www.sciencemag.org/cgi/content/full/science.1196005/DC1

Supporting Online Material for

The Role of Discharge Variation in Scaling of Drainage Area and Food Chain Length in Rivers

John L. Sabo, Jacques. C. Finlay, Theodore Kennedy, David M. Post

Published 14 October 2010 on *Science* Express
DOI: 10.1126/science.1196005

This PDF file includes:

Materials and Methods
Figs. S1 to S3
Tables S1 to S3
References

Supplementary Online Materials

Materials & Methods

Our goal was to assess the effects of ecosystem size (drainage area, or A_d in km^2), environmental stability ($\propto \frac{1}{\sigma_{hf}}$, and return times of $2\sigma_{HF}$ events, described below) and energy supply (gross primary production, *GPP*) on food chain length in stream ecosystems. The dataset analyzed in this paper derives from 36 localities on the Colorado (AZ), Hudson-Delaware (NY), Eel (CA), Mississippi (several states), Owens (CA), Great Lakes-St. Lawrence (MN and Quebec), Columbia (OR) and several other North American drainages (**Table S1**). Of these 36 records, **23** were based largely on our own primary measurements of the four required variables for the analysis. The remaining **13** records were drawn entirely from published studies (**Table S1**).

Methods overview

We used published information (USGS or from published papers) as estimates of drainage area (A_d). Cross sectional area (*CSA*) was estimated at our primary sites based on 1-3 cross sectional depth profiles. A_d and *CSA* are two complementary metrics of ecosystem size (*S1*); here we rely on A_d as it is mechanistically linked to flow variation and various channel features including, *CSA*. Energy supply was estimated as gross primary production (*GPP*) and community respiration (*CR*). Environmental stability was quantified as the inverse of discharge variation. Here we used "catastrophic" variation in high flows (*S2*), or σ_{HF}, as a broad measure of discharge variation. Several other more specific measures of discharge variation were also explored (and described below). Finally we estimated realized food chain length (*S3*) using stable isotopes of carbon and nitrogen (^{13}C and ^{15}N). We describe our methods for estimating GPP, σ_{hf}, and *FCL* in more detail below.

Energy supply via GPP

Energy supply was characterized by measurements of ecosystem metabolism. Ecosystem metabolism (i.e. Gross primary production and ecosystem respiration) provide comprehensive metrics of resource availability because they integrate small scale spatial heterogeneity, and measure activity of small organisms at the base of the food web that have rapid turnover times. Measurements of standing stocks give misleading assessments of energy supply because many potential resources are not accessible to consumers due to low nutritional quality or defenses against consumption. Ecosystem metabolism was assessed using the open channel diel oxygen technique described by Bott et al. (*S4*) during summer, which represent the period of peak productivity in most streams and rivers. In most cases, metabolism was measured 1-6 times in a one to three year period,

but for a small number of sites, up to 20 measurements were made spanning multiple years. Oxygen data were recorded with data loggers; reaeration rates were determined with volatile tracers or estimated from physical parameters; oxygen mass balances were calculated using single station or two station techniques (*S4*).
For the majority of sites, metabolism was measured either as part of the Lotic Intersite Nitrogen Experiment (LINX) project (http://www.biol.vt.edu/faculty/webster/linx/) or the Enhanced Water Quality Monitoring in the Source Areas for the New York City Water Supply project (http://www.stroudcenter.org/research/nyproject/index.htm). Detailed information for methods and data for these sites is available on these websites. Other data were provided by our measurements or recently published data in the literature (Table S1).

