Springs and Nutrients

Are There Effects at the Ecosystem Level?

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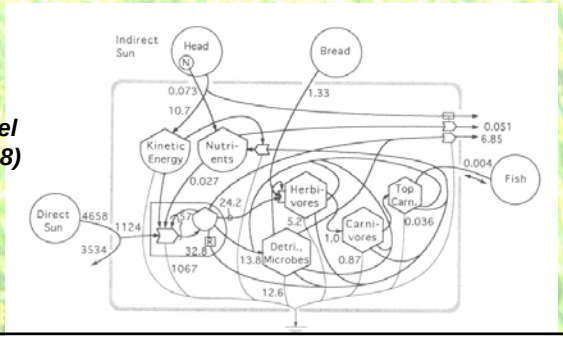
Ecosystem-Level Effects – Chapter Outline

- Chapter 1 - Springs as Ecosystems
  - Springs Ecosystem Model
  - Environmental Forcing Functions
  - Energy Storages/Structure
  - Ecosystem-Level Processes
  - Human and Aesthetic Uses
- Chapter 6 - Effects of Nutrients on Spring Ecosystems
  - Primary Producers
  - Community Metabolism
  - Community Structure
  - Human and Aesthetic Effects
  - Additional Research Needs and Questions

Springs as Ecosystems

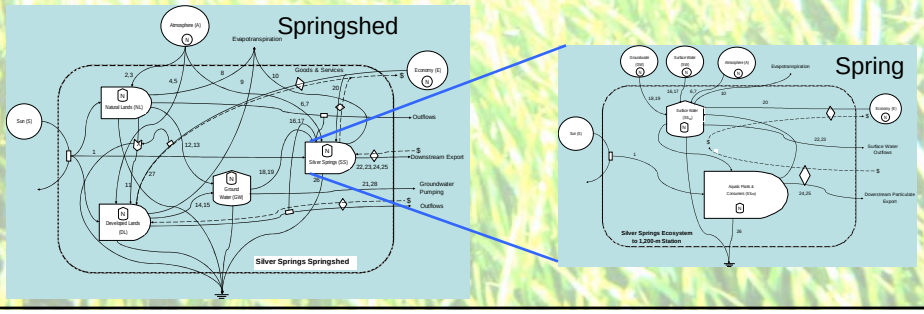
- Springs and spring runs represent a unique class of aquatic ecosystems with distinct structures and processes.
- Due to their complexity, a holistic approach to spring studies is necessary to understand anthropogenic effects on these ecosystems.

Silver Springs Ecosystem Model (Odum et al. 1998)



Springshed-Spring Linkages

- Development of a ***management strategy*** for springs will be dependent upon a better understanding of the relative importance and synergism of direct stressors at the local level and indirect stresses that occur at the regional scale.



The Study of Springs

Why study springs at the ecosystem level?

- Most springs' studies:
  - examined one or a few components of the ecosystem, such as aquatic plants, invertebrates, or water chemistry
  - components are measured as amounts rather than rates, for example, aquatic plant biomass vs. aquatic plant productivity
  - focused on the factors that are different between springs rather than on their underlying similarities.

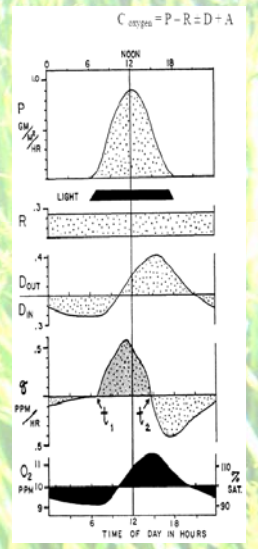
The Study of Springs

Why study ecosystem metabolism?

- Ecosystem metabolism is measured by techniques that record the activity of the entire ecosystem through its effects upon dissolved oxygen concentrations.
- Ecosystem metabolism is inclusive of all living organisms that transform carbon through the biological processes of primary productivity and respiratory metabolism.
- Allows quantification and comparison of multiple forcing functions, the trophic level structure, ecosystem-level processes, and provides a more holistic view of springs.
- Fortunately, there are some historical measures of spring ecosystem metabolism for comparison to current conditions.

