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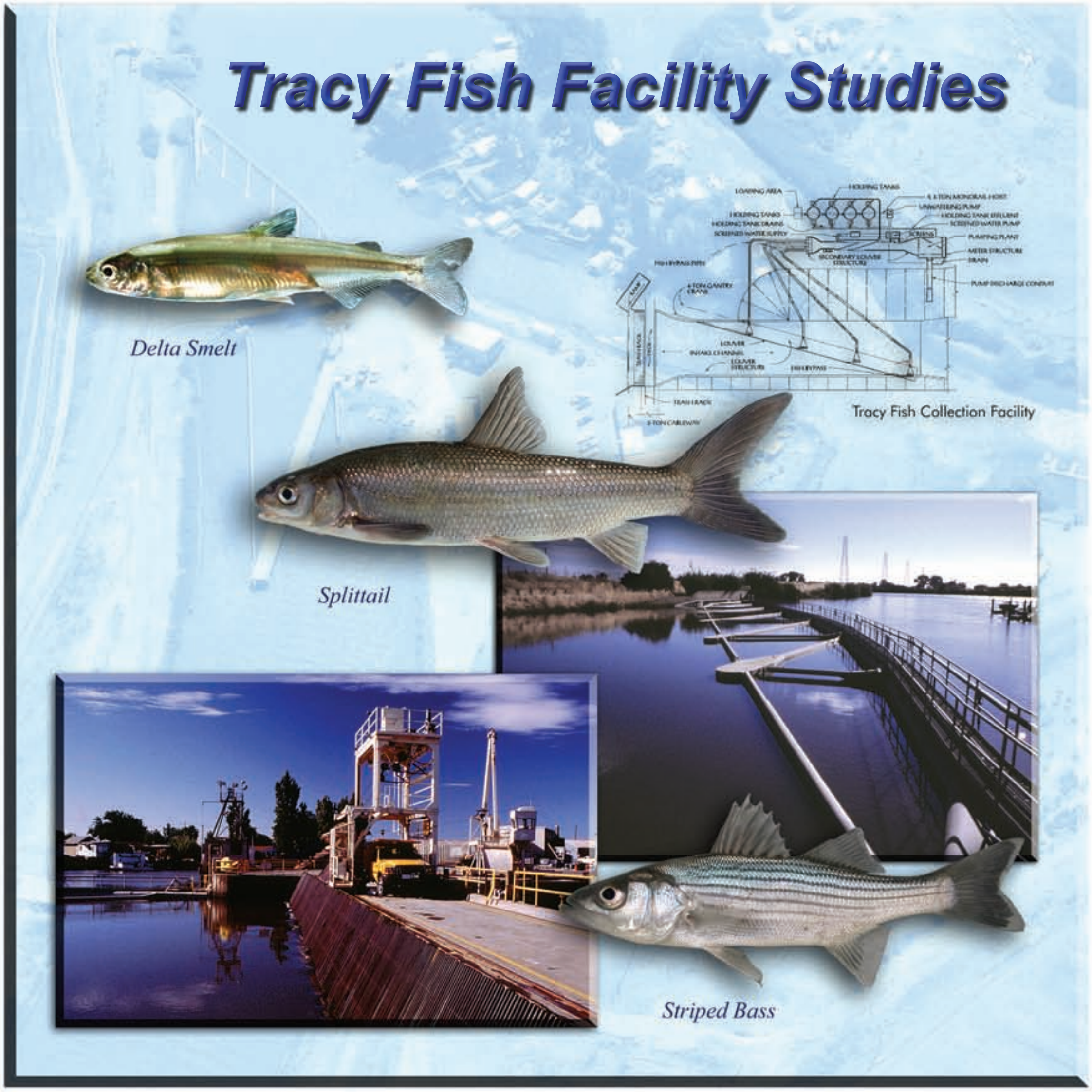

Water Born Debris Removal Evaluations Using a Traveling Screen at the Tracy Fish Collection Facility, California

Volume 33

U.S. Department of the Interior
Bureau of Reclamation
Mid-Pacific Region
Technical Service Center

January 2007

REPORT DOCUMENTATION PAGE	*Form Approved* *OMB No. 0704-0188*

1. REPORT DATE *(DD-MM-YYYY)* January 2007	2. REPORT TYPE Final	**3. DATES COVERED** *(From - To)*

4. TITLE AND SUBTITLE Water Born Debris Removal Evaluations Using a Traveling Screen at the Tracy Fish Collection Facility, Tracy, California	**5a. CONTRACT NUMBER** **5b. GRANT NUMBER** **5c. PROGRAM ELEMENT NUMBER**
6. AUTHOR(S) John E. Boutwell and David Sisneros	**5d. PROJECT NUMBER** **5e. TASK NUMBER** **5f. WORK UNIT NUMBER**
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Bureau of Reclamation, Technical Service Center, Environmental Applications and Research Group, 86-68220, PO Box 25007, Denver CO 80225-0007	**8. PERFORMING ORGANIZATION REPORT NUMBER** Volume 33
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	**10. SPONSOR/MONITOR'S ACRONYM(S)** **11. SPONSOR/MONITOR'S REPORT NUMBER(S)**

12. DISTRIBUTION/AVAILABILITY STATEMENT
Available from the National Technical Information Service (NTIS)
Operations Division, 5285 Port Royal Road, Springfield VA 22161

13. SUPPLEMENTARY NOTE

14. ABSTRACT

The traveling screen; a rotating, belt type, mechanical screen was built to remove the invasive Chinese mitten crab (*Eriocheir sinensis*), at the Tracy Fish Collection Facility (TFCF). Because the screen has been demonstrated to be fish friendly during mitten crab removal (1996–1999), it was natural to test the traveling screen as a general debris removal device. The goals of this study were to determine if the screen could be used to remove debris flowing through the primary fish guidance louvers to the secondary fish guidance louvers, and also to determine if improvements to the debris removal system could be made to improve collection and transport of collected debris to the debris hauling truck. Three different evaluation techniques were used to determine the effectiveness of the traveling screen to remove debris: (1) The addition of known amounts of debris, introduced upstream of the traveling screen, compared to the debris recovered by the traveling screen. (2) Overnight collection of debris in which the traveling screen was operated, on average, 15.5 hours per night. (3) Ten-minute debris collections within the below ground circular holding tank, coinciding with routine fish counts being made every 2 hours at the TFCF. Two hundred sixty-one fish were collected by the traveling screen during these three different evaluations. Of this total, 210 were dead, and 173 (66 percent) of these dead fish had been dead long before being collected, indicated by old injuries and decomposition of the body. The traveling screen has proven to be effective at removing green vegetative debris greater than 189 mm (7.4 inches) and woody debris greater than 105 mm (4.1 inches) in length or longer from the secondary channel. The experiments presented in this report demonstrate the effectiveness of the traveling screen, especially during routine cleaning operations and when debris loading is heavy.

15. SUBJECT TERMS
delta smelt, fish collection facility, count screen, traveling screen, debris removal

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON** Doug Craft
a. REPORT	**b. ABSTRACT**	**a. THIS PAGE**		46	**19b. TELEPHONE NUMBER** *(Include area code)* 303-445-2182

Tracy Fish Facility Studies
California

Water Born Debris Removal Evaluations Using a Traveling Screen at the Tracy Fish Collection Facility, Tracy, California

Volume 33

by

John E. Boutwell and David Sisneros[1]

January 2007

U.S. Department of the Interior
Bureau of Reclamation
Mid-Pacific Region
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Cover

Fish photography by René Reyes, Tracy Fish Collection Facility, Tracy, California.
Design by Doug Craft.

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EXECUTIVE SUMMARY

The U.S. Department of the Interior, Bureau of Reclamation (Reclamation) has had an ongoing fish collection facility at Tracy, California for nearly 50 years. Reclamation has also developed an interdisciplinary research program aimed at improving fish salvage activities for the existing Tracy Fish Collection Facility (TFCF) as well as for new technological developments for a possible future research facility, the Tracy Fish Test Facility (TFTF). As part of these activities, fish guidance, fish removal, and reintroduction of salvaged fish into Sacramento and San Joaquin Rivers are of great importance. The effect of the catadromous Chinese mitten crab (*Eriocheir sinensis*), water hyacinth (*Eichornia crassipes*), Brazilian elodea (*Egeria densa*) and various other types of debris are also of great concern related to the effectiveness of the facility to guide fish with louvers, remove and relocate fish in a safe and healthy manner.

A rotating, belt type, mechanical screen (the traveling screen) was installed in the autumn of 1999 to remove the large number of mitten crabs at the TFCF, whose high populations had become detrimental to fish collection efforts. Since the autumn of 1999 the population of the Chinese mitten crabs, at the TFCF, has been declining from more than 1 million to less than 100 in the autumn of 2003 (Hess, 2003). Aquatic and terrestrial debris has replaced the mitten crabs as the problematic material hindering fish collection. Because the screen demonstrated that it was generally fish friendly during mitten crab removal (1996–1999), it was the natural succession to test it for effective debris removal as well.

The goal of these studies was to determine if the traveling screen could be used to remove debris traveling, from the primary fish guidance louvers to the secondary fish guidance louvers, now that the mitten crab population is no longer a hindrance to fish collection. Other goals were to improve debris collection by modifying the debris removal system as well as improving the transport of collected debris to the debris hauling truck. The experiments presented in this report demonstrate the effectiveness of the traveling screen, especially during routine cleaning operations and when debris coming into the facility is heavy.

Three different techniques were used to determine the effectiveness of the traveling screen to remove debris.

These included:

(1) The addition of known amounts of debris, introduced upstream from the traveling screen, compared to the amount of debris recovered by the traveling screen.

(2) Overnight collection of debris in which the traveling screen was operated continuously, on average, for 15.5 hours per night.

(3) Ten minute debris collections within the below ground circular holding tank, coinciding with routine fish counts which were made every 2 hours at the TFCF.

Many improvements to the TFCF and the traveling screen were made during the debris removal tests. These improvements increased the recovery of added debris from 29 percent, at the start of these studies, to 56 percent after all modifications and repairs had been made. Improvement in the transport of this recovered debris, from the debris removal system (the traveling screen, hopper, conveyor, and other debris removal components within the secondary channel) to the debris hauling truck, also increased more than 30 percent. The traveling screen has proven to be effective at removing green aquatic debris, greater than 189 mm (7.4 inches), and woody debris, greater than 105 mm (4.1 inches), in length, or longer. The debris removal system has also proven to be mechanically reliable with minimal maintenance and repair.

The screen was operated for a total of 571 hours during the different studies, it collected 261 fish, of which 173 arrived at the traveling screen already dead from previous causes. Fifty-one live fish were collected and 37 dead fish with fresh wounds.

Seventeen fish of TFCF concern were collected, including:

(1) One dead Chinook salmon (*Oncorhynchus tshawytscha*).

(2) Sixteen splittail (*Pogonichthys macrolepidotus*), of which 10 were dead prior to collection by the traveling screen.

INTRODUCTION

Large quantities of debris are often present within the TFCF system. The first river-borne debris is encountered at the trash boom and trash racks, where water is first diverted into the facility. Debris passing through the trash rack can be deposited on the primary and secondary louvers, and within the large circular fish holding tanks and finally within the fish hauling tanker truck. Fish recovery and health are impacted by this debris. Therefore, as much debris removal as possible is beneficial to fish passage, salvage, and survival, the main objectives of the TFCF.

Debris loads entering the TFCF can be immense at certain times of the year due to natural debris accumulation, storm activity or because of up river events, such as dredging or barrier removal, to the point of interrupting and halting water delivery to the Tracy Pumping Plant. However, at other times, debris can be nearly nonexistent. The debris load often varies from year to year and even day by day so that debris coming into the TFCF is unpredictable and ever changing. The type of debris coming into the facility also fluctuates seasonally indicated by the change in debris composition and percentages of each type of debris. The debris composition is generally made up of aquatic macrophytes, terrestrial plant material both green and woody, as well as, peat, animals, and animal parts (mitten crabs, clams, and shells), and general manmade materials (trash). The seasonal differences in debris composition were noted during these studies.

