Ecological and Evolutionary Physiology of Sexual Dimorphism in Body Size in Eastern Fence Lizards (*Sceloporus undulatus*)

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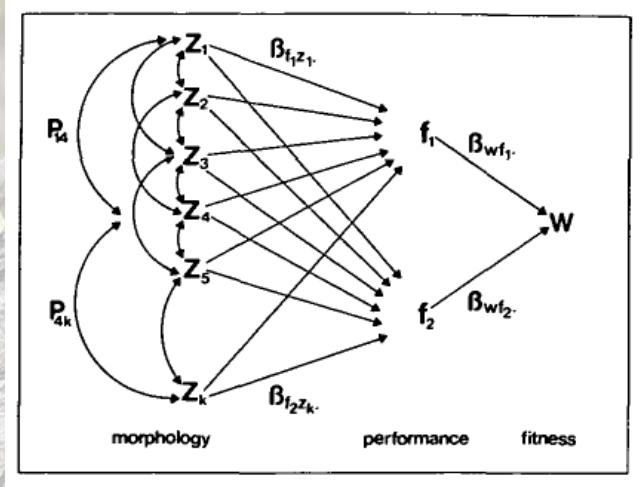
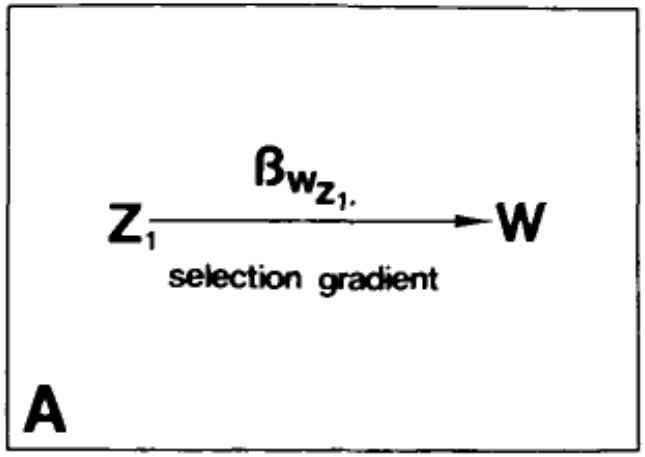
RUTGERS

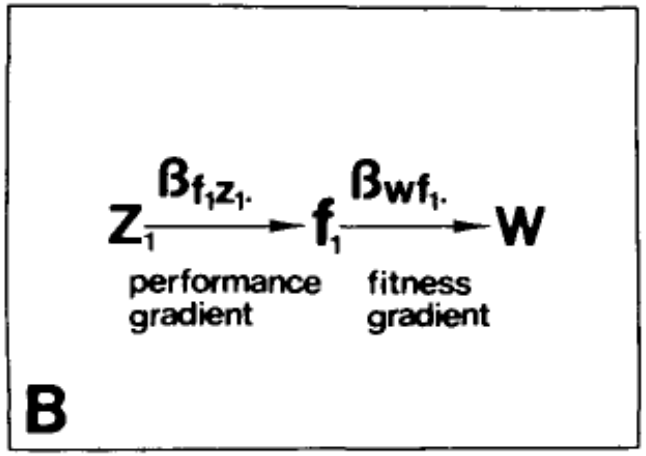
Morphology, Performance, and Fitness

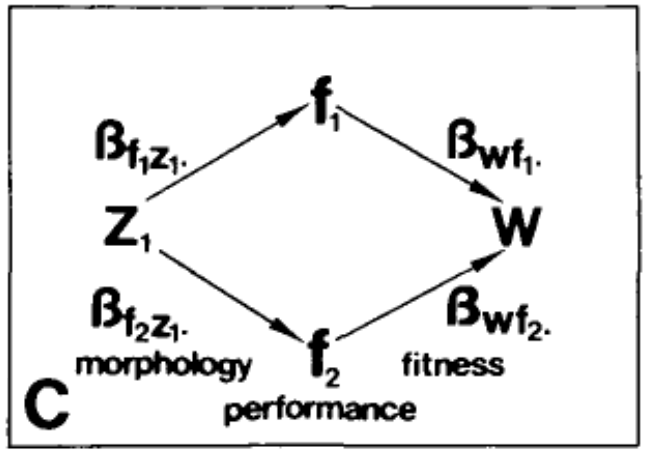
-S. Arnold, *Am. Zool.*, 1983



Ultimate goal of integrative biology is to reveal the adaptive significance of phenotypic traits through their functional linkages to fitness.







Morphology, Performance, and Fitness

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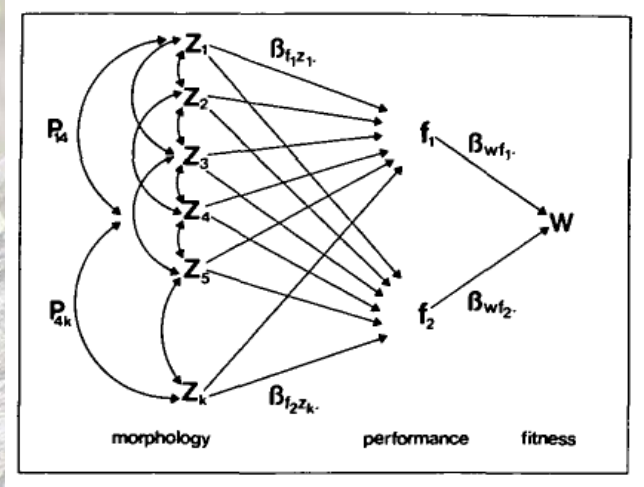
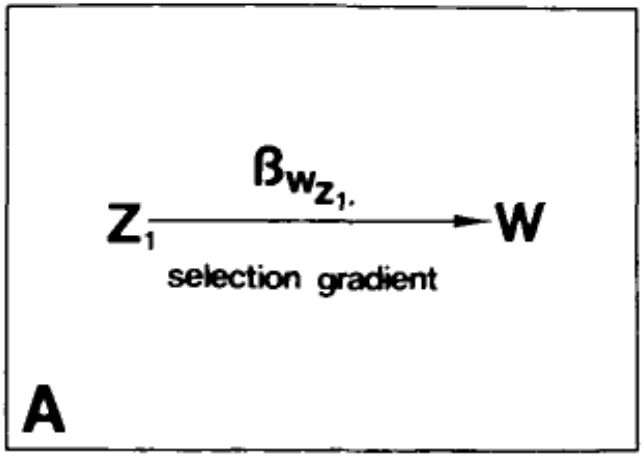
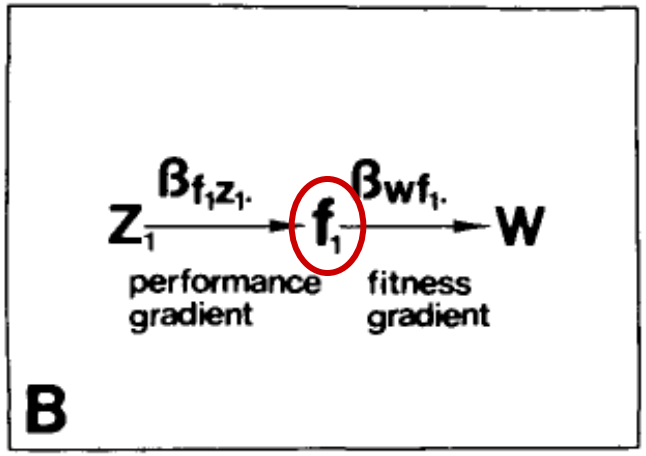
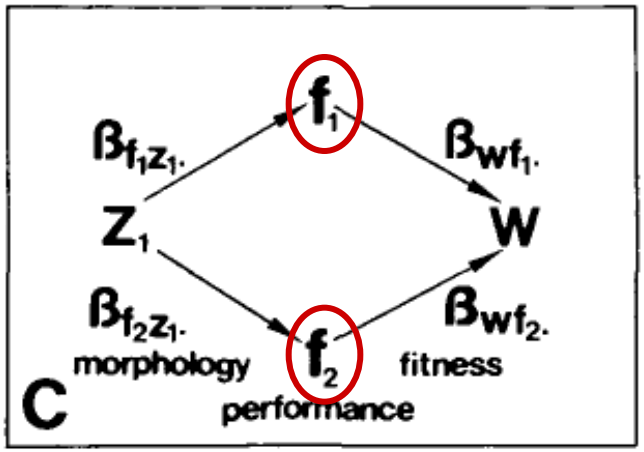


"PERFORMANCE" is what animals do in nature. It is about all that they do to work and succeed.







"… endocrine system interprets environmental variation to produce a range of phenotypes from the same genotype."

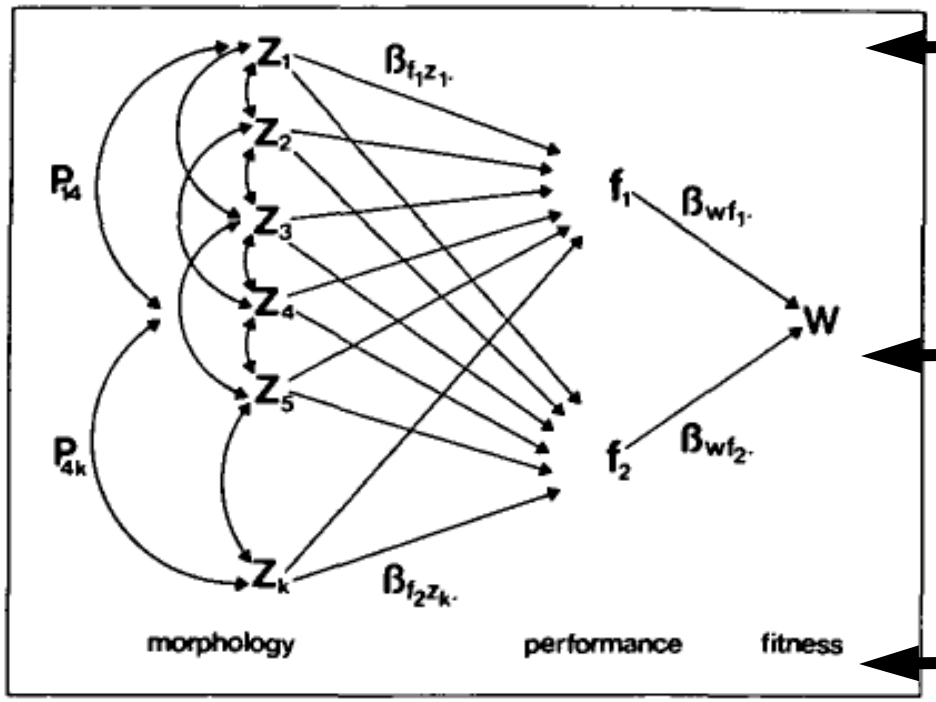
Dufty, Clobert, and Møller, 2002

Hormones are biological agents of phenotypic covariance.

Hormones can regulate performance.

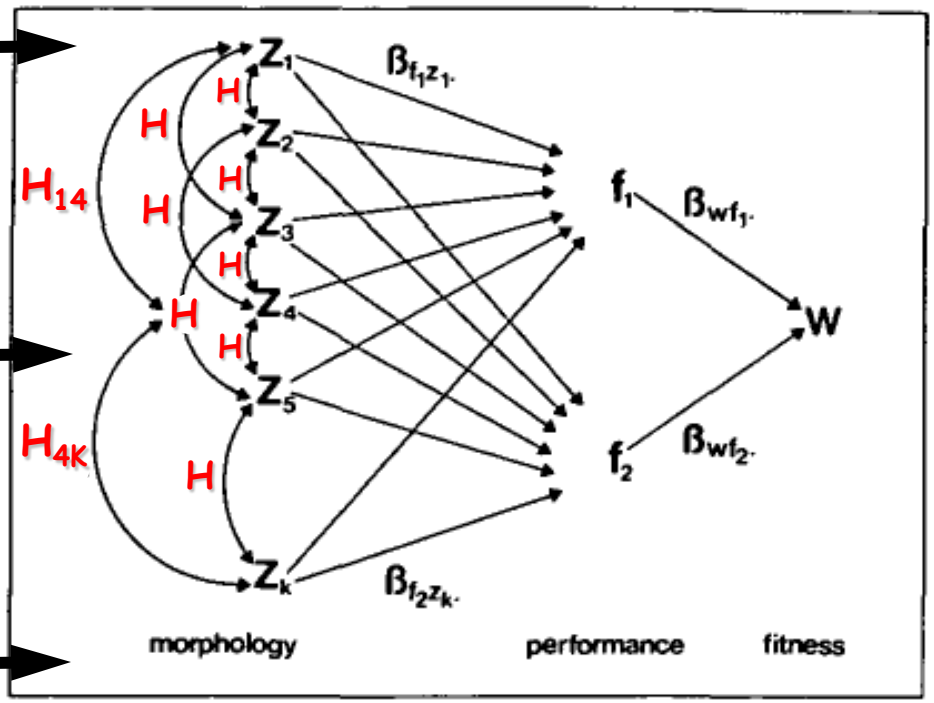
Statistical Relationships

"P" = phenotypic covariance



Endocrine Integration

H = hormonal pleiotropy



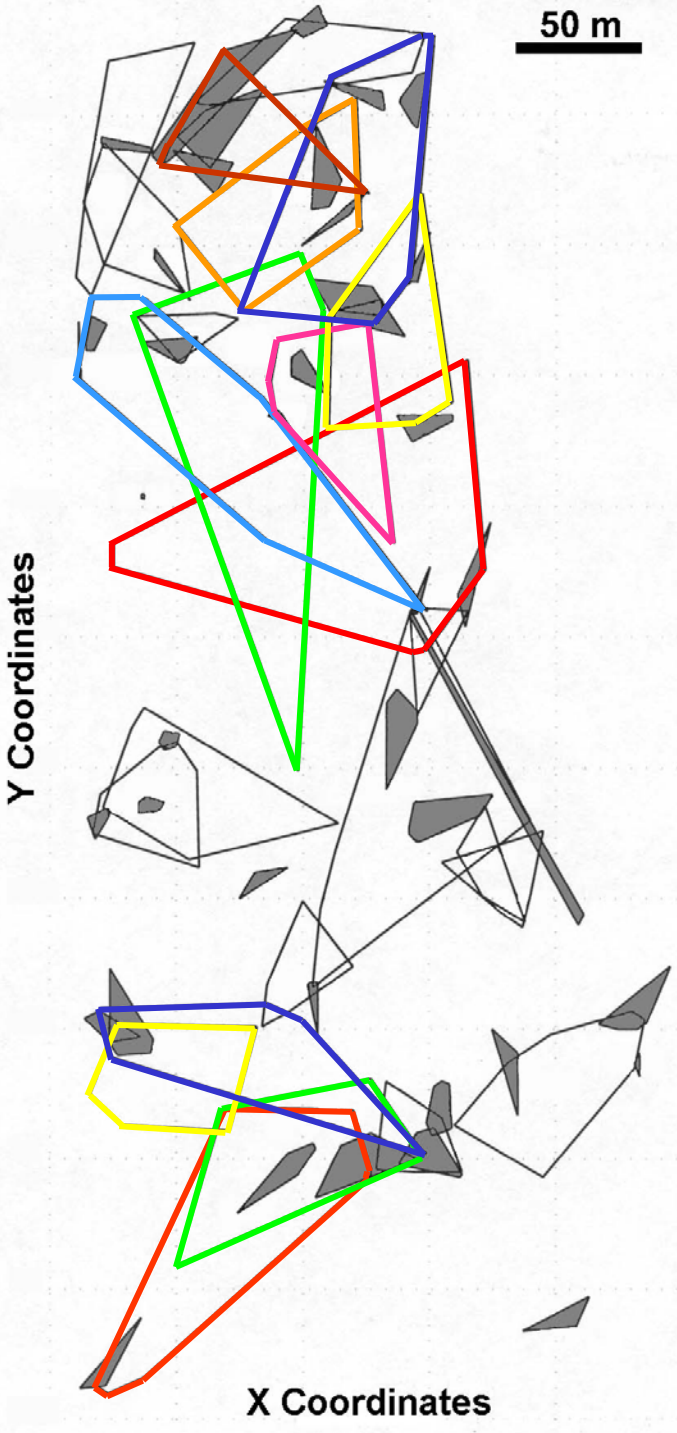
Home Range Analysis:

Spacing Patterns and Reproductive Success

Sceloporus undulatus

Eastern Fence Lizard

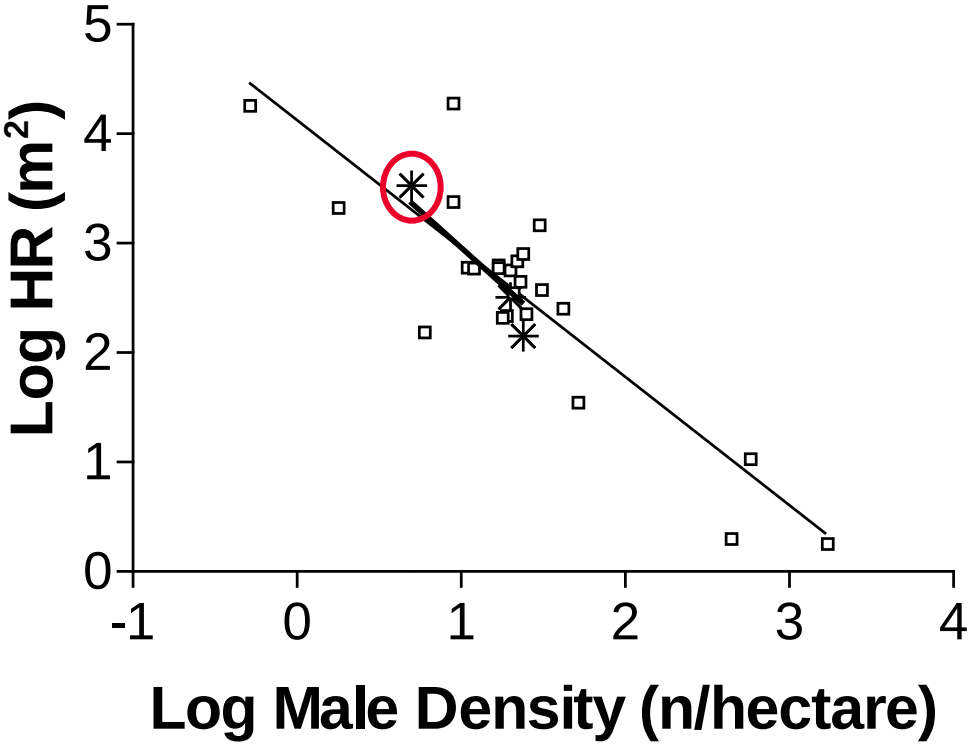
Unique Paint Mark for Identification



Male *Sceloporus undulatus*

Home ranges are large and overlapping.

