RECLAMATION

Managing Water in the West

American River Steelhead (*Oncorhynchus mykiss*) Spawning – 2013, with comparisons to prior years

Central Valley Project, American River, California
Mid-Pacific Region

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Table of Contents

List of Figures

List of Tables

Abstract

The 2013 steelhead spawning surveys in the lower American River were conducted December 26, 2012 through April 3, 2013. The survey spanned the majority of the spawning reach of the lower American River from Nimbus Dam (Mile 23) to the J Street Bridge (Mile 7). Redd locations and descriptive attributes were mapped with GPS and incorporated into a GIS database. A total of 314 steelhead redds was observed. Steelhead redds were observed from January 9 to March 20 and steelhead holding on redds were observed January 9 to March 8. Population estimates based on redds observed ranged from 287 to 575 and the population estimate based on occupied redds was 437. Redd density was 17.6 redds per river mile in the spawning reach and 46.5 redds per mile in the higher density spawning area in the upper seven miles of the river, between Nimbus Dam and Ancil Hoffman Park. Additional data was collected on Pacific lamprey spawning and is presented here. This report contains a cross years comparison and compilation of results from 2002 through 2013.

Introduction

Steelhead returns to Nimbus Hatchery have historically provided the only index of steelhead abundance in the American River (Figure 1). The Central Valley Steelhead distinct population segment (DPS) includes only the naturally spawning steelhead in the American River. Fish produced in the Nimbus Hatchery are excluded from the DPS. Staley (1976) estimated steelhead populations in the American River in the 1971-72 run to be 19,583 fish and in the 1973-74 run to be 12,274 fish. Numbers of steelhead entering the hatchery during these years were 2,256 and 3,237 respectively. He used three to five hexagonal wire fyke traps between Watt and Howe Avenue to capture and mark steelhead. Recaptures were made from fish entering Nimbus Hatchery. These were the only early post-dam steelhead run size estimates made for the American River other than the hatchery returns. During Staley's studies he captured steelhead in the American River that had been marked from the Feather River, Coleman Hatchery, and Mokelumne River.

Our primary objective in this work is to provide yearly estimates of in-river spawning steelhead abundance or an index of abundance that will be comparable from year to year. Secondary objectives include determining how flows affect steelhead spawning locations, timing, and egg to fry survival and determining what proportion of in-river spawning steelhead are of natural (vs. hatchery) origin.

Steelhead spawning surveys have been conducted in the American River for the years 2002-2007 and 2009 – 2013 to provide a yearly index of in-river steelhead spawning abundance. In-river spawner population estimates were produced from redd counts each year except 2006, when flows were too high, and 2008. Additionally spawner population estimates were produced from an area under the curve method (Hilborn et al. 1999) using observations of steelhead occupying redds in 2002-2005, 2007, and 2011-2012. This report provides results of the 2013 surveys along with comparisons to prior year surveys.

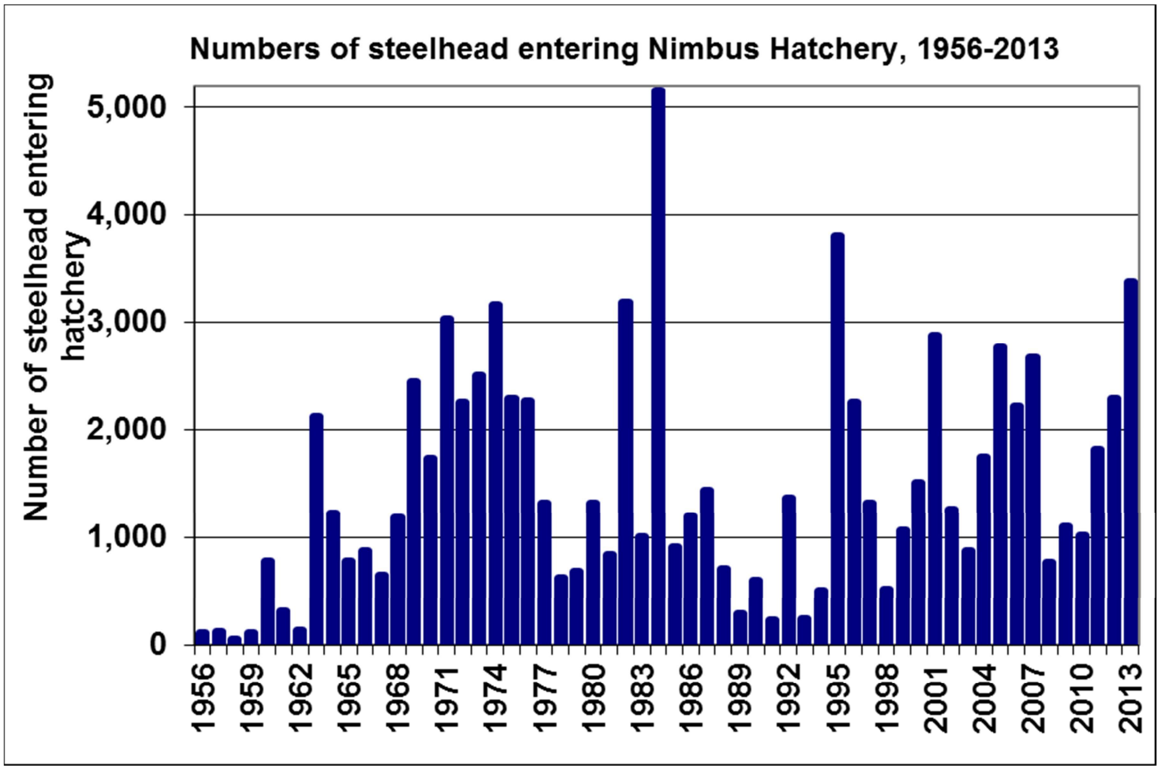


Figure 1. Number of steelhead entering Nimbus Hatchery, 1956 - 2013. Data from CDFW Nimbus Hatchery records.

Methods

Field Surveys

The American River was surveyed for steelhead redds using a jet boat and by snorkeling and wading. The survey encompassed the majority of the spawning reach of the Lower American River from Nimbus Dam (top of anadromous habitat) down to the J Street bridge, mile 7 to 23 (Figure 2). The Paradise Beach area at mile 5 was surveyed on one occasion, March 6. The boat was maneuvered so that nearly all areas that appeared to be potential spawning habitat (i.e. suitable water velocity and substrate) could be viewed (Figure 3). Crew members stood in the bow of the boat to obtain a viewing position well elevated above the water surface. The elevated position of surveyors above the water enhanced viewing efficiency in comparison with wading or using a lower profile boat. Surveyors wore polarized sunglasses to help see through glare on the water surface. When water was too shallow for the boat the section was walked. Spacing between transects covered by the boat in potential spawning habitat was generally about 20 meters. The boat operator adjusted spacing between transects to maintain visibility of the river bottom between transects.

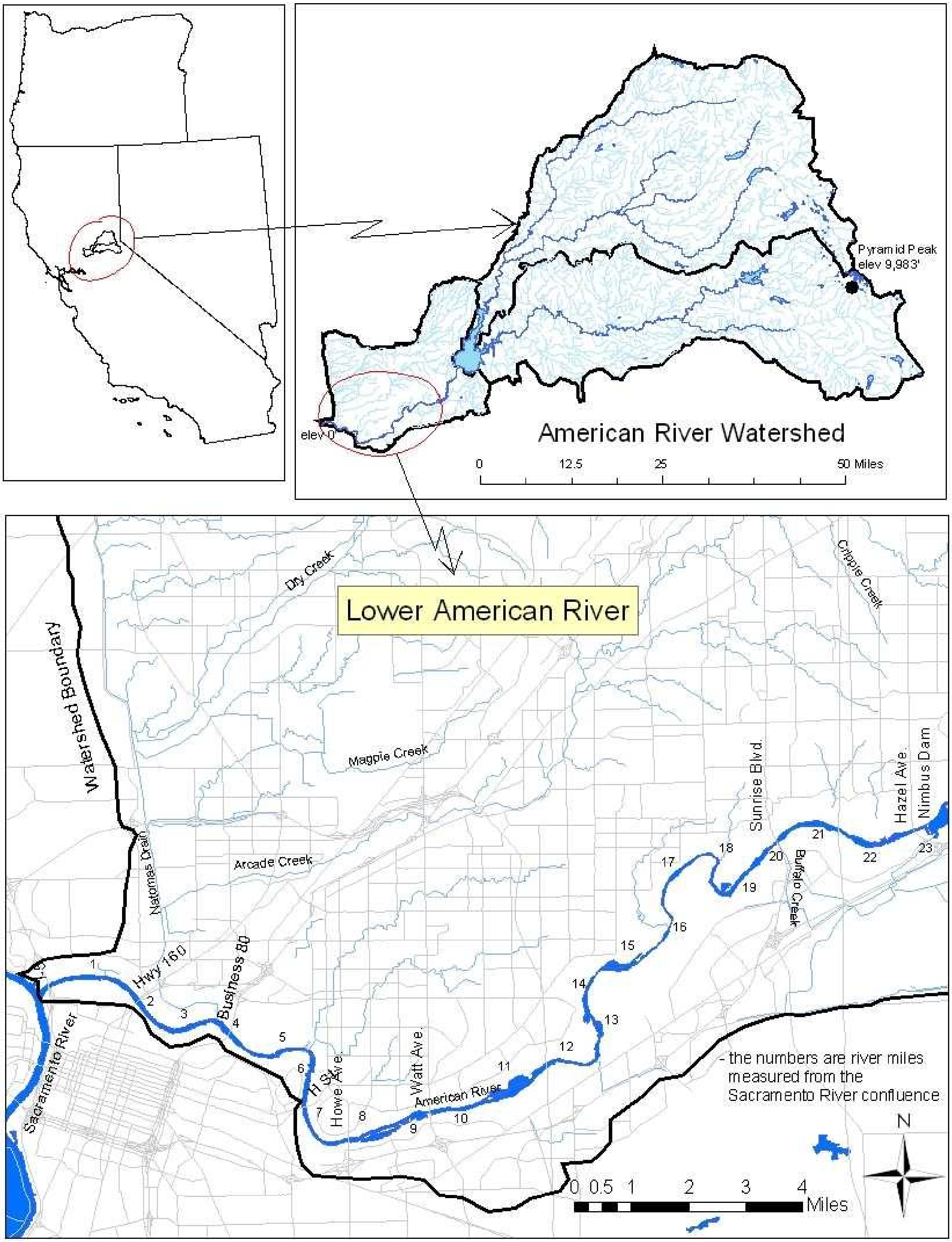


Figure 2. The American River watershed and Lower American River where steelhead spawning surveys were conducted. The spawning reach extends from mile 5 (Paradise Beach area) to Nimbus Dam at mile 23.

