LIFE HISTORY AND DEMOGRAPHY OF TURTLES OF THE UNITED STATES

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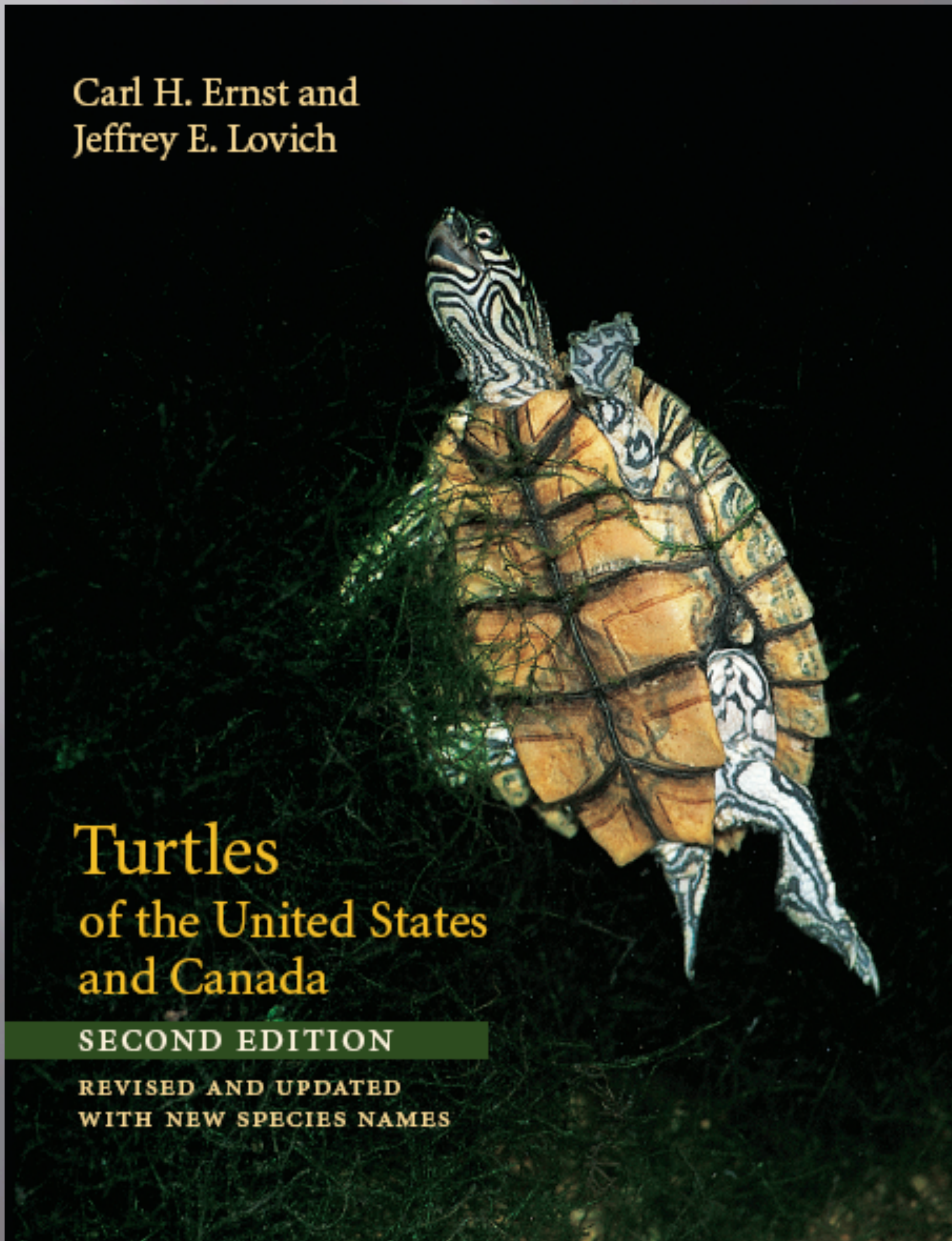
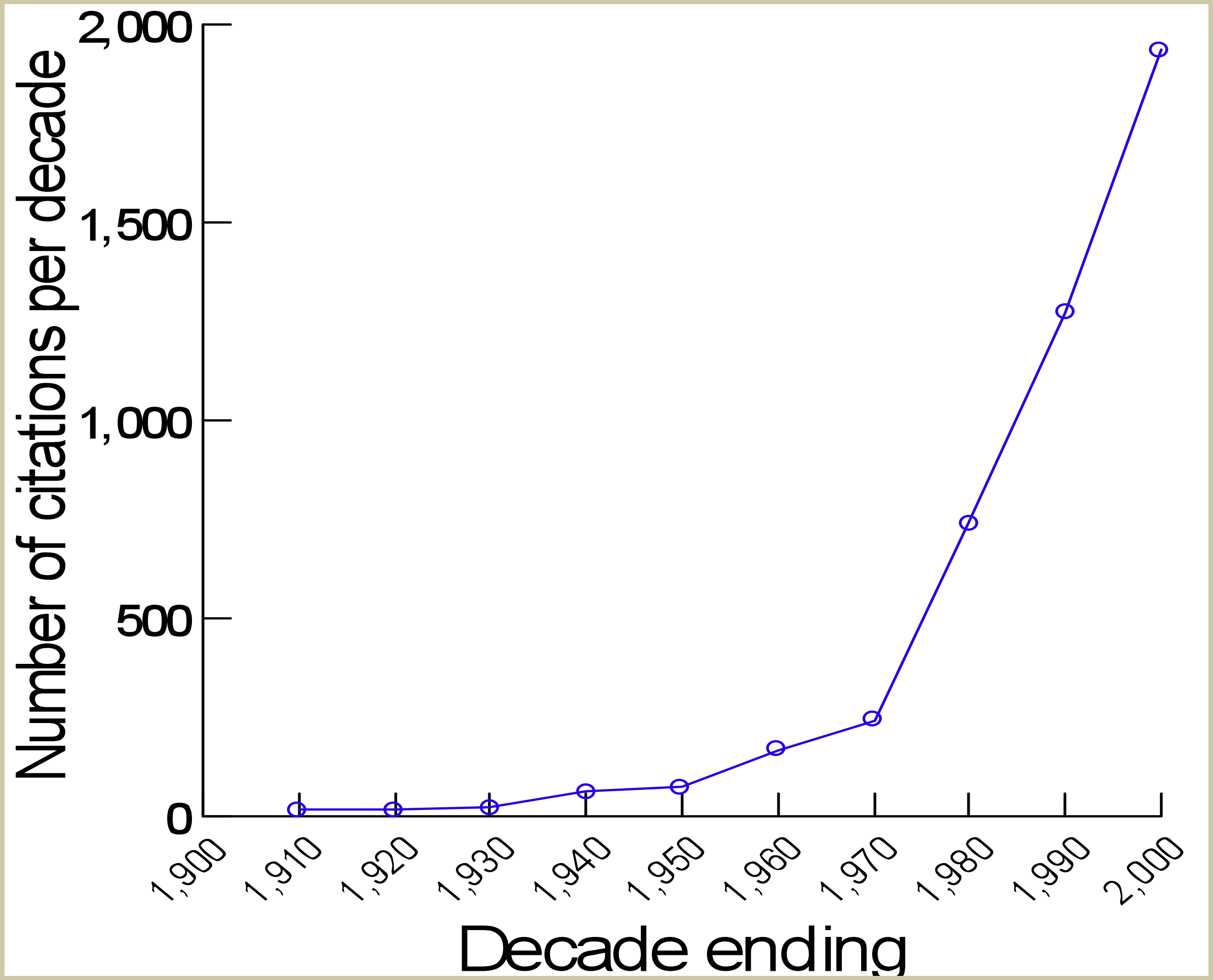
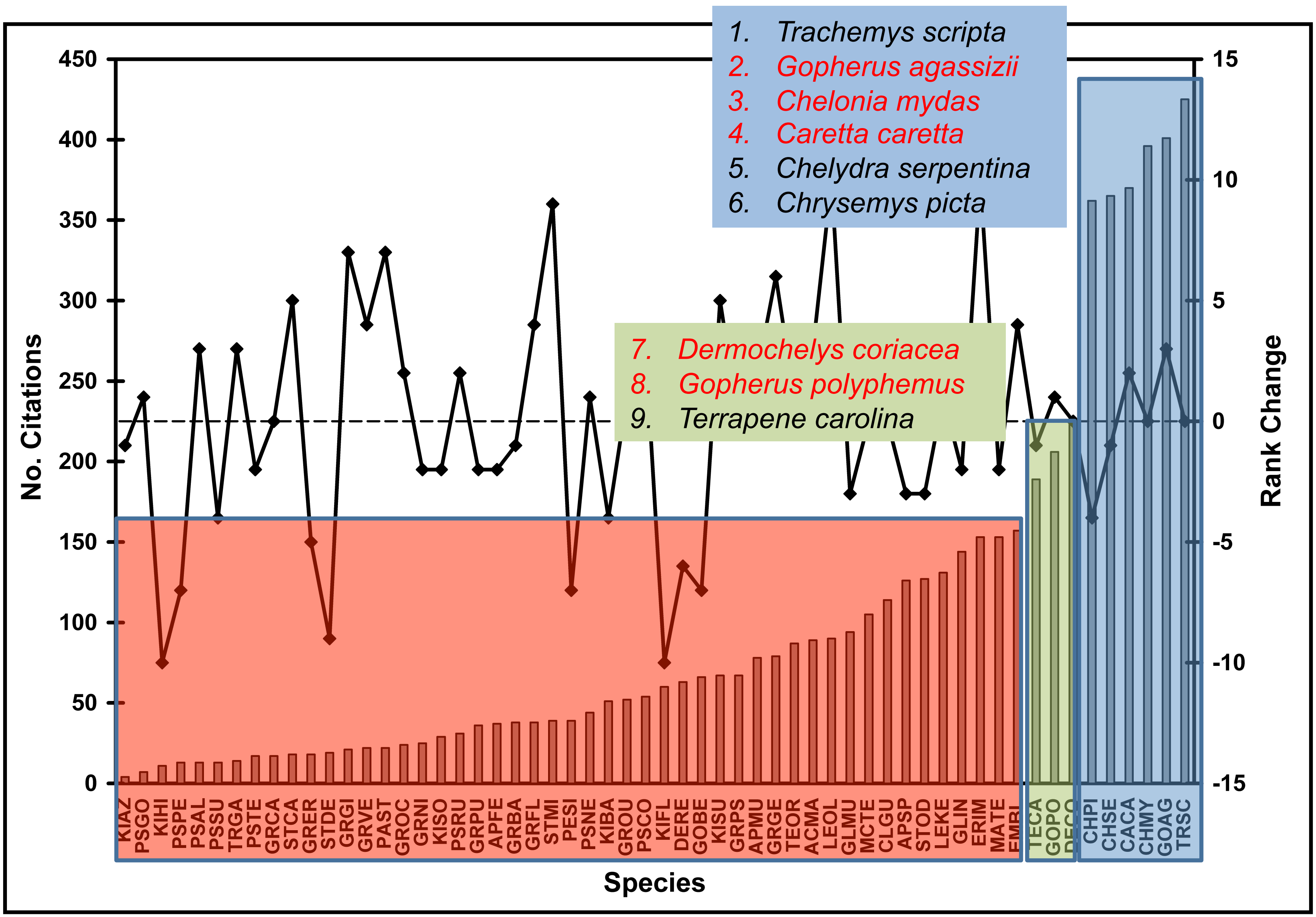


