Supplementary material

Temporal eligibility rules alter country composition and ecoregion representation in global river water-quality monitoring networks

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ANALYTICAL PROTOCOL

This supplement documents the complete Caravan-Qual Lite version 1.1 analysis. Published censored values are retained, release-flagged outliers are excluded from the primary analysis, and no station-bootstrap confidence intervals are used because the reported networks are fixed census descriptors. Six constituents at three minimum-eligible-year thresholds plus five within-year rules for two cohorts produced 28 configurations; eligible calendar years were not required to be consecutive. EC at five years and the primary Cohort A calendar-quarter rule are the same station set, leaving 27 distinct networks. Every distinct network is compared with 10,000 equal-size draws and with 10,000 draws that preserve its country counts. Hill numbers q=0, 1 and 2 are reported for both references. Endpoint values such as 0/10,000 and 10,000/10,000 are empirical ranks among the simulated draws, not exact p-values of zero or one. Within-country residuals are interpreted from their own dispersion, empirical rank and available within-country ecological variation; the separate feasible-range audit applies only to the two primary networks.

Software environment. The final validation used Linux 6.18.35, Python 3.12.13, NumPy 2.3.5, pandas 2.2.3, SciPy 1.17.0 with HiGHS 1.8.0, Matplotlib 3.10.8, scikit-learn 1.8.0 (BallTree proximity-duplicate audit), and Pillow 12.3.0. FEOW geometry was read with the deterministic shapefile/DBF parser; GeoPandas was not used.

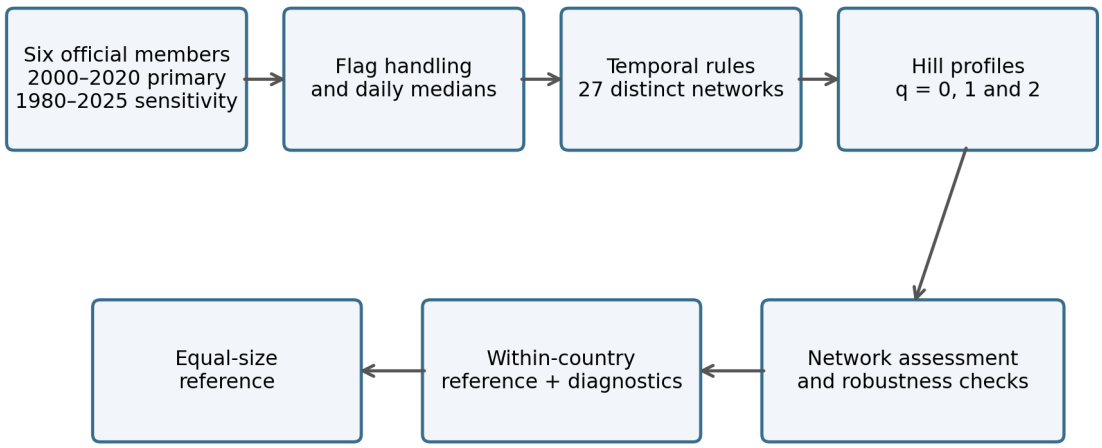


Figure S1. Workflow from complete version 1.1 ZIP members through flag handling, temporal eligibility, equal-size and within-country references, and robustness diagnostics.

Table S1. Frozen analytical decisions used for this analysis.

Component	Definition
Release	Caravan-Qual Lite version 1.1; official complete ZIP
Primary period	2000-01-01 through 2020-12-31; 1980-01-01 through 2025-12-31 sensitivity window; recent-year completeness not assumed
Constituents	EC, TP, DO, NO3-N, TSS and DOC
Censored rows	Retain published numeric obs with flag '<'; report LOD/2 and ROS
Outlier rows	Exclude flag '*' from eligibility and summaries; include in sensitivity
Daily collision	Median within station and date
Primary year	≥4 distinct days in ≥3 calendar quarters
Primary station	Primary-year condition in ≥5 eligible calendar years; years need not be consecutive
Cohort A	All primary EC stations
Cohort B	Station-level intersection of independently eligible EC, TP and DO networks; no overlap in eligible years or dates required
Geography	Official country plus 426-unit FEOW point overlay and seven realms
Support	Hill q=0 richness, q=1 exponential-Shannon diversity and q=2 inverse-Simpson effective diversity
Intervals	None; fixed-network census descriptors
Size-only reference	10,000 equal-size draws; master seed 20260810
Within-country reference	10,000 within-country draws; master seed 20260811
Monte Carlo order	Pools sorted by wqms_id; categories lexical; named substream for each analysis × hierarchy
Distinct networks	28 reported configurations; one exact overlap; 27 unique station sets
Within-country interpretation	Residual magnitude, 95% range, empirical rank and available within-country ecological variation; no fixed threshold
Primary-network q2 feasible range	Exact maximum-evenness MILP plus a concentrated feasible allocation; fixed country and assigned-station counts; Cohorts A and B only

Table S2. Observation flags and published imputation methods during 2000–2020.

Variable	Rows	Stations before * exclusion	< rows	LOD/2	ROS	* rows	* stations
EC	6,240,092	57,767	6,853	807	6,046	227,311	8,004
TP	1,470,393	38,903	89,129	27,107	62,022	2,272	1,143
DO	2,193,655	48,856	11,021	1,473	9,548	3,784	1,632
NO3-N	2,322,415	45,416	110,718	30,064	80,654	4,149	1,907
TSS	1,581,588	32,630	269,837	76,632	193,205	1,625	925
DOC	745,264	23,029	22,662	4,329	18,333	1,745	752

Note: Row and station totals precede exclusion of release-flagged outliers. All censored rows used LOD/2 or ROS; no other imputation label occurred among retained finite censored rows. The 19 finite rows with another nonblank flag (17 EC, one DO and one TSS) were retained because none was release-flagged as an outlier; they entered the same date-based eligibility and daily-median processing.

Table S3. Source files, ZIP members and complete cryptographic hashes.

File	Role	Bytes	Full SHA-256
wqms-csv.zip	official source	641,285,380	2a688788c5af6598c2598251f0f2b68743d18eee252cce7fc88f3adae31e45f6
wqms_site_info.csv	official source	14,770,683	b2286ebac01b7f1dbabf0f44153c09fc18a229363453d3fb5f76c232754e7951
Caravan-Qual_linkages.parquet	official source	34,485,276	b2feb54ac56770fc6fdffe2af3314c908d49bcee5c1429ddf76df0ccd0e0b57a
package-metadata-table.parquet	official source	138,976,855	9e9885a6a6d78430b0e85b14e5eaa5528b718b4dc97519ad7a776833cbf7e92e
vpu605_linkno.csv	derived source	2,869,057	5249c8efff79d742fb4fd15d257ba1a177f02e4067a8df0606de9aa67d4bf854

File	Role	Bytes	Full SHA-256
feow_hydrosheds.shp	official source	70,841,368	5c64eb69ce0f1dbcdaf7c6e955be696107519a61de24af6d345e882c5b1b2408
feow_hydrosheds.dbf	official source	10,425	e230da14dc8c1a7ef105ceea8ece3d14bbd75000d3e0b435114b9aeb2c2f5388
EC.csv	wqms-csv.zip member	476,774,760	d19944e97c44aa735ca25f716aff85fa79afd4d4e3bed433fb484d719ab1ea9b
TP.csv	wqms-csv.zip member	145,475,282	4a999a01d4be5caec32df315320a736f5d52e064f5fddfc9d261c69c2162e6fe
DO.csv	wqms-csv.zip member	151,702,889	461d7a8ee4481cd6718a6e645a54456a801a9ccd5f699e197b6f29c137c98c5b
NO3N.csv	wqms-csv.zip member	179,634,013	7a88af199eb8c18e03a7fe07d4e5ccae1c230922a3fb2cec89b4d34a704c068f
TSS.csv	wqms-csv.zip member	106,836,786	7dfbe2285701708a0da6f020ea2a3c0e5ff978f2c879557fbda5b99a4b6d3eaf
DOC.csv	wqms-csv.zip member	54,463,140	369c75e571772d987c72800f63ac286303e383d72966d379262ed0d36cfaabf9

Source versions and geospatial references: Caravan-Qual Lite v1.1, Zenodo record 21337532 (https://doi.org/10.5281/zenodo.21337532; accessed 20 August 2026); Caravan-Qual construction code, commit 0cc1527015449c4b4498d6854fd860af7ab0cde0 (https://github.com/SustainableWaterSystems/Caravan-Qual/tree/0cc1527015449c4b4498d6854fd860af7ab0cde0; accessed 20 August 2026); FEOW first edition, HydroBASINS-aligned January 2013 boundary update (https://www.feow.org/files/downloads/GIS_hs_snapped.zip; accessed 20 August 2026), WGS 84 geographic coordinates in decimal degrees (EPSG:4326); and the GEOGLOWS v2 metadata snapshot (http://geoglows-v2.s3-website-us-west-2.amazonaws.com/tables/package-metadata-table.parquet; accessed 20 August 2026), used only for a tabular LINKNO–VPUCode join (CRS not applicable). Complete SHA-256 hashes identify the exact local inputs.

NULL REFERENCES

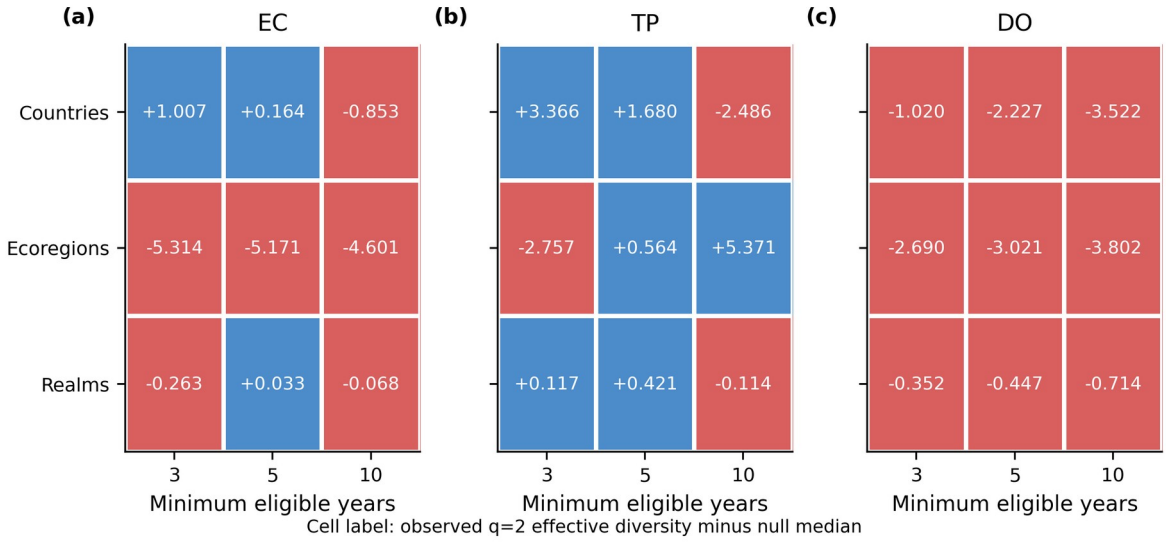


Figure S2. Observed minus equal-size-null median q=2 effective diversity for the EC, TP and DO minimum-eligible-year filters. Cell labels give Δq2 to three decimals; colour denotes position relative to the 95% reference.

