Salmonid Redd Superimposition in the Feather River, CA: The Association Between Spawning Habitat Characteristics and Salmonid Species

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INTRODUCTION

Chinook Salmon and Steelhead Trout are of cultural economic, and recreational importance, as well as being an essential part of the riverine and ocean ecosystem. Unfortunately, they are a species of concern with declining wild populations.

This can be attributed to a myriad of reasons, one being decreasing in-river spawning success due to a loss in spawning habitat[1] which has lead to intraspecies Chinook redd superimposition[2] - the creation of one redd (fish-nest) on top of another. Steelhead spawn while Chinook eggs are still in the gravel, and the earlier spawning species are likely to have reduced spawning success[3]. It is however unknown whether Steelhead spawning habitat characteristics in the Feather River overlaps sufficiently with that of Chinook to make redd superimposition likely to occur.

Major factors determining spawning habitat suitability are gravel size[4], water velocity, and depth[5]. To analyze the possibility of steelhead superimposition on chinook redds in the Feather River, CA (figure 1), we examined the most influential variables with regard to salmonid spawning habitat suitability and how these variables compare between species.

We hypothesize that there is sufficient difference in spawning habitat that a model can accurately determine which salmonid species a redd belongs to.

METHODS

- Steelhead and Chinook redd data collected by the Department of Water Resources. Redd survey (wading through the river to visually identify redds and take data)was conducted from fall 2015 to Winter 2024
- Steelhead redds near comprehensive, Chinook redds were subsampled
- Variables used: water velocity, depth, channel width, and substrate size class. MudSiltsSand and Boulder were log transformed due to right skew.
- A multivariable logistic regression model was used to model the likelihood the redd was made by a Steelhead
- Variables were added or removed based on model fit and ANOVA results to create new models. For example: CobbleLog was found to not be significantly predicting which species made a redd, and could be removed from the model.
- Models were compared using AIC and BIC, and the model with the lowest scores was chosen.
- pROC was used to find the best threshold using Youden's J (combines sensitivity and specificity)

TABLES & FIGURES

Study Area: Feather River, CA

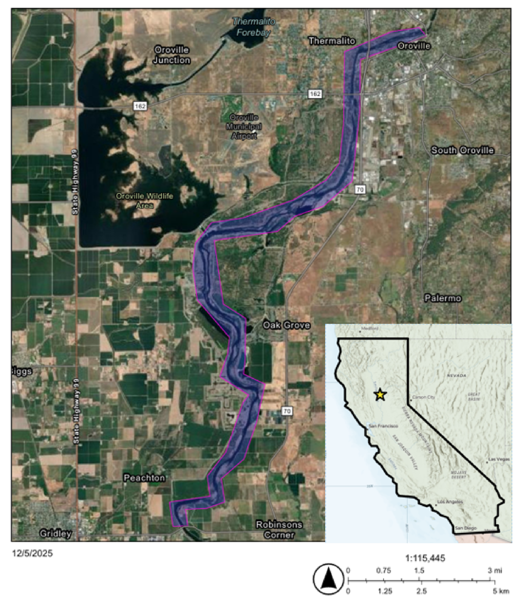

Figure 1. Study area: Feather River in Oroville CA below the Fish Barrier Dam, Rivermile 66 to 48.

Table 1. Sample Characteristics

Characteristic	N = 4,911
Species, n / N (%)	
Chinook	3,854 / 4,911 (78%)
Steelhead	1,057 / 4,911 (22%)
Velocity (m/s), Mean (SD)	0.49 (0.22)
Depth (m), Mean (SD)	0.43 (0.18)
Mud, Silt, and Sand (%), Mean (SD)	8 (10)
Pebble (%), Mean (SD)	41 (16)
Gravel (%), Mean (SD)	32 (17)
Boulder (%), Mean (SD)	3.1 (6.8)
Channel Width, n / N (%)	
Medium	1,793 / 4,911 (37%)
Broad	1,348 / 4,911 (27%)
Narrow	1,010 / 4,911 (21%)
VeryNarrow	760 / 4,911 (15%)

