Water Chemistry Gradient Effects on Apple Snail (*Pomacea paludosa*, Say) Reproductive Patterns in the Northern Everglades

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Introduction to the Apple Snail, *Pomacea paludosa*

- Largest Native Freshwater Gastropod in the Everglades
- Life Span and Reproduction
- Hydrology Effects on Reproduction (Darby, 2008)

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Apple snails serve as an important food source to a host of marsh animals including…

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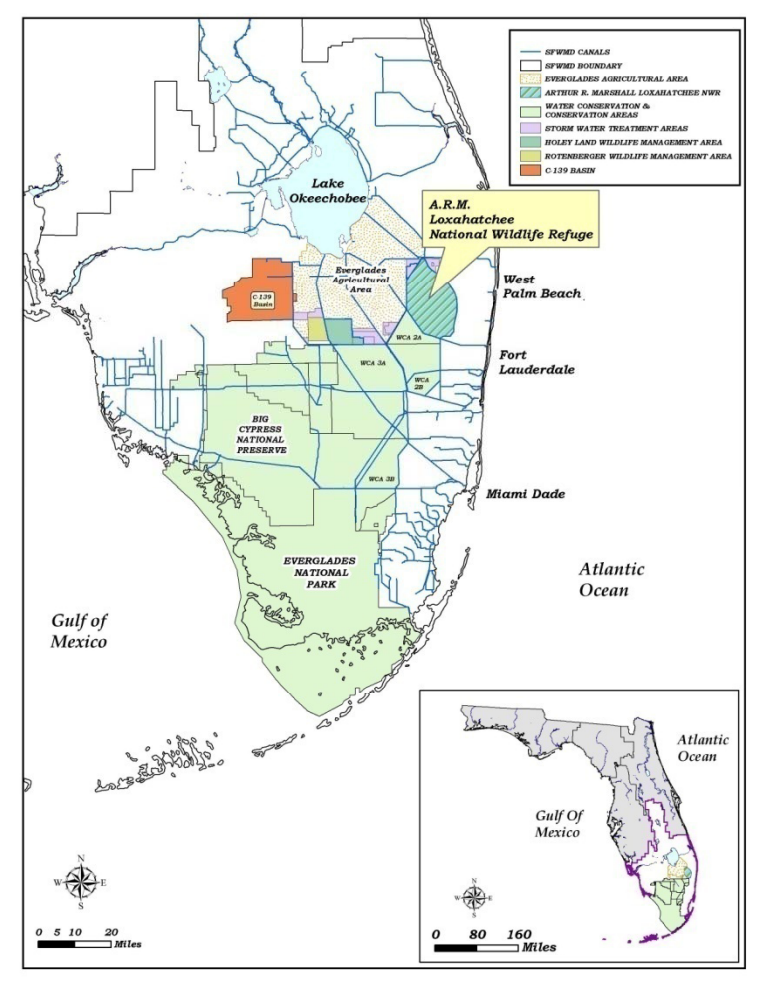
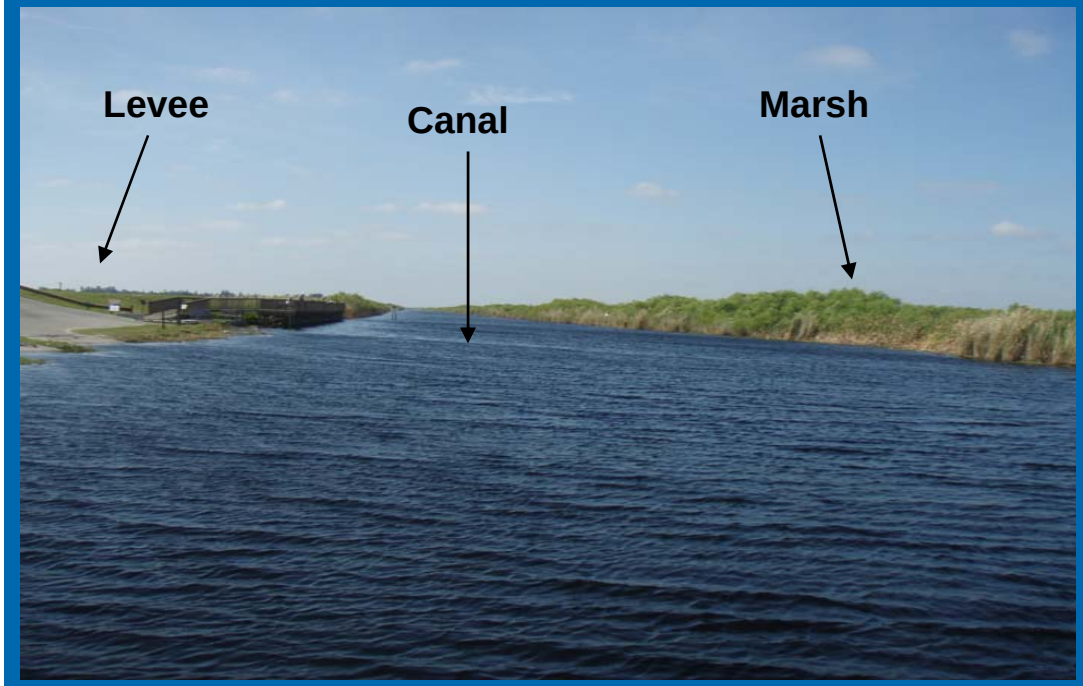
(Darby *et al*., 1999; Cottam and Knappen, 1939)

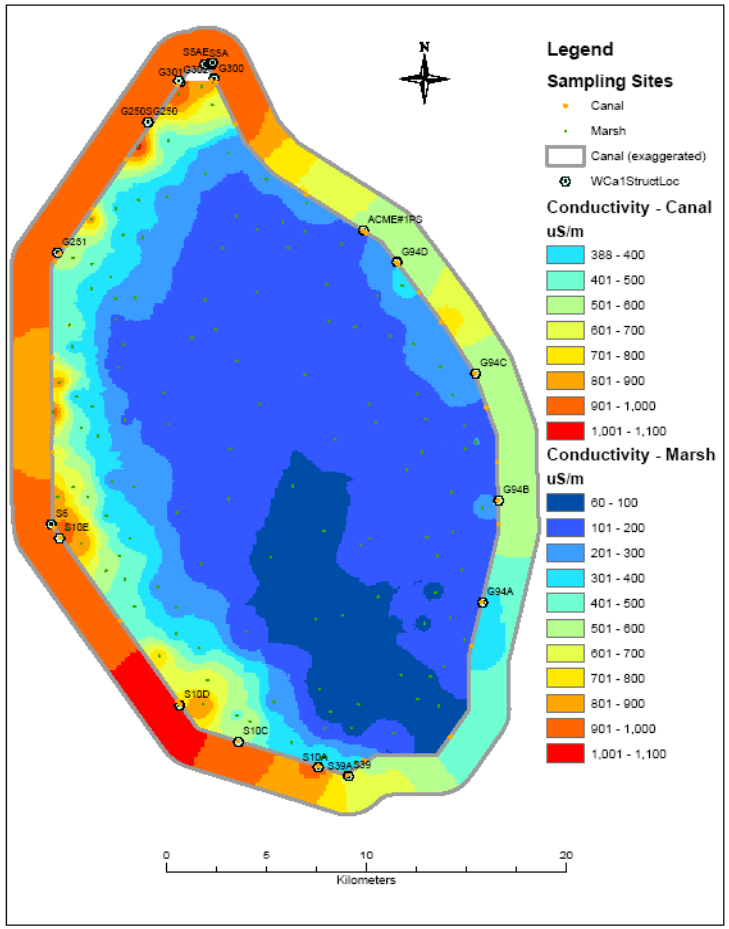
A.R.M. Loxahatchee N.W.R.

