Central Coast Watershed Studies

CCoWS

Large Woody Debris on the Carmel River From the Dam Keeper's House to Carmel Lagoon Fall 2017

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Preface

The following report documents the Fall 2017 locations and characteristics of large woody debris (LWD) along the lower reach of the Carmel River in California, from the former Dam Keepers House to the Carmel Lagoon.

This report may be cited as:

Steinmetz, C. and Smith DP. 2018. Large Woody Debris on the Carmel River from the Former Dam Keeper's House to Carmel Lagoon, Fall 2017: Watershed Institute, California State University Monterey Bay, Publication No. WI-2018-02, 25 pp.

Previous Carmel River LWD survey reports:

2016

MacCarter L, Fields J, Smith DP. 2017. Large Woody Debris on the Carmel River from the Dam Keeper's House to Carmel Lagoon, Fall 2016: Watershed Institute, California State University Monterey Bay, Publication No. WI-2017-03, 27 pp.

2015

MacCarter L, Fields J, Smith DP. 2016. Large Woody Debris on the Carmel River from Camp Steffani to the Carmel Lagoon, Fall 2015: Watershed Institute, California State University Monterey Bay, Publication No. WI-2016-05, 25 pp.

2013

ENVS 660, CSUMB Class. Beck E, Geisler E, Gehrke M, Goodmansen A, Leiker S, Phillips S, Rhodes J, Schat A, Snyder A, Teaby A, Urness J, Wright D. 2013. A Survey of Large Wood on the Carmel River: Implications for Bridge Safety Following San Clemente Dam Removal: The Watershed Institute, California State Monterey Bay, Publication No. WI-2013-04, 46 pp.

2003

Smith DP, Huntington P. 2004. Carmel River large woody debris inventory from Stonepine to Carmel Lagoon, Fall 2003: Watershed Institute, California State University Monterey Bay, Publication No. WI-2004-01, 72 pp.

2002 pilot study:

Smith DP, Huntington P, Harter K. 2003. Carmel River Large Woody Debris Inventory from San Clemente Dam to the Lagoon Fall 2002: Watershed Institute, California State University Monterey Bay, Publication No. WI-2003-13, 38 pp.

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Executive Summary

Large woody debris (LWD) serves multiple functions in stream channel morphology and ecology. It provides services and habitat for several life stages of steelhead trout, improves riparian habitat, connects aquatic and terrestrial habitats, fosters hydraulic habitat complexity, and influences streambank stability. LWD also poses potential risks to infrastructure; surges in the accumulation and abundance of LWD in a channel can increase flood frequency and threaten bridge safety.

Flow of LWD to the lower Carmel River (Monterey County, California) was restricted by the San Clemente Dam (SCD), built in 1921. The dam was removed in fall of 2015 before the 2016 water-year runoff. We conducted a before-and-after dam removal study to assess changes in LWD that occurred as a result of dam removal. This report documents the position and general description of all LWD in the lower Carmel River after the 2017 water-year runoff, the second year after SCD removal. The 2017 survey occurred after an exceptionally wet water year, in which Carmel River gages recorded three events greater than the 10-year flood and one peak near the 30-year flood. This inventory followed the the Soberanes fire, which extended into the upper Carmel Watershed in summer and fall 2016.

There were approximately 817 instances of single or multiple LWD recorded in the 2017 study area, which included the same seventeen reaches as the 2016 survey from the former dam keeper's house to near the Carmel Lagoon (26.39 km). The 2017 count was less than 1% different than the 2016 count of 824 instances of LWD, showing that the average density of LWD (occurrences/km) in the Carmel River was relatively stable after strong hydrologic events. Although the overall density did not change from 2016, each of the seventeen reaches showed changes, with large increases found at the upper-middle reaches near Garland Park (reaches seven through nine). The LWD was overall less embedded, less decomposed, and found more frequently in the active channel in 2017 compared to 2016. The 2017 LWD density underestimates the amount present immediately following winter 2017 because of wood removal work performed to reduce risk of flood, erosion, and bridge damage that occurred before our survey.

Despite the recent Soberanes fire, only one piece of LWD was observed with burn marks. The piece was observed directly upstream of the study area, and below the former SCD.

Introduction

The San Clemente Dam (SCD) was removed in 2015 to improve safety, improve fish migration, and to reconnect flows of large wood debris (LWD) and sediment past the dam site (Bouton *et al.* 2016). This "process-based" restoration (e.g., Beechie *et al.* 2010) was expected to restore ecological benefits of LWD and spawning gravels to areas that had been deprived of natural sources by dam construction in 1921 (Bouton *et al.* 2016). A series of LWD inventories spanning the periods before and after dam removal were designed to record the dam removal impact. Previous reports further describe the background and context of the LWD study which began in 2002 (Smith and Huntington 2004, MacCarter *et al.* 2016, 2017). This report is the 2017 LWD inventory, the second in the post-SCD dam removal period.

A pre-SCD removal 2015 LWD survey found 62.4 % increase in LWD density (occurrences/km) in the lower Carmel River from the initial 2002 and 2003 LWD surveys (MacCarter e*t al.* 2016). With the SCD blocking passage of LWD during those years, the increase was likely due to MPWMD management activities that promoted native riparian tree growth along the lower Carmel River. The overall density of LWD in the lower Carmel River dropped slightly between 2015 (33.3 LWD/km) and 2016l (31.2 LWD/km) during the first year after the SCD removal (MacCarter e*t al.* 2017). However, the 2016 survey showed increases of LWD density in reaches just below the former SCD, suggesting that LWD was free to pass through the former dam site, but had not yet moved further downstream. The 2016 report predicted that subsequent years would show an increase in LWD density further downstream of the former SCD (MacCarter e*t al.* 2017).

The 2017 water-year brought several large storm events, with maximum flow reaching 10,900 cfs at the USGS Robles Del Rio gage (USGS 2017); the highest peak in over two decades. Prior to the nearly 30-year flood event, stream gauges recorded 3 hydrologic events close to the 10-year flood.

Flood events in 2017 were preceded by the summer 2016 Soberanes fire, which extended into the upper Carmel Watershed above the former SCD. The combination of high flow events and recently burned forest is favorable for LWD accumulation.

We surveyed the density and distribution of LWD in the Carmel River below the former SCD after the 2017 water-year runoff using the methods described in the previous three (2003, 2015, and 2016) surveys (Smith and Huntington 2004, MacCarter *et al.* 2016, 2017). We surveyed the same reaches that were inventoried in 2016 from the former dam keepers house to the Carmel Lagoon for a total of 26.39 km (Fig. 1). This report compares the 2017 LWD survey to the 2015 and 2016 pre- and post-dam removal surveys.

