RECLAMATION
Managing Water in the West

American River Steelhead (*Oncorhynchus mykiss*) Spawning 2001 – 2007

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

Steelhead redds at lower Sunrise side channel

marking a steelhead redd at Watt Avenue

by

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Abstract

We conducted steelhead spawning surveys in the lower American River during the spawning season in 2001 through 2007. Redd locations and descriptive attributes were mapped with GPS and entered into a GIS database. During 2001, two surveys were conducted to assess effects of flows below 1,500 cfs on steelhead redds. The shallowest redds measured at 1,500 cfs had 20 cm of water over them. Because of sufficient precipitation upstream, flow decreases below 1,500 cfs were not made and all redds remained underwater.

Surveys during 2002 were conducted to develop an index of in-river spawning steelhead abundance by enumerating redds. We found 159 steelhead redds between February 7 and April 2, 2002. Redd density was 8.8 redds per mile in the area of river with available spawning habitat. Redd density was highest in the upstream seven mile reach with a density of 16.1 redds per mile. The 2002 estimate of in-river spawning steelhead, based on one to two redds per female and using the hatchery male per female ratio of 1.52 : 1.00, was 201 to 400 steelhead. The peak in spawning activity occurred in early March.

During 2003, we found 215 steelhead redds from January 7 to April 4. Redd density was 11.9 redds per mile throughout the spawning section of river down to Paradise Beach. Redd density was again highest in the upstream seven mile reach at 19.6 redds per mile. The middle seven mile reach had 17.7 redds per mile in 2003 vs. 4.4 redds per mile in 2002. The redd based population estimate was 240 to 479 in-river spawners. An area under the curve population estimate based on fish observations was 343 steelhead spawning in the river and 967 steelhead in the river within the survey period but not spawning in the river. The peak in spawning activity occurred in mid-February. We closely monitored redds in jeopardy of being lost to dewatering to determine the fate of the eggs in those redds and the extent of dewatering.

During 2004, we counted 197 steelhead redds from December 17 to June 17, counted 68 steelhead occupying redds, and counted 407 total adult steelhead with the spawning survey method. The redd count based population estimate was 221 to 441 in-river spawners. The area under the curve population estimate based on steelhead observed occupying redds was 330 in-river spawners. Redd density was 19.8 redds per mile in the upper reach, 9.1 redds per mile in the middle reach, and 0.8 redds per mile in the lower reach. We observed the peak spawning activity in mid-February.

During 2005, we counted 155 steelhead redds from December 20 to May 3, counted 48 steelhead occupying redds, and counted 230 total adult steelhead using the spawning survey protocol. The redd count based population estimate was 162 to 324 in-river spawners. The area under the curve population estimate based on steelhead observed occupying redds was 266 in-river spawners. Redd density was 17.6 redds per mile in the upper six mile reach, 4.3 redds per mile in the middle seven mile reach, and 2.8 redds per mile in the lower five mile reach. We observed the peak spawning activity in mid-February.

River flows and low water clarity during the 2006 steelhead spawning season precluded conducting effective redd counts so no spawner population estimate could be made. Dewatered steelhead and Chinook redds were marked following flow peaks.

During 2007, we counted 178 steelhead redds from December 12 to April 2, counted 105 steelhead occupying redds, and counted 429 total adult steelhead using the spawning survey protocol. The redd count based population estimate was 186 to 372 in-river spawners. The area under the curve population estimate based on steelhead observed occupying redds was 504 in-river spawners. Redd density was 19.9 redds per mile in the upper six mile reach, 5.0 redds per mile in the middle seven mile reach, and 0.2 redds per mile in the lower five mile reach. We observed the peak spawning activity (steelhead holding on redds) in mid-February through early March.

We conducted Pacific Lamprey peak redd and spawner counts in 2002 – 2007. The peak in Pacific lamprey spawning in the American River is around April 1. There appears to be a greater variation in Pacific lamprey numbers between years than the variation in steelhead or Chinook. Only one potential Pacific lamprey redd weas observed in 2007.

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 ESU includes only the naturally spawning steelhead in the American River. Fish produced in the Nimbus Hatchery are excluded from the ESU. Populations of naturally spawning steelhead since Folsom and Nimbus Dams were constructed are mostly unknown. 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 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.

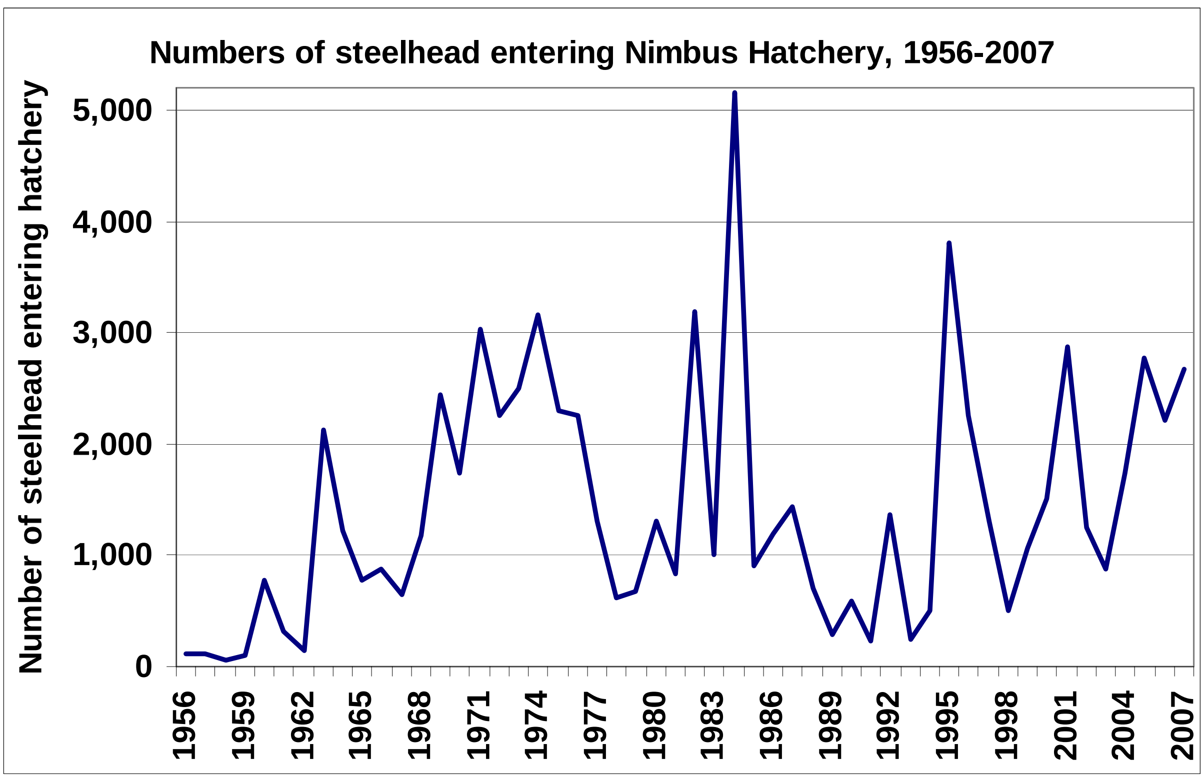


Figure 1. Number of steelhead entering Nimbus Hatchery, 1956 - 2007.

The California Department of Fish and Game (CDFG) has conducted aerial photography of the American River during Chinook spawning activities for many years up to 2000 (Snider, Titus, and Vyverberg 2001) and Reclamation conducted aerial photography flights in 2002, 2003, and 2004, 2006, and 2007 (three flights each year). We reviewed existing aerial photos with CDFG biologists and decided that resolution was not good enough to accurately discern steelhead redds in the photos. Therefore we decided in 2001 to attempt ground based steelhead redd surveys.

Steelhead redd counts were conducted in the American River during 2001 through 2007. Two counts were performed during 2001 to determine effects to steelhead redds if flows decreased below 1,500 cfs. More effort was devoted to redd counts in 2002 to estimate the number of steelhead redds in the river and to begin development of a protocol for estimating steelhead spawning escapement for subsequent years when flow and water visibility are suitable. In 2003 - 2007 we took detailed redd measurements and mapped fish observations to more accurately identify steelhead redds and produce population estimates.

Methods

Field Surveys

The American River was surveyed for steelhead redds using a jet boat and by snorkeling and wading. The survey reach encompassed the entire Lower American River from Nimbus Dam (top of anadromous habitat) down to Paradise Beach (bottom of potential spawning habitat), mile 5 to 23 (Figure 2). The boat (canoe, drift boat, or jet boat) was usually oriented pointing upstream against the current and maneuvered diagonally back and forth across the river from one bank to the other working in a downstream direction or otherwise maneuvered to cover all potential spawning habitat (Figure 3). Surveyors wore polarized sunglasses and baseball caps to help see through glare on the water surface. The boat was maneuvered so that nearly all areas that appeared to be potential spawning habitat could be viewed. Crew members stood in the bow of the boat to increase visibility. A special railing was constructed on the bow for the surveyors to hold onto (cover photo). When water was too shallow for the boat (generally in side channels) the section was waded or snorkeled. During the first two years single strand channels for all surveys were more thoroughly surveyed for steelhead redds than areas with multiple channels (side channels) because of difficulty in getting the canoe or drift boat back upstream. Generally only one channel of multiple thread channel areas was surveyed with the boat in 2001 and 2002. During 2003 – 2005 and 2007 most of the spawning habitat was observed during each survey, either by boat or on foot. Spacing between transects covered by the boat in potential spawning habitat was generally about 20 meters. The boat operator adjusted transect spacing to maintain visibility of the river bottom between transects.

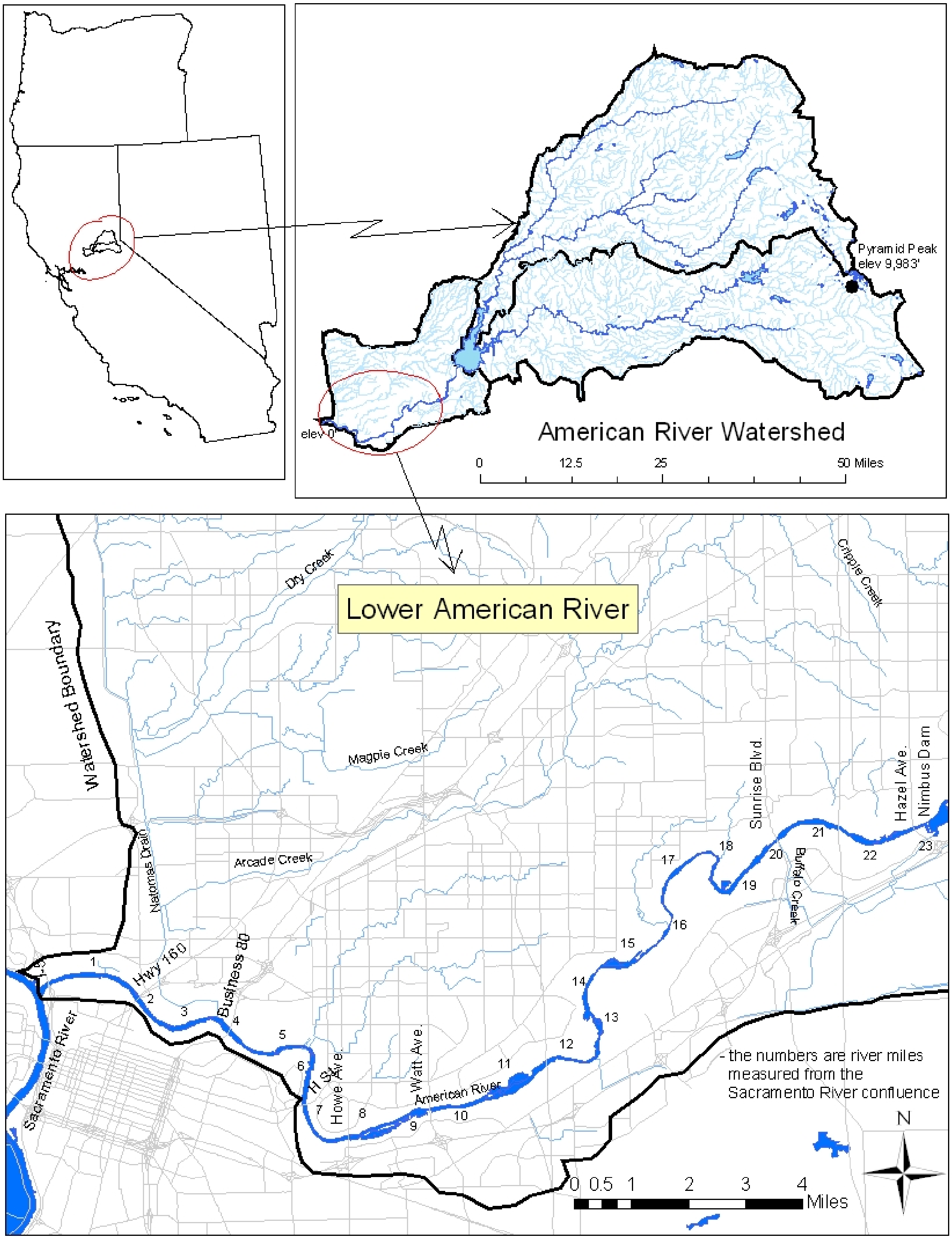


Figure 2. The American River watershed and Lower American River where steelhead spawning surveys were conducted. The spawning reach extends from mile 5 to Nimbus Dam at mile 23.

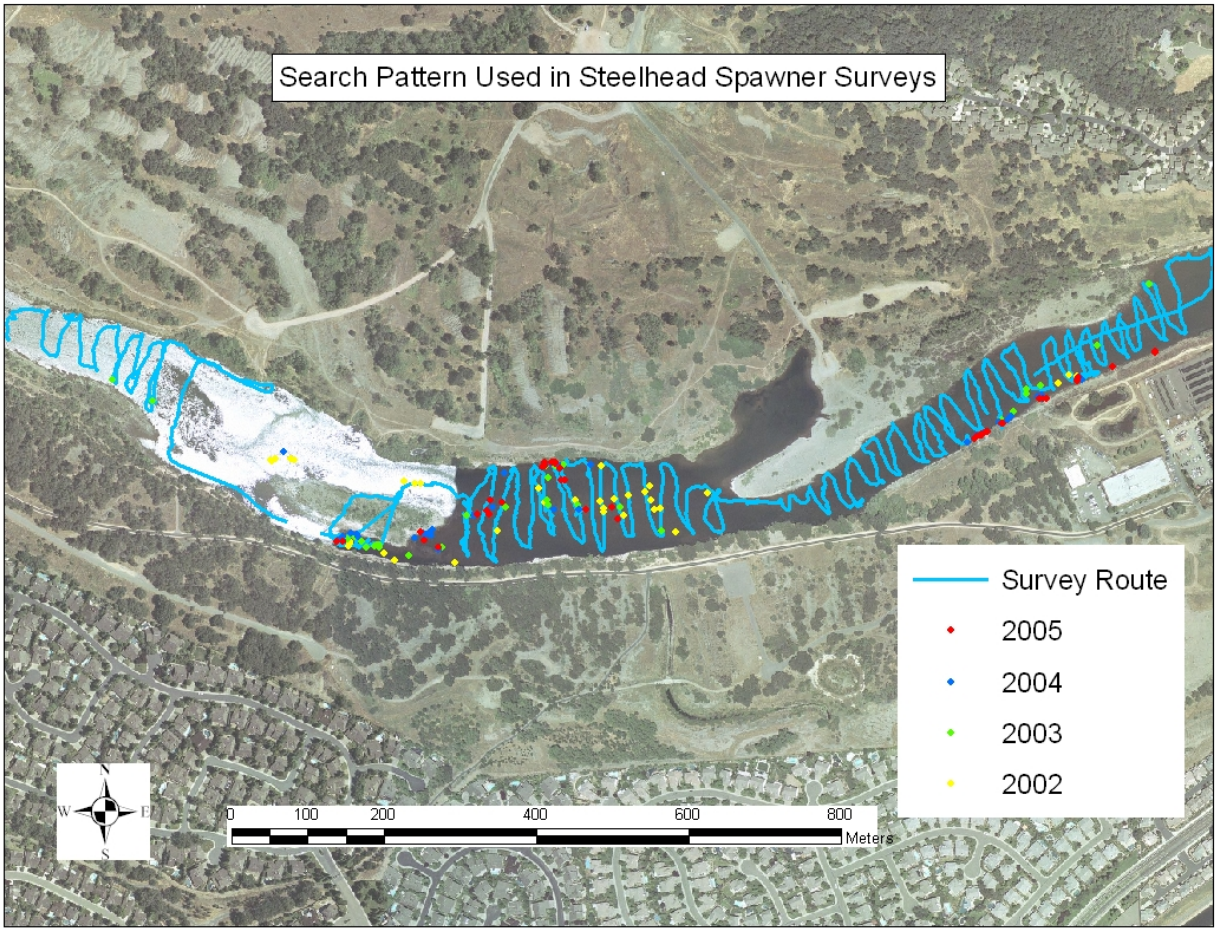


Figure 3. Typical survey route collected with GPS during one American River steelhead redd survey.

Redd Measurements

When a potential steelhead redd was observed it was marked with the GPS unit, measured, and dimensions entered. 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 Global Water hand-held flow meter with six foot expandable flow probe for taking measurements. The redd measurements were taken to the nearest centimeter with the water velocity meter 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. For water velocity measurements the meter was held in the current until the average velocity reading stabilized, generally about 20 seconds. 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 compared between years.

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
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 includes species, count, length, size category, position accuracy, presence or absence of fungus, and presence or absence of adipose fin. Secchi depth measurements were saved in the fish observation file.

