Steelhead and Late-fall Chinook Salmon Redd Surveys on Clear Creek, California 2008 Annual Report.

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*Abstract.***—**We conducted spawning redd surveys on Clear Creek to track population trends of Central valley steelhead (*Oncorhynchus mykiss)* and late-fall Chinook salmon (*Oncorhynchus tshawytscha)* and to evaluate the effectiveness of restoration efforts including dam removal, increased flows, stream channel restoration, and spawning gravel supplementation. Environmental conditions during surveys were excellent due to low turbidities and stream flows. The 2008 steelhead redd index was 148, which was 28% higher than the previous 5 year average. Steelhead redds were generally concentrated in areas downstream of gravel injection sites or in Renshaw Riffle in Reach 6. In Reach 6, 22% of the steelhead redds were observed in the Phase 3A and 3B new channels of the Restoration Project. In the upper five reaches, 30% of steelhead redds were located in injection gravel. The late-fall Chinook salmon redd index was 17, compared to a 5-year average of 22. We counted 55 late-fall Chinook salmon carcasses, compared to a 5-year average of 31. Twenty-four percent of the carcasses recovered were adipose fin clipped. We recovered coded wire tags from 16% of the carcasses recovered. All coded wire tagged carcasses were late-fall Chinook from Coleman National Fish Hatchery.

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Introduction

The Red Bluff Fish and Wildlife Office (RBFWO) conducted redd surveys to monitor Central Valley steelhead (*Oncorhynchus mykiss*) and late-fall Chinook salmon (*Oncorhynchus tshawytscha*) populations in Clear Creek, California (Figure 1). We used redd counts to develop an index for both species to monitor population trends, determine spawn timing, spatial distribution, and to evaluate the effects of stream restoration actions on these species. In addition, we collected biological data on all steelhead and late-fall Chinook salmon carcasses. This annual monitoring report summarizes the information collected from the 2008 surveys.

Central Valley steelhead were listed as threatened under the Federal Endangered Species Act (ESA) in 1998. They are considered winter steelhead because they mature in the ocean and typically enter freshwater in the fall, winter or spring and spawn soon thereafter (McEwen 2001). Based on counts at the Red Bluff Diversion Dam (RBDD) prior to 1988, adult migration into the upper Sacramento River occurs from July through May, peaks in late September, with spawning occurring from December through May (Hallock 1989). Resident and potadromous life history forms of rainbow trout coexist in the upper Sacramento River watershed and non-hatchery rainbow trout in anadromous fish bearing watersheds are considered part of the same evolutionary significant unit (ESU) as Central Valley steelhead (Moyle 2002). Little data exists concerning the current population of wild Central Valley steelhead in the upper Sacramento River watershed because their life history strategy makes in-river population assessments difficult. Spawning occurs in the winter and spring, which often corresponds with difficult surveying conditions due to high flows, elevated turbidities, short daylight hours, and cold temperatures.

Late-fall Chinook salmon share similar spawn timing as steelhead and migrate into the upper Sacramento beginning in December and spawn through April (Vogel and Marine 1991). However, for reasons similar to steelhead assessments, surveys of naturally spawning late-fall Chinook on the tributaries are difficult. We previously determined that a mark recapture based population estimate was not feasible in Clear Creek because carcass recoveries were few and too variable and high flows moved too many carcasses out of the system.

Over the past century, several human actions have degraded anadromous fish habitat in Clear Creek. In 1903, Saeltzer Dam was constructed at river mile 6.5, which blocked upstream adult fish passage. Whiskeytown Dam (river mile 18.1), constructed in 1963, completely eliminated fish passage and altered downstream habitat quality by changing flows, temperatures, and sediment transport processes necessary to maintain spawning habitat. Gravel and gold mining further degraded salmonid habitat in Clear Creek throughout the 19th century.

Although habitat has been degraded, efforts have been underway to restore and manage Clear Creek to support populations of spring, fall, and late-fall Chinook salmon as well as steelhead, (DeStaso and Brown 2008). The Central Valley Project Improvement Act (CVPIA) Clear Creek Fish Restoration Program and the California Ecosystem Restoration Program (CALFED) have taken actions necessary to recover these species in Clear Creek through increased flows, gravel supplementation, dam removal, and stream channel restoration (Destaso and Brown 2008).

Since 1995, increased water releases from Whiskeytown Dam have provided habitat and suitable temperatures for rearing and spawning salmonids. Gravel supplementation projects began in 1996 to increase the amount of spawning habitat for salmonids. Saeltzer Dam was removed in 2000 and this provided fish passage and access to an additional 12 miles of salmonid habitat. The Lower Clear Creek Floodway Rehabilitation Project *(*Restoration Project) was designed to restore the natural form and function of a 1.6-mile section of Clear Creek that was severely degraded by gravel mining. Our monitoring will determine if restoration actions are benefitting steelhead and late-fall Chinook salmon in Clear Creek.

Study Site

Clear Creek is a west side tributary of the Sacramento River, located in Shasta County, California (Figure 1). The US Bureau of Reclamation (BOR) controls water releases into Clear Creek at Whiskeytown Dam. Our study area extends from Whiskeytown Dam downstream to the RBFWO lower rotary screw trap (LRST), located at river mile 1.7 (Figure 2). We divided our study area into six reaches based on accessibility and distance. The first 2 miles downstream of Whiskeytown Dam are alluvial (Reach 1) and the next 8 miles (Reaches 2 to 4) are canyon bound. The remainder of the study area (Reaches 5 and 6) is mostly alluvial; however, a steep, long cascade that is a partial barrier to fall Chinook salmon is located at river mile 6.5.

The BOR releases 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 rearing. Throughout the summer months, flows are maintained to provide adequate water temperatures for holding adult spring Chinook salmon and rearing salmonids. Clear Creek currently supports populations of spring, fall, and late-fall Chinook salmon, and Central Valley steelhead.

Methods

Kayak survey.—We used three kayaks distributed evenly across the width of the creek to visually survey Clear Creek for the presence of steelhead and late-fall Chinook salmon redds and carcasses, and live late-fall Chinook salmon adults. Each survey covered one to three reaches per day. Field crewmembers kneeled on the pontoons or stood in the bottom of the boats when possible to obtain the best vantage point for viewing redds. To reduce glare and improve visibility through the water, field crewmembers 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 crewmembers (who had completed at least one kayak survey season) were always present on each survey.

Environmental data.—We collected water samples at the beginning and end of each survey and measured turbidity using a Hach® Turbidimeter. Field crewmembers also collected water temperature data at the beginning and end of the survey using a submersible thermometer. We retrieved flow data from the U.S. Geological Survey (USGS) Igo gaging station via the internet to summarize creek flows throughout the survey period.

Survey timing.—We scheduled our surveys biweekly from late December through early April. However, our survey schedule changed based on the prediction or occurrence of heavy rain, resulting in high flows and turbidities. We did not survey if flows were greater than 500 cfs because of turbid water and our inability to keep a slow enough pace to detect redds. Because of variable weather conditions, the number and timing of surveys vary yearly. High flow events can smooth or scour redds making them difficult for crews to detect. If a storm event was forecast, we attempted to perform a survey before the storm. If high flows occurred that may have flattened or scoured redds (>1000 cfs) immediately prior to a scheduled survey, we postponed the survey at least one week to allow enough time for new redds to be built. If heavy rain began after a survey started and water surface turbulence interfered with the visibility, the field crew would stop the survey for 15 minutes and wait for the rain to lessen. If rain intensity did not decrease, the crew cancelled the remaining survey.

Redd identification and detection.—Three species build redds in Clear Creek during our surveys including: (1) non-migratory (resident rainbow trout) and migratory (anadromous steelhead and potadromous rainbow trout from the Sacramento River) *O. mykiss* (2) late-fall Chinook salmon, and (3) Pacific lamprey. We did not distinguish between anadromous and non-anadromous *O. mykiss* redds because the differences were not outwardly apparent. Although the different life history forms of *O. mykiss* may be temporally separated during spawning, they may interbreed. We refer to all *O. mykiss* redds as steelhead redds in this report.

