Fish passage monitoring at the Freeman diversion

1993-2014

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Initial monitoring efforts (1993-1998)

The Vern Freeman diversion project was permitted through U.S. Army Corps of Engineers (USACE) 404 Permit No. 86-116-T5 on September 8, 1987. Special Condition B of the 404 permit included fisheries mitigation features of the project and required a “functional, mutually agreeable device for counting fish passage through the ladder” to be implemented for five years. ENTRIX (1991) developed a study plan to monitor steelhead use of the fish ladder, centered on the installation of a counting device (consisting of counting tubes) that became operational in February 1993. However, because of difficulties with the counting tubes, United Water Conservation District (UWCD) and California Department of Fish and Game (CDFG) viewed the 1993 trapping season as a preliminary effort to determine appropriate operating procedures. The USACE-required five year monitoring phase began with the 1994 water year. Monitoring efforts were composed of stranding surveys within the facility (fish screen bay, fish ladder, canal), an upstream fish trap and counting tubes within the fish ladder, and a downstream migrant trap at the downstream end of the fish screen bay (Figure 1).

The first upstream fish trap (1993-1994) was installed in the fish ladder upstream of the counting tubes to capture upstream migrating steelhead in a removable, low-velocity live car once fish passed through the tubes. Due to concerns that this design allowed fish to turn around and exit the live car downstream (yet be prevented from migrating upstream), the trap was modified in 1994 to include a screen funnel entrance to prevent steelhead from moving back downstream through the tubes. The live car was replaced with a large holding compartment, formed by the upstream trash rack and downstream guide bars. Checking the holding compartment for migrants required dewatering of the fish ladder, which was combined with full ladder stranding surveys. However, high debris loads and the passage of numerous lampreys through the tubes prevented the counters from providing reliable counts of adult steelhead passing through the ladder. Due to their poor performance, the counting tubes were removed at the beginning of the 1996 sampling season, while the fish trap remained in place. In June 1997, CDFG requested that the upstream trap be taken out of service, as the final listing for steelhead was expected prior to the 1998 sampling season. Upstream passage for the 1998 sampling season was only assessed via occasional stranding surveys in the fish ladder.

From 1994-1998, the downstream migrant trap was typically operated between January and June whenever

Figure 1. Freeman diversion and fish passage monitoring facilities

UWCD was diverting water (1997 monitoring began in November 1996; 1998 monitoring began in April due to permitting delays and continued through July). During this initial monitoring period, changes in diversion operations had a strong impact on trapping effectivity. Rapidly fluctuating river levels caused a lack of flow into the trap on some occasions, and siphons were installed to maintain water levels in the trap bay and prevent fish stranding. In 1998, UWCD completed automation of the canal control and head control gates at the diversion, which regulate water levels in the fish screen bay. Automated regulation reduced water level fluctuations in the fish screen bay, ensuring continuous and consistent flow of water to the fish trap area. The downstream migrant trap underwent several design iterations during this period; the original trap had coarse mesh (≈1/4 in) and an open top, which was subsequently covered after observing predation on fish in the trap by piscivorous birds. Sometime following 1997, the fish trap was redesigned with finer mesh and was fully enclosed to prevent predation as well as fish escape.

All life stages of steelhead were collected in the downstream trap, counted, and measured (FL). In 1995, scale samples were analyzed to determine fish age and origin. In 1995 and 1996, tissue samples were collected for genetic analysis (disposition unknown). Tissue samples were not collected in 1994 or 1998 and few tissue samples were collected in 1997 due to stress caused by high water temperatures. Prior to 1998, hatchery trout (typically distinguished by malformed fins and poor fin condition) were stocked in the Santa Clara River or tributaries and regularly encountered in the fish traps.

Both during the initial and later monitoring years, effectivity of the downstream migrant trap likely varied depending on diversion and bypass flow operations. Downstream migrants have four potential routes through the Freeman diversion, but only one pathway (the downstream migrant trap) was consistently monitored. These pathways include: 1) over the crest of the diversion, 2) through the Freeman bypass channel, 3) through the fish ladder, and 4) the downstream migrant trap. At high discharge values, a greater proportion of the flow travels through pathways 1-3, and thus may cause underestimates of total smolt numbers. During low flow years, nearly all flow will travel through the downstream migrant trap and may provide more accurate estimates of downstream migrants.

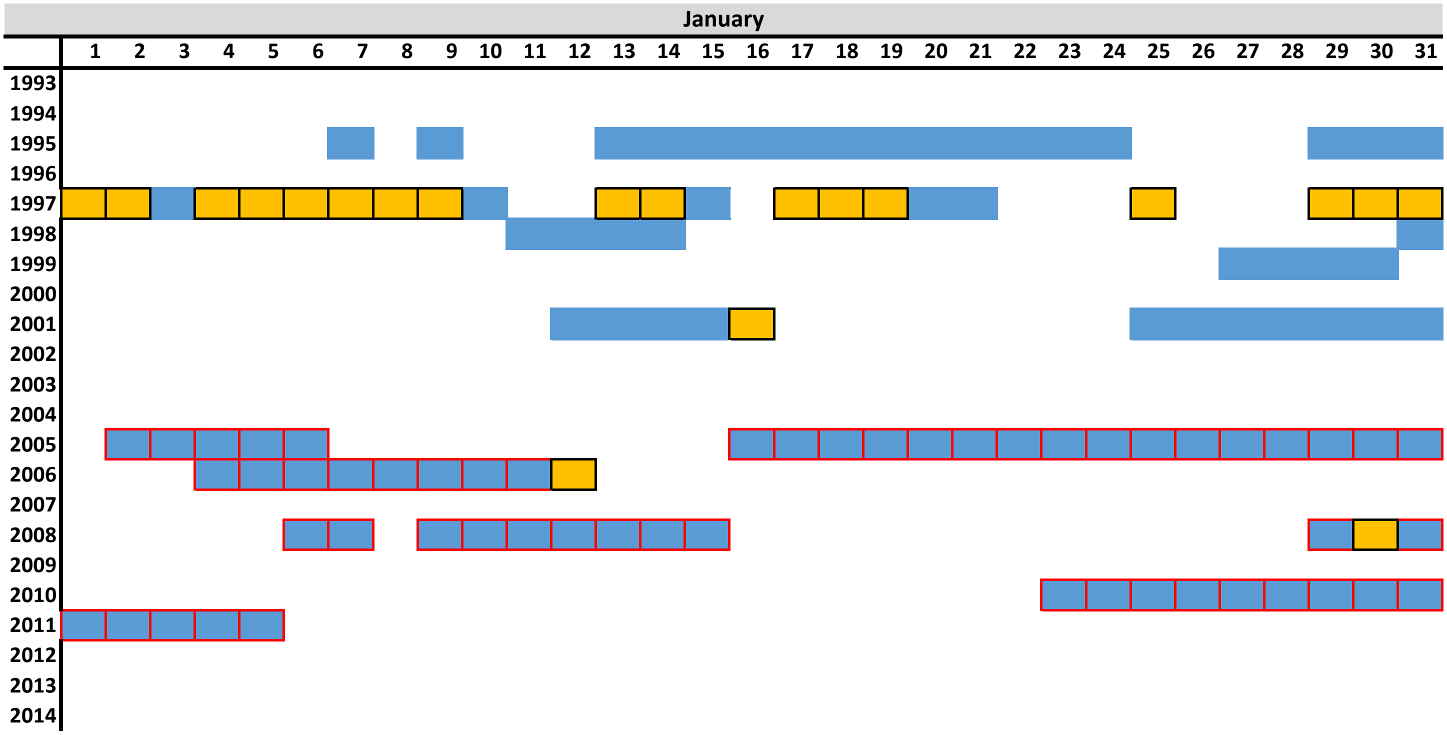
Later Monitoring (1999-2014)