This report focuses on the use of a traveling screen and its effectiveness to remove water borne debris traveling from the primary fish guidance louvers to the secondary fish guidance louvers, the modifications that were made to improve collection of debris as well as the transporting of collected debris to the debris hauling truck. Monitoring of the fish collected by the traveling screen was also added to these studies.

The traveling screen, (affectionately known as Crabzilla), was originally designed to remove Chinese mitten crabs moving downstream through the system in the autumn of the year. The traveling screen was designed to allow fish to pass through the screen so they could be retrieved, from the circular holding tank, for later release back into the Sacramento and San Joaquin Rivers. The mitten crabs were first detected in 1992 in the South San Francisco Bay area (Veldhuizen and Stanish, 1999) and populations increased dramatically between 1996 and 1998 at the TFCF. Over 750,000 mitten crabs were entrained during fish salvage work at the facility in 1998 (Siegfried, 1999) and the number of crabs surpassed 1 million by 1999. By the autumn of 2003, the crabs seem to have almost disappeared with less than 100 salvaged at the facility. Therefore, it was a logical step to determine if this traveling screen could be put to another use, that of removing water borne debris, which has become more prevalent and problematic in recent years. Removal of debris, like crab removal, from the secondary channel should lessen fish injury and make fish collections from the circular holding tanks, the final fish guidance area, easier and less stressful on the collected fish. The TFCF was designed to use water hydraulics and fish behavior to guide fish through the facility to the circular holding tanks where they can be collected for transport back to the Sacramento River downstream from the facility. Aquatic debris removal should keep the secondary louvers clean, for longer periods, providing closer design hydraulics at the secondary louvers and therefore better fish guidance. Debris reduction will also benefit the salvaged fish within the haul-out bucket and the fish hauling truck where fish are in close quarters with debris and more susceptible to injury.

Fish injury and death that might have been caused by the traveling screen, as well as uninjured fish collected by the screen, were recorded during the studies. The screen was operated for a total of 571 hours during the different studies; it collected 261 fish of which only 17 fish were of TFCF concern. These species of concern included: one dead Chinook salmon (*Oncorhynchus tshawytscha*), an experimental or hatchery fish, that was dyed red and the rest were splittail (*Pogonichthys macrolepidotus*); of which 10 were already dead before being collected by the traveling screen, three were possibly killed by the traveling screen and three were alive and uninjured. Of the 210 dead fish collected, 173 had old injuries and 37 had fresh wounds.

METHODOLOGY

The traveling screen was developed at Reclamation's, Water Resources Research Laboratories (WRRL), with the help of the Fisheries and Wildlife Resources Group. The traveling screen is approximately 8 feet wide (2.4 m) and spans the entire width of the secondary channel. It is lowered into the secondary channel via an overhead winch and steel guides built into a large framework designed to hold both the traveling screen and a guide plate above the secondary channel, when not in use. The traveling screen is approximately 19 feet in length (5.7 m), set in the secondary channel on an angle of 10 degrees off of vertical, sloping upstream from top to bottom. In addition, a guide plate is mounted in the same plane as the traveling screen at a distance of 4 inches (10 cm) upstream from the traveling screen. The guide plate was added to prevent the mitten crabs from dropping back into the secondary channel once they had been captured on the traveling screen. The traveling screen is a moving, belt type, screen composed of plastic coated stainless steel wire, and stainless steel link chains that are driven by drive sprockets at each end of a horizontal roller. These plastic coated wires are spaced approximately 1.5 inches (4 cm) apart, horizontally, and are kept in alignment with horizontal guides that run the width of the screen. These guides are spaced 4.5 inches (11 cm) apart, vertically, up and down the screen. This traveling screen, therefore, has openings 1.5 inches wide by 4.5 inches high for fish to pass through (4 x 11 cm). Eight to 12 stainless steel, angle brackets attached horizontally across the chain and plastic coated wires approximately every 4 feet (1.2 m), are equipped with 3 inches (7.5 cm) nylon brushes that worked as lifts to prevent the crabs, as well as debris, from falling back into the secondary once impinged on the traveling screen surface. Crabs, as well as debris, are trapped between the traveling screen on which they are deposited, an upper and lower lift and the guide plate, mounted in front of the screen. The crabs and debris are then lifted upward until they fall or are dislodged, by a series of three spray booms, into a collection hopper on the traveling screens downward travel (White and Mefford, 2000). Crabs and debris in the hopper are then transported upward out of the hopper into the bed of a debris hauling truck via a solid rubber conveyor belt having solid rubber paddles approximately 4 inches (10 cm) high. The conveyor is housed within a stainless steel box, designed to prevent crabs or debris from falling back down into the hopper or off to the sides of the conveyor to the ground below.

Three different experiments were used to evaluate the traveling screen and the debris removal system for its effectiveness to remove debris from the secondary channel. These experiments included:

(1) Addition of known amounts of aquatic plant material (debris), upstream from the transition boxes at the primary louvers, compared to the amount of debris recovered by the traveling screen.

(2) Evaluation of debris collected during overnight screen operation.

(3) Debris collected during the routine 10-minute fish counts.

For all experiments, the traveling screen speed was approximately 8 feet per minute (2.4 m/min), the conveyor speed was approximately 10 feet per minute (3 m/min).

Throughout these three different experiments, recommendations and modifications were made to the traveling screen, hopper, conveyor, and other components of the debris removal system, to make it more effective at removing debris.

Characterization of the debris collected by the traveling screen was recorded. The type, amount, species, percentages of each type of debris was noted during the 10-minute counts and the overnight debris collections. The debris, in the addition experiments, was composed of green aquatic vegetation, mostly Egeria, as well as, some woody and terrestrial debris. The seasonality of different types of debris, occurring at the TFCF during these experiments, was observed and is presented in this report.

Added Debris Experiments

Debris used in the debris addition studies was collected from the trash rack during routine maintenance and stored in large, water filled, tanks to keep it fresh until use. This debris was composed mostly of Egeria, with some Eurasian water milfoil (*Myriophyllum specatum*), coontail (*Ceratophyllum demersum*), and green and woody terrestrial vegetation. Most manmade objects, large branches, and terrestrial vegetation were removed from the debris prior to experimentation. Because the aquatic vegetation tends to fragment into smaller pieces with use, added debris material was used only once and then discarded.

There are four primary louver arrays, four transition boxes and four bypass tubes that deliver water from the primary channel to the secondary louvers, via the secondary channel. Each set (louver, transition box and bypass tube) is referred to by number, (No. 1 through No. 4), the upstream primary louver array closest to the trash rack is designated as transition box and bypass No. 1.

Debris was added to only one of the four transitions boxes, at a time, per test. The debris traveled from the primary louvers, through one of the bypass tubes to the traveling screen that was lowered into the secondary channel just upstream from the secondary louvers (figure 1). The amount of debris recovered by the debris removal system and the amount of debris transported to the debris hauling truck was compared to the known debris amount that was initially added at the transition box. The debris removal system refers to all of the components that work together to remove the debris within the secondary channel (the traveling screen, hopper, conveyor, stainless steel tray and sluice box, etc.). The percentage of recovered debris that was transported to the truck and the basket, a secondary debris collection location, compared to the percentage of recovered debris that was lost within the debris removal system and not transported to the truck or the basket was also calculated.

debris in truck
debris in hopper
debris below the hopper
debris in basket
\+ debris not recovered
= 100 percent of added debris

debris in truck
debris in hopper
debris below hopper
\+ debris in basket
= recovered debris

debris in truck
\+ debris in basket
= transported debris

The success or failure of the traveling screen to remove debris, as well as the success or failure of the rest of the debris removal system to deliver collected debris to the debris hauling truck for disposal, via the hopper and the conveyor, was evaluated by weighing the wet debris before addition and after recovery and transport. Several different evaluations of debris recovery were made based upon repairs, modifications, and additions to the debris removal system, over several years.

Debris added in front of the transition boxes took approximately 4 minutes to arrive at the traveling screen. This was determined initially using spray painted debris, where a different color was added to each of the four transition boxes. Each of the evaluations, using added debris, was set to a 20-minute time interval to provide plenty of time for the added debris to arrive at the traveling screen and be transported to the debris hauling truck. Naturally, occurring debris, within the water, was collected by the traveling screen during 20-minute time periods, in which no debris was added, and served as background information. Background debris values were subtracted from the much larger added debris quantities (approximately 12.5 kg) prior to calculating the recovery and distribution of the added debris. All added debris trials were conducted with the traveling screen completely down and rotating continuously in the secondary channel.

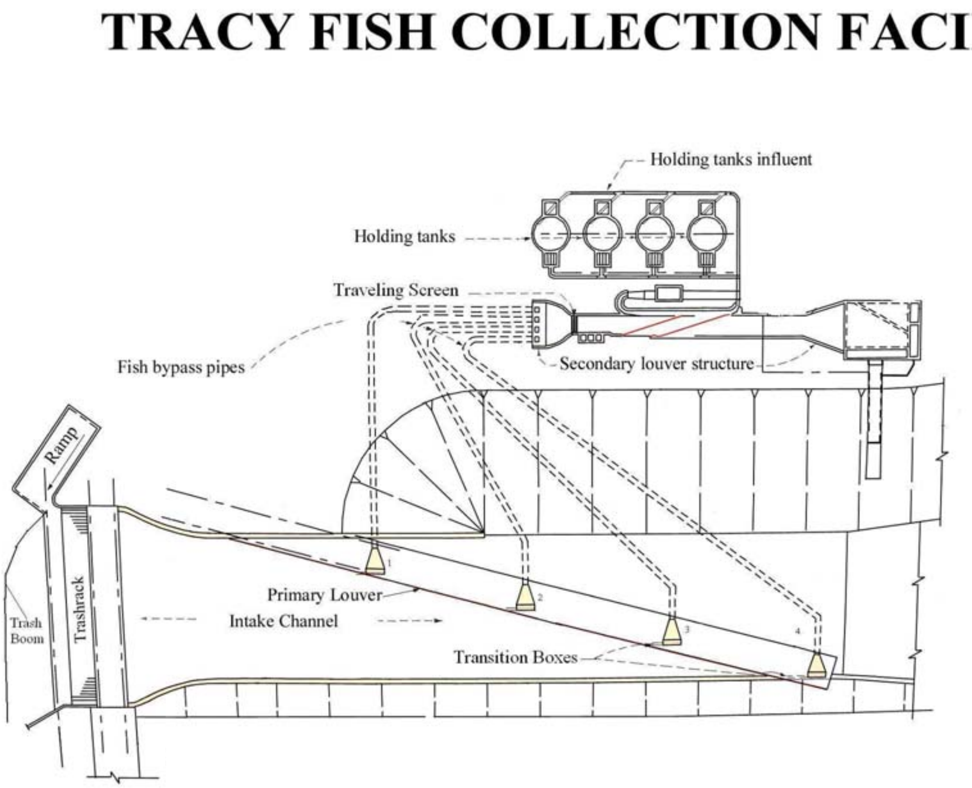

FIGURE 1.—Schematic diagram of Reclamation's Tracy Fish Collection Facility, Tracy, California.

Overnight Debris Collections

Overnight debris collections at the TFCF were started in March 2002, and went through April 2005. During this period, the traveling screen was operated for 27 nights during most months except January, May, and September. The average debris collection, for each of the 27 overnight runs, was 15.5 hours of operation per night. Debris was separated into the following categories: green and woody debris, and other natural debris, such as shells and rocks, as well as manmade trash. Wet weights, of each debris category, were collected as well as a total weight for all the debris collected within a single night. Debris accumulations were also separated according to the debris collection location. Although it was desired that the debris be collected and transported to the debris hauling truck, debris was often found deposited within the hopper corners, against the back wall of the hopper or in the hopper drain tube, especially prior to hopper modifications. Debris was also collected from below the hopper and conveyor, in a suspended net or on the wooden deck below the conveyor belt, prior to the construction of the stainless steel tray, sluice box, and basket. Wet debris weights, from each of these locations, were recorded as well as the percent debris transported to the debris hauling truck compared to percentages of debris deposited in the other locations mentioned above. Species of aquatic plants were identified and the major type of debris for that field trip was recorded so that a record of debris seasonality could be composed to help predict debris loads as well as debris type, dependent upon the time of year.

