ADULT AND JUVENILE STEELHEAD POPULATION SURVEYS, GUALALA RIVER, CALIFORNIA, 2007

Richard W. DeHaven
Fish and Wildlife Biologist
December 31, 2007
(As Revised April 8, 2008)

A dry South Fork, looking upstream from the South Fork bridge at Twin Bridges.

Downstream end (pool right center) of site #4A, beneath the Annapolis Road bridge.

Site #6-Twin Bridges (pool center foreground), looking downstream from the W. Fork bridge.

Downstream end of the House Creek site, with a dry Wheatfield Fork entering from right.

In recent decades, summertime dewatering of the stream, as shown here in 2007, has become pervasive in all but the wettest years. Stream dewatering eliminates aquatic habitat needed by juvenile steelhead for rearing, raises water temperatures of remaining habitat, and blocks access to critical travel corridors juveniles use to escape high water temperatures when moving to cool-water refugia. Dewatering is presently most severe in the vicinity of the South and Wheatfield forks confluence, but is incrementally increasing systemwide and is now a serious impediment to river restoration, including efforts to recover steelhead and coho salmon.

ADULT AND JUVENILE STEELHEAD POPULATION SURVEYS, GUALALA RIVER, CALIFORNIA, 2007

Richard W. DeHaven[1]
December 31, 2007
(As Revised April 6, 2008)

SUMMARY: Seasonal steelhead spawning surveys (counts of adults and redds) conducted in 2002-2006 along an 18.7-mile reach (Index Reach) of the Wheatfield Fork, Gualala River, California, were continued in 2007. The Index Reach was surveyed 9.5 times (176 miles) during the 5-month spawning season from a small, aluminum drift-boat. A total of 762 adult steelhead, the highest number to date, and 38 redds, were recorded; numbers of adult fish peaked in March when 532 (70%) were recorded. Based on area-under-the-curve-trapezoidal (AUC-T) methods, 2007 survey results and 5 preceding years of count data provided the first provisional population estimates, suggesting an annual spawning population on the Wheatfield Fork of from a low of about 400-500 fish to a high of about 1,800-2,400 fish, with an average of about 1,100-1,500 fish. These provisional estimates are considered conservative and are subject to revision, as estimates of survey life (SL) and observer efficiency (OE) used in the AUC-T methodology are improved and validated during future work. Annual population estimates were more closely associated with expanded (from OE) mean annual counts (R^2=0.85) than with either mean annual counts (R^2=0.80) or peak annual counts (R^2=0.80). Summertime snorkeling surveys of JSH were also continued in 2007 at 15 established sites. Snorkeling results suggested that: (1) summertime 2007 conditions for JSH rearing and production were relatively poor, owing to well below average annual and springtime rainfall; (2) Wolf Creek continued to be important to JSH rearing and production; (3) JSH undertook large-scale movements towards the estuary in mid-summer, followed later in summer with an exodus seaward, in response to summertime breaching of the estuary impoundment; (4) over summertime, JSH rearing became greatly diminished in the main stem of the Wheatfield Fork, due to low flow and elevated water temperatures. To complement standard spawning and snorkeling surveys in 2007, three related reconnaissance-level surveys were conducted via low-level helicopter flights. During two flights in mid-March, 169 adult steelhead and 6 redds were counted during survey of 83 miles of stream, with results showing that the main stem of the Wheatfield Fork (including Index Reach), lower House Creek and the lower South Fork were good candidates for a long-term spawning survey protocol based on helicopter methodology. A third and final helicopter survey along 29 miles of main-stem stream in late September suggested utility of this approach for monitoring dewatering. During 2007, dewatering, which poses a serious impediment to river restoration and salmonid population recovery, was most pervasive as usual in the vicinity of the South and Wheatfield forks confluence.

---

[1]Senior Fish and Wildlife Biologist (Retired 2004); U.S. Fish and Wildlife Service (Service), Sacramento, California. **Recommended Report Citation:** DeHaven, R. W. 2007. Adult and juvenile steelhead population surveys, Gualala River, California, 2007. Prepared by the author (drdehave@hotmail.com), December 31, 2007, for use by agencies, groups and individuals involved in steelhead recovery efforts. 106 pp. (This report and Appendix available on the author's website at http://www.gualalariversteelhead.info/homepage.html by mid-2008.)

CONTENTS

Summary---------- 2.
Introduction and Background---------- 4.
Acknowledgements---------- 4.
Methods---------- 5.
Spawning Surveys---------- 5.
Snorkeling Surveys---------- 7.
Surveys by Helicopter---------- 8.
March 15 Survey---------- 8.
March 24 Survey---------- 9.
September 27 Survey---------- 10.
Preliminary Population Estimates and Trend Analysis---------- 10.
Introduction and Background---------- 10.
Unique Index Reach Features Affecting Methodology Choice---------- 12.
Metrics 1-2-3: Mean Survey Count-Expanded Mean Count-Peak Survey Count---------- 13.
Metric 4: AUC-T Population Estimate---------- 13.
Precipitation and Hydrology---------- 15.
Angling Surveys---------- 15.
File Memos---------- 15.
Results and Discussion---------- 16.
2007 Spawning Surveys---------- 16.
Number and Timing of Surveys---------- 16.
Number of Redds---------- 16.
Number of Steelhead Carcasses and Live Adult Steelhead---------- 17.
Precipitation and Hydrology---------- 18.
Population Estimates and Indices---------- 22.
Snorkeling Surveys---------- 26.
Surveys by Helicopter---------- 28.
Initial Spawning Survey---------- 28.
Second Spawning Survey---------- 28.
Spawning Surveys: Common Findings and Conclusions---------- 29.
End-of-Summer Stream Dewatering Survey---------- 30.
Angling Surveys---------- 31.
Conclusions---------- 31.
Literature Cited---------- 33.

Tables:
1-Steelhead Spawning Survey Results for 2007---------- 17.
2-Annual Rainfall and Flow-Event Log for 2007---------- 19.
3-Steelhead Spawning Population Metrics, 2002-2007---------- 24.
4-Results of Three Summertime Snorkeling Surveys for 2007---------- 27.
Figures:
1-Hydrographs for Navarro and Gualala rivers, Steelhead Spawning-Season, for 2006---------- 20.
2-Hydrographs for Navarro and Gualala rivers, Steelhead Spawning-Season, for 2007---------- 21.
3-Steelhead Spawning-Season Rainfall, FRR and VEN gages, 2005-2007---------- 23.
4-Steelhead Spawning Population Trend, based on Metrics 1-4, 2002-2007---------- 25.

Appendix 1:
File Memos 63-81 for 2007 Surveys---------- 36.

INTRODUCTION AND BACKGROUND

Due to a lack of current information on the population status of steelhead in the Gualala River, a mid-sized northern California coastal stream, I initiated annual spawning surveys of steelhead on the river in 2001 (DeHaven 2001). These surveys were continued and expanded in 2002 through 2006, focusing on an 18.7-mile reach of the Wheatfield Fork delineated as an Index Reach for long-term population-indexing (DeHaven 2002-2006). In this report, I present results of 2007 spawning surveys along the Index Reach.

In addition, during summer 2004, I conducted reconnaissance-level snorkeling surveys of juvenile steelhead (JSH) at several locations in the watershed. From the initial snorkeling results, I developed and implemented, beginning in 2005, a long-term snorkeling-survey protocol to complement the spawning surveys. The 2007 results of the snorkeling surveys are also presented here.

Finally, in 2007 I also undertook three reconnaissance-level surveys of selected river reaches by helicopter. These surveys were designed to evaluate the utility of low-level helicopter flights for: (a) counting adult steelhead and their redds; (b) delineating the extent of summertime dewatering of the stream; and (c) identifying stream perturbations linked to the dewatering and/or other threats to steelhead.

Results from my various surveys and studies will be coalesced over at least a 10-year period in an effort to describe the current status and trend of the river's steelhead population. Related objectives of my work include adding to knowledge of life history of the river's steelhead; helping identify the most serious threats to the river's steelhead and coho salmon; and helping to develop the most effective strategies for recovering these listed species. Dissemination of information towards these objectives occurs through reports, such as this one, and via my website (gualalariversteelhead.info). In addition, starting in mid-to-late 2008, I will begin providing a series of seminars and lectures to disseminate findings, conclusions and recommendations.

ACKNOWLEDGMENTS

I thank Marc Felton for company during one of the spawning surveys and for his assistance on two of the reconnaissance helicopter flights–but more importantly, for funding one-half the charter cost for the three helicopter flights. I also thank "C. A.," for substituting for Felton during the second helicopter survey; and "E. B." and Greg Benke, each for their company during one spawning survey along the Index Reach.

METHODS

Spawning Surveys

Spawning surveys involve periodic counts of adult steelhead and their redds along the Index Reach of the Wheatfield Fork of the river. The Index Reach extends from the mouth of House Creek downstream to the confluence of the South and Wheatfield forks. This reach, which is navigable, was initially (2002) determined from USGS 7.5-minute topographic maps to be 18.3 miles in length. However, in 2007, a more accurate measurement taken using GPS "tracking" from the boat, showed the actual sinuous stream length (length actually surveyed) to be 18.7 miles, including 9.3 and 9.4 miles, respectively, on upper and lower sections (as separated by the Annapolis Road–or Clark's Crossing–bridge).

The Index reach is surveyed from a small (8-foot), aluminum drift-boat. In 2007, I conducted seven surveys alone and three surveys with one assistant following closely behind in a second survey boat. However, I always kept in the lead, and to maintain consistency over seasons, the data and observations recorded were mine alone.

A standard spawning-survey protocol, as developed and reported in 2002 (DeHaven 2002) was followed, with one addition–the estimated size of adults observed was also recorded. During 2002 through 2005 surveys, the size of adults observed was not recorded. I assumed there would be substantial difficulty in accurately estimating sizes of individual adult fish which are usually seen just briefly in groups in the deepest pools as the observer passes over in the small boat; and variation among different observers in size estimation would almost certainly be problematic. Size estimation would clearly be more reliable if the fish were actually being handled, or at least observed from underwater while snorkeling or diving. Nevertheless, as my overall experience has grown with the completion of almost 750 miles of surveys of the Index Reach, I believe that my accuracy in size estimation has improved to the point where it is probably worth attempting. Also, it is now clear that observer variation is not a viable issue, because I am maintaining my status as the primary observer for nearly every survey.

Thus, starting in mid-2006 and continuing throughout the 2007 spawning season, I recorded (estimated) all adult steelhead by the following size classes: size 1=≤24 inches (about 2-4 pounds) Total Length (TL); size 2= 25-31 inches TL (about 5-10 lbs); and size 3=≥32 inches TL (roughly >10 lbs). Any very large adults ≥34 inches TL (roughly ≥15 lbs) were also recorded.

In addition to standard surveys of the Index Reach, on January 27, 2007, I conducted one brief spawning survey (adult steelhead counts only) in the estuary, from the mouth of the North Fork downstream to the Highway 1 bridge. This survey was prompted by the very low river flow (<30 cfs at the Wheatfield Fork gage) which prevented navigation of the Index Reach. The river mouth was closed by a sandbar at the time of this survey.

During both the standard Index Reach surveys and the single estuary survey in 2007, survey protocol, including guidelines for using the survey boat, was strictly followed. It is worth reviewing this protocol again now, because it is critical for minimizing biases and generating the most useful possible survey data (at least using this particular boat-survey approach).

During my first few seasons on the river, I tested and evaluated several different kinds of survey boats. Kayaks and canoes were both tried and deemed unsuitable, because the observer sits too low for the best (glare-free) view of the stream bottom and adult fish; there are also numerous reaches that are unnavigable using such boats. Medium-and large-size drift-boats were also ineffective, due to their lack of maneuverability on such a relatively small, rocky stream and inability of the observer to see clearly into the water over the (relatively high) sides of the boat.

I eventually selected an 8-ft aluminum mini-drift-boat manufactured by Redwood Welding Service of Crescent City, California (1020 Hwy 101 North; 707-464-6218) for the survey vessel. These boats (two, presently) are highly maneuverable on water and for the past 4 years have been by far the vessel of choice for standard surveys of the Index Reach. They are similar in size and shape to the one-person (inflatable) survey boats that the Oregon Department of Fish and Wildlife has found to be the best choice for standard surveys of steelhead in coastal Oregon streams (Jacobs and Susac 2004).