Redd characteristics vary among species and we used the following criteria to identify redds to species: (1) observation of a fish on a redd or (2) redd size, location, and substrate type. The most reliable way to identify what species constructed the redd was to observe a fish on the redd, but this occurs infrequently. On Clear Creek, steelhead redds are typically smaller than Chinook salmon redds, constructed in smaller substrate (1-2 inches compared to 1-3 inches), and are often built closer to the shoreline. Lamprey redds are circular and tailings may be found on all sides of the pit.

While searching for redds, crewmembers stopped at places where the substrate was clean and contrasted with the surrounding substrate. Redds were identified by the presence of a pit and a tail. We did not count incomplete redds but marked them as test redds. Crews used a snorkel and mask to examine redds more thoroughly if necessary. In areas of spawning habitat where the swift water moved kayaks through too quickly, crews would park the kayaks and snorkel or wade in the creek to look for redds.

Field crews kept track of individual redds throughout the spawning season to prevent double counting of redds on a subsequent survey. Each new redd identified was marked with flagging and assigned an identification number which included the date, reach and number for the survey day. We used a Garmin eTrex© GPS unit to record the location coordinates of each redd. Additional flagging was used if the redd needed to be revisited during the next survey because it was not measured. In areas with a high density of redds, sketch maps and aerial photos were used to draw and label redds. This map was brought into the field during subsequent surveys to help differentiate redds as they accumulated at a site.

Redd index and redd distribution.—Our yearly steelhead and late-fall Chinook index includes redds counted during kayak surveys, snorkel comparison surveys, and non-comparison snorkel surveys from April through June. We imported coordinates collected using GPS units into Geographic Information System (GIS) to evaluate the temporal and spatial distribution of redds and calculate redds per mile.

Redd measurements.—We took redd measurements to describe the physical characteristics of redds and the spawning habitat used. We also provided the data to the Sacramento Fish and Wildlife Office for their Instream Flow Incremental Methodology (IFIM) study, which is used to model flows on Clear Creek (USFWS 2005). Since 2003, one of our goals was to measure at least 300 redds per species. We have completed over 300 measurements for steelhead but we have yet to obtain this sample size for late-fall Chinook salmon. During our surveys, field crews attempted to measure all late-fall Chinook salmon redds. However, survey time constraints due to high numbers of carcasses and steelhead redds can limit field crews from taking measurements on all redds. We continue to measure a sample of steelhead redds each reach (per survey) so that we can increase our sample size and evaluate redd characteristics over time, within and between years.

Time permitting, redds were measured when they were first found unless there was a fish on the redd. We took mean column velocity (feet/second) measurements using a Marsh McBurney® or an Oceanic flow meter immediately upstream of the redd pit, (i.e., pre-redd). If the Oceanic® flow meter was used, it was run for a minimum of 100 seconds, and 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 unless the water depth was greater than 2.5 ft, then, flow measurements were taken at 20 percent and 80 percent from the water surface and the values were averaged obtain a velocity. We classified redd substrate size using methods described in USFWS (2005). We classified substrate size at the (1) pre-redd, (2) one side of the pit (based on the side that best represented the substrate the redd was built in), and (3) tail-spill. Other measurements included maximum length and width of the total disturbed area, pre-redd depth (depth of the substrate immediately upstream of the pit), maximum pit depth, and tail-spill depth (shallowest measurement of the tailspill). Redd area was calculated by using the formula for an ellipse (area = πX½ widthX½ length).

Redd age.—Algal growth, flattening from high flows, and accumulation of fines can diminish the contrast of redds against the substrate which makes redds difficult to detect. During the first three years of our redd survey, we tracked redd age each survey to determine the visibility of redds over time and after high flow events. Based on our results, we found that redds may be visible for up to four weeks in Clear Creek without high flows, and flows above 3,000 cfs may scour redds. Depending on duration of a high flow event, flows over 500 cfs may flatten tailspills, fill redds with fines, and clean the substrate surrounding redds of algal growth, which can make redds difficult to see.

Although we no longer track redd age, we assign redds an age when we first observe them to estimate when they may have been built. This is of particular interest if we missed a survey because of high flows. Redd age was broken into four categories based on the redd's physical characteristics. Age 2 was clearly visible and clean; age 3 was older with tail spill flat or pit with fines or algal growth; age 4 was old and hard to discern.

Live fish.—We recorded live steelhead, late-fall Chinook salmon, or lamprey actively spawning or guarding redds. In addition, we counted and took a location coordinate of all live adult late-fall Chinook salmon.

Carcasses.—We marked all carcasses by chopping off the tail to prevent double counting on a subsequent survey. We recorded fork length, gender, spawning status, and adipose fin clip status from each carcass and collected heads from carcasses with adipose fin clips or unknown clips for coded wire tag detection. All males were recorded as unknown spawning condition. We also collected quadruplicate tissue samples for genetic analysis. Tissue samples were usually collected from a fin but the operculum was sampled if the carcass was highly decayed. If we could not retrieve the carcass, we counted it, took a waypoint, and recorded as much information as possible.

Aging scales.—We collected and read scales to determine the age of late-fall Chinook carcasses. Although we collect steelhead scales, we do not present steelhead scale reading results. Field crews collected 5 to 10 scales from the left side of a carcass from the second and third row of scales above the lateral line, in the region bisected by a line drawn between posterior insertion of the dorsal fin to the anterior insertion of the anal fin. We used a microfiche reader to count the number of annuli and the age was determined to be the number of annuli plus one (Borgerson 1998).

Spawning gravel supplementation.—Spawning gravel supplementation projects have been implemented since 1996 to increase the amount of spawning habitat for salmonids in Clear Creek. Projects typically consisted of placing 1-4 inch clean gravel into the creek using an "injection method". The injection method involves trucking in clean gravel and dumping it over the steep canyon wall to form a talus cone extending into the creek (WSRCD 2000). While some of the gravel enters into the creek during this process, the majority remains in the talus cone and only becomes available for spawning after high flows transport it downstream.

Supplementation sites are located from Whiskeytown Dam to the Restoration Project in Reach 6 (Figure 2). To evaluate the use of spawning habitat created by the gravel supplementation projects, we noted when redds were constructed in injection gravel. Supplemental gravel can be identified by presence of tracer rock (non-native chert supplemented into gravel at some sites), its uniform appearance, and based on the distance the gravel moved downstream from the placement sites each year. Different amounts of injection gravel become available each year, depending on the amount of new gravel injected and the magnitude and duration of the high flow events that move the gravel. Although injection gravel was added in Reach 6 in several locations, it was mixed throughout the reach with native material following the Saeltzer Dam removal as well as high flow events and could not easily be distinguished in redds. Therefore, we assume that all redds in Reach 6 contain injection gravel.

Redds in the Restoration Project.—The Restoration Project has involved several phases in which the channel has been moved and filled with spawning gravel. Phase 3A of the Restoration Project realigned 0.6 miles of creek channel, added 11,700 tons of spawning gravel to the new channel, and was completed in 2002. Phase 3B realigned 0.68 miles of creek channel, added 20,350 tons of clean spawning gravel to the new channel, and was completed in November 2007. During our redd surveys, we determined if steelhead and late-fall Chinook salmon were using the newly created channels of Phase 3A and Phase 3B.

Snorkel-kayak comparison survey.—In 2008, we conducted a concurrent snorkel and kayak comparison survey to determine if there were differences in redd counts between methods. We performed the comparison survey during peak steelhead spawning, based on historic data. The kayak crew surveyed first and the snorkel crew followed on the same or next day. Each crew assigned redds with an identification number, flagged them, and marked them with a GPS waypoint. If the redd was in a high-density spawning area, crews drew the redds on a sketch map. Flagging was placed in an inconspicuous location by the kayak crew to prevent the snorkel crew from seeing the flagging before they saw a redd. When the snorkel crew observed a redd, they looked for the flagging and if it was found, recorded the identification number. Any unmarked or "new" redds were assigned a new unique identification number. Each crew recorded details about the location of each redd so when we compared results, we could identify reasons for missed redds by either crew. The comparison survey was carried out in Reaches 1, 4, 5, and 6. We did not survey Reaches 2-3 due to a storm earlier in the week. Faced with the choice of eliminating some of the snorkel comparison surveys, we chose to eliminate snorkel surveys in Reaches 2 and 3 because they typically have fewer redds than all other reaches.

