PIT Tag Monitoring for Emigrating Juvenile Chinook Salmon at Three Flow Conditions

Introduction

Historically, California's upper San Joaquin River (SJR) supported stable populations of fall- and spring-run Chinook salmon (*Oncorhynchus tshawytscha*). However, both populations were extirpated from the system in the mid-twentieth century following the development of Friant Dam (Moyle 2002). In response to the San Joaquin River litigation Settlement, the San Joaquin River Restoration Program (SJRRP) has implemented an objective to restore a naturally reproducing and self-sustaining population of Chinook salmon, as well as other fishes, in the system. Because the anadromous life-cycle of SJR Chinook salmon requires conveyance of juveniles from a riverine system to the Pacific Ocean to support the return of spawning adults, meeting this objective requires the consideration of environmental conditions and a connected river system. Though there are likely a multitude of environmental parameters that impact emigrating juvenile salmon, flow regime and predation are often cited as having a significant effect on travel speed and survivability (Raymond 1968; Berggren and Filardo1993; Michel *et al*. 2013). Flows in the SJR are highly regulated as means to support agricultural production, and non-native piscivorous fish in the restoration reach tend to occur more frequently downstream of Reach 1 (Gravelly Ford to confluence of Merced River; SJRRP 2013 I&M Report). Anecdotal evidence collected during SJRRP fish inventory and monitoring efforts suggests many of the non-native piscivores tend to reside in anthropogenic altered habitats (*e.g*., mine pits, altered channels, etc), which may pose a challenge to emigrating salmon. River flow conditions and water temperatures were managed during spring releases to elicit downstream fish movement with pulse flows and receding flows benches to avoid stranding. To ascertain effects of environmental conditions, Passive Integrated Transponder (PIT) tag antenna systems were constructed to evaluate mortality and migration rate through the Restoration Area under a variety of flow conditions in 2012 and 2013. These data will also be used to estimate reach specific and Restoration Area-wide juvenile Chinook salmon survival rates providing more accurate information for the Emigrating Salmonid Habitat Estimation model to predict the number of juvenile production needed to meet the program population goals. This data can be used to gain a better understanding of the survival and migration paths of juvenile Chinook salmon while adaptively managing future decisions toward reaching the Restoration Goal.

Methods

Site Selection

PIT tag arrays were installed at six sites immediately downstream of Friant Dam (Friant, CA) to San Mateo Crossing (Mendota, CA) in 2012 and 2013. In 2012, three sites were selected in Reach 1: Lost Lake, Wildwood, and Scout Island, and three were selected in Reach 2: Skaggs Bridge, Flood Plain, and San Mateo Crossing (Figure 1). In 2013 three sites were selected in Reach 1: Lost Lake Park, Owl Hollow, and Scout Island, and three were selected in Reach 2: Gragnanai Property, Chowchilla Bifurcation Structure, and San Mateo Crossing (Figure 1).

Antenna Design and Construction

The basic components of the half duplex arrays consisted of an RFID reader, a power source, a tuning capacitor, and an antenna (http://www.oregonrfid.biz/). Readers store detection data with tag number, date and time stamp, number of times tag was detected, and number of scans since last detection. Two twelve volt deep cycle batteries were generally hooked up in in parallel to achieve desired voltage output. Batteries were kept charged with a pair of 60 watt 12 volt solar panels(Power UP, Tyler, TX). Tuning capacitors provided a link between the antenna and the reader. Antennas were typically constructed in a loop (swim-through design) to generate a magnetic field and charge the tag when implanted salmon passed through the field, and were typically constructed of 4 – 10 gauge wire (Figure 2 and Figure 3). The antennas built for this study ranged from a simple loop covering a shallow section of river or side channel, to an antenna with several loops covering deep sections. When multiple loops were necessary, they were constructed on opposing banks in close proximity (< 100m) to permit spanning the majority of the rivers width. To maximize tag detection, we attempted to achieve an eight to nine inch read range (upstream, downstream, above, and below the antenna) for all antennas. A summary of 2013 PIT Tag antenna locations and designs are summarized in Table 1.