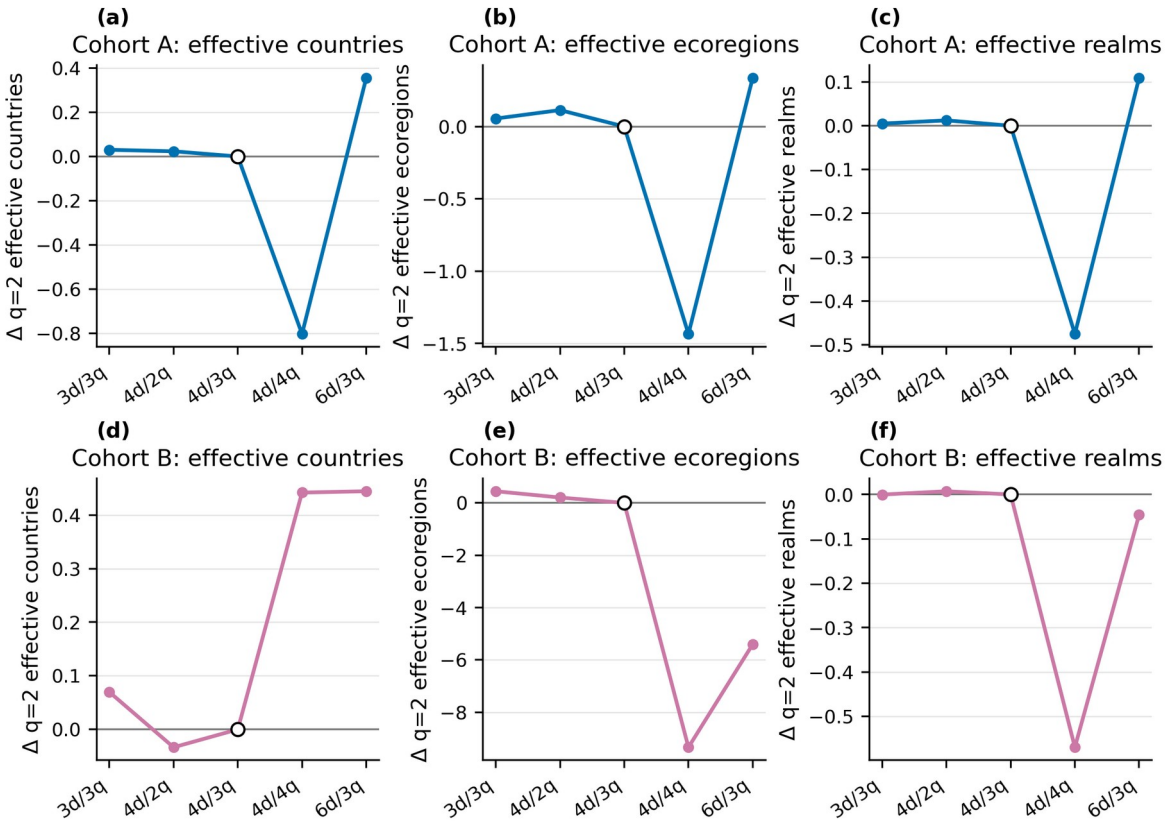


Figure S3. Change in effective support relative to the primary within-year rule for Cohorts A and B.

Table S4. Equal-size Hill-number references for all 27 distinct networks.

Analysis	Scale	Pool / retained	q0 obs / median [95%]; Δ; rank	q1 obs / median [95%]; Δ; rank	q2 obs / median [95%]; Δ; rank
EC: ≥4d/≥3q in ≥3 years	Country	56,816 / 20,460	53.000 / 76.000 [71.000–80.000]; -30.3%; r 0/10000	9.761 / 8.849 [8.705–8.992]; +10.3%; r 10000/10000	5.682 / 4.675 [4.597–4.755]; +21.5%; r 10000/10000
EC: ≥4d/≥3q in ≥3 years	Ecoregion	56,816 / 20,460	154.000 / 192.000 [187.000–196.000]; -19.8%; r 0/10000	23.417 / 38.534 [37.760–39.298]; -39.2%; r 0/10000	5.403 / 10.717 [10.411–11.030]; -49.6%; r 0/10000
EC: ≥4d/≥3q in ≥3 years	Realm	56,816 / 20,460	7.000 / 7.000 [7.000–7.000]; +0.0%; r 10000/10000	3.222 / 3.313 [3.281–3.345]; -2.7%; r 0/10000	2.410 / 2.673 [2.652–2.695]; -9.9%; r 0/10000
EC: ≥4d/≥3q in ≥5 years	Country	56,816 / 14,387	48.000 / 71.000 [65.000–76.000]; -32.4%; r 0/10000	8.318 / 8.842 [8.662–9.028]; -5.9%; r 0/10000	4.839 / 4.675 [4.576–4.779]; +3.5%; r 9992/10000
EC: ≥4d/≥3q in ≥5 years	Ecoregion	56,816 / 14,387	143.000 / 187.000 [181.000–192.000]; -23.5%; r 0/10000	24.217 / 38.443 [37.468–39.430]; -37.0%; r 0/10000	5.541 / 10.713 [10.329–11.118]; -48.3%; r 0/10000
EC: ≥4d/≥3q in ≥5 years	Realm	56,816 / 14,387	7.000 / 7.000 [7.000–7.000]; +0.0%; r 10000/10000	3.541 / 3.313 [3.271–3.353]; +6.9%; r 10000/10000	2.706 / 2.673 [2.646–2.701]; +1.2%; r 9910/10000
EC: ≥4d/≥3q in ≥10 years	Country	56,816 / 5,328	19.000 / 55.000 [49.000–61.000]; -65.5%; r 0/10000	4.985 / 8.800 [8.469–9.135]; -43.3%; r 0/10000	3.821 / 4.674 [4.489–4.861]; -18.3%; r 0/10000
EC: ≥4d/≥3q in ≥10 years	Ecoregion	56,816 / 5,328	91.000 / 166.000 [159.000–174.000]; -45.2%; r 0/10000	20.198 / 37.988 [36.259–39.793]; -46.8%; r 0/10000	6.108 / 10.709 [10.031–11.469]; -43.0%; r 0/10000
EC: ≥4d/≥3q in ≥10 years	Realm	56,816 / 5,328	4.000 / 7.000 [7.000–7.000]; -42.9%; r 0/10000	3.006 / 3.312 [3.238–3.386]; -9.2%; r 0/10000	2.605 / 2.673 [2.625–2.723]; -2.5%; r 27/10000
TP: ≥4d/≥3q in ≥3 years	Country	38,888 / 14,088	49.000 / 54.000 [51.000–58.000]; -9.3%; r 44/10000	14.134 / 11.552 [11.349–11.759]; +22.3%; r 10000/10000	9.717 / 6.352 [6.209–6.500]; +53.0%; r 10000/10000
TP: ≥4d/≥3q in ≥3 years	Ecoregion	38,888 / 14,088	122.000 / 140.000 [136.000–143.000]; -12.9%; r 0/10000	28.473 / 33.322 [32.580–34.038]; -14.5%; r 0/10000	8.500 / 11.257 [10.889–11.633]; -24.5%; r 0/10000
TP: ≥4d/≥3q in ≥3 years	Realm	38,888 / 14,088	7.000 / 7.000 [7.000–7.000]; +0.0%; r 10000/10000	3.408 / 3.190 [3.153–3.227]; +6.8%; r 10000/10000	2.724 / 2.607 [2.582–2.631]; +4.5%; r 10000/10000

Table S4 (continued). Equal-size Hill-number references for all 27 distinct networks.

Analysis	Scale	Pool / retained	q0 obs / median [95%]; Δ; rank	q1 obs / median [95%]; Δ; rank	q2 obs / median [95%]; Δ; rank
TP: ≥4d/≥3q in ≥5 years	Country	38,888 / 9,554	47.000 / 52.000 [48.000–56.000]; -9.6%; r 191/10000	12.581 / 11.542 [11.277–11.813]; +9.0%; r 10000/10000	8.031 / 6.350 [6.160–6.546]; +26.5%; r 10000/10000
TP: ≥4d/≥3q in ≥5 years	Ecoregion	38,888 / 9,554	115.000 / 136.000 [132.000–140.000]; -15.4%; r 0/10000	34.570 / 33.231 [32.277–34.226]; +4.0%; r 9956/10000	11.815 / 11.251 [10.785–11.762]; +5.0%; r 9842/10000
TP: ≥4d/≥3q in ≥5 years	Realm	38,888 / 9,554	7.000 / 7.000 [7.000–7.000]; +0.0%; r 10000/10000	3.670 / 3.189 [3.140–3.238]; +15.1%; r 10000/10000	3.028 / 2.607 [2.574–2.638]; +16.2%; r 10000/10000
TP: ≥4d/≥3q in ≥10 years	Country	38,888 / 2,163	20.000 / 41.000 [37.000–46.000]; -51.2%; r 0/10000	6.263 / 11.438 [10.818–12.062]; -45.2%; r 0/10000	3.861 / 6.347 [5.898–6.812]; -39.2%; r 0/10000
TP: ≥4d/≥3q in ≥10 years	Ecoregion	38,888 / 2,163	73.000 / 114.000 [108.000–121.000]; -36.0%; r 0/10000	31.010 / 32.366 [30.246–34.672]; -4.2%; r 1079/10000	16.589 / 11.218 [10.132–12.443]; +47.9%; r 10000/10000
TP: ≥4d/≥3q in ≥10 years	Realm	38,888 / 2,163	6.000 / 7.000 [6.000–7.000]; -14.3%; r 1509/10000	3.271 / 3.185 [3.074–3.297]; +2.7%; r 9267/10000	2.491 / 2.605 [2.533–2.681]; -4.4%; r 11/10000
DO: ≥4d/≥3q in ≥3 years	Country	48,817 / 18,775	53.000 / 53.000 [49.000–57.000]; +0.0%; r 5441/10000	7.696 / 8.303 [8.183–8.425]; -7.3%; r 0/10000	4.185 / 5.205 [5.132–5.282]; -19.6%; r 0/10000
DO: ≥4d/≥3q in ≥3 years	Ecoregion	48,817 / 18,775	128.000 / 138.000 [133.000–143.000]; -7.2%; r 0/10000	10.713 / 20.464 [20.016–20.925]; -47.7%; r 0/10000	2.865 / 5.555 [5.423–5.693]; -48.4%; r 0/10000
DO: ≥4d/≥3q in ≥3 years	Realm	48,817 / 18,775	5.000 / 7.000 [6.000–7.000]; -28.6%; r 9/10000	2.502 / 2.649 [2.626–2.673]; -5.5%; r 0/10000	1.902 / 2.254 [2.236–2.272]; -15.6%; r 0/10000
DO: ≥4d/≥3q in ≥5 years	Country	48,817 / 13,594	47.000 / 51.000 [46.000–55.000]; -7.8%; r 810/10000	5.720 / 8.297 [8.143–8.452]; -31.1%; r 0/10000	2.978 / 5.204 [5.110–5.301]; -42.8%; r 0/10000
DO: ≥4d/≥3q in ≥5 years	Ecoregion	48,817 / 13,594	118.000 / 134.000 [128.000–139.000]; -11.9%; r 0/10000	8.871 / 20.427 [19.853–21.028]; -56.6%; r 0/10000	2.533 / 5.554 [5.385–5.733]; -54.4%; r 0/10000
DO: ≥4d/≥3q in ≥5 years	Realm	48,817 / 13,594	5.000 / 7.000 [6.000–7.000]; -28.6%; r 71/10000	2.292 / 2.649 [2.620–2.678]; -13.5%; r 0/10000	1.807 / 2.254 [2.230–2.277]; -19.8%; r 0/10000

Table S4 (continued). Equal-size Hill-number references for all 27 distinct networks.

