# Assigning species to redds: exploring uncertainty in a central California coastal creek

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## Background

The California Coastal Monitoring Plan (CMP; Adams et al. 2011) advocates a two-stage approach (i.e., redd counts and fixed counting/trapping stations) to estimate adult salmonid abundance in the northern monitoring area (Figure 1).

Redd counts often fail to produce robust estimates of abundance for coho salmon and steelhead in watersheds at the southern end of the Central California Coast (CCC) ESU/DPS for two reason:

1. Sandbars form across creek mouths each summer and persist until large winter storms produce sufficient streamflow to erode the sandbar (Figure 2A,B). Once the sandbar is opened, adult coho salmon and steelhead often concurrently move into the stream and begin spawning (Table 1, Figure 2C).

**Table 1**: Variable timing in sandbar opening results in strong temporal overlap of coho salmon and steelhead in the Scott Creek (Santa Cruz Co.)

| Spawn year | Date of sandbar opening | First weir capture | |
|---|---|---|---|
| (water year) | (Scott Creek) | Coho salmon | Steelhead |
| 2014 | 09 February | 11 February | 10 February |
| 2015 | 03 December | 17 December | 07 December |
| 2016 | 21 December | 25 December | 25 December |
| 2017 | 27 November | 12 December | 01 December |
| 2018 | 21 November | 10 January | 09 January |

2. Redds are most often encountered after construction without live fish or carcasses in the immediate vicinity. Hence, definitive species assignments are often not possible (Figure 3).

To address the uncertainty surrounding redds of unknown origin, two species assignment methods are frequently applied in support of the CMP:

- A logistic regression model that makes species predictions based on the timing of redd construction and redd geometry (Gallagher & Gallagher 2005, hereinafter G&G).
- The k-nearest neighbors (kNN) algorithm which assigns species based on a majority rule of known nearest neighbors in time and space (Ricker et al. 2014).

The relative performance of these methods, and their applicability to watersheds at the southern end of the CCC ESU/DPS, remain poorly understood.

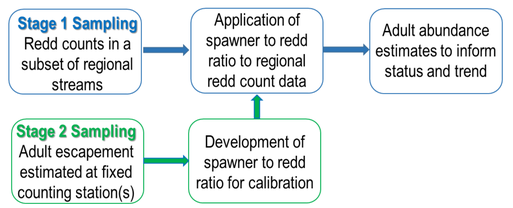


**Figure 1**: Two stage monitoring framework adopted by the CMP to estimate adult abundance.


**Figure 2.** Mouth of Scott Creek (A) closed by sandbar formation (barrier beach) during the summer and (B) opened following the onset of winter storms. Panel C shows the temporal overlap of coho salmon and steelhead on the spawning grounds (spawn year 2015).

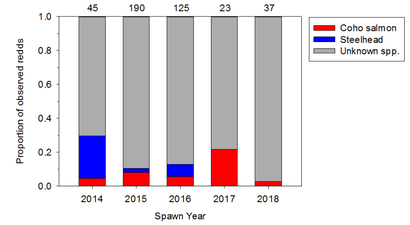


**Figure 3.** The proportion of redds encountered during redd surveys in Scott Creek attributed with 100% certainty to coho salmon (red) or steelhead (blue), versus those of unknown origin (gray), 2014–2018. The number above each bar is the total number of redds in a given spawn year.

## The Question

**How well do commonly used redd assignment methods perform in Scott Creek, a typical central California coastal watershed with high temporal and spatial overlap of spawning coho salmon and steelhead?**

## Methods

This study was conducted in Scott Creek (Santa Cruz, County), a regional Life Cycle Monitoring Station which has a weir to enumerate returning adults. Our steps included:

1) Completed Spawning Ground Surveys (SGS) in all 25 km of anadromous habitat, every 7–10 days, using standard protocols (e.g., Gallagher and Knechtle (2005) and Gallagher et al. (2007)).
2) Assessed the performance of the two commonly applied species assignment methods (discussed above) to redds which had fish on them (100% certainty).
3) Applied the species assignment methods to unknown redds.
4) Estimated spawner to redd ratios (S:R) using both assignment methods and applied the resulting ratios to regional redd count data in San Mateo and Santa Cruz County streams.

