Bug Flows:
Don't Count Your Midges Until They Hatch

Whether it was a bony run at Horn Creek or a restful two nights of sleep because you didn't have to extend your bowline at camp, you may have noticed a change in dam releases during the past two seasons. May to August of 2019 marked the second season of Bug Flows, a flow experiment that is predicted to give the Grand Canyon food web a boost by increasing aquatic insect production. Aquatic insects are a fundamental component of a healthy river ecosystem. Most aquatic insects spend their juvenile life stages (egg, larva, pupa) in the river and their winged adult life stage flying along the riparian corridor. Throughout these metamorphoses one thing is for certain, aquatic insects are prey for fish, birds, bats, lizards, and even other invertebrates. In Grand Canyon, food web studies conducted by the U.S. Geological Survey (USGS) has demonstrated that populations of both native and sport fish are food limited (Cross et al. 2013, Kennedy et al. 2013). In other words, fish in Grand Canyon are consistently facing a calorie deficit. Indeed, the U.S. Fish and Wildlife Service has cited the inadequate and unreliable food supply as the single greatest problem facing endangered Humpback Chub populations in Grand Canyon (USFWS 2019).

To better understand the factors limiting aquatic insect populations in Grand Canyon, our USGS lab group began to collaborate with Grand Canyon River Guides in 2012 to collect samples of aquatic insects using a citizen science approach. The citizen science project is simple yet powerful. We provide river guides, Grand Canyon Youth trips, and private boaters with battery-powered light traps that capture the adult life stage of aquatic insects, and boaters deploy these traps for one hour each evening during Grand Canyon river trips. The roughly 1,000 insect samples that have been collected every year with light traps represent an unprecedented dataset that far exceeds any effort that the USGS could achieve working on our own (see our article in the Fall 2016 BQR). We are learning a lot from the ongoing sampling effort and the more than 6,000 light trap samples that have already been collected by river runners. These data from light trap samples were used to design the ongoing Bug Flows experiment at Glen Canyon Dam, which represents the first time in history that a large dam has been operated with the goal of increasing insect abundance.

Bug Flows are designed to increase insect abundance by decreasing mortality at the egg life stage. Adult female insects lay their eggs along the river's shoreline, cementing strings of hundreds of eggs to exposed rocks and vegetation just below the water surface. In Grand Canyon, the daily fluctuating river "tide" reflects the ebbs and flows of western U.S. demand for hydropower from Glen Canyon Dam. The daily drops in water level expose sensitive eggs to the hot and arid terrestrial environment, which leads to drying and mass egg mortality. For example, in a field experiment on the Green River examining caddisfly and mayfly egg exposure, only seventeen percent of eggs hatched