Analysis	Scale	Pool / retained	q0 obs / median [95%]; Δ; rank	q1 obs / median [95%]; Δ; rank	q2 obs / median [95%]; Δ; rank
DO: ≥4d/≥3q in ≥10 years	Country	48,817 / 6,560	19.000 / 45.000 [40.975–49.000]; -57.8%; r 0/10000	2.411 / 8.281 [8.043–8.525]; -70.9%; r 0/10000	1.682 / 5.204 [5.052–5.357]; -67.7%; r 0/10000
DO: ≥4d/≥3q in ≥10 years	Ecoregion	48,817 / 6,560	69.000 / 123.000 [117.000–129.000]; -43.9%; r 0/10000	4.190 / 20.306 [19.426–21.254]; -79.4%; r 0/10000	1.750 / 5.552 [5.290–5.837]; -68.5%; r 0/10000
DO: ≥4d/≥3q in ≥10 years	Realm	48,817 / 6,560	4.000 / 6.000 [5.000–7.000]; -33.3%; r 0/10000	1.865 / 2.649 [2.603–2.693]; -29.6%; r 0/10000	1.539 / 2.253 [2.218–2.290]; -31.7%; r 0/10000
NO3-N: ≥4d/≥3q in ≥3 years	Country	45,403 / 18,635	52.000 / 66.000 [62.000–69.000]; -21.2%; r 0/10000	7.871 / 10.650 [10.497–10.808]; -26.1%; r 0/10000	4.198 / 6.638 [6.547–6.733]; -36.8%; r 0/10000
NO3-N: ≥4d/≥3q in ≥3 years	Ecoregion	45,403 / 18,635	122.000 / 155.000 [151.000–159.000]; -21.3%; r 0/10000	8.530 / 18.276 [17.855–18.703]; -53.3%; r 0/10000	2.554 / 4.611 [4.512–4.714]; -44.6%; r 0/10000
NO3-N: ≥4d/≥3q in ≥3 years	Realm	45,403 / 18,635	7.000 / 7.000 [7.000–7.000]; +0.0%; r 10000/10000	2.151 / 2.652 [2.626–2.680]; -18.9%; r 0/10000	1.639 / 2.086 [2.064–2.107]; -21.4%; r 0/10000
NO3-N: ≥4d/≥3q in ≥5 years	Country	45,403 / 14,633	50.000 / 63.000 [59.000–67.000]; -20.6%; r 0/10000	6.461 / 10.646 [10.462–10.834]; -39.3%; r 0/10000	3.462 / 6.639 [6.529–6.750]; -47.8%; r 0/10000
NO3-N: ≥4d/≥3q in ≥5 years	Ecoregion	45,403 / 14,633	111.000 / 152.000 [147.000–157.000]; -27.0%; r 0/10000	7.768 / 18.258 [17.740–18.793]; -57.5%; r 0/10000	2.412 / 4.612 [4.488–4.740]; -47.7%; r 0/10000
NO3-N: ≥4d/≥3q in ≥5 years	Realm	45,403 / 14,633	6.000 / 7.000 [7.000–7.000]; -14.3%; r 0/10000	2.192 / 2.652 [2.621–2.685]; -17.3%; r 0/10000	1.665 / 2.085 [2.060–2.111]; -20.2%; r 0/10000
NO3-N: ≥4d/≥3q in ≥10 years	Country	45,403 / 6,144	22.000 / 56.000 [51.000–60.000]; -60.7%; r 0/10000	2.401 / 10.610 [10.288–10.941]; -77.4%; r 0/10000	1.571 / 6.635 [6.438–6.829]; -76.3%; r 0/10000
NO3-N: ≥4d/≥3q in ≥10 years	Ecoregion	45,403 / 6,144	66.000 / 140.000 [134.000–146.000]; -52.9%; r 0/10000	3.430 / 18.107 [17.216–19.021]; -81.1%; r 0/10000	1.583 / 4.609 [4.399–4.830]; -65.7%; r 0/10000
NO3-N: ≥4d/≥3q in ≥10 years	Realm	45,403 / 6,144	5.000 / 7.000 [7.000–7.000]; -28.6%; r 0/10000	1.722 / 2.652 [2.596–2.708]; -35.1%; r 0/10000	1.399 / 2.085 [2.042–2.130]; -32.9%; r 0/10000

Table S4 (continued). Equal-size Hill-number references for all 27 distinct networks.

Analysis	Scale	Pool / retained	q0 obs / median [95%]; Δ; rank	q1 obs / median [95%]; Δ; rank	q2 obs / median [95%]; Δ; rank
TSS: ≥4d/≥3q in ≥3 years	Country	32,627 / 14,765	51.000 / 59.000 [56.000–62.000]; -13.6%; r 0/10000	9.831 / 11.131 [10.953–11.316]; -11.7%; r 0/10000	5.516 / 6.284 [6.165–6.406]; -12.2%; r 0/10000
TSS: ≥4d/≥3q in ≥3 years	Ecoregion	32,627 / 14,765	111.000 / 137.000 [132.000–141.000]; -19.0%; r 0/10000	13.374 / 17.356 [16.927–17.796]; -22.9%; r 0/10000	3.876 / 4.572 [4.464–4.684]; -15.2%; r 0/10000
TSS: ≥4d/≥3q in ≥3 years	Realm	32,627 / 14,765	7.000 / 7.000 [7.000–7.000]; +0.0%; r 10000/10000	2.765 / 2.813 [2.781–2.847]; -1.7%; r 12/10000	2.045 / 2.118 [2.093–2.143]; -3.4%; r 0/10000
TSS: ≥4d/≥3q in ≥5 years	Country	32,627 / 11,488	46.000 / 57.000 [54.000–61.000]; -19.3%; r 0/10000	8.399 / 11.126 [10.904–11.350]; -24.5%; r 0/10000	4.948 / 6.282 [6.137–6.432]; -21.2%; r 0/10000
TSS: ≥4d/≥3q in ≥5 years	Ecoregion	32,627 / 11,488	98.000 / 133.000 [128.000–138.000]; -26.3%; r 0/10000	12.313 / 17.333 [16.795–17.877]; -29.0%; r 0/10000	3.605 / 4.571 [4.440–4.710]; -21.1%; r 0/10000
TSS: ≥4d/≥3q in ≥5 years	Realm	32,627 / 11,488	6.000 / 7.000 [7.000–7.000]; -14.3%; r 0/10000	2.792 / 2.813 [2.774–2.854]; -0.7%; r 1555/10000	2.054 / 2.118 [2.088–2.149]; -3.0%; r 0/10000
TSS: ≥4d/≥3q in ≥10 years	Country	32,627 / 3,786	25.000 / 49.000 [46.000–54.000]; -49.0%; r 0/10000	3.504 / 11.071 [10.613–11.528]; -68.4%; r 0/10000	2.015 / 6.283 [5.985–6.586]; -67.9%; r 0/10000
TSS: ≥4d/≥3q in ≥10 years	Ecoregion	32,627 / 3,786	50.000 / 116.000 [110.000–122.000]; -56.9%; r 0/10000	5.131 / 17.121 [16.089–18.262]; -70.0%; r 0/10000	2.056 / 4.571 [4.307–4.862]; -55.0%; r 0/10000
TSS: ≥4d/≥3q in ≥10 years	Realm	32,627 / 3,786	5.000 / 7.000 [6.000–7.000]; -28.6%; r 0/10000	2.225 / 2.813 [2.731–2.895]; -20.9%; r 0/10000	1.661 / 2.118 [2.056–2.182]; -21.6%; r 0/10000
DOC: ≥4d/≥3q in ≥3 years	Country	23,009 / 8,735	40.000 / 42.000 [38.000–46.000]; -4.8%; r 2496/10000	7.689 / 7.176 [7.032–7.316]; +7.1%; r 10000/10000	5.599 / 4.941 [4.847–5.035]; +13.3%; r 10000/10000
DOC: ≥4d/≥3q in ≥3 years	Ecoregion	23,009 / 8,735	96.000 / 102.000 [98.000–106.000]; -5.9%; r 32/10000	12.385 / 18.810 [18.245–19.374]; -34.2%; r 0/10000	3.909 / 6.257 [6.047–6.477]; -37.5%; r 0/10000
DOC: ≥4d/≥3q in ≥3 years	Realm	23,009 / 8,735	6.000 / 6.000 [6.000–6.000]; +0.0%; r 10000/10000	2.482 / 2.452 [2.427–2.477]; +1.2%; r 9896/10000	2.078 / 2.224 [2.204–2.243]; -6.5%; r 0/10000

Table S4 (continued). Equal-size Hill-number references for all 27 distinct networks.

Analysis	Scale	Pool / retained	q0 obs / median [95%]; Δ; rank	q1 obs / median [95%]; Δ; rank	q2 obs / median [95%]; Δ; rank
DOC: ≥4d/≥3q in ≥5 years	Country	23,009 / 6,410	35.000 / 39.000 [35.000–43.000]; -10.3%; r 474/10000	7.051 / 7.169 [6.993–7.352]; -1.6%; r 977/10000	5.156 / 4.941 [4.823–5.061]; +4.4%; r 9998/10000
DOC: ≥4d/≥3q in ≥5 years	Ecoregion	23,009 / 6,410	92.000 / 99.000 [94.000–103.000]; -7.1%; r 26/10000	12.750 / 18.761 [18.053–19.483]; -32.0%; r 0/10000	4.212 / 6.256 [5.993–6.537]; -32.7%; r 0/10000
DOC: ≥4d/≥3q in ≥5 years	Realm	23,009 / 6,410	6.000 / 6.000 [5.000–6.000]; +0.0%; r 10000/10000	2.617 / 2.452 [2.420–2.484]; +6.8%; r 10000/10000	2.234 / 2.223 [2.200–2.248]; +0.5%; r 7956/10000
DOC: ≥4d/≥3q in ≥10 years	Country	23,009 / 812	12.000 / 24.000 [20.000–29.000]; -50.0%; r 0/10000	5.259 / 7.030 [6.491–7.613]; -25.2%; r 0/10000	4.065 / 4.923 [4.561–5.317]; -17.4%; r 0/10000
DOC: ≥4d/≥3q in ≥10 years	Ecoregion	23,009 / 812	46.000 / 71.000 [64.000–77.000]; -35.2%; r 0/10000	15.033 / 17.793 [15.737–20.082]; -15.5%; r 35/10000	6.594 / 6.233 [5.437–7.186]; +5.8%; r 7811/10000
DOC: ≥4d/≥3q in ≥10 years	Realm	23,009 / 812	3.000 / 5.000 [4.000–6.000]; -40.0%; r 242/10000	2.173 / 2.446 [2.344–2.551]; -11.2%; r 0/10000	2.016 / 2.222 [2.144–2.301]; -9.3%; r 0/10000
Cohort A: ≥3 days in ≥3 quarters for ≥5 years	Country	56,816 / 14,773	48.000 / 71.000 [66.000–76.000]; -32.4%; r 0/10000	8.418 / 8.842 [8.660–9.022]; -4.8%; r 0/10000	4.869 / 4.674 [4.576–4.776]; +4.2%; r 10000/10000
Cohort A: ≥3 days in ≥3 quarters for ≥5 years	Ecoregion	56,816 / 14,773	149.000 / 187.000 [182.000–192.000]; -20.3%; r 0/10000	24.832 / 38.451 [37.506–39.449]; -35.4%; r 0/10000	5.597 / 10.717 [10.339–11.117]; -47.8%; r 0/10000
Cohort A: ≥3 days in ≥3 quarters for ≥5 years	Realm	56,816 / 14,773	7.000 / 7.000 [7.000–7.000]; +0.0%; r 10000/10000	3.543 / 3.313 [3.272–3.354]; +6.9%; r 10000/10000	2.711 / 2.674 [2.646–2.701]; +1.4%; r 9963/10000
Cohort B: ≥3 days in ≥3 quarters for ≥5 years	Country	21,524 / 4,506	36.000 / 38.000 [34.000–41.000]; -5.3%; r 2531/10000	7.741 / 7.661 [7.396–7.946]; +1.0%; r 7186/10000	4.530 / 4.307 [4.135–4.493]; +5.2%; r 9914/10000
Cohort B: ≥3 days in ≥3 quarters for ≥5 years	Ecoregion	21,524 / 4,506	92.000 / 102.000 [98.000–106.000]; -9.8%; r 0/10000	40.574 / 31.814 [30.608–33.074]; +27.5%; r 10000/10000	19.512 / 13.045 [12.277–13.877]; +49.6%; r 10000/10000
Cohort B: ≥3 days in ≥3 quarters for ≥5 years	Realm	21,524 / 4,506	4.000 / 5.000 [4.000–5.000]; -20.0%; r 1493/10000	3.157 / 2.635 [2.590–2.679]; +19.8%; r 10000/10000	2.903 / 2.352 [2.319–2.385]; +23.4%; r 10000/10000

Table S4 (continued). Equal-size Hill-number references for all 27 distinct networks.