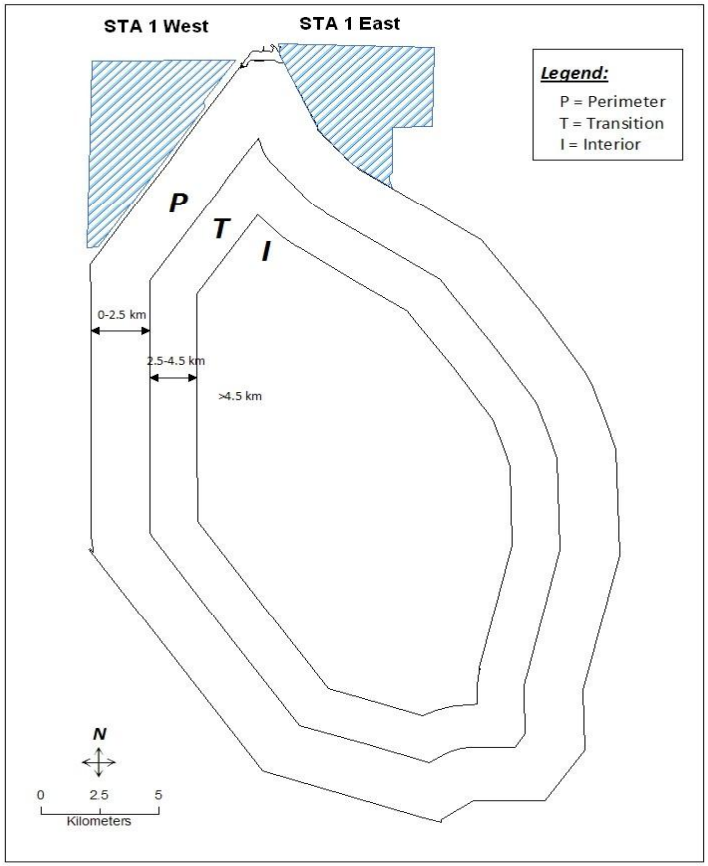




- 147,000 acres
- Canal Levee system
- Water intrusion from perimeter canals to marsh interior
- Water chemistry gradient
- Vegetation alterations

Refuge Map





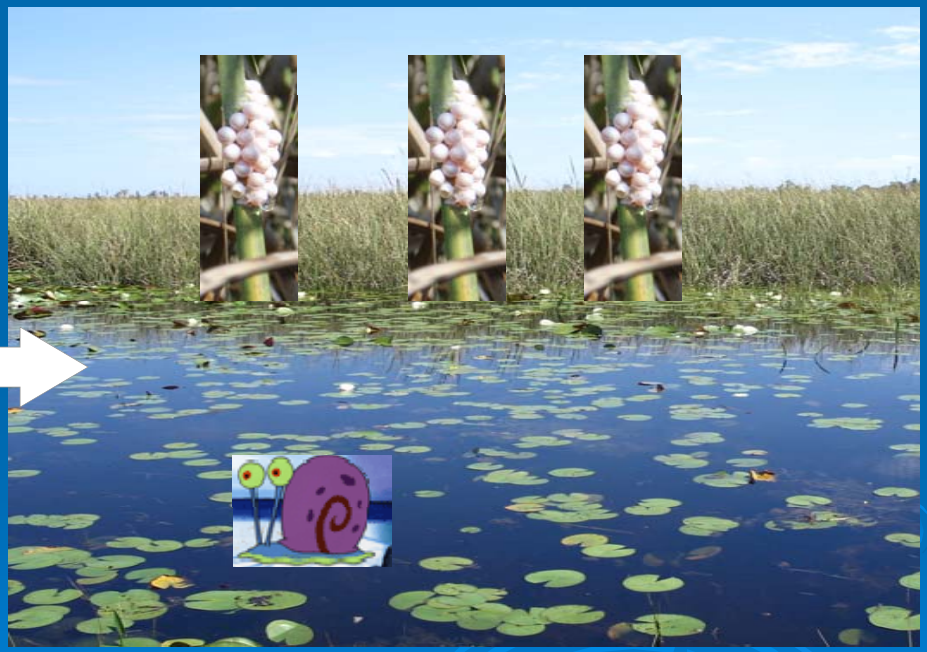
Perimeter Zone: Canal – 2.5 km Transition Zone: 2.5 km - 4.5 km
Interior Zone: Greater than 4.5 km (USFWS, 2007)

Egg Cluster Field Observations

Clusters from Interior Zone **Clusters from Perimeter West Zone**

Are Egg Per Cluster and Egg Size Significantly Different?

How will nutrient and mineral enrichment in the Everglades affect reproductive patterns of the apple snail?