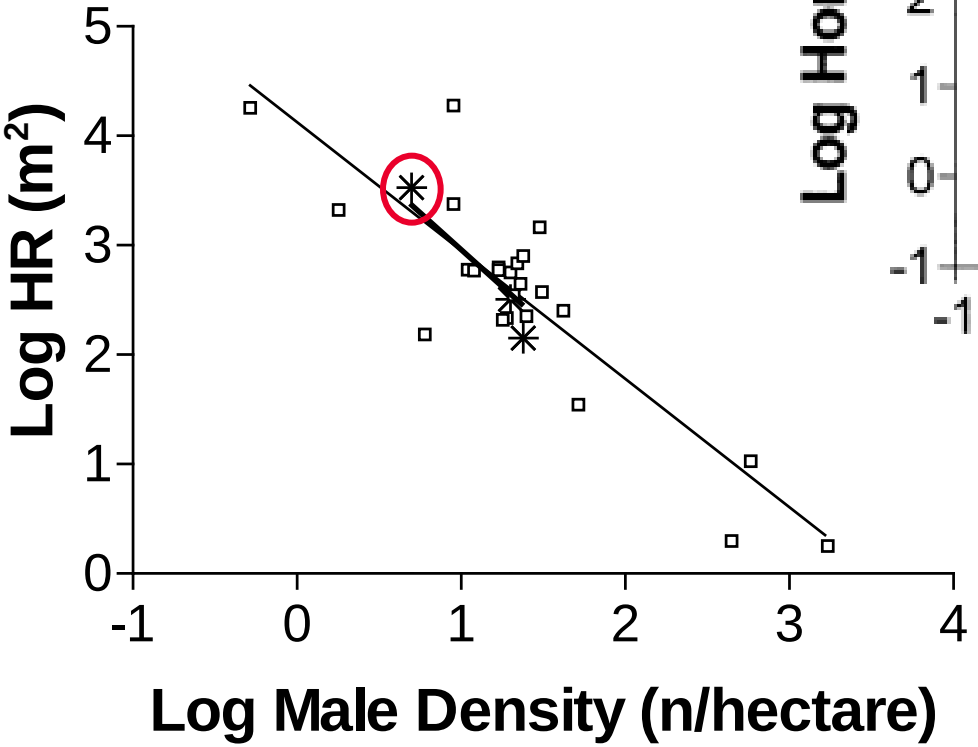
Home range area of males is 10X greater than females.

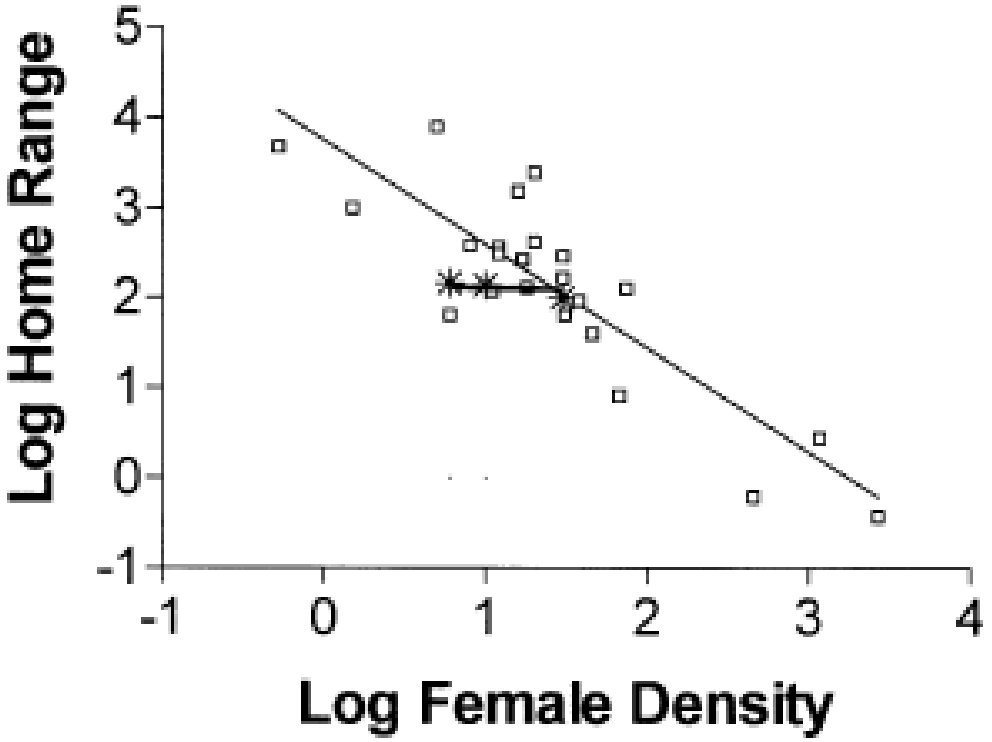


Home ranges of males are large and overlapping.

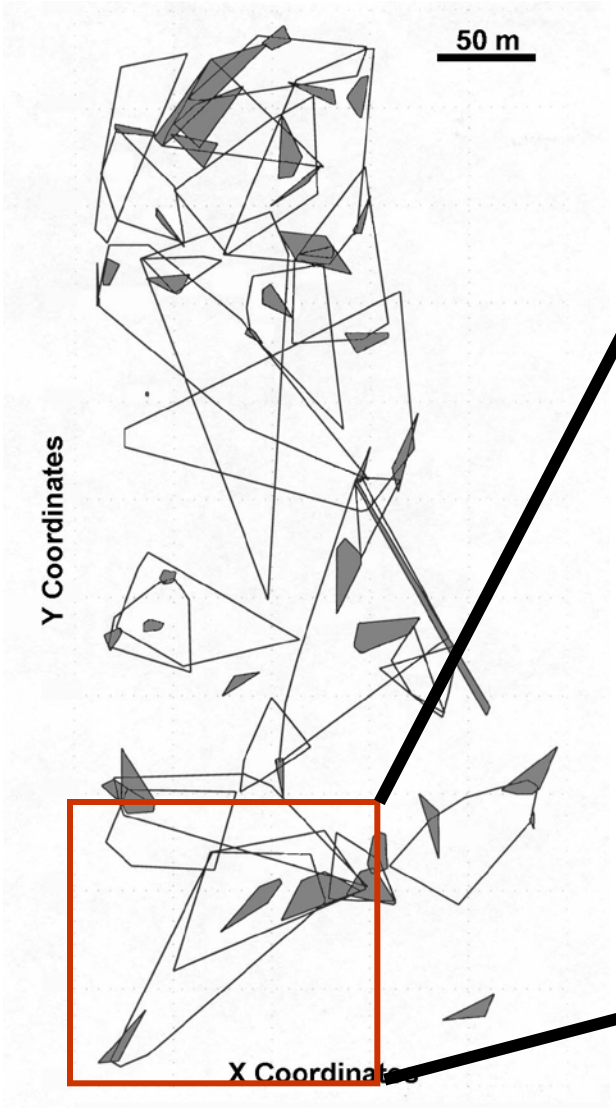
Home range area depends on population density.

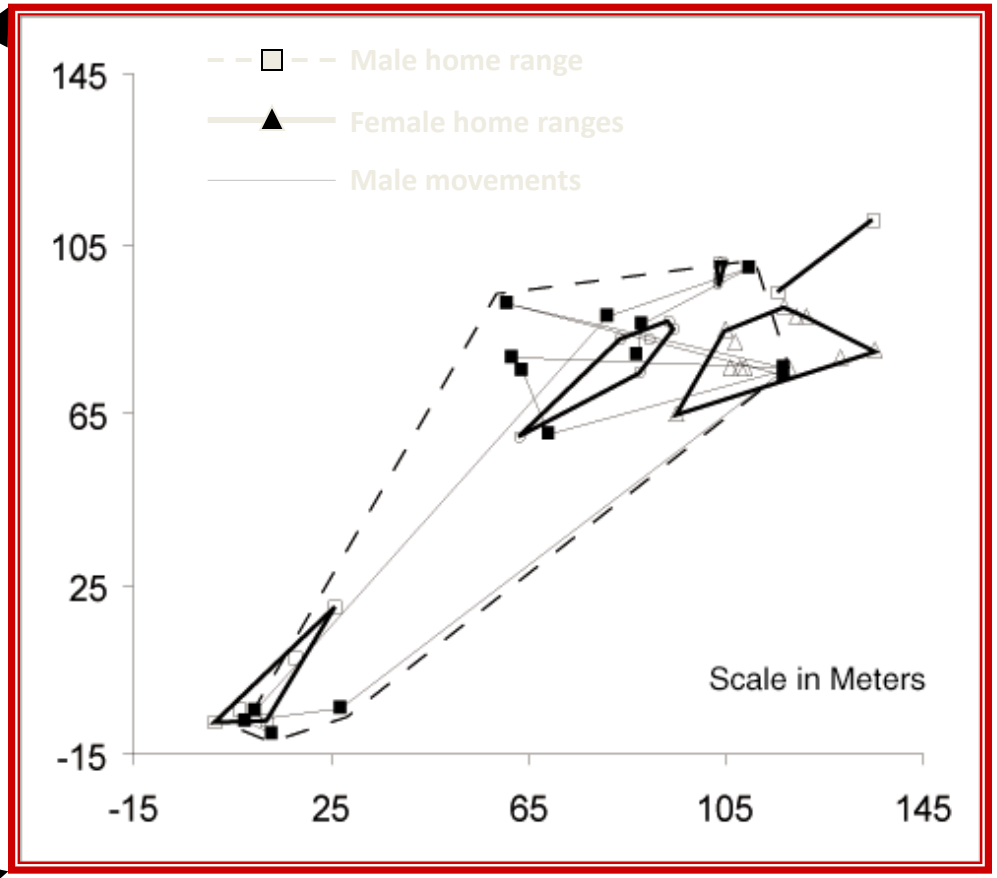
Home range area is an order of magnitude greater in NJ than in other populations.

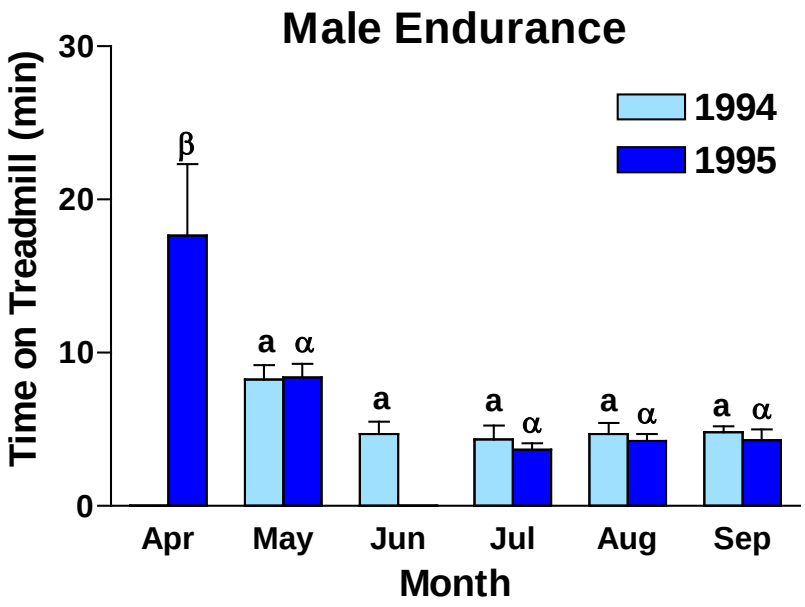

Log HR (m²)
5
4
3
2
1
0
-1
0
1
2
3
4
Log Male Density (n/hectare)


Log Home Range
5
4
3
2
1
0
-1
-1
0
1
2
3
4
Log Female Density

Spatial distribution of females drives movement and home range behavior of males.



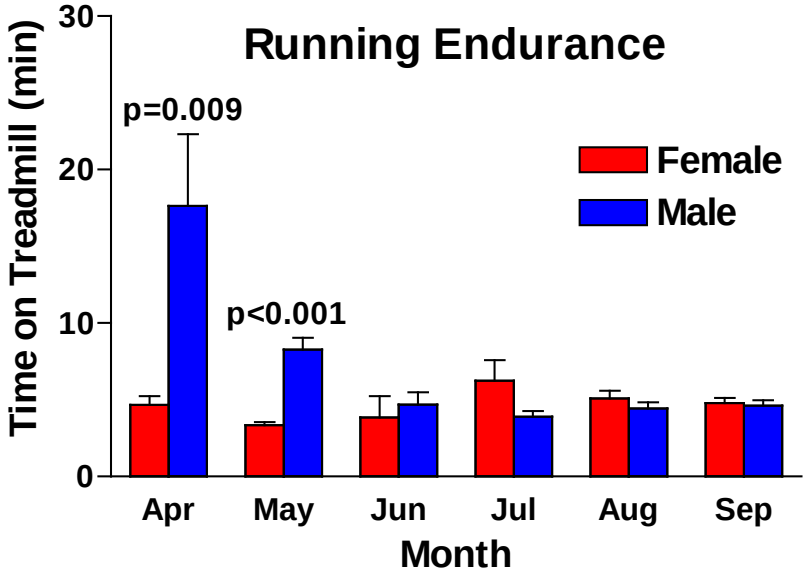




Environmental Variation:

A "Natural Experiment"

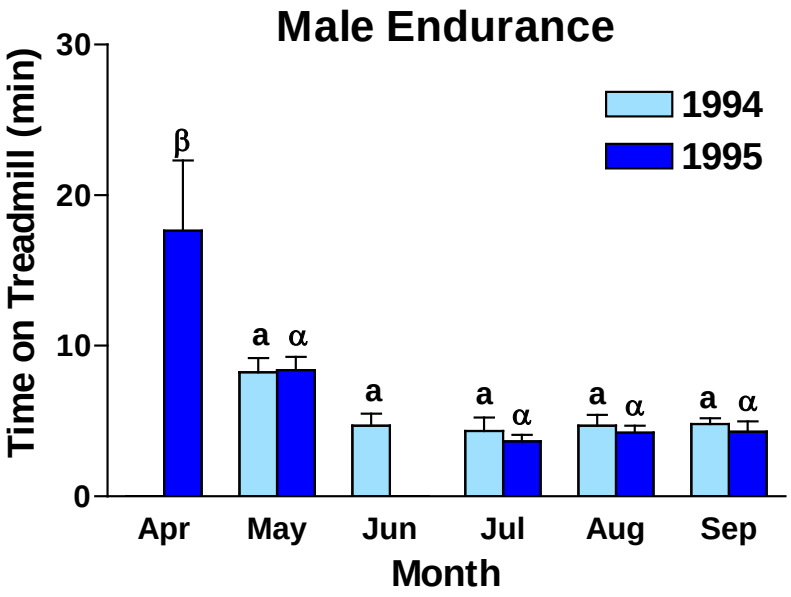
Exercise endurance in males is greatest during the breeding season …

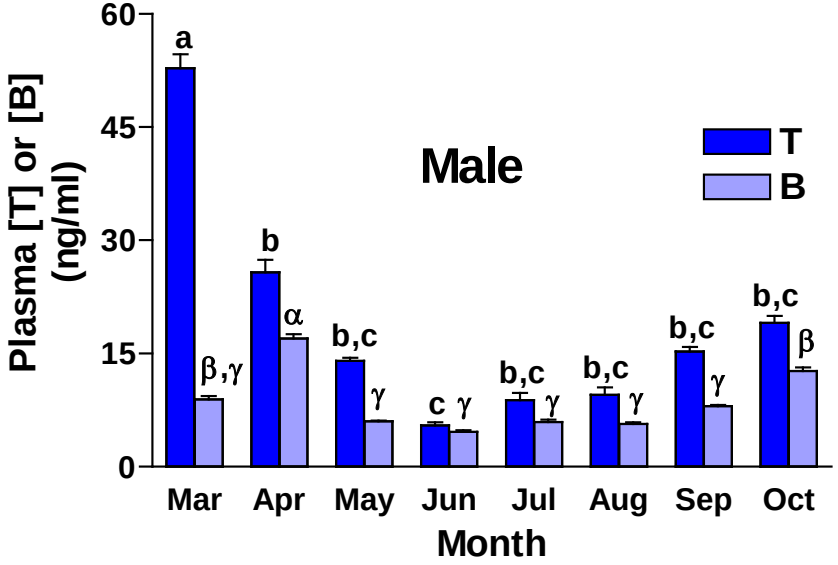


… and is greater in males than in females during the breeding season.

Environmental Variation:

A "Natural Experiment"





Testosterone and corticosterone vary roughly in parallel with endurance.