Environmental stability via flow variation

We used average daily discharge data from USGS (National Water Information System), Environment Canada, US Forest Service, LTER and other government agencies (**Table S**1) to estimate catastrophic high- and low-flow variation (σ_{HF} and σ_{LF}, respectively) at each of our study sites following (*S2*). Using 16-20 years of data, we estimated the long term (16-20 year) seasonal trend in the daily flow time series using the fast Fourier transform (FFT). We then identified high- and low-flow events as residual flows above or below this long term seasonal trend. To do this we identified strings of dependent residual flows above (high-flow) or below (low-flow) the seasonal average. We extract the maximum or minimum value in each event and compile a set of positive (high-flow) and negative (low-flow) residual flows. Extracting the maximum and minimum in each string removes temporal autocorrelation and allows us to examine the statistical properties of the whitened dataset. The residual flows are then binned by magnitude (x), transformed to achieve linearity, and regressed against frequency (y). The resulting slope is analytically equivalent to the standard deviation of the frequency distribution of the magnitude of residual flow events—above or below the seasonal average. In this way, positive and negative residual flows are treated separately as either the right or left hand side of a normal distribution after transformation leading to separate indices of catastrophic high- and low-flow variation (σ_{HF} and σ_{LF}, respectively). Catastrophic low-flow variation (σ_{LF}) is an index of the probability of anomalously low—but positive, non-zero—to be distinguished from zero-flow (intermittency).

In this paper, we examine the relationship between FCL and one of three flow variables: i) catastrophic high-flow variation (σ_{HF}), ii) the presence of zero flows ("Flow Type") and iii) "return time" of anomalous high flow events. Return times are defined by the time (in years) since the last recorded flow > $2\sigma_{HF}$ in magnitude (within the 20-year record used for σ_{HF} estimation). We ignore the effects of σ_{LF} because the correlation between σ_{HF} and σ_{LF} in our dataset is high ($R^2 > 0.9$) such that the relationship between σ_{LF} .and FCL is nearly identical (below).

Food chain length

In this paper, we used natural abundance carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) stable isotopes to estimate FCL as:

$$\text{Max FCL} = [\text{Max } \delta^{15}\text{N Dev}]/\Delta \quad (1).$$

where Max $\delta^{15}N$ Dev is the maximum deviation in $\delta^{15}N$ between putative baseline groups and top predator species, and Δ is a trophic fractionation factor assumed to be 3.4 ‰ (*S3, S5*). Here, stable isotope data are expressed using the standard "delta" notation:

$$\delta 13C \text{ or } d15N = (R_{sample}/R_{standard} - 1) \times 1000 ‰ \quad (2)$$

where δ is the delta value of the sample for carbon or nitrogen in parts per thousand (‰) and R is the ratio (molar) of the heavy to light (and more common) isotope in the sample and in an international standard, respectively. We used Max $\delta^{15}N$ Dev instead of a 2-end member approach (*S3*) with consistent or fixed end-member groups (e.g., collector-gatherers and filter feeders in all rivers) for three reasons. First, certain functional feeding groups were not present at all of our study locations, making a fixed end-member approach (1- or 2-source) infeasible. Second, some of the published work we used provided $\delta^{15}N$ but not $\delta^{13}C$ data. Third, recent published work in streams suggests that max FCL is a valid index of "true" FCL for comparative purposes (*S5*).

Field methods—For all of our primary data collection sites, we collected putative top predators (invertebrate predators, aquatic salamanders and fish). Collections of top predators were typically made once, near the end of the growing season (typically August or September, except in desert streams where the growing season is interrupted by monsoon storms and floods. In addition to top predator collections, we sampled all putative end members contributing energy to top predators including: grazers, collector-gatherers, filter feeders and shredders. End member collections were done three time at monthly intervals during the growing season, twice prior to and once concurrently with top predator collections. Where possible, we made measurements of whole stream metabolism during the two month end member collection period.

Basic lab methods—End-member and putative top-predator samples were frozen upon collection, and later dried to constant mass in the lab. All samples were dried and ground to a find powder. Samples were analyzed for $\delta^{15}N$ and $\delta^{13}C$ on a Thermo Delta-plus Advantage Isotope ratio mass spectrometer located at the Yale Institute of Biosphere Studies, Earth Systems Center for Stable Isotopic Studies. Our $\delta^{13}C$ values were adjusted for lipid content following (*S6*). Stable isotope data ($\delta^{15}N$ and $\delta^{13}C$) were averaged among replicate (individuals) of each top predator species and within groups (of species) of end-members with a common functional feeding group.

