GRAND CANYON MONITORING AND RESEARCH CENTER

Protocols Evaluation Program

Aquatic Food Base Research and Monitoring

Final Report
of the
Aquatic Food Base Study and Protocol Evaluation Panel

January 27, 2012

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Executive Summary

Maintenance of key native and non-native fish species is a strategic goal of the Glen Canyon Dam Adaptive Management Program, and has been translated into specific policies as part of the strategic plan. Goal 1 of this policy is to *"Protect or improve the aquatic food base so that it will support viable populations of desired species at higher trophic levels,"* which explicitly recognizes the importance of the aquatic food web to the viability of desired fish populations.

The Grand Canyon Monitoring and Research Center initiated research to understand the food-base resources of desired native and non-native fishes. This research quantified, for the first time, aquatic food webs of the Colorado River in Glen and Grand Canyons. Subsequently, the Grand Canyon Monitoring and Research Center proposed long-term monitoring of various food web components in the Colorado River. This review panel was convened as part of the Protocol Evaluation Program and charged with evaluating the validity of the findings from the Aquatic Food Base Study, as well as the adequacy of the proposed long-term monitoring plan. Our comments and recommendations follow.

The Aquatic Food Base Study was highly successful in at least three ways. First, it identified the invertebrate food resources that support Colorado River fishes and provided strong evidence that production of humpback chub and rainbow trout are limited by their food. Second, it clearly showed how management actions, like the 2008 High Flow Experiment, can influence desired fish populations via the aquatic food web. This information is critical to Glen Canyon Dam Adaptive Management Program Strategic Goal 1. Finally, the Aquatic Food Base Study was remarkably cost effective because it employed a great deal of resource leveraging by, and synergism among, the principal investigators. The panel commends the principal investigators, science support staff, the Grand Canyon Monitoring and Research Center and other supporting institutions for this excellent body of work.

In general, we found adequate evidence to support the primary conclusions drawn from the Aquatic Food Base Study (Appendix A). Our major recommendation is to continue to develop clear management-relevant conclusions from the Study that can subsequently be synthesized into a publication that is intended for managers, stakeholders, and the public. We also identify several major information gaps that were revealed by the Study, and urge the Grand Canyon Monitoring and Research Center to make filling these gaps a priority for future research efforts.

After review of the Aquatic Food Base Study and the proposed long-term monitoring plan, the panel has several findings and recommendations. The panel firmly believes that the proposed monitoring will be successful in meeting information needs of Glen Canyon Dam Adaptive Management Program Strategic Goal 1 ***only*** if it is accompanied by a flexible research program that is capable of

exploiting both planned and unforeseen events. Indeed, a primary goal of the long-term monitoring and research program must be more than just characterization of current ecological conditions; ***it must also build the knowledge base required to predict ecological responses to anticipated changes in water management.*** The research and monitoring program must therefore be coordinated and adaptive as more information becomes available and new questions arise. The review panel offers three general recommendations that will strengthen the monitoring and research efforts of the Grand Canyon Monitoring and Research Center:

1) ***Develop a monitoring and research program that is flexible enough to exploit learning opportunities from both planned and unforeseen events. Such event-driven ecological response monitoring and research will build the knowledge base required to predict the effects of water management on key fish species.***

2) ***Expand monitoring and research beyond the Colorado River mainstem within Glen and Grand Canyons; information from key tributaries and mainstem locations above Lake Powell is critical to understanding the aquatic food webs of the Colorado River and what potential exists for successful alterations to the system.***

3) ***The Grand Canyon Monitoring and Research Center should strive for improved integration of research across disciplines internally, and also with the Southwest Biological Center and Arizona Water Science Center.***

Background and Scope of Review

Maintenance of key native and non-native fish species is a strategic goal of the Glen Canyon Dam Adaptive Management Program. This goal has been translated into specific policies as part of the Glen Canyon Dam Adaptive Management Program strategic plan. Goal 1 of this policy is to *"Protect or improve the aquatic food base so that it will support viable populations of desired species at higher trophic levels."* (hereafter "Goal 1"). Goal 1 explicitly recognizes the importance of the aquatic food web to the viability of desired fish populations.

Understanding food webs is critical to managing ecosystems, yet the aquatic food web of the Colorado River within Glen and Grand Canyons had never been fully described. The Grand Canyon Research and Monitoring Center therefore initiated the Aquatic Food Base Study intending to fill this information gap. Specifically, the Study focused on describing key feeding linkages connecting basal resources to fish. The field component of the Aquatic Food Base Study was completed in 2009, from which the Grand Canyon Research and Monitoring Center developed a long-term monitoring plan to address key information needs for Goal 1. This panel was convened to review the food-base research and proposed monitoring plan.

Panelists convened January 9-13 at the Grand Canyon Monitoring and Research Center in Flagstaff, AZ and Lees Ferry, AZ. The panel (and several stakeholders) was given a series of presentations from the Principal Investigators of the Aquatic Food Base Study and then visited the Glen Canyon section of the Colorado River. This was followed by a series of presentations and subsequent discussions in Flagstaff, AZ between Grand Canyon Monitoring and Research Center staff, the Principal Investigators, and the panel. Grand Canyon Research and Monitoring Center staff and the Principal Investigators of the Aquatic Food Base Study provided a written summary of the research and proposed monitoring (Kennedy et al., 2012), which was the primary information source provided to the review panel. The panel was also provided with original reports during the review session. The panel was given three primary charges:

1) Comment on the validity of the research findings and conclusions of the Aquatic Food Base Study,

2) Comment on whether the proposed monitoring protocols described in Kennedy et al. (2012) are a logical next step given the overall research findings, and

3) Comment on whether the proposed monitoring protocols will be successful in meeting the information needs for the Glen Canyon Dam Adaptive Management Program Goal 1.