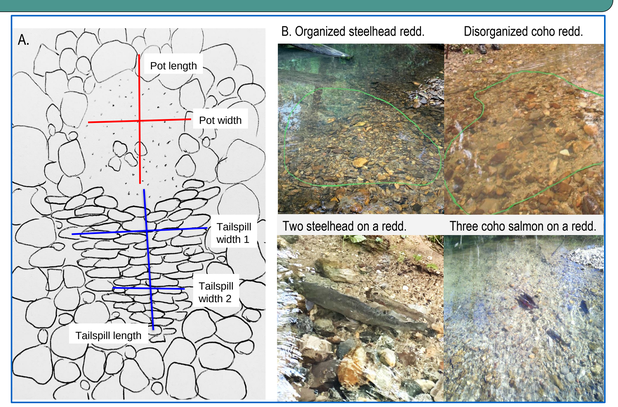


**Figure 4:** Diagram of a salmonid redd (A). Redd geometry was calculated using pot (red lines) and tailspill (blue lines) measurements. Examples of salmonid redds in the Scott Creek Watershed (B).

## Key Findings

The use of redd counts for population monitoring can be particularly challenging in locations where multiple salmonid species are present and adults exhibit considerable overlap in spawning timing. We found the two species assignment methods produced very different predictions (Figures 5,6).

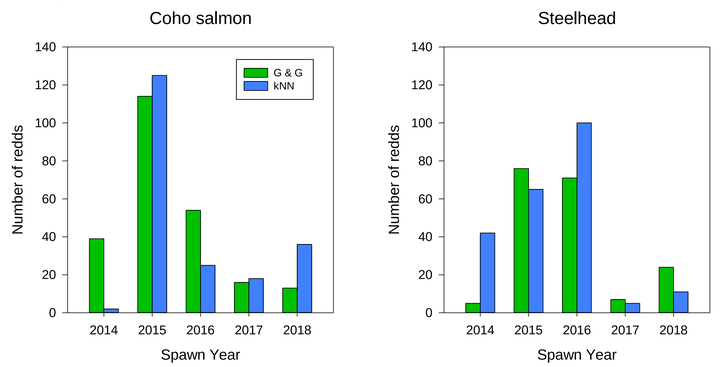


**Figure 5:** The two species assignment methods examined produced substantially different results in most spawn years.

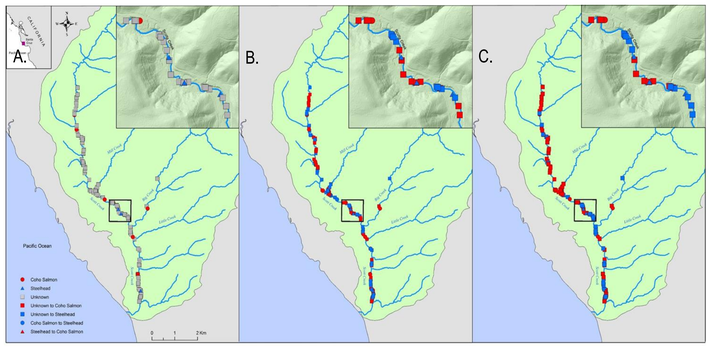


**Figure 6:** During spawn year 2015, most of the redds encountered in the Scott Creek watershed were classified as unknown in the field (A). Unknown redds were subsequently assigned to species using the G & G (B) and kNN (C) assignment methods.

**Table 3:** Regional escapement estimates derived from spawner to redd ratios developed using alternative methods to classify redds of unknown origin. San Mateo and Santa Cruz County streams, spawn year 2015.

| Species | Watershed | Estimated redds (SGS)[1] | Estimated escapement[2] | | | |
|---|---|---|---|---|---|---|
| | | | G & G | | kNN | |
| | | | *N* | 95% CI | *N* | 95% CI |
| Coho salmon | San Gregorio Creek | 0 | 0 | | 0 | |
| | Pescadero Creek | 7 | 10 | 8 - 11 | 9 | 8 - 10 |
| | Gazos Creek | 0 | 0 | | 0 | |
| | Waddell Creek | *no data* | | | | |
| | Scott Creek | 90 | 129 | 110 - 147 | 117 | 100 - 134 |
| | San Vicente Creek | 39 | 56 | 48 - 64 | 51 | 44 - 58 |
| | San Lorenzo River | 17 | 25 | 21 - 28 | 23 | 19 - 26 |
| | Soquel Creek | 0 | 0 | | 0 | |
| | **Regional total** | **153** | **219** | **187 - 250** | **200** | **171 - 228** |
| Steelhead | San Gregorio Creek | 132 | 149 | 139 - 160 | 175 | 163 - 186 |
| | Pescadero Creek | 203 | 230 | 214 - 245 | 269 | 250 - 286 |
| | Gazos Creek | 4 | 5 | 4 - 5 | 5 | 5 - 6 |
| | Waddell Creek | *no data* | | | | |
| | Scott Creek | 90 | 102 | 95 - 109 | 119 | 111 - 127 |
| | San Vicente Creek | 120 | 136 | 127 - 145 | 159 | 148 - 169 |
| | San Lorenzo River | 156 | 177 | 164 - 189 | 206 | 192 - 220 |
| | Soquel Creek | 8 | 9 | 8 - 10 | 11 | 10 - 11 |
| | **Regional total** | **713** | **807** | **752 - 862** | **943** | **879 - 1005** |