Scaling of σ_{HF} with A_d

Given the strong correlation between σ_{HF} *with* A_d in our FCL dataset (N = 36; 31 perennial and 5 intermittent streams; Table S2), we sought to bolster the quantitative evidence for scaling between drainage area and catastrophic high flow variation (σ_{HF}). To do this, we downloaded mean daily streamflow records from the USGS National Water Information Service Web portal. We used only stations from the conterminous US reporting 20 years (7300 days) of consecutive data with less than 110 (1.5%) missing observations and no more than 2 consecutive missing observations. In this paper we report only those stations for which "drainage area" estimates were available via USGS NWISWeb, for which significant signals (seasonality) were detected, and for which σ_{HF} was defined, consistent with stations associated with the majority of our FCL records. This set of search and analysis filters resulted in 3687 perennial and 866 intermittent streams ranging over 7 orders of magnitude in drainage area. The resulting datasets were analyzed in a mixed model framework via linear regression of A_d *vs.* σ_{HF} using the two digit HUC hydrologic regions as blocks. In this way, we estimated a common slope and a unique intercept for each hydrologic region. We compared the slopes of the perennial and intermittent datasets in a similar mixed-model framework using ANCOVA and inferring slope differences from the interaction term between Flow Type and Drainage Area.

Statistical Analysis

We applied linear mixed effects models (LMEs) to our data using R 2.10.1 and the *lme* package. We analyzed our data in three ways with LMEs: **1)** Univariate LMEs—a single putative control of FCL (e.g., A_d, σ_{HF} or *GPP*) and a single random effect (basin), **2)** Scaling equations in a LME environment, again using basin as a single random effect. Here we fitted data in log-log space (logs were all base 10) to the power function:

$$\sigma_{hf} = cA_d^n \tag{3a}$$

This equation is linear in log-log space, viz:

$$\log 10(\sigma_{hf}) = \log 10(c) + nA_d + MSE \tag{3b}$$

We used linear regression with σ_{hf} as the dependent variable and A_d and basin as the single fixed and random effects. **3)** Path analysis for a model in which we specified direct effects of A_d and σ_{HF} on FCL as well as an indirect effect of A_d on FCL mediated through the effect of A_d on σ_{HF}. We applied this structural model to two datasets: our full dataset including perennial and intermittent streams, and a reduced dataset that included only perennial streams. Sample size was not high enough for intermittent streams to apply the path model to this subset of the full dataset. *GPP* was eliminated from these models based on both low R^2 in univariate analyses.

ANCOVA to test for common slopes and intercepts

We used the interaction term from ANCOVA and *t*-tests, respectively, to analyze differences in the slopes and intercepts between perennial and intermittent rivers from regressions of σ_{HF} vs. FCL and A_d vs. FCL. Where the variances were >3-fold different, we performed a t-test assuming unequal variances (hence adjusted degrees of freedom reported below). The interaction term was not significant for either regression relationship (F=0.07, df=1,27, P=0.8; F=2.2, df=1,27, P=0.15 for σ_{HF} vs. FCL and A_d vs. FCL, respectively); intercepts were similarly not significantly different for σ_{HF} vs. FCL (mean ± se: 0.53±0.04 and 0.49±0.03, perennial and intermittent, respectively; t= -0.33, df= 25.21 , P>0.7) or A_d vs. FCL (mean ± se: 0.5±0.04 and 0.5±0.06, perennial and intermittent, respectively; t= -0.008, df= 7.67 , P > 0.9).

Correlation among putative independent variables

Given the high correlation coefficients between the three independent variables in our Multivariate LME (**Table S2**, we attempted to reduce bias introduced by collinearity by reducing the three independent variables (Flow Type = intermittent/perennial, A_d , σ_{HF}) into a single orthogonal main effect using Factor Analysis ("factanal" command in R) and using the factor scores for each site as a single fixed effect in a univariate LME model. Flow Type and σ_{HF} loaded positively (0.65 and 0.99, respectively) and A_d loaded negatively (-0.55) and the single factor explained only ~57% of the variance. The model was intermediate in fit to the two best multivariate models (*AIC* = -56.48 vs. bolded values in **Table S4**) and R^2_{LR} was only slightly higher (R^2_{LR}=0.45).

