The currency of life-history evolution: why old turtles are valuable, and how they got that way.

Painted Turtle
Chrysemys picta marginata

Blanding's Turtle
Emydoidea blandingii

Snapping Turtle
Chelydra serpentina

Things most long – term studies have in common:

Model organisms
Questions or hypotheses

The PI or PIs
Place
Dedicated people

Funding

Other things that can help:

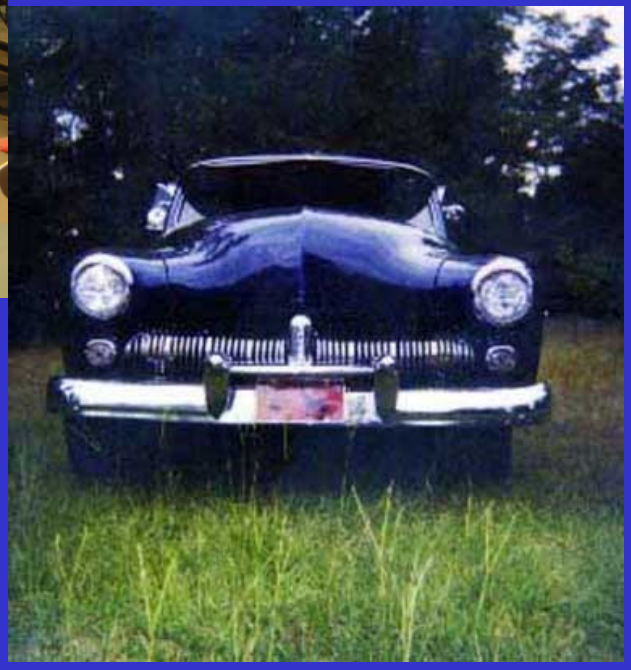
Have a supporter where you work (for me at SREL that = J. W. Gibbons)

Tolerant spouse = Nancy

Win the lottery
Find big bag of unmarked bills
Marry rich person
BETTER = Marry tolerant rich person

My day job at Savannah River Ecology Lab: TOXICOLOGY

Largest Mercury Program



SIX PHASES OF A PROJECT

I. ENTHUSIASM

II. REALITY AND DISILLUSIONMENT

III. PANIC

IV. SEARCH FOR THE GUILTY

V. PUNISHMENT OF THE INNOCENT

VI. PRAISE AND HONORS FOR THE NON-PARTICIPANTS

Long-term studies

“Long term studies are just short-term studies that go on”. J. W. Gibbons

“But not the E. S. George Reserve study oh wise one!” J.D. Congdon

Long-term studies, academic titles, and recognition

Can Turtles Live Forever? A quiet backwoods study opens a huge window on aging. Barry Yeoman, Discover Magazine (06.01.2002)

"The two sides of Congdon's temperament— researcher and **cowboy**— fit naturally together…."

A few pages later: The impression he creates is that of someone who lives far more happily outside polite society, someone who is simultaneously a meticulous biologist and **a swashbuckling cowboy.**

"A few years back, Gianni Versace was killed in Florida," says Mike Plummer, a biologist at Harding University, who was eating dinner with Congdon the night the fashion designer was murdered. "Somebody came out on the news and said, 'Tonight the world mourns for Versace.' Justin said, 'Can you believe that? The world mourns for the death of a guy who sews pants?'"

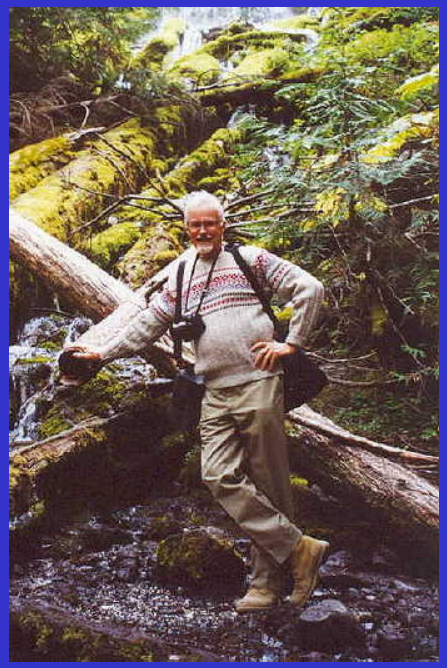
Five years later:

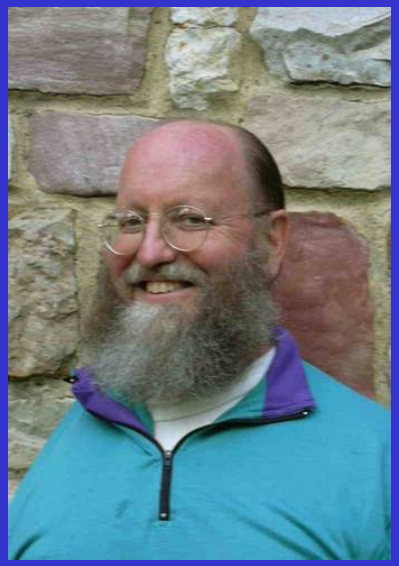
National Wildlife Magazine (2007)
Animal Aging
by Barry Yeoman

"For the reptiles living in the University of Michigan's E.S. George Reserve, Justin Congdon is something of **a troll under the bridge.** A 66-year-old population biologist whose long face and scraggly beard have won him the nickname Fidel Congdon"

The PIs

Dr. Owen Sexton
(Ph. D. Research)
1953 – 1957
(marked 1000 C.p.
and E.b.)





Dr. Henry Wilbur
(Mich. Fellow),
1968 – 1973
(marked 1000 C.p.
and E.b)

Dr. Donald Tinkle (Dir. UMMZ)
1975 - 1979

Justin Congdon, Postdoc 1975 – 1979 - PI (1980 – 2007)

FUNDING

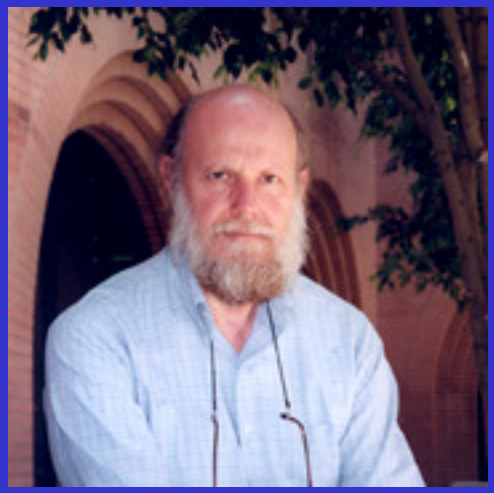
NSF

UNIVERSITY OF MICHIGAN
MUSEUM OF ZOOLOGY
"Go to Nature - Take the facts into your own hands, Look and see for yourself" ....Agassiz

The University of Georgia
Savannah River Ecology Laboratory

Nancy Dickson, field and financial help

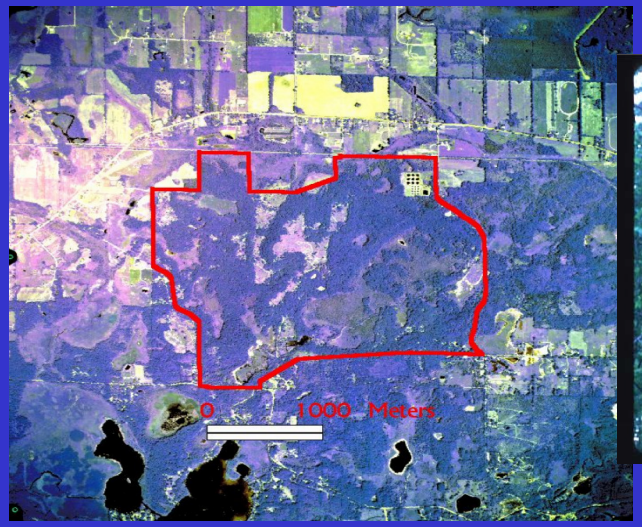
Caleb Finch (University of Southern California), and the SOSA meetings



FOUNDATION IPSEN
"Prix Longevite" 2001
(Medal + $15,000)

Margie Tinkle
The Fabbro Foundation

THE PLACE: University of Michigan's Edwin S George Reserve



THE INDESPENSIBLE PEOPLE

Dick van Loben Sels (9yr)
and me in 1977

Roy Nagle
(18 yr)

Owen
Kinney
(12 yr)