Table 2. Logistic Model Results

Characteristic	OR (95% CI)	p-value
(Intercept)	0.22 (0.11 to 0.40)	<0.001
Depth	0.07 (0.04 to 0.12)	<0.001
Velocity	0.70 (0.49 to 0.98)	0.039
MSSlog	1.10 (1.07 to 1.14)	<0.001
Pebble	1.01 (1.00 to 1.01)	0.065
GravelLog	1.19 (1.06 to 1.36)	0.006
BoulderLog	0.86 (0.82 to 0.91)	<0.001
ChannelWidth		
Medium	—	
Broad	1.43 (1.18 to 1.75)	<0.001
Narrow	1.16 (0.92 to 1.45)	0.20
VeryNarrow	3.24 (2.61 to 4.03)	<0.001

Abbreviations: CI = Confidence Interval, OR = Odds Ratio

Table 3. pROC Values

Threshold:	0.217
Sensitivity:	0.661
Specificity:	0.701
PPV:	0.378
NPV:	0.883

Water Depth and Velocity Distribution at Redds

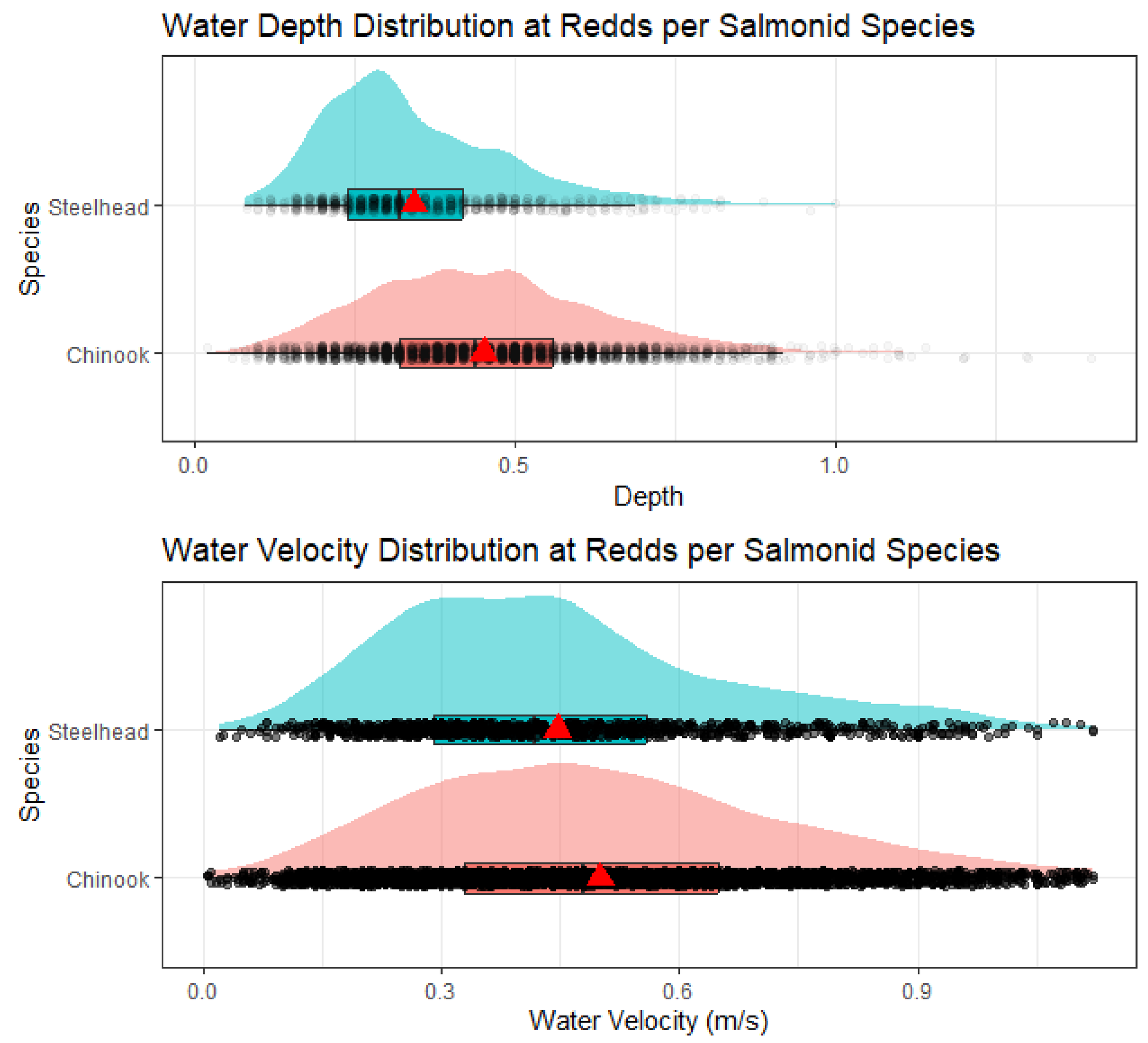

Figure 2. Water depth and velocity distribution per salmonid species. On average, Chinook build redds significantly deeper 0.45m (0.23 , p<0.001) and in swifter 0.50 m/s (0.18, p<0.001) water compared to Steelhead (0.45m/s and 0.34m respectively).