- 57 native species
- 22 native genera
- 7 native families
- approx. 18% of the worlds' living turtle species
- SE US is a global "Turtle Priority Area" for conservation

Rate of increase in turtle publications





1. Trachemys scripta
2. Gopherus agassizii
3. Chelonia mydas
4. Caretta caretta
5. Chelydra serpentina
6. Chrysemys picta
7. Dermochelys coriacea
8. Gopherus polyphemus
9. Terrapene carolina
No. Citations
450
400
350
300
250
200
150
100
50
0
Rank Change
15
10
5
0
-5
-10
-15
KIAZ PSGO KIHI PSPE PSAL PSSU TRGA PSTE GRCA STCA GRER STDE GRGI GRVE PAST GROC GRNI KISO PSRU GRPU APFE GRBA GRFL STMI PESI PSNE KIBA GROU PSCO KIFL DERE GOBE KISU GRPS APMU GRGE TEOR ACMA LEOL GLMU MCTE CLGU APSP STOD LEKE GLIN ERIM MATE
TECA GOPO
CHPI CHSE CACA CHMY GOAG TRSC
Species

2009

"Bottom 10" based on 2009 citations

1. *Kinosternon arizonense*
2. *Pseudemys gorzugi*
3. *Kinosternon hirtipes*
4. *Pseudemys peninsularis*
5. *Pseudemys alabamensis*
6. *Pseudemys suwanniensis*
7. *Trachemys gaigeae*
8. *Pseudemys texana*
9. *Graptemys caglei*
10. *Sternotherus carinatus*

Conservation status does not greatly influence status of knowledge indices*

- IUCN status was not correlated with any metric based on our knowledge indices
- ESA listing was generally non-significant in all comparisons except:
  - means for ESA-listed vs non-ESA listed NCS values
- *Gopherus agassizii* is one of the most-studied, most-funded turtle species yet listed populations have yet to be "recovered"

* Body size and range size do

• 22 out of 56 (39%) US turtles require conservation action*

• 14 species (25%) protected under ESA

• no species of freshwater turtle or tortoise listed under ESA has ever been recovered or de-listed

* ESA, IUCN vulnerable and above , and/or CITES Appendix I

How does US turtle status compare to the world?

	Threatened	Not threatened	Percentage
US*	22	32	41%
World**	143	190	44%

Yate's Chi-square = 0.24, P = 0.88

Sources

*Ernst, C.H. and J.E. Lovich. 2009. Turtles of the United States and Canada. Johns Hopkins University Press. Baltimore. 827 p. NATIVE SPP. ONLY

**Rhodin, A. G. J., J. F. Parham, et al. 2009. Turtles of the world: annotated checklist of taxonomy and synonymy, 2009 update, with conservation status summary. Conservation biology of freshwater turtles and tortoises: a compilation project of the IUNN/SSC Tortoise and Freshwater Turtle Specialist Group. Chelonian Research Monographs. A. G. J. Rhodin, P. C. H. Pritchard, P. P. van Dijk al: 000.039-000.084.

