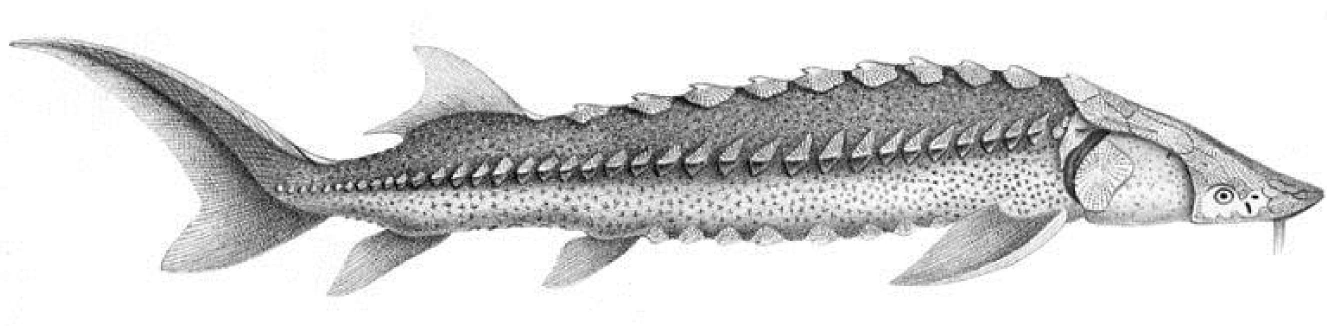
Rocky Reach Reservoir White Sturgeon Indexing and Monitoring Annual Report 2013



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Final Report

14 August 2014

This report is a summary of the Public Utility District No. 1 of Chelan County *Rocky Reach Reservoir White Sturgeon Indexing and Monitoring* annual research studies that were conducted in 2012 and 2013. This research project is currently being led by Blue Leaf Environmental, Inc. in collaboration with LGL Limited and Columbia Research Specialists. Presiding project research scientists and contact information are listed below.

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Executive Summary

Chelan County Public Utility District (PUD) has initiated a white sturgeon (*Acipenser transmontanus*) hatchery supplementation program in the Rocky Reach Reservoir (Reservoir) on the Columbia River. The goal of the supplementation program is to promote white sturgeon population growth to a level that is commensurate with available habitat in the Reservoir by 2039. The first release of juvenile sturgeon was completed in 2011, where 6,376 fish were injected with passive integrated transponder (PIT) tags and released. Since then, additional annual releases of juvenile sturgeon have occurred (137 in 2012 and 7,975 in 2013); a total of 14,488 hatchery-reared, PIT-tagged juvenile sturgeon have been released into the Reservoir.

In 2012, we began a three-year acoustic telemetry monitoring program to investigate sturgeon movements within the Reservoir. A total of 15 acoustic receivers were deployed; and 104 sturgeon were captured, tagged (surgical implantation of an acoustic transmitter) and released (35 in 2012 and 69 in 2013). To date, movement information has shown that fish movement has been predominantly upstream, especially soon after release. In both years, the upper reservoir has been an important area. For example, 63% (37 of 59) of sturgeon that were released in the lower Reservoir moved into the upper quarter of the Reservoir. The majority of sturgeon (62%) moved more than 10 km. The amount of movement following release generally decreased over time for all release groups. The rate of emigration into areas downstream of the reservoir was 4.8%. The telemetry data set is expected to grow substantially in 2014 and 2015 with additional releases and continued monitoring.

In 2013, we began a three-year indexing study using PIT tags for mark and recapture analysis. Experimental fishing occurred over 50 days from 19 August to 23 October 2013. 'Systematic' sampling locations were randomly determined, and were supplemented by 'targeted' locations (the latter selected to maximize catch rates). Setlines with treble or circle hooks were baited and deployed for ~22 hours. Habitat data were collected from the approximate mid-point of each setline, including depth, dissolved oxygen, temperature, velocity and turbidity. Substrate composition was determined visually using an underwater video camera. Catch Per Unit Effort (CPUE) was highest in the upper reservoir and was higher for circle hooks than for treble hooks. Both gear types captured a similar range of sizes, but the average fork length was larger for circle hooks (411 mm) than for treble hooks (353 mm). Habitat models suggested that fish released in 2013 were more likely to be caught in areas of lower velocity.

Indexing data from 2013 were combined with recapture data from the Chelan and Douglas PUD *Northern Pikeminnow Removal Program* to allow estimates of survival to be calculated for fish released in 2011. True survival (calculated from apparent survival by taking emigration rate, 4.8%, into account) of the hatchery fish released in 2011, during their first 2.8-5.4 months in the Reservoir ($S_{R-0.5}$), was estimated to be 28.8% (SE=5.7%). Survival during the subsequent year ($S_{0.5-1.5}$) was estimated to be 45.8% (SE=14.3%). For fish reared at Chelan Falls, survival estimates were 35.0% (SE=8.3%) for $S_{R-0.5}$ and 76.2% (SE=26.1%) for $S_{0.5-1.5}$. For the progeny of wild-origin broodstock, survival estimates were 41.5% (SE=7.7%) for $S_{R-0.5}$, and 48.9% (SE=12.1%) for $S_{0.5-1.5}$.

The recorded increase in weight from tagging in 2013 to recapture after 4.9-7.4 months ranged from 11 g to 177 g (mean 75.2 g, SE=6.1). Fish that were tagged in 2011 and recaptured in 2012 (after 16.4-19.7 months) showed changes in weight ranging from a decrease of 13 g to an increase of 533 g (mean 135.3 g, SE=26.3). Fish that were tagged in 2011 and recaptured in 2013 (after 29.2-31.5 months) increased in weight from 35 g to 1,601 g (mean 670.8 g, SE=83.2). In all cases, the increases in weight appeared to be commensurate with recorded increases in length.

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Introduction

White sturgeon (*Acipenser transmontanus*), the largest species of freshwater fish in North America, is a native fish in the Columbia River basin and has provided the region with an important cultural, recreational and ecological resource. The population of white sturgeon in the unimpounded reach of the Columbia River below Bonneville Dam is presumed to be one of the largest and most productive populations in the world (DeVore et al. 1995). Conversely, populations in upstream impounded reservoirs of the Columbia River, though varied, have been generally smaller and less productive (Beamesderfer et al. 1995). Reductions from historical abundance were believed to be a result of several anthropogenic factors, including commercial harvest rates in the late 1800s which peaked at over 2,500 tons, and the construction and operation of hydropower dams that restricted sturgeon movements and modified local habitat features (North et al. 1993, Parsley and Beckman 1994, Beamesderfer et al. 1995, Wydoski and Whitney 2003).

To better understand the resident population of white sturgeon in the Rocky Reach Reservoir (hereafter the Reservoir), Chelan County Public Utility District (Chelan PUD) initiated a mark and recapture study in 2001 and 2002, prior to the Federal Energy Regulatory Commission (FERC) relicensing of Rocky Reach Hydroelectric Project (Project). The purpose of those studies was to estimate the population status, which included size and structure characteristics and resulted in an estimated sturgeon population of approximately 50 to 115 fish. The 2001-2002 studies found the presence of younger age classes, which indicated either that emigration from upstream populations or natural recruitment had occurred (perhaps during high water years with favorable spawning conditions; Golder Associates 2003). Inspired by these findings, the *White Sturgeon Technical Group* was formed in 2004 and is currently comprised of stakeholders from Washington State, federal and tribal agencies along with Chelan PUD biologists. The role of the *White Sturgeon Technical Group* is to advise and coordinate the effort to develop the *Rocky Reach Comprehensive White Sturgeon Management Plan* (WSMP).

In 2005, the WSMP was completed and has been adaptively implemented over the term of the new FERC license, which began in 2009. Overall, the goal of the WSMP has been to promote white sturgeon population growth to a level commensurate with available habitat in the Reservoir by 2039. The following objectives are planned to assist in meeting this goal: 1) increase the white sturgeon population in the Reservoir through supplementation, specifically to a level commensurate with available habitat and that will allow for an appropriate and reasonable future harvest; 2) determine the effectiveness of the supplementation program; 3) determine the carrying capacity of available habitat in the Reservoir; and 4) determine the natural reproduction potential in the Reservoir, with corresponding adjustments made to the WSMP supplementation program as needed. In 2010, Chelan PUD began employing measures to fulfill the first objective with the initiation of the supplementation program through the capture of wild fish for broodstock. In 2011, the first group of hatchery-reared juvenile sturgeon were injected with Passive Integrated Transponder (PIT) tags (March) and released into the Reservoir (April; n=6,376).

In 2012, Chelan PUD began addressing the second objective of the WSMP and began measuring the effectiveness of the supplementation program which is outlined by the WSMP. The monitoring program includes two distinct focuses: 1) the initiation of a long term indexing program with a preliminary three year indexing study that uses PIT tags for mark and recapture, and 2) a three year acoustic telemetry investigation of sturgeon movement within the Reservoir. The indexing study entails a focused fishing effort in the Reservoir to recapture juvenile sturgeon released during each year's supplemental hatchery release. All PIT-tagged and released fish were electronically tracked, and with their recapture information, has allowed Chelan PUD to assess survival and growth rates as well as identify their distribution and habitat selection in the Reservoir. The primary goal of the acoustic telemetry investigation has been to assess the emigration rates of each supplementation release over three years, while also providing some insight into the seasonal behavior and habitat use of sturgeon in the Reservoir. Throughout the duration of the monitoring program, information from both PIT and acoustic telemetry studies will be used to define factors that may be contributing to population growth, the availability and carrying capacity of suitable rearing habitats, and the carrying capacity of the Reservoir.

This report summarizes the activities carried out in the first two years of research, 2012 and 2013.

Methods

Study Site

The Reservoir on the Columbia River is formed by Rocky Reach Dam (river kilometer, RKM 762) and extends 67 km upstream, northeast to Wells Dam (RKM 829; Figure 1). There are two tributaries that enter the Reservoir from the west, the Entiat River (RKM 778) and the Chelan River (RKM 810). Seasonal mean discharge through the Reservoir typically ranges from a minimum flow of 1,700 m^3/s (60 kcfs) to a maximum flow of 5,100 m^3/s (180 kcfs), and mean temperatures range from 4°C to 19°C.

Flow conditions and habitat types transition from high flow velocities and riverine conditions in the Wells Dam tailrace to low flow velocities and Reservoir conditions in the Rocky Reach Dam forebay. The Reservoir was divided into four zones to reflect these changes: 1) Upper Reservoir, 2) Mid-Reservoir North, 3) Mid-Reservoir South, and 4) Lower Reservoir. The Upper Reservoir zone extended from the Wells Dam to Beebe Bridge and was characterized by high flow velocities and riverine conditions. The Mid-Reservoir North (Beebe Bridge to Orondo) and Mid-Reservoir South (Orondo to Entiat River) zones were characterized by intermediate flow velocities and riverine/reservoir conditions, but with the latter zone having more reservoir type habitat. The Lower Reservoir zone extended from the Entiat River to Rocky Reach Dam and was characterized by low flow velocities and reservoir conditions.

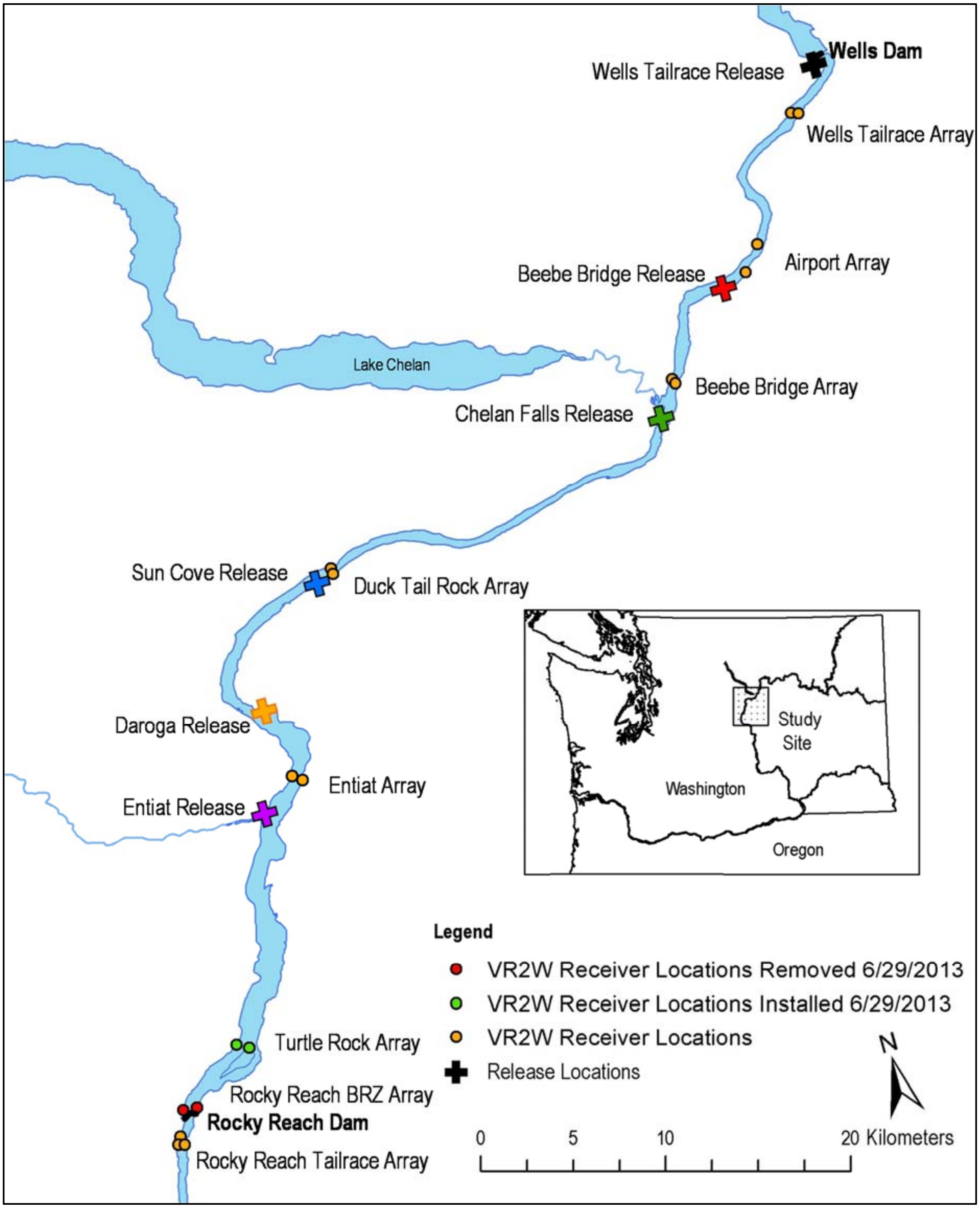


Figure 1. **Overview of Rocky Reach Reservoir study area with locations of Vemco VR2W receiver deployment locations and fish release locations in 2012 and 2013.**

Timeline Shift

In the original study design, PIT-tagged hatchery sturgeon were scheduled to be released in the spring of 2011, 2012, and 2013, with active (acoustic) tracking and indexing studies to occur between 2012 and 2014. However, due to the detection of iridiovirus in the juvenile white sturgeon, few hatchery sturgeon were available for release in 2012. The goal was to release 6,500 PIT-tagged as well as 65 acoustic-tagged juvenile sturgeon in 2012, but only 137 were PIT tagged and 10 of the 137 were acoustically taggedand released. Due to these circumstances, the timeline was extended to maximize the ability to collect informative results, as follows:

- ≤ 6,500 PIT-tagged juvenile sturgeon to be released in 2011, 2013, and 2014, with subsequent stocking levels to be determined by the *Rocky Reach Fish Forum* (RRFF);
- Indexing surveys were rescheduled to occur each year from 2013 to 2015; and
- Active acoustic tagging and tracking schedule to remain the same, occurring from 2012-2015.

This altered timeline, when coupled with recapture data from the *Northern Pikeminnow Removal Program* (see below) and acoustic tagging efforts, will allow for seven independent survival estimates to be generated. For the fish released in 2011, we will estimate survival from release to year 0.5, from 0.5 to 1.5, from 1.5 to 2.5, and from 2.5 to 3.5 years post-release. For the fish released in 2013, we will estimate survival from release to year 0.5 and from 0.5 to 1.5 years post-release. For the fish released in 2014, we will estimate survival from release to 0.5 years post-release (Table 1).

Table 1. Chelan PUD's spring releases of PIT-tagged juvenile sturgeon by year, annual autumn recapture methods, and the specific survival estimates that can be generated. Since two surveys were required to estimate any single survival value, population indexing will continue through 2015 to support the 2014 estimates in 2013.

		Recapture Method and Year[1]				
PIT Tag Release Year	**n**	**Pikeminnow 2011**	**Pikeminnow / Acoustic 2012**	**Indexing 2013**	**Indexing 2014**	**Indexing 2015**
2011	6,376	$\Phi_{\text{rls - 0.5 y}}$	$\Phi_{\text{0.5 - 1.5 y}}$	$\Phi_{\text{1.5 - 2.5 y}}$	$\Phi_{\text{2.5 - 3.5 y}}$	req'd to est. $\Phi_{\text{2.5 - 3.5 y}}$
2012	137		n-limited	n-limited	n-limited	n-limited
2013	7,975			$\Phi_{\text{rls - 0.5 y}}$	$\Phi_{\text{0.5 - 1.5 y}}$	req'd to est. $\Phi_{\text{0.5 - 1.5 y}}$
2014	≤6500				$\Phi_{\text{rls - 0.5 y}}$	req'd to est. $\Phi_{\text{rls - 0.5 y}}$

[1] In 2011 and 2012, PIT-tagged juvenile white sturgeon were captured as incidental bycatch during the fish effort associated with the *Northern Pikeminnow Removal Program*, which is funded by Chelan and Douglas PUDs and indicated in Table 1 as "Pikeminnow". Acoustic tag tracking commenced in 2012 and population indexing in 2013 throughout the Rocky Reach Reservoir.

PIT-Tag Releases

Chelan PUD staff PIT tagged hatchery-reared, juvenile sturgeon in 2011, 2012 and 2013. Further tagging of approximately 6,500 fish is planned for 2014 (Table 1). In each year, all fish were measured (fork length) at the time of tag implantation, and some of the individuals were also weighed. PIT-tagged fish were held prior to release, and only those that survived the tagging and handing procedures were released. In 2011, tagging occurred from 8 to 15 March, and 6,376 fish were released between 20 to 21 April; tagged fish were held for 36-44 days. In 2012, 137 fish were tagged on 29 March and released on 16 May; post-tagging holding duration was 48 days. In 2013, tagging occurred from 12 to 22 March and 7,975 fish were released between 20 to 23 May; fish were held post-tagging for 59-72 days. Recaptured sturgeon that were believed to have shed or failed PIT tags were re-tagged; however, only fish from the larger 'group' releases were included in subsequent analyses.

Northern Pikeminnow Removal Program

Occurring concurrently with the present sturgeon study is a *Northern Pikeminnow Removal Program*, sponsored by Chelan and Douglas County PUDs. Fishing for northern pikeminnow (*Ptychocheilus oregonensis*) occurred throughout the Reservoir, but with added effort in the tailrace of Wells Dam. Details of the rationale, methods and results can be found elsewhere (e.g., Jerald 2012). Since sufficient numbers of juvenile white sturgeon were captured as by-catch, and since these data were included in several of the analyses that are described in this report, we include some details of the *Northern Pikeminnow Removal Program* here.

In 2011, northern pikeminnow fishing occurred throughout the Reservoir, but primarily in the tailrace of Wells Dam (the 3.2 km area immediately downstream of the dam), for 88 days between 7 April and 11 November. In 2012, the fishing effort was conducted in 64 days between 21 June and 13 October, which was a slightly decreased effort compared to 2011. In 2013, the fishing dates ranged from 31 March to 1 November. Typically, 12 to 14 setlines were deployed on each day of fishing. Each setline was comprised of a main line attached to a buoy and another line that was weighted at each end with ~100 baited hooks attached. The bait consisted of pet-store crickets (*Gryllus assimilis*) and night crawlers (*Lumbricus terrestris*). Hook leaders were comprised of 6-pound monofilament line, allowing for the break-away of larger fish such as walleye (*Sander vitreus*) or adult salmonids. Treble hooks of varying sizes (sizes 2-6) were deployed randomly at approximately 60 cm intervals along each setline. Setlines were checked once per day, at which time crews released all non-target fish into the river unharmed.

All sturgeon that were incidentally captured on *Northern Pikeminnow Removal Program* setlines in 2012 and 2013 were measured (fork length and girth) and weighed, examined for scute marks, and scanned for PIT tags. Those captured with PIT tags were presumed to be of known identity (with known age, length, and weight at the time of tagging). If any fish had been captured without PIT tags and without scute marks to indicate hatchery origin, they would have been aged using fin-ray analysis (Rien and Beamesderfer 1994), and a PIT tag would have been inserted. All recaptured hatchery-origin fish with unreadable PIT tags were injected with a new tag. All fish were released in a live and healthy state.

Acoustic Tagging and Tracking

Acoustic Tags and Releases

In order to monitor the movements, habitat use, and emigration rates of stocked juvenile white sturgeon, a subset of individuals were tagged with acoustic transmitters. The WSMP calls for the acoustic tagging of 1% of each year's supplementation release, which is a target of 6,500 juvenile sturgeon PIT tagged, with 65 of those PIT and acoustic tagged. The primary tagging for each year takes place in the hatchery prior to release. In 2012, the hatchery release was very small (137) and only ten individuals (7% of the total released) were acoustic tagged on 18 April 2012 and released upstream of Beebe Bridge on 16 May 2012 (Figure 1). These sturgeon were tagged with Vemco *Model V7-2* acoustic tags (1.6 g in air, mean delay 600 sec, estimated battery life 185 days), which had an expected battery life until early November 2012. In 2013, a total of 7,975 juvenile sturgeon were released, with 65 (0.82%) sturgeon acoustic tagged and released in four locations from 20 to 23 May 2013: Above Beebe Bridge, Chelan Falls, Daroga and Entiat (Figure 1, Table 1). These fish were tagged with three types of tags: 10 fish were tagged with *Model V7-2* tags (1.6 g in air, mean delay 120 sec, estimated battery life 168 days); 50 fish were tagged with *Model V9-2* tags (4.7 g in air, mean delay 210 sec, estimated battery life 838 days); and five were tagged with *Model V9P-2* tags (6.4 g in air, mean delay 210 sec, estimated battery life 581 days). The *Model V9P-2* tags had pressure sensors and transmitted the depth of the tag with the acoustic detection. The *Model V7-2* tags were used on smaller sturgeon so that information on emigration and behavior was not biased toward the larger individuals within the release group.

In both 2012 and 2013, setlines were deployed (see methods described above) in order to capture juvenile sturgeon and implant acoustic tags. The focus of this effort in was to deploy some larger-sized tags (with longer battery life), by capturing some larger-sized (2011-released) fish. In 2012, during one week in September and one week in October, a total of 25 recaptured fish were acoustic tagged and released in four locations: Wells Tailrace, Chelan Falls, Sun Cove and Daroga State Park (Figure 1, Table 2). These tags were V9-2 tags with the exception of five *Model V9P-2* tags. On 22 October 2013, three *Model V13-1* tags (11 g in air, mean delay 210 sec, estimated battery life 1,462 days) and one *Model V13P-2* tag (12.3 g in air, mean delay 210 sec, estimated battery life 1,163 days) were implanted.

Surgical Implantation

The surgical implantation of acoustic transmitters for the hatchery releases took place at the Chelan Hatchery (11-13 September 2012, 24-25 April 2013) and/or the Columbia Basin Hatchery (April 2013). Recaptured fish were tagged in various locations using a truck-based mobile tagging station. Chelan PUD hatchery staff performed all surgeries in the hatchery, and both Chelan PUD and Blue Leaf Environmental (Blue Leaf) staff performed mobile surgeries. Sturgeon selected for tagging were placed in an anesthetic bath (MS-222; 60-80 mg/L) until a loss of equilibrium was attained, at which time they were examined for markings/abnormalities and had biometrics recorded. The fish were then transferred to a surgical table and administered a maintenance dose of anesthesia (MS-222; 19 mg/L). Acoustic transmitters were implanted through an incision centered approximately between both the pectoral and pelvic fins and the lateral and ventral scute lines. The incision was then closed with two to three sutures and the fish was transferred to a recovery bucket with fresh water and aeration. The surgical procedures followed the most up-to-date basinwide standards (described by Liedtke et al. 2012). Sturgeon were held for at least 30 minutes post-surgery to ensure adequate recovery prior to release.

Table 2. Tagged and released white sturgeon including number, location, and type of tags during 2011, 2012 and 2013. All fish were PIT tagged at initial release.

Release	Location	RKM	Release Date	PIT Tags Released	Acoustic Tags Released
BB01	Above Beebe Bridge	817	4/20/2011	3541	
BB02	Above Beebe Bridge	817	4/21/2011	2835	
			2011 Total	**6376**	**0**
BB03	Above Beebe Bridge	817	5/16/2012	137	10
WT01-05	Wells Dam Tailrace	829	9/10, 10/24-26 2012		11
CF01-02	Chelan Falls Boat Launch	809	9/11, 10/25 2012		5
SC01-02	Sun Cove Boat Launch	794	9/12, 10/27 2012		5
DR01-02	Daroga Boat Launch	785	9/13, 10/26 2012		4
			2012 Total	**137**	**35**
BB04-05	Above Beebe Bridge	817	5/20, 5/22 2013	2800	22
DR03-04	Daroga Boat Launch	785	5/21, 5/23 2013	2551	23
ET01-03	Entiat	778	5/20-21, 5/23 2013	2624	20
CF03	Chelan Falls Boat Launch	809	10/22/2013		2
WT06	Wells Dam Tailrace	829	10/22/2013		2
			2013 Total	**7975**	**69**

Receiver Deployment and Data Management

In order to monitor the movements of acoustically-tagged juvenile sturgeon, 15 Vemco *Model VR2W* (hereafter VR2W) receivers were deployed throughout the Reservoir and in the Rocky Reach tailrace. Prior to deployment, range testing was performed in a variety of acoustic environments in the Reservoir and Rocky Reach tailrace to determine a reasonable expectation of detection coverage of the VR2W receivers. There were two methods of deployment: (a) mounted to a steel or concrete anchor built for the purpose of positioning telemetry equipment on the riverbed; or (b) deployed directly on a line using an anchor with floats to keep the line upright in the water column. For both methods, the gear was secured to the shoreline with steel cable or polypro line. Receivers were deployed in pairs at detection locations spread throughout the Reservoir to create zones between which movements could be detected (Figure 1). Two receivers were used at each location to ensure adequate detection coverage over varied bathometry and to provide a failsafe if a receiver was damaged or lost. A total of three receivers were deployed below Rocky Reach Dam to ensure detection of emigration in a noisy and fast moving environment.

On 29 June 2013, the receivers located in the Rocky Reach BRZ were moved upstream 5 km to the Turtle Rock array (Figure 1). Prior to this date, the VR2W receivers deployed along the BRZ consistently missed fish moving downstream, likely due to noise interference from the dam. The new location has successfully detected all known fish moving past.

Receivers were pulled to the surface, inspected, and downloaded approximately bi-monthly. Data were downloaded to a field laptop running Vemco VUE software and then subsequently transferred to a SQL Server database for processing and analysis. Detections of acoustic tags were filtered for invalid data including non-study tags, detections before release, and detections recorded less than 3 times in a 30 minute period.

For analysis purposes, sturgeon with detections showing active movement into, out of, or within the study area were assumed to be live, while the fate of undetected or motionless fish was considered unknown. Residence times were calculated by grouping detections of individual fish on an individual receiver that occurred within two hours of each other and assigning a first and last detection date and time (if a fish was absent from a receiver for more than two hours a new residence period was assigned).

Population Indexing

The first year that a full indexing study was performed was in 2013. Prior to this, sturgeon recaptures had been recorded in both 2011 and 2012 as part of the *Northern Pikeminnow Removal Program* or during efforts to capture sturgeon for acoustic tag application.

Experimental fishing occurred over five 10-day sessions from 19 August to 23 October 2013 (

Table 3). All field data (setline and recaptured sturgeon data) were entered directly into a *Microsoft Access* database developed specifically for this project by Blue Leaf. The fishing effort included both systematic and targeted sampling. Systematic sampling was conducted during the first six days of the first three sessions. Targeted sampling focused fishing effort in areas either known or thought to provide higher sturgeon catch rates. Most of the targeted sites were in the upper reservoir, upstream of Beebe Bridge. Targeted sampling occurred during the last four days of sessions 1-3 and throughout sessions 4 and 5.

Table 3. The number of sites sampled for juvenile white sturgeon in the Rocky Reach Reservoir by sampling session, sample type, and location in 2013.

		Reservoir Zone							
		Upper		Mid North		Mid South		Lower	
Session	Dates	Systematic	Targeted	Systematic	Targeted	Systematic	Targeted	Systematic	Targeted
1	19-28 Aug	16	28	14	0	12	0	14	0
2	2-11 Sep	16	26	12	0	12	0	16	0
3	16-25 Sep	14	26	12	0	14	0	14	2
4	30 Sep - 9 Oct	0	78	0	0	0	0	0	0
5	14-23 Oct	0	64	0	15	0	0	0	0
	Total	**46**	**222**	**38**	**15**	**38**	**0**	**44**	**2**

Systematic sampling locations were determined using randomization techniques. The reservoir length was divided into 83 transects, each running perpendicular to the river flow and separated by 0.8 km (0.5 miles). On each transect, two sites were randomly selected, one within the lower 50% of the transect length, and one within the upper 50% (thus a site was selected on each 'river bank'). Ideally this process would randomize fishing sites across depths, flows, substrates and microhabitats. At most of the randomly-determined sites, setlines were deployed as planned, but occasionally the random location was near a dock, weed bed, or other impediment, in which case setlines were deployed in safer or more suitable habitats within 0.8 km of the planned location. 'Targeted' setlines were deployed at the discretion of the field crew, with efforts to maximize catch rates for the mark-recapture analyses.

Setlines were deployed and recovered by Columbia Research Specialists. Each setline was approximately 76 m in length (250 ft). Some lines were deployed with 60 to 92 treble hooks (sizes 2-6) baited with crickets or earth worms (sessions 1-5) and some were deployed with 33 to 65 circle hooks (sizes 3/0,4/0,5/0, and 6/0) baited with squid (sessions 4 and 5). Treble hooks were spaced about every meter (2-4 ft) and circle hooks were spaced every 1.2-2.4 m (4-8 ft). Eight setlines were usually deployed each day during systematic sampling, and up to 10 setlines were deployed during targeted sampling. Setlines were usually deployed at an angle to the shore to cover a range of depths and habitats. For each setline, the date, time, latitude, longitude, and depth of the start and end of the line were recorded. Each setline was fished for an average of 22 hours (fishing duration ranged from 17 to 30 hours).

Habitat Measurements

Habitat data were collected from the approximate mid-point of each setline immediately following deployment (with the exception of the first eight setlines of each sampling session, for which habitat data were recorded just prior to setline recovery). We recorded the latitude, longitude, and depth of the location where habitat variables were measured, along with the date and time.

Measured habitat parameters included dissolved oxygen (mg/L; *YSI ProODO*), temperature (°C; *YSI ProODO*), velocity (m/s; *Marsh-McBirney Flow Mate 2000* or *Hach FH950*), and turbidity (NTU; *YSI 600 OMS V2 Sonde* with *YSI 6136* turbidity probe). All parameters were measured at or near the bottom with the exception of velocity during session 1. During session 1, the only velocity meter available was a *Marsh-McBirney Flow Mate* with a short (12 m) cable and limited weight, thus velocity was measured at the bottom or at ~10 m depth (in calm waters; measurement depths were shallower where the current prevented the sensor from sinking). For sessions 2-5, we used a *Hach FH950* velocity meter that had a 30 m cable and a 9 kg weight, thus permitting velocity measurements to be recorded at or near the bottom for most sites.

Substrate composition was determined visually using an underwater video camera. Substrate was classified and proportioned by particle size (Table 4). Fine substrate composition (i.e., sand, silt, clay) was confirmed using a *Wildco Petite Ponar* sediment grab. The presence of mussels was also noted.

Table 4. Size classes used to classify substrate in the Rocky Reach Reservoir, 2013.

Substrate Type	Size (mm)
Organic Detritus	n/a
Silt, Clay	< 0.05
Sand	0.05-2
Small Gravel	2-12
Medium Gravel	12-38
Large Gravel	38-76
Small Cobble	76-152
Large Cobble	152-306
Boulder	> 306
Bedrock	n/a

Fish Capture

For each sturgeon caught, the depth, latitude and longitude of the setline were recorded, along with the approximate hook number. Sturgeon were scanned for a PIT tag (*BioMark Model 601 Reader*) and measured for fork length (mm), girth (mm), and weight (g). Girth was measured directly behind the pectoral fins. Each fish was examined for missing scutes (which indicate hatchery origin), and the location and pattern of missing scutes was documented. All sturgeon captured without a PIT tag were implanted with a new tag (*Biomark Model HPT12*) on the left dorsal side, just posterior of the head. All injuries or abnormalities (e.g., stunted or missing fins) were documented. Sturgeon were released near their capture location immediately after measurements were completed. Catch Per Unit Effort (CPUE) was calculated by dividing catch counts (numbers of sturgeon) by the number of hooks deployed and by the set duration (in hours), and then multiplying by 1000 hooks to give CPUE in units of ‘catch per 1000 hook hours’. All bycatch was identified by species and enumerated.

Sturgeon recapture data were used for analyses of growth rates (change in length or weight over time; DeVries and Frie 1996), condition factor (weight × FL^{-3} × 10^5; Anderson and Neumann 1996, Bolger and Connolly 1989) and survival (see below). For fish caught more than once in a given year, data from the first recapture was used in analyses of growth and condition factor.

Habitat Associations

Habitat association models were built with all available habitat variables used to explain the variability in catch rates of sturgeon. The explanatory variables included *Zone* (the reservoir was divided into four zones, see above), *Session* (the indexing surveys were conducted over five 10-day sessions), the *Zone* × *Session* interaction, *Temperature*, *Turbidity*, *DO*, *Velocity*, *Depth* (all measured at the approximate center-point of the setline), *Depth Profile* (measured as the difference between the depth at the start of the setline and that at the end), *Dominant Substrate* type (i.e., boulder, cobble, gravel, or fines), and *Hook Type* (circle vs treble). For all models, each individual setline was the unit of replication. Catch models were run separately for each of the sturgeon cohorts (i.e., separately for fish released in 2011 and 2013).

All models were run with *Catch* of sturgeon as the dependent variable. At least initially, *Catch* was offset by *Hook Hours* (i.e., CPUE was the *de facto* dependent variable). All models were initially run with a Poisson-distributed error structure, but if residual deviances were large relative to the degrees of freedom (suggesting over dispersion), then alternative models (such as quasipoisson, negative binomial, or Zero-Inflated models) were considered.

Starting with a saturated model, stepwise AIC selection methods were used to reduce the model, one variable at a time, until any further removals produced models with significantly poorer fit than the saturated model. The catches predicted from the final model were correlated with the observed values, and the squared correlation coefficient was used as an approximate measure of model fit (i.e., the approximate R^2). For continuous variables, the sign of the coefficients were used to assess whether their relationship with *Catch* was a positive or negative association. For categorical variables, catches were plotted (along with a boxplot showing the first and third quartiles, and with vertical bars extending to the highest value that was within 1.5 times the distance between the first and third quartiles) to reveal patterns.

Survival Estimation

Survival of the hatchery-released juvenile sturgeon was assessed using mark recapture data and a Cormack-Jolly-Seber (CJS) model (Lebreton et al. 1992). The CJS method allows the simultaneous estimation of the probability of detection during survey events (p), and the apparent survival between events (Φ). The number of PIT-tagged sturgeon released in 2012 was too low for adequate model fitting. Since the CJS model requires at least two surveys ‘post release’ to be able to distinguish the effects of survival from detection probability, survival estimates of fish released in 2013 cannot yet be calculated (see Table 1). At present, the following detection and survival parameters could be estimated:

- The 2011 detection probability of fish released in 2011;
- The 2012 detection probability of fish released in 2011;
- The survival of fish released in 2011 for the period from release (April 2011) until the *Northern Pikeminnow Removal Program* sampling period in 2011 (i.e., for the first 2.8-5.4 months in the Reservoir); and
- The survival of fish released in 2011 for the period between the *Northern Pikeminnow Removal Program* sampling efforts in 2011 and 2012 (i.e., from 2.8-5.4 months to 15.2-18.3 months in the Reservoir).

For each population being examined, four CJS models were run. One model ($\Phi_{.}\ p_{.}$) assumed that survival and detection probability were constant across years. The second model ($\Phi_{time}\ p_{.}$) allowed survival to vary between years, but assumed detection probability was constant over time. The third model ($\Phi_{.}\ p_{time}$) allowed detection probability to vary between years but assumed survival was constant across years. The fourth model ($\Phi_{time}\ p_{time}$) allowed both survival and detection probability to vary over time. For each model, AICc (the small-sample-size corrected version of Akaike information criterion, AIC) was calculated following Burnham and Anderson (2002).

$$\text{relative likelihood}_i = e^{(AIC_{min} - AIC_i)/2} ,$$

which indicated the probability that model *i* was that which minimized information loss. Lastly, 'AICc weight' was calculated as $\text{relative likelihood}_i \Big/ \sum_i \text{relative likelihood}_i$.

Models with the lowest AICc were selected as the most parsimonious. The 'significance' of the differences between each model's AICc vs. that of the most the parsimonious model (i.e, the ΔAICc) was judged using Anderson and Burnham's 'rule of thumb' (i.e., no real difference when ΔAICc < 2; considerable support for a real difference when 2 < ΔAICc < 7; strong evidence for differences when ΔAICc > 7; see Cooch and White 2013). To account for model uncertainty, model averaging was performed to calculate 'final' parameter estimates (i.e., Φ's and p's). Where possible, the rule of thumb was backed-up with a *Likelihood Ratio Test* (Cooch and White 2013).

The sturgeon released in 2011 came from four sources: progeny of two parental origin types (i.e., wild-origin broodstock versus captive broodstock) were reared at two locations (i.e., Marion Drain versus Chelan Falls hatcheries). While it should have been possible to test for effects of parental origin and rearing location, in fact, too few fish from Marion Drain and too few captive-origin fish were recaptured to allow a rigorous statistical comparison. Therefore, the survival rates of Chelan Falls fish, and those derived from wild-origin broodstock are presented, but no estimates are compared statistically.

All survival models were fit using the R (R Development Core Team 2011) package called 'RMark' (Laake and Rexstad 2013), which allows models to be constructed and fed to the program 'MARK' (White and Burnham 1999) for analysis, or by using the program 'MARK' directly.

Note that the survival models described above do not explicitly allow for emigration. 'True' survival rates (S) were calculated from apparent survival rates (Φ) using emigration rates that were determined from the active tracking results. Tag shed rates were assumed to be negligible.

Results

Environmental Conditions

The mean river flows during 2012 were considerably higher than the ten year mean (Δ= 61.3 kcfs spring and summer, Δ= 27.5 kcfs overall). In 2013, they were also higher than the mean for the spring and summer but to a lesser degree and more variable when compared to 2012 (Δ= 12.3 kcfs spring and summer, Δ= 9.1 kcfs overall; Figure 2). Early in 2012, temperatures were fairly close to the 10 year mean, whereas those from mid-June through September ranged from 1-2°C below the 10 year mean. Temperatures in 2013 averaged 0.8°C above the 10 year mean for the spring and summer (Figure 2).

Acoustic Telemetry

From the first release of acoustically-tagged sturgeon on 16 May 2012 to the final data download of 2013 (22 and 25 November 2013), 706,797 unique detections were recorded on VR2W receivers (Table 5; Appendix A). Of the 104 acoustic-tagged sturgeon, 99 (95%) were detected on at least one receiver with three or more detections within a 30 minute period. A majority, 65% of all detections, were recorded in the Wells Dam tailrace (Table 5, Appendix B and C). In 2013, more acoustic detections were spread to lower Reservoir detection sites, compared to detections recorded in 2012, likely a result of the releases in the lower Reservoir locations of Daroga and Entiat (i.e., no fish were released in the lower part of the reservoir in 2012; Figure 1, Table 5). Despite these lower releases, there were still very few detections in the bottom 4 km of the Reservoir, at the Turtle Rock array or in the tailrace of Rocky Reach Dam (0.001% of total). The number of individual sturgeon detected on each receiver ranged from 4-5 on the lower reservoir receivers (Rocky Reach Dam tailrace and Turtle Rock) and increased in number moving upstream to 70-71 on the uppermost receivers (Wells Dam tailrace; Table 5).

Similar to what was seen in 2012, there continues to be more upstream movements than downstream movements in the Reservoir. To date, there have been 223 upstream movements over 1,834 km compared to 124 downstream movements over 1,121 km (a net upstream movement of 713 km). For individual acoustic-tagged sturgeon, there was a mean of 2.1 movements upstream between detection arrays over 17.6 km and 1.2 movements downstream over 10.8 km, and the mean movement per fish in either direction was 29.7 km (Table 6). The mean distance traveled upstream by release location increased in distance moving toward the lower Reservoir (range: 7.9-32 km), while mean downstream distance traveled remained fairly steady regardless of release location among the larger release groups (range: 10.8-12.4 km, excluding smaller releases of CF and SC). Individual movements ranged from 0 to 124 km with 64 individuals (62%) moving greater than 10 km. There was considerable upstream movement of sturgeon released in the lower Reservoir (below Beebe Bridge) with 37 of 59 fish (63%) moving as far upstream as Beebe Bridge, into the top 18 km of the 70 km study area. Only 6 fish moved back downstream below Beebe Bridge after some period of residence. Residence times were also the greatest in the upper portion of the Reservoir although the Entiat array experienced much higher residence times in 2013 than were observed during 2012 (0.4 days in 2012; 353 days in 2013), which was likely a result of the additional releases in the lower portion of the Reservoir (Figure 3). Complete detection histories for each fish can be found in Appendix C.

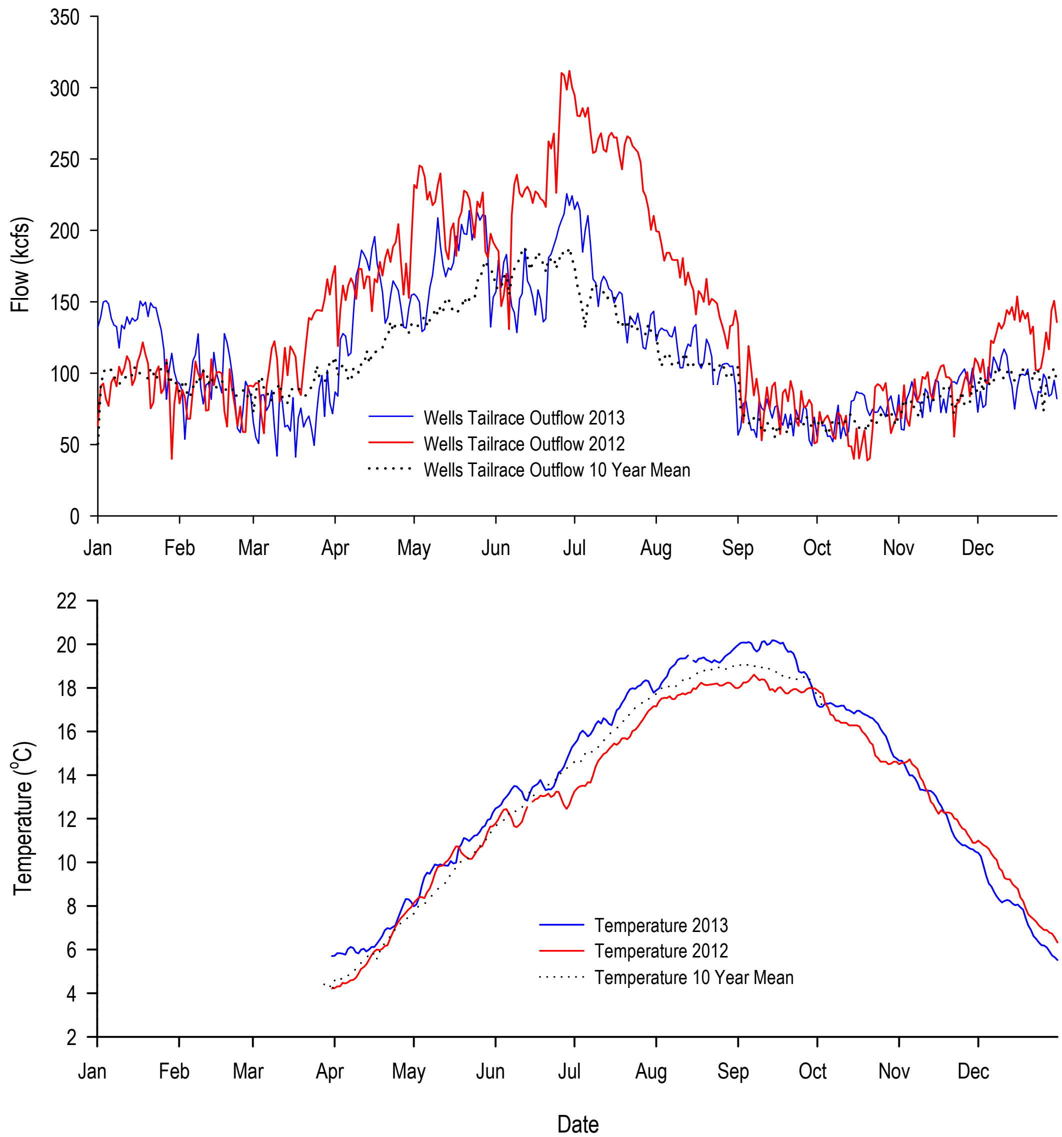


Figure 2. River flow (top) and temperature (bottom) including the ten year mean measured in the Wells Dam tailrace water quality site in 2012 and 2013 (data source: http://www.cbr.washington.edu/dart/river.html).

Table 5. Number of individual white sturgeon detected at each receiver along with the total number of detections for each receiver, 2012-2013.

Detection Location	RKM	Number of individual tags detected	Total Detections
Wells Tailrace 1	826.8	70	144,168
Wells Tailrace 2	826.7	71	312,909
Airport 1	819	64	6,123
Airport 2	817.8	72	58,229
Beebe Bridge 1	811.2	50	34,595
Beebe Bridge 2	811.1	48	42,484
Duck Tail Rock 1	794	53	27,838
Duck Tail Rock 2	793.8	53	21,137
Entiat 1	780.7	36	32,440
Entiat 2	780.7	34	26,014
Turtle Rock 1	766.3	5	292
Turtle Rock 2	766.3	4	436
Rocky Reach Tailrace 1	761.8	5	26
Rocky Reach Tailrace 3	761.2	5	63
Rocky Reach Tailrace 2	761.2	4	43
	Total	106	706,797

Seasonal movements were examined, based on the year of release and year of detection, to attempt to separate immediate post-release movements from seasonal movements that occurred after the first year of release. This was done with two methods, by month with direction of movement and by season showing the location of movement (Figure 4, Figure 5). Winter was excluded from the location figures due to almost no movement during this season. Initial upstream movements near their release locations were present after the 2012 releases (May, September and October), and while there were very few downstream movements at any time during the summer following the May hatchery release, September to December 2012 showed an increase in downstream movements (the mean distance traveled increased over time through the end of 2012). The detection locations of the 2012 released fish (in 2012) was a function of their release location: there was little activity below the upper Reservoir until the late summer and fall releases at the lower river sites (Figure 5).

During 2013, 14 of the 25 (56%) acoustic-tagged fish that were released in 2012 were detected; however, only 6 of the 25 fish (24%) moved between any of the detection arrays, and only 3 of the 25 fish (12%) moved more than 3 km. The six fish that moved showed little to no movements from January to July, and in November (*December 2013 not included in dataset*). Yet, there was an increase in movement upstream in

Table 6. Number of tags released by release site with number detected at a minimum of one receiver including movements up and downstream between release and detections arrays and total distance covered, 2012-2013.

Release Site	Tags Released	Tags Detected	Upstream Movements	Mean Upstream Movements	Total km Upstream	Mean Upstream km	Downstream Movements	Mean Downstream Movements	Total km Downstream	Mean Downstream km	Net Upstream Movement	Total km Movement	Mean km Movement
Wells Dam Tailrace	13	12					22	1.7	161.6	12.4	-161.6	161.6	12.4
Above Beebe Bridge	32	31	57	1.8	251.4	7.9	37	1.2	344.4	10.8	-93.0	595.8	18.6
Chelan Falls Boat Launch	7	7	18	2.6	97.3	13.9	3	0.4	22.1	3.2	75.2	119.4	17.1
Sun Cove Boat Launch	5	5	11	2.2	67.9	13.6	3	0.6	32.7	6.5	35.2	100.6	20.1
Daroga Boat Launch	27	25	77	2.9	864.0	32.0	37	1.4	313.0	11.6	551.0	1,177.0	43.6
Entiat	20	19	60	3.0	553.7	27.7	22	1.1	247.4	12.4	306.3	932.3	46.6
Totals	104	99	223	2.1	1,834.3	17.6	124	1.2	1,121.2	10.8	713.1	3,086.7	29.7

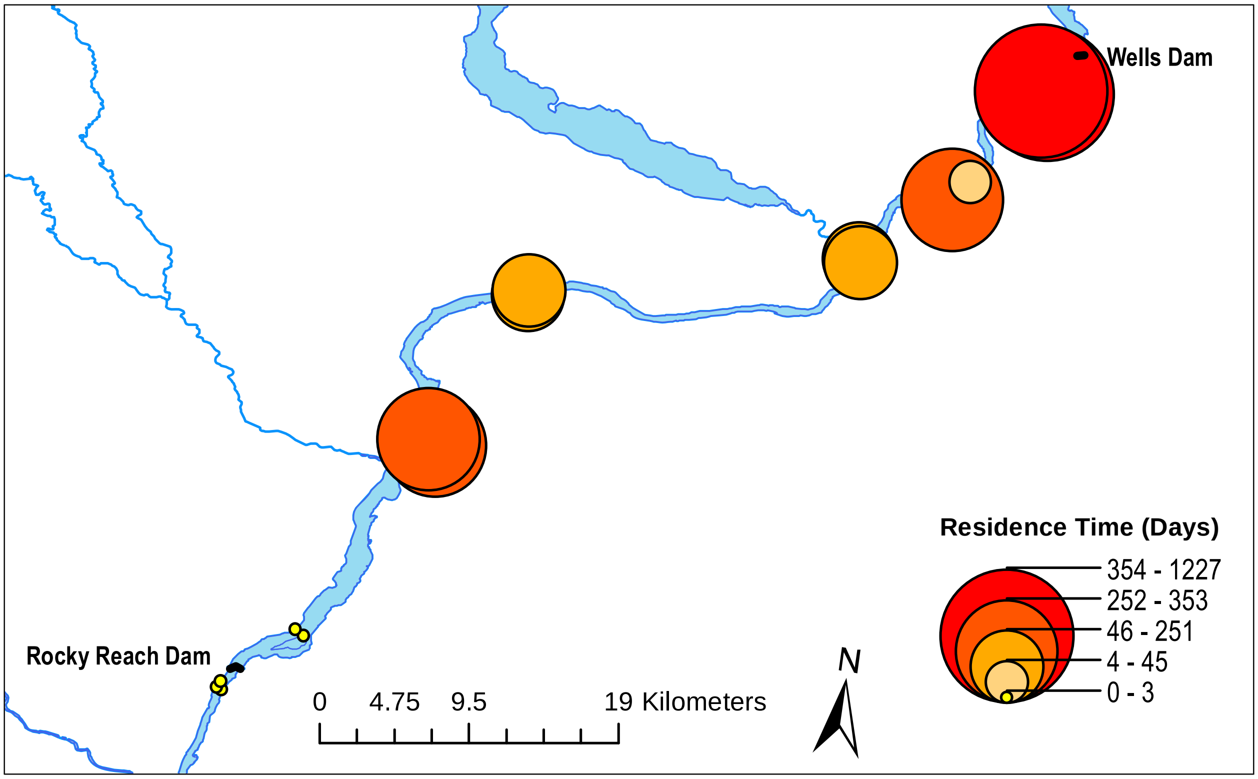


Figure 3. Residence time in days of all tagged sturgeon at each receiver throughout the study area, from the first release (16 May 2012) to the last download (21 and 25 November 2013).

August and September, followed by downstream movements in October, similar to the pattern of movement recorded in 2012 (Figure 4). Most of the increased movement in the fall was in the upper Reservoir (Figure 5). Sturgeon released in 2013 steadily increased in both the number of upstream movements and the mean distance traveled upstream in May-July, followed by a decrease in upstream movements and increase in downstream movements beginning in August, and decreasing in number though increasing in mean distance through October (Figure 4). Looking at the location of these detections in the spring months (20 March to 20 June) fish showed the most movement close to their release locations of Entiat, Daroga and Beebe Bridge (Figure 5). In the summer, movements of sturgeon shifted upstream to the top 18 km of the reservoir above Beebe Bridge with the highest total proportion of movements of any season. This was followed by a redistribution downstream in the fall, fairly equally spread between the Airport arrays and the Entiat array, though showing fewer movements overall than in the summer. Very little movement was seen below Entiat at any time of the year for the 2013 released fish.

When looking only at the number of individual fish that made movements between detection arrays, by month, regardless of direction, the fish released in 2012 showed the highest number of movements in both years during late summer and early fall. Fish released in 2013 showed a steadily decreasing number of individuals moving from the time of release through November (Figure 4). The complete detection histories of each sturgeon by detection array and release group can be found in Appendix C, and detection array deployment locations are displayed in Appendix D.

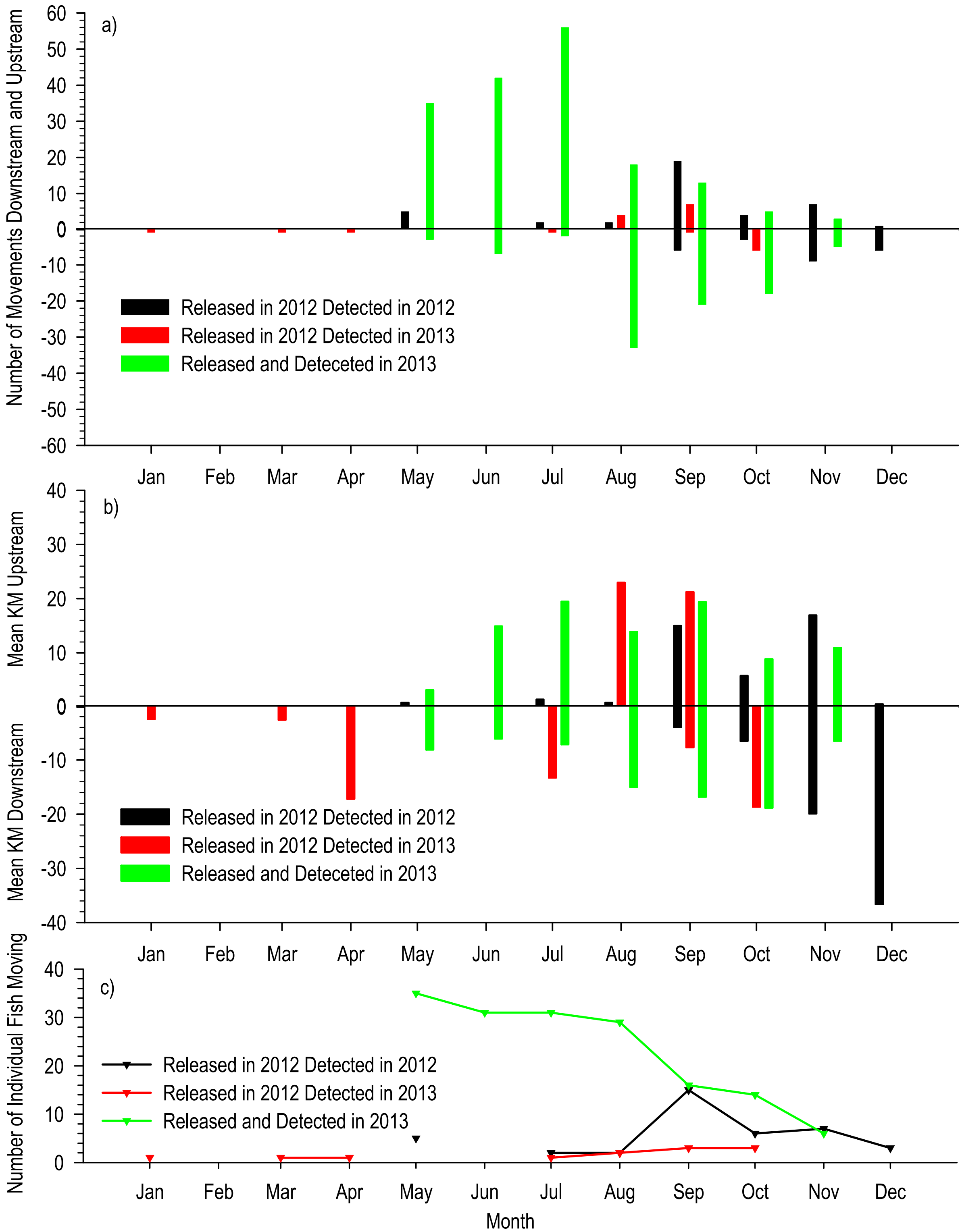


Figure 4. Seasonal movement information for all acoustically-tagged sturgeon, by month. Data are presented as: a) the number of movements upstream and downstream; b) the mean distance traveled for each fish that made a movement; and c) the total number of individual fish moving. In each panel, data are segregated by year of release and detection.

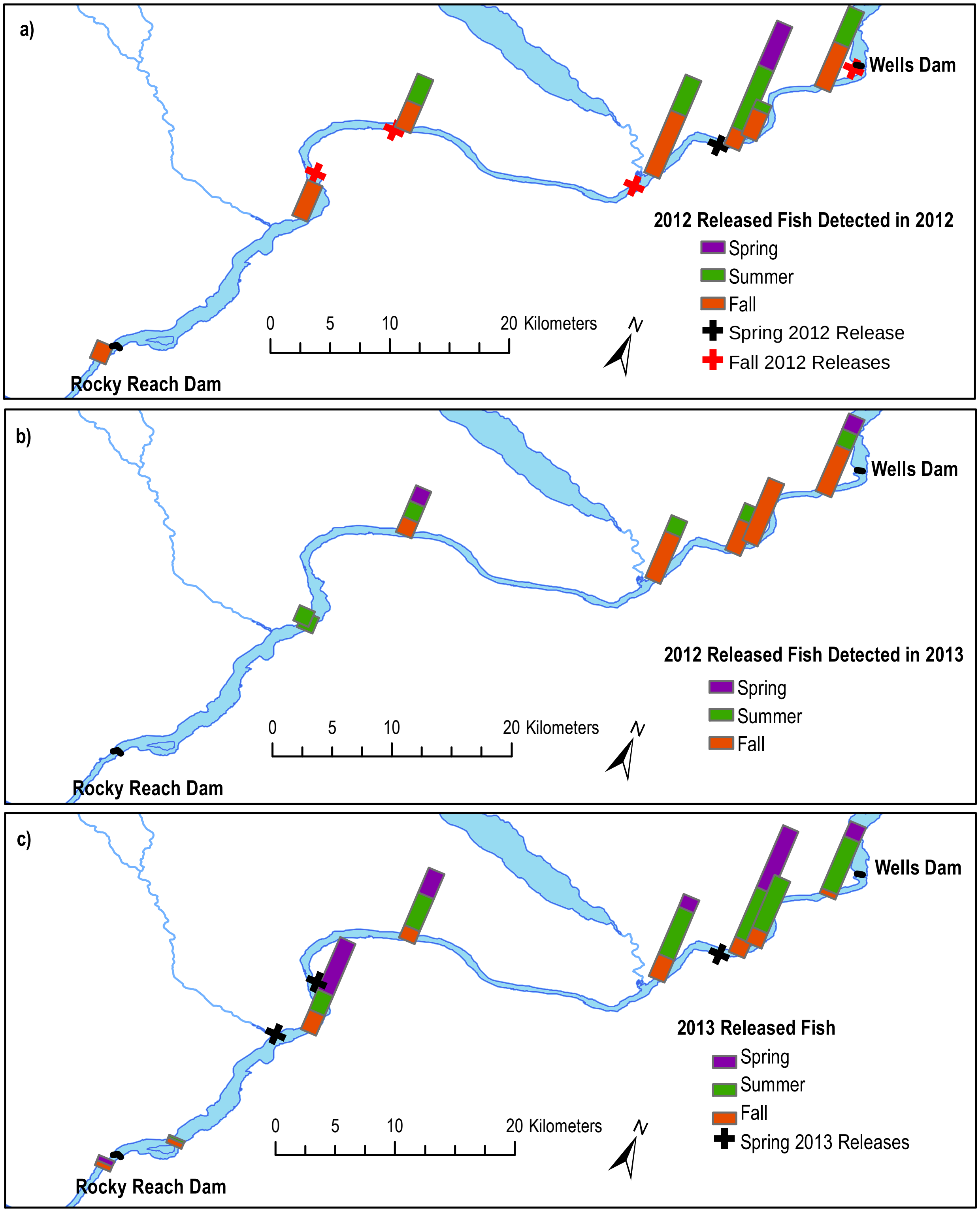


Figure 5. **The proportion of movements to a new detection array for the spring (purple), summer (green) and fall (red) periods for: a) 2012 released fish detected in 2012; b) 2012 released fish detected in 2013; and c) 2013 releases detected in 2013. The location of releases each year are also shown. Movement bars are proportional within figures but not between figures.**

Five sturgeon were released with pressure sensor tags in 2012 and an additional six were released in 2013. Of the total 11 fish released, 10 (91%) were detected on individual receivers during the study period for periods ranging from 25 minutes to 193 days (median = 8.4 hours). One fish (ID 8017) was detected at the Duck Tail array from early December 2012 to early July 2013 with a mean depth of 2.5 m (range: 1.1 to 3.5 m). The mean depth and depth range of this particular sturgeon was considerably shallower and smaller than any other sensor-tagged fish. It effectively didn't change depth over its extended period of residence. This, combined with a pattern of slight increases in depth during periods of higher discharges indicated a high likelihood that this fish was either deceased or the tag was shed. It was therefore excluded from further depth analysis. The remaining nine tags showed a combined mean depth of 15.4 m (median = 15.8 m, range: 0.4 m to 43.3m). The majority of detections of sensor-tagged fish (102,838, 85% of total) were from one fish, ID 8013 (mean depth 15.3 m), as it resided near the Wells Tailrace receivers for 193 days. When looking at individual sturgeon's detections at specific receivers, mean depths varied from 2.2 m to 21.4 m, and residence times varied from 2.4 hours to 241 days (Table 7). Mean depth for individual fish, regardless of location, ranged from 9.1 m to 21.4 m; while mean depth of all fish at each detection array varied from 10.0 m to 20.4 m. With the exception of ID 8013, which resided near receivers for extended periods, most depth sensor fish were picked up for short periods while moving en route past receivers.

Table 7. Mean depth (m) by tag code and detection array with residence times (days) in parenthesis. Mean depth by tag code for all locations on far right column and mean depth by detection array for all tags on bottom row.

Tag Code	Entiat	Duck Tail	Beebe	Airport	Wells	Mean / Tag Code
13476					12.9 (1.0)	12.9
8013					15.3 (241.0)	15.3
8014			3.8 (0.1)	13.7 (0.4)	11.0 (0.5)	11.7
8015	2.2 (0.1)	11 (0.4)				9.6
8016		15.8 (0.9)				15.8
9203				9.4 (2.0)	8.6 (0.4)	9.1
9204	20.2 (7.8)	19.6 (0.4)	16.6 (1.1)	9.9 (0.3)	6.0 (0.1)	19.4
9205	21.4 (2.9)					21.4
9206	8.2 (0.1)	17.5 (1.3)	20.8 (0.4)	8.4 (0.2)	11.7 (0.3)	16.3
Site Mean	20.4	16.3	17.4	10.0	15.2	

For at least part of its long term residence, ID 8013 showed a distinct diel pattern of moving shallower at night and returning to deeper areas during daylight hours (Figure 6). However other behaviors were also observed. From 2 to 4 March 2013, ID 8013 came within detection range at Wells Tailrace array but maintained a specific depth of approximately 15 m with little movement up or down, seeming to indicate a resting behavior (Figure 6, b). This is in contrast to most of the spring and summer, where we observed a regular daily cycle, changing depth by 10-15 m between day and night. Late April showed variable depth-use at night (~11-18 m) but narrow depth-use in daylight (~20 m), suggesting a daytime resting behavior (Figure 6, c). Mid-August showed separate but variable depth-use both night and day (seeming to indicate constant movement), followed by a period (14 August to 18 August) of relatively little depth change or diel movement (Figure 6, d). When looking at the hour of each detection for all fish at all receiver locations, there was a 25% increase in the quantity of detections during nighttime hours compared to day, likely a result of movements into shallower water (close to near-shore receiver locations), further evidence of a diel pattern in the population (Figure 7).