R^2 estimation for LME models— R^2_{LR}

We used the Likelihood-Ratio test to estimate the R^2 of mixed effects linear models (*S7*). Here we compare the fit of the mixed model of interest to the intercept-only model and estimate R^2_{LR} as:

$$R^2_{LR} = 1 - \exp\left[-\frac{1}{2}\left(LL_m - LL_{io}\right)\right] \quad (2)$$

Where LL is log-likelihood of the model of interest (*m*) or the intercept only (*io*) model.

Supplementary figures

Figure S1. *Food chain length vs. channel cross sectional area (CSA), both log10 transformed. Points are weighted by log10* σ_{HF}*, red and blue points are intermittent and perennial rivers, respectively.*

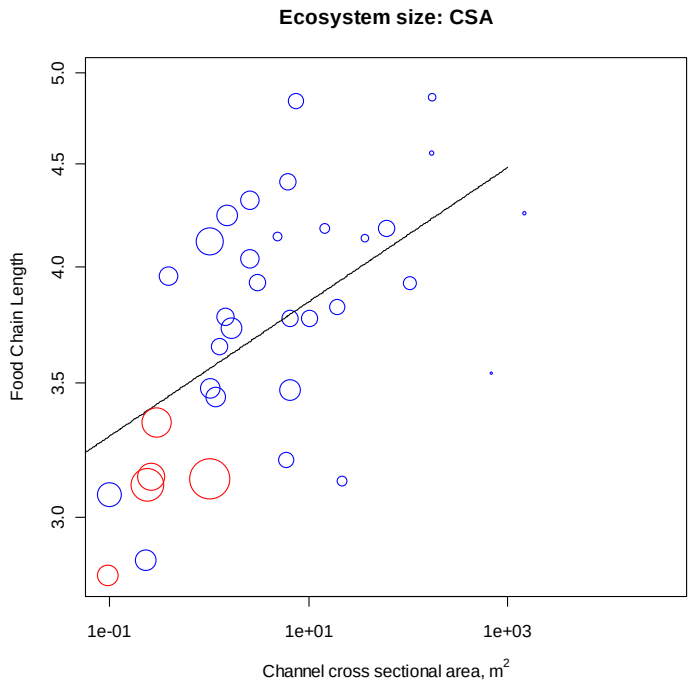


Figure S2: *Food chain length vs. community respiration, both log10 transformed. Circle diameter proportional to log 10 transformed cross sectional area of the stream channel where top predators were collected.*

