Signal vs Noise for Watershed Health Monitoring Habitat Metrics, 2009-2019

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Abstract

The Washington State Department of Ecology's (Ecology's) Watershed Health Monitoring (WHM) program surveyed random stream sites across Washington state each year, 2009-2019. Stream surveys are ongoing, and more data are being collected after 2019. Field habitat data were used to calculate habitat metrics. The metrics help define regional stream characteristics within the state. These physical habitat metrics describe instream and riparian features.

Signal-to-Noise ratio (SNR) is a comparison of a metric's variability across sites with the variability of repeated measurements and is indicative of which metrics provide discernable monitoring information relative to errors. We calculated statewide SNR values for habitat metrics and assigned them to three levels of precision.

Analyses in this report are confined to data collected in wadeable streams using the WHM narrow protocol. Data collected with this protocol comprise over 80% of WHM data and nearly all of the data submitted by external collaborators to the WHM Database.

In this report, we present statewide results for a total of 132 habitat metrics. Of these metrics, 112 were classified as precise or moderately precise. These results provide insight into habitat metrics in the WHM Database demonstrating high precision and repeatability. These results can help end-users and groups implementing the narrow protocol for monitoring in order to better understand those metrics which might be useful in evaluating habitat quality.

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Background

Ecology's Watershed Health Monitoring Program (WHM) is designed to assess biological and habitat conditions at the regional and statewide scale. WHM uses a probabilistic sampling design to sample randomly-selected streams and rivers across Washington state. The state is divided into eight Status and Trends Regions (STRs; Figure 1) that are sampled on a rotating basis. The STRs were delinetated using Washington's Salmon Recovery Regions (SRR; GSRO, 2017) with some modification. Surveys collect biological, chemical, and habitat data. For each survey, 10% of sites were visited a second time within the given sample season, to generate the pooled variance of repeated measurements. Random sampling started in 2009. When sampling began, WHM staff sampled multiple STRs during a field season. Currently, only one STR is being sampled during a field season.

WHM staff collected data at each stream site location. This includes assemblage data for fish/amphibians, macroinvertebrates, and algae. Water and sediment chemistry data, as well as physical habitat data, were also collected to help us understand stressors affecting the biological communities. WHM staff use these data to generate a suite of metrics to describe conditions across the state or its component regions.

Using these field and laboratory data, there are more than 1000 metrics (habitat and biological) that can be generated for each sample site. Hundreds of habitat metrics are routinely calculated by the WHM database for public view and are freely available to downloaded.

Metric categories include bed stability, channel dimmensions, fish cover, habitat unit dimensions, habitat unit extent, large woody debris, riparian cover, riparian disturbance, riparian vegetation structure, sinuousity, and substrate (Janisch, 2013). In this report, we emphasize the reliability of the metrics calculated for physical habitat data.

To evaluate habitat metrics for reliability and repeatability, Signal-to-Noise Ratios (SNR) were generated. SNR enable comparisons across metrics with different measurement units. The SNR value is the ratio of variance among streams, or signal, to the pooled variance from within-season repeated site visits: the noise (Kaufmann et al., 1999). If the variability due to sampling is large compared to variability of the population sampled (e.g., low SNR), then the metric is unlikely to be a reliable indicator of change. These values can help us determine which metrics are more informative when conducting regional or statewide assessments. The higher a SNR value is above 1, the more discernable the signal. Here, we report SNR values for habitat metrics generated by the WHM database. This information can assist with further reporting choices and plans for improved training of staff.