Emigration

In all, 25 sturgeon from the 2011 supplementation program release were acoustic tagged following recapture in 2012. To date, two of these fish (8%) have been detected emigrating from the Reservoir. The first one, ID 29544, moved 58 km from the Airport 2 receiver to the Rocky Reach tailrace receivers in 78 hours (Wells tailrace release, Appendix C). The movement occurred at the end of November 2012, 583 days after initial release and approximately one month following release. In contrast the second fish to emigrate in 2012, ID 29819, was released in the Wells Dam tailrace and, 23 days following release, was detected on the Wells tailrace receivers, and then slowly moved down and out of the Reservoir over the next 22 days, finally being detected in the Rocky Reach Dam tailrace on 9 December 2012. Four additional recaptured 2011 sturgeon were tagged in October of 2013 with long life V13 tags and none have emigrated to date.

For the 2012 Chelan PUD supplementation release, ten sturgeon were tagged with acoustic tags on 16 May and none were detected emigrating over their six month battery life. During the 2013 supplementation release, 20-23 May, 65 acoustic-tagged fish were released. To date, three fish (4.6%, 1 V7 and 2 V9 tags) have emigrated out of the Reservoir. One fish (ID 28075), released at Entiat, was detected below Rocky Reach Dam within two days of release, and then remained in the Rocky Reach tailrace within detection range for 19 days until 6 June (Appendix C). The second fish (ID 9585, a V7 tag) was released at Daroga, moved as far upstream as Beebe Bridge during August, began movement downstream on 5 October (five months after release), and was detected in the Rocky Reach tailrace seven days later on 12 October. The third fish (ID 28051) was released above Beebe Bridge, moved up into the Wells Dam tailrace, remained in the upper reservoir for the entire summer, left Airport array on 21 September, and moved downstream over ten days to be detected in Rocky Reach tailrace on 1 October (again, five months after release).

The weighted average emigration rate is currently 4.8%, which is based on current records of monitoring 104 acoustically-tagged sturgeon.

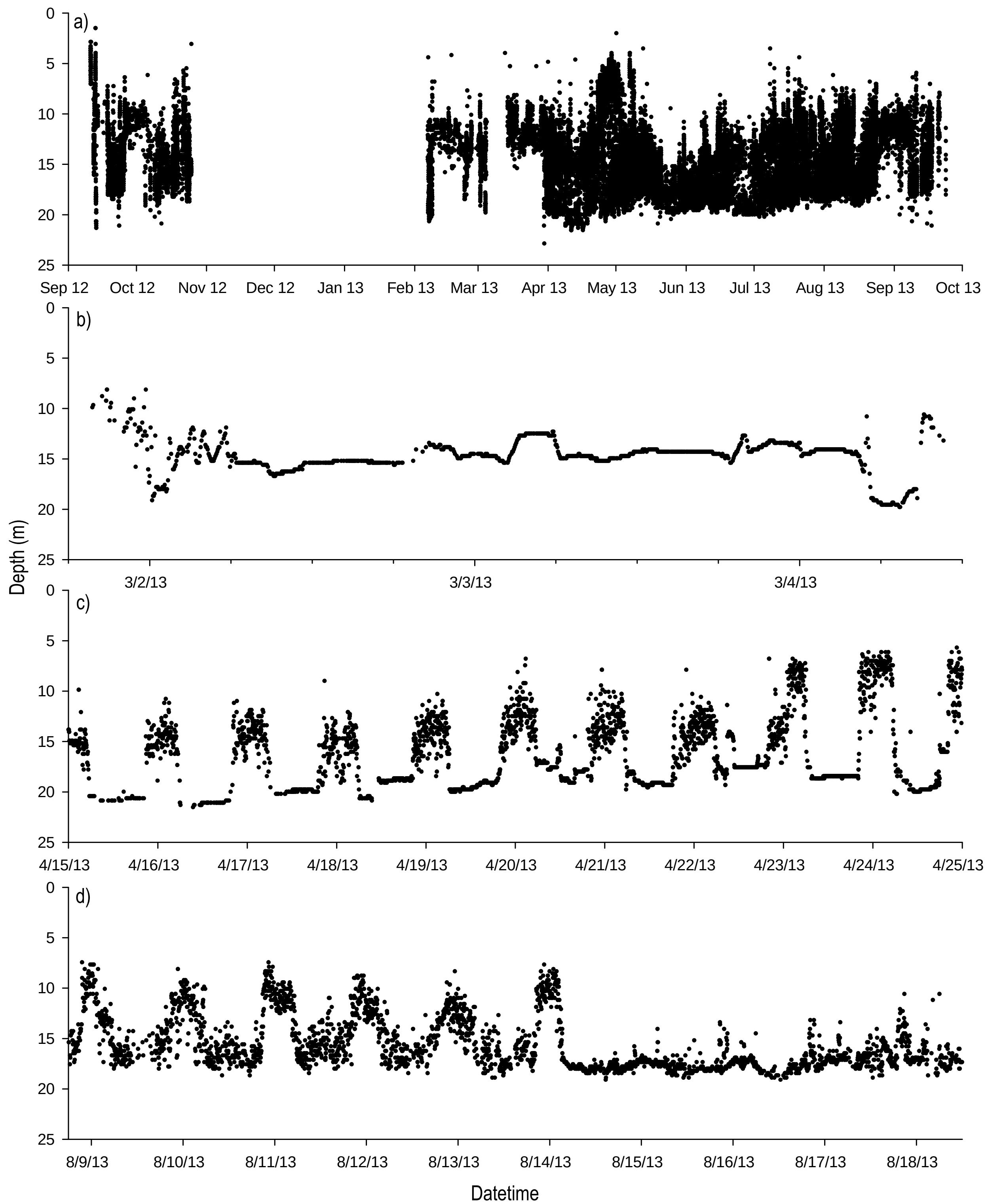


Figure 6. Depth sensor data (m) of ID 8013 at the Wells Tailrace receivers over the entire period of its detection (Panel a). Also shown (Panels b,c,d) are close-up views of various periods within its detection period.

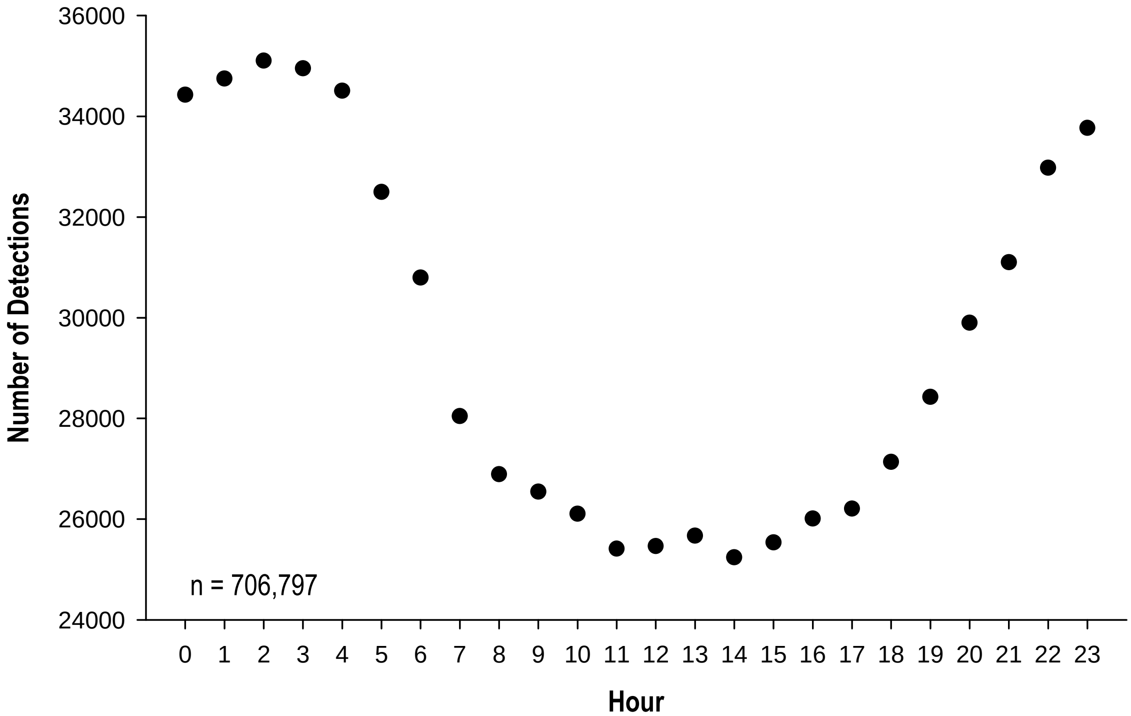


Figure 7. Detections of acoustic tags by hour of day for all locations and throughout the entire study period, 2012-2013.

PIT-Tag Recaptures

PIT-Tagged Fish Recaptured in 2011

In 2011, a total of 65 white sturgeon capture events were recorded during pikeminnow fishing efforts (Figure 8). Of the 65 fish, three were captured twice in 2011, leaving a total of 62 unique individuals. Based on PIT-tag identities, all 62 sturgeon were PIT tagged by Chelan PUD in March 2011 (as part of the group of 6,376 PIT-tagged hatchery sturgeon that were tagged in March and released in April 2011). Seven fish that were in the Reservoir for less than 60 days were not included in analyses of growth, condition or survival, leaving 55 unique fish that were recaptured between 15 July and 30 September 2011 (i.e., that were at large for between 2.8 and 5.4 months at the time of recapture).

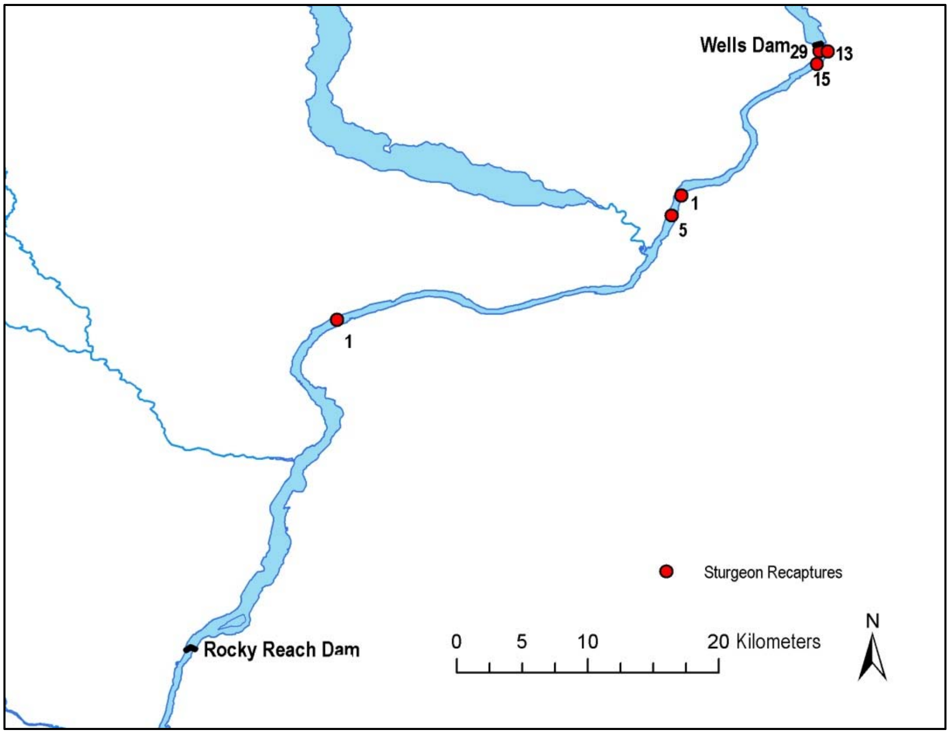


Figure 8. Approximate locations and numbers of juvenile white sturgeon recaptured incidentally during northern pikeminnow removal effort (n=65) in Rocky Reach Reservoir in 2011. Northern pikeminnow removal effort was spread throughout the Reservoir from April to November 2011.

PIT-Tagged Fish Recaptured in 2012

In 2012, there were a total of 98 capture events (Figure 9) that included 91 unique fish. 89 of the capture events involved fish that were PIT tagged by Chelan PUD in 2011, of which 83 were unique fish. The remaining nine capture events involved eight unique fish, none of which were included in analyses of growth and condition or survival. Six of the eight fish were PIT tagged by Chelan PUD in 2012. The last two fish did not have PIT tags, so they each were injected with a tag subcutaneously and were released (one of the two was recaptured a few weeks later). All 83 fish that were PIT tagged by Chelan PUD in 2011 (i.e., that were released between 15.2 and 18.3 months prior to recapture) were included in analyses of growth, condition and survival.

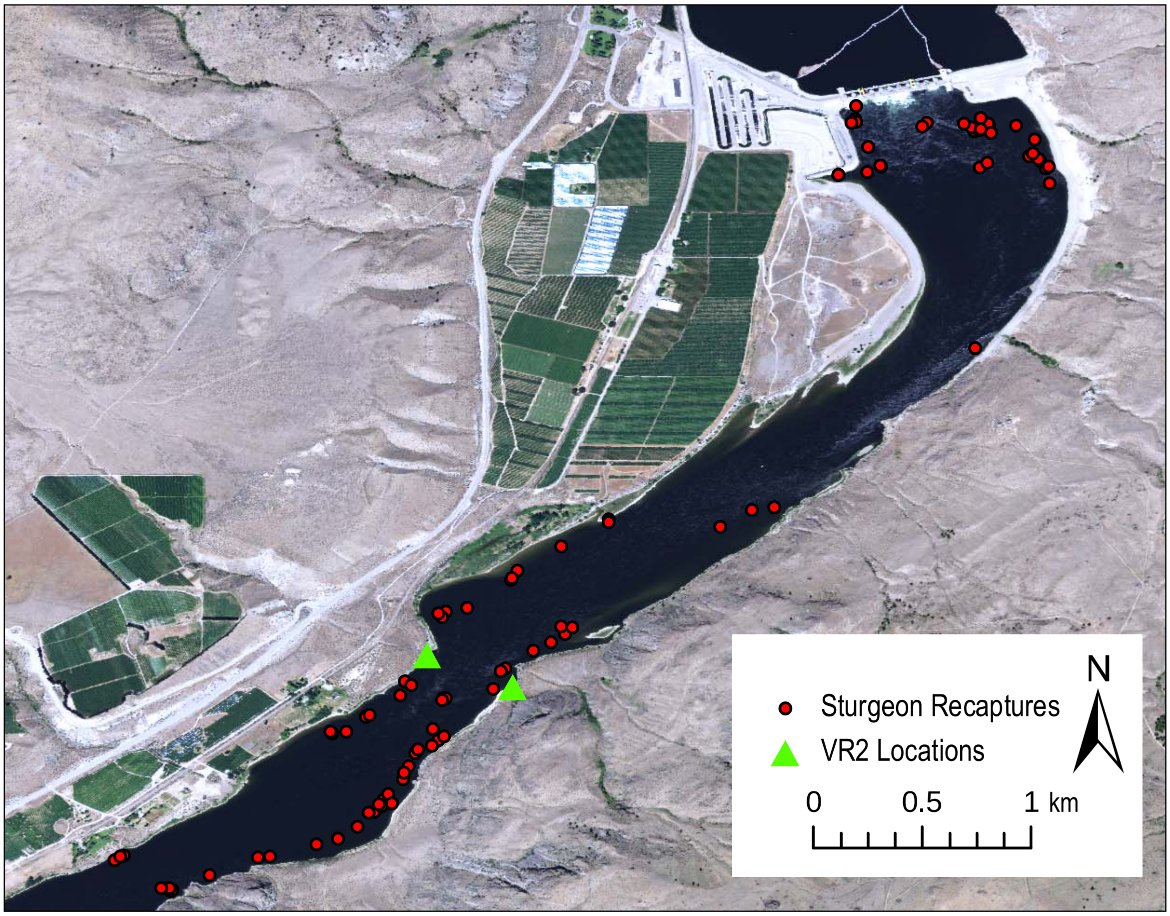
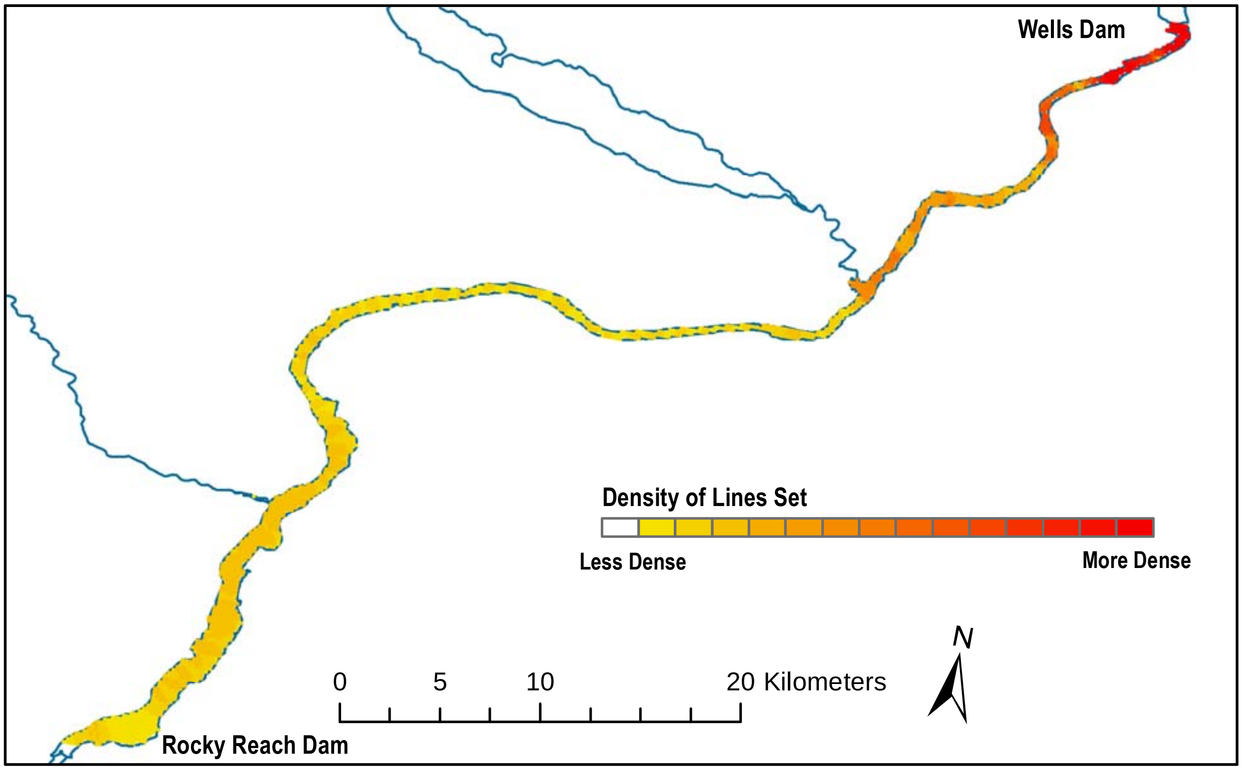


Figure 9. Locations of juvenile white sturgeon recaptured incidentally during northern pikeminnow removal effort (n=72) and during focused sturgeon fishing for tagging efforts (n=26) in Rocky Reach Reservoir in 2012. *Northern Pikeminnow Removal Program* **effort was spread throughout the Reservoir from June to October 2012. Each red dot is a unique recapture.**

PIT-Tagged Fish Recaptured in 2013

During the 2013 indexing efforts, a total of 568 capture events were recorded (Figure 10) that included 495 unique fish. Of these, 96, 5, and 372 fish had been PIT tagged by Chelan PUD in the spring of 2011, 2012 and 2013, respectively. One additional fish had been previously captured in September 2012, when it was PIT and acoustic tagged. In addition, 25 sturgeon were recaptured in 2013 that had scute-marks indicating hatchery origin, but their PIT tags had been shed or failed (these were re-tagged and released; these data were used to calculate a shed-tag rate of 5% for the sturgeon released in 2013, i.e., 25 of 495).

All 96 of the fish PIT tagged by Chelan PUD in 2011 (i.e., which had been released 28.0 and 30.1 months prior to recapture) were included in analyses of growth, condition and survival. All of the fish that were PIT tagged in 2013 (n=372), which had been released 2.9 to 5.1 months prior to recapture, were included in analyses of growth and condition factor. In 2013, there were only six sturgeon caught during the northern pikeminnow capture efforts (four of which were scanned for PIT tags) and these have been excluded from the analyses presented in this report.



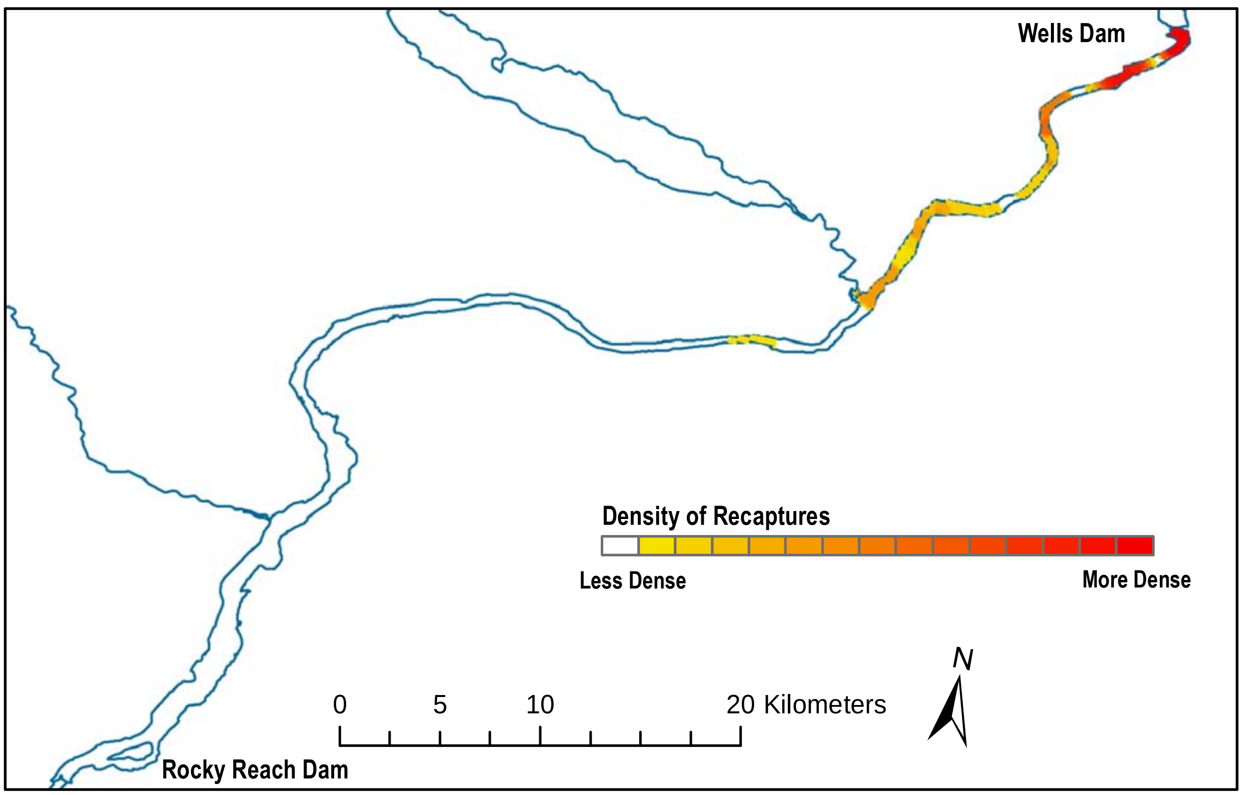


Figure 10. Density of setlines fished throughout the Reservoir (above) along with density of catch (below) during the 2013 indexing effort (19 August – 23 October).

Indexing Catch per Unit Effort

During systematic sampling, 75% (n=40) of sturgeon captured were in the upper reservoir and only 6% (n=3) were captured downstream of Orondo, Washington, in the lower portion of the Reservoir. Based on this result, 95% of targeted setlines were deployed in the upper reservoir to maximize the number of fish captured (Table 8).

During Indexing Sessions One to Three, 93% of captured sturgeon were from the 2013 release year and only four 2011 fish were captured. All of these fish were caught on treble hooks baited with crickets or worms. To determine if the paucity of 2011 release year sturgeon was gear related, we deployed setlines configured with circle hooks baited with squid in Indexing Sessions Four and Five. This combination proved effective at capturing both 2013 and 2011 fish. Of the 104 fish from 2011 that were captured in Indexing Sessions Four and Five, 86 (83%) were caught on circle hooks.

CPUE was highest in the upper reservoir and was higher for circle hooks (baited with squid) than for treble hooks (baited with crickets; Table 9). This was especially true for 2011 fish in the upper reservoir where catch per 1000 hook hours was 1.070 and 0.077 for circle and treble hooks, respectively. Both gear types captured a similar range of sizes (Figure 11), but the average fork length was significantly larger for circle hooks (411 mm; range: 275-660 mm) than for treble hooks (353 mm; range: 235-635 mm; $F_{1,565}$=122, P<0.0001).

Table 8. Sampling effort and catch by reservoir zone and gear type for juvenile white sturgeon captured in the Rocky Reach Reservoir from 19 August - 23 October, 2013. The Rocky Reach Reservoir was divided into four zones, see text. To capture larger 2011 sturgeon, circle hooks baited with squid were used during Indexing Sessions Four and Five at targeted sampling locations. Fish with unknown release year were captured without a PIT tag but the pattern of missing scutes indicated hatchery origin.

				Catch, by Release Year				
Zone	**Gear**	**Setlines**	**Hooks**	**2011**	**2012**	**2013**	**Unknown**	**Total**
Upper	Treble	204	16,110	28	3	278	17	326
	Circle	64	3,381	81	2	109	10	202
Mid-North	Treble	38	3,050	0	0	10	0	10
	Circle	15	721	5	1	21		27
Mid-South	Treble	38	3,048	0	0	1	0	1
	Circle	0						
Lower	Treble	46	3,679	0	0	2	0	2
	Circle	0						
Total		405	29,989	114	6	421	27	568

Table 9. Sampling effort and catch by reservoir zone and gear type for juvenile white sturgeon captured in the Rocky Reach reservoir from 19 August - 23 October, 2013.

			Catch per 1000 Hook Hours				
Zone	**Gear**	**Effort (Hook-Hours)**	**2011**	**2012**	**2013**	**Unknown**	**Total**
Upper	Treble	364,744	0.077	0.008	0.762	0.047	0.894
	Circle	75,722	1.070	0.026	1.439	0.132	2.668
Mid-North	Treble	63,273	0.000	0.000	0.158	0.000	0.158
	Circle	15,952	0.313	0.063	1.316	0.000	1.693
Mid-South	Treble	60,599	0.000	0.000	0.017	0.000	0.017
	Circle	0					
Lower	Treble	76,827	0.000	0.000	0.026	0.000	0.026
	Circle	0					
Total		657,118	1.460	0.097	3.719	0.179	5.455

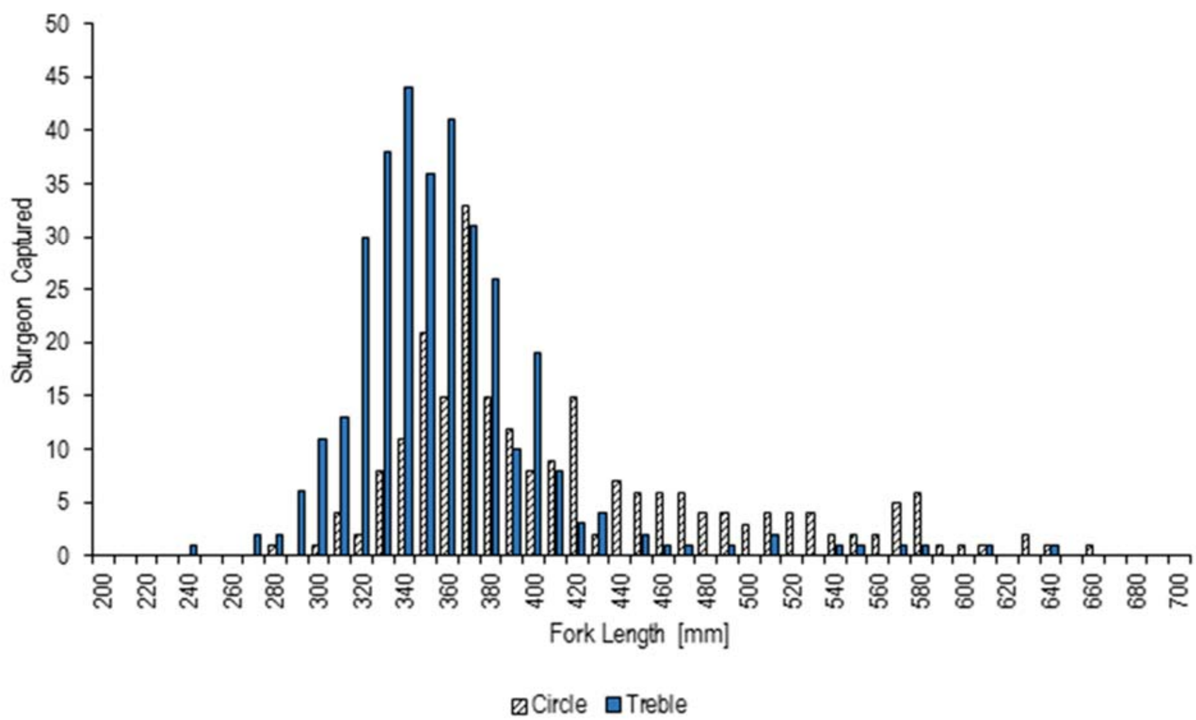


Figure 11. Size-frequency distribution for sturgeon captured during 2013 indexing by gear (hook) type.

Growth and Condition Factor

Analysis of fish length, weight and condition was restricted to fish tagged as part of the 2011 release group that were at large for at least 60 days before recapture (this included 55 fish captured during northern pikeminnow fishing in 2011, 83 fish captured during northern pikeminnow fishing or acoustic tagging in 2012, and 96 fish captured during indexing efforts in 2013). Also included in the growth analyses were 372 fish tagged by Chelan PUD in 2013, which were recaptured 2.9-5.1 months post-release during indexing efforts in 2013. The individual weight was not recorded for every fish at the time of tagging and was also not recorded for any recaptured fish in 2011.

On average, fish caught during the 2011 surveys (i.e., after their first 4.0-6.8 months post-tagging) increased in length by 58.8 mm (n=54, SE=3.1), with length increases ranging from 12 to 124 mm (Figure 12). Also growing for less than a year were the fish that were tagged in 2013 and recaptured from 4.9-7.4 months later, which increased in length by 81.1 mm on average (n=374, SE=1.2; range: 16 to 202 mm). Fish from the 2011 release groups that were caught during the 2012 surveys (i.e., after 16.4-19.7 months post-tagging) increased in length by 85.5 mm (n=83, SE=4.0), with increases ranging from 26 to 216 mm (Figure 12). Fish from the 2011 release groups that were caught during the 2013 surveys (i.e., after 29.2-31.5 months post-tagging) increased in length by 215.4 mm (n=96, SE=6.6), with increases ranging from 70 to 367 mm (Figure 12). Average growth values for the 2011 releases suggested that growth between 2011 and 2012 was 26.7 mm, and that from 2012 to 2013 was 129.9 mm. However, measured values for the fish that were recaptured during multiple survey years (n=5 fish caught in both 2011 and 2012; n=10 fish caught in both 2012 and 2013) varied widely (2011-2012 growth range: 4-37 mm; 2012-2013 growth range: 13-136 mm) and averaged 16.2 mm between 2011 and 2012 and 79.0 mm from 2012 to 2013.

The recorded increases in weight from tagging in 2013 to recapture after 4.9-7.4 months ranged from 11 g to 177 g (mean = 75.2 g, n=39, SE=6.1; Figure 13). Fish that were tagged in 2011 and recaptured in 2012 (after 16.4-19.7 months) showed changes in weight ranging from a decrease of 13 g to an increase of 533 g (mean = 135.3 g, n=24, SE=26.3; Figure 13). Fish that were tagged in 2011 and recaptured in 2013 (after 29.2-31.5 months) increased in weight from 35 g to 1601 g (mean = 670.8 g, n=24, SE=83.2; Figure 13). In all cases, the increases in weight appeared to be commensurate with recorded increases in length (Figure 14). Average weight changes for the 2011 releases suggests that growth between 2012 and 2013 was 535 g. However measured values for the three fish that were recaptured in both years varied from 188 to 532 g, and averaged 401 g.

After the first 4.9-7.4 months post-tagging (i.e., fish tagged in and recaptured in 2013), none of the fish measured showed an increase in condition factor: changes ranged from -0.30 to -0.04, and averaged a decline of 0.17 (n=39, SE=0.01; Figure 15). This indicates that weight increased at a rate that was less than a cubic function of length. Fish that were measured after 16.4-19.7 months (i.e., those tagged in 2011 and recaptured in 2012) showed an average decline in condition factor of 0.07 (n=24, SE=0.01), although some fish showed an increase (range: -0.17 to 0.06; Figure 15). Fish that were recaptured 29.2-31.5 months after tagging (i.e., those tagged in 2011 and recaptured in 2013) increased in condition factor by 0.02 on average (n=24, SE=0.02, range: -0.30 to 0.16; Figure 15). Further information is required to assess potential implications of these rates.

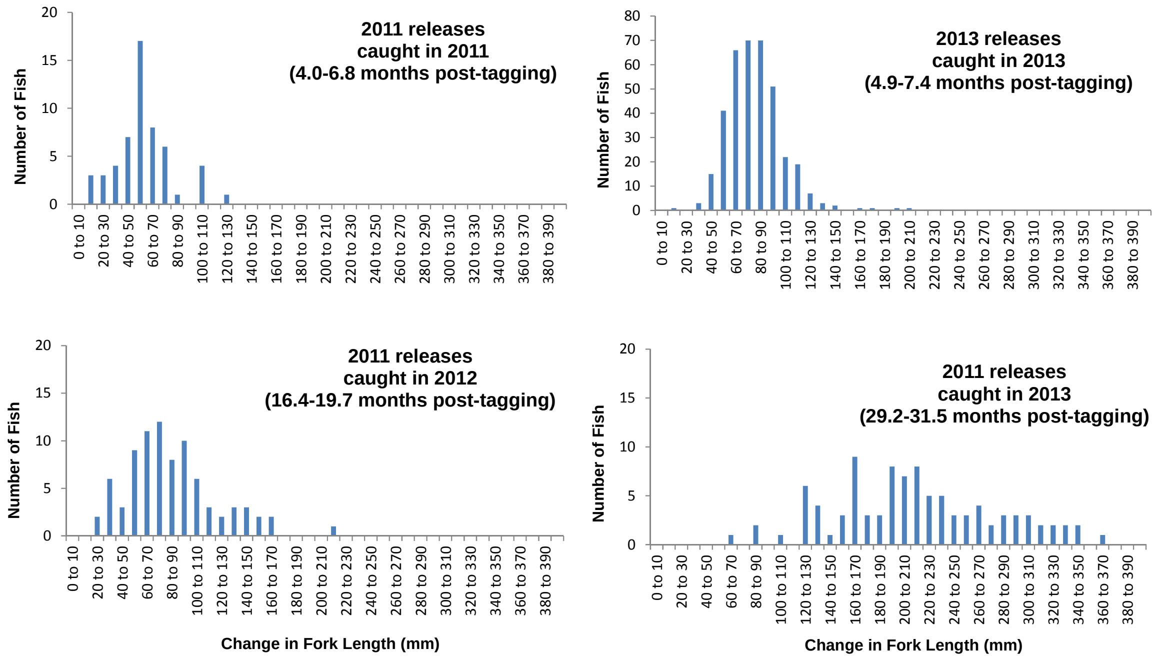


Figure 12. **Change in length between tagging and recapture for white sturgeon that were PIT tagged by Chelan PUD. Lengths at recapture are presented separately for each release cohort and survey year.**

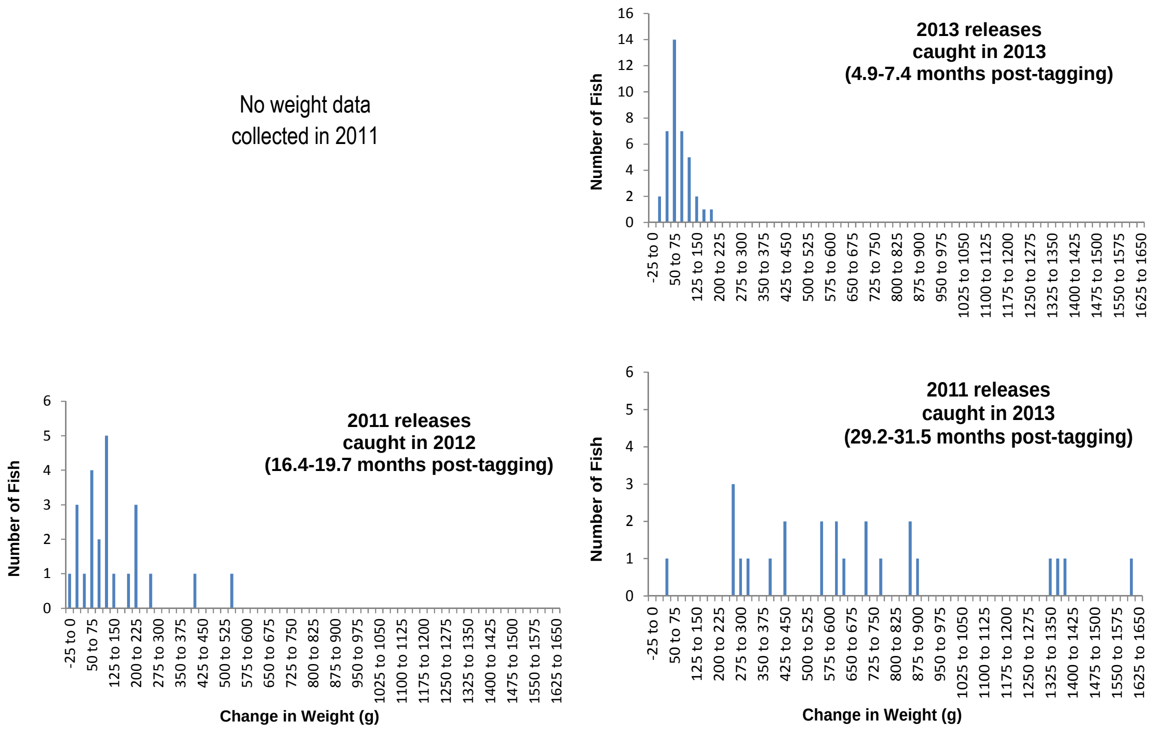


Figure 13. **Change in weight between tagging and recapture for white sturgeon that were PIT tagged by Chelan PUD. Weights at recapture are presented separately for each release cohort and survey year. Weight was not measured at recapture in 2011. Weight at the time of tagging was not recorded for every individual fish.**

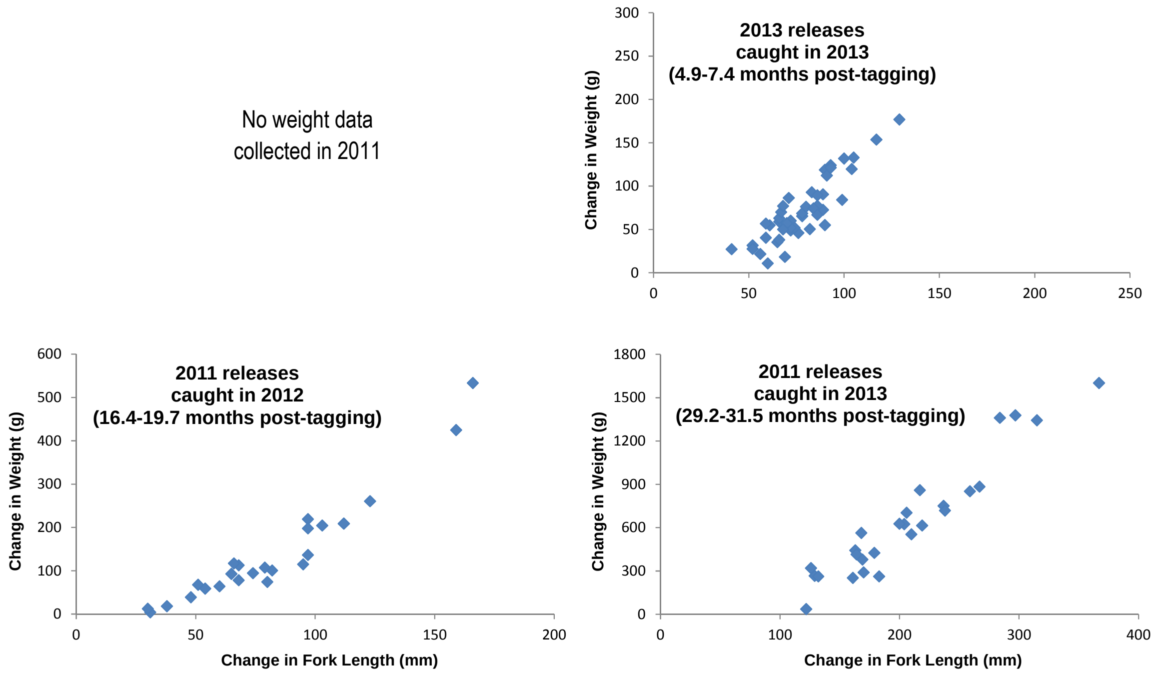


Figure 14. **Relationship between the change in weight and the change in fork length for white sturgeon that were PIT tagged by Chelan PUD. Data are presented separately for each release cohort and survey year. Weight was not measured at recapture in 2011. Weight at the time of tagging was not recorded for every individual fish.**

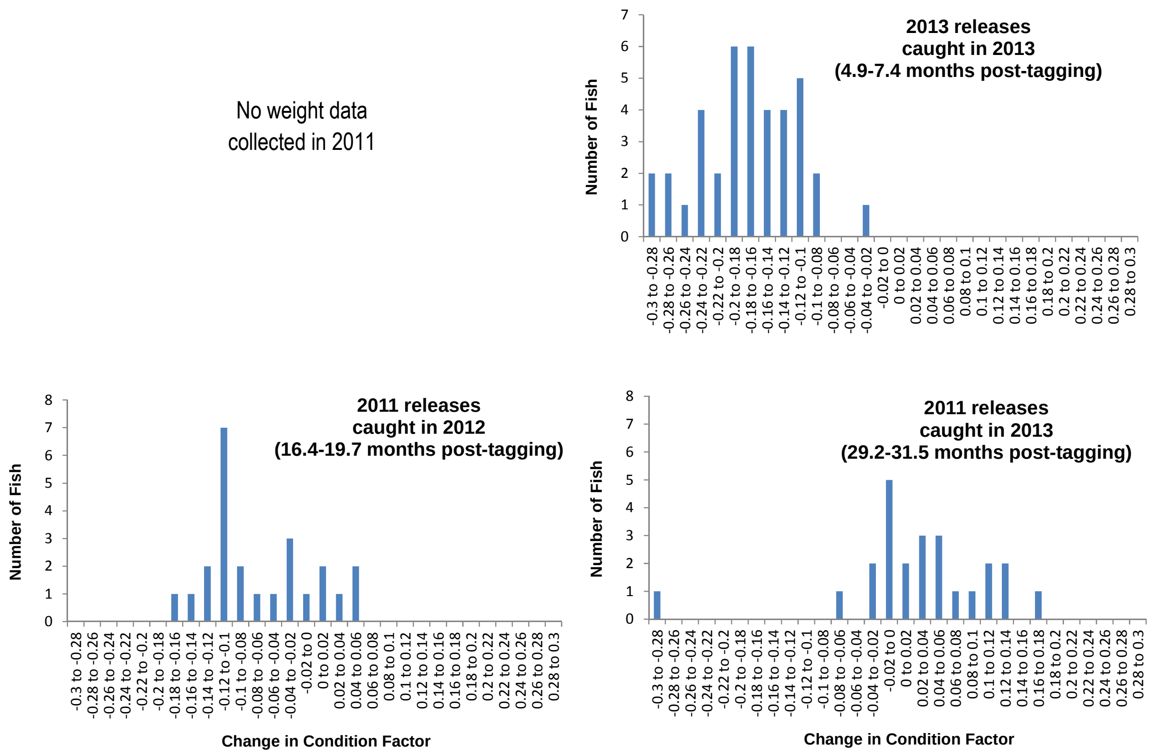


Figure 15. Change in condition factor between tagging and recapture for white sturgeon that were PIT tagged by Chelan PUD. Data are presented separately for each release cohort and survey year. Weight was not measured at recapture in 2011. Weight at the time of tagging was not recorded for every individual fish.

Habitat Associations

During the systematic portion of the indexing survey, 166 setlines were deployed. Of these, five were excluded from habitat association analyses due to missing data (three had no *DO* values, and two were missing *Velocity* values). A further 19 setlines had no substrate data. Given the relatively large number of setlines without substrate data, it was decided to run the analyses two ways: once including the *Dominant Substrate* term (thus, excluding the 19 setlines, n=142), and once without substrate data (including the 19 setlines, n =161).

Habitat association models with *CPUE* as the dependent variable would not resolve. As a result, all models had *Catch* (counts) as the dependent variable, and included effort (*Hook Hours*) as a predictor term. All models were run with a Poisson-distributed error structure, and no residual deviances suggested overdispersion.

During the systematic portion of the indexing survey, four sturgeon released in 2011 were captured, which was too few to allow models to resolve. All results presented below are from models with catch of sturgeon released in 2013 as the dependent variable (49 were caught in all).

During the systematic portion of the indexing survey, *Turbidity* values did not vary widely among sets, and caused singularity errors in the model runs, hence term was excluded from subsequent modelling exercises. Also, *Hook Type* was excluded since no circle hooks were deployed during the systematic portion of the indexing survey.

Starting with a saturated model that excluded *Dominant Substrate*, stepwise AIC selection produced a model that included *Zone*, *Session*, the *Zone* × *Session* interaction, *DO*, *Velocity*, and *Hook Hours* as factors (i.e., *Temperature*, *Depth*, and *Depth Profile* were not important factors; Table 10). Any further removal of factors produced models with significantly poorer fit than the saturated model. The catches (of the 2013 cohort) predicted from the model were highly correlated with the observed values (approximate $R^2 = 0.63$). Model coefficients showed that *Catch* decreased with increasing *DO* and *Velocity*, and *Catch* increased with increasing *Hook Hours*. Catches were highest in the Upper Zone (Wells Dam tailrace to Beebe Bridge), but only in Indexing Sessions One and Two. Catches in the Mid-North Zone (Beebe Bridge to Orondo) were higher during Indexing Session One, as compared to later sessions (Figure 16).

Table 10. Coefficients for a model built from catch data from 161 setlines with complete habitat information, but for which substrate data were not considered. Coefficients that were significantly different from zero were marked with an asterisk.

Coefficients:	Estimate (Log Link)	Std. Error	z value	Pr(>|z|)	
Intercept	29.15	16.7	1.750	0.080	
Zone 2 (Mid-N)	-1.14	1.1	-1.057	0.290	
Zone 3 (Mid-S)	-20.80	4282.0	-0.005	0.996	
Zone 4 (Lower)	-21.35	4005.0	-0.005	0.996	
Session 2	-0.87	1.2	-0.737	0.461	
Session 3	-21.75	3911.0	-0.006	0.996	
DO	-3.67	1.9	-1.968	0.049	*
Velocity	-1.94	0.9	-2.206	0.027	*
Hook Hours	0.00	0.0	3.434	0.001	*
Zone 2 (Mid-N) - Session 2	-1.45	1.3	-1.112	0.266	
Zone 3 (Mid-S) - Session 2	18.55	4282.0	0.004	0.997	
Zone 4 (Lower) - Session 2	17.82	4005.0	0.004	0.996	
Zone 2 (Mid-N) - Session 3	18.81	3911.0	0.005	0.996	
Zone 3 (Mid-S) - Session 3	20.48	7045.0	0.003	0.998	
Zone 4 (Lower) - Session 3	38.26	5598.0	0.007	0.995	

Starting with a saturated model that included *Dominant Substrate*, stepwise AIC selection produced a model that included *Zone*, *Session*, *Velocity*, and *Hook Hours* as factors (i.e., *Dominant Substrate*, the *Zone* × *Session* interaction, *DO*, *Temperature*, *Depth*, and *Depth Profile* were not important factors; Table 11). Any further removal of factors produced models with significantly poorer fit than the saturated model. The catches (of the 2013 cohort) predicted from the model were highly correlated with the observed values (approximate R^2 = 0.72). Model coefficients showed that *Catch* decreased with increasing *Velocity*, and *Catch* increased with increasing *Hook Hours*. Catches were highest in the Upper Zone (Wells Dam tailrace to Beebe Bridge), especially during Indexing Session Two (Figure 17).

Table 11. Coefficients for a model built from catch data from 142 setlines with complete substrate information). Coefficients that were significantly different from zero were marked with an asterisk.

Coefficients:	Estimate (Log Link)	Std. Error	z value	Pr(>|z|)	
Intercept	-6.62	2.4	-2.743	0.006	*
Zone 2 (Mid-N)	-0.45	0.7	-0.685	0.494	
Zone 3 (Mid-S)	-2.02	1.1	-1.835	0.067	
Zone 4 (Lower)	-2.37	0.8	-2.991	0.003	*
Session 2	1.13	0.5	2.104	0.035	*
Session 3	-1.02	0.8	-1.321	0.186	
Velocity	-3.13	1.0	-3.051	0.002	*
Hook Hours	0.00	0.0	3.141	0.002	*

Apparent Survival Estimation

Analysis of survival was restricted to fish that were PIT tagged as part of the 2011 Chelan PUD hatchery supplementation releases. Recapture events were grouped into three protracted ‘surveys’. Included in the first survey were 55 fish that were recaptured in northern pikeminnow gear between 15 July and 30 September 2011 (i.e., they were in the Reservoir between 2.8 and 5.4 months after they were originally released). Included in the second survey were 83 fish that were recaptured between 29 July and 27 October 2012 (i.e., they were in the Reservoir between 15.2 and 18.3 months after release). The 83 fish included 64 that were recaptured in northern pikeminnow gear between 29 July and 9 October 2012, and 19 additional fish captured only during acoustic tagging efforts between 10 September and 27 October 2012. Included in the third survey were 96 fish that were recaptured in the formal indexing study between 19 August and 23 October 2013 (i.e., they were in the Reservoir between 28.0 and 30.1 months after they were originally released).

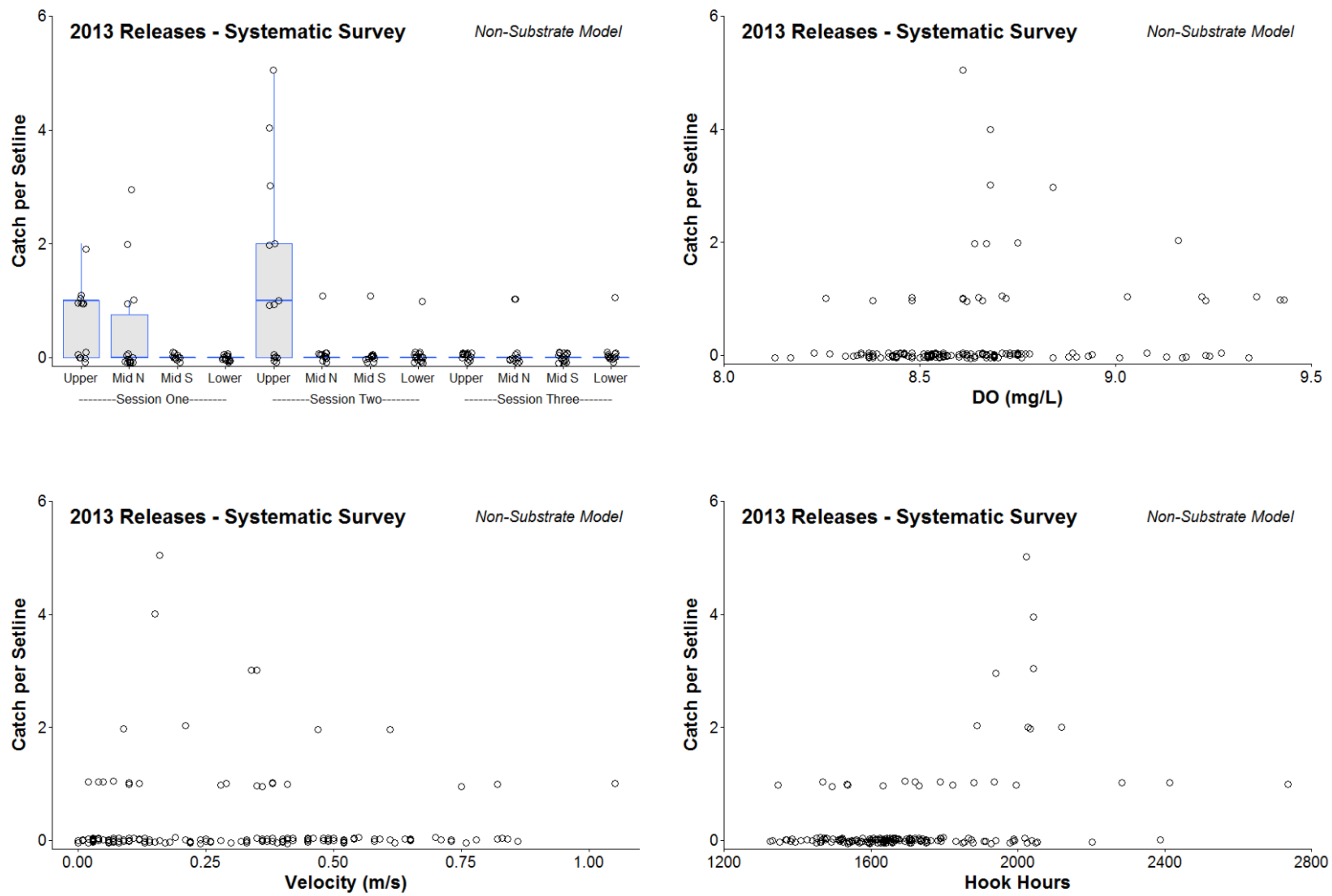


Figure 16. **Catch of 2013 sturgeon during the systematic portion of the indexing survey, plotted against various habitat variables (*Zone* and *Session*, *DO*, *Velocity*, and *Hook Hours*). A small random value was added to the Y values of all data points ('jittering'), all plotted values would otherwise have been integers, to help reveal where points would have otherwise overlapped. The plotted positions were also jittered along the X-axis in the top left panel. Boxes extend from the 25th to the 75th percentiles. Model built from catch data from 161 setlines (i.e., substrate information was not included in the initial model).**

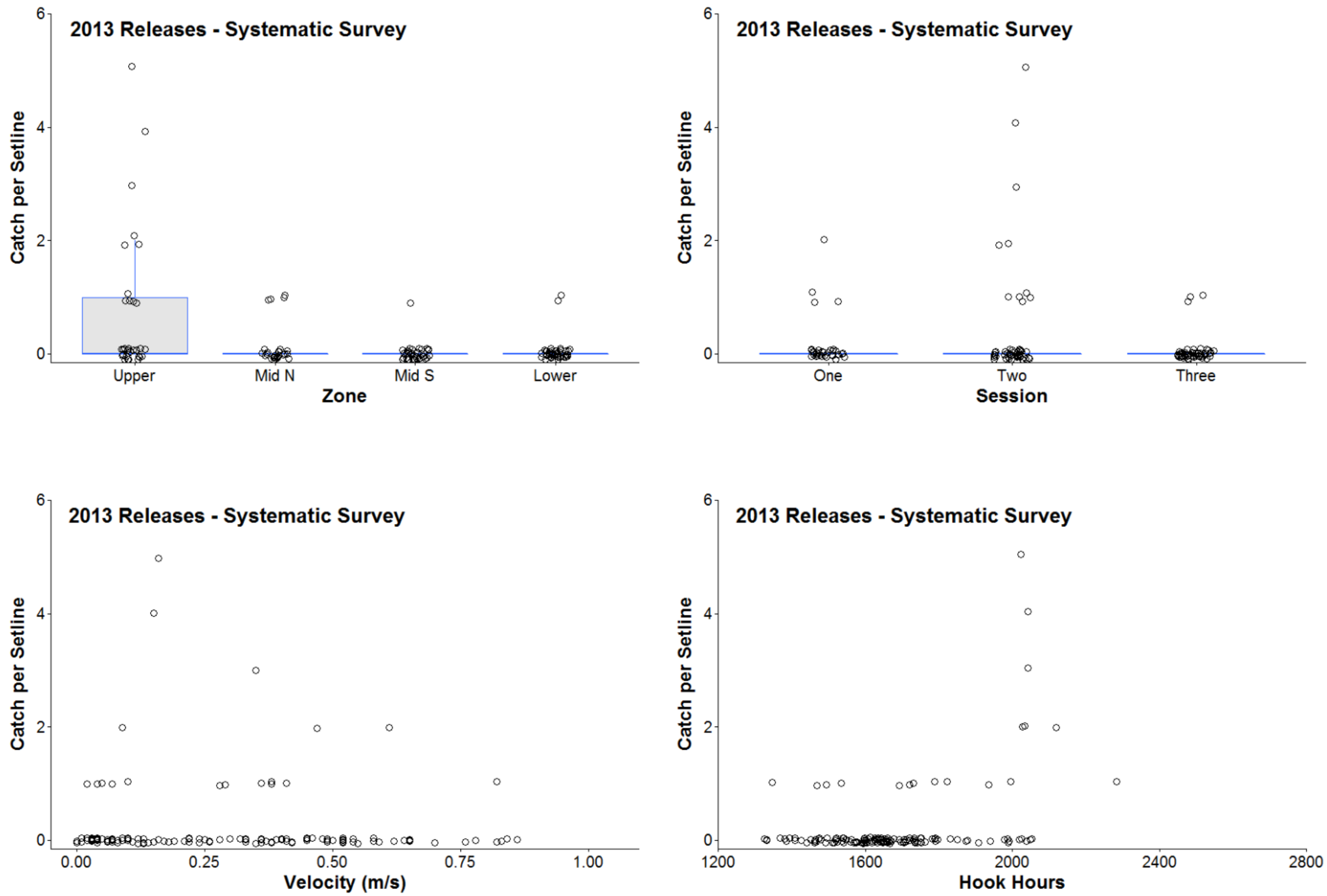


Figure 17. Catch of 2013 sturgeon during the systematic portion of the indexing survey, plotted against various habitat variables (*Zone*, *Session*, *Velocity*, and *Hook Hours*). A small random value was added to the Y values of all data points ('jittering'), all plotted values would otherwise have been integers, to help reveal where points would have otherwise overlapped. The plotted positions were also jittered along the X-axis in the two top panels. Boxes extend from the 25th to the 75th percentiles. Model built from catch data from 142 setlines (i.e., including only those setlines with complete substrate information).

Since CJS models require two surveys 'post release' to be able to distinguish the effects of survival from detection probability, the data available allowed us to estimate the survival of fish released in 2011 for the first 2.8-5.4 months after release ($\Phi_{R-0.5}$, called 'survival for the first half year'), and for the period from 2.8-5.4 months to 15.2-18.3 months ($\Phi_{0.5-1.5}$, called 'survival from year 0.5 to 1.5'). In addition, the probability of detection during the 2011 and 2012 surveys were estimated (p_{2011} and p_{2012}, respectively).

Having fish recaptured in multiple years was a minimum criterion for survival calculation. No fish were caught in all three surveys. However, five fish were recaptured in both 2011 and 2012, two fish were caught in both in 2011 and 2013, and ten fish were caught in both 2012 and 2013 (Table 12). All the multi-year recaptures were progeny of wild-origin broodstock (Table 12). Given the recapture rates, it was not possible to independently estimate survival for Marion Drain fish or for those from captive broodstock, or any combination thereof. Therefore, it was not possible to resolve differences between rearing locations (Marion Drain vs. Chelan Falls) or between parental origins (wild-origin vs. captive broodstock).

The detection history data (Table 12) were fit to four CJS survival models for: 1) all 2011 fish combined; 2) fish reared at Chelan Falls; and 3) fish that were progeny of wild-origin broodstock. Model Fitting results are shown in Table 13.

Table 12. The number of fish in each population by detection history.

	Years in which Fish were Recaptured						
Population	2011 & '12	2011 & '13	2012 & '13	2011 only	2012 only	2013 only	none
All 2011 Releases	5	2	10	48	68	84	6159
Rearing Location							
Marion Drain Hatchery	0	0	5	10	24	25	3477
Chelan Falls Hatchery	5	2	5	38	44	59	2682
Parental Origin							
Wild-origin Broodstock	5	2	10	48	67	81	3633
Captive Broodstock	0	0	0	0	1	3	2526
Location × Origin							
Marion Drain × Wild-origin Broodstock	0	0	5	10	23	24	1905
Marion Drain × Captive Broodstock	0	0	0	0	1	1	1572
Chelan Falls × Wild-origin Broodstock	5	2	5	38	44	57	1728
Chelan Falls × Captive Broodstock	0	0	0	0	0	2	954

Table 13. Model-fitting results for four CJS models, for hatchery-reared juvenile white sturgeon released in 2011. Separate analyses were performed for all fish, fish reared at Chelan Falls Hatchery, and fish with wild-caught parents.

Population/ Model	# of params	AICc	ΔAICc	AICc Weight	-2 log Likelihood
All 2011 Releases					
$\Phi_{.}\ p_{time}$	4	2486.2	0.0	0.536	2478.2
$\Phi_{time}\ p_{time}$	5	2486.5	0.3	0.461	2476.5
$\Phi_{time}\ p_{.}$	3	2496.6	10.3	0.003	2490.6
$\Phi_{.}\ p_{.}$	1	2528.0	41.8	0.000	2526.0
Total Support for Φ_{time}				0.464	
Total Support for p_{time}				0.997	
Rearing Location = Chelan Falls					
$\Phi_{time}\ p_{time}$	5	1617.5	0.0	0.465	1607.5
$\Phi_{.}\ p_{time}$	4	1617.9	0.4	0.391	1609.9
$\Phi_{time}\ p_{.}$	4	1619.9	2.4	0.144	1611.9
$\Phi_{.}\ p_{.}$	2	1631.8	14.3	0.000	1627.8
Total Support for Φ_{time}				0.609	
Total Support for p_{time}				0.856	
Parental Origin = Wild-origin Broodstock					
$\Phi_{.}\ p_{time}$	4	2229.9	0.0	0.678	2221.9
$\Phi_{time}\ p_{time}$	5	2231.4	1.5	0.321	2221.4
$\Phi_{time}\ p_{.}$	4	2242.1	12.2	0.002	2234.1
$\Phi_{.}\ p_{.}$	2	2260.4	30.5	0.000	2256.4
Total Support for Φ_{time}				0.322	
Total Support for p_{time}				0.998	

For all 2011 fish combined (n=6,376), the most parsimonious model was $\Phi_{.}\ p_{time}$ (constant survival; detection probability varied between surveys; Table 13). However, the AICc for that and the next most probable model ($\Phi_{time}\ p_{time}$) differed by less than 2 (ΔAICc = 0.3), indicating that both models have approximately equal weight in the data (and a Likelihood Ratio Test confirmed no significant difference between these models: $\chi^2 = 1.7$, df = 1; $P = 0.193$). Although there was considerable model uncertainty, the sum of the AICc weights for models that included p_{time} was 0.997, indicating strong support for variable detection probability between surveys. In contrast, the support for Φ_{time} was only 0.464, suggesting that survival from 'release to year 0.5' did not differ greatly from the 'year 0.5 to 1.5' survival rate. The results were very similar when analyses were restricted to the progeny of wild-origin broodstock (n=3,846; Table 13). When analyses were restricted to fish reared at Chelan Falls (n=2,835), the most parsimonious model was Φ_{time} p_{time} (survival and detection probability varied over time; Table 13). Again, the ΔAICc for the next most probable model ($\Phi.$ p_{time}) differed by less than 2 (ΔAICc = 0.4), providing little support for a real difference between these two models (Likelihood Ratio Test: $\chi^2 = 2.4$, df = 1; $P = 0.125$). Overall support for p_{time} was 0.856, and that for Φ_{time} was only 0.609.

The model that allowed apparent survival (Φ) to vary over time indicated that for all fish released by Chelan PUD in 2011, survival from 'release to year 0.5' ($\Phi_{R\text{-}0.5}$) was 20.8%, and that from 'year 0.5 to 1.5' ($\Phi_{0.5\text{-}1.5}$) was 60.0% (Table 14). However, the standard error of the $\Phi_{0.5\text{-}1.5}$ estimate was large (i.e., 27%), indicating that there was considerable uncertainty associated with the estimate. Moreover, the overall support for models including the Φ_{time} parameter was relatively low (0.464; Table 13), which lends further uncertainty to the individual-year survival estimates. Therefore, model uncertainty was taken into account by calculating a weighted average of the parameter estimates (i.e., weighting the estimates by the AICc weight), thus producing 'model average' survival estimates of 27.6% (SE=5.6%) for $\Phi_{R\text{-}0.5}$, and 45.9% (SE=14.6%) for $\Phi_{0.5\text{-}1.5}$ (Table 14). The model averaged survival estimates for fish reared at Chelan Falls were 33.3% (SE=7.9%) for $\Phi_{R\text{-}0.5}$, and 76.7% (SE=26.6%) for $\Phi_{0.5\text{-}1.5}$ (Table 14). Equivalent estimates for the progeny of wild-origin broodstock were of 40.1% (SE=7.5%) for $\Phi_{R\text{-}0.5}$, and 48.2% (SE=12.1%) for $\Phi_{0.5\text{-}1.5}$ (Table 14).

