Modeling Habitat for Mojave Desert Tortoises in a Non-Stationary World

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Climate Change and Tortoises

- How will tortoise populations respond to climate change and urbanization/fragmentation?
  - ~~Rapid evolution *in situ*~~
  - ~~Long distance movement to suitable patches~~
  - Adjust/acclimate *in situ*
- How much environmental change can populations withstand while remaining viable?

Assessing Climate Resilience

Compare among populations

Compare within populations

Translocated vs resident

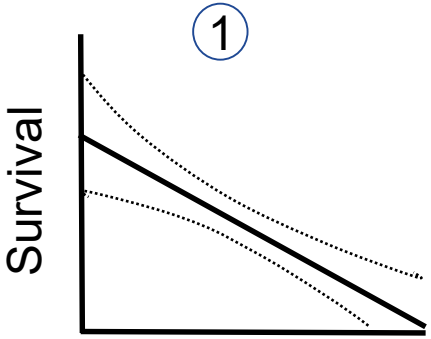
Q1: Can DT populations remain viable across a wide range of different environmental regimes?

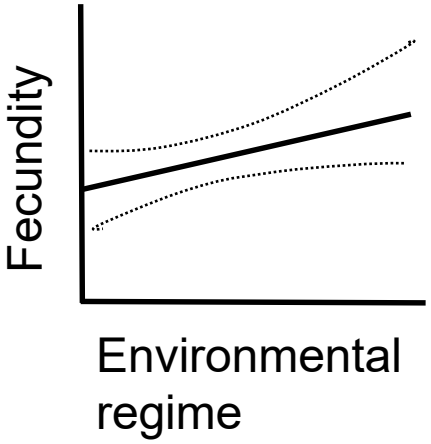
Q2: Can apparent tolerance of different environments be attributed to inherent resilience rather than local adaptation?

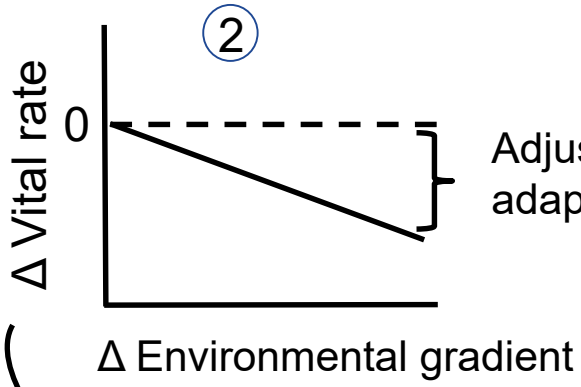
IF yes AND yes THEN

High resilience!

Assessing Habitat Breadth







Adjustment for local adaptation

<u>Predictive Demographic model:</u>
Resilience to environmental changes *after removing signal from local adaptation*

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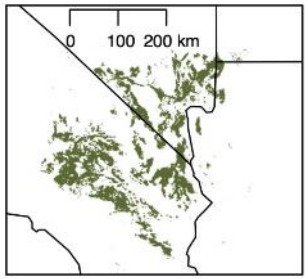
Conservation tool:



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Habitat areas likely to support DT populations into the future

$\lambda \geq 1$

Data availability

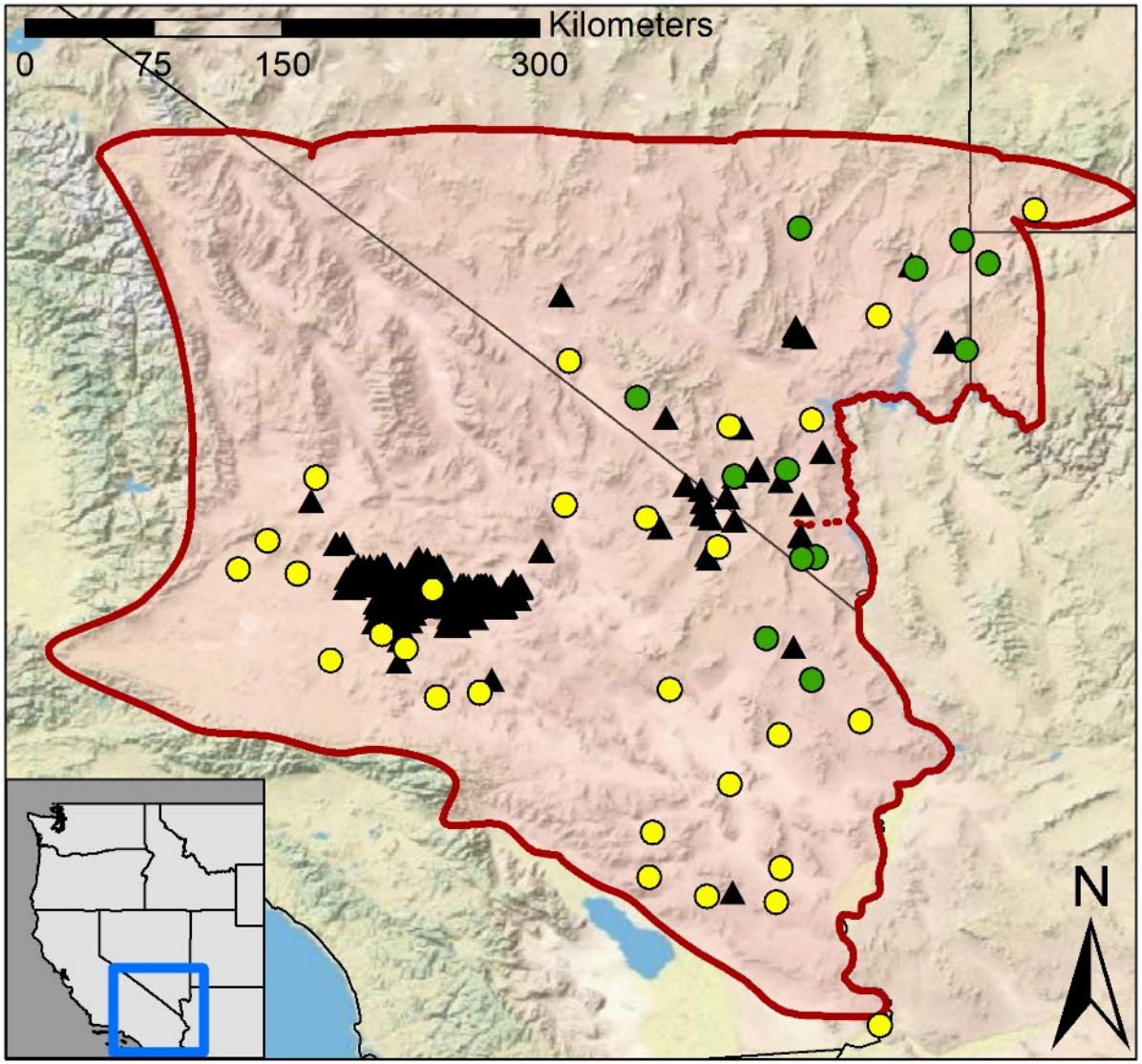
	VITAL RATE	AVAILABILITY
SURVIVAL	Juvenile survival	✓
	Adult survival	✓
FECUNDITY and RECRUITMENT	Recruitment	✓
	Age & size at maturity	✓
	Clutch size	✓
	Nest success	⊘
	Hatchling sex ratio	⊘

