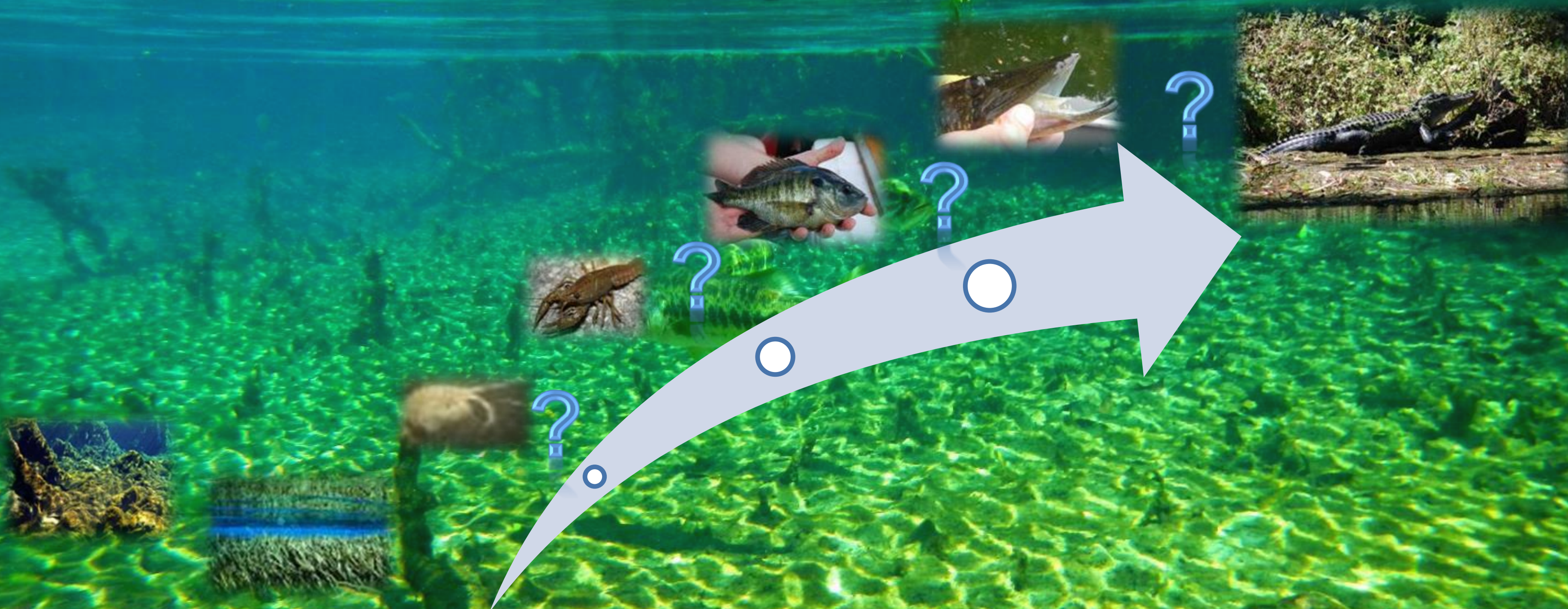
From algae to alligators: Examining food web structure in Florida's spring ecosystems



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CRISPS Work Group 5: Trophic Interactions

Overview

1. Research Questions
2. Methods
3. Results
4. Conclusions
5. Preliminary Data: Grazing Trials
6. Future Directions: Exclusion Experiments

Research Questions

1. What are the major pathways of energy flow and material transport in Florida spring ecosystems?

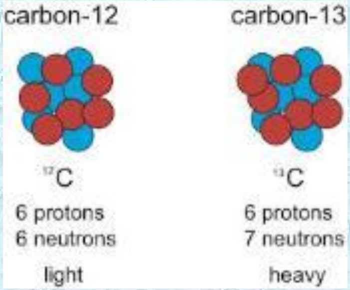
2. Which grazers consume benthic filamentous algae (a.k.a, nuisance algae) and to what degree?

3. Which predators consume algal grazers?

Methods

- Stable Isotope Analysis-SIA ($\delta^{13}C$ & $\delta^{15}N$)
  - **Integrated** signal of consumers' dietary choices
  - Isotopic mixing models provide estimates of the **proportional dietary contributions** from discrete resource pools
- Stomach/Scat Content Analysis-SCA
  - **'snap-shot'** of diet in time
  - Confirm predator-prey links: **Who's eating who?**
  - Inform isotopic models: **'prior information'**

Stable Isotope Analysis-SIA



Ratio of heavy to light isotopes (^{13}C:^{12}C, ^{15}N:^{14}N)

δX (‰) = [$\mathbf{R}_{sample}$/$\mathbf{R}_{standard}$ -1]×1000, where X is element of interest

You are what you eat (± trophic enrichment, $\Delta X_{tissue\text{-}diet}$)

$\delta^{13}C$ has small trophic enrichment $\Delta\,^{13}C_{tissue\text{-}diet}$ ≈ 1.0‰ ± 0.5

-Differs among plants with different photosynthetic pathways (i.e., C3, C4, CAM, etc.)

-Varies in aquatic producers due to **$\delta^{13}C$ of dissolved inorganic carbon-DIC sources , $\delta^{13}C$-CO_2aq** and **$\delta^{13}C$-HCO_3^- ,** as well as relative concentrations of **[CO_2aq],** and **[HCO_3^-].**

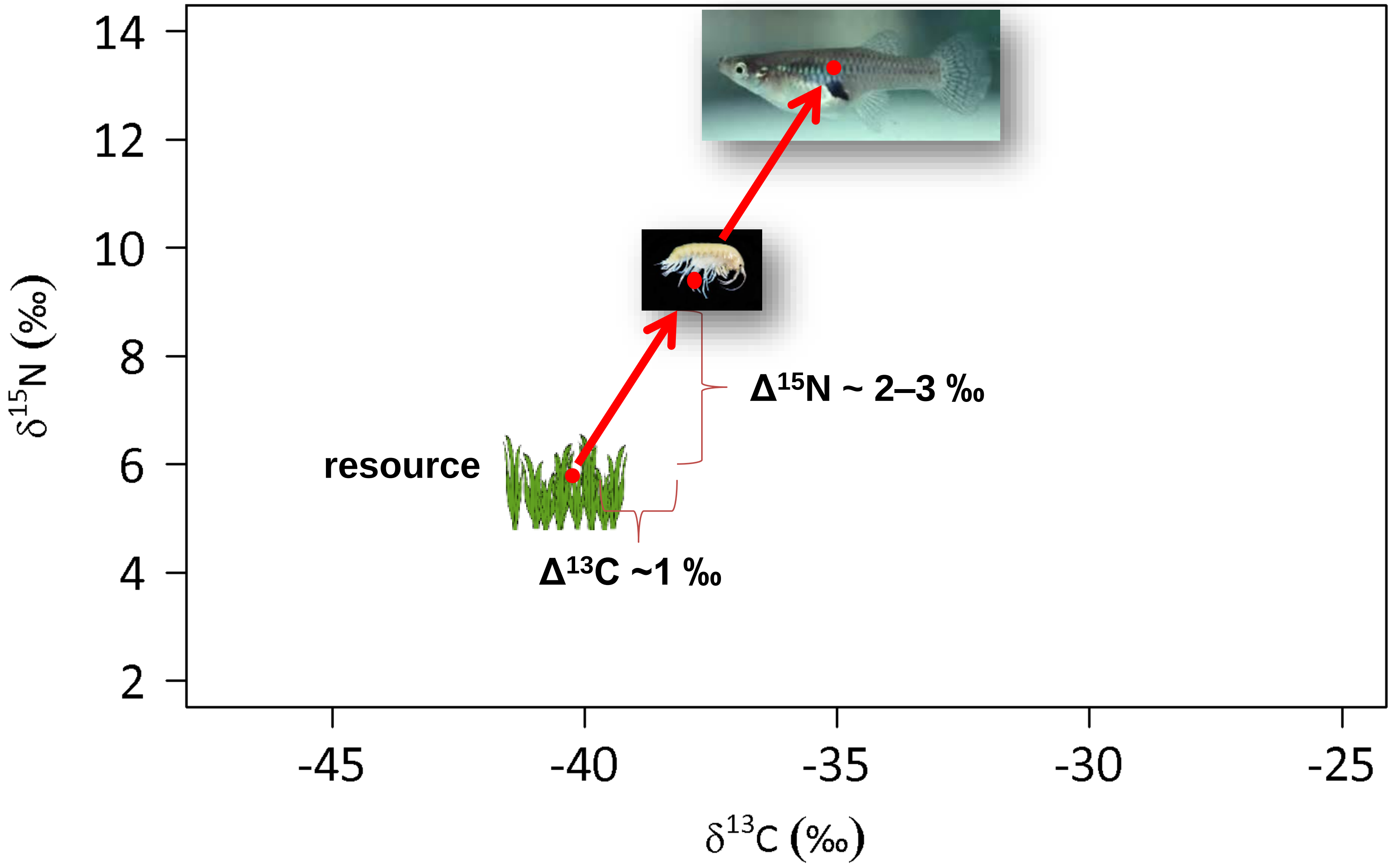
-Indicator of **carbon pools (resource categories)** used by consumers

$\delta^{15}N$ has larger trophic enrichment $\Delta\,^{15}N_{tissue\text{-}diet}$ ≈ 2.2 ‰ ± 0.7

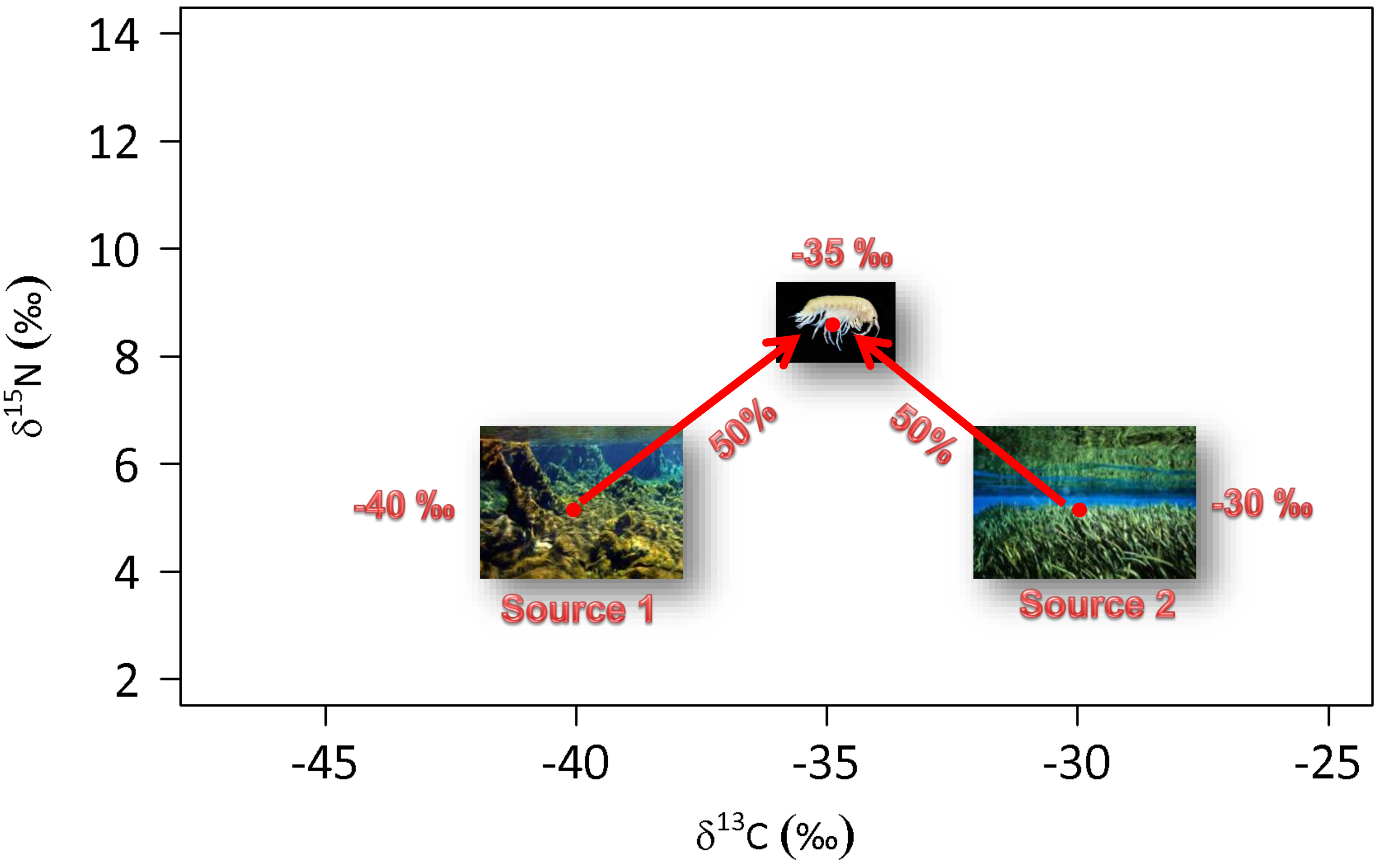
-Indicator of **nitrogen sources** and **cycling processes** at food web base

