Cooperator Report: Habitat Requirements of Steelhead in the Upper Salinas River Watershed

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Photo by Jenna Voss

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Figure 1. Large California sycamore on Atascadero Creek. Photo by Ryan Cooper.

1. GOALS

Little is known about the abundance, distribution, and habitat requirements of steelhead in the upper Salinas River watershed. We conducted this study in order to provide landowners and other stakeholders with information to make better informed decisions concerning these fish in this area. We were specifically interested in how distribution and habitat use of steelhead and other fish species were related to large wood (LW) availability in streams.

2. INTRODUCTION

Steelhead and rainbow trout are the same species (*Oncorhynchus mykiss*). Steelhead are the anadromous form, that hatch in fresh water, migrate to the ocean where they grow until mature, and then return to fresh water to spawn (Thompson & Larsen 2004). For the remainder of this report we will refer to all *O. mykiss* as steelhead. As cold-water fishes, steelhead require cool to cold water temperatures in order to maintain body mass, grow, find food, and reproduce (Thompson & Larsen 2004). The Salinas River and its tributaries have been designated by the National Marine Fisheries Service as critical habitat for steelhead, where spawning fish can still migrate upstream (Figure 2).

Figure 2. Steelhead/Rainbow trout swimming in a scour pool created by a boulder in Trout Creek. *Photo by Jenna Voss*.

The coast of California has a Mediterranean climate, characterized by a cool, rainy winter season, and hot, dry weather the rest of the year (Opperman 2005). With the exception of Rinconada Creek and the mainstem Salinas River, the headwaters of the streams in our study arise from the eastern side of the Coast Mountain range and experience more rainfall and coastal fog influence. The Salinas River watershed as a whole, however, receives little precipitation the majority of the year. Similarly to other hardwood-dominated watersheds in California, these conditions can lead to high maximum water temperatures and critical low flows (Opperman 2005).

Deep, cool pools can often serve as refugia for salmonids such as steelhead in streams that can reach a maximum temperature at or near the lethal limit for cold-water fish species (Opperman et al. 2006). Pools occur naturally in streams, formed by water plunging over boulders or bedrock, channel meandering, or on the downstream side of large wood, such as logs, root wads, or living tree roots (Opperman 2005). Large wood, both individually and contained within wood jams, contributes roughness elements to the stream channel, increases habitat and flow complexity, and may aid water retention in streams (Gurnell et al. 2002). In our surveys, conducted between 5 July and 10 August 2006, we focused on the amount of LW at fifteen stream sites within the upper Salinas River watershed, and the ability of this LW to form pools.

3. SITE DESCRIPTIONS

The sites encompassed a broad range of substrate types, bankfull widths, degree of canopy cover, tree species composition, water temperature, and pool types (Figures 3-8).