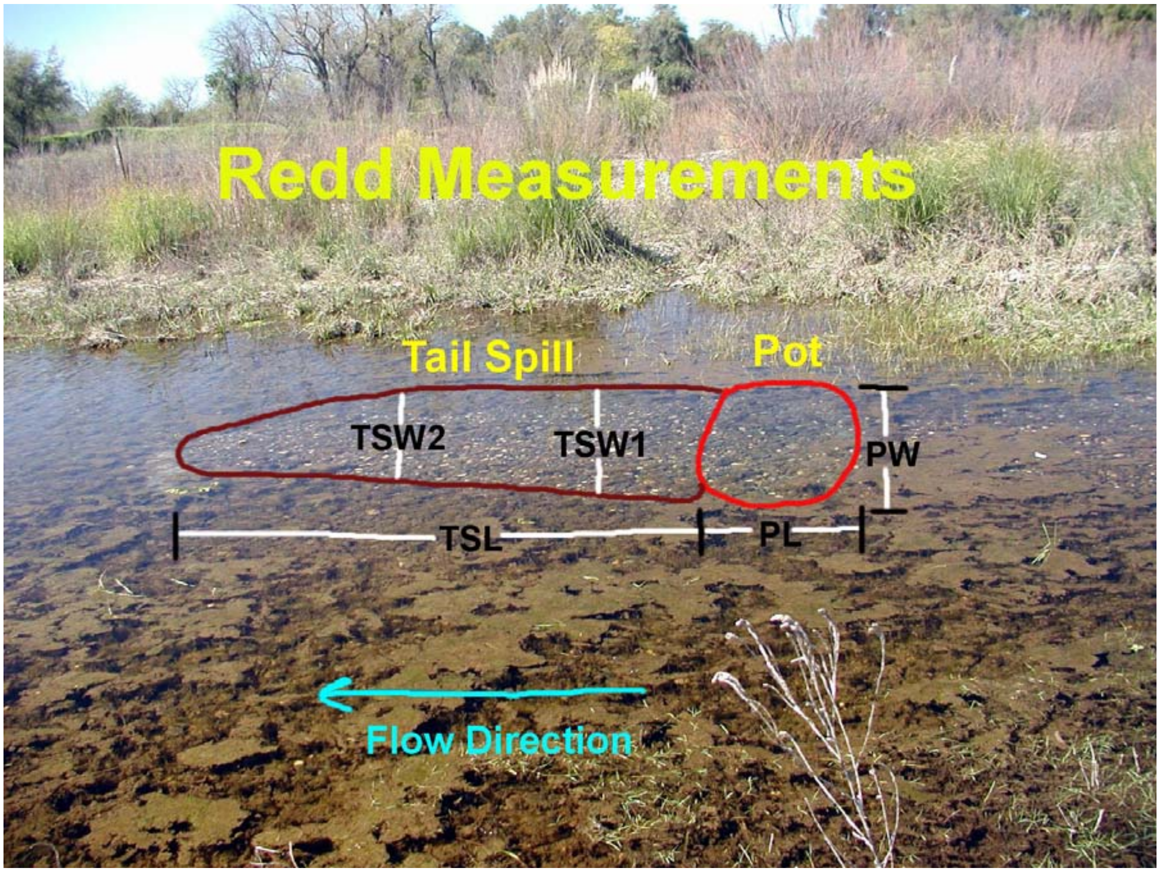


Figure 4. Illustration of measurements taken of steelhead redds. This redd was constructed under a higher flow than pictured. The lower flow made the redd show up well in the photo.

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. Only partial survey route data was collected because the line file had to be closed whenever a redd was marked. In areas with multiple redds the line data was often not collected, since the redd locations indicate they were surveyed. When redds from two different surveys were marked in the proximity of each other (within about 5 meters of each other), the data was examined to determine whether these were the same redd. 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 weights 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 then differentially corrected using established and accepted methods by Trimble Inc.

The data was edited and displayed on orthophotos using ArcMap. The 2002 - 2004 shapefiles are in UTM zone 10 NAD 27 projection and the 2005 - 2007 files are in UTM zone 10 NAD 83. Redd locations in a couple instances during 2001 and 2002 surveys were estimated on aerial photos and then digitized manually when only one surveyor was present. Redd locations were sometimes mapped in GPS using an offset point function while standing a distance away from the redd. This was to avoid working in the middle of anglers casting to the the area of the redds.

Population Estimates

We estimated steelhead populations in 2002 – 2005 and 2007 based on redd counts and steelhead observations. 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.

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.

An area under the curve population estimate (English et al 1992) was calculated in 2003, 2004, 2005, and 2007 from observations of live steelhead in the river. Both in-river spawners and non-spawners were estimated with the area under the curve estimate and summed for a total population estimate.

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. Steelhead often build multiple redds, each redd immediately upstream of the prior one (Shapovalov and Taft 1954). This was observed for some redds in the American River, but the resulting contiguous area of disturbed gravel was counted and measured as only one individual redd. Comprehensive surveys of redds and steelhead passed through weirs in Oregon Rivers found that the ratio of redds to females averaged about one redd per female (Susac and Jacobs 1999). Susac and Jacobs (2001) observed 1.5 redds per female in the West Fork Smith River calibration site and believe it is the best available estimate for an Oregon coastal stream during low flow conditions. Freymond and Foley (1985) reported 1.2 redds per female in rivers surveyed in Washington. Gallagher and Gallagher (2005) calculated the number of redds per female in the Noyo River, California using population estimates produced by two methods. An estimate of 2.49 redds/female was calculated using the number of adults observed during each survey, the estimated residence time of steelhead in the river (area under the curve method), and the number of redds counted. An estimate of 2.30 redds/female was obtained based on the measured area of redds assuming that larger redds represented fish that constructed only one redd and smaller redds represented fish that made multiple redds. Steelhead snorkel escapement surveys conducted to index steelhead abundance in Prince of Wales Island Alaska streams consistently counted more than two times as many adult steelhead as redds although some steelhead were still unspawned as of the final survey each season (Hannon 2000 and Jones 2001). Pairs of redds just a couple meters apart were often observed during these snorkel surveys with steelhead present on only one redd of the pair, potentially indicating construction of more than one redd by a female. Farzan (2002) documented the highest ratio of redds per female found in any of the Prince of Wales surveys at 1.57 redds per female in Twelve Mile Creek (assuming one male per female and that all fish in the river were counted). It is likely that observer efficiency at detecting redds varies by river depending on type of substrate and water clarity and varies within a river over time with changing conditions. For the American River estimate we used one redd and two redds per female as the lower and upper bounds of the population estimate calculations. During 2002 surveys some redds were likely missed in un-surveyed side channels and prior to the first survey. In addition, during 2002 some Pacific Lamprey redds were called steelhead redds.

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. what proportion of the fish in the river at the time of a survey that the surveyers 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). 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.

We estimated wild smolt production by using 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 gave an estimate of the number of wild smolts produced two years prior.

The thalweg profile of the river was constructed using two foot topography of the river bottom. The topography of the river was then used to estimate the elevation on the thalweg profile where groups of redds were located. We graphed locations of groups of redds along the longitudinal transect of the river constructed on the thalweg to illustrate where spawning occurred relative to channel gradient.

We predicted steelhead fry emergence dates based on the date redds were constructed and water temperature during the subsequent incubation period. Predicted emergence dates were compared to observations of newly emergent fry to help determine whether we were covering the entire spawning period with the redd surveys.

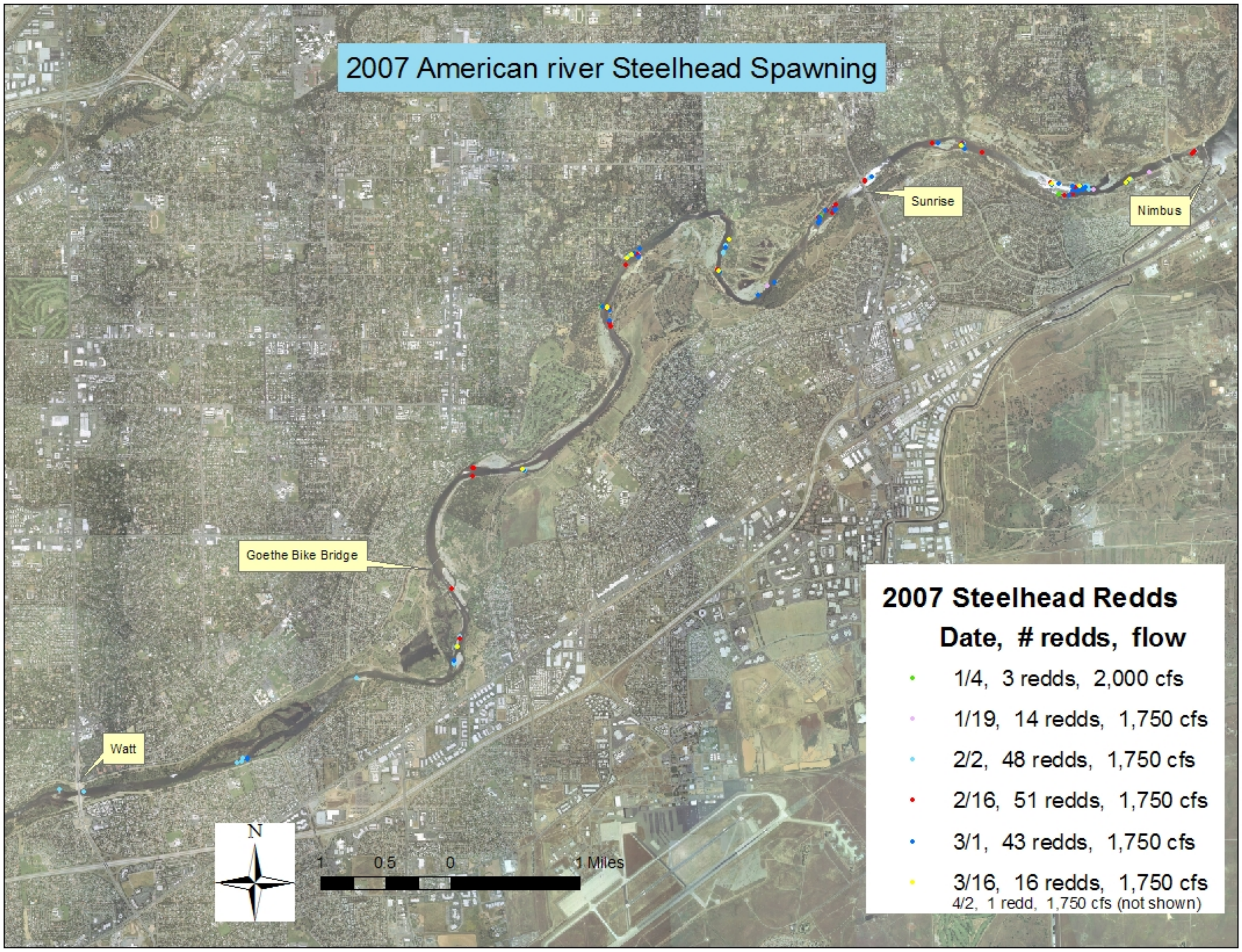
Midway through the spawning season when streamflow was lowered following creation of redds in side channels we monitored redds that were dewatered or in jeopardy of being dewatered to determine the condition of the eggs. Dewatered redds in areas where survival was not anticipated were excavated by hand and the condition of the eggs and fry was determined.

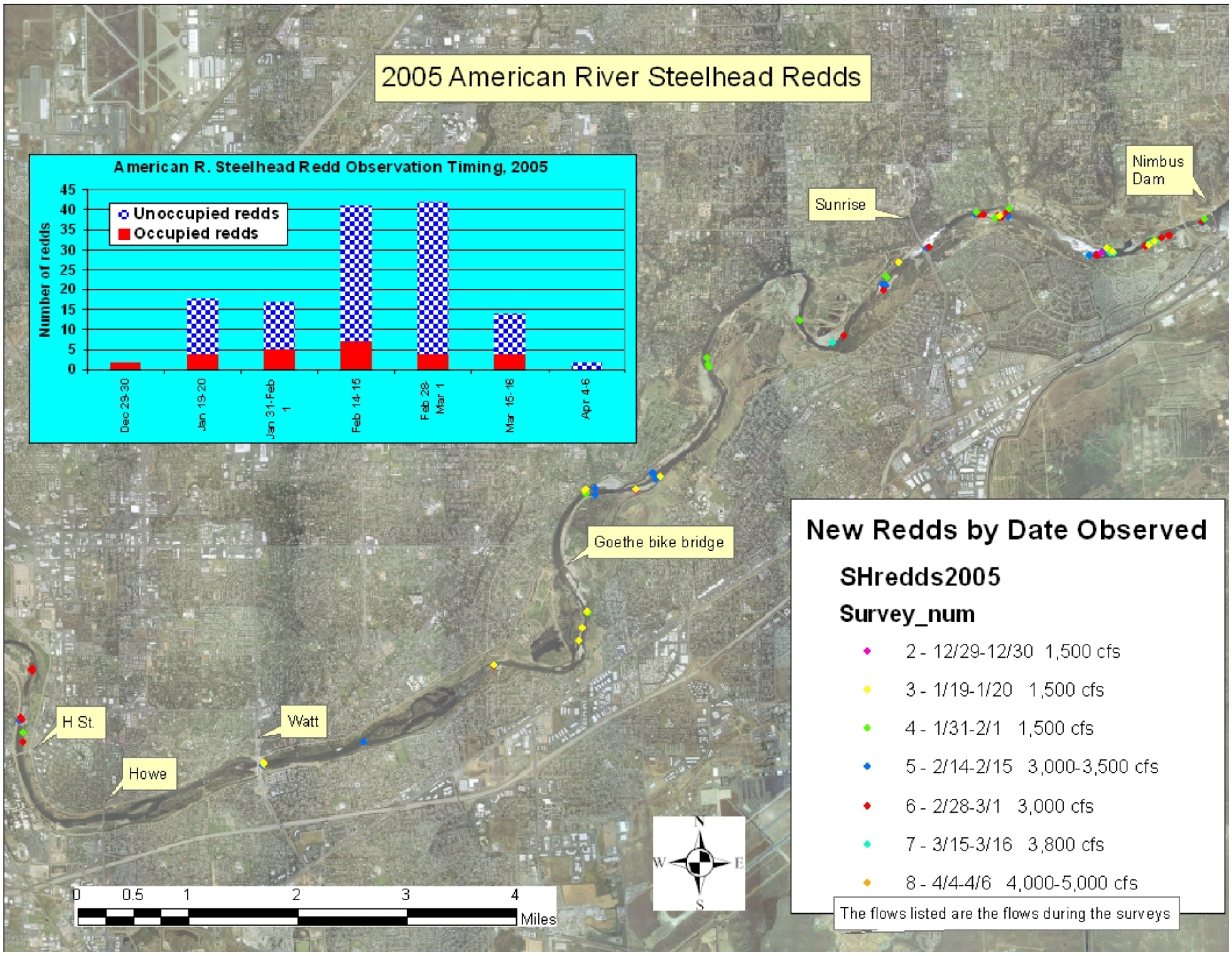
We attempted to determine adipose clip status of all steelhead observed. Most observations were made from the boat but we often could not tell adipose status. Some observations were made snorkeling. We experimented with underwater video cameras in 2004 and 2005 to determine clip status of fish on redds. The camera was placed underwater facing an occupied redd while the observers waited nearby with the video screen until the steelhead returned to the redd. When steelhead that we observed occupying a redd could be approached closely by boat we held the camera underwater to attempt to record adipose status.

Results and Discussion

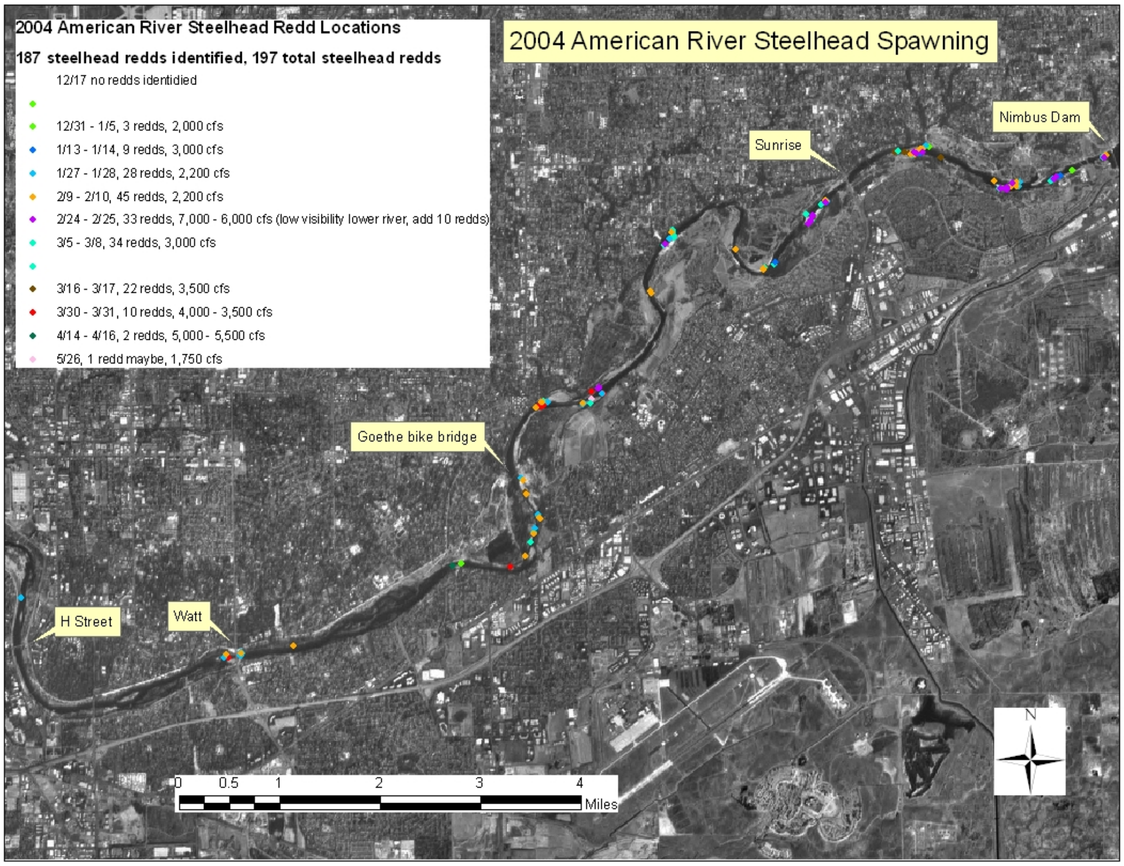
We conducted steelhead redd surveys on the American River during the 2001 through 2007 spawning seasons. Data from the 2001 - 2005 surveys is in Hannon and Deason (2005), Hannon and Deason (2004), Hannon and Healey (2002) and Hannon et al (2003) and summarized here.