Long-term monitoring data

Mojave desert tortoise:

- Permanent Study Plots
  - capture-mark recapture data
  - >9,000 marked over 2-3 decades
- Long-term telemetry data
  - 30+ sites
  - 1,800+ tortoises monitored for over one year

Previous monitoring efforts: data re-analysis



Permanent study plots
- Available
- Currently unavailable

Long-term telemetry sites (data available)

G. agassizii range margin

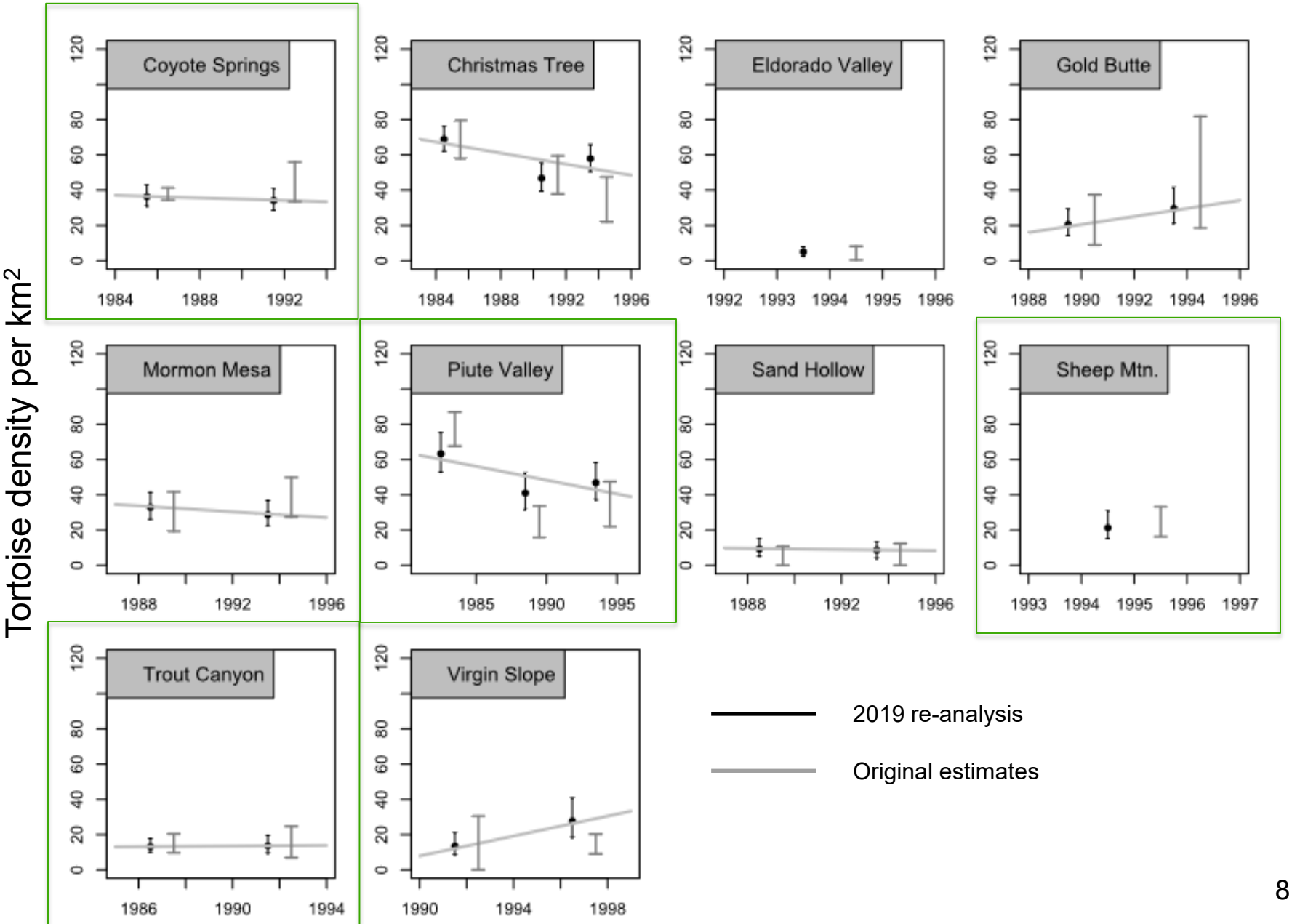
‘Permanent Study Plots’