Why are turtles threatened?

- Habitat loss and degradation
- Introduced invasive species (including turtles!)
- Environmental pollution
- Disease
- Unsustainable use
- Global climate change

Gibbons, J.W., Scott, D.E., Ryan, T.J., Buhlmann, K.A., Tuberville, T.D., Metts, B.S., Greene, J.L., Mills, T., Leiden, Y., Poppy, S., and Winne, C.T. 2000. The global decline of reptiles, déjá vu amphibians. Bioscience 50: 653-666.

What life history traits are thought to make most turtles vulnerable to exploitation?

- High egg and nestling mortality (-)
- Delayed maturity (-)
- High adult survival (+)
- Longevity (+)

The paradigm

High adult survivorship is necessary to ensure the persistence of organisms with delayed maturity, high and variable nest mortality, and long life spans.

"Among tetrapods, turtles are the paragon of delayed reproduction, longevity, and repeated cycles of reproduction (iteroparity)."

Wilbur and Morin, 1988

What are life history traits?

- age of sexual maturity
- first reproduction
- number of offspring
- level of parental investment
- senescence
- survivorship

Selected predictions from life history theory relevant to turtles

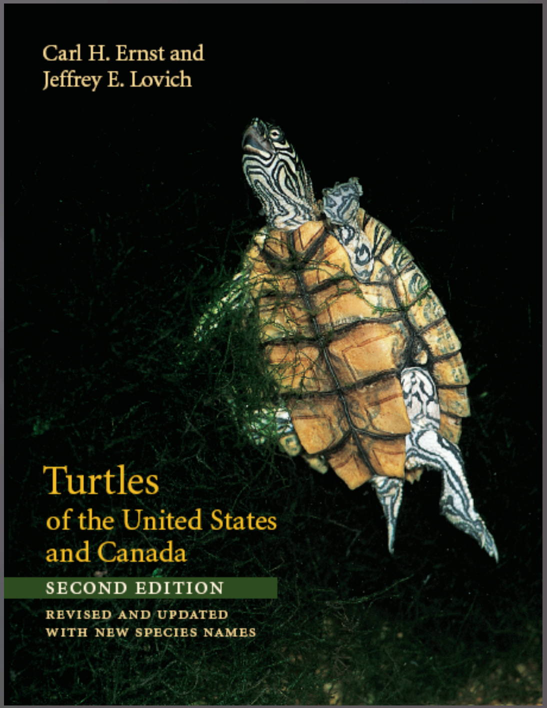
1. When juvenile exceeds adult mortality iteroparity should be favored
2. Clutch size should maximize the number of young surviving to maturity summed over the lifetime of the parent but when optimal brood size is unpredictable smaller clutches are favored (bet hedging)

Stearns (1976)

Life history and other traits of US turtles

(excluding *G. pearlensis*)

- Max. carapace length
- Min. length at maturity females (cm)
- Min. length at maturity males (cm)
- Min. age of maturity females
- Mean hatchling size (cm)
- Mean clutch size
- Max. clutch frequency
- Adult survivorship
- Juvenile survivorship
- Hatchling survivorship
- Max. longevity



Summary of traits

	Min. length at maturity females (cm)	Min. length at maturity males (cm)	Max. carapace length (cm)	Min. age at maturity females (yr)
N of Cases	50	42	56	46
Minimum	5.70	5.10	11.50	3.00
Maximum	130.00	75.20	243.80	26.00
Mean	21.72	13.51	41.02	8.99
Standard Deviation	21.54	14.89	44.29	5.18
Coefficient of Variation	0.99	1.10	1.08	0.58

Summary of traits (cont.)

	Mean clutch size	Max. clutch frequency*	Mean hatchling size (cm)
N of Cases	54	51	51
Minimum	2.50	1	2.13
Maximum	140.00	11	6.020
Mean	20.69	3.84	3.30
Standard Deviation	34.45	2.024	0.78
Coefficient of Variation	1.67	0.53	0.24

* Does not account for inter-annual nesting periodicity

Summary of traits (cont.)

	Adult survivorship (%)	Juvenile survivorship (%)	Hatchling survivorship (%)	Longevity (yr)
N of Cases	15	10	6	40
Minimum	25.00	46.00	6.40	20.00
Maximum	96.00	96.00	69.50	138.00
Mean	82.88	72.59	38.70	43.73
Standard Deviation	17.11	15.66	27.85	23.14
Coefficient of Variation	0.21	0.22	0.72	0.53

