Analysis of Social Trails in Mt. Rainier National Park - Pilot Study -

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Dr. L. Monika Moskal, Principal Investigator
Meghan Halabisky, Project Assistant
University of Washington
College of Forest Resources

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Introduction:

Social trails are informal trails created by erosion due to foot traffic from people and animals. Social trails are not part of the official National Park trail network and are an indication of human disturbance. Inventorying social trails combined with spatial analysis is one way to detect and monitor the level of impact to natural areas within the park (Leung, 2008). This report closely follows the Visitor Experience and Resource Protection Data Analysis Protocol: Social Trails for Yosemite National Park (Leung, 2008). The goal of this pilot project was to test out the relevance of the techniques developed for Yosemite and adapt them for Mt. Rainier National Park. Our document does not attempt to replace the Yosemite report, but explains the exact methodology as applied specifically to Mt. Rainier and should be used in conjunction with the report generated for Yosemite. The primary purpose of this document is to provide the results of the pilot project and to outline the adapted method for future analysis of social trails in Mt. Rainier National Park.

For this pilot project we analyzed the impacts of social trails and unofficial campsites in two management units within Mt. Rainier National Park; Paradise Meadows, and Spray Park South[1]. In addition, to these two management zones, we examined the impacts within Paradise Meadows by individual subunit[2]. Analyzing the impacts of social trails and unofficial campsites at these two scales provides information for prioritizing management decisions at the Park-wide level as well as within the individual management units. We chose Paradise Meadows and Spray Park South as the two management units for two reasons: 1.) The ground data was complete for these areas 2.) It offers a comparison between an area of high impact (Paradise meadows) and an area of moderate impact (Spray Park South).

In addition, we wanted to test the effects of including an influence zone in the analysis. This follows the Yosemite report, which based the width of the influence zone on work by Holmquist (2005) that showed impacts from social trails on insects extended to 5 meters on each side of the trail. We used a 5-meter buffer to calculate the influence zone for this analysis. The

[1] We used GMP_Mgmt_Zones.shp supplied by the NPS
[2] We used ParadiseStudyAreas.shp supplied by the NPS

exact width of the influence zone that should be employed for Mt. Rainier has not yet been determined and warrants further research.

Inventories of social trails were conducted between 1986 and 1988 by mapping trails on aerial photos and topographic maps during field surveys. Social trails were then digitized and entered into an ArcGIS database and a tabular database. Some areas within Mt. Rainier have very detailed information regarding the width and depth of the trail, while other areas lack specific trail information. Collecting exact trail width measurements can take a significant amount of time. One objective of this pilot project was to determine if it was necessary to collect detailed spatial information for analysis of social trails. To test this we used Paradise Meadows, which had detailed social trail information, to determine if there was a significant difference in the results of the analysis when we used a default trail width of ½ meter (¼ meter buffer on each side of the polyline) as opposed to the actual recorded trail width. The specific trail widths for Paradise Meadows is summarized in a separate excel file, which we brought into ArcGIS for analysis.

In addition, we wanted to analyze the impacts of official park trails as a baseline for comparison to disturbance caused by social trails and informal campsites. This was only done for Paradise Meadows as Spray Park South did not have any official park trails located within its' boundary.

In this report we outline the steps used for the analysis of social trails and summarize the results for Spray Park South and Paradise Meadows as well as for the subunits within Paradise Meadows. We conclude this report with recommendations for extending this methodology to the entire park.

Methodology:

In order to determine how to adapt the method outlined in the Yosemite report for Mt. Rainier we ran variations of the technique used in Yosemite several times.

The basic workflow of the project is as follows:

1. Acquire all necessary input data for analysis
2. Clean-up input data
3. Buffer line data
4. Create individual patches
5. Calculate geometry for individual patches
6. Export data into MS Excel
7. Run analysis in MS Excel
8. Summarize into comparison table

All input shapefiles used for the analysis were combined into a geodatabase and set to the same spatial projection[3].