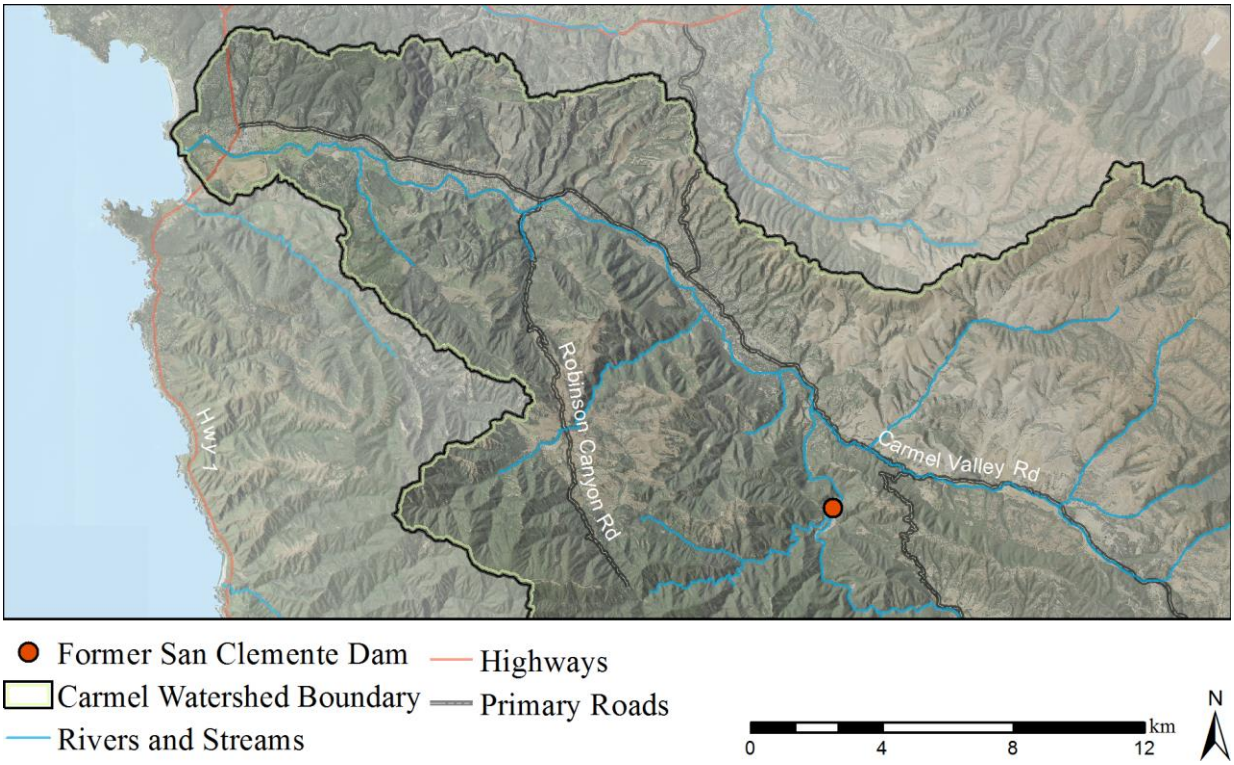


Figure 1. Survey area overview below former San Clemente Dam, Carmel Watershed, CA.

Methods

Following the Smith and Huntington (2004) survey protocol, we inventoried all single pieces of wood with a diameter and length of at least 15 cm and 1.5 m, respectively. LWD was included if it occurred in the active channel of the Carmel River. The active channel was defined as the approximate bankfull channel. We identified bankfull when at least two of the following indicator criteria were met:

1. A consistent break in slope to a lower angle indicating the presence of a floodplain.
2. ≥ 50% vegetated cover, including woody and herbaceous species.
3. A fining in surface sediment particle size.

We recorded LWD that had the greatest potential to move within the channel and documented whether they were positioned in the active channel or in the area connecting the active channel to the floodplain (Table 1, Appendix A, B). Pieces found in the intermediate area were recorded as <50% within the active channel. Several instances of LWD occurred on the floodplain and were recorded when they had the potential to be recruited at high flow conditions. The study did not include all floodplain areas because they were not usually accessible; the inclusion or exclusion of perichannel wood has the potential to vary between inventories.

When two or more qualifying pieces of LWD were touching, we considered them a "multiple" piece accumulation. Beginning in 2016, we considered multiple pieces an accumulation when two or more pieces of LWD were not touching but were grouped together with smaller wood. We documented the approximate length and width of the accumulation, the average length and width of the pieces within the accumulation by size categories, and the number of LWD in the accumulation (Appendix A, B). We noted the presence of rootballs for both single and multiple LWD occurrences. We recorded rootballs separately if they had a diameter and length of at least 15 cm and 1.5 m respectively and were detached from the trunk.

We visually approximated the dominant substrate directly below LWD as sandy, pebbles, cobble, or boulders.

LWD embeddedness was documented by how well it was anchored in the vegetative bank or the streambed. Pieces of LWD that rested above the sediment were considered not embedded. LWD that were incompletely embedded in either the streambed or vegetative bank were marked as partially embedded and pieces that were entrenched along their entire length were recorded as fully embedded.

Table 1. Data fields for Carmel large woody debris survey. See Appendix A for category descriptions and Appendix B for a sample data sheet.

Category	Description
Date, reach, surveyors	General reach name assigned
Location	Eastings and northings in feet (NAD 1983 California State Plane Zone IV)
Log type	Single, multiple, +/- rootball
Width (cm)	LWD diameter in centimeters (15 cm minimum, measured in size classes)
Length (m)	LWD length in meters (1.5 m minimum, measured in size classes)
# Pieces	Estimated number of LWD pieces in a multiple
Condition	Degree of wood decay
Embedment	How well anchored the wood is in the bed or vegetative bank
Part of channel	Main channel, <50% in active channel, not in active channel
Bank Location	Location of the wood on river right, river left, or main channel.
Type of Substrate	Visual approximation of median grain size beneath LWD
Estimated Length	Approximate length of LWD accumulations and jams (m)
Estimated Width	Approximate width of LWD accumulations and jams (cm)
Comments	

We recorded the condition of LWD as less than 5% decomposed, partially decomposed, or greater than 75% decomposed (Appendix A, B). Pieces that still had most their bark and smaller branches intact were marked as less than 5% decomposed. Pieces were considered greater than 75% decomposed if they easily broke apart. See Appendix A for descriptions of the data collected.

In the fall of 2017 (August 28 – October 7), seventeen reaches of the Carmel River were surveyed for LWD (Fig. 2). From upstream to downstream, these reaches were:

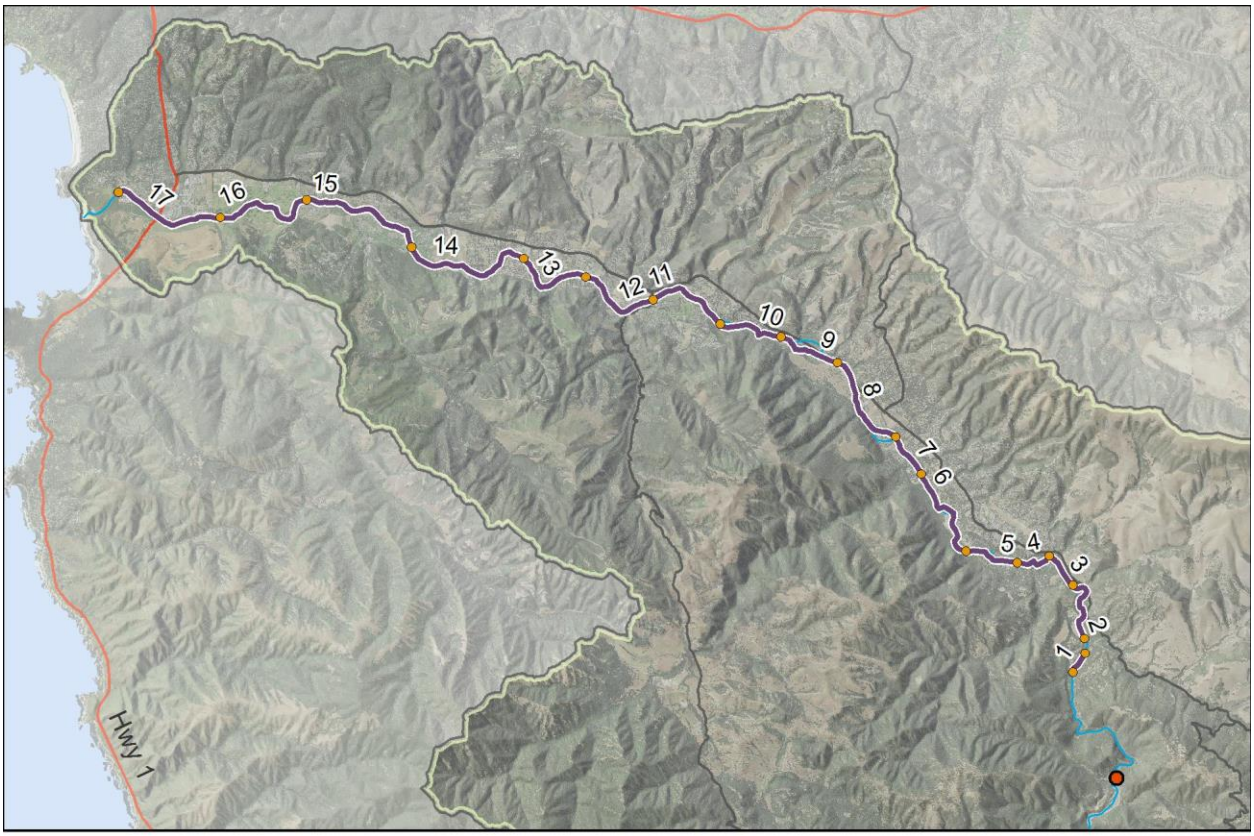
1. Dam Keeper's House to Sleepy Hollow (not surveyed in 2003 or 2015)
2. Sleepy Hollow to Camp Steffani Road (not surveyed in 2003 or 2015)
3. Camp Steffani Road to Lower Circle
4. Lower Circle to Rosie's Bridge (not surveyed in 2003)
5. Rosie's Bridge to de Dampierre
6. De Dampierre to the Carmel Valley Trail and Saddle Club at Borronda Road
7. Borronda Road to Garland Park Stables
8. Garland Park Stables to Garland Park
9. Garland Park to the Narrows
10. Narrows to Scarlett Road
11. Scarlett Road to Robinson Canyon Road
12. Robinson Canyon Road to Upstream Schulte Road
13. Upstream Schulte to Downstream Schulte Road
14. Downstream Schulte Road to Quail Lodge Golf course
15. Quail Lodge Golf Course to Via Mallorca Road
16. Via Mallorca Road to Rancho Cañada Golf Course
17. Rancho Cañada Golf Course to the head of the Carmel Lagoon.

The 2017 census re-inventoried reaches from the 2016 survey and were based on the 2003 survey by Smith and Huntington (2004, Table 2). The former Dam Keeper's House marked the upper limit of the 2017 study. The structure was razed in 2016, following the 2016 survey. The upper end of the reach is UTM NAD83 615028E 4035151N. As in the 2016 survey, we did not survey a 0.33 km section between the Dam Keeper's House and Sleepy Hollow because the channel was braided and identification of the main channel and bankfull was difficult. We ended the survey in the Carmel Lagoon when the water became too deep to wade during low-flow conditions. This point was approximately in-line with the Carmel Valley Mission.

We recorded LWD locations with a handheld Trimble GeoExplorer-III receiver set to SBAS real-time processing. We differentially corrected the GPS coordinates in Pathfinder Office.

We created maps using ArcMap (v.10.4) GIS that displayed each single and multiple LWD occurrence over a high resolution NAIP digital orthophoto.

We compared the 2017 results to LWD censuses completed in 2015 and 2016 to identify trends in the distribution and density of wood and to assess how the amount and composition of LWD below the SCD changed over time.



2017 Survey Reach

1. Dam Keeper to Sleepy Hollow **
2. Sleepy Hollow to Camp Steffani Road **
3. Camp Steffani Road to Lower Circle
4. Lower Circle to Rosies Bridge *
5. Rosies Bridge to Dedampierre
6. DeDampierre to Borronda
7. Borronda to Garland Stables
8. Garland Stables to Garland Park
9. Garland Park to Narrows
10. Narrows to Scarlett
11. Scarlett to Robinson Canyon Road
12. Robinson Canyon Road to Upstream Schulte
13. Upstream Schulte to Downstream Schulte
14. Downstream Schulte to Quail Lodge
15. Quail Lodge to Via Mallorca
16. Via Mallorca to RanchoCanada
17. Rancho Canada to Lagoon

Reach Start/End
Former San Clemente Dam
Carmel River
Highways
Primary Roads

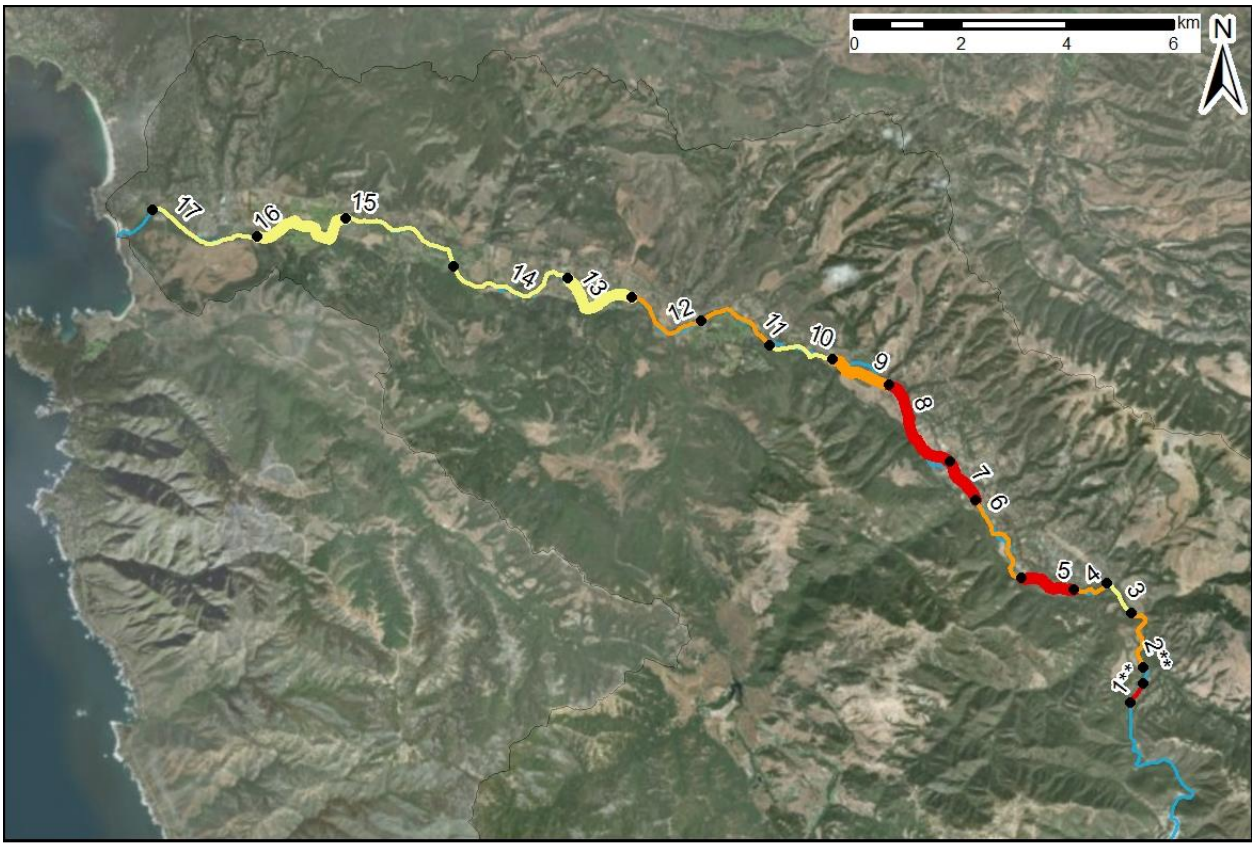
** 2016 and 2017 survey only * Not surveyed in 2003

Figure 2. Lower Carmel River survey reaches based on the 2003 Smith and Huntington survey.