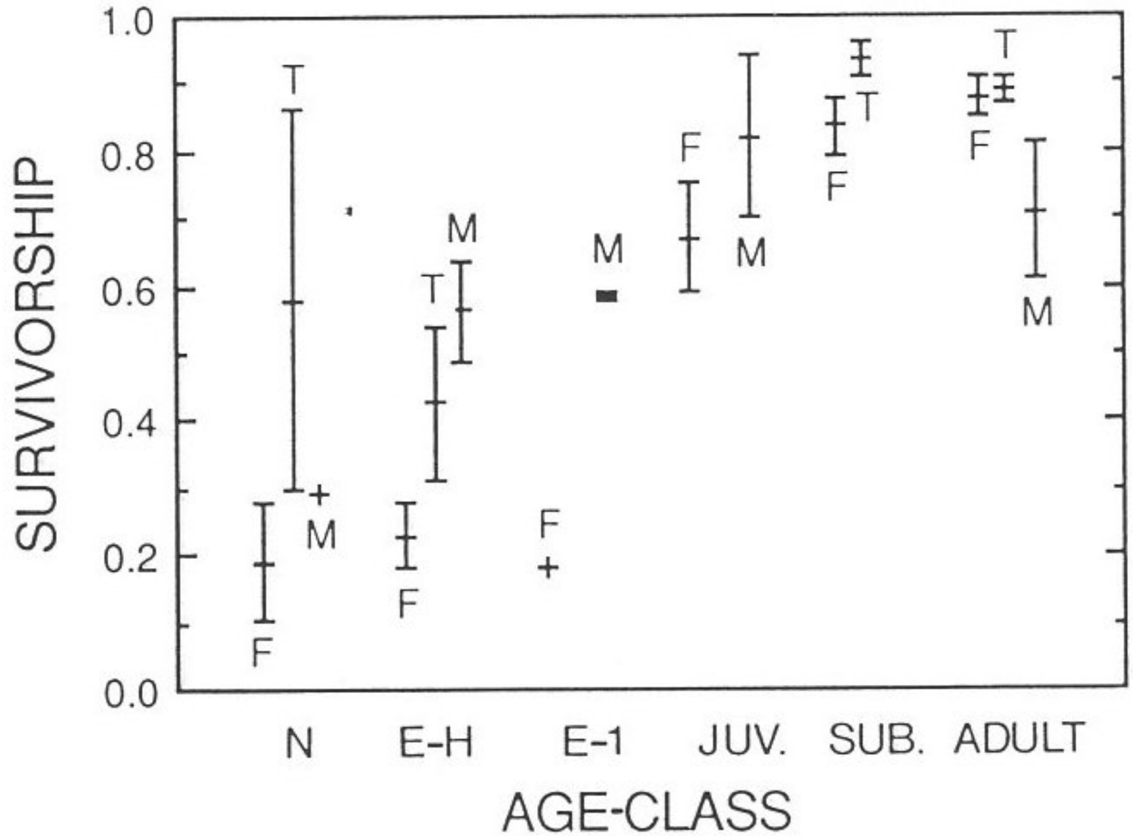
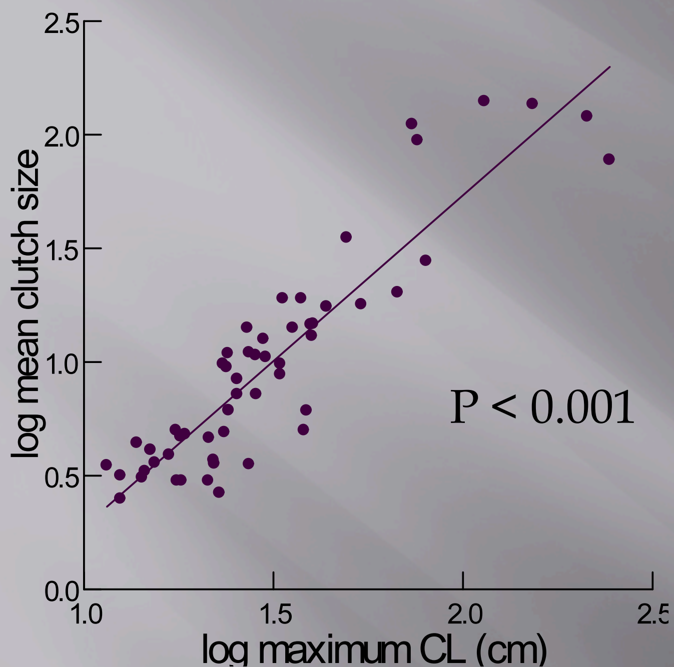
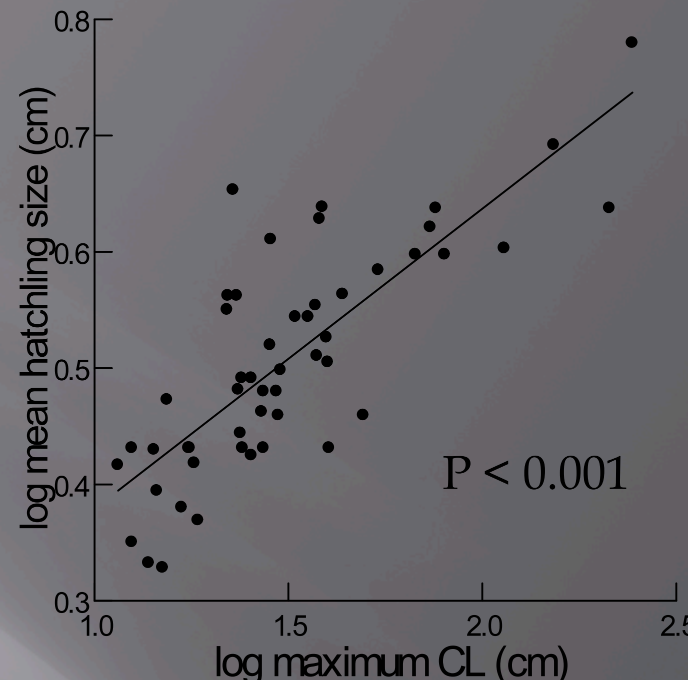
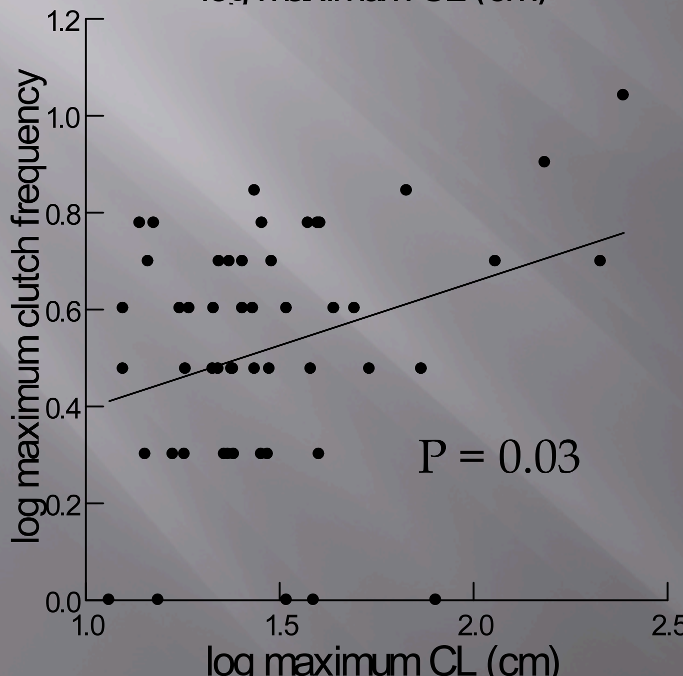


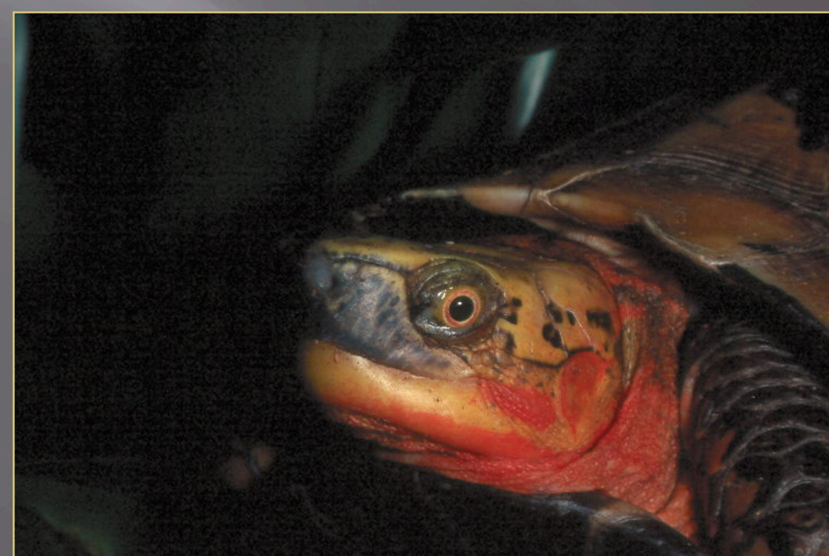
FIG. 1. Annual survivorship of turtles across age-classes and habita
types. See text for explanation of age-classes. Horizontal bars show th
mean; vertical lines indicate ±1 standard error. M, marine; F, fresh
water, T, terrestrial.

