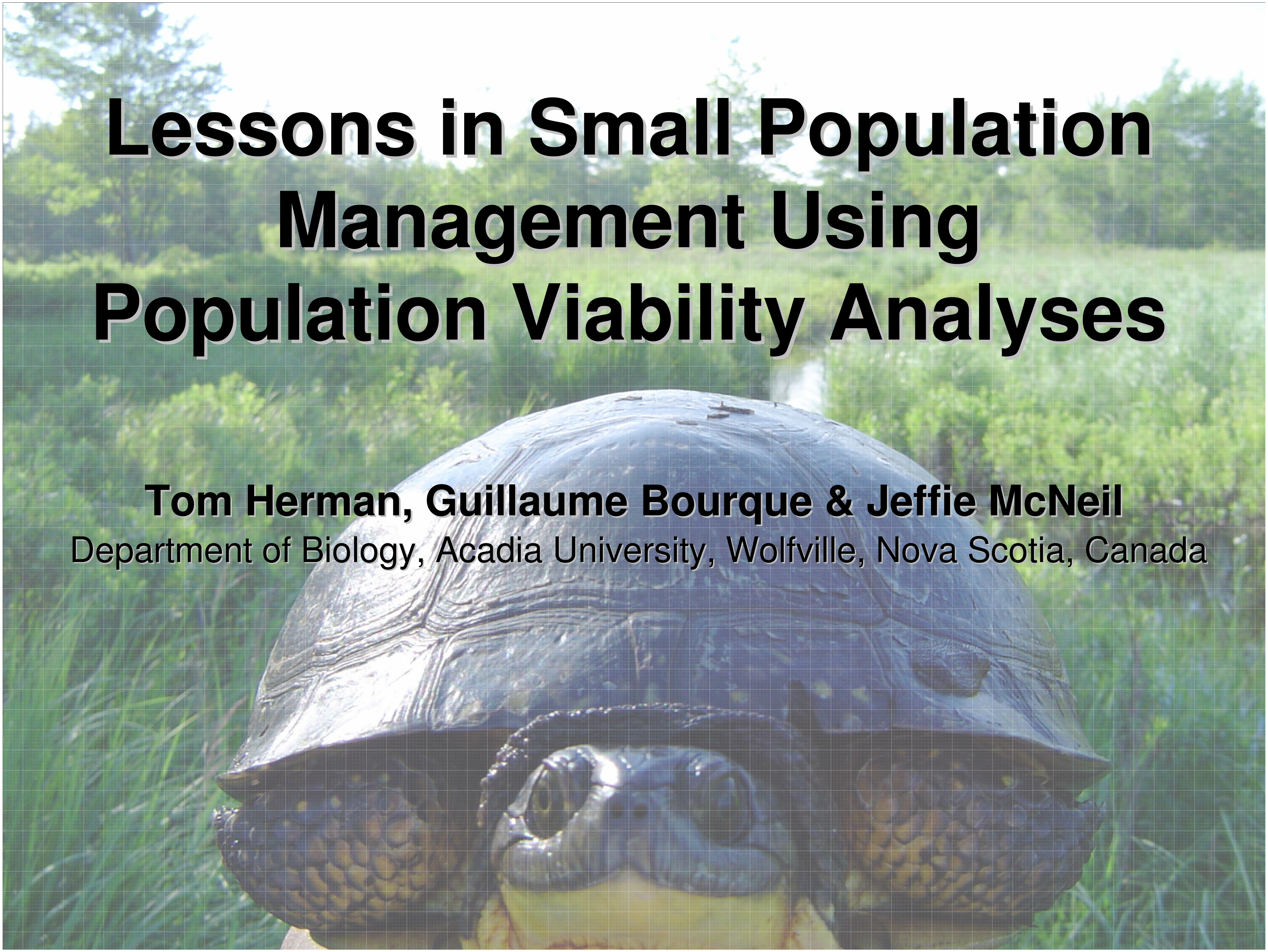
Lessons in Small Population Management Using Population Viability Analyses



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Our Intent?

- Provide a case study examining the history and development of a PVA for a Blanding's turtle population complex in Nova Scotia and its application and limitations to management (Tom)
- Examine a PVA developed for a small Illinois population closer to centre of species range (Dan)
- Engage participants in a discussion that explores the broader issues of inherent value in small populations and their management.

Value of models

- Describe systems
- Explain (reveal processes)
- Predict past, present and future outcomes
- Simplify complex systems (noise filter)
- Identify gaps in understanding (data, processes)
- **Models are most valuable when they are wrong**

Definitions

- **PVA** (population viability analysis) – attempts to identify factors that increase a population's vulnerability to extinction; usually employ models
- ***deterministic*** vs. ***stochastic*** (life is not always predictable, and chance does funny things)
- ***simple*** vs. ***complex***

Bottom Line

- All populations go extinct....eventually, but figuring out the 'when' is tricky.
- But even time is relative – best measured (and understood) in an organism's time frame

Value of PVA models

- Insights on a long-lived, late maturing species
- Reveal stages of concern and their impact on ΔN
- Allow us to assess management efficacy before-hand
- Show population trends obscured in CMR data
- Focus future research to fill knowledge gaps in demography and management
- **Models are most valuable when they are wrong**

Steps of a PVA

1. Project a population's behaviour over time interval, based on initial N and a random choice from pre-determined range of parameter values (*e.g.*, survival, reproduction)
2. Re-iterate many times
3. Assess proportion of projections that hit an absorbing boundary (usually near zero) in that time interval

Varying the range of parameters allows you to assess the risk of different management scenarios, and to identify those parameters to which the population's behaviour is most ***sensitive***

Life's really a crapshoot....
Schaffer's (1981) Four Stochasticities

1. Demographic- affect sex and age structure by varying survivorship and reproduction [turtle longevity is a useful buffer] [N, age- and sex-specific natality and mortality rates useful but scarce]
2. Environmental- easy to qualify and conceptualize but difficult to quantify directly
3. Catastrophe- more severe, acute and uncommon, usually causes outright mortality; can be brief but disastrous; rarity makes it hard to quantify
4. Genetic- changes in gene frequencies from drift, founder effect, inbreeding, etc. - virtually unknown for most populations and unlikely to affect MVP estimates in short term, but long term?

The Four Stochasticities cont'd

- Not simple to model collectively- interactions are complex, often involving runaway positive feedback, generating 'perfect storm' scenarios: the "extinction vortex" (Gilpin and Soule 1986)
- Even if you can build complex models, you sacrifice generality for precision - beware the seduction of numeracy!
- V. complex models susceptible to overfitting- lose predictive or forecasting power (start to model noise)
- **Models should inform our imagination as much as enhance our numeracy**

Relevant Literature on PVA

- Beissinger, S.R. and D. McCullough. 2002. *Population Viability Analysis*. U. Chicago Press.
- Caswell, H. 2001. *Matrix Population Models*. 2nd ed., Sinauer, Sunderland, Massachusetts.
- Morris, W.F. and Doak, D.F. 2002. *Quantitative Conservation Biology*. Sinauer, Sunderland, Massachusetts.
- Reed, J.M. *et al.* 2002. Emerging issues in population viability analysis. Cons. Biol. 16: 7-19.

