Foodbase Update

U.S. Department of the Interior
U.S. Geological Survey

Outline

- FY12 Publications
- Major findings of Foodbase research project (2006-2009) and outcomes of PEP
- Choose your own foodbase adventure:
  1. Effects of discharge and benthic abundance on invertebrate drift at Lees Ferry
  2. Invertebrate drift and rainbow trout diets—Glen and Marble Canyon
  3. Harnessing the power of citizen science—emergent aquatic insect monitoring using light traps
  4. Drift distances—characterizing invertebrate drift throughout Glen Canyon
  5. Identifying controls on algae production at Diamond Creek

- **Hall, Kennedy, and Rosi-Marshall. 2012. Air-water oxygen exchange in a large whitewater river. *Limnology and oceanography: fluids and environments* 2: 1-11.**

- **Kennedy, Baxter, Hall, Rosi-Marshall. 2012. A summary of research conducted in support of the Glen Canyon Dam Adaptive Management Program's Goal 1—Aquatic Foodbase—Including Proposed Monitoring Protocols. Administrative Report provided to TWG and PEP**

- **Kennedy. *In press*. Identification and evaluation of scientific uncertainties related to fish and aquatic resources in the Colorado River, Grand Canyon: summary and interpretation of an expert elicitation questionnaire. USGS Scientific Investigations Report.**

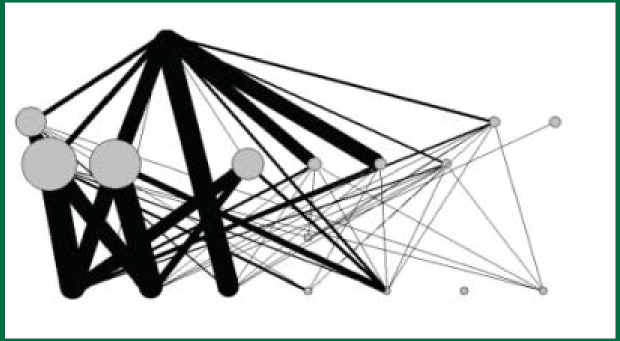
- **Wellard-Kelly, Rosi-Marshall, Kennedy, Hall, Cross, Baxter. *In press*. Macroinvertebrate diets reflect tributary input and turbidity-driven changes in food availability in the Colorado River downstream of Glen Canyon Dam. *Freshwater Science***

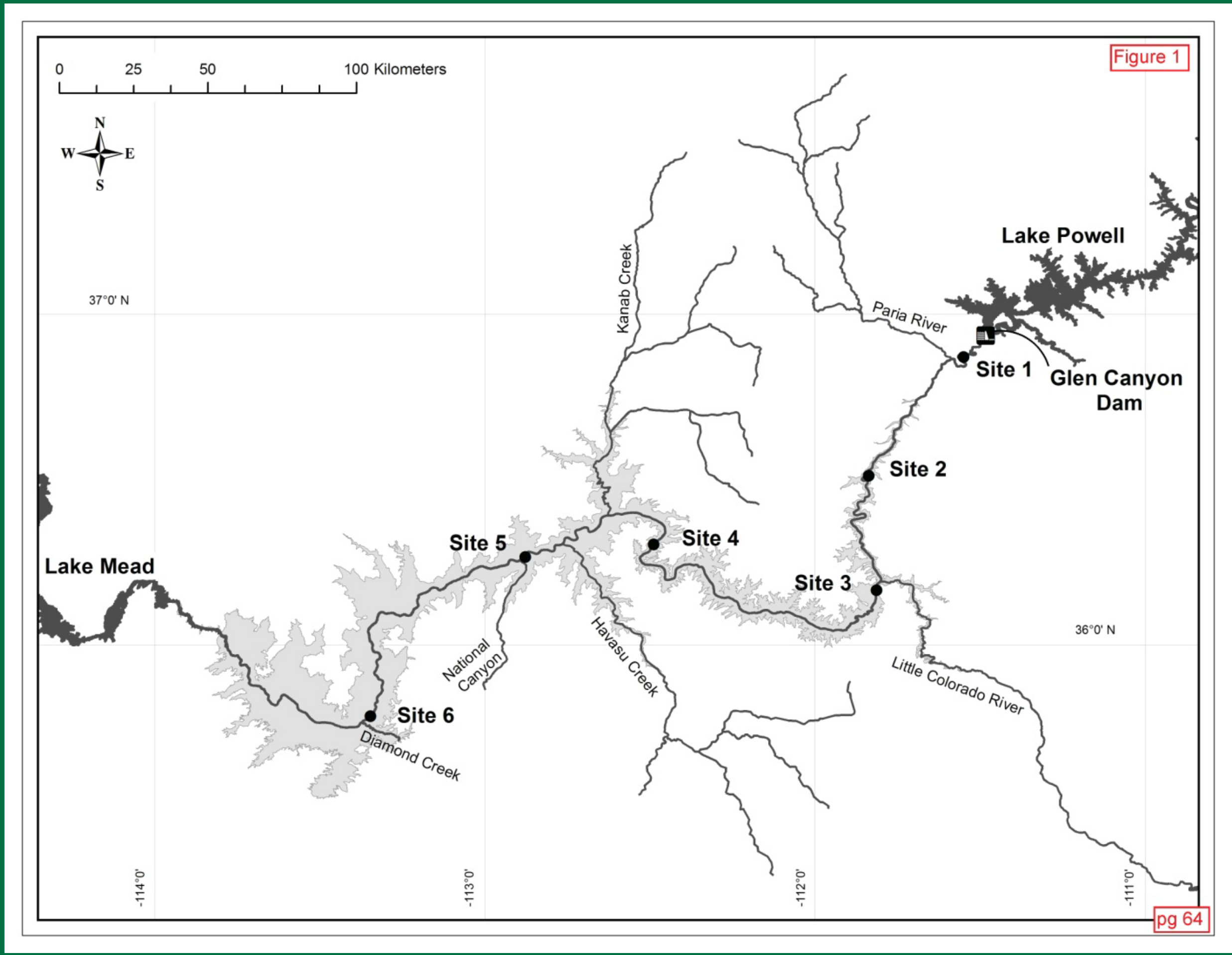
- **Cross, Baxter, Rosi-Marshall, Hall, Kennedy, Donner, Wellard-Kelly, Seegert, Behn, and Yard. *In revision.* Foodweb dynamics in a large river discontinuum. *Ecological Monographs.***

Foodbase Research—Brief Methods

Developed quantitative food webs for 6 sites across 3 years (2007-2009)

Quantitative food webs describe how energy moves through the web





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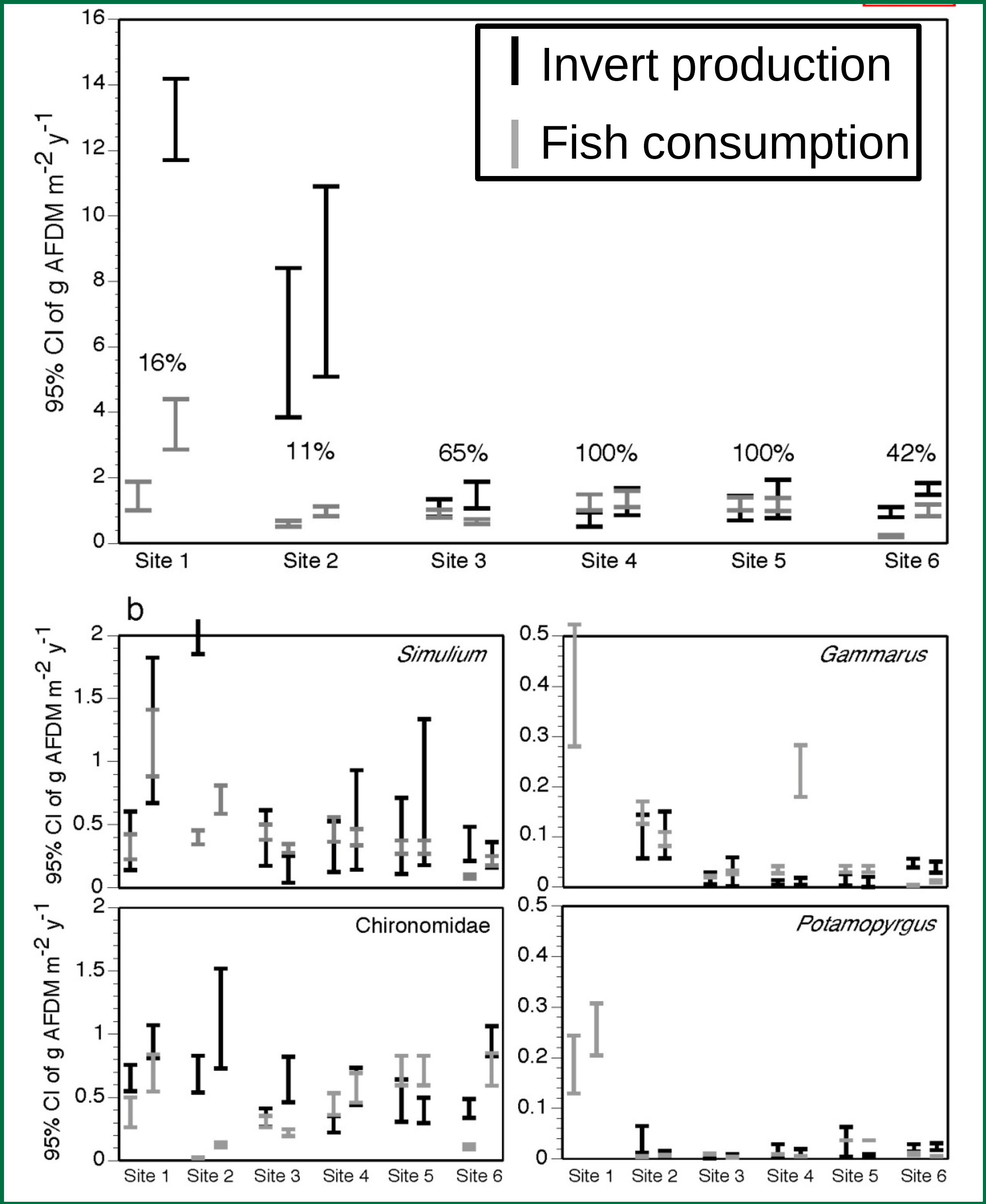
Findings

As distance from Dam increases we see:

-Increasing eco-trophic efficiency



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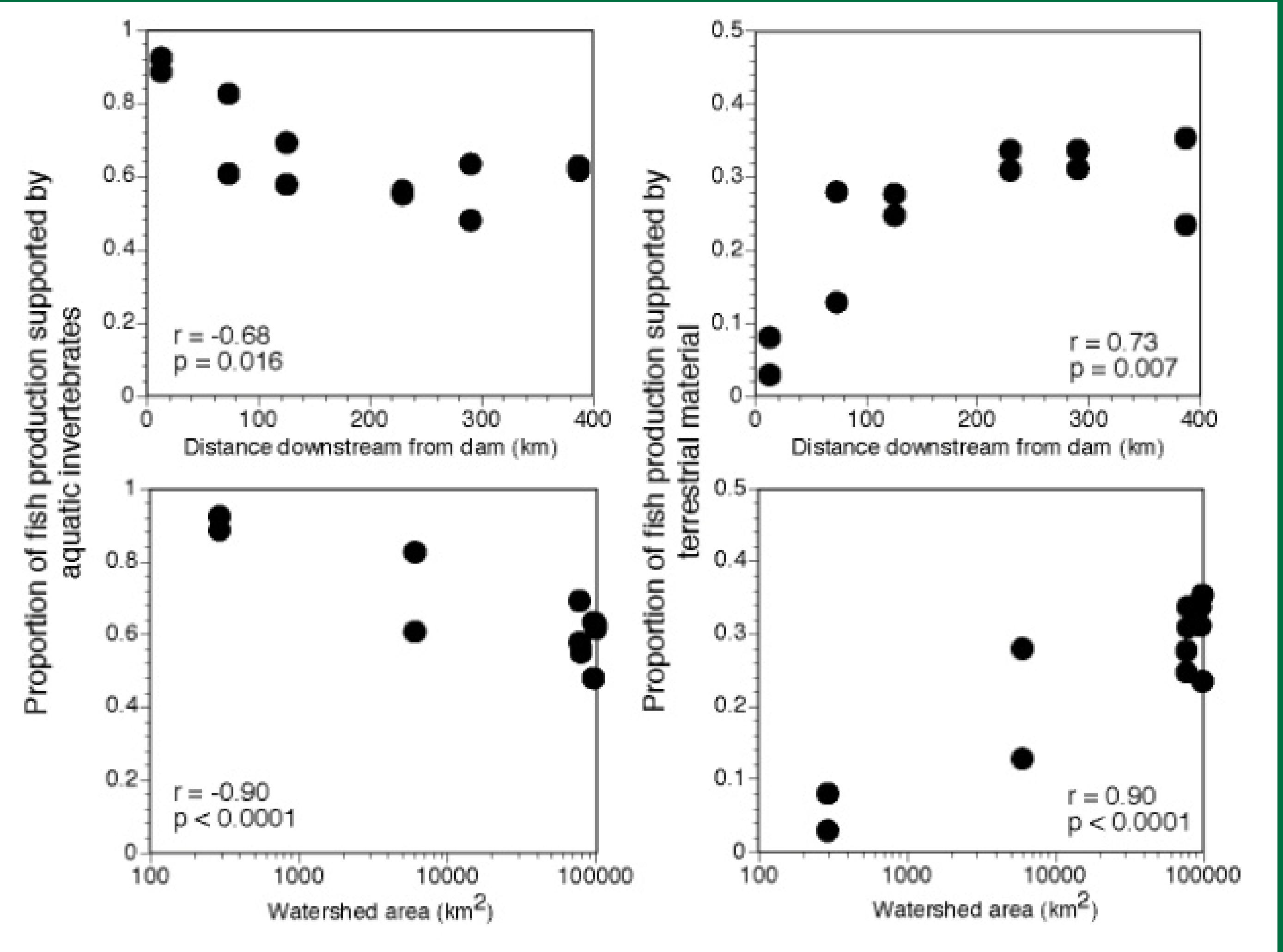
Findings

