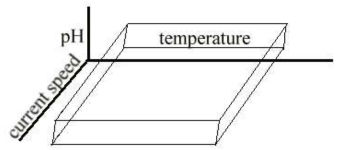
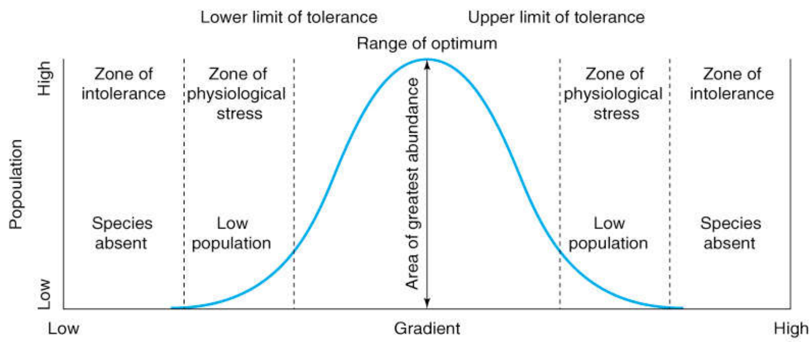
Niche

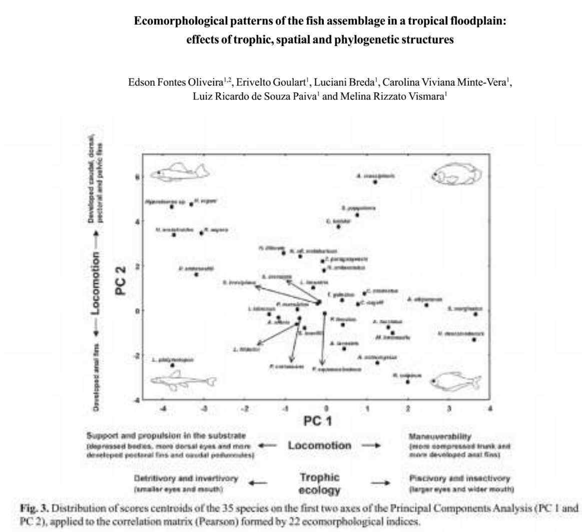
- The sum of all interactions a species has with biotic/abiotic components of the environment
  - **N-dimensional hypervolume**
    - Each dimension is a biotic or abiotic resource





Ecomorphology

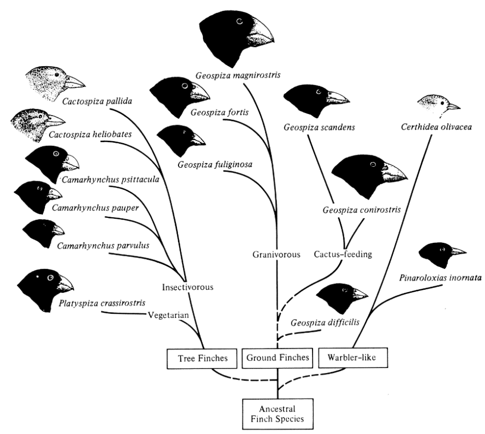
- Ecology (niche) of a species can often be inferred from morphology.
- Gut morphology
  - Longer gut for lower quality food, shortest guts for carnivory
- Mouth size and position
  - Superior mouth for surface feeding, large gape for piscivory
- Gill rakers
  - Finer gill rakers for filtering smaller particles
- Body shape
  - compressed body, large paired fins = maneuverability
  - High aspect ratio, hydrodynamic body = acceleration



Evolutionary and Ecological Patterns

- **Niche conservatism** – Closely related species are expected to have similar morphology. By extension, closely related species should have similar niches.
  - Niches should show a strong phylogenetic signal.

- By extension, closely related species should tend not to coexist.



