GCDAMP Knowledge Assessment: Status & Trend

Resource Topic:	Aquatic food base
Preparer(s):	Ted Kennedy, Jeff Muehlbauer, Chris Budwig, Shane Capron, Bill Davis, Craig Ellsworth
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Resource Characteristic	Specific Measure	Status	Trend	Confidence	Rationale: Status/Trend	Rationale: Confidence	Recommendations	Key References
Secondary production	Invertebrate drift concentration. Detail: Drift concentration (# or mg per m^3)	Significant Concern	Deteriorating	High	A Lees Ferry food base in GOOD condition is characterized by drift biomass and density seen in 2008-2011 while a Grand Canyon food base in GOOD condition is characterized by drift biomass and density seen at LCR confluence in 2012. However, intensive drift sampling in Grand Canyon only started in 2012, so benchmark for Grand Canyon food base may need to be updated in the future as additional years of data become available. Monitoring of drift in Lees Ferry and in Marble Canyon as part of Natal Origins research indicate depressed drift biomass in recent years (2014-2016). Condition of native fishes at LCR confluence, and number of HBC spawning in the LCR, has been similarly low. Drifting invertebrates are the stage most available to fish, and so decline in drift biomass represents a tangible decline in fish food availability.	Drift data are robust (sampled frequently, and at many locations throughout Glen and Marble Canyons). Deteriorating drift trend is clear across multiple sites ranging from Lees Ferry to the LCR confluence, indicating a system-wide constraint on drift.	Management 1) Consider testing alternative HFE timing (spring) to benefit insects, which readily drift and are strongly selected for by fish. 2) Consider testing bug flows to increase insect numbers via reduced egg mortality. Research 1) Continue monitoring of Lees Ferry drift. 2) Continue monitoring of drift downstream, especially adjacent to LCR. 3) Consider comparing drift across a range of daily fluctuations, including weekends vs. weekdays, 4) Consider modeling what effect low summer steady flows might have on drift concentrations and bioenergetics of fish.	1) Kennedy, et al., 2014, Freshwater Biology, v. 59, no. 3, p. 557-572. 2) Kennedy, et al., 2016, BioScience, v. 66, no. 7, p. 561-575.
Secondary production	Emergent adult insect abundance. Detail: Standing stock using light traps and sticky traps (# per trap)	Significant Concern	Deteriorating	High	A food base in GOOD condition is characterized by light trap catch rates seen in 2012. Note: Light trap sampling only started in 2012. Comprehensive sticky trap sampling only started in 2014, and food base had deteriorated significantly at that point (i.e., don't have a sense of what constitutes GOOD condition for sticky traps, and definition of GOOD light trap catches may need to be updated as more data become available). Citizen science light trapping indicates patterns of midge abundance along entire river segment (GCD to Diamond Creek) that are strongly correlated with daily timing of hydropeaking waves. These observations and life history models of aquatic insects strongly suggest MLFF operations are constraining midge populations through egg mortality, thereby affecting the food-limited status of fish (reported in Cross et al. 2013 Ecological Monographs and Kennedy et al. 2016 BioScience). Midge catch rates in light traps throughout Marble and Grand Canyon have declined by >50% since 2012. Significantly, the condition of humpback chub and other native fishes has also declined over this time period.	Observed spatial pattern in light trap data is strong and consistent over all years of light trapping. Year-over-year declines in light trap catches of midges since 2012 are strong and derived from large numbers of samples and correlate with declines in native fish condition. The large sample size of this dataset is unprecedented in aquatic ecology.	Management 1) Consider testing alternative HFE timing (spring) to benefit insects. 2) Consider testing bug flows to increase insect numbers via reduced egg mortality. Research 1) Continue monitoring of emergent insects using citizen science. 2) Continue sticky trap monitoring at LF. 3) Interrogate LF and downstream data for spatial and temporal patterns.	1) Cross, et al., 2013, Ecological Monographs, v. 83, no. 3, p. 311-337. 2) Kennedy, et al., 2016, BioScience, v. 66, no. 7, p. 561-575.