Results

Kayak survey.—We completed seven kayak surveys of the study area from January 2 - April 3, 2008. We conducted an additional kayak survey on December 17, 2007 of Reaches 1 and 5 only. Survey turbidity values ranged from 0.9-3.5 NTU (nephelometric turbidity units) and flows ranged from 214-383 cfs (Table 1). The peak flow event for the season was 1,930 cfs (Figure 3). We completed all surveys as scheduled.

Steelhead.—The 2008 steelhead redd index was 148, 28% higher than the 5 year average of 116 (Table 2). Of the 148 redds, 2 were counted during snorkel surveys in June and 13 were counted during the snorkel comparison survey. The first January survey recorded the most redds of any survey week accounting for 30% of the season total. The highest density of redds occurred in river mile 5 (Reach 6) and river mile 17 (Reach 1) where 47% of the season's total redds were located (Figure 4). Steelhead were observed building or guarding five redds. Steelhead redds were 95% and 5% age 2 and 3, respectively. We measured 35 redds and the average size was 25.0 ft^2. Average pre-redd water velocity was 1.93 feet/second, average pre-redd depth was 1.74 feet, and median substrate size was 1-2 inches (Table 3).

Four steelhead carcasses were retrieved during surveys. One was a 390 mm fork length male retrieved on January 22 in Reach 6. The second was an unmeasured, partially eaten carcass (gender unknown) retrieved on January 22 in Reach 6. The third was a 450 mm fork length spent female retrieved on March 6 in Reach 6. The last carcass was observed on April 1 during a snorkel survey, but was too deep to retrieve. Tissue samples, otoliths, and scales were taken from the retrievable carcasses.

Late-fall Chinook salmon.—The late-fall Chinook salmon redd index was 17, compared to a 5-year average index of 22 (Table 4). The highest number of redds counted during a single survey occurred during the first January survey accounting for 53% of the season total (Figure 5). In addition, we counted 50 live fish, compared to a 5-year average of 67 (Table 4). Late-fall Chinook salmon redds, live fish, and carcasses were only found in Reach 6. Chinook salmon were observed building or guarding one redd. Redds were 94% and 6% age 2 and 3, respectively. We were not able to measure all redds in 2008 due to time constraints. Of the three redds that were measured, redd size averaged 111.39 ft^2, velocity 2.03 ft/sec, pre-redd depth 2.00 feet, and median substrate was 1-3 inches (Table 3).

We counted 55 late-fall Chinook salmon carcasses, compared to a 5-year average of 31 (Table 4). Seventy-two percent of the carcasses were collected during the first January survey. Carcass fork lengths ranged between 630-1020 mm was (0 = 838 mm, n=29). Sex ratios were 36% female, 18% male, and 46% unknown. Carcasses recorded with unknown lengths and genders were the result of predation or decomposition. Of the female carcasses, 17 were spawned, and the spawning condition of 3 was unknown because of predation or decomposition. Twenty-four percent of the carcasses recovered were adipose fin clipped (compared to an average of 12% since 2003), 49% were unmarked and presumed wild, and 27% were unknown (n=55; Table 4). One adipose fin clipped carcass was missing a head and was not processed for coded wire tag recovery. During coded wire tag extraction in the laboratory, we did not detect a coded wire tag in three adipose fin clipped carcasses. Nine coded wire tag codes were referenced to be 3-year old late-fall Chinook salmon from Coleman National Fish Hatchery (Table 5). In addition, we collected 10 fin tissue samples for genetic analysis, 13 otolith samples, and 8 scale samples. Based on scale reading results, all samples were derived from 3-

yr-old fish (n=8). One scale from an adipose fin clipped fish we verified as age 3 from the associated coded wire tag information.

Spawning gravel supplementation.— In Reaches 1-5, 30% of steelhead redds contained injection gravel compared to a 5-year average of 37% (Table 6). Based on our direct observations of movement of the supplemental spawning gravel as of June 2008, approximately 15% of the length of the creek channel in Reaches 1-5 contains supplemental spawning gravel, which is similar to 2007. Prior to the 2004 spawning season, approximately 6% of the channel contained injection gravel. The percentage has increased yearly following high flows, depending on their duration and magnitude.

Redds in the Restoration Project.—In Reach 6, 22% of the steelhead redds were observed in the Phase 3A and 3B new channels. We observed eight steelhead redds in the Phase 3A new channel, compared to a 5-year average of 2.8 redds (Figure 6). We also observed one late-fall Chinook salmon redd in Phase 3A. 2008 was the first year the Phase 3B new channel was available for spawning and we observed eight steelhead redds and no late-fall Chinook salmon redds (Figure 6). Since 2003, we have not observed late-fall Chinook salmon or steelhead redds in the old channel location of Phase 3B.

Snorkel-kayak comparison survey.—We completed the snorkel-kayak comparison survey from February 4 to February 8 in Reaches 1, 4, 5, and 6. The average survey turbidity was 1.9 NTU. The kayak crew overlooked 13 steelhead redds, accounting for 52% of what the snorkel crew observed. In comparison, 72% and 32% were overlooked during the 2004 and 2005 comparison surveys, respectively (Figure 7).

Discussion

Kayak survey.—We began our survey in mid-December in 2008. However, a relatively high flow event occurred, which resulted in an incomplete December survey. The survey results from Reaches 1 and 5 indicated steelhead spawning had begun. It is unknown if spawning occurred in the reaches we did not survey (Reaches 2-4 and 6). Overall, the December flow event did not exceed 1,000 cfs and it is likely redds would have been visible on the next survey that was completed in early January. From January to April, survey conditions were excellent due to low flow conditions. As a result, we were able to consistently survey every two weeks beginning in January.

Late-fall Chinook salmon.—Since we began our kayak redd surveys in 2003, late-fall Chinook salmon returns on Clear Creek have been relatively low. Although flow and temperature conditions are suitable for all life stages of late-fall Chinook salmon and recent stream restoration is expected to increase available spawning and rearing habitat, our redd index currently does not indicate an increasing population or cohort replacement rate > 1.0. Rather, our redd index indicates there is a small but stable late-fall Chinook salmon population in Clear Creek. However, in 2003 to 2005, we conducted additional kayak surveys in Reaches 5 and 6 in December, specifically for late-fall Chinook salmon. The redd, carcass, and live counts from these December surveys may have inflated our counts because of the overlap in fall and late-fall Chinook salmon spawn timing. In addition, the December carcass counts are likely higher because fall Chinook salmon carcasses may still be present if high flows have not flushed them out of the survey area. If we exclude the December counts, the data suggests a population that may be slightly increasing, however, it is possible that some redds or carcasses would have been detected during the January surveys. Additional data is necessary to determine if the population is actually increasing.

The late-fall Chinook salmon populations in Clear Creek may not be increasing due to other factors such as unscreened diversions in the Sacramento River and the possible influence of hatchery fish on naturally produced populations. We speculate that higher diversion rates from the Sacramento River during the juvenile late-fall Chinook salmon outmigration in the late spring and summer may reduce their survival. The majority of juvenile late-fall Chinook salmon in Clear Creek appear to out-migrate as fry, whereas CNFH late-fall Chinook salmon are released in late December to early January as smolts; therefore, CNFH fish are less likely to be entrained because diversions are relatively low at that time. In addition, hatchery fish may be less susceptible to predation due to their larger size.