However, achieving the best possible counts of adult steelhead necessitates following some very specific guidance for use of this boat during Index-Reach surveys:

- The bottom of the boat is covered (and recovered, as needed, during each season) with "Coat-It," a two-part epoxy material (Tap Plastics, Inc. and other outlets) containing graphite. This facilitates easy and quietest passage through the shallowest water and while sliding over rocks and boulders at the side of the stream during portages.

- Oars are 6.5-ft in length, made of aluminum, with fixed (clamped-on) oarlocks, which are either oiled liberally prior to each survey or appropriately "bushed" to eliminate any rowing noise which might otherwise frighten fish and "push" them ahead of the boat.

- A padded seat is added to the boat's standard aluminum rowing seat, to raise the observer (and reduce low-back strain during the 19-mile float) another 4-6 inches for a better view of the stream bottom.

- Surveys are restricted to periods of low turbidity, minimal surface turbulence (which can result from both wind and high flows), and good weather (without rainfall, fog or overcast conditions) to the extent possible. The goal is to always have conditions which allow the entire stream bottom–including the deepest pools–to be seen by the observer.

- The observer always wears good-quality polarized sunglasses for seeing into the water and a cap or hat suitable for shading from glare.

- The observer always sits facing the wide end of the boat (i.e., the stern) and "pushes" the boat downstream with the oars, maintaining a continuous, downstream view of the bottom (and thus any fish) as he goes. It is important to keep moving slightly faster than the current, so that fish are approached quickly and not "pushed" ahead of the boat, preventing their detection or causing recounts. When shallow or otherwise impassable sections of stream are encountered, the observer exits the boat briefly and drags it around the obstacle(s).

- Prior knowledge of traditional fish-holding places along the sample reach is essential. When approaching shallower holding places, the boat is "pushed through" with the oars, while keeping slightly to one side (shallower side) and maintaining speed faster than the current (to avoid "pushing" fish downstream ahead of the boat), *with the observer remaining seated*. When approaching the deepest holding places, the same approach is followed, except *the observer remains standing* (thus the need for a specific oar length–to allow rowing while standing) for a better view of the bottom (and any fish).

- When a group of fish is first detected, a single count is made and recorded on the first "pass" over them. Numerous attempts at repeat passes during dozens of surveys have shown that they invariably (90% of times) result in fewer fish being seen and recorded than on the initial pass.

- Survey start times each day are kept within a 90-minute (0830-1000 hrs) window in the morning. This helps ensure that differences in visibility of fish during the day due to the angle of the sun and daily wind patterns (e.g., afternoon upstream breezes) are held roughly constant among seasons. (Parken et al. [2003] and others have reported on the variability that different conditions at different times of the day can add to counts due to sun-angle changes and daily riffling patterns on the stream surface from wind.)

- Every survey is conducted by the same experienced observer(s).

Snorkeling Surveys

Snorkeling protocol and sites were detailed in my 2005 annual report (DeHaven 2005). Initially, nine study sites were selected across eight widely scattered locations in the watershed. The protocol was designed to be easily conducted over a 2-day period by a two-person team, with one person snorkeling while the other recorded data, including air and water temperatures. Generally, three snorkeling surveys are conducted over each summer, usually beginning in June.

In 2006, I added six new snorkeling sites in the vicinity of the nine original sites: **#3a**-Wheatfield Fork, 1/4-mi upstream from the Lady-in-the-Car site; **#4a**-Wheatfield Fork, directly beneath the Annapolis Road (Clark's Crossing) Bridge; **#4b**-Wheatfield Fork, 3/8-mi downstream from the Annapolis Road Bridge (i.e., about 100 yards upstream from the mouth of Haupt Creek); **#9**-Main stem, at the Highway 1 bridge in the vicinity of the unimproved boatlanding area; **#5c**-Main stem, the pool at the mouth of the North Fork where it empties into the main stem; and **#5d**-Main stem, about 100 yards upstream from the North Fork mouth.

Also, in 2007, I deleted one protocol element–measurement of water volume within each snorkeling site. Thus, JSH densities cannot be directly estimated. And discussions later in this report of relative JSH densities at certain sites are my best professional estimates (BPEs), based on the snorkeling counts (and flows) of JSH compared to previous counts, densities, and flows at the same sites.

In 2007, the three summertime snorkeling surveys were on June 14-15, July 15, and September 6.

Surveys by Helicopter

The three surveys conducted by helicopter in 2007 were on March 15th, March 24th, and September 27th. The aircraft for each survey was a Bell 206B-1 JetRanger III helicopter chartered from Wine Country Helicopters of Napa, California. Owner Wayne Lackey was the pilot. A total of 9.75 hours of air time was chartered. The two surveys in March were specifically to evaluate aerial counting of adult steelhead and steelhead redds; the September flight was designed to assess the extent of dewatering of main-stem stream reaches at end of summertime.

March 15 Survey– March 15th was selected as the first survey date, due to excellent weather (clear and calm, with high pressure aloft), the likelihood of adult steelhead being in the river in good numbers (based on 2007 and previous years' surveys), and a survey-friendly flow of about 131 cfs (Wheatfield Fork gage). The stream was quite clear, but to enhance visibility into the water, the flight was scheduled between 1200 and 1500 hours, when the sun was at its highest position in the sky. With 4.50 hours of air-time chartered, we planned to survey, in succession, four stream reaches: (1) Rockpile Creek, from its mouth upstream 10-15 miles; (2) Buckeye Creek, from 5-10 miles upstream of its mouth downstream to its mouth; (3) Wheatfield Fork, from its confluence with the South Fork upstream about 25-30 miles to the vicinity of its confluence with Tombs Creek (i.e., including the 18.7-mile Index Reach); and (4) House Creek, from its mouth upstream for 5-10 miles. Ranges of distance were set, since it was unknown how far we could survey in the allotted air time (note: all charters also included air time to and from the Napa County Airport).

The aircraft was flown in a meandering pattern following the stream at an average speed of 25-30 mph and average altitude of 200-250 feet. DeHaven was the primary observer. He rode in the rear seat behind the pilot (right side) with the rear sliding door fastened opened; both feet were outside on the right-side skid and his head extended from the aircraft for continuous viewing straight down into the stream. Felton rode in front to the left of the pilot and recorded data, both on field data forms and the GPS, a Garmin GPSmap 76Cx with external antenna fastened to the aircraft's roof. The GPS record included a "track" of each surveyed stream reach (and related transition flights between survey reaches), a starting and ending waypoint (WP) for each reach, odometer readings at various points of interest, and WPs recorded for redds and sightings of adult steelhead. Since the aircraft could not be flown perfectly above the meander of the stream, the "track" distance along each survey route was always less than the actual sinuous length of stream being surveyed.

The flight along each stream reach was continuous, without slowing or stopping to hover, except just briefly at beginning and end to record starting and ending points. However, about mid-way through the survey, a flight to Ukiah (also part of our air time) had to be made for refueling. We then returned and continued the survey along another reach. WPs and tracks were recorded onto Garmin's 1:100,000 topographic map of the Western U.S.

Neither still nor video photography was attempted during this initial survey. Nevertheless, photography will likely play an important role in any long-term helicopter survey protocol that may be implemented. In particular, high-quality, TV-station-grade, gyro-stabilized video would likely prove to be a useful and essential adjunct.

Five days before the survey (i.e., on March 9-10), I conducted a standard spawning survey of the Index Reach by boat. During this pre-survey I marked (short-lived marking paint on the nearby ground) each of 15 "favored" adult steelhead holding and resting pools of the Index Reach to ensure their identification from the air 5 days later. In addition, during the 2 days after the helicopter survey, I conducted another standard spawning survey of the Index Reach by boat.

Immediately after each stream reach was surveyed by Helicopter, Felton and I each recorded an independent (i.e., without knowledge of the other's estimate) estimate of the percentage of stream length we had been able to see clearly without obstruction from vegetation, shadows, wind ripples or terrain features. The two estimates, which were relatively close (maximum 15% difference) in each instance, were then averaged to provide a BPE of the actual survey coverage of each stream reach.

March 24 Survey–A second spawning survey, involving a total of 2.80 hours of air time, was flown 9 days later on March 24th. Only 0.04-inch of rainfall occurred during the interim period, thus the hydrograph had dropped even lower (<90 cfs at the Wheatfield Fork gage) and water clarity remained excellent. And weather remained clear and calm, with high atmospheric pressure aloft.

Survey procedures were the same as for the first survey on March 15th, except: (a) a biologist (C.A.) from the U.S. Fish and Wildlife Service in Sacramento assisted in place of Marc Felton; (b) only the Index Reach (18.7 "sinuous stream" miles) and South Fork, from Wheatfield Fork confluence upstream to the Hauser Bridge (13.7 "track" miles) were flown (c) average air speed (20-30 mph) was slightly slower and average altitude (175-200 feet) slightly lower; (d) a flight to Ukiah for refueling was unnecessary, because of the shortened routes; and (e) due to a redesigned safety harness, the primary observer was able to lean farther out of the aircraft, thereby improving visibility of the stream directly below.

During the 2 days just before the survey (i.e., on March 22-23), I conducted a standard spawning survey of the Index Reach by boat. I marked the seven redds that were found with spray paint or engineer's flagging, as appropriate, so that they could be assessed for visibility from the air the following day.

September 27 Survey–The final survey, involving a total of 2.35 hours of air time, was flown on September 27th. With the objective being to assess dewatering, our only concern was whether a continuous surface flow, however small, existed beneath the aircraft. This allowed flying slightly faster (25-35 mph) and higher (200 feet) than during the second survey. The three reaches surveyed were: (a) South Fork, from North Fork confluence upstream 7.25 miles (all mileages are "track"distances) to Wheatfield Fork confluence; (b) then upstream another 4.85 miles along the South Fork to the Stewart's Point-Skaggs Springs Road (Clipper Mill) bridge; and (c) then upstream along the entire Index Reach of the Wheatfield Fork for 16.6 miles. Otherwise, procedures were the same as during the first two aerial surveys.

Preliminary Population Estimates and Trend Analysis

This report is the first in which I present specific data and analyses focusing on the primary objective of my work–describing the present status and trend of the river's steelhead population. My initial data, estimates and discussions herein are my BPEs at this point in time. However, all such results are provisional; they may undergo revision and adjustment in 2008 and beyond, based on new information, analyses, and any constructive input received from qualified reviewers, including Department of Fish and Game and NOAA Fisheries.

Introduction and Background–Visual survey methods, in which observers periodically count fish throughout the spawning season in streams, have been used for assessing interannual trends of Pacific salmon (*Oncorhynchus* spp.) for more than 50 years (Holt and Cox 2008). Such methods are generally employed when direct enumeration of the population, using fences, weirs, sonar or similar absolute-count procedures are impractical, or where observers cannot determine which fish present in the stream entered since the previous count (Hilborn et al. 1999). Visual survey counts are most commonly acquired from the air over the stream or the ground along the stream, but can also be obtained from swimmers, divers or boaters traveling along the stream.

One of the most widely used methods for assessing visual count data is the area-under-the-curve-trapezoidal (AUC-T) approach (Ames and Phinney 1977; English et al. 1992; Hilborn et al. 1999; Holt and Cox 2008). AUC-T methodology involves several basic elements. One is the determination of observer efficiency (OE), also referred to as catchability, which is the proportion of fish counted on each survey to the total number in the stream during that survey. Using OE, the number of fish counted on each survey is expanded to the total fish present, which become the values plotted (graphed) by date. Typically, a zero fish count on day zero at the start of the survey and another zero count at the end of the survey are included. Next, fish-days, the sum of all the area under the resulting curve, are derived using the most common mathematical approach–the trapezoidal approximation. Survey life (SL) must also be determined. SL, also known as residence time, is the time that fish actually spend within the survey area–which can be either the entire stream or just a portion (e.g., a marked section, spawning grounds, tributary etc.). Then, an estimate of the population is derived by simply dividing fish-days by SL. A number of disadvantages of AUC-T methodology have been identified, including: (a) lack of rigorous methods for placing confidence bounds on population estimates; (b) problems posed by very sparse data sets or data sets where first or last counts are non-zero; (c) accuracy being highly dependent on year- and stream-specific estimates of SL and OE; and (d) the need for relatively high precision in SL estimates to obtain the most useful results.