How will this

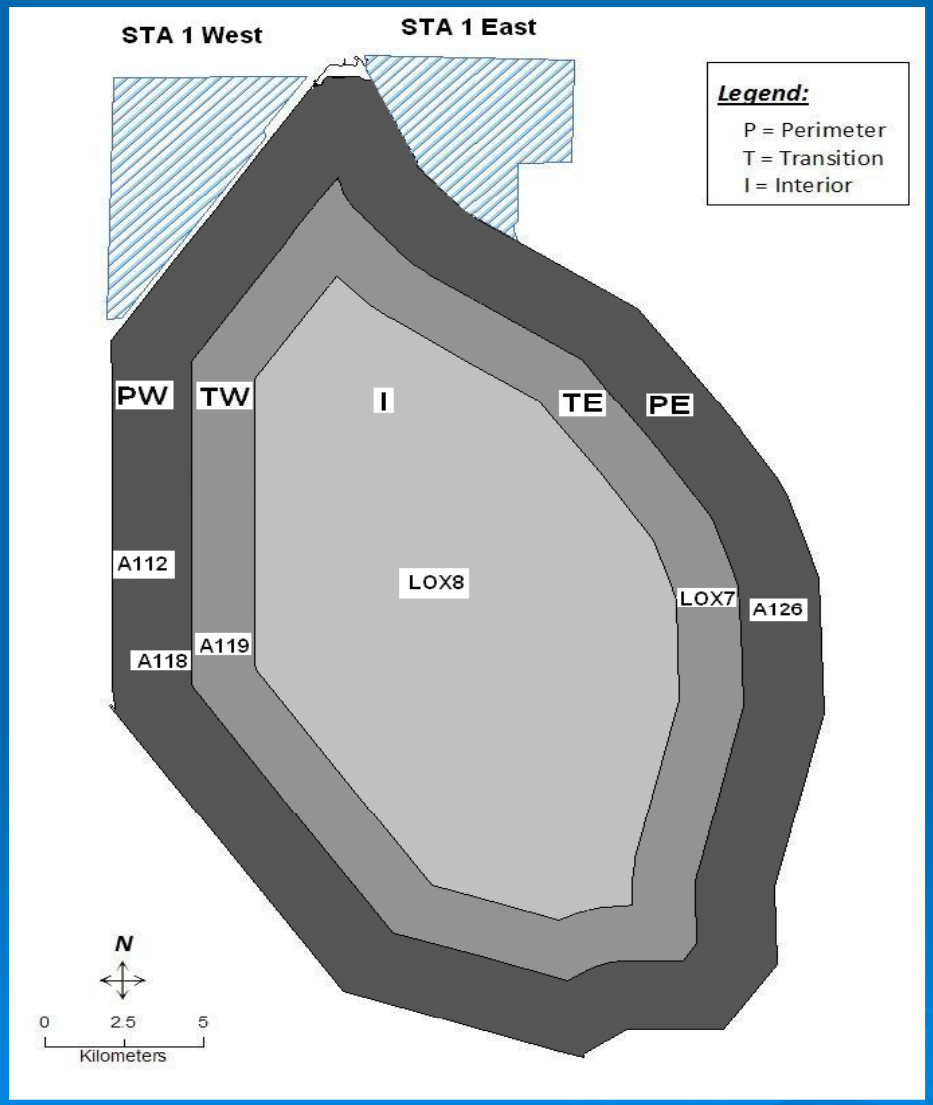
Affect this?

Objectives

- To determine the effects of water chemistry on apple snail egg clutch size, egg diameter, and C and N contents: *I hypothesize that these dependent variables will increase from the pristine interior zone toward the perimeter zones.*

- To determine reproduction timing effects on egg clutch, egg size, and C and N contents on egg clusters. *I hypothesize that egg dependent variables will be significantly higher in June than in August.*

Methods



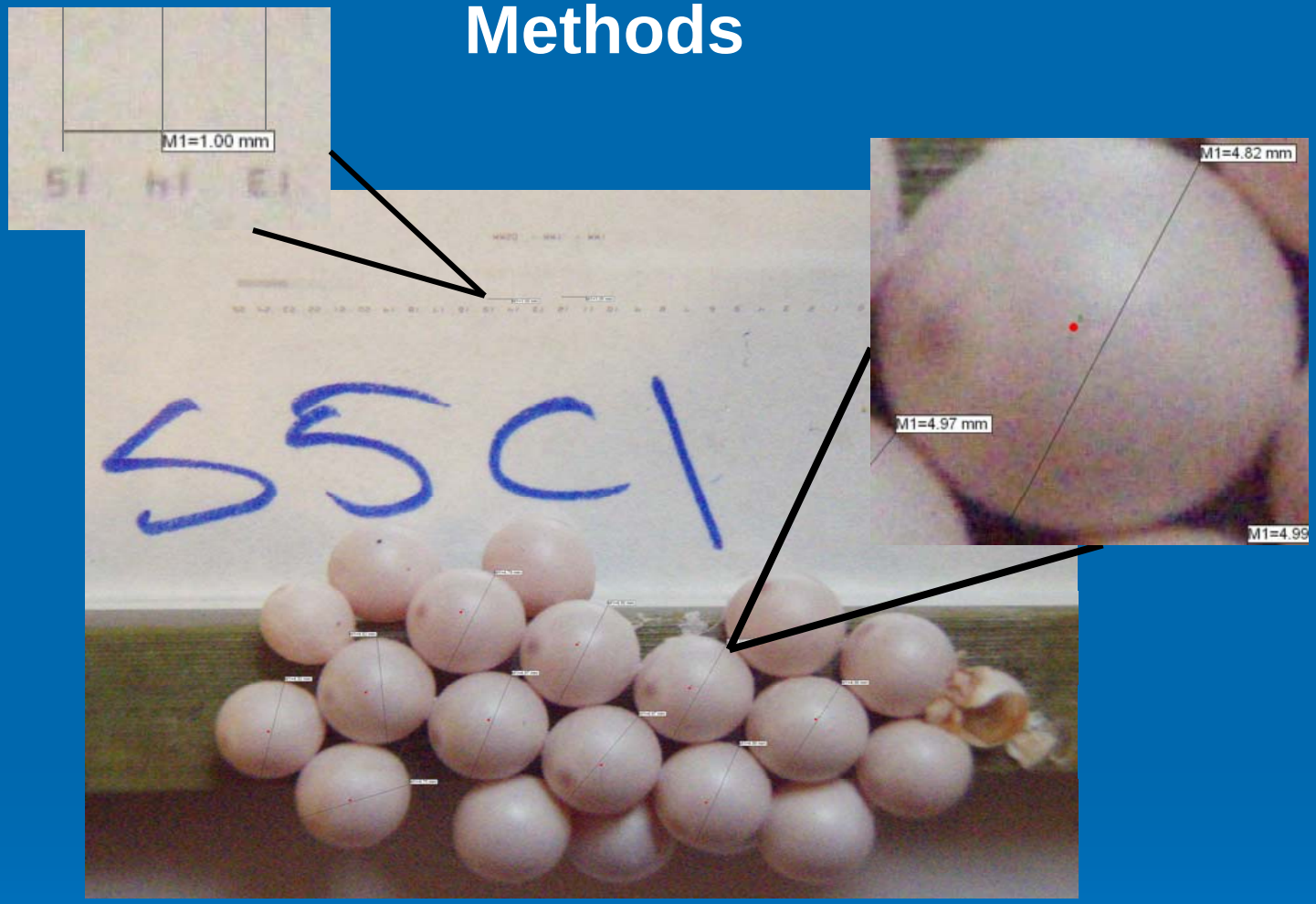
-Sites selected along similar latitudes, to avoid effects of hydrology (Darby *et al.*, 2002 and 2005)

-Sampling in June and August

-30 egg clusters were collected at each site.