Reed *et al*. 2002. *Cons. Biol. 16: 7-19*

Urged caution in use of PVA:

- Model validity depends on appropriateness of structure and data quality
- Need some measure of confidence
- External review essential
- Treat model input, structure and output as testable hypotheses
- Restrict definition to formally quantifiable models
- Do not use to determine min pop’n or specific probability of extinction

Best use:

- Assess relative effects of different management actions on population growth and persistence

María B. García. 2008. **Life history and population size variability in a relict plant. Different routes towards long-term persistence.** *Diversity and Distributions, (Diversity Distrib.)* 14: 106–113

- “Vulnerable” rupicolous herb in Pyrenees; crevice-dweller, pollinated by hoverflies; sticky seeds, rarely ventures far from Mom....gene flow restricted
- How do small, fragmented relict populations persist for 1000’s of years?
- How will they respond to increased fragmentation and climatic variability?
- Recorded reproductive and demographic parameters for 6 y, and built deterministic and stochastic matrix models to explore population dynamics and extinction risk.

García's Aims:

1. "assess the spatio-temporal variability of reproductive and survival parameters in three adjacent populations of dramatically different sizes";
2. "model how vital rates translate into population growth rates, and examine the life-history components that most contributed to such spatio-temporal variability in population dynamics";
3. "assess the long-term vulnerability, by exploring the relative importance of life history and population size."

What did she find?

- Structure, fecundity, recruitment, survival rate, and life span varied among populations.
- Life-history parameters and their temporal variability were significantly differentiated- as a consequence population vulnerability under current conditions and simulated global changes, *e.g.,* habitat fragmentation or higher climatic fluctuations, varied substantially.
- *Differences in growth rates of seedlings* and *timing of adulthood* contributed most strongly to differences in population structure.

Lessons from García?

- A direct *population size - extinction risk* relationship can be too simplistic
- Knowledge of life history may be most important in predicting future population behaviour
- So, perhaps not all small populations are created equal from a conservation viewpoint
- Although you'd expect significant variation in demography and reproduction across large geographic ranges, you may not expect it in small localized populations. But it turns out that the spatial scale of variation can be strikingly small....
- A cautionary tale....*perhaps even in turtles!*

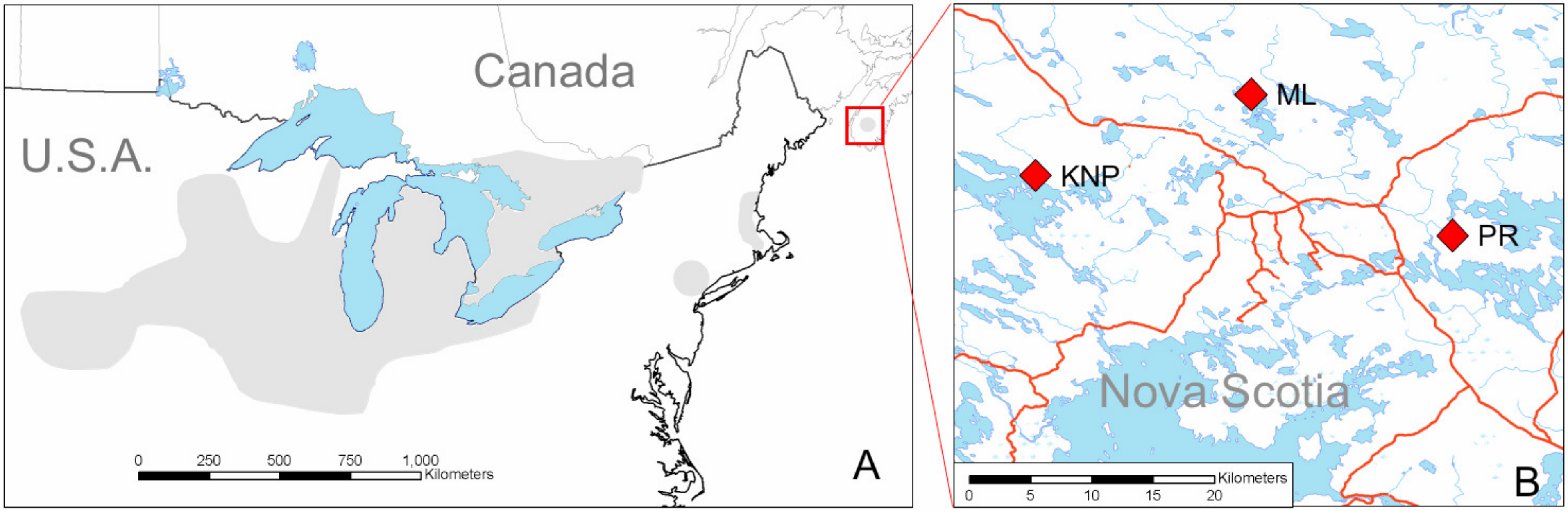
MVP’s

- MVP (minimum viable population)?..... how small depends on your sense of time and your expectation of future conditions
- Highly variable within and among spp.
- Rules of thumb? - for vertebrates Soulé (1987) suggests several 1000’s to survive several centuries with 95% certainty (assuming isolation)
- Therefore most small populations receiving attention today are << MVP, and sophisticated and precise PVA’s are probably irrelevant (although they may be useful to assess appropriate re-introduction scenarios after populations fail)

Scale and Population Structure

- Underscores importance of scale and of understanding population structure (recognize genetically distinguishable units)
- Unfortunately ‘functional’ populations can be perishingly small!
- But, if we can identify discrete subpopulations we can measure key demographic and environmental parameters in each, Δ’s in N, Δ’s in number of populations, and degree of movement among them (either directly by monitoring or indirectly by genetics)
- “Movement” easily manipulated for some spp. - **and the rules of movement have fundamentally changed**.

Nova Scotia Blanding's complex



Origin of concern about state of population

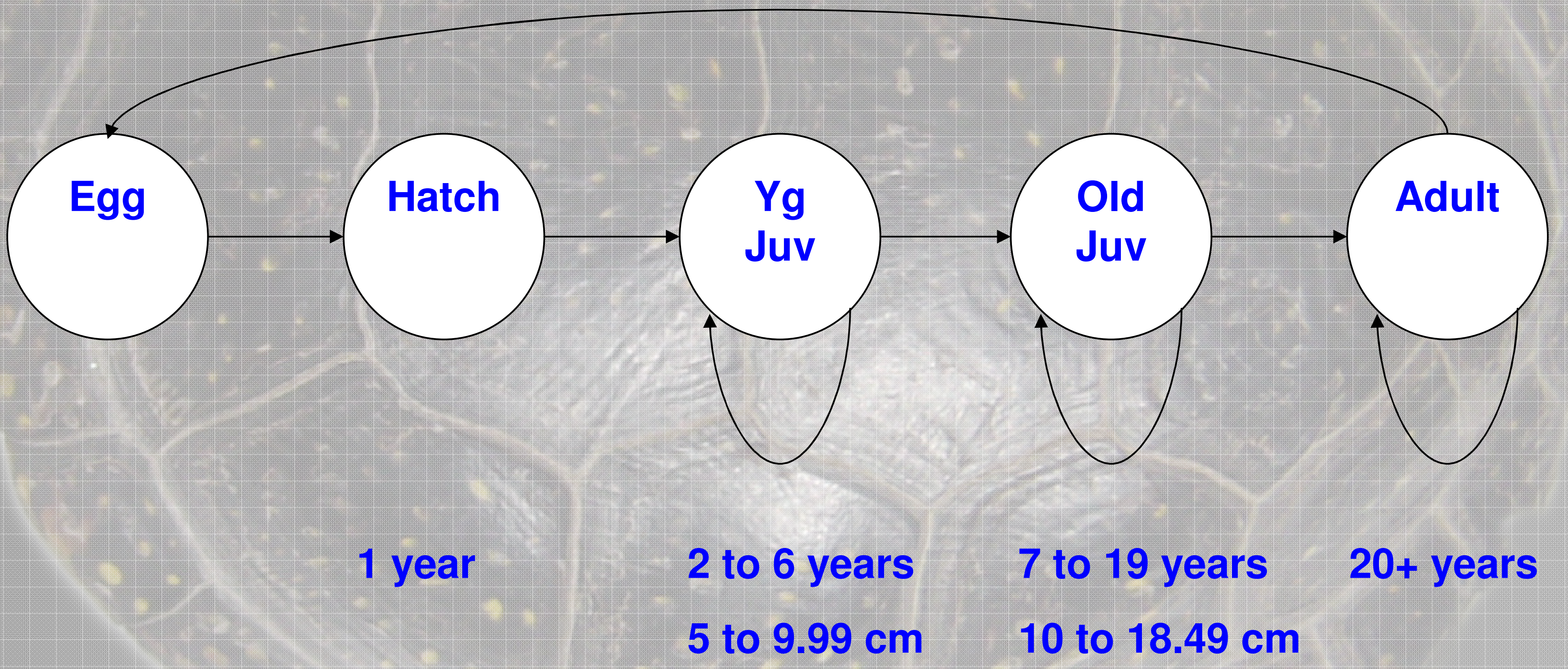
- The Nova Scotia population complex was originally designated "Threatened" federally (COSEWIC) and is designated "Endangered" provincially (NSESA).
- In the early '90s, virtually no apparent adult recruitment and few recorded juveniles - a small and apparently declining population (Herman *et al.* 1995).
- COSEWIC reclassified this population complex as "Endangered" following earlier PVA work.