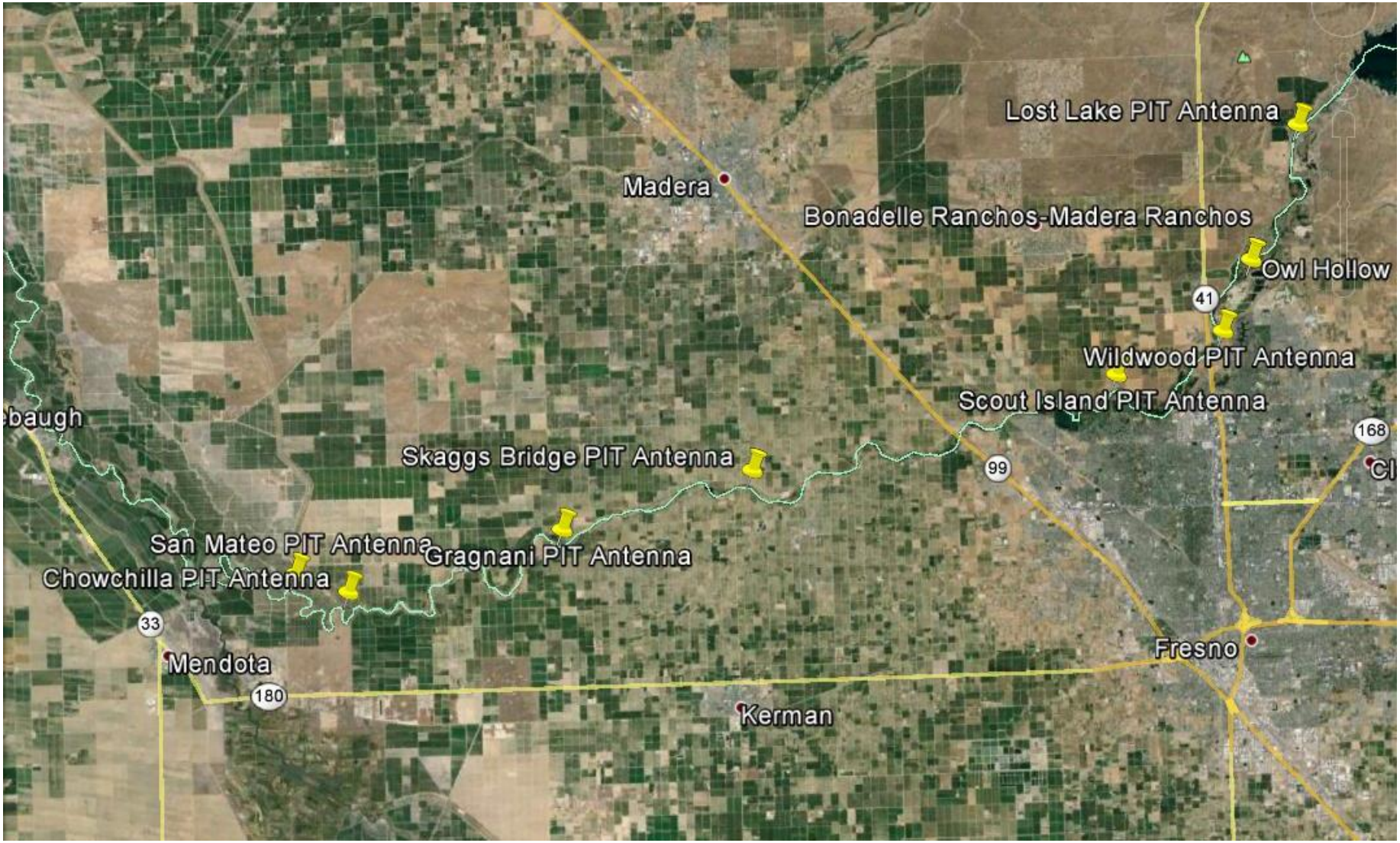

Figure 1. – Location of 2012 and 2013 PIT Tag antennas (arrays) used to monitor emigration of juvenile Chinook salmon through Reach 1 and Reach 2 in the San Joaquin River Restoration Area. Sites in Reach 1 used in 2102 included Los Lake, Wildwood, and Scout Island, and sites used in Reach 2 in 2012 included Skaggs Bridge, Flood Plain, and San Mateo Crossing. Sites used in Reach 1 in 2013 included Lost Lake, Owl Hollow, and Scout Island, and sites used in Reach 2 in 2013 included Gragnani Farms, Chowchilla, and San Mateo Crossing.