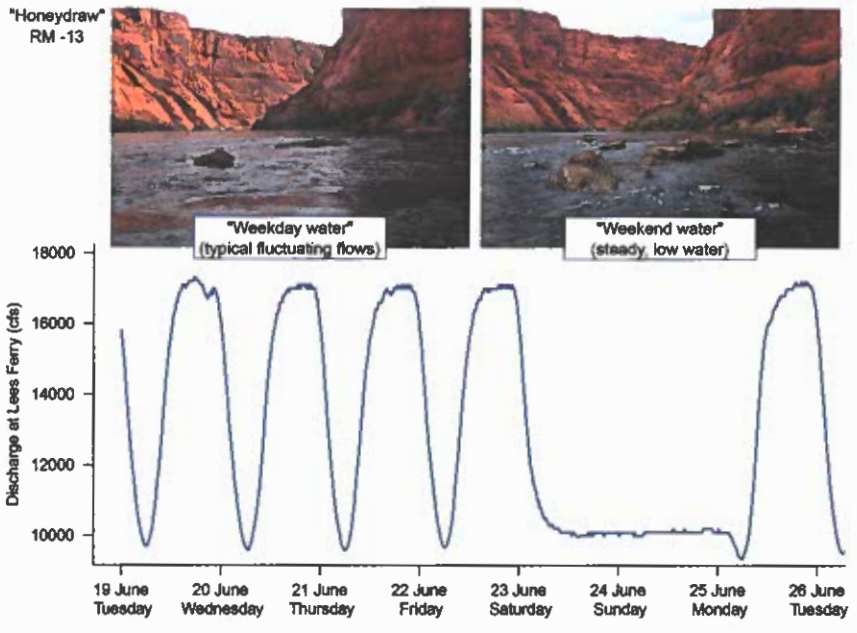

Figure 1. A hydrograph from mid-June 2018 showing a typical week of Bug Flows at Lees Ferry. Flows are optimized to maximize the number of insect eggs that remain submerged throughout the river corridor as waves of dam released water travels downstream. Note the large number of exposed rocks during Bug Flow weekends compared to high water during weekday fluctuations; exposed rocks at the water line are preferred egg laying substrates for midges and other aquatic insects. Photos by David Herasimtschu, Freshwaters Illustrated.

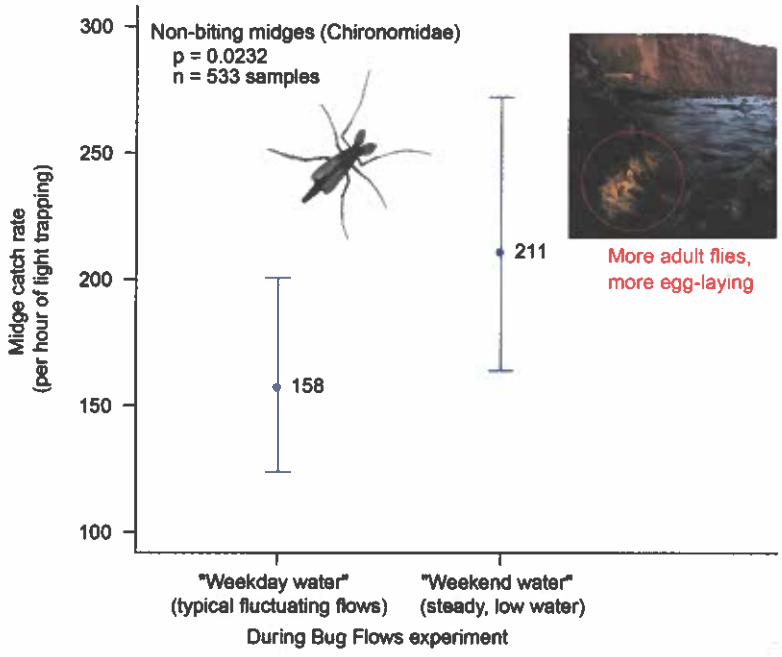

Figure 2. During Bug Flows in 2018, more adult non-biting midges (Chironomidae) emerged during low and steady Bug Flow weekend water conditions than during normal, fluctuating weekday water conditions. Bars represent standard error and numbers represent mean light trap catch rates. Inset photo shows hundreds of yellow "egg ropes" laid by midges at the air-water interface on a rock in Glen Canyon. Each egg rope contains hundreds of midge eggs. Photos by David Herasimtschuk, Freshwaters Illustrated.

after one hour of exposure to air and exposure longer than an hour led to nearly complete mortality of eggs (Kennedy et al. 2016). Bug Flows aim to reduce egg mortality by releasing low steady flows on weekends (Figure 1), providing two days each week when eggs that are laid will never be dried out. Flows are optimized to maximize the number of eggs that remain submerged throughout the canyon and throughout the week. Reducing flows on weekends rather than on weekdays helps preserve hydropower revenue. The first Bug Flows experiment was carried out on weekends from May to August 2018, and the experiment was repeated during the same months in 2019.

Our lab group is currently processing citizen science samples from 2019, but preliminary results from 2018 are in and we are beginning to understand how this flow experiment affected bugs, fish, and recreation. Using light trap data, we found that more adult non-biting midges (*Chironomidae*) emerged from the river during Bug Flow weekends than during adjacent weekdays with normal flow fluctuations (Figure 2). The four-stage midge life cycle (egg, larva, pupa, adult) takes several months to a year to complete and the increase in weekend emergence suggests that low steady flows are changing conditions not only for eggs, but at other life stages as well. For example, low steady flows may be cueing midges in their pupal life stage to emerge from the river as adults, which would account for the increase in weekend emergence. Regardless of the underlying cause, greater midge emergence during Bug Flow weekends is good news, because it means more eggs are being laid by adult midges during low flows on the weekends that optimize egg-laying conditions. Low flows on weekends, as opposed to steady flows, expose more rocks and vegetation for midges to lay eggs on. Steady flows guarantee that those eggs will remain wetted, greatly improving their chances of hatching and maturing into larvae.

