“Life Is Life,

and Fun Is Fun,

But it’s So Quiet

when the Goldfish

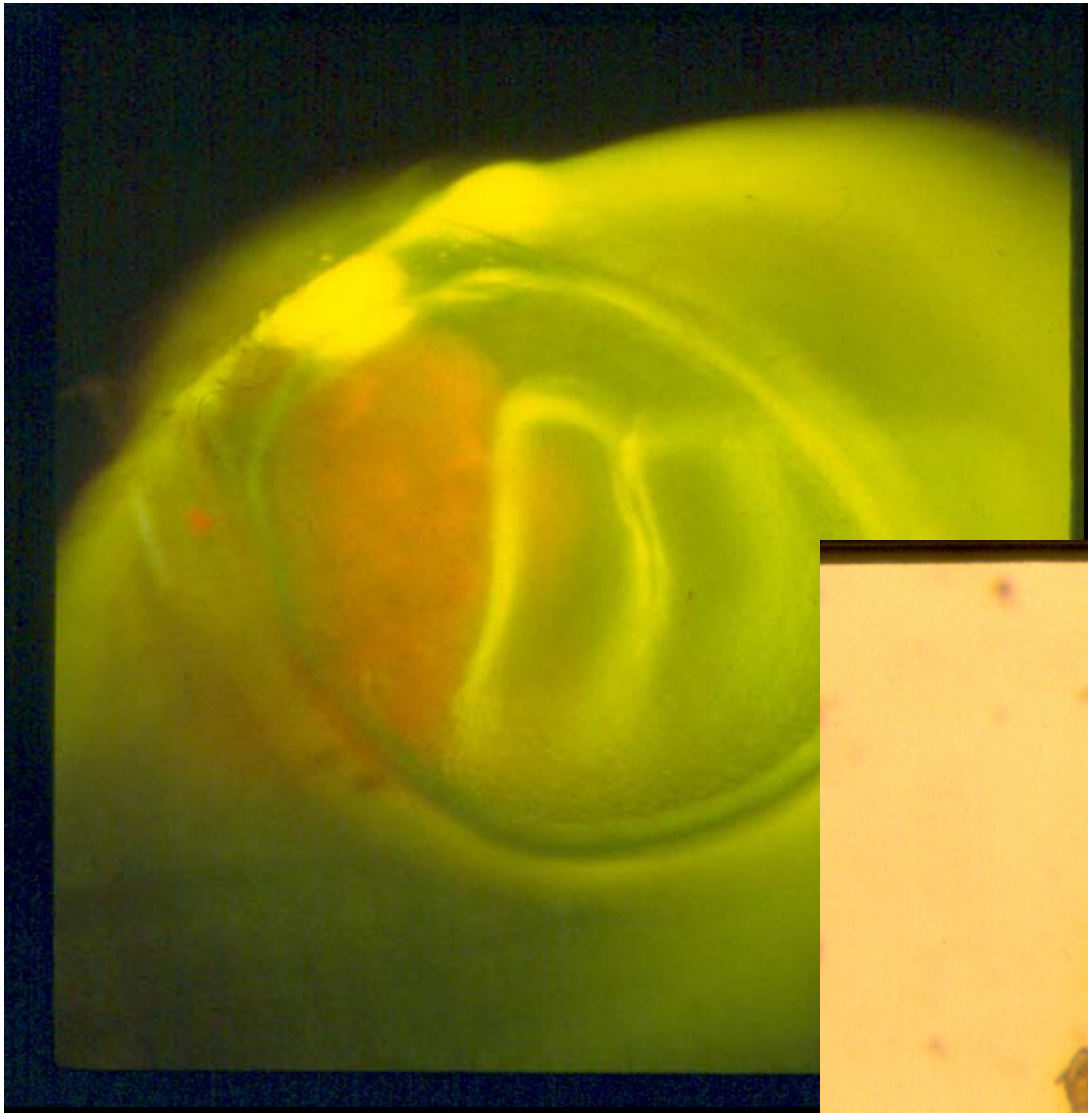
Die.”

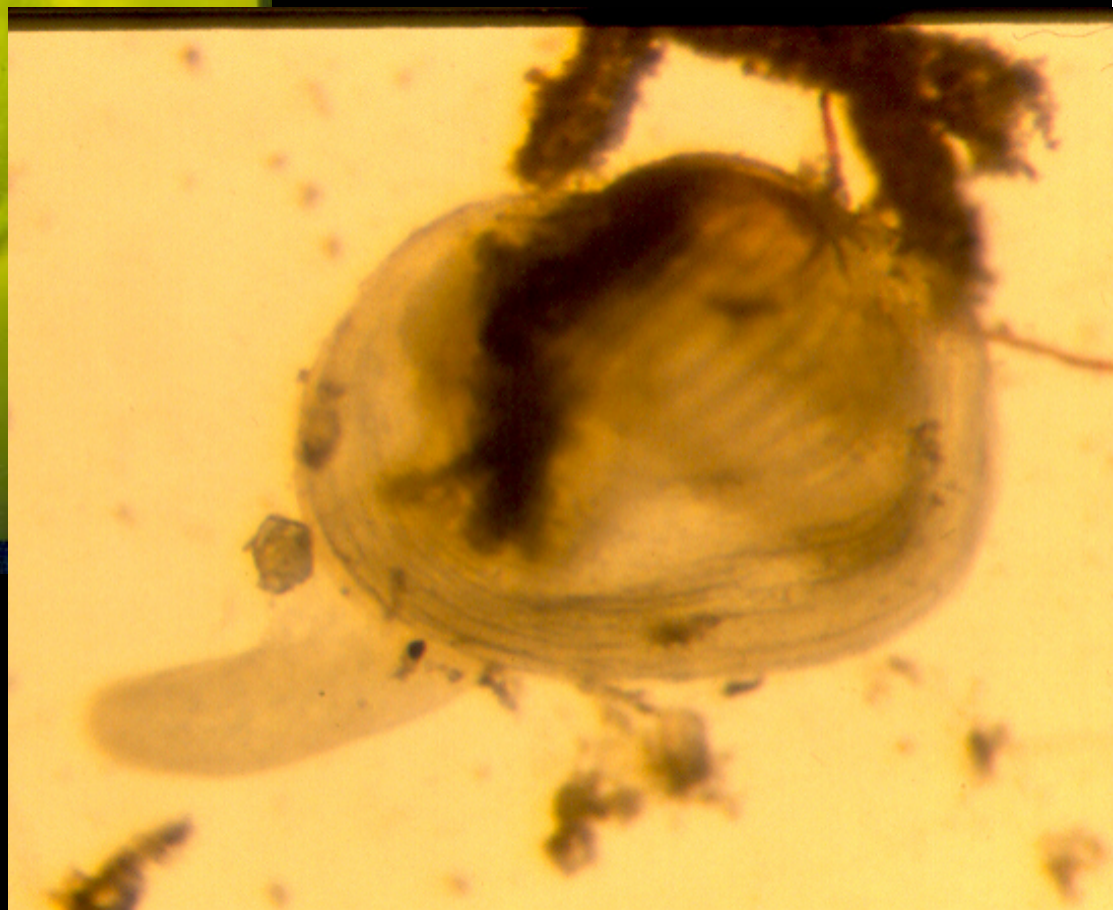
Egyptian Coptic saying.

Cobbles with Gills and Guts: Conserving Freshwater Mussel Beds and Water Quality.

Seminar Agenda

- Biology
- Why Do We Care?
- What Can We Do?
- What We Need to Know . . .
- What Do We Know?
- Challenges
- Opportunities……the FUTURE!!!





Why Do We Care?

- Biodiversity

72% imperiled

(E, T, SC)

43.2 % T and E

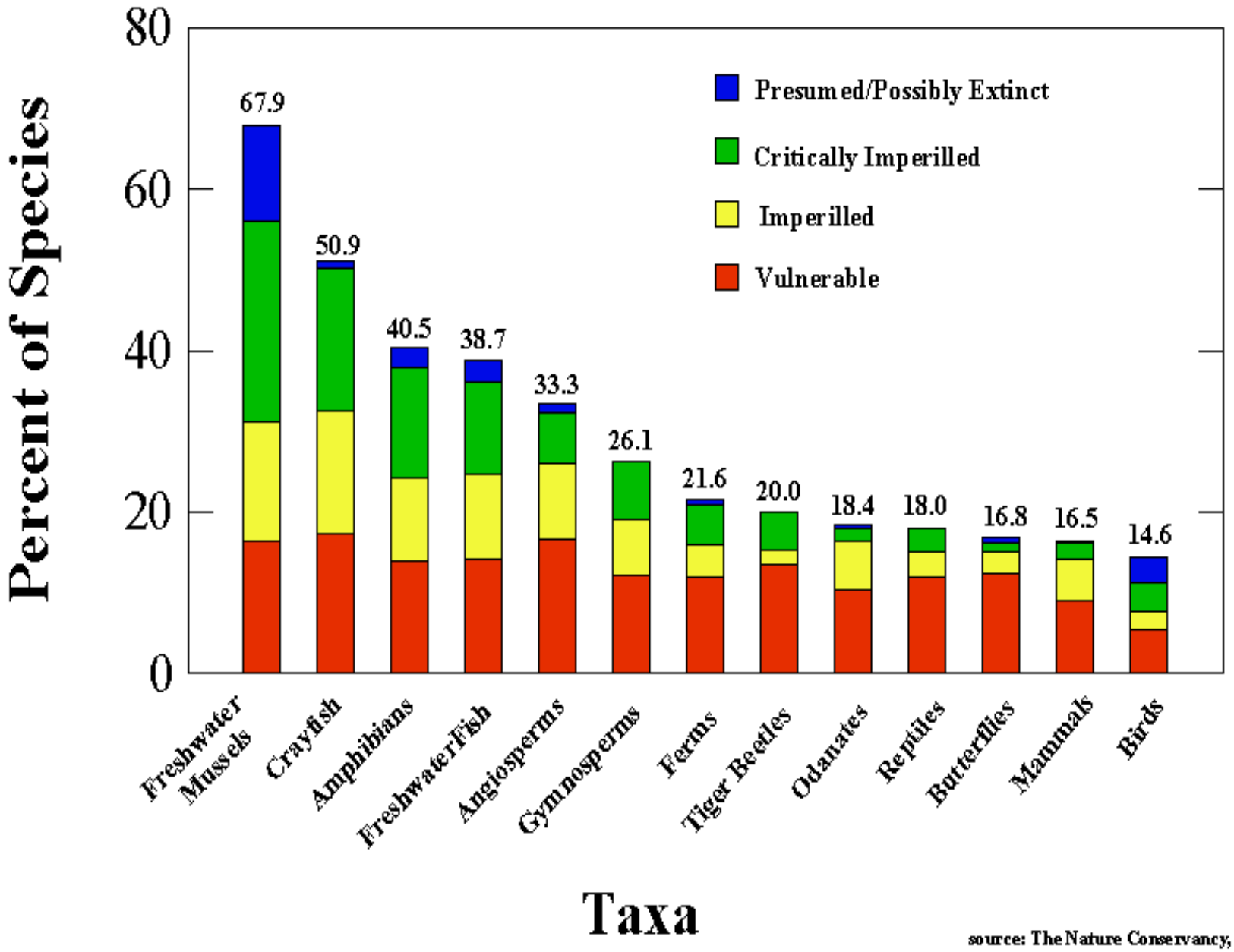
27.7 % End

7.1 % listed & possibly extinct

- **Largest diversity in the world**

  297 species in North America.

Conservation Status of United States Taxa



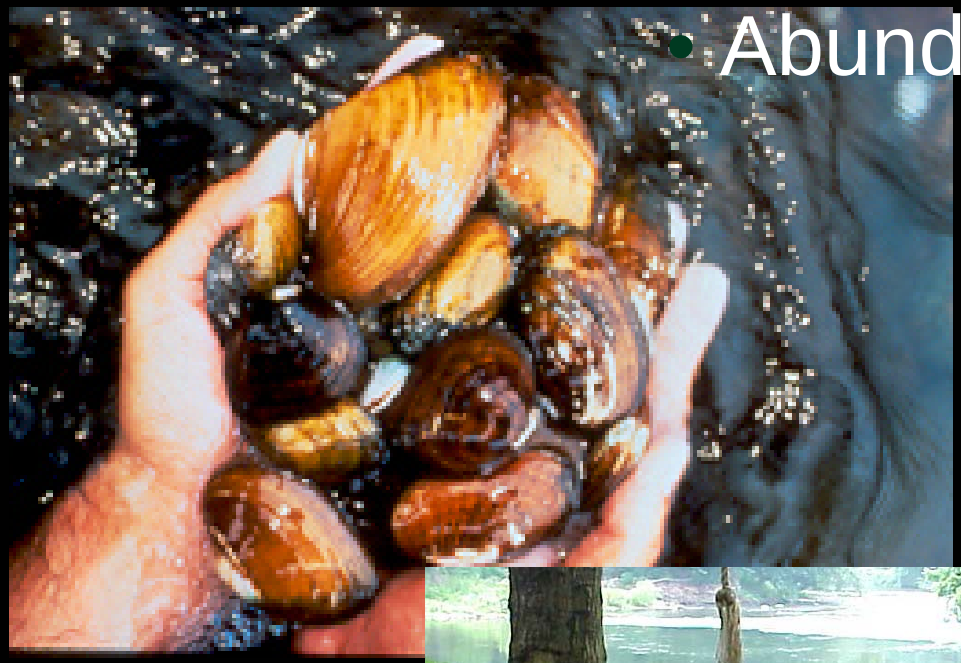
source: The Nature Conservancy, 1997

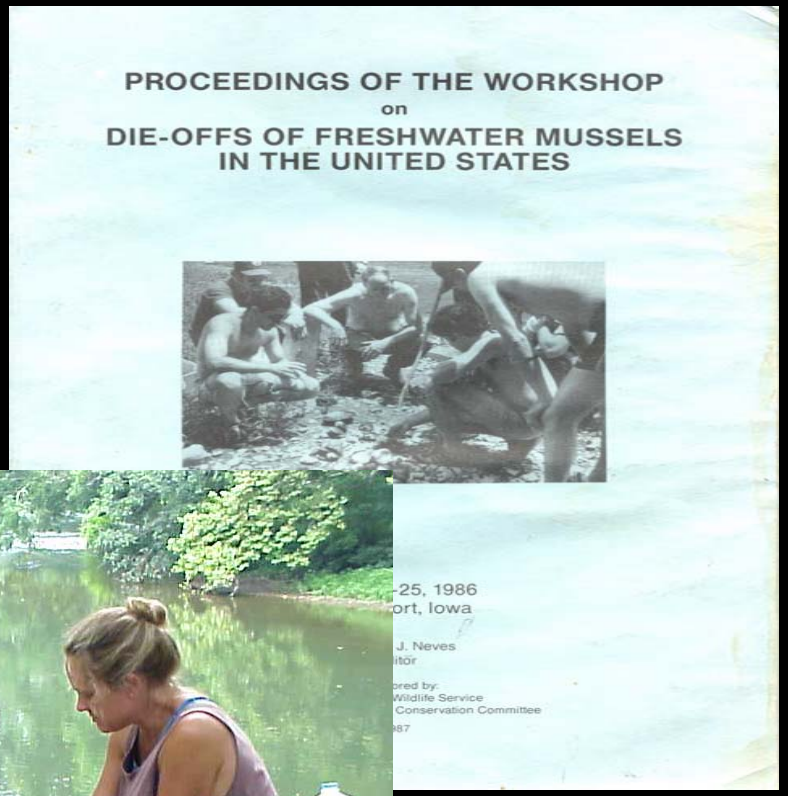
Why Do We Care?

- Economic Value

Why Do We Care?