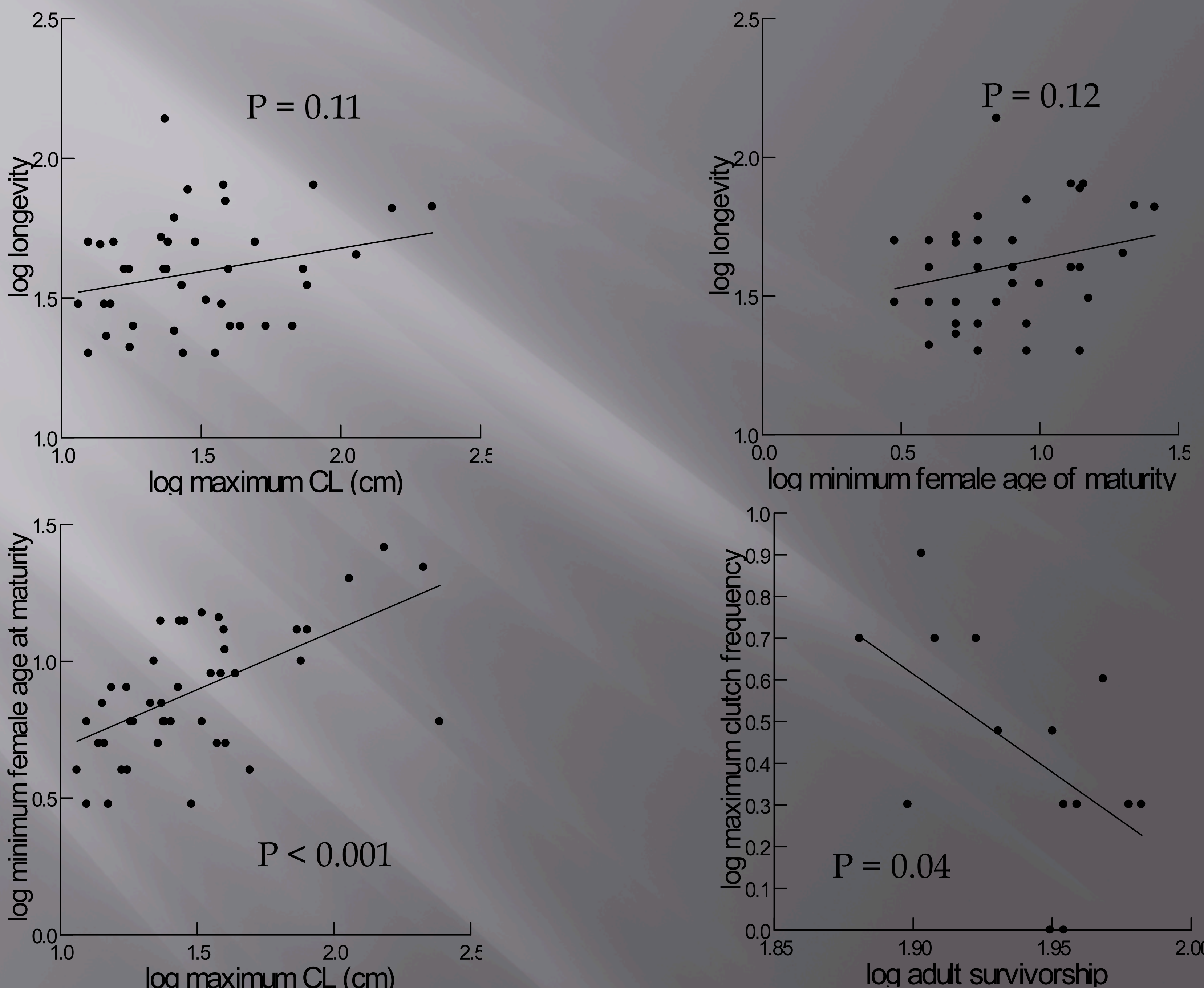
Iverson, J.B. 1991. Patterns of survivorship in turtles (Order Testudines). Can. J. Zool. 69:385-391.


log mean clutch size
2.5
2.0
1.5
1.0
0.5
0.0
1.0
1.5
2.0
2.5
log maximum CL (cm)
P < 0.001


log mean hatchling size (cm)
0.8
0.7
0.6
0.5
0.4
0.3
1.0
1.5
2.0
2.5
log maximum CL (cm)
P < 0.001


log maximum clutch frequency
1.2
1.0
0.8
0.6
0.4
0.2
0.0
1.0
1.5
2.0
2.5
log maximum CL (cm)
P = 0.03




P = 0.11
log longevity
log maximum CL (cm)
1.0
1.5
2.0
2.5
P = 0.12
log longevity
log minimum female age of maturity
0.0
0.5
1.0
1.5
P < 0.001
log minimum female age at maturity
log maximum CL (cm)
P = 0.04
log maximum clutch frequency
log adult survivorship
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.85
1.90
1.95
2.00

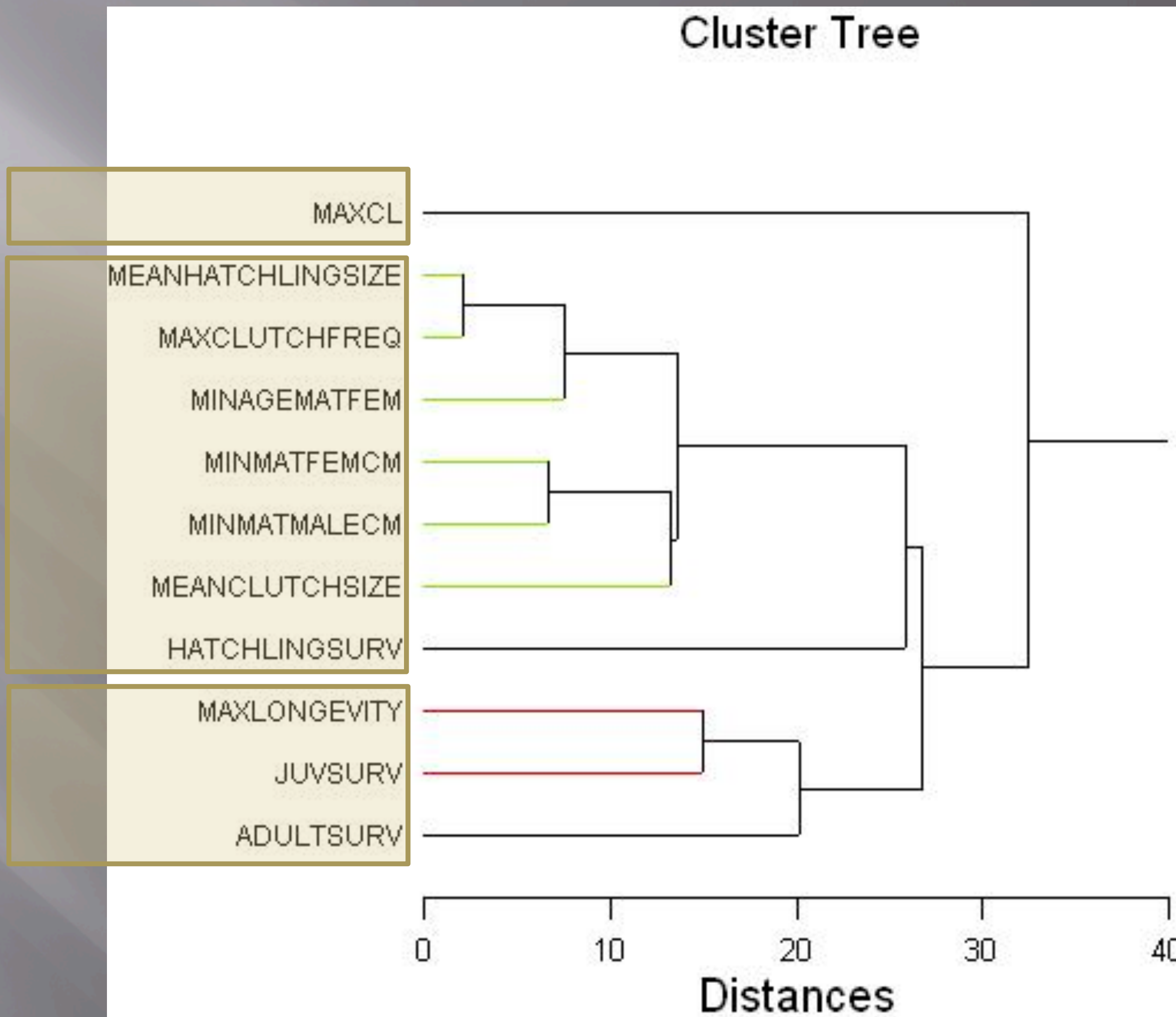
Summary of relationships among measured life history traits