Analysis	Scale	Pool / retained	q0 obs / median [95%]; Δ; rank	q1 obs / median [95%]; Δ; rank	q2 obs / median [95%]; Δ; rank
Cohort A: ≥4 days in ≥2 quarters for ≥5 years	Country	56,816 / 15,096	48.000 / 71.000 [66.000–77.000]; -32.4%; r 0/10000	8.314 / 8.843 [8.665–9.021]; -6.0%; r 0/10000	4.862 / 4.676 [4.579–4.775]; +4.0%; r 9999/10000
Cohort A: ≥4 days in ≥2 quarters for ≥5 years	Ecoregion	56,816 / 15,096	144.000 / 188.000 [182.000–193.000]; -23.4%; r 0/10000	24.725 / 38.452 [37.505–39.403]; -35.7%; r 0/10000	5.655 / 10.713 [10.345–11.111]; -47.2%; r 0/10000
Cohort A: ≥4 days in ≥2 quarters for ≥5 years	Realm	56,816 / 15,096	7.000 / 7.000 [7.000–7.000]; +0.0%; r 10000/10000	3.556 / 3.312 [3.273–3.353]; +7.3%; r 10000/10000	2.719 / 2.673 [2.647–2.700]; +1.7%; r 9994/10000
Cohort B: ≥4 days in ≥2 quarters for ≥5 years	Country	21,524 / 4,551	36.000 / 38.000 [34.000–41.000]; -5.3%; r 2494/10000	7.521 / 7.660 [7.397–7.934]; -1.8%; r 1512/10000	4.427 / 4.307 [4.132–4.486]; +2.8%; r 9082/10000
Cohort B: ≥4 days in ≥2 quarters for ≥5 years	Ecoregion	21,524 / 4,551	91.000 / 103.000 [98.000–106.000]; -11.7%; r 0/10000	40.147 / 31.833 [30.615–33.095]; +26.1%; r 10000/10000	19.272 / 13.049 [12.276–13.898]; +47.7%; r 10000/10000
Cohort B: ≥4 days in ≥2 quarters for ≥5 years	Realm	21,524 / 4,551	4.000 / 5.000 [4.000–5.000]; -20.0%; r 1480/10000	3.172 / 2.635 [2.591–2.679]; +20.4%; r 10000/10000	2.911 / 2.352 [2.319–2.386]; +23.8%; r 10000/10000
Cohort B: ≥4 days in ≥3 quarters (primary) for ≥5 years	Country	21,524 / 4,373	36.000 / 37.000 [34.000–41.000]; -2.7%; r 2949/10000	7.583 / 7.660 [7.385–7.941]; -1.0%; r 2982/10000	4.460 / 4.307 [4.133–4.495]; +3.5%; r 9471/10000
Cohort B: ≥4 days in ≥3 quarters (primary) for ≥5 years	Ecoregion	21,524 / 4,373	91.000 / 102.000 [98.000–106.000]; -10.8%; r 0/10000	39.665 / 31.818 [30.574–33.066]; +24.7%; r 10000/10000	19.066 / 13.046 [12.260–13.905]; +46.1%; r 10000/10000
Cohort B: ≥4 days in ≥3 quarters (primary) for ≥5 years	Realm	21,524 / 4,373	4.000 / 5.000 [4.000–5.000]; -20.0%; r 1631/10000	3.158 / 2.635 [2.590–2.682]; +19.8%; r 10000/10000	2.904 / 2.352 [2.319–2.387]; +23.4%; r 10000/10000
Cohort A: ≥4 days in 4 quarters for ≥5 years	Country	56,816 / 11,055	43.000 / 67.000 [61.000–72.000]; -35.8%; r 0/10000	7.572 / 8.833 [8.613–9.054]; -14.3%; r 0/10000	4.036 / 4.675 [4.554–4.796]; -13.7%; r 0/10000
Cohort A: ≥4 days in 4 quarters for ≥5 years	Ecoregion	56,816 / 11,055	130.000 / 182.000 [176.000–188.000]; -28.6%; r 0/10000	16.736 / 38.358 [37.192–39.551]; -56.4%; r 0/10000	4.106 / 10.712 [10.254–11.195]; -61.7%; r 0/10000
Cohort A: ≥4 days in 4 quarters for ≥5 years	Realm	56,816 / 11,055	7.000 / 7.000 [7.000–7.000]; +0.0%; r 10000/10000	2.997 / 3.312 [3.264–3.363]; -9.5%; r 0/10000	2.231 / 2.673 [2.641–2.706]; -16.5%; r 0/10000

Table S4 (continued). Equal-size Hill-number references for all 27 distinct networks.

Analysis	Scale	Pool / retained	q0 obs / median [95%]; Δ; rank	q1 obs / median [95%]; Δ; rank	q2 obs / median [95%]; Δ; rank
Cohort B: ≥4 days in 4 quarters for ≥5 years	Country	21,524 / 2,621	33.000 / 35.000 [31.000–38.000]; -5.7%; r 2871/10000	9.357 / 7.638 [7.273–8.019]; +22.5%; r 10000/10000	4.902 / 4.305 [4.070–4.563]; +13.8%; r 10000/10000
Cohort B: ≥4 days in 4 quarters for ≥5 years	Ecoregion	21,524 / 2,621	82.000 / 97.000 [92.000–102.000]; -15.5%; r 0/10000	26.284 / 31.553 [29.855–33.311]; -16.7%; r 0/10000	9.722 / 13.020 [11.971–14.205]; -25.3%; r 0/10000
Cohort B: ≥4 days in 4 quarters for ≥5 years	Realm	21,524 / 2,621	4.000 / 5.000 [4.000–5.000]; -20.0%; r 3495/10000	2.630 / 2.635 [2.573–2.697]; -0.2%; r 4426/10000	2.334 / 2.352 [2.307–2.399]; -0.8%; r 2238/10000
Cohort A: ≥6 days in ≥3 quarters for ≥5 years	Country	56,816 / 11,550	46.000 / 67.000 [62.000–73.000]; -31.3%; r 0/10000	8.464 / 8.835 [8.627–9.046]; -4.2%; r 3/10000	5.194 / 4.674 [4.561–4.789]; +11.1%; r 10000/10000
Cohort A: ≥6 days in ≥3 quarters for ≥5 years	Ecoregion	56,816 / 11,550	136.000 / 183.000 [177.000–189.000]; -25.7%; r 0/10000	24.530 / 38.379 [37.285–39.558]; -36.1%; r 0/10000	5.878 / 10.713 [10.268–11.193]; -45.1%; r 0/10000
Cohort A: ≥6 days in ≥3 quarters for ≥5 years	Realm	56,816 / 11,550	7.000 / 7.000 [7.000–7.000]; +0.0%; r 10000/10000	3.659 / 3.312 [3.265–3.360]; +10.5%; r 10000/10000	2.816 / 2.673 [2.642–2.704]; +5.3%; r 10000/10000
Cohort B: ≥6 days in ≥3 quarters for ≥5 years	Country	21,524 / 3,218	33.000 / 36.000 [32.000–39.000]; -8.3%; r 1142/10000	7.964 / 7.652 [7.323–7.982]; +4.1%; r 9668/10000	4.904 / 4.309 [4.101–4.533]; +13.8%; r 10000/10000
Cohort B: ≥6 days in ≥3 quarters for ≥5 years	Ecoregion	21,524 / 3,218	85.000 / 99.000 [95.000–104.000]; -14.1%; r 0/10000	33.803 / 31.663 [30.174–33.211]; +6.8%; r 9963/10000	13.658 / 13.047 [12.085–14.064]; +4.7%; r 8817/10000
Cohort B: ≥6 days in ≥3 quarters for ≥5 years	Realm	21,524 / 3,218	4.000 / 5.000 [4.000–5.000]; -20.0%; r 2708/10000	3.132 / 2.635 [2.580–2.690]; +18.9%; r 10000/10000	2.858 / 2.352 [2.312–2.393]; +21.5%; r 10000/10000

Note: The 28 reported configurations contain one exact overlap: EC at five years equals primary Cohort A. Percent departures use the order-specific null median; r is the empirical number of draws at or below the observation and is not an exact p-value; endpoint ranks do not imply probabilities of exactly zero or one.

Table S5. Within-country Hill-number references for all 27 distinct networks.

Analysis	Scale	Retained / country strata	q0 obs / median [95%]; Δ; rank	q1 obs / median [95%]; Δ; rank	q2 obs / median [95%]; Δ; rank
EC: ≥4d/≥3q in ≥3 years	Ecoregion	20,460 / 53	154.000 / 172.000 [168.000–176.000]; -10.5%; r 0/10000	23.417 / 23.805 [23.612–24.000]; -1.6%; r 0/10000	5.403 / 5.310 [5.268–5.350]; +1.8%; r 10000/10000
EC: ≥4d/≥3q in ≥3 years	Realm	20,460 / 53	7.000 / 7.000 [7.000–7.000]; +0.0%; r 10000/10000	3.222 / 3.225 [3.217–3.233]; -0.1%; r 2200/10000	2.410 / 2.407 [2.403–2.410]; +0.1%; r 9742/10000
EC: ≥4d/≥3q in ≥5 years	Ecoregion	14,387 / 48	143.000 / 161.000 [157.000–165.000]; -11.2%; r 0/10000	24.217 / 24.743 [24.487–25.002]; -2.1%; r 0/10000	5.541 / 5.503 [5.461–5.546]; +0.7%; r 9612/10000
EC: ≥4d/≥3q in ≥5 years	Realm	14,387 / 48	7.000 / 7.000 [7.000–7.000]; +0.0%; r 10000/10000	3.541 / 3.547 [3.535–3.560]; -0.2%; r 1672/10000	2.706 / 2.701 [2.696–2.707]; +0.2%; r 9506/10000
EC: ≥4d/≥3q in ≥10 years	Ecoregion	5,328 / 19	91.000 / 102.000 [98.000–106.000]; -10.8%; r 0/10000	20.198 / 22.142 [21.710–22.597]; -8.8%; r 0/10000	6.108 / 6.223 [6.142–6.307]; -1.8%; r 24/10000
EC: ≥4d/≥3q in ≥10 years	Realm	5,328 / 19	4.000 / 6.000 [6.000–6.000]; -33.3%; r 0/10000	3.006 / 3.029 [3.011–3.048]; -0.7%; r 62/10000	2.605 / 2.602 [2.593–2.610]; +0.1%; r 7611/10000
TP: ≥4d/≥3q in ≥3 years	Ecoregion	14,088 / 49	122.000 / 134.000 [131.000–137.000]; -9.0%; r 0/10000	28.473 / 29.267 [28.963–29.570]; -2.7%; r 0/10000	8.500 / 8.524 [8.423–8.628]; -0.3%; r 3290/10000
TP: ≥4d/≥3q in ≥3 years	Realm	14,088 / 49	7.000 / 7.000 [7.000–7.000]; +0.0%; r 10000/10000	3.408 / 3.410 [3.401–3.420]; -0.1%; r 2805/10000	2.724 / 2.723 [2.718–2.727]; +0.0%; r 6909/10000
TP: ≥4d/≥3q in ≥5 years	Ecoregion	9,554 / 47	115.000 / 127.000 [124.000–131.000]; -9.4%; r 0/10000	34.570 / 35.580 [35.104–36.060]; -2.8%; r 0/10000	11.815 / 12.093 [11.889–12.296]; -2.3%; r 35/10000
TP: ≥4d/≥3q in ≥5 years	Realm	9,554 / 47	7.000 / 7.000 [7.000–7.000]; +0.0%; r 10000/10000	3.670 / 3.694 [3.681–3.708]; -0.7%; r 3/10000	3.028 / 3.042 [3.033–3.051]; -0.5%; r 9/10000
TP: ≥4d/≥3q in ≥10 years	Ecoregion	2,163 / 20	73.000 / 83.000 [79.000–88.000]; -12.0%; r 0/10000	31.010 / 32.522 [31.330–33.727]; -4.7%; r 73/10000	16.589 / 16.265 [15.705–16.844]; +2.0%; r 8679/10000
TP: ≥4d/≥3q in ≥10 years	Realm	2,163 / 20	6.000 / 7.000 [6.000–7.000]; -14.3%; r 805/10000	3.271 / 3.309 [3.280–3.341]; -1.1%; r 17/10000	2.491 / 2.512 [2.500–2.525]; -0.8%; r 0/10000

Table S5 (continued). Within-country Hill-number references for all 27 distinct networks.