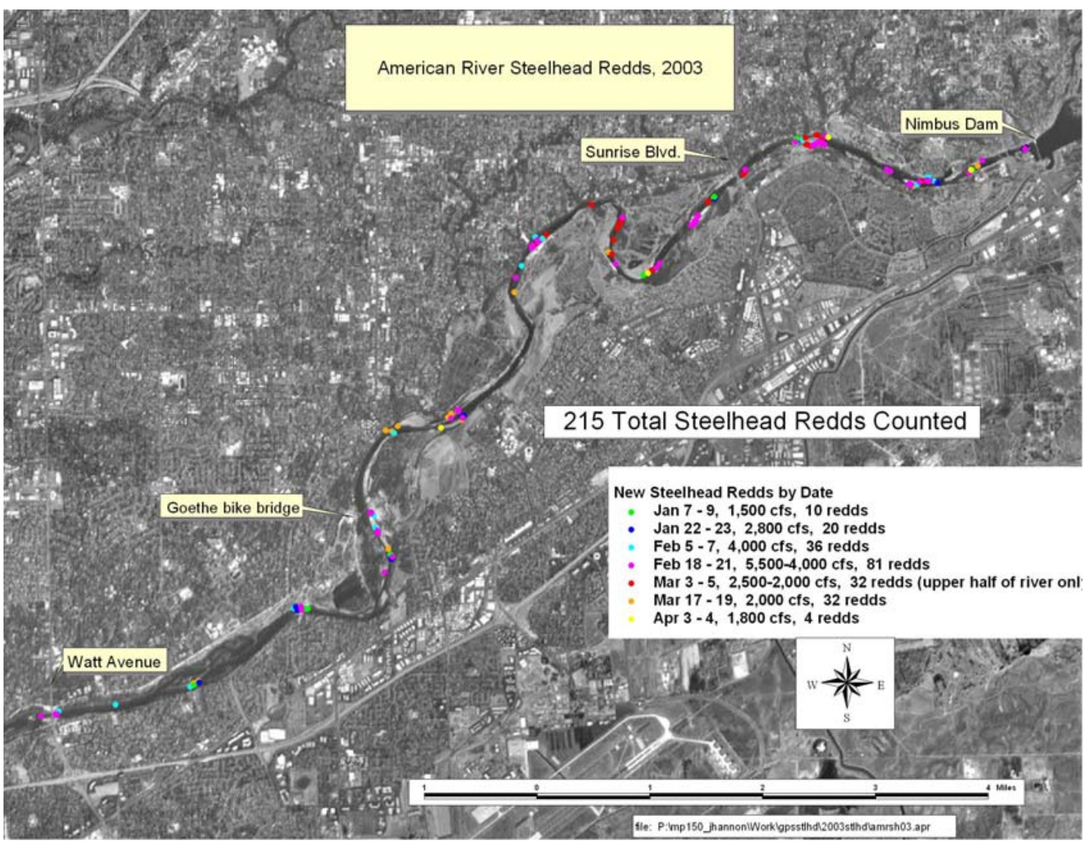
During the 2007 survey we found a total of 178 steelhead redds and saw 429 adult steelhead between December 12 and April 2. Of the adult steelhead observations, 105 were observed on redds and 324 were not on redds. Figure 5 shows maps of redd distribution and timing for each year, 2002 – 2005 and 2007.





2005 American River Steelhead Redds
American R. Steelhead Redd Observation Timing, 2005
Unoccupied redds
Occupied redds
Number of redds
45
40
35
30
25
20
15
10
5
0
Dec 29-30
Jan 19-20
Jan 31-Feb 1
Feb 14-15
Feb 28-Mar 1
Mar 15-16
Apr 4-6
Nimbus Dam
Sunrise
Goethe bike bridge
H St.
Watt
Howe
New Redds by Date Observed
SHredds2005
Survey_num
2 - 12/29-12/30 1,500 cfs
3 - 1/19-1/20 1,500 cfs
4 - 1/31-2/1 1,500 cfs
5 - 2/14-2/15 3,000-3,500 cfs
6 - 2/28-3/1 3,000 cfs
7 - 3/15-3/16 3,800 cfs
8 - 4/4-4/6 4,000-5,000 cfs
The flows listed are the flows during the surveys
0 0.5 1 2 3 4
Miles
N
W
E
S


2004 American River Steelhead Redd Locations
187 steelhead redds identified, 197 total steelhead redds
12/17 no redds identidied
12/31 - 1/5, 3 redds, 2,000 cfs
1/13 - 1/14, 9 redds, 3,000 cfs
1/27 - 1/28, 28 redds, 2,200 cfs
2/9 - 2/10, 45 redds, 2,200 cfs
2/24 - 2/25, 33 redds, 7,000 - 6,000 cfs (low visibility lower river, add 10 redds)
3/5 - 3/8, 34 redds, 3,000 cfs
3/16 - 3/17, 22 redds, 3,500 cfs
3/30 - 3/31, 10 redds, 4,000 - 3,500 cfs
4/14 - 4/16, 2 redds, 5,000 - 5,500 cfs
5/26, 1 redd maybe, 1,750 cfs
2004 American River Steelhead Spawning
Nimbus Dam
Sunrise
Goethe bike bridge
H Street
Watt
N
0 0.5 1 2 3 4
Miles


American River Steelhead Redds, 2003
Nimbus Dam
Sunrise Blvd.
215 Total Steelhead Redds Counted
New Steelhead Redds by Date
Jan 7 - 9, 1,500 cfs, 10 redds
Jan 22 - 23, 2,800 cfs, 20 redds
Feb 5 - 7, 4,000 cfs, 36 redds
Feb 18 - 21, 5,500-4,000 cfs, 81 redds
Mar 3 - 5, 2,500-2,000 cfs, 32 redds (upper half of river onl
Mar 17 - 19, 2,000 cfs, 32 redds
Apr 3 - 4, 1,800 cfs, 4 redds
Goethe bike bridge
Watt Avenue
N
W
E
S
file: P:\mp150_jhannon\Work\gpsstlhd\2003stlhd\amrsh03.apr

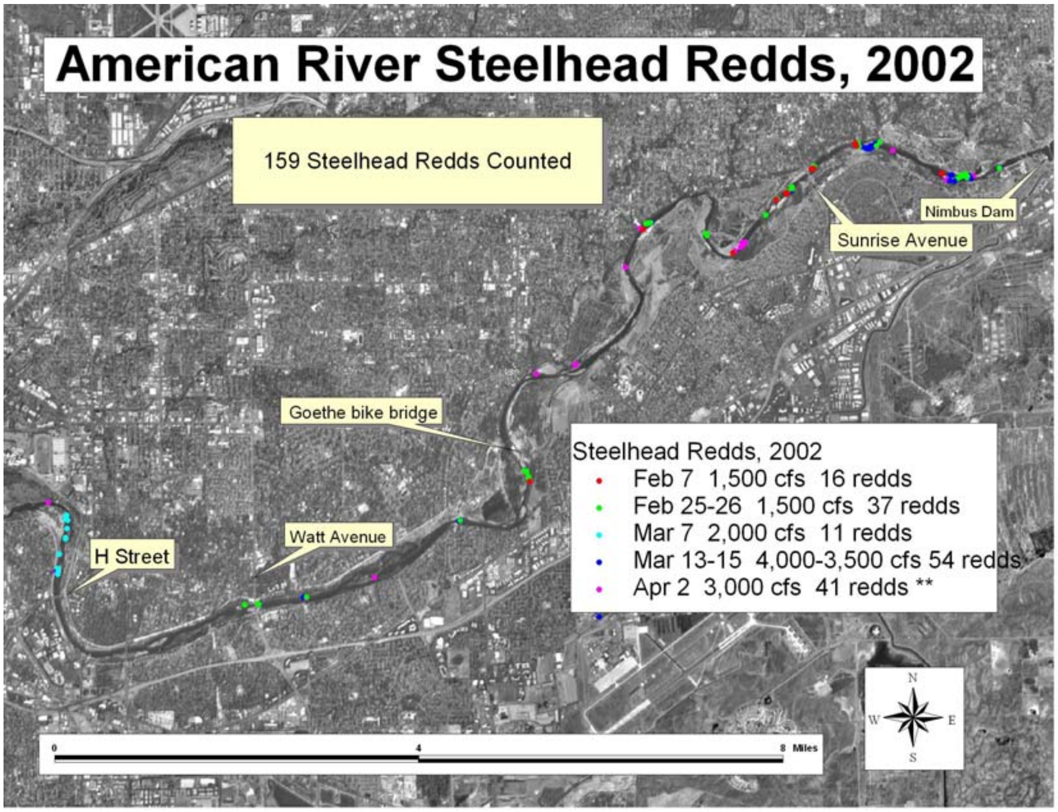


Figure 5. Map of American River steelhead redds in 2002 (bottom) through 2007 (top). No map available for 2006.

Spawning Distribution

Redd density in the 18 miles of the river with spawning habitat was 9.9 redds per mile in 2007, 7.9 redds per mile in 2005, 10.9 redds per mile in 2004, 11.9, in 2003 and 8.8 redds per mile in 2002 (table 2). The first five miles of the 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. Thirty nine percent of the steelhead redds (67) of the steelhead redds occurred in the upper three miles of the river, above Sunrise Avenue at mile 20 in 2007, 48% (74) occurred there in 2005, 42% (78) occurred there in 2004, and 40% (85) occurred there in 2003. This equates to 24, 28, 27 and 30 redds per mile in 2007, 2005, 2004 and 2003 respectively. Redds are concentrated in the upper section of the river, although not as concentrated as in the similar sized Feather River where Kindopp and Kurth (2003) found 48% of the redds constructed in the upper one mile of the Feather River. The redd distribution is broken down by common name of areas of the river in table 3 and in table 4 by reaches used in a planning model that evaluates Chinook salmon temperature related egg-to-fry mortality.

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. Areas of multiple thread channel had a high proportion of the steelhead spawning activity relative to their occurrence in the 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, and 2007 51%, 56%, and 43% respectively occurred in these areas.

Table 2. Redd density by river reach

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

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

Location	Steelhead Redds, 2003	Steelhead Redds, 2004	Steelhead Redds, 2005	Steelhead Redds, 2007
Nimbus, above weir	10	9	6	5
Upper Sailor (down to boat ramp)	8	14	21	6
Sailor Bar	10	8	13	22
Sailor Bar side channel	11	13	10	4
lower Sailor Bar	2	1	0	6
Upper Sunrise above side channel	5	7	5	14
upper Sunrise side channel	28	24	12	1
upper Sunrise below side channel	6	2	3	1
Sunrise Ave, above bridge	5	0	3	8
lower Sunrise	5	8	3	21
lower Sunrise side channel	16	13	7	0
Sacramento Bar	7	7	2	5
El Manto to San Juan Rapids	9	1	1	8
below San Juan Rapids	1	0	0	0
Rossmoor	10	10	0	18
below Rossmoor/Ancil Hoffman top	4	2	3	18
SMUD cable crossing side channel	22	20	11	7
upper Goethe side channel	4	9	5	3
Goethe side channel	11	4	0	0
lower Goethe sc, Arden Rapids	8	6	0	1
below Goethe side channel	7	0	3	0
below Goethe	4	15	2	6
below Goethe mined sc outlet	1	2	0	3
Gristmill	7	2	3	1
above Watt side channel	5	0	1	12
Watt	8	6	3	1
Watt side channel	1	3	0	1
Paradise Beach	0	1	14	0

Table 4. Steelhead spawning distribution by reach used in the Chinook egg incubation planning model.

American River Steelhead redd distribution

		Redds per mile					Summary			
Reach	Reach Miles	2002	2003	2004	2005	2007	Total redds 2002 2007	Average redds/mile	Steelhead Total %	Chinook %
Above weir										
Nimbus to Sunrise bridge	2.86	28	30	27	28	24	334	29	38%	31%
Sunrise to Ancil Hoffman	4.73	7	11	9	4	28	213	11	24%	59%
Ancil Hoffman to Goethe bike bridge	1.89	2	13	15	9	42	84	11	10%	5%
Arden Rapids (Goethe bridge) to Watt bridge	4.1	7	12	9	3	9	151	9	17%	3%
Watt to Fairbairn water intake	2.02	0	0	1	0	13	6	1	1%	1%
Fairbairn to H Street bridge	0.75	0	0	0	0	1	0	0	0%	0%
H Street bridge to Paradise Beach	1.09	12	0	1	13	0	28	6	3%	1%
Paradise Beach to 16th st	3.49	0	0		0		0	0	0%	0%
16th st to Sacramento River	2.01	0	0		0		0	0	0%	0%
Total	22.94	7	9	8	6	8	874	10	100%	100%

Flow and Temperature

Temperatures and flows from 2001 through 2007 are shown in Figure 6 with the spawning and incubation periods denoted.

2007
Flows in 2007 started out at 2,000 cfs until January 8 when they dropped to 1,750. Flow stayed constant at 1,750 through the spawning season until March 30 when it increased to 2,500 cfs for 11 days and then dropped to 1,500 cfs to the end of emergence.

2006
Flows in late December of 2005 were increased to 35,000 cfs during heavy rains. They were lowered to 8,000 cfs in late January until February when they were increased back to 15,000 cfs for two weeks then back down to 4,000 cfs till mid-March when they were increased up to 35,000 cfs by April 5 after spawning was most likely completed. Flows were lowered back down to 6,000 cfs by June when emergence was completed. The minimum daily average water temperature at Hazel Avenue was 47 F on February 3 and 6. Water temperatures below 56 F occurred from November 26 through June 10.

2005
Flows started out at 1,500 cfs in 2005 through January, followed by two two-day flood control pulses up to 8,000 cfs in February, and had a ramped flood control pulse up to 15,000 cfs in late March after most spawning was completed. A final flood control pulse occurred in late May up to 25,000 cfs after most steelhead emergence had been completed. The minimum daily average temperature at Hazel Avenue was on January 24 when the daily average was 47 F. The minimum temperature was 46.9 and occurred on January 23, 24, and 25. Little diurnal temperature fluctuation occurs at Hazel Avenue because it is near Nimbus Dam where release temperature is fairly constant.

2004
Flows started out at 2,000 cfs in 2004, had a brief flood control release in mid January then resumed at 2,200 cfs until Delta X2 standards required a high release pulse in late February. Flows then dropped back to 3,000 with flood control operations requiring one additional pulse of 8,000 cfs in April after spawning was completed and coinciding with the VAMP period. There

was a mechanical problem at Nimbus Dam on January 27 that reduced flows at the Fair Oaks gauge down to 644 cfs for about half an hour. This occurred during a spawning survey. It does not show up on the chart because the chart is based on daily average flow. The minimum daily average temperature at Hazel Avenue was in late January and early February when the daily average was 48 F. The minimum temperature for the year at Hazel was 47 F. Optimal egg incubation temperatures of 56 F and below were from November 27 through April 25.

2002-2003
During both 2002 and 2003 flows started out at about 1,500 cfs when spawning began. During 2002 flows remained near that level up into March when flood control operations began with two brief peak flow periods, in March and in April. During 2003 conditions were wetter earlier and flow increases began in January up to a peak spawning period release of 5,500 cfs to meet a Delta water quality standard in mid-February. Flows then ramped down to 2,000 cfs through the remainder of the spawning period before heavy precipitation began again and releases were later increased.

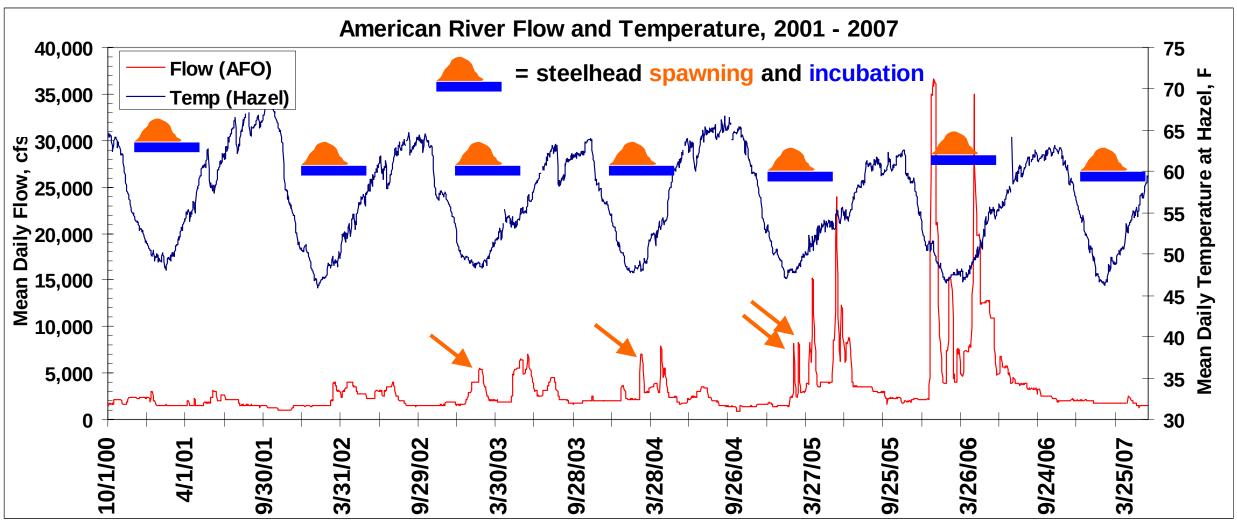


Figure 6. American River flow at Fair Oaks (gauge USGS 11446500) and average daily water temperature at Hazel Avenue from 2001 through 2005. The steelhead spawning and incubation periods are denoted on the chart. The arrows show flood control releases when steelhead spawning occurred in shallow areas.

Emergence

Figure 7 shows a temperature comparison between Hazel Avenue and Watt Avenue, a distance of about 13 river miles. These two locations were used for calculating fry emergence dates. The warmer Watt Avenue temperatures later in the spring result in an incubation period a few days shorter than near Hazel Avenue. The river was not surveyed in 2007 for steelhead fry during early steelhead emergence so actual emergence dates were not determined. We calculated that the first fry from redds that we found, on January 4 would emerge March 11, 2007 based on water temperature during development (Table 5). During past years the appearance of newly emergent fry matched up well with the calculated emergence date based on the appearance of redds and 600 accumulated temperature units (degrees C). Surveys conducted earlier than late

December would be difficult to detect steelhead spawners without observing them on redds because adult Chinook salmon and fresh Chinook redds are still abundant into December.

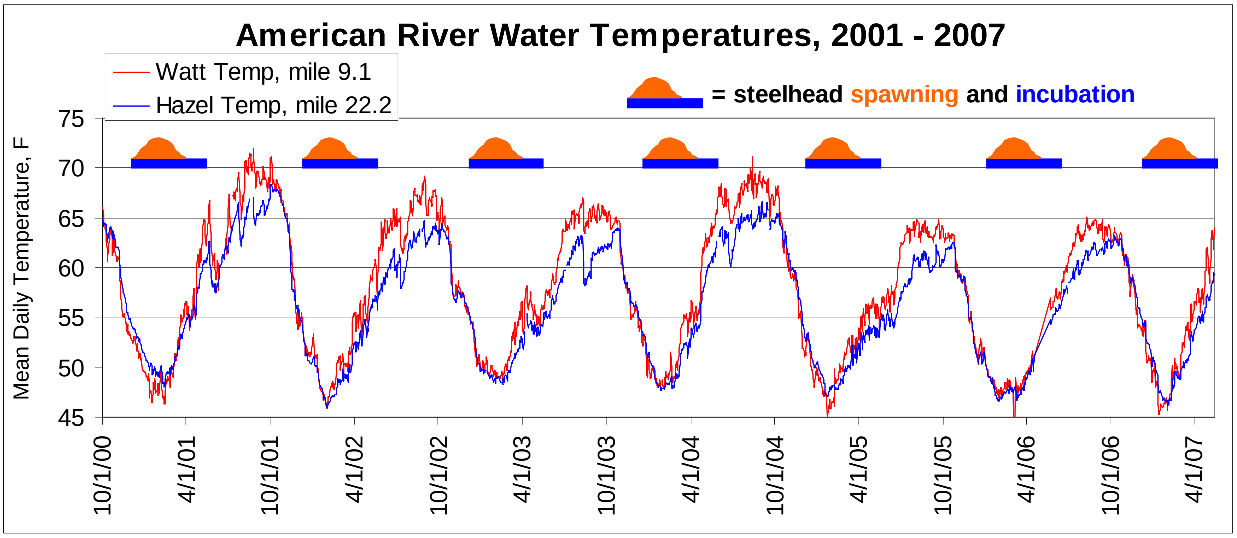


Figure 7. Water temperatures at Hazel Avenue and Watt Avenue used for calculating steelhead fry emergence dates from spawning date.