As distance from Dam increases we see:

-Increasing reliance on organic matter

-More incorporation of detritus into food web



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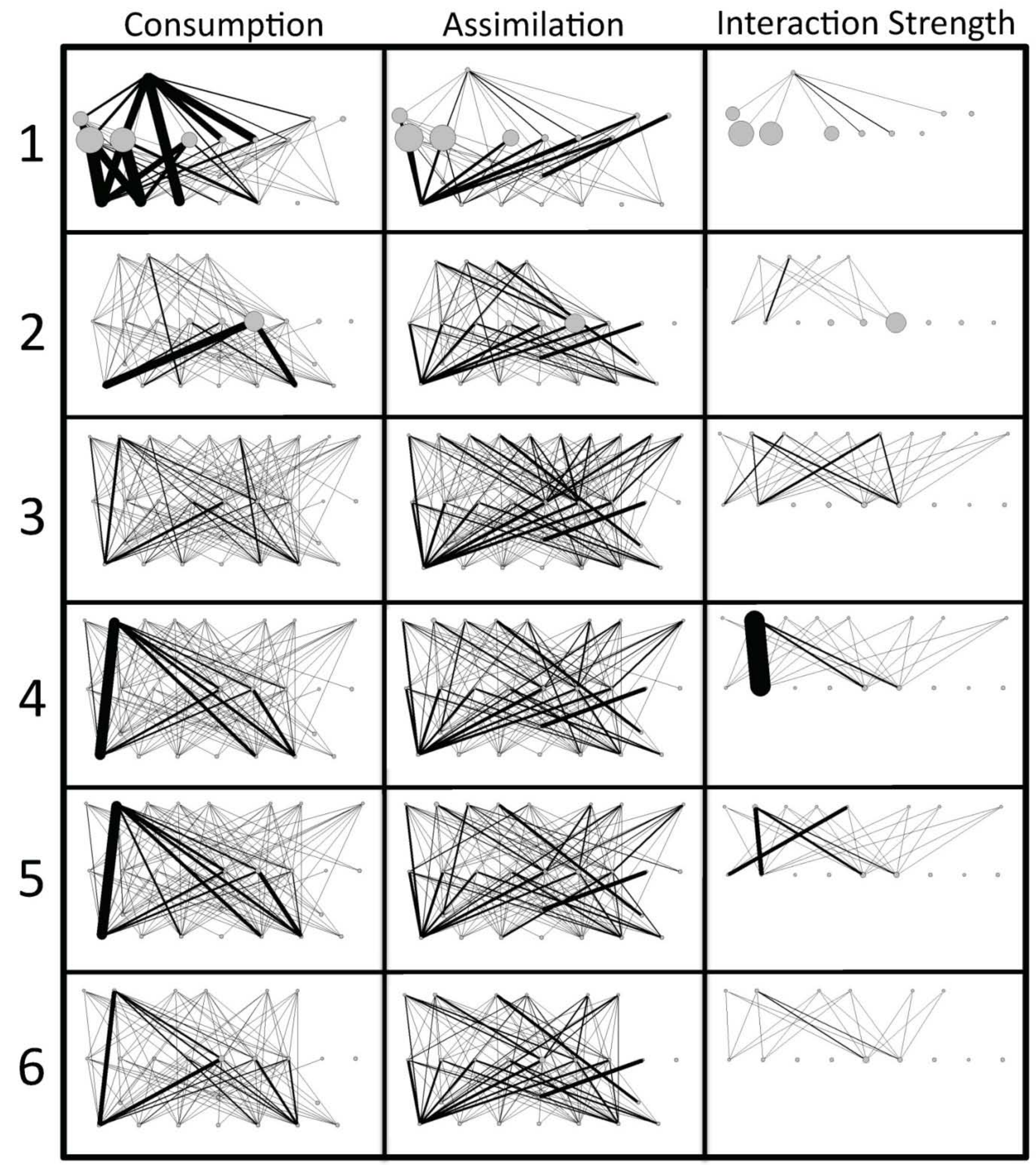
Findings

As distance from Dam increases we see:

-Increasing complexity in food webs:

1) greater number of interactions

2) higher number of interactions per species



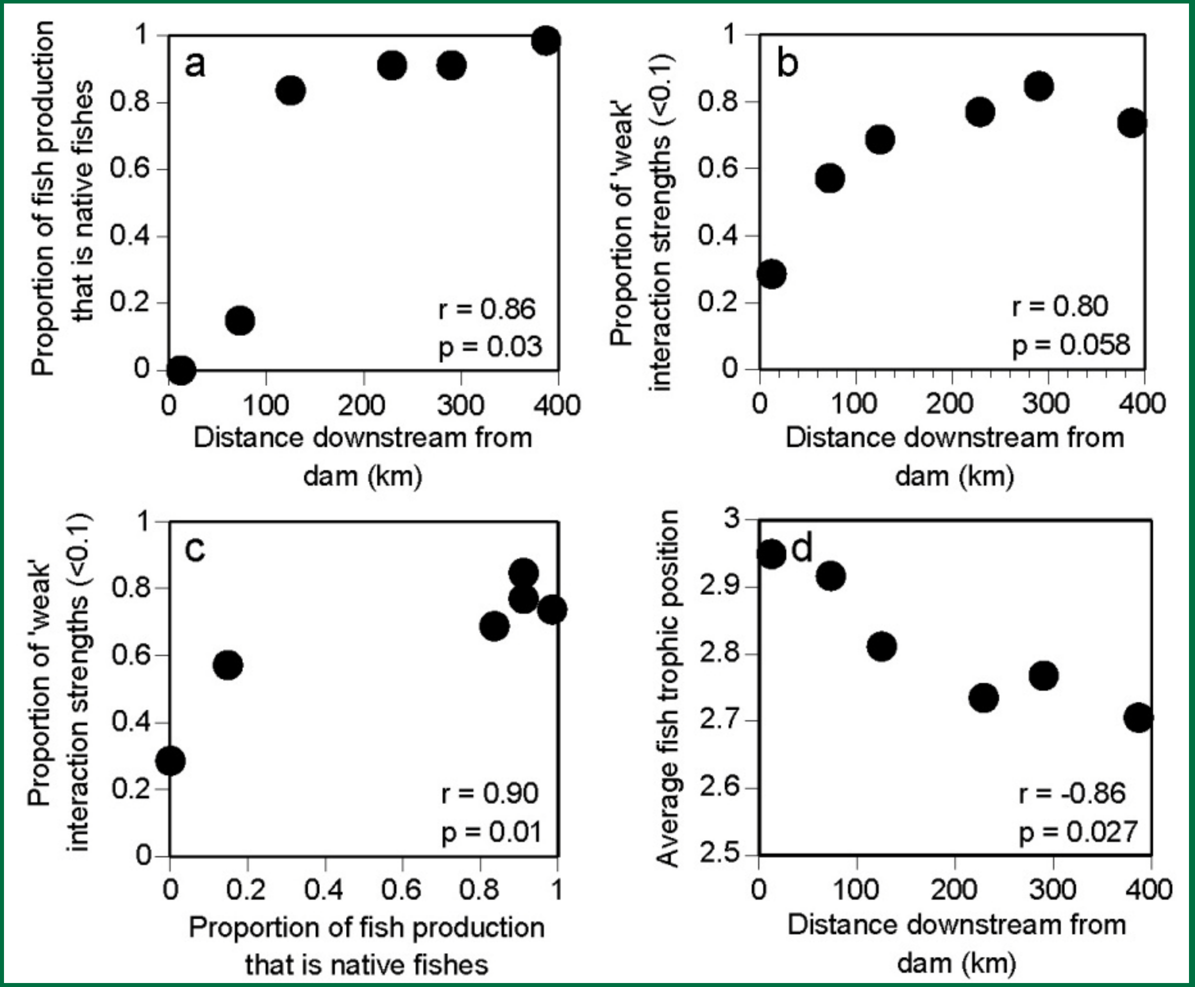
Findings

As distance from Dam increases we see:

-Native fishes dominate

-Food webs have a higher proportion of ‘weak’ interactions

-Fish trophic position decreases



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Food web metrics—Summary

Metric	Glen Canyon	Grand Canyon
Eco-trophic Efficiency	Low	High
Complexity	Less Complex	More Complex
Resource Base	Algae	Algae and Detritus
Proportion of weak interactions	Low	High

Food web stability

- **What is it?**
  - “The likelihood of the persistence of some set of interacting species.” (**Rooney and McCann 2012)**

- **Why does this matter?**
  - **Complex > Simple**
  - **Algae + detritus > algae alone**
  - **Strong and weak > strong only**

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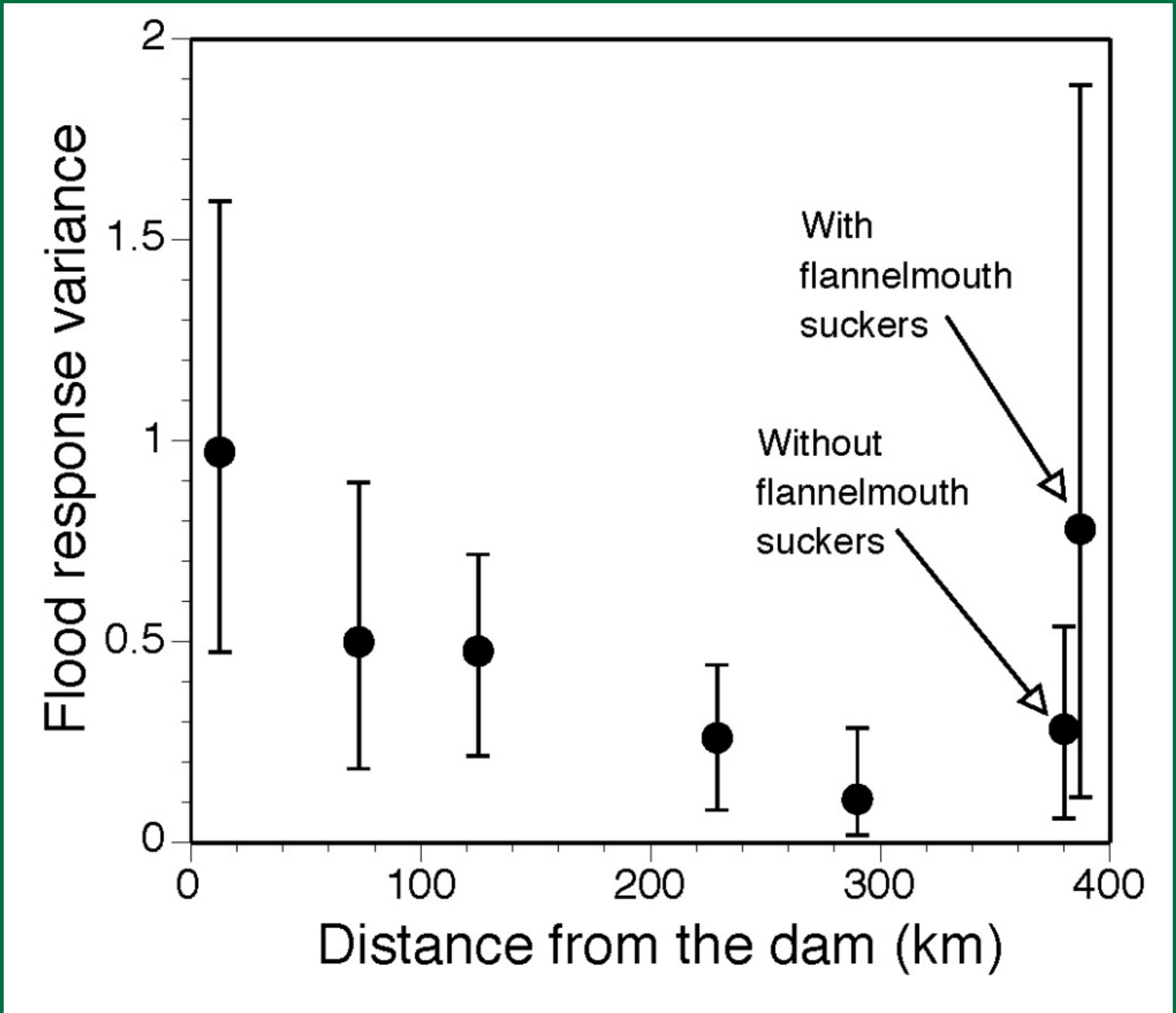
Food web response to 2008 HFE

The 2008 artificial flood caused a larger shift in the structure and function of Glen Canyon food web relative to downstream food webs

In other words, the Glen Canyon food web appears less resistant to perturbation than Grand Canyon food webs



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Conclusions

- Based on theory and other studies, Glen Canyon food web appears relatively unstable
- Food webs as stock portfolios:
  - Glen Canyon food web has a small number of very volatile stocks
  - Downstream food webs have a larger and more balanced portfolio of stocks
- In the absence of changes in food web structure (i.e., more diverse invertebrate assemblage), it is possible that rainbow trout populations will continue to fluctuate through time

PEP review

- Timeline
  - PEP convened Jan 2012
  - Panel Chair and Kennedy Report at April 2012 TWG
  - Outcomes/recommendations incorporated into FY 13-14 workplan

- Outcomes
  - Focus on invertebrate drift as monitoring metric, but need a better handle on spatial and temporal variation
  - Continue integrating information on prey base with information on fish feeding habits
  - Evaluate emergence monitoring as a surrogate for benthic monitoring

