California Tiger Salamander Biology and Conservation

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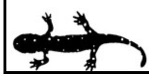
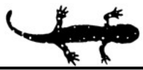



Workshop Topics

1) Tiger salamander evolution – how is CTS unique
2) Range and habitat basics
3) Causes of decline; future threats
4) CTS life cycle and identification of different stages
5) Life history, demography, and population dynamics
6) Predators and prey
7) Habitats and ecology
8) Movements, populations, metapopulations, and landscapes
9) Strategies for avoidance, minimization, conservation and recovery
10) Survey methods, requirements, and strategies

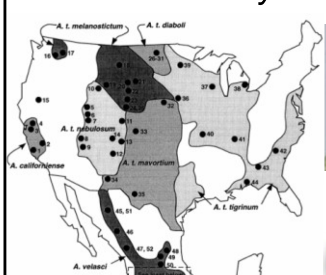
Key Facts for Understanding CTS

- Breed in ponds – develop as aquatic larvae
  - ponds must hold water until at least May
- Larger ponds are better (but not permanent ponds)
- The CTS is primarily a terrestrial beast
  - lives mainly in small mammal burrows
  - observed to move >1.5 km overland
- Large areas of contiguous or interconnected habitat is what's needed for its conservation
  - CTS coexist with certain human land uses
  - Habitat loss (and hybridization) are main threats

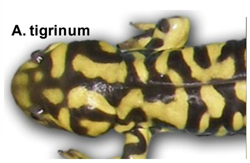
What is a CTS

- **Amphibian**
  - aquatic eggs, thin scale-less skin
- **Salamander**
  - four legs and a tail
- **Mole salamander**
  - Family Ambystomatidae
- **Tiger salamander**
  - large terrestrial salamanders and the only group to occupy grasslands
- ***Ambystoma californiense***

Pattern and Head Shape Differ From *Ambystoma tigrinum*

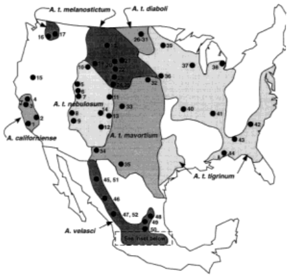


Shaffer and McKnight 1996



CTS larvae are smaller and are not known to become sexually mature larvae (paedomorphs)

CTS is Genetically Different
(est. 3-5 million years independent evolution)



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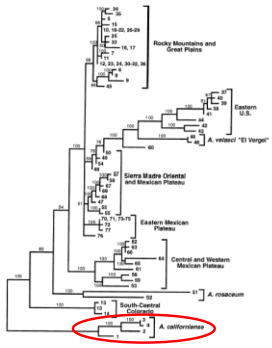


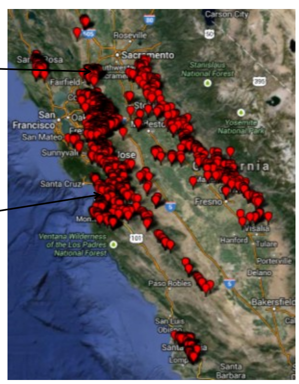
CTS Distribution

- extremely broad range
  - to 3900 ft in Coast Range
  - to 1200 ft in Sierra foothills
- habitat/climate differs
  - 9 to 38 in rainfall
- often generalizing based on studies from a few sites ★

Focal populations

Jepson Prairie Preserve:
9 years of data
(2005-2013)

Hastings Natural History Reservation:
6 years of data
(1992-1997)

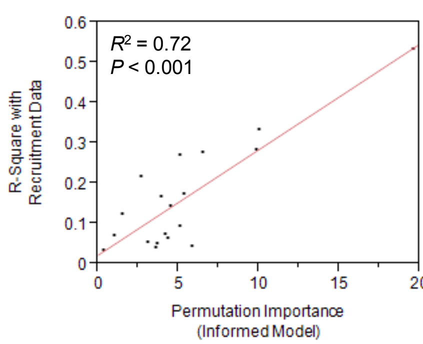


Climatic factors significantly correlated with recruitment

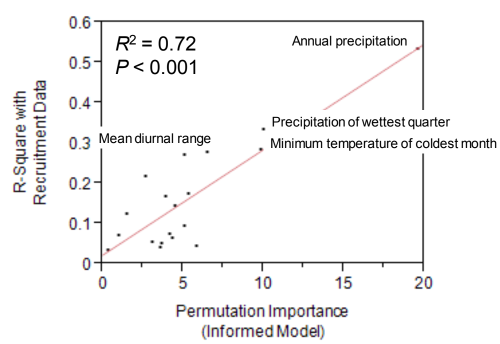
Bioclim variable	Sign	R^2
Annual precipitation	+	0.53
Precipitation wettest quarter	+	0.33
Minimum temperature of coldest month	+	0.28
Mean diurnal range	-	0.28
Precipitation wettest month	+	0.27
Precipitation coldest quarter	+	0.22

Searcy, C. A. & H. B. Shaffer. In revision. *The American Naturalist*.

Concordance with factors governing spatial distribution



Concordance with factors governing spatial distribution



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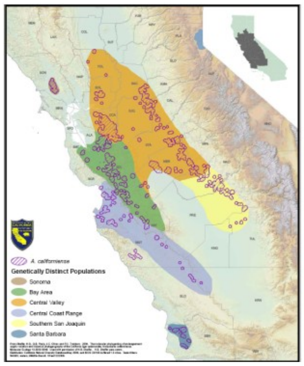
CTS Genetics

Six Genetic Groups

Sonoma

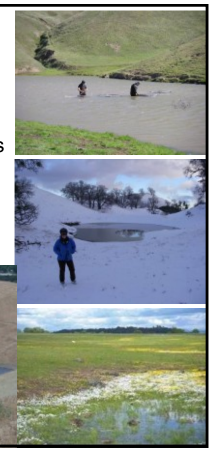
Central Valley
Bay Area
Southern San Joaquin
Central Coast Range

Santa Barbara

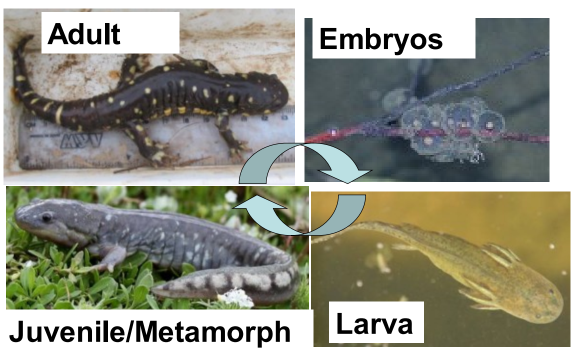


Habitat Basics

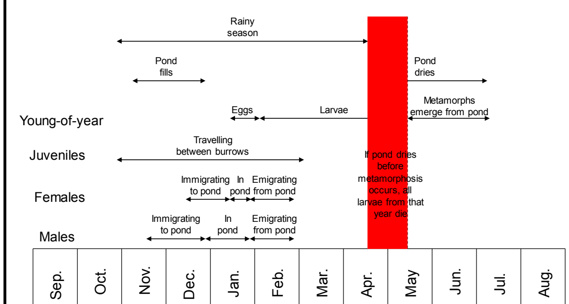
- Aquatic Habitat
  - Ponds*
  - Vernal Pools*
  - Ditches
- Upland Habitat
  - Grassland*
  - Oak savanna*
  - Oak woodlands
  - Sometimes chaparral and shrublands