From 1998 until 2002, adult upstream passage was monitored haphazardly, through stranding surveys of the dewatered fish ladder (Table 1). In 2002, United installed a false weir upstream of the denil plates in the fish ladder. The false weir creates a barrier within the ladder that forces upstream migrant steelhead to jump out of the water approximately six inches to traverse a small cascade and continue migrating upstream. An infrared (IR) scanner was installed across the false weir; a fish jumping over the weir would disrupt the IR beams and be detected by the scanner (Figure 2). The IR scanner was linked to a video surveillance system composed of single camera mounted upstream of the false weir, a Digital Video Recorder (DVR), and Video Cassette Recorder (VCR). The camera was positioned so it would clearly capture the path of migrant steelhead jumping over the weir structure. A twenty-five watt fluorescent light was used to illuminate the false weir at night. The video surveillance system was triggered to record a video clip of any event that disrupts the beams of the IR scanner. The DVR recorded events for twenty seconds before and ten seconds after being triggered. The video system was checked once per day and any video was reviewed for fish activity. In 2010, the DVR/VCR system was upgraded to a computer based surveillance system and two additional cameras were added to the weir. From 2011-2014, several additional cameras were installed to provide different viewing angles that could be used for motion detection (early efforts to use motion triggers with the original cameras failed because moving water in the camera view frame would cause false triggers).

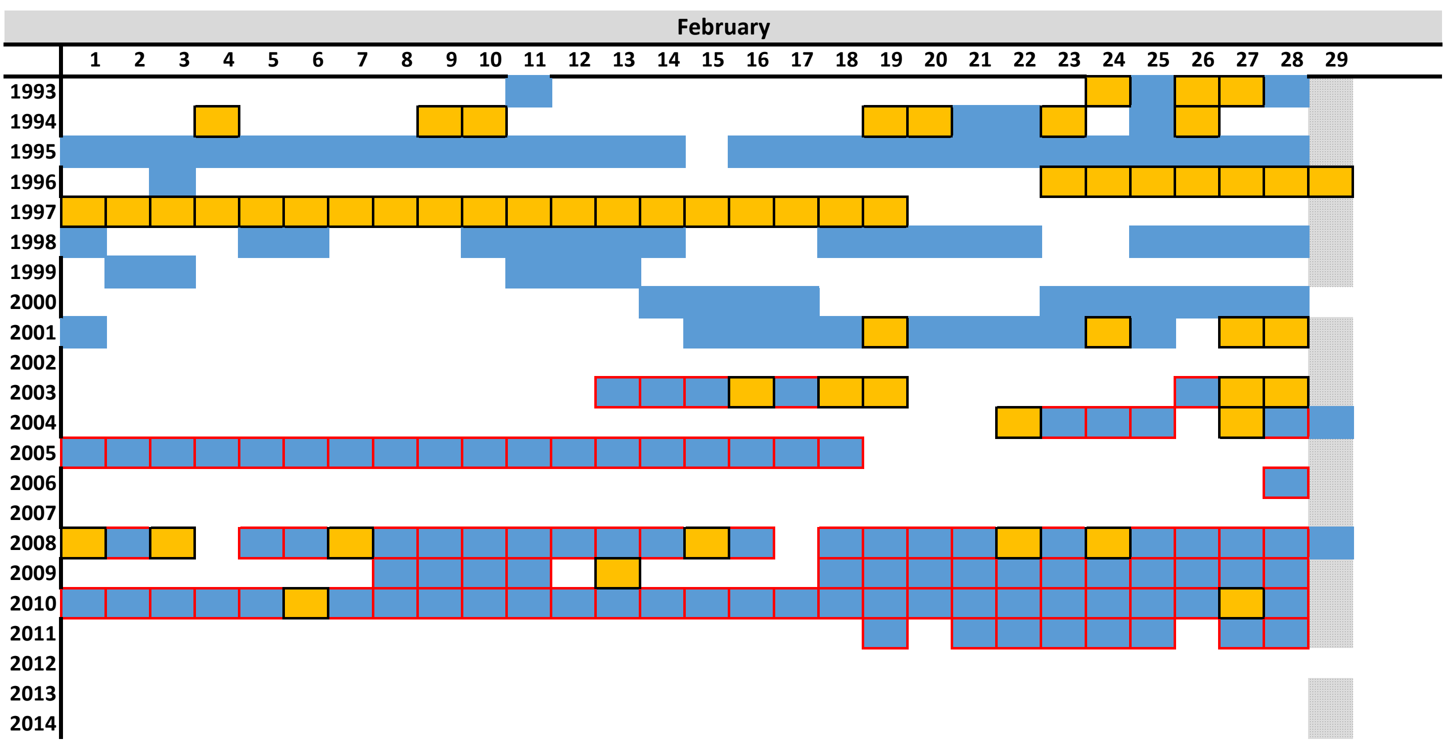
Figure 2. Denil fish ladder false weir

From 1999 to 2014, the downstream migrant trap was operated from January to June when flows in the Santa Clara River were sufficient to maintain consistent water levels in the fish screen bay. No monitoring data was collected in 2005 due to regular flood conditions, facility damage, sedimentation, and extended turnouts. Despite improvements to the automated gate system that controls water levels in the fish screen bay, occasionally river flows fluctuated more than can be compensated for by the system, causing temporary cessation of flow into the fish trap. This typically occurred during patchy storms or when river discharge was extremely low. When water levels in the fish screen bay could not be reliably maintained,