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Technicians

- Adam Copp (natal origins river trips, database)
- Joshua Smith (natal origins river trips, diet samples)
- Moriah Evans (drift samples)
- Connor Phillips (drift samples)
- Thomas Quigley (drift samples)
- Anya Fayfer (light trap samples)
- Eric Kortenhoeven (light trap samples)

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Outline

- **Choose your own foodbase adventure:**
  1. Effects of discharge and benthic abundance on invertebrate drift at Lees Ferry
  2. Invertebrate drift and rainbow trout diets—Glen and Marble Canyon
  3. Harnessing the power of citizen science—emergent aquatic insect monitoring using light traps
  4. Drift distances—characterizing invertebrate drift throughout Glen Canyon
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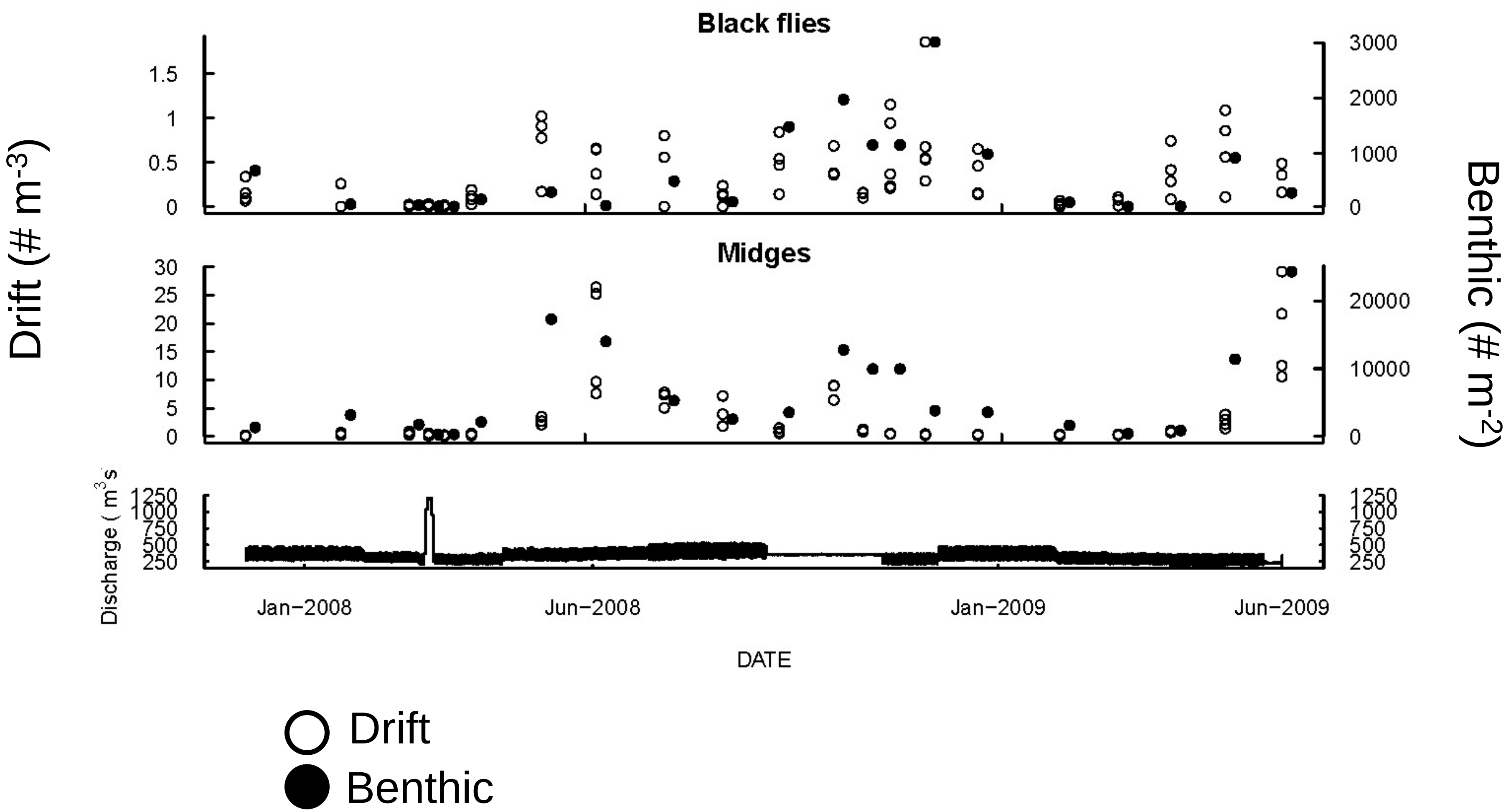
Invertebrate Drift at Lees Ferry

- Goal: Identify relative roles of discharge and benthic density on invertebrate drift rates in Glen Canyon
- Data: Monthly measurements of benthic and drifting invertebrates (Dec 2007—May 2009)
  - Benthic—20 samples per month from all habitat types (from RM-8.5 to -3.5)
  - Drift—15 samples per month across a range of discharges (at boatramp only)

The Data



Black flies
Midges
Drift (# m-3)
Benthic (# m-2)
Discharge (m3s
Jan−2008
Jun−2008
Jan−2009
Jun−2009
DATE
Drift
Benthic

Modeling Drift

$$C = aB^f Q^g$$

C = Drift concentration (#/m^3)

B = benthic density (#/m^2)

Q = Discharge (m^3/s)

a = intercept (estimated)

f and g = exponents (estimated)

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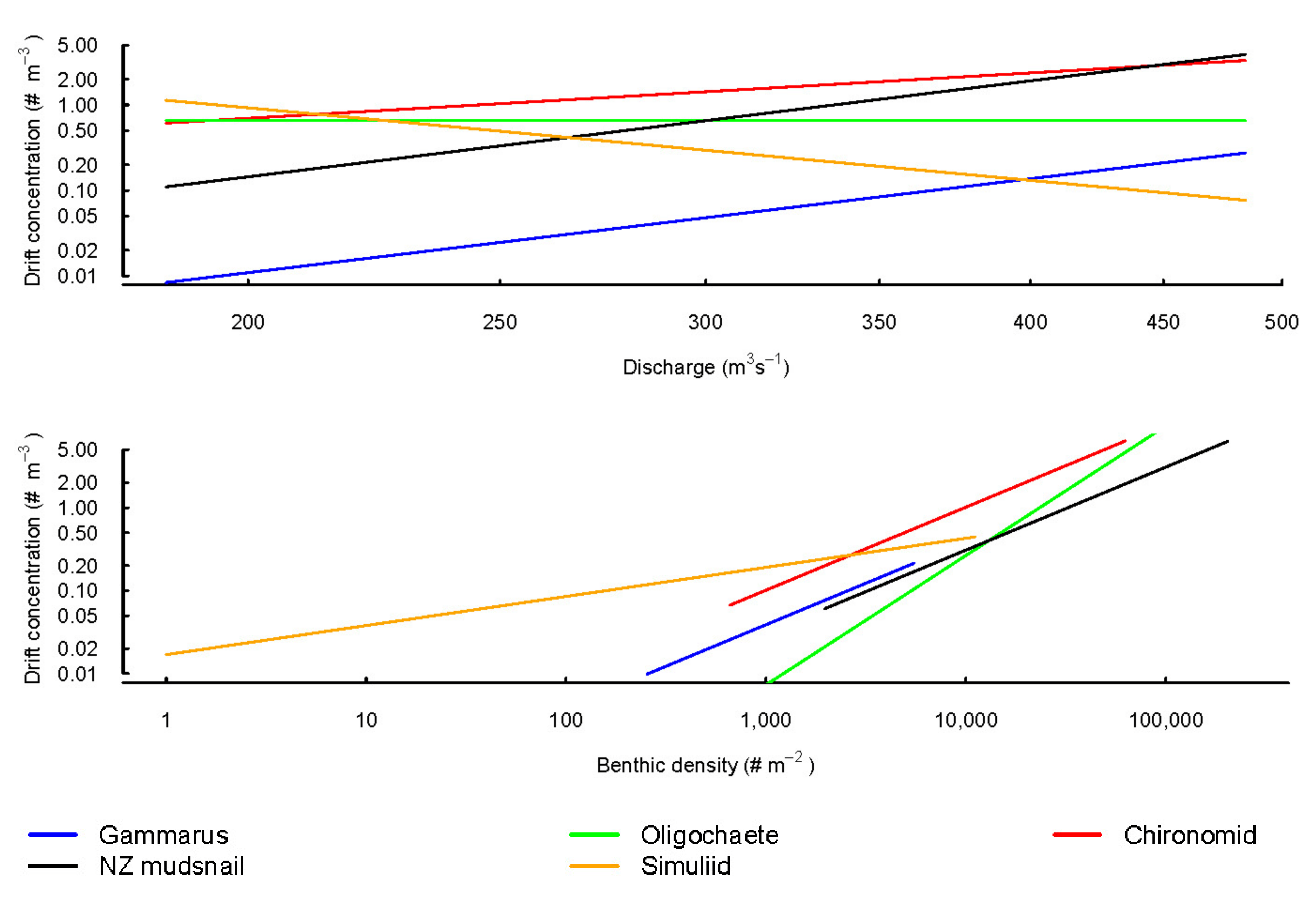
Model Output



Model Summary

$$C = aB^f Q^g$$

Taxa	f (benthic)	g (discharge)
Gammarus	1.0	3.7
Mudsnails	1.0	3.7
Oligochaete worms	1.6	0
Black flies	0.35	-2.8
Midges	1.0	1.7

Caveats

- Only evaluated short-term effects of discharge on drift (i.e., what happens over the course of a day)
- Over longer-time scales (i.e., weeks-months)

  High discharge → high drift → low benthic?

Conclusions

- Benthic density and discharge both affect drift densities in Glen Canyon
- Variation among taxa is consistent with other studies
  - Black flies and midges drift at high rates relative to other taxa
  - Larger taxa (Gammarus and mudsnails) show stronger relation with discharge

Acknowledgements: Thanks to WAPA for providing funding for this study.

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Invertebrate drift and RBT Diets

- Collaborating with Natal Origins project to estimate growth potential for RBT throughout Glen and Grand Canyon
- Up to 20 RBT diets from each of 5 sampling reaches
  - stratified by fork length (>200mm vs. < 200 mm)
- Drift—20 drift samples from each of 5 sampling reaches
  - 6 midday
  - 14 during crepuscular period
  - 5 minute tows or ~50 m^3 per sample

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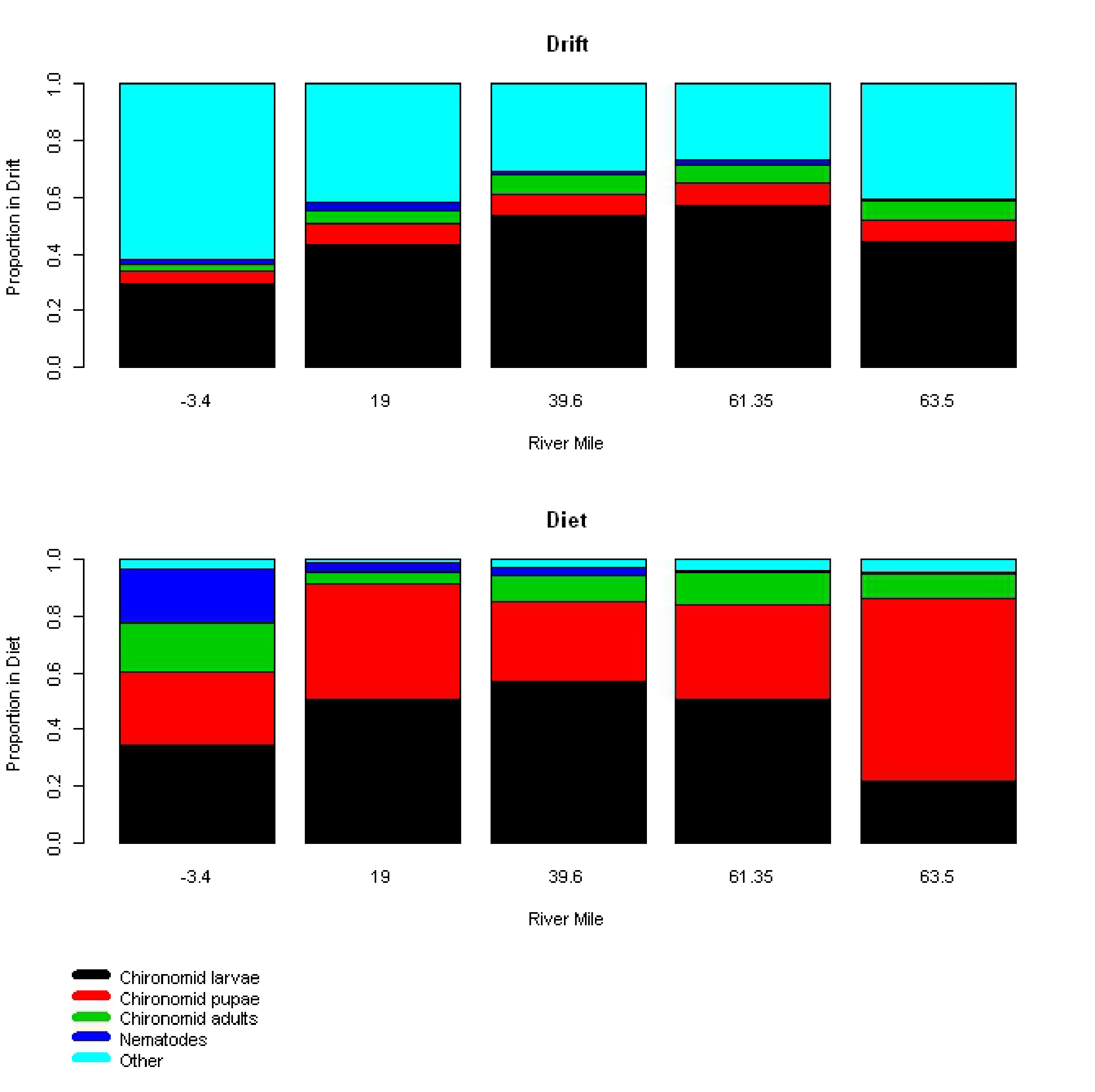
April



