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Reference Condition Approach 2020

An updated water quality monitoring approach to defining least disturbed areas

DEQ

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Executive Summary

The Biomonitoring Program is responsible for implementing Oregon Department of Environmental Quality's Reference Condition Approach. Since 2014, the agency has conducted multiple efforts to bring the RCA up to date, improving methods for determining 'least disturbed' reference conditions and applying them equally across the state. This report summarizes DEQ's most recent RCA methodology, providing rationales for the analytical approaches used, as well as a summary of the RCA outputs.

DEQ's updated RCA methods (herein, "RCA-2020", noted for the year the methods were finalized) built on those established in an Interagency RCA covering the Pacific Northwest Forest Plan area (Miller et al. 2016). The RCA-2020 expands on DEQ's 2016 interagency methods by building internal capacity to auto-delineate pour-point watersheds, update human disturbance screening metrics, and apply them equally across all of Oregon. In addition, a separate step-by-step Standard Operating Procedures document (DEQ 2021) was created to ensure the ability to carry this work forward into the future, despite personnel changes.

A total of 3,279 sampling stations were assessed for human disturbances within their watersheds (Table 1). Of these, 2,324 stations were provided by DEQ. Another 929 stations were provided by Utah State University's National Aquatic Monitoring Center. California Fish and Wildlife provided 26 sites that were previously determined to meet that agency's qualifications as 'least disturbed.'

Table 1. Sources and numbers of sites in each of three different classes of human disturbances.

Disturbance Class	DEQ	USU	CDFW	Totals
Least Disturbed	265	111	26	402
Moderately Disturbed	1625	613	0	2238
Most Disturbed	434	205	0	639

DEQ will use the RCA-2020 to update the following::

- DEQ's models for assessing biological condition of wadeable streams and rivers
- DEQ's listing methodology for the narrative Biocriteria water quality standard
- Reference thresholds for physical habitat and physical/chemical water parameters

There are additional benefits of this work by using it as follows:

- Reference thresholds from habitat and physical/chemical parameters to identify causes of biological impairments (Stressor Identification)
- Supporting information in applying other narrative water quality standards, such as sedimentation and nutrients
- Supporting information in developing new, or updating existing water quality standards

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Introduction

Oregon DEQ's Biomonitoring Program updated the agency's Reference Condition Approach in response to a variety of needs. First, the original RCA methods (Drake 2004) had become problematic by the year 2008. Through loss of key personnel and budget reductions leaving those skilled positions vacant, DEQ no longer had the ability to implement the RCA-2004 methodology. Part of this was due to lacking a step-by-step Standard Operating Procedure for determining reference condition at sampling sites. Recognizing this skill and resource gap, in 2014 DEQ partnered with multiple other agencies sharing a similar need to develop a broad-scale RCA.

While the resulting Interagency RCA (Miller et al. 2016) brought to DEQ a much-improved process, the Biomonitoring Program continued to face resource and technical skills limitations, making it difficult to fully implement the Interagency RCA. Additionally, the Interagency RCA only covered the western half of Oregon. Recognizing these issues, as well as desiring to meet peer-review recommendations for improving the Biocriteria assessment methodology, there was a need to improve upon the Interagency RCA by building the internal skills and tools necessary to create an improved statewide reference condition network.

DEQ's key objectives for a revised RCA were as follows:

- Develop internal tools for auto-delineating watersheds
- Utilize Geographic Information System screening metrics to assess levels of human disturbance equally across all of Oregon
- Improve and better document the use of satellite imagery to validate GIS screening metrics
- Incorporate a Best Professional Judgement step to validate GIS screens and satellite imagery disturbance scores
- Improve spatial coverage of reference sites across Oregon to increase the representativeness of models used for assessing biological condition (and physical habitat and water quality parameters)
- Develop a step-by-step SOP to allow for this work to be smoothly carried forward into the future

What is the Reference Condition Approach?

At its most basic level, the RCA is used to assess the ecological integrity of a sampled ecosystem, and to determine if a study site is showing signs of stress or impairment **due to human disturbances** (Bailey, Norris, and Reynoldson 2004). As such, DEQ's primary objective in developing an RCA is to factor out human disturbances as much as possible.

There are multiple ways to define reference populations (Stoddard et al. 2006), but DEQ's RCA has always implemented a definition of "least disturbed" to represent the population of reference sites. Here, the term "least disturbed" means "a maximum allowable level of any specific human disturbance, e.g., roads or mines, above which a site can no longer be considered part of the reference population." If a site shows disturbance levels below those thresholds, it remains in the reference population. DEQ's RCA **is not** an attempt to set biological, physical or chemical expectations to fit historic conditions, e.g., pre-Columbian settlement, or even minimally disturbed conditions, e.g., long-term wilderness areas. Rather, DEQ uses a middle-ground approach, allowing the least number of human disturbances to maximize representativeness of reference sites to all assessed locations. This allows DEQ's bioassessment models and assessment conclusions to be both fair and accurate across the landscape.

The RCA can also be used to assess more than biological conditions. In addition to sampling biological assemblages (fish, benthic macroinvertebrates, periphyton, etc.), biomonitoring programs often collect data on physical/chemical water parameters and instream and riparian physical habitat parameters. These additional parameters are frequently referred to in biomonitoring programs as "stressor indicators," as they can give clues to potential causes of biological impairments. DEQ can use the RCA to develop reference population "thresholds" (or "benchmarks") beyond which stressor indicators, e.g., nutrients, sediment, may be causing stress or impairment to biological assemblages.

RCA methodology: an overview

To construct the RCA-2020, DEQ leaned heavily on the methods employed in the Interagency RCA (Miller et al. 2016). The primary steps involved were mostly the same; however, to meet the objectives of expanding to a statewide coverage with equal disturbances, DEQ needed to adjust several of the initial GIS screening metrics and calculations. Additionally, acknowledging that DEQ's Biomonitoring sampling had decreased substantially since 2010, it seemed unlikely to get an increase in reference sites by looking at DEQ sites alone.

To rectify this issue, DEQ partnered with the National Aquatic Monitoring Center and the California Department of Fish and Wildlife. All RCA-2020 procedures were developed utilizing DEQ sites only (n = 2324). The RCA-2020 methodology was then applied to 929 sites from NAMC and 26 sites from CAFW. These sites covered wide areas across Oregon, as well as some sites located in neighboring states (California, Idaho, and Nevada) that were also in ecoregions found in Oregon. In the end, the final RCA-2020 represents an assessment of 3279 sites across Oregon (71% DEQ, 28% NAMC, < 1% CAFG).