Table 1. Freeman fish ladder operations 1993-2014



Ladder Running   Surveillance system   Fish ladder survey



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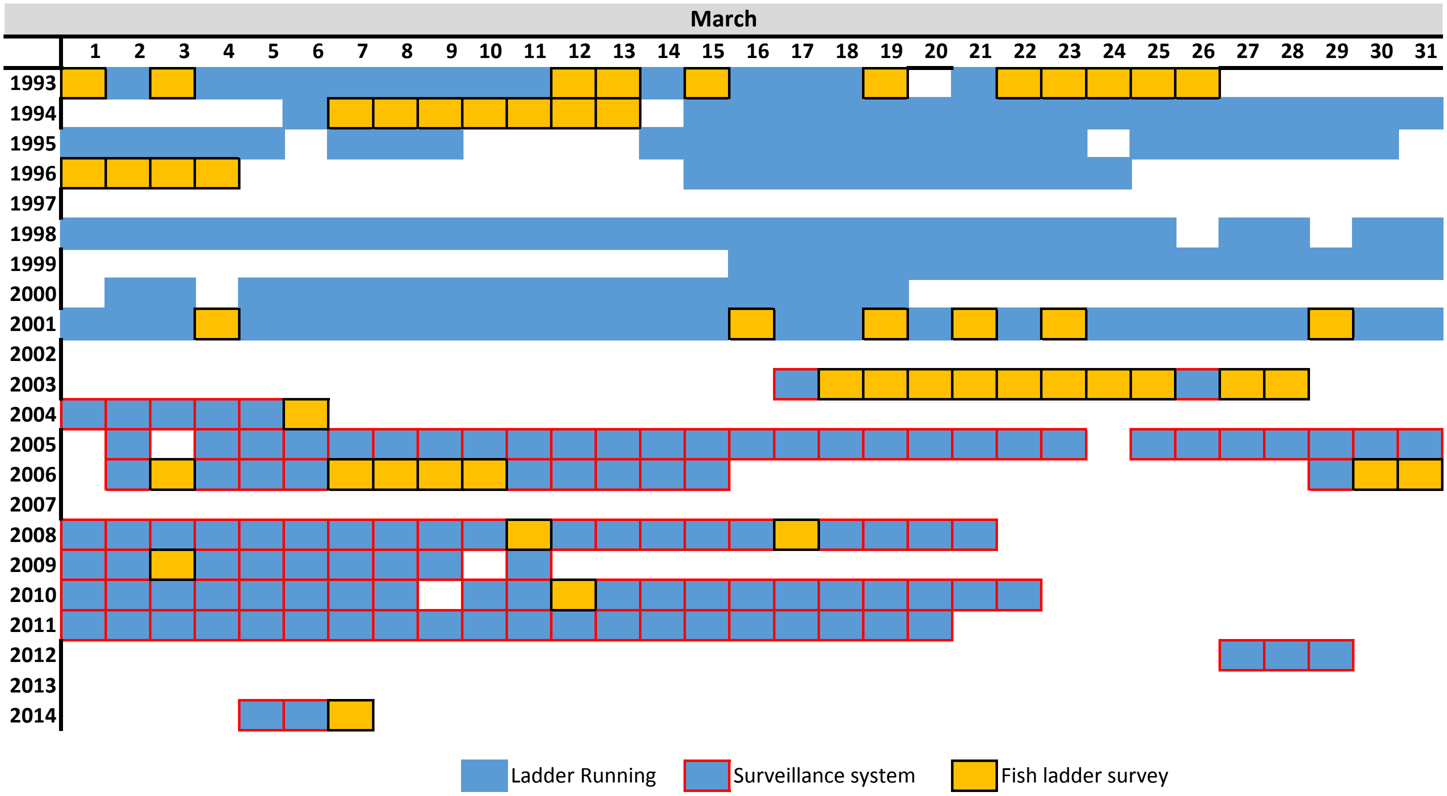