Basic Life Cycle and Morphology



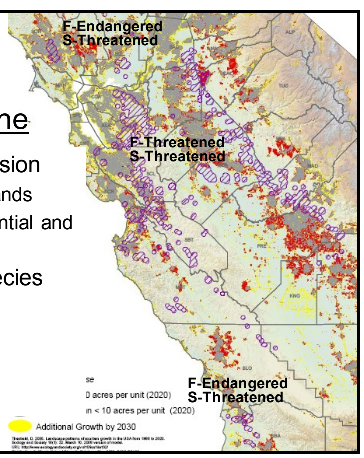
CTS Life Cycle



Causes of Decline

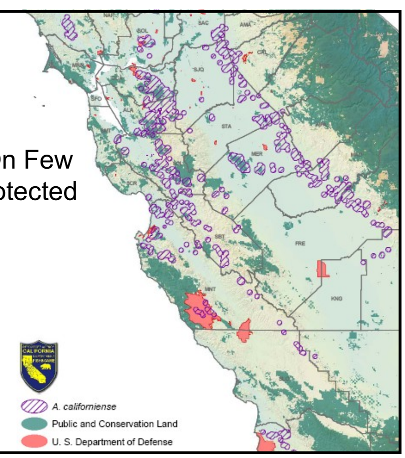
- #1 – Habitat Conversion
  - of wetlands and uplands
  - to agriculture, residential and urban uses
- #2 – Introduced Species

*From: CDFG 2009 Status Evaluation



- CTS Occur On Few Currently Protected Lands

*From: CDFG 2009 Status Evaluation



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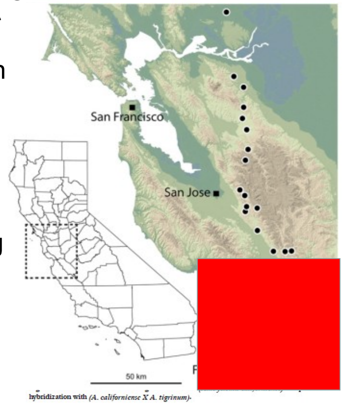
Cause of Decline *#2 - Hybrids*

- initial introduction
  - South of Salinas
  - 1940's
- discovered late 1990's
- situation evolving

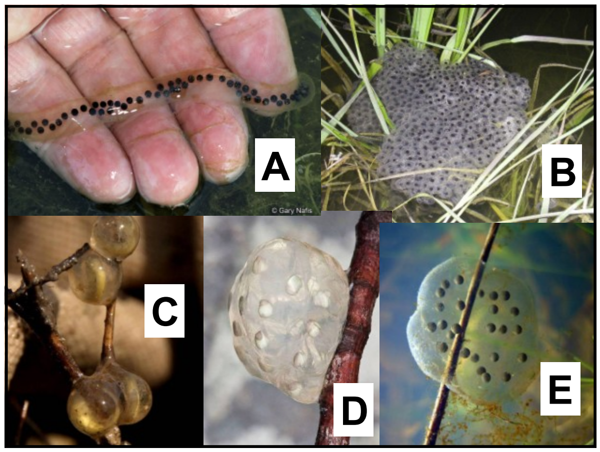


Introductory Main Points

- CTS habitat and range
  - Breed in ponds
  - Upland habitat with grasslands
  - From Sonoma Co. to Santa Barbara Co., in areas with appropriate climate
- Annual cycle driven by rainfall and pond drying
- Key threats/reasons for listing
  - Habitat loss
  - Hybridization

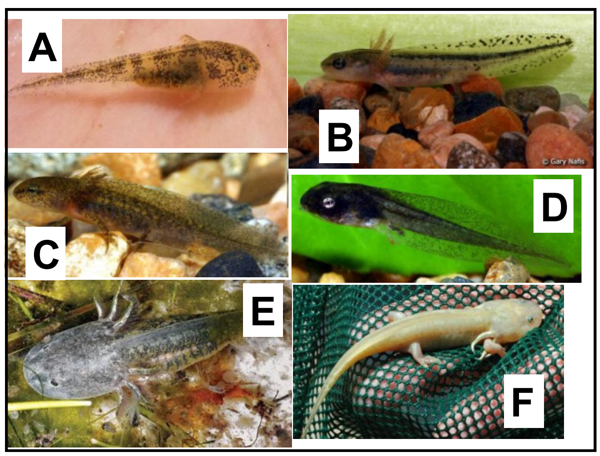
Embryo Identification/Morphology

- 2-3mm diameter
- whitish to grey to yellow
- w/jelly 4.5-10mm
- attached to vegetation or other materials
- singly or small clusters
- grape-like (each in its own separate membrane)
- Detectable mainly Dec-Feb



Larvae - Identification/Morphology

- Fish-like
- Feathery external gills
- Four legs
- 30 to 150 mm
  - 1 to 6 inches
- Color variable
- No stripes or real pattern
- Potentially detectable year-round (mainly March-June)

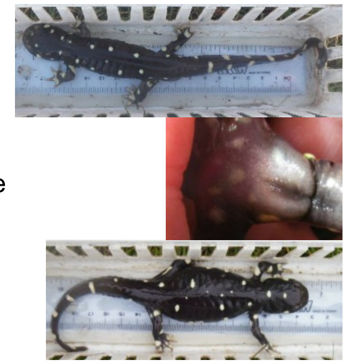


Adult Identification/Morphology

- 6-10 inches long
- NO nasolabial groove
- black to light brown backgound
- white to light yellow rounded spots
  - size/amount of spots varies
- toes pointed
  - NOT squared

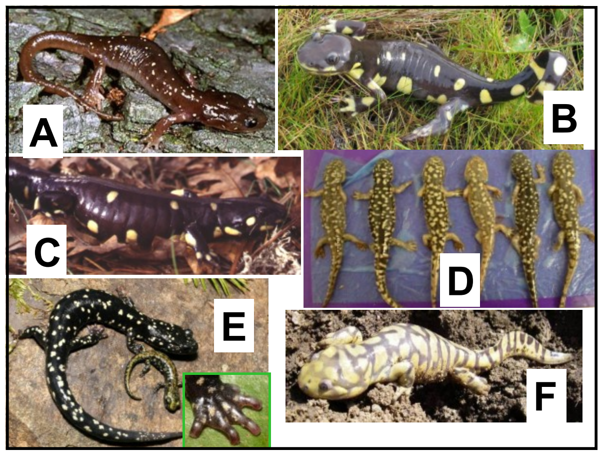
Sexing Adults

- Males have longer tail and a swollen vent
- Females appear fat when they are gravid with eggs
- Both sexes have a laterally compressed tail