In brief, the general procedures for RCA-2020 are as follows (for full details, see the official RCA-2020 SOP):

1) Verify site location and associate with spatial stream networks
    a. High Resolution National Hydrography Dataset (NHD) – Reachcode and Measure
    b. Medium Resolution NHD – COMID
    c. Watershed Boundary Dataset – HUC codes
    d. NHD Plus Flow Accumulation Network – For automated delineation
2) Auto-delineate the pour-point watershed
3) Calculate GIS screening (human disturbance) metrics using an automated process
4) Calculate reference screening thresholds based on the percentiles of all DEQ sites
5) Apply thresholds for each disturbance metric to determine GIS status:
    a. "GIS Candidate" (least disturbed; meets lowest threshold for all GIS metrics)
    b. "Moderately disturbed"
    c. "Most Disturbed" (highest levels of human activities: > 95th percentile for at least one GIS metric)
6) Use satellite imagery (Google Earth) to visually score human disturbances at GIS Candidate Reference sites
7) As a team, use Best Professional Judgement (BPJ) to determine if any final site scorings (based on GIS and Google Earth) should be overridden

GIS screening metrics

Where possible, the same GIS human disturbance screening metrics used in the Interagency RCA (Miller et al. 2016) were adopted for the DEQ's RCA-2020. Seven final metrics were chosen (Table 1), with some minor and some fairly significant changes in data sources and calculations. One GIS screening metric, Distance to dam, was dropped from RCA-2020 due to an inability to accurately replicate the calculations used in Miller et al. (2016), as well as the small number of sites this metric influenced.

DEQ developed internal methods to calculate each GIS metric, based on notes and conversations with our USFS co-authors from the Interagency RCA. Quality control steps were employed to ensure consistency in DEQ GIS metric calculations and those defined by Miller et al. (2016). For example, internal metric values were plotted against the metric results from DEQ sites used in the Interagency RCA (metrics were calculated by USFS AREMP Program staff) and methodologies were adapted until there was little deviation from the 1:1 line.

Table 2. GIS screening metrics and GIS_status thresholds used in DEQ's RCA-2020. Values in parentheses represent the percentile of all sites assessed that was selected to define the GIS_candidate status. Results are based on 2350 watersheds sampled by DEQ.

Disturbance type	GIS screening metric	Units	Different from Interagency RCA?	Source	GIS candidate Threshold	Most disturbed
Road density	rdden_km_km2	Km/km2	YES	BLM roads layer	≤ 1.19 (25^{th})	> 4.91 (95^{th})
Road Stream crossings	xings_km2	#/km2	YES	Medium Resolution NHD and BLM roads layer	≤ 0.11 (30^{th})	> 1.36 (95^{th})
Agriculture	P_AgLand	%	No	NLCD (2016)	0 (60^{th})*	> 30.05 (95^{th})
Developed, Open Space	P_21Land	%	No	NLCD (2016)	1.60 (50^{th})	> 9.65 (95^{th})
Gravel mines	mines	Count	No	Mineral Resources Data System	0 (75^{th})*	> 0.005 (95^{th})
Mines	grvl_mn_km2	#/km2	No	Mineral Resources Data System	0 (85^{th})*	> 15 (95^{th})
Canals	P_canal	%	No	Medium Resolution NHD	0 (90^{th})*	> 2.55 (95^{th})

Modifications to the GIS roads layer

The GIS roads layer used in the Interagency RCA was a combination of a widely available coverage provided by the Bureau of Land management (BLM), plus a customized roads layer developed by United States Forest Service (USFS) to more accurately capture roads on each USFS district. While this customized USFS roads layer was more accurate, DEQ staff did not have access to the source data or adequate staffing resources to recreate a similar coverage for the area outside of the Interagency RCA focus area (Northwest Forest Plan boundary).

To optimize reproducibility and minimize manipulation of GIS roads data for the RCA-2020, DEQ opted to use publicly available data sources. Roads layers were selected from publicly available transportation data portals that are current and actively managed and provide the most comprehensive coverage for a given state. To reduce dataset size, roads layers from states bordering Oregon (CA, ID, NV) were clipped down to Omernik Level III Ecoregions that overlapped state boundaries, then merged into one dataset.

- Oregon: BLM road layer for Oregon
  - merged GTRN_PUB_ROADS_ARC & highways_arc = **OR_Roads_BLM_all**
- California: Validated shapefile from CDFW; combination of CalFire, USFS (MVUM) and Business Analyst (BA) roads layers, clipped to Ecoregions common to OR/CA
- Idaho: 1) (Idaho BLM Transportation Routes and GTLF (Line) geodatabase) and 2) USFS MVUM transportation map
- Nevada: Roads data resources had limited coverage on Nevada's Oregon border; the most comprehensive option was Nevada USGS NTD Road Segments.

The individual state roads layers were merged after a visual inspection to ensure there was not overlap. The result was one road layer which covers all Omernik Level III Ecoregions boundaries within Oregon. To verify this change from the 2016 process, DEQ compared the candidate reference screening designation calculated from the road layer used for the Interagency RCA and the new layer. There was a 2% increase in sites that passed the GIS candidate reference screen. DEQ felt this slight increase was justified not only by the reproducibility of the new roads layers, but also because of a manual satellite imagery screen conducted later in the process.

Updated "Agriculture Land Use" layer

Percent agriculture was derived from the National Land Cover Dataset. This dataset was updated in 2016, whereas the Interagency RCA used the 2011 dataset. For the RCA 2020, DEQ adopted the new 2016 dataset to ensure the most up-to-date coverage was used.

Updated "Developed, Open Space Land Use" layer

Code 21 is defined as "Developed, Open Space" and is a surrogate for urban-type disturbances. Code 21 was derived from the National Land Cover Dataset (NLCD). This dataset was updated in 2016, whereas the Interagency RCA used the 2011 dataset. For the RCA 2020, DEQ adopted the new 2016 dataset to ensure the most up-to-date coverage was used.

NLCD data are downloaded in raster format. To work with data tools in GIS (specifically calculating % land use), the raster data was converted to polygon (*Conversion Tools…Raster to Polygon*) using the 'simplified' option on this tool (Figure 1). The difference in polygon areas of simplified vs not simplified polygons from the 2011 NLCD dataset was around 3%. Best professional judgment will be applied to evaluate sites that were rejected from the GIS screening process owing solely to percent code 21 for possible inclusion in the candidate reference list.