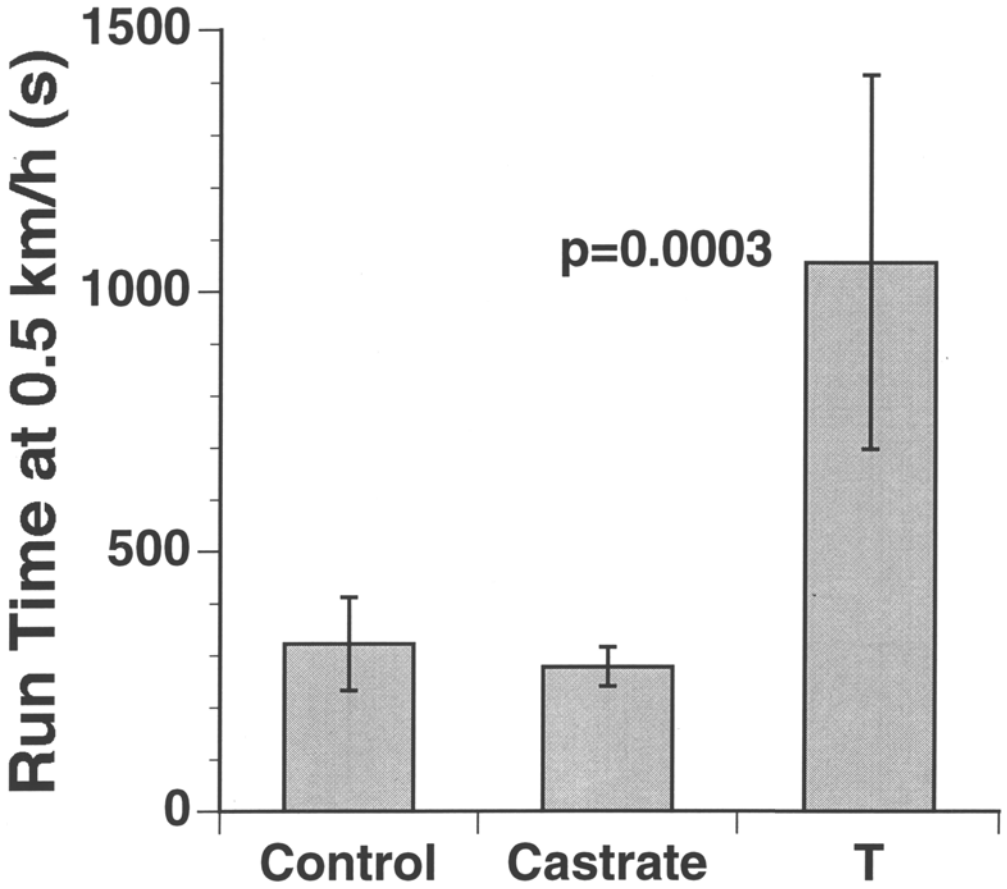
Experimental Manipulation

Surgical Castration

+

Testosterone Replacement

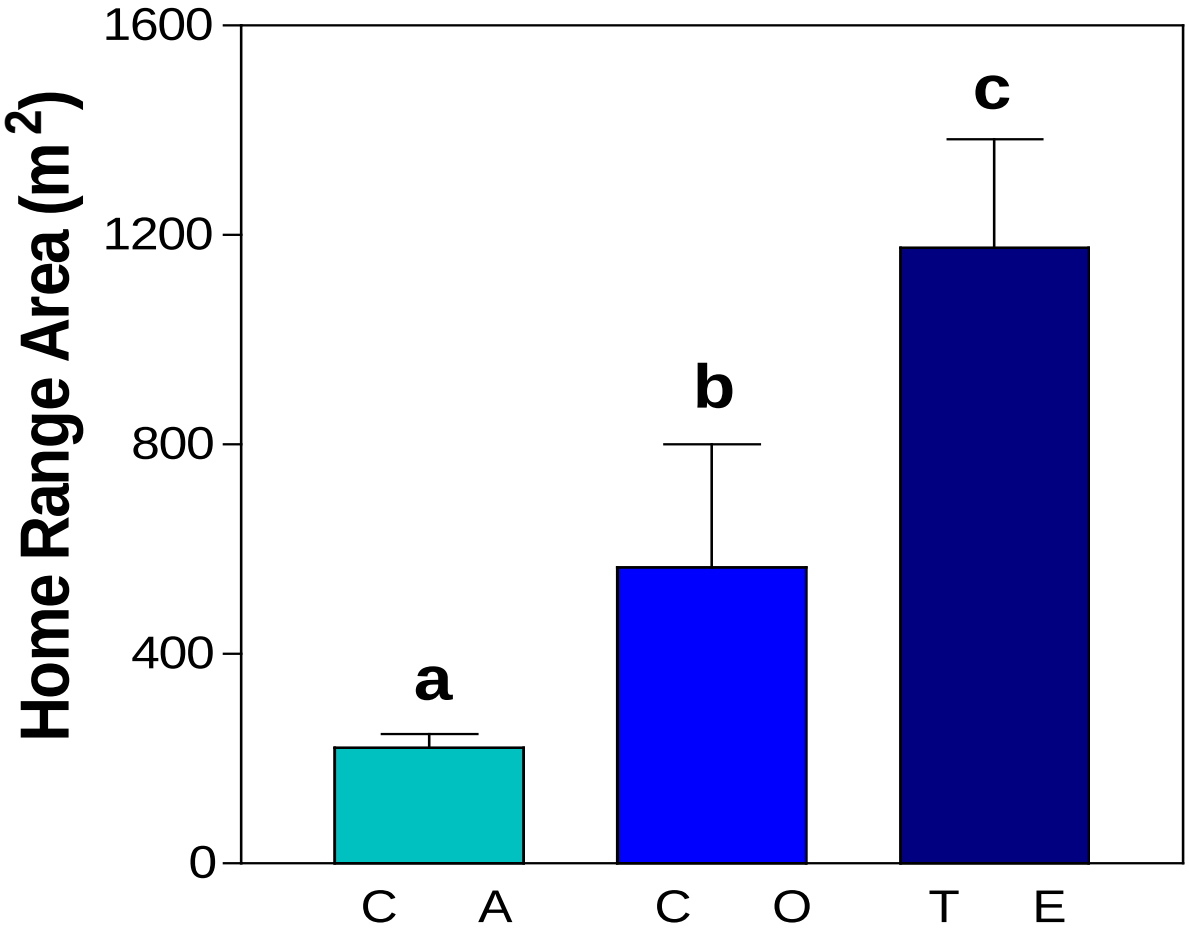
Sceloporus undulatus



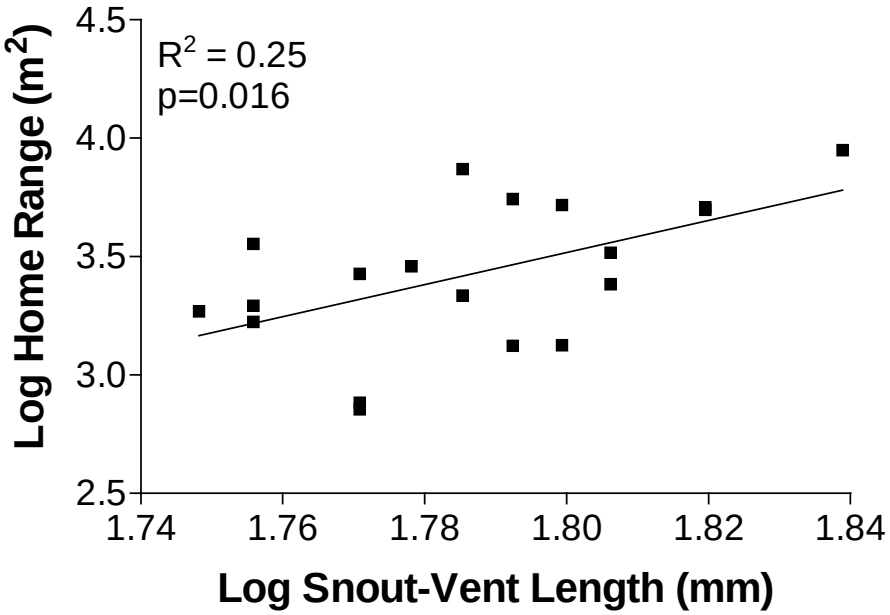
Exogenous testosterone → ↑ endurance.

(But corticosterone has no effect.)

TESTOSTERONE promotes home range acquisition.

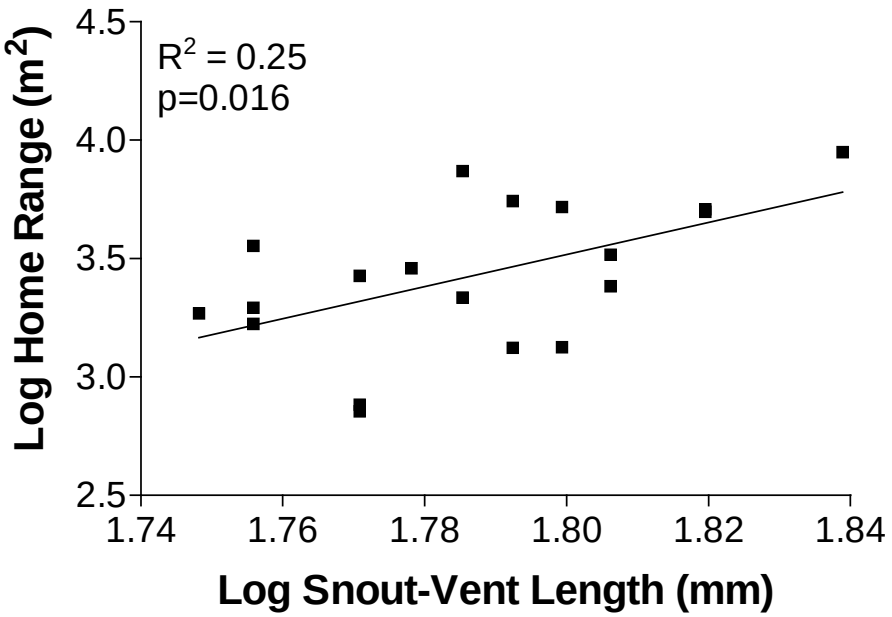


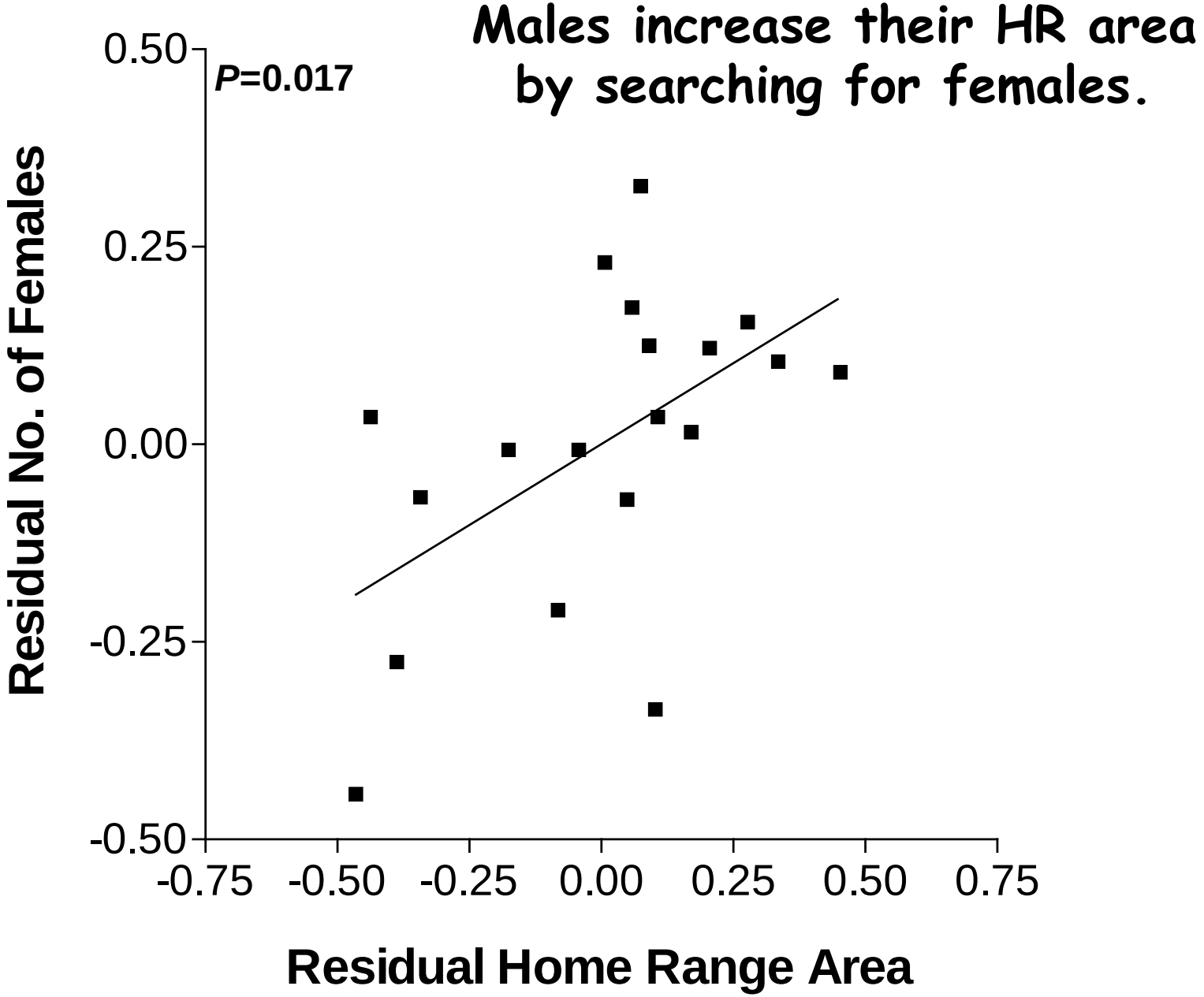
HR area increases with body size …

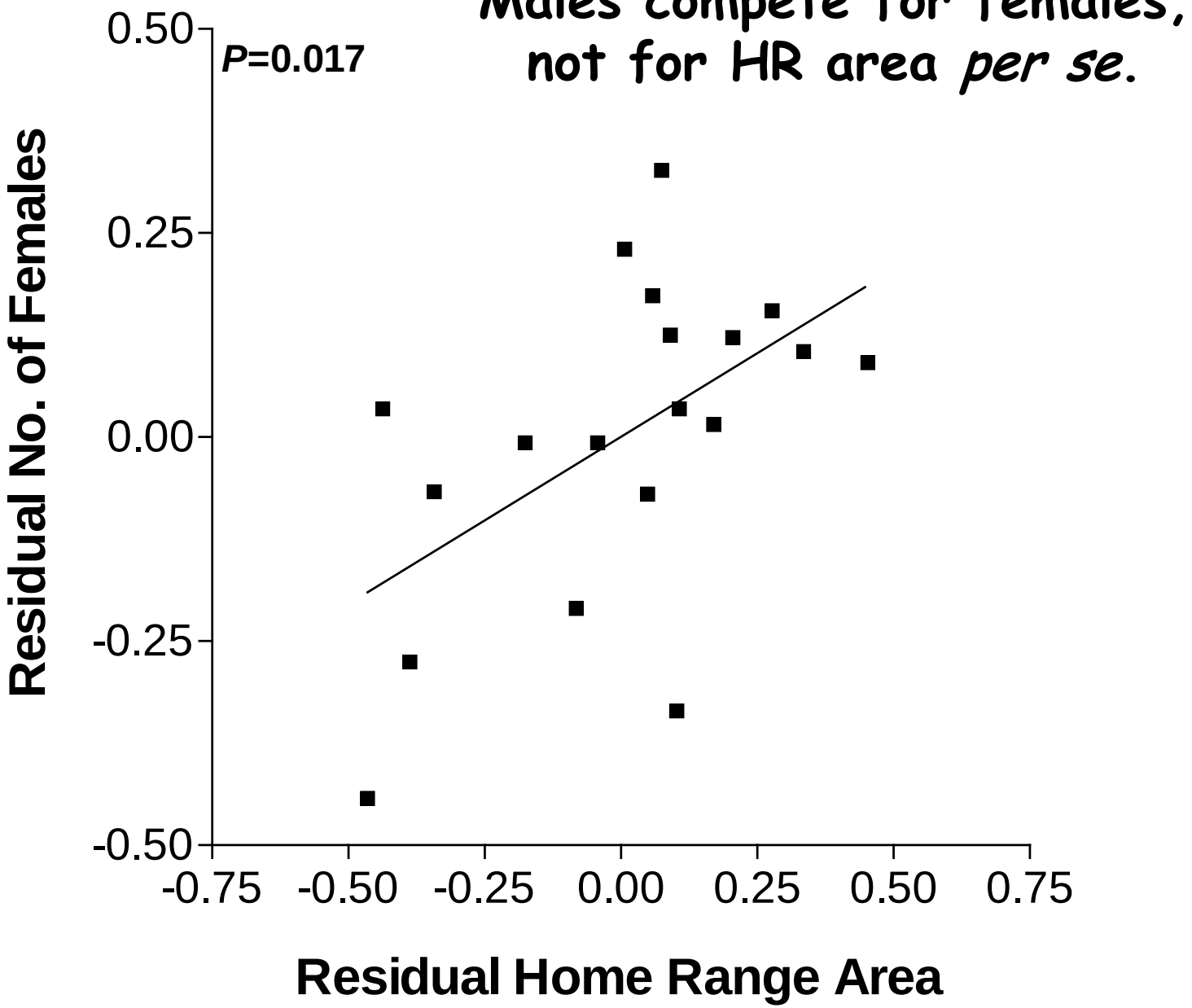


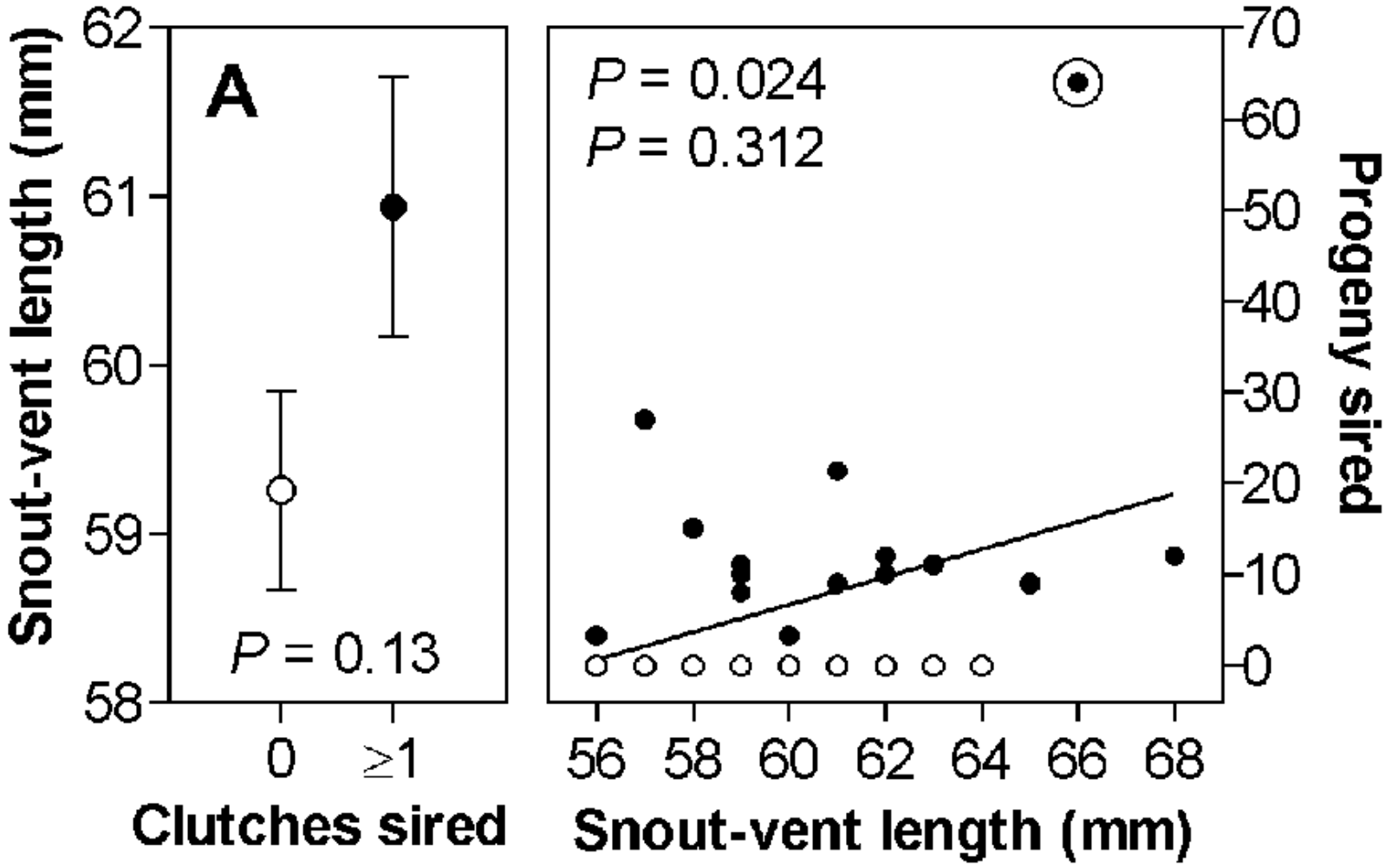
HR area increases with body size …

… and with age.