-Quantify **trophic level** of consumers

Trophic Enrichment: $\Delta X_{tissue\text{-}diet}$

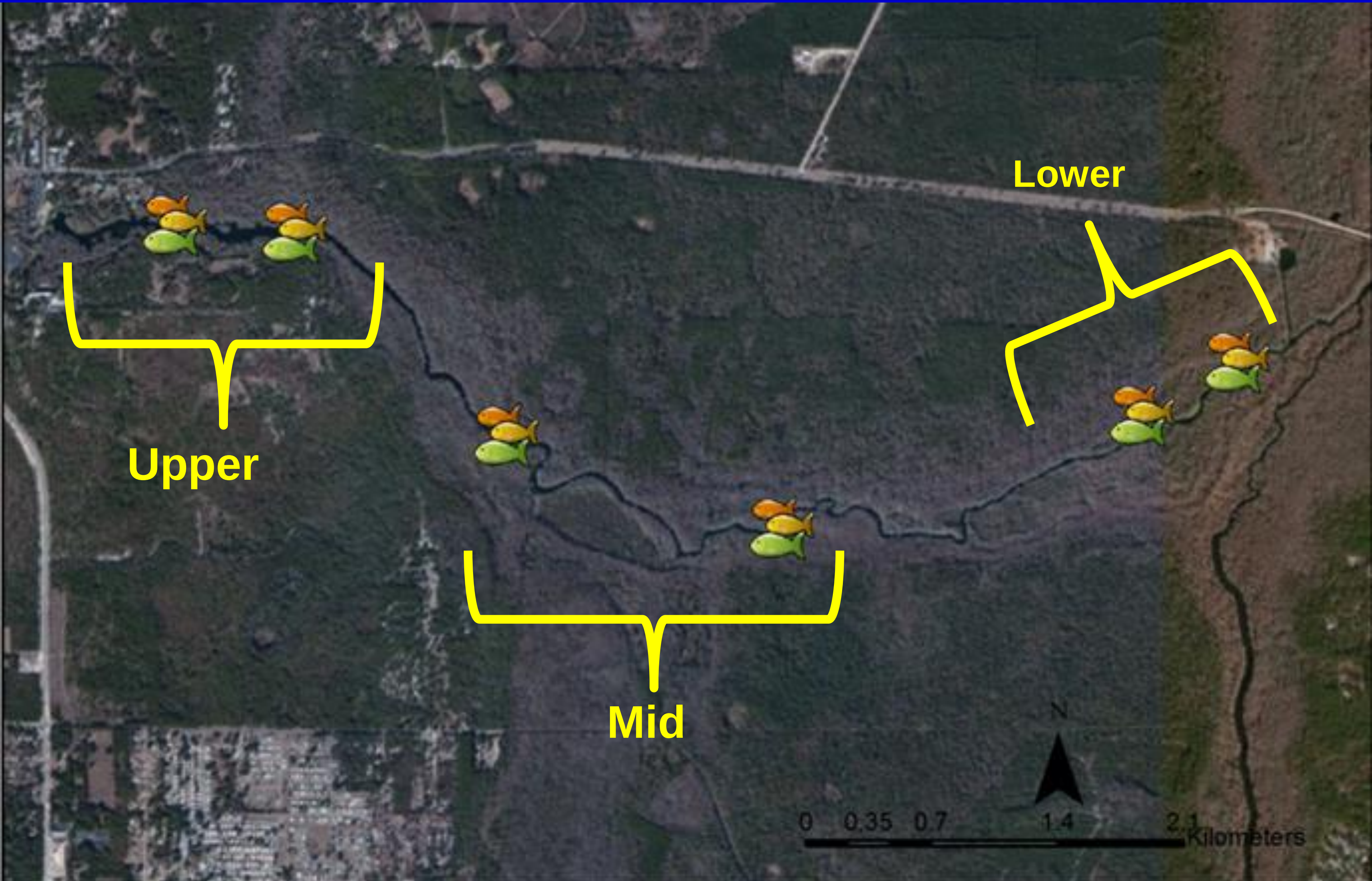


Isotopic Mixing: Multiple Sources



Silver Springs/Silver River

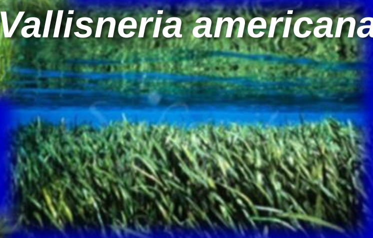
Sampling Sites

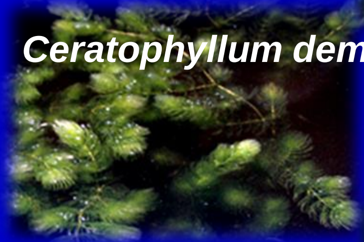


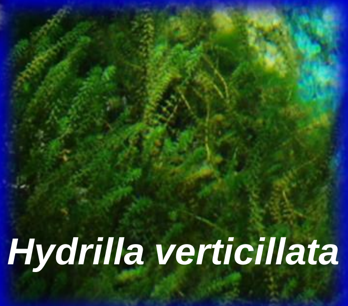
Primary Producers

Submersed Aquatic Vegetation (SAV)


Sagittaria kurziana


Vallisneria americana


Ceratophyllum demersum


Hydrilla verticillata

Macroalgae and diatoms

Benthic Filamentous Algae- a.k.a Nuisance Algae


Lyngbya


Vaucheria

Unattached Algae


Spirogyra

Epiphytic Filamentous Algae and Diatoms

Emergent and Floating Vegetation


Nuphar avenda (spatterdock)


Sagittaria lancifolia (arrowhead)


Pistia (water lettuce)


Pontedera cordata (pickerel weed)

Herbivores and Omnivores (Inverts)

Emergent Insects:

Trichoptera
(caddisfly)

Chironomidae
(midge)

Lepidoptera
(moth)

Gastropods:

Hydrobiids
(mud snail)

Physids
(silt snail)

Pleurocerids
(elimia snails)

Planorbids
(ramshorn snail)

Viviparids
(mystery snail)

Ampullariids
(apple snail)

Crustaceans:

Gammaridae
(amphipod)

Palaemonids
(grass shrimp)

Parastacids
(crayfish)

Herbivores and Omnivores (Verts)

Fish:

Pterygoplichthys disjunctivus
(vermiculated sailfin catfish)

Dorosoma cepedianum
(gizzard shad)

Mugil cephalus
(striped mullet)

Notemigonus crysoleucas
(golden shiner)

Notropis petersoni
(coastal shiner)

Pteronotropis hypselopterus
(sailfin shiner)

Erimyzon sucetta
(lake chubsucker)

Percina sp.
(darter)

Poecilia latipinna
(sailfin molly)

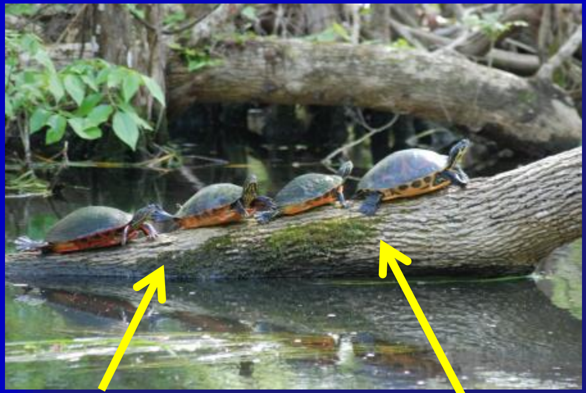
Gambusia affinis
(mosquito fish)

Heterandria formosa
(least killifish)

Menidia beryllina
(inland silverside)

Turtles:

Chelydra serpentina
(common snapping turtle)



Pseudemys nelsoni
(Florida redbelly cooter)

Pseudemys peninsularis
(peninsular cooter)

Pseudemys suwanniensis
(suwannee cooter)

Secondary Consumers

Invertebrates:

Belostomatidae, Gerridae, Nepidae
(predaceous water bugs)

Odonata larvae
(dragonfly larvae)

Pisauridae
(fishing spiders)

Fish:

Amia calva
(bowfin)

Lucania goodei
(bluefin killifish)

Ameiurus spp.
(catfish)

Micropterus salmoides
(Florida largemouth bass)

Lepomis spp.
(sunfish)

Aphredoderus sayanus
(pirate perch)

Turtles/Snakes:

Sternotherus minor
(loggerhead musk turtle)

S. Odoratus
(common musk turtle)

Agkistrodon piscivorus
(cottonmouth)

Nerodia fasciata
(banded watersnake)

N. taxispilota
(brown watersnake)

Top predators

Fish:

Micropterus salmoides
(Florida largemouth bass)

Esox niger
(chain pickerel)

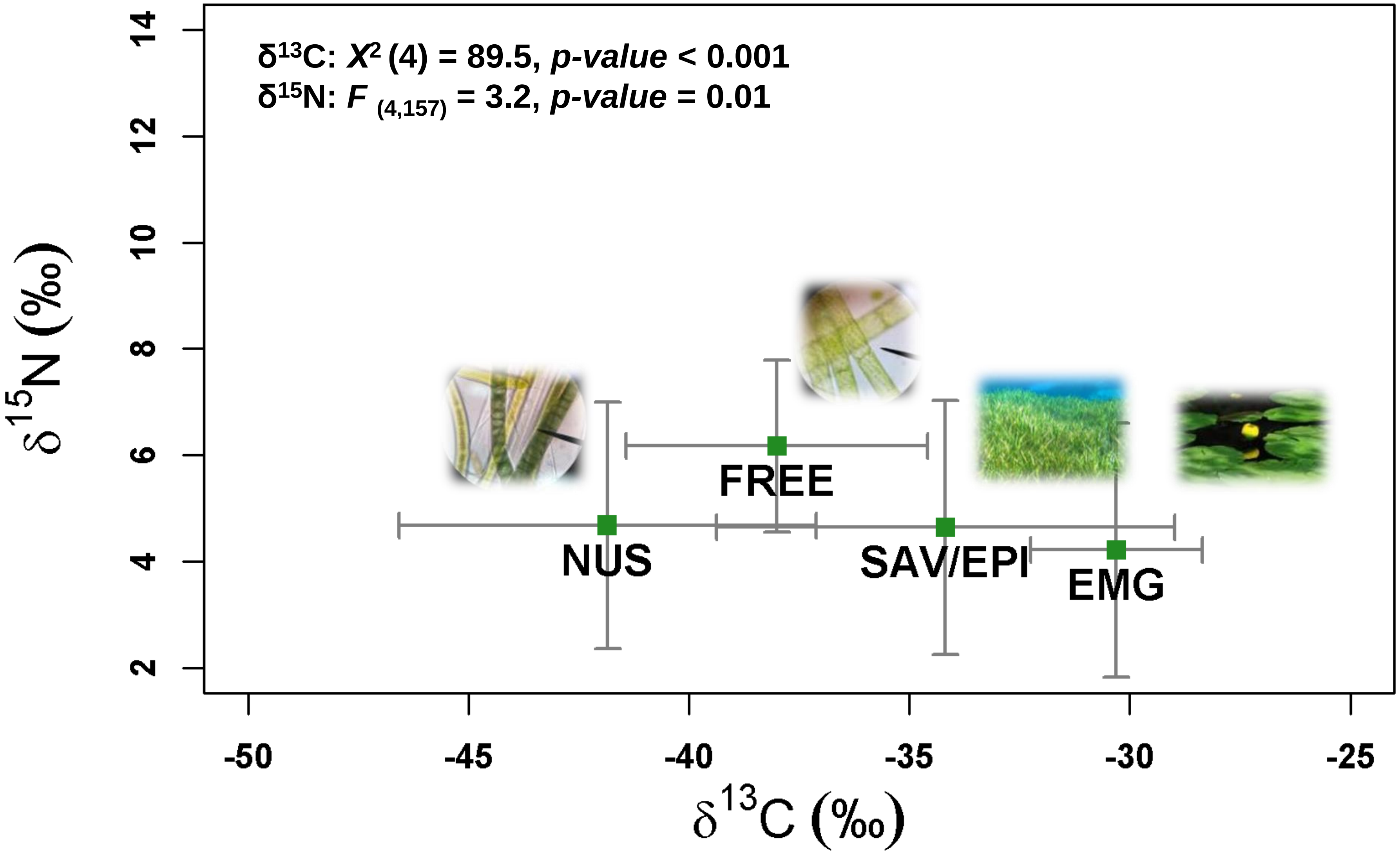
Lepisosteus platyrhincus
(Florida gar)

Lepisosteus osseus
(longnose gar)