Over the past 2 decades or so, a number of analytical approaches for estimating populations have advanced well beyond original AUC-T methodology, but have generally become much more cumbersome and complex (Korman et al. 2007; Holt and Cox 2008) in the process. For example, an area-under-the-curve likelihood (AUC-L) approach has been developed that allows uncertainty in SL, OE, and the arrival timing of fish entering the survey area to be incorporated into escapement estimates (Hilborn et al. 1999; Korman et al. 2002). Korman et al. (2007) took this issue a step further with some AUC-L refinements, including incorporation of information on departure timing of fish leaving the survey area. Nevertheless, Hilborn et al. (1999) compared results of AUC-T and AUC-L methodology across 18 streams where fish numbers were also evaluated by weir and carcass counts to conclude that for most data sets, the AUC-T method was reasonably adequate for estimating escapement. Parken et al. (2003) reported on a bootstrap computer simulation procedure for the AUC-T method that incorporates the uncertainty associated with fish counts, the shape of the spawner curve, OE, and SL.

In the latest advancement in survey-count analyses, Holt and Cox (2008) reported on a Monte Carlo simulation procedure they performed to evaluate the ability of four visual survey methods–AUC-T, AUC-L, peak count, and mean count–to detect 30% declines in coho salmon escapement over 10 years (i.e., the magnitude of trend that would warrant listing a coho population as threatened using present [Canadian] listing criteria). The mean count method outperformed all other approaches across a wide range of scenarios about true population dynamics and survey designs, suggesting that the mean count method may be suitable for monitoring coho escapements in relation to listing guidelines. In addition, based on the wide range of sensitivity analyses they conducted, the authors suggested that the mean count method has potential to outperform peak count and AUC methods for other salmon species, including steelhead. They also reported an advantage to clustering surveys near the historic peak date of abundance, a phenomenon expected to apply across most streams with anadromous salmonids.

Holt and Cox (2008) also reported, however, that the peak count method was capable of providing a level of monitoring performance similar to the mean count method, if daily escapement patterns among years were consistent. And Parken et al. (2003) reported from their bootstrap procedure that escapement estimates derived from peak counts (which are then expanded) were relatively precise although less reliable and accurate than AUC-T, when compared to independent mark-recapture escapement estimates for chinook salmon.

Meanwhile, since 2000 the California Department of Fish and Game has stepped up monitoring of salmon populations and development of the most effective survey procedures for various small streams and rivers along the north coast of the State. Redd surveys, live fish counts (for AUC applications), and salmon carcass capture-recapture are among the approaches being considered for long-term regional monitoring of California coastal salmonids (Boydstun and McDonald 2005). Also, in Oregon, redd counts have become the primary population monitoring metric of the Coast Salmon Inventory Project (Jacobs and Susac 2004). One promising application of redd counts involves estimating chinook, coho and steelhead populations in streams using redd areas generated in a stratified index sampling approach (Gallagher and Gallagher 2005). Because of difficulties in estimating uncertainty and the need for well-defined estimates of SL and OE, Gallagher and Gallagher (2005) and Gallagher (2005a) suggested that AUC methodologies may prove too cumbersome for long-term population monitoring efforts in coastal northern California.

Unique Index-Reach Features Affecting Methodology Choices–Consideration of the unique features of the survey area (Index Reach) and methodology provides a basis for selecting the most reasonable population monitoring metrics and procedures for initial examination. The Index Reach extends along the Wheatfield Fork for 18.7 miles, from the confluence with the South Fork upstream to the confluence with House Creek. Both the South Fork and House Creek are major spawning tributaries, as is Fuller Creek, the largest stream entering the Index Reach, at about Mile 7. Haupt Creek, at Mile 9 (smaller than Fuller Creek), is also a spawning tributary.

The Index Reach is a main-stem section of river, with the Wheatfield Fork being the largest of the river's five main branches. Flows through the Index Reach, as estimated from the former (currently present, but inoperable) USGS Wheatfield Fork gage located near Mile 1, range up to 30-40,000 cfs and ≥10,000 cfs flows are recorded in most years.

As a result, while the Index Reach has steelhead spawning in most years, it is limited and the reach is better characterized as a migration corridor to upstream spawning reaches on the Wheatfield Fork and tributaries. Fish typically move relatively quickly through, when the hydrograph is either rising or falling, however, "holding" (or "reverse" movement) can and does occur during protracted periods of high and low flows.

As a result of such features, encounters with adult fish during surveys are atypical of what occurs on smaller coastal streams and/or areas that are more important for spawning. Most Index-Reach adult steelhead occur in small groups of from 8 to 40 fish; groups are generally scattered throughout the survey area during any given survey. While actual numbers of fish in groups might easily be miscounted, a group is generally less likely to be completely missed during survey than an individual fish or pair of fish. Moreover, in the Index Reach, adult fish are rarely initially encountered hiding in cover (which makes them more likely to be seen); they typically move into hiding only if a second pass with the boat is attempted or a second boater is following behind the first. The Index Reach is closed to all fishing and thus other humans, except for an occasional poacher, are rarely seen during surveys. Such characteristics are in sharp contrast to smaller streams where adult fish are often first encountered hidden or partially hidden under cut banks or woody cover. Only in low-rainfall low-flow periods and at the end of the spawning season does the Index Reach take on greater importance as a spawning reach, with resultant adult fish behavior becoming more typical of smaller northern California coastal streams.

Metrics 1-2-3: Mean Survey Count-Expanded Mean Count-Peak Survey Count–On the basis of the recent work by Holt and Cox (2008), I have employed a simple mean annual survey count as one of the initial analysis metrics. As these authors pointed out, the success of the mean count method can be attributed to its simple, data-based estimation procedure that requires no assumptions to be made about the shape of the daily abundance curve or the length of time fish remain in the survey area. Nevertheless, as a second metric for the initial analyses, I have also included the expanded (based on OE [see below]) mean annual survey count. And finally, I have included one other metric which could prove useful–the peak survey count recorded each season. I have not included any metrics relative to redd counts or redd area, since the Index Reach is not primarily a spawning reach consistently used for spawning.

Metric 4: AUC-T Population Estimate–Population size is also estimated here through basic AUC-T methodology, with the survey area being the Index Reach and the survey period being the steelhead spawning season each year. Based on several previous surveys during mid-to-late April over a wide range of flow conditions in which at least a few adult fish and/or new redds were always recorded, the end of the spawning season was assumed to be April 30th (i.e., an assumed zero count) for all years. The start of the spawning season each year (another assumed zero count) was the first day after November 1st that a flow ≥500 cfs was recorded at the Wheatfield Fork gage (or Navarro River gage at Navarro, when the Wheatfield Fork gage was/is inoperable). My experience indicates that such a flow threshold must occur before adult fish begin moving upstream into the survey area, although fish can and do sometimes enter the river mouth and hold in the estuary before this.

Under these assumptions, the 2002-2007 spawning seasons were from 137 to 159 days in length, starting between November 22nd and December 14th annually. To the extent that rainfall and flows allowed, the goal each year was to spread five to ten surveys as uniformly as possible over each spawning season.

OE was determined for each survey based on criteria for stream flow, water clarity, and weather that I established in 2002 and recorded in the respective File Memo (FM) for each survey. Flow was rated either **H**igh (>200 cfs), **M**oderate (75-200 cfs), or **L**ow (<75 cfs), based on the Wheatfield Fork gage (or Navarro River gage when the Wheatfield Fork gage was inoperable); water clarity was rated either **E**xcellent (bottoms of all pools visible) or **F**air (bottoms of up to 50% of deepest pools not visible); and weather was also rated either **E**xcellent (sunny and clear, with little or no wind during the survey) or **F**air (clouds, rain, fog, wind, or other adverse weather factors hampering visibility of pool bottoms during 50% or more of the survey). Higher flows, lower water clarity, and adverse weather factors (for observing fish) were all assumed to lower OE. A matrix of potential (to date) three-letter acronym combinations representing flow-clarity-weather and their equivalent OEs was developed from BPEs (with consideration of literature) as follows: HFF=0.2; HEF, MFF, and HFE=0.4; MFE, HEE, and MEF=0.5; MEE=0.6; LEF=0.7; and LEE=0.8. OEs thus ranged from 20 to 80%; while there is presently no data with which to begin validation of these estimates, this is an objective I will be pursuing starting in 2008.

Nevertheless, because of the unique physical and biological characteristics of the Index Reach combined with the unique survey methodology, there was no justification for applying any OEs reported for other streams (including those recently studied in California) directly to the Index Reach. For example, Gallagher (2005a) reported that OEs for steelhead (several different estimates) on the much smaller Noyo River and Pudding Creek, California from various foot and kayak surveys ranged from 4.5 to 25%. Gallagher (2005b) did report, however, on predictive models he developed based on stream flow and water clarity for estimating steelhead OE from foot and kayak surveys along the north coast. In a more distant example (British Columbia) on a different type of stream (5^{th}-order, glacially-fed) with a different survey method (snorkeling), Korman et al. (2007) found average OEs for steelhead of 13-27% and his earlier work on the same stream generated OEs for individual surveys of from 3-91% (Korman et al. 2002).

Weekly estimates of SL were generated and used to calculate mean SL for each season. SL was based on the premise that adult steelhead "go with the flow" upon entering the Index Reach. An underlying assumption was that under the most favorable migratory conditions, as represented by either a rising or falling hydrograph accompanied by sub-maximum turbidity, basic SL was 6 days. Thus, a fish moving all the way up then back down the entire Index Reach (not all fish do) would average about 6.2 miles/day. Such a rate of travel would not appear to be unreasonable, given that for actively migrating adult steelhead in various main stem river reaches, telemetry and trapping studies have recorded movement rates ranging from a low of about 3-5 miles/day to a high of about 20-24 miles/day. In addition, however, a second underlying assumption for SL estimates was that movements of adult fish essentially stop at certain high and low flows, and are incrementally reduced at certain other low, "transitional" flows.

The "zero movement" high- and low- flow criteria were set, respectively, at ≥3,000 cfs and ≤75 cfs; the number of consecutive days at such flows were added to the basic SL of 6 days when deriving weekly SL estimates. In addition, a transitional period was assumed to occur from 150 cfs to 75 cfs (*see* FM 86-87 for 2008), with zero movement days increasing linearly from zero to 1.0 as flow declined (i.e., 135 cfs=0.2, 120 cfs=0.4, 105 cfs=0.6, 90 cfs=0.8, etc.); these increments were also added to basic SL as appropriate. Thus, the first step in the procedure was to print out the hydrograph for the whole spawning season. All zero and low movement days were then identified and marked. Next, the seasonal weekly SL schedule was superimposed on the hydrograph and the weekly SLs determined. For example, for weeks 17 and 18 in 2007, SL was 21 (6+15) and 12 (6+6) days, respectively, due to low-flow criteria being exceeded during a 33-consecutive-day period of late March through April. Similarly, high-flow excedences in 2006 resulted in several weekly SL estimates of from 8 to 15 days. Overall, with this derivation procedure, SL estimates for the 2002-2007 seasons averaged from 6.4 (2005) to 10.2 (2007) days, with the underlying weekly estimates ranging from 6 to 31 days.

In comparison, Gallagher and Gallagher (2005) reported seasonal SLs for steelhead in a number of smaller north-coast (California) streams of 12.6 days for tributaries and 41.3 days for main-stem sections. Further study of two of these streams in 2004-05 resulted in an overall stream SL of 16.8 days for steelhead. On Freshwater Creek, California, Ricker (2002) reported a SL of 50 days for steelhead. From long-term studies on Waddell and Scott creeks, California Shapovalov and Taft (1954) estimated that steelhead spawning took 14 days. However, in each of these examples, the study area was the entire stream, i.e., all migration and spawning reaches. Thus, along with numerous other examples from the literature, none of these earlier SL estimates were deemed appropriate for direct application to the Index Reach. Basing SL instead on flow was considered a reasonable alternative. While there is presently no data with which to begin validation of the SL derivation procedure, just as with OE, this is a goal I will be vigorously pursuing starting in 2008.

Precipitation and Hydrology

Now in my 8th year of work on the river, I continue to find new reinforcement of how numerous aspects of steelhead behavior, and indeed, their very populations, are strongly and inextricably tied to seasonal rainfall and resulting stream flows. The metaphor that steelhead "go with the flow"could not describe this relationship any better. Moreover, precipitation and flows govern when surveys are feasible and how results relate to the real populations–for both individual surveys and over entire seasons.

