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Hydrobiological & Landscape Sciences

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TO: Mary Scurlock, Scurlock and Associates, Portland, OR

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RE: Review of Three Recent Oregon Paired Watershed Study Publications: Small Samples Size Greatly Limits Power of Inference About Effectiveness of Current Forest Practices, Compared to Synoptic Surveys and Studies.

In this memo I discuss the findings and limitations of inference of three recently published paired watershed research papers from western Oregon: Arismendi et al. (2016) on suspended sediment and turbidity associated with roads in the Trask Watershed Study, Hatten et al. (2017) on suspended sediment in the revisited Alsea Watershed Study, and Bladon et al. (2016) on stream temperature in the Alsea Watershed Study.

OVERALL FINDINGS

Paired watershed studies are extremely limited in time frame and sample size, limiting their power to detect the full suite of impacts from logging that are more readily observed in synoptic studies such as landscape-extensive landslide and road inventories, and the RipStream temperature study.

While each of these paired watershed studies relied on intensive instrumentation and detailed measurements, in each case a very small number of logging or road treatment and unlogged or no road treatment control sites were actually measured. As a result of extremely small sample sizes, variance due to natural or other sources not related to the recent logging or road activity was unsurprisingly high among unlogged control sites relative to variance in the treatment sites, and the power to detect change associated with logging and road activity was consequently low. Synoptic studies using data from large numbers of both control and logged treatment streams is necessary for significant power to detect effects from management practices under current rule regimes. Examples of synoptic studies include comprehensive road and landside inventories covering large landscape areas with data accrued for hundreds of road miles, stream crossings, and erosion-prone sites, and large-sample planned experimental studies such as Groom et al.'s RipStream research. Larger sample sizes and longer study time frames allow both more accurate characterization of natural variance in unlogged control streams and more expansive and reliable measurement of logging-related responses, both short-term and longer-term. A partial drawback of synoptic studies is they often detect accrued effects of previous logging events and management regimes, but the converse view is that this reflects the reality of the status quo on the ground, and the effectiveness of present-day logging practices to protect water quality and aquatic resources must be evaluated with regard to how they interact with the lasting legacy of past practices.

These experimental watershed studies are principally useful to detect whether very short term, low-level impacts are occur that are below the resolution of large-sample synoptic studies to detect. The results indicate that within the initial 1-2 years post logging, these sites saw few logging-attributable effects that were below detection thresholds in the data commonly used to inform synoptic studies.

The *results of paired watershed studies do not substantiate that current forest practices in general do not produce adverse impacts to streams.* In this regard, the results of these very short term, tiny-sample watershed studies are relatively trivial compared to the results of synoptic studies account for longer-term process-response cycles and stochastic triggering events such as drought, windthrow (blowdown) and long duration or high-intensity precipitation events. These are well recognized in past research as the events that trigger large-magnitude and highly persistent responses in streams; they will eventually affect most or all logged watersheds, but are highly unlikely to occur within the 1-2 year time frame and within the very small number of sites measured in these paired watershed studies.

Synoptic studies of interest include various road and landslide inventories, Oregon Dept. of Forestry's RipStream study[1], and other published scientific analyses, some from other regions, such as Klein et al.'s (2012) quantitative analysis of turbidity data from a multitude of sampling stations across northern California.[2]

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[1] E.g., Groom, J. D., Dent, L., & Madsen, L. J. 2011. Stream temperature change detection for state and private forests in the Oregon Coast Range. *Water Resources Research*, *47*(1). Groom, J. D., Dent, L., Madsen, L. J., & Fleuret, J. 2011. Response of western Oregon (USA) stream temperatures to contemporary forest management. *Forest Ecology and Management* 262(8): 1618-1629.

[2] Klein, R. D., J. Lewis, J., & M.S. Buffleben. 2012. Logging and turbidity in the coastal watersheds of northern California. *Geomorphology*139*:*136-144. Online at: http://www.wildcalifornia.org/wp-content/uploads/2012/12/Klein-et-al-2011-Logging-and-Turbidity.pdf

NOTES

1) Arismendi et al. 2016, suspended sediment and turbidity after road construction/improvement and forest harvest in streams of the Trask River Watershed Study, Oregon.

