The State of Spotted Turtles in Rhode Island:

Occupancy Along a Landscape Gradient and Characterization of Population Genetic Structure

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Acknowledgements

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Research Article

Occupancy of Freshwater Turtles Across a Gradient of Altered Landscapes

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ABSTRACT Turtles are one of the most threatened groups of vertebrates worldwide. In the northeastern United States, a legacy of centuries of dramatic landscape alteration has affected freshwater turtle populations, but the relationships between the current landscape and distributions and abundances of freshwater turtles remain poorly understood. We used a stratified random approach to select 88 small, isolated wetlands across a gradient of forest cover throughout Rhode Island, USA, and systematically sampled freshwater turtles in these wetlands. We report estimates of relative abundance and used a canonical correspondence analysis to investigate relationships between species relative abundance and environmental covariates. We also investigated which environmental covariates affect the occurrence and detection probabilities of each species. Eastern painted turtles (*Chrysemys picta picta*) and common snapping turtles (*Chelydra serpentina*) were widespread (occurring in 83% and 63% of wetlands, respectively) and relatively abundant. Spotted turtles (*Clemmys guttata*) were far less common, occurring in 8% of wetlands, and exhibited a positive association with shallow wetlands surrounded by forest. Non-native red-eared sliders (*Trachemys scripta elegans*) occurred in 10% of wetlands and exhibited a positive association with road density, likely reflecting a positive relationship between slider occurrence and human population density. Identifying landscape-scale habitat features that are associated with the occurrence of sensitive species can improve the ability of biologists to identify and protect turtle populations. © 2018 The Wildlife Society.

KEY WORDS *Chelydra serpentina*, *Chrysemys picta*, *Clemmys guttata*, endangered species, invasive species, occupancy analysis, pet trade, *Trachemys scripta elegans*.

Human-induced landscape alteration is often implicated as compromising vertebrate biodiversity, with habitat loss and degradation widely recognized as the leading causes of a loss of population stability across taxa (Gibbons et al. 2000, Brooks et al. 2002). New England, in the northeastern United States, has experienced substantial shifts in landscape composition since the time of European settlement. Deforestation associated with agriculture and logging peaked in the mid-nineteenth century when as much as 80% of the landscape had been cleared. Beginning around 1850 agriculture shifted to states farther west, ushering in a period of reforestation lasting approximately 100 years (Foster and Aber 2004). In Rhode Island, USA, this period was followed by another phase of deforestation for urban and suburban development. Total forested land area in Rhode Island has been decreasing since at least 1953, when an estimated 65% of the state was forested (Butler and Payton 2011). A recent estimate suggested that approximately 54% of the state is forested (Butler 2013). This extreme landscape alteration in a relatively short period of time has certainly led to changes in the distribution and abundance of wildlife, but the legacy of this change is poorly understood for many species, including freshwater turtles.

As a vertebrate group, turtles have an extremely high rate of extinction risk (Lovich et al. 2018). In the United States, freshwater turtles are of particular conservation concern largely because of a significant loss in wetland area beginning in the eighteenth century. An estimated 37% of the wetlands in Rhode Island were drained, filled, or otherwise lost between 1780 and 1980 (Dahl 1990). Additional factors putting freshwater turtle populations at risk include the loss of meta-population structure associated with terrestrial habitat loss and degradation (Dodd 1990, Gibbs 2000), collection for pet, food, and medicine trades (Shiping et al. 2006, Luiselli et al. 2016), and life-history characteristics that include delayed sexual maturity and low recruitment (Congdon et al. 1994, Heppell 1998). In Rhode Island, native freshwater turtles include the common snapping turtle (*Chelydra serpentina*), eastern painted turtle (*Chrysemys picta picta*), spotted turtle (*Clemmys guttata*), wood turtle (*Glyptemys insculpta*), and musk turtle (*Sternotherus odoratus*).