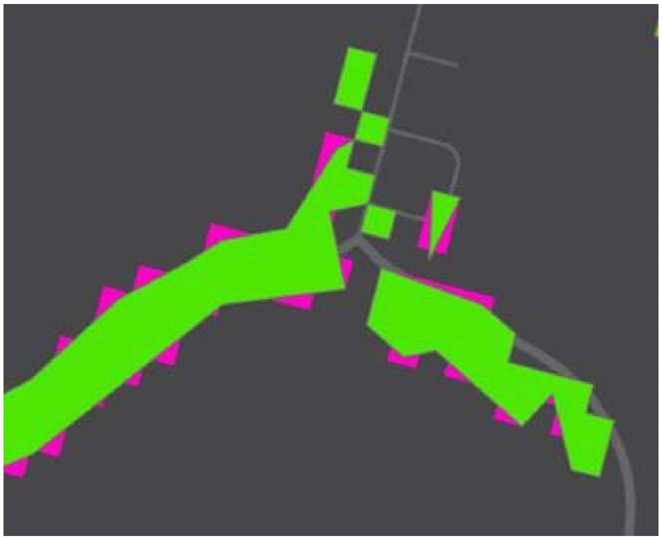

Figure 1. Example showing simplified (green) vs. not simplified (pink) polygons.

Updates to Gravel/Mines/Canals GIS coverages

The mining data used was consistent with the Interagency RCA, however the data was downloaded in 2020 to stay up to date. For both mining and gravel mining, the filter of dev_stat = 'Producer' was applied. For the gravel mine layer, the filter of commod1 IN (‘Sand and Gravel, Construction’) was applied.

GIS screening metric threshold development

To determine the appropriate GIS screening metric thresholds, only DEQ sites (n = 2324) were utilized. The initial plan was to use the same percentile thresholds for all GIS screening metrics as in the Interagency RCA (Miller et al. 2016). The 25th percentile was chosen as the initial target for the least-disturbed class (GIS Candidate), rather than some lower percentile, because of the ”all-or-nothing” approach for inclusion in the GIS Candidate population. This means that to move to the next step in the RCA (satellite imagery screens), a site must fall below all of the lower GIS disturbance metric thresholds. Using thresholds lower than the 25th percentile would mean fewer reference sites, reducing the representativeness of our final reference population in making assessments of Oregon’s streams.

To meet this goal of high reference sample size and overall representativeness, DEQ had to make some concessions and use higher percentiles (allow more disturbance) for both stream road crossing (*xings_km2)* and developed open space (*Code21)* screening metrics (Table 1). A similar approach was utilized by CAFW in setting their own statewide reference thresholds (Ode et al. 2016). It should also be noted that several of the metrics showed highly left-skewed distributions, with high frequencies of zero values. Ultimately this lead to seemingly high percentiles chosen for the lowest threshold (Table 1), but in reality these high percentiles mark the point at which a metric first showed values above zero. This means that to qualify as a reference site, the watersheds have no agriculture, no mines, no gravel mines, and no canals (Table 1).

For all disturbance metrics the 95th percentile was used as a threshold for identifying "most disturbed" sites. To be classified as "most disturbed", only a single disturbance metric needed to exceed the 95th percentile.

A total of 454 stations were identified as "GIS candidate" reference sites. These were the only sites to move on to the next round of validation via satellite imagery.

Satellite imagery and best professional judgement

Recognizing that GIS data is not perfect, DEQ created a process for verifying GIS screening metric results for candidate reference sites. We used Google Earth satellite imagery to visually scan each watershed for a suite of human disturbances, along with a scoring system for summarizing human disturbances in two zones: the extent (whole watershed) and proximity (within 2km of the downstream-most sampling point). To ensure conditions at the time of sampling were captured, DEQ used GE's "historical imagery" feature set to the point in time closest to the actual sampling date.

In addition, Best Professional Judgement was employed in two ways:

1. To set the initial GE scoring threshold for inclusion in the final reference population.
2. As a check on the GE scoring process and a resulting collaborative final assessment process.

Quality control

Most all watersheds were scored using GE by a single person. To validate the process and ensure the methodology was consistent, DEQ assigned 22 sites to be scored by all three members of the Biomonitoring team. The results of the QC screens ensure consistency among scorers. A few lessons were learned through this process:

- Much of the variability in scoring of QC stations (Figure 2) was due to inconsistencies in scoring hiking trail disturbances. To account for this, and given the low amount of disturbance hiking trails contribute to overall disturbance, a maximum score for hiking disturbances was enforced at the "intermediate" level.

- Following QC scoring, it was determined that randomly assigning stations across the landscape to individual scorers would help to limit scorer bias by regions.

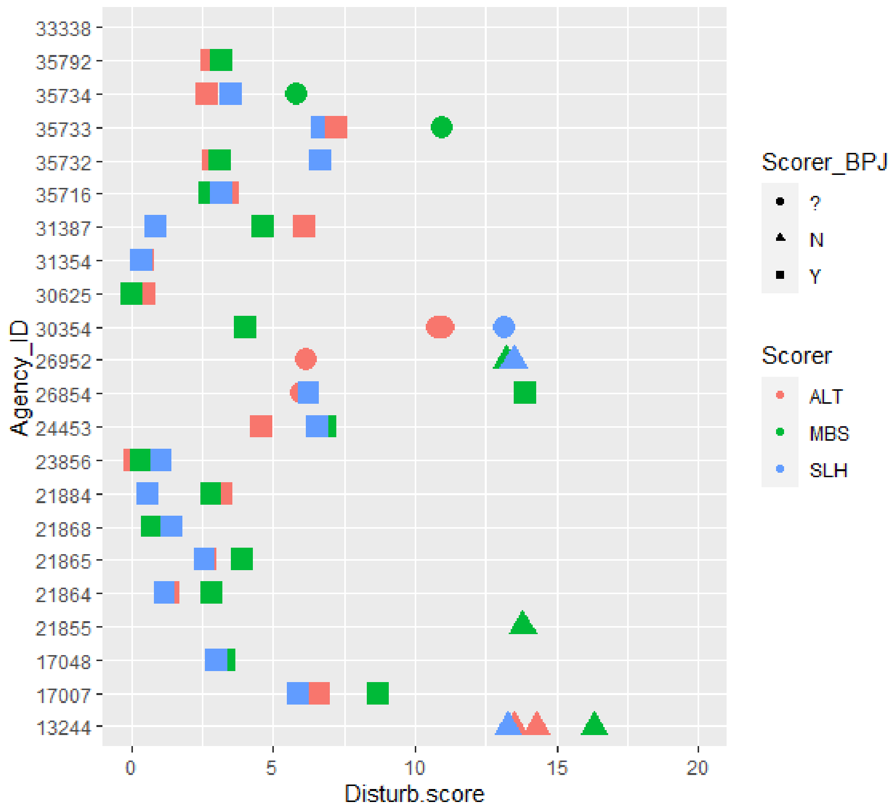

Figure 2. Google Earth scores for Quality Control sites. These 22 DEQ stations were each scored by three independent reviewers. Where less than three symbols are observed, GE scores overlapped completely.