- Permanent plots (n = 36) established across the species range between 1971 and 1994 by BLM, FWS and others
  - In survey years, at least 2 complete passes in the spring (ca 30 person-days)

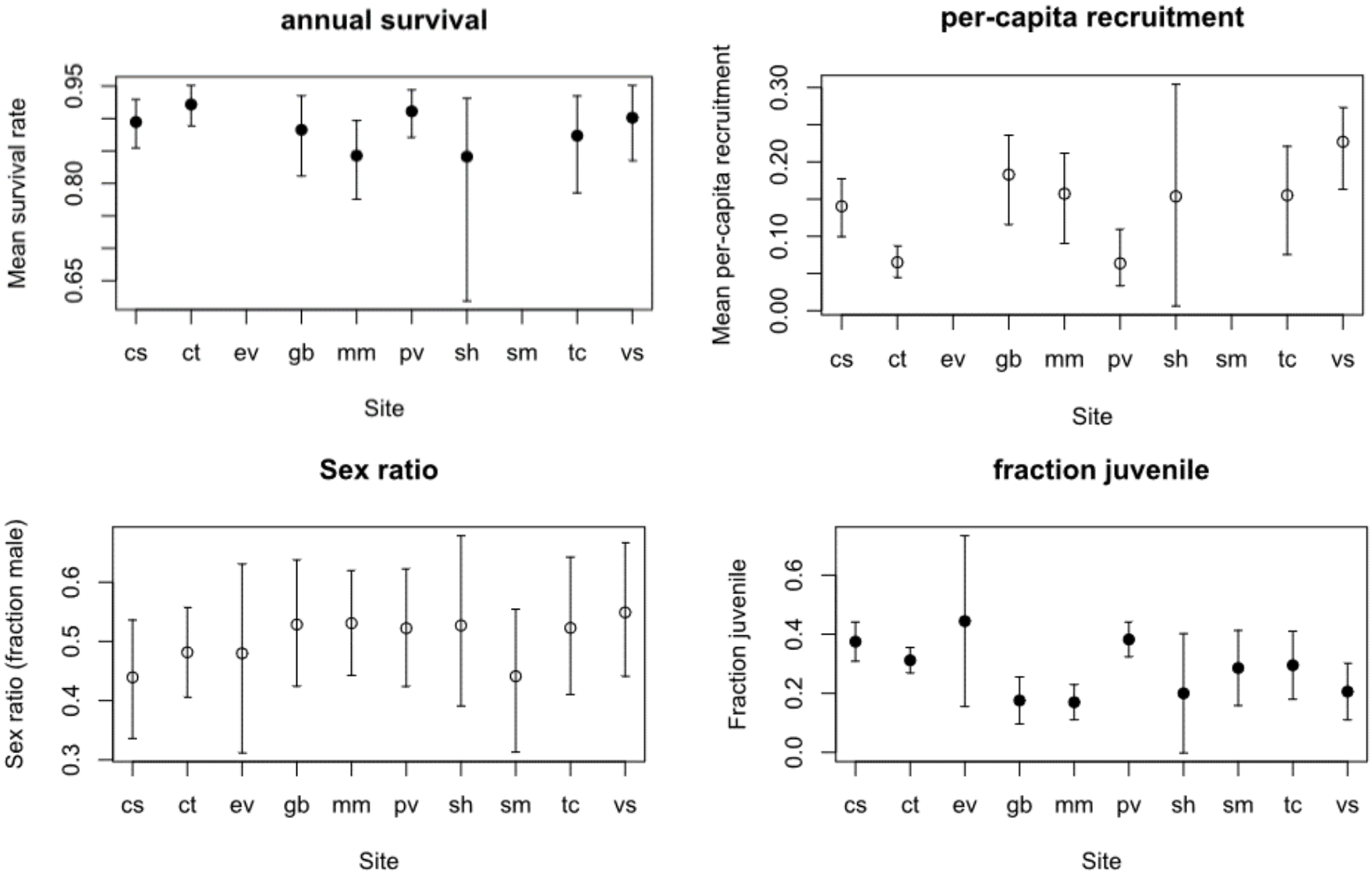
- Gold mine for re-analysis!
  - DT Recovery plan assessment report 2005
  - Campbell et al. 2018: Sonoran DT survival, recruitment, population viability
  - Longshore 2003; Zylstra et al. 2013; Lovich et al. 2014: PSP reanalyses indicate Sonoran DT and Mojave DT are sensitive to extended drought.