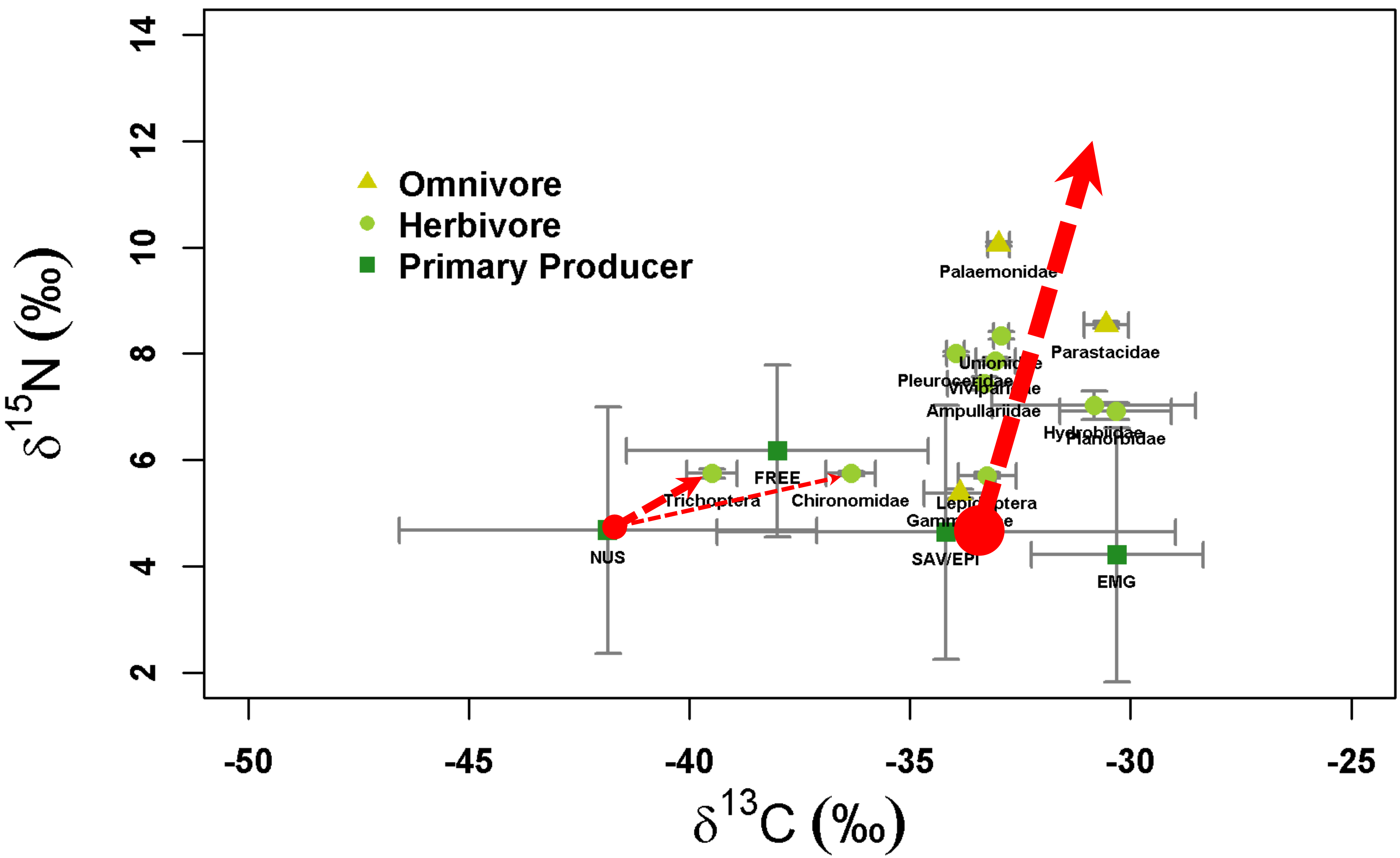
American alligator:

Q1-What are the major pathways of energy flow and material transport in Florida spring ecosystems?

Primary Producer Groups (Sources)

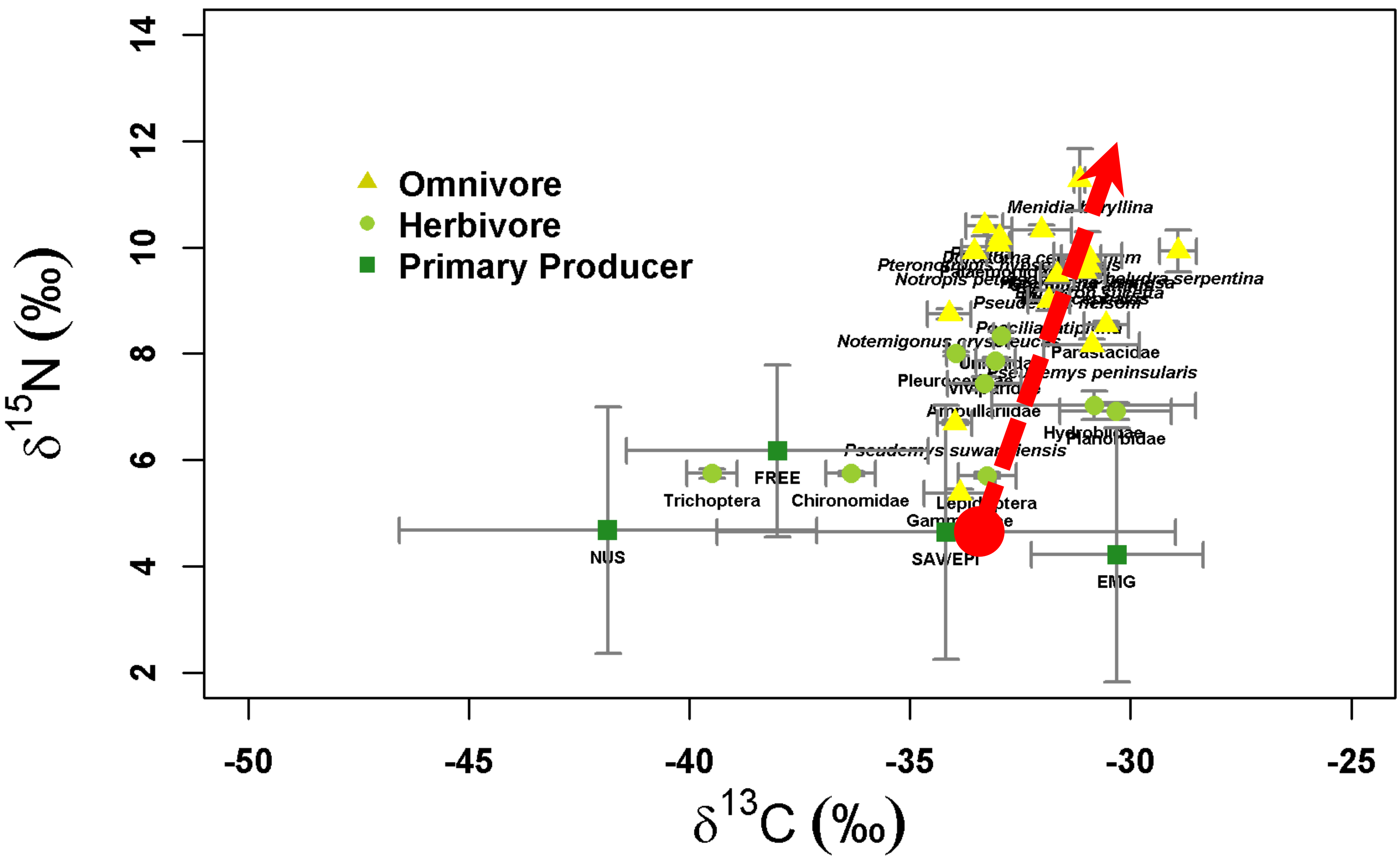


Herbivores and Omnivores (inverts)



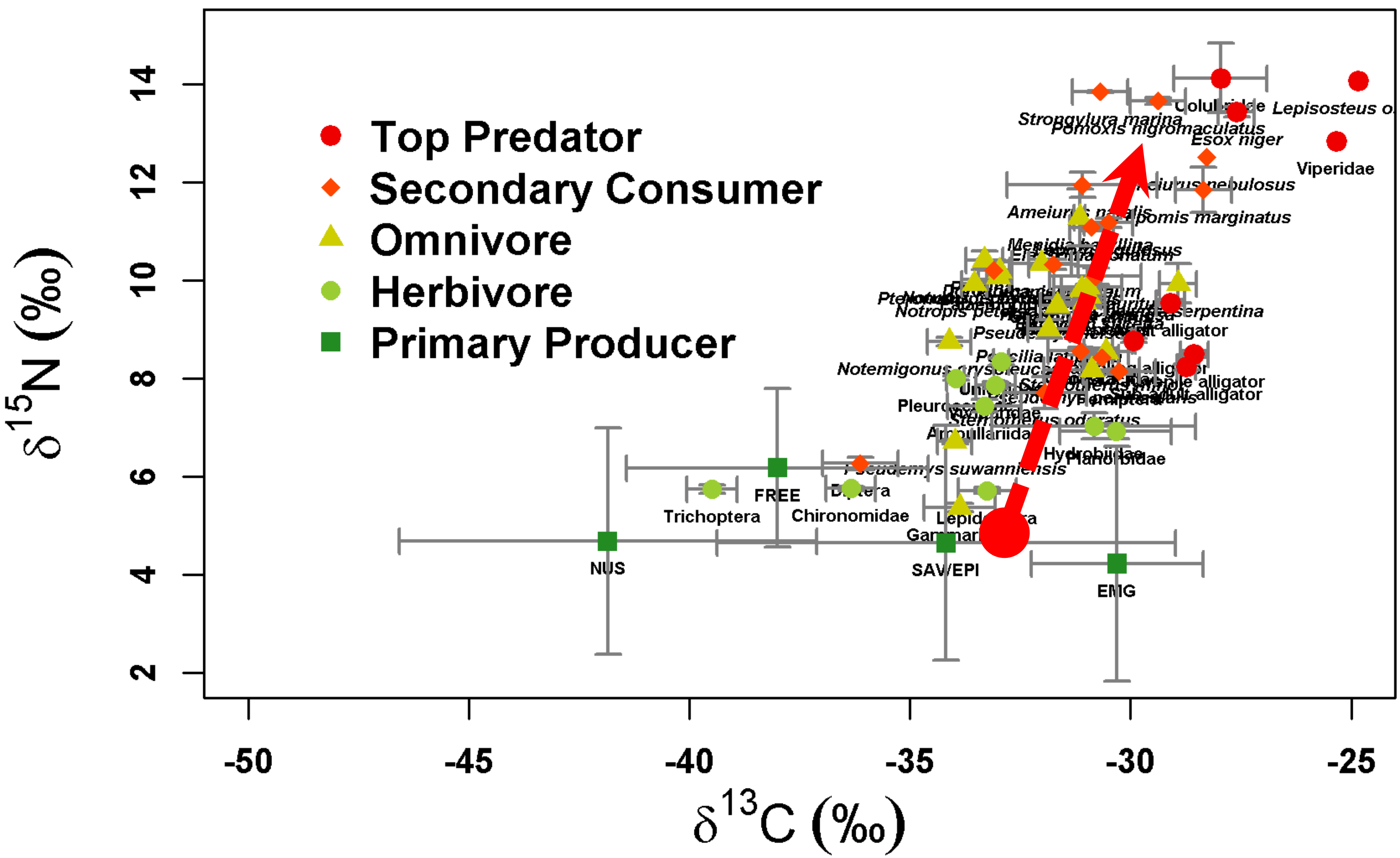
Flow of energy and material transport

Herbivores and Omnivores



Flow of energy and material transport

Secondary Consumers and Top Predators



Flow of energy and material transport

Bayesian Isotopic Mixing Model: SIAR

Consumer tissue
$\delta^{13}C$ & $\delta^{15}N$
X_{ij}

Diet Sources
$\delta^{13}C$ & $\delta^{15}N$
s_{jk}

Discrimination factors
$\Delta^{13}C_{\text{tissue-diet}}$
$\Delta^{15}N_{\text{tissue-diet}}$
c_{jk}

$$X_{ij} = \frac{\sum^{K} p_k \, (s_{jk} + c_{jk})}{\sum^{K} p_k} + \epsilon_{ij}$$

$$s_{jk} \sim N(\mu_{jk}, \omega_{jk}^2)$$

$$c_{jk} \sim N\left(\lambda_{jk}, \tau_{jk}^2\right)$$

$$\epsilon_{ij} \sim N\left(0, \sigma_j^2\right)$$

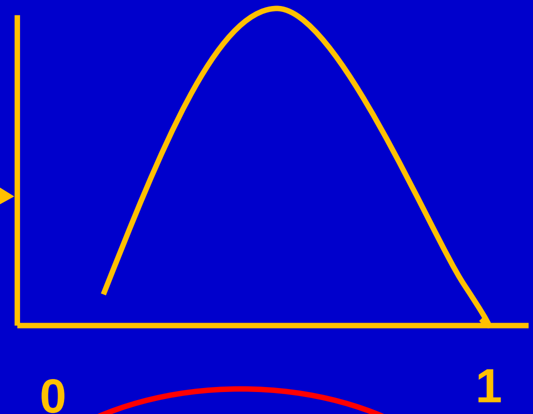
Dirichlet Prior:

$$\alpha_T = \sum^{K} \alpha_k$$

$$\bar{p}_k = \alpha_k / \alpha_T$$

$$var(p_k) = \frac{\alpha_k(\alpha_T - \alpha_k)}{\alpha_T^2(\alpha_T + 1)}$$

$$cov\left(p_k, p_p\right) = -\frac{\alpha_k \alpha_p}{(\alpha_T^2(\alpha_T + 1))}$$

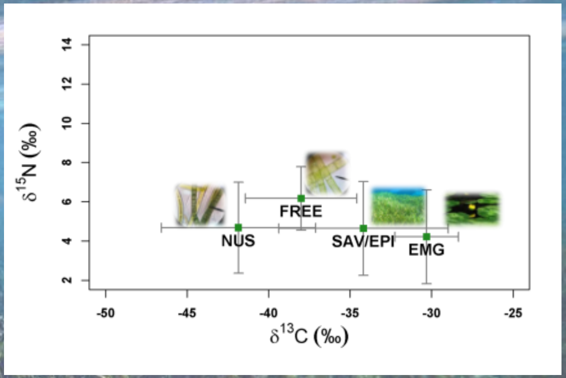


Proportion of diet composed of prey source k
(p_k)