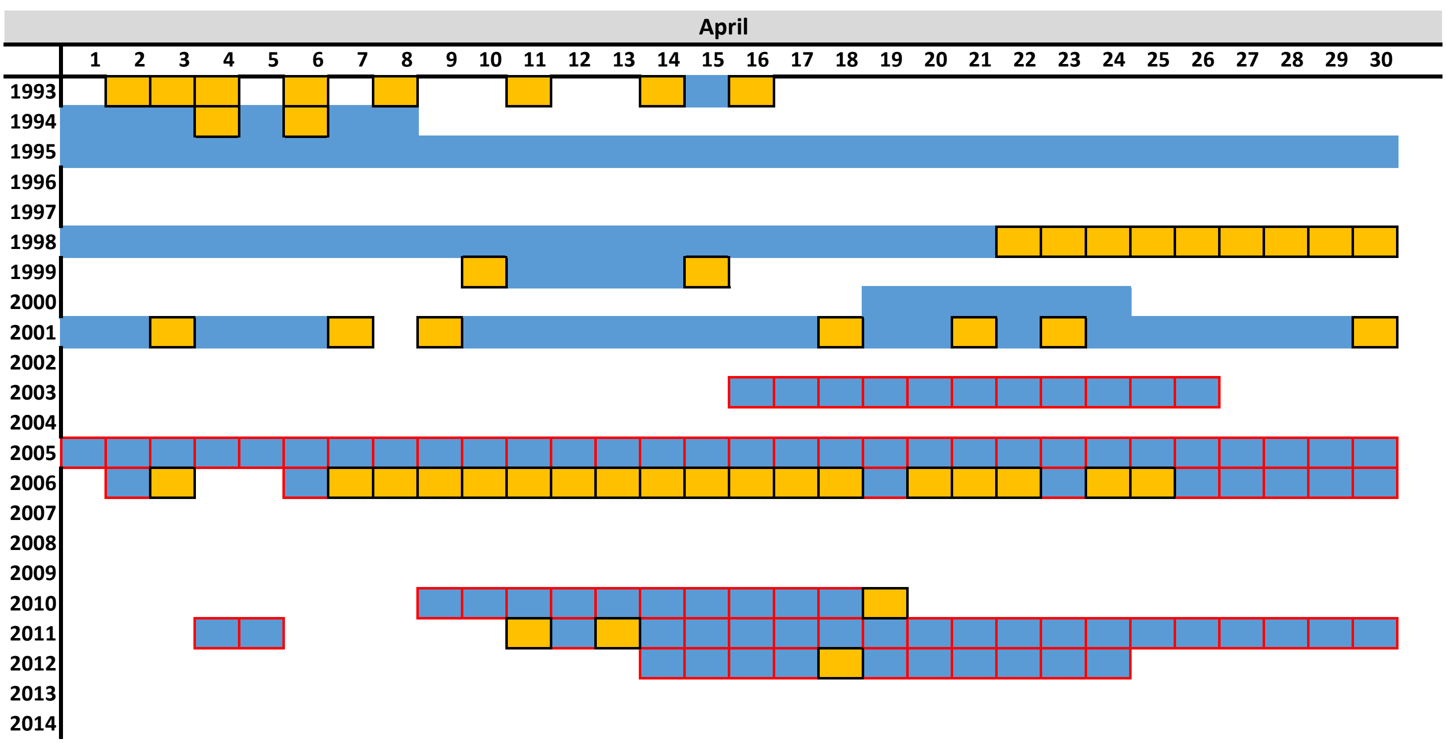

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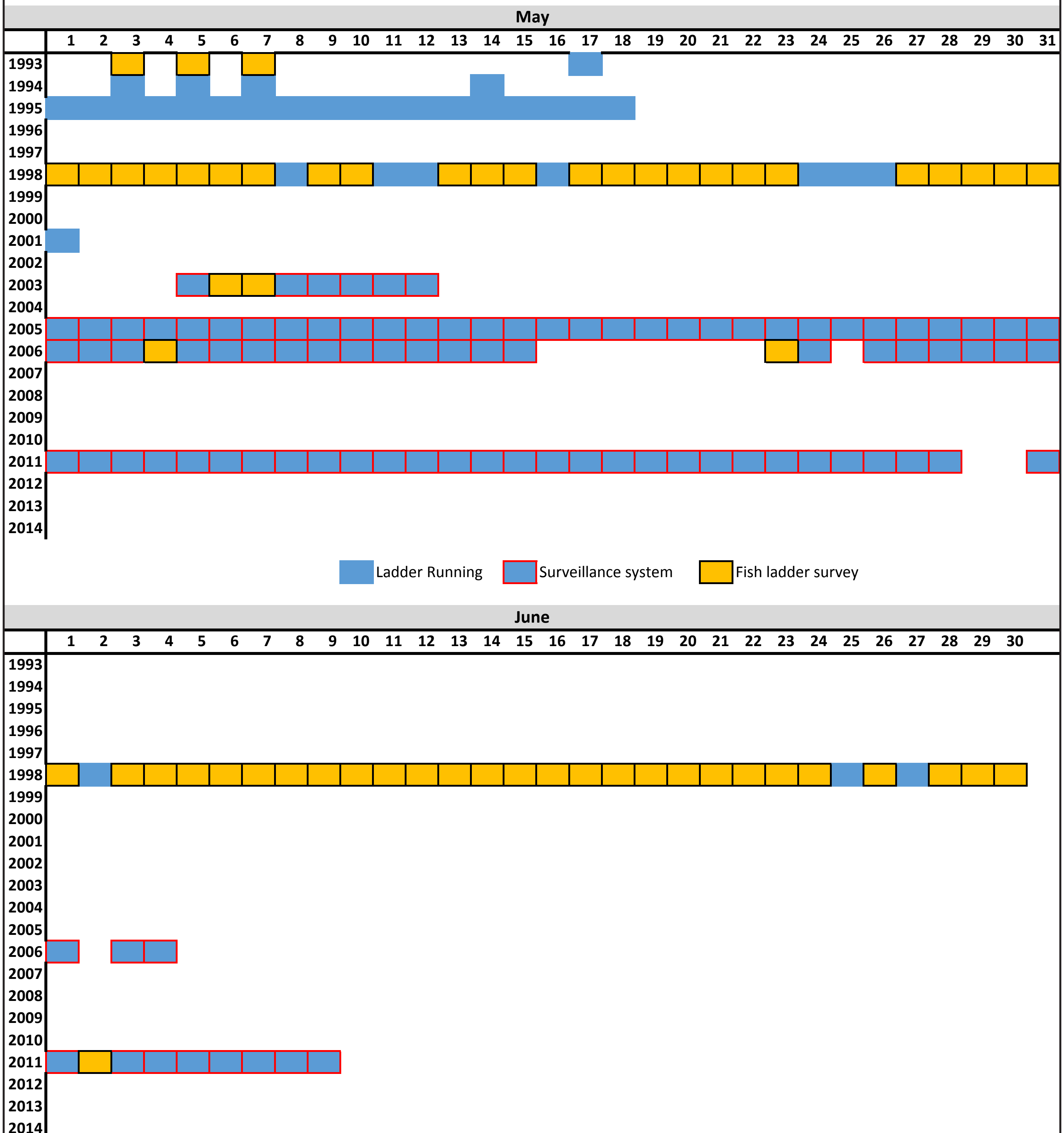

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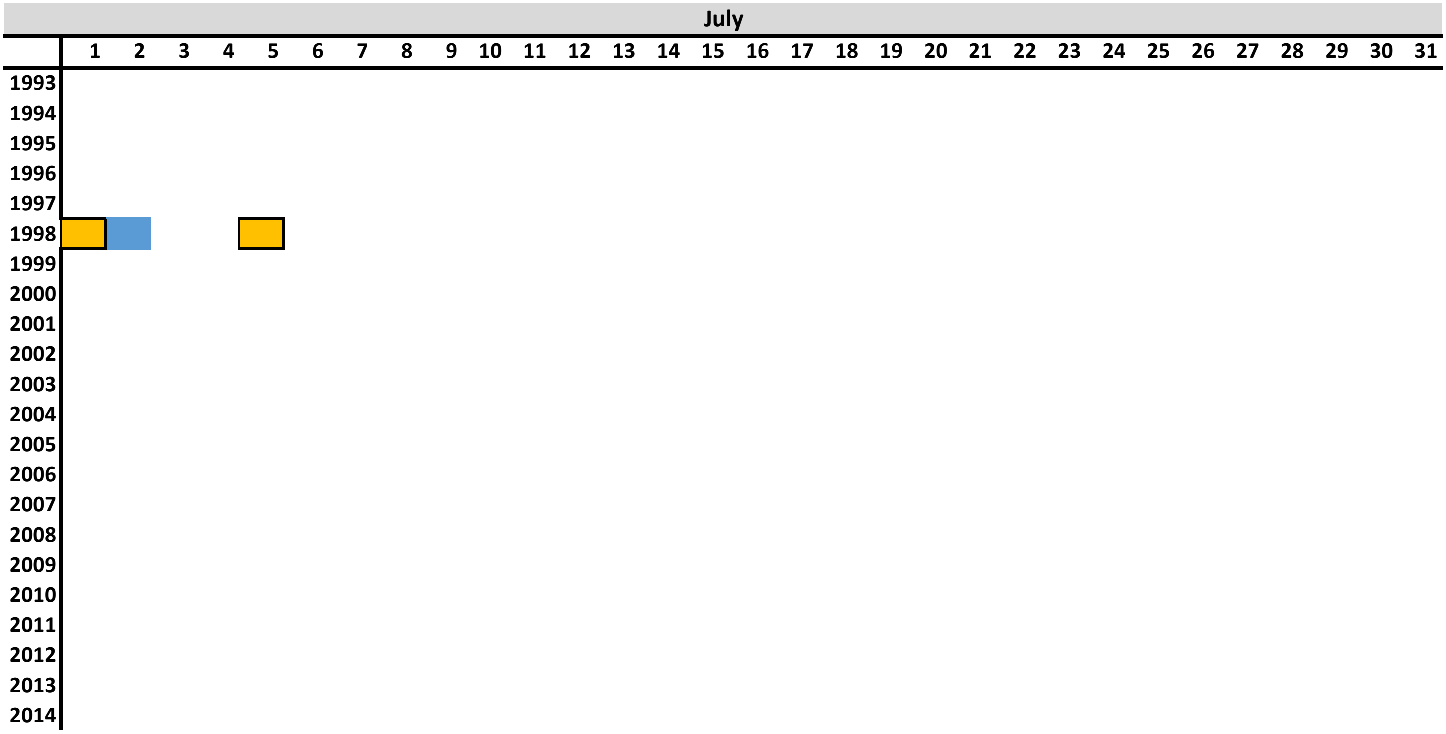
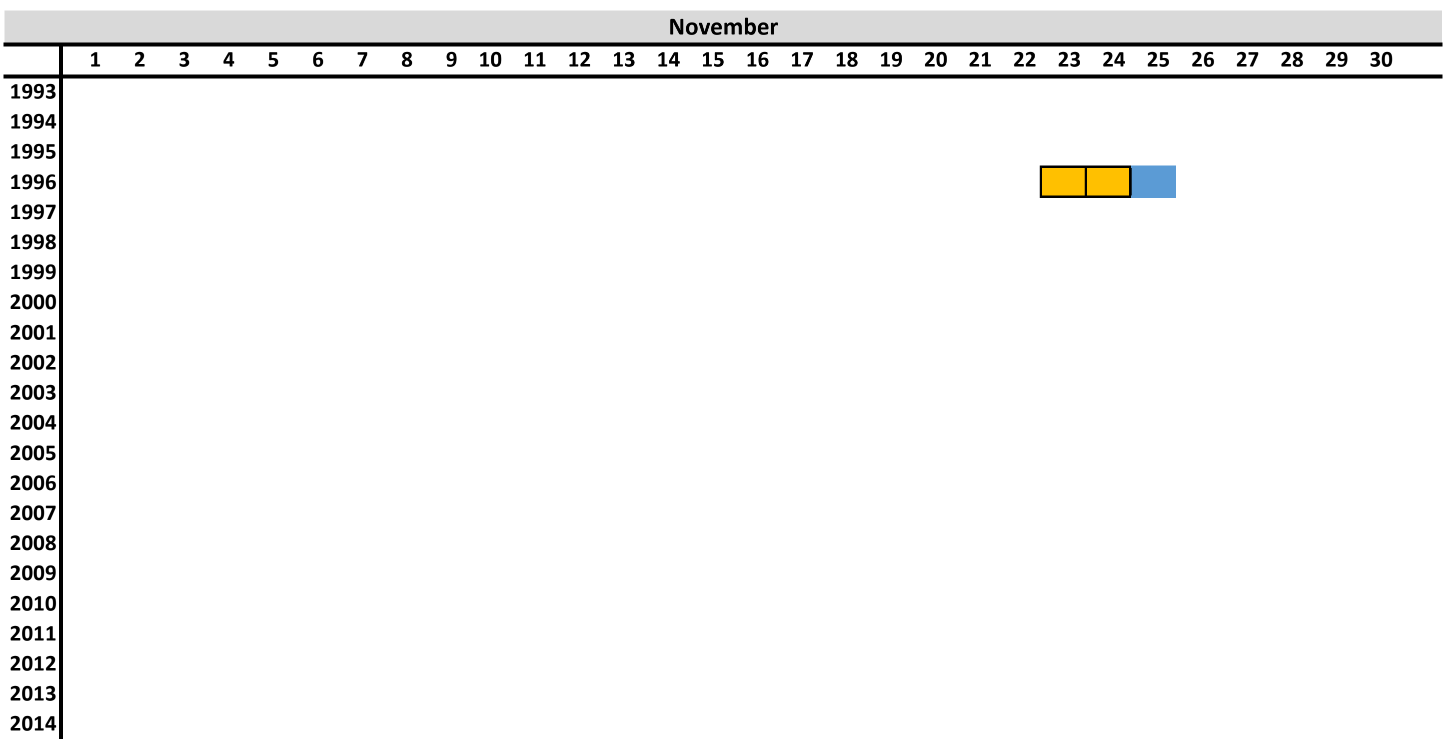