Results

We recorded 817 instances of single or multiple LWD occurrences within 26.39 km (16.36 mi; Fig. 3, Tables 2 to 7). Most of the wood surveyed was between 15 cm and 30 cm in diameter (74%) and 1.5 to 3.0 meters long (40%, Fig. 4, 5). The dominant substrates were sand (44%) and cobble (32%; Table 4). The proportion of sand on the bed increased in nearly all reaches in 2017 (Fig. 6). The sand proportion was greater in 2017 than it was in 2015 and 2016.

The average density of LWD for the entire 2017 study area was 31.0 occurrences per kilometer (Table 2). LWD densities were highest in the upper-middle reaches (seven through nine), with the greatest density occurring near Garland Park. The overall density of LWD in 2017 was nearly identical to the 2016 density (31.2 LWD/km). Differences in LWD densities occurred between all individual reaches from 2016 to 2017, with increases in six of the seventeen reaches (Fig. 7). LWD in 2017 was less embedded and less decomposed than previous years (Fig. 8, 9). We found a greater percentage of LWD in the active channel compared to previous years (Fig. 10).



LWD Denisty (Occurences/ km)
Low (8- 29)
No increase from 2016
Increase from 2016
Medium (30- 45)
No increase from 2016
Increase from 2016
High (46- 85)
No increase from 2016
Increase from 2016

1. Dam Keeper to Sleepy Hollow **
2. Sleepy Hollow to Camp Steffani Road **
3. Camp Steffani Road to Lower Circle
4. Lower Circle to Rosies Bridge *
5. Rosies Bridge to Dedampierre
6. DeDampierre to Borronda
7. Borronda to Garland Stables
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11. Scarlett to Robinson Canyon Road
12. Robinson Canyon Road to Upstream Schulte
13. Upstream to Downstream Schulte
14. Downstream Schulte to Quail Lodge
15. Quail Lodge to Via Mallorca
16. Via Mallorca to RanchoCanada
17. Rancho Canada to Lagoon

** 2016 and 2017 survey only * Not surveyed in 2003

Figure 3. Single and multiple LWD occurrences per km for each survey reach. Thicker lines indicate an increase in LWD from 2016 to 2017. The greatest wood density in Fall 2017 was present in reaches near Garland Park (seven and eight).

Table 2. Positions of fifteen sample reaches in 2017 large woody debris (LWD) survey of the Carmel River, California including the number of LWD occurrences per kilometer.

#	Reach	Reach length (km)	Cumulative Distance (km)	Cumulative Distance (mi)	Occurrences of LWD	LWD/ km
1	Dam Keeper- Sleepy Hollow	0.44	26.4	16.4	25	57
2	Sleepy Hollow- Camp Steffani	1.40	26.0	16.1	59	42
3	Camp Steffani-Lower Circle	0.74	24.6	15.2	6	8
4	Lower Circle-Rosie's Bridge	0.75	23.8	14.8	23	31
5	Rosie's Bridge-De Dampierre	1.07	23.1	14.3	62	58
6	De Dampierre-Borronda	2.01	22.0	13.6	63	31
7	Borronda-Garland Stable	0.89	20.0	12.4	76	85
8	Garland Stable-Garland Park	2.01	19.1	11.8	104	52
9	Garland Park-Narrows	1.25	17.1	10.6	57	45
10	Narrows-Scarlett	1.33	15.8	9.8	35	26
11	Scarlett-Robinson	1.67	14.5	9.0	58	35
12	Robinson-Upstream Schulte	1.69	12.8	8.0	65	39
13	Upstream-Downstream Schulte	1.61	11.2	6.9	34	21
14	Downstream Schulte-Quail Lodge	2.66	9.5	5.9	45	17
15	Quail Lodge-Via Mallorca	2.50	6.9	4.3	35	14
16	Via Mallorca-Racnho Canada	2.14	4.4	2.7	50	23
17	Rancho Canada-Lagoon	2.24	2.2	1.4	20	9
	Total and Weighted Mean[1]		**26.4**	**16.4**	**817**	**31.0**

1. Average is weighted by the length of each reach.

Table 3. Summary statistics for 2017 LWD survey of the Carmel River showing LWD occurrence type and whether a rootball was present. See data descriptions in Appendix A.

Reach #	Occurrences of LWD	LWD Occurrence Type (% of total reach)			
		Single	Multiple	Rootball Only	Rootball Present
1	25	76%	24%	0%	40%
2	59	86%	14%	0%	36%
3	6	100%	0%	0%	0%
4	23	74%	17%	9%	14%
5	62	71%	29%	0%	29%
6	63	68%	30%	2%	44%
7	76	80%	18%	1%	40%
8	104	78%	20%	2%	32%
9	57	75%	23%	2%	25%
10	35	97%	3%	0%	17%
11	58	76%	24%	0%	29%
12	65	83%	17%	0%	20%
13	34	74%	26%	0%	32%
14	45	93%	7%	0%	20%
15	35	89%	11%	0%	37%
16	50	84%	14%	2%	20%
17	20	95%	5%	0%	35%
Wt. mean[1]	**817**	**80%**	**19%**	**1%**	**30%**

1. Averages are weighted by the number of occurrences of LWD in each reach.

Table 4. Summary statistics for 2017 LWD survey of the Carmel River showing LWD bank location and underlying substrate for each reach. See data descriptions in Appendix A.

	Bank Location (% of total reach)			Substrate (% of total reach)			
Reach #	Main Channel	River Left	River Right	Sand	Gravel	Cobble	Boulder
1	8%	48%	44%	20%	0%	36%	44%
2	17%	34%	49%	19%	7%	29%	46%
3	0%	33%	67%	83%	0%	17%	0%
4	9%	17%	70%	48%	4%	30%	17%
5	31%	35%	34%	34%	19%	34%	13%
6	30%	46%	24%	33%	16%	38%	13%
7	24%	32%	45%	41%	11%	34%	14%
8	9%	38%	54%	47%	8%	32%	13%
9	26%	39%	35%	37%	5%	58%	0%
10	14%	43%	43%	57%	11%	29%	3%
11	33%	38%	29%	53%	14%	33%	0%
12	17%	38%	45%	60%	15%	23%	2%
13	32%	47%	21%	50%	12%	38%	0%
14	13%	51%	36%	56%	13%	24%	7%
15	20%	40%	37%	54%	20%	23%	3%
16	42%	20%	38%	32%	34%	30%	4%
17	5%	40%	55%	95%	5%	0%	0%
Wt. mean[1]	**21%**	**38%**	**41%**	**44%**	**13%**	**32%**	**11%**

1. Averages are weighted by the number of occurrences of LWD in each reach.

Table 5. Summary statistics for 2017 LWD survey of the Carmel River showing the condition of LWD for each reach. See data descriptions in Appendix A.

	Condition (% of total reach)		
Reach #	<= 5% decomposed	Partially decomposed	>=75 % decomposed
1	28%	72%	0%
2	32%	61%	7%
3	50%	33%	17%
4	39%	52%	9%
5	42%	53%	5%
6	37%	63%	0%
7	63%	37%	0%
8	44%	53%	3%
9	23%	75%	2%
10	43%	54%	3%
11	43%	50%	5%
12	45%	49%	6%
13	29%	62%	9%
14	42%	42%	16%
15	54%	40%	6%
16	28%	70%	2%
17	45%	50%	5%
Wt. mean[1]	**41%**	**55%**	**4%**

1. Averages are weighted by the number of occurrences of LWD in each reach.

Table 6. Summary statistics for 2017 LWD survey of the Carmel River showing LWD embedment for each reach. See data descriptions in Appendix A.