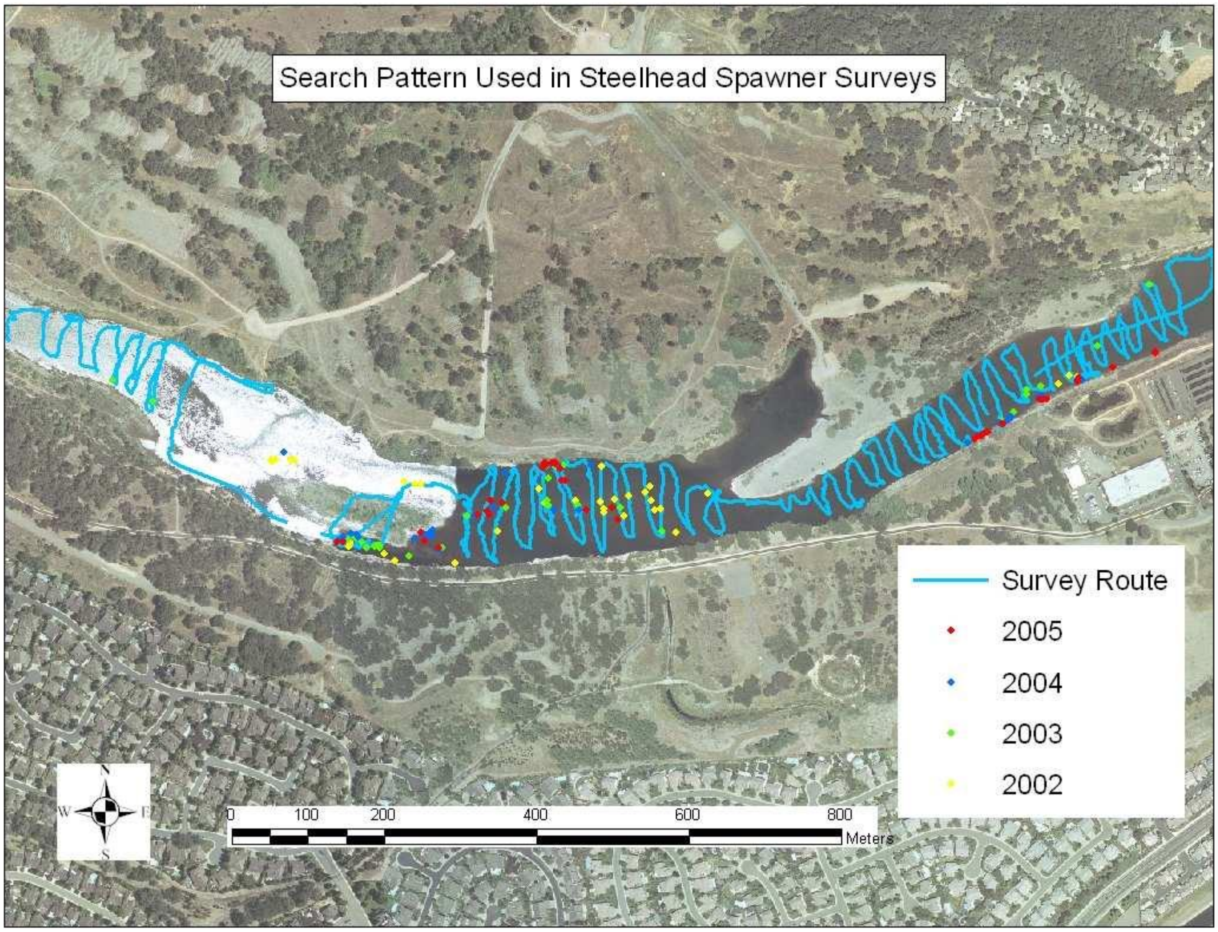


Figure 3. Survey route collected with GPS during one American River steelhead redd survey. Search patterns varied depending on flow conditions and related factors that influence vessel operations.

Redd Measurements

When a steelhead redd was observed it was marked with the GPS unit, physical measurements were made, and the data entered into the GPS unit. A Trimble Geoexplorer GPS unit was used to mark steelhead redd locations and record redd measurements. A data dictionary was created using Trimble Pathfinder Office software so that attribute data could be attached to each data point. Redd measurements were based on measurements used in California coastal spawning surveys (Gallagher 2002). We used a Marsh-McBirney Flo-Mate™ 2000 Flow Meter and top-setting wading rod for taking measurements. The redd measurements were taken to the nearest centimeter with the wading rod and recorded on the GPS unit. Table 1 describes the redd measurements and Figure 4 shows a picture of a steelhead redd with the measurements denoted. Water velocity measurements were taken over a 20 second average. All the attributes collected on each redd are attached to the point in the GIS coverage so that data on each specific spawning location can be analyzed spatially through time.

Table 1. Data recorded for redds.

Data Field	Description
Species	Steelhead, chinook, lamprey, sucker, pikeminnow, unknown
Depth	Water depth in centimeters measured near pot in a location to approximate depth prior to redd construction
Redd Age	0=test redd, 1=fish on, 2=new still clear, 3=older some algae, 4=old obscure, 5=marker only, 6=visible on aerial photo
Fish size	Estimated length of a fish on a redd, cm
Fish size 2	Estimated length of a second fish on a redd, cm
Velocity	Water velocity measured near the front of the redd in a location near the bottom where a fish would be when beginning to construct a redd (about 10-20 cm off the bottom)
Velocity column	Mean water column velocity
Pot length (PL)	Length of pot parallel to flow
Pot width (PW)	Maximum width of pot perpendicular to flow
Pot depth (PD)	Maximum depth of excavation relative to the undisturbed stream bed = water depth in pot minus water depth to undisturbed stream bed
Pot substrate (PS)	Size of dominant substrate in pot, visually estimated after calibrating with measuring device
Tail spill length (TSL)	Length of tail spill parallel to flow
Tail spill width 1 (TSW1)	Width of tail spill perpendicular to flow at 1/3 of the distance down from the upstream end of the tail spill
Tail spill width 2 (TSW2)	Width of tail spill perpendicular to flow at 2/3 of the distance down from the upstream end of the tail spill
Tail spill substrate (TS)	Size of dominant substrate in tail spill, visually estimated after calibrating with measuring device
Background substrate (BS)	Size of dominant substrate adjacent to redd used to represent substrate conditions at redd prior to redd creation
Cover distance (CD)	Distance to cover that could be used by adult steelhead, such as vegetation on the bank, woody debris, large substrates, or artificial structures
Marker	Denotes that a colored marker was placed on the redd
Flow	River flow in cfs released to the river from Nimbus Dam
Method	Motor boat, drift boat, canoe, snorkeling, wading, aerial

Fish Observations

An additional data coverage was created for fish observations not associated with redds. Data collected in this coverage included species, count, visually estimated length, size category, position accuracy, presence or absence of fungus, and presence or absence of adipose fin. Secchi depth readings were used to measure water clarity. Secchi depth was taken at least once during each survey day and saved in the fish observation file. The upper river water clarity measurement location was at the old Fair Oaks bridge (RM 20) and the lower river location was at the Fairbairn Water Intake (RM 7). Both sites had sufficient water depth for secchi readings.

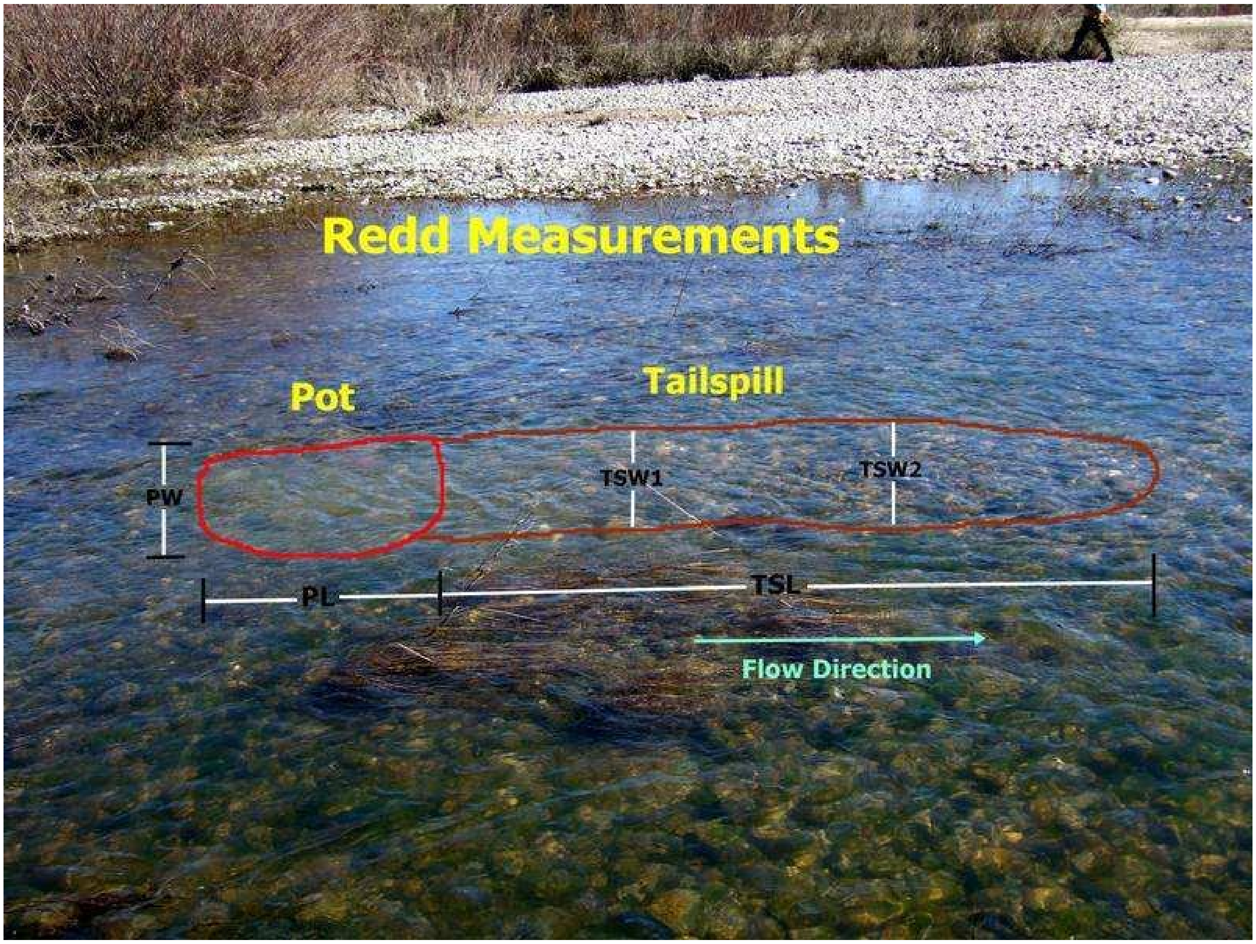


Figure 4. Illustration of measurements taken of steelhead redds. Abbreviations: PW=pot width, PL=pot length, TSW1=tailspill width 1, TSW2=tailspill width 2, TSL=tailspill length.