GE scoring threshold development

For each station scored via GE, the scorer would assign a BPJ category for overall reference status:

- "Y" = yes, regardless of GE score, this site should be included in the final reference population
- "N" = no, regardless of GE score, this site should not be included in the final reference population
- "?" = uncertain, needs to be confirmed by all GE scorers in a "Reference Council"

After using GE imagery to score all 454 DEQ "GIS Candidate" stations, a threshold was established by plotting GE scores against the individual scorer's BPJ designation (Figure 2). Based on this, 15 was established as the GE scoring threshold for inclusion in the final reference population. This value was chosen because no instances of a GE scorer rated the site with BPJ as "Y", meaning they felt the site belonged in the final "least disturbed" reference population. Additionally, all of the sites with an uncertain BPJ status ("?") had GE scores less than 15. However, as shown in Figure 2, there were multiple instances where GE scores were less than this threshold, yet the BPJ status would indicate the site should not be included in the final reference population, showing that GE Scoring process was not perfect by itself, and suggesting the need for a final validation step.

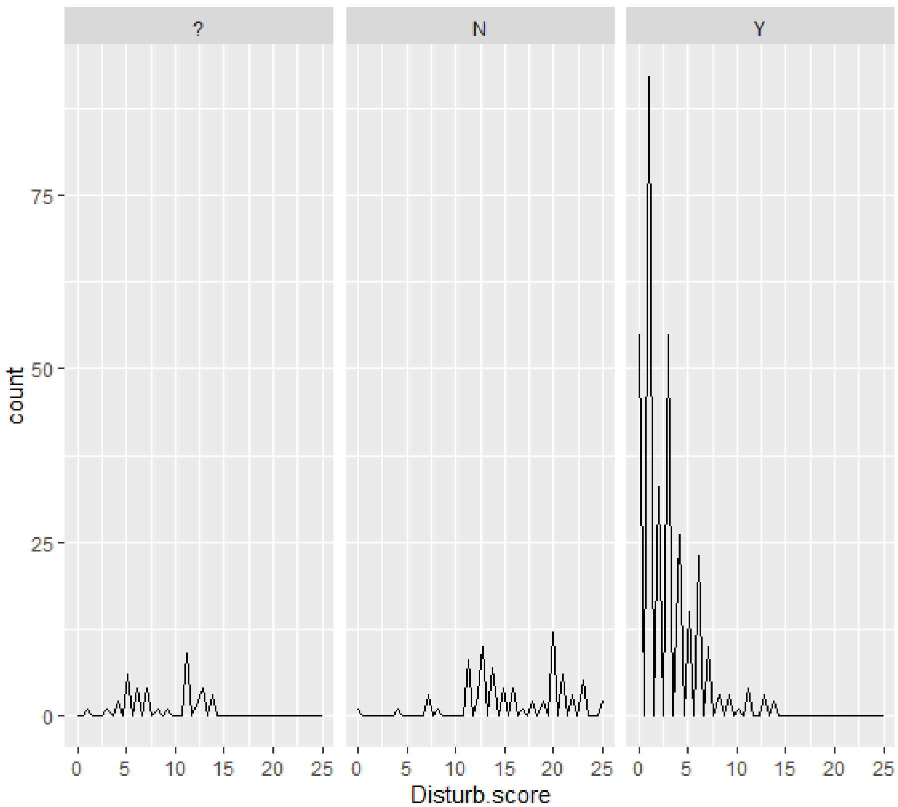

Figure 3. Results of GE scoring and initial BPJ status for 454 DEQ "GIS candidate" stations. These sites passed the initial GIS disturbance metric screens.

Reference Council

To evaluate each of the sites with inconsistent GE scores and BPJ status, a consensus-based approach was established, which was named the "Reference Council". Within the Reference Council, for each station meeting the criteria shown in Table 3, each member of the council independently generated GE scores and a BPJ status. Additionally, the narrative logic behind each BPJ status conclusion was documented. Finally, the full Reference Council reviewed scores and BPJ status, looked over satellite imagery for the watersheds, and discussed each station. The GE scoring threshold (15) could be overruled based on BPJ only if all three members of the

Reference Council agreed in their final BPJ designation. If consensus could not be reached, the GE score and threshold were used to determine the final reference status.

Table 3. Criteria used to determine which sites moved onto the final BPJ step, a consensus-based review and assessment by the Reference Council.

GE Score	BPJ Status
< 15	N
>= 15	Y
any	?

Of the 78 stations reviewed by the Reference Council, 72 stations were provided by DEQ, while 6 stations were brought in from CAFW's existing reference population. Together, all of these sites represented a 17% review rate for GE scores. Consensus could not be reached for 13 stations, thus the original GE score assigned by a single reviewer was used to establish the final reference designation.

Applying DEQ's RCA-2020 to an outside dataset

DEQ followed the procedures above, as developed using DEQ sites only, to complete the following steps for 1929 stations provided by Utah State University's National Aquatic Monitoring Center:

1) Associate with STREAM NETWORK. Due to ambiguous naming and/or inaccurate coordinates, we were only able to move forward with 929 (48%) NAMC stations.
2) Auto-delineate pour-point watersheds
3) Calculate GIS human disturbance metrics
4) Apply GIS disturbance metrics thresholds
    a. GIS Candidate = 138 stations
    b. Not reference = 685 stations
    c. Most disturbed = 106 stations
5) Assign 15 stations for GE scoring QC procedures to document scorer variability.
6) GE Scoring and individual reviewer BPJ status for 138 GIS Candidate stations
7) Reference Council to review 39 stations meeting the criteria in Table 2.
8) Determine final RCA-2020 status.

The majority of these stations were associated with federal monitoring programs at the Bureau of Land Management and the United States Forest Service. Smaller numbers of sites were associated with watershed councils and universities.

