Knowledge Assessment: Foodweb

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[1]USGS, [2]Idaho State University, [3]U of Wyoming, [4]Cary Institute, [5]Montana State University, Dept.

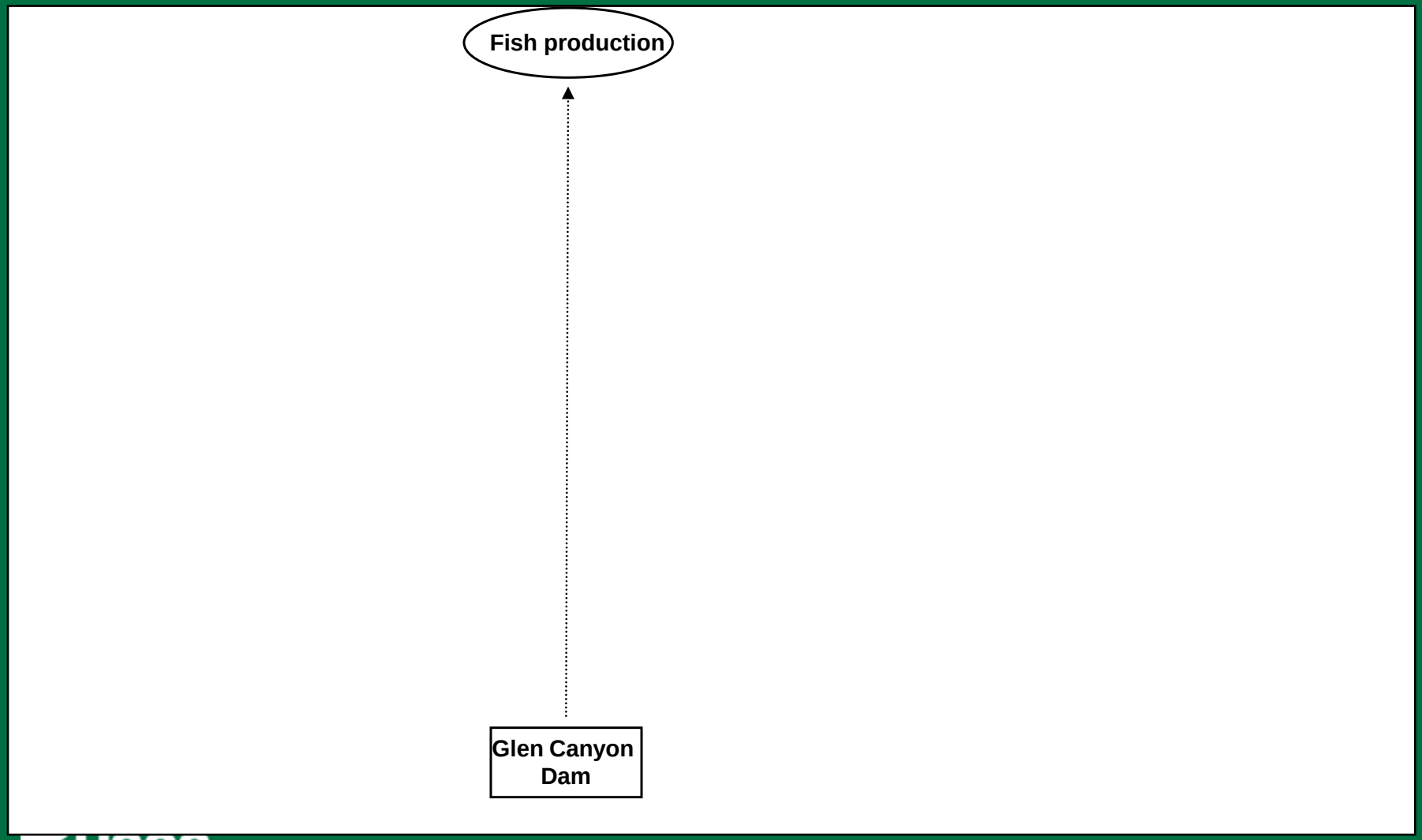
U.S. Department of the Interior
U.S. Geological Survey

Outline

- Conceptual Diagram
- Lees Ferry
- Grand Canyon

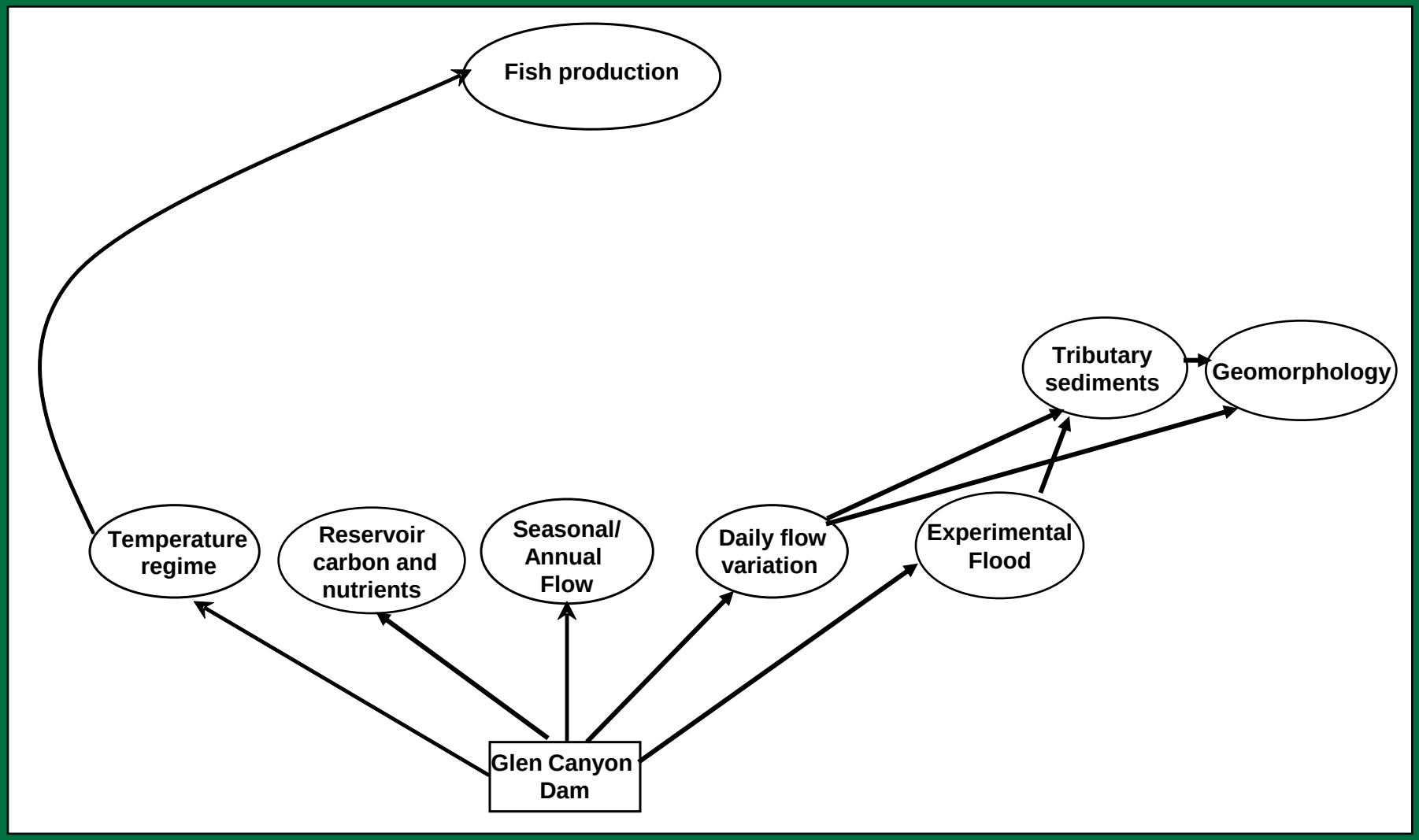
USGS

Direct Impact of Dam Itself is Relatively Minor



USGS

Glen Canyon Dam has Dramatically Altered the Physical Template



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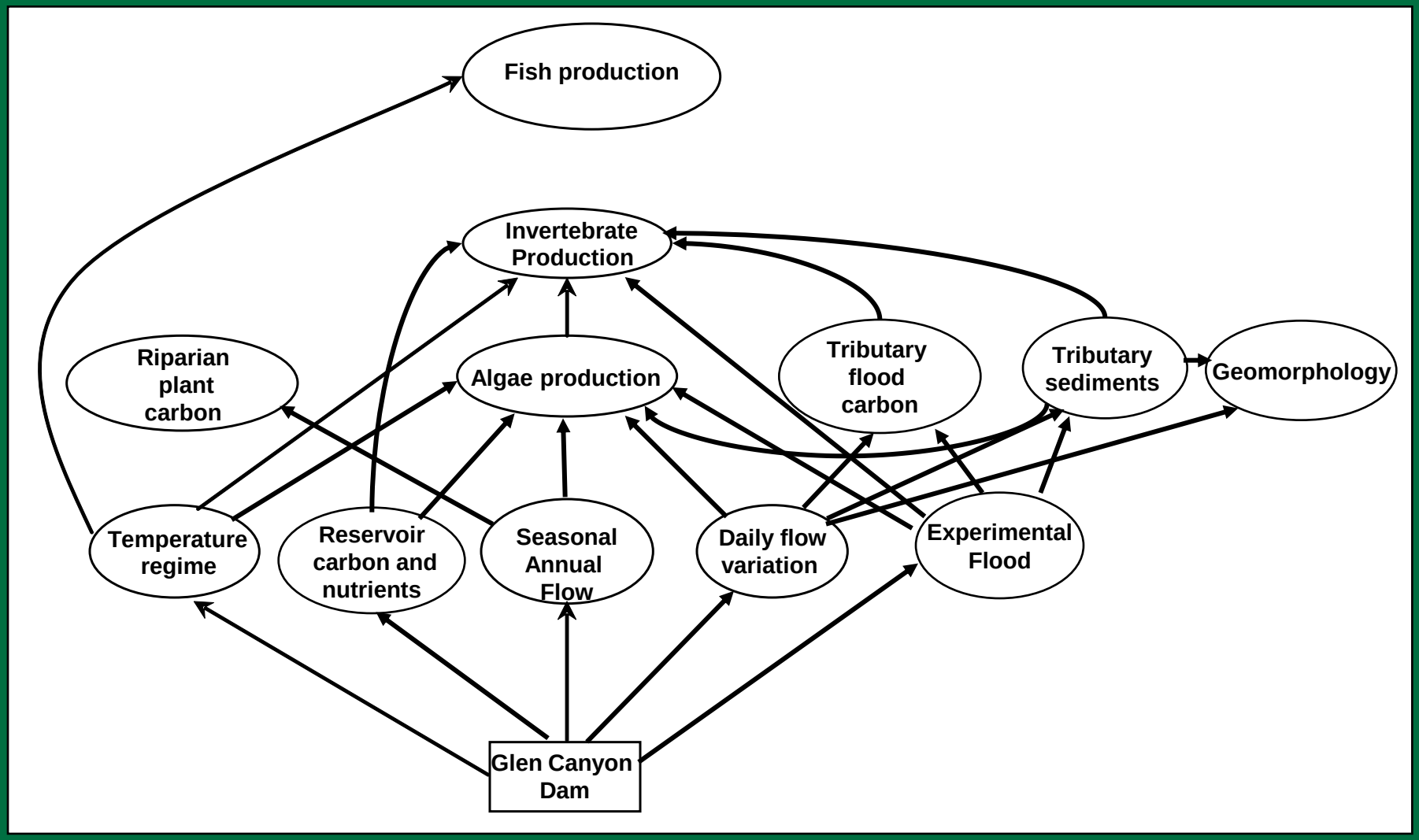
Changes in Physical Template Affect Habitat and Food Resources of Fishes



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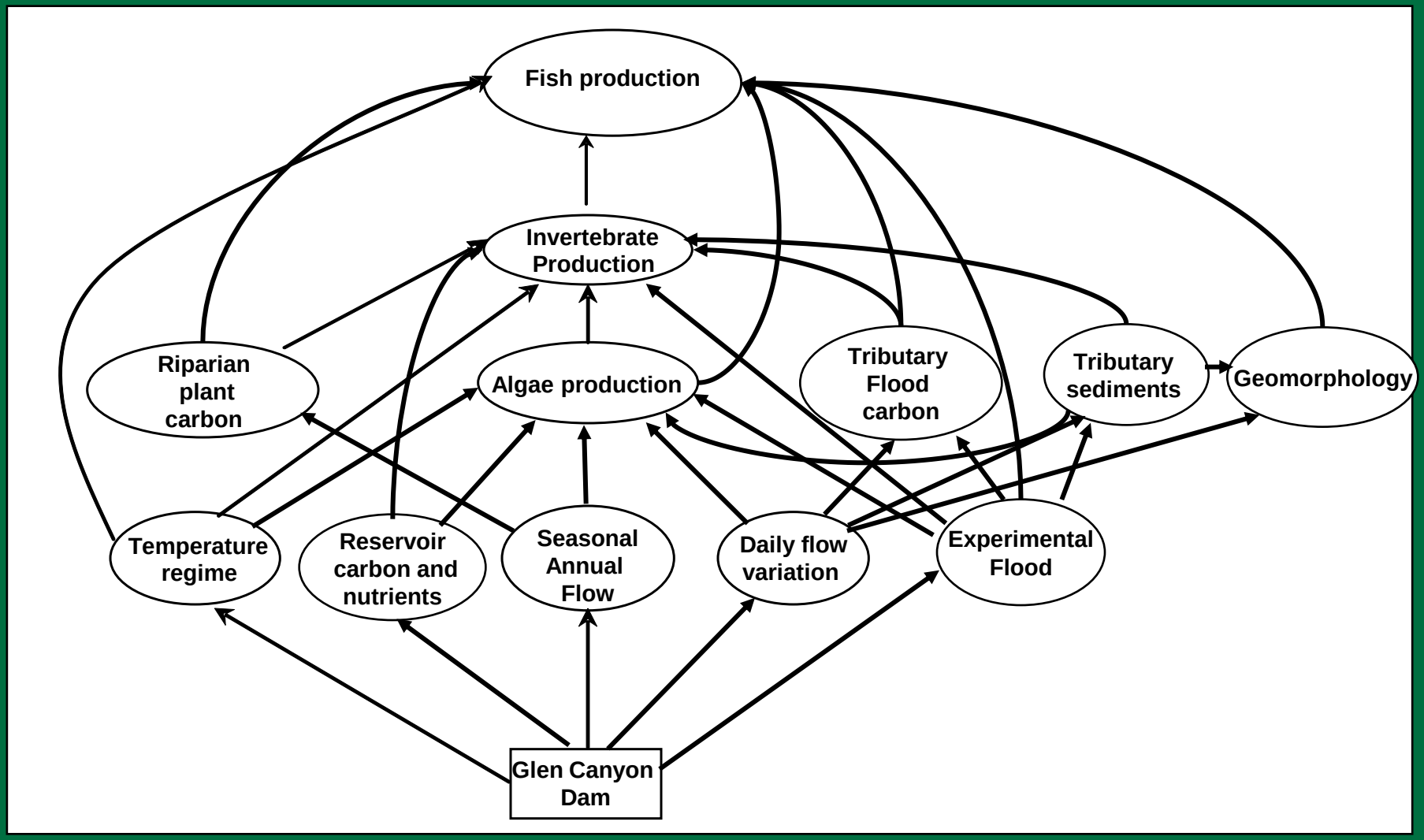
Requires Interdisciplinary Studies



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Overarching Questions

1. To what degree are fishes food limited? Where does the food base come from?

2. How do patterns of carbon flow through the food web affect fishes?

3. How do dam operations affect all of these things?

These questions require an ecosystem approach based upon flows of energy.

USGS

To address questions we have…

1. Measured inputs, stocks, outputs, and transport of primary production and terrestrial inputs in the Colorado River.

2. Measured secondary production of components of food web.

3. Identified trophic linkages to estimate what resources support higher trophic levels.

4. Quantified organic matter flow in the Colorado River food web from basal resources to fishes.

USGS

Why an ecosystem approach based on energy flows?