Figure 2. – Example of a pass over PIT tag antennae constructed at on the San Joaquin River, California, at the Lost River downstream site (Reach 1).

Figure 3. - Example of a swim through PIT tag antennae constructed at on the San Joaquin River, California, at the Chowchilla upstream site (Reach 2.

Table 1. – Location, dimensions, and type of PIT tag antennas developed in 2013 to monitor emigration of juvenile Chinook salmon through Reach 1 and Reach 2 in the upper San Joaquin River, California. Similar designs were used in 2012, but dimensions, read range and wire gauge were not recorded.

Antenna Location	Antenna Depth (meters)	Antenna Length (meters)	Antenna Design	Number of Loops	Read Range (meters)	Gauge Wire	Inductance (Henries)
Lost Lake Upstream	0.91	12.19	Swim through	2	0.2	4	78.6
Lost Lake Downstream	0.96	16.76	Pass over	1	0.22-0.35	4	42.6
Owl Hollow Upstream	0.91	12.19	Swim through	2	0.12-0.15	4	66.9
Owl Hollow Downstream	0.5	14.63	Swim through	1	0.17	10	42.1
Owl Hollow Side Channel	0.45	9.14	Swim through	1	0.15	4	24.8
Scout Island Upstream	0.91	9.14	Swim through	2	0.17	4	49.3
Scout Island Downstream	0.91	10.66	Swim through	2	0.17	4	55.6
Gragnani Upstream	0.5	14.63	Swim through	1	0.2	10	38.8
Gragnani Downstream	0.91	13.71	Swim through	2	0.2	4	63
Chowchilla Upstream	0.45	19.5	Swim through	1	0.12	10	52.5
Chowchilla Downstream	0.81	12.19	Swim through	2	0.12	8	67.8
San Mateo Upstream	0.4	13.71	Swim through	1	0.15	8	30.7
San Mateo Downstream	0.81	18.28	Swim through	2	0.2	8	90.1

PIT tagging

Half duplex PIT tags (Texas Instrument) were selected over other common tags used to track fish movements (*i.e.*, radio and acoustic tags) because they are small, permitting easy insertion into the body cavity of smaller salmon, and inexpensive, allowing tagging and tracking of numerous fish. The tags also have a theoretic infinite life, allowing tracking of the fish over the duration of their lifespan. During the first release in 2012, both 12 and 23 mm PIT tags were used. For all other releases in 2012 and 2013, only 12 mm tags were implanted in salmon. For all tagging efforts, fish were netted from cage pens using a knotless 1/8 inch nylon mesh dip net, transferred into a 18.93 L bucket (~ 50 fish/bucket). Fish were carried to a riverside fish tagging station, where they were provided a mild anesthetic (Tricaine Methanesulfonate; MS-222) at levels recommended for salmonid anesthesia (40 mg/L; Columbia Basin Fish and Wildlife Authority 1999). Once fish lost equilibrium, fish length (fork length in mm) and weight (g) were obtained, and a viable PIT tag (confirmed by a portable tag reader) was inserted. To insert PIT tags a plastic spring loaded injector, with a Luer lock needle, was used to generate a small incision (< 2 mm) on the side of the fish ahead of the anal fin and posterior to the pelvic fins (Figure 4). Side insertion and manual PIT tag implantation was employed because fish were too small to insert the tag ventrally, and there was concern that fully inserting the spring loaded injector would result in internal organ damage (Figure 4). All PIT tagged salmon were taken back to the cage pens where they were inserted into an empty pen (water to water transfer). The fish were held in the pens for 42 to 72 hours before release to monitor any latent mortality due to the tagging process.

Figure 4. - Small incision being made for PIT tag using Luer lock needle (left image), and a 12 mm PIT tag being manually inserted into a juvenile Chinook salmon (right image).

