Welcome to the Conservation Lecture Series

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Questions? Contact margaret.mantor@wildlife.ca.gov

Lecture Schedule

- **Shasta Crayfish, Dr. Maria Ellis**

  April 29, 10:00-11:30, **Redding**
- **Desert Tortoise, Rebecca Jones**

  May 22, 1:00-3:00, **Los Alamitos**
- **Amargosa Vole, Dr. Janet Foley & Dr. Robert Klinger**

  June 9, 1:00-3:00, Sacramento

Conservation and Management of the California Tiger Salamander

Searcy, C. A.

University of Toronto Mississauga, Department of Biology

Threatened and endangered salamanders

Common Name	Scientific Name	Number of Papers
California tiger salamander	*Ambystoma californiense*	81
Ozark hellbender	*Cryptobranchus alleganiensis bishopi*	53
Frosted flatwoods salamander	*Ambystoma cingulatum*	39
San Marcos salamander	*Eurycea nana*	31
Cheat Mountain salamander	*Plethodon nettingi*	30
Red Hills salamander	*Phaeognathus hubrichti*	29
Shenandoah salamander	*Plethodon shenandoah*	28
Sonora tiger salamander	*Ambystoma tigrinum stebbinsi*	20
Texas blind salamander	*Typhlomolge rathbuni*	18
Santa Cruz long-toed salamander	*Ambystoma macrodactylum croceum*	16
Barton Springs salamander	*Eurycea sosorum*	13
Reticulated flatwoods salamander	*Ambystoma bishopi*	10
Jollyville Plateau salamander	*Eurycea tonkawae*	7
Desert slender salamander	*Batrachoseps aridus*	5
Austin blind salamander	*Eurycea waterlooensis*	2

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Outline

1) Brief natural history

2) When are CTS active?
   a) seasonality
   b) response to weather patterns

3) Where are CTS active?
   a) migration distances
   b) density distribution

4) Hybridization with the invasive barred tiger salamander

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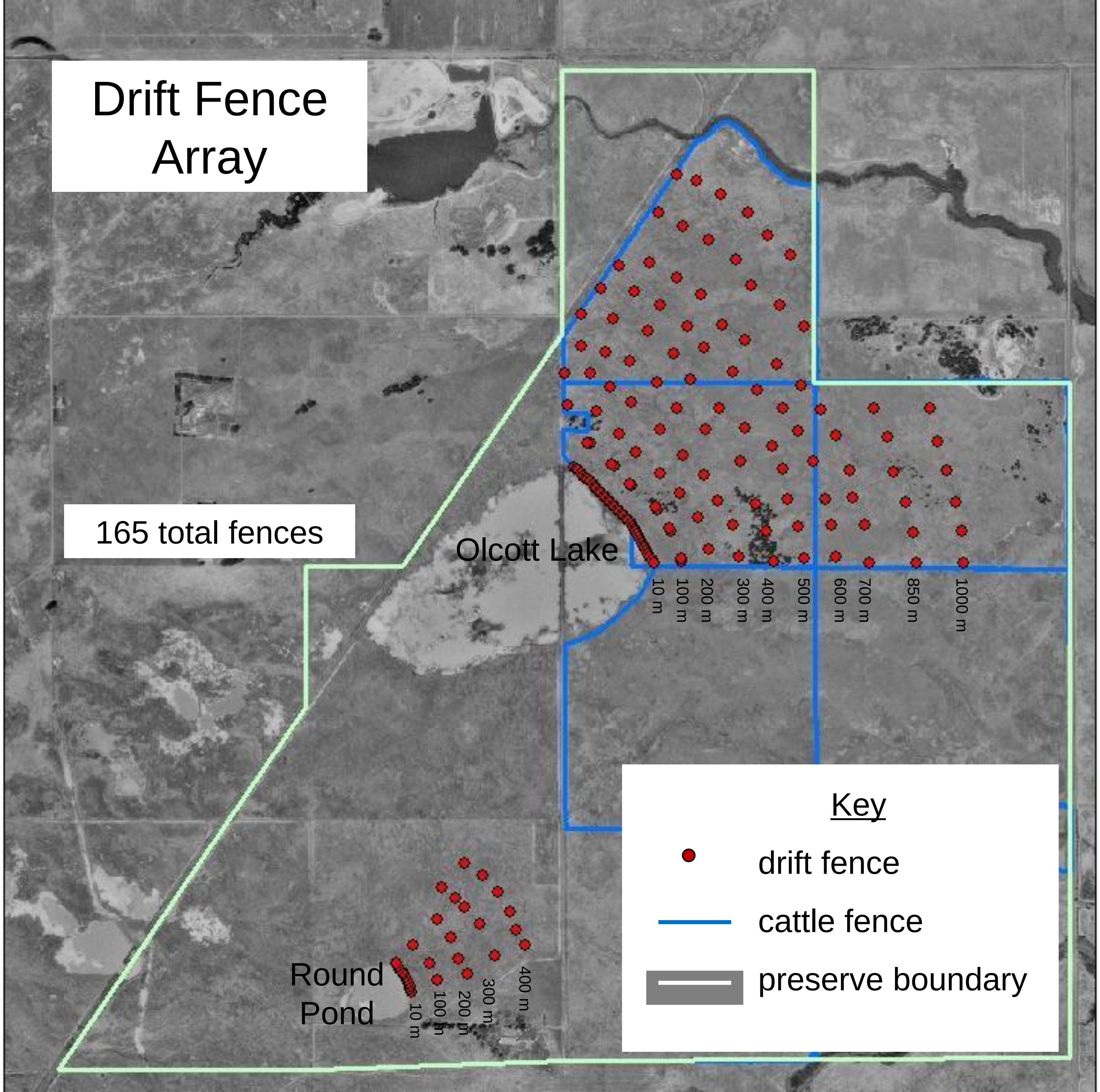
Drift Fence Array
165 total fences
Olcott Lake
10 m
100 m
200 m
300 m
400 m
500 m
600 m
700 m
850 m
1000 m
Round Pond
10 m
100 m
200 m
300 m
400 m
Key
drift fence
cattle fence
preserve boundary

Seasonality

1) CTS are active in the terrestrial landscape during two distinct periods
   a) An adult/juvenile movement period in the fall/winter
   b) A metamorph emergence period in the spring/summer

2) CTS mostly breed in temporary ponds, which means there is a distinct seasonality to their presence in the aquatic environment as well

Adult/juvenile movement period

Year	Start	End
05-06	29-Nov	27-Feb
06-07	14-Nov	22-Feb
07-08	11-Nov	20-Feb
08-09	2-Nov	2-Mar
09-10	14-Oct	24-Feb
10-11	24-Oct	2-Mar
11-12	11-Oct	15-Mar
12-13	17-Nov	20-Mar
Overall	30-Oct	28-Feb

Adult/juvenile movement period

Positively correlated with date at which annual precipitation reaches 0.56 in.

Year	Start	End
05-06	29-Nov	27-Feb
06-07	14-Nov	22-Feb
07-08	11-Nov	20-Feb
08-09	2-Nov	2-Mar
09-10	14-Oct	24-Feb
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09-10	14-Oct	24-Feb
10-11	24-Oct	2-Mar
11-12	11-Oct	15-Mar
12-13	17-Nov	20-Mar
Overall	30-Oct	28-Feb

Positively correlated with Nov. rainfall, negatively correlated with Feb. rainfall

Metamorph emergence period

Year	Start	End
04-05	19-May	20-Jun
05-06	30-May	10-Jul
07-08	14-May	20-May
08-09	23-May	10-Jun
09-10	21-May	26-Jun
10-11	2-Jun	30-Jun
11-12	1-Jun	19-Jun
12-13	7-May	18-May
Overall	17-May	3-Jul

Metamorph emergence period

Positively correlated with Mar. rainfall

Year	Start	End
04-05	19-May	20-Jun
05-06	30-May	10-Jul
07-08	14-May	20-May
08-09	23-May	10-Jun
09-10	21-May	26-Jun
10-11	2-Jun	30-Jun
11-12	1-Jun	19-Jun
12-13	7-May	18-May
Overall	17-May	3-Jul

Metamorph emergence period

Year	Start	End
04-05	19-May	20-Jun
05-06	30-May	10-Jul
07-08	14-May	20-May
08-09	23-May	10-Jun
09-10	21-May	26-Jun
10-11	2-Jun	30-Jun
11-12	1-Jun	19-Jun
12-13	7-May	18-May
Overall	17-May	3-Jul

Positively correlated with drying date of breeding pond

Conclusions

Avoid activities that will impede salamander movement in the terrestrial environment:

- after the first ~0.5 inches of rain in the fall until mid-March
- from mid-May until the breeding ponds are dry

Breeding pond occupancy

Year	Start	End
05-06	2-Dec	5-Jul
06-07	14-Nov	25-Feb
07-08	11-Nov	17-May
08-09	2-Nov	9-Jun
09-10	12-Dec	25-Jun
10-11	21-Nov	29-Jun
11-12	15-Dec	18-Jun
12-13	17-Nov	17-May
Overall	11-Nov	29-Jun

Breeding pond occupancy

Positively correlated with first 0.82 in. after the end of October

Year	Start	End
05-06	2-Dec	5-Jul
06-07	14-Nov	25-Feb
07-08	11-Nov	17-May
08-09	2-Nov	9-Jun
09-10	12-Dec	25-Jun
10-11	21-Nov	29-Jun
11-12	15-Dec	18-Jun
12-13	17-Nov	17-May
Overall	11-Nov	29-Jun

Breeding pond occupancy

Year	Start	End
05-06	2-Dec	5-Jul
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10-11	21-Nov	29-Jun
11-12	15-Dec	18-Jun
12-13	17-Nov	17-May
Overall	11-Nov	29-Jun

Positively correlated with drying date of breeding pond

A Word on Hydroperiod

Year	Average Breeding Date	Average Date of Metamorph Emergence	Average Number of Days in Pond
05-06	22-Dec	19-Jun	178
07-08	5-Jan	16-May	131
08-09	14-Feb	31-May	106
09-10	21-Jan	6-Jun	136
10-11	10-Jan	16-Jun	157
11-12	15-Mar	11-Jun	88
12-13	14-Dec	12-May	148

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11-12	15-Mar	11-Jun	88
12-13	14-Dec	12-May	148

Conclusions

Avoid activity in the aquatic habitat:

-Once ~0.8 in. have accumulated after the end of October

-Until the pond has dried for natural vernal pools or until late dry season for artificial ponds

For adequate hydroperiods:

-Breeding ponds must hold water until mid-May

-The target should be breeding ponds that hold water until at least early June in the average year

Weather Patterns

1) Even during seasonal activity periods, CTS are active in the terrestrial environment on a small fraction of the days.

2) Daily activity is driven by weather patterns.

Adult/Juvenile Activity

Out of a ~140 day activity season, only 15 days (11% of days) have 95% of the movement

Year	Movement Days
05-06	21
06-07	16
07-08	18
08-09	6
09-10	11
10-11	23
11-12	14
12-13	13
Average	15.25

Correlations

- Movement days are correlated with:
  - Precipitation
  - High minimum temperature
  - Wind speed
  - Humidity

- However, amongst nights when rain is predicted (~32 per year), there is no clear rule for when CTS will be active

Metamorph Activity

Year	Movement Days
04-05	35
05-06	48
06-07	0
07-08	1
08-09	5
09-10	34
10-11	30
11-12	0
12-13	8
Average	17.88889

91% of the movement days are from just 4 of the 9 years, which account for 94% of the metamorphs

Conclusions

- During the adult/juvenile season, avoid all nights when rain is predicted (~32/year) in order to avoid ~15 nights of actual movement
- During the metamorph emergence, avoid all nights between mid-May and pond drying (~30/year) in order to avoid ~18 nights of actual movement

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   b) response to weather patterns

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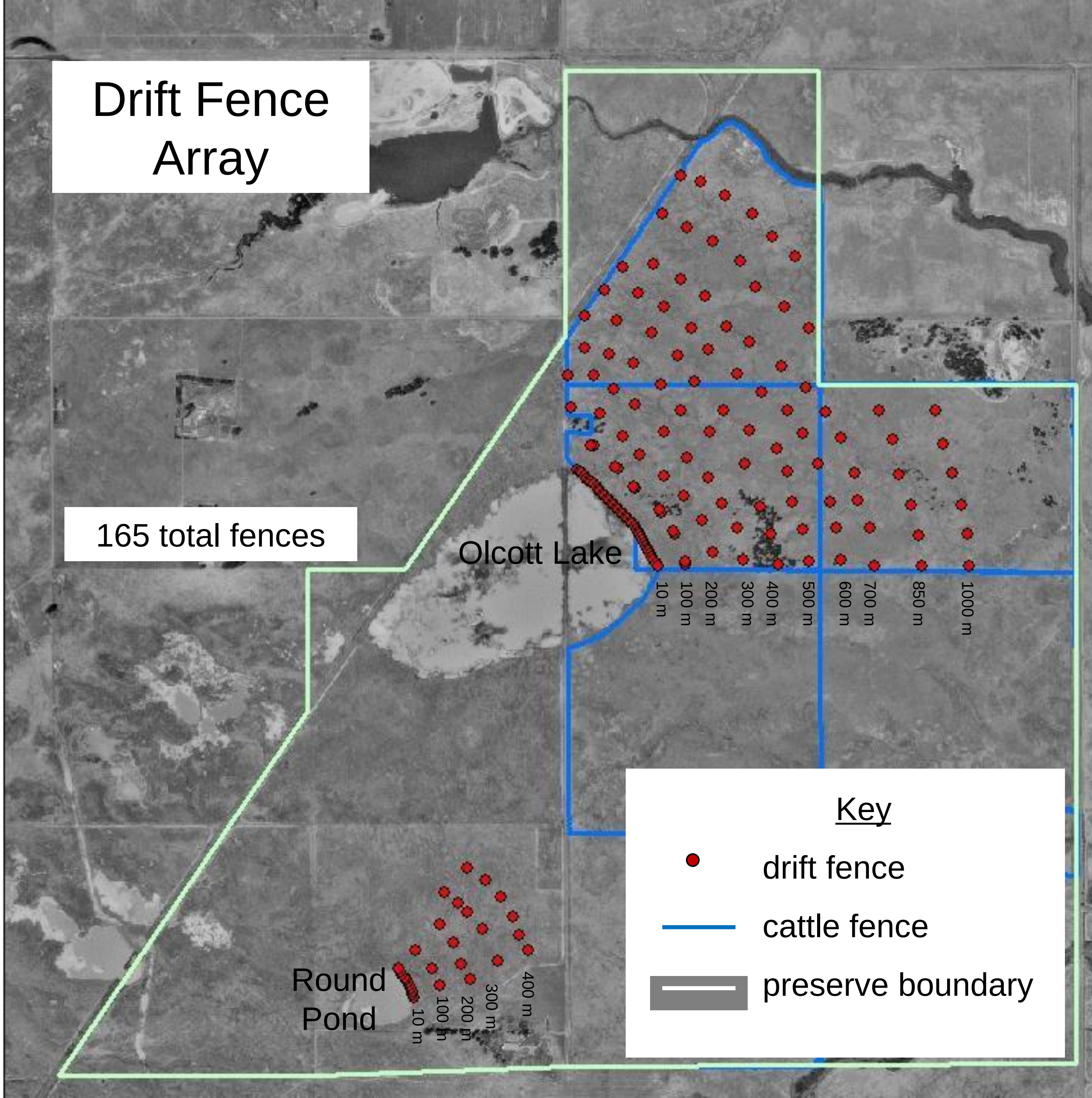
   b) density distribution