Upstream-Downstream Ecosystem Metabolism Method

- Ecosystem-level metrics have promise for providing a better understanding of the properties that many springs have in common.
- Specifically, the upstream-downstream oxygen change method for ecosystem metabolism measurement pioneered in these aquatic systems should be a standard method to accompany all new springs' biological studies.

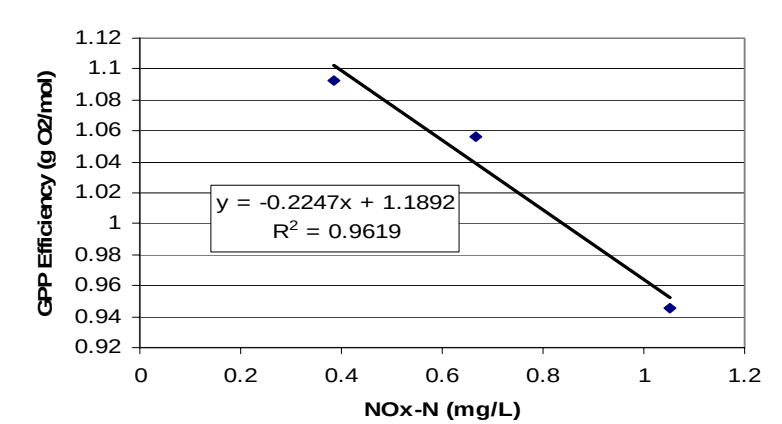


Effects of Nutrients on Spring Ecosystems

- There are consistent inverse correlations between rising nutrient concentrations (for both ***nitrogen and phosphorus***) and declining ecosystem primary production and photosynthetic efficiency.

Silver Springs: A 50-Year Retrospective Study (Munch et al. 2006)

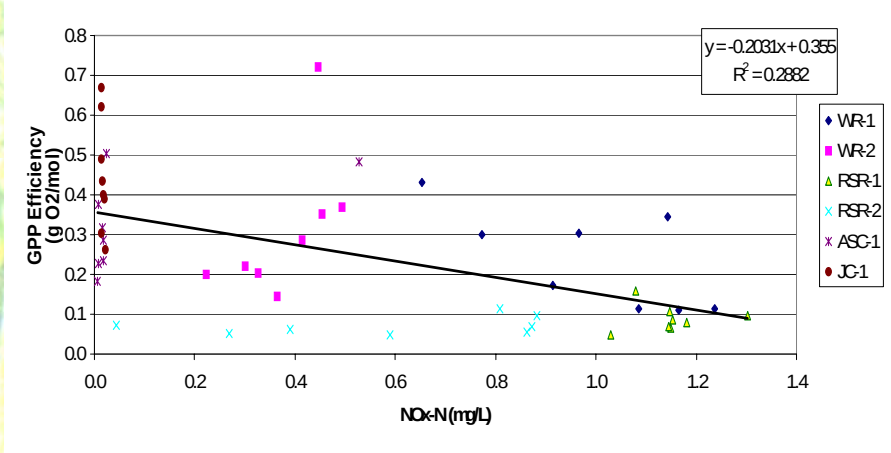
Ecological Efficiency vs. Nitrate-N



* Phosphorus concentrations are relatively stable at this spring

Wekiva River and Rock Springs Run PLRG Analysis (Mattson et al. 2006)

Corroborative Ecosystem-Level Findings (Wekiva, Rock, Alexander, Juniper Springs)

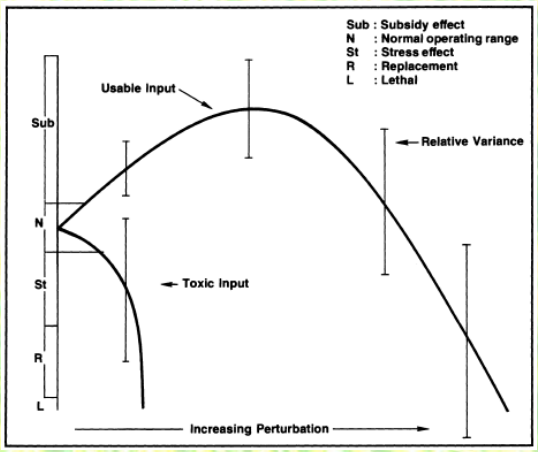


* A similar correlation between TP and GPP Efficiency was also observed.