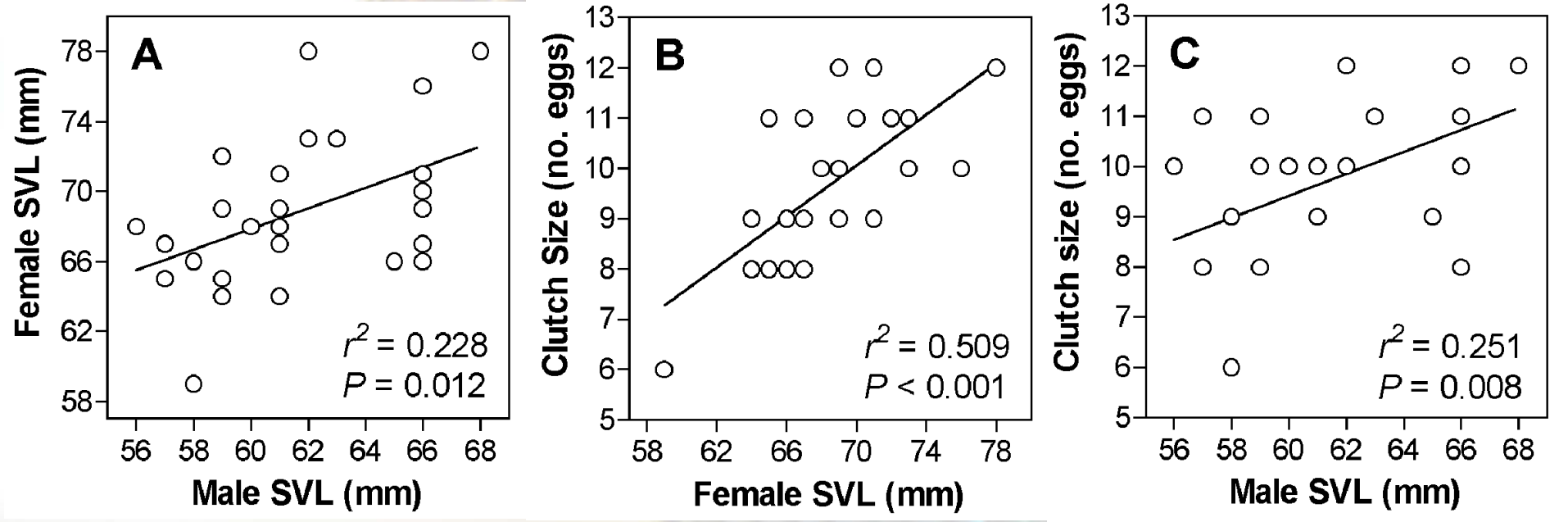


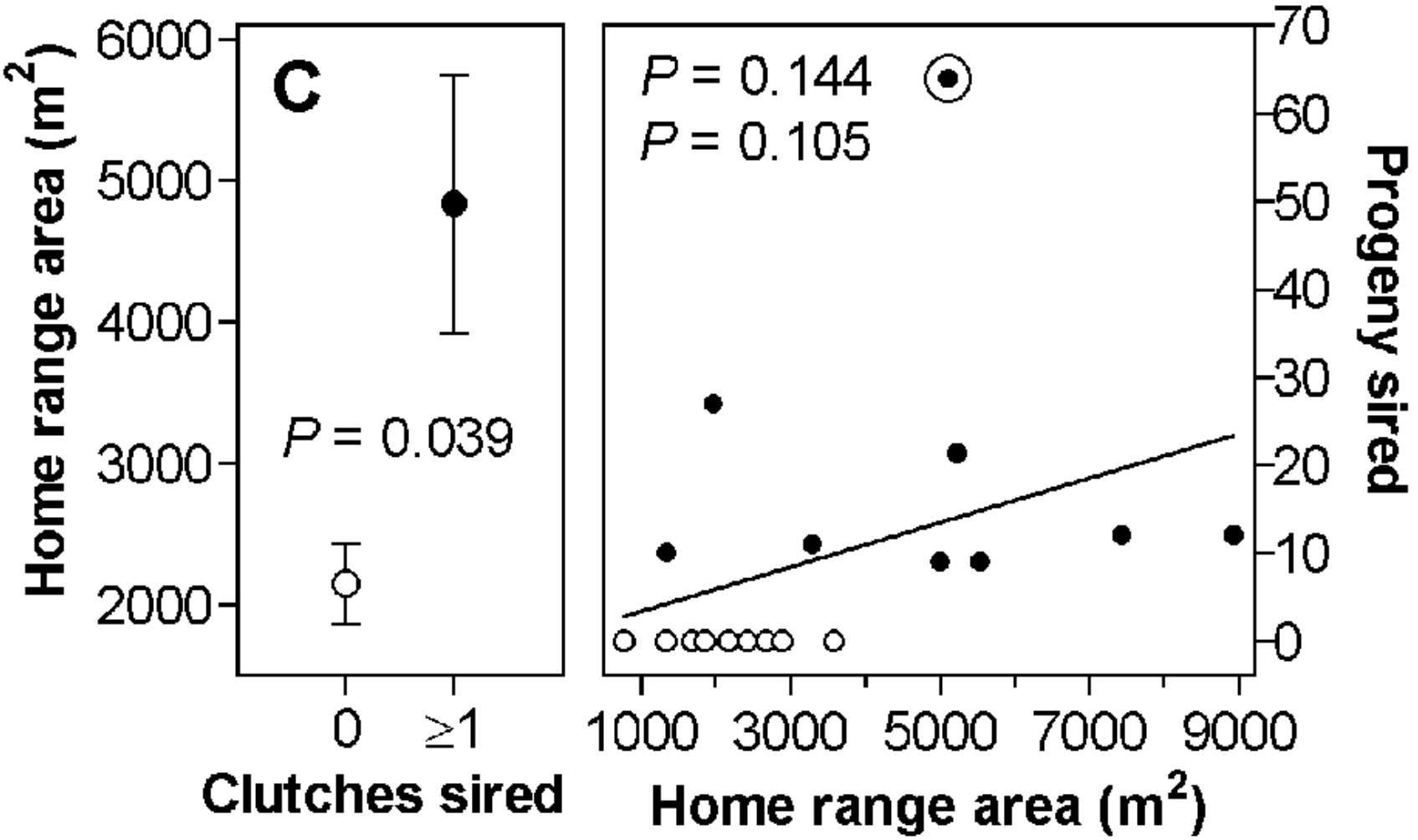

Males increase their HR area by searching for females.
P=0.017
Residual No. of Females
0.50
0.25
0.00
-0.25
-0.50
-0.75
-0.50
-0.25
0.00
0.25
0.50
0.75
Residual Home Range Area


Males compete for females, not for HR area *per se*.
P=0.017
Residual No. of Females
0.50
0.25
0.00
-0.25
-0.50
-0.75
-0.50
-0.25
0.00
0.25
0.50
0.75
Residual Home Range Area


A
P = 0.13
Snout-vent length (mm)
62
61
60
59
58
0
≥1
Clutches sired
P = 0.024
P = 0.312
70
60
50
40
30
20
10
0
Progeny sired
56
58
60
62
64
66
68
Snout-vent length (mm)

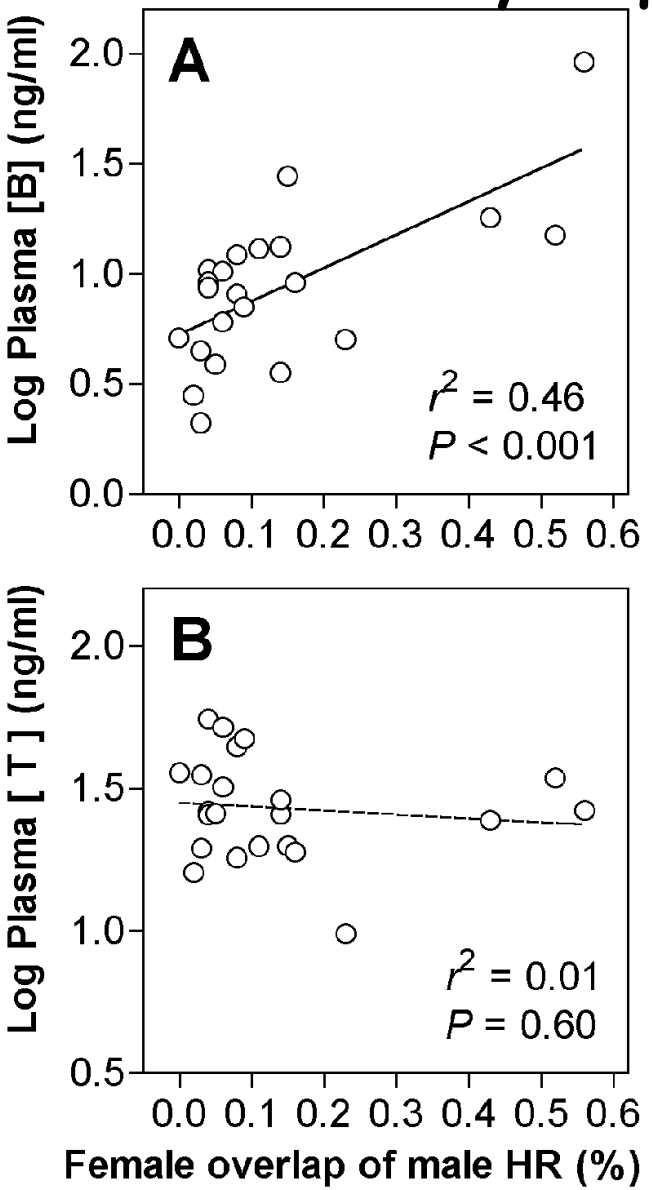
Larger males sire more and larger clutches.




C
P = 0.039
P = 0.144
P = 0.105
Home range area (m2)
6000
5000
4000
3000
2000
0
≥1
Clutches sired
1000
3000
5000
7000
9000
Home range area (m2)
70
60
50
40
30
20
10
0
Progeny sired

CORTICOSTERONE

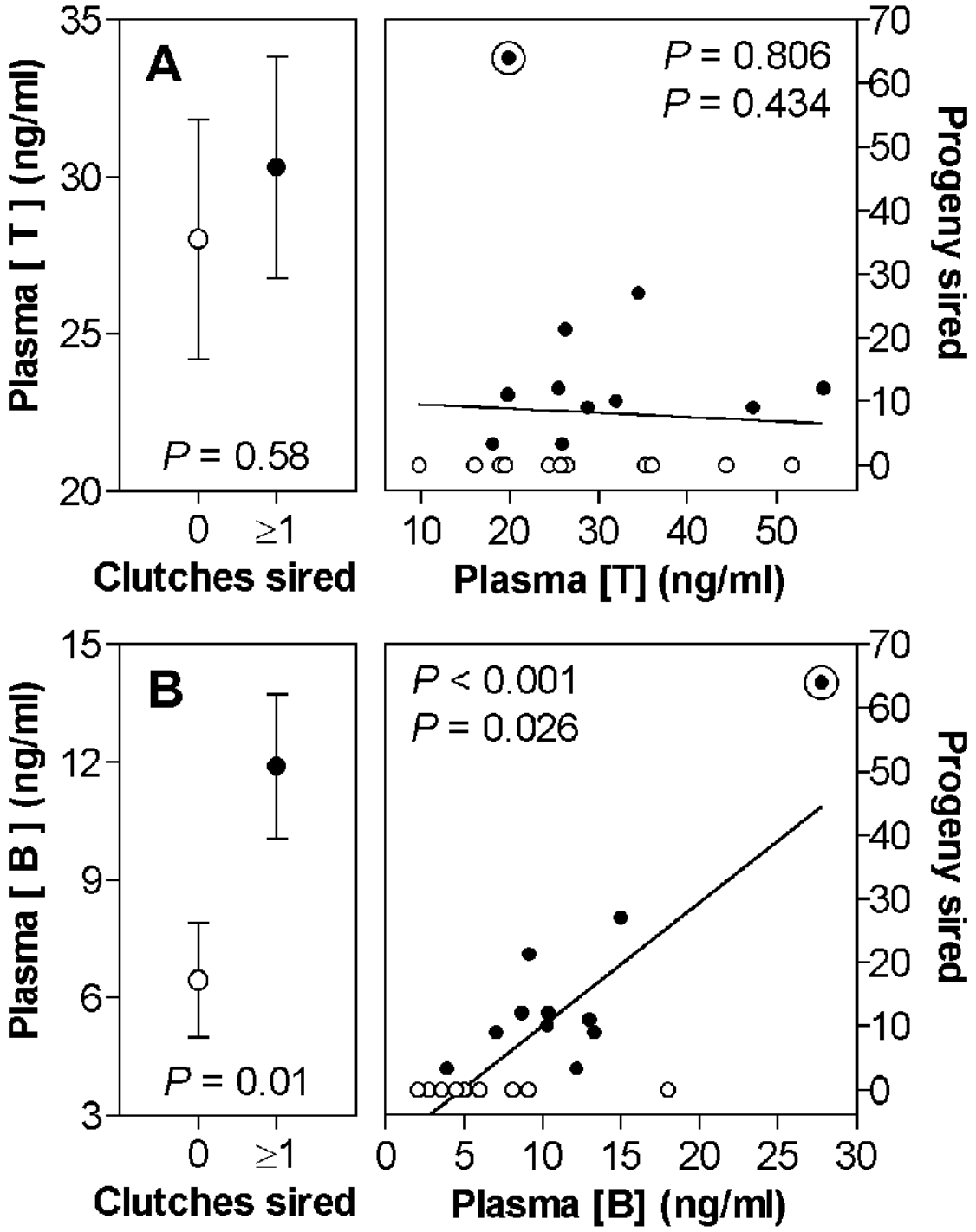
"Successful" home range behavior is strenuous and may require high endurance.

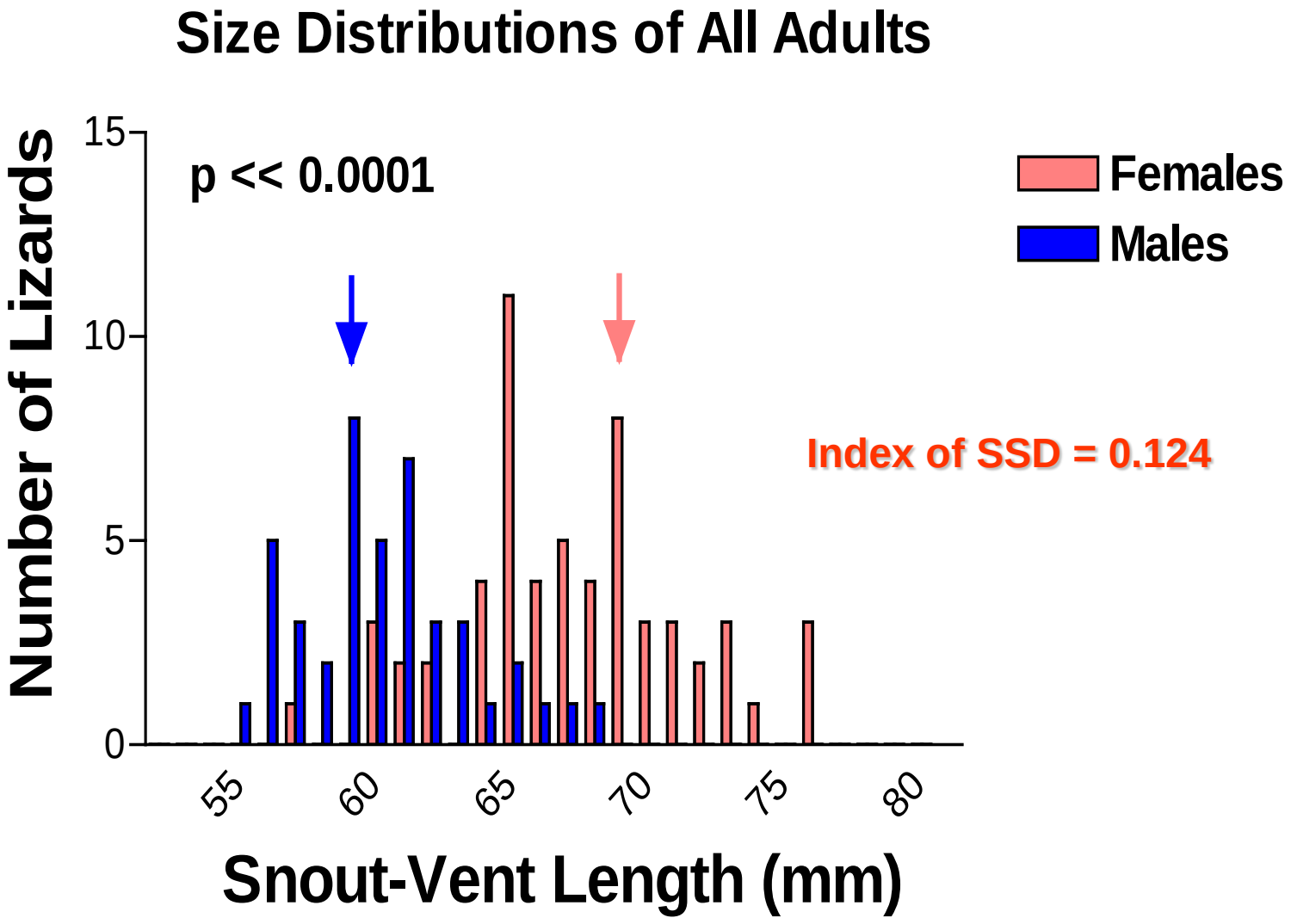


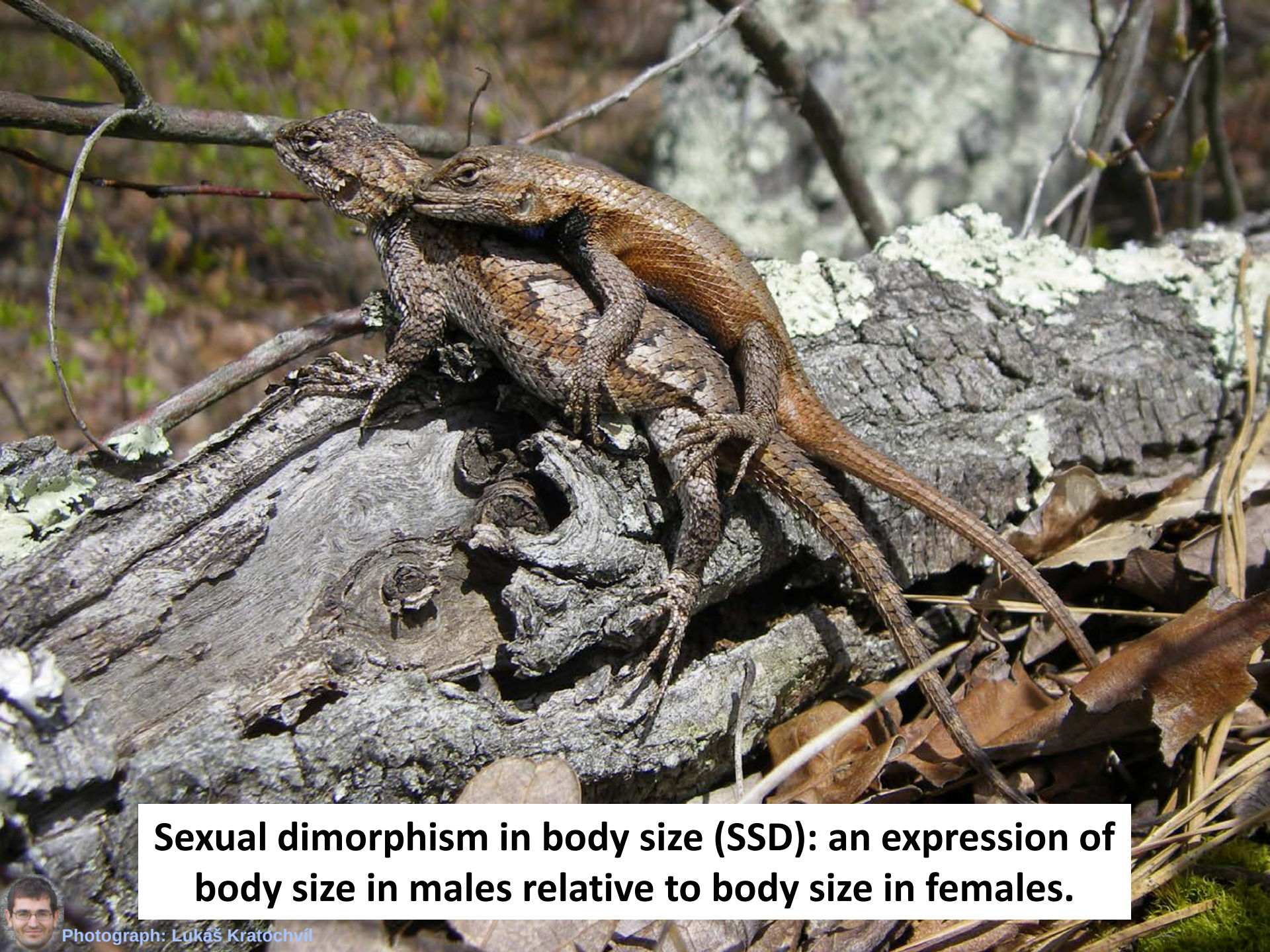
Plasma [CORT] is correlated with endurance:

r = 0.414, p = 0.0002, n = 76

Attainment of high fitness can be stressful.




Size Distributions of All Adults
p << 0.0001
Females
Males
Index of SSD = 0.124
Number of Lizards
15
10
5
0
55
60
65
70
75
80
Snout-Vent Length (mm)



Sexual dimorphism in body size (SSD): an expression of body size in males relative to body size in females.