1. Animal population dynamics depends on ecosystem properties such as
   a. Amount, source and quality of food
   b. Physical template (flow, turbidity, temperature)
   c. Competition and predation with other animals
   d. Interaction of the above

2. Energy flow allows a common currency from everything from organic matter inputs to fish production

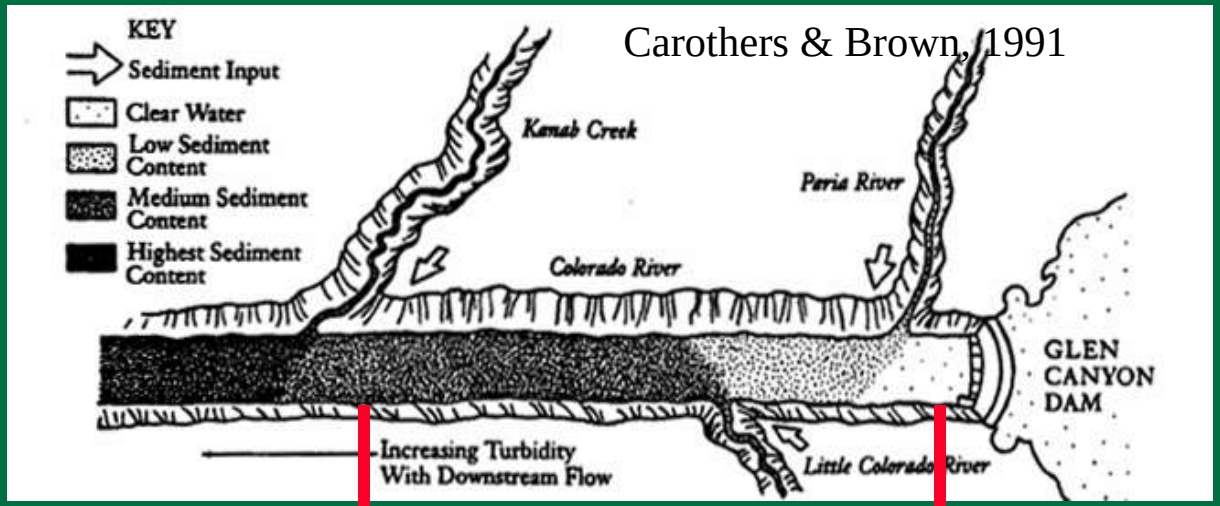
Units:

$$\frac{\text{grams organic matter}}{\text{meter}^2\ \text{year}}$$

Energy is more or less equivalent to organic matter

USGS

Two Different Rivers

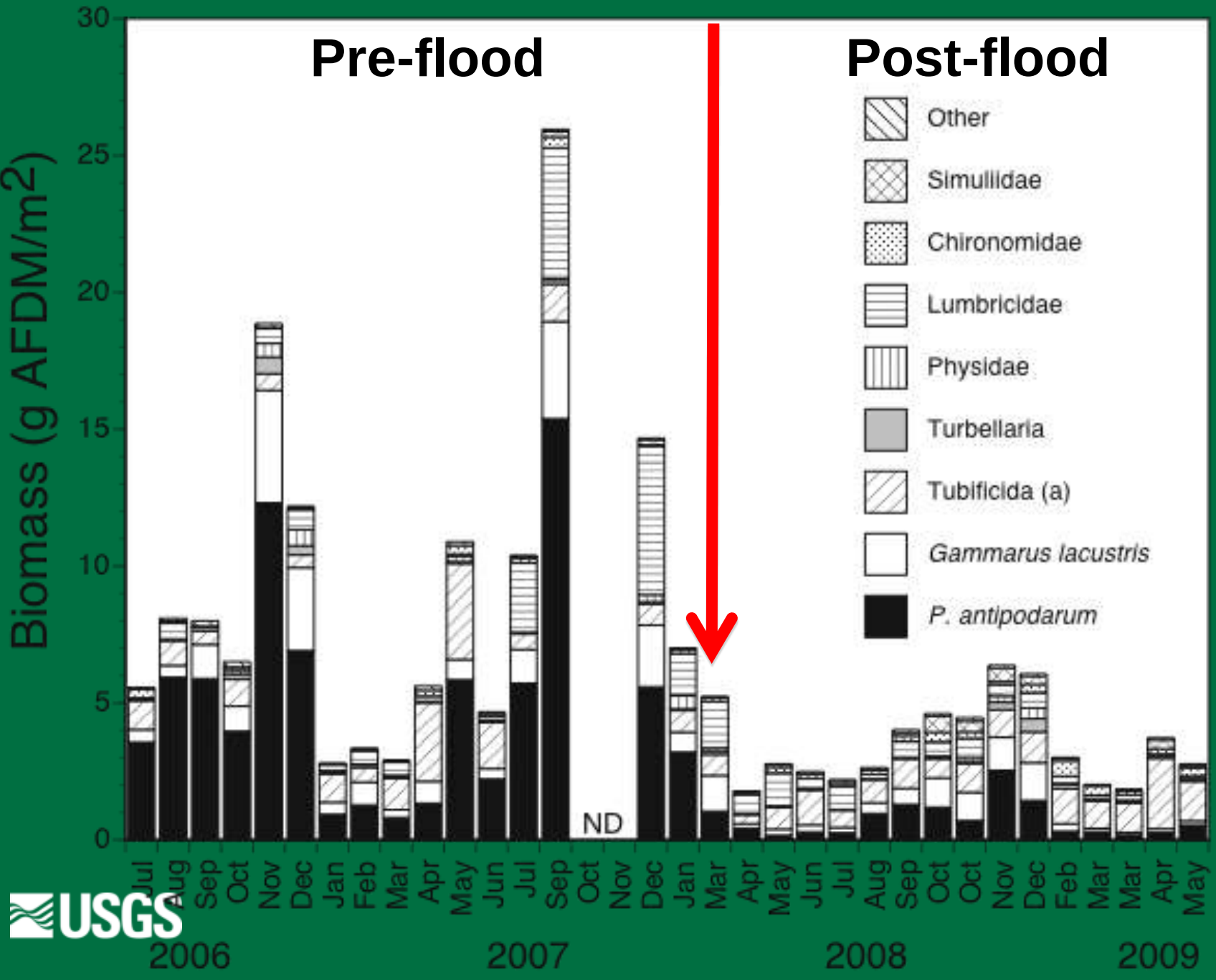


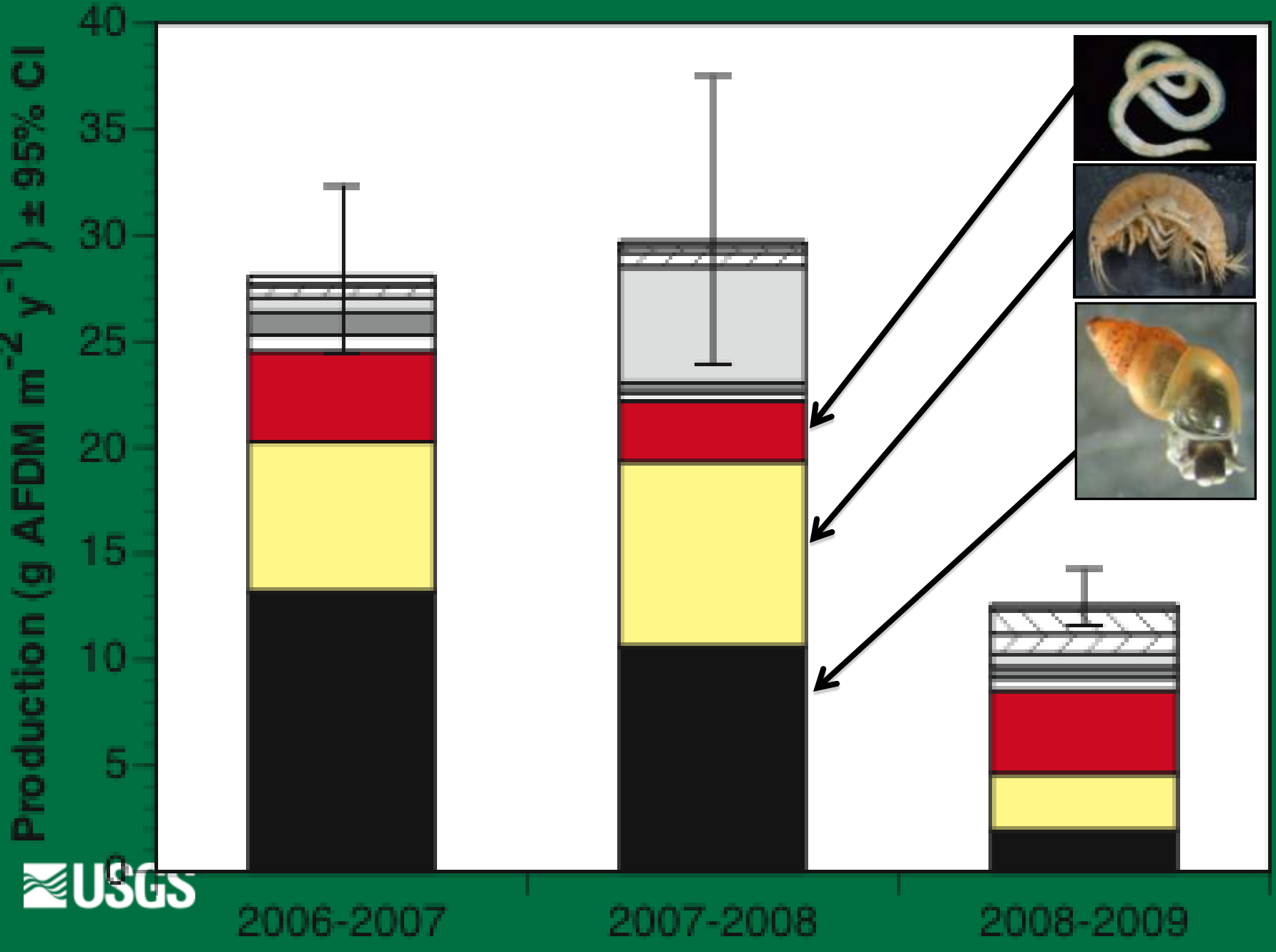
Carothers & Brown, 1991

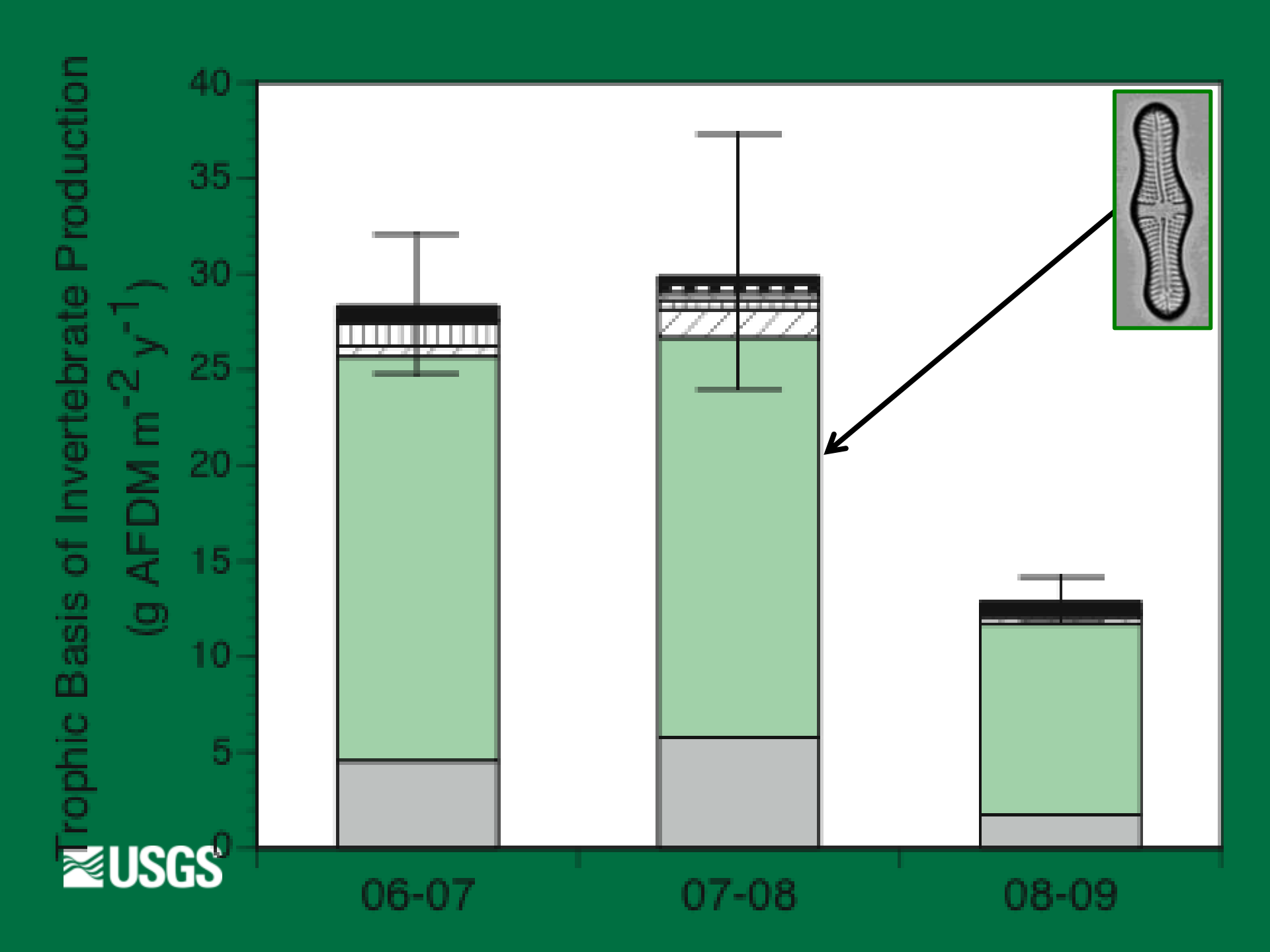
Increased trout production despite reduced total prey production following the 2008 controlled flood

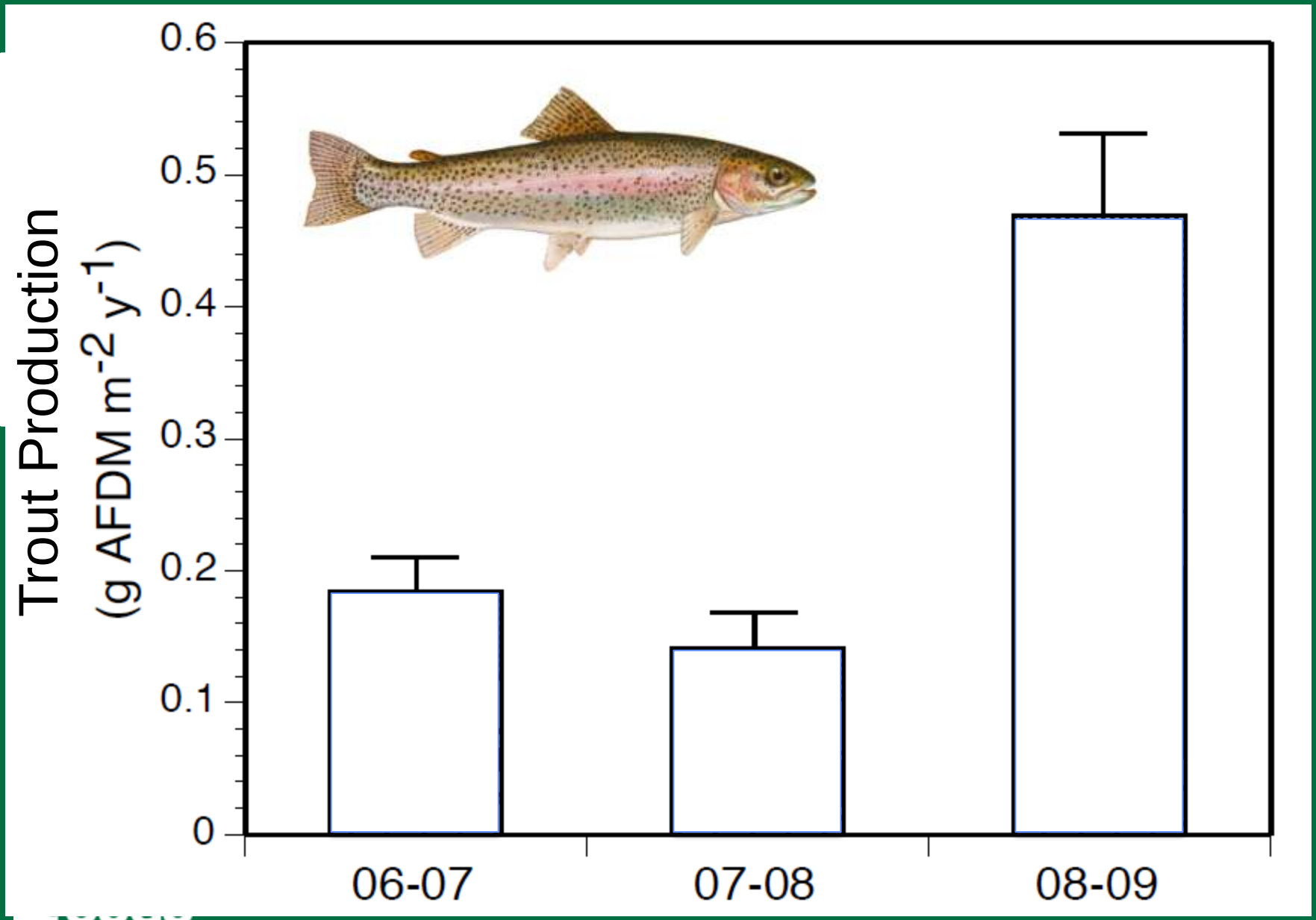
USGS

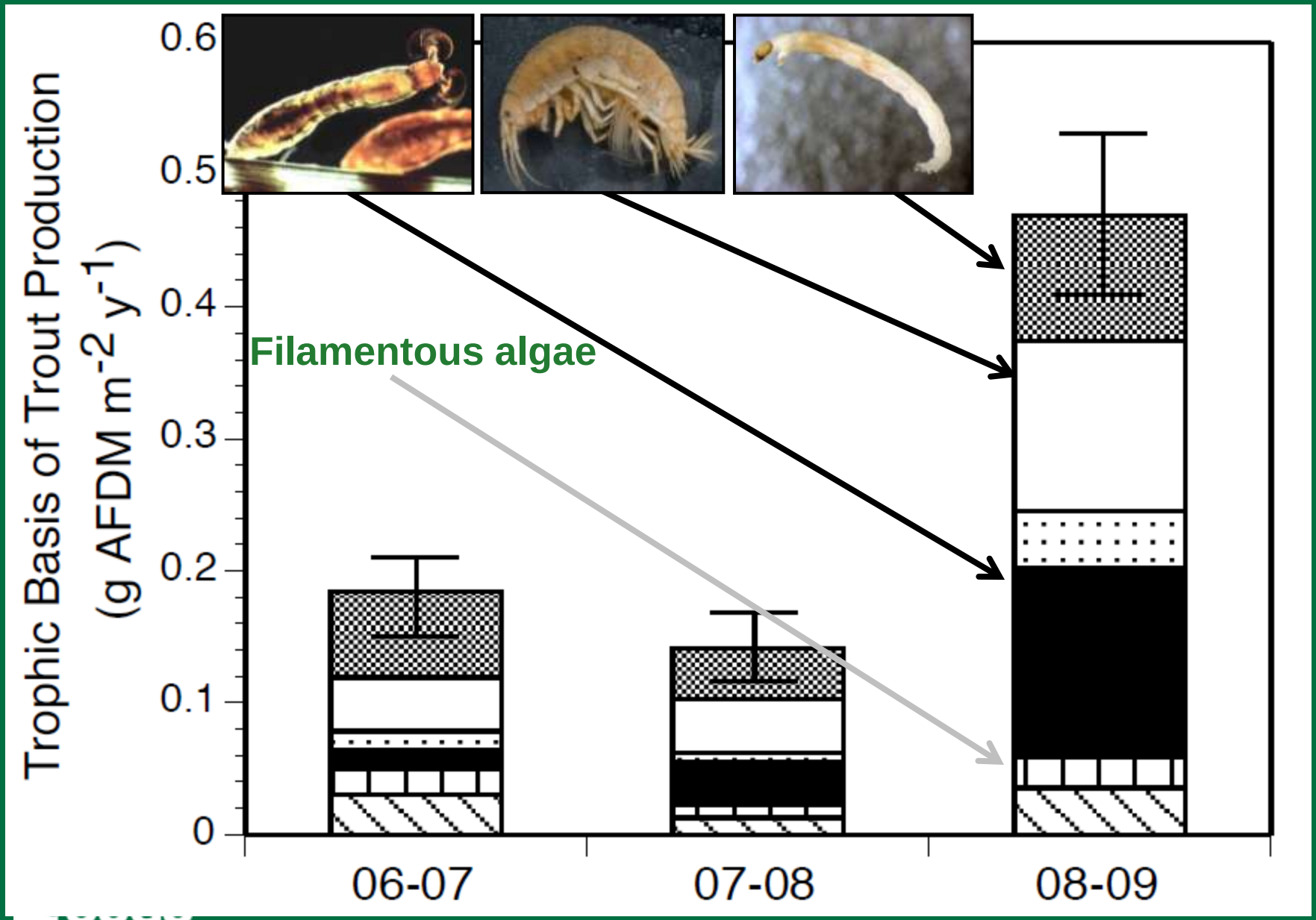
Cross and others 2011 *Ecological Applications*