Our coded-wire tag data indicated that all carcasses with adipose fin clips were late-fall Chinook salmon produced at CNFH. Of the nine coded wire tags we recovered, two were from fish released at locations other than Battle Creek (Table 5). Off-site releases (those released not in Battle Creek) of hatchery fish have been associated with higher straying rates. In 2005, 18% of the CNFH late-fall Chinook salmon juveniles were released off-site. Although our sample size was small, the proportion of off-site releases recovered in Clear Creek in 2008 (22%) was slightly higher than percentage released off-site. The long-term effects of hatchery fish on the Clear Creek late-fall Chinook salmon population are unknown at this time.

Injection gravel and restoration.—Based on our observation of steelhead redds in injection gravel since we began our surveys, it appears that gravel supplementation projects have successfully provided suitable spawning habitat. Steelhead may be using areas with injection gravel because there is limited spawning habitat available throughout the creek or because the gravel quality may be better. Steelhead redds have been observed in injection gravel at all sites except for Reach 2. However, we have observed spring Chinook salmon redds in Reach 2 injection gravel. Total available spawning habitat usually increases after high flow events redistribute injection gravel downstream. The length of creek that contains injection gravel has increased since gravel supplementation began.

The frequency and magnitude of high flows and amount of injection gravel at each site can influence how much gravel moves and the distance it moves downstream. At the Placer Road gravel site in Reach 4, the distance the leading edge of the injection gravel has moved downstream since 2006 was negligible. However, in 2008, there were changes in the spawning habitat at this site that may have reduced steelhead spawning.

Gravel has been placed at Placer Road since 2001 and approximately 3,000 tons of gravel has been added annually. Although gravel moved downstream in 2001 and 2002 approximately 0.13 miles, the majority moved following the high flows in December 2002 and the "Gloryhole" spill from Whiskeytown dam in April 2003. Subsequently, steelhead began spawning in the more dispersed Placer Road injection gravel by 2004. Each year the number of redds at the Placer Road gravel site may vary due to the changing habitat following flow events that annually move gravel downstream. The number of redds probably also varies with the number of spawners. The leading edge of the Placer injection gravel has not currently distributed beyond a half of a mile because it is filling in a long, deep pool. However, fresh gravel from the injection site continues to move downstream during smaller (1000-2000 cfs) flow events. In 2008, there was a decline in redds downstream of the Placer Gravel Site. Two redds were first observed on January 3, 2008 and no new redds were observed for the remainder of the season. Field crews noticed the gravel shifted through this section throughout the survey season following high flow events. New injection gravel covered some of the spawning habitat used in previous years. As new gravel is annually added to the injection site and it continues to distribute downstream and settle, changes in spawning gravel use by steelhead is a likely result. Moreover, with no large flow events occurring in 2007 or 2008, the lower extent of the injection gravel has only moved downstream slightly and subsequently, new injection gravel has piled on top of the older injection gravel. More frequent high flows would greatly benefit the spawning habitat by moving injection gravel further downstream.

In Reach 6, restoration actions coupled with high flows have helped to improve and create spawning habitat for steelhead in Clear Creek. For the second consecutive season, Reach 6 had the highest number of steelhead redds counted for the season. Steelhead redds have been observed in most years since the Phase 3A new channel was built. Although 2008 was the first year post-construction of the Phase 3B new channel, 11% of the steelhead redds in Reach 6 were built in the Phase 3B new channel.

Snorkel-kayak comparison survey results.—Similar to our comparison snorkel-kayak surveys performed in 2004 and 2005, the 2008 snorkel crews observed more redds than kayak crews did. Although kayak surveys allow for more frequent surveys, redds are frequently overlooked that would likely be detected by a snorkel survey. Generally, kayak crews move downstream more quickly than snorkel crews and viewing redds through the water surface can be more difficult. Redds located under overhanging vegetation or near undercut banks can also be easily missed by kayak crews.

Our first comparison survey in 2004 helped us to improve our kayaking technique for observing redds, and redd detection improved during the 2005 comparison survey. In 2008, the percent of redds observed by our kayak crews decreased. Our comparison surveys results consistently have shown that snorkelers observe more redds than kayakers.

Recommendations

We recommend doing snorkel-kayak comparison surveys each year to develop a redd estimate based on our index.

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Tables

TABLE 1.—Environmental conditions during Clear Creek kayak surveys from 2003 to 2008, including mean (range) flow, mean (range) turbidity, and range of temperatures.

Year	Surveys	Flow (cfs)	Turbidity (NTU)	Water temperature (ºF)
2003	4	257 (227-485)	2.0 (1.0-3.9)	44-56
2004	6	289 (247-354)	1.5 (0.8-2.6)	42-52
2005	6	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	249 (214-383)	1.5 (0.9-3.5)	41-48

TABLE 2.—Clear Creek steelhead redd index and carcass recovery from 2003-2008. Redd index includes redds counted during kayak surveys, snorkel comparison surveys, and snorkel surveys from April-June. Additional kayak surveys in some reaches were completed in 2003, 2004, 2005, and 2008 between the full creek surveys. No adipose fin clipped steelhead have been found in Clear Creek to date.

Survey year	2003	2004	2005	2006	2007	2008
n=(full creek kayak surveys)	4[a]	6[b]	6[c]	4	6	7[d]
Kayak survey redds	75	74	122	41	163	133
Snorkel survey redds from snorkel-kayak comparison survey	NA	54	19	NA	NA	13[e]
Snorkel survey redds	3	23	3	1	2	2
Redd index	78	151	144	42	165	148
Carcasses	2	0	4	1	7	4

[a]Two additional kayak surveys were completed in Reaches 1 (35 stt redds), 5 (0 redds), and 6 (0 redds).
[b]Three additional kayak surveys were completed in Reaches 5 (0 redds) and 6 (2 stt redds).
[c] One additional kayak survey was completed on Reach 6 (4 stt redds).
[d]Two additional kayak surveys were completed in Reaches 1 (9 stt redds) and 5 (6 stt redds) on December 17, 2007.
[e]Snorkel calibration surveys were not completed on Reaches 2-3.

TABLE 3.—Summary of redd characteristics of steelhead and late-fall Chinook redds in Clear Creek from 2003-2008. Values represent the mean (standard deviation) for 2008 and 2003-2007 years redds combined, except substrate size values are medians.

Species	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)
Steelhead	2008	35	7.52 (2.63)	4.05 (1.74)	26.01 (20.85)	1.74 (0.61)	1.98 (0.61)	1.33 (0.66)	1.93 (0.63)	1-2
	2003-07	309	6.51 (3.05)	3.62 (1.48)	20.87 (17.82)	1.71 (0.67)	1.88 (0.64)	1.45 [a] (0.71)	1.99 [b] (0.63)	1-2 [c]
Late-fall Chinook salmon	2008	3	16.67 (7.51)	8.14 (1.95)	111.39 (61.37)	2.00 (0.83)	2.39 (0.76)	1.17 (0.36)	2.03 (0.35)	1-3
	2003-07	43	15.34 (8.07)	8.22 (3.94)	117.68 (120.65)	1.38 (0.46)	1.71 (0.45)	0.94 (0.44)	2.17 [d] (0.65)	1-3 [e]

[a] n=308
[b] n=282
[c] n=288
[d] n=40
[e] n=42

TABLE 4.— Late-fall Chinook salmon redd index, live count, and carcass recoveries from Clear Creek kayak surveys from 2003-2008. The percentage of carcasses with an adipose fin clip is in parentheses. One unknown adipose fin clip carcass was found in 2004 and four were found in 2005, and although heads were processed for coded wire tag detection, none were recovered. In 2008, 17 unknown clip status were identified, seven were returned for coded wire tag, detection, and two had coded wire tags.

Survey Year	Redds	Live	Total carcasses
2003[a]	24	110	42 (7%)
2004[b]	20	48	60 (5%)
2005[c]	28	94	34 (6%)
2006	14	42	7 (14%)
2007	25	39	13 (30%)[d]
2008[e]	17	50	55 (24%)[f]

.[a]Two additional kayak surveys were completed in Reaches 6 in December (13 redds, 29 carcasses, 67 live).
[b]Three additional kayak surveys were completed in Reaches 6 (10 redds, 35 carcasses, 37 live).
[c] Two additional kayak surveys were completed on Reach 6 (14 redds, 26 redds, 67 live).
[d]Two carcasses were observed with adipose fin clips were missing heads, so no tag information could be collected.
[e]Two additional kayak surveys were completed in Reaches 1 (9 redds) and 5 (6 redds) on December 17, 2007.
[f]Two carcasses with adipose fin clips were missing heads, so no tag information could be collected.