Life stages (duration)




- Egg (3 months)
- Hatchling (1 year)
- Young Juvenile (5 years) CL=[5,10]
- Old Juvenile (13 years) CL=[10,18.5]
- Adult (estimated to be around 60 years)

Stage structure



Stage structure

	Egg	Hatch	Yg Juv	Old Juv	Adult		N
Egg	0	0	0	0	5		200
Hatch.	0.5	0	0	0	0		100
Yg Juv	0	0.1	0.75	0	0	X	40
Old Juv	0	0	0.1	0.90	0		20
Adult	0	0	0	0.05	0.99		60

Management options

- No management
- Screening nests
- Ex-situ incubation
- Headstarting hatchlings
  - Conservative (1 yr)
  - Liberal (2 yr)

Sampling history- KNP

	Years	Total # of records
Adults	<1987	**405**
	1987-1988 (Terry Power years)	**1568**
	1989-1993	**147**
	1994-2005 (Nest monitoring, intensive trapping)	**1806**
Juveniles	<1987	**10**
	1987-1988 (Terry Power years)	**23**
	1989-1993	**2**
	1994-1996 (Nat McMaster and Ian Morrison)	**263**
	1997-2000	**40**
	2001-2005 (Directed juvenile sampling)	**304**

Varying effort (in spatial extent, intensity and methodology) in long-term studies is a fact of life.

Reliability of data - identifying the knowledge gaps at KNP

	Quantity	Quality	Spatial Extent	Temporal Extent	Notes
Age classes/transitions					
Eggs	H	H	M-H	H	Good data from caged nests only
Eggs - hatchlings	H	M	M-H	H	Good data from caged nests excluding escapees
Hatchling - young juveniles	L	L	L	L	**This is a critical information gap**
Young juveniles	L	H	L	M	Mostly from 3 years in 2 areas
Old juveniles	L	H	M	M-H	Mostly since 1995
Adult males	M	H	H	H	Lacking effort in some areas over time
Adult females	H	H	H	H	Good data from 5 areas (monitoring program)
Parameters					
Nesting frequency	H	L	M-H	H	Lack of secure ID's on ~30% each year
Clutch size	H	H	M-H	H	
Flooding intensity	H	H	M-H	M	Need long term data on this factor
Predation	L	M	M-H	L	Few years without nest screening
Nest location	M	H	M-H	H	Good data from 5 areas; lacking 2+
Adult sex ratio	H	H	H	H	
Percent of nests caged	M	M	M-H	H	Even from known nesting sites, we miss ~30%
Survival incubated eggs	L	H	N/A	L	Estimates based on other studies/ species
Survival captive headstarts	H	H	N/A	M	7 years of data from 2 studies

Sampling history- McGowan

- West Bog sampled 1997-2005 relatively even effort
  - First juvenile – 1998
  - First nesting observations – 2000
  - First overwintering observations – 2000

- East Brook sampled 1997-2005 less intensively and with varying effort and timing
  - First nest 2005

- Other areas sampled less consistently and intensively

Reliability of data - identifying the knowledge gaps at McGowan

Reliability of data	Quantity	Quality	Spatial Extent	Temporal Extent	Notes
Age classes/transitions					
Eggs	M	H	M	M	Good data from caged nests only
Eggs - hatchlings	M	H	M	M	Good data from caged nests
Hatchling - young juveniles	L	L	L	L	**This is a critical information gap**
Young juveniles	L	L	L	L	**This is a critical information gap**
Old juveniles	M	H	M	M	Low N but high re-capture of some individuals
Adult males	H	H	M	M	High recapture and mating observations
Adult females	H	H	M	M	High recapture and mating observations
Parameters					
Nesting frequency	M	H	M	M	Good data from West Bog females
Clutch size	M	H	M	M	Good data from West Bog
Flooding intensity	L	H	M	L	Need long term data on this factor
Predation	L	M	M	L	Few years without nest screening
Nest location	M	H	M	M	Good data from West Bog
Adult sex ratio	H	H	M	M	Good data from West Bog
Percent of nests caged	M	M	M	M	Good data from West Bog