Pre-flood
Post-flood
Biomass (g AFDM/m2)
30
25
20
15
10
5
0
Other
Simulidae
Chironomidae
Lumbricidae
Physidae
Turbellaria
Tubificida (a)
Gammarus lacustris
P. antipodarum
ND
Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Sep Oct Nov Dec Jan Mar Apr May Jun Jul Aug Sep Oct Oct Nov Dec Feb Mar Mar Apr May
2006
2007
2008
2009
USGS

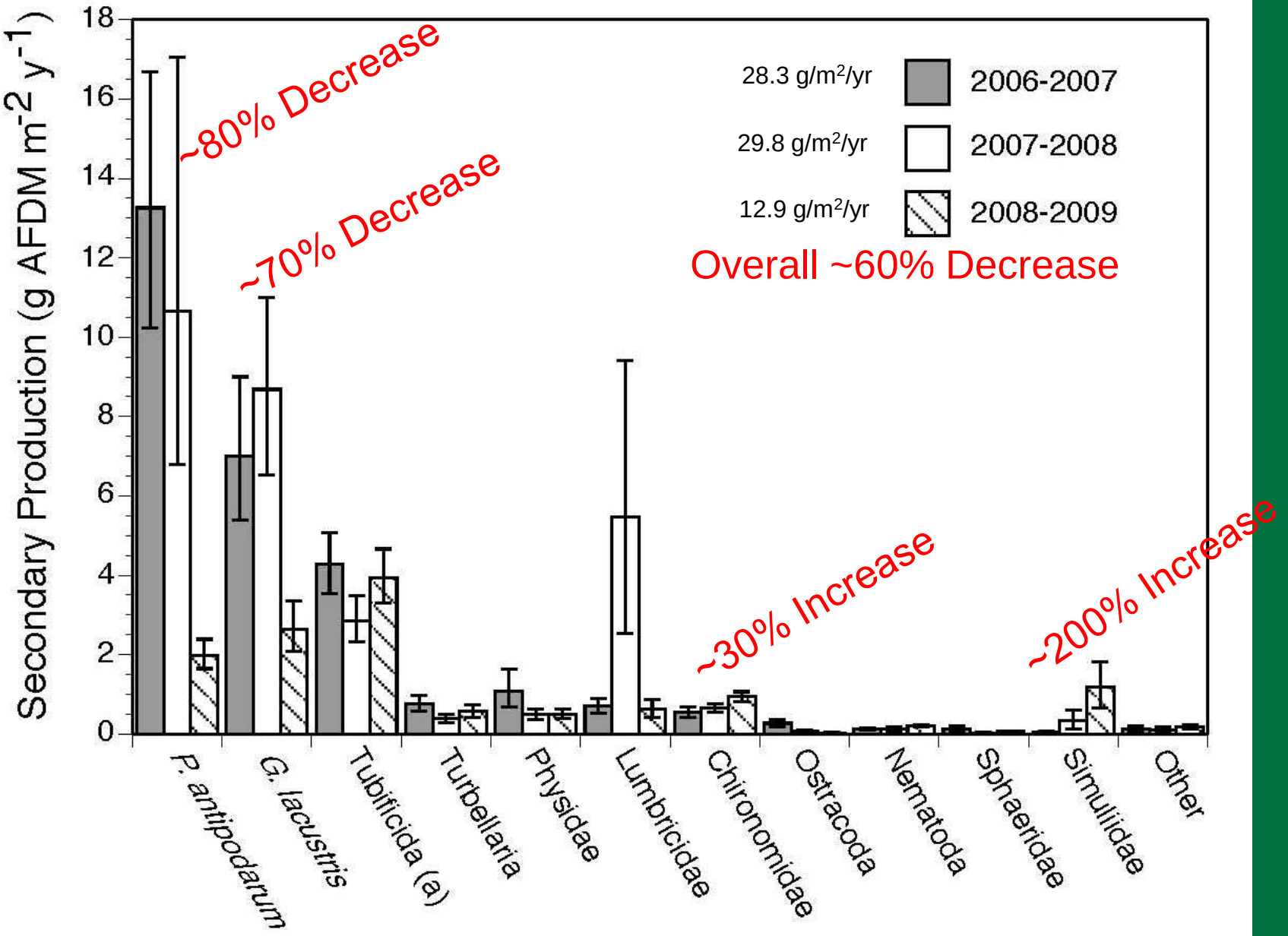

Production (g AFDM m-2 y-1) ± 95% CI
40
35
30
25
20
15
10
5
0
2006-2007
2007-2008
2008-2009
USGS

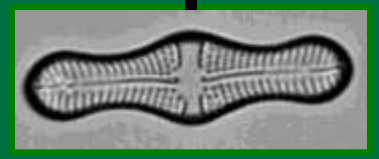

Trophic Basis of Invertebrate Production
(g AFDM m-2 y-1)
40
35
30
25
20
15
10
5
0
06-07
07-08
08-09
USGS


Trout Production
(g AFDM m-2 y-1)
0.6
0.5
0.4
0.3
0.2
0.1
0
06-07
07-08
08-09


Trophic Basis of Trout Production
(g AFDM m-2 y-1)
0.6
0.5
0.4
0.3
0.2
0.1
0
Filamentous algae
06-07
07-08
08-09

The 2008 artificial flood stimulated production of key invertebrate taxa





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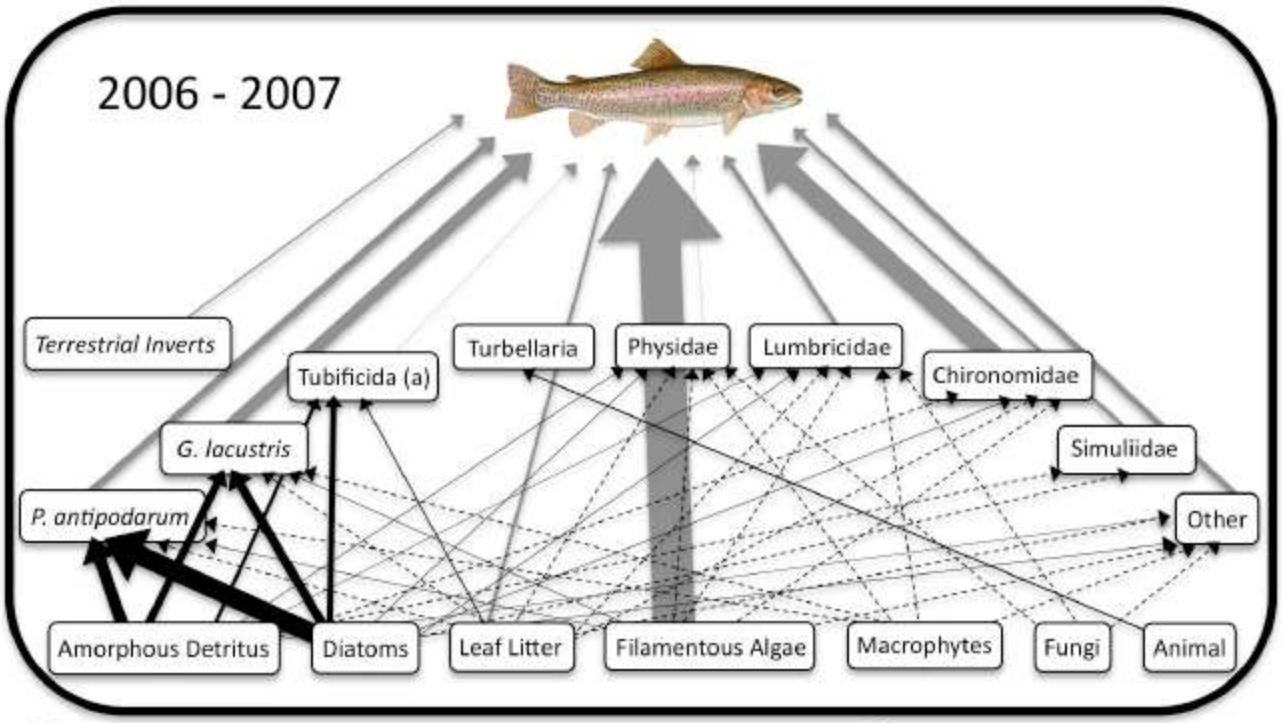
Quantitative Food Webs



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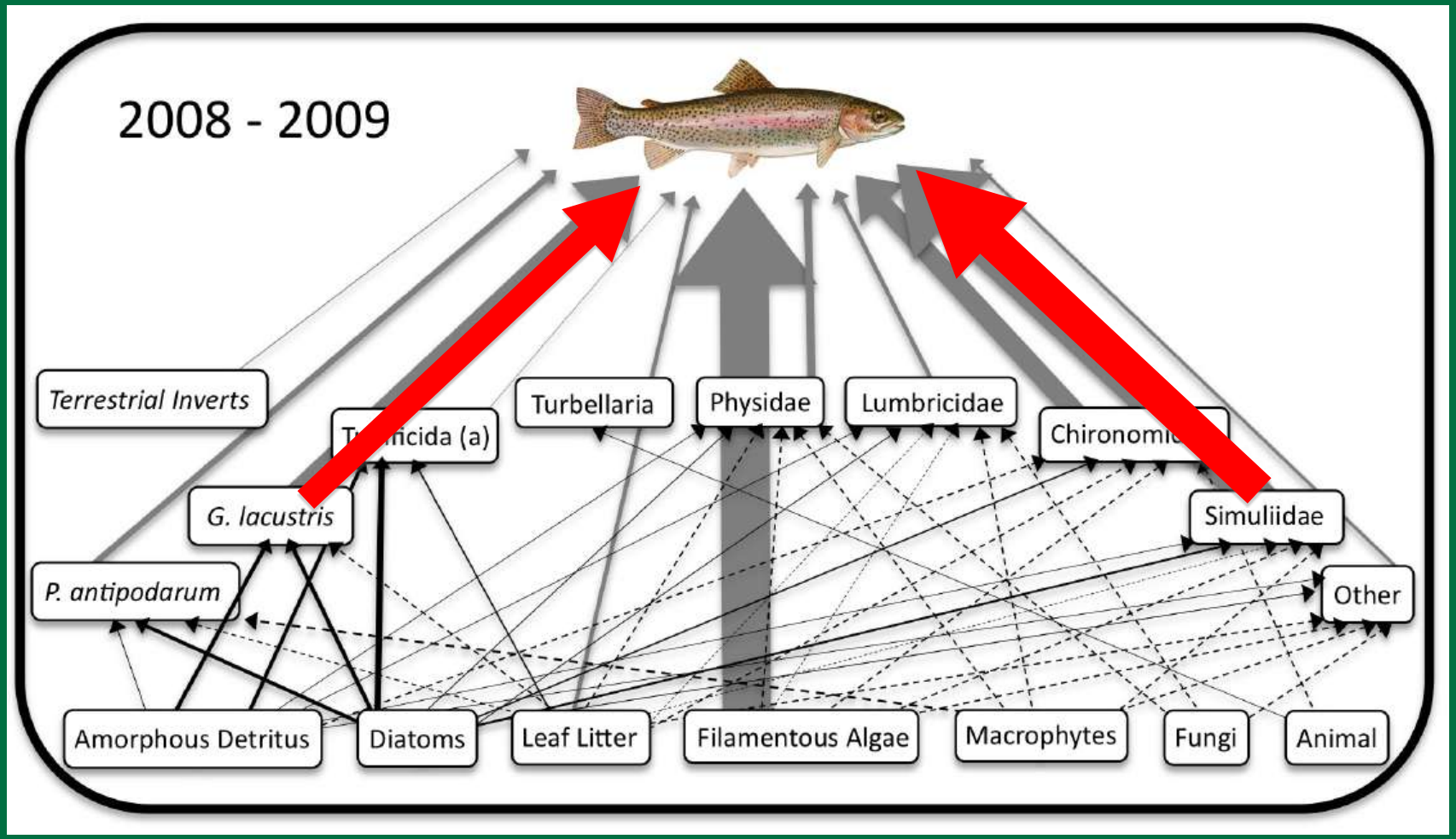
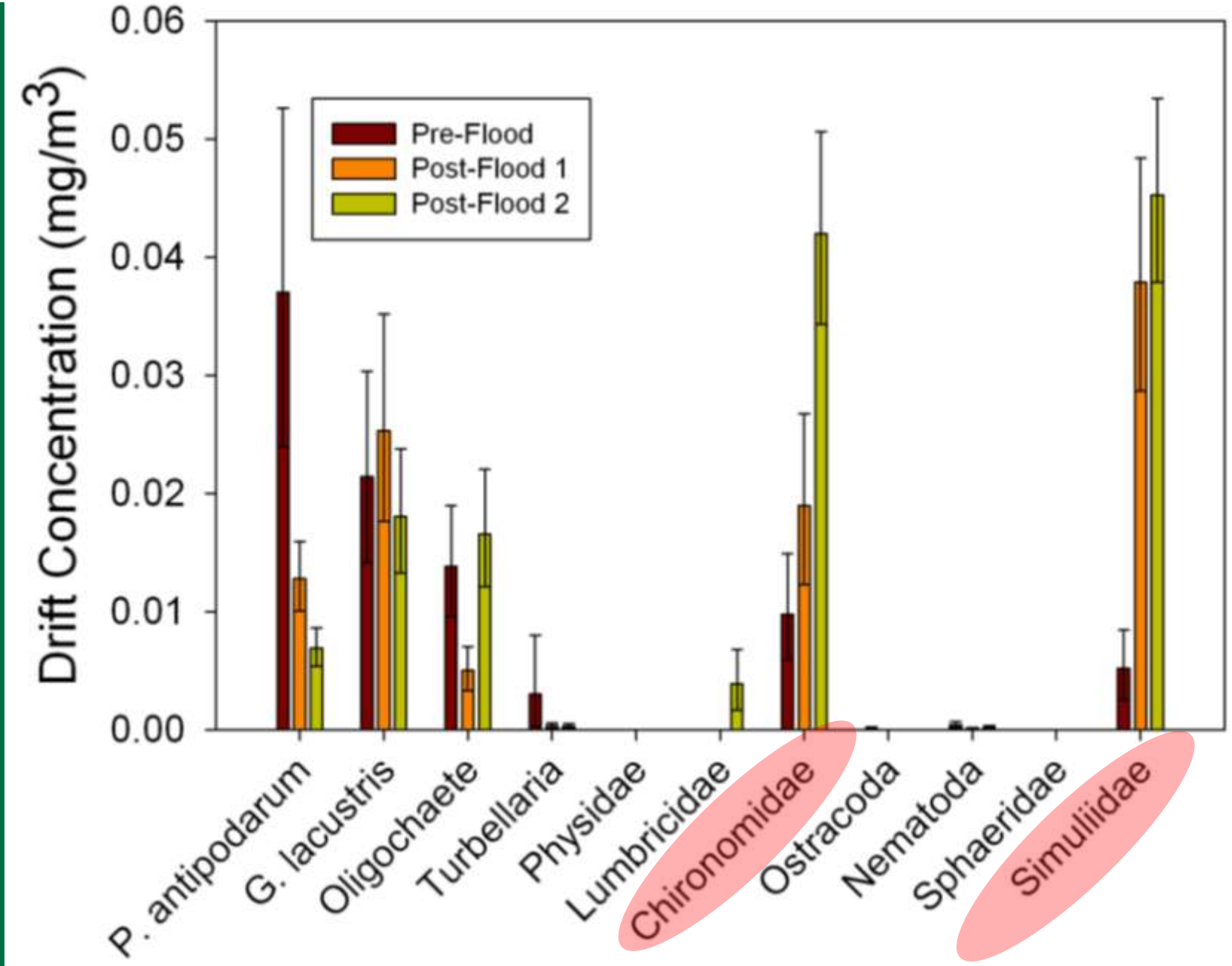


