Data Summary – Carmel River steelhead population 2013 - 2016

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Introduction

To facilitate understanding of the impacts of the recent drought on Carmel River steelhead, here I provide a summary of population data collected for Carmel River steelhead during 2013 - 2016. In addition, I summarize some relevant flow data from the river, and also provide brief commentary on the data summarized. The data presented here are not exhaustive: We at the SW Fisheries Science Center are currently in the process of assembling various datasets collected by us and by the Monterey Peninsula Water Management District (MPWMD) into a unified database, and this process is not yet complete. Here we summarize the datasets that have been compiled and that have received a first round of QA/QC. We hope that this summary provides useful information for people interested in the management and recovery of the Carmel River steelhead population.

Migration connectivity

Figure 1 shows streamflows at two Carmel River gauges during Jan – May for the years 2011 through 2017. These months are the height of the rainy season and also the period when most steelhead migration occurs. USGS gauge 11143200 (left column of Figure 1) is located near the point where the river emerges from its canyon section (upstream of Carmel Valley Village) into the alluvial Carmel Valley, and can be regarded as an approximation of flow prior to infiltration into the aquifers underlying Carmel Valley. USGS gauge 11143250 (right column of Figure 1) is further downstream—about 3.5 miles from the river mouth—and differences between it and the upper gauge reflect losses of streamflow to infiltration into the aquifer, as well as relatively modest local contributions of runoff and tributaries.

Adult steelhead returning from the ocean to spawn may migrate as early as December, but the vast majority typically migrate January through April, with most arriving in February or March. However, the precise timing in dry years is determined more by sufficient instream flow to migrate upstream from the ocean. Downstream migrants consist of smolts migrating to the ocean and juveniles (parr) migrating to the lower river and estuary to rear through the summer. Most downstream migration of smolts occurs in April and May, with parr migration overlapping but often continuing into June depending on flow conditions.

In Year 2013, streamflow began the year at about 200 cfs (cubic feet per second) due to rainfall in late 2012. However, the months of Feb through May saw very little rainfall, and connectivity became problematic by April. The MPWMD began rescuing stranded steelhead from drying reaches on 19 April, which is unusually early for reaches to begin drying out.

Year 2014 had exceptionally low flow throughout the migration season (Figure 1, Year 2014). A modest peak flow event occurred at the end of February and a smaller event occurred in early April (Figure 1, left column), but both of these completely infiltrated into the aquifer before reaching the lower gauge (Figure 1, right column). Large sections of channel between the two gauges remained completely dry during the entire season. The small pulses discernable at the lower gauge were due to local runoff. Thus there were no opportunities for adult steelhead to migrate upstream to spawn or for smolts to migrate downstream to the ocean during 2014.

The effects of the drought continued in Year 2015, with one significant storm pulse in February eventually establishing connectivity during the migration season (Figure 1, Year 2015). Relatively good connectivity was re-established in Year 2016 by significant rainfall in January and March, and the wet year of 2017 maintained exceptionally high flows for the duration of the migration season.