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Open Access Article

A Comparison of the Population Genetic Structure and Diversity between a Common (*Chrysemys p. picta*) and an Endangered (*Clemmys guttata*) Freshwater Turtle

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Abstract

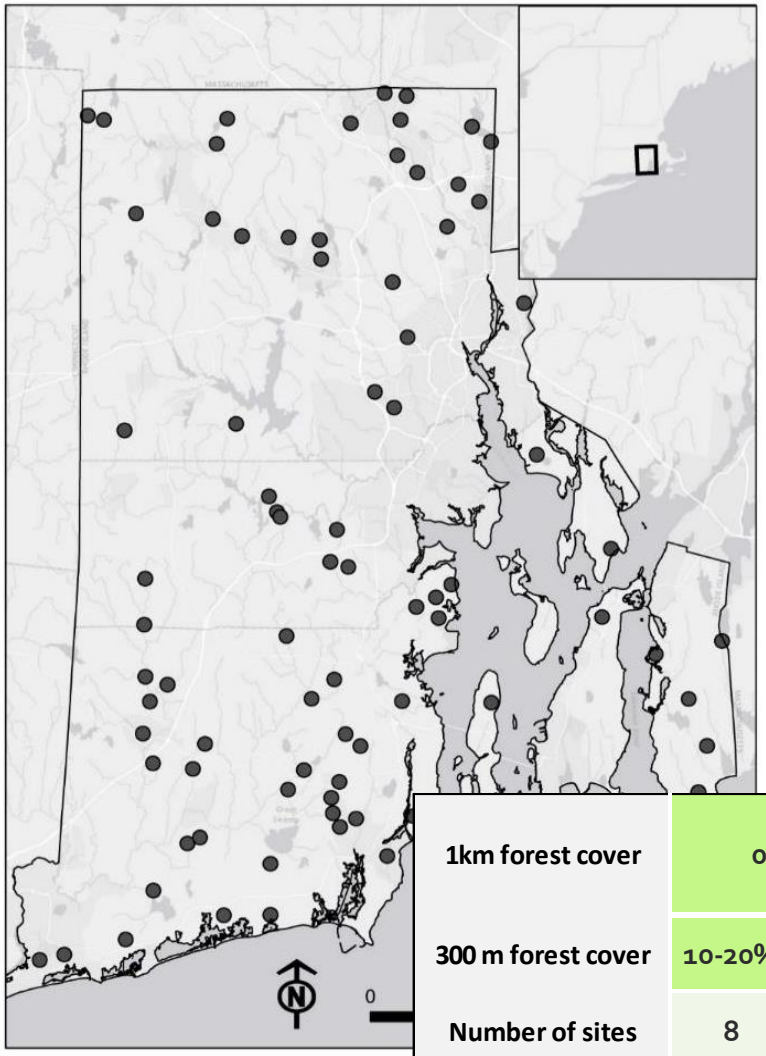
The northeastern United States has experienced dramatic alteration to its landscape since the time of European settlement. This alteration has had major impacts on the distribution and abundance of wildlife populations, but the legacy of this landscape change remains largely unexplored for most species of freshwater turtles. We used microsatellite markers to characterize and compare the population genetic structure and diversity between an abundant generalist, the eastern painted turtle (*Chrysemys p. picta*), and the rare, more specialized, spotted turtle (*Clemmys guttata*) in Rhode Island, USA. We predicted that because spotted turtles have disproportionately experienced the detrimental effects of habitat loss and fragmentation associated with landscape change, that these effects would manifest in the form of higher inbreeding, less diversity, and greater population genetic structure compared to eastern painted turtles. As expected, eastern painted turtles exhibited little population genetic structure, showed no evidence of inbreeding, and little differentiation among sampling sites. For spotted turtles, however, results were consistent with certain predictions and inconsistent with others. We found evidence of modest inbreeding, as well as tentative evidence of recent population declines. However, genetic diversity and differentiation among sites were comparable between species. As our results do not suggest any major signals of genetic degradation in spotted turtles, the southern region of Rhode Island may serve as a regional conservation reserve network, where the maintenance of population viability and connectivity should be prioritized. View Full-Text

Keywords: conservation biology; endangered species; freshwater turtles; herpetology; population genetics; reptile ecology; wildlife

▼ Show Figures

Diversity – June 2019

Trapping across a gradient of forest cover:



- Considered all wetlands 0.1 – 1.8 hectares statewide.
- Binned by forest cover at 300m and 1km.
- Stratified by size as well.
- Randomly selected
- Lots of phone calls.