<u>Spray Park South (Ran analysis 3 times):</u>

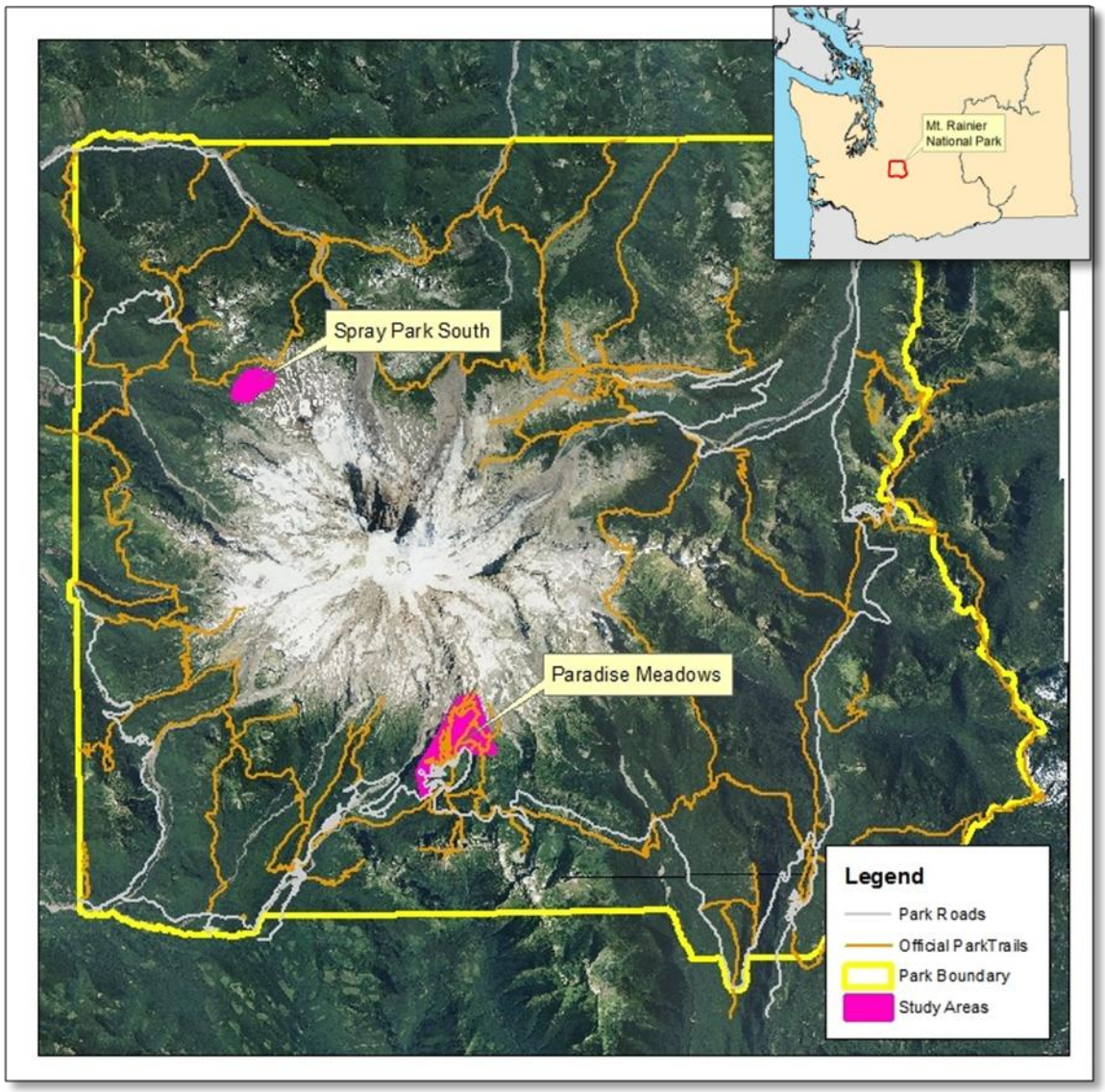
1. Social Trails (using a default width)
2. Social Trails (using a default width) + Influence Zone
3. Social Trails (using a default width) + Influence Zone + Campsite

<u>Paradise Meadows Analysis (Ran analysis 7 times):</u>

1. Park Trails
2. Park Trails + Influence Zone
3. Park Trails + Social Trails (using actual width)
4. Park Trails + Social Trails (using default width)
5. Park Trails + Social Trails (using actual trail width) + Influence Zone
6. Park Trails + Social Trails (using default trail width) + Influence Zone
7. Park Trails + Social Trails (using actual trail width) + Influence Zone + Campsites

[3] Geodatabase is titled ST_inputs_NP_MORA.gdb. Spatial projection was consistent with files sent to UW; NAD_1927_UTM_Zone_10N

Figure 1: Study Areas - Spray Park South and Paradise Meadows



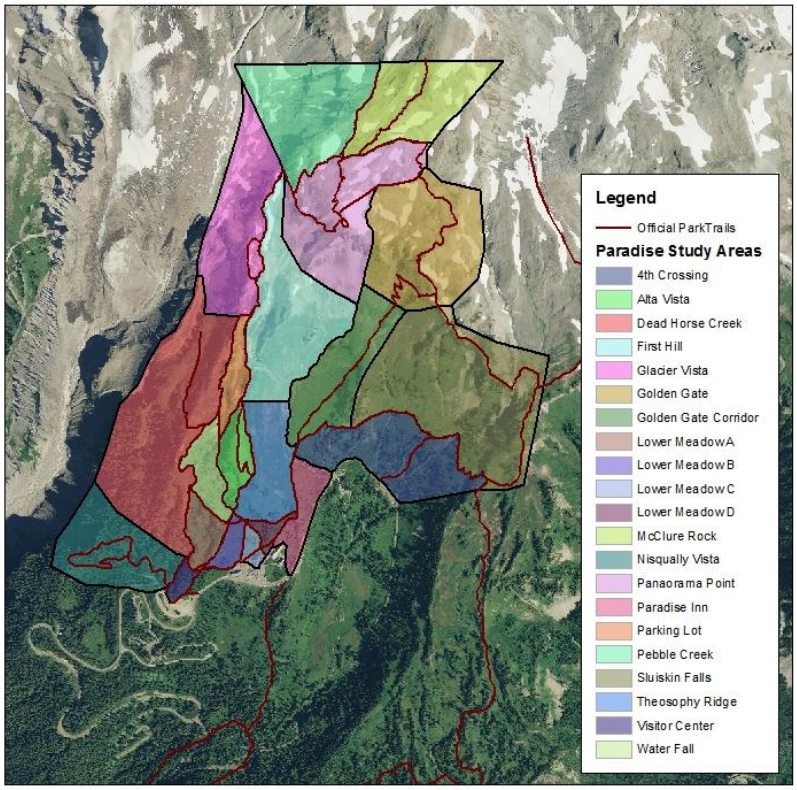
Paradise Meadows Analysis at the Subunit level (Ran analysis 2 times):

1. Park Trails + Social Trails (actual trail width)
2. Park Trails + Social Trails (actual trail width) + Influence Zone

Paradise Meadows Subunits:

4th Crossing	McClure Rock
Alta Vista	Nisqually Vista
Dead Horse Creek	Panorama Point
First Hill	Paradise Inn
Glacier Vista	Parking Lot
Golden Gate	Pebble Creek
Golden Gate Corridor	Sluiskin Falls
Lower Meadow A	Theosophy Ridge
Lower Meadow B	Visitor Center
Lower Meadow C	Waterfall
Lower Meadow D	

Figure 2: Paradise Meadows - Subunits



This document does not provide a step-by-step technical procedure for spatial analysis of social trails. For a more detailed "how to" refer to the data analysis protocol outlined for Yosemite National Park (Leung, 2008). Additionally, Leung provides a more thorough description and formulas for Weighted Mean Patch Index and Largest Patch Index. We chose these metrics because they are simple and easily comparable between landscapes.