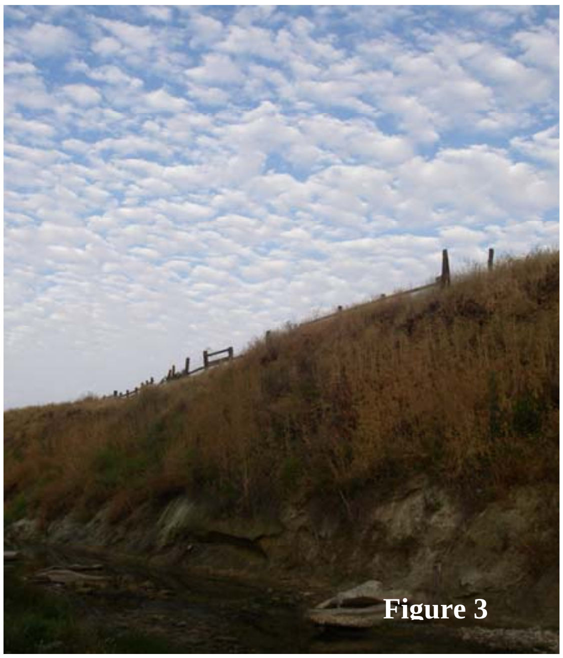
Figure 3

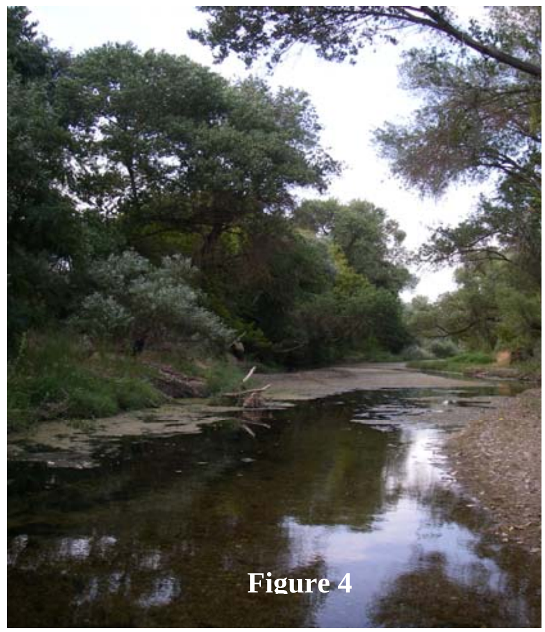
Figure 4


Figure 5
Photo by Lisa Thompson

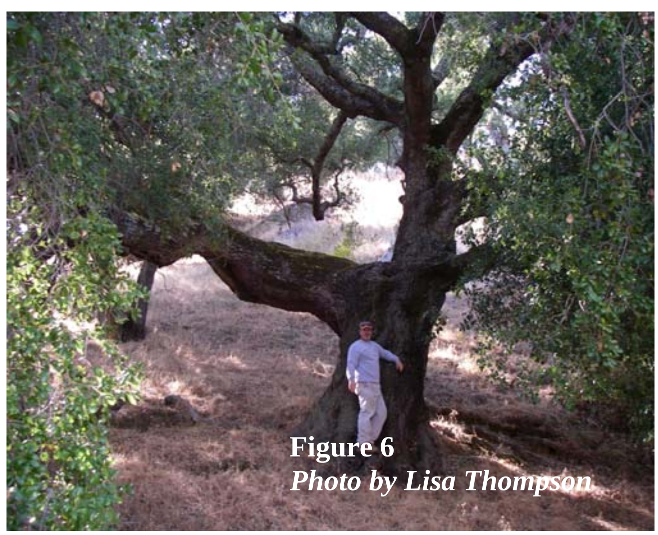
Figure 6
Photo by Lisa Thompson

Figures 3-8 show the diversity of site composition. The range of site characteristics included wide bankfull width, open canopy, and bedrock substrate (Figure 3), wide bankfull width, dense riparian canopy outside of bankfull, little flow and high temperatures (Figure 4), wide bankfull width, dry creek bed, a few very large trees flanking the stream bank (Figure 5), narrow bankfull width, bedrock substrate, cold water temperatures, high elevation, dense riparian foliage (Figure 6), variable bankfull width, cold water temperatures, large sycamores, high degree of cover (Figure 7), and open canopy, large oaks and sycamores, warmer water temperatures, some sections with dry creek bed (Figure 8). *Photos by Jenna Voss, except where noted*.

4. METHODS

A. Large Wood

Reaches approximately 984 feet long were marked using a hip chain. Measurements of bankfull width were made at approximately 164 foot intervals. We measured pieces of fallen dead wood, standing trees, and exposed roots within the bankfull width with length equal to or greater than 3.3 feet, and diameter equal to or greater than 3.9 inches. Diameter was measured using a diameter at breast height (DBH) tape or stadia rod (Figure 9). We also measured length, species (if identifiable), channel position, angle to stream flow, state of decay, relationship to wood jams, and function (e.g., formed pool, caused wood jam, stabilized bank).

Figure 9. DBH measurement of standing California sycamore on Trout Creek. *Photo by Jenna Voss*.

The height of standing trees from the base to the point at which all branches were estimated to be less than 10 cm diameter was measured with a clinometer (Haglof Electronic Clinometer – Metric Degrees®). Volume for each piece of LW was calculated using the formula, $v=l\pi r^2$, where v = volume, l = length, and r = radius = diameter/2.