- Abundance





Ecosystem Function

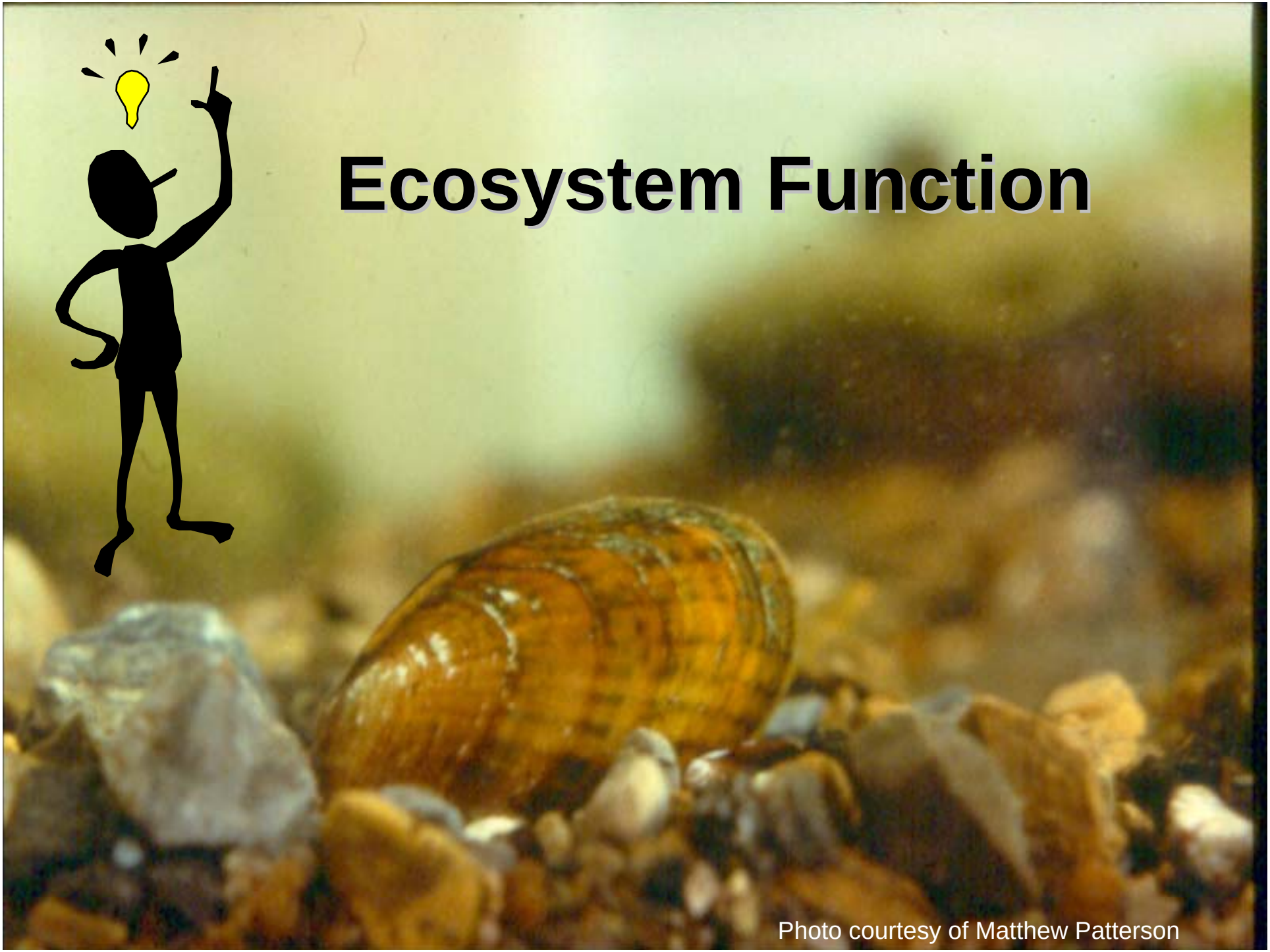
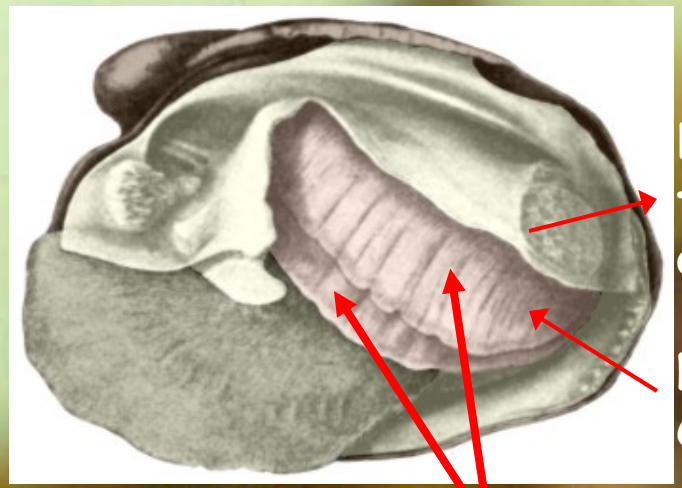


Photo courtesy of Matthew Patterson

Ecosystem Function

- Water Quality
- Riverbed Stability
- Ecosystem Stability



Biotrans-formation of CPOM

Nutrient Cycling

Ctenidia pump large amounts of water

Shells 'R' Habitat

Bioturbation - O_2 and H_2O content

In a reach of river 200 yards long
(e.g.two football fields),
A bed of 100,000 freshwater mussels
Is filtering
30,000 gallons of water per day
FOR FREE!!!
No electricity, no fancy filters, no scrubbers,
no chemical treatments.

Culprits

•Water Quality

- Habitat Degradation and Habitat Loss

- Exotic Species

What Can We Do?

- Culture and Propagation –
  - Augmentation or Stock Enhancement and Species Preservation.
  - Identify populations needing immediate attention.
  - Field surveys.
- Salvage and Refuge of T&E sp.
- Propagation of Commercial Sp.- pearls.
- Stream Habitat Restoration.

What We Know ...

Figure courtesy of Dan Graf

The Unionoida is unique among bivalves in that the larvae are parasitic.

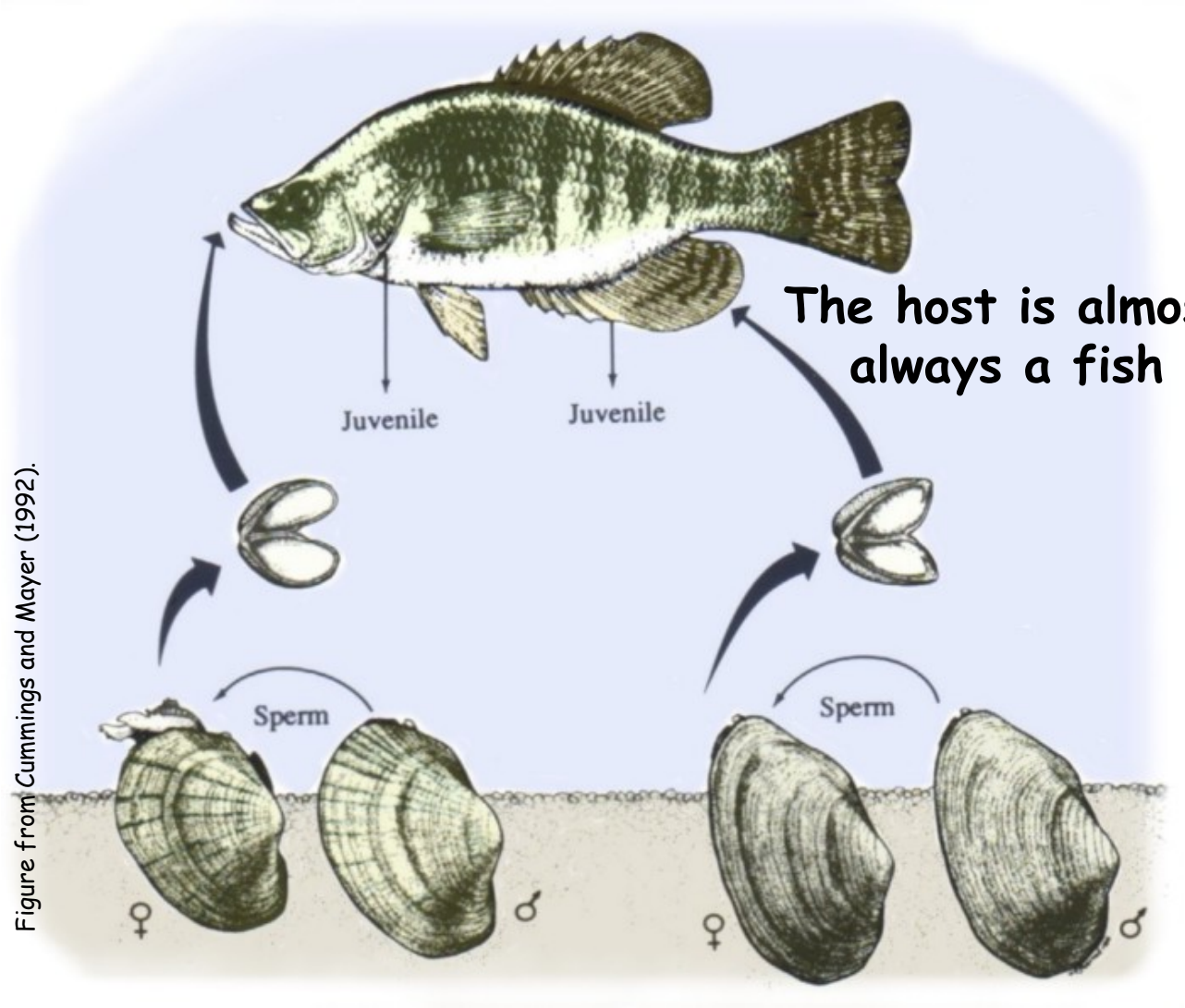
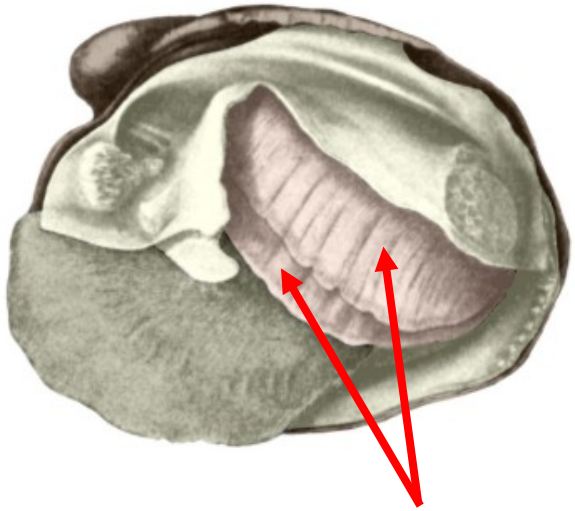


Figure from Cummings and Mayer (1992).

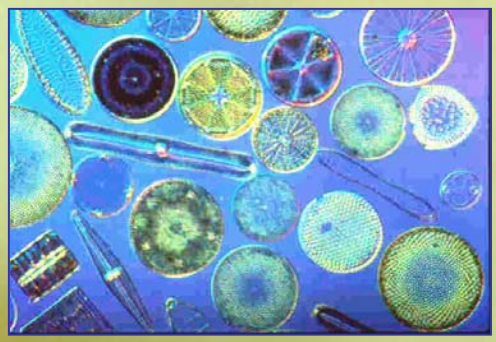
The host is almost always a fish

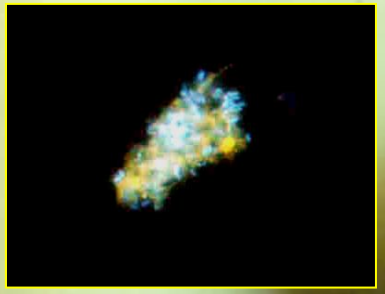


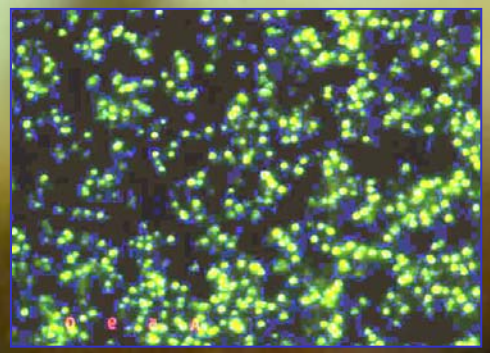
Larvae are brooded in the ctenidia

So…
mussels are typical of freshwater bivalves in that they exhibit parental care

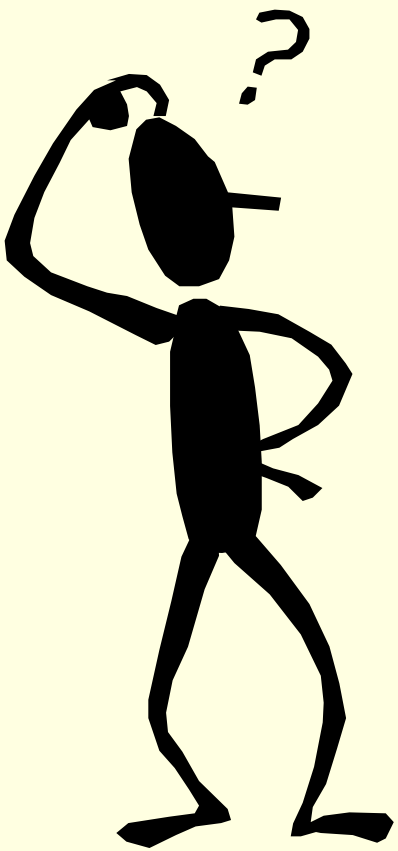
The Suspension-Feeder Diet







What Do We Need To Know?

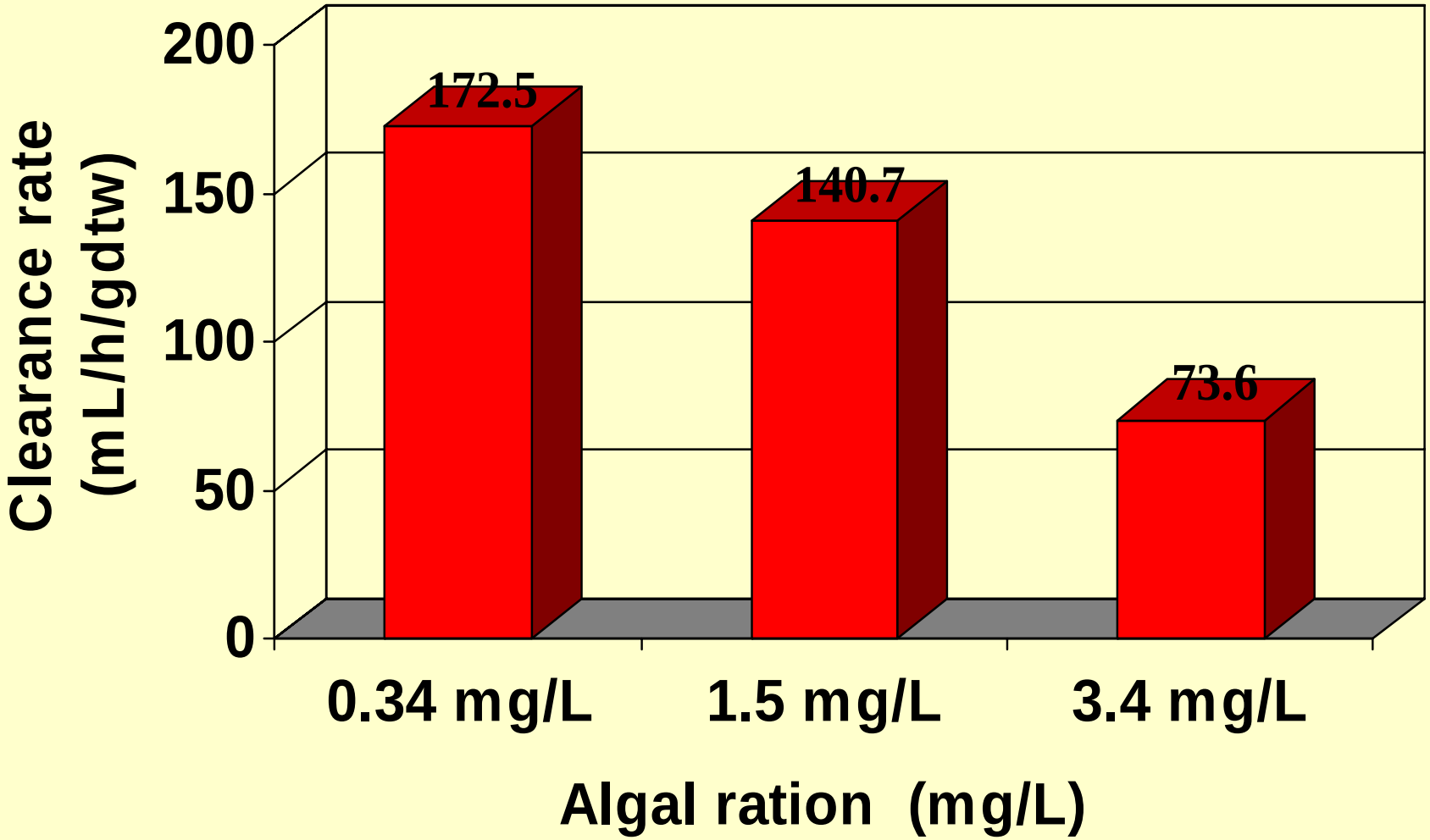


- Aquaculture Requirements.
  - How do we hold them?
  - What, How Much, and How Often?
  - Multispecies Management
- Habitat Requirements.
- Ecological Function, Role in Maintaining Water Quality.

