Ten Years of Macroinvertebrate Data from the Henry's Fork: *What have we learned?*

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Summary

To address angler concerns about decreased hatches, particularly at Last Chance and the upper Ranch, and holistically assess ecological function throughout the mainstem Henry's Fork, we implemented a statistically rigorous study of aquatic invertebrates in 2015. This followed implementation of a watershed-wide water-quality monitoring program in 2014 and prompted subsequent expansion of stream gaging. The result to date is a unique data set of 50 independent observations of macroinvertebrates collected at six different sites on the river over a 10-year period, each accompanied by a full suite of water-quality and streamflow variables. The sites—Flat Rock, Last Chance, Osborne Bridge, Marysville, Ashton Dam, and St. Anthony—represent conditions over the 80 miles of river most popular among anglers. We analyzed invertebrate abundance, five standard community metrics—abundance, Shannon's diversity, EPT taxa richness (the number of mayfly, stonefly, and caddisfly species), Hilsenhoff Biotic Index (HBI), percent non-insects, and percent EPT—as well as the abundance of Pale Morning Duns (*Ephemerella* sp.), *Drunella* mayflies (Flavs + Green Drakes), and Spotted Sedge caddis (Hydropsychidae), three species of interest to anglers. For each of these response variables, we tested for dependence on distance downstream from Big Springs as would be predicted by the River Continuum Concept, difference across sites independent of the river continuum, and dependence on seven streamflow and water-quality variables: annual streamflow, 3-day maximum streamflow, 21-day minimum streamflow, daily flow variability across the year, suspended sediment concentration, conductivity, and 7-day maximum water temperature. The primary results are:

1. By all measures, the aquatic invertebrate communities of the Henry's Fork are abundant, diverse, and stable. Most metrics change predictably with distance downstream as temperature, sediment, and effects of water management increase. However, metrics are as good as or better than on other popular western trout streams and as good or better than they were on the Henry's Fork in previous decades. HBI scores indicate good to excellent water quality all the way to St. Anthony, with little to no evidence of organic pollutants such as wastewater and pesticides. There is no evidence that temperature or sediment are decreasing insect numbers.
2. While most metrics are either improving or stable across the watershed, the number of Pale Morning Duns is decreasing at the watershed scale, driven primarily by a decrease at Flat Rock.
3. Other measures of the invertebrate community at Flat Rock have also degraded substantially over the past decade, likely due to warming temperatures and decreased water supply.
4. None of the metrics we analyzed show any trend one way or the other at Last Chance.
5. Changes in the dry-fly angling experience at Last Chance and the upper Ranch are likely due to a combination of lower trout populations, increased temperatures, and decreased water supply and not likely due to decreased insect numbers.

Why analyze aquatic invertebrates?

Whenever we ask anglers what they value most about their fishing experience on the Henry's Fork, the top answer is invariably the opportunity to fish to rising fish. While this is especially true on the Harriman State Park ("Ranch") reach of the river, it is true on other reaches as well. Whether it is a Green Drake hatch at Flat Rock, Pale Morning Duns at Last Chance, Mother's Day caddis at Ora Bridge, or Gray Drakes on the lower river, the prolific hatches of mayflies, stoneflies, and caddisflies up and down the river are what put the Henry's Fork on the global trout fishing map.

To have rising fish, we obviously need two ingredients: fish and emerging insects. Decades of research and monitoring by Idaho Department of Fish and Game, HFF and other partners are unequivocal about the "fish" ingredient. By river reach, the trout population upstream of Island Park Reservoir is determined by reservoir volume, the population between Island Park Dam and Riverside is determined by winter outflow from Island Park Dam, and the population downstream of St. Anthony is determined by summertime streamflow. There is no doubt that water supply and management determine trout populations in these reaches, which is why the centerpiece of HFF's work is to work with water users and managers to keep as much water in Island Park Reservoir as possible all year, maximize outflow from Island Park Dam during the winter, and maintain stable streamflow downstream of St. Anthony at a scientifically determined summertime target that maintains ecological function while keeping as much water in the reservoir as possible. Everywhere else (Mesa Falls downstream to St. Anthony), trout populations are stable and vary little from year to year no matter what the water supply looks like. And, regardless of river reach, we have never seen any evidence that trout growth is limited by food supply. Despite the large amount of angler concern we receive about streamflow, water quality, river crowding, trout numbers, and hatches, we consistently hear from anglers—even when fishing is tough—that the fish they do catch are always fat and healthy.

So, while we are very confident in our knowledge of what drives trout numbers in the Henry's Fork (simple answer: water), we are much less certain about what drives insect hatches. To help get some answers, we implemented a scientifically rigorous long-term project in 2015 to monitor aquatic insects (and other invertebrates) in the Henry's Fork. In 2024, we collected our 10th year of samples, finally giving us a large enough data set to draw some statistically valid conclusions about aquatic invertebrates and what they tell us about the river.

How do we collect aquatic invertebrates?

Sampling locations

At the start of the program, we recruited a regional aquatic invertebrate expert, Brett Marshall, to oversee field data collection and to conduct all of our laboratory analysis. Brett has over 40 years of experience in aquatic ecology, specifically in the sampling and analysis of aquatic invertebrates as indicators of stream health. Brett has owned and managed a commercial laboratory in Bozeman since 2007, providing services to government agencies and nongovernmental organizations throughout the western U.S. With Brett's input, we selected five permanent sites on the Henry's Fork that were of interest to anglers and represented the range of habitat conditions found on the river between its headwaters at Big Springs and the confluence of the North Fork Teton River. These five locations are Flat Rock, Last Chance, Osborne Bridge, Marysville, and St. Anthony. We added a sixth site downstream of Ashton Dam to monitor any effects of the Ora Bridge construction that took place in 2020. We have collected samples every year for 10 years at Flat Rock, Last Chance and Osborne Bridge, every year but

2020 (due to covid) at Marysville and St. Anthony, and in 2019 and 2021 at Ashton Dam. This has given us a sample of 50 independent observations that represent conditions over the past decade along 80 miles of the river, not coincidentally the same 80 miles referred to in the subtitle of Mike Lawson's book "Fly Fishing Guide to the Henry's Fork".

At the same time as we began designing the invertebrate sampling procedure, we implemented a water-quality monitoring program centered around continuous-recording water quality sondes. More recently, we expanded our stream gaging and hydrologic data compilation programs so that we now have water quality and streamflow data to accompany the invertebrate data at all six locations. This allows us to see whether aquatic insects and other invertebrates respond to changes in streamflow and water quality. See the table below and accompanying map for more details on the sampling locations. Sonde locations and data can be viewed on our water-quality website at https://henrysforkdata.shinyapps.io/scientific_website/, and daily streamflow data can be viewed on our water-quantity site at https://henrysforkdata.shinyapps.io/WaterQuantity/.

Table 1. Aquatic invertebrate sampling locations on the Henry's Fork.

Map ID	Name	Colloquial location description	Elevation (feet)	Dist. from Big Springs (miles)	Years sampled	Streamflow location	HFF water quality sonde(s)
FL	Flat Rock	Flat Rock Club	6388	6.0	2015-2024	Coffee Pot	Flat Rock
LC	Last Chance	Btw. LC boat ramp and Angler's Lodge	6171	23.1	2015-2024	Box Canyon (IP + Buffalo)	Island Park E + Buffalo
OS	Osborne	Btw. hwy. 20 bridge and stock bridge	6112	29.8	2015-2024	Pinehaven	Pinehaven
MY	Marysville	Btw. Jumpoff Cyn. and hwy. 20 bridge	5167	61.6	2015-2019 2021-2024	Ashton	Marysville
AD	Ashton Dam	Ora boat ramp	5107	66.9	2019, 2021	Ashton	Ashton Dam
SA	St. Anthony	Riverside Cemetery	4922	80.1	2015-2019 2021-2024	Trestle (St. A. minus diversions)	St. Anthony