4) Hybridization with the invasive barred tiger salamander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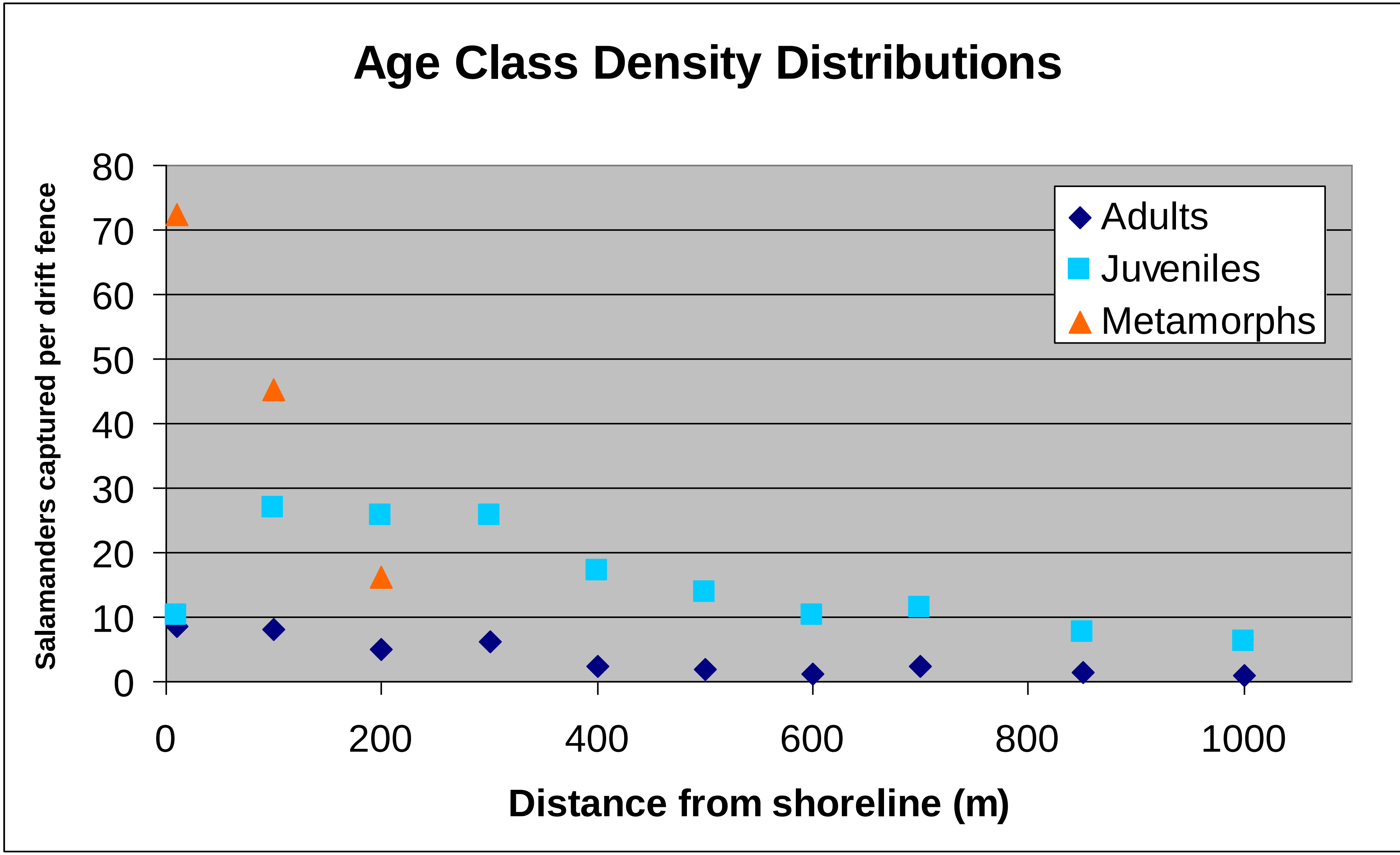
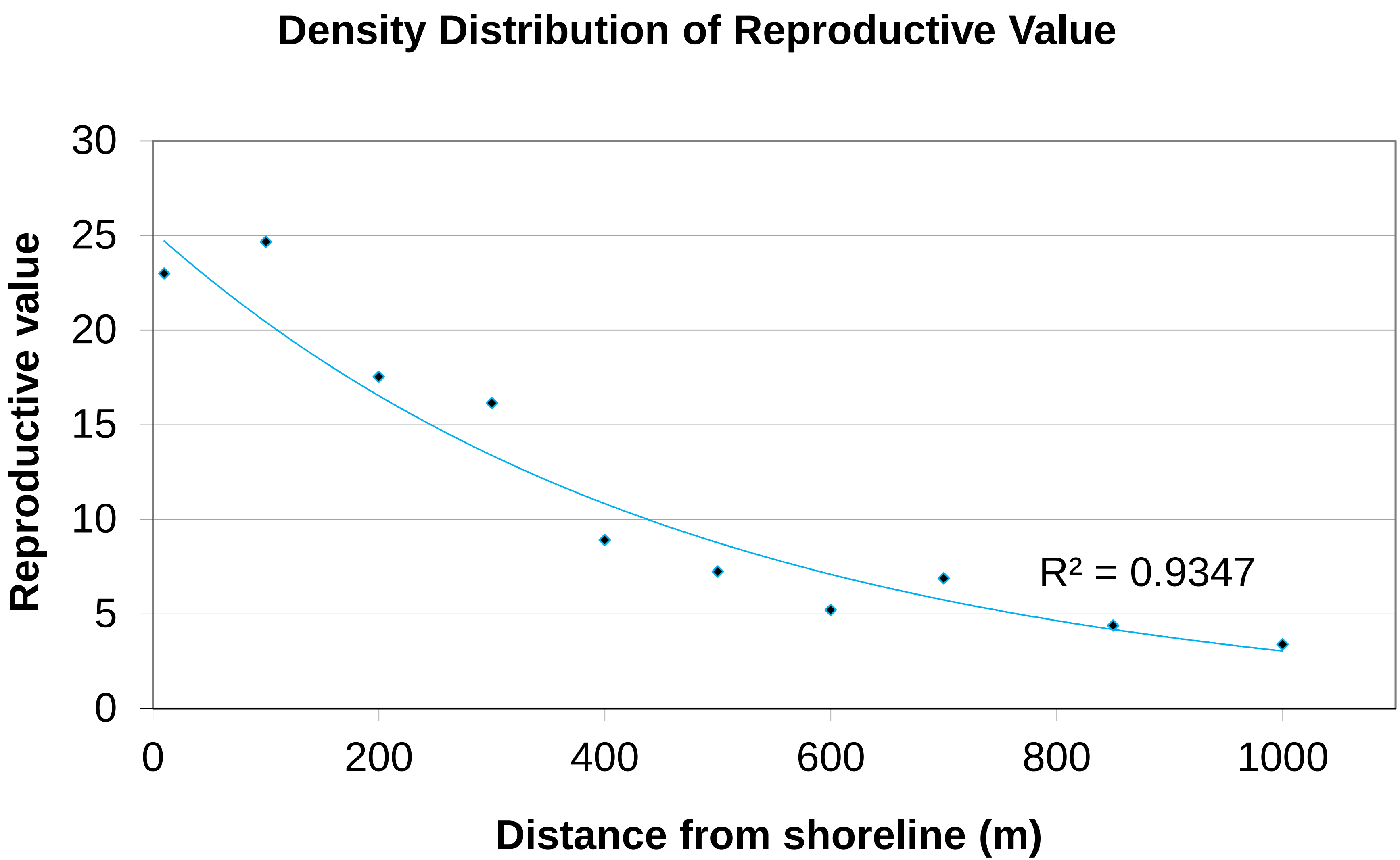


Searcy, C. A. and H. B. Shaffer. 2008. Calculating biologically accurate mitigation credits: insights from the California tiger salamander. Conservation Biology 22:997-1005.

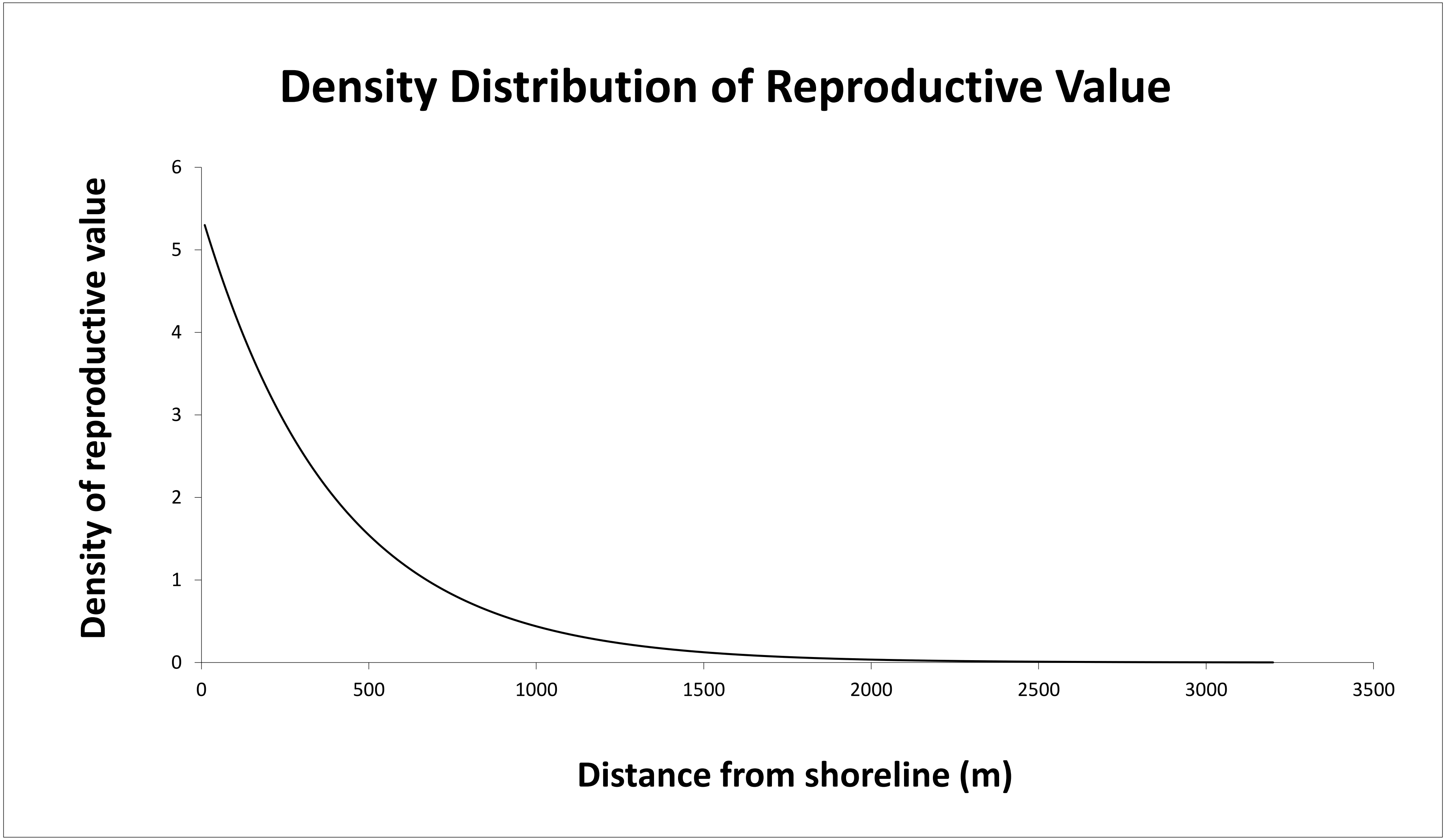
What is the relative importance of the different age classes?

reproductive value = adult density + 0.38*juvenile density + 0.14*metamorph density

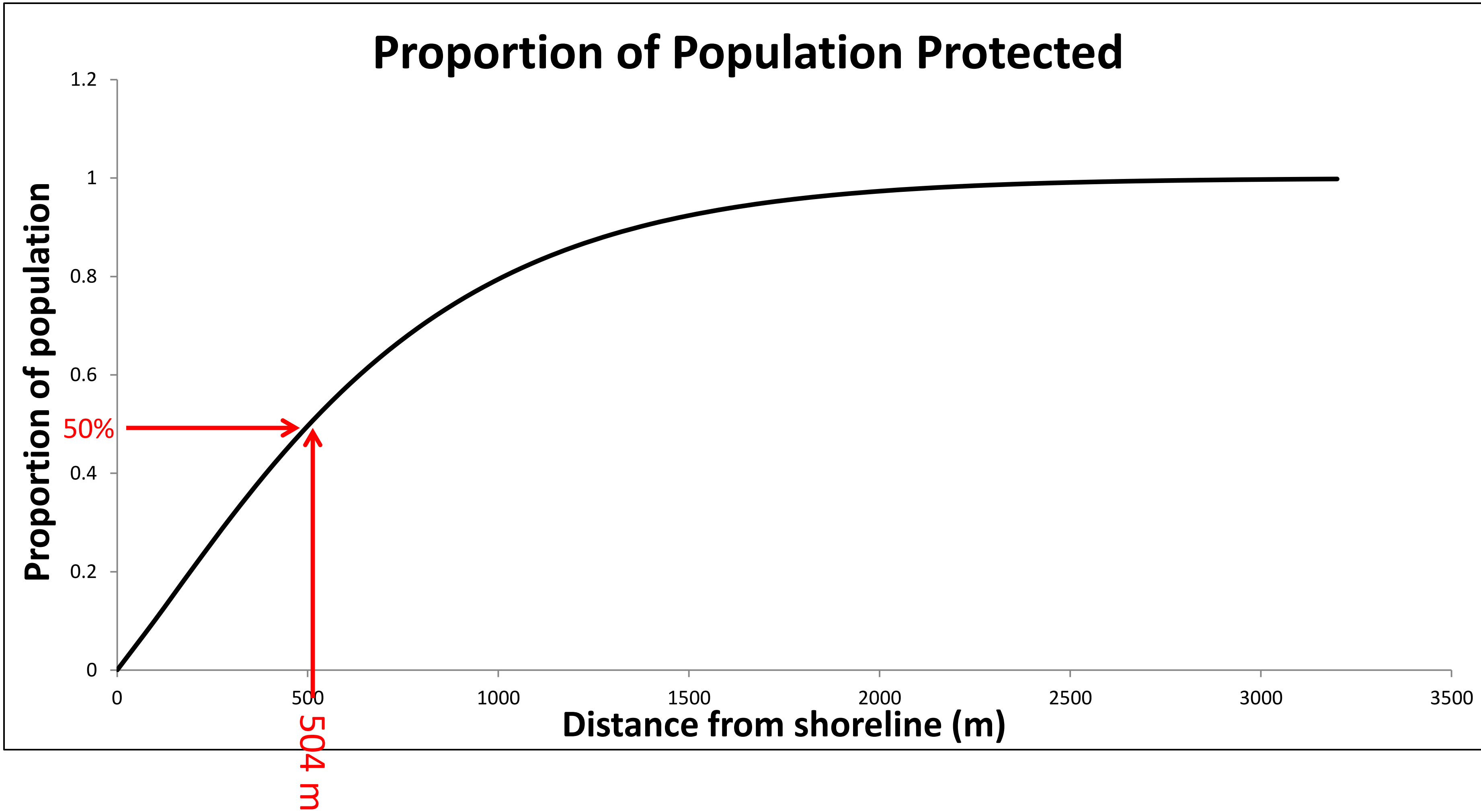

Density Distribution of Reproductive Value
Reproductive value
30
25
20
15
10
5
0
0
200
400
600
800
1000
Distance from shoreline (m)
R² = 0.9347

What is the role of spatiotemporal heterogeneity?

