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Central Valley Steelhead and Late Fall Chinook Salmon Redd Surveys on Clear Creek, California 2007.

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Abstract.— We conducted spawning surveys in 2007 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 for these species. Restoration efforts in Clear Creek have included dam removal, increased flows, stream channel restoration and spawning gravel supplementation. The surveys were used to develop redd indices and evaluate the spatial and temporal distribution of redds within the creeks. Conditions during surveys were excellent with low turbidity and stream flow. The steelhead index was 165 redds. Steelhead redds were generally concentrated in areas downstream of gravel injection sites or in Renshaw Riffle in reach six. In the upper five reaches, 40 percent of redds were located in injection gravel which only comprised 15 percent of the length of these reaches. The late fall Chinook index was 25 redds. Late-fall Chinook redds were only found in the reach six.

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Introduction

Central Valley steelhead, the anadromous form of rainbow trout, were listed as threatened under the Federal Endangered Species Act 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 upon counts at the Red Bluff Diversion Dam, adult migration into the upper Sacramento River occurs from July through May, peaks in late September and spawning occurs from December through May (Hallock 1989). Resident and potadromous life history forms of rainbow trout also exist in the upper Sacramento River watershed and non-hatchery rainbow trout in anadromous watersheds are considered in the same evolutionary significant unit (ESU) as Central Valley steelhead (Moyle 2002). Although non-anadromous life history forms are not listed under the ESA, they are important for maintaining a viable population of the species. Based upon otolith analysis, anadromous and non-anadromous rainbow trout do interbred, although spawn timing may create some segregation (Zimmerman and Reeves 2000). Juvenile steelhead typically spends 1 to 2 years in fresh water before migrating to the ocean. Regardless of whether they are progeny of anadromous or non-anadromous fish or of both, juveniles use the same rearing habitats (McEwen 2001).

Prior to the 1950's, limited documentation exists concerning Central Valley steelhead populations in the upper Sacramento River watershed. However, most of their spawning and rearing habitat was lost following the construction of dams which began in the early 1900's. Dams also altered habitat downstream by changing temperatures and flows and reducing sediment transport vital for maintaining spawning habitat. Counts of steelhead migrating into the upper Sacramento River were made after the installation of the RBDD in 1966 and a downward trend was noted through 1988, which was likely due to passage problems at the dam (Hallock 1989) and other water development and management practices that degraded habitat (McEwen 2001). After modification of operations at RBDD in 1993 for the recovery of winter Chinook, counts of steelhead became unavailable because the dam was removed during their migration period. Coleman National Fish Hatchery began producing and releasing juvenile steelhead into the Sacramento River in the late 1950's and estimates are made based upon adult returns at the barrier weir.

There is very little data concerning the current population of wild Central Valley steelhead in the upper Sacramento River watershed because their life history strategy makes population assessments difficult. Spawning occurs in the 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 share similar spawn timing as steelhead and migrate into the upper Sacramento beginning in December and spawn through April. Although late fall Chinook spawning surveys are carried out on the mainstem Sacramento by the California Department of Fish and Game (CDFG), surveys of naturally spawning late-fall Chinook on the tributaries are difficult for the same reasons as steelhead.

Clear Creek Restoration and Monitoring. **—**Clear Creek is a western tributary to the upper Sacramento River and has 18 miles of anadromous habitat. Flows are regulated at

Whiskeytown dam, an impassable barrier to anadromous salmonids. Although habitat has been degraded, efforts have been underway to restore and manage Clear Creek to support populations of anadromous salmonids, including Central Valley steelhead.

Over the past century, several human actions have degraded anadromous fish habitat in Clear Creek. In 1903, a small dam (McCormick-Saeltzer) was constructed on Clear Creek at river mile 6.5 which blocked 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 necessary to maintain habitat and provide spawning gravel. Gravel and gold mining further degraded salmonid habitat in Clear Creek throughout the 19th century.

Restoration efforts have been implemented on Clear Creek to target the recovery of salmonids. These projects have been funded primarily by the Central Valley Project Improvement Act (CVPIA) Clear Creek Fish Restoration Program and the California (CALFED) Ecosystem Restoration Program. 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. McCormick-Saeltzer Dam was removed in 2000 and this provided fish passage and access to an additional 12 miles of salmonid habitat. Floodplain and channel reconstruction projects in the lower watershed have restored the natural form and function of degraded spawning habitat.

The Red Bluff Fish and Wildlife Office (RBFWO) conducted spawning ground surveys to track the recovery of steelhead and late fall Chinook and monitor the effectiveness of these restoration efforts. Funding was provided by the Central Valley Project Improvement Act (CVPIA) Clear Creek Restoration Program. The Multi-Species Conservation Strategy (CBDP 2000) identifies spring, fall, and late-fall Chinook and steelhead as “R” species. “R” species are those for which California Bay Delta Authority (CBDA) has established the goal to recover within the Ecological Restoration Program (ERP) ecological management zones. Similarly, the ERP goals include recover at-risk species (goal 1) and maintain or enhance harvested species populations (goal 3) such as federally listed salmonids (CBDP 2001). The CBDA and CVPIA have undertaken actions necessary to recover these species in Clear Creek. Our monitoring will directly determine if steelhead and late-fall Chinook recovery goals are being met in Clear Creek.

Redd counts were used to index the population for both species and to determine spawn timing and distribution. Kayaks were found to be an effective method for carrying out surveys during winter weather conditions when efficient and frequent surveys are needed so high flows do not make redds indistinguishable. This report summarizes data collected during the 2007 spawning season. Data from previous years are provided for comparison, but it is beyond the scope of this report to describe yearly variations in methods and to discuss their implications.

Study Site

Clear Creek is a west side tributary that enters the Sacramento River at river mile 289 (Figure 1). The study area extends from Whiskeytown Dam (river mile 18.1) to the Red Bluff Fish and Wildlife Office’s rotary screw trap (RST) (river mile 1.7). Most salmonid spawning habitat is upstream of the RST and the dam is a complete barrier.