Predictive Model Performance

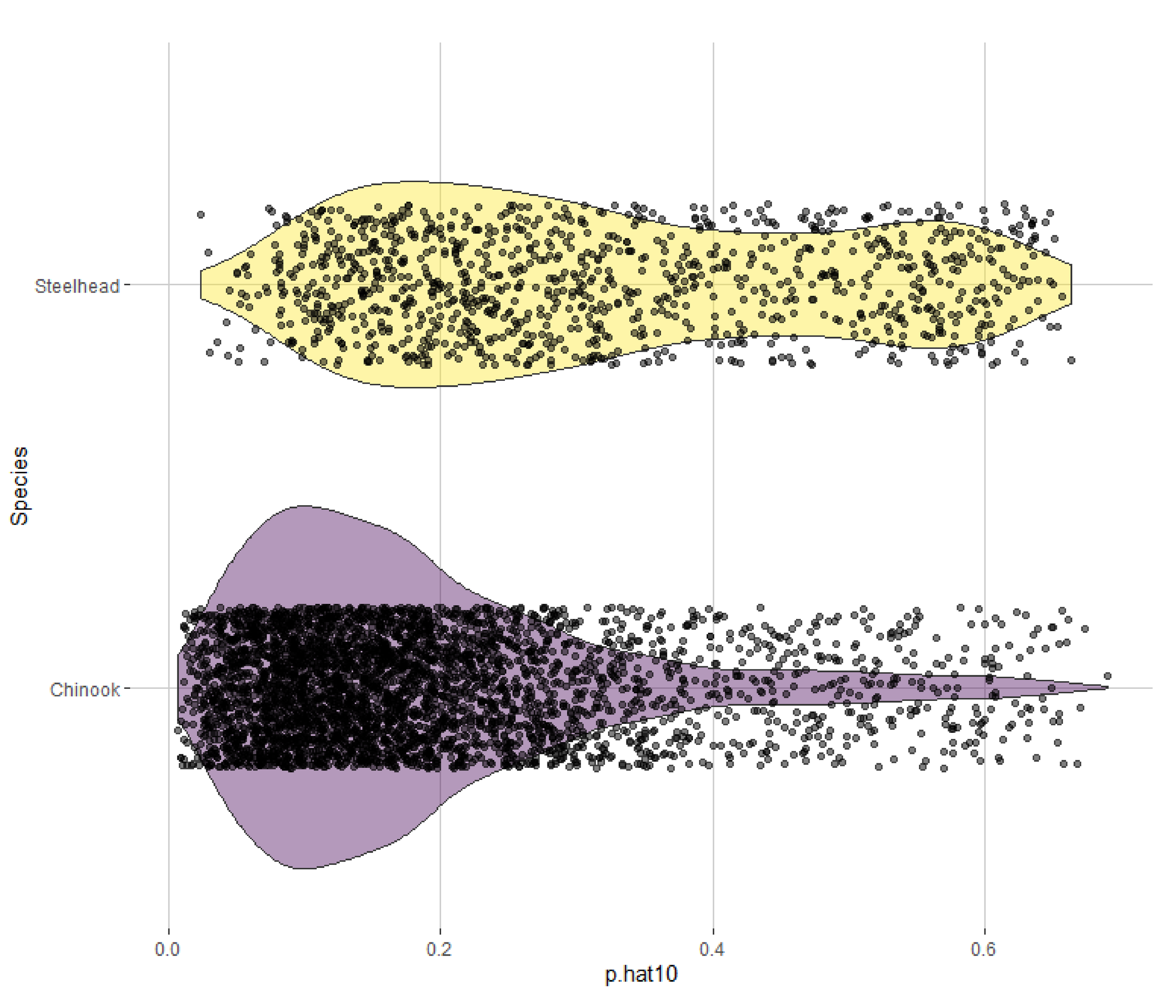

Figure 3. Predictive model performance: The model predicted probability of a redd being made by a Steelhead is on the y-axis and the true outcome category is on the x. There seems to be somewhat of a separation of outcome category based on predicted probability

RESULTS

- Table 1 shows the sample characteristics, 78% of which are associated with Chinook Salmon.
- On average, Chinook build redds significantly deeper and in swifter water compared to Steelhead (figure 2), yet the distributions show a high degree of overlap.
- After controlling for velocity, substrate, and channel width, every additional meter a redd is deep is associated with 0.07 (0.04, 0.12) times the odds that the redd was made by a Steelhead (p<0.001).
- The following habitat components were significantly associated with whether a redd was built by a Steelhead: water depth; water velocity; channel width; and the relative proportion of substrates mud/silt/sand, pebble, gravel, and boulders (table 2).
- As expected, more of the redd observations with low predicted probabilities correspond with Chinook Salmon (figure 3). Both Chinook and Steelhead redd observations exhibit probabilities between near 0 to 0.7, yet Steelhead redd predictions are more evenly distributed than Chinook redd predictions.
- This indicates the model may be slightly better than flipping a coin in predicting whether a redd belongs to a Chinook or a Steelhead, but due to the large overlap it is by no means conclusive.
- 66.1% of true Steelhead and 70.1% of true Chinook were correctly classified as their respective species at a threshold of 0.217 (table 3).
- The model predicts steelhead right about 37.8% of the time, yet predicts Chinook right about 88.3% of the time. Only 11.7% of fish predicted to be Chinook are actually Steelhead.

CONCLUSION/DISCUSSION