Juvenile Salmon Releases

2012 Chinook Salmon Releases - Three releases of juvenile PIT tagged Chinook salmon were completed on 4/16, 4/23, and 4/30/2012, across three different San Joaquin River flows: 355, 505, and 709 cfs. Juvenile salmon were released at the most upstream location in Lost Lake, and were tracked with fixed station PIT tag antenna arrays to San Mateo Crossing (Kerman, CA). PIT tag antennas remained operational, collecting emigration data, through the third week of May.

2013 Chinook Salmon Releases - Three releases of juvenile PIT tagged Chinook salmon were completed on 3/1, 4/5, and 4/19/2013, across three different San Joaquin River flows: 392, 600, and 1059 cfs. Juvenile salmon were released below Friant Dam (Friant, CA) and were tracked with fixed station PIT tag antenna arrays to San Mateo Crossing (Kerman, CA). PIT tag antennas remained operational, collecting emigration data, through the third week of May.

For both years of data collection, percent survival of emigrating juvenile salmon is reported as the percentage of fish compared to the total released immediately downstream of Friant Dam that were encountered at each described antenna location.

Results

In 2012, release 1, 2 and 3 were comprised of 95, 277, and 743 salmon, respectively. Mean (± standard deviation) fork lengths (mm) / wet weights (g) of fish in release 2 and 3 were 101.8 ± 12.2 / 11.2 ± 3.9 and 104.2 ± 12.2 / 18.6 ± 2.3, respectively. In 2013, release 1, 2, and 3 were comprised of 1130, 1025, and 1388, fish respectively. Mean (± standard deviation) fork lengths (mm) / wet weights (g) of fish in releases 1, 2, and 3 were 74.1 ± 3.7 / 4.4 ± 0.8, 71.1 ± 3.3 / 4.2 ± 0.7, 69.2 ± 4.1 / 3.8 ± 0.9, respectively. Across all releases in 2012 and 2013, < 0.05% of tagged salmon experienced mortality during the holding phase following tagging and prior to release. Specific flow regimes in 2013, as a function of release, and over the duration of data collection, are reported in Appendix A. Similar data for 2012 has yet to be summarized, but will be included in future reports. Percent survival of Chinook salmon smolts released in 2012 and 2013, as a function of flows, are reported in Figure 5. Travel time (hours) of salmon smolts between PIT tag antennas in 2012 and 2013 are reported in Table 2.