Evolutionary and Ecological Patterns

PISCIVORY LIMITS DIVERSIFICATION OF FEEDING MORPHOLOGY IN CENTRARCHID FISHES

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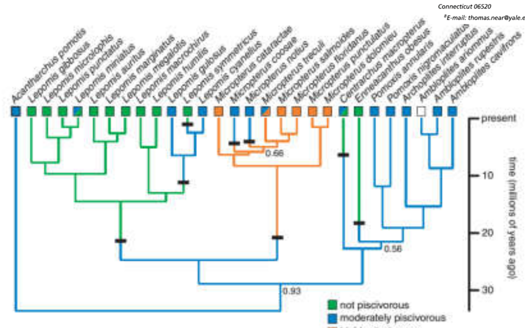
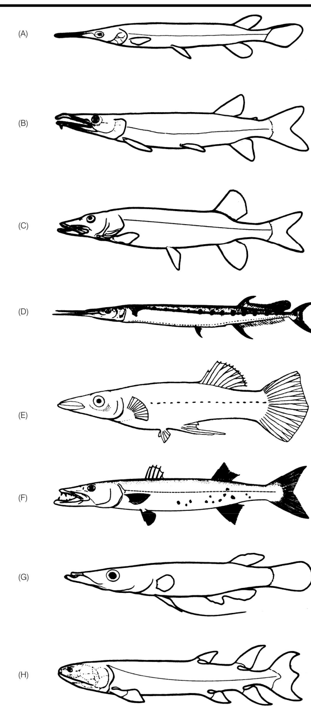


Figure 1. Reconstruction of piscivory in centrarchid lineages. Phylogenetic relationships and fossil-calibrated divergence time estimates are based on Near et al. (2005); nodes are supported by greater than 0.95 Bayesian posterior probabilities unless indicated. The 29 recognized centrarchid species (out of 33 total) shown here are those for which we obtained morphological data; colored boxes next to species' names denote piscivory states based on our diet synthesis (see Table 1); green is not piscivorous, blue is moderately piscivorous, orange is highly piscivorous, white is unknown, and boxes with two colors indicate uncertainty between piscivory states in that species. This ancestral reconstruction of piscivory represents a single character history from the 500 character histories we obtained by stochastic mapping of piscivory states in SIMMAP (Bollback 2006) and illustrates the modal number of state changes, the most common ancestral state for Centrarchidae, and the most common ancestral state for the *Micropterus* clade. Colors of branches indicate inferred piscivory state and black bars show transitions between states. We used this reconstruction and the other 499 sampled character histories as the basis for evaluating the fit of multiple-peak OU and multiple-rate Brownian motion models in which model parameters were allowed to differ between lineages inferred to have different piscivory states.

Convergent Evolution



Multiple examples of convergent evolution. Here, multiple lineages have converged on a similar predator morphology.

Morphological adaptations for **cursorial** vs. **lurking** (ambush) predators.

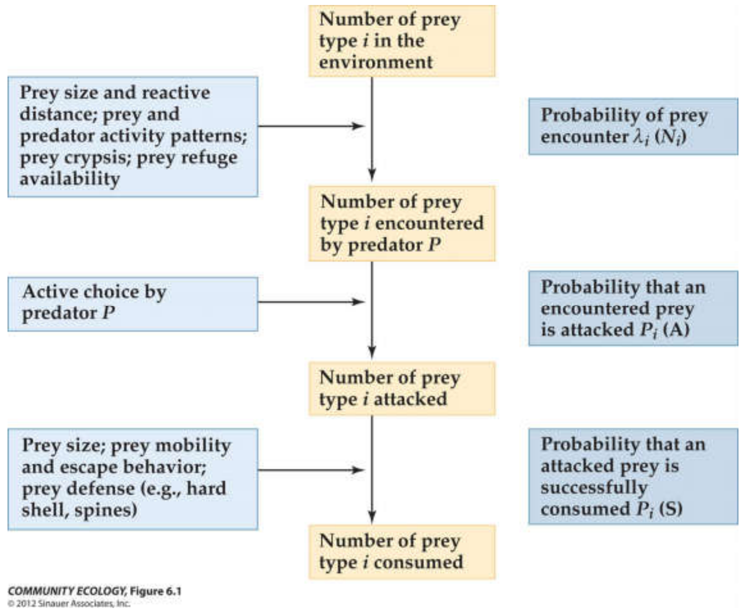
The two differ markedly in the cost of capturing a single prey item and their ability to choose prey…Why different strategies?

Ultimately, fish should be optimized to maximize fitness (reproductive output) in their niche.