One of the goals of Bug Flows is to provide a foothold for more sensitive insect groups, such as caddisflies (*Trichoptera*), to colonize the river. During the first year of Bug Flows, we found a nearly fourfold increase in the abundance of caddisflies caught in citizen science light traps relative to the year prior (Figure 3). Adult caddisflies are premium food items for fish as well as terrestrial predators like birds and bats. Caddisflies are rare in the mainstem Colorado River in Grand Canyon and are thought to have been practically extirpated by fluctuating flows (Kennedy

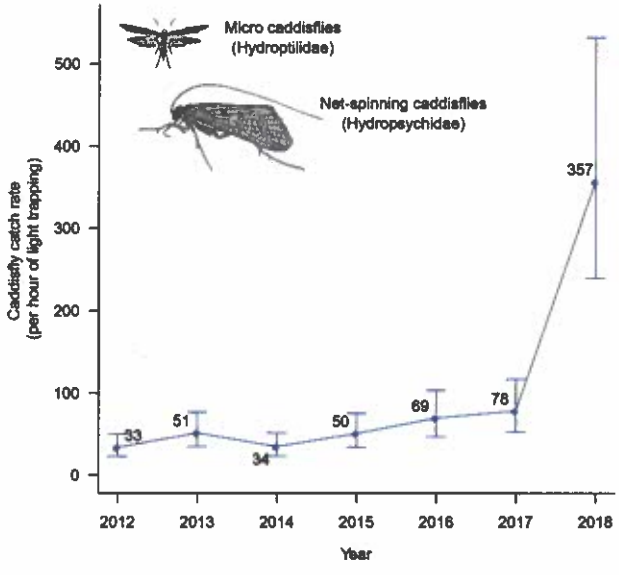

Figure 3. There was a significant increase in the number of adult caddisflies captured in citizen science light traps during the first year of Bug Flows in 2018. Bars represent standard error and numbers represent mean light trap catch rates. Caddisflies are a premium food item for fish, birds, and other wildlife.

Natural History

Non-biting midges (Order: Diptera)

Non-biting midges (Chironomidae) are the most common and abundant family of aquatic insects in the Colorado River in Grand Canyon. There are at least 43 unique species of midges present in Grand Canyon (Stevens et al. 1998). The types of midge species change with distance from Glen Canyon Dam, with midges that specialize in cold clear water decreasing with downstream distance, and midges that prefer warm and turbid water increasing (Stevens et al. 1998). Adult midges in Grand Canyon can be observed flying in aerial swarms, or "leks", throughout the year, but are most abundant from April to July.

Midge. Photo by Jeremy Monroe, Freshwaters Illustrated.

Caddisflies (Order: Trichoptera)

The 2018 increase in adult caddisflies along the Colorado River was primarily within two families—microcaddisflies (Hydroptilidae) and net-spinning caddisflies (Hydropsychidae).

As the name implies, microcaddisflies are small. They are typically less than five mm in length, shorter than a grain of rice. During their larval life stage they construct tiny, waxy homes that lay flat against rocks and vegetation and shield them from predators. Net-spinning caddisflies can reach 19 mm in length, the diameter of a penny. They are uncommon along the mainstem Colorado River in Grand Canyon. As larvae, net-spinning caddisflies use specialized silk glands to construct loose cases of sticks and pebbles. At the upstream end of the case, they deploy a fine mesh net that filters the water column for morsels of organic matter, smaller invertebrates, and other food items.

Net-spinning caddisfly. Photo by Eric Kortenhoeven.

et al. 2016). Nonetheless, adults commonly fly into the mainstem river from tributaries and are often collected in citizen science light traps, especially in the western canyon. We find it encouraging that the number of caddisflies quadrupled during the first year of Bug Flow experimentation.