- In larger species females mature at a later age
- Hatchling size is larger in larger species
- Mean clutch size and frequency is greater in larger species
- Longevity is not necessarily greater in larger species
- Later minimum age of female maturity does not necessarily mean greater longevity
- Clutch frequency decreases with adult survivorship across species
- Preliminary analyses suggest weak correlations between female repro. lifespan (or longevity) and all other traits

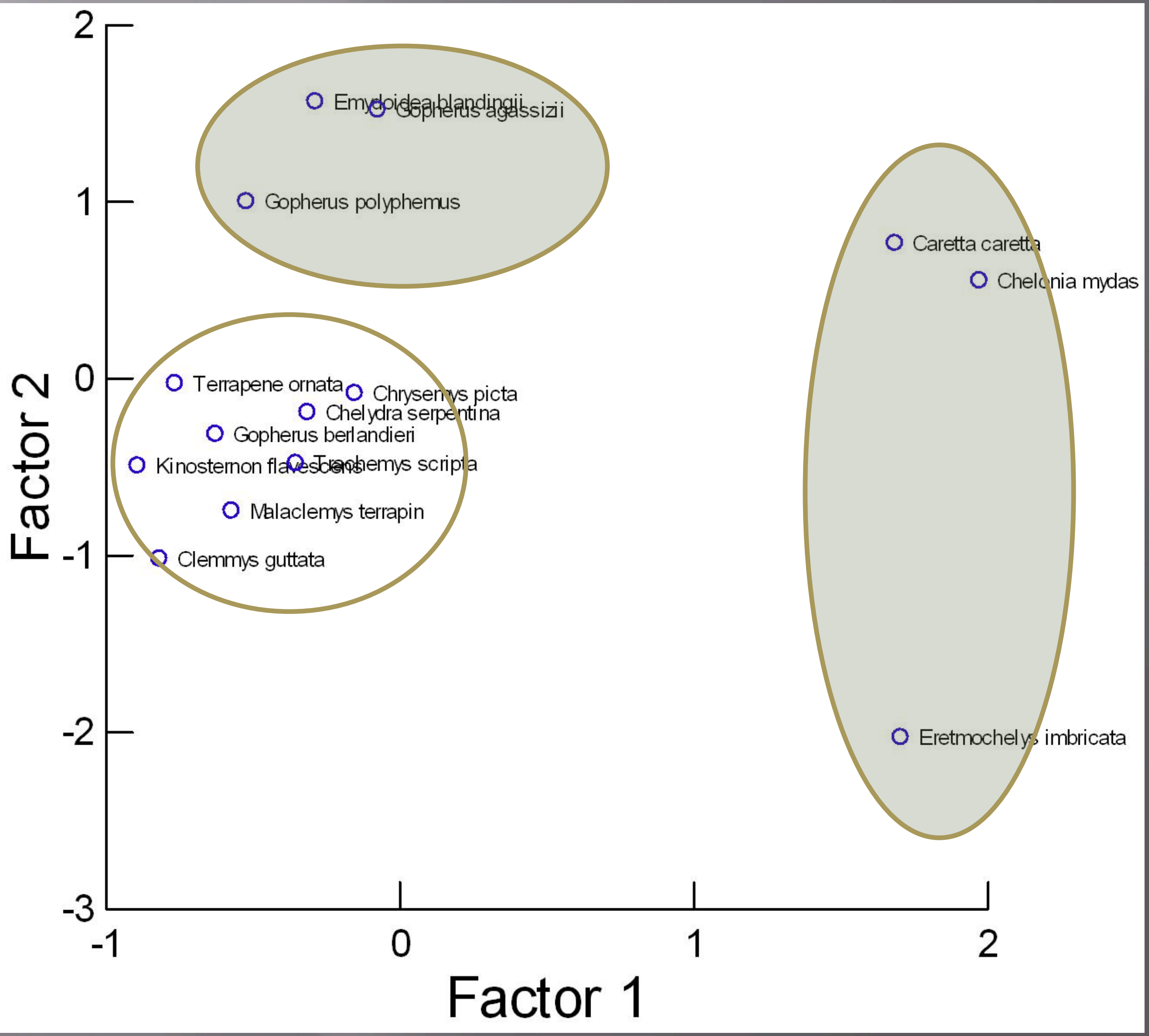
Body size

Maturation, reproductive output, hatchling survivorship

"Survivorship"



Adult survivorship, longevity
Eigenvalue = 1.25



82.5% of variance explained

Max. body size, female maturity size, clutch size
Eigenvalue = 3.71

Case study *Emydoidea blandingii* Congdon et al.

- 23 years of data
- Observed nests surviving predation = 21.8%
- Surviving nests producing hatchlings = 80.4%
- Rate of hatchling survivorship = 1.76%
- Average annual adult survivorship = 96%
- Cohorts declined 50% in 78 years
- Increasing adult survivorship 1.5% (97.5%) or juvenile from 78.3 to 80.5% resulted in a stable population
- CONCLUSION – Population most sensitive to adult and juvenile survival, NOT age at maturity, nest survival or fecundity.

Case study *Chelydra serpentina* Congdon et al.

- Nest survivorship over 17 years = 0-64% (mean 23%)
- Survivorship of juveniles over 65% by age 2, 77% between age 2-12
- Annual survivorship adult females = 88-97%
- Cohort generation time of 25 years
- Increase in adult annual mortality of 0.1 over 15 years of age with no density-dependent compensation would halve the number of adults in <20 years
- CONCLUSION – population stability most sensitive to changes in adult or juvenile survival, not age at sexual maturity, nest survival or fecundity. "*Carefully managed sport harvests of turtles or other long-lived organisms may be sustainable: however, commercial harvests will certainly cause substantial population declines.*"