Final RCA-2020

A total of 3279 stations were assessed using the RCA-2020 methodology, with 72% of stations contributed by DEQ and 28% by NAMC. A total of 402 Reference sites were identified (72% DEQ, 28% NAMC). A total of 639 stations were classified as Most Disturbed (68% DEQ, 32% NAMC). The geographic representation of RCA-2020 final status is shown in Table 4, as well as Figures 3 &4.

Comparisons to previous RCAs

The total numbers presented for the final RCA-2020 classifications are slightly inflated, so it is expected there will be a decrease for any final bioassessment index or model for establishing stressor thresholds. The reason for this can be seen in Figures 4 and 5, where there is a fair amount of overlap between DEQ and NAMC stations. Some of this overlap will occur on the same stream network and in close proximity (effectively the same, or nearly the same stations). However, this will eventually bear out to be an advantage as it will provide the opportunity to set aside these overlapping stations into sites used to build a given model (calibration data set) and an independent validation data set. Having an independent validation data set directly works to achieve an improvement goal identified by peer-review of PREDATOR models.

Table 4. Final status for all sites assessed under the RCA-2020, summarized by Level III Ecoregion.

Level III Ecoregion *	Not Reference	Most Disturbed	Reference	Totals
Blue Mountains	579	124	94	**797**
Cascades	306	47	119	**472**
Columbia Plateau	42	32	1	**75**
Coast Range	832	128	82	**1042**
East Cascades	75	46	20	**142**
Klamath Mountains	200	55	51	**306**
NA			6	**6**
Northern Basin and Range	108	29	34	**171**
Snake River Plains	3	7	0	**10**
Willamette Valley	93	171	0	**264**
Totals	**2238**	**639**	**402**	**3279**

* Omernik 1987

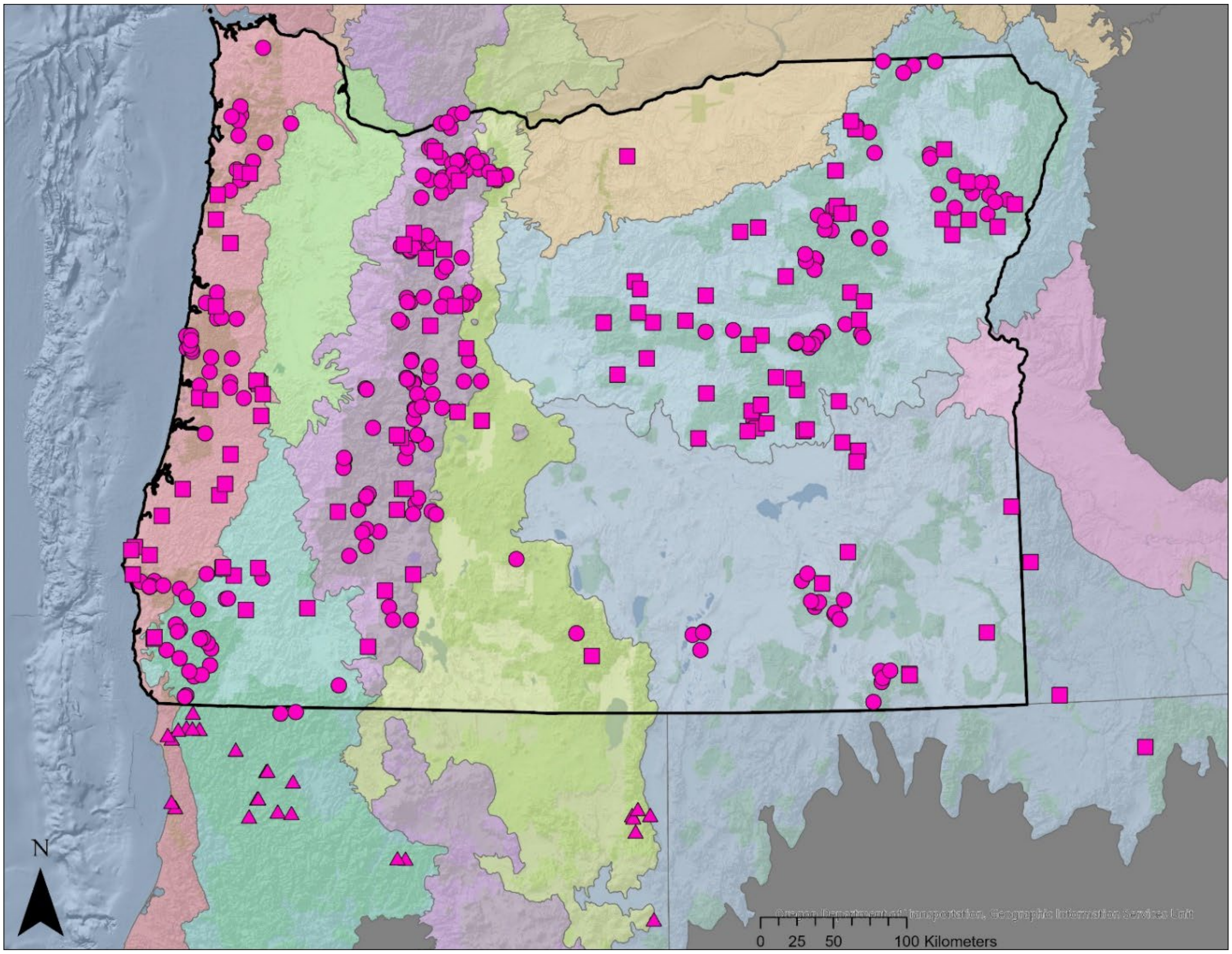

Figure 4. The 402 least disturbed Reference sites identified in the RCA-2020. Circles represent DEQ sites (n = 265), squares represent USU sites (n = 111), and triangles represent CAFW sites (n = 26).