Ladder Running   Surveillance system   Fish ladder survey



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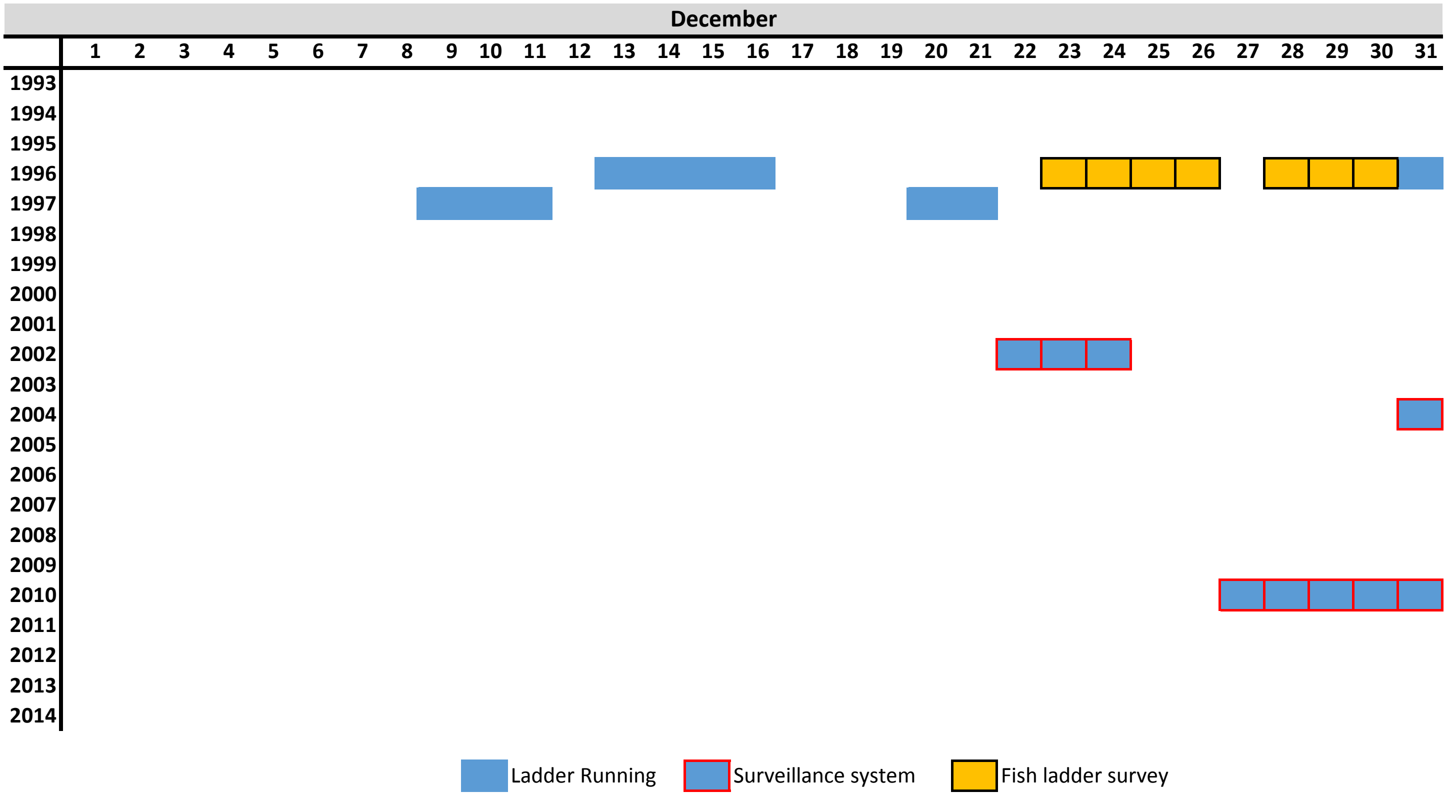

downstream migrant trapping was ended.

In 2008, United assisted with a tagging and acoustic telemetry study of migrating smolts in the Santa Clara estuary (Kelley 2008). Smolts were captured in the downstream migrant trap, surgically implanted with acoustic and passive integrated transponder (PIT) tags, transported in aerated coolers to the estuary, and released. Acoustic receivers were placed in a grid surrounding the mouth of the estuary to detect emigration from the estuary; fish subsequently detected by the receivers were considered to have survived their migration.