Parnell et al. 2010

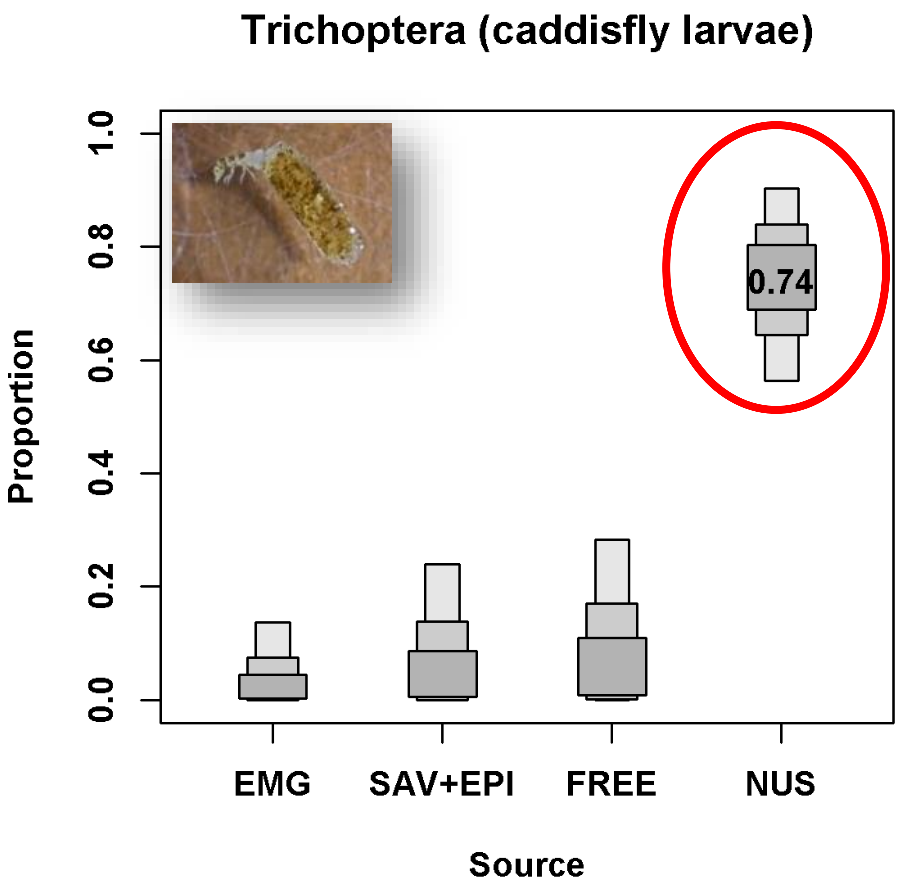
Mixing Model Results

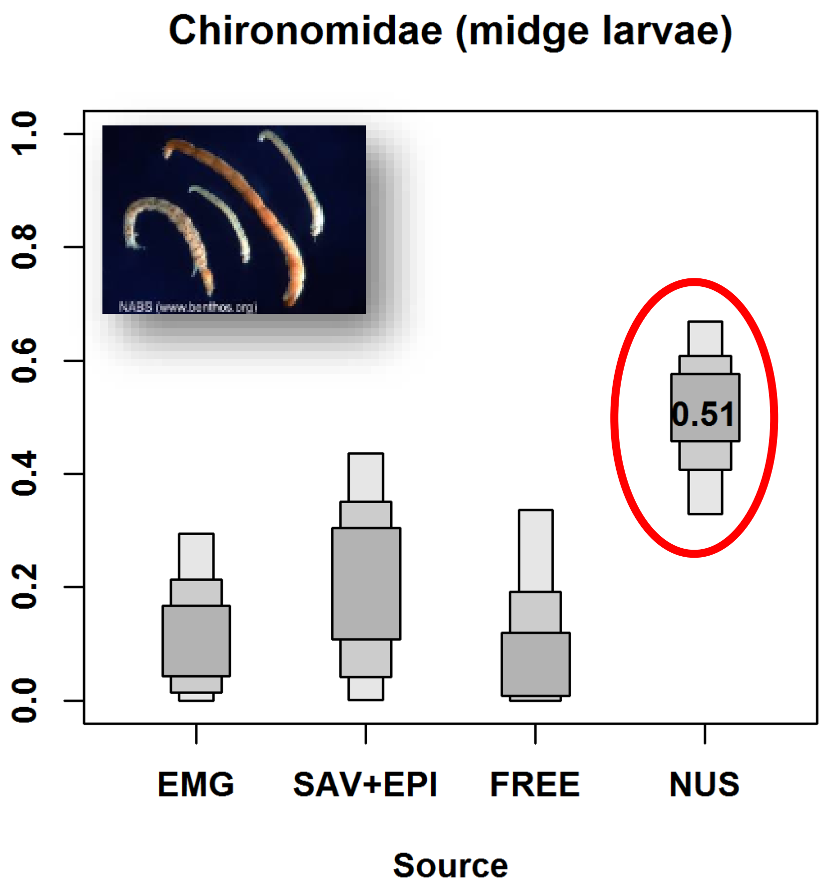
- Four end-member model
  - **Sources: NUS, FREE, SAV+EPI, and EMG**
  - **28 herbivore and omnivore taxa**



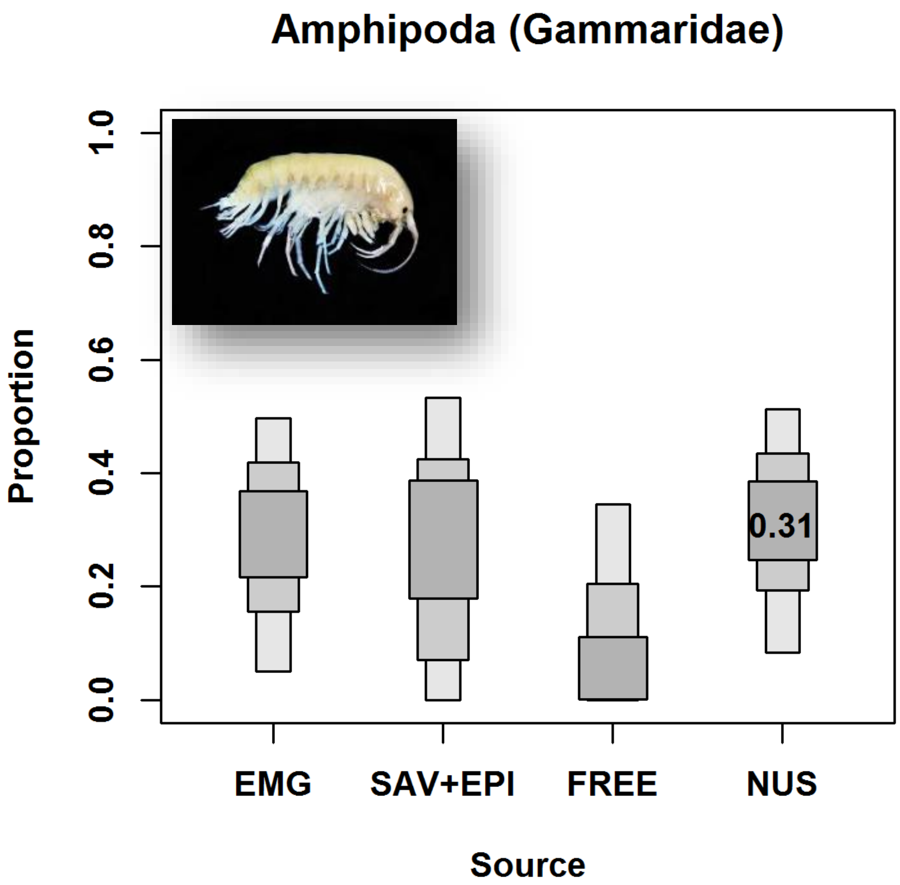
- Contribution of nuisance algae to consumers' diets
  - **Median range = 0.04 – 0.74**
  - **8 consumer diets predicted to contain > 30 % nuisance algae**