The redd locations with corresponding attribute data were saved as a point shapefile after differentially correcting the rover files collected in the field. The survey routes were stored as line shapefiles so that the specific areas of river surveyed could be viewed on a map. The mapped survey route allowed us to determine track areas that were surveyed and not surveyed. The survey route could be overlayed on a habitat-type map of the river to determine if all areas were adequately surveyed. When redds from two different surveys were marked close to each other (within about 5 meters of each other), the data was examined to determine whether these were the same redd based on the judgement of the surveyors. If it was believed to be the same redd from a previous survey, it was not used in the composite shapefile. Many redds in areas not frequented by wading anglers were marked on the ground with colored rocks to help determine how long redds remain identifiable. Data from each day was stored in a separate file, downloaded at the end of each survey period, and then exported into a composite GIS shapefile. Data was differentially corrected using Trimble Pathfinder Office software. The data was edited and displayed on orthophotos using ArcMap.

Redd Survey from Aerial Photography

Each year aerial photography is used to conduct river-wide redd counts for Chinook salmon in the fall. In 2013, good survey conditions during the peak of steelhead spawning allowed a test of an aerial survey for detecting steelhead redds. The reach of the river from Nimbus Dam to the Business 80 bridge was flown on February 13, 2013 and photographed at a scale of 1:2,400. Selected spawning areas were visited on the ground concurrent with the photography. The resulting 66 color photo negatives were scanned at 1,000 pixels per inch. This resulted in individual TIFF file sizes of 232.5 megabytes per photo. The pixel density was reduced from a density of 1,800 pixels per inch (1.12 gigabytes per photo), used in prior flights, to reduce file size for less computer processing time when viewing and editing. The resulting digital images were viewed with the help of photo editing software to enhance the visibility of the river bottom for easier redd identification. The redds that were visible in the photos and not previously mapped in ground surveys were digitized manually and added to the composite steelhead redd shapefile.

Population Estimates

We estimated steelhead populations in 2002 – 2005, 2007 and 2011-2013 based on redd counts and live steelhead observations. Estimates in 2009 and 2010 were based on redd counts. Susac and Jacobs (2003) tested the relationship between steelhead redd counts and spawner abundance over five years in Oregon streams. They compared redd counts to adult counts at fish ladders and weirs. Their relationship between adult abundance and redd counts is strong ($R^2 = 0.97$, $P<0.001$) suggesting that redd counts are a consistent indicator of run-size over the range of run sizes they observed, from 35 to 2,131 fish. No similar comparison has been available for steelhead in the American River.

The redd based spawning population estimate is based on the number of redds counted, the number of redds per female, and the ratio of males per female steelhead in the river. The ratio of male to female steelhead entering Nimbus Hatchery during each year was used as the in-river ratio of males per female.

An area under the curve population estimate (English et al 1992) was calculated yearly in 2003-2005, 2007, and 2011-2013 from observations of live steelhead in the river. Because an estimate of the number of redds per female was not obtained for the American River, we used information from redd per female estimates in other rivers (Hannon and Deason 2007).

The area under the curve population estimate (Hilborn et al 1999) was based on live steelhead observations. We calculated this estimate by dividing the number of fish days (one fish in the river for one day = one fish day) during each survey period by the average number of days a steelhead is thought to remain in the river within the survey reach (survey life). This total was then divided by a correction factor for fish visibility (estimated observer efficiency, ie. the proportion of the fish in the river at the time of a survey that the surveyors see) to determine the area under the curve. The sum of all the area under the curve results was the population estimate. Population estimates were calculated separately for fish on redds (representing in-river spawning) and fish not on redds (representing fish that were in the river but did not spawn in the river). During the 2011 - 2013 surveys only the in-river spawning estimate was made because observer efficiency was highly variable for of steelhead not occupying redds . The in-river spawning population estimate was used to estimate potential fry production based on the fecundity of fish spawned in the hatchery and an assumed egg to fry survival rate.

Smolt Production

We estimated wild smolt production by calculating the return rate of smolts released from the hatchery ((clipped adults entering hatchery + estimated inland sport harvest + in-river hatchery produced spawners) divided by smolts released two years prior) and assumed the same return rate for in-river produced smolts. Returning unclipped steelhead divided by the hatchery smolt return rate provides an estimate of the number of wild smolts produced two years prior.

We attempted to determine adipose clip status of all steelhead observed. Most live steelhead observations were made from the boat; therefore we often could not determine adipose clip status.

Results and Discussion

We conducted steelhead redd surveys on the American River during the 2001-2007 and 2009-2013 spawning seasons. High flows prevented completion of the 2006 surveys and no surveys were conducted in 2008. Results from past surveys are reported in Hannon (2012), Hannon (2011) Chase (2010), See and Chase (2009), Hannon and Deason (2007), Hannon and Deason (2005). Hannon and Deason (2004), Hannon and Healey (2002) and Hannon et al (2003) and partially summarized here.

During the 2013 survey a total of 314 steelhead redds were observed between December 26 and April 3. Of the 314 steelhead redds, 50 were observed to be occupied by adult steelhead. Figure 5 shows redd distribution and timing in 2013. Figure 6 shows redd distribution at a spawning gravel placement and side channel construction project implemented in September 2012. Zeug et al. (2013) provides an analysis of gravel augmentation project effectiveness in the American River. Figure 7 shows the February 13, 2013 aerial photo of the same habitat improvement site at Lower Sailor Bar from Figure 6 for comparison.

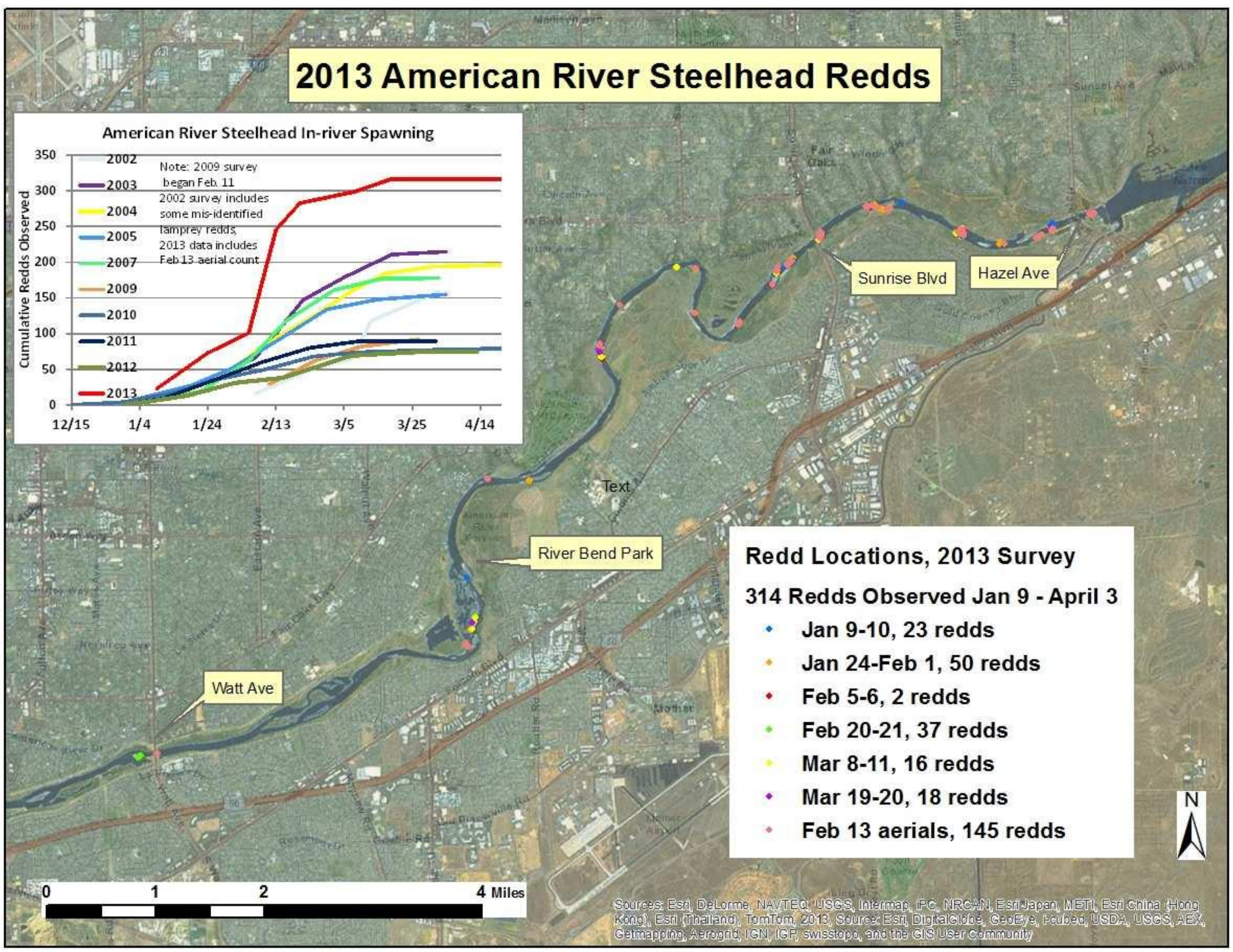


Figure 5. American River steelhead redd distribution and timing in 2013.