Effects of Nutrients on Spring Ecosystems

- While this possible cause and effect relationship appears counter-intuitive, it may be explained based on the ***subsidy-stress hypothesis***.

Subsidy-Stress Hypothesis



Hypothetical example of two types of inputs and their resulting ecosystem perturbations due to increasing input levels. Nutrients and nitrate in particular could be viewed as an example of a usable input (top curve), which have a subsidy effect on ecosystem productivity to a point, beyond which stress is incurred (Figure from E. P. Odum et al. 1979).

Effects of Nutrients on Spring Ecosystems

- Subsidy-Stress Hypothesis
  - Low nitrate levels may be optimal for ***ecosystem*** productivity while higher levels may have the opposite effect of reducing ***overall*** production.
  - In their natural, low nutrient state, springs may be adapted for optimal efficiency of light utilization and maximum ecosystem metabolism.
  - Rising nutrient levels may result in the competitive advantage of "weedy" plant species that can capture light and spatial resources through higher rates of net productivity but lower gross productivity.

Effects of Nutrients on Spring Ecosystems

- Elevated nutrient levels in concert with changes in other control mechanisms (such as recreation, flow rates, or grazing) may be linked to the observed plant community shifts, from adapted submerged aquatic plants with sparse but productive periphyton communities to systems dominated by benthic and attached filamentous algae.

Effects of Multiple Stressors on Spring Ecosystems

- Other possible stresses affecting primary producers in springs include:
  - decreased dissolved oxygen in groundwater inflows
  - altered grazer populations and introduction of exotic species
  - reductions in flow volume
  - recreational disturbance
  - increased stormwater runoff
  - dams and other water management activities
  - aquatic plant management
  - invasion by exotic plant and animal species
- The diversity of anthropogenic stressors illustrates the importance of an ecosystem-function level examination of springs.

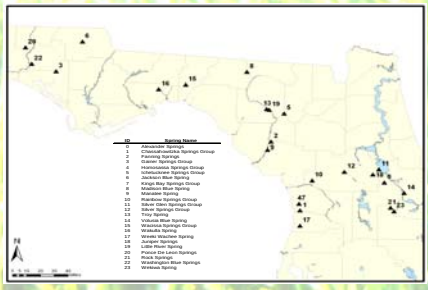
Recommendations for the Quantification of Nutrient Effects on Spring Ecosystems

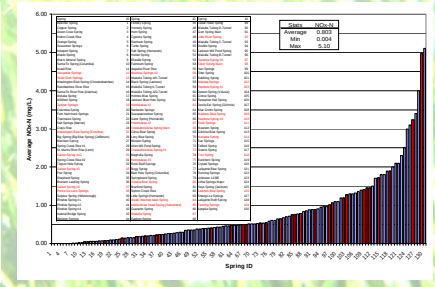
- The manner in which spring ecosystems can be monitored for impacts resulting from nitrate or other nutrient pollutants as well as other stressors are presented as well as remaining research needs.
- Three recommended approaches for springs' ecosystem nutrient-effects research:
  - Synoptic studies of multiple springs to provide a better baseline for inter-spring comparisons
  - Intra-spring comparisons
  - *In situ* mesocosm studies
  - Whole spring manipulation studies

Springs Research Recommendations

Synoptic Inter- and Intra-Spring Study

- State-wide spring ecosystem metabolism baseline study over a wide range of nutrient conditions, flows, and conditions.