All analyses indicated strong support (0.856 to 0.998) for a difference between 2011 and 2012 in detection probability. For all fish released by Chelan in 2011, the probability of detection in 2011 and 2012 was 3.3% (SE=1.0%) and 11.0% (SE=3.1%), respectively (Table 14). For fish reared at Chelan Falls, p_{2011} and p_{2012} were 5.3% (SE=1.6%) and 8.3% (SE=3.1%), respectively (Table 14). For progeny of wild-origin broodstock, p_{2011} was 3.6% (SE=0.9%) and p_{2012} was 11.2% (SE=3.2%; Table 14).

True Survival Estimation

The survival models described above do not explicitly allow for emigration. Thus 'true' survival rates were calculated from apparent survival rates by accounting for emigration rates. The best available estimate of the emigration rate (i.e., that from active tracking results) was 4.8%. If 4.8% of the PIT-tagged population were not available for recapture because of emigration, then the numbers of fish in the rightmost column of Table 12 are too high. Reducing these values by 4.8% produces the true survival estimates shown in Table 15. The 'model averaged' $S_{R\text{-}0.5}$ estimate for fish released in 2011 increased to 28.8% (SE=5.7%); that for fish reared at Chelan Falls increased to 35.0% (SE=8.3%); and for progeny of wild-origin broodstock, $S_{R\text{-}0.5}$ increased to 41.5% (SE=7.7%).

Table 14. Apparent CJS survival estimates and detection probabilities of hatchery-reared juvenile white sturgeon, released in 2011. $\Phi_{R\text{-}0.5}$ is the probability of survival from release until the first survey (Summer 2011), 2.8-5.4 months post-release. $\Phi_{0.5\text{-}1.5}$ is the probability of survival from the first until the second survey (Summer 2012), which was 16.5-19.7 months post-release. The parameters p_{2011} and p_{2012} refer to the probability of being captured in setlines during northern pikeminnow removal efforts in 2011 and 2012, respectively. Standard errors of each of the parameter estimates are also shown. Separate analyses were performed for all fish, fish reared at Chelan Falls Hatchery, and fish with wild-caught parents.[2]

	$\Phi_{R\text{-}0.5}$		$\Phi_{0.5\text{-}1.5}$		p_{2011}		p_{2012}	
Population/ Model	**Estimate**	**SE**	**Estimate**	**SE**	**Estimate**	**SE**	**Estimate**	**SE**
All 2011 Releases								
$\Phi_{.}\ p_{time}$	0.335	0.042	0.335	0.042	0.026	0.005	0.116	0.031
$\Phi_{time}\ p_{time}$	0.208	0.072	0.600 †	0.268	0.041	0.015	0.104	0.031
$\Phi_{time}\ p_{.}$	0.164	0.036	1.000 *	0.000	0.074	0.017	0.074	0.017
$\Phi_{.}\ p_{.}$	1.000 *	0.000	1.000 *	0.000	0.012	0.001	0.012	0.001
Averaged	0.276	0.056	0.459	0.146	0.033	0.010	0.110	0.031
Rearing Location = Chelan Falls								
$\Phi_{time}\ p_{time}$	0.261	0.088	0.964 †	0.511	0.061	0.022	0.076	0.033
$\Phi_{.}\ p_{time}$	0.446	0.073	0.446	0.073	0.036	0.008	0.096	0.034
$\Phi_{time}\ p_{.}$	0.260	0.068	1.000 *	0.000	0.075	0.020	0.075	0.020
$\Phi_{.}\ p_{.}$	1.000 *	0.000	1.000 *	0.000	0.019	0.001	0.019	0.001
Averaged	0.333	0.079	0.767	0.266	0.053	0.016	0.083	0.031
Parental Origin = Wild-origin Broodstock								
$\Phi_{.}\ p_{time}$	0.431	0.055	0.431	0.055	0.033	0.006	0.115	0.031
$\Phi_{time}\ p_{time}$	0.337	0.117	0.588 †	0.262	0.042	0.016	0.108	0.032
$\Phi_{time}\ p_{.}$	0.263	0.058	1.000 *	0.000	0.076	0.017	0.076	0.017
$\Phi_{.}\ p_{.}$	1.000 *	0.000	1.000 *	0.000	0.020	0.001	0.020	0.001
Averaged	0.401	0.075	0.482	0.121	0.036	0.009	0.112	0.032

[2] Asterisks indicate that a model failed to solve for a parameter; and † indicates that an estimate is a poorly resolved.

Table 15. True CJS survival estimates and detection probabilities of hatchery-reared juvenile white sturgeon, released in 2011, assuming a 4.8% emigration rate.[3] See Table 13 for other details.

Population/ Model	$S_{R-0.5}$ Estimate	$S_{R-0.5}$ SE	$S_{0.5-1.5}$ Estimate	$S_{0.5-1.5}$ SE	p_{2011} Estimate	p_{2011} SE	p_{2012} Estimate	p_{2012} SE
All 2011 Releases								
$S.\ p_{time}$	0.344	0.043	0.344	0.043	0.026	0.005	0.116	0.031
$S_{time}\ p_{time}$	0.219	0.076	0.600 †	0.268	0.041	0.015	0.104	0.031
$S_{time}\ p.$	0.172	0.038	1.000 *	0.000	0.074	0.017	0.074	0.017
S. p.	1.000 *	0.000	1.000 *	0.000	0.013	0.001	0.013	0.001
Averaged	0.288	0.057	0.458	0.143	0.033	0.010	0.110	0.031
Rearing Location = Chelan Falls								
$S_{time}\ p_{time}$	0.274	0.093	0.964 †	0.511	0.061	0.022	0.076	0.033
$S.\ p_{time}$	0.458	0.075	0.458	0.075	0.036	0.008	0.095	0.033
$S_{time}\ p.$	0.273	0.072	1.000 *	0.000	0.075	0.020	0.075	0.020
S. p.	1.000 *	0.000	1.000 *	0.000	0.020	0.002	0.020	0.002
Averaged	0.350	0.083	0.762	0.261	0.053	0.016	0.084	0.031
Parental Origin = Wild-origin Broodstock								
$S.\ p_{time}$	0.443	0.057	0.443	0.057	0.034	0.006	0.114	0.031
$S_{time}\ p_{time}$	0.354	0.123	0.588 †	0.262	0.042	0.016	0.108	0.032
$S_{time}\ p.$	0.276	0.061	1.000 *	0.000	0.076	0.017	0.076	0.017
S. p.	1.000 *	0.000	1.000 *	0.000	0.021	0.001	0.021	0.001
Averaged	0.415	0.077	0.489	0.121	0.037	0.009	0.112	0.032

[3] Asterisks indicate that a model failed to solve for a parameter; and † indicates that an estimate is a poorly resolved.

Mortality

To date, two mortality events have been confirmed for the white sturgeon that were released in 2011 (Table 16). The PIT tags for both of these fish were recovered on Badger Island, a known American white pelican (*Pelecanus erythrorhynchos*) colony in the McNary National Wildlife Refuge (RM 318). One tag was recovered on 28 September 2011 and the other on 24 September 2012. These fish have no other detection information, thus the locations and timing of the predation events are unknown.

Table 16. Details on confirmed mortality events of PIT tags recovered on Badger Island American White Pelican breeding colony.

PIT ID	Release Date	Recovery Site	Recovery Date	Rearing Location	Parental Origin
3D9.1C2D89AF3E	4/20/2011	Badger Island	9/28/2011	Marion Drain	Wild-Origin
3D9.1C2D8E9506	4/20/2011	Badger Island	9/24/2012	Marion Drain	Captive

Discussion

Acoustic Telemetry

Sturgeon tagged with acoustic transmitters exhibited movements following release, predominantly in an upstream direction. Large numbers of both the 2012 fish recaptured in the upper Reservoir, tagged and released downstream, as well as the lower Reservoir hatchery releases from 2013 exhibited considerable upstream movement in the months following release. In all, 53% (31 of 59) of the acoustic-tagged sturgeon released in locations below Beebe Bridge moved upstream into the upper quarter of the Reservoir and have remained to date. This upper Reservoir is also where, regardless of release location, acoustic-tagged sturgeon had the majority of detections and the longest residence times. The indexing fishing effort specifically catch of 2013 released fish corroborates high use of this area with the highest proportion of catch compared with other zones (Table 8, Figure 10). The upper Reservoir is characterized by the highest flows and most riverine-like conditions in the reach; the high use of this area suggests it may contain preferred habitat types and/or alimental conditions. This contrasts with the habitat-use data collected during the indexing effort which showed a preference for low velocities. This difference may signify that areas with combined higher flows (food or prey movement) and lower velocity (low energy use, i.e., eddies or deep pools just outside the current), could be important habitat types for juvenile sturgeon and this habitat preference and has been seen in similar studies (RL&L 1994). Other studies in the upper-middle Columbia (Golder 2010) have shown a preference for deep lower velocity and less riverine conditions, however it is most likely that the available habitat types differ between these study areas and a direct comparison of actual velocities and depths would account for discrepancies. When comparing release locations, there was increased mean upstream movement and mean total movement for the farthest downstream release sites (Table 6). The lower areas of the Reservoir are characterized by relatively lower velocity, more reservoir-like conditions. Lepla and Chandler (1995) hypothesized that sturgeon in lower velocity (reservoir-like) environments need to move more to actively search for food when compared to sturgeon residing in more riverine environments, where food is more likely to be actively transported into areas of residence. This could explain the increase in movements in lower-Reservoir-released fish, some moving all the way to the more riverine upper Reservoir (which seems to be a preferred habitat).

Movement of more than 10 km was exhibited by 62% (64 of 104) of the acoustic-tagged sturgeon, with 13% (14 of 104) of these fish moving more than 64 km, or approximately equal to or greater than the length of the Reservoir. The amount of movement following release generally decreased over time for both years of fish released, 2012 and 2013. The sturgeon released in 2012, following movement in the few months post release, showed little to no movements in the winter months: a well-established behavior in sturgeon (Haynes et al. 1978, Golder 2003, Howell and McLellan 2007). This dearth of movement of the 2012-released fish continued well into 2013 with almost no movement until August and September, when the three 2012 fish that moved more than 3 km in 2013 moved above the Wells Dam tailrace array in August and September. Two of these three fish moved back downstream within a couple of months in September and October. The paucity of movements in 2013 of the 2012-tagged population, along with a steadily decreasing number of 2013-released fish moving over time, seems to indicate that, once suitable conditions (i.e., habitat, alimental, environmental) are found, there is a settling behavior. This has been observed in other studies of juvenile movements (Golder 2010). The slight increase in late summer and fall movements in the year after release could potentially be a seasonal response, likely due to decreasing discharge (Figure 2), though food availability or other environmental conditions could be a factor. The behavior of the 65 fish released in 2013, when detected in 2014 should provide further insights into seasonal movement patterns.

The total amount of data from depth sensor tags increased substantially over 2013, however the vast majority (85%) was from one fish (ID 8013) that resided near the Wells Tailrace array for 241 days (Appendix C.) This fish exhibited definite diel patterns as well as what seem to be seasonal patterns of behavior, similar to what was seen in adult sturgeon by Parsley et al. (2008). Following limited movements between depths in late winter (Figure 6, b) this sturgeon showed regular diel depth movements between deep areas during day and shallow areas at night during the spring and summer (Figure 6, c). Within the diel patterns of ID 8013, there was seasonal or periodic variation. For example, early in the spring this sturgeon was fairly stationary and deep during the day but showed constant movement throughout a 5-10 m depth band during the night, likely foraging. Later in the summer, the same diel depth preferences were shown, however both the daytime and nighttime depth zones showed constant movements within a ~5 m depth band, indicating constant movement over multiple days at a time. These differences could be attributed to changes in alimental conditions or associated with water temperatures or other environmental factors. The other nine sensor-tagged fish spent less than eight days near receivers, seven of the nine spent less than a single day of residence near a receiver. These remaining fish showed depth use that varied among them and among detection arrays, likely related to bathymetry available around each location. The mean and median depths of all 10 sensor-tagged fish (including and excluding ID 8013) were ~15-16 m, suggesting a preference for deeper residence.

Emigration

Because of the low detection efficiency of PIT tags at hydropower projects, especially for bottom-oriented juvenile sturgeon, one of the primary objectives of acoustic tagging was to measure emigration rates from the Reservoir. To date 5 of 104 (4.8%) sturgeon acoustic-tagged during this study (2 of 35 (5.7%) in 2012, 3 of 69 (4.3%) in 2013) have been detected emigrating out of the Reservoir, moving below Rocky Reach Dam. Only one of these emigrations happened quickly following release, when ID 28075 was detected below Rocky Reach Dam within two days of release at Entiat. The other four emigrations happened in the fall, three to four weeks after tagging for the 2012 released fish, and four to five months post release for the 2013 fish. With the exception of the Entiat-released fish, which quickly left the Reservoir, the remaining fish were either released in the upper Reservoir or traveled to the upper Reservoir prior to emigration, suggesting that release location was not a factor in emigration fate.

The increase in downstream movements of tagged sturgeon during the fall months regardless of emigration fate, combined with these examples of fall emigrations out of the Reservoir, could suggest that emigration events, rather than random movements, my result from seasonal volitional movements. These fall movements could be in response to the low discharge and high temperatures of this period encouraging exploration, searching for overwintering habitat, or moving in response to food availability. When fish begin downstream movements they move steadily until stopping varying distances downstream. Regardless of the trigger, fish that emigrate may just be redistributing farther than others in the population, which results in leaving the Reservoir. Battery life of 74 of the currently active tags will last at least through the fall of 2014 which, along with additional releases in 2014, should provide additional evidence of the number, timing, and nature of emigration events.

Survival Estimation

All analyses indicated strong support (85.6% to 99.8%) for a difference between 2011 and 2012 in detection probability. In all cases, the 2011 detection probability estimates were lower (range: 3.3% to 5.3%) than those for 2012 (8.3% to 11.2%). Encounters in 2011 were recorded only during pikeminnow removal efforts. Those in 2012 were made during pikeminnow efforts, *and* during attempts to capture for acoustic tagging. While there was more effort in 2012, it is also possible that some of the increase in detectability could have been the result of the sturgeon recruiting more fully to the setline gear. Further data will be required to assess ontogenic shifts in sturgeon setline catchability. Nevertheless, sturgeon released in 2011, which were regularly caught in 2011 and 2012 with crickets on treble hooks, and which had relatively poor catch rates on this gear in 2013, were caught significantly more frequently in 2013 on circle hooks with squid. This result suggests an ontogenic shift in setline catchability, except that sturgeon released in 2013 were also caught more effectively on circle hooks with squid. Thus, the recent decline in catch of 2011 fish on the traditional hook type may be related to other unknown factors.

In this report we generated two post-release survival estimates for juvenile hatchery sturgeon released in April 2011. The estimate of apparent survival from 'release to year 0.5' ($\Phi_{R\text{-}0.5}$) was 27.6% overall, 33.3% for fish reared at the Chelan Falls Hatchery, and 40.1% for fish from wild-origin parents. In comparable juvenile sturgeon survival studies, conducted from 2002 to 2006 in the Upper Columbia River, survival in the first half-year post-release was between 27% and 29% (Golder Associates 2009). Further investigations on the 2011 cohort may yield additional insights, but results to date indicate that progeny of wild-origin broodstock reared at Chelan Hatchery have outperformed other juveniles in the first half-year post-release. Note that the sturgeon released in the 2013 cohort were not derived from the same sources as the 2011 releases, thus the newer release cohorts will not provide additional information on the effects of rearing location and parental origin.

In the Golder Associates (2009) study, hatchery sturgeon had the highest mortality rates soon after release, after which survival probability increased substantially. After the first half-year at large, sturgeon survival in the Upper Columbia River basin was consistently between 84% and 90% per year (Golder Associates 2009). Initial results indicate that $\Phi_{0.5\text{-}1.5}$ survival of the 2011 cohort in the Rocky Reach Reservoir (45.9% overall) was not as high as that seen elsewhere. However, $\Phi_{0.5\text{-}1.5}$ survival of the fish reared at Chelan Falls was 76.7%, indicating that conditions may be fine for survival, if the correct hatchery and broodstock can be found. Our planned indexing surveys will provide additional late-summer recapture opportunities in 2014, and 2015. With these surveys and the data in hand, we should be able to generate 2 additional survival estimates for the 2011 cohort (survival from 1.5 to 2.5 years at large; and that from 2.5 to 3.5 years at large). Similarly, our methods will allow estimation of the $\Phi_{0.5\text{-}1.5}$ survival for the sturgeon released in 2013.

Note that our survival estimates may have been biased (too low) as a result of being based only on incidental sturgeon recapture data collected during northern pikeminnow removal efforts in 2011 and 2012 (catches during the 2013 indexing study served to produce estimates of 2012 detection probability, rather than contribute to survival rate estimation, *per se*). If the hatchery sturgeon moved little during the fishing period, or if some fish were resident in areas where little northern pikeminnow fishing occurred, they would have ‘appeared dead’ to the survival model (the model assumes that there was an equal probability of recapture for all individuals), thus resulting in an underestimated survival value. The formal annual indexing surveys scheduled to continue into 2015 will not simply target areas of known catch rate, but they will include a systematic/random component to ensure that a variety of habitats are sampled throughout the Reservoir. Thus, the $\Phi_{0.5\text{-}1.5}$ survival estimate for the sturgeon released in 2013 should not suffer from the same bias as that potentially affecting the 2011 cohort, nor will the $\Phi_{1.5\text{-}2.5}$ and $\Phi_{2.5\text{-}3.5}$ survival estimates for the 2011 fish.

The survival model assumes that fish did not lose their marks during the study period, and that all marks were detectable and recorded on recovery. In 2013, 25 fish were recaptured without functional PIT tags, indicating an approximate ‘shed/failure’ rate of 5%. In our study, these 25 recapture events were censored from the survival analysis. Assuming that the probability of shedding a tag was equal for all fish, then our estimates of detection probability are probably unbiased, but apparent survival may have been underestimated. Biases could also result if shedding rates vary among years.

Justice et al. (2009) found evidence of density- and size-dependent mortality of age 1 hatchery-reared juvenile sturgeon in the Kootenai River. In the Reservoir, density-dependent mortality is not likely a critical factor as the supplementation program is in its infancy, and the overall abundance of sturgeon is not yet expected to be approaching the carrying capacity. However, size-dependent effects may have impacted survival for Chelan PUD releases. The survival-at-length curves for hatchery reared Kootenai fish presented in Justice et al. (2009) show a general increase in survival with size-at-release. Moreover, the average size of Chelan PUD's 2011 supplementation fish (243 mm) fell onto curves that predicted lower-than-average survival rates. It is possible that Reservoir survival of age 1 fish could be improved by releasing sturgeon of a larger size, though increased time in the hatchery environment may have negative consequences (increased risk of disease, etc.).

The survival estimates described above do not include any adjustment for emigration. Since sturgeon that emigrate from the study area are not available for recapture, they will appear to have died. As such, the estimates reported (ϕ) are equal to $S \cdot (1-E)$, where S is the 'true' survival and E is the probability of emigrating from the study area. Tracking data available to date, suggest a minimum 4.8% emigration rate. Using this value, we estimated true survival from 'release to year 0.5' ($S_{R\text{-}0.5}$) to be 28.8% overall, and that from 'year 0.5 to 1.5' ($S_{0.5\text{-}1.5}$) to be 54.8%. Emigration is not mentioned in Golder Associates (2009), so their reported rates ('year 0.5 to 1.5' = 27-29%; '0.5 to 1.5' = 84-90%) are presumably ϕ and not S. Regardless, mitigation population abundance goals will probably be calculated based apparent survival.

Growth

Growth in length rates of juvenile white sturgeon released in 2011, and recaptured in 2011, when extrapolated to 365 days, averaged 171 mm/year. That for juvenile sturgeon released and recaptured in 2013 was 233 mm/year. These rates are within the range reported for age 1 sturgeon in the Keenleyside and Roosevelt reaches (280 mm/year; n=326; Golder Associates 2009), in the middle Columbia River (143 mm/year; n=3; Golder Associates 2010), or in the Kootenay River (120 mm/year; n=52; Neufeld and Spence 2002). Over the next year, rates of growth in length slowed such that extrapolated growth rates of sturgeon released in 2011 and caught in 2012 and 2013, integrated over their entire time at large, averaged 61 and 88 mm/year, respectively. Again, these values were within the range of growth rates reported for age 2 sturgeon in the Keenleyside and Roosevelt reaches (160 mm/year; n=422; Golder Associates 2009) and in the middle Columbia River (54 mm/year; n=2; Golder Associates 2010). White sturgeon released in 2011 that were caught in the Reservoir in 2012 and 2013 gained 97 and 262 g/year (extrapolated), respectively. Literature values for age 2 hatchery-released sturgeon ranged wildly, with calculated mean values spanning from 37 g/year in the middle Columbia River (n=2, Golder Associates 2010) to 389 g/year in the Keenleyside and Roosevelt reaches (n=422, Golder Associates 2009).

Habitat Associations

Habitat association modelling based on the 2013 indexing study provided preliminary information with respect to the sturgeon released in 2013. Catches of the 2011 release group were too sparse during the systematic portion of the indexing survey to allow for analysis of their habitat associations. However, since catches of the 2011 release group were greatly increased after the field crews included circle-hooks baited with squid (these setlines were restricted to the 'targeted' portion of the survey), future surveys will be able to catch these fish, hence providing insights into their habitat associations.

For the fish released 2013, there appeared to be a trend for increased catch rates in the northern parts of the study area. Also, catch rates appeared to decline over time, with catches being highest in the first two sessions, and generally poorer in Indexing Session Three. Not surprisingly, there was a consistently positive effect of *Hook Hours*. Even with effort (*Hook Hours*), and with seasonal (*Session*) and spatial (*Zone*) effects included in the linear model, several habitat factors were nevertheless considered important explanatory variables. In both of the fitted models, *Catch* declined with increasing *Velocity*. At this time, it is not known whether this is a function of fish distribution or gear efficiency. In addition, the model that was run on the larger proportion of the setline data (i.e., that which ignored substrate data, and included 161 setlines in the analysis), showed that *Catch* declined with increasing *DO*. However, this effect was not observed when the model was re-run using a smaller portion of the dataset (that which included complete substrate data). Neither model showed any significant effect of *Temperature*, *Depth*, or *Depth Profile*, and the one analysis that included substrate data found no significant effect of it.

Our results, showing that catch declined with increasing velocity, agree with other studies in the Columbia and Kootenay rivers. For example, Golder (2006) found that juvenile sturgeon preferred velocities <0.5 m/s. Specifically, Golder (2006) found juvenile sturgeon in the Waneta eddy on the Columbia River (near Trail, BC) at an average velocity of 0.27 m/s (range: 0.08-0.55 m/s). In the Kootenai River, Young and Scarnecchia (2005) observed juvenile sturgeon at velocities ranging from 0-0.47 m/s. Howell and McLellan (2005) recorded highest catches of juveniles in low velocity areas (i.e., eddies), but no velocity values were provided.

Our results also showed that catch declined with increasing DO. However, this relationship changed from statistically significant to not significant, depending on the inclusion / exclusion of 19 setlines – indicating that the result is not robust. We have not seen other literature addressing DO as a factor of importance for juvenile white sturgeon.

Depth is frequently reported as a factor of interest in other juvenile white sturgeon studies in the Columbia and Kootenay rivers. Golder (2009) found that 84% of juveniles in the Columbia River (between Castlegar, BC and the US-Canada border) were caught between 15 and 19.9 m. Golder (2003) captured juveniles in the Rocky Reach reservoir between 8 and 28 m. In the Kootenay River, juvenile sturgeon have been captured at depths from 3 to 23 m (Young and Scarnecchia 2005), or from 9.1 to 27.4 m (Paramagian et al. 1999). By contrast, our habitat model outputs indicated that depth was a not an important factor affecting catch of the 2013 cohort of white sturgeon in the Rocky Reach Reservoir. Similarly, Howell and McLellan (2011) found that hatchery sturgeon in Lake Roosevelt were captured over most of the depths sampled, ranging from 6.6 to 51.4 m (mean=23.1).

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Appendices

APPENDIX A.

Details on Acoustic-Tagged Sturgeon

Table A - 1. Fish characteristics and transmitter details for all acoustic-tagged fish in 2012 and 2013.

Acoustic Tag Code	PIT ID	Fish Source	Brood Year	Tagging Location	Tag Type	Length (mm)	Weight (g)	Release Date/Time	Release	Release Site	Estimate Tag Failure Date
4603	3D9.1C2E0A6EDD	Hatchery	2011	Chelan Fish Hatchery	V7-2x	255	98.8	5/16/2012 14:20	BB03	Beebe Bridge	11/2/2012
4604	3D9.1C2E0A5DFA	Hatchery	2011	Chelan Fish Hatchery	V7-2x	279	139.6	5/16/2012 14:20	BB03	Beebe Bridge	11/2/2012
4605	3D9.1C2E0A87AC	Hatchery	2011	Chelan Fish Hatchery	V7-2x	245	103.9	5/16/2012 14:20	BB03	Beebe Bridge	11/2/2012
4606	3D9.1C2E0A6C1F	Hatchery	2011	Chelan Fish Hatchery	V7-2x	242	94.4	5/16/2012 14:20	BB03	Beebe Bridge	11/2/2012
4607	3D9.1C2E0A792C	Hatchery	2011	Chelan Fish Hatchery	V7-2x	205	57.4	5/16/2012 14:20	BB03	Beebe Bridge	11/2/2012
4608	3D9.1C2E0A3858	Hatchery	2011	Chelan Fish Hatchery	V7-2x	279	133.2	5/16/2012 14:20	BB03	Beebe Bridge	11/2/2012
4609	3D9.1C2DF7700A	Hatchery	2011	Chelan Fish Hatchery	V7-2x	250	109.7	5/16/2012 14:20	BB03	Beebe Bridge	11/2/2012
4610	3D9.1C2DF7CA31	Hatchery	2011	Chelan Fish Hatchery	V7-2x	245	101.1	5/16/2012 14:20	BB03	Beebe Bridge	11/2/2012
4611	3D9.1C2E0A91FB	Hatchery	2011	Chelan Fish Hatchery	V7-2x	225	72.8	5/16/2012 14:20	BB03	Beebe Bridge	11/2/2012
4612	3D9.1C2DF7E289	Hatchery	2011	Chelan Fish Hatchery	V7-2x	241	82.8	5/16/2012 14:20	BB03	Beebe Bridge	11/2/2012
29811	3D9.1C2D8B02F0	Recap	2010	Wells Tailrace Boat Launch	V9-2x	360	272	9/10/2012 17:45	WT01	Wells Dam Tailrace	12/27/2014
29812	3D9.1C2D8F1384	Recap	2010	Wells Tailrace Boat Launch	V9-2x	340	163.4	9/10/2012 17:45	WT01	Wells Dam Tailrace	12/27/2014
29813	3D9.1C2D89D292	Recap	2010	Wells Tailrace Boat Launch	V9-2x	315	161	9/10/2012 17:45	WT01	Wells Dam Tailrace	12/27/2014
8013	3D9.1C2DF7D29C	Recap	2010	Wells Tailrace Boat Launch	V9P-2x	395	356.5	9/10/2012 17:45	WT01	Wells Dam Tailrace	4/14/2014
29814	3D9.1C2D89F35F	Recap	2010	Chelan Falls Hatchery	V9-2x	355	255.5	9/11/2012 18:00	CF01	Chelan Falls Boat Launch	12/28/2014
29815	3D9.1C2D8CB8BE	Recap	2010	Chelan Falls Hatchery	V9-2x	315	191.5	9/11/2012 18:00	CF01	Chelan Falls Boat Launch	12/28/2014
29816	3D9.1C2D8F0504	Recap	2010	Chelan Falls Hatchery	V9-2x	365	237.8	9/11/2012 18:00	CF01	Chelan Falls Boat Launch	12/28/2014
8014	3D9.1C2D8AEEA4	Recap	2010	Chelan Falls Hatchery	V9P-2x	395	376.3	9/11/2012 18:00	CF01	Chelan Falls Boat Launch	4/15/2014
29820	3D9.1C2DF7C54D	Recap	2010	Chelan Falls Hatchery	V9-2x	345	216.5	9/12/2012 16:27	SC01	Sun Cove Boat Launch	12/29/2014
8016	3D9.1C2D89B262	Recap	2010	Chelan Falls Hatchery	V9P-2x	368	233.5	9/12/2012 16:27	SC01	Sun Cove Boat Launch	4/16/2014
8017	3D9.1C2D89BD1C	Recap	2010	Chelan Falls Hatchery	V9P-2x	405	337.4	9/12/2012 16:27	SC01	Sun Cove Boat Launch	4/16/2014

Acoustic Tag Code	PIT ID	Fish Source	Brood Year	Tagging Location	Tag Type	Length (mm)	Weight (g)	Release Date/Time	Release	Release Site	Estimate Tag Failure Date
29818	3D9.1C2D8F11AF	Recap	2010	Chelan Falls Hatchery	V9-2x	333	192.7	9/13/2012 17:34	DR01	Daroga Boat Launch	12/30/2014
8015	3D9.1C2D8B24A3	Recap	2010	Chelan Falls Hatchery	V9P-2x	373	266.5	9/13/2012 17:34	DR01	Daroga Boat Launch	4/17/2014
29538	3D9.1C2E0AB462	Recap	2011	Wells Tailrace Boat Launch	V9-2x	315	146	10/24/2012 12:45	WT02	Wells Tailrace	2/9/2015
29543	3D9.1C2D89DC11	Recap	2010	Wells Tailrace Boat Launch	V9-2x	321	155	10/24/2012 12:45	WT02	Wells Tailrace	2/9/2015
29819	3D9.1C2D8A034B	Recap	2010	Wells Tailrace Boat Launch	V9-2x	463	703	10/25/2012 13:24	WT03	Wells Tailrace	2/10/2015
29540	3D9.1C2D89C8A4	Recap	2010	Wells Tailrace Boat Launch	V9-2x	421	397	10/25/2012 15:37	CF02	Chelan Falls Boat Launch	2/10/2015
29539	3D9.1C2D8A00A2	Recap	2010	Wells Tailrace Boat Launch	V9-2x	450	564	10/26/2012 11:00	WT04	Wells Tailrace	2/11/2015
29545	3D9.1C2D89B21A	Recap	2010	Wells Tailrace Boat Launch	V9-2x	323	183	10/26/2012 11:00	WT04	Wells Tailrace	2/11/2015
29541	3D9.1C2D89C48A	Recap	2010	Wells Tailrace Boat Launch	V9-2x	410	411	10/26/2012 14:10	DR02	Daroga Boat Launch	2/11/2015
29544	3D9.1C2D89AC96	Recap	2010	Wells Tailrace Boat Launch	V9-2x	397	296	10/27/2012 13:23	WT05	Wells Tailrace	2/12/2015
29547	3D9.1C2D8EB45A	Recap	2010	Wells Tailrace Boat Launch	V9-2x	348	228	10/27/2012 13:23	WT05	Wells Tailrace	2/12/2015
29542	3D9.1C2D8D6374	Recap	2010	Wells Tailrace Boat Launch	V9-2x	350	244	10/27/2012 15:43	SC02	Sun Cove Boat Launch	2/12/2015
29546	3D9.1C2D8CB9D8	Recap	2010	Wells Tailrace Boat Launch	V9-2x	364	244	10/27/2012 15:43	SC02	Sun Cove Boat Launch	2/12/2015

Acoustic Tag Code	PIT ID	Fish Source	Brood Year	Tagging Location	Tag Type	Length (mm)	Weig ht (g)	Release Date/Time	Release	Release Site	Estimate Tag Failure Date
28086	3D9.1C2E0A6012	Hatchery	2012	Columbia Basin Hatchery	V9-2x	330	213.5	5/20/2013 16:50	BB04	Beebe Bridge	8/9/2015
28085	3D9.1C2DF7A317	Hatchery	2012	Columbia Basin Hatchery	V9-2x	296	167.8	5/20/2013 16:50	BB04	Beebe Bridge	8/9/2015
28084	3D9.1C2DF796A2	Hatchery	2012	Columbia Basin Hatchery	V9-2x	285	151.7	5/20/2013 16:50	BB04	Beebe Bridge	8/9/2015
28083	3D9.1C2DF7F856	Hatchery	2012	Columbia Basin Hatchery	V9-2x	330	229.3	5/20/2013 16:50	BB04	Beebe Bridge	8/9/2015
28087	3D9.1C2E0A9620	Hatchery	2012	Columbia Basin Hatchery	V9-2x	295	165.5	5/20/2013 16:50	BB04	Beebe Bridge	8/9/2015
28081	3D9.1C2DF765A9	Hatchery	2012	Columbia Basin Hatchery	V9-2x	340	265.1	5/20/2013 16:50	BB04	Beebe Bridge	8/9/2015
28066	3D9.1C2DF7C660	Hatchery	2012	Columbia Basin Hatchery	V9-2x	346	260	5/20/2013 16:50	BB04	Beebe Bridge	8/9/2015
28074	3D9.1C2DF0B668	Hatchery	2012	Columbia Basin Hatchery	V9-2x	285	165.2	5/20/2013 16:50	BB04	Beebe Bridge	8/9/2015
28065	3D9.1C2DF7EF5F	Hatchery	2012	Columbia Basin Hatchery	V9-2x	373	300.6	5/20/2013 16:50	BB04	Beebe Bridge	8/9/2015
28082	3D9.1C2DF7CB49	Hatchery	2012	Columbia Basin Hatchery	V9-2x	329	223.8	5/20/2013 16:50	BB04	Beebe Bridge	8/9/2015
9583	3D9.1C2E0A54D2	Hatchery	2012	Columbia Basin Hatchery	V7-2x	292	165	5/20/2013 16:50	BB04	Beebe Bridge	10/8/2013
28064	3D9.1C2DF7A46C	Hatchery	2012	Columbia Basin Hatchery	V9-2x	316	193.2	5/20/2013 16:50	BB04	Beebe Bridge	8/9/2015
28088	3D9.1C2DF79036	Hatchery	2012	Columbia Basin Hatchery	V9-2x	298	160.4	5/20/2013 16:50	BB04	Beebe Bridge	8/9/2015
9584	3D9.1C2DF5FC67	Hatchery	2012	Columbia Basin Hatchery	V7-2x	302	172.8	5/20/2013 16:50	BB04	Beebe Bridge	10/8/2013
28058	3D9.1C2E0A5FB3	Hatchery	2012	Chelan Hatchery	V9-2x	343	308.1	5/22/2013 14:30	BB05	Beebe Bridge	8/9/2015
28059	3D9.1C2E0A6C6D	Hatchery	2012	Chelan Hatchery	V9-2x	325	236.7	5/22/2013 14:30	BB05	Beebe Bridge	8/9/2015
28057	3D9.1C2E0A3960	Hatchery	2012	Chelan Hatchery	V9-2x	334	283.9	5/22/2013 14:30	BB05	Beebe Bridge	8/9/2015
28051	3D9.1C2DF7C675	Hatchery	2012	Chelan Hatchery	V9-2x	267	123.5	5/22/2013 14:30	BB05	Beebe Bridge	8/9/2015
28050	3D9.1C2DF76D08	Hatchery	2012	Chelan Hatchery	V9-2x	275	138.3	5/22/2013 14:30	BB05	Beebe Bridge	8/9/2015
9203	3D9.1C2DF7C9DE	Hatchery	2012	Chelan Hatchery	V9P-2x	354	291.2	5/22/2013 14:30	BB05	Beebe Bridge	11/25/2014
9578	3D9.1C2E0A6D20	Hatchery	2012	Chelan Hatchery	V7-2x	272	132.7	5/22/2013 14:30	BB05	Beebe Bridge	10/8/2013
9579	3D9.1C2DF7BC55	Hatchery	2012	Chelan Hatchery	V7-2x	252	100	5/22/2013 14:30	BB05	Beebe Bridge	10/8/2013
9585	3D9.1C2DF7AE71	Hatchery	2012	Chelan Hatchery	V7-2x	270	138.4	5/21/2013 15:45	DR03	Daroga Boat Launch	10/8/2013
28070	3D9.1C2DF78194	Hatchery	2012	Chelan Hatchery	V9-2x	329	216.9	5/21/2013 15:45	DR03	Daroga Boat Launch	8/9/2015
28071	3D9.1C2DF7834C	Hatchery	2012	Chelan Hatchery	V9-2x	340	290.1	5/21/2013 15:45	DR03	Daroga Boat Launch	8/9/2015
28072	3D9.1C2DF74FE1	Hatchery	2012	Chelan Hatchery	V9-2x	305	183.9	5/21/2013 15:45	DR03	Daroga Boat Launch	8/9/2015
28073	3D9.1C2DF685F3	Hatchery	2012	Chelan Hatchery	V9-2x	300	196.4	5/21/2013 15:45	DR03	Daroga Boat Launch	8/9/2015
9587	3D9.1C2E0A7AAB	Hatchery	2012	Chelan Hatchery	V7-2x	255	104	5/21/2013 15:45	DR03	Daroga Boat Launch	10/8/2013
28077	3D9.1C2E0A795E	Hatchery	2012	Chelan Hatchery	V9-2x	316	187.3	5/21/2013 15:45	DR03	Daroga Boat Launch	8/9/2015

Acoustic Tag Code	PIT ID	Fish Source	Brood Year	Tagging Location	Tag Type	Length (mm)	Weig ht (g)	Release Date/Time	Release	Release Site	Estimate Tag Failure Date
9206	3D9.1C2E0A7780	Hatchery	2012	Chelan Hatchery	V9P-2x	346	268.4	5/21/2013 15:45	DR03	Daroga Boat Launch	11/25/2014
9204	3D9.1C2DF79705	Hatchery	2012	Chelan Hatchery	V9P-2x	345	279.9	5/21/2013 15:45	DR03	Daroga Boat Launch	11/25/2014
9586	3D9.1C2E0A6DC2	Hatchery	2012	Chelan Hatchery	V7-2x	252	106	5/21/2013 15:45	DR03	Daroga Boat Launch	10/8/2013
28043	3D9.1C2DF7CA7E	Hatchery	2012	Chelan Hatchery	V9-2x	295	196.3	5/23/2013 15:00	DR04	Daroga Boat Launch	8/9/2015
28039	3D9.1C2E0A7DA7	Hatchery	2012	Chelan Hatchery	V9-2x	325	216.6	5/23/2013 15:00	DR04	Daroga Boat Launch	8/9/2015
28040	3D9.1C2E0A2F59	Hatchery	2012	Chelan Hatchery	V9-2x	305	187.4	5/23/2013 15:00	DR04	Daroga Boat Launch	8/9/2015
28046	3D9.1C2DF7971A	Hatchery	2012	Chelan Hatchery	V9-2x	320	218.6	5/23/2013 15:00	DR04	Daroga Boat Launch	8/9/2015
28042	3D9.1C2E0A476B	Hatchery	2012	Chelan Hatchery	V9-2x	290	159.2	5/23/2013 15:00	DR04	Daroga Boat Launch	8/9/2015
28044	3D9.1C2DF7A385	Hatchery	2012	Chelan Hatchery	V9-2x	290	153.4	5/23/2013 15:00	DR04	Daroga Boat Launch	8/9/2015
9202	3D9.1C2E0A3895	Hatchery	2012	Chelan Hatchery	V9P-2x	404	489.3	5/23/2013 15:00	DR04	Daroga Boat Launch	11/25/2014
28053	3D9.1C2DF7CF1E	Hatchery	2012	Chelan Hatchery	V9-2x	304	191.7	5/23/2013 15:00	DR04	Daroga Boat Launch	8/9/2015
28054	3D9.1C2E0A39B6	Hatchery	2012	Chelan Hatchery	V9-2x	300	195.3	5/23/2013 15:00	DR04	Daroga Boat Launch	8/9/2015
28055	3D9.1C2DF785D8	Hatchery	2012	Chelan Hatchery	V9-2x	331	245.5	5/23/2013 15:00	DR04	Daroga Boat Launch	8/9/2015
28056	3D9.1C2DF77D05	Hatchery	2012	Chelan Hatchery	V9-2x	269	132.7	5/23/2013 15:00	DR04	Daroga Boat Launch	8/9/2015
28041	3D9.1C2DF7D39A	Hatchery	2012	Chelan Hatchery	V9-2x	262	119.8	5/23/2013 15:00	DR04	Daroga Boat Launch	8/9/2015
28080	3D9.1C2DF78680	Hatchery	2012	Columbia Basin Hatchery	V9-2x	326	201.9	5/20/2013 15:30	ET01	Entiat	8/9/2015
28069	3D9.1C2DF7CE48	Hatchery	2012	Columbia Basin Hatchery	V9-2x	312	200	5/20/2013 15:30	ET01	Entiat	8/9/2015
28075	3D9.1C2DF7B05D	Hatchery	2012	Columbia Basin Hatchery	V9-2x	308	194.9	5/20/2013 15:30	ET01	Entiat	8/9/2015
28076	3D9.1C2DF77517	Hatchery	2012	Columbia Basin Hatchery	V9-2x	325	209	5/20/2013 15:30	ET01	Entiat	8/9/2015
28079	3D9.1C2DF7C5D2	Hatchery	2012	Columbia Basin Hatchery	V9-2x	285	145.8	5/20/2013 15:30	ET01	Entiat	8/9/2015
9205	3D9.1C2DF6B43C	Hatchery	2012	Columbia Basin Hatchery	V9P-2x	342	255.3	5/20/2013 15:30	ET01	Entiat	11/25/2014
28067	3D9.1C2DF78ACF	Hatchery	2012	Columbia Basin Hatchery	V9-2x	316	191.5	5/21/2013 14:05	ET02	Entiat	8/9/2015
28068	3D9.1C2E0AB743	Hatchery	2012	Columbia Basin Hatchery	V9-2x	322	198.6	5/21/2013 14:05	ET02	Entiat	8/9/2015
28047	3D9.1C2DF7911F	Hatchery	2012	Chelan Hatchery	V9-2x	299	167.5	5/23/2013 14:35	ET03	Entiat	8/9/2015
28045	3D9.1C2DF7EFD6	Hatchery	2012	Chelan Hatchery	V9-2x	306	198.6	5/23/2013 14:35	ET03	Entiat	8/9/2015
9582	3D9.1C2DF7CBC4	Hatchery	2012	Chelan Hatchery	V7-2x	230	67.5	5/23/2013 14:35	ET03	Entiat	10/8/2013
28048	3D9.1C2DF7B204	Hatchery	2012	Chelan Hatchery	V9-2x	314	213.6	5/23/2013 14:35	ET03	Entiat	8/9/2015
28049	3D9.1C2DF7AFAA	Hatchery	2012	Chelan Hatchery	V9-2x	270	139	5/23/2013 14:35	ET03	Entiat	8/9/2015
28052	3D9.1C2E0A62E9	Hatchery	2012	Chelan Hatchery	V9-2x	265	149.4	5/23/2013 14:35	ET03	Entiat	8/9/2015

Acoustic Tag Code	PIT ID	Fish Source	Brood Year	Tagging Location	Tag Type	Length (mm)	Weig ht (g)	Release Date/Time	Release	Release Site	Estimate Tag Failure Date
28060	3D9.1C2DF793D5	Hatchery	2012	Chelan Hatchery	V9-2x	280	140.5	5/23/2013 14:35	ET03	Entiat	8/9/2015
28061	3D9.1C2DF7CD49	Hatchery	2012	Chelan Hatchery	V9-2x	272	136.4	5/23/2013 14:35	ET03	Entiat	8/9/2015
28062	3D9.1C2DF7EF7E	Hatchery	2012	Chelan Hatchery	V9-2x	307	246	5/23/2013 14:35	ET03	Entiat	8/9/2015
28063	3D9.1C2DF7B6E3	Hatchery	2012	Chelan Hatchery	V9-2x	300	167.8	5/23/2013 14:35	ET03	Entiat	8/9/2015
9580	3D9.1C2E0A5327	Hatchery	2012	Chelan Hatchery	V7-2x	195	479	5/23/2013 14:35	ET03	Entiat	10/8/2013
13476	3D9.1C2D8EE0DD	Recap	2010	Chelan Falls Boat Launch	V13P-1	577	1083	10/22/2013 15:30	WT06	Wells Tailrace	12/26/2016
27171	3D9.1C2D8A0424	Recap	2010	Chelan Falls Boat Launch	V13-1x	508	754	10/22/2013 15:30	WT06	Wells Tailrace	10/23/2017
27170	3D9.1C2D899DD0	Recap	2010	Chelan Falls Boat Launch	V13-1x	460	531	10/22/2013 11:30	CF03	Chelan Falls	10/23/2017
27169	3D9.1C2D89E88D	Recap	2010	Chelan Falls Boat Launch	V13-1x	465	614	10/22/2013 11:30	CF03	Chelan Falls	10/23/2017

APPENDIX B.

Detections History of Arrays by Acoustic Tag ID and Release of Acoustically-Tagged Juvenile White Sturgeon

Complete detection histories for all acoustic tagged sturgeon for each detection array by release location over the 2012-2013 study period from 16 May, 2012, to 25 November 2013. Detections are shown as horizontal bars with color indicating release location.

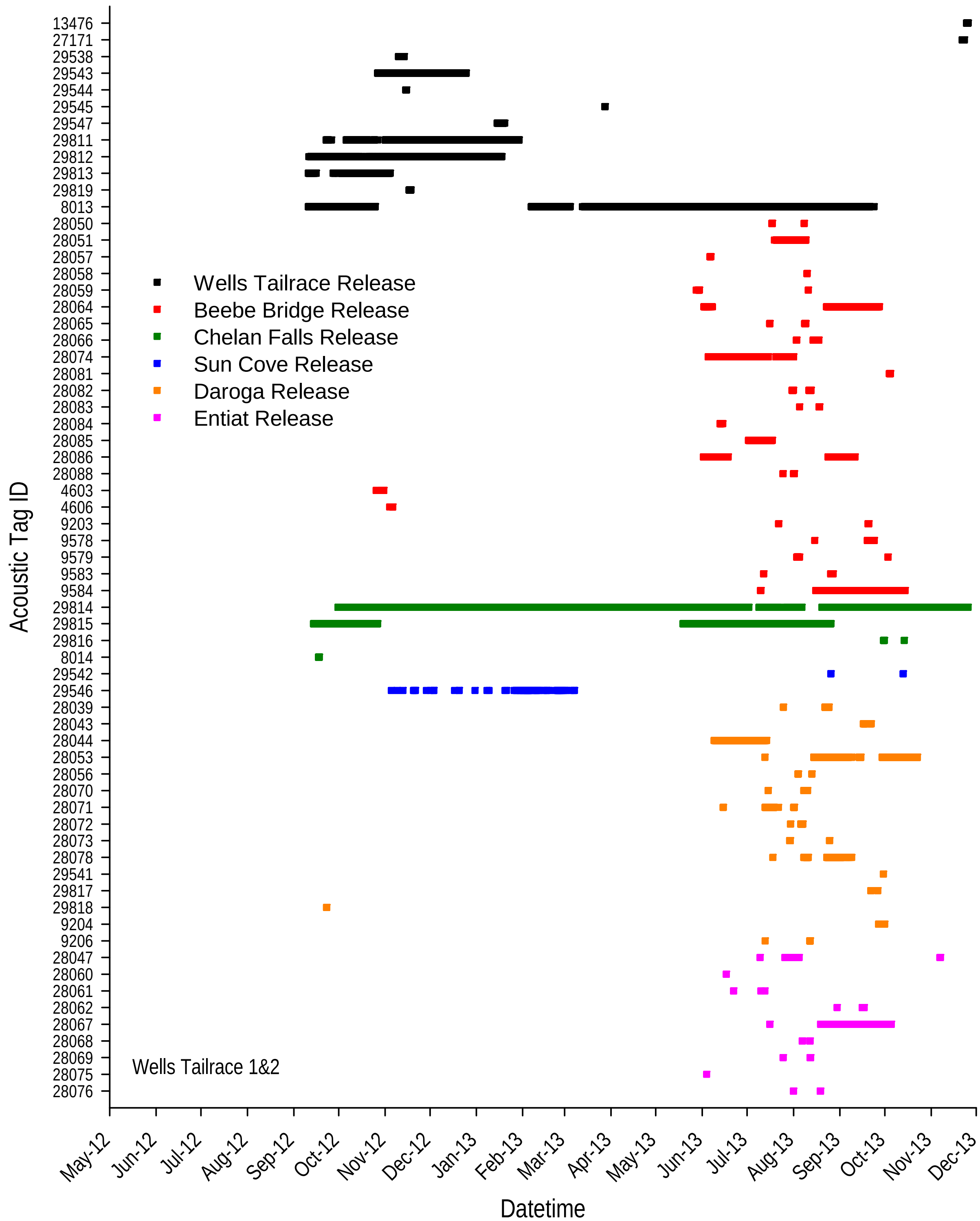


Figure B -1. Detections of all acoustically-tagged study fish at the Wells Tailrace receivers from the first release (16 May 2012) to the last download (22 and 25 November 2013). Detections are colored by release location as follows: Wells Tailrace (black), Beebe Bridge (red), Chelan Falls (green), Sun Cove (blue), Daroga (orange), and Entiat (pink).

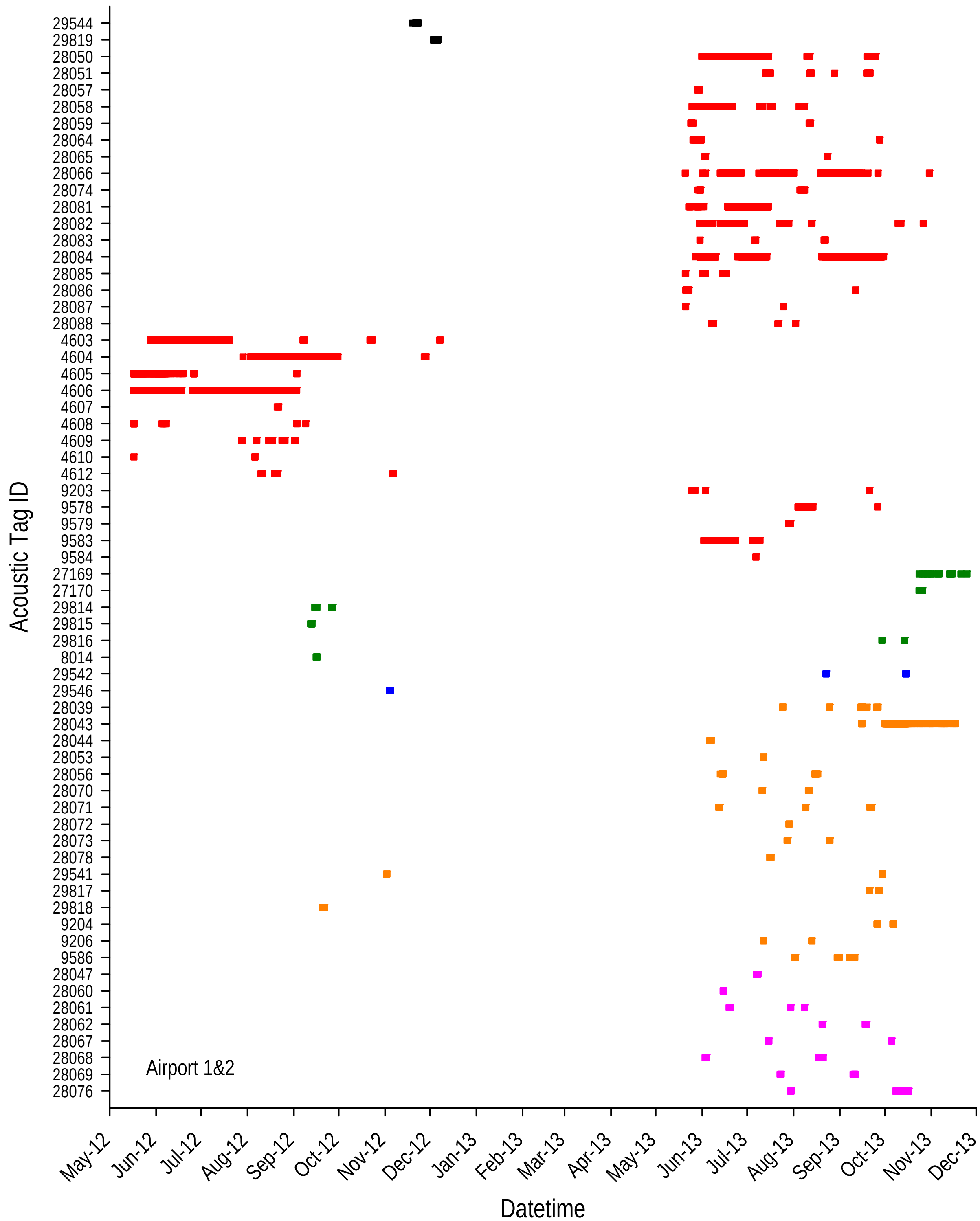


Figure B -2. Detections of all acoustically-tagged study fish at the Airport receivers from the first release (16 May 2012) to the last download (22 and 25 November 2013). Detections are colored by release location as follows: Wells Tailrace (black), Beebe Bridge (red), Chelan Falls (green), Sun Cove (blue), Daroga (orange), and Entiat (pink).

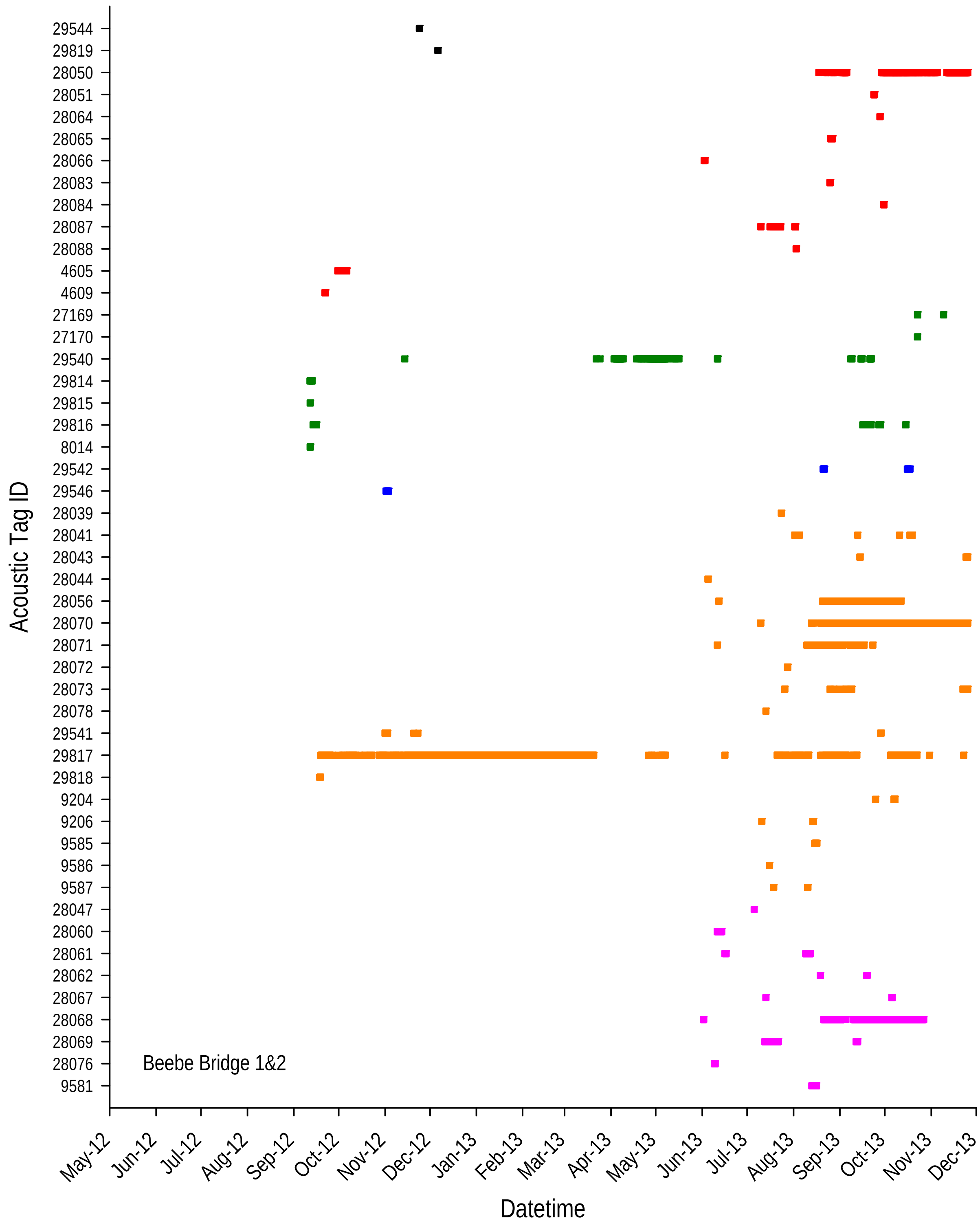


Figure B -3. Detections of all acoustically-tagged study fish at the Beebe Bridge receivers from the first release (16 May 2012) to the last download (22 and 25 November 2013). Detections are colored by release location as follows: Wells Tailrace (black), Beebe Bridge (red), Chelan Falls (green), Sun Cove (blue), Daroga (orange), and Entiat (pink).

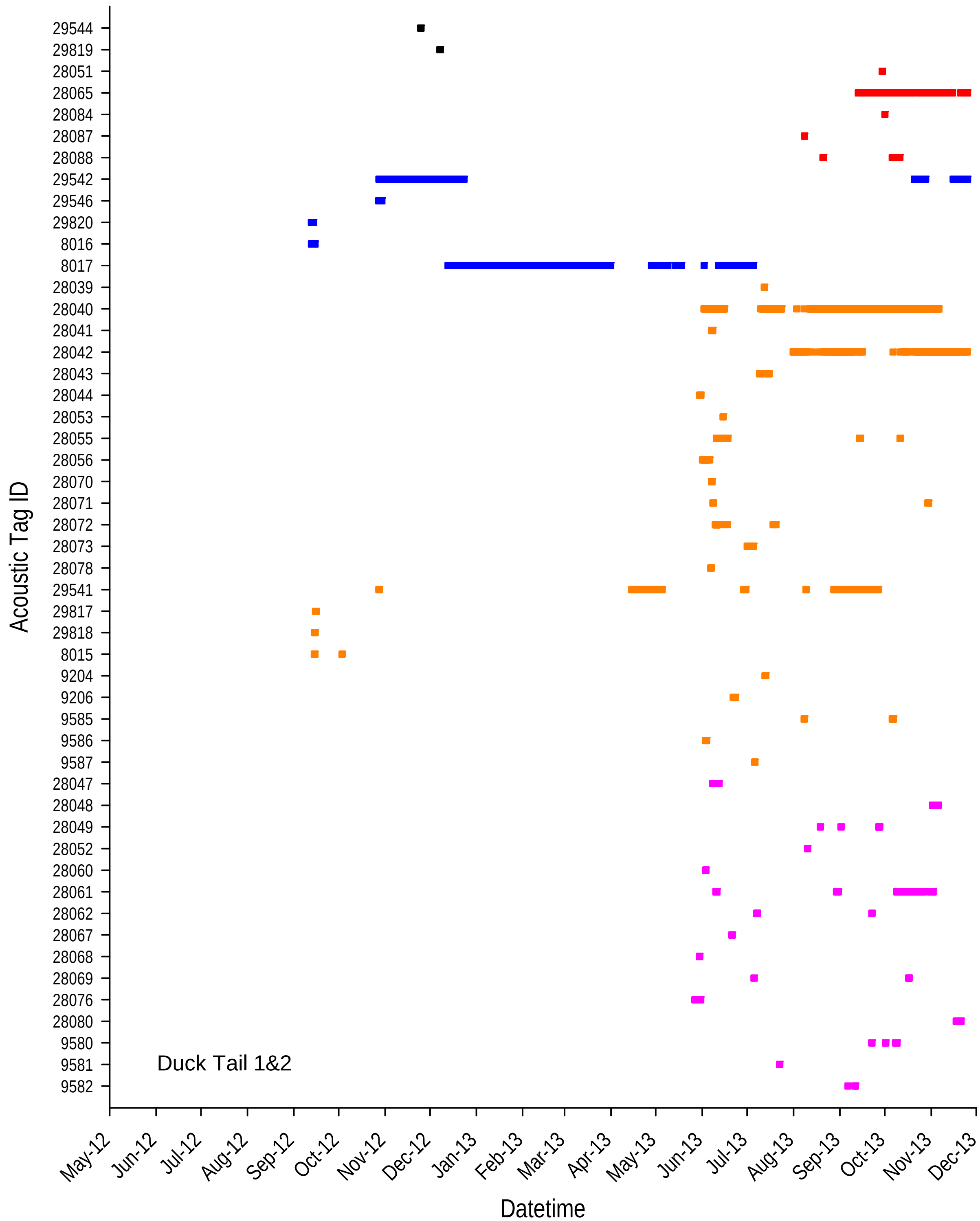


Figure B -4. Detections of all acoustically-tagged study fish at the Duck Tail receivers from the first release (16 May 2012) to the last download (22 and 25 November 2013). Detections are colored by release location as follows: Wells Tailrace (black), Beebe Bridge (red), Chelan Falls (green), Sun Cove (blue), Daroga (orange), and Entiat (pink).