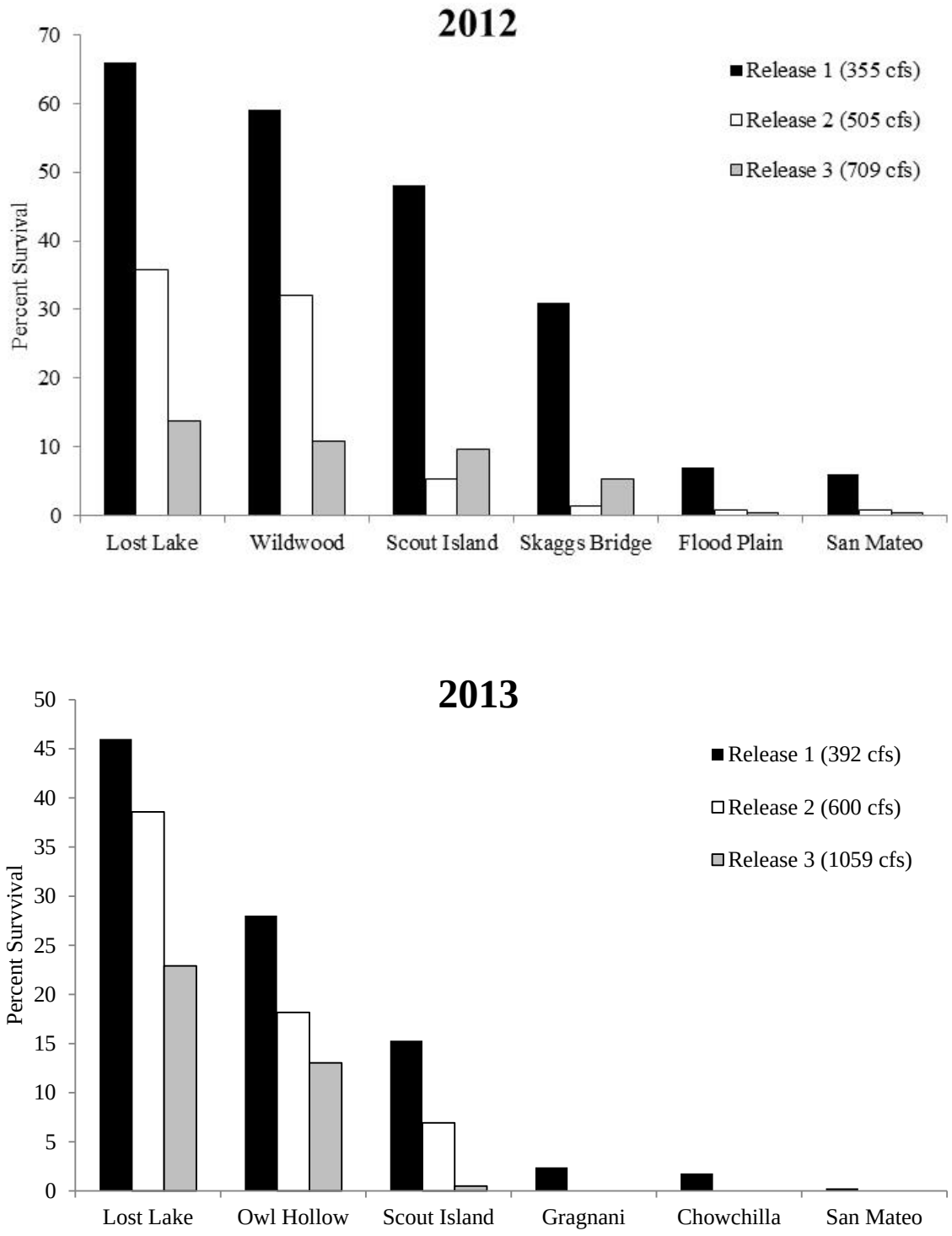

Figure 5. – Percent survival of juvenile Chinook salmon, as monitored by PIT tag antennas, at six locations from downstream of Friant Dam (Lost Lake) to San Mateo Crossing as a function of flows released from Friant Dam in 2012 and 2013.

Table 2. – Mean travel time (hours, ± standard deviation) of juvenile Chinook salmon between PIT tag antenna arrays in 2012 and 2013. Site name abbreviations are as follows: Lost Lake (LL), Wildwood (WW), Scout Island (SI), Skaggs Bridge (SB), Flood Plain (FP), San Mateo Crossing (SMC), Owl Hollow (OH), Gragnani Farms (GF), Chowchilla (CH).

Sites	Distance (RM)	Travel Time (h)		
		Release 1	Release 2	Release 3
2012				
LL - WW	9	61 ± 89.5	15.3 ± 4.2	NA
LL - SI	15	65.3 ± 70.2	25.5 ± 0.0	35.9 ± 22.3
LL - SB	30	141.3 ± 30	NA	79.6 ± 0.0
WW - SI	6	27.8 ± 11.1	60.8 ± 86.2	NA
WW - SB	21	80.6 ± 36.0	74.2 ± 7.9	NA
SI - SB	15	81.6 ± 68.5	NA	34.4 ± 1.9
SB - FP	20	191.3 ± 0.0	NA	NA
SB - SMC	23	110.4 ± 45.6	101.6 ± 35.1	NA
LL - SMC	53	NA	NA	204 ± 0.0
2013				
LL - OH	6	191.6 ± 434.8	10.1 ± 1.7	7.8 ± 7.2
LL - SI	15	782.3 ± 625.5	710.3 ± 212.4	NA
LL - GF	37	485.3 ± 505.7	NA	NA
LL - CH	49	1316.9 ± 198.2	NA	NA
OH - SI	9	430.6 ± 501.1	720.3 ± 205.9	492.3 ± 88.3
OH - GF	31	1459.7 ± 0.0	NA	NA
SI - GF	22	395.3 ± 507.9	NA	NA
SI - CH	34	239.4 ± 227.1	NA	NA
SI - SMC	38	203.4 ± 0.0	NA	NA
CH - SMC	4	22.2 ± 0.0	NA	NA