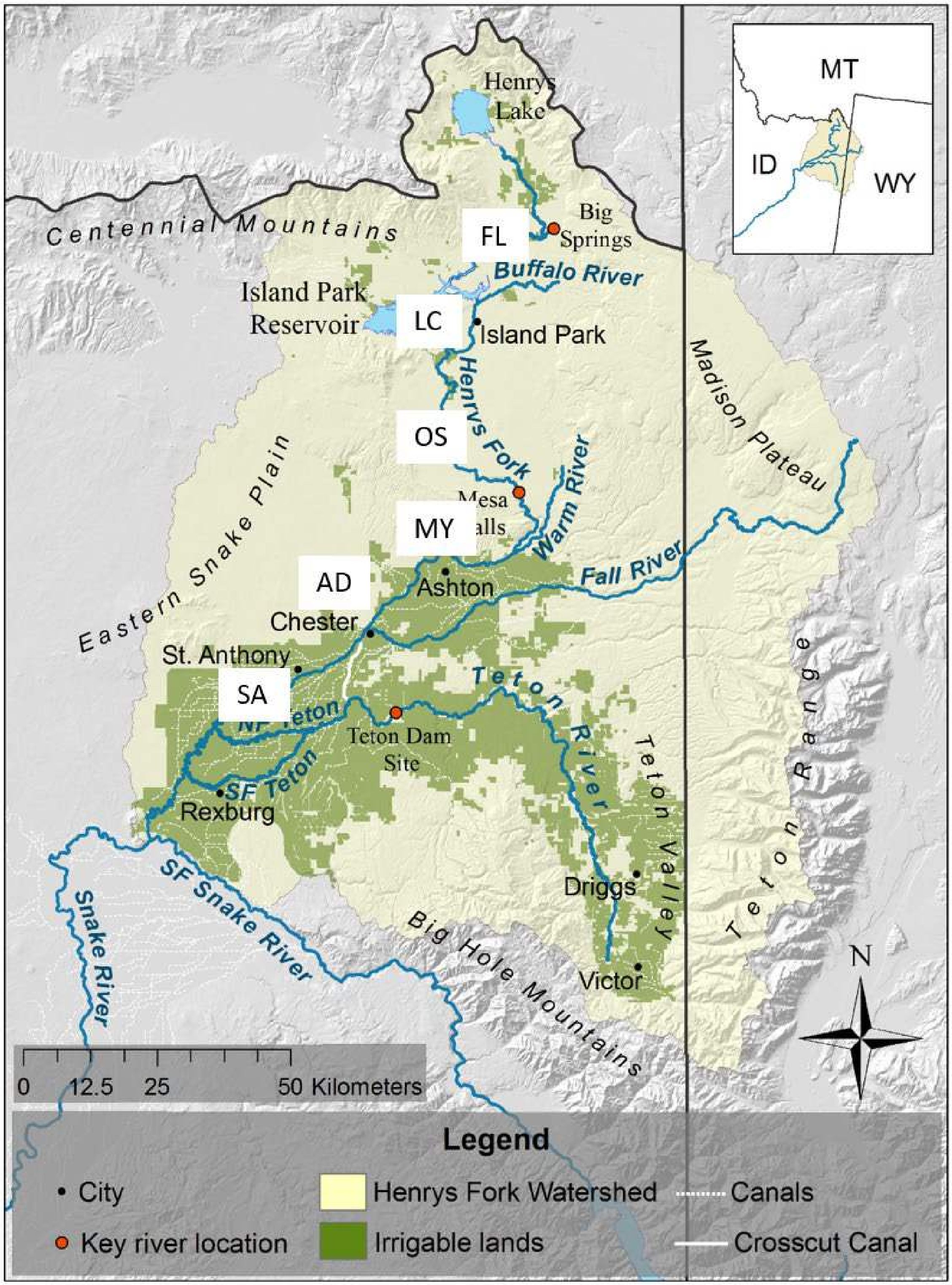

Figure 1. Map of invertebrate sampling locations.

Sample timing

Our sample timing is based on the fact that the vast majority of aquatic insects in the Henry's Fork have a one-year life cycle. Adults emerge at a given time during the year, they mate and lay eggs shortly after emergence, the eggs hatch shortly after that, and the nymphs spend the next 350 days or so in the river before emerging as adults at the same time the following year. So, we collect samples on March 16 every year (plus or minus a day or two), which is several months after the last mayfly hatches of the fall and immediately prior to the first mayfly hatches of the spring. This means that the nymphs of all species that live in the river are large enough to be collected in the samples. If we selected any other time to do the sampling, we would miss species that had just recently laid eggs. For example, if we sampled in early July, we would likely miss Green Drakes, because they would all be eggs at that point and neither available to be captured in the sampler nor identifiable even if we were able to capture them. Exceptions to the one-year life cycle are some of stoneflies such as the giant salmonfly, whose nymphs live several years before emerging and so will always be present no matter when we sample.

Here is one important thing to note about our sample timing. If a given species is present in the sample one March and is also present at roughly the same number the following March, it means that they successfully reproduced. In other words, nymphs present in March of the first year survived and matured, the duns emerged, they molted into spinners, the spinners laid eggs, the eggs hatched, and the nymphs survived until the following March. This happened even if duns or spinners were never observed in large numbers at a given location on a given day of the fishing season at a given time of day. Further, even if a large hatch did not occur under the right conditions to entice fish to rise on the surface, the nymphs provided food for fish feeding underwater for the 350 days they lived in the river.

Field sampling methods

Brett trained us in use of a particular sampler called a "Hess sampler", which is basically an open metal cylinder with mesh on the upstream side of the cylinder to allow water to flow into it and a net sticking out of the downstream side. The cylinder is placed on the stream bottom and pressed down roughly 2 to 3 inches into the bottom substrate, which can range from silt to large cobbles at our Henry's Fork sites. We stir the stream bottom thoroughly to loosen the individual invertebrates, which float up into the water column and are carried by the current down into the net. We then pick up each individual rock within the sampler and scrape all invertebrates off of the rock with a brush. These are also carried by the current down into the net. Everything in the net is poured into jars and preserved with alcohol. See the photo below of Brett and HFF's data manager Melissa Muradian using a Hess sampler.

In 2015, with little funding, a small staff, and no initial data to guide us, we collected three samples at each site. In 2016 and 2017 we collected five samples at each site to improve statistical power, and since then, we have collected six samples at each site each year. Although a larger number of samples is always better from a statistical standpoint, each sample costs almost $695 in staff time, travel, supplies, and Brett's lab costs, and we have found that six samples provides a good balance between data quality and cost. To give you some idea of the effort that goes into Brett's careful field method, it takes four HFF staff and three of Brett's staff around nine hours to collect 30 samples each year at our five permanent sites.

Figure 2. Brett Marshall and Melissa Muradian use the Hess sampler to collect invertebrates at our Marysville site.

Laboratory analysis

The Hess sampler has a known area, in our case 0.1 square meter, so our sampling method is what is known as "quantitative" sampling. That means that we can estimate the number of insects per unit of area of river bottom and compare apples-to-apples estimates of abundance from year to year. Invertebrates in the Henry's Fork are so abundant that each sample contains several thousand individuals, prohibiting Brett from counting every single individual. Thus, he and his crew use what is known as "subsampling," which is a precisely defined method in which around 200 individuals from each sample (an average of around 7% in our case) are randomly selected from the full sample to be identified and counted. The method provides an accurate estimate of the subsampling fraction, so that results from the subsample can be scaled up and reported for the whole sample. As good as this method is, it can still result in very large or rare species being missed, so for the reporting of certain measures, Brett and his crew conduct what is called a "large and rare" search that is biased toward such species to make sure that the total number of species reported is as accurate as possible. We use data from the random subsampling for most of our analyses but use the large and rare value for total number of mayfly, stonefly and caddisfly species present in the sample. The numbers Brett reports for each sample are multiplied by 10 to obtain numbers per square meter of river bottom, and then we can use that to estimate roughly total numbers of individuals over whole river reaches.

How did we analyze the data?

Invertebrate response variables

With hundreds of species observed over the 10 years of sampling, dozens of species that are of interest to anglers, and only 50 independent data points to work with, we had to pare hundreds of possible analyses down to a small number in order to learn as much as possible while minimizing the chance of obtaining spurious statistical relationships. We ultimately chose to analyze total invertebrate abundance, five so-called "community metrics" (discussed individually below), and abundance of Pale Morning Dun (PMD) mayflies, *Drunella* mayflies (Flavs *Drunella flavilinea* and Green Drakes *Drunella grandis* combined), and the Spotted Sedge caddis (Hydropsychidae). The community metrics are well established measures of the relative abundance and types of invertebrates that indicate the overall health and function of the river. They have been used all over the world for decades as indicators of water quality and aquatic ecosystem health. We chose to analyze PMDs and the Spotted Sedge caddis because those are the two hatches we hear most often from anglers that have declined substantially at Last Chance and the upper Ranch in recent years. We chose *Drunella* mayflies because they are iconic on the Henry's Fork, important to anglers, and extremely sensitive to water quality and habitat degradation. *Drunella* mayflies and PMDs were collected at all sites in all years, and the Spotted Sedge caddis was collected at all sites in all years except Flat Rock in 2023 and 2024.

Potential environmental predictors

It is well established that the types and numbers of aquatic invertebrates in streams are primarily dependent on streamflow, aquatic ecosystem productivity, fine sediment, and water temperature. We used seven variables measuring these four environmental characteristics that could potentially influence invertebrates in the Henry's Fork.

1. **Annual streamflow**. Overall water quality and habitat availability is better in years with higher streamflow.
2. **3-day maximum streamflow (aka "freshet")** during the spring (prior to July 1). A higher springtime freshet is expected to remove fine sediment and have other positive effects on habitat quality for species that do not tolerate fine sediment.
3. **21-day minimum streamflow.** Long-duration low flows limit the amount of habitat available in the stream channel, thereby potentially limiting the abundance of invertebrates.
4. **Streamflow variability,** as measured by the coefficient of variation in daily streamflow across the year. Some species prefer relatively stable flows, as would be observed in a groundwater-dominated stream or a constant-flow tailwater. On the other hand, high flow variability is likely to create a higher diversity of physical habitat, leading to higher species diversity.
5. **Conductivity** during the growing season (April 1 – October 31). Conductivity measures the concentration of soluble ions in the water. In the range of values we observe in the Henry's Fork, conductivity is a surrogate for primary production potential, with higher values indicating higher productivity.
6. **Suspended sediment concentration** during summer/fall (July 1 – October 31). Sediment delivered to river reaches in the Henry's Fork during this time period is likely to be trapped on the stream bottom by macrophytes or deposited because of low flows, thereby reducing habitat quality for sediment-intolerant species.
7. **7-day maximum water temperature**. The literature suggests that maximum temperature limits presence of individual species, especially mayflies and stoneflies valued by anglers.