1km forest cover	0-40%		20-60%		40-80%		80-100%		
300 m forest cover	10-20%	20-30%	30-40%	40-50%	50-60%	60-70%	80-90%	90-100%	Total
Number of sites	8	12	11	12	12	11	10	12	88

Turtle trapping:

- Small and large traps
- Spaced every ~30m around perimeter
- Checked daily for two consecutive nights
- Repeated up to four times (May-October)
- 2013-2015
- 5824 trap nights

Trapping across a gradient of forest cover:

Table 1. Detection and occupancy covariates considered for aquatic turtle occupancy models, Rhode Island, USA 2013-2015. Asterik indicates variables where both a linear and quadratic functional form were modeled.

Covariate	Description
Detection (p)	
julian*	Julian date (1-365) of day two of each site visit
temp*	Mean of maximum daily temperature (from nearest weather station) for days one and two of each site visit
precip*	Mean of total daily precipitation (from nearest weather station) for days one and two of each site visit
time*	Site visit number (1,2,3, or 4)
Occupancy (Ψ)	
site variables	
wetland.age	Age of wetland as determined using historic imagery (continuous variable 1-72)
hectares	Surface area (ha) of wetland as measured via GIS
max.depth	Maximum detected (m) depth measured using a weighted measuring tape
ph*	pH
tds	Total dissolved solids
ammonia	Dissolved ammonia (ppb) as measured from the water column
nitrate	Dissolved nitrate (ppb) as measured from the water column
phos	Dissolved phosphorous (ppb) as measured in the water column
graminoid*	Percent of wetland surface containing emergent graminoid vegetation
herbaceous*	Percent of wetland surface containing emergent forbs and other non-woody vegetation (including Nymphaea)
open.water*	Percent of unvegetated wetland surface
surficial*	Percent of wetland surface containing floating algae or Lemnaceae
woody*	Percent of wetland surface containing woody vegetation (including dead wood and *Decadon verticillatus*)
patch variables	
forest (300, 1000)*	Percent of forest within buffers of 300m and 1 km
wetland (300, 1000)*	Percent of wetland within buffers of 300m and 1 km
esh (300, 1000)*	Percent of early successional habitat (agriculture, grassland, upland shrubland) within buffers of 300m and 1km
develop (300, 1000)	Percent of human development within buffers of 300m and 1km
road.dens (300, 1000)	Road density (m/ha) within buffers of 300m and 1km
prox.forest (300, 1000)	Proximity index for forest patches within buffers of 300m and 1km (300m search radius for both scales)
prox.esh (300, 1000)	Proximity index for ESH patches within buffers of 300m and 1km (300m search radius for both spatial scales)
prox.wetland (300, 1000)	Proximity index for wetland patches within buffers of 300m and 1km (300m search radius for both spatial scales)
landscape variables	
edge.dens (300, 1000)*	Edge density (m/ha) within buffers of 300m and 1km
juxta (300, 1000)*	Interspersion/juxtaposition index within buffers of 300m and 1km
shannon (300, 1000)*	Shannon diversity index within buffers of 300m and 1km

Chapter 2
Occupancy analysis:

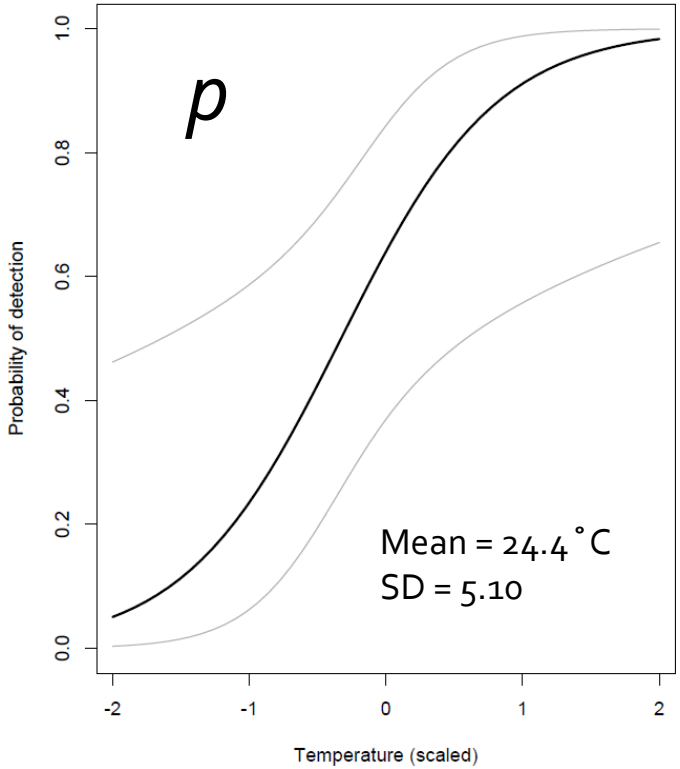
Single species, single season models with heterogeneous detection and occupancy probabilities.

