-haul truck with little debris after the HTSL removed 259 kg of woody debris and sacrificed 5,436 fish (1 percent). If the disposal of fish is deemed inappropriate by management and/or regulatory agencies, Sample #1 could be loaded into an additional fish-haul truck for transport to the confluence of the Delta. This would likely alleviate problems at the release site and make the disposal of fish in Sample #1 unnecessary.

Finally, it is recommended that the effectiveness of the HTSL at retaining fish be further investigated with, and without, the incorporation of screen vibration or weak electrical fields at the base of the screen to determine if these modifications substantially improve the separation of debris and fish.

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APPENDIX 1

Summary of Holding Tank Screen Lift Replicates with Large Numbers of Fish and Woody Debris

Table A1-1.— Summary of Holding Tank Screen Lift replicates in which there were large numbers of fish (453–695,883) with woody debris during facility fish-counts (n = 10) and a facility haul-out (n = 1). Sacramento splittail and common carp were the dominant species during these replicates. N/A = Value Not Available.

		Fish-Counts										Haul-Out
	Repetition	1	2	3	4	5	6	7	8	9	10	1
	Time	14:15	14:00	13:30	13:15	12:45	12:30	10:15	9:45	9:15	13:00	15:00
	Date	6/6/2006	6/6/2006	6/6/2006	6/6/2006	6/6/2006	6/6/2006	6/6/2006	6/6/2006	6/6/2006	6/22/2011	6/7/2006
Sample 1	Amount of Woody Debris (kg)	0.62	0.95	0.90	1.45	1.70	4.90	2.55	3.15	12.80	5.40	259.25
	Number of Sacramento Splittail	38	34	32	60	69	29	99	26	76	141	1444
	Number of Common Carp	25	107	5	108	7	15	17	6	25	0	3914
	Number of Other Fish	4	2	3	3	1	0	0	0	0	6	78
Sample 2	Amount of Woody Debris (kg)	0.03	0.15	0.15	0.09	0.10	1.60	0.02	0.05	0.30	3.05	N/A
	Number of Sacramento Splittail	396	1555	364	464	924	1848	283	101	1363	11650	N/A
	Number of Common Carp	396	806	1820	288	974	682	447	302	202	0	N/A
	Number of Other Fish	0	31	28	28	46	214	23	18	0	48	N/A
Summary	Total Woody Debris Load (kg)	0.65	1.10	1.05	1.54	1.80	6.50	2.57	3.20	13.10	8.45	N/A
	Percent of Woody Debris Removed in Sample 1 (%)	95.4	86.4	85.7	94.1	94.4	75.4	99.2	98.4	97.7	63.9	N/A
	Total Number of Fish	859	2535	2252	951	2021	2788	869	453	1666	11845	695883
	Number of Fish Lost in Sample 1	67	143	40	171	77	44	116	32	101	147	5436
	Number of Fish Remaining in Sample 2	792	2392	2212	780	1944	2744	764	421	1565	11698	690447
	Percent of Fish Lost in Sample 1 (%)	7.8	5.6	1.8	18.0	3.8	1.6	13.2	7.1	6.1	1.2	0.78
	Percent of Fish Remaining in Sample 2 (%)	92.2	94.4	98.2	82.0	96.2	98.4	87.9	92.9	93.9	98.8	99.22
	Percent of Sacramento Splittail Lost in Sample 1 (%)	8.8	2.1	8.1	11.5	6.9	1.5	25.9	20.5	5.3	1.2	N/A
	Percent of Common Carp Lost in Sample 1 (%)	5.9	11.7	0.3	27.3	0.7	2.2	3.7	1.9	11.0	0.0	N/A
	Mean Length of Sacramento Splittail Lost in Sample 1 (mm)	47.8	44.0	46.0	45.6	40.6	47.0	46.5	44.8	48.9	36.2	N/A
	Mean Length of Common Carp Lost in Sample 1 (mm)	38.9	39.5	37.6	45.5	40.4	43.3	43.3	41.0	43.2	N/A	N/A
	Mean Length of Sacramneto Splittail Remaining in Sample 2 (mm)	41.1	42.3	43.0	46.2	37.9	48.8	39.0	45.0	44.9	N/A	N/A
	Mean Length of Common Carp Remaining in Sample 2 (mm)	39.9	37.0	44.0	51.5	41.9	50.6	48.0	43.8	52.0	N/A	N/A