As a result, starting in 2007, I will devote more time and effort to annual analyses of rainfall and flows. This is essential not only for interpreting my findings now, but for fairly and accurately contrasting my findings with past work, any collateral studies that others may do now, and future studies of the river. Accordingly, I have introduced a rainfall- and flow-event log beginning with this season. In this, a rainfall event is defined as 1 or more consecutive days with measurable precipitation, as determined by the realtime rain gage at Venado (VEN) on the Russian River watershed (but near the easterly, upper elevations of the Gualala watershed and thus a good index). Resulting effects of rainfall on flows are inferred from the realtime USGS gage on either the Wheatfield Fork or Navarro River, as appropriate. The log also tracks cumulative seasonal rainfall.

Angling Surveys

In 2007, I made two angling trips to the river, primarily to assist two friends in catching (and releasing) one of these magnificent fish. The first trip with one friend was February 16th, a float-fishing trip from Twin Bridges to the mouth of the North Fork. A second trip with the other friend was on March 5th, a float-fishing trip from the mouth of the North Fork downstream to the Highway 1 bridge.

File Memos

As in the past, for each survey (i.e., spawning, snorkeling, helicopter, or angling) a Memorandum to the File (File Memo=FM) was prepared. FMs are diary-type reports which have undergone minimal editing. FMs often include procedures, raw data, findings, discussions, conclusions, and photographs–often in greater detail than presented in annual reports such as this one. Altogether for 2007, 19 FMs (#063-#081) were prepared; these, as well as this annual report, will be available on the internet (gualalariversteelhead.info) by about mid-2008.

RESULTS AND DISCUSSION

The 2007 findings follow below. The relevant FMs from individual surveys are referenced, as appropriate.

2007 Spawning Surveys.

***Number and Timing of Surveys*–**Nine complete surveys of the Index Reach were conducted (Table 1) between December 17, 2006 and April 18, 2007 (FMs 64-67, 71, 73-74, 76-77). In addition, one partial survey of the uppermost 7.5 miles of the Index Reach (excluded from various analyses) occurred on November 29-30, 2006 (FM 63); this was the earliest spawning survey attempted to date. Unfortunately, this survey had to be aborted, due to extremely low (unnavigable) flow and discovery after the first day, that the river mouth was still (following early-season rainfall) closed by a sandbar. Of the nine complete surveys, one was in December, three were in January, four were in March, and one was in April. Substantial rainfall and high stream flows during February precluded surveys during that month.

***Number of Redds*–**A total of 38 steelhead redds were found, including 22 and 16 in upper and lower survey reaches, respectively, of the Index Reach (Table 1). However, on surveys through mid-March, only 4 (11%) redds were found on the Index Reach. Thirty-six (95%) of the redds were found during four late-March to mid-April surveys and more than half (20=53%) were found during the final survey in mid-April.

The total number of redds exceeded the two redds recorded for the 2006 spawning season, but was less than numbers in several earlier seasons. Locations (GPS coordinates) of the 2007 redds will later be coalesced with previous years' results and plotted on maps; resulting data will be available on my website by about mid-2008.

Numbers of lamprey redds found in 2007 remained low compared to previous seasons. The first two lamprey redds of the season were found on March 9-10 (FM 71). On the following four surveys (FMs 72-73, 75-76) several dozen more lamprey redds were tallied, up to a maximum of 35 on March 29-30. However, because no effort was made to identify and track "new" redds (i.e., only total counts were made during each survey), many were recounted during subsequent

Table 1. Steelhead spawning survey results, Wheatfield Fork index reach, Gualala River, 2007 season.[1]

Date(s) and Observer(s)	Conditions			Number Adults							% Kelts	Number Redds		
						By Size Class								
	F	C	W	Up. Rch.	Lwr. Rch.	1	2	3	4	T		Up. Rch.	Lwr. Rch.	T
11/29-30; RD	L	E	E	0	NS	0	0	0	0	0	0	0	NS	0
12/17-18; RD	M	F	E	6	0	0	6	0	0	6	17	0	0	0
1/1-2; RD/MF	H	F	E	10	10	1	9	10	0	20	5	1	0	1
1/10-11; RD/GB	M	E	F	51	44	3	49	41	2	95	11	0	0	0
1/19; RD/EB	M	E	F	67	13	8	50	22	0	80	21	1	0	1
3/9-10; RD	M	F	F	41	73	32	60	22	0	114	21	0	0	0
3/16-17; RD	M	E	E	37	105	35	81	26	0	142	11	1	1	2
3/22-23; RD	M	E	E	55	102	64	72	21	0	157	4	2	3	5
3/29-30; RD	M	E	F	15	104	33	59	27	0	119	17	7	2	9
4/17-18; RD	L	E	F	2	27	14	15	0	0	29	28	10	10	20
Totals	-	-	-	284	478	190	401	169	2	762	15	22	16	38

[1]*See individual survey reports (File Memos) for further detail. Conditions as follows:* ***flow (F)****:* ***H****igh=>200 cfs;* ***M****oderate=75-200 cfs;* ***L****ow=<75 cfs.* ***clarity (C)****:* ***E****xcellent=bottom of all pools visible;* ***F****air=bottom of up to one-half of the deepest pools not visible.* ***weather (W)****:* ***E****xcellent=sunny and clear, with little or no wind during most of day;* ***F****air=clouds, rain, fog, wind, or other adverse weather factors hampered visibility of the bottoms of the deepest pools during half of more of the survey.* Adult size criteria: size 1=≤24 inches TL (roughly 2-4 lbs); size 2=25-31 inches TL (roughly 5-10 lbs); size 3=≥32 inches TL (roughly ≥10 lbs); and special note made of any very large adults over ≥34 inches TL (size 4=roughly ≥15 lbs). NS=Not Surveyed

surveys and a total count of lamprey redds for the season is not available. Only three live lampreys were observed during the season.

Number of Steelhead Carcasses and Live Adult Steelhead–One carcass of an adult steelhead was found during the January 1-2 survey. No other carcasses were found during the 2007 spawning season.

A total of 762 adult steelhead was counted during the nine compete surveys, including 284 (37%) and 478 (63%), respectively, on upper and lower survey reaches (Table 1). This was by far the most fish counted to date on the Index Reach for a single spawning season. The four March surveys alone yielded a total of 561 (74%) adults, with most counted on the March 22-23 (157=21%) and March 16-17 (142=19%) surveys. In addition, on the January 27th survey in the estuary, 60 adult fish were recorded in one group in the Thompson Pool; however, over about half of the survey that day, I was unable to see to the bottom of the deepest pools due to turbidity and surface turbulence due to wind (FM 68).

Steelhead kelts were recorded during each survey of the Index Reach (Table 1). The proportion of kelts peaked at 28% for the April 17-18 survey and averaged 15% per survey. Kelts were estimated at 17% during the first survey on December 17-18, 2007, just 5 days after the start of the steelhead spawning season for the river, based on the 500 cfs flow criterion (and 9 days after a 400 cfs rise of flow starting December 8th).

Adult numbers estimated by size classes were: 190 (25%) size #1, 401 (53%) size #2, and 169 (22%) size #3; and 2 (0.3%) unusually large adults ≥34 inches TL. Also, the results suggested a trend towards smaller fish at the end of the spawning season.

Precipitation and Hydrology–Overall, 2007 was a below-average water year for the watershed. While there were 23 seasonal rainfall events lasting from 1 to 6 days and depositing up to 12.5 inches each (Table 2), the 41.0 inches of total seasonal precipitation recorded was only about 75% of average and 49% of 2006 rainfall. The maximum (6-day) event of 12.5 inches began on February 6th.

Noteworthy maximum 1-day rainfall amounts were 4.0 inches during the February 6th event and 3.9 inches during a December 26th event. The wettest months were February (18.8 inches) and December (11.6 inches), while October (0.4 inch), March (0.5 inch), and January (0.7 inch) totals were far below average. Spring months were relatively dry, as evidenced by only 4.2 inches of rain during the entire March-May period.

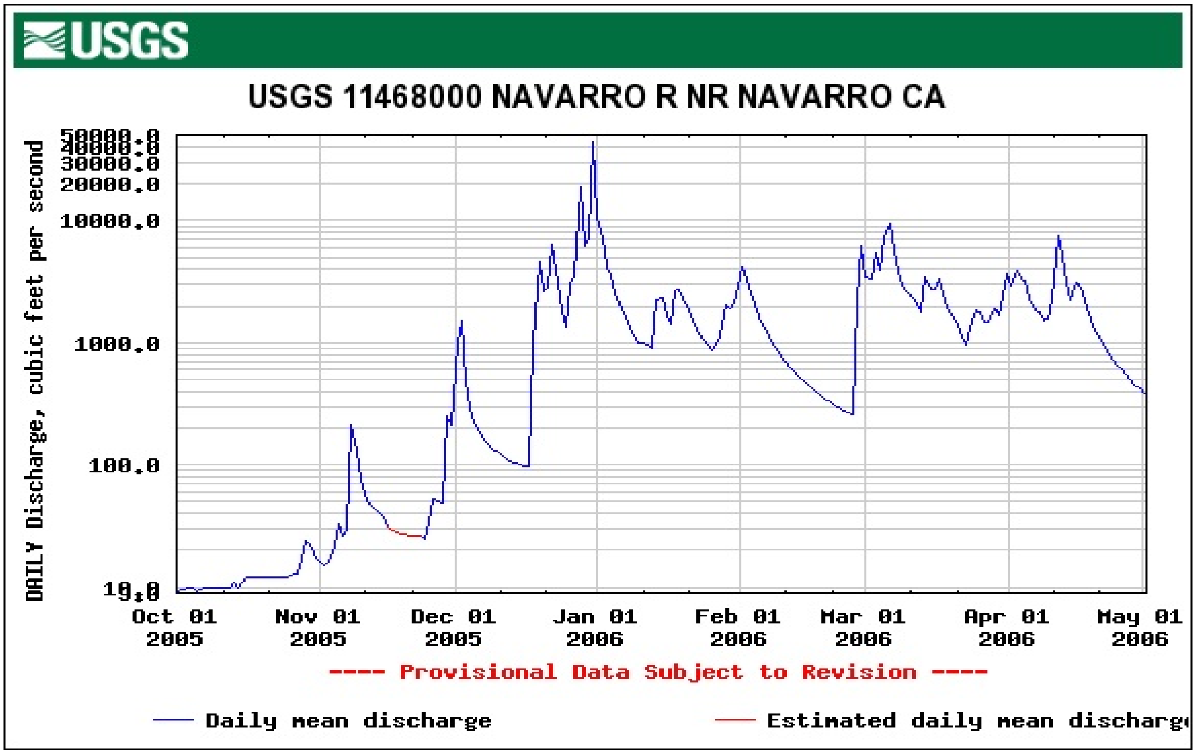
Maximum direct effects of 2007 rainfall events on flows were: +9,000 cfs (February 7th event); +6,000 cfs (December 26th event); and +2,600 cfs (February 24th event). All other hydrograph increases during the season were <2,000 cfs, with most (49%) ≤500 cfs (Table 2). During March-May, the largest flow increase was about 467 cfs on April 21st; no other flow increase exceeded 50 cfs during this period.

USGS's provisional hydrographs for the 2007 season for the Wheatfield Fork compared to the Navarro River illustrate the seasonal flow peaks and durations (Figure 2). (Minor deviations from Table 2 data occur due to provisional changes by USGS.) Two important points are illustrated. First, by May 1st, at least 1 month before the start of the critical summertime rearing period for JSH, the Wheatfield Fork had already declined to <40 cfs. Second, there was clear and close association between Wheatfield Fork and Navarro River flows over the entire season. This has important implications in support of using Navarro River flows to index Wheatfield Fork flows, as necessary, when the USGS Wheatfield Fork gage is inoperable.

Close association between Navarro River and Wheatfield Fork flows is also evidenced from the respective 2006 seasonal hydrographs (Figure 1). However, with 2006's much higher rainfall and flows, there were a few notable exceptions to hydrograph parallelism. In particular, the peak flow at the end of December was recorded as about 30,000 cfs for the Navarro, but only about 12,000-15,000 cfs for the Wheatfield Fork. Also, at the critical May 1st milepost just prior to

Table 2. Annual precipitation and rainfall event log for the Gualala River watershed, 2006-2007 season (October-September), as inferred from the realtime rainfall gage located at Venado on the Russian River watershed. (Flow effects as inferred from the realtime stream gage at Navarro on the Navarro River through Event No. 13; thereafter, based on the realtime gage on the Wheatfield Fork, Gualala River.)