The first two miles downstream of the dam are alluvial (Reach 1) and the next 8 miles (Reach 2-4) are canyon bound. The remainder of the study area (Reach 5 and 6) is mostly alluvial but a steep, long cascade which is a partial barrier to fall Chinook is located at river mile 6.5. Water released from Whiskeytown Dam is consistently 200 cfs from October through June and allocated by the Service s' Increased Project Yield Program of the CVPIA to provide adequate habitat for salmonids. Throughout the summer months, flows are maintained to provide adequate holding and rearing temperatures for adult spring Chinook and rearing salmonids

Methods

Our surveys were initiated in 2001 and 2002, using snorkeling to look for steelhead redds. Limited surveys were conducted in some of the reaches. Snorkel surveys consisted of three snorkelers moving downstream, equally distributed across the width of the creek. Two to four miles were snorkeled each day, requiring up to six days to complete a survey. In addition to redd and carcass counts, live trout were counted and classified into three categories based upon age and size. While snorkeling is an effective method for observing redds and fish in Clear Creek used to survey for spring Chinook, we found that during the winter months, storms and cold temperatures made it difficult to complete many surveys.

In addition, walking carcass surveys were conducted in reach six beginning in 1999 to evaluate late-fall Chinook spawning. These surveys were initiated to conduct a mark and recapture survey of late-fall Chinook but due to the low number of carcasses that were encountered, a population estimate could not be made with this technique. Also, carcass surveys can not be used for monitoring populations of steelhead which are sometimes repeat spawners.

In order to consolidate our efforts into one type of survey that would cover both species and work efficiently during the winter months, we began using Hyside© inflatable kayaks in 2003. Kayaks could cover a much greater distance in a shorter time period and the creek could be surveyed for redds in three days or less. To gain a better understanding concerning the efficiency of the kayak method for counting redds and carcasses, we conducted concurrent snorkel surveys and walking surveys in 2004 and 2005 with the kayak surveys to compare the methods.

Kayak Survey.—We used three kayaks and distributed evenly across the width of the creek for complete coverage. Crew members kneeled on the pontoons or stood in the bottom of the boats when possible to obtain the best vantage point for viewing redds. Polarized sunglasses and caps with visors were worn to reduce glare and improve the visibility. Crew members were trained in the office and field for one full day before conducting a survey and two experienced crew members, who had completed at least one kayak survey season, were always present on a survey. While searching for redds, we stopped at places on the creek where patches of gravel were clean, sorted or otherwise contrasted with the surrounding substrate. A snorkel and mask were used to examine redds more thoroughly. In spawning habitat where swift water moved kayaks through too quickly, we would park our boats and snorkel or walk to look for redds.

Environmental Data.—Turbidity and stream flow can affect the surveyor's ability to detect redds. Water samples were collected at the beginning and end of each survey and analyzed for turbidity using a Hach Turbidimeter. Flow data was retrieved from the US Geological Survey (USGS) Igo gaging station via the internet and averaged for each survey. Temperature data was also collected at the beginning and end of the survey using a submersible thermometer.

High flow events may affect the survey data because they may reduce the number of surveys that can be carried out and they may smooth or scour redds making them undetectable. Hourly flows were retrieved from the California Data Exchange Center (CDEC) and used to describe flow conditions throughout the survey period.

In an attempt to count as many redds as possible in a season, surveys were scheduled every two weeks and carried out depending upon conditions including flows, turbidity and rain. Surveys were not usually carried out during rain events because the disturbance on the surface of the water limited visibility and flows were usually elevated. If it began to rain after a survey started and water surface turbulence interfered with the visibility, the crew would stop the survey for 15 minutes and wait for the rain to lighten. If rain did not let up, the survey would be cancelled. Surveys were not done if flows were greater than 500 cfs because of turbid water and the survey could not be done at a slow enough pace to detect redds. We scheduled surveys to prevent missing redds due to high flows. If high flows occurred immediately prior to a scheduled survey, the survey was postponed at least 1 week to allow enough time for new redds to be constructed and, if a large rain event was forecasted, an attempt was made to perform a survey earlier than scheduled. The number of whole creek surveys carried out varied each year based upon weather and staff availability.

Redd Identification and Detection.—There are three species that build redds in Clear Creek during our surveys: (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 rainbow trout redds because the differences are not apparent. Although there may be some temporal separation between spawn timing, it is also likely that they interbreed. Redd characteristics vary between species and the following criteria (based upon field experience and literature) were used to identify them: (1) observing a fish on a redd or (2) redd size, location and substrate type. The most reliable way to identify what species made a redd is to observe a fish on the redd, but this occurs infrequently. On Clear Creek, *O. mykiss* redds are typically smaller than Chinook redds, constructed in smaller substrate, and often built closer to the shoreline or near structure. Lamprey redds have a circular appearance and tailings may be found on all sides of the pit. Redds were defined by the presence of a pit and a tail. Incomplete redds were not counted as redds but marked as test redds and flagged so they could be checked on the next survey so we could see if it changed. A consensus was made by the crew when determining what species made a redd or if it was a test redd.

Individual redds were kept track of throughout the spawning season to prevent counting redds more than once on a subsequent survey. Each new redd identified was assigned an identification number which included the date, reach and number for the survey day. A Garmin eTrex© gps was used to record the coordinates and a flag was tied to the nearest tree branch or vegetation upstream of the pit on the side of the creek closest to the redd. Different colored flagging was used to represent the different species and the identification number and information about the redd was written on the flagging. 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 the next surveys to help differentiate redds as they accumulated at a site.

Redd Measurements.—We collected data on the physical characteristics of redds to gain a better understanding of the spawning habitat being used. Measurements were also used for another study modeling instream flow needs. All redds were measured when they were first found unless there was a fish on the redd or if the time required to complete the survey was limited. Mean column velocity (ft/sec) was taken using a Marsh McBurney flow meter or an Oceanic flow bomb at the pre-redd depth. The flow bomb 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% from the water surface unless the water depth was greater than 2.5 ft, then, flow measurements were taken at 20% and 80% from the water surface and the values were averaged obtain a velocity. Dominant substrate size was classified using methods described by USFWS (2005). Redd substrate size was described using dominant size categories at three locations at the redd (1) pre-redd, (2) along one of the sides of the pit, and (3) tail-spill. Only one side of the pit was categorized and this was based upon the side that most best represented the substrate the redd was built in. Other measurements included maximum length and width of the total disturbed area; pre-redd depth (depth of the substrate immediately upstream of the pit); pit depth (deepest measurement in the pit); and tail depth (shallowest measurement of the tailspill). Redd area was calculated by using the formula for an ellipse (area = $\pi \cdot \frac{1}{2}$ width$\cdot \frac{1}{2}$ length).