This report summarizes the panel's findings and recommendations. We first provide general recommendations relevant to both the research and long-term monitoring. We then address each of the charges listed above.

General Recommendations

1. Successful adaptive management requires a monitoring and research program that is flexible enough to exploit learning opportunities from both planned and unforeseen events. Such event-driven ecological response monitoring and research will build the knowledge base required to predict the effects of water management on key fish species; this ability is critical for Glen Canyon Dam Adaptive Management Program Strategic Goal 1. We agree that routine monitoring of carefully selected indicators of the food base and fish production will inform the Glen Canyon Dam Adaptive Management Program, but this alone will be insufficient to meet the information needs of Strategic Goal 1. The Aquatic Food Base Study and associated monitoring successfully identified the effects of a single High Flow Experiment in 2008 on the rainbow trout fishery. However, it is important to recognize that this study represents a sample size of one, limited to a single type of flow event, magnitude, and duration at a specific time of year. The ability to predict how future flow management affects the food base of key fish populations will require continued research associated with natural and human-caused flow events.

Episodic discharge events are a prominent feature of the Colorado River system. It is likely that the ecological effects of other types of high flow events will differ from those observed in the Aquatic Food Base Study. For example, large monsoon events supply sediment-rich water from tributaries, but may have no effect on flow, turbidity, and primary production in the Glen Canyon Reach. High-flow events that differ in origin and magnitude also likely affect the food supply of humpback chub and rainbow trout, and therefore provide valuable opportunities to develop the information needed to predict effects of flow on these fishes. Sustained high flows, such as occurred during 2011 when more water was released from Glen Canyon Dam than at any time during the last decade, provide even greater nutrient loadings to the system than episodic releases or monsoons. While sustained high releases are not expected to have as much impact on habitat as high-flow events, their impact on the food web and fish populations may be more important and should be investigated.

The review panel strongly encourages the Grand Canyon Monitoring and Research Center to initiate an adaptive monitoring and research program as soon as possible. Over two years have passed since the Aquatic Food Base Study team completed the field component of their project and the delay in having a plan in place has already resulted in missing major opportunities to learn more about the system. Specifically, having a monitoring and research program in place prior to 2011, would have allowed the Grand Canyon Monitoring and Research Center to directly study the impacts of the sustained high flows throughout the past year. Additionally, it is already known that there will be numerous manipulated flow events and other management actions, such as non-native fish removal, in the future and it is important to have an adaptive plan in place to study the impacts of these events.

An ecological response monitoring and research program would minimally comprise the following six features:

1. A funding mechanism analogous to the USGS Capital Equipment Fund is needed to support irregular multi-year episodes of investigation bracketing extreme-flow events that cannot be anticipated within the annual budgeting process.
2. Decisions to engage in opportunistic ecological response monitoring and research must be made based on accumulated scientific knowledge and information about changes in runoff and water management within the Colorado River basin.
3. General anticipatory research and monitoring protocols should be developed for major types of extreme flow events (e.g., large monsoons, stranding flows, unusually large winter snowpack conditions, major planned changes in water management).
4. Accrued dedicated financial resources should be sufficient to repeat major aspects of the Aquatic Food Base Study and to address new hypotheses about effects of flows on the food supply to humpback chub and rainbow trout.
5. Because management of rainbow trout and recovery of humpback chub depends on knowledge about effects of different types of flow events and hydrological conditions, the program should exploit opportunities provided by extreme flow events (both extreme high and low flows) in regulated and unregulated tributaries of the Colorado River. This feature is critical because it will reveal the practical limits and constraints on populations of humpback chub and rainbow trout.
6. The program should accommodate new research that addresses critical information gaps.

2. Understanding the Colorado River mainstem within Glen and Grand Canyons requires a watershed approach; monitoring and research confined to the Colorado River mainstem downstream of Glen Canyon Dam will be inadequate in providing the information needs of Strategic Goal 1. Just as the major storage

reservoirs in the Colorado River Basin are managed as a synchronized network, ecological monitoring and research must also take a system-wide approach. This need is clearly underscored by the Aquatic Food Base Study, which found that the supply of fish food resources within the mainstem Colorado was influenced by tributaries. However, because the study was limited to the mainstem and to periods of relatively low releases from Glen Canyon Dam, it is still unknown how the hydrology, geology, and food webs of the tributaries influence the food webs and, ultimately, the populations of desired fish species within the Colorado mainstem. Similarly, comparisons of the aquatic food web in Grand Canyon with those of relatively free-flowing sections of the Colorado River (e.g., Cataract Canyon) would provide valuable insights to the ways in which flow dynamics, turbidity, temperature, and non-native fishes influence the food resources and populations of native fishes. It is obvious to the review panel that the geographic scope of future monitoring and research must be determined solely by the scientific questions; institutional constraints on geographic scope will undermine the ability of the Grand Canyon Monitoring and Research Center to address key information needs.

