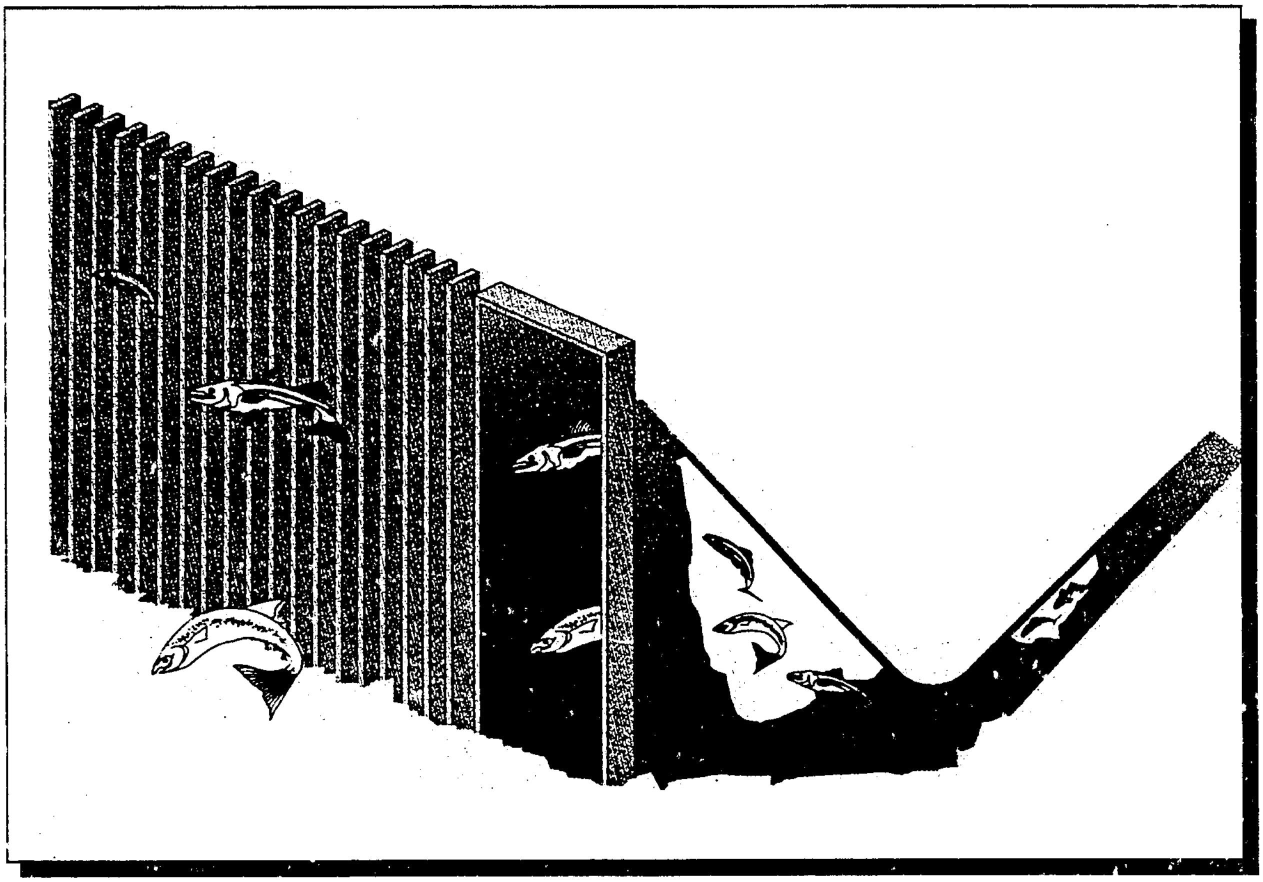

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Evaluation of Mitten Crab Exclusion Technology During 1999 at the Tracy Fish Collection Facility, California

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EVALUATION OF MITTEN CRAB EXCLUSION TECHNOLOGY DURING 1999 AT THE TRACY FISH COLLECTION FACILITY, CALIFORNIA

BY

Robert White[1,2], Brent Mefford[3], and Charles Liston[4],
Tracy Fish Collection Facility Studies, California

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ABSTRACT

The catadromous Chinese mitten crab, native to the coastal rivers and estuaries of the Yellow Sea, is a recent invader to the San Francisco Estuary and associated watersheds. Adult crabs leave up-river freshwater habitats in fall and migrate to the ocean to spawn. During this migration they are drawn into the BOR Tracy Fish Collection Facility (TFCF). Crab entrainment increased exponentially between 1996 and 1998. The large numbers entrained in 1998 severely hampered normal functioning of fish salvage operations resulting in high fish mortality. New technology for separating and removing crabs from fish was developed. A traveling belt screen was installed at the TFCF in fall 1999 and tested from September 19 through October 14, when the screen malfunctioned and was replaced with the standard screen provided by the manufacturer. The goal of the study was to evaluate the effectiveness of the belt screen in removing mitten crabs and debris and to examine its effect on fish passage and health. Forty two evaluations, each consisting of 3-10 minute samples, were completed for the belt screen. The screen had a minimum crab removal efficiency of about 90%, but marking experiments indicated efficiency was higher. We detected no significant effect on total fish passage or passage of any of the five most abundant species (overall or during day or night). Similar results were obtained for fish >100 mm FL except there was a significant delay in passage at night associated with the belt screen. Of 33,341 fish sampled (25 species), only three of ESA concern were encountered (splittail). Only 17 fish were removed by the belt screen and more than one half were diseased or in poor condition; 10 of these were > 200 mm FL. Except on one occasion, debris was low. However in this one 10 minute sample, 13 fish were removed by the screen compared to 17 removed during 42-10 minute samples (7 hours). Ten (78%) of these were > 200 mm FL. Our data suggest that fish > 200 mm FL are more susceptible to removal by the screen and that during periods of high debris, more fish and more larger fish may be removed. We found no evidence that the belt screen caused physical damage to fish other than an occasional catfish caught in the mesh.

BACKGROUND

The Chinese mitten crab, *Eriocheir sinensis*, is a recent invader to the San Francisco Estuary and associated watershed and has spread rapidly. Adult crabs leave up-river freshwater habitats in the fall and migrate towards the ocean to spawn. During the spawning migration, mitten crabs are drawn into the Bureau of Reclamations Tracy Fish Collection Facility (TFCF). There was an exponential increase in crabs entrained at the TFCF between 1996, when first observed, and 1998 when over 775,000 entered the facility (Siegfried 1999). Larger numbers were expected in1999. The 1998 invasion severely hampered normal functioning of the fish salvage operation and identified the need to develop methods for separating and removing crabs from fish (Liston et al. 1998). Research and development of crab exclusion technology was conducted on site during fall 1998 and spring 1999 by engineers and biologists at Tracy, and at Reclamations Denver Water Resources Research Laboratory and Fisheries Applications Research Group . This research resulted in the design of a moving belt type screen (traveling screen) for removing mitten crabs from the secondary channel, while allowing fish to pass into the collection facility.

The screen system was installed in the TFCF secondary channel in late August, 1999 and became fully operational in early September. The goal of this study was to evaluate the effectiveness of the screen in removing mitten crabs and debris and to examine the screens' effect on fish passage and health.

Tracy Fish Collection Facility

The U.S. Government has assisted the State of California in water development in the Central Valley since 1873 (U.S. Congress, 1874). A comprehensive plan for water development was in place by 1931 (Anonymous, 1931) and resulted in the Central Valley Project (CVP). Construction began in 1935. Water is supplied mainly from the Sacramento River drainage from the north and the San Joaquin drainage from the south. Important components of the CVP are the Tracy Pumping Plant (TPP) and associated Delta Mendota Canal, which transports water to the south for irrigation, domestic, and industrial use. The TPP pumps water from the Old River channel of the San Joaquin River into the intake for the Delta Mendota Canal. The TFCF is located on the Old River and operates to salvage fish that would otherwise be drawn into the Delta Mendota Canal intake channel by the TPP. The facility has been in operation since 1957.

Fish salvage at the TFCF is facilitated by a louver-bypass-collection system (Figure 1). Two louver systems function to guide fish for salvage. Each louver screen resembles a vertical Venetian blind, and contains 1-inch spaced slats that extend the depth of the channel. The louvers create a disturbance in flow that causes fish to turn away and eventually be carried into a nearby bypass (Liston et al. 1998). Primary louvers (about 320 feet long and angled at 15 degrees across an 84 foot wide channel) lead into four bypass openings which convey water and fish to the secondary louvers (two parallel lines of louvers 32 feet long which span the 8 foot wide channel and angled at 15 degrees), where fish and debris are diverted into a common bypass which leads to one of four large circular holding tanks.

Fifty one species of fish have been collected during fish salvage activities at TFCF and annual salvage rates range into millions of individuals. Fish salvage is continuous when the pumps are operating at the Tracy Pumping Facility. Diverted fish accumulate in a recessed circular holding tank for 8-24 hours before being trucked to release sites. In preparation for transport, all but about 500 gallons of water are drained from holding tanks and fish are concentrated in a 500 gallon bucket. They are then transferred to an aerated tank truck and returned to the Sacramento/San Joaquin Delta. Release sites are downstream and away from pumping influences (Liston et al. 1998).

Mitten Crab Biology and Distribution

The Chinese mitten crab is native to the east coast of China and coastal areas of Korea, and occurs inland in rivers and lakes with connections to the Yellow Sea (Hymanson et al. 1999; Veldhuizen and Stanish 1999). Mitten crabs are catadromous, with adults reproducing in brackish or salt water and juveniles migrating upstream in fresh or brackish water where they mature in 1-5 years, depending upon environmental conditions (Veldhuizen and Stanish 1999). Juvenile mitten crabs migrate 1400 km (870 miles) up the Yangtze River in China (Panning 1939). Adults migrate downstream in fall, reproduce, and die.

Mitten crabs were accidentally introduced into Europe in the early 1900's and distribution and abundance expanded rapidly. In Germany, population control measures were necessary by 1930 (Panning 1939). Only intermittent collections of mitten crabs have been reported in many European countries since the population explosions of the 1930's. However, mitten crab abundance is increasing in portions of southern Holland, Belgium, England, and Germany, coinciding with improved water quality (Veldhuizen and Stanish 1999).

In North America, mitten crabs have been reported from the Great Lakes region, the Mississippi River Delta in Louisiana, and the San Francisco estuary watershed, California, the only location where they have become established. Since initial detection in South San Francisco Bay in 1992, distribution and abundance has rapidly expanded (Veldhuizen and Stanish 1999).

As of January1999, the known distribution of mitten crab in California extended north of Delevan National Wildlife Refuge in the Sacramento River drainage, north of Marysville in the Feather River drainage, east of Roseville in the American River drainage, in Littlejohns Creek and Mormon Slough to eastern San Joaquin County, south in San Joaquin River drainage near San Luis National Wildlife Refuge, and south in the California Aqueduct near Kettleman City and Taft. Mitten crab are also present throughout most tributaries to San Pablo, Suisun, and South bays. Potential distribution in the San Francisco Estuary watershed extends through all waterways up to major migration barriers (Veldhuizen and Stanish 1999).

During the fall (September-October) seaward spawning migration, mitten crabs are drawn to the south Delta State and Federal pumping facilities. Adult mitten crabs were first observed at the TFCF in fall, 1996 when 40-50 individuals appeared in the fish salvage operation. In 1997, an estimated 16,000 adult crabs were collected. By 1998, an exponential increase had occurred, and over three quarters of a million mitten crabs were entrained during fish salvage (Siegfried 1999). Large numbers of crabs were also entrained at the state facility. In both cases, crab entrainment impacted the facilities, causing mortality of fish during collection and transport.

Development of a Traveling Screen for Mitten Crab Removal

The large crab invasion in 1998 severely hampered normal functioning of the fish salvage operations and identified the need to develop methods of controlling crab entrainment. Research on crab exclusion technology was initiated by engineers and biologists at Tracy, and Reclamations Water Resources Research Laboratory (WRRL) and Fisheries Applications Research Group (FAR) in Denver. First, a study was conducted to determine the best means of removing crabs from the secondary louver structure, thus preventing crabs from entering the fish salvage holding tanks. The secondary louver structure was chosen because it is positioned upstream of the main facility, where the channel can be quickly dewatered and accessed. These factors allow crab removal methods to be quickly adjusted, modified or repaired if needed, with minimal impact on the normal pumping and fish salvage operation. Preliminary testing of a traveling screen (originally designed for experimentation with debris removal in the secondary channel laboratory model at the WRRL) at TFCF during fall 1998 showed promise in efficiently removing mitten crabs and was further evaluated and modified during early 1999. Because a functioning system was needed by September 1999, technology development for removing crabs in the secondary channel was the priority (Hanna and Mefford 1999).

A traveling belt type screen was selected for removing mitten crabs from the secondary channel (Appendix A). The screen was fabricated by Farm Pump and Irrigation Company and a fish-friendly custom cable belt designed by Reclamation's WRRI engineers in Denver replaced the standard belt normally installed by the manufacturer (Hanna and Mefford 1999). The 8 foot by 19 foot screen spanned the entire width of the secondary channel, and was installed at an angle of 10 degrees from the vertical. An overhead winch allowed the screen to be lifted above the water surface (Appendix A). The belting was made of plastic coated cable that ran vertically at 1.5 inch intervals. The cable was held in place by 5/16 inch diameter horizontal rods spaced at 4.5 inch intervals. The resulting screen mesh was rectangular in shape with an opening of 1.5 inches horizontal and 4.5 inches vertical. Four-inch-long brushes were attached at approximately 4 foot intervals. A guide plate, positioned parallel to the screen at a distance of 4 inches, was placed on the upstream face of the screen to prevent crabs from escaping once they were lifted from the water. The plate was automated to maintain a distance of 6 inches above the water surface. When activated, the screen turned counter clockwise (looking downstream). Although the speed of the screen could be varied, the motor overheated at slow speeds, so the screen was operated at a setting of 5.5-6.0 (10.5-12 ft/min) during all tests. Mitten crabs encountering the screen grasped the mesh and were carried upward and over the top. A high pressure spray wash system dislodged crabs and debris, which were deposited in a hopper located on the back (down stream) side of the screen. A grain auger in the bottom of the hopper moved crabs and debris into a disposal container (Appendix A).