Redd age.—Each redd was aged to determine how long it may have been there. This helped us to determine if a redd was missed on a previous survey or what flows may scour a redd. Algal growth, flattening and accumulation of fines can diminish the contrast of the redd against the substrate, which makes the redd difficult to detect. Age was broken into four categories based on the visibility of the redd which included age 2, clearly visible and clean; age 3, older, tail spill flat or pit with fines or algal growth; age 4, old and hard to discern; and age 5, no redd only a flag. From 2003-2005, we tracked the age of redds during each survey to determine the visibility of redds over time and after high flow events. This initially was done to determine how frequently surveys should be carried out, what flows may scour redds, and how many redds may be missed on a survey. If a survey week was missed, redd age could also help determine when a redd was first built. From this data we learned that without high flows, redds may be visible for 4 weeks in Clear Creek and flows above 3000 cfs may scour redds. In 2007, we only aged redds when they were first encountered.

Gravel injection in redds.—The presence of injection gravel in each redd was recorded to evaluate the use of spawning habitat created by gravel additions. Injection gravel has increased the amount of spawning habitat in Clear Creek. Observations of the distribution of injection gravel were made during snorkel and kayak surveys each year following high flows. Varying 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 (Figure 1). Gravel could be identified based upon the presence of tracer rock (non-native chert supplemented into gravel at the time of some injections), the uniform size, and observations concerning injection gravel movement. Although injection gravel was added in the lower alluvial section of the creek (reach six) it has mixed with native material and can not easily be distinguished in redds. The percentage of redds that contained injection gravel in reaches one to five is presented.

Redd index and redd distribution.—Our yearly steelhead index includes all redds counted during the kayak surveys. The index also includes redds that were observed during our spring Chinook snorkel surveys that occurred in June. Our yearly late fall Chinook index includes redds counted during kayak surveys only. Redd indexes from surveys since 2003 are presented for comparison and they may include redds counted during snorkel surveys in April-June or from the concurrent snorkel surveys used compare methods. Coordinates collected using GPS units were imported into Geographic Information System (GIS) to show the temporal and spatial distribution of redds both species.

Live fish and carcasses.—Observations of steelhead, late fall Chinook or lamprey on redds were recorded. In addition, all live adult late fall Chinook were counted. All carcasses were marked so they were not double counted on a subsequent survey. Fork length (FL), gender, spawning status and adipose fin clip were recorded and all carcasses with an adipose fin clip or an unknown clip status were returned for coded wire tag detection. Tissue, scale and otolith samples were also collected but not all of these samples have been processed and this information will not be presented here. Samples are stored at the RBFWO.

Results

In 2007, we conducted 6 full creek kayak surveys from January through April. Survey conditions were excellent based upon flow and turbidity data and only one scheduled survey was missed due to high flows in February (Table 1 and Figure 2 and Figure 3). For all six surveys combined, mean flow was 240 cfs and mean turbidity was 1.0 NTU. Table 1 includes survey conditions from previous years for comparison.

Steelhead

The steelhead redd index was 165 for the 2007 spawning season. Of this total, 2 redds were counted during snorkel surveys in June. Redd indexes since 2003 are provided for comparison (Table 2). The highest number of steelhead redds counted during a survey occurred during the second week of January (40% of the season total). Although 54% of the redds were counted during the 3 surveys in March, some may have been built in February because we did not survey that month. The highest density of redds occurred in river mile 17 and the second highest density was in river mile 5 (Figure 4 and Figure 5). In reaches one to five, 40% of steelhead redds contained injection gravel (Table 3). Steelhead were observed building or guarding seven redds. Redds were 92% and 8% age 2 and age 3, respectively. A total of 17 redds were measured and the average size was 23.12 ft^2. Average velocity was 1.69 ft/sec and average pre-redd depth was 1.56 ft. Substrate was evaluated at 23 redds and median size was 1-2 inches. A summary of redd measurements including previous years is presented in Table 4.

A total of 5 carcasses were retrieved during kayak surveys and 2 additional carcasses were retrieved in June during snorkel surveys (5 female, 1 male, 1 unknown). Only one female was spawned, the others were unspawned or unknown. They ranged in size from 250 mm FL to 420mm FL (mean FL=356mm).

Late fall Chinook

The late fall Chinook redd index was 25 for 2007. In addition, 39 live fish and 13 carcasses were counted (Table 5). Survey data collected since 2003 is included in Table 5 for comparison. Late fall Chinook redds were only found in reach six and their distribution is displayed in Figure 5. Of the 25 redds, 12% were in river mile 3, 48% were in river mile 4 and 40% were in river mile 5. Chinook were observed building or guarding 2 redds. Redds were 84% and 16% age 2 and age 3, respectively. A total of 11 late fall Chinook redds were measured and the average size was 151.63 ft^2. Average velocity was 2.19 ft/sec and average pre-redd depth was 1.40 ft. Substrate was evaluated at 11 redds and median size was 2-4 inches. A summary of redd measurements including previous years are presented in Table 4.

The average FL of late fall Chinook carcasses was 880 mm and there were 4 unknown lengths due to predation or decomposition. Sex ratios were 69.2% female, 15.4% male and 15.4 % unknown. Of the 9 female carcasses, 7 were spent and the spawning condition of 2 was unknown because predators ate part of the bodies. All males were recorded as unknown spawning condition. We retrieved 4 adipose fin clip carcasses but 3 of them were missing heads and could not be processed for coded wire tag recovery. The only coded wire tag that was recovered was from a 4 year old late-fall Chinook from Coleman National Fish Hatchery (Table 6). Coded wire tag information from adipose fin clipped fish retrieved from other survey years is shown in this table for comparison.

Discussion

The 2007 steelhead redd index was the highest since surveys began in 2003, suggesting that the population may be increasing due to restoration actions. The redd index may be difficult to interpret because it is uncertain to what degree differences in redd counts are related to surveying conditions or to changes in the population size. The effect of high flows on survey results varies each year, depending on their frequency and magnitude. High flows may result in fewer surveys or redd scour, which could lead to an under-estimate of the population.

Survey conditions were very good this season because turbidities and flows were low. Conditions were excellent for viewing redds during surveys and flows between surveys were low, making it likely that redds would not be obscured and therefore more apt to be detected. Only two high flows occurred during our survey season which caused us to cancel our scheduled survey in mid February. Since we could not reschedule due to weather, we did have a 4.5 week gap between surveys.