Table 5. Steelhead redd counts, adult observations, and estimated fry emergence dates, 2005 (top) and date of first steelhead fry observations (bottom).

Survey Date, 2006-7	Flow range, cfs	# new redds	# steelhead	600 ATU's at Hazel, fry to emerge by	600 ATU's at Watt, fry to emerge by
12-Dec	2,000		43	12-Feb	15-Feb
20-Dec	2,000		25	22-Feb	24-Feb
Jan 4-5	2,000	3	32	11-Mar	11-Mar
Jan 19-22	1,750	14	98	24-Mar	21-Mar
Feb 2-5	1,750	48	49	3-Apr	30-Mar
Feb 15-16	1,750	51	85	12-Apr	7-Apr
Mar 1-2	1,750	43	86	22-Apr	17-Apr
Mar 15-16	1,750	16	13	2-May	28-Apr
2-Apr	2,400	1		16-May	12-May

Water Clarity

Water clarity was generally suitable for conducting redd surveys during all surveys in 2001 – 2003. During 2007 water clarity was suitable during all spawning surveys. Water clarity in 2006 was unsuitable for conducting redd surveys after heavy rains in December clouded Folsom Reservoir for the remainder of the spring. Water clarity was unsuitable in late December through early January in 2005 (secchi depth less than two meters) due to rains December 28 into early January that apparently clouded the water in Folsom Reservoir so that water clarity in the lower river remained low for longer than usual. Some attempted surveys in early January had to be abandoned. Water clarity was suitable in February through May. Water clarity was unsuitable during one survey day in 2004 in the lower river. Secchi disc depths in the upper river (Fair Oaks bridge) and lower river (Fairbairn Water Intake) were taken in 2003, 2004, 2005, and 2007 (Figure 8). Redds seemed to be visible to a depth of about 1 to 1.5 meters less than the secchi depth readings, but this was variable depending on surface turbulence.

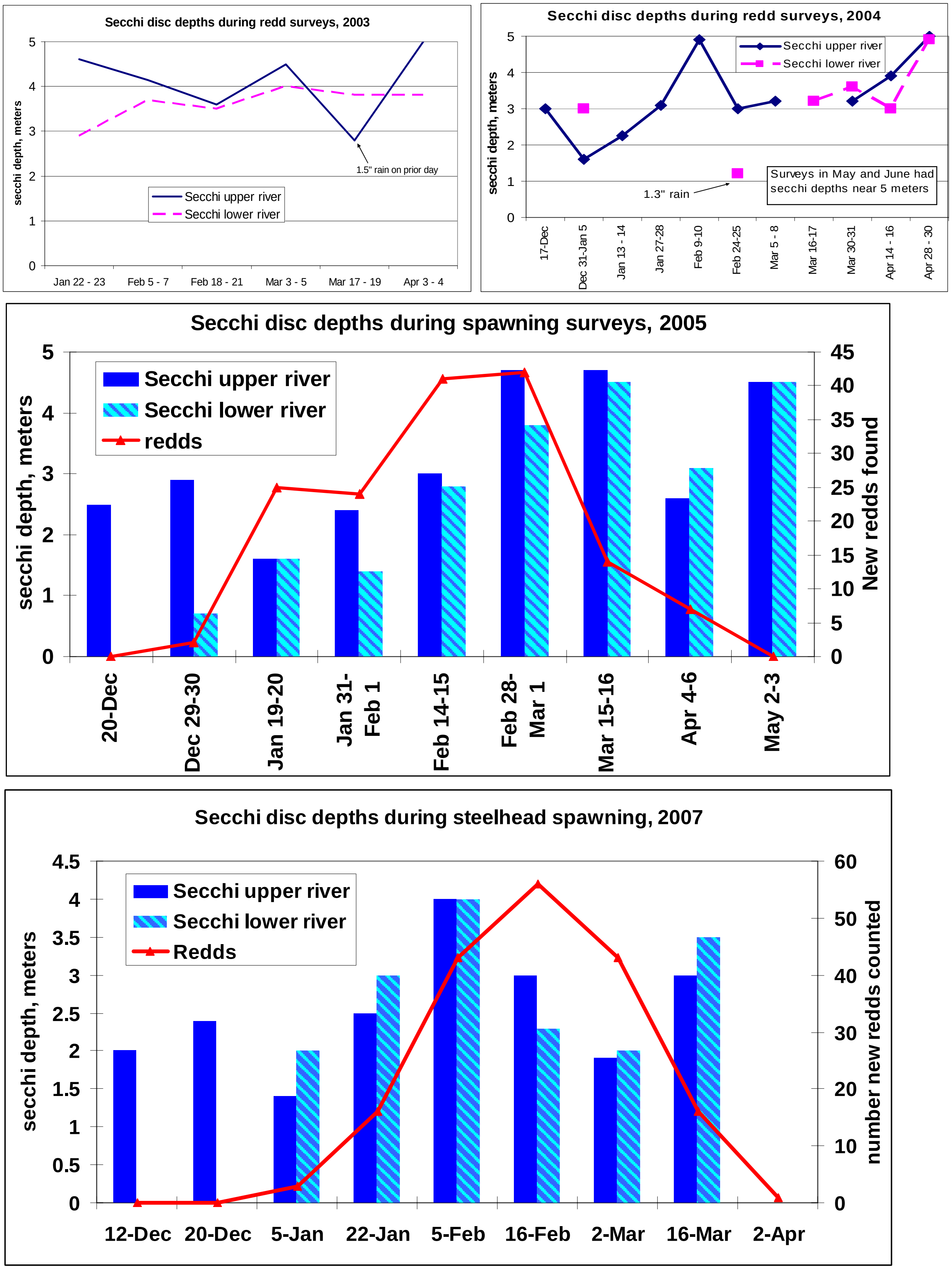


Figure 8. Secchi disc depths in the upper and lower river during 2003, 2004, 2005, and 2007 surveys.

Side Channel Spawning

Eleven areas were identified containing side channels with habitat likely to support spawning steelhead, especially at flow levels above 3,000 to 4,000 cfs. These areas are highlighted in Figure 9.

The biggest spawning concentrations occurred at Sailor Bar and upper Sunrise side channel. The area around the upper Sunrise side channel was heavily used by steelhead each year through 2006 (Figure 10). This same area is a popular fishing area with easy access for wading anglers. Many steelhead anglers practice catch and release fishing. We observed steelhead on redds get caught, released, and then return to the redd within a minute or two of being released. Spawning steelhead often did not leave redds even with multiple anglers within about 20 meters. High flows during 2005-2006 increased head cut in the main channel at upper Sunrise. Water surface elevation at the entrance to the side channel dropped, resulting in a decrease in the amount of time the side channel has water deep enough for spawning. The side channel becomes dry below about 1,500 cfs (Figure 11).

Redd Dewatering

High flows during the end of the 2005-6 Chinook spawning season and early in the steelhead spawning season resulted in some spawning in subsequently dewatered areas. Figure 11 shows dewatered redds that showed up after flow decreases in January 2006. Most of these were Chinook redds based on size and excavation of eggs in a few, but positive identification was not made for most of them.

Steelhead constructed seven redds in the lower Sunrise side channel during two flood control releases of 8,000 cfs in mid-February 2005. Steelhead constructed 11 redds in the lower Sunrise side channel between February 19 and 28, 2004 during flows up to 7,000 cfs. Steelhead constructed 15 redds in the lower Sunrise side channel between February 11 and 18, 2003 following a flow increase to 5,500 cfs (Figure 12). This side channel was unavailable for spawning in 2001, 2002 and 2007. Redds in this area were more closely monitored through emergence because they appeared vulnerable to dewatering.

The high releases during spawning were modified in 2005 compared to 2003 and 2004 in an attempt to minimize effects on steelhead spawning. Higher releases were used over a shorter time period to minimize the amount of time that higher elevation areas were available for spawning. Flows were 6,000 – 8,000 cfs during a three day period during both of the 2005 pulses and redds were still constructed, although fewer than in prior years. A higher flow peak followed by a quicker downramp may further minimize redd dewatering in the future when flood control releases coincide with steelhead spawning. There are concerns over Chinook and steelhead fry stranding with higher releases that sometimes preclude emulating an un-regulated storm runoff event. Figure 12 shows lower Sunrise steelhead redd locations by flow at 2,700 cfs and 1,500 cfs.

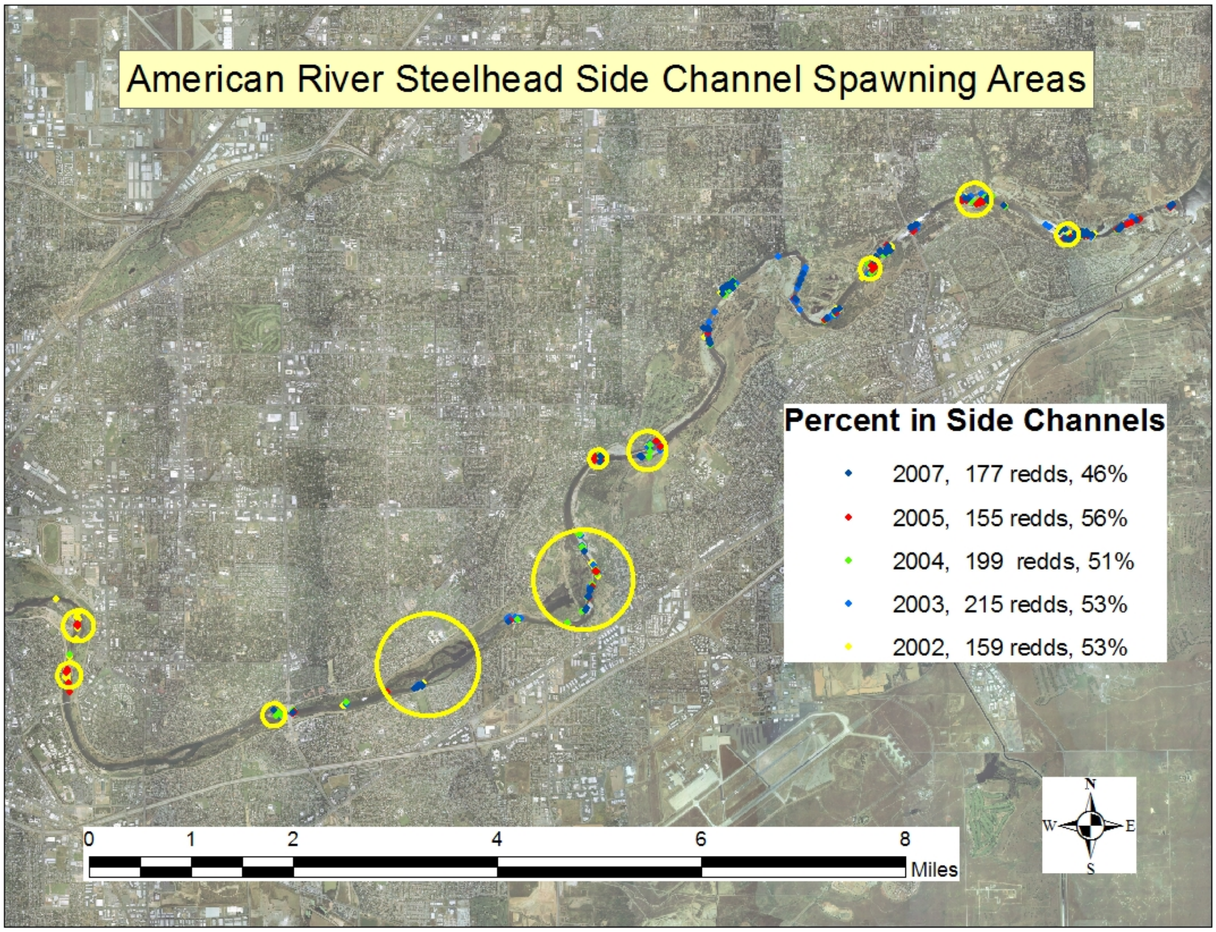


Figure 9. American River side channel reaches (yellow circled areas) where steelhead spawning is likely to occur.

Four of the redds at the lower Sunrise side channel were dewatered of surface flow in 2005, five were dewatered in 2004 and five were dewatered in 2003. The other redds in this side channel remained under water, but in a backwater pool with no water movement and heavy algae growth (Figure 4).

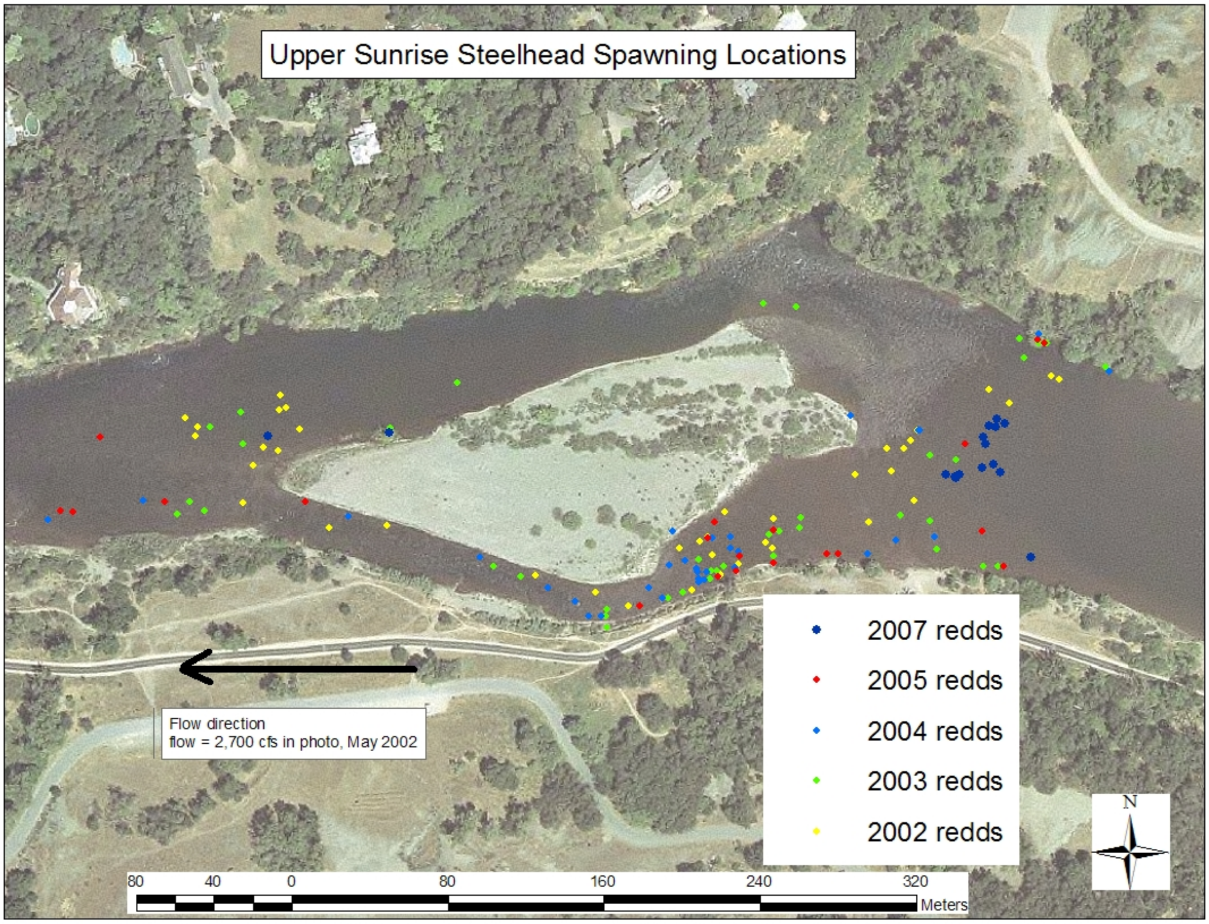


Figure 10. Upper Sunrise side channel steelhead redds in 2002 - 2005 and 2007.

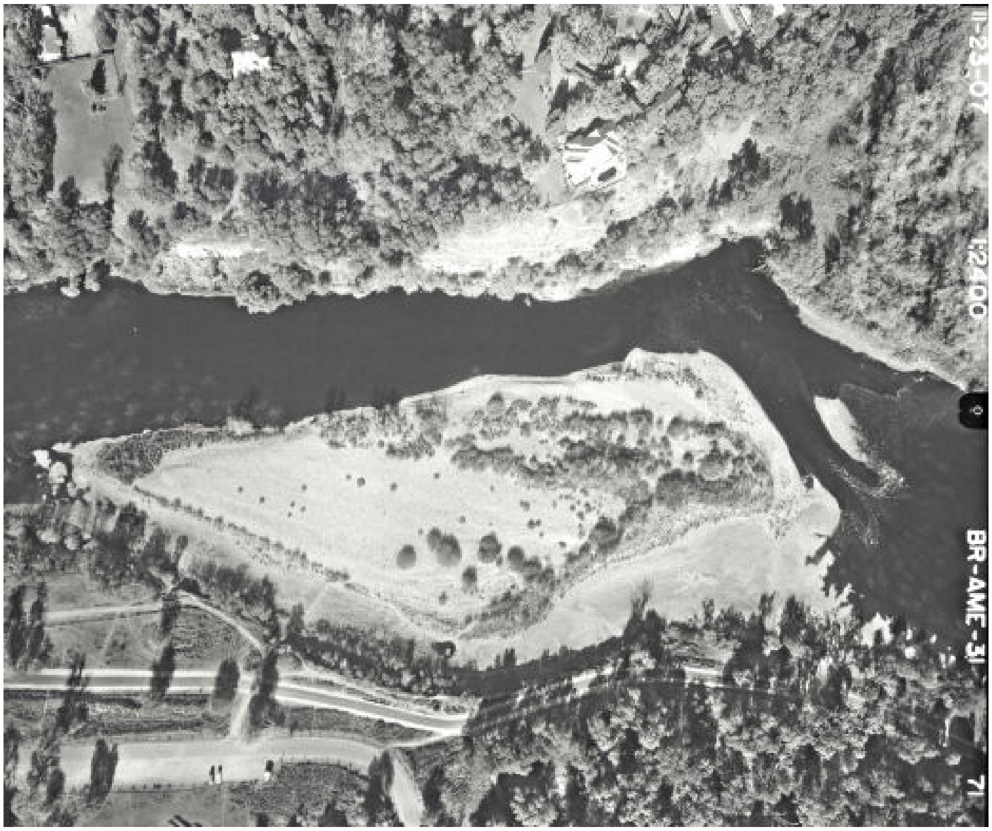


Figure 11. Upper Sunrise side channel dry at 1,200 cfs.