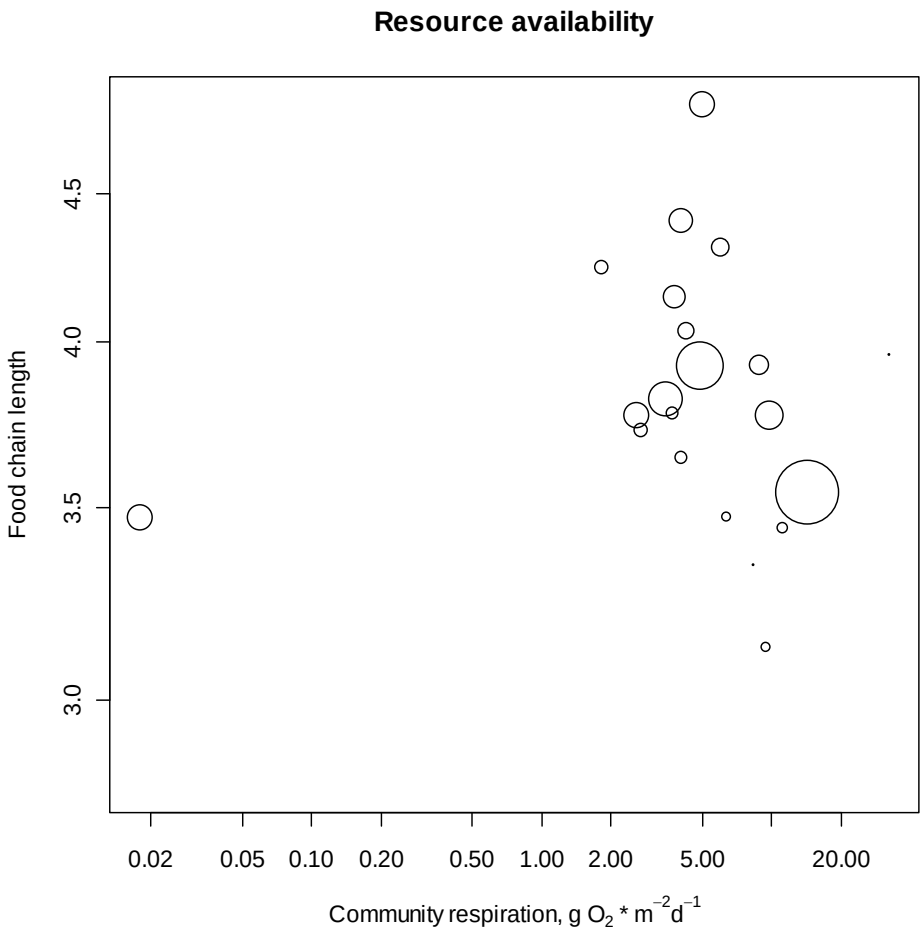
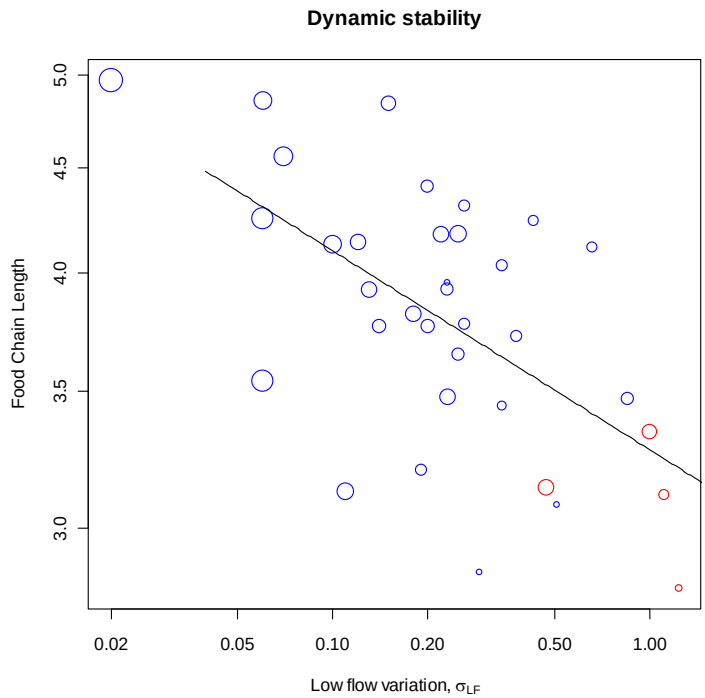


Figure S3: *Food chain length vs.* σ_{LF}*, the standard deviation of residual low flow events (blue and red circles for perennial and intermittent streams, respectively).* σ_{HF} *and* σ_{LF} *are strongly correlated (Table SI2).* σ_{LF} *is undefined for rivers with frequent zero-flows (see Sabo and Post 2008), so the sample size and df are different in analyses of* σ_{HF} *and* σ_{LF}*.*