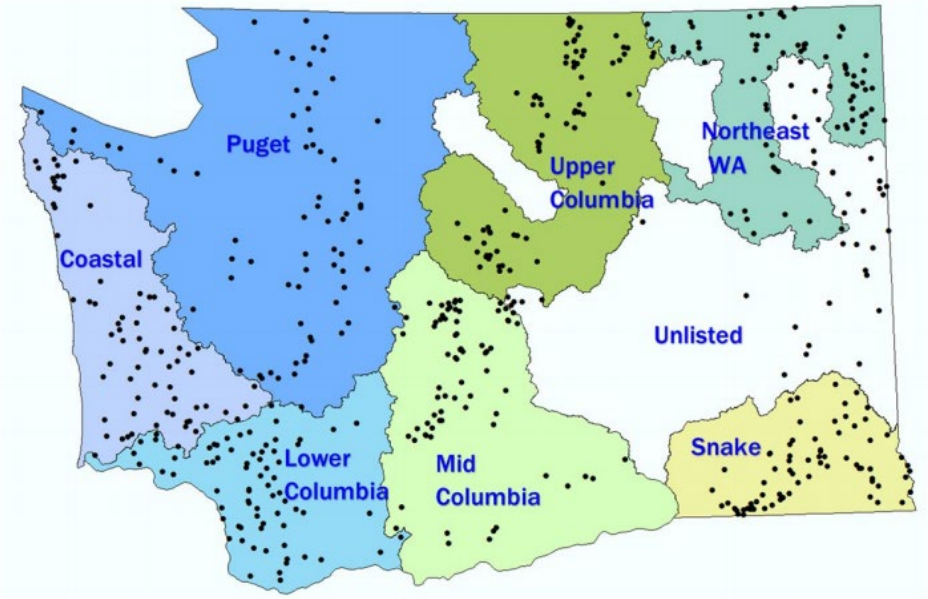

Figure 1. Map of 544 sites sampled during 2009-2019, shown by Status & Trends Region

Methods

Habitat metrics were calculated as described in Janisch (2013). The project home page, https://ecology/wa/gov/WatershedHealth, provides links to:

- An interactive map of the sampled sites (see "Previous Monitoring"), and
- Standard Operating Procedures (see page bottom of "Habitat Monitoring Methods")

There are multiple users and projects conducted under the WHM umbrella. Data collected by WHM staff and collaborators go into electronic field forms (eforms). To calculate the SNR values for habitat metrics, we used data from the Study ID "WHM_WAM0". This Study ID corresponds with the randomized stream sampling conducted in the different STRs. This study is statewide and randomized. These data are downloadable by searching the WHM Database, linked on the project home page.

The SNR values were calculated by comparing the variance of habitat metrics among survey sites to the pooled variance calculated from within-season replicate pairs:

$$\text{SNR} = \text{Signal:Noise Ratio} = \sigma^2_{site} / \sigma^2_{rep}$$

where

σ_{site} is the among site standard deviation, and

σ_{rep} is the pooled standard deviation of repeated sampling visits

SNR calculations were limited to sampling events that used the standard operating procedures (SOPs) for the narrow protocol. This protocol applies to small (< 25 m width) wadeable streams. Length of sample sites ranged from 150 m to 500 m. Metrics with infrequent observations, metrics without standardization (i.e., large woody debris size classes), and metrics that count field observations were omitted from this evaluation.

SNR assumes a normal distribution (Kaufmann et al. 1999). Some metrics were transformed to improve normality (Table 1). Mean values of a proportion likely do not require transformation. Many concentration measurements required log-transformation. Percentages required converting to proportions and then arcsine transforming. Integer data was square-root transformed.

SNR values were classified into three categories following Kaufmann et al. (1999): low, moderate, and precise. If a metric had a SNR value less than 2 it was considered to have low precision. Metrics with SNR values between 2 and 7 were considered to have moderate precision. Metrics with SNR values higher than 7 were considered precise.

Results

Throughout the 2009-2019 statewide sampling, 82.3% of data collection events were surveyed using the narrow protocol.

SNR values of "NA" indicated zero variance in the repeated samples, i.e., Noise = 0. SNR values that were not "NA" but those having zero noise values were due to rounding (Table 1).

Statewide, the narrow protocol habitat methods generated 44 precise metrics, 68 moderately precise metrics, and 20 low or NA precision metrics. Precise and moderately precise metrics made up 84.8% of calculated metrics. The precise and moderately precise metrics fell across all 11 habitat categories: bed stability, channel dimensions, fish cover, habitat unit dimensions, habitat unit extent, large woody debris, riparian cover, riparian disturbance, riparian vegetation structure, sinuosity, and substrate (Table 1).

Categories with predominately precise metrics included bed stability, channel dimensions, large woody debris, and riparian cover. Categories with predominately moderate metrics included fish cover, habitat unit dimensions, habitat unit extent, riparian disturbance, riparian vegetation structure, and sinuosity (Table 1).

Table 1. Signal-to-Noise Ratio values, transformations, and general descriptions for habitat metrics collected with narrow protocol calculated with statewide data from the WHM_WAM0 sites.