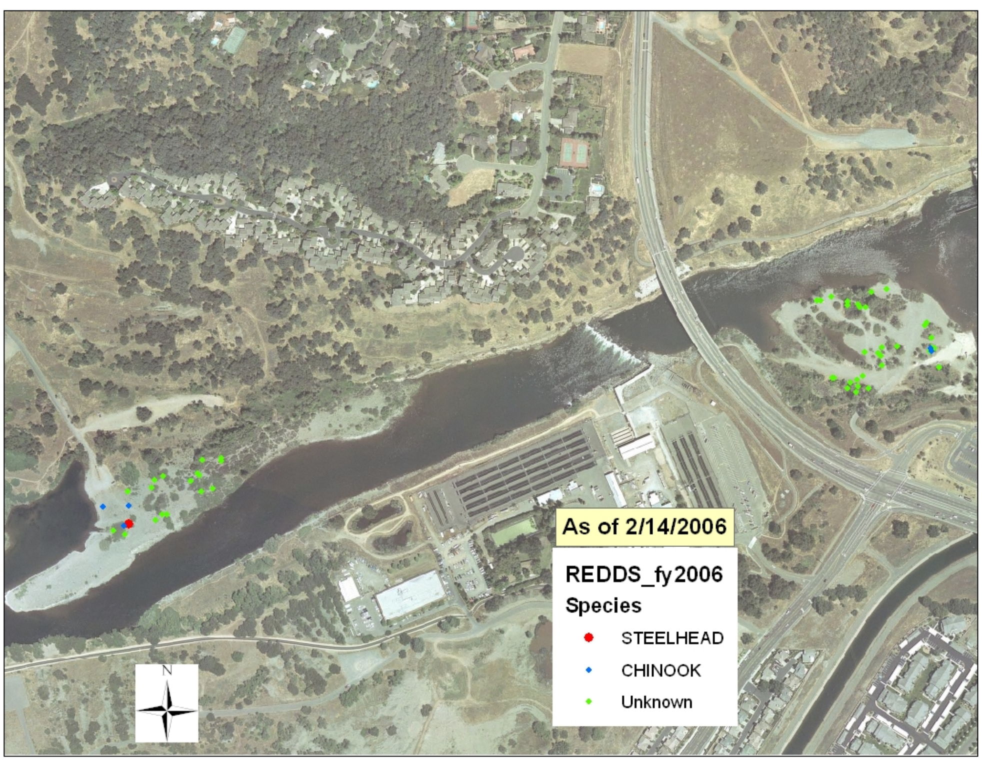
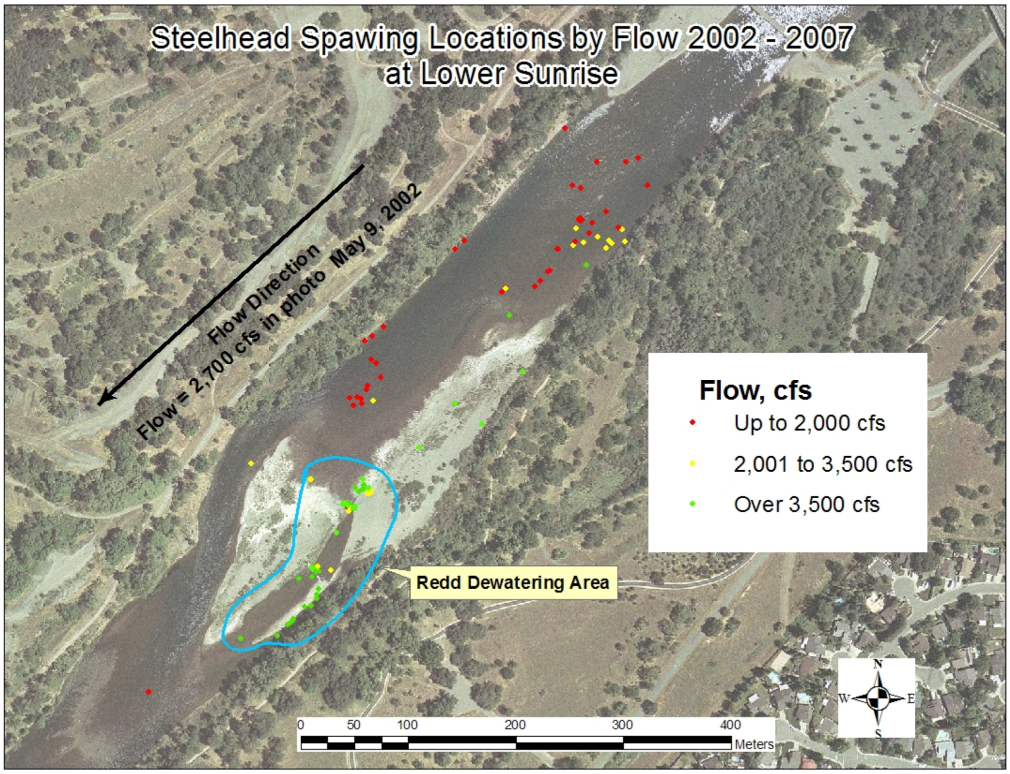


Figure 12. Dewatered redds at Nimbus Basin and Sailor Bar, February 2006.



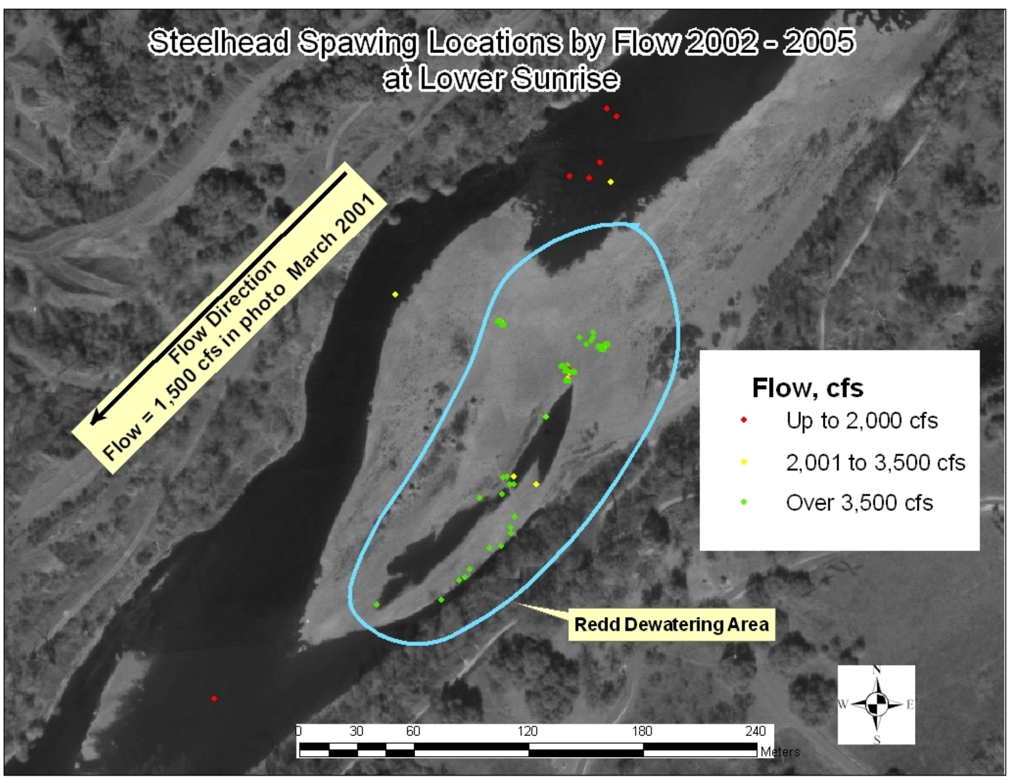


Figure 13. Steelhead redds at the lower Sunrise side channel at 2,700 cfs (top) and 1,500 cfs (bottom). No flow is flowing through the channel in the photo at 1,500 cfs. Flow provides spawning habitat in the side channel (where 2003 and 2004 redds are located) at greater than about 3,500 cfs.

Nimbus Basin Spawning

Adult steelhead are abundant in the run below Nimbus Dam based on angler success. The spawning habitat in the area is poor because much of the smaller gravel has been scoured away. We surveyed Nimbus Basin since 2003 by wading and snorkeling. We found steelhead redds each year, ten redds in 2003, nine in 2004, six in 2005, and five in 2007 (Figure 15). The gravel being used by most of the steelhead for spawning was large making it difficult to dig a very deep redd. Similar habitat conditions lower in the river would not likely be utilized for spawning. Because this is the upstream extent of habitat access it does get used for spawning. Some redds were likely missed in Nimbus Basin during flows above about 2,500 cfs because the velocity washed the snorkelers downstream before they could swim to the habitat furthest out in the main channel. Newly emerged steelhead fry were found each year in Nimbus Basin, confirming that at least some of the spawning was successful in the large gravel.

Pacific lampreys appeared to be more successful at creating distinguishable redds in the Nimbus basin area than steelhead. The lampreys we saw spawning in Nimbus Basin appeared to be larger than the average size of the ones we saw lower in the river.

The top of the riffle at Nimbus basin is an area of the river that could potentially be improved for steelhead and salmon spawning and rearing by adding spawning sized gravel or reconfiguring gravel from some of the adjacent gravel bar deposits. Gravel was last added there in 1991 (1,000 cubic yards). There would be the chance that addition of smaller gravel could get washed out during high releases following spawning so that would need to be taken into consideration.

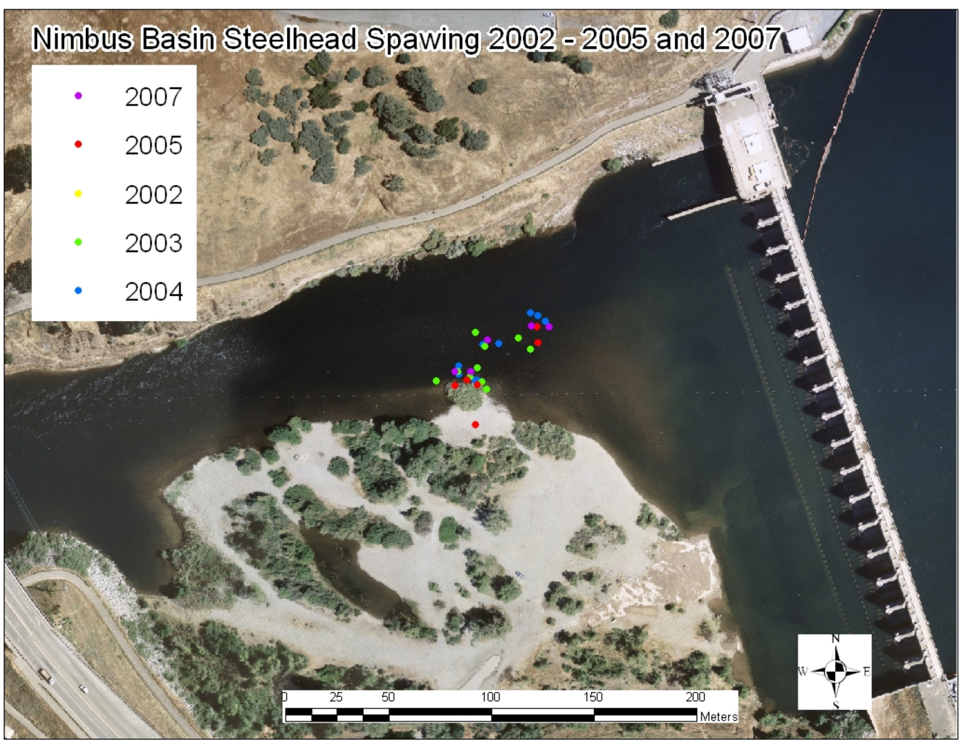


Figure 14. Steelhead spawning in Nimbus Basin in 2003 - 2005 and 2007.

The GIS and GPS mapping allows comparisons of spawning locations to be made at different flows between years. Figure 15 shows spawning locations in the Sunrise Boulevard vicinity by flow. The redds constructed at the higher flows we have seen over the years we have conducted the survey tended to be closer to the banks and more often in side channels than those constructed at the mid range or lower flows.

Figure 16 shows locations of groups of redds on the thalweg profile. This coarse scale analysis shows that steelhead spawning occurred primarily near the major riffle crests in the river. Groups of steelhead redds were marked on 20 of the approximately 24 major riffle crests along the thalweg profile.

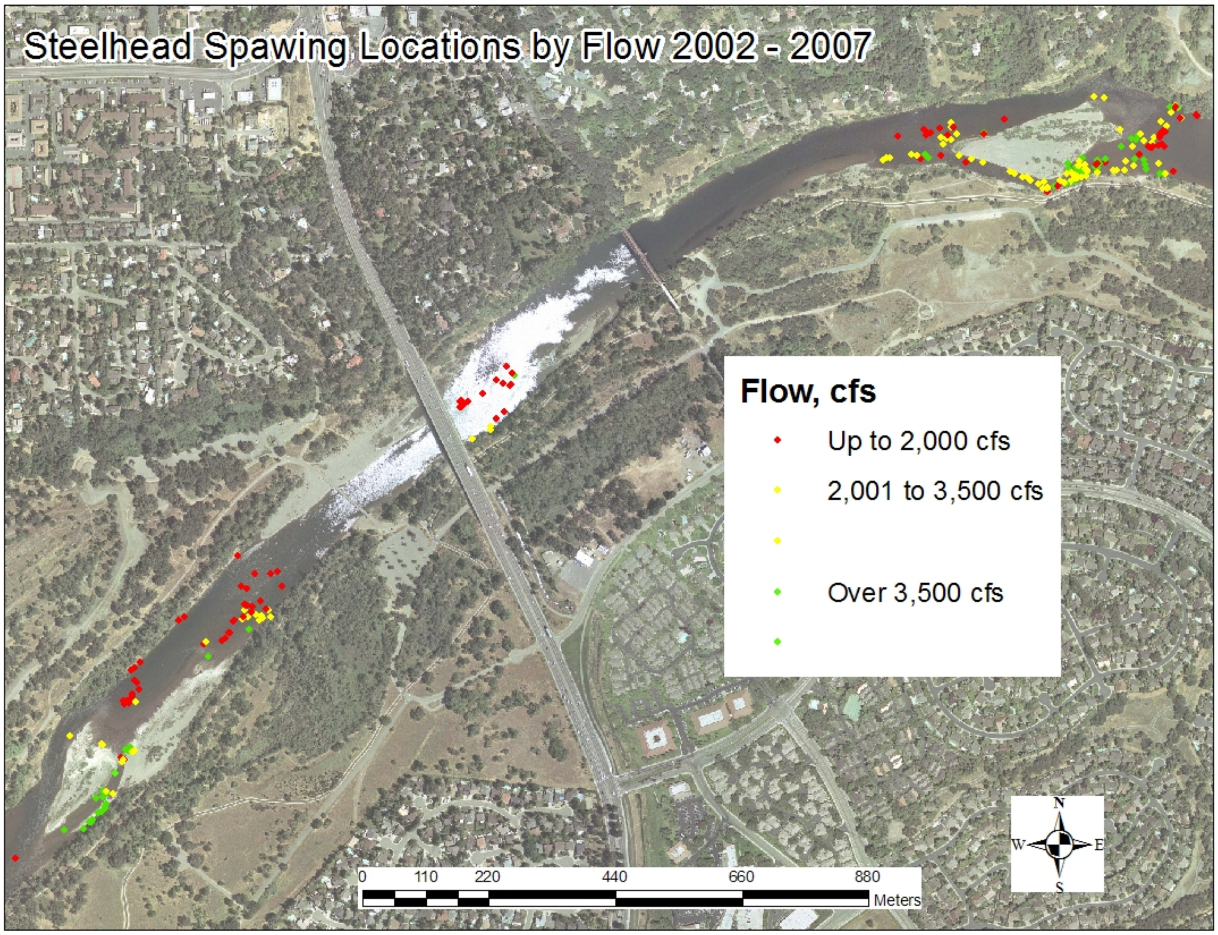


Figure 15. Steelhead spawning by flow at Sunrise, 2002 – 2005 and 2007. High flows of 3,500 cfs and above are in green, mid-range flows of 2,001 to 3,500 are in yellow and flows up to 2,000 cfs are in red.

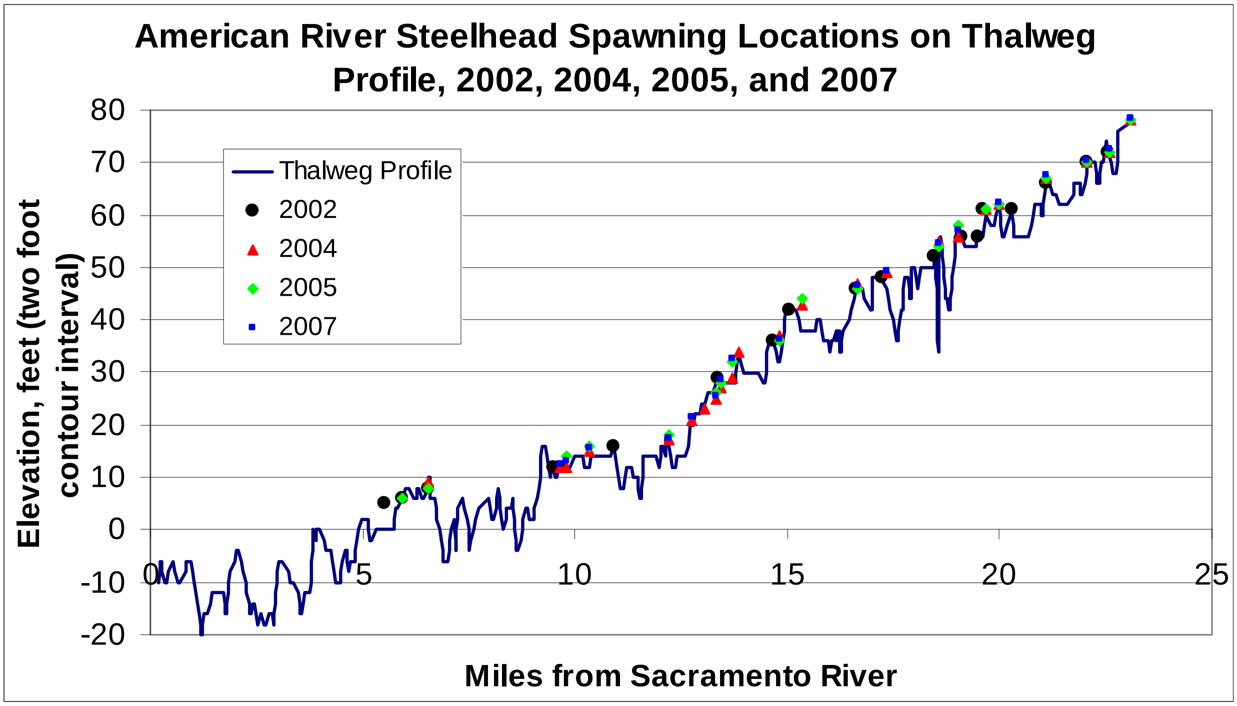


Figure 16. Locations of groups of steelhead redds (dots) along the American River thalweg profile in 2002, 2004, 2005, and 2007.

Population Estimates

We estimated the number of steelhead that spawned in the river in 2002 through 2005 and 2007. The 2002 estimate was based on redd counts only. The estimates in 2003 – 2005 and 2007 were made using two methods: 1) redd counts and 2) counts of adult steelhead observed spawning.