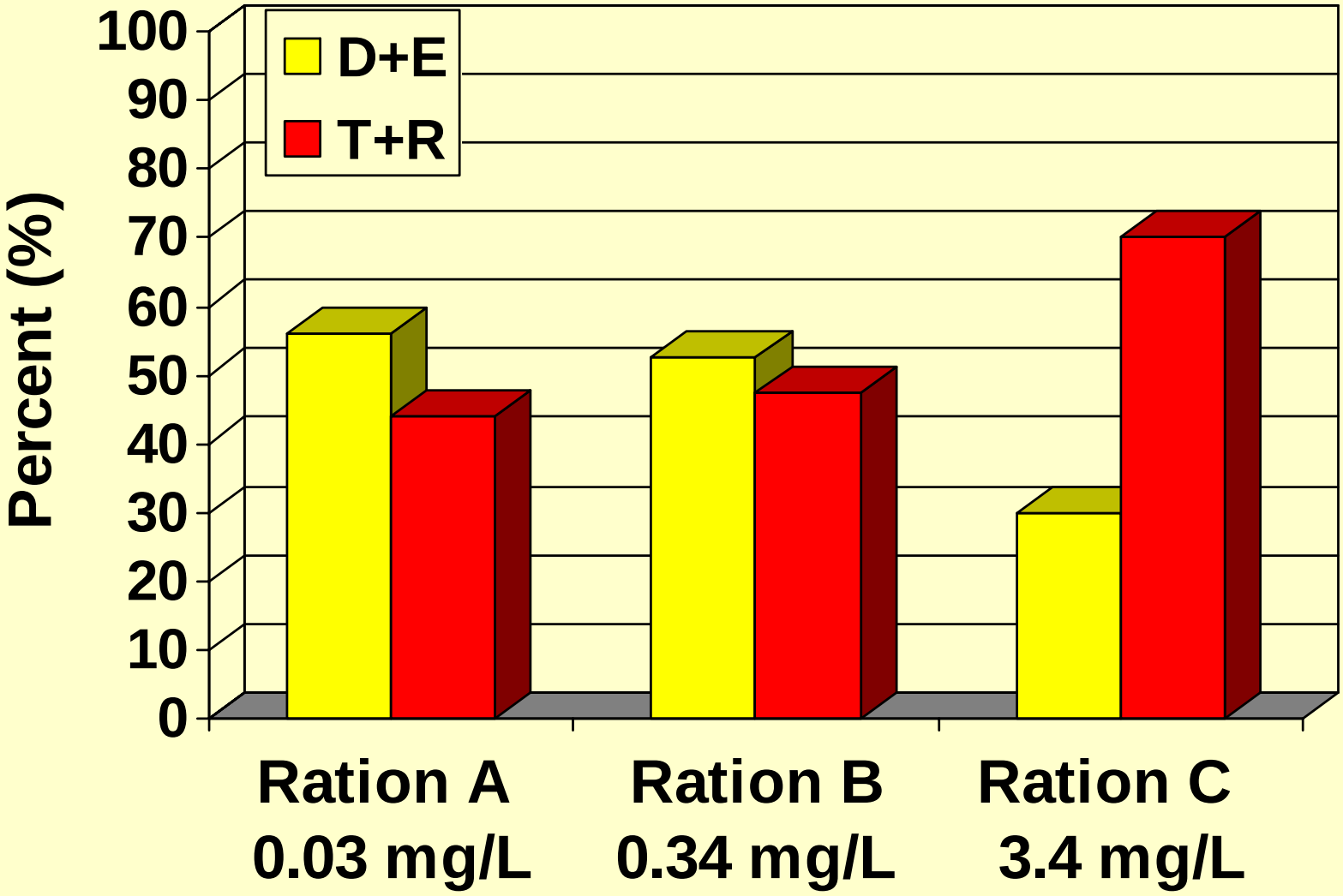
Challenges to Captive Care: Diet Suitability

- **Food Quantity - mg/L**
  - **Rate Functions -i.e. clearance, consumption, excretion, defecation.**
- **Food Quality**
  - **Physical - particle size, type**
  - **Biological**
    - **biochemical composition**
    - **caloric - energy value**
    - λ **Seasonal nutritional demands.**
    - λ **Scope for Growth.**

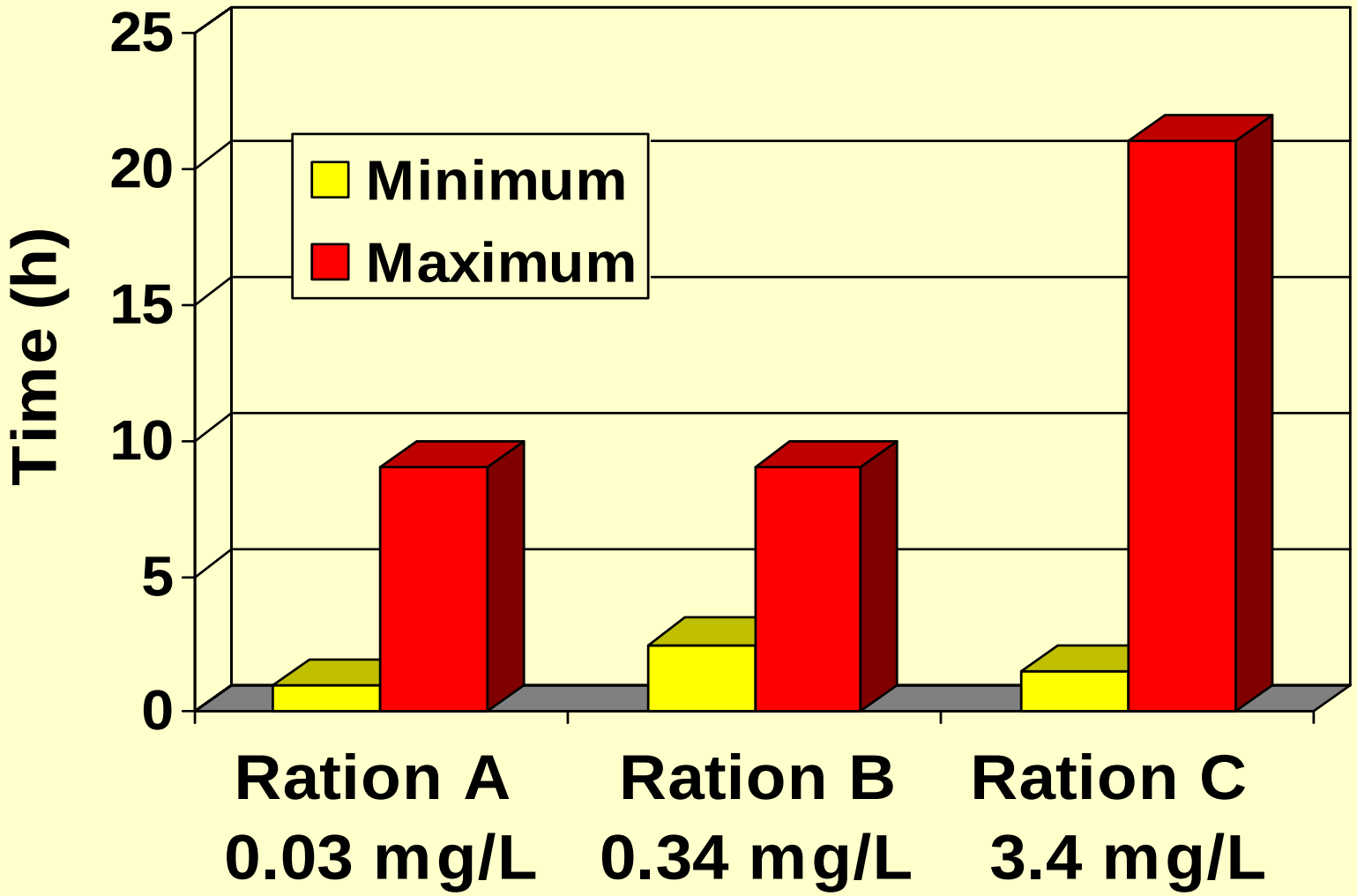
Effect of algal ration on mean clearance rate in *Villosa iris*



Assimilation efficiency in *Villosa iris* fed three rations of algae



Gut passage and gut purge time in *Villosa iris* fed three rations of algae



PUMPER System

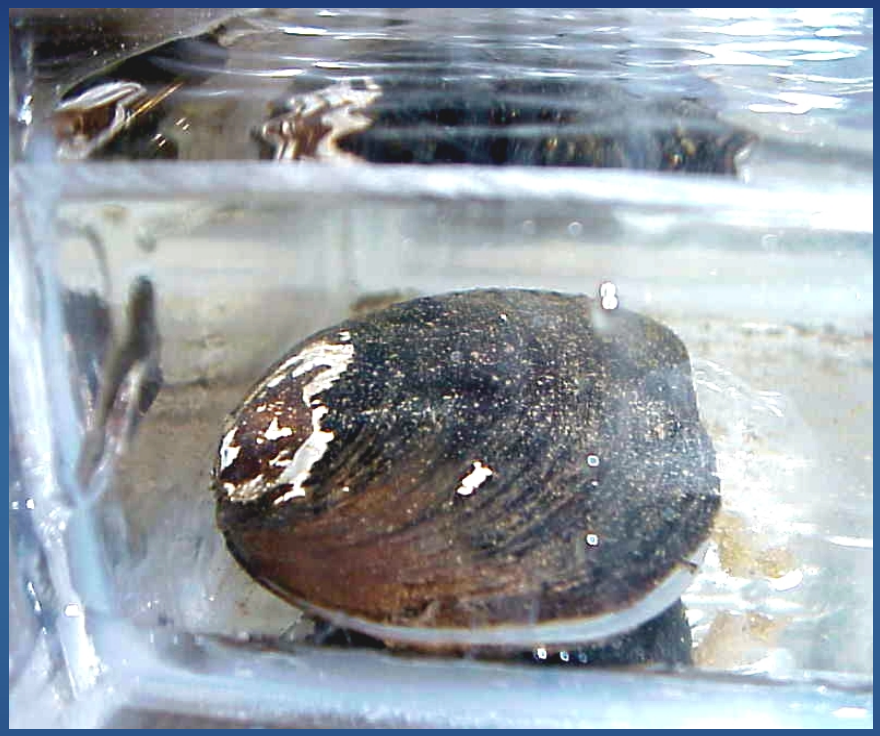
- Continuous-Flow-Through System
- 4, 100 L reservoir tanks
- 4, 20 L header tanks
- 40, 2 L test chambers

Questions

What is the effect of sediment on the clearance rate (CR) of mussels?

What particle size do mussels clear most efficiently?

Elliptio complanata



No Sediment

- seston

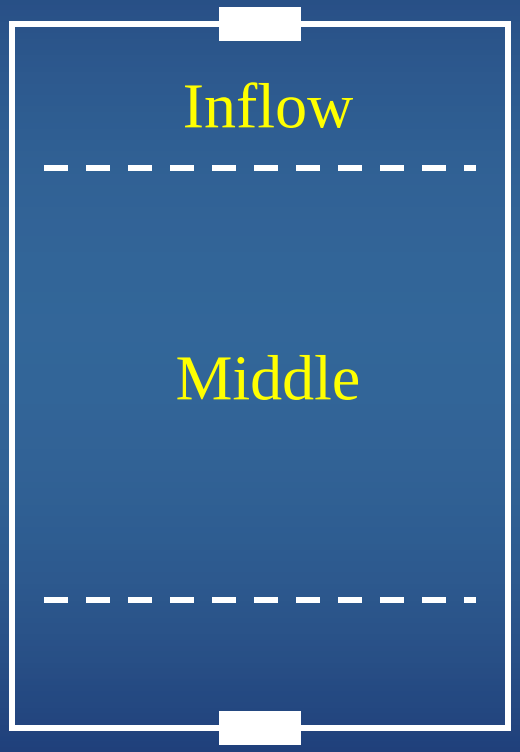
Sediment

- seston
- algae

Mussel chambers

water

air

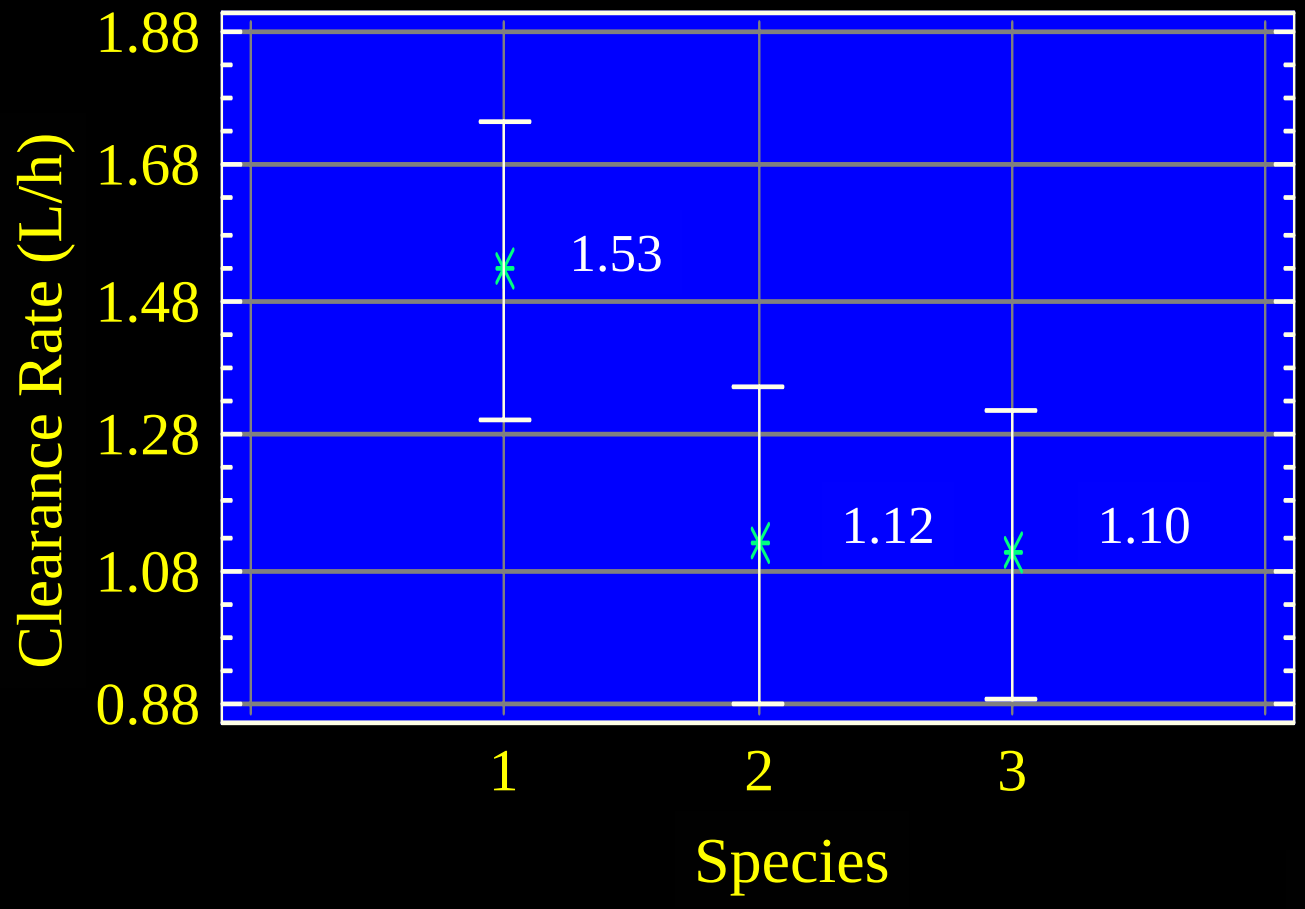


Mean CR of unionids held for 29d on four different feeding treatments

Treatment	CR (L/h)	SE	p-value
1	1.8	0.37	0.84 diet
2	2.3	0.37	
3	2.0	0.36	0.53 day
4	1.7	0.45	

1 = Seston
2 = Seston,NO SUBSTRATE
3 = 0.5 pt Seston/ 0.5 pt Algae
4 = Algae

Mean Clearance Rate of Mussels in the Allegheny River (Afternoon)