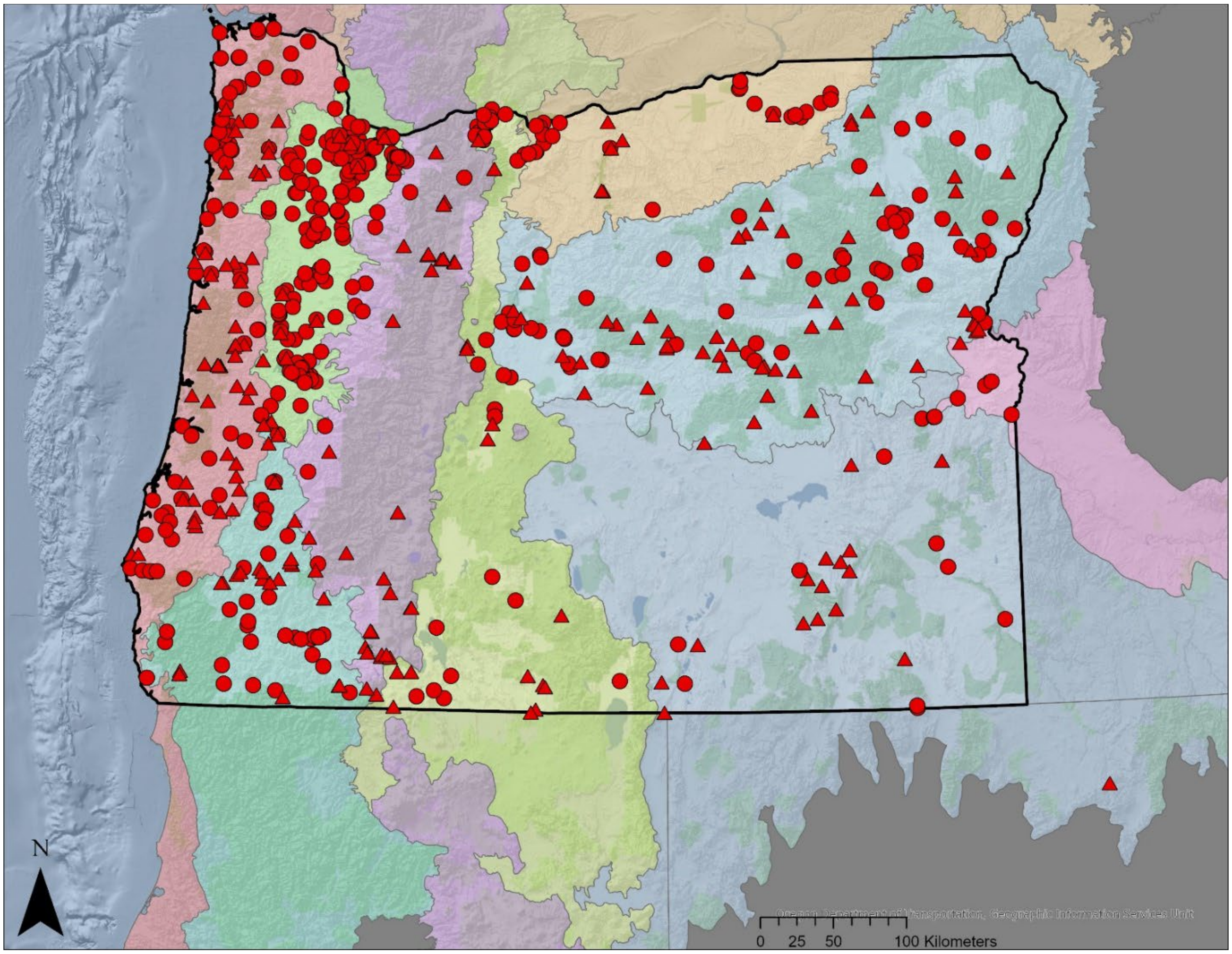

Figure 5. The 639 Most Disturbed sites identified in the RCA. Circles represent DEQ sites (n = 434) and triangles represent USU sites (n = 205).

How representative is the RCA-2020?

To test how well the new reference population represents other wadeable streams across Oregon, DEQ compared several natural factors across each of the final reference classes (Reference, Intermediate Disturbance, Most Disturbed.) For watershed–scale metrics, 25 natural factors included in USEPA's StreamCat dataset (Hill et al. 2016) were assessed (Table 5). To qualitatively assess the representativeness of the RCA-2020 reference population, DEQ examined boxplots for the natural gradients across each reference class population (Figure 6). Overall, the three reference class populations showed considerable overlap. However, a few general patterns were observed. Sites in the least disturbed "Reference" class showed a tendency to have slightly higher elevation and precipitation, along with lower watershed area and air temperature. "Most disturbed" sites, conversely, tended to have slightly lower elevation and precipitation, along with slightly higher watershed areas and temperatures.

For a more thorough examination of representativeness, DEQ assessed the overlap of the reference classes within a multivariate ordination. We used a Principal Components Analysis (PCA) using the R-package "FactoMineR". Only the natural gradients listed in Table 5 were included in the PCA. The first three principal components explain ~ 37%, 13%, and 13% (respectively) of the total variance in the dataset, for 64% variance explained cumulatively. The first principal component was most strongly related to lithological composition and secondarily to temperature (Figure 7). Sites to the right side (positive PCA1) tend to have more volcanic lithologies, while sites to the left side (negative PCA1) had higher temperatures. The second principal component is most strongly related to precipitation, followed by potassium oxide (K2OWs). The representativeness of the Reference class to the Moderately Disturbed and Most Disturbed classes is shown in Figure 8. The 95% confidence interval ellipse of the Reference population shows that the newly defined Reference sites are highly representative of wadeable sites sampled across Oregon.