-Clusters collected around a 0.5 km radius of each sites and more than 30 meters apart (to avoid collecting siblings; Darby, pers comm)

Methods



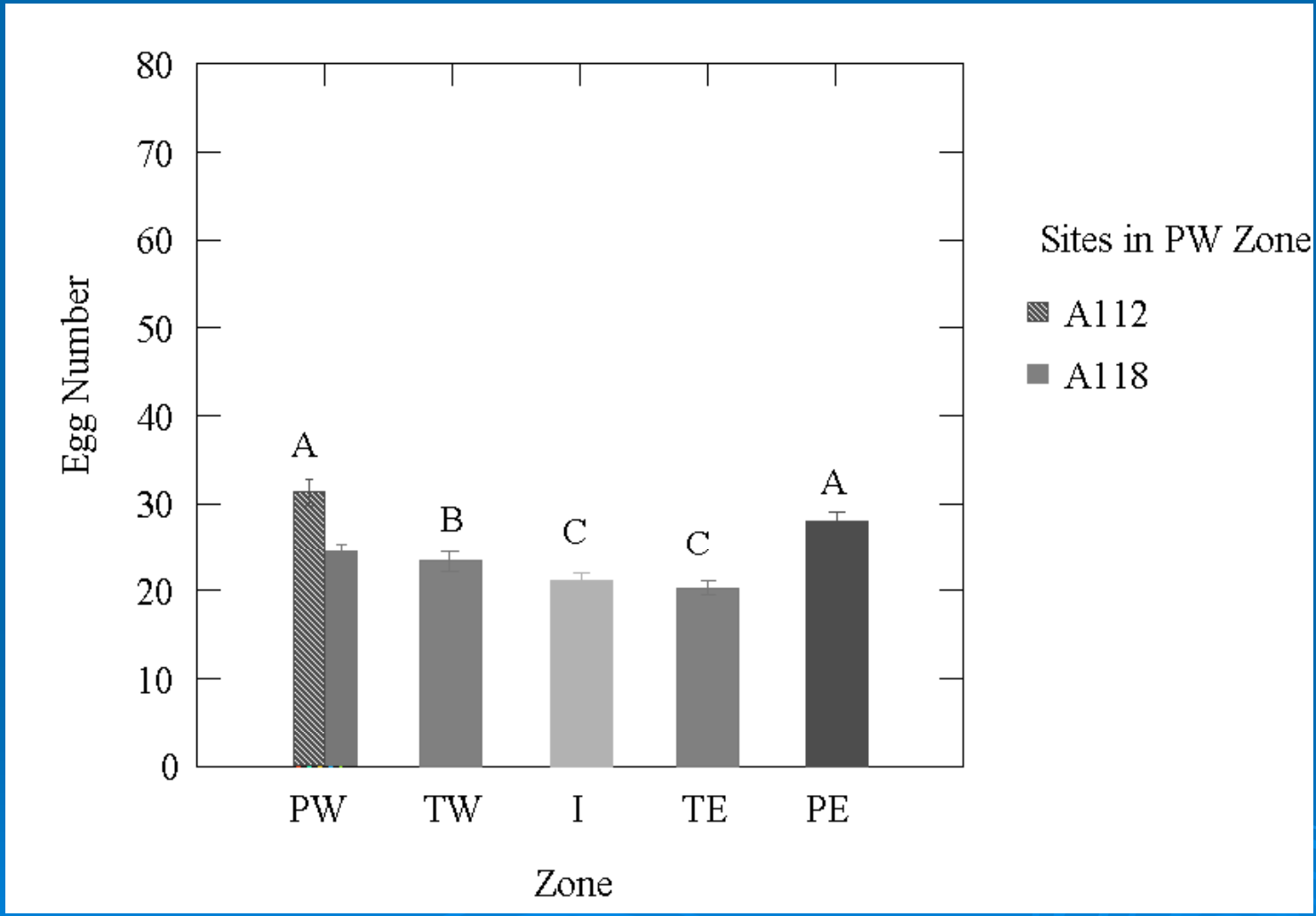
-TpsDig2 software used to measure egg diameters.
-CNS Analyzer used to measure carbon and nitrogen content in clusters.

Data Analyses

- To normalize data residuals (Kéry and Hatfield, 2003), dependant variable egg diameter was square root transformed, and egg number, C content, and N content were log transformed.
- GLMs were performed to detect differences in dependent variables among sites, zones, and months.
- Models that showed significant differences among independent variables ($p<0.05$) were further analyzed using Tukey's pairwise comparisons.
- Statistical analysis were performed in SAS (version 8.0), Systat (version 11), and XLSTAT 2010.