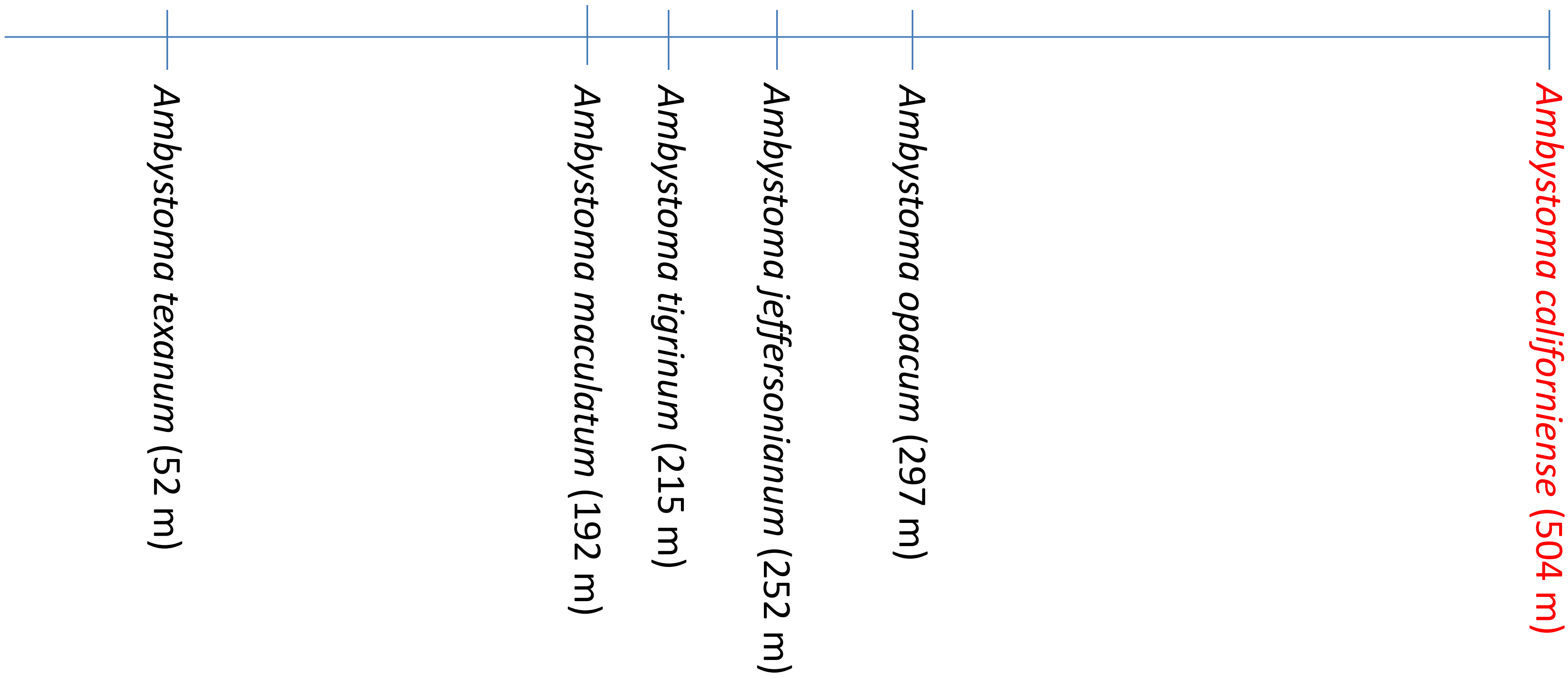
Term	*P*-value
Intercept	<0.0001*
Distance	<0.0001*
Pond	<0.0001*
Year	<0.0001*
Distance*Pond	0.0601
Distance*Year	0.0414*
Pond*Year	0.0905
Pond*Year*Distance	0.0337*



Searcy, C. A. and H. B. Shaffer. 2011. Determining the migration distance of a vagile vernal pool specialist: How much land is required for conservation of California tiger salamanders? Pages 73-87 in D. G. Alexander and R. A. Schlising (Editors), Research and Recovery in Vernal Pool Landscapes. Studies from the Herbarium, Number 16. California State Universtiy, Chico, CA.

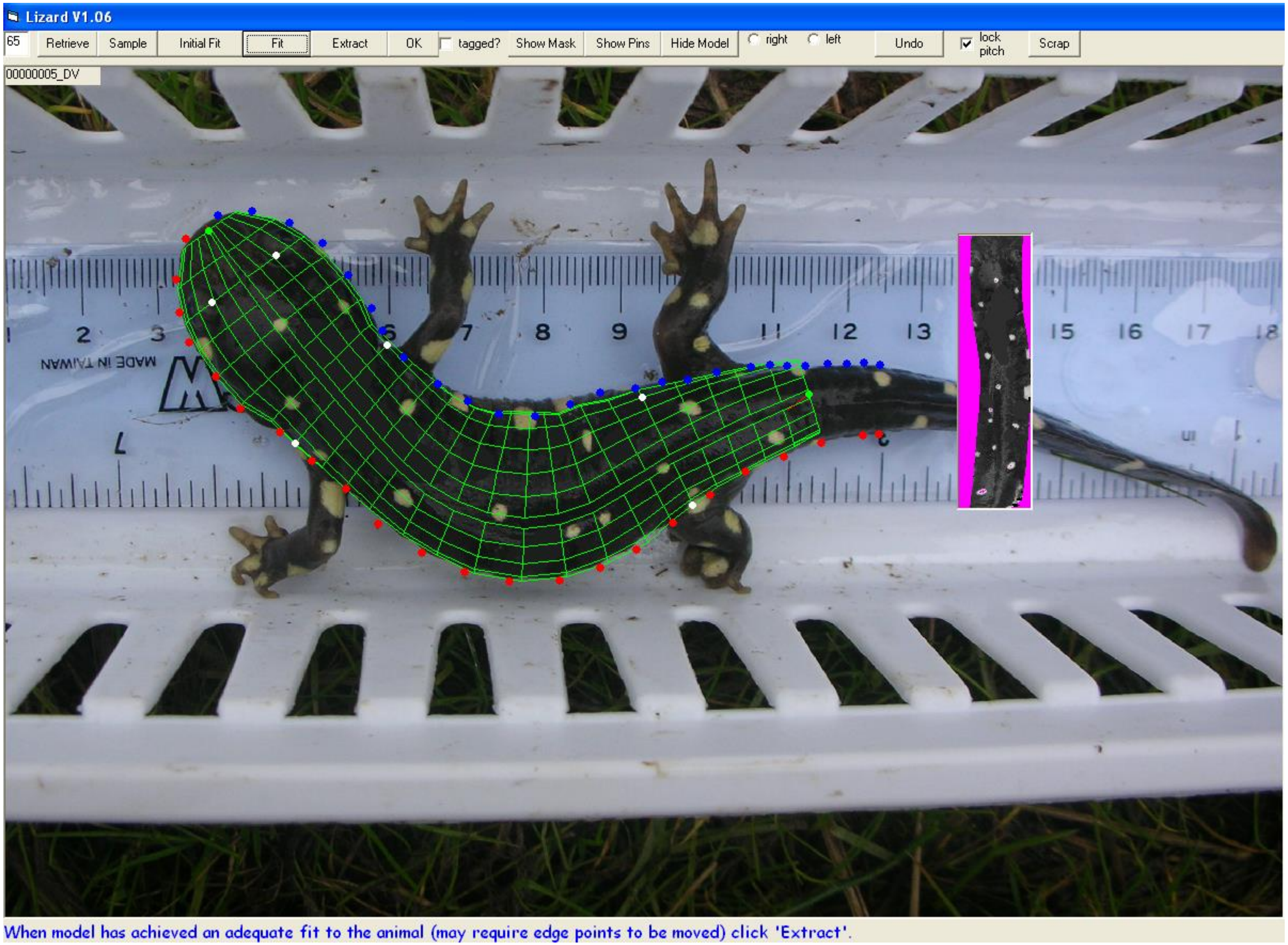

Proportion of Population Protected
Proportion of population
Distance from shoreline (m)
1.2
1
0.8
0.6
0.4
0.2
0
50%
0
500
1000
1500
2000
2500
3000
3500
504 m

Average Migration Distances



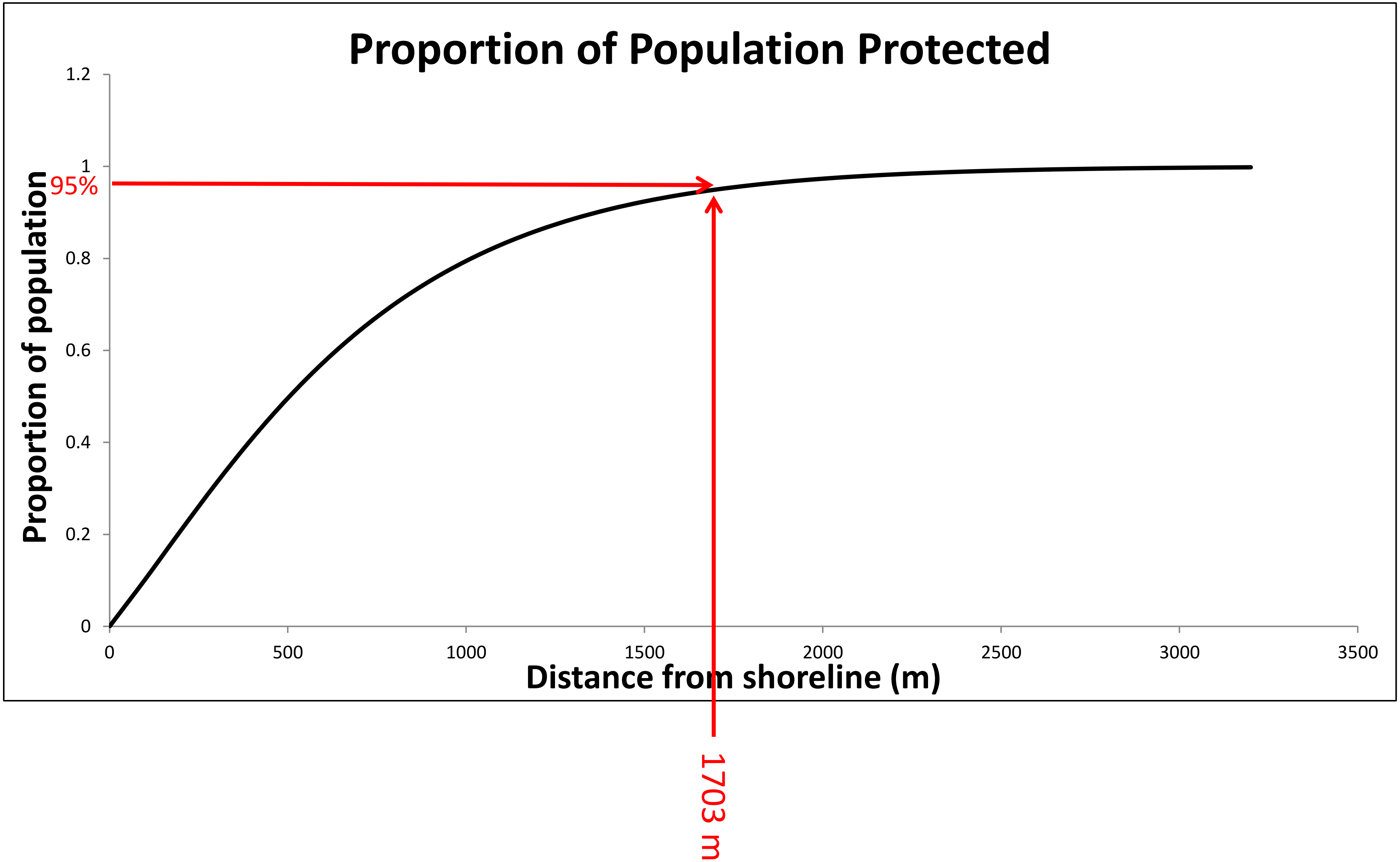
Searcy, C. A., E. Gabbai-Saldate, and H. B. Shaffer. 2013. Microhabitat use and migration distance of an endangered grassland amphibian. Biological Conservation 158: 80-87.

Pattern recognition



How far does the average salamander move in a season?

- Average rate = 150 m/night
- Most adults are active for 2 to 5 nights during both immigration and emigration
- (150 m/night)(3.5 nights) = 525 m
- This is pretty similar to the 504 m estimate from the integration method

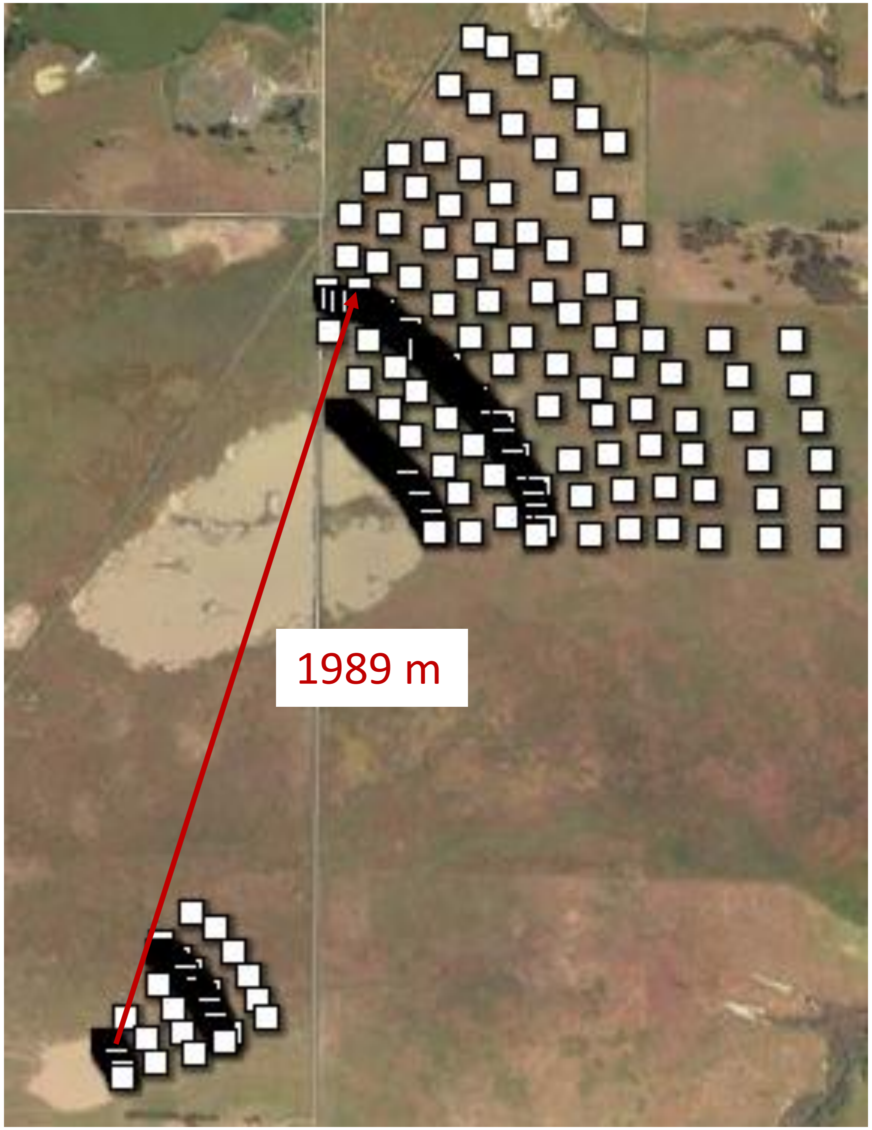


Proportion of Population Protected
Proportion of population
Distance from shoreline (m)
1.2
1
0.8
0.6
0.4
0.2
0
0
500
1000
1500
2000
2500
3000
3500
95%
1703 m

How far can a salamander move in a season?