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APPENDIX A

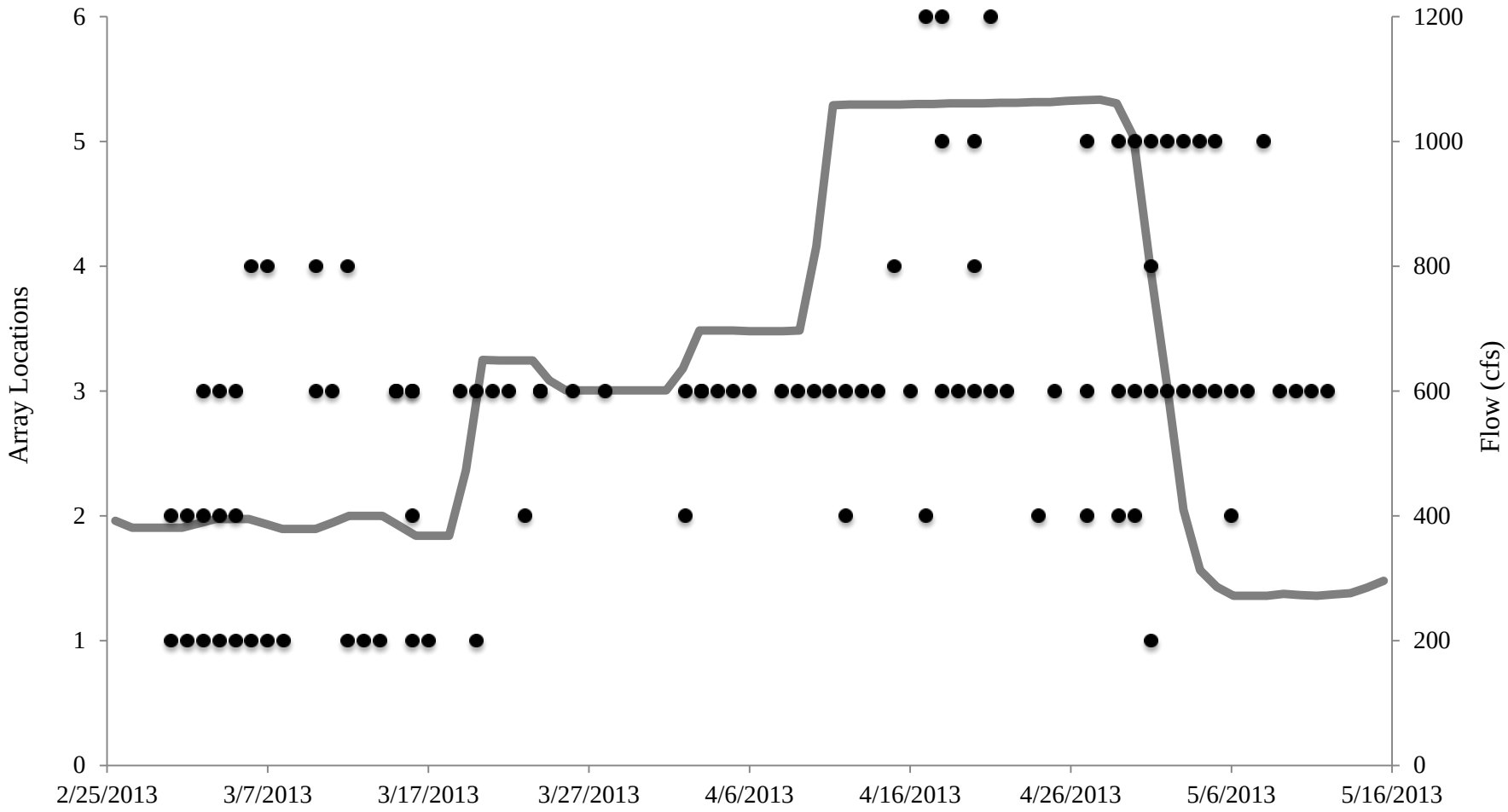

Figure 1A. – Release 1 PIT tag detections (black circles) by date and array location (1 = Lost Lake, 2 = Owl Hollow, 3 = Scout Island, 4 = Gragnani Farms, 5 = Chowchilla, 6 = San Mateo Crossing) as a function of flow (grey line) over the duration of data collection in 2013.