TABLE 5.—Coded wire tag information retrieved from adipose fin clipped or unknown clip status Chinook salmon carcasses on Clear Creek during the 2008 kayak surveys. After tags were extracted, data concerning their origin was retrieved from the Regional Mark Information System (www.rmpc.org). Unknown adipose fin clipped fish were changed to absent if a tag was extracted.

Collection Date	Adipose Fin Clip Status	Sex	Fork Length (mm)	Tag Code	Hatchery Origin	Run	Brood Year	Release Location
1/2/2008	Absent	Male	680	052867	CNFH	Late Fall	2005	CNFH
1/2/2008	Absent	Female	730	NTD	NTD	NA	NA	
1/2/2008	Absent	Female	850	052867	CNFH	Late Fall	2005	CNFH
1/2/2008	Unknown	Unknown	0	NTD	NA	NA	NA	
1/2/2008	Unknown	Unknown	0	NTD	NA	NA	NA	
1/3/2008	Unknown	Unknown	0	NTD	NA	NA	NA	
1/22/2008	Absent	Unknown	720	NTD	NA	NA	NA	
1/22/2008	Absent	Female	630	052794	CNFH	Late Fall	2005	Port Chicago
1/22/2008	Absent	Male	0	NTD	NA	NA	NA	
1/22/2008	Absent	Female	790	052867	CNFH	Late Fall	2005	CNFH
1/22/2008	Absent	Male	840	052870	CNFH	Late Fall	2005	CNFH
1/22/2008	Absent	Male	780	052867	CNFH	Late Fall	2005	CNFH
1/22/2008	Unknown	Male	0	NTD	NA	NA	NA	
1/22/2008	Unknown	Unknown	0	NTD	NA	NA	NA	
1/22/2008	Absent	Unknown	0	052787	CNFH	Late Fall	2005	Georgiana Slough
3/6/2008	Absent	Unknown	950	052866	CNFH	Late Fall	2005	CNFH
3/6/2008	Absent	Unknown	0	052868	CNFH	Late Fall	2005	CNFH

TABLE 6.—Steelhead redds in Reaches 1-6 in Clear Creek in 2008. The percent of redds in reach that contained injection gravel is in parenthesis. All redds in Reach 6 are assumed to contain injection gravel. Reaches 1-5 are associated with 0-2 gravel supplementation sites: Reach 1: Whiskeytown; Reach 2: Need Camp Bridge and Guardian Rock[a]; Reach 3: none; Reach 4: Placer; Reach 5: Clear Creek Road Bridge and Reading Bar.

Year	Reach 1	Reach 2 [b]	Reach 3	Reach 4	Reach 5[c]	Total 1-5	Reach 6
2003	71 (45%)	2	1	2 (0%)	2	78 (41%)	0
2004	54 (22%)	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	61 (36%)	9 (0%)	6	18 (89%)	8 (38%)	102 (40%)	63
2008	60 (35%)	3 (0%)	1	5 (40%)	10 (10%)	79 (30%)	70

[a] In our 2007 annual report, the Guardian Rock Gravel site was referred to as the Need Camp Gravel Site.
[b] Need Camp Bridge injection gravel was not available until 2004 and Guardian Rock injection gravel was not available until 2006.
[c] Injection gravel was not available until 2004.

Figures

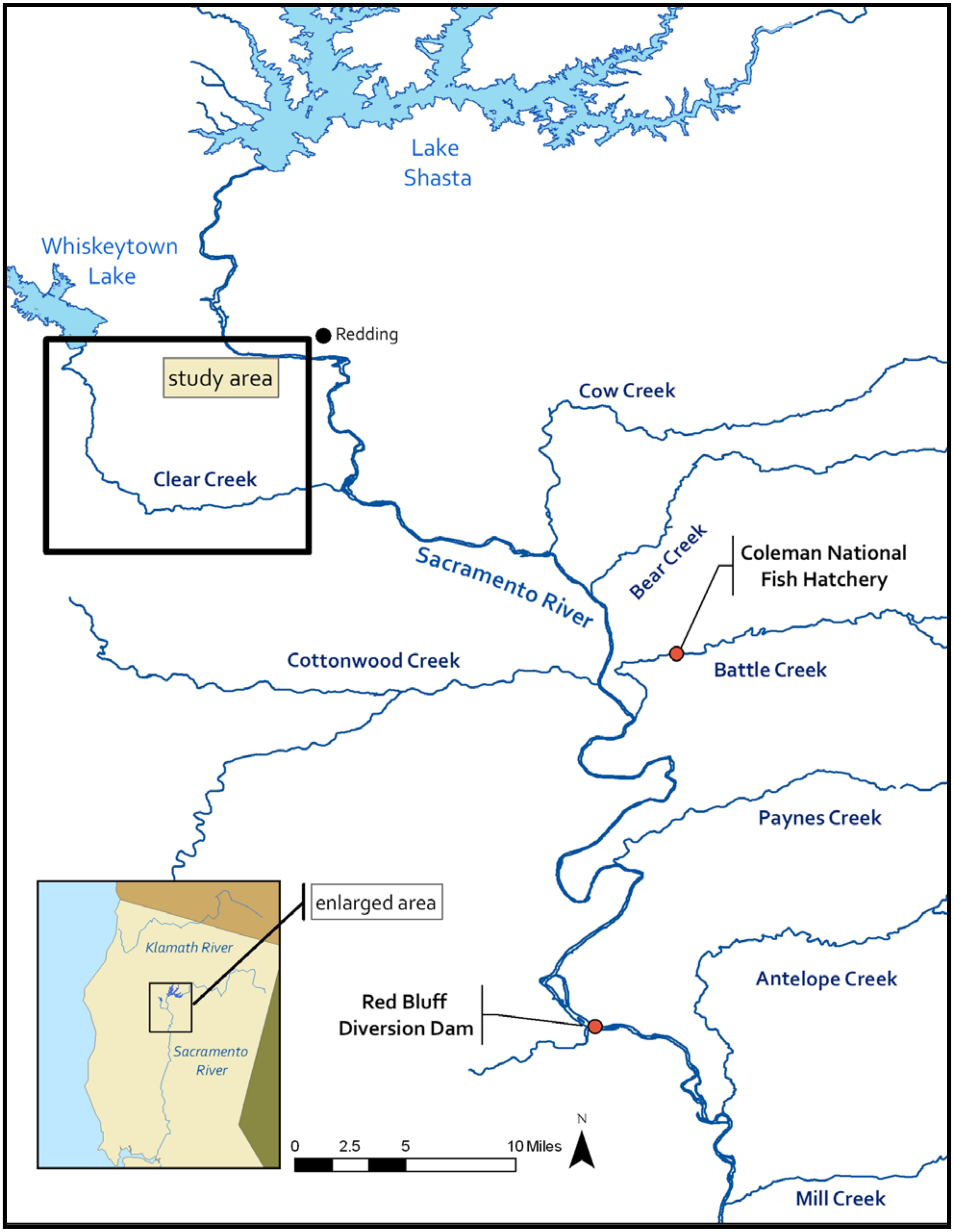

FIGURE 1.—Map of the study area, Clear Creek, Shasta County, California.