B. Wood Jams

We defined a wood jam as a group of three or more pieces of LW, within the bankfull channel. We measured the distance each wood jam expanded onto the floodplain, noted whether it was held by a key piece, stabilized by standing trees, and whether it had caused a pool to form. A key piece was defined as one that stabilized a jam, or had a major role in blocking the downstream movement of other LW pieces.

C. Riparian Plots

To estimate future LW recruitment, we measured the standing trees within the riparian zone along six (two per 328 feet), randomly chosen transects perpendicular to the channel. Each standing tree, live or dead, that met the LW criteria and was tall enough that it could potentially fall into the bankfull width was measured. We recorded species, height, DBH, distance from the stream, and landform on which the trees were located.

D. Pools

One main pool was sampled extensively at each site. One air temperature logger and two water temperature loggers (Onset Optic Stowaway®) were installed near/in each main pool per reach from 15 July to 7 August 2006, inclusive, recording temperature every 30 minutes. We also recorded temperature and dissolved oxygen with a handheld meter (YSI 550A) once per main pool, to detect stratification in the vertical profile of the pool. For each reach we measured stream width, depth, and velocity (Global Water® flowmeter) to calculate flow. Water samples were collected, kept on ice during transport to the University of California at Davis, then frozen until they were analyzed for nitrogen and phosphorus at the University of California Division of Natural Resources Laboratory.

For each pool within the reach we measured length, maximum width, maximum depth, noted the pool type (e.g., plunge pool over boulder, mid-channel, lateral scour), and recorded the degree of LW influence on pool formation. Pools were considered to be either (1) caused by LW, (2) enhanced by LW, (3) influenced by LW, or (4) no influence of LW. Canopy cover was measured at the center of each pool with a spherical densiometer, and substrate composition (e.g., gravel, cobble, bedrock) was assessed at the downstream end of the main pool.

E. Fish Snorkel Sampling

The entire reach length marked with the hip chain was snorkeled in the upstream direction so that fish density per length of stream and LW loading would be comparable (Figure 10). Fish were identified to species where possible, and the approximate length of each fish was recorded on a wrist-mounted underwater plastic card. To ensure consistency of counts, species identification, and size estimates, the same person conducted all surveys.

Figure 10. Snorkeler conducts fish survey in Trout Creek. *Photo by Lisa Thompson*.

F. Data Analysis

Raw data were entered into Excel® and tables transferred to an ACCESS® database. Descriptive statistics were calculated in S-Plus®, and graphics were developed in Excel and SigmaPlot®. We also developed linear mixed-effects models (S-Plus version 6.1 software, Pinheiro and Bates 2000) to test relationships between steelhead and habitat factors.

5. RESULTS

A. Large Wood

Wood was categorized as fallen dead (commonly referred to as large woody debris in studies of coastal streams in the Pacific Northwest), not-standing live (live trees growing or fallen horizontally, exposed live roots), standing (both live trees and snags), and other (pieces of wood that did not fit the other categories, for example, a piece for which we could not determine whether it was alive or dead). For three pieces of wood in the fallen live and standing categories (out of a total of 953) it was not possible to determine status as standing or fallen. These pieces were included in the calculation of total LW, but excluded from calculations where wood was separated into fallen live and standing categories.

Fallen dead LW loading within the bankfull width averaged 681 cubic feet/acre across the 15 sites (Standard Deviation = 832). The loading of not-standing live LW was about a third less than that of fallen dead LW, averaging 215 cubic feet/acre (SD= 160). Standing live and dead trees contributed a high loading within the bankfull width, averaging 2,279 cubic feet/acre (SD= 2,465) (Figure 11).

Total LW loading including fallen dead LW, not-standing live LW, and standing trees averaged 3,175 cubic feet/acre (SD= 2,484).