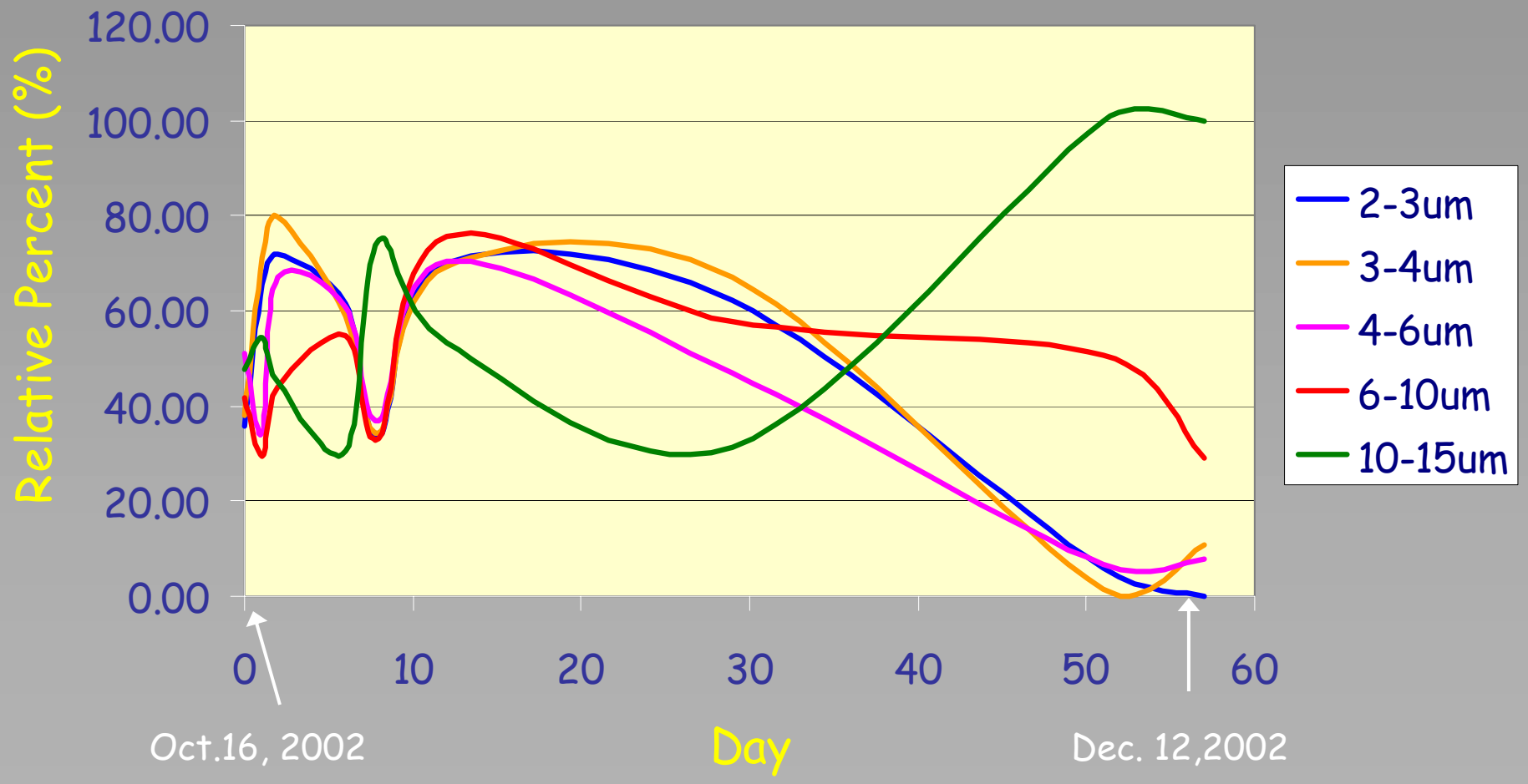


1=A.ligmentina
2= E. dilatata
3= L. costata

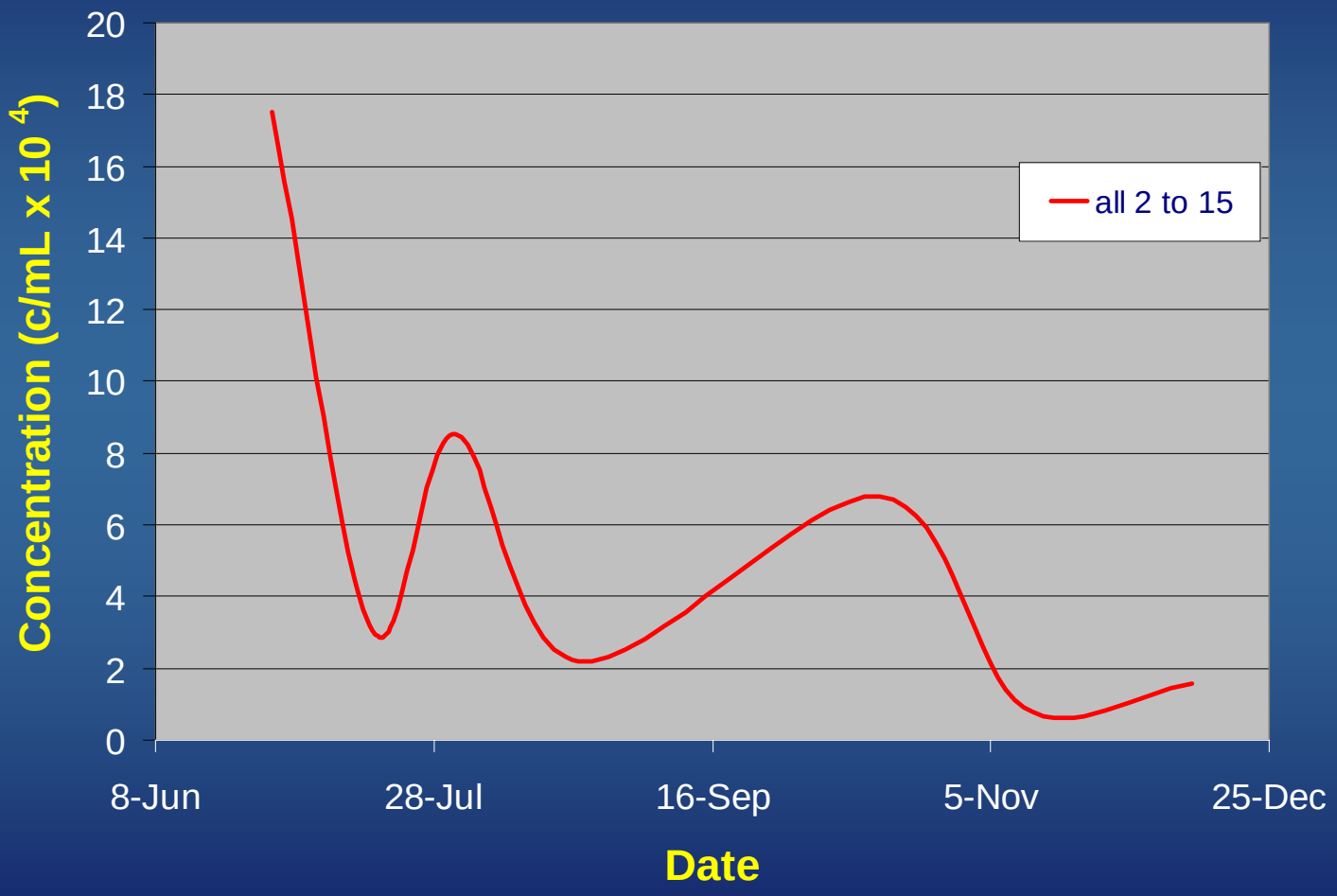
p=0.23 Spp
0.50 Test

CR #2
CR #3

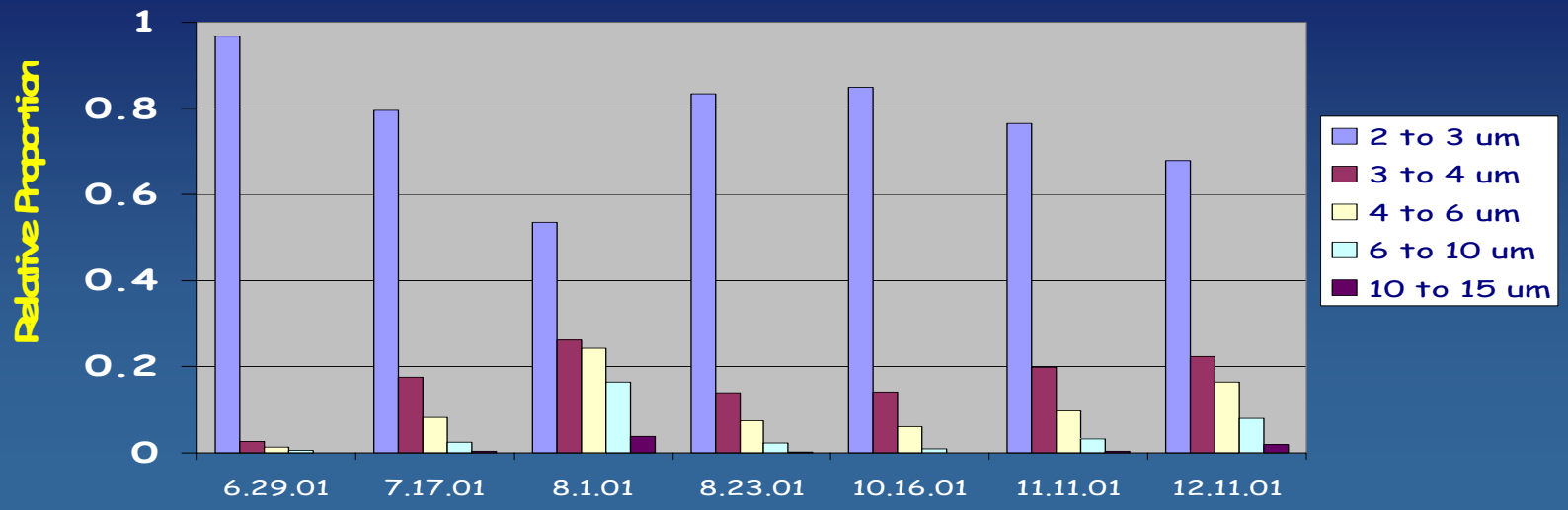
Filtration Efficiency for Various Particle Sizes Over Time by Elliptio complanata



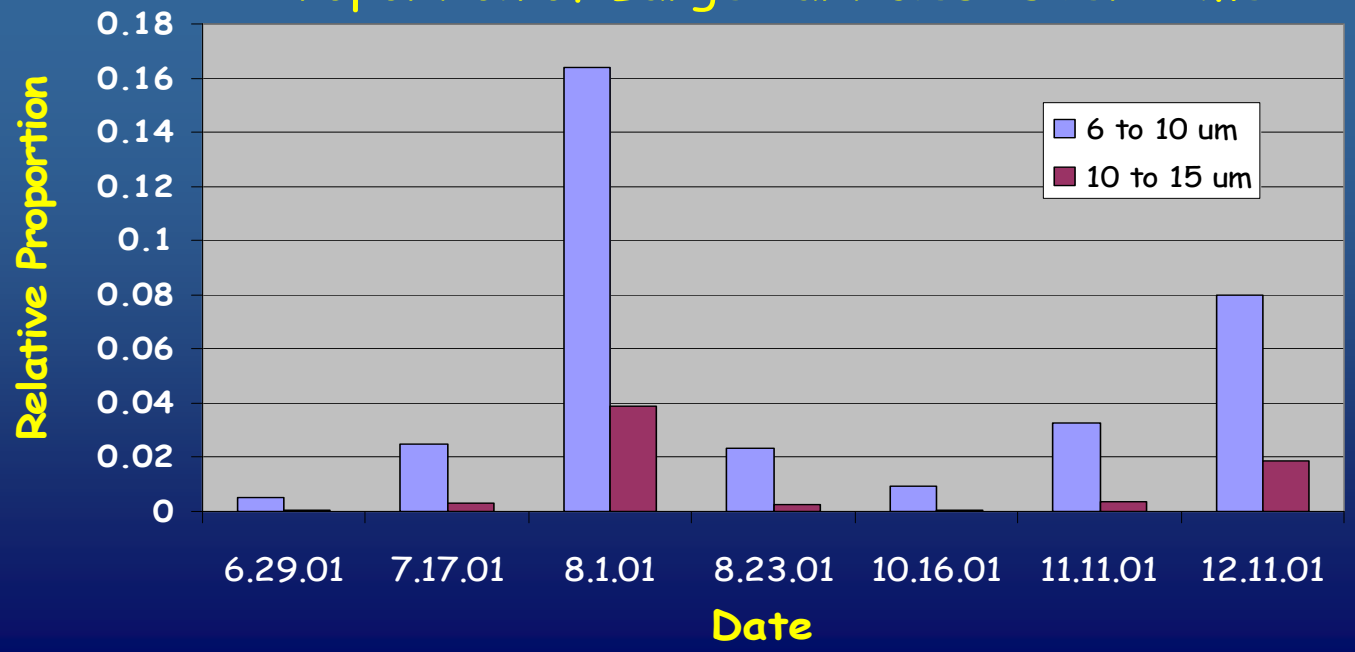
Seston Concentration in the Brandywine River from June through December, 2001



Proportion of Particle Size Categories in the Brandywine River Seston Over Time



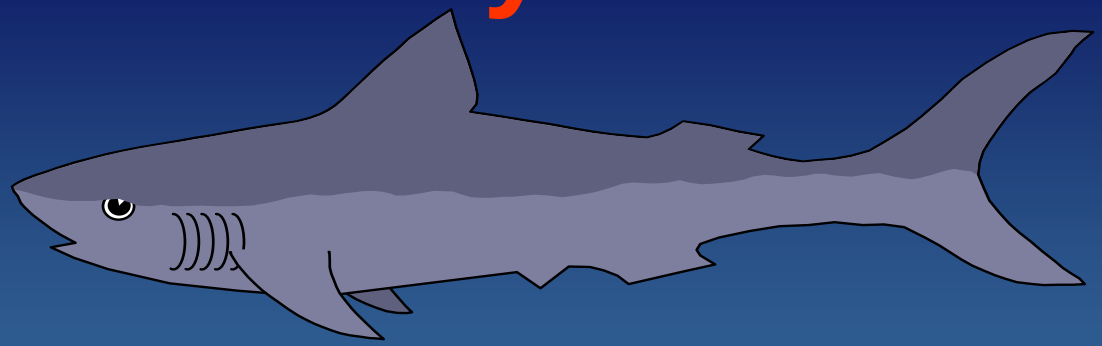
Proportion of Large Particles Over Time



QUALITY

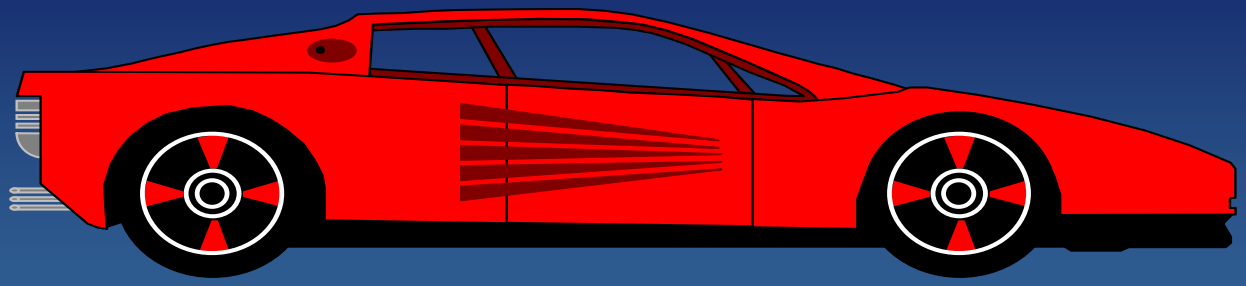
- **Successful growth and development of cultured species depends to a large extent on the nutritional value of the feed provided.**
- **If quantity does not limit growth, then quality is of increased importance in maintaining health of captive animals.**

Dietary Protein



- Critical for maintaining condition and breeding success of cichlid fishes.
- Very important to marine mussels undergoing reproductive development (Kreeger 1993).
- Greatest effect on growth in juvenile hard clams; however, lipid had to be sufficient to support rapid growth.
- Important for tissue growth and maintenance in adults (Hawkins and Bayne 1991).

Dietary Carbohydrate

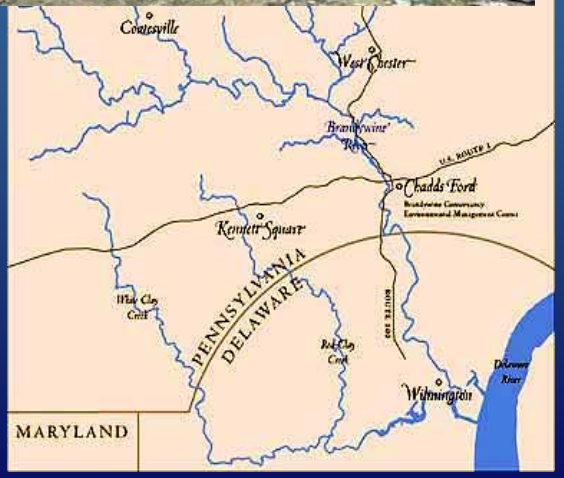


- **Primary energy source for adults**
  - **immediate use in respiration**
  - **long-term storage as fuel for over-wintering and subsequent gametogenesis.**
  - **glycogen ~ 40-50% of CHO.**
- **Energy source for juveniles, however,**
  - **High CHO diet was of little use to juvenile oysters and adult mussels when protein became limiting.**

Dietary Lipids

- **Bivalves have limited abilities in**
  - **FA elongation to UFA**
  - **Synthesis of cholesterol.**
- **Dietary requirement for sterols and fa PUFA's.**
- **Synthesis, transport, and regulation of hormones.**
- **Membrane function .**
- **Energy storage compounds - triglycerides.**
  - **Important for developing larvae and growing juveniles.**

Brandywine River, PA



Allegheny River, Foxburg, PA

New River, Hinton, VA

Sampling Periods

- 30 mussels / sp. /sample in Allegheny & Brandywine R. , 1 year.
- 6 mussels/sp./sample in New R., 2 y.

Kreeger and Langdon, 1993

Breeding Strategies

- Short-term:
  - spawn April-**May**,
  - brood glochidia May-July,
  - release glochidia Jun-Aug.
- Long-term:
  - spawn July,
  - brood glochidia Sep-April,
  - release glochidia April-Jun.