Analysis	Scale	Retained / country strata	q0 obs / median [95%]; Δ; rank	q1 obs / median [95%]; Δ; rank	q2 obs / median [95%]; Δ; rank
DO: ≥4d/≥3q in ≥3 years	Ecoregion	18,775 / 53	128.000 / 137.000 [134.000–140.000]; -6.6%; r 0/10000	10.713 / 10.782 [10.690–10.869]; -0.6%; r 667/10000	2.865 / 2.846 [2.830–2.864]; +0.7%; r 9851/10000
DO: ≥4d/≥3q in ≥3 years	Realm	18,775 / 53	5.000 / 6.000 [5.000–6.000]; -16.7%; r 1795/10000	2.502 / 2.501 [2.497–2.505]; +0.1%; r 7395/10000	1.902 / 1.901 [1.898–1.903]; +0.1%; r 7847/10000
DO: ≥4d/≥3q in ≥5 years	Ecoregion	13,594 / 47	118.000 / 133.000 [129.000–136.000]; -11.3%; r 0/10000	8.871 / 9.070 [8.979–9.162]; -2.2%; r 0/10000	2.533 / 2.528 [2.512–2.544]; +0.2%; r 7193/10000
DO: ≥4d/≥3q in ≥5 years	Realm	13,594 / 47	5.000 / 6.000 [5.000–6.000]; -16.7%; r 2759/10000	2.292 / 2.284 [2.278–2.289]; +0.4%; r 9995/10000	1.807 / 1.802 [1.800–1.805]; +0.3%; r 9999/10000
DO: ≥4d/≥3q in ≥10 years	Ecoregion	6,560 / 19	69.000 / 91.000 [87.000–95.000]; -24.2%; r 0/10000	4.190 / 4.490 [4.424–4.553]; -6.7%; r 0/10000	1.750 / 1.776 [1.763–1.790]; -1.5%; r 1/10000
DO: ≥4d/≥3q in ≥10 years	Realm	6,560 / 19	4.000 / 5.000 [4.000–5.000]; -20.0%; r 4603/10000	1.865 / 1.862 [1.855–1.869]; +0.2%; r 8090/10000	1.539 / 1.536 [1.532–1.539]; +0.2%; r 9793/10000
NO3-N: ≥4d/≥3q in ≥3 years	Ecoregion	18,635 / 52	122.000 / 135.000 [131.000–138.000]; -9.6%; r 0/10000	8.530 / 8.652 [8.577–8.726]; -1.4%; r 5/10000	2.554 / 2.551 [2.534–2.569]; +0.1%; r 6164/10000
NO3-N: ≥4d/≥3q in ≥3 years	Realm	18,635 / 52	7.000 / 7.000 [7.000–7.000]; +0.0%; r 10000/10000	2.151 / 2.148 [2.144–2.152]; +0.1%; r 8852/10000	1.639 / 1.637 [1.635–1.638]; +0.1%; r 9919/10000
NO3-N: ≥4d/≥3q in ≥5 years	Ecoregion	14,633 / 50	111.000 / 129.000 [125.000–133.000]; -14.0%; r 0/10000	7.768 / 7.979 [7.894–8.060]; -2.6%; r 0/10000	2.412 / 2.432 [2.412–2.452]; -0.8%; r 260/10000
NO3-N: ≥4d/≥3q in ≥5 years	Realm	14,633 / 50	6.000 / 7.000 [6.000–7.000]; -14.3%; r 260/10000	2.192 / 2.192 [2.186–2.197]; +0.0%; r 5396/10000	1.665 / 1.663 [1.661–1.665]; +0.1%; r 9492/10000
NO3-N: ≥4d/≥3q in ≥10 years	Ecoregion	6,144 / 22	66.000 / 77.000 [73.000–80.000]; -14.3%; r 0/10000	3.430 / 3.607 [3.549–3.664]; -4.9%; r 0/10000	1.583 / 1.602 [1.590–1.615]; -1.2%; r 8/10000
NO3-N: ≥4d/≥3q in ≥10 years	Realm	6,144 / 22	5.000 / 6.000 [5.000–6.000]; -16.7%; r 1244/10000	1.722 / 1.721 [1.714–1.727]; +0.1%; r 6417/10000	1.399 / 1.395 [1.392–1.398]; +0.3%; r 9981/10000

Table S5 (continued). Within-country Hill-number references for all 27 distinct networks.

Analysis	Scale	Retained / country strata	q0 obs / median [95%]; Δ; rank	q1 obs / median [95%]; Δ; rank	q2 obs / median [95%]; Δ; rank
TSS: ≥4d/≥3q in ≥3 years	Ecoregion	14,765 / 51	111.000 / 130.000 [126.000–135.000]; -14.6%; r 0/10000	13.374 / 14.200 [14.082–14.320]; -5.8%; r 0/10000	3.876 / 3.875 [3.854–3.895]; +0.0%; r 5673/10000
TSS: ≥4d/≥3q in ≥3 years	Realm	14,765 / 51	7.000 / 7.000 [7.000–7.000]; +0.0%; r 10000/10000	2.765 / 2.770 [2.765–2.776]; -0.2%; r 303/10000	2.045 / 2.047 [2.045–2.048]; -0.1%; r 811/10000
TSS: ≥4d/≥3q in ≥5 years	Ecoregion	11,488 / 46	98.000 / 118.000 [114.000–123.000]; -16.9%; r 0/10000	12.313 / 12.801 [12.667–12.931]; -3.8%; r 0/10000	3.605 / 3.581 [3.559–3.604]; +0.7%; r 9829/10000
TSS: ≥4d/≥3q in ≥5 years	Realm	11,488 / 46	6.000 / 7.000 [7.000–7.000]; -14.3%; r 77/10000	2.792 / 2.800 [2.794–2.807]; -0.3%; r 101/10000	2.054 / 2.055 [2.053–2.057]; -0.1%; r 1519/10000
TSS: ≥4d/≥3q in ≥10 years	Ecoregion	3,786 / 25	50.000 / 70.000 [65.000–75.000]; -28.6%; r 0/10000	5.131 / 5.639 [5.519–5.757]; -9.0%; r 0/10000	2.056 / 2.097 [2.074–2.122]; -2.0%; r 2/10000
TSS: ≥4d/≥3q in ≥10 years	Realm	3,786 / 25	5.000 / 6.000 [5.000–6.000]; -16.7%; r 1079/10000	2.225 / 2.233 [2.224–2.244]; -0.4%; r 415/10000	1.661 / 1.661 [1.658–1.665]; -0.0%; r 3728/10000
DOC: ≥4d/≥3q in ≥3 years	Ecoregion	8,735 / 40	96.000 / 98.000 [95.000–101.000]; -2.0%; r 1810/10000	12.385 / 12.105 [11.955–12.257]; +2.3%; r 10000/10000	3.909 / 3.845 [3.796–3.896]; +1.7%; r 9927/10000
DOC: ≥4d/≥3q in ≥3 years	Realm	8,735 / 40	6.000 / 6.000 [5.000–6.000]; +0.0%; r 10000/10000	2.482 / 2.480 [2.476–2.485]; +0.1%; r 8155/10000	2.078 / 2.076 [2.074–2.078]; +0.1%; r 9753/10000
DOC: ≥4d/≥3q in ≥5 years	Ecoregion	6,410 / 35	92.000 / 92.000 [88.000–96.000]; +0.0%; r 5771/10000	12.750 / 12.754 [12.549–12.951]; -0.0%; r 4801/10000	4.212 / 4.238 [4.162–4.311]; -0.6%; r 2509/10000
DOC: ≥4d/≥3q in ≥5 years	Realm	6,410 / 35	6.000 / 6.000 [5.000–6.000]; +0.0%; r 10000/10000	2.617 / 2.613 [2.609–2.619]; +0.2%; r 8998/10000	2.234 / 2.231 [2.228–2.234]; +0.1%; r 9625/10000
DOC: ≥4d/≥3q in ≥10 years	Ecoregion	812 / 12	46.000 / 54.000 [49.000–58.000]; -14.8%; r 3/10000	15.033 / 16.355 [15.255–17.469]; -8.1%; r 85/10000	6.594 / 6.766 [6.473–7.098]; -2.5%; r 1329/10000
DOC: ≥4d/≥3q in ≥10 years	Realm	812 / 12	3.000 / 4.000 [3.000–5.000]; -25.0%; r 932/10000	2.173 / 2.207 [2.173–2.242]; -1.5%; r 479/10000	2.016 / 2.026 [2.015–2.039]; -0.5%; r 540/10000

Table S5 (continued). Within-country Hill-number references for all 27 distinct networks.