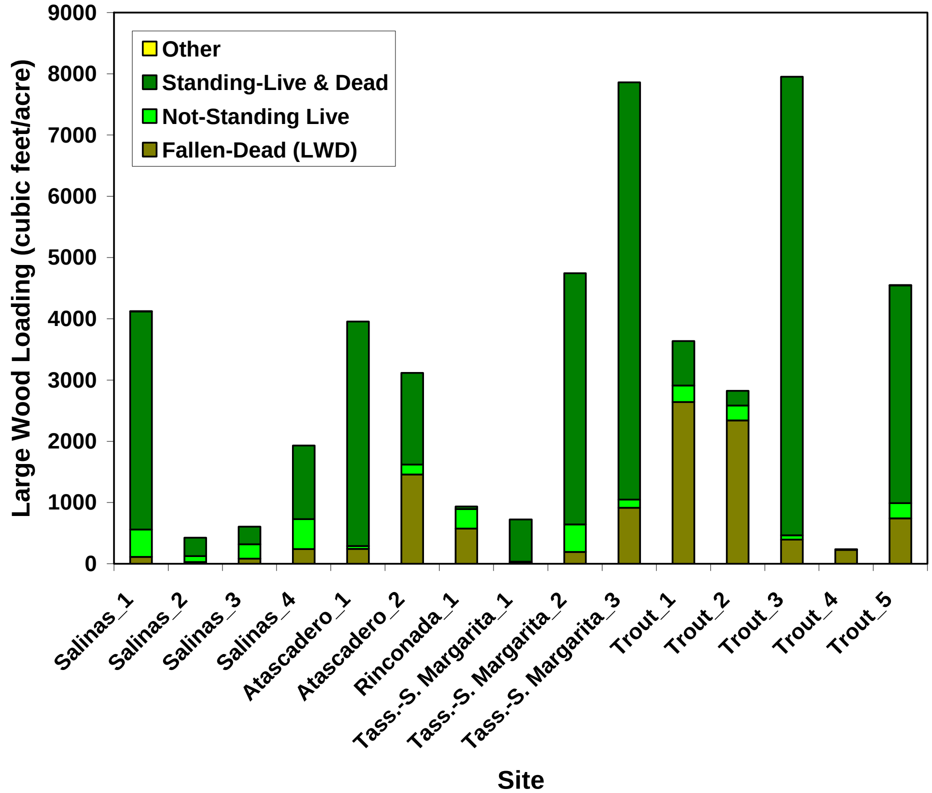

Figure 11. LW loading by site and type. Sites arranged by tributary, from most upstream (e.g., Salinas_1) to most downstream (e.g., Salinas _4). Standing trees within the bankfull width contributed a large proportion of total LW loading.

Of the tributaries in our study, Trout Creek had the most sites along an altitude gradient. Site types transitioned from high gradient hardwood forest to hardwood rangeland on the lower gradient valley floor. Fallen dead wood volume was highest at the more upstream sites, and declined along the gradient (Figure 11). Standing wood contributed greatly to total LW volume at the lower gradient sites, Trout_3, Trout_4, and Trout_5 (Figure 11). The large volume of standing wood at Trout_3 was composed mainly of mature California sycamore (*Platanus racemosa*), often with many large, exposed roots. Live trees at Trout_4, however, were mainly willows (*Salix* spp.) with DBH less than the LW criterion, resulting in a low total LW volume. Standing trees at Trout_5 were mainly red willow (*Salix laevigata*).

A total of fourteen tree species were identified at one or more of the fifteen study sites (Table 1). Sites were dominated by willow (*Salix* spp.) and oak species (*Quercus* spp.), California sycamore and Fremont cottonwood (*Populus fremontii*). Red willow was the most prolific of the tree species observed in our study, documented as LW or a standing tree at 12 of 15 sites.

Table 1. Tree species identified as large wood and/or standing trees within our fifteen sites. An asterisk designates large wood identifiable to genus only.