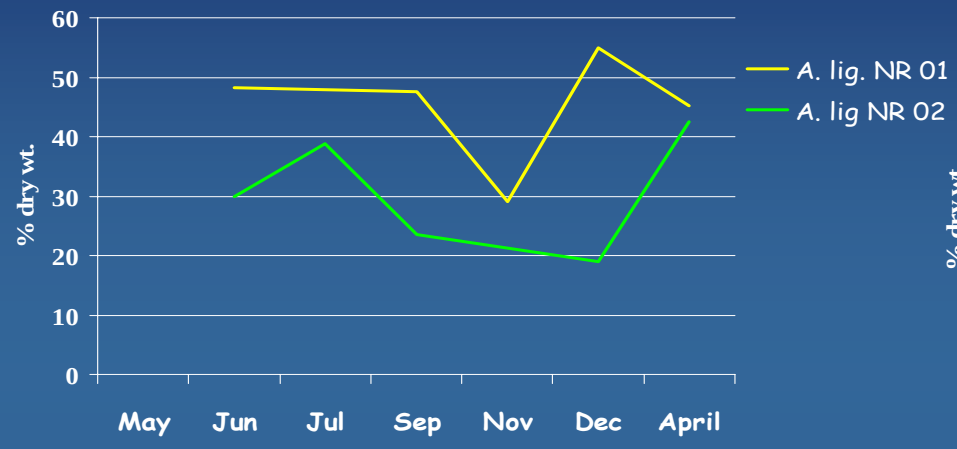
Ambleminae*: Elliptio complanata, E. dilatata, Cyclonaias tubercultata*

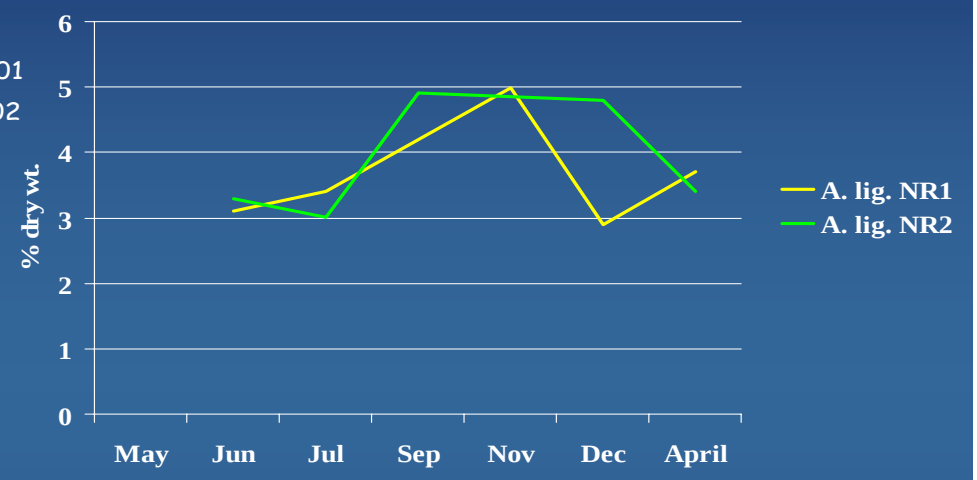
Anodontinae*, Lasmigona costata*

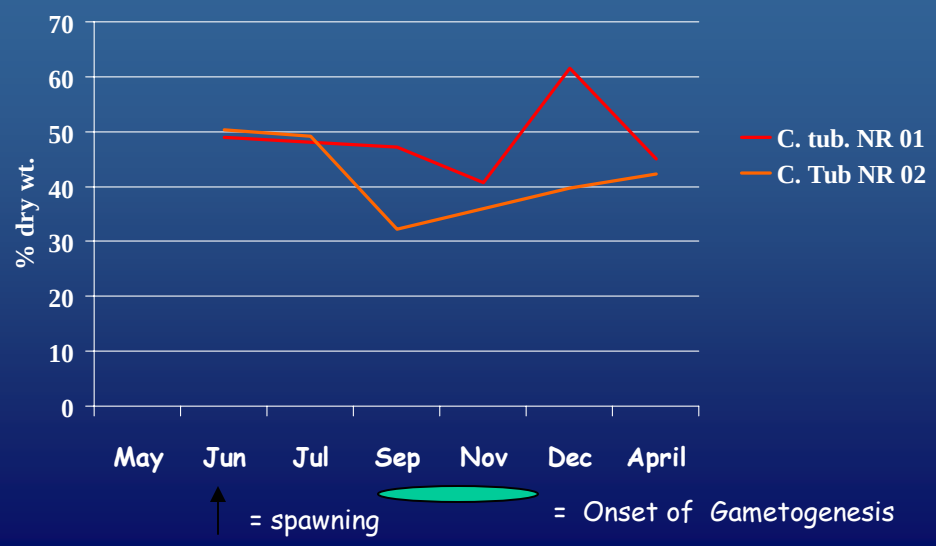
Lampsilinae*, Actinonaias ligamentina*

Seasonal variation in energy substrates:
long vs. short term brooders

Carbohydrate New River, VA **Lipids**





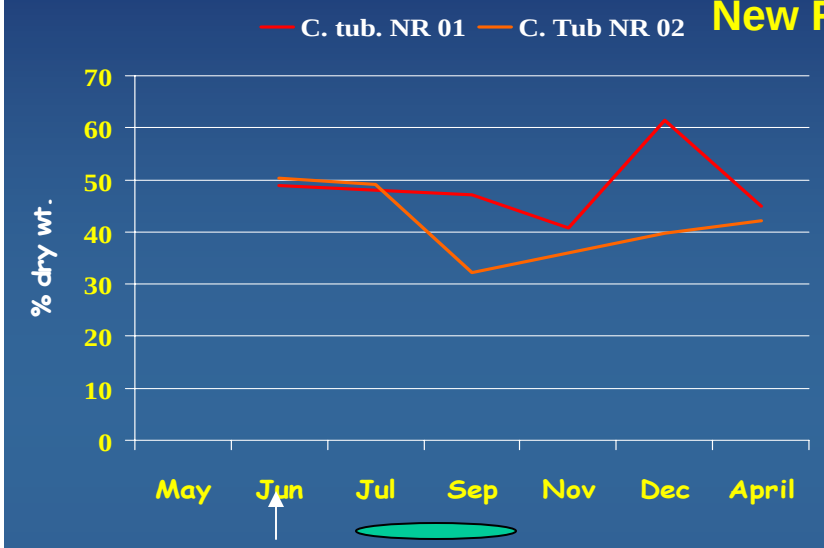


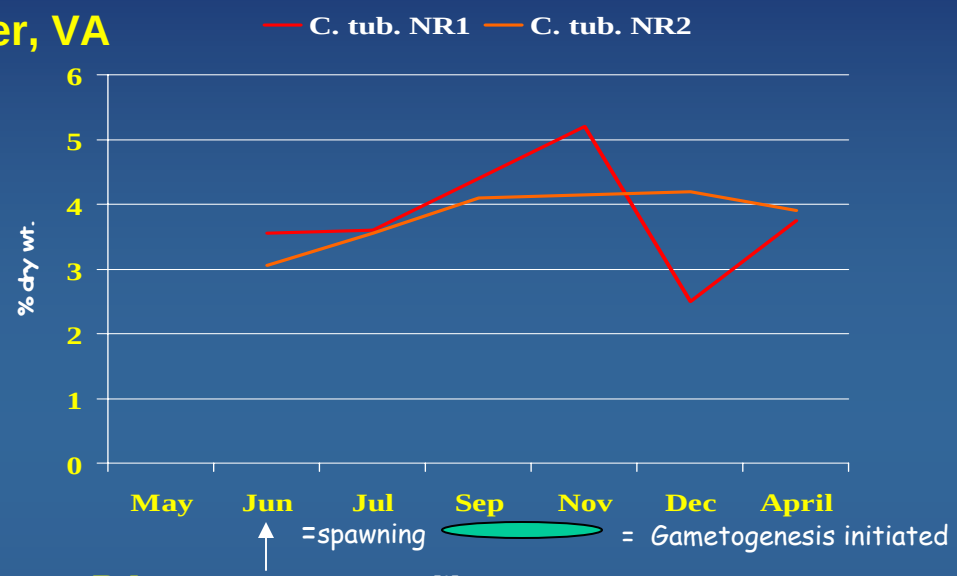
Seasonal variation in energy substrates: short term brooders

Carbohydrate

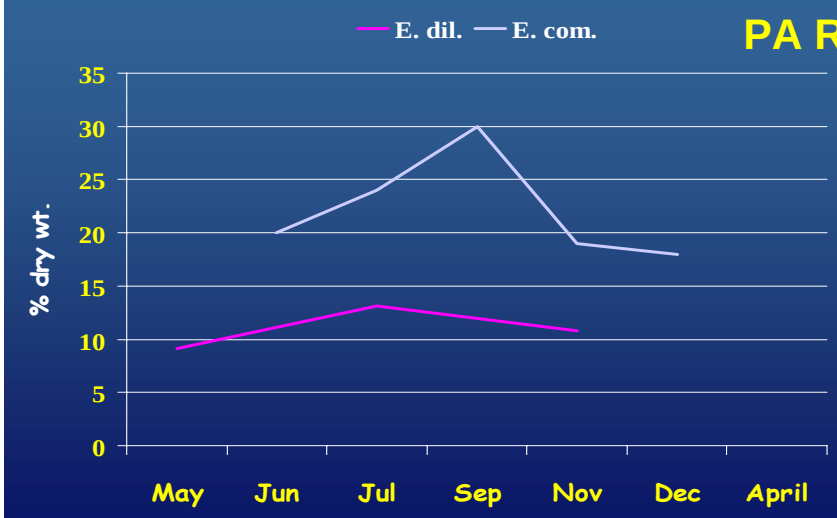
Lipids

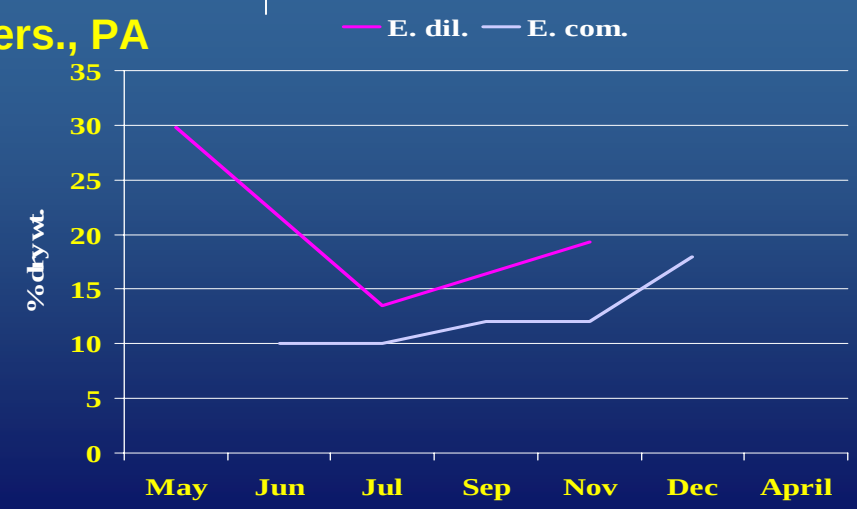
New River, VA





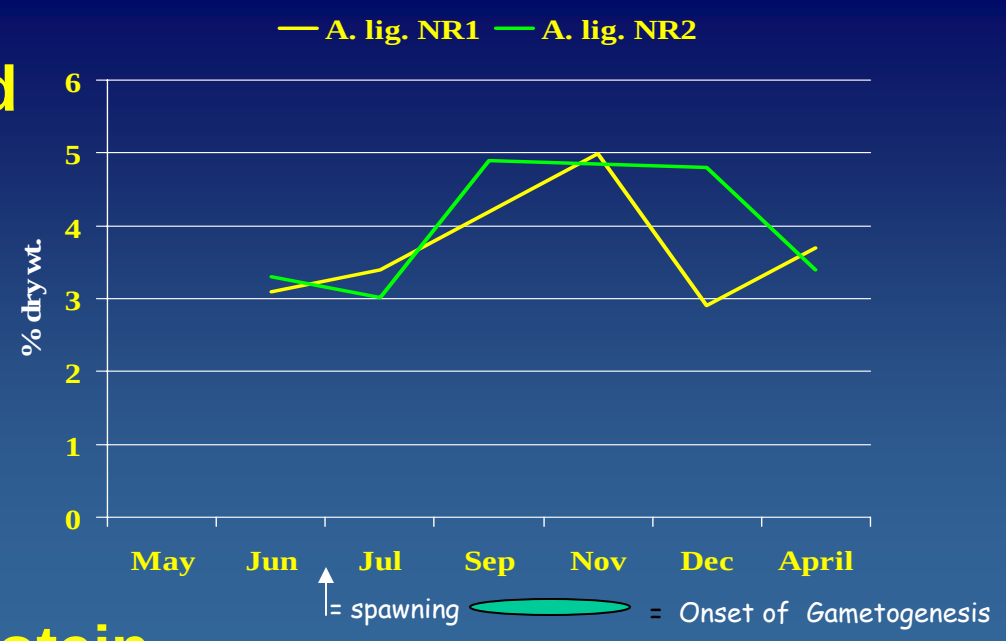
PA Rivers., PA



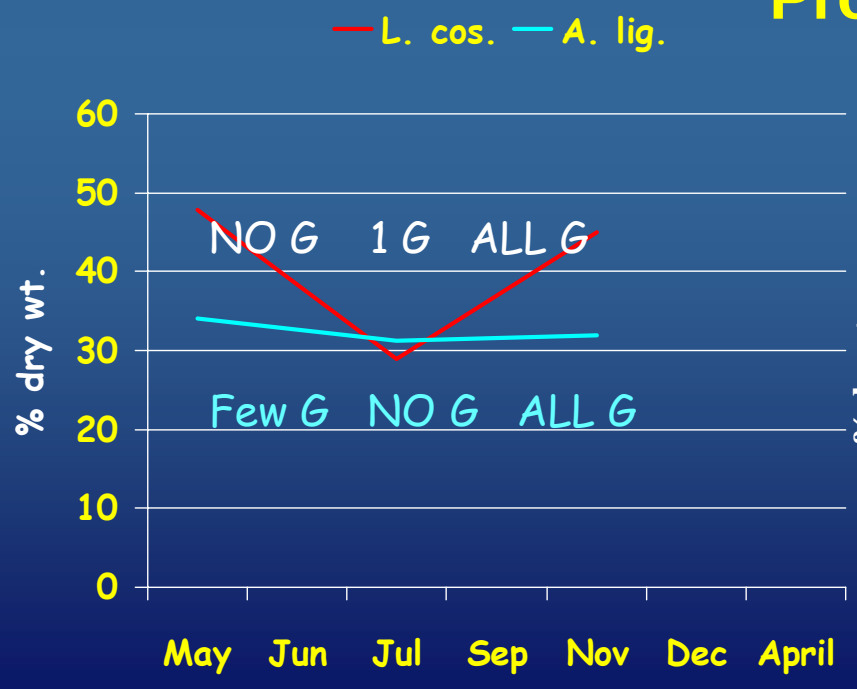


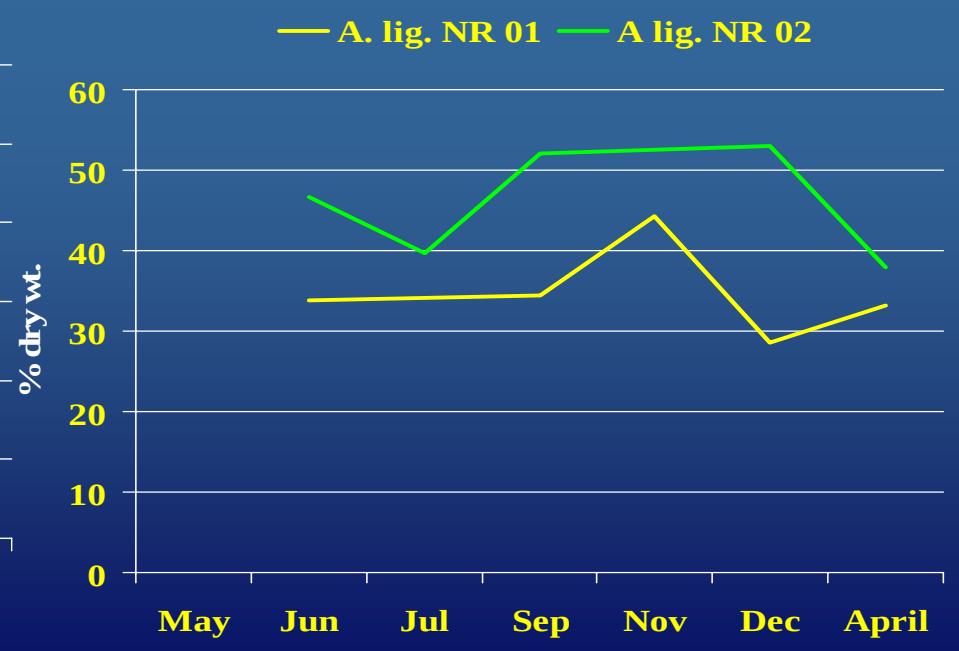
Seasonal variation in lipid and protein content: long term brooders, New River

Lipid

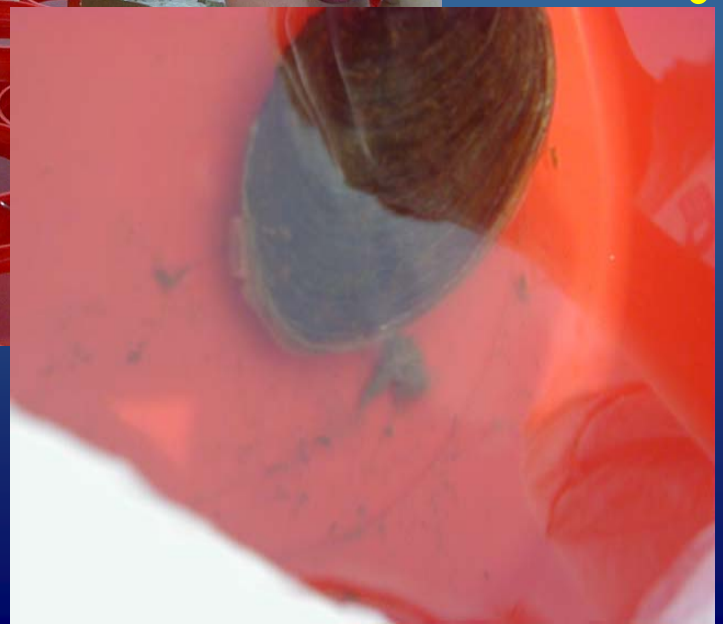


Protein





Mean Absorption Efficiency (%): Mussels fed natural river seston.