The superstructure for supporting the screen was installed in late July and early August, 1999. The screen, guide plate, guide system, and auger were in place by late August and the screen became fully operational September 8, 1999. The system operated successfully with only minor adjustments until October 16, when the traveling belt screen became disabled and was removed. The screen was replaced on October 22 with the manufacturers conventional wire mesh that was similar in shape to that of a chain link fence (cyclone). The diamond shaped mesh openings were 4 inches high, with maximum width of 2 inches. Due to the small number of crabs at this time, and laboratory observations indicating that this screen design was not as fish friendly, the screen was removed on November 3, 1999 following our last test.

METHODS

Each of 42 evaluations of the traveling belt screen and 12 evaluations of the traveling cyclone screen consisted of a series of three 10 min sampling periods (Table 1). During the first period (Test), two samples were taken simultaneously with the screen operating; one collected materials removed by the screen (basket) and the other collected materials that passed through the screen (holding tank). Because only two holding tanks were available, test samples (basket and holding tank) were processed before lifting the screen and collecting the "flush", which was followed immediately with the "reference" sample. The "flush" was designed to identify any buildup of fish or crabs due to the screen and the "reference" was assumed to represent conditions as they would exist without the screen in place. Both day and night samples were collected to represent the range of conditions present and to account for known differences in abundance of fish and crabs between light and dark periods. Samples were collected at 1400h, 1600h, 2000h, and 2200h. The first sample of each series coincided with the routine fish salvage sampling at the TFCF which occurs every 2 h.

The basket used to collect materials removed by the screen (Test) was rectangular in shape and constructed of 1/8th inch stainless steel sheeting, solid on the sides and perforated on the bottom (Appendix A). The basket was 13 inches wide and 12 inches deep with a top length of 84.8 inches and a bottom length of 63.8 inches. A hinged plexiglass top sealed the basket on the screen side when open. A 4 inch rubber gasket overlaid by a stiff nylon brush of the same width sealed the opposite side of the basket and a 4 inch rubber gasket sealed both ends. Before positioning the basket in the hopper using a rope and pulley system, the spray wash, auger, and screen were turned off. Placement of the basket took 2-4 minutes. Once in place, the water spray was turned on and the traveling screen was engaged at exactly the same time as screened water was turned into a new holding tank. After 10 min, the screen and holding tank were turned off simultaneously. The water spray was turned off in the hopper, the lid of the basket was closed and the basket removed. The screen and auger were put back in operation while these samples were processed. When processing was complete, the auger, screen and spray wash were turned off, the water lines disconnected, and the screen lifted. At the same time as the screen was lifted, water was diverted to the "flush" holding tank for 10 min, then water was immediately diverted to the "reference" tank for the next 10 min. During each test, screen speed was held constant.

Although the screen became operational September 8, 1999, we did not conduct a complete sample series until September 19, due to safety concerns and perceived problems with frequently lifting the screen for test comparisons. Beginning the week of September 19, 1999, two day and two night sample series were collected during 3 days most weeks through the week of October 10, 1999. One series of tests of the "cyclone" screen was conducted November 1-3, 1999, for comparative purposes.

Maximum carapace width and body depth were measured in millimeters with a caliper on mitten crabs sampled, and sex was recorded. During the first week of November, we also weighed all crabs collected during our tests and facility operations. Fish specimens were identified to species, counted, physical condition noted, and fork length of fish >100 mm was recorded. Debris was divided into green vegetation, woody, and other and quantified volumetrically.

Based on behavioral observations of mitten crabs in experimental flumes at the WRRL facility in Denver, two marking experiments were conducted on October 14, 1999 to determine if crabs hold up in the system. We dried the carapace of two groups of 30 crabs. One group was marked with red ink and the other with blue ink, using Sharpie permanent markers. Marked crabs were then released immediately down stream of the traveling screen. The red marked group was released during day and the blue during night. We monitored return of marked crabs by examining all crabs coming into the holding tank during each 10 min period for 1 h and 10 min for the red marked group and 1 hour and 40 min for the blue marked group. We also made observations at 2 h intervals in conjunction with routine fish salvage sampling for the 6 h following the 10 min samples for the red marked group.

We conducted two tests related to the assumption that 500 crabs would plug the large 500 gallon fish loading bucket which has a 10 inch opening. In the first, we introduced 465 live crabs and 10 gallons of debris into the loading bucket. In the second, we used 250 crabs and 10 gallons of debris. No fish or large pieces of woody material were included in the debris. We also did one test to determine if 500 live crabs and 10 gallons of debris would plug the 2,000 gallon fish hauling truck which has a 9 inch discharge opening.

STATISTICS

Numbers of fish and crabs sampled during tests of the traveling belt and cyclone screens varied widely within and among sample sequences. Because of this variation we used a cumulative binomial probability ranking test (Function: CDF, SAS, Inc., Version 8.0, Cary, NC, USA) rather than testing for differences between absolute numbers of fish or crabs. For example, we counted the number of trials in which the number of fish in the reference holding tank exceeded the number in the test holding tank. The cumulative binomial probability of this many reference trials exceeding test trials or a more extreme result was calculated. If the cumulative binomial probability was less than 0.05, there was less than a 5% chance that the given result or a more extreme result would occur at random, and we would conclude that there was a statistically significant difference between the reference and test trials.

RESULTS

Mitten Crab

Forty two evaluations of the traveling belt screen (167 samples) were conducted between September 19 and October 14, 1999 and 12 evaluations (48 samples) of the cyclone screen were completed, November 1-3, 1999. Traveling screen efficiency in removing mitten crabs, defined as the number of crabs in the basket divided by the total number sampled, was 89.6% for the belt screen and 89.9 % for the cyclone screen. Marking experiments showed that some crabs hold up in the secondary channel, suggesting that removal efficiency was probably higher. In the first hour and 10 min (seven 10 min samples) following release of 30 marked crabs immediately down-channel of the belt screen during day light hours, only 6 crabs were recovered, and crabs from this group were still being recovered 10 h and 30 min later. Although the group of marked crabs released after dark were recovered at a slightly faster rate, only 12 of 30 were recovered during the first hour and a half after release (Table 2).

We sampled 1,586 mitten crabs. Weekly sex ratio's (males to females) ranged from 2.56 the week of October 4, to 4.3 the week of November 1 (Table 3). The average sex ratio over the sampling period was 2.86 males to 1 female. We measured maximum carapace width and maximum body depth of 1,562 crabs. Females had smaller average carapace width (mean 66.7 mm) than males (mean 70.1 mm) but mean maximum body depth was similar (34.5 mm for females vs. 34.8 mm for males) (Table 4). Ninety seven crabs were weighed the last week of sampling. Males, on average, weighed more than females (189.4 g vs. 133.9 g) but were more variable in weight (Table 4).

Both the belt and cyclone screens significantly reduced abundance of crabs in the holding tank (Table 5). The general pattern of crab abundance in samples during all test sequences was similar (Figure 2; Tables 6 and 7) and did not differ between the belt and cyclone traveling screens. In all but three cases there were more crabs removed by the screen than were collected simultaneously in the holding tank. The three exceptions occurred when crab numbers were very low. In these cases, there were equal numbers collected in both the basket and holding tank. In 36 of 48 tests where numbers were different between the basket and reference sample (belt and cyclone screens combined), more crabs were removed by the screen than were collected in the reference sample (Table 7). On average, crab numbers in night samples were about double those of day samples (12.5 vs. 6.8/10 min), however variation in number was large (Table 6).

Fish

During evaluations of the belt and cyclone traveling screens, 33,341 fish, representing 25 species, were collected (Table 8). Six species (threadfin shad, American shad, white catfish, bluegill, striped bass, yellowfin goby), made up 98.6 % of the fish sampled. Threadfin shad was the most abundant species, comprising 84% of the catch. Fish numbers in 10 minute samples varied from 0 to more than 1300 (Figure 3). There was often large variation in fish abundance among tests during a single sample sequence, as well as through time (Figure 4;Table 9). Only three splittail, the only ESA species of concern encountered, were sampled during tests and none were removed by either screen (Table 8).

The traveling belt screen did not significantly affect fish passage overall or during day or night operation (Table 10). In 50% of sample sequences (21 of 42; p=0.43881), more fish were collected in the holding tank during screen operation ("test") compared to the "reference" sample (Table 9). Similar comparisons between the "flush" and "test" and between the "reference" and "flush" were not significant. Of the total fish collected during the 42 belt screen tests, 31% passed through the screen, 34.7% were collected in "flush" samples, and 34% in "reference" samples. Similar results were obtained in 12 tests of the cyclone traveling screen. No significant effect on fish passage was detected overall or during day or night (Table 10). However, the difference in total number between the test, flush and reference was larger: 26%, 39%, and 34%, respectively.

Few fish collected during the sampling period were > 100 mm FL (3.7% of total; Table 8). These were predominantly American shad, white catfish, yellowfin goby and striped bass. During belt screen tests, 2.8% of the 29,698 fish sampled were > 100 mm FL (Table 11) and only 0.4 % (120) were > 200 mm FL (60% white catfish, 14% channel catfish, 13 % striped bass, 9 % American shad, 4% other; Table 12). Number of fish > 100 mm FL in each of 40 sample sequences associated with belt screen evaluation was not significantly affected (p=0.13409) by belt screen operation (Table 13). However, when analyzed by time, more fish > 100 mm FL were collected in 14 of 21 (p=0.03918) reference samples (screen out) at night than in associated test samples (screen in), indicating that night time passage of larger fish was significantly affected. No significant differences in the number of fish > 100 mm FL were detected overall or among day or night samples during the 12 tests of the cyclone screen (Table13).

The five most abundant fish species sampled during belt and cyclone screen evaluations were threadfin shad, American shad, white catfish, bluegill, and striped bass. Analysis by species of pooled numbers from each of the four test, four flush, and four reference samples for each sample date (belt = 11; cyclone = 3)(Table 14) showed no significant effect of either screen on overall passage of any of these species (H3 reference v H1 test; Table 15). The only significant difference identified was for threadfin shad between flush and test samples for both the belt (p = 0.05469) and cyclone screen (p = 0.0).

Only 17 fish, ranging in fork length from 45-390 mm, were removed by the belt screen during 42 10 min samples (7 h) (Table 16). Five were < 100 mm FL (threadfin shad), 2 were > 100 but < 200 mm FL, and 10 were > 200 mm FL. White catfish made up 47% of fish removed by the screen . More than one half (9) of the fish removed had external evidence of disease or were in poor physical condition. Only two fish were removed during daylight hours and both were diseased. Fish removed by the belt screen made up 0.057% of the 29,698 fish sampled during the 42 test sequences.

Debris

Debris was low in all completed tests and did not affect screen efficiency (Appendix B). However, one test sequence was aborted because of a large debris load associated with removal of the South Delta Old River and Middle River barriers. During this 10 minute sample on September 28, 1999, 9.2 L of green debris (two 5 gallon buckets) were collected in the basket and 1 L in the holding tank. Thirteen fish were removed by the screen, 10 of which were > 200 mm FL. In comparison, 1,043 fish passed through the screen into the holding tank and only 10 of these were >100 mm FL and none were > 200 mm FL (Table 17). This suggests that during periods of high debris load, more larger fish (> 200 mm FL) may be removed by the screen, while most fish < 200 mm FL pass through the screen. White catfish made up 64% of the fish >

100 FL and 60% of those > 200 mm FL that were removed by the screen. Other fish species removed were channel catfish, striped bass, redear sunfish, and Sacramento sucker.

Loading Bucket and Hauling Tank Clogging Test

An ancillary test was conducted to provide guidance on how many mitten crabs would clog the fish loading bucket and the fish hauling truck. When 465 live crabs and 10 gallons of debris were introduced, the 500 gallon loading bucket would not empty, while 250 live crabs and 10 gallons of debris were successfully unloaded without clogging. The one test of the 2,000 gallon fish hauling truck using 500 live crabs and 10 gallons of debris determined that this quantity of crabs and debris did not affect unloading efficiency.

DISCUSSION

Mitten crab abundance increased exponentially at the TFCF between 1996 when they were first collected and 1998 when over 750,000 were entrained (Siegfried 1999). The large numbers entrained in 1998 severely hampered normal functioning of fish salvage operations and identified the need to develop fish friendly technology for crab removal . The only other known efforts to control mitten crabs occurred about 2 decades after they were introduced into Germany. In the 1930's the population exploded and interference with net and trap fisheries and damage to riverbanks caused by burrowing prompted development of control measures (Panning 1939; Cohen and Carlton 1997). In this case, mitten crabs were trapped by various means at dams during the juvenile upstream migration. In 1935, from January to May, about 3.5 million crabs were captured (113,960 in 1 day) at a single dam. In 1936, 2.9 million were taken at this dam (Panning 1939). Overall, more than 21 million juveniles were caught during their upstream migration in five rivers in Germany in 1936 (Gollasch 1999 unpublished). It is unknown if these measures were effective in population control, as documentation in the literature is scarce. The population did decline in the late 1940's and has not returned to large numbers (Vincent 1996 as reported by Veldhuizen and Stanish 1999). Since the 1940's a population increase has occurred about every 15 years, with the most recent increase in the late 1990's (Gollasch 1999 unpublished).

Due to the negative impact of mitten crabs at the TFCF, engineers and biologists developed and tested a prototype traveling belt screen in the laboratory and found it to be very effective in removing mitten crabs while allowing safe passage of fish (Hanna and Mefford 1999). A full scale screen was installed in the secondary channel at the TFCF and became operational in September 1999.

The traveling belt screen was extremely effective in removing mitten crabs from the secondary channel at the TFCF and had no significant effect on overall fish passage. The screen had a minimum crab removal efficiency of 89.6%. Visual observations during screen operation, however, suggested that efficiency was greater. Only on rare occasions, when the high pressure spray wash was partially plugged, did we observe a few crabs being carried down past the hopper.

Also we rarely saw evidence that crabs had gone through the screen mesh. During laboratory tests mitten crabs often clung to irregularities along the walls of the channel and remained there for varying lengths of time. Based on this observation, two experiments in which marked crabs were released immediately downstream of the traveling belt screen confirmed that some crabs do hold up in the secondary channel. After 10.5 hours, marked crabs were still being collected.

The origin of crabs holding in the secondary channel down stream of the traveling belt screen is unknown. These could be crabs that were not removed by the screen but this is highly unlikely. If this were the case, efficiency would be less than 89.6%. More likely, these crabs entered the area downstream of the screen during periods when the screen was not in place. In this case, efficiency would be better than 89.6% since some or all crabs collected in the holding tank during "test" samples were already downstream of the screen when tests began.

In most sample sequences more crabs were collected in the "test" sample (screen in) than the "reference" sample (screen out). This was likely due to accumulation of crabs on the screen while it was disengaged for 2-4 minutes during positioning of the collection basket.