These variables are calculated from raw data measured by HFF's water-quality sonde and stream gage network, our weekly water samples, and U.S. Geological Survey stream gages. The values were calculated over the year (or portion of the year) immediately preceding annual mid-March sampling, to capture the habitat conditions present over the life span of the most of the insects being collected.

While these fundamental characteristics are expected to influence aquatic invertebrates, we also tested the effect of location along the river, since other variables such as stream-bottom substrate type (sand, gravel, cobble, etc.), shading, stream width-to-depth ratio, and growing season length vary across locations and may not be represented by the streamflow and water-quality variables. The simplest potential effect of location is measured by **distance** downstream from the river's headwaters at Big Springs, according to the "River Continuum Concept" (RCC), a fundamental tenet of stream ecology. The RCC states that a river's ecosystem varies predictably from the headwaters downstream as the stream gets wider, the growing season gets longer, water temperatures increase, floodplain complexity increases, and the effects of watershed processes such as erosion and deposition accumulate over a larger and larger area. The RCC predicts that with increased distance downstream, invertebrate abundance and species diversity should increase, while the fraction of species that are intolerant of fine sediment, habitat degradation, and warm temperatures should decrease.

However, we expect that the RCC may not apply very well to the Henry's Fork for two reasons. First, the river is groundwater fed, geologically very young, very wide relative to its depth right from the source at Big Springs, and generally disconnected from surface watershed processes because the watershed is flat and there are few tributaries connecting upland areas to the main river. Second, the river continuum is interrupted by Island Park Dam, Ashton Dam, and diversion of much of the river's streamflow at and downstream of Chester Dam. These disruptions alter streamflow, temperature, and/or nutrient and sediment transport, thus altering otherwise predictable changes in the river as it flows downstream. Thus, we also tested the possibility that differences across **sites** that were not easily measured by the raw environmental variables or distance downstream had the greatest impacts on aquatic insects and other invertebrates. Lastly, we tested whether the types and numbers of invertebrates present in the Henry's Fork show any systematics **trends** over our 10 years of investigation.

Statistical methods

I'll spare you the details of statistical methods in this document except to say that we used well accepted statistical methods for handling what we refer to as "hierarchical" or "nested" data. In particular, the samples taken within a given site in a given year were averaged to obtain a single value for that site and year. For watershed-wide analysis of invertebrate responses to streamflow and water quality, we used all 50 of the independent site-year observations in what is referred to as multi-model inference. For analysis of trends over time, we omitted the two observations taken at Ashton Dam in 2019 and 2021 but used all data from each of the other five sites. We calculated individual trends within each site and then averaged the within-site trends over all five sites to obtain a watershed average.

What did we learn?

Habitat characteristics

Before even looking at the insects themselves, the streamflow and water-quality data clearly showed both the expected changes along the river continuum and the disruptions to the continuum we anticipated at Island Park Dam, Ashton Dam, and Chester Dam. See Figure 3, at the end of the text.

The streamflow variables were divided by the 1978–2024 average streamflow at each site to allow apples-to-apples comparisons across sites at different locations in the watershed. This also allowed us to put the last 10 years in the context of the longer period of record, given that the river's natural streamflow was much greater in the 1970s–1990s that it has been since 2000. For example, you can see that over the last 10 years, annual streamflow at all locations was less than the long-term average (values on the graph less than 1) in almost all years of our study. It is also apparent that average annual streamflow within a given year was fairly constant from Flat Rock downstream to Marysville, since Island Park Dam changes only the timing of streamflow throughout the water year and not the total amount of annual flow. However, annual flow at St. Anthony was quite a bit different than at the other four locations because the relative amount of the river's annual flow diverted for irrigation differs substantially across years. Thus, the year-to-year variability in annual flow is much greater at St. Anthony. The apparent lower variability at Ashton Dam is just an artifact of having only two years of data there. The 3-day maximum flow largely reflects natural flow availability and was higher both in magnitude and variability at St. Anthony than at the other locations. Despite delivery of managed freshets at Island Park Dam during the spring of several years in the dataset, the magnitude and variability of freshet flows was lower at Last Chance and Osborne Bridge than elsewhere. Conversely, flow regulation at Island Park resulted in much higher variability in low flows—and generally lower minimums—at Last Chance and Osborne than at the other locations. Not surprisingly, because of adherence to a low-flow target at St. Anthony set to keep as much water in Island Park Reservoir as possible, minimum flows at St. Anthony were the lowest across all sites, with little year-to-year variability. Daily flow variability was highest—and had the highest variability from year-to-year—at Last Chance and Osborne Bridge. Taken together, the flow variables clearly show the effects of storage and delivery at Island Park Dam and diversion between Ashton Dam and St. Anthony, illustrate that flow regimes do not follow predictable changes along the river continuum, and indicate that our sample sites vary substantially in flow characteristics.

While conductivity generally increased from headwaters to St. Anthony as would be expected, conductivity at Osborne Bridge was higher than expected based on this trend, primarily because of higher summertime water temperatures. That said, conductivity varied relatively little across sites and was very low in comparison to most other trout streams in our region because the volcanic rocks in the Henry's Fork watershed contain very low concentrations of soluble ions. Suspended sediment concentrations also generally increased from headwaters to St. Anthony as would be expected, with the exception of much higher sediment concentrations at Last Chance due to export of fine sediment from Island Park Reservoir during the summer and fall. Most of that fine material is either trapped or consumed between Last Chance and Osborne, where suspended sediment concentrations are about what we would expect at that location along the river. Lastly, maximum water temperatures generally increase with distance downstream as would be expected, with the exception of warmer-than-expected temperatures at Osborne Bridge as a result of the naturally wide, shallow, unshaded river reach through Harriman State Park. In this case, the disruption to the river continuum comes from the natural volcanic geology, not from Island Park Dam.

Invertebrate abundance

We measure abundance as the number of individuals per square meter (m^2) of stream bottom. Abundances ranged from 12,390 individuals/m^2 at Last Chance in 2022 to 86,540 at Osborne Bridge in 2015. The average over all sites and years was 35,920 individuals/m^2, or in more familiar units, around

3,337 individuals per square foot. To give you some idea of just how many individual insects (and other invertebrates) that is, the river at Last Chance is about 300 feet wide, so one mile (5,280 linear feet) of river there has an area of 300×5280 = 1.58 million square feet. Average abundance at Last Chance is around 2,800 individuals per square foot, so one mile of river in the vicinity of our Last Chance sampling location contains about 4.4 billion individual invertebrates. As a more specific example, in 2024 there were around 289 million Pale Morning Duns and 23 million Green Drakes per mile at Last Chance.

An obvious question is "Is 35,920 individuals/m^2 high or low?" Comparable data are hard to come by, because few organizations or institutions collect data that are this extensive and rigorous. However, the Bighorn Alliance and the Upper Missouri Watershed Alliance each conduct annual macroinvertebrate monitoring using similar methods as HFF. The average abundance in springtime samples taken on the Bighorn River from 2021 to 2023 is 30,000 individuals/m^2, comparable to the Henry's Fork. The average abundance reported from the upper Missouri River between 2015 and 2023 is somewhat lower, at around 12,500 individuals/m^2, but some of the samples were taken in the summer and fall, when abundances are likely to be lower. Average abundance was 21,697 individuals/m^2 in the Henry's Fork at Last Chance and Osborne Bridge in the spring of 1993, after the 1992 sediment event at Island Park Dam. Average abundance at Coffee Pot (comparable to our current Flat Rock site) in the spring of 1993 (affected by upstream land use and the 1988 Yellowstone fires but not the reservoir sediment event) was around 12,000 individuals/m^2. In his work around the western U.S., Brett Marshall has observed abundances upwards of 100,000 individuals/m^2, and in fact we have observed abundances close to 100,000 individuals/m^2 in some years on the South Fork. In these cases, however, the samples are dominated by midges and/or non-insects to the point where 100,000 individuals in total may contain far fewer mayflies, stoneflies, and caddisflies than present in 35,000 individuals on the Henry's Fork.

Further insight into abundance on the Henry's Fork is provided by the upper left panel in Figure 4, which shows abundance values as a function of distance down the river continuum, with the sites indicated along the top of the graph. We found no change in abundance along the river continuum and no average difference across our sampling sites. In addition, we found no statistically significant dependence of abundance on any of the predictor variables (see Table 3). The best statistical model included distance downstream as a predictor variable, but it was not statistically significant, and the model explained only 10% of total variability in abundance. That means that abundance of invertebrates in the Henry's Fork is essentially constant across our sampling sites and although variable from year to year, does not vary in response to any of the standard streamflow or water quality variables we measure. We rarely, if ever, hear that hatches have declined in river reaches such as Warm River to Ashton or Ora to Vernon, which have the same overall invertebrate abundances as places like Last Chance, where we consistently hear that hatches have declined. If 35,000 individuals/m^2 are sufficient to maintain good hatches, healthy fish, and good fishing conditions in the river reaches downstream of Warm River, any perceived decline in the fishing experience in the Ranch must be due to some factor other than the number of invertebrates. As a final observation on abundance, we have observed a significant decreasing trend over the past 10 years (Figure 5), driven by significant decreases at Flat Rock, Osborne, and St. Anthony. Reasons for this decline are discussed in subsequent sections.