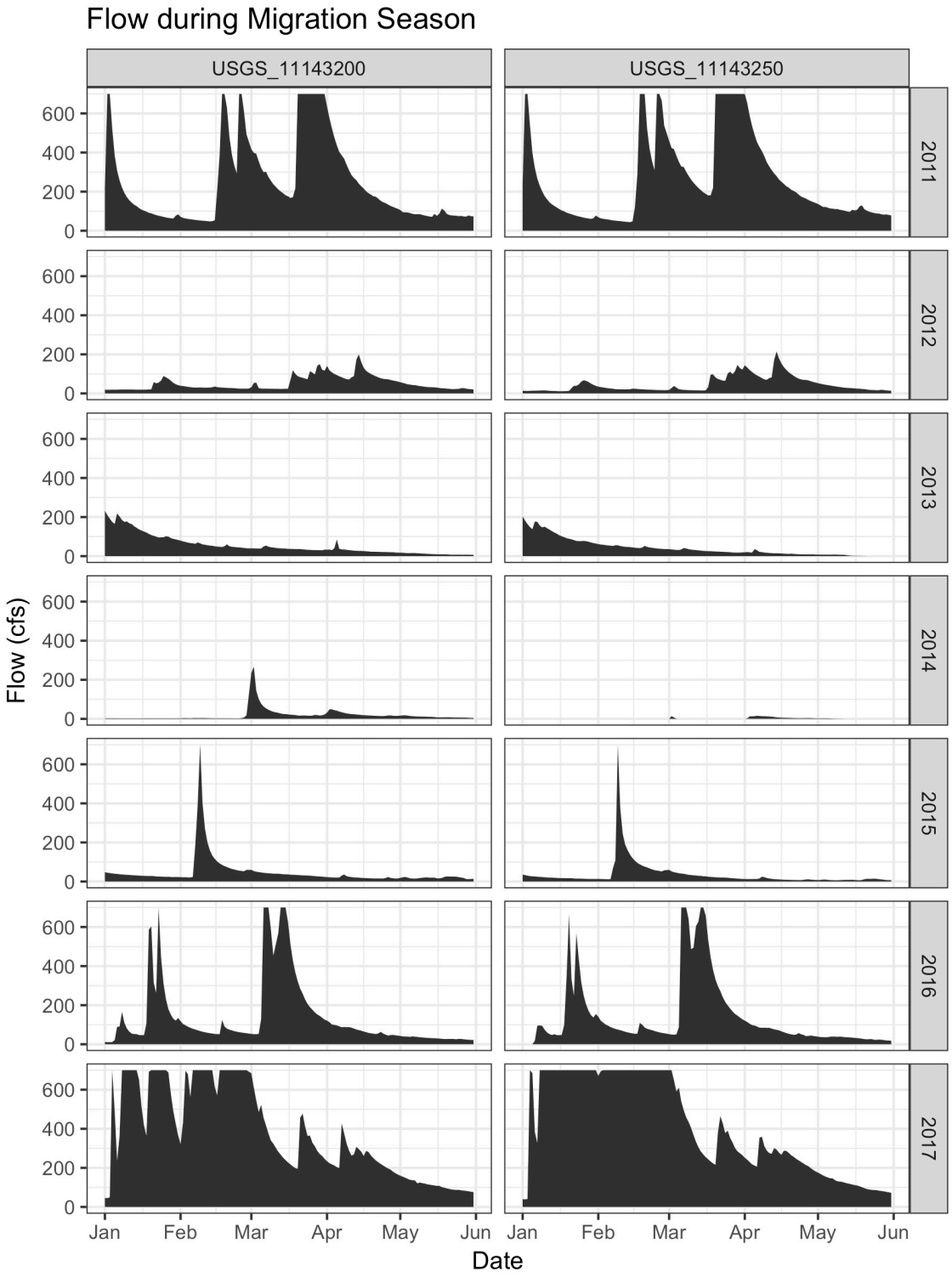

Figure 1. Recent flows in the Carmel River during steelhead migration season, near the upper end of Carmel Valley (left column, USGS 11143200, Carmel R a Robles del Rio CA), and near the lower end (right column, USGS 11143250, Carmel R nr Carmel CA). Flows greater than 700 cubic feet per second (cfs) are truncated in the graphs to focus on low-flow limitations to migration.

Counts of Migrating Adults

The size of the annual steelhead run in the Carmel has been tracked for the past 30 years by counting the number of adults ascending the fish ladder on San Clemente Dam (SCD) and also by the number of adults arriving at the fish trap below Los Padres Dam (LPD) (Table 1). Steelhead arriving at the LPD trap are transported up to the dam and released into the reservoir to continue their upstream migration. Since LPD is upstream of SCD, the difference between the two counts (Table 1, right column) represents the number of fish spawning between the two dams (including tributaries). In addition, there is potentially a significant number of uncounted adults spawning downstream of SCD whose abundance may fluctuate with a similar pattern as the counts. Thus it is appropriate to regard the SCD counts as an index of relative population size rather than true population size per se.

Table 1. Annual counts of adult steelhead at San Clemente Dam (SCD) and Los Padres Dam (LPD) since 1988.

Year	At SCD	At LPD	Difference
1988	0	0	0
1989	0	0	0
1990	0	0	0
1991	1	0	1
1992	15	5	10
1993	283	26	257
1994	91	4	87
1995	310	30	280
1996	438	94	344
1997	775	227	548
1998	861	121	740
1999	505	120	385
2000	472	204	268
2001	804	347	457
2002	642	283	359
2003	483	105	378
2004	388	111	277
2005	328	106	222
2006	368	91	277
2007	222	74	148
2008	412	158	254
2009	95	21	74
2010	157	55	102
2011	452	204	248
2012	470	174	296
2013	249	65	184
2014	0	0	0
2015	7	0	7
2016	Dam	0	-
2017	gone	7	-

Connectivity problems associated with recent drought ensured that very few steelhead were able to migrate upstream during 2014 – 2017. It should be noted that the counts were in decline prior to the drought: After peaking around the turn of the century at 500 – 800 fish, the SCD counts in the years leading up to the recent drought were in the neighborhood of 100 – 400 adults.

The count at San Clemente Dam in 2015 (7 adults) does not reflect a full migration season at that location because the fish ladder ceased operation on 16 March due a leak, meaning that later-migrating adults were confined to the lower river. Later that year San Clemente Dam was completely removed, along with its fish ladder, so that fish can no longer be readily counted at that location. However, counts at LPD remained exceptionally low in 2016 and 2017 (Table 1, bottom). When LPD counts are low, the differences in counts between the two dams also tend to be low (Figure 2), so it is reasonable to infer that the counts at the former SCD site, like the counts at LPD, have been exceptionally low for the past two years.

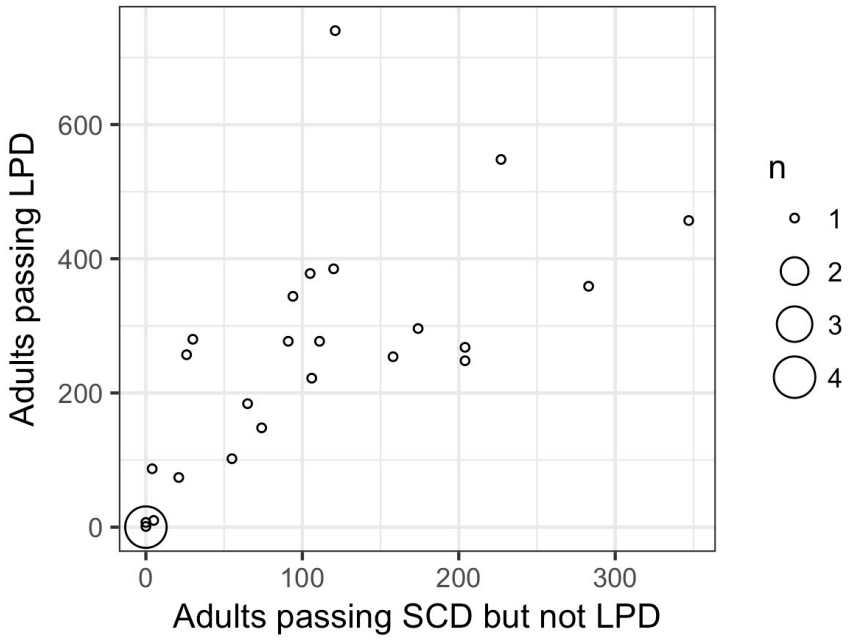

Figure 2. Counts of adults spawning between SCD and LPD and adults spawning above LPD, illustrating the relationship between the two. Size of circles ("n") is the number of years with that observation.