Reduced flows to invertebrates

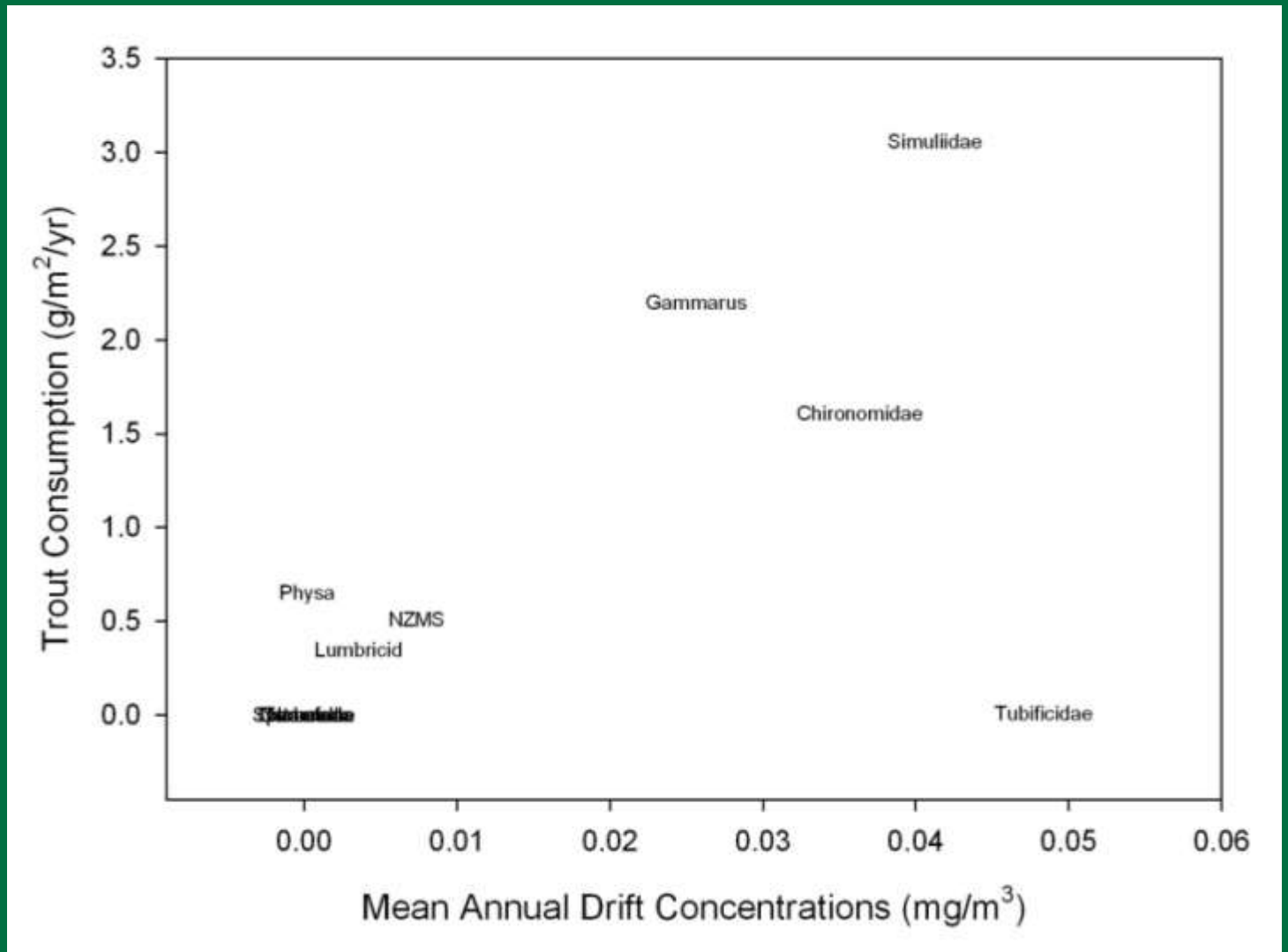
Increased flows to trout

USGS

Midge and black fly drift increased after the flood



Trout Consumption Determined by Availability = Drift



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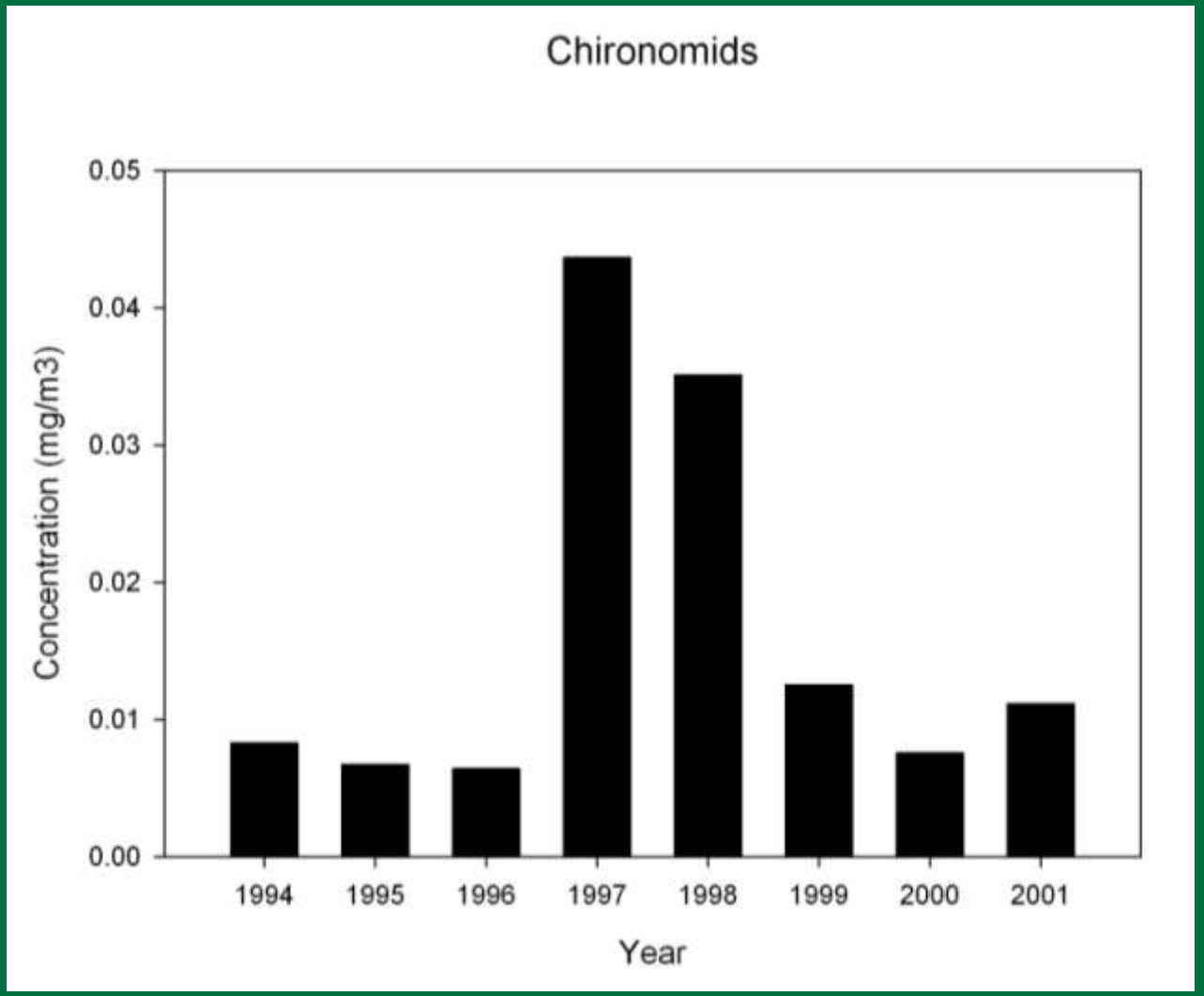
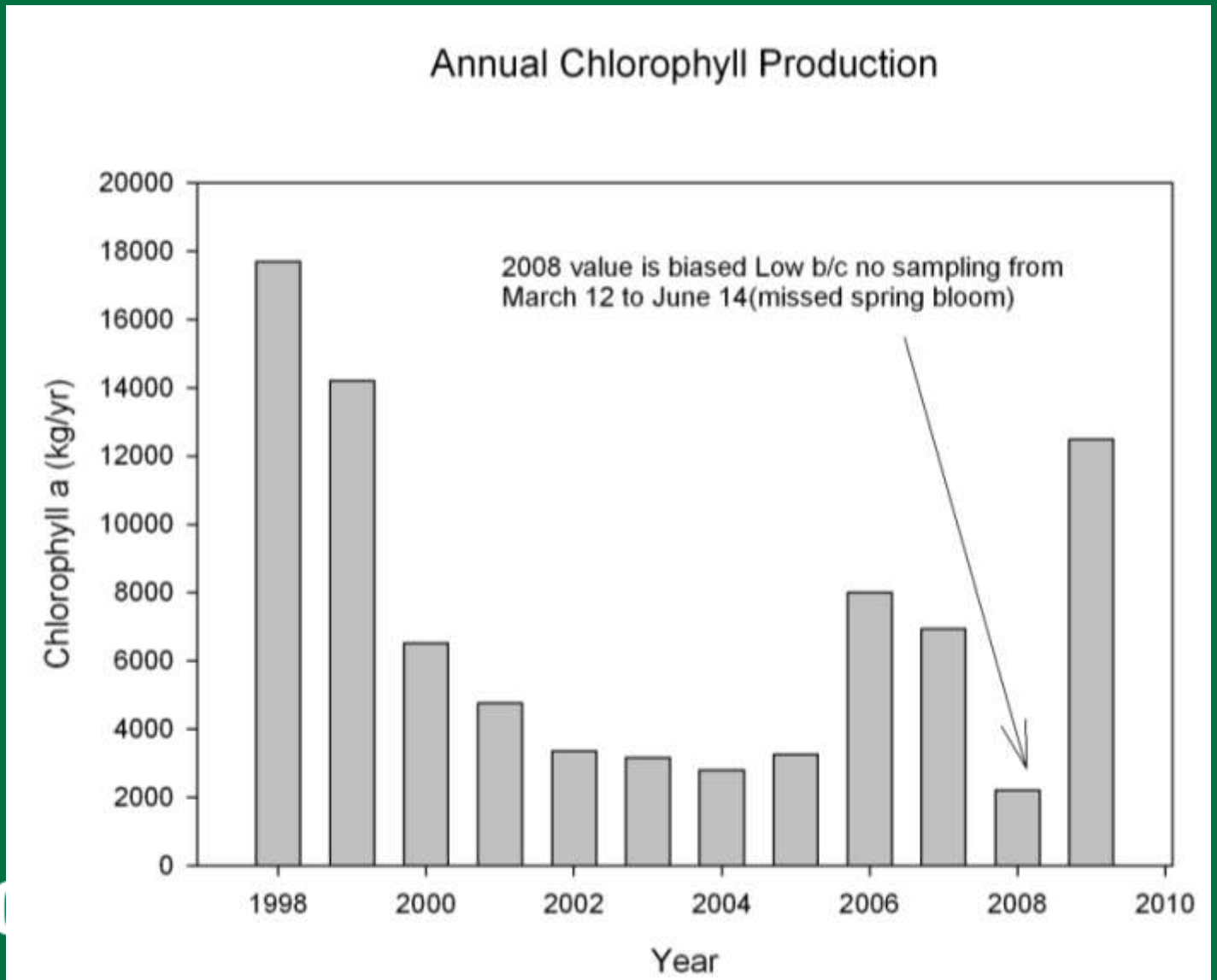
Midge Drift Increased Following 1996 HFE



USGS

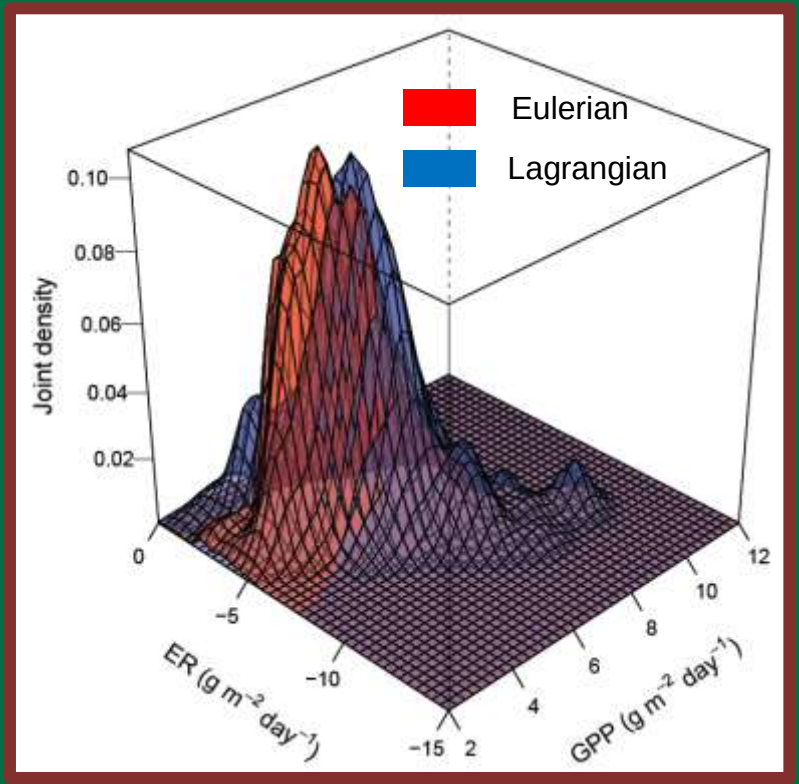
Shannon and others, unpublished data

Trout production tracks Chlorophyll Production



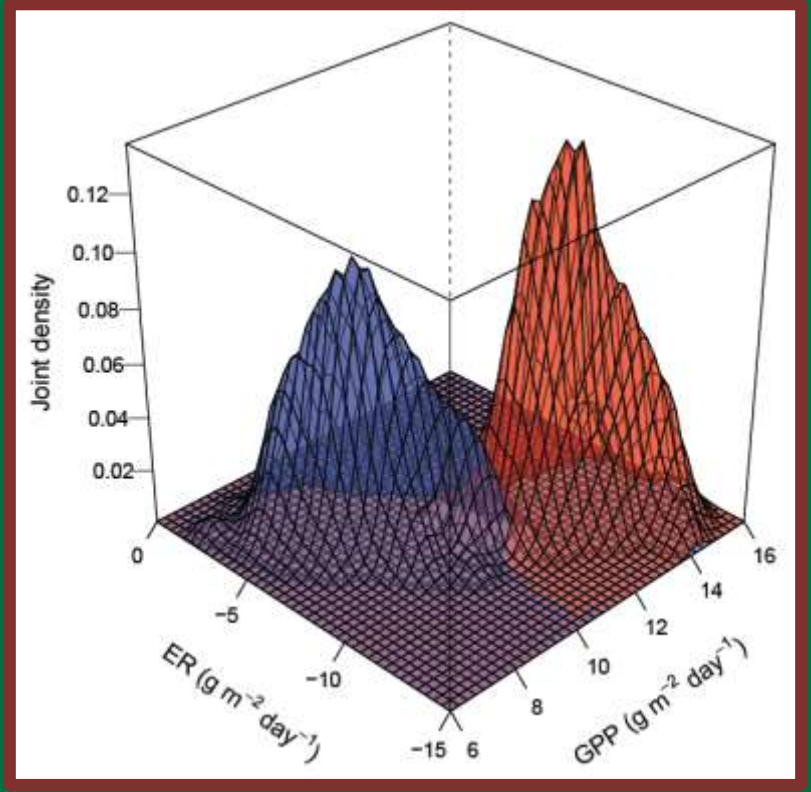
We Now Have A Working Lees Ferry Dissolved Oxygen Model—3 Years Worth of Daily GPP Estimates Coming Soon!!