Drift
Proportion in Drift
0.0
0.2
0.4
0.6
0.8
1.0
-3.4
19
39.6
61.35
63.5
River Mile
Diet
Proportion in Diet
0.0
0.2
0.4
0.6
0.8
1.0
-3.4
19
39.6
61.35
63.5
River Mile
Chironomid larvae
Chironomid pupae
Chironomid adults
Nematodes
Other

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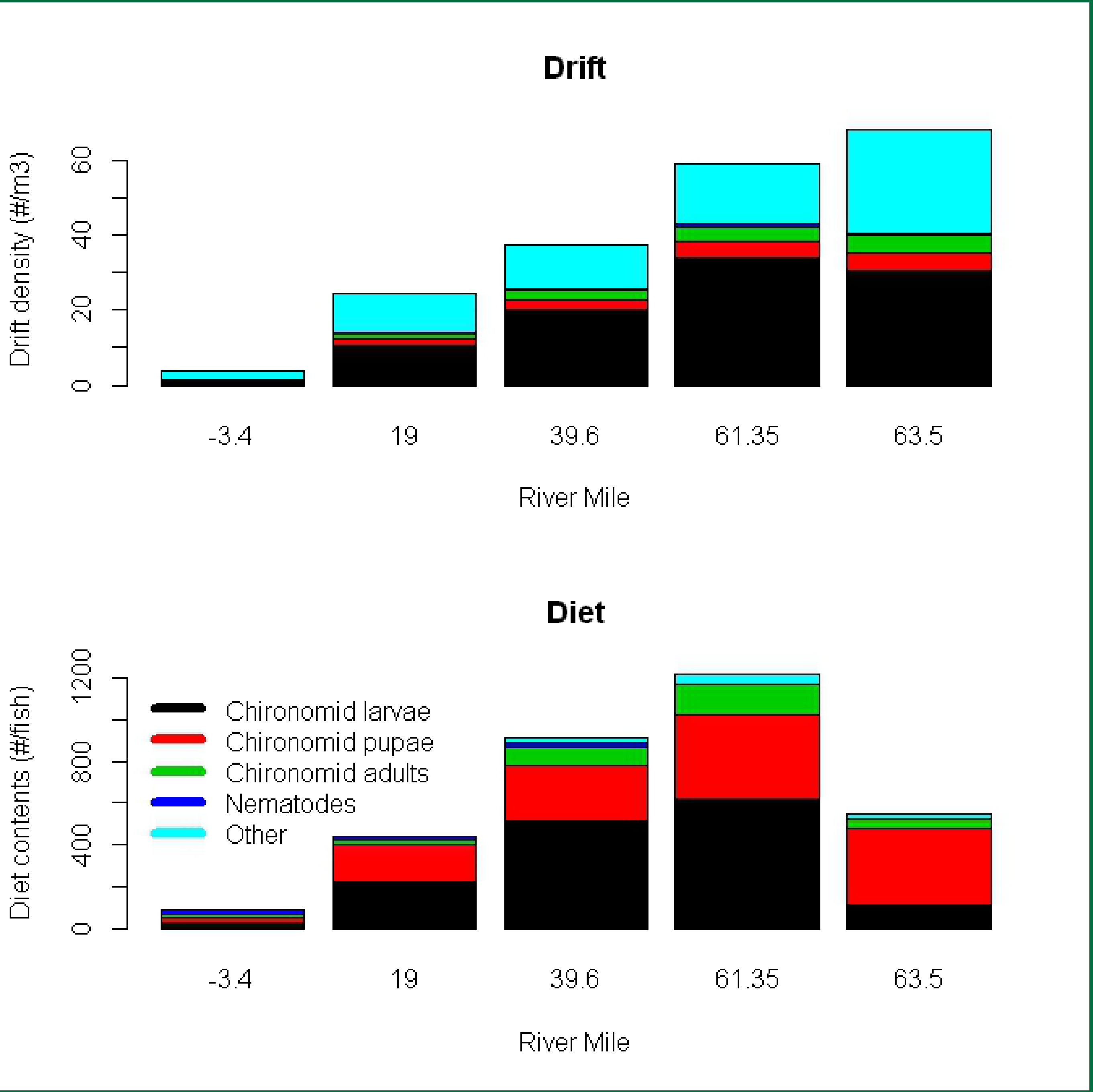
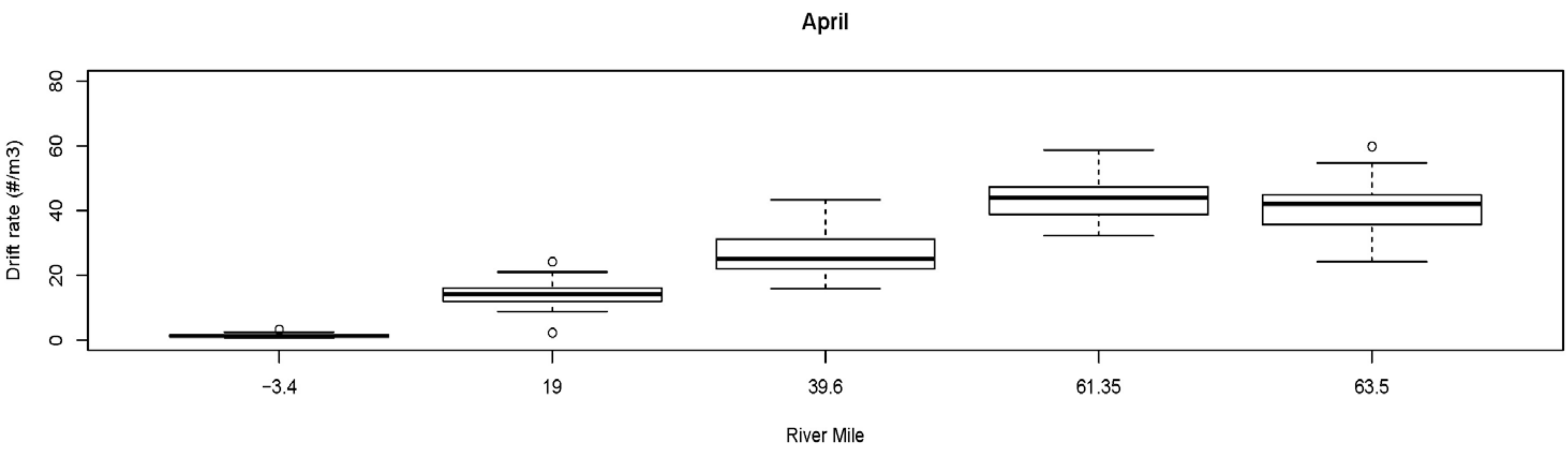
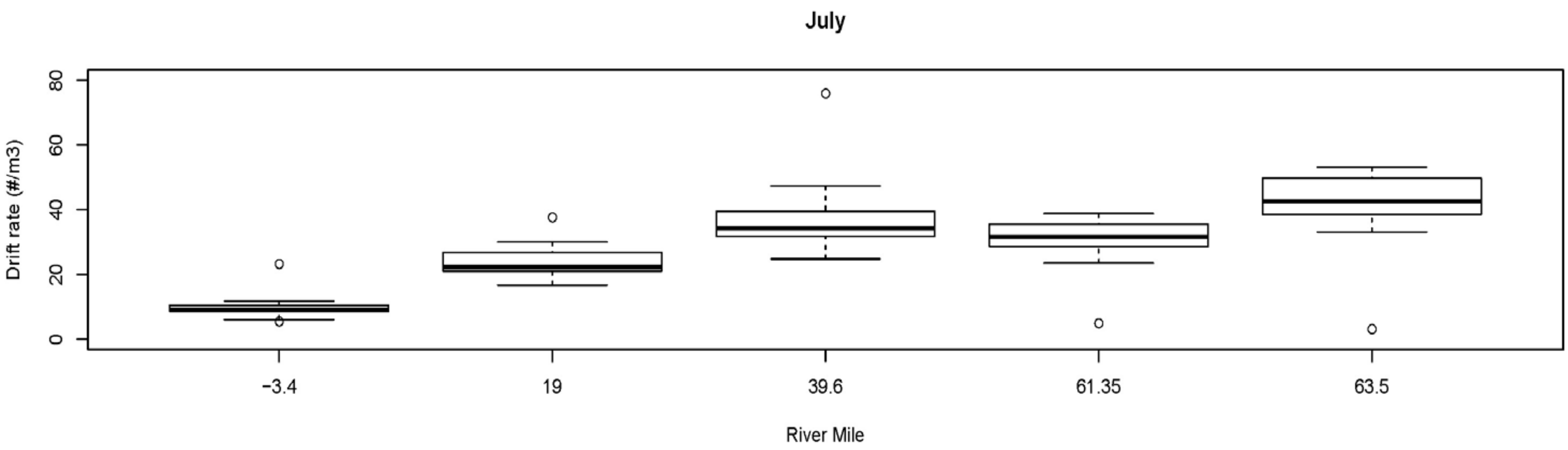
April



Drift
Drift density (#/m3)
0
20
40
60
-3.4
19
39.6
61.35
63.5
River Mile
Diet
Diet contents (#/fish)
0
400
800
1200
Chironomid larvae
Chironomid pupae
Chironomid adults
Nematodes
Other
-3.4
19
39.6
61.35
63.5
River Mile

Seasonal Changes in Drift





Conclusions

- Diets mirror drift rates, with some exceptions
  - Apparently high selectivity for midge pupae, avoidance of tubificid worms
- Midges dominate drift and diets in April (>90% of diet at sites in Grand Canyon)
- Downstream increase in drift and diet contents defies conventional wisdom about prey availability in the Colorado River
  - Competition?

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Emergence monitoring

- One major flaw of previous invertebrate monitoring in Grand Canyon is inadequate temporal and spatial resolution of sampling
  - E.g., Entire cohorts of short-lived midges and black flies could be missed with quarterly sampling
- Two dominant invertebrate prey items for fish are both insects—black flies and midges (Cross and others in review)
- Emergence flux is highly correlated with benthic production (Statzner and Resh 1993)

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Emergence monitoring

- Goal: Evaluate whether monitoring emergence flux is a useful surrogate for traditional benthic monitoring
- Worked with 7 commercial river guides to pilot in FY2012
  - Bob Dye — NPS
  - Kelsey Wogan — Grand Canyon Youth
  - Gibney Siemion
  - Walker McKay
  - Derrick Spice
  - Eric Baade
  - Scott Jernigan

Emergence monitoring

- Standardized light trapping conducted every night in camp
  - 2 traps per night (waters edge, 45k cfs stage line)
  - Traps turned on within an hour of sunset
  - Trap left on for 1hr
  - River mile, air temp, substrate (e.g., grass, sand), and wind speed recorded
- Sampling conducted from April-October
- N= >950 samples (230 processed)

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Outreach Flier

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science for a changing world

Citizen Science—Quantifying Food for the Fishes of the Grand Canyon

In the Grand Canyon segment of the Colorado River, the endangered humpback chub (*Gila cypha*) and other native fish rely on aquatic insects as a primary food source. Two insects are particularly important food items consumed by fish: black flies and midges. Adult midges and black flies are also important food items for terrestrial animals including spiders, birds, and bats. Midges and black flies spend part of their lifecycle in aquatic environments (egg and larval stages) and part of their lifecycle in the terrestrial environment (reproductive winged adults). Monitoring the abundance of these key food items consumed by fish helps scientists understand whether food availability is playing a role in the distribution or abundance of native fishes. Traditional insect monitoring programs typically involve monitoring the abundance of larvae in a river. However, collecting samples of larval midges and black flies from the Colorado River is extremely challenging because of swift currents, deep water (average depth is over 15 feet), and fluctuating river levels associated with hydropower generation.

Your river guide is participating in a citizen science project evaluating alternative techniques for monitoring midges and black flies. Tracking the abundance of adult midges and black flies caught in the light trap samples collected by your river guide may provide an alternative insect monitoring method. Additionally, light traps will catch terrestrial insects, which will provide scientists with data needed to monitor change's in the terrestrial environment. Citizen science light trap sampling occurs along the entire Grand Canyon segment of the Colorado River from the Lees Ferry boat ramp to Lake Mead; a distance of approximately 240 river miles.

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Common Name: Midges (non-biting flies)
Scientific Name: Chironomidae (famliy)
Life History: Adult female midges lay their eggs on the water surface. The eggs sink to the bottom of the river and hatch to larvae within 2–7 days. Larvae then burrow into the river bottom or construct tubular casings on rocks and algae for protection. Larvae feed on organic matter and algae. The larvae can be found by picking up a rock from the river bottom and watching for movement. Anywhere from two to seven weeks after hatching, the larvae transform into winged adults and emerge from the river. Adult midges live for 3–7 days, which is the amount of time required for them to reproduce and lay eggs before dying. Since adult midges are short-lived, most do not eat during this lifestage.

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Common Name: Black flies
Scientific Name: Simuliidae (family)
Life History: Black flies have a life history similar to midges, with adult females laying eggs on the water surface and larvae hatching a short time after. Like midges, black flies spend several weeks in the river as larvae. Black fly larvae (on the left) have a different feeding mode than midges; they have two fan-like structures on their head that are used to capture food particles carried by the water. Because black fly larvae rely on the current to deliver food to them, they are found in places with swift current such as cobble bars. Black fly larvae appear plumper and fatter than midge larvae. Adult black flies feed and live longer than adult midges. There are two different types of adult black flies (on the right) in Grand Canyon: (1) nectar and honeydew feeders (also known as sponge-feeders), and (2) blood-sucking black flies that pierce and suck blood from mammals. Sponge-feeding black flies are common throughout the Colorado River in Grand Canyon, whereas blood-sucking black flies are mostly found near tributaries, particularly Diamond Creek.