Diversity of Invertebrates

Diversity of an ecological community is a measure both of how many different types of organisms are present and how the total number of individuals is distributed across those different types. Higher diversity is indicative of high availability of a variety of different habitat types and of good function of the ecological processes that maintain those habitat types. In stream ecosystems, this means that streamflow regimes, riparian conditions, stream substrate scour and deposition, and nutrient availability are in balance and functioning to create and maintain good numbers of a variety of different invertebrate types. Further, high diversity indicates a high degree of resilience to changes in any of these characteristics; if one element of the stream ecosystem changes and no longer favors a particular species, there is always another one present that will benefit from the change. We measured the diversity of the invertebrate community with Shannon's diversity index, a very common measure used in ecology and a number of other scientific disciplines. Shannon's index ranges from 0 at the extreme case in which the community essentially consists of only one species up to the natural logarithm of the total number of different species present in the case that each species is equally represented. So, for example, if 20 species are present, the theoretical maximum diversity would be the logarithm of 20, which is 3. In our samples, the number of species present ranged from about 20 to 40, with an average close to 30. That means that the maximum diversity possible in the Henry's Fork ranges from around 3 to 3.7, if those 20–40 species were equally represented.

Diversity ranged from 1.7 at Flat Rock in 2023 to 3.1 at St. Anthony in 2016 and averaged 2.7 across all sites and all years. These numbers indicate very diverse invertebrate communities overall, with values at St. Anthony close to the maximum possible for the given numbers of species present. Shannon's diversity is not reported directly in publicly available data from the upper Missouri and Bighorn, but the total number of species reported on the Bighorn River is comparable to those in our Henry's Fork samples, around 20-40. In the spring of 1993, Shannon's diversity averaged 2.4 at Last Chance and Osborne Bridge and 2.2 at Coffee Pot, just a little lower than what we have observed. Over all invertebrate data collected on the Henry's Fork between 1993 and 2007—much of it admittedly not directly comparable to our modern data—Shannon's index averaged 2.1, quite a bit lower than our modern average of 2.7. Unlike abundance, diversity increased significantly with distance downstream (Figure 4), as would be expected from the RCC. The best statistical model for diversity included distance as a predictor but also temperature, with higher diversity being associated with lower temperatures, after accounting for the strong distance effect (Table 3). While we observed a significant change in diversity with distance downstream, we have observed no changes in diversity over time (Figure 5), indicating robust, stable, and resilient invertebrate communities.

Number of Mayfly, Stonefly, and Caddisfly Species (EPTT)

These three insect orders (**E**phemeroptera, **P**lecoptera, and **T**ricoptera, respectively) are not only the most important to anglers but are also highly indicative of water and habitat quality. Thus, a standard metric for assessing water quality is the so-called EPT Taxa richness, EPTT for short. The term "taxa" is used instead of species to acknowledge the fact that sometimes, it is not possible to distinguish individual insect larvae ("nymphs") down to the species level, so that higher taxonomic levels such as genus or even family might be used in the calculation. In any case, you can think of it as the number of different species of mayflies, stoneflies, and caddisflies present. In our samples, EPTT ranged from 8.2 at Osborne Bridge in 2020 to 17.2 at Marysville in 2023, with an average of 12.9 over all sites and years. Generally, EPTT values of 10 or more (or roughly 30% of all species present) is considered good, and our values fall in that range, similar to values observed on the Bighorn. We found no systematic dependence of EPTT on distance downstream along the river (Figure 4), but we did observe significant differences across sites, with EPTT consistently higher at Marysville than at the other locations. After accounting for difference across sites, EPTT was higher when streamflow variability throughout the water year was higher (Table 3). In addition, we observed a significant increasing trend in EPTT at Marysville and across all five sites as a whole over the past 10 years (Figure 5).

Hilsenhoff Bioitic Index (HBI)

The HBI score is a widely used index of water quality, specifically degradation due to organic pollution such as untreated wastewater, fertilizers, petrochemicals, and pesticides. The score is based on tolerance of each type of invertebrate to such pollution. The most sensitive species, such as Flavs and the giant salmonfly, have a tolerance score of 0, while the species most tolerant of water pollution have a score of 10, for example many aquatic worm species. Most mayfly, stonefly and caddisfly species have tolerance values in the range of 1–4. For example, tolerance scores for Pale Morning Duns, *Tricorythodes* mayflies (tricos) and *Brachycentrus* caddis (for example, the "Mother's Day Caddis") have tolerance scores of 2, 4, and 1, respectively. The HBI is simply the average of species-level tolerance scores across all individuals present in the sample, where the average is weighted by the number of individuals of each species. This produces a score between 0 and 10, where 0 is indicative of the best possible water quality, and 10 is indicative of the worst water quality. Specifically, larger numbers of intolerant species (most of the mayflies, stoneflies, and caddisflies) will produce a lower score. The numeric scores are interpreted qualitatively according to a widely used scale:

- 0–3.75: Excellent water quality; no apparent organic pollution
- 3.76–4.25: Very good water quality; slight organic pollution possible
- 4.26–5.00: Good water quality; some organic pollution apparent
- 5.01–5.75: Fair water quality; fairly significant organic pollution
- 5.76–6.50: Fairly poor water quality; significant organic pollution
- 6.51–7.25: Poor water quality; very significant organic pollution
- 7.26–10: Very poor water quality; severe organic pollution

In our samples, HBI ranged (from worst to best) from 5.9 at St. Anthony in 2015 to 2.4 at Flat Rock in 2016 and averaged 4.0 over all sites and all years. So, our average score falls into the very good range, indicating possible slight organic pollution. The average HBI over all invertebrate samples collected on the Henry's Fork between 1993 and 2007 was 4.2, indicating no substantial change over the past 30 years. For comparison, the average HBI reported for the Missouri River is 5.7 and that for the Bighorn River is around 6.0, with most sites in most years having HBI scores greater than 5. As predicted by the River Continuum Concept, we observed a significant increase in HBI score (decrease in water quality) from headwaters to St. Anthony (Figure 4), although differences across individual sites was a better predictor of HBI than simply distance downstream. This is primarily because HBI was a little higher than expected (worse water quality) at Osborne Bridge and a little lower (better water quality) at Marysville. After accounting for the differences across site, HBI was lower (better water quality) in years following higher annual streamflow and warmer temperatures. The HBI showed no significant trend one way or the other over the past decade, despite a significant improvement at Osborne Bridge (Figure 5).

Percent Non-insects

This is simply a measure of what fraction of individuals in the sample is made up of species other than insects. These include worms, leeches, and snails. Although many of these species provide fish food and are relatively intolerant of pollution, their presence is often associated with high amounts of fine sediment and other types of physical habitat degradation. Percent non-insects ranged from 7.8% at St. Anthony in 2024 to 38.7% at St. Anthony in 2015 and averaged 22% across all sites and all years. As with total abundance of invertebrates, we found no difference in percent non-insects along the river continuum or across sites (Figure 4) and no significant environmental predictors (Table 3). Also similar to the trends we saw in total abundance, the percent of non-insects has been declining over the past 10 years, led by significant decreases at Osborne and Marysville (Figure 5). One potentially troubling trend, however, is an increase in non-insects at Flat Rock.

Percent Mayflies, Stoneflies, and Caddisflies (%EPT)

This is a measure of the fraction of individuals present in the sample that are mayflies, stoneflies, and caddisflies and, along with HBI, is a standard measure of water quality. Values greater than 30% are considered good. In our samples, %EPT ranged from 22.2% at St. Anthony in 2016 to 74.9% at Flat Rock in 2016, with an average of 53% over all sites and years. This is similar to the average of 51% reported for the upper Missouri but quite a bit higher than the average of around 30% on the Bighorn. The average over all data we have from the Henry's Fork from 1993 to 2007 is 49%, pretty close to its current average. We observed a significant decrease in %EPT with distance downstream, as would be expected by the River Continuum Concept (Figure 4). However, as with HBI, variability across individual sites was greater than predicted by the river continuum, again driven primarily by higher values than expected at Marysville. Also similar to HBI, we found that after accounting for the site differences, %EPT was higher when temperatures were warmer (Table 3), and %EPT has improved significantly over the past 10 years, driven again by an improvement at Osborne Bridge (Figure 5).

Given an increase in EPT Taxa and %EPT and a corresponding decrease in percent non-insects, it is apparent that the decrease in overall abundance has resulted mostly from decreases in non-insects and in insects other than mayflies, stoneflies, and caddisflies (midges, for example). The result is an overall improvement in the community composition, potentially reflecting improved habitat conditions and ecological function, especially at Osborne and Marysville.

