Adult Steelhead and Late-fall Chinook Salmon Monitoring on Clear Creek, California: 2011 Annual Report.

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Abstract.— We have monitored adult Central valley steelhead (*Oncorhynchus mykiss)* and late fall Chinook salmon (*Oncorhynchus tshawytscha)* using kayak based surveys in Clear Creek since 2003. The purpose of our monitoring is to assess population trends of these species, thereby assessing the effectiveness of stream restoration actions. In 2011, the steelhead redd count was 218, and the late-fall Chinook salmon redd count was 21. Our surveys covered the entire spawning season and we were able to complete almost all scheduled surveys. Surveys began approximately two weeks earlier than survey previous years, and redds were observed redds on the first survey. However, some reaches and surveys were missed high flows from storms, we reduced our effort in the canyon reaches following a safety incident after Survey 5. Spawning gravel supplementation projects were successful in spawning habitat. In Reaches 1–5, 43% of steelhead redds contained injection gravel, and all of the Reach 1 gravel sites were used. In Reach 6, 10% of steelhead redds, and 5% of late-fall Chinook redds were in the Restoration Project. Of late fall Chinook salmon carcasses recovered, 47% were clipped (compared to an average of 26% since 2003). All were late fall from Coleman National Fish Hatchery.

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Introduction

California Central Valley steelhead (*Oncorhynchus mykiss*) were listed as threatened under the Federal Endangered Species Act in 1998 (NOAA 1998), and following a five-year review in 2011 by the National Marine Fisheries Service (NMFS), their threatened status remained (NOAA 2011). Central Valley late-fall run Chinook salmon (*Oncorhynchus tshawytscha*) (LFCS) were listed as a species of special concern in 2004 (NOAA 2004).

The Central Valley Project Improvement Act (CVPIA), Clear Creek Fish Restoration Program and the California Ecosystem Restoration Program (CALFED) have directed actions to recover steelhead and LFCS populations in Clear Creek, which have included increased flows, gravel supplementation, dam removal, and stream channel restoration (BOR and USFWS 2009). Since 1995, the U.S. Bureau of Reclamation (BOR) has maintained water releases from Whiskeytown Dam to improve salmonid holding, spawning, and rearing habitat. The Western Shasta Resource Conservation District (WSRCD) has implemented spawning gravel supplementation projects since 1996 to improve and increase spawning habitat. The removal of Saeltzer Dam in 2000 provided salmonid passage and access to 12 miles of additional habitat. The Lower Clear Creek Floodway Rehabilitation Project (Restoration Project) began in 1998 to repair and restore the natural form and function of a 2.0-mile section of creek severely degraded by aggregate and gold mining (GMA 2011a).

The Red Bluff Fish and Wildlife Office (RBFWO) has monitored adult steelhead and LFCS in Clear Creek using kayak surveys since 2003. The purpose of our monitoring is to assess population trends of steelhead and LFCS, thereby assessing the effectiveness of stream restoration actions and providing input for future restoration efforts on Clear Creek. We have found kayak surveys to be an effective method for obtaining redd and carcass counts during the spawning period, which occurs from December through April. This annual report summarizes monitoring efforts for the 2011 spawning season.

Study Area

Clear Creek is a west side tributary of the Sacramento River, located in Shasta County, California (Figure 1). The BOR controls water releases into Clear Creek at Whiskeytown Dam (river mile (RM) 18.3), which is also a complete barrier to fish passage. Releases are approximately 200 cubic feet per second (cfs) from October 1 to June 1 from Whiskeytown Dam to provide sufficient habitat and water temperatures for salmonid egg incubation and juvenile salmonid rearing. Throughout the summer months, flows are released to maintain adequate water temperatures for holding adult spring run Chinook salmon and juvenile salmonid rearing.

Our study area is 16.5 miles and extends from Whiskeytown Dam downstream to the RBFWO lower rotary screw trap (LCC RST) (RM 1.8) (Figure 2). This area covers the majority of steelhead and late fall Chinook spawning habitat in Clear Creek. The LCC RST is located at the end of the survey reach and is used to estimate fall, LFCS, and steelhead juvenile production. We divided the survey area into six reaches, based on distance and access points. The first two miles downstream of Whiskeytown Dam are alluvial (Reach 1). In Reaches 2, 3 and 4 (RM 16.1 (Need Camp Bridge) to RM 8.5 (Clear Creek Road Bridge)), steep canyon walls confine the creek and habitat consists of falls, high gradient riffles, and deep pools. Downstream of RM 8.5 (Reach 5 and 6), the creek is more alluvial. A steep cascade (called the Gorge Cascade) at RM

6.5, divides Reach 5 and Reach 6, and is a partial barrier to fall Chinook salmon (FCS) and LFCS (Newton and Brown 2004, Giovannetti and Brown 2010).

Methods

Survey techniques

Survey timing.—We scheduled kayak surveys every two weeks from approximately mid-December through early April. In Clear Creek, most redds are visible to surveyors for at least two weeks, unless there are high stream flows between surveys (Giovannetti and Brown 2007). Redd age tracking data has shown that redd visibility diminishes after high flows due to flattening, scouring, and accumulation of fines (Giovannetti and Brown 2007). To avoid missing redds due to the effects of high flows, we altered our schedule to survey before predicted storms. Similarly, if high flows (>1000 cfs) occurred less than four days before a scheduled survey, we postponed the survey at least several days to allow sufficient time for salmonids to construct new redds. When rain and high flows occur during surveys, water surface turbulence and turbidity increase, which reduce visibility, and make it difficult for surveyors to detect redds. Higher than normal flows can also diminish surveyors' ability to keep a slow enough pace to detect redds. We postponed surveys if flows were greater than 500 cfs, or visibility through the water was approximately three feet or less.

Kayak technique.—Each survey covered from two to six miles per day (one to three reaches), and the survey area was completed within two to four days. We used a three or four member crew, each with their own Highside® inflatable kayak. To obtain the best vantage point for viewing, kayaks distributed evenly across the width of the creek, and crews kneeled on the kayak pontoons or stood up in the kayak. To reduce glare and improve visibility through the water, crews wore polarized sunglasses and caps with visors. Experienced biologists trained new field crewmembers for one full day prior to conducting a field survey. At least two experienced field crewmembers (those who had completed at least one kayak survey season) were present on all surveys.

Data collection.—Crews counted redds, live adults, and salmonid carcasses. For each observation, crews took location points and associated data using a Trimble® GeoExplorer 2008 XH GPS (Trimble). We used Garmin® Etrex GPS units and paper datasheets as a backup if the Trimble was not available. At the end of each survey day, we transferred data files from the Trimble to the desktop computer. Location points from the Trimble were differentially corrected in Pathfinder Office® to obtain the most accurate locations.

At the beginning and end of each survey, crews collected water samples and measured turbidity using a Hach® Turbidimeter. Crews also collected water temperature data at the beginning and end of the survey using a submersible thermometer. Flow data was obtained from the U.S. Geological Survey (USGS) Clear Creek Igo gaging station (site 11372000 (IGO)) to determine the feasibility of a survey on a given day, and to summarize creek flows throughout the survey period (www.waterdata.usgs.gov).

Redds

Species identification.—Three species build redds in Clear Creek during our survey period, which include: (1) *O. mykiss* (which likely includes non-migratory (resident rainbow trout) and migratory (anadromous steelhead and potadromous rainbow trout from the Sacramento River)) (2) LFCS, and (3) Pacific lamprey. We did not distinguish between anadromous and non-anadromous *O. mykiss* redds because differences were not outwardly apparent, and they likely interbreed. However, different life history forms of *O. mykiss* may be temporally separated during spawning (residents spawn later in the spring). We refer to all *O. mykiss* redds as steelhead in this report.

Redd characteristics vary among species and we used either (1) observation of a fish on a redd, or (2) physical characteristics of the redd to identify species. We frequently observe LFCS on redds, and occasionally see steelhead and lamprey on redds. If we did not observe a fish on a redd, we used a combination of the following characteristics to differentiate between species: (a) redd size, (b) redd location, and (c) substrate type. We based redd characteristic criteria on measured redds of known species from our previous years' data. Steelhead redds are smaller and have smaller substrate than LFCS (21 ft^2 compared to 116 ft^2, and 1-2 inch gravel compared to 1-3 inch gravel). Steelhead redds are usually located closer to the shoreline, or in side-channel habitat, while LFCS are usually located mid-channel. Lamprey redds are circular and tailings are found on all sides of the pit.

Detection.—While searching for redds, kayakers looked for clean gravel patches and areas of mounded and sorted gravel, both which contrasted from the surrounding substrate. In areas of spawning habitat where swift water moved kayaks through too quickly or there was overhanging vegetation, crews parked the kayaks and snorkeled or waded the creek to look for redds. Redds needed to have a clearly defined pit and tail, and consensus among the crew to be counted. Crews used a snorkel and mask to examine redds underwater more thoroughly if necessary. We did not count incomplete redds (areas of clean substrate that fish may have disturbed without both a pit and tail) but marked them as test redds and checked them on the next survey.

We kept track of individual redds throughout the spawning season to prevent double counting redds on subsequent surveys. Each new redd was marked with flagging and assigned an identification number which included date, reach, channel location, and number. Flagging was tied to the nearest vegetation at the most upstream part of the redd. We used the Trimble to record location coordinates for each redd and all associated data. When examining new redds, we checked for flagging to see if the redd was counted on a prior survey. If no flagging was present and the redd was older, or if there was a high density of redds, the Trimble was used to navigate to individual redds that were recorded on previous surveys. At least one of the same crew from the previous survey was present to help better keep track of redd locations.