Monitoring results

Lamprey

Migrating adult lamprey were commonly observed in the fish ladder and downstream migrant trap until 1997 and the last adult lamprey were observed in 2001 (Table 2). Ocean fresh adults (500-700 mm, Figure 3) typically entered the system from late January to May and are likely to have oversummered for one year prior to spawning (Figure 4). Downstream migrating adults (post-spawn, about 30% smaller than upstream migrating adults, Figure 3) began arriving in the downstream trap from late February and continued through late May. Although anecdotal accounts suggest that ammocoetes had been impinged in large numbers on fish screens in the diversion facility (assumedly prior to the monitoring program as no available data corroborates these accounts), there are relatively few records of juvenile lamprey (macropthalmia or ammocoetes), even during the period when adult lamprey were abundant and frequently observed. The last juvenile was observed in 2006, five years after the last adults. Juvenile lamprey typically rear in freshwater for ≈7 years, which likely explains the extended presence of juveniles despite a lack of returning adults (Table 2).

Steelhead

Adult steelhead

A total of 16 adult steelhead were observed at the Freeman Diversion from 1993 to 2014, typically 2 or less per year, with most years having no fish observed (Table 2). All adults and kelts were observed in March or April. Fourteen adult

Table 2. Pacific lamprey and steelhead detected at the Freeman Diversion 1993-2014

Year	Pacific lamprey (adult)*	Pacific lamprey (juvenile)	Pacific lamprey (macropthalmia)	Steelhead adult	Steelhead kelt	Steelhead smolt	Young-of-the-Year	Resident trout	Hatchery trout
1993	478 [0]	4						1	
1994	1185 [279]			1		69		18	
1995	496 [114]	13	1	1		97	2	16	64
1996	374 [59]	2		1	1	83	2	11	27
1997	33 [17]	20				413	1	8	1
1998		1				2	3	1	
1999	2 [0]			1		3	2		
2000				2		839	37	14	
2001	48 [16]			2		123		1	
2002						3			
2003		5				36		5	
2004		6				2		1	
2005									
2006		1				13	4	4	
2007						12	60	2	
2008				2†		133	12	12	
2009				1	1	167		3	
2010						72	23	5	
2011						19		4	
2012				2	1	31	59	6	
2013							1		
2014						11	4	4	
Total	**0**	**52**	**1**	**13**	**3**	**2128**	**210**	**116**	**92**

*Bracketed values indicate the number of downstream migrants (post-spawn)