1 ***Supplementary tables***

2 ***Table S1****: Study sites used in analysis.*

Site	Basin grouping	River System	Top Predator ID	A_d	CSA	GPP Method	Discharge Source†	Zero-flows	Zero-flows Fig 1d††	FCL Sampling Date	FCL Data Source	Citations
Sycamore Creek (AZ)	Desert SW	Salt	Cyprinidae	505	0.3	Open 2	09510200	Yes	Yes	1998	Primary	(*S8*)
Agua Fria River (AZ)	Desert SW	Gila	Cyprinidae	1515	0.266	Open 2	09512500	Yes	Yes	2006	Primary	Primary
Aravaipa Creek (AZ)	Desert SW	Gila	Green Sunfish	1391	1.02	Open 2	09473000	No	No	2006	Primary	Primary
Colorado River, Glen Canyon	Desert SW	Colorado	Rainbow Trout	289303	684	Open 1	09380000	No	NA	2006	Primary	Primary
Owens River (CA)	Desert SW	Owens	Largemouth Bass	1544	4.839	Open 2	LADWP	No	No	2006	Primary	Primary
Salt River (Phoenix, AZ)	Desert SW	Salt	Dragonfly	34247	1.0328	Open 2	09512165	Yes	Yes	2006	Primary	(*S8*)
Catamaran Brook (NF)	Great Lakes-St Lawrence	Miramichi	Brooktrout	12	1.014	NA	EC	No	No	1992	Literature	(*S9*)
Little SW Miramichi River (NF)	Great Lakes-St Lawrence	Miramichi	Atlantic Salmon	1200	61.2	NA	EC	No	NA	1992	Literature	(*S9*)
St Lawrence River, Quebec	Great Lakes-St Lawrence	St. Lawrence	Striped Bass	1000000	37800	NA	EC	No	NA	2000	Literature	(*S10, S11*)
St. Louis River (CR29)	Great Lakes-St Lawrence	St. Louis	Sauger	4745	21.88821	NA	04024000	No	NA	2005	Primary	Primary
St Louis River (Forbes)	Great Lakes-St Lawrence	St. Louis	Sauger	4000	14.6845	NA	04018750	No	NA	2005	Primary	Primary
Cross River (NY)	Hudson Delaware	Croton	Smallmouth Bass	44	1.44	Open 2	01374890	No	No	2005	Primary	(*S12*)
East Branch	Hudson	Delaware	Smallmouth	422	7.406	Open 2	01413500	No	No	2005	Primary	(*S12*)

Delaware River (NY)	Delaware		Bass									
Haviland Hollow (NY)	Hudson Delaware	Croton	Brown Trout	32	1.679	Open 2	01374559	No	No	2005	Primary	(*S12*)
Muscoot River (NY)	Hudson Delaware	Croton	Pumpkinseed	35	2.568	Open 2	01374930	No	No	2005	Primary	(*S12*)
Neversink River (NY)	Hudson Delaware	Delaware	Brook Trout	172	10.212	Open 2	01435000	No	No	2005	Primary	(*S12*)
Titicus River (NY)	Hudson Delaware	Croton	Largemouth Bass	62	1.275	Open 2	01374821	No	No	2005	Primary	(*S12*)
Tremper Kill (NY)	Hudson Delaware	Delaware	Brown Trout	86	3.08	Open 2	01415000	No	No	2005	Primary	(*S12*)
Trout Creek (NY)	Hudson Delaware	Delaware	Black Bullhead	52	2.59	Open 2	0142400103	No	No	2005	Primary	(*S12*)
Hugh White Creek (TN)	Mississippi	Tennessee	Stonefly	0.611	0.096	Open 2	LTER	Yes	Yes	1995	Linx	(*S13-S15*)
Kings Creek (KS)	Mississippi	Kansas	Darter	10.6	0.24	Open 2	06879650	Yes	Yes	1998	Linx	(*S16*)
Upper Ball Creek (NC)	Mississippi	Tennessee	Brook Trout	0.39	0.39	Open 2	USFS	No	No	1998	Linx	(*S17*)
West Fk Walker Branch (TN)	Mississippi	Tennessee	Salamander	0.384	0.1	Open 2	LTER	No	No	1998	Linx	(*S18, S19*)
Mississippi River (Winona)	Mississippi	Upper Mississippi	Longnose Gar	162651	1487.77	NA	05378500	No	NA	2005	Literature	(*S20*)
Kettle River (MN)	Mississippi	St. Croix	Smallmouth Bass	2248	104.95	Open 2	05336700	No	NA	2005	Primary	Primary
Mississippi River (Brainerd)	Mississippi	Upper Mississippi	Smallmouth Bass	18959	37.38	NA	05242300	No	NA	2005	Primary	Primary
Mississippi River (Sauk)	Mississippi	Upper Mississippi	Sauger	34499	171.24	NA	05270700	No	NA	2005	Primary	Primary
Snake River (CR5)	Mississippi	St. Croix	Northern Pike	2481	19.48	Open 1	05338500	No	NA	2005	Primary	Primary
St. Croix River (Osceola)	Mississippi	St. Croix	Sauger	16224	175.1411	NA	05339500	No	NA	2005	Primary	Primary
Quebrada Bisley (PR)	Other	Puerto Rico	Shrimp	0.35	0.23	Open 2	LTER	No	No	1998	Linx	(*S21*)
Kuparuk River (AK)	Other	North Slope	Grayling	150	6.62	Chambers	15896000	No	No	1986	Literature	(*S22, S23*)