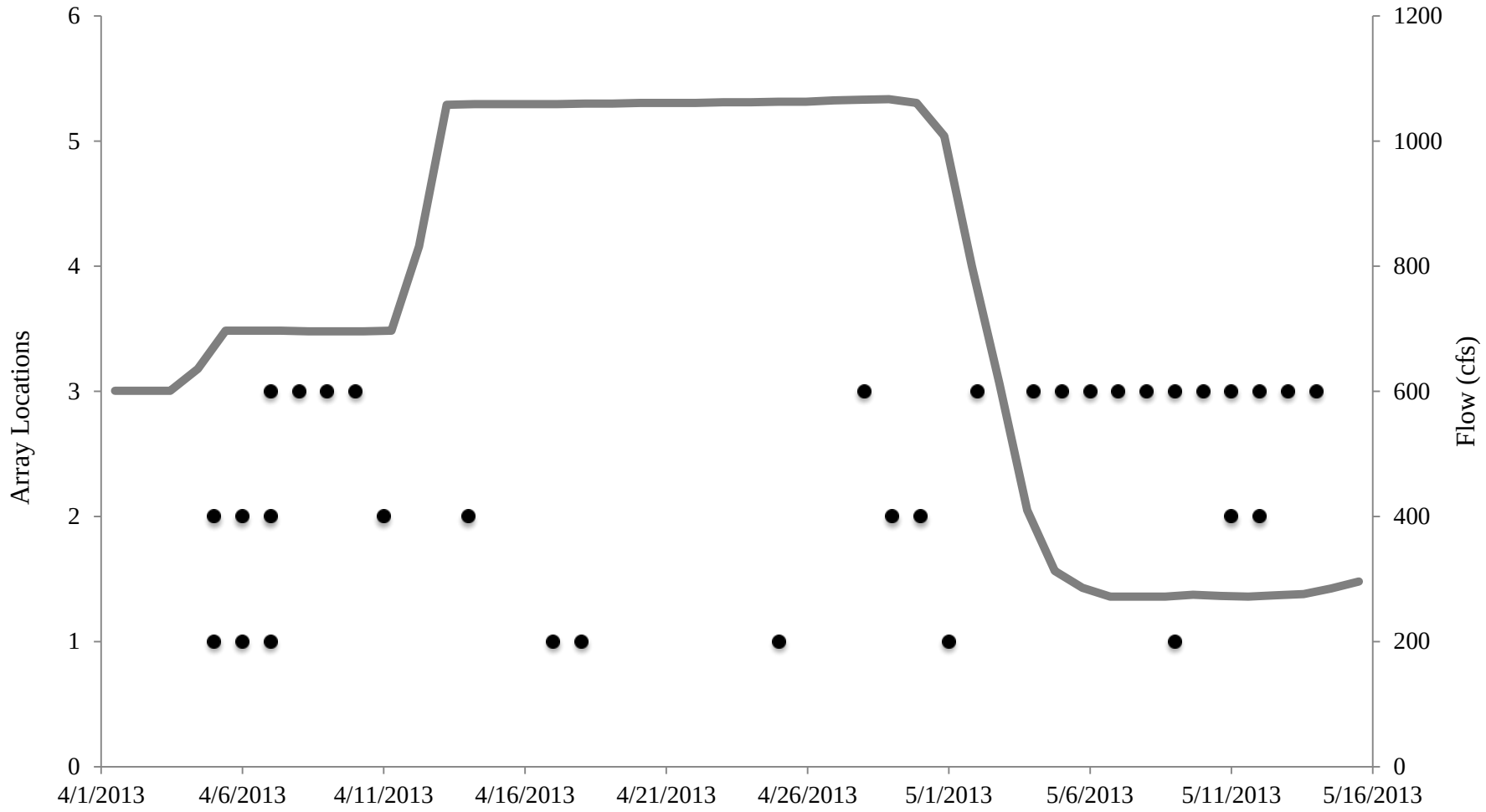

Figure 2A. - Release 2 PIT tag detections (black circles) by date and array location (1 = Lost Lake, 2 = Owl Hollow, 3 = Scout Island) as a function of flow (grey line) over the duration of data collection in 2013.