Landscape Metrics Used For Analysis: (Leung, 2008)

Patch density, patch size and variability metrics:

- Median Patch Size
  Decreasing values would suggest increasing degrees of fragmentation
- Density of Trails
  Increasing values would suggest that more of the area is being impacted.

Area metrics:

- Weighted Mean Patch Index (WMPI)
  Decreasing values indicate increasing degrees of fragmentation. Increasing spatial extent of informal trails would result in reduced index values even if the average patch size does not change.
- Largest Patch Index – 3 (LPI -3)
  Decreasing values would suggest increasing degrees of fragmentation
- Largest Patch Index – 5 (LPI – 5)
- Decreasing values would suggest increasing degrees of fragmentation
- Percent of Impact Area
  Increasing values would suggest that a greater percentage of the overall area is affected.

We wanted to add one additional metric to account for the shape of patches within a landscape and to describe the spatial extent of the social trails. We tested several shape indices and chose "percent core area" to describe the quality of patch shapes within a landscape. This metric is an adaptation of the Core Area Index (McGarigal & Marks, 1995).

Additional landscape shape metric / core area metric:

- Percent of Core Area
  Decreasing values suggest that patches are less compact and contain more edge.

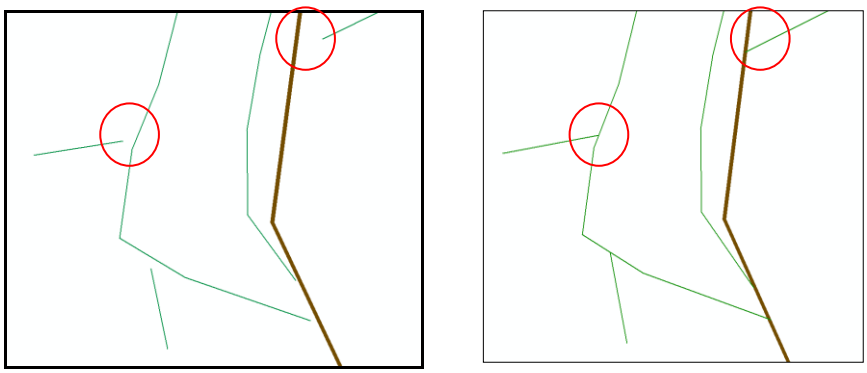
Analysis Steps:

1. Acquire all necessary input data: Combine input data into a geodatabase and re-project data so that it is all in the same projection. We used NAD 1927 UTM Zone 10N as most of the NPS data layers used this projection.

Input data:

- Unofficial campsites (allimpacts_camps.shp)
- Park wide social trails (allimpacts_trails.shp)
- Management zone boundaries (GMP_Mgmt_Zones.shp)
- Park boundary (MORABoundary.shp)
- Park roads (MORARoads.shp)
- Paradise impact areas (ParadiseImpactAreas.shp)
- Paradise-specific social trails (ParadiseSocialTrails.shp)
- Paradise Management Areas – subunits (ParadiseStudyAreas.shp)
- Official park trails (ParkTrails.shp)
- Paradise-specific social trail data (PARADISE1987.dbf)

2. Clean-up input data: First, edit the polyline for social trails by extending line segments so that they connect to each other. Extend trails to connect to the boundary of the management area or subunit. We only connected a line segment to other lines or to the boundary if:
    a. It was obvious it originated from a larger trail.
    b. It was less than 5 meters away.



3. Buffer social trails polyline data with trail width (using actual width or default width) and influence zone if necessary.
    a. When analyzing for impacts without the inclusion of an influence zone by ¼ meter on each side (or the actual width if you choose). This will be used to create "Patches_No_influence_zone.shp" to be used for analysis.

b. When analyzing for impacts of an influence zone buffer social trails by 5 meters + width (1/4 m default = 5.25 m) on each side. This will be used to create "Patches_With_Influence_zone.shp".

Buffer Distances:

Default Trail Width	¼ meter each side
Influence Zone	5 meters each side
Campsites	30.48 meters (100 feet) radius
Core Area Buffer	50 meters each side

4. Erase buffered trails from landscape (either GMP area, subunit, or other)
    a. This can be done using the ArGIS "erase" feature found in the arc toolbox.
    b. Erase any additional mapped impact areas from the landscape.
5. Edit Patch_XX.shp
    a. Explode patch into a multiple patches (advanced editing tool). This is necessary to analyze patches.
6. Calculate individual patches
    a. Add field Area_m2.
    b. Calculate geometry for each patch in meters^2 or hectares.
7. Combine output shapefiles into a file geodatabase

Outputs (products):