Measurements.—We took redd measurements to describe the physical characteristics of redds and the spawning habitat used. Approximately every fifth redd was measured per survey reach. When there were time constraints, redds were not measured. Water depth measurements were taken at the pre-redd depth (measured in the undisturbed substrate immediately upstream of redd), maximum pit depth, and minimum tail-spill depth. Mean column velocity was measured at the same location as the pre-redd depth and taken with a General Oceanics® model 2030 mechanical flow meter, which was run for a minimum of 100 seconds. Velocity was calculated by subtracting the start and end read of the meter, dividing by 100 and multiplying by 0.0875. Velocities were taken at 60 percent from the water surface if the water depth was < 2.5 ft. If it was greater than 2.5 ft., we took flow measurements at 20 percent and 80 percent from the water surface, and took the average between the two. We measured redd length parallel to the flow, and redd width perpendicular to the length, both at the widest part of the disturbed area. Redd area was calculated by using the formula for an ellipse (area = πX½ width X½ length). We classified redd substrate size using methods described in USFWS (2005).

Aging.—When redds were first observed, we recorded redd age (visibility of redds to surveyors). Age classification was as follows: Age 2: clearly visible and clean (no periphyton or fines), or Age 3: older and darker (periphyton growth, flattened tailspill, or fines) but defined pit and tail. During the first survey of the season, we only counted clean, Age 2 Chinook salmon redds because FCS redds are still visible if there were no high flow events to smooth and age redds. Excluding older redds on the first survey helped to eliminate FCS redds in the LFCS redd count, although there is likely overlap in spawn timing between the runs.

Redd index

Our yearly steelhead and LFCS redd indexes included redds counted during (1) kayak surveys, (2) snorkel-kayak comparison surveys, and (3) spring-run Chinook salmon snorkel surveys (which usually occur monthly in May and June, after the kayak surveys end). This year instead of a snorkel-kayak comparison survey, we conducted a survey to compare observer differences between surveyors using kayaks only, and new redds counted on this survey were included in the redd index. Redd location data was imported into Geographic Information System (GIS) to evaluate the temporal and spatial distribution of redds, calculate redds per mile, and determine habitat use of injection gravel and restoration areas.

Spawning habitat improvement projects

The two methods used to increase available spawning habitat on Clear Creek are (1) supplementation of spawning gravel, and (2) the reconstruction of degraded channels. Gravel supplementation projects have been implemented in all survey reaches except Reach 3, and channel reconstruction projects have only been implemented in Reach 6 (The Restoration Project) (Figure 2).

Projects.—Approximately 152,000 tons of supplemental spawning gravel (injection gravel) was added to Clear Creek from 1996 through the summer of 2010, to replenish the sediment transport blocked by Whiskeytown Dam (GMA 2011a). Sites are located from the bottom of Whiskeytown Dam pool downstream to RM 2.5 (Figure 2; Table 1). Injection gravel projects consist of placing 3/8–6 inch gravel into the creek using several different methods, which include talus cones, channel reconstruction, riffle construction, and lateral berms. Gravel from talus cones and lateral berms are dependent on high creek flows for transport downstream to become usable spawning habitat. Riffle and channel reconstruction may create habitat available for immediate use by spawning salmonids. Contractors replenish many injection sites on an annual basis, after gravel moves downstream from the site following high flows.

The Restoration Project is located in Reach 6 (Figure 2). Two phases of the project moved and lengthened portions of the degraded channel that contained very little spawning habitat, and filled the new channels with clean spawning gravel (GMA 2011a). Phase 3A was completed in fall 2002. This phase realigned 0.34 miles of the creek channel, and added 11,721 tons of spawning gravel (plus 1,401 tons at multiple lateral berm sites). Phase 3B was completed in the fall of 2007. This phase realigned 0.67 miles of the creek channel, and added 20,350 tons of spawning gravel. Spawning gravel was placed at various sites within the Restoration Project area since 2002 via lateral berms and constructed instream riffles, to recharge Phase 3A and Phase 3B new channels (Table 1).

In 2010, new gravel was added to several sites and approximately 8,290 tons were added in various reaches. In Reach 1, gravel was added to Dog Gulch (1,000 tons), Guardian Rock (1,000 tons), and in Reach 5, Clear Creek Road Bridge (1,450 tons). In Reach 6, injection gravel was added at the Pump Site (3,000 tons) as a lateral berm, and at a new site immediately downstream of 3A New Channel, Tule Backwater (1,200 tons) as a lateral berm, and the Grove (640 tons) (Figure 2).

Evaluation.—To evaluate the use of spawning habitat created by the spawning gravel supplementation projects, we (1) recorded the downstream extent of injection gravel at each site annually based on visual observations and using GPS(using a point at talus cones mapping the perimeter of instream gravel projects using a Trimble), and (2) identified when redds contained injection gravel. Redds described as containing injection gravel were usually mixed with native material.

Crews distinguished injection gravel from native gravel based on the physical characteristics of the gravel, and the proximity to placement sites. Injection gravel size composition has varied among years and sites but in general, it is more uniform in shape, size, and color (and much more abundant, especially near the placement site) than native material. Injection gravel from some of the older placements (prior to 2004) also contained chert (reddish color with white veins), which is not native to the watershed. Most native spawning-size gravel located in Reaches 1–4 is more angular in shape, and has a more granitic composition (based on the appearance of the gravel coming from the South Fork and Dog Gulch tributaries), and is sparsely distributed in the canyon.

The downstream distribution of injection gravel varies at each site, and is dependent on site type, and the number, duration, and magnitude of annual high flows. At all sites, injection gravel can mix with native gravel, while the degree of mixing is dependent upon the amount native material present, and the distance the injection gravel moved. Gravel injection can be more difficult to track over time as it mixes, spreads more thinly, and disperses downstream.

In Reaches 1, 2, and 4, injection gravel remains distinguishable from native material for longer periods because there is little native material present. In addition, Reaches 1 and 2 are subjected to fewer high flow events due to their proximity to Whiskeytown Dam. In Reaches 5 and 6, injection gravel is difficult for observers to distinguish over time because there is a greater amount of native spawning gravel, and the channel is more alluvial and dynamic. However, the lower extents of Reach 5 injection gravel could still be distinguished during this spawning season. Since injection gravel was placed at the top of Reach 6 beginning in 1996, it is indistinguishable from native gravel in this reach, except at newly placed instream riffles for the first spawning season or two.

At talus cone sites, we took a GPS location point at the downstream extent of the gravel each year, following the winter storm season. This was done at Whiskeytown, Guardian Rock, Placer, and Clear Creek Road Bridge. For created instream riffles, we used a Trimble to trace the boundaries injection gravel site when it was initially constructed, and yearly until it was no longer discernible from native gravel. We did not trace Half-moon, North moon, or the Grove (except for at the new 2010 gravel at the Grove in October 2010) as we did and reported in the 2009 and 2010 kayak reports because the gravel has dispersed and is difficult to identify (Giovannetti et al 2013). Tule backwater was not traced because it was a lateral berm and mostly out of the creek channel. In Reach 1, we traced the boundaries of 2009 spawning injection riffles in summer of 2010, and again in 2011 following the spawning season.

Live fish and carcasses

When steelhead, LFCS, or lamprey were observed actively spawning or guarding redds, we recorded the observation with the associated redd in the Trimble. In addition, we counted and took a location coordinate of all live adult LFCS observed. Crews counted and biologically sampled all salmonid carcasses. On natural origin LFCS and steelhead, otolith, genetic, and scale samples were taken, unless the portion of the carcass to be sampled was missing (ex. no head) too decomposed, or the carcass was unreachable. Crews recorded carcass location with a location waypoint and removed the caudal fin so not to recount it on a subsequent survey. Biological data was collected when possible, and included fork length, gender, spawning status, adipose fin status, and carcass condition. We collected heads from adipose fin clipped carcasses, and from carcasses when the presence of an adipose fin could not be determined due to decomposition or predation, for coded-wire tag (CWT) retrieval. Coded-wire tags were extracted from heads in the laboratory. If the electronic detector did not detect a CWT on unknown adipose fin clipped salmon, we reported it as a non-hatchery origin LFCS. If the tunnel detector did not detect coded wire tags in known adipose clipped salmon, we reported them as hatchery origin with no tag detected (NTD).

Kayak replication survey

In previous survey years, we conducted a concurrent snorkel and kayak comparison survey to look at differences in redd counts between methods (Giovannetti and Brown 2009). In 2011, per recommendation of the 2009 report, we completed a kayak replication survey to see if there were observer differences in redd counts between two different crews. We carried out the replication survey in Reaches 1, 2 and 5. The "lead" kayak survey crew surveyed first, and the "follow" crew started on the same day, but about an hour later so they did not see the lead crew. Each crew assigned redds an identification number, and marked them with a Trimble GPS location coordinate. Both crews recorded details about the redd locations. Test redds and other area of disturbance in the substrate (mammal digging, hydraulics) were also marked and noted. Data was imported into GIS to make comparisons concerning redd locations.

Results

We completed ten kayak surveys between December 7 and April 14 (Table 2 and Figure 3). Comparatively, from 2003–2010, we completed and average of five surveys during each spawning season (Table 3).