Todd
Quinter
(7 yr)

many other high school, undergraduate and graduate students

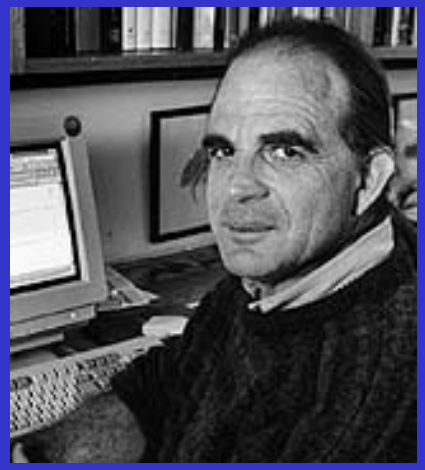
Some notable biologists associated with the ESGR study

Dr. J. Whitfield Gibbons

Dr. Ron Brooks

Dr. Willem Roosenburg

Dr. Arthur Dunham



Dr. Laurie Vitt

Outline:

1) Methods
2) Turtles
3) Demographic parameters
    1) Nest survivorships
    2) Indeterminate growth
    3) Juvenile growth rates and attainment of maturity
    4) The value of long-lived adults in evolutionary currency
        - Adult survivorships
        - Size and age specific reproductive traits

5 Lessions

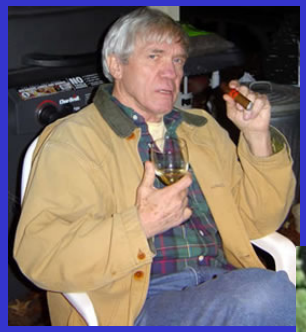
First definitions for turtle biologists interested in life histories, aging and senescence

- Ageing: determining or assigning an age to an individual

(see the turtle literature for ages of > 20 years based on "annuli" counts)

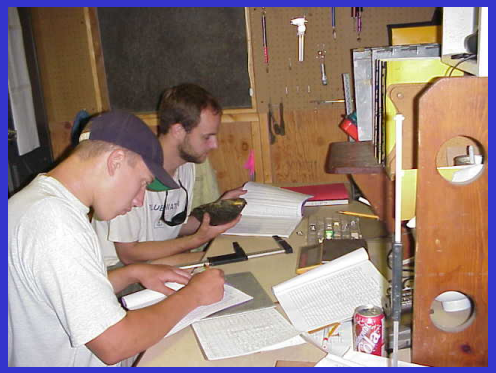
Aging: growing old

(see below)



1. Capture turtles (baited traps, fykes, basking traps, muddling, dip netting, land, fences, nests)

2. turtles to THQ



3. mark or identify individuals

4. measure, weigh, notes on injuries and abnormalities

5. X-ray gravid females

Give a temporary # and release

6. ageing

1. find nesting turtles, locate and flag exact location of the nest

2. monitor fate of nests

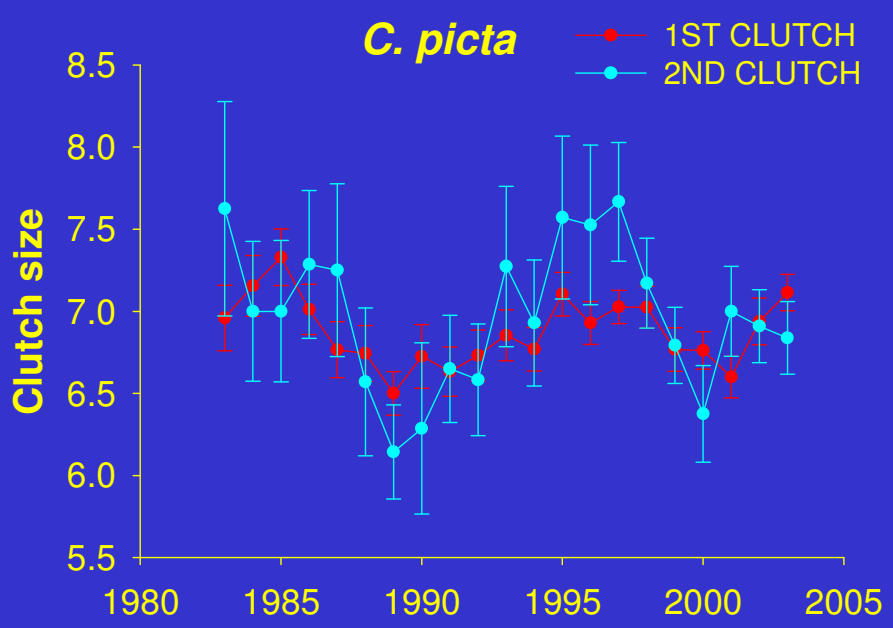
3. in fall and spring capture, & mark hatchlings at nests, fences, and in shallow water

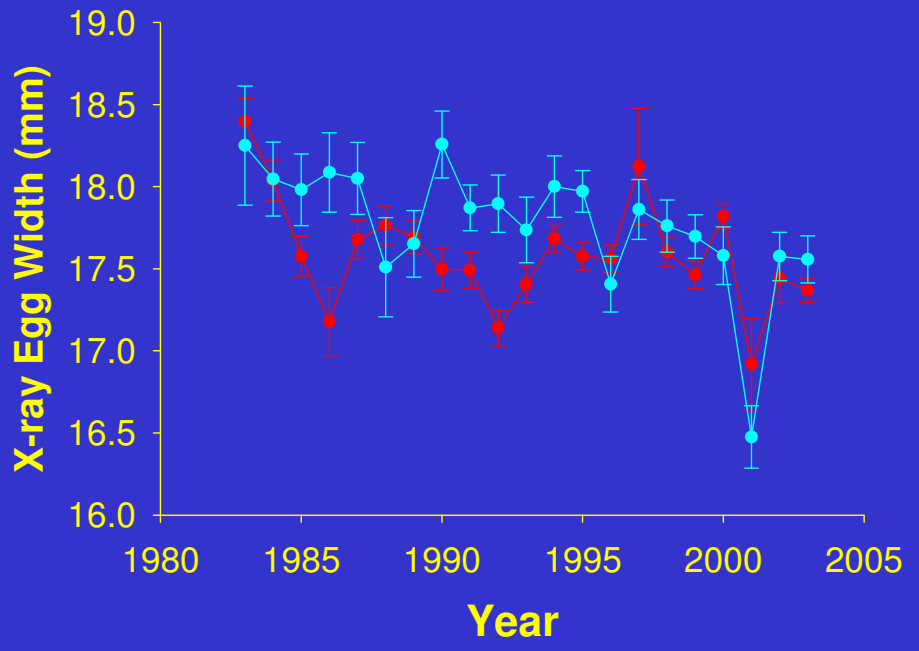
Data summary: 1975 – 2007

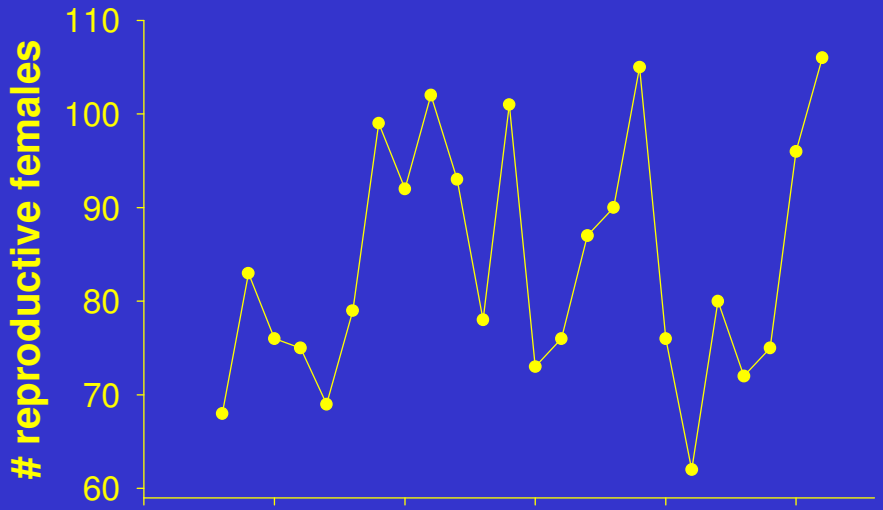
Species	Indiv.	Recaps.	Xrad.	Nests
Painted	6,463	24,623	3,843	2,564
Blanding's	2,074	5,823	1,041	615
Snapping	3,180	4,021	815	1,148
TOTAL	11,717	34,467	5,699	4,327