Steelhead Rescues

Datasets in our collection at this time include counts of steelhead rescued by MPWMD each year from the mainstem Carmel River. Each year, fisheries staff of MPWMD closely monitor flow conditions in the "Valley" section of the river, located roughly between the upstream gauge near Carmel Valley Village and the estuary. This section of the river is underlain by two aquifers, and surface flow in the river channel is vulnerable to being completely lost to infiltration into the aquifers, stranding steelhead in drying reaches and eventually killing them as the channel dries completely. Fisheries staff endeavor to rescue these fish before they are killed, and either transfer them to other sections of the river that typically retain surface flow during the entire summer ("Translocated fish"), or transfer them to the Sleepy Hollow Steelhead Rearing Facility (SHSRF). There they are captively reared and eventually released back to the river the following winter, after flow conditions improve ("Captively-reared fish").

Year 2013

In 2013, the low-flow conditions associated with a dry spring (Figure 1) led to rescues starting relatively early (19 April). A very large number of young-of-the-year fish (YOY) were rescued during this late spring period (Table 2), along with modest numbers of other life stages, including 13 anadromous adults that were trapped before they could return to the ocean. About 28,000 rescued fish, mostly YOY, were taken to SHSRF for captive rearing, with the remaining fish translocated to various locations of Carmel River retaining perennial flow (Table 3).

Table 2. Year 2013 rescues reported by MPWMD, 19 April to 12 Sept.

Count	Lifestage	Fate
41893	YOY	See Table 3 and Table 4
650	1+	See Table 3 and Table 4
0	Smolts	
13	Adults	See Table 3 and Table 4
249	Any	Mortality

Table 3. Fate of Year 2013 rescued steelhead reported by MPWMD.

Count	Fate (RM = River Mile)
28139	Captive Rearing at SHSRF (see Table 4)
5915	Immediately Released RM 17.4
367	Immediately Released RM 16.4
254	Immediately Released RM 16.2
342	Immediately Released RM15.6
2027	Immediately Released RM 15.1
1159	Immediately Released RM 14.6
1078	Immediately Released RM 14.4
1501	Immediately Released RM 12.1
1764	Immediately Released RM 10.8
10	Immediately Released Stewarts Cove

A substantial portion of the captively-reared fish suffered mortality in 2013 (Table 4; see MPWMD Annual Report for details). By late September 2013 the flow in Carmel River had become so low that operation of the water intake system for the captive-rearing facility had become problematic, and it became necessary to transfer the remaining steelhead elsewhere. Approximately 9800 steelhead were released to various sites in the river (Table), but 1051 were transferred to four large round tanks at the NMFS SW Fisheries Science Center (SWFSC) facility in Santa Cruz, California. These fish were transferred for dual management and scientific goals: The management goal was to provide insurance against the possibility of further deterioration of river conditions and thus loss of the 2013 cohort of captively-reared YOYs. The scientific goal was to conduct a pilot tagging study on Carmel River steelhead, described later in this data summary. Of the fish transferred to SWFSC, 996 were released back to the Carmel River during 2 – 14 February 2014.

Table 4. Fate of steelhead captively-reared at SHSRF, Year 2013 rescues

Count	Fate
1791	Apparent Counting Error (reported in MPWMD Annual Report)
15531	Mortality at SHSRF
6845	Released at RM 18.3 - 17.0, late Sept.
1788	Released at RM 16.3, late Sept.
89	Released at RM 15.8, late Sept.
1044	Released at RM 23.8, late Sept.
1051	Transferred to SWFSC, early Oct.
1027	Tagged at SWFSC, 2 – 9 Dec
996	Released from SWFSC to Carmel River “holes,” 2 – 14 Feb 2014
55	Mortality at SWFSC

Years 2014 - 2015

Low-flow conditions in the dry seasons of 2014 and 2015 continued to prevent operation of the captive-rearing facility, and all rescued fish were translocated. Rescues in 2014 began after the one brief flood pulse in late Feb 2014 (Figure 1, left column), which completely infiltrated into the aquifer before reaching the estuary, leaving large numbers of downstream migrants stranded in the lower river channel. Exceptional low-flow conditions kept the migration corridor impassible during the entire 2014 spring migration season and a substantial portion of the 2015 season (Figure 1). Consequently, staff of the MPWMD conducted smolt-trapping operations during these two years, translocating the captured smolts to Carmel Bay. Substantial numbers of juvenile parr were also captured moving downstream, as well as modest numbers of freshwater-resident adults; these were translocated to upstream habitats retaining surface flow. These data are summarized below in Tables 5 through 10.

Table 5. Year 2014 rescues by MPWMD from lower mainstem Carmel, 3 Mar to 20 Oct.

Count	Lifestage	Fate
873	Smolts	Carmel Bay
596	YOY	See Table 6
2341	1+	See Table 6
8	ResidentAdults	See Table 6
2	Any	Mortality

Last smolt rescued on 18 April.