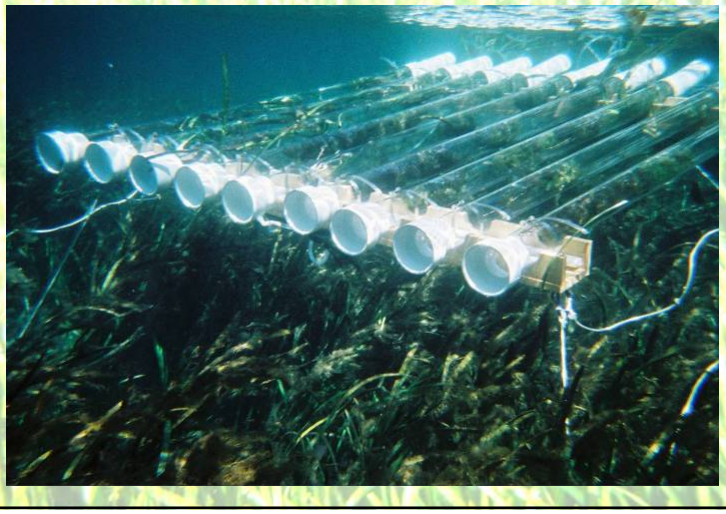
Springs Research Recommendations

Synoptic Inter-Spring Study

- Comparisons of Control and Affected Springs:
  - Define the range of normal and altered ecosystem metabolism in springs over a wide range of nutrient conditions, including upstream/downstream studies along nutrient gradients
  - Implement controlled treatments in downstream reaches for comparison to upstream “control” reaches
  - Define the trophic-level biomass pyramids and energy flows in these reference spring systems

Springs Research Recommendations

In Situ Flow-Through Mesocosm Studies



Springs Research Recommendations

In Situ Flow-Through Mesocosm Studies

- Controlled Ecosystem-Level Studies:
  - Mesocosm studies *in situ* to determine the effects of nutrient levels on key primary producers and effects of consumers on various natural and "weedy" benthic and periphytic algal assemblages
  - Nutrient addition studies
  - Single species macrophyte and macroalgae productivity studies
  - Consumer manipulation studies

Springs Research Recommendations

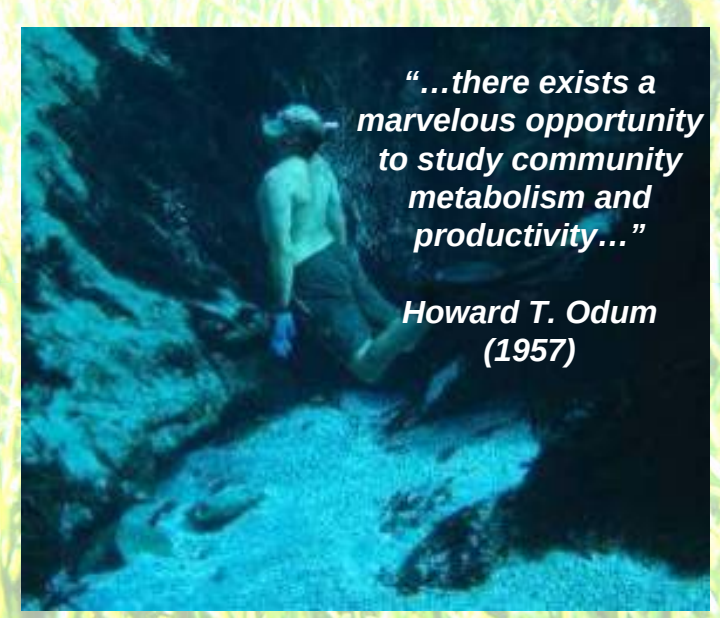
Whole-Spring Manipulation Studies

- Before-and-after recreation reduction/elimination studies
- Exotic plant management studies
- Consumer control studies

Summary Effects of Nutrients on Spring Ecosystems

- Evidence that the nutrients nitrogen and phosphorus can have negative impacts on springs (reduced ecosystem metabolism, increased coverage/abundance of filamentous algae and periphyton).
- Nutrients are not the entire story, declines in springs appearance are also linked to recreation impacts, the management of exotic plants and animals, and reductions in spring discharge.
- Springs ecology studies can be improved by measuring whole ecosystem metabolism.

Florida's Springs



"…there exists a marvelous opportunity to study community metabolism and productivity…"

Howard T. Odum (1957)