Photograph: Lukáš Kratochvíl

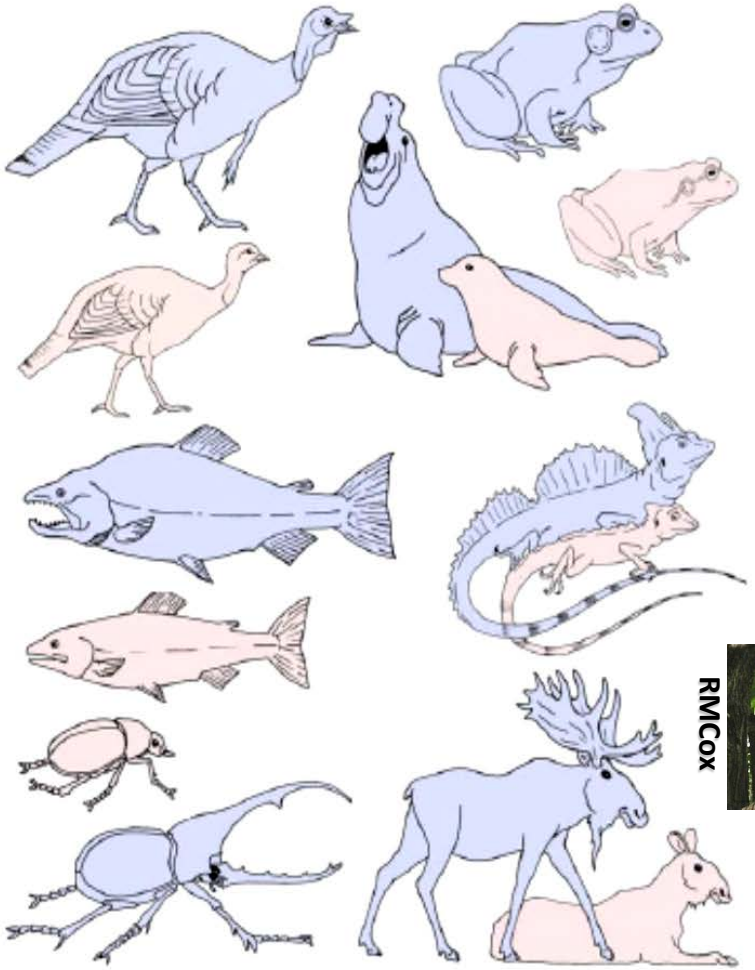
♀ > ♂

Sexual Size Dimorphism (SSD)

♂ > ♀

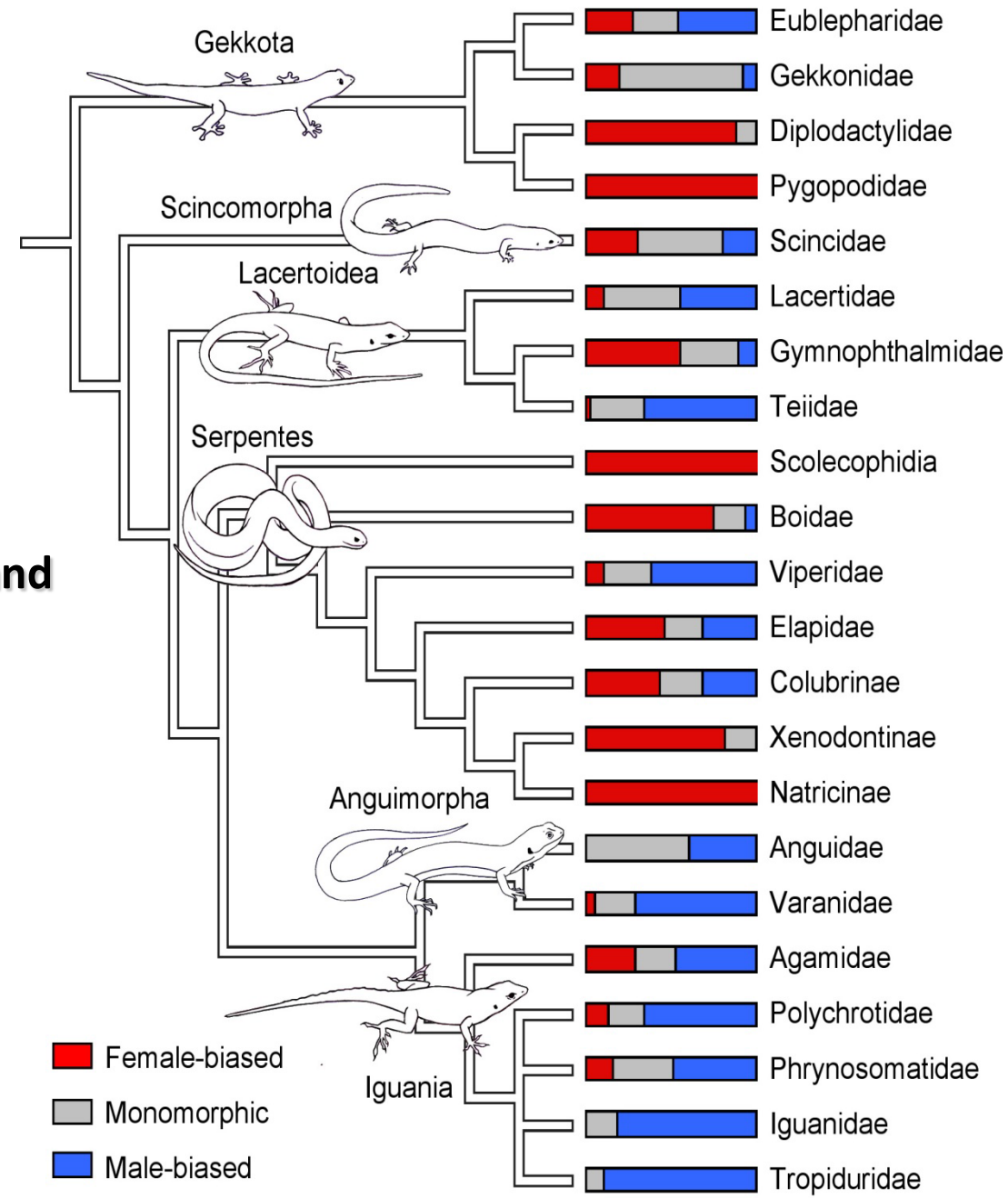
Why are females larger than males in some species …

… while males are larger than females in many others?

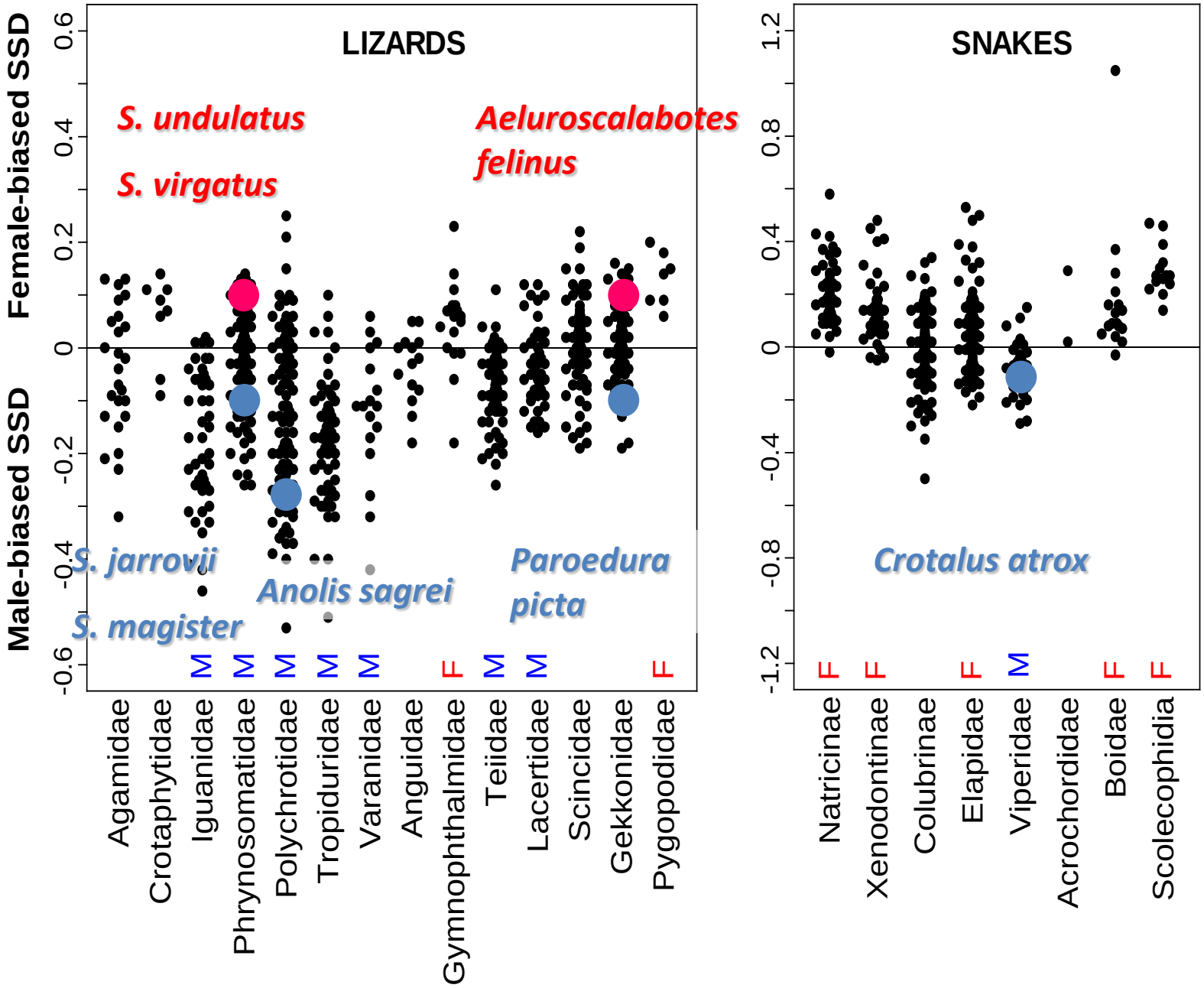


RMCox

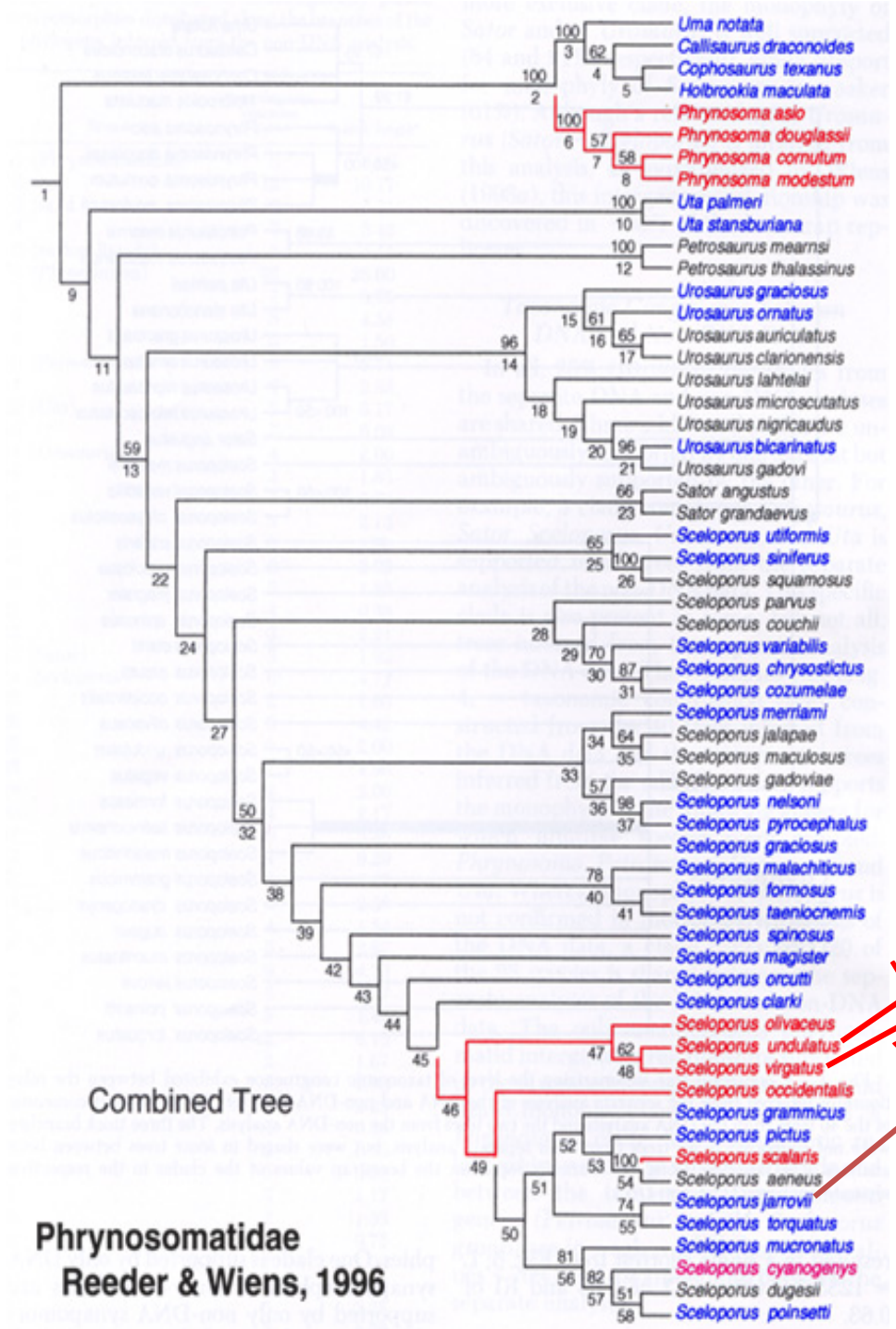
SSD in lizards and snakes



Cox, Stenquist, & Calsbeek,

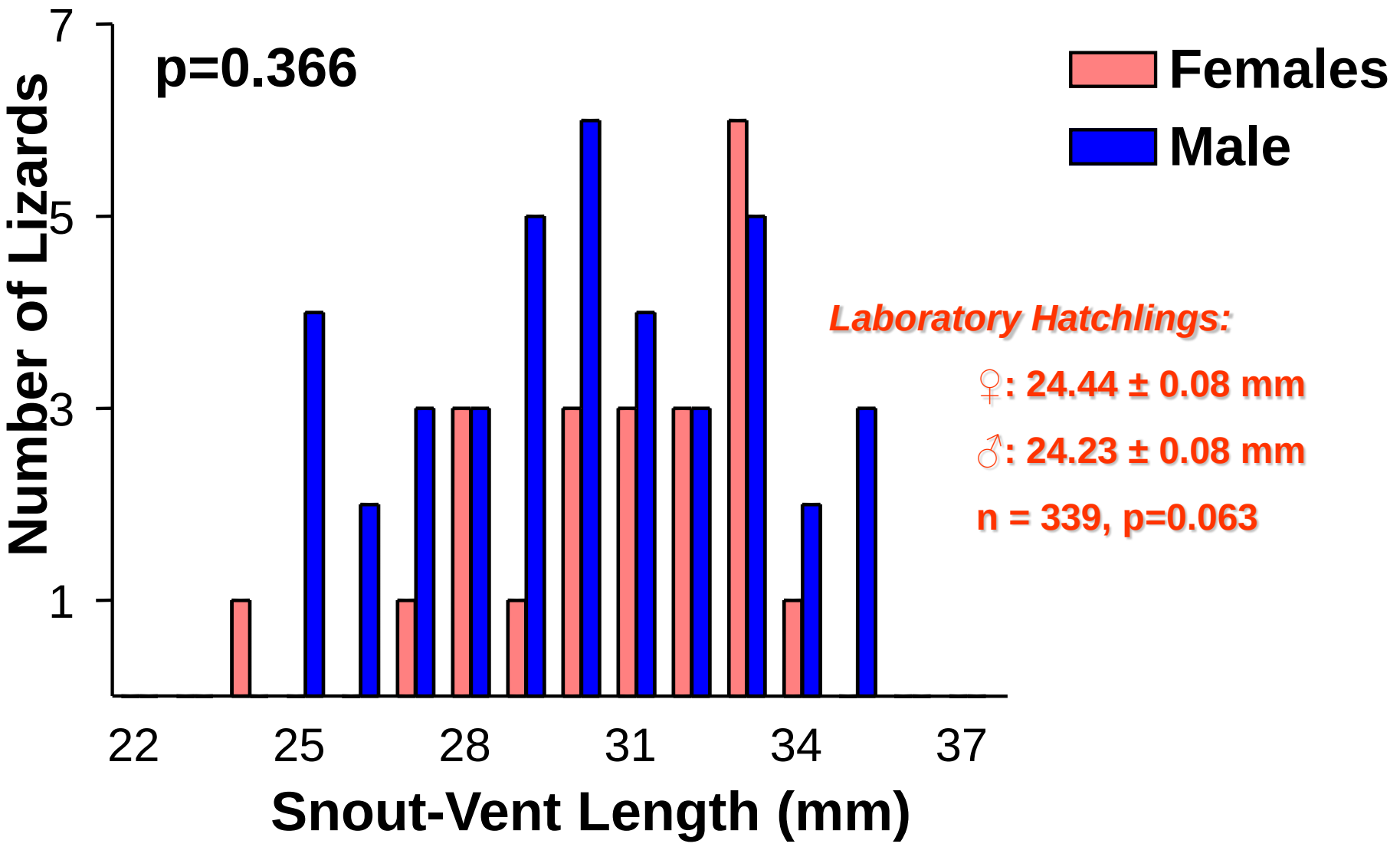


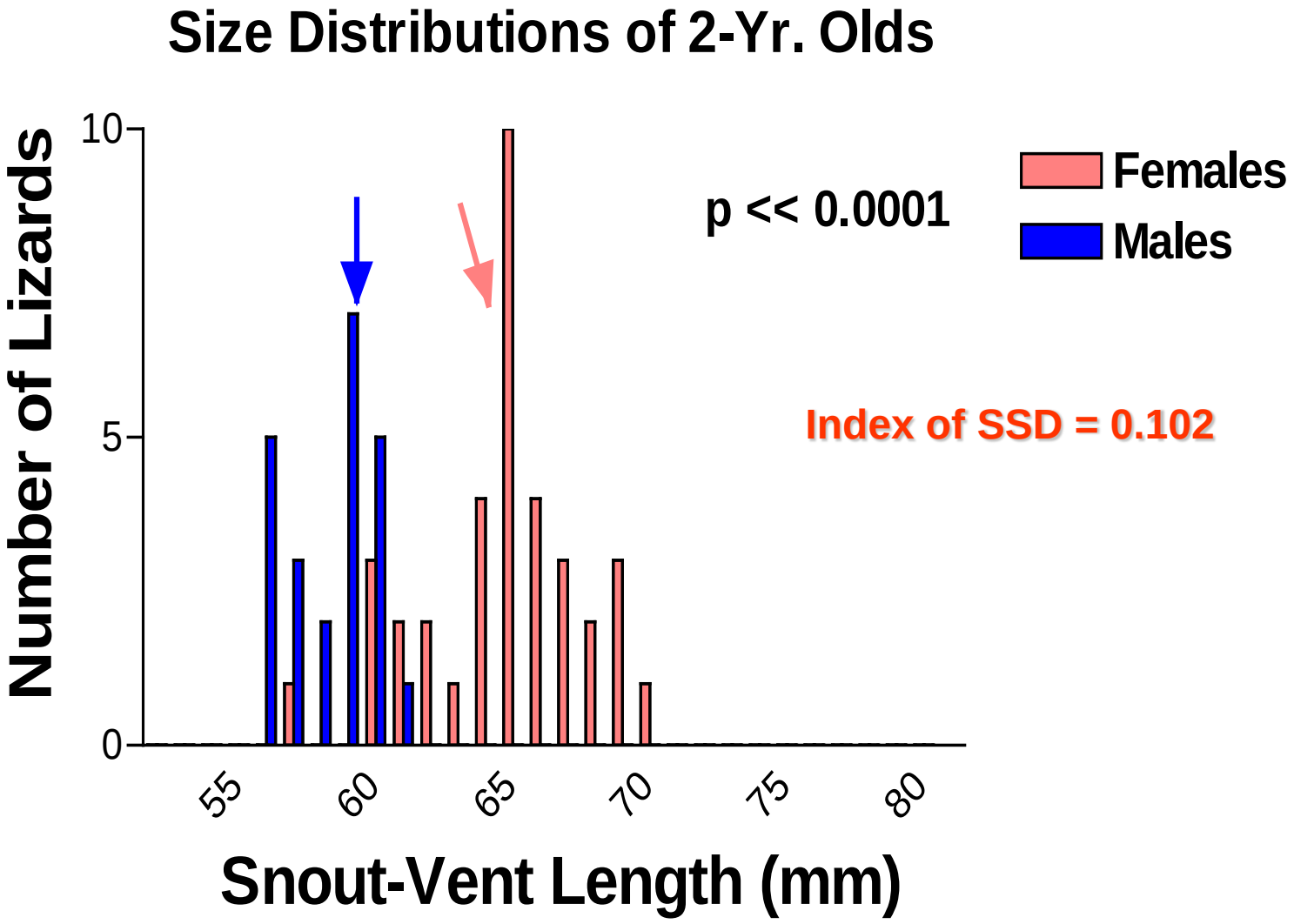
Cox, Butler, & John-Alder, 2007; John-Alder, Cox, & Taylor, 2007; Cox, Stenquist, and Calsbeek, 2009; Kratochvil, Kubicka, Golinski, & John-Alder, unpubl.