Occupancy (ψ): Which features of wetlands and the surrounding landscape best explain the occurrence of each species?

Detection (*p*): Which variables that change from one sampling occasion to the next best explain our likelihood of detection for each species?

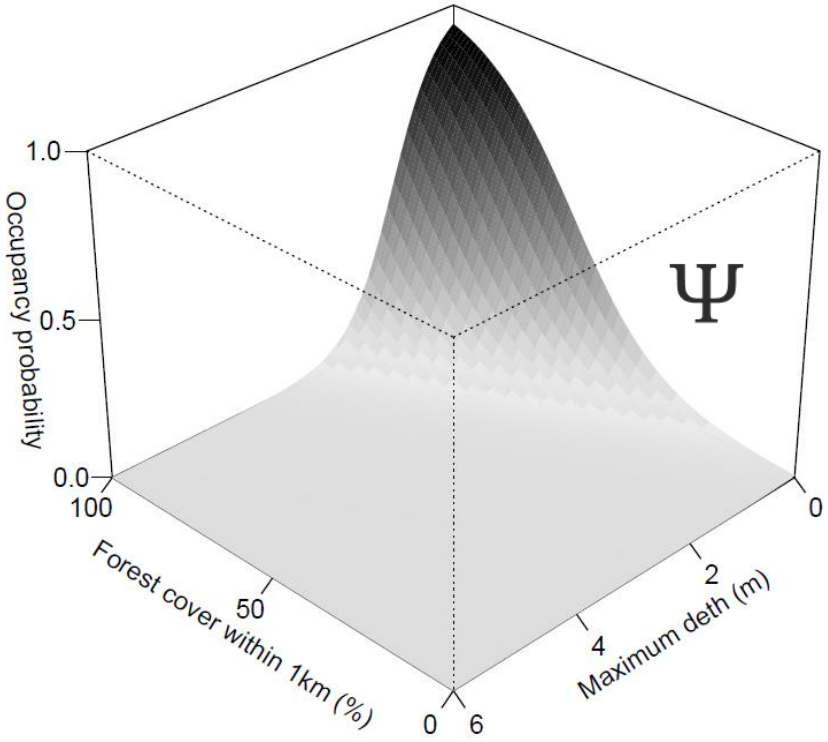
Spotted Turtle Top Detection Models:

Null estimate of detection = 0.554 ± 0.121



p intercept	*p* temp	Ψ intercept	Ψ forest.1000	Ψ max.depth	Ψ wetland.age	Ψ woody
0.40 (0.59)	**1.97 (0.78)**	**-4.10 (1.06)**	**1.86 (0.68)**	**-2.52 (1.19)**		
0.14 (0.64)	1.57 (0.72)	-4.11 (1.43)	2.20 (1.22)			1.65 (0.83)
0.26 (0.69)	1.69 (0.77)	-4.01 (1.17)	1.80 (0.95)	-1.45 (1.17)		1.15 (0.72)
-0.53 (0.48)	1.22 (0.58)	-11.00 (10.14)	6.15 (6.59)	-4.50 (4.79)	3.52 (6.16)	3.47 (3.27)

Spotted Turtle Top Occupancy Model:



Null estimate of occupancy
= 0.086 ± 0.032

p intercept	*p* temp	Ψ intercept	Ψ forest.1000	Ψ max.depth	Ψ wetland.age	Ψ woody
0.40 (0.59)	**1.97 (0.78)**	**-4.10 (1.06)**	**1.86 (0.68)**	**-2.52 (1.19)**		
0.14 (0.64)	1.57 (0.72)	-4.11 (1.43)	2.20 (1.22)			1.65 (0.83)
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-0.53 (0.48)	1.22 (0.58)	-11.00 (10.14)	6.15 (6.59)	-4.50 (4.79)	3.52 (6.16)	3.47 (3.27)

Takeaways:

- Spotted turtles are rare relative to other freshwater turtle species that use the same wetlands.
- Air temperature emerged as the most important covariate influencing detection.
- Spotted turtles occur in shallow wetlands surrounded by forest. Generally speaking, these are systems that have experienced less human-associated disturbance.