Mitten crab sex ratio on any particular date was always more than 2 males to 1 female which is similar to other observations for migrating adults in the Delta (Kathy Hieb and Scott Siegfried personal communication). Also mean carapace width was similar to that reported by Nepszy and Leach (1973) and by Veldhuizen and Stanish (1999).

The traveling belt screen did not significantly affect total fish passage overall or during day or night operation. Also the screen had no significant overall effect on passage of fish > 100 mm FL. However, when day and night samples were tested independently, there was a significant effect of the screen on passage of fish >100 mm FL at night. The reason for this result is unknown. The opposite result would seem more logical based on visual detection of the screen. Analyses of the five most abundant species (threadfin shad, American shad, white catfish, bluegill, and striped bass) detected no significant effect of the belt screen on fish passage. No significant differences were detected in similar analyses of the cyclone screen but sample size was much smaller (12 vs. 42). In laboratory tests, this screen type was less fish friendly than the belt screen (Hanna and Mefford 1999).

Only 17 fish (0.057%) were removed by the belt screen during the 42 tests (7 hours) and none of these were species of ESA concern. More than half of the fish removed were diseased or in poor body condition. White catfish made up 47% of those removed. If our tests are representative of fish that would be removed during continuous operation of the screen under low debris conditions, an average of 2.4 fish would be removed per hour, totaling 58 fish per day. At least 30 of these fish would be diseased or in poor body condition and likely would not survive under any condition. Considering the huge benefit of removing mitten crabs to fish salvage, this is not an alarming number.

Except on one occasion, debris was low during all tests of the traveling screens and did not affect efficiency. However, the one sample taken during high debris load provides an indication of how different the results might have been regarding fish removal if debris load had been high. In this one 10 minute sample, 13 fish were removed, compared to 17 removed in 7 hours of sampling during low debris conditions. Although inconclusive, this does suggest that more fish would be removed by the screen during periods of high debris. Seventy eight percent of these fish were > 200 mm FL compared to 58 % of those removed during low debris periods. Both of these results indicate that fish > 200 mm FL are more susceptible to removal by the screen. Although only 120 fish > 200 mm FL were collected during the 42 tests, more fish this size were collected in the holding tank during the flush and reference samples compared to the test, suggesting that not only are larger fish more susceptible to removal by the screen, but that passage of fish this size and larger is likely affected.

We found no evidence that the screen caused physical damage to fish other than an occasional catfish that was caught in the mesh. We had planned to experimentally examine potential physical damage and fish passage by conducting fish injection experiments after crab abundance declined. However, the belt screen malfunctioned and was replaced with the cyclone mesh. Since this mesh will not be used in the future no tests were conducted.

Mitten crab abundance at the TFCF was only about one tenth that of 1998 numbers (Figure 5), far fewer than the anticipated 20 million based on previous exponential population growth pattern. Had these numbers materialized, it is unknown how screen efficiency might have differed. Based on our findings in 1999, we know of no reason why crab removal efficiency would decline. Fish passage effects are more difficult to predict. If crabs were abundant enough to cover much of the screen, fish passage would likely be negatively affected.

CONCLUSIONS

The traveling belt screen was very effective in removing mitten crabs from the secondaries at the TFCF while allowing safe passage of the species and size range of fishes encountered. A minimum of 89.6% of the crabs entrained were removed, but efficiency is probably higher since some crabs were found to hold up in the secondary below the screen for over 10 hours. We found no significant effect of the traveling belt screen on total fish passage or passage of any of the five most abundant fish species. The screen was effective in removing debris but debris was low except when the Old River barriers were removed. The one sample taken during high debris load removed 13 fish (10 >200 mm FL) in 10 minutes compared to 17 fish (10 > 200 mm FL) removed in 42-10 minute samples (7 hours) taken during low debris periods. These data suggest that fish > 200 mm FL are more susceptible to removal by the screen and that during periods of high debris, more fish and more larger fish may be removed. Mitten crab abundance in 1999 was only about one tenth that of 1998. If the anticipated numbers (20 million) based on previous exponential entrainment had materialized, screen efficiency would probably have been similar but fish passage probably would have been affected. We recommend a similar evaluation be conducted during the adult mitten crab migration in 2000, with more emphasis on sampling during the high debris period expected in late September-early October following removal of the barrier dams.

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Table 1. Experimental design used in the evaluation of mitten crab exclusion technology at the Tracy Fish Collection Facility, California, August-November, 1999.

Treatment	Sampling Method	Minutes	Screen In	Screen Out
Test	Basket	10	X	
	Holding Tank (HT1)	10	X	
Flush	Holding Tank (HT2)	10		X
Reference	Holding Tank (HT3)	10		X

Table 2. Time to recapture of marked mitten crabs released immediately downstream of the traveling belt screen on October 14, 1999, Tracy Fish Collection Facility, California.

Day	Number Recaptured (30 Marked)	Total
30 min	4	4
1 hr	2	6
1 hr 10 min	0	6
1 hr 40 min	3	9
9 hrs	2	11
9 hrs 30 min	1	12
10 hrs	2	14
10 hrs 30 min	1	15

Night	(30 marked)	
30 min	4	4
1 hr	8	12
1 hr 30 min	0	12

Table 3. Weekly number, sex and sex ratio of mitten crabs sampled during traveling belt and cyclone screen tests, Tracy Fish Collection Facility, California, September-November, 1999.

Date	Total	Male	Female	Sex Ratio
Sept 21-22	213	164	49	3.35 to 1
Sept 27-29	472	348	124	2.80 to 1
Oct 4-6	612	440	172	2.56 to 1
Oct 12-14	236	180	56	3.21 to 1
Nov 1-3	53	43	10	4.30 to 1
Total	1586	1175	411	2.86 to 1

Table 4. Mean carapace width, body depth and weight of mitten crabs sampled during tests of the traveling belt and cyclone screens, Tracy Fish Collection Facility, California, September-November, 1999

	Width and Depth		
	All (1562)	Male (1155)	Female (407)
Mean carapace width (mm)	70.1	71.3	66.7
Standard deviation	6.2	6.3	4.3
Range	40 - 90	40 - 90	50 - 79
Mean body depth (mm)	34.7	34.8	34.5
Standard deviation	3.2	3.4	2.5
Range	22 - 49	22 - 49	25 - 47

	Weight (November 1-3)		
	All (97)	Male (79)	Female (18)
Mean weight (g)	179.1	189.4	133.9
Standard deviation	54.7	53.7	31.9
Range	63 - 308.5	63 - 308.5	81.5 - 206

Table 5. Rank and number of trials (N) comparing mitten crab abundance in test, flush and reference samples, Tracy Fish Collection Facility, 1999. P = cumulative probability of achieving the observed result or a more extreme result at random. Ties were assigned a rank of 0.5. H1 = Test; H2 = Flush; H3 = Reference.

Screen		Comparison	Number of Rank 1's	N	P
Belt	All	H3 v H1	38*	42	0.00000003
		H2 v H1	34.5	40	0.00000073
		H3 v H2	29	40	0.0011107
	Day	H3 v H1	20	21	0.0000004
		H2 v H1	15	19	0.0022125
		H3 v H2	14	19	0.0096054
	Night	H3 v H1	20	21	0.0000005
		H2 v H1	19.5	21	0.0000055
		H3 v H2	15	21	0.013302
Cyclone	All	H3 v H1	7.5	8	0.00195
		H2 v H1	4.5	7	0.14453
		H3 v H2	5	8	0.14453
	Day	H3 v H1	2	2	0
		H2 v H1	1	2	0.25
		H3 v H2	1.5	2	0.125
	Night	H3 v H1	5.5	6	0.007812
		H2 v H1	3.5	5	0.109375
		H3 v H2	3	6	0.34375

*Interpretation: In 38 of 42 samples more crabs were collected in the reference sample (H3) than in the test sample (H1).

Table 6. Average number of mitten crabs collected in 42 tests of the traveling belt screen and 12 tests of the traveling cyclone screen and overall average number collected during day and night periods, Tracy Fish Collection Facility, California, September-November 1999.

	Belt Screen		Cyclone Screen	
	Average Number (SD)	Number of Samples	Average Number (SD)	Number of Samples
Basket	16.1 (10.5)	42	2.3 (2.5)	12
Holding tank 1	1.8 (1.9)	42	0.3 (0.5)	12
Holding tank 2	9.0 (8.4)	41	0.7 (1.2)	11
Holding tank 3	11.8 (8.2)	42	1.2 (1.0)	12
Day	6.6 (17.0)	83	0.6 (1.7)	25
Night	12.5 (10.7)	84	1.6 (1.5)	22

Table 7. Number of mitten crabs collected in 42 tests of the traveling belt screen and 12 tests of the traveling cyclone screen, Tracy Fish Collection Facility, California, September-November, 1999.

			Test	Flush	Reference
Date	Day/Night	Basket	Holding Tank 1	Holding Tank 2	Holding Tank 3
			BELT SCREEN		
9/21	D	7	0	--	3
9/21	N	33	3	17	22
9/22	D	12	2	5	3
9/22	D	5	1	0	0
9/22	N	21	2	9	22
9/22	N	24	6	10	20
9/27	D	24	1	13	10
9/27	N	33	2	6	19
9/27	N	18	0	5	17
9/28	D	22	4	11	16
9/28	N	12	0	11	8
9/28	N	16	2	4	9
9/29	D	15	0	5	28
9/29	D	17	1	13	16
9/29	N	38	5	34	27
9/29	N	14	4	4	7
10/4	D	26	4	4	17
10/4	D	3	3	2	5
10/4	N	20	3	25	19
10/4	N	16	0	23	24
10/5	D	19	0	8	18
10/5	D	13	0	0	19
10/5	D	5	0	3	5
10/5	N	25	0	10	14
10/5	N	31	1	19	23
10/6	D	24	6	16	9
10/6	D	8	1	1	2

Table 7. Number of mitten crabs collected in 42 tests of the traveling belt screen and 12 tests of the traveling cyclone screen, Tracy Fish Collection Facility, California, September-November, 1999 (continued).

10/6	N	38	3	13	14
10/6	N	39	4	32	27
10/12	D	2	2	1	3
10/12	D	5	1	2	3
10/12	N	15	1	2	5
10/12	N	4	1	0	2
10/13	D	3	0	5	8
10/13	D	3	0	2	6
10/13	D	9	0	6	4
10/13	N	13	7	8	3
10/13	N	8	2	4	4
10/14	D	4	0	10	9
10/14	D	9	1	3	8
10/14	N	12	0	19	15
10/14	N	10	1	3	3
TOTAL		**675**	**74**	**368**	**496**
			CYCLONE SCREEN		
11/1	D	0	0	1	1
11/1	D	0	0	0	0
11/1	N	3	0	0	2
11/1	N	4	1	1	1
11/2	D	1	1	0	2
11/2	D	0	0	0	0
11/2	N	5	0	3	2
11/2	N	3	0	3	3
11/3	D	2	0	0	0
11/3	D	0	0	0	0
11/3	N	8	1	0	2
11/3	N	1	0	1	1
TOTAL		**27**	**3**	**9**	**14**

Table 8. Fish species, number and number larger than 100 mm FL collected in all samples (including incomplete samples not used in analysis), Tracy Fish Collection Facility, California, September-November, 1999.

Species	Number	Number <100 mm	Number >100 mm
Threadfin shad	27,993	27,872	121
American shad	2,101	1,699	402
White catfish	1,305	1,020	285
Bluegill	722	694	28
Striped bass	466	356	110
Yellowfin goby	278	28	250
Inland silverside	162	160	2
Largemouth bass	138	136	2
Channel catfish	84	52	32
Black crappie	30	29	1
Golden shiner	16	15	1
Mosquitofish	8	8	0
Carp	6	1	5
Bigscale logperch	6	6	0
Prickly sculpin	6	6	0
Brown bullhead	3	3	0
Splittail	3	1	2
Warmouth	3	3	0
Lampreys	3	0	3
Starry flounder	2	1	1
Sacramento sucker	2	0	2
Threespine stickleback	1	1	0
Sacramento blackfish	1	0	1
Smallmouth bass	1	0	1
Redear sunfish	1	0	1
Total	33,341	32,091	1,250

Table 9. Number of fish collected in 42 tests of the traveling belt screen and 12 tests of the traveling cyclone screen, Tracy Fish Collection Facility, California, September-November, 1999.

Date	Day/Night	Basket	Test Holding Tank 1	Flush Holding Tank 2	Reference Holding Tank 3
			BELT SCREEN		
9/21	D	0	10	--	4
9/21	N	0	157	128	146
9/22	D	0	1	5	0
9/22	D	0	0	1	2
9/22	N	0	24	61	82
9/22	N	1	64	48	61
9/27	D	1	303	115	85
9/27	N	1	729	252	692
9/27	N	0	147	156	232
9/28	D	0	104	57	111
9/28	N	1	305	348	408
9/28	N	1	54	127	87
9/29	D	0	35	23	97
9/29	D	0	91	55	39
9/29	N	2	397	322	320
9/29	N	0	111	67	39
10/4	D	0	145	252	388
10/4	D	0	30	105	42
10/4	N	1	483	487	399
10/4	N	1	600	1118	1006
10/5	D	1	166	81	335
10/5	D	0	1369	733	756
10/5	D	0	117	96	119
10/5	N	0	359	767	671
10/5	N	2	987	1369	1192
10/6	D	0	91	529	487
10/6	D	0	49	46	32
10/6	N	0	751	589	548
10/6	N	0	806	1009	870
10/12	D	0	27	25	64
10/12	D	0	44	92	39
10/12	N	2	82	193	59
10/12	N	0	24	83	36

Table 9. Number of fish collected in 42 tests of the traveling belt screen and 12 tests of the traveling cyclone screen, Tracy Fish Collection Facility, California, September-November, 1999 (continued).

10/13	D	0	8	33	253
10/13	D	0	7	340	51
10/13	D	0	58	51	29
10/13	N	0	195	241	97
10/13	N	2	64	113	67
10/14	D	0	24	16	15
10/14	D	0	21	6	18
10/14	N	1	134	162	123
10/14	N	0	46	30	30
TOTAL		**17**	**9219**	**10331**	**10131**
			CYCLONE SCREEN		
11/1	D	0	12	8	39
11/1	D	0	0	9	5
11/1	N	0	126	149	155
11/1	N	1	73	166	161
11/2	D	0	18	15	16
11/2	D	0	5	6	4
11/2	N	1	39	66	59
11/2	N	0	112	308	207
11/3	D	0	6	7	3
11/3	D	0	1	6	2
11/3	N	0	160	122	96
11/3	N	1	79	70	74
TOTAL		**3**	**631**	**932**	**821**

Table 10. Rank and number of trials (N) comparing fish abundance in test, flush and reference samples, Tracy Fish Collection Facility, 1999. P = cumulative probability of achieving the observed results or a more extreme result at random. Ties were assigned a rank of 0.5. H1 = Test; H2 = Flush; H3 = Reference.