Immature Age Classes

- Metamorphs
  - At metamorphosis
  - Muddy color patterns
  - Remnant gill stubs
  - 100-150 mm long
    - 4 – 6 inches
  - Fat
- Juveniles (after 1st summer)
  - Resemble adults, but smaller



Hybrids

- Genetic test needed for conclusive ID
  - Adults with barring are suspicious
  - Giant larvae are suspect also (CTS larvae usually <6" total length)

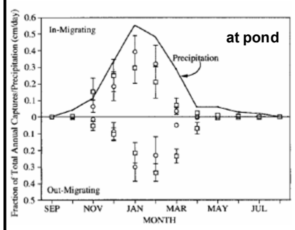
Identification – Main Points

- Embryos are distinctive and detectable
  - Single embryos alone or in clumps
- Larvae are easily differentiated from newt larvae by larger size and no eye stripe
- Metamorphs have muddy/blotchy color
  - Often with remnants of gills/fins
- Juveniles and adults
  - Black/brown ground with cream/yellow spots
  - Lack nasolabial groove, pointed toe tips
- Hybrid/Natives?
  - Genetic test required for conclusive ID
  - Large size and odd color patterns *suggest* hybrid

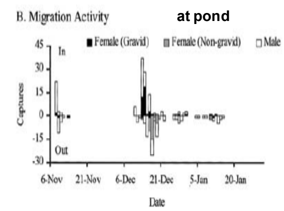
Group Exercise 1 - Identification

- In a group of 3-4 discuss the different stages of *A. californiense* and how you would identify them.
- What other amphibians might you encounter and how are they different from *A. californiense*?

Timing of Captures: Adults At Ponds



Trenham et al. 2000 (Monterey Co.)



Cook et al. 2006 (Sonoma Co.)

Activity differs by region!
Largely driven by rainfall.

Adult/juvenile movement period

Positively correlated with date at which annual precipitation reaches 0.56 in. (Jepson Data)

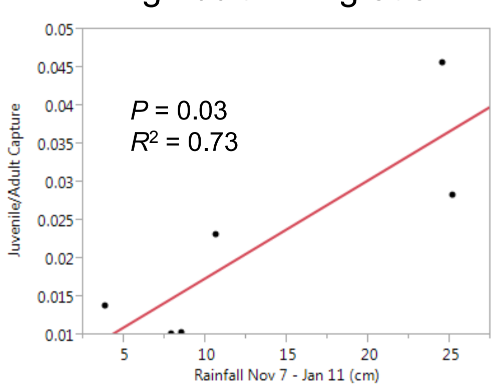
Year		End
05-06		27-Feb
06-07		22-Feb
07-08		20-Feb
08-09		2-Mar
09-10		24-Feb
10-11		2-Mar
11-12		15-Mar
12-13		20-Mar
Overall		28-Feb

Adult/juvenile movement period

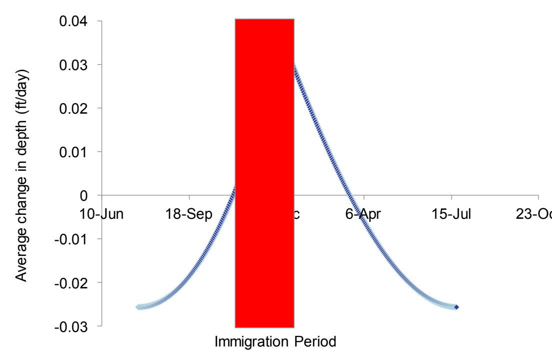
Year	Start	
05-06	29-Nov	
06-07	14-Nov	
07-08	11-Nov	
08-09	2-Nov	
09-10	14-Oct	
10-11	24-Oct	
11-12	11-Oct	
12-13	17-Nov	
Overall	30-Oct	

Positively correlated with Nov. rainfall, negatively correlated with Feb. rainfall (Jepson Data)

Timing Adult Immigration



Timing Adult Immigration



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 emergence period

Positively correlated with Mar. rainfall (Jepson Data)

Year		End
04-05		20-Jun
05-06		10-Jul
07-08		20-May
08-09		10-Jun
09-10		26-Jun
10-11		30-Jun
11-12		19-Jun
12-13		18-May
Overall		3-Jul

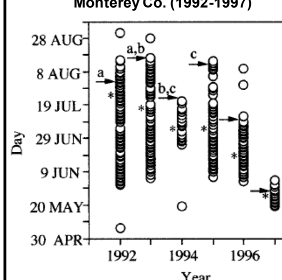
Metamorph emergence period

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

Positively correlated with drying date of breeding pond (Jepson Data)

Dates of Metamorph Capture

Monterey Co. (1992-1997)



Trenham et al. 2000

Contra Costa Co. (1992-1993)

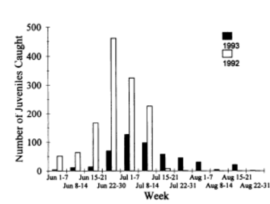


Fig. 3. Number of juvenile *Ambystoma californiense* caught by week in summer 1992 and summer 1993, Contra Costa County, California. Numbers of individuals include original captures and recaptures.

Loredo and Van Vuren 1996

Conclusions – To Avoid Migrating Salamanders

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-larvae

Year		End
05-06		5-Jul
06-07		25-Feb
07-08		17-May
08-09		9-Jun
09-10		25-Jun
10-11		29-Jun
11-12		18-Jun
12-13		17-May
Overall		29-Jun

Positively correlated with first 0.82 in. after the end of October (Jepson Data)

Breeding pond occupancy - larvae

Year	Start	
05-06	2-Dec	
06-07	14-Nov	
07-08	11-Nov	
08-09	2-Nov	
09-10	12-Dec	
10-11	21-Nov	
11-12	15-Dec	
12-13	17-Nov	
Overall	11-Nov	

Positively correlated with drying date of breeding pond (Jepson Data)

Conclusions – Avoiding in Ponds

Avoid activities 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

Metamorph Activity At Jepson

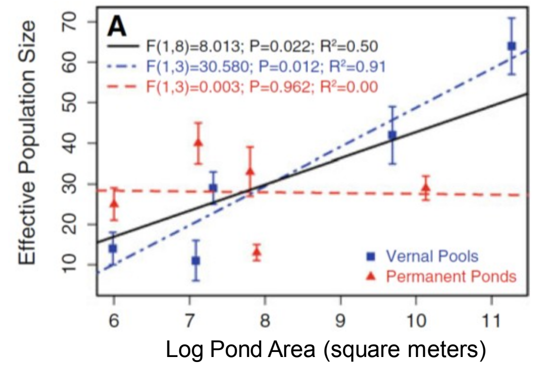
Year	Movement Days
06-07	0
07-08	1
08-09	5
11-12	0
12-13	8
Average	17.88889

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

Relationship to Hydroperiod

Year	Average Breeding Date	Average Date of Metamorph Emergence	Average Number of Days in Pond
07-08	5-Jan	16-May	131
08-09	14-Feb	31-May	106
11-12	15-Mar	11-Jun	88
12-13	14-Dec	12-May	148