Pale Morning Duns

Abundance of PMDs ranged from 365 individuals/m^2 at St. Anthony in 2017 to 30,511 at Flat Rock in 2016, with an average of 7,701 individuals/m^2 over all sites and years. Another way of looking at PMD abundance is that it has ranged from 2% to 61% of the total invertebrate community, with an average of 21%. That is, over all sites and all years, over 20% of all individual invertebrates present on the stream bottom are PMDs. Data from the Bighorn River show that PMDs are typically less than 4% of all individuals. We have not dug into the details of Henry's Fork datasets from the 1990s and 2000s enough to pull out estimates of PMD abundance. However, in our modern data, PMD abundance shows a systematic decrease with distance downstream, as we would expect from the River Continuum Concept (Figure 6). Unlike in the statistical models for EPTT, HBI, and %EPT, the river continuum dependence provided a better predictive model of PMD abundance than individual differences across the six sites. After accounting for dependence on distance downstream from Big Springs, none of the streamflow or water quality variables had any explanatory power. This is especially noteworthy because 7-day maximum temperatures have generally been in the upper 60s to mid-70s (Fahrenheit) over the course of our study, and the literature suggests a maximum of tolerance of around 65 degrees for PMDs. Thus, PMDs are persisting in the Henry's Fork at much higher temperatures than suggested by other studies, and we saw no strong relationship between PMD abundance and temperature. That could be because the temperatures recorded at our sonde locations are not fully indicative of localized cooler water refuges associated with groundwater inputs, which we know occur throughout the river. That said, PMD abundance has been systematically decreasing across the watershed for the past decade, driven primarily by a large decrease at Flat Rock and to a lesser degree by a modest decline at St. Anthony (Figure 7). Our data show no evidence of systematic trends in PMD abundance one way or the other at Last Chance, Osborne, or Marysville.

Drunella (Flav + Green Drake) abundance

Drunella abundance ranged from 51 individuals/m^2 at St. Anthony in 2017 to 4,822 individuals/m^2 at Last Chance in 2020 and averaged 1,311 individuals/m^2 over all sites and all years. This is an average of 4% of all invertebrates present at any given time and location on the Henry's Fork. Again as expected, *Drunella* abundance decreases with distance down the river (Figure 6), although numbers at Last Chance are much higher than expected based solely on distance. Indeed, the best statistical predictor of *Drunella* abundance was simply differences across the individual sites, with no environmental predictor adding any explanatory power (Table 3). *Drunella* abundance shows no significant trend one way or the other across the watershed; a significant decrease at Flat Rock is offset by significant increases at Osborne and Marysville (Figure 7). As with PMDs, no significant trend in *Drunella* is apparent at Last Chance.

Hydropsychidae Caddis (Spotted Sedge) abundance

Spotted Sedge abundance ranged from 0 at Flat Rock in 2023 and 2024 to 8,206 individuals/m^2 at Marysville in 2021 and averaged 1,452 individuals/m^2 across all sites and years. On average this is about the same as abundance of Flavs and Green Drakes. However, Spotted Sedge numbers were much more variable across locations, being far more abundant at Last Chance and Marysville than anywhere else (Figure 6). After accounting for this substantial variability across sites, Spotted Sedge numbers were higher following years of higher suspended sediment concentrations (Table 3). No significant trend in Spotted Sedge abundance was apparent at any of our sites (Figure 7).

So What?

While it is obvious that this dataset—combining rigorous invertebrate sampling with extremely detailed water-quality and streamflow monitoring—provides a unique and unprecedented view of aquatic ecosystem function in a unique river system, the results will no doubt disappoint many anglers, who would like to see a "smoking gun" that points to an easily identifiable (and hopefully rectifiable) reason for the apparent decline in hatches at Last Chance and the upper Ranch. The reality is that even a dataset this rich cannot capture the level of detail in insect life histories and behavior to explain why a particular hatch occurs at a particular location at a particular time of day. And remember where we started; to have rising fish, you need fish, and we know with certainty that trout numbers at Last Chance and in the Ranch are around 50% to 75% lower than they were in the 1970s through 1990s due to lower water supply. But, here are some take-home messages from the insect part of the equation.

The Henry's Fork Invertebrate community is robust and stable

By any measure, the aquatic invertebrate community up and down the river is abundant, diverse, and indicative of good to excellent water and habitat quality. Over half of the individuals are mayflies, stoneflies, and caddisflies, and that percentage has been improving over the past decade, along with the number of mayfly, stonefly, and caddisfly species present. Other community metrics are stable; none are showing any indication of degradation of habitat or water quality at the watershed scale. All metrics on the Henry's Fork are as good or better than on the two other popular trout rivers from which we have comparable data. Further, conditions over the past 10 years on the Henry's Fork are at least as good as they were when measured between 1993 and 2007 and in most cases are better. Upstream of Island Park Reservoir, improvements are likely related to recovery from sediment originating with the 1988 Yellowstone fires, improvements in grazing management on Henry's Lake Flat implemented in the 1990s, and more stable outflow from Henry's Lake over the past decade. Immediately downstream of Island Park Dam, improvements are due to recovery from the 1992 sediment event, some occurring incidental to routine water management and others occurring because of intentional release of freshet flows to remove fine sediment from the stream bottom. In the lower watershed, improvements are likely due to more careful streamflow management designed first and foremost to save water in Island Park Reservoir but that also have the benefits of reducing variability in summertime streamflows downstream of St. Anthony and allowing a more natural hydrograph there during spring runoff.

Fine sediment and water pollution are not limiting invertebrates

Suspended sediment concentration was a significant statistical predictor of only one of our response variables, and the relationship was positive—more sediment was associated with higher Spotted Sedge abundance. This is because that species feeds on fine particles of organic matter suspended in the water column. Otherwise, we found no evidence that suspended sediment was associated with lower numbers of PMDs or *Drunella* mayflies or with decreased invertebrate community quality. Further, the HBI scores indicate little to no effects of organic pollution overall, although we saw some evidence of effects of organic pollution at Osborne and St. Anthony during the first few years of the study, which occurred during or immediately after the extended drought of 2013–2016. We also observed evidence of organic pollution at St. Anthony in 2022, after the very dry year of 2021. Indeed, water supply was a significant predictor of HBI, with lower values (better water quality) following years of good water supply. We would expect this observation, since higher streamflow provides more dilution of any pollutants that might be present. However, while HBI varies from year to year according to water supply, the facts that the average HBI is within the "very good" range and that HBI shows no significant trend over time provide strong evidence that water pollution is not affecting the quality of the Henry's Fork aquatic invertebrate community.

Trends at Flat Rock are concerning

Despite our observations that conditions over the whole watershed appear to be stable if not improving, Flat Rock is a major exception. While the percent of non-insects is decreasing over most of the watershed, it is increasing at Flat Rock. The number of EPT Taxa and %EPT are increasing at the watershed scale, while Flat Rock shows no improvement. The watershed-scale decrease in PMDs is being driven primarily by a substantial decrease at Flat Rock, and while *Drunella* abundance is stable or increasing over the rest of the watershed, it is decreasing significantly at Flat Rock. Our water-quality data show that turbidity, water temperature, and phosphorus concentrations are increasing throughout the watershed, but they are not increasing any faster at Flat Rock than anywhere else. And even with these watershed-scale trends, water temperature, suspended sediment concentrations, and phosphorus concentrations at Flat Rock are lower than at any of our other sites even as it is changing. Further, the streamflow regime at Flat Rock is the least altered due to water storage and diversion than anywhere else in the watershed. So, the invertebrate trends we are seeing at Flat Rock are puzzling and concerning. These declines could be occurring because Flat Rock is the most pristine of our sites and hence has the most to lose in a changing climate. In other words, a couple of degrees of warming may not make that much of a difference at St. Anthony, where summertime water temperatures are already well into the 70s and have been for decades. But at Flat Rock, where temperatures have historically stayed in the 50s and 60s all summer, a couple of degrees is proportionally a much greater increase. Further, we know that the location in the Henry's Fork watershed that has seen the greatest decrease in streamflow per unit of precipitation is the upper Henry's Fork. While annual water supply over the whole watershed (including Fall River and Teton River) has decreased by 15% since 2000, water supply in the upper Henry's Fork (above Island Park Dam) has decreased by 22%. We saw clear statistical evidence that HBI scores are higher (worse) when streamflow is lower, and this would have the greatest proportional effect at Flat Rock.

No invertebrate trends are apparent at Last Chance

None of the nine response variables we analyzed show any systematic trend over the past decade one way or the other at Last Chance, and that includes PMD abundance, which is of greatest concern to anglers. Our data show that average PMD abundance at Last Chance is lower than that at Flat Rock and Osborne, so it is possible that PMDs at Last Chance were formerly as abundant as they still are at those other two locations and declined substantially prior to the initiation of this study. We will do some digging into the data archives here to see if we can find some comparable numbers for PMDs from the 1970s, 1980s and 1990s, but at least over the past 10 years, we have no evidence of the systematic and some would say "catastrophic" decline in PMD hatches at Last Chance and the upper Ranch that we have been hearing a lot about over the past few years. Certainly there is year-to-year variability, but the point is that the invertebrate community at Last Chance has not changed systematically over the past 10 years. Further, the year-to-year variability in PMD abundance at Last Chance we have observed over the past 10 years does not generally correspond with angler experience. More on that in the next section.