Estimates are comparable to previous approaches



Similar metabolism estimates under steady flow conditions

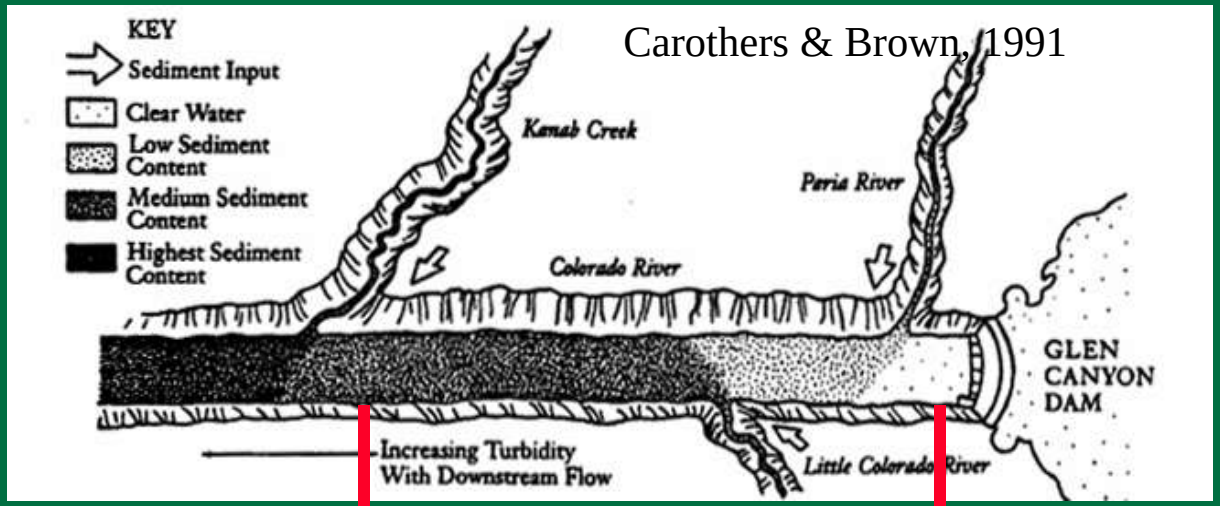
Simulation of unsteady flow matters



Different metabolism estimates under unsteady flow conditions

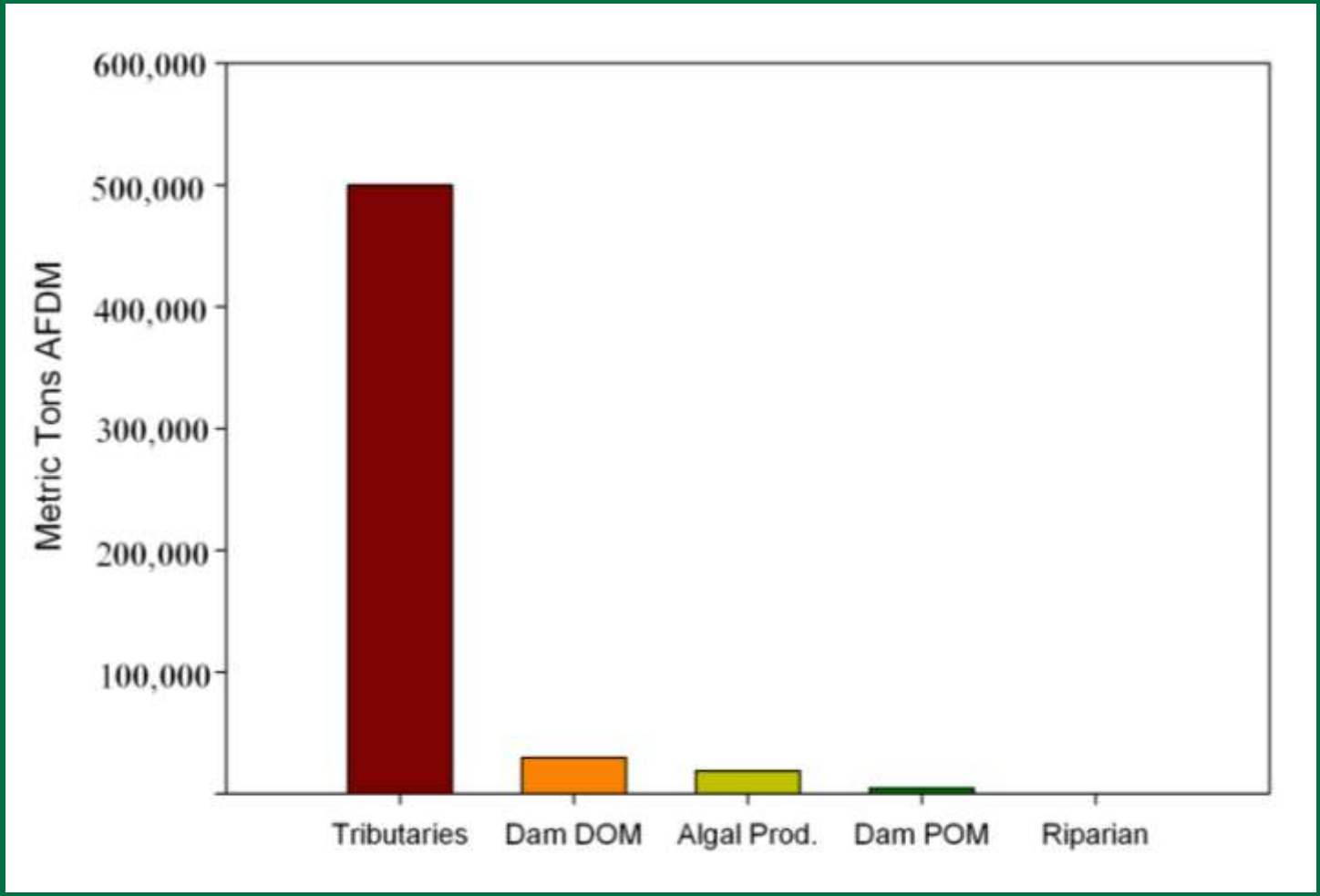
Rob Payn et al., *in prep*

Two Different Rivers



Carothers & Brown, 1991

Tributary-Derived Organic Matter Dominates the Input Budget



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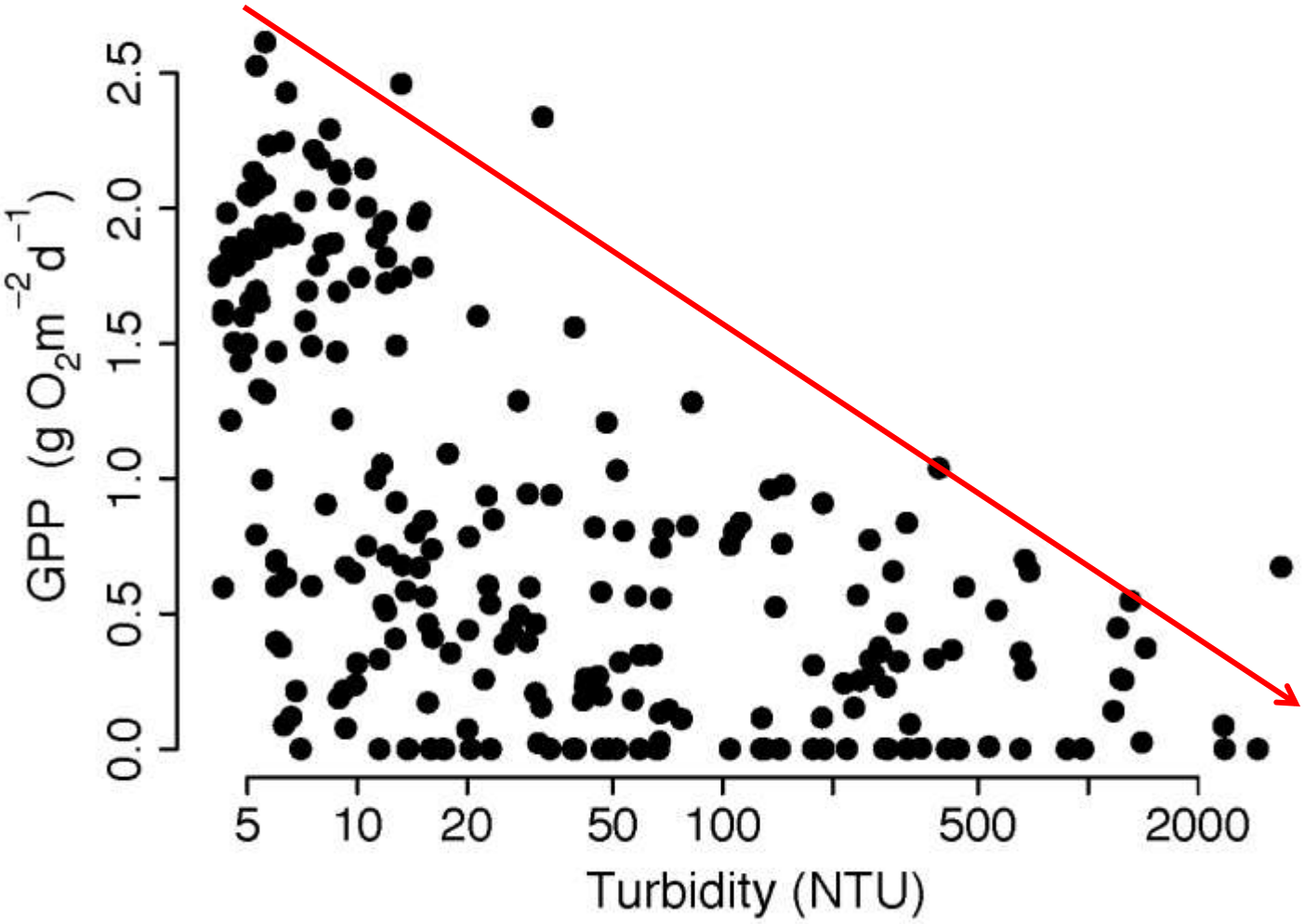
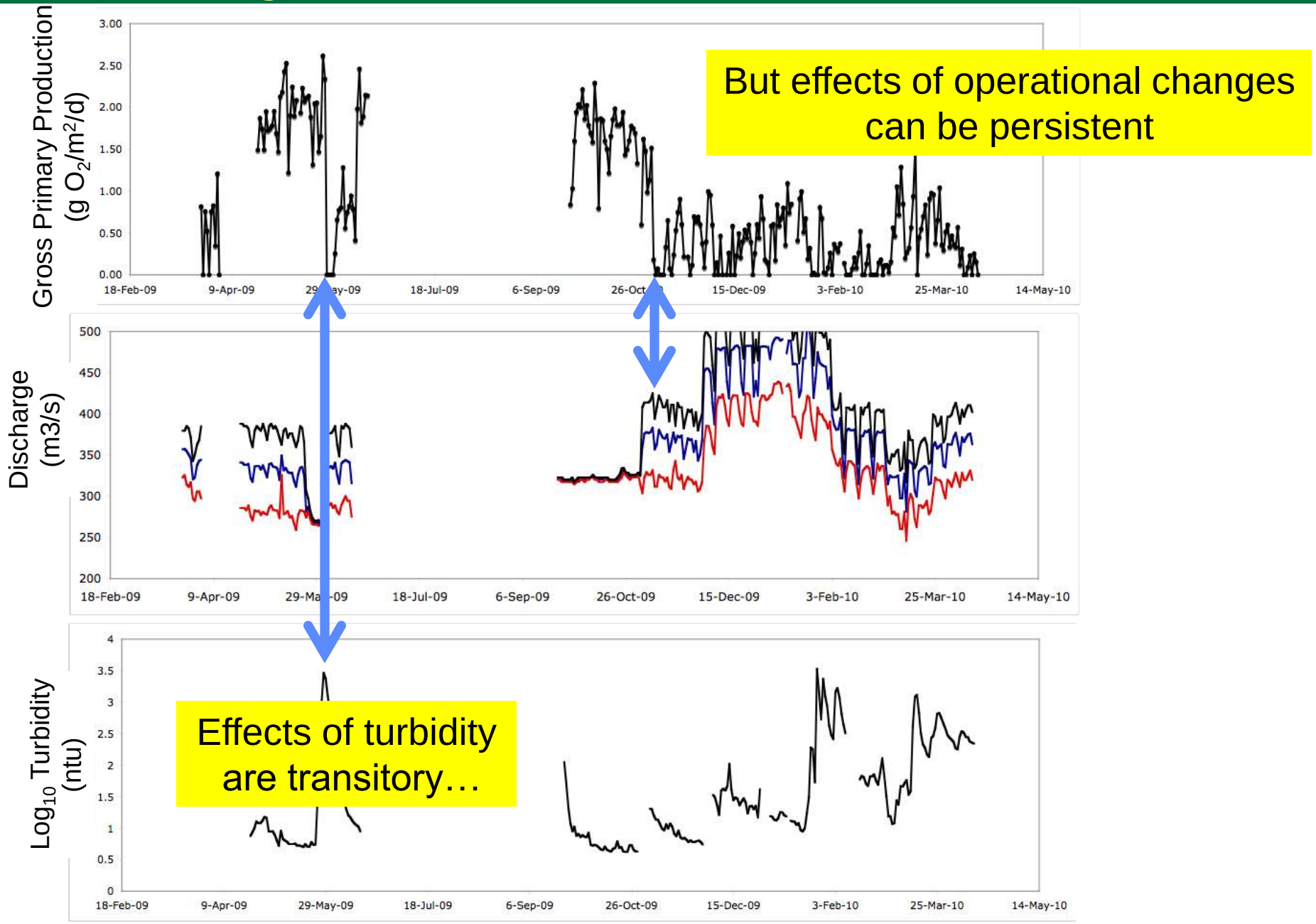
Turbidity Limits Primary Production in Grand Canyon

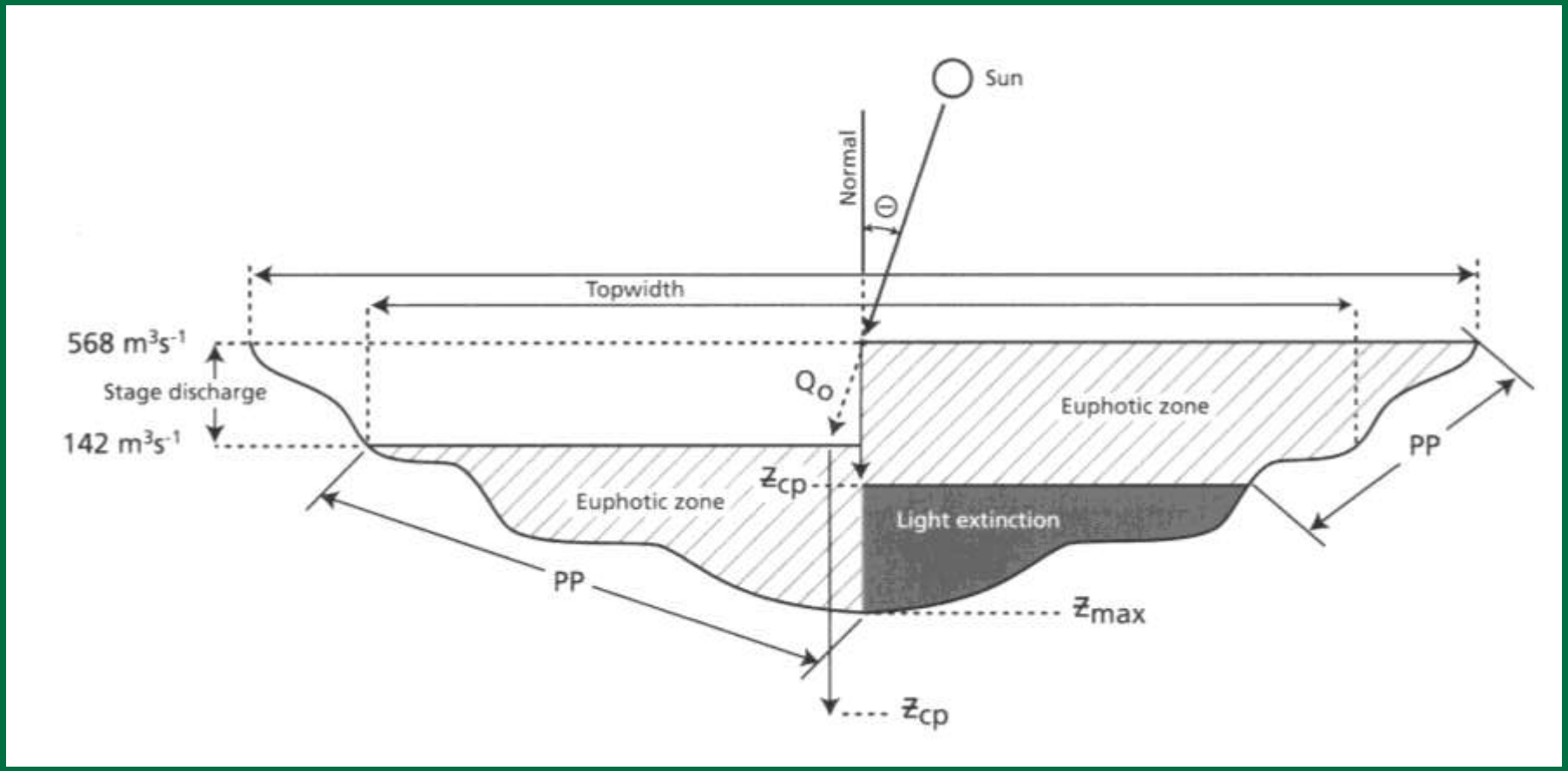


Bob Hall, unpublished data

Primary Production—Diamond Creek



Why Does Production Approach Zero When Discharge Fluctuates in November?



USGS

Yard (2003)

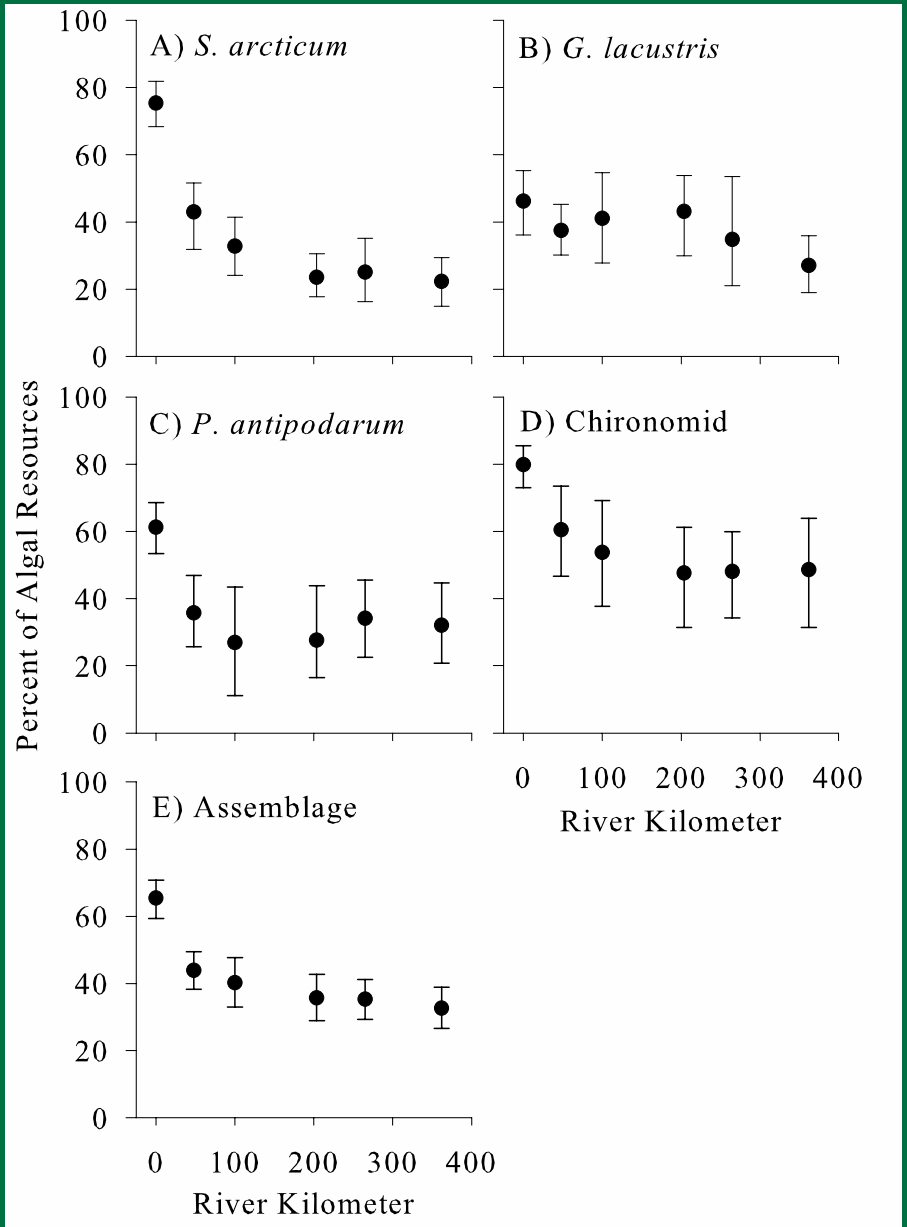
High discharge, but not necessarily fluctuations, decreases total algae production in Grand Canyon

Table 2. Areal estimates were calculated for the geomorphic reaches and include: total wetted area (TWA), mean channel depth (Z), light attenuation coefficient (K_O), photosynthetically available area (PAA) and areal percent (PAA%). Zenith angles used for estimating K_O (mid-day estimate) varied seasonally from 60.4° to 13.5°. Maximum photosynthetic photon flux density (PFD) for summer and winter seasons range between 2020-1980, and 1200-1150 μmol quanta m^{-2} s^{-1} respectively. Compensation point used (30 μmol quanta m^{-2} s^{-1}) was specific to *C. glomerata*.