Screen		Comparison	Number of Rank 1's	N	P
Belt	All	H3 v H1	21*	42	0.43881
		H2 v H1	22	41	0.26635
		H3 v H2	17	41	0.82556
	Day	H3 v H1	11	21	0.33181
		H2 v H1	8	20	0.74828
		H3 v H2	11	20	0.25172
	Night	H3 v H1	10	21	0.500000
		H2 v H1	14	21	0.039177
		H3 v H2	6.5	21	0.63056
Cyclone	All	H3 v H1	7.5	12	0.19385
		H2 v H1	8	12	0.072998
		H3 v H2	4	12	0.80615
	Day	H3 v H1	3	6	0.34375
		H2 v H1	4	6	0.10938
		H3 v H2	2	6	0.65625
	Night	H3 v H1	4	6	0.10938
		H2 v H1	4	6	0.10938
		H3 v H2	2	6	0.65626

*Interpretation: In 21 of 42 samples more fish were collected in the reference sample (H3) than in the test sample (H1).

Table 11. Number of fish >100 mm FL in 42 tests of the traveling belt screen and 12 tests of the traveling cyclone screen, Tracy Fish Collection Facility, California, September-November, 1999.

Date	Day/Night	Basket	Test Holding Tank 1	Flush Holding Tank 2	Reference Holding Tank 3
			BELT SCREEN		
9/21	D	0	1	--	1
9/21	N	0	9	3	5
9/22	D	0	0	1	0
9/22	D	0	0	0	0
9/22	N	0	3	6	2
9/22	N	1	2	3	4
9/27	D	1	6	2	0
9/27	N	1	12	2	13
9/27	N	0	4	1	10
9/28	D	0	5	3	3
9/28	N	1	12	11	8
9/28	N	1	6	6	7
9/29	D	0	5	2	2
9/29	D	0	1	4	0
9/29	N	2	32	33	45
9/29	N	0	15	5	8
10/4	D	0	1	7	5
10/4	D	0	2	3	2
10/4	N	1	9	13	12
10/4	N	1	9	19	12
10/5	D	1	5	8	12
10/5	D	0	1	2	4
10/5	D	0	3	3	1
10/5	N	0	5	10	7
10/5	N	2	7	17	9
10/6	D	0	10	0	4
10/6	D	0	2	3	3
10/6	N	0	7	11	15
10/6	N	0	13	18	8
10/12	D	0	11	5	3
10/12	D	0	1	5	6
10/12	N	0	2	19	2
10/12	N	0	5	3	4

Table 11. Number of fish >100 mm FL in 42 tests of the traveling belt screen and 12 tests of the traveling cyclone screen, Tracy Fish Collection Facility, California, September-November, 1999 (continued).

10/13	D	0	2	1	5
10/13	D	0	3	10	10
10/13	D	0	3	3	5
10/13	N	0	11	25	13
10/13	N	0	7	13	10
10/14	D	0	8	1	1
10/14	D	0	2	0	1
10/14	N	0	6	12	19
10/14	N	0	3	3	3
TOTAL		**12**	**251**	**296**	**284**
			CYCLONE SCREEN		
11/1	D	0	3	0	14
11/1	D	0	0	4	1
11/1	N	0	16	23	21
11/1	N	1	24	29	23
11/2	D	0	6	7	1
11/2	D	0	1	3	1
11/2	N	1	6	2	12
11/2	N	0	25	32	18
11/3	D	0	5	1	1
11/3	D	0	0	5	2
11/3	N	0	25	26	17
11/3	N	1	16	9	12
TOTAL		**3**	**124**	**141**	**123**

Table 12. Fish species and number >200 mm FL collected during 42 tests of the traveling belt screen, Tracy Fish Collection Facility, California, September-October, 1999.

	Fish in Belt Screen				
		Test	Flush	Reference	
	Basket (B)	Holding Tank (HT1)	Holding Tank (HT2)	Holding Tank (HT3)	Total
White catfish	6	3	33	30	72
Striped bass	1	3	6	5	15
American shad	1	3	5	2	11
Channel catfish	2	2	8	5	17
Miscellaneous	0	0	2	3	5
Total	10	11	54	45	120

Table 13. Rank and number of trials (N) comparing number of fish >100 mm FL in test, flush and reference samples, Tracy Fish Collection Facility, 1999. P = cumulative probability of achieving the observed results or a more extreme result at random. Ties were assigned a rank of 0.5. H1 = Test; H2 = Flush; H3 = Reference.

Screen		Comparison	Number of Rank 1's	N	P
Belt	All	H3 v H1	23*	40	0.13409
		H2 v H1	23.5	40	0.10551
		H3 v H2	21	40	0.31791
	Day	H3 v H1	9	19	0.50000
		H2 v H1	9.5	19	0.41190
		H3 v H2	10.5	19	0.25172
	Night	H3 v H1	14	21	0.03918
		H2 v H1	14	21	0.03918
		H3 v H2	10.5	21	0.41591
Cyclone	All	H3 v H1	5.5	12	0.50000
		H2 v H1	8	12	0.07210
		H3 v H2	3	12	0.92700
	Day	H3 v H1	3.5	6	0.22656
		H2 v H1	4	6	0.10938
		H3 v H2	1	6	0.89063
	Night	H3 v H1	2	6	0.65625
		H2 v H1	4	6	0.10938
		H3 v H2	2	6	0.65625

*Interpretation: In 23 of 40 samples more fish were collected in the reference sample (H3) than in the test sample (H1).

Table 14. Number of threadfin shad, American shad, white catfish, bluegill, and striped bass collected in 42 tests of the traveling belt screen and 12 tests of the traveling cyclone screen, Tracy Fish Collection Facility, California, September-November, 1999. Numbers were combined for each of the four test, four flush and four reference samples for each sample date.

	Belt Screen		
Threadfin shad Date	Test Holding tank 1	Flush Holding tank 2	Reference Holding tank3
Sept 21	146	--	133
Sept 22	79	90	134
Sept 27	1403	489	965
Sept 28	374	397	467
Sept 29	324	167	217
Oct 4	1159	1822	1756
Oct 5	2869	2928	2968
Oct 6	1599	2111	1882
Oct 12	131	280	155
Oct 13	205	570	393
Oct 14	166	124	99
Total	8455	8978	9169
		Cyclone Screen	
Nov 1	42	74	67
Nov 2	48	84	81
Nov 3	51	65	42
Total	141	223	190
American shad		Belt Screen	
Sept 21	4	--	1
Sept 22	3	8	5
Sept 27	5	2	8

Table 14. Number of threadfin shad, American shad, white catfish, bluegill and striped bass collected in 42 tests of the traveling belt screen and 23 tests of the traveling cyclone screen, Tracy Fish Collection Facility, California, September-November, 1999 (continued).

Sept 28	14	5	10
Sept 29	29	79	47
Oct 4	11	27	13
Oct 5	25	17	23
Oct 6	18	18	13
Oct 12	15	75	11
Oct 13	39	95	30
Oct 14	17	38	23
Total	180	364	184
		Cyclone Screen	
Nov 1	111	192	233
Nov 2	94	242	156
Nov 3	145	79	97
Total	350	513	486
White catfish		Belt Screen	
Sept 21	3	--	3
Sept 22	3	5	0
Sept 27	32	22	19
Sept 28	34	76	66
Sept 29	179	133	108
Oct 4	16	33	17
Oct 5	16	20	16
Oct 6	45	27	28
Oct 12	7	7	6

Table 14. Number of threadfin shad, American shad, white catfish, bluegill and striped bass collected in 42 tests of the traveling belt screen and 23 tests of the traveling cyclone screen, Tracy Fish Collection Facility, California, September-November, 1999 (continued).

Oct 13	30	48	26
Oct 14	15	29	34
Total	380	400	323
		Cyclone Screen	
Nov 1	11	11	21
Nov 2	8	8	4
Nov 3	6	3	2
Total	25	22	27
Bluegill		Belt Screen	
Sept 21	0	--	0
Sept 22	0	1	0
Sept 27	6	1	2
Sept 28	14	16	21
Sept 29	55	38	64
Oct 4	47	41	38
Oct 5	31	17	26
Oct 6	6	3	2
Oct 12	11	17	12
Oct 13	17	12	13
Oct 14	8	4	6
Total	195	150	184

Table 14. Number of threadfin shad, American shad, white catfish, bluegill and striped bass collected in 42 tests of the traveling belt screen and 23 tests of the traveling cyclone screen, Tracy Fish Collection Facility, California, September-November, 1999 (continued).

		Cyclone Screen	
Nov 1	12	6	14
Nov 2	7	15	8
Nov 3	22	28	15
Total	41	49	37
Striped bass		Belt Screen	
Sept 21	2	--	0
Sept 22	0	0	2
Sept 27	12	4	8
Sept 28	10	16	22
Sept 29	18	20	19
Oct 4	7	13	7
Oct 5	7	23	12
Oct 6	7	5	4
Oct 12	3	3	5
Oct 13	18	27	19
Oct 14	9	6	12
Total	93	116	110
		Cyclone Screen	
Nov 1	18	13	7
Nov 2	5	20	10
Nov 3	2	10	4
Total	25	43	21

Table 15. Rank and number of trial sequences (N) comparing abundance of the five most abundant fish species in test, flush and reference samples, Tracy Fish Collection Facility, 1999. Fish numbers were combined for each sample date. P = cumulative probability of achieving the observed results or a more extreme result at random. Ties were assigned a rank of 0.5. H1 = Test; H2 = Flush; H3 = Reference.

Species	Screen	Comparison	Number of Rank 1's	N	P
Threadfin shad	Belt	H3 v H1	7*	11	0.11328
		H2 v H1	7	10	0.054688
		H3 v H2	5	10	0.37695
	Cyclone	H3 v H1	2	3	0.125
		H2 v H1	3	3	0
		H3 v H2	2	3	0.125
American shad	Belt	H3 v H1	5	11	0.5
		H2 v H1	6.5	10	0.11328
		H3 v H2	3	10	0.82812
	Cyclone	H3 v H1	2	3	0.125
		H2 v H1	2	3	0.125
		H3 v H2	2	3	0.125
White catfish	Belt	H3 v H1	4	11	0.72559
		H2 v H1	6.5	10	0.11328
		H3 v H2	2	10	0.94531
	Cyclone	H3 v H1	2	3	0.125
		H2 v H1	1	3	0.5
		H3 v H2	1	3	0.5

Table 15. Rank and number of trial sequences (N) comparing abundance of the five most abundant fish species in test, flush and reference samples, Tracy Fish Collection Facility, 1999 (continued).

Bluegill	Belt	H3 v H1	3	9	0.74609
		H2 v H1	2	9	0.91016
		H3 v H2	6	9	0.08984
	Cyclone	H3 v H1	2	3	0.125
		H2 v H1	2	3	0.125
		H3 v H2	1	3	0.5
Striped bass	Belt	H3 v H1	7.5	11	0.07299
		H2 v H1	5.5	9	0.17187
		H3 v H2	5	10	0.37695
	Cyclone	H3 v H1	2	3	0.125
		H2 v H1	2	3	0.125
		H3 v H2	0	3	0.875

*Interpretation: In 7 of 11 samples more threadfin shad were collected in the reference sample (H3) than in the test sample (H1).

Table 16. Number and species of fish removed by the traveling belt screen during 168-10 minute samples, Tracy Fish Collection Facility, California, September-October, 1999.

Fish in Basket				
Time	Samples	Number of Fish	Fork Length (mm)	Diseased
Day	21	2	205, 325	2
Night	21	15	45 - 390	8

Time	Species	Fork Lengths (mm)
Day	White catfish	205
	Striped bass	325
Night	White catfish	190, 195, 205, 225, 240, 282, 370
	Channel catfish	281, 390
	American shad	350
	Threadfin shad	45, 87, 90, 95, 97

Table 17. Fish species and size collected during one 10 minute sample during a period of high debris September 28, 1999 (1435-1445 hrs), Tracy Fish Collection Facility, California.