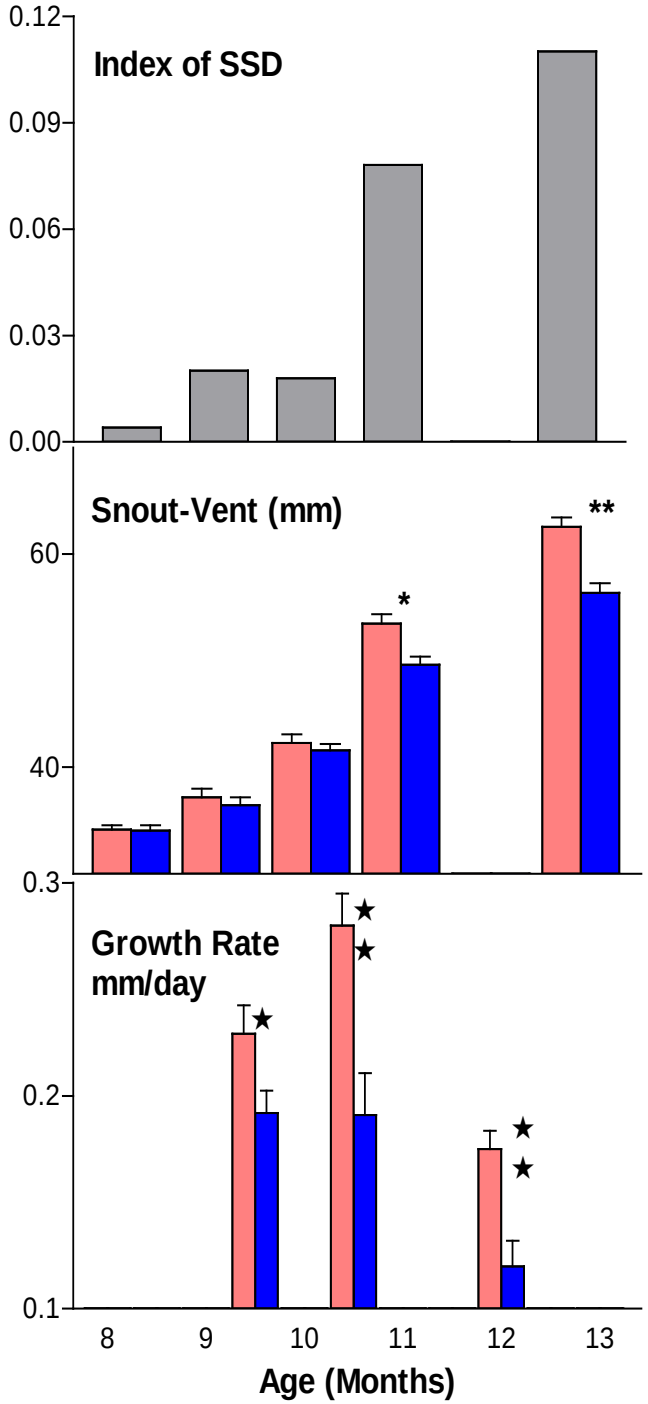

Uma notata
Callisaurus draconoides
Cophosaurus texanus
Holbrookia maculata
Phrynosoma asio
Phrynosoma douglassii
Phrynosoma cornutum
Phrynosoma modestum
Uta palmeri
Uta stansburiana
Petrosaurus mearnsi
Petrosaurus thalassinus
Urosaurus graciosus
Urosaurus ornatus
Urosaurus auriculatus
Urosaurus clarionensis
Urosaurus lahtelai
Urosaurus microscutatus
Urosaurus nigricaudus
Urosaurus bicarinatus
Urosaurus gadovi
Sator angustus
Sator grandaevus
Sceloporus utiformis
Sceloporus siniferus
Sceloporus squamosus
Sceloporus parvus
Sceloporus couchii
Sceloporus variabilis
Sceloporus chrysostictus
Sceloporus cozumelae
Sceloporus merriami
Sceloporus jalapae
Sceloporus maculosus
Sceloporus gadoviae
Sceloporus nelsoni
Sceloporus pyrocephalus
Sceloporus graciosus
Sceloporus malachiticus
Sceloporus formosus
Sceloporus taeniocnemis
Sceloporus spinosus
Sceloporus magister
Sceloporus orcutti
Sceloporus clarki
Sceloporus olivaceus
Sceloporus undulatus
Sceloporus virgatus
Sceloporus occidentalis
Sceloporus grammicus
Sceloporus pictus
Sceloporus scalaris
Sceloporus aeneus
Sceloporus jarrovii
Sceloporus torquatus
Sceloporus mucronatus
Sceloporus cyanogenys
Sceloporus dugesii
Sceloporus poinsetti
Combined Tree
Phrynosomatidae
Reeder & Wiens, 1996


undulatus
virgatus
jarrovii

No Sexual Difference in Neonatal Body Size

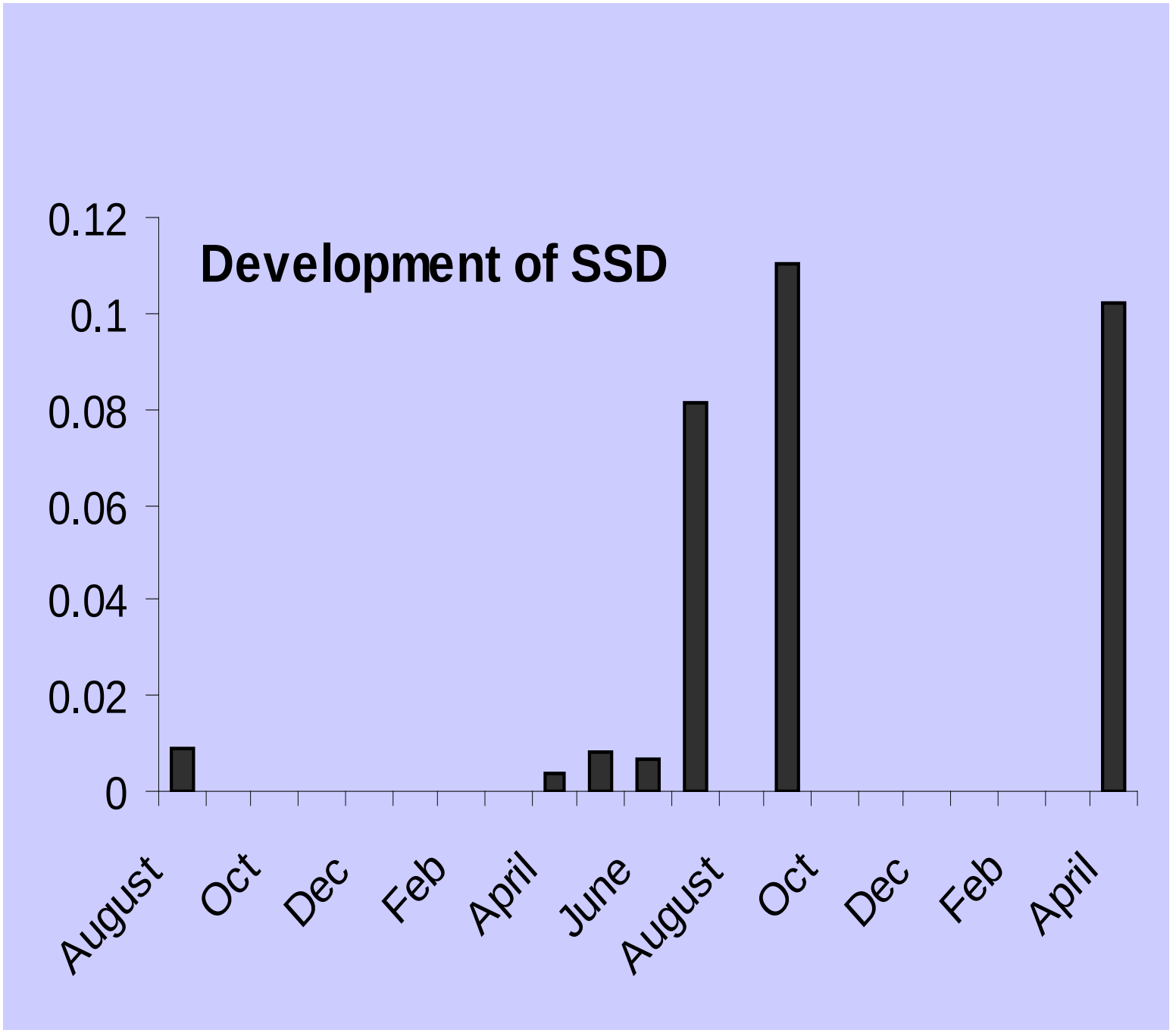



Size Distributions of 2-Yr. Olds
Number of Lizards
10
5
0
55
60
65
70
75
80
Snout-Vent Length (mm)
p << 0.0001
Females
Males
Index of SSD = 0.102



Females are larger than males by 11 months of age.

Growth rates diverge sharply between 10 and 11 months of age.


Development of SSD
0.12
0.1
0.08
0.06
0.04
0.02
0
August
Oct
Dec
Feb
April
June
August
Oct
Dec
Feb
April

Sceloporus undulatus

Sexual divergence in growth is correlated with:

- ↑ Male coloration
- ↑ Male aggression
- ↑ Male activity

} **Correlated effects of testosterone ??**

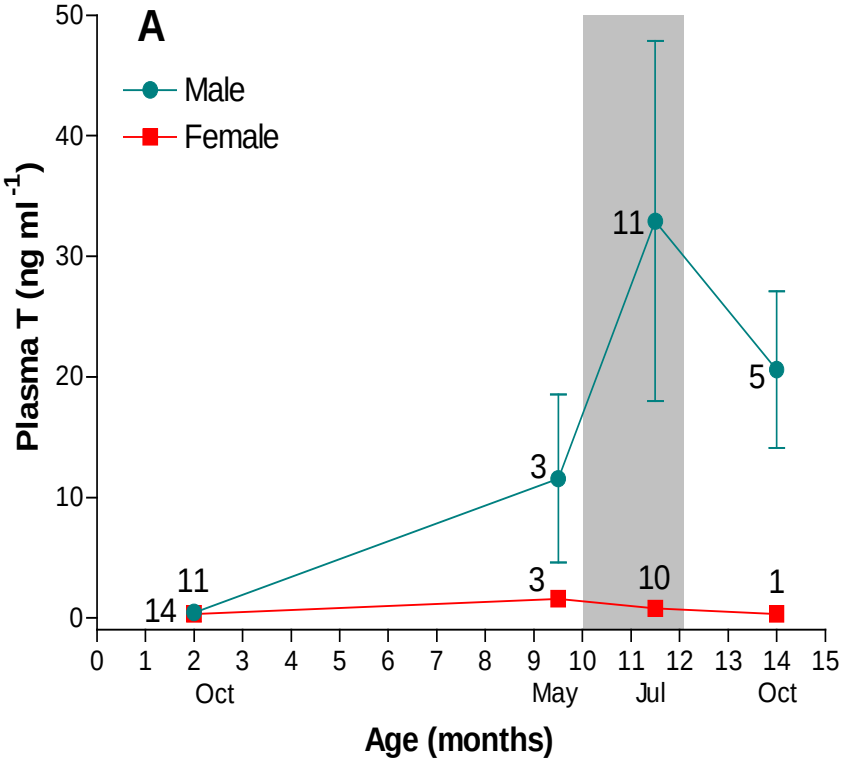
Skelly & John-Alder, Unpubl.

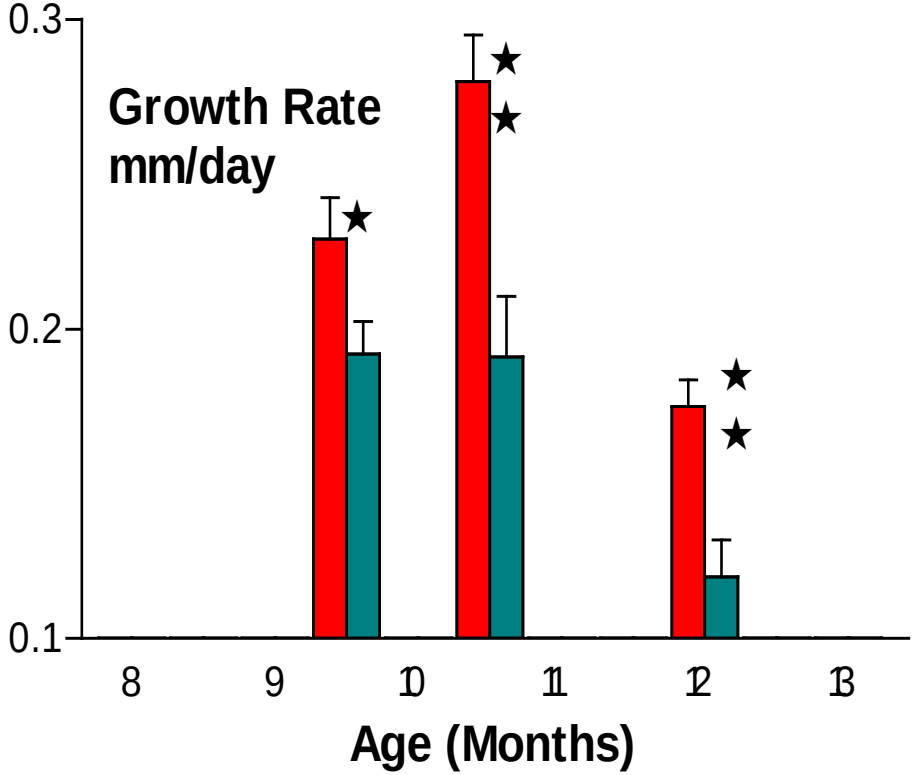
Experimental Enclosure

Rutgers University Pinelands Research Center, New Lisbon, NJ

Sceloporus undulatus

Testosterone is implicated in the development of SSD.





Cox, Skelly, & John-Alder, 2005

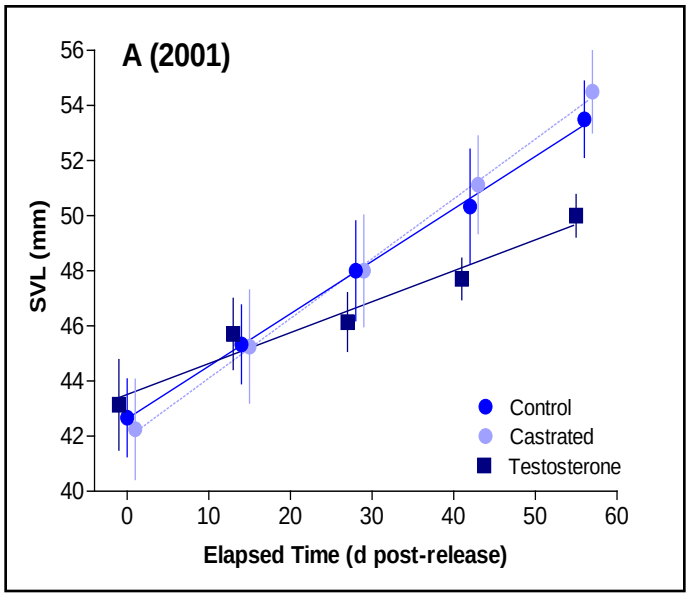
Scanned images of live lizards

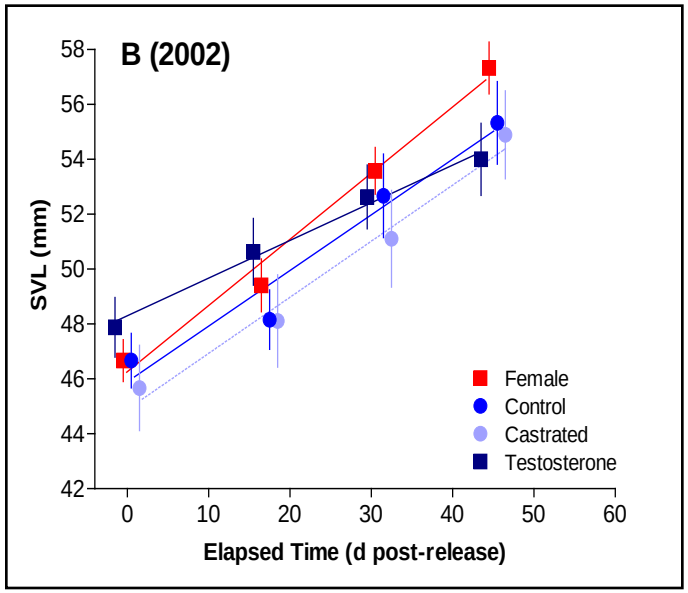
One Year: **~1 ng / h**

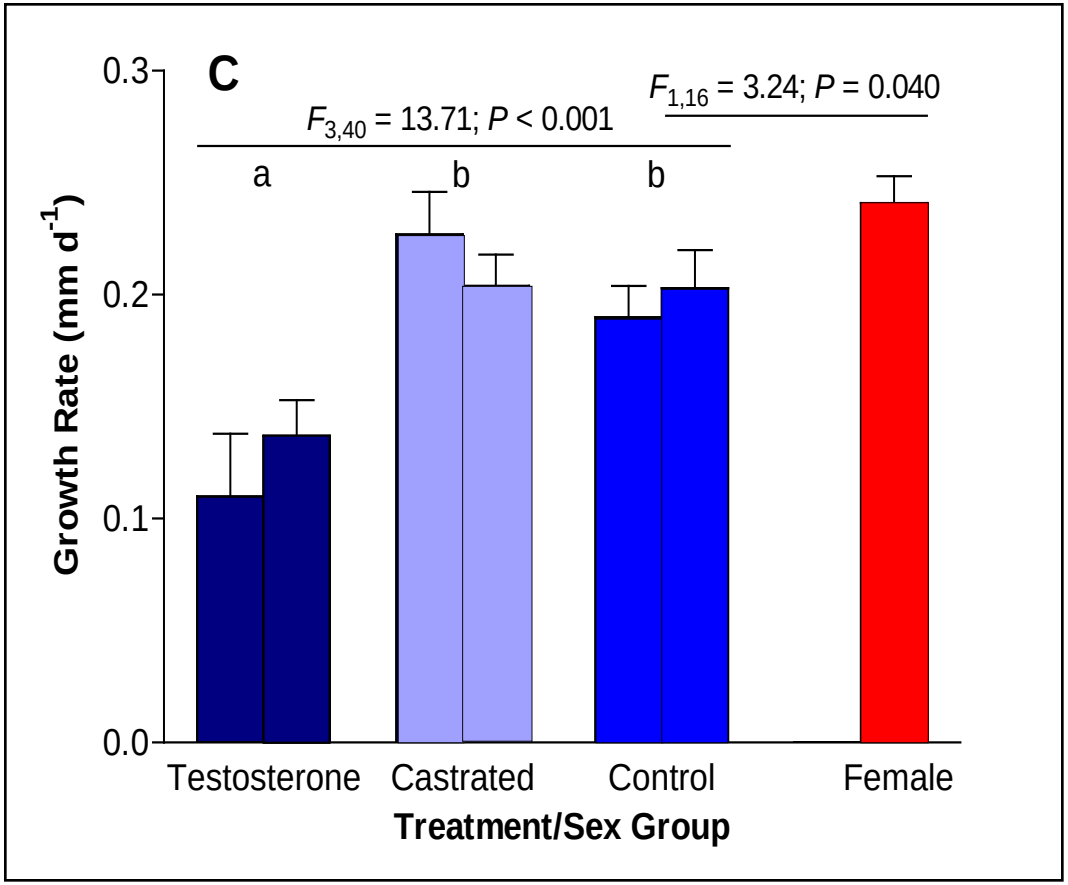
300 µg → **~175 µg**

Cox, Skelly, Leo, & John-Alder, 2005

Testosterone inhibits growth in *Sceloporus undulatus*.