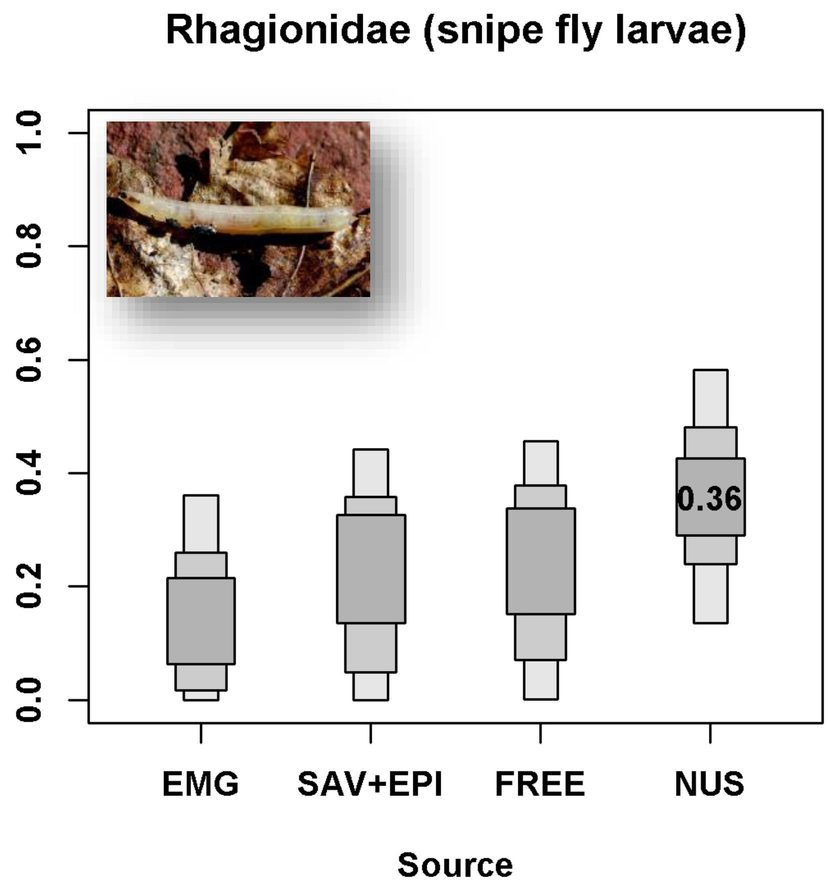
Isotopic Mixing Model Results





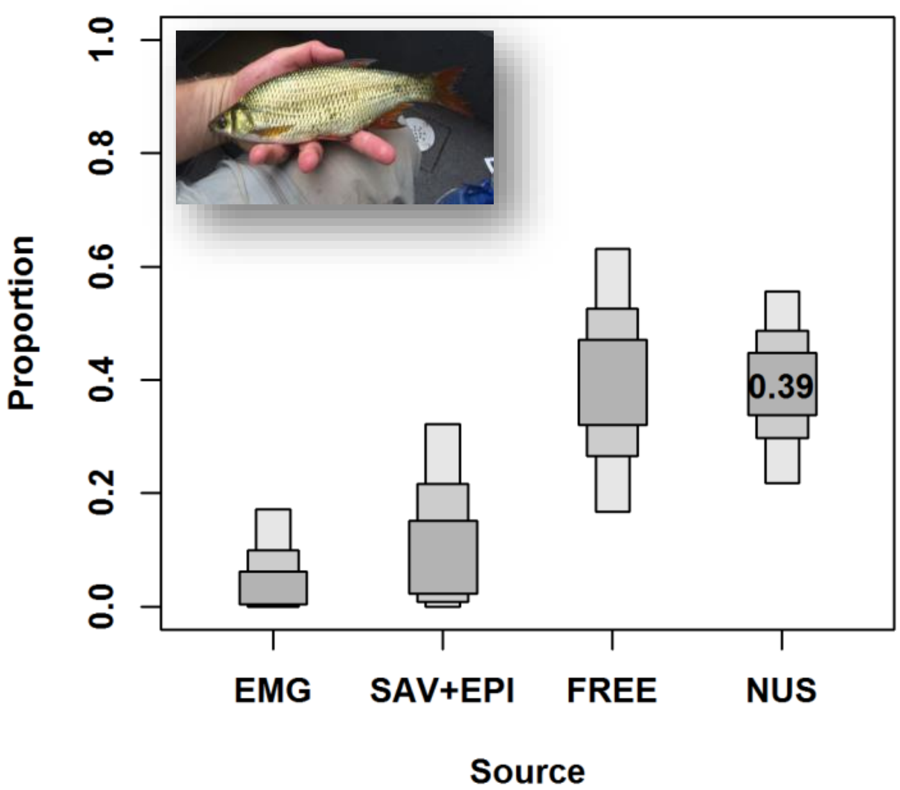
Isotopic Mixing Model Results



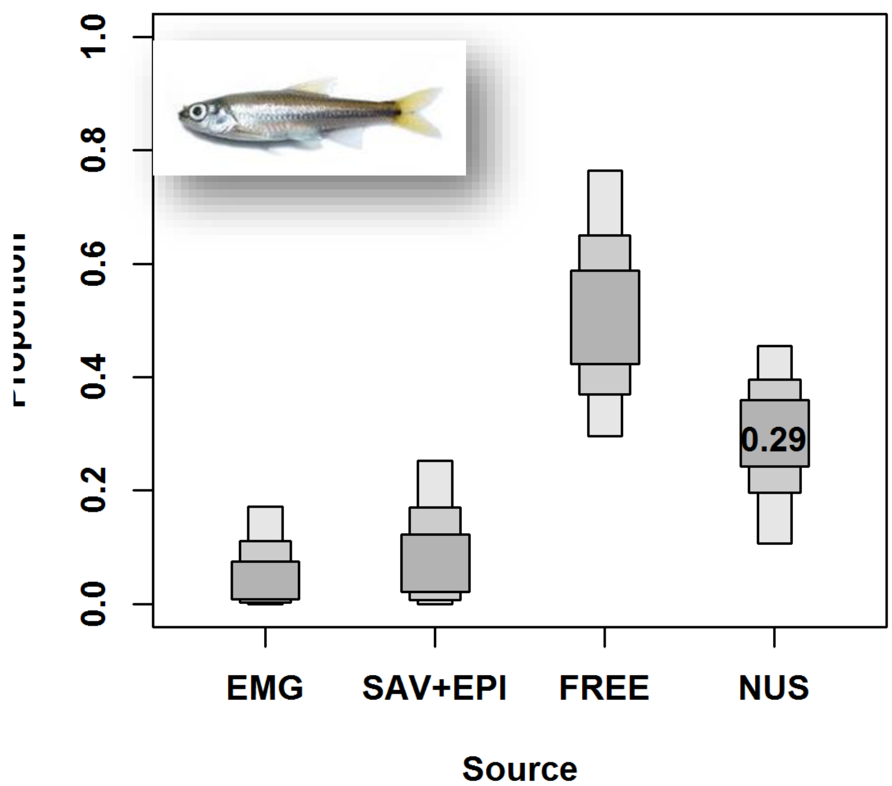


Isotopic Mixing Model Results

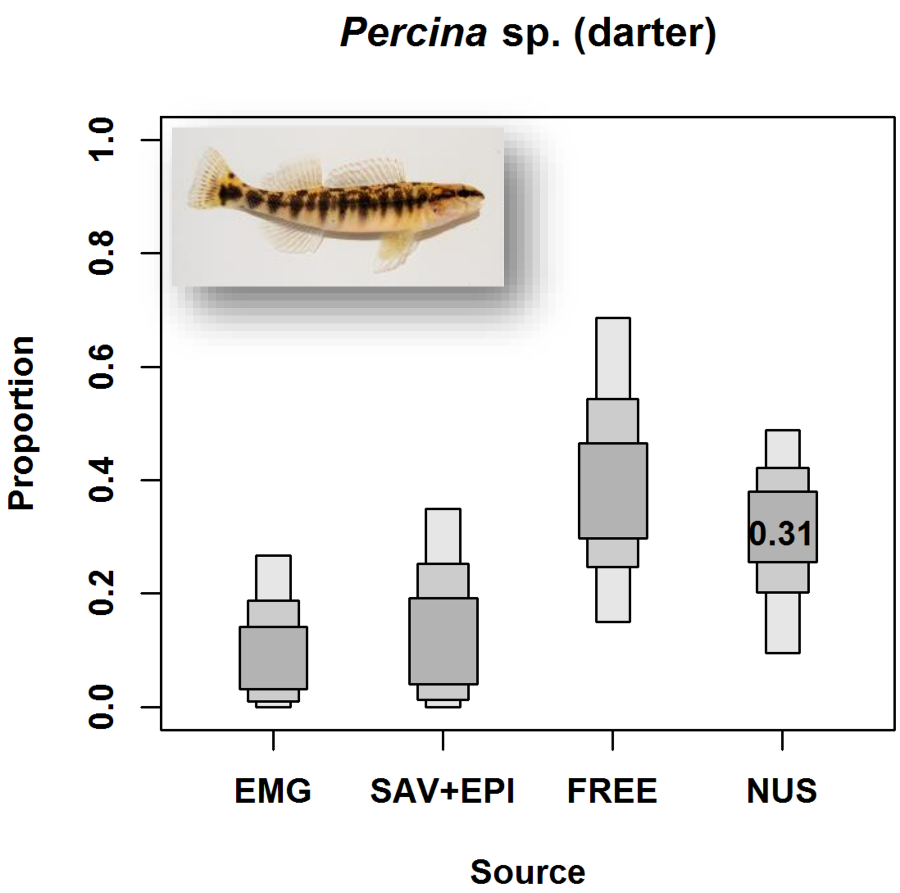
Notemigonus crysoleucas **(golden shiner)**

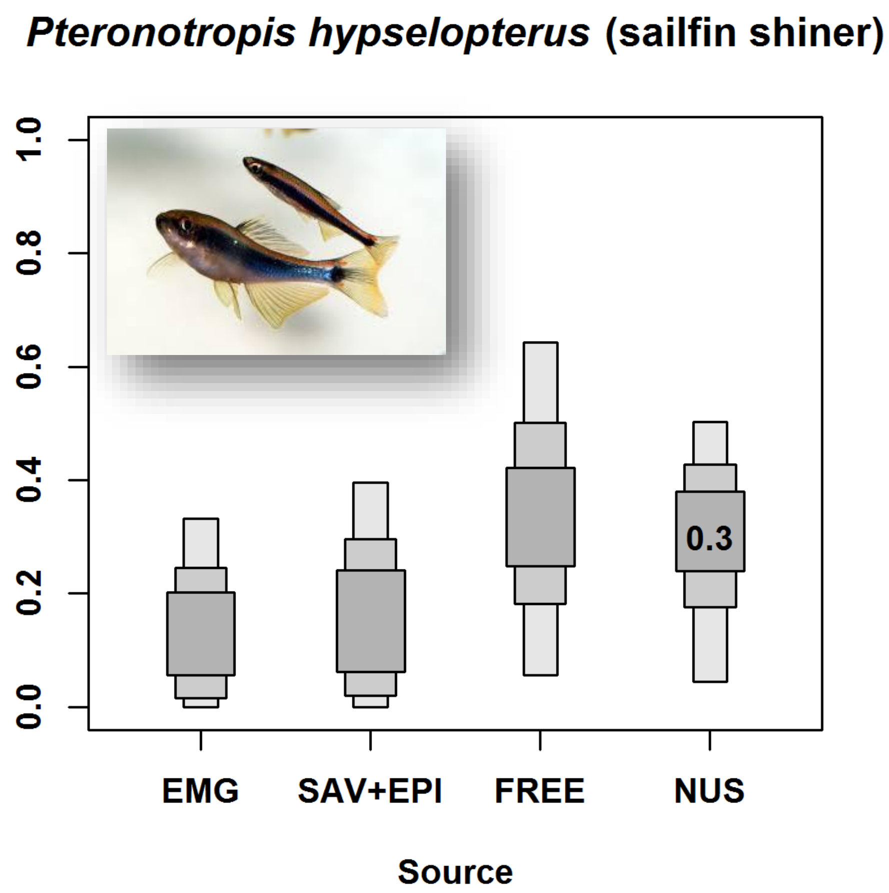


Notropis petersoni **(coastal shiner)**



Isotopic Mixing Model Results



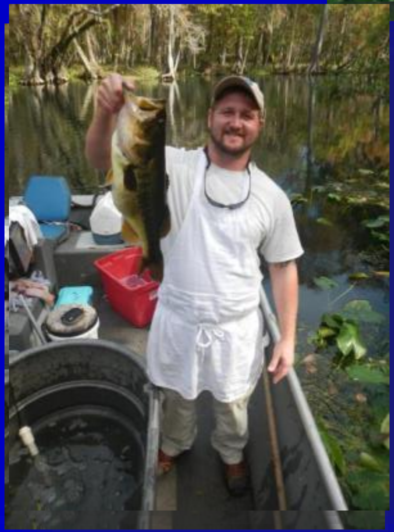



What can classical dietary data tell us?
Evidence of algal consumption?
Who is eating the algal grazers?

Stomach Content Analysis (SCA)

Fish








Turtles (scat)

Alligators



Diet Quantification

Percent Index of Relative Importance (%IRI)

% Numerical abundance

$$\%N = \frac{100N_i}{\sum_{i=1}^{n} Ni}$$

% Gravimetric abundance

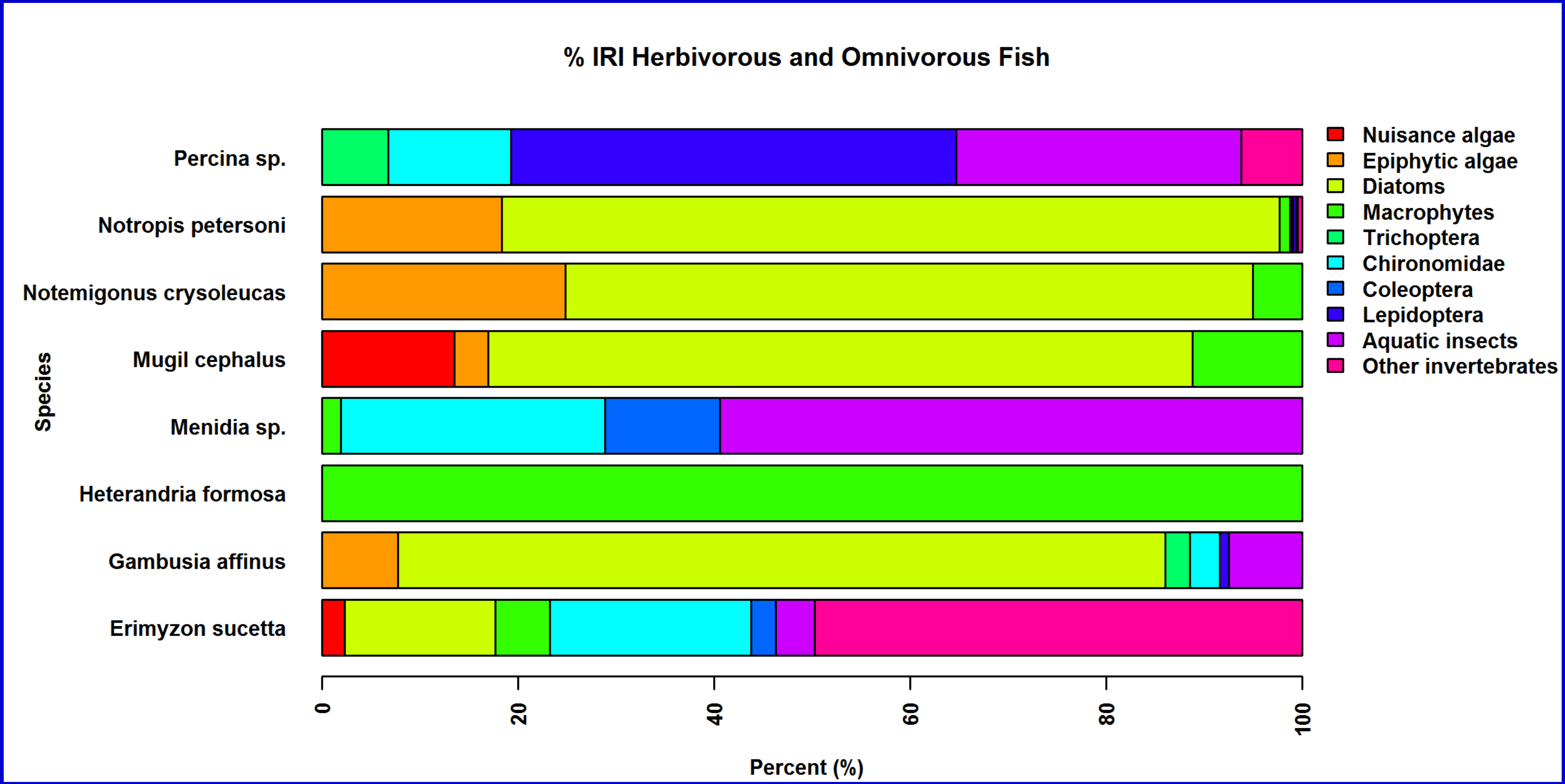
$$\%W = \frac{100W_i}{\sum_{i=1}^{n} Wi}$$

% Frequency of Occurrence

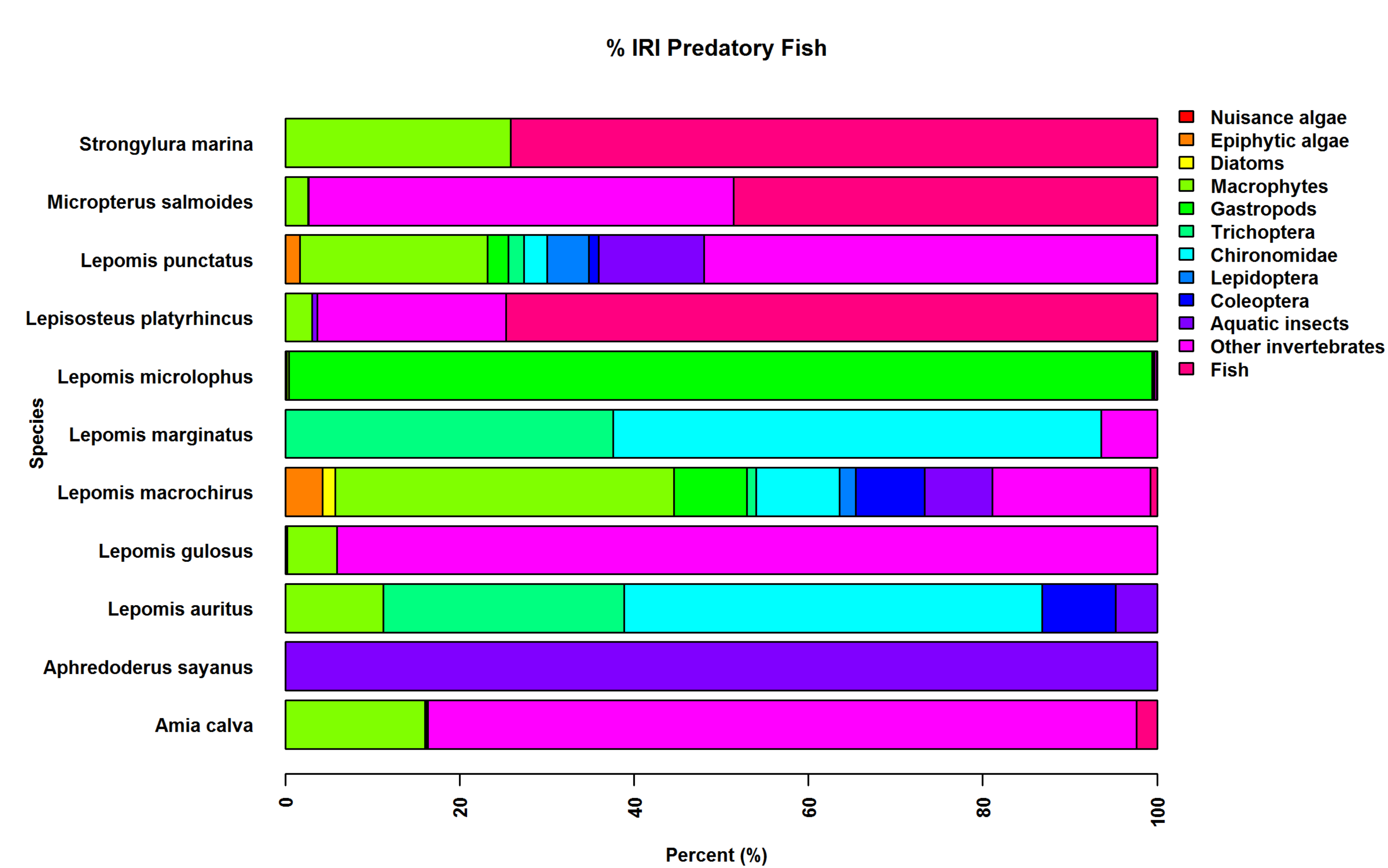
$$\%FO = \frac{100FO_i}{\sum_{i=1}^{n} FOi}$$