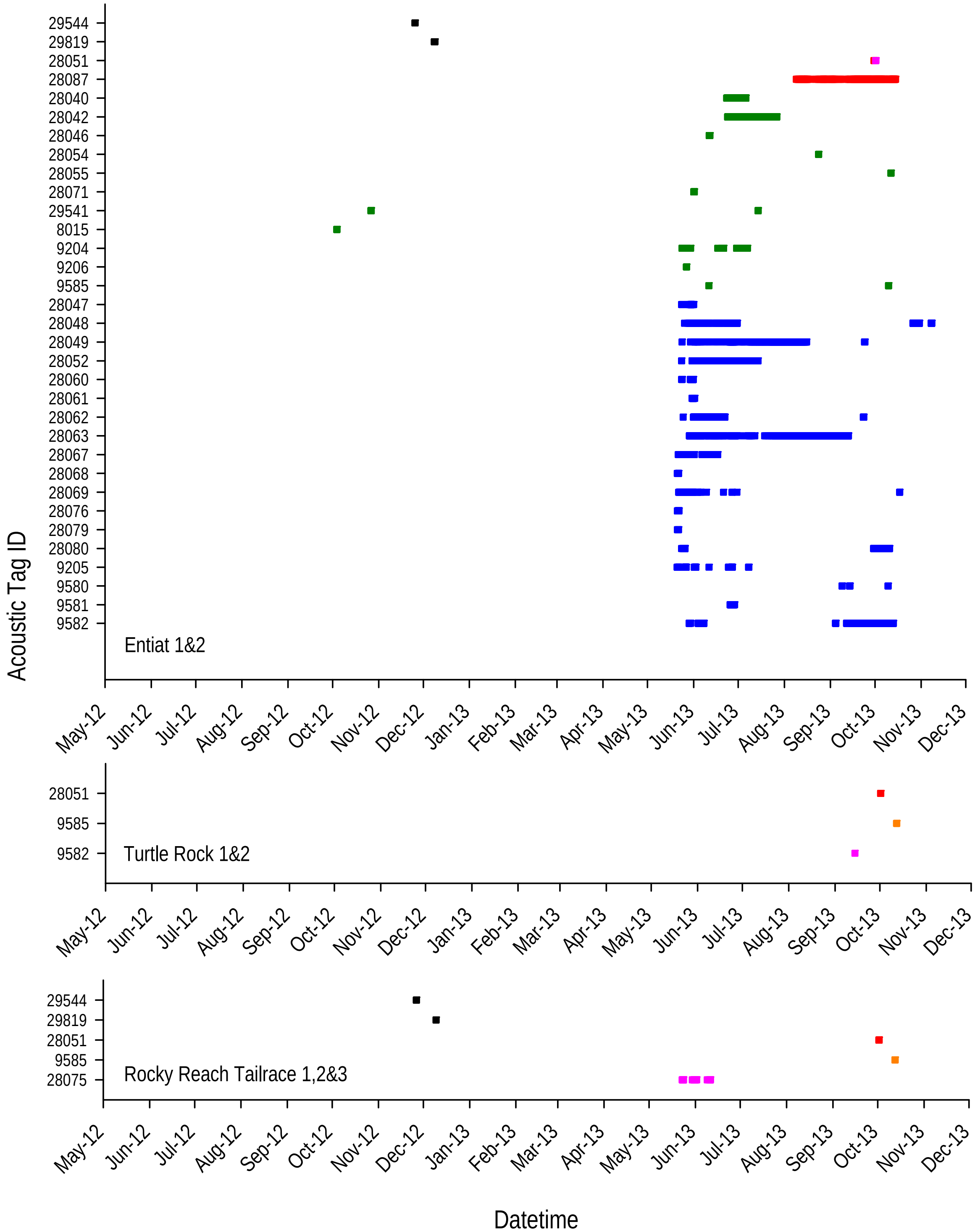
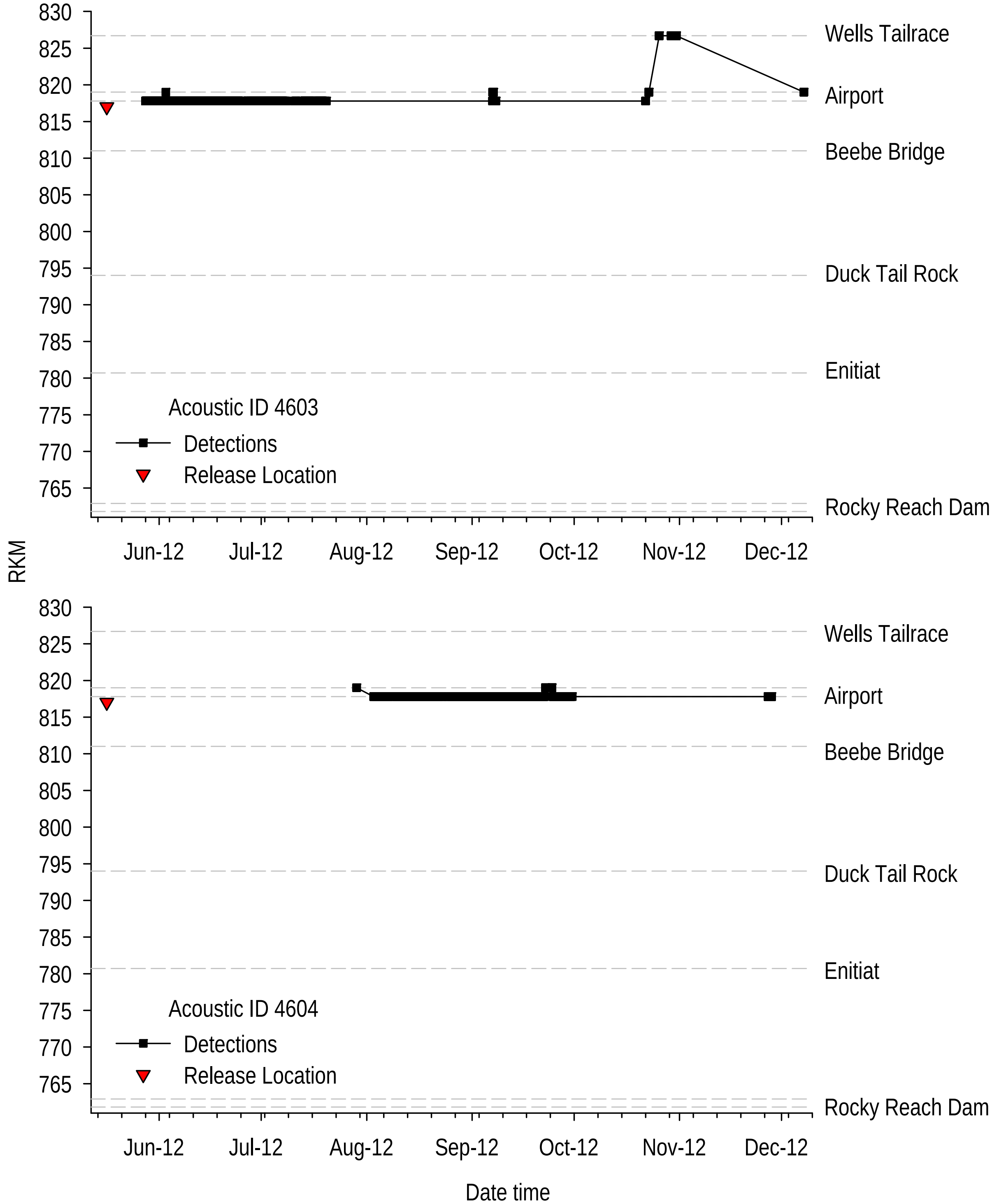


Figure B -5. Detections of all acoustically-tagged study fish at the Entiat, Turtle Rock, and Rocky Reach Tailrace receivers from the first release (16 May 2012) to the last download (22 and 25 November 2013). Detections are colored by release location as follows: Wells Tailrace (black), Beebe Bridge (red), Chelan Falls (green), Sun Cove (blue), Daroga (orange), and Entiat (pink).

APPENDIX C.

Detection Histories of Individual Acoustically-Tagged Juvenile White Sturgeon

Complete individual detection histories for all acoustic-tagged sturgeon over the study period from 16 May 2012 to 25 November 2013 are shown in the presented figures. Detections are shown as black squares with sequential connecting black lines showing upstream and downstream movements between detections. Release locations are shown as red triangles. Vertical axis illustrate river kilometer with horizontal dashed grey lines at each VR2W receiver detection array.



RKM
830
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815
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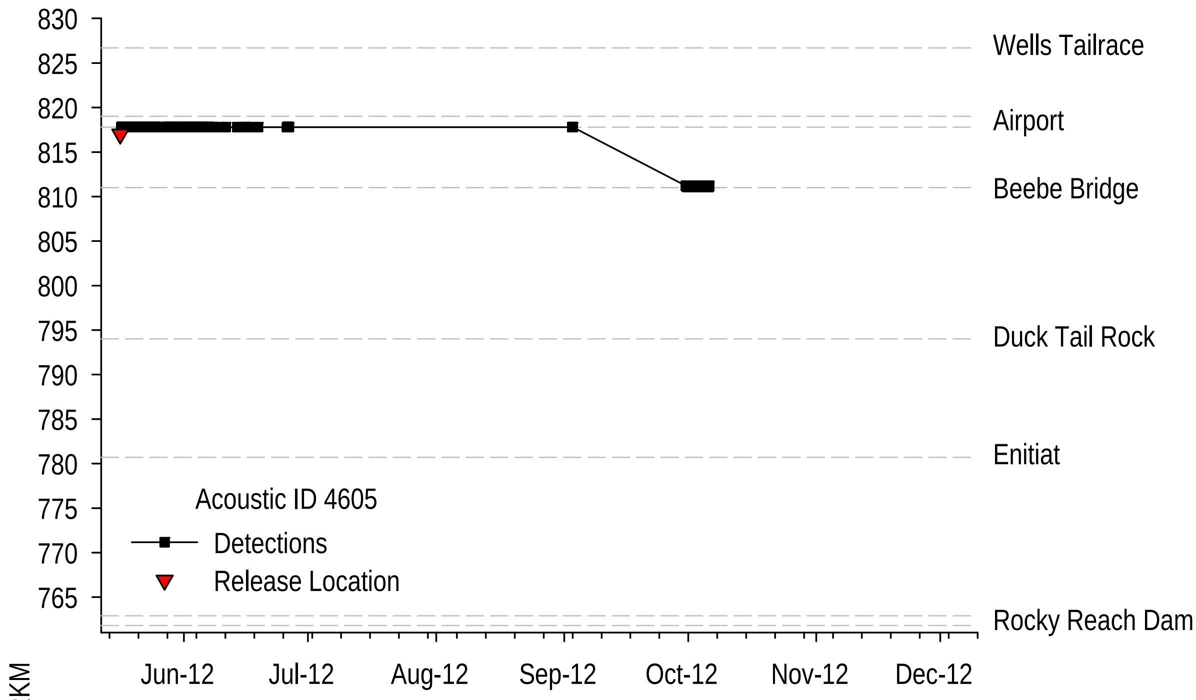
795
790
785
780
775
770
765
Wells Tailrace
Airport
Beebe Bridge
Duck Tail Rock
Enitiat
Rocky Reach Dam
Acoustic ID 4603
Detections
Release Location
Jun-12
Jul-12
Aug-12
Sep-12
Oct-12
Nov-12
Dec-12
Acoustic ID 4604
Date time



830
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Duck Tail Rock
Enitiat
Rocky Reach Dam
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Detections
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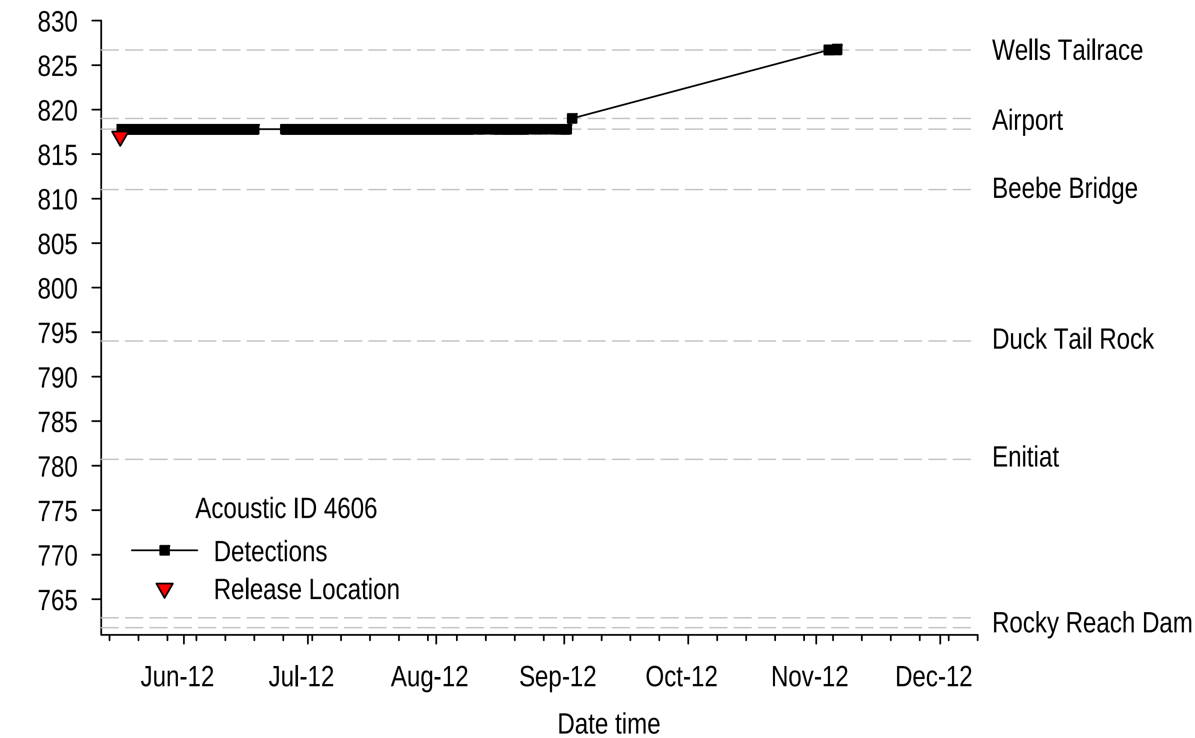
RKM



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Airport
Beebe Bridge
Duck Tail Rock
Enitiat
Rocky Reach Dam
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Detections
Release Location
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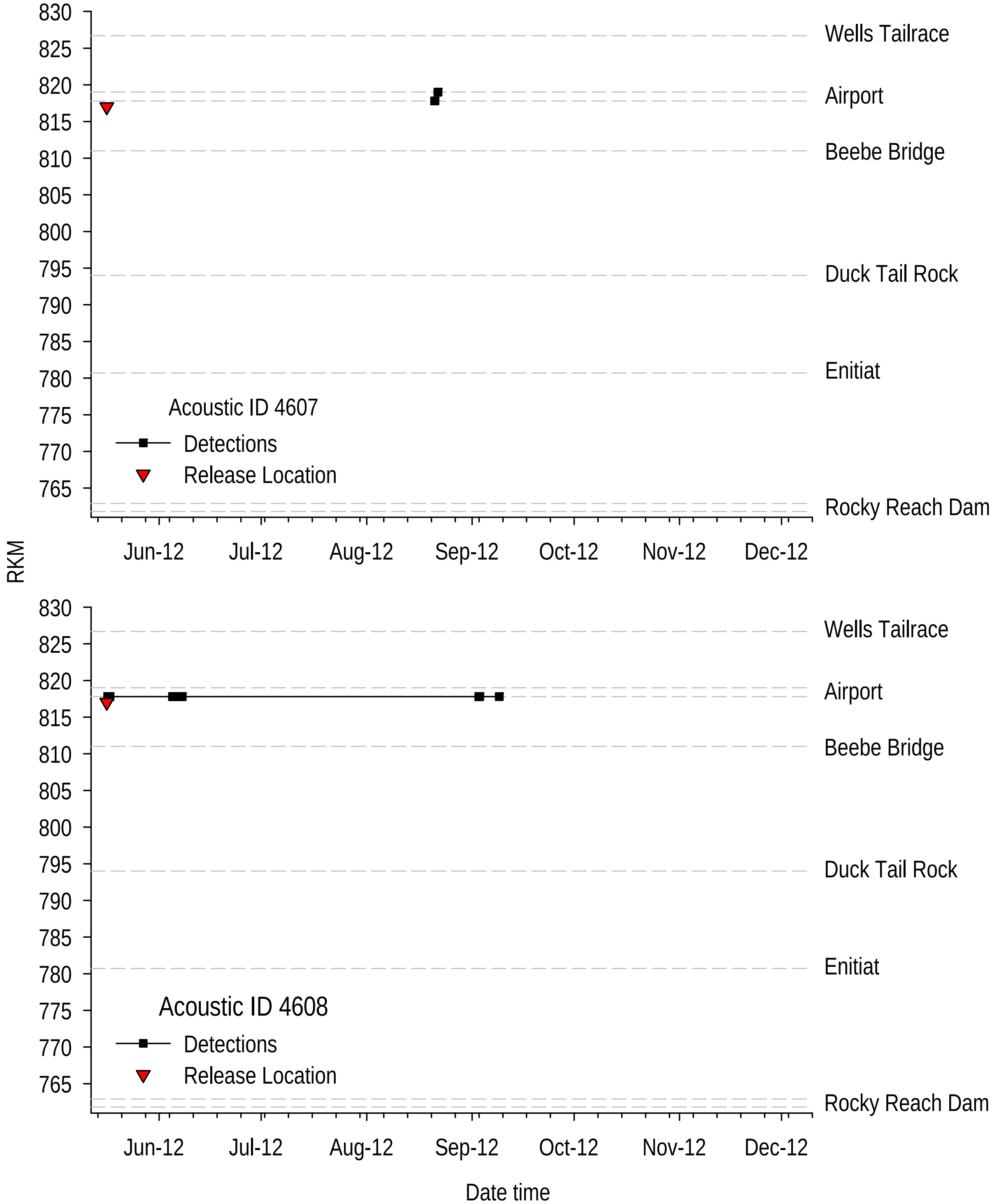
Nov-12
Dec-12
Date time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Airport
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Duck Tail Rock
Enitiat
Rocky Reach Dam
Acoustic ID 4607
Detections
Release Location
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Jul-12
Aug-12
Sep-12
Oct-12
Nov-12
Dec-12
RKM
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Wells Tailrace
Airport
Beebe Bridge
Duck Tail Rock
Enitiat
Rocky Reach Dam
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Release Location
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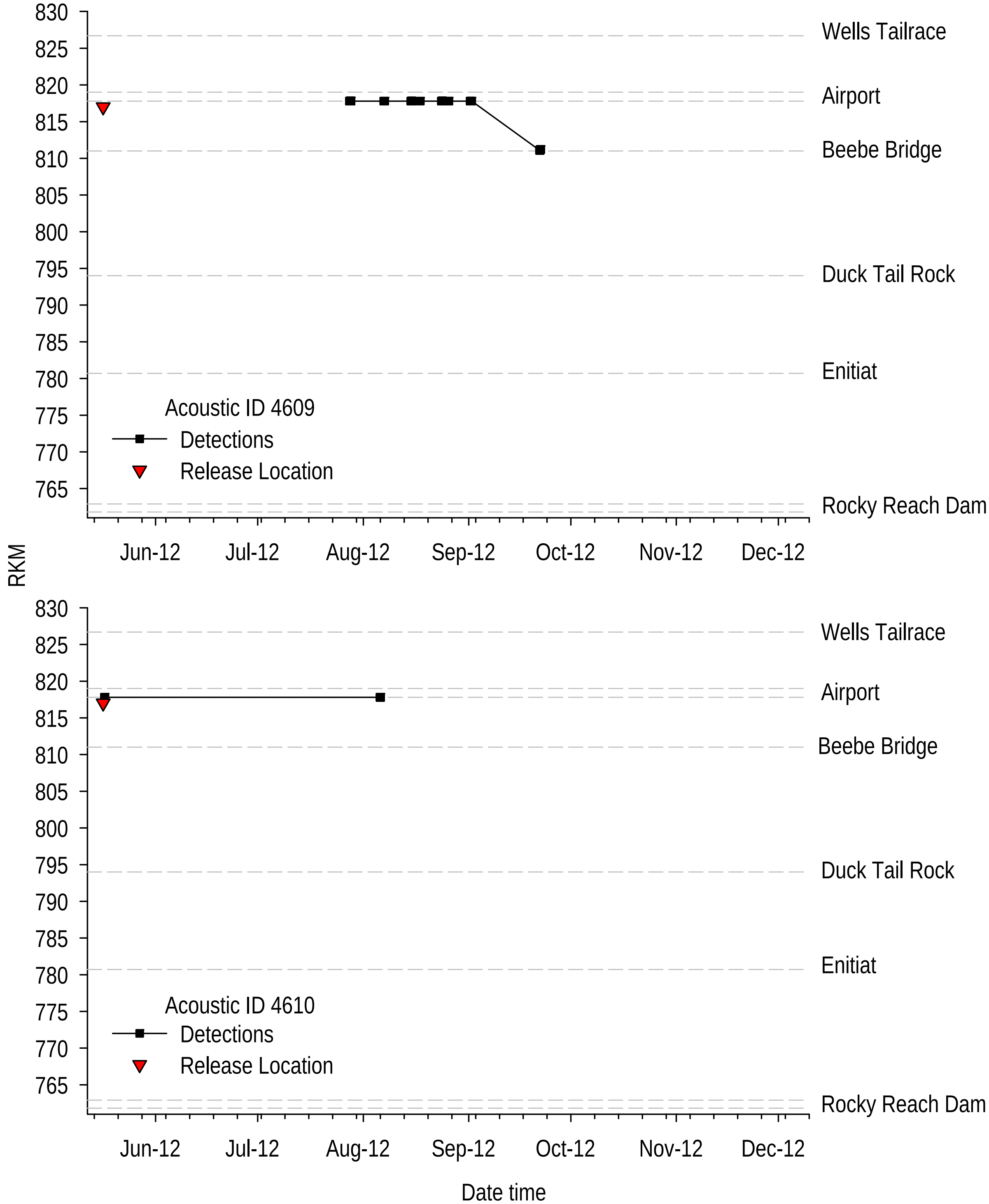
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Duck Tail Rock
Enitiat
Rocky Reach Dam
Acoustic ID 4609
Detections
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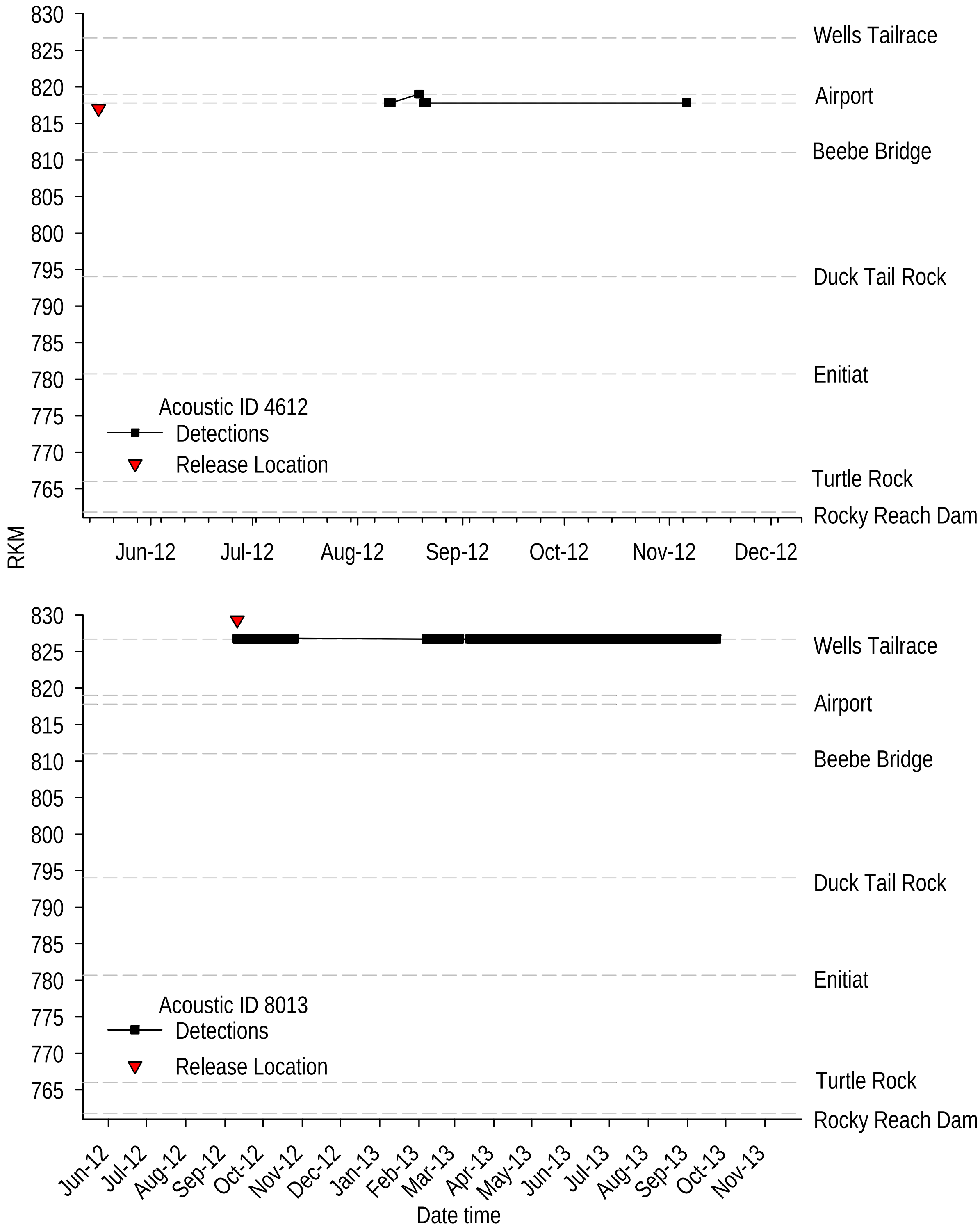
Release Location
Date time



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Duck Tail Rock
Enitiat
Turtle Rock
Rocky Reach Dam
Acoustic ID 4612
Detections
Release Location
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Aug-12
Sep-12
Oct-12
Nov-12
Dec-12
RKM
Acoustic ID 8013
Detections
Release Location
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Oct-13
Nov-13
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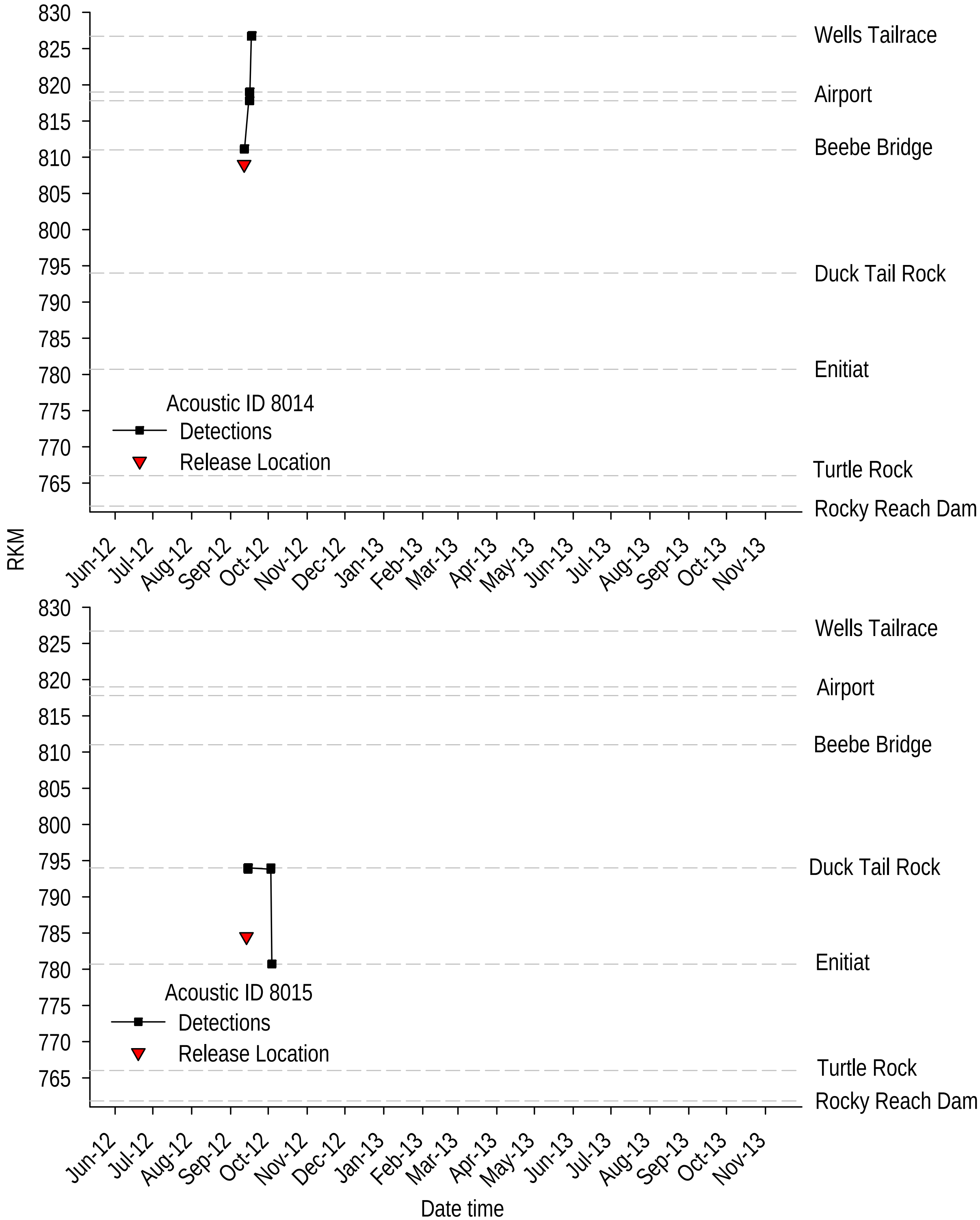

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Duck Tail Rock
Enitiat
Turtle Rock
Rocky Reach Dam
Acoustic ID 8014
Detections
Release Location
RKM
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Oct-12
Nov-12
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Feb-13
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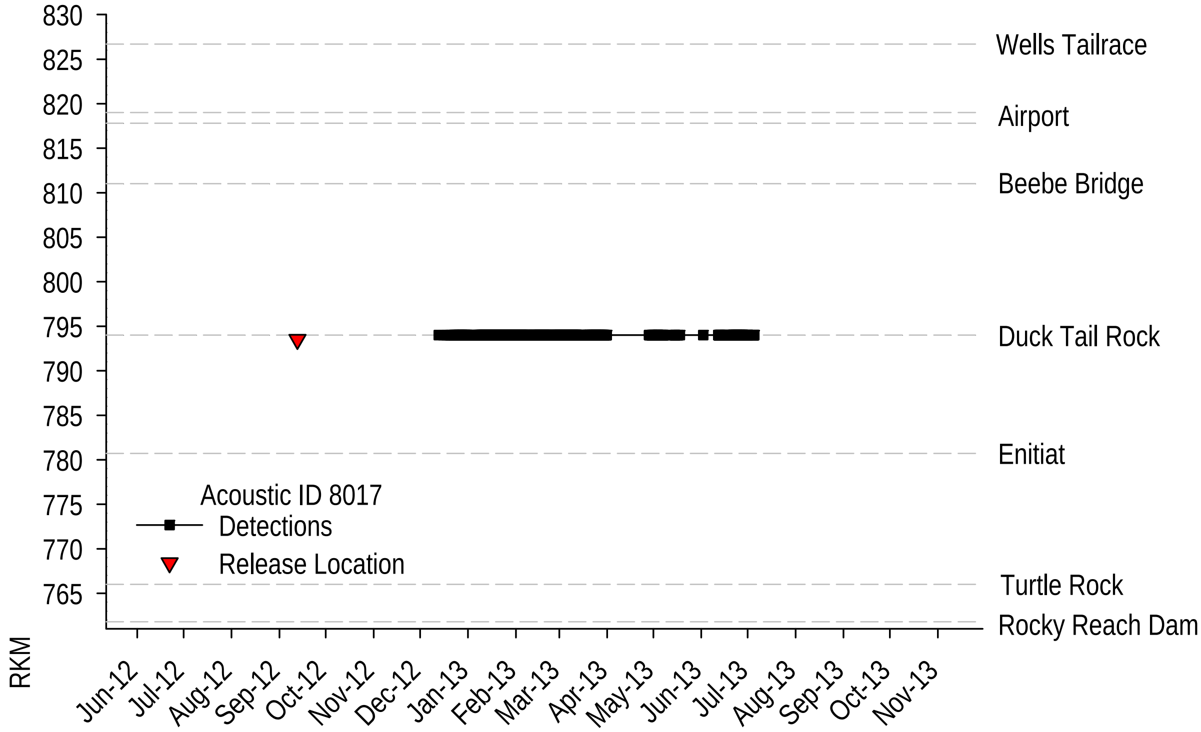
Acoustic ID 8015
Detections
Release Location
Date time

Appendix C - 6



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Airport
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Duck Tail Rock
Enitiat
Turtle Rock
Rocky Reach Dam
Acoustic ID 8017
Detections
Release Location
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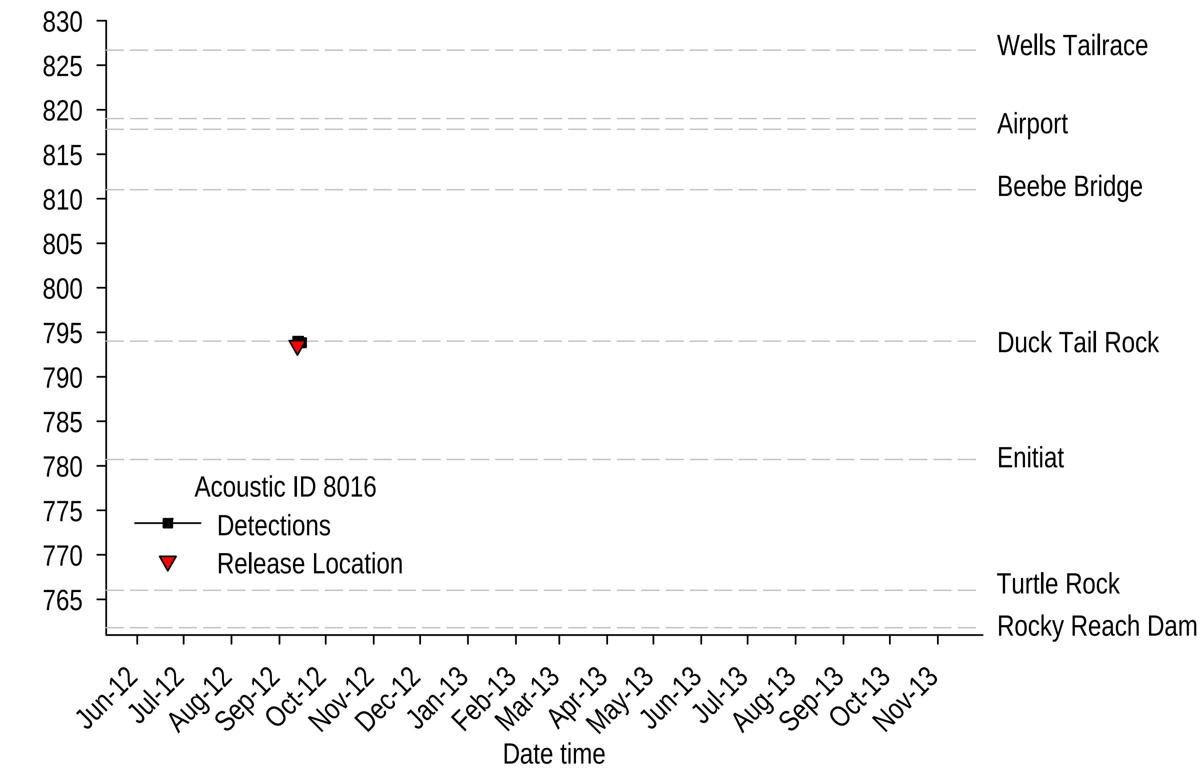

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Duck Tail Rock
Enitiat
Turtle Rock
Rocky Reach Dam
Acoustic ID 8016
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Release Location
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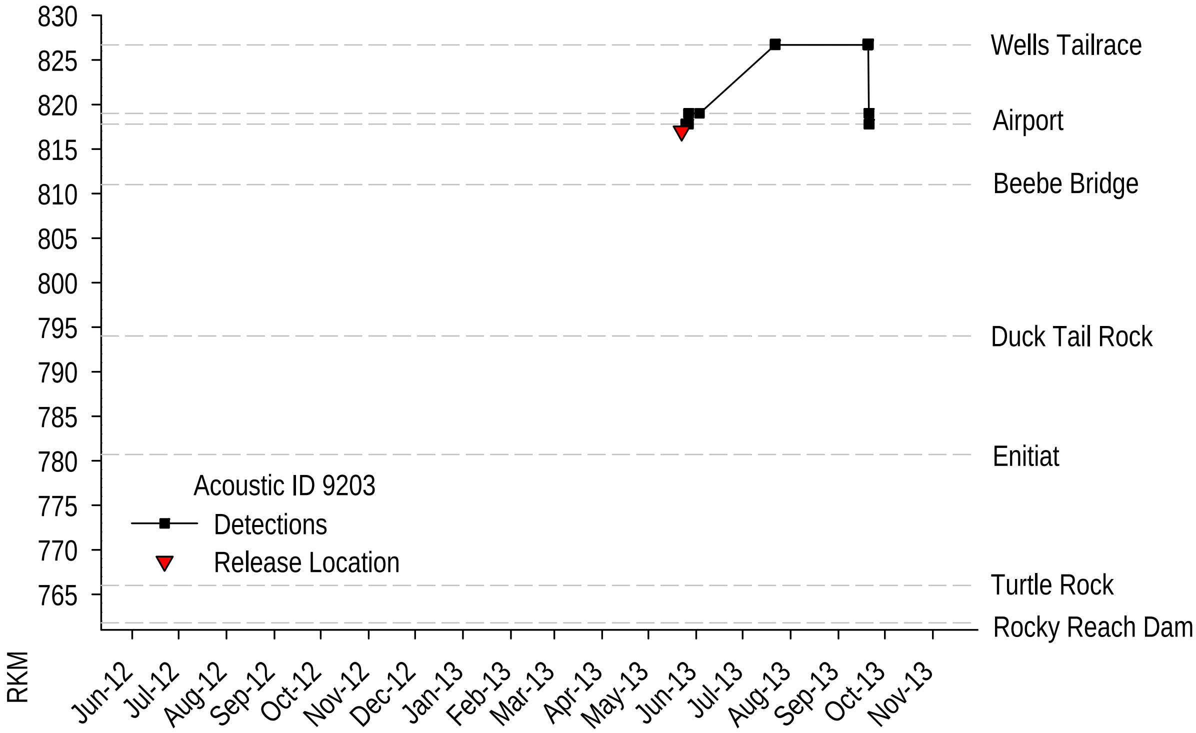
Nov-13
Date time



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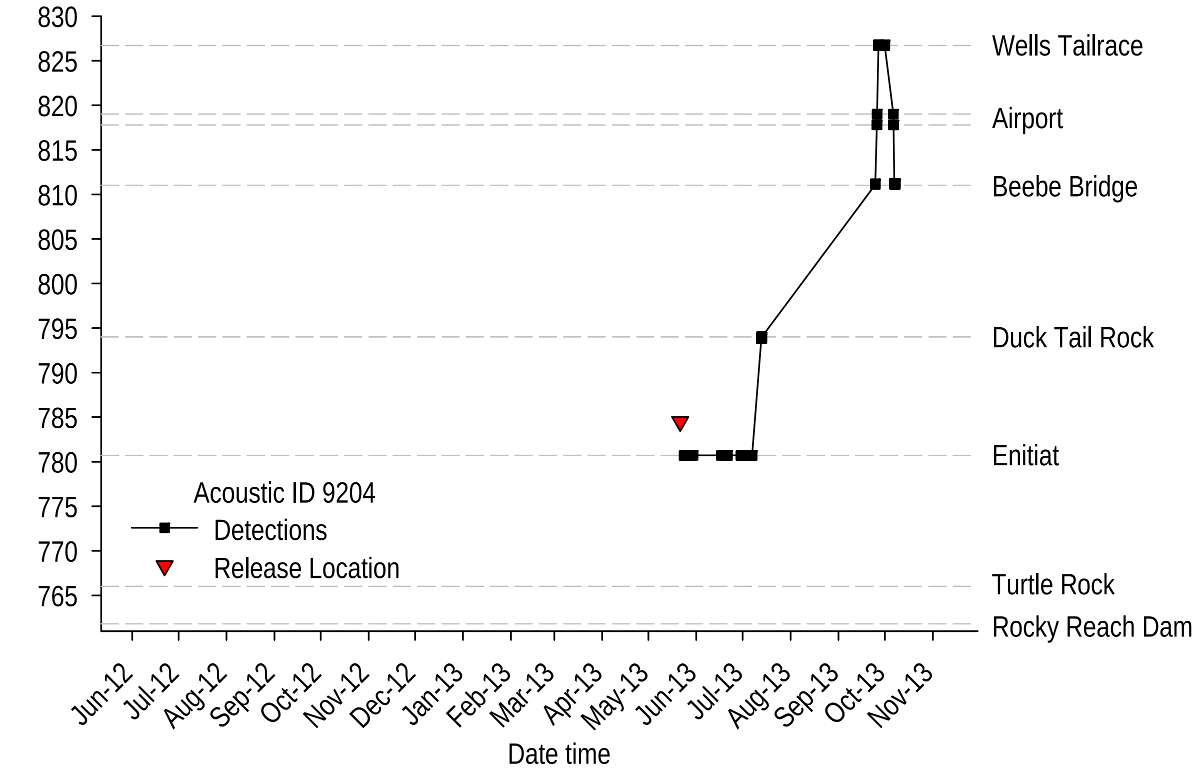
Duck Tail Rock
Enitiat
Turtle Rock
Rocky Reach Dam
Acoustic ID 9203
Detections
Release Location
RKM



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Duck Tail Rock
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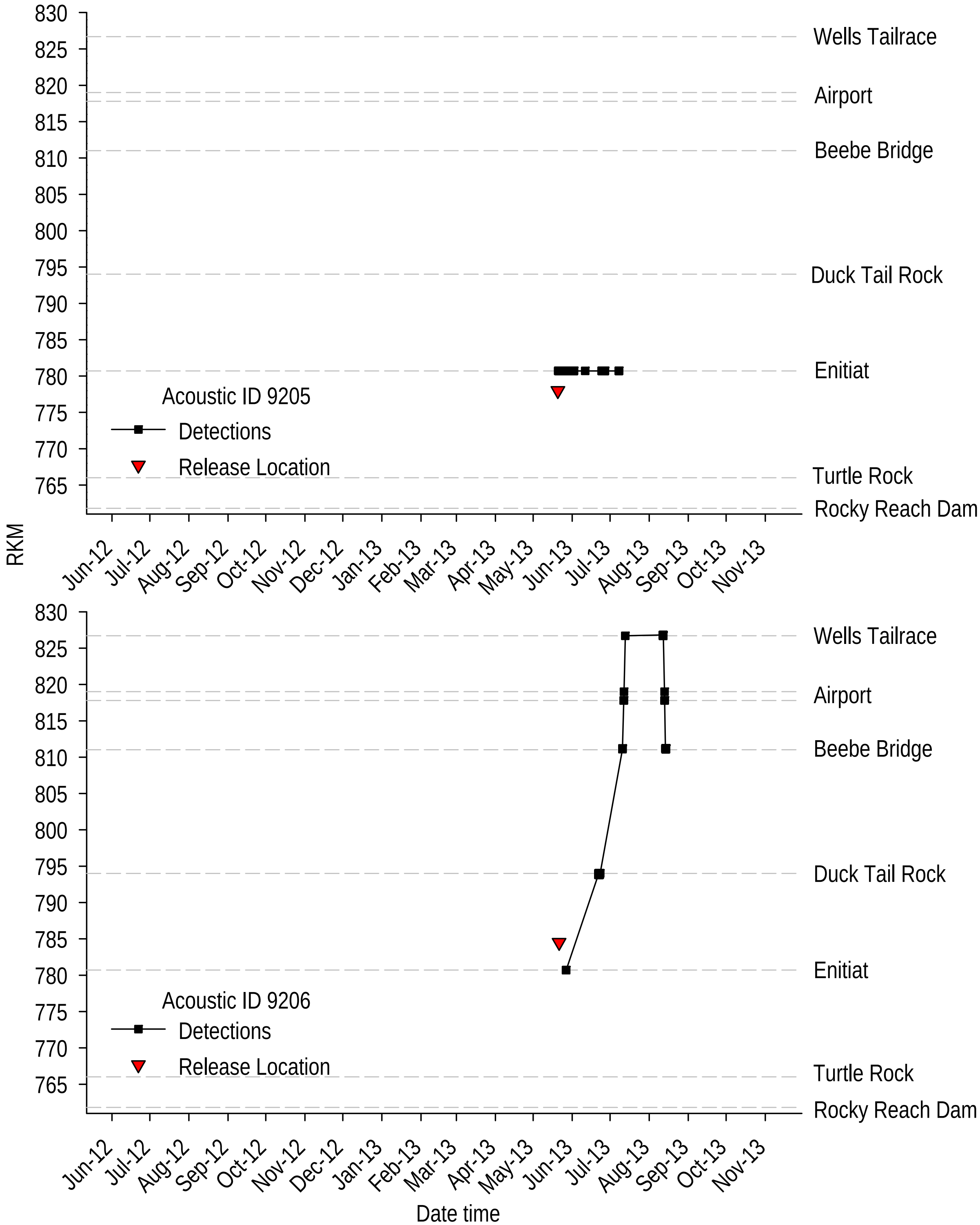
Rocky Reach Dam
Acoustic ID 9204
Detections
Release Location
Date time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Duck Tail Rock
Enitiat
Turtle Rock
Rocky Reach Dam
Acoustic ID 9205
Detections
Release Location
RKM
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Jul-12
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Sep-12
Oct-12
Nov-12
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Feb-13
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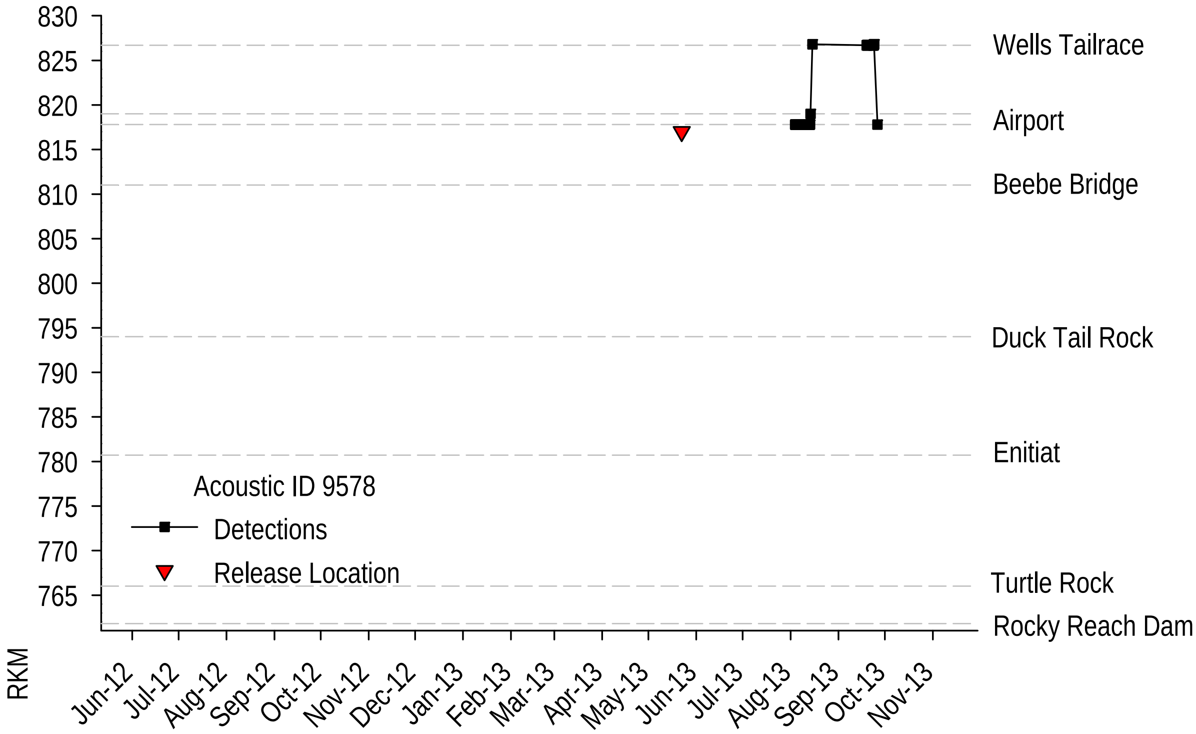
Detections
Release Location
Date time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Duck Tail Rock
Enitiat
Turtle Rock
Rocky Reach Dam
Acoustic ID 9578
Detections
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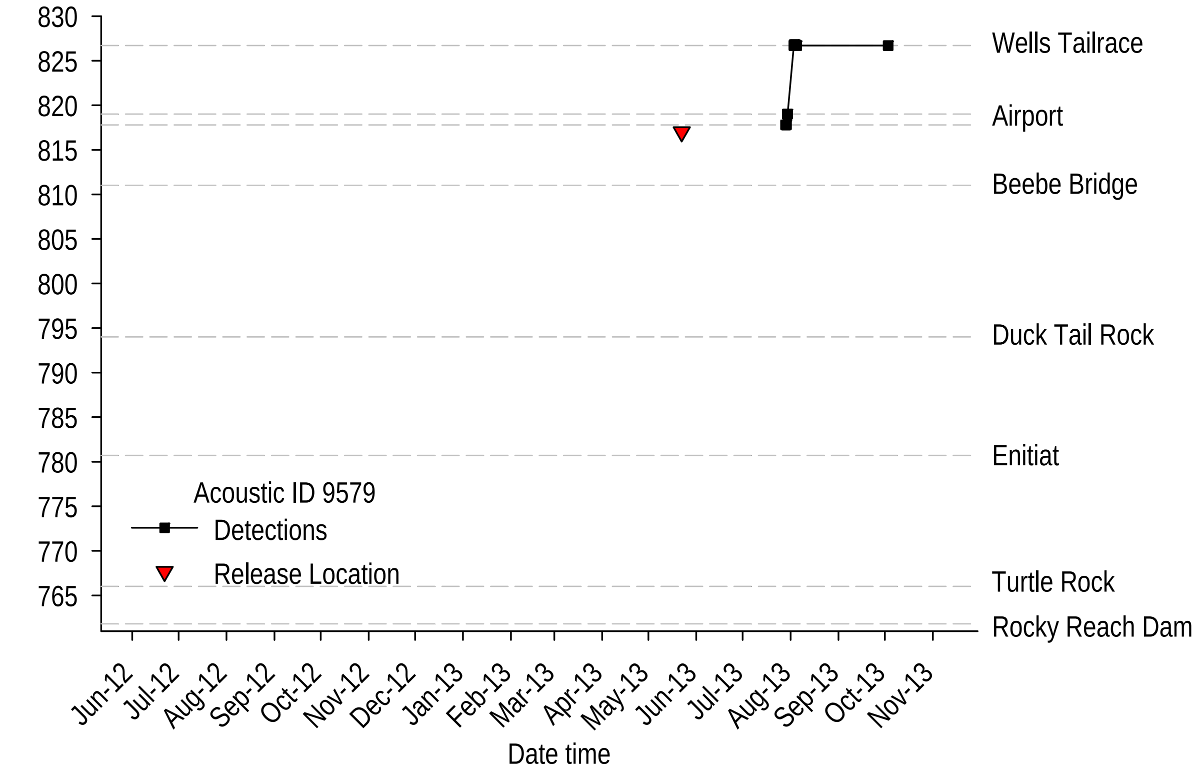
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Duck Tail Rock
Enitiat
Turtle Rock
Rocky Reach Dam
Acoustic ID 9579
Detections
Release Location
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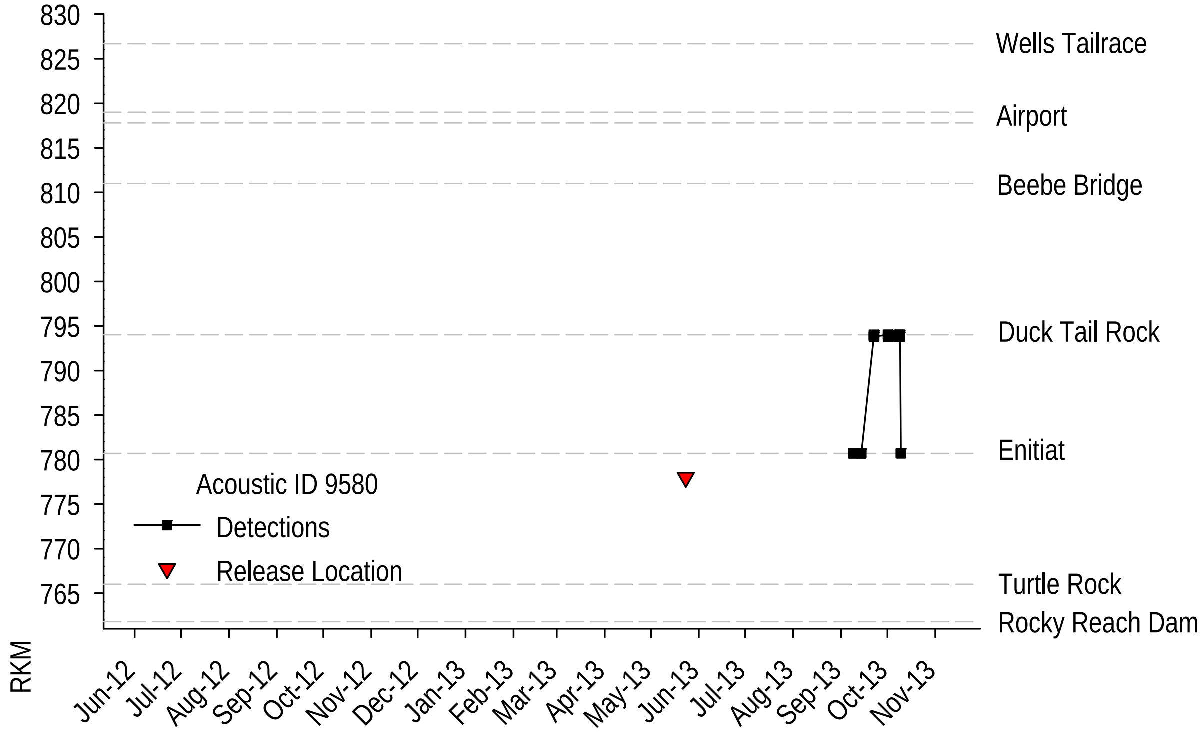
Date time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Duck Tail Rock
Enitiat
Turtle Rock
Rocky Reach Dam
Acoustic ID 9580
Detections
Release Location
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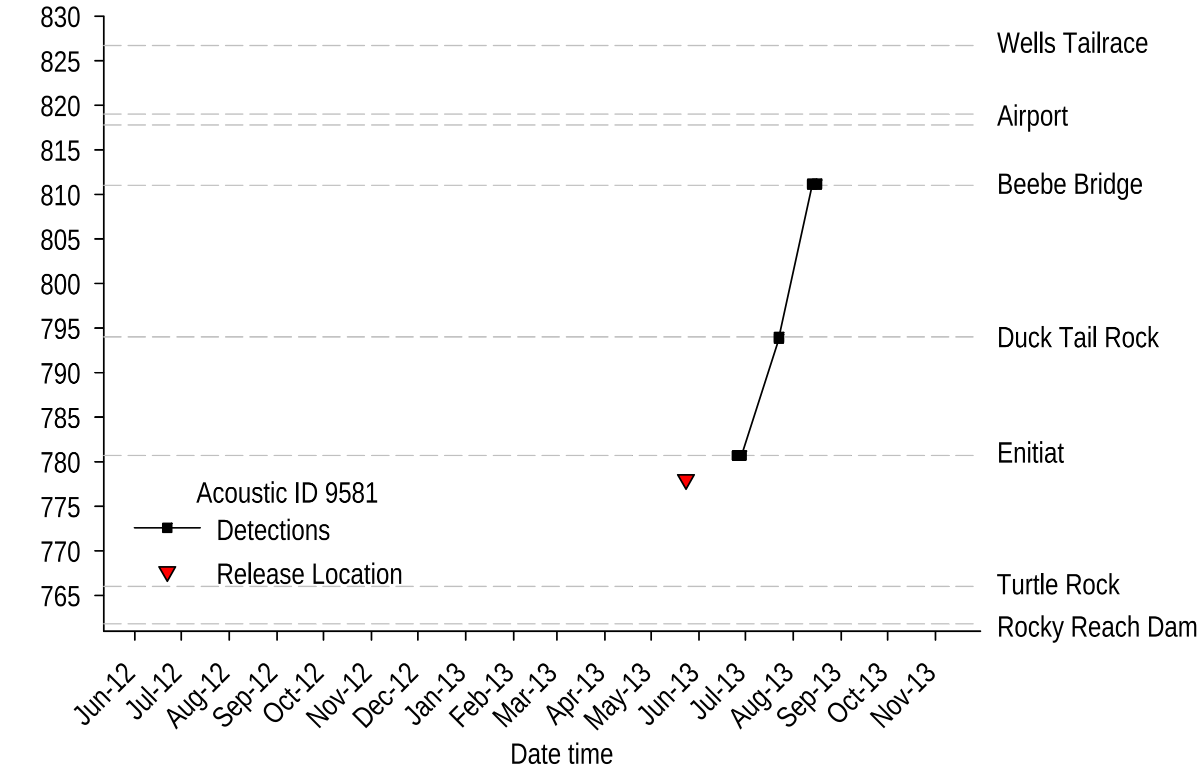
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Duck Tail Rock
Enitiat
Turtle Rock
Rocky Reach Dam
Acoustic ID 9581
Detections
Release Location
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Nov-12
Dec-12
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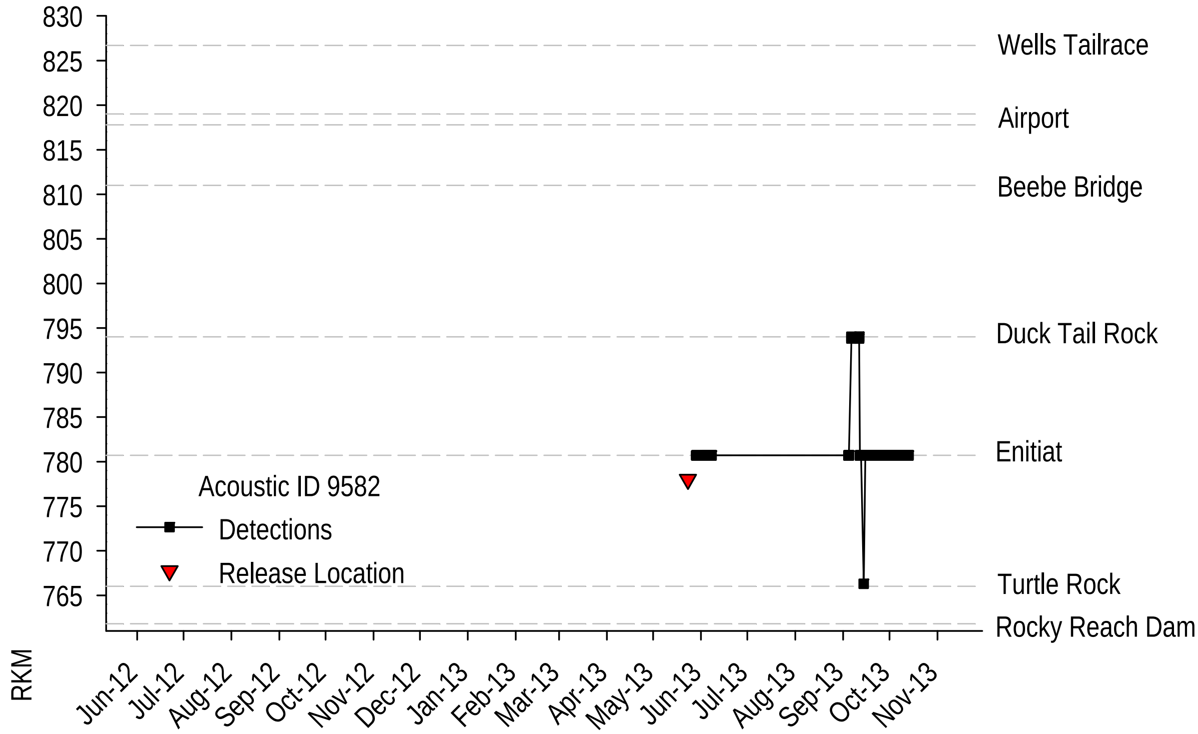
Date time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Duck Tail Rock
Enitiat
Turtle Rock
Rocky Reach Dam
Acoustic ID 9582
Detections
Release Location
RKM
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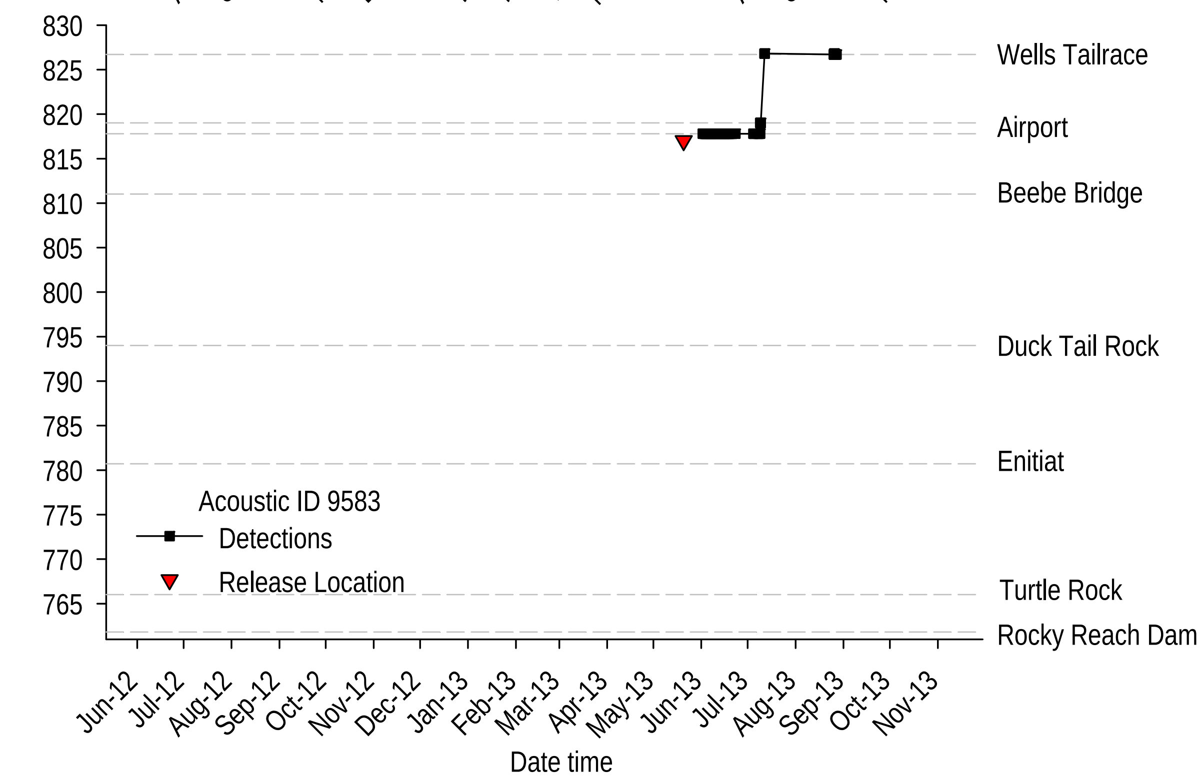
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Duck Tail Rock
Enitiat
Turtle Rock
Rocky Reach Dam
Acoustic ID 9583
Detections
Release Location
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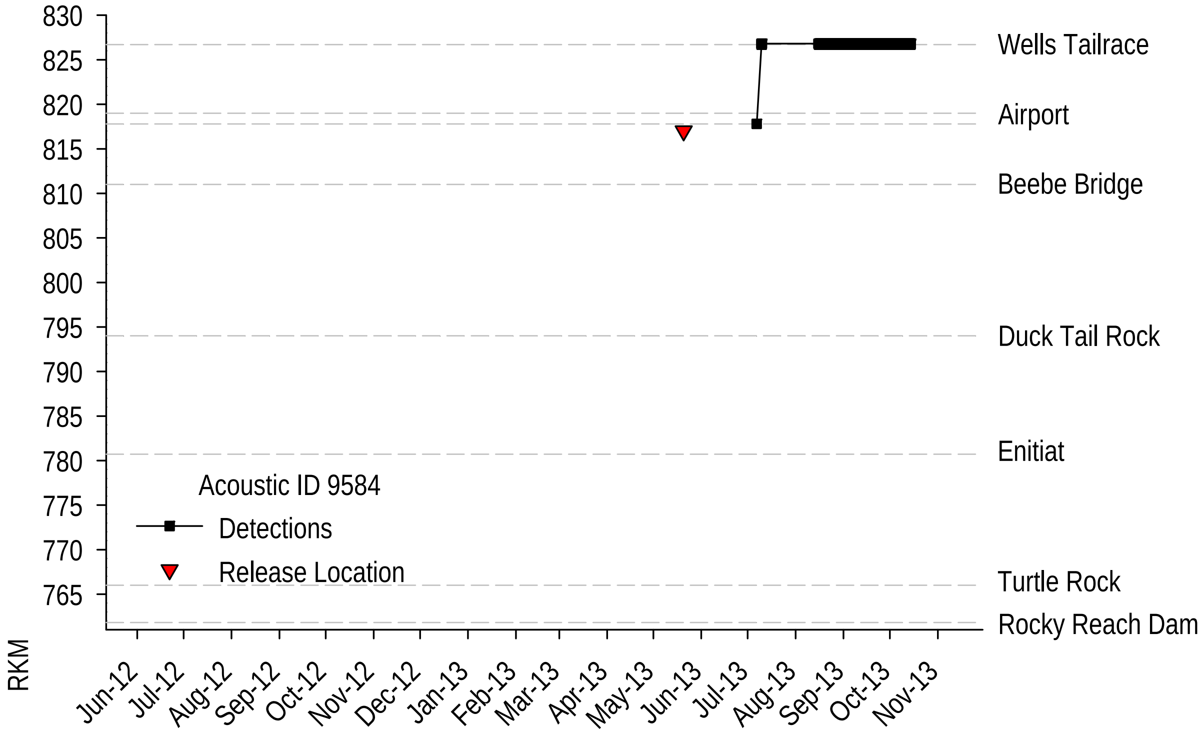
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RKM
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Duck Tail Rock
Enitiat
Turtle Rock
Rocky Reach Dam
Acoustic ID 9584
Detections
Release Location
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Sep-12
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Nov-12
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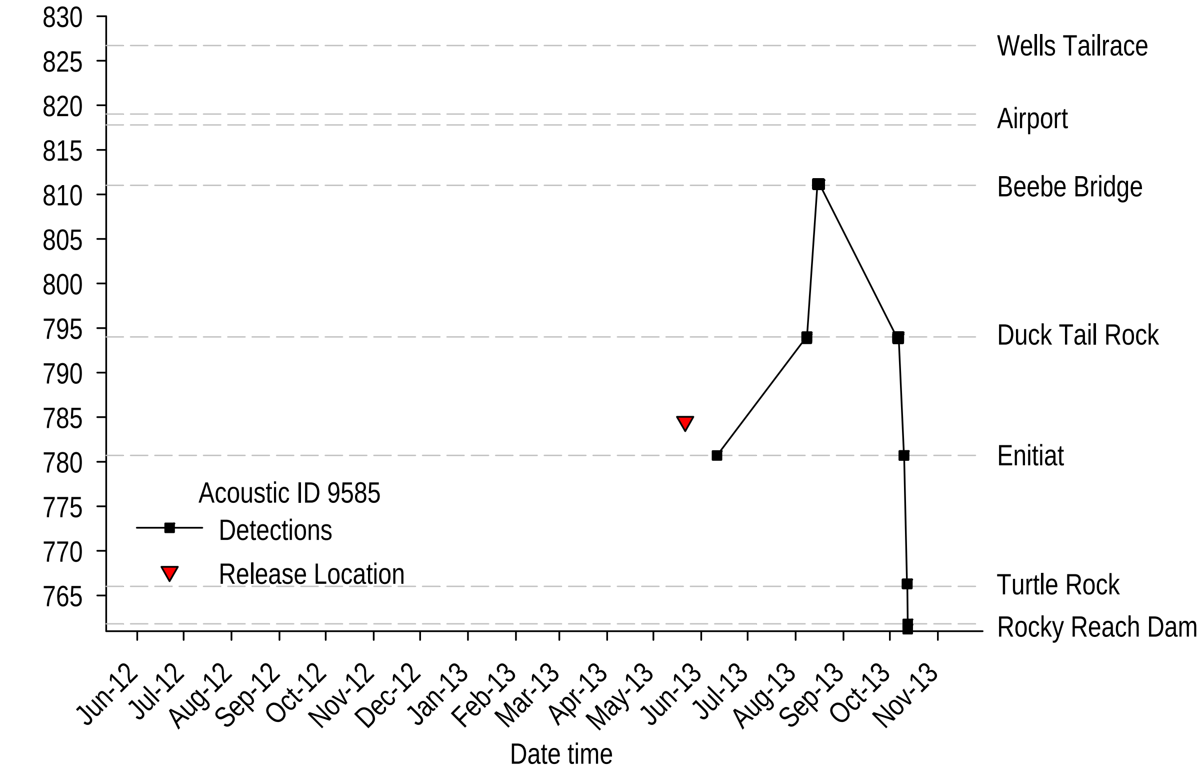
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Duck Tail Rock
Enitiat
Turtle Rock
Rocky Reach Dam
Acoustic ID 9585
Detections
Release Location
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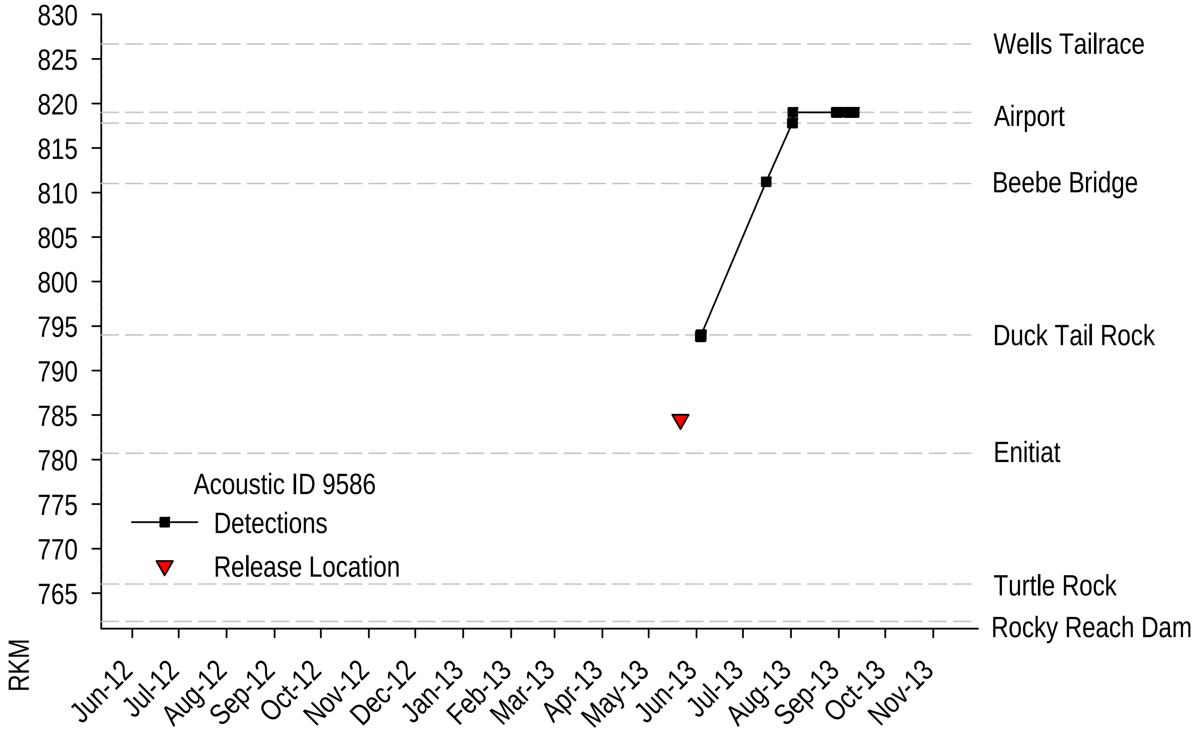
Date time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Duck Tail Rock
Enitiat
Turtle Rock
Rocky Reach Dam
Acoustic ID 9586
Detections
Release Location
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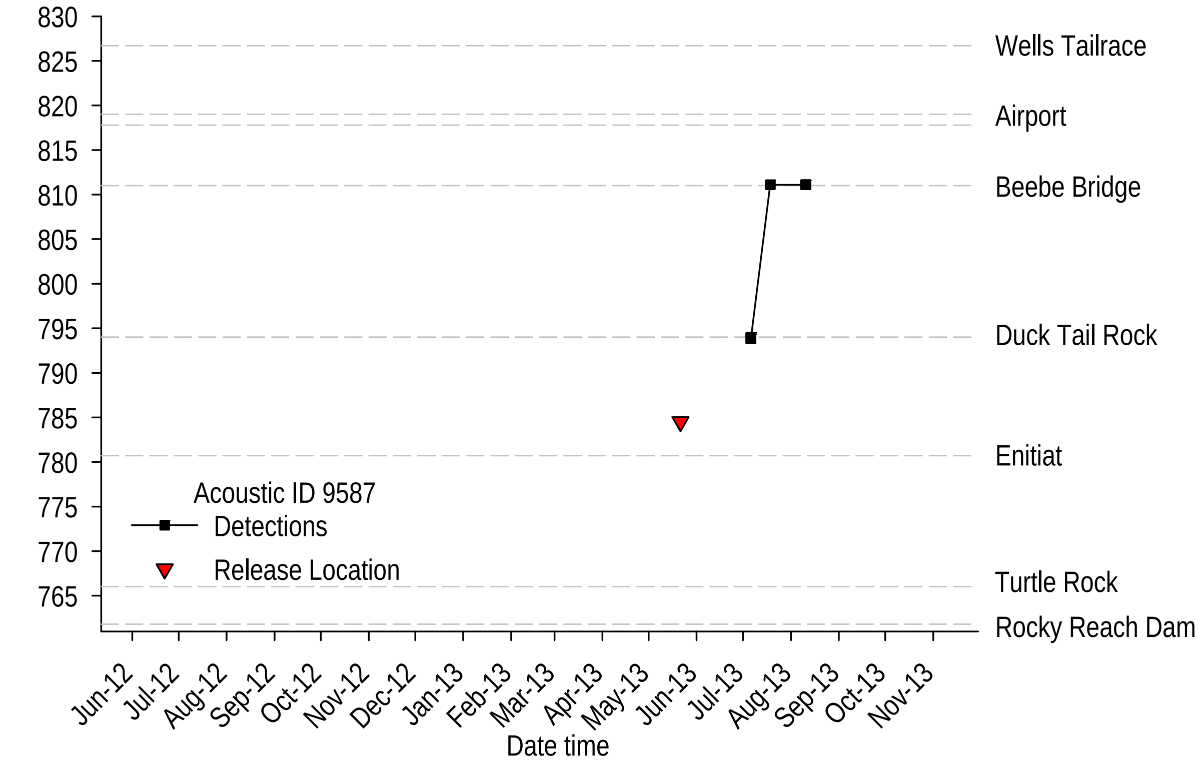
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Beebe Bridge
Duck Tail Rock
Enitiat
Turtle Rock
Rocky Reach Dam
Acoustic ID 9587
Detections
Release Location
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Nov-12
Dec-12
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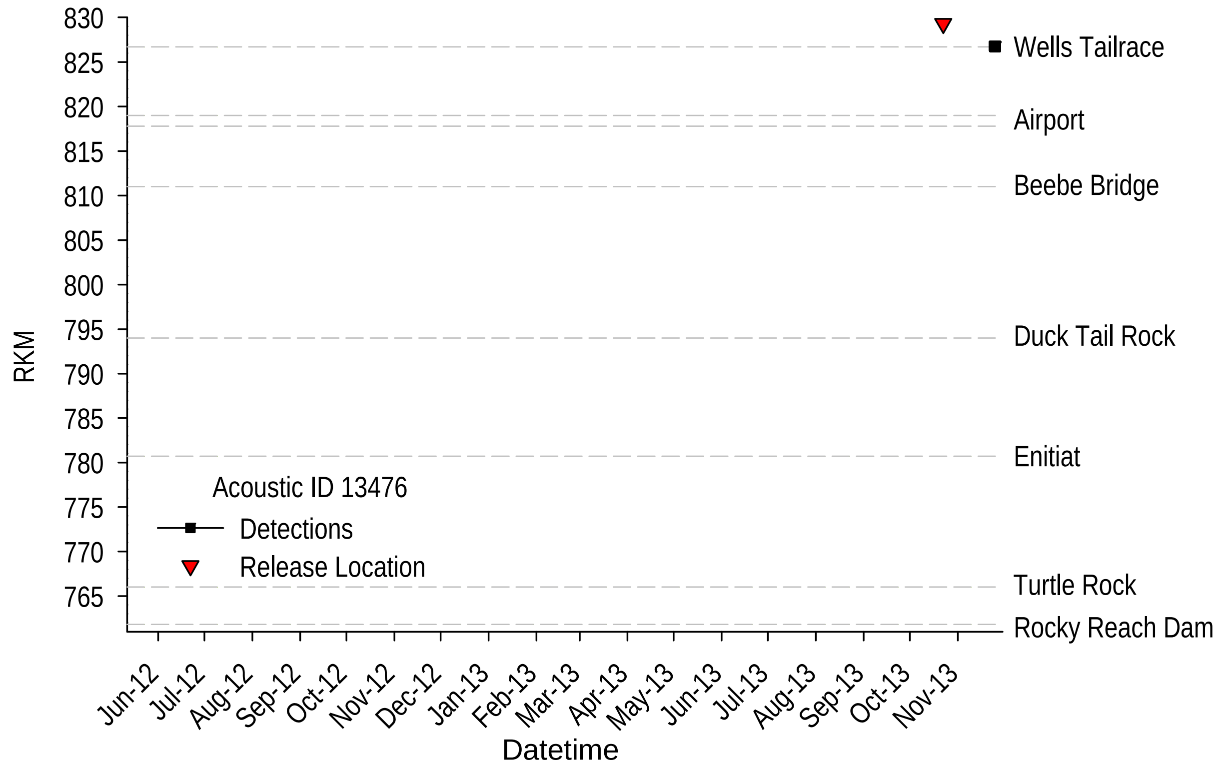
Date time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Wells Tailrace
Airport
Beebe Bridge
Duck Tail Rock
Enitiat
Turtle Rock
Rocky Reach Dam
Acoustic ID 13476
Detections
Release Location
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Nov-12
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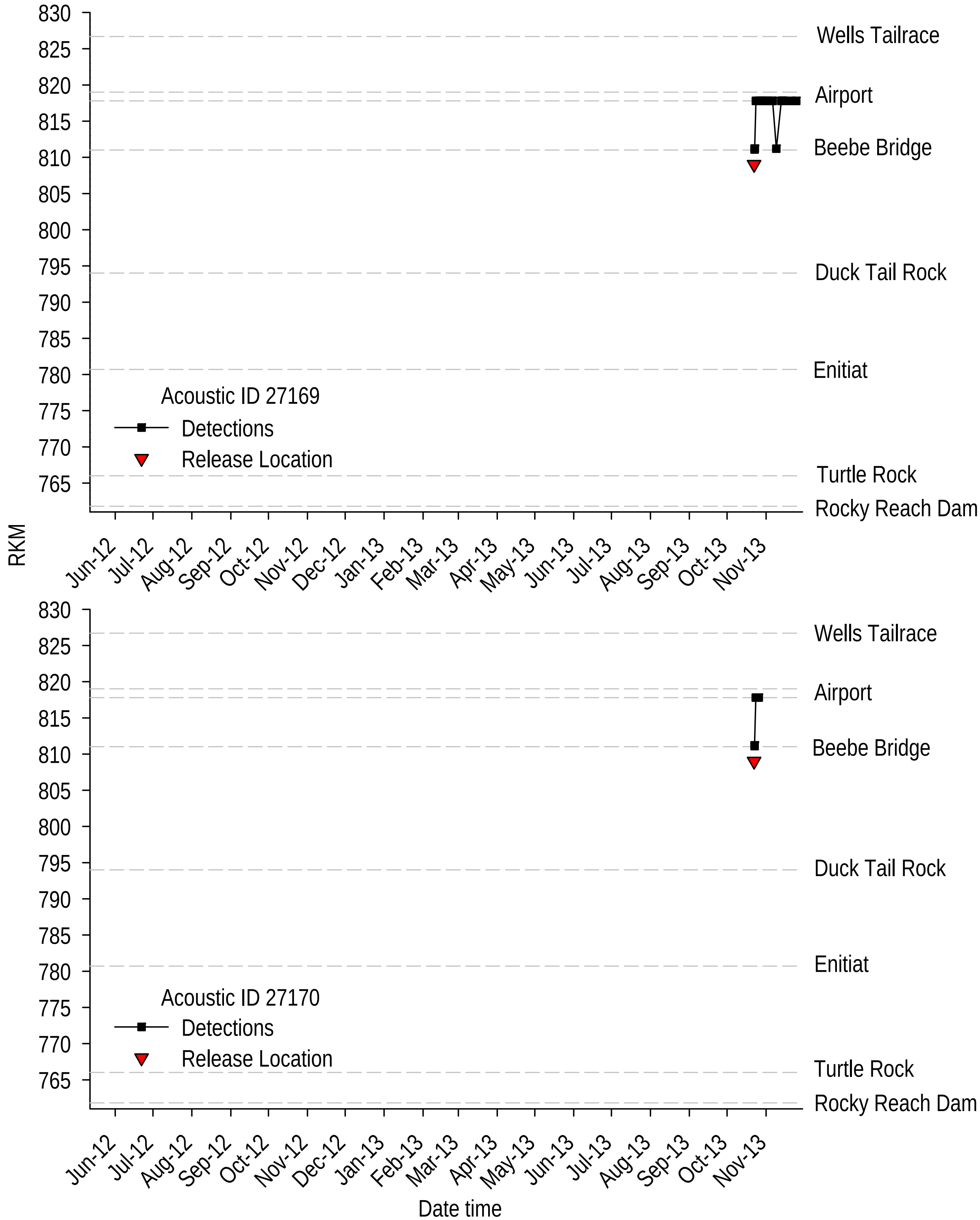
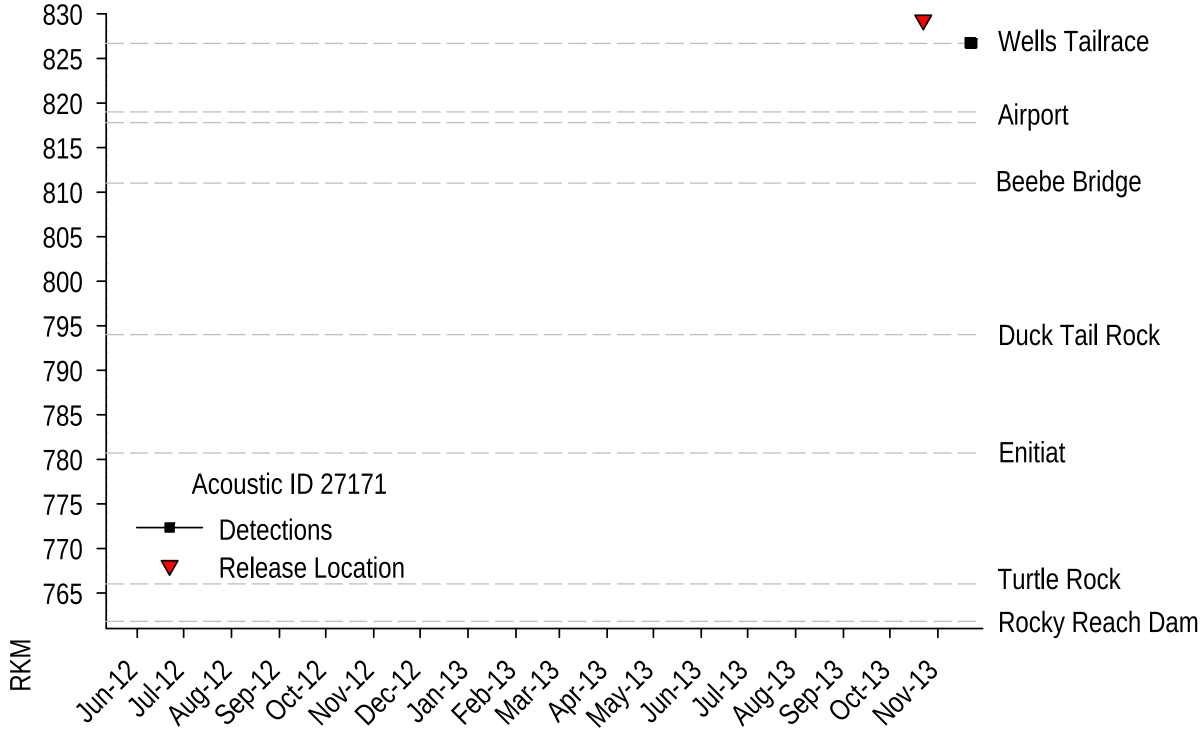