Lower Lookout Creek (OR)	Pacific Rim	Willamette	Trout	60.5	5.948745	NA	USFS	No	No	1987	Linx	(*S24, S25*)
Mack Creek (OR)	Pacific Rim	Willamette	Salmon	5.81	1.17	Open 2	USFS	No	No	1998	Linx	(*S26*)
South Fk. Eel River (CA)	Pacific Rim	Eel	Steelhead Trout	130	6.24608	Open 2	11475800	No	No	1999	Primary	(*S27*)
Elder Creek (CA)	Pacific Rim	Eel	Steelhead Trout	17	1.519	Open 2	11475560	No	No	1999	Primary	(*S27*)
Ten Mile Creek (CA)	Pacific Rim	Eel	Steelhead Trout	170	6.6	Open 2	11475800	No	No	1997	Primary	(*S27*)
McKinley Creek (CA)€	Pacific Rim	Eel	Stonefly	0.5	0.111	Open 2	None	Yes	Yes	1998	Primary	Primary
Skunk Creek (CA) €	Pacific Rim	Eel	Stonefly	0.6	0.107	Open 2	None	Yes	Yes	1998	Primary	Primary

† Symbols as follows: EC: Environment Canada; LTER: Long Term Ecological Research network; LADWP: Los Angeles Department of Water and Power; USFS: United States Forest Service; numbers correspond to US Geological Survey gage numbers from the National Water Information System.

†† This column indicates which streams in our dataset were used for the comparison in Figure 1d. We filtered large rivers from this dataset such that groups with and without zero-flow days had a similar range of drainage areas.

€ These streams were included in Figure 2b. They were ungaged and thus we could not reliably estimate $\sigma_{hf.}$ However, we observed them dry during sampling for FCL and thus include them in the intermittent Flow Type category in our analysis of the effects of stream drying on FCL.

Table S2. *Correlations among putative independent variables. All data were transformed to the log 10 scale prior to analysis exept for return times (Return HF and Return LF). Non-significant correlation coefficients are bracketed, significance levels adjusted with Bonferroni correction. Note that these correlation coefficients are univariate with no random effects of basins and thus, may differ from results in the main body of the paper which include random effects.*

	A_d	CSA	GPP	σ_{HF}	σ_{LF}	*Return HF*	*Return LF*
A_d	**1.000**	0.819	0.665	-0.547	-0.749	(0.348)	(0.099)
CSA	**.**	**1.000**	(0.384)	-0.816	-0.868	(0.175)	(0.035)
GPP	**.**	**.**	**1.000**	(-0.092)	(-0.277)	(0.088)	(0.198)
σ_{HF}	**.**	**.**	**.**	**1.000**	0.922	(-0.091)	(-0.218)
σ_{LF}	**.**	**.**	**.**	**.**	**1.000**	(-0.170)	(-0.013)
Return HF	**.**	**.**	**.**	**.**	**.**	**1.000**	(0.139)
Return LF	**.**	**.**	**.**	**.**	**.**	**.**	**1.000**

Table S3: *Results from linear mixed effects model of log10 (FCL) vs. log10 (CSA), with Basin as a random effect.*

Term	df	F	P
Intercept	1, 29	5101.7	<.0001
Log10 (CSA)	1, 29	24.86	<0.0001
Basin	5, 0	1.77	NaN

R^2_{LR} **=0.54**

References

S1. D. M. Post, M. W. Doyle, J. L. Sabo, J. C. Finlay, *Geomorphology* **89**, 111 (2007).