Redds may have been missed during this 4.5 week time period but probably not because flows scoured redds. It has been observed that flows that scour redds on Clear Creek are usually over 3,000 cfs. However, scouring may occur at a higher threshold depending on the duration of the flow and location of a redd. On Clear Creek, steelhead redds are often built near structure or banks which may protect them from scour. The first peak flow was 1280 cfs, and the duration of this flow event was short so it probably did not scour redds. The second storm event lasted over a few days but flows did not exceed 637 cfs. Although redds were probably not scoured during these storm events, flows may have flattened redd tailspills and made them more difficult to see.

Time can also make redds more difficult for surveyors to see because the movement of sediment may reduce the contrasting depth between the pit and the tail, and algae growth and aquatic insect re-colonization may darken the redd and make it difficult to stand out from the surrounding substrate. However, in previous years we kept track of the condition of redds between kayak survey weeks and results have shown that redds may remain visible on Clear Creek for at least 2-4 weeks if no scouring flows occur. The temporal distribution of redds may have been earlier than survey results suggest because we missed a survey in mid February. It is uncertain when redds observed on the late February survey were first built. The condition of redds during this survey showed that 15% had evidence of algae growth or fines in the tailspill (age 3), indicating that they may have been first built 2-4 weeks prior to this date.

Inaccuracies in redd counts and their use as an indication of spawning population size have been identified in Dunham et al. (2001) and Holecek and Walters (2007). We have taken several measures to minimize observer error in redd counts including providing extensive training to all surveyors. To further reduce inaccuracy, we survey the entire creek, use three surveyors to visually cover the full width of the creek, use labeled flagging to keep track of all redds, and time surveys as frequently as possibly, especially around storm events. Holecek and Walters (2007) also demonstrated that redd counts may over-estimate the number spawning females, due to the presence of redds without eggs, and construction of multiple redds per female.

Our results suggest that gravel supplementation has benefited steelhead. Gravel supplementation in Clear Creek has substantially increased the amount of available spawning habitat. The distance gravel has moved continues to increase as supplementation continues and high flows move more gravel. Consequently the amount that is available as spawning habitat has increased. As of 2007, injection gravel has distributed into approximately 15% of the length of the creek channel in reaches one to five. In 2007, 40% of redds in reaches one to five had injection gravel in them. Since 2003, an average of 34% of redds contained injection gravel. Earlier surveys of steelhead redds in 2001 and 2002 in reach one, which includes the Whiskeytown injection site, also showed that 30% of redds contained injection gravel. The 1-2 inch gravel at the Whiskeytown injection site was specifically provided for steelhead. 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. Two of the three areas with the highest redd density are immediately below gravel injection sites. The third area with high redd density is in Renshaw Riffle at river mile 5 in reach six.

In 2004, there was a large increase in total steelhead redds in reach six (Figure 4, which may be due to an increase in spawning habitat from gravel supplementation, dam removal and channel reconstruction and high flows re-distributing spawning gravel. Since 2004, an average of 35% of steelhead spawning occurs in reach six. Our late fall Chinook walking surveys from 1999 to 2002 suggested that no steelhead redds were detected prior to 2003 in reach six (M.R. Brown, RBFWO, unpublished data). However, these surveys targeted late fall Chinook carcasses and may have missed steelhead redds.

Restoration actions coupled with high flows helped to improve spawning gravel for steelhead in this reach. Gravel has been supplemented in this reach since 1996 using 1-4 inch gravel but this gravel size may be more suitable for Chinook salmon spawning than steelhead. When the McCormick Saeltzer Dam (located at the top of reach six) was removed in 2000, it opened the way for sediment transport of material located upstream of the dam which included smaller size gravel. In addition, in 2002, the 3A channel reconstruction project at river mile 3 provided more spawning gravel. The gloryhole spill high flow event in April of 2003 transported sediment and altered habitat in reach six which may also have created more suitable steelhead spawning habitat.

Beginning in fall 1995, flows were increased during steelhead and late fall Chinook spawning resulting in a large increase in available spawning habitat. In the following years, stream flows and the duration of the flow have increased to provide suitable flows and temperatures for all life stages.

Providing suitable water temperatures for rearing juvenile steelhead throughout the year may also have played a role in increasing the population. Clear Creek flows are managed at Whiskeytown Dam to provide optimal temperatures for rearing juvenile steelhead and adult spring Chinook. Optimal growth temperatures for juvenile steelhead are 59-64.4°F while lethal temperatures began at 75.2 °F (Moyle 2002). Since 1999, mean daily temperatures have been maintained at 60° F or less at the USGS Igo Gaging Station at river mile 10.9. Although temperatures may exceed this downstream, the mean daily temperatures at river mile 1.7 rarely exceed 70°F. In 1999, additional summer flows were provided in an attempt to maintain 60°F water temperatures down to river mile 5.1 in reach six. The improved temperatures may have been responsible for the increase in returns to reach six seen in 2003. Young-of-year steelhead that over-summered in 1999 would have returned to Clear Creek as 4 year olds in 2003.

Unlike fall Chinook (CDFG 2007), late fall Chinook have not increased in Clear Creek. Increased flows and habitat restoration would be expected to increase the late-fall population. We speculate that higher diversion rates from the Sacramento River during late fall outmigration in the late spring and summer, may have a greater impact on the late fall population than on the fall Chinook population which out-migrate in winter and early spring when diversions are relatively low.

Recommendations

We recommend doing concurrent snorkel and kayak surveys during the peak steelhead week each year to help assess how many redds may be missed by kayak surveys. Concurrent “calibration” surveys performed in 2004 indicated that snorkel surveys detected more redd than the kayak surveys. Although kayak surveys are efficient and allow for more frequent surveys, some redds are missed that would likely be detected by a snorkel survey. The 2004 calibration survey helped us to improve redd detection techniques during kayak surveys. Results from the 2005 calibration survey showed improved detection during the kayak survey. Redds that are only detected by the snorkel crew during the concurrent survey would be added to the redd index to give a better estimate of the total redds in the creek. It may be possible to develop a correction factor that could be applied to the redd index from kayak surveys alone, to more accurately estimate redd totals.

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TABLE 1.—Environmental conditions during kayak surveys conducted from 2003 to 2007. Mean (range) flow, median turbidity (range), and range of temperatures during the surveys.