Appendix C - 16



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Airport
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Duck Tail Rock
Enitiat
Turtle Rock
Rocky Reach Dam
Acoustic ID 27171
Detections
Release Location
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Nov-12
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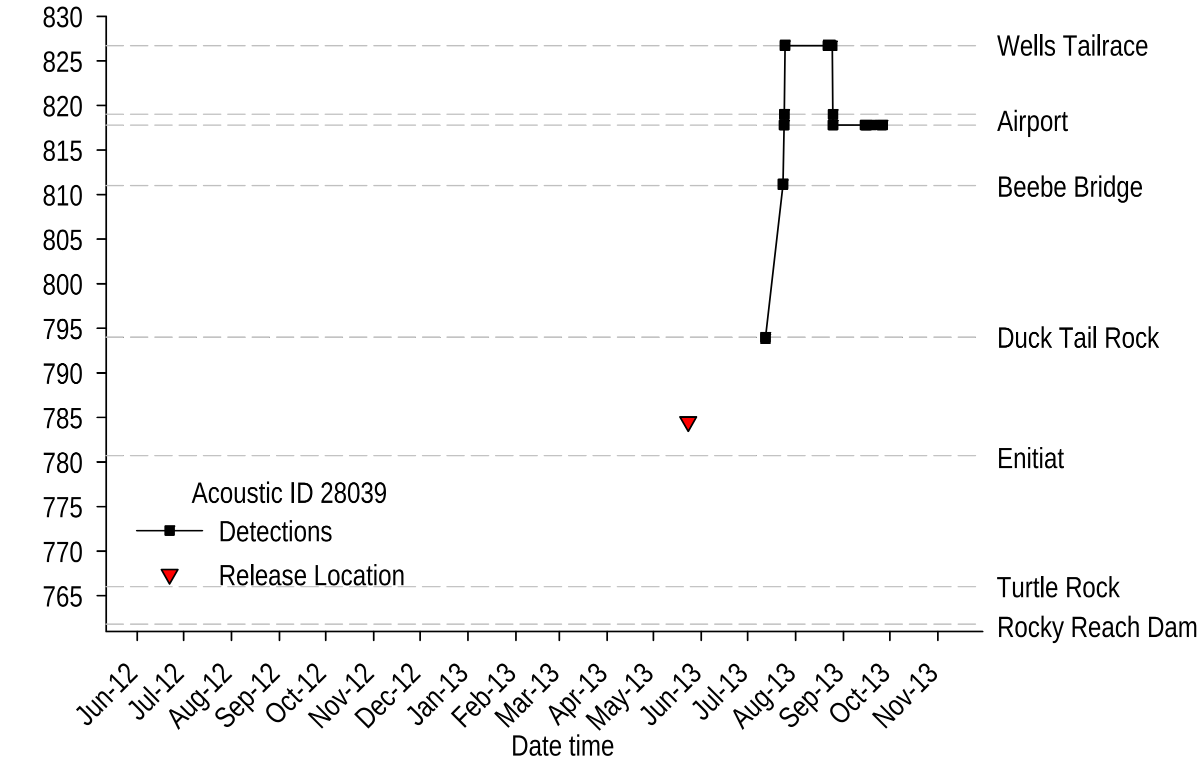

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Beebe Bridge
Duck Tail Rock
Enitiat
Turtle Rock
Rocky Reach Dam
Acoustic ID 28039
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Release Location
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Nov-12
Dec-12
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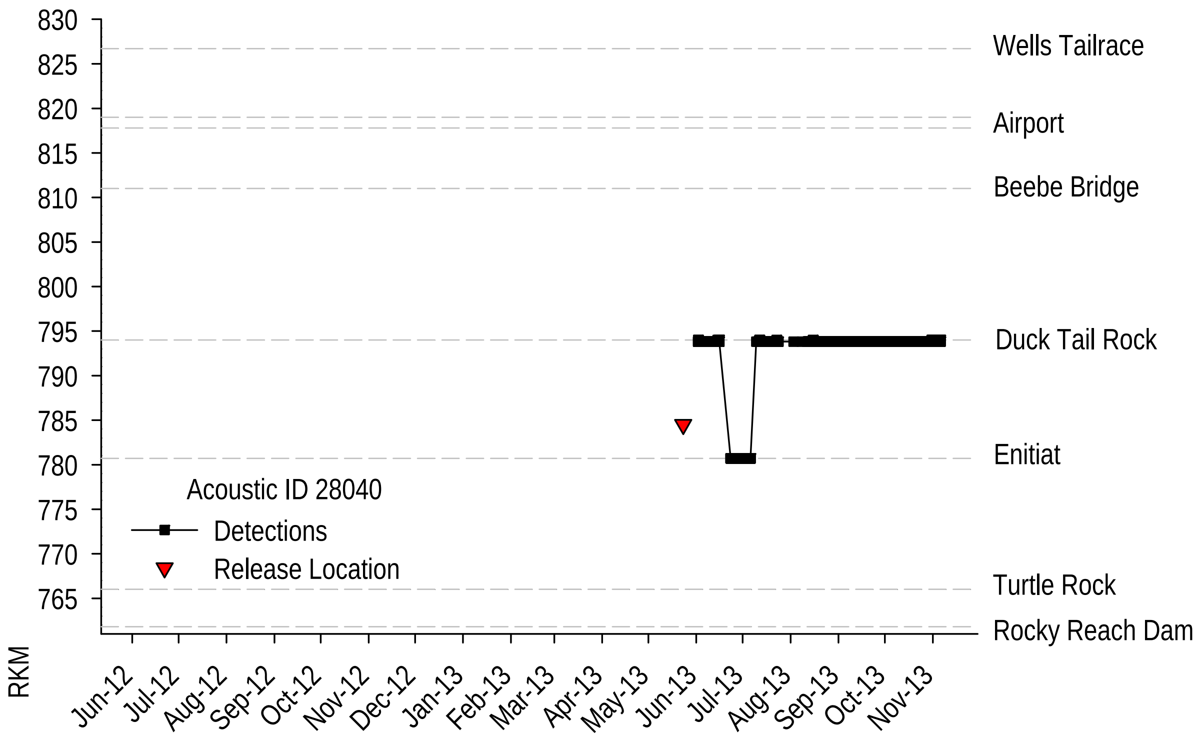
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Duck Tail Rock
Enitiat
Turtle Rock
Rocky Reach Dam
Acoustic ID 28040
Detections
Release Location
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Aug-12
Sep-12
Oct-12
Nov-12
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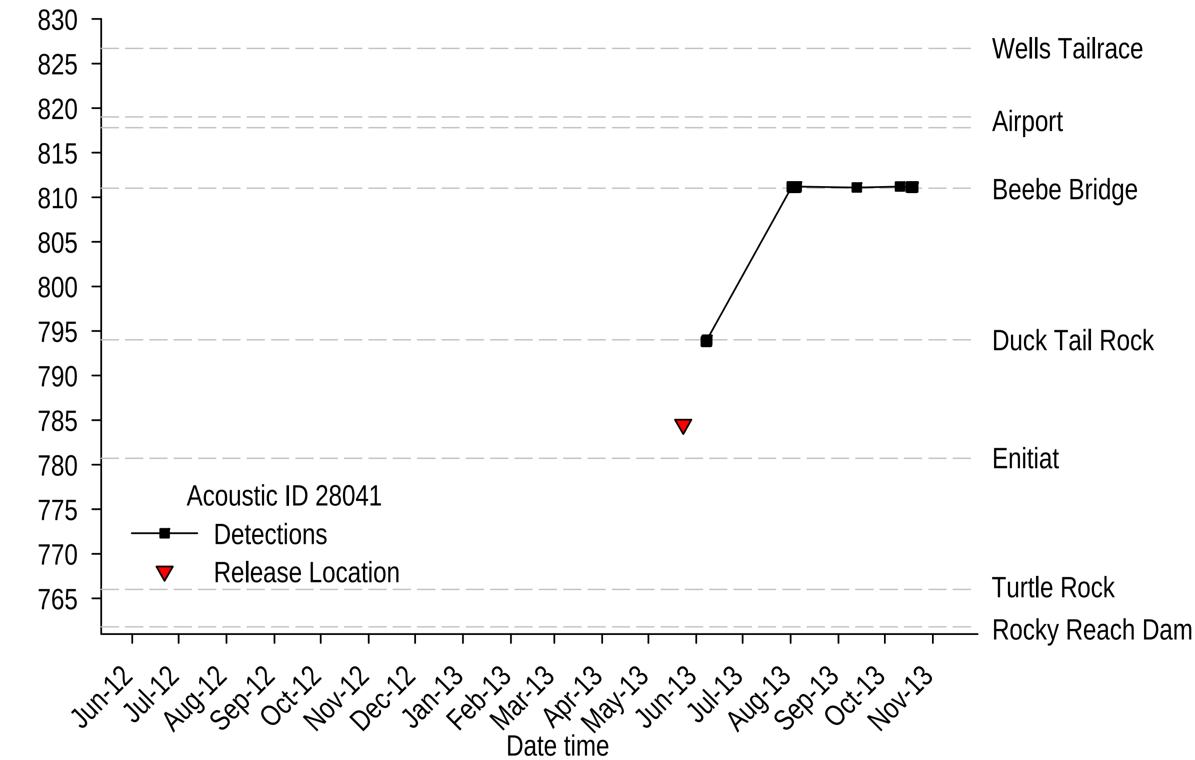
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Duck Tail Rock
Enitiat
Turtle Rock
Rocky Reach Dam
Acoustic ID 28041
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Release Location
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Oct-12
Nov-12
Dec-12
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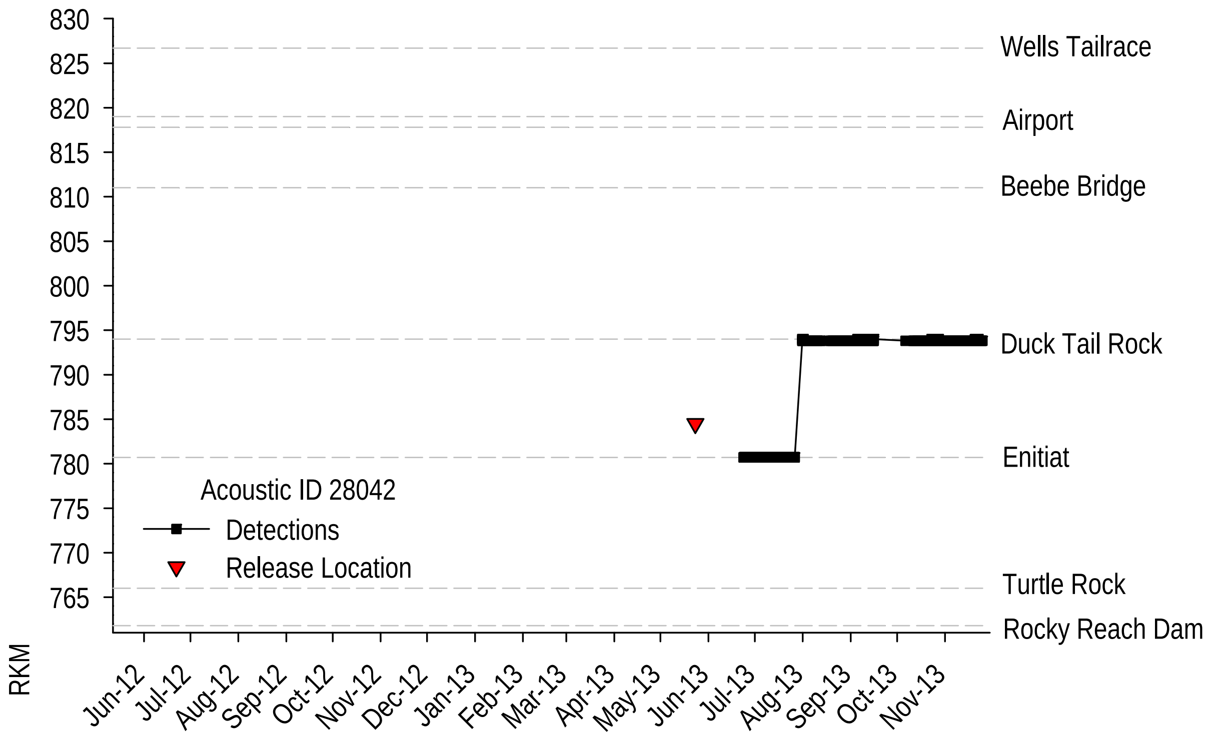
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Duck Tail Rock
Enitiat
Turtle Rock
Rocky Reach Dam
Acoustic ID 28042
Detections
Release Location
RKM
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Oct-12
Nov-12
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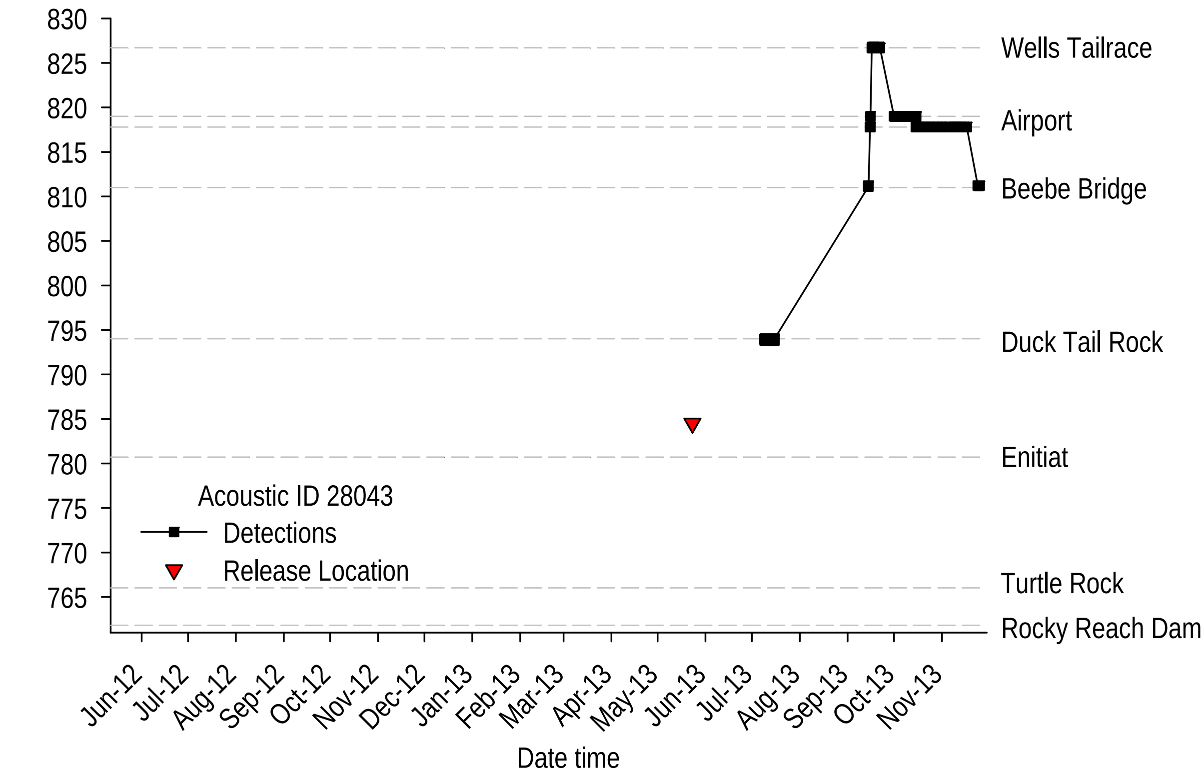
Nov-13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Duck Tail Rock
Enitiat
Turtle Rock
Rocky Reach Dam
Acoustic ID 28043
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Release Location
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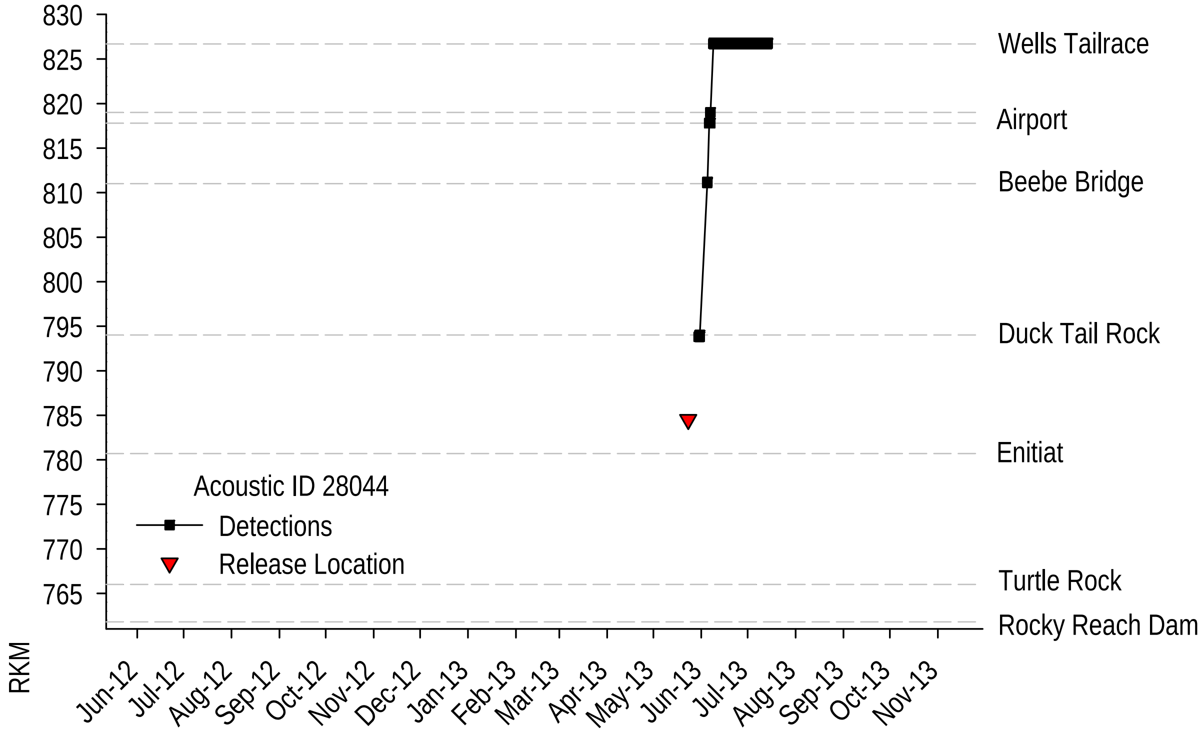
Date time



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Beebe Bridge
Duck Tail Rock
Enitiat
Turtle Rock
Rocky Reach Dam
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765
Jun-12
Jul-12
Aug-12
Sep-12
Oct-12
Nov-12
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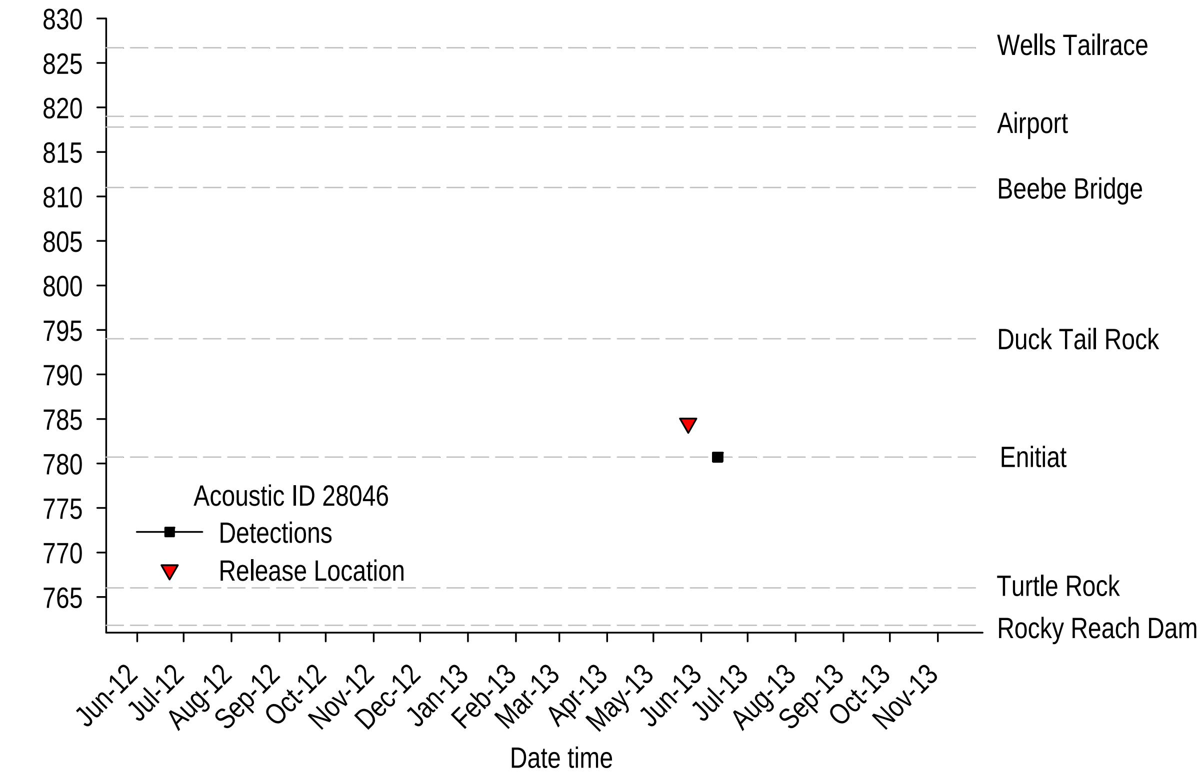

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Airport
Beebe Bridge
Duck Tail Rock
Enitiat
Turtle Rock
Rocky Reach Dam
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815
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805
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795
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765
Jun-12
Jul-12
Aug-12
Sep-12
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Dec-12
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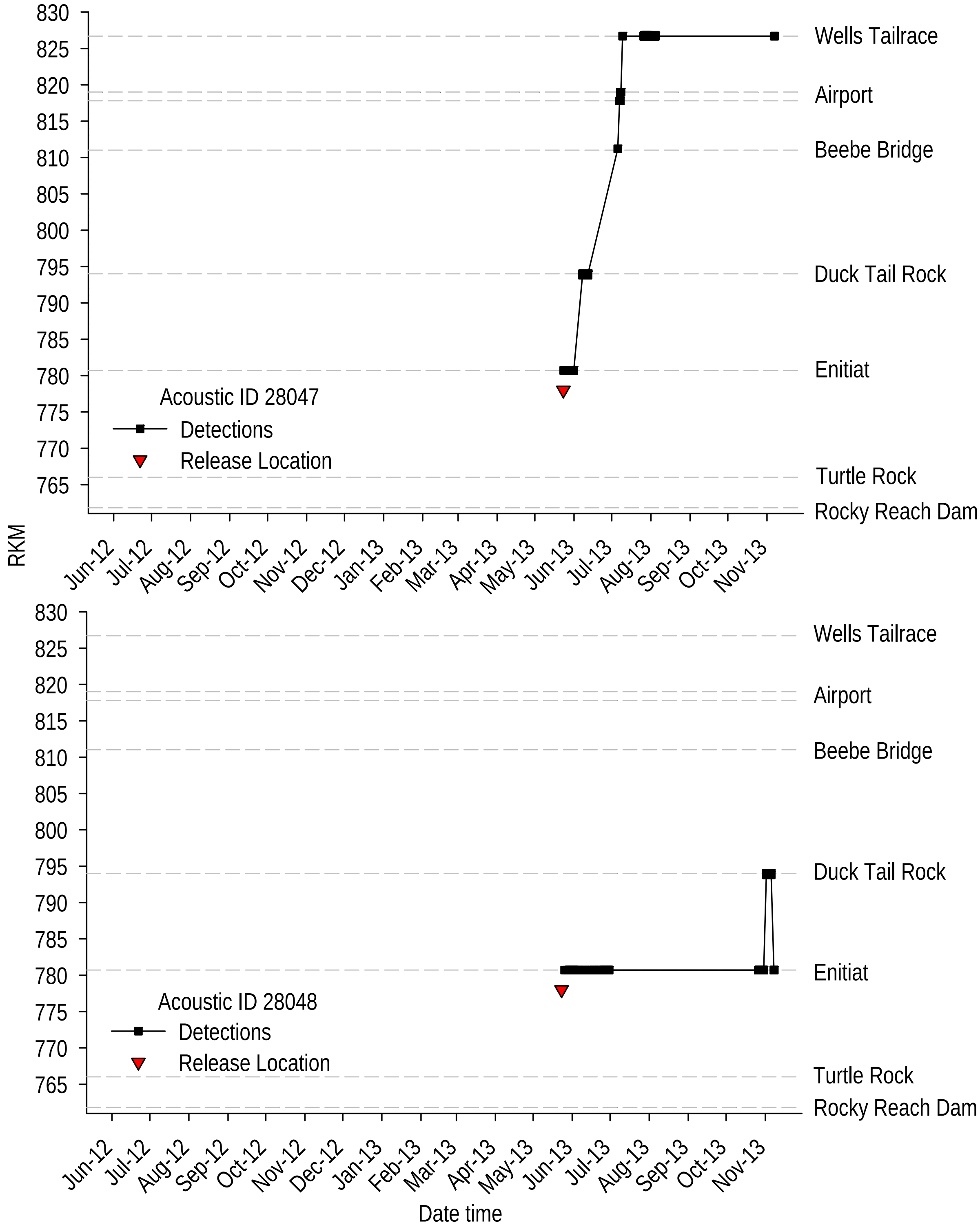
Oct-13
Nov-13
Date time



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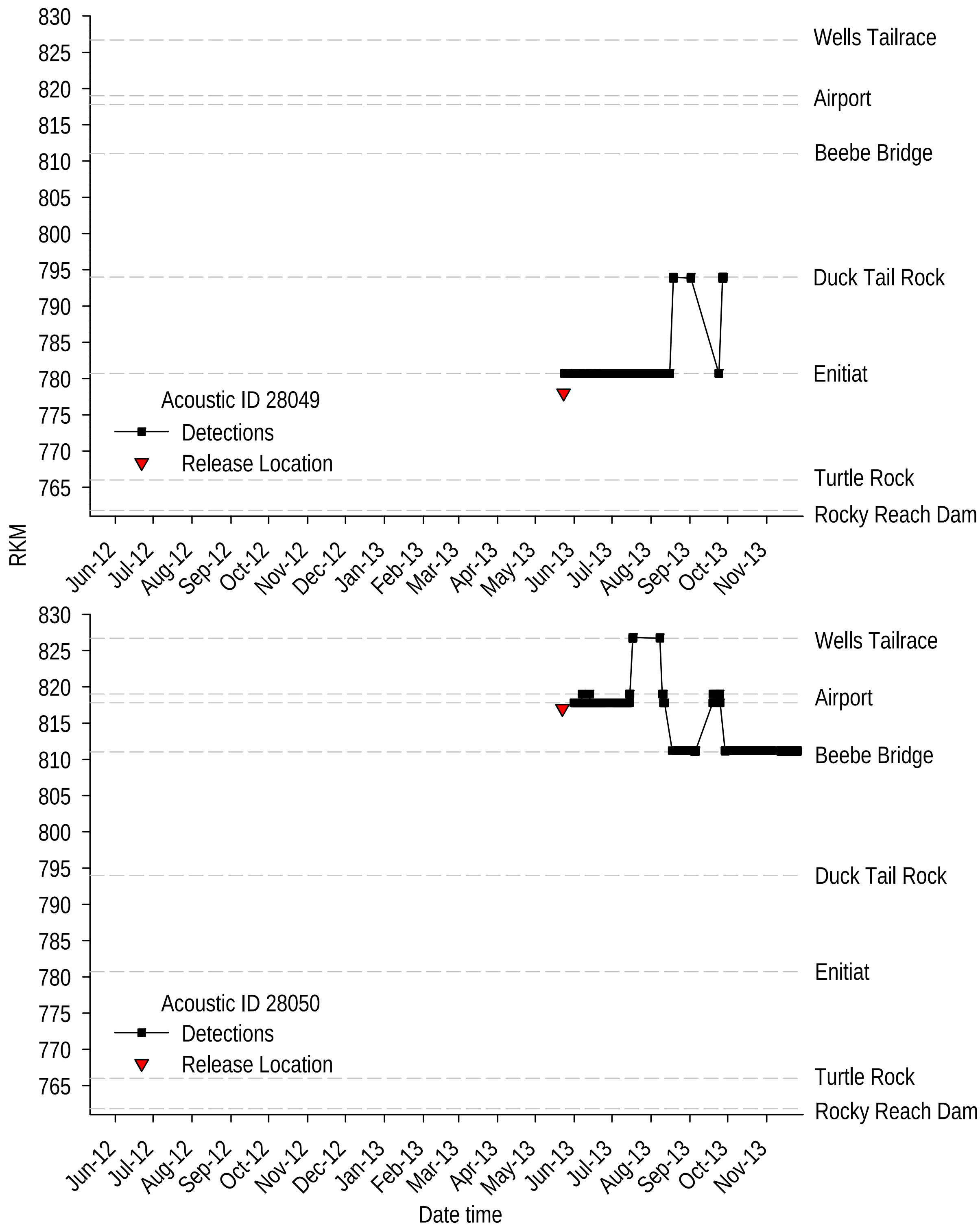
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Airport
Beebe Bridge
Duck Tail Rock
Enitiat
Turtle Rock
Rocky Reach Dam
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Acoustic ID 28050
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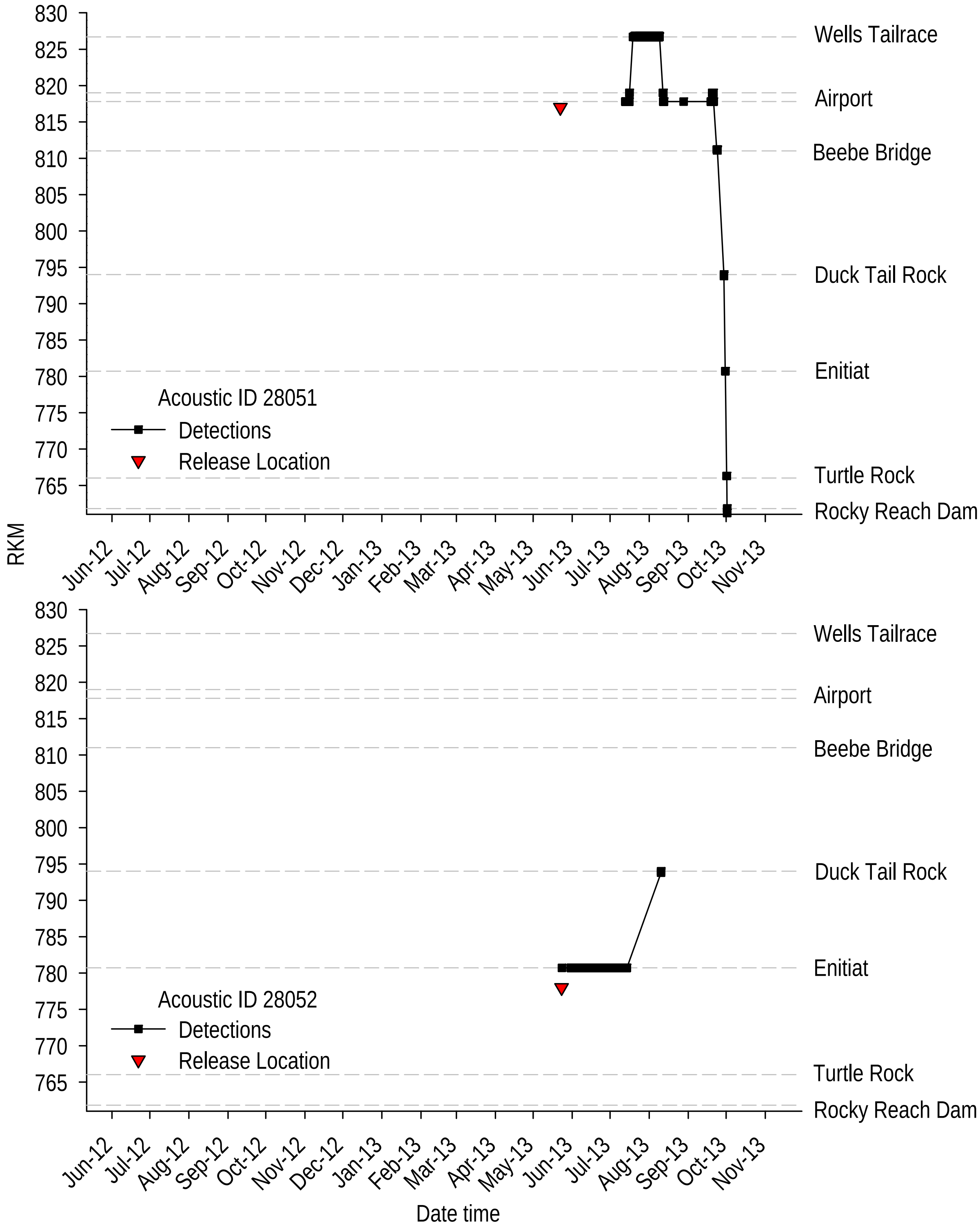
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RKM
Wells Tailrace
Airport
Beebe Bridge
Duck Tail Rock
Enitiat
Turtle Rock
Rocky Reach Dam
Acoustic ID 28051
Detections
Release Location
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Jul-12
Aug-12
Sep-12
Oct-12
Nov-12
Dec-12
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Feb-13
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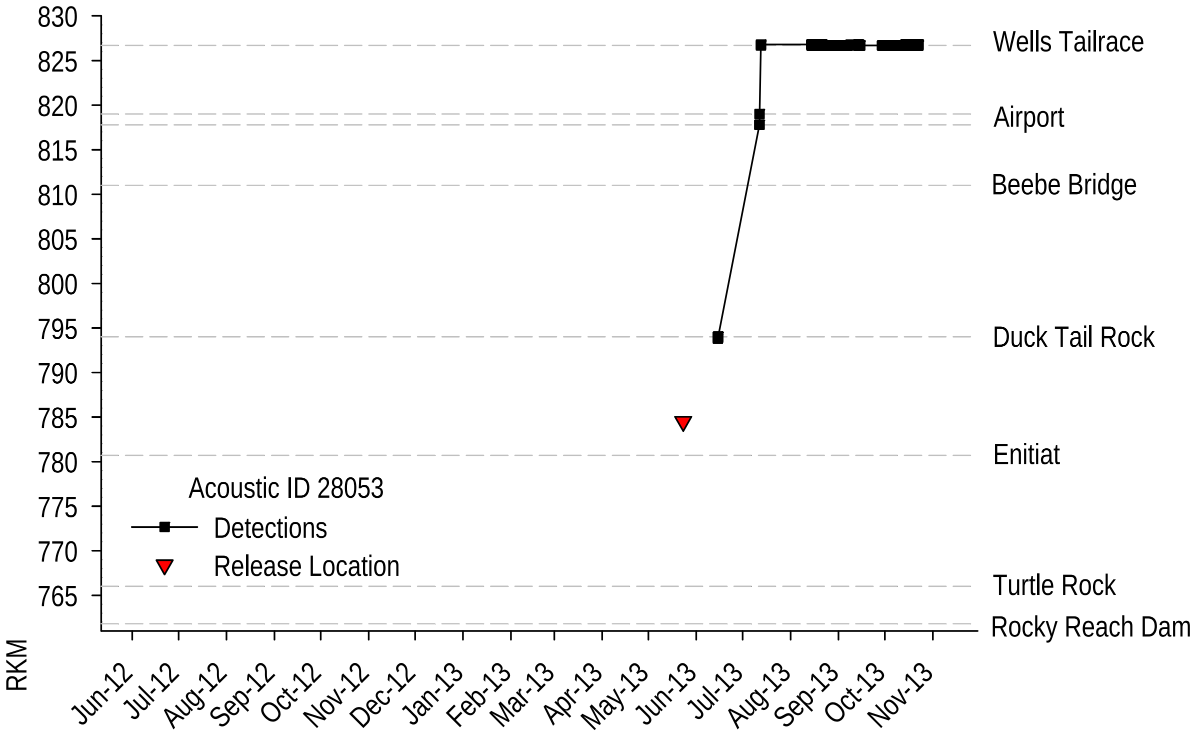
Detections
Release Location
Date time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Airport
Beebe Bridge
Duck Tail Rock
Enitiat
Turtle Rock
Rocky Reach Dam
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Detections
Release Location
RKM
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Jul-12
Aug-12
Sep-12
Oct-12
Nov-12
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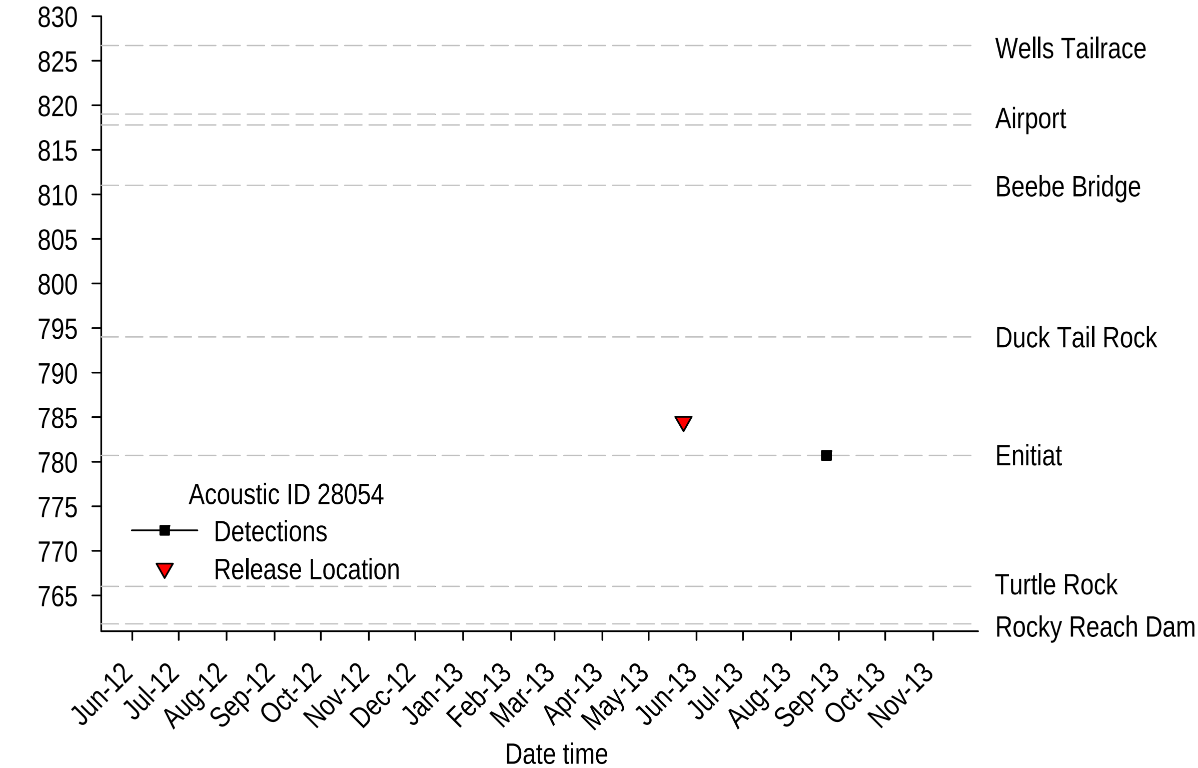
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Airport
Beebe Bridge
Duck Tail Rock
Enitiat
Turtle Rock
Rocky Reach Dam
Acoustic ID 28054
Detections
Release Location
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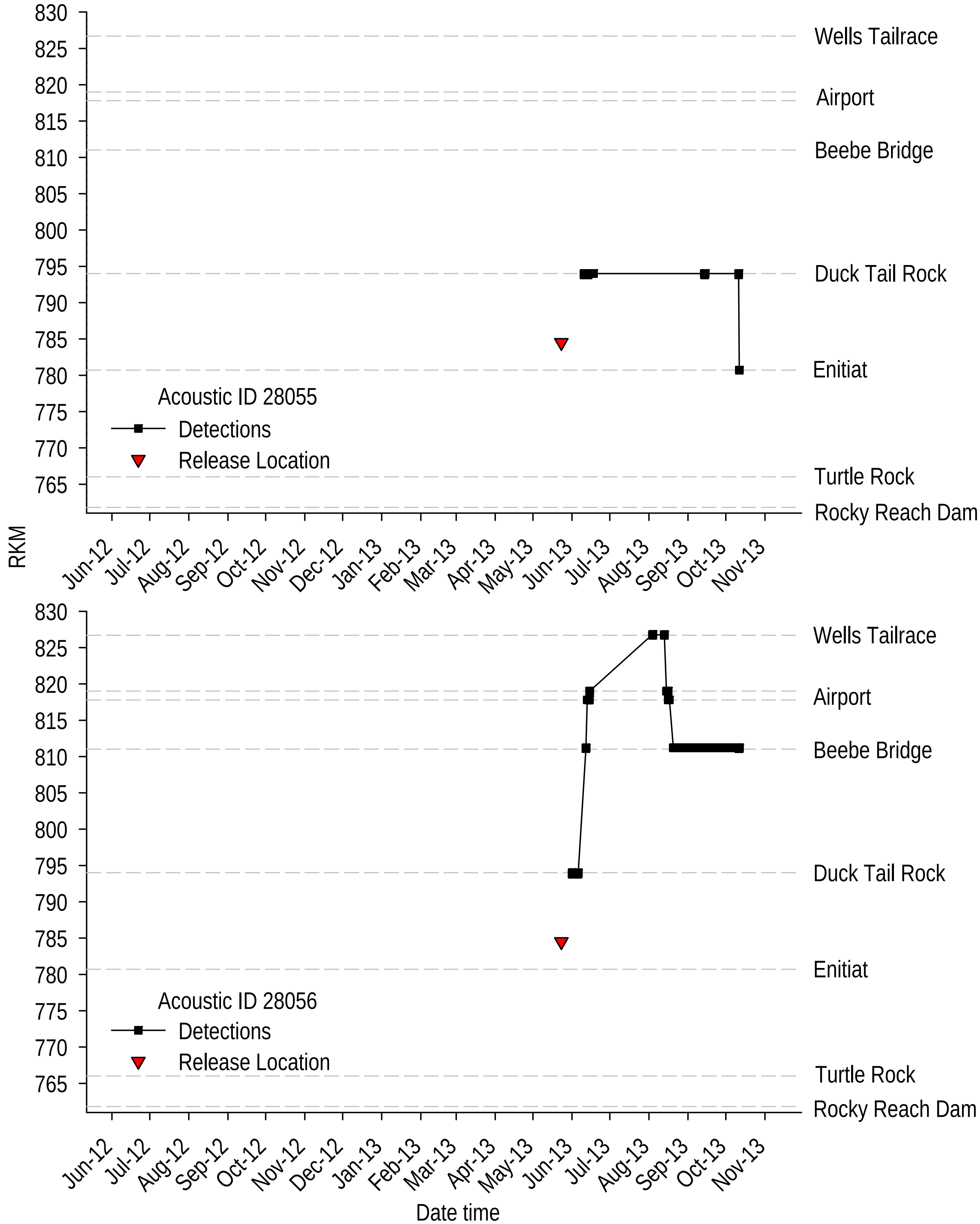
Date time



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Duck Tail Rock
Enitiat
Turtle Rock
Rocky Reach Dam
Acoustic ID 28055
Detections
Release Location
RKM
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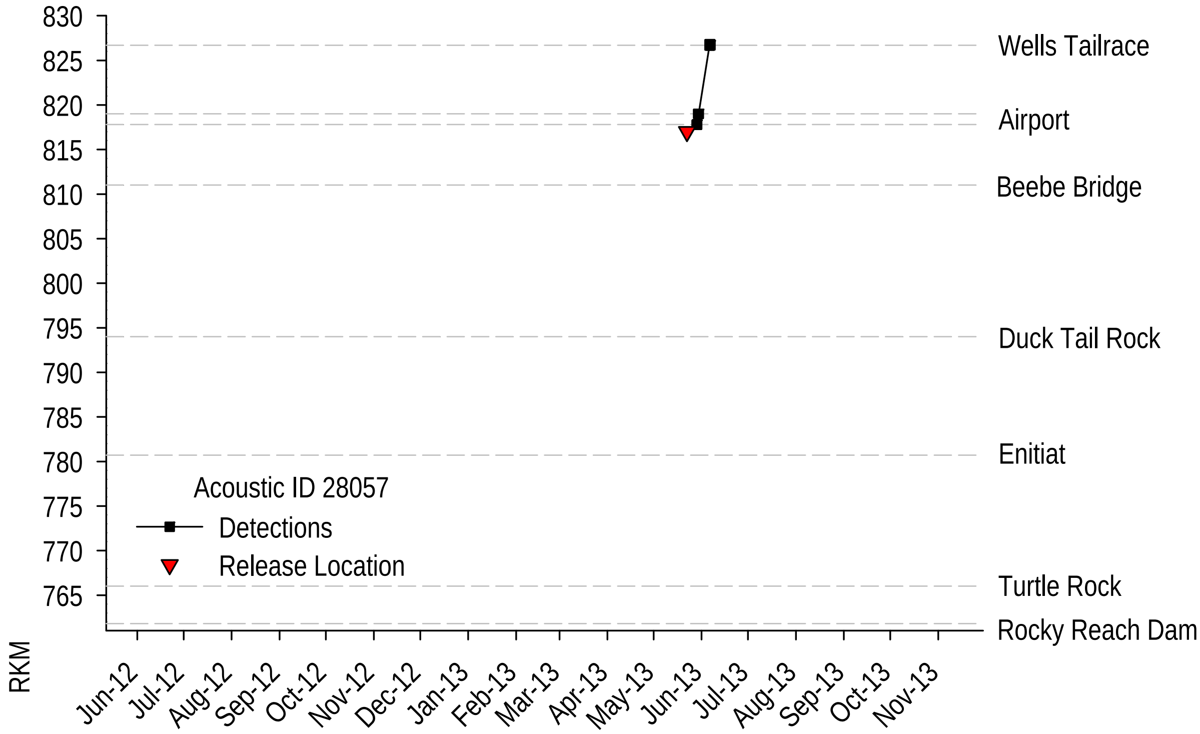
Date time