This year, we did not survey some reaches during each full creek survey due to weather conditions, and safety concerns. During Survey 1 and 2, we did not survey Reaches 2, 3 and 4 due storms that caused high flows and turbidities. For Surveys 3, 4, and 5, we conducted full-creek surveys every two weeks. After Survey 5, we discontinued surveys in the canyon reaches for the season. Following a crew safety situation with a foot entrapment, we decided to eliminate surveying these reaches, at least temporarily, while we re-evaluated our safety plans and swift water techniques. We also felt that the redd index would not be affected considerably if those reaches were not surveyed because they represented an average of 8% of the steelhead redd index from 2003–2010 (2% in each Reaches 2 and 3, and 6% in Reach 4). We did not completely eliminate surveys of Reach 2 and 4 however, and conducted snorkel surveys in the upstream sections, where the majority of redds in Reach 4 have been observed in previous years, and to the downstream extents of injection gravel from Guardian Rock and Placer Road. In Reach 2, snorkel surveys were conducted to from the top of the Reach to the bottom of Guardian Rock pool, and in Reach 4 from the pipeline to the bottom of S-long pool. Reaches 2 and 4 were not snorkeled during Survey 7, and Reach 6 was not surveyed during Survey 8 due to storm conditions.

Average survey turbidity values ranged from 1.2 to 4.1 NTU (nephelometric turbidity units), and average flows ranged from 233 to 454 cfs during surveys (Table 2). The peak hourly flow event for the spawning season was 3,320 cfs on March 26, and there were eleven separate flow events ranging from 374 to 2,490 cfs (hourly peak flows) that occurred from December 5 to March 26 (Figure 3).

Steelhead

The steelhead redd index was 218, compared to an 8-year average of 171 (Figure 4). Of the 218 redds, four were observed during the kayak comparison survey by the second crew, and no redds were observed during the spring Chinook snorkel surveys conducted in May and June (Table 4; Figure 4).

Crews measured 17 steelhead redds. Average surface area was 13.4 ft^2, average pre-redd water velocity was 2.2 feet/second, average pre-redd depth was 1.3 feet, and median dominant substrate size was 1–2 inches (Table 5). Steelhead redds were 94% and 5% Age 2 and Age 3, respectively. Steelhead were observed guarding or constructing 13 redds. Crews recovered and sampled three naturally produced steelhead carcasses (Table 6).

Late-fall Chinook salmon

The LFCS salmon redd count was 21, compared to an 8-year average of 33 (Table 7). All redds were located in Reach 6. Eighty-one percent of the redd count was by Survey 3 (early January), and there were no new redds after Survey 6 (late February) (Table 2 and Figure 3). We observed Chinook salmon building or guarding five redds, and all redds but one were Age 2. The LFCS carcass count was 18, compared to an 8-year average of 44 (Table 7). Median fork length was 710 mm (*n* =13; range 300–890 mm). Sex ratios were 39% female, 33% male, and 28% unknown *(n* =18). Carcasses with unknown lengths and genders were the result of predation or decomposition. Spawning status of one female was unknown due to decomposition. Genetic, scale, and otolith samples were taken from seven natural origin carcasses (Table 8). One otolith was taken from a hatchery origin carcass. All samples were stored at the RBFWO.

Of the known adipose fin status carcasses, 47% were clipped (compared to an average of 26% since 2003) (Table 9). Six percent of the total carcasses had an unknown clip status (Table 9). We retrieved ten heads in the field for CWT extraction (eight known, and two unknown clip status), and detected five CWTs (Table 10). Both unknowns did not have CWTs, and three heads were lost in the office, and never run for CWTs (therefore coded as LT). According to the Regional Mark Processing Center (RMPC) (www.rmpc.org) database, 100% of the CWTs were 3-year old (BY 2007) LFCS from CNFH (Table 10).

Redd distribution and spawning habitat improvement projects

The majority of steelhead redds were located in Reach 6 (64%), followed by Reach 1 (25%), Reach 5 (11%), and Reach 2 (1%) (Table 11; Figure 5). There were no redds in Reaches 3 or 4 this year, possibly a result of the reduced sampling effort in these reaches. The highest density of steelhead redds occurred in RM 5, which was 43% of the redd index (Figure 6). Forty-three percent of steelhead redds in Reaches 1–5 contained injection gravel, compared to an 8-year average of 40% (Table 11). Whiskeytown and Peltier gravel injection sites were the most used, 13% and 12%, respectively (Figure 7).

In Reach 1, 50% of the steelhead redd count was in injection gravel, compared to an average of 40% from 2003–2010. Redds were located in all of the new 2009 injection sites (Figure 8). Comparatively, of the Reach 1 redds that were located at the sites from 2003–2009 prior to gravel injection, an average of 3% were at Dog Gulch, 2% were at Peltier, 5% were at Paige Bar/Dino Pool, and 0% at Need.(Figure 8). Based on the August 2011 Trimble mapping, injection gravel at the Dog Gulch moved downstream an additional 500 feet since it was traced in summer of 2010 (Figure 9). However, the additional distance was mostly small patches identified downstream, and the majority of the site did not move much past the previous year's trace (Figure 9).We attempted to separate the old (2009) and new (2010) gravel while tracing, but it was somewhat integrated into the original injection gravel (see Figure 9). The distribution of the Paige Bar gravel also changed but did not move downstream much further than the 2010 boundaries. Peltier Valley and Need Camp only moved downstream slightly.

In Reach 6, 10% of the steelhead redds were located in the Restoration Project, compared to an average of 18% from 2004–2010 (there were no redds in Reach 6 in 2003). Of the steelhead redds in Reach 6, 3% were in 3A New Channel, compared to 6% from 2004–2009, and 2% was in 3B New Channel, compared to an average of 11% from 2008–2010 (post construction). No redds were in 3B New Channel area prior to construction (2003–2007).

All LFCS redds were located in Reach 6. Of the LFCS redd index, 5% was located in the Restoration Project, compared to an average of 15% from 2003–2010. No redds were located in the 3A New Channel, compared to an average of 3% from 2003–2010, and 5% were located in the 3B New Channel, compared to an average of 11% from 2008–2010 (post construction). Prior to 3B New Channel construction, an average of 1% of redds were located here.

Kayak replication survey.

We completed the snorkel-kayak comparison survey from January 31 through February 2 in Reaches 1, 2, and 5. Survey conditions were similar for each reach, average survey turbidity was 1.4 NTU, and flows were 233 cfs. A total of 24 new redds were observed by crews combined. The lead crew missed 17% of the redds, and the follow crew missed 26%. Crews observed 13 (54%) of the same redds (Table 12). Crews disagreed on 13% of the same areas observed.

Discussion

Based on recommendations from our 2010 monitoring report, we conducted the kayak survey two weeks earlier to detect the onset of steelhead spawning. On December 1, 2010, while performing a spawning mapping survey on Clear Creek, we identified two steelhead redds in Reach 6, which also triggered us to begin surveys as soon as possible. As suspected, we counted redds on the first survey, in Reach 6 and Reach 1. Storm events in December increased flows, and caused us to eliminate the canyon reaches during the first two full-creek survey, so it is unknown if there was earlier spawning in the canyon. Since we still had a relatively high redd count on the first survey, we recommend beginning surveys even earlier to determine when spawning begins.

We timed our surveys before and around storm events, but storms early and late in the season caused us to miss surveys and certain reaches. There were no redds in Reach 4 or in the Placer injection gravel this year. This may have partly been a result of missing surveys. The first two surveys in December, and the survey in late February were missed due to storm events. We also reduced our sampling efforts in Reach 4 following Survey 5, due to a safety incident with a crew member, which caused us to eliminate kayak surveys in the canyon (Reaches 2, 3, and 4) for the season, at least temporarily. As mentioned in the methods, we continued to conduct snorkel surveys in the upper sections of Reach 4 to see if spawning occurred in the injection gravel. It is also possible that there was no spawning in Reach 4 because of sand transport through the reach, which may have caused the decrease spawning habitat quality. In the 2010 report, we documented that sand had transported downstream through Reach 4, as a result of erosion in the South Fork caused by a fire in the summer of 2008 (Giovannetti et al 2013). During kayak surveys of Reach 4 this year, we observed sand further downstream following high flow events, and documented that it had moved almost to Clear Creek Road Bridge by April 2011. The movement of sand through the Placer injection gravel may have made it unsuitable during the 2011 spawning season. The Placer injection gravel moved further downstream this spawning season. In May 2011, we documented that Placer injection gravel moved an additional 800 feet downstream since September 2010.

In Reach 1, steelhead used all of the new injection sites. In the 2010 report, we noted a decline the in the pool tail immediately upstream of the Dog Gulch injection site (Pool Tail 3) that was likely caused by Dog Gulch injection gravel backing up the flow (Giovannetti et al 2013). This year, 9% of Reach 1 redds were in Pool Tail 3, compared to 3% in 2010, but still lower than the average from 2003 to 2009 (15%). Conditions likely changed again in Pool Tail 3 when new gravel was placed at Dog Gulch in the summer of 2010.

This year's steelhead redd count was the third highest since surveys began. As concluded in our previous monitoring reports, the population may be improving due to restoration projects that have improved spawning and rearing habitat. Although we missed some surveys due to storms, and surveys could have started earlier, we felt as though we were able to survey at the appropriate times, and the redd index is representative of steelhead spawning. Our kayak replication gave us further insight into the redd observation rates between crews, and we would like to continue to conduct these surveys to gain a better understanding of those differences. Based on our comparison and replication surveys, we may be underestimating the total redds, but our method provides a good index, and is comparable from year to year.

As recommended in our 2010 monitoring report, we would like to improve methods for assessing steelhead population on Clear Creek by addressing questions of residency verses anadromy by conducting otolith studies, and understanding migration rates of steelhead into Clear Creek by using a counting weir.

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Tables

Table 1. Gravel injection sites and locations in Clear Creek through 2011. Type refers to method that gravel was placed. TC = Talus Cone; IR = Instream riffle; LB = Lateral Berm; and NC = New channel. Table includes total tons supplied through 2010, and when gravel was first available for steelhead spawning. Distance available refers to the approximate length of creek channel the gravel moved downstream and does not account for usable spawning habitat, or total area.