†Stray hatchery steelhead with clipped adipose fins

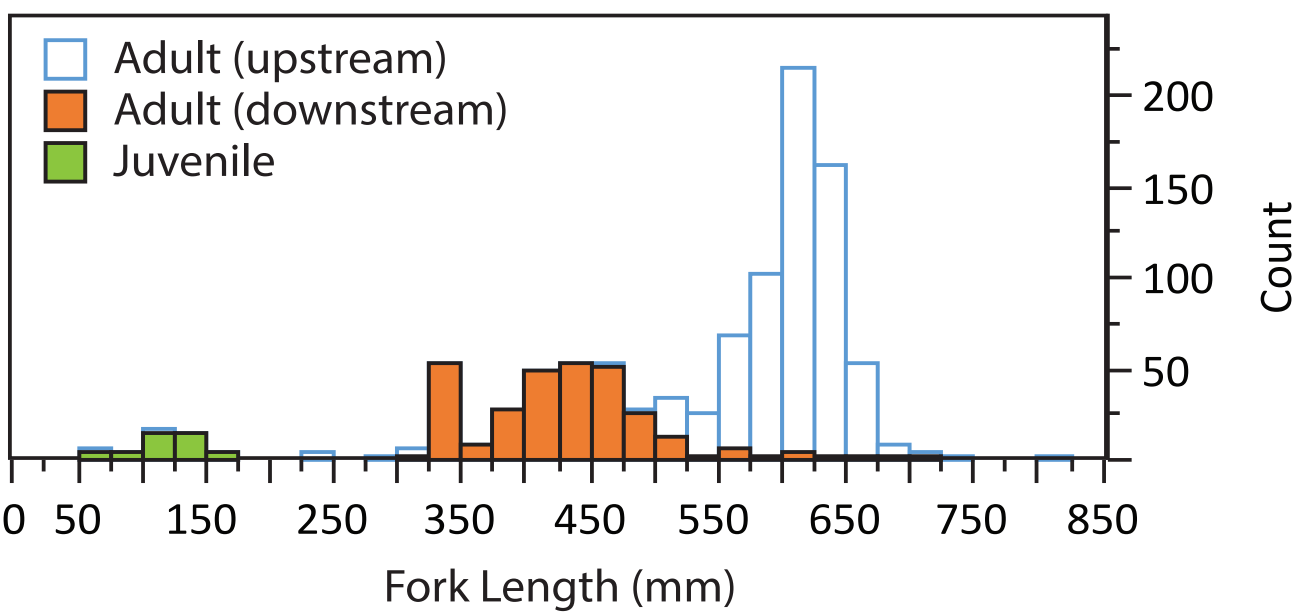

Figure 3. Size distribution of Pacific lamprey observed at the Freeman diversion

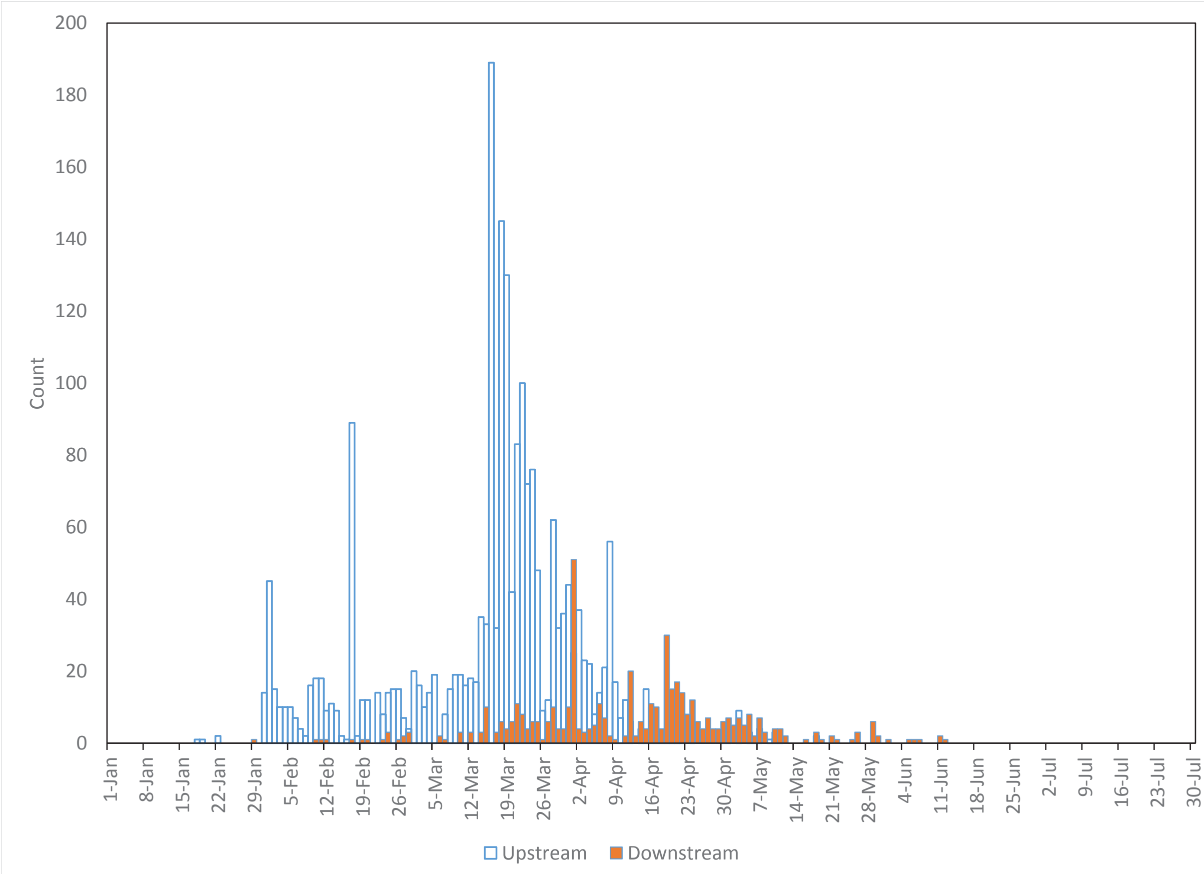

Figure 4. Pacific lamprey migration timing

steelhead (including three kelts) were observed passing the Freeman Diversion facility. Two adult steelhead with clipped adipose fins, indicating that they were strays from a hatchery (no steelhead are stocked south of Santa Cruz) were observed in March 2008 (Table 2) at the entrance of the fish ladder, but did not pass through the ladder. These hatchery adults were observed attempting to unsuccessfully build a redd in the sand of the tailout pool of the diversion, but were not detected passing through the fish ladder. The only adults detected using the IR and video surveillance system were observed in 2012.

Two lines of evidence suggest that the number of fish that observed passing the Freeman Diversion likely underestimates actual total number of adults: 1) The three kelts observed do not match any detected upstream migrants and 2) controlled tests of the video/IR surveillance system suggest that it was not 100% effective at detecting movement over the false weir.

Adult steelhead and kelts ranged in size from 400-600 mm (Figure 5), smaller than typical steelhead from Waddell Creek on the central coast of California (600-750mm, Shapovalov and Taft, 1954).

Smolts

Smolt numbers were extremely variable from year to year, ranging from 0 to 839. Some of the variability was due to changes in stream discharge from year to year: in years where the tributaries have minimal connection to the mainstem of the Santa Clara, smolt numbers are very low. However, as mentioned previously, during wet years, fish may take several pathways (i.e., fish ladder, dam crest, bypass channel) that avoid detection, leading to underestimates of fish numbers. Smolts were typically observed in the fish trap and fish bay between early March and late May, but have been observed as late as mid-July (Figure 6). Smolts typically are 120-160mm, though occasionally small smolts (<100mm) were captured in the fish trap (Figure 5).

Hatchery, resident, and young-of-the-year trout

It is not clear when or to what extent hatchery trout were stocked in the Santa Clara and its tributaries during the early monitoring period; between 1995 and 1997, 93 identifiable hatchery trout (damaged, missing, or deformed fins) were captured in the fish ladder and downstream migrant trap. It is likely that some of the fish described as resident trout in 1994 were also hatchery fish, but biologists did not describe individuals with sufficient detail to determine their origin. In

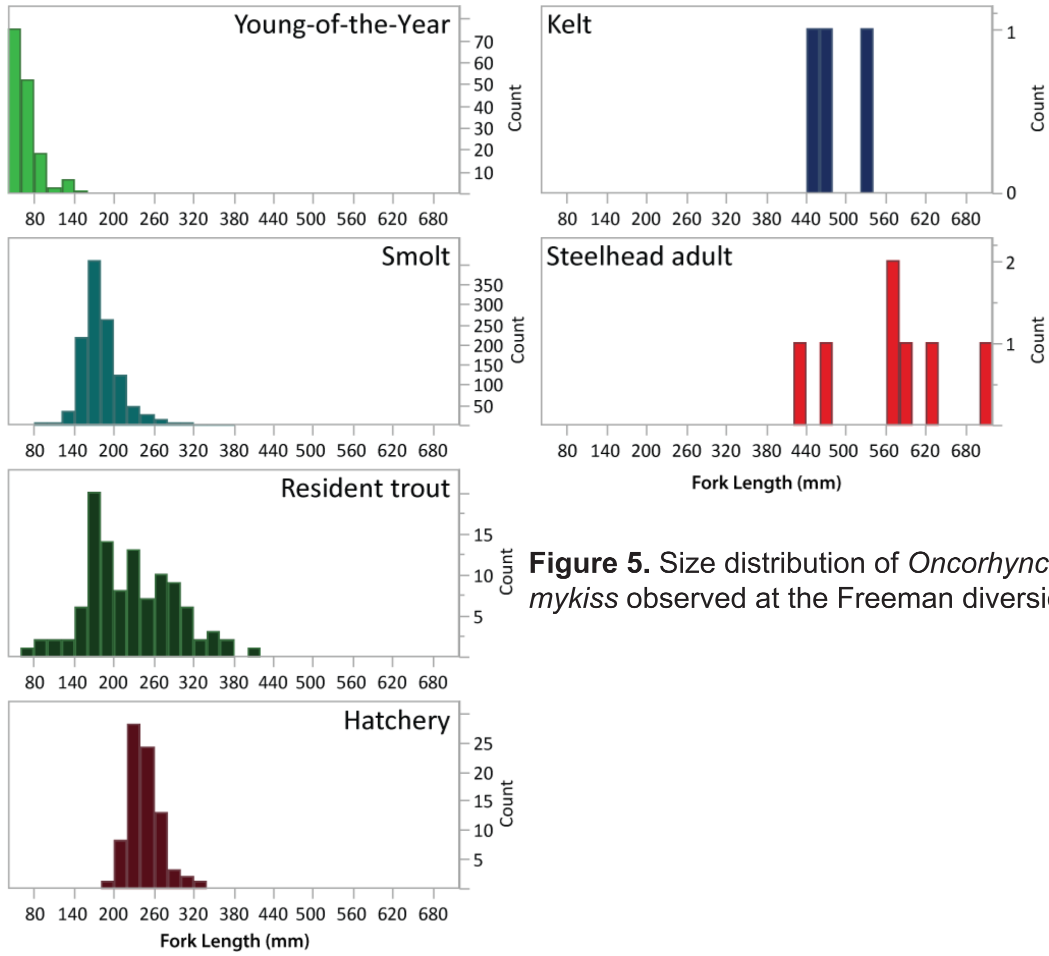

Figure 5. Size distribution of *Oncorhynchus mykiss* observed at the Freeman diversion

most years, resident fish were captured in the downstream migrant trap or fish bay, but counts were typically less than 10 fish per year (Table 2). It is possible that some of the individuals classified as residents may have been "pre-smolt" or smolts that reverted back to resident coloration at the end of the migration season; most of the fish classified as residents were in size classes that overlap with smolts (Figure 5). Young of the year were occasionally common (Table 2). These fish may have originated from the tributaries and volitionally moved to the mainstem of the Santa Clara or been swept from the tributaries during high flows; there is currently no evidence to suggest that spawning occurs in the mainstem, but trout have been observed in permanently wetted parts of the river year-round (e.g., Ventura County Flood Control Project, upstream of Santa Paula; S. Howard, United Water Conservation District, pers. comm.) and may potentially rear there during summer.