	Embedment (% of total reach)				
Reach #	No embedment	Partially in bed	Partially in veg bank	Fully in bed	Fully in veg bank
1	88%	4%	8%	0%	0%
2	83%	5%	12%	0%	0%
3	83%	17%	0%	0%	0%
4	91%	0%	9%	0%	0%
5	79%	10%	10%	0%	2%
6	73%	11%	6%	8%	2%
7	74%	11%	16%	0%	0%
8	76%	11%	11%	2%	1%
9	75%	11%	12%	2%	0%
10	63%	9%	20%	3%	6%
11	72%	9%	16%	2%	0%
12	86%	5%	9%	0%	0%
13	88%	6%	3%	3%	0%
14	76%	16%	4%	4%	0%
15	46%	17%	34%	0%	3%
16	40%	20%	36%	4%	0%
17	45%	5%	50%	0%	0%
Wt. mean[1]	**73%**	**10%**	**14%**	**2%**	**1%**

1. Averages are weighted by the number of occurrences of LWD in each reach.

Table 7. Summary statistics for 2017 LWD survey of the Carmel River showing whether LWD was part of the active channel for each reach. See data descriptions in Appendix A.

	Part of Channel (% of total reach)		
Reach #	In Active Channel	<50% in Active Channel	Not in Active Channel
1	72%	12%	16%
2	80%	7%	14%
3	67%	33%	0%
4	70%	9%	22%
5	84%	6%	10%
6	78%	11%	11%
7	76%	13%	11%
8	69%	19%	12%
9	74%	14%	12%
10	74%	17%	9%
11	91%	3%	5%
12	71%	17%	12%
13	82%	9%	9%
14	62%	29%	9%
15	69%	20%	11%
16	84%	12%	4%
17	75%	15%	10%
Wt. mean[1]	**76%**	**14%**	**11%**

1. Averages are weighted by the number of occurrences of LWD in each reach.

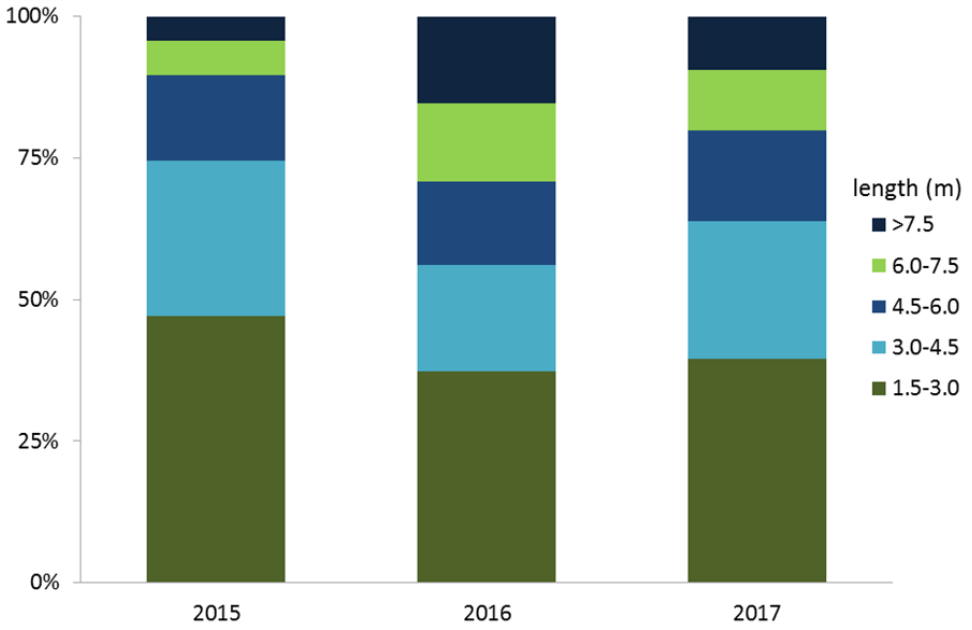
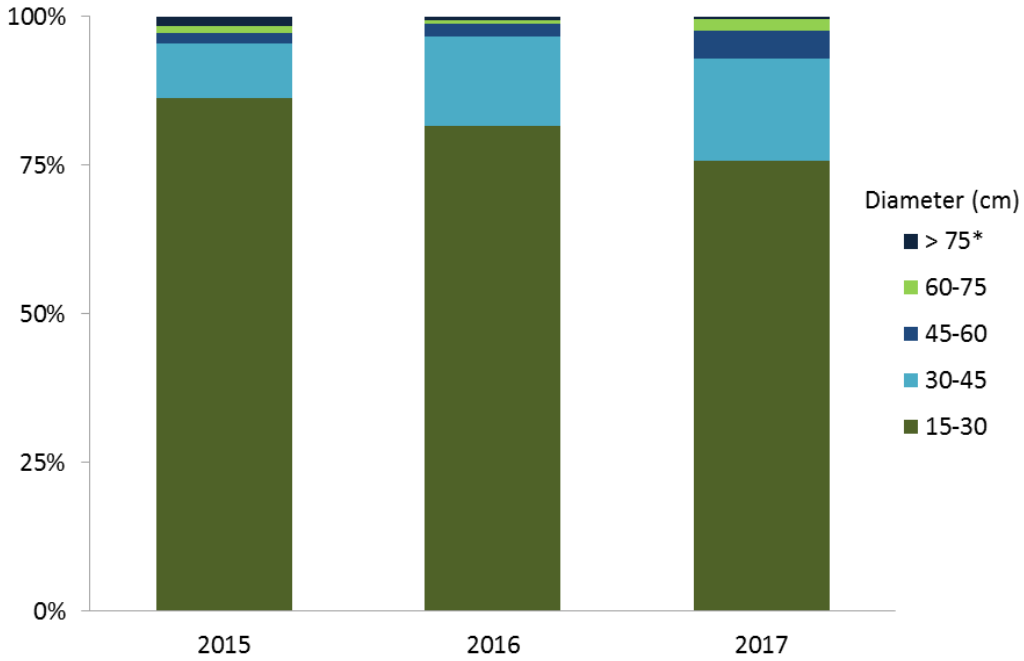
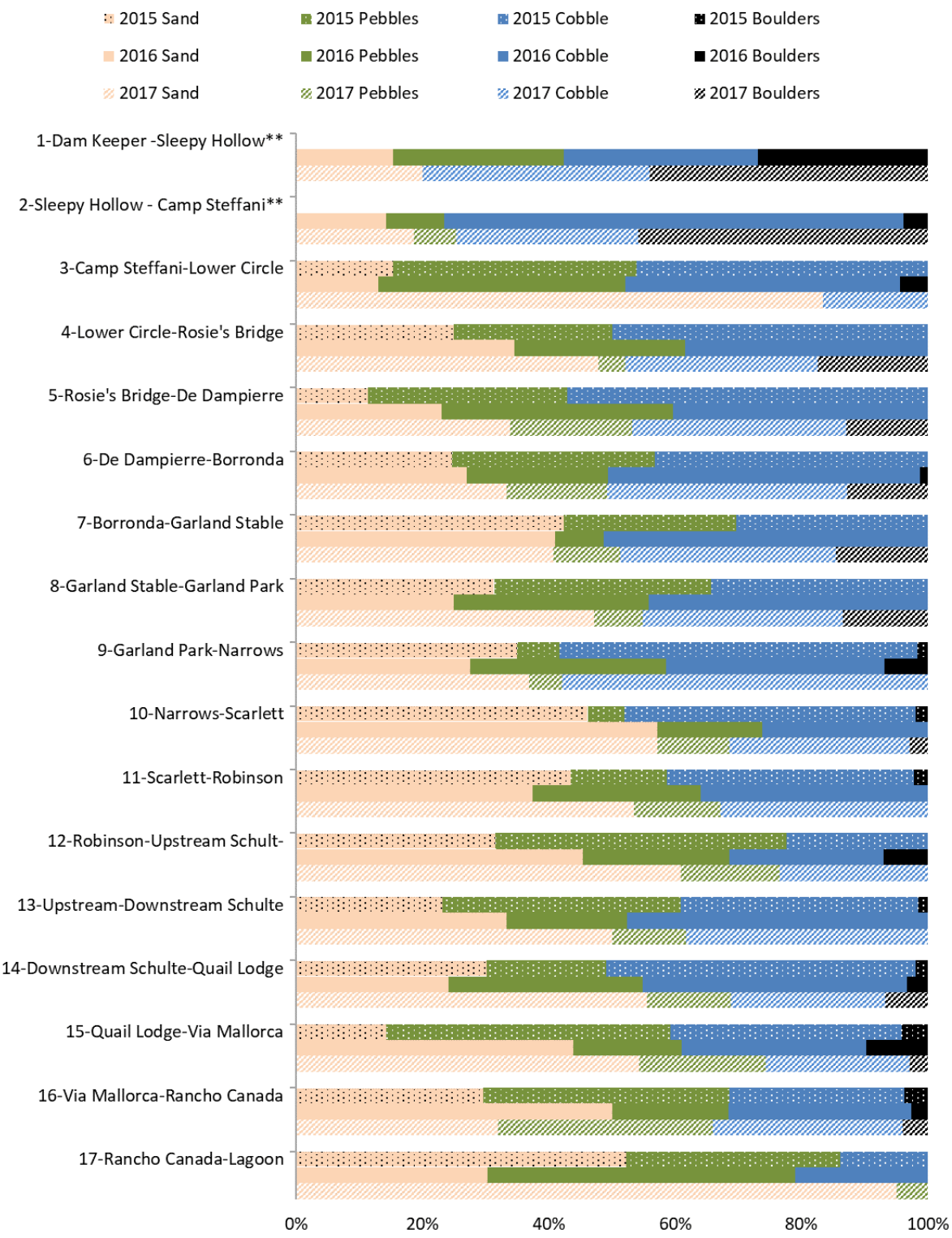