Metric Category	Metric Name	Transformation Type	Signal	Noise	SNR	SNR Rating	Description
BedStability	DgmLog10*	none	1.50	0.04	33.68	Precise	Log_{10} of geometric mean substrate diameter
BedStability	LRBS*	none	1.12	0.15	7.71	Precise	Log_{10} of relative bed stability
ChannelDimensions	ResPoolArea_m2	log(x+1)	0.30	0.01	29.74	Precise	Vertical residual pool area, total in square meters
ChannelDimensions	ResPoolArea100_cm*	log(x+1)	0.19	0.01	22.35	Precise	Standardized vertical residual pool area, total in centimeters
ChannelDimensions	SD_BF_WxD_m2	none	16.12	0.98	16.42	Precise	Standard deviation of bankfull cross section in square meters
ChannelDimensions	SD_BFDepth_cm	none	161.49	59.68	2.71	Moderate	Standard deviation of bankfull depth in centimeters
ChannelDimensions	SD_BFHeight_cm	none	24.05	21.55	1.12	Low	Standard deviation of bankfull height in centimeters
ChannelDimensions	SD_BFWidth_m	none	3.52	0.21	16.50	Precise	Standard deviation of bankfull width in meters
ChannelDimensions	SD_TWDepth_cm	none	126.01	9.91	12.72	Precise	Standard deviation of thalweg depth in centimeters
ChannelDimensions	SD_Wet_WxD_m2	none	6.53	0.48	13.57	Precise	Standard deviation of wetted cross section in square meters
ChannelDimensions	SD_WetWidth_m	none	2.70	0.10	26.53	Precise	Standard deviation of wetted width in meters
ChannelDimensions	X_BF_WxD_m2	log(x+1)	0.15	0.01	25.64	Precise	Average bankfull cross section in square meters
ChannelDimensions	X_BFDepth_cm	log(x+1)	0.06	0.01	7.87	Precise	Average bankfull depth in centimeters
ChannelDimensions	X_BFHeight_cm	log(x+1)	0.05	0.02	3.09	Moderate	Average bankfull height in centimeters
ChannelDimensions	X_BFWidth_m	log(x+1)	0.09	0.00	58.61	Precise	Average bankfull width in meters
ChannelDimensions	X_Slope_prcnt	log(x+1)	0.13	0.01	18.88	Precise	Average channel slope in percentage
ChannelDimensions	X_TWDepth_cm	log(x+1)	0.13	0.00	36.75	Precise	Average thalweg depth in centimeters
ChannelDimensions	X_Wet_WxD_m2	log(x+1)	0.10	0.00	56.57	Precise	Average wetted cross section in square meters
ChannelDimensions	X_WetWidth_m	log(x+1)	0.09	0.00	57.57	Precise	Average wetted width in meters
FishCover	PFC_Algae	arcsine	0.00	0.00	1.35	Low	Proportion cover of algae
FishCover	PFC_Artificial	arcsine	0.00	0.00	2.08	Moderate	Proportion cover of artificial structures
FishCover	PFC_Boulders	arcsine	0.00	0.00	3.59	Moderate	Proportion cover of boulders
FishCover	PFC_Brush	arcsine	0.00	0.00	4.86	Moderate	Proportion cover of brush/woody debris, <0.3 m diameter