<u>Paradise Meadows:</u>

- Paradise Meadows Social Trails – clipped, cleaned up *(ParadiseSocialTrails_edited.shp)*
- Paradise Meadow patches resulting from trails using a default trail width (*PAR_patches_defaulttrailwidth.shp)* and trails using an actual trail width *(PAR_patches_actualtrailwidth.shp)*
- Paradise Meadows patches resulting from trails using a default trail width plus an influence zone *(PAR_patches_defaulttrailwidth_InfluenceZone.shp)* and trails using an actual trail width plus an influence zone (*PAR_patches_actualtrailwidth_InfluenceZone.shp)*

- Paradise Meadows patches resulting from trails using a default trail width plus an influence zone plus campsites buffered at 100'
  (PAR_patches_deftrail_InfZon_campsites.shp)
- Paradise Subunit patches resulting from trails using actual trail width
  (PAR_subunits_patches_actualtrailwidth.shp)
- Paradise Subunit patches from trails using an actual trail width plus an influence zone
  (PAR_subunits_patches_actualtrailwidth_InfluenceZone.shp)

<u>Spray Park South:</u>

- Spray Park Social Trails – clipped, cleaned up (SprayPark_Socialtrails.shp)
- Spray Park patches resulting from trails using a default trail width
  (SprayPark_patches_defaulttrailwidth.shp)
- Spray Park patches resulting from trails using default trail width plus an influence zone *(SprayPark_patches_defaulttrailwidth_InfluenceZone.shp)*
- Spray Park patches resulting from: trails using default trail width plus an influence zone plus campsites buffered at 100'
  (SprayPark_patches_deftrail_InfZon_campsites.shp)

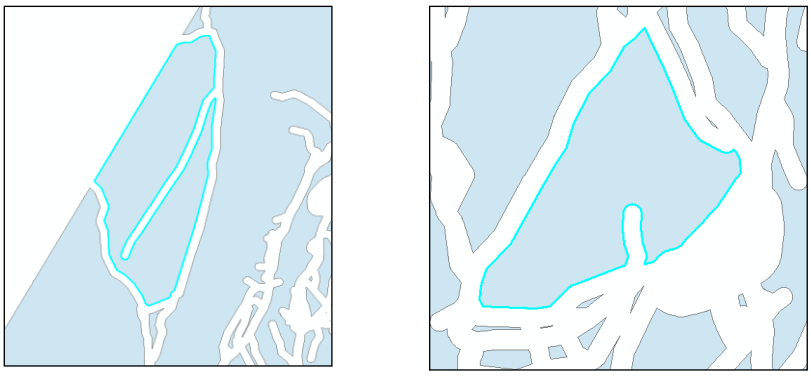
8. Export data into MS Excel
   a. Convert into a dbf file and export into MS Excel.
   b. Convert dbf into an excel file.
9. Run analysis in MS Excel
   a. Run analysis on each landscape area (either GMP area, subunit, or other).
   b. Summarize results in a table. We used a pivot table to help with summarizing.
10. Bring results back into ArcGIS
    a. Symbolize shapefile using a color gradient by landscape metric

Additional Metrics:

We added an additional metric to the analysis to account for the shape of the patches within each management unit, with the assumption that there is a difference in quality between compact patches and those that are less compact (Figure 3). Many social trails are close together and form corridors of high disturbance, while some social trails cut ¾ the way through a patch and then run out. If a trail cutting ¾ of the way through a patch had extended a little further the patch would have been divided into two patches and this fragmentation would be captured in the above landscape metrics. However, because the social trail does not cut the entire way through the patch it may inflate the landscape metrics, causing the landscape to look less disturbed than it actually is. This is especially apparent in Spray Park South where many of the trails do not

connect to each other and therefore the landscape metrics are only run on a relatively few patches. To account for the shape of patches, we buffered all disturbances by 50 meters and used this to calculate core area. We then divided the core area by the landscape area (Figure 4) to determine the percent of core area within a landscape. Percent core area is based on the Core Area Index described by McGarigal and Marks (1995) where all patch edges are buffered by a selected distance. A more fragmented configuration of habitat (greater edge-to-interior ratio) will have a smaller percent core area (McGarigal and Marks, 1995). Instead of buffering all edges we chose to buffer all disturbances (i.e. trails and campsites) but not management area boundaries. We chose a somewhat arbitrary buffer distance of 50 meters because it effectively delineated most disturbances into disturbance corridors. The buffer distance around all disturbances is strongly dependent upon site-specific variables and warrants further research.

Figure 3: Example of differences in patch shapes.



(a) Less compact patch (b) More compact patch

Figure 4: Percent of Core Area

% Core Area = Core Area / Total Landscape Area

Core Area = Total landscape area – 50-meter buffered area of all disturbances

Analysis Steps:

1. Buffer disturbances by 50 meters.
2. Erase buffered area from landscape using arc toolbox. This will create a new shapefile, which represents core area.
3. Add field to attribute table – “Area-M2”.
4. Calculate geometry in square meters.
5. Divide “Area_M2” by Total Landscape Area (in square meters) Core Area/ Total Landscape Area.

Results:

Park-Wide Comparison

Between the two study areas; Spray Park and Paradise Meadows, Paradise Meadows showed the greatest fragmentation and greatest human impacts as demonstrated by the landscape metrics. Fragmentation is defined here as broken up habitat or cover type into smaller disconnected parcels (Forman 1995). This aligns with local knowledge of these areas. Paradise Meadows is more heavily used than Spray Park South and therefore one would assume that it would have greater human caused impacts. Analysis results are compiled in a companion MS Excel spreadsheet.