[1] Redd data from Goin et al. 2015. Escapement estimates for Central California Coast coho salmon (*Oncorhynchus kisutch*) and steelhead (*Oncorhynchus mykiss*) in coastal San Mateo and Santa Cruz County streams. Scott Creek data are partial as the complete spawning run was not surveyed. Report submitted to the California Department of Fish and Wildlife in partial fulfillment of FRGP Grant Agreement Number P1230418.

[2] Derived using spawner to redd ratio calibrations developed at the Scott Creek life Cycle Monitoring Station (see table 2).

**Challenges with each species assignment method:**

- G & G equation is based on timing and redd geometry. In Scott Creek, the equation often failed due to temporal overlap of coho salmon and steelhead on the spawning grounds.

  We found, the G & G equation consistently misclassified early returning steelhead as coho salmon. This tendency substantially overinflated coho salmon abundance at the regional scale (Tables 2 and 3).

- The kNN algorithm performed well when there were sufficient numbers of known (100% certainty) observations (i.e., plenty of neighbors).

  Spawn year 2015 was the only year with enough known observations for the kNN to make accurate predictions. For all other years, the method consistently classified unknown redds as steelhead, thereby overinflating steelhead abundance at the regional scale (Tables 2 and 3).

**Table 2:** Escapement estimate derived at the Scott Creek LCMS and the corresponding spawner to redd ratios generated using G & G and kNN.

| | Estimated escapement | Spawner to redd ratios (S:R) | | | |
|---|---|---|---|---|---|
| | | G & G | | kNN | |
| Species | *N* ± 1 SE | S:R | 95 % CI | S:R | 95 % CI |
| Coho salmon | 163 ± 12 | 1.43 | 1.22 - 1.64 | 1.30 | 1.12 - 1.49 |
| Steelhead | 86 ± 3 | 1.13 | 1.05 - 1.21 | 1.32 | 1.23 - 1.41 |

### Recommendations and Next Steps

- Between the two species assignment methods examined, we recommend using the kNN algorithm over the G & G equation for populations at the southern end of the CCC ESU/DPS.
- Relaxing the 100% certainty criteria applied in our study (e.g. incorporating information on live fish and/or carcass observations in the "area" of the redd) may be useful in some cases.
- Resources should be devoted to the development of alternative kNN approaches that utilize predictors beyond time and space (e.g., redd morphology).

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**Literature Cited:**

Adams, P. B., L. B. Boydstun, S. P. Gallagher, M. K. Lacy, T. McDonald, and K. E. Shaffer. 2011. California coastal salmonid population monitoring: strategy, design, and methods. California Department of Fish and Game, Fish Bulletin no. 180. 82 pp.

Gallagher, S. P. and C. M. Gallagher. 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. North American Journal of Fisheries Management 25:284-300.

Gallagher, S. P., and M. K. Knechtle. 2005. Coastal northern California salmon spawning survey protocol. California State Department of Fish and Game, Fort Bragg, California.

Gallagher, S. P., P. K. Hahn, and D. H. Johnson. 2007. Redd Counts. Pages 197-234 in D. H. Johnson, B. M. Shrier, J. S. O'Neal, J. A. Knutzen, X. Augerot, T. A. O'Neil, and T. N. Pearsons, editors. Salmonid field protocols handbook. Techniques for assessing status and trends in salmon and trout populations. American Fisheries Society, Bethesda, Maryland.

Ricker, S., J., Ferreira, S. P. Gallagher, D. McCanne, and S. A. Hayes. 2014. Methods for classifying anadromous salmonid redds to species. Coastal Salmonid Population Monitoring Technical Team Report. California Department of Fish and Wildlife, Arcata, California. 24p