Life history comparison:

Eastern Painted Turtles
Chrysemys p. picta

- Max SCL = 25.4 cm
- Maturity 2-6 years
- 2-11 eggs/clutch; > 1/year
- Long distances (overland and waterways)
- ~84% of sampled wetlands in RI.
- Common and abundant.

Spotted Turtles
Clemmys guttata

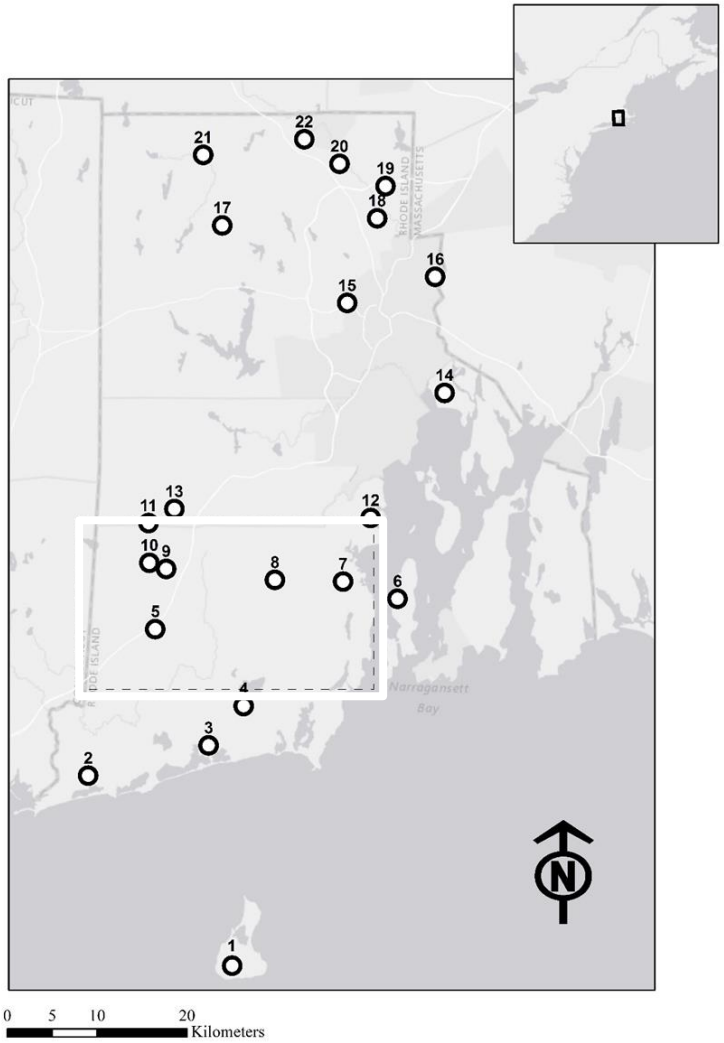
- Max SCL = 14.25 cm
- Maturity 7-15 years
- 2-6 eggs/clutch; < 1/year
- Limited movement; smaller home ranges.
- ~8% of sampled wetlands.
- Endangered.

Illustrations: Toronto Zoo; Used with permission.

Predictions:

- Greater differentiation among populations of spotted turtles.
- Genetic diversity of painted turtles > spotted turtles.
- More inbreeding within subpopulations of spotted turtles.

Sampling Results



- Sampling was opportunistic
- Microsatellite markers
- Painted turtles: **22 sites, 647 individuals**
- Spotted turtles: **11 sites, 148 individuals**

Painted Fst = 0.0185 (0.0143-0.0231)
Spotted Fst = 0.0144 (0.0045–0.0264)

Genetic Diversity:

	Number of Individuals	He	Ho	Allelic Richness
Painted Turtles	130	0.64	0.66	10.27
Spotted Turtles	137	0.68	0.66	8.59