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Airport
Beebe Bridge
Duck Tail Rock
Enitiat
Turtle Rock
Rocky Reach Dam
Acoustic ID 28057
Detections
Release Location
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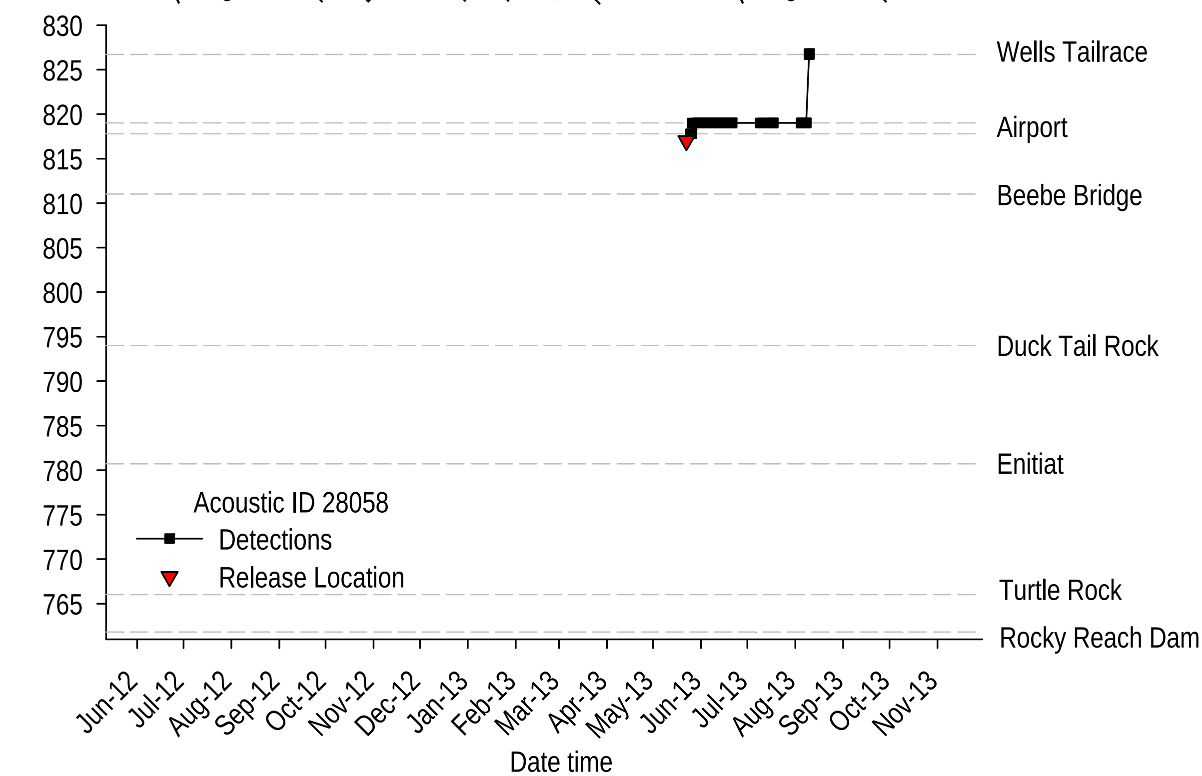
Nov-13



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Airport
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Duck Tail Rock
Enitiat
Turtle Rock
Rocky Reach Dam
Acoustic ID 28058
Detections
Release Location
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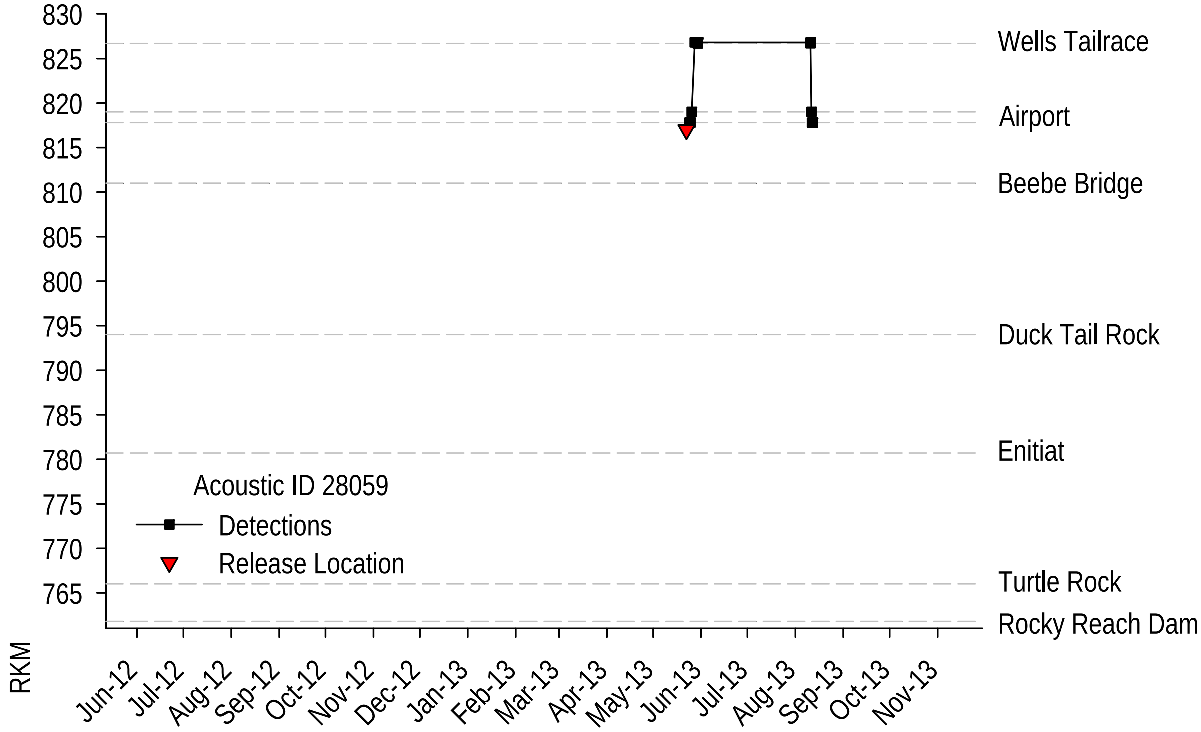

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Duck Tail Rock
Enitiat
Turtle Rock
Rocky Reach Dam
Acoustic ID 28059
Detections
Release Location
RKM
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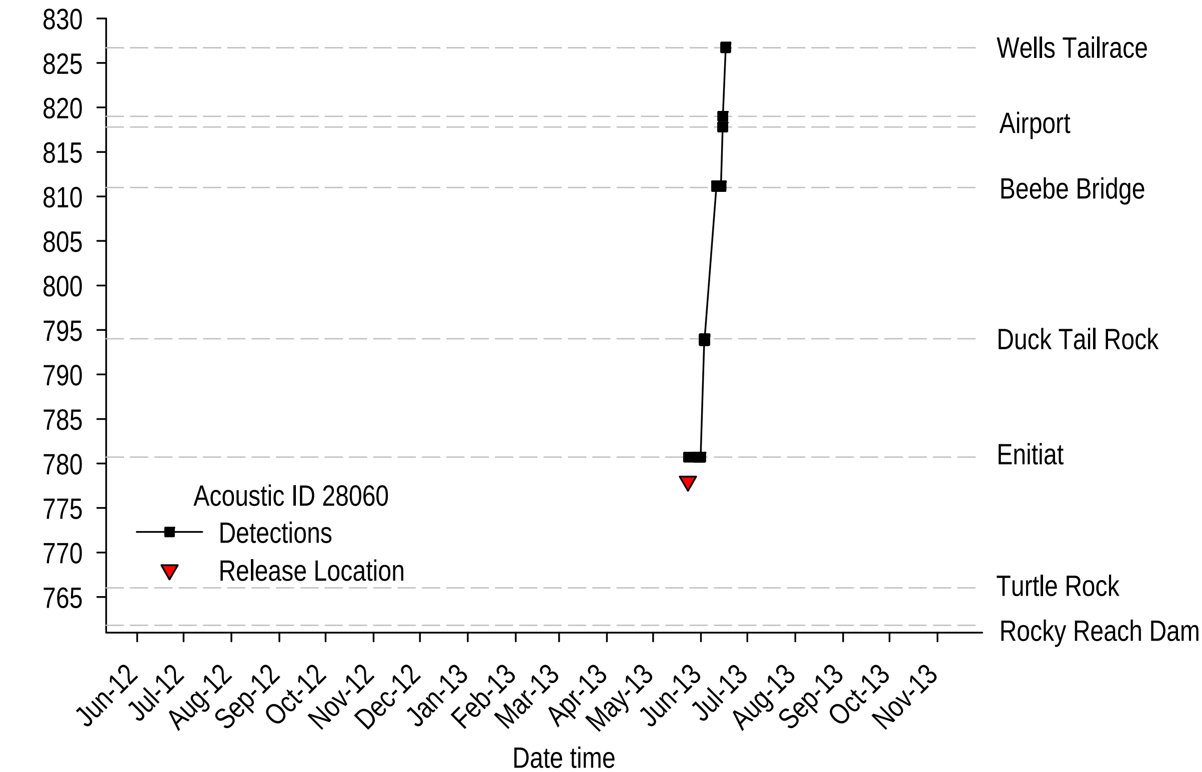

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Duck Tail Rock
Enitiat
Turtle Rock
Rocky Reach Dam
Acoustic ID 28060
Detections
Release Location
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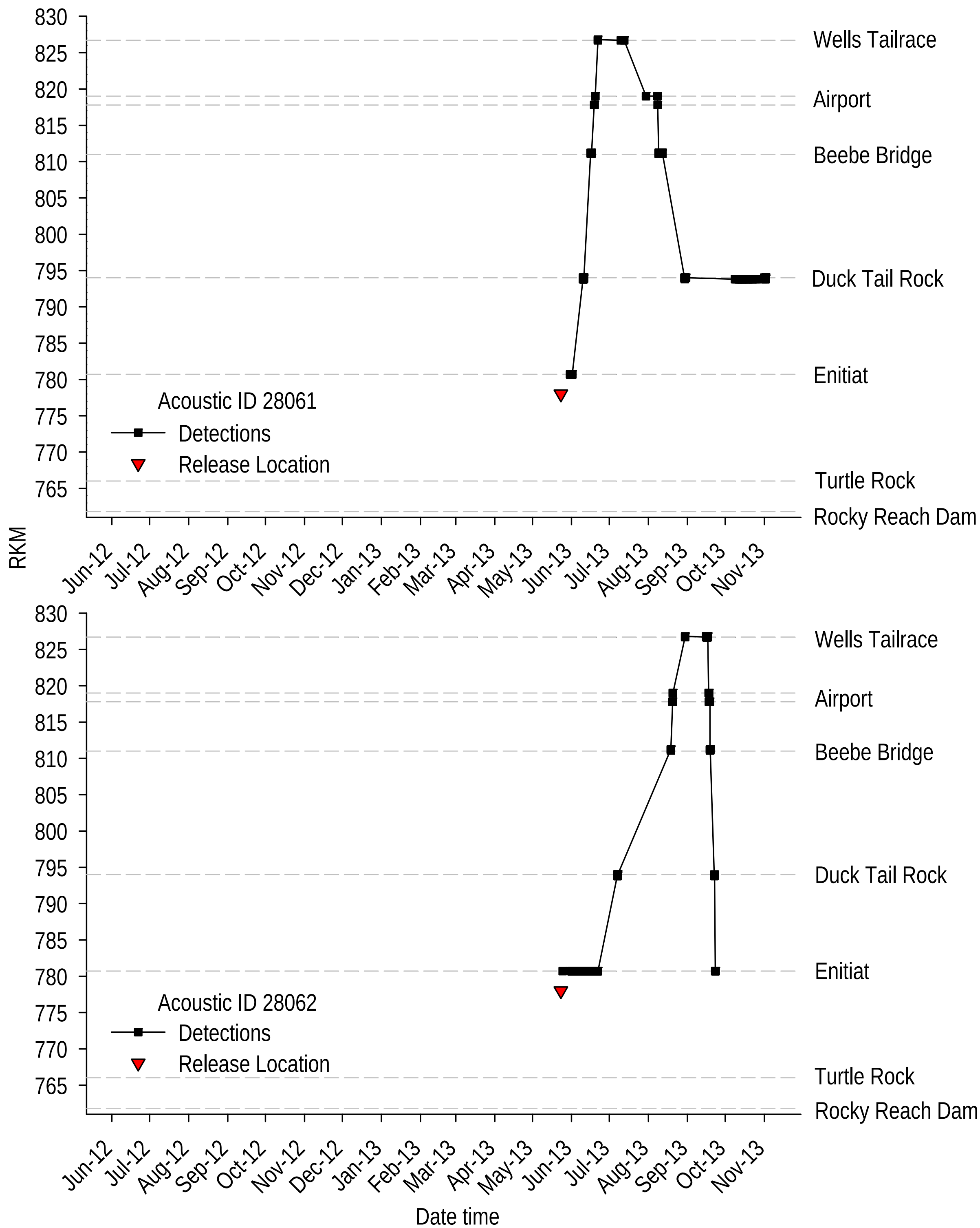
Oct-13
Nov-13
Date time



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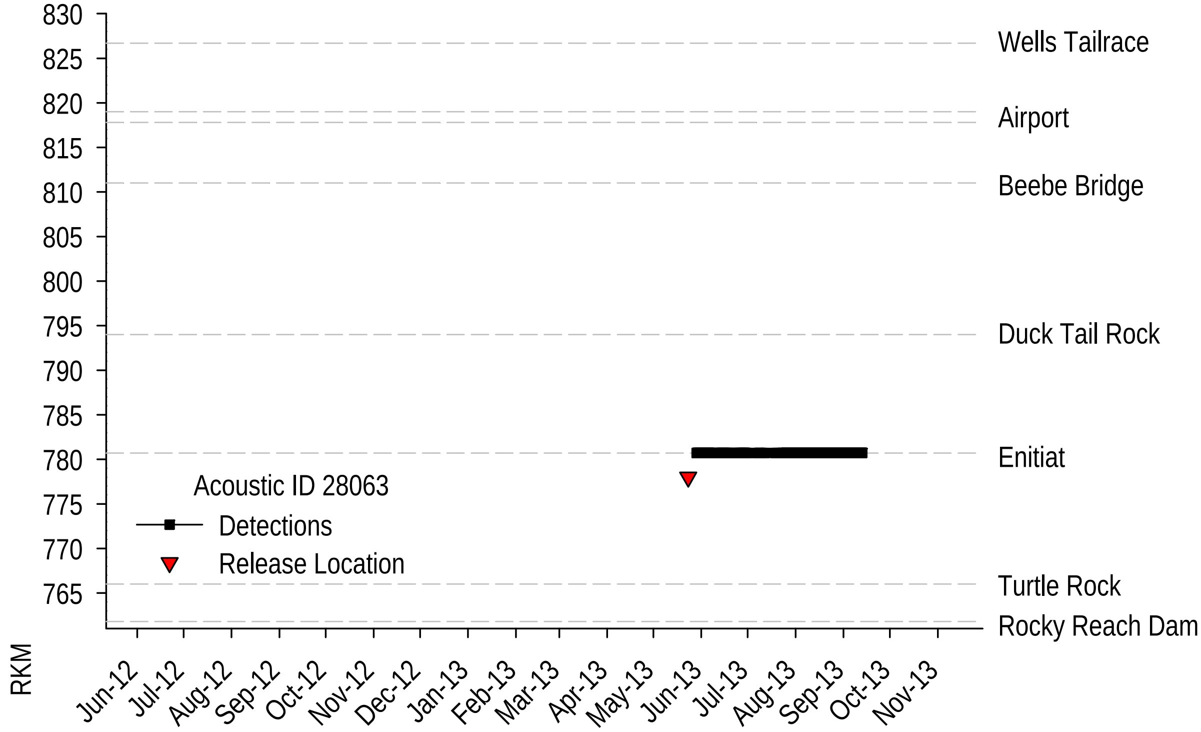
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Duck Tail Rock
Enitiat
Turtle Rock
Rocky Reach Dam
Acoustic ID 28063
Detections
Release Location
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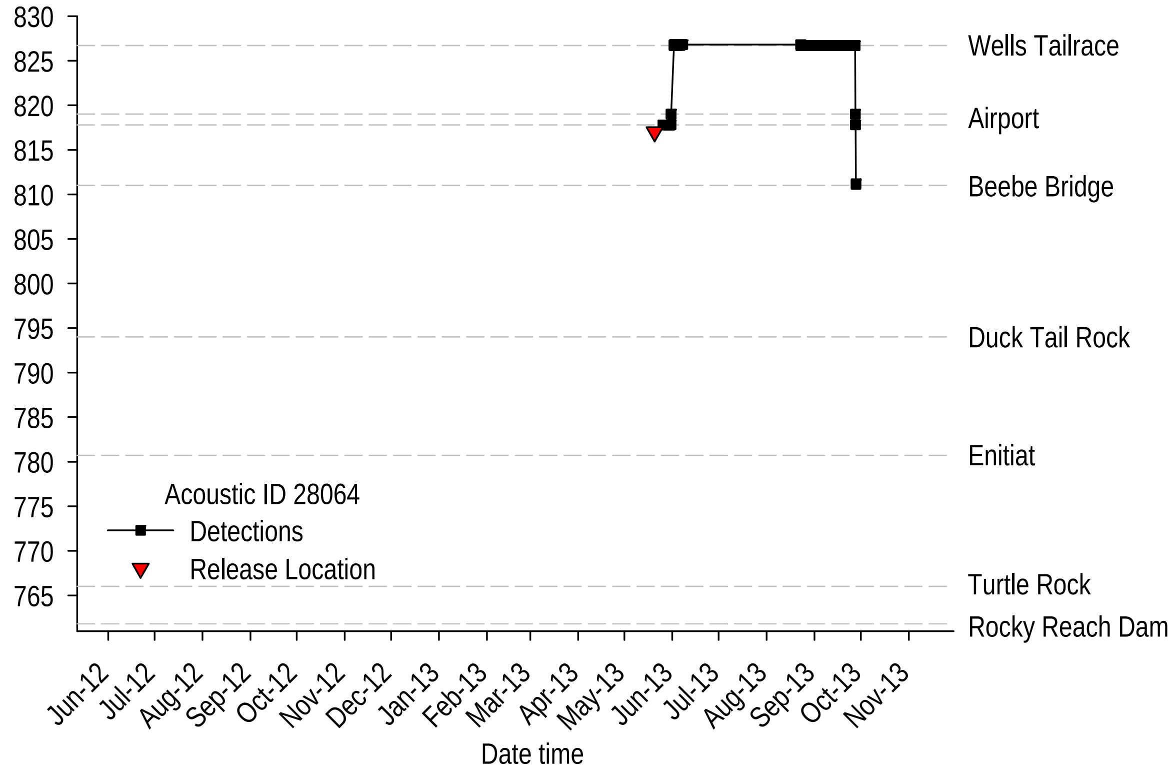
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Duck Tail Rock
Enitiat
Turtle Rock
Rocky Reach Dam
Acoustic ID 28064
Detections
Release Location
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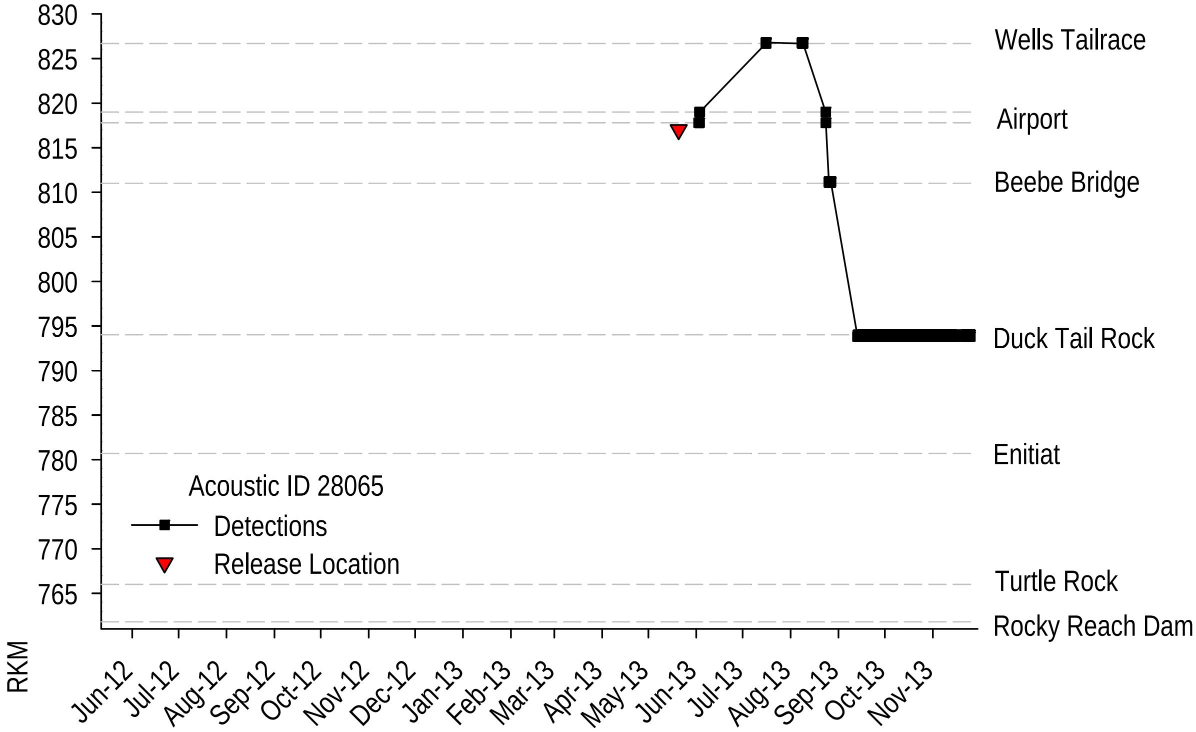
Date time



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Duck Tail Rock
Enitiat
Turtle Rock
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Acoustic ID 28065
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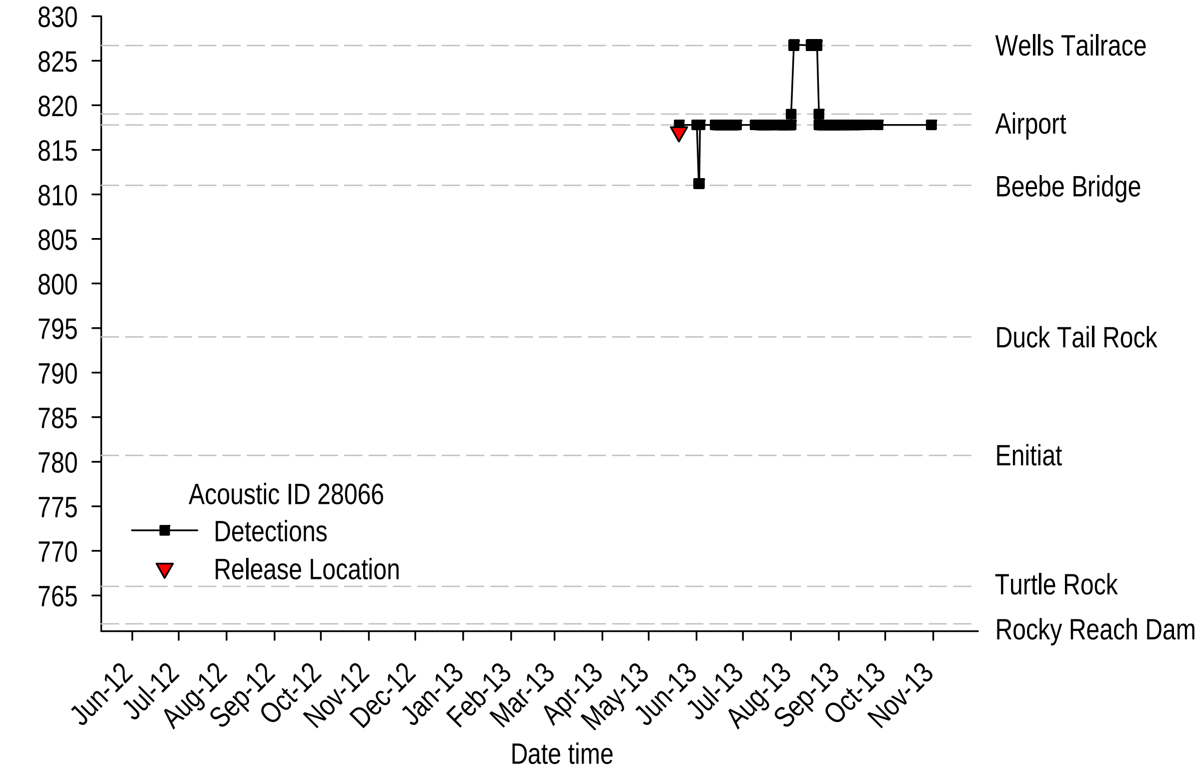

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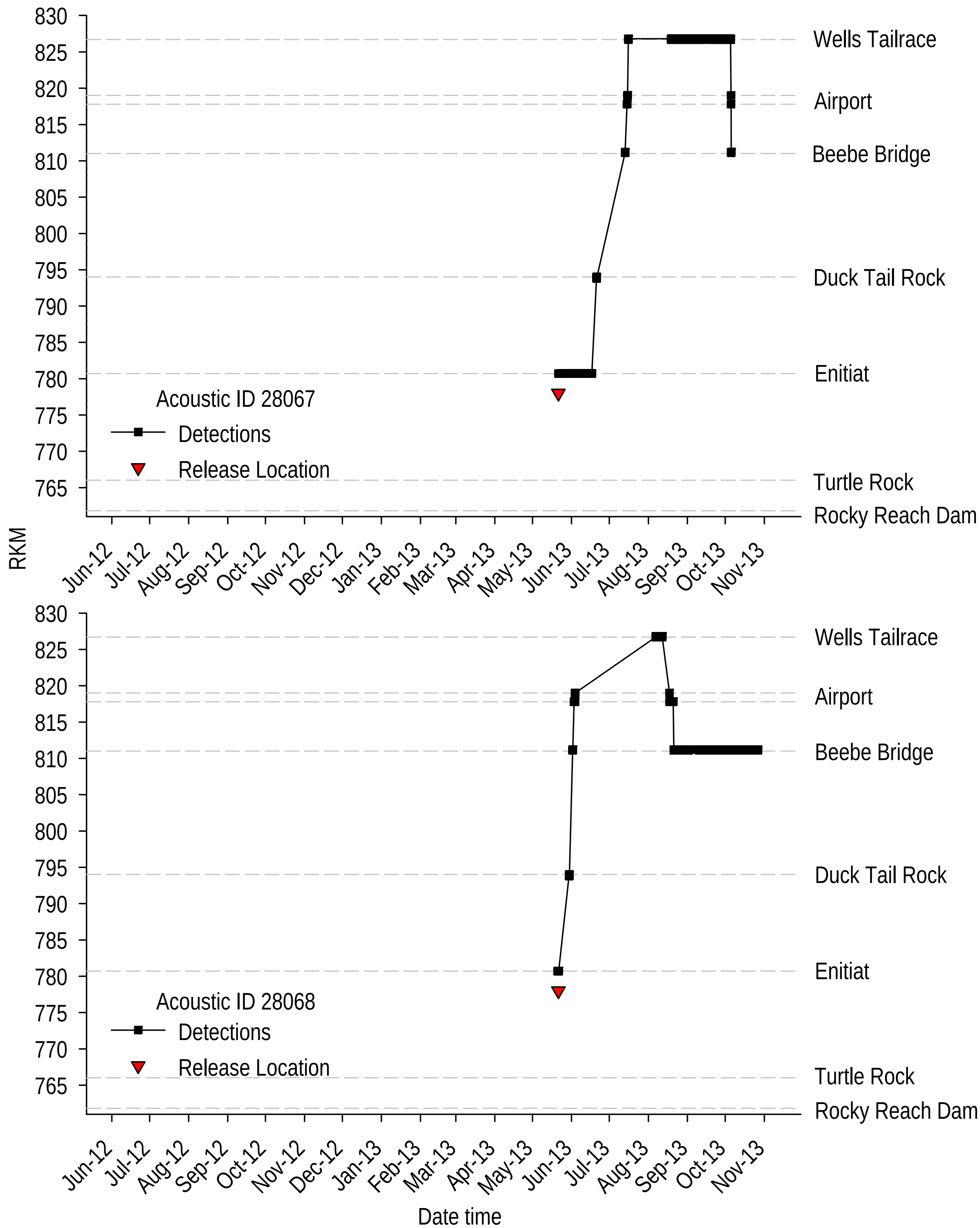
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Beebe Bridge
Duck Tail Rock
Enitiat
Turtle Rock
Rocky Reach Dam
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Detections
Release Location
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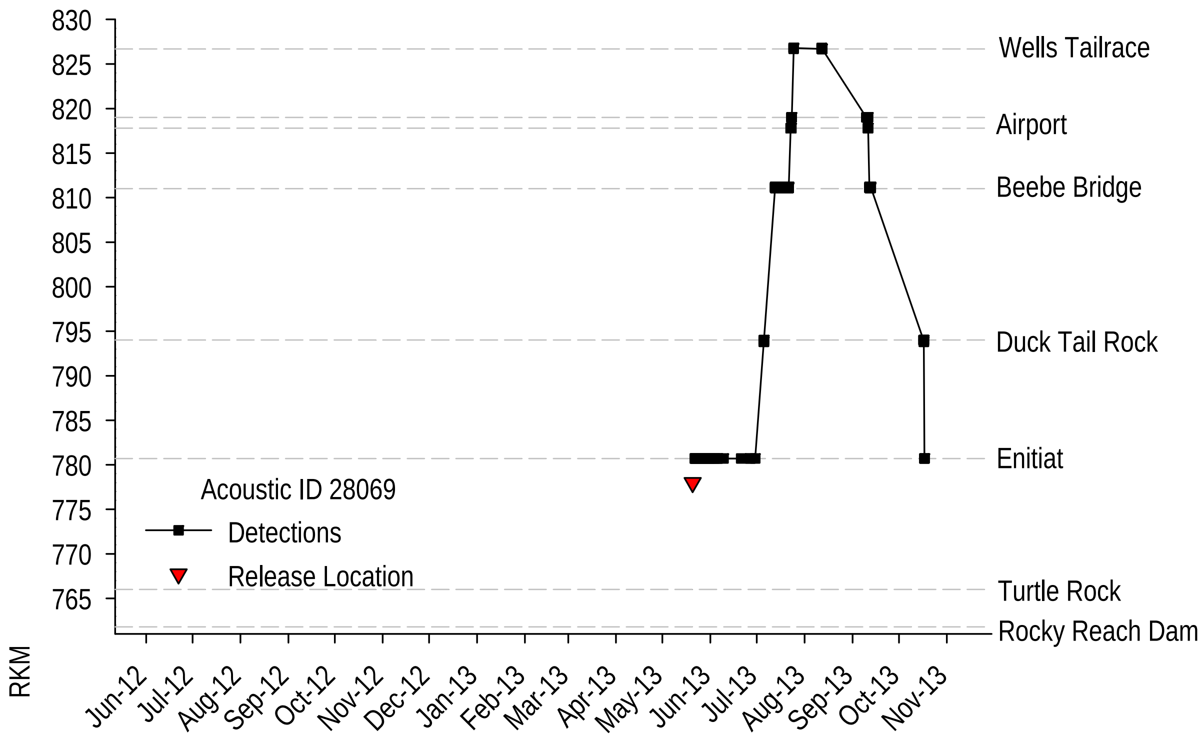
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Enitiat
Turtle Rock
Rocky Reach Dam
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Detections
Release Location
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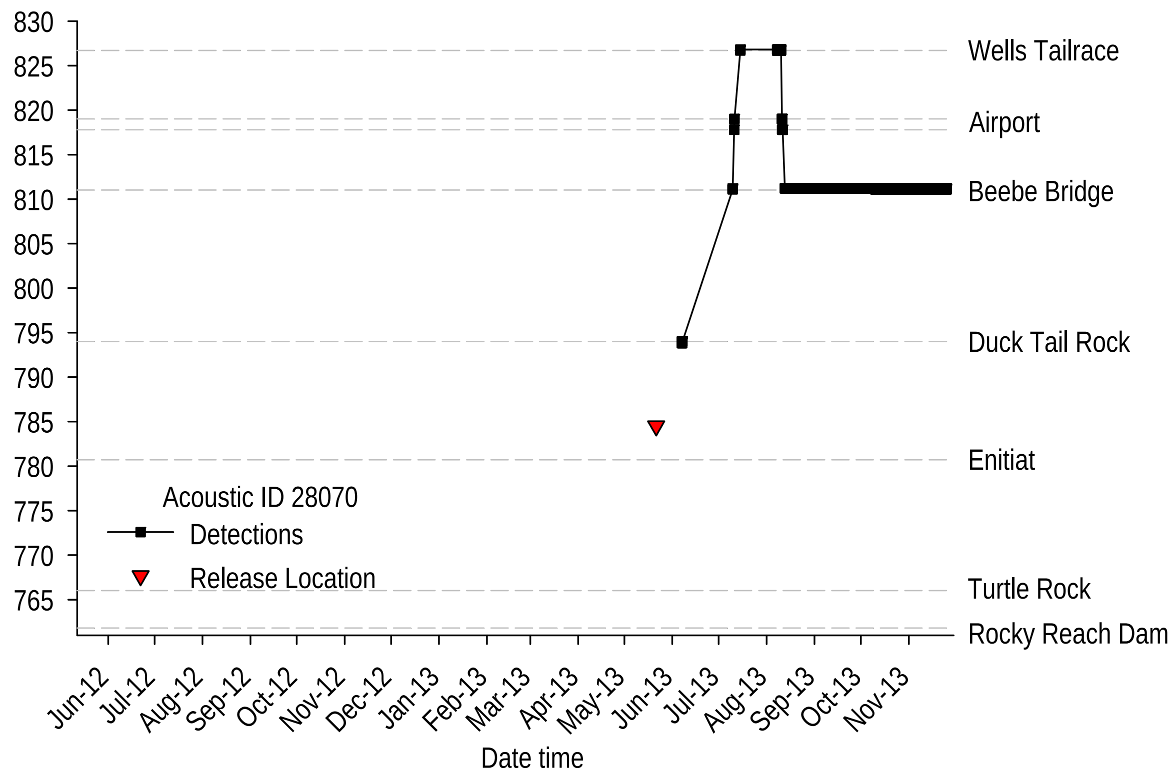
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Enitiat
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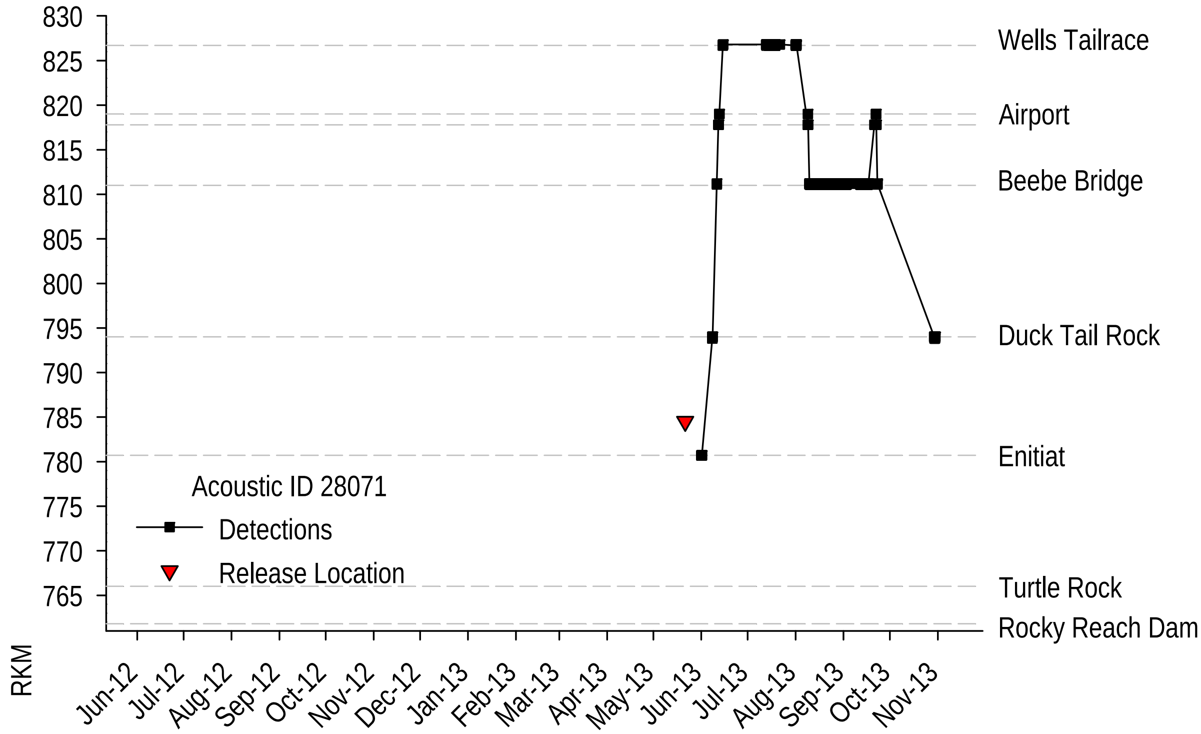
Date time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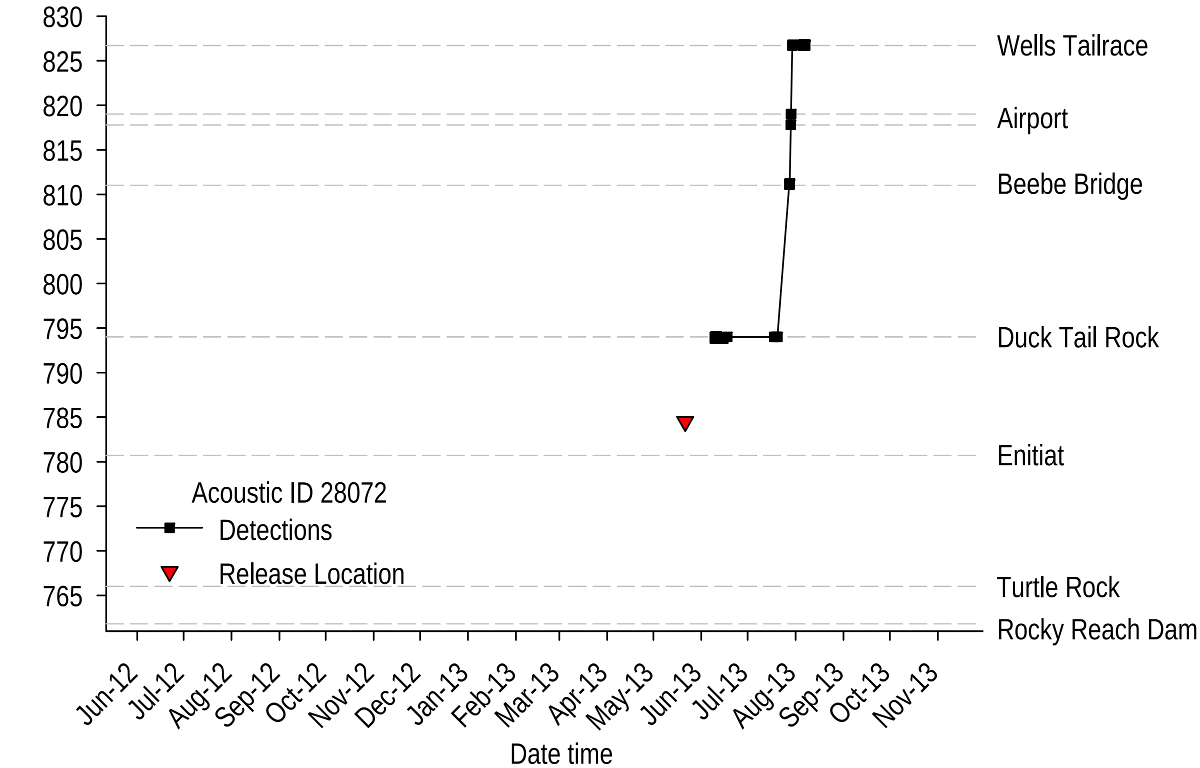
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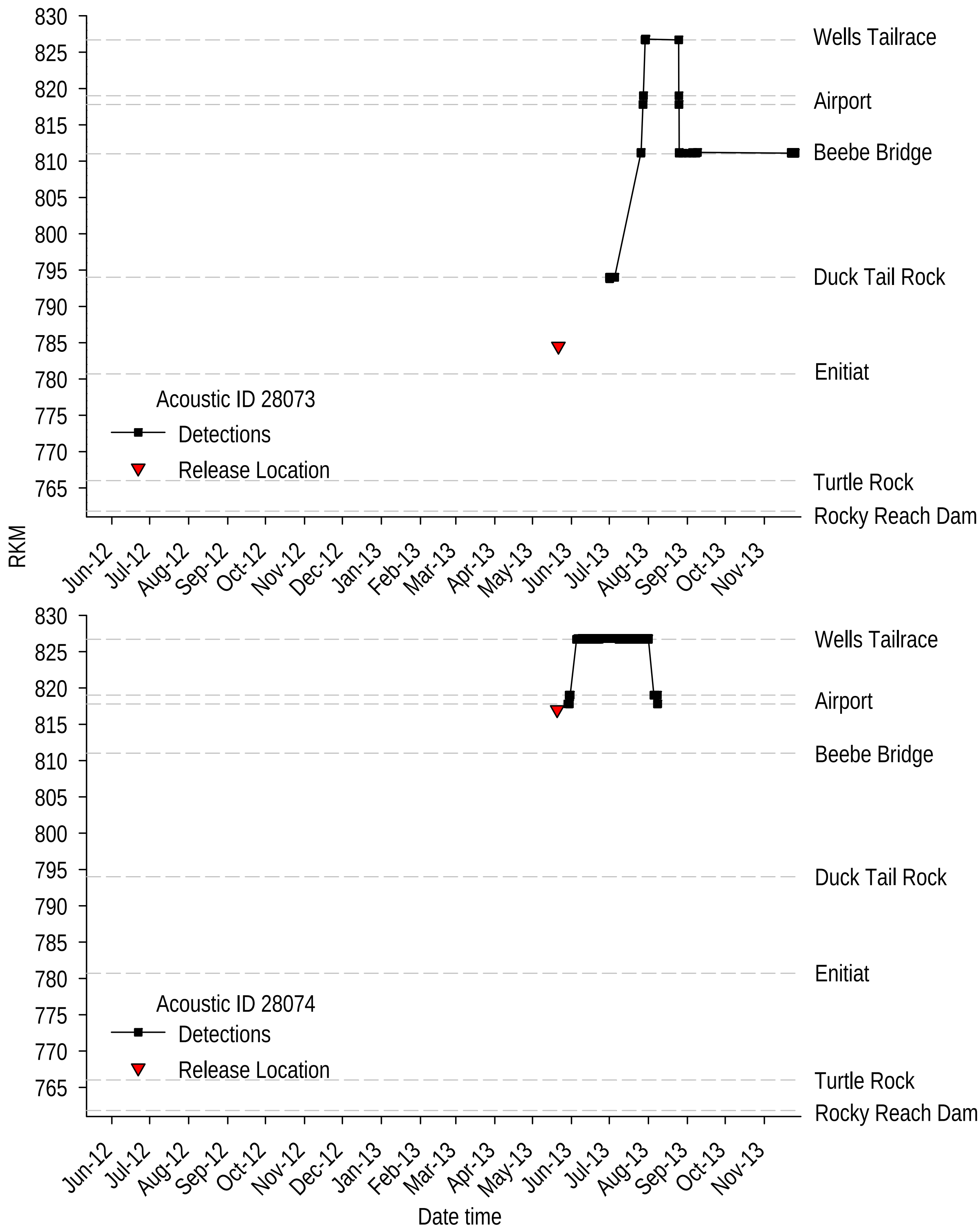

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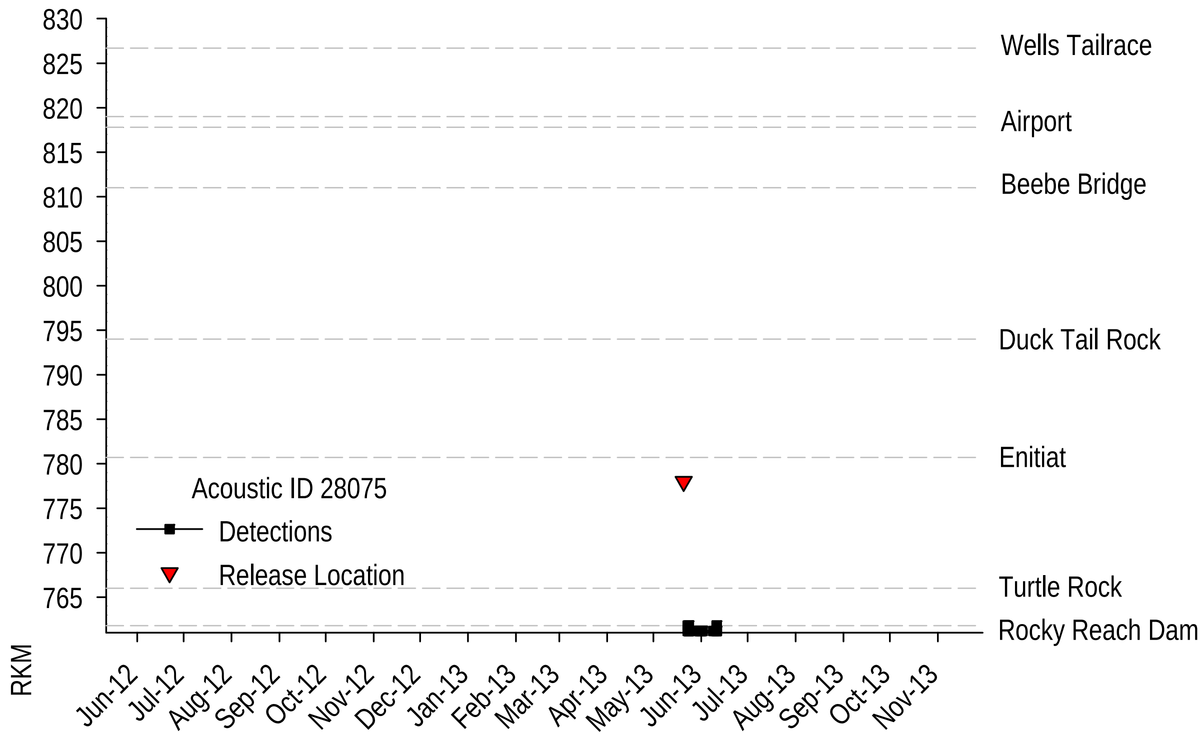

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Enitiat
Turtle Rock
Rocky Reach Dam
Acoustic ID 28075
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Release Location
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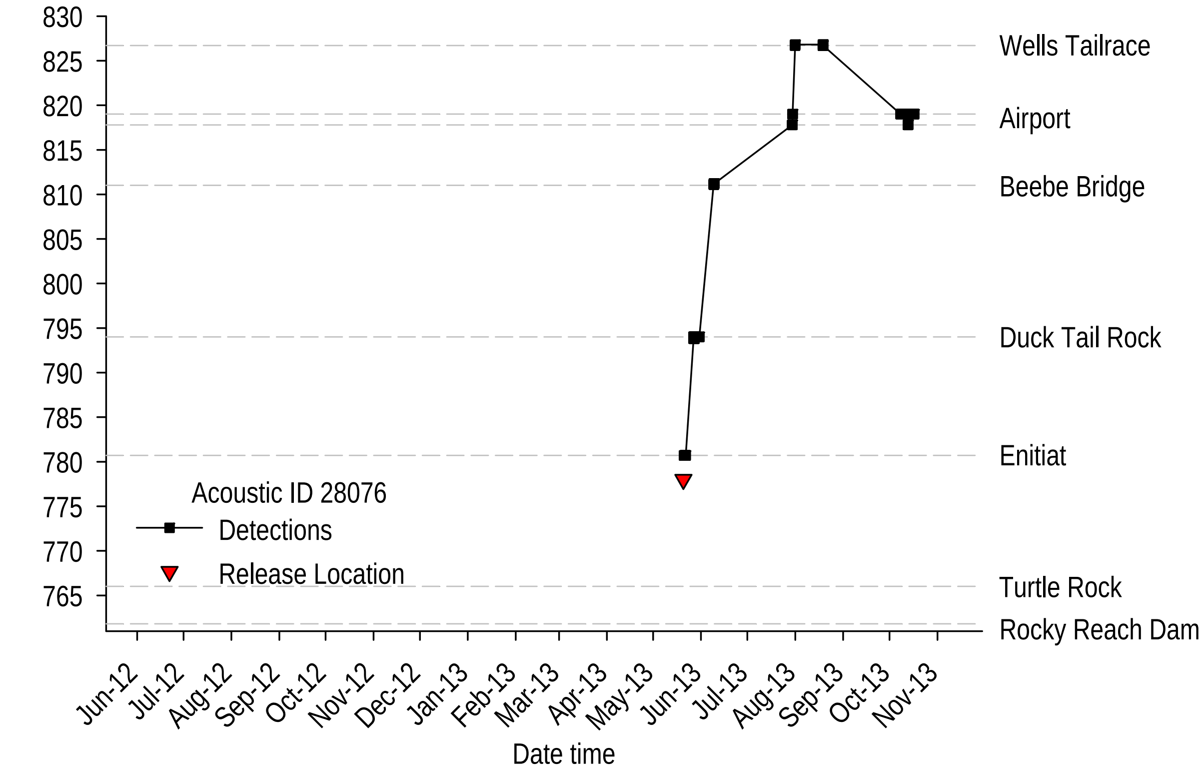

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Duck Tail Rock
Enitiat
Turtle Rock
Rocky Reach Dam
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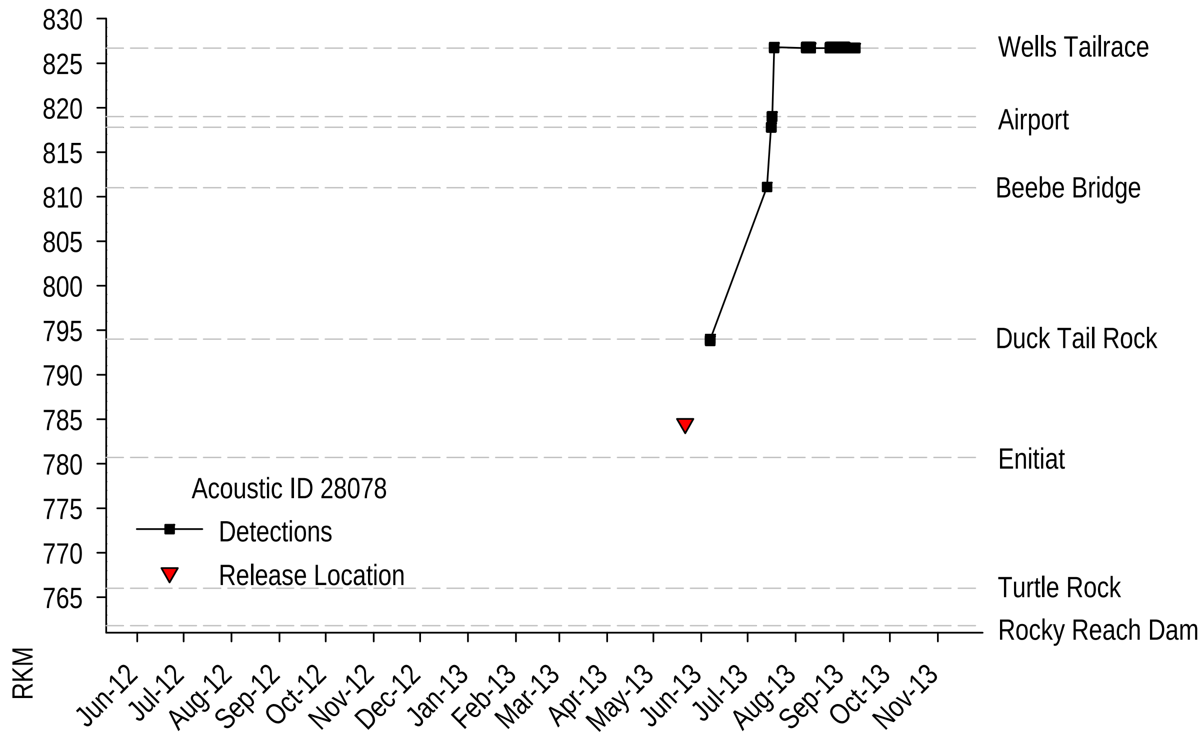

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Duck Tail Rock
Enitiat
Turtle Rock
Rocky Reach Dam
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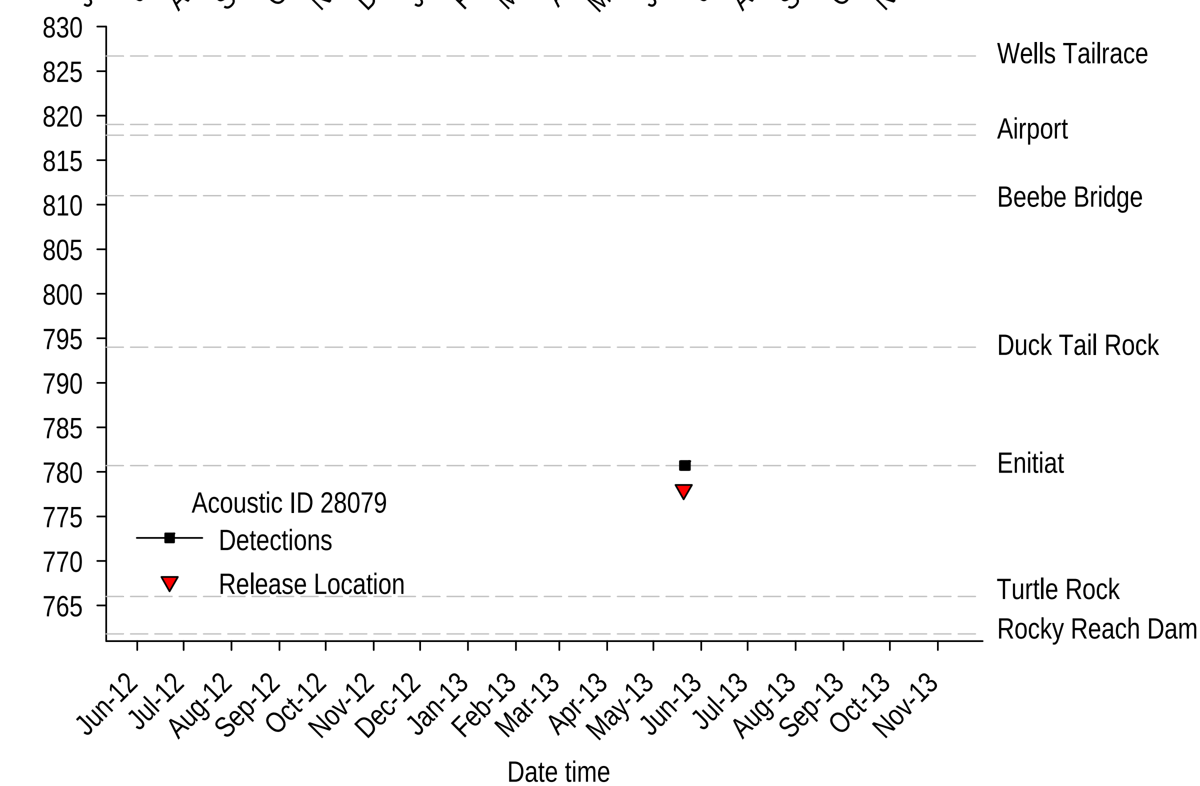

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Duck Tail Rock
Enitiat
Turtle Rock
Rocky Reach Dam
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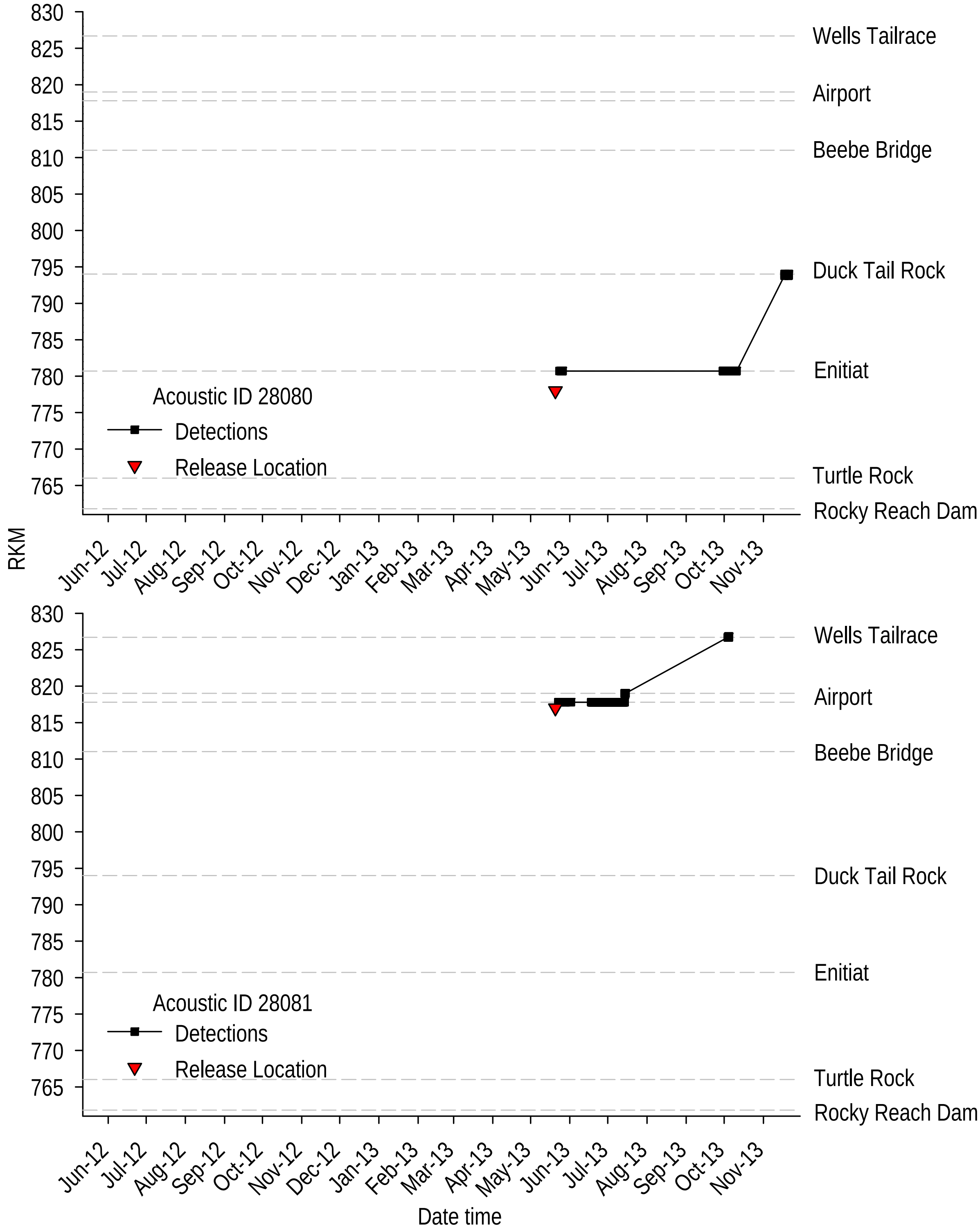