	Basket Green Debris 9.2 L		Holding Tank Green Debris 1.0 L	
Species	<100 mm	>100 mm (Range)	<100 mm	>100 mm (Range)
White catfish	0	7 (182-283)	105	3 (118-135)
Channel catfish	0	1 (380)	0	1 (140)
Striped bass	0	1 (512)	54	0
Redear sunfish	0	1 (208)	0	0
Sacramento sucker	0	1 (395)	0	0
Threadfin shad	2 (65-72)	0	740	0
American shad	0	0	8	2 (195-200)
Black crappie	0	0	0	1 (134)
Yellowfin goby	0	0	0	2 (146-155)
Inland silverside	0	0	20	0
Bigscale logperch	0	0	2	0
Bluegill	0	0	65	1 (175)
Golden shiner	0	0	3	0
Largemouth bass	0	0	36	0
TOTAL	2	11	1033	10

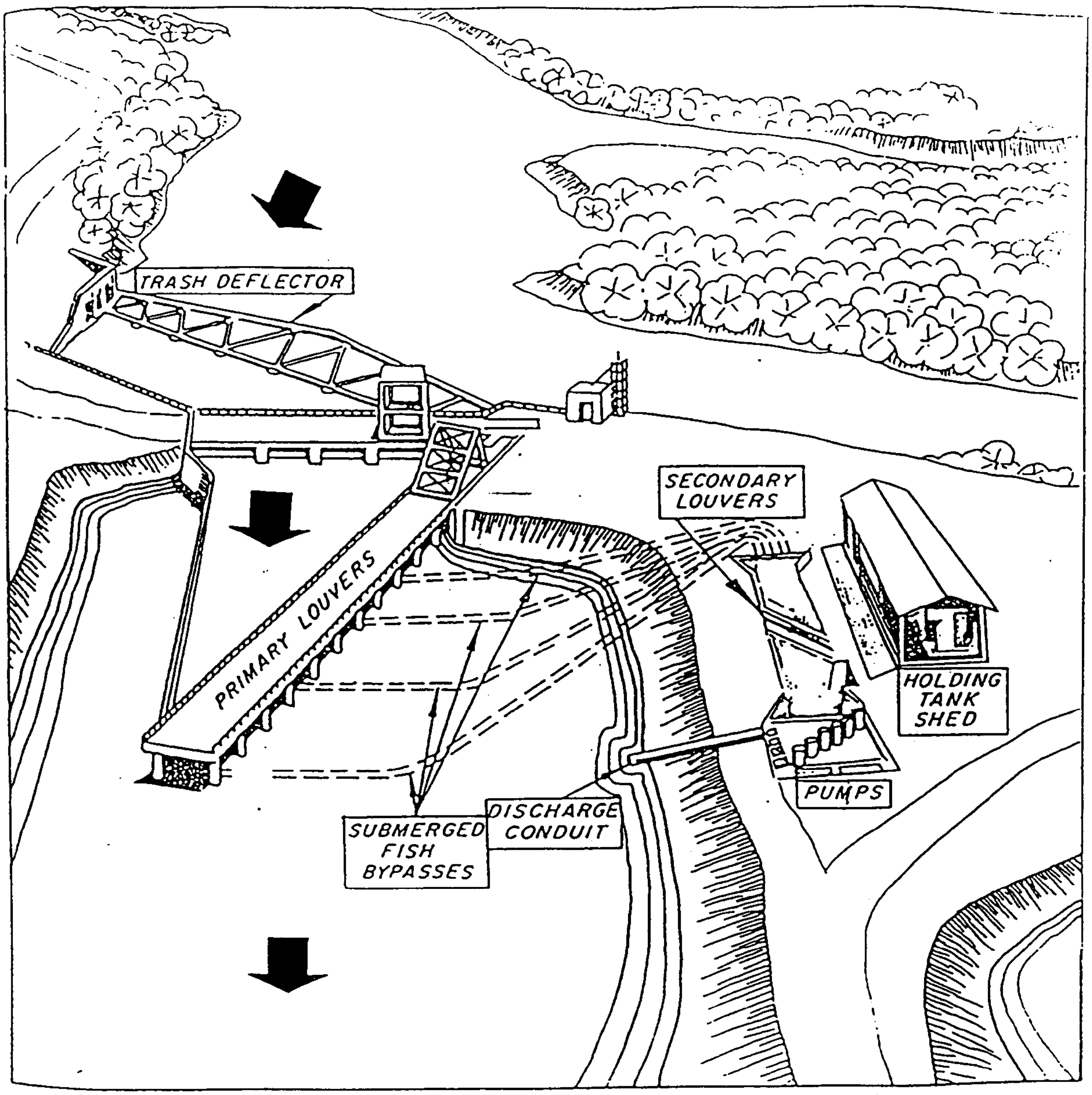


Figure 1. Plan view of the layout of Tracy Fish Collection Facility (TFCF) showing location of the traveling belt screen and holding tanks.

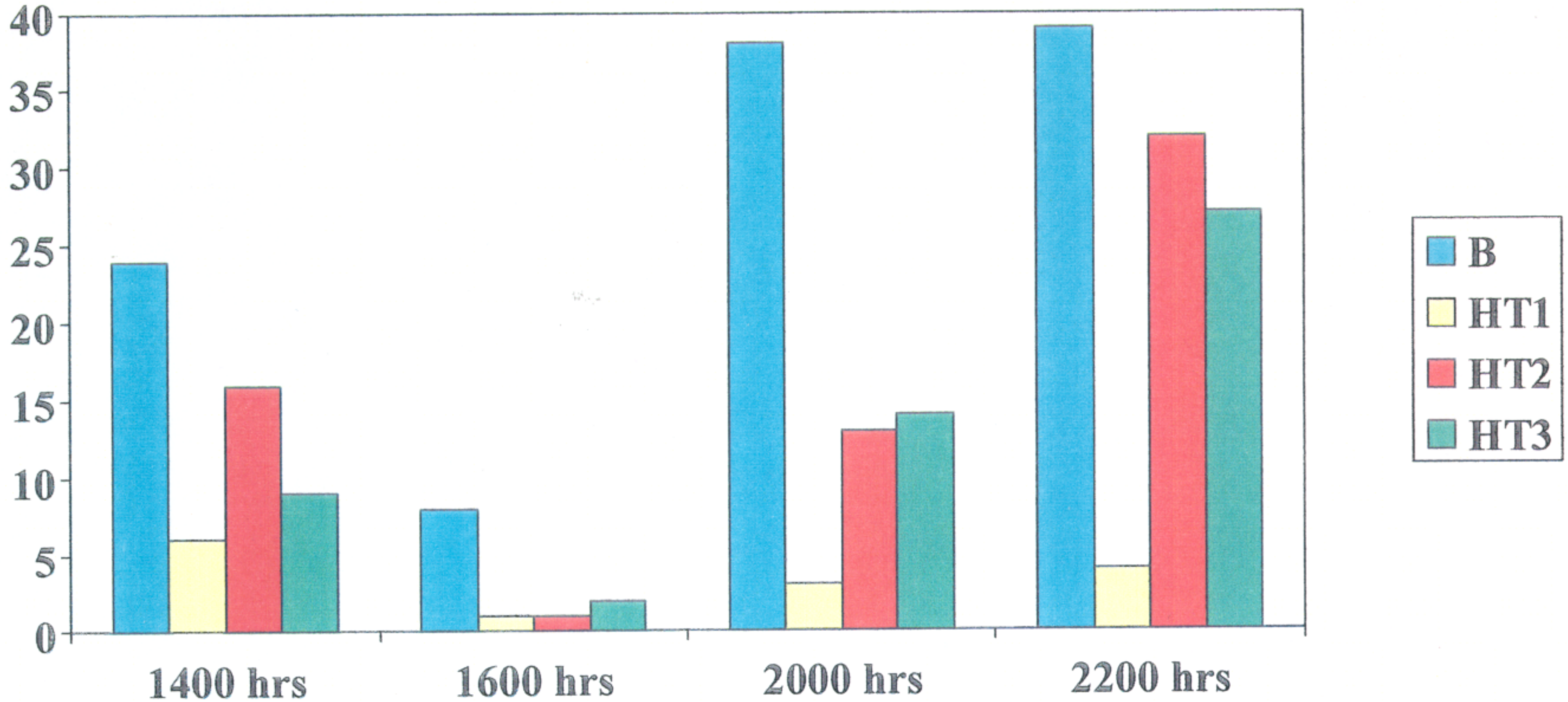


Figure 2. Pattern of mitten crab abundance in four test sequences, October 6, 1999, Tracy Fish Collection Facility, California.
B and HT1 = Test; HT2 = Flush; HT3 = Reference

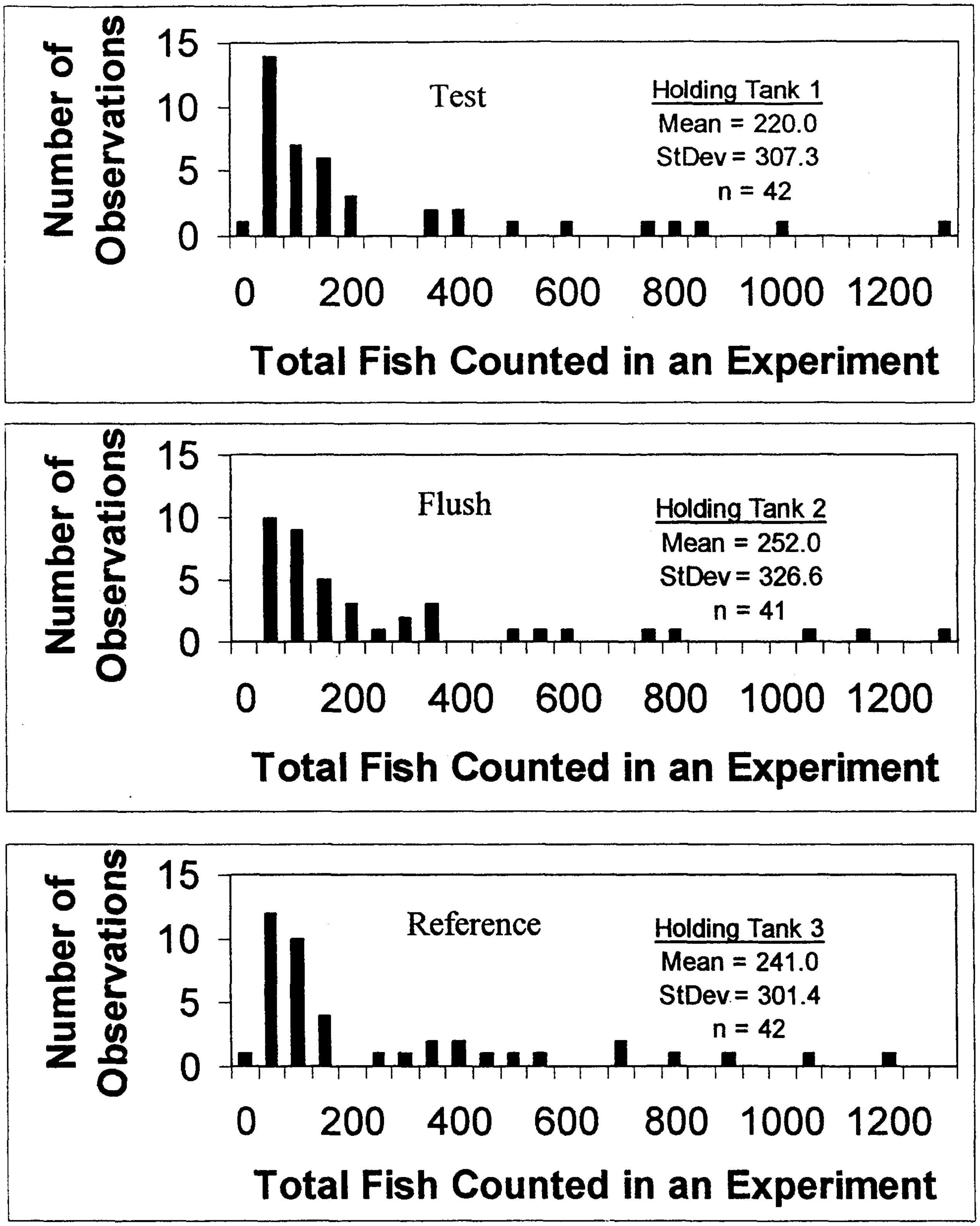


Figure 3. Distribution of fish numbers in 42 evaluations of the traveling belt screen, September 21 through October 14, 1999, Tracy Fish Collection Facility, California

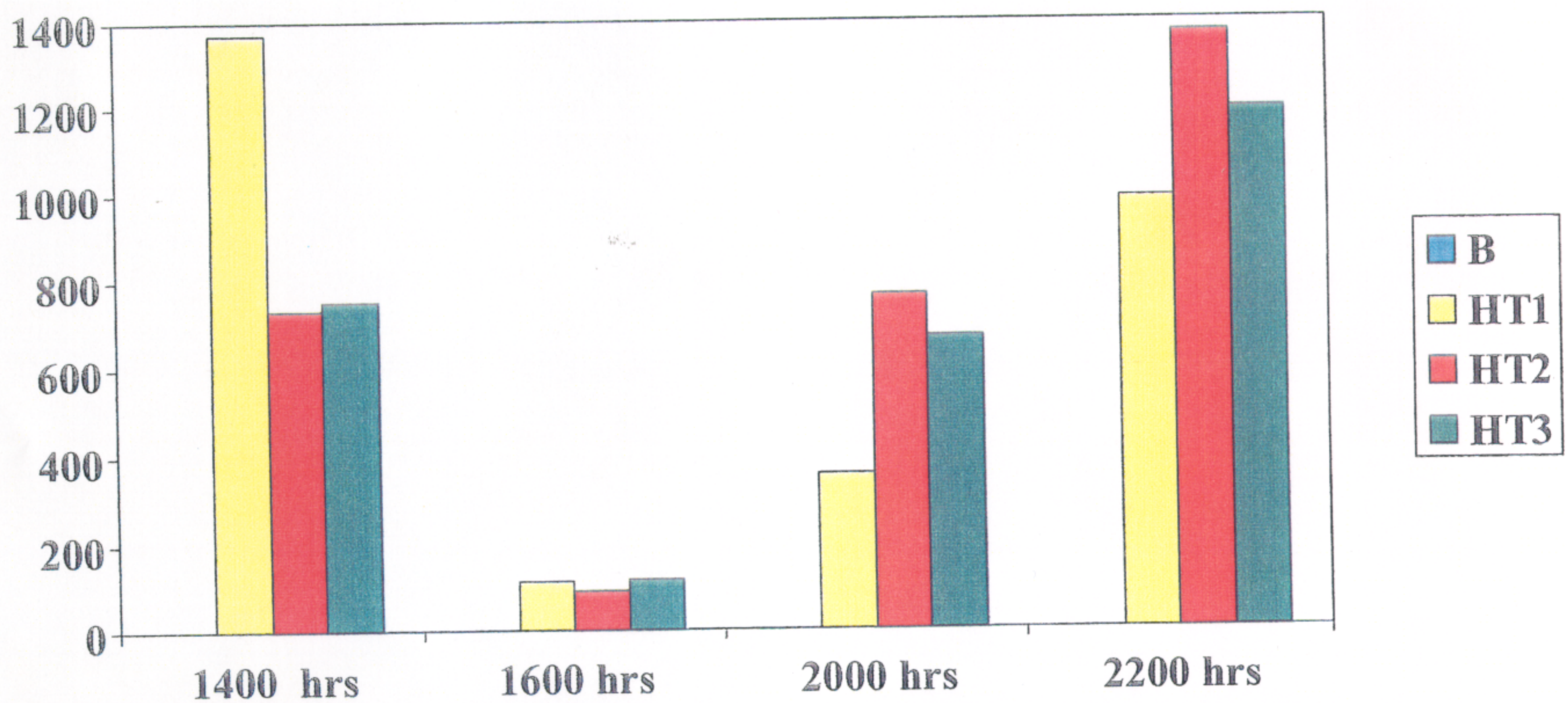


Figure 4. Pattern of fish abundance in four test sequences, October 5, 1999,Tracy Fish Collection Facility, California.
B and HT1 = Test; HT2 = Flush; HT3 = Reference