Redd Based Population Estimate

The redd based population estimate, based on number of redds observed, the male to female ratio (from the hatchery) and assuming 1 to 2 redds per female was 200 - 401 steelhead in 2002, 243 – 486 steelhead in 2003, 221 – 441 steelhead in 2004, 162 – 324 steelhead in 2005, and 186 – 372 steelhead in 2007 (Tables 6 and 7). The population likely lies somewhere in the range between the 1 redd per female estimate and the 2 redds per female estimate. We made no adjustments in the estimates to account for missed redds or mis-classified redds other than the adjustments for redds missed on days when water clarity was low in 2004 and 2005. These adjustments were based on the prior and subsequent survey results and on the temporal distribution in other years.

Table 6. Male to Female ratio from Nimbus Hatchery returns.

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

Table 7. Redd based population estimate.

Year	Redd Count [1]	Males/Female [2]	Population with 1 redd/female	Population with 2 redds/female
2002	159	1.52	**401**	**200**
2003	215	1.23	**479**	**240**
2004	197	1.24	**441**	**221**
2005	155	1.09	**324**	**162**
2006	Unsuccessful	1.17		
2007	178	1.09	**372**	**186**

[1] corrected for surveys with low visibility by linear regression between previous and following surveys.
[2] from table 6

Area Under the Curve Population Estimate

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 we were taking measurements. We estimated that we were seeing 90% of the fish that were on redds during the survey days. 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.

In order to determine residence time, individual marked fish with a counting station or radio telemetry are 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. 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 on 22%, 23%, 20%, and 36% of the redds counted during the formal surveys in 2003, 2004, 2005, and 2007 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%, and 20% that we observed in the field in 2003 - 2005. The 36% of redds occupied in 2007 is higher than expected and would indicate either steelhead remained on redds longer in 2007 (five days) or observer efficiency for unoccupied redds was lower in 2007 than in prior years. This resulted in an area under the curve estimate higher than the redd count based estimate range in 2007. 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 more northerly 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 and 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 2007 was 504 steelhead and the number in the river but not spawning in the river was 2,168 for a total escapement of 2,672 steelhead. Angler harvest may account for the additional fish not included in the estimate (2,673 entered the hatchery, not likely inclusive of steelhead that spawned in the river. Table 8 shows the area under the curve calculations for each year. Figure 18 shows both population estimate types and Figure 19 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 in the American River, whereas 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 2005 is illustrated in Table 9.

Steelhead observation timing in 2002 through 2005 and 2007 is illustrated in Figure 19 and fresh redd observation timing is in Figure 20. Steelhead observation timing is similar to that observed through a fishway on the Eel River (Table 10).   During 2003 surveys we did not survey the pool below the hatchery weir because it is not spawning habitat. During 2004, 2005, and 2007 surveys we surveyed the hatchery area and found schools of steelhead hanging below the hatchery outfall pipe, especially in January surveys. The number of steelhead holding below the hatchery is likely related to the timing of steelhead spawning in the hatchery. The hatchery spawns steelhead one day each week and holds the steelhead that enter the hatchery for the week up to the spawning day. More fish are present in t+he river near the hatchery the day following spawning when the steelhead have been released from the hatchery. In the days before spawning many steelhead are holding in the hatchery so are not present in the river.

Table 8. Steelhead observations by location and date and area under the curve population estimates in 2007 (top) 2005, 2004, and 2003 (bottom).

Steelhead observations and area under the curve population estimate, 2007

Steelhead observations not on redds 2007

	Day	Nimbus	Hatchery pool	Sailor up	Sailor low	Sunrise up	Sunrise low	El Manto	Ross moor	Ancil Hoffman	Goethe	Grist mill	Watt	Para dise	clips checked	clipped	fungus	Fish Observed	Total Fish	AUC (Hillborn)
12-Dec	1		43												1	1		43	430	452
20-Dec	9		21	3		1									3	3	18	25	250	272
5-Jan	25		12	7	1	4	2		2		1	1			3	3	16	30	300	440
22-Jan	42	5	22	31	2	13	1	5		7	1	2	4		4	4	60	93	930	1,046
5-Feb	56	1	11	7		5	1	2	3	3	1		2	2	1	1	25	38	380	917
16-Feb	67	2	12	11	1	10	4	1	2	2	4		3		4	3	29	52	520	495
2-Mar	81		6	12	1	7	1	2	2		2	2	3		3	3	27	38	380	630
16-Mar	95		2	3											1	1	5	5	50	301
Total		8	129	74	5	40	9	10	9	12	9	5	12	2	20	19	180	324		4,552

Escapement not spawning in river = 2,168

observer efficiency = 0.1

residence time = 21 days

Steelhead on redds

	Day	Nimbus	Hatchery	Sailor up	Sailor low	Sunrise up	Sunrise low	El Manto	Ross moor	Ancil Hoffman	Goethe	Grist mill	Watt	Para dise	clips checked	clipped	fungus	Fish Observed	Total Fish	AUC (Hillborn)
12-Dec	1																	0	0	0
20-Dec	9																	0	0	0
5-Jan	25			1			1								1	1		2	2	16
22-Jan	42			1		2	1			1								5	6	60
5-Feb	56			1		7			1	2								11	12	112
16-Feb	67	2		5	7	3	6	2	1	3	4				3	3	5	33	37	242
2-Mar	81			19	2	9	4		3	7			2		5	5	13	46	51	553
16-Mar	95				1			1		4	2							8	9	378
Total		2	0	27	10	21	12	3	5	17	6	0	2	0	9	9	18	105		1,361

Escapement spawning in river 504

observer efficiency = 0.9

residence time = 3 days

Total escapement = not on redds + on redds = 2,672

Steelhead Observations and area under the curve population estimate 2005

Steelhead observations, fish not on redds 2005

	Day	Nimbus	Hatchery pool	Sailor up	Sailor low	Sunrise up	Sunrise low	El Manto	Ross moor	Ancil Hoffman	Goethe	Grist mill	Watt	Para dise	low visibility	ad-clips checked	ad clipped	fungus	Fish Observed	Total Fish	AUC (Hillborn)
20-Dec	1		4				1	1								1	1	1	6	60	63
Dec 29-30	10		31	10	3	2	1								4	2	2	13	51	510	257
Jan 19-20	31		31	3	3	4									17	2	2	23	58	580	1,145
Jan 31-Feb 1	43	1	1	4	3	7	1			2				1		2	1	13	20	200	468
Feb 14-15	57	1	4	7	5	2	1			1						2	1	10	21	210	287
Feb 28-Mar 1	71			4	4	3	1	1								3	1	9	13	130	238
Mar 15-16	86		5	2		1												6	8	80	158
Apr 4-6	106		1												4				5	50	130
Total		2	77	30	18	19	5	2	0	3	0	0	0	1	25	12	8	75	182		2,745

Escapement not spawning in river = 1,307

observer efficiency = 0.1

residence time = 21 days

Steelhead observations, fish on redds

	Day	Nimbus	Hatchery	Sailor up	Sailor low	Sunrise up	Sunrise low	El Manto	Ross moor	Ancil Hoffman	Goethe	Grist mill	Watt	Para dise	low visibility	clips checked	clipped	fungus	Total fish	p	AUC (Hillborn)
20-Dec	1																		0	0	0
Dec 29-30	10				3					2								2	5	6	23
Jan 19-20	31				1		1				1		2		1	1	1	3	6	7	116
Jan 31-Feb 1	43					4	2			4								1	10	11	96
Feb 14-15	57				5	3	2											4	10	11	140
Feb 28-Mar 1	71			2	4	2										1	1	1	8	9	126
Mar 15-16	86			6	2	1												4	9	10	128
Apr 4-6	106																		0	0	90
Total		0	0	8	15	10	5	0	0	6	1	0	2	0	1	2	2	15	48		718

Escapement spawning in river = 266

observer efficiency = 0.9

residence time = 3 days

Total escapement = not on redds + on redds = **1,573**

Steelhead Observations and area under the curve population estimate 2004

Steelhead not on redds

	Day	Nimbus	Hatchery pool	Sailor up	Sailor low	Sunrise up	Sunrise low	El Manto	Ross moor	Ancil Hoffman	Goethe	Grist mill	Watt	Para dise	Feb 25	ad-clips checked	ad clipped	fungus	Fish Observed	Total Fish	AUC (Hillborn)
Dec 17	1			1			1											0	2	20	21
Dec 31-Jan 5	14		71	16	12	3	3	2			2	1	1			5	5	21	111	1110	735
Jan 13 - 14	27	1	5	5	13	10	1	1	3	2	4		1			3	3	18	46	460	1,021
Jan 27-28	41	2		19	6	4	3		3				1			2	2	30	38	380	588
Feb 9-10	54	1	10	13	17	11	2	2	1	1	7		1	1		9	9	35	67	670	683
Feb 24-25	69	1	4	4	5	1	4				4				2	1	1	15	25	250	690
Mar 5 - 8	79		5	6	4	6	4	3		1	1					5	4	17	30	300	275
Mar 16-17	90		4	6		5			1							1	1	11	16	160	253
Mar 30-31	104			2		2										1	1	1	4	40	140
Apr 14 - 16	119																		0	0	30
Apr 28 - 30	133							1 from angler report							1 from angler re		0		0	0	0
no adult steelhead observations March 31 through June using spawner survey methods																					
Total		5	99	72	57	42	18	8	8	4	18	1	4	1	2	27	26	148	339		

Escapement not spawning in river = 2,112

observer efficiency = 0.1

residence time = 21 days

Steelhead on redds

	Day	Nimbus	Hatchery	Sailor up	Sailor low	Sunrise up	Sunrise low	El Manto	Ross moor	Ancil Hoffman	Goethe	Grist mill	Watt	Para dise	Feb 25	ad-clips checked	ad clipped	fungus	Fish Observed	Total Fish	AUC (Hillborn)
Dec 17	1																		0	0	0
Dec 31-Jan 5	14		1			1										1	1	1	2	2	13
Jan 13 - 14	27			2		3	2	1										1	8	9	65
Jan 27-28	41				3	3					1		3					4	10	11	126
Feb 9-10	54				1	3	2	3	2		3		4			1	1	3	18	20	182
Feb 24-25	69				10	4	1		3	1					3	3	2	3	22	24	300
Mar 5 - 8	79						1		1		1								3	3	125
Mar 16-17	90			1	2	2												1	5	6	44
Mar 30-31	104																		0	0	35
Apr 14 - 16	119																		0	0	0
Apr 28 - 30	133																		0	0	0
no adult steelhead observations March 31 through June using spawner survey methods																					
Total		0	1	3	16	16	6	4	6	1	5	0	7	0	3	5	4	13	68		890

Escapement spawning in river = 330

observer efficiency = 0.9

residence time = 3 days

Total escapement = not on redds + on redds = **2,441**

Steelhead observations 2003

Steelhead not on redds

	Day	Nimbus	Sailor up	Sailor low	Sunrise up	Sunrise low	El Manto	Rossmoor	Ancil Hoffman	Goethe	Grist mill	Watt	Paradise	clips checked	clipped	fungus	Fish Observed	Total Fish	AUC (Hillborn)
Jan 7 - 9	7		4	3	1	2			1	1	2	2		3	3	4	16	160	168
Jan 22 - 23	22	8	2	1	4	2	2			1		1		3	3	2	21	210	278
Feb 5 - 7	36		3	6	5	1	2			5		1	1			14	24	240	315
Feb 18 - 21	49		2	8	8	4		1		9						16	32	320	364
Mar 3 - 5	62		2	3	5	7		1						4	3	10	18	180	325
Mar 17 - 19	76	6	5	4	3	2			1			1		1	1	11	22	220	280
Apr 3 - 4	93	2	3		1									4	3	2	6	60	238
																			63
Total		16	21	25	27	18	4	2	2	16	2	5	1	15	13	59	139		2,031

Escapement not spawning in river = 967

observer efficiency = 0.1

residence time = 21 days

Steelhead on redds

	Day	Nimbus	Sailor up	Sailor low	Sunrise up	Sunrise low	El Manto	Rossmoor	Ancil Hoffman	Goethe	Grist mill	Watt	Paradise	clips checked	clipped	fungus	Fish Observed	Total Fish	AUC (Hillborn)
Jan 7 - 9	7		2		1						1						4	4	6
Jan 22 - 23	22	3		1		2					1			1	1	1	7	8	83
Feb 5 - 7	36	1		5	4					3	2	3		2	2	6	18	20	175
Feb 18 - 21	49			1	5	2	4	2	2	5				2	2	4	21	23	254
Mar 3 - 5	62	1			7		1	2								3	11	12	208
Mar 17 - 19	76	3	2		3											2	8	9	133
Apr 3 - 4	93																0	0	68
Total		8	4	7	20	4	5	4	2	8	4	3	0	4	4	16	69		926

Escapement spawning in river = 343

observer efficiency = 0.9

residence time = 3 days

Total escapement = not on redds + on redds = 1,310

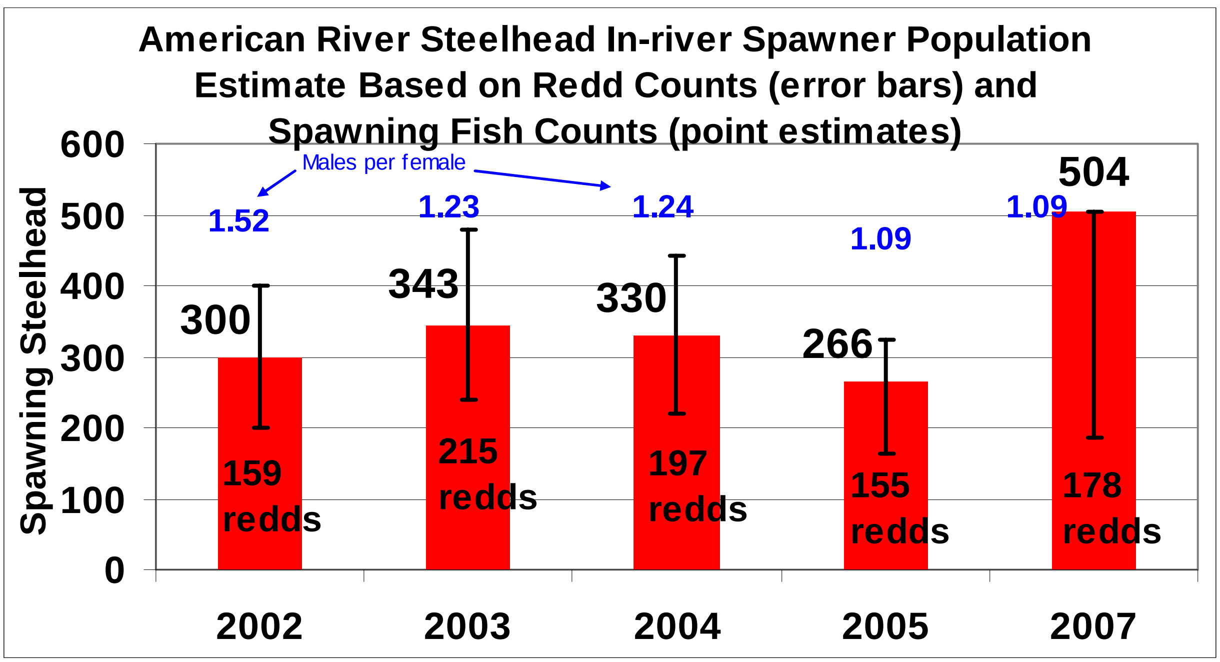


Figure 17. In-river steelhead spawner population estimates based on redd counts (error bars) and spawning steelhead observations (point estimates).

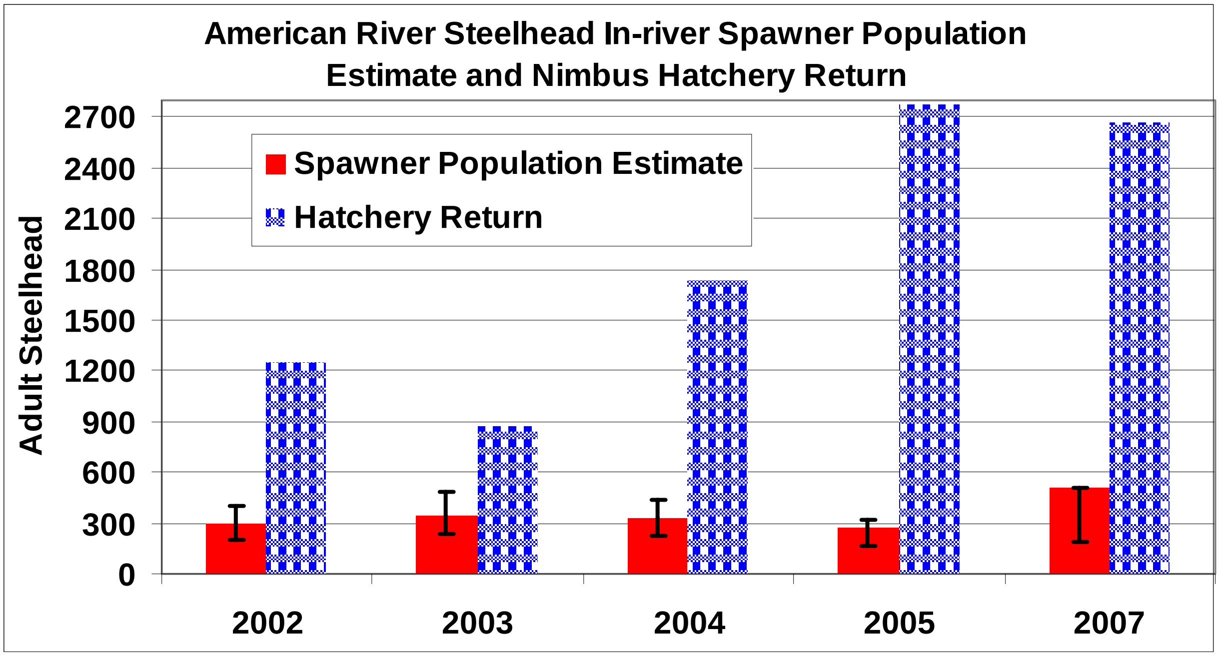


Figure 18. Steelhead spawner population estimate compared to Nimbus hatchery steelhead return.