FULL CITATION:
Arismendi, I., J. D. Groom, M. Reiter, S. L. Johnson, L. Dent, M. Meleason, A. Argerich, and A. E. Skaugset (2017), Suspended sediment and turbidity after road construction/improvement and forest harvest in streams of the Trask River Watershed Study, Oregon, Water Resour. Res., 53, 6763–6783, doi:10.1002/2016WR020198.
Online at: http://onlinelibrary.wiley.com/doi/10.1002/2016WR020198/full

And supporting data online at:
http://onlinelibrary.wiley.com/store/10.1002/2016WR020198/asset/supinfo/wrcr22757-sup-0001-2016WR020198-s01.pdf?v=1&s=88bdc983407d0ebc1cfa178b06dcfae37b981e03

This study design rests on a single control stream with no replication, compared against three treatment streams with road construction of improvement activity. It is not valid to treat the two consecutive study years as replication of the treatments or controls, as it is a well known aspect if sediment relations that sediment processes in year one can affect sediment processes in year 2. The treatments and effects are therefore not independent across years.

The lack of control replication of control watersheds means that variance in natural background is not effectively accounted for. Interpretations are confounded in that this control stream experienced localized sediment-generating events not related to road treatments that produced elevated sediment loads. This illustrates why replication is important in both control and treatment categories, to provide some statistical means to account for natural variation and elucidate any departures associated with road treatments.

At most, the study sites at the stream crossings in these very small watersheds register effects from a few kilometers of new road construction, reconstruction, and haul ; this is relative to a few kilometers of unaltered road potentially affecting the stream crossing in the control watershed. By contrast, a typical third or fourth-order western Oregon HUC 6 Subwatershed of roughly 25 square kilometer drainage area, with a typical average road density for the Oregon Coast Range, would contain something more like 50 km of road segments, potentially delivering sediment to streams at dozens of road crossings, and additional stream proximal sites. This is important because in terms of watershed impact, even if just 5 of 50 km of road generate sediment-laden runoff and if it is delivered to streams at 3 of 15 road crossings, there is a very good chance of extensive suspended sediment and turbidity impairment of the stream system. In other words, the landscape of a Coast Range watershed geographically "samples" hundreds of road miles and hundreds of road crossings. Simply because 3 or 4 experimental road treatments and stream crossings do not deliver much sediment doesn't mean that some of the many other road segments and crossings in a watershed will not, given similar treatment. The response is stochastic, not strictly deterministic, because site features like soils, slope, riparian vegetation, channel location, and road drainage structures are varied; hence the probability of impact, even if low at any single site, accrues over space and time because the practices are implemented over large areas encompassing hundreds of sites.

It is important to note that the short study period of 1-2 years doesn't allow for a natural range of erosion-triggering weather conditions to occur. Also, many road erosion processes occur as a cumulative result of use and weather conditions testing road integrity; e.g., deformation of road surface and subgrades with haul during periods of sustained high ground moisture.

Unfortunately the published paper presents no data on relative intensity or return interval of storm event intensities within the study period, compared to the patterns observed over time in the area. A preliminary examination of weather records for Astoria, OR would be helpful to inform what range of weather patterns was seen during the study period. The authors plot some daily precipitation data in the Supplemental information (Figure S2), but the source of this precipitation data is nowhere documented. And the potential role of precipitation events and timing on measured SSC and Turbidity in the experimental period is not addressed in the analysis, despite the discussion emphasizing the potential significance of storm-event-scale hysteresis (i.e., sediment source depletion) in the observed relationships. There is no way to tell from this paper whether individual storms of sufficient intensity occurred to effectively test the treatments under the range of high-intensity and high antecedent soil moisture precipitation conditions that a road will experience during its active life span. If the experiment were repeated in other years, some roads would likely have experienced such stressing events within the first year or two of construction or alteration, and the results could be dramatically different than the non-effects observed in this study.

The authors say in the discussion that logging above the upstream control sites could have elevated background sediment levels in these controls. This could potentially obscure road sediment effects, but curiously the paper does not consider the implications for the adequacy of the design and conclusions.

There is evidence prior to this study that on a per mile basis, forest roads constructed to current ideal standards and practices cause less erosion and sedimentation and turbidity in streams compared to roads constructed in past decades. However, confidence in this generalization is problematic because more recently constructed roads have very rarely or never stood the tests of multiple seasons of use coupled with episodes of extreme rainfall intensity and other stress-causing weather conditions. This study does not solve this fundamental problem; only a sustained period of application of current practices and monitoring over a large enough field of sites, road segments and watersheds to account for temporal and spatial variation will allow sufficient certainty to support claims that sediment delivery from roads overall, especially on a catchment area basis, as opposed to a site or road mile basis, is reduced under current practices.