3. The Grand Canyon Monitoring and Research Center should strive for improved integration of research across disciplines internally, and also with the Southwest Biological Center and Arizona Water Science Center. The Grand Canyon Monitoring and Research Center has a rich history of high quality research. It was clear to the review panel, however, that more collaboration would improve the synergy and efficiency of monitoring and research efforts. Monitoring fish populations and their food resources have been linked to separate goals of the Glen Canyon Dam Adaptive Management Program and typically assigned to groups of scientists working separately. Yet, the Aquatic Food Base Study clearly shows that learning is enhanced when they are linked. This integration was driven by necessity, in order to construct quantitative food webs for the Colorado River. There are other examples where more interdisciplinary efforts may be fruitful, including the possibility of improved linkages between water quality and biology programs. Internally, there needs to be better integration of information between efforts supporting Strategic Goal 1, and ongoing monitoring and research of fish populations by Grand Canyon Monitoring and Research Center staff and external partners (e.g., Arizona Game and Fish).

Increased collaboration will also help the Grand Canyon Monitoring and Research Center more efficiently collect and interpret a growing stream of data. The Aquatic Food Base Study produced a wealth of data. Routine monitoring and event-driven ecological response monitoring and research will produce additional data needed to inform adaptive management of the Colorado River in Glen and Grand Canyon. There also exists a large body of data and knowledge from tributaries and other systems that contain information relevant to prediction of how the Colorado River food web and fishes will respond to other types of hydrological events, including water-management strategies and long-term regional trends in precipitation. However, it is important to recognize that data are not knowledge.

Knowledge is created by the analysis of data and integration of the resulting new information with existing relevant information. The current scientific assets of the Grand Canyon Monitoring Research Center are excellent in quality, but currently too meager in quantity to analyze monitoring data and integrate that information with other relevant information to ultimately build robust predictive capability and continually update and publish syntheses for both lay and scientific audiences. *The review panel recommends the acquisition of at least one additional Research Grade scientist to assist the Grand Canyon Research and Monitoring Center with this growing need for expertise.*

Food Base Study: Review of Key Conclusions

The Aquatic Food Base Study was remarkably successful in at least three ways. First, it identified the invertebrate and algal food resources that support Colorado River fishes and provided strong evidence consistent with the hypothesis that production of humpback chub and rainbow trout are limited by production of their food. Second, it clearly showed how management actions, like the 2008 High Flow Experiment, influence desired fish populations via the aquatic food web. Finally, this panel believes the Aquatic Food Base Study was remarkable in the way it was executed; there was a great deal of resource leveraging by and synergism among the Principal Investigators.

This Panel reviewed the primary conclusions of the Aquatic Food Base Study that were articulated in Kennedy et al. (2012). These conclusions were drawn from the body of work primarily because they were deemed most relevant to managers and stakeholders, and particularly to Glen Canyon Dam Adaptive Management Program Strategic Goal 1. It should be noted that the Principal Investigators are still in the early stages of synthesizing the results from their data-rich project and it is likely additional conclusions will arise from this effort that should be incorporated into the adaptive monitoring and research plan. In this section, we systematically evaluate the evidence for each of the conclusions and offer suggestions for improvement. After discussing these comments and recommendations with the Principal Investigators during the review session, the Principal Investigators subsequently revised the conclusions (Appendix A).

In general, we find adequate evidence within the body of work for most of the major conclusions. In some cases, this evidence was unclear or absent from Kennedy et al. (2012), but was made available to the panel by the Principal Investigators throughout the course of the review session. In other cases, we suggest relatively minor changes to the wording or reorganization of conclusions, including qualifying some statements or more clearly explaining the evidence. Of

greatest importance, the review panel strongly urged the Principal Investigators to clearly and succinctly explain the management implications for each conclusion for inclusion in subsequent revisions of Kennedy et al. (2012) and/or other synthesis product(s). Each of the conclusions is discussed below in more detail.

Conclusion 1: A combination of autochthonous and allochthonous organic matter serves as the base of the aquatic food web in Grand Canyon, but high quality algal matter plays a role disproportionate to its availability.

The panel finds that evidence is sufficient to support this conclusion. We also suggest the Principal Investigators include findings from Glen Canyon, which show very high contributions from autochthonous sources to the aquatic food web.

Conclusion 2: Flow operations and turbidity are strong controls on autochthonous production

The panel finds that evidence is sufficient to support this conclusion.

Conclusion 3: Artificial floods can exert a strong control on invertebrate secondary production in the tailwater reach

The panel finds that evidence is sufficient to support this conclusion, and suggest rewording to "high-flow events."

Conclusion 4: Invertebrates in downstream reaches of Grand Canyon may be limited by the availability of high quality algal resources

Evidence was not made available to the review panel for this conclusion. Discussions with the Principal Investigators indicated that analyses supporting this conclusion are ongoing. We also suggested specifying invertebrate "growth" or "production" or "populations." We also suggest using more informative language.

Conclusion 5: The production of native and non-native fishes throughout Glen and Grand Canyon is fueled by key aquatic insects (i.e., Chironomidae and Simuliidae) that are in limited supply.

Evidence was sufficient to support this conclusion. We suggested greater clarity would be attained by limiting this conclusion to the first clause.