Year	n=	Flow (ft^3/s)	Turbidity (ntu)	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

TABLE 2.—Steelhead redd index from 2003-2007. Redd index includes total redds counted during kayak surveys and snorkel surveys from December through June. Additional kayak surveys in some reaches were completed in 2003, 2004, and 2005 between the full creek surveys. Carcasses recovered include all fish during kayak, calibration or snorkel surveys from December through June and no adipose fin clipped fish have been found on Clear Creek to date.

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

[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).

TABLE 3.— Steelhead redds located in each survey reach and (% that contained injection gravel). Each reach is associated with 0-2 gravel injection sites. Reach 1: Whiskeytown; Reach 2: Need Camp Bridge and Need Camp; Reach 3: none; Reach 4: Placer; Reach 5: Clear Creek Road Bridge and Reading Bar.

Year	Reach 1	Reach 2	Reach 3 [a]	Reach 4	Reach 5	TOTAL
2003	71 (45%)	2[a]	1	2 (0%)	2[a]	78 (41%)
2004	54 (22%)	4[b] (0%)	9	18 (33%)	4 (0%)	88 (20%)
2005	78 (24%)	1 (0%)	7	15 (53%)	4 (25%)	105 (27%)
2006	23 (61%)	1 (0%)	0	2 (100%)	1 (0%)	27 (59%)
2007	61 (36%)	9 (0%)	6	18 (89%)	8 (38%)	102 (40%)

[a] Injection gravel was not available

[b] Injection gravel from Need Camp gravel was not available.

TABLE 4.—Summary of redd characteristics of steelhead and late fall Chinook redds for Clear Creek from 2003-2007. The mean (standard deviation) is provided for 2007 and 2003-2006.

Species	Year	n	Length (ft)	Width (ft)	Area (ft^2)	Pre-Redd Depth (ft)	Pit Depth (ft)	Tailspill Depth (ft)	Velocity (ft/s)
Steelhead	2007	17	7.16 (2.49)	3.83 (1.64)	23.12 (14.37)	1.56 (0.86)	1.75 (0.83)	1.07 (0.72)	1.69 (0.56)
Steelhead	2003-2006	292	6.47 (3.08)	3.60 (1.47)	20.74 (18.01)	1.72 (0.66)	1.89 (0.63)	1.48[a] (0.71)	2.01[a] (0.63)
Late-fall Chinook	2007	11	15.77 (9.85)	9.67 (5.01)	151.63 (178.80)	1.40 (0.37)	1.79 (0.22)	1.02 (0.36)	2.19 (0.74)
Late-fall Chinook**	2003-2006	32	15.20 (7.54)	7.72 (3.45)	106.01 (94.13)	1.38 (0.50)	1.68 (0.51)	0.91 (0.46)	2.16[b] (0.63)

[a] n=291 for tailspill depth and n=265 for velocity.

TABLE 5.—Late-fall Chinook redd index, live fish count, and carcass recoveries. The percentage of carcasses with an adipose fin clip is in parentheses. One unknown adipose fin clipped carcass was found in 2004 and four were found in 2005 and although heads were processed for coded wire tag detection, none were recovered.

	2003	2004	2005	2006	2007
Redds	24	20	28	14	25
Live	110	48	94	42	39
Total carcasses	42 (7%)	60 (5%)	34 (6%)	7 (14%)	13 (30%)[a]

[a]Two of the carcasses observed with no adipose fin were missing heads, so no tag information could be collected

TABLE 6.—Coded wire tag information retrieved from adipose fin clipped or unknown clip status Chinook carcasses. After tags were extracted data concerning their origin was retrieved from the Regional Mark Information System (RMIS) on the internet.

Collection Date	Adipose Fin Clip Status	Sex	Fork Length (mm)	Tag Code	Hatchery Origin	Run	Brood Year
1/9/2003	Clip	Female	820	055210	CNFH	Late Fall	1999
1/9/2003	Clip	Male	845	055207	CNFH	Late Fall	1999
1/17/2003	Clip	Male	Unknown	055134	CNFH	Late Fall	1999
1/15/2004	Clip	Female	900	050397	CNFH	Late Fall	2000
1/15/2004	Clip	Male	740	050768	CNFH	Late Fall	2001
1/23/2004	Unknown	Unknown	Unknown	NTD	NA	NA	NA
1/30/2004	Clip	Female	760	050768	CNFH	Late Fall	2001
12/16/2004	Unknown	Female	Unknown	NTD	NA	NA	NA
12/16/2004	Unknown	Unknown	Unknown	NTD	NA	NA	NA
12/16/2004	Unknown	Unknown	Unknown	NTD	NA	NA	NA
12/16/2004	Unknown	Male	Unknown	NTD	NA	NA	NA
12/16/2004	Clip	Unknown	470	051778	CNFH	Late Fall	2003
2/4/2005[a]	Clip	Unknown	Unknown	051166	CNFH	Late Fall	2002
2/8/2006	Clip	Unknown	870	NTD	NA	NA	NA
2/8/2006	Unknown	Unknown	Unknown	NTD	NA	NA	NA
1/11/2007	Clip	Female	Unknown	051699	CNFH	Late Fall	2003
1/11/2007	Clip	Unknown	810	NTD	NA	NA	NA
1/11/2007	Clip	Female	Unknown	no head	NA	NA	NA
1/23/2007	Clip	Female	Unknown	no head	NA	NA	NA

[a] This carcass was recovered downstream of the survey and coded wire tag information is only presented in this table and not part of the total recovered carcasses.