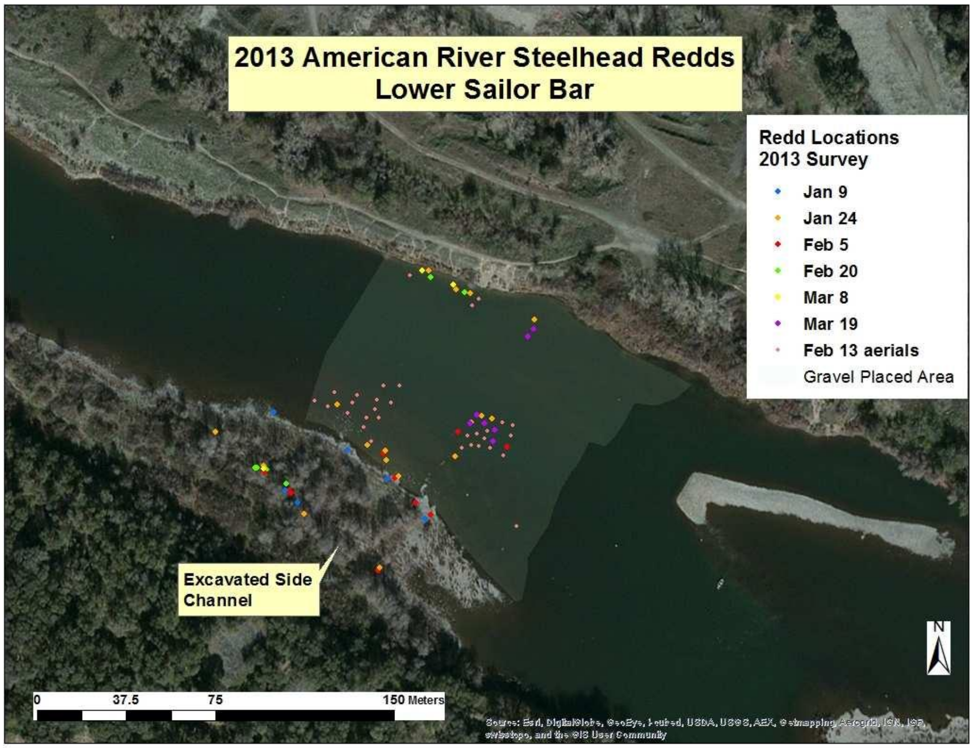


Figure 6. Steelhead redds observed at lower Sailor Bar in 2013. This is the site of a habitat improvement project implemented in September 2012.

Figure 7. Example aerial photo from the aerial survey on 2/13/2013 at the newly placed gravel and excavated side channel at lower Sailor Bar. The new gravel, added in September 2012, can be seen as the brown shaded river bottom (see Figure 6 for outline of gravel addition area) and the fresh redds are lighter oval shapes.

Spawning Distribution

Redd density in the 18 miles of the river with spawning habitat was 17.6 redds per mile in 2013 (Table 2). The first five miles of the lower American River from Discovery Park to just below Paradise Beach is deficient of steelhead spawning habitat because tides and Sacramento River flows back the water up to this point. The river bottom in the lower four miles of the American River is below sea level. Sixty four percent of the steelhead redds occurred in the upper three miles of the river, above Sunrise Avenue at mile 20 in 2013. The redd distribution is broken down by common name of areas of the river and by river mile in Table 3.

Side channels appeared marginally suitable and were less likely used for steelhead spawning at flows of 2,000 cfs or less. However, steelhead appeared to select side channel spawning habitat at flows above 3,000 cfs. Multiple thread channel areas had a high proportion of the steelhead spawning activity relative to their occurrence in the lower American River. For example, in 2002, 84 of the 159 redds (53%) occurred in river reaches with multiple channels while of 21% of the river (3.8 miles out of 18 miles with spawning habitat) contains multiple thread channels on a macro scale. In 2003, 114 out of 215 redds (53%) occurred in multiple thread reaches and in 2004, 2005, 2007, 2011, 2013 and 2013 51%, 56%, 43%, 47%, 33%, and 29% respectively occurred in these areas. Spawning flows during 2013 were less than 3,000 cfs after mid-January.

Table 2. Redd density by river reach.

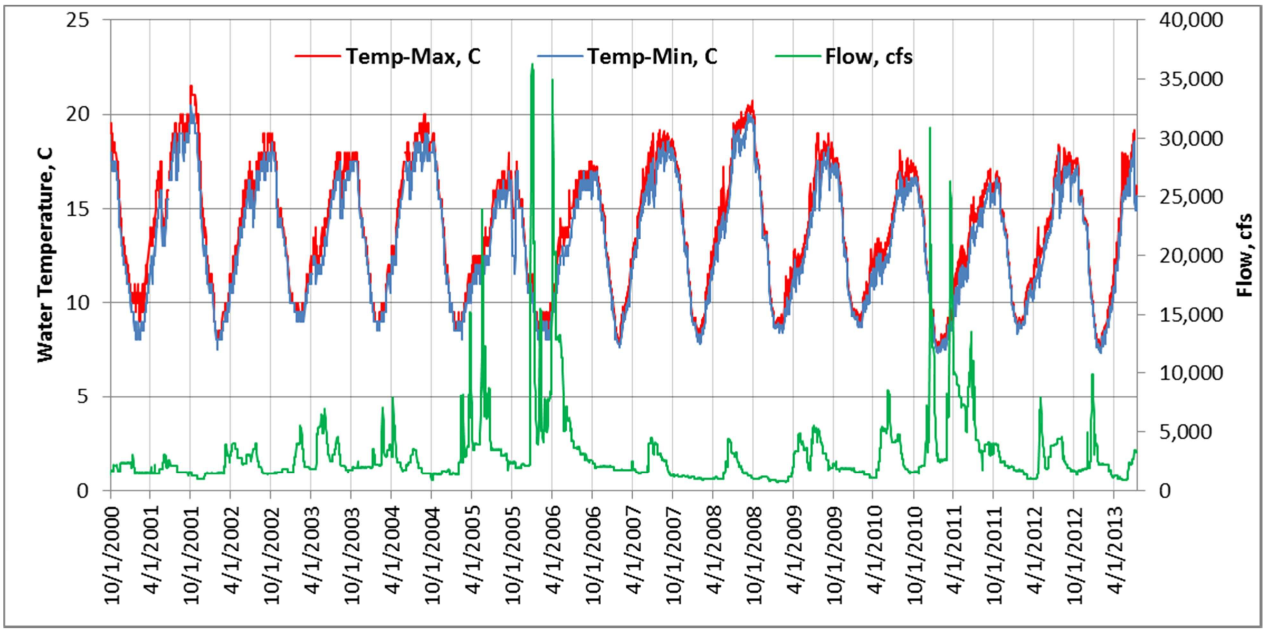
Steelhead Spawning Distribution	**River miles**	**Redds per Mile**							
Reach		**2002**	**2003**	**2004**	**2005**	**2007**	**2011**	**2012**	**2013**
Nimbus Dam to Sacramento River	1-23	6.9	9.3	8.6	6.1	7.7	3.9	3.3	13.8
Nimbus to Paradise Beach	5-23	8.8	11.9	10.9	7.9	9.9	4.9	4.2	17.6
Nimbus to Ancil Hoffman Park	17-23	16.1	19.6	19.8	17.6	19.9	10.8	12.5	46.5
Ancil Hoffman Park to Watt Avenue	10-17	4.4	17.7	9.1	4.3	5.0	3.3	0	4.4
Watt Avenue to Paradise Beach	5-10	3.7	0	0.8	2.8	0.2	0.2	0.2	1.4
Percent Associated with Multiple Thread Channel		53%	53%	51%	56%	43%	47%	33%	29%
Percent of River with multiple thread channel		4 miles out of 18 miles = 22%							

Table 3. Distribution of steelhead redds in 2003, 2004, 2005, 2007, 2011, 2012, and 2013 (number counted) by common name of areas of the river, listed from upstream to downstream.

Location (river mile in parenthesis)	Steelhead Redds, 2003	2004	2005	2007	2011	2012	2013
Nimbus, above hatchery weir (22)	10	9	6	5	4	0	9
Upper Sailor (weir to boat ramp) (22)	8	14	21	6	28	36	52
Sailor Bar (22)	10	8	13	22	0	2	4
Sailor Bar side channel (21)	11	13	10	4	1	0	0
lower Sailor Bar (21)	2	1	0	6	0	2	81
Upper Sunrise above side channel (21)	5	7	5	14	0	1	0
upper Sunrise side channel (21)	28	24	12	1	16	14	37
upper Sunrise below side channel (20)	6	2	3	1	0	1	5
Sunrise Blvd, above bridge (20)	5	0	3	8	0	5	14
lower Sunrise (19)	5	8	3	21	0	2	19
lower Sunrise side channel (19)	16	13	7	0	2	8	14
Sacramento Bar (18)	7	7	2	5	1	1	6
El Manto to San Juan Rapids (18)	9	1	1	8	0	0	5
below San Juan Rapids (17)	1	0	0	0	0	0	2
Rossmoor (17)	10	10	0	18	3	1	2
below Rossmoor/Ancil Hoffman top (16)	4	2	3	18	9	1	28
SMUD cable crossing side channel (15)	22	20	11	7	10	0	2
Upper River Bend side channel (14)	4	9	5	3	0	0	0
River Bend side channel (14)	11	4	0	0	4	0	2
lower River Bend sc, Arden Rapids (13)	8	6	0	1	0	0	1
below River Bend side channel (13)	7	0	3	0	0	0	0
below River Bend (12)	4	15	2	6	9	0	14
below River Bend mined sc outlet (12)	1	2	0	3	0	0	7
Gristmill (11)	7	2	3	1	0	0	0
above Watt side channel (10)	5	0	1	12	0	0	0
Watt (9)	8	6	3	1	0	0	5
Watt side channel (9)	1	3	0	1	0	0	7
Paradise Beach (5)	0	1	14	0	1	1	0

Flow and Temperature

Water temperatures and flows from 2001 through 2013 are shown in Figure 8. Flows during the 2012-2013 spawning period started out with flood control releases of 10,000 cfs in late December. Flows then decreased to 2,000 cfs and lower from mid-February to the end of the spawning period in April. Water temperatures were generally suitable for egg incubation throughout the spawning season (9-12^{o}C) and increased to 16^{o} C during May at the tail end of egg incubation and fry emergence.