- Continued potential for PSP reanalysis
  - Spatial capture-recapture (Royle et al. 2013)
  - Integrating additional data types
    - e.g., Integrated Population Models (e.g., Shaub and Abadi 2011)
    - Telemetry data
    - Line-distance transects

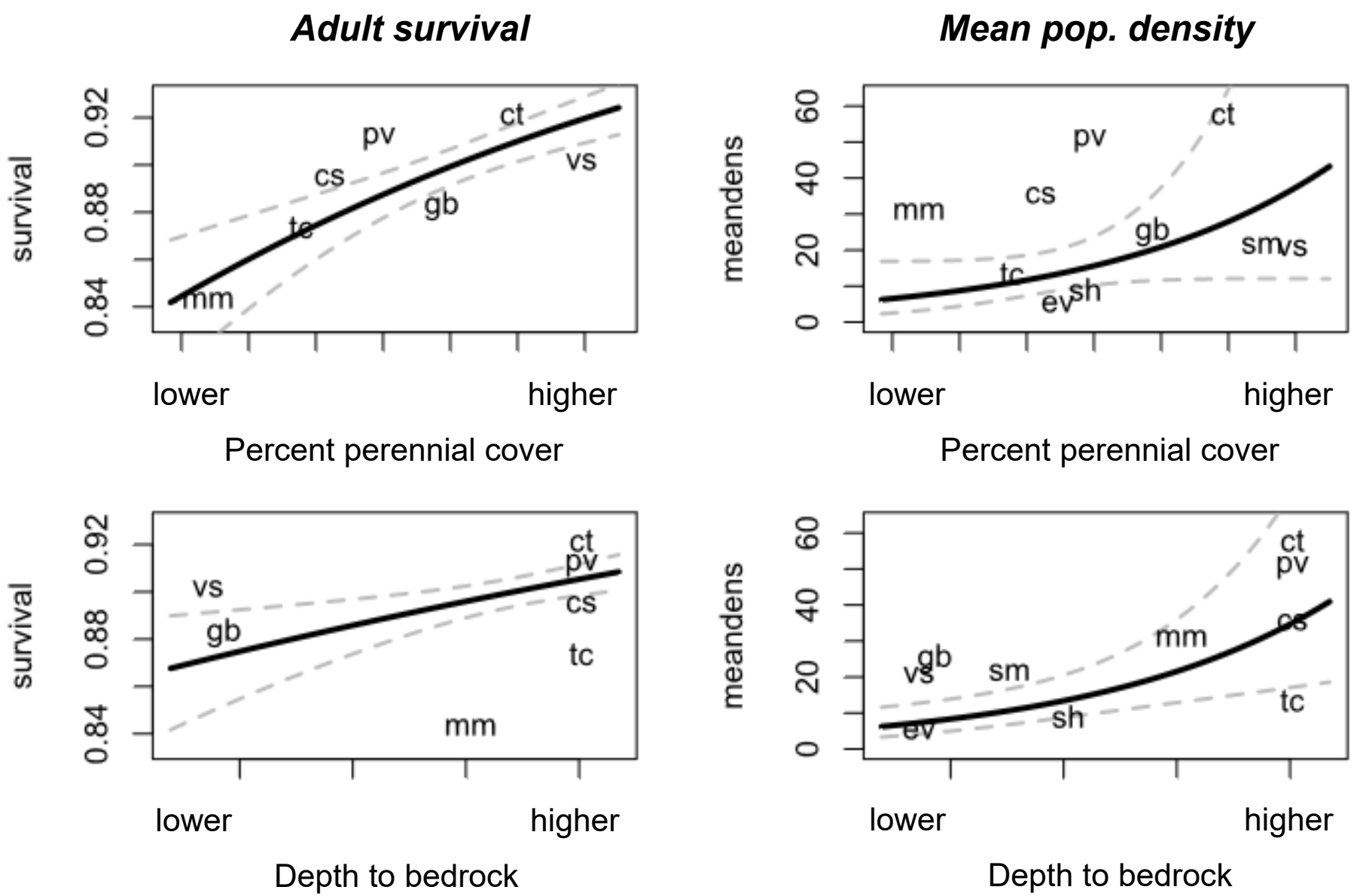
Tortoise density and trend estimates (preliminary)



Site-level demographic rates (preliminary)

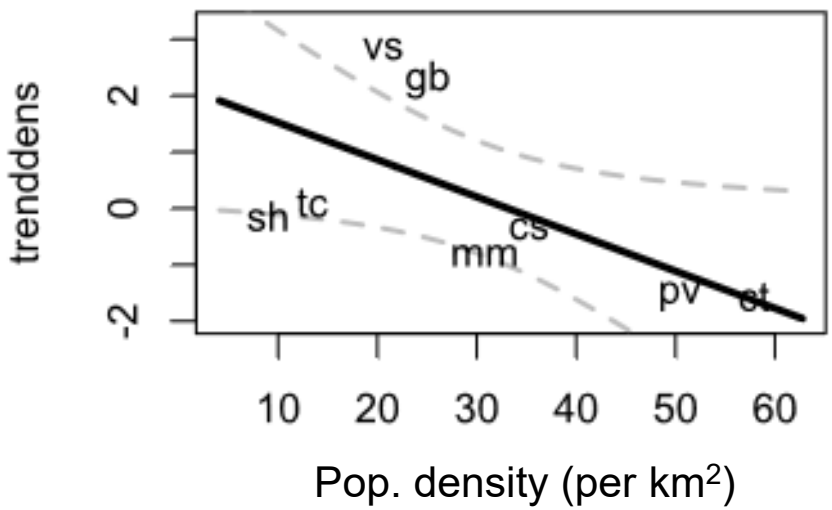


Environmental sensitivities (preliminary)