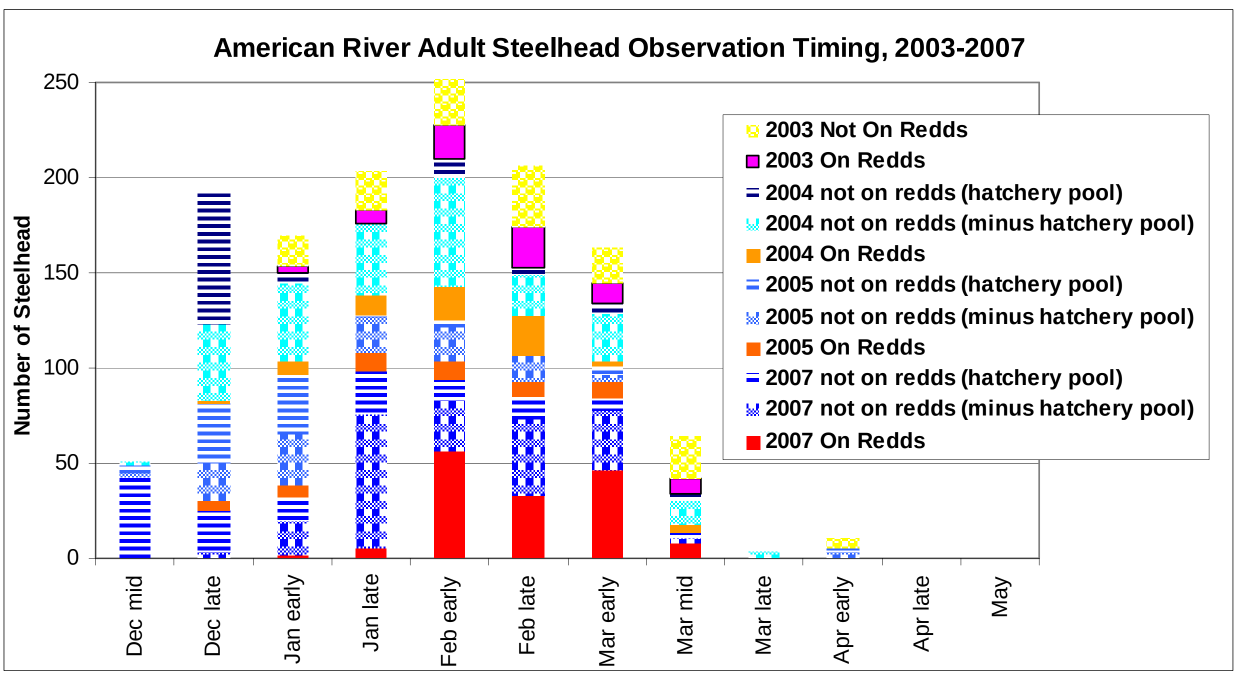


Figure 19. American River steelhead observations for fish on redds and not on redds during the 2003 run (left) and 2004 run (right).

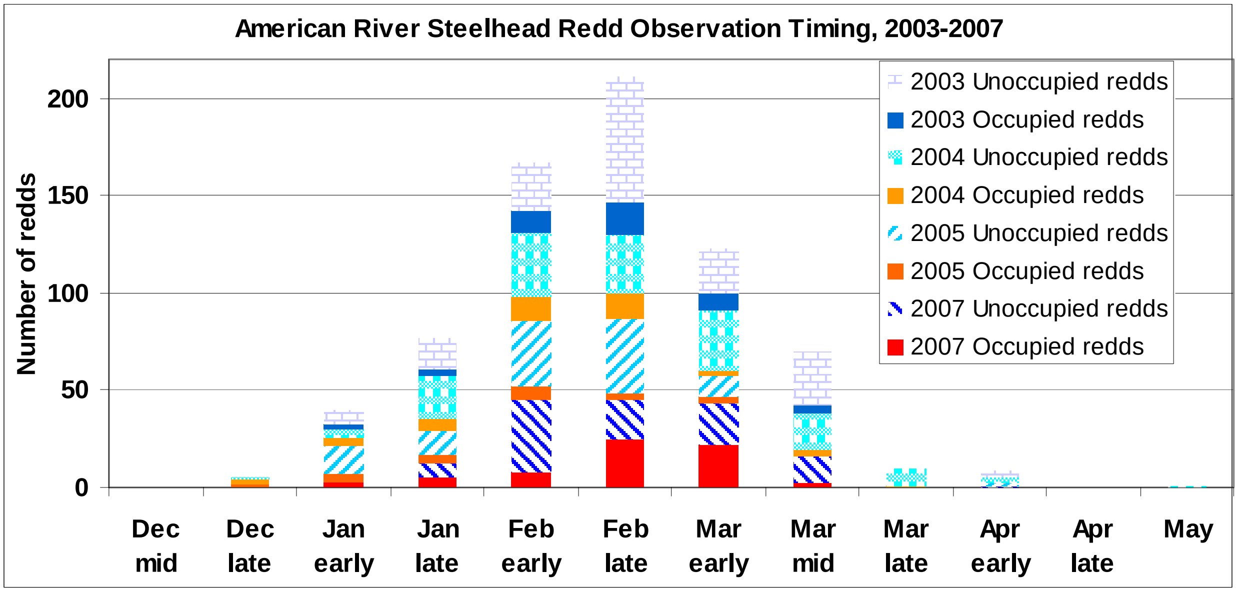


Figure 20. American River steelhead redd counts by date, 2003 (left) and 2004 (right). Surveys were conducted December 17 through June 17 in 2004.

Table 9. Effects of different observer efficiency and fish residence time on population estimates in 2005.

Fish on Redds (in-river spawners)			Fish not on Redds		
Observer Efficiency	Residence Time on Redds	Population	Observer Efficiency	Residence Time in River	Population
0.9	3	266	0.1	21	1,307
0.9	5	159	0.1	50	566
0.9	2	399	0.1	14	1,945
0.8	3	299	0.05	21	2,614
0.99	3	242	0.2	21	653

Table 10. Steelhead timing in the South Fork Eel River, 1938 – 1944 (from Shapovalov and Taft (1954).

South Fork of Eel River, Steelhead: Adults Counted Upstream Through Fishway at Benbow Dam, by Two-week Periods

Period	1938-39	1939-40	1940-41	1941-42	1942-43	1943-44	Total	Percentage of total run
Oct. 1-14	-	-	-	-	-	-	-	-
Oct. 15-28	-	-	1	-	3	-	4	+
Oct. 29-Nov. 11	3	-	17	9	9	-	38	+
Nov. 12-25	-	-	2	19	139	26	186	0.2
Nov. 26-Dec. 9	691	-	16	76	694	43	1,520	1.4
Dec. 10-23	208	784	47	62	1,394	215	2,710	2.4
Dec. 24-Jan. 6	507	1,126	5,123	1,515	3,484	1,690	13,445	12.0
Jan. 7-20	3,414	1,202	4,498	4,491	221	4,622	18,448	16.5
Jan. 21-Feb. 3	1,479	5,526	2,799	2,130	7,517	4,165	23,616	21.2
Feb. 4-17	2,901	1,572	2,708	985	5,525	3,892	17,583	15.7
Feb. 18-Mar. 3	424	1,765	1,147	1,820	2,047	2,103	9,306	8.3
Mar. 4-17	2,390	1,141	872	3,775	2,900	4,251	15,329	13.7
Mar. 18-31	746	645	809	1,643	649	1,339	5,831	5.2
Apr. 1-14	188	609	194	771	436	1,099	3,297	3.3
Apr. 15-28	42	33	44	36	14	-	169	0.2
Apr. 29-May 12	2	73	21	24	-	-	120	0.1
May 13-26	-	-	10	-	-	-	10	+
May 27-Sept. 30	-	-	-	-	-	-	-	-
Totals	12,995	14,476	18,308	17,356	25,032	23,445	111,612	-

Estimates of Steelhead Fry and Smolt Production

Potential steelhead fry production based on 1.5 redds per female, an average fecundity of 6,300 eggs (this is the average fecundity at Nimbus Hatchery 1975 – 1987 (ADF&G 1987)[1]), 1.5 redds per female, and an egg to fry survival rate of 50% was 450,000 in 2007, 220,000 in 2005, 405,000 in 2004, 450,000 in 2003 and 334,000 in 2002 (Table 9). Based on snorkel observations and seining surveys high mortality of juvenile steelhead occurs during the first couple months following emergence.

The estimate of naturally produced smolts that emigrated each year assuming survival of smolts to adult is the same for wild as for hatchery fish ranges from 6,132 to 22,827 between 2001 and 2007 compared to hatchery releases of around 400,000 smolts (Table 10). 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 2004 and returned as adults in the winter of 2006-2007 to be 5% (Table 10). This is based on the estimated wild fry production in 2004 and the estimated survival of hatchery smolts that returned as adults in 2007 and the in-river spawning population estimate in 2007. An assumption of 20% angler harvest was added in based on angler surveys in 1999 and 2001.

Table 9. Potential fry production estimated from redd count data in 2002 - 2005.

	2007	*2005*	*2004*	*2003*	*2002*
Redds counted	178	155	197	215	159
Females spawning (at 1.5 redds per female)	119	103	131	143	106
Fecundity [1]	7,542	4,291	6,190	6,238	6,300
Total eggs spawned	897,498	441,973	810,890	892,034	667,800
Fry produced at 50% egg to fry survival	448,749	220,987	405,445	446,017	333,900

Average fecundity in 2003 - 2007 was based on the number of eggs obtained per female spawned in the hatchery. 2002 fecundity was based on the Nimbus average for1975-1987, Ducey 1987.

Table 10. Estimates of wild smolt production and hatchery smolt survival based on adult hatchery counts, spawner surveys and hatchery yearling releases.

Adult Spawning Year	2007	2006	2005	2004	2003	2002	2001	2000
Year smolts released or outmigrated	2005	2004	2003	2002	2001	2000	1999	1998
Hatchery smolts released in Jan/Feb. of above year[3]	400,000	400,000	419,160	414,819	467,023	402,300	416,060	385,887
In-river spawning adults	504		266	330	343	300		
Total Hatchery Produced Adult Return[1]	3,613	2,660	3,472	2,425	1,386	1,745	3,392	2,057
Unclipped Adults in hatchery	116		118	17	27	69	50	
Percent return of hatchery fish (clipped adult return divided by smolts released two years prior)	0.90%	0.67%	0.83%	0.58%	0.30%	0.43%	0.82%	0.53%
Wild smolts that outmigrated (two years prior)[2]	18,424		17,457	8,552	20,661	22,827	6,132	
Estimate of fry produced based on redd surveys	448,749		220,987	405,445	446,017	333,900		
Fry to smolt survival estimated	available 2010		available 2008	5%		5%		
[1] assumes 20% recreational harvest based on angler surveys in 1999 and 2001								
[2] assumes same smolt to adult survival of wild smolts as for hatchery released smolts and that 10% of in-river spawners are naturally produced fish								
[3] values for 2004 and 2005 are estimates								

Figure 21 shows hatchery spawning data versus redd observations in the river in each year. In-river spawning appears to occur a few weeks after the peak in hatchery spawning.

Anglers report immature adult steelhead in the American River during the summer. A few medium sized trout have been observed during snorkel surveys in the summer (Fishery Foundation and USBR data). These were thought to be over-summering trout from the American or other Central Valley tributaries which may or may not have been to the ocean (Hannon and Healey 2002). These could be also be remnants from the attempts to establish summer run steelhead in the American River. We continued redd surveys until June 17 in 2004 to look for late-spawning steelhead. We marked one potential steelhead redd on May 26. No steelhead over 40 cm were observed in the surveys of spawning habitat after March 30. During 2005 the final survey was on May 2-3. No steelhead or redds were observed after April 4-6. Durinig 2007 we concluded surveys on April 2 and found one redd on that date.

Staley (1976) provided a summary of American River steelhead management after the completion of Folsom and Nimbus Dams in 1955. During early years of hatchery operations (1955 – 1962) nearly all fish entered the hatchery from January through April and were called winter run fish. Because returns were low during these early years supplements of eggs from the upper Eel River, 150 miles upstream from saltwater at 1,500 feet elevation (Van Arsdale Fisheries Station), were made. Later, in 1969 – 1973, attempts were made to establish an earlier run to provide earlier steelhead fishing by stocking summer run steelhead from the Skamania

Hatchery on the Washougal River in Washington and from the Roaring River Hatchery on the Siletz River in Oregon. The fish came primarily from the Washougal River which has a run that enters the river from May through November and spawns March through June. Washougal River strain was again stocked in 1980 and 1981. Skamania hatchery steelhead from the Washougal River have experienced strong selection for larger size and earlier timing since the 1950's which moved their spawning earlier by as much as three months so they were asynchronous with their native Washougal steelhead and most other steelhead populations (Brannon et al 2004). Early returning steelhead in the American and some trapped from the Sacramento River were isolated and spawned separately from later fish in an attempt to select for earlier returning steelhead for fishing. The goal was to have a large number of steelhead arrive in October. Steelhead have also been transferred between Nimbus Hatchery and all other Central Valley steelhead hatcheries.

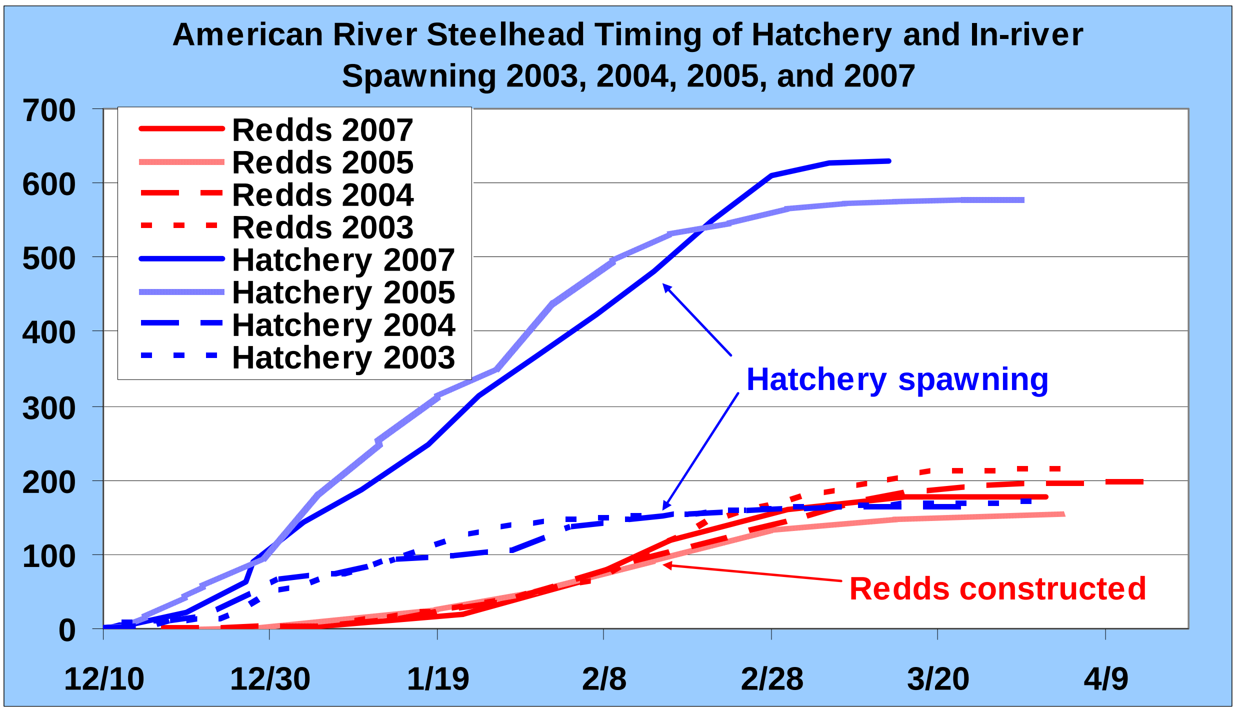


Figure 21. American River steelhead timing of hatchery spawning, unspawned female releases, and redd counts, 2003 – 2005 broods.

Proportion of Returning Adults that were Naturally Spawned in River

All hatchery reared steelhead in the Central Valley now 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, 2004, 2005, and 2007 9.5%, 6.3%, 28.6%, and 3.4% respectively of the steelhead we observed in the river were unclipped. We were able to determine status of the adipose fin of five steelhead on redds in 2003 and 2004 and of two in 2005 and of nine in 2007. All five steelhead on redds had missing adipose fins in 2003 and one steelhead had the adipose fin present in 2004. Both steelhead on redds were clipped in 2005. All nine on redds were clipped in 2007 Unclipped steelhead entering Nimbus Hatchery were 1.7%, 5.5%, 3.1%, 1.0%, 4.3%, and 4.3% of the total in 2001 through 2005 and 2007 (Table 11).

Most of the observations when we successfully determined the status of the adipose fin were made when drifting by adult steelhead when snorkeling. These observations were primarily of steelhead that were not occupying redds. Steelhead on redds often left the redd when a snorkeler approached before the snorkeler could get a good look for the adipose fin. We seemed to be able to approach steelhead on redds closer in the boat or from the bank above than by wading in the river or snorkeling. We were able to successfully view steelhead on redds using the underwater video camera. Most steelhead observations occurred during peak abundance and spawning times so there was not time to deploy the camera on many redds and finish the day's survey reach. The camera could be used successfully to determine adipose status if more time was devoted to the survey.

Table 11. Adipose clip status of steelhead observations in the river (top) and of steelhead entering Nimbus Hatchery (bottom).

Year	Number able to determine 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

Year	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%

Individual Steelhead Characteristics

The length frequency distribution of steelhead observed on redds is in Figure 22. The average visually estimated size of steelhead observed on redds was 58 cm in 2003, 65 cm in 2004, 66 cm in 2005, and 68 cm in 2007 and ranged from 36 to 80 cm (n=61, SD = 9), 45 to 80 cm (n=64, SD=7), and 45 to 80 cm (n=47, SD=7), and 60 to 85 cm (n=104, SD=5) in the four years respectively.

Many steelhead in the American River developed Saprolegnia fungus on the body each year. We observed fungus on 36% of the adult steelhead observed (n = 208) in 2003 , 40% in 2004 (n = 407), 39% in 2005 (n = 230), and 46% in 2007 (n=432). Of steelhead not occupying redds, 42% , 44%, 41%, and 56% were noted as having fungus and 23%, 19%, 31%, and 17% of steelhead occupying redds had fungus in 2003, 2004, 2005, and 2007 respectively. The white fungus stands out in the water and made steelhead more visible so the 41% to 44% values is probably high for the overall percentage of steelhead not on redds with fungus. Steelhead with fungus and not holding on redds were more likely to be seen and counted than those without fungus, likely inflating the percentage with fungus.

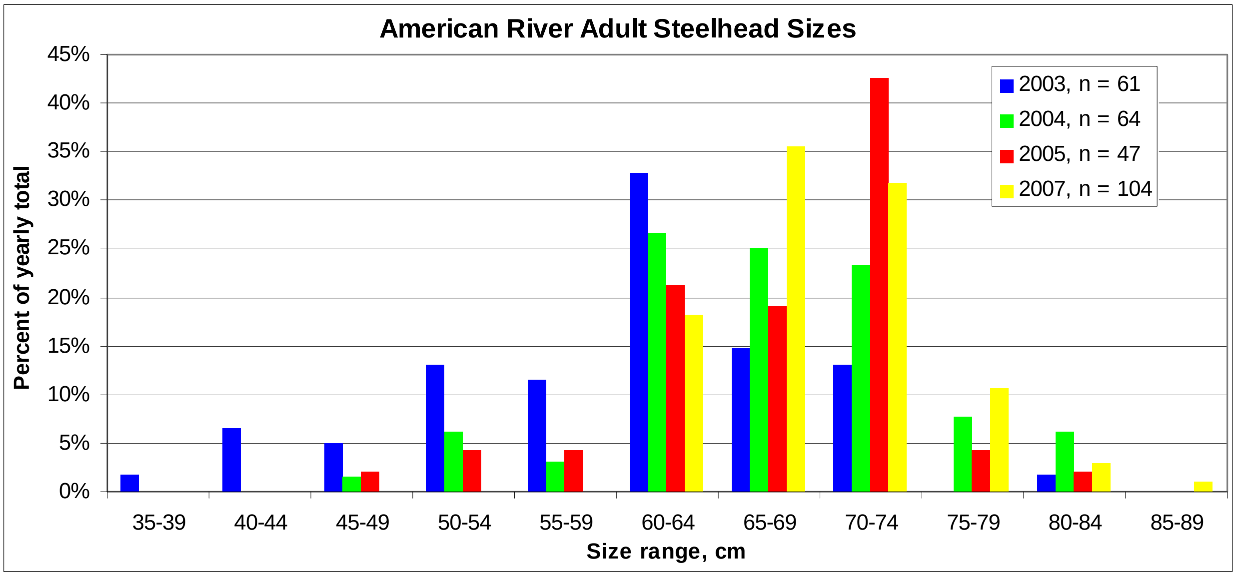


Figure 22. Length frequency of steelhead observed spawning (holding on redds) in the American River in 2003, 2004, 2005, and 2007.