Secondary production	Benthic invertebrate abundance, measured by standing stock biomass of benthic invertebrates (# or mg per m^2)	Moderate Concern	Unknown	Medium	A food base in GOOD condition is characterized by standing stock biomass of midges and black flies similar to what was observed in 2008 and 2009. Benthic invertebrate abundance was consistently found to be low in Grand Canyon during exhaustive food base study in mid-2000s (culminating in Cross et al. 2013 Ecological Monographs paper). In these same studies, standing stock in LF was found to be high and dominated by NZMS, which are not edible for fish. Current benthic sampling is more sporadic, however, so current trends are unknown. Likely, however, that benthic patterns are following those observed in drift over past few years (i.e., drift concentration is proportional to benthic density, so observed declines of midges and blackflies in drift are indicative of benthic population trends).	Kennedy et al. 2014 (Freshwater Biology) showed that benthic densities were proportional to drift concentrations in LF. However, no benthic monitoring program is currently in place, and cannot comment on status of this measure with certainty without implementing new benthic monitoring.	Management 1) Consider testing alternative HFE timing (spring) to benefit insects. 2) Consider testing bug flows to increase insect numbers via reduced egg mortality. Research 1) Consider targeted benthic sampling in LF to better understand role of macrophytes in driving changes in invertebrate prey base. 2) Consider targeted benthic sampling in zones thought to be most susceptible to showing a response (e.g, recolonization or increased abundance) under bug flows, including near tributaries and at locations of midge abundance peaks and troughs shown in Kennedy et al. 2016 (BioScience). 4) Consider implementation of new, large-scale benthic monitoring program if benthic invertebrates are of renewed interest. Note: Unclear why this would be of interest, given the huge effort (comparable to channel mapping) required to obtain accurate estimates of benthic stocks, and the presence of existing, related, more cost-effective monitoring tools (i.e., drift, sticky traps, and light traps).	1) Cross, et al., 2013, Ecological Monographs, v. 83, no. 3, p. 311-337. 2) Kennedy, et al., 2014, Freshwater Biology, v. 59, no. 3, p. 557-572. 3) Kennedy, et al., 2016, BioScience, v. 66, no. 7, p. 561-575.
Food base diversity	Relative abundance of "big 4" invertebrate groups - Chironomidae, Simuliidae, Gammarus, Potamopyrgus - by # or %	Moderate Concern	Deteriorating	High	A food base in GOOD condition is characterized by HIGH abundance of Chironomidae, Simuliidae, Gammarus, and LOW abundance of Potamopyrgus. Big 4 groups remain established in the same large-scale river segments where they have occurred since at least the mid-1990s. However, recent drift data from Lees Ferry (LF) indicate shifts to increased dominance of Potamopyrgus (New Zealand mud snails, NZMS) and sludge worms (Tubificidae), possibly coincident with several years of fall HFEs. Drift biomass at the LCR confluence has also declined by >50% from 2012-2016. Ongoing invasion of Dreissena bugensis (quagga mussel) in Lees Ferry since 2014 may also cause shifts in species dominance, potentially toward less palatable species (i.e., quagga and NZMS).	Patterns in drift data with respect to relative abundance of Big 4 are clear, and drift data are robust (sampled frequently, and at many locations throughout Glen and Marble Canyons). Monitoring of drift and light trap data for 10 and 4 years, respectively, are intensive and would show arrival of any new species. Quagga effects downstream are unknown, but Kennedy (2007) report suggests limited potential for invasion downstream of Paria River due to turbidity effects.	Management 1) Consider change in HFE timing (from predominantly fall to predominantly spring) to benefit insects and supress nonnative invasive New Zealand mudsnails. See Table 1 in Chapter 5 of HFE Circular for such alternatives 2) Consider testing macroinvertebrate production flows ("bug flows") to increase insect numbers via reduced egg mortality. Research 1) Continue monitoring of food base in LF, Marble Canyon, and LCR confluence, especially through drift measurements (life stage most available to fish). 2) Consider benthic monitoring in FY18-20 to track downstream progression of quagga. 3) Consider targeted benthic sampling to better understand role of macrophytes in driving changes in invertebrate prey base, especially in LF.	1) Kennedy, 2007, A Dreissena risk assessment for the Colorado River ecosystem, 24 p. 2) Kennedy, et al., 2016, BioScience, v. 66, no. 7, p. 561-575.

Food base diversity	EPT (Ephemeroptera-Plecoptera-Trichoptera) abundance relative to total invertebrate abundance (%)	Moderate Concern	Unchanging	High	A food base in GOOD condition is characterized by >10% EPT abundance (similar to what is seen in the Flaming Gorge Dam tailwater). The Colorado River downstream of Glen Canyon Dam is one of the few places in the world that doesn't have populations of EPT. Lack of EPT has been documented by food base research going back decades at this point.	Food base efforts, including intensive efforts beginning ca 2006, have indicated that EPT % is zero/low and unchanging under MLFF. Kennedy et al. (2016, BioScience) proposes mechanism for this depauperate EPT condition promulgated by MLFF.	Management 1) Consider testing bug flows to increase insect numbers via reduced egg mortality. 2) Consider repatriation of native Colorado River taxa present in other tailwaters. Research 1) Continue research into candidate taxa for repatriation, experiments on egg mortality, and monitoring of aquatic food base throughout Glen, Marble, and Grand Canyons. 2) Consider evaluating species effects of other parameters, including temperature, nutrients, and dissolved oxygen (DO) by comparing and contrasting invertebrate assemblages in mainstem vs. tributaries and other tailwaters.	1) Kennedy, et al., 2016, BioScience, v. 66, no. 7, p. 561-575.