Bugs, bugs, and more bugs!
Common Terrestrial Insects Caught in Light Traps

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Common Name: Green lacewing
Scientific Name: Chrysopidae (family)
Ecological Role: Larvae are predatory, often feeding on aphids found on plants. Adults eat insects, or they eat nectar and pollen from flowers. Because larvae eat common garden pests like aphids, they are sometimes sold by nurseries as an alternative to pesticides.

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Common Name: Antlion
Scientific Name: Myrmeleontidae (family)
Ecological Role: Larvae live in the bottom of small pits that they dig in sand and loose dirt. When ants fall into the pit, the antlion larvae pulls them into the sand and eats them. Look for these pits in Grand Canyon, especially under overhangs that are sheltered from the rain. It can take up to 2 or 3 years for larvae to attain their maximum size because of the uncertainty of their food supply. Once maximum size is reached, larvae transform into the winged adults.

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Common Name: Crane fly or mosquito hawk
Scientific Name: Tipulidae (family)
Ecological Role: Larvae can be aquatic or terrestrial. In either environment, they eat live and dead plant material. Despite their name, adult crane flies do not eat mosquitoes or bite humans—they feed on nectar or do not eat at all. Adult Crane Flies are widespread and can be found in both urban and natural settings.

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Common Name: Angel Lichen Moth
Scientific Name: Erebidae (family)
Ecological Role: The larvae of these moths feed upon lichen or algae. Once adults, they feed on pollen and nectar. The Angel Lichen Moth has been one of the most common insects caught in light traps this spring.

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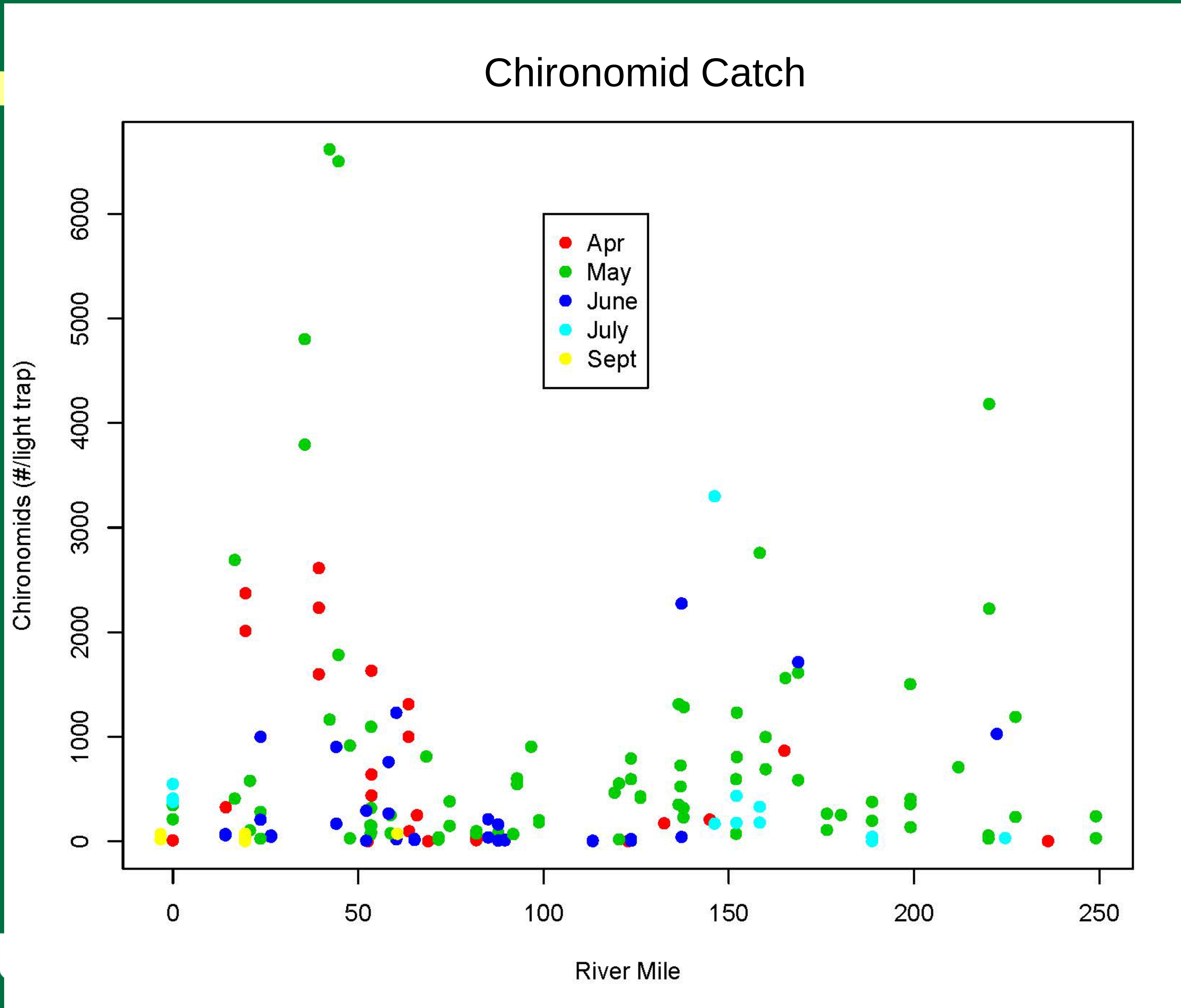
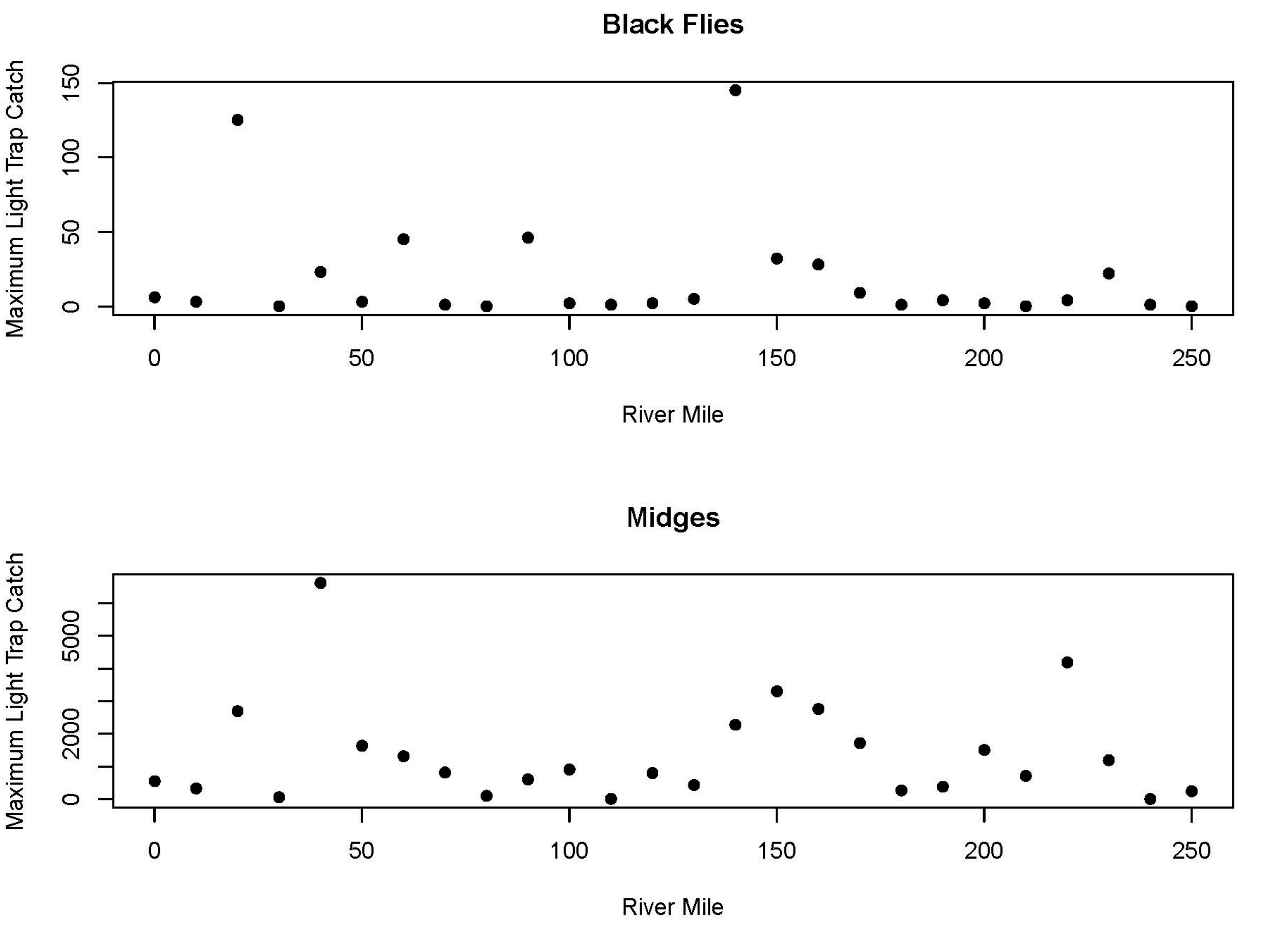


Chironomid Catch
Apr
May
June
July
Sept
Chironomids (#/light trap)
0
1000
2000
3000
4000
5000
6000
0
50
100
150
200
250
River Mile


Black Flies
Maximum Light Trap Catch
0
50
100
150
0
50
100
150
200
250
River Mile
Midges
Maximum Light Trap Catch
0
2000
5000
0
50
100
150
200
250
River Mile

Conclusions

- Extremely cost effective means of sampling
- Good opportunity for public outreach
- Preliminary data appear promising

Drift distances—characterizing invertebrate drift throughout Glen Canyon

- Downstream increase in drift densities through Marble Canyon could arise if invertebrate drift distances are long (>miles)
- Interpretation of drift densities would therefore benefit from an improved understanding of drift distances

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Drift distances—characterizing invertebrate drift throughout Glen Canyon

- **But how can begin to get a handle on drift distances in a large river?**
  - **Sample intensively along a downstream gradient starting from the Dam, where upstream supply = 0, to Lees Ferry**
- **Hypotheses:**
  - **Drift densities increase as a function of distance from the dam**
  - **Smaller scale variation in drift densities related to local geomorphology and/or hydrology**

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Drift distances—characterizing invertebrate drift throughout Glen Canyon

- Sampling done over 4 consecutive days (Oct 10-13)
- 32 locations through Glen Canyon sampled each day
- Sampled intensively from dam to RM-8
- Also sampled intensively in a portion of the natal origins reach (~RM -5 to -1.5)
- Constant 8,000 cfs discharge
- 5 minute tows or ~50 m^3 per sample

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Drift distances—characterizing invertebrate drift throughout Glen Canyon

- Sampling design allows us to separate spatial from temporal variation in drift rates

- Day 1—top to bottom
- Day 2—middle to bottom, then middle to top
- Day 3—bottom to middle, then lost bomb (samples not analyzed)
- Day 4—middle to top, middle to bottom

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The Data

Taxa	Midge larvae	Midge pupae	Midge adults	Worms (tubificid)	Mud snails	Scuds	Black fly Larvae	Black fly adults	Black fly pupae
Catch	20,156	709	430	12,699	5,998	236	199	4	1