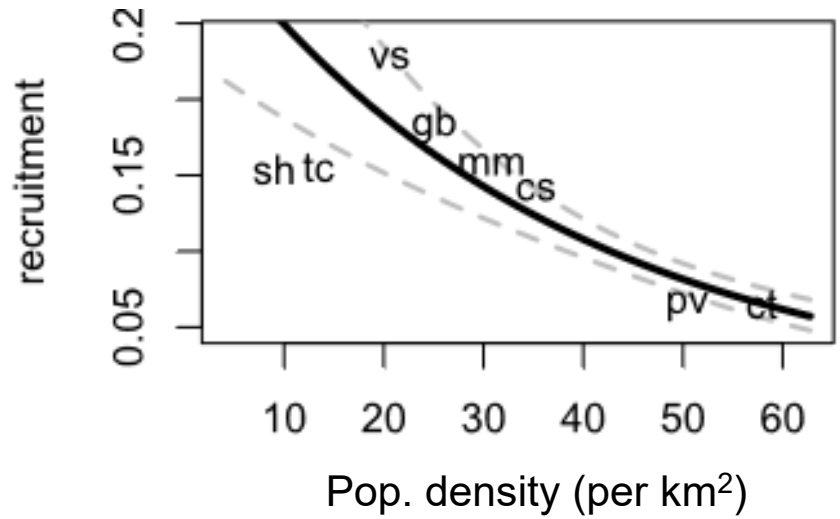


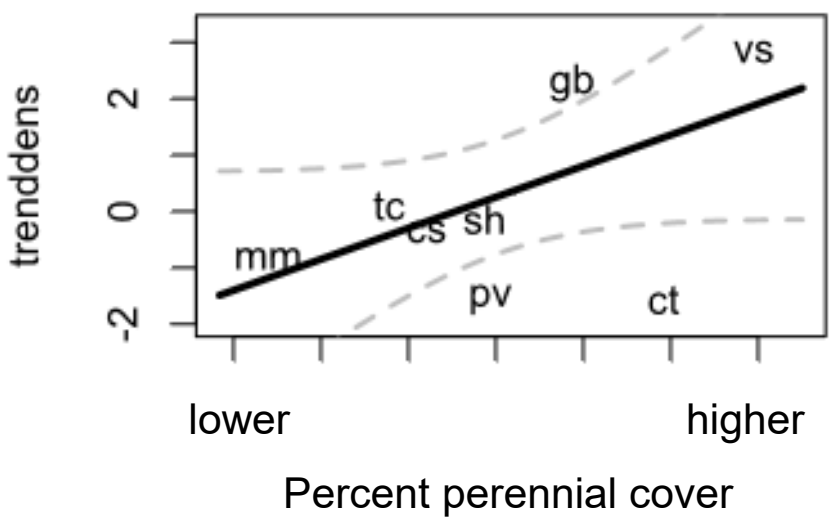
Environmental sensitivities (preliminary)