Table 6. Fate of Year 2014 rescues

Count	Fate (RM = River Mile)
84	Immediately released RM 24.8
911	Immediately released RM 24.0
2	Immediately released RM 17.4
28	Immediately released RM 16.2
1338	Immediately released RM 14.8
207	Immediately released RM 12.5
375	Immediately released RM 10.8

Table 7. Results of downstream-migrant trapping in Year 2014 by MPWMD, 19 Mar to 30 May

Count	Lifestage	Fate
187	Smolts	Released to Carmel Bay
1089	Juveniles	Released upstream
4	Resident Adults	Released upstream
15	Any	Mortality

Table 8. Year 2015 rescues by MPWMD, 22 May to 28 Sep

Location	Count	Lifestage	Fate
Mainstem			
	2231	YOY	See Table 9
	244	1+	See Table 9
	30	Resident Adults	See Table 9
	1	Kelt	See Table 9
	15	Any	Mortality
Tributaries			
	62	YOY	See Table 9
	19	1+	See Table 9
	42	Resident Adults	See Table 9
	5	Any	Mortality

Table 9. Fate of Year 2015 rescues

Source	Count	Fate
Mainstem	34	Immediately released to Scarlett Well Area
	2472	Immediately released to Cachagua Community Center Area
Tributaries	123	Immediately released to Cachagua Community Center Area

Table 10. Results of downstream-migrant trapping in Year 2015 by MPWMD, 1 Apr to 30 Jun

Count	Lifestage	Fate
58	Smolts	Immediately released to Carmel Bay
325	Juveniles	Immediately released to Cachagua Area
1	ResidentAdults	Immediately released to Cachagua Area
2	Any	Mortality

Year 2016

In Year 2016 the flows of the migration season were sufficient to maintain connectivity, giving anadromous adults access to the river and smolts access to the ocean. As a result no smolt-trapping was initiated. The first rescues were necessary on 13 Jun and continued through to the beginning of December (Table 11). Flow was sufficient to operate the captive-rearing facility. 351 Captively-reared fish were released in the lower river on 2 Dec 2016.

Table 11. Year 2016 rescues by MPWMD from mainstem Carmel River, 13 Jun to 2 Dec.

	Count	Fate
Rescued	510*	Immediately released upstream
	407	Captively reared at SHSRF
Captively Reared at SHSRF		
	351	Released below Narrows, 2 Dec.
	56	Mortality

Fall Surveys of Steelhead Size-Distribution and Density

The MPWMD fisheries staff have conducted fall surveys of steelhead population density since the mid-1990s. In recent years these surveys have involved depletion-electrofishing at 9 sites on the mainstem Carmel River between Los Padres Dam and the ocean. The sites were subjectively selected to give broad spatial coverage, conditions conducive to efficient sampling, and habitat conditions believed to be representative of the mainstem river. In 2016, NMFS SWFSC initiated a pilot study of depletion-electrofishing in eight randomly selected sites in the same section of river. The sampling of reaches used generalized random tessellation stratified sampling (GRTS sampling), similar to that used by California's Coastal Monitoring Plan (CMP), but with some differences to accommodate specific characteristics of depletion-electrofishing.

The resulting data provide two sorts of information—information on the size-distribution of juvenile steelhead (weights and lengths), which gives insight into annual production of YOY fish; and information on the population density (fish per unit length of stream channel).

Size Distribution, Evidence of Reproduction

With sufficient food, YOY fish may reach large sizes by October, but typically most wild YOY fish are < 100mm Fork Length at that time. In addition it is unusual for older fish (yearlings and older) to be shorter than 100mm Fork Length, so a prevalence of juvenile steelhead shorter than100mm in October is an indicator of relatively successful reproduction the previous spring and YOY survival the previous summer.

Figure 3 shows histograms (frequency distributions) for the Fork Lengths of steelhead sampled during the MPWMD surveys in years 2013 – 2016. Empty panels depict sites that were dry that year and thus not sampled for fish (or, in a few cases, which were not sampled for logistical reasons). Except in the unusually dry autumn of 2013, most sites could be successfully sampled in most years. The histograms show an abundance of fish with lengths less than 100 mm in all sampled sites in all years, indicating substantial reproduction and over summer survival of YOY in each year. Even 2014, the year in which the river remained completely unconnected to the ocean throughout the migration season, showed evidence of YOY production at the seven sites sampled (Figure 3). These are presumably the progeny of freshwater-resident *O. mykiss* rather than of anadromous steelhead. As is typical, older (larger) size classes also occurred at lower abundance in many sites. Older fish occurred at comparable abundance as YOY in the Garland site in 2014. Histograms for the NMFS random sites (Figure 7), sampled in 2016, show a generally similar pattern as the MPWMD sites.