	Flow Discharge 142 m^3s^{-1}								Flow Discharge 568 m^3s^{-1}							
	CHANNEL		SUMMER			WINTER			CHANNEL		SUMMER			WINTER		
	TWA	Z	K_O	PAA	PAA	K_O	PAA	PAA	TWA	Z	K_O	PAA	PAA	K_O	PAA	PAA
	ha	m	m^{-1}	ha	%	m^{-1}	ha	%	ha	m	m^{-1}	ha	%	m^{-1}	ha	%
GLEN CANYON	298	7.2	0.22	297	100%	0.34	284	95%	484	8.9	0.22	474	98%	0.33	331	69%
MARBLE CANYON SECTION																
Permian	147	6.1	0.39	96	65%	0.59	86	58%	163	7.9	0.42	121	74%	0.65	67	41%
Supai Gorge	105	6.4	0.36	78	74%	0.55	72	68%	120	8.9	0.55	67	56%	0.84	39	32%
Redwall Gorge	127	6.4	0.36	103	81%	0.55	98	77%	146	8.9	0.57	99	68%	0.88	56	38%
Lower Marble Canyon	376	5.2	0.52	241	64%	0.80	221	59%	410	7.1	0.52	319	78%	0.80	177	43%
CENTRAL GRAND CANYON SECTION																
Furnace Flats	238	3.7	0.76	167	70%	1.18	141	59%	266	5.4	0.52	251	94%	0.80	160	60%
Upper Granite Gorge	352	5.7	0.66	173	49%	1.02	152	43%	416	8.2	0.75	190	46%	1.16	89	21%
Aisles	71	5.7	0.45	50	71%	0.69	47	67%	85	8.1	1.27	25	29%	1.96	12	14%
Middle Granite Gorge	131	7.0	0.45	95	73%	0.69	90	69%	154	9.5	1.38	42	27%	2.12	18	12%
WESTERN GRAND CANYON SECTION																
Muav Gorge	152	5.4	0.58	95	63%	0.89	84	56%	185	8.1	1.11	53	29%	1.71	28	15%
Lower Canyon	607	3.9	0.59	472	78%	0.91	446	73%	722	6.4	1.36	187	26%	2.09	94	13%
Lower Granite Gorge	143	5.9	0.45	94	66%	0.69	91	63%	157	8.3	2.66	10	7%	4.0	6	4%
TOTAL	2,746	5.3	-	1,961	71%	-	1,813	66%	3,308	7.7	-	1,838	56%	-	1,078	33%

Yard (2003)

Invertebrates consume a high proportion of diatoms relative to availability

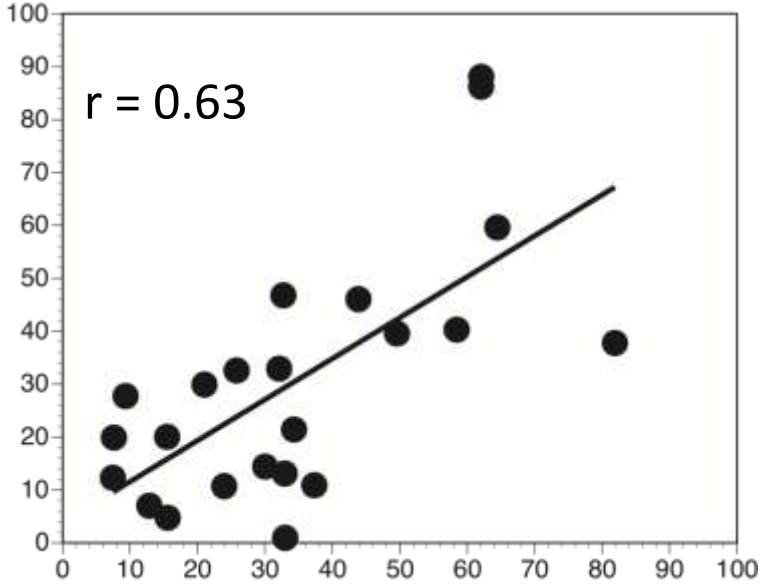


Wellard-Kelley and others, *in prep*

Provisional Data – Subject to Change

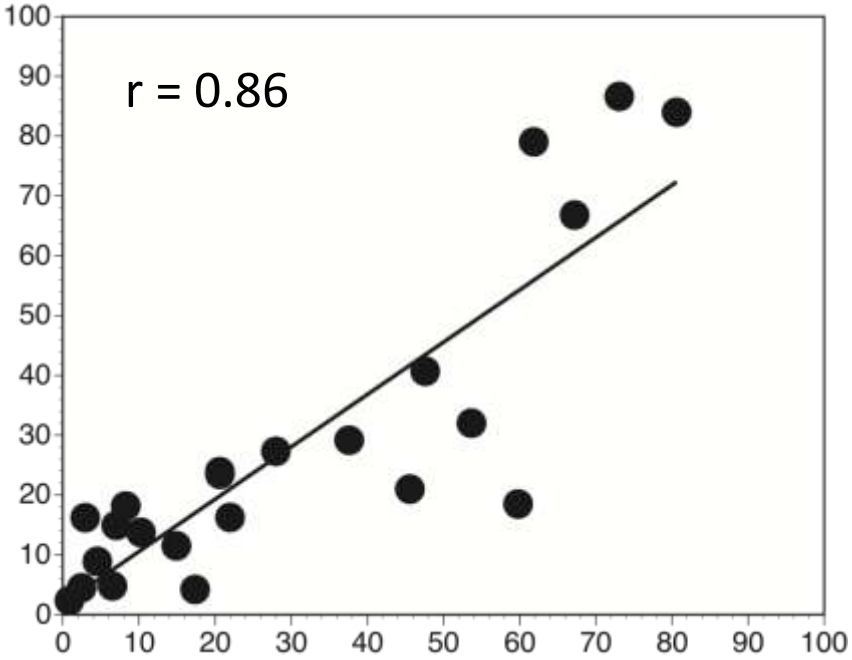
Invertebrate Diets Track Diatom Availability

% of diet that is diatoms



% of epilithon that is diatoms

% of diet that is diatoms

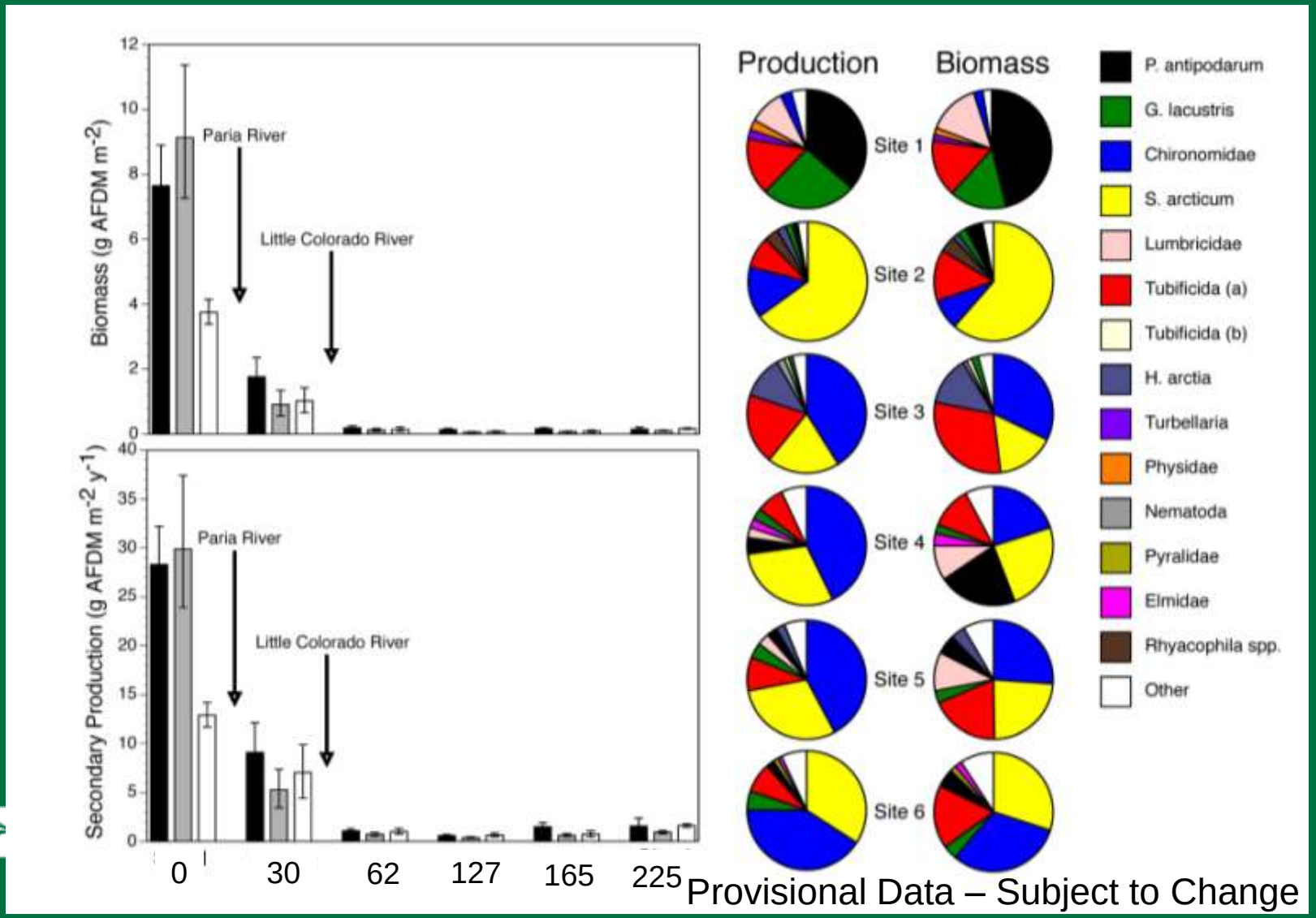


% of seston that is diatoms

Provisional Data – Subject to Change

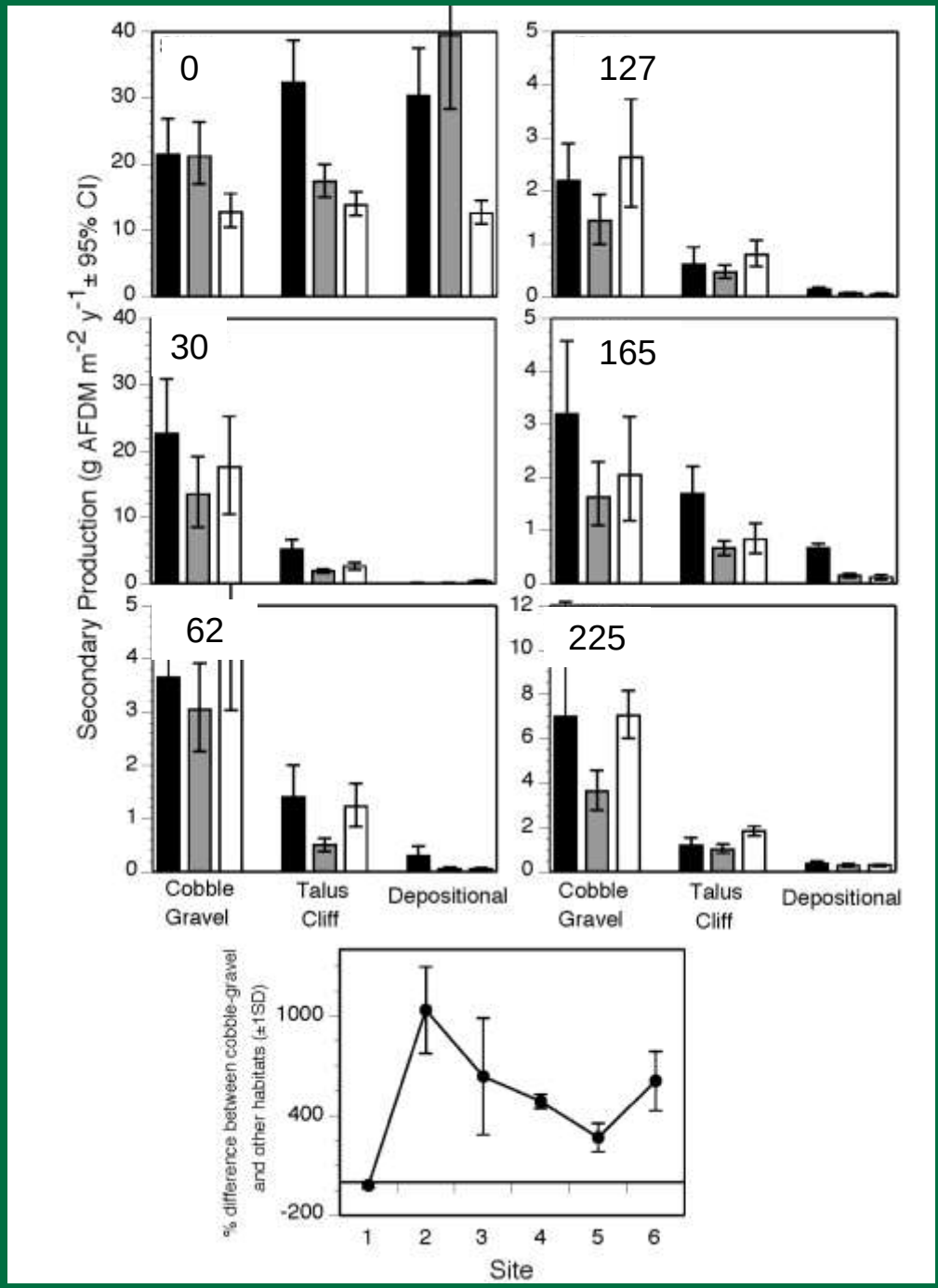
Wellard-Kelley and others, *in prep*

Invertebrate Production Decreases Downstream



Provisional Data – Subject to Change

Most Invertebrate Production is on Cobble



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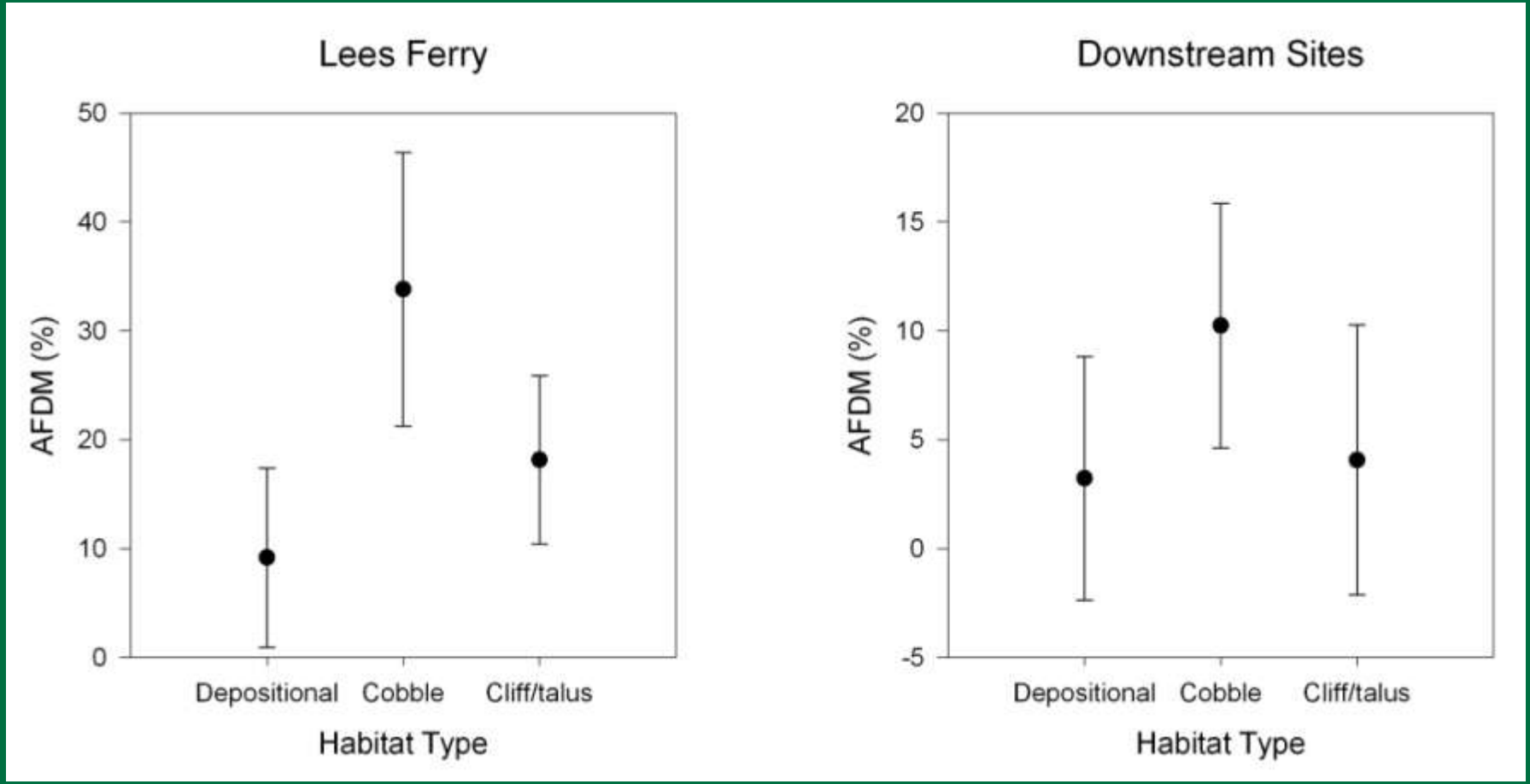
Provisional Data – Subject to Change