Analysis	Scale	Retained / country strata	q0 obs / median [95%]; Δ; rank	q1 obs / median [95%]; Δ; rank	q2 obs / median [95%]; Δ; rank
Cohort A: ≥3 days in ≥3 quarters for ≥5 years	Ecoregion	14,773 / 48	149.000 / 166.000 [162.000–170.000]; -10.2%; r 0/10000	24.832 / 25.212 [24.953–25.469]; -1.5%; r 17/10000	5.597 / 5.555 [5.513–5.597]; +0.7%; r 9724/10000
Cohort A: ≥3 days in ≥3 quarters for ≥5 years	Realm	14,773 / 48	7.000 / 7.000 [7.000–7.000]; +0.0%; r 10000/10000	3.543 / 3.546 [3.534–3.558]; -0.1%; r 3306/10000	2.711 / 2.706 [2.701–2.711]; +0.2%; r 9749/10000
Cohort B: ≥3 days in ≥3 quarters for ≥5 years	Ecoregion	4,506 / 36	92.000 / 100.000 [96.000–103.000]; -8.0%; r 0/10000	40.574 / 42.065 [41.316–42.824]; -3.5%; r 0/10000	19.512 / 19.495 [19.025–19.995]; +0.1%; r 5268/10000
Cohort B: ≥3 days in ≥3 quarters for ≥5 years	Realm	4,506 / 36	4.000 / 5.000 [4.000–5.000]; -20.0%; r 2813/10000	3.157 / 3.156 [3.143–3.170]; +0.0%; r 5821/10000	2.903 / 2.893 [2.877–2.909]; +0.4%; r 9133/10000
Cohort A: ≥4 days in ≥2 quarters for ≥5 years	Ecoregion	15,096 / 48	144.000 / 161.000 [157.000–165.000]; -10.6%; r 0/10000	24.725 / 25.225 [24.975–25.470]; -2.0%; r 0/10000	5.655 / 5.603 [5.562–5.644]; +0.9%; r 9933/10000
Cohort A: ≥4 days in ≥2 quarters for ≥5 years	Realm	15,096 / 48	7.000 / 7.000 [7.000–7.000]; +0.0%; r 10000/10000	3.556 / 3.557 [3.545–3.569]; -0.0%; r 4065/10000	2.719 / 2.712 [2.706–2.717]; +0.2%; r 9926/10000
Cohort B: ≥4 days in ≥2 quarters for ≥5 years	Ecoregion	4,551 / 36	91.000 / 100.000 [96.000–103.000]; -9.0%; r 0/10000	40.147 / 41.658 [40.907–42.373]; -3.6%; r 0/10000	19.272 / 19.205 [18.745–19.671]; +0.3%; r 6121/10000
Cohort B: ≥4 days in ≥2 quarters for ≥5 years	Realm	4,551 / 36	4.000 / 5.000 [4.000–5.000]; -20.0%; r 2721/10000	3.172 / 3.170 [3.157–3.184]; +0.1%; r 6243/10000	2.911 / 2.898 [2.883–2.913]; +0.4%; r 9497/10000
Cohort B: ≥4 days in ≥3 quarters (primary) for ≥5 years	Ecoregion	4,373 / 36	91.000 / 99.000 [96.000–103.000]; -8.1%; r 0/10000	39.665 / 41.341 [40.577–42.113]; -4.1%; r 0/10000	19.066 / 18.976 [18.508–19.456]; +0.5%; r 6497/10000
Cohort B: ≥4 days in ≥3 quarters (primary) for ≥5 years	Realm	4,373 / 36	4.000 / 5.000 [4.000–5.000]; -20.0%; r 2994/10000	3.158 / 3.155 [3.141–3.169]; +0.1%; r 7005/10000	2.904 / 2.889 [2.872–2.905]; +0.5%; r 9628/10000
Cohort A: ≥4 days in 4 quarters for ≥5 years	Ecoregion	11,055 / 43	130.000 / 152.000 [148.000–157.000]; -14.5%; r 0/10000	16.736 / 17.324 [17.100–17.538]; -3.4%; r 0/10000	4.106 / 4.097 [4.064–4.132]; +0.2%; r 6880/10000
Cohort A: ≥4 days in 4 quarters for ≥5 years	Realm	11,055 / 43	7.000 / 7.000 [7.000–7.000]; +0.0%; r 10000/10000	2.997 / 3.008 [2.994–3.022]; -0.4%; r 622/10000	2.231 / 2.229 [2.224–2.234]; +0.1%; r 7438/10000

Table S5 (continued). Within-country Hill-number references for all 27 distinct networks.

Analysis	Scale	Retained / country strata	q0 obs / median [95%]; Δ; rank	q1 obs / median [95%]; Δ; rank	q2 obs / median [95%]; Δ; rank
Cohort B: ≥4 days in 4 quarters for ≥5 years	Ecoregion	2,621 / 33	82.000 / 95.000 [90.000–99.000]; -13.7%; r 0/10000	26.284 / 28.728 [27.909–29.549]; -8.5%; r 0/10000	9.722 / 9.609 [9.323–9.921]; +1.2%; r 7681/10000
Cohort B: ≥4 days in 4 quarters for ≥5 years	Realm	2,621 / 33	4.000 / 5.000 [4.000–5.000]; -20.0%; r 3747/10000	2.630 / 2.655 [2.624–2.685]; -0.9%; r 531/10000	2.334 / 2.350 [2.328–2.371]; -0.7%; r 749/10000
Cohort A: ≥6 days in ≥3 quarters for ≥5 years	Ecoregion	11,550 / 46	136.000 / 152.000 [149.000–156.000]; -10.5%; r 0/10000	24.530 / 25.422 [25.116–25.731]; -3.5%; r 0/10000	5.878 / 5.882 [5.829–5.936]; -0.1%; r 4395/10000
Cohort A: ≥6 days in ≥3 quarters for ≥5 years	Realm	11,550 / 46	7.000 / 7.000 [7.000–7.000]; +0.0%; r 10000/10000	3.659 / 3.662 [3.647–3.677]; -0.1%; r 3942/10000	2.816 / 2.807 [2.799–2.814]; +0.3%; r 9863/10000
Cohort B: ≥6 days in ≥3 quarters for ≥5 years	Ecoregion	3,218 / 33	85.000 / 96.000 [93.000–100.000]; -11.5%; r 0/10000	33.803 / 36.053 [35.198–36.933]; -6.2%; r 0/10000	13.658 / 13.930 [13.541–14.337]; -2.0%; r 856/10000
Cohort B: ≥6 days in ≥3 quarters for ≥5 years	Realm	3,218 / 33	4.000 / 5.000 [4.000–5.000]; -20.0%; r 3930/10000	3.132 / 3.123 [3.101–3.146]; +0.3%; r 7733/10000	2.858 / 2.836 [2.806–2.865]; +0.8%; r 9279/10000

Note: No fixed percentage threshold is applied. Interpret each residual together with its 95% range, empirical rank and the country–ecology variation summarized in Table 9; r is the empirical number of draws at or below the observation and is not an exact p-value.

ROBUSTNESS

Table S6. Sensitivity to including observations flagged as outliers.

Configuration	* rows	Stations	Countries n / q2	Ecoregions n / q2	Realms n / q2
EC	Excluded	14,387	48 / 4.839	143 / 5.541	7 / 2.706
EC	Included	14,813	50 / 5.027	146 / 5.769	7 / 2.715
TP	Excluded	9,554	47 / 8.031	115 / 11.815	7 / 3.028
TP	Included	9,565	47 / 8.041	115 / 11.838	7 / 3.029
DO	Excluded	13,594	47 / 2.978	118 / 2.533	5 / 1.807
DO	Included	13,595	47 / 2.978	118 / 2.533	5 / 1.807
Cohort B	Excluded	4,373	36 / 4.460	91 / 19.066	4 / 2.904
Cohort B	Included	4,447	36 / 4.412	92 / 19.202	4 / 2.912

Table S7. Proximity-based duplicate-collapse sensitivity.

Cohort	Collapse definition	Pairs	Collapsed	Retained	Country Δq2	Ecoregion Δq2	Realm Δq2
Cohort A	baseline	0	0	14,387	+0.000	+0.000	+0.000
Cohort A	all pairs <=10 m with overlapping EC intervals	58	55	14,332	-0.005	+0.012	+0.003
Cohort A	all pairs <=100 m with overlapping EC intervals	338	320	14,067	+0.044	+0.097	+0.019
Cohort A	high-confidence duplicate signature <=100 m	47	45	14,342	-0.027	-0.021	-0.001
Cohort B	baseline	0	0	4,373	+0.000	+0.000	+0.000
Cohort B	all pairs <=10 m with overlapping EC intervals	20	20	4,353	-0.018	+0.141	+0.000
Cohort B	all pairs <=100 m with overlapping EC intervals	78	76	4,297	-0.054	+0.166	+0.006
Cohort B	high-confidence duplicate signature <=100 m	19	19	4,354	-0.036	+0.076	+0.001

Table S8. Exposure to the documented VPU 605 processing correction.

Configuration	Stations	VPU 605	Share	FEOW assigned	Countries	Ecoregions	Realms
v1.1 candidate stations (six files)	77,258	200	0.3%	200	7	11	1
v1.1 Cohort A	14,387	13	0.1%	13	2	3	1
v1.1 Cohort B	4,373	0	0.0%	0	0	0	0

SCALE, COMPOSITION AND RESPONSE CHECKS

Table S9. Area-proportional FEOW and realm comparisons.

Cohort	Hierarchy	Occupied / total units	Observed q2	Area q2 (full)	Area / observed	Area q2 (occupied)	Occupied area / observed
Cohort A	Ecoregions	143 / 426	5.541	126.044	22.746	63.837	11.520
Cohort A	Realms	7 / 7	2.706	4.039	1.493	4.039	1.493
Cohort B	Ecoregions	91 / 426	19.066	126.044	6.611	46.018	2.414
Cohort B	Realms	4 / 7	2.904	4.039	1.391	2.754	0.948

Note: Ratios divide the area reference by the observed q=2 effective diversity. The occupied-support result conditions on empirical occupancy; neither reference is an optimization target.

Table S10. Realm composition and within-realm effective ecoregions.

Cohort	Realm	Stations	Share	Ecoregions n	Ecoregions q2
Cohort A	Afrotropic	543	3.8%	9	2.085
Cohort A	Australasia	947	6.6%	9	3.290
Cohort A	Indo-Malay	305	2.1%	11	6.909
Cohort A	Nearctic	3,781	26.3%	59	25.471
Cohort A	Neotropic	1,069	7.4%	20	7.996
Cohort A	Oceania	1	0.0%	1	1.000
Cohort A	Palearctic	7,707	53.7%	34	1.648
Cohort B	Afrotropic	0	—	0	—
Cohort B	Australasia	0	—	0	—
Cohort B	Indo-Malay	114	2.6%	8	6.570
Cohort B	Nearctic	1,994	45.7%	56	24.392
Cohort B	Neotropic	1,021	23.4%	13	7.789
Cohort B	Oceania	0	—	0	—
Cohort B	Palearctic	1,231	28.2%	14	2.170

Note: Absent realms are shown as em dashes; no q2 = 0 is assigned.

Table S11. Geographic selection under alternative constituent intersections.

Constituent set	Stations	Countries n / q2	Ecoregions n / q2	Realms n / q2	Dominant country
EC	14,387	48 / 4.839	143 / 5.541	7 / 2.706	United Kingdom (38.5%)
EC+TP+DO	4,373	36 / 4.460	91 / 19.066	4 / 2.904	Mexico (34.4%)
EC+TP+DO+TSS	3,014	32 / 3.208	67 / 17.401	4 / 2.957	Mexico (49.8%)
EC+TP+DO+DOC	2,611	24 / 2.848	76 / 14.205	3 / 2.942	Mexico (56.7%)
All six	2,013	23 / 1.826	49 / 14.685	3 / 2.677	Mexico (73.1%)

Table S12. Station-level chemical summaries under the primary rule.

Cohort / constituent	Stations	Unit	Median [IQR]
Cohort A EC	14,387	µS/cm	502.5 [234.5–805.4]
Cohort B EC	4,373	µS/cm	435.8 [231.0–745.8]
Cohort B TP	4,373	mg/L	0.0872 [0.0395–0.2172]
Cohort B DO	4,373	mg/L	8.70 [6.75–10.20]

Note: Each station value is the median of its eligible-year medians.

Table S13. Constituent-specific counts underlying the within-year intersections.

Rule	Variable	Stations with ≥5 eligible years
3d/3q	EC	14,773
3d/3q	TP	9,772
3d/3q	DO	13,811
4d/2q	EC	15,096
4d/2q	TP	10,019
4d/2q	DO	14,023
4d/3q	EC	14,387
4d/3q	TP	9,554
4d/3q	DO	13,594
4d/4q	EC	11,055
4d/4q	TP	6,928
4d/4q	DO	11,180
6d/3q	EC	11,550
6d/3q	TP	8,105
6d/3q	DO	11,944

COUNTRY INFLUENCE, WINDOW AND INPUT INTEGRITY

Table S14. Three strongest absolute ecoregion-q2 leave-one-country-out effects for each distinct network.