Metric Category	Metric Name	Transformation Type	Signal	Noise	SNR	SNR Rating	Description
FishCover	PFC_Bryophytes	arcsine	0.00	0.00	2.37	Moderate	Proportion cover of bryophytes
FishCover	PFC_LWD	arcsine	0.00	0.00	2.63	Moderate	Proportion cover of large woody debris, >0.3 m diameter
FishCover	PFC_Macrophytes	arcsine	0.00	0.00	2.65	Moderate	Proportion cover of macrophytes
FishCover	PFC_Natural	arcsine	0.00	0.00	1.52	Low	Proportion cover of combined types, natural cover types
FishCover	PFC_NoAqVeg	arcsine	0.00	0.00	4.52	Moderate	Proportion cover of combined types, non-aquatic vegetation types
FishCover	PFC_OvHgVeg	arcsine	0.00	0.00	2.38	Moderate	Proportion cover of overhanging vegetation
FishCover	PFC_Persistent	arcsine	0.00	0.00	NA	NA	Proportion cover of combined types, persistent types
FishCover	PFC_TreesRoots	arcsine	0.00	0.00	2.15	Moderate	Proportion cover of live trees and roots
FishCover	PFC_Undercut	arcsine	0.00	0.00	3.11	Moderate	Proportion cover of undercut banks
FishCover	XFC_Algae_prcnt	arcsine	0.02	0.01	2.45	Moderate	Average cover of algae as a percent
FishCover	XFC_Artificial_prcnt	arcsine	0.01	0.00	2.34	Moderate	Average cover of artificial structures as a percent
FishCover	XFC_Boulders_prcnt	arcsine	0.05	0.02	3.31	Moderate	Average cover of boulders as a percent
FishCover	XFC_Brush_prcnt	arcsine	0.03	0.01	2.84	Moderate	Average cover of brush/woody debris, <0.3 m diameter as a percent
FishCover	XFC_Bryophytes_prcnt	arcsine	0.01	0.01	1.93	Low	Average cover of bryophytes as a percent
FishCover	XFC_LWD_prcnt	arcsine	0.02	0.01	2.17	Moderate	Average cover of large woody debris, >0.3 m diameter as a percent
FishCover	XFC_Macrophytes_prcnt	arcsine	0.05	0.01	6.04	Moderate	Average cover of macrophytes as a percent
FishCover	XFC_Natural_prcnt*	none	1281.47	603.29	2.12	Moderate	Average cover of combined types, natural cover as a percent
FishCover	XFC_NoAqVeg_prcnt	none	1008.14	525.22	1.92	Low	Average cover of combined types, non-aquatic vegetation types as a percent
FishCover	XFC_OvHgVeg_prcnt	arcsine	0.05	0.01	4.90	Moderate	Average cover of overhanging vegetation as a percent
FishCover	XFC_Persistent_prcnt	none	0.00	0.00	NA	NA	Average cover of combined types, persistent types as a percent
FishCover	XFC_TreesRoots_prcnt	arcsine	0.01	0.01	1.75	Low	Average cover of live trees and roots as a percent
FishCover	XFC_Undercut_prcnt	arcsine	0.02	0.01	2.13	Moderate	Average cover of undercut banks as a percent
HabitatUnitDimensions	SD_PoolUnitDepth_cm	none	257.32	139.22	1.85	Low	Standard deviation of pool unit depth in centimeters

Metric Category	Metric Name	Transformation Type	Signal	Noise	SNR	SNR Rating	Description
HabitatUnitDimensions	X_PoolCrestDepth_cm	log(x+1)	0.20	0.09	2.10	Moderate	Average pool crest depth in centimeters
HabitatUnitDimensions	X_PoolMaxDepth_cm	log(x+1)	0.31	0.13	2.34	Moderate	Average pool maximum depth in centimeters
HabitatUnitDimensions	X_PoolUnitDepth_cm	log(x+1)	0.28	0.11	2.57	Moderate	Average pool unit depth in centimeters
HabitatUnitExtent	PCT_Dry_prcnt	arcsine	0.01	0.00	5.09	Moderate	Relative length of site reach as dry channel as a percent
HabitatUnitExtent	PCT_Fast_prcnt	arcsine	0.12	0.02	5.09	Moderate	Relative length of site reach as fast (turbulent + non-turbulent) as a percent
HabitatUnitExtent	PCT_FastNT_prcnt	arcsine	0.20	0.04	4.60	Moderate	Relative length of site reach as fast non-turbulent as a percent
HabitatUnitExtent	PCT_FastT_prcnt	arcsine	0.21	0.04	5.62	Moderate	Relative length of site reach as fast turbulent as a percent
HabitatUnitExtent	PCT_Pool_prcnt	arcsine	0.11	0.02	4.86	Moderate	Relative length of site reach as pools (plunge + scour + dammed) as a percent
HabitatUnitExtent	PCT_PoolDammed_prcnt	arcsine	0.06	0.02	3.17	Moderate	Relative length of site reach as dammed pools as a percent
HabitatUnitExtent	PCT_PoolPlunge_prcnt	arcsine	0.03	0.01	3.63	Moderate	Relative length of site reach as plunge pools as a percent
HabitatUnitExtent	PCT_PoolScour_prcnt	arcsine	0.11	0.04	3.05	Moderate	Relative length of site reach as scour pools as a percent
HabitatUnitExtent	PCT_Wet_prcnt	arcsine	0.05	0.00	18.44	Precise	Relative length of site reach as wetted channel as a percent
LargeWoodyDebris	LWDPieces100m_100m	log(x+1)	0.29	0.03	9.88	Precise	Normalized count, pieces per 100 m, all large wood, size classes 1 to 5 per 100 m
LargeWoodyDebris	LWDPiecesMSq_m2	log(x+1)	0.00	0.00	14.87	Precise	Normalized count, pieces per square meter, all large wood, size classes 1 to 5 per m^2
LargeWoodyDebris	LWDSiteVolume100m_m3_100m	log(x+1)	0.34	0.04	8.46	Precise	Normalized volume, per 100 m, all large wood, size classes 1 to 5 per 100 m
LargeWoodyDebris	LWDVolumeMSq_m3_m2*	log(x+1)	0.00	0.00	19.42	Precise	Normalized volume, per square meter, all large wood, size classes 1 to 5 per m^2
RiparianCover	X_DensioBank_prcnt*	arcsine	0.06	0.01	8.83	Precise	Average densiometer readings at bank(s) as a percent
RiparianCover	X_DensioCenter_prcnt*	arcsine	0.11	0.01	19.47	Precise	Average densiometer readings at channel center as a percent
RiparianDisturbance	PCT_BankAg_prcnt	arcsine	0.18	0.04	4.09	Moderate	Percent disturbance at bank of agricultural human-influence types
RiparianDisturbance	PCT_BankAny_prcnt	arcsine	0.20	0.04	4.74	Moderate	Percent disturbance at bank of all human-influence types
RiparianDisturbance	PCT_CloseAg_prcnt	arcsine	0.22	0.07	3.22	Moderate	Percent disturbance close to bank of agricultural human-influence types