No.	Starting Date	No. Consecutive Days Rainfall	Max. 1-Day Rainfall (in)	Total Event Rainfall (in)	Max. Effect on River Flow at Twin Bridges	Season Cum. Total Rainfall (in)
1	Oct 04	2	0.28	0.44	+<10 cfs	0.44
2	Nov 02	1	1.16	1.16	+15 cfs	1.60
3	Nov 11	3	1.12	2.08	+100 cfs	3.68
4	Nov 16	1	0.32	0.32	+<10 cfs	4.00
5	Nov 21	2	0.24	0.28	+<10 cfs	4.28
6	Nov 26	2	0.96	1.08	+100 cfs	5.36
7	Dec 08	3	1.44	3.28	+400 cfs	8.68
8	Dec 11	5	1.56	2.48	+1,200 cfs	11.16
9	Dec 21	1	1.48	1.48	+550 cfs	12.64
10	Dec 26	2	3.88	4.32	+6,000 cfs	16.96
11	Jan 03	2	0.52	0.60	+125 cfs	17.56
12	Jan 27	1	0.13	0.13	No change	17.68
13	Feb 07	6	3.96	12.48	+9,000 cfs	30.16
14	Feb 21	2	1.92	2.68	+1,800 cfs	32.84
15	Feb 24	4	1.32	3.68	+2,600 cfs	36.52
16	Mar 20	1	0.04	0.04	No change	36.56
17	Mar 26	1	0.44	0.44	+25 cfs	37.00
18	Apr 11	1	0.24	0.24	+13 cfs	37.24
19	Apr 14	1	0.28	0.28	+11 cfs	37.52
20	Apr 19	1	0.48	0.48	+10 cfs	38.00
21	Apr 21	2	1.76	2.08	+467 cfs	40.08
22	May 03	3	0.28	0.64	No change	40.72
23	Jul-Oct	--	0.12	0.16	No change	40.88



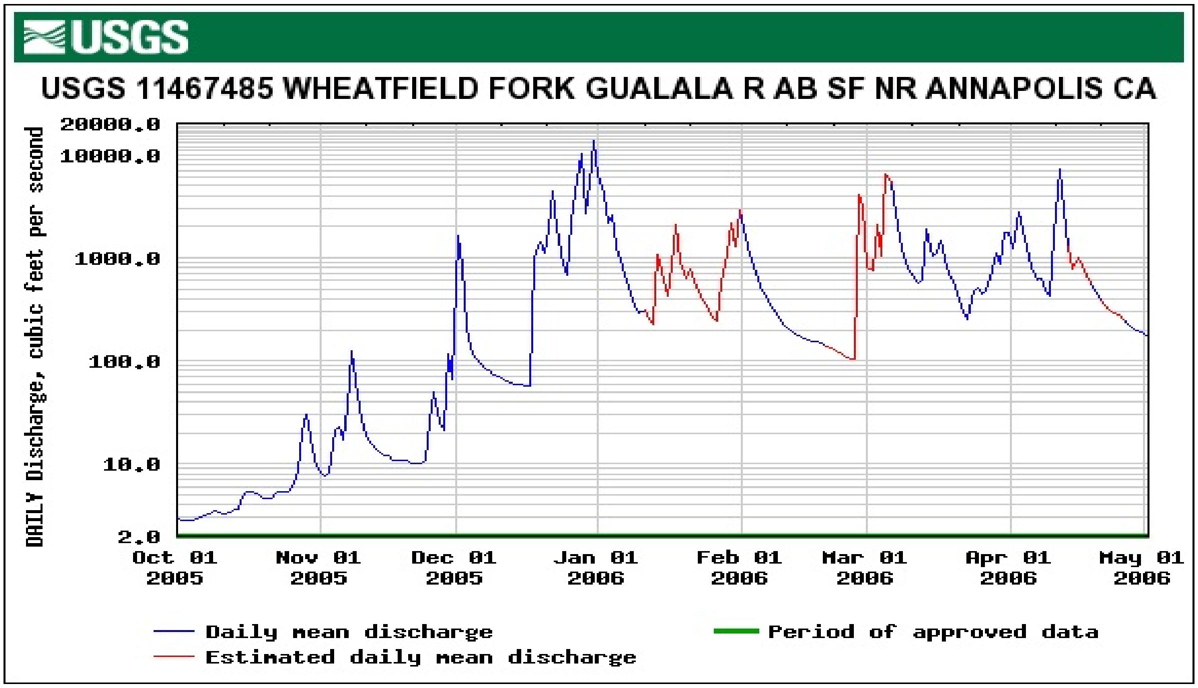
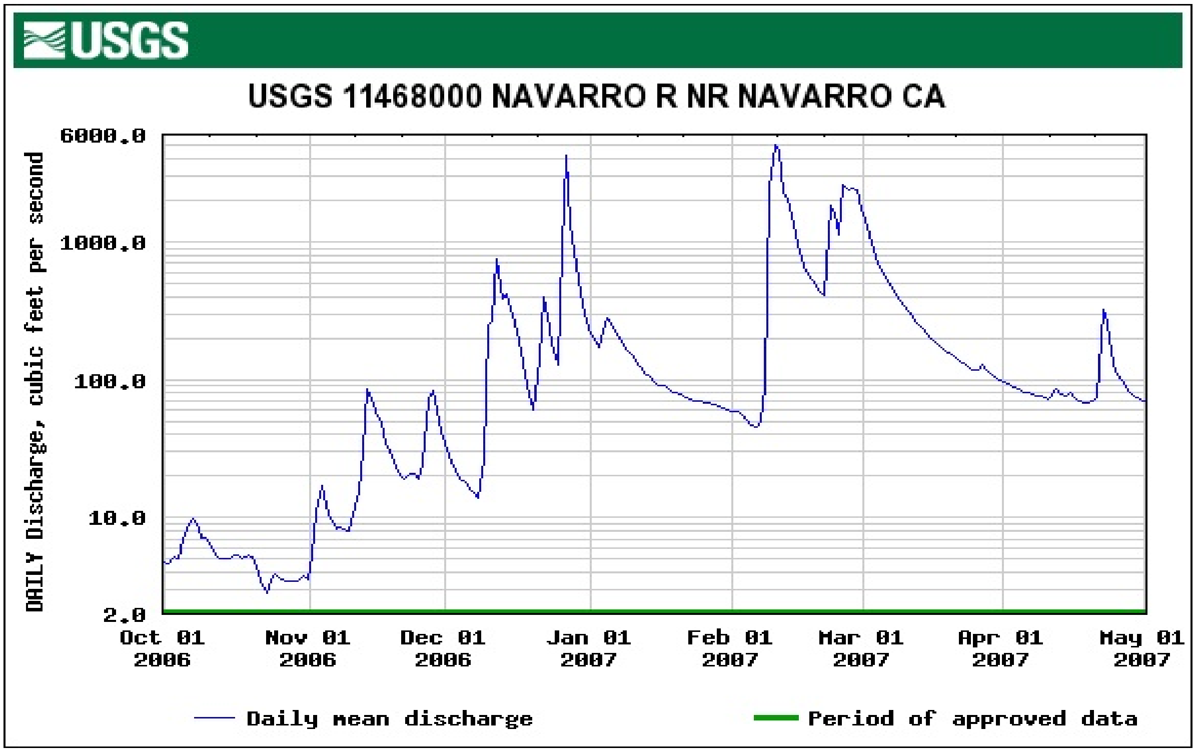


Figure 1. Navarro and Gualala river hydrographs for the 2006 steelhead spawning season, October 2005 to May 2006, from provisional USGS gaging data.



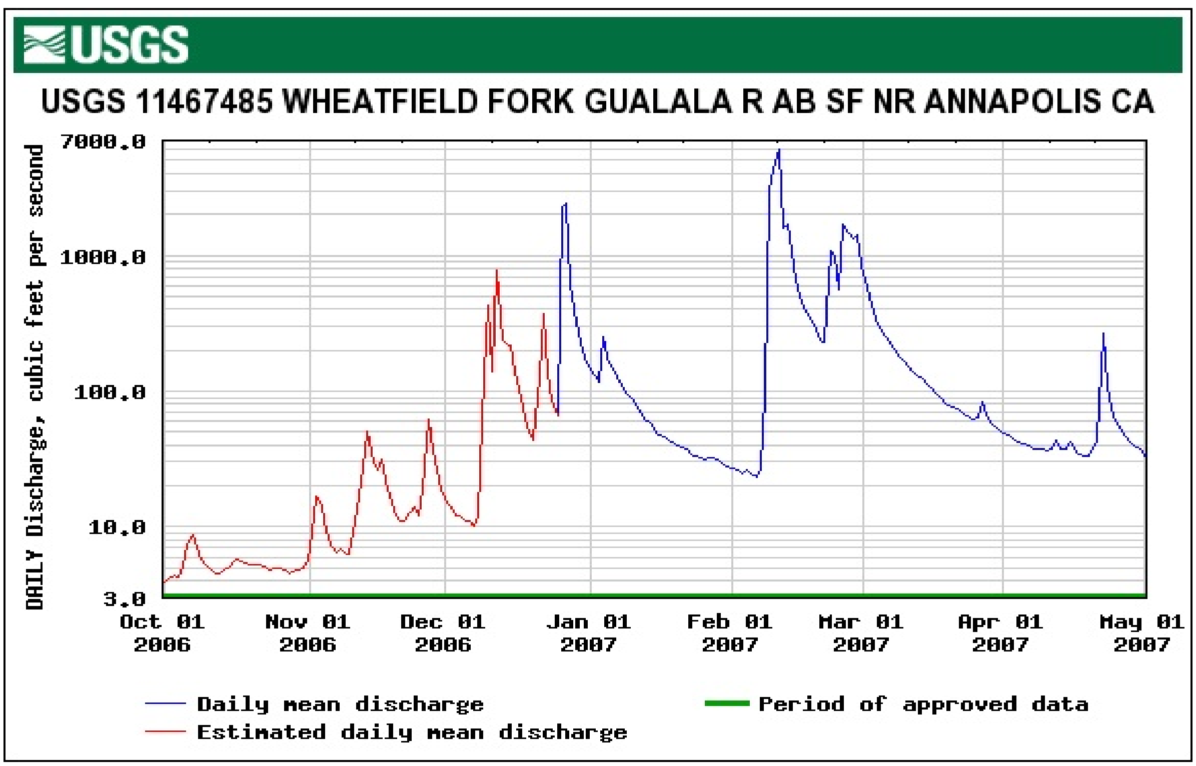


Figure 2. Navarro and Gualala rivers hydrographs for the 2007 steelhead spawning season, October 2006 to May 2007, from provisional USGS gaging data.

summertime, the Navarro and Wheatfield Fork indicated about 400 versus 200 cfs, respectively. Such differences for the two rivers could have been real (i.e., actually reflecting different rainfall and runoff levels in the two watersheds), "noise" in the gaging data, or some combination of both. Regardless, one salient point is that the Wheatfield Fork entered the May 1st milestone just prior to summertime at a much higher flow in 2006 than in 2007, due to rainfall differences in the two years. River flow at the start of summertime has important implications for the degree of summertime dewatering (and related water temperature impairment)–and thus JSH production–that ultimately occurs in the river prior to the start of the next rainy season.

The reason for 2006's steelhead-friendly summertime flows is also evident from the rainfall graphs for the Venado and Fort Ross gages over the last three seasons (Figure 3). In particular, March and April 2006 rainfall was over three times average. And this was preceded in 2005 by March and May rainfall that were also well above average. These are important anomalies to consider. They show that while total seasonal rainfall is to some degree an important driver of stream flow entering and throughout the summertime (and ultimately JSH production), annual temporal rainfall patterns are frequently very powerful summertime flow determinants. It is likely that the high springtime rainfall of 2005 and 2006 would have dramatically improved summertime conditions for JSH rearing, even if overall annual precipitation had been much less than was actually recorded.

Late-season rainfall of high magnitude, even when annual precipitation remains average or below, benefits watershed hydrodynamics. Ground and surface water is replenished just before the onset of summer, thus reducing and delaying inevitable summertime declines of surface stream flow. With higher summertime flows, little or no main-stem dewatering occurs (which was the case in 2005) and rearing conditions for JSH, especially with respect to water temperatures, are markedly improved. Also, with widespread, continuous surface flows (versus dewatered conditions), JSH can more readily move to cool-water refugia as needed when excessive water temperatures do occur. The payoff is that improved summertime rearing ultimately results in both more and healthier JSH emigrating to sea.