Site	Type	Survey reach	River mile	Tons through 2010	Spawning season first available	Approximate distance available as of May 2011
Whiskeytown	TC	R1	18.3	24,257	1998	3,000 ft
Dog Gulch	IR	R1		2,003	2010	600-1000 ft[a]
Peltier Valley	IR	R1		769	2010	260 ft
Dino Pool/ Paige Bar	LB/IR	R1		1,786	2010	1,200 ft
Need Camp	IR	R1	16.2	981	2010	168 ft
Need Bridge	IR	R2	16.1	NA	2004	300 ft
Guardian Rock	LB	R2	16.0	5,830	2006	1,700 ft
Placer Road	TC	R4	10.4	27,799	2004	5,800 ft
Clear Creek Road Bridge	TC	R5	8.6	4,453	2004	2,000 ft
Reading Bar	IR	R5	8.2	1,000	2006	850 ft
Gorge	TC	R6	6.5	36,952	1996	dispersed
North Moon	LB/IR	R6	4.3	1,483	2009	500 ft
Pump	LB	R6	4.1	6,729	2006	300 ft[b]
Phase 3A	NC	R6	3.9	13,125	2003	1,400 ft
Tule Backwater	LB	R6		1,200	2011	500 ft
Grove	IR /LB	R6	3.6	3,645	2009	750 ft
Phase 3B	NC	R6	3.0	20,350	2008	3,000 ft

[a] Major slug is 600 ft, and small patches distributed downstream.
[b] Beyond this distance is in Phase 3A.

Table 2. Late-fall Chinook salmon and steelhead redd, carcass, live counts, and environmental conditions per survey week, collected during kayak surveys in Clear Creek, 2011. Survey season total counts, and average environmental conditions are also shown.

	Chinook			Steelhead		Environmental conditions		
Survey week (average date)	Redds	Carcass	Live	Redds	Carcass	Average turbidity (NTU)	Average flow (cfs)	Average water temperature (ºF)
1 (12/07/10)	6	6	15	15	1	2.1	314	50
2 (12/18/10)	9	5	18	47	0	1.6	295	47
3 (01/05/11)	2	1	7	18	0	2.1	294	44
4 (01/19/11)	1	2	16	24	0	1.2	259	46
5 (02/01/11)	2	1	6	83[a]	0	1.4	233	45
6 (02/18/11)	1	2	0	11	1	1.9	370	46
7 (02/28/11)	0	1	1	13	1	2.02	274	45
8 (03/17/2011)	0	0	0	3	0	1.5	451	48
9 (03/31/11)	0	0	0	0	0	4.1	454	51
10 (04/13/11)	0	0	0	1	0	3.1	302	50
Total	21	18	63	214	3			

[a] This was the replication survey and four additional redds were counted by follow crew, which are not included here but part of the final redd index.

Table 3. Number of kayak surveys conducted annually on Clear Creek from 2003–2011. 'Surveys' refers to the number of full creek surveys (all reaches) conducted annually. Annual survey environmental conditions are included.

		Flow (cfs)		Turbidity (NTU)		Water temperature
Year	Surveys	Mean	Range	Mean	Range	(ºF) range
2003	4 [a]	257	227–485	2.0	1.0–3.9	44–56
2004	6 [b]	289	247–354	1.5	0.8–2.6	42–52
2005	6 [c]	290	223–466	1.3	0.6–2.6	43–52
2006	4	329	255–493	2.7	1.3–4.8	42–48
2007	6	240	212–310	1.0	0.6–2.3	42–54
2008	7 [d]	249	214–383	1.5	0.9–3.5	41–48
2009	5	233	211–269	1.5	1.0–2.3	42–52
2010	5 [e]	316	230–428	2.8	1.7–4.6	43–49
2011	10 [f]	324	233–454	2.1	1.2–4.1	42–54

[a] In addition to the number of full creek surveys, we performed two surveys each of Reaches 1, 5, and 6.
[b] In addition to the number of full creek surveys, we performed three surveys of Reach 5, and two of Reach 6.
[c] In addition to the number of full creek surveys, we performed one survey of Reach 6.
[d] In addition to the number of full creek surveys, we performed one survey of Reach 1, and one of Reach 5.
[e] In addition to the number of full creek surveys, we performed two surveys of Reach 6. Reach 2 and 3 were not surveyed on Survey 3 but it was considered a full creek survey.
[f] Reaches 2 and 4 were not surveyed on three surveys, Reach 3 was not surveyed on seven surveys, and Reach 6 was not surveyed on one survey. In addition, on the last four surveys, partial sections of Reaches 2 and 4 were surveyed and done by snorkeling instead of kayaking.

Table 4. Annual steelhead redd index and carcass count on Clear Creek, 2003–2011. Redd index includes redds counted during kayak surveys (approximately every two weeks from December–April), snorkel comparison surveys or kayak replication survey (single survey in January or February in select reaches and years), and spring Chinook salmon snorkel surveys (approximately monthly in April, May and June). NS= no survey.

Year	2003	2004	2005	2006	2007	2008	2009	2010	2011
Kayak survey	75	74	122	41	163	133	399	224	214
Comparison survey	NS	53	19	NS	NS	13[a]	10[b]	7[c]	NS
SCS snorkel survey	3	24	3	1	2	2	NS	2	0
Replication survey									4[d]
Redd index	78	151	144	42	165	148	409	233	218
Carcasses	2	0	4	1	7	4	5	3	3

[a] Comparison survey was only Reaches 2 and 3.
[b] Comparison survey was only Reaches 5 and 6.
[c] Comparison survey was only Reaches 1 and 2.
[d] Replication survey was only Reaches 1, 2, and 5.

Table 5. Steelhead redd characteristic data collected in Clear Creek, 2003–2011. Values represent the mean (standard deviation), except for substrate, which is the median.

Year	*n* =	Length (ft)	Width (ft)	Area (ft^2)	Pre-redd depth (ft)	Pit depth (ft)	Tail-spill depth (ft)	Velocity (ft/sec)	Substrate (in)
2011	17	5.6 (2.0)	2.9 (1.1)	13.4 (9.2)	1.3 (0.6)	1.6 (0.5)	1.1 (0.6)	2.2 (0.8)	1–2
2003–2010	377	6.6 (3.0)	3.6 (1.5)	21.2 (18.0)	1.7 (0.7)	1.9 (0.6)	1.4 (0.7)	2.0 (0.7)	1–3

Table 6. *Oncorynchus mykiss* carcasses recovered on Clear Creek during the 2011 kayak survey season. Table includes biological sampling data collected from each carcass. NA=Not available.

Collection Date	Reach	Adipose status	Fork Length (mm)	Tissue sample	Scale sample	Otolith sample	Gender	Spawn status
	R1	Present	300	Yes	Yes	No	Male	Unknown
	R6	Present	392	Yes	Yes	Yes	Male	Unknown
	R1	Present	462	Yes	Yes	Yes	Unknown	Unknown

Table 7. Annual late-fall Chinook salmon redd, live adult, and carcass counts collected during kayak surveys in Clear Creek, 2003–2011. 'Surveys' refers to number of surveys of Reach 5 and Reach 6.

Survey year	Surveys	Survey period	Redd	Live adult	Carcass
2003[a]	9	12/09/02 – 04/11/03	24	110	42
2004	9	12/11/03 – 04/07/04	20	48	60
2005	10	12/16/04 – 04/01/05	28	94	34
2006	4	01/12/06 – 03/31/06	14	42	7
2007	6	01/11/07 – 04/20/07	25	39	13
2008	7	01/02/08 – 04/03/08	17	50	55
2009	5	01/06/09 – 04/01/09	122	94	97
2010	7	12/17/09 – 03/18/10	33	54	45
2011	9	12/07/10 – 4/15/2011	21	63	18

[a] Redds were not counted during first survey.

Table 8. Number of tissue, otolith, and scale samples collected from late-fall Chinook salmon carcasses during 2011 Clear Creek kayak.

	Adipose Clip	Natural	Total
Tissue	0	5	5
Otolith	1	5	6
Scale[a]	0	5	5

Table 9. Chinook salmon carcass and coded-wire tag (CWT) recovery data from Clear Creek kayak surveys, 2003–2011. Carcass count is the number of carcasses retrieved, and in parenthesis is the percent with unknown clip status. Percent adipose clip refers to known adipose fin clip status only (absent or present),and includes all carcasses that were noted as clipped in the field (even if the head was not available for coded wire extraction) and heads of unknown status clips that were verified in the laboratory as having a coded wire tag. Coded wire tag hatchery information was retrieved from the Regional Mark Information System (www.rmpc.org). NA= not applicable.

Year	Carcass count	Adipose clip	CWT retrieved	Age 3	Age 4	CNFH LFCS	FR FCS	CNFH FCS	Recovery from juvenile offsite releases
2003	42 (5%)	10%	4	1	3	75%	25%	0%	50%
2004	60 (3%)	5%	3	1	2	100%	0%	0%	67%
2005	34 (9%)	3%	1	1	0	100%	0%	0%	100%
2006	7 (14%)	0%	NA	NA	NA	NA	NA	NA	NA
2007	13 (0%)	4%	1	0	1	100%	0%	0%	0%
2008	55 (16%)	26%	9	9	0	100%	0%	0%	22%
2009	97 (11%)	72%	55	49	6	98%	2%	0%	45%
2010	45 (9%)	59%	21	15	6	95%	0%	5%	14%
2011	18(6%)	47%	8[a]	5		100%	0%	0%	0%

[a] Three CWT detected in heads were discarded before tags were processed.