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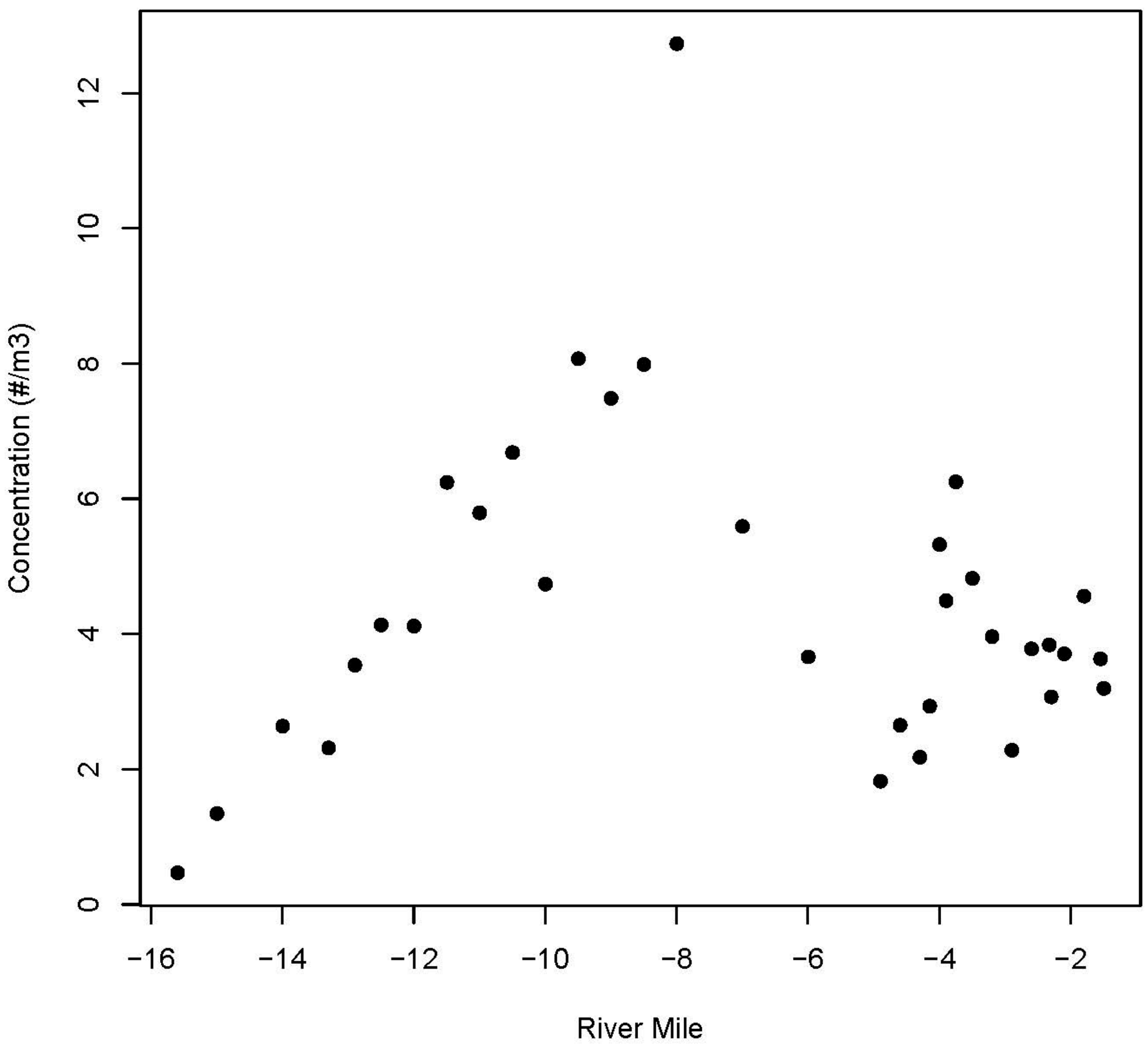
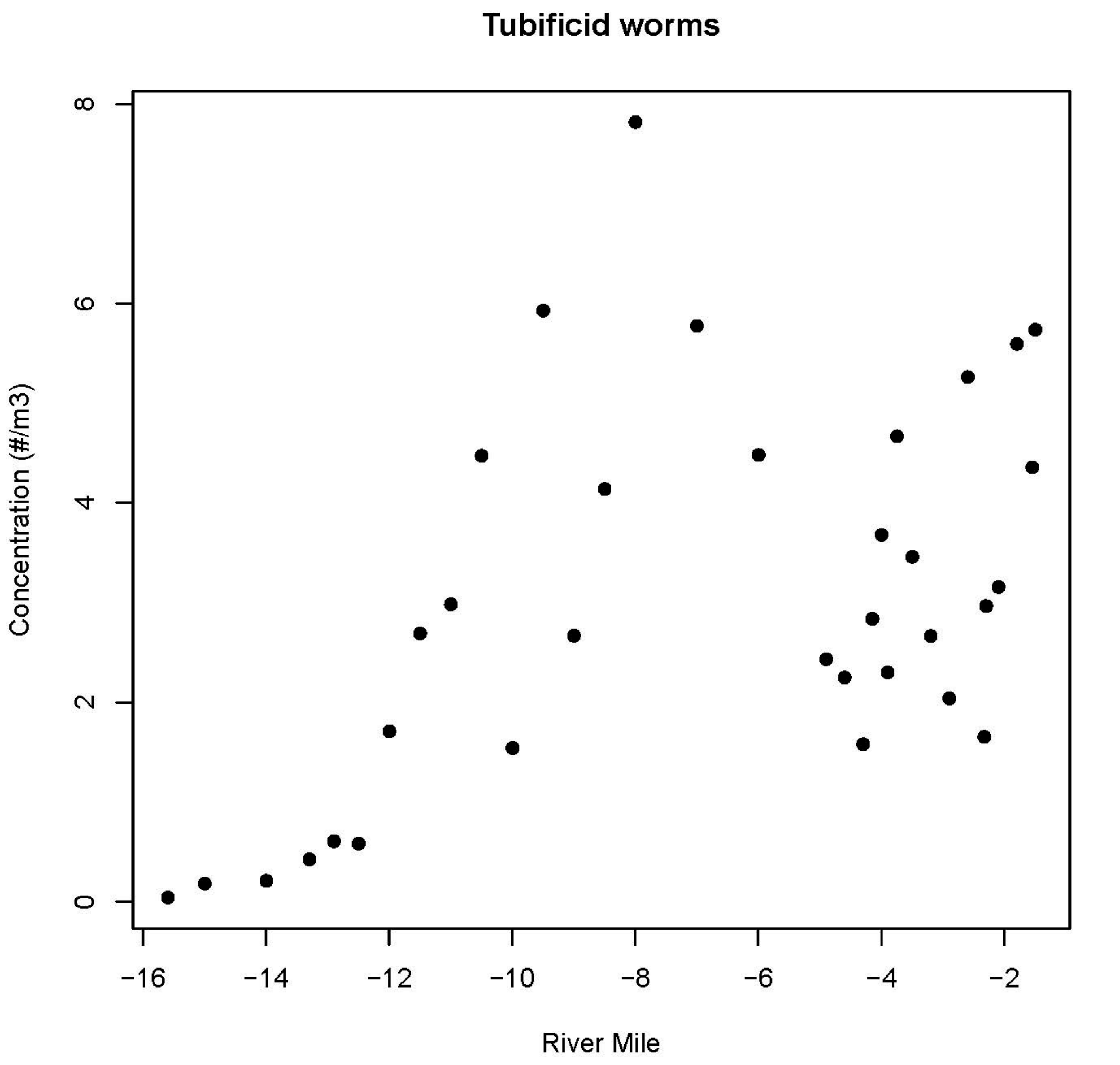
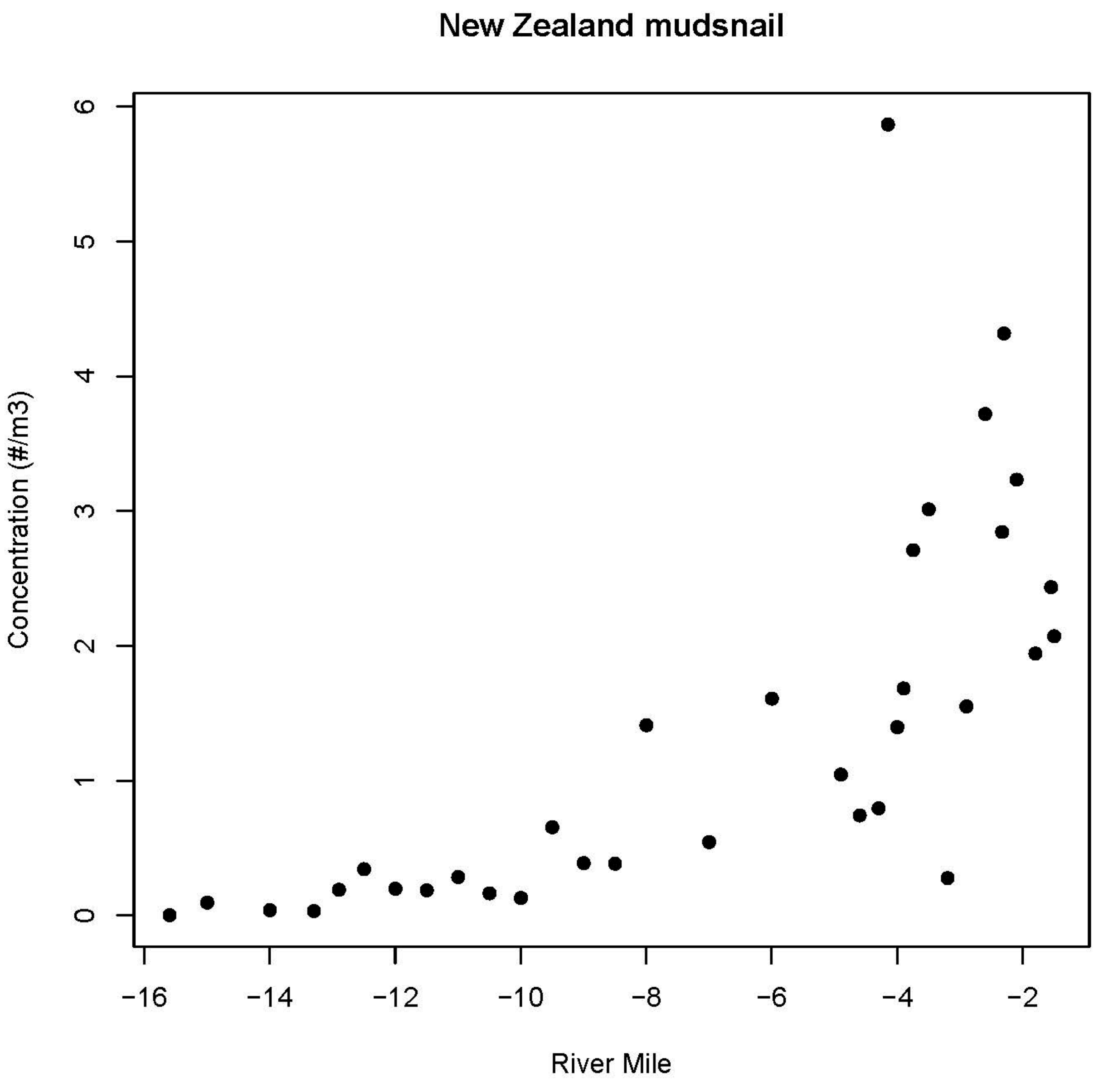
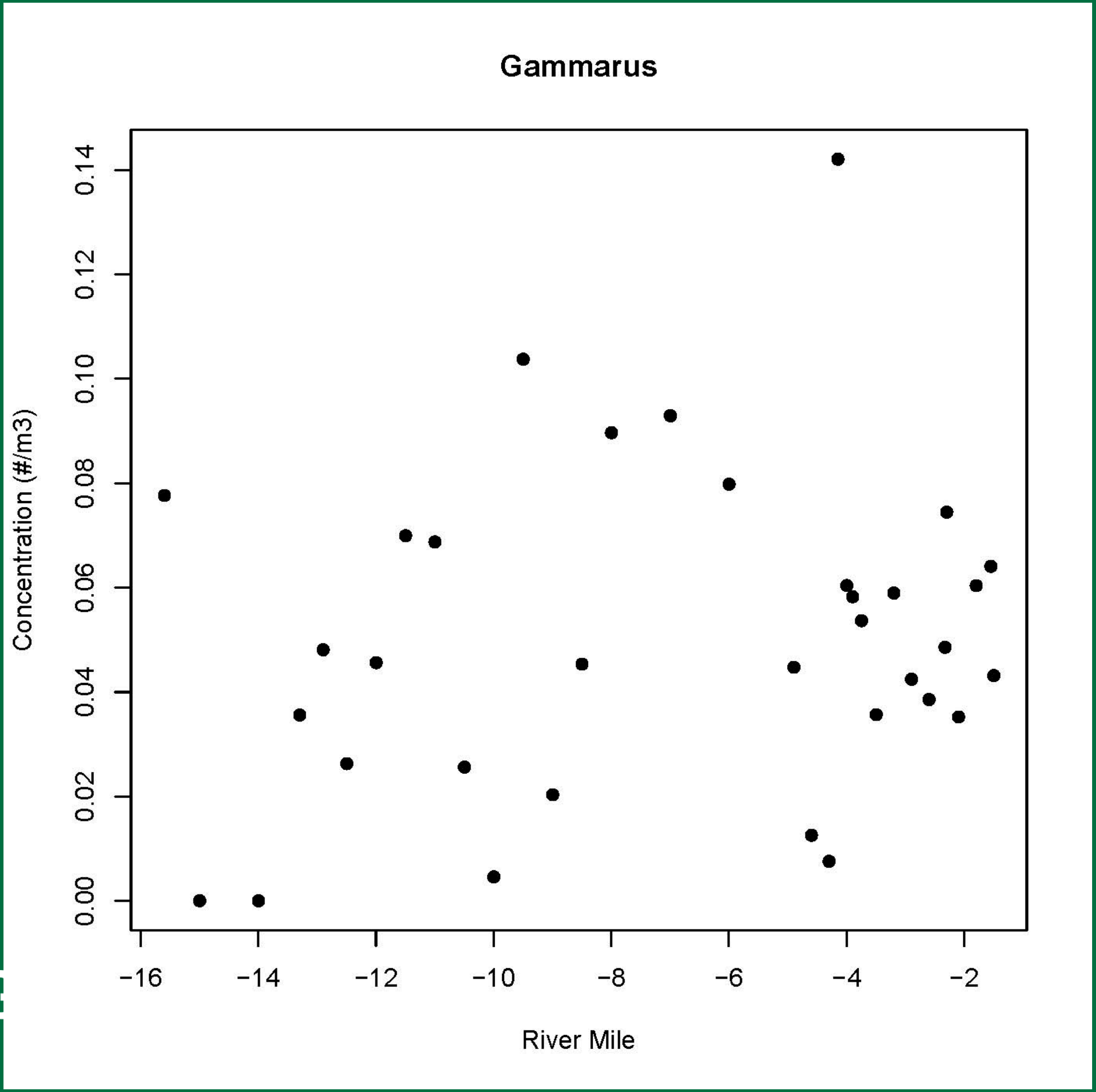
Chironomids