Inbreeding

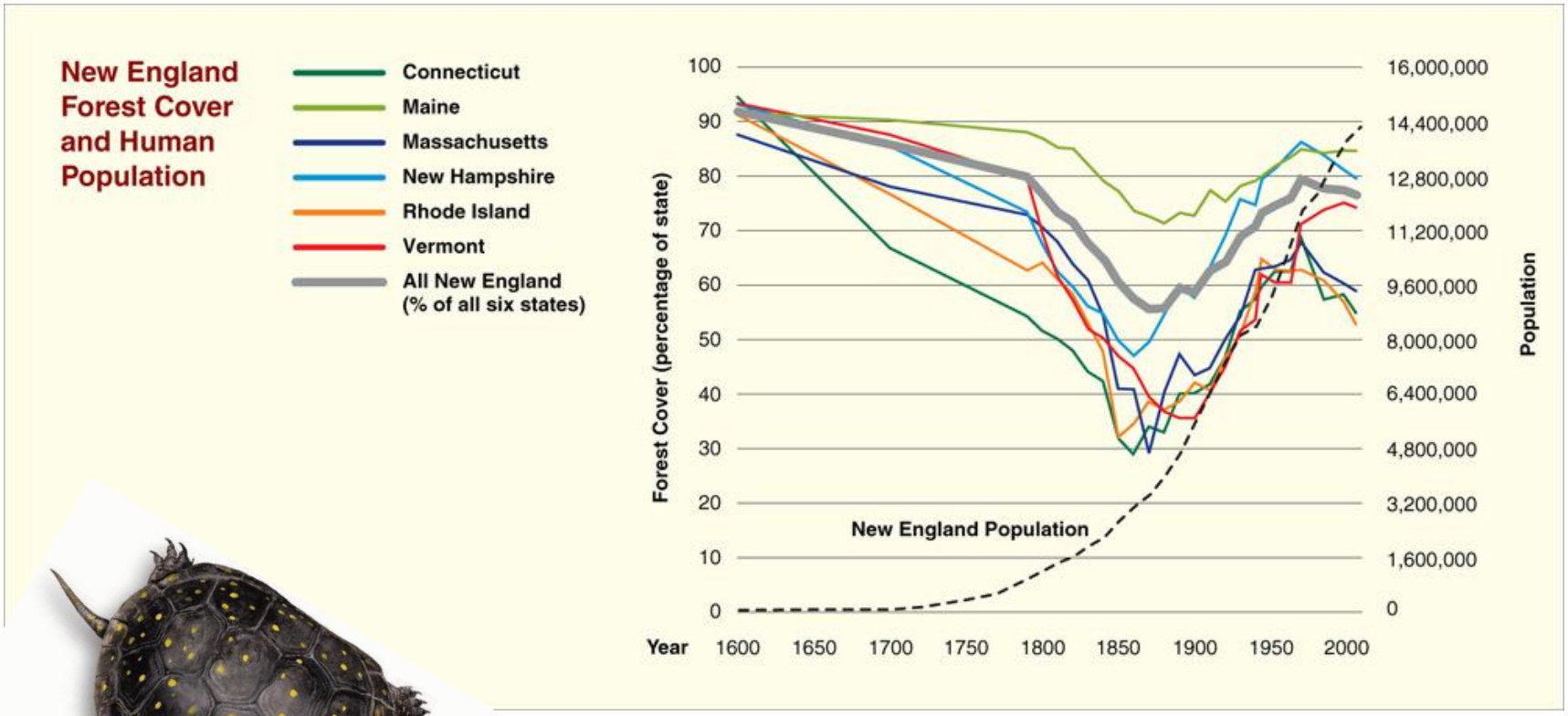
	Fis
Painted Turtles	-0.026 (-0.051– -0.001)
Spotted Turtles	0.039 (0.015–0.064)

Predictions:

- Greater differentiation among populations of spotted turtles.
- Genetic diversity of painted turtles > spotted turtles.
- More inbreeding within subpopulations of spotted turtles.

END

Intro: The New England Perspective



Illustrations courtesy of Toronto Zoo

Foster, et al. (2010)