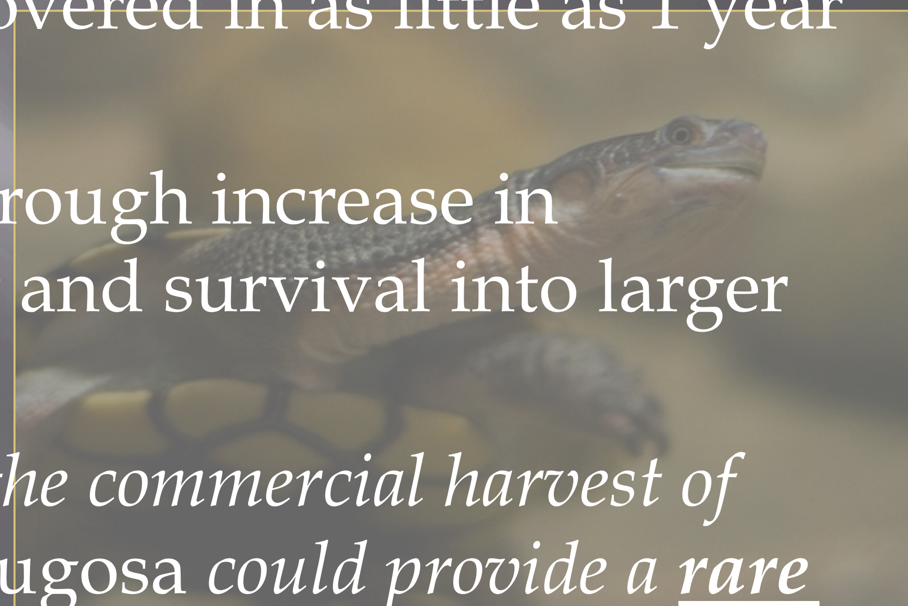
Limited evidence that turtles are able to counteract increased harvest

- Diamondback terrapin change in female body size
  Wolak et al. 2010. A contemporary, sex-limited change in body size of an estuarine turtle in response to commercial fishing. Conservation Biology
- Australian snake-necked turtles* population compensation
  Fordham et al. 2008. Experimental evidence for density-dependent responses to mortality of snake-necked turtles. Oecologia

** "…fast growing, early maturing, and highly fecund in comparison with other turtles…"*

Case study *Chelodina rugosa* Fordham et al.

- >50% reduction in adult population
- Turtle abundance recovered in as little as 1 year in some populations
- Recovery achieved through increase in hatchling recruitment and survival into larger age size classes
- *"If managed correctly, the commercial harvest of subadult and adult* C. rugosa *could provide a* ***<u>rare</u>*** *example of a biologically sustainable turtle industry."*



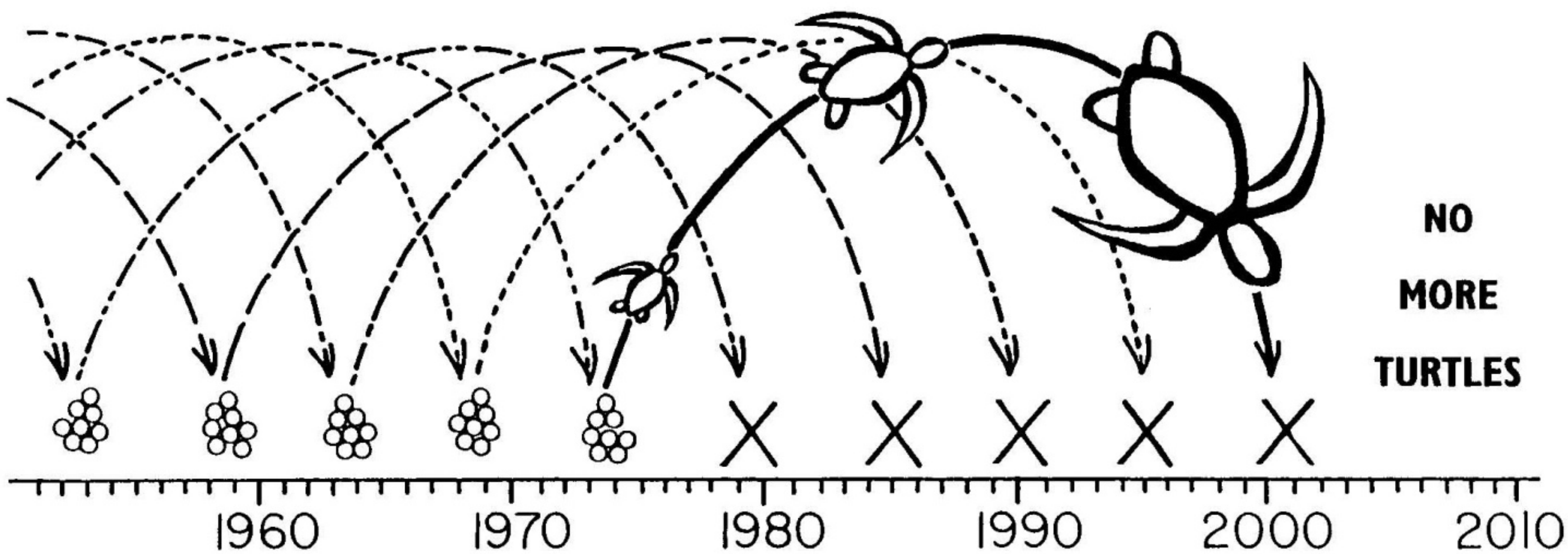
Density-dependent responses are possible in organisms with “fast life histories”

Do we have evidence of the effects of exploitation on US turtles?