Insects on the stream bottom are not the same as a hatch

This research is all based on invertebrates that we sample during their nymph stage and is not designed to predict when or where a given aquatic insect hatch will occur. We focus on nymphs as they are present on the stream bottom in March because they provide the greatest amount of information about water and habitat quality, via the community metrics we measure. Further, an aquatic insect's role in the stream ecosystem occurs primarily when it is in the nymph stage. After all, most of the species anglers are interested in spend 350 days in the river as nymphs and only two weeks or less, and in most cases only a few days, as winged adults. Yes, those few days provide the core of the Henry's Fork fishing experience, but it's the other 350–360 days that reflect the overall health and productivity of the river and how it might respond to changes in water quality, streamflow, and climate.

To be a little more specific—and to follow up on the last sentence in the previous paragraph—the four years in our study with the highest PMD abundance at Last Chance were 2017 (9,700 individuals/m^2), 2020 (7,700 individuals/m^2), 2018 (5,990 individuals/m^2), and 2023 (5,950 individuals/m^2). Of these, by far the year with the best perceived hatches was 2020—and even most long-time anglers said that 2020 had the best hatches in decades, comparable to what was commonplace in the 1970s and 1980s. Yet, PMD abundance was quite a bit higher in 2017, a year that wasn't bad by most accounts but also wasn't particularly noteworthy. On the other hand, 2023 was widely considered to have very poor PMD hatches. We observed the same number of PMDs in our 2023 samples as we observed in 2018, which at least at the time wasn't noteworthy one way or the other. By far the two years with lowest PMD abundance at Last Chance were 2022 (1,744 individuals/m^2) and 2024 (1,963 individuals/m^2). Based on angler comments, PMD hatches in 2024 were widely considered to be the worst ever at Last Chance and the upper Ranch, yet there were fewer PMDs in our samples in 2022, when we heard relatively little about poor hatches. Further, we generally heard the same negative comments about PMD hatches in 2023 as we heard in 2024, yet PMD abundance in 2023 was over three times what it was in 2024.

The only other observation I will make about this is that of the past 10 years, those with the highest trout populations by far were 2019, 2020 and 2021 and those with the lowest trout populations (also by large margins) were 2023 and 2024. Thus, is it generally the case that the greatest concern over poor hatches is expressed during years with the lowest fish populations and that in other years with similar insect numbers, there is less concern over hatches if those years also coincide with high trout populations.

What about temperature?

Our water-quality sonde data clearly show a trend toward increasing water temperatures over the past 10 years, and that trend applies over the whole watershed. Average summer water temperatures have increased by around 2 degrees F over the past 10 years, while 7-day maximum temperatures have increased by 1 degree F. As discussed above, almost all of the 7-day maximum temperatures we observed were above the maximum tolerance of PMDs reported in the literature and also above the maximum tolerance of other mayflies such as blue-winged olives (*Baetis*) and Flavs that are abundant and widespread in the Henry's Fork. So, either the temperature tolerances observed in studies conducted in other river systems do not apply to the Henry's Fork or the numerous groundwater inputs to all reaches of the Henry's Fork maintain locally cooler areas in the river than where our water-quality sondes are located.

We did observe that invertebrate community diversity was higher at cooler temperatures, but the other two times temperature appeared as a significant predictor (Table 3), its effect was opposite of what we would expect. Percent EPT was higher at higher temperatures, and HBI was lower (indicative of better water quality) when temperatures were higher. And, %EPT was one of the community metrics that has actually improved over the past decade. Taken together, the temperature observations suggest that warming temperatures are likely opening up more favorable conditions for species that do better in warmer water, while the cool groundwater inputs are maintaining at least locally favorable conditions for the species that prefer cooler water. This is a mechanism that could explain the increase in EPT Taxa and %EPT we have observed even as temperatures warm. Negative dependence of Shannon's diversity on temperature (warmer water = lower diversity) may reflect additional species appearing in the samples as temperatures warm but less uniform distribution of individuals across the species when this happens, leading to lower diversity.

In any case, our results do not indicate that invertebrate community structure or abundance of the three types of insects we looked at are being negatively impacted by warming temperatures at the watershed scale. However, it is very likely that increased water temperatures are affecting the life cycle of the insects that are present. It is well known that emergence behavior of aquatic insects is strongly determined by water temperature, and even small water temperature changes could result in large changes in emergence timing, both time of year and time of day. Further, our Harriman State Park temperature study shows that water temperature regimes (both the daily average and the variability around that average) vary greatly with location around the Ranch. As atmospheric temperatures warm, the difference between "warm" locations and locally "cool" locations will be greater than in the past, with hatches of specific insects being much more specific to location and time of day. The more localized a particular insect emergence is, the less likely it is that large numbers of the same insect will appear across large reaches of the river at the same time. This occurrence is exactly what produces the hatches for which the Henry's Fork is famous.

As a final observation about temperature, Jack McLaren and I have been integrating all that we know about invertebrates, temperature and streamflow downstream of Island Park Dam and have put together what we think is probably the most likely explanation for changes in hatches, especially PMDs, between Last Chance and Pinehaven. First, we know that outflow temperatures from Island Park Dam are lower when the reservoir stays full. Second, we know that water temperatures between Last Chance and Pinehaven are more resistant to warming from solar radiation and to cooling from the localized effects of cool groundwater inputs when outflow is high. Third, we know from our own angling experience and from the angling community in general that PMDs (and a few other mayflies) produce the most prolific hatches when water temperatures are relatively cool and relatively constant. That is why spring creeks and large reservoir tailwaters are generally most well known for their PMD hatches. In the Ranch, this would occur when Island Park Reservoir stays full but outflow is high. Over the past several decades, this condition is not physically possible, because high outflow leads to high reservoir drawdown, which leads to warmer outflow temperatures. Keeping the reservoir as full as possible requires low outflow, which is then susceptible to rapid warming once it hits Last Chance, especially because air temperatures are warmer now. However, back in the 1970s, 1980s, and 1990s, reservoir *inflows* were so high that it was possible to maintain high reservoir levels and high outflows at the same time. This would have produced a situation in which cool reservoir water remained cool all the way through the Ranch (not to mention the fact that air temperatures were lower), thus producing PMD hatches in large numbers at predictable times of year and times of day, all the way through the reach from Box Canyon to Pinehaven at the same time.

What is HFF doing about any of this?

- Continue to monitor invertebrates, water quality, and streamflow to add to the 10-year dataset presented in this report.
- Scour our old hard-copy reports for invertebrate data collected prior to this study and incorporate those into formal analysis as much as possible.
- With Idaho Department of Environmental Quality, complete a water temperature model for the river downstream of Island Park Dam so that we can assess how different weather conditions, reservoir management, and water supply affect water temperature in the Ranch.
- Continue the collaborative precision water management program that has saved over 20,000 ac-ft of water per year in Island Park Reservoir, increased winter outflow by 100 cfs, and resulted in small but measurable improvements in summertime water quality downstream.
- Contingent upon funding availability, pursue infrastructure and habitat improvements in Island Park Reservoir and on the river downstream to decrease turbidity and water temperatures.
- Develop and implement research in the future that will specifically investigate "hatches" as their own phenomenon, not necessarily reflective of the invertebrate community as a whole.