Metric Category	Metric Name	Transformation Type	Signal	Noise	SNR	SNR Rating	Description
RiparianDisturbance	PCT_CloseAny_prcnt	arcsine	0.27	0.09	3.10	Moderate	Percent disturbance close to bank of all human-influence types
RiparianDisturbance	PWP_Ag	log(x+1)	0.02	0.00	3.91	Moderate	Proximity weighted presence of all combined agricultural human-influence types
RiparianDisturbance	PWP_All*	log(x+1)	0.03	0.01	3.46	Moderate	Proximity weighted presence of all combined human-influence types
RiparianDisturbance	PWP_Bldg	log(x+1)	0.00	0.00	9.99	Precise	Proximity weighted presence of buildings
RiparianDisturbance	PWP_Clear	log(x+1)	0.00	0.00	14.87	Precise	Proximity weighted presence of clearing or lot
RiparianDisturbance	PWP_Crop	log(x+1)	0.00	0.00	12.52	Precise	Proximity weighted presence of row crops
RiparianDisturbance	PWP_Dike	log(x+1)	0.00	0.00	2.15	Moderate	Proximity weighted presence of wall, dike, or revetment
RiparianDisturbance	PWP_Lawn	log(x+1)	0.00	0.00	5.39	Moderate	Proximity weighted presence of park or lawn
RiparianDisturbance	PWP_Log	log(x+1)	0.01	0.00	3.24	Moderate	Proximity weighted presence of logging
RiparianDisturbance	PWP_Mine	log(x+1)	0.00	0.00	NA	NA	Proximity weighted presence of mining
RiparianDisturbance	PWP_Path	log(x+1)	0.00	0.00	2.12	Moderate	Proximity weighted presence of human foot path
RiparianDisturbance	PWP_Pave	log(x+1)	0.00	0.00	8.84	Precise	Proximity weighted presence of paved road or railroad
RiparianDisturbance	PWP_Pipe	log(x+1)	0.00	0.00	0.80	Low	Proximity weighted presence of pipes, in or out
RiparianDisturbance	PWP_Range	log(x+1)	0.01	0.00	3.71	Moderate	Proximity weighted presence of pasture, rangeland, or hayfield
RiparianDisturbance	PWP_Trash	log(x+1)	0.00	0.00	1.13	Low	Proximity weighted presence of landfills or trash
RiparianDisturbance	PWP_Unpav	log(x+1)	0.00	0.00	5.72	Moderate	Proximity weighted presence of unpaved road or motor trail
RiparianVegetationStructure	IDX_Canopy_prcnt	none	490.83	193.17	2.54	Moderate	Index, as percent of plot as woody ground cover
RiparianVegetationStructure	IDX_CanopyLT_prcnt	none	231.39	135.92	1.70	Low	Index, as percent of plot as large overstory trees
RiparianVegetationStructure	IDX_CanopyST_prcnt	none	189.40	102.12	1.85	Low	Index, as percent of plot as small overstory trees
RiparianVegetationStructure	IDX_CanUnderstory_prcnt	none	1110.00	662.99	1.67	Low	Index, as percent of plot as (large + small overstory trees) + (woody + herbaceous understory)
RiparianVegetationStructure	IDX_CanUnderstoryGnd_prcnt	none	1924.86	1116.14	1.72	Low	Index, as percent of plot as (large + small overstory trees) + (woody + herbaceous understory) + (woody + herbaceous ground cover)
RiparianVegetationStructure	IDX_CanUnderstoryWood_prcnt	none	1120.66	498.06	2.25	Moderate	Index, as percent of plot as (large + small overstory trees) + (woody understory)