- We know that a rate of 188 m/night is sustainable for at least 6 nights in a row
- There are 10 to 19 nights with appropriate weather conditions during both immigration and emigration
- (188 m/night)(10 nights) = 1880 m
- Even in a dry year, a salamander should be capable of migrating 1703 m

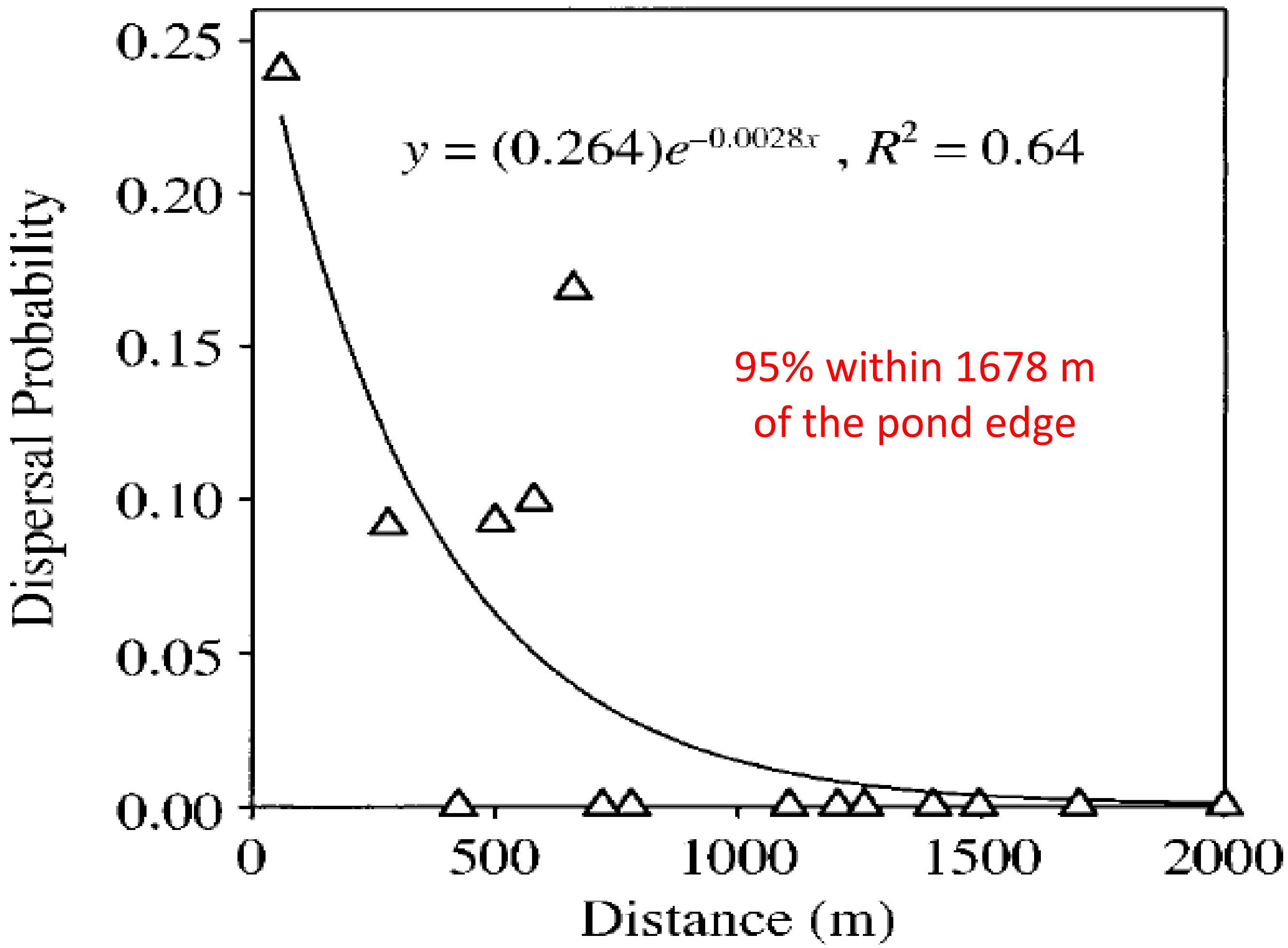
Longest observed migration



Conclusion

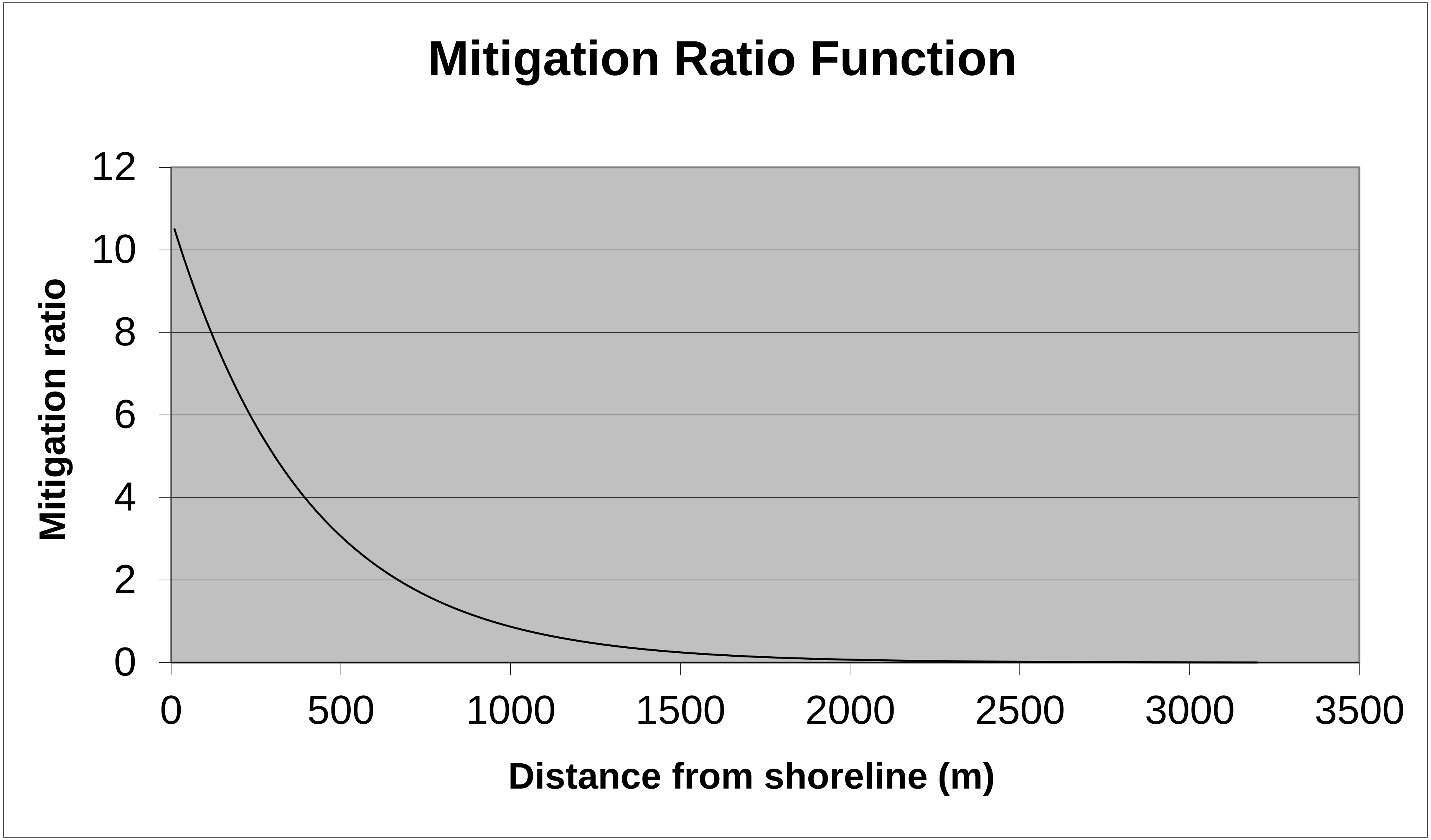
- The two methods agree very well
- The average adult probably travels ~500 meters from the pond – almost twice the distance of any of its congeners
- There is no reason to doubt that the top 5% of migrants travel 1703 m or more from the pond edge
- The 2092 m buffer currently used by USFWS is within the ecophysiological capacity of the salamander in most years and is within the 95% confidence interval of the integration method

Other Landscapes



Source: Trenham, P. C., W. D. Koenig, and H. B. Shaffer. 2001. Spatially autocorrelated demography and interpond dispersal in the salamander *Ambystoma californiense*. Ecology 82: 3519-3530.

Single species conservation



Mitigation factor at the shoreline should be 10.8:1, mitigation factor at 945 m should be 1:1, and mitigation factor at 1.3 mi should be 0.06:1.

Multi-species conservation

- Due to their large habitat requirements, California tiger salamanders can serve as an umbrella species for conservation of vernal pool grasslands in central California.
- Vernal pools are a bastion for rare California endemics due to their harsh climate, and as a result 89 other listed species live within the 2092 m buffer around California tiger salamander breeding ponds.

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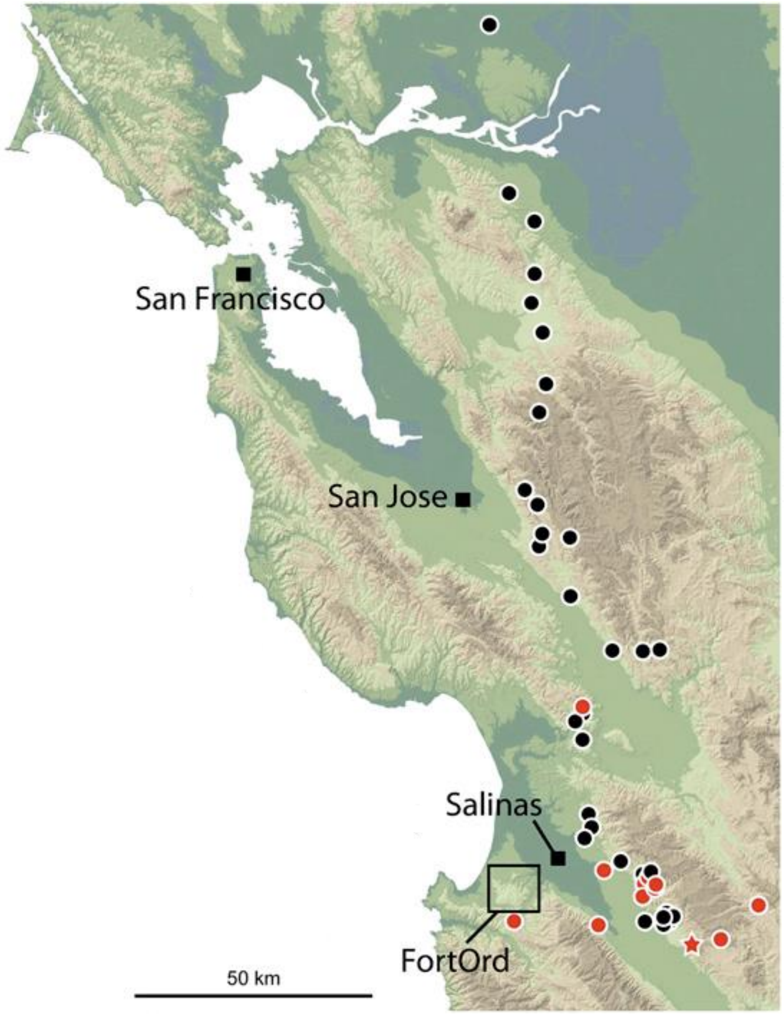
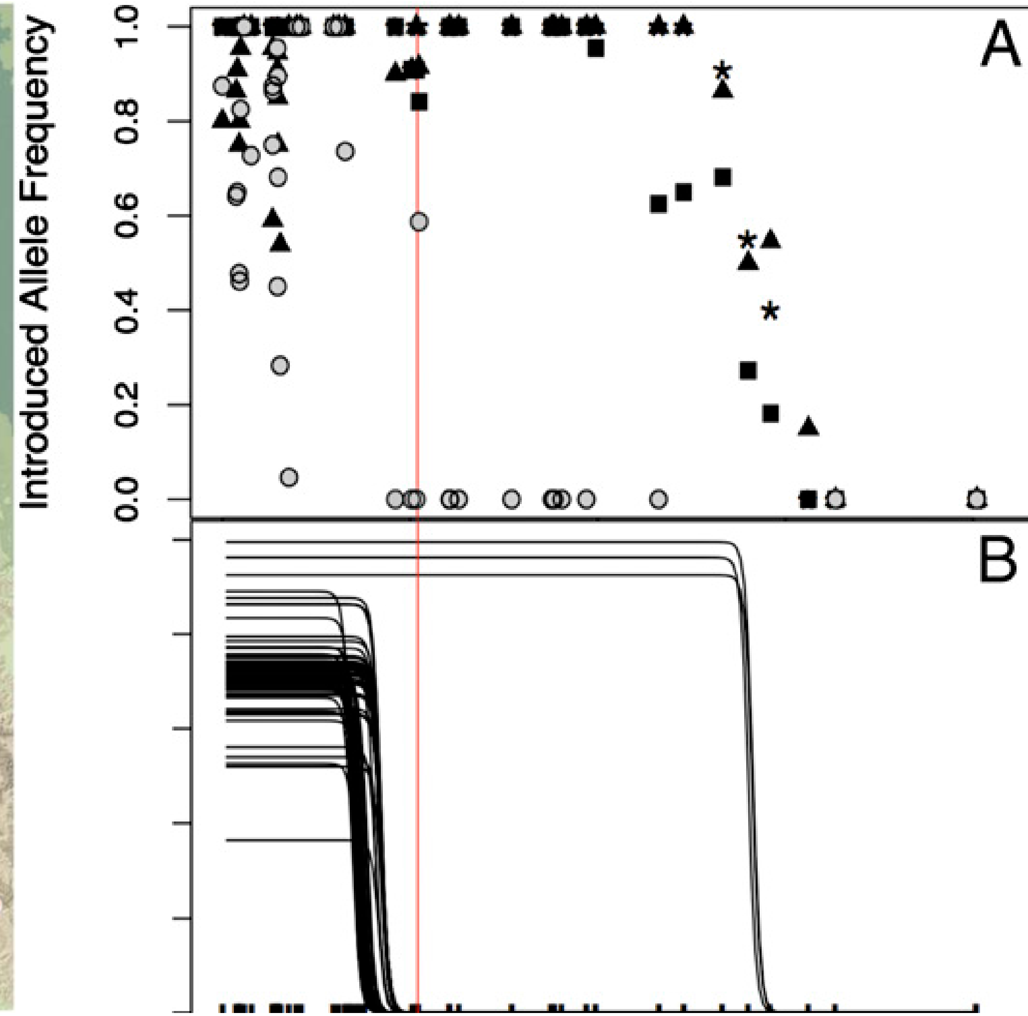
Waterdogs

The Problem

Source: Ryan, M. E., J. R. Johnson, and B. M. Fitzpatrick. 2009. Invasive hybrid tiger salamander genotypes impact native amphibians. Proceedings of the National Academy of Sciences 106: 11166-11171.

Invasive Spread





Source: Fitzpatrick, B. M., J. R. Johnson, D. K. Klump, J. J. Smith, S. R. Voss, and H. B. Shaffer. 2010. Rapid spread of invasive genes into a threatened native species. Proceedings of the National Academy of Sciences 107: 3606-3610.

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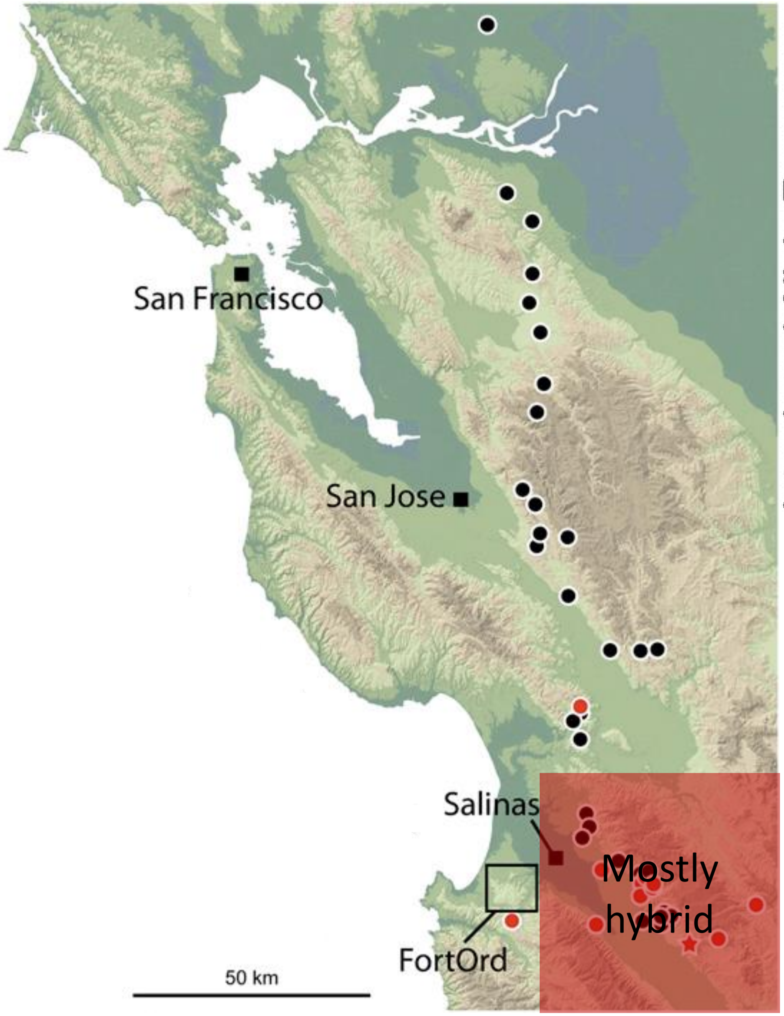