Table 10. Summary of coded wire tag (CWT) data from Chinook salmon carcasses collected on Clear Creek during kayak surveys, 2011. Crews collected heads from carcasses with absent and unknown adipose clip status for CWT detection. If a CWT was not found during head dissection, the carcass was assigned NTD (No tag detected). If a CWT was extracted but lost before reading, the carcass was assigned LT (lost tag). Hatchery information was retrieved from the Regional Mark Information System (www.rmpc.org). If a CWT was not retrieved, hatchery information was assigned NA (not available).

Creek	Date	Clip status	Gender	Fork length (mm)	CWT code	Hatchery	Run	Brood year	Release site
Clear	12/7/2010	Absent	Female	890	LT				
Clear	12/16/2010	Absent	Male	530	LT				
Clear	12/16/2010	Unknown	Unknown	NA	NTD				
Clear	12/16/2010	Unknown	Unknown	NA	NTD				
Clear	12/16/2010	Absent	Female	710	LT				
Clear	1/5/2011	Absent	Female	Unknown	052491	CNFH	Late-fall	2008	CNFH
Clear	1/21/2011	Absent	Male	735	052491	CNFH	Late-fall	2008	CNFH
Clear	1/21/2011	Absent	Female	760	054292	CNFH	Late-fall	2008	CNFH
Clear	2/17/2011	Absent	Female	745	054287	CNFH	Late-fall	2008	CNFH
Clear	2/23/2011	Absent	Male	750	053991	CNFH	Late-fall	2008	CNFH

Table 11. Steelhead redds per reach in Clear Creek, 2003–2011. The percent of redds in injection gravel is in parenthesis. Injection gravel was not available in years or Reaches without a percent. Except for new gravel sites, it is not possible to distinguish injection gravel from native gravel in Reach 6 due to mixing, and injection gravel status is not shown. Reaches 1–5 are associated with gravel injection sites shown in Table 1.

Year	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Total Reach 1–5	Reach 6
2003	71 (45%)	2	1	2 (0%)	2	78 (41%)	0
2004	53 (23%)	4(0%)	9	18 (33%)	4 (0%)	88 (20%)	63
2005	78 (24%)	1 (0%)	7	15 (53%)	4 (25%)	105 (27%)	39
2006	23 (61%)	1 (0%)	0	2 (100%)	1 (0%)	27 (59%)	15
2007	63 (35%)	9 (0%)	6	18 (89%)	8 (38%)	104 (39%)	61
2008	60 (35%)	3 (0%)	1	5 (40%)	10 (30%)	79 (33%)	69
2009	69 (48%)	5 (40%)	7	18 (78%)	25 (32%)	124 (46%)	285
2010	32 (50%)	3 (33%)	1	8 (100%)	10 (30%)	52 (52%)	179
2011	54 (50%)	2 (100%)	0[a]	0	21 (14%)	77 (43%)	141

[a]After Survey 5, Reach 3 was not surveyed, and only partial sections of Reach 2 and Reach 4 were snorkeled.

Table 12. Results from kayak replication survey conducted on Clear Creek in 2011. Total redds refers to new redds observed by both crews. The number of redds each crew observed, missed, or disagreed on are shown.

	Reach 1	Reach 2	Reach 5	Total
Total redds	**17**	**2**	**5**	**24**
Observed by both	13	1	1	15
Disagreed on	*2*	*0*	*0*	*2*
Agreed on	*11*	*1*	*1*	*13*
Lead missed	2	1	1	4
Follow missed	4	0	3	7
Lead counted	15	1	5	21
Follow counted	11	0	2	15

Figures

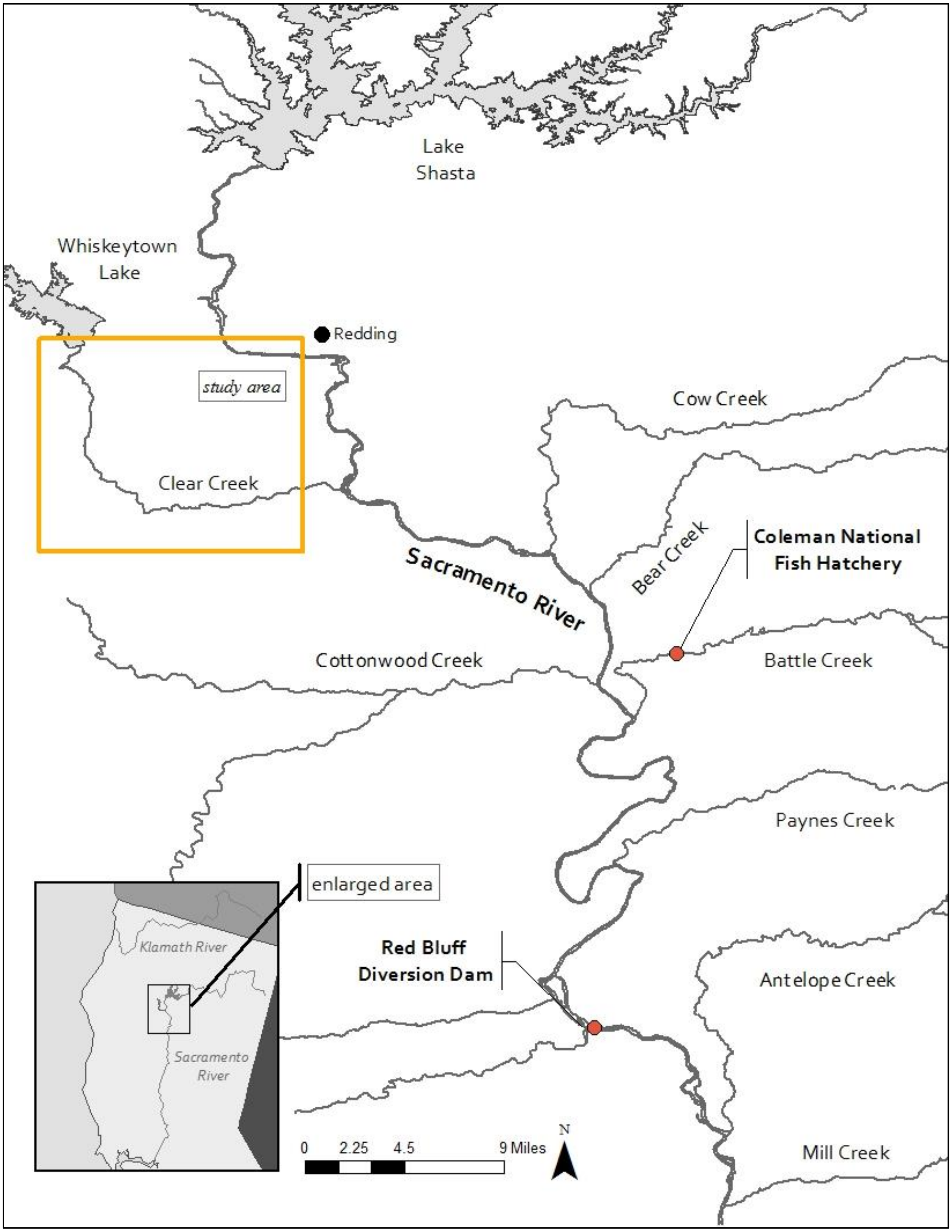

Figure 1. Map showing location of Clear Creek along the Sacramento River, Shasta County, California.