- A. ligamentina = 60.0 ± 5.0
- E. dilatata = 63.0 ± 4.0
- L. costata = 66.5 ± 4.0

  p=0.5

E. complanata = 75 ± 7.8

Discussion

- Seasonal timing and relative changes in BIOCHEM different between River systems.
  - Protein and lipid varied more than carbohydrate in mussels from the Allegheny River.
  - CHO may play a role in over-wintering conditioning in mussels in the New R. Whereas, lipids may play a more seasonal role in over-wntering, as well as gametogenesis and spawning in the New R.
- Lipid and PRO showed similar seasonal trends.
  - Increased in Fall - onset of **gametogenesis**, Declined in winter- quiessence, Increase in spring followed by sharp decline post- **spawning**.
- As lipid (and protein) increased, CHO decreased.
- Long-term brooders may be considered dabblers.

Conclusions

- Until empirical data become available, a diet high in protein and lipid is recommended for all mussels, especially in the Fall.
- Carbohydrates, however, should not be ignored. Indeed, carbohydrate may be linked to late summer conditioning in some short-term brooders.
- We recommend the following diet for captive freshwater mussel: ~10-15% carbohydrate, ~20-40% protein, ~30% lipid, and ash ~ 20%.
- Focus on identifying seasonal patterns to enable the development of “smart” diets that will maintain fitness of brood stock and the progeny.
- Consider base feeding level of **1-1.5 mg/L or 20, 000 c/mL.**

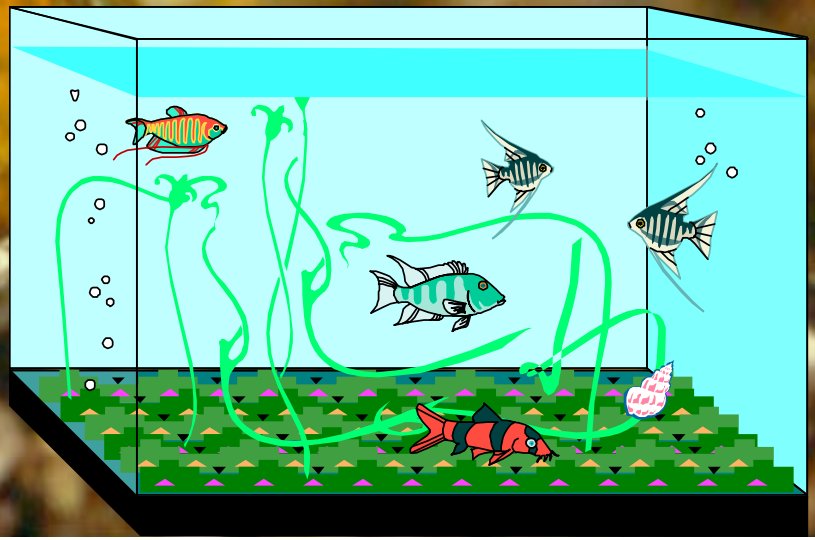
Challenges to Propagation: Fish Host

What is it?

How do we hold it?

How do we maintain disease-free brood stock stations?

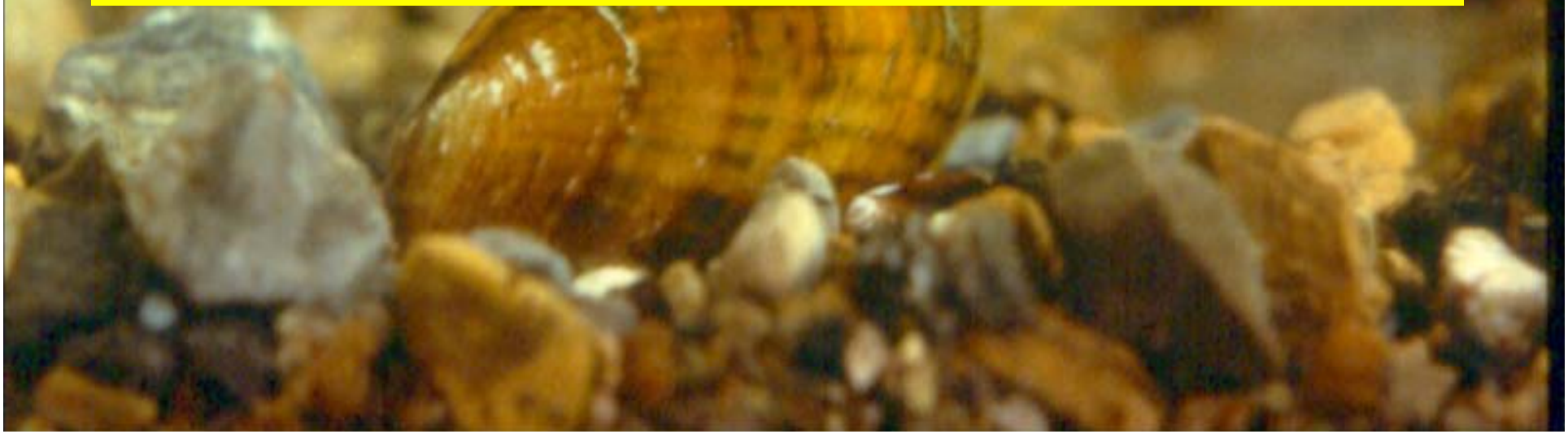
Other contamination issues?



Challenges to Reintroduction

Genetics!!!

- **Source Population.**
- **Where and which source population.**
- **Is it really a species?**
  - ***Lexingtonia subplana*, Virginia pigtoe.**
  - **Occurs only in VA . . .hmmmm.**



Challenges to Reintroduction:

- **Who Wants An Endangered Species?**

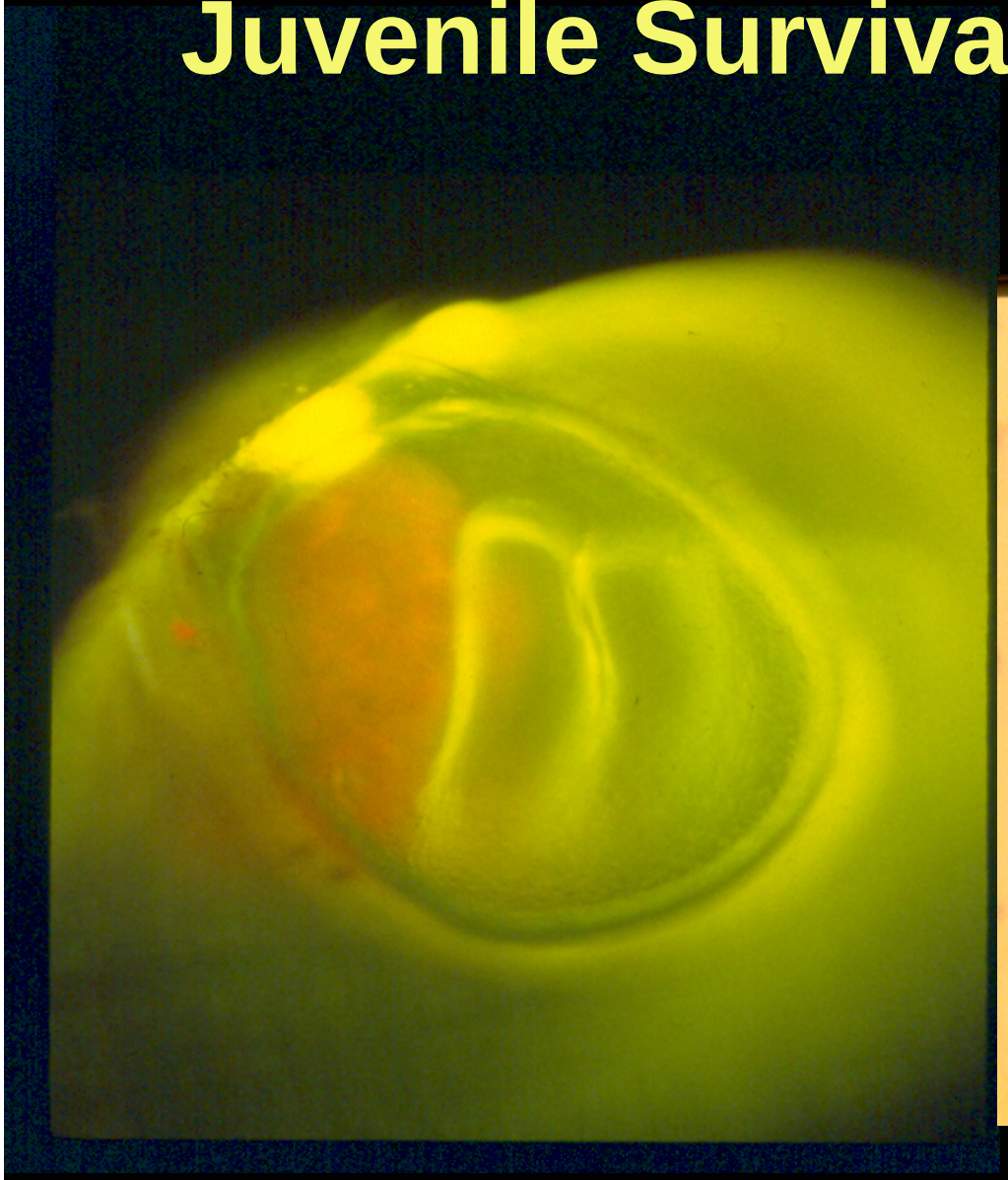
…. in their backyard ….

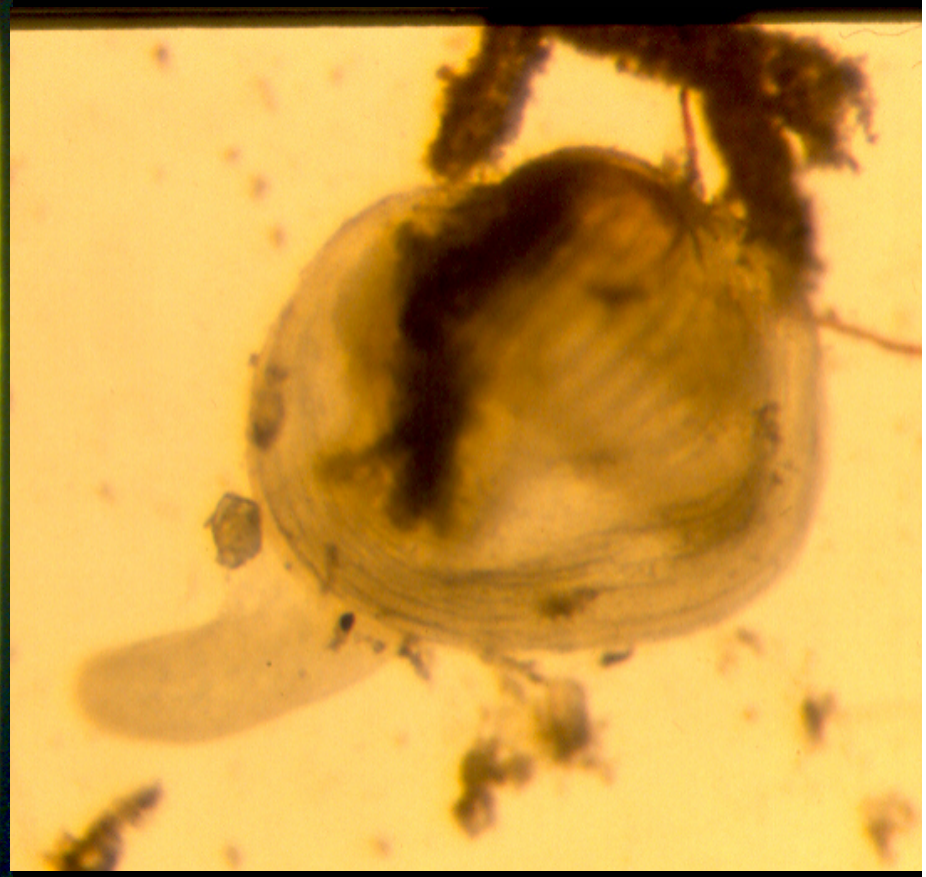
The Juggling Act

- Begin setting the stage –
  - ES-USFWS, State, others …
- Identify species in need.
- Identify Interest Groups . . .
  and priorities.
- Identify reintroduction sites.
- Identify source populations.
- On the ground working with the public. . . . OUTREACH.

Challenge . . .