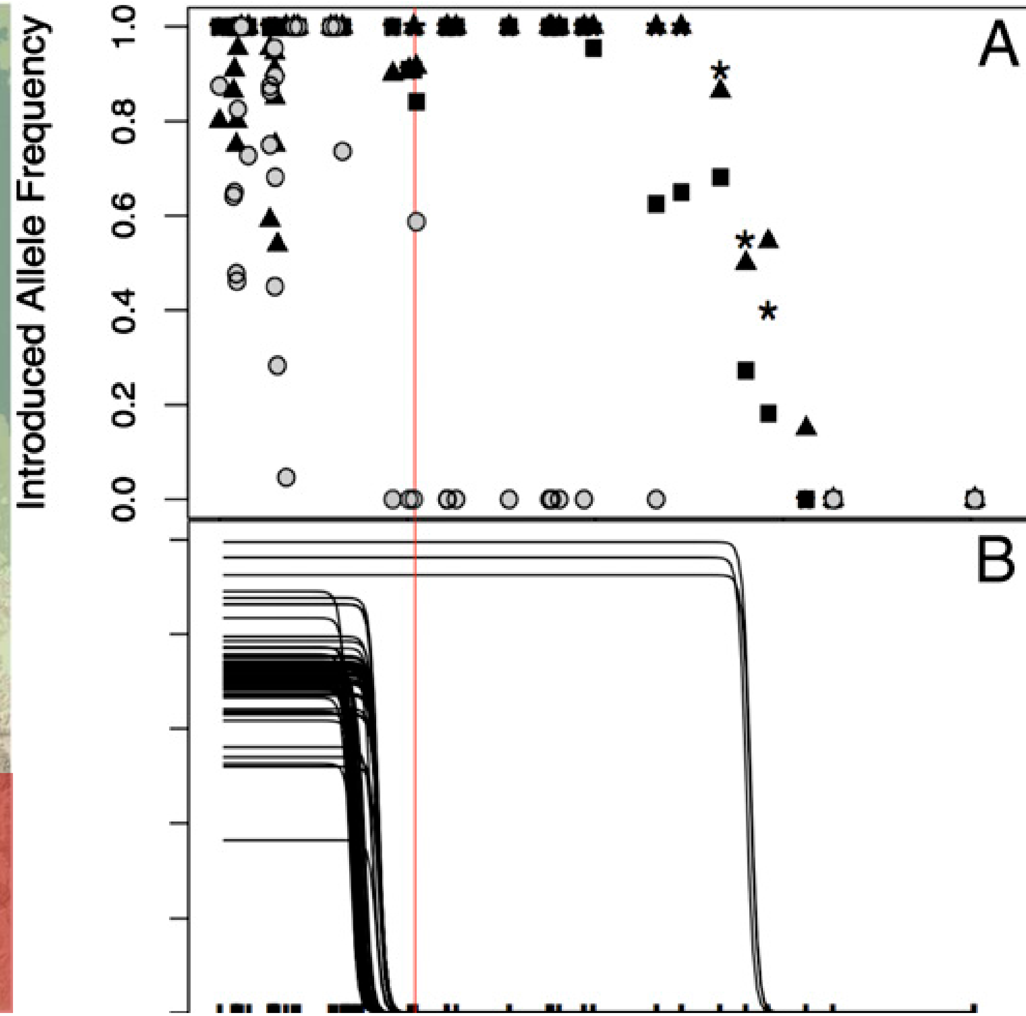

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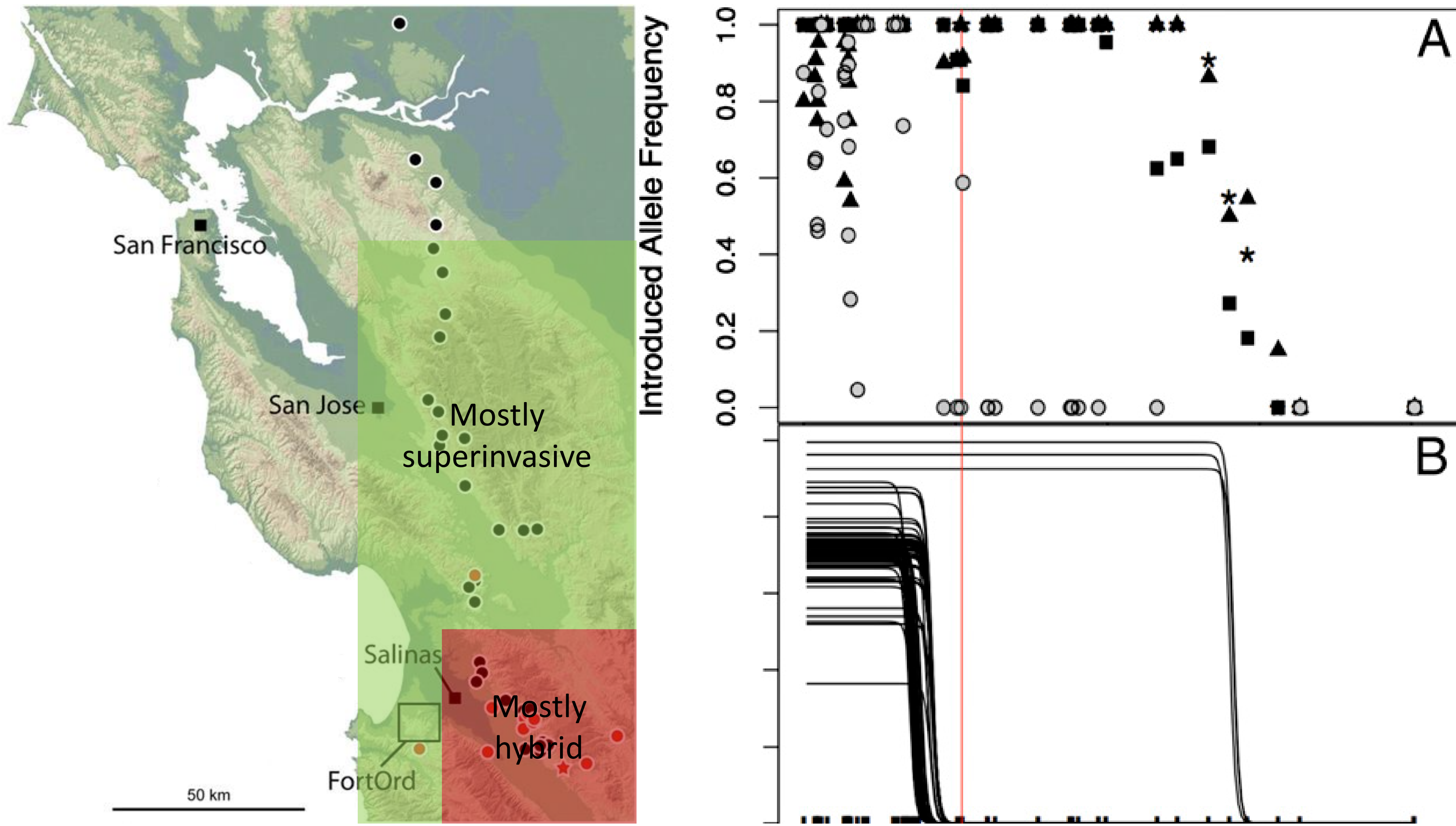

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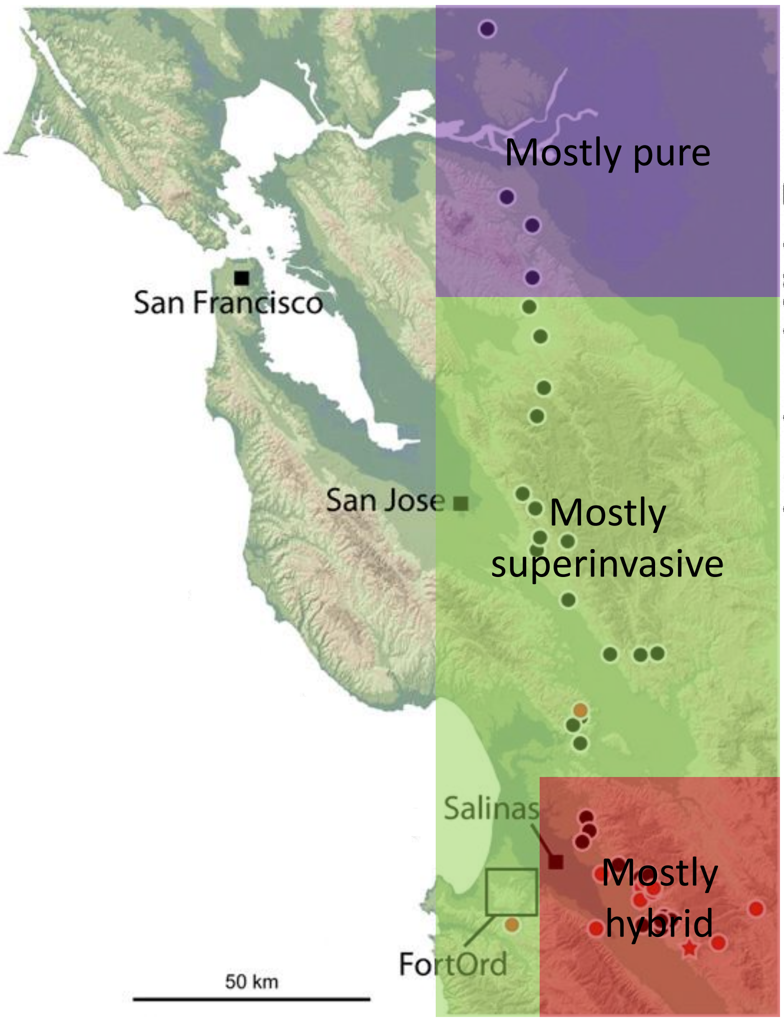

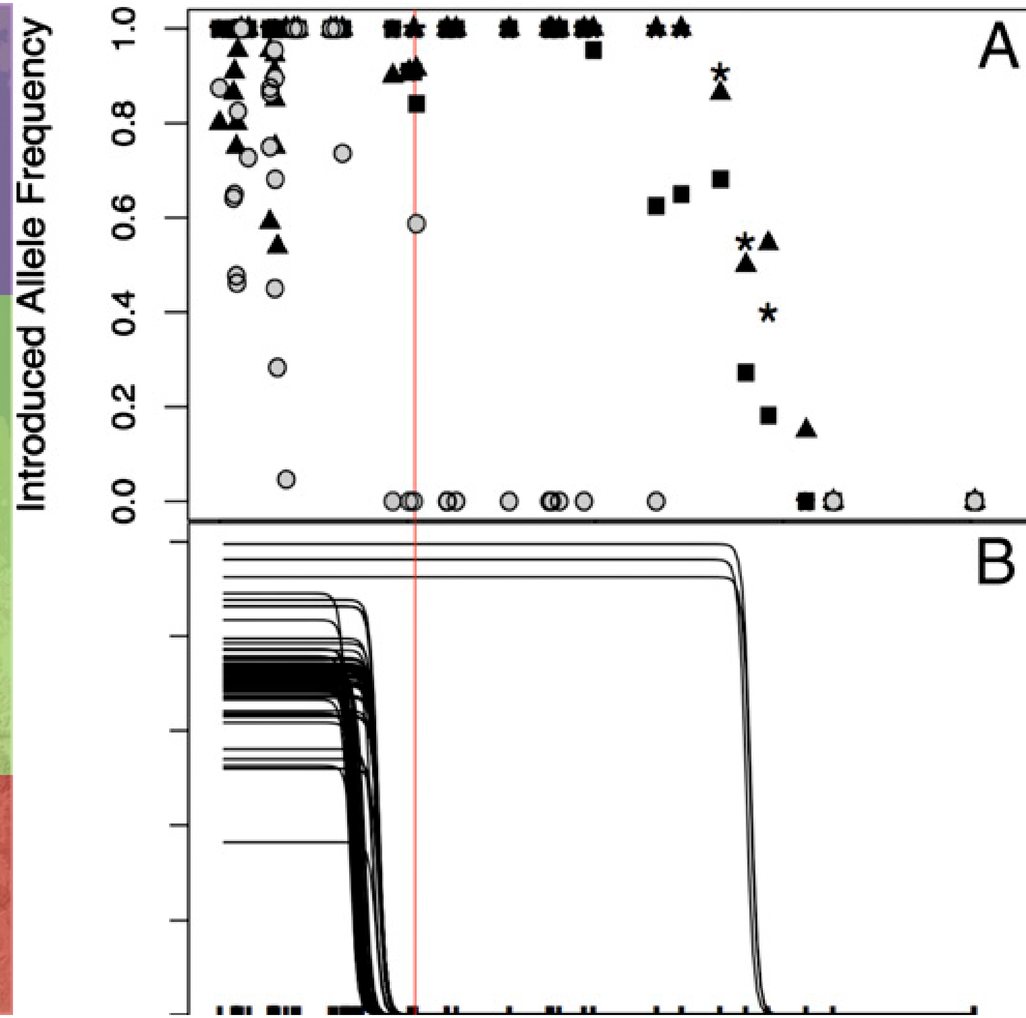

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Questions

1) How should hybrids be managed?

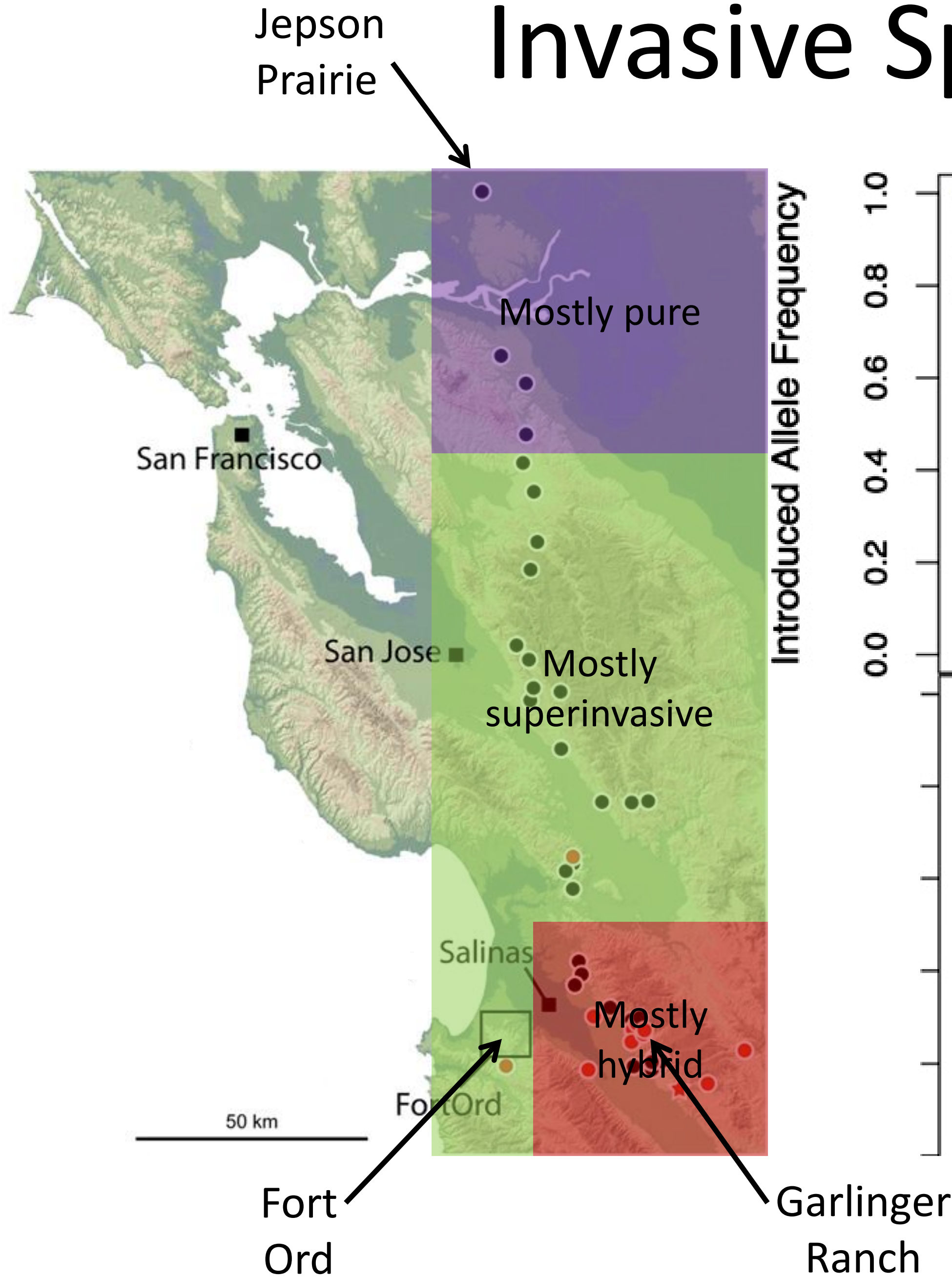
2) Does this answer change based on whether they are full hybrids or superinvasives?