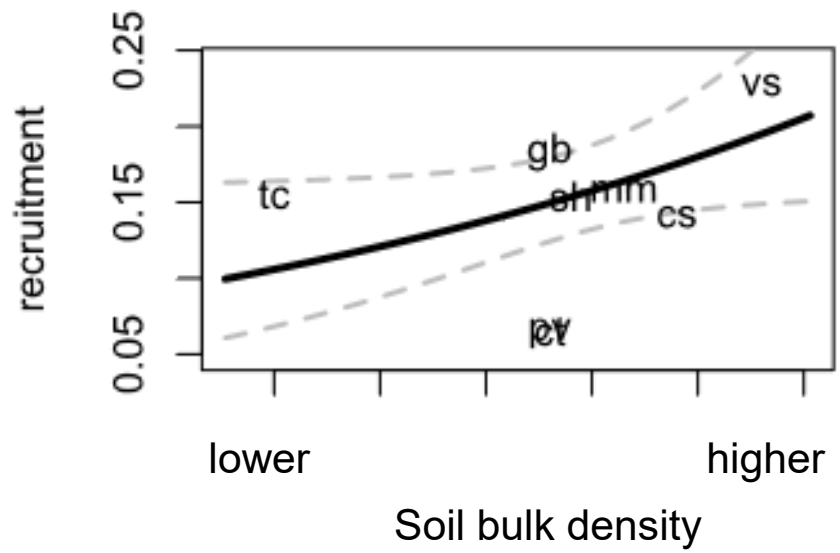
Abundance trend



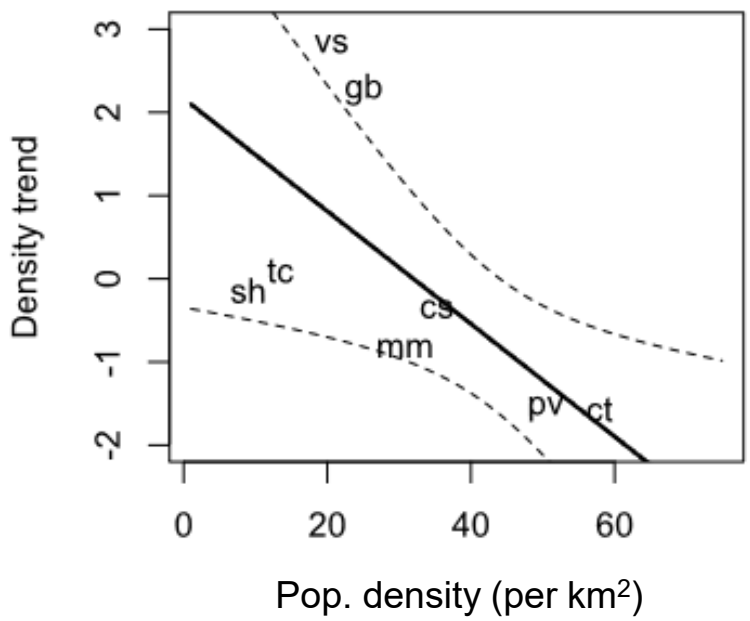
Adult recruitment

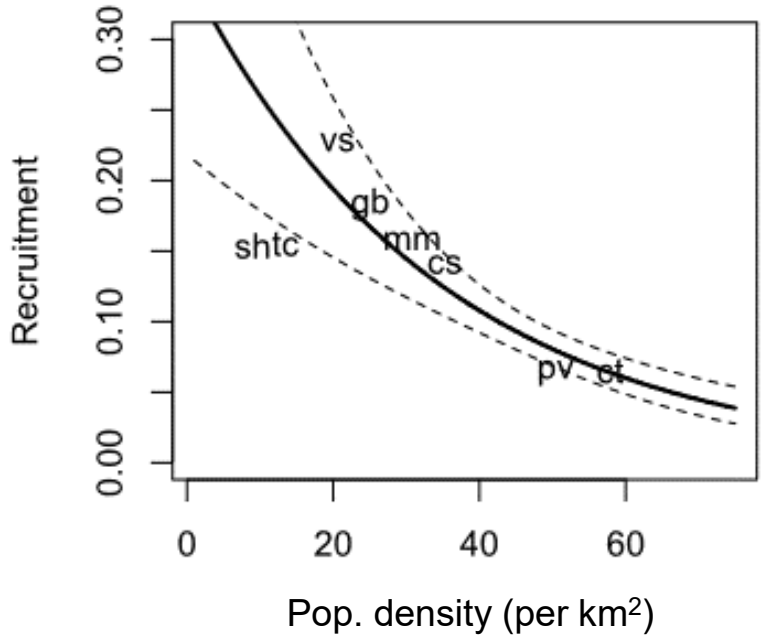






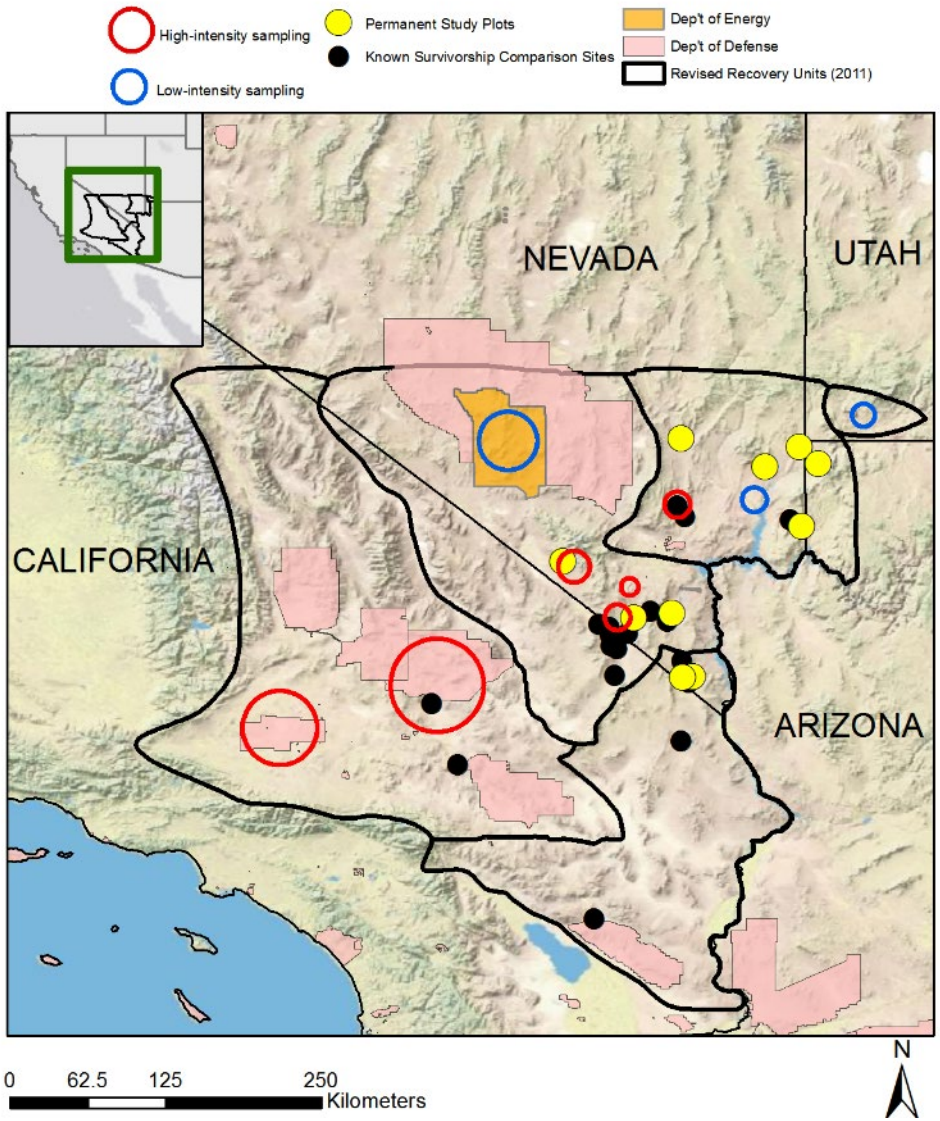
Evidence for density dependence? (preliminary)