Invertebrate production is highest on cobble because there is more food there

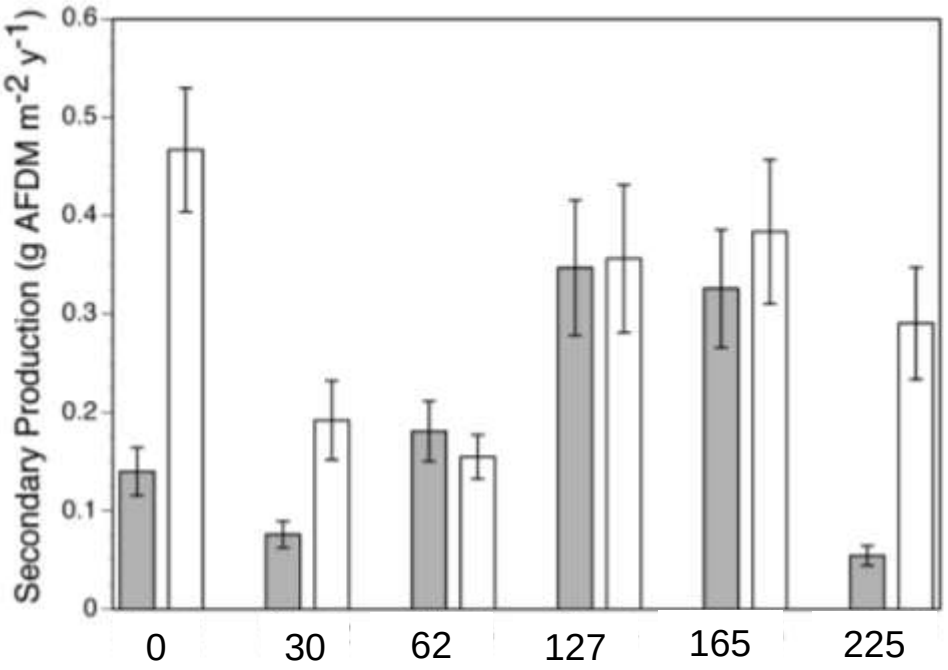


USGS

Kennedy, unpublished data

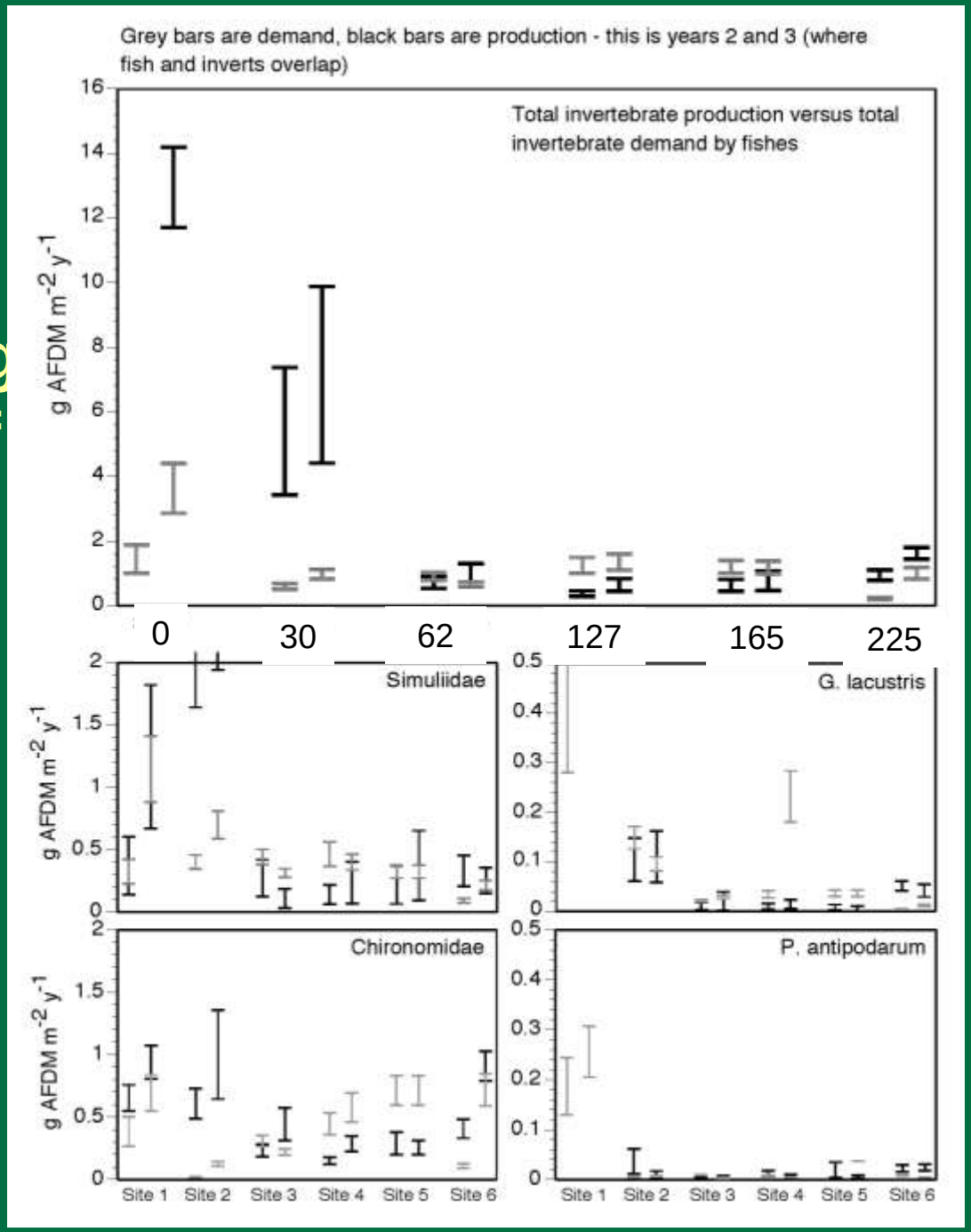
Provisional Data – Subject to Change

Fish Production +/- Doesn't Decrease Downstream



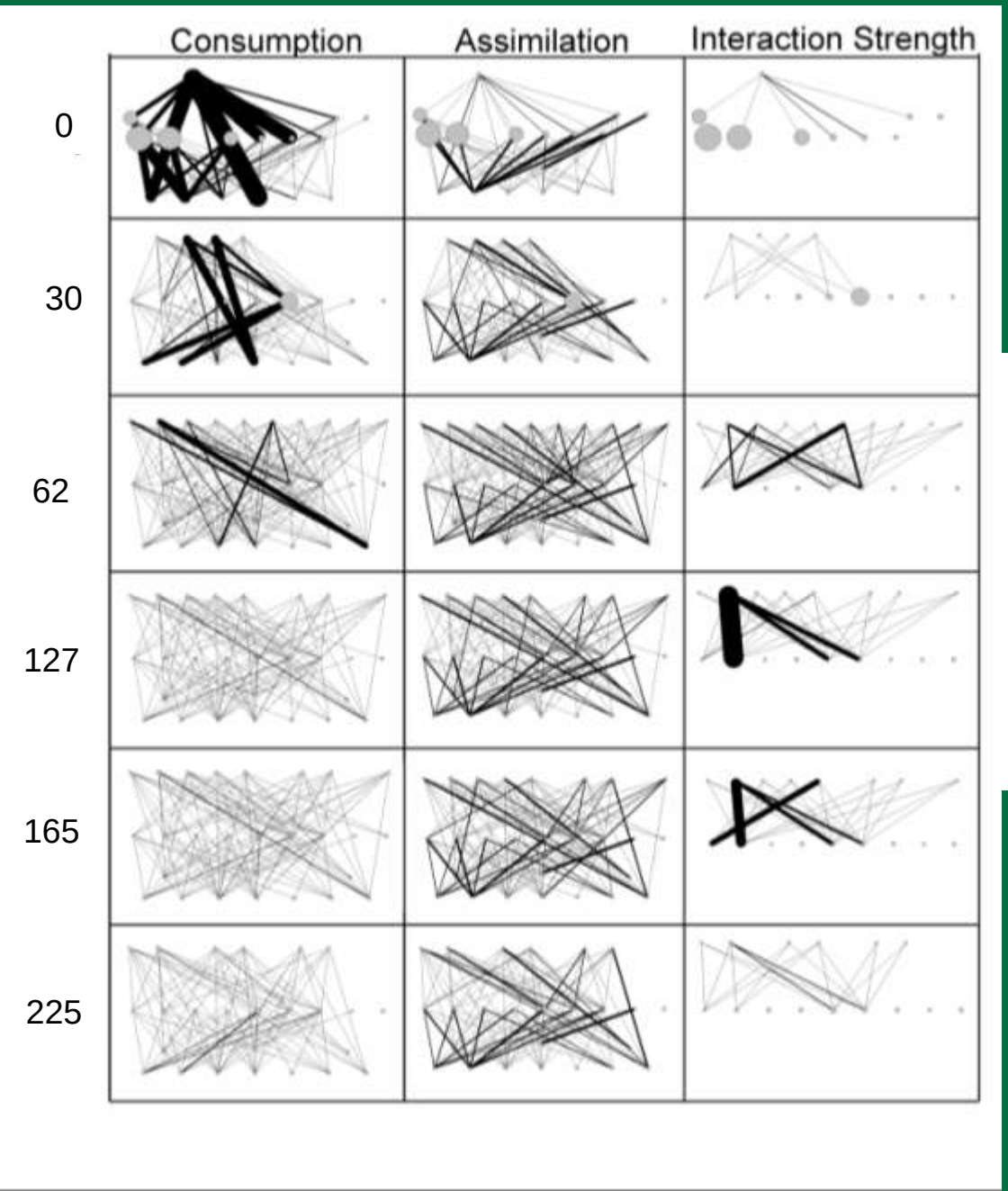
Provisional Data – Subject to Change

Downstream fish assemblage is making more complete use of the limited prey base

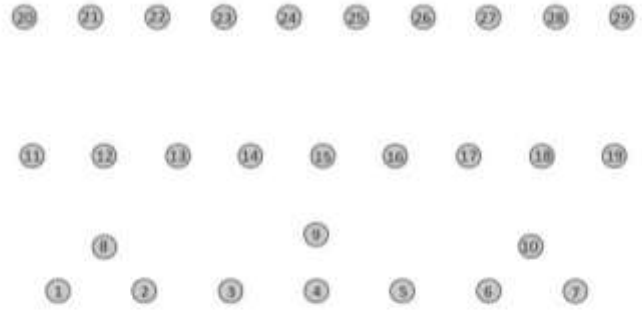


USGS

Provisional Data – Subject to Change

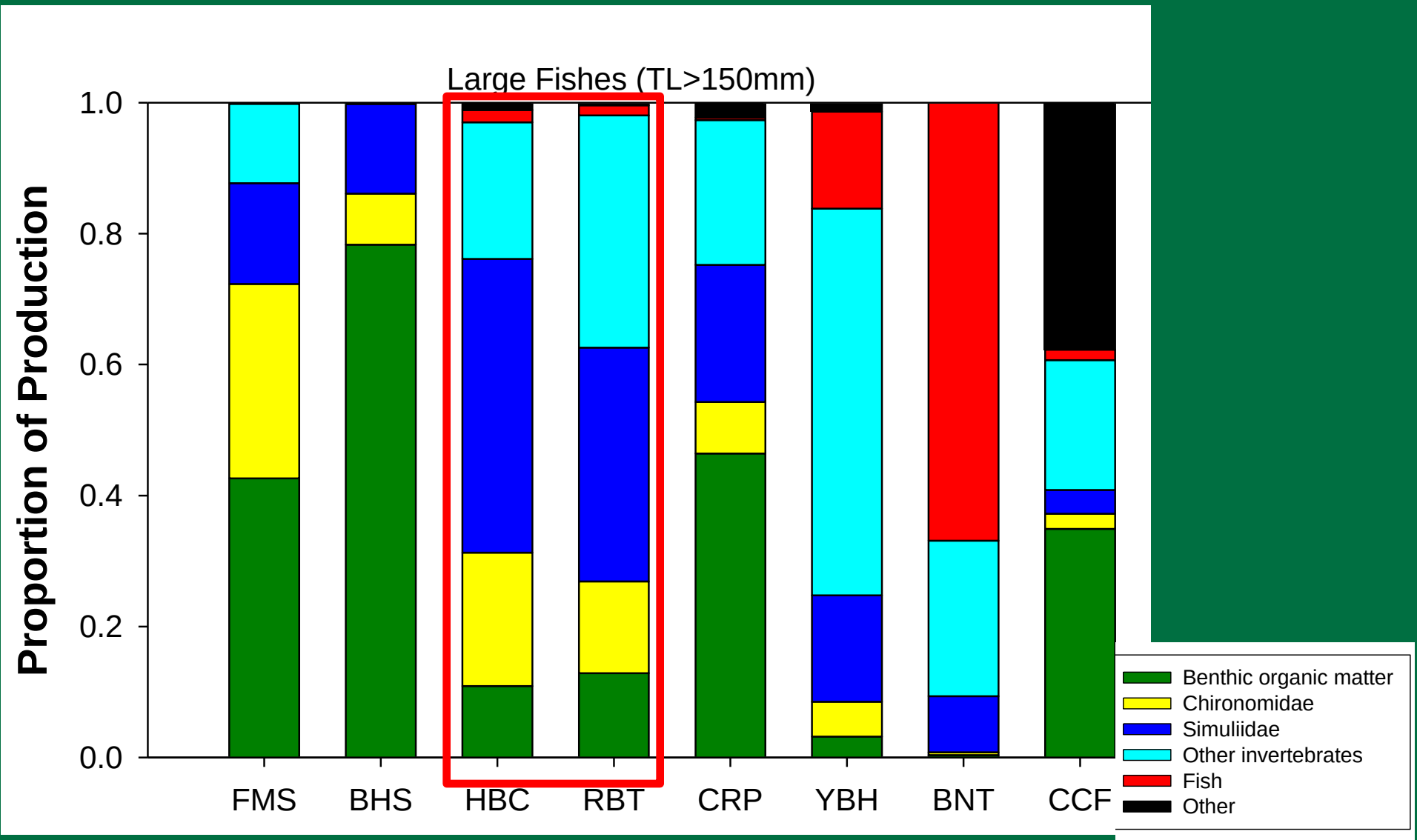


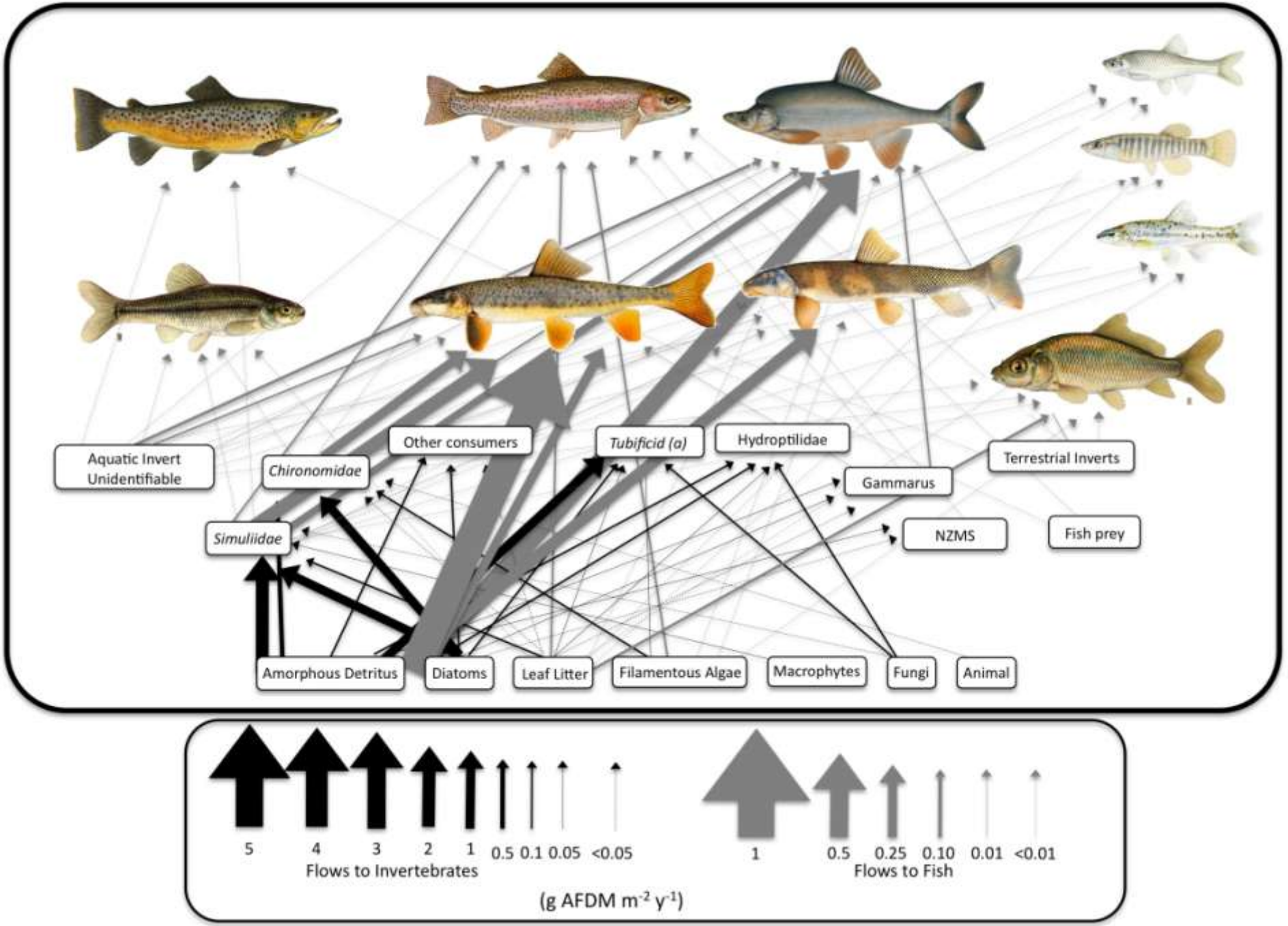
High interaction strengths for some inverts suggest fish may be suppressing production



1: amorphous detritus, 2: diatoms, 3: plant detritus, 4: filamentous algae, 5: macrophyte, 6: fungi, 7: amorphous detritus/diatom mixture, 8: terrestrial invertebrates, 9: animal prey, 10: fish prey, 11: P. antipodarum, 12: G. lacustris, 13: Hydroptilidae, 14: Tubificida (a), 15: Chironomidae, 16: S. arctícum, 17: other invertebrate primary consumers, 18: other invertebrate predators, 19: human food, 20: bluehead sucker, 21: flannelmouth sucker, 22: rainbow trout, 23: brown trout, 24: common carp, 25: humpback chub, 26: speckled dace, 27: fathead minnow, 28: red shiner, 29: plains killifish

Rainbow Trout and Humpback Chub have High Dietary Overlap




Aquatic Invert Unidentifiable
Chironomidae
Other consumers
Tubificid (a)
Hydroptilidae
Terrestrial Inverts
Gammarus
Simuliidae
NZMS
Fish prey
Amorphous Detritus
Diatoms
Leaf Litter
Filamentous Algae
Macrophytes
Fungi
Animal
5
4
3
2
1
0.5
0.1
0.05
<0.05
Flows to Invertebrates
1
0.5
0.25
0.10
0.01
<0.01
Flows to Fish
(g AFDM m-2 y-1)

Relevant Strategic Science Questions:

5. What are the important pathways, and the rate of flux among them, that link lower trophic levels with fish and how will they link to dam operations?

- **Part I**
  - **Any pathway involving midges or black flies**
  - **Direct consumption of algae and detritus might also be important**
- **Part II**
  - **HFEs stimulate important pathways in Lees Ferry**
    - **May have also occurred downstream but ecological buffering masked this**
  - **High discharge during winter appears to reduce algal pathways**
  - **Low production of prey items in varial zone**

USGS

Relevant Strategic Science Questions:

6. Are trends in the abundance of fish populations, or indicators from fish such as growth, condition, and body composition (for example, lipids), correlated with patterns in invertebrate flux?

- **Definitely true in Lees Ferry**
- **Some evidence downstream**
  - **High overlap of invertebrate production and fish demand**
  - **Annual variation in sucker condition correlated with invertebrate biomass (Paukert 2005)**

USGS

Relevant Strategic Science Questions:

5. How is invertebrate flux affected by water quality (for example, temperature, nutrient concentrations, turbidity) and dam operations?

- **HFEs stimulate invertebrate flux in Lees Ferry (and possibly downstream)**
- **Turbidity depresses algal production and probably invertebrate flux**
- **High discharge during winter months may depress invertebrate flux**

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Relevant Strategic Science Questions:

5. How is invertebrate flux affected by water quality (for example, temperature, nutrient concentrations, turbidity) and dam operations?