Population Estimates and Indices**–**The estimated 2007 spawning population, based on AUC-T methodology and nine complete surveys (i.e., n=9) of the Index Reach, was 2,086 fish (Table 3; Figure 4). For the five previous seasons, estimated populations ranged from a low of 486 in 2004 (n=8) to a high of 2,375 in 2005 (n=7). For the 2 years with the fewest (n=4) surveys–2003 and 2006–population estimates were 1,543 and 1,036, respectively. Average estimated spawning population over the six-season period was 1,518.

Mean (unadjusted) number of adult fish counted per survey for the six seasons ranged from 15.1 (2004) to 84.7 (2007) and averaged 50.0 (Table 3; Figure 4). The high average in 2007 was partially the result of fish "stacking" (and thus being recounted to some degree) in the Index Reach during two extended low-flow periods. The 2007 season had both the most zero and low movement days (72) and longest SL (10.2 days). The expanded mean number of fish per survey (adjusted using OEs) ranged from 31 (2004) to 163 (2007) and averaged 97.2. Peak (unadjusted) survey counts over the six seasons ranged from 74 (2004) to 163 (2005) and averaged 126.0.

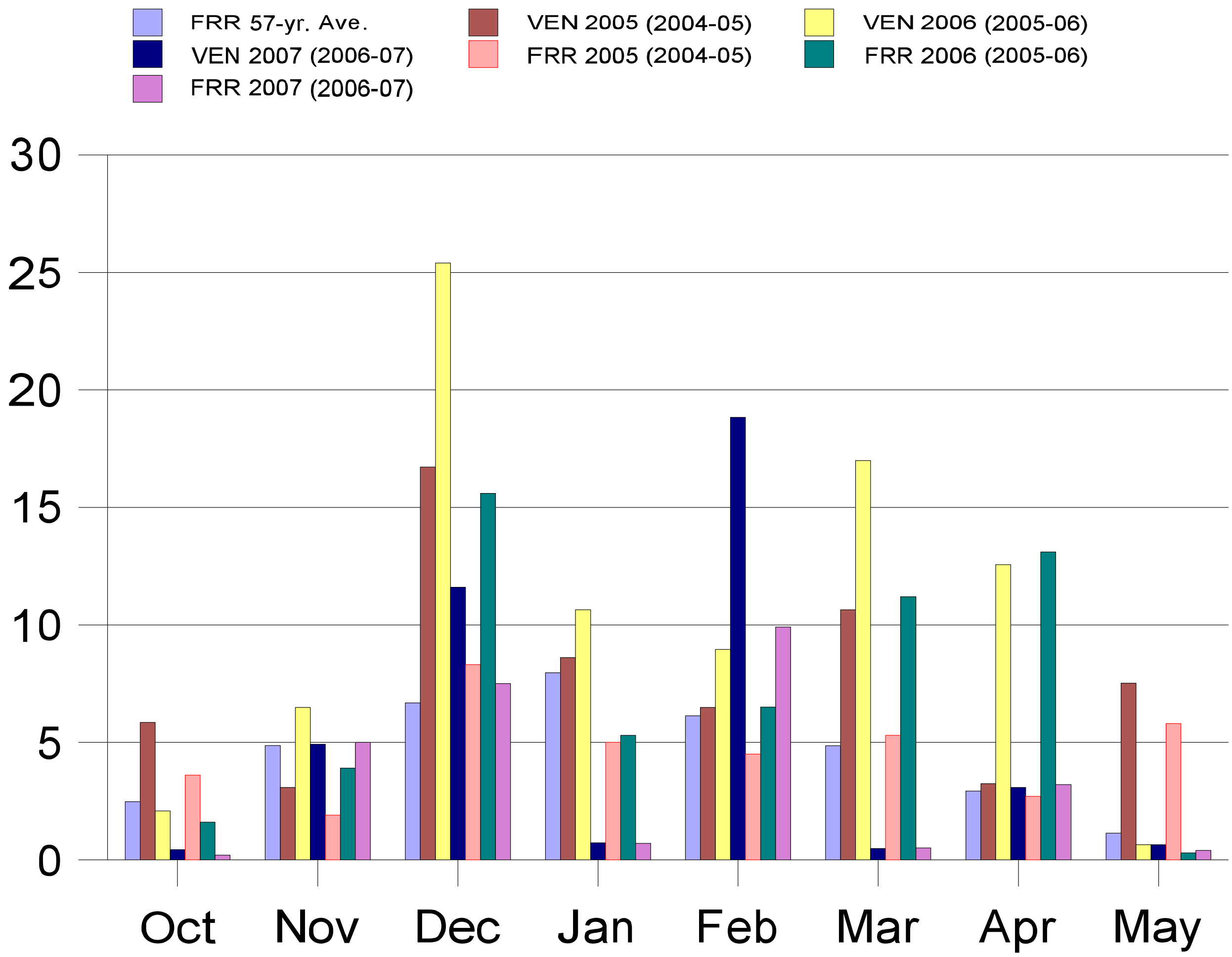


Figure 3. Gualala River steelhead spawning-season monthly rainfall patterns, in inches, 2005-07 versus average, as inferred from the Venado (VEN) rain gage and Fort Ross (FRR) rain gage versus average for the FRR gage.

Peak counts occurred between February 10th and March 22nd annually, with three each in February and March over the 2002-2007 seasons.

AUC-T population estimates and expanded (from OE) mean counts showed a reasonably similar trend over the six seasons (Figure 4). These two variables also exhibited a moderately high (considering the small sample size) coefficient of determination (R^2) of 0.85, thus explaining 85% of variation. Relationships between population estimates and both mean (unadjusted) counts and peak annual counts were not as close, with both having R^2 values of 0.80.

These provisional results suggest a spawning population varying widely over the past six seasons by a factor of five. As for how close the population estimates are to the real populations, the answer is problematic, since these initial population estimates lack any measure of uncertainty.

Table 3. Index Reach adult steelhead spawning population parameters, 2002-2007. *(Provisional results subject to revision from further refinement of Observer Error and Survey Life estimates used in AUC-T methodology.)*

Year	N	Total Adult Count	Ave.	Spawning Season[1]		Low[2] or No Move Days	Survey Life[3] (days)	Obs.[4] Eff. (%)	AUC-T Population Estimate(s)[5]		
				Start Date	Lngth Days				Est. (E)	.75E	.50E
2002	8	377	47.1	11/22	159	60	9.7	40-80	1584	1188	792
2003	4	211	52.8	12/14	137	25	7.0	40-50	1543	1157	772
2004	8	121	15.1	12/07	144	27	7.1	20-80	486	365	243
2005	7	433	61.9	12/07	144	19	6.4	20-80	2375	1781	1188
2006	4	86	38.3	12/01	151	31	7.6	20-80	1036	777	518
2007	9	762	84.7	12/12	139	72	10.2	40-80	2086	1565	1043
Ave.	6.7	331.7	50.0	12/05	145.7	39.0	8.0	20-80	1518	1139	759

[1]The start of each season's spawning run within the survey area (Index Reach) was assumed to occur on the day when the first seasonal stream flow (Wheatfield Fork gage) was ≥500 cfs. End of the spawning season was always assumed to be April 30. [2]In deriving Survey Life (SL), adult steelhead movement rate was assumed to be reduced, thus extending SL, when stream flows were either ≥3,000 cfs or ≤150 cfs (*see* Methods). [3]Survey Life (SL) is also known as Residence Time. SL is the average time adult steelhead were estimated to spend in the survey area (Index Reach) each season, as determined from weekly estimates derived from seasonal hydrology (*see* text for further detail). [4]Observer Efficiency (OE) is the estimated proportion of the true population counted during surveys. OE was estimated separately for each survey (*see* text), based on stream flow, water clarity, and key weather parameters, all of which affected counts of fish. [5]The 75% and 50% values are not statistically-derived population estimates and are provided only for evaluating reasonableness of the estimates (E).

How close reality was reflected depends on the accuracy of SL and OE values used in the estimates. Until further advancements are made to improve and eventually validate both of these variables, the best that can be done now is to attempt to qualitatively address a fundamental question: Are these initial estimates reasonable? Certainly, in view of previous population estimates by the Department of Fish and Game of between roughly 6,000 (mid 1970s) to 16,000 (mid-1960s) adult fish for the entire river, a population today for the Wheatfield Fork, which is the largest of the river's five main branches, in the range of the values given in Table 3 (column "E") would not seem unreasonable.

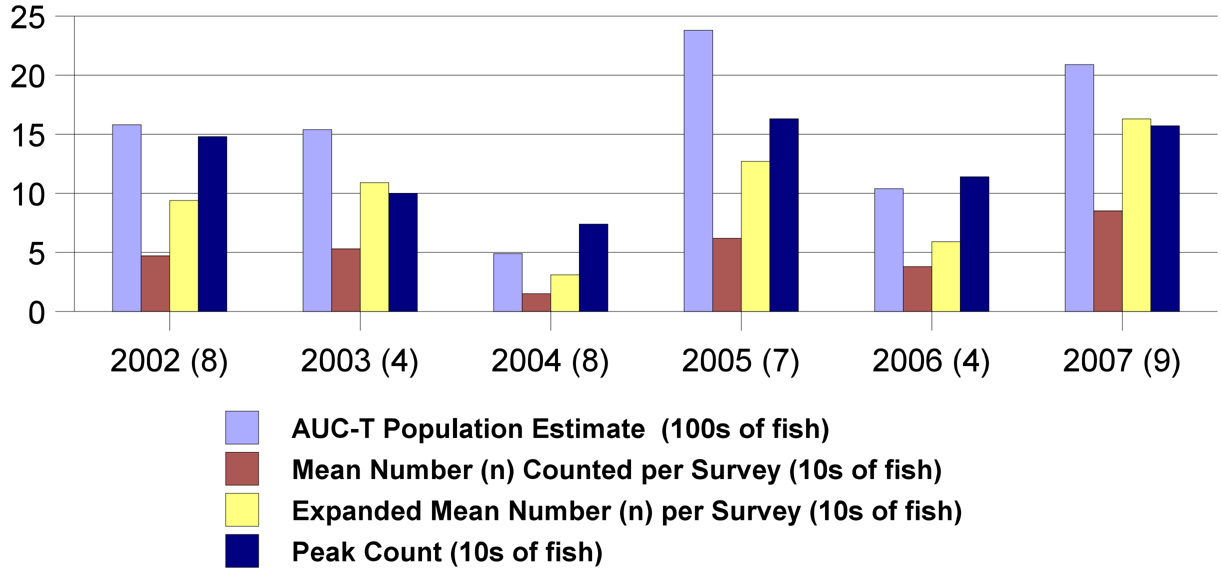


Figure 4. Index Reach spawning population trend of steelhead, 2002-2007, based on AUC-T population estimates compared to mean, expanded mean, and peak survey counts. *(Provisional results subject to revision from further refinement of Observer Error and Survey Life estimates used in AUC-T methodology.)*

Another approach for judging reasonableness involves examining effects of different assumed levels of error in the SL estimates. If, for example, SL was underestimated by 50% (i.e., real SL=2 x estimate), population estimates were from 243 (2004) to 1,188 (2005) and averaged 759 over the 6-year period (Table 3; column ".50E"). However, this would mean that the total counts of adults on surveys in some seasons were as high as 50-73% of estimated populations, an assumption that appears unreasonable, given the survey methodology and life history of steelhead, including 5-month spawning season. On the other hand, a SL underestimate of 25% (i.e., real SL=1.5 x estimate) yields annual spawning populations of from 365 to 1,781, with a mean of 1,139 over the 6-year period (Table 3; column ".75E") and these values are more difficult to reject as unreasonable. There is also potential error in the population estimates from inaccurate estimates of OE. However, in deriving the OE matrix, I attempted to err on the side of conservancy (i.e., to over-, rather than under-estimate OEs). Moreover, the population estimates are much less sensitive to 25 and 50% under-estimates of OE than for the same errors in SL.

Therefore, these initial provisional population estimates from AUC-T methodology appear to suggest an annual 2002-2007 Wheatfield Fork adult steelhead spawning population ranging from a low of at least 400-500 fish to a high of at least 1,800-2,400 fish, with an average of at least 1,100-1,500 fish. A population in this range of magnitude for the Wheatfield Fork would in turn suggest a total spawning population for the whole river of $\geq$5,000 fish in one or more seasons of the sampled period. Provisional results also suggest that expanded (using OE) mean annual survey counts may eventually provide a simple and effective metric for population indexing and trend analyses over spawning seasons. Alternatively, mean annual or peak annual counts may eventually provide the same thing. These possibilities will have to be examined further over at least several future seasons of work on the Index Reach.