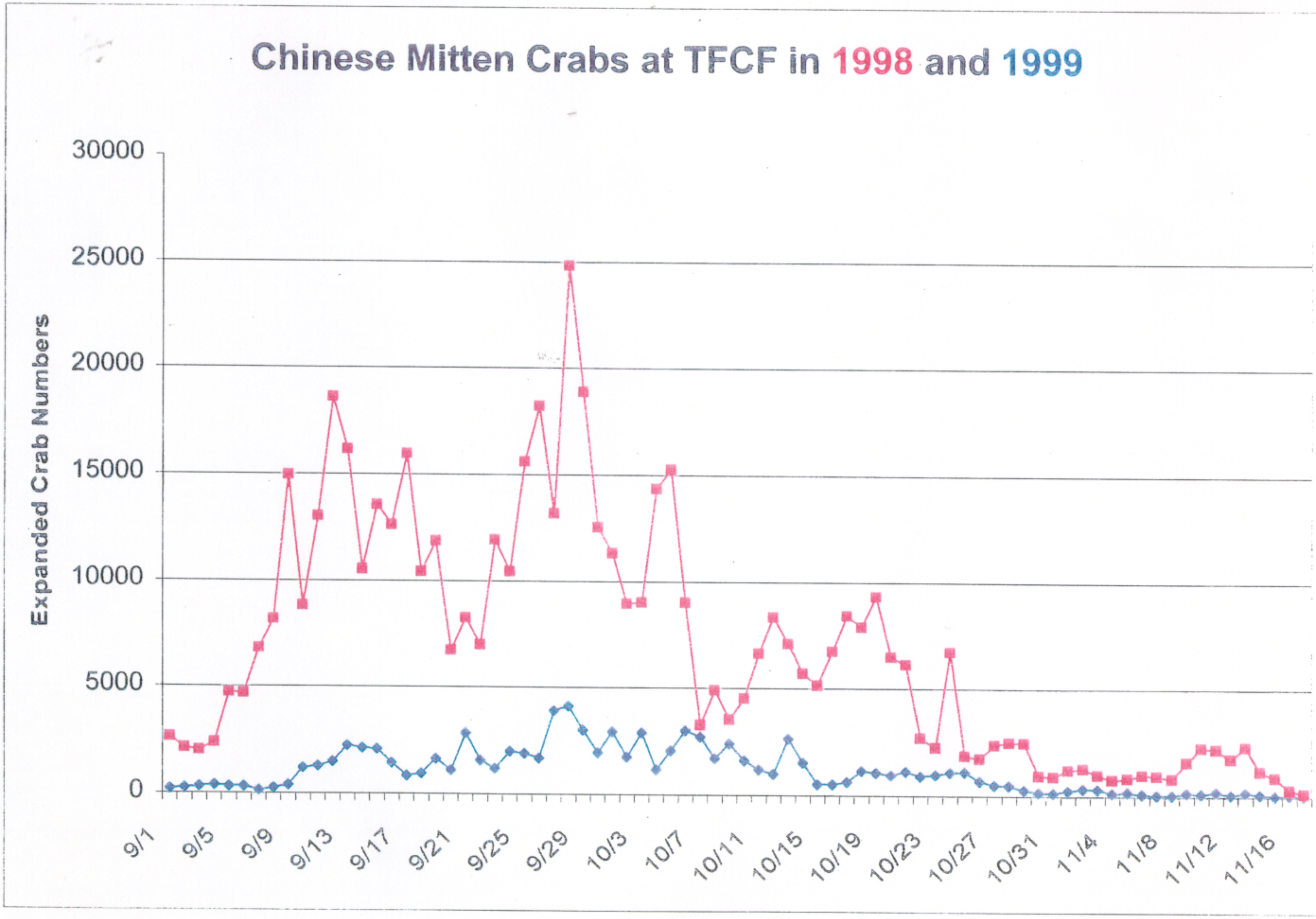
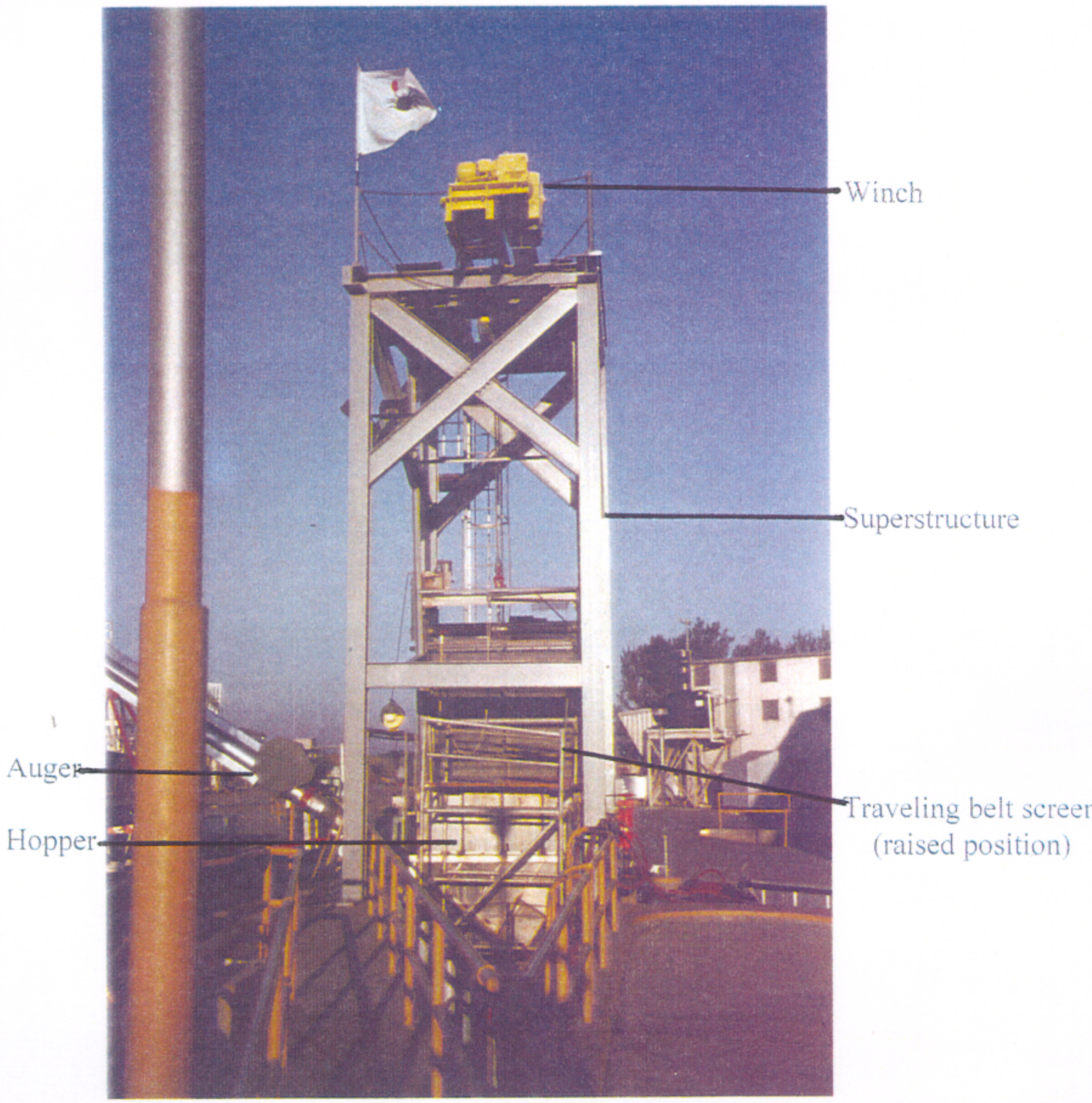


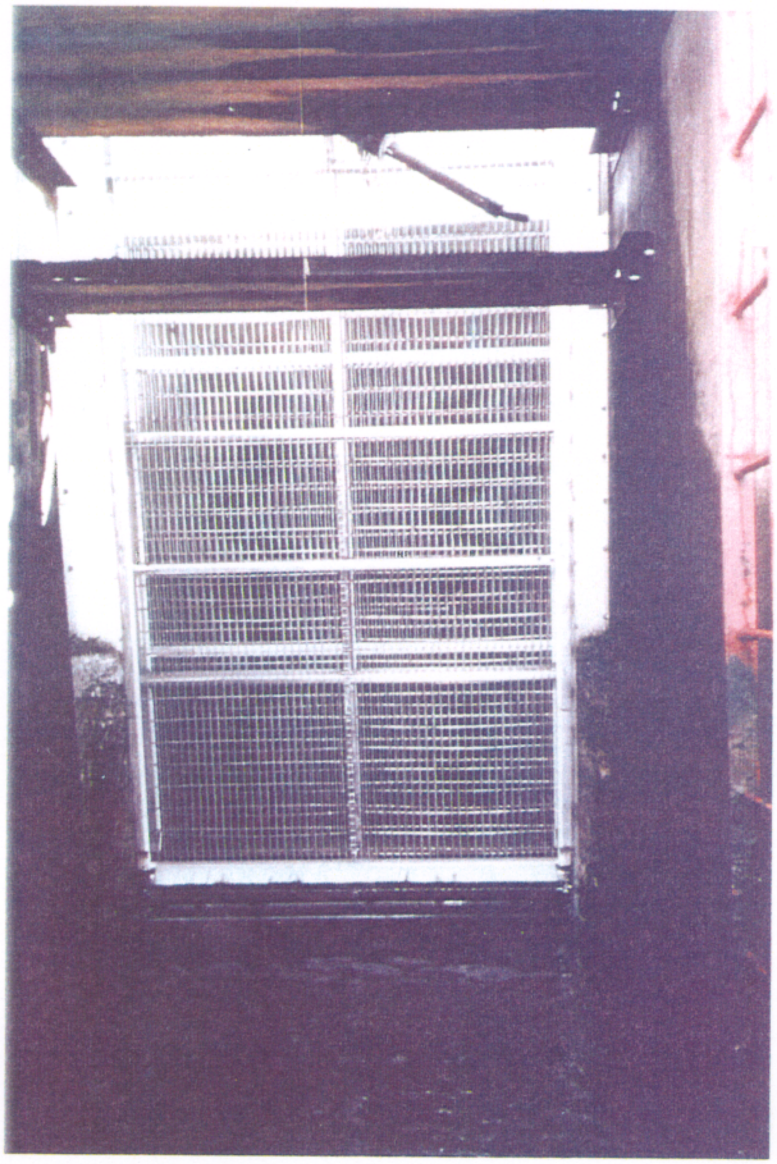
Figure 5. Daily comparison of 1998 and 1999 estimated mitten crab entrainment at the Tracy Fish Collection Facility, California (Siegfried, personal communication).

APPENDIX A

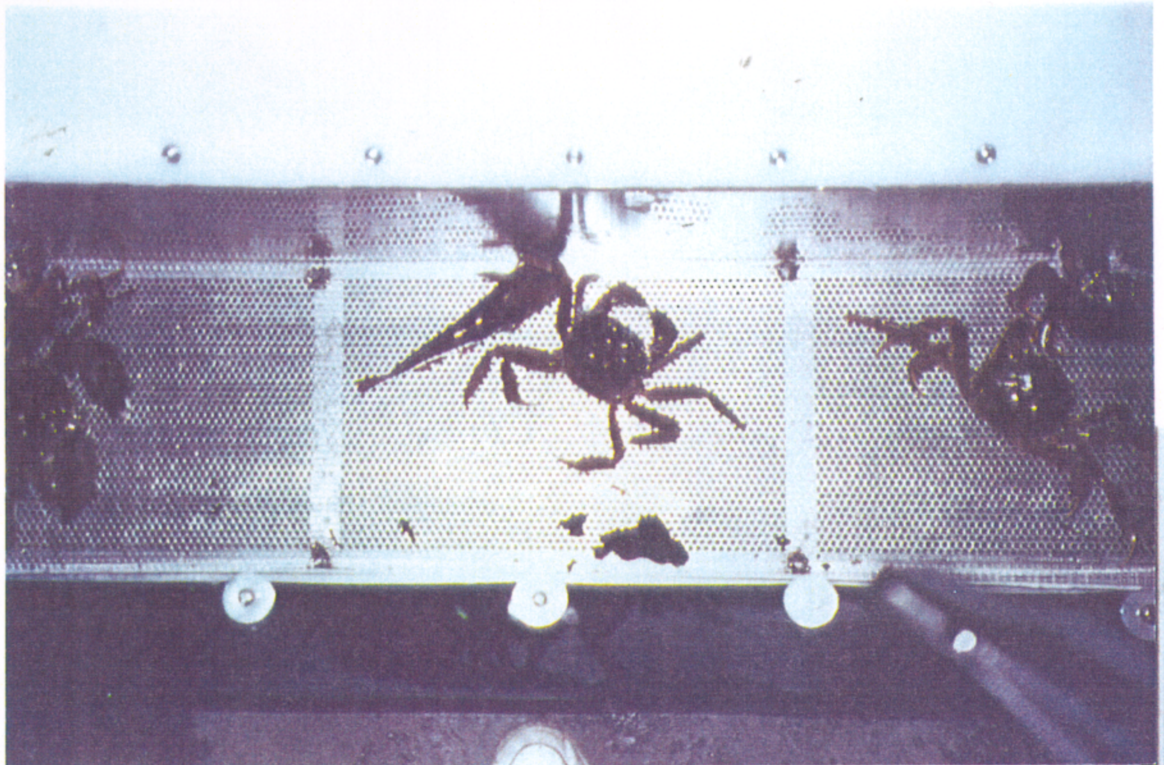
Photos pertaining to the 1999 mitten crab studies, Tracy Fish Collection Facility, CA.