Pond Size Influences Population Size



Aquatic Habitat – Important Issues

- Vernal pools and playa pools (natural habitat)
  - Constructed ponds (more common today)
- Hydroperiod
  - Must persist into May (July or August, even better)
  - Permanent ponds often unsuitable due to predators
- Pool area and depth
  - Bigger pools = more metamorphs
  - Deeper pools = >hydroperiod
- Vegetation? Water quality?
  - With or without vegetation
  - Abundant livestock waste

Aquatic Prey and Predators

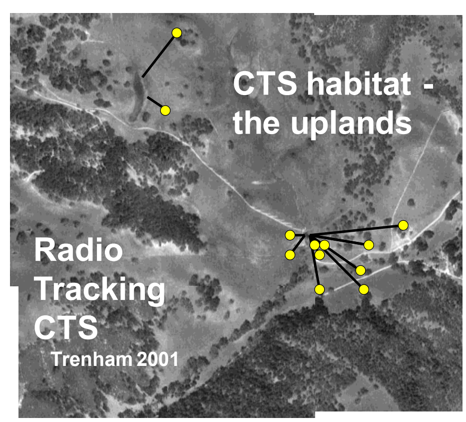
- Prey
  - CTS larvae
  - Insect larvae (corixids, notonectids)
  - Macrocrustaceans (California clam shrimp, vernal pool tadpoles shrimp*)
  - Newt larvae
  - Pacific chorus frog tadpoles
  - Snails
  - Zooplankton (cladocera, copepods)

  *endangered prey
- Predators
  - Adult newts
  - Avocets
  - Bullfrogs*
  - Crayfish*
  - Fish*
  - Garter snakes
  - Herons
  - Hybrid larvae
  - Insect larvae (dytiscid beetles, giant water bugs)*
  - Terns

  *a big problem with permanent ponds!

Group Exercise

- You are responsible for designing habitat restoration for a failing vineyard in Sonoma County.
- The property is 2000 acres and has no ponds, but CTS exist on a neighboring reserve. The vineyard has been deep ripped and leveled.
- List your top 5 priority actions for restoring CTS to this site.



CTS and Small Mammal Burrows

FIBER-OPTIC VIDEO
courtesy of Michael Van Hattem

Upland Habitat Main Points

- After metamorphosis, CTS are almost always underground
- Aestivation has not been observed
- Occupy mainly ground squirrel and gopher burrows
  - Emerge to move to pond or another burrow
  - Emerge only at night, usually when raining
- Most do not remain near edge of pond

CTS do not stay near ponds!
Sam Sweet – obs. 2km away

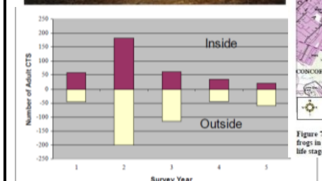


Figure 16. Adult California tiger salamander captures on the inside and outside of the trap line – Five survey years.

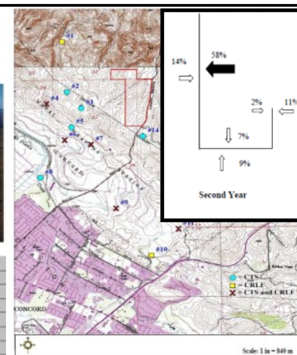
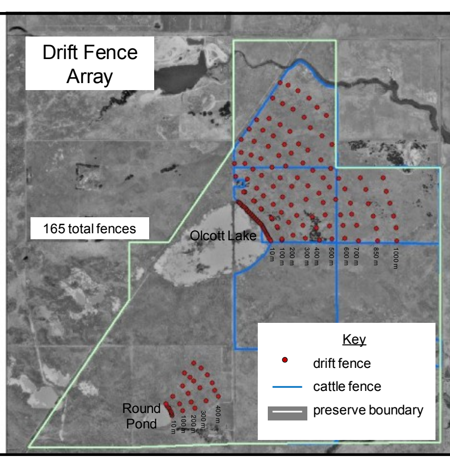
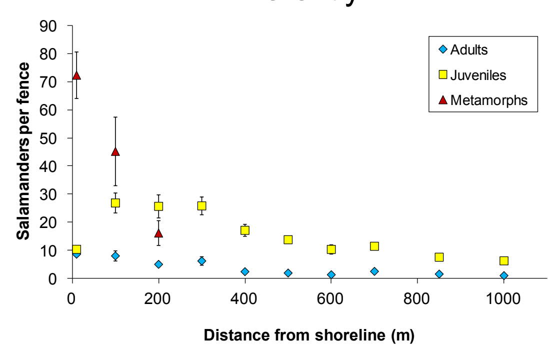


Figure 7. Known occurrence of California tiger salamanders and California red-legged frogs in the project vicinity (all locations are of aquatic habitats with occurrence of some life stage of CTS and/or CRLF).

Sue Orloff, Ibis Associates (2007)



Age Classes Are Distributed Differently



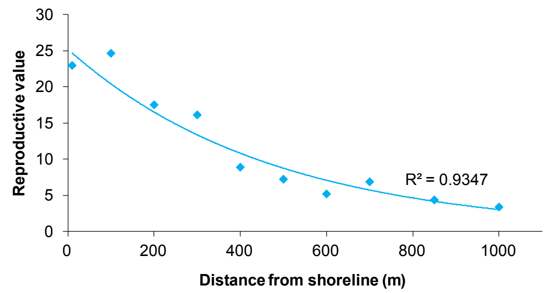
What is the relative importance of the different age classes?

Adult

Juvenile

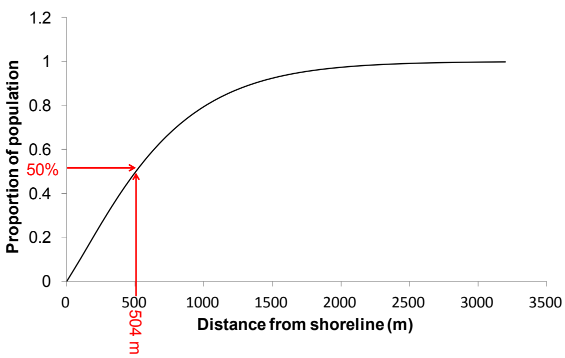
Metamorph

Reproductive value declines with distance from pond

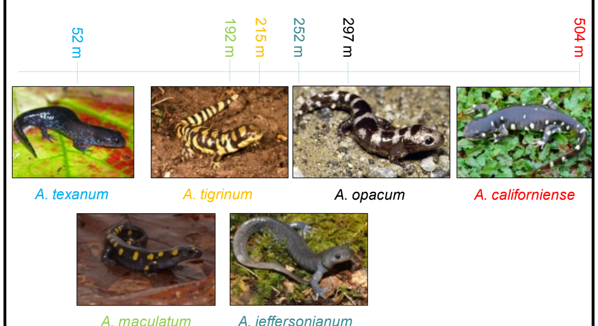


Searcy, C. A. & H. B. Shaffer. 2008. *Conservation Biology*.