Figure 4. Percent of LWD in each length class by year. The 2015 survey was ~24 km while the 2016/2017 studies surveyed 26 km. The lengths of LWD have been relatively consistent since 2015.



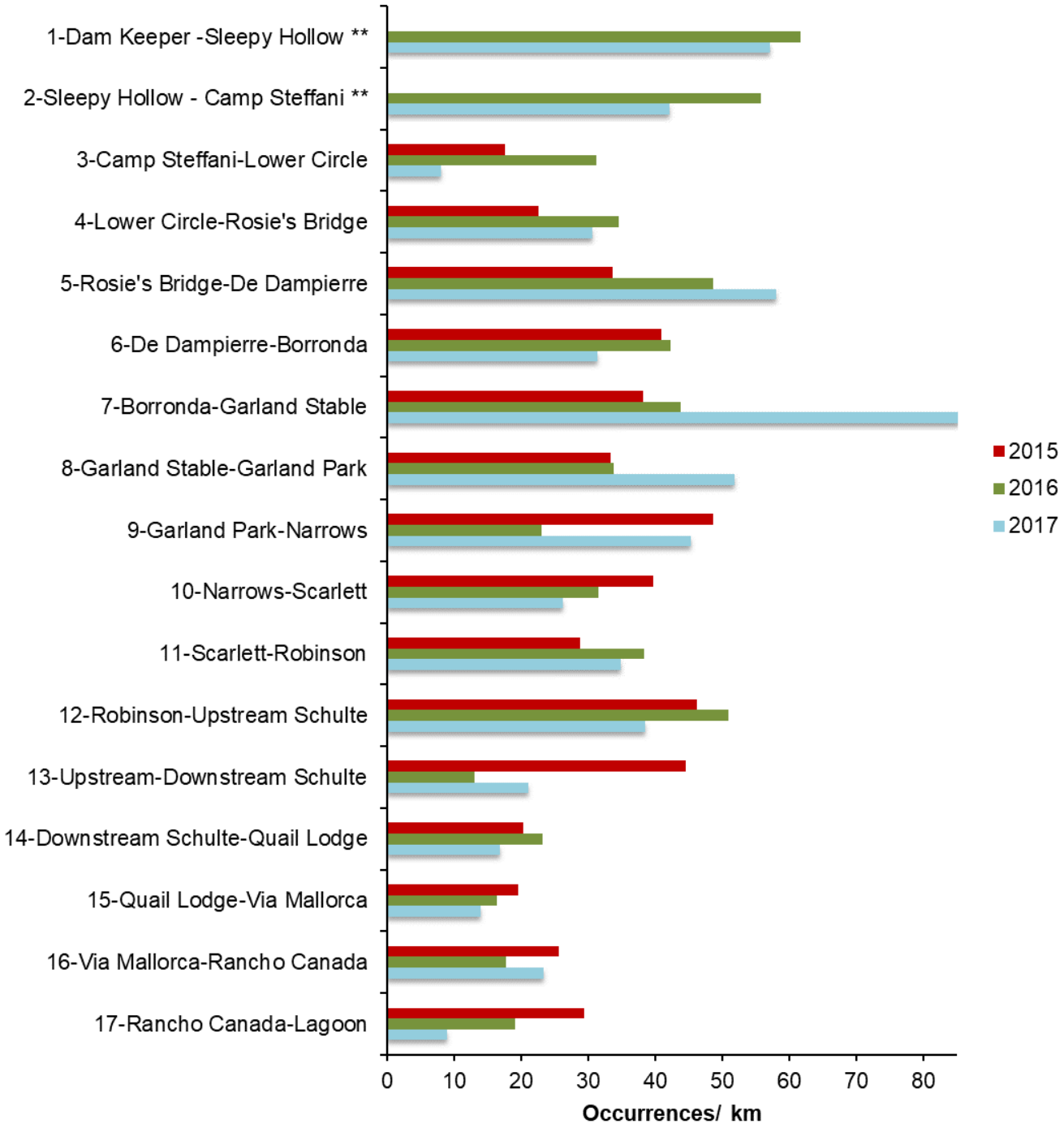
* 2003 did not use the > 75 cm size category, the largest measurement was > 60 cm.

Figure 5. Percent of LWD in each diameter class by year. The 2015 survey was ~24 km while the 2016/2017 studies surveyed 26 km. There was a slight increase in the proportion of LWD with diameters greater than 30 cm from 2015 to 2017.



** Dam Keeper to Camp Steffani was not surveyed in 2015.

Figure 6. Percent of dominant substrate underlying each LWD occurrence from 2015 to 2017. Substrates were estimated visually.



** Dam Keeper to Camp Steffani was not surveyed in 2015.

Figure 7. Occurrences of large woody debris (LWD) per kilometer by reach for 2015, 2016, and 2017. Accumulations were considered a single occurrence for this figure.