Social Trails

As expected, fragmentation increased when social trails were added to official park trails. There are no park trails within Spray Park South and therefore it should be assumed that the baseline of the landscape area contains no impacts and no human caused fragmentation. Number of patches, median patch size, length of trails, and total impact area, although descriptive, are not useful for comparisons between landscapes as the metrics are all influenced by the size of the landscape. Because Spray Park South is much smaller than Paradise Meadows these metrics may be misleading when making comparisons between these two landscapes. For example, the median patch size is much larger in Paradise Meadows (72.82 m^2) than in Spray Park South (31.89m^2), but this does not mean the Paradise Meadows is less impacted by social trails. The density of trails, weighted mean patch index, largest patch indices, percent impact area, and percent core area metrics are more useful when comparing impacts between landscapes. All of these metrics are normalized by area.

Influence Zone

Use of an influence zone also increased the total area impacted within the landscape area. However, the fragmentation of the landscape area reduced when using an influence zone. This is due to the fact that buffering lines creates fewer patches (ex. 474 v. 291 for Paradise) because many of the small patches are combined into this buffered area. This influences the median patch size, raising it dramatically (72.82 v. 191.73 for Paradise). Because there are fewer social trails within Spray Park South the influence zone had a less dramatic effect on the landscape metrics measuring fragmentation than it did for Paradise Meadows.

Campsites

As expected, fragmentation also increased when campsites were added to the analysis. Because there are more campsites in Spray Park South than Paradise Meadows the campsites had a greater impact on the landscape metrics calculated for Spray Park South. This is best exemplified in the percent impact metric and the percent core area metric, which was more

effected by the addition of campsites for Spray Park South than Paradise Meadows, indicating that campsites within Spray Park South are a bigger contributor of impacts than campsites within Paradise Meadows.

Table 1: Summary of Analysis Results for Paradise Meadows

Data Analysis of Social Trails - **Paradise Meadows**										
	Patch Density, Patch Size and Variability Metrics				Area Metrics					Shape metric / Core area metric
Approach	Number of patches	Median patch size (m2)	Length of trails (m.)	Density of Trails (m/ha)	WMPI (ha.)	LPI - 3	LPI - 5	Total Impact Area (ha.)	Percent Impact Area	Percent core area (50m)
No Influence Zone										
Park Trails	26	36810.9	19675.45	49.51	15.09	67.17%	81.81%	2.59	0.65%	60.41%
Park Trails + Social Trails (Actual Width)	465	74.112	61491.76	154.73	0.82	51.30%	60.41%	7.59	1.91%	41.55%
Park Trails + Social Trails (Default Width)**	474	72.8195	61491.76	154.73	0.81	51.25%	60.36%	7.74	1.95%	41.55%
With Influence Zone*										
Park Trails + Influence Zone	27	39855.5	19675.45	49.51	13.15	64.97%	77.50%	21.83	5.49%	60.41%
Park Trails + Social Trails (Actual Width) + Influence Zone	287	192.5	61491.76	154.73	1.03	47.31%	54.48%	54.36	13.68%	41.55%
Park Trails + Social Trails (Default Width)** + Influence Zone	291	191.733	61491.76	154.73	1.02	47.31%	54.48%	54.56	13.73%	41.55%
With Influence Zone and Campsites										
Park Trails + Social Trails (Def. Width)** + Influence Zone + Campsites	285	195.36	61491.76	154.73	1.03	47.31%	54.48%	56.19	14.14%	41.32%

* Using a default buffer of ¼ meter. ** Using a buffer of 5 m *** Using a buffer of 100'

Number of Social Trails: 848

Number of Campsites: 22

Table 2: Summary of Analysis Results for Spray Park - South

Data Analysis of Social Trails - **Spray Park South**										
	Patch Density, Patch Size and Variability Metrics				Area Metrics					Shape metric / Core area metric
Approach	Number of patches	Median patch size (m2)	Length of trails (m.)	Density of Trails (m/ha)	WMPI (ha.)	LPI - 3	LPI - 5	Total Impact Area (ha.)	Percent Impact Area	Percent core area (50m)
Social Trails*	25	31.89	2867.44	30.11	3.80	99.77%	99.80%	0.14	0.15%	68.69%
Social Trails* + Infl. Zone**	4	1035.27	2867.44	30.11	22.49	97.20%	97.20%	2.67	2.80%	68.69%
Social Trails* + Infl..zone** + campsites***	6	246.81	2867.44	30.11	11.85	86.40%	86.42%	12.93	13.58%	55.38%

* Using a default buffer of ¼ meter. ** Using a buffer of 5 m *** Using a buffer of 100'

Number of Social Trails: 40

Number of Campsites: 43

Sub-unit Comparison - Paradise Meadows:

Analysis by management unit is useful to determine overall impacts within the park. We analyzed impacts of social trails within each management unit to assist with development of protection strategies. To do this we used the study areas within Paradise Meadows as outlined by park staff. We ran the analysis twice with and without an influence zone. The results are summarized in Table 3 & Table 4. Smaller subunits are most affected when using an influence zone because they have more edges influenced by park trails. Again, the median patch size metric is very sensitive to inclusion of an influence zone.

The "Visitor Center" subunit was the most heavily impacted subunit within Paradise Meadows. However, "Parking Lot" had the greatest density of social trails. The values from the analysis can be used to rank subunits by heavily impacted to least impacted. Although the addition of an influence zone affected the metric values it did not affect the ranking of the most heavily impacted areas.