Juvenile Survival Bottleneck





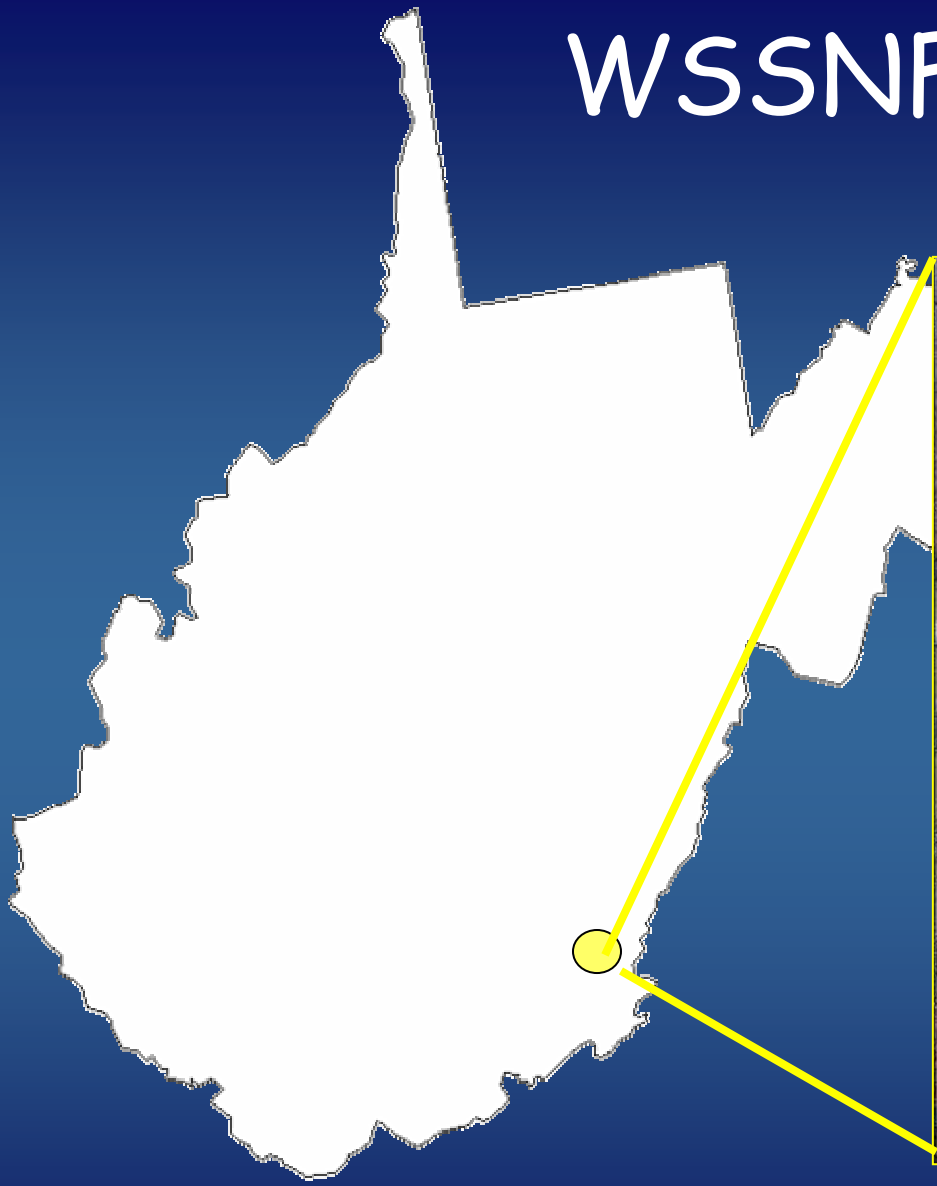
OPPORTUNITIES

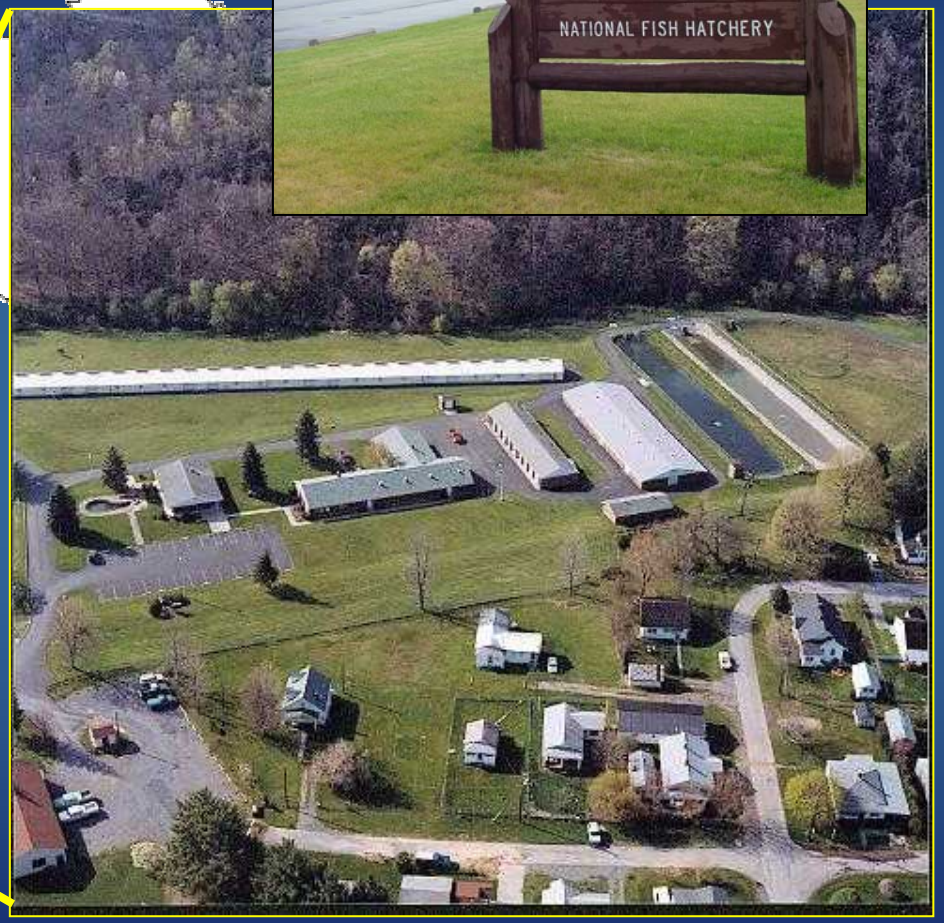
- CLEAN WATER!
  - Restore mussels = Restore streams.
  - Species Preservation and Restoration
- National Collaborations - Regions.
- International Collaboration.
- NGO Conservation Partnerships .
  - Raise Public Awareness.

OPPORTUNITIES

- **National and International Collaboration.**
  - ***Margaritifera falcata* - Species of concern. Disappearing at alarming rates on the west coast.**
  - ***Margaritifera margaratifera* - Disappearing at alarming rates throughout Europe. Ireland, Scotland interested in propagation.**
  - ***Cumberlandia monodonta* – Threatened. Mississippi drainage.**
  - ***Margaritifera auricularia* – was presumed extinct; population found in Spain; propagation program developing.**

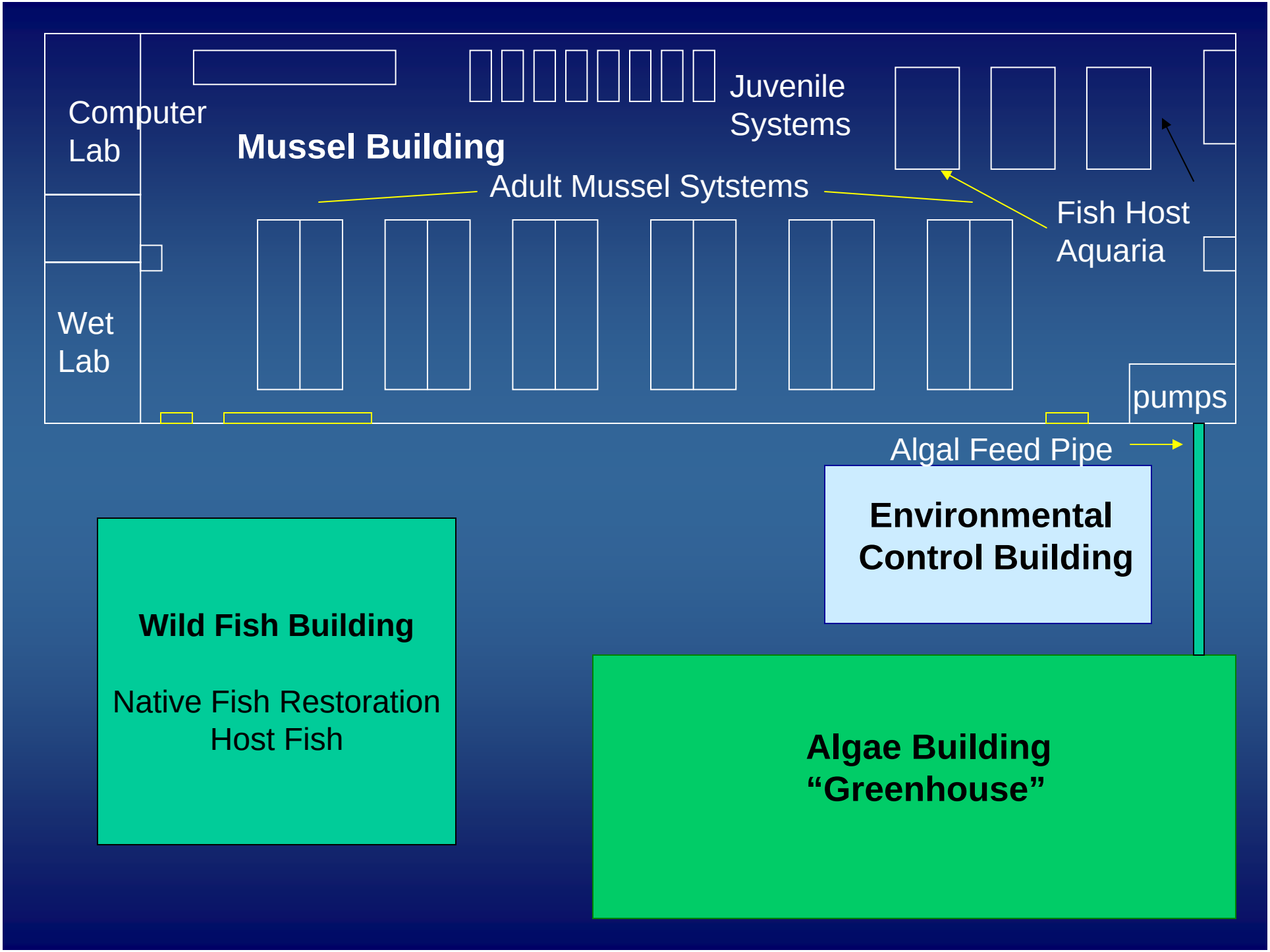
WSSNFH





Propagation: population augmentation and species preservation
Salvage and Refugia: adult holding and maintaining brood stock.

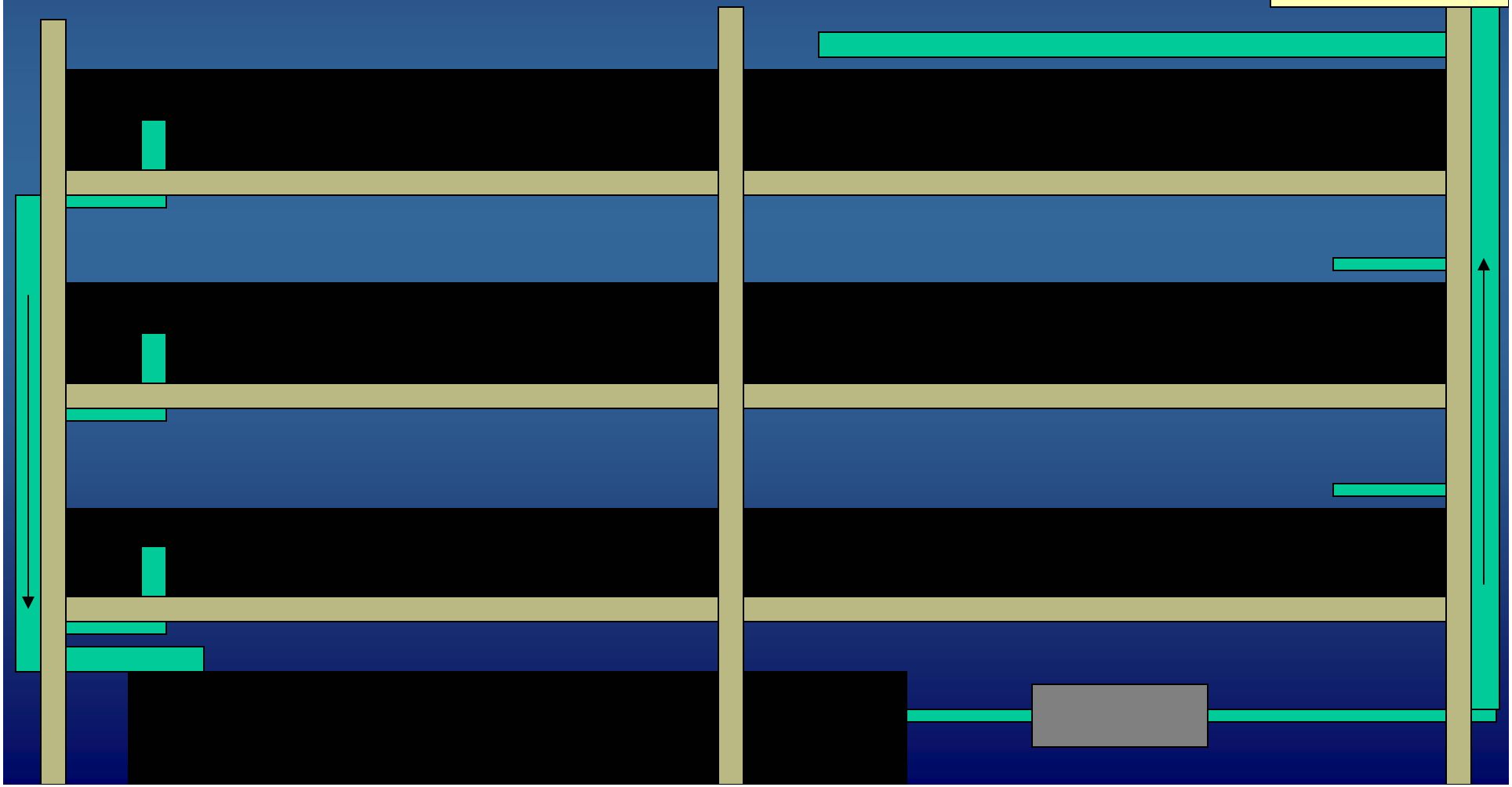
Imperiled Species Aquaculture Center


Computer Lab
Mussel Building
Juvenile Systems
Adult Mussel Sytstems
Fish Host Aquaria
Wet Lab
pumps
Algal Feed Pipe
Environmental Control Building
Wild Fish Building
Native Fish Restoration
Host Fish
Algae Building
"Greenhouse"