Metric Category	Metric Name	Transformation Type	Signal	Noise	SNR	SNR Rating	Description
RiparianVegetationStructure	IDX_CanUnderstoryWoodGndWood_prcnt*	none	1811.57	618.43	2.93	Moderate	Index, as percent of plot as (large + small overstory trees) + (woody understory) + (woody ground cover)
RiparianVegetationStructure	IDX_Ground_prcnt	none	439.38	134.83	3.26	Moderate	Index, as percent of plot as bare soil and litter
RiparianVegetationStructure	IDX_GroundBare_prcnt	none	410.49	118.65	3.46	Moderate	Index, as percent of plot as herbaceous ground-cover
RiparianVegetationStructure	IDX_GroundHerb_prcnt	none	461.61	146.12	3.16	Moderate	Index, as percent of plot as woody understory
RiparianVegetationStructure	IDX_GroundWood_prcnt	none	226.13	68.64	3.29	Moderate	Index, as percent of plot as herbaceous + wood understory
RiparianVegetationStructure	IDX_Understory_prcnt	none	446.65	241.27	1.85	Low	Index, as percent of plot as herbaceous + woody ground cover
RiparianVegetationStructure	IDX_UnderstoryHerb_prcnt	none	284.62	115.37	2.47	Moderate	Index, as percent of plot as large + small trees
RiparianVegetationStructure	IDX_UnderstoryWood_prcnt	none	301.16	119.06	2.53	Moderate	Index, as percent of plot as herbaceous understory
RiparianVegetationStructure	PPN_CanBrdlf	arcsine	0.00	0.00	2.72	Moderate	Ratio of broadleaf overstory to total observations
RiparianVegetationStructure	PPN_CanConif	arcsine	0.00	0.00	6.12	Moderate	Ratio of coniferous overstory to total observations
RiparianVegetationStructure	PPN_CanDecid	arcsine	0.00	0.00	10.22	Precise	Ratio of deciduous overstory to total observations
RiparianVegetationStructure	PPN_CanMixed	arcsine	0.00	0.00	7.96	Precise	Ratio of mixed overstory types to total observations
RiparianVegetationStructure	PPN_Canopy	arcsine	0.00	0.00	10.54	Precise	Ratio of presence of riparian vegetation of overstory to total observations
RiparianVegetationStructure	PPN_CanUnderstoryGnd	arcsine	0.00	0.00	10.46	Precise	Ratio of presence of riparian vegetation of overstory or understory or ground-covering to total observations
RiparianVegetationStructure	PPN_RipVegAboveGnd	arcsine	0.00	0.00	10.52	Precise	Ratio of presence of riparian vegetation of overstory or understory to total observations
RiparianVegetationStructure	PPN_Understory	arcsine	0.00	0.00	4.24	Moderate	Ratio of presence of riparian vegetation of understory to total observations
RiparianVegetationStructure	PPN_UnderstoryBrdlf	arcsine	0.00	0.00	NA	NA	Ratio of broadleaf understory to total observations
RiparianVegetationStructure	PPN_UnderstoryConif	arcsine	0.00	0.00	4.47	Moderate	Ratio of coniferous understory to total observations
RiparianVegetationStructure	PPN_UnderstoryDecid	arcsine	0.00	0.00	7.23	Precise	Ratio of deciduous understory to total observations
RiparianVegetationStructure	PPN_UnderstoryMixed	arcsine	0.00	0.00	8.17	Precise	Ratio of mixed understory to total observations
Sinuosity	Sinuosity*	log(x+1)	0.00	0.00	5.20	Moderate	Sinuosity of site reach, index
Substrate	PCT_Bedrock_prcnt	arcsine	0.03	0.01	3.28	Moderate	Percent substrate of bedrock, smooth and rough
Substrate	PCT_BedrockR_prcnt	arcsine	0.01	0.00	2.47	Moderate	Percent substrate of rough bedrock