Table 3: Summary of Analysis Results for Paradise Meadows Subunits

Paradise Meadows Subunits - Social Trails (Actual Trail Width) , NO Influence zone								
Management Area	**Number of patches**	**Median patch size (m2)**	**Length of Social trails (m.)**	**Density of Social Trails (m/ha)**	**WMPI**	**LPI -3**	**LPI - 5**	**Percent of Impact Area**
4th Crossing	53	12.31	3165.34	124.15	0.47	81.37%	91.39%	1.15%
Alta Vista	37	44.02	1586.53	241.19	0.16	81.67%	87.50%	5.15%
Dead Horse Creek	43	72.87	5656.16	110.51	1.15	91.97%	95.49%	1.77%
First Hill	41	19.44	3497.05	107.78	0.77	98.18%	98.43%	1.13%
Glacier Vista	46	53.36	3298.35	116.25	0.59	93.62%	96.85%	2.15%
Golden Gate	26	23.74	2785.77	76.47	1.35	92.51%	96.46%	1.80%
Golden Gate Corridor	10	35.99	1594.73	75.47	2.06	96.45%	98.74%	1.24%
Lower Meadow A	11	289.00	755.85	136.07	0.46	93.10%	94.60%	4.71%
Lower Meadow B	4	1515.77	381.99	119.68	0.74	96.25%	96.25%	3.75%
Lower Meadow C	11	75.80	497.01	260.24	0.16	90.57%	95.33%	4.01%
Lower Meadow D	15	251.33	505.81	263.87	0.12	73.16%	89.61%	4.91%
McClure Rock	39	5.80	1569.84	66.85	0.59	98.87%	99.18%	0.60%
Nisqually Vista	16	392.39	1434.43	64.57	1.34	93.71%	96.37%	1.70%
Panorama Point	64	21.71	4132.55	123.00	0.51	76.73%	93.81%	1.86%
Paradise Inn	22	12.58	1708.81	233.23	0.32	96.82%	97.40%	1.98%
Parking Lot	35	43.65	2142.68	401.82	0.13	83.85%	86.76%	7.68%
Pebble Creek	31	55.93	1678.98	57.11	0.94	96.89%	98.16%	0.66%
Sluiskin Falls	62	78.81	4994.93	86.45	0.90	80.00%	92.33%	1.46%
Theosophy Ridge	24	99.95	1533.89	102.57	0.61	95.94%	97.35%	1.22%
Visitor Center	11	143.14	702.09	357.65	0.11	68.18%	76.73%	20.92%
Water Fall	26	174.00	2236.99	314.78	0.23	68.38%	82.35%	8.41%
Grand Total	627		45859.76	3439.71				

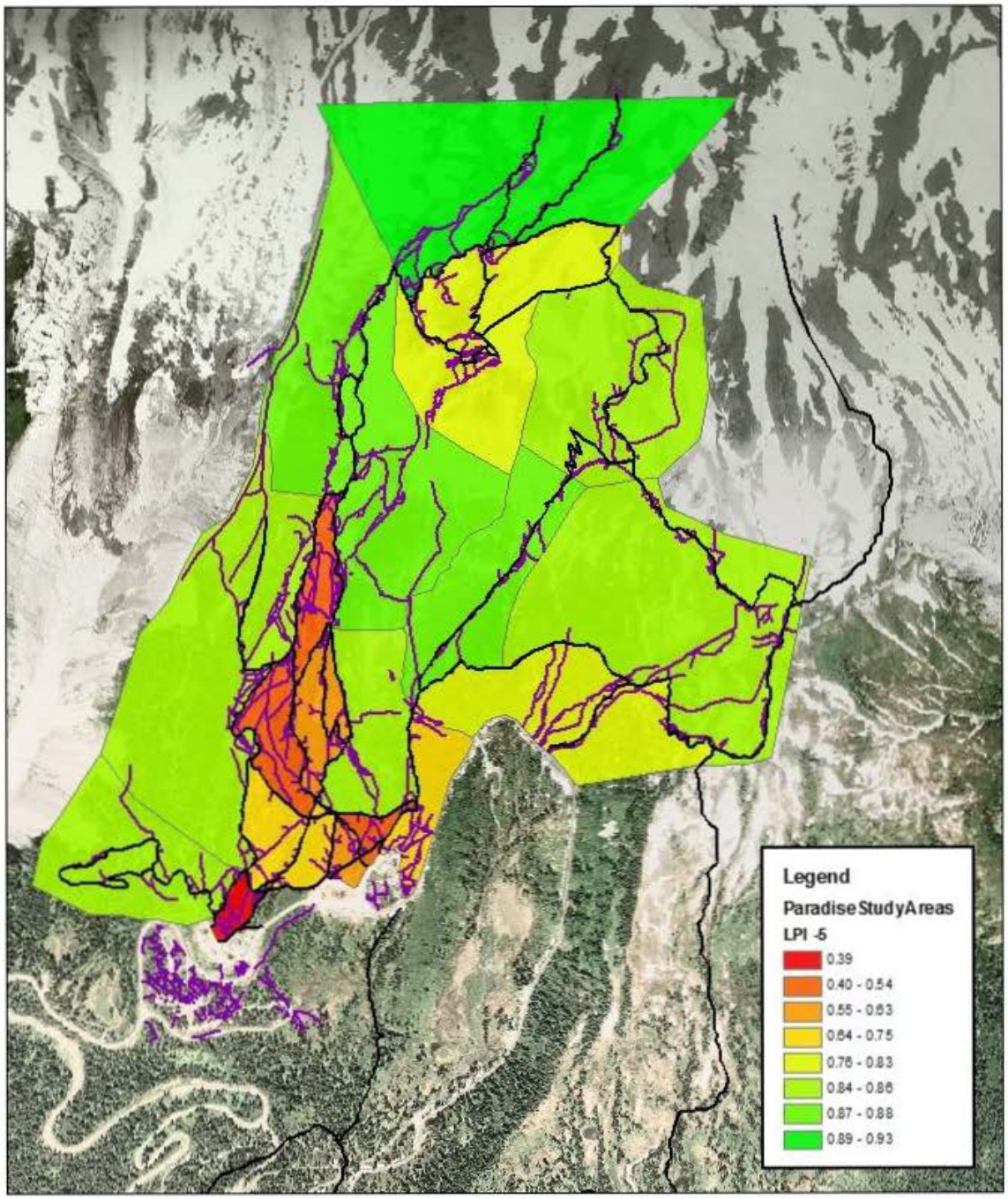
* Highlighted cells indicate greatest impacts