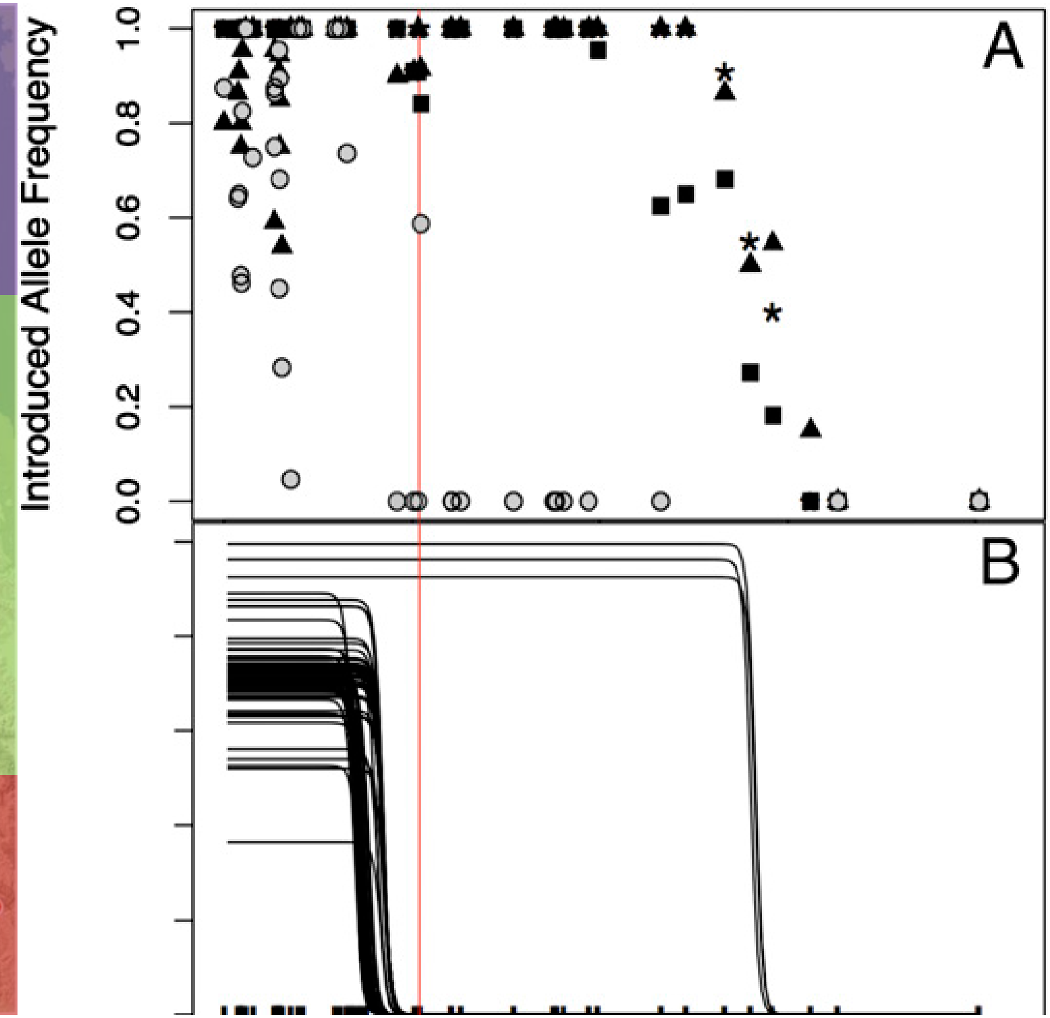
Our Approach: Ecological Equivalency

- Mesocosm experiment (4 x 2 factorial)
- Treatments: larval genotype, larval density
- 4 levels of larval genotype:
  - pure CTS
  - superinvasive
  - full hybrid
  - no tiger salamander
- 2 levels of larval density:
  - 4 larvae per tank
  - 8 larvae per tank
- 5 replicates of each – 40 cattle tanks total

Searcy, C. A., H. B. Rollins, and H. B. Shaffer In prep. Ecological equivalency of endangered and invasive tiger salamanders.

Invasive Spread

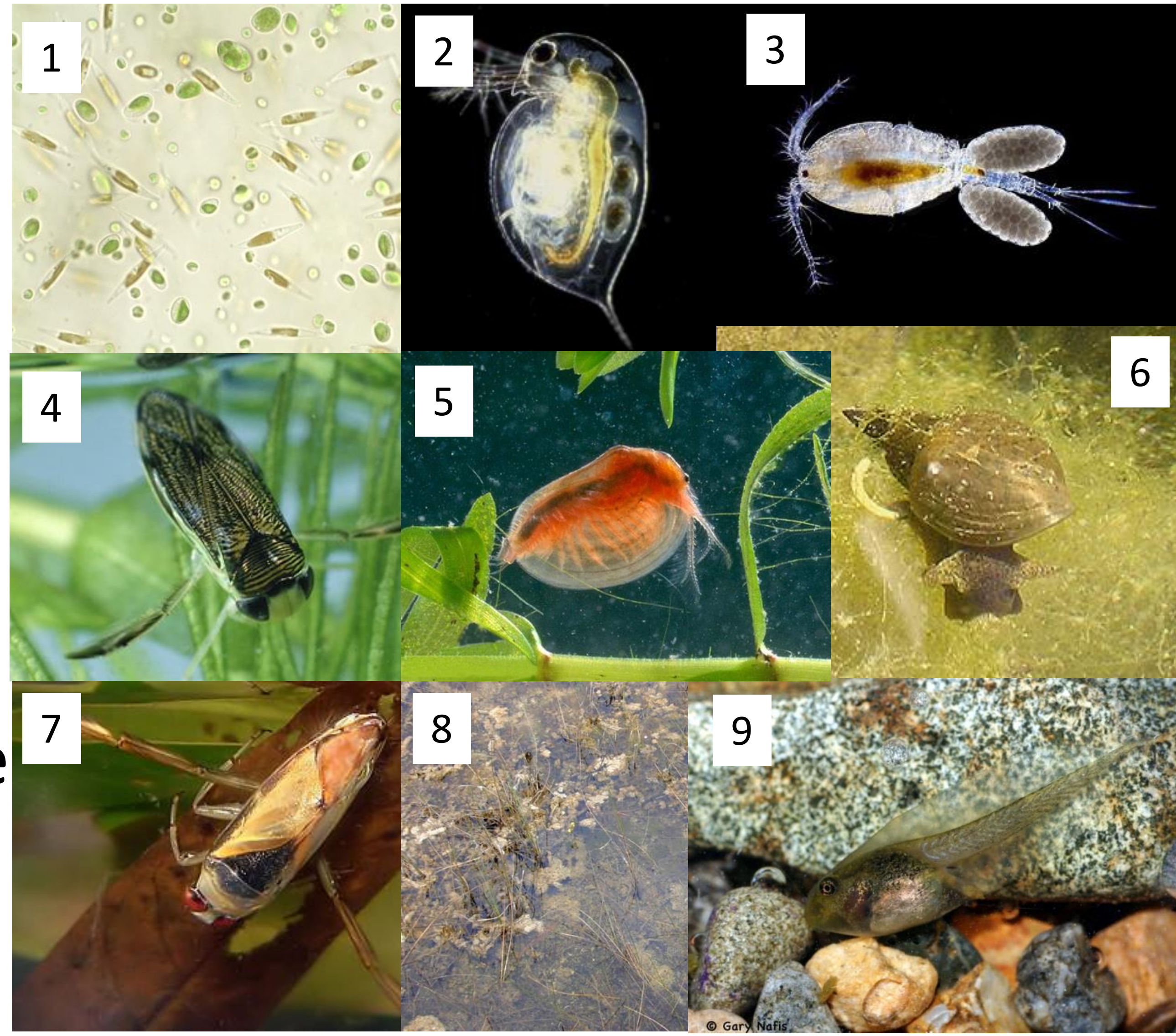




Community Metrics

Densities of:

1) Chlorophyll
2) Cladocera
3) Copepoda
4) Corixidae
5) *Cyzicus*
6) Gastropoda
7) Notonectidae
8) Periphyton
9) *Pseudacris*



Experimental Procedure: Setup

1) Added phytoplankton and periphyton on December 18/19 when tanks were filled.

2) Added cladocerans and copepods on January 17.

3) Added 18 *Cyzicus*, 8 corixids, and 4 gastropods on March 18.

4) Added tiger salamander larvae on March 26.

5) Added 102 *Pseudacris*, 13 corixids, 11 notonectids, 2 gastropods, and 1 dytiscid larva on April 19 & 23.

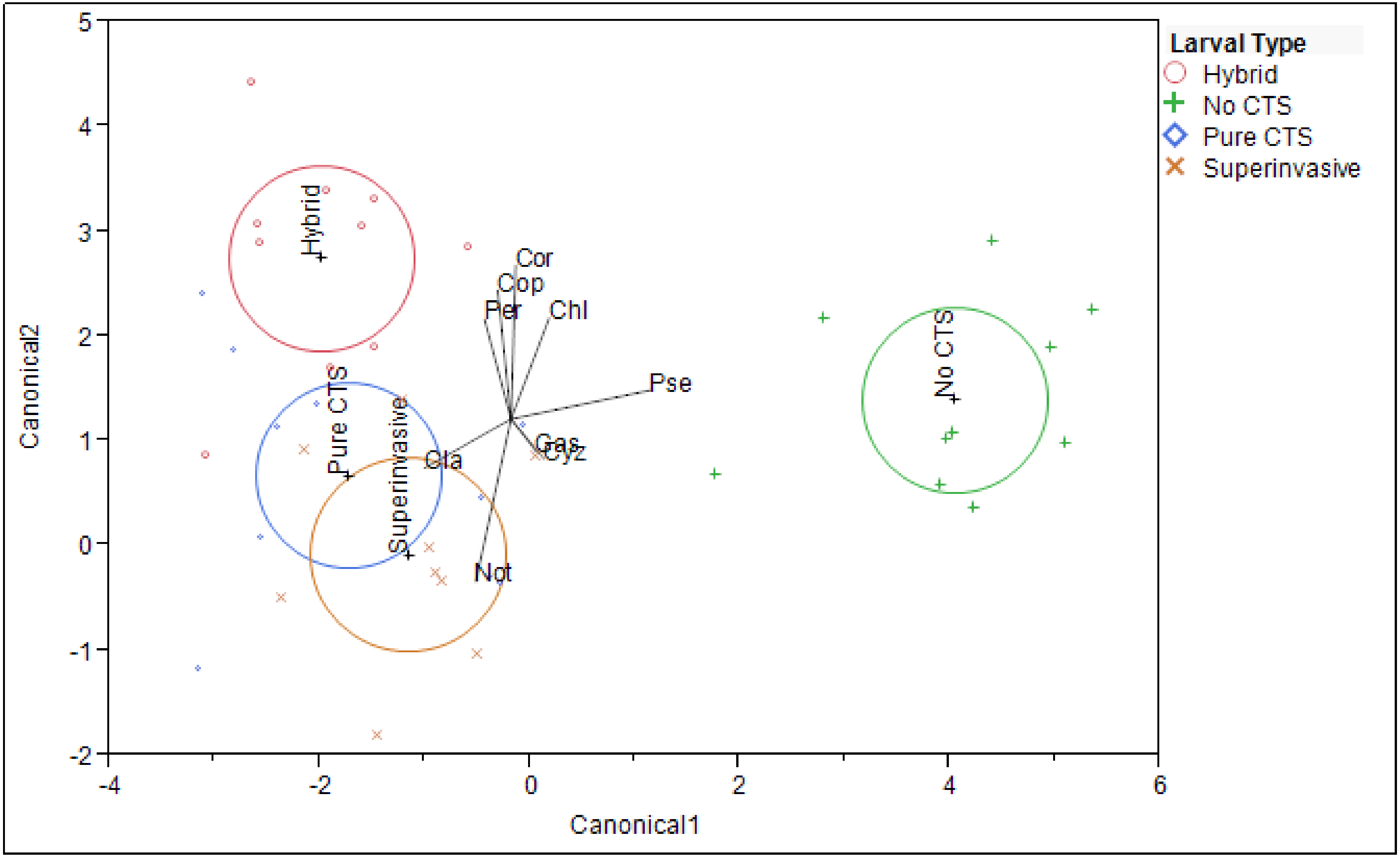
Experimental Procedure: Data Collection

1) Measured chlorophyll, cladoceran, copepod, and periphyton densities on May 24/25 during peak metamorphosis.

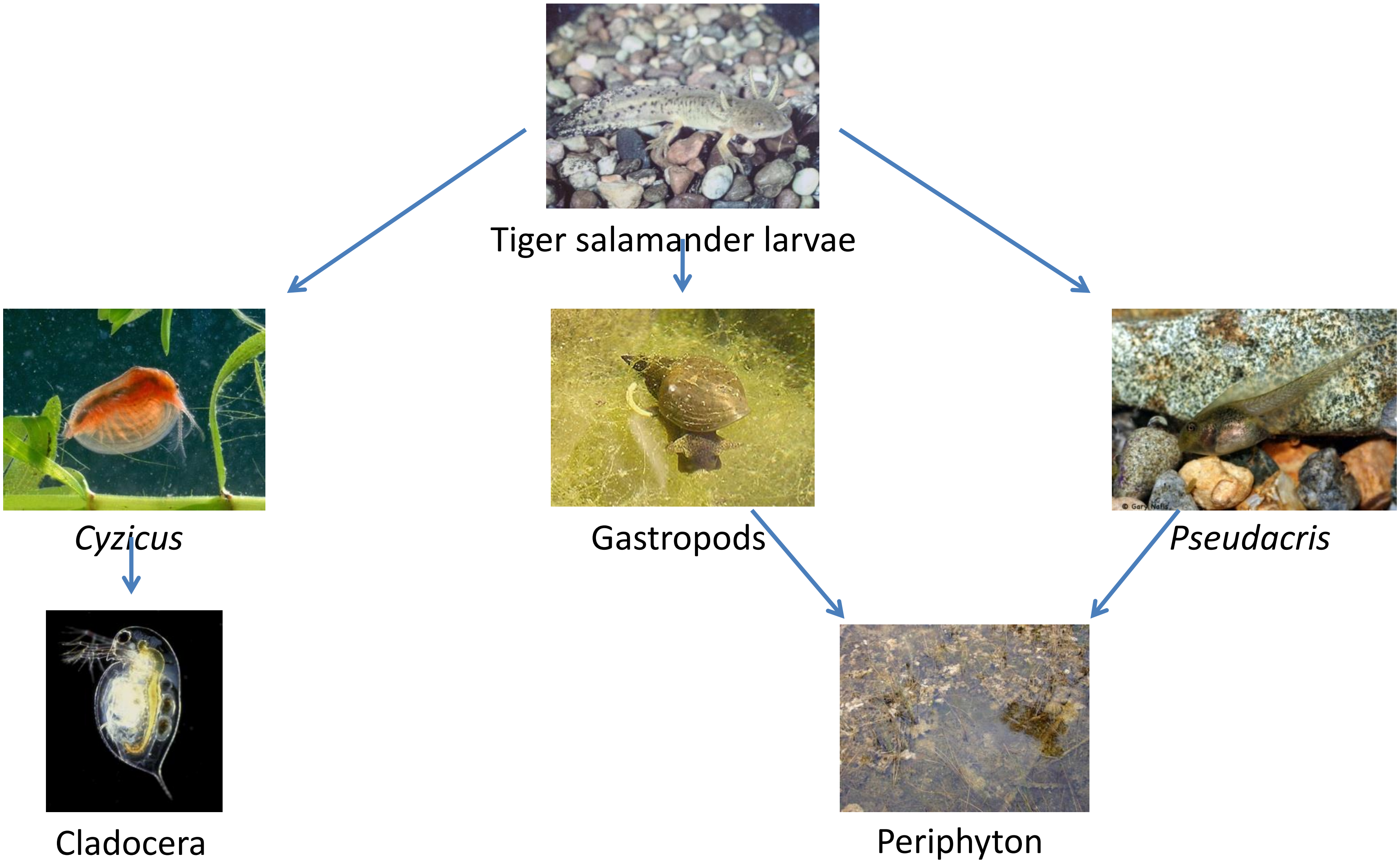
2) Counted corixids, *Cyzicus*, gastropods, and notonectids when tanks were drained on June 27/28.

3) Collected metamorphosed *Pseudacris* and tiger salamanders every third day from May 9 – June 26.