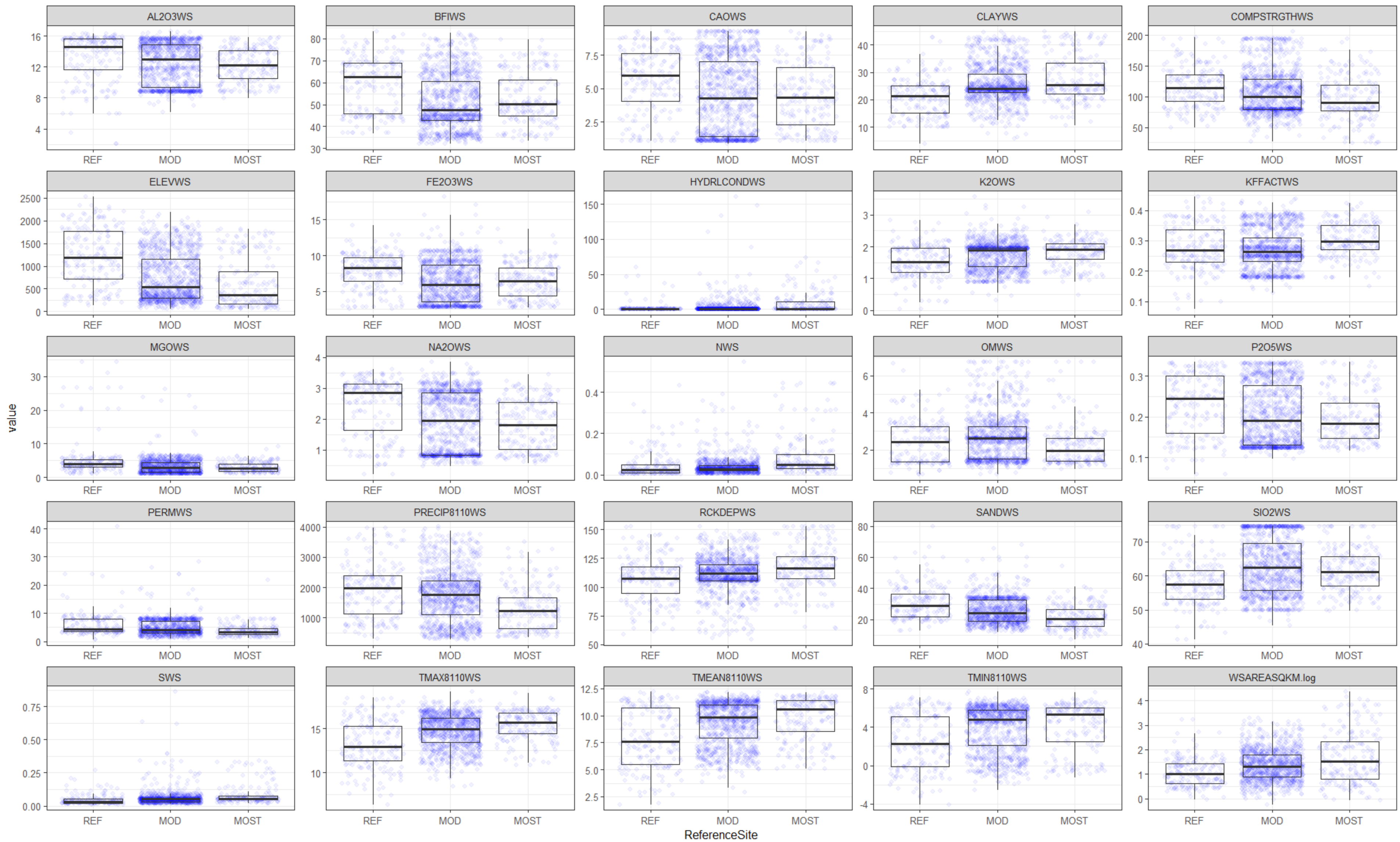

Figure 6. Boxplots of StreamCat metrics for natural gradients. “REF” = reference sites (n = 187), “MOD” = moderately disturbed sites (n = 1048), and “MOST” = most disturbed sites (n = 195).

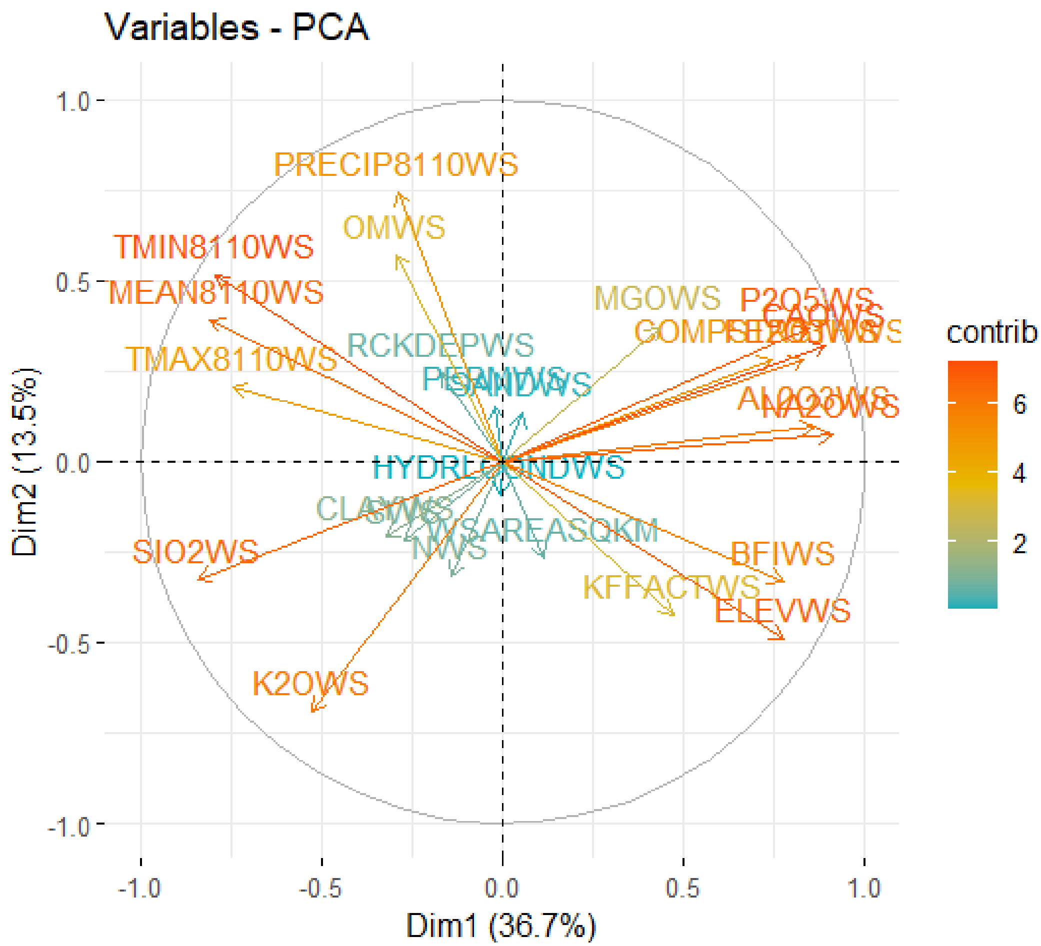

Figure 7. The first two principal components of natural gradients for all sites (n=1430) in our analysis. Longer arrows and warmer colors represent variables with greater power in explaining differences in natural gradients across Oregon's wadeable streams. Shorter, cooler arrows represent metrics with lower abilities to explain differences in natural gradients among sites. (See Table 5 for metric definitions.)