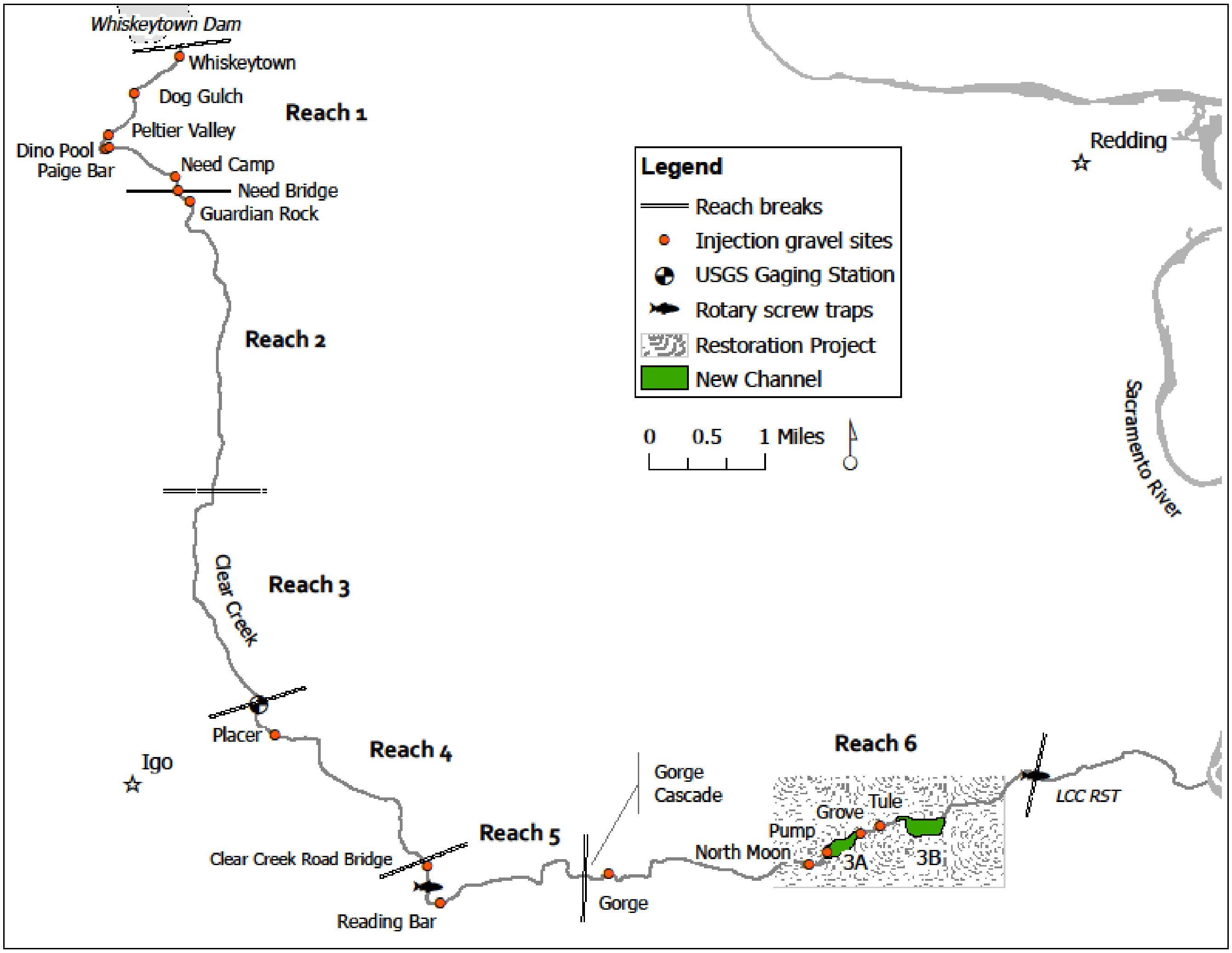

Figure 2. Map of Clear Creek kayak survey study area, Shasta County, California, 2011. Map includes locations of survey reach boundaries, gravel injection sites, channel restoration areas, the USGS flow and water temperature gaging site, and juvenile outmigration traps.

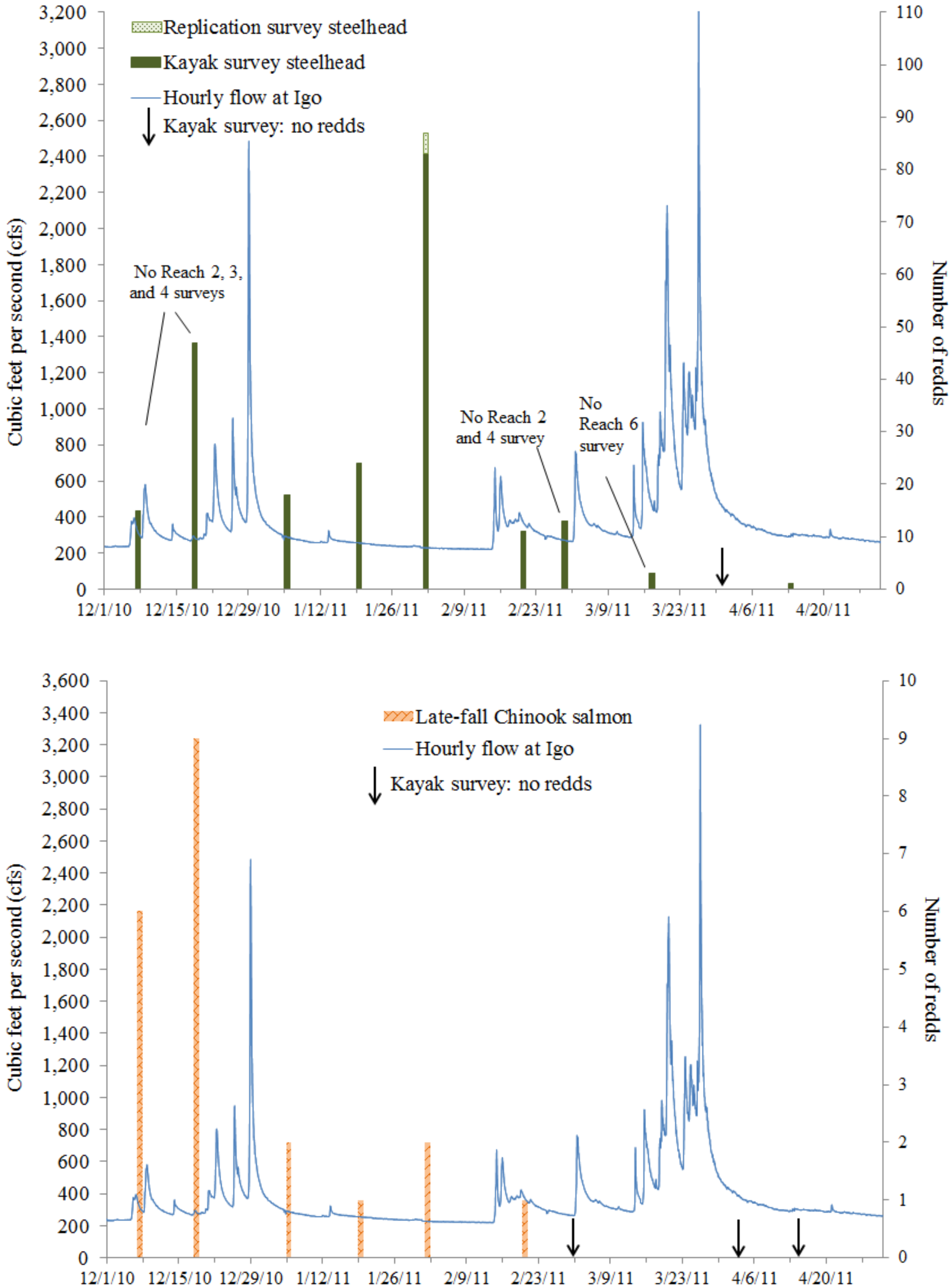

Figure 3. Steelhead and late-fall Chinook salmon redds observed during kayak surveys on Clear Creek during the 2011 spawning season. Bars represent new redds counted each survey. The timing and duration of flow events during the survey period are displayed. Reach 3 was not surveyed after Survey 5.

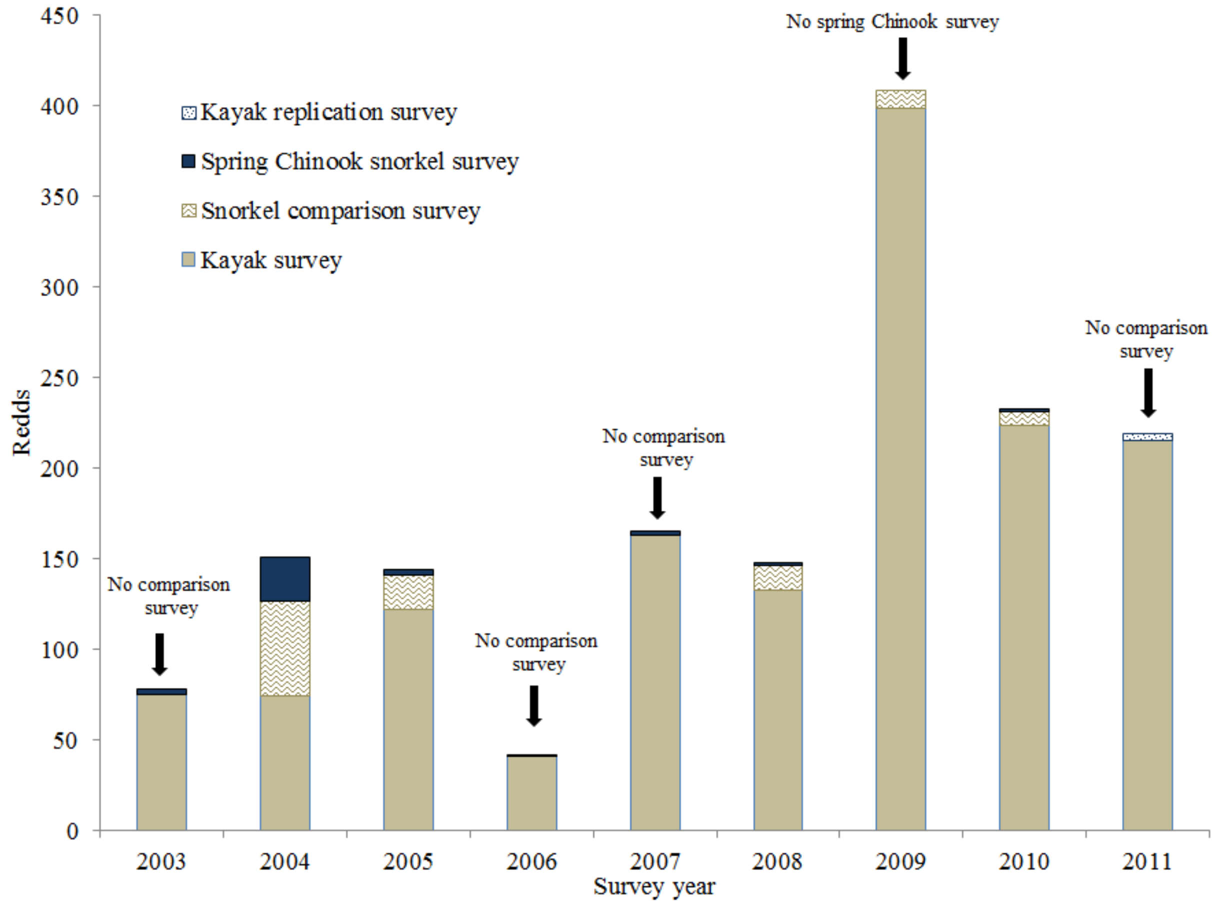

Figure 4. Clear Creek steelhead redd index, 2003–2011. Redd index includes redds counted during (1) kayak surveys (approximately two surveys per month from December through April), (2) snorkel comparison surveys or kayak replication surveys (single survey in January or February in select reaches and years), and (3) spring Chinook salmon snorkel surveys (monthly surveys generally April–June).