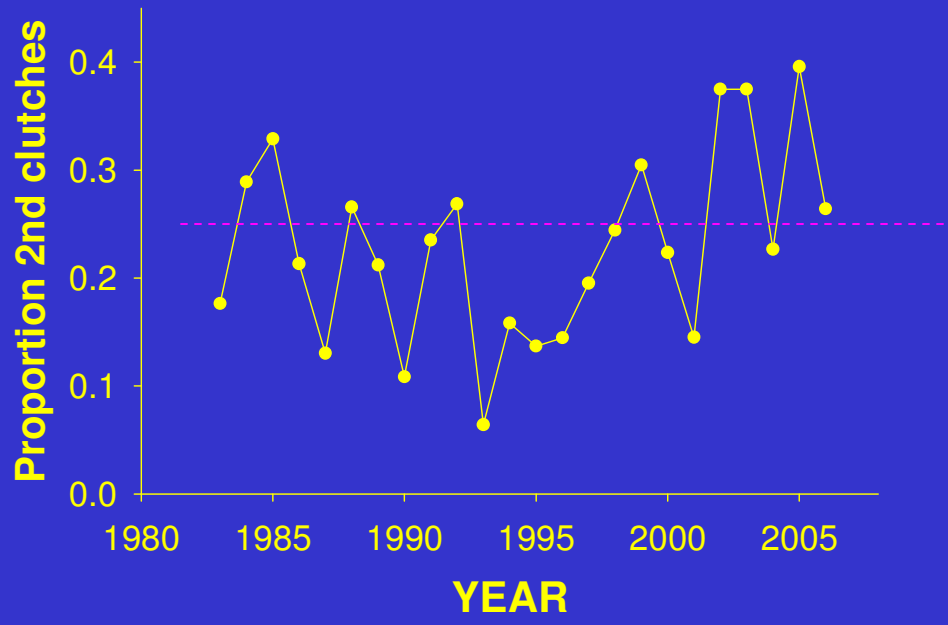
Sexton	1953-1957	930	2,311
Wilbur	1968–1972	784	1,434

Females (East Marsh only)









Indeterminate Growth

- "…Reptiles, Amphibians and Fishes, as a rule grow rapidly when young, and then settle down to a period of very slow growth, which in the course of years becomes negligible, and, if the animal lives long enough, eventually ceases." p.451, Flower 1944
- "…our knowledge of growth in amphibians and reptiles is very incomplete…in most species we cannot yet say whether growth is determinate or indeterminate." p. 266, Oliver 1955
- "It is known that reptiles continue growing throughout their lives . . " p. 112, Goode 1967
- "Both indeterminate (attenuated) and determinate (asymptotic) growth exist in amphibians and reptiles, but the evidence for one or the other is lacking for most species." p. 43, Zug et al. 2001

Answers to the most frequently asked important questions about indeterminate growth (provided by – from north to south – Brooks, Congdon, and Gibbons long-term data sets)

- YES
- NO
- IN SOME SPECIES
- NO
- YES
- NOT AS MUCH AS PREVIOUSLY THOUGHT

Is indeterminate growth a mechanism for the evolution of longevity in turtles?

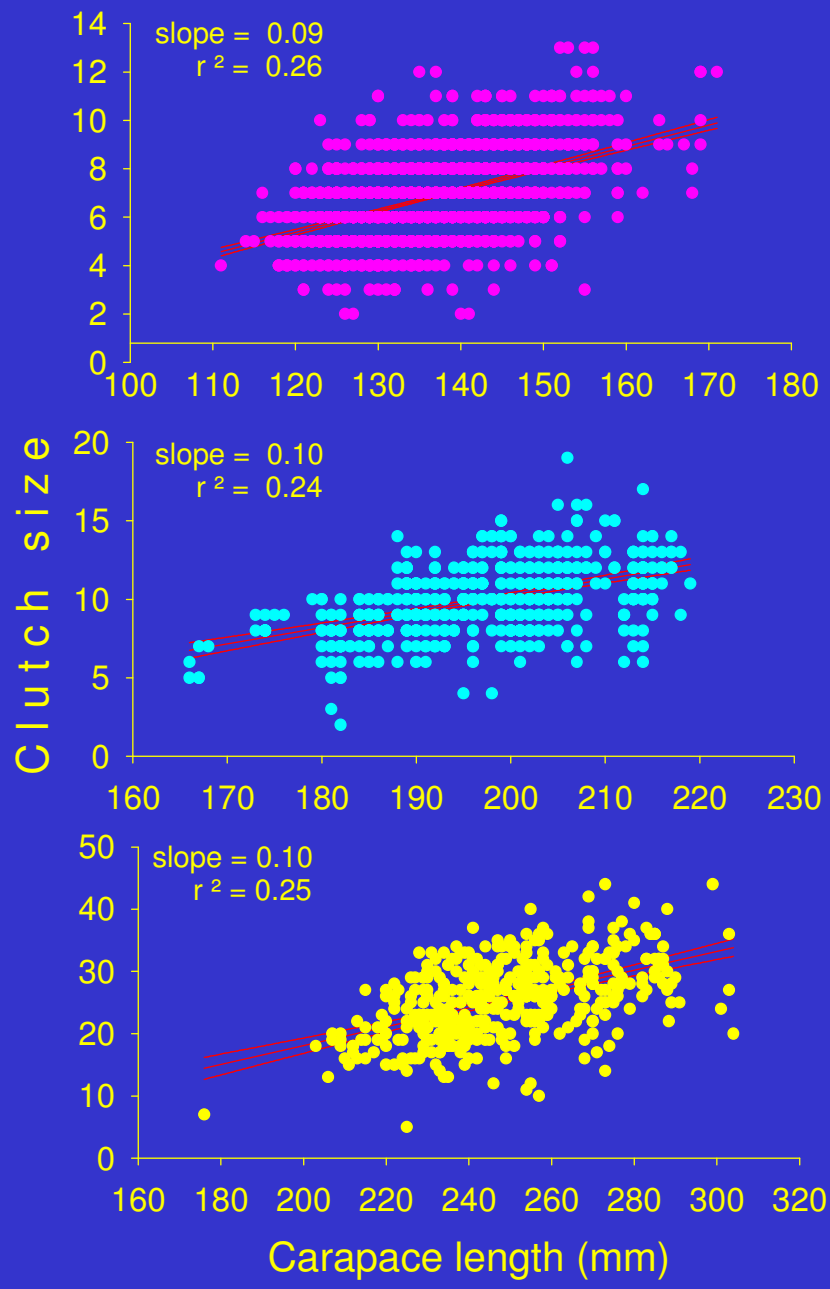
Indeterminate growth:

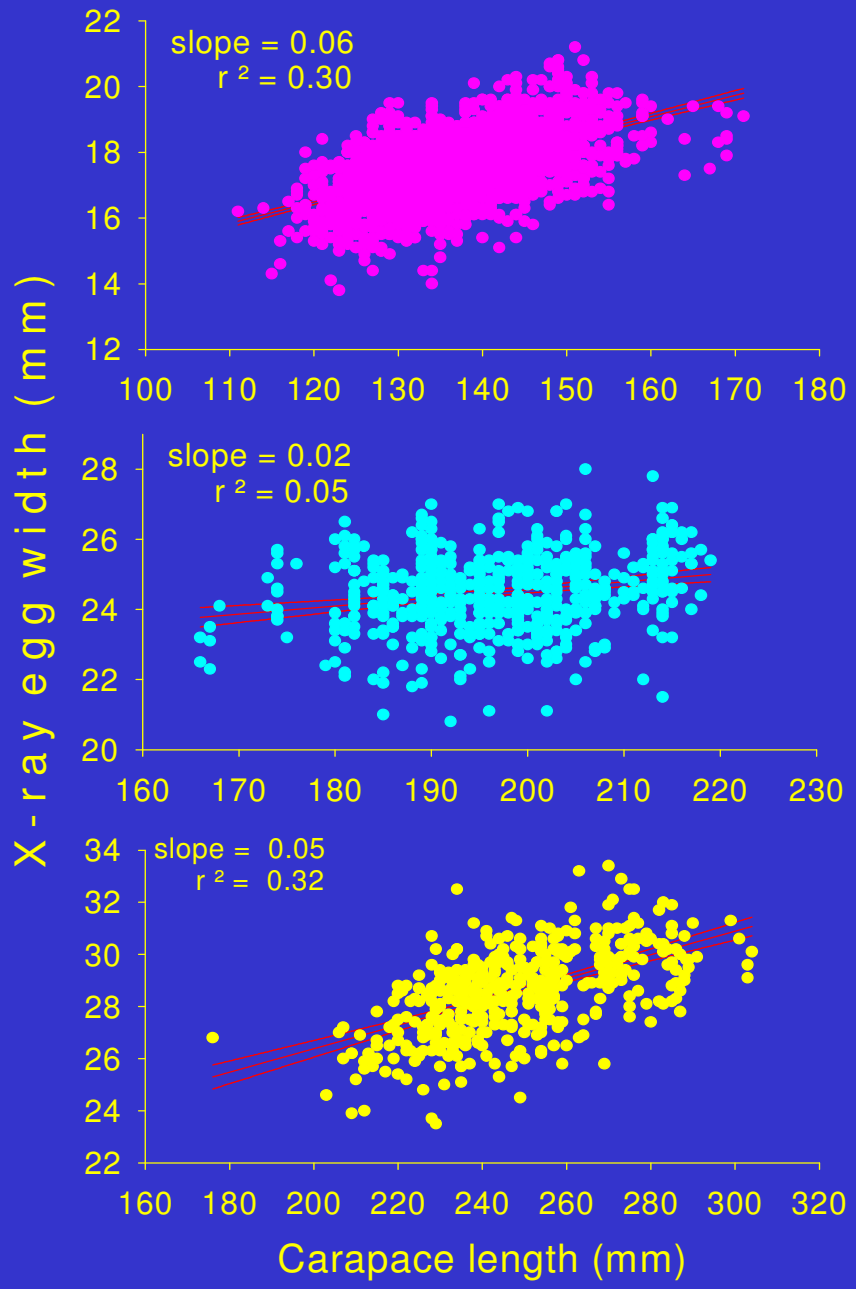
1) is a juvenile trait that is retained by adults
2) is an individual trait, but not a population trait (i.e. individual get larger as they become older, but large individuals in a population are not necessarily older than smaller individuals)
3) results in increased reproductive output (of individuals and for the population)
4) may result in increased survivorship
5) alters the age specific fitness landscape in populations that exhibit the trait compared to those that do not
6. is thought to be an important proximate mechanism for increasing the proportion of late to early births in individuals – the mechanism by which evolutionary currency is spent for the evolution of longevity.