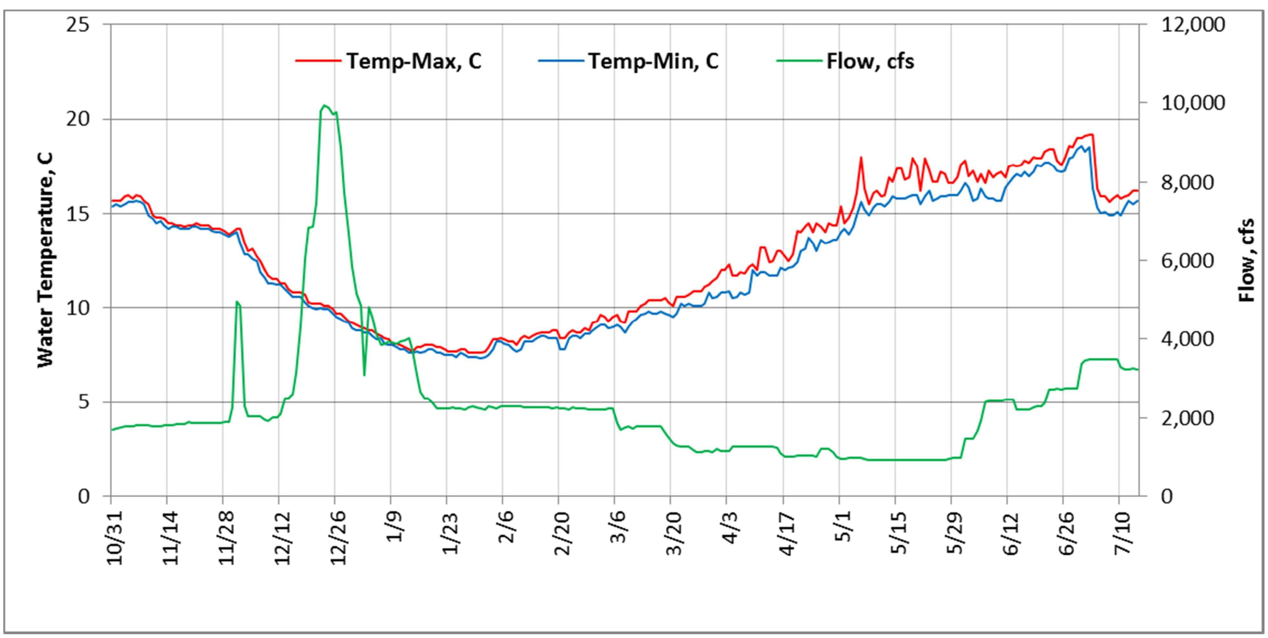


Figure 8. Fair Oaks gauge (USGS 11446500) flow and daily maximum and minimum water temperature at Hazel Avenue (mile~22) from 2001 – 2013 (top) and during the 2012-2013 spawning and incubation period (bottom).

Side Channel Spawning

Ten areas were identified, during the years of spawning surveys, containing side channels with habitat likely to support spawning steelhead, especially at flow levels above 3,000 to 4,000 cfs. These areas are circled in Figure 9 along with steelhead redd point locations. The highest density spawning occurred at Sailor Bar and upper Sunrise side channel. During 2013 a lower percentage of redds were found in side channels than in prior years. This may be because flows were below average during the peak of the spawning period so side channel locations were less suitable.

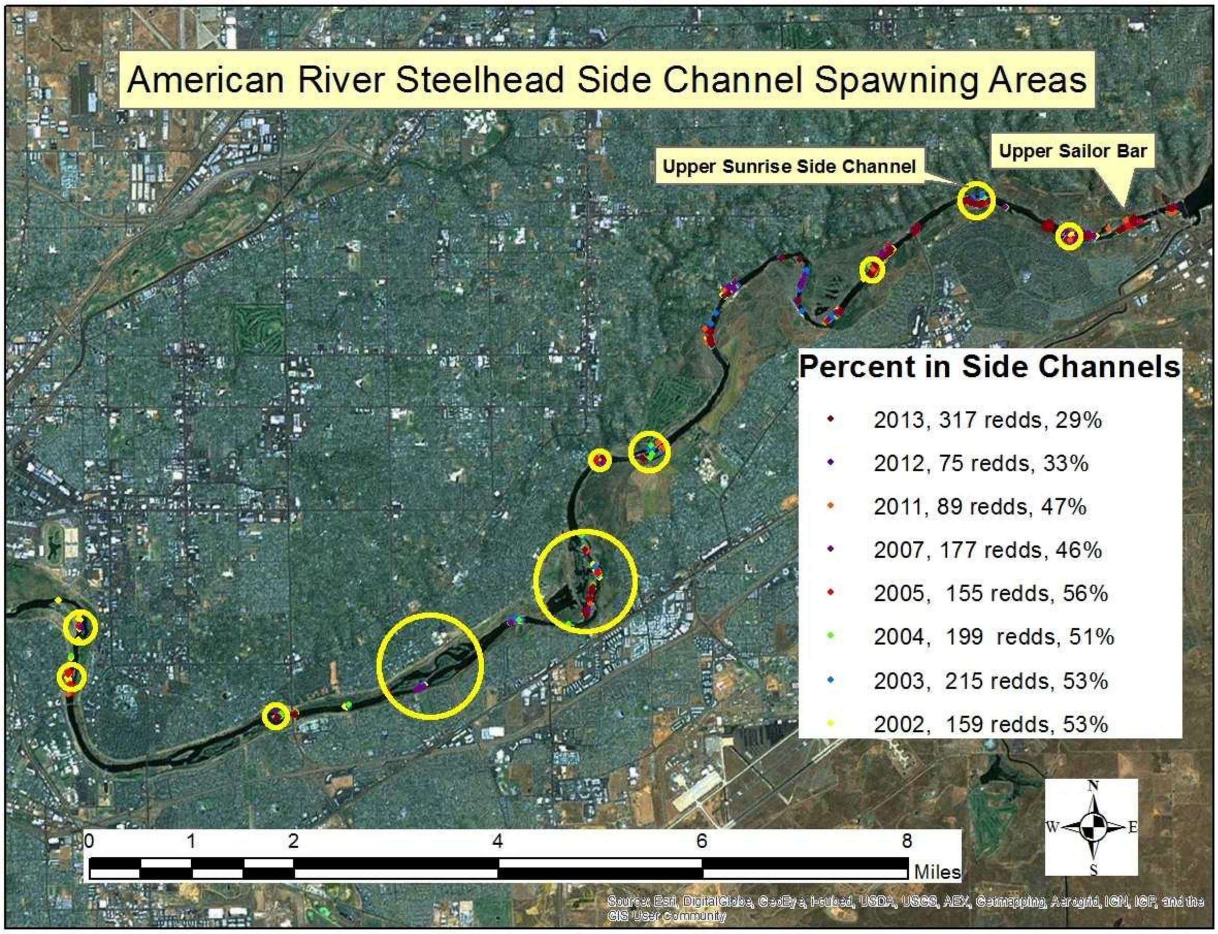


Figure 9. Lower American River side channel reaches (yellow circled areas) where steelhead spawning is likely to occur. In 2013, 92 redds (29% of total) were observed in the side channel areas.

Population Estimates

We estimated the number of steelhead that spawned in the river in 2002 through 2005, 2007, and 2009 - 2013. The 2009 and 2010 estimates were based on redd counts only. The estimates in 2003 – 2005, 2007, and 2011-2013 were made using two methods: 1) redd counts and 2) counts of adult steelhead observed occupying redds.

Redd Count Based Population Estimate

The redd count based population estimate, which is based on number of redds observed, the male to female ratio from the hatchery (Table 4) and number of redds per female (assumes 1 to 2 redds per female) was 287 - 575 steelhead in 2013. Table 5 shows redd based population estimates since 2002. We made no adjustments in the estimates to account for missed redds or mis-classified redds (i.e. redds identified as steelhead that were Chinook salmon, Pacific lamprey, or other species) other than the adjustments for redds missed on individual survey days when water clarity was low in 2004, 2005, and 2007. These adjustments were based on the prior and subsequent survey results and on the temporal distribution in other years. Water clarity was marginal for redd observations during much of 2011 so the 2011 estimates are likely low. Prolonged low water clarity in 2011 prevented adjustments for low water clarity as occurred in other years. These redd count based population estimates should be considered minimums.

Table 4. Male to Female ratio from Nimbus Hatchery returns. Data provided by Nimbus Hatchery.

Year	Adults	Males	Females	Males/Female
2002	1,253	755	498	1.52
2003	873	482	391	1.23
2004	1,741	965	776	1.24
2005	2,772	1,444	1,328	1.09
2006	2,339	1,262	1,077	1.17
2007	2,673	1,396	1,277	1.09
2008	758	432	326	1.33
2009	1,231	675	556	1.21
2010	1,015	527	488	1.08
2011	1,811	892	919	0.97
2012	2,294	1,139	1,155	0.99
2013	3,371	1,533	1,838	0.83

Table 5. Redd count based population estimate.

Year	Redd Count [1]	Males/Female [2]	Population with 1 redd/female	Population with 2 redds/female	AUC population estimate
2002	159	1.52	**401**	**200**	**300**
2003	215	1.23	**479**	**240**	**343**
2004	197	1.24	**441**	**221**	**330**
2005	155	1.09	**324**	**162**	**266**
2006	Unsuccessful	1.17			
2007	178	1.09	**372**	**186**	**504**
2008	Unsuccessful	1.33			
2009	96	1.21	**210**	**105**	
2010	79	1.08	**164**	**82**	
2011	89	0.97	**175**	**88**	**172**
2012	75	0.99	**149**	**75**	**389**
2013	314	0.83	**575**	**287**	**437**

[1] corrected for surveys with low visibility (one survey in each of 2004, 2005, and 2007) by linear regression between previous and following surveys.
[2] from Table 4

Area Under the Curve Population Estimate (from Spawning Adult Counts)

The population estimate based on live steelhead observations (area under the curve) required an estimate of observer efficiency and residence time. Observer efficiency is the proportion of the fish in the river on the survey day that the observers see. Residence time is the amount of time (days) a fish remains within the survey area. In order to determine observer efficiency a known number of fish in the river from some other counting method is required. We did not obtain a known number so made an estimate based on information we could obtain. Steelhead holding on redds were much easier to observe than those not on redds. They tended to hold on the redd until the boat or walking surveyor approached well within eyesight. When they did leave the redd they could still often be seen lingering near the redd while measurements were taken. We estimated that we were seeing 90% of the fish that were on redds during the survey days when survey conditions were good. We assumed no difference in steelhead holding on redds during the day when surveys were conducted versus during the night when no observations were attempted. We estimated observer efficiency for fish not occupying redds based on fish entering the hatchery and angler success. We estimated that we were seeing 10% of the fish that were in the river in spawning habitat but that were not on redds. For 2011 - 2013, the population estimate for non-in-river spawners (i.e., fish not on redds) was not calculated.