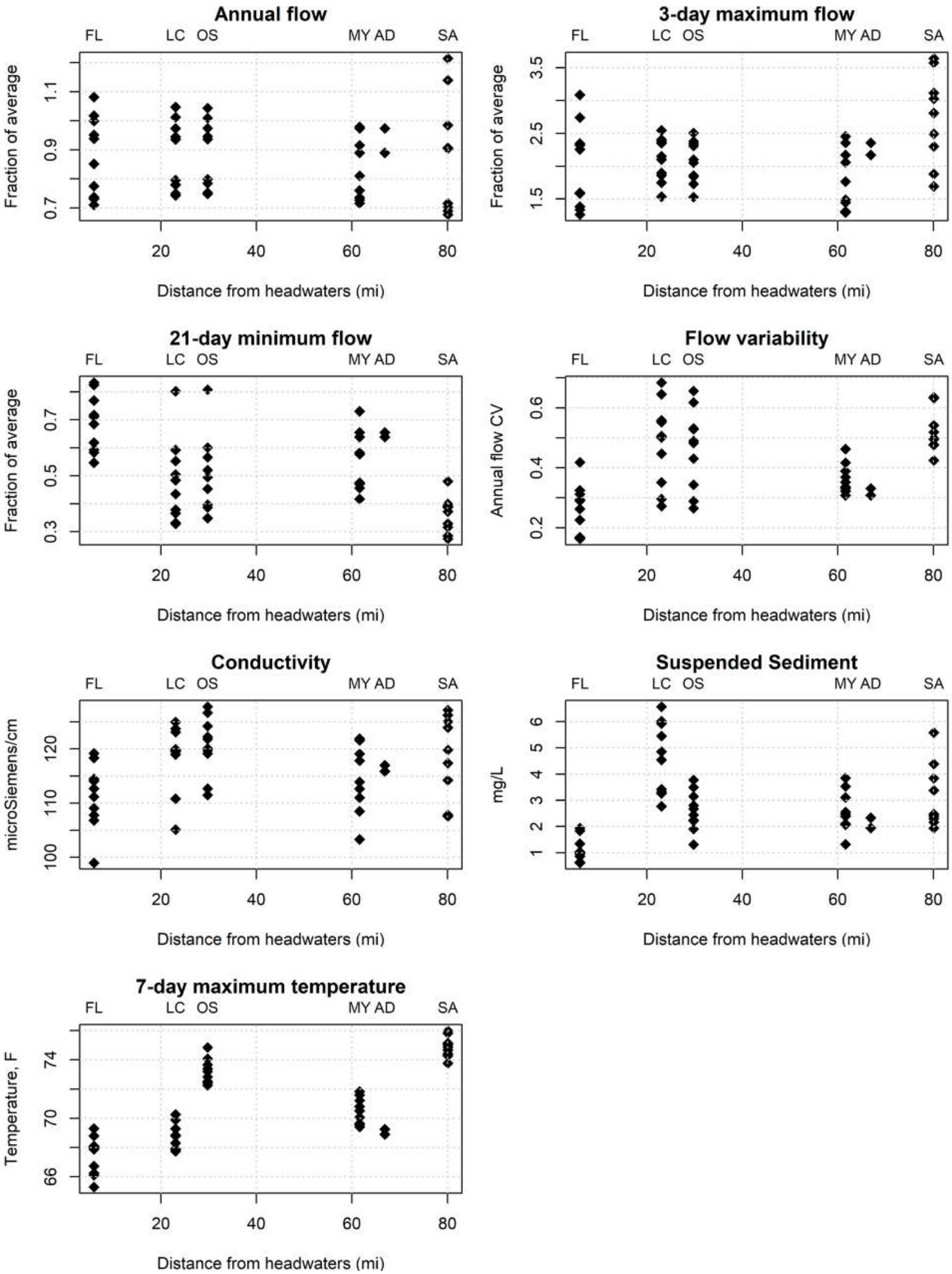

Figure 3. Habitat data for each site and year, plotted vs. distance downstream from Big Springs.

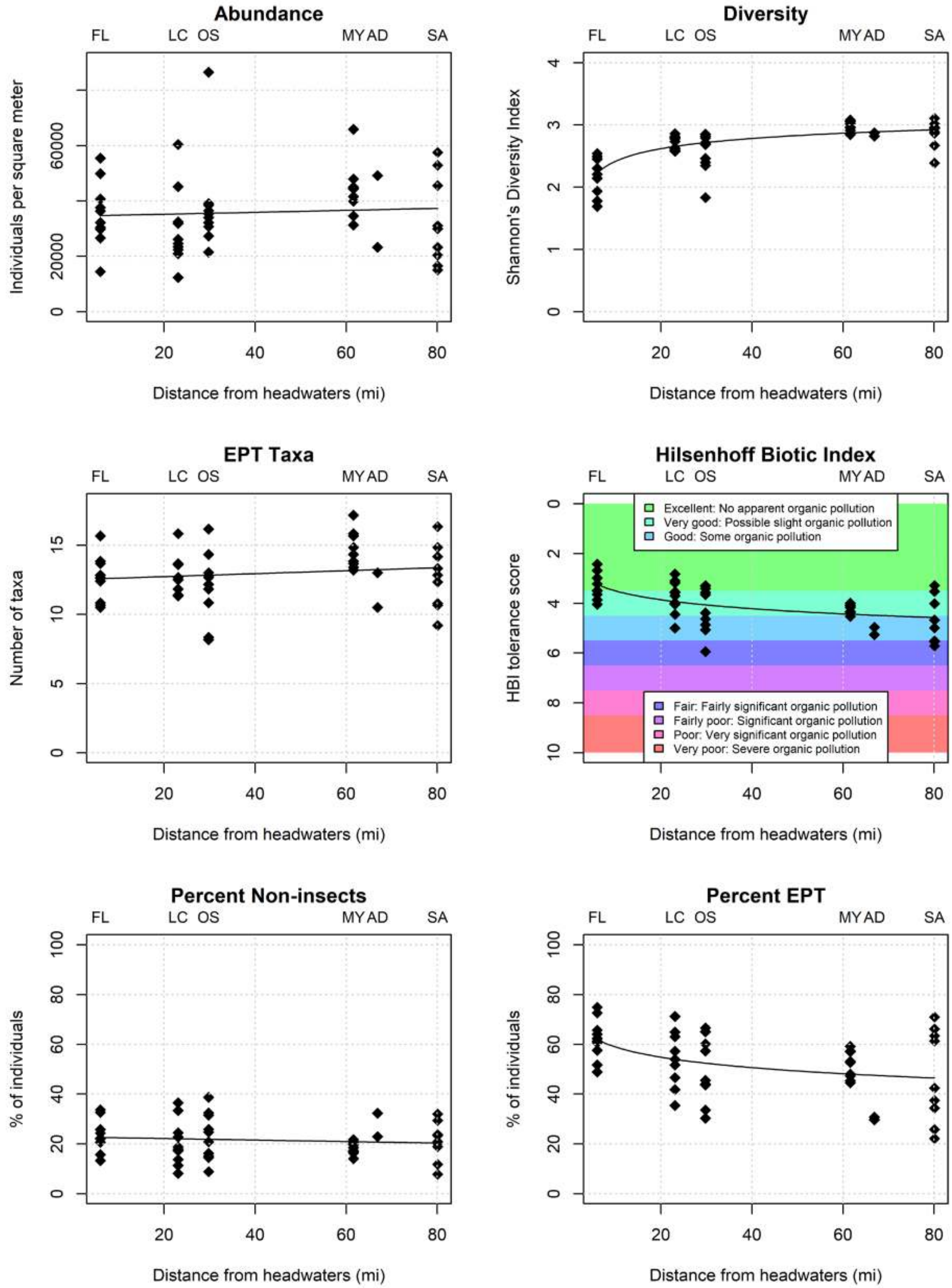

Figure 4. Invertebrate community metrics for each site and year, plotted against distance downstream from Big Springs.

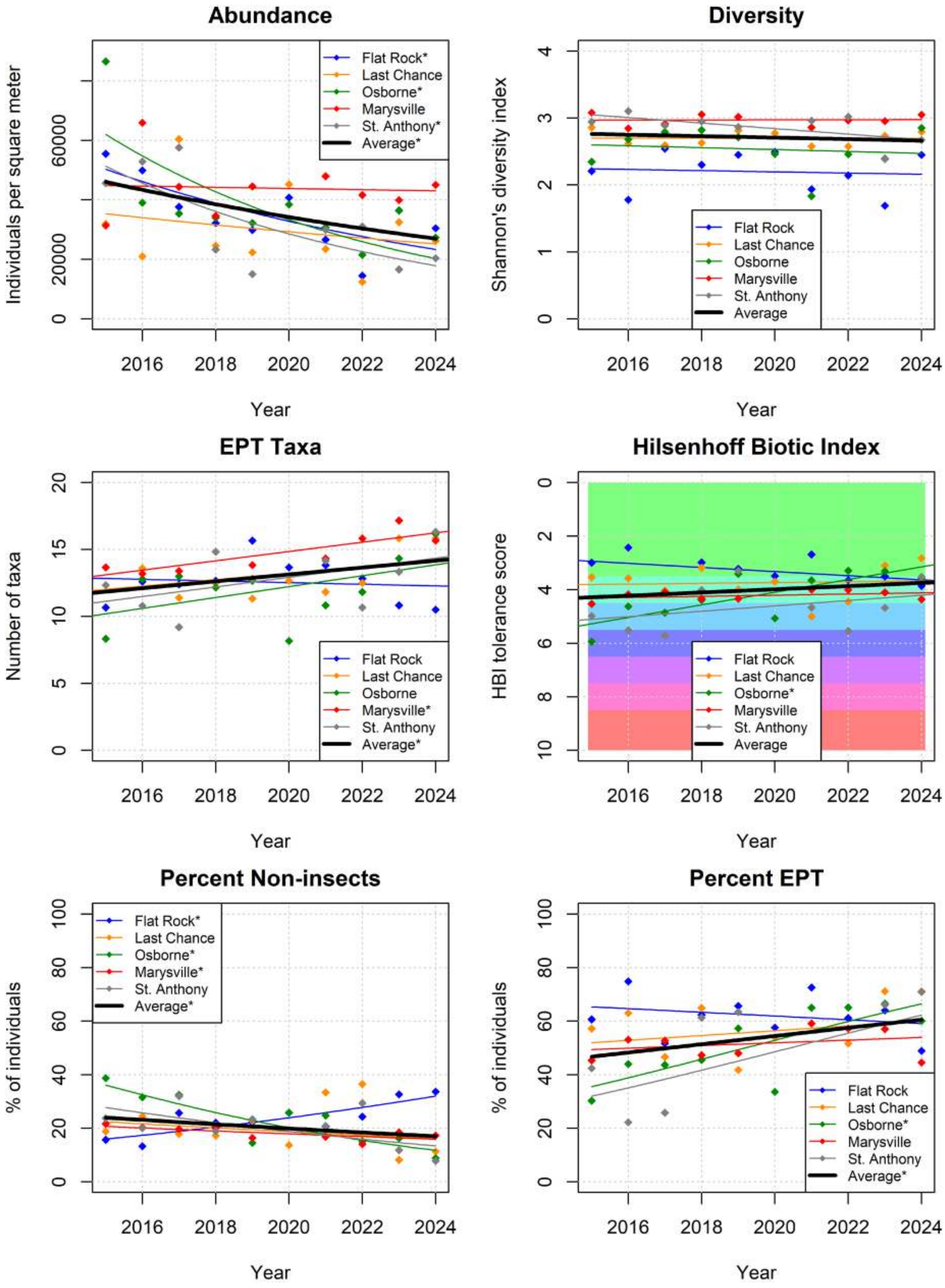

Figure 5. Time series of invertebrate community metrics for the five sites with 2015–2024 data. Asterisks indicate statistically significant trends over time.