Painted turtle (6 eggs, 4 mm EW)

Blanding's turtle (5 eggs, 2mm EW)

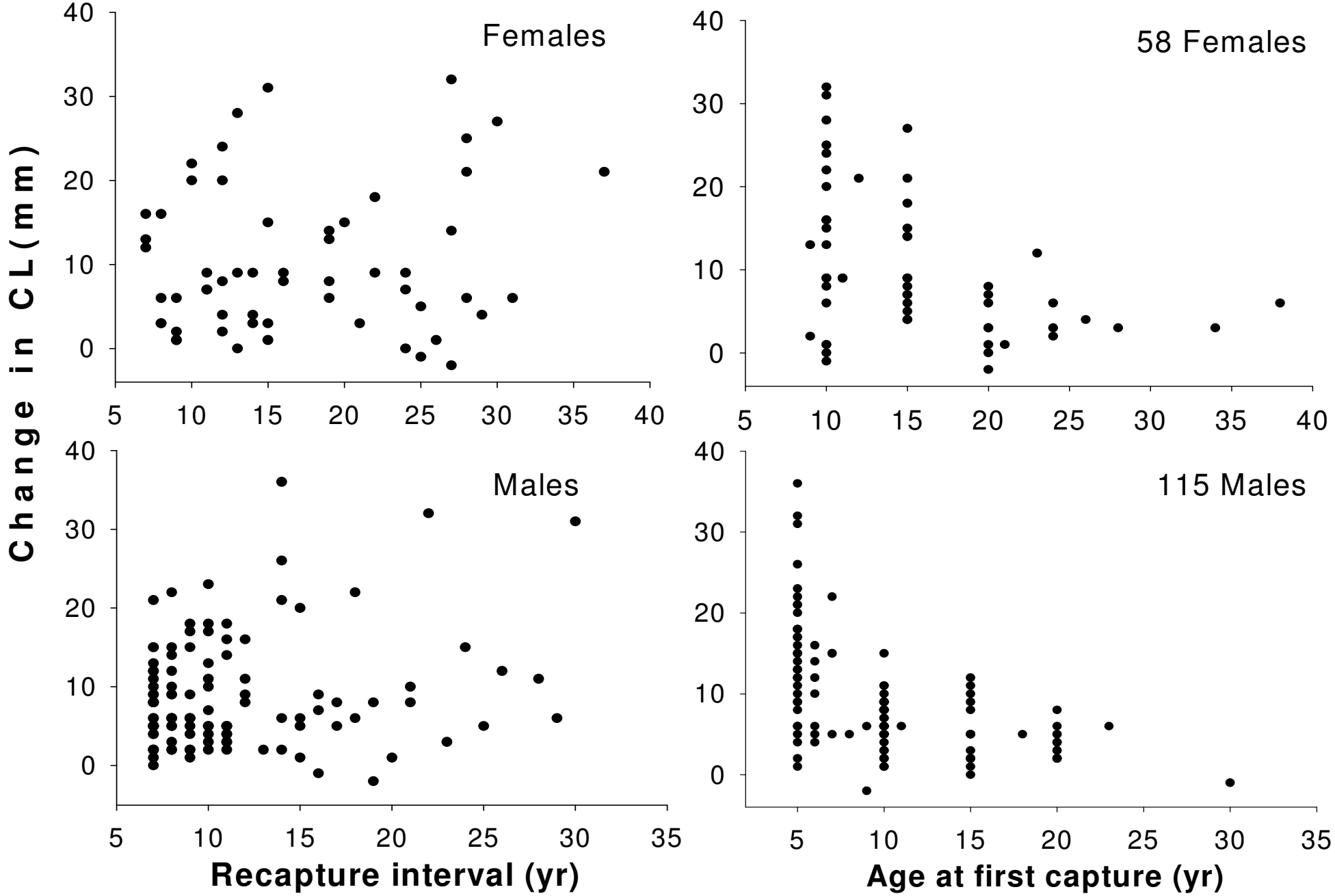
Snapping turtle (15 eggs, 6 mm EW)



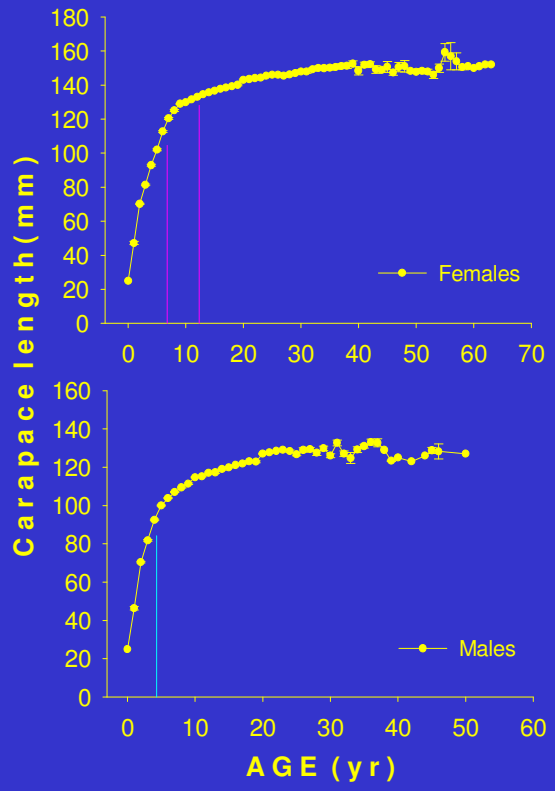


% of individuals with no growth (10 - 33yr interval)

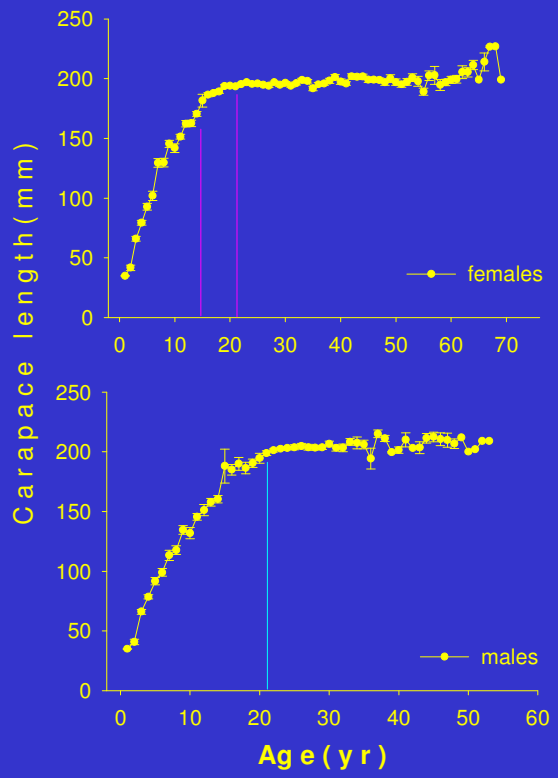
	Male	Female
Chrysemys picta (Can)	21.8	14.2
Chrysemys picta (MI)	9.8	2.1
Chelydra serpentina (Can)	37.5	13.8
Chelydra serpentina (MI)	10.2	3.3
Emydoidea blandingii (MI)	26.0	32.0
Kinosternon subrubrum (SC)	16.3	4.5
Kinosternon sononiense (AZ)	15.4	10.0
Trachemys scripta (SC)	7.7	3.1
Malaclemys terrapin (SC)	40.0	19.0
Emys insculpta (Can)	60.0	25.5