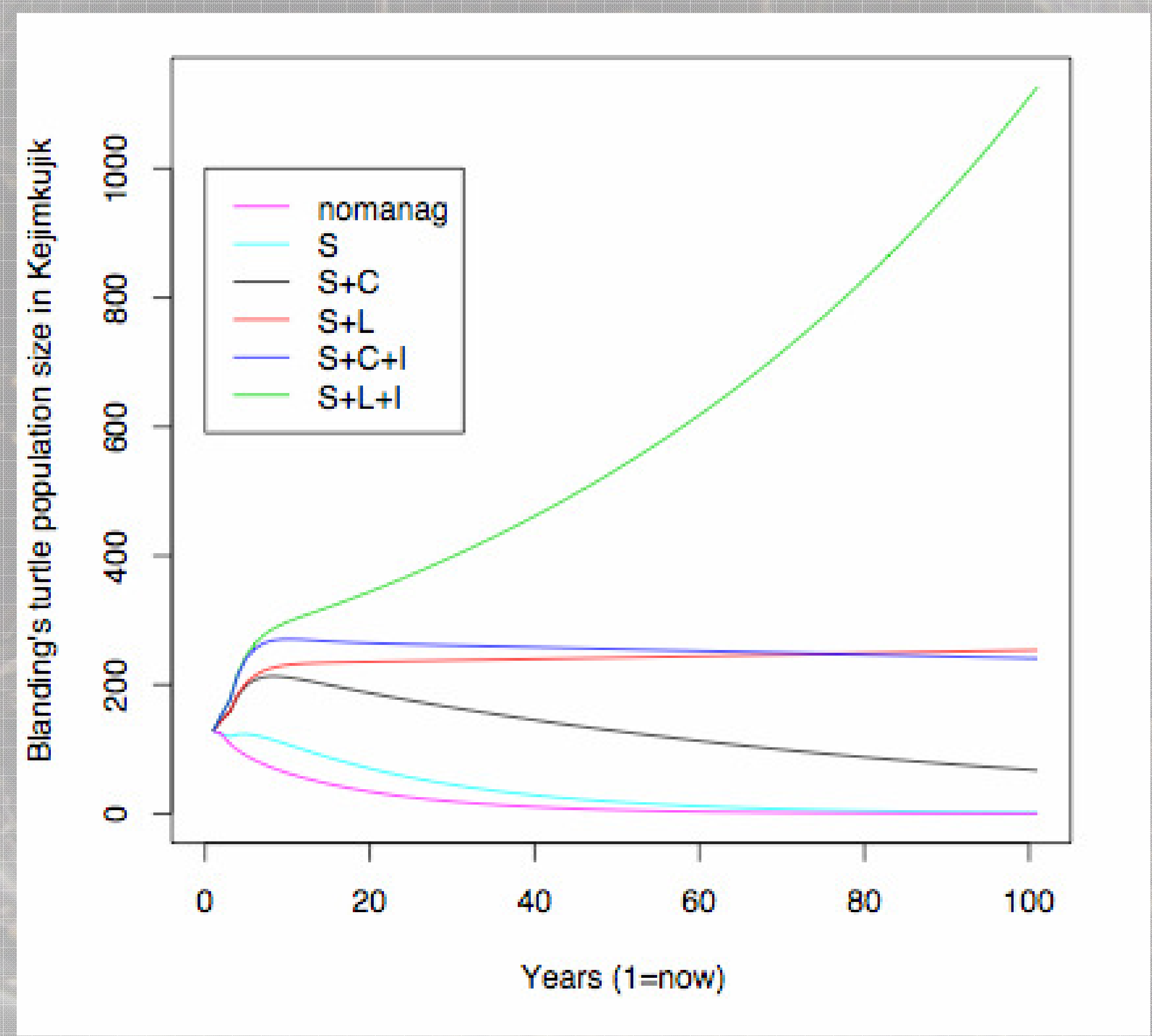
Uncertainty and variability

- Deterministic models consider only the mean, no error modeled
- Stochastic models add variability (process or environmental error); this is error due to stochastic factors (winter kill, flooding, cold summer)
- Stochastic models can be enhanced by adding uncertainty (non-process or measurement error); this is error due to the estimation process, declining asymptotically with sample size (detectability, statistical error)
- One criticism of PV models is innate dependency of model on parameter values - if you add uncertainty you can assess how dependent your conclusions are on parameter values

Phase I

- Simple deterministic model (*i.e.* no uncertainty or variability)
- Kejimkujik National Park and National Historic Site (KNP) only
- All parameters were estimated from our own data
- Employed a stage-based transition matrix
- Compared 6 management regimes, applied constantly over 100 years
- Weakest element was juvenile survivorship estimates

Model predictions : Phase I

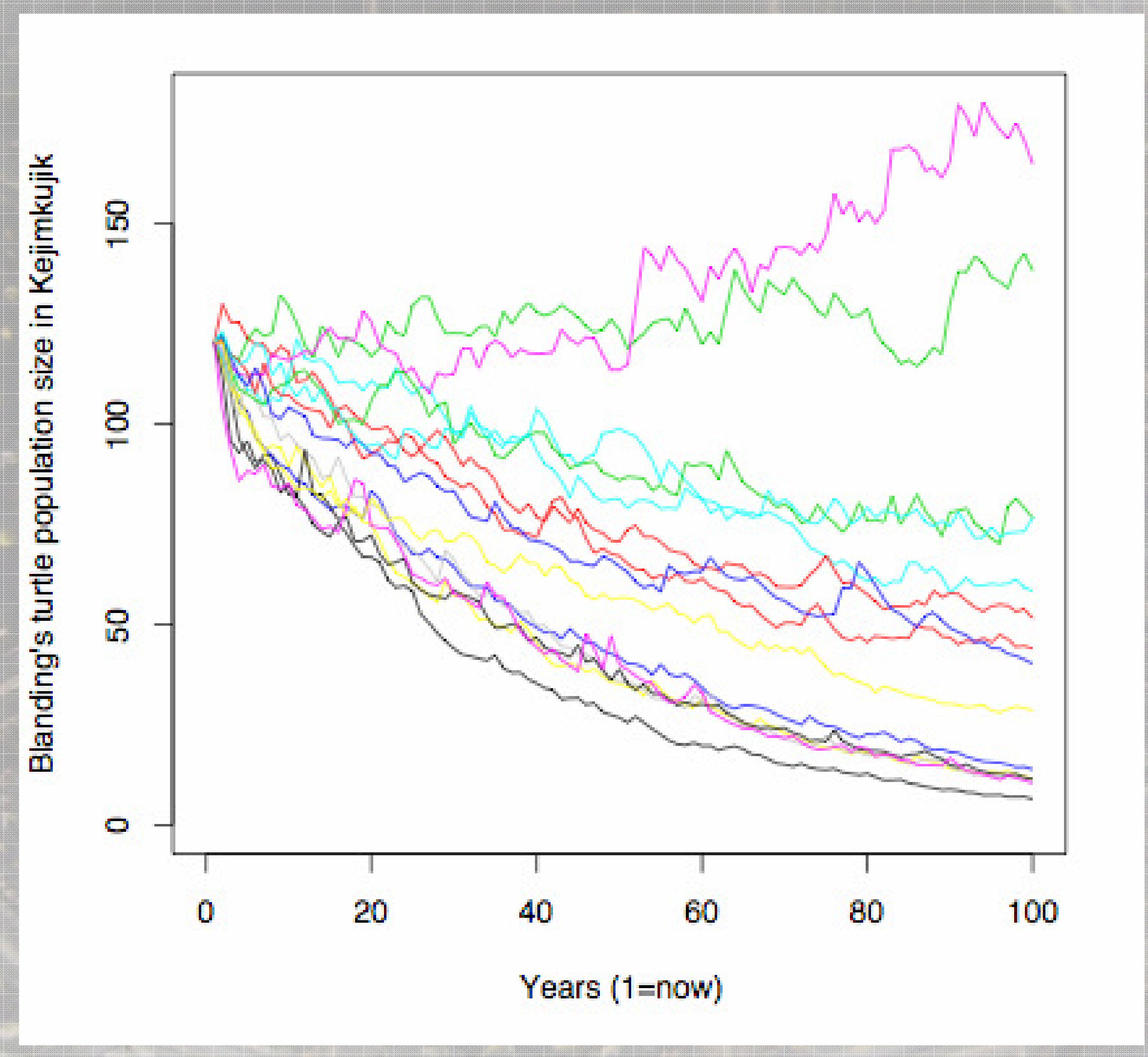


% of eggs incubated or hatchlings headstarted = 25 %

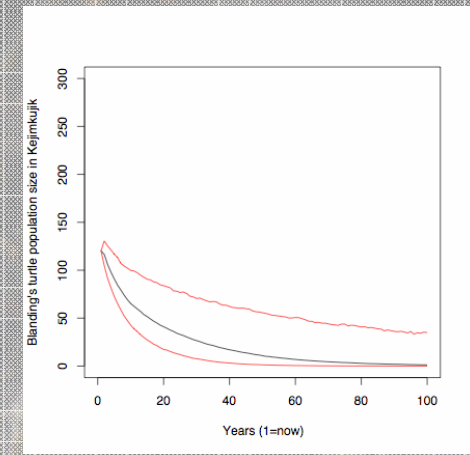
Phase II, and beyond

- Addition of inter-annual stochastic variability
- Incorporation of uncertainty in parameter estimates
- Additional important variables were included (flooding, nest location, % nest caged, % females nesting)
- Parameter estimates were refined using 2003-4 data
- More management regimes were assessed, and allowed to fluctuate in their application over 100 years
- Effect of adult survivorship, as well as juvenile survivorship, on ΔN was investigated more closely
- Weakest elements were omission to account for recapture probability in juveniles and sampling effort in adults