In order to determine residence time, individual fish are marked at a counting station or radio telemetry is sometimes used (Korman et al 2002). Residence time for fish on redds can be estimated by repeated observations of individual redd sites with fish holding on them. A requirement of the area under the curve estimate is that the time interval between surveys should be less than the residence time of the fish. If the survey interval is greater than the residence time then pulses of fish can enter and leave the survey area without being detected. Repeated visits to the river between formal surveys in 2002 - 2007 did not detect larger pulses of fish entering and leaving the survey area between surveys. Residence time for fish on redds was estimated to be three days based on return visits to redds during 2003 when fish were observed on a redd. Steelhead were occupying 22%, 23%, 20%, 36%, 22%, 45%, and 17% of the redds counted during the formal surveys in 2003, 2004, 2005, 2007, 2011, 2012, and 2013 respectively and counts occurred every 14 days. If steelhead are on redds for three days then we would expect to see steelhead on 21% of the redds, agreeing closely with the 22%, 23%, 20%, and 22% that we observed in the field in 2003 – 2005 and 2011. The 17% of redds occupied in 2013 indicates that fish may have had a residence time between two and three days in 2013 or the presence of adults was not consistently recorded. Steelhead occupying redds were visible in the aerial survey but some could have been missed in areas of the river with lower visibility (e.g. in shadows). Still, the percentage of occupied redds in the ground survey was about the same as in the aerial survey (both close to 17%). The 36% and 45% of redds occupied in 2007 and 2012 is higher than expected and would indicate either steelhead remained on redds longer in 2007 and 2011 (five days in 2007 and six days in 2012) or observer efficiency for unoccupied redds was lower in 2007 and 2012 than in prior years. It appears that observer efficiency for unoccupied redds was low in at least 2012. This resulted in area under the curve estimates higher than the redd count based estimate ranges in 2007 and 2012. Estimates of residence time in the survey area for fish not on redds were based on experience from repeated snorkel surveys conducted for indexing steelhead escapement in other rivers (Hannon 2000) and on weir counts from other rivers (Lohr and Bryant 1999) where residence time is variable with sporadic movements corresponding to changes in discharge. Based on these data from Southeast Alaska rivers we used 21 days as the average residence time in the survey reach for steelhead. This number may be on the low end. Other studies have found residence times for winter steelhead extending up to 100 days. Steelhead tend to hold in the shallower spawning habitat where they are most visible to surveyors for only a portion of the time they are present in the survey area.

Based on the above estimates the in-river spawning estimate for 2013 was 437 steelhead. The number not spawning in the river was not estimated for 2013. Table 6 shows the area under the curve calculations for 2013. Figure 10 shows both population estimate types and Figure 11 shows the in-river spawning estimate compared to the hatchery return. The area under the curve estimate for fish spawning in the river is more precise than the estimate for fish not spawning in the river because observer efficiency is high for fish on redds and the residence time is based on observations of spawning steelhead in the lower American River. In contrast, observer efficiency for fish not on redds is low and the residence time is based on steelhead in other rivers far from the American. When observer efficiency is low, as for steelhead in a large river, small changes in observer efficiency can make a big difference in the population estimate. When observer efficiency is high with a low residence time, as for fish on redds, small changes in residence time can have a large effect on the population estimate. The effect of changing observer efficiency and residence time on the population estimate in 2013 is illustrated in Table 7.

Fresh steelhead redd observation timing is shown in Figure 12.

Table 6. Spawning steelhead observations by date and area under the curve population estimate in 2013.

Date	Day	Steelhead Observed Occupying Redds	Area Under the Curve
12/26/2012	1	0	
1/9/2013	15	14	21
1/24/2013	30	29	322.5
2/5/2013	42	15	264
2/13/2013	50	45	240
2/20/2013	57	7	182
3/8/2013	73	7	112
3/19/2013	84	0	38.5
4/3/2013	99	0	0
Total		117	1180
Escapement spawning in river =			**437**
Observer efficiency = 0.9			
Residence time = 3 days			

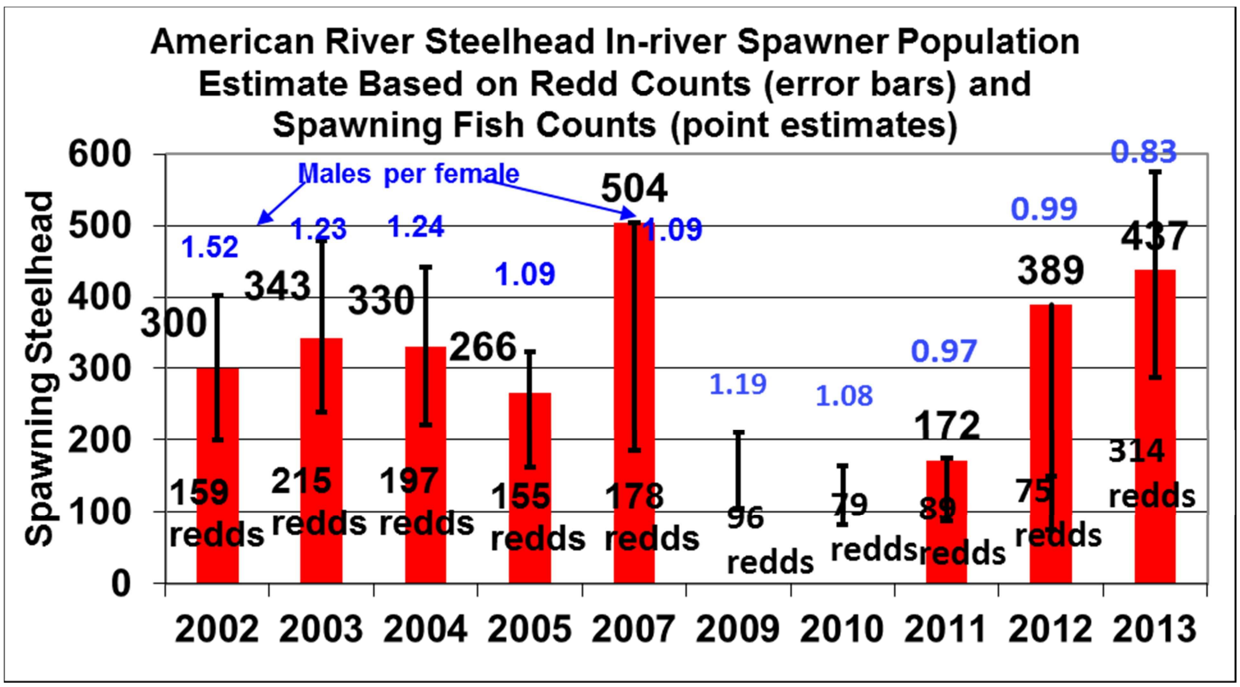


Figure 10. In-river steelhead spawner population estimates based on redd counts (error bars) and spawning steelhead observations (point estimates). The 2009 and 2010 estimates were based on redd counts only. Note: surveys not conducted in 2006 or 2008.

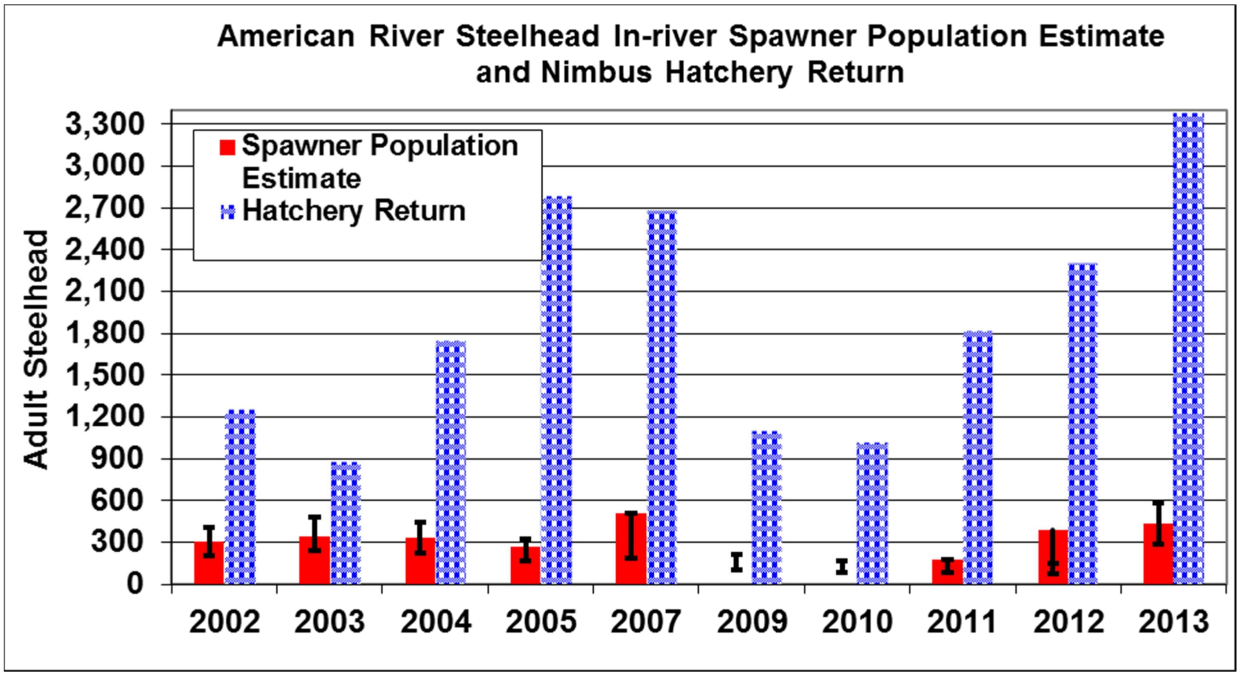


Figure 11. Steelhead spawner population estimate compared to Nimbus hatchery steelhead return. The bars are the area under the curve population estimates and the error bars are the redd count based estimates.