Genus	Species	Common name
Acer	*macrophyllum*	Bigleaf maple
Acer	*negundo*	Boxelder
*Alnus**		Alder
Fraxinus	*velutina*	Velvet (or Arizona) ash
Juglans	*californica*	California black walnut
*Pinus**		Pine
Pinus	*sabiniana*	Grey pine
Platanus	*racemosa*	California sycamore
Populus	*fremontii*	Fremont cottonwood
*Quercus**		Oak
Quercus	*agrifolia*	Coast live oak
Quercus	*douglasii*	Blue oak
Quercus	*lobata*	Valley oak
Salix	*laevigata*	Red willow
Salix	*lasiolepis*	Arroyo willow
Sequoia	*sempervirens*	Redwood
Umbellularia	*californica*	California laurel

Red willow also comprised the highest percent of key pieces in wood jams (Table 2). The lowest elevation site on Trout Creek, Trout_5, contained the highest number of wood jams, the majority of which contained at least one red willow key piece. Of all LW pieces measured in our study, 31.8% were contained within a wood jam, and 6.9% were a key piece.

Table 2. Proportion of key pieces in debris jams formed by different tree species. Mean values are the average of 15 sites (average size of key pieces at each site, averaged across the 15 sites). Not all sites contained all species as a key piece.

Species	Percentage of total key pieces (%)	Percentage of fallen dead and non-standing key pieces (%)	Percentage of standing key pieces (%)
California black walnut	1.56	--	4.17
California laurel	6.25	7.50	4.17
California sycamore	9.38	--	25.00
Coast live oak	9.38	13.75	2.08
Fremont cottonwood	3.91	--	10.42
Red willow	45.31	40.00	54.17
Unknown	24.22	38.75	0

B. Pools and Large Wood

We assessed the proportion of pools at each site for which (1) LW was the primary cause of the pool, (2) LW contributed to pool formation, or enhanced the habitat value of an existing pool, or (3) LW had no influence on the pool. Site Trout_3 was dry throughout the study so no pools were present and the site was excluded from this assessment. At five of fourteen sites, LW formed the majority of the pools. At an additional four sites, LW contributed to pool formation for a majority of pools, or enhanced pool habitat value. At least half the pools experienced some influence of LW at thirteen of fifteen sites. Salinas_3 was the only site at which LW did not influence a majority of pools.

C. Fish

Fish were observed at all fourteen sites with water. We observed seven native and six non-native fish species (Table 3). Between one and seven native species were seen at a given site, and between zero to five non-native species. Salinas_1 had only one identified native species, Sacramento sucker, while Tassajera-Santa Margarita_1, Trout_1 and Trout_2 had only steelhead. Total fish density averaged 1.22 fish/foot (SD = 0.94). Native fish density, excluding steelhead, averaged 0.92 fish/foot (SD = 0.90), while non-native fish density averaged 0.01 fish/foot (SD = 0.04).

Table 3. Native and non-native species observed in the upper Salinas River watershed.

Native		Non-native	
Catostomus occidentalis	Sacramento sucker	*Ameiurus* sp.	Bullhead
Gasterosteus aculeatus	Threespine stickleback	*Cyprinus carpio*	Carp
Lavinia exilicauda	Hitch	*Lepomis cyanellus*	Green sunfish
Lavinia symmetricus subditus	Monterey roach	*Lepomis macrochirus*	Bluegill
Oncorhynchus mykiss	Rainbow trout / steelhead	*Micropterus dolomieu*	Smallmouth bass
Ptychocheilus grandis	Sacramento pikeminnow	*Micropterus salmoides*	Largemouth bass
Rhinichthys osculus	Speckled dace		

Steelhead were observed at nine out of fourteen sites, averaging 0.07 fish/foot (SD = 0.11). Steelhead were not observed at any mainstem sites during regular surveys, although one juvenile steelhead was observed during a preliminary survey on 13 July 2006. Our study coincided with a statewide heat wave. Air temperatures at our sites peaked at 120.8 ^{o}F at Salinas_2 on 22 July 2006. For comparison, the average maximum air temperature for the town of Paso Robles in July is 94 ^{o}F, and the record maximum, observed in June and July 1961, was 115 ^{o}F (Source: http://www.weather.com). Mean water temperature at fourteen sites ranged from 61.3 to 74.3 ^{o}F, and maximum water temperature ranged from 65.7 to 89.6 ^{o}F. The presence of steelhead during the hot, mid-summer period was correlated with water temperature. Sites with steelhead had maximum water temperatures that were 11.1 ^{o}F cooler than sites without steelhead ($p=0.02$) (Figure 12). Mean water temperatures were 5.5 ^{o}F cooler at sites with steelhead ($p=0.07$).