Females
58 Females
Males
115 Males
Change in CL (mm)
Recapture interval (yr)
Age at first capture (yr)
40
30
20
10
0
5
10
15
20
25
30
35
40

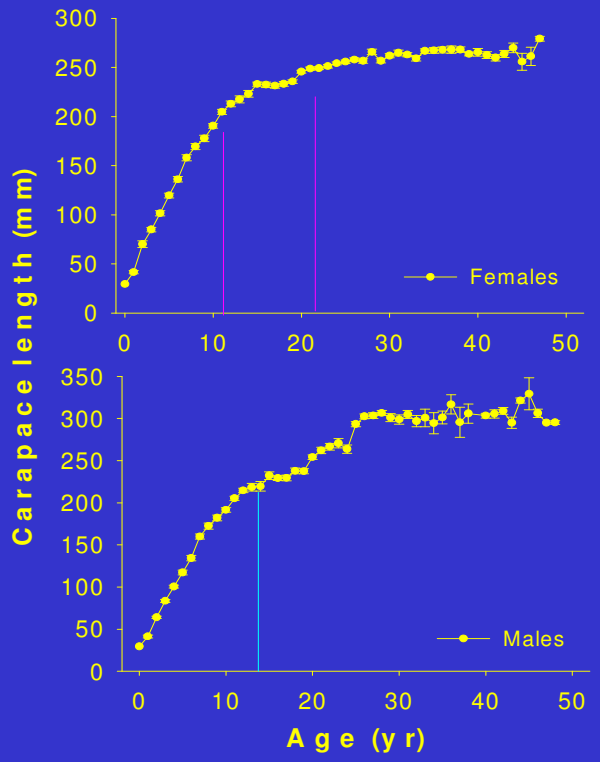
Painted turtles



Blanding's turtle



Snapping turtles



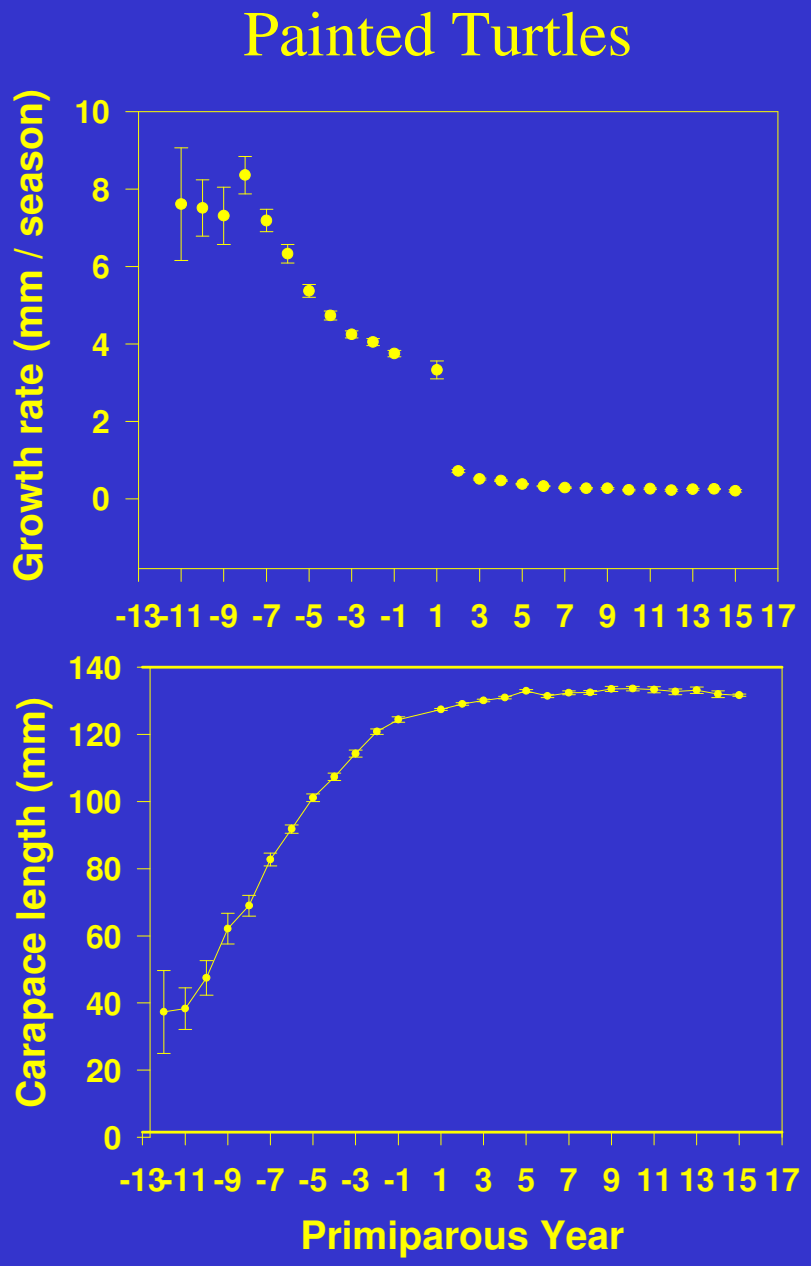
Components of Variation in Body Size of Adult Females

Species	primiparous	all gravid	% mean	% of range
Painted	128 (110 – 149)	137.0 (110 – 171)	93.4	63.9
Blanding's	185.0 (166 – 204)	196.2 (162 – 223)	94.3	62.3
Snapping	222.9 (176 – 251)	252.1 (176 – 304)	88.4	58.6

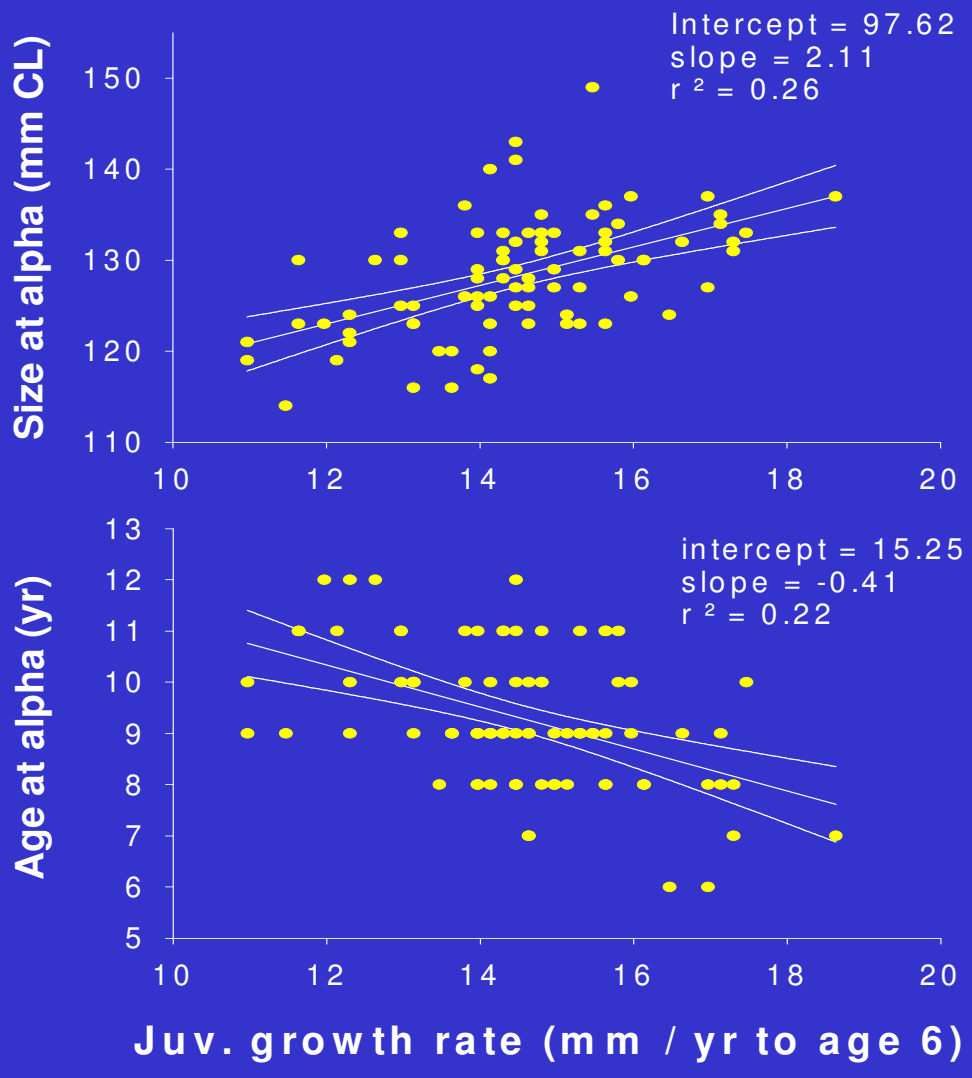
Stearns and Koella (1986)

If juvenile traits have consistent influence on adult demographics, then individuals should act as if those influences are predictable.