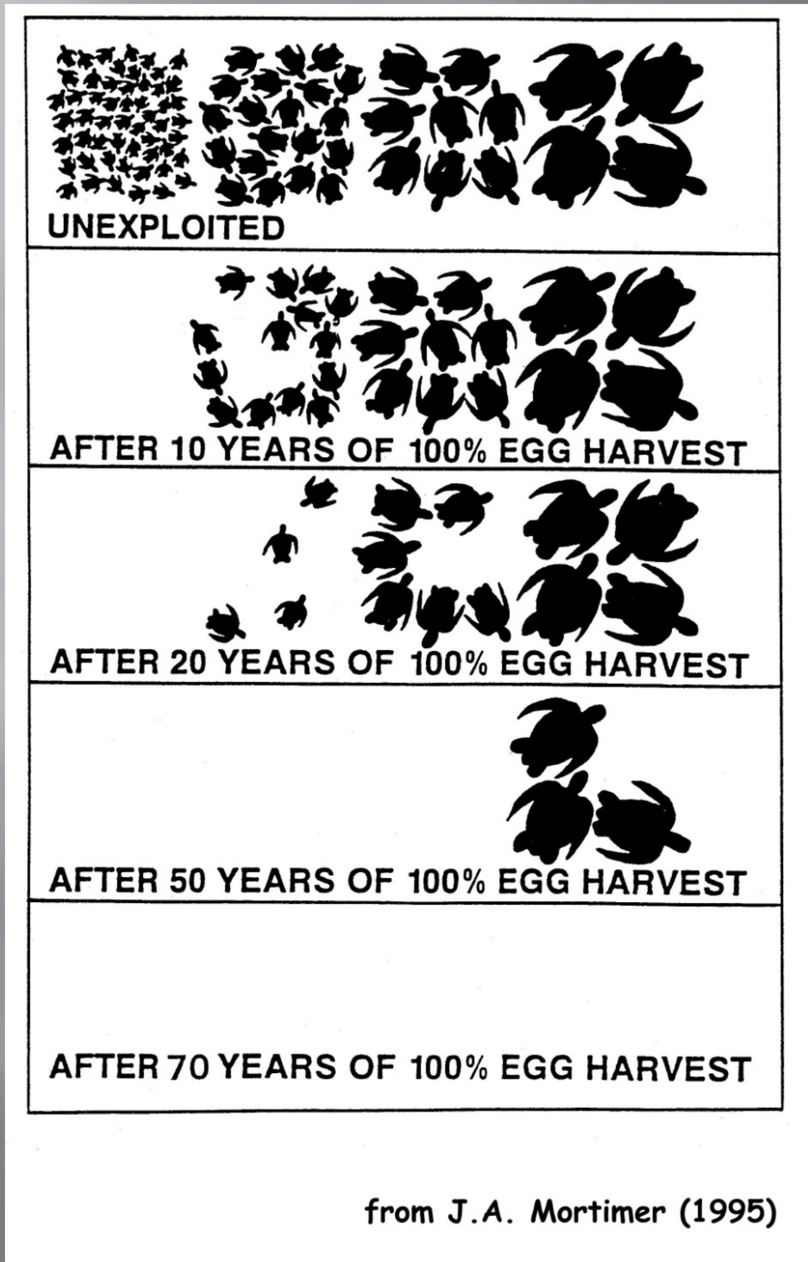
- Sea turtles
- Diamondback terrapins

- Red-eared sliders (Close and Seigel, 1997)
  - body size differed between public and protected sites
- Alligator snapping turtles (Boundy and Kennedy, 2006)
  - trap rate varied by harvest pressure level at sites, and by season but not by hydrology

Example 1: overharvest of females



from J.A. Mortimer (1995)

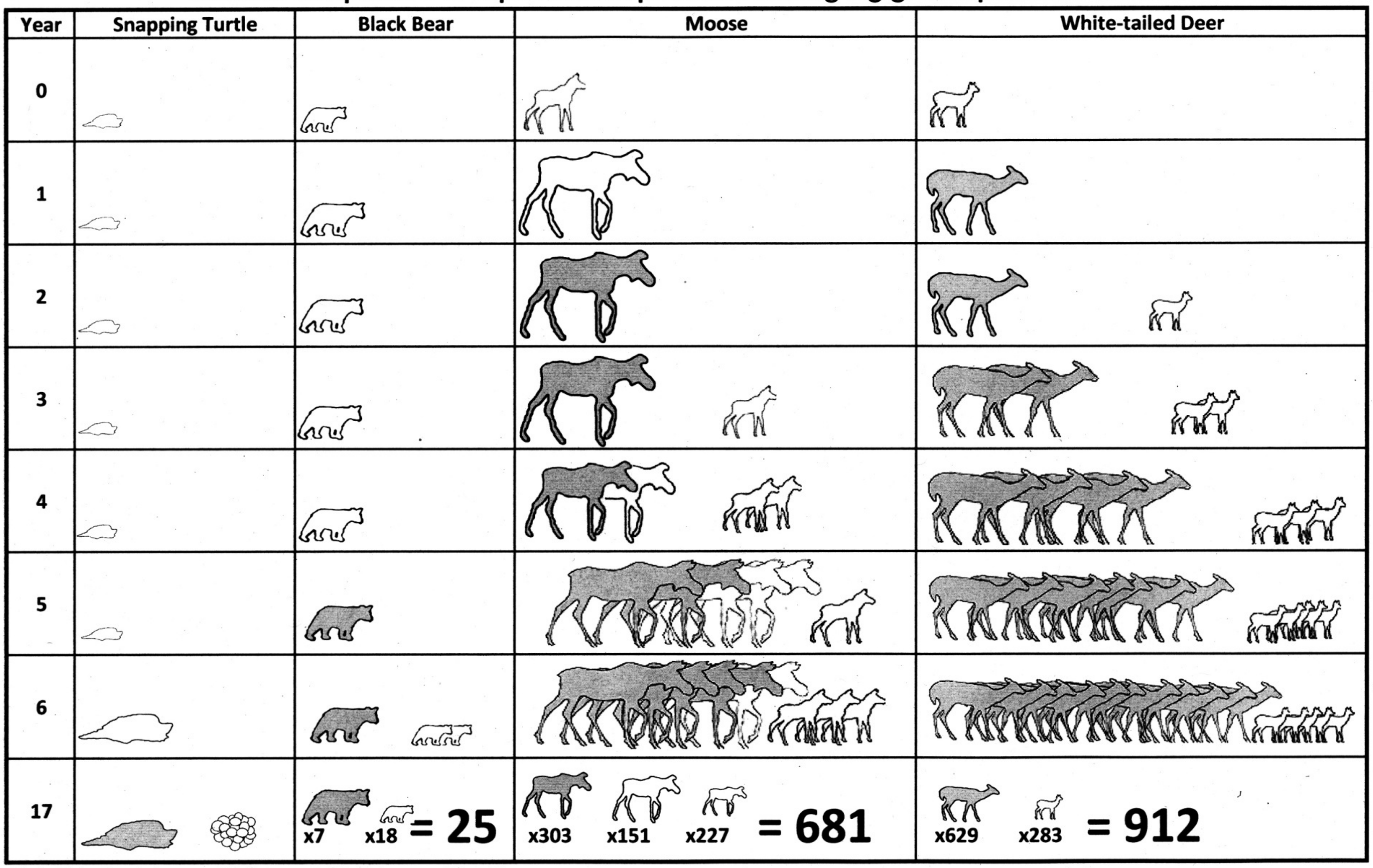


Example 2: overharvest of eggs

The perception of persistence

Life history traits not only constrain turtles in their response to harvest but also mask early detection by observers.

General comparison of reproductive potential among big-game species in Ontario

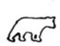


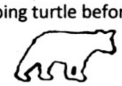
Note this chart does not take mortality into consideration.

This chart was developed by the OMNR Black Bear Technical Team in 2005 based on an original idea by George Kolenosky.

Snapping Turtle column was added by the Ontario Multi-Species Turtle Recovery Team in 2008.

Please note that up to 1400 eggs need to be laid by a snapping turtle before one offspring reaches maturity. This may not occur until year 50.

 **= young of the year**

 **= sexually immature**

 **= sexually mature**

Credit Ron Brooks Co-Chair of OMSTARRT
(Ontario Multi-Species of Turtles At Risk Recovery Team)

"As a group, turtles indeed have the greatest development of iteroparity and the lowest intrinsic rates of increase of any large order of tetrapods."

Wilbur and Morin, 1988

"The singular difficulty in understanding these concepts [life history of turtles] stems from the long delay between the cause and the visible effect of certain devastating practices."

Mortimer, 1995

Indirect effects of turtle commercial harvest and export

- Spread of invasive turtle species to other countries compounding their own native turtle problems (e.g., "Asian Turtle Crisis")
- Potential spread of pathogens to other turtle species (e.g., URTD)
- Genetic "pollution"
- Demographic effects
- Ecologic effects

Conclusion

Almost all turtle species that are now critically endangered or rare were once abundant and overharvest is the main reason (Klemens and Thorbjarnarson, 1995)

- Amazon river turtles
- Galapagos tortoises
- All Madagascar tortoises
- Indian Ocean giant tortoises
- Asian turtles in general
- Sea turtles

No species of freshwater turtle or tortoise listed under ESA in the United States has ever been recovered or de-listed

Conclusion (cont.)

- Based on a review of the literature, the paradigm is supported with very few exceptions: **High adult survivorship is necessary to ensure the persistence of turtles with delayed maturity, high and variable nest mortality, and long life spans.**

- Life history evolution of turtles is constrained by a conservative and rigid morphology essentially unchanged since the Triassic