The Bug Flow experiment also appears to have boosted conditions for fishing at Lees Ferry. According to anglers, the low and stable flows during weekends provide greater access to wadable cobble bars and aggregate trout into higher densities in popular fishing areas, all of which improve the quality of the angling experience. For example, after the first month of Bug Flows in 2018, fishing outfitter Steve Kelly opened a blog post with the exclamation that, "bug flows have significantly improved fly fishing on the weekends!" (Kelly 2018). The Glen Canyon Dam Adaptive Management Program (AMP) asked USGS scientists to investigate the veracity of these observations, so we headed to Lees Ferry for some scientific angling this summer (yes, we love our jobs!). We got together a team of 31 anglers for two long weekends and fished Friday through Monday in both June and August of 2019 (a total of four weekdays and four weekend days). In our study, the average angler caught 33 percent more fish on weekend days compared to weekdays (average of 6.8 fish per angler on weekends versus 5.1 fish per angler on weekdays, see Figure 4). Anglers are famous for hyperbole and spinning yarns, but our study indicates that the blog posts are true; fishing is significantly better on Bug Flow weekends (for the statisticians out there, the t-value =1.751 and p =0.045).

We are excited to continue working with the Grand Canyon boating and guiding community to understand the effects of the Bug Flow experiment on the Colorado River ecosystem. Results from the first

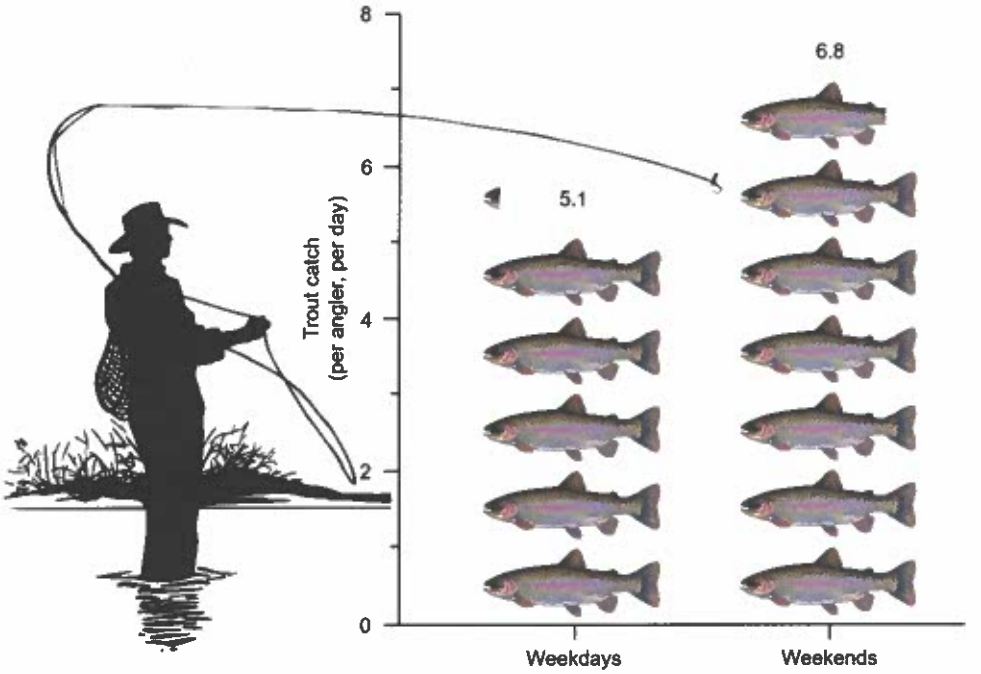

Figure 4. Average number of fish captured by anglers during weekdays when flows fluctuate compared to steady Bug Flow weekends. In our study involving 31 anglers, we caught 368 fish over 8 days (4 weekdays and 4 weekend days). On average, 5.1 fish were caught per angler on the weekdays compared to 6.8 fish caught per angler on weekend days (+/- standard error of 0.62 and 1.02, respectively).

year of Bug Flows are preliminary but encouraging. Continuation of the flow experiment is decided on a year-to-year basis by the U.S. Department of the Interior, based on recommendations from the AMP. To learn more, you can get in touch with your Grand Canyon River Guides stakeholder representative. We are always looking for new citizen scientists. Becoming a citizen scientist is simple—just come over to our table and get signed up at the next Guides Training Seminar in March 2020. We are grateful for the continued engagement and support of Grand Canyon river runners and especially to all the incredible citizen scientists that have helped us over the years. You make this research possible!

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U.S. GEOLOGICAL SURVEY

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