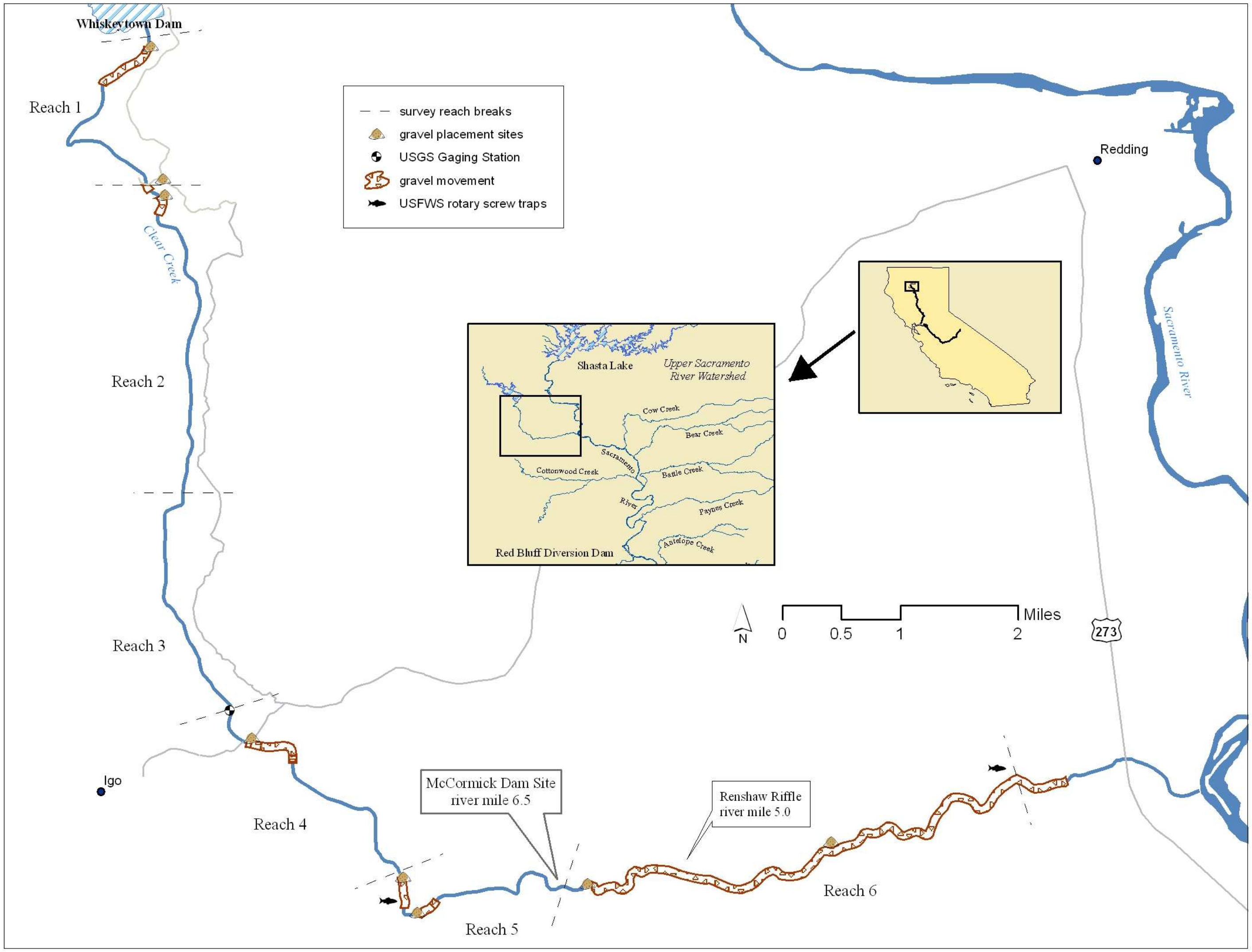

FIGURE 1.— Map of the study area, Clear Creek Shasta County, California depicting kayak reaches, the location of gravel injection sites and the distribution of injection gravel as of 2007.

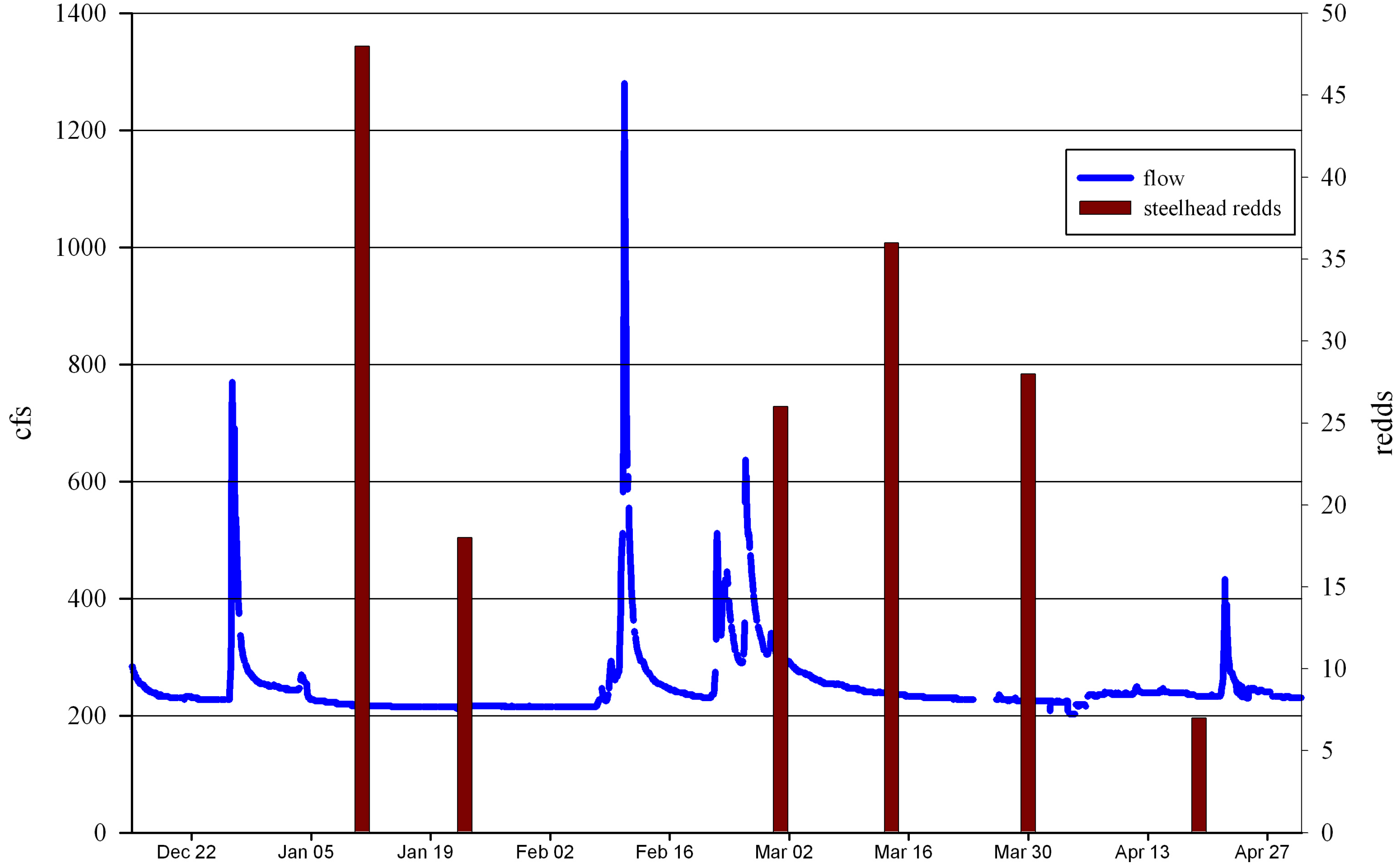

FIGURE 2.—Steelhead redds observed during each full creek kayak survey on Clear Creek in 2007. Hourly flows from the USGS gaging station at Igo are plotted to show the timing and duration of flows during the survey period.