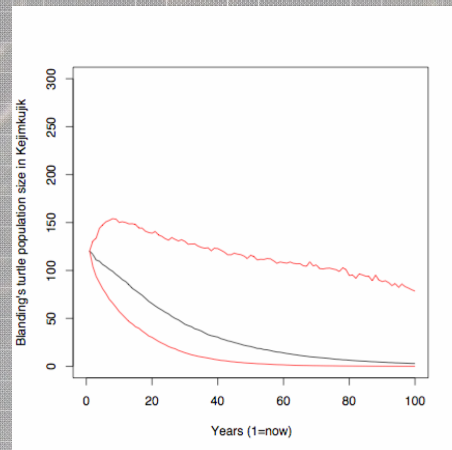
Variability vs Uncertainty



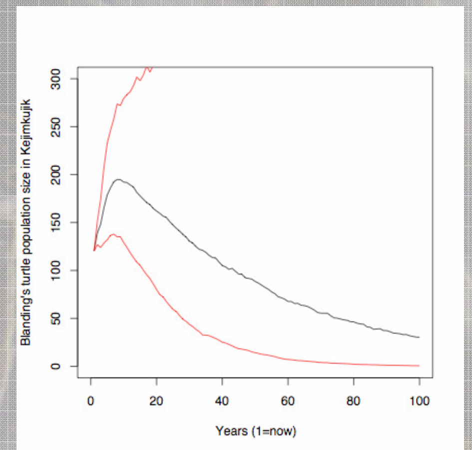
Model predictions : Phase II



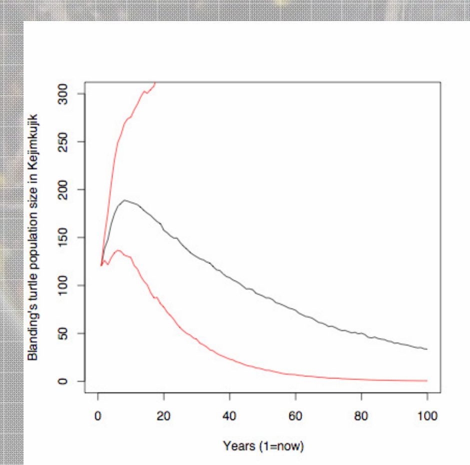
No management



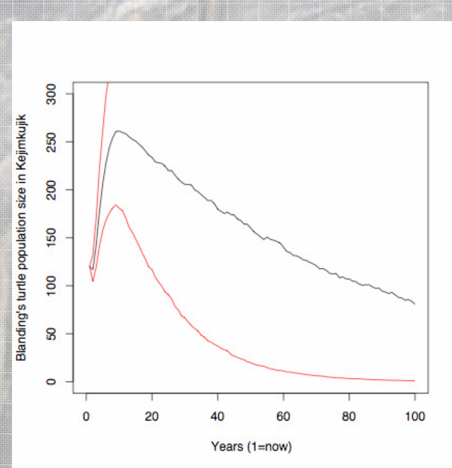
Screening



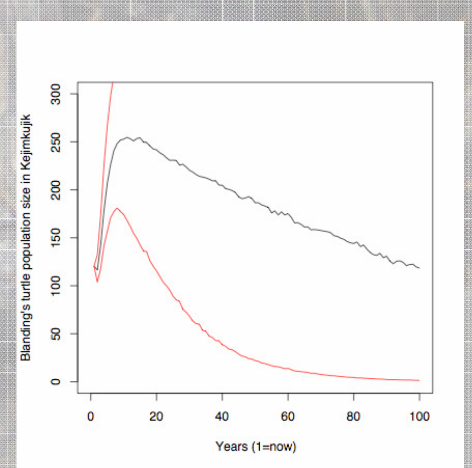
Screen + Conserv H



Screen + Lib H



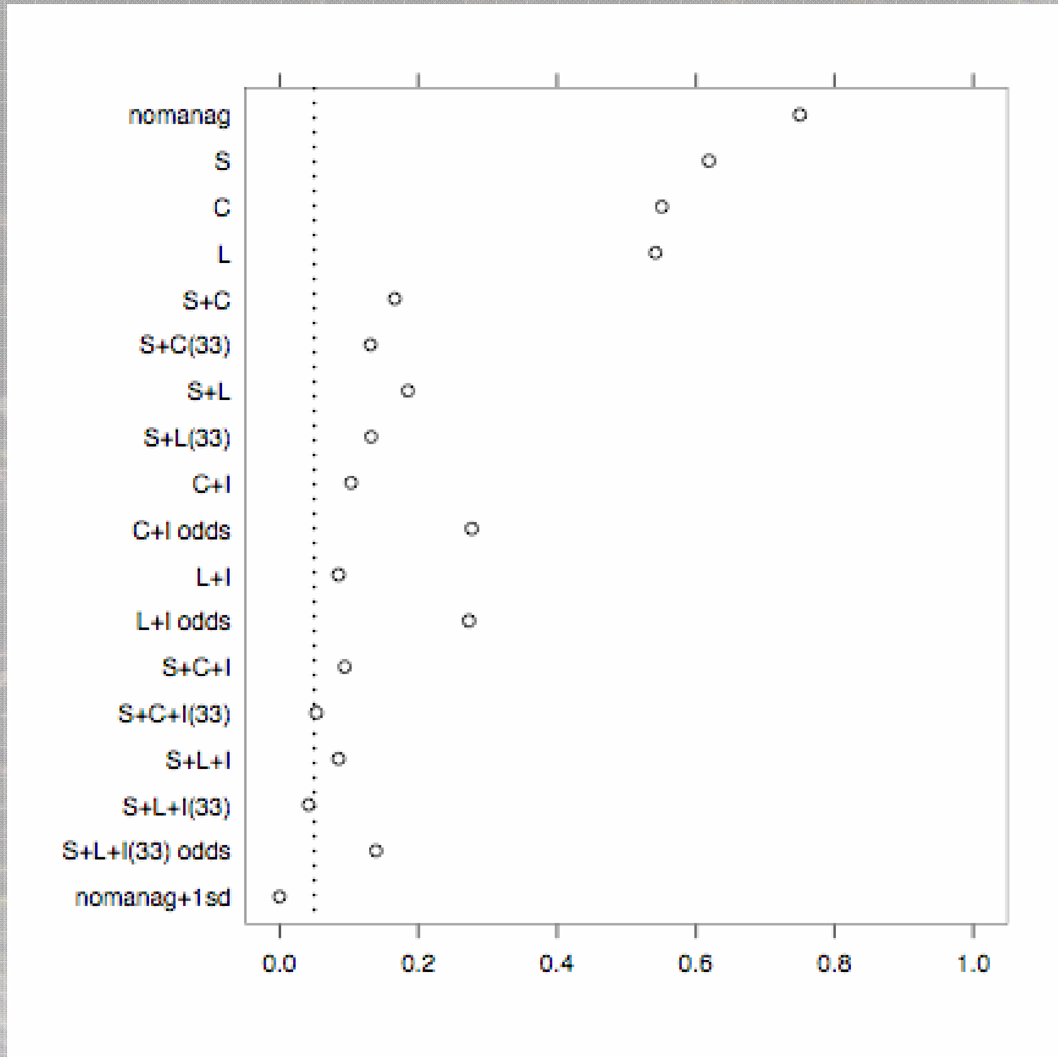
Screen + Conserv H + Incub



Screen + Lib H + Incub

% of eggs incubated or hatchlings headstarted = 25 %

Risk of extinction



Risk of extinction (% of simulation with ≤ 5 ind. after 100yrs)