Age vs. Size

Scale samples collected in 1995 and 1996 were used to assess age versus size. There was substantial overlap between age 1 and age 2 fish of all life stages (the majority of the sample), with sizes typically ranging from 130-240 mm (Figure 7).

Acoustic telemetry study

In 2008, 81 smolts were acoustically tagged, transported to the estuary, and released. The acoustic receivers detected 48 individuals, suggesting that a minimum of 59% of the tagged smolts survived to successfully emigrate from the estuary. Smolts typically emigrated from the estuary within a few days of release, with all but six of the 48 individuals exiting in less than four days. In addition, once smolts exited the estuary, they typically moved beyond the detection range of the receiver array with day, and over half could no longer be detected within an hour. Two tagged smolts were incidentally detected by non-project hydrophone receivers off Point Año Nuevo and South Farallon Island in northern California, 21 and 30 days after exiting the Santa Clara estuary, but not reported until 2013 (M. Capelli., NMFS to S. Howard, UWCD, 12/16/2013).

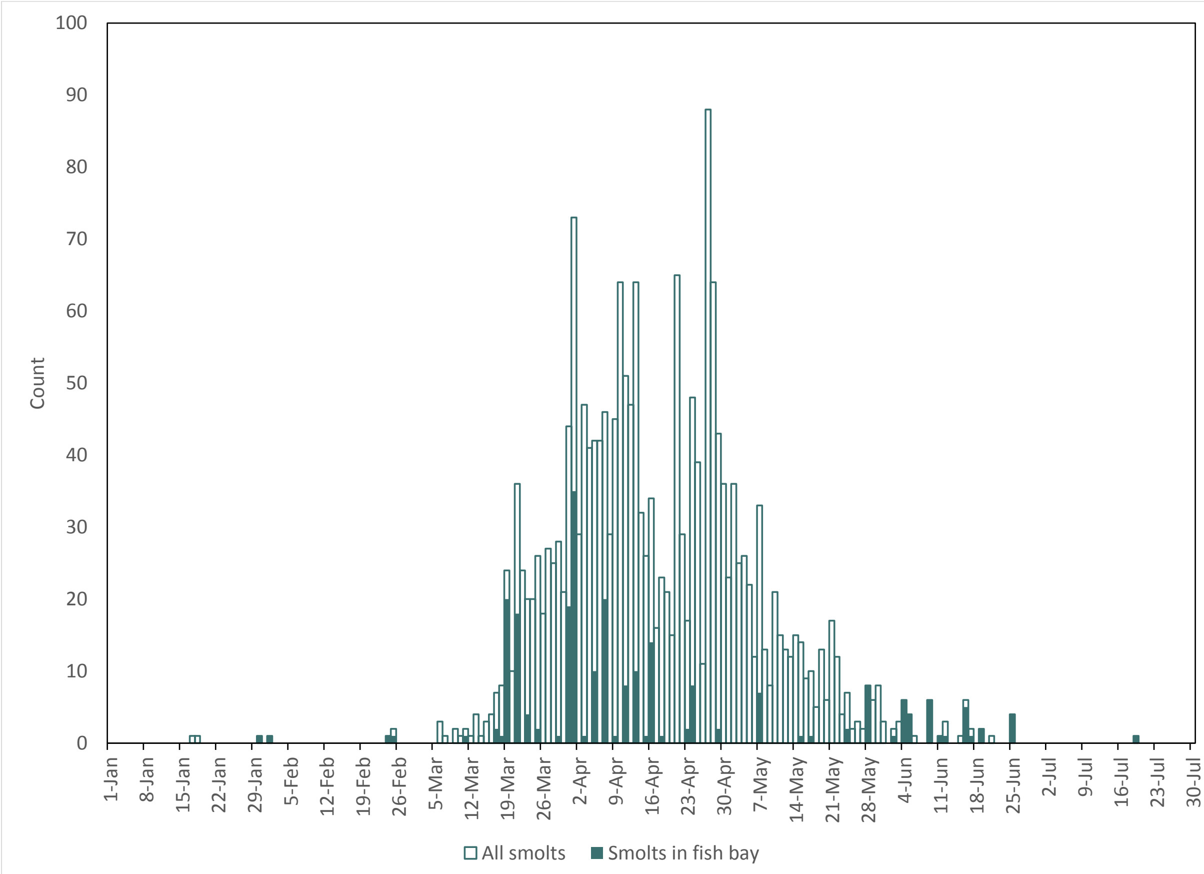

Figure 6. Steelhead smolt migration timing observed at the Freeman diversion

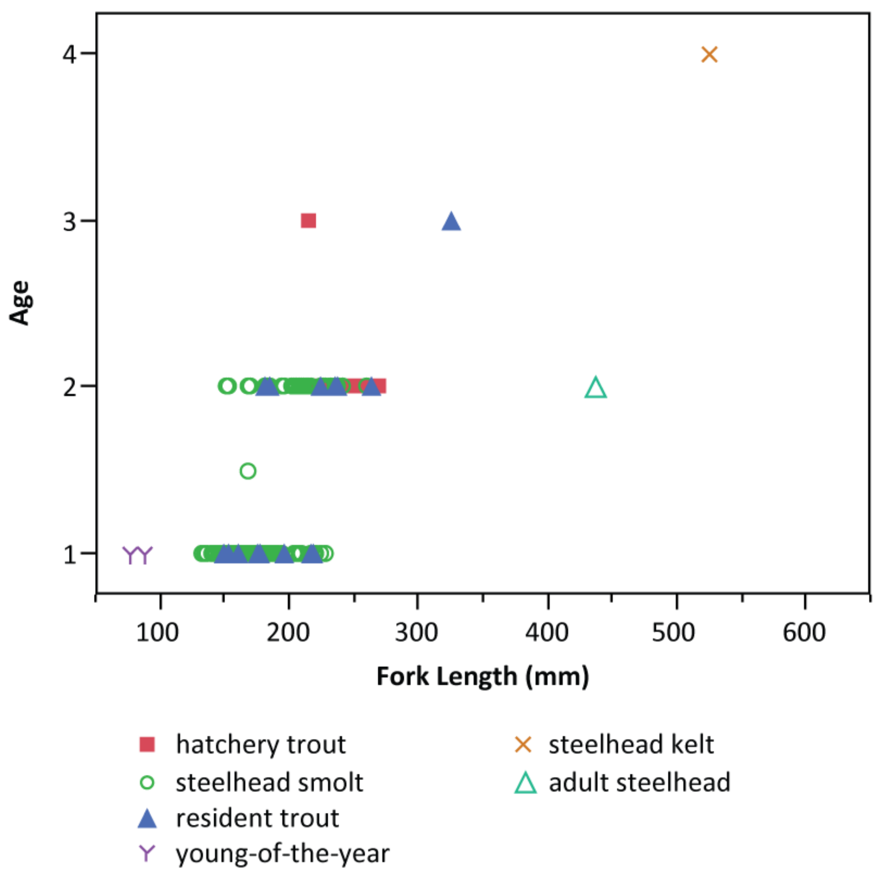

Figure 7. Age versus size of *Oncorhynchus mykiss* observed at the Freeman diversion determined by scale analysis

Works Cited

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