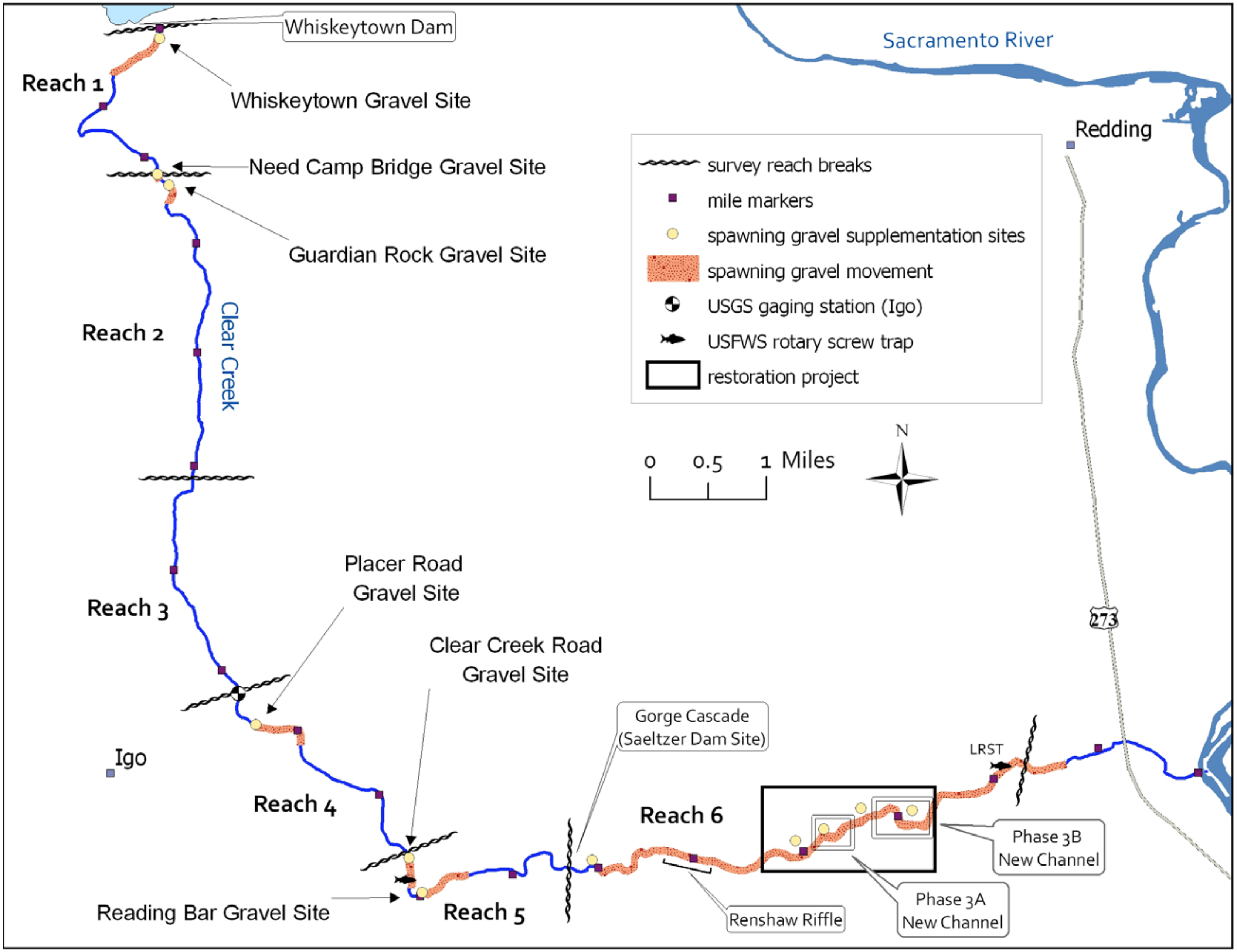

FIGURE 2.— Map of the study area, Clear Creek Shasta County, California, depicting survey reaches, important features, location of gravel injection sites, and the distribution of injection gravel as of June 2008.

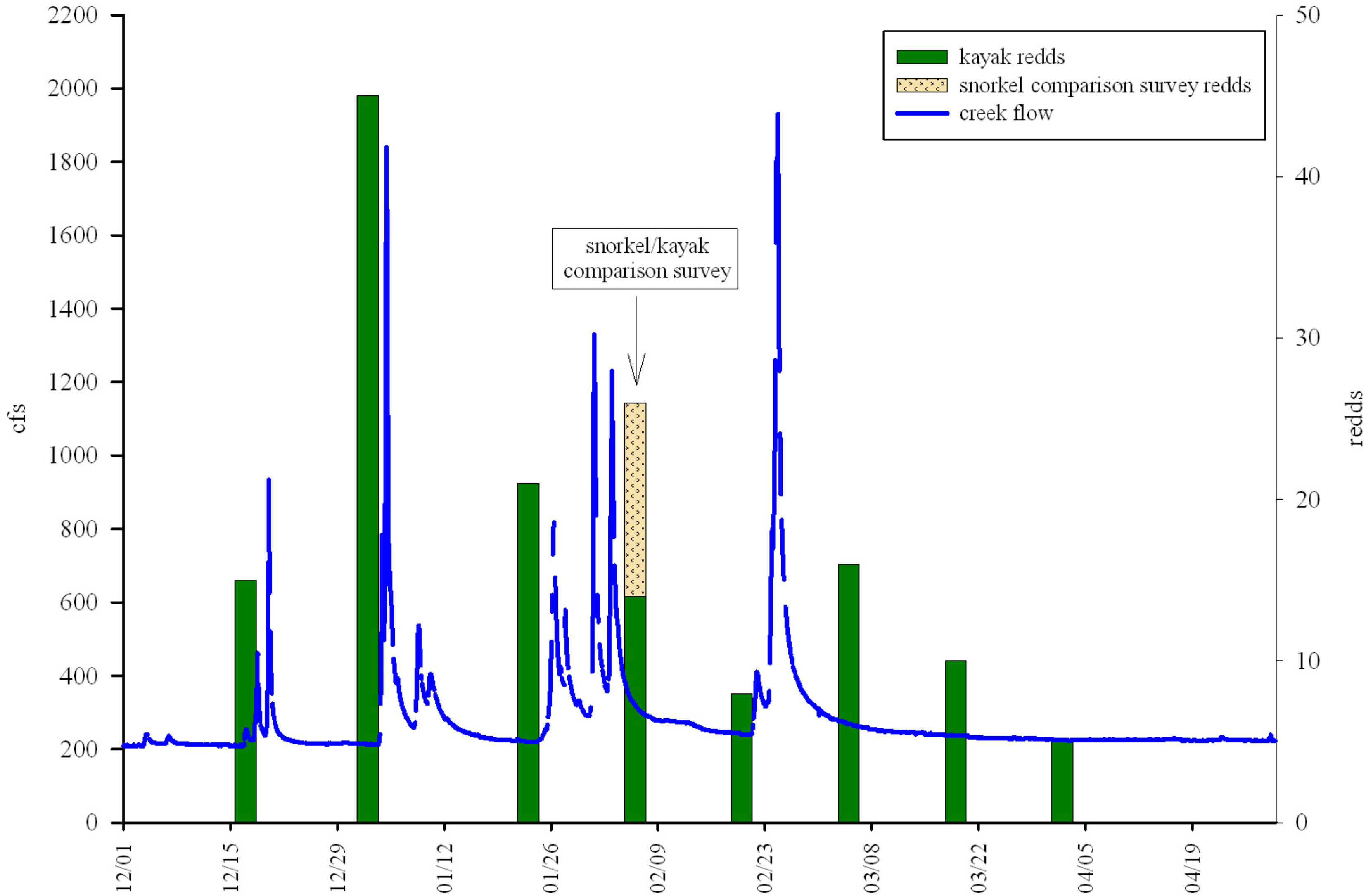

FIGURE 3.—Steelhead redds observed during redd surveys on Clear Creek in 2008. Each solid bar represents redd counts during a survey of the entire creek except for the December bar, which only represents Reaches 1 and 5. Redds counted during the kayak-snorkel comparison survey are displayed in the dotted stacked bar. Hourly flows from the USGS gaging station at Igo are plotted to show the timing and duration of creek flows during the survey period.