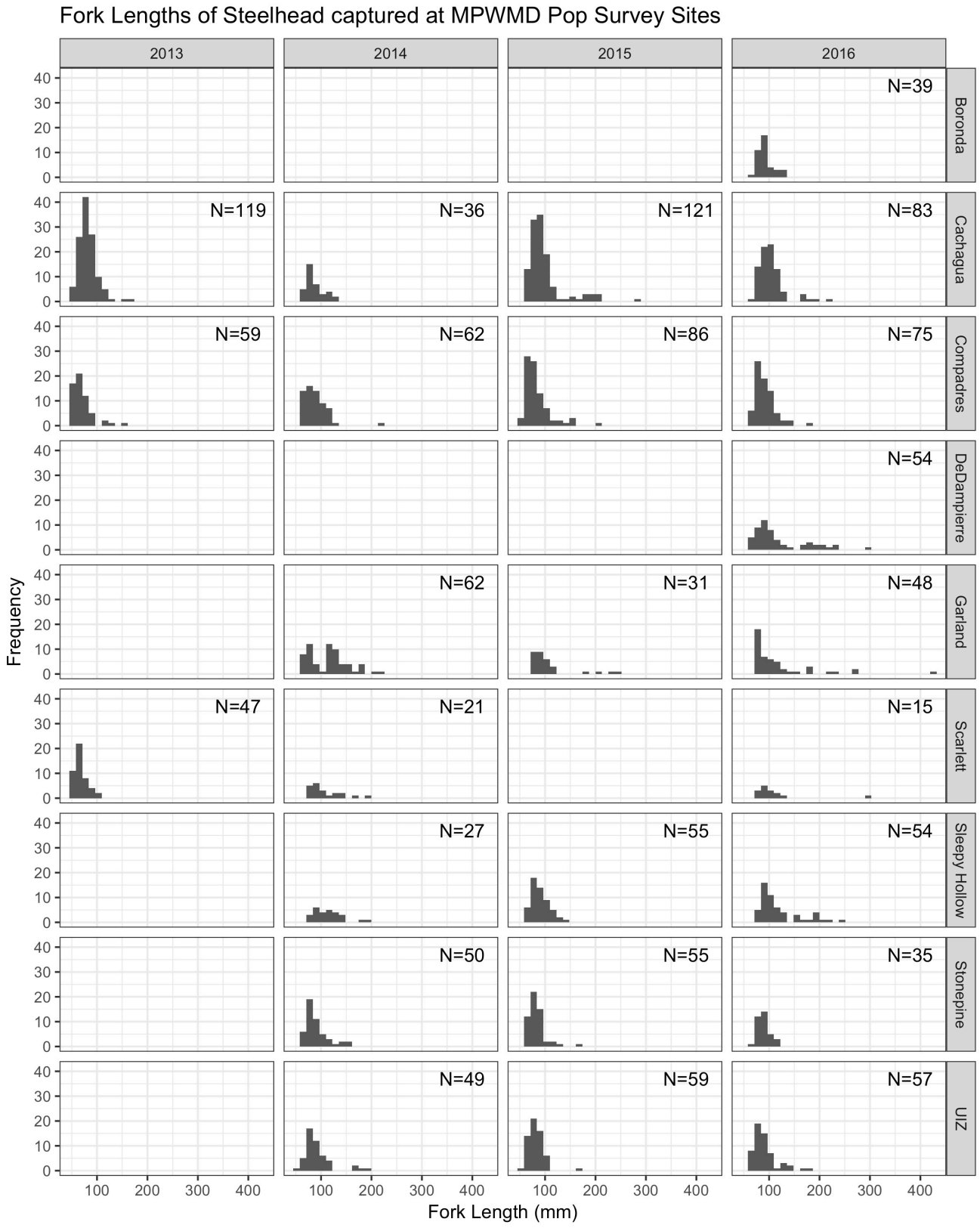

Figure 3. Histograms of Fork Length for steelhead captured during Fall Population Surveys conducted by MPWMD N = the total number of steelhead captured in the sampling event.