Table 4: Summary of Analysis Results for Paradise Meadows Subunits using an Influence Zone

Paradise Meadows Subunits - Social Trails (Actual Trail Width) + Influence zone (5m buffer each side of trail)								
Management Area	**Number of patches**	**Median patch size (m2)**	**Length of Social trails (m.)**	**Density of Social Trails (m/ha)**	**WMPI**	**LPI -3**	**LPI - 5**	**Percent of Impact Area**
4th Crossing	20	254.36	3165.34	124.15	0.93	75.04%	81.63%	14.64%
Alta Vista	14	148.78	1586.53	241.19	0.20	59.31%	63.00%	34.98%
Dead Horse Creek	27	313.52	5656.16	110.51	1.46	82.41%	86.14%	12.31%
First Hill	12	143.95	3497.05	107.78	2.10	83.69%	88.09%	11.77%
Glacier Vista	13	425.96	3298.35	116.25	1.66	82.25%	86.83%	12.69%
Golden Gate	16	1842.79	2785.77	76.47	1.77	80.32%	84.81%	11.81%
Golden Gate Corridor	13	531.56	1594.73	75.47	1.27	79.07%	86.56%	11.53%
Lower Meadow A	8	168.42	755.85	136.07	0.39	74.44%	75.05%	24.91%
Lower Meadow B	4	680.53	381.99	119.68	0.41	71.53%	71.54%	28.46%
Lower Meadow C	11	32.24	497.01	260.24	0.06	58.48%	59.87%	39.78%
Lower Meadow D	9	888.95	505.81	263.87	0.06	40.30%	51.08%	47.11%
McClure Rock	11	292.73	1569.84	66.85	1.82	91.38%	91.97%	7.72%
Nisqually Vista	15	629.99	1434.43	64.57	1.11	83.75%	85.28%	13.38%
Panorama Point	34	200.65	4132.55	123.00	0.72	69.77%	83.26%	14.48%
Paradise Inn	21	188.80	1708.81	233.23	0.19	69.83%	71.60%	25.34%
Parking Lot	27	61.03	2142.68	401.82	0.06	47.65%	51.29%	45.33%
Pebble Creek	14	348.71	1678.98	57.11	1.82	90.81%	92.56%	6.95%
Sluiskin Falls	27	395.31	4994.93	86.45	1.70	74.36%	85.12%	10.84%
Theosophy Ridge	14	99.55	1533.89	102.57	0.79	84.39%	85.59%	13.99%
Visitor Center	9	410.57	702.09	357.65	0.04	31.26%	38.66%	59.72%
Water Fall	16	246.51	2236.99	314.78	0.16	40.57%	54.04%	40.76%
Grand Total	335		45859.76	3439.71				

* Highlighted cells indicate greatest impacts

Figure 5: Example of symbolizing subunits using a gradient based on landscape metrics (LPI- 5)



Considerations Regarding Landscape Metrics:

Each metric chosen for this analysis has its strengths and weaknesses. Below we discuss the strengths and weaknesses of each metric in describing human caused disturbances. All of these metrics would benefit from further testing in other management areas within Mt. Rainier National Park.

Density of Trails: Increasing values would suggest that more of the area is being impacted by trails.

This metric is useful when making comparisons between landscapes regarding trails. It does not provide any descriptive information regarding patches and therefore, is not sensitive to the width of the trail, inclusion of an influence zone, or inclusion of campsites.

Weighted Mean Patch Index (WMPI): Decreasing values indicate increasing degrees of fragmentation. Increasing spatial extent of informal trails would result in reduced index values even if the average patch size does not change.

WMPI is useful for making comparisons between landscapes as it is normalized by landscape area. It was used by Leung et al. to capture the increasing spatial extent of informal trails even if average patch size does not change. The issue with this metric is that it is sensitive to the number of patches within a landscape. Therefore, when the influence zone is added to the analysis the WMPI actually goes up as the number of patches is reduced. This is caused by small patches being consumed by the influence zone. This metric may be confusing to interpret.

Largest Patch Index (3&5): Decreasing values would suggest increasing degrees of fragmentation

The largest patch index is useful for comparison between landscapes and can also be used to monitor changes over time. However, this metric is sensitive to the number of patches within a landscape. LPI-5 was chosen as the most useful metric for Yosemite National Park, however, this was less useful for Mt. Rainier National Park, which contained fewer patches per landscape.

For example, Spray Park South had only 4 patches when social trails and an influence zone were used in the analysis. LPI-3 may be more appropriate than LPI-5 when making comparisons in landscapes with fewer patches. Because it focuses on patch size it does not capture the spatial extent of social trails as described in figure 3.

Percent of Impact Area: Increasing values would suggest that a greater percentage of the overall area is affected.