In conclusion, this study is severely limited in its scope for inference and therefore does not push the envelope on-- nor does it come anywhere near settling--the question of the adequacy of current forest road construction, reconstruction, operation and maintenance practices to protect streams from road-related sediment. The study only provides a few interesting data points that shows near-term sediment delivery from roads might at some handful of road crossings over a couple of years be less than some interpretations of past literature would indicate. Further study is warranted to provide reasonably definitive data that could actually answer the key question about the effectiveness of road management practices

2) Hatten et al. 2017, Effects of Contemporary Forest harvesting on suspended sediment in the Oregon Coast Range: Alsea Watershed Study Revisited.

FULL CITATION: Hatten, J.A., C. Segura, K.D. Bladon, V.C. Hale. G. G. Ice, and J.D. Stednick 2017. Effects of Contemporary Forest harvesting on suspended sediment in the Oregon Coast Range: Alsea Watershed Study Revisited *Forest Ecology and Management 408*: 238-248. Online at:
http://staticweb.fsl.orst.edu/bladon/publications/Hatten_ForEcolManage_2018.pdf

In this study suspended sediment concentrations were monitored in four small watersheds; two were adjacent watersheds within Needle Branch, and were logged during this study; one control was previously logged but not logged in this study, and one control remains in an unlogged state. Current forest practices implemented in Needle Branch treatments included buffers on fish-bearing stream segments, and equipment exclusion zones in non-fish-bearing stream channels, and no debris removal from streams. Existing roads were maintained or reconditioned for haul, but new roads were not constructed.

The study found no effect of harvesting on suspended sediment concentrations relative to temporal variation observed in the control streams.

The important limitation of this study is the logging treatment sample size of two. As the paper acknowledges, other published studies have reported a range of suspended sediment responses to similar forest harvest practices. Some watersheds are inherently more vulnerable to disturbance, due to recognized factors such as soils, geology, geomorphology, and vegetation. Moreover, Needle Branch might have shown increased sediment if different weather conditions had prevailed during the post logging measurement period.

While this study shows the impacts of current practices are very likely less than those of forest practices of the 1970s in the treatment watersheds, by itself it says comparatively little about whether contemporary practices are on balance adequate and effective to protect aquatic resources under the weather and other conditions that prevail over longer time frames as logging is implemented over large land areas and multiple streams and stream types.

3) Bladon et al. 2016, A catchment-scale assessment of stream temperature response to contemporary forest harvesting in the Oregon Coast Range.

FULL CITATION: Bladon, K. D., N. A. Cook, J.T. Light, and C. Segura. 2016. A catchment-scale assessment of stream temperature response to contemporary forest harvesting in the Oregon Coast Range Forest Ecology and Management 379:153-164. Online at: http://nrforum.forestry.oregonstate.edu/bladon/publications/Bladon_ForEcolManage_2016.pdf

With a similar basic design as the Hatten paper, except using a single stream as the unlogged control and Needle Branch as a single logged treatment stream. Although three sites were monitored in each stream, with regard to the logging effects on the stream, the sample size for treatment and control is one. That is, this is strictly a case study that provides no empirical or statistical basis for extrapolating the results to other streams.

Although observed temperature increases were relatively small in comparison to those historically observed post-logging in Needle Branch, it is important to note the paper acknowledges the observed 7-day mean daily maximum temperature for the summer months exceeded Oregon's water quality standard of no measureable increase in (> 0.5 degrees C) after logging, when the three measured sites were grouped and evaluated together.

This paper clearly establishes that logging following contemporary practice in one stream had less drastic impact on stream temperature than logging in the 1970s did. However, the contemporary practices were not clearly effective in preventing violation of Oregon's cold water temperature standard.

With time, continuing vulnerability of riparian leave trees to blowdown could result in further or more sustained stream warming in the logged watershed, Needle Branch. Three years, the response time frame reported in this study post-harvest, is often insufficient time for stands to experience the range of windthrow stress they are likely to experience under prevailing weather conditions in the Coast Range.

In that regard, this case study shows that contemporary forest practice standards are not fully protective of stream temperatures, which is fully consistent with the findings of Oregon's RipStream study. RipStream results indicate that the riparian vegetation retention rules current when the Alsea Watershed Study Revisited was logged in 2009 were protective in some streams, but not protective in many others.