Ten-Minute Count Collections

Ten-minute debris collections were made coinciding with routine 10-minute fish counts, a 10-minute sub-sample taken every 2 hours, that is used to estimate fish salvage at the TFCF. This debris collection was made by passing water from the secondary channel into a circular holding tank for 10 minutes. The water coming into the holding tank was shut off, the water within the holding tank was then slowly drained, and the fish and debris that had entered the holding tank, during the 10 minutes of collection, were gathered into a collection bucket at the bottom of the circular holding tank. Debris, collected during these 10-minute time periods, was weighed (wet weight) and 10 green stems were measured for length. The length and diameter of 10 woody stems were also measured that represented the size of woody debris entering the circular holding tank for each of the collections. This provided an evaluation of debris size that passed through the trash rack and past by the primary louvers to the transition boxes and through the secondary channel, with the traveling screen, both in and out and into the below ground circular holding tank.

Effectiveness of the Traveling Screen

The traveling screen was initially designed to remove crabs and, at the same time, allow fish to pass through unharmed, so that they could be collected within the circular holding tank. As part of this study, each part of the debris removal system was evaluated for its effectiveness to harvest debris of all types and ultimately move that debris to a debris hauling truck. The traveling screen, the spray booms, the hopper, the drain tube, the conveyor and the area below the conveyor were all part of this evaluation. Modifications to some of the different components listed above were made and reevaluated to confirm that these modifications truly did improve debris collection or the debris transport capability of the debris removal system. Recommendations, to replace some portions of the system rather than modify components, were made to personnel of the TFCF.

Collected Fish

Fish collected by the traveling screen, during experimentation, were identified, weighed (grams), and measured, from the snout of the nose to the inner opening in the fork of the tail, (fork length, mm). Notations on the fish's appearance were also made.

These included:

(1) Whether the fish was dead or alive.

(2) The cause of death and how long they had been dead, when possible.

(3) If the fish was alive, any injuries, and location of those injuries were documented. The time and cause of death or injury were also noted.

(4) The location where the fish was collected within the debris removal system.

Fish information was recorded on the “Federal Facility – Fish Salvage Form” for the information of the TFCF as well as National Oceanic and Atmospheric Administration (NOAA) and California Department of Fish and Game (CDFG). Fish that were alive were maintained in a below ground, circular, holding tank and later transported back to the Sacramento River via the fish hauling, tanker truck along with other salvaged fish.

A comparison of fish length was also made between fish collected by the traveling screen and fish that were collected the same day within the circular holding tank during the routine 10-minute fish counts. This comparison was made to determine if there was a size difference between fish collected by the traveling screen and fish collected in the circular holding tank. A difference in length might indicate a possible size limit or deterrent to fish passage through the traveling screen.

The mean, standard deviation, percentages, and sample size (n) were recorded and calculated for the data on debris removal and transport as well as for the fish collected by the traveling screen. This statistical information is presented within the text of this report and in the figures, tables, and appendices to help determine the significance of the data.

RESULTS AND DISCUSSION

The use of the traveling screen and its effectiveness to remove water borne debris traveling from the primary fish guidance louvers to the secondary fish guidance louvers was evaluated. The traveling screen was originally designed to remove Chinese mitten crabs moving downstream through the system in the autumn of the year and at the same time allowing fish to pass through the screen. Modification to the components of the debris removal system, other than the screen size, was done to increase the effectiveness of debris removal, as well as, the transport of the collected debris to the debris hauling truck. The screen opening size was not altered because tests done at the Reclamation’s, WRRL. With the help of the Fisheries and Wildlife Resources Group, indicated that the current screen was a good compromise between crab removal and fish passage.

Maintenance

Routine screen, hopper, and conveyor maintenance and inspection was performed, throughout all of the traveling screen studies, to prevent mechanical failure. Inspections and tightening of hardware were conducted after approximately each 75 to 100 hours of operation. The traveling screen and the rest of the debris removal system were operated a total of 571 hours, without any failures other than a few loose fittings, corrosion of the ramp brush bracket (located on the floor of the secondary channel), and some debris deflection tines coming loose. Greasing the moving parts and conveyor belt alignment was conducted by the Fish Facility Branch at the TFCF. The vertical brushes, which provided a positive seal between the screen and the secondary channel, were replaced once during the 4 years of experimentation and the brush on the ramp at the bottom of the secondary channel was replaced three times. Corrosion, of the different metals used in the manufacturing of the brackets, to hold the brushes, was a problem only on the ramp brush, because it was submerged within the secondary channel, continually. All of the other components of the debris removal system proved to be reliable and long-lived.

Seasonal Debris and Debris Types

The debris type was observed to change with the yearly seasons. During January through April, woody debris (sticks, culms from riparian plants and bark) was most often the dominant debris collected. Egeria, a submerged aquatic macrophyte, became more prevalent during the summer months and dominated the debris loads from June through December. Between 2001 and 2004, Egeria constituted the most common problematic debris material within the TFCF. Egeria debris loads increase during the months of October to December, table 1. Water hyacinth (*Eichornia crassipes*) was common, in autumn and winter, at the trash boom, the boom conveyor, and the trash rack and creates a severe debris problem at these locations. Water hyacinth floats and it tended to hold together in mats outside the facility, and therefore, presented fewer debris problems inside the TFCF. Egeria and terrestrial green vegetation was often common after the barriers on the San Joaquin, Old River Channel, and the Grant Line Canal were removed in the autumn of each year. Although not seasonally dependant, large balls of peat were observed two or three times a year at the trash boom and trash rack. Peat created debris problems upon removal from the trash rack because it would tend to break apart sending peat fragments throughout the facility. Other aquatic vegetation recovered included: coontail, milfoil, American elodea (*Elodea canadensis*) as well as emergent vegetation such as cattails (*Typha sp.*), bulrush (*Schoenoplectus sp.*), pale yellow iris (*Iris pseudacorus), and* water primrose (*Ludwigia sp.*). Crabs, in the autumn and manmade trash throughout the year were common, but only constituted a small percent of the debris. Shells, metal, and rocks were collected by the screen but infrequently and in small amounts.

Changes to the TFCF and the Debris Removal System

During the summer of 2002, it was discovered that the transition boxes, at the end of each of the four primary louver arrays; had holes and were badly corroded. Divers were contracted to patch these holes, in the autumn of 2002, until replacement transition boxes could be constructed and installed. The repaired transition boxes were removed and replaced with newly constructed transition boxes, during the spring of 2004, when water delivery demands are usually low. These changes made at the TFCF improved debris delivery from the primary louver arrays to the secondary channel.

TABLE 1.—Seasonality of debris types at the Tracy Fish Collection Facility observed during debris experiments

Month	**Year**				
	2001	**2002**	**2003**	**2004**	**2005**
January		Wood	Wood		Egeria, Water Hyacinth
February			Wood		Wood
March		Peat, Egeria		Egeria	Egeria, Wood
April		Wood			Wood, Egeria
May					
June			Egeria, Wood		
July		Egeria		Egeria, Water Hyacinth	
August		Egeria, Peat			
September					
October					
November	Egeria, Terrestrials *	Egeria	Egeria, Wood		
December			Egeria, Wood	Egeria	

* If two or more debris types are listed for a month and year, the first one was the more prevalent.

Modifications to the debris removal system affected the collection and transport of debris from the traveling screen to the debris hauling truck. Most of the modifications to the debris removal system were done during the summer prior to the anticipated crab migration, which occurs in the autumn of each year. The hopper and the conveyor were modified during the summer of 2003. Later, it was determined, using a suspended net below the hopper, conveyor, and a portion of the traveling screen, that much of the debris that was collected by the traveling screen was lost back into the secondary. It fell from the traveling screen before or after reaching the hopper, or the debris was flushed out the bottom of the hopper by excess water, or fell out of the hopper and back into the secondary, through the opening by the traveling screen. Therefore, a stainless steel tray was added below the hopper, conveyor, and a portion of the traveling screen during the summer 2004.

Changes made to the debris removal system between 2002 and 2004:

(1) At the top of the conveyor, some of the debris fell off either side of the conveyor or hung up on the conveyor axle. This problem was solved by building sheet metal guides for both sides of the conveyor so that the debris

stays on the conveyor belt (winter, 2002). This helped insure that the debris traveling up the conveyor was deposited into the debris hauling truck (see figure 2a and 2b).

(2) Stainless steel punch plate, having a hole size of 3/32 inch (2.25 mm), was installed on the west (downstream side) wall of the hopper (July 2003). This prevented debris from collecting on the west ledge or within the gutter area, thereby, maintaining flow of excess water through the hopper drain tube. Before, the punch plate installation, debris would clog the drain tube within a few hours of operation (see figure 3a and 3b). Aluminum punch plate was first used to cover the gutter area and drain tube. However, this material was unsuitable because it was not as slick as stainless steel and plant material would tend to cling on the punch plate (July 2002). Also, the hole diameter was larger, approximately 1/8 inch (2.9 mm) allowing Egeria stems to catch in the holes and clog the surface of the punch plate.

(3) The stainless steel tines intercept and drop much of the debris, sprayed off of the traveling screen, onto the conveyor. By lowering these tines further into the hopper, less debris passed under the tines, to the punch plate screen mounted on the back wall of the hopper (see figure 4). This was done in July of 2003. The same time the aluminum punch plate was replaced with stainless steel punch plate.

(4) Within the hopper, on the east side (upstream direction) of the conveyor, there were two steel ledges that met approximately in the middle of the hopper. These two ledges met at differing heights and therefore, did not deliver aquatic vegetation, crabs, woody debris, and other material to the conveyor effectively. The shallow sloped ledge was cut and sloped more steeply to match the slope of the other ledge, thereby forming a single ledge, improving the flushing of debris off this ledge and into the hopper (July 2003). This new ledge was then covered in stainless steel providing a slicker surface to help slide debris onto the conveyor (see figure 5a and 5b).

(5) The conveyor wall rises approximately 6 inches into the hopper. This conveyor sidewall created a vertical wall against which debris would be deposited by the force of the water from the spray booms. The slope of the conveyor was as shallow as possible and could not be changed without major modifications to the entire conveyor and hopper system or cutting into the concrete secondary channel. Therefore, during July 2003, this vertical wall was covered with smooth, rounded, and curved stainless steel plate. In addition two spray jets were added to the north end of the hopper to help force debris off of this portion of the conveyor wall (see figure 6a and 6b).

FIGURE 2a.—Before: Debris would fall off the sides of the conveyor or be blown away by the wind and therefore was not collected in the debris hauling truck.

FIGURE 2b.—After: Sheet metal guides keep debris on conveyor to the end of the belt so that it is collected.

FIGURE 3a.—Before: At the back wall of the hopper (west ledge) debris too large to flow through the drain tube would accumulate at the base of the hopper.