Other environmental factors also appeared to influence steelhead presence. Sites with steelhead (any age class) had more canopy cover ($p=0.054$) and more pools per reach than those where steelhead were absent (p=0.055). For sites with steelhead, steelhead were more abundant at sites with higher fallen dead LW loading (p=0.014). We also compared the habitat of sites with and without adult steelhead. Sites with adult steelhead had more wood jams (p=0.005), more pools (p=0.006), and more canopy cover (p=0.008) than sites where adult steelhead were absent (Thompson et al. In prep).

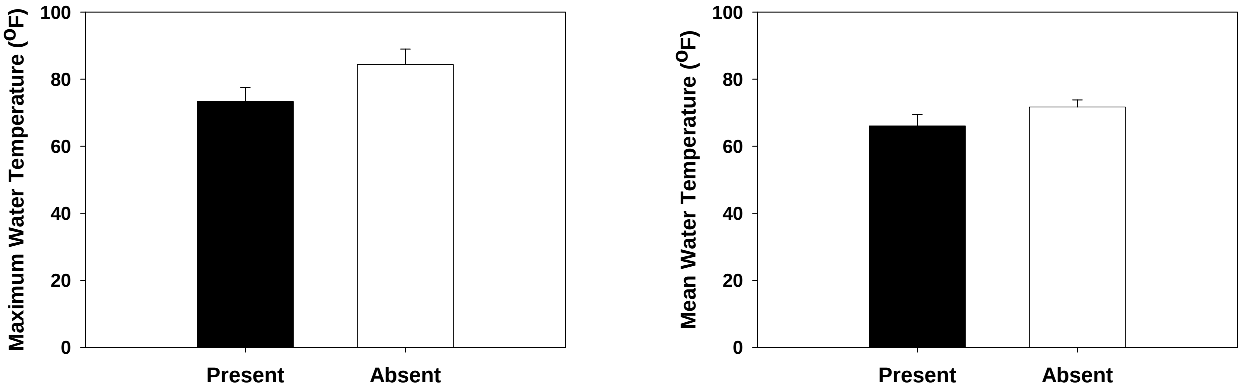

Figure 12. A) Maximum and B) mean water temperature for sites with and without steelhead. Error bars are one standard deviation.

6. DISCUSSION

The presence of LW in the upper Salinas River watershed may be important in the formation of suitable habitat for steelhead. LW was the primary agent in the formation of a majority of pools at about one third of our sites, and was influential in forming pool shape or providing overhead cover at another third of the sites. Since adult steelhead presence is tied to the presence of pools, hardwood LW may provide fish habitat in this watershed through its influence on pool formation.

Steelhead abundance is correlated with fallen dead LW frequency, and fallen dead LW is important in the formation of wood jams. However, standing trees contributed a large proportion of total LW loading across all of our sites and may be important in the formation of suitable habitat for steelhead. Due to the Mediterranean climate of southern California, water temperatures and stream flows vary greatly from the short, rainy winter to the hot, dry weather the rest of the year. The variation in precipitation creates wide bankfull widths during short-term high winter flows, scouring out deep pools around the roots of standing trees. During the hot, dry summer months, the wetted stream channel becomes very narrow, sometimes drying up completely. The receding wetted channel allows establishment of trees within the moist bankfull width, but limits the habitat area for fish. The pools formed around tree roots were very important, becoming the last refuges for fish at some sites.