Latest Phase

- Parameter estimates were recalculated by adding new data and re-evaluating existing data
- Reevaluated variability and uncertainty estimates
- Assessed a wide range of heterogenous management regimes, that fit within the constraints of cost and implementation
- Considered the population outcome after
  - 100 yrs (2.5 generations)
  - 400 yrs (10 generations)
  - 2000 yrs (50 generations)
- Assessed effect of varying mgmt. regularity and intensity
- Effect of adult survivorship on ΔN was also investigated

Model Mechanics

- Model code was written within the R framework (www.r-project.org)
- Each simulation was run 1000 times
- Population size is defined as the sum of young juveniles, old juveniles and adults
- Output shows median population sizes with 95 % CI
- Absorbing boundary set at N=5
- Risk of extinction is the proportion of simulations that reaches extinction
- Probability of decline is the proportion of simulations that had a lower final N than initial N

Survivorship calculations

- Adult survivorship: Pradel model (including estimates of survival, recapture probability and recruitment) run in MARK, correcting for Terry Power's years and for varying effort (http://www.cnr.colostate.edu/~gwhite/mark/mark.htm)
- Old juvenile survivorship: Stage-specific Cormack-Jolly-Seber model (including estimates of survival and recapture probability) run in MARK, correcting for varying effort
- Hatchling and young juvenile survivorship: Age-specific Cormack-Jolly-Seber model run in MARK, correcting for diff's in effort across time

Uncertainty and variability estimation

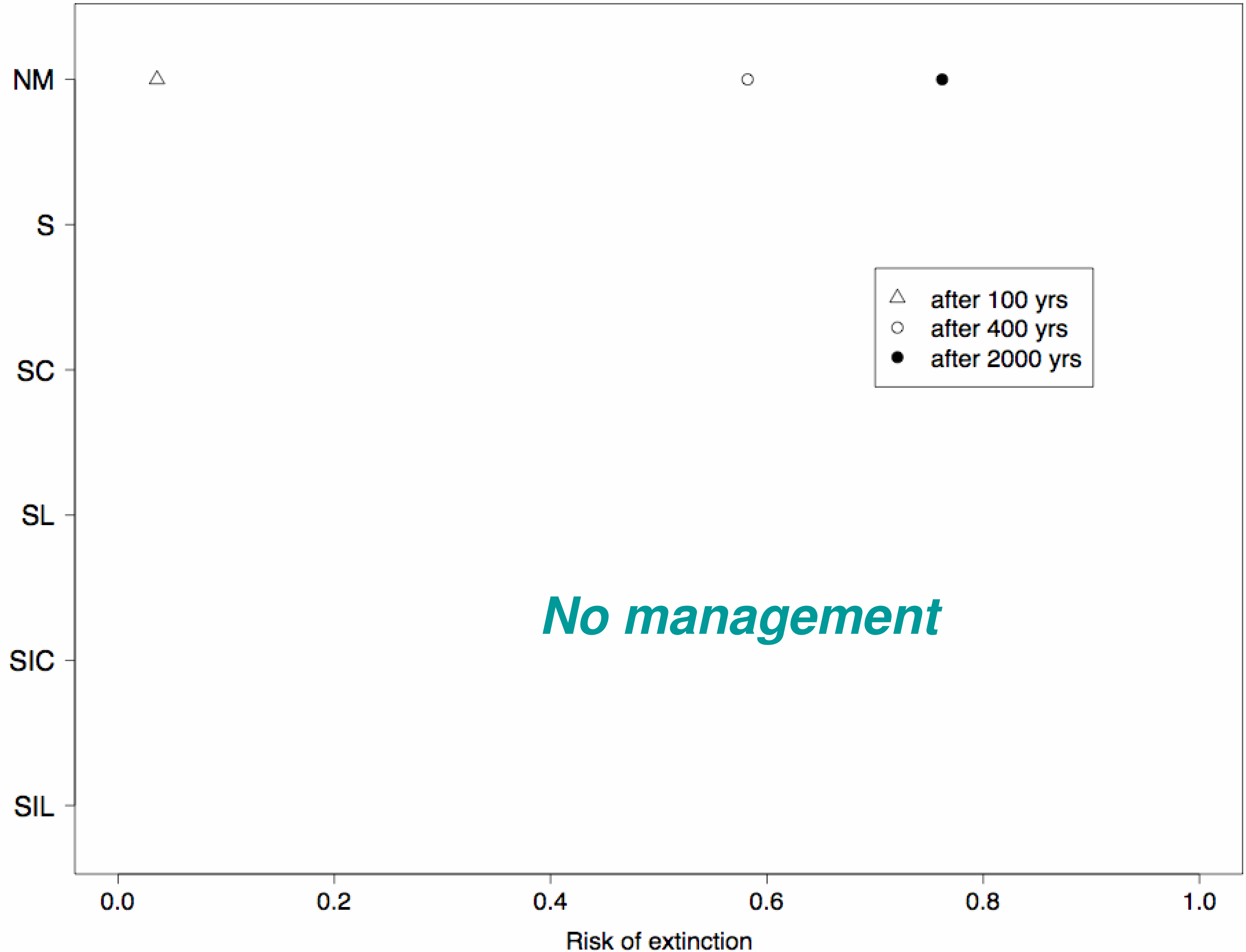
- Both uncertainty and variability were estimated based primarily on standard deviations of calculations and ecological knowledge of the system