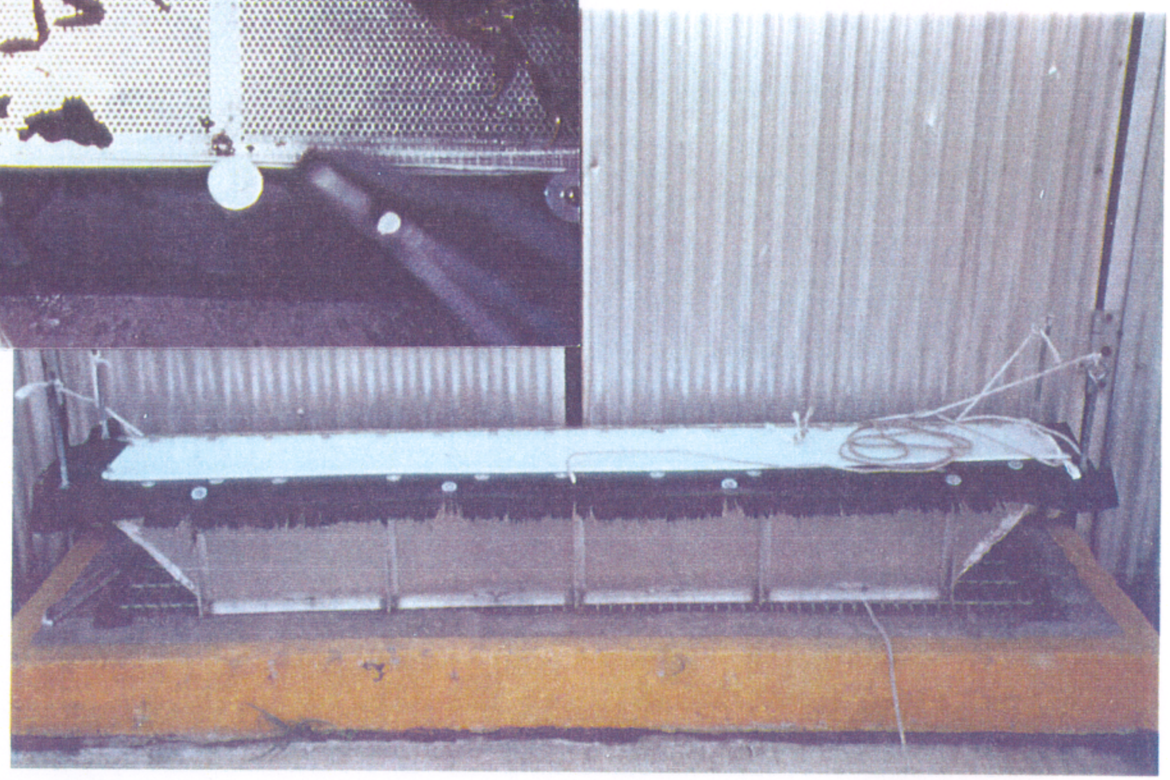


Superstructure and components of the traveling belt screen system used to remove mitten crabs while allowing safe passage of fish, Tracy Fish Collection Facility, California, 1999.



Traveling belt screen in position in the dewatered secondary channel. The screen was 8 ft wide, 19 ft high; mesh size was 4.5 inches x 1.5 inches.





Basket used to collect materials removed by the traveling belt screen. Upper: open basket showing perforated bottom and a partial sample. Lower: closed basket showing brush, rubber seal, and ropes used to lower the basker into the hopper.

APPENDIX B

Volume of green, woody and other debris collected during traveling belt and cyclone screen tests, Tracy Fish Collection Facility, 1999

Appendix: Debris

Volume of green, woody and other debris collected during traveling belt and cyclone screen tests, Tracy Fish Collection Facility, 1999.

lechanical Debris Screen 9/21-9/22/99									
ebris displacing less than 0.1 liters is listed as 0.05 liters (the mean between 0 and .01)									
ATE	TIME	SCREEN	TEST		DEBRIS				
				Green	Woody	Other			
09/21/1999	9:48-9:58	Screen In	Basket	<0.1 liter	<0.1 liter	<0.1 liter	0.05	0.05	0.05
09/21/1999		Screen In	Hold Tank	<0.1 liter	0.5 liter	<0.1 crab parts and bivalves	0.05	0.5	0.05
09/21/1999	13:39-13:49	Screen In	Basket	0	<0.1 liter	<0.1 crab legs	0	0.05	0.05
09/21/1999		Screen In	Hold Tank	<0.1 liter	0.2	0.4 crabs,bivalves and snails	0.05	0.2	0.4
09/21/1999	16:04-16:14	Screen In	Basket	0	<0.1 liter	0	0	0.05	0
09/21/1999	16:34-16:44	Screen In	Hold Tank	<0.1 liter	<0.1 liter	<0.1 liter	0.05	0.05	0.05
09/21/1999	16:44-16:54	Screen Out		<0.1 liter	<0.1 liter	<0.1 liter	0.05	0.05	0.05
09/21/1999	19:58-20:08	Screen In	Basket	<0.1 liter	<0.1 liter	<0.1 liter	0.05	0.05	0.05
09/21/1999	20:55-21:05	Screen Out		0	<0.1 liter	<0.1 liter	0	0.05	0.05
09/21/1999	21:05-21:15	Screen Out		<0.1 liter	<0.1 liter	<0.1 liter	0.05	0.05	0.05
09/21/1999	22:00-22:10	Screen In	Basket	<0.1 liter	<0.1 liter	<0.1 liter	0.05	0.05	0.05
			Hold tank	<0.1 liter	<0.1 liter	<0.1 Mostly crab parts	0.05	0.05	0.05
09/22/1999	10:30-10:50	Screen In	Basket	<0.1 liter	1.5 liters	<0.1 liter	0.05	1.5	0.05
		Screen In	Hold tank	<0.1 liter	2 liters	2.5 liters mostly crab parts	0.05	2	2.5
09/22/1999	12:0012:10	Screen In	Basket	<0.1 liter	<0.1 liter	<0.1 liter	0.05	0.05	0.05
		Screen In	Hold Tank	<0.1 liter	<0.1 liter	<0.1 liter	0.05	0.05	0.05
09/22/1999	14:05-14:15	Screen In	Hold Tank	<0.1 liter	0.4liters	0.4 liters	0.05	0.4	0.4
		Screen In	Basket	<0.1 liter	0.6 liters	<0.1 liter	0.05	0.6	0.05
	14:30-14:40	Screen Out	Flushing	<0.1 liter	0.4 liter	<0.1 liter	0.05	0.4	0.05
	14:40-14:50	Screen Out	Control	<0.1 liter	0.4 liter	<0.1 liter	0.05	0.4	0.05
09/22/1999	15:50-16:00	Screen In	Hold Tank	0	<0.1 liter	<0.1 liter	0	0.05	0.05
		Screen In	Basket	<0.1 liter	<0.1 liter	<0.1 liter	0.05	0.05	0.05
	16:10-16:20	Screen Out	Flushing	<0.1 liter	<0.1 liter	1 liter	0.05	0.05	1
	16:20-16:30	Screen Out	Control	0	<0.1 liter	<0.1 liter	0	0.05	0.05
09/22/1999	20:10-20:20	Screen In	Hold Tank	<0.1 liter	<0.1 liter	<0.1 liter	0.05	0.05	0.05
		Screen In	Basket	<0.1 liter	<0.1 liter	0	0.05	0.05	0
	20:36-20:46	Screen Out	Flushing	<0.1 liter	<0.1 liter	<0.1 liter	0.05	0.05	0.05
	20:46-20:56	Screen Out	Control	<0.1 liter	1.5 liters	<0.1 liter	0.05	1.5	0.05
	22:00-22:10	Screen In	Hold Tank	<0.1 liter	0	0	0.05	0	0
		Screen In	Basket	0	<0.1 liter	<0.1 liter	0	0.05	0.05
	22:20-22:30	Screen Out	Flushing	<0.1 liter	<0.1 liter	<0.1 liter	0.05	0.05	0.05
	22:30-22:40	Screen Out	Control	<0.1 liter	<0.1 liter	<0.1 liter	0.05	0.05	0.05

/lechanical Debris Screen			9/27-9/29/99					
)ebris displacing less than 0.1 liters is listed as 0.05 liters (the mean between 0 and .01)								~~Sheet 2~~
ıne 5-gallon bucket = approximately 4.6 liters				green vegetation only				
)ATE	TIME	SCREEN	TEST	DEBRIS (l				
				Green	Woody	Other			
09/27/1999	13:40-13:50	Screen In	Hold Tank	<0.1 liters	0.6 liters	0.4 liters	0.05	0.6	0.4
		Screen In	Basket	<0.1 liters	0.5 liters	1.5 liters	0.05	0.5	1.5
		Screen out	Flushing						
		Screen out	Control						
09/27/1999	16:00-16:10	Screen In	Hold Tank	<0.1 liters	0.4	1.5	0.05	0.4	1.5
		Screen In	Basket	<0.1 liters	0.8	<0.1 liters	0.05	0.8	0.05
	16:33-16:43	Screen out	Flushing	<0.1 liters	0.8	0.7	0.05	0.8	0.7
	16:43-16:53	Screen out	Control	<0.1 liters	1	1.3	0.05	1	1.3
09/27/1999	20:00-20:10	Screen In	Hold Tank	<0.1 liters	0.2	0.6	0.05	0.2	0.6
		Screen In	Basket	0.25	0.4	0.1	0.25	0.4	0.1
	20:50-21:00	Screen out	Flushing	<0.1 liters	<0.1 liters	0.9	0.05	0.05	0.9
	21:00-21:10	Screen out	Control	0	<0.1 liters	0.6	0	0.05	0.6
09/27/1999	22:00-22:10	Screen In	Hold Tank	<0.1 liters	0.1	1.3	0.05	0.1	1.3
		Screen In	Basket	0.5	0.2	0.1	0.5	0.2	0.1
	22:20-22:30	Screen out	Flushing	0	<0.1 liters	0.5	0	0.05	0.5
	22:30-22:40	Screen out	Control	<0.1 liters	1.4	0.25	0.05	1.4	0.25
09/28/1999	14:35-14:45	Screen In	Hold Tank	1	0.5	2.75	1	0.5	2.75
		Screen In	Basket	2-5gal buc	2	0.75	9.2	2	0.75
		Screen out	Flushing						
		Screen out	Control						
09/28/1999	16:15-16:20	Screen In	Hold Tank	<0.1 liters	0.3	0.3	0.05	0.3	0.3
		Screen In	Basket	0.5	<0.1 liters	1	0.5	0.05	1
	16:55-17:00	Screen out	Flushing	0.5	<0.1 liters	0.6	0.5	0.05	0.6
	17:00-17:05	Screen out	Control	0.1	<0.1 liters	0.45	0.1	0.05	0.45
09/28/1999	19:55-20:45	Screen In	Hold Tank	0.1	<0.1 liters	0.6	0.1	0.05	0.6
		Screen In	Basket	0.1	0.25	<0.1 liters	0.1	0.25	0.05
		Screen out	Flushing	<0.1 liters	0.6	0.1	0.05	0.6	0.1
		Screen out	Control	0.5	0.85	0.6	0.5	0.85	0.6
09/28/1999	22:00-22:55	Screen In	Hold Tank	1	0.8	1.5	1	0.8	1.5
		Screen In	Basket	0.5	1.8	0	0.5	1.8	0
		Screen out	Flushing	0.1	2	2.2	0.1	2	2.2
		Screen out	Control	0.8	2.9	0.5	0.8	2.9	0.5
09/29/1999	14:00-14:55	Screen In	Hold Tank	0.6	0.5	0.5	0.6	0.5	0.5
		Screen In	Basket	1-5galbuc	0.5	0.5	4.6	0.5	0.5
		Screen out	Flushing	0.1	0.5	0.5	0.1	0.5	0.5
		Screen out	Control	0.9	0.5	0.2	0.9	0.5	0.2
09/29/1999	15:50-16:35	Screen In	Hold Tank	0.2	0.6	0.5	0.2	0.6	0.5
		Screen In	Basket	0.7	<0.1	0	0.7	0.05	0
		Screen out	Flushing	0.5	0.6	0.75	0.5	0.6	0.75
		Screen out	Control	<0.1	0.25	1.75	0.05	0.25	1.75
09/29/1999	19:55-20:45	Screen In	Hold Tank	0.5	1	0.65	0.5	1	0.65
		Screen In	Basket	0.5	<0.1	0	0.5	0.05	0
		Screen out	Flushing	0.2	1.4	1.5	0.2	1.4	1.5
		Screen out	Control	1.9	0.4	0.5	1.9	0.4	0.5
09/29/1999	21:50-22:45	Screen In	Hold Tank	0.6	1	1	0.6	1	1
		Screen In	Basket	1.1	1	0.1	1.1	1	0.1
		Screen out	Flushing	0.6	1	0.6	0.6	1	0.6
		Screen out	Control	0.1	0.4	0.25	0.1	0.4	0.25

lechanical Debris Screen 10/4-6/99

ebris displacing less than 0.1 liters is listed as 0.05 liters (the mean between 0 and .01)