This metric is useful in describing overall impacts to a landscape. It adequately explains increases in impacts from social trails, influence zones, and campsites. However, it does not provide a description of the patch shape or spatial extent of impacts.

Percent of Core Area: Decreasing values suggest that patches are less compact and impacts are more spread out.

This metric is useful in describing the amount of core area within a landscape. Core area is defined here as any part of a patch that is at least 50 meters away from a disturbance. This method works well when examining the impacts of non-linear disturbances, such as campsites, or when examining the impacts of disconnected social trails. However, 50 meters was chosen somewhat arbitrarily and may not be the correct buffer distance for all landscapes.

Recommendations:

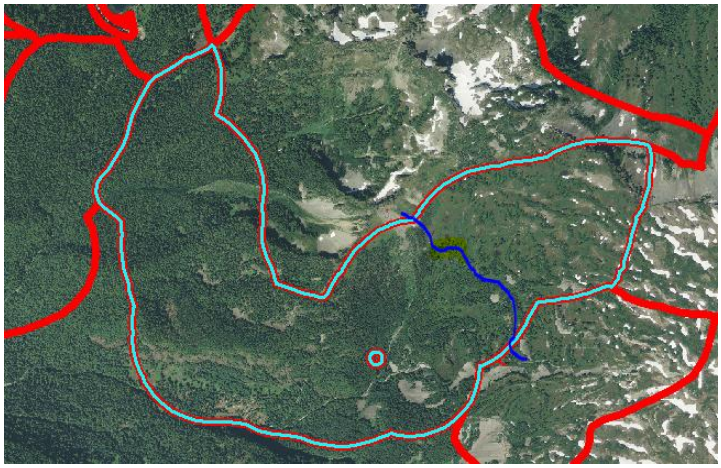
1. Monitor impacts by habitat type.

We used management areas as the "landscape" for our analysis. This worked out well in the case of Paradise Meadows and Spray Park South. However, many of the management areas are part of a trail zone, which contain multiple habitat types. For example, Spray - Seattle Park management area contains both forest and meadow. We recommend that management areas should be split up into multiple landscapes for separate analysis if they contain multiple habitat types. Dividing management areas up into habitat types is important for the following reasons:

- When habitat types are grouped into one management area it is difficult to see where the greatest impacts are occurring park-wide for specific habitat types (Figure 6). Delineating management areas into habitat types will allow for comparison between different habitats (i.e. Comparing Paradise Meadows with meadows in Spray – Seattle Park).
- Certain habitat types have more social trails than others. It is likely that meadows contain more social trails than forests. If a management area is not split up into habitat types such as meadow and forest one may erroneously conclude that a meadow is not heavily impacted by social trails and campsites. A management area with a large forest area will inflate the landscape metrics for the meadow if they are grouped together in a management area.
- Social trails may not be mapped as successfully within forested areas as they are within meadows. Similar to the above statement undermapped areas may inflate landscape metrics for the entire management unit.

Further analysis and/or expert advice from park employees is needed to determine how habitat types should be defined and delineated. Although this pilot study did not examine social trails in forests the same methodology could be extended to forested areas.

Figure 6: Spray – Seattle Park Trail Zone. Blue line roughly delineates meadow from forest.



2. Use an approximated width of ½ meter to account for trail width.

There was not a significant difference in the landscape metrics when we used an approximated default width versus the actual trail width. The benefit of using the actual trail width is outweighed by the cost of collecting that information in the field specifically for this analysis. In addition, many areas do not have the actual width of the trail measured. The average trail width is close to a ½ meter. The metrics used for this analysis only estimates levels of fragmentation rather than soil loss or supplies required for restoration. Therefore, we recommend that the default width is an acceptable substitution. If available, using the actual trail width is preferred; however, it is important to be consistent for all landscape areas when choosing between the default width and the actual width.

3. Compare impacts of social trails to baseline impacts created by official park trails.

Park trails wind through meadows and create fragmentation of the landscape. Social trails increase this fragmentation. If official park trails exist within a landscape they should be used as a baseline of existing fragmentation.

4. Include the use of an influence zone in the analysis.

It is likely that an influence zone has significant impacts on the landscape area. However, it can be misleading when used on its own. We recommend that the analysis should be run twice; first, using the trail width and second, using the trail width + the influence zone. The use of an influence zone decreases fragmentation within the landscape while increasing total impacts to the area. Effects of an influence zone are greatest on smaller landscape units.

5. Determine the most relevant influence zone.

The difference in total percent impact area increases substantially when including an influence zone into the analysis. A five meter buffer on each side of the trail is acceptable until a more suitable influence zone is determined from further research.

6. Run analysis at two scales: Park-wide & within management areas.

We tested impacts within management areas to help prioritize management actions at a smaller scale. This can be useful when prioritizing management decisions. The method held up well when applied to the subunits of Paradise Meadows.

7. Buffer Campsites at 30.5 meters (100').

We buffered campsites by 30.5 meters for analysis. This is based on the suggested distance for storing food and cooking away from camp for bears. This also accounts for the trampling that occurs around a campsite.

8. Calculate percent of core area to describe quality of patches within a landscape.

Some patches are compact, while others are less compact and contain smaller areas of undisturbed core area. This metric is useful because it describes the quality of patches within a landscape. We chose 50 meters as it most effectively grouped nearby social trails into disturbance corridors. More research should be conducted to determine exact measurement which should be used for Mt. Rainier National Park. This landscape metric describes the amount of core area.

9. Use the top three largest patches to calculate largest patch index.

Largest patch index using the top three largest patches is more appropriate for Mt. Rainier National Park as it is more sensitive to management areas that have fewer patches.

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