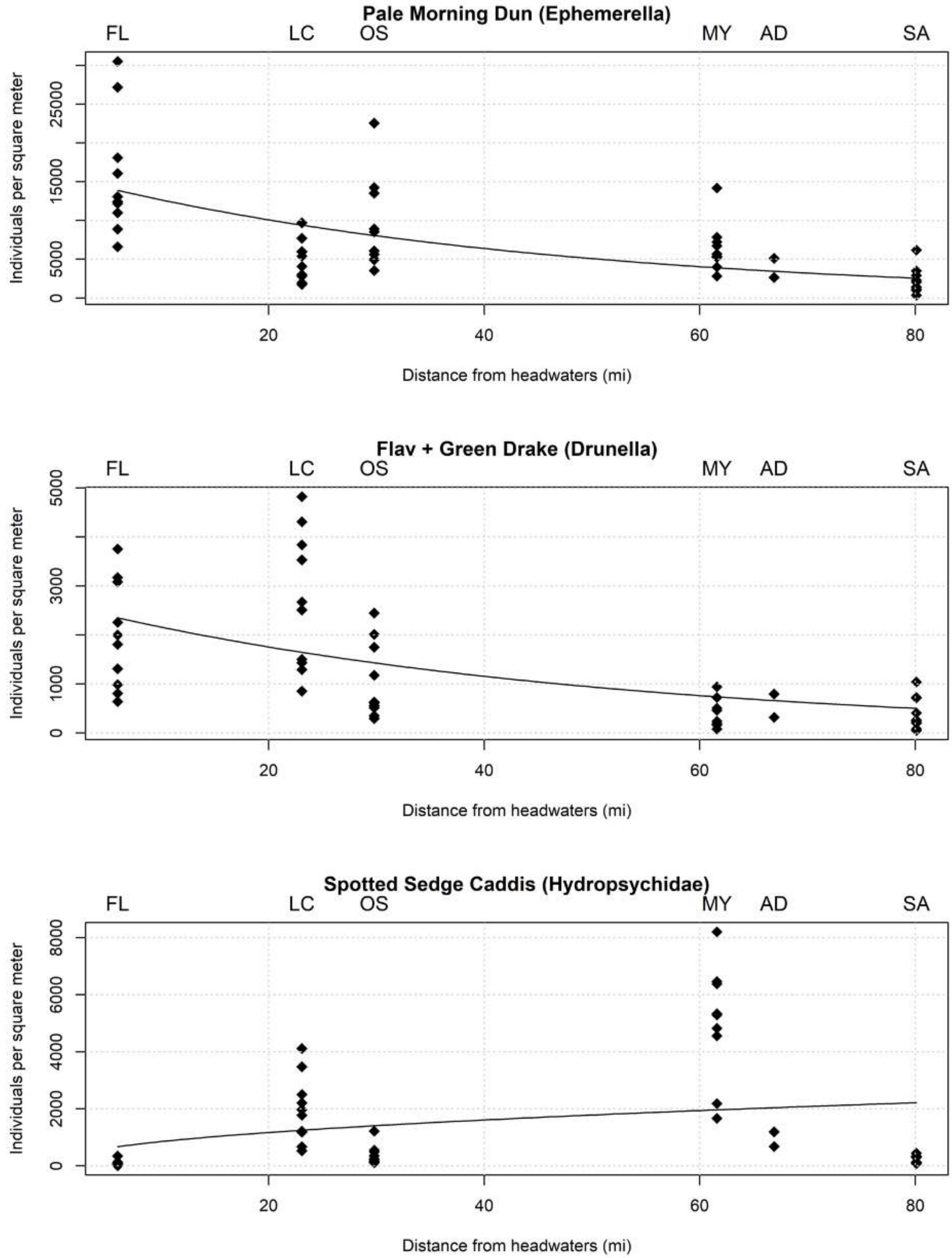

Figure 6. Abundance of PMDs, *Drunella*, and Spotted Sedge for all sites and years, plotted by distance downstream of Big Springs.

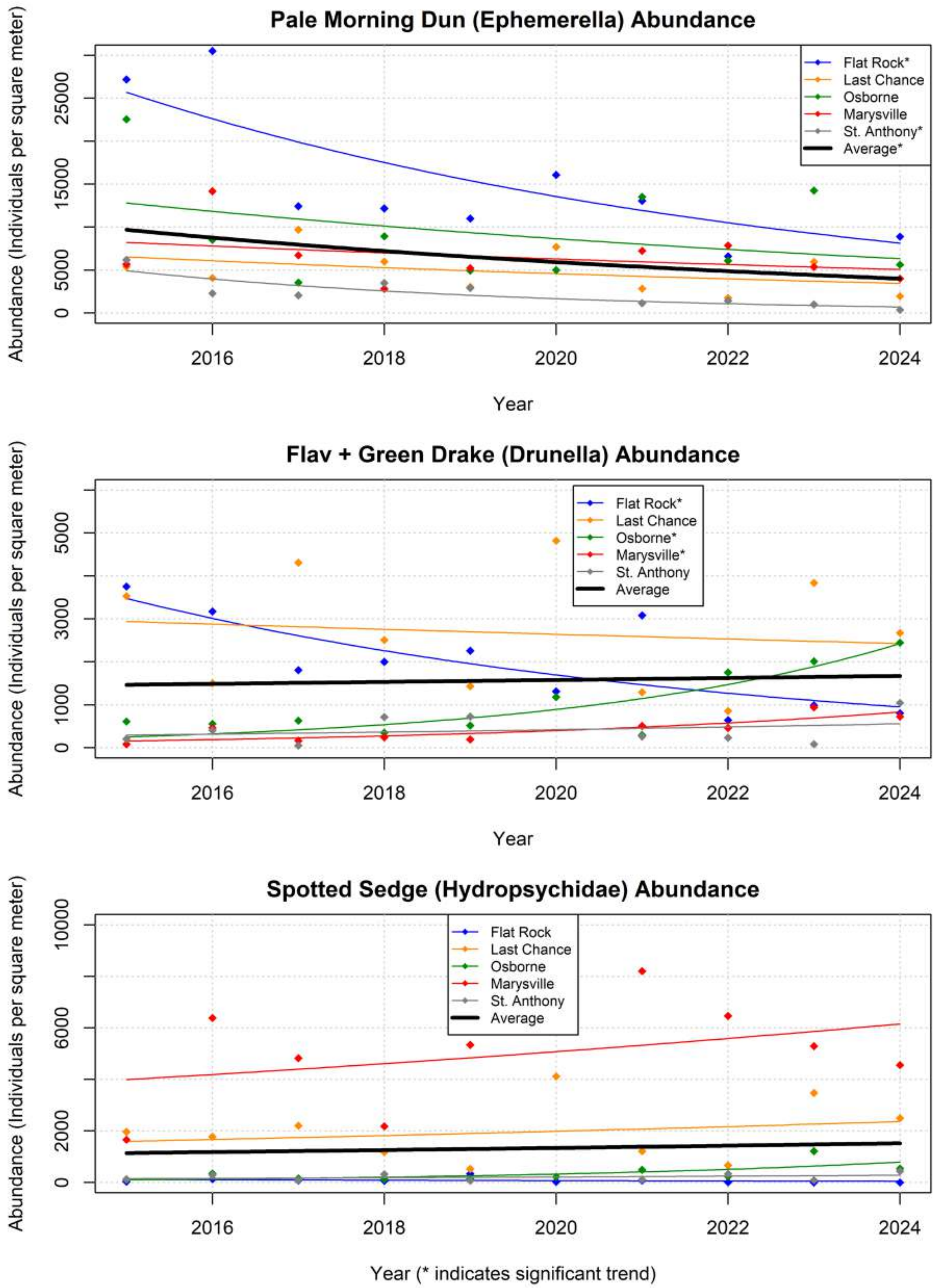

Figure 7. Time series of PMDs, *Drunella*, and Spotted Sedge for the five sites with 2015–2024 data. Asterisks indicate statistically significant trends over time.

Table 3. Summary of the best statistical model for each response. “Distance” measures distance along the river downstream from Big Springs, and “SITE” accounts for differences among the six individual sites. R^2 is the percent of variability in the response variable explained by the top model. “+” indicates that the given predictor has a statistically significant positive effect on the response variable, and “–“ indicates that the given predictor has a statistically significant negative effect on the response variable.

				Predictor variables					
Response variable	Distance included	SITE included	R^2	Annual Flow	21-day minimum flow	3-day maximum flow	Flow variability	Sediment concentration	7-day maximum temperature
Abundance	YES	NO	10%						
Diversity	YES	NO	65%						–
EPT Taxa	NO	YES	33%				+		
HBI	NO	YES	57%	–					–
%Non-insects	NO	NO	0%						
%EPT	NO	YES	42%						+
PMD	YES	NO	50%						
Drunella	NO	YES	57%						
Spotted Sedge	NO	YES	84%					+	