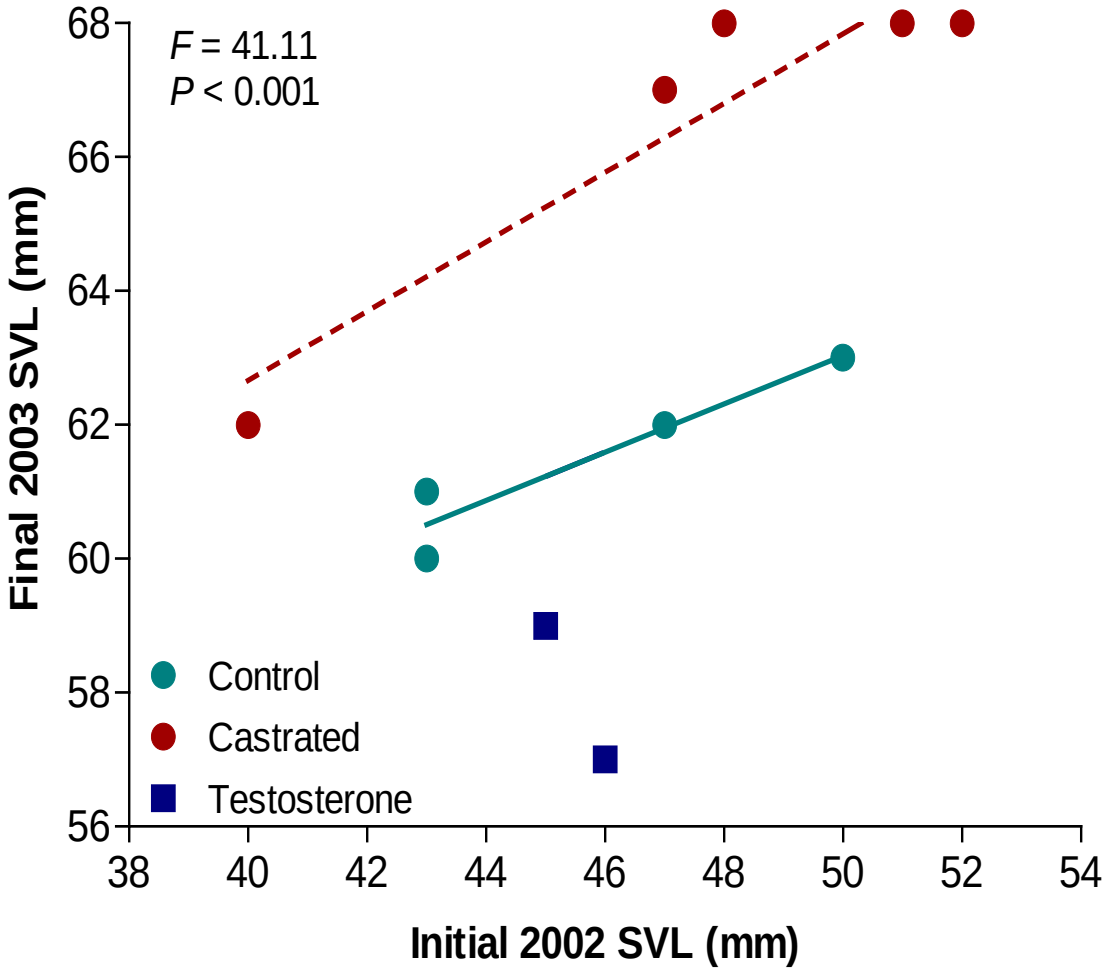




Cox, Skelly, & John-Alder, 2005

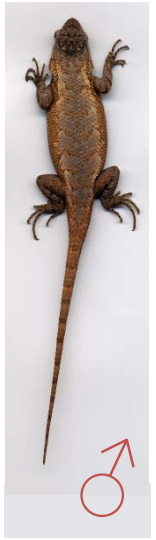
Sceloporus undulatus

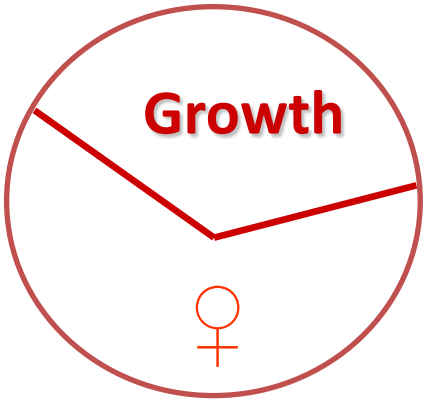
Castration → ↑ Growth; Testosterone → ↓ Growth



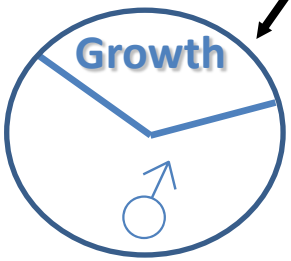
Cox, Skelly, & John-Alder, 2005

Acquisition / Allocation?

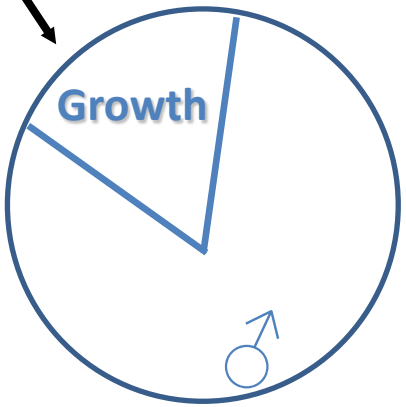




↓ Food Consumption



Smaller Pie



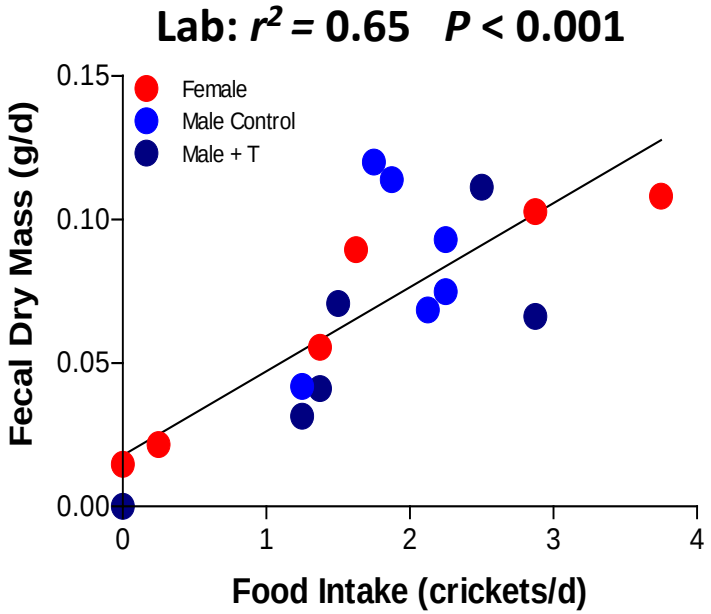
Δ Energy Distribution

Smaller Piece

T and Energy Acquisition

T does not reduce Consumed Energy in the field or lab.

F+U estimates C in the lab.



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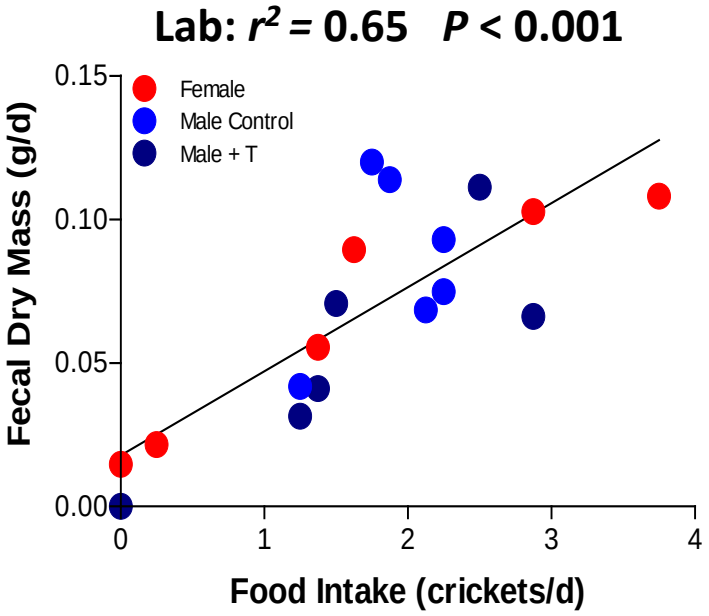
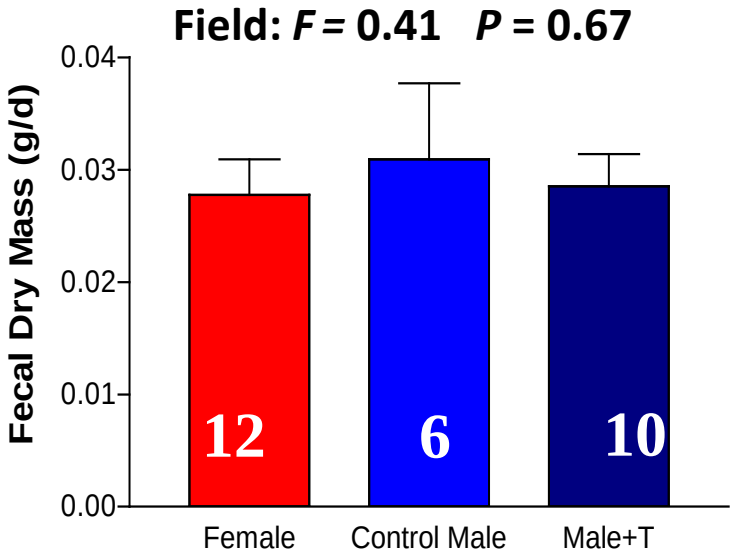
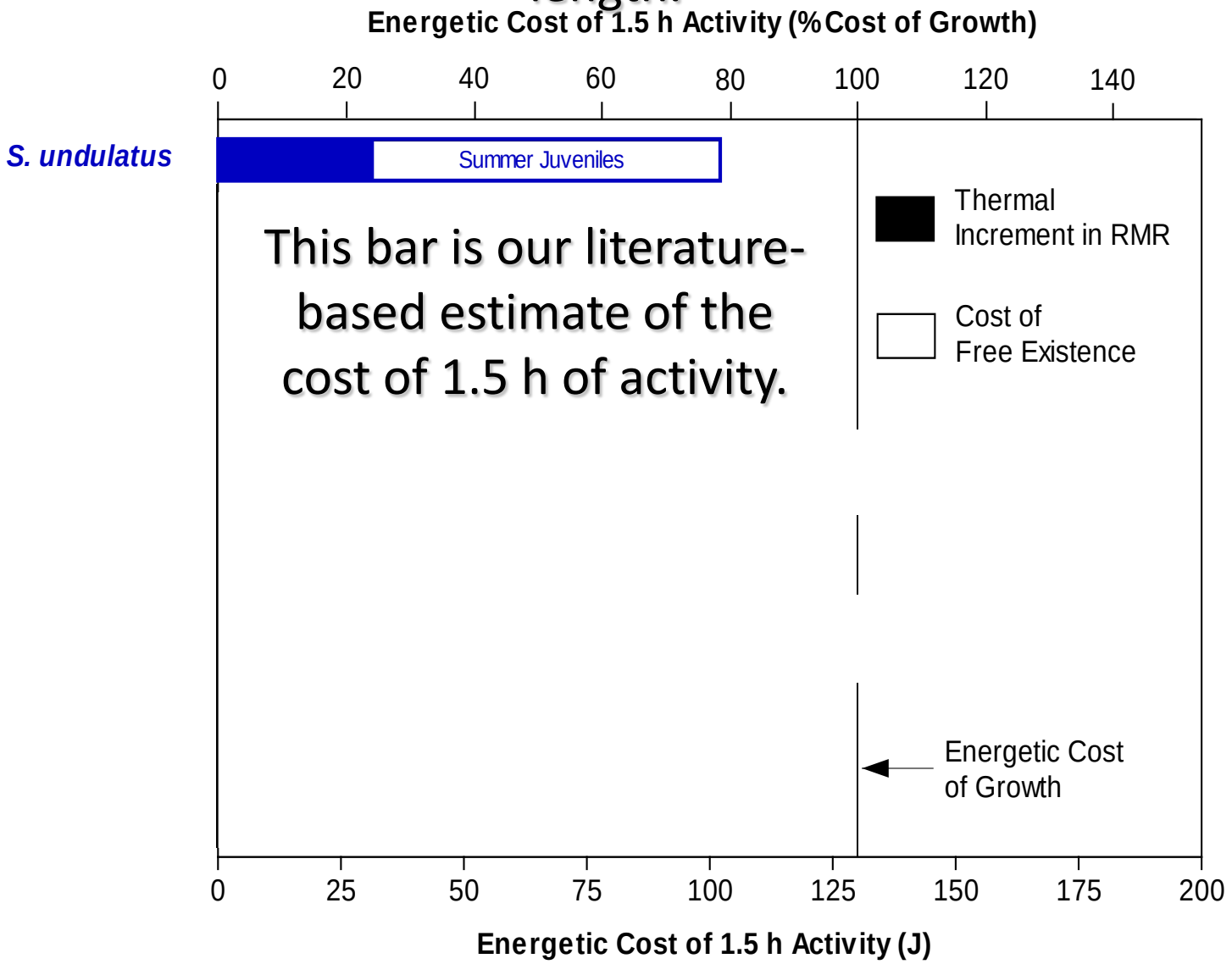


T does not affect F+U in the field.

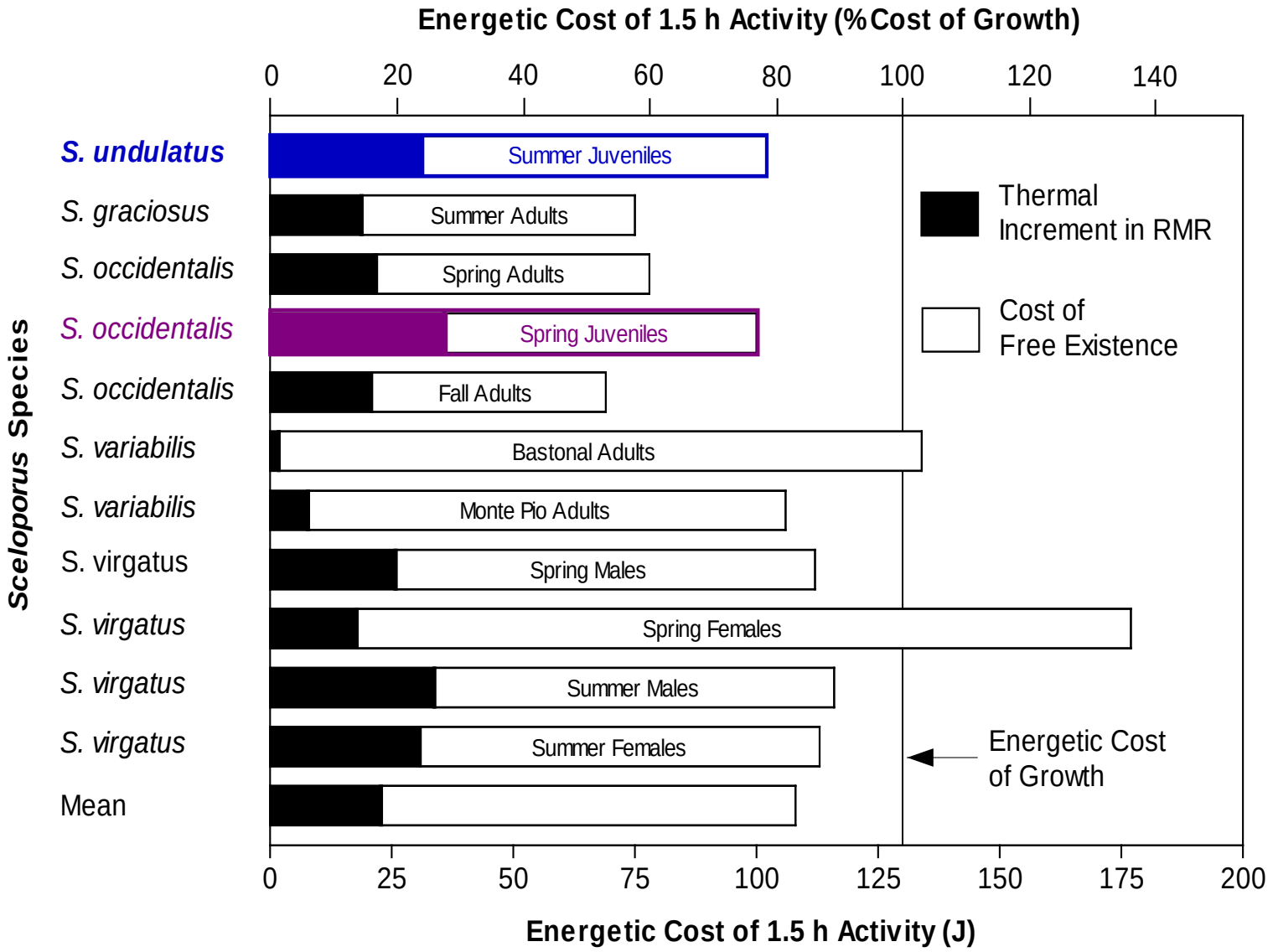


Testosterone stimulates activity and a 1.5 h extension in active day length.



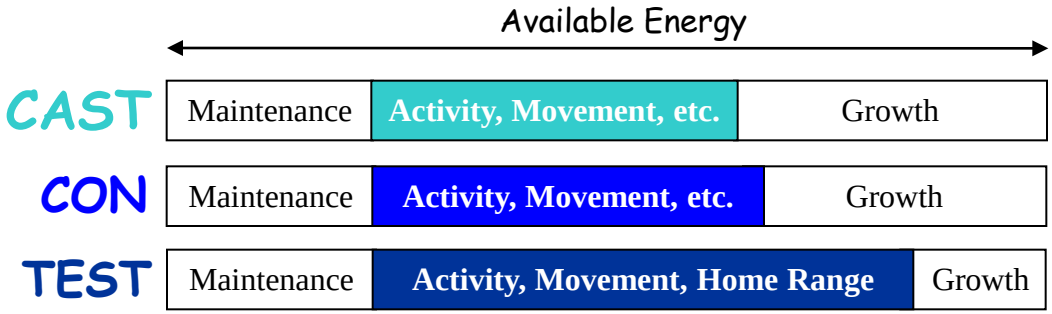
Cox, Skelly, & John-Alder, 2005

Our estimate of energy expenditure is validated by these doubly-labeled water measurements of field metabolism in lizards.