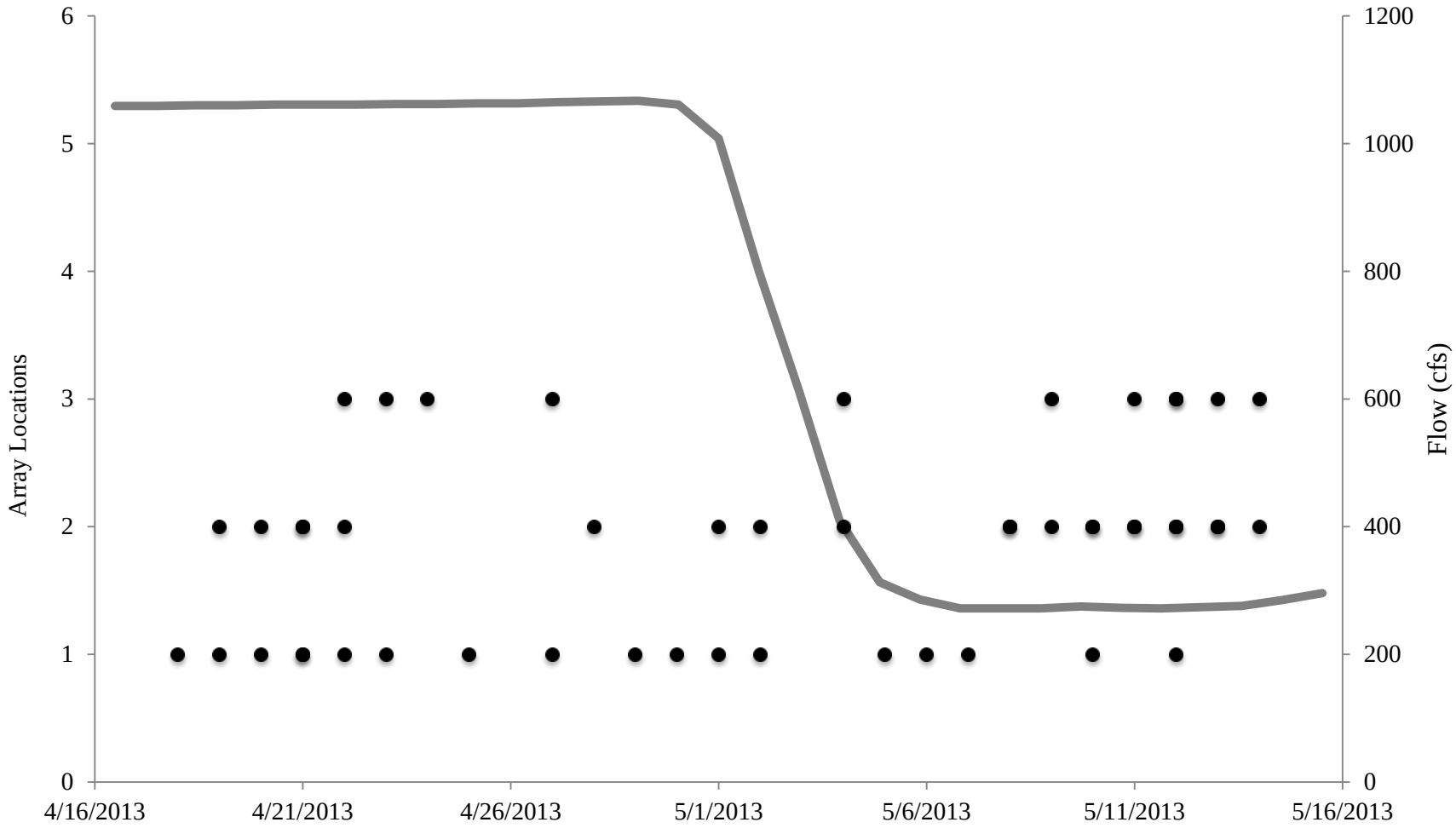

Figure 3A. - Release 3 PIT tag detections (black circles) by date and array location (1 = Lost Lake, 2 = Owl Hollow, 3 = Scout Island) as a function of flow (grey line) over the duration of data collection in 2013.