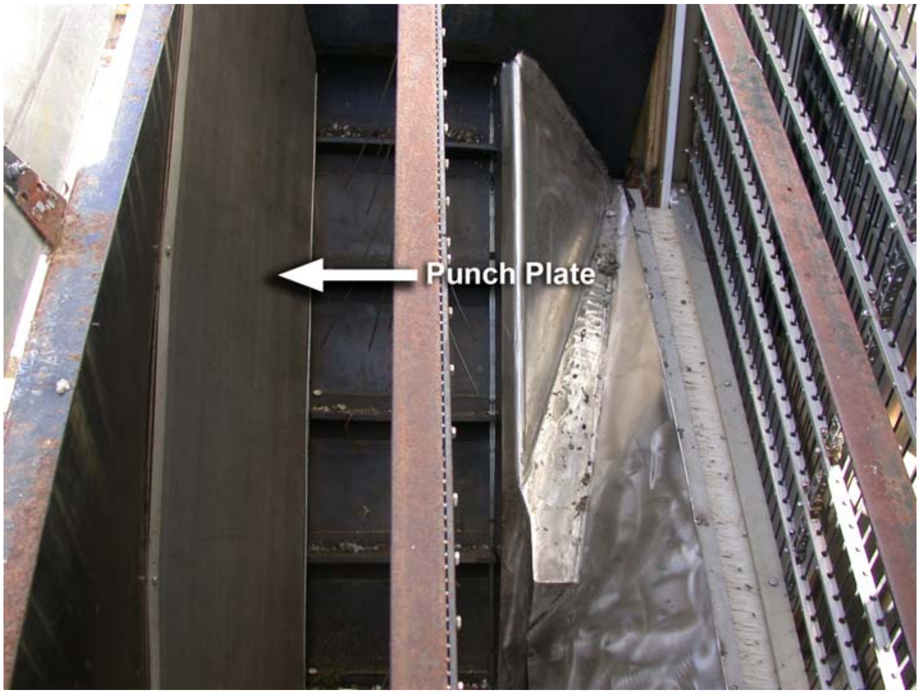

FIGURE 3b.—After: Stainless steel punch plate was installed to cover the drain tube and west gutter. This punch plate provides a slick surface, which allows most of the debris to slide onto the conveyor.

FIGURE 4.—The stainless steel tines were lowered further into the hopper and closer to the conveyor belt to intercept and drop more debris onto the conveyor.

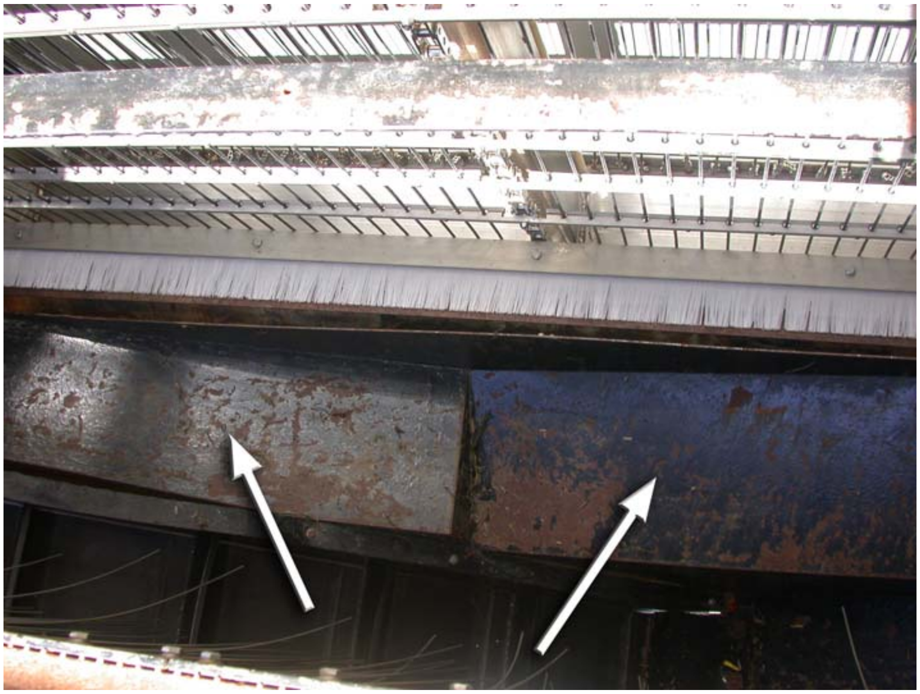

FIGURE 5a.—Before: Two, different angle, steel ledges, on the east side of the hopper (upstream side), collected much debris that the sprayers were unable to move onto the conveyor.

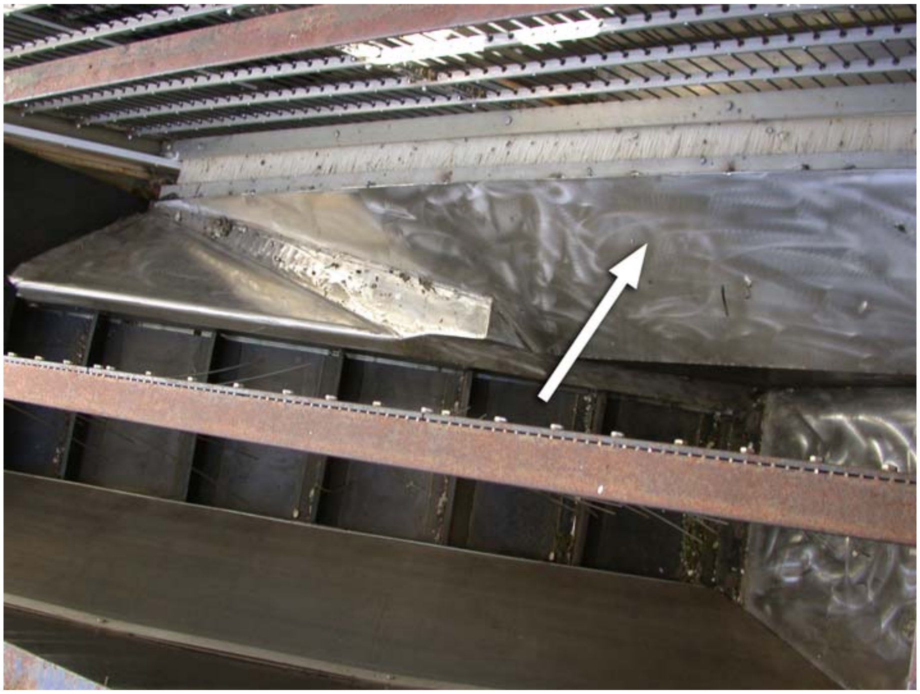

FIGURE 5b.—After: The two ledges were cut and sloped more steeply into a single ledge. The single ledge was then covered with stainless steel so that debris would slide, onto the conveyor, more easily.

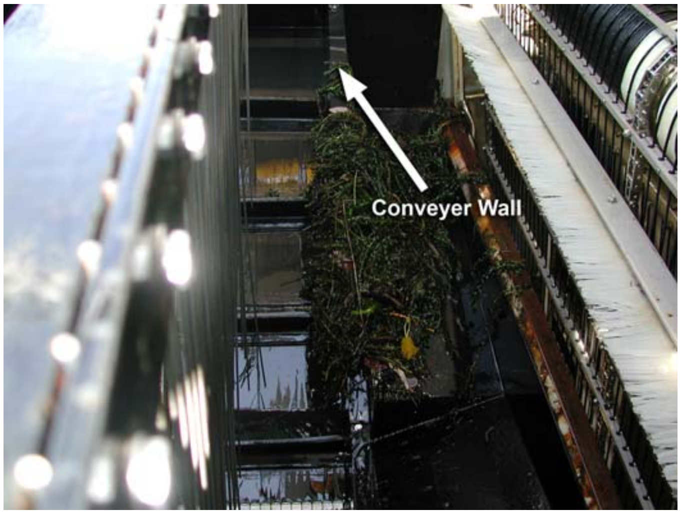

FIGURE 6a.—Before: A vertical wall of the conveyor stopped debris from being flushed off the northeast hopper ledge and onto the conveyor.

FIGURE 6b.—After: This wall was clad in smooth, rounded stainless steel allowing more debris to slide onto the conveyor. Two spray nozzles (white dots at top) were also added to this corner of the hopper to help move debris out of this area and on to the conveyor.

(6) Extra lifts were added to the traveling screen, increasing the number of lifts from 8 to 12, in the spring of 2004 (see figure 7).

(7) A stainless steel tray was built and attached below the hopper, conveyor, and a portion of the traveling screen (spring and summer, 2004). This was done to catch debris that failed to fall into the hopper or was back flushed off the bottom of the conveyor. This material was previously lost back into the secondary channel after being collected by the traveling screen. The tray is sloped to one corner where the debris is flushed with excess water, from the conveyor and hopper, into a sluice box which delivers the debris to a basket, a secondary debris collection point (see figure 8).

(8) The cover to the hopper was replaced with one made of stainless steel. The previous steel plate cover was extremely heavy, hard to lift and was a safety concern (August 2003).

(9) The brush array that lays across the bottom of the secondary channel, attached to a steel ramp, was replaced three times during 4 years of study due to corrosion problems. This brush was replaced January 2001 at the start of the studies, in June of 2002 and again in 2004. Because this brush is continually submerged and provides a positive seal between the traveling screen and the bottom of the secondary channel it was replaced when corrosion became obvious, approximately every year and a half.

Added Debris

Many of the initial traveling screen studies involved the addition of debris in front of the transition boxes at the primary louvers (mean of 12.5 kg/test, 27.5 lbs). Although debris delivery from the primary louver array to the traveling screen in the secondary channel took approximately 4 minutes, some of the obvious variables that altered the arrival time of debris at the traveling screen included; incoming or outgoing tides, river velocity and volume and the number of pumps operating at the Tracy Pumping Plant. The conditions of the four transition boxes before they were repaired; after they were repaired in the autumn of 2002; and again after they were replaced altered the debris delivery time.

Many other factors that affected the water flow through the transition boxes and the bypass tubes included the flow differential at the trash rack, how clean the primary and secondary louvers were, the number of constant velocity pumps operating at the TFCF, the number of holding tank pumps in operation, as well as Clifton Court operations.

After several debris evaluation and collection trips, using the traveling screen, it was found that the transition boxes were corroded and holes were present in the sidewalls of the transition boxes. Mean debris recovery prior to the transition box repairs ranged from 21, 23, 41, and 30 percent for bypasses No. 1, No. 2, No. 3, and No. 4 respectively. This represents an average of 29 percent recovery of added debris, for all of the debris additions

FIGURE 7.—Additional lifts were added to the traveling screen to help collect more debris.

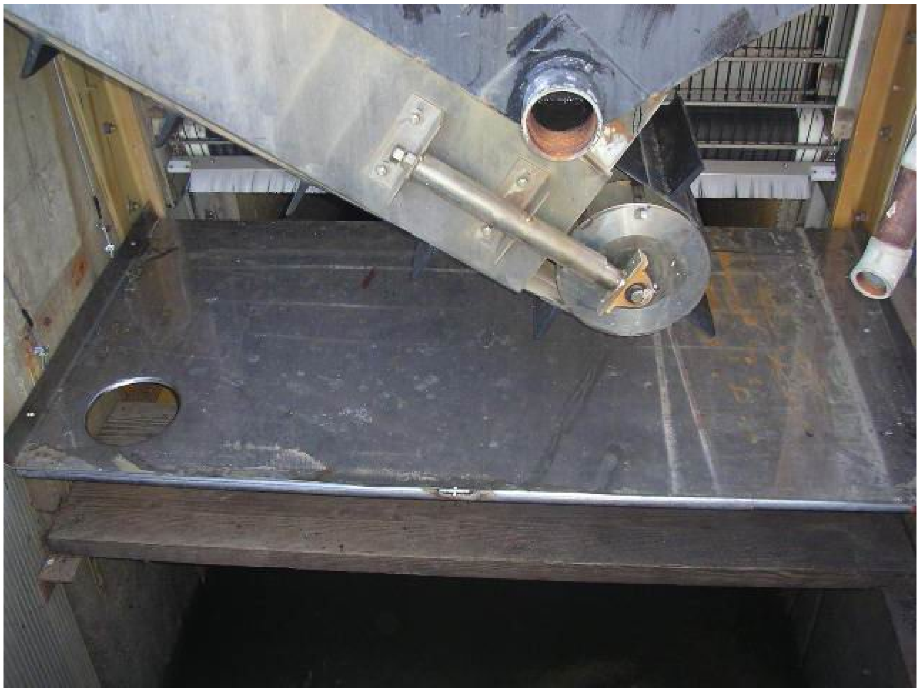

FIGURE 8.—Initially, only 54 percent of the debris collected by the traveling screen was transported to the hauling truck. The remainder would fall beneath the hopper or be washed back into the secondary channel. A stainless steel tray was built and mounted below the (hopper, conveyor and a portion of the traveling screen) to collect and sluice previously lost debris into an easily retrievable basket, a secondary collection point.

prior to repairing the transition boxes. Individual tests, of recovered added debris, varied greatly, from less than 17 percent, for three of the bypass tubes, No. 1, No. 2, No. 4, too as great as 70 percent for bypass No. 3 for a one time maximum recovery. Bypass No. 3 provided the highest initial percentage of debris recovery, 41 percent, prior to transition box repair. In figure 9, the mean percent debris recovered prior to any repairs is given in the left-hand bars for each bypass tube. Field evaluations of the primary louvers and the transition boxes, in May of 2001 by Reclamation personnel, also indicated that transition box No. 3 and bypass tube No. 3 "exhibited the greatest degree of uniformity" based on water velocity going through the transition box, at all depths. Therefore, transition box No. 3 and bypass No. 3 were performing closer to design criteria (Kubitschek, 2001). It was also found upon underwater inspection, of all the transition boxes, that transition box No. 3 had the least damage of the four transition boxes (Larsen, 2002). Because of the corroded holes in the transition boxes, recovery of known amounts of added debris was impossible to evaluate consistently and accurately. It is believed that much of the added debris was lost through the holes in the transition boxes and therefore was unable to arrive at the traveling screen for collection. Prior to transition box repair, each of the bypasses was tested four times (n = 4) using added debris.