Proximity of steelhead redds to cover

Sixty four percent and 63% of the steelhead redds were within 100 meters of some type of identified cover such as vegetation on the bank, woody debris, large substrates, deep water, or artificial structures in 2005 and 2007. Of those redds within 100 meters of cover, the mean distance away was 14 meters and 36 meters and distances from cover ranged from one to 100 meters. Fifteen percent of redds were less than 10 meters from cover in 2007.

Differentiation of steelhead redds from redds of other species

Steelhead spawning in the American River overlaps somewhat with Chinook salmon, Pacific lamprey, Sacramento suckers, and Sacramento pikeminnows. During each year we observed live Chinook into late January. The last fresh Chinook redd we observed and measured was on January 22 in 2003, January 13 in 2004 and January 31 in 2005. The in-river spawning Chinook population was over 100,000 fish each year so Chinook redds were present throughout much of the river. Chinook spawning peaked in mid-November and most was completed by mid-December. The Chinook redds were clearly larger with deeper pots than steelhead redds. By the time steelhead spawning was occurring most Chinook redds were covered by epilithic algae so could be identified as not freshly constructed and were not counted. Many depressions from Chinook spawning were visible throughout the steelhead spawning period.

Sacramento suckers and Sacramento pikeminnows were often seen in concentrations near areas with algae cleared from the rocks in small diameter circles (~0.5 m diameter). There was generally little gravel displaced in these areas so they were clearly not steelhead redds and were not counted.

Summary statistics for measurements of redds that steelhead were observed occupying are given in table 14. Figure 23 shows redd area and spawning depths of lamprey redds versus steelhead and unknown redds. Redds were classified as unknown if they were believed by the surveyors to be steelhead redds but accurate species identification (usually lamprey vs steelhead) was somewhat questionable. Lamprey redds were generally smaller and often had little or no tail spill. More fines were usually present in the pot of lamprey redds than in the pot of steelhead redds. When spawning, lampreys pick up the larger rocks with their sucker and carry them to the tailspill leaving much of the sand and small gravel in the pot. Some lampreys were observed scouring rock from the redd pot in a manner similar to steelhead. With their small bodies their scouring motions may not remove as much fines as steelhead so more fines tended to remain. Most of the unknown redds were ultimately classified as steelhead redds based on redd dimensions. Figure 23 shows the calculated redd areas of steelhead, lamprey, and unknown redds from the initial field classification. Some lamprey redds were similar to steelhead redds and a few were possibly misclassified as steelhead redds. Gallagher and Gallagher (2005) used principle components analysis to develop a linear discriminant function that identified redds to species in the Noyo River. This could be pursued in the American. Figure 24 shows water depth, velocity, and substrates used by spawning steelhead in the American River.

Habitat Suitability Indices

We developed habitat suitability index curves from the redd data. The mean water column velocity curve was developed from velocity measurements over 94 redds and the focal velocity curve was developed from 331 focal velocity measurements (Figure 25). The spawning water depth curve was developed from 513 water depth measurements (Figure 26). Sixth order polynomial equations were fit to the suitability index curve to use for calculating a global habitat suitabity index using the geometric mean of the depth and velocity suitability values (Elkins et al. 2007).

Pacific Lamprey spawning

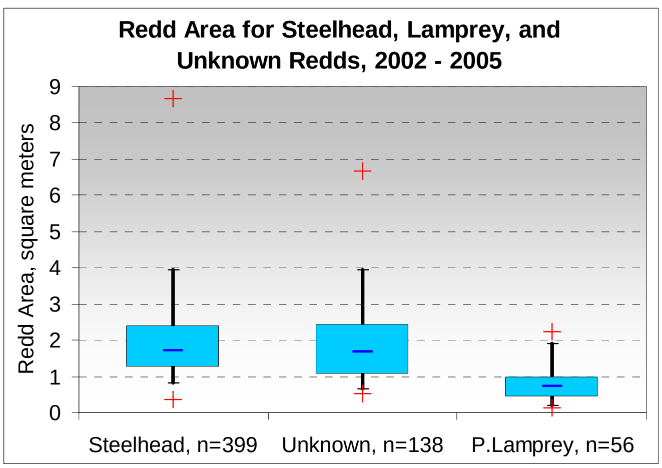
We observed Pacific lampreys spawning in January, February, March, and April in 2003. The surveys in 2004 continued into June. During 2004 fewer lampreys spawned than in 2002 or 2003 and they were only observed from March 30 into June. The peak in lamprey spawning was after the peak in steelhead spawning (Table 15). During the final survey in 2003, on April 3 – 4, we counted 278 lamprey redds, 42 of them with lampreys actively spawning on them. Dead, presumably spawned out, lampreys were found in March and April of 2003. No more than about 15 likely lamprey redds were observed in any survey in 2004 and the maximum number of redds observed with lampreys occupying them was three on both March 30 and May 26, 2004. The peak lamprey count in 2005 occurred on April 4 – 6 when we counted 71 likely Pacific lamprey redds with 10 of them occupied by spawning lampreys. We encountered commercial lamprey harvesters during our surveys on March 15 and April 5. During the April 5 survey at Paradise Beach, where we usually see the most spawning lampreys, the commercial crew had just worked most of the area by boat when we arrived. The harvest appeared to result in few spawning lamprey observations there.

No spawning lampreys were observed in 2007 and only one potential lamprey redd was identified, on February 2. During surveys in March and April lamprey harvesting was occurring in the lower river. No harvested lampreys were observed but harvesters were present during the redd surveys in mid March and April.

Experience gained by the survey crew during 2001 and 2002 surveys aided greatly in differentiating steelhead and lamprey redds. During the final survey in 2002 some lamprey redds were undoubtedly mis-classified as steelhead redds. At least one experienced survey crew member needs to be present for identification of species constructing the redds. Because the lamprey run was smaller in 2004 there was less chance that we mis-classified lamprey redds as steelhead redds that year.

Table 12. Summary statistics for measurements taken of redds that were observed with steelhead occupying them in 2003, 2004, and 2005.

	2003				2004				2005			
	Mean Value	Range	Standard Error	Measurements	Mean Value	Range	Standard Error	Measurements	Mean Value	Range	Standard Error	Measurements
Fish Size, m	0.58	0.36-0.80	0.01	61	0.65	0.45-0.80	0.01	64	0.66	0.45-0.80	0.01	47
Redd Area, m2	1.97	0.6-4.8	0.13	44	2.11	0.38-4.49	0.14	43	2.14	0.81-6.67	0.26	23
Water Depth, m	0.66	0.30-1.12	0.03	45	0.69	0.20-1.05	0.03	44	0.51	0.24-0.93	0.03	24
Velocity (focal), m/sec	0.80	0.15-1.75	0.05	45	0.76	0.14-1.31	0.05	32	0.49	0.14-1.14	0.06	22
Velocity (colm), m/sec									0.53	0.19-1.29	0.07	22
Pot Length, m	0.83	0.4-1.8	0.04	44	0.95	0.50-1.10	0.03	43	0.88	0.55-2.00	0.06	23
Pot Width, m	0.94	0.5-2.0	0.04	44	1.03	0.35-1.80	0.04	43	1.01	0.60-1.80	0.05	23
Pot Depth, m	0.13	0.03-0.35	0.01	43	0.09	0.04-0.20	0.01	43	0.12	0.01-0.20	0.01	23
Pot Substrate, m	0.08	0.02-0.15	0.00	44	0.06	0.02-0.12	0.00	43	0.06	0.04-0.12	0.00	23
Tail Spill Len, m	1.39	0.5-3.0	0.10	44	1.40	0.35-2.20	0.06	43	1.37	0.75-2.40	0.09	23
Tail Spill Wid, m	0.97	0.55-2.0	0.04	44	0.98	0.35-1.70	0.04	43	1.03	0.60-1.90	0.07	23
Tail Spill Wid2, m	0.79	0.3-1.4	0.03	44	0.81	0.20-1.40	0.04	43	0.90	0.50-2.80	0.10	23
Tail Spill Sub, m	0.05	0.01-0.13	0.00	43	0.04	0.01-0.07	0.00	43	0.04	0.03-0.07	0.00	23



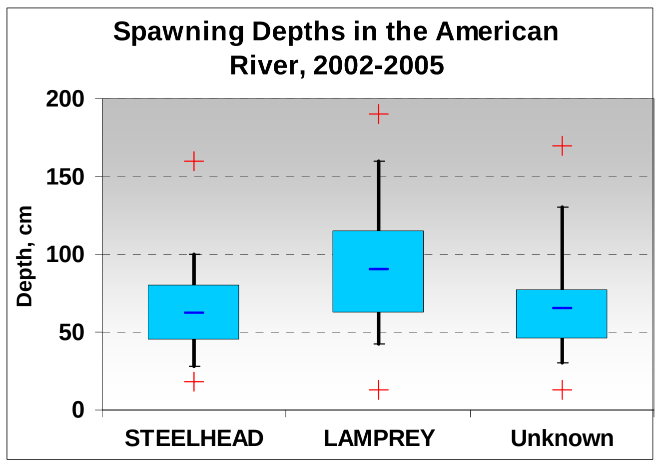


Figure 23. Redd area (left) and spawning depth (right for steelhead, lamprey, and unknown species redds in the American river in 2002 – 2005. The mid-point is the median value, the boxes encompass the 25th to 75th percentile values, error bars extend to the 5th and 95th percentile values and the crosses are the maximum and minimum values.

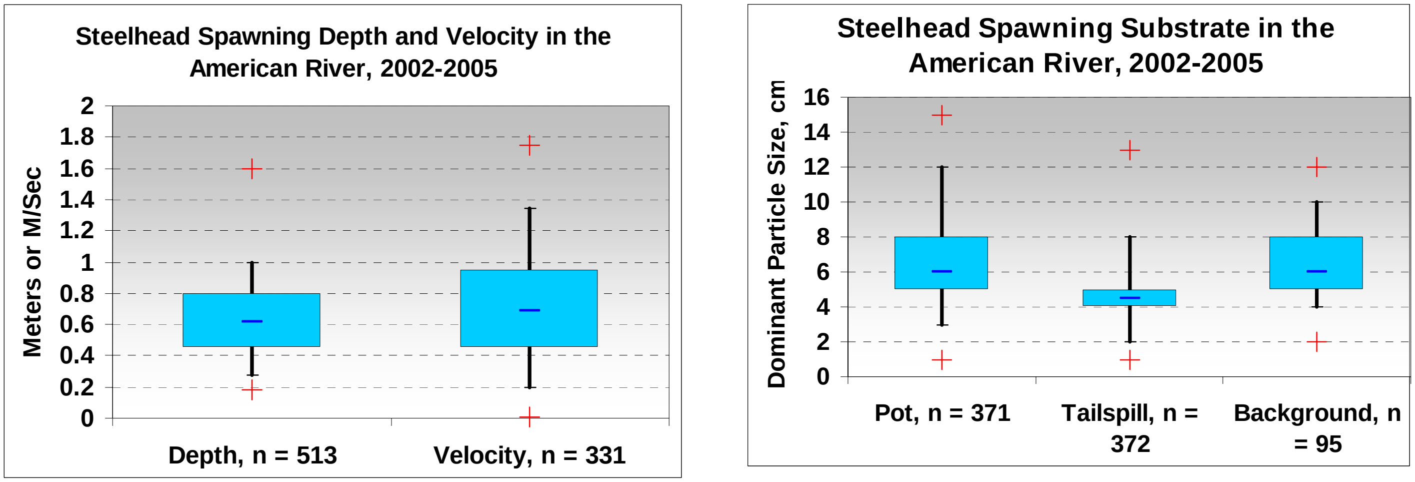


Figure 24. Steelhead spawning water depth and velocity (left) and dominant spawning substrates (right) in the American River.

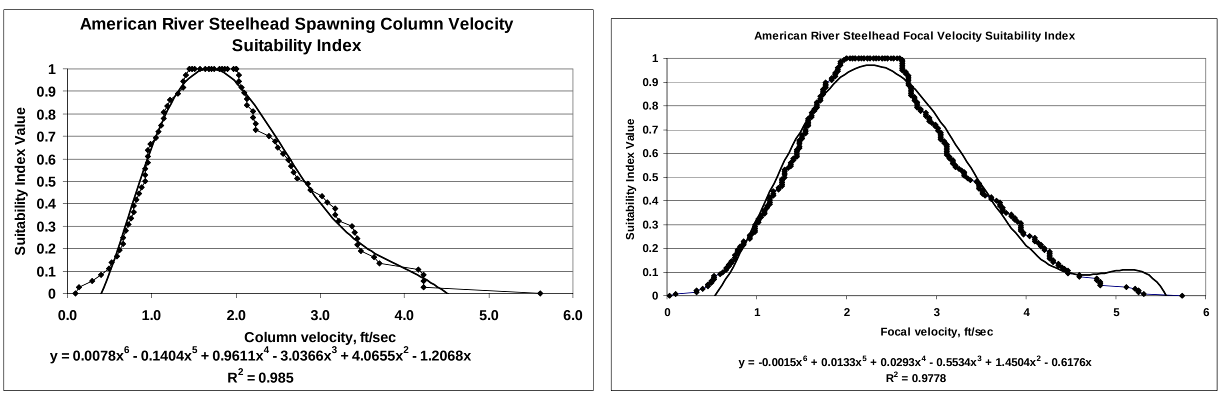


Figure 25. American River steelhead spawning column velocity and focal velocity suitability curves.

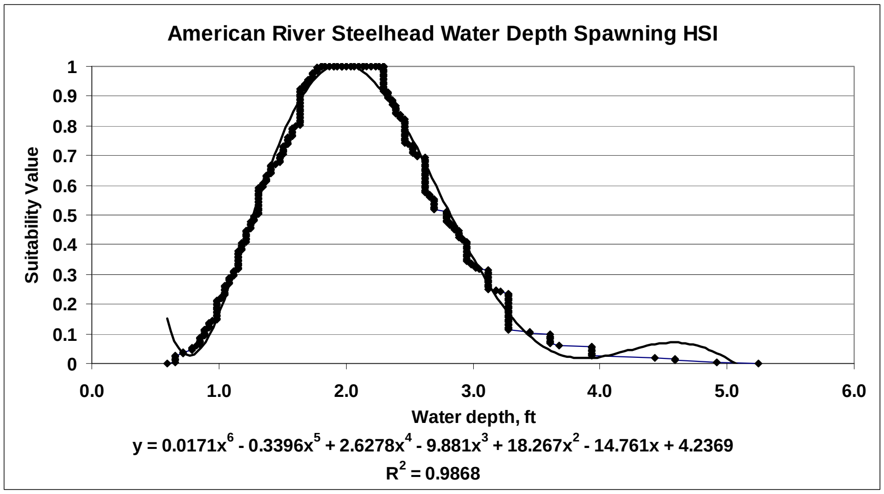


Figure 26. American River steelhead spawning depth suitability curve.

Table 15. 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

Conclusions

The following are conclusions reached from the 2001 – 2007 steelhead spawning surveys.

1. Redd surveys in conjunction with visual counts can be used to monitor trends in in-river spawning steelhead abundance in the American River at flows up to at least 7,000 cfs.
2. Approximately 50% of steelhead spawning is associated with multiple thread channel (side channel) reaches.
3. The peak spawning period in the river occurs later than in the hatchery.
4. Many steelhead redds in the American River remain identifiable for not much more than two weeks.
5. Spawning is concentrated in the upper river but occurs throughout the area with suitable spawning habitat (down to Paradise Beach).
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 emerge from the redd provided surface flow is available for emergence.

8. The average residence time for steelhead on redds in the American River is estimated to be three days based on return visits to redds when fish were observed on a redd and proportion of occupied redds.
9. The area under the curve population estimate based on steelhead occupying redds appears to produce reliable population estimates and can be used by surveyors with less training in redd identification than is required for identifying redds when no fish are present.
10. A majority of the steelhead enter the hatchery and more steelhead are spawned in the hatchery than in the river.

Recommendations for future surveys

The entire river can be surveyed in two work days with a 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.

The survey operation runs most smoothly with a three-person crew. 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, February through early March. If adequate staff or boat with motor are not available for a complete survey of the river, then the area from Sailor Bar to Ancil Hoffman Park or Rossmoor can be surveyed in a day by drift boat or canoe and used as an index reach. The GPS locations on GIS maps allow comparisons to be made between years in specific reaches of the river and on individual riffles.

More effort could be focused on determining presence/absence of the adipose fin of steelhead observed spawning. The underwater video camera could be used on return visits to active redds during non-survey days. 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.

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 and higher nutrient loads 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.

A final recommended protocol will be needed to maintain long-term survey consistency to allow tracking of in-river steelhead spawning abundance over time. We have not calculated confidence intervals for our population estimates. Some measure of precision needs to be devised.

Much interest has been expressed in Pacific lamprey populations recently so future surveys should document the extent of Pacific lamprey spawning including peak counts and timing of spawning.

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Elizabeth Vasquez and Bill Carlson assisted with redd surveys. Much of the work for this project was funded by a grant from the Bureau of Reclamation's Science and Technology Program in 2003 through 2005. Mike Healey made the 2002 and 2003 surveys possible. Rob Titus, Bill Snider, and Mike Brown provided guidance for initiating redd surveys and provided input on where spawning was likely to occur throughout the season. Tom Cannon and Trevor Kennedy provided information on steelhead observed during snorkeling and angling surveys. Bruce Oppenheim was instrumental in getting surveys initiated and assisted with surveys. Terry West and Bob Burke provided Nimbus Hatchery steelhead data. Lorri Peltz-Lewis and Barbara Simpson provided invaluable GPS and GIS support.

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The GIS shapefiles containing the data collected during redd surveys is available in UTM zone 10 NAD 83 and NAD 27 from John Hannon at the Bureau of Reclamation Mid-Pacific Regional Office, 2800 Cottage Way MP-150, Sacramento, CA 95825 and is stored on the GIS server at P:\mp150_jhannon\Geolib\.