Standing trees may also be important in forming fish habitat due to their ability to anchor wood jams. While fallen dead LW pieces may form the key piece in a jam, the rapid decay rate of hardwood may make these jams short-lived. A jam anchored by a standing tree is likely to be more persistent in a hardwood-dominated system. Standing trees within the bankfull width are also likely to fall within the bankfull width once they die, contributing to fallen dead LW. As a result, a standing tree, though often interacting only with high flows reaching the base of the trunk, may be important to the formation of fish habitat in the Salinas River watershed.

Native fish species were present at all fourteen sites with water. The number of native species increased with decreasing gradient for each tributary and the mainstem Salinas. Upstream sites, such as Tassajera-Santa Margarita_1, Trout_1, and Trout_2, had only steelhead. These higher elevation sites were cooler, had higher flow velocities, and a higher proportion of overhead cover. Other native fish species may have been naturally excluded from these sites because they are less adapted to colder water temperatures and/or higher flow velocities. Non-native fish species were in lower abundance than native species at all sites, and tended to be observed at the more downstream sites on the mainstem and tributaries. These sites were typically warmer and had lower flow velocities than upstream sites (L.C. Thompson, unpublished data).

Steelhead were present at sites with more overhead cover, more pools, and in the case of adults, more wood jams. Young-of-the-year steelhead were usually observed in shallow riffles over a gravel bottom, whereas juvenile and adult steelhead were observed in deeper water, such as pools or runs, and under large wood. Steelhead were present at nine of fourteen sites (64 percent). We conducted our sampling at the hottest time of the year, when we would expect steelhead to be restricted to the coolest locations, such as deep, cool pools. As a result, our data may represent the minimum distribution of steelhead across these sites in 2006.

Sites in the upper Salinas River watershed had loadings of fallen dead LW comparable to privately owned sites studied by Opperman (2005) in northern California (Table 4). Mean loading was one third that of conifer-dominated Sierra Nevada sites, and only one sixteenth that of conifer-dominated sites in the Pacific Northwest. While it may be unreasonable to expect hardwood-dominated areas to contribute the volume of LW possible in conifer forests, average volumes at our predominantly private sites were less than half that of hardwood-dominated public sites (e.g., protected watersheds within parks) studied by Opperman (2005) in northern California.

Table 4. Large woody debris loading by geographic region. Data describe the equivalent of fallen, dead large wood loading in our study. [a]Data from Andrus and others (1988), Harmon and others (1986), and Keller and Tally (1979). [b]Data from Berg and others (1998). [c]Data from Opperman (2005).

Region	Number of sites	Mean (SD) (cubic feet/acre)	Median (cubic feet/acre)	Maximum (cubic feet/acre)
Pacific Northwest (BC, WA, OR) [a]	62	10,754 (11,583)	7,651	64,350
Sierra Nevada conifer [b]	12	2,288 (1,416)	2,274	5,463
No. CA hardwood, protected watersheds [c]	9	1,645 (472)	1,530	2,474
No. CA hardwood, private land [c]	23	601 (615)	286	2,088
So. CA hardwood (this study)	15	672 (829)	243	2,345

Since LW appears to be important in the formation and maintenance of habitat for steelhead, it may be beneficial to increase the volume of fallen dead hardwood LW in streams through the use of best management practices (BMPs) as suggested in Opperman et al. (2006). Landowners whose properties include steelhead streams could adopt BMPs such as: (1) the promotion of hardwood riparian tree regeneration such as oaks, California sycamore, Fremont cottonwood, and willows; (2) promoting the survival of hardwood seedlings; (3) allowing trees to reach a size at which their DBH would be sufficient to allow them to function as LW; and (4) leaving fallen dead LW in the channel to contribute to fish habitat such as pools. Given the broad distribution of fish in the watershed, the concerns of landowners over fish-related regulations, and the role of hardwood LW in contributing to pool habitat, the adoption of voluntary BMPs should increase the capacity of private landowners, resource agency staff, and public interest groups to cooperate in the management of fish-bearing streams on hardwood-dominated lands.

7. ACKNOWLEDGEMENTS

We would like to thank all of the cooperators on our project. Granting us access to private property to conduct our research was an invaluable contribution to the furthering of knowledge about the abundance, distribution, and habitat characteristics of steelhead in the Salinas River watershed.

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