Field data collection (2018-2020)

- **High-intensity sites** (red circles: monitor reproductive rates)
- **Low-intensity sites** (red and blue circles; determine size and age at maturity, body condition, etc.)
- **Thermal drone imagery** characterize incubation temperatures and potential sex ratios
- **Camera traps** record predation and hatching events

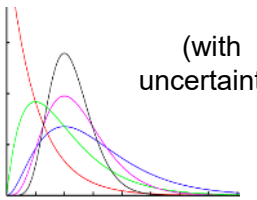


Field data collection (2018-2020)

- Nest monitoring (high intensity sites)
  - Pilot season (2017): 14 monitored females, 10 located nests
  - 2018: 22 monitored females, 25 located nests
  - 2019: 23 monitored females, 19 located nests
  - All nests monitored and tissue samples are now being processed
- 270 incidental tortoises processed (reproductive status, size, body condition, etc.)

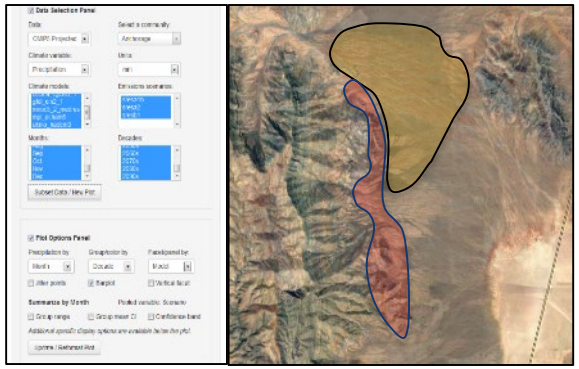
Technical Approach: Conservation Planning Tool

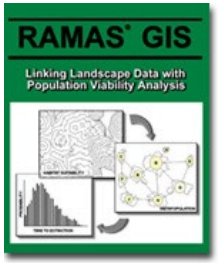
Habitat Breadth model



(with uncertainty)

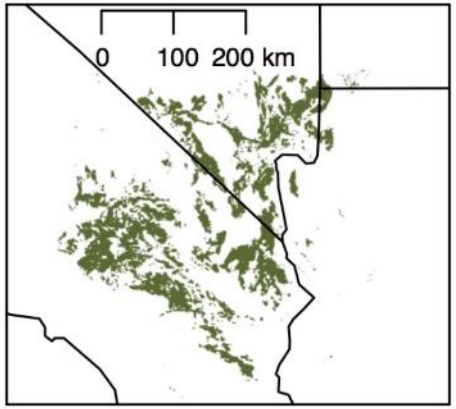
$\lambda \geq 1$

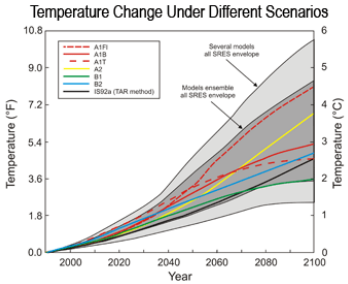




Metapopulation model

Online DT conservation tool





Climate change projections

Outputs:

Habitat maps

Population viability

Translocation site ID

Conclusions

- We hope our efforts will be useful for management planning!
  - Identify core populations likely to weather environmental changes
  - Identify areas that are likely to serve as useful connectivity habitat now and in the future
  - Identify areas that require increased connectivity to ensure long-term persistence
  - Assess viability of low-density populations

- Conservation tool should be available by fall/winter 2021

Acknowledgments

- Funding: SERDP
- Thanks to all who contributed to the long-term data collection efforts at the Permanent Study Plots (too many to name!)
- Thanks to Roy Averill-Murray, Dave Rostal, Kristina Drake, Resit Akcakaya, Jill Heaton for assistance with data sharing and intellectual contributions.

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QUESTIONS?

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ANCILLARY SLIDES

Mojave DT: “permanent study plots”

- 2.6 km^2 (1 mi^2) permanent plots
- 36 plots established across the species range between 1971 and 1994 by BLM, USFWS and others
- In survey years, at least 2 complete passes in the spring (ca 30 person-days)