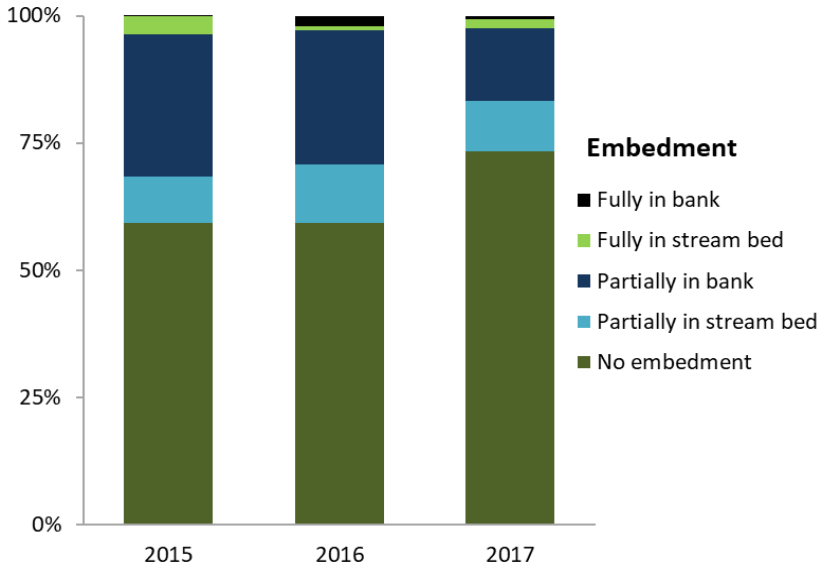


Figure 8. Percent of LWD embedment type. We found a 14% increase in the proportion LWD with no embedment in 2017. See data descriptions in Appendix A for embedment category.

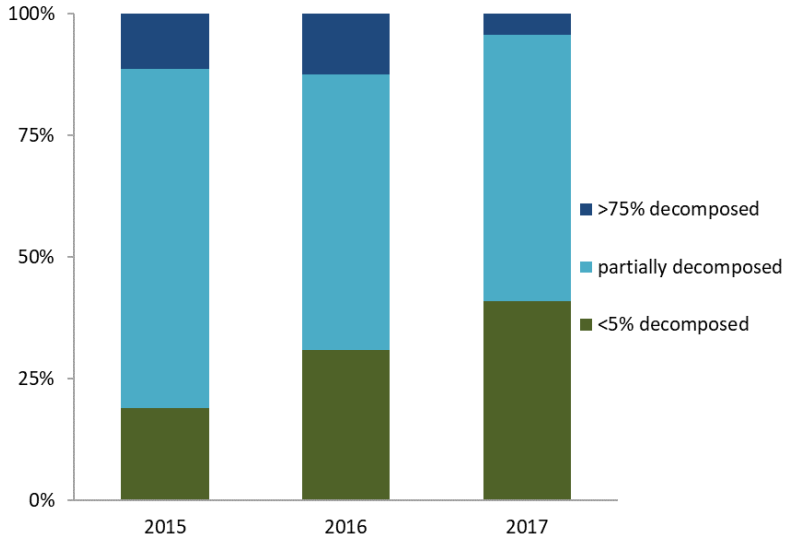


Figure 9. Percent of LWD condition type. The proportion of <5% decomposed LWD doubled from 2015 to 2017. See data descriptions for condition category in Appendix A.

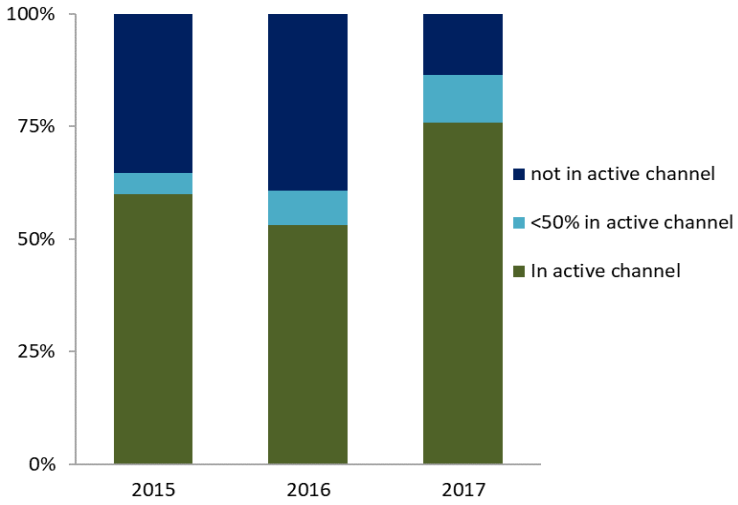


Figure 10. Percent of LWD location with respect to the active channel defined in the methods. The proportion of LWD in the active channel increased by 27%. See data descriptions for part of channel category in Appendix A .

A Hydrograph of the Carmel River from the Robles Del Rio gage (Esquiline Rd.) depicts discharge from the 2002 through 2017 water years with arrows indicating when LWD surveys occurred (Fig. 11). There were several high flow events recorded during the 2017 water year, with flows reaching as high as 10,900 cfs (USGS 2017). The exceptionally wet year marked the highest flows since the pilot study in 2002.

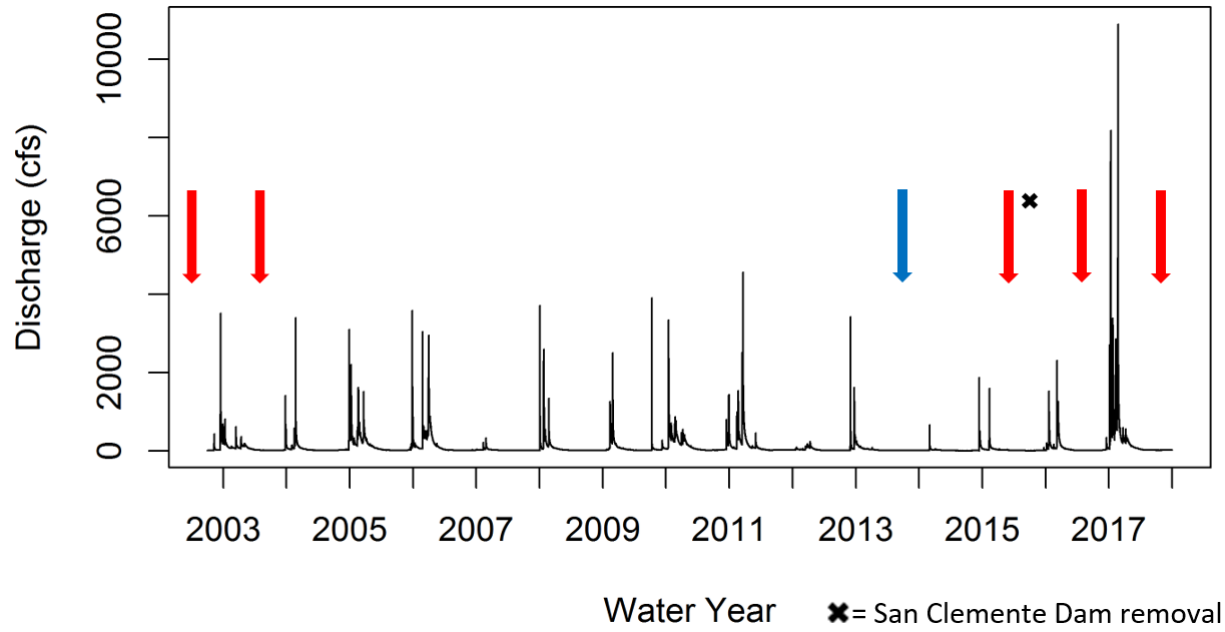


Figure 11. Discharge from the Carmel river USGS gage at Robles Del Rio, measured every 15 minutes. Red arrows indicate when LWD surveys using Smith and Huntington (2004) methods took place. The blue arrow indicates when a sub-sample of LWD was inventoried (CSUMB 2013).