Results

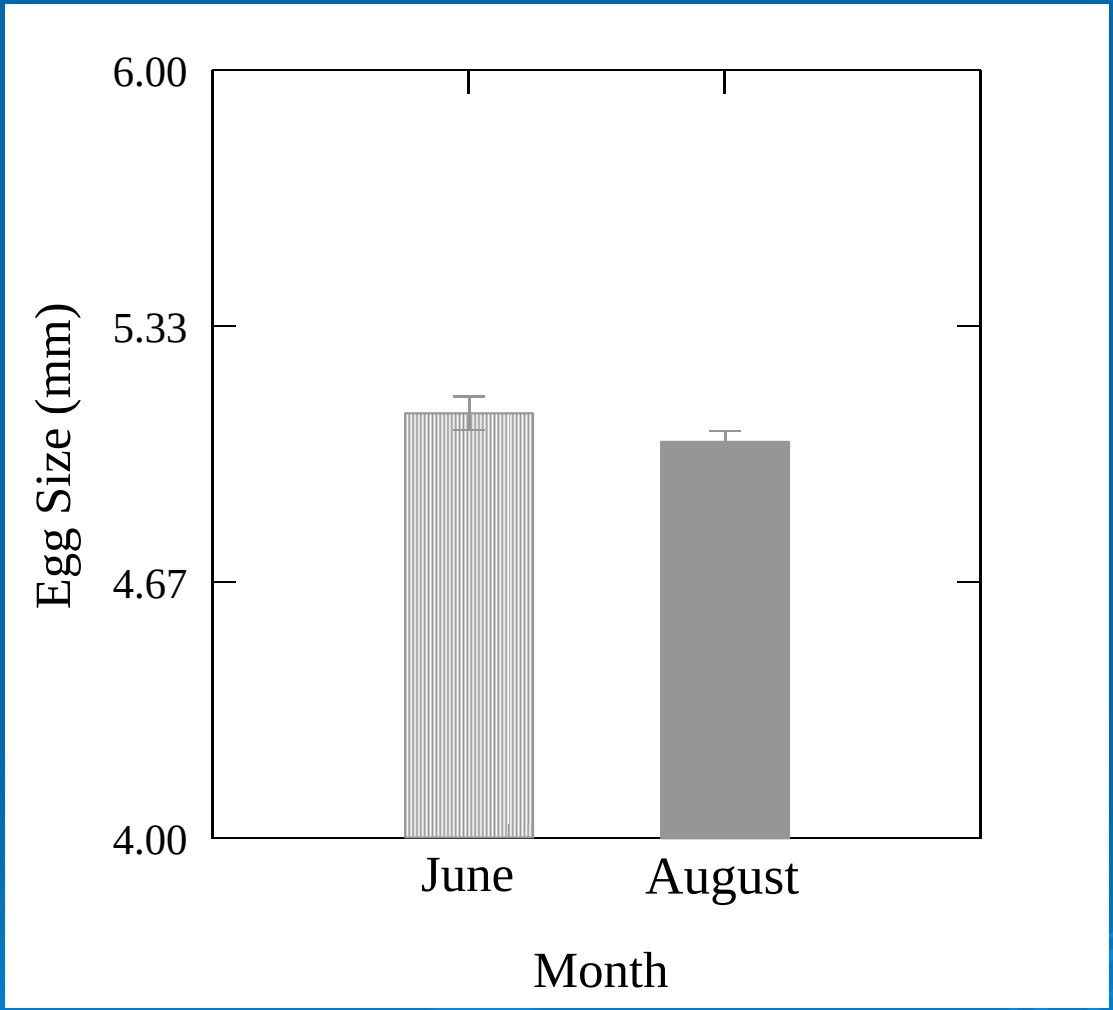
Egg Number Greater in Perimeter Zones



Comparison of the effects of zone on egg number (±1SE). Significant pairwise differences ($p<0.05$) between zones are indicated by different uppercase letters.

Results

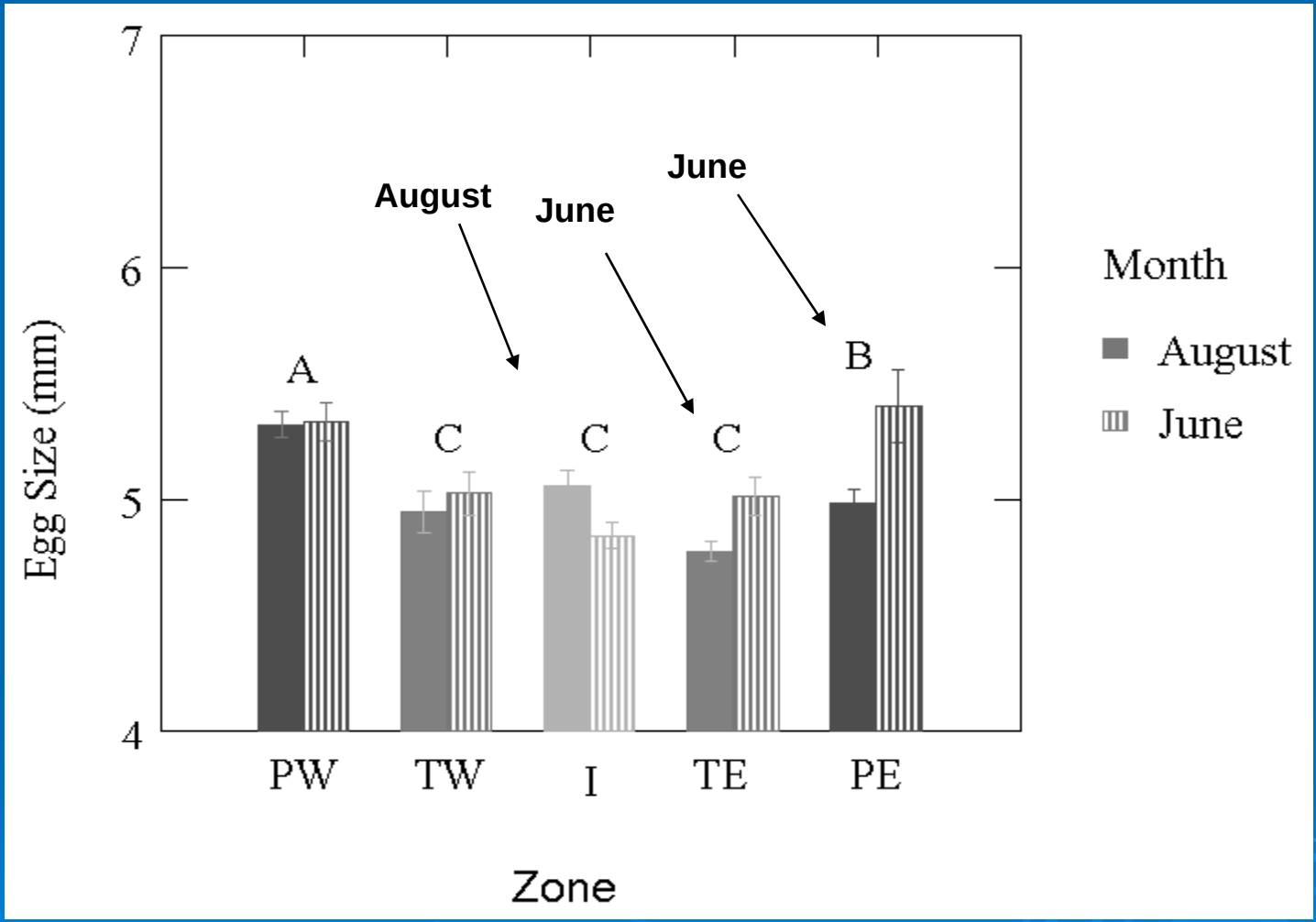
Egg Diameter Greater in June



Comparison of the effects of month on egg diameter (mm) (±1SE). Tukey's pairwise comparisons revealed that June is significantly ($p<0.05$) greater than August.