The various population estimates (and discussion) presented here are provisional–subject to revision, as estimates of SL and OE used in the AUC-T calculations are improved and eventually validated from future work.

Snorkeling Surveys

During the first survey on June 14-15 (Table 4; FM 78), all sites were snorkeled except two–#5B (near the North Fork mouth [lower section]) and #9 (Highway 1 bridge). The 13 sampled and 2 un-sampled sites all still had continuous surface flows. JSH of various ages were present, in generally low-to-moderate numbers and densities, at every sampled site except the Twin Bridges (#6) site. Water temperatures were in the upper 70s (^{0}F) at all of the Wheatfield Fork locations, but generally within much lower ranges at the other sites. Several large schools of JSH were observed moving downstream in the vicinity of various Wheatfield Fork sites. This novel observation, plus the lack of JSH at Twin Bridges, combined with relatively low JSH numbers at the various estuary sites, suggests that a widespread downstream migration (or other form of redistribution within the watershed) of JSH was underway.

During the second survey on July 15th (Table 4; FM 79), all 15 sites were snorkeled. Flows were uniformly low at all sites, but all except Haupt Creek (#8) still had continuous surface flows. At the Haupt Creek site, there was no surface flow present and only two small, rapidly-drying pools remained; these contained about 50 YOY JSH each. Four of six Wheatfield Fork sites were devoid of JSH. However, increases of JSH (from the June survey) numbers and densities were apparent at the Twin Bridges site and several of the estuary sites. These observations suggest that mass movement of JSH towards the estuary had occurred since the mid-June survey. Overall, JSH numbers and densities remained low-to-moderate, however. Water temperatures were lower, especially for the Wheatfield Fork sites, than in mid-June and generally within mid-to-upper tolerances for JSH. Water temperature amelioration was likely due to mild, marine-influenced air temperatures which occurred for 6 consecutive days prior to the survey.

During the final survey on September 6th (Table 4; FM 80), snorkeling was done at all sites except Haupt Creek, which was completely dry. All sites had very low flows, with 6 of the 14 being reduced to intermittent surface flow (i.e., one or more drying pools). The Wolf Creek site (#1) had the lowest flow I have yet observed, but was still flowing continuously and supported a moderate number (200) of YOY JSH just as during the mid-July survey. Aside from the Wolf Creek site, JSH numbers were low (five sites ≤5 fish) or nonexistent (five sites) at ten of the sites and low-to-moderate (35-200 fish) at the four remaining sites. Such low end-of-summertime JSH abundance was likely a reflection of either high summertime mortality or a mass exodus from the river during two major summertime breaches of the river's mouth, or some combination of both. Low numbers of JSH in the estuary lend credence to the mass exodus theory. This survey also recorded relatively high numbers of Gualala roach and

Table 4. Flow, water temperature, and JSH counts from three summertime 2007 snorkeling surveys at 15 standard survey sites.[1]

#	Location	14-15 June Flow	June 14-15, 2007 Survey				15 July Flow	July 15, 2007 Survey				06 Sept Flow	September 6, 2007 Survey			
			H_20 Temp	Numbers of JSH				H_20 Temp	Numbers of JSH				H_20 Temp	Numbers of JSH		
				YOY	1+	2+			YOY	1+	2+			YOY	1+	2+
1	Wolf Cr.	CF	68	38	2	0	CF	59	200	0	0	CF	60	200	0	0
2	House Cr.	CF	73-79	100	50	0	CF	65-67	80	1	0	IF	62-63	3	2	0
3	WF Fk. (Ldy)	CF	79	50	10	5	CF	66	0	0	0	CF	65	0	0	0
3a	WF Fk. (Ldy)	CF	77	75	5	2	CF	66	0	0	0	CF	66	0	0	0
4	WF Fk. (Bdg)	CF	77	110	10	2	CF	72	0	0	0	IF	69	5	0	0
4a	WF Fk. (Bdg)	CF	78	2	0	0	CF	72	0	0	0	IF	71	0	0	0
4b	WF Fk (Bdg)	CF	75	50	5	2	CF	68	100	12	0	IF	65	0	35	0
5a	Nr. N. Fk.-U	CF	60	10	40	0	CF	70	150	25	0	CF	70	0	0	0
5b	Nr. N. Fk.-L	CF	--	--	--	--	CF	70	150	100	25	CF	66	200	0	0
5c	N. Fk. Mouth	CF	61	5	20	0	CF	64	200	0	0	CF	62	1	0	0
5d	Up. N. Fk. Mo.	CF	64	50	0	0	CF	72	50	10	5	CF	72	1	0	0
6	Twin Bridges	CF	70	0	0	0	CF	72	50	0	0	IF	69	5	0	0
7	S. Fork Bridge	CF	69	150	15	0	CF	64	25	50	5	IF	61	100	25	5
8	Haupt Cr.	CF	67	35	0	0	IF	65	100	0	0	D	--	--	--	--
9	Hwy 1 Bridge	CF	--	--	--	--	CF	74	150	50	0	CF	72	0	0	0

[1] Descriptions of sample locations are provided in the 2005 annual report and File Memo #060; Flows: CF=Continuous surface flow; IF=Intermittent surface flow; D=Dry–No surface flow, except, in some cases (see File Memos), drying pools; Water Temperatures are maximums, in degrees F, recorded at the sites at time of sampling (*see* File Memos).

threespine stickleback. However, water temperatures by the time of this survey were no longer a factor affecting JSH survival.

Overall, the snorkeling results demonstrate that summertime 2007 was relatively poor for JSH rearing and production. The key limiting factor was low springtime rainfall, which in turn resulted in extensive stream dewatering by summer's end. Nevertheless, the deleterious effects of low rainfall were likely greatly ameliorated by a relatively mild summer, with many days of below-average air temperatures (mainly due to marine air intrusions).

Surveys by Helicopter

Initial Spawning Survey–The initial spawning survey on March 15th covered 14 miles (all distances are GPS "tracking" miles, not sinuous miles of stream) along Rockpile Creek, 9 miles of House Creek, 10 miles of the upper Wheatfield Fork, and all (17 miles) of the Index Reach of the Wheatfield Fork (FM 72). Survey of Buckeye Creek was cancelled, due to an inadvertent waypoint error resulting in our getting lost en route to the starting point. Estimated percentages of survey stream reaches considered fully viewable from the air were: Rockpile Creek-35%; Wheatfield Fork Index Reach-75%; upper Wheatfield Fork-73%; and House Creek-83%.

A total of 66 adult steelhead was recorded, including 5 on the upper Wheatfield Fork, 14 on House Creek, and 47 along the Index Reach. In comparison, the Index Reach standard counts by boat 5-6 days before and 1-2 days later resulted in 114 and 142 adult steelhead, respectively. Two redds were also recorded from the air, one each on the upper Wheatfield Fork and House Creek. While no redds were found from the air along the Index Reach, two were recorded during the follow-up survey 1-2 days later.

Three of the previously marked "favored" holding pools and runs along the Index Reach planned for inspection from the air were missed. This was believed due to (a) flying the reach in the opposite direction that it is surveyed by boat (thus causing key landmarks to be confused), and (b) known landmarks not being seen at all by the primary observer, who was hanging from the aircraft seat and essentially looking straight down into the stream.

Refer to FM 72 for additional detail of this initial aerial survey, including maps with waypoints where fish and redds were recorded.

Second Spawning Survey–The March 24th survey of the Index Reach tallied nine occurrences of adult steelhead totaling 103 fish. Twenty adults each were recorded in the Concrete Slab and Snagging pools; seven other occurrences of adults totaling 1 to 15 fish each were recorded in various un-named pools and runs. Good views (i.e., likely that any groups of fish present were actually detected) were obtained of Bedrock Run, Log Pool, YMCA Pool, Park Pool, Mossy Rock Pool, Indian Spearing Pool, Big Landslide Pool, Yellow Rope Pool, Angle-Log Pool, and Lower Cable Run–and none of these sites appeared to be holding any adult steelhead. Likewise, no adult fish were seen in the Lady-Car Falls Pool or ATV Pool, however, a 100% view of these sites was not achieved, due to shading and vegetation overhang. Shading and vegetation overhang was also a problem at the Snagging Pool where 20 adults were counted, thus the actual number present could easily have been higher.

The 2-day standard survey of the Index Reach by boat on March 22-23, just before the aerial survey, yielded 157 adult steelhead in 13 occurrences, with numbers ranging from 1 to 46 at sighting locations. Four named holding/resting sites held 66 (42%) of these adults as follows: Concrete Slab Pool-46 (new single-pool count record); YMCA Pool-2; Park Pool-6; and Snagging Pool-12. The 3 consecutive days of surveys thus appeared to show that adult fish were still actively moving upstream (and downstream) in the Index Reach.

Of seven steelhead redds found and marked during the two prior standard boating surveys, four were readily detected during the aerial survey, two could not be seen from the air due to shade and/or dense overhanging vegetation, and one was inadvertently missed. Nevertheless, due to various improvements made in aerial survey technique (i.e., flying slower and lower; hovering, as necessary to achieve a better view; and primary observer extended farther out of the aircraft for viewing) after the first survey, the estimated fully-viewed percentage of stream along the Index Reach increased to 82.5%.

For the South Fork reach of the aerial survey, five occurrences of adult steelhead totaling 63 fish, in groups of from 1 to 25 fish, were recorded. One redd was also recorded. Due to steep terrain, high stream sinuosity, relatively dense forest, and extensive stream-side shade, only an estimated 52.5% of the stream was fully viewable from the air. Nevertheless, many large, deep potential holding and resting pools were fully viewable from the air.

Refer to FM 75 for additional detail of this second helicopter survey, including maps with waypoints where fish and redds were recorded.

Spawning Surveys: Common Findings and Conclusions–I was definitely encouraged by our ability to detect and count adult steelhead from the helicopter. Especially with calm wind and direct sunlight on the water, the bottom of the stream, including throughout most of the deepest pools, was readily visible. I suspect that OE for adult fish was relatively good, although almost certainly lower that OE for standard boat surveys of the Index Reach. Our ability to detect redds also appeared reasonably good, but redd OE may have also been lower than for foot or boat surveys.

A fundamental problem identified during the preliminary helicopter surveys was that any wind caused surface rippling (higher flows have a similar effect) reducing viewable stream bottom which in turn greatly hampered–and in some cases completely precluded–counting any fish that were present. Helicopter surveys would thus need to be carefully planned in consideration of weather patterns and time-of-day, to avoid as much as possible wind-rippling effects.

These two initial helicopter surveys lead to a conclusion that the main stem of the Wheatfield Fork is an excellent candidate for such surveys for counting both steelhead and their redds. Both the Index Reach and the next 5-10 miles upstream of it should be considered for inclusion in a long-term spawning-survey protocol.

The South Fork showed less feasibility for aerial survey than the Wheatfield Fork. Nevertheless, it does have a significant number of large, deep potential holding and resting sites where adult fish could potentially be regularly surveyed from the air. Thus, the South Fork as well as the surveyed reach of House Creek should also be considered for inclusion in a long-term helicopter spawning-survey protocol.

Both Rockpile Creek and Buckeye Creek (which wasn't surveyed, but is physically quite similar to Rockpile Creek) appear to have relatively low helicopter-survey potential.

Videos of the survey flights was not undertaken in this initial work. Nevertheless, video would no doubt be quite useful for enhancing the accuracy of the counts of both redds and adult fish. Frame-by-frame analyses, as necessary, could be accomplished back at the office. Gyro-stabilized, TV-station-quality video should be incorporated into any long-term spawning-survey protocol, assuming that it does not become cost-prohibitive.

***End-of-Summer Stream Dewatering Survey*–**The September 27th flight demonstrated the feasibility of aerial survey by helicopter for quickly and efficiently finding and recording end-of-summertime stream dewatering of main-stem reaches of the river. (Refer also to FM 81 for additional detail, including maps and waypoints showing dewatered locations.)

In general, dewatering was less severe than anticipated, given 2007's dry springtime conditions and 75% of average rainfall for the season. I suspect that dewatering severity was significantly ameliorated by a relatively mild summer, with somewhat below-average air temperatures and many periods with marine-air intrusion. (I am currently developing methodology to examine this issue quantitatively each season and plan to begin incorporating it with the 2008 annual report.) Nevertheless, any dewatering of the stream has, as discussed earlier herein, serious potential adverse consequences for JSH rearing and production.