sheet 3

ATE	TIME	SCREEN	TEST	DEBRIS (liters displac					
				Green	Woody	Other			
10/04/1999	14:00	Screen In	Hold Tank	1L, 5:1 egeria: other	1.2	0.9	1	1.2	0.9
		Screen In	Basket	1L, 7:1 egeria : other	1	0.25	1	1	0.25
		Screen out	Flushing	0.7L, 5:1 egeria:other	1.5	1.5	0.7	1.5	1.5
		Screen out	Control	0.3L, 4:1 egeria:other	0.4	0.25	0.3	0.4	0.25
10/04/1999	16:00	Screen In	Hold Tank	2	0.2	0.45	2	0.2	0.45
		Screen In	Basket	0.3	0.2	1	0.3	0.2	1
		Screen out	Flushing	0.2	0.2	0.2	0.2	0.2	0.2
		Screen out	Control	0.25	0.1	0.1	0.25	0.1	0.1
10/04/1999	20:00	Screen In	Hold Tank	0.2	0.2	0.1	0.2	0.2	0.1
		Screen In	Basket	<0.1	0.1	<0.1	0.05	0.1	0.05
		Screen out	Flushing	<0.1	0.2	0.3	0.05	0.2	0.3
		Screen out	Control	0.2	<0.1	<0.1	0.2	0.05	0.05
10/04/1999	22:00	Screen In	Hold Tank	0.1	<0.1	0.1	0.1	0.05	0.1
		Screen In	Basket	0.6	0.2	0.25	0.6	0.2	0.25
		Screen out	Flushing	0.1	0.1	0.25	0.1	0.1	0.25
		Screen out	Control	0.25	<0.1	<0.1	0.25	0.05	0.05
10/05/1999	12:00	Screen In	Hold Tank	0.25	1.1	0.5	0.25	1.1	0.5
		Screen In	Basket	0.7	0.8	0.2	0.7	0.8	0.2
	12:32-12:42	Screen out	Flushing	0.2	0.5	0.3	0.2	0.5	0.3
	12:42-12:52	Screen out	Control	0.2	0.25	0.2	0.2	0.25	0.2
10/05/1999	14:00	Screen In	Hold Tank	<0.1 liters	1	0.4	0.05	1	0.4
		Screen In	Basket	<0.1 liters	0.6	<0.1 liters	0.05	0.6	0.05
	16:55-17:00	Screen out	Flushing	<0.1 liters	0.8	0.3	0.05	0.8	0.3
	17:00-17:05	Screen out	Control	<0.1 liters	0.5	0.25	0.05	0.5	0.25
10/05/1999	16:00	Screen In	Hold Tank	<0.1 liters	0.7	0.1	0.05	0.7	0.1
		Screen In	Basket	<0.1 liters	1	<0.1 liters	0.05	1	0.05
		Screen out	Flushing	<0.1 liters	0.1	<0.1 liters	0.05	0.1	0.05
		Screen out	Control	<0.1 liters	0.25	<0.1 liters	0.05	0.25	0.05
10/05/1999	20:00	Screen In	Hold Tank	<0.1 liters	0.1	0	0.05	0.1	0
		Screen In	Basket	<0.1 liters	0.1	0.1	0.05	0.1	0.1
		Screen out	Flushing	<0.1 liters	0.25	<0.1 liters	0.05	0.25	0.05
		Screen out	Control	<0.1 liters	<0.1 liters	<0.1 liters	0.05	0.05	0.05
10/05/1999	22:00	Screen In	Hold Tank	0.1	0.5	0.1	0.1	0.5	0.1
		Screen In	Basket	<0.1 liters	0.25	0.2	0.05	0.25	0.2
		Screen out	Flushing	1.5	0.5	0.25 trash rack cleaning in progres	1.5	0.5	0.25
		Screen out	Control	1	0.2	<0.1 trash rack cleaning in progres	1	0.2	0.05
10/06/1999	14:00	Screen In	Hold Tank	0.2	3.1	0.6 fresh water sponge	0.2	3.1	0.6
		Screen In	Basket	0	0.9	0	0	0.9	0
		Screen out	Flushing	0.2	1.1	0.7	0.2	1.1	0.7
		Screen out	Control	0.1	0.4	0.2	0.1	0.4	0.2
10/06/1999	16:00	Screen In	Hold Tank	<0.1 liters	0.9	0.1	0.05	0.9	0.1
		Screen In	Basket	<0.1 liters	0.25	<0.1 liters	0.05	0.25	0.05
		Screen out	Flushing	0.1	0.4	0.2	0.1	0.4	0.2
		Screen out	Control	0.1	<0.1 liters	<0.1 liters	0.1	0.05	0.05
10/06/1999	20:00	Screen In	Hold Tank	<0.1 liters	0.8	0.2	0.05	0.8	0.2
		Screen In	Basket	<0.1 liters	0.2	<0.1 liters	0.05	0.2	0.05
		Screen out	Flushing	<0.1 liters	0.3	0.2	0.05	0.3	0.2
		Screen out	Control	<0.1 liters	0.2	<0.1 liters	0.05	0.2	0.05
10/06/1999	22:00	Screen In	Hold Tank	<0.1 liters	0.6	0.5 two ground up thread fin shad	0.05	0.6	0.5
		Screen In	Basket	<0.1 liters	0.2	<0.1 liters	0.05	0.2	0.05
		Screen out	Flushing	<0.1 liters	0.5	0.5	0.05	0.5	0.5
		Screen out	Control	0.1	0.25	0.1	0.1	0.25	0.1

Mechanical Debris Screen 10/12-14/99

Debris displacing less than 0.1 liters is listed as 0.05 liters (the mean between 0 and .01)

Sheet 4

DATE	TIME	SCREEN	TEST	DEBRIS (liters displac					
				Green	Woody	Other			
10/12/1999	14:00-14:35	Screen In	Hold Tank	<0.1 liters	<0.1 liters	<0.1 liters	0.05	0.05	0.05
		Screen In	Basket	<0.1 liters	0.1	0	0.05	0.1	0
		Screen out	Flushing	<0.1 liters	<0.1 liters	<0.1 liters	0.05	0.05	0.05
		Screen out	Control	0.2 liters	<0.1 liters	<0.1 liters	0.2	0.05	0.05
10/12/1999	16:00-16:40	Screen In	Hold Tank	NA	NA	NA	0.05	0.05	0.05
		Screen In	Basket	<0.1 liters	<0.1 liters	<0.1 liters	0.05	0.05	0.05
		Screen out	Flushing	<0.1 liters	<0.1 liters	<0.1 liters	0.05	0.05	0.05
		Screen out	Control	<0.1 liters	0.5	<0.1 liters	0.05	0.5	0.05
10/12/1999	19:55-20:45	Screen In	Hold Tank	<0.1 liters	0.35	0.5	0.05	0.35	0.5
		Screen In	Basket	0	0	0	NA	NA	NA
		Screen out	Flushing	<0.1 liters	0.3	0.5	0.05	0.3	0.5
		Screen out	Control	<0.1 liters	0	0	0.05	0	0
10/12/1999	22:00	Screen In	Hold Tank	<0.1 liters	<0.1 liters	<0.1 liters	0.05	0.05	0.05
		Screen In	Basket	<0.1 liters	0.5	0.1	0.05	0.5	0.1
		Screen out	Flushing	<0.1 liters	1	<0.1 liters	0.05	1	0.05
		Screen out	Control	<0.1 liters	<0.1 liters	<0.1 liters	0.05	0.05	0.05
10/13/1999	9:55-10:19	Screen In	Hold Tank	0.1	0.75	0.2	0.1	0.75	0.2
		Screen In	Basket	<0.1 liters	0.25	<0.1 liters	0.05	0.25	0.05
		Screen out	Flushing	1	0.2	0	1	0.2	0
		Screen out	Control	0.5	0.5	0.5	0.5	0.5	0.5
10/13/1999	13:55-14:35	Screen In	Hold Tank	0.1	0.5	0.1	0.1	0.5	0.1
		Screen In	Basket	<0.1 liters	<0.1 liters	0	0.05	0.05	0
		Screen out	Flushing	<0.1 liters	1	0.5	0.05	1	0.5
		Screen out	Control	<0.1 liters	0.2	0.5	0.05	0.2	0.5
10/13/1999	17:00-17:33	Screen In	Hold Tank	0.4	0.2	0.5	0.4	0.2	0.5
		Screen In	Basket	<0.1 liters	0.65	0.5	0.05	0.65	0.5
		Screen out	Flushing	<0.1 liters	1	0.5	0.05	1	0.5
		Screen out	Control	<0.1 liters	<0.1 liters	<0.1 liters	0.05	0.05	0.05
10/13/1999	20:05-20.40	Screen In	Hold Tank	<0.1 liters	0.5	1.5 crab parts	0.05	0.5	1.5
		Screen In	Basket	<0.1 liters	0.1	0.3	0.05	0.1	0.3
		Screen out	Flushing	<0.1 liters	0.1	1.0 crab parts	0.05	0.1	1
		Screen out	Control	<0.1 liters	0.2	<0.1 liters	0.05	0.2	0.05
10/13/1999	21:55	Screen In	Hold Tank	<0.1 liters	4.5	0.25	0.05	4.5	0.25
		Screen In	Basket	<0.1 liters	1.4	1.1	0.05	1.4	1.1
		Screen out	Flushing	<0.1 liters	1	0.2	0.05	1	0.2
		Screen out	Control	<0.1 liters	0.25	<0.1 liters	0.05	0.25	0.05
10/14/1999	14:00-14:36	Screen In	Hold Tank	<0.1 liters	<0.1 liters	0.2	0.05	0.05	0.2
		Screen In	Basket	<0.1 liters	<0.1 liters	<0.1 liters	0.05	0.05	0.05
		Screen out	Flushing	0.3	<0.1 liters	0.3	0.3	0.05	0.3
		Screen out	Control	0.5	0.5	<0.1 liters	0.5	0.5	0.05
10/14/1999	15:52-16:40	Screen In	Hold Tank	0.4	0.25	<0.1 liters	0.4	0.25	0.05
		Screen In	Basket	<0.1 liters	0.5	0.2	0.05	0.5	0.2
		Screen out	Flushing	<0.1 liters	0	<0.1 liters	0.05	0	0.05
		Screen out	Control	0.4	0.3	<0.1 liters	0.4	0.3	0.05
10/14/1999	20:00-20:39	Screen In	Hold Tank	0.25	0.8	0.35	0.25	0.8	0.35
		Screen In	Basket	0?	0?	0?	0	0	0
		Screen out	Flushing	<0.1 liters	0.6	<0.1 liters	0.05	0.6	0.05
		Screen out	Control	<0.1 liters	0.5	0.1	0.05	0.05	0.1
10/14/1999	21:50	Screen In	Hold Tank	<0.1 liters	<0.1 liters	<0.1 liters	0.05	0.05	0.05
		Screen In	Basket	<0.1 liters	0.4	0	0.05	0.4	0
		Screen out	Flushing	<0.1 liters	0.2	<0.1 liters	0.05	0.2	0.05
		Screen out	Control	<0.1 liters	<0.1 liters	0.1	0.05	0.05	0.1

lechanical Debris Screen			11/1-3/99						
urricane fence		(chain link)					Sheet 5		
ebris displacing less than 0.1 liters is listed as 0.05 liters (the mean between 0 and .01)									
ATE	TIME	SCREEN	TEST	DEBRIS (l					
				Green	Woody	Other			
11/01/1999	13:50-14:00	Screen In	Hold Tank	<0.1 liters	<0.1 liters	<0.1 liters	0.05	0.05	0.05
		Screen In	Basket	<0.1 liters	<0.1 liters	0	0.05	0.05	0
	14:10-14:20	Screen out	Flushing	<0.1 liters	<0.1 liters	0.2, 1 dead amer. shad	0.05	0.05	0.2
	14:20-14:30	Screen out	Control	<0.1 liters	0.25	<0.1 liters	0.05	0.25	0.05
11/01/1999	15:50-16:00	Screen In	Hold Tank	<0.1 liters	0.15	<0.1 liters	0.05	0.15	0.05
		Screen In	Basket	0	<0.1 liters	0	0	0.05	0
	16:05-16:15	Screen out	Flushing	<0.1 liters	<0.1 liters	<0.1 liters	0.05	0.05	0.05
	16:15-16:25	Screen out	Control	<0.1 liters	<0.1 liters	<0.1 liters	0.05	0.05	0.05
11/01/1999	19:50-20:00	Screen In	Hold Tank	0	0	0	0	0	0
		Screen In	Basket	<0.1 liters	0.5	0	0.05	0.5	0
		Screen out	Flushing	<0.1 liters	0.24	<0.1 liters	0.05	0.24	0.05
		Screen out	Control	<0.1 liters	<0.1 liters	<0.1 liters	0.05	0.05	0.05
11/01/1999	21:55-22:05	Screen In	Hold Tank	<0.1 liters	0.15	<0.1 liters	0.05	0.15	0.05
		Screen In	Basket	<0.1 liters	<0.1 liters	<0.1 liters	0.05	0.05	0.05
	22:10-22:20	Screen out	Flushing	<0.1 liters	0.25	<0.1 liters	0.05	0.25	0.05
	22:20-22:30	Screen out	Control	<0.1 liters	0.25	<0.1 liters	0.05	0.25	0.05
11/02/1999	13:53-14:03	Screen In	Hold Tank	0.1	0.23	<0.1 liters	0.1	0.23	0.05
		Screen In	Basket	<0.1 liters	0.1	0	0.05	0.1	0
	14:08-14:18	Screen out	Flushing	<0.1 liters	0.26	<0.1 liters	0.05	0.26	0.05
	14:18-14:28	Screen out	Control	<0.1 liters	0.25	0	0.05	0.25	0
1/2/199	15:50-16:00	Screen In	Hold Tank	<0.1	0.27	0.1	0.05	0.27	0.1
		Screen In	Basket	0.15	0.15	0.15, dead amer. shad	0.15	0.15	0.15
	16:05-16:15	Screen out	Flushing	<0.1 liters	0.24	0.25, dead white cat fish	0.05	0.24	0.25
	16:15-16:25	Screen out	Control	<0.1 liters	0.24	0	0.05	0.24	0
1/2/199	19:50-20:00	Screen In	Hold Tank	<0.1 liters	0.25	<0.1 liters	0.05	0.25	0.05
		Screen In	Basket	<0.1 liters	<0.1 liters	0	0.05	0.05	0
	20:05-20:15	Screen out	Flushing	<0.1 liters	0.23	<0.1 liters	0.05	0.23	0.05
	20:15-20:25	Screen out	Control	<0.1 liters	<0.1 liters	<0.1 liters	0.05	0.05	0.05
1/2/199	21:50-22:00	Screen In	Hold Tank	<0.1 liters	0.15	<0.1 liters	0.05	0.15	0.05
		Screen In	Basket	<0.1 liters	<0.1 liters	<0.1 liters	0.05	0.05	0.05
	22:05-22:15	Screen out	Flushing	<0.1 liters	<0.1 liters	<0.1 liters	0.05	0.05	0.05
	22:15-22:25	Screen out	Control	<0.1 liters	0.3	<0.1 liters	0.05	0.3	0.05
11/03/1999	13:50-14:00	Screen In	Hold Tank	0.2	1.9	0.15	0.2	1.9	0.15
		Screen In	Basket	0.1	0.25	0.15 one catfish only	0.1	0.25	0.15
	14:25-14:15	Screen out	Flushing	0.1	0.9	<0.1 liters	0.1	0.9	0.05
	14:15-14:25	Screen out	Control	0.2	0.25	<0.1 liters	0.2	0.25	0.05
11/03/1999	15:50-16:00	Screen In	Hold Tank	<0.1 liters	0.25	0	0.05	0.25	0
		Screen In	Basket	<0.1 liters	<0.1 liters	<0.1 liters	0.05	0.05	0.05
	16:05-16:15	Screen out	Flushing	<0.1 liters	0.4	<0.1 liters	0.05	0.4	0.05
	16:15-16:25	Screen out	Control	<0.1 liters	<0.1 liters	<0.1 liters	0.05	0.05	0.05
11/03/1999	19:50-20:00	Screen In	Hold Tank	0.2	1.1	<0.1 liters	0.2	1.1	0.05
		Screen In	Basket	0.2	0.5	<0.1 liters	0.2	0.5	0.05
	20:05-20:15	Screen out	Flushing	<0.1 liters	1.2	<0.1 liters	0.05	1.2	0.05
	20:12-20:25	Screen out	Control	<0.1 liters	0.3	0	0.05	0.3	0
11/03/1999	21:50-22:00	Screen In	Hold Tank	<0.1 liters	<0.1 liters	0	0.05	0.05	0
		Screen In	Basket	<0.1 liters	0	0	0.05	0	0
		Screen out	Flushing	<0.1 liters	<0.1 liters	0	0.05	0.05	0
		Screen out	Control	<0.1 liters	<0.1 liters	0	0.05	0.05	0