Protecting 50% of the Population



Average *Ambystoma* Migration Distances



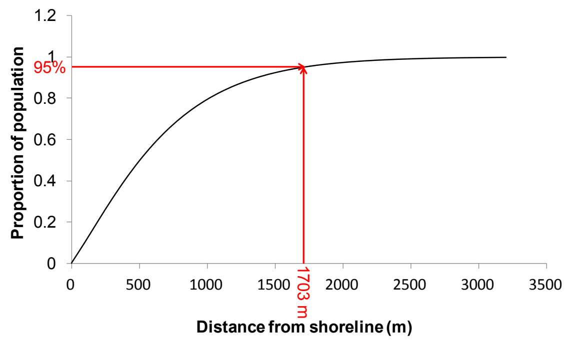
Searcy, C. A. et al. 2013. *Biological Conservation*.

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

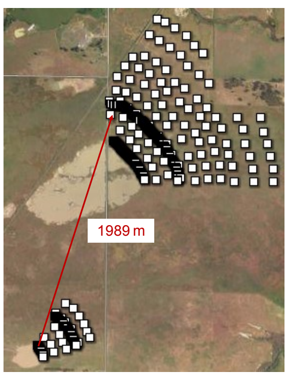
Protecting 95% of the Population



How far can a salamander move in a season?

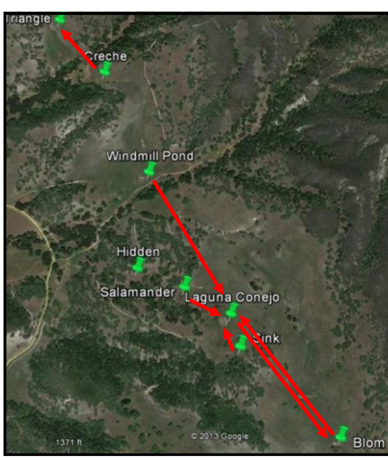
- We know that a rate of 188 m/night is sustainable for at least 6 nights in a row
- There are 10 to 19 nights with appropriate weather conditions during both immigration and emigration
- (188 m/night)(10 nights) = 1880 m
- Even in a dry year, a salamander should be capable of migrating 1703 m

Longest observed migration



Jepson Study - 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.

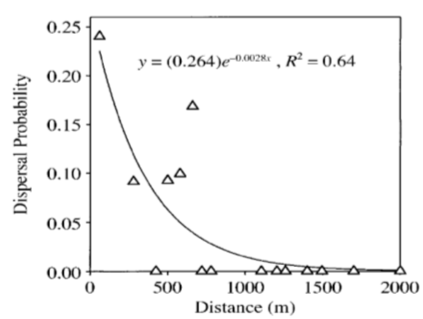


Landscape Ecology

- ~20% moved between ponds
- Most moved <600 m
- Estimated some disperse up to 1 to 2 km

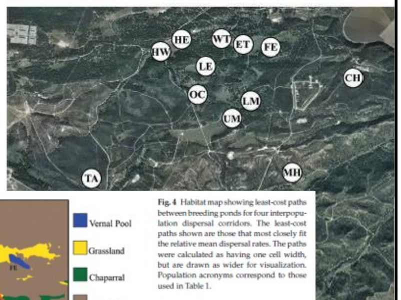
- **Trenham et al. 2001 Ecology**

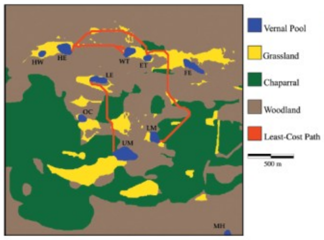
Other Landscapes



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.

Fort Ord Genetic Evaluation of Recent Migration History





Data suggest grassland and chaparral favored over woodland for migration

Wang et al. 2009

How many acres/hectares do CTS need?

- About how many hectares/acres are encompassed by a pond buffered by 1.7 km?

$$AREA = \Pi r^2$$

- r = 1,703 m
- hectare = 10,000 m^2
- acre = 2.5 hectares

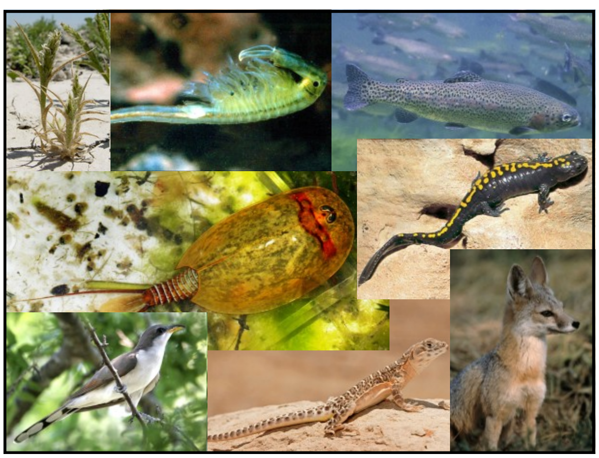
~9,000,000 m^2
= ~900 ha
= ~2,300 acres

Landscape Habitat Points

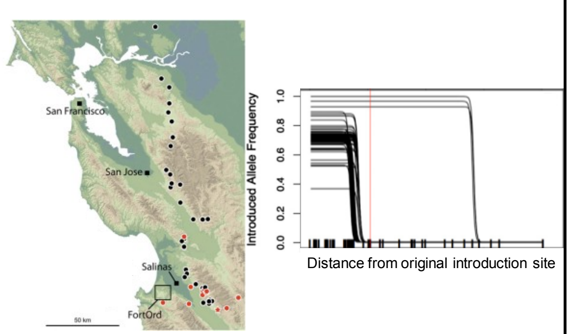
- Major upland habitats – for burrows/migration
  - grassland
  - oak woodland
  - chaparral/sage scrub
- Most do not remain near edge of pond
  - >1 km is not rare
- Movement between ponds 1 - 2 km estimated
  - 680 m observed - ~800 m genetically estimated
  - introduced genes show large scale of movement over generations

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.

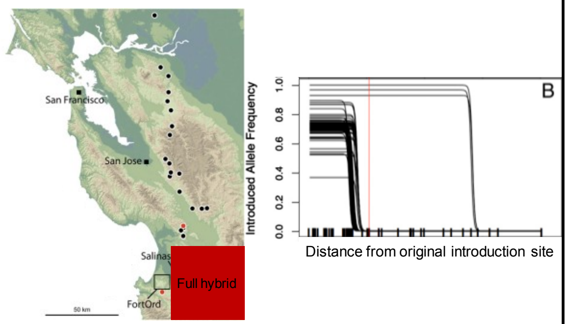


Spread of Invasive Salamander Genes



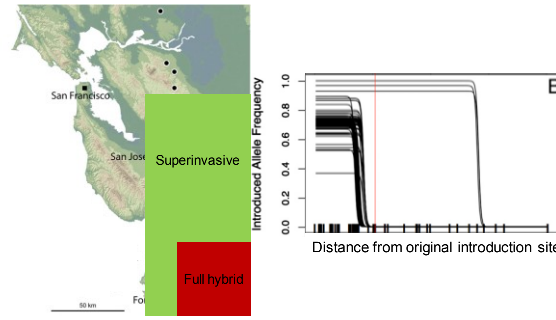
Source: Fitzpatrick, B. M. et al. 2010. *Proceedings of the National Academy of Sciences.*