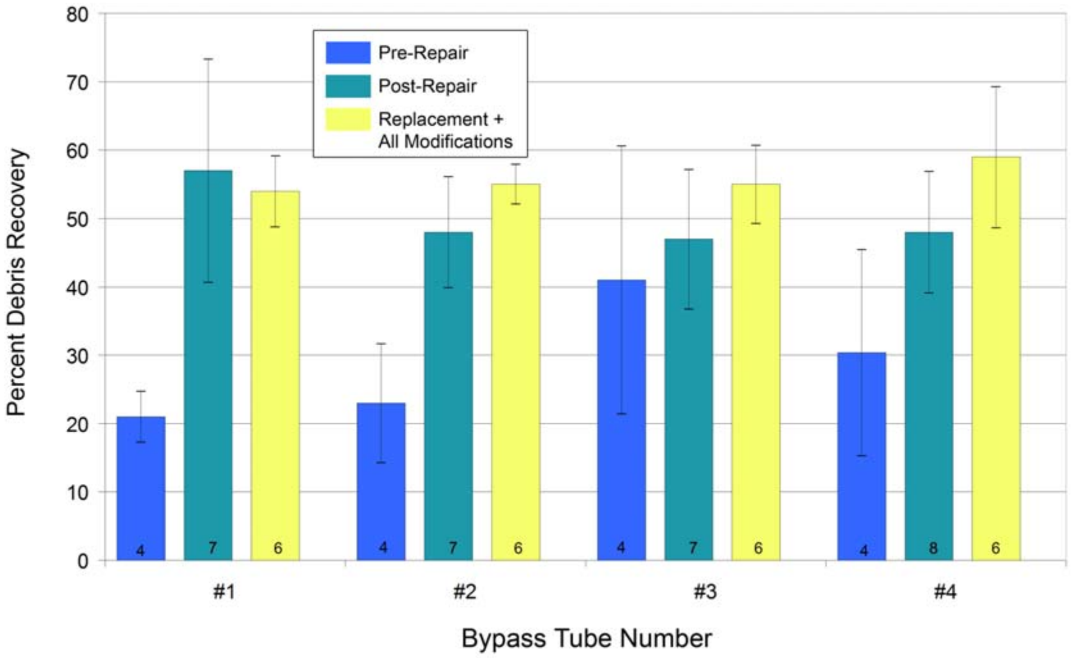

FIGURE 9.—Mean percent debris recovery and standard deviation, of added material for each bypass, using the traveling screen. Number at the base of each bar is the number of samples (n) collected for each mean value.

After the transition boxes were repaired, as well as, the addition of the debris guides at the top of the conveyor and covering the drain tube in the hopper with perforated plate, debris addition experiments were once again commenced. Experiments conducted between September 2002 and April 2004 showed a substantial improvement in debris delivery and recovery. Mean debris recoveries of 57, 48, 47, and 48 percent, for bypasses No. 1 (n = 7), No. 2 (n = 7), No. 3 (n = 7), and No. 4 (n = 8) respectively, were obtained (middle bars for each bypass tube in figure 9). A mean debris recovery of 50 percent for all of the transition boxes and bypass tubes was observed, an increase of 21 percentage points over the amount of debris recovered prior to transition box repair and any modifications to the debris removal system.

After all modifications to the debris removal system were made, as well as the transition boxes being replaced, improvements were once again seen. Mean debris recoveries of 54, 55, 55, and 59 percent for bypasses No. 1 (n = 6), No. 2 (n = 6), No. 3 (n = 6), and No. 4 (n = 6), respectively and a $\bar{x}$ 56 percent overall debris recovery was obtained for all debris addition tests (figure 9, right-hand bars for each bypass tube). This indicates further improvement of 6 percentage points, from 50 to 56 percent between the repaired transition boxes and the new transition boxes, as well as, completion of all of the modifications to the debris removal system.

Transition box improvements, pre-repair to post-repair, are mostly seen as improvements, in debris delivery to the traveling screen from the primary channel to the secondary channel. Whereas, the additions to the debris removal system and completion of all of the modifications to the debris removal system, i.e., the screen, hopper, conveyor and the addition of the stainless steel tray are viewed as benefits to debris collection and debris transport from the traveling screen to the debris hauling truck, the primary debris collection point. A secondary debris collection point, the basket below the stainless steel tray, was added to the debris removal system and, therefore, the percent of debris recovery and the percent of debris transport data include this additional debris biomass, after transition box replacement and all modifications have been made.

Debris recoveries listed above for the pre transition box repairs, post transition box repairs and transition box replacement as well as all the modifications to the debris removal system are the percentages of debris recovered by the traveling screen, but not necessarily delivered to the debris hauling truck. Included in these recovery percentages is not only the debris that was delivered to the debris hauling truck but also the debris collected elsewhere. Debris caught by the traveling screen but remaining in the hopper, or debris that fell below the hopper and the traveling screen into a suspended net below and later into the stainless steel tray, which replaced the net, as well as, debris deposited into the collection basket were included. This cumulative recovery reporting was done to confirm that modifications, to the debris removal system, were making the system more efficient. It became important that information on recovered debris in areas other than just the debris hauling truck be gathered to verify that the modifications made to the debris removal system were truly improvements in debris collection and debris transport.

Figure 10 compares the percent material collected by the traveling screen and delivered to the debris hauling truck, to the percent that was collected by the traveling screen but was not delivered to the debris hauling truck. This debris was hung up in the hopper, below the hopper and conveyor or elsewhere after being collected by the traveling screen. Note, that the effectiveness of the debris removal system, to transport the debris to the debris hauling truck, improved because of the modifications. Efficiency improved from a mean of 54 percent for all bypasses tubes, pre repairs, (n = 4 four for each bypass x 4 bypasses for n = 16), to a mean of 74 percent after the transition boxes were repaired (n = 29) and some modifications were made, to a mean of 96 percent (n = 24) after all modifications were made and the transition boxes had been replaced. Some of this improvement, between before and after repairing the holes in the transition boxes (54 to 74 percent), is no doubt the result of being able to deliver the added debris material to the traveling screen and not just improvements to the debris removal system, which were ongoing concurrently.

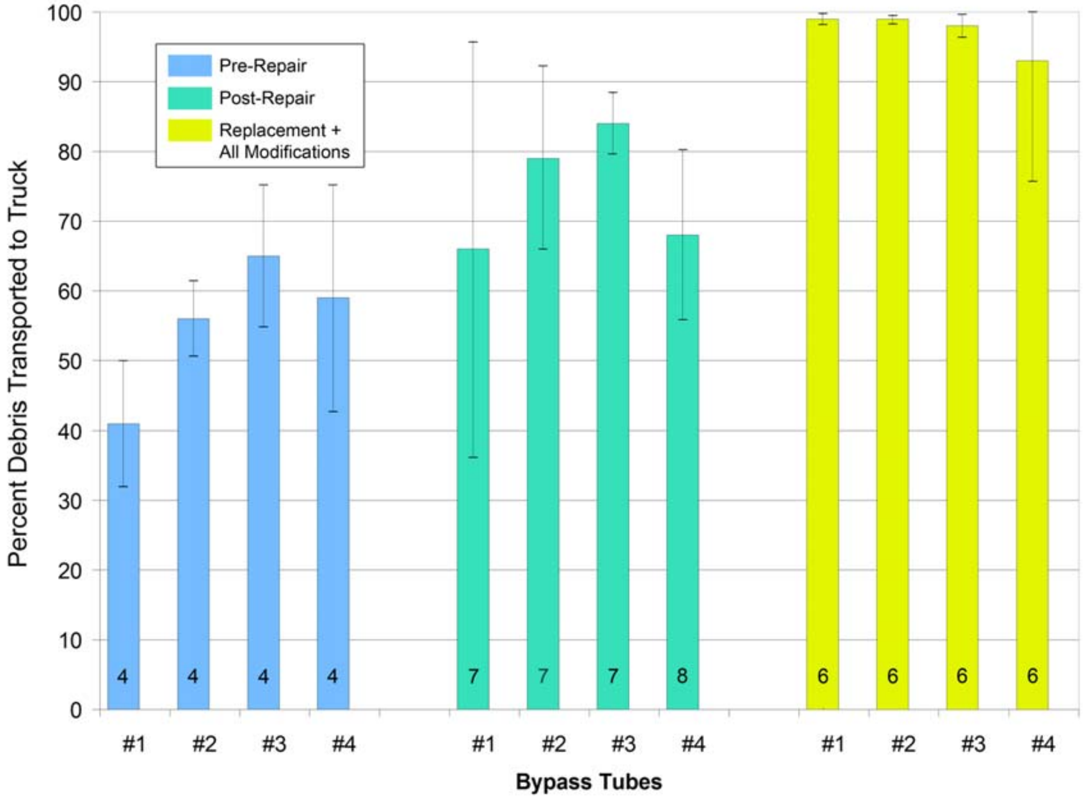

FIGURE 10.—Mean percent transport of recovered debris and standard deviation, added debris collected and delivered to the debris hauling truck by the debris removal system. Number at the base of each bar is the number of samples (n) collected for each mean value.

Overnight Debris Collection

Overnight operation of the traveling screen took place during all kinds of debris conditions such as; light and heavy debris loads, with crabs present and absent, during retrieval of aquatic plants as well as woody and manmade material. The overnight debris collection ranged from 13.5 to 17 hours per night, with an average of 15.5 hours per night. The traveling screen and the rest of the debris removal system were operated for 27 nights between 2002 and 2004 for a total of 492 hours of operation. Debris collected by the traveling screen varied from night to night, as well as, season to season. The most debris collected during a single night was 115 kg (253 lbs) in November 2002. Sixty-nine kg (60 percent) of the debris was transported to the debris hauling truck. The remaining 46 kg (40 percent) was stuck in the hopper or deposited in the net below the hopper and conveyor, and therefore, would have been lost back to the secondary. This debris collection occurred prior to the completion of all modifications to the debris removal system at which time debris transport to the debris hauling truck showed marked improvement. The average amount of debris recovered per overnight run was 36 kg (79 lbs). Figure 11 illustrates the amount of debris in kilograms collected by the traveling screen for each of the 27 overnight runs.