- The model is more accurate at predicting whether a redd belongs to a Chinook than to a Steelhead. This may have resulted from the large proportion of observations belonging to Chinook Salmon (78%).
- Although the preferred habitat characteristics of Chinook and Steelhead differ based on water flow, depth, channel width, and substrate, there is overlap in the model. This means that there may indeed be superimposition happening of Steelhead on Chinook redds in the shallower, slower moving environments with more gravel and less boulder in its substrate constitution.
- This is especially true in very narrow channels. Given the relative abundance of medium and broad channels in the study area when compared to very narrow channels, the impact of Steelhead redd superimposition on Chinook redds is likely to be minimal enough to not be a management concern.
- This outcome reinforces the findings of Togaki et al (2003), who concluded that superimposition is likely to occur in the narrow channels that were studied.
- For river systems with predominantly very narrow channels, management action by means of increasing Chinook-optimized spawning habitat may positively impact the Chinook runs.

IMPLICATIONS

- Conservation biologists working on river systems with both Steelhead and Chinook runs may use this information to determine whether redd superimposition may be affecting their broodstock.
- To improve the model and understanding of differences between optimal Steelhead and Chinook spawning habitat, future research may focus on the distance of redds from the bank, instream cover (logs, small woody debris, obstructions), overhead cover (obstructions for predation by birds of prey and/or birds feeding on juveniles), and which river 'section' a redd is found in (riffle, run, glide, pool). These variables can help zero in on salmonid spawning habitat preference differences.

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