Conclusion 6: At certain locations and times, grazing pressure by fish populations may be a significant control on invertebrate biomass and production

Conclusion 7: At certain locations and times, fish populations are limited by the availability of high-quality prey, competition for these food resources is important, and flow management (e.g., artificial flooding) that affects these invertebrates will act as a lever to change fish populations

Evidence presented is consistent with competition, but does not alone demonstrate its existence. Actual demonstration of competition is extremely difficult—especially with observational data—and rarely done. Evidence is also unclear whether dynamics are top down (as suggestion in #6) or bottom up (#7). We suggested the authors tone down both conclusions and consider combining them.

Priority Information Gaps Identified by the Food Base Study

The Aquatic Food Base Study provided a great deal of critical information needed for Glen Canyon Dam Adaptive Management Program Strategic Goal 1, but also identified several key information gaps. These gaps were identified and prioritized by both the review panel and the Principal Investigators. The top five are listed in this section, and the remaining topics are listed in Appendix B.

- What were the food web and ecosystem characteristics of the pre-dam Colorado River?

- What is the importance of tributaries in influencing or augmenting the food base for fishes in the Colorado River mainstem?

- To what degree do desired fish species limit their food base, and does this limitation directly influence the reproduction and recruitment of desired fishes—particularly humpback chub?

- How do flow manipulations affect aquatic food webs and food resources for desired fish species in Glen and Grand Canyons? Will future planned spring-timed High Flow Events elicit a similar food web and ecosystem response as observed in 2008?

- How might aquatic food webs and food resources for desired fish species be affected by changes to Glen Canyon Dam releases anticipated to result from long-term changes in climate, runoff, and water management? In particular,

future dam releases may include wider swings in water temperature and quality.

Proposed Long-Term Monitoring: Review Comments

Grand Canyon Monitoring and Research Center staff and the Principal Investigators of the Aquatic Food Base Study provided the review panel with a description of proposed long-term monitoring activities (part 3 of Kennedy et al. 2012). The review panel's charge was to evaluate whether the proposed monitoring 1) is a logical extension of the food base study and appropriate based on our current understanding, and 2) will be successful in meeting the information needs for the Glen Canyon Dam Adaptive Management Program Goal 1.

As we previously explained in the General Comments, the review panel firmly believes that the proposed monitoring will be successful in meeting the information needs of Objective 1 ***only*** if it is accompanied by an flexible research and monitoring program that is capable of exploiting both planned and unforeseen events. Again, the panel emphasizes that monitoring programs need to be adaptive as more information becomes available and new questions arise. It is likely that additional monitoring adjustments will be necessary as new information arises.

The proposed long-term monitoring plan is focused on collecting data to determine ecosystem metabolism rates (primarily gross primary production but potentially ecosystem respiration in the Glen Canyon tailwaters), water column organic matter (dissolved, fine particulate and coarse particle fractions) concentrations, invertebrate drift composition, emergent insect production, and benthic algae/ invertebrate biomass (also includes benthic organic matter). They propose sampling at time scales ranging from daily (metabolism rates) to yearly (benthic sampling) with other sampling occurring 10 times per year. Sampling is proposed to occur at between 5 and 8 locations depending on the metric. This proposed plan is summarized in Table 4 of Kennedy et al. (2012).

Below, we provide comments and recommendations for several specific elements of the proposed monitoring plan.

Sampling frequency: The Grand Canyon Monitoring and Research Center should consider whether the information gained by sampling 10X/year (particularly at the less accessible sites) is greater than the effort required beyond the already scheduled trips to the sampling sites, which appears to be 4-6X/year.

Ecosystem Metabolism: It should be made clear that this largely refers to quantifying rates of gross primary production since currently it is not possible to accurately quantify rates of ecosystem respiration in the Grand Canyon. There is a large need for routine data processing and interpretation of these data. Is the expertise and resources available at Grand Canyon Monitoring and Research Center? It is not clear why gross primary productivity (GPP) monitoring is needed at all of the proposed sites, especially given the large need for data processing.

Organic Matter: When practical, organic inputs from tributaries and episodic events should be characterized.

Invertebrate Drift: It appears that pilot work is needed. Specifically, do samples from the margin (remote sites) compare to samples from the thalweg? Also, what is the needed sampling duration at remote sites?

Emergent Insect Production: The review panel does not feel that the proposed emergence monitoring is feasible, but encourages pilot efforts to evaluate the feasibility of sticky traps in this unique environment—especially given the need to deploy over several week time periods. We suggest that these pilot efforts be attempted at Lees Ferry and Diamond Creek—which represent contrasting river conditions.

Benthic Algae & Invertebrates: Consider the use of basket or Hester-Dendy sampling to characterize drift/colonization of blackflies and other drifting insects, and to track patterns in biological diversity.

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Wellard Kelly, H.A., E.J. Rosi-Marshall, T.A. Kennedy, R.O. Hall, Jr., W.F. Cross and C.V. Baxter. *In review.* Macroinvertebrate diets reflect longitudinal and seasonal changes in food availability downstream of a large dam.

APPENDIX A—Revised Conclusions from Food Base Study

1) **Autochthonous organic matter, specifically diatoms, is the base of the aquatic food web in Glen Canyon.** Evidence for this conclusion comes from diet and stable isotope analyses, and trophic basis of production calculations for invertebrates and rainbow trout (see Objective 3 and figure 8 in Kennedy et al. 2012; Cross et al. 2011, Donner 2011, Kelly et al. in review).