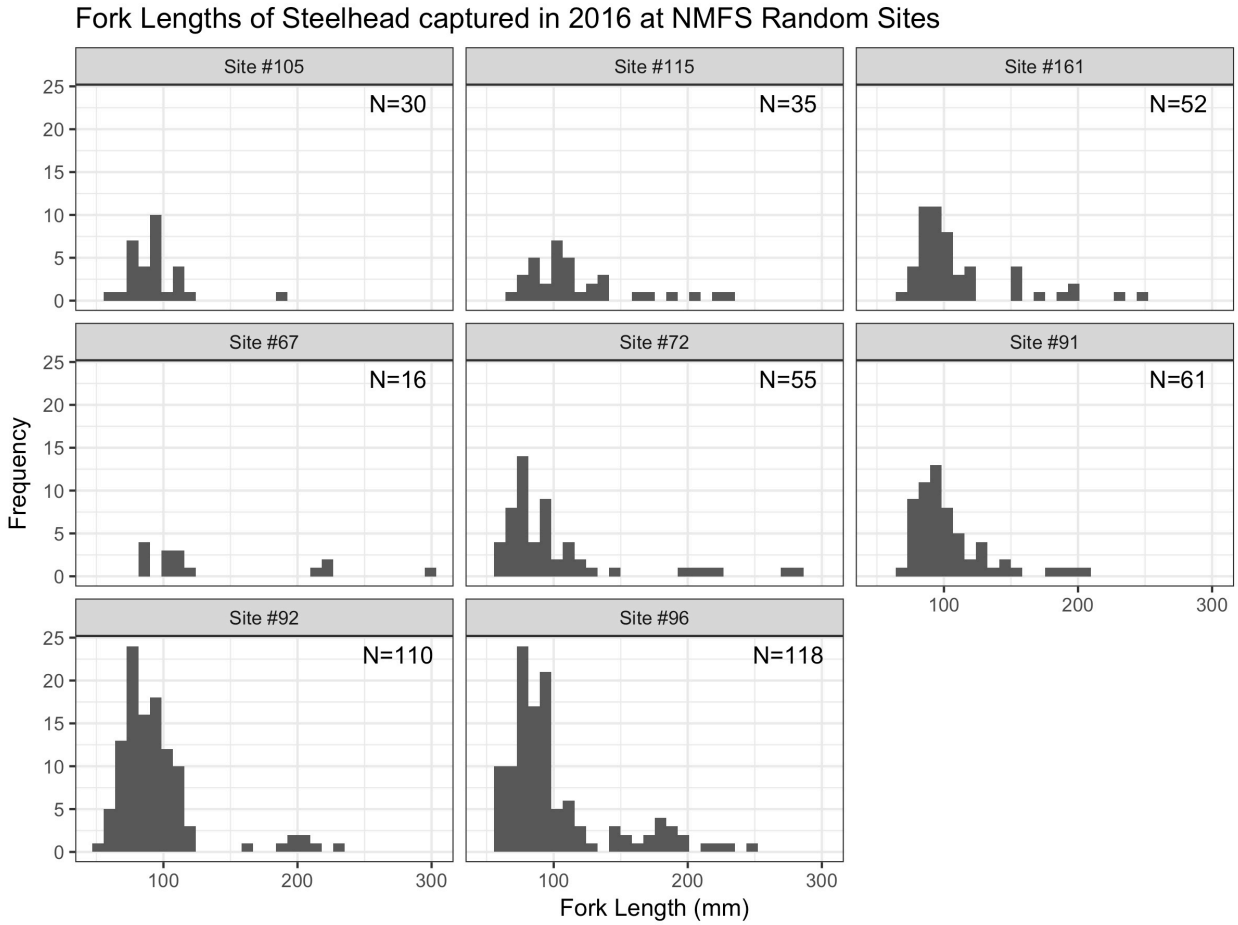

Figure 4. Histograms of Fork Length for steelhead captured at nine random sites in 2016. Sites were randomly selected using the GRTS algorithm from the section of river between Los Padres Reservoir and the Carmel Estuary.

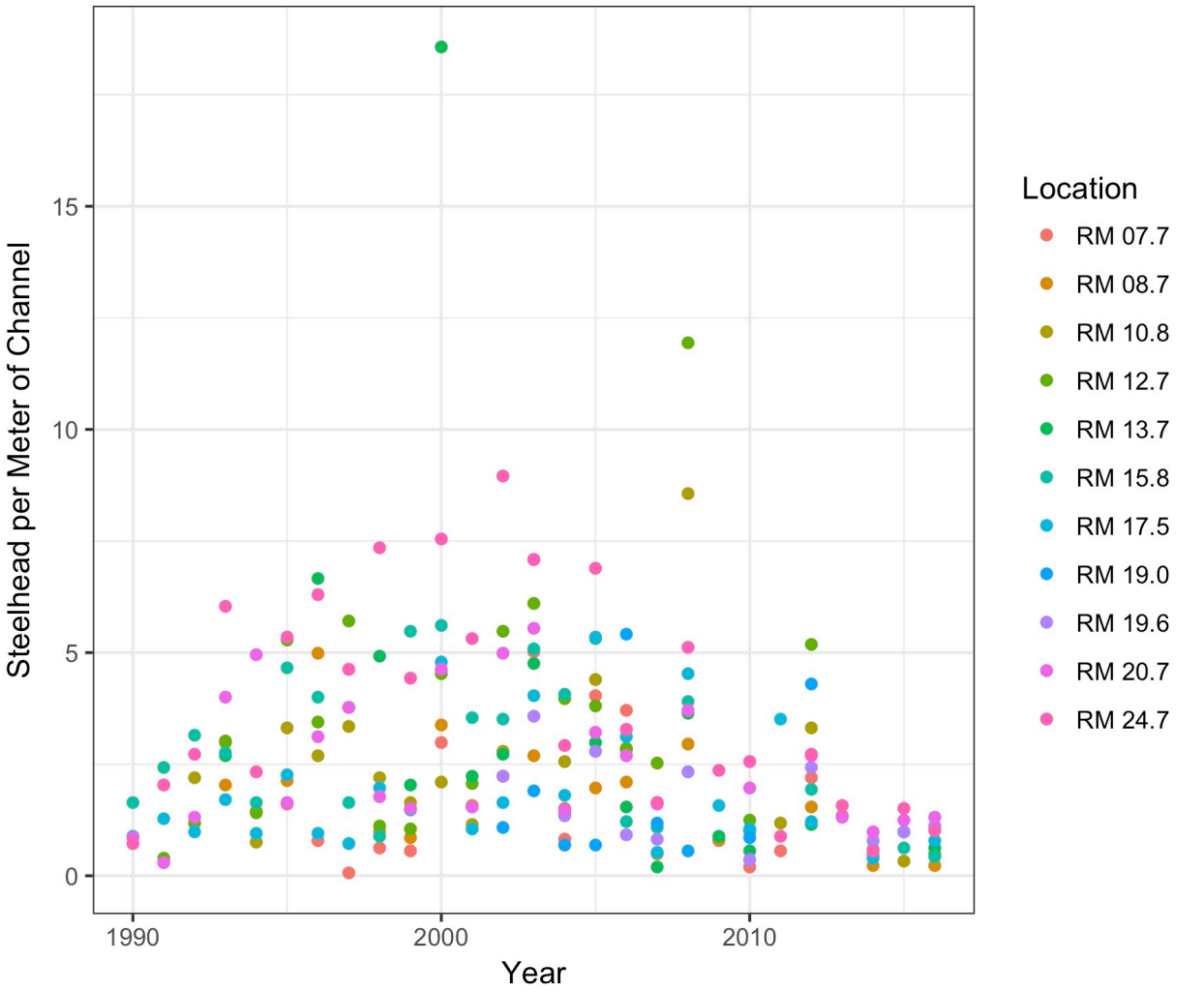

Figure 5. Population density of steelhead at MPWMD index sites, since the initiation of juvenile monitoring in the early 1990s. Notice that the smaller scatter of densities early in the period are at least partly a statistical artifact due to fewer sites being monitored. Locations are given as river miles (RM), the distance upstream from the ocean.