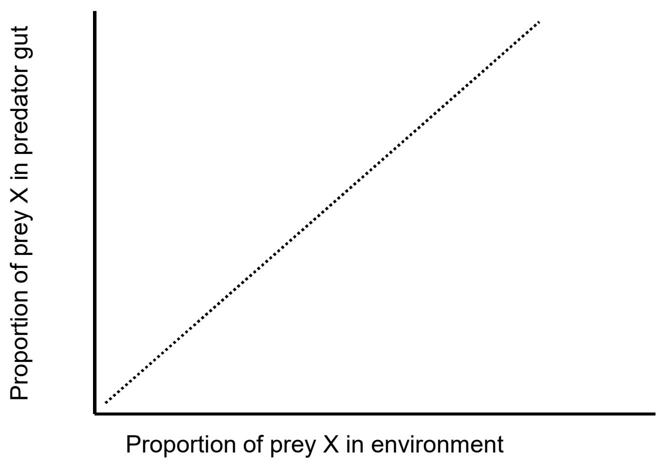
Energetics of Predation

- Predator benefit = calories in meal – search cost – handling cost
- Predator strategies – maximize benefit by minimizing search or handling
- Prey strategies – minimize calories in meal, maximize search, maximize cost
  - Crypsis
  - Escape
  - Avoidance
  - Prey quality
- **Evolutionary arms race (Red Queen hypothesis) –** why don't they "end" ?

Process of Predation



How do you quantify predatory preference for prey?



$$E = \frac{(r_i - p_i)}{(r_i + p_i)}$$

Selectivity index (E)
r_i = % of diet is prey type i
p_i = % of available prey is type i

How do you quantify predatory preference for prey?

- Chesson's index (a)
- $a_i = \frac{d_i/N_i}{\sum_{j=1}^{k}\left(d_j/N_j\right)}$
- Where
  - K – number of types of prey
  - d – number of prey in the diet (d_i=in diet, d_j=in environment)
  - N – number of prey available (in diet or in environment)

Generalist vs. Specialist Predator

- Advantages/disadvantages of broad or specific diet

Optimal Foraging Theory

- Predict foraging strategy based on:
  - Handling time (T_h)
  - Search time (T_s)
  - Energy in prey item
- Predators should forage to maximize energy gains (E)

$$\frac{E}{T_s + T_h}$$

- For any given prey, E/T is the net energy gain:

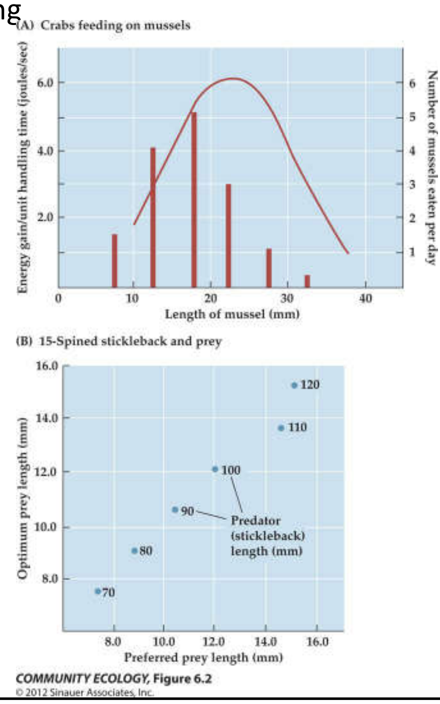
$$E_n/_T = \frac{E}{T_s + T_h}$$

Assumptions and Predictions of OFT

- Perfect Knowledge of environment, including distribution of *i* prey items
  - energy content
  - handling and search time
- Fitness optimized by maximizing energy intake.
- Predictions (for prey type i):
  - Specialist -> Generalist gradient
    - Specialist: maximize E_i even though s_i and h_i high
    - Generalist: minimize T_s and T_h, take whatever E available
  - Predators with long handling times ($T_h > T_s$) should be specialists
  - Predators in unproductive habitats (large T_s) should be generalists
  - Predators should ignore unprofitable prey, regardless of abundance