2) **A combination of autochthonous and allochthonous organic matter is the base of the aquatic food web in Grand Canyon, but high quality algal matter supports the food web to an extent disproportionate to its availability.** Evidence for this conclusion comes from organic matter budgets, diet and stable isotope analyses, and trophic basis of production calculations for invertebrates and rainbow trout (see Objective 1, 3 and figure 10 in Kennedy et al. 2012; Cross et al. 2011, Donner 2011, Kelly et al. in review).

3) Flow operations and turbidity strongly control autochthonous production. Daily estimates of metabolism for the Colorado River near Diamond Creek across a range of flows and turbidity support this conclusion (see Objective 1 and figures 3 and 4 in Kennedy et al. 2012).

4) Invertebrate production exhibits stepped declines below the Paria and Little Colorado Rivers, and production at sites below the Little Colorado River is extremely low relative to other streams and rivers. Evidence for this conclusion comes from three years of benthic invertebrate sampling and secondary production calculations at six sites (see Objective 2 and figure 5 in Kennedy et al. 2012; Cross et al. 2011).

5) High flow events can exert a strong control on invertebrate assemblages and secondary production in the tailwater reach. Evidence for this conclusion comes from intensive sampling of benthic and drifting invertebrates before and after the March 2008 artificial flood (see Objective 2 and figures 5 and 8 in Kennedy et al. 2012; Rosi-Marshall et al. 2010, Cross et al. 2011).

6) Fish production was dominated by rainbow trout at upstream sites (i.e., RKM 0 and 48) and flannelmouth sucker at downstream sites (i.e., RKM 204, 266, and 362), and production was comparable among sites. Evidence for this conclusion comes from fish production calculations for two years and six sites (see Objective 2 and figure 6 in Kennedy et al. 2012; Donner 2011).

7) **The production of native and non-native fishes throughout Glen and Grand Canyon is principally fueled by two aquatic insect taxa—Chironomidae and Simuliidae.** Evidence for this conclusion comes from diet and trophic basis of

production calculations for the entire assemblage of fishes (see Objective 3 and figures 8 and 12 in Kennedy et al. 2012; Cross et al. 2011, Donner 2011).

8) **Fish production throughout Glen and Grand Canyon appears limited by the availability of high quality prey, particularly Chironomidae and Simuliidae, and fish may exert top-down control on these prey.** This conclusion derives from calculations of the trophic basis of fish production and interaction strengths between fishes and their invertebrate prey (see Objective 3 and figure 12 in Kennedy et al. 2012; Donner 2011).

9) **Dam operations (e.g., artificial flooding) that affect these invertebrates can change fish production, and fish movements downstream may change those food webs.** Evidence for this conclusion comes from detailed descriptions of food webs in Glen and Grand Canyons before and after the 2008 artificial flood (see Objective 2 and 3 and figures 5 and 6 in Kennedy et al. 2012; Cross et al. 2011 and Donner 2011).

10) **The trophic basis of production of fishes overlaps and because these resources may be in limited supply there is strong potential for competition among native and non-native species.** This conclusion stems from detailed analysis of fish diets, and calculations of trophic basis of fish production, and interaction strengths between fishes and their invertebrate prey (see Objective 3 and figure 12 in Kennedy et al. 2012; Donner 2011).

APPENDIX B—Other Important Information Gaps Identified by the Food Base Study

- There is a need for linking food-base resources to long-term expectations for water availability and climate change.

- There is a need for studying heterotrophs/microbes, especially given the need to follow dissolved organic carbon into the food web. This is needed to understand the bioavailability of this carbon and particulate carbon in the system

- What prevents tributary or regional native invertebrates from persisting in the Colorado River in Glen and Grand canyons?

- How have increases in the rainbow trout population near the Little Colorado River confluence altered the food web and potential competition for food?

A Review of GCMRC's Aquatic Food Base Study & Proposed Monitoring Plan

The Review Panel

- S. Gutreuter, Research Statistician, USGS
- G. Holdren, Biologist, USBoR
- B. Roberts, Assistant Professor, LUMC
- C. Robinson, Research Scientist, EAWAG
- D. Carlisle, Ecologist, USGS (chair)

Our Charge

Our Charge

- Technical review of aquatic food base study

Our Charge

- Technical review of aquatic food base study
- Appropriateness and effectiveness of proposed monitoring plan

GCDAMP Strategic Goal:

"Protect or improve the aquatic food base so that it will support viable populations of desired species at higher trophic levels."

General Recommendations

Need More:

- **Agile research & monitoring program**
- **River network perspective**
- **Integrated research**

Agility in Monitoring and Research

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- Potential to learn is highest when ecosystem components are "manipulated" by nature or humans

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- Potential to learn is highest when ecosystem components are "manipulated" by nature or humans
- Develop anticipatory research & monitoring protocols for alternative scenarios, e.g., extreme monsoon event

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- Make resources available

Agility in Monitoring and Research

- Potential to learn is highest when ecosystem components are "manipulated" by nature or humans
- Develop anticipatory research & monitoring protocols for alternative scenarios, e.g., extreme monsoon event
- Make resources available
- A single, fixed approach probably insufficient

River Network Perspective

River Network Perspective

- Tributaries crucial to mainstem food web

River Network Perspective

- Tributaries crucial to mainstem food web
- Need to know "ecological potential"--may be above Lake Powell