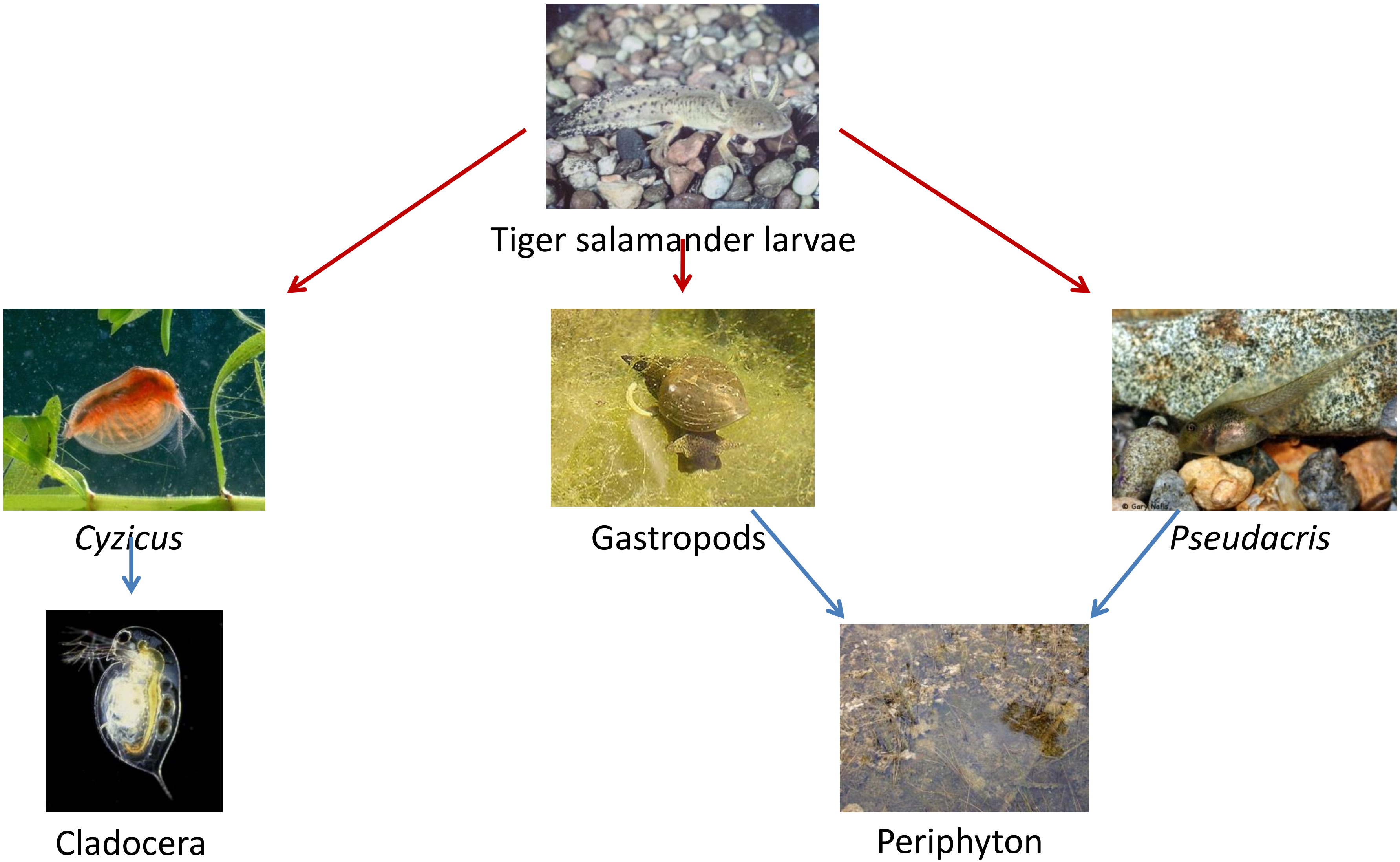
Community Composition



Food Web

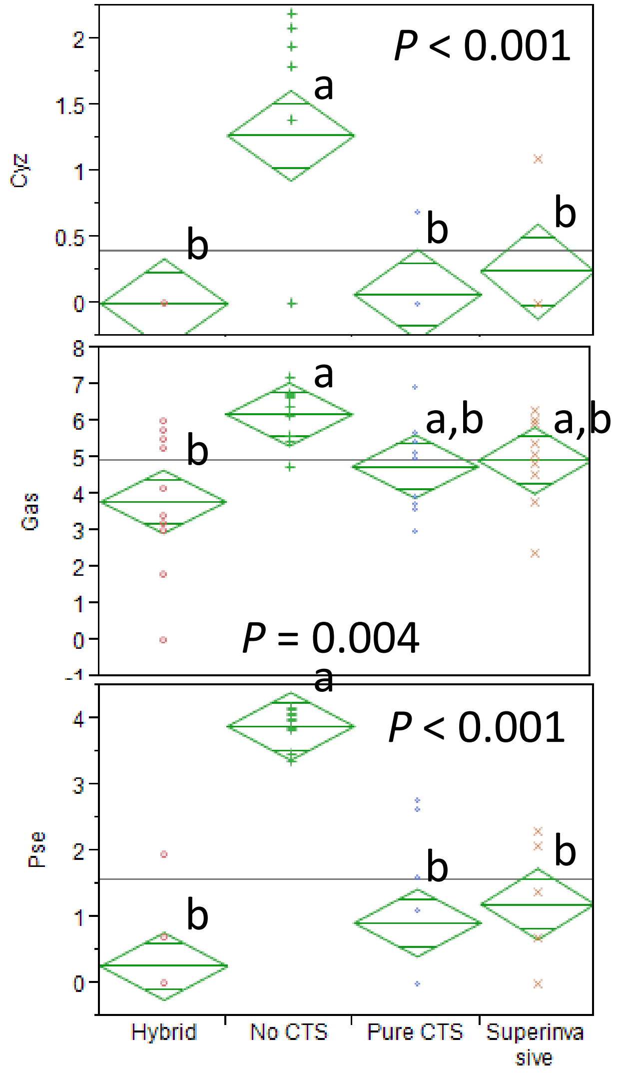

Tiger salamander larvae
Cyzicus
Gastropods
Pseudacris
Cladocera
Periphyton

Food Web

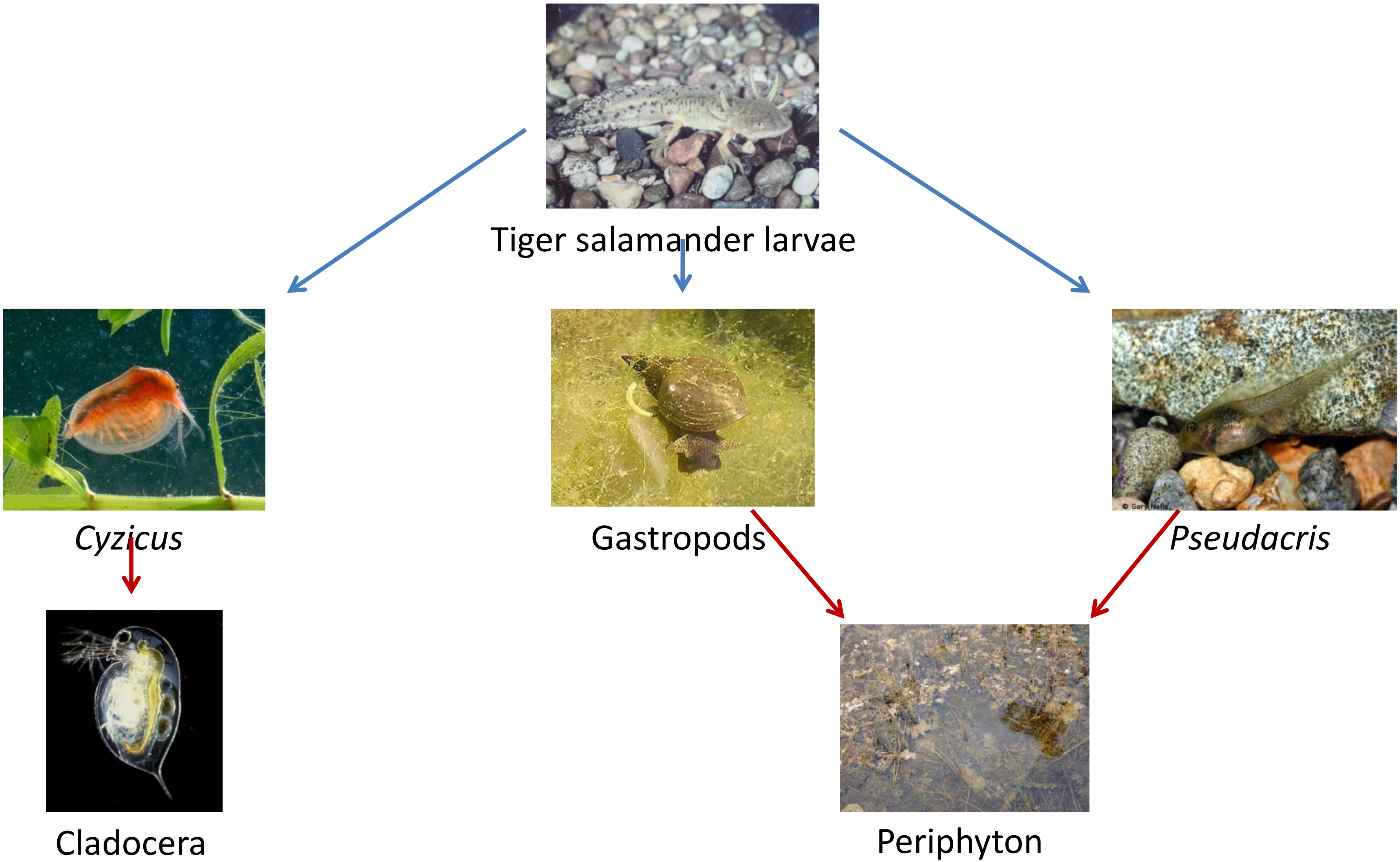


Tiger salamander larvae
Cyzicus
Gastropods
Pseudacris
Cladocera
Periphyton

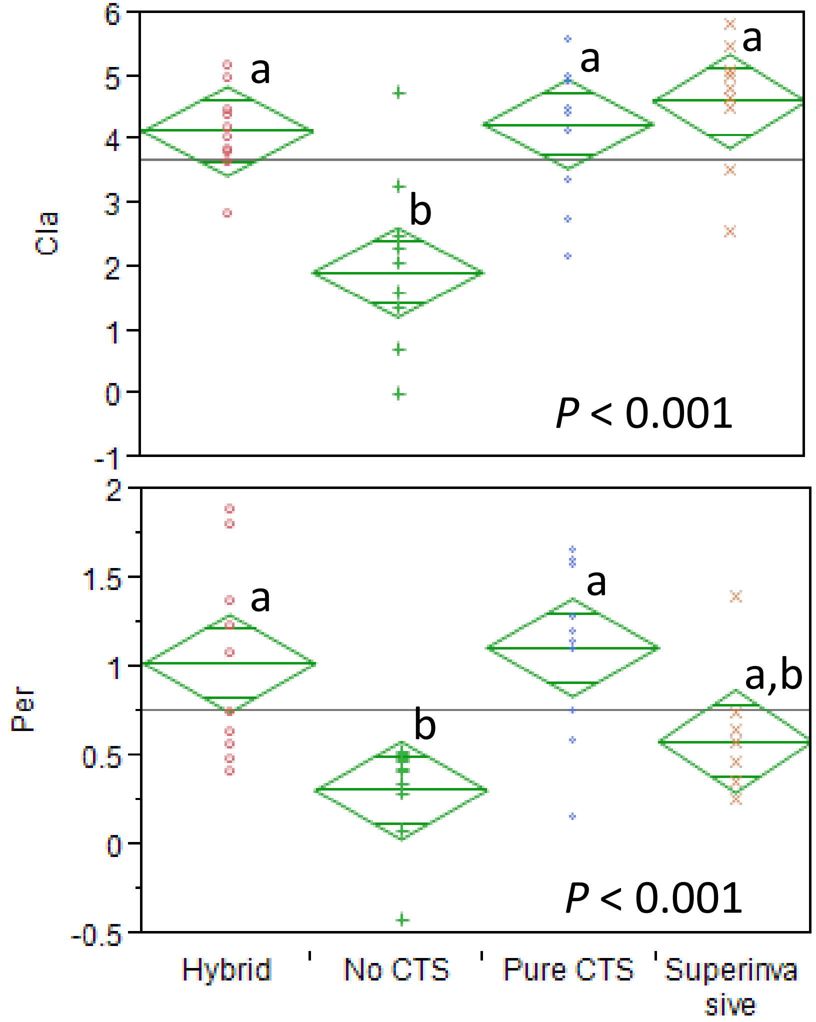
Tiger salamander prey



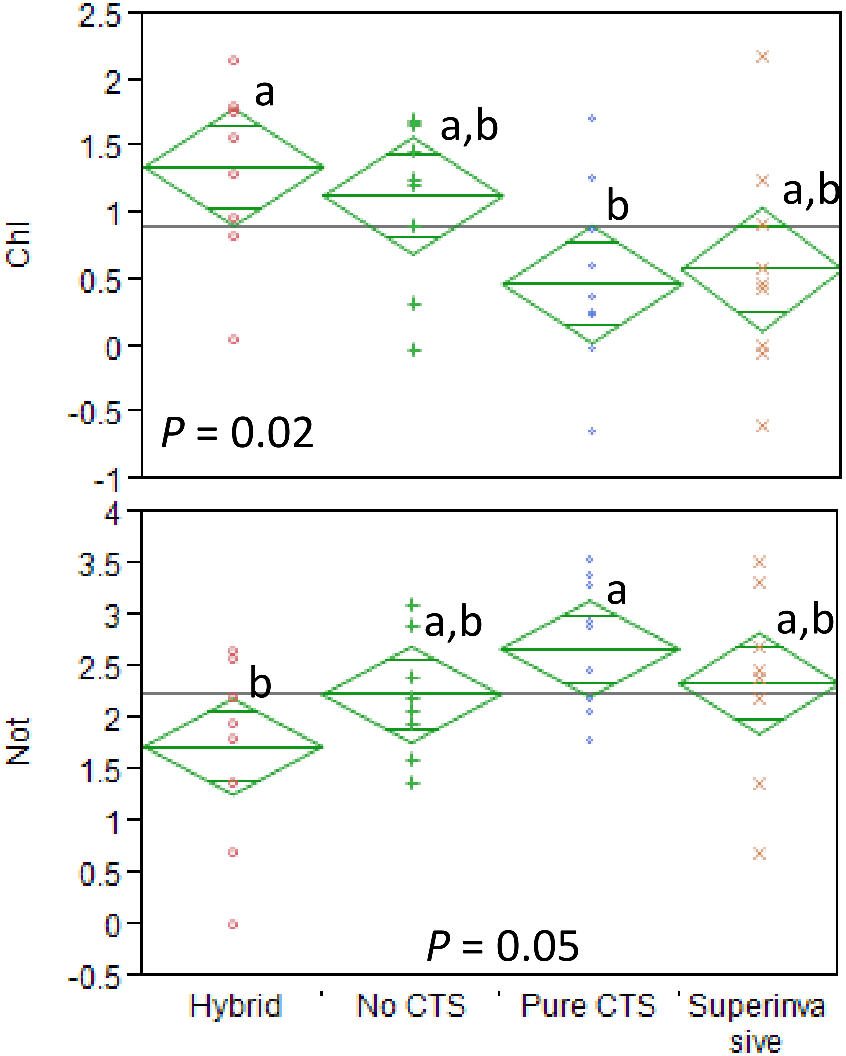
Food Web


Tiger salamander larvae
Cyzicus
Gastropods
Pseudacris
Cladocera
Periphyton

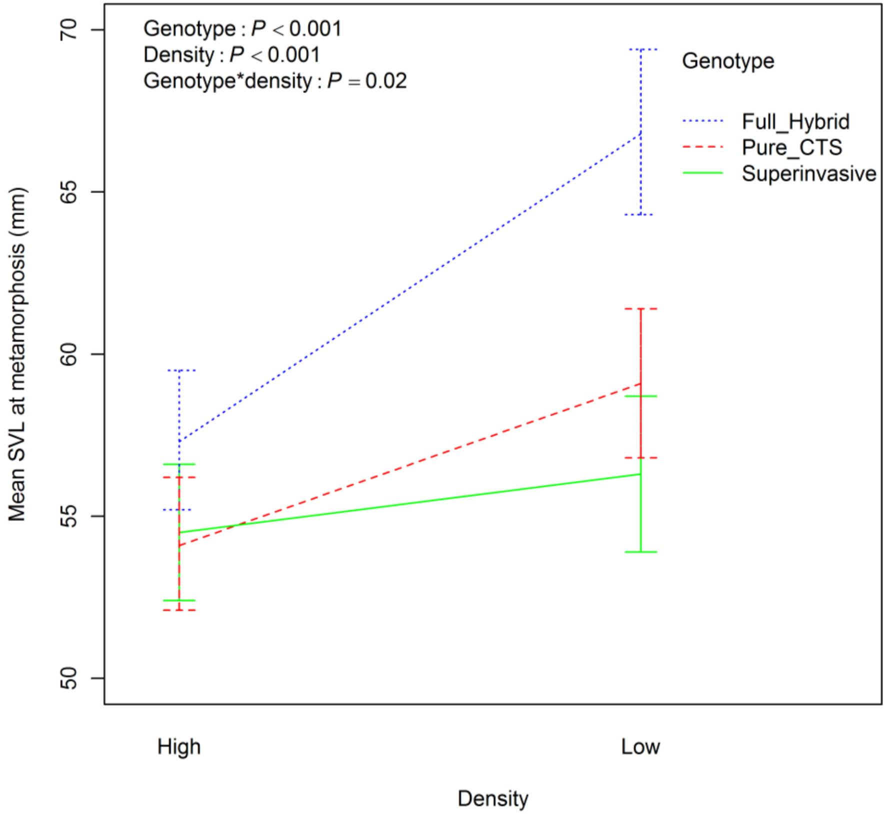
Trophic Cascade

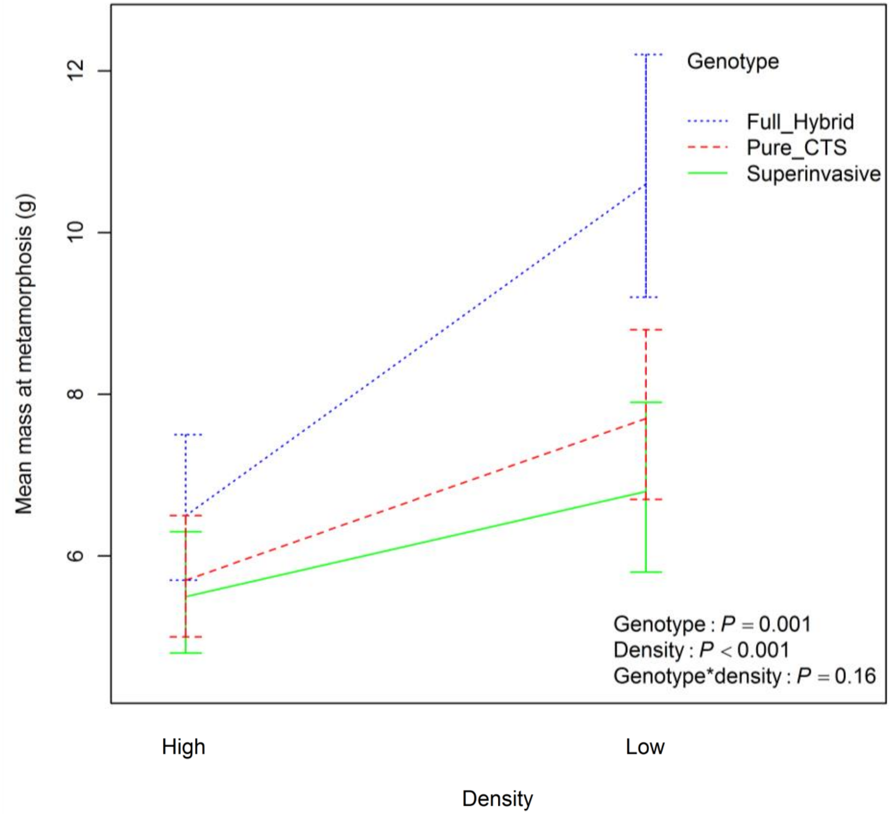


Hybrid Effect

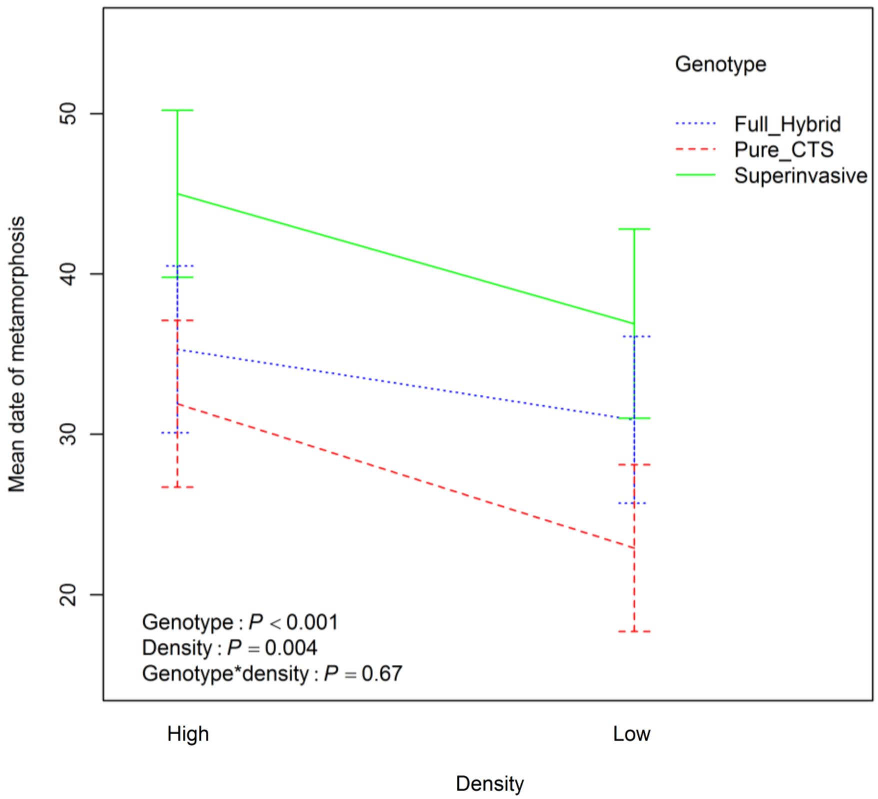


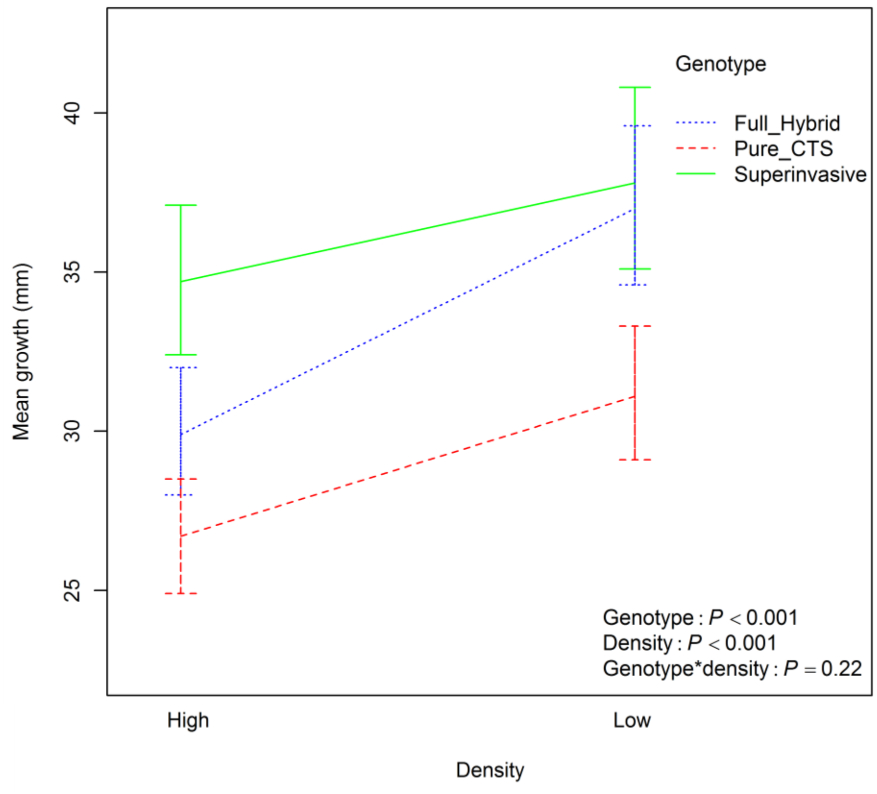
Morphological Differences



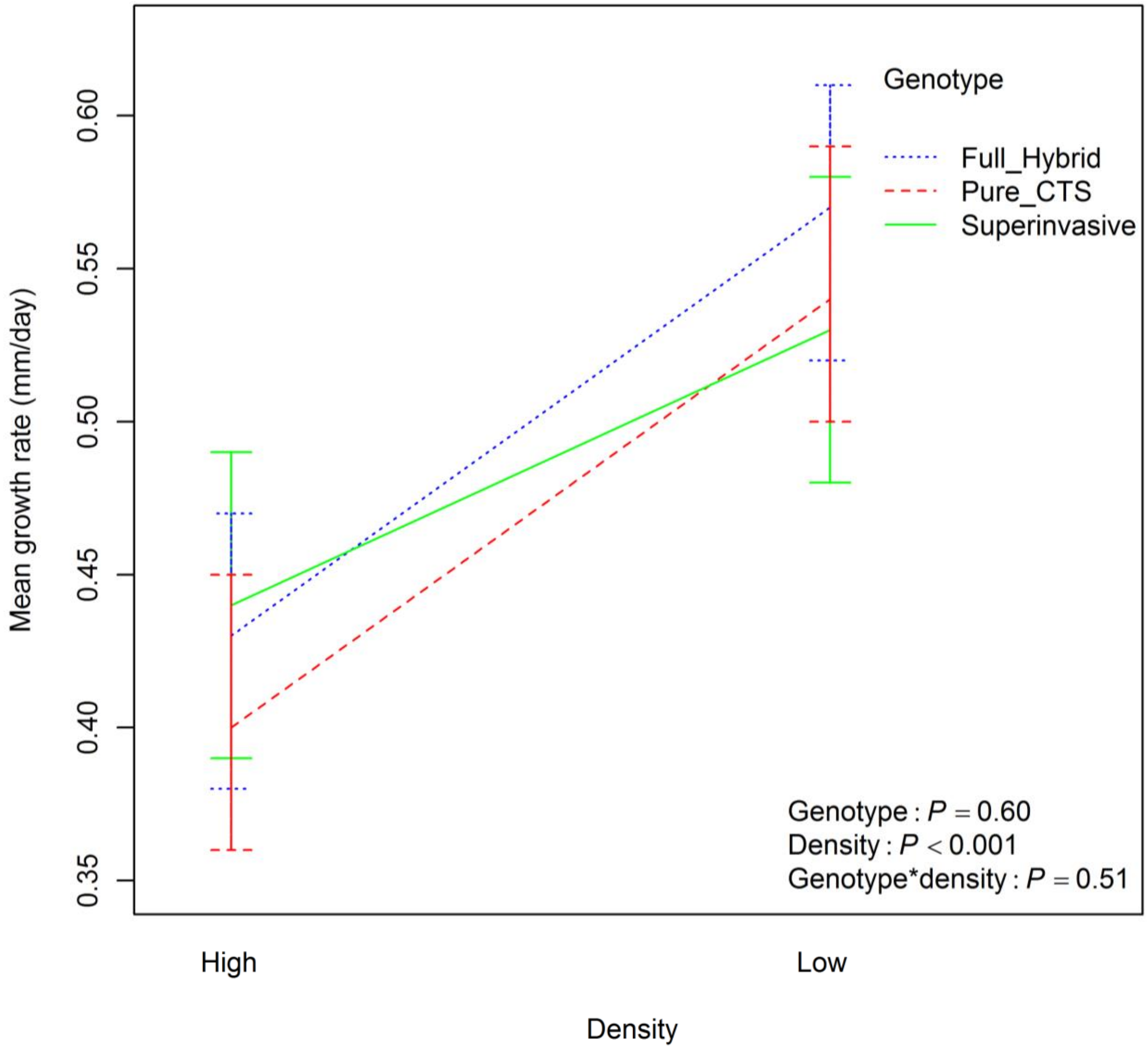


Morphological Differences

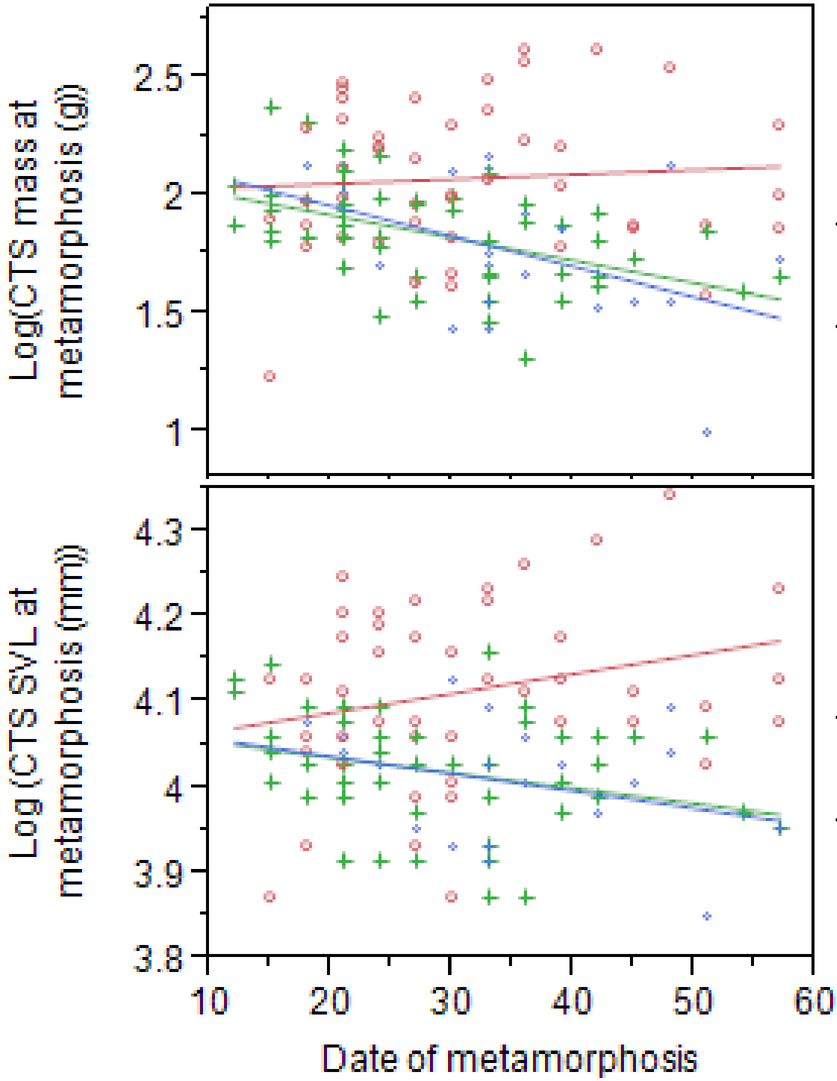




Morphological Differences



Life History Strategies



Treatment: *P* < 0.001
Date: *P* = 0.007
Treatment*date: *P* = 0.02

Treatment: *P* < 0.001
Date: *P* = 0.50
Treatment*date: *P* = 0.01

Conclusions

1) If we can get to pure CTS, we should

2) Superinvasives are the most ecologically similar to pure CTS, because their community effects and life history strategy are not statistically distinguishable from pure CTS.

3) Having no tiger salamanders is less desirable than having hybrids, because hybrids do fulfill some of the roles of CTS in the aquatic environment

4) We should manage habitat to decrease the percentage of invasive genes by decreasing hydroperiods.

Future Questions

1) If pure CTS and superinvasives are ecologically similar, then why are superinvasive genes racing across the landscape?

2) We know that there are many genomic regions that differ between hybrids and pure CTS, but what genes do these regions actually code for?

3) In this study we tested the ecological equivalency of salamanders with ~4% and ~71% non-native genes. What about salamanders with 50% or 25% non-native genes? Would managing a pond such the gene frequencies shifted between these two levels be a meaningful improvement?

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