	1976-2001	1987-2002	1991	**1992-1997**	1976-1999	1976-1997	1980-1991	1979-2002	1979-2002	1976-2000	1976-1993	1976-2001	1979-2002	1980-1994	1980-1995	1980-1994	1978-2002	1971-72	1981-1991	1980-2002	**1986-1995**	**1994**	**1986-1994**	1992-1995	1980	1992-2000	1992-2000	**1989-1994**	**1979-1994**	**1989-1994**	**1979-1995**	**1987-1992**	**1985-1994**	1991	1988-1994	1980-1998	TOTAL
State	AZ	AZ	AZ	**AZ**	CA	CA	CA	CA	CA	CA	CA	CA	CA	CA	CA	CA	CA	CA	CA	CA	**NV**	**NV**	**NV**	NV	NV	NV	NV	**NV**	**NV**	**NV**	**NV**	**NV**	**NV**	UT	UT	UT	
Total	7	4	1	**2**	7	9	4	6	6	9	7	6	5	4	5	4	4	1	3	6	**3**	**1**	**3**	4	1	9	8	**2**	**5**	**2**	**4**	**2**	**3**	1	2	6	156
Available	0	0	0	**2**	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	1	**3**	**1**	**3**	0	1	0	0	**2**	**4**	**2**	**3**	**2**	**3**	0	0	0	29
This analysis	0	0	0	**2**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**2**	**1**	**2**	0	0	0	0	**2**	**3**	**2**	**1**	**2**	**3**	0	0	0	20

Estimating Fecundity

Age at maturity

Morphometrics

Clutch size

Diagnostic imaging

Nest success

Hatchling sex ratio

Nest site identification

(High-intensity sites only)

Radio-telemetry, tracking

Nest site identification

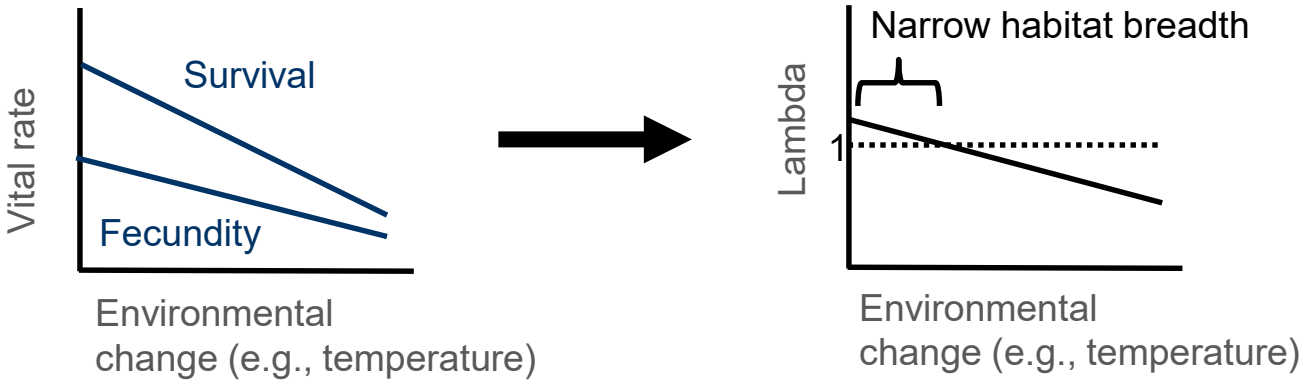
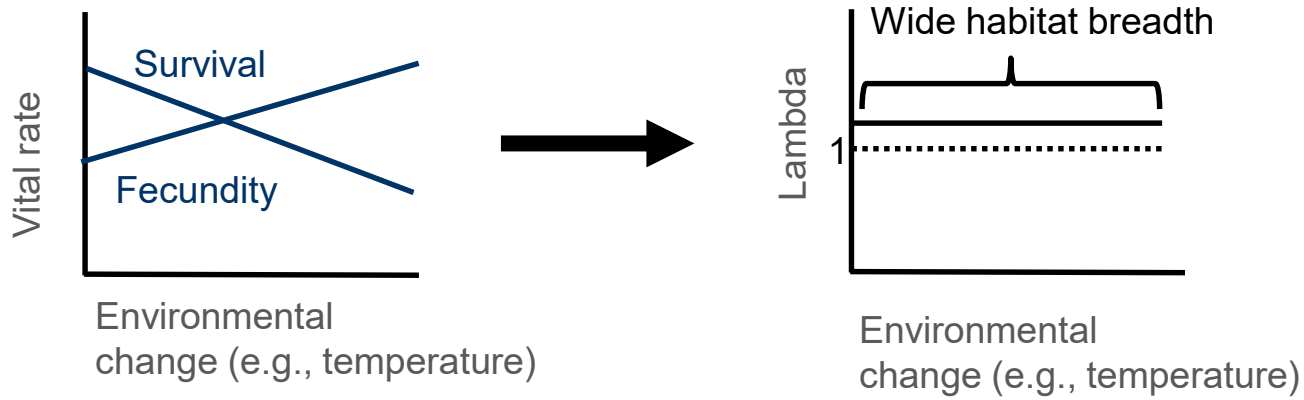
Nest monitoring

Environmental data loggers and thermal mapping

Testosterone assay

Environmental variables

Variable	Description	Source
Blkdens	Soil bulk density	STATSGO
Dpth2bdrk	Depth to bedrock	STATSGO
Pctcov	Perennial plant cover	Wallace et al. (2008)
Annprox	Annual green-up potential	Derived from NDVI (MODIS)
Rufavg	Average surface roughness	DEM
Precip_dry	Precipitiation, May-Oct, 30-year normal	PRISM
Precip_wet	Precipitiation, Nov-Apr, 30-year normal	PRISM
Temp_dry	Temperature, May-Oct, 30-year normal	PRISM
Temp_wet	Temperature, Nov-Apr, 30-year normal	PRISM
Meandens	Mean population density, estimated	PSP re-analysis

(Nussear et al. 2009)

Assessing Critical Habitat Breadth