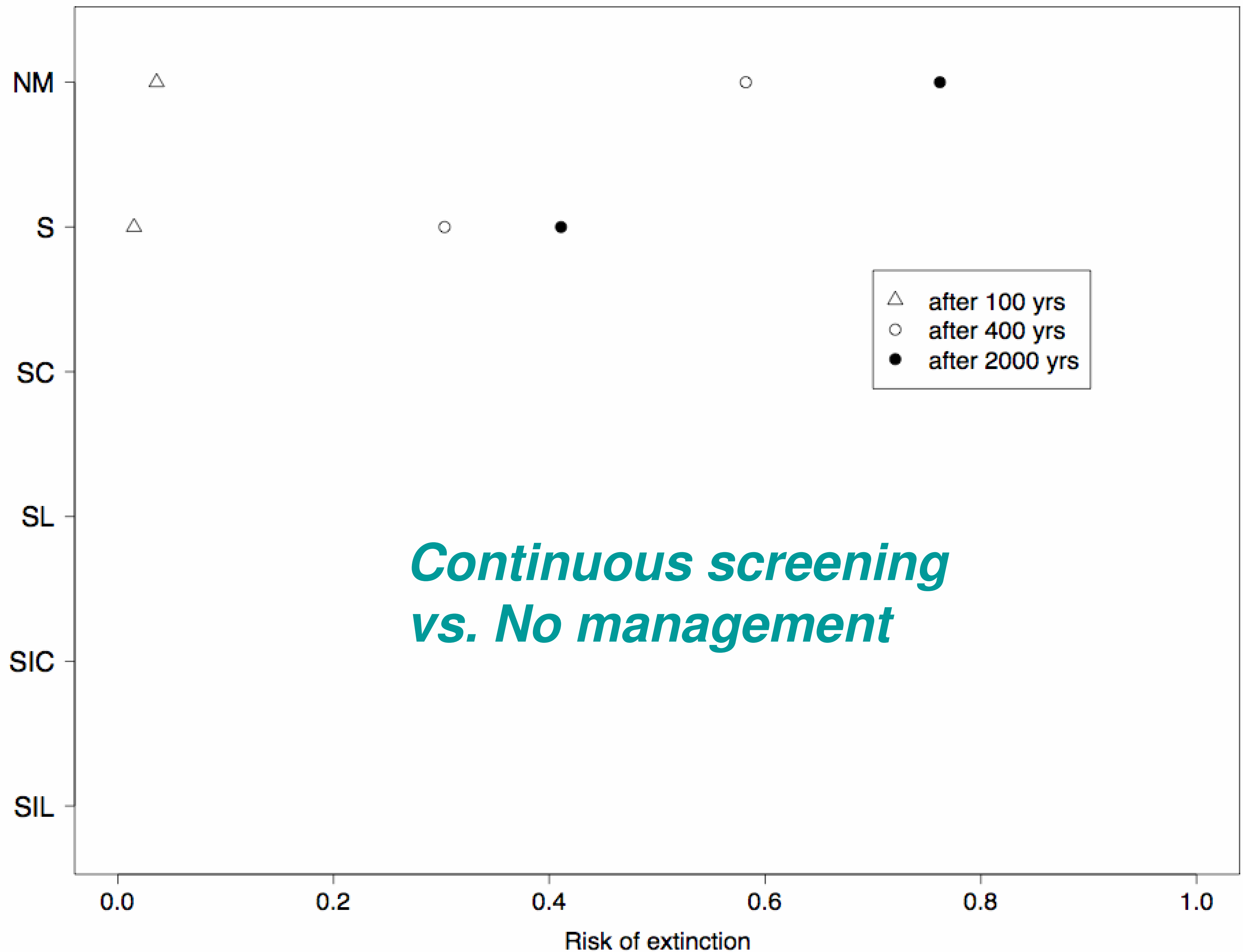
66 000 simulations,

132 000 000 population sizes,

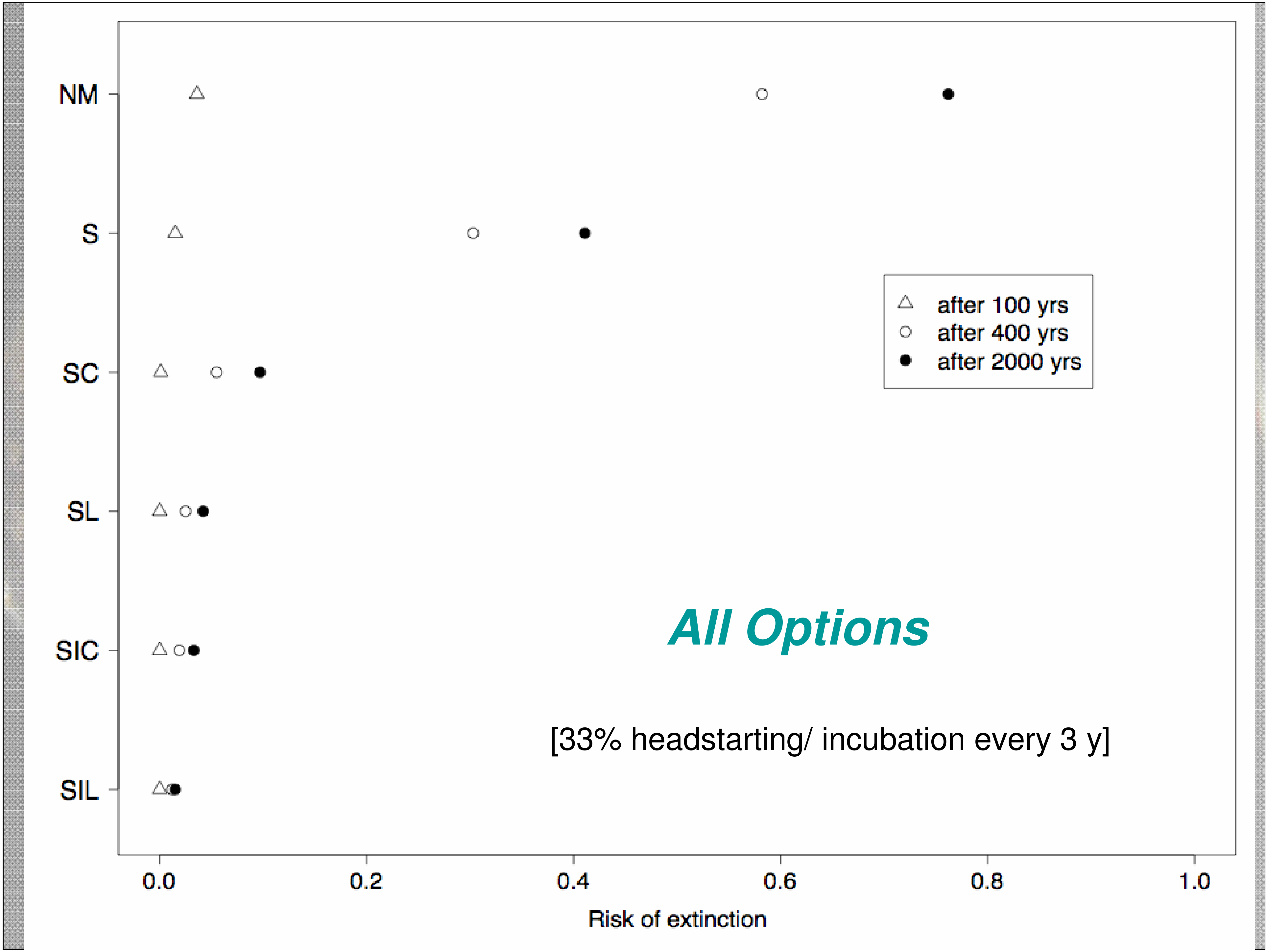
and

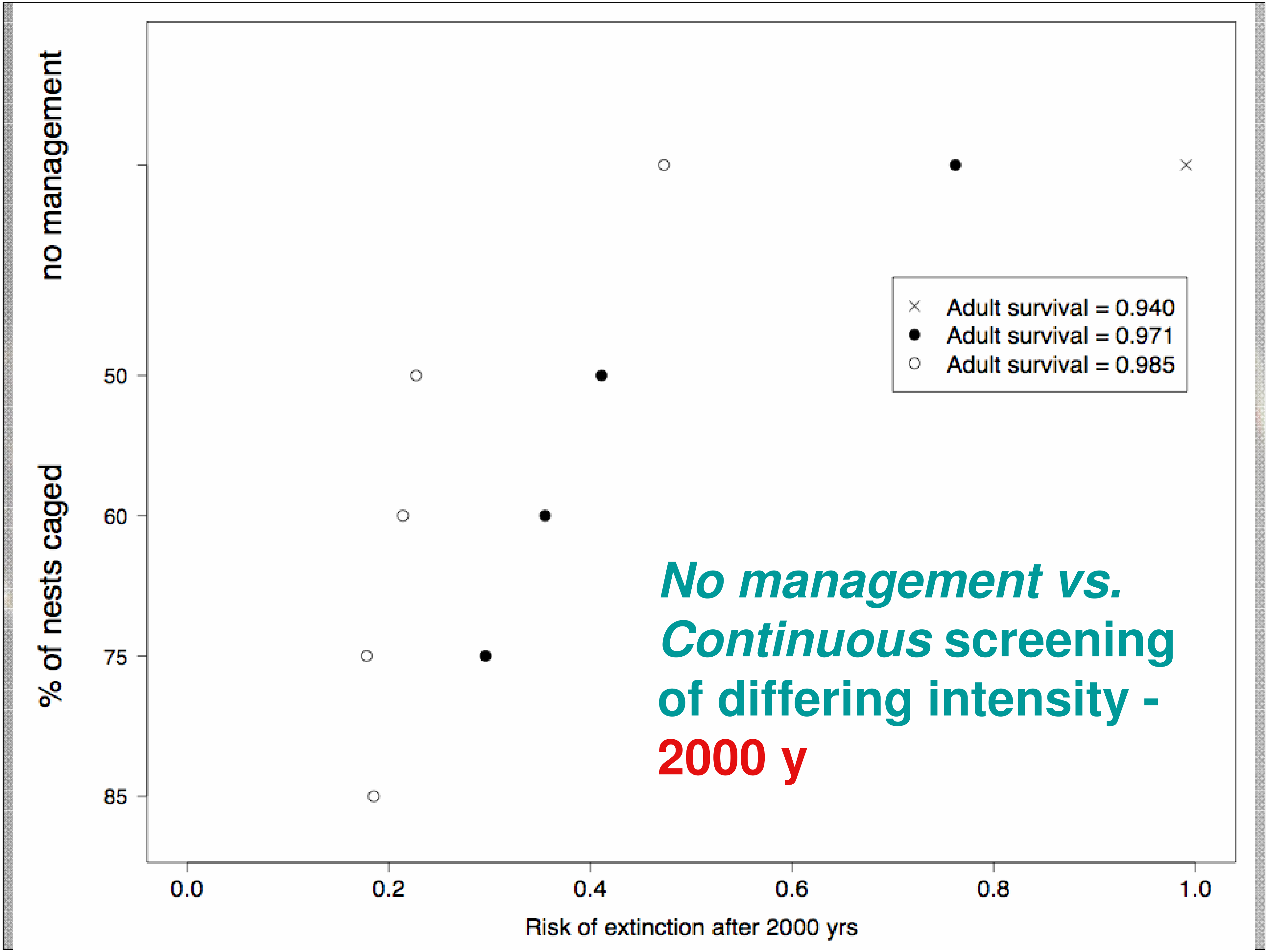
1.75 Gb of text files later…

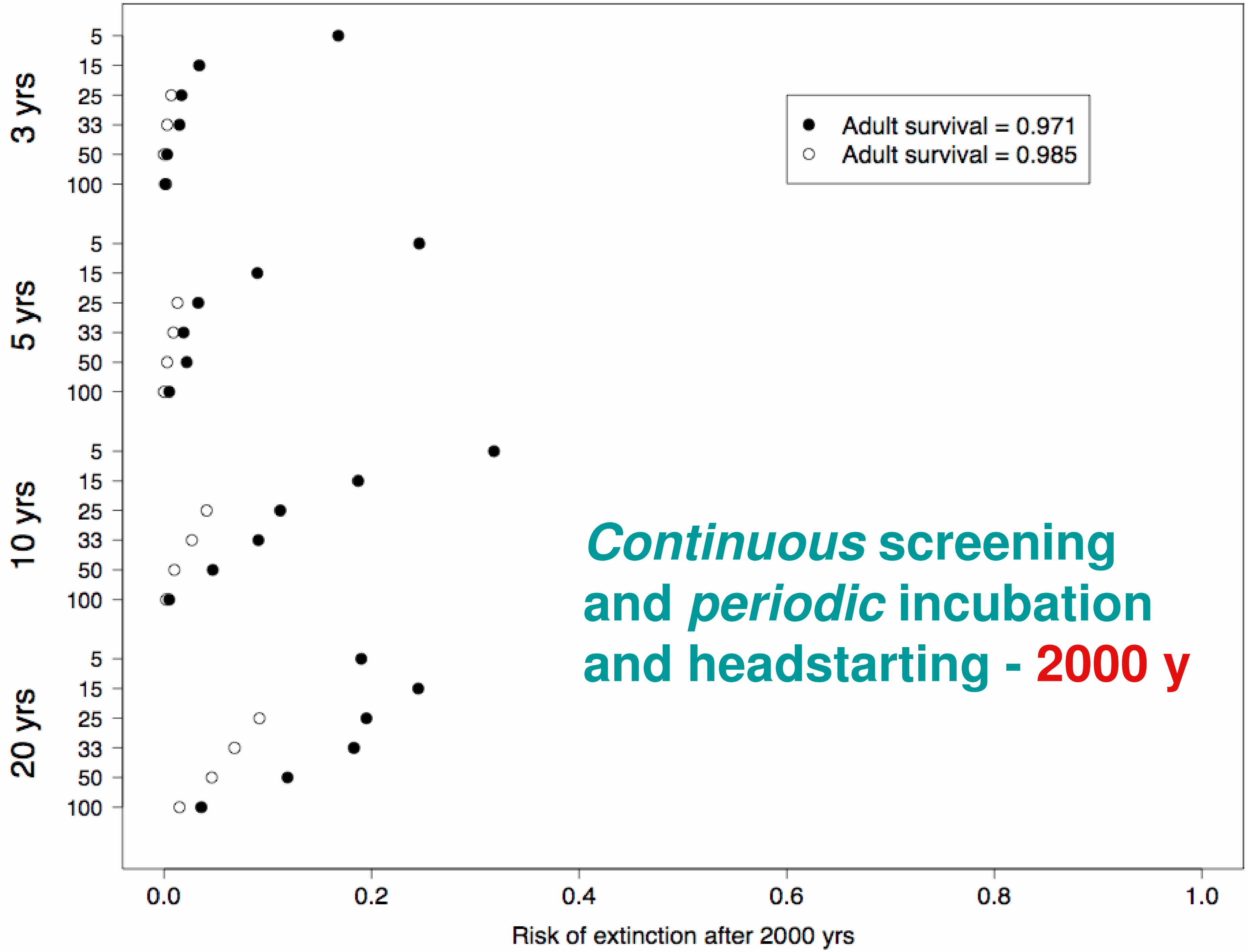

NM
S
SC
SL
SIC
SIL
after 100 yrs
after 400 yrs
after 2000 yrs
No management
0.0
0.2
0.4
0.6
0.8
1.0
Risk of extinction



NM
S
SC
SL
SIC
SIL
after 100 yrs
after 400 yrs
after 2000 yrs
Continuous screening
vs. No management
0.0
0.2
0.4
0.6
0.8
1.0
Risk of extinction


NM
S
SC
SL
SIC
SIL
after 100 yrs
after 400 yrs
after 2000 yrs
All Options
[33% headstarting/ incubation every 3 y]
0.0
0.2
0.4
0.6
0.8
1.0
Risk of extinction


no management
% of nests caged
50
60
75
85
Adult survival = 0.940
Adult survival = 0.971
Adult survival = 0.985
No management vs.
Continuous screening
of differing intensity -
2000 y
0.0
0.2
0.4
0.6
0.8
1.0
Risk of extinction after 2000 yrs



3 yrs
5 yrs
10 yrs
20 yrs
5
15
25
33
50
100
Adult survival = 0.971
Adult survival = 0.985
0.0
0.2
0.4
0.6
0.8
1.0
Risk of extinction after 2000 yrs
Continuous screening
and *periodic* incubation
and headstarting - 2000 y

Lessons from Nova Scotia?

- Simulations revealed significant extinction risks without management intervention
- Management substantially improved long-term survival chances
- Power of numeracy lies in the rapid response of the authorities to alter regulations; intrusion tolerance increased dramatically!

BLANDING’S TURTLE (*Emydoidea blandingii)* RECOVERY PROJECT IN DUPAGE COUNTY, ILLINOIS

Dan Thompson
Forest Preserve District of DuPage County
Wheaton, IL USA

Blanding's Turtle Program History

- 1987-1990: County-wide reptile & amphibian surveys
- 1994: Blanding's Turtle population study
- 1996: Head-start program initiated
- 1998-2000 Population viability analysis
- 1999: State of Illinois listed as threatened
- 2001: Nesting activity monitored