Results

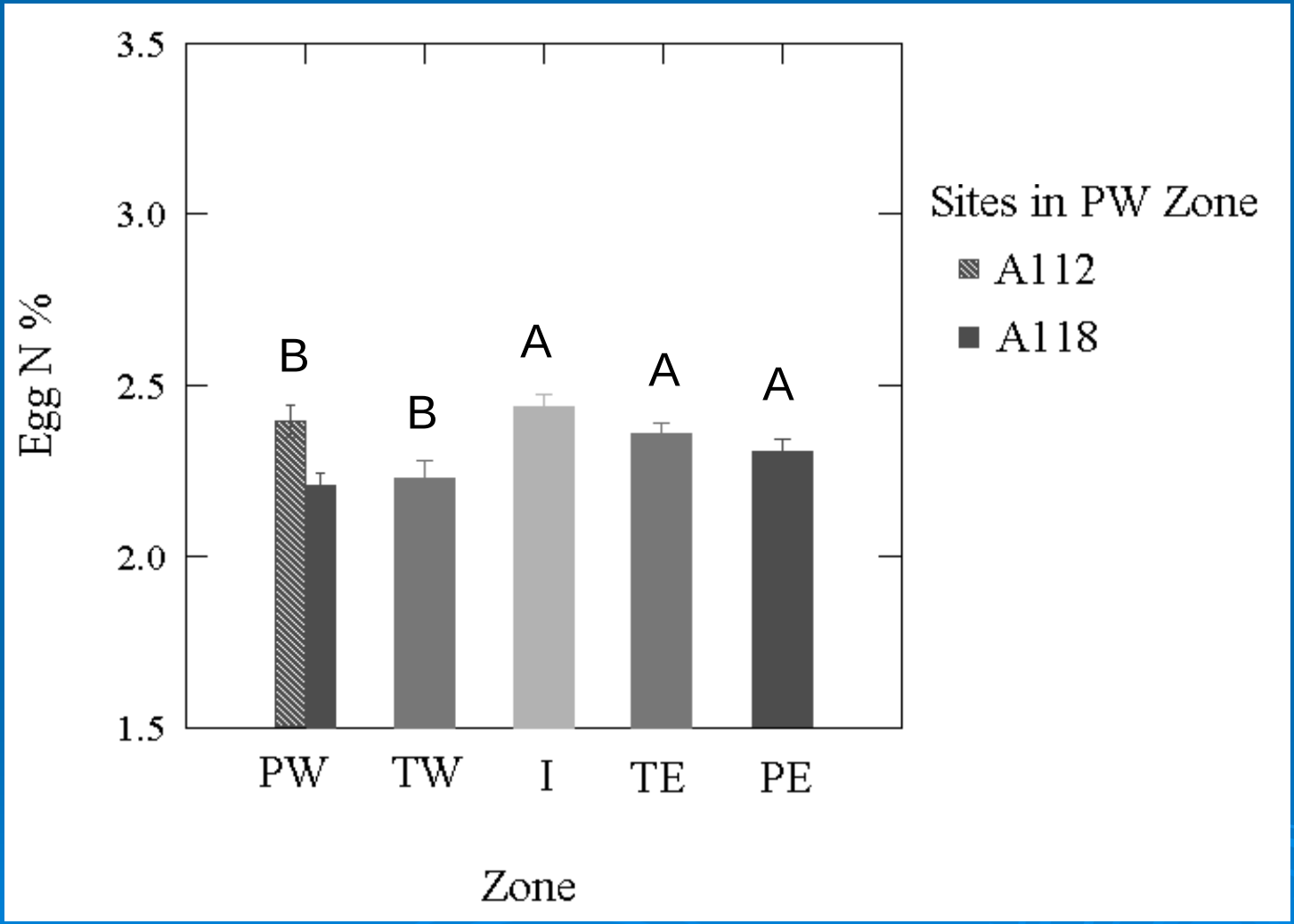
Egg Diameter Greater in Perimeter Zones



Comparison of the effects of zone and month on egg diameter (mm) (±1SE). Significant pairwise differences ($p<0.05$) between zones are indicated by different uppercase letters.

Results

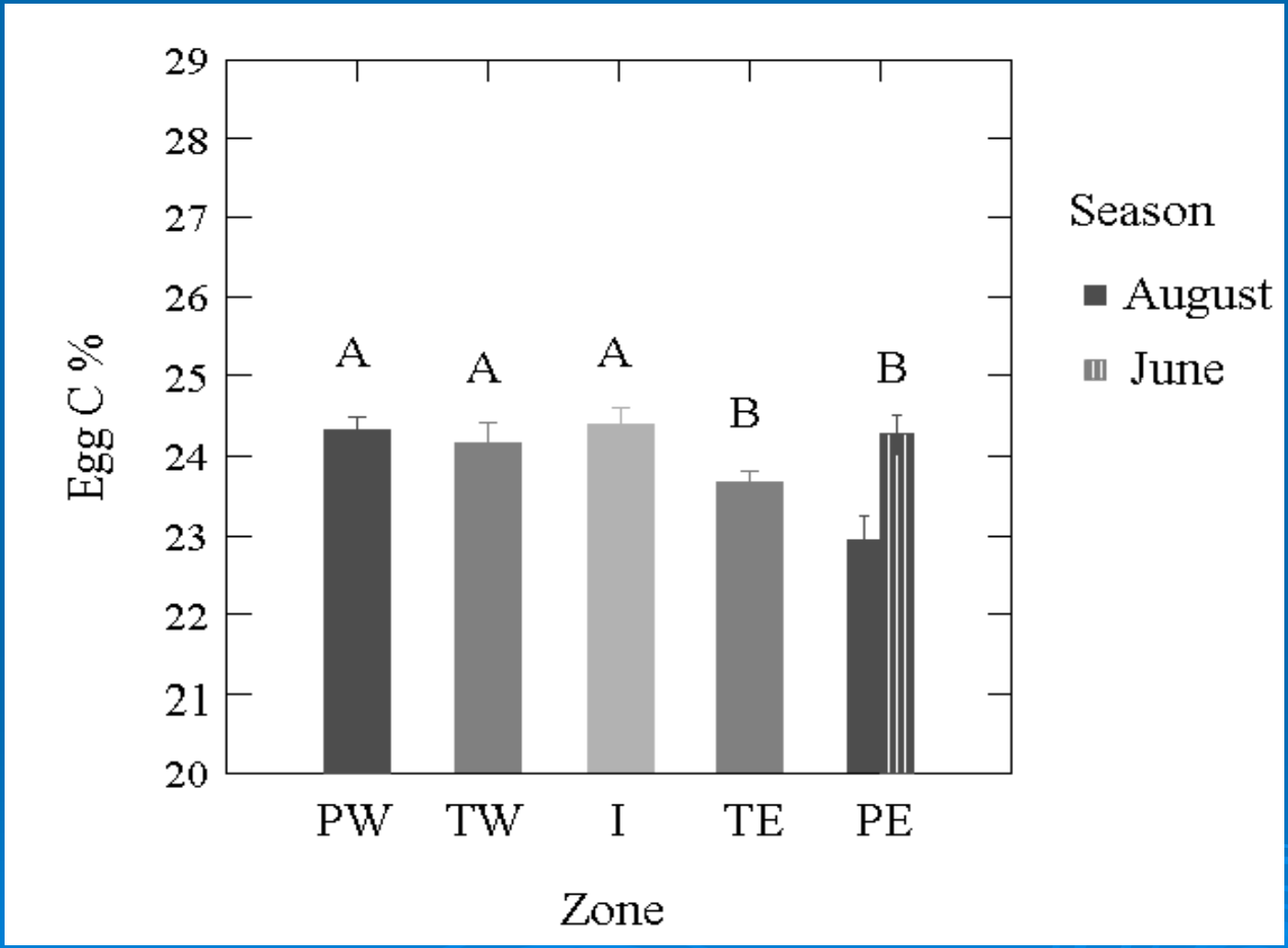
Egg N % Greater in I and E Zones



Comparison of the effects of zone and season on egg N % (±1SE). Significant Pairwise comparisons ($p<0.05$) between zones are indicated by different uppercase letters.

Results

Egg C % Greater in I and W Zones



Comparison of the effects of zone and month on egg C % (±1SE). Significant Pairwise comparisons ($p<0.05$) between zones are indicated by different uppercase letters.