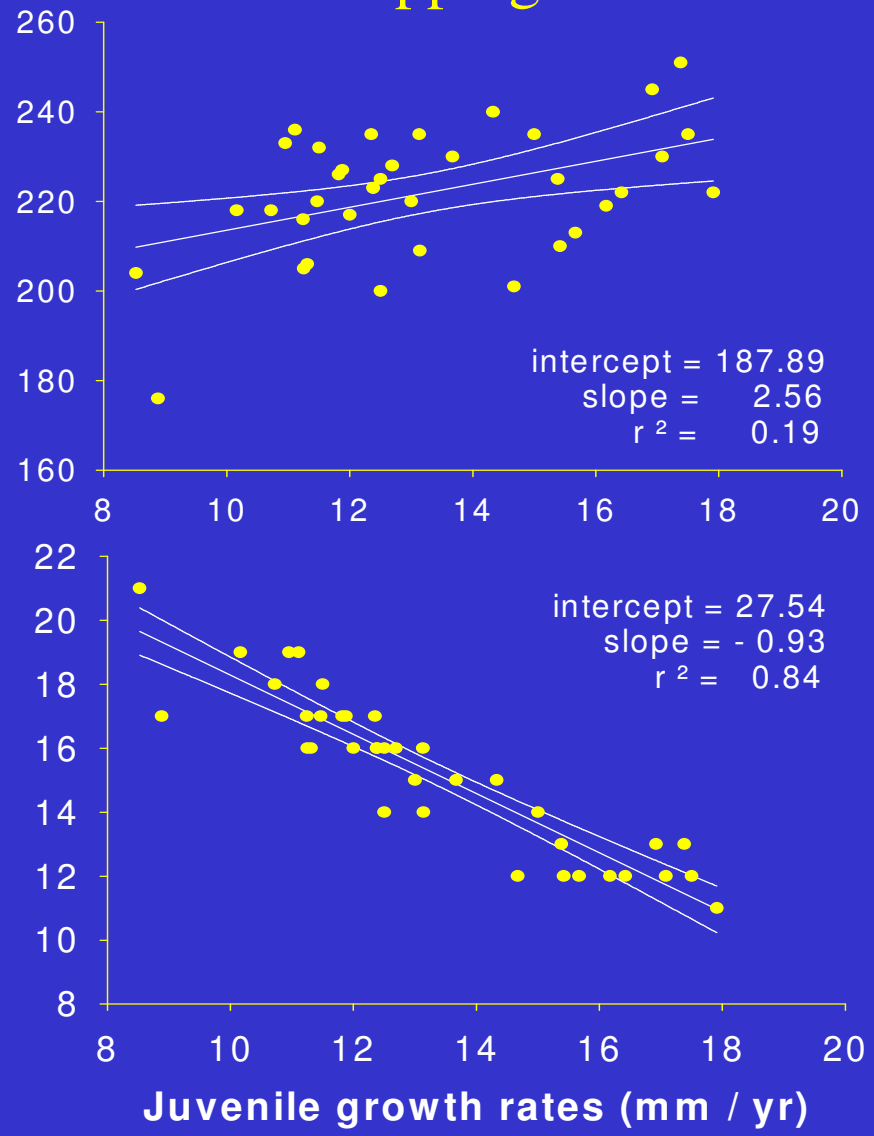
Are juvenile growth rates important in determining size and age at maturity?