Discussion

The San Clemente Dam removal was predicted to foster "process-based" (Beechie et al, 2010) restoration of LWD density to the lower Carmel River (Boughton et al. 2016). The 2016 survey documented a post-dam increase of LWD density, and the 2017 survey indicated that the density remained stable. The 2016 survey documented increased density in reaches directly below the former SCD one year after removal, suggesting that wood previously trapped behind the SCD was free to pass downstream. The report predicted that LWD would increase in the lower reaches in subsequent years as flows transported the head of the "wood wave" further downstream (MacCarter e*t al.* 2017). Water-year 2017, the second year after SCD removal, was an exceptionally wet year. High flows in 2017 were favorable for recruiting and transporting wood; however, there was no significant change between 2016 and 2017 overall LWD density. Changes in LWD density between each reach, reduced embeddedness of pieces, lesser decayed pieces, and higher percent of pieces in the active channel show that LWD was actively moving through the lower Carmel river (Fig. 7, 8, 9, 10). High flows are capable of releasing wood from embedment by eroding embedding material, as well as transporting recently fallen trees. The high flow and long duration storm events in 2017 likely flushed a large portion of existing LWD to the ocean, which was replaced by upstream wood deposited as flows decreased. The very high abundance of LWD on Carmel River Beach supports that inference.

Flooding events in early 2017 prompted the Monterey Peninsula Water Management District (MPWMD) to activate a vegetative management project to remove selected vegetation and downed trees encroaching the Carmel river (MPWMD 2017). The project description outlines the removal of fallen trees, debris, and vegetation at 15 sites along the Carmel river, all located within the study area. The 2017 LWD survey began after completion of the management project, which reduced the quantity and size of surveyed LWD to an unknown degree.

The summer 2016 Soberanes fire extended into the upper Carmel watershed. Only one piece of LWD in the Carmel river was recognized with burn marks. The burned piece was observed just upstream of the start of the survey area. This observation suggests that either the Soberanes burned trees were transported to the ocean, or that there is a time lag between the Sobranes fire and the accumulation of burned trees into the lower Carmel river. Future surveys should include observations of burned wood.

We observed several to many recently toppled red and arroyo willows (*Salix laevigata* and *S. lasiolepis*) in every reach of the survey. Trees often fell into the active channel, but showed small adventitious roots and continued to grow as the trees laid horizontally. We recognized trees as recently fallen by fresh soil trapped in the main up-rooted rootball and/or fresh adventitious roots along the length of the tree. Similarly to LWD, toppled trees contribute to channel complexity, but were not counted as LWD since they displayed signs of life. The channel

complexity after the high 2017 water year is underrepresented when only considering LWD and ignoring the addition of toppled trees.

We recognize the potential for variation between the 2003, 2015/2016, and 2017 surveys such as observer bias. The 2003 survey was conducted by a single individual that did not participate in the 2015/2016 surveys. The 2015/2016 surveys maintained continuity between observers and study methods. The 2017 survey was conducted by a single individual that did not participate in previous surveys, but communicated questions with the 2015/2016 surveyors. Although protocols were in place for defining the active channel, channel complexity varied throughout the survey area, making bank-full width difficult to distinguish at times. Carmel River banks are dense with vegetation and sometimes cover LWD from clear sight. This survey likely missed pieces of LWD hidden by vegetation.

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Appendix A: Data Category Descriptions

Category	Characteristic	Description
Reach		Name of the stretch of Carmel River surveyed
		LWD locations recorded using easting and northing in feet (NAD 1983 California State Plane Zone IV)
Piece #		LWD were assigned a unique ID as they were recorded
LWD Occurrence Type	Single	A single piece of LWD at least 15 cm by 1.5 m
	Multiple	2 or more touching pieces of LWD
	Rootball	Rootball only, tree no longer attached
Type of Substrate	Sandy	Sediment <2 mm, assessed qualitatively without gravelometer
	Pebbles	Golf ball sized, assessed qualitatively without gravelometer
	Cobble	Fist-sized, assessed qualitatively without gravelometer
	Boulders	Cinderblock size or larger, assessed qualitatively
Rootball present	Yes/ No	Rootball attached to LWD or not
Part of Channel	Yes	LWD >50% in active channel
	<50% active channel	LWD partially in active channel, but >50% was in the floodplain
	No	LWD just outside the active channel that had the potential to be recruited into the river at high flow conditions
Length (m)	1.5 m size classes	LWD length in meters (1.5 m minimum)
		1.5-3.0, 3.0-4.5, 4.5-6.0, 6.0-7.5, >7.5
		For multiple pieces, this was the average log length
Width (cm)	15 cm size classes	LWD diameter in centimeters (15 cm minimum)
		15-30, 30-45, 45-60, 60-75, >75
		For multiple pieces, this was the average log diameter
Length of Accumulation		Multiple pieces only, approx. length of entire accumulation (m)
Width of Accumulation		Multiple pieces only, approx. width of entire accumulation (cm)
# Pieces in Accumulation		Multiple pieces only, # pieces LWD present
Condition	<5% decomposed	Bark intact, smaller branches present
	Partially decomposed	Bark missing, branches deteriorating
	>75% decomposed	Would break apart if stepped on
Embedment	No embedment	LWD not buried in sediment at all
	Partially in river bed	LWD embedded in the streambed along part of its length
	Partially in vegetative bank	LWD embedded in the vegetative bank along part of its length
	Fully embedded in river bed	LWD embedded in the streambed along its entire length
	Fully embedded in bank	LWD embedded in the vegetative bank along its entire length
Bank location	River Left	Left bank looking down river
	Main Channel	LWD in the main channel, not associated with either bank
	River Right	Right bank looking down river
NA		Data was either not applicable or missing

Appendix B: 2017 Survey Data Sheet

Data sheet: **Single Piece**
Date:
Surveyors:
Reach:
Piece #:

Type of Substrate:
Sandy
Pebbles
Cobble
Boulders

Rootball present:
Yes/ No

Part of Channel:
Yes/ No
<50% active channel

Length (m):
1.5-3.0
3.0-4.5
4.5-6.0
6.0-7.5
>7.5

Width (cm):
15-30
30-45
45-60
60-75
>75

Condition:
<5% decomposed
Partially decomposed
>75% decomposed

Embedment:
No embedment
Partially in bed
Partially in veg bank
Fully embedded in bed
Fully embedded in veg bank

Bank location:
River left
Main Channel
River Right

Data sheet: **Multiple Pieces**
Date:
Surveyors:
Reach:
Piece #:

Type of Substrate:
Sandy
Pebbles
Cobble
Boulders

Rootball present:
Yes/ No

Part of Channel:
Yes/ No
<50% active channel

Average Length of LWD (m):
1.5-3.0
3.0-4.5
4.5-6.0
6.0-7.5
>7.5

Average Width of LWD (cm):
15-30
30-45
45-60
60-75
>75

Length of Accumulation (m):
Width of Accumulation (cm):
 # LWD in Accumulation:

Condition:
<5% decomposed
Partially decomposed
>75% decomposed

Embedment:
No embedment
Partially in bed
Partially in veg bank
Fully embedded in bed
Fully embedded in veg bank

Bank location:
River left/ Main Channel/ River right

Data sheet: **Rootball Only**
Date:
Surveyors:
Reach:
Piece #:

Type of Substrate:
Sandy
Pebbles
Cobble
Boulders

Part of Channel:
Yes/ No
<50% active channel

Length (m):
1.5-3.0
3.0-4.5
4.5-6.0
6.0-7.5
>7.5

Width (cm):
15-30
30-45
45-60
60-75
>75

Condition:
<5% decomposed
Partially decomposed
>75% decomposed

Embedment:
No embedment
Partially in bed
Partially in veg bank
Fully embedded in bed
Fully embedded in veg bank

Bank location:
River left
Main Channel
River Right