Analysis	Rank	Excluded country	Removed	Share	Ecoregion q0 Δ	q1 Δ	q2 Δ
EC: ≥4d/≥3q in ≥3 years	1	United Kingdom	7,098	34.7%	+0.0%	+161.2%	+460.2%
EC: ≥4d/≥3q in ≥3 years	2	United States	3,664	17.9%	-19.5%	-42.2%	-31.9%
EC: ≥4d/≥3q in ≥3 years	3	Mexico	1,779	8.7%	-9.7%	-24.0%	-16.4%
EC: ≥4d/≥3q in ≥5 years	1	United Kingdom	5,538	38.5%	+0.0%	+194.5%	+739.1%
EC: ≥4d/≥3q in ≥5 years	2	United States	2,717	18.9%	-21.0%	-42.7%	-33.4%
EC: ≥4d/≥3q in ≥5 years	3	Mexico	1,574	10.9%	-10.5%	-27.4%	-20.3%
EC: ≥4d/≥3q in ≥10 years	1	United Kingdom	2,073	38.9%	-1.1%	+127.0%	+393.9%
EC: ≥4d/≥3q in ≥10 years	2	United States	1,539	28.9%	-34.1%	-56.9%	-47.8%
EC: ≥4d/≥3q in ≥10 years	3	Australia	617	11.6%	-8.8%	-17.1%	-19.5%
TP: ≥4d/≥3q in ≥3 years	1	Poland	1,224	8.7%	+0.0%	+21.9%	+40.9%
TP: ≥4d/≥3q in ≥3 years	2	France	2,411	17.1%	-1.6%	+25.4%	+38.1%
TP: ≥4d/≥3q in ≥3 years	3	United States	2,503	17.8%	-23.0%	-36.2%	-30.5%
TP: ≥4d/≥3q in ≥5 years	1	France	1,888	19.8%	-1.7%	+35.7%	+81.3%
TP: ≥4d/≥3q in ≥5 years	2	United States	1,909	20.0%	-24.3%	-35.7%	-33.3%
TP: ≥4d/≥3q in ≥5 years	3	Mexico	1,628	17.0%	-13.9%	-31.0%	-29.2%
TP: ≥4d/≥3q in ≥10 years	1	United Kingdom	296	13.7%	-1.4%	+21.4%	+66.2%
TP: ≥4d/≥3q in ≥10 years	2	United States	993	45.9%	-39.7%	-54.5%	-60.6%
TP: ≥4d/≥3q in ≥10 years	3	Canada	247	11.4%	-13.7%	-19.8%	-18.6%
DO: ≥4d/≥3q in ≥3 years	1	United Kingdom	8,425	44.9%	+0.0%	+236.4%	+299.7%
DO: ≥4d/≥3q in ≥3 years	2	United States	2,280	12.1%	-22.7%	-40.3%	-22.7%
DO: ≥4d/≥3q in ≥3 years	3	Mexico	1,815	9.7%	-12.5%	-31.9%	-18.2%
DO: ≥4d/≥3q in ≥5 years	1	United Kingdom	7,463	54.9%	+0.0%	+393.3%	+607.7%

Table S14 (continued). Three strongest absolute ecoregion-q2 leave-one-country-out effects for each distinct network.

Analysis	Rank	Excluded country	Removed	Share	Ecoregion q0 Δ	q1 Δ	q2 Δ
DO: ≥4d/≥3q in ≥5 years	2	United States	1,770	13.0%	-24.6%	-43.4%	-24.2%
DO: ≥4d/≥3q in ≥5 years	3	Mexico	1,577	11.6%	-13.6%	-37.6%	-21.7%
DO: ≥4d/≥3q in ≥10 years	1	United Kingdom	4,933	75.2%	-1.4%	+733.9%	+1325.9%
DO: ≥4d/≥3q in ≥10 years	2	United States	1,096	16.7%	-43.5%	-57.2%	-30.5%
DO: ≥4d/≥3q in ≥10 years	3	Canada	135	2.1%	-8.7%	-10.2%	-4.0%
NO3-N: ≥4d/≥3q in ≥3 years	1	United Kingdom	8,283	44.4%	+0.0%	+196.4%	+192.7%
NO3-N: ≥4d/≥3q in ≥3 years	2	Mexico	1,828	9.8%	-13.1%	-33.9%	-18.5%
NO3-N: ≥4d/≥3q in ≥3 years	3	United States	1,709	9.2%	-24.6%	-33.9%	-17.4%
NO3-N: ≥4d/≥3q in ≥5 years	1	United Kingdom	7,304	49.9%	+0.0%	+256.0%	+262.2%
NO3-N: ≥4d/≥3q in ≥5 years	2	Mexico	1,632	11.2%	-14.4%	-37.7%	-20.9%
NO3-N: ≥4d/≥3q in ≥5 years	3	United States	1,273	8.7%	-27.0%	-32.9%	-16.6%
NO3-N: ≥4d/≥3q in ≥10 years	1	United Kingdom	4,841	78.8%	-1.5%	+842.1%	+1296.9%
NO3-N: ≥4d/≥3q in ≥10 years	2	United States	744	12.1%	-50.0%	-47.4%	-22.7%
NO3-N: ≥4d/≥3q in ≥10 years	3	India	104	1.7%	-12.1%	-9.3%	-3.4%
TSS: ≥4d/≥3q in ≥3 years	1	United Kingdom	5,457	37.0%	+0.0%	+139.2%	+245.1%
TSS: ≥4d/≥3q in ≥3 years	2	Mexico	1,824	12.4%	-14.4%	-35.6%	-22.8%
TSS: ≥4d/≥3q in ≥3 years	3	United States	1,289	8.7%	-22.5%	-28.0%	-16.3%
TSS: ≥4d/≥3q in ≥5 years	1	United Kingdom	4,441	38.7%	+0.0%	+148.8%	+253.1%
TSS: ≥4d/≥3q in ≥5 years	2	Mexico	1,635	14.2%	-16.3%	-39.7%	-26.0%
TSS: ≥4d/≥3q in ≥5 years	3	United States	1,005	8.7%	-23.5%	-28.6%	-16.5%
TSS: ≥4d/≥3q in ≥10 years	1	United Kingdom	2,607	68.9%	+0.0%	+470.6%	+1005.9%
TSS: ≥4d/≥3q in ≥10 years	2	United States	498	13.2%	-40.0%	-44.9%	-24.4%

Table S14 (continued). Three strongest absolute ecoregion-q2 leave-one-country-out effects for each distinct network.

Analysis	Rank	Excluded country	Removed	Share	Ecoregion q0 Δ	q1 Δ	q2 Δ
TSS: ≥4d/≥3q in ≥10 years	3	Australia	213	5.6%	-6.0%	-17.8%	-10.8%
DOC: ≥4d/≥3q in ≥3 years	1	United Kingdom	1,829	20.9%	+0.0%	+52.1%	+64.9%
DOC: ≥4d/≥3q in ≥3 years	2	Mexico	1,810	20.7%	-16.7%	-49.9%	-36.3%
DOC: ≥4d/≥3q in ≥3 years	3	France	2,376	27.2%	-2.1%	+33.9%	+21.5%
DOC: ≥4d/≥3q in ≥5 years	1	United Kingdom	1,078	16.8%	+0.0%	+38.5%	+49.9%
DOC: ≥4d/≥3q in ≥5 years	2	Mexico	1,601	25.0%	-17.4%	-55.1%	-42.5%
DOC: ≥4d/≥3q in ≥5 years	3	France	1,902	29.7%	-2.2%	+41.3%	+34.3%
DOC: ≥4d/≥3q in ≥10 years	1	United Kingdom	179	22.0%	-2.2%	+42.4%	+93.1%
DOC: ≥4d/≥3q in ≥10 years	2	United States	312	38.4%	-54.3%	-59.5%	-55.5%
DOC: ≥4d/≥3q in ≥10 years	3	Canada	162	20.0%	-13.0%	-32.9%	-32.7%
Cohort A: ≥3 days in ≥3 quarters for ≥5 years	1	United Kingdom	5,660	38.3%	+0.0%	+195.5%	+749.6%
Cohort A: ≥3 days in ≥3 quarters for ≥5 years	2	United States	2,815	19.1%	-20.1%	-42.8%	-33.7%
Cohort A: ≥3 days in ≥3 quarters for ≥5 years	3	Mexico	1,588	10.7%	-10.1%	-27.0%	-19.9%
Cohort B: ≥3 days in ≥3 quarters for ≥5 years	1	United Kingdom	371	8.2%	+0.0%	+16.2%	+53.2%
Cohort B: ≥3 days in ≥3 quarters for ≥5 years	2	Mexico	1,529	33.9%	-16.3%	-35.9%	-46.9%
Cohort B: ≥3 days in ≥3 quarters for ≥5 years	3	United States	1,369	30.4%	-30.4%	-42.2%	-45.1%
Cohort A: ≥4 days in ≥2 quarters for ≥5 years	1	United Kingdom	5,782	38.3%	+0.0%	+191.6%	+736.2%
Cohort A: ≥4 days in ≥2 quarters for ≥5 years	2	United States	2,875	19.0%	-20.8%	-42.7%	-33.7%
Cohort A: ≥4 days in ≥2 quarters for ≥5 years	3	Mexico	1,616	10.7%	-10.4%	-26.9%	-19.8%
Cohort B: ≥4 days in ≥2 quarters for ≥5 years	1	United Kingdom	396	8.7%	+0.0%	+17.1%	+56.4%
Cohort B: ≥4 days in ≥2 quarters for ≥5 years	2	Mexico	1,582	34.8%	-16.5%	-36.1%	-47.6%
Cohort B: ≥4 days in ≥2 quarters for ≥5 years	3	United States	1,376	30.2%	-30.8%	-42.5%	-45.1%

Table S14 (continued). Three strongest absolute ecoregion-q2 leave-one-country-out effects for each distinct network.

Analysis	Rank	Excluded country	Removed	Share	Ecoregion q0 Δ	q1 Δ	q2 Δ
Cohort B: ≥4 days in ≥3 quarters (primary) for ≥5 years	1	United Kingdom	370	8.5%	+0.0%	+16.6%	+54.3%
Cohort B: ≥4 days in ≥3 quarters (primary) for ≥5 years	2	Mexico	1,506	34.4%	-16.5%	-36.6%	-47.6%
Cohort B: ≥4 days in ≥3 quarters (primary) for ≥5 years	3	United States	1,327	30.3%	-30.8%	-42.3%	-45.2%
Cohort A: ≥4 days in 4 quarters for ≥5 years	1	United Kingdom	4,912	44.4%	+0.0%	+252.1%	+741.2%
Cohort A: ≥4 days in 4 quarters for ≥5 years	2	United States	2,125	19.2%	-23.1%	-48.2%	-34.2%
Cohort A: ≥4 days in 4 quarters for ≥5 years	3	Australia	868	7.9%	-6.2%	-16.7%	-14.4%
Cohort B: ≥4 days in 4 quarters for ≥5 years	1	United Kingdom	348	13.3%	+0.0%	+29.9%	+74.6%
Cohort B: ≥4 days in 4 quarters for ≥5 years	2	United States	1,074	41.0%	-35.4%	-58.6%	-60.6%
Cohort B: ≥4 days in 4 quarters for ≥5 years	3	Germany	186	7.1%	+0.0%	+15.9%	+33.9%
Cohort A: ≥6 days in ≥3 quarters for ≥5 years	1	United Kingdom	4,166	36.1%	+0.0%	+166.7%	+603.1%
Cohort A: ≥6 days in ≥3 quarters for ≥5 years	2	United States	2,207	19.1%	-21.3%	-42.3%	-33.7%
Cohort A: ≥6 days in ≥3 quarters for ≥5 years	3	Mexico	1,239	10.7%	-11.8%	-26.9%	-19.9%
Cohort B: ≥6 days in ≥3 quarters for ≥5 years	1	United Kingdom	340	10.6%	+0.0%	+23.6%	+71.6%
Cohort B: ≥6 days in ≥3 quarters for ≥5 years	2	United States	1,033	32.1%	-31.8%	-47.4%	-49.4%
Cohort B: ≥6 days in ≥3 quarters for ≥5 years	3	Mexico	917	28.5%	-20.0%	-39.1%	-43.9%

Note: The complete country-by-network matrix is included in the derived CSV package.