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Rocky Reach Dam
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Release Location
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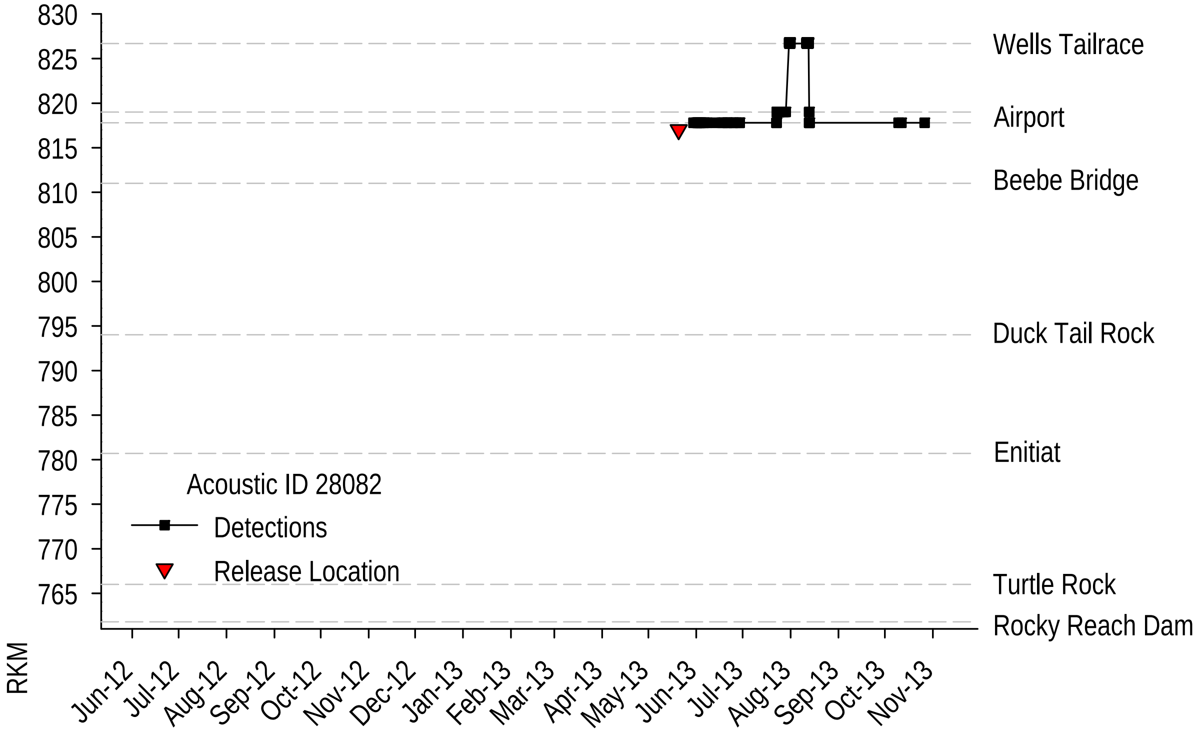
Release Location
Date time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Airport
Beebe Bridge
Duck Tail Rock
Enitiat
Turtle Rock
Rocky Reach Dam
Acoustic ID 28082
Detections
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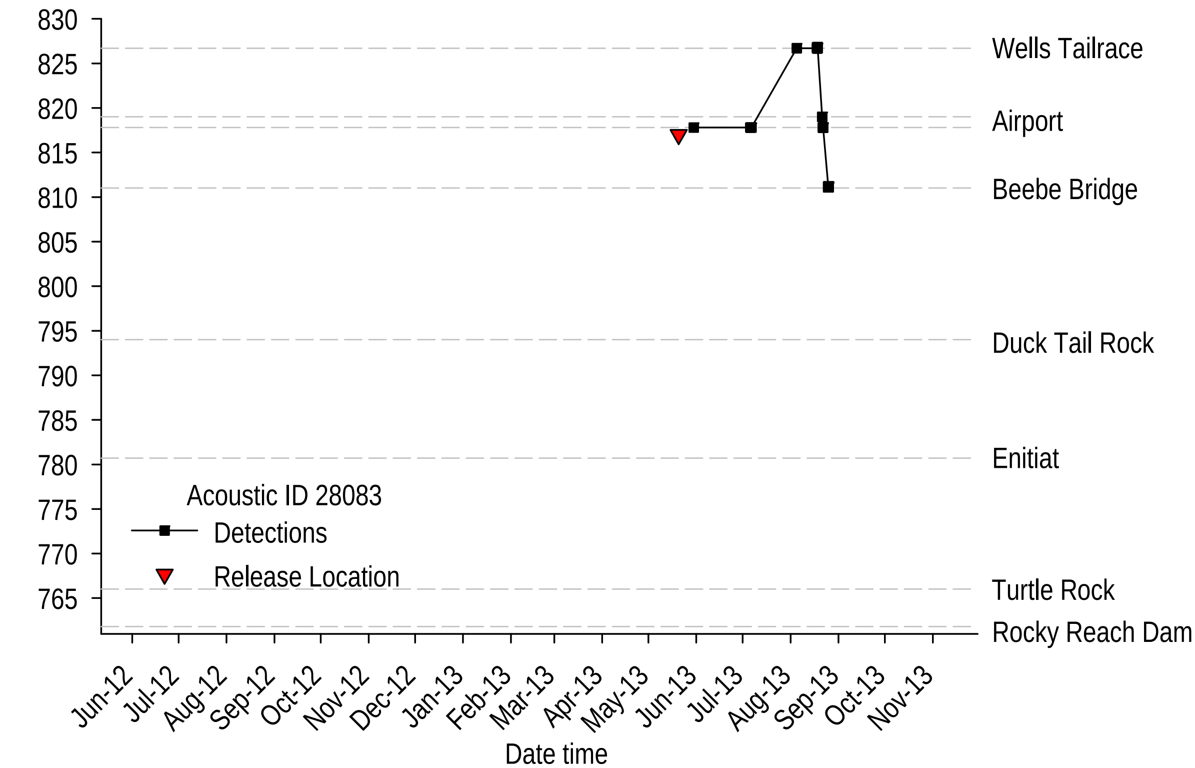
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Duck Tail Rock
Enitiat
Turtle Rock
Rocky Reach Dam
Acoustic ID 28083
Detections
Release Location
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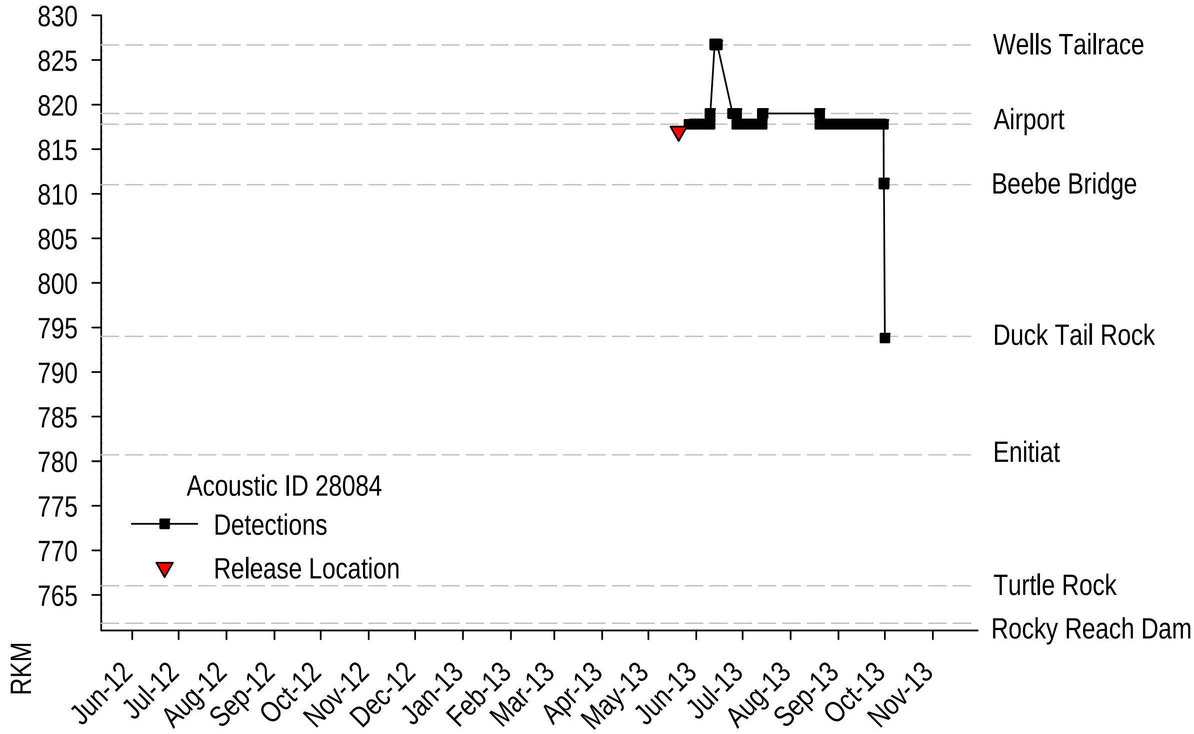
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Rocky Reach Dam
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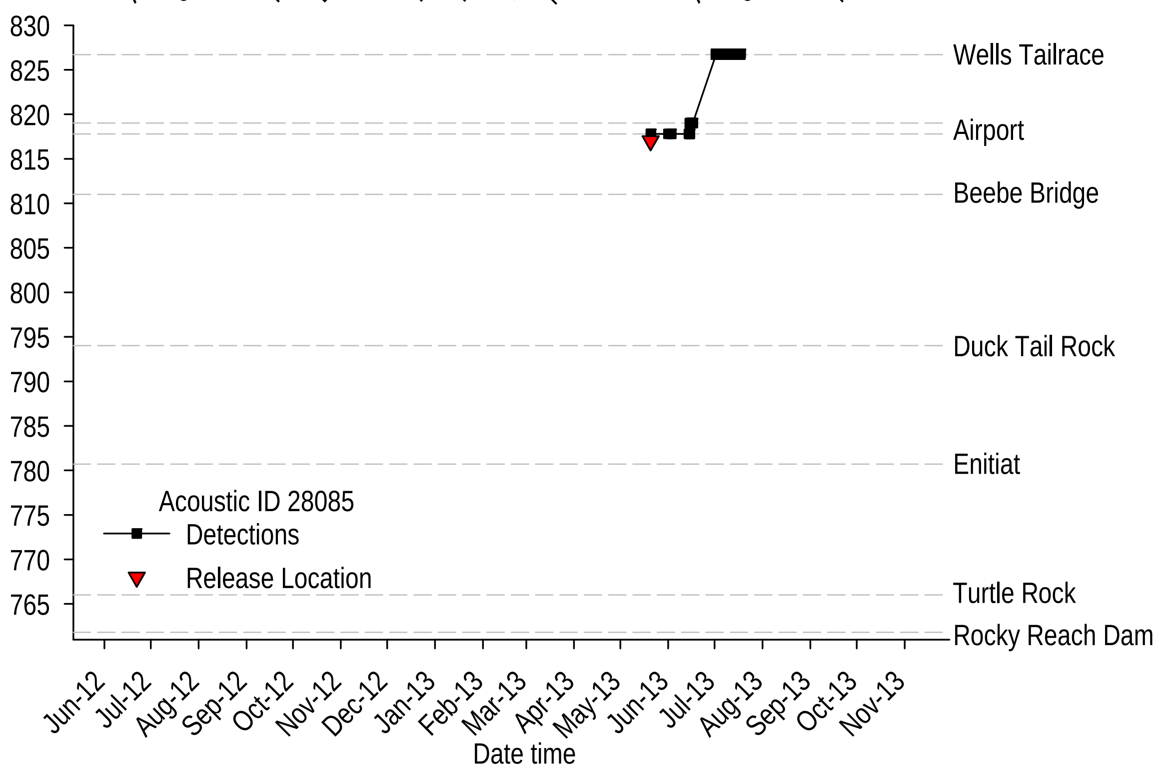
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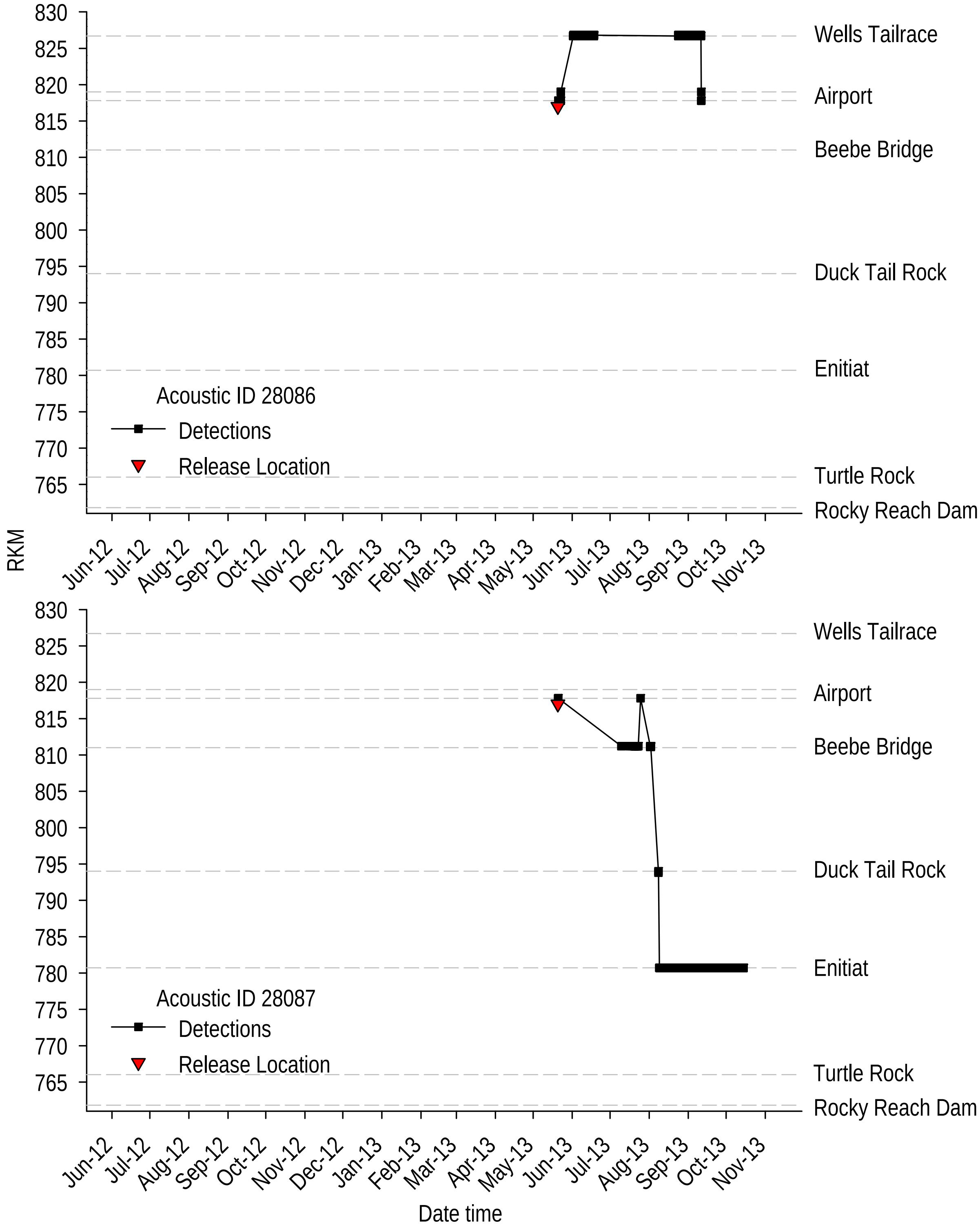
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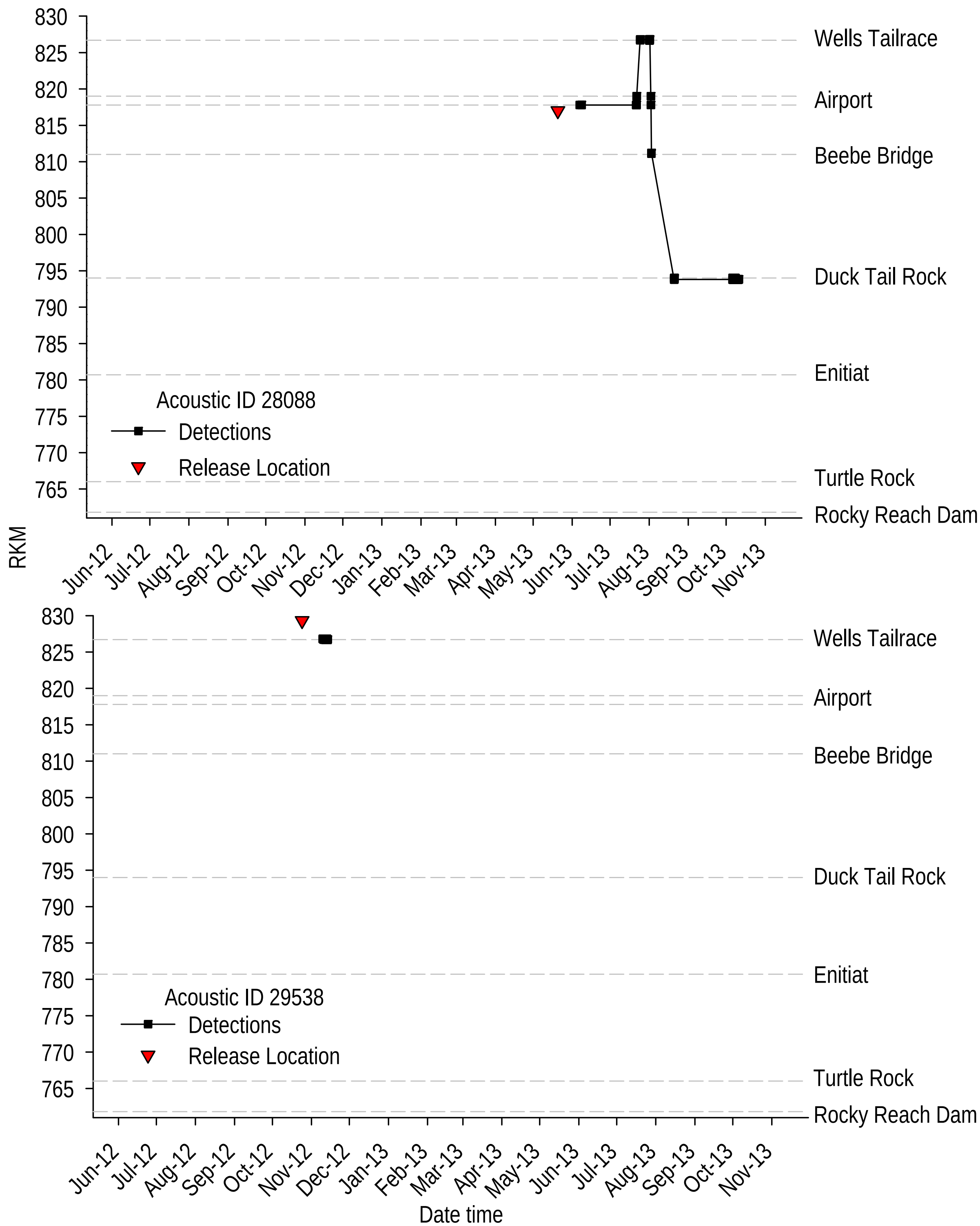
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Acoustic ID 28088
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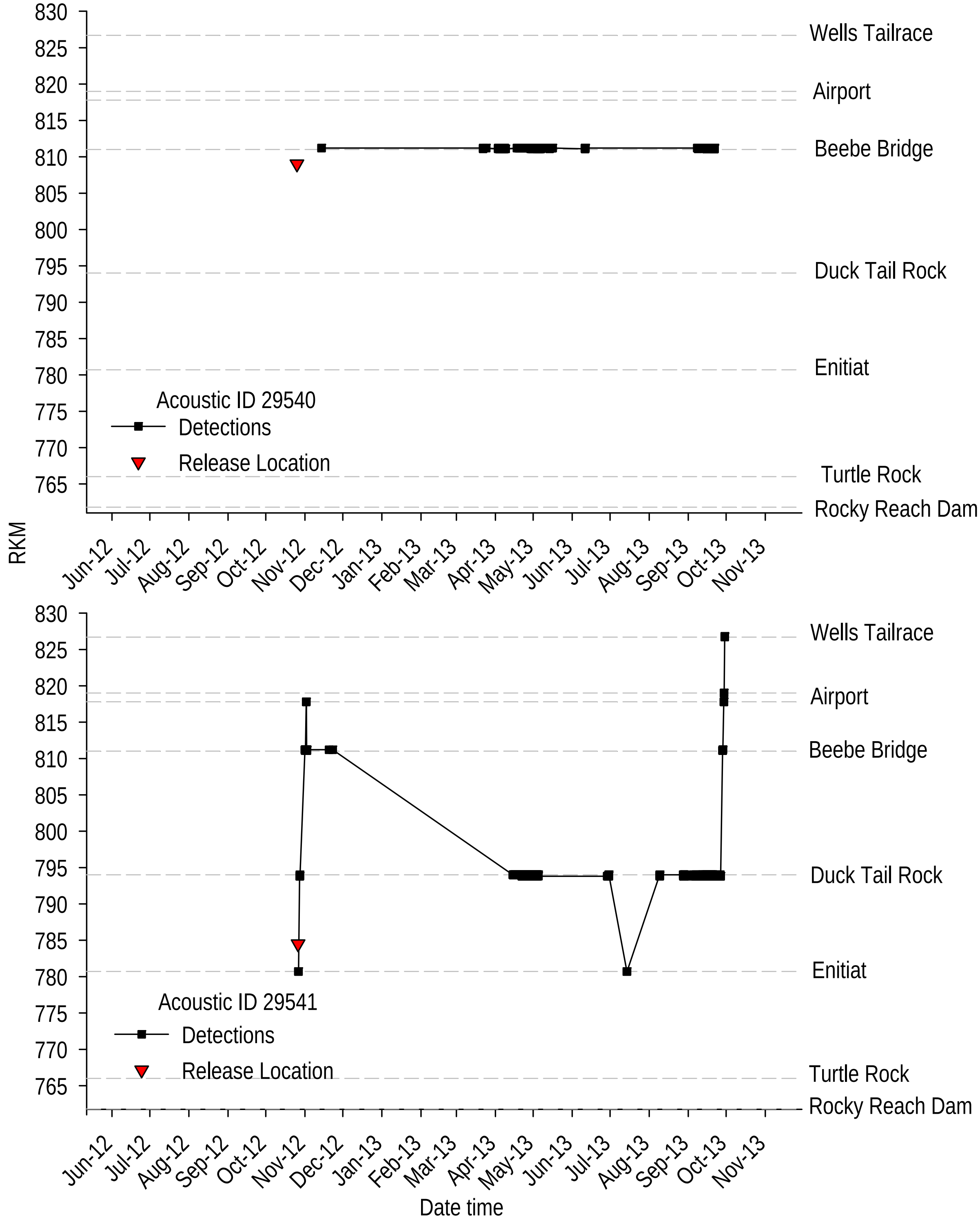
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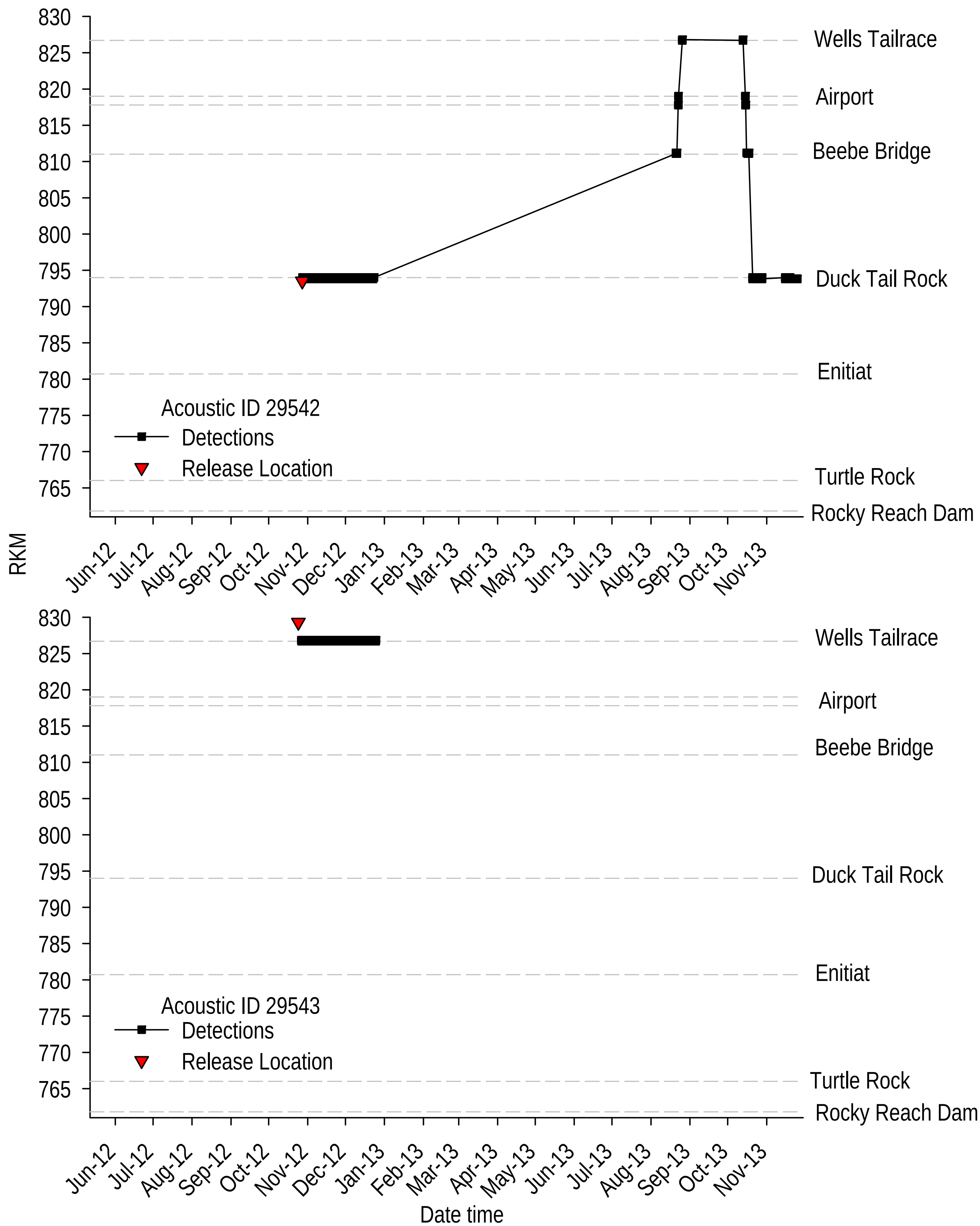
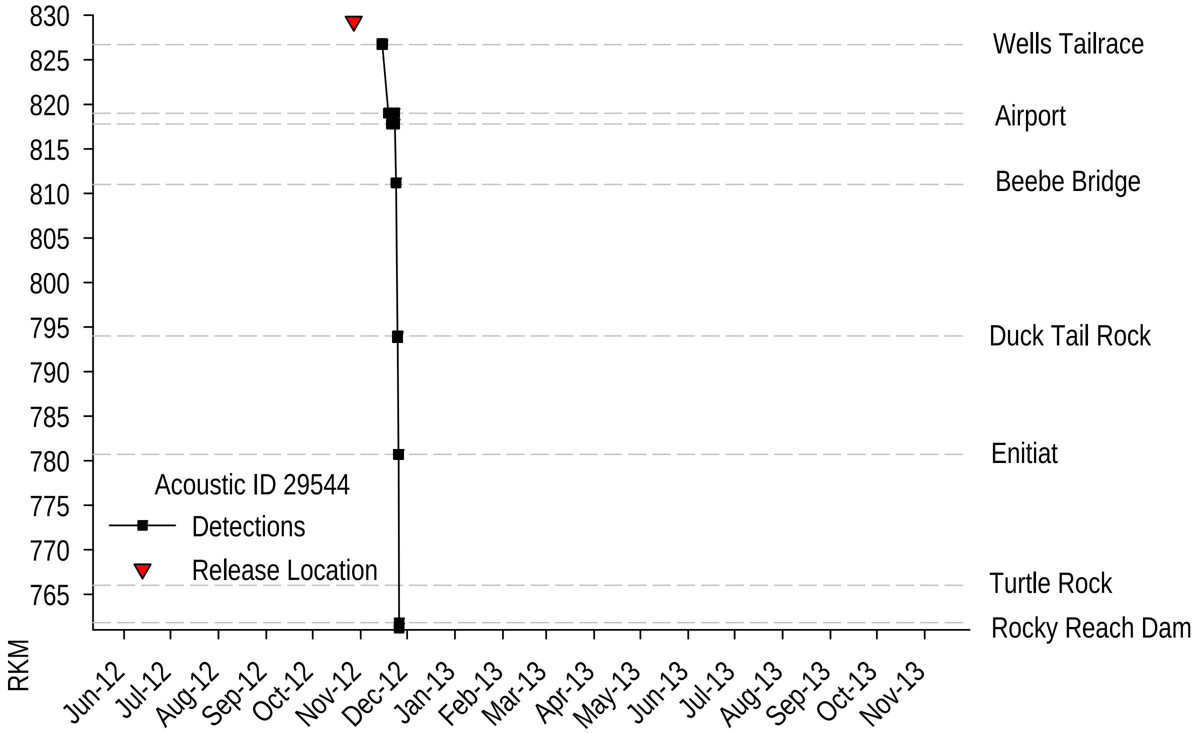


Appendix C - 43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Turtle Rock
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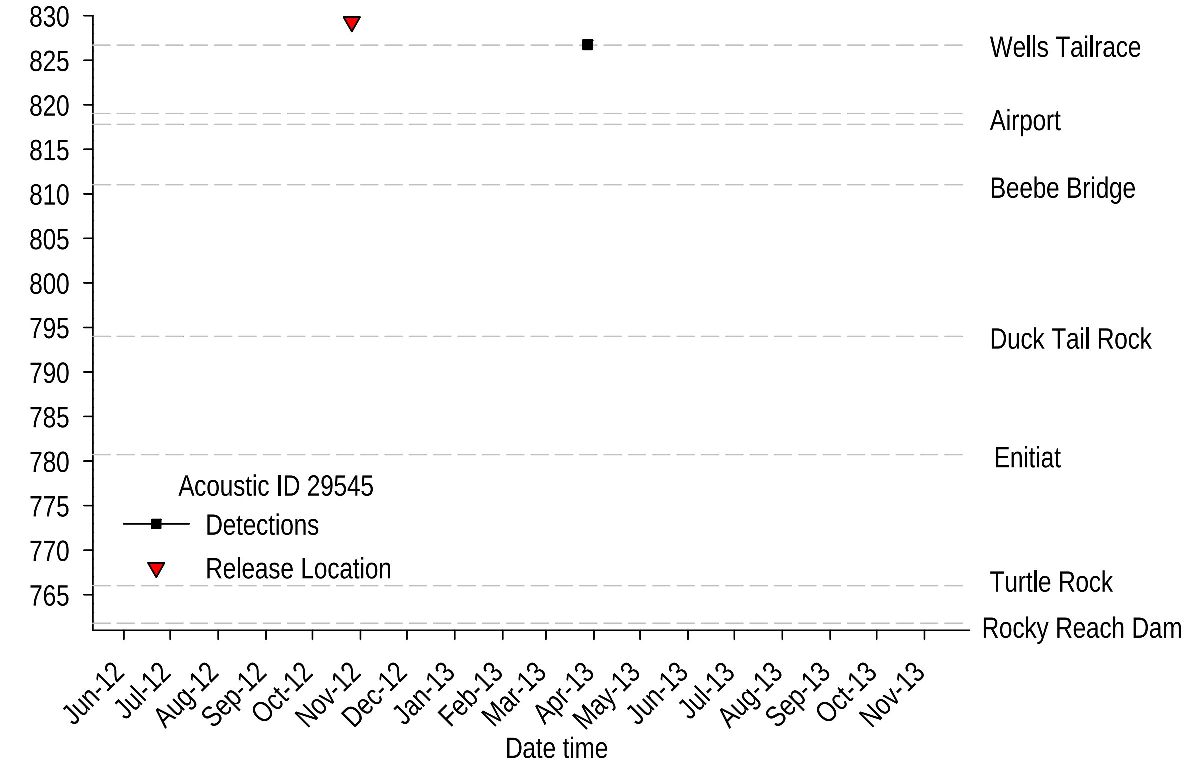
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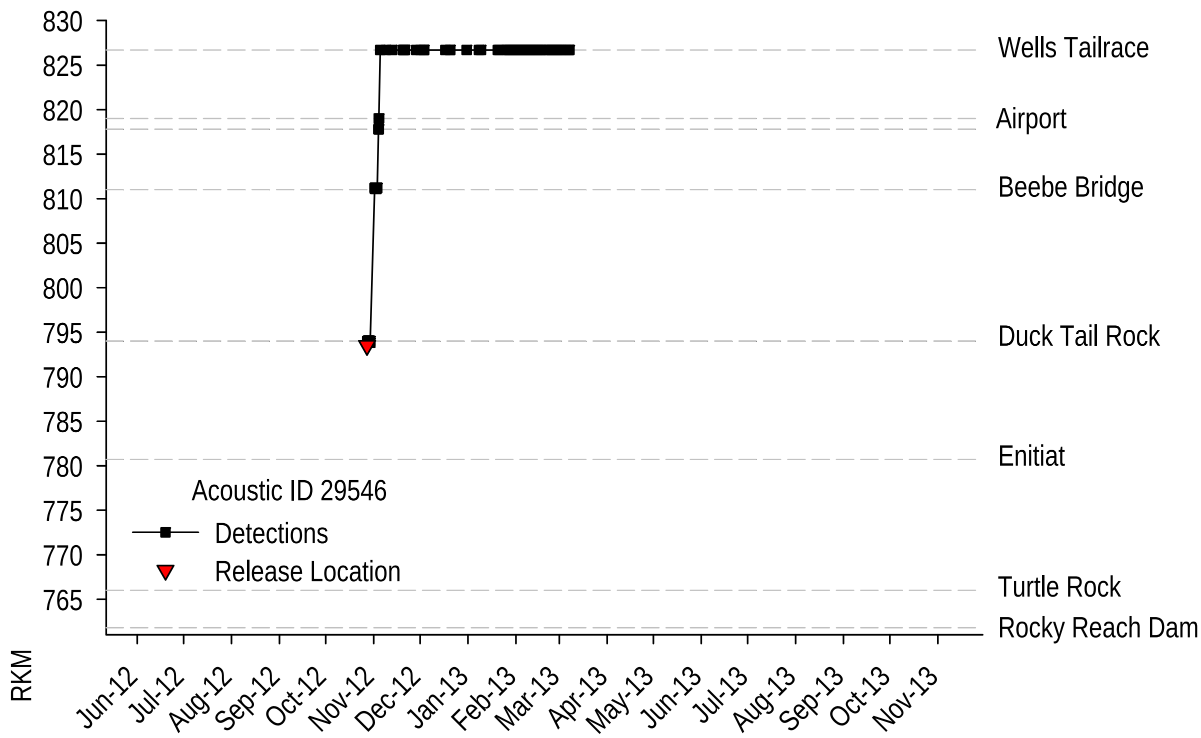
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Turtle Rock
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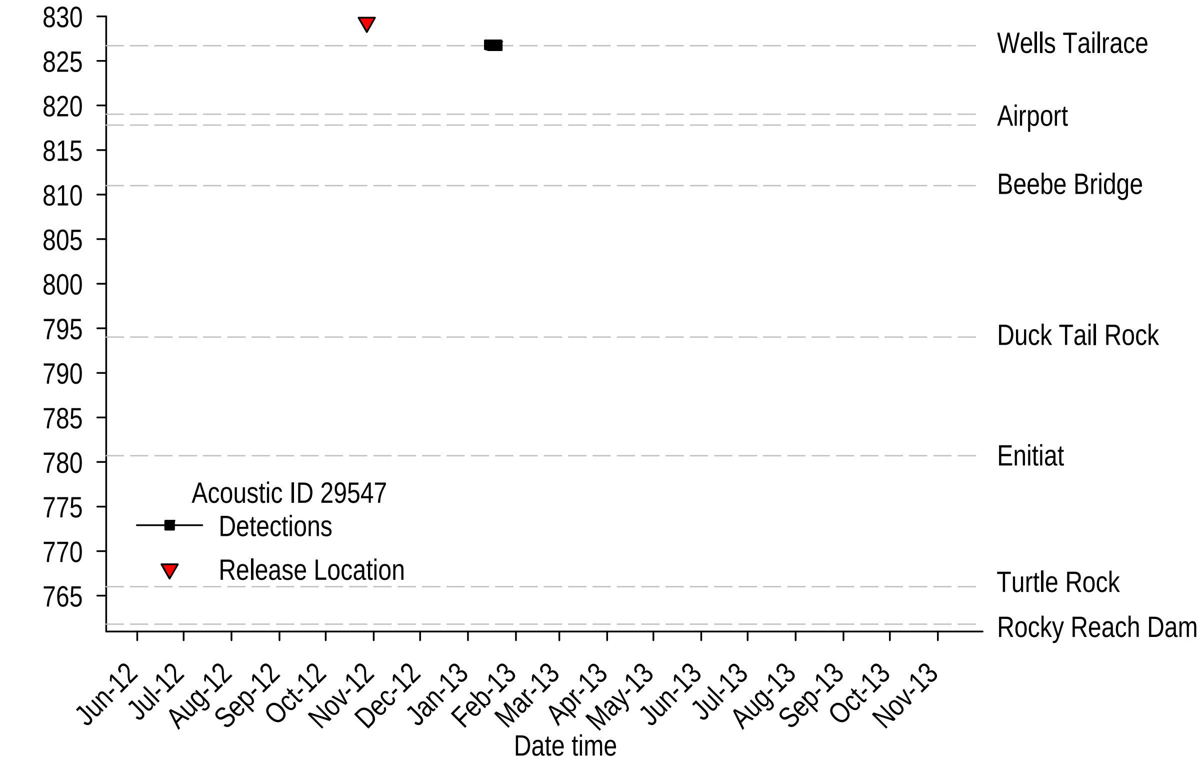
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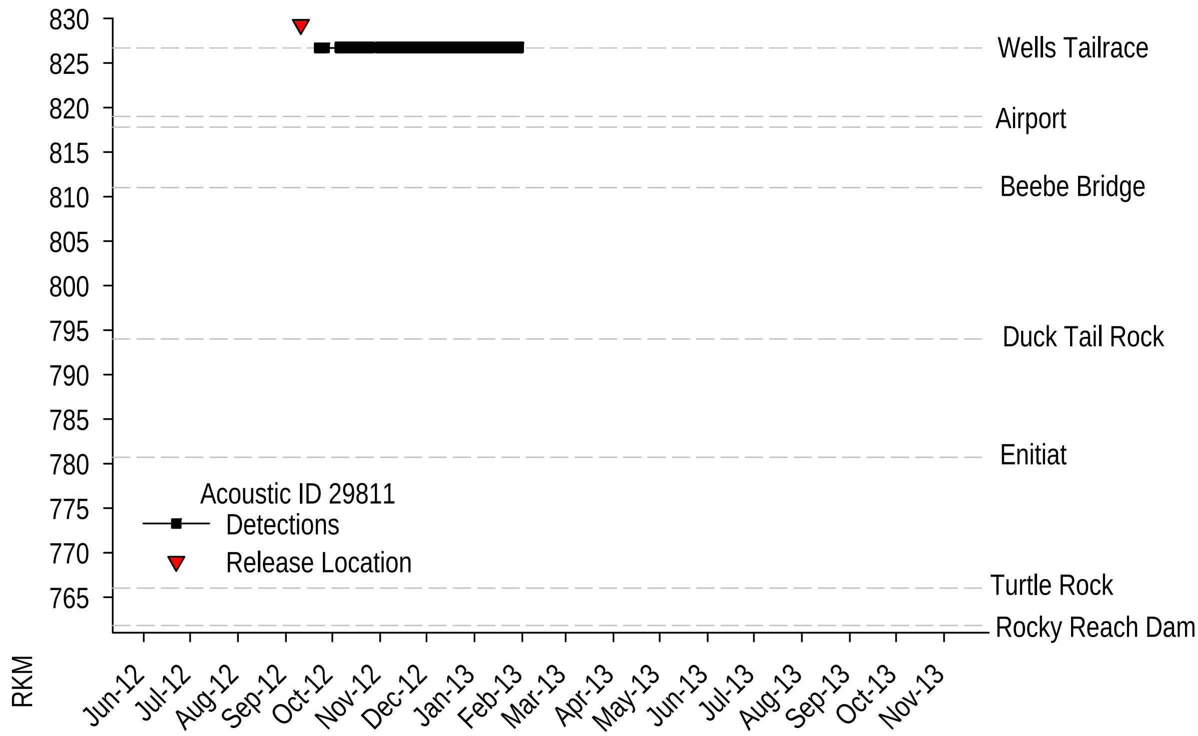
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Duck Tail Rock
Enitiat
Turtle Rock
Rocky Reach Dam
Acoustic ID 29811
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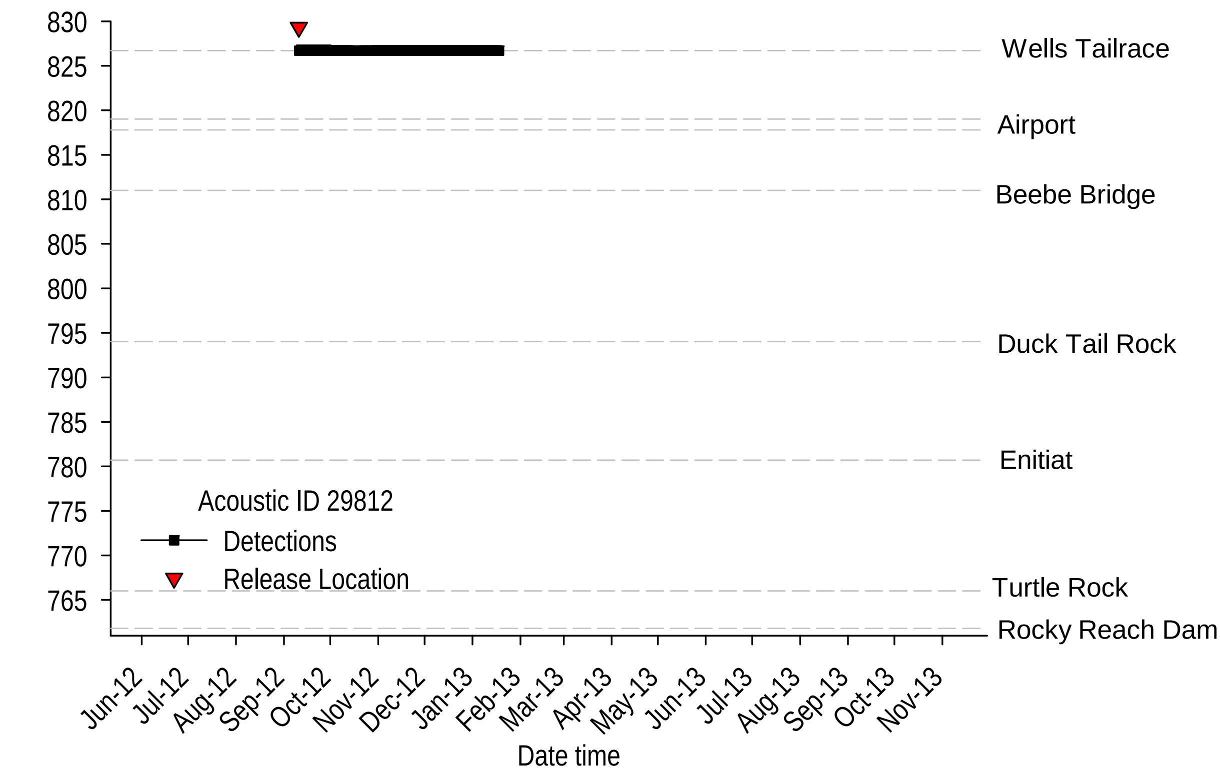
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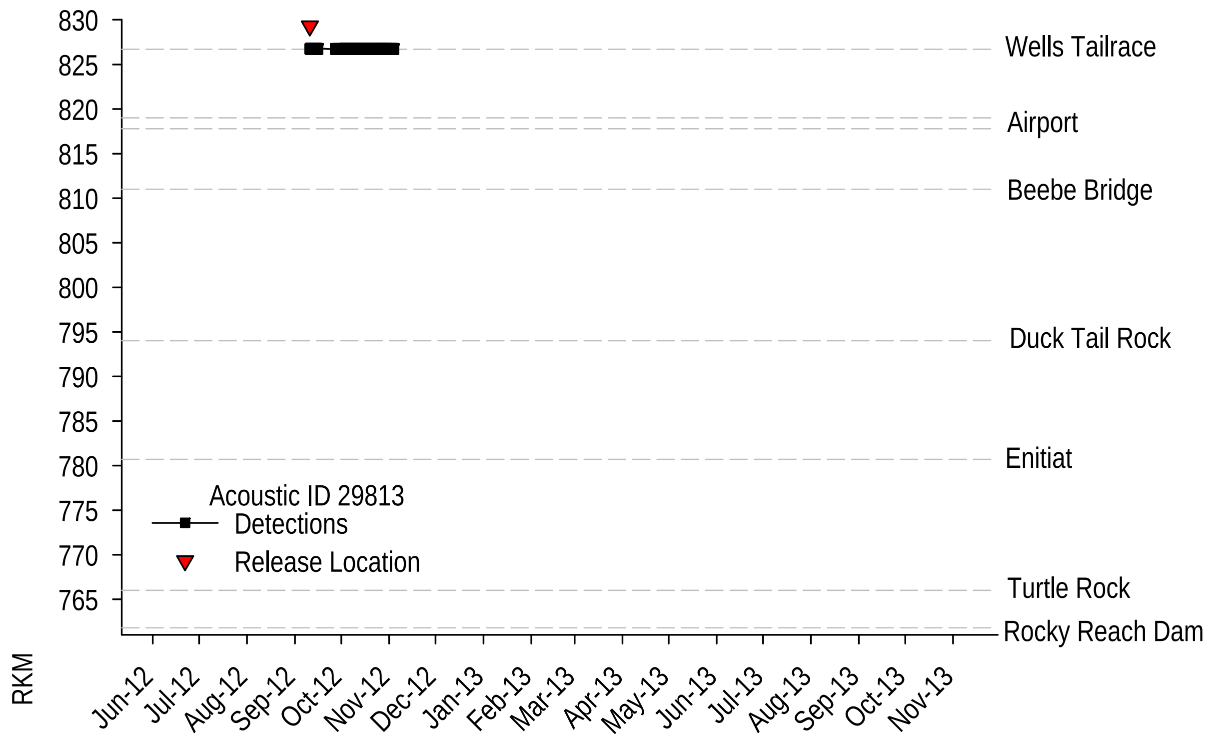
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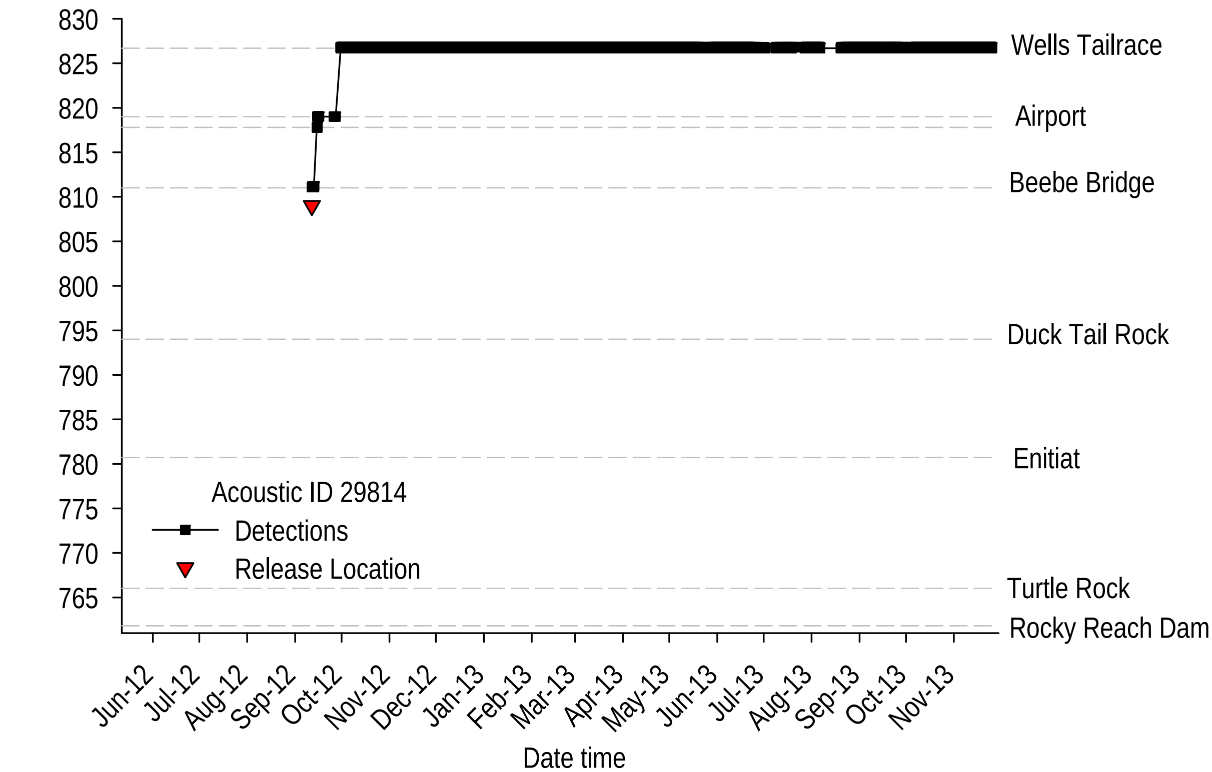
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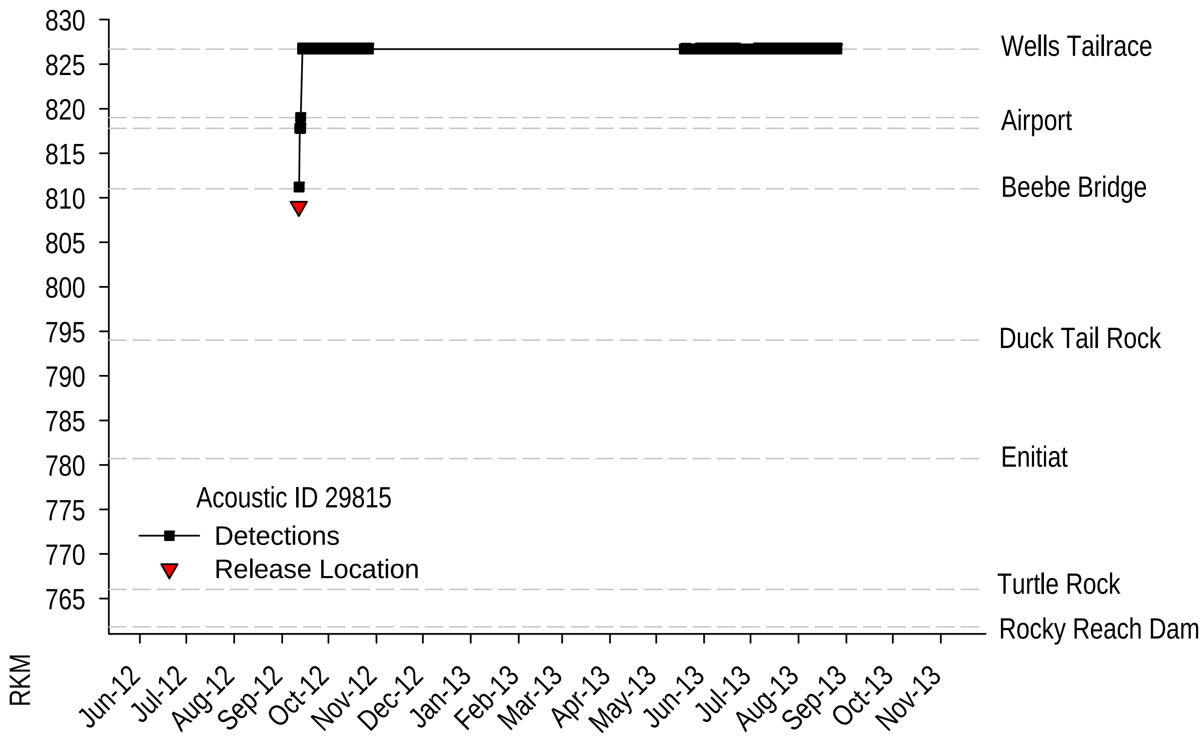

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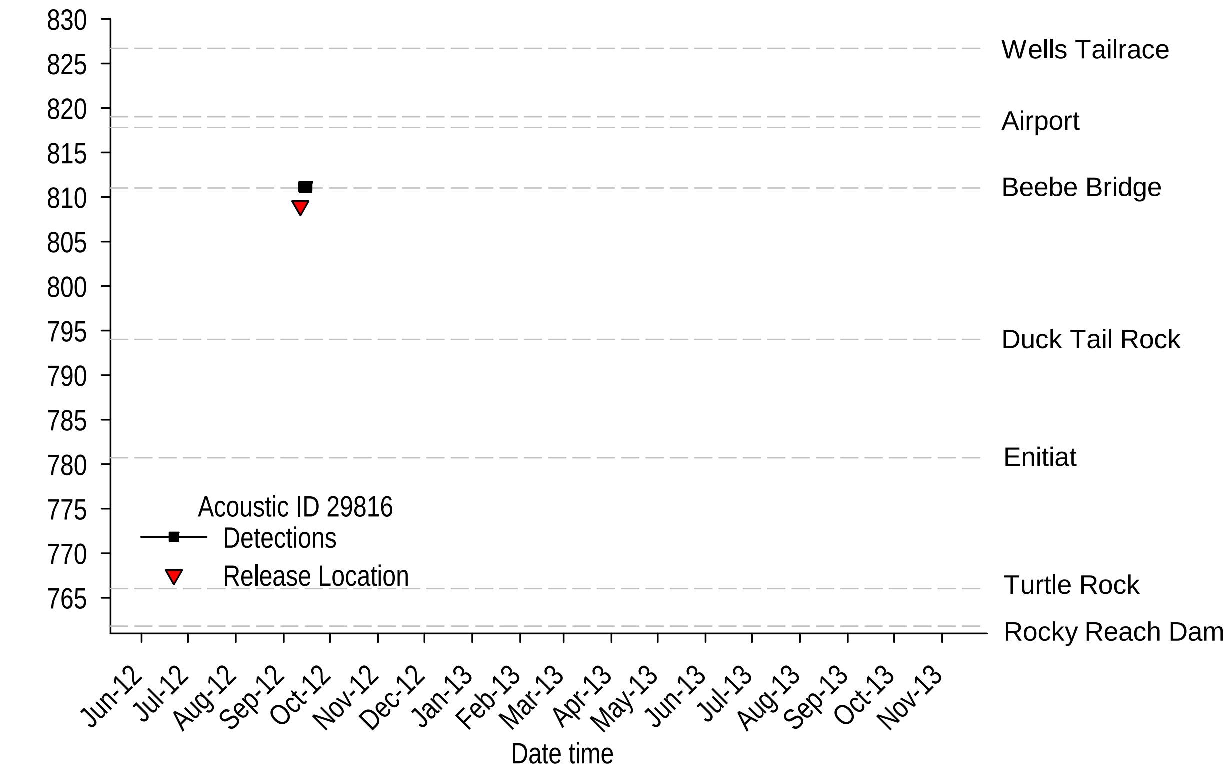

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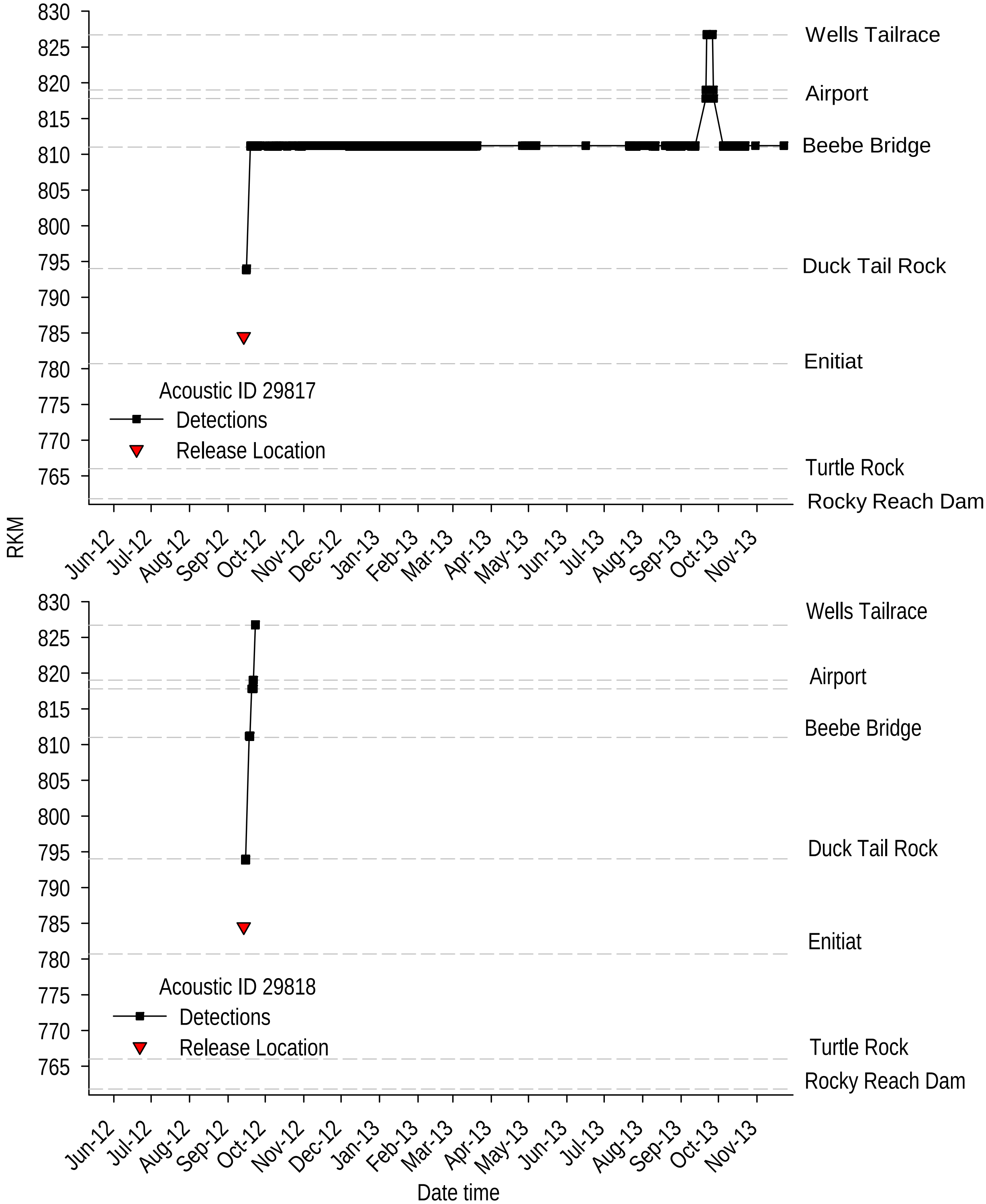

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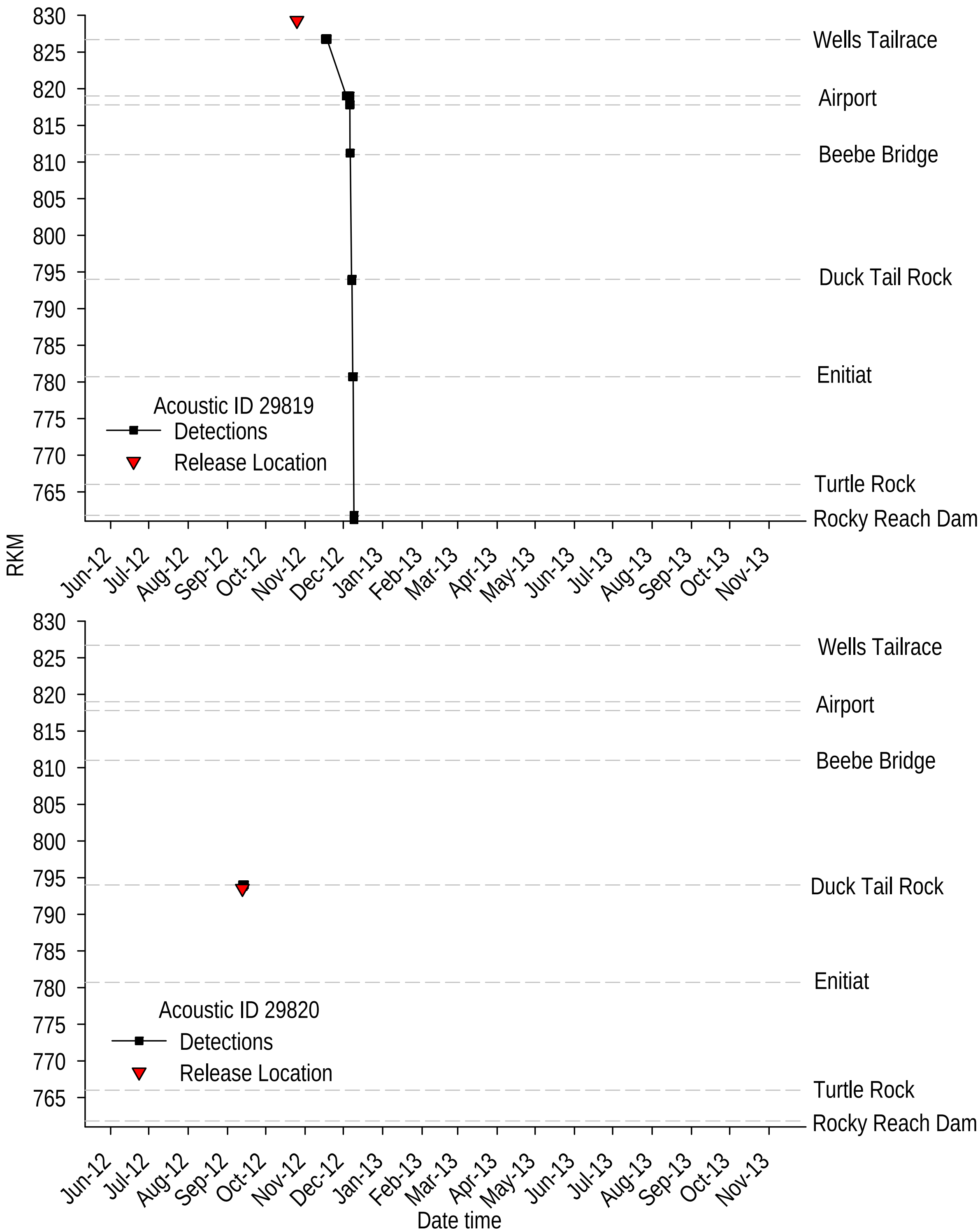

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Release Location
Date time

APPENDIX D.

Detailed Locations of Vemco VR2 Receiver Deployments

Receiver location details of all receivers, including coordinates, river kilometer and installation dates (Table D - 1), along with satellite images showing receiver locations as orange circles and fish release locations as red triangles (Figures D - 1-5).

Table D - 1. Locations of deployed Vemco VR2W receivers and dates of installation, 2012-2013.

Receiver Location	RKM	Latitude	Longitude	Installation Date	Removal Date
Wells Tailrace 2	826.7	47.92234736	-119.8808663	7/11/2012	
Wells Tailrace 1	826.6	47.9236313	-119.8844112	7/11/2012	
Airport 1	819.0	47.86654995	-119.9173299	5/7/2012	
Airport 2	817.8	47.85476994	-119.9263199	5/7/2012	
Beebe Bridge 1	811.2	47.8142291	-119.9745545	5/15/2012	
Beebe Bridge 2	811.1	47.81196993	-119.9733999	5/7/2012	
Duck Tail Rock 1	794.0	47.76960997	-120.15913	5/15/2012	
Duck Tail Rock 2	793.8	47.766832	-120.158827	5/15/2012	
Entiat 1	780.7	47.67756527	-120.2041153	5/9/2012	
Entiat 2	780.7	47.6742499	-120.1995688	5/9/2012	
Turtle Rock 1	766.3	47.5589	-120.26466	6/29/2013	
Turtle Rock 2	766.3	47.55602	-120.25919	6/29/2013	
Rocky Reach BRZ 1	762.9	47.53544726	-120.2979207	5/8/2012	6/29/2013
Rocky Reach BRZ 2	762.9	47.53499639	-120.2913055	5/9/2012	6/29/2013
Rocky Reach Tailrace 1	761.8	47.52356088	-120.3027499	5/8/2012	
Rocky Reach Tailrace 2	761.2	47.52007644	-120.3046328	5/8/2012	
Rocky Reach Tailrace 3	761.2	47.51904027	-120.3017141	5/8/2012	

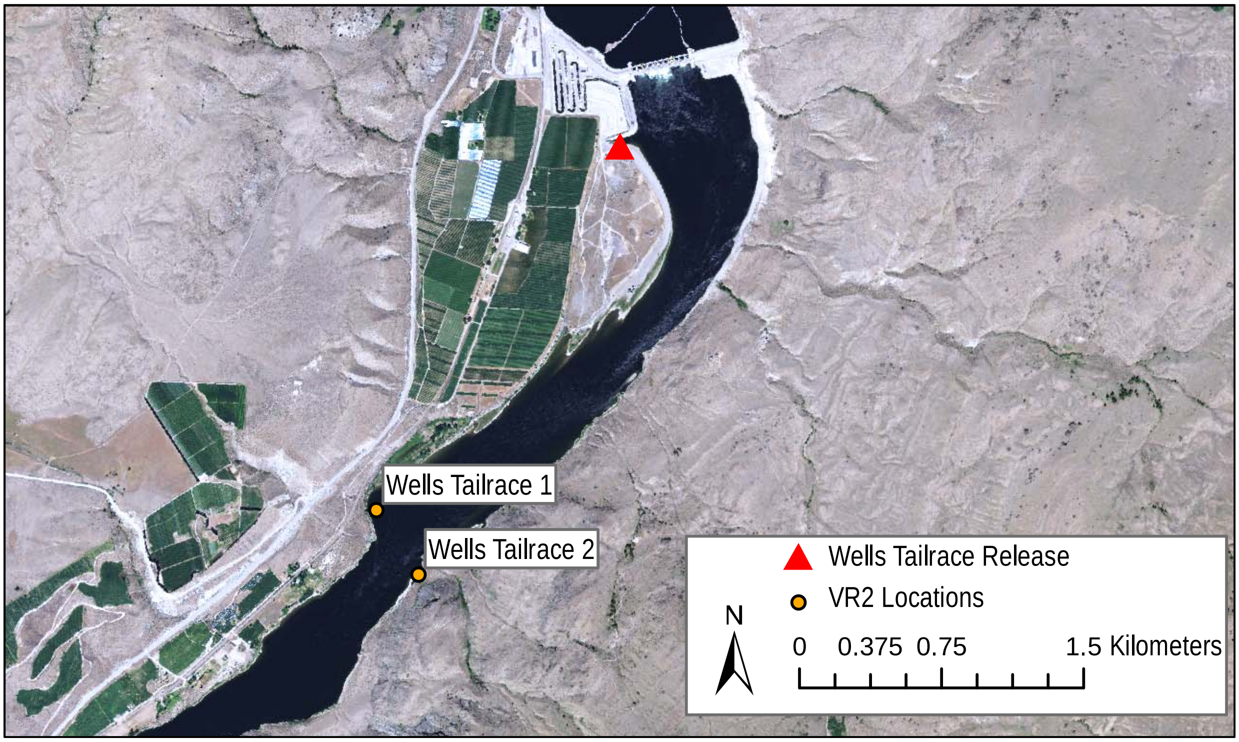

Figure D - 1. Locations of Vemco VR2 receivers deployed in the Wells Dam tailrace array (RKM = 827) and the Wells Tailrace release location (red triangle).

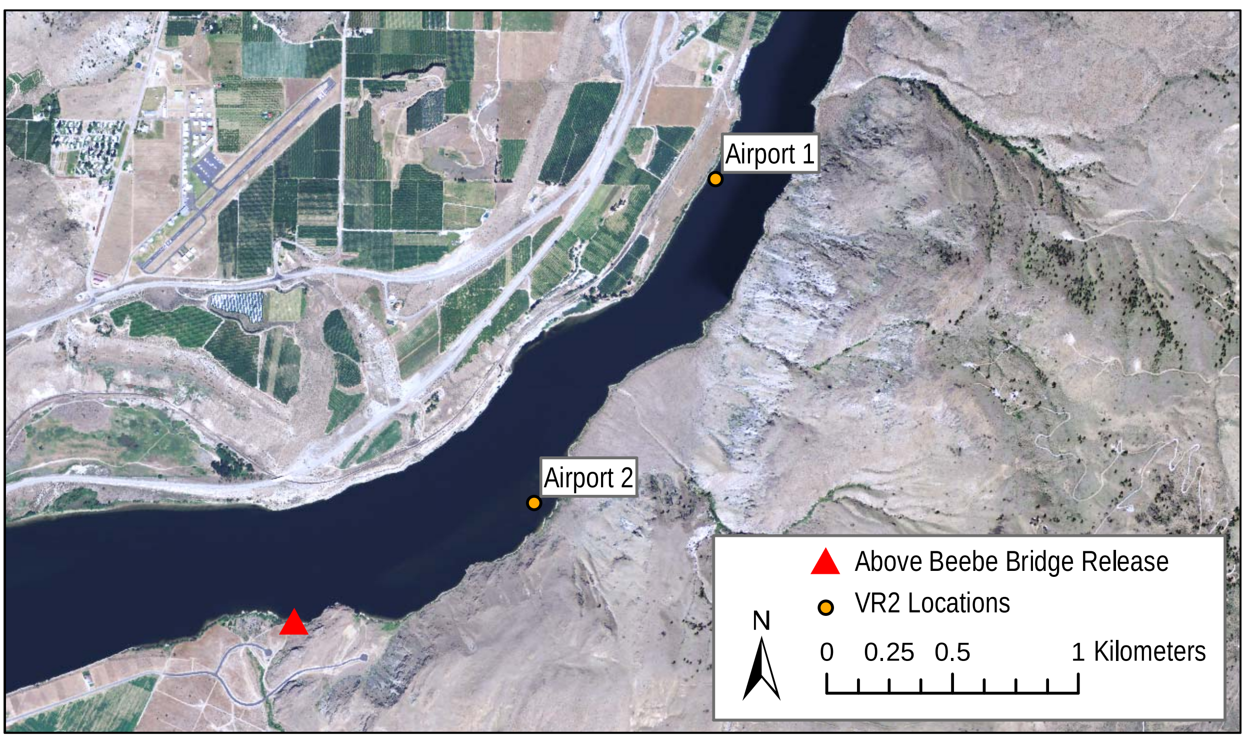

Figure D - 2. Locations of Vemco VR2 receivers deployed in the Airport array (Airport A = RKM 819, Airport B = RKM 818) and the Above Beebe Bridge release location (red triangle).