Spread of Invasive Salamander Genes



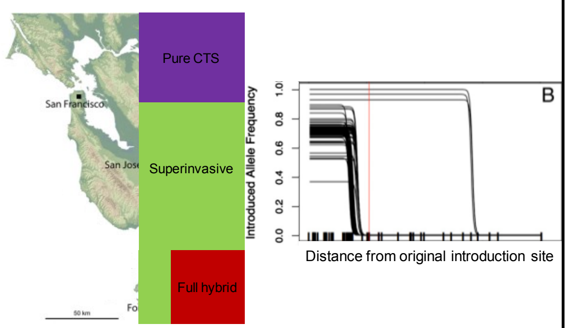
Source: Fitzpatrick, B. M. et al. 2010. *Proceedings of the National Academy of Sciences.*

Spread of Invasive Salamander Genes



Source: Fitzpatrick, B. M. et al. 2010. *Proceedings of the National Academy of Sciences.*

Spread of Invasive Salamander Genes

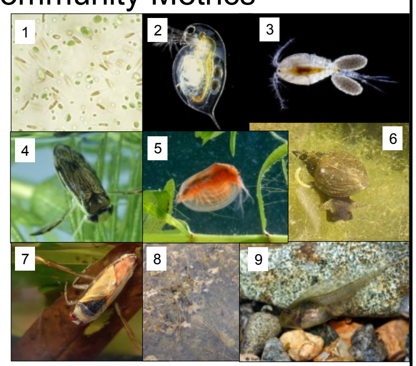


Source: Fitzpatrick, B. M. et al. 2010. *Proceedings of the National Academy of Sciences.*

Community Metrics

Densities of:

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

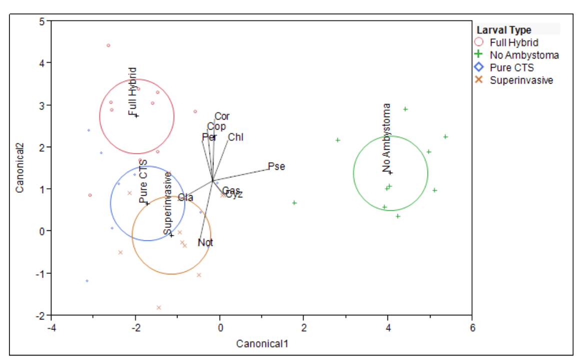


Searcy, C. A., et al. In press. *Oikos.*

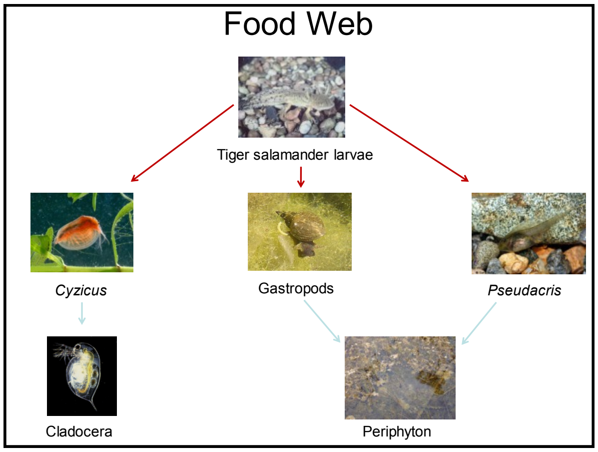
Mesocosm Experiment

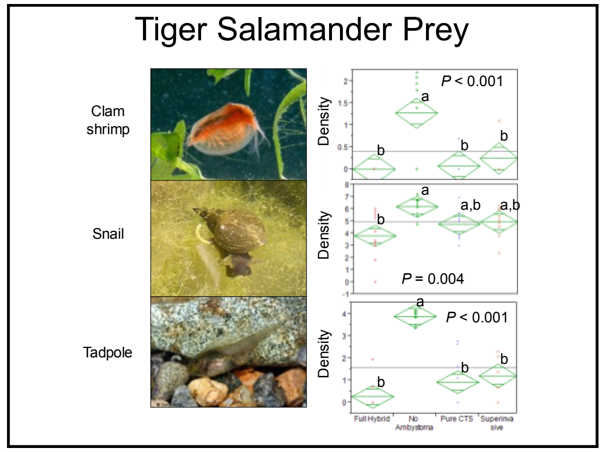
- 4 x 2 factorial
- Treatments:
  - 4 salamander genotypes
  - 2 larval densities
- 5 replicates of each - 40 cattle tanks total

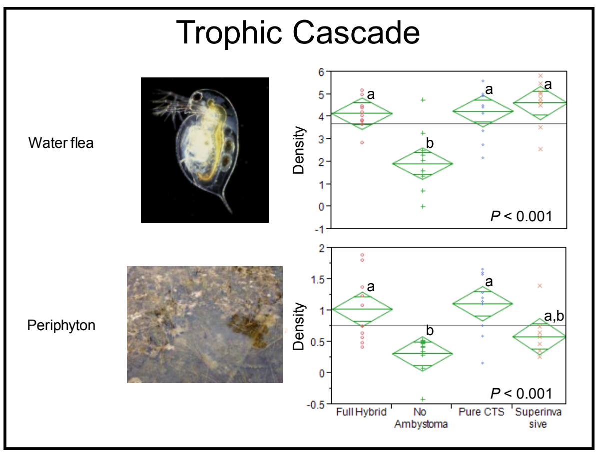
Community Composition

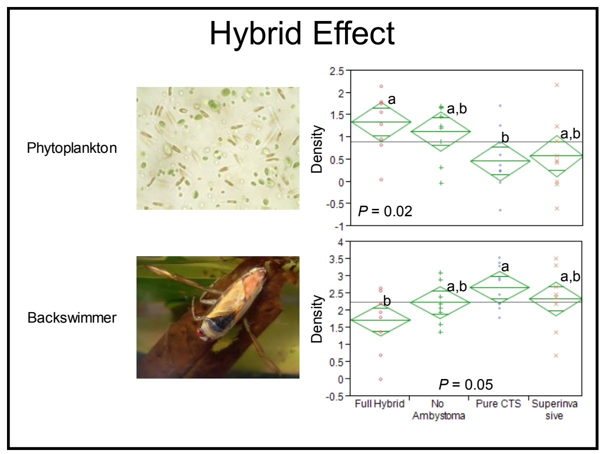


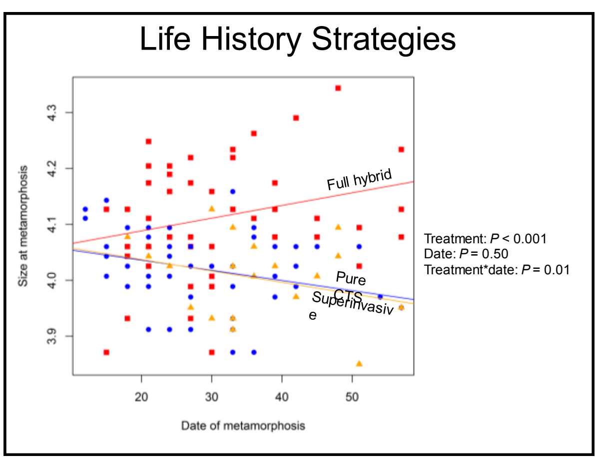
Pete Trenham and Chris Searcy, presenters
Elkhorn Slough Coastal Training, sponsor