Discussion

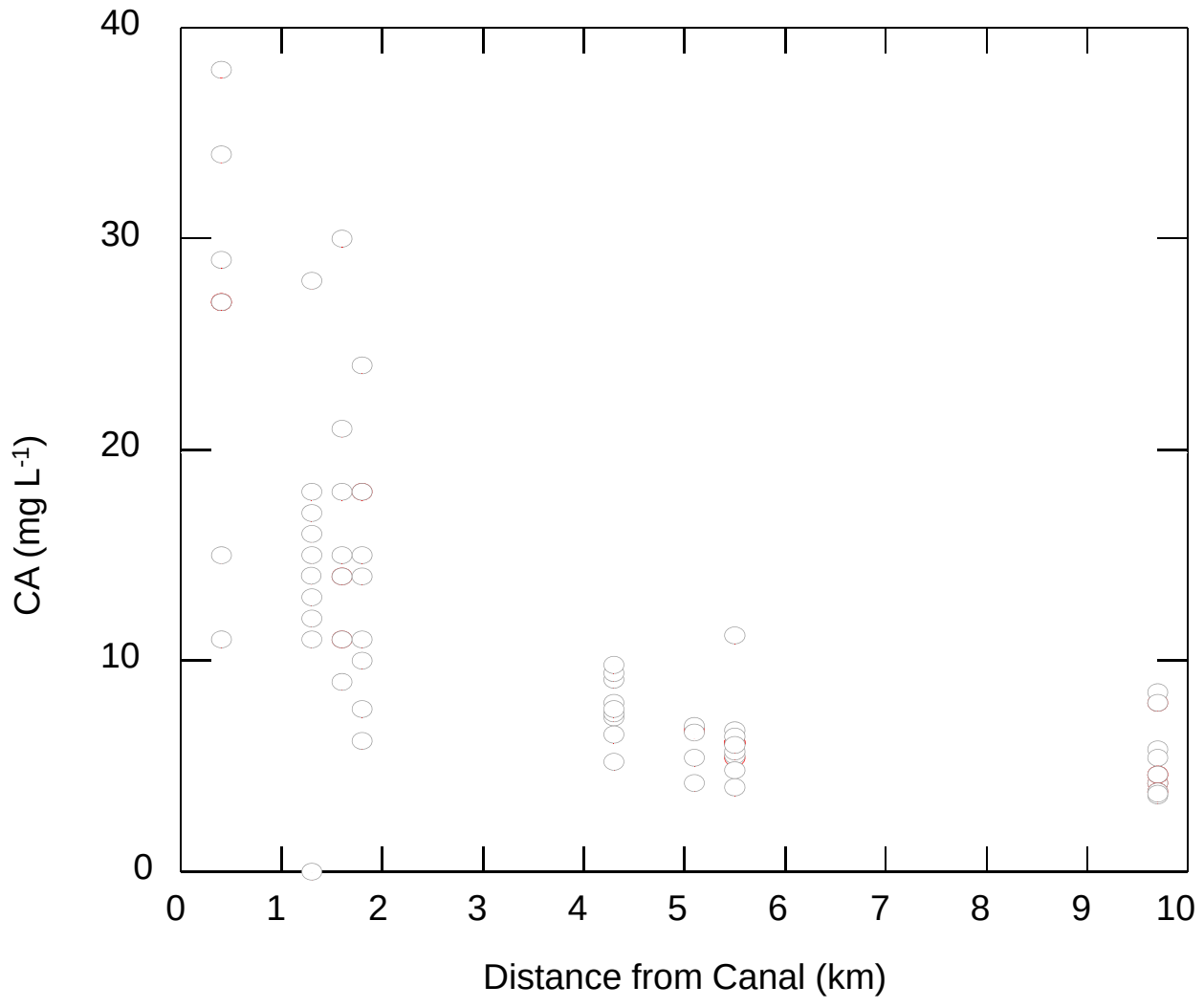
Larger Clutches with Larger Sizes Concentrated in Perimeter Zones..

This may have resulted from 2 key mechanisms of nutrient uptake:

First, higher concentrations of minerals and nutrients in perimeters zones, particularly calcium.

- ✓ In gastropods, Ca is assimilated by absorption through the skin and food consumption (Fournié and Chétail, 1984).
- ✓ Ca is a Key element for the production of eggs in general (Johnson and Barclay, 1996; Tiglar *et al.,* 2002, Patten, 2007).
- ✓ In P. paludosa, hatchlings grow faster and have higher survivorships in higher calcium waters (Glass, 2007).

Discussion



Calcium concentrations in relation to distance from canals. Measurements were taken at egg cluster collection sites from June 2007 – August 2008.

Discussion

Larger Clutches with Larger Sizes Concentrated in Perimeter Zones.

Second, food quality. Apple snails are generally non-selective periphyton grazers (Pennak, 1989).

• Water Chemistry is very influential on periphyton composition and abundance (Swift and Nicholas, 1982; McCormick et al., 1996).

• McCormick et al. (1996) found that algal growth and biomass accumulation of periphyton increased with decreasing distance from nutrient-rich canals.

• Many studies have highlight the benefits of increased food concentrations to female size and fecundity (Spight and Emlen, *1976*; Kiørboe *et al.,* 1985; Estoy, *et al.,* 2002)

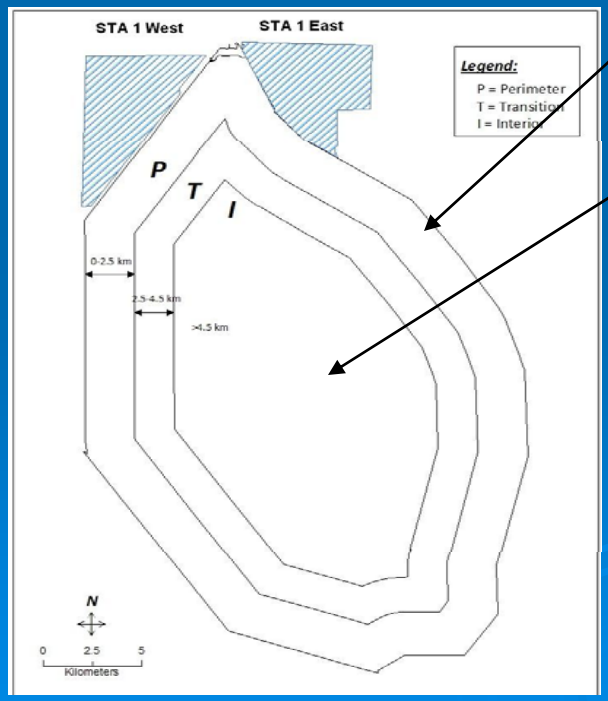
So, the increased biomass of periphyton in close vicinity of canals might help to make apple snails larger and hence, more fecund…right?....

Discussion

Well, maybe not…

• Waters typical of the interior support desmid and filamentous green algae (higher nutritive value).

• Peripheral ares contain filamentous blue greens and hardwater diatoms (Swift and Nicholas, 1982).