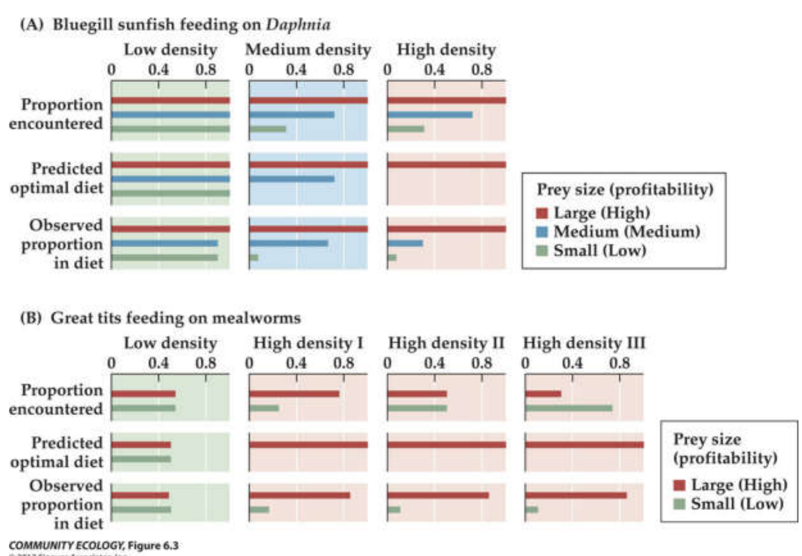
Prey quality, abundance and switching

- Optimal foraging model works well. Lots of data indicating this is how predators behave.
- Some other predictions:
  - **Zero rule** – in any specific set of conditions prey are either ignored or pursued 100% of the time (P_i= 0 or 1.0). This is the basis of **switching behavior**.



Empirical Evidence for OFT from Experiments

- No selectivity at low density, focus on higher profit prey as density increased.



Giving Up Density (GUD)

- **Giving Up Density** (GUD) – density of prey at which a predator will abandon a prey type or area.
  - Prey are depleted – cost/benefit of pursuing prey no longer beneficial
  - Competing predator more efficient – cost/benefit of prey no longer beneficial
  - Predator response – switch or find new patch

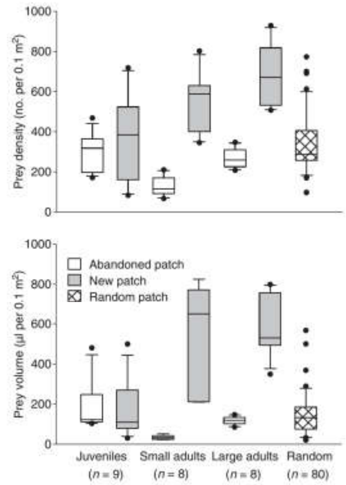


Fig. 2 Box and whisker plots of prey density and volume at abandoned, newly occupied, and randomly located patches in Shope Fork. Horizontal lines within boxes are median values. Box edges are 25th and 75th percentiles. 'Whisker' caps identify the 5th and 95th percentiles, and black circles represent outliers. The median of the abandoned patches can be interpreted as field giving-up densities (GUDs) for each sculpin size class.

Freshwater Biology (2010) 55, 780–793 doi:10.1111/j.1365-2427.2009.02321.x

Giving-up densities and ideal pre-emptive patch use in a predatory benthic stream fish

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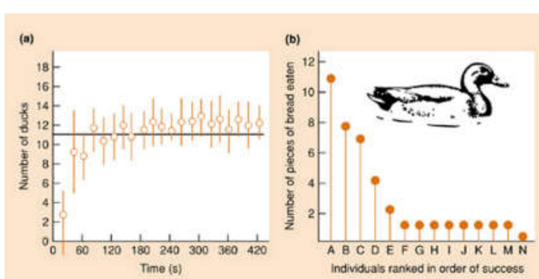
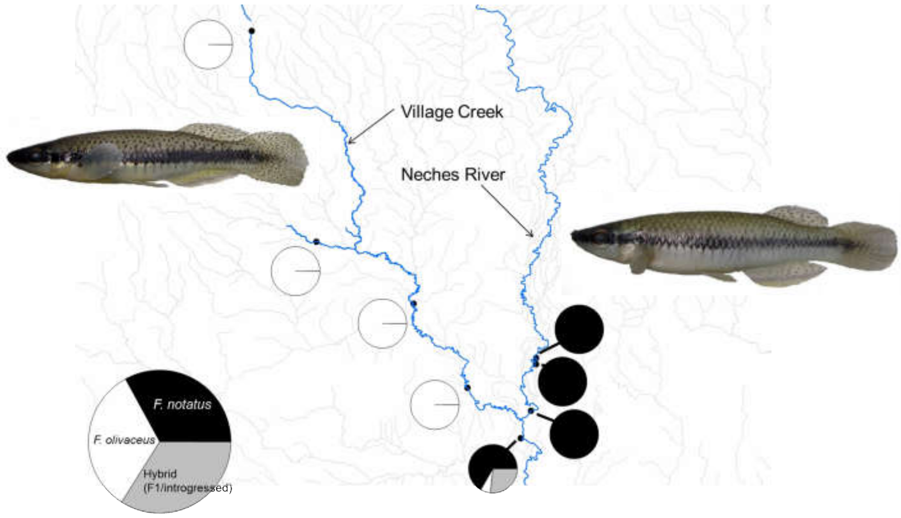
Ideal Free Distribution (IFD – Fretwell and Lucas 1970)