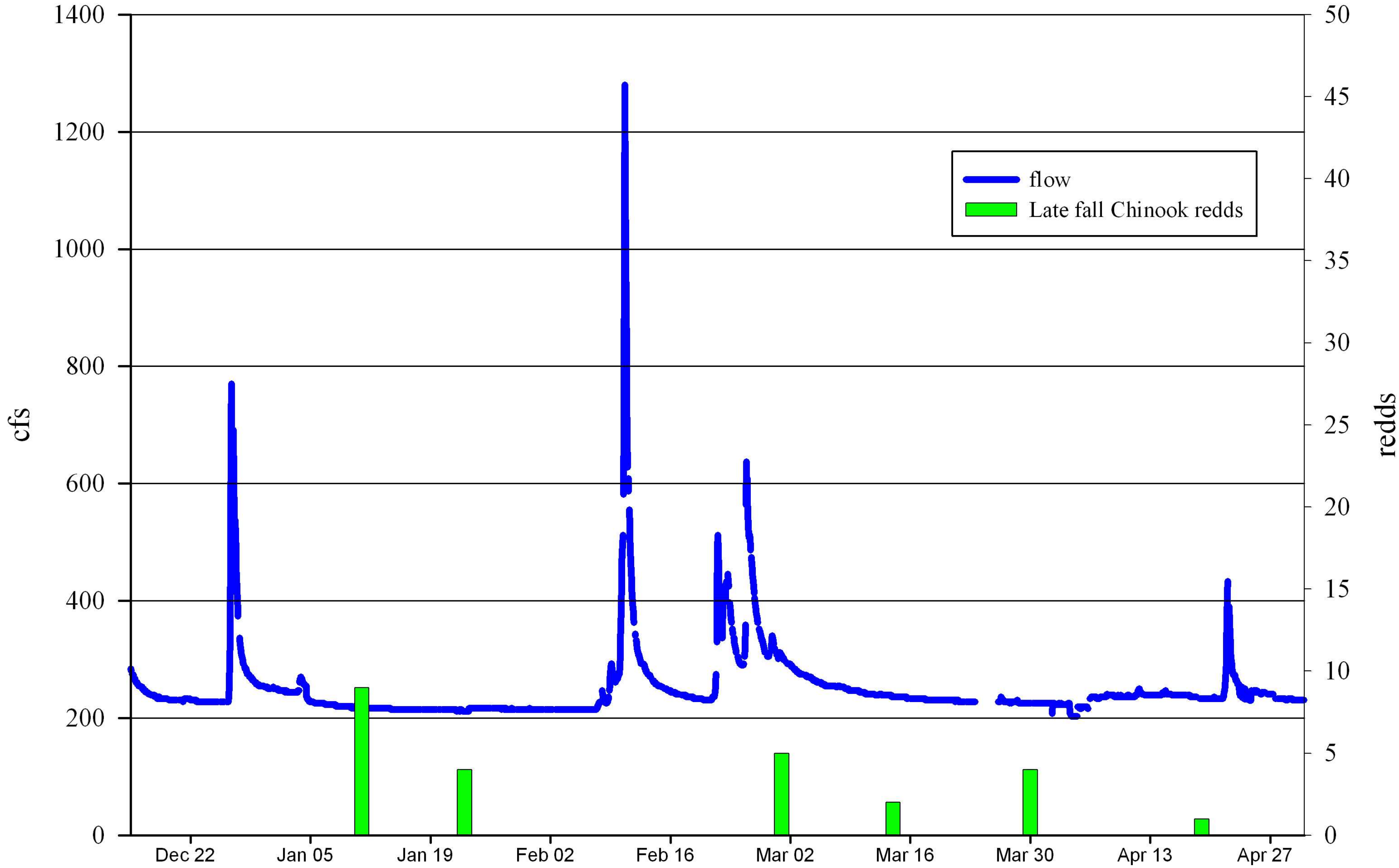

FIGURE 3. —Late fall Chinook redds observed during each full creek kayak survey in Clear Creek in 2007. Hourly flows from the USGS gaging station at Igo are plotted to show the timing and duration of flows during the survey period.