Information Integration

Information Integration

- Multiple USGS, other federal, & state entities collect data

Information Integration

- Multiple USGS, other federal, & state entities collect data
- Priorities on different components of food web

Information Integration

- Multiple USGS, other federal, & state entities collect data
- Priorities on different components of food web
  - native fish population recruitment

Information Integration

- Multiple USGS, other federal, & state entities collect data
- Priorities on different components of food web
  - native fish population recruitment
  - water quality

Information Integration

- Multiple USGS, other federal, & state entities collect data
- Priorities on different components of food web
  - native fish population recruitment
  - water quality
  - ecosystem processes

Information Integration

- Multiple USGS, other federal, & state entities collect data
- Priorities on different components of food web
    - native fish population recruitment
    - water quality
    - ecosystem processes
- Integration of research vs. information

Food Base (web) Study

What went right:

Food Base (web) Study

What went right:

- Revealed energetic pathways and constraints

Food Base (web) Study

What went right:

- Revealed energetic pathways and constraints
- Revealed effects of management actions & *mechanisms*

Food Base (web) Study

What went right:

- Revealed energetic pathways and constraints
- Revealed effects of management actions & *mechanisms*
- Leveraged resources & synergistic efforts

Food Base (web) Study

Where it lacks:

Food Base (web) Study

Where it lacks:

- Connection of food web energetics to population dynamics (e.g., recruitment) of key fish species

Food Base (web) Study

Where it lacks:

- Connection of food web energetics to population dynamics (e.g., recruitment) of key fish species
- Limited to Colorado River mainstem