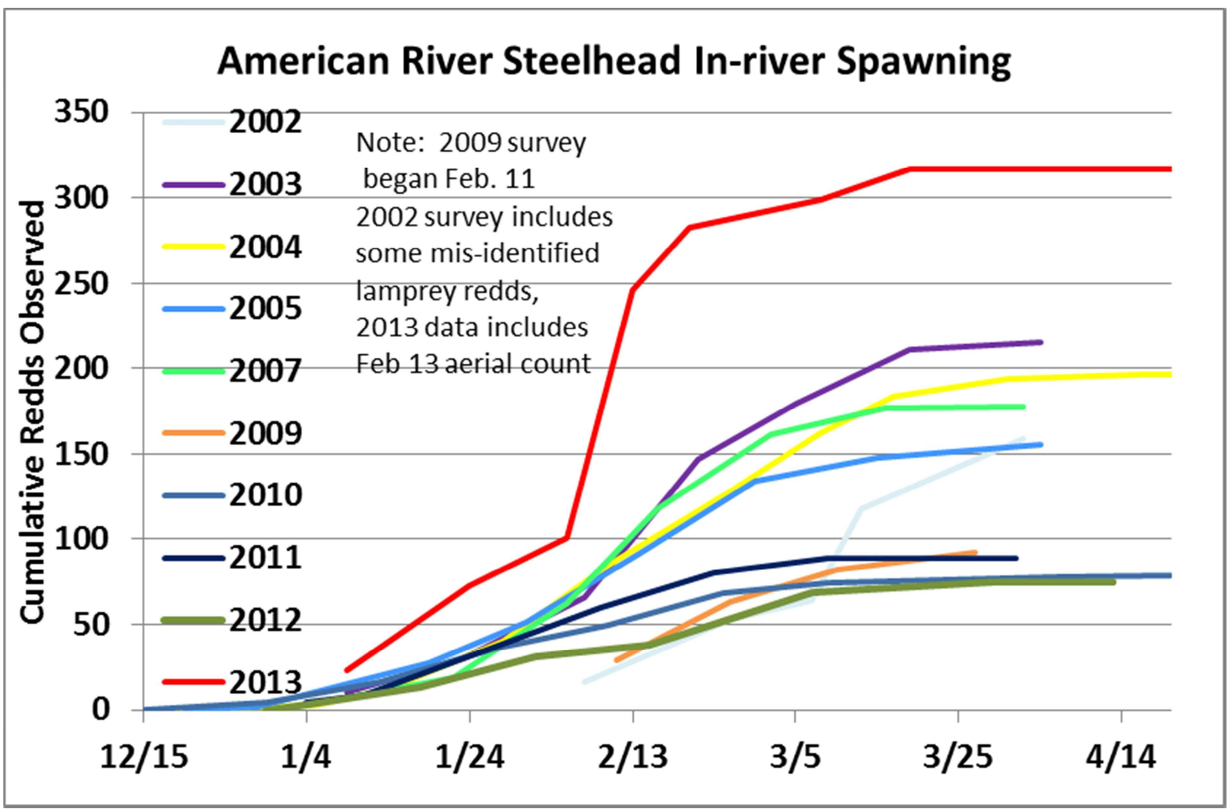


Figure 12. American River fresh steelhead redd observation timing, 2002 – 2013. The 2013 data also includes redd count data from February 13, 2013 aerial photos. Surveys were unsuccessful in 2006 and 2008.

Table 7. Effects of different observer efficiency and fish residence time (days) on population estimate in 2013.

Fish on Redds (in-river spawners)		
Observer Efficiency	Residence Time on Redds	Population
0.9	1	1,296
0.9	2	652
0.9	3	437
0.9	5	265
0.8	3	492
0.7	3	562
0.7	2	838
0.7	1	1,666
0.5	3	787

Estimates of Steelhead Fry and Smolt Production

Potential steelhead fry production based on 1.5 redds per female, the yearly average fecundity at Nimbus Hatchery, and an egg to fry survival rate of 50% ranged from 175,000 to 825,000 in 2002 – 2013 (Table 8). Based on snorkel observations and seining surveys high mortality of juvenile steelhead occurs during the first couple months following fry emergence.

The estimate of naturally produced smolts that emigrated each year assuming survival of smolts to adult is the same for wild fish as for hatchery released fish ranges from about 5,531 to 25,041 between 2001 and 2013 compared to hatchery releases of around 425,000 smolts each year (Table 9). The wild smolts are likely to have a higher survival to adult than the hatchery reared smolts so these are probably maximum wild smolt production numbers.

We estimated fry to smolt survival for wild fish that were spawned in the river and returned as adults to range from 5% to 11% (Table 9). This is based on the estimated wild fry production in the spawning year and the estimated survival of hatchery smolts that returned as adults at age 3 and the in-river spawning population estimate in that year. An assumption of 20% angler harvest was added in based on angler surveys in 1999 and 2001 (Murphy et al 2001). The estimated angler harvest in 2009 of 565 hatchery steelhead (Titus 2009) and in 2010 of 706 hatchery steelhead (Titus 2010) was used for those years. Adult steelhead were assumed to return at age three although preliminary scale reading indicates that some that enter the hatchery return at age 4. Preliminary genetic analyses by NMFS identified a low repeat spawn rate from fish entering Nimbus Hatchery (0.03%).

Table 8. Potential fry production estimated from redd count data in 2002 - 2013.

	2013	*2012*	*2011*	*2010*	*2009*	*2007*	*2005*	*2004*	*2003*	*2002*
Redds counted	314	75	89	79	96	178	155	197	215	159
Females spawning (at 1.5 redds per female)	209	50	59	53	64	119	103	131	143	106
Fecundity [1]	7,903	7,285	6,112	6,667	7,706	4,590	4,464	6,136	6,238	6,149
Total eggs spawned	1,651,727	364,250	362,645	351,129	493,184	544,680	461,280	805,861	894,113	651,794
Fry produced at 50% egg to fry survival	825,864	182,125	181,323	175,564	246,592	272,340	230,640	402,931	447,057	325,897

[1]Fecundity is based on the average number of eggs per female spawned in the hatchery each year.

Table 9. Estimates of wild smolt production and hatchery smolt survival based on adult hatchery counts, spawner surveys and hatchery yearling releases.

Adult Spawning Year	**2013**	**2012**	**2011**	**2010**	**2009**	**2008**	**2007**	**2006**	**2005**	**2004**	**2003**	**2002**	**2001**	**2000**
Year smolts released or outmigrated	**2011**	**2010**	**2009**	**2008**	**2007**	**2006**	**2005**	**2004**	**2003**	**2002**	**2001**	**2000**	**1999**	**1998**
Hatchery smolts released in Jan/Feb. of above year	426,920	439,490	250,440	422,380	394,292	454,570	410,330	455,140	419,160	281,705	467,023	402,300	400,060	385,887
In-river spawning adults	437	389	172	121	155		504		266	330	343	300		
Total Hatchery Produced Adult Return[1]	4,449	3,124	2,318	1,905	1,885	853	3,613	2,660	3,472	2,425	1,386	1,745	3,392	2,057
Unclipped Adults in hatchery	57	41	34	34	58	47	116		118	17	27	69	50	
Percent return of hatchery fish (clipped adult return divided by smolts released two years prior)	1.04%	0.71%	0.93%	0.45%	0.48%	0.19%	0.88%	0.58%	0.83%	0.86%	0.30%	0.43%	0.85%	0.53%
Wild smolts that outmigrated (two years prior)[2]	9,664	11,241	5,531	10,222	15,374	25,041	18,900		17,457	5,808	20,661	22,827	5,896	
Estimate of fry produced based on redd surveys[3]	825,864	182,125	181,323	175,564	246,592		272,340		230,640	402,931	447,057	325,897		
Fry to smolt survival estimated	In 2016	In 2015	In 2014	6%	5%	No Estir	4%	No Estir	11%	5%	No Estir	5%		

[1] assumes 20% recreational harvest based on angler surveys in 1999 and 2001 except 2009 and 2010 use actual creel survey estimates

[2] assumes same smolt to adult survival of w ild smolts as for hatchery released smolts and that 10% of in-river spaw ners are naturally produced fish

[3] no adjustments made for potential missed redds

Proportion of Returning Adults that were Naturally Spawned in the River

All hatchery reared steelhead in the Central Valley have the adipose fin clipped. When we observed steelhead in the river we attempted to determine whether the adipose fin was present or missing. During 2003 – 2013 the percentage of unclipped steelhead observed in the river ranged from 0% to 29%. During 2013, zero of nine steelhead holding on redds that the observers were able to positively determine the adipose clip status were recorded as being unclipped (Table 10). The sample size of steelhead in the river for which we were able to determine adipose fin clip status was low, ranging from 4 to 29 fish per year. The proportion of unclipped steelhead entering Nimbus Hatchery ranged from 1.0% to 6.2% from 2001 through 2013 with 1.6% being unclipped in 2013 (Table 11).

Table 10. Adipose clip status of steelhead observations in the river.

Year	Sample size - presence/absence of adipose fin	Number unclipped (adipose present)	Percent unclipped	Number on redds able to determine presence/absence of adipose	Number of unclipped steelhead observed on redds
2002	Adipose status not	determined			
2003	21	2	9.5%	5	0
2004	32	2	6.3%	5	1
2005	14	4	28.6%	2	0
2007	29	1	3.4%	9	0
2008	No Survey				
2009	4	0	0%	0	0
2010	5	1	20%	5	1
2011	15	0	0%	0	0
2012	8	5	63%?	0	0
2013	9	0	0%	9	0

Table 11. Adipose clip status of steelhead entering Nimbus Hatchery.