Intro: The Global Perspective

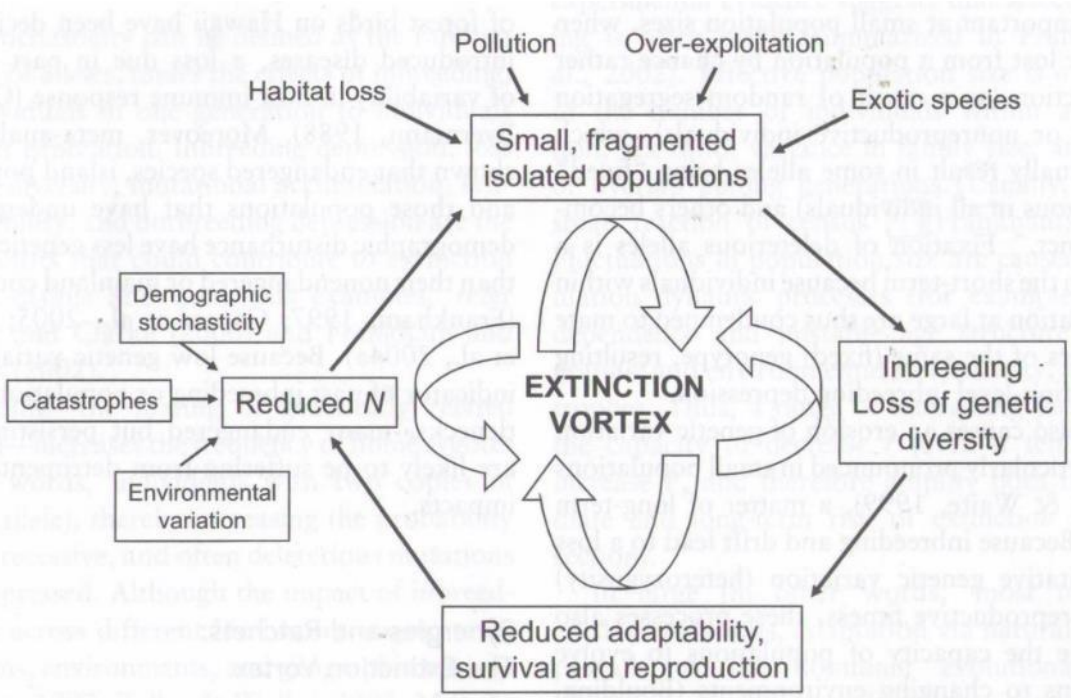


Fig 3.2 Carroll and Fox (2008)

- 50% of turtles are threatened with extinction (IUCN 2013).

Biggest Threats:

- Habitat Loss
- Illegal Collection
- Climate Change
- Pollution
- Road Mortality

Freshwater Turtles of Rhode Island:

Eastern Painted Turtle
(*Chrysemys p. picta*)

Snapping Turtle (*Chelydra serpentina*)

Spotted Turtle (*Clemmys guttata*)*

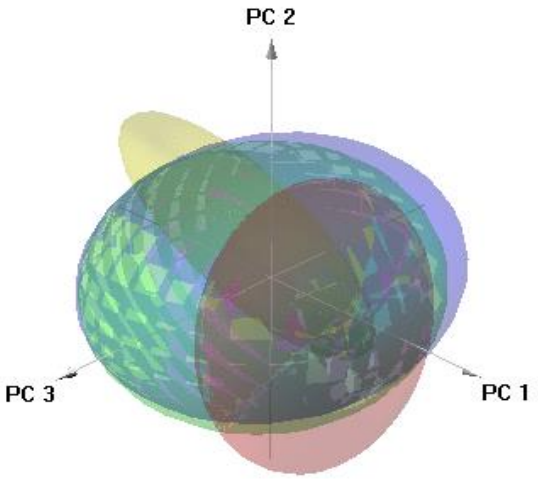
Musk Turtle
(*Sternotherus odoratus*)

Wood Turtle (*Glyptemys insculpta*)

Pond Slider
(*Trachemys s. scripta.*)

Principal components analysis:

- Species as a grouping factor
- Using all occupancy covariates (300m only scale for landscape covariates)
- Ellipses are 68% confidence intervals



	Loadings (negative -> positive)	Variance Explained (%)
PC 1	Forest dominant -> Landscape diversity	21.3
PC 2	Development -> ESH	13.1
PC 3	Shallow (woody) -> Deep (open)	10.9

- Painted Turtle
- Snapping Turtle
- Spotted Turtle
- Red-eared slider

Tissue Collection:

- < 0.25 ml of blood collected from subcarapacial vein using a sterile syringe.

- Preserved immediately in the field on Whatman FTA Cards.

Images: Douglas Knox

Summary Results:

Painted Turtles

- 647 individuals from 22 sites (mean = 29.4 turtles/site).
- 12 of 18 microsatellite loci retained.

Spotted Turtles

- 148 individuals from 11 sites; 5 sites used for population analysis (mean = 27.4 turtles/site).
- 16 of 17 microsatellite loci retained.