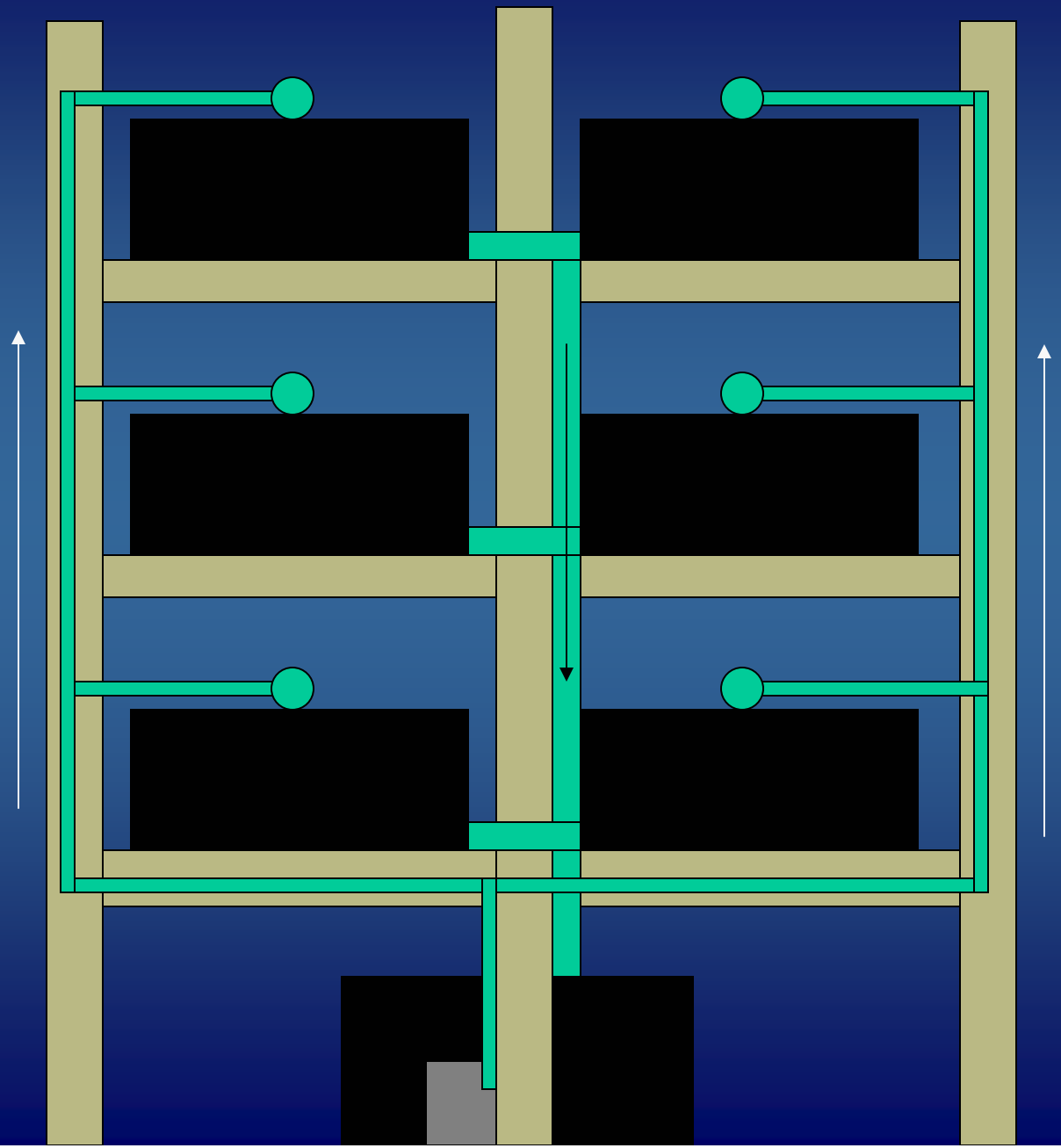
Bunkbeds for Bivalves

Freshwater Mussel Culture System

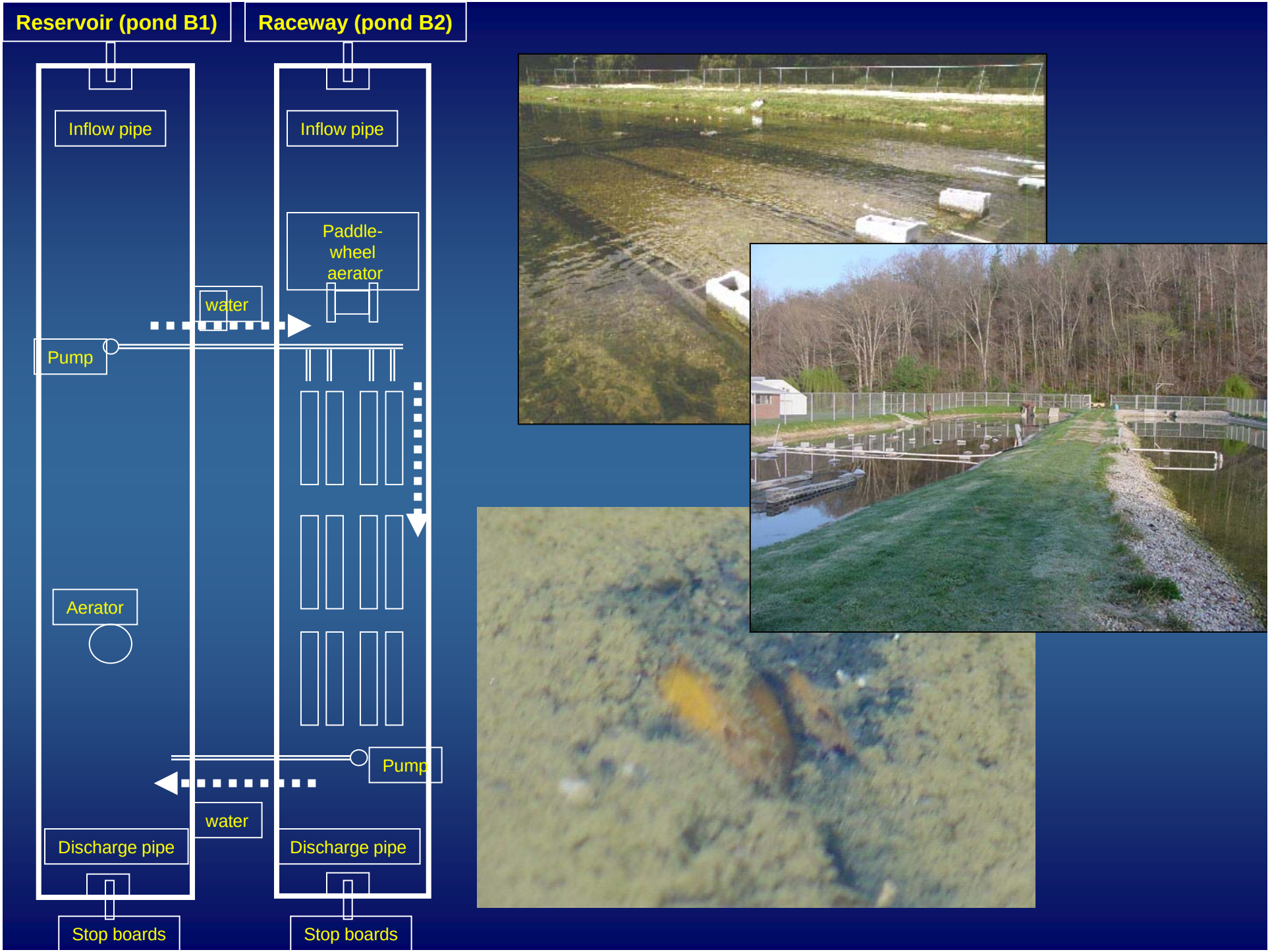
Longitudinal View



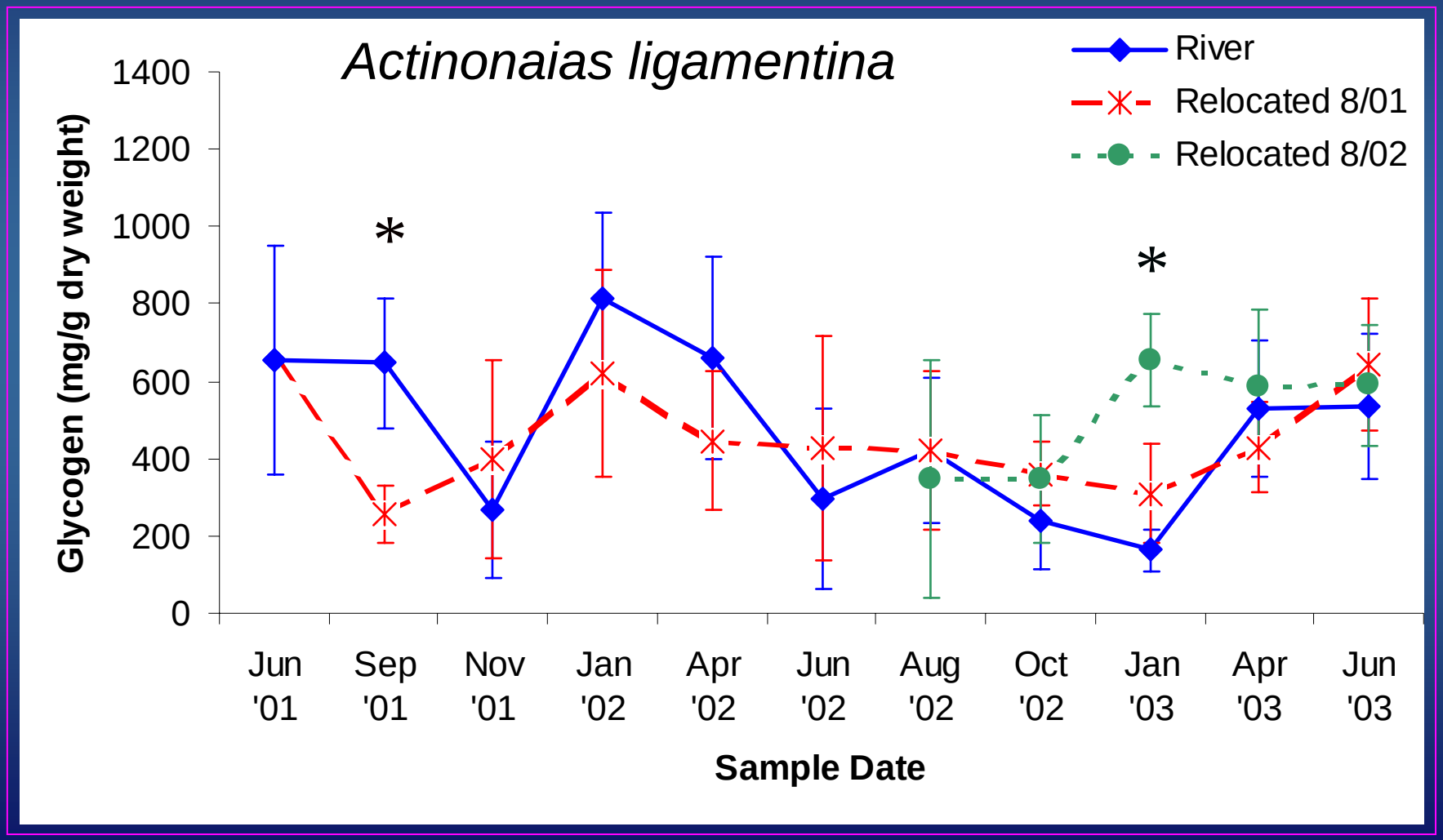
Bivalve Bunkbeds: Down Stream Cross View of



REZNOR


Reservoir (pond B1)
Raceway (pond B2)
Inflow pipe
Inflow pipe
Paddle-wheel aerator
water
Pump
Aerator
Pump
water
Discharge pipe
Discharge pipe
Stop boards
Stop boards

Glycogen results



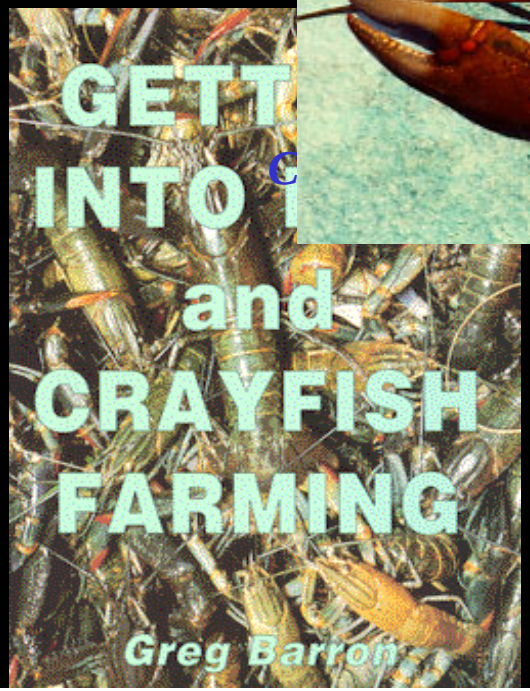
Future Opportunities - Applied

- Salvage and Refuge

- Biomonitoring

The Future > Conservation Aquaculture for the Recovery of Endangered and Imperiled Species (CARES)

460 turtles harvested in 2000 to over 23,000 harvested in 2002



Cheat Mountain Salamander *Plethodon nettingi*

Sustainable Aquaculture Opportunities

International Food Trade - Turtles

Photo by D. Sharma/Courtesy TRAFFIC

Photo: Chris R Shepherd/TRAFFIC Southeast Asia

Many hundreds of adult Southeast Asian box turtles in a holding pen in Sumatra, Indonesia, awaiting international export. This represents an average day's volume in the trade of this species at this site.

Freshwater Pearl Industry

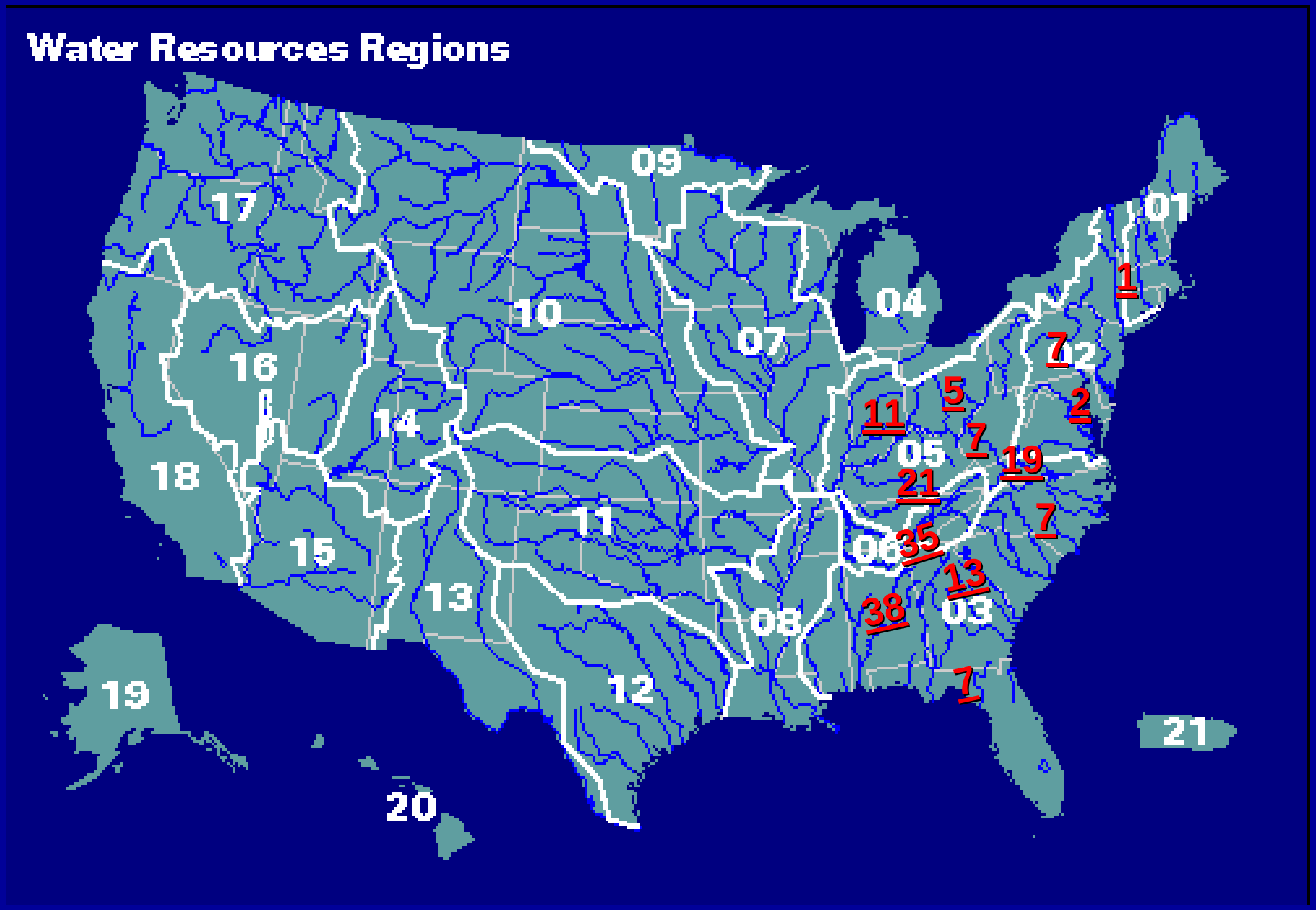
Summary

- Where present, mussels likely perform **ecological services** that are key to maintaining water quality and ecosystem stability.
- Culture and **propagation** of endangered species may be the last hope for reversing the current downward trend in diversity and abundance of aquatic species and aquatic habitats.

Healthy Mussels = Healthy Streams = Healthy Fish = Healthy Economy =Healthy People.

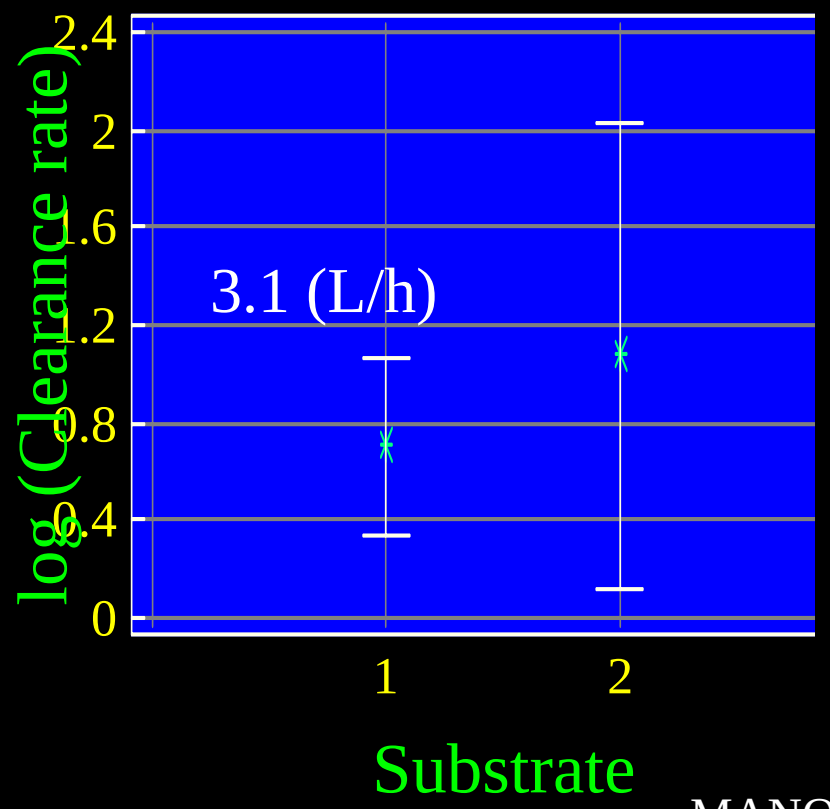
Acknowledgements

- Mussel Mitigation Trust Fund.
- American Zoological and Aquarium Association.
- Academy of Natural Sciences.
- United States Fish and Wildlife Service.
- Biological Resources Division, USGS.
- Virginia Tech.


Water Resources Regions
09
17
01
1
04
10
07
7
12
16
5
2
11
14
7
05
19
18
21
11
7
35
06
15
13
13
38
03
08
7
19
12
21
20

Effect of Substrate on Clearance Rates

Particles over 20,000

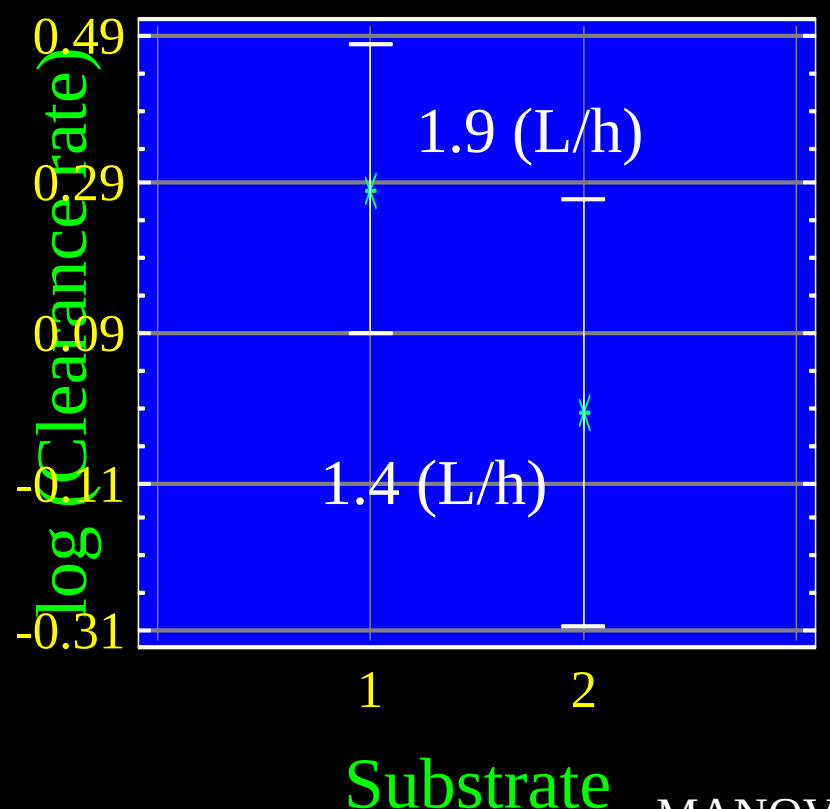


MANOVA

p=0.64, treat

0.62, day

Particles under 20,000



MANOVA

p=0.22, treat

0.78, day