- Consumers should aggregate where resources are most abundant (OFT)
- Consumers will compete and interfere.
- Thus, patches with fewer competing consumers are most profitable
- Consumers should continually redistribute themselves to match patch quality
  - Assumes movement among all patches equal
  - Simultaneous knowledge of all patches



Evolutionary and Ecological Patterns

- **Coexistence –** Species with similar niches should compete for similar resources. Limiting recourses should result in **competitive exclusion**.
  - Coexistence of similar species should be rare.



Evolutionary and Ecological Patterns

- **Character Displacement** - Competitive interactions will select for divergence in traits to reduce competitive pressure.
- As species differences increase, changes in the niche allow for coexistence with less competitive pressure.
- Observe a relationship between the amount of dissimilarity and range overlap.
- **Specialization** – selection for specializing (shrinking the niche) in particular resources to reduce competitive pressure.

Ecology Letters, (2007) **10**: 146–152 doi: 10.1111/j.1461-0248.2006.01005.x

Species co-existence and character divergence across carnivores

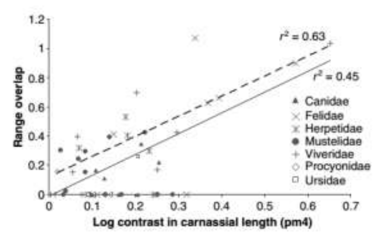


Figure 1 Scatter plot of range overlap against divergence in upper carnassial length. Range overlap scores are arcsine-transformed (see Material and methods). Fitted lines represent the fit of the regression model for all sister pairs (solid line) and for sympatric sister pairs only (dashed line). The regression models were robust to the exclusion of points of high leverage and to the removal of felids, which are overrepresented among the contrasts with both high range overlap and large differences in carnassials (see text for details).

- Species radiations of fish often feature rapid evolution of feeding morphology.
- See also cichlid species radiations in African great lakes.

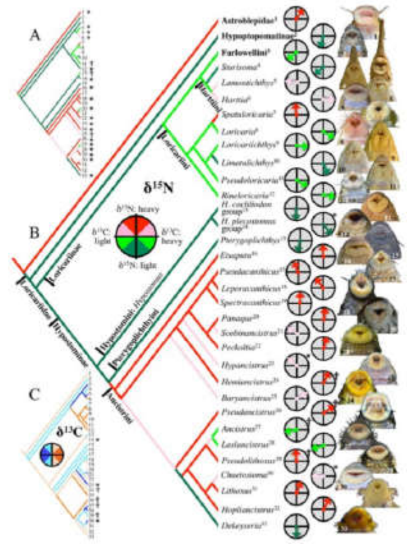


Figure 3 Evolutionary patterns of loricariid trophic diversification revealed by assemblage centroid-standardized isotope vector analysis (ACSIVA) of C and N stable isotope data (Figure 3; See Additional file 4: Figures 3–10 for isotope biplots of all local assemblages examined). Cladograms **A** and **B** represent the hypothesized ancestral distributions of lineages along a vertical axis of ^{15}N-enrichment relative to assemblage centroid (pink to red being ^{15}N-enriched relative to centroid, light green to green being ^{15}N-depleted relative to centroid). Cladogram A represents a phylogenetic regression of 649 individual vectors (Figure 3A) grouped by genus irrespective of site (see Additional file 2: Figure S1 for a full size version of this phylogeny), and cladogram B represents a regression of 120 mean genus x site vectors (Figure 3 C). Circle plots illustrate the direction of mean genus x site vectors for each genus and statistical significance of the mean vector is indicated by * (Rayleigh's Z test: $P < 0.05$) or † ($0.10 > P > 0.05$; Tables 1, 2). Cladogram **C** resulted from the same analysis as B, but is color-coded to reflect hypothesized distributions of ancestral lineages along a horizontal axis of ^{13}C-enrichment relative to assemblage centroid (see Additional file 3: Figure S2 for a full size version of this phylogeny). Oral disk photos by N. K. Lujan or M. H. Sabaj Pérez.

Trophic diversity in the evolution and community assembly of loricariid catfishes