$$IRI_i = \%FO_i(\%W_i + \%N_i)$$

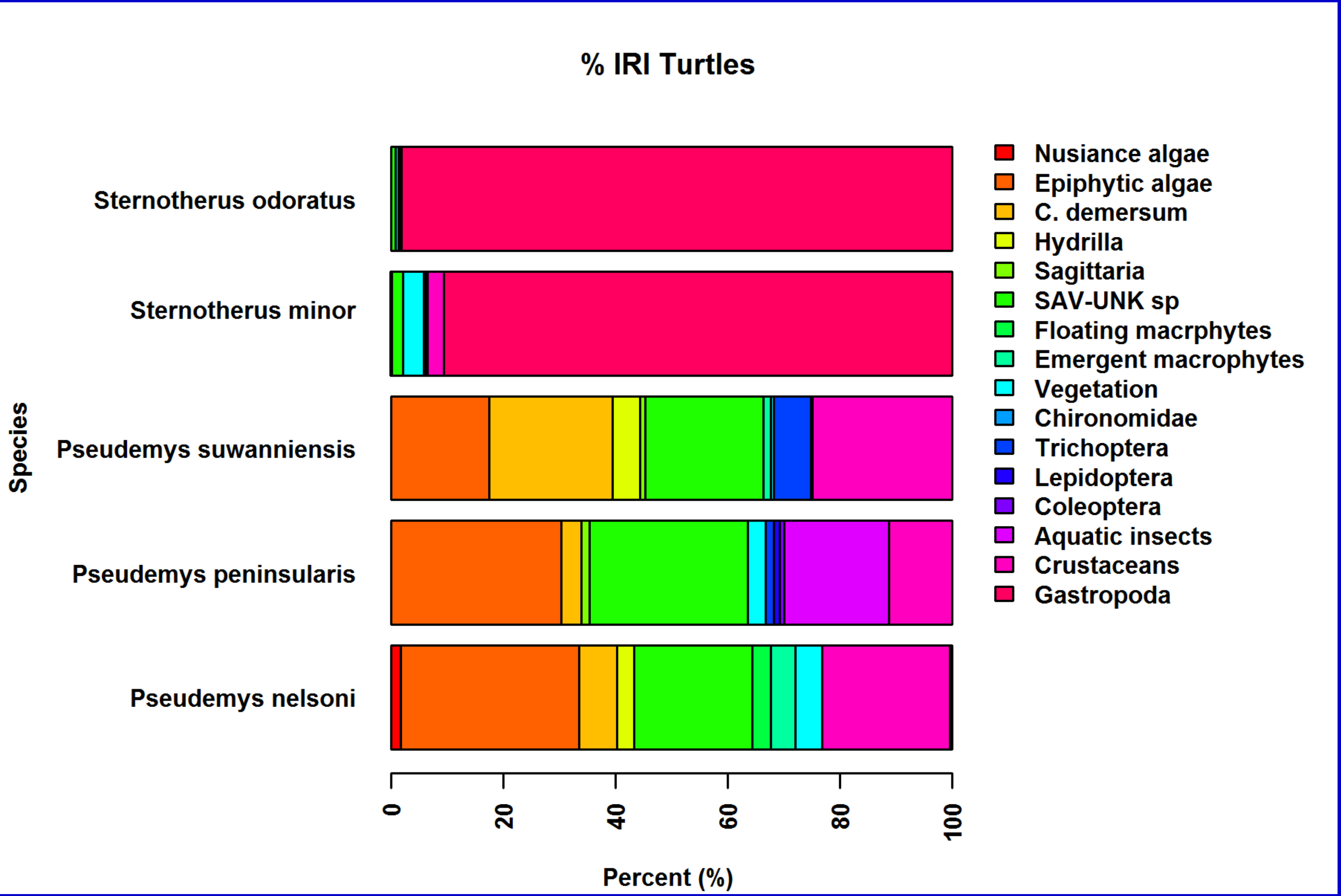
$$\%IRI = 100 \times IRI_i \sum_{i=1}^{n} IRI_i$$



1. Diatoms highly important resource.
2. Trichopterans and chironomids relatively unimportant prey.
3. Little evidence of nuisance algal consumption.

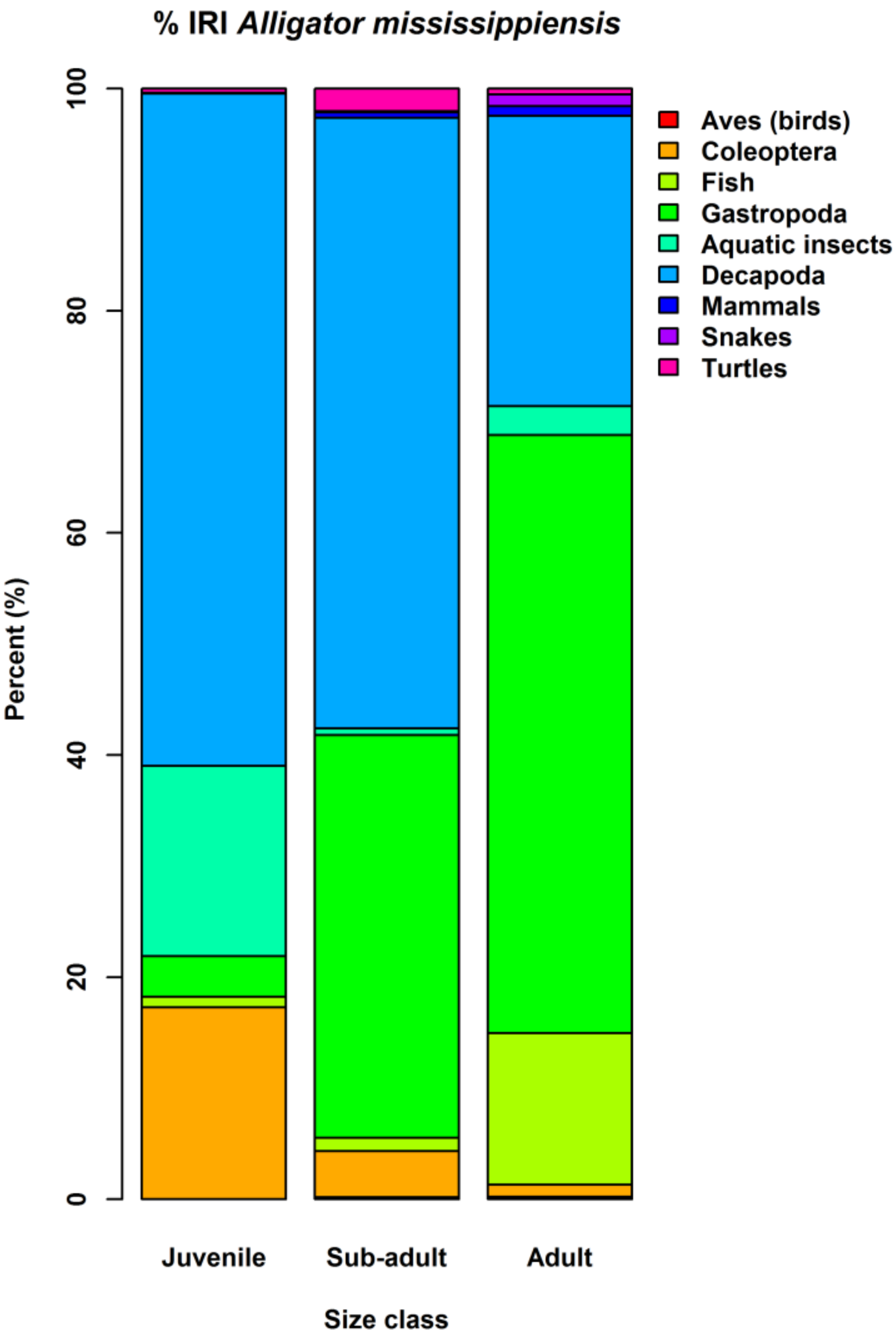


1. *L. marginatus* and *L. auritus* major predators of trichopterans.
2. *L. microlophus* major gastropod predator.
3. Other invertebrates (i.e., decapods , amphipods) and fish are primary prey for most species



1. *S. odoratus* and *S. minor* chiefly predators of small benthic gastropods (i.e., physids, hydrobiids, planorbids)
2. River cooters (*Pseudemys* spp.) mainly consume macrophytes and to lesser extent small invertebrates.

Alligators


% IRI Alligator mississippiensis
Percent (%)
0
20
40
60
80
100
Juvenile
Sub-adult
Adult
Size class
Aves (birds)
Coleoptera
Fish
Gastropoda
Aquatic insects
Decapoda
Mammals
Snakes
Turtles

Conclusions

- Nuisance filamentous contributes little to aquatic food web

- Few grazers heavily rely of nuisance algae
  - **Inverts**: Trichopterans>Chironomids>Rhagionids>Amphipods>Lepidopterans>Gastropods*
  - **Verts**: Shiners > Darters

- Major predators of algal grazers include Redear Sunfish, other Sunfish species, and kinosternid turtles

- Alligators are **not** ‘Apex predators’ rather they primarily feed on species occupying lower trophic levels (i.e., gastropods, decapods, insects)

Determining Grazing Rates of Herbivores on Dominant Macrophyte and Macroalgae Taxa

Elimia floridensis
(rasp elimia)

Planorbella scalaris
(rams horn snail)

Viviparus georgianus
(banded mystery snail)

Pomaca paludosa
(Florida apple snail)

Palaemonetes paludosus
(Eastern grass shrimp)

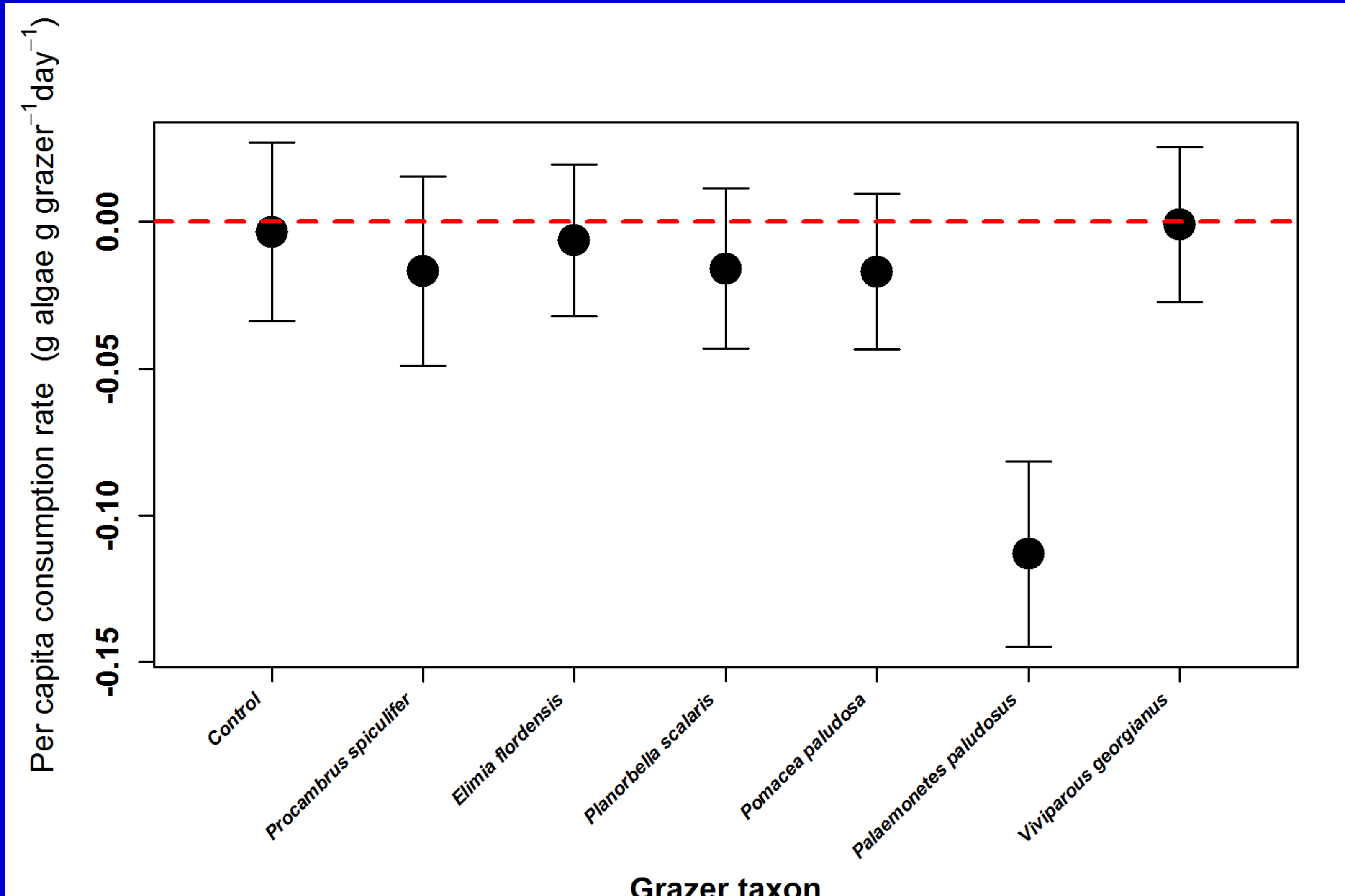
Procambarus spiculife
(spring crayfish)