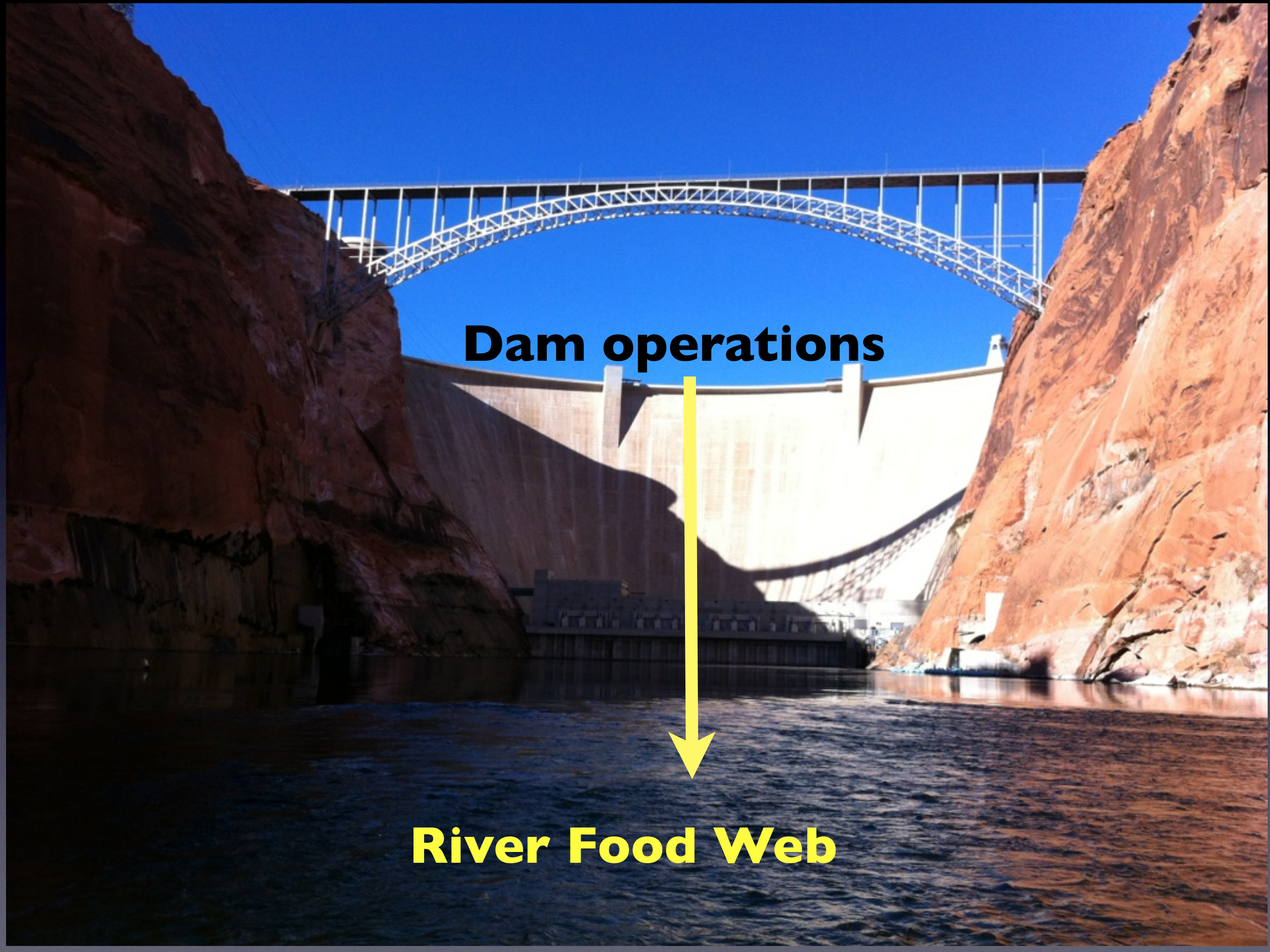
Food Base (web) Study

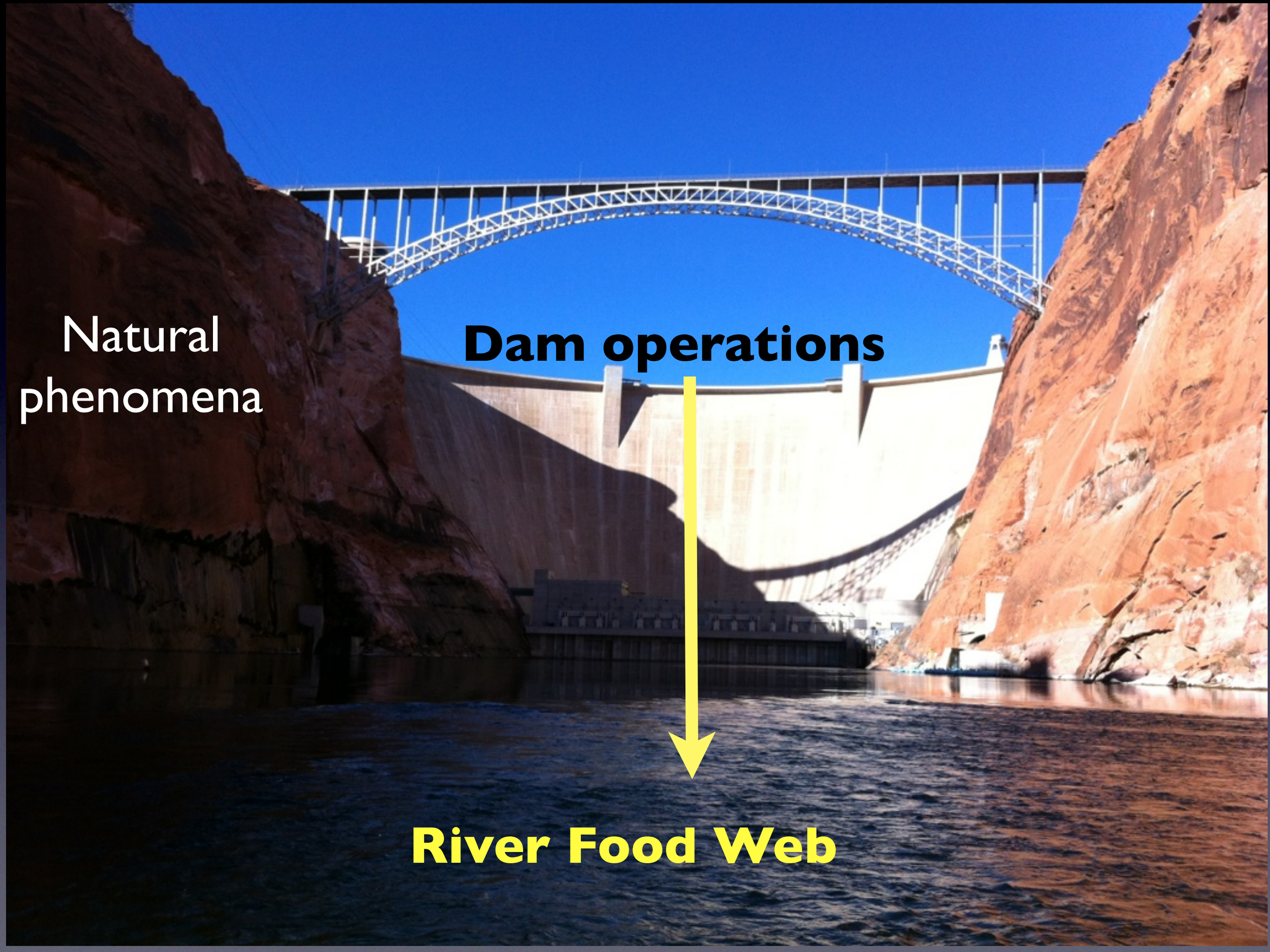
Where it lacks:

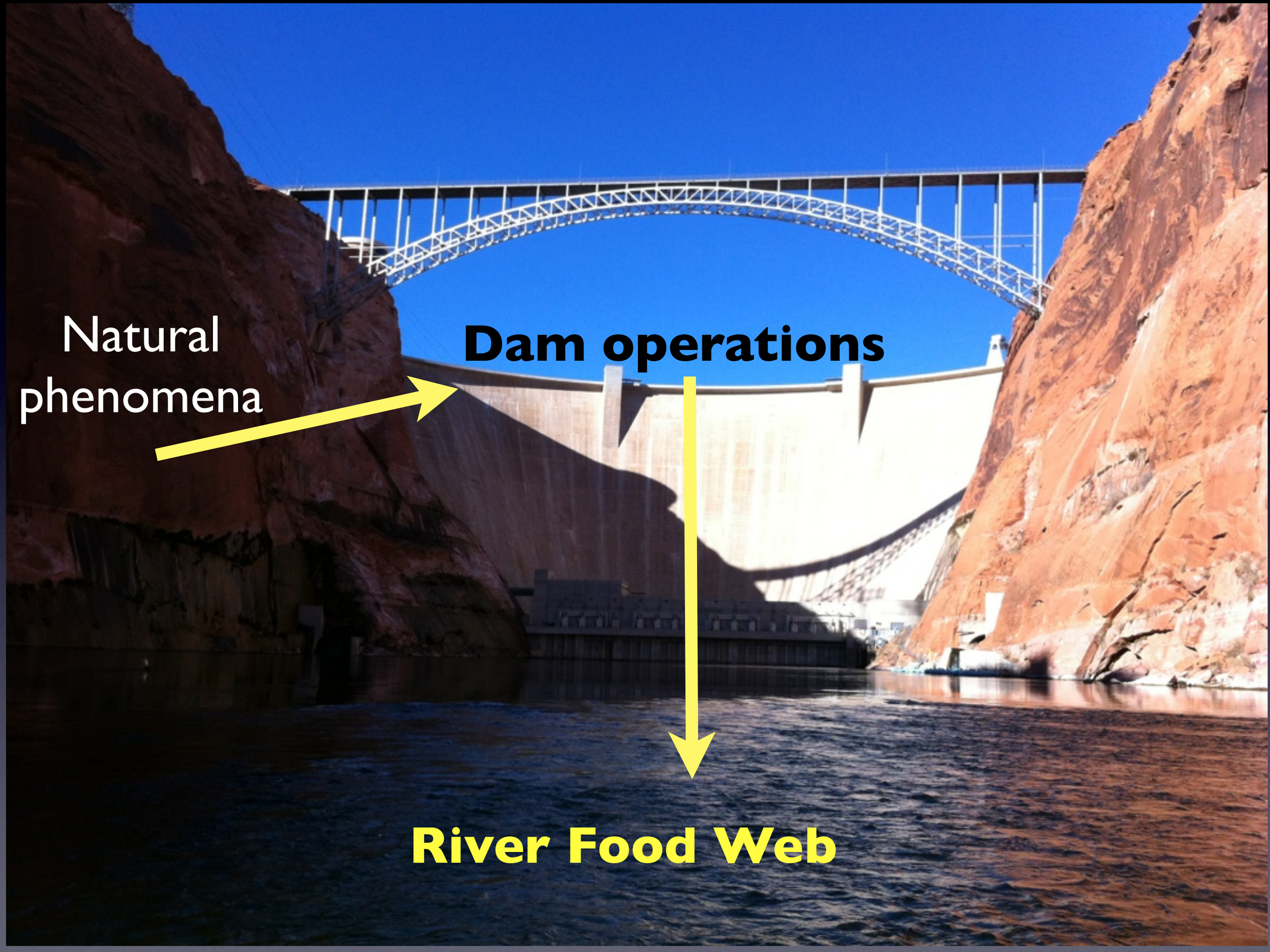
- Connection of food web energetics to population dynamics (e.g., recruitment) of key fish species
- Limited to Colorado River mainstem
- One-time (3 yrs) study

Dam operations

Dam operations


Dam operations
River Food Web


Natural phenomena
Dam operations
River Food Web


Natural phenomena
Dam operations
River Food Web

Natural phenomena

Dam operations

River Food Web

Extreme Sampling Challenges!

Long-term Monitoring Plan

- Sampling frequency
- Ecosystem metabolism
- Organic matter
- Invertebrate drift
- Emergent insect production
- Benthic communities

Long-term Monitoring Plan--
Sampling Frequency

Proposal: 10X / year for most components

Long-term Monitoring Plan-- Sampling Frequency

Proposal: 10X / year for most components

- For many ecosystem components, rationale for sampling frequency appears to be convenience.

Long-term Monitoring Plan--
Sampling Frequency

Proposal: 10X / year for most components

- For many ecosystem components, rationale for sampling frequency appears to be convenience.
- What frequency is most synchronous with system dynamics & management activities?

Long-term Monitoring Plan--
Metabolism & Organic Matter

Proposal: Metabolism (daily), organic matter (10X / yr)

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- How will monitoring data for organic matter concentrations & primary production be used & interpreted?

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Proposal: Metabolism (daily), organic matter (10X / yr)

- How will monitoring data for organic matter concentrations & primary production be used & interpreted?
- How will basal resource dynamics/trends be linked to upper trophic levels?

Long-term Monitoring Plan--
Invertebrate Drift

Proposal: 5 min samples from margin & thalweg

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Invertebrate Drift

Proposal: 5 min samples from margin & thalweg

- Still unknowns about methods, e.g., sampling duration (hrs vs mins) & location (margin vs. thalweg)

Long-term Monitoring Plan-- Emergent Insects

Proposal: Sticky traps deployed continuously

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- Question whether proposed approach is feasible

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Proposal: Sticky traps deployed continuously

- Question whether proposed approach is feasible
- Recommend pilot efforts at accessible sites

Long-term Monitoring Plan--
Benthic Communities

Proposal: Annual sampling in select (<20% of) habitats

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- Consider basket or Hester-Dendy type sampling for aquatic insects

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Benthic Communities

Proposal: Annual sampling in select (<20% of) habitats

- Consider basket or Hester-Dendy type sampling for aquatic insects
- How will periodic benthic community data be linked to process measurements? Fish populations?

Conclusions

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- Food web study was well executed, cost effective, and provided groundbreaking new and management-relevant information

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- Food web study was well executed, cost effective, and provided groundbreaking new and management-relevant information
- Proposed monitoring plan is understandably complex, and requires additional analysis of existing data and pilot efforts

Questions?