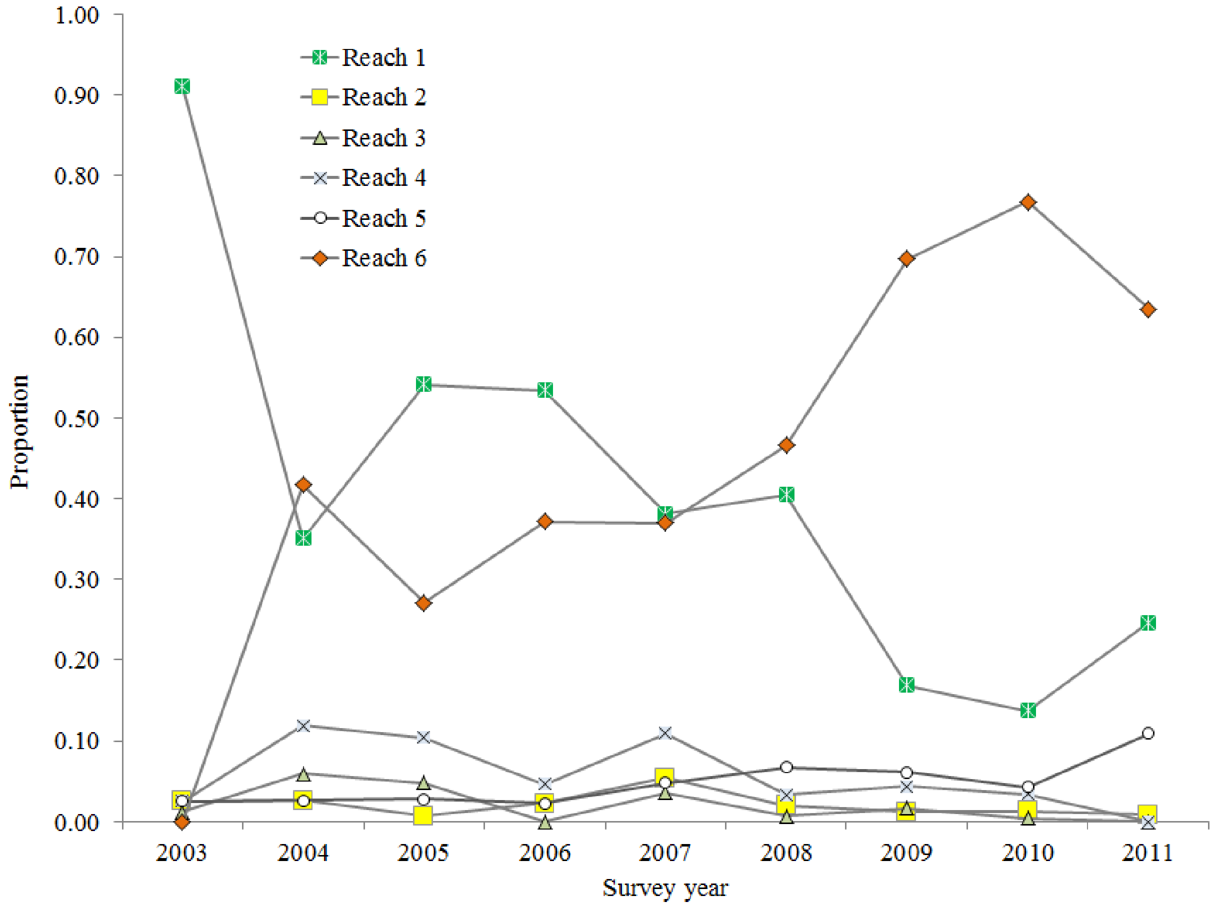

Figure 5 Proportion of steelhead redds per reach in Clear Creek, from 2003–2011.

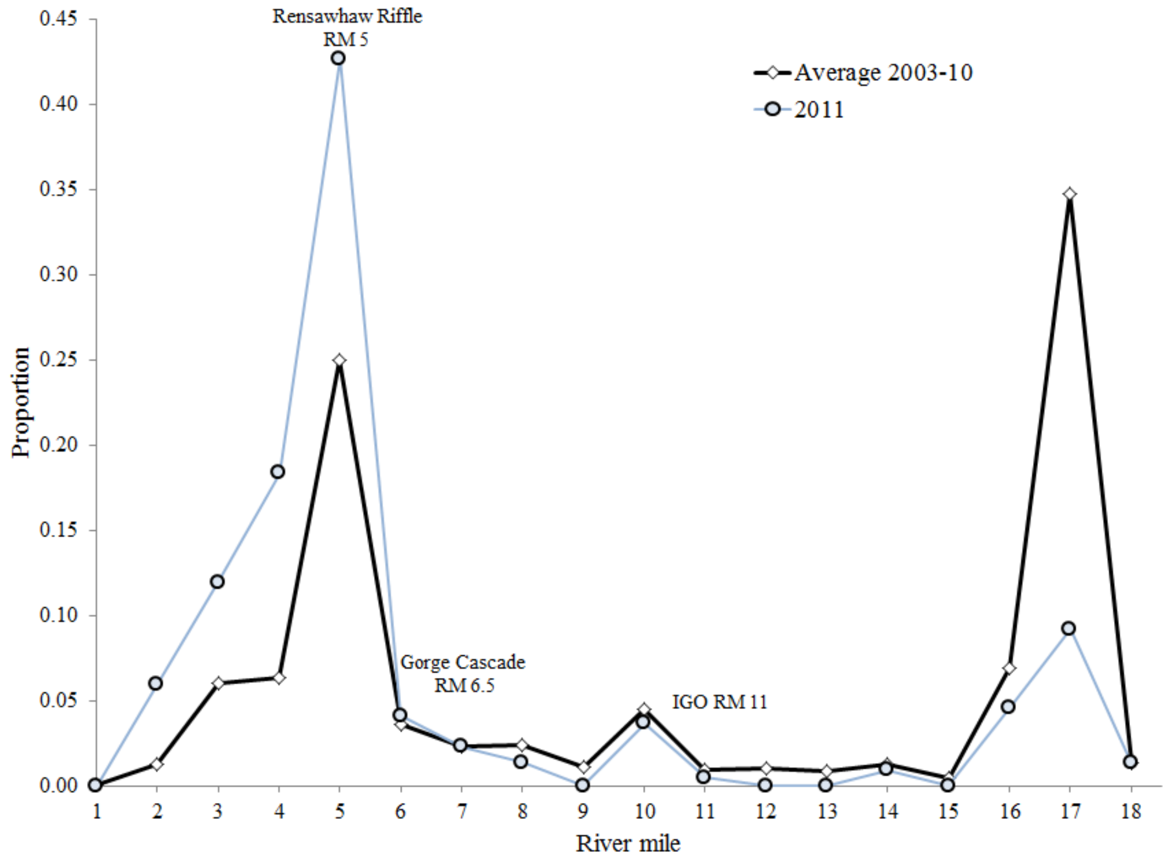

Figure 6. Proportion of steelhead redds per river mile in Clear Creek, 2011, compared to the average proportion from 2003–2010.

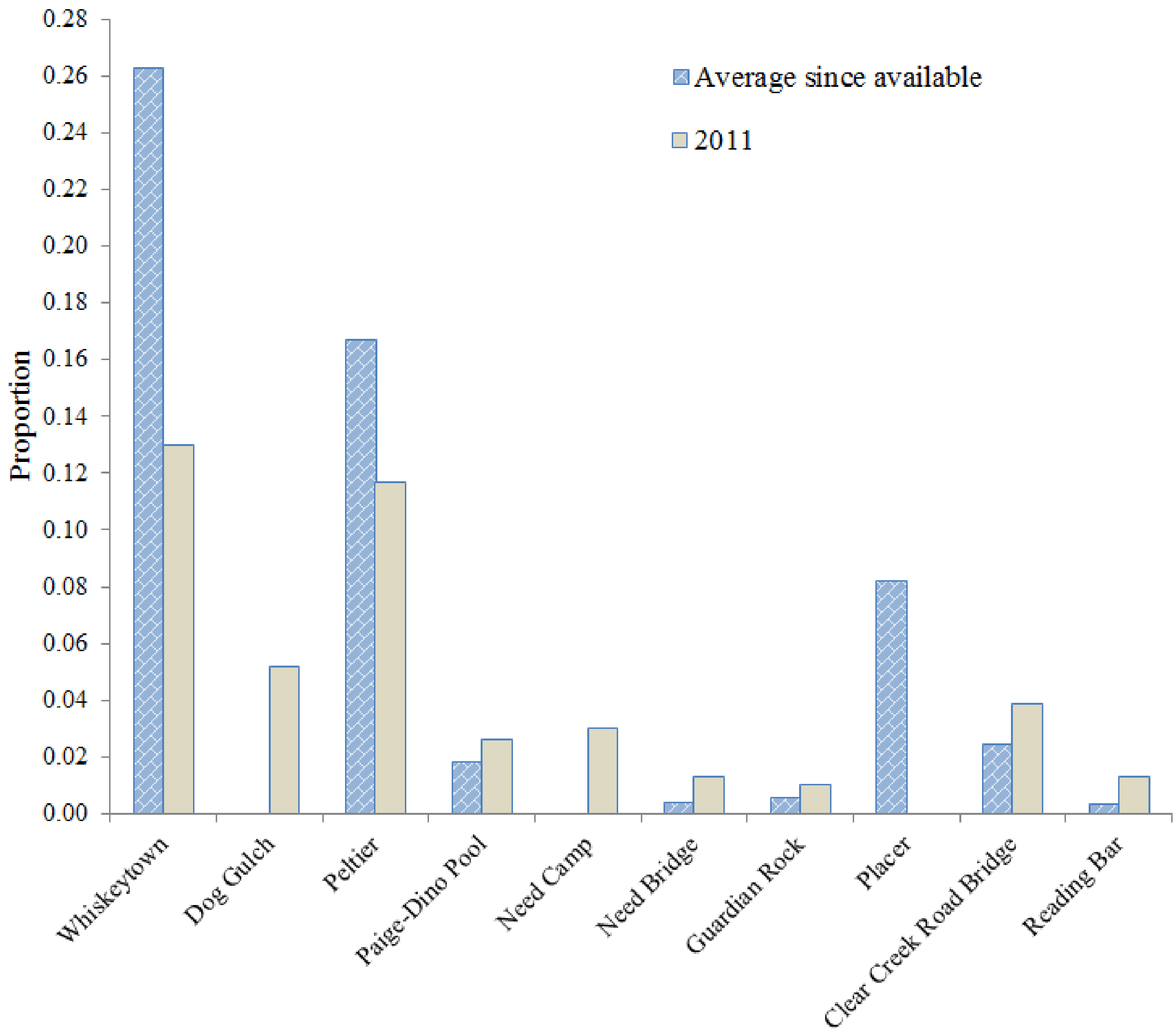

Figure 7. Proportion of steelhead redds in injection gravel for each site in Reaches 1–5 in 2011, compared to the average since each site was first available for steelhead spawning. See Table 1 for spawning dates available.