- We calculated the per capita consumption rate (g vegetation g grazer^{-1} day^{-1}) as follows:

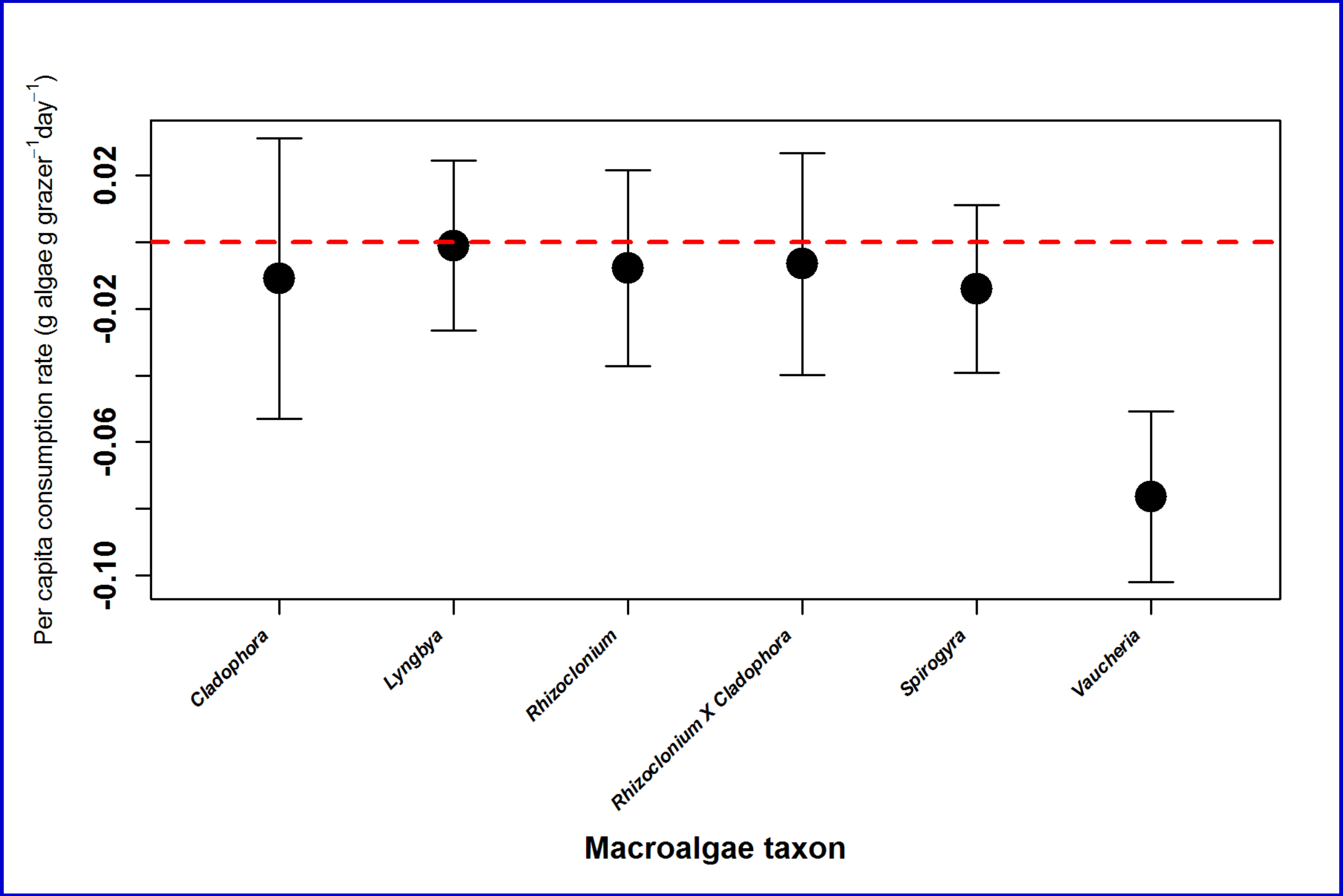
$$Per\ capita\ consumption\ rate\ = \left. \frac{final\ veg\ mass - initial\ veg\ mass}{final\ grazer\ mass} \right/ 3\ days$$