S2. J. L. Sabo, D. M. Post, *Ecological Monographs* **78**, 19 (2008).

S3. D. M. Post, *Ecology* **83**, 703 (Mar, 2002).

S4. T. L. Bott, in *Methods in stream ecology*. (1996) pp. 533-556.

S5. C. Anderson, G. Cabana, *Journal of the North American Benthological Society* **26**, 273 (Jun, 2007).

S6. D. M. Post *et al.*, *Oecologia* **153**, 179 (2007).

S7. L. Magee, *The American Statistician* **44**, 250 (1990).

S8. S8. M. J. Bernot, D. J. Sobota, R. O. Hall, P. J. Mulholland, e. al., *Freshwater Biology* **55**, 1874–1890 (2010).
DOI: 10.1111/j.1365-2427.2010.02422.x
Online link: http://onlinelibrary.wiley.com/doi/10.1111/j.1365-2427.2010.02422.x/suppinfo

S9. R. R. Doucett, G. Power, D. R. Barton, R. J. Drimmie, R. A. Cunjak, *Canadian Journal of Fisheries and Aquatic Sciences* **53**, 2058 (Sep, 1996).

S10. J. A. C. Barth, J. Veizer, B. Mayer, *Earth and Planetary Science Letters* **162**, 111 (Oct, 1998).

S11. A. M. H. deBruyn, J. B. Rasmussen, *Ecological Applications* **12**, 511 (Apr, 2002).

S12. T. L. Bott *et al.*, *Journal of the North American Benthological Society* **25**, 1018 (Dec, 2006).

S13. R. O. Hall, B. J. Peterson, J. L. Meyer, *Ecosystems* **1**, 283 (May-Jun, 1998).

S14. R. O. Hall, J. B. Wallace, S. L. Eggert, *Ecology* **81**, 3445 (Dec, 2000).

S15. P. J. Mulholland, E. R. Marzolf, J. R. Webster, D. R. Hart, S. P. Hendricks, *Limnology and Oceanography* **42**, 443 (May, 1997).

S16. W. K. Dodds *et al.*, *Ecosystems* **3**, 574 (Nov-Dec, 2000).

S17. J. L. Tank *et al.*, *Limnology and Oceanography* **45**, 1013 (Jul, 2000).

S18. P. J. Mulholland *et al.*, *Ecological Monographs* **70**, 471 (Aug, 2000).

S19. P. J. Mulholland *et al.*, *Journal of the North American Benthological Society* **19**, 145 (Mar, 2000).

S20. M. D. Delong, J. H. Thorp, K. S. Greenwood, M. C. Miller, *Regulated Rivers-Research & Management* **17**, 217 (May-Jun, 2001).

S21. J. L. Merriam *et al.*, *Freshwater Biology* **47**, 143 (Jan, 2002).

S22. B. J. Peterson *et al.*, *Ecology* **74**, 653 (Apr, 1993).

S23. K. Slavik *et al.*, *Ecology* **85**, 939 (Apr, 2004).

S24. B. Fry, *Ecology* **72**, 2293 (Dec, 1991).

S25. L. C. Chasar, B. C. Scudder, A. R. Stewart, A. H. Bell, G. R. Aiken, *Environmental Science & Technology* **43**, 2733 (Apr, 2009).

S26. L. R. Ashkenas, S. L. Johnson, S. V. Gregory, J. L. Tank, W. M. Wollheim, *Ecology* **85**, 1725 (Jun, 2004).

S27. T. A. Warnaars, M. Hondzo, M. E. Power, *Water Resources Research* **43** (Aug, 2007).