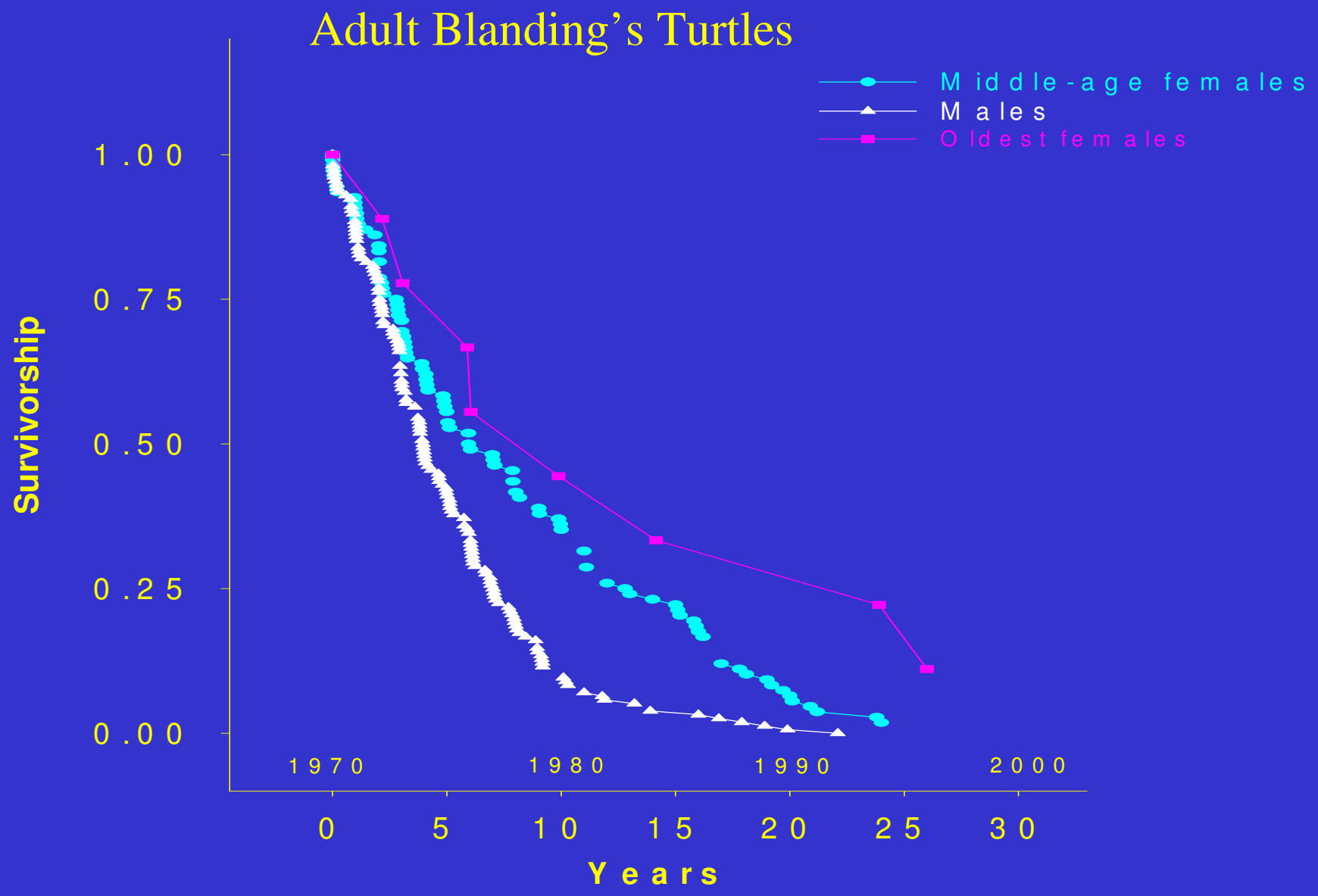


Painted turtle



Snapping turtle

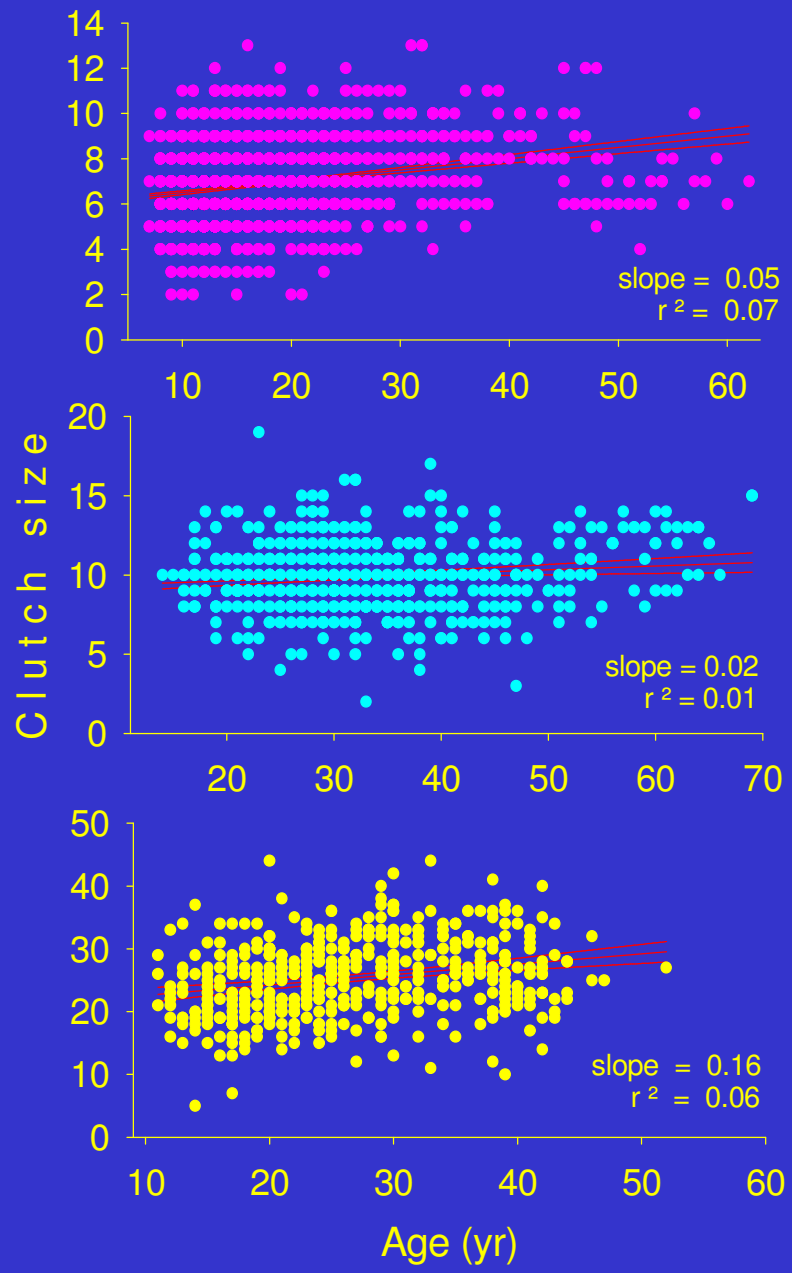


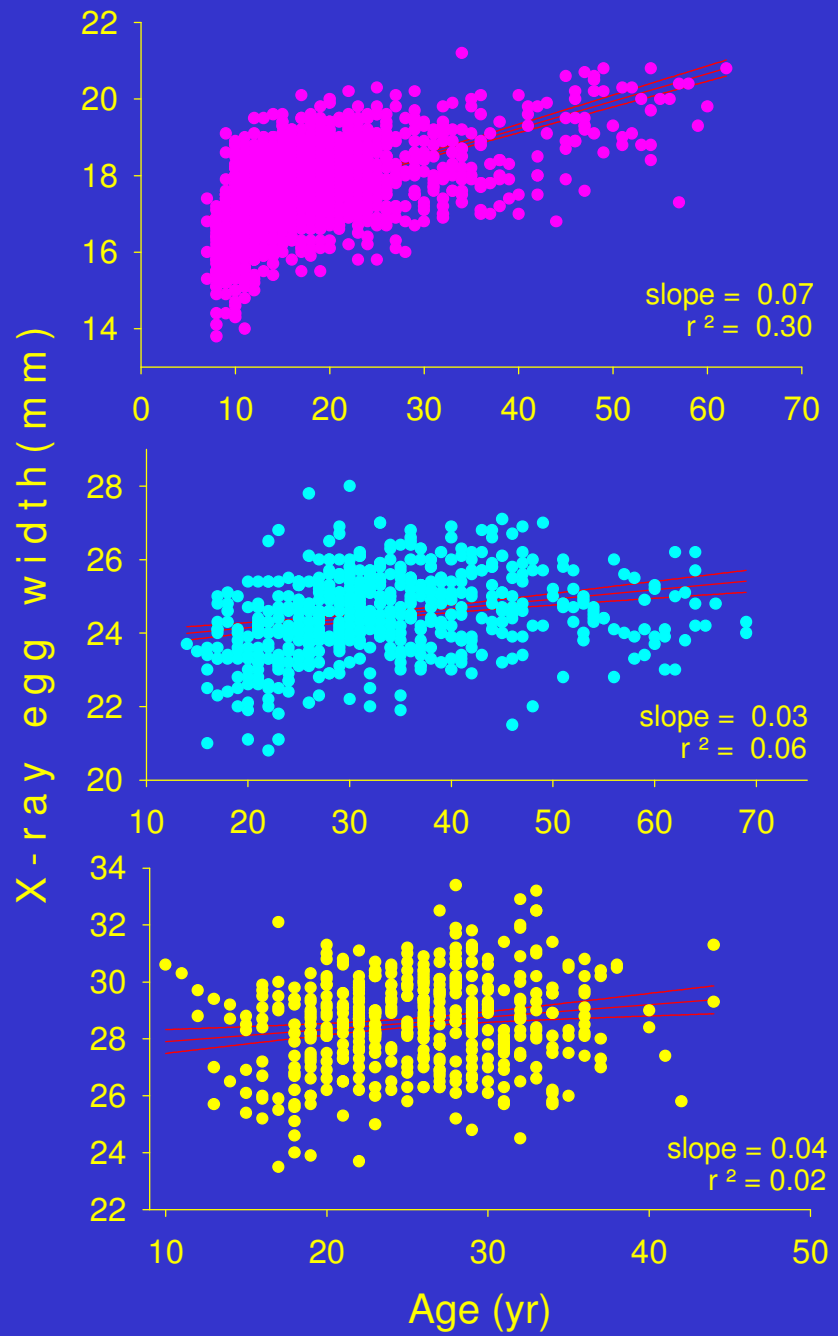

Adult Blanding's Turtles
Middle-age females
Males
Oldest females
Survivorship
1.00
0.75
0.50
0.25
0.00
1970
1980
1990
2000
0
5
10
15
20
25
30
Years