Population Density

Population density can also be estimated from the survey data, because the reduction in catch with each iteration of the sampling method (the "depletion") can be used to estimate the probability of capture, and thus the abundance of uncaptured fish.[1] Abundance is than standardized to population density by dividing by the length of channel sampled.

Figure 5 shows the population densities estimated by MPWMD staff at index sites since 1990. In general the population has exhibited a diversity of densities across sites for most of this time, but from 2013 to 2016 the densities were uniformly low: fewer than 2 fish per meter of channel throughout the river. It is likely that the drought was a major contributing factor to the

[1] Note that this is "non-destructive" sampling: Captured fish are kept alive during the procedure and returned to the river after completion.

low densities. However, other impacts coincided: for example disruptions potentially caused by activities associated with dam removal. Notably, the year with the lowest densities (2014) was the year in which the river never opened to the ocean, such that no anadromous steelhead were able to reproduce. Years thereafter probably had nonzero, but very low, numbers of anadromous steelhead returning (see previous section on adult counts). Thus the low densities observed in these years are the progeny of a very low number of anadromous spawners and some unknown number of resident spawners.

The randomly-selected NMFS sites sampled in 2016 showed a similar pattern, with the mean of estimated density generally below 2 steelhead per meter of channel (Figure 6). The one exception (Site 72) had a poor depletion and therefore exceptionally wide confidence intervals that do not exclude the possibility of low density.

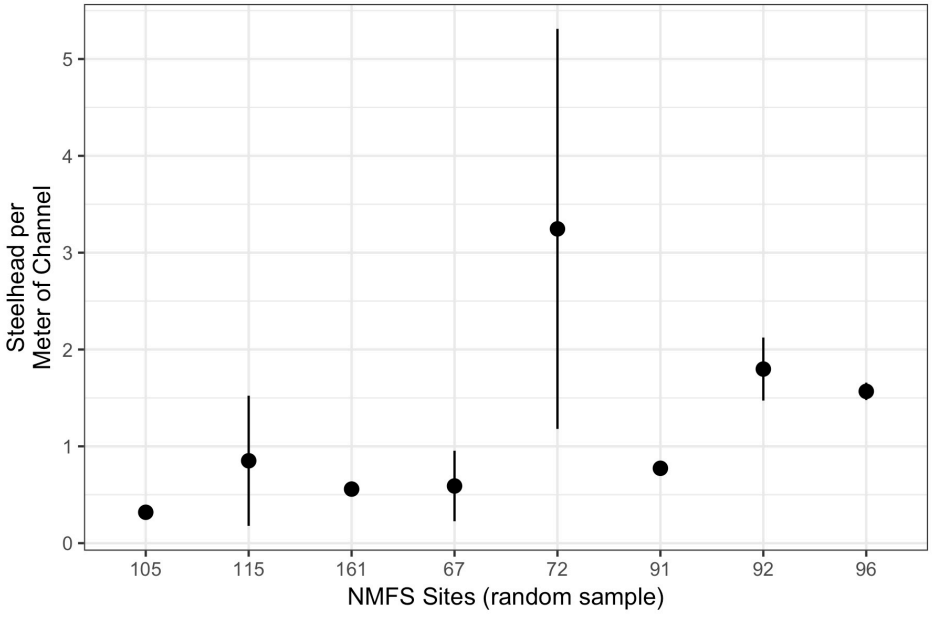

Figure 6. Estimated steelhead density for 8 NMFS sites sampled in 2016. Sites were selected randomly using the GRTS algorithm. Density was estimated using a Bayesian approach. Dots depict the mean of estimated density; bars depict standard deviation of estimated density.

Tagging Pilot Studies

Starting in the fall of 2013, NMFS and MPWMD collaborated on pilot studies to examine feasibility of using PIT-tagging to estimate smolt production. Steelhead handled during fall population surveys or captive-rearing were implanted with PIT tags (Passive Integrated Transponder tags). PIT tags are small glass-encapsulated tags that encode unique ID numbers, which can be detected by scanning fish with specialized electronic equipment. Tagged fish can be subsequently detected during handling with hand scanners, or they can be detected while migrating downstream by establishing monitoring stations at selected sites in the river. These monitoring stations use antenna loops of wire placed in the stream channel, allowing electronic equipment to interrogate the tags for their ID numbers as the fish pass by. Detection distances are rather short, on the order of 30 cm but depending greatly on the configuration of the antenna.

During the migration seasons of 2014 – 2017, a monitoring station was established at the Carmel Area Wastewater District plant (CAWD plant), which is located along the river at its transition into an estuary. The station design in 2014 – 2016 involved a pair of vertical antenna loops crossing the river, with the bottom limbs of the two loops running along the streambed and the top limbs suspended about 1.0 m above the bed. This design was effective at detecting tags but was vulnerable to debris snagging and tearing out the upper limb during high flow events. In 2017 the station was reconfigured with pass-over loops, which lie on the bottom of the channel but which have poorer detection rates.

2014 Migration Season

In late 2013-early 2014, 38 wild and 1033 captively-reared steelhead were tagged and released (Table 12). In the spring of 2014, the monitoring station was established, but as described previously, the lower river never developed surface flow and no tagged steelhead even had the opportunity to be detected. The flow pulse in late February, described previously, percolated completely into the aquifer, leaving many downstream migrants stranded in drying channel. During rescue and smolt-trapping operations (see Table 5 and Table 7), MPWMD hand-scanned the captured fish and detected 190 tagged steelhead. All the recaptures were of fish released in February from the SW Fisheries Science Center (Table 13).