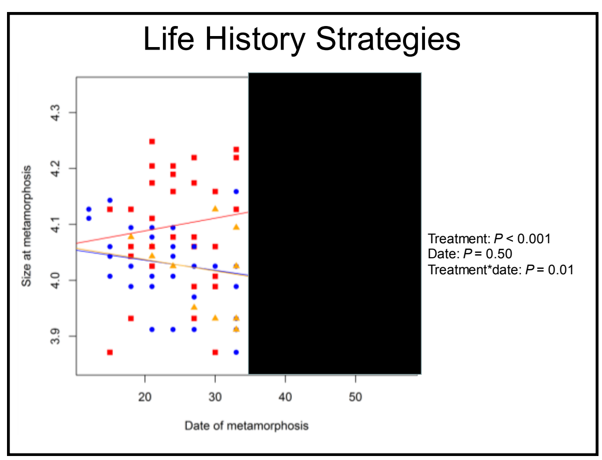

Food Web
Tiger salamander larvae
Cyzicus
Gastropods
Pseudacris
Cladocera
Periphyton


Tiger Salamander Prey
Clam shrimp
Snail
Tadpole
Density
P < 0.001
P = 0.004
P < 0.001
Full Hybrid
No Ambystoma
Pure CTS
Superinvasive


Trophic Cascade
Water flea
Periphyton
Density
P < 0.001
P < 0.001
Full Hybrid
No Ambystoma
Pure CTS
Superinvasive


Hybrid Effect
Phytoplankton
Backswimmer
Density
P = 0.02
P = 0.05
Full Hybrid
No Ambystoma
Pure CTS
Superinvasive


Life History Strategies
Size at metamorphosis
Date of metamorphosis
Full hybrid
Pure CTS
Superinvasive
Treatment: P < 0.001
Date: P = 0.50
Treatment*date: P = 0.01


Life History Strategies
Size at metamorphosis
Date of metamorphosis
Treatment: P < 0.001
Date: P = 0.50
Treatment*date: P = 0.01

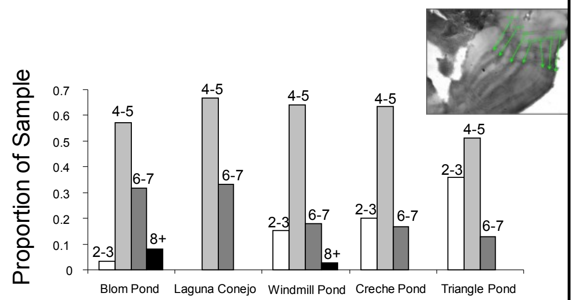
Conclusions on Hybridization

1) Superinvasives are ecologically equivalent to pure CTS.

2) Full hybrids are ecologically similar, but not equivalent, to pure CTS.

3) We should manage habitat by decreasing hydroperiods.

Demography: Age of Adults Differed Among Five Ponds in Carmel Valley



Trenham (unpub. data)

- Modeled probability of extinction most sensitive to
  - 1) *subadult survival
  - 2) adult survival
- This emphasizes importance of minimally disturbed upland habitat
- Trenham and Shaffer, 2005, Ecological Applications

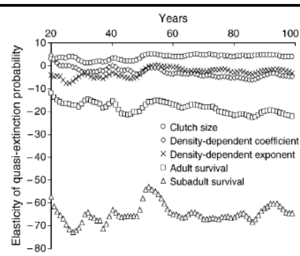
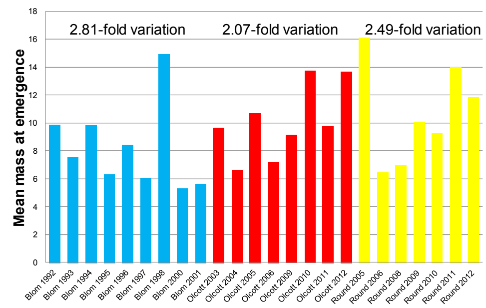


FIG. 5. Estimated elasticity values for cumulative quasi-extinction probabilities in response to perturbations of mean vital rates. Symbols represent elasticity in response to perturbation of various model parameters: subadult survival, adult survival, coefficient and exponent in larval density-dependent survival function, and number of eggs deposited per breeding female. Five adult females was the quasi-extinction threshold. The baseline model parameter values for this analysis were those indicated in Table 1. Elasticities for <20 years are not plotted because few extinctions occurred before this time, and as a result estimates of extinction probabilities and elasticities during this interval are highly variable and unreliable. Methods for elasticity analysis of density-dependent stochastic models are adapted from Morris and Doak (2002).

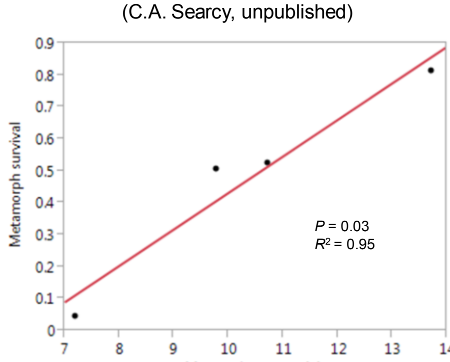
Variation in Metamorph Quality



Searcy, C. A. et al. 2014. *Ecology*.

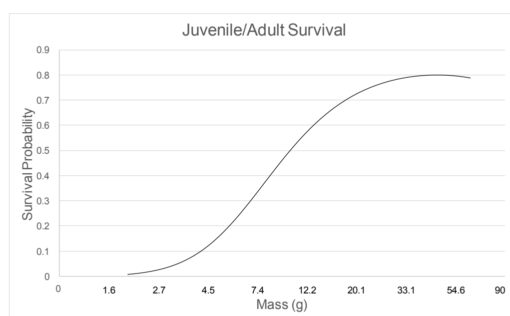
Cohort-level selection on mass at metamorphosis

(C.A. Searcy, unpublished)



Individual-level selection on mass

(C.A. Searcy, unpublished)



Demography of Average Pond

Age (yr)	0	1	2	3	4	5	6	7	8	9	10	11	12	13	Total
Mass (g)	8.7	8.0	13.2	17.7	21.1	23.4	24.8	25.7	26.3	26.6	26.8	26.9	27.0	27.0	
Fraction mature	0.00	0.00	0.06	0.65	0.91	0.97	0.98	0.99	0.99	0.99	0.99	0.99	0.99	0.99	
Survivorship	0.61	0.37	0.60	0.70	0.73	0.75	0.76	0.77	0.77	0.77	0.77	0.77	0.77	0.77	
Fertility	0	0	0	336	574	714	796	845	873	890	900	905	909	911	
Metamorphs	727	0	0	0	0	0	0	0	0	0	0	0	0	0	727
Juveniles	0	441	154	35	6	2	1	0	0	0	0	0	0	0	639
Adults	0	0	10	64	63	49	37	28	22	17	13	10	8	6	327
Individuals	727	441	164	99	69	51	38	29	22	17	13	10	8	6	1693
Eggs	0	0	0	4083	6864	6618	5628	4564	3618	2834	2205	1709	1322	1021	40466