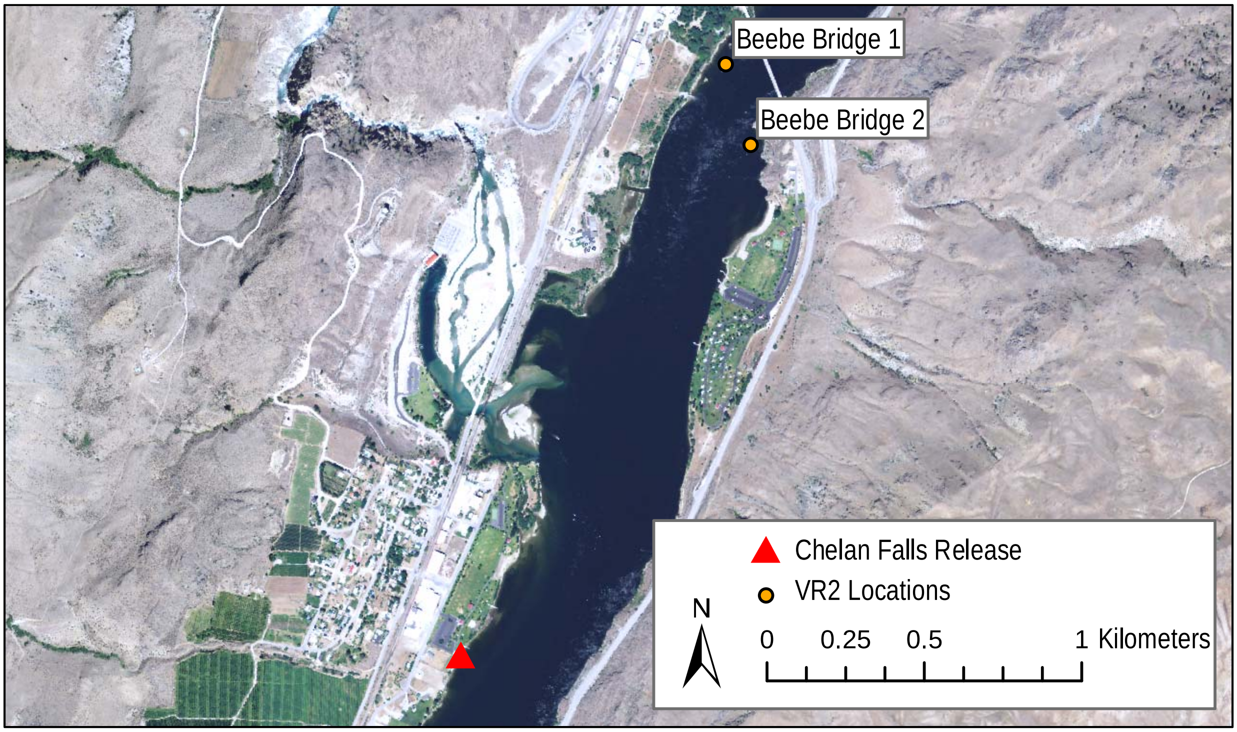

Figure D -3. Locations of Vemco VR2 receivers deployed in the Beebe Bridge array (RKM 811) and the Above Chelan Falls release location (red triangle).

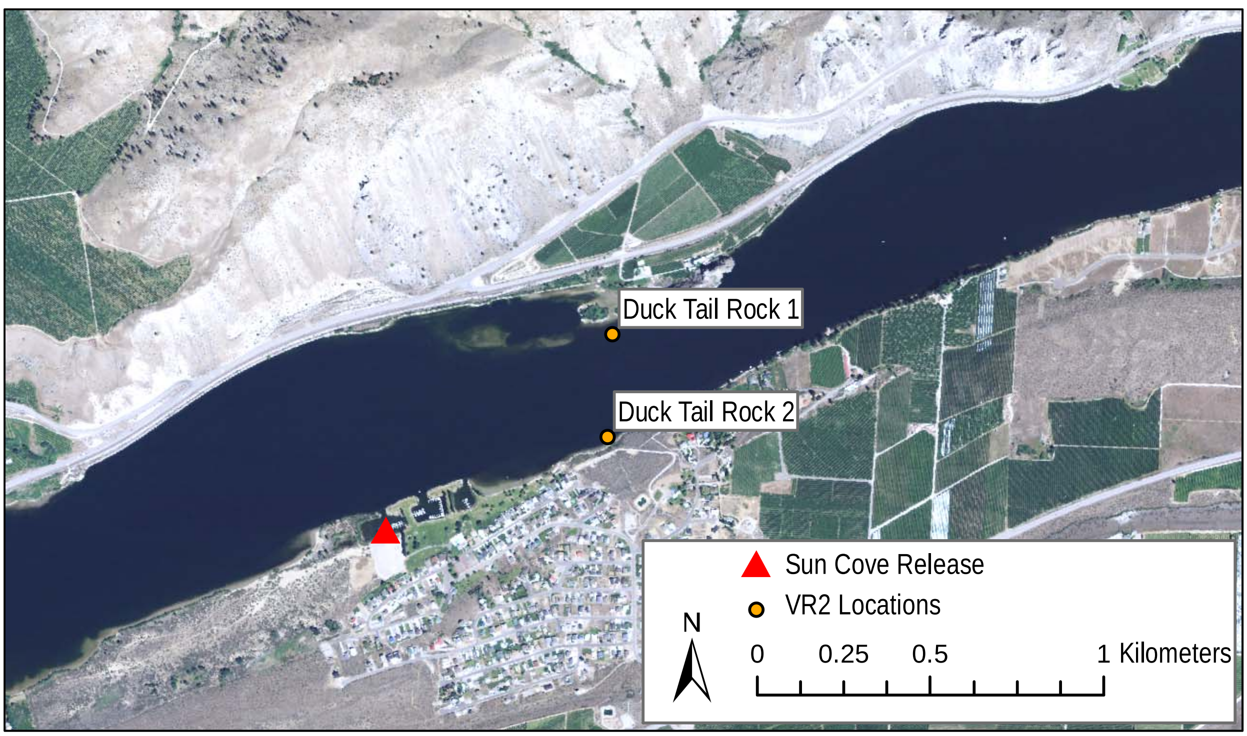

Figure D -4. Locations of Vemco VR2 receivers deployed in the Duck Tail Rock array (RKM 794) and the Duck Tail Rock release location (red triangle).

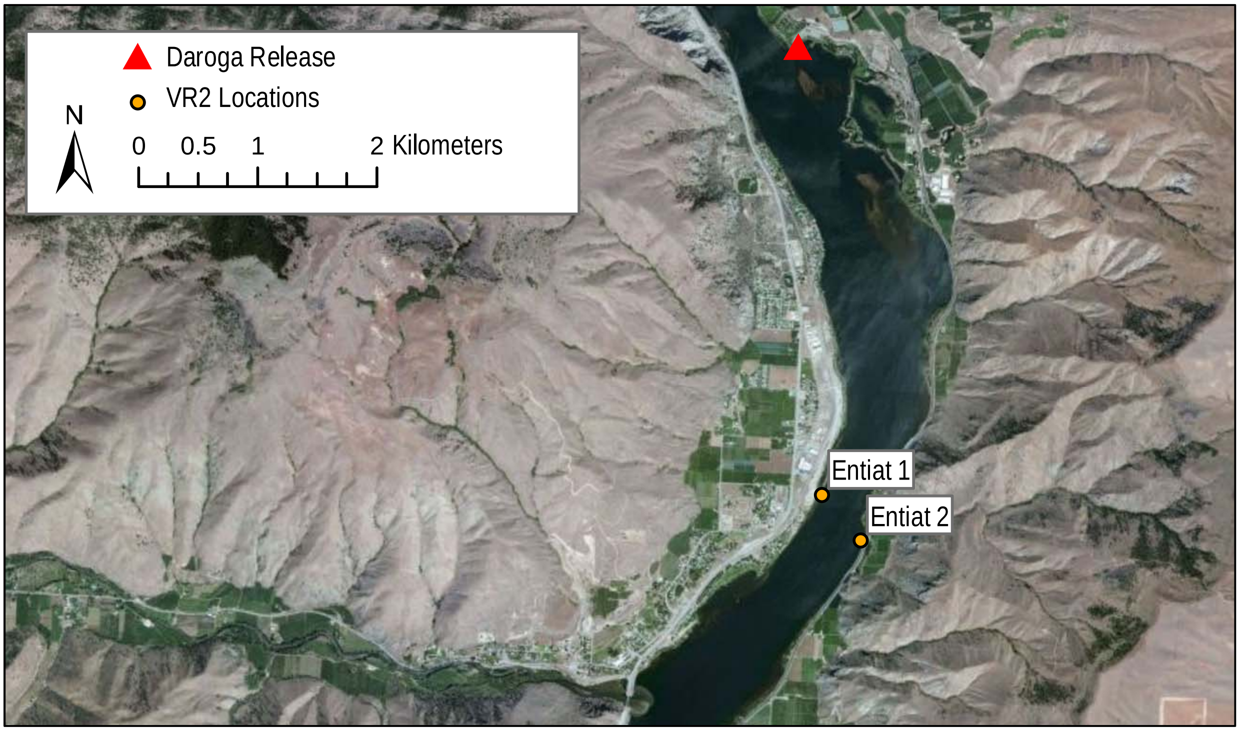

Figure D -5. Locations of Vemco VR2 receivers deployed in the Entiat array (RKM 781) and the Daroga release location (red triangle).

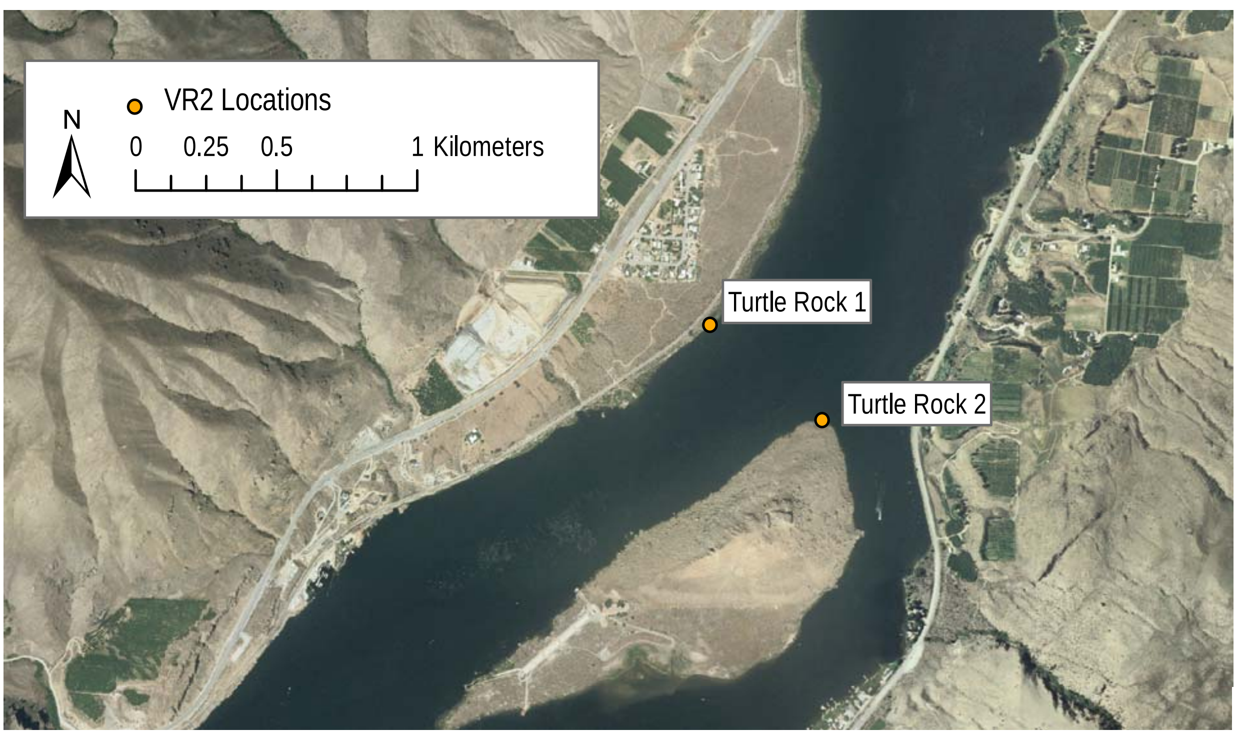

Figure D - 6. Locations of Vemco VR2 receivers deployed in the Turtle Rock array (RKM 766).

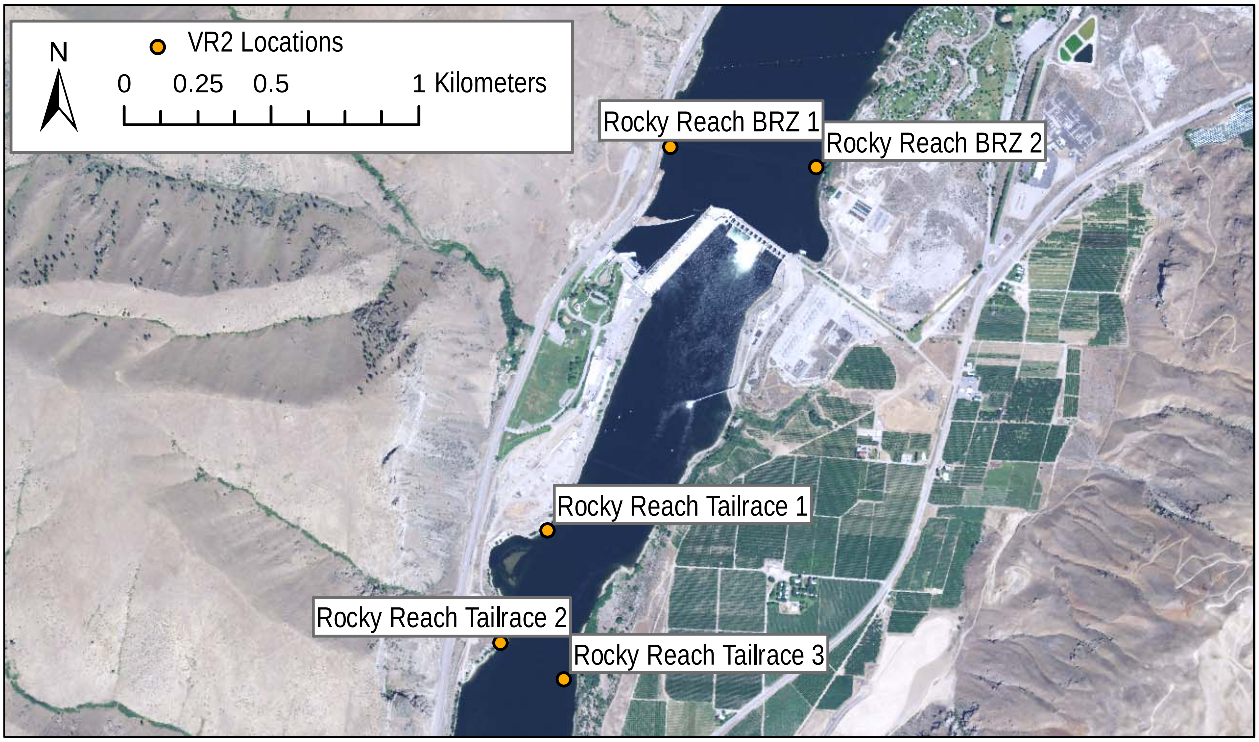

Figure D -7. Locations of Vemco VR2 receivers deployed comprising the Rocky Reach BRZ array (RKM 763) and the Rocky Reach Tailrace array (RKM 761-762).

APPENDIX E.

Sturgeon recapture locations during the 2013 population indexing fishing efforts.

Sturgeon recapture locations during the 2013 indexing fishing effort are shown with red dots. Setline fishing locations are represented with green lines and bathymetry contours are depicted with blue lines.

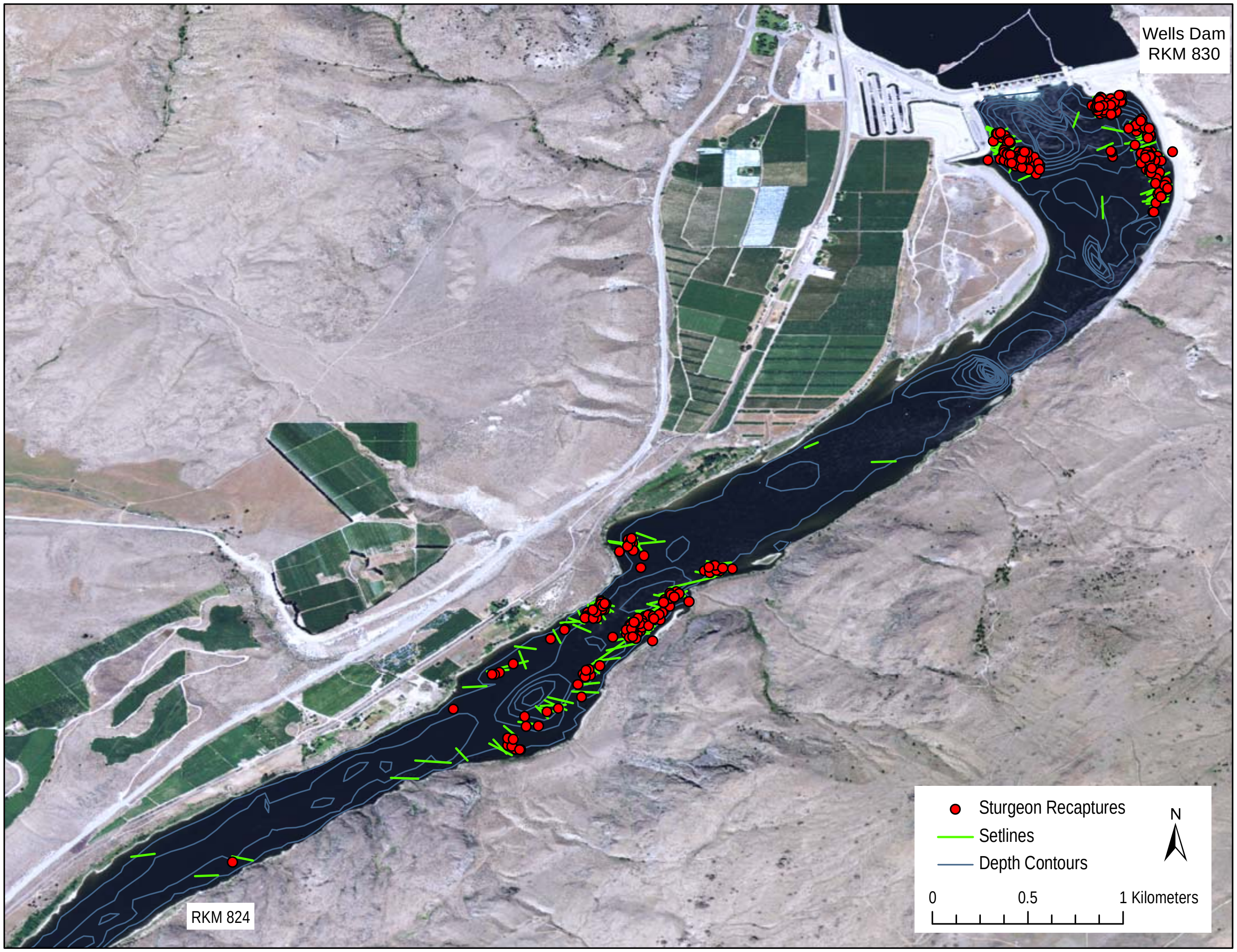

Figure E - 1. Sturgeon recapture locations during the 2013 population indexing fishing effort are shown with red dots. Setline fishing locations are represented with green lines and bathymetry contours are depicted with blue lines.

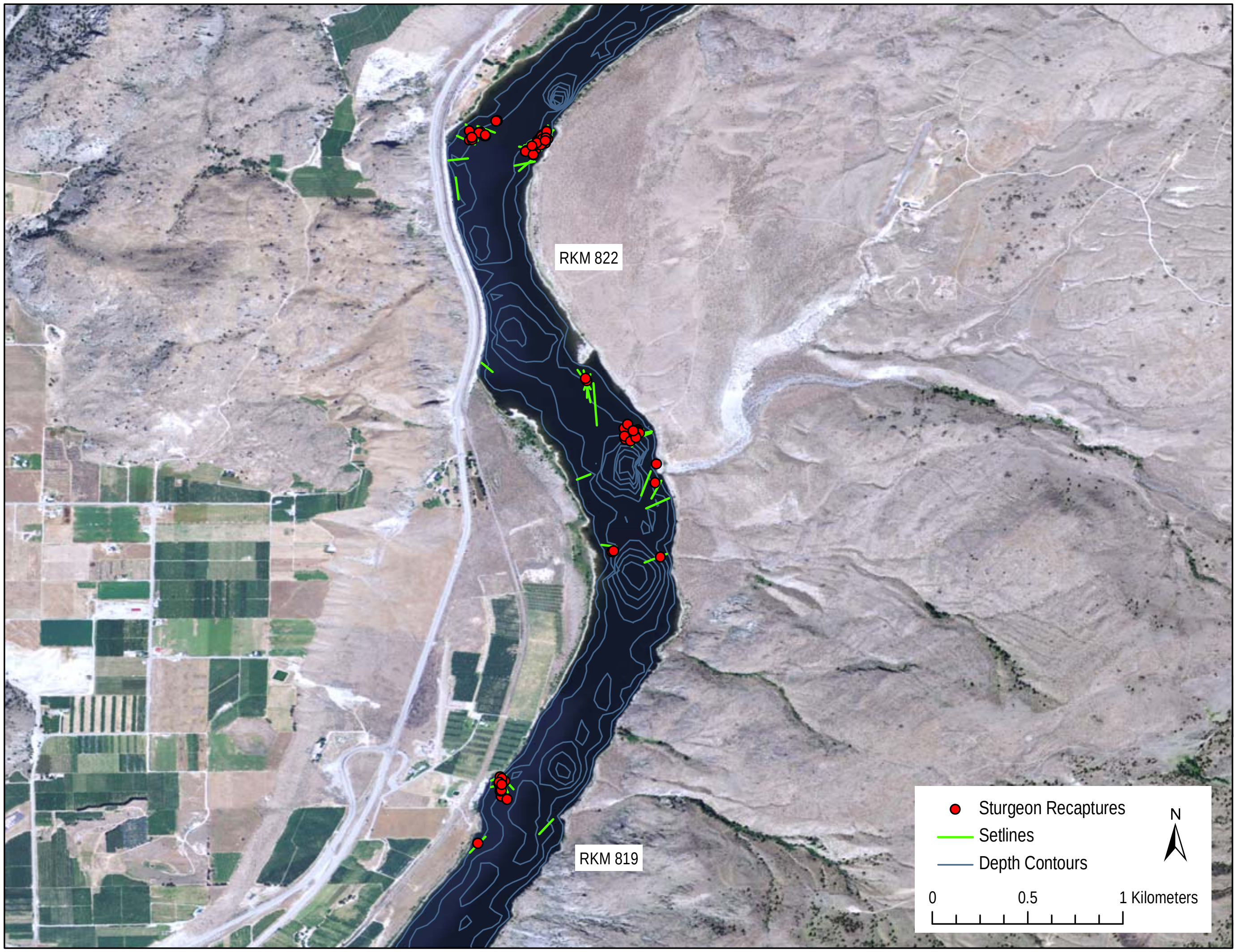

Figure E - 2. Sturgeon recapture locations during the 2013 population indexing fishing effort are shown with red dots. Setline fishing locations are represented with green lines and bathymetry contours are depicted with blue lines.

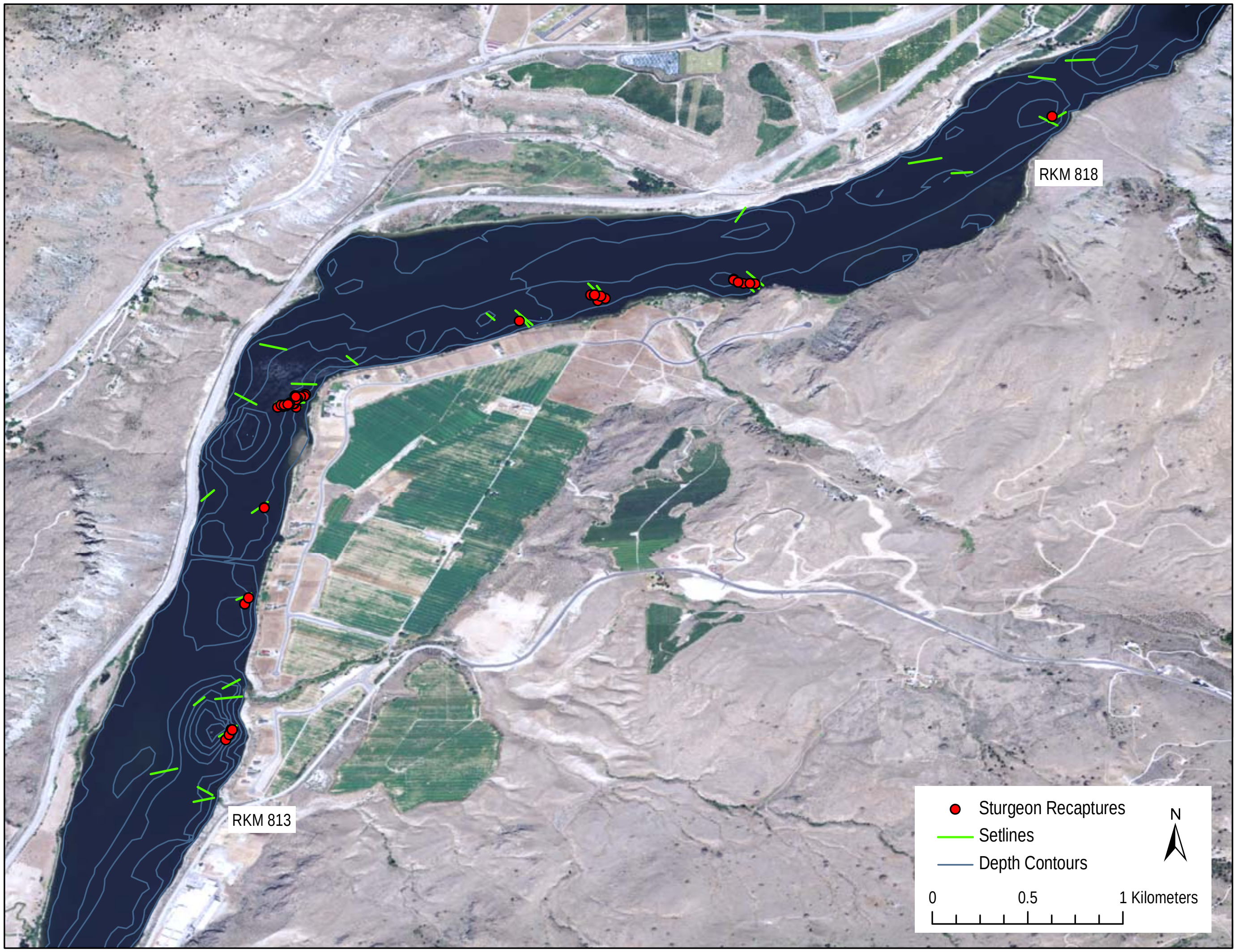

Figure E - 3. Sturgeon recapture locations during the 2013 population indexing fishing effort are shown with red dots. Setline fishing locations are represented with green lines and bathymetry contours are depicted with blue lines.

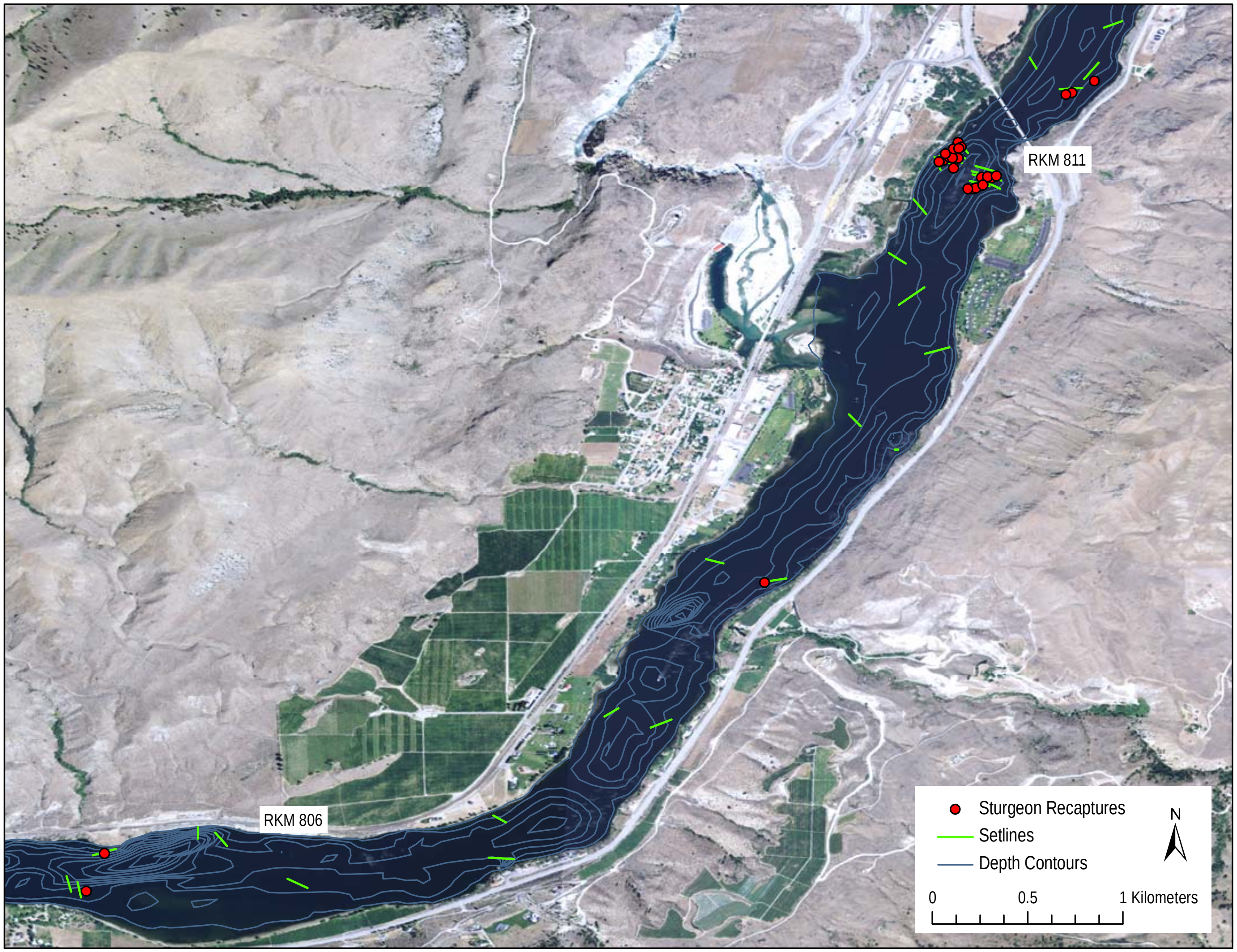

Figure E - 4. Sturgeon recapture locations during the 2013 population indexing fishing effort are shown with red dots. Setline fishing locations are represented with green lines and bathymetry contours are depicted with blue lines.

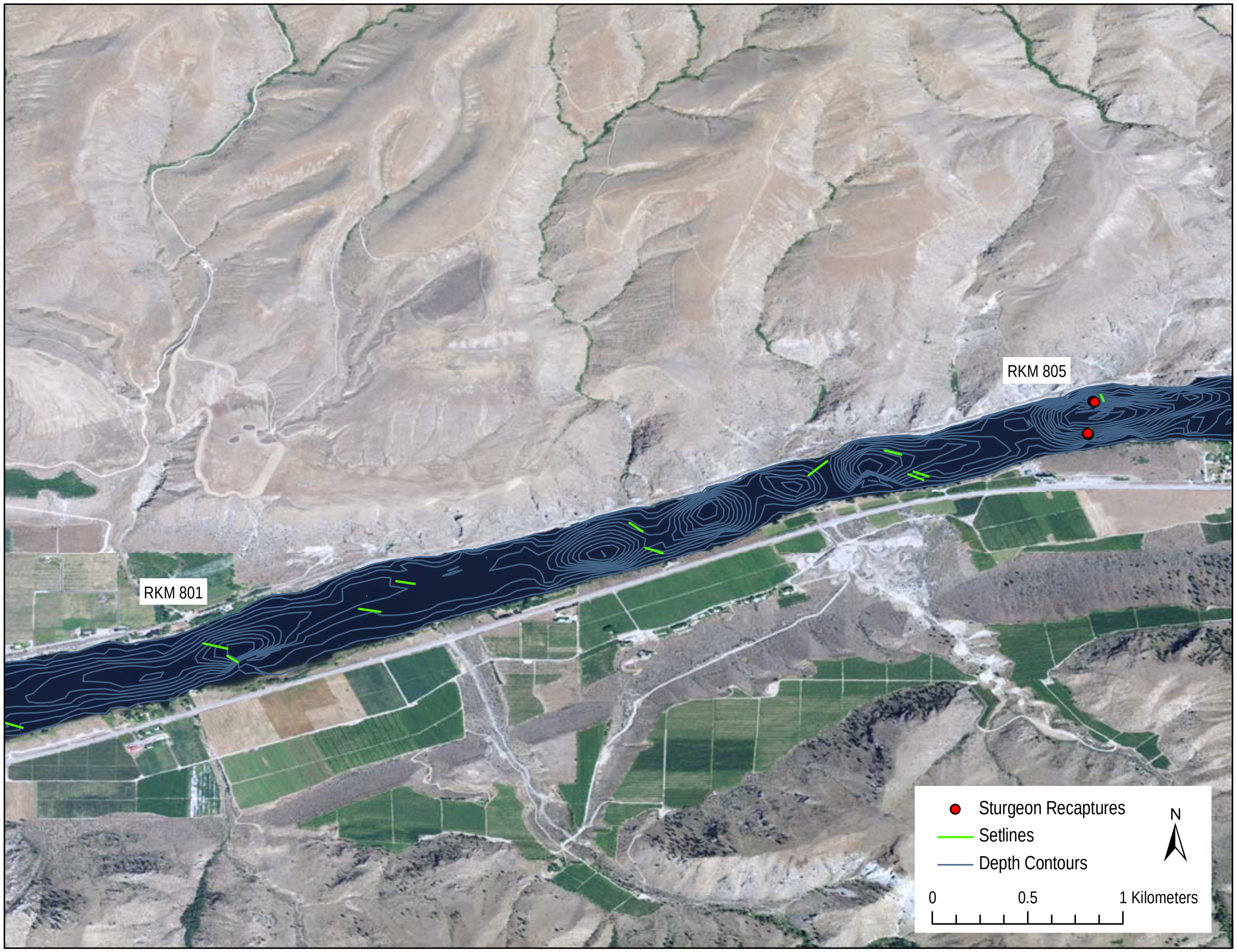

Figure E - 5. Sturgeon recapture locations during the 2013 population indexing fishing effort are shown with red dots. Setline fishing locations are represented with green lines and bathymetry contours are depicted with blue lines.

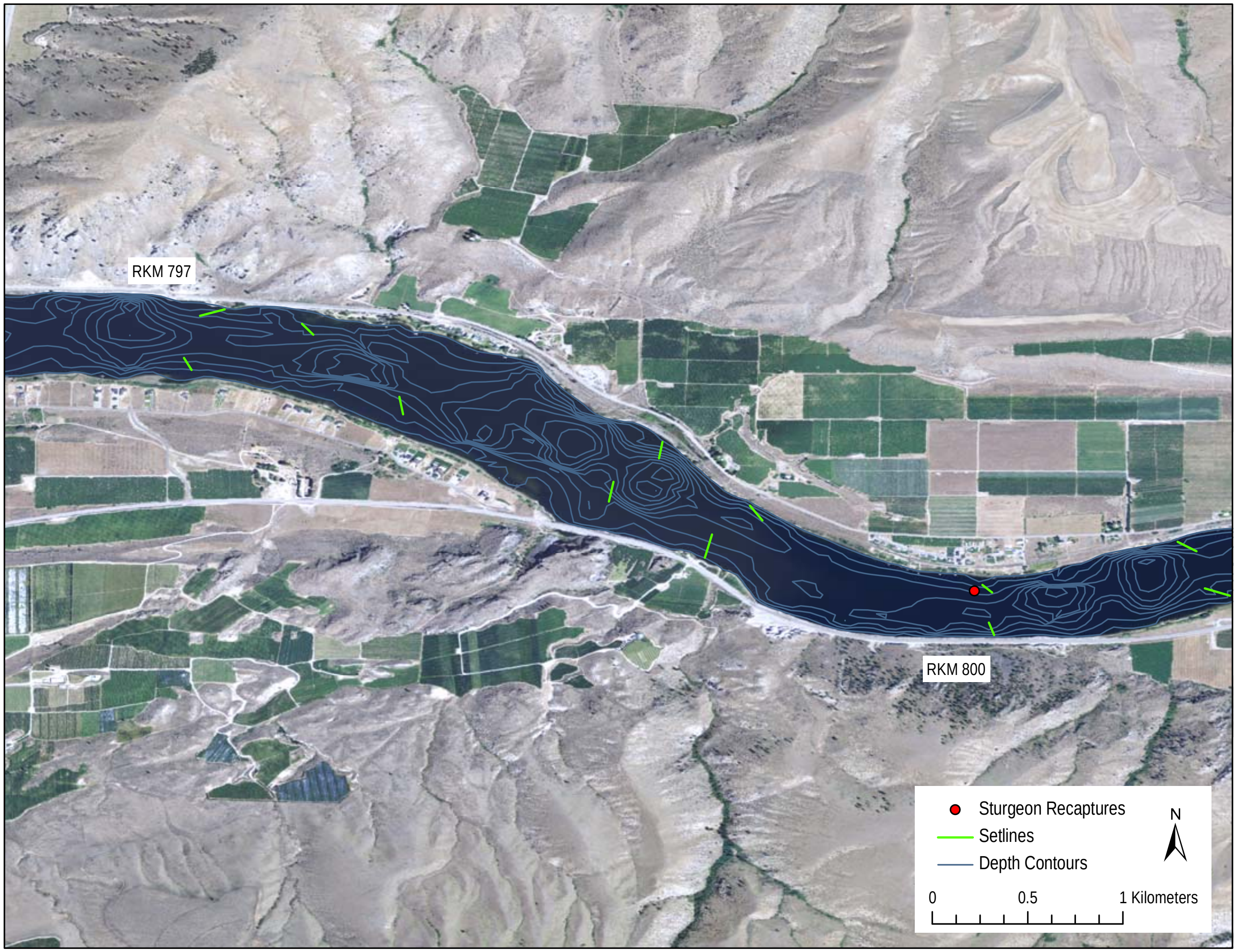

Figure E - 6. Sturgeon recapture locations during the 2013 population indexing fishing effort are shown with red dots. Setline fishing locations are represented with green lines and bathymetry contours are depicted with blue lines.

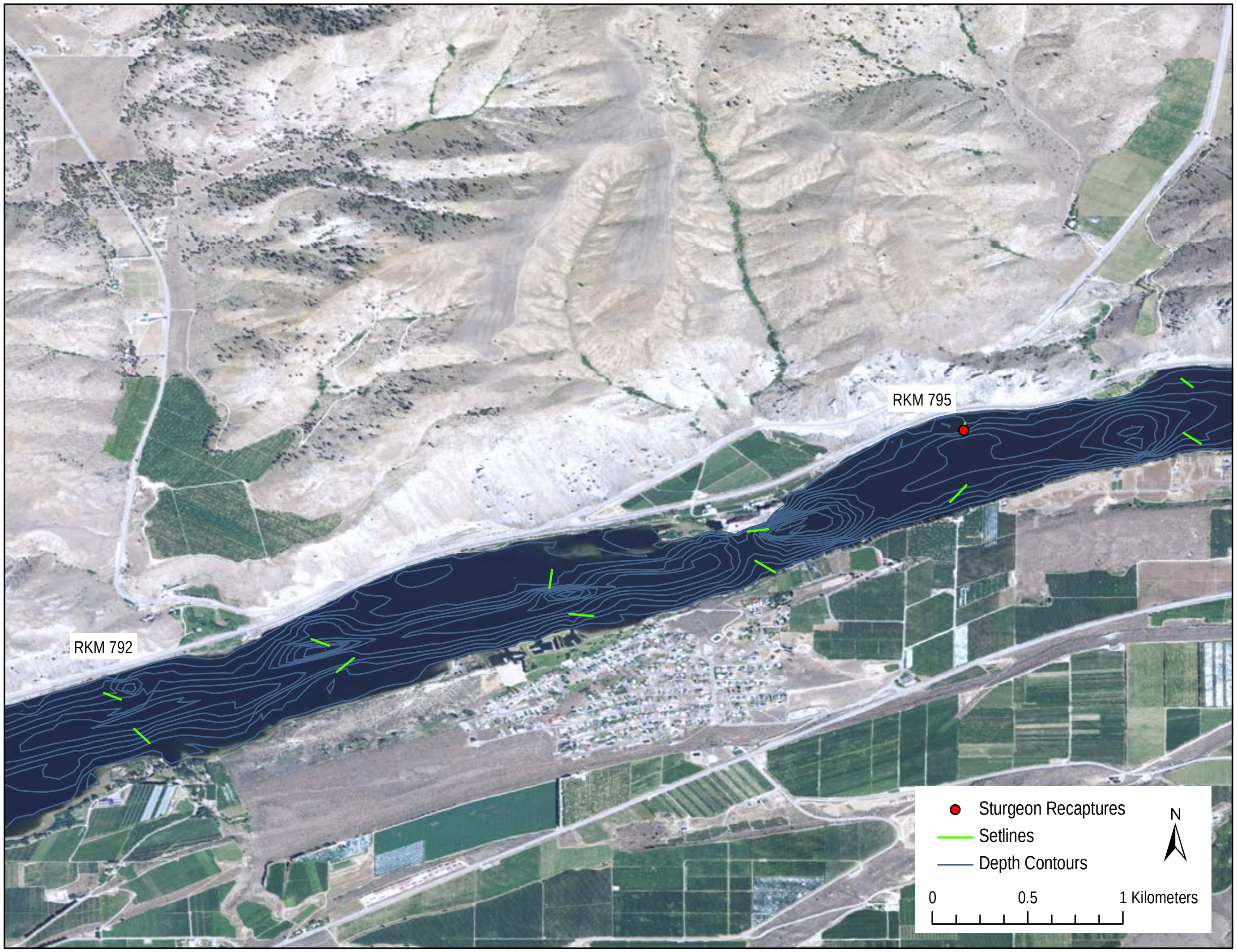

Figure E - 7. Sturgeon recapture locations during the 2013 population indexing fishing effort are shown with red dots. Setline fishing locations are represented with green lines and bathymetry contours are depicted with blue lines.

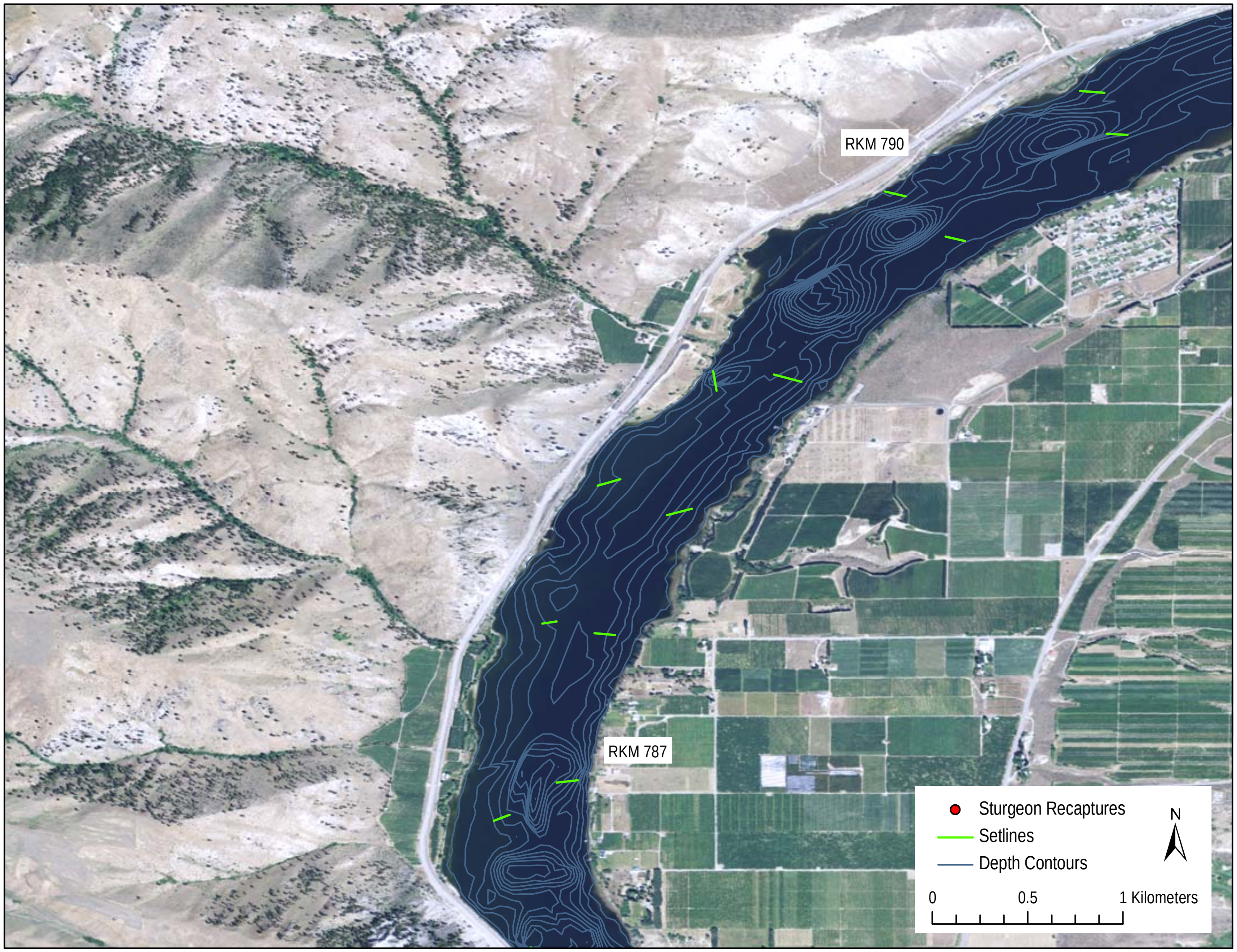

Figure E - 8. Sturgeon recapture locations during the 2013 population indexing fishing effort are shown with red dots. Setline fishing locations are represented with green lines and bathymetry contours are depicted with blue lines.

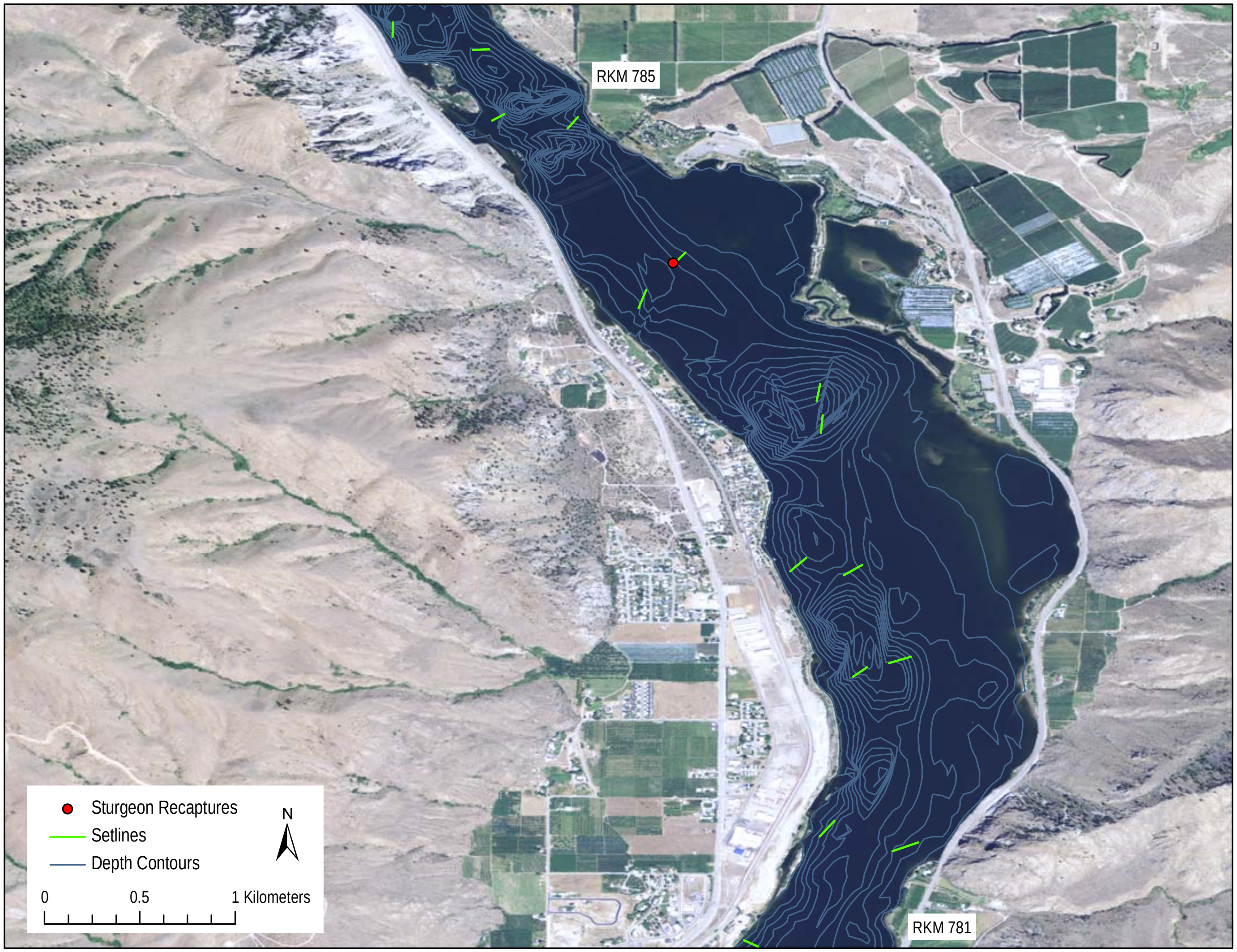

Figure E - 9. Sturgeon recapture locations during the 2013 population indexing fishing effort are shown with red dots. Setline fishing locations are represented with green lines and bathymetry contours are depicted with blue lines.

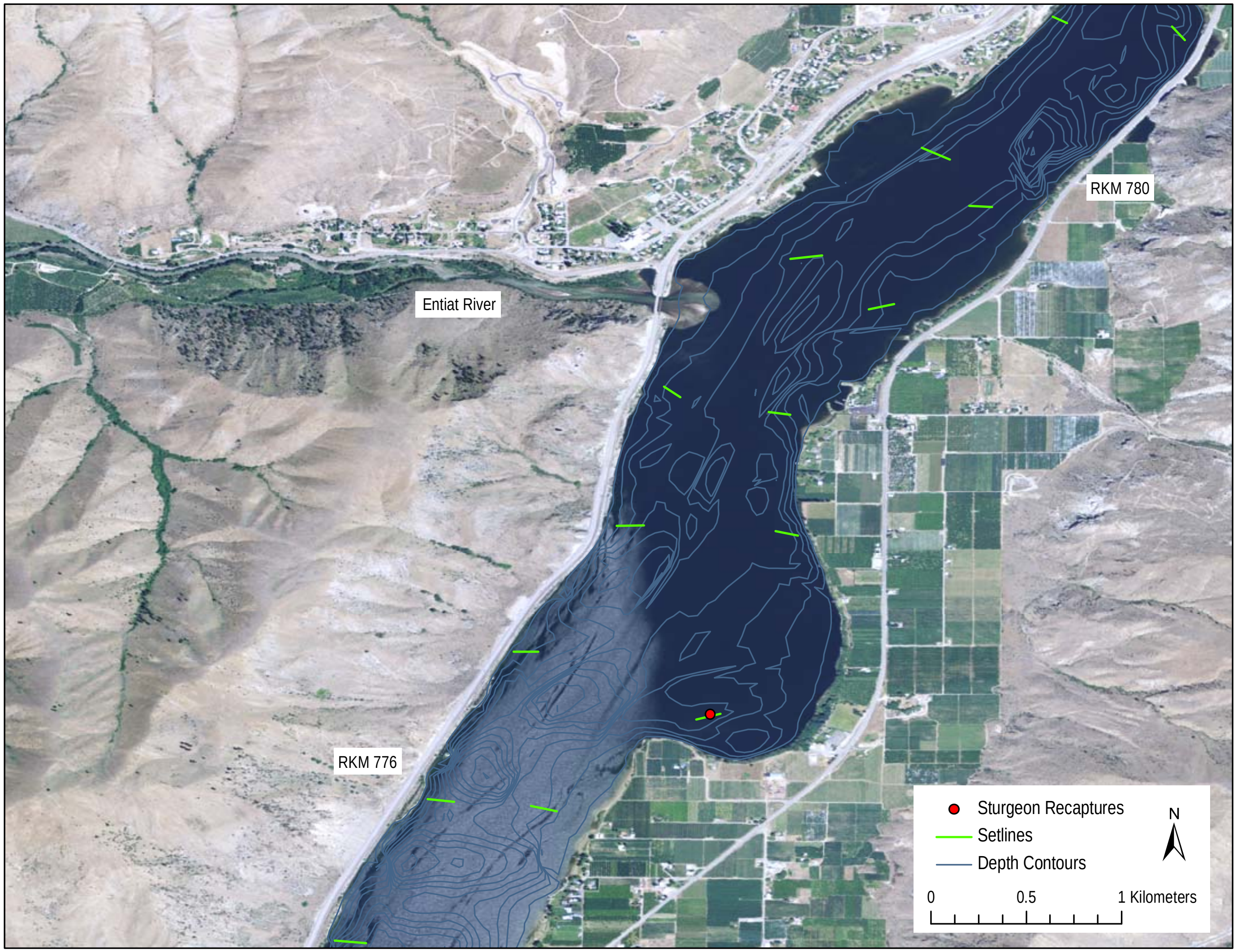

Figure E - 10. Sturgeon recapture locations during the 2013 population indexing fishing effort are shown with red dots. Setline fishing locations are represented with green lines and bathymetry contours are depicted with blue lines.

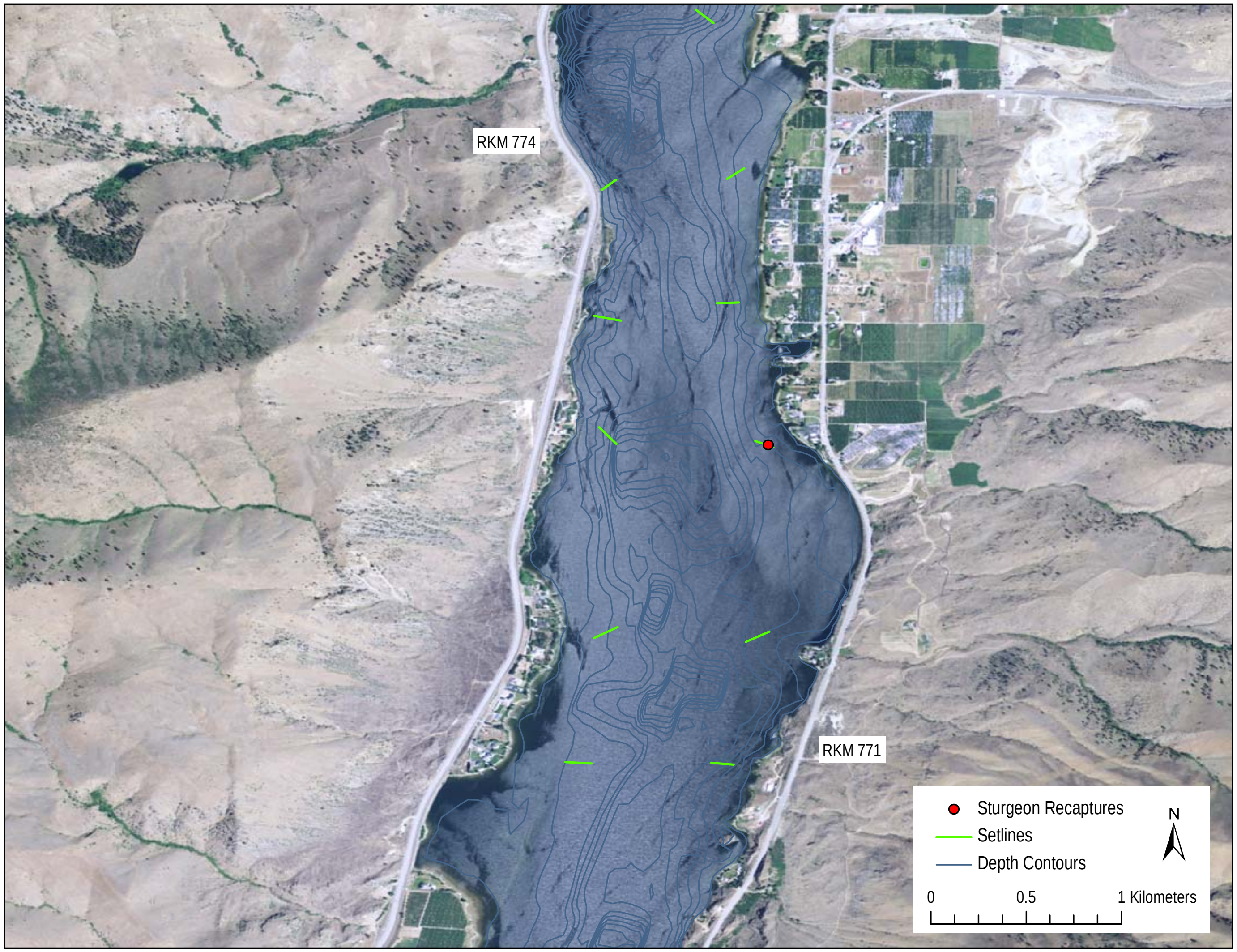

Figure E - 11. Sturgeon recapture locations during the 2013 population indexing fishing effort are shown with red dots. Setline fishing locations are represented with green lines and bathymetry contours are depicted with blue lines.

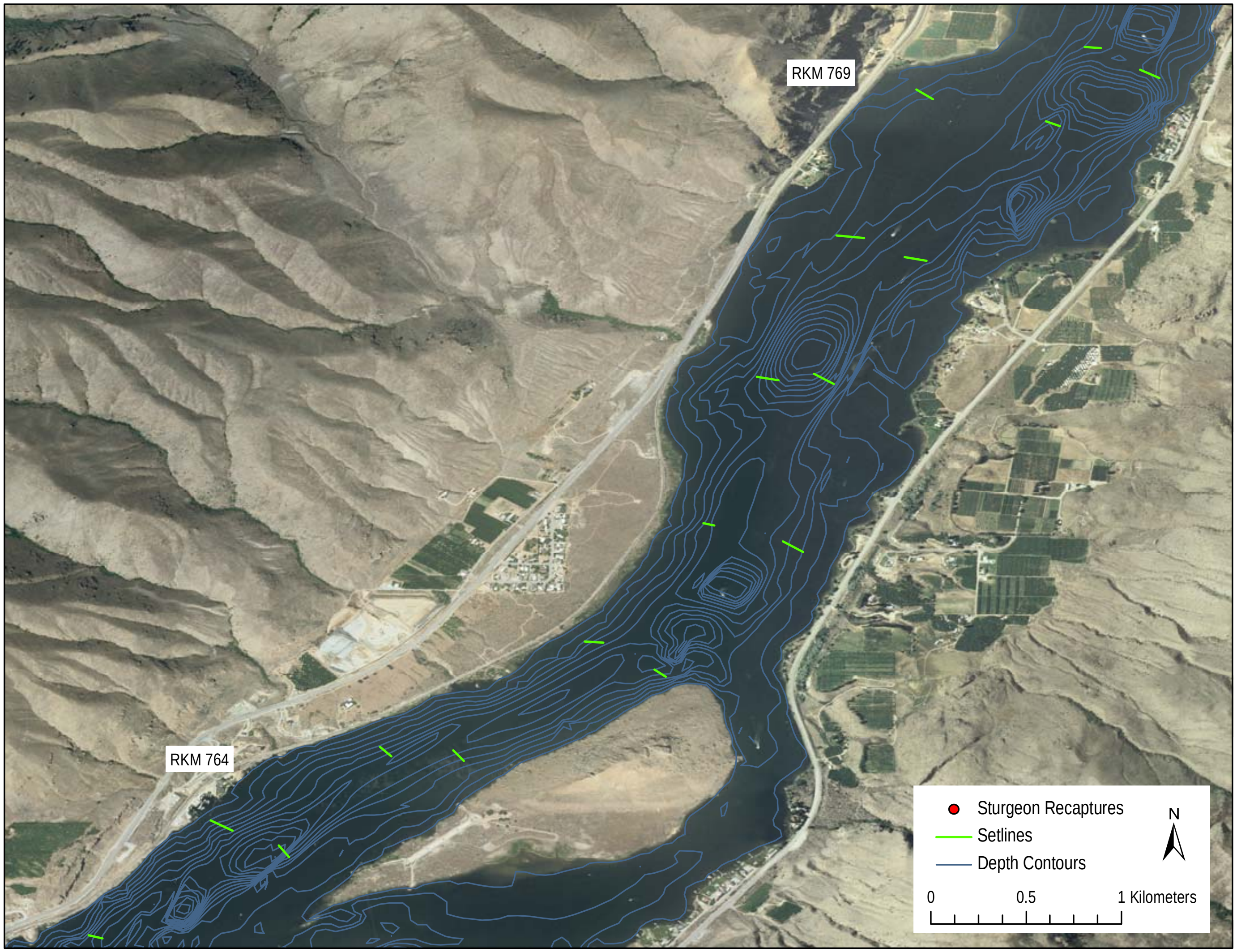

Figure E - 12. Sturgeon recapture locations during the 2013 population indexing fishing effort are shown with red dots. Setline fishing locations are represented with green lines and bathymetry contours are depicted with blue lines.

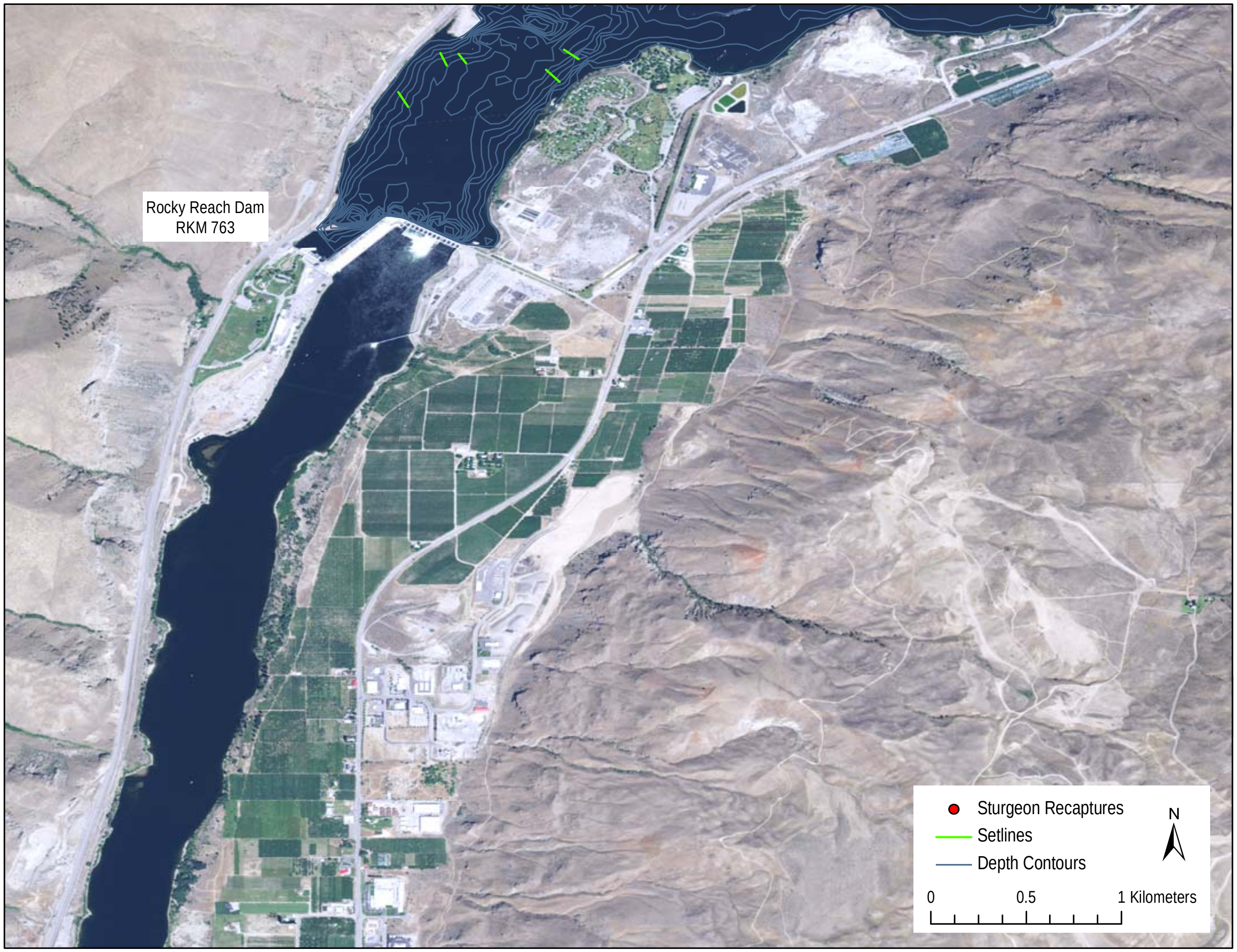

Figure E - 13. Sturgeon recapture locations during the 2013 population indexing fishing effort are shown with red dots. Setline fishing locations are represented with green lines and bathymetry contours are depicted with blue lines.