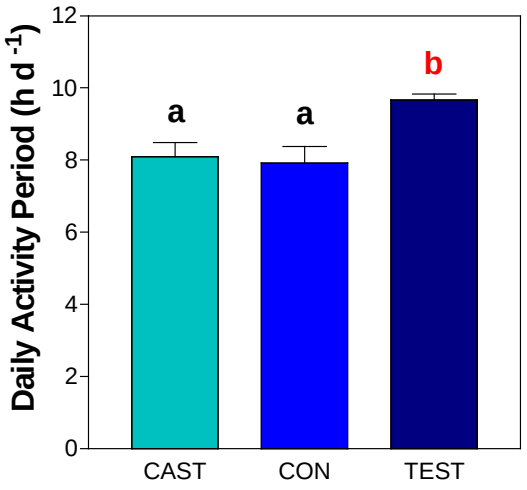


Cox, Skelly, & John-Alder, 2005

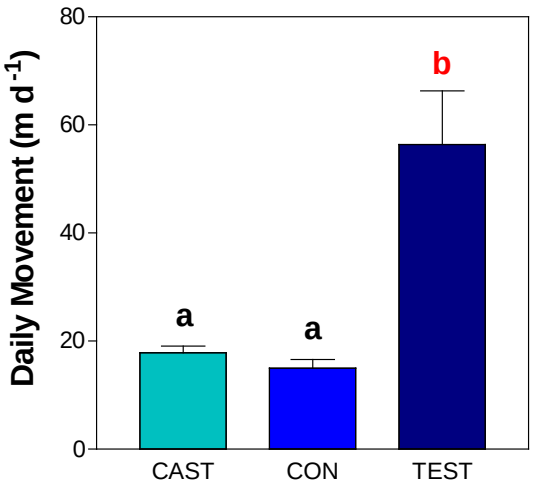
Energy Allocation Trade-Off



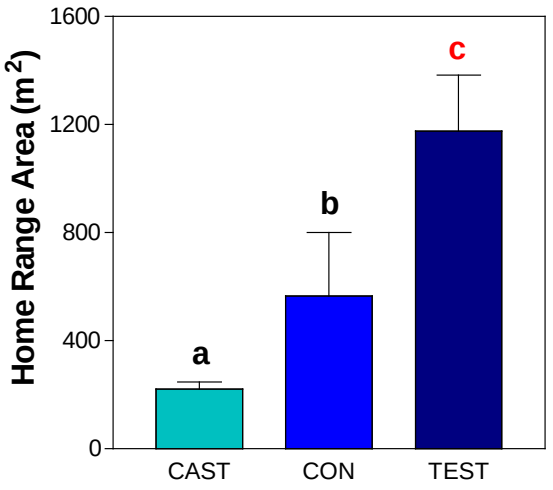
Activity Period



Movement

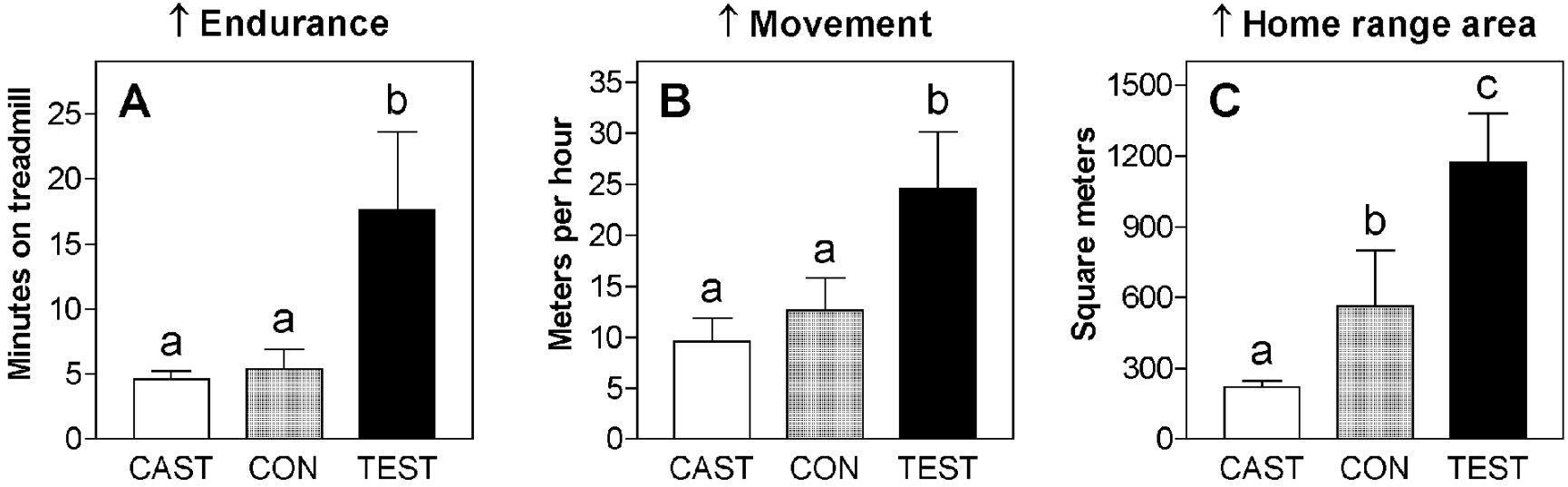


Home Range Area



Cox, Skelly, & John-Alder (2005) *Physiol. Biochem. Zool.*

Testosterone stimulates performance measures that may increase reproductive success:



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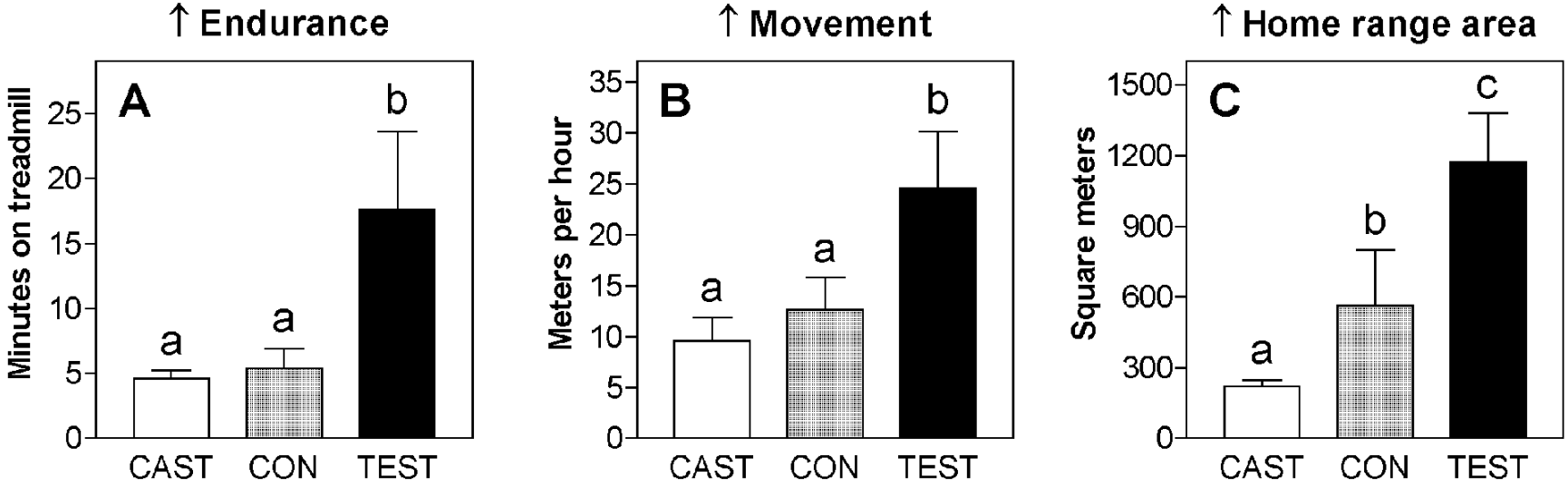
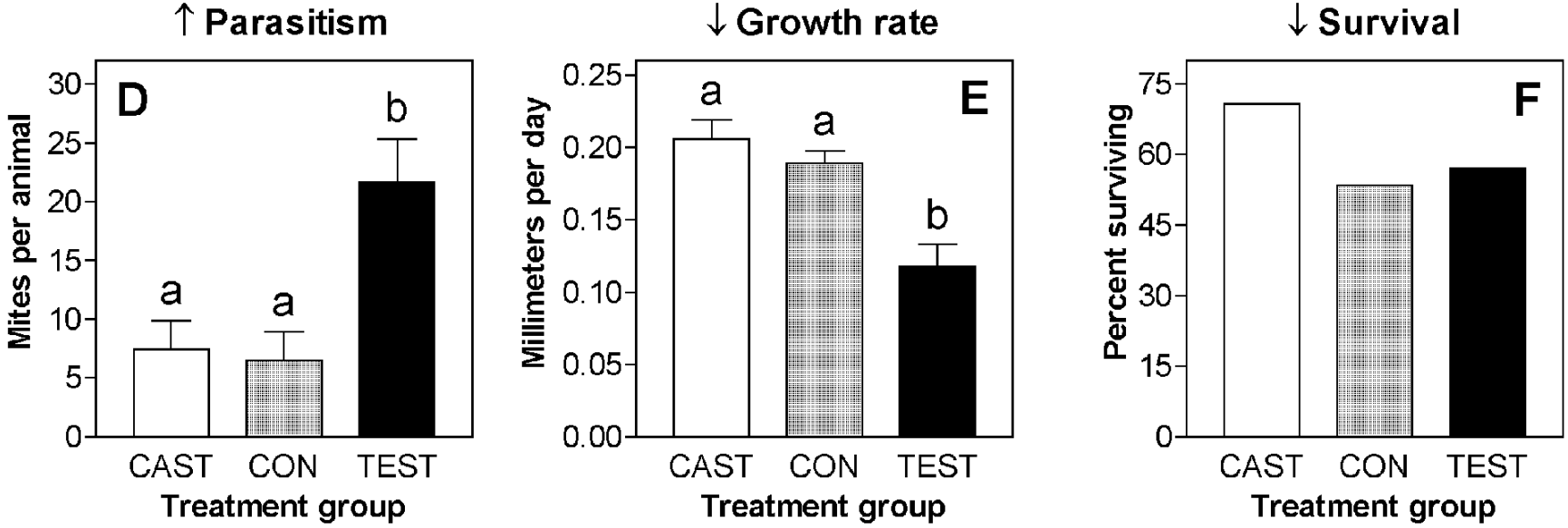


Testosterone also introduces costs that may reduce reproductive success and survival:

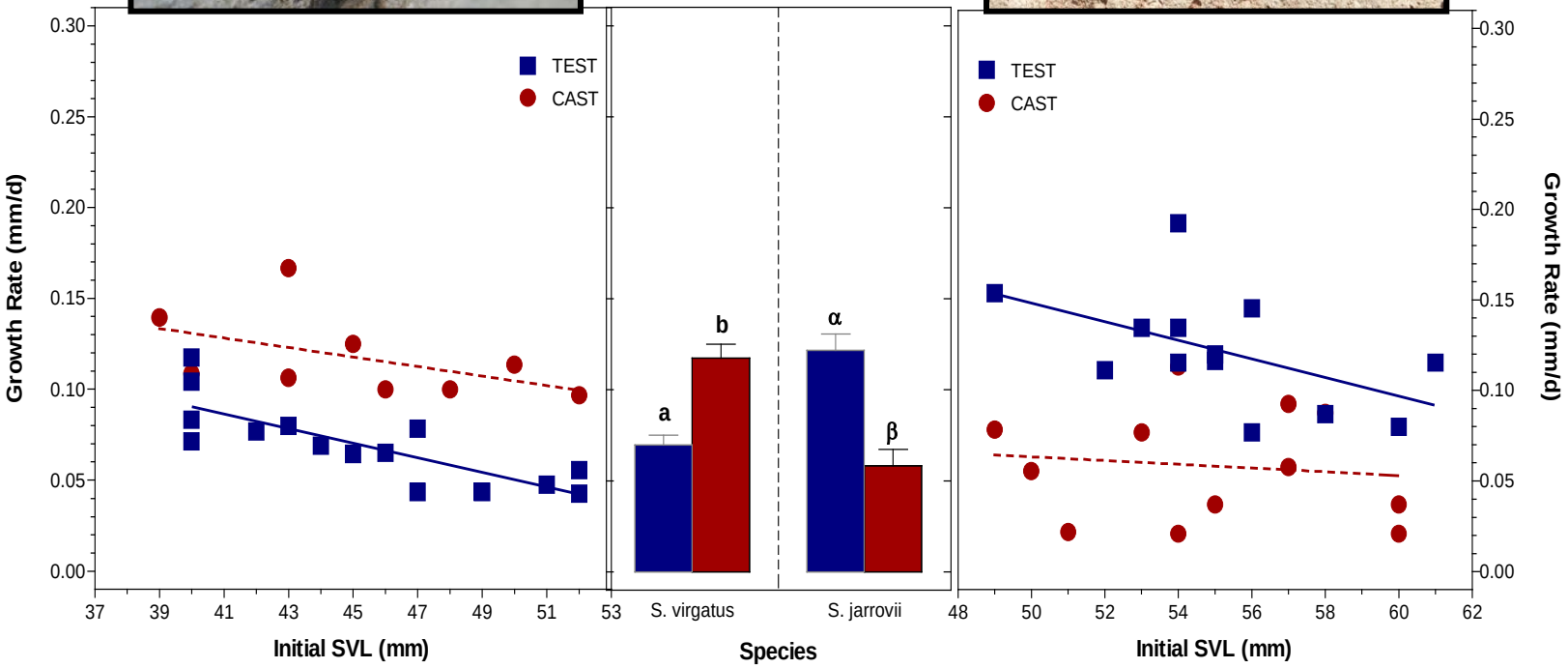


S. virgatus

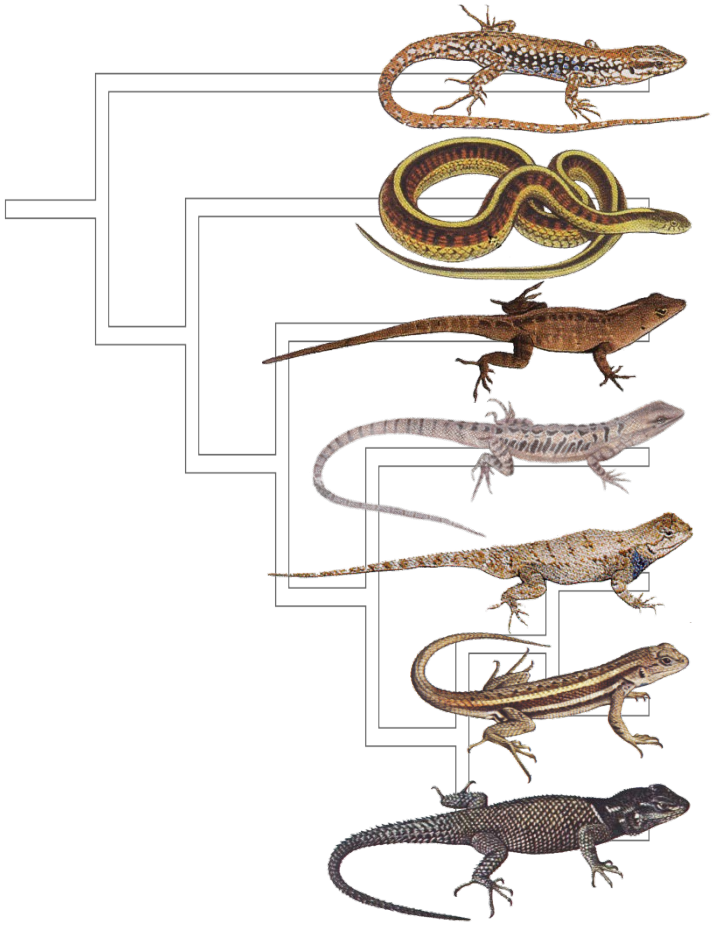
SSD: ♀ > ♂

S. jarrovii

SSD: ♂ > ♀



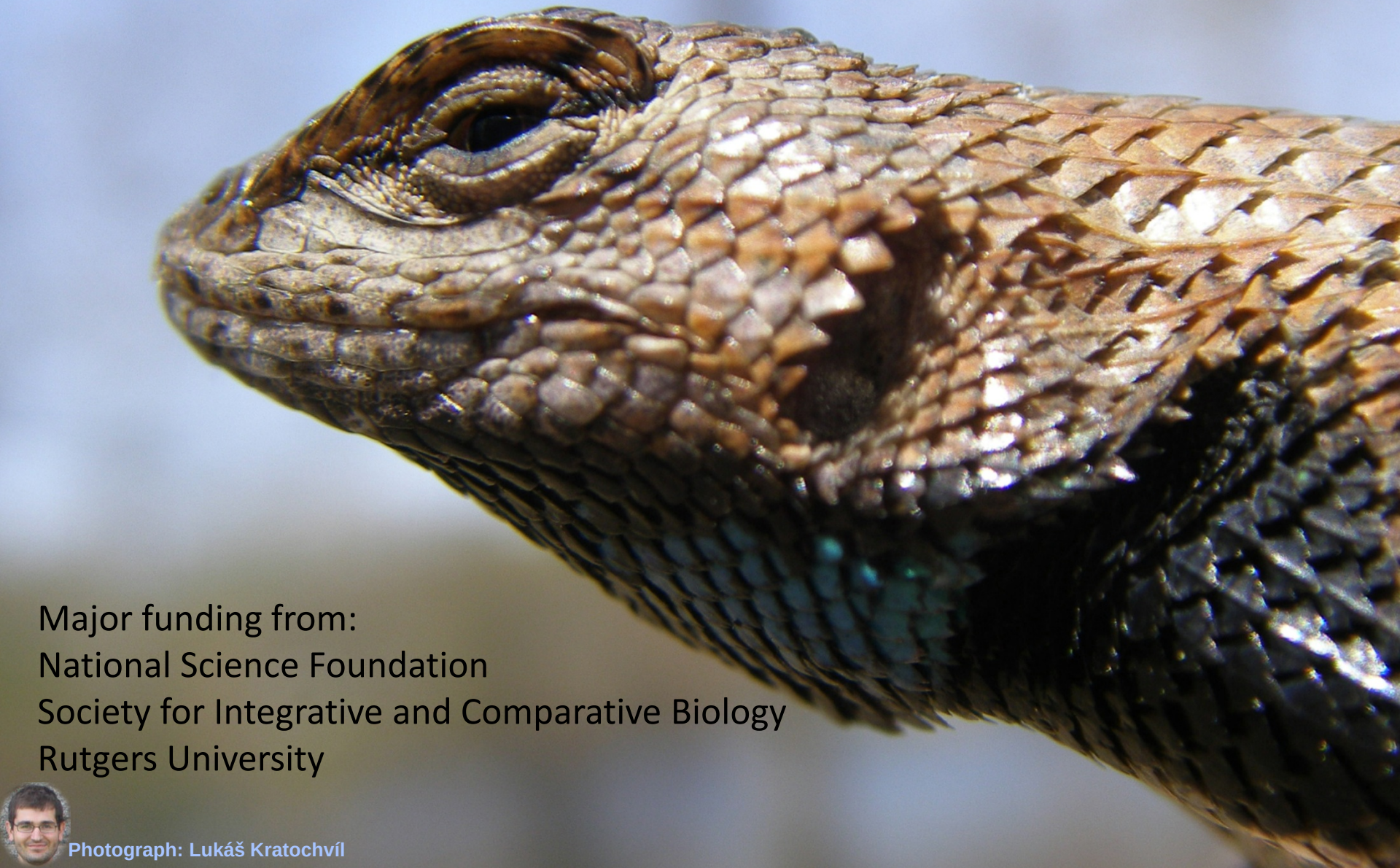
Bipotential Growth Regulation Hypothesis



SSD	Effect of T	Species	Study
●	none	*Psammodromus algirus*	Salvador & Veiga 2000
●	↓	*Thamnophis sirtalis*	Crews et al. 1985 Lerner & Mason 2001
●	↑	*Anolis sagrei*	Cox et al. 2009
●	↕	*Urosaurus ornatus*	Hews et al. 1994 Hews & Moore 1995
●	↓	*Sceloporus undulatus*	Klukowski et al. 1996 Cox et al. 2005
●	↓	*Sceloporus virgatus*	Abell 1998 Cox & John-Alder 2005
●	↑	*Sceloporus jarrovii*	Cox & John-Alder 2005

Cox, Stenquist, & Calsbeek, 2009

Special thanks to:
Bob Cox (UVa), Christine Duncan (Fresno State), Greg Haenel (Elon Univ), Linda Smith (Richard Stockton College)



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Photograph: Lukáš Kratochvíl