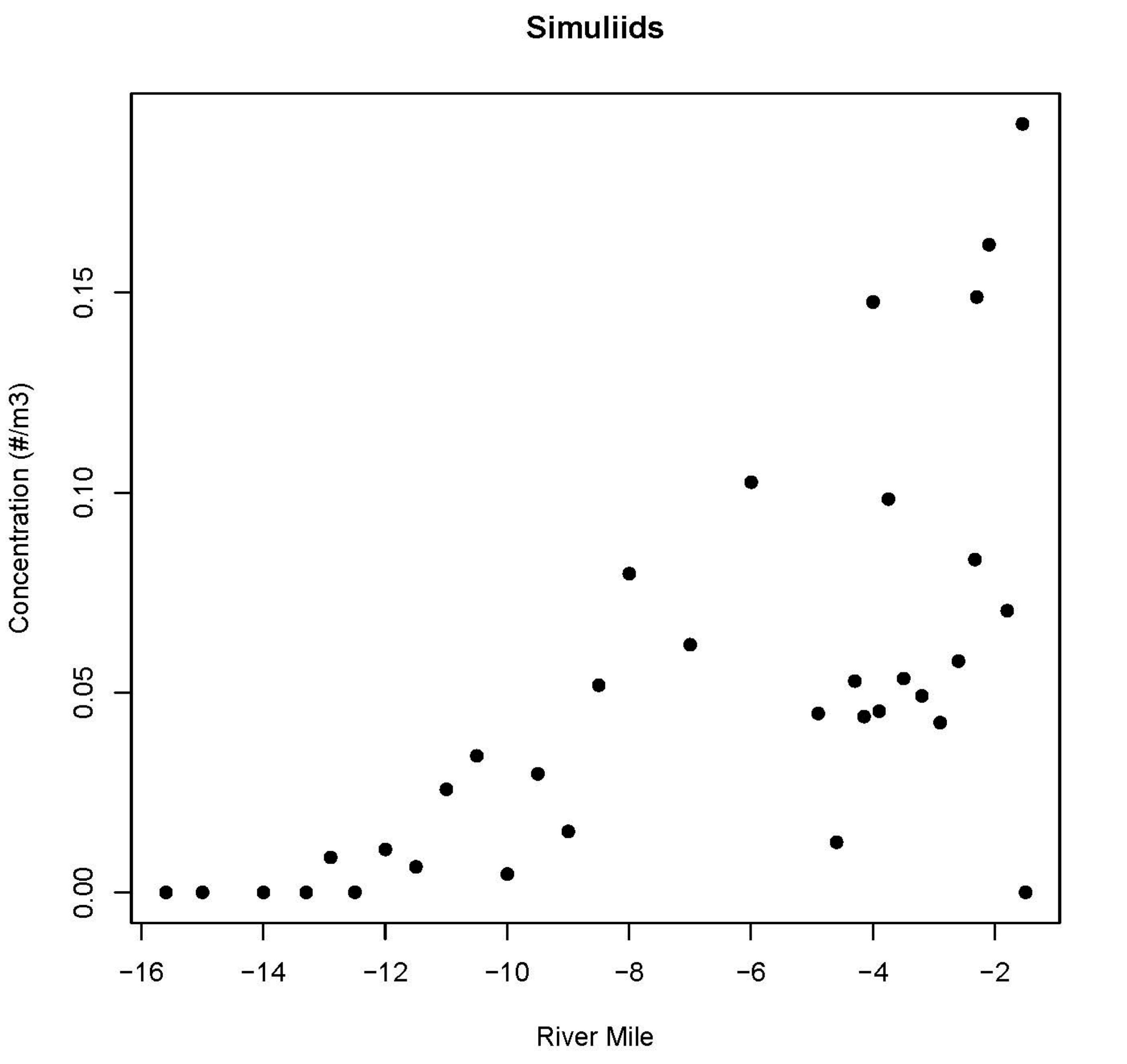




Tubificid worms
Concentration (#/m3)
0
2
4
6
8
−16
−14
−12
−10
−8
−6
−4
−2
River Mile


New Zealand mudsnail
Concentration (#/m3)
0
1
2
3
4
5
6
−16
−14
−12
−10
−8
−6
−4
−2
River Mile


Gammarus
Concentration (#/m3)
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
−16
−14
−12
−10
−8
−6
−4
−2
River Mile


Simuliids
Concentration (#/m3)
0.00
0.05
0.10
0.15
−16
−14
−12
−10
−8
−6
−4
−2
River Mile

Conclusions

- Midges dominate the drift in Glen Canyon
- Spatial variation in drift rates of all taxa appear to be a function of local conditions (substrate, hydrology, predation?) and upstream supply
- Formal analysis….stay tuned

Gross primary production at Diamond Creek

- Continuously monitored since spring 2009
- GPP estimated using dissolved oxygen budgeting
- Daily GPP estimates modeled as a function of:
  - Turbidity
  - Discharge variation
  - Light (from Yard et al 2005)
  - Clouds
  - Temperature

  * Note that several of these are interrelated

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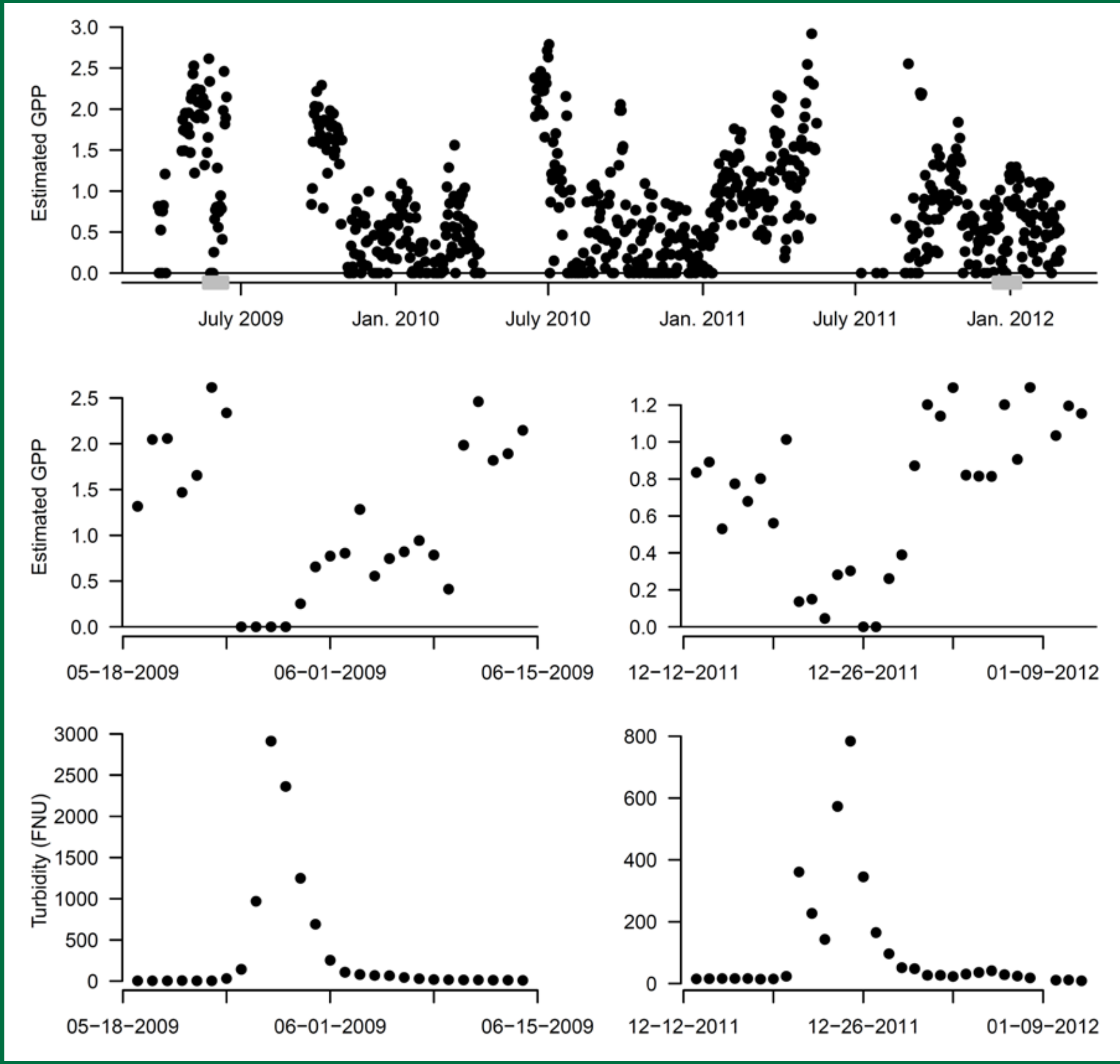
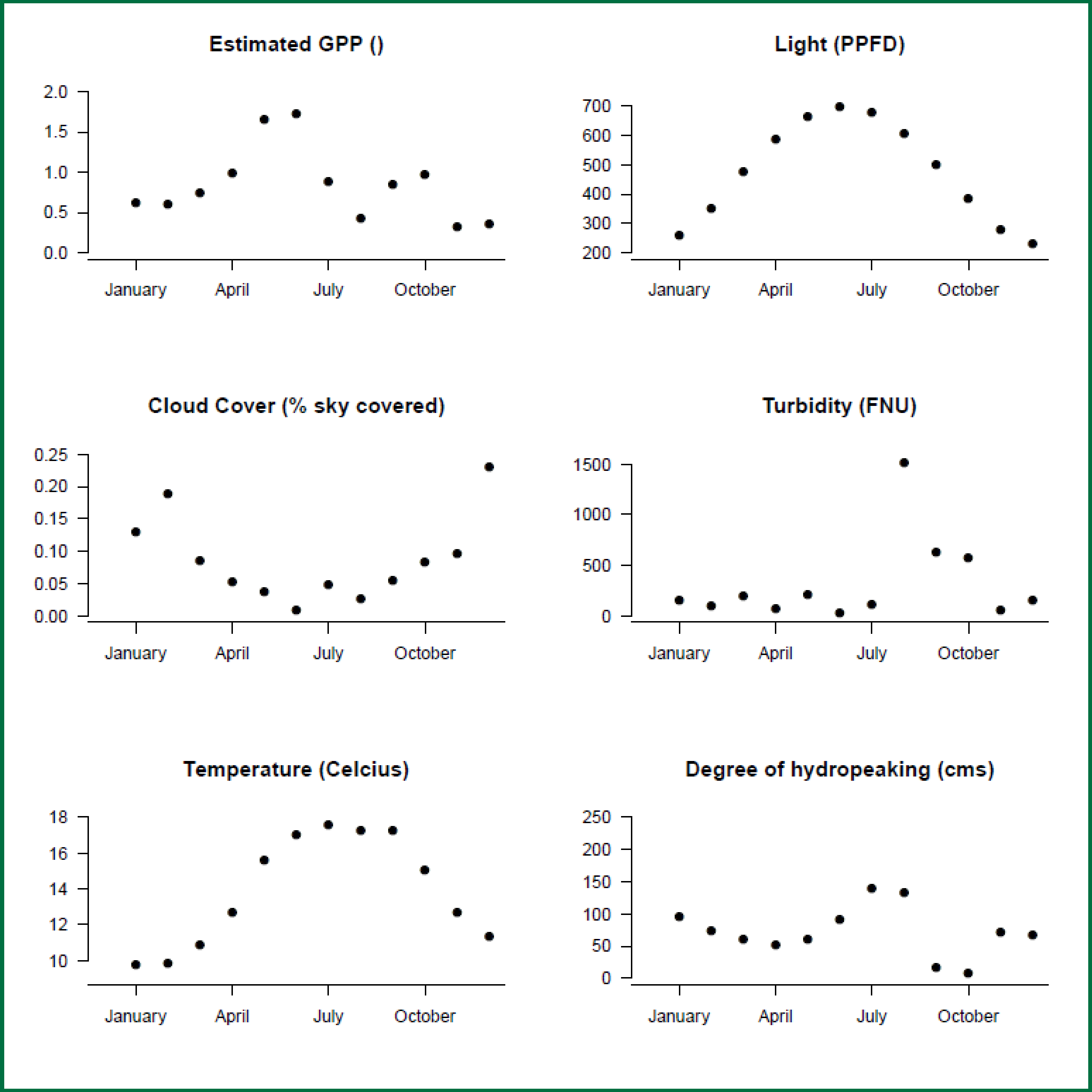
The Data