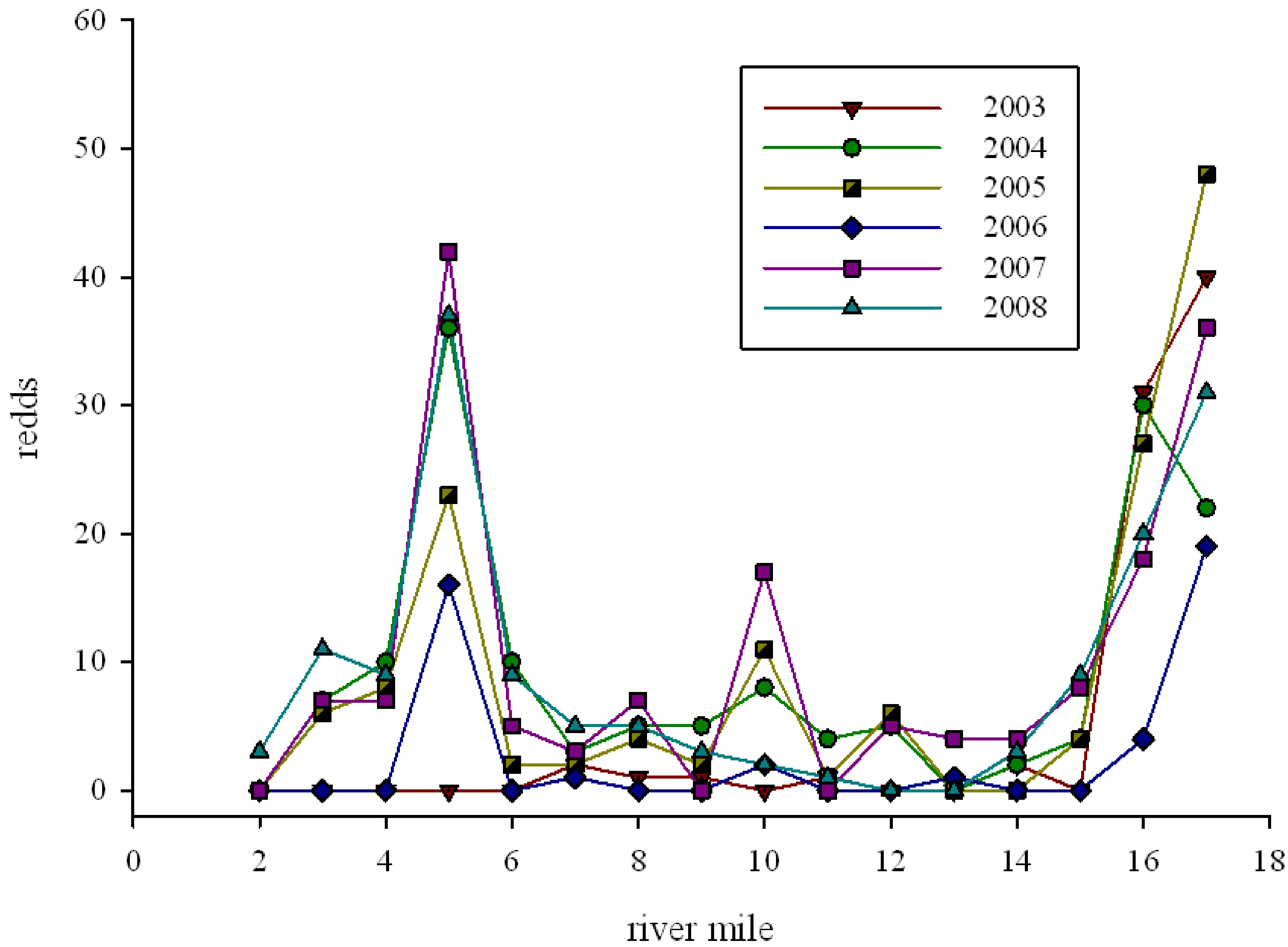

FIGURE 4.—Steelhead redds per mile in Clear Creek from 2003-2008. River miles begin at the confluence at 0 and end at Whiskeytown Dam at 18.1. Our study area ends at river mile 1.7.

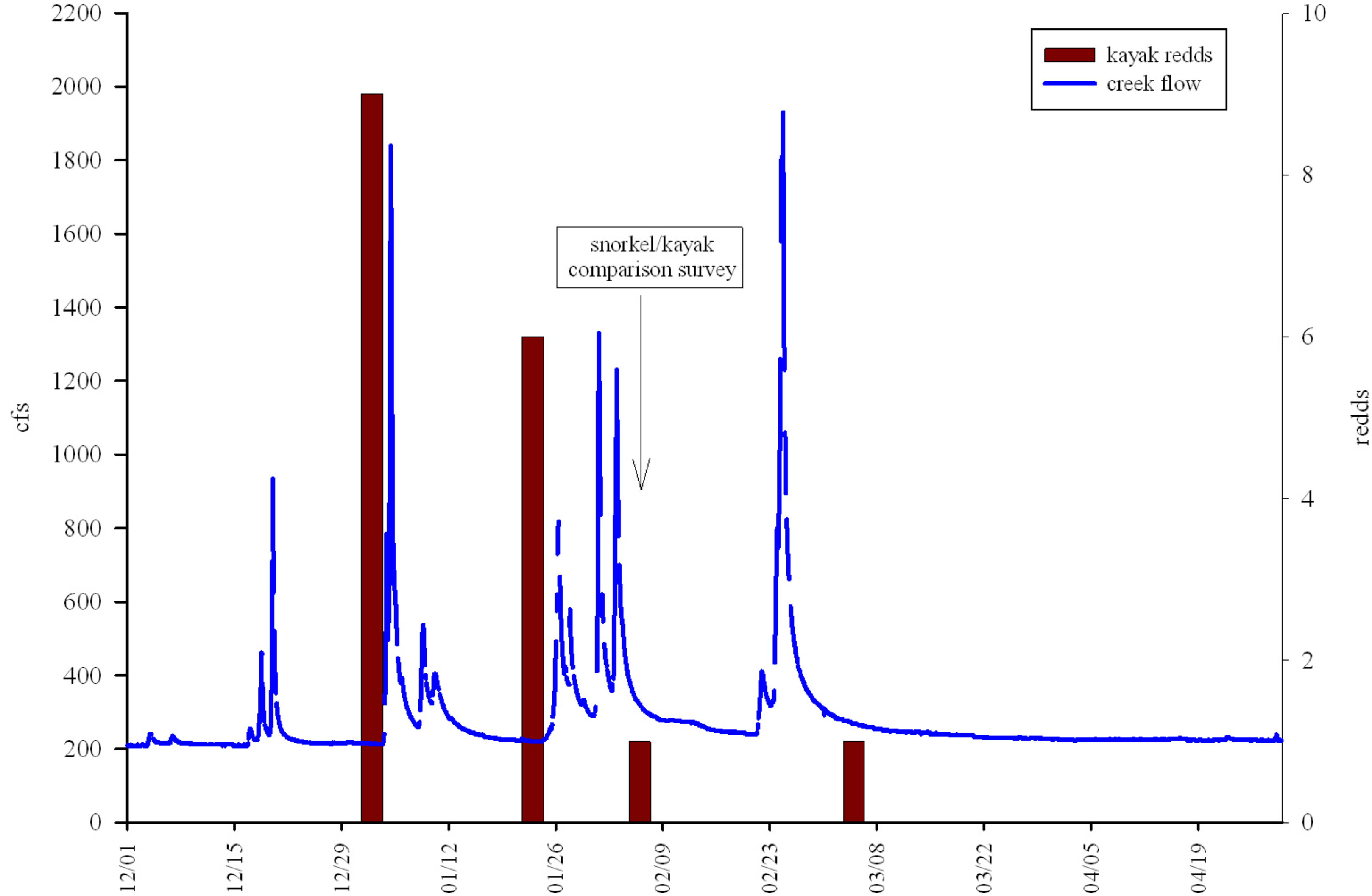

FIGURE 5.—Late-fall Chinook redds observed during redd surveys of Clear Creek in 2008. Each solid bar represents redd counts during a survey of the entire creek. No additional redds were counted during the snorkel-kayak calibration survey. Surveys were also conducted on 02-20, 03-20, and 04-03, but no redds were observed. Hourly flows from the USGS gaging station at Igo are plotted to show the timing and duration of creek flows during the survey period.