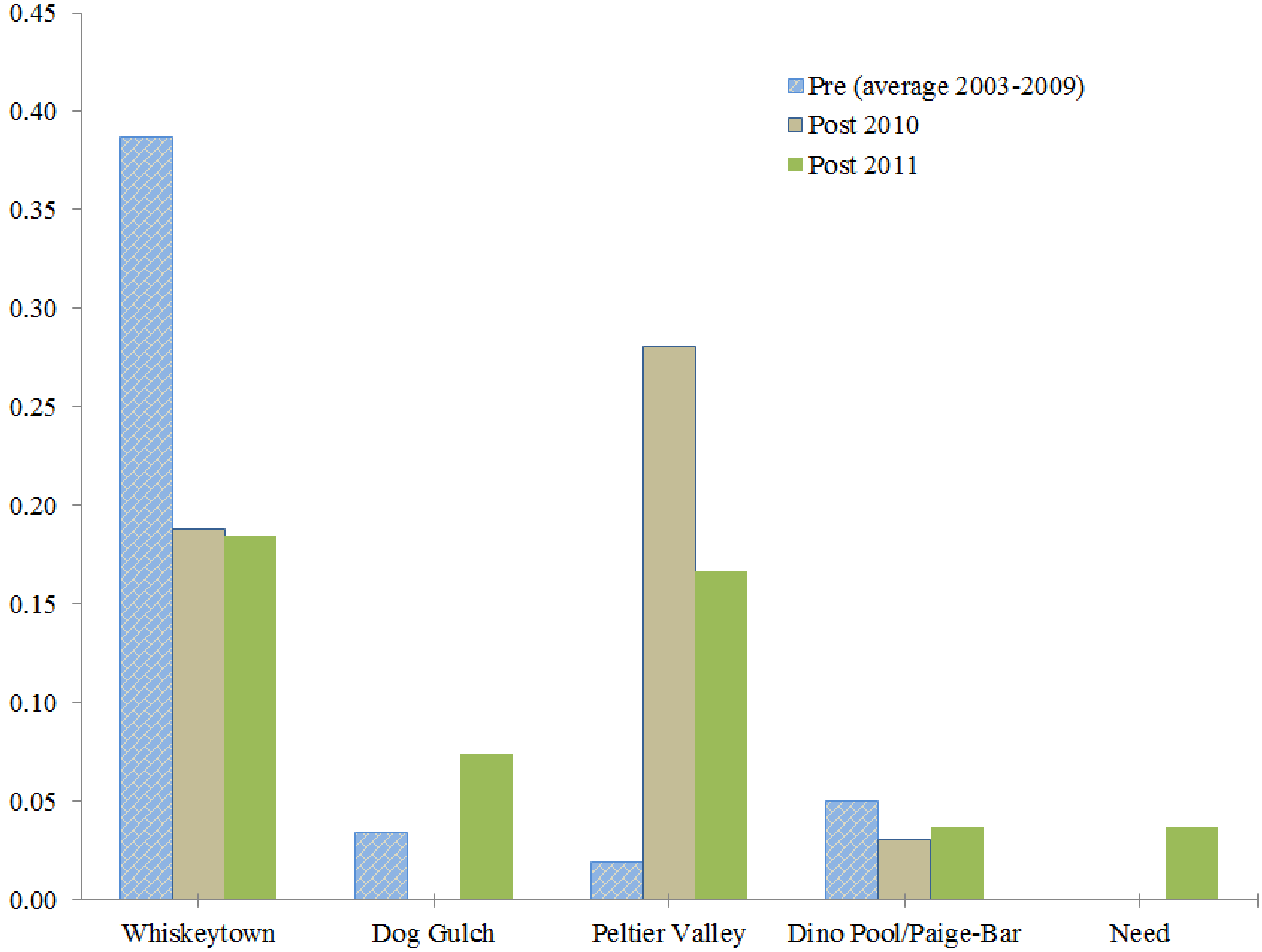

Figure 8. Proportion of Reach 1 steelhead redds at gravel injection sites in 2010 and 2011, compared to the average from 2003–2009. Redd proportion data at the 2009 sites (Dog Gulch, Peltier Valley, Dino Pool, Paige-Bar, and Need) prior to 2010 (Pre) refers to redds before injection gravel was available. Whiskeytown injection gravel was available since 2003.

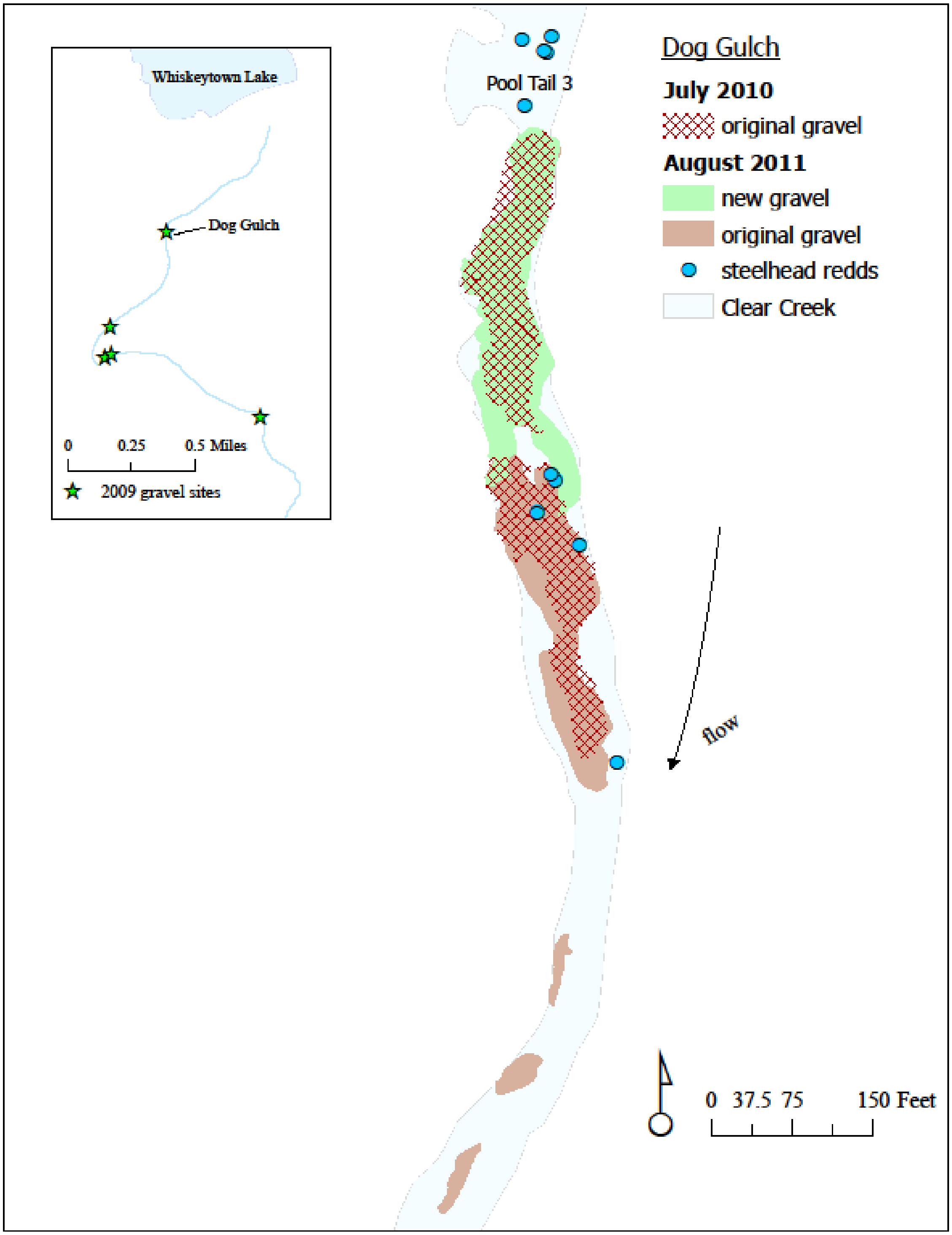

Figure 9. Map showing the Dog Gulch injection gravel site in Reach 1. The hatched orange shows the gravel distribution of injection gravel in the summer of 2010. In August 2011, the site was retraced. The solid green shows the perimeter of the newly injected gravel, and the solid brown shows the distribution of the original gravel. The blue circles show steelhead redds from 2011 kayak surveys.