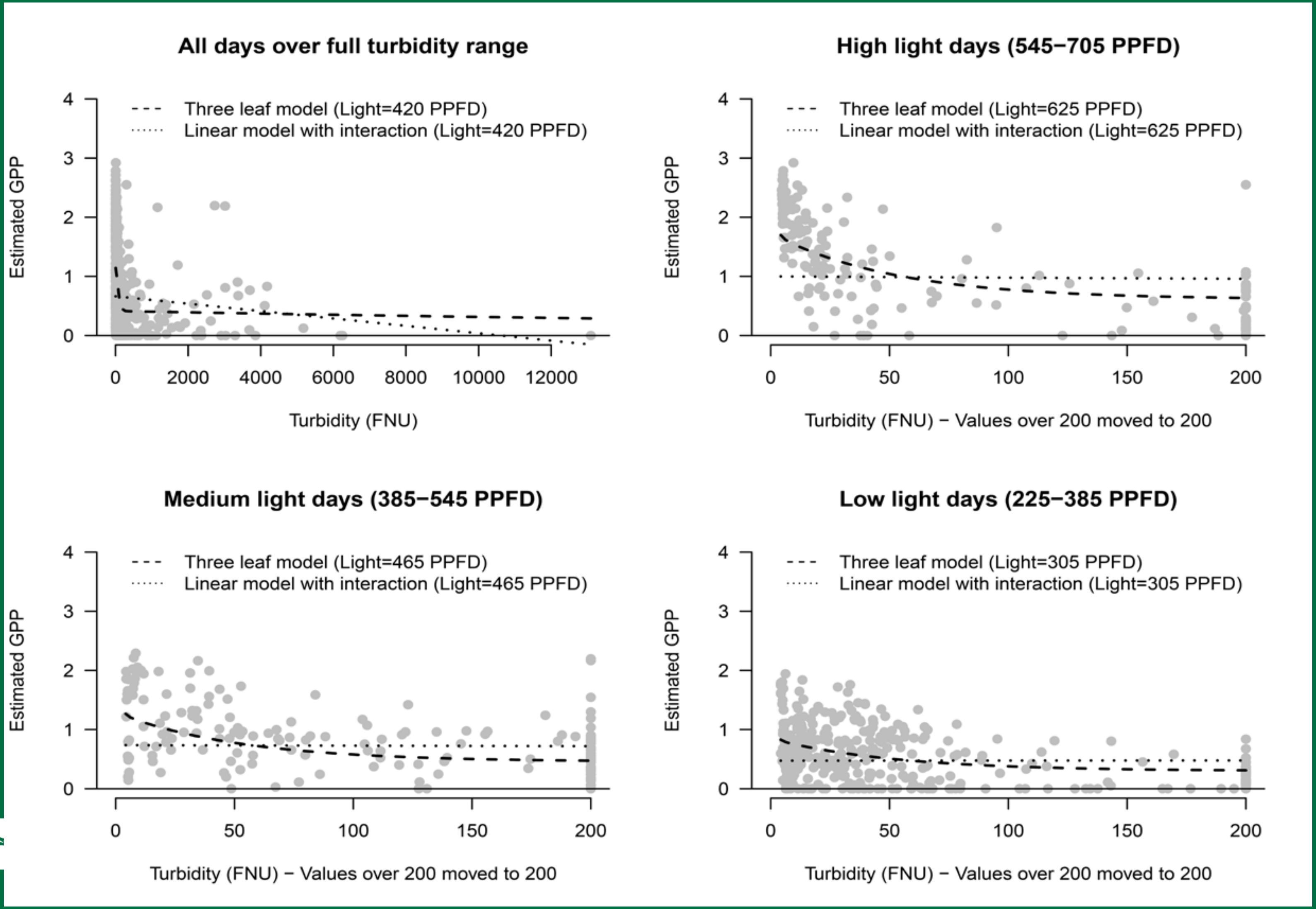


Estimated GPP
3.0
2.5
2.0
1.5
1.0
0.5
0.0
July 2009
Jan. 2010
July 2010
Jan. 2011
July 2011
Jan. 2012
Estimated GPP
2.5
2.0
1.5
1.0
0.5
0.0
05−18−2009
06−01−2009
06−15−2009
1.2
1.0
0.8
0.6
0.4
0.2
0.0
12−12−2011
12−26−2011
01−09−2012
Turbidity (FNU)
3000
2500
2000
1500
1000
500
0
05−18−2009
06−01−2009
06−15−2009
800
600
400
200
0
12−12−2011
12−26−2011
01−09−2012

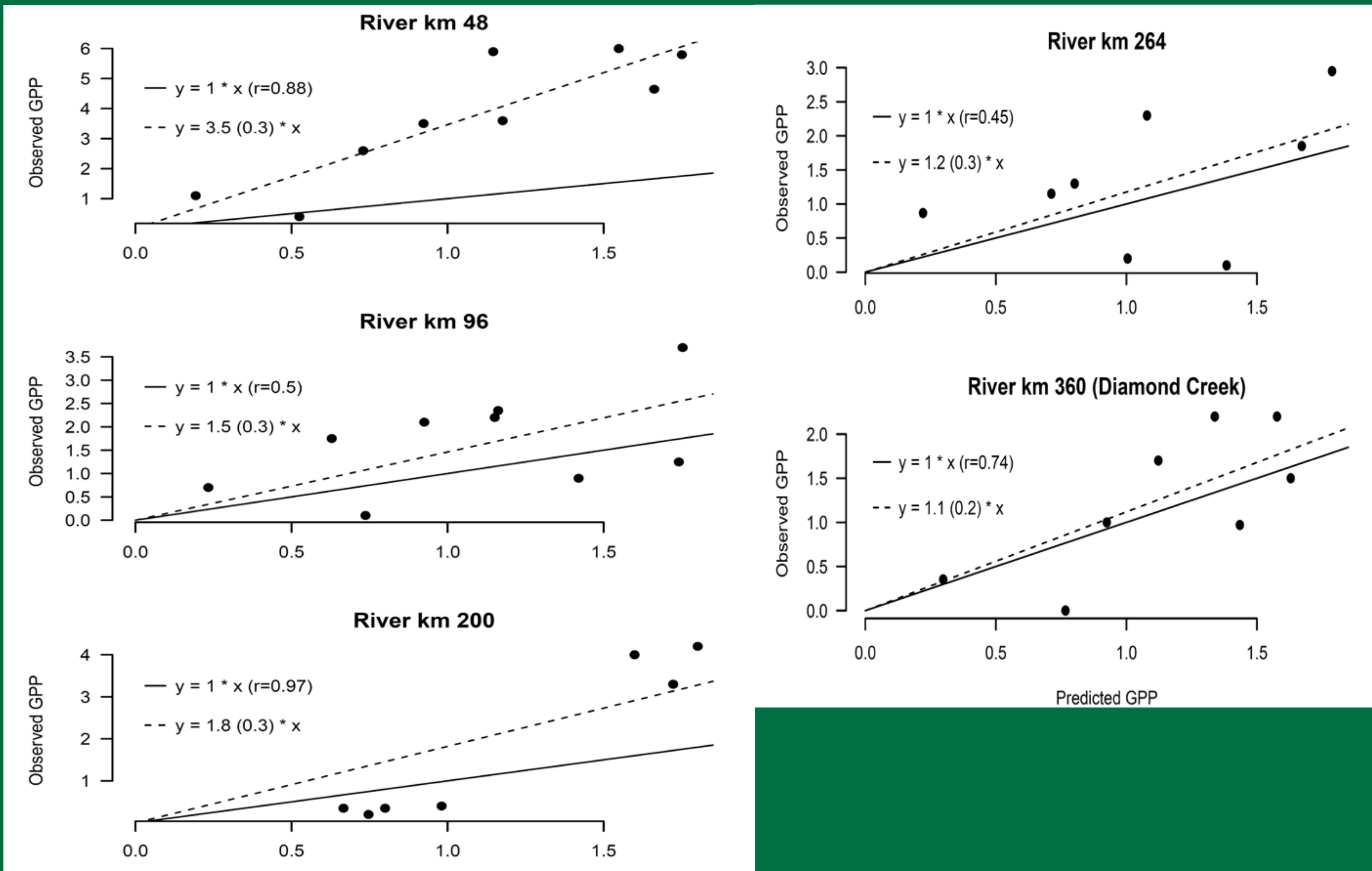
Environmental Conditions



Model output



Out of Sample Comparison



Conclusions

- **Numerous factors control algae production at Diamond Creek**
  - **Turbidity**
  - **Cloud cover**
  - **Water temperature**
  - **Light**
  - **Discharge variation**

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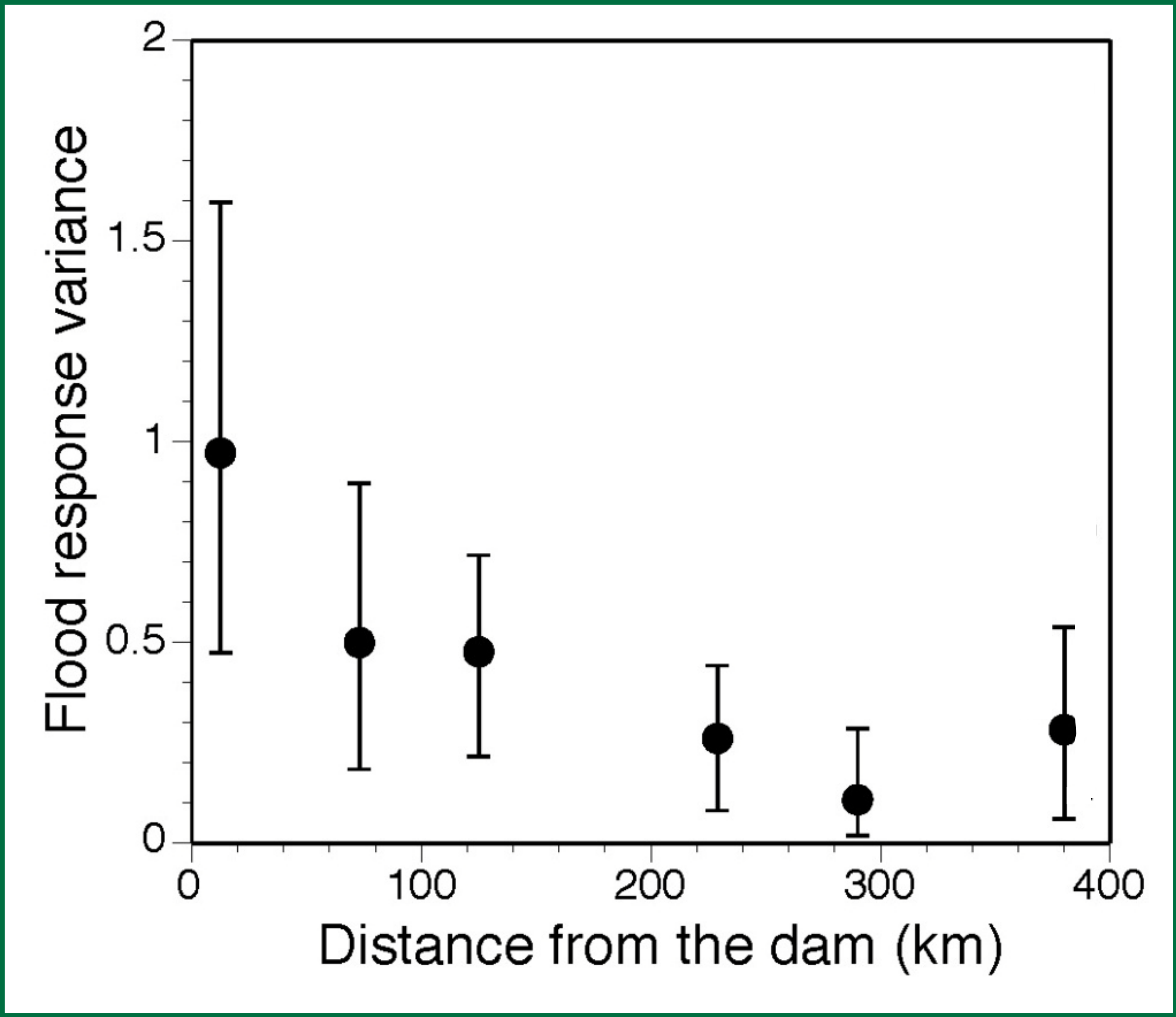
Food web response to 2008 HFE

The 2008 artificial flood caused a larger shift in the structure and function of Glen Canyon food web relative to downstream food webs

In other words, the Glen Canyon food web appears less resistant to perturbation than Grand Canyon food webs



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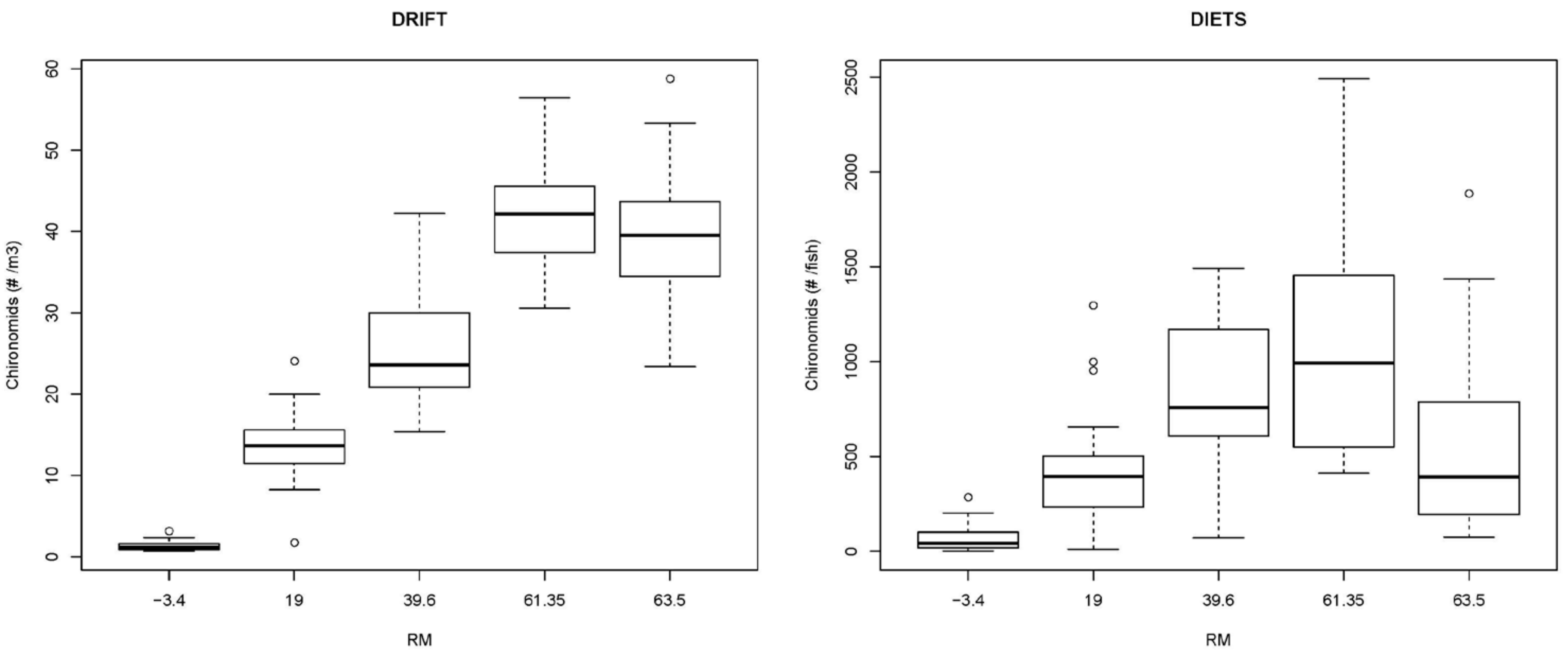
The Data


DRIFT
Chironomids (# /m3)
0
10
20
30
40
50
60
-3.4
19
39.6
61.35
63.5
RM
DIETS
Chironomids (# /fish)
0
500
1000
1500
2000
2500
-3.4
19
39.6
61.35
63.5
RM