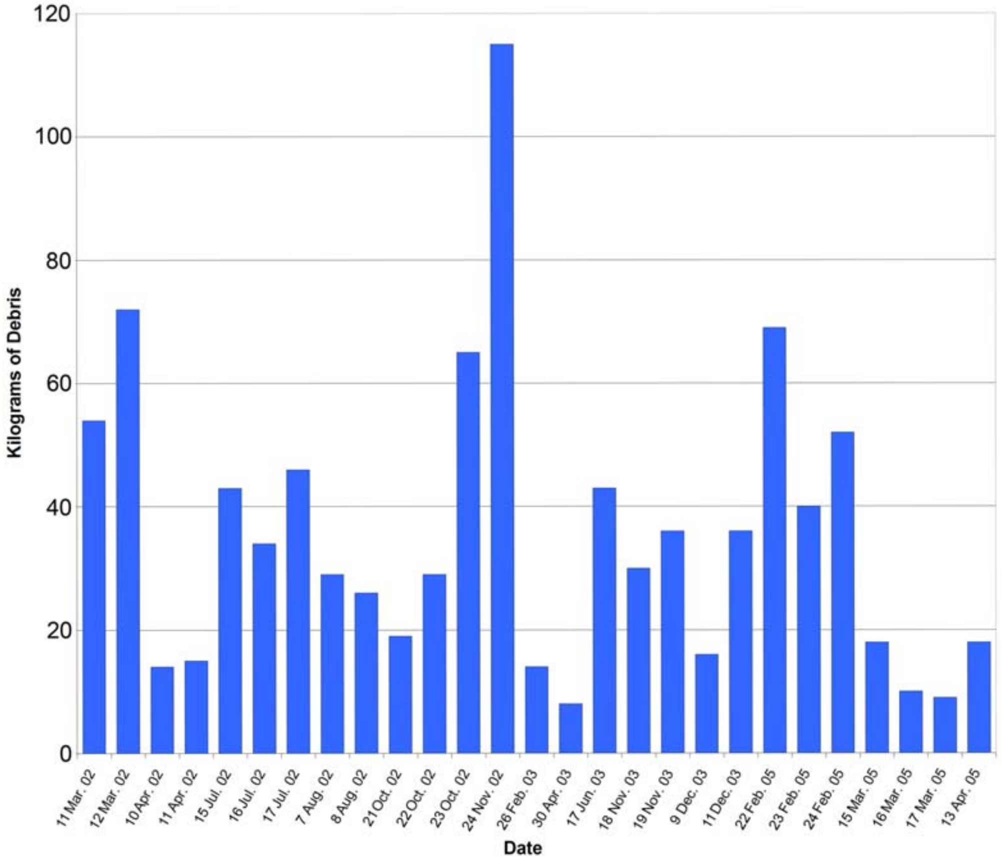

FIGURE 11.—Kilograms of debris collected per night, using the traveling screen. Each of the 27 overnight runs averaged 15.5 hours in length.

The kilograms of debris being reported in the overnight collections in figure 11, is total debris and not all of this collected debris was delivered to the debris hauling truck. Initially only a mean of 63 percent of the overnight debris collected was transported to the debris hauling truck. After all modifications to the debris removal system were made the percentage of debris being transported to the debris hauling truck including the debris sluiced to the collection basket increased to a mean of 94 percent (see figure 12). This increase in effectiveness to transport collected debris to the debris hauling truck is very similar to the improvement in debris transport, seen in the debris addition studies, where debris was added at the different transition boxes. In those studies, 96 percent of the added debris was delivered to the debris hauling truck or the basket after all repairs and modifications were made. Values for n are presented in figure 12 at the bottom of each bar for the pre-repair, repair, replacement, and modifications as they occurred.

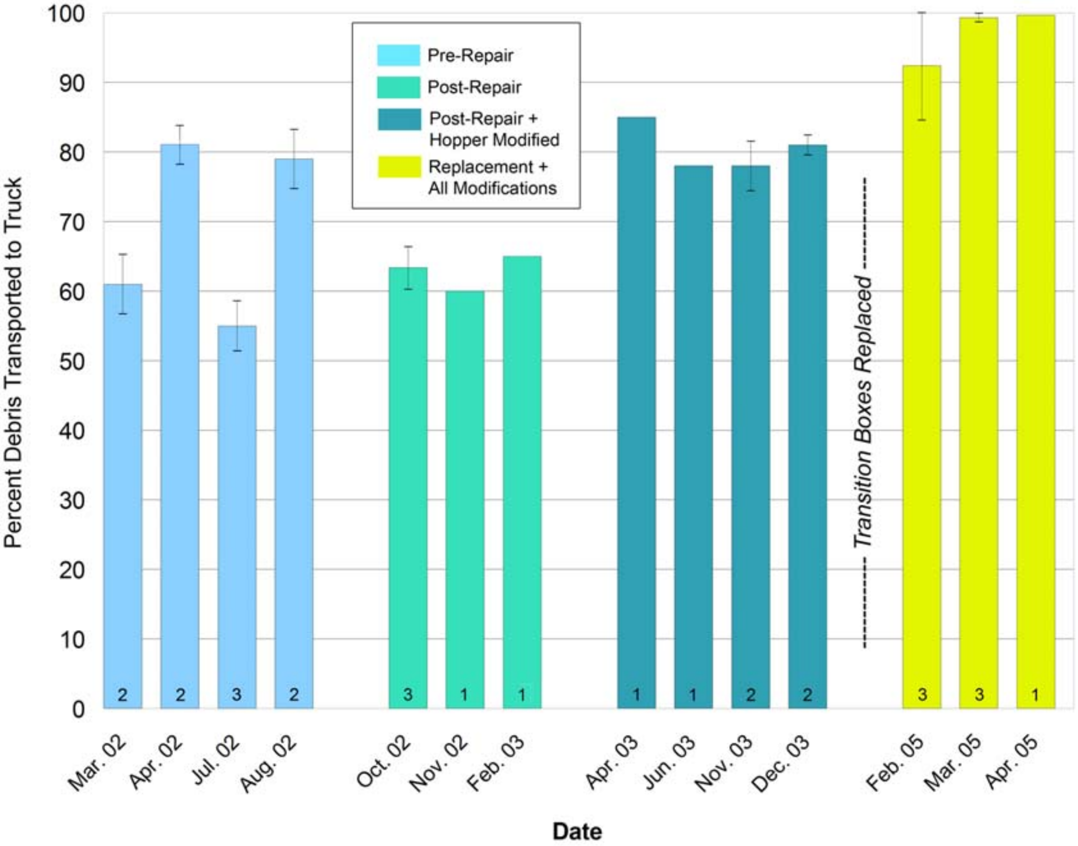

FIGURE 12.—Mean percent transport of recovered debris and standard deviation, of debris collected during overnight runs and delivered to the debris hauling truck by the debris removal system. Number at the base of each bar is the number of samples (n) collected for each mean value.

Ten-Minute Counts

Collection of debris during the 10-minute counts proved to be an effective way to evaluate the amount of debris dislodged within the TFCF during routine cleaning operations such as cleaning of the trash racks and the primary louvers. Although these samples, collected from within the circular holding tanks, were considerably smaller in size, $\bar{x}$ 1.4 kg (3.0 lbs), during cleaning and $\bar{x}$ 0.4 kg (0.9 lbs) during non cleaning operations, in comparison to the debris collected overnight, $\bar{x}$ 36 kg (79 lbs), or during debris addition experiments, $\bar{x}$ 12.5 kg (27.5 lbs), they were useful in determining the effectiveness of the traveling screen during routine cleaning periods. Ten-minute count, fresh weight, debris data (mean grams per field trip, standard deviation, and n values) are presented in figure 13. A three-fold increase in mean fresh debris weight was observed entering the circular holding tank during 10-minute counts in which cleaning operations occurred during the preceding 2 hours compared to no cleaning during the preceding 2 hours. This increase in debris within the circular holding tank was apparent after routine cleaning, regardless of traveling screen operation or not, indicating the use of the traveling screen was not the source of increased debris. This also indicates that the current size screen on the traveling screen is ineffective at removing short length debris dislodged during cleaning operations. Green aquatic debris less than $\bar{x}$ 189 mm (7.4 inches) in length and woody debris less than $\bar{x}$ 105 mm (4.1 inches) in length was common within the circular holding tank with the screen in operation. Debris in the holding tank was slightly larger when the screen was not in use $\bar{x}$ 215 mm (8.5 inches) and $\bar{x}$ 119 (4.7 inches) green and woody debris respectively. Even though the sample size (n) of the mean length values are relatively large (736 to 1,334), both the screen in and screen out data have large standard deviations. This large standard deviation further demonstrates the ineffectiveness of a screen, with a large size opening, 4 cm (1.5 inches) wide by 11cm (4.5 inches) in height when debris moving through the system are short length fragments.

Small woody debris tends to tumble on through the traveling screen, whereas some vegetative debris of similar length can still be captured by the traveling screen, because it will wrap around the plastic coated cables or the brushes of the traveling screen.

Woody debris mean diameters collected, from the circular holding tank, with and without the screen in place, were very similar 29 mm (n = 84) and 30 mm (n = 124) respectively.

Typical mean Egeria debris lengths used during debris addition experiments and mean lengths of green and woody debris transported to the debris hauling truck are presented in table 2.

Differences in debris loads were also evaluated during high tide and low tide but no conclusions from these data could be drawn.

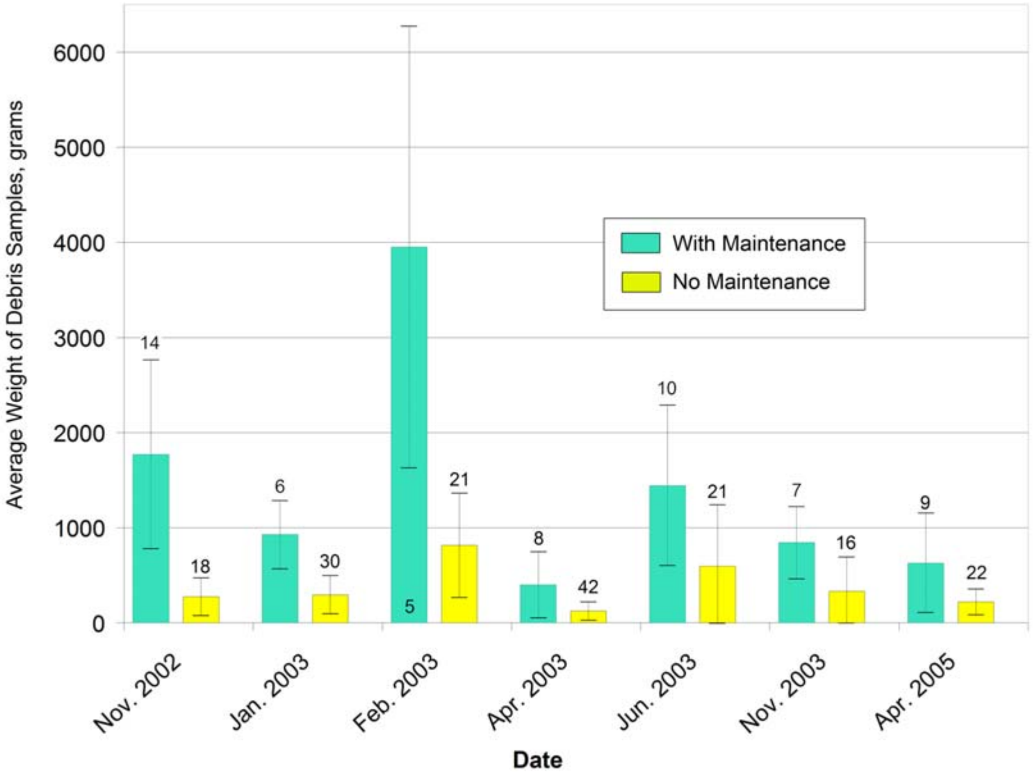

Figure 13.—Mean fresh debris weight and standard deviation, per field trip. Debris was collected during ten-minute fish counts, with and without routine cleaning of the facility two hours preceding the collection. Number at each bar is the number of samples (n) collected for each mean value.