Metric Category	Metric Name	Transformation Type	Signal	Noise	SNR	SNR Rating	Description
Substrate	PCT_BedrockS_prcnt	arcsine	0.02	0.01	1.46	Low	Percent substrate of smooth bedrock
Substrate	PCT_Boulder_prcnt	arcsine	0.04	0.00	13.66	Precise	Percent substrate of boulder, large and small
Substrate	PCT_BoulderL_prcnt	arcsine	0.01	0.00	7.18	Precise	Percent substrate of large boulders
Substrate	PCT_BoulderS_prcnt	arcsine	0.03	0.00	10.61	Precise	Percent substrate of small boulders
Substrate	PCT_Cobble_prcnt	arcsine	0.05	0.00	11.66	Precise	Percent substrate of cobble
Substrate	PCT_Fines_prcnt	arcsine	0.13	0.01	10.46	Precise	Percent substrate of fines
Substrate	PCT_GravelC_prcnt	arcsine	0.05	0.00	9.04	Precise	Percent substrate of coarse gravel
Substrate	PCT_GravelCx_prcnt	arcsine	0.14	0.00	28.60	Precise	Percent substrate of coarse gravel and larger
Substrate	PCT_GravelF_prcnt	arcsine	0.03	0.01	3.41	Moderate	Percent substrate of fine gravel
Substrate	PCT_GravelFb_prcnt	arcsine	0.12	0.01	18.04	Precise	Percent substrate of fine gravel and smaller
Substrate	PCT_Hardpan_prcnt	arcsine	0.01	0.01	1.60	Low	Percent substrate of hardpan
Substrate	PCT_Other_prcnt	arcsine	0.01	0.00	2.35	Moderate	Percent substrate of other
Substrate	PCT_Pavement_prcnt	arcsine	0.00	0.00	3.57	Moderate	Percent substrate of pavement (i.e. concrete)
Substrate	PCT_Sand_prcnt	arcsine	0.05	0.01	3.21	Moderate	Percent substrate of sand
Substrate	PCT_SandFines_prcnt*	arcsine	0.12	0.00	27.88	Precise	Percent substrate of sand and fines
Substrate	PCT_Wood_prcnt	arcsine	0.01	0.00	3.30	Moderate	Percent substrate of wood
Substrate	SD_Embed_prcnt	none	120.43	26.30	4.58	Moderate	Standard deviation of embeddedness of entire reach as a percent
Substrate	SD_EmbedCenter_prcnt	none	140.63	36.31	3.87	Moderate	Standard deviation of mid-channel embeddedness as a percent
Substrate	X_Embed_prcnt*	arcsine	0.10	0.02	5.59	Moderate	Average embeddedness of entire reach as a percent
Substrate	X_EmbedCenter_prcnt	arcsine	0.12	0.01	8.65	Precise	Average mid-channel embeddedness as a percent

*Metrics analogous with those in National Rivers and Streams Surveys. Metrics derived from EPA (2020a).

Conclusions

The calculation of SNR values helps to determine which metrics are the most repeatable and likely to detect trends. Most habitat metrics evaluated in this study were classified as precise or moderately precise. These results help to demonstrate the precision and repeatability of many of the sampling procedures employed by WHM staff. High SNR values showed distinct differences across sites and that variability was real and not due to error.

These data support the monitoring of stream habitat quality, including habitat for threatened or endangered salmonid species. Results will vary by survey region and year, yet as was demonstrated here, the habitat metrics reported by WHM can allow for effective evaluations of stream habitat quality at different spatial scales. Habitat data collected using standardized protocols implemented by WHM and other entities can be used to evaluate the status and long-term trends of stream habitat and also link patterns in biological condition to habitat quality.

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