Survey of the South Fork by air showed that it had very low, but nevertheless continuous surface flow from the North Fork mouth upstream to a point about 800 feet downstream of the South-Wheatfield forks confluence (i.e., Twin Bridges). From there upstream for about 1 mile the stream was completely dry. Another completely dry reach, about 1,000 feet in length, was found just downstream from the Clipper Mill Bridge. In addition, a total of 38 less-lengthy dry reaches (<100 feet in length) were recorded between just upstream of Twin Bridges and the Clipper Mill bridge. Most of the dry reaches along the South Fork were readily detectable from the air without slowing or stopping the aircraft; only along about 15% of stream length did dense riparian vegetation or terrain shade prevent ready determination of stream flow status (i.e., watered or dewatered).

Aerial survey of the Wheatfield Fork revealed two dry reaches. The first was about 900 feet in length, extending upstream of the South-Wheatfield forks confluence. The second was about

260 feet in length and occurred just downstream of the Annapolis Road bridge. I am relatively confident that these were the only dry sections along this entire (surveyed) fork of the stream.

Thus, once again, the most extensive and serious dewatering of 2007 occurred in the vicinity of Twin Bridges. A similar pattern was found during 2004 (DeHaven 2004), when rainfall was about average overall, but below average for the critical March-April period of springtime.

As discussed previously (DeHaven 2004), the prevalence of dry and intermittent stream conditions during summertime is a relatively new phenomenon for the watershed. Such losses of stream surface flows appear to have been a gradual occurrence over the past several decades. For example, when I hiked extensively throughout the watershed during late summer of 1977–the end of a record drought period–I observed many extremely low flows but few completely dry or intermittent stream reaches, except for some uppermost 1st- and 2nd-order streams. Routine summertime drying of 4th- and 5th-order main-stem reaches today is both surprising and disturbing.

Such summertime dewatering occurs from surface flows moving sub-surface into extensive aggregation and when surface flows become diminished over time below certain critical thresholds. Certainly, sub-surface flow through aggregation is at least partially implicated by virtue of the stream's relatively poor physical condition. Moreover, especially in the vicinity of Twin Bridges, aggregation effects have for decades been exacerbated by the gravel mining which has occurred there and by "back-up-and-settling-out (of aggregate)" effects due to the two streams merging together within a relatively low-gradient zone. However, flow diminishment is likely at work also. Flow diminishment results from the cumulative effects of (1) incremental upstream water diversions–legal and illegal–from multiple sources; and (2) incremental watershed hydrodynamics (e.g., water absorption, storage, release and dispersal from the landscape) changes, due to adverse land-use conversions (especially to vineyards) and timber harvesting.

Angling Surveys

On the February 16th angling trip, neither any adult or juvenile steelhead were caught. On the March 5th trip, Marc and I each caught one fresh-run adult steelhead and I also caught one kelt. Other anglers we spoke to reported catching two kelts. I also caught about 10 JSH smolts. Refer to FMs 69-70 for further detail.

CONCLUSIONS

- Seasonal steelhead spawning began in early December 2006 in response to the first moderate seasonal increases of flow and extended through April 2007.

- Highest seasonal counts of adult fish occurred in mid-to-late March compared to the 5 preceding years, when the peak annual survey count ranged from February 10th to March 20th.

- A record high number of adult fish (762) was recorded during surveys, reflecting some combination of (a) a population upsurge; (d) good survey conditions, which improved count efficiency; and (c) decreased migration rates of adult fish due to low-flow conditions, which in turn increased “stacking” and recounting of fish.

- Despite below-average rainfall and flows, the previous observed seasonal trend of most adult fish spawning upstream of the Index Reach until late in the spawning season, continued.

- Provisional estimates for 2002-2007 based on AUC-T methodology suggest a spawning population on the Wheatfield Fork varying by a factor of up to five annually, from a low of 400-500 fish to a high of 1,800-2,400 fish. Such numbers in turn suggest a spawning population for the whole river of at least 5,000 fish in some years. However, all such estimates must be considered provisional, subject to later modification, as estimates of SL and OE used in the AUC-T methodology are improved and validated in the future.

- The 2002-2007 estimated populations were more closely associated with expanded mean annual counts than with either mean annual or peak annual counts, but any one of these three metrics could, through further work, prove itself to be a useful population monitoring metric.

- Low-altitude surveys by helicopter have potential as an effective spawning population monitoring tool, particularly along the Index Reach, the Wheatfield Fork upstream of the Index Reach, lower House Creek, and at selected holding pools along the lower South Fork (in that order). A long-term helicopter survey protocol should be initiated, if secure funding is obtained.

- Summertime stream dewatering is severe in the vicinity of the confluence of the South and Wheatfield forks of the river. Such dewatering, especially of main-stem reaches, creates serious threats to JSH rearing and production, and therefore to efforts to recover steelhead (and coho salmon) populations. Low-altitude helicopter surveys could provide a rapid and efficient means of monitoring dewatering status and trends. A long-term helicopter survey protocol to monitor dewatering should be initiated, if secure funding is obtained.

- Just as in 2004, and in contrast to 2005-2006, summertime rearing conditions for JSH in 2007 were relatively poor, largely due to both annual and springtime rainfall being well below average.

- Overall for 2007, JSH numbers (and production) were relatively low, a large-scale movement of JSH toward the estuary occurred in early summer, and a mass exodus of JSH seaward apparently occurred during one or more summertime breaches of the estuary sandbar.

- Just as in 2004, and in contrast to 2005-2006, the Wheatfield Fork became a less-important producer of JSH as summer progressed, due to low flow, elevated water temperatures, and dewatering.

- Just as in 2004-2006, Wolf Creek remained important to JSH rearing throughout the summer of 2007.

LITERATURE CITED

Ames, J., and Phinney, D. E. 1977. 1977 Puget Sound summer-fall chinook methodology: escapement goals, run size forecasts, and in-season run size updates. Wash. Dep. Fish. Tech. Rep. No. 29. 71pp.

Boydstun, L. B., and McDonald, T. 2005. Action plan for monitoring California's coastal salmonids. Final (Unpub) report to NOAA Fisheries, Santa Cruz, California. Contract #WASC-3-1295. 78 pp.+ Appendices.

DeHaven, R. W. 2001. Reconnaissance-level spawning and habitat surveys of steelhead trout, Gualala River, California, 2001. Prepared by the author (Richard_DeHaven@fws.gov), April 2001, for use by agencies, groups and individuals involved in steelhead recovery efforts. 23pp.

DeHaven, R. W. 2002. Steelhead spawning surveys, Wheatfield Fork and other selected reaches, Gualala River, California, 2002. Prepared by the author (Richard_DeHaven@fws.gov or drdehave@hotmail.com), September 2002, for use by agencies, groups and individuals involved in steelhead recovery efforts. 42pp.

DeHaven, R. W. 2003. Steelhead spawning surveys, Wheatfield Fork, Gualala River, California, 2003. Prepared by the author (Richard_DeHaven@fws.gov or drdehave@hotmail.com), December 2003, for use by agencies, groups and individuals involved in steelhead recovery efforts. 14pp.

DeHaven, R. W. 2004. Adult and juvenile steelhead population surveys, Gualala River, California, 2004. Prepared by the author (drdehave@hotmail.com), December 2004, for use by agencies, groups and individuals involved in steelhead recovery efforts. 56pp.

DeHaven, R. W. 2005. Adult and juvenile steelhead population surveys, Gualala River, California, 2005. Prepared by the author (drdehave@hotmail.com), December 31, 2005, for use by agencies, groups and individuals involved in steelhead recovery efforts. 64pp.

DeHaven, R. W. 2006. Adult and juvenile steelhead population surveys, Gualala River, California, 2006. Prepared by the author (drdehave@hotmail.com), December 31, 2006, for use by agencies, groups and individuals involved in steelhead recovery efforts. 47pp.

English, K. K., Bocking, R. C., and Irvine, J. R. 1992. A robust procedure for estimating salmon escapement based on the area-under-the-curve method. Can. J. Fish. Aquat. Sci. 49:1982-1989.

Gallagher, S. P. 2005a. Evaluation of coho salmon (*Oncorhynchus kisutch*) and steelhead (*O. mykiss*) spawning ground escapement estimates for monitoring status and trends of California coastal salmonids: 2000 to 2005 escapement estimates for several Mendocino County, coast streams. Calif. Dept. Fish & Game, 50 Ericson Court, Arcata, CA 95521. 57pp. Unpub. Draft.

Gallagher, S. P. 2005b. Annual coho salmon (*Onacorhynchus kisutch*) and steelhead (*O. mykiss*) spawning ground escapement estimates 2000 to 2004 in several coastal Mendocino County, California streams and recommendations for long term monitoring of coastal salmonids. Calif. Dept. Fish & Game, 50 Ericson Court, Arcata, CA 95521. 57pp. Unpub.

Gallagher, S. P., and Gallagher, C. M. 2005. Discrimination of chinook salmon, coho salmon, and steelhead redds and evaluation of the use of redd data for estimating escapement in several unregulated streams in northern California. N. Amer. J. Fish. Manage. 25:284-300.

Hilborn, R., Bue, B. G., and Sharr, S. 1999. Estimating spawning escapements from periodic counts: a comparison of methods. Can. J. Fish. Aquat. Sci. 56:888-896.

Holt, K. R. and S. P. Cox. 2008. Evaluation of visual survey methods for monitoring Pacific salmon (*Oncorhynchus* spp.) escapement in relation to conservation guidelines. Can. J. Fish. Aquat. Sci 65:212-226.

Jacobs, S., and G. Susac. 2004. Coastal steelhead spawning survey procedures manual 2004. Oregon Dept. Fish & Wildl. Coast Salmon Inventory Project. 57pp. Unpub. (Obtained online at https://nrimp.dfw.state.or.us/crl/Reports/OASIS/04steelheadmanual.pdf)

Korman, J., Ahrens, R. N. M., Higgins, P. S., and Walters, C. J. 2002. Effects of observer efficiency, arrival timing, and survey life on estimates of escapement for steelhead trout (*Oncorhynchus mykiss*) derived from repeat mark-recapture experiments. Can. J. Fish. Aquat. Sci. 59:1116-1131.

Korman, J., Melville, C. C., and Higgins, P. S. 2007. Integrating multiple sources of data on migratory timing and catchability to estimate escapement for steelhead trout (*Oncorhynchus mykiss*). Can. J. Fish. Aquat. Sci. 64:1101-1115.

Parken, C. K., Bailey, R. E., and Irvine, J. R. 2003. Incorporating uncertainty into area-under-the-curve and peak count salmon escapement estimation. N. Amer. J. Fish. Manage. 23:78-90.

Ricker, S. 2002. 2000-2001 annual report escapement and life history patterns of adult steelhead in Freshwater Creek, California Project 1a1. Calif. Dept. Fish & Game Steelhead Research and Monitoring Program. 15pp. Unpub.

Shapovalov, L., and A. C. Taft. 1954. The life histories of steelhead rainbow trout (*Salmo gairdneri*) and silver salmon (*Oncorhynchus kisutch*) with special reference to Waddell Creek, California and recommendations regarding their management. Calif. Dept. Fish & Game Bulletin No. 98. 375 pp.

APPENDIX 1: File Memos #063-#081 for 2007 Surveys.

FM 063–First (Incomplete) Spawning Survey-- 37.
FM 064–Second Spawning Survey--- 40.
FM 065–Third Spawning Survey--- 42.
FM 066–Fourth Spawning Survey--- 45.
FM 067–Fifth Spawning Survey--- 48.
FM 068–First Estuary Spawning Survey-- 51.
FM 069–First Angling Survey-- 53.
FM 070–Second Angling Survey--- 54.
FM 071–Sixth Spawning Survey--- 55.
FM 072–First Helicopter Survey-- 59.
FM 073–Seventh Spawning Survey-- 66.
FM 074–Eighth Spawning Survey-- 69.
FM 075–Second Helicopter Survey-- 72.
FM 076–Ninth Spawning Survey-- 78.
FM 077–Tenth Spawning Survey-- 82.
FM 078–First Snorkeling Survey-- 85.
FM 079–Second Snorkeling Survey--- 89.
FM 080–Third Snorkeling Survey-- 95.
FM 081–Third Helicopter Survey---101.