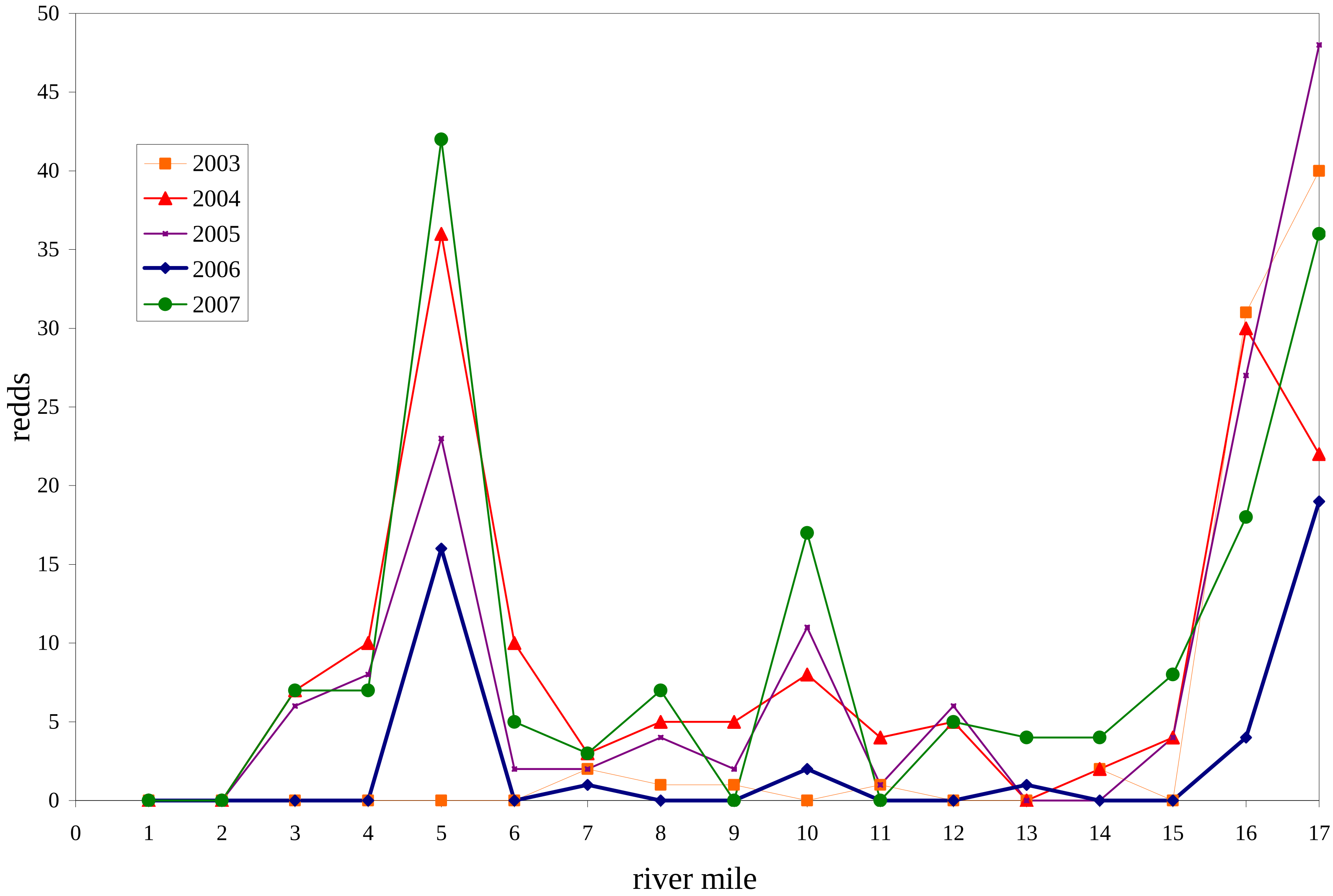

FIGURE 4.— Yearly redd index of steelhead redds per mile in Clear Creek from 2003-2007. The survey ends at the Lower Rotary Screw trap at RM 1.7.

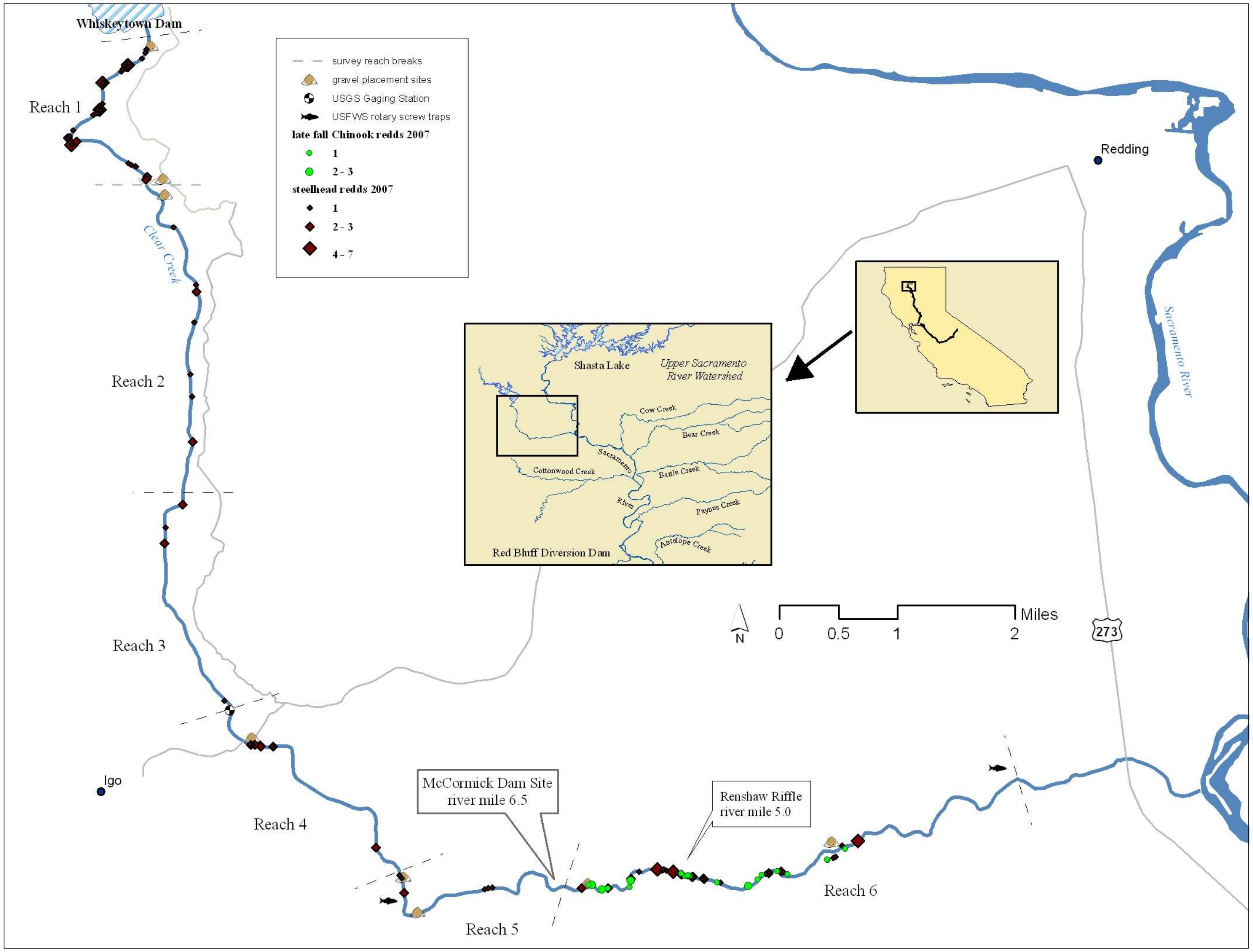

FIGURE 5.— Map depicting distribution of steelhead and late fall Chinook redds in Clear Creek during 2007.