TABLE 2.—Lengths of green debris and lengths and diameters of woody debris collected at different locations within the Tracy Fish Collection Facility

Mean debris lengths added at bypasses		**Mean debris lengths found in the truck**				**Mean of longest debris lengths found in the truck**			
Green		**Green**		**Woody**		**Green**		**Woody**	
Mean length, mm	438	Mean length, mm	383	Mean length, mm	252	Mean length, mm	1,169	Mean length, mm	380
(n) sample #	33	(n) sample #	40	(n) sample #	10	(n) sample #	10	(n) sample #	10
				Diameter Range	5 to 40			Diameter Range	7 to 69

Mean debris lengths from 10-minute counts (circular holding tanks)

Green with mechanical screen		**Green without mechanical screen**		**Woody with mechanical screen**		**Woody without mechanical screen**	
Mean length, mm	189	Mean length, mm	215	Mean length, mm	105	Mean length, mm	119
Maximum length, mm	834	Maximum length, mm	1,220	Maximum length, mm	600	Maximum length, mm	950
Minimum length, mm	11	Minimum length, mm	21	Minimum length, mm	4	Minimum length, mm	14
(n) sample #	869	(n) sample #	1,334	(n) sample #	736	(n) sample #	1,021
Standard deviation	129	Standard deviation	134	Standard deviation	71	Standard deviation	79
				Mean diameter, mm	29	Mean diameter, mm	30
				(n) sample #	84	(n) sample #	23
				Maximum diameter, mm	91	Maximum diameter, mm	70
				Standard deviation	15	Standard deviation	16

Effectiveness of the Traveling Screen

Repairs to the transitions boxes, and later replacement of the transitions boxes, improved delivery of the debris from the primary louver to the secondary louvers.

Some modifications to the debris removal system have improved collection of debris from the secondary channel.

Collection was improved by:

(1) The addition of four more brush lifts to the traveling screen.

(2) The installation of the stainless steel tray below the hopper and conveyor.

Other modifications to the debris removal system have improved the effectiveness to transport collected debris to the debris hauling truck.

These modifications include:

(1) Covering the hopper drain tube with stainless steel punch plate mounted on the back wall of the hopper.

(2) Covering the bottom of the hopper with stainless steel plate and eliminating many of the abrupt angles within the hopper, providing a slicker surface to promote debris transport to the conveyor belt.

(3) Lengthening the debris deflection tines and lowering them further into the hopper.

(4) The addition of two spray nozzles within the hopper

(5) The addition of debris guides at the top of the conveyor.

(6) A secondary debris collection point (the basket) was added after the stainless steel tray was put in place. Debris is transported from the stainless steel tray to the basket via a sluice box.

Collections of added debris by the traveling screen compared to the amount of debris initially added at the primary louvers just in front of the transition boxes still, remains somewhat low, 56 percent recovery by the debris removal system. This leaves 44 percent, of the added debris, unaccounted for, following transition box replacement and after all modifications have been made. However, this is nearly twice the debris recovery that was possible prior to any repairs or modifications (29 percent compared to 56 percent = an increase of 27 percentage points). It should be noted that the added debris is not cleaned or separated and some loss in weight (dirt and small debris) which is uncollectible by the current traveling screen must be expected. It is estimated that dirt and small debris comprise 10 to 20 percent or more of the fresh weight of added debris. This was arrived at by weighing, washing, and reweighing sample debris collected from the trash rack, and therefore, even 80 percent recovery of added debris may not be practical to obtain.

Initially, only 54 percent of the captured added debris was transported to the debris hauling truck. This has increased to 96 percent (an increase of 42 percentage points), of the captured added debris, being delivered to the debris hauling truck after all repairs, replacements and modifications have been made. This 96 percent may be misleading because it also includes the additional debris in the basket, which comes from the stainless steel tray; this debris was previously lost back to the secondary channel.

Collected Fish

A total, of 261 fish were collected with the traveling screen, during all of the debris evaluation studies. The traveling screen was operated a total of 571 hours, most of this during overnight debris tests. The overnight debris collections amounted to 492 hours, or 86 percent of the operation time for all of the various debris evaluations. The average amount of fish caught, by the traveling screen, was one fish per every 2.2 hours of operation. Of the 261 fish collected, 210 were dead upon collection and most of these (173) appeared to be dead long before collection, evident by the deterioration of the fish's body or fungus and other infections covering the fish. Fifty-one fish were collected alive, although many of these appeared to have been injured prior to being collected by the traveling screen, evident by old wounds and fungus. The live fish ranged in fork length and weight from 462 mm (18.2 inches) and 1,150 grams (2.53 lbs), for the largest fish; to 93 mm (3.7 inches) and 5 grams (.01 lb.), for the smallest fish, with a mean length of 261 mm (10.3 inches) and a mean weight of 282 grams (0.62 lb.) for the 51 live fish collected by the traveling screen. Thirty-seven dead fish had fresh injuries. Therefore, a maximum of 37 fish caught by the traveling screen could have been killed by it (14 percent of the total collected). This averages out to be one collected fish killed every 15.4 hours of operation. This assumes that all fresh injuries found on dead fish were caused by the traveling screen and not by other sources within or outside the facility, which is highly unlikely. Dead fish collected in other areas, i.e., the circular holding tank and the secondary channel, were not evaluated so there is no data about fish possibly killed by the traveling screen but not collected by it. However, no increase in dead or injured fish in the 10-minute counts, during traveling screen operation, was observed. Suspected fish injuries and kills caused by California sea lions (*Zalophus califorianus*) were observed in the autumn of 2004 and winter of 2005 indicated by many fish being bitten in half. This was evident by many catfish missing tails just behind the dorsal and pectoral fins so that the head portion still had all of the heavy dorsal and pectoral spines. This type of injury was not found before or after the appearance of the sea lions. Figure 14 shows the 16 species of fish caught during the 571 hours of traveling screen operation and the number of each fish species. Larger fish, such as 77 striped bass

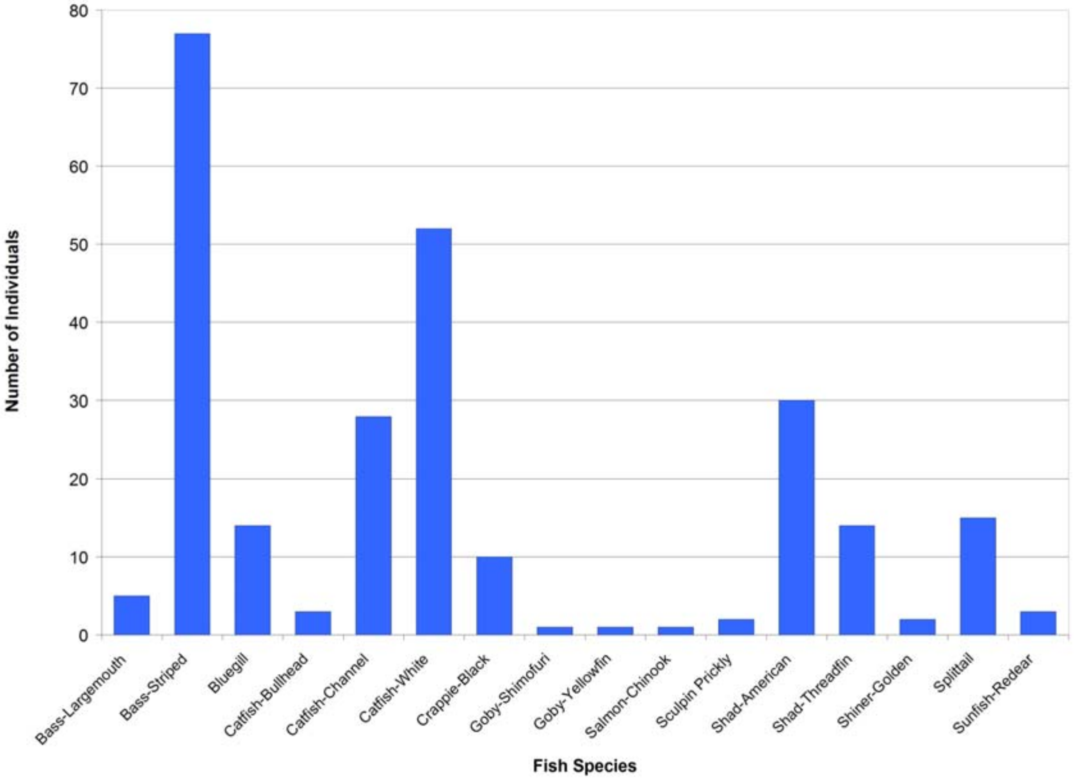

FIGURE 14.—Different fish species collected by the traveling screen during all experiments (571 hours of screen operation).

(*Morone saxatilis*), 52 white catfish (*Ictalurus catus*) and 28 channel catfish (*Ictalurus punctatus*), were caught more frequently as would be expected. This is because they are not only numerous but many are too large to pass through the traveling screen openings easily. However, during high debris loads and when smaller fish were very numerous, such as American shad (*Alosa sapidissima*) and threadfin shad (*Dorosoma petenense*), some of these smaller fish were also caught by the traveling screen. One species of concern, splittail, was collected routinely each winter. It should be noted that 10 of the 16 splittail collected (63 percent) were dead prior to reaching the traveling screen. Three of the splittail collected by the traveling screen were uninjured and the other three could possibly have been killed by the traveling screen because they had fresh injuries to their bodies.

Only one Chinook salmon was collected by the traveling screen during the 571 hours of operation. It was small, 73 mm (2.9 inches) in length and weighed 7 grams (0.02 lb.), recently dead, and had been dyed red indicating that it was used in experimental work (no salmon experiments were underway at the TFCF when the salmon was collected). It is possible that the salmon was from another agency's experiment or it could have been marked at a hatchery prior to release. No steelhead (*Salmo gairdneri*) or Delta smelt (*Hypomesus transpacificus)* were collected by the traveling screen.

A comparison of fish fork length was made between fish collected by the traveling screen and fish that were collected the same day during the 10-minute fish counts. Table 3 presents' data by fish species on the maximum, mean, maximum, and minimum fork lengths as well as standard deviation of that mean and the sample size (n) of nine common species collected by the traveling screen as well as within the circular holding tank. The sample size of each fish species represents, live, recently injured or killed fish. No fish with old wounds or fish covered with fungus were included in the data in table 3.

In table 3, the fish species sample size, under the column labeled "Holding Tank," is a sub-sample of fish being collected during 10-minute counts, which occur every 2 hours; whereas the sample size under the column labeled "Traveling Screen" represents the total number of fish by species that were collected by the traveling screen. Figure 15 visually displays these table 3 data, which is the mean fork length, standard deviation and n values, of each of these nine common fish species collected by the traveling screen and during the 10-minute counts. These data indicate that there may be a fish size difference being collected at these two different locations. In figure 15, the mean fork length of Chinook salmon maybe misleading because only one fish was collected by the traveling screen and it just happens to equal the mean length of 79 mm (2.9 inches) of 46 Chinook salmon collected within the circular holding tank. Also, note that no Delta smelt were collected by the traveling screen. This fish species was included in the figure because it is a species of concern within the Sacramento Delta.

No correlation between the amount of debris and the collection of fish by the traveling screen could be made other than a few small fish were collected when debris loads were heavy. These small fish could have been injured or dead within the debris being collected or they could have been alive, and trapped within the debris, unable to escape collection by the traveling screen. No determination on cause of death could be made.