Painted turtle

Blanding's turtle

Snapping turtle

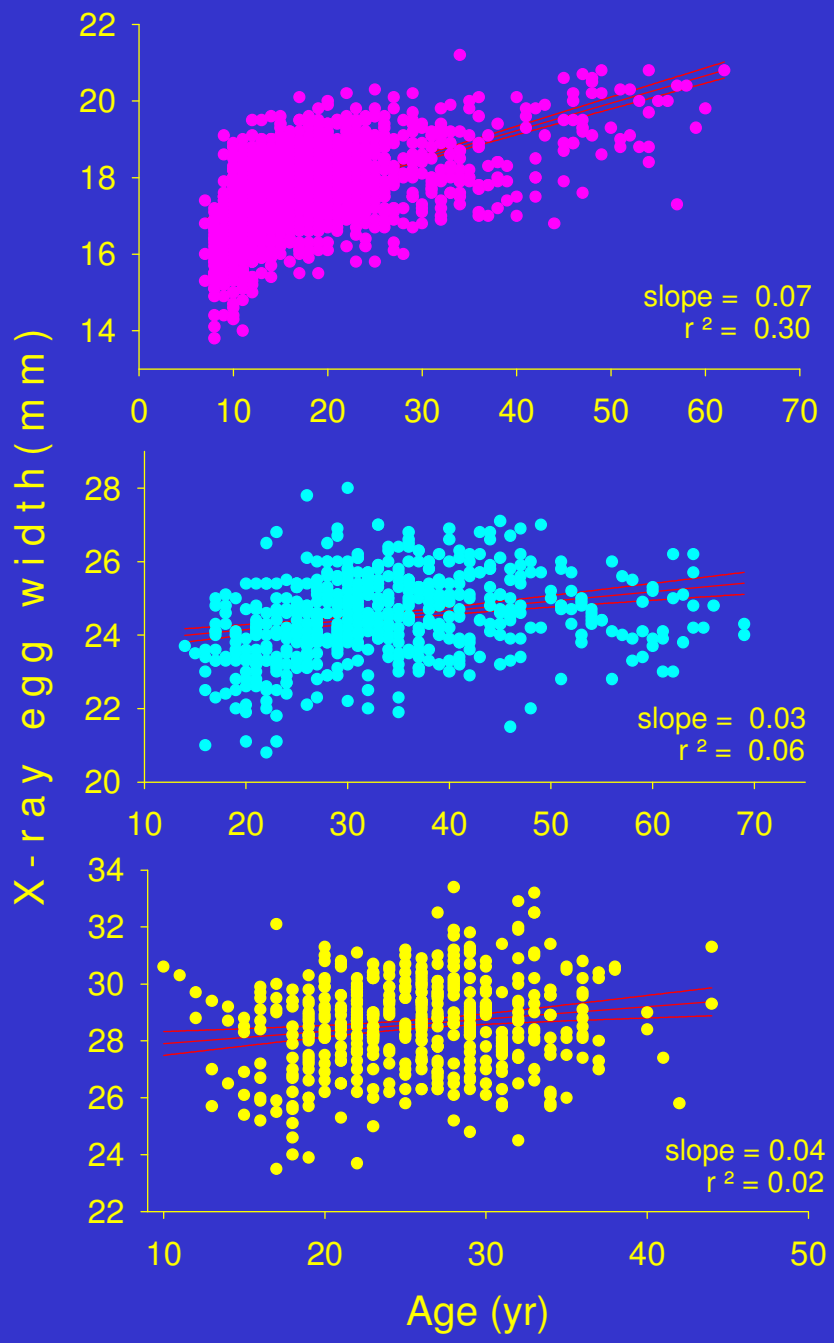


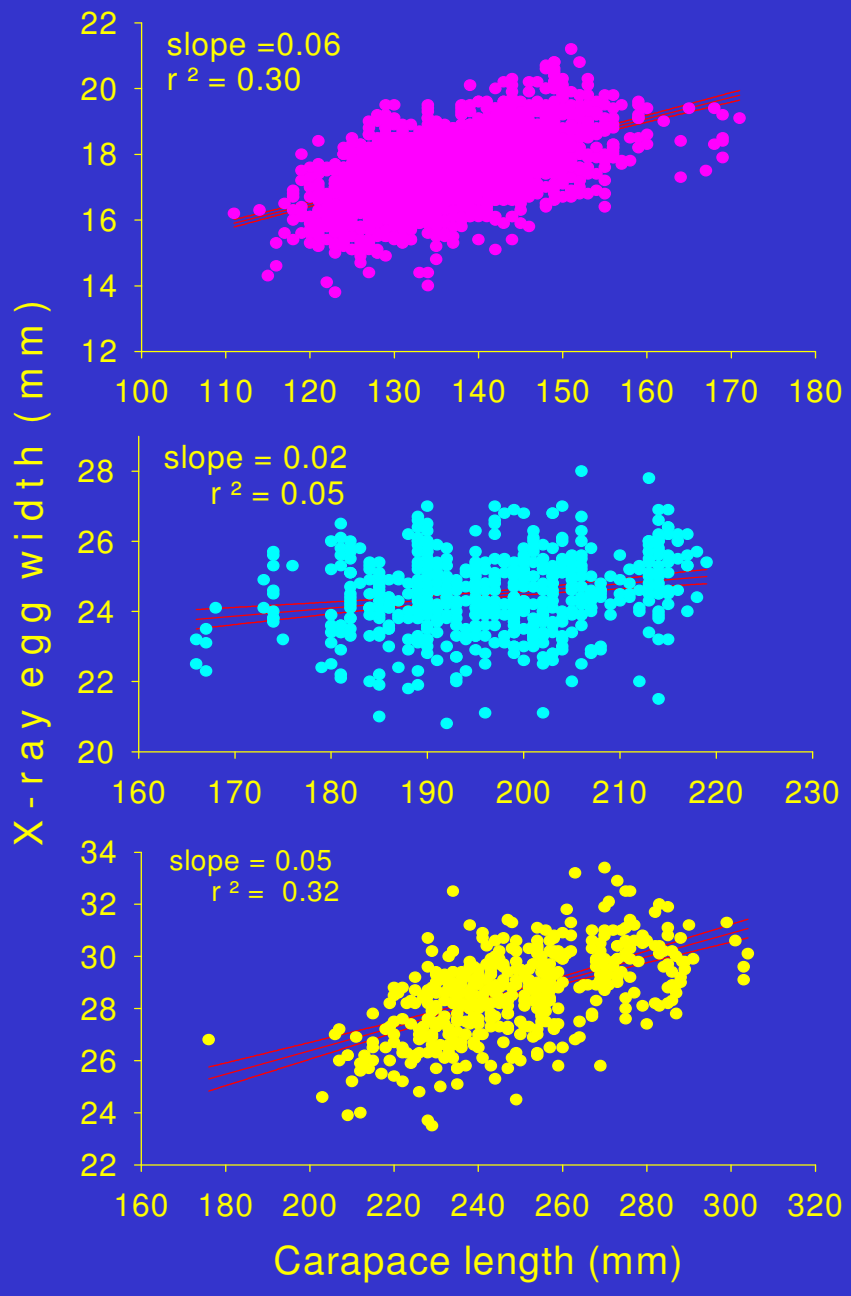


Painted turtle

Blanding's turtle

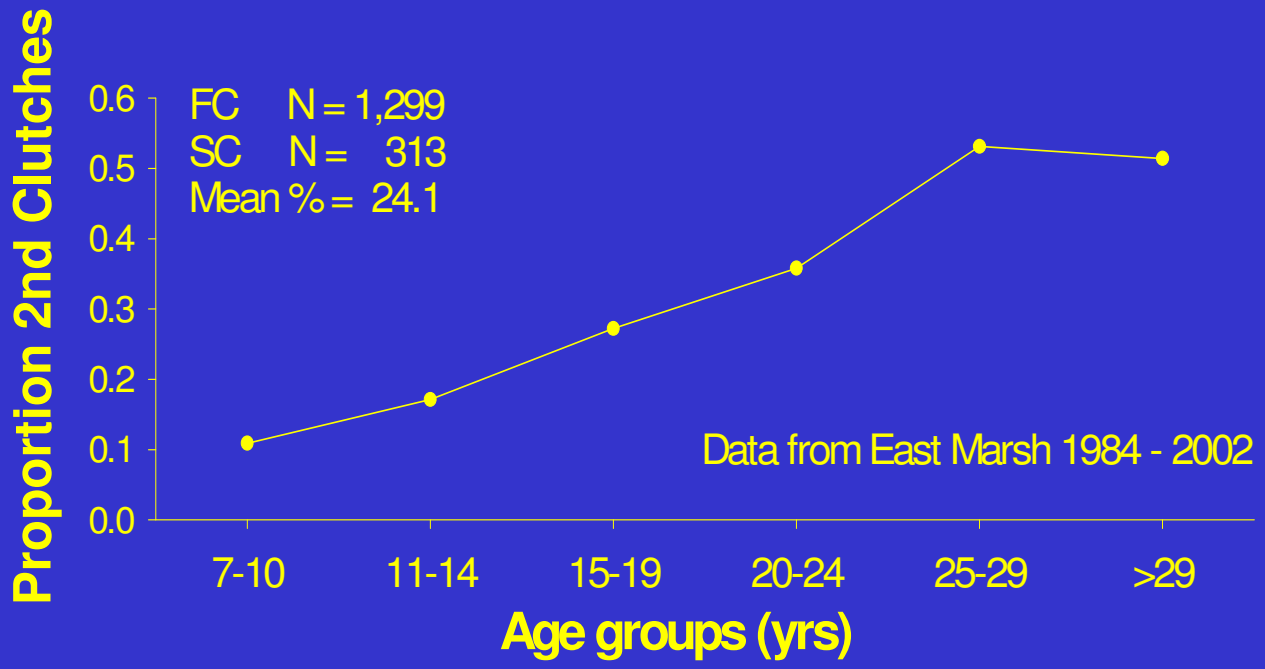
Snapping turtle





Painted Turtle

Mean age values based on 2,318 X – radiographs and recapture histories of 806 known age females from East Marsh



THREE LESSIONS

LESSION #1.

The evolutionary currency is births.

The evolutionary currency of deaths is births.

The way currency is spent on attaining longevity is by increasing the proportion of late in life births (compared to early in life births).

LESSION #2.

Indeterminate growth in turtles means that "some adults grow and others do not".

Adults grow slowly.

Benefits from increases in body attained through indeterminate growth accrue over many years and have to be discounted by mortality rates.

Adults grow much slower than do juveniles, and variation in juvenile growth rates and ages at maturity accounts for most of the variation in adult body size within a population.

Therefore: BIGGER DOES NOT MEAN OLDER!

BIGGER DOES NOT MEAN OLDER!

BIGGER DOES NOT MEAN OLDER!

LESSION #3. Compared to young individuals,

Older turtles have higher survivorships (longer reproductive life spans)
Older turtles have higher clutch frequencies (more evolutionary currency)
Older turtles have larger eggs (increased offspring quality ~ a 10 vs. a 5 dollar bill)

THEREFORE:

Older adults are worth more in terms of population stability and evolutionary currency compared to younger individuals.

Traits of older females promote an increase in the proportion of late in life births vs. early in life births (the mechanism for evolving longevity).

Uncontrolled and chronic increases in adult mortality (harvesting, road mortality - particularly on females) will almost certainly result in serious reductions in populations.

BECAUSE OLDER ADULTS PRODUCE MORE EVOLUTIONARY CURRENCY AND CONTRIBUTE MORE TO POPULATION DYNAMICS,

PROLONGED COMMERCIAL HARVESTS OF LONG-LIVED ORGANISMS HAVE A VANISHINGLY LOW PROBABILITY OF BEING SUSTAINABLE