More negative values indicate higher rates of consumption

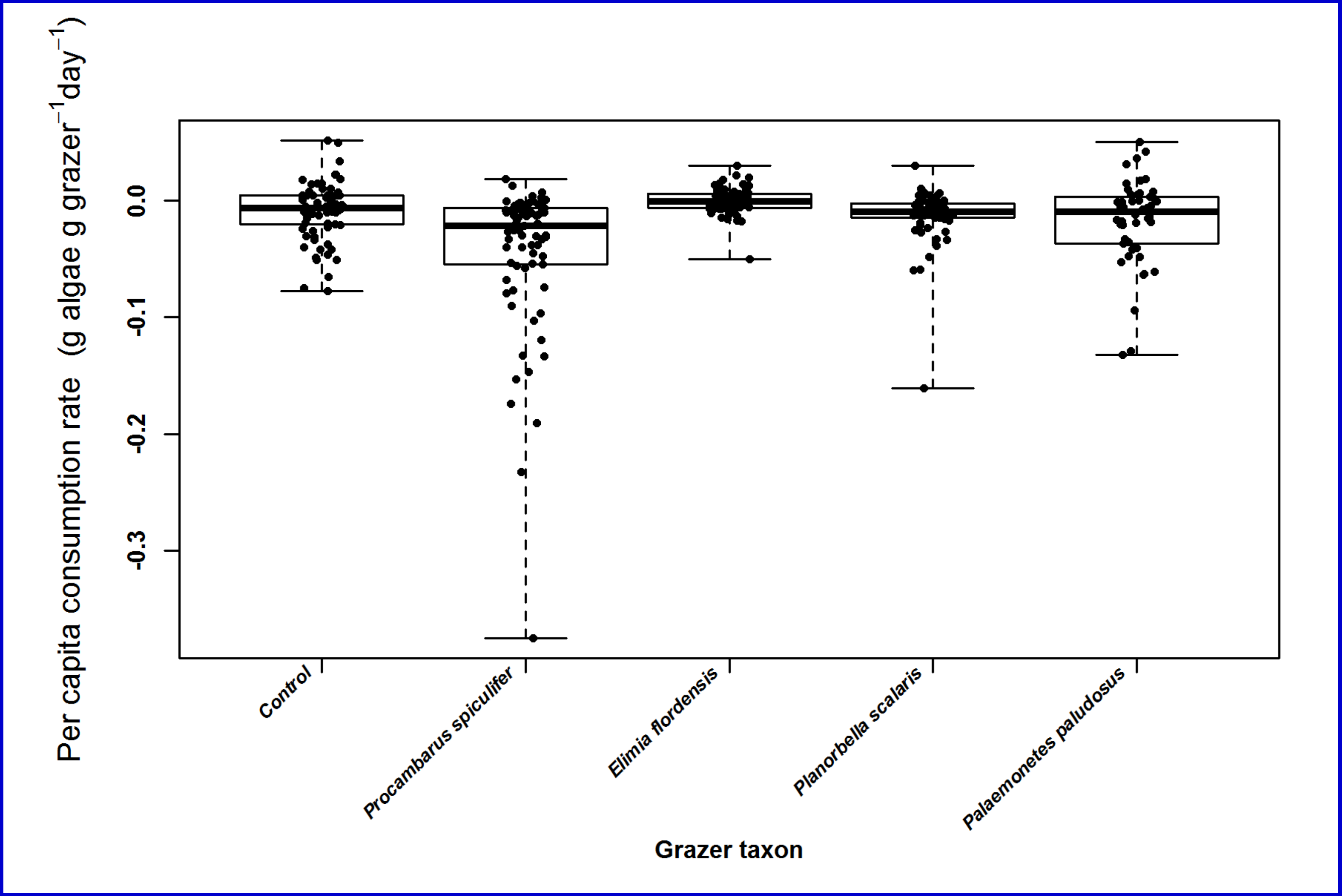
Macroalgae Grazing



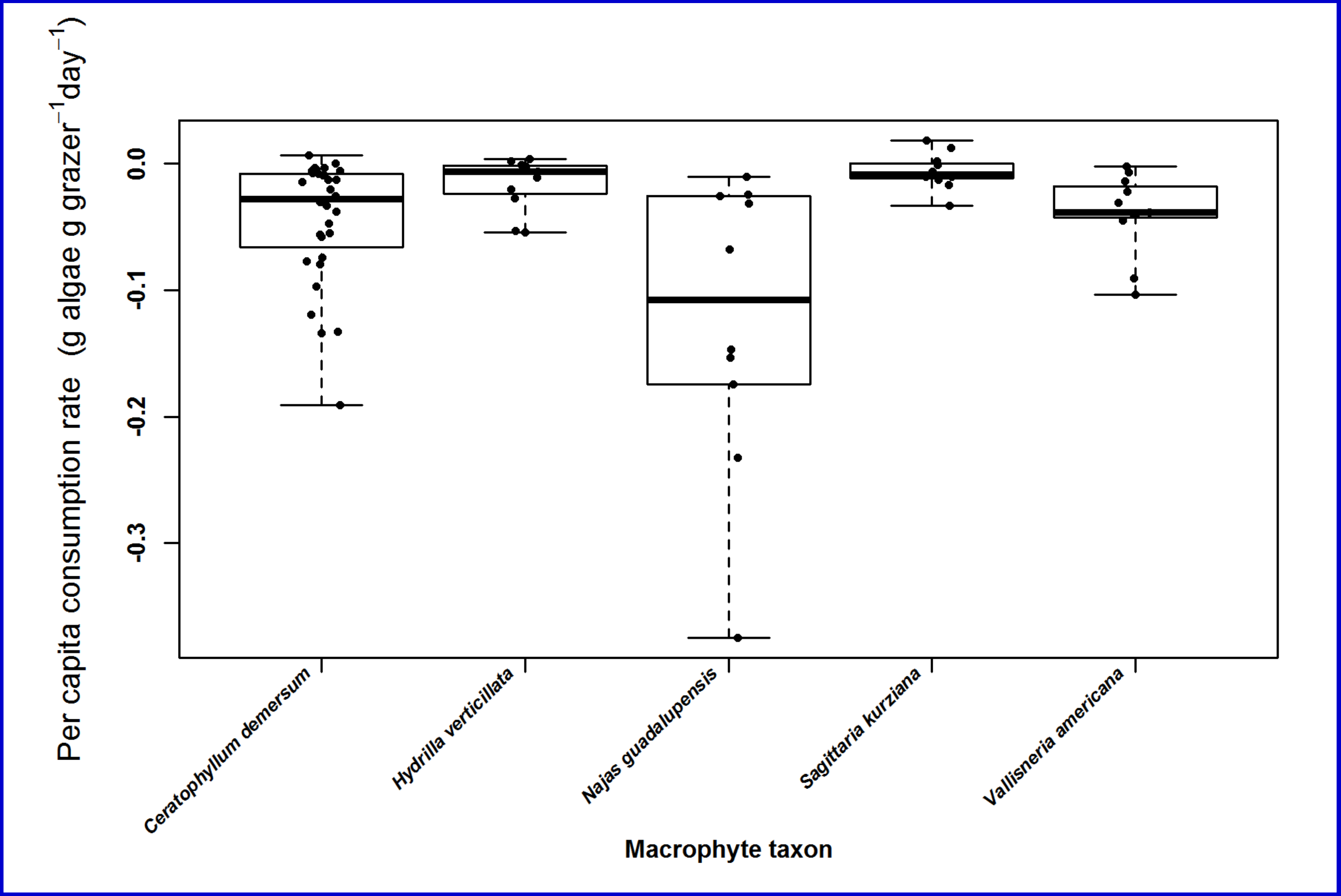
Macroalgae Grazing



Macrophyte Grazing



Macrophyte Grazing



Future Directions

1. Complete Grazing Trials

2. Predator Exclusion Experiments

Cage Design

Frame

-0.625 cm Galvanized Steel Rods and hoops

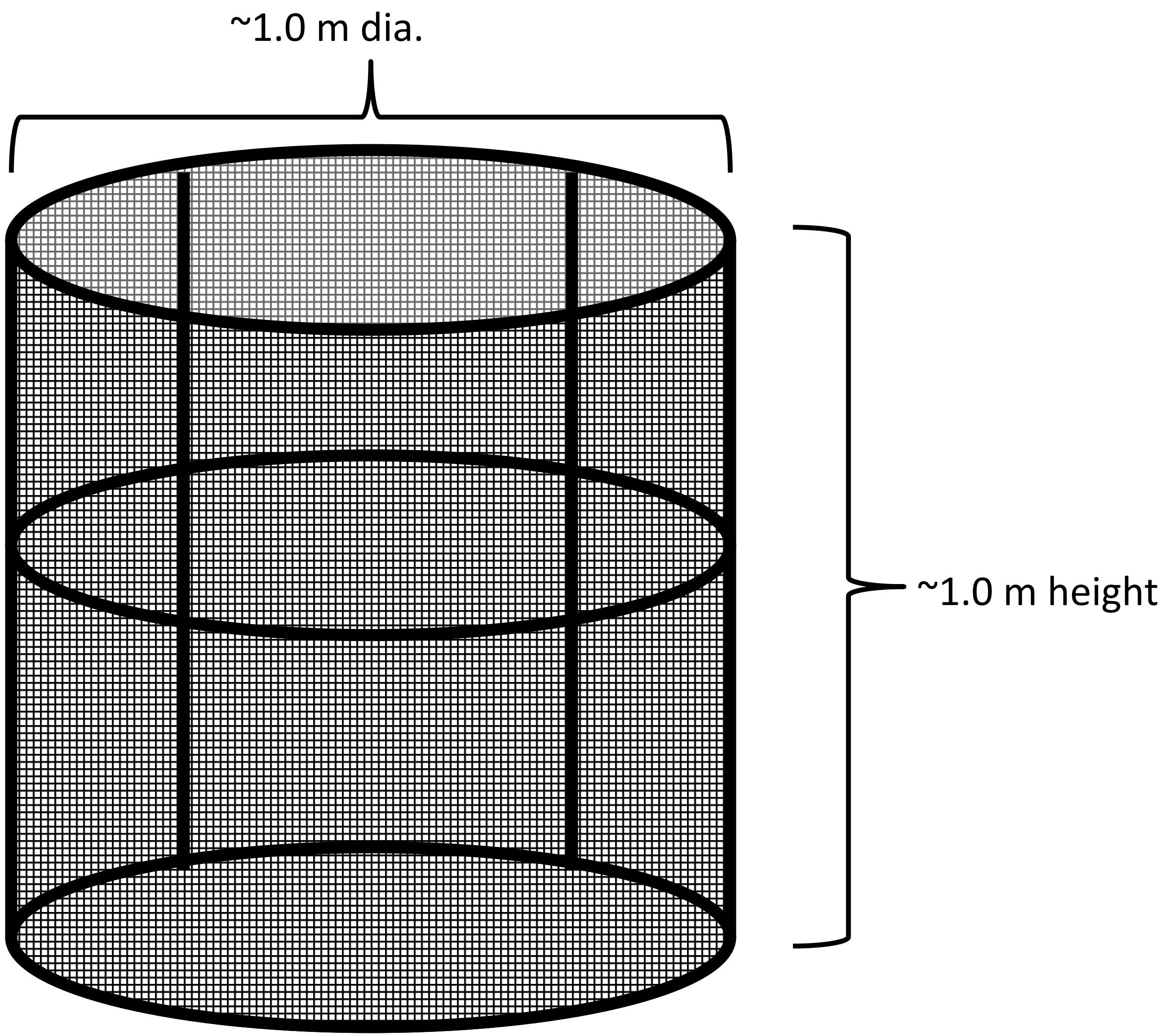
-All welded

Mesh

-2.5 cm mesh Hexagonal

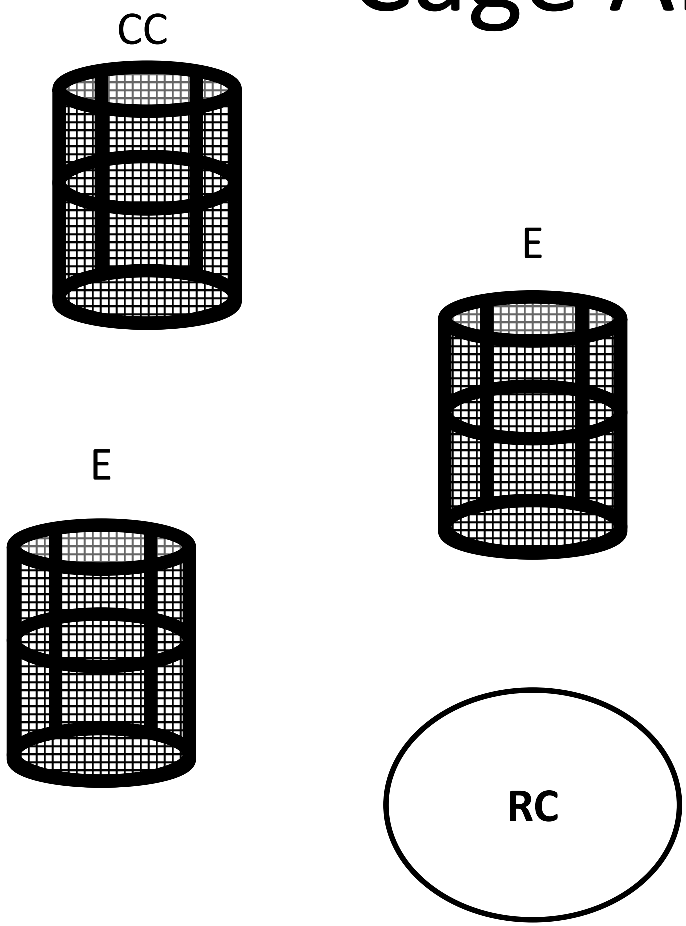
-Vinyl Coated Galvanized Steel

-Secured with Galvanized Hog Rings




WELDING

Cage Array Design



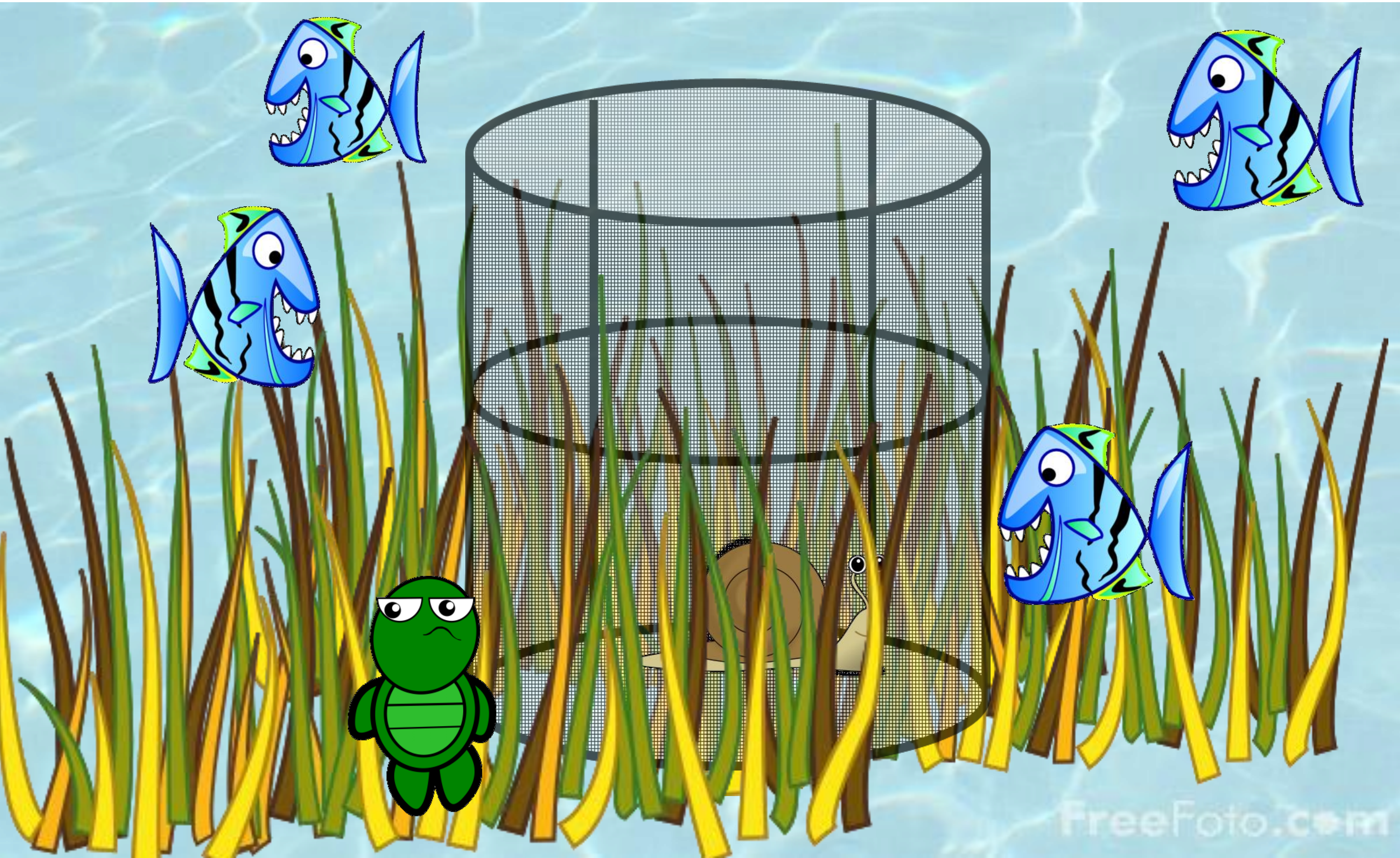
Array

-2 Exclusion Cages-E
-1 Cage Control-CC
-1 Reference Control-RC

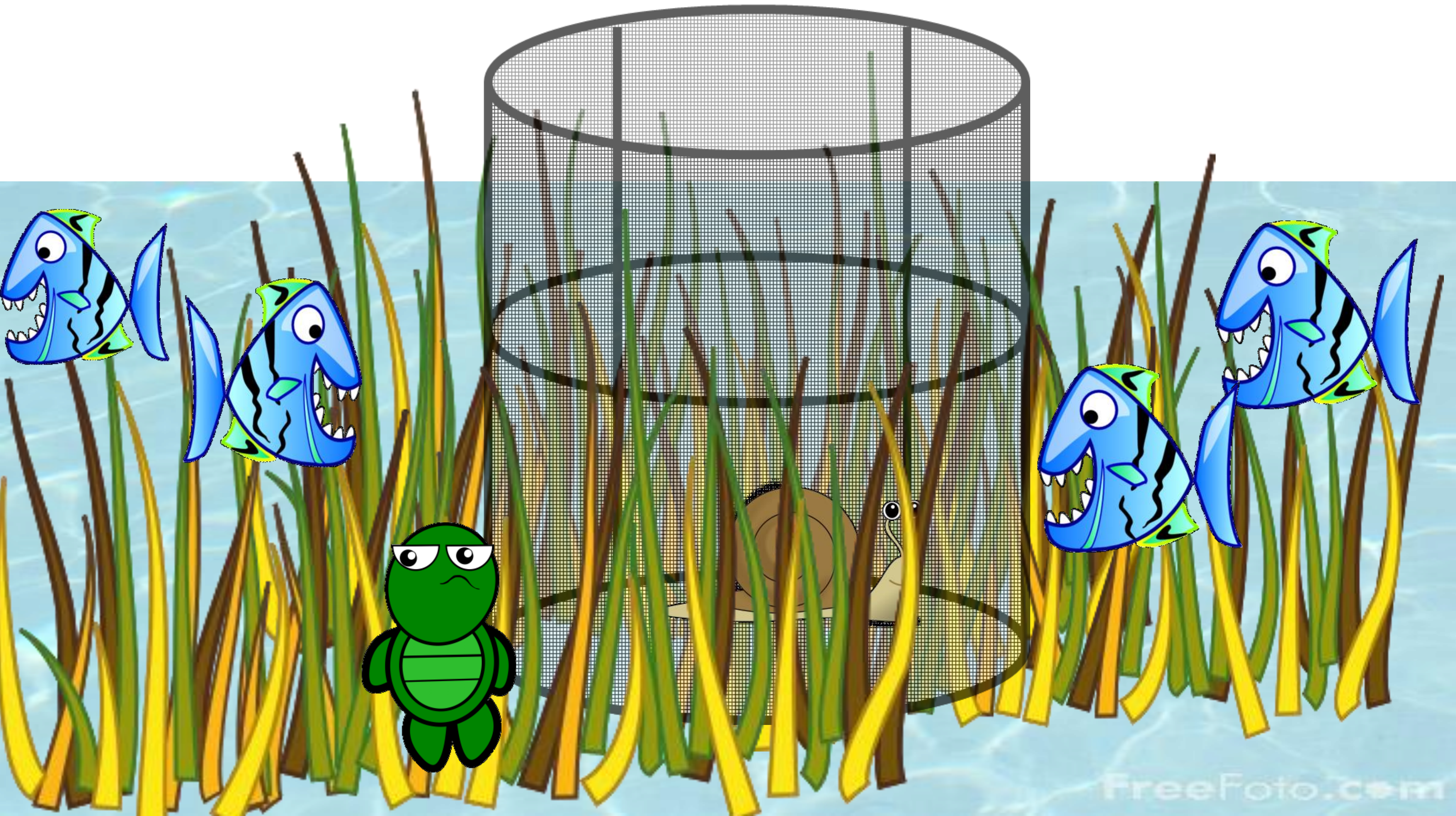
*Cage Control treatment will have bottom 30 cm of mesh removed from cage to allow organisms uninhibited access while replicating shading and flow effects of true exclusion cages.

*Reference Control is simply a monitoring area with same footprint as cages.

Cages may be fully submerged



Cages may protrude from water’s surface



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Questions?

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