- **Temperature has a huge effect on algae and invertebrate flux**

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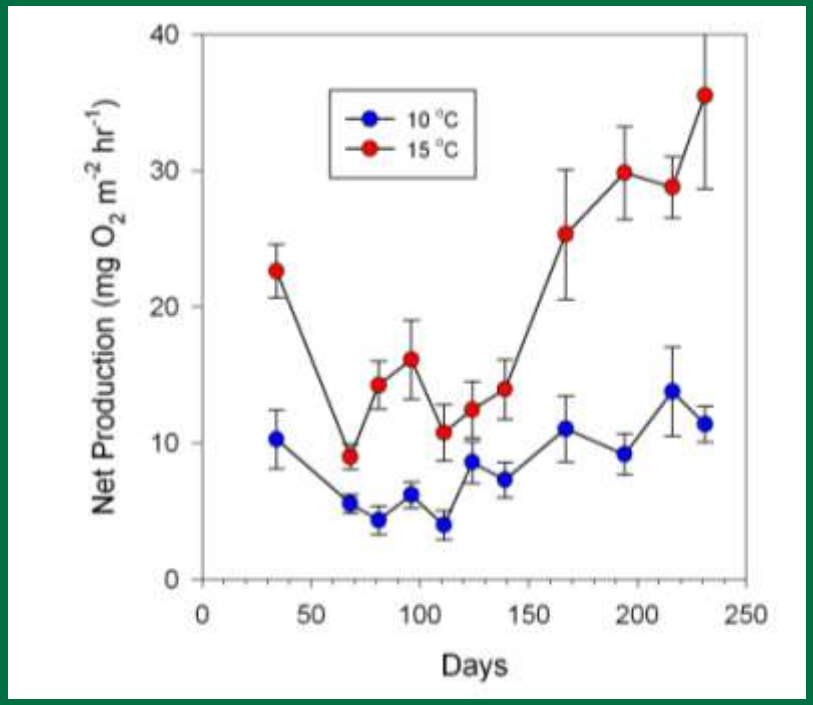
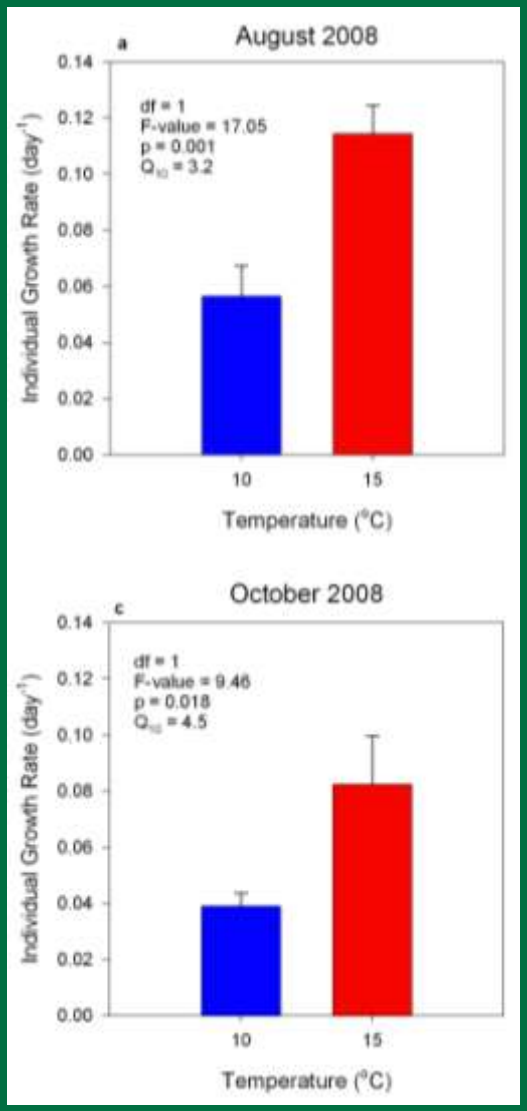
Warming Increases Growth/Production of Algae and Invertebrates

Algae Production



Black Fly Growth



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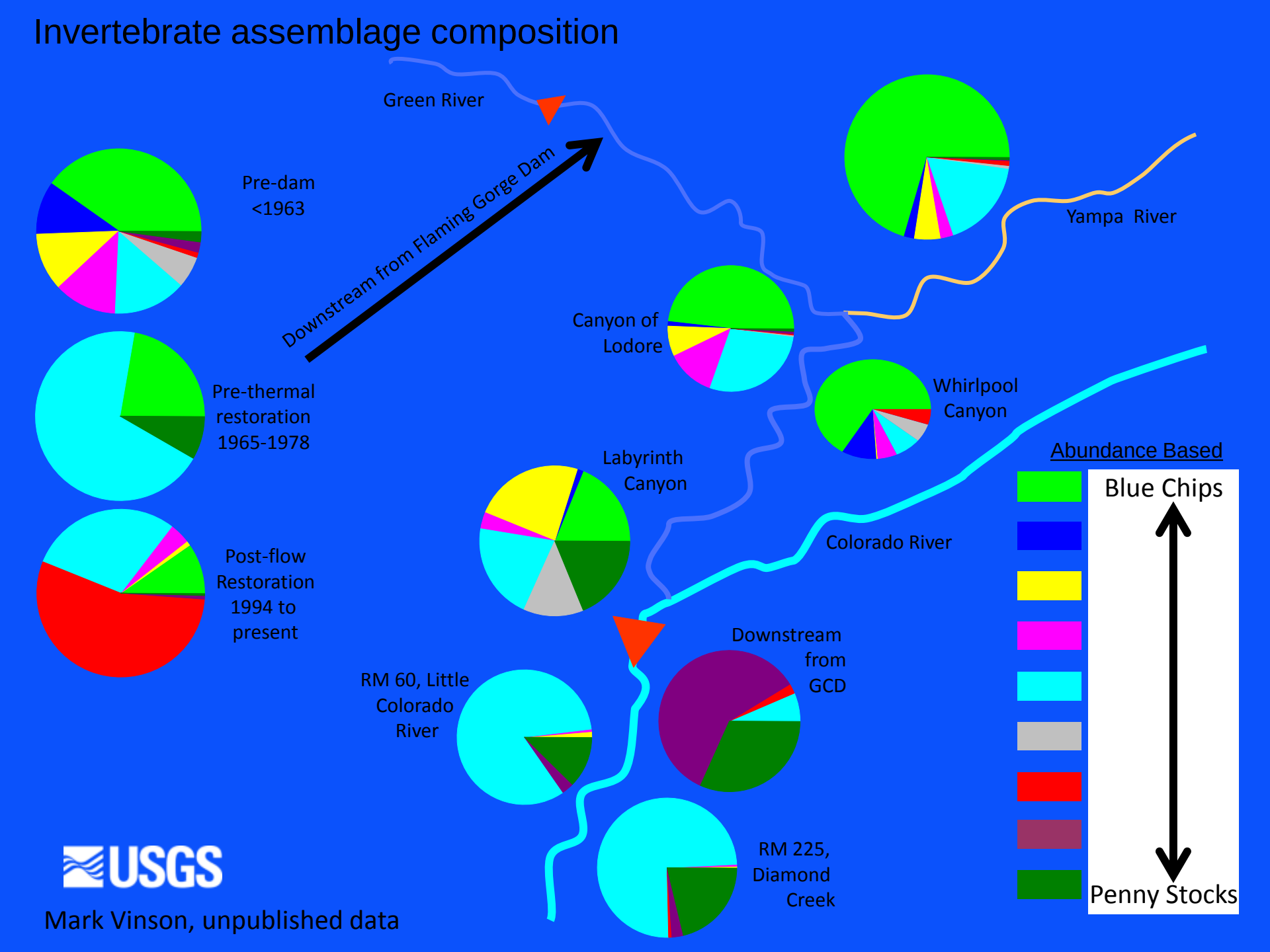
Kennedy and others, unpublished data

Invertebrate assemblage composition



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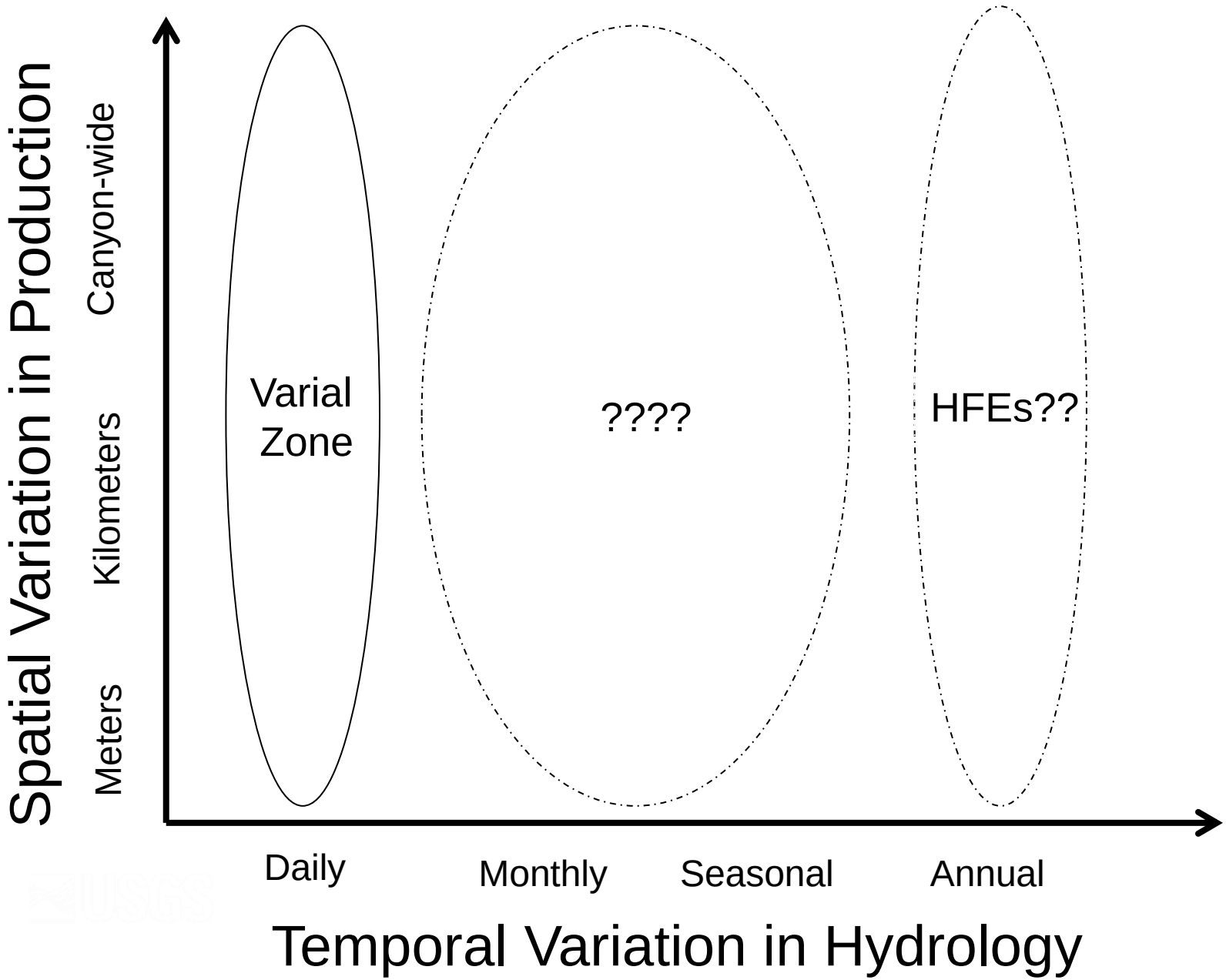
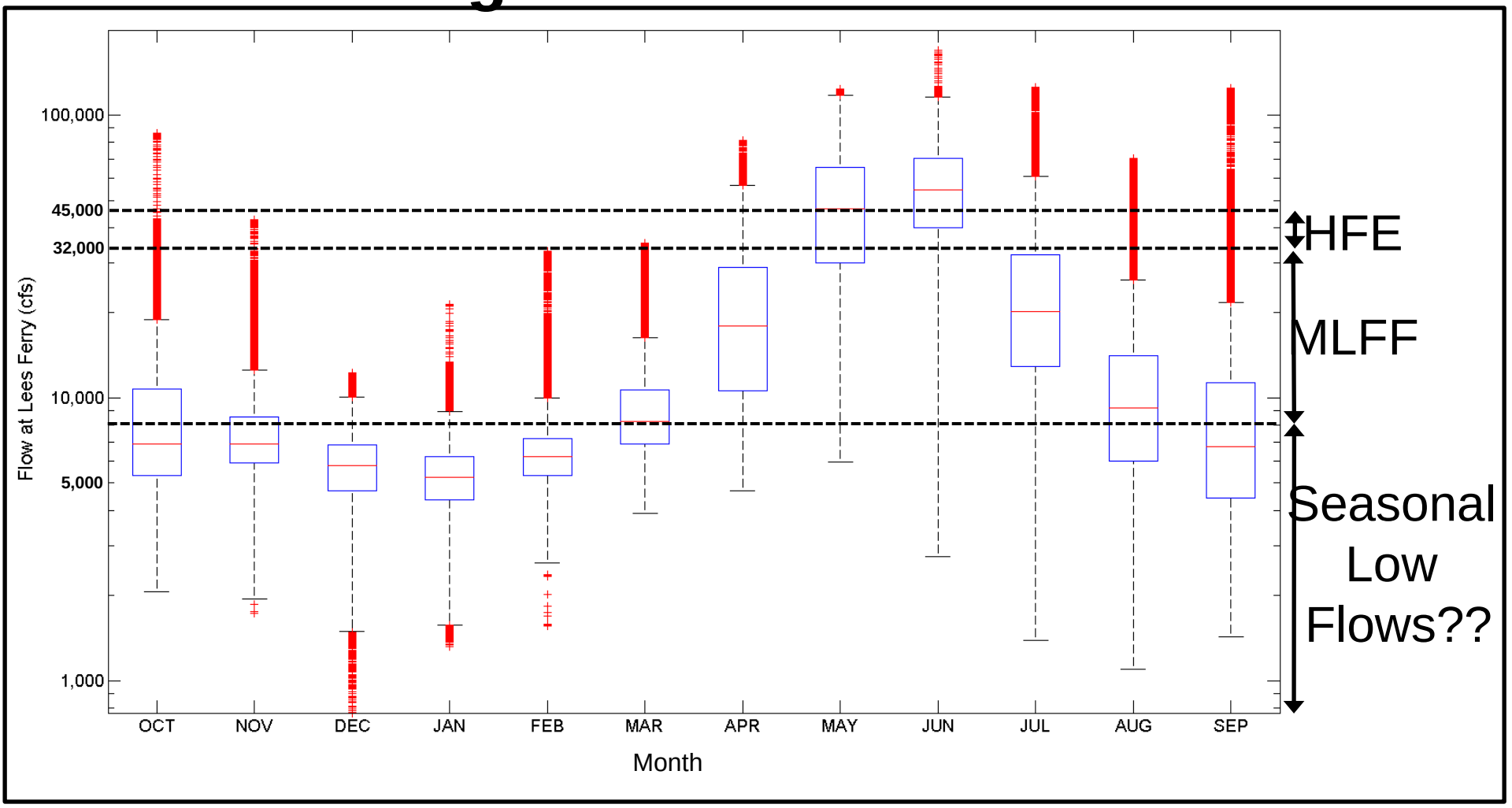
Mark Vinson, unpublished data

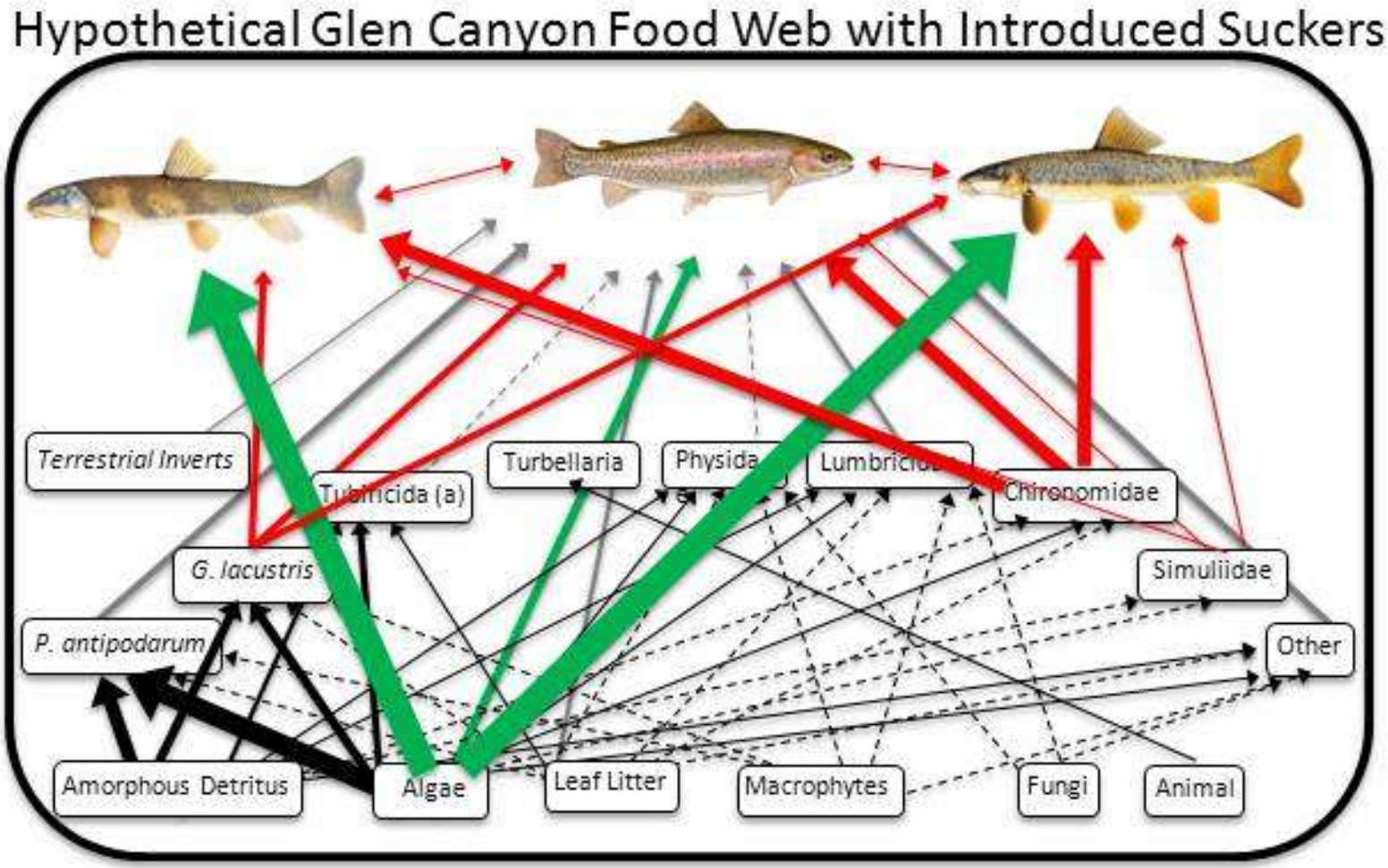
Temporal Scales of Flow Regime



Ecologically Important Processes Could Occur During Low Flows



Add ecological buffering capacity to Lees Ferry



Provisional Data – Subject to Change