Filamentous blue greens and hard water diatoms

Desmid-filamentous green algae (higher quality food here)

But, higher quality food may not translate into larger specimens, or higher fecundity. Ongoing research by Refuge staff is investigating influence of food levels on *P. paludosa*.

Discussion

Egg Carbon and Nitrogen Contents

- Egg C contents were higher in the I, TW and PW zones, and Egg N contents were higher in the I, TE, and PE zones.
- This does not match the pattern seen in egg size and egg number, which increased (more or less) from the Interior to Perimeter zones.
- It could be that C and N contents are not the best indicator for maternal investment in *P. paludosa*. In Gypsy moths, vitellin and glycine-rich proteins are an accurate measure of maternal investment (Capinera *et al.,* 1977).

Discussion

Month Effects

- Overall, Eggs were larger early in the reproductive season. Studies have shown that egg size will decrease with maternal age and/or a progressing reproductive season (Buckley *et al.,* 1991; Begon and Parker, 1986; Ito, 1997).
- We don’t know if larger eggs have any added benefits.

Discussion

Environmental effects accounted and unaccounted for:

- *P paludosa* aquatic predators in different zones

  --Turtles, drop off burial responses (Synder and Synder, 1971)

  --Time spent in predator avoidance can alter feeding patterns, hence reproduction (Sih, 1982; Holomuzki, 1986)

- Parasites on breeding snails

  --Can cause castration in males and females (Hanning, 1979)

  --Affect clutch size, egg size, or contents?

- Drastic changes in temperature (don't expect this to be a factor)

  --Water temps below 21°C decline snail activity (Darby 2008)

  --Snails show burial responses at <10°C (Stevens, *et al*., 2002)

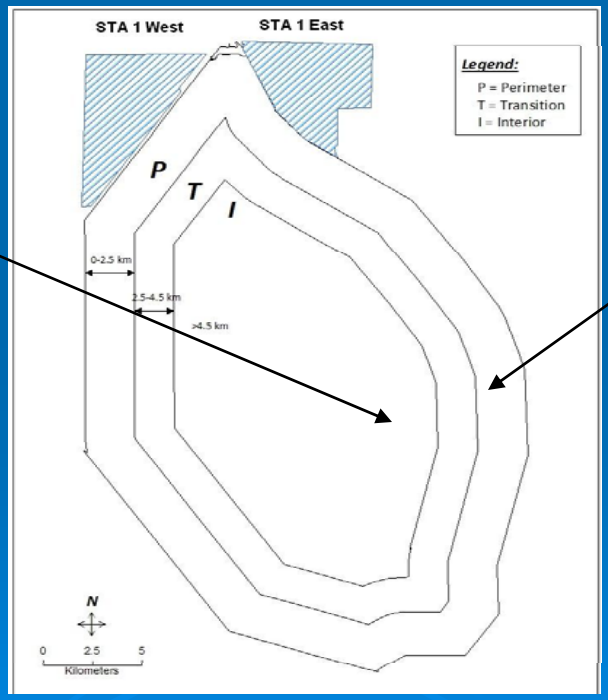
- Drastic changes in hydrology (don't expect this to be a factor)

  --Sites were selected E-W to avoid the N-S elevation gradient

Conclusions

- Areas closer to the Refuge may produce greater numbers of apple snail egg per clutch; but it is unclear how viable these offspring are.
- Nutrient enrichment in the Everglades also increases species richness and density of invertebrates (Rader and Richardson, 1994) and local fish productivity (Rehage and Trexler, 2006). This could increase predation on snail hatchlings!!

Karunaratne et al (2006) found more snails here



And almost no snails here

61% of *P paludosa* 10mm in diameter are eaten (Darby, oral presentation, 2009)

By increasing snail predator biomass, increase hatchling consumption rates

Implications

- Although influences of canal water brings in more Ca, which we suspect can enhance snail egg number and size, it also contains elevated levels of phosphorus. This encourages changes in plant and algal community structure (Newman, *et al.,* 1998).
- At high enough concentrations of P, periphyton mats collapse and are replaced by plant biomass (Gaiser, *et al.,* 2004 and 2005).
- Increases in P also encourages unnaturally high levels of cattail, which push out native sawgrass and wet prairie habitat, which apple snails depend upon.

From this

To this

Future Studies

- Manipulate certain key nutrient levels to better understand the relationship between key compounds and snail reproductive strategies.

- Starvation tests of snail neonates within different zones and egg sizes may give more accurate indications of egg size and offspring viability.

- Ongoing research by Refuge staff is exploring the effects of food sources and water chemistry on fitness levels in *P paludosa.*

Questions?

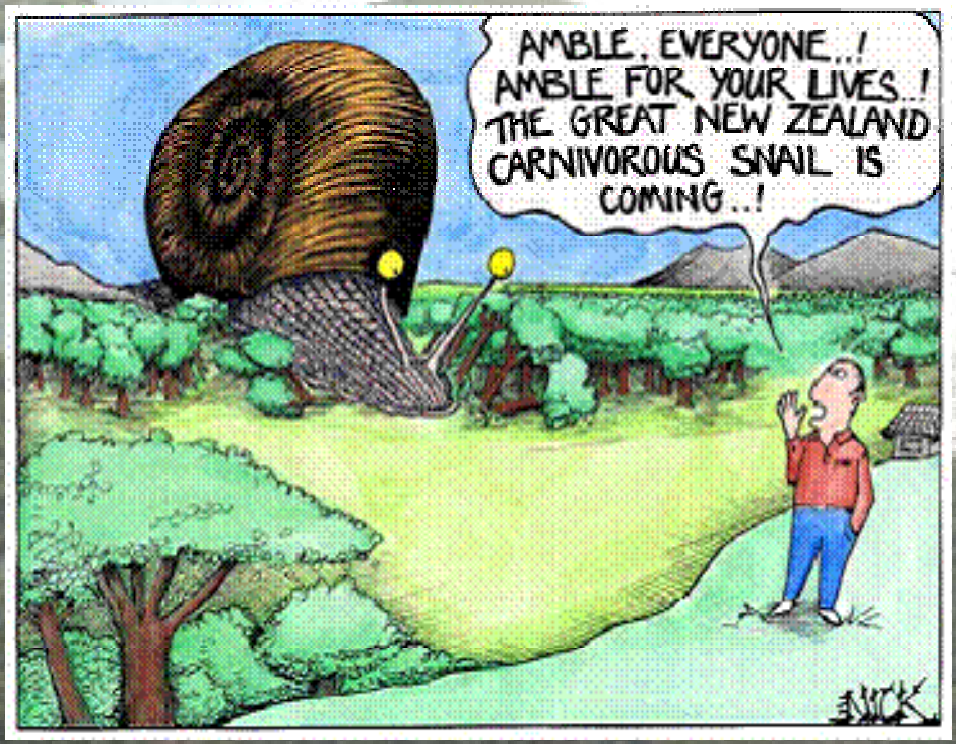


Image courtesy of: okeechobee.ifas.ufl.edu