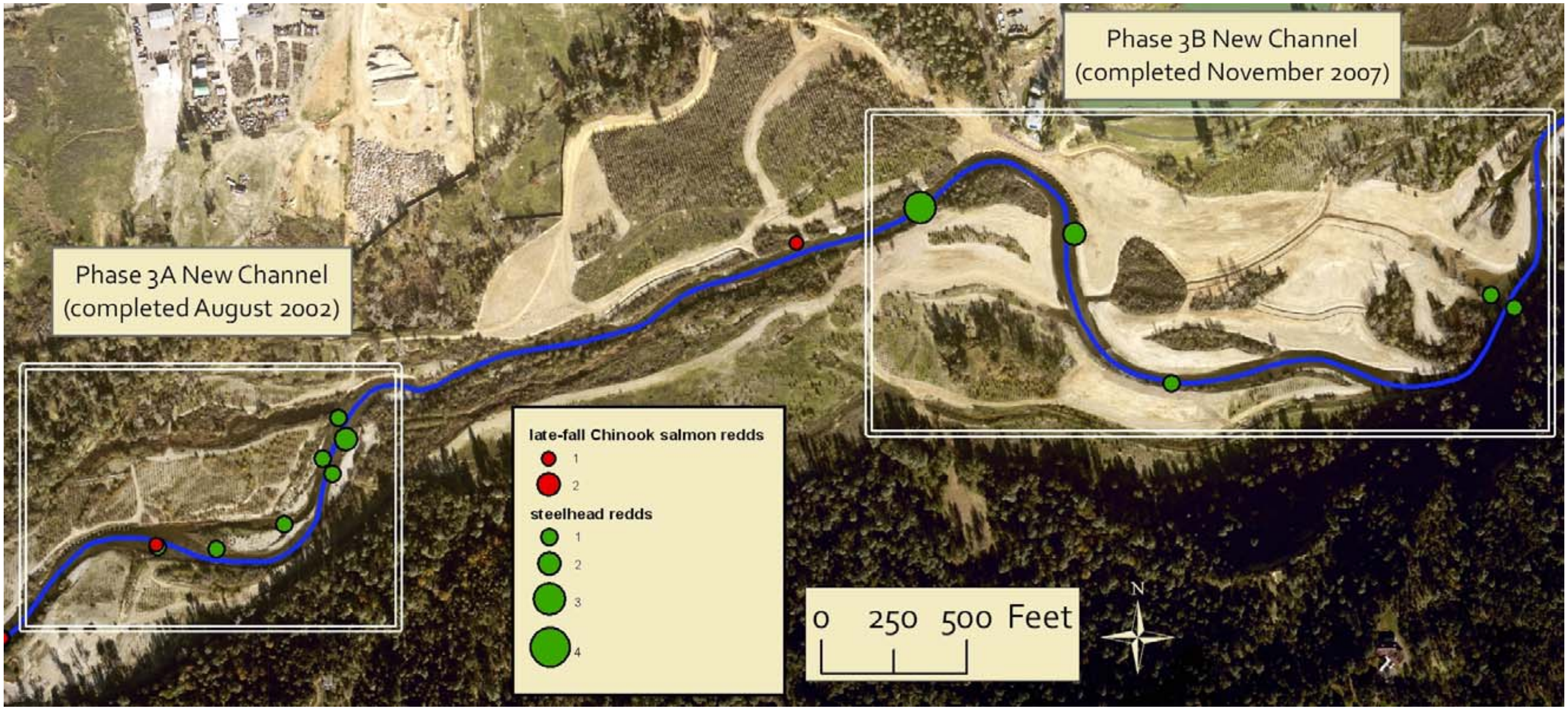

FIGURE 6.—Steelhead and late-fall Chinook salmon redds in the Phase 3A and 3B new channels in the Restoration Project, Clear Creek 2008.

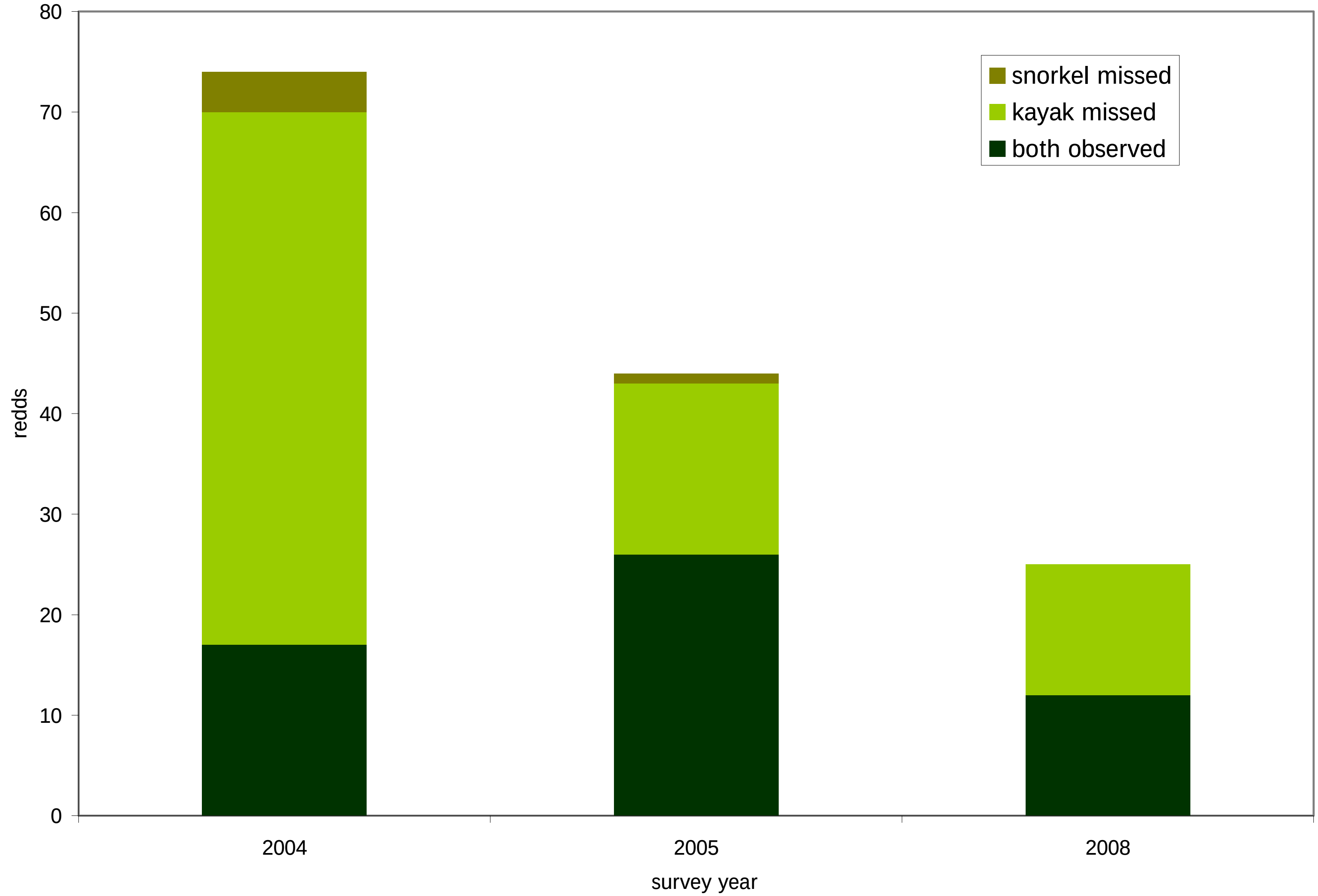

FIGURE 7.—Kayak-snorkel comparison survey results for 2004, 2005, and 2008. Each bar represents the total number of redds observed by snorkel and kayak crews.