Area = 1361 m^2
Egg Density = 30/m^2
Embryonic/larval survivorship = 0.018
Average age at maturity = 3.1 years

Demography – Main Points

- Female CTS can produce large numbers of eggs
  - but most breeders are at least 3 yrs old
  - and they don't breed every year
- Some individuals can live 10+ years
  - Most don't ever make it to metamorphosis
  - Protection against drought years
- Population size is much more sensitive to upland survival than to larval survival

Conservation Strategies

- Protect occupied landscapes
  - Ideally >>1000 acre blocks; minimally 100 acres
    - As large as possible given limitations
  - Ideally with multiple breeding ponds
- Maintain/promote habitat connectivity
  - Minimize effects of new or improved roads
  - Other potential "barriers": aqueducts and canals, agricultural fields, landfills
- Other approaches
  - Creating/enhancing/restoring habitats
  - Compensation through conservation banks
- Unproven approaches
  - tunnels under roads
  - salvage/translocation

Ideas for Avoidance and Minimization

- Habitat Management Issues: disking, mowing, burning, trenching, herbicides, mammal control, pond repair, road maintenance, irrigation, etc.
- Aquatic habitats
  - Avoid use of pesticides in area of pond
  - Disturb habitat only after pond has dried
- Upland habitats
  - Avoid mammal burrows wherever possible
    - Excavate burrow/relocate CTS
  - Limit activities to daylight hours
  - Limit activities to dry season
  - Disturb only part of site at a time over several years
  - Use drift fences to remove animals from site

Managing Habitat for CTS

- Aquatic
  - Modify/manage ponds to maintain appropriate hydroperiod
  - Eliminate predators by periodic drying
  - Maintain existing berms/remove excessive siltation
  - Create additional ponds
  - Allow livestock grazing (esp. vernal pools)

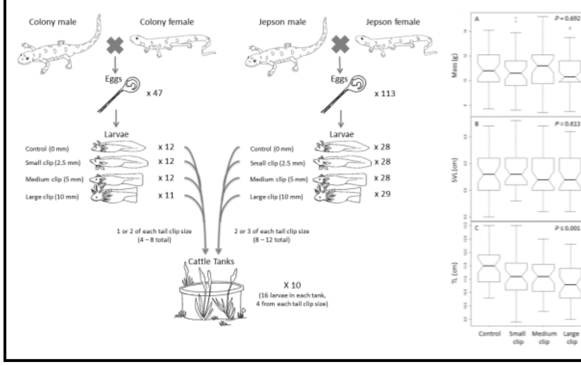
Managing Habitat for CTS

- Uplands
  - Maintain habitat connectivity between ponds and uplands AND between ponds
  - Maintain natural habitat, especially near breeding ponds
  - Maintain burrowing mammal populations
  - Effects of grazing unknown, but anecdotally positive

Aquatic Sampling

- Dip nets
- Minnow Seine
- 1/8" mesh or smaller
- <u>Move through the water quickly</u>
- Neither works well in deep ponds

Tissue Sampling with Tail Clips

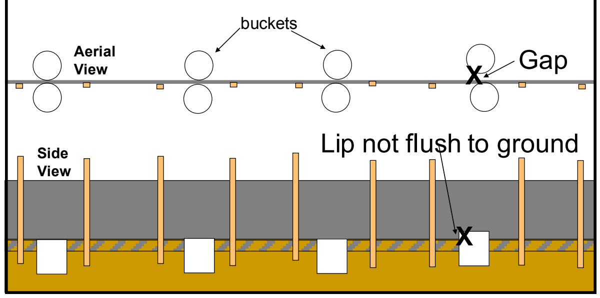


What if there is no pond on the property?

Figure 9. Southern trap line facing west.

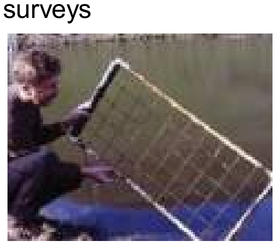
Sue Orloff, Ibis Associates (2007)

Upland Sampling - Drift Fences with Pitfall Traps



Alternate CTS <u>Detection</u> Methods

- Minnow traps
- Egg surveys
- Nocturnal walking surveys



First Consideration – Are You In The Range?

(check with agencies for latest range info)

CA Dept. of Fish and Game

Sampling for CTS – CDFW/USFWS Guidance
requirements for a negative determination

- 1) Site assessment – assess upland and aquatic habitat onsite and within 2 km
- 2) If pond within 2km and upland habitat only…
  - Two seasons of drift fence sampling
  - ≥1 ft tall drift fence w/ pitfalls ≥ 90% site perimeter
  - Pitfall buckets <33 ft apart, ≥ 2 gallon buckets
  - Traps opened for rain events Oct. 15 – Mar. 15
- 3) If potential breeding habitat on-site
  - 2 seasons aquatic sampling for CTS larvae
    - Sample >10 days apart in March, April and May
    - Sample using dipnets and seines (if none detected in dipnets)
  - One season drift fence sampling as above
    - With drift fences also around potential breeding habitat

USFWS/CDFG Reports

- Provide Complete Information
  - Dates and times sampled
  - Rainfall/temperature data for area during study period
  - Records of all animals captured
  - Photographs of representative specimens
  - Photographs of sampling apparatus
  - Records of all communications with USFWS
  - For aquatic sampling, calculations of the total effort expended/area covered each time

Getting your own permit

- Start early! It may take >1 year
  - talk to agency representatives throughout process
- FWS requirements
  - B.S. in biology (or equivalent experience)
  - Course work in herpetology (or eq. exp.)
  - Study/survey design experience (5surveys/40hrs)
  - Handling experience (>25, including >5 larve)
  - Familiarity with habitats
  - Familiarity with co-occurring amphibians
  - Ability to identify vegetative components of habitat

CTS Basics – Final Review

- Aquatic Habitat – just for breeding
  - Good ponds are temporary but dry only after May
  - Bigger, longer lasting ponds are better
- Upland Habitat – the rest of their lives
  - On land CTS occupy small mammal burrows
  - Move hundreds of meters from ponds
  - Only return to ponds to breed (not even every year)
- Landscape Considerations
  - More ponds = more security against local catastrophes
  - Ideally want ponds within 1-2 km of each other
- Weather/Rainfall
  - drives migrations and population dynamics

Thanks and Acknowledgements

- The Dorrance family, Grey Hayes and the Elkhorn Slough Foundation
- CDFW and USFWS for working to protect native ecosystems and helping us get the permits we need
- All the other biologists working on CTS
- You for applying your enhanced knowledge to make the world safer for CTS and our other neighbors