TABLE 3.—Fish size (fork length in mm) for fish species commonly collected by both the traveling screen and the circular holding tank

Fish Species	**Holding Tank**		**Traveling Screen**	
Bass-Striped	99	mean (mm)	297	mean (mm)
	67	std deviation	125	std deviation
	21	minimum (mm)	97	minimum (mm)
	346	maximum (mm)	780	maximum (mm)
	80	(n)	72	(n)
Bluegill	58	mean (mm)	156	mean (mm)
	35	std deviation	21	std deviation
	24	minimum (mm)	113	minimum (mm)
	165	maximum (mm)	185	maximum (mm)
	66	(n)	13	(n)
Catfish-Channel	187	mean (mm)	302	mean (mm)
	62	std deviation	89	std deviation
	61	minimum (mm)	85	minimum (mm)
	225	maximum (mm)	425	maximum (mm)
	6	(n)	17	(n)
Catfish-White	144	mean (mm)	293	mean (mm)
	63	std deviation	58	std deviation
	43	minimum (mm)	204	minimum (mm)
	458	maximum (mm)	428	maximum (mm)
	106	(n)	28	(n)
Chinook Salmon	79	mean (mm)	79	mean (mm)
	19	std deviation	0	std deviation
	34	minimum (mm)	79	minimum (mm)
	105	maximum (mm)	79	maximum (mm)
	46	(n)	1	(n)
Shad-American	95	mean (mm)	316	mean (mm)
	26	std deviation	92	std deviation
	51	minimum (mm)	94	minimum (mm)
	260	maximum (mm)	445	maximum (mm)
	52	(n)	28	(n)
Shad-Threadfin	79	mean (mm)	97	mean (mm)
	18	std deviation	24	std deviation
	28	minimum (mm)	60	minimum (mm)
	132	maximum (mm)	150	maximum (mm)
	113	(n)	12	(n)
Smelt- Delta	22	mean (mm)	0	mean (mm)
	2	std deviation	0	std deviation
	20	minimum (mm)	0	minimum (mm)
	25	maximum (mm)	0	maximum (mm)
	6	(n)	none	(n)
Splittail	276	mean (mm)	301	mean (mm)
	16	std deviation	38	std deviation
	256	minimum (mm)	246	minimum (mm)
	292	maximum (mm)	355	maximum (mm)
	5	(n)	12	(n)

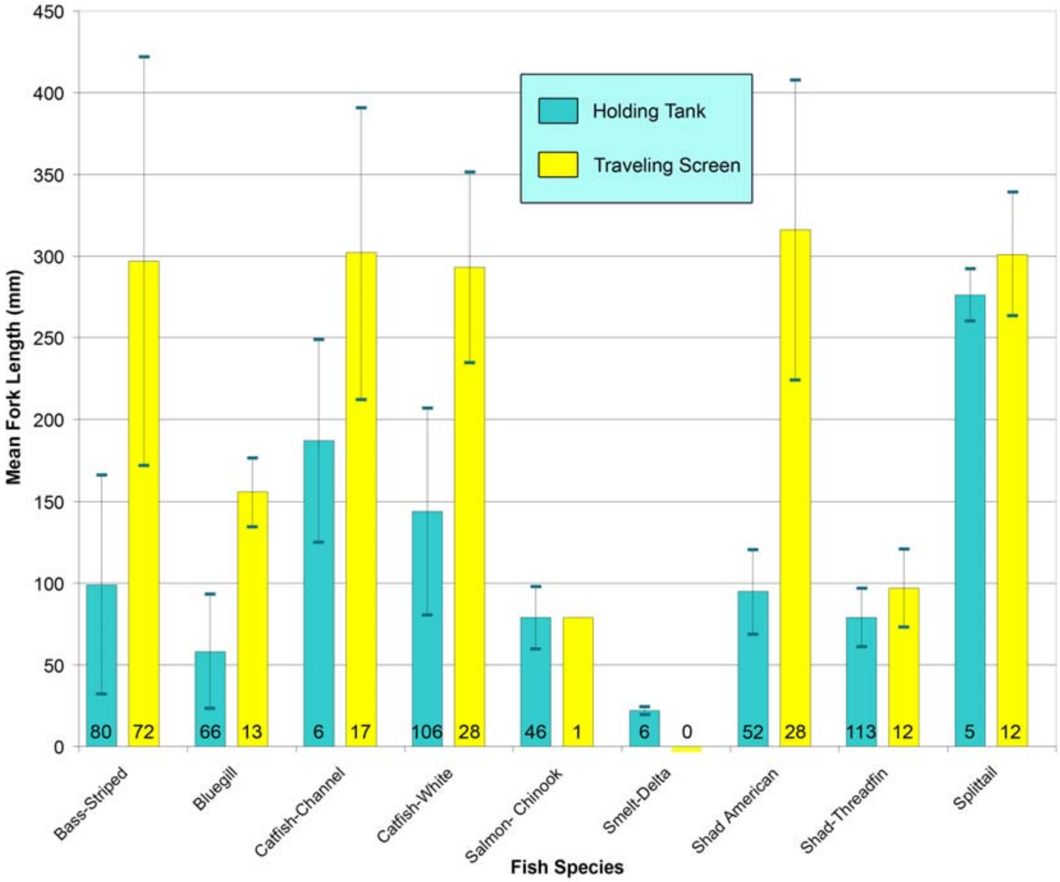

FIGURE 15.—Comparison of mean fork length and standard deviation of different fish species collected by the traveling screen and within the holding tank. Number at the base of each bar is the number of fish (n) collected for each mean value.

CONCLUSIONS

The traveling screen was initially developed to remove the catadromous Chinese mitten crabs. However, the studies contained within this report have demonstrated that the mechanical screen can be of benefit in removing debris from the secondary channel at the TFCF when heavy debris loads are coming into the facility and during routine cleaning operations at the facility.

The traveling screen was inspected prior to operation, at the start of weeklong experiments. It has proven to be reliable, with a minimal amount of maintenance, and never failed during our operation. Some of the main repair or adjustments routinely needed were tightening of the debris deflection tines within the hopper and the cleaning of the water filters for the spray booms. The realignment of the conveyor belt was needed yearly as well as checking and tightening of the nuts and bolts on the screen.

Underwater brushes were short lived, approximately 1 ½ years, the brackets holding them degraded due to cathodic action. However, with routine inspection and replacement the brushes and the brackets holding them were easily maintained.

The debris delivery from the primary louvers to the secondary channel via the transition boxes and the bypass tubes has improved at the TFCF because of transition box repair and later replacement. The effectiveness of the traveling screen to remove and transport debris has been improved due to more than seven modifications to the debris removal system. These improvements increased recovery of added debris from 29 percent at the start of these studies, to 56 percent after repairs and replacement of the transition boxes, as well as after all modifications to the debris removal system had been made. Improvement in the transport of recovered debris, from the debris removal system to the debris hauling truck, also increased from 54 percent at the start of the study to 96 percent, in the added debris experiments, and from 63 to 94 percent for natural debris collected during overnight runs. These similar removal percentages indicate that the added debris experiments correlate well with natural debris moving through the TFCF and the collection and transport of natural debris to the debris hauling truck.

Overnight debris collections were made, during 27 nights, throughout different months of the year. The most debris collected during a single night was 115 kg (253 lbs) with a mean collection of 36 kg (79 lbs) per night (mean of 15.5 hours). It is speculated that much of the debris collected, during overnight operations, actually occurred during early morning when cleaning operations at the TFCF took place and before the traveling screen was shut down after a night of operation.

Higher debris loads were common during the autumn and winter months. It is reasonable to expect removal of 56 kg (123 lbs) of debris when heavy debris loads are present during a 24-hour.

The fish facility operates as a behavioral louvering system and proper hydraulics that existed when the facility was built and operated; do not necessarily exist at the facility today. It has been suggested that present day river elevations are not similar to elevations when the facility was built. Keeping the primary and secondary louvers clean for longer periods of time can only help to guide fish and maintain proper hydraulics within the facility

Debris samples taken from the 10-minute fish counts, every 2 hours at the TFCF, indicate that debris flowing through the secondary channel increases three fold during routine maintenance at the facility, as seen in figure 13, approximately 381 to 1,425 grams per 10-minute count. This routine maintenance includes cleaning of the trash rack and cleaning of the primary louvers. Cleaning at the trash boom and operation of the boom conveyor that removes floating debris collected by the trash boom may also contribute to debris within the facility.

Because the screen was constructed with large openings, 1.5 x 4.5 inches (4 cm x 11 cm), to allow fish to pass through the screen, while still capturing the Chinese mitten crabs, smaller woody debris less than 105 mm (4.1 inches) and green aquatic debris less the 189 mm (7.4 inches) in length, based on the mean, tends to pass through the screen and accumulate in the circular holding tanks. This indicates the limit of the traveling screen, with its current screen size to remove smaller debris effectively and still provide openings for fish to swim through. Therefore, very little difference could be seen in the amount of debris entering the circular holding tank with the screen in or out. The amount of debris collected during the 10-minute fish counts was routinely small and any clump of debris dislodged by water surge or other operations can cause erroneous results.

During the traveling screen studies, the screen was operated a total of 571 hours. A total, of 261 fish were collected by the traveling screen of these 210 were dead prior to collection and 51 were alive. Of the 210 dead fish collected by the traveling screen, a maximum of 37 could have been killed by the traveling screen as indicated by their fresh injuries. Using the value of 37 fish killed by the screen, an average of one fish per every 15.4 hours could have been killed by the traveling screen. No data on fish injury or fish killed by the screen and not collected by the traveling screen was available. Although no increase in dead or injured fish were noticed, in the 10-minute fish counts, when the traveling screen was in operation.

More fish were killed during the startup of the traveling screen than at other times of operation.

More fish were collected by the traveling screen at night than during the day.

A difference in fish size (fork length), was also observed between those collected by the traveling screen and those collected within the circular holding tank indicating that the screen might have some effect upon large fish. An optimum fish passage size for this particular screen size was not determined nor was it the focus of this study. Fish passage size would have to be based upon each individual species because of differing morphology and physiology of each species.

Many variables within the system, such as debris types, tides, river flow, and velocity, cleaning and maintenance activities, pumping changes both at the pumping plant and at the TFCF, made consistent evaluation difficult. Unknown variables such as activities on the river, both recreational and maintenance, above and below the facility added to this difficulty. Therefore, just as important as improved debris recovery is the predictability and consistency of that debris removal. It is felt that the debris removal system is operating as well as possible without redesigning the hopper or changing the type of screen or other major rebuilding efforts.

RECOMMENDATIONS

Any future debris removal system designs should use the water from the spray booms to its advantage, to sluice the debris into a slipper slide type hopper and onto a porous conveyor. This would drain most of the water away prior to lifting the debris to the debris hauling truck avoiding the back flushing problems encountered with the current hopper and conveyor. It is realized that the traveling screen, hopper, and conveyor presently used were designed for the removal of the Chinese mitten crabs and allow the passage of fish and not designed for the removal of debris specifically. The traveling screen removes crabs well.

It is recommended the traveling screen be used when debris loads, coming into the facility, are heavy, as well as, during and for an hour after routine cleaning of the trash rack and the primary louvers. When debris is heavy and accumulating in front of the trash boom and boom conveyor use of the traveling screen might be of benefit, especially if debris is rolling under the boom and on to the trash rack.

An additional traveling screen that is easily raised and lowered into the circular holding tanks (within a few minutes) would be ideal for removing the smaller debris that accumulates in the holding tank. This smaller traveling screen should be lightweight, it should not close off the entire radius of the holding tank, giving fish the opportunity to swim below and around the screen as well as find refuge out of the current behind the screen. It could have a smaller mesh opening than the traveling screen that is currently in the secondary channel so that it would remove the smaller debris that is entering the circular holding tanks. Experiments with this smaller traveling screen could be conducted with added fish and debris to confirm effectiveness.

A few additional experiments might be warranted operating the traveling screen and the convey, in the secondary channel, at faster or slower speeds to see if such simple changes increase or decrease the effectiveness of the traveling screen. One possibility would be to start and stop the screen for short durations of time (5 minutes intervals, advancing the traveling screen in 1 or 2 feet segments), allowing it to accumulate more debris prior to arriving at the spray booms. In this manner, the cleanest portion of the screen would always be on the bottom of the secondary channel where fish are known to congregate, therefore maintaining open screen at the bottom for fish passage.

Additional experiments might be of value during routine cleaning of the trash racks and the primary louvers, focusing on the dissemination of debris, caused by cleaning, throughout the TFCF, with and without the traveling screen in operation. This would help establish a numeric benefit value during cleaning and heavy debris time periods.

ACKNOWLEDGMENTS

This study was funded by the Mid-Pacific Region (Sacramento, California) as part of the Central Valley Project Improvement Act (CVPIA), Section 3406(b) (4) of 1992. We thank Gary Jordan and Ron Silva and the operations and maintenance staff of the Tracy Fish Collection Facility for their support and assistance throughout the study. Special thanks to Alex Luna for his help and loan of the Tracy operations and maintenance shop and numerous tools needed to complete many of the maintenance and construction tasks.

We also want to thank the Tracy staff of biologists for their help with fish species identification, as well as, the understanding and complexities of the Sacramento Delta ecology, the Tracy facility, and Tracy pumping plant operations.

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