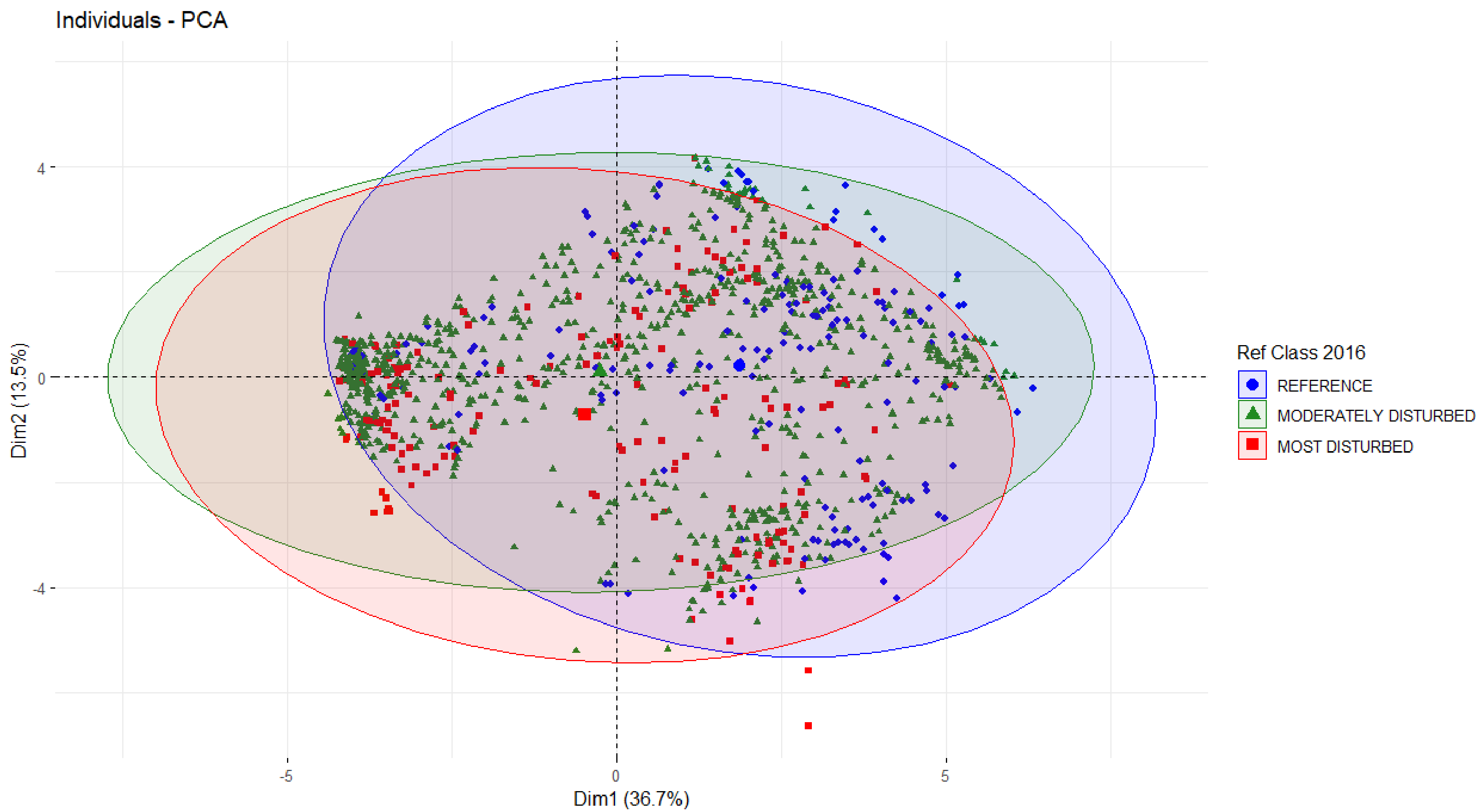

Figure 8. The first two principal components of natural gradients for all sites (n=1430). Sites are represented by final reference class. Ellipses represent 95% confidence intervals around the reference class.

Table 5. Definitions of StreamCat natural gradient metrics used in boxplots (Figure 6) and PCA (Figure 7).

Metric	Description
AL2O3WS	Mean % of lithological aluminum oxide (Al2O3) content in surface or near surface geology within watershed
BFIWS	Base flow is the component of streamflow that can be attributed to ground-water discharge into streams. The BFI is the ratio of base flow to total flow, expressed as a percentage, within watershed
CAOWS	Mean % of lithological calcium oxide (CaO) content in surface or near surface geology within watershed
CLAYWS	Mean % clay content of soils (STATSGO) within watershed
COMPSTRGTHWS	Mean lithological uniaxial compressive strength (megaPascals) content in surface or near surface geology within watershed
ELEVWS	Mean watershed elevation (m)
FE2O3WS	Mean % of lithological ferric oxide (Fe2O3) content in surface or near surface geology within watershed
HYDRLCONDWS	Mean lithological hydraulic conductivity (micrometers per second) content in surface or near surface geology within watershed
K2OWS	Mean % of lithological potassium oxide (K2O) content in surface or near surface geology within watershed
KFFACTWS	Mean soil erodibility (Kf) factor (unitless) of soils within watershed. The Kffactor is used in the Universal Soil Loss Equation (USLE) and represents a relative index of susceptibility of bare, cultivated soil to particle detachment and transport by rainfall.
MGOWS	Mean % of lithological magnesium oxide (MgO) content in surface or near surface geology within watershed
NA2OWS	Mean % of lithological sodium oxide (Na2O) content in surface or near surface geology within watershed
NWS	Mean % of lithological nitrogen (N) content in surface or near surface geology within watershed
OMWS	Mean organic matter content (% by weight) of soils (STATSGO) within watershed
P2O5WS	Mean % of lithological phosphorous oxide (P2O5) content in surface or near surface geology within watershed
PERMWS	Mean permeability (cm/hour) of soils (STATSGO) within watershed
PRECIP8110WS	PRISM climate data - 30-year normal mean precipitation (mm): Annual period: 1981-2010 within the watershed
RCKDEPWS	Mean depth (cm) to bedrock of soils (STATSGO) within watershed
SANDWS	Mean % sand content of soils (STATSGO) within watershed
SIO2WS	Mean % of lithological silicon dioxide (SiO2) content in surface or near surface geology within watershed
SWS	Mean % of lithological sulfur (S) content in surface or near surface geology within watershed
TMAX8110WS	PRISM climate data - 30-year normal maximum temperature (C°): Annual period: 1981-2010 within the watershed

Metric	Description
TMEAN8110WS	PRISM climate data - 30-year normal mean temperature (C°): Annual period: 1981-2010 within the watershed
TMIN8110WS	PRISM climate data - 30-year normal minimum temperature (C°): Annual period: 1981-2010 within the watershed
WSAREASQKM	Watershed area (square km) at NHDPlus stream segment outlet, i.e., at the most downstream location of the vector line segment

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