Table S15. 1980–2025 sensitivity-window analysis.

Constituent / cohort	Years	Stations	Ecoregions q0 / q1 / q2	Realms q0 / q1 / q2	Leading country
EC	3	28,841	176 / 31.964 / 7.794	7 / 3.291 / 2.594	United States (28.7%)
EC	5	20,681	160 / 34.672 / 8.634	7 / 3.497 / 2.776	United States (30.4%)
EC	10	10,628	122 / 31.286 / 9.755	7 / 3.326 / 2.736	United States (39.4%)
TP	3	21,041	129 / 34.724 / 11.149	7 / 3.357 / 2.734	United States (29.6%)
TP	5	14,102	128 / 43.981 / 17.801	7 / 3.567 / 2.895	United States (33.6%)
TP	10	7,103	87 / 30.604 / 12.978	7 / 3.068 / 2.489	United States (44.4%)
DO	3	24,599	148 / 13.891 / 3.549	6 / 2.552 / 2.012	United Kingdom (36.9%)
DO	5	17,246	130 / 12.102 / 3.216	6 / 2.371 / 1.931	United Kingdom (45.8%)
DO	10	9,004	86 / 7.338 / 2.432	6 / 2.077 / 1.788	United Kingdom (59.3%)
NO3-N	3	23,431	134 / 10.898 / 3.001	7 / 2.243 / 1.729	United Kingdom (38.1%)
NO3-N	5	17,275	128 / 10.662 / 2.919	7 / 2.295 / 1.773	United Kingdom (44.9%)
NO3-N	10	7,961	83 / 5.101 / 1.908	7 / 1.862 / 1.507	United Kingdom (66.1%)
TSS	3	18,821	130 / 19.664 / 5.209	7 / 3.000 / 2.341	United Kingdom (31.2%)

Constituent / cohort	Years	Stations	Ecoregions q0 / q1 / q2	Realms q0 / q1 / q2	Leading country
TSS	5	14,392	119 / 18.601 / 4.971	7 / 3.026 / 2.357	United Kingdom (32.5%)
TSS	10	5,801	73 / 12.769 / 3.902	7 / 2.772 / 2.259	United Kingdom (47.1%)
DOC	3	10,748	98 / 16.346 / 4.973	6 / 2.514 / 2.168	France (22.2%)
DOC	5	7,611	95 / 15.400 / 4.818	6 / 2.602 / 2.246	France (25.0%)
DOC	10	1,714	56 / 12.651 / 4.770	5 / 2.143 / 2.057	United States (26.1%)
Cohort A	5	20,681	160 / 34.672 / 8.634	7 / 3.497 / 2.776	United States (30.4%)
Cohort B	5	6,540	95 / 44.692 / 23.604	5 / 2.976 / 2.628	United States (40.4%)

Note: Cohort A equal-size q2 -42.5%; within-country q2 +0.9%; Cohort B equal-size q2 +81.4%; within-country q2 -3.1%.

Table S16. FEOW non-assignment in every distinct network.

Analysis	Stations	FEOW assigned	Unassigned	Unassigned share
EC: ≥4d/≥3q in ≥3 years	20,460	20,416	44	0.215%
EC: ≥4d/≥3q in ≥5 years	14,387	14,353	34	0.236%
EC: ≥4d/≥3q in ≥10 years	5,328	5,316	12	0.225%
TP: ≥4d/≥3q in ≥3 years	14,088	14,062	26	0.185%
TP: ≥4d/≥3q in ≥5 years	9,554	9,535	19	0.199%
TP: ≥4d/≥3q in ≥10 years	2,163	2,160	3	0.139%
DO: ≥4d/≥3q in ≥3 years	18,775	18,727	48	0.256%
DO: ≥4d/≥3q in ≥5 years	13,594	13,556	38	0.280%
DO: ≥4d/≥3q in ≥10 years	6,560	6,543	17	0.259%
NO3-N: ≥4d/≥3q in ≥3 years	18,635	18,589	46	0.247%
NO3-N: ≥4d/≥3q in ≥5 years	14,633	14,592	41	0.280%
NO3-N: ≥4d/≥3q in ≥10 years	6,144	6,125	19	0.309%
TSS: ≥4d/≥3q in ≥3 years	14,765	14,734	31	0.210%
TSS: ≥4d/≥3q in ≥5 years	11,488	11,465	23	0.200%
TSS: ≥4d/≥3q in ≥10 years	3,786	3,772	14	0.370%
DOC: ≥4d/≥3q in ≥3 years	8,735	8,720	15	0.172%
DOC: ≥4d/≥3q in ≥5 years	6,410	6,398	12	0.187%
DOC: ≥4d/≥3q in ≥10 years	812	810	2	0.246%
Cohort A: ≥3 days in ≥3 quarters for ≥5 years	14,773	14,738	35	0.237%
Cohort B: ≥3 days in ≥3 quarters for ≥5 years	4,506	4,493	13	0.289%
Cohort A: ≥4 days in ≥2 quarters for ≥5 years	15,096	15,060	36	0.238%
Cohort B: ≥4 days in ≥2 quarters for ≥5 years	4,551	4,537	14	0.308%
Cohort B: ≥4 days in ≥3 quarters (primary) for ≥5 years	4,373	4,360	13	0.297%
Cohort A: ≥4 days in 4 quarters for ≥5 years	11,055	11,031	24	0.217%
Cohort B: ≥4 days in 4 quarters for ≥5 years	2,621	2,617	4	0.153%
Cohort A: ≥6 days in ≥3 quarters for ≥5 years	11,550	11,530	20	0.173%
Cohort B: ≥6 days in ≥3 quarters for ≥5 years	3,218	3,214	4	0.124%

Table S17. Complete-read verification for the six official water-quality members.

Official archive member	Bytes	Complete SHA-256
wqms-csv/EC.csv	476,774,760	d19944e97c44aa735ca25f716aff85fa 79afd4d4e3bed433fb484d719ab1ea9b
wqms-csv/TP.csv	145,475,282	4a999a01d4be5caec32df315320a736f 5d52e064f5fddfc9d261c69c2162e6fe
wqms-csv/DO.csv	151,702,889	461d7a8ee4481cd6718a6e645a54456a 801a9ccd5f699e197b6f29c137c98c5b
wqms-csv/NO3N.csv	179,634,013	7a88af199eb8c18e03a7fe07d4e5ccae 1c230922a3fb2cec89b4d34a704c068f
wqms-csv/TSS.csv	106,836,786	7dfbe2285701708a0da6f020ea2a3c0e 5ff978f2c879557fbda5b99a4b6d3eaf
wqms-csv/DOC.csv	54,463,140	369c75e571772d987c72800f63ac2863 03e383d72966d379262ed0d36cfaabf9

Note: Each member was streamed from wqms-csv.zip through end-of-file while its SHA-256 digest was calculated. All six reads completed successfully, and the values match the source register in Table S3.

Table S18. Mexico FEOW composition in primary and four-quarter Cohort B networks.

Rule	Cohort B	Mexico	FEOW unit	Stations	Share of Mexico
Primary 4d/3q	4,373	1,506	167	215	14.3%
Primary 4d/3q	4,373	1,506	173	170	11.3%
Primary 4d/3q	4,373	1,506	165	148	9.8%
Primary 4d/3q	4,373	1,506	169	133	8.8%
Primary 4d/3q	4,373	1,506	164	111	7.4%
Primary 4d/3q	4,373	1,506	168	99	6.6%
Primary 4d/3q	4,373	1,506	170	98	6.5%
Primary 4d/3q	4,373	1,506	162	91	6.0%
Primary 4d/3q	4,373	1,506	138	81	5.4%
Primary 4d/3q	4,373	1,506	171	76	5.0%
Primary 4d/3q	4,373	1,506	160	46	3.1%
Primary 4d/3q	4,373	1,506	135	41	2.7%
Primary 4d/3q	4,373	1,506	201	33	2.2%
Primary 4d/3q	4,373	1,506	159	31	2.1%
Primary 4d/3q	4,373	1,506	137	25	1.7%
Primary 4d/3q	4,373	1,506	163	25	1.7%
Primary 4d/3q	4,373	1,506	130	18	1.2%
Primary 4d/3q	4,373	1,506	134	15	1.0%
Primary 4d/3q	4,373	1,506	172	15	1.0%
Primary 4d/3q	4,373	1,506	202	11	0.7%
Primary 4d/3q	4,373	1,506	174	8	0.5%
Primary 4d/3q	4,373	1,506	161	6	0.4%
Primary 4d/3q	4,373	1,506	131	3	0.2%
Primary 4d/3q	4,373	1,506	132	3	0.2%
Primary 4d/3q	4,373	1,506	Unassigned	2	0.1%
Primary 4d/3q	4,373	1,506	166	2	0.1%
Four-quarter 4d/4q	2,621	166	168	34	20.5%
Four-quarter 4d/4q	2,621	166	162	24	14.5%
Four-quarter 4d/4q	2,621	166	167	18	10.8%

Rule	Cohort B	Mexico	FEOW unit	Stations	Share of Mexico
Four-quarter 4d/4q	2,621	166	171	15	9.0%
Four-quarter 4d/4q	2,621	166	164	14	8.4%
Four-quarter 4d/4q	2,621	166	163	13	7.8%
Four-quarter 4d/4q	2,621	166	160	9	5.4%
Four-quarter 4d/4q	2,621	166	165	8	4.8%
Four-quarter 4d/4q	2,621	166	170	6	3.6%
Four-quarter 4d/4q	2,621	166	135	6	3.6%
Four-quarter 4d/4q	2,621	166	134	5	3.0%
Four-quarter 4d/4q	2,621	166	169	5	3.0%
Four-quarter 4d/4q	2,621	166	201	4	2.4%
Four-quarter 4d/4q	2,621	166	130	3	1.8%
Four-quarter 4d/4q	2,621	166	161	1	0.6%
Four-quarter 4d/4q	2,621	166	131	1	0.6%

Table S19. United Kingdom station concentration across EC minimum-eligible-year thresholds.

Eligible years	UK stations	FEOW unit	Stations in unit	Share of UK
3	7,098	404	6,861	96.7%
3	7,098	402	218	3.1%
3	7,098	Unassigned	19	0.3%
5	5,538	404	5,353	96.7%
5	5,538	402	170	3.1%
5	5,538	Unassigned	15	0.3%
10	2,073	404	2,011	97.0%
10	2,073	402	57	2.7%
10	2,073	Unassigned	5	0.2%

Note: Unassigned stations are retained in the country total but excluded from ecoregion Hill numbers.

Table S20. Feasible range of within-country q=2 departures in the two primary networks.

Cohort	Hierarchy	Within-country median	Concentrated feasible q2 (%Δ)	Exact maximum-even q2 (%Δ)
Cohort A	Ecoregions	5.503	4.466 (-18.8%)	6.303 (+14.5%)
Cohort A	Realms	2.701	2.617 (-3.1%)	2.791 (+3.3%)
Cohort B	Ecoregions	18.976	8.381 (-55.8%)	28.825 (+51.9%)
Cohort B	Realms	2.889	2.703 (-6.4%)	3.106 (+7.5%)

Note: Country totals and the observed FEOW-assigned count are fixed. At fixed assigned N, maximizing $q2=N^2/\Sigma j\ nj^2$ is equivalent to minimizing $\Sigma j\ nj^2$. Binary marginal variables yjk encode the kth count in unit j, so $nj^2=\Sigma k(2k-1)yjk$ and the objective is linear. SciPy scipy.optimize.milp (HiGHS) certified the maximum-evenness solution with relative MIP gap 0.0. The concentrated assignment is feasible and reproducible but is not claimed as the global minimum q2. Results apply only to Cohorts A and B; 'not demonstrated' does not mean mathematically impossible.