Year	Adult Steelhead Entering hatchery	Number unclipped	Percent unclipped
2001	2,877	50	1.7%
2002	1,253	69	5.5%
2003	873	27	3.1%
2004	1,741	17	1.0%
2005	2,772	118	4.3%
2007	2,673	116	4.3%
2008	758	47	6.2%
2009	1,095	58	5.3%
2010	1,015	34	3.3%
2011	1,811	34	1.9%
2012	2,294	41	1.8%
2013	3,371	57	1.6%

Pacific Lamprey Spawning Data

Pacific lamprey spawning timing overlaps somewhat with steelhead spawning in the American River. Pacific lamprey redds and spawning Pacific lampreys were observed in steelhead spawning surveys each year in 2002 through 2005. Observations during these years indicated a peak Pacific lamprey spawning period of about April 1. Surveys in 2007 through 2012 documented no spawning lampreys and only one potential lamprey redd was observed, in 2007 (Table 12). During 2013 the area from Gristmill down to the Business 80 Bridge (river miles 4 to 11) was surveyed for Pacific lampreys on April 11 and April 26, following completion of the formal steelhead spawning surveys. Forty redds (8 occupied by spawning adults) and 28 live adults were observed on April 11 and 70 redds (one occupied by spawning adults) and two live adults were observed on April 26 (Figure 13). The low number of adults versus redds observed indicates that spawning was nearly complete by April 26. The survey in 2013 is the first observation of Pacific lamprey redds since 2007. Lamprey redds are typically concentrated in higher densities in the lower river, below Watt Avenue, when Sacramento River flows are low and not backing water up onto the lower river riffles. Redd surveys in this area have been less thorough in the years after 2007.

Table 12. Pacific Lamprey peak spawning counts.

Year	Survey period	First observed lamprey spawning	Last observed fresh lamprey redd	Peak redd count date	Peak redd count	Occupied redds during peak count
2002	2/7 – 4/2	April 2	April 2	April 2	~350	53
2003	1/7 – 4/4	January 9	April 4	April 3-4	278	42
2004	12/17 – 6/17	March 5	May 26	March 30-31	15	3
2005	12/20 – 5/3	March 15	May 2	April 4 - 6	71	10
2007	12/12 – 4/2	February 2*	February 2*	February 2*	1	0
2009	2/11 – 3/27	NONE OBSERVED			0	
2010	12/15 – 4/20	NONE OBSERVED			0	
2011	12/28 – 4/15	NONE OBSERVED			0	
2012	12/30 – 4/14	NONE OBSERVED			0	
2013	12/30 - 4/26	April 11 #	April 26	April 26	70	1

*Positive identification not confirmed.
#28 live lampreys occupying 8 of the redds observed on April 11, 2013 in Paradise Beach area

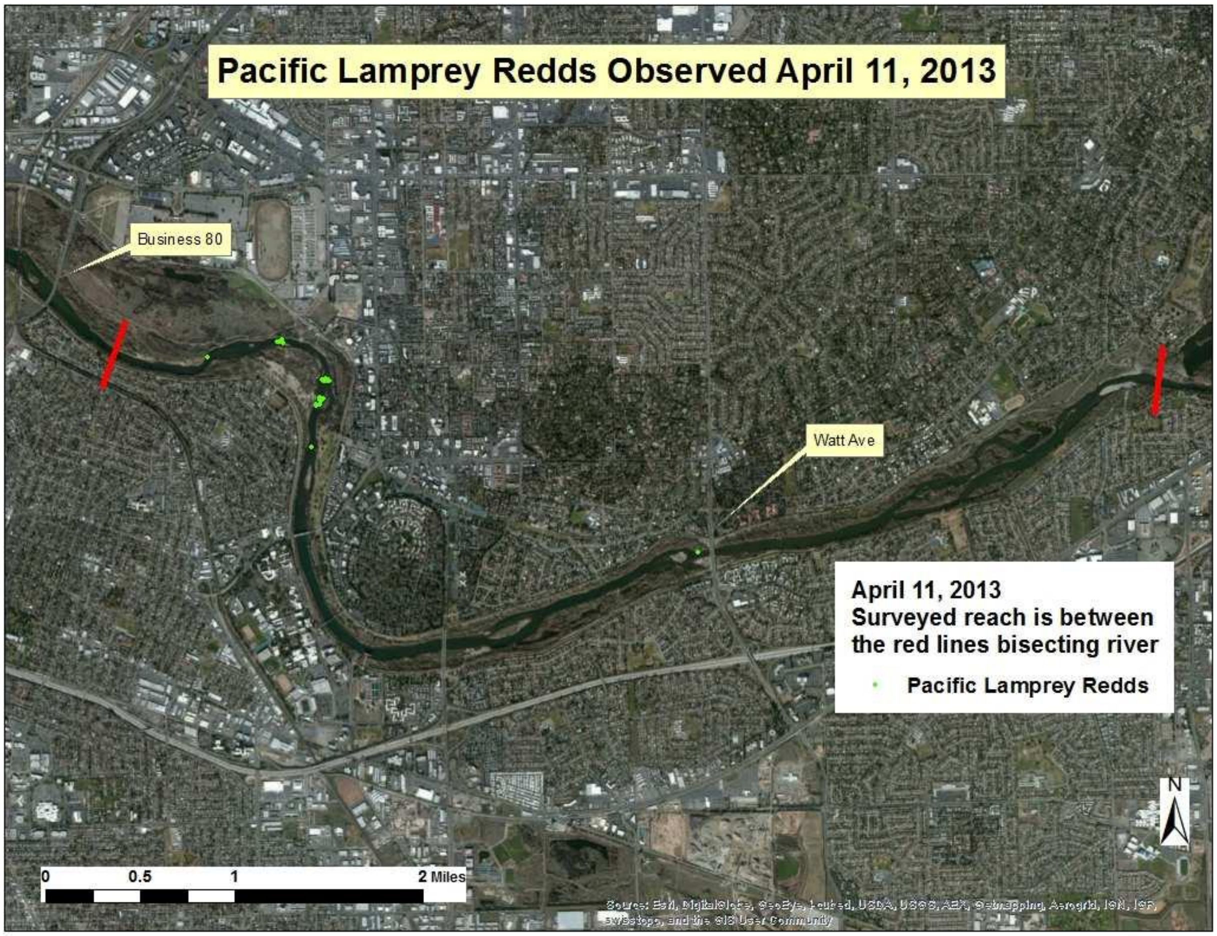


Figure 13. Pacific lamprey redds observed on April 11, 2013.

Conclusions

The following are conclusions reached from steelhead spawning surveys conducted from 2001 through 2013.

1. Redd surveys in conjunction with visual adult counts can be used to monitor trends in in-river spawning steelhead abundance in the lower American River at flows up to at least 7,000 cfs. At flows higher than this, visibility and safety concerns may preclude the ability to conduct surveys.
2. Approximately 50% of steelhead spawning is associated with multiple thread channel (side channel) reaches. Side channels receive more use at flows over 3,000 cfs.
3. The peak spawning period in the river occurs around mid-February, later than the peak of the spawning in the hatchery.
4. Many steelhead redds in the lower American River remain identifiable for not much more than two weeks due to epilithic algae growth.

5. Spawning is concentrated in the upper river but occurs throughout the area with suitable spawning habitat (down to Paradise Beach). Spawning below Watt Avenue happens mostly in years with lower Sacramento River flows.
6. Many steelhead tend to develop fungus which may limit repeat spawning.
7. Eggs in some redds survive periods of dewatered surface flow and fry can successfully emerge from the redd provided surface flow is available for emergence.
8. Steelhead in spawning condition can select a spawning site and spawn within three days of a flow change in the river.
9. The average residence time for steelhead on redds in the American River is estimated to be three days. This estimate is based on return visits to redds when fish were observed holding on a redd and on the proportion of all redds observed that were occupied by steelhead.
10. The area under the curve population estimate based on steelhead occupying redds appears to produce reliable population estimates for indexing the population and can be used by surveyors with less training in redd identification than is required for identifying redds when no fish are present.
11. A majority of the steelhead enter the hatchery and more steelhead are spawned in the hatchery than spawn in the river.

Recommendations for future surveys

The entire river can be surveyed in two work days with a small flat bottomed boat with jet motor to navigate through shallow water areas. Surveys without a motor are more time consuming below Rossmoor because of the long slack water reaches. Lack of a boat ramp below Howe Avenue restricts boat surveys in the Paradise Beach area without a motor.

The survey operation runs most smoothly with a three-person crew. More effort could be focused on determining presence/absence of the adipose fin of steelhead observed spawning. This would provide more information on wild and hatchery fish spawning and on how long steelhead remain on redds for producing the area under the curve population estimate.
One person should wear a dive suit to attempt to determine presence/absence of adipose fins, make measurements in deep water, snorkel through side channel areas, and identify questionable redds by observing the redds underwater. Disturbed gravel is more easily identified when observed underwater. A two-person crew can conduct the survey by boat if the third person is not available, but this is not recommended during peak spawning periods; i.e., February through early March. The GPS locations on GIS maps allow comparisons to be made between years in specific reaches of the river and on individual riffles.

The two week survey interval appeared to be adequate for detecting spawning activity, although a one-week interval would better reveal redd longevity, or how long individual redds remain identifiable. Susac and Jacobs (1999) found that longevity averaged nearly 30 days-in Oregon Rivers, but was variable within and between survey areas. Longevity in the American River appears to be less, possibly because warmer water temperatures support epilithic algae, which quickly covers recently excavated redds. In addition, water velocity over redds, which changes with flow, influences how long the pit and tail spill are visible.

We have not calculated confidence intervals for our population estimates. Some measure of precision needs to be devised. A better estimate of the population entering the river and of the hatchery proportion could be obtained by installing a counting weir near the lower end of the spawning reach. A weir would not provide spawning information but could be used for genetic sampling programs that could determine the origin of each fish.

Because Pacific lamprey spawning overlaps with steelhead surveys, the surveys should attempt to document the extent of Pacific lamprey spawning including peak counts and timing of spawning. Pacific lamprey are believed to have experienced population declines throughout the region and data on their status is limited.

Acknowledgements

Bonnie Van Pelt organized survey crews and insured that surveys occurred. Chelsea Stewart, Matt See, and Bill Beckett conducted redd surveys. Paula Hoover provided Nimbus Hatchery steelhead data. Bonnie Van Pelt and Chelsea Stewart provided valuable review comments on this report.

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