Table 12. Steelhead tagged in Oct – Dec 2013

Count	Treatment
981	Tagged and released from SWFSC in Feb 2014
15	Shed tag prior to release from SWFSC
55	Mortality prior to release at SWFSC
52	Tagged and released from SHSRF in Oct 2013
38	Tagged during MPWMD Fall Pop. Survey in Sep-Oct 2013

Table 13. Recoveries of tagged steelhead in Mar – June 2014

Treatment	Fate	Count
Tagged and released from SWFSC	Not Recaptured	788
	Rescued as Parr	29
	Rescued as Smolt	159
	Recovered as Mortality	2
	Recaptured at Release Point	3
Tagged and released from SHSRF	Not Recaptured	52
Tagged during MPWMD Fall Pop. Survey	Not Recaptured	38

The overall recovery rate was 19% for tagged SWFSC fish rescued as parr or smolts, which is remarkably high. Fully 15% of rescued smolts were tagged, indicating that the 996 captively-reared fish released from SWFSC in early February comprised a substantial portion of smolt production in spring 2014. The other 85% would be a mixture of wild production and smolts from the 9766 steelhead released in late September from the captive-rearing facility when it had to shut down due to low-flows.

A histogram of Fork Lengths measured at SWFSC in Dec 2013 (Figure 7) shows the size distribution of the fish most likely to subsequently smolt. Three tagged fish were found still at the release points in June, though these should be viewed as under-represented due to difficulties involved in sampling the release points.

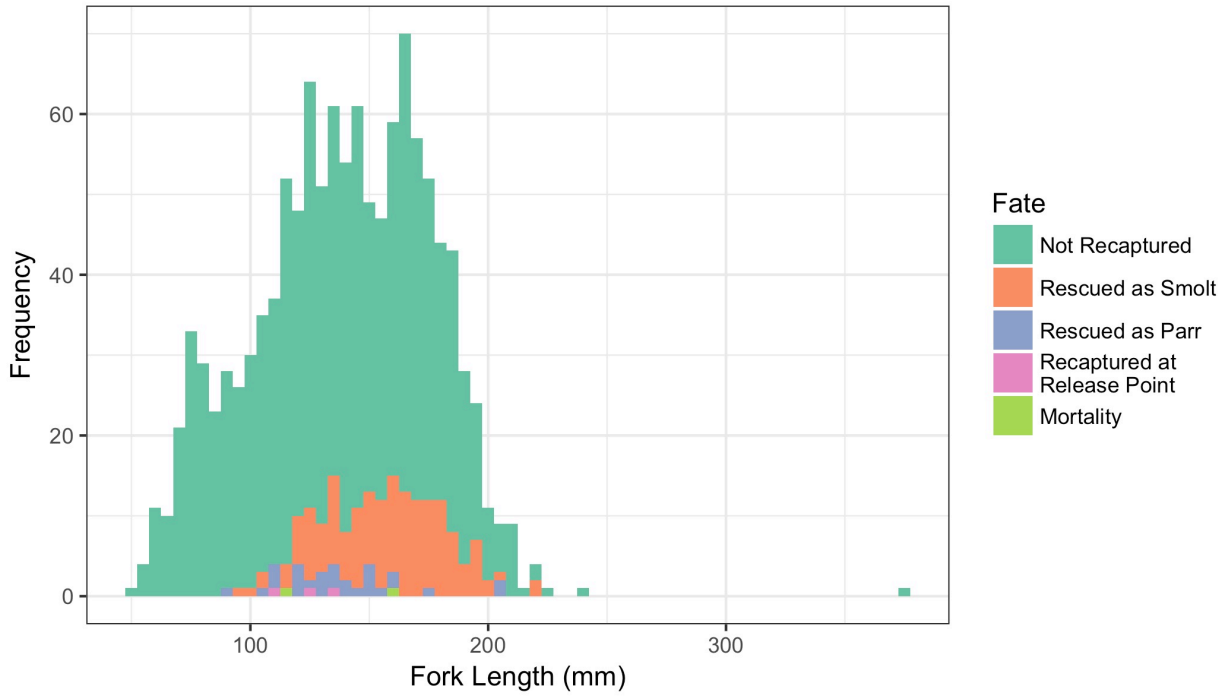

Figure 7. Fork lengths of steelhead parr tagged at SWFSC (Dec 2013), and their subsequent fates in spring of 2014.

Migration Seasons 2015 – 2017

The monitoring station at the CAWD plan was operated in the migration seasons of 2015 through 2017, although with many interruptions due to high-flows disrupting the antennae and one equipment failure. Nevertheless, tagged downstream migrants were detected in every year of operation, and originated from both wild production and captively-reared groups (Table 14). Interestingly, three of the tagged fish released in February 2013, and prevented from migrating to the ocean in 2014 by the dewatered channel, were subsequently detected at the CAWD plant in 2015. All other detections at the CAWD plant were detected in the migration season immediately after the autumn or winter that they were tagged and released.

Table 14. Detection of tagged steelhead at the CAWD plant monitoring station, 2015 – 2017.

Year Detected	Count	Origin	Number Released	Detection Rate
2015	3	Captively reared in 2013. Released Feb. 2014	981	0.3%
	0	Captively reared in 2013. Released Sep. 2013	52	-
	0	Wild fish tagged Oct 2013	38	-
2016	1	Wild fish tagged Oct 2015	371	0.3%
2017	1	Captively reared in 2016. Released Dec. 2016	387	0.3%
	3	Wild fish tagged in Sep – Oct 2016	819	0.4%