Research to develop a food base monitoring program: Linking whole-river carbon cycling to quantitative food webs in the Colorado River

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Scientific challenges for the Colorado River food web

We know:
Colorado river is altered from changes in physical habitat from Glen Canyon dam

Invaded by New Zealand mud snail

We don't know:
How changes in productivity and edibility of basal food resources will impact productivity of native and exotic fishes

Therefore:
We need to monitor food web flows to assess future changes from invasions or dam management

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?

Both of these questions require an ecosystem approach based upon flows of energy.

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. Interaction of the above
   d. Competition and predation with other animals

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

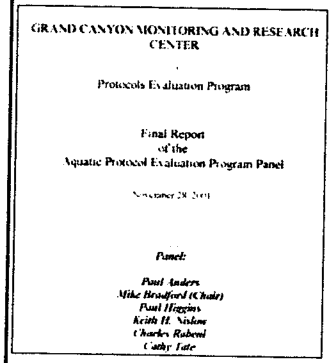
Units:

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

← Energy is more or less equivalent to organic matter

Scientific reviews of the food base program emphasize:

1) Ecosystem approach
2) Primary and secondary production
3) Trophic linkages including fish



GRAND CANYON MONITORING AND RESEARCH CENTER

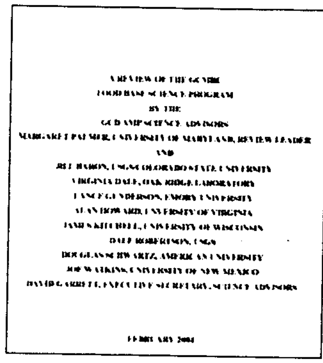
Protocols Evaluation Program

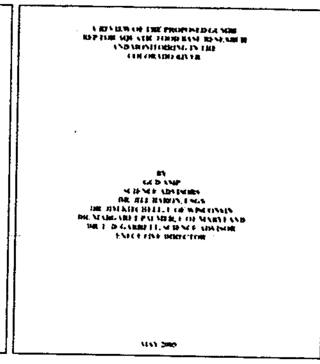
Final Report
of the
Aquatic Protocol Evaluation Program Panel

November 28, 2001

Panel:

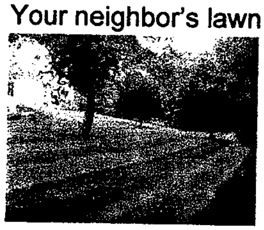
Paul Anders
Mike Bradford (Chair)
Paul Higgins
Keith H. Nislow
Charles Rabeni
Cathy Tate





Why is measuring production, and not just biomass, important?

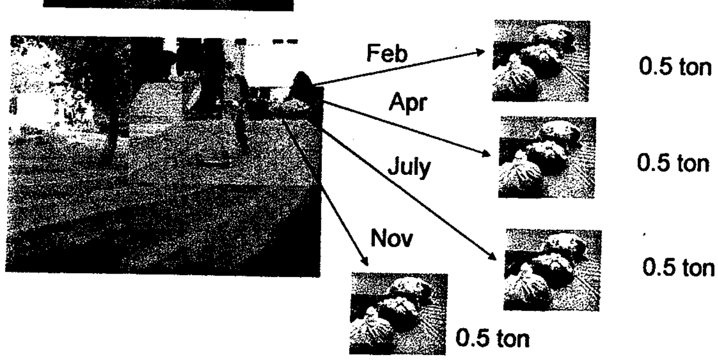
Your neighbor's lawn



January – 1 ton
March – 1 ton
June – 1 ton
September – 1 ton
December – 1 ton

Your Answer

1 ton



3 tons

Objectives:

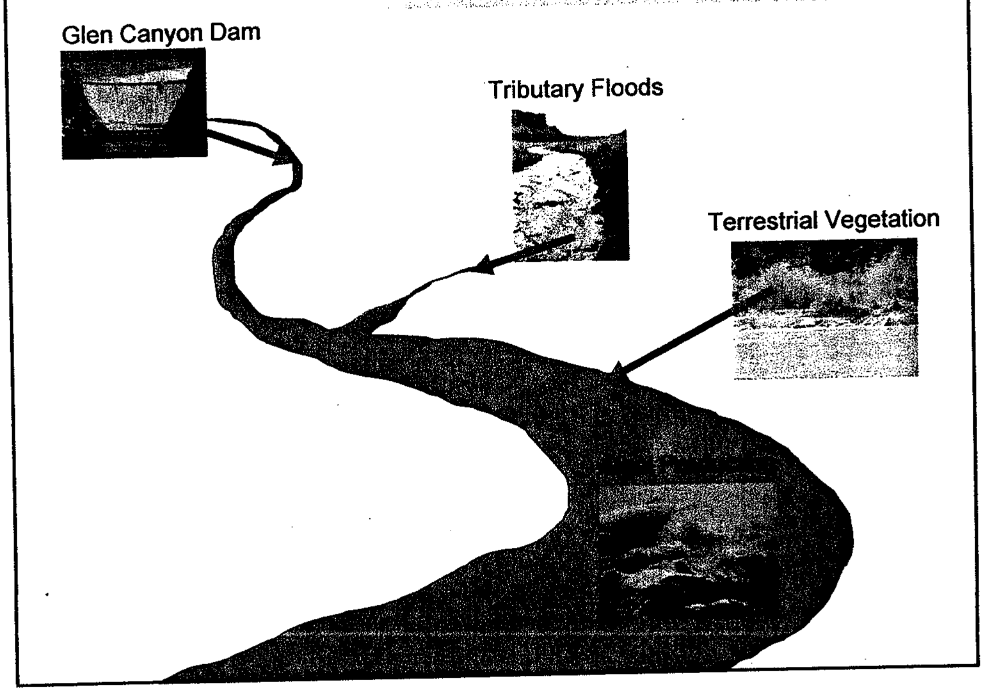
1. Measure inputs, stocks, outputs, and transport of primary production and terrestrial inputs in the Colorado River.

2. Measure secondary production of components of food web.

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

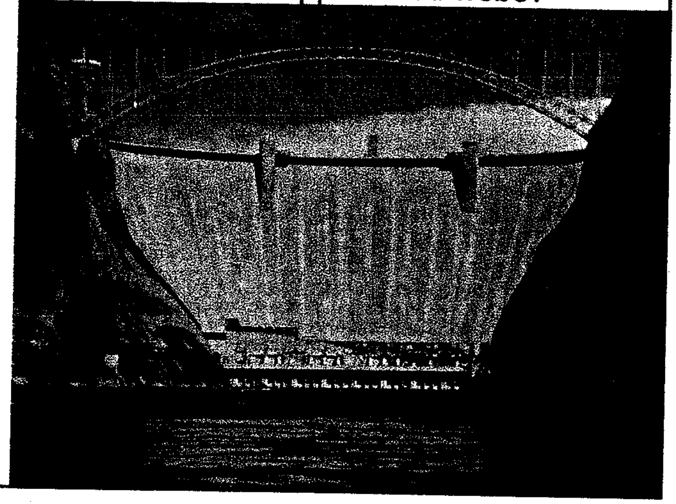
4. Quantify organic matter flow in the Colorado River food web from basal resources to fishes.

Dominant inputs of organic matter

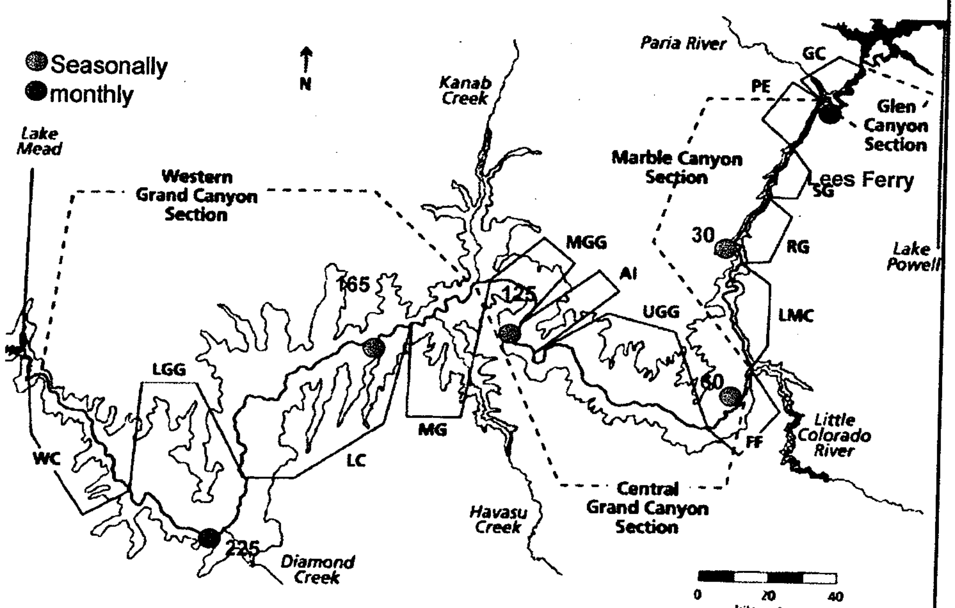


Glen Canyon dam disconnected Colorado River from upstream organic carbon and sediment

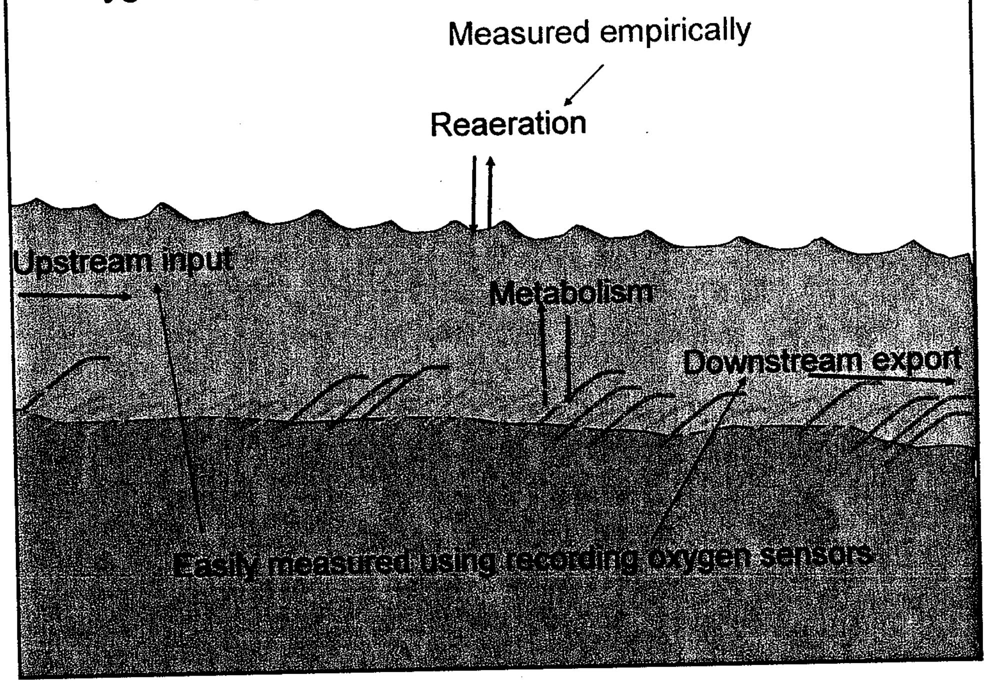
-clearer water
-much less organic matter transport
-a larger role for primary production to support food webs?
-a reduced role of allochthonous inputs?

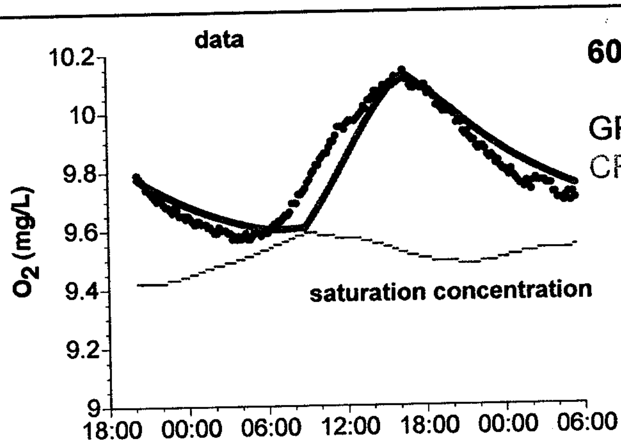


Sampling regime



An oxygen budget for a stream reach





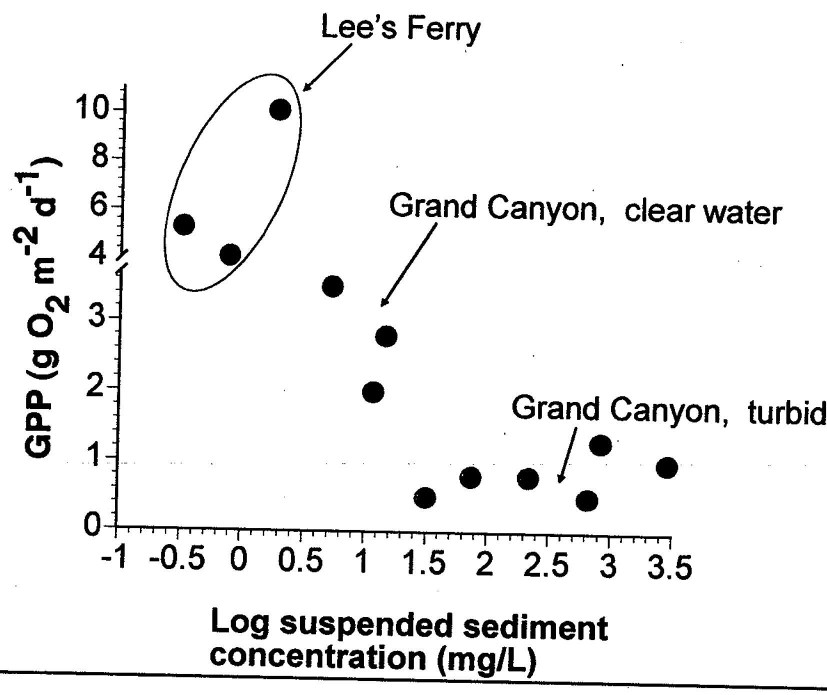
60 mile, June 2006

GPP = 2.7 g $O_2 m^{-2} d^{-1}$

CR = -0.4g $O_2 m^{-2} d^{-1}$

$$C_t = C_o + \frac{GPP}{z_t} \times \frac{PAR_t}{\Sigma PAR} + \frac{CR\Delta t}{z_t} + K(C_s - C_0)\Delta t$$

(Van de Bogert et al. unpublished)

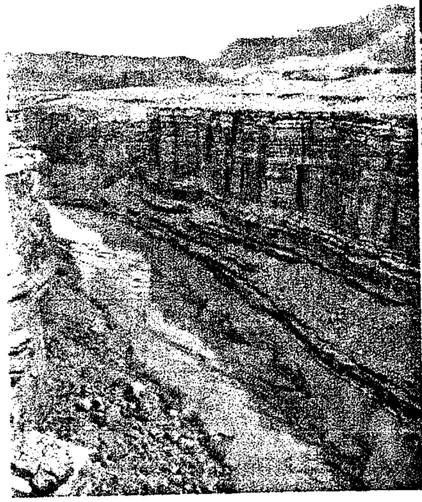


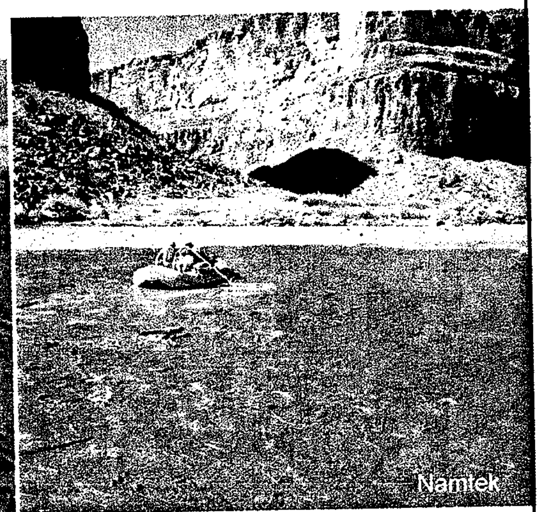
The rest of the inputs

Output from Lake Powell and Lees Ferry

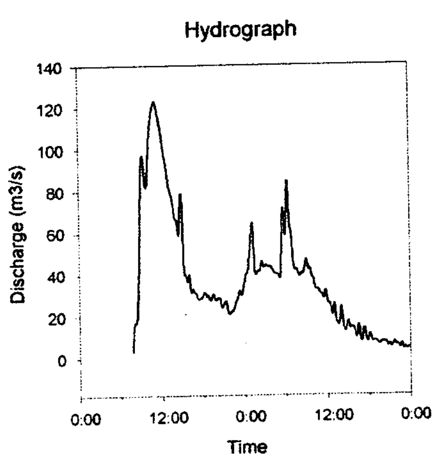
Type	~Average Concentrations (g/m^3)	Discharge (m^3/yr)	Export (metric tons/yr)
Coarse POM	0.04	10Billion	400
Fine POM	0.4	10Billion	4000
Dissolved OM	4	10Billion	40,000

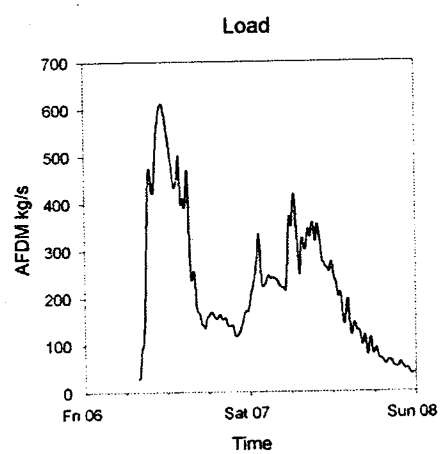
Tributary inputs are pulsed and huge





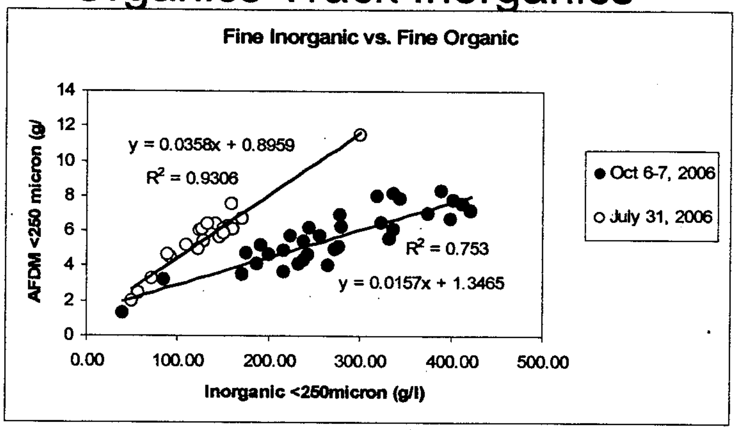
Paria River October 6-7, 2006





POM Concentrations were 3-9g/L
Total POM Inputs = ~33,000 metric tons

Organics Track Inorganics



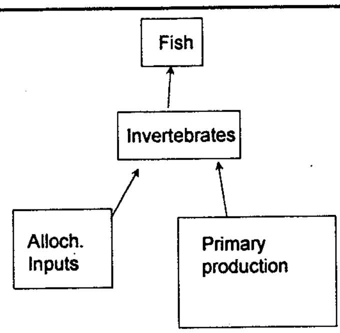
Annual tributary sediment inputs may be as high as 17M metric tons (Wright, personal communication)

Therefore organic inputs may be ca. 400,000 metric tons!

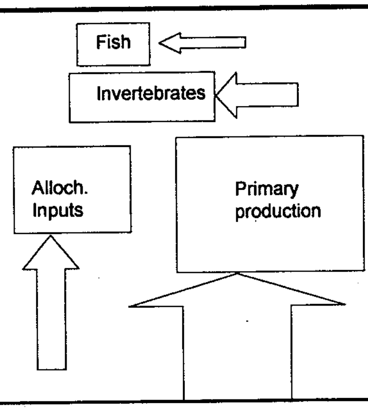
Organic Matter Inputs to Downstream Ecosystem

Source	Annual Inputs (organic matter metric tons)	Annual Inputs (organic matter g/m²)
Lake Powell & Tailwater POM / DOM	4,400 / 40,000	128 / 1167
Litter Inputs from Riparian Zone	500	14
Algal Production Downstream	2000-5000	60-150
Tributary Allochthonous Inputs	400,000	13,000

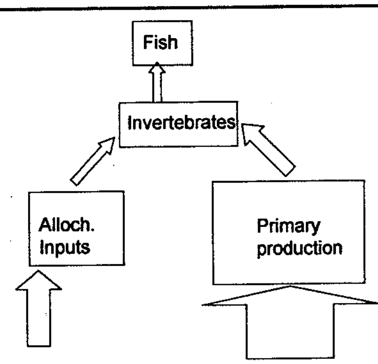
But low primary production relative to trib inputs does not mean low importance to food webs!



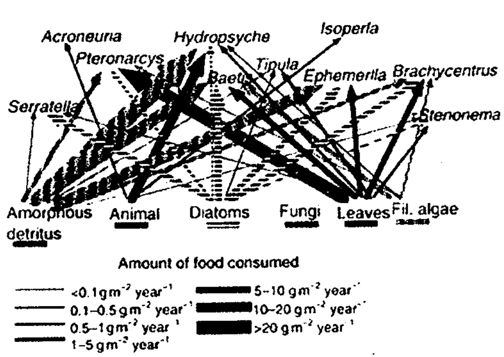
Linkage-based web. Diet or isotopes to estimate food sources



Primary and secondary production. Calculate flows of energy through a population of animals or through the primary producers.



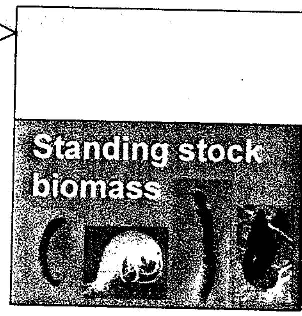
Trophic basis of production methods. Combines the two approaches to describe flow between components of the food web.



A example of the high-resolution food web that can be estimated using this method. From Rosi-Marshall and Wallace (2002).

Objective 2. Measure secondary production of components of food web

Inputs= accumulation of biomass
Secondary production



Outputs= death, predation, etc.

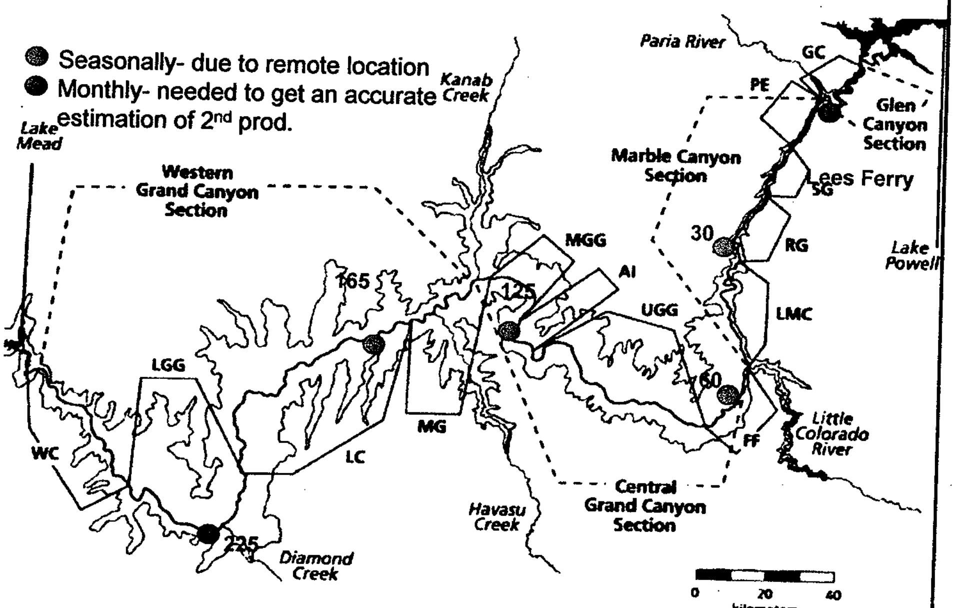
Secondary production is a rate, usually expressed in g/m^2/yr

Typically measured using monthly samples of biomass in combination with growth.

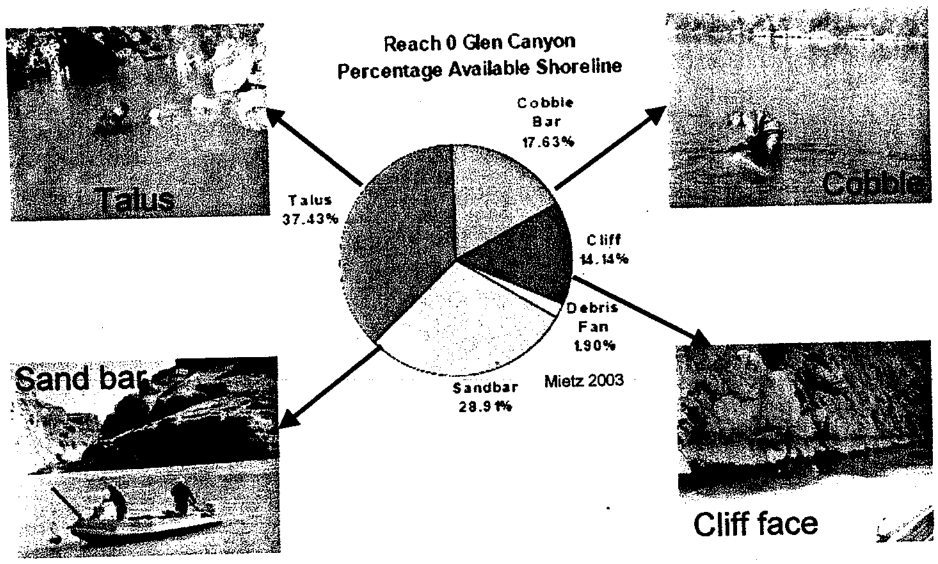
Remote location has required a bit of sampling creativity.

Sampling regime

- Seasonally- due to remote location
- Monthly- needed to get an accurate estimation of 2[nd] prod.



Sampling dominant habitat types



Secondary production calculations

Units= g m^{-2} yr^{-1}

*Secondary production is essentially= Biomass * Growth rate*

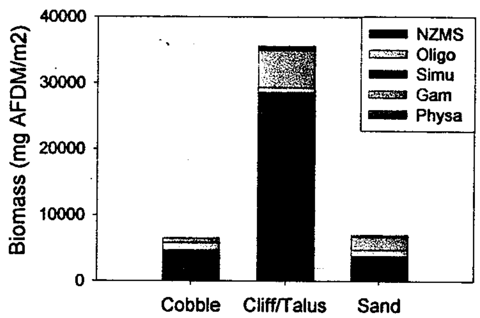
Gammarus: Size frequency methods

Black flies, NZMS, midges: Instantaneous growth methods. Empirically measure growth rates, multiply by biomass.

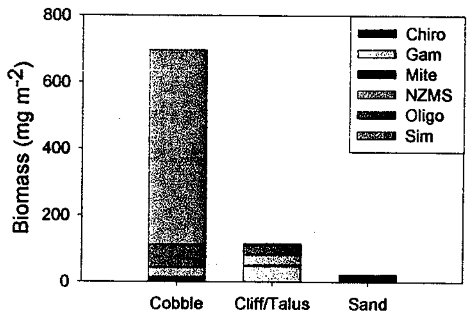
Fishes: Bioenergetics models using measured biomass-back-calculating fish production for previous years in collaboration with AZ Game and Fish.

Invertebrate Biomass:
example of across habitat variability

Lees Ferry

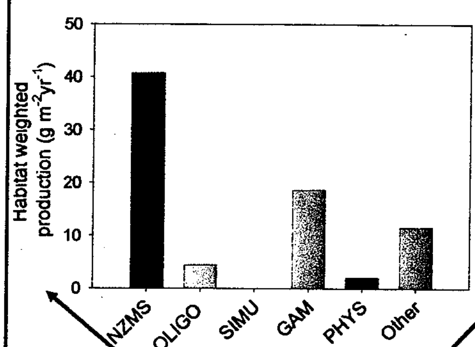


RM 225



Secondary Production:
example of variability in food resource availability among sites

Lees Ferry



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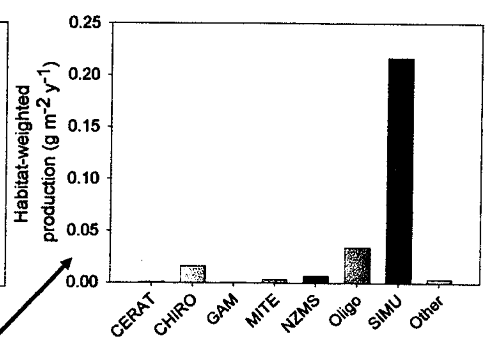
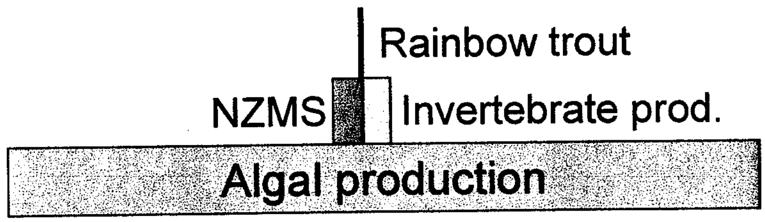


Note difference in scale

Energetic food pyramid:
example from Lees Ferry

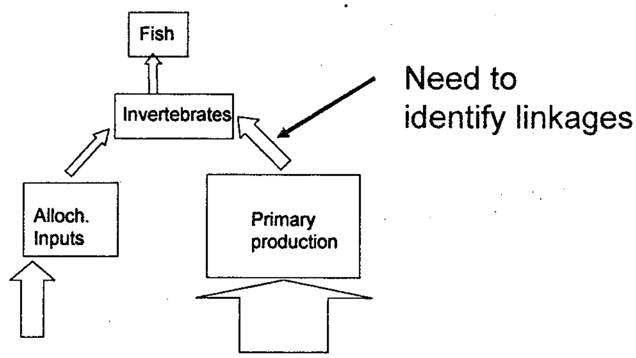


Food demand relative to availability:
Example prey demands of rainbow trout at Lees Ferry

- To support the production of RBT at LF, they need to consume ~ 2 g m^{-2} yr^{-1} of prey.
- Non-NZMS invert. production is ~32 g m^{-2} yr^{-1}
- We will make similar calculations for all components of food webs at all 6 sites
- At LF, the "grocery store is full" but what can/do consumers actually eat?

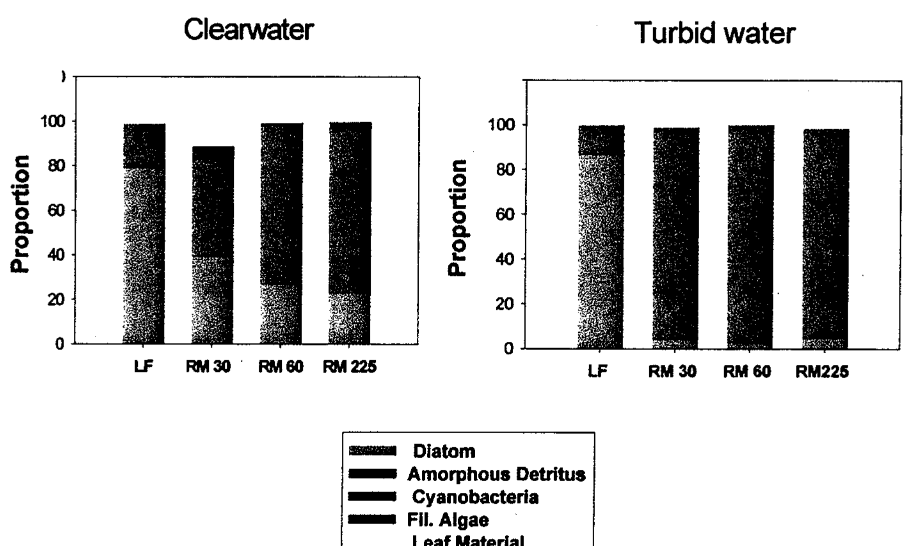
Objective 3. Identify food web to estimate what resources support higher trophic levels.

- Combination of gut contents and stable isotopes to reconstruct food webs at all 6 sites.



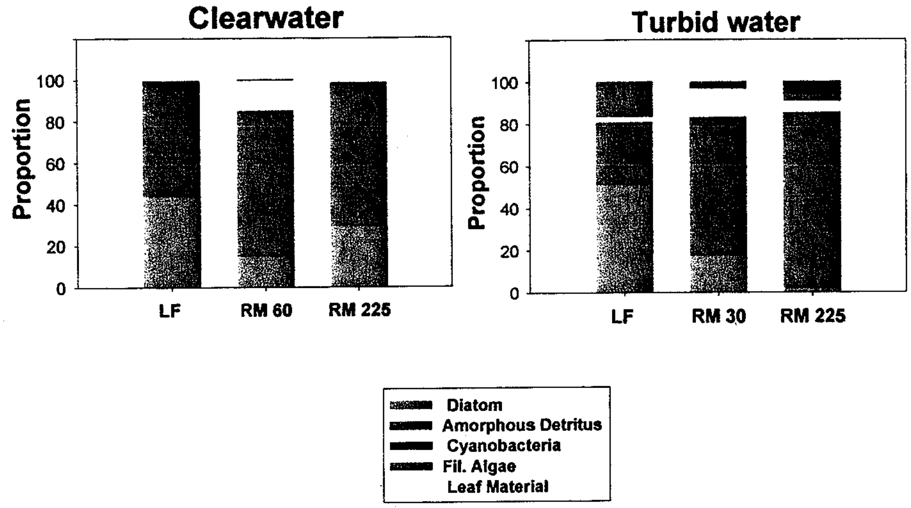
Diet composition using gut content analysis:

example black flies

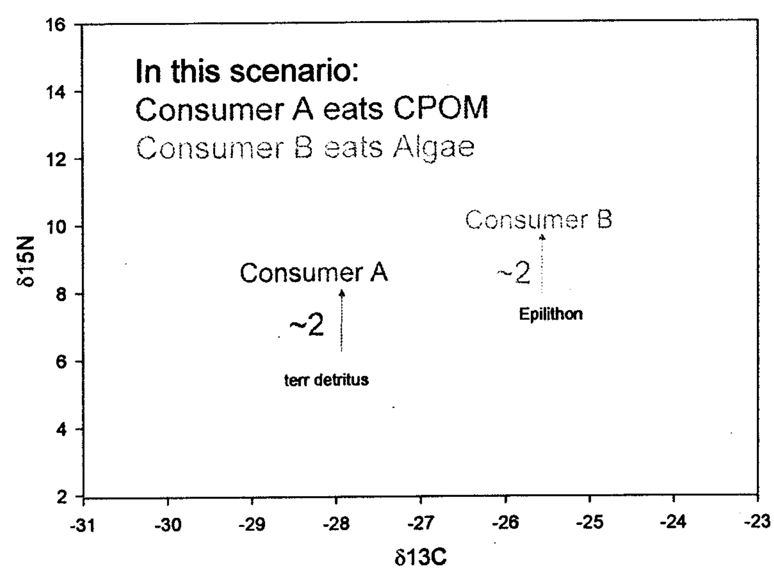


Diet composition using gut content analysis:

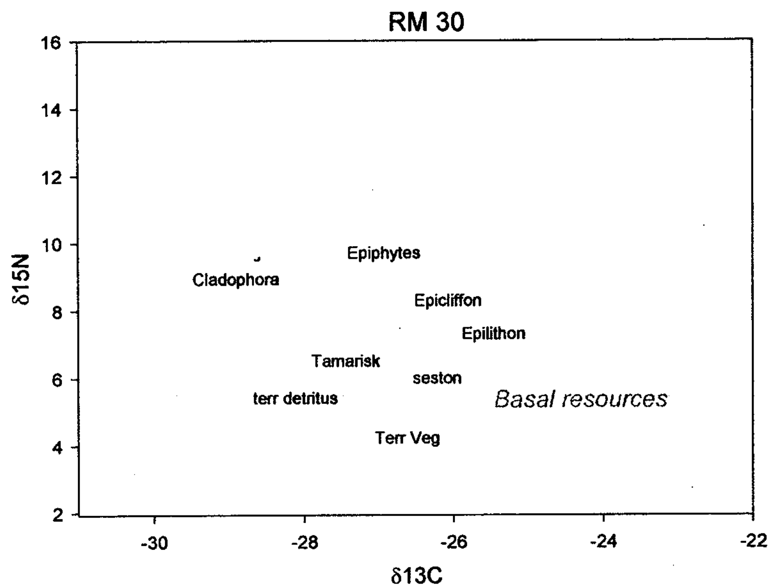
example *Gammarus*



Food web reconstruction using stable isotopes

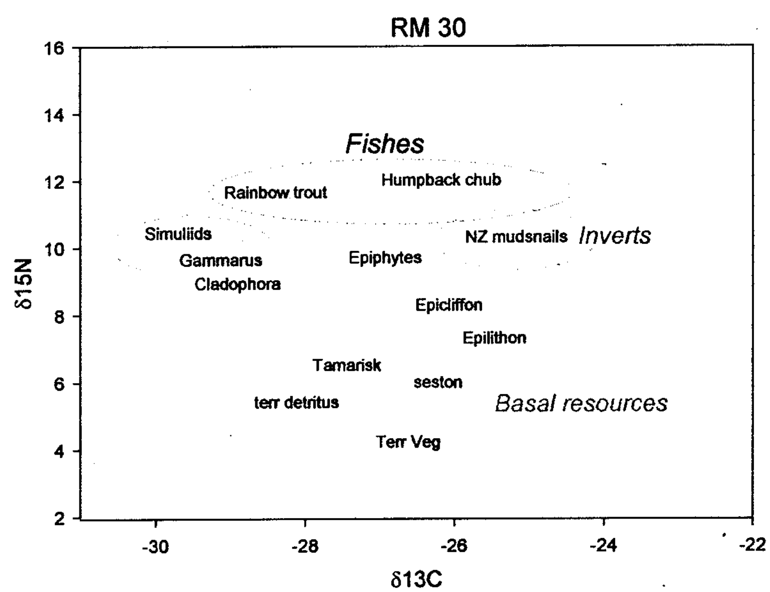


Food web reconstruction using stable isotopes



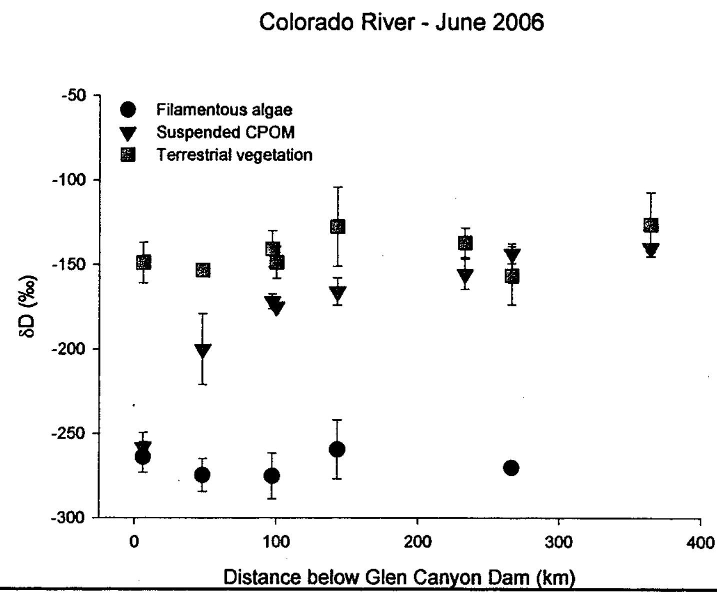
Note:
LCR
Algae
-10

Food web reconstruction using stable isotopes

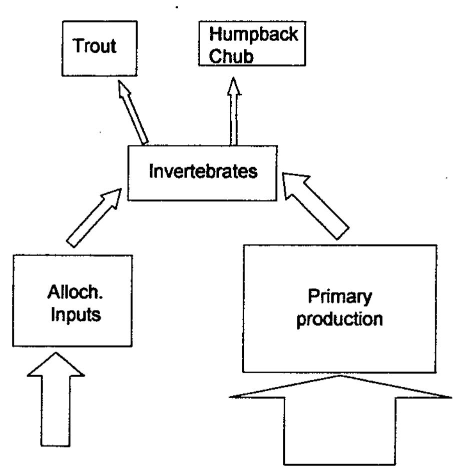


Note:
LCR
Algae
-10

Promising new isotope for further discrimination of food webs



Keeping our eyes on the prize: energetic food webs



- "Real" food webs:
  - much more complicated than illustrated here
  - For example, highly site and season specific
  - Realistic food webs are essential to understand what is supporting higher trophic levels!

Utility of Approach

We predict that

- Changes in water temperature
- Mechanical removal of trout
- Reduction of primary production from suspended sediment

Will alter energy flow in the food webs of the river and this method can detect these changes.

Conclusion

- Ecosystem-level responses can be used to *monitor* to the responses of the system to riverine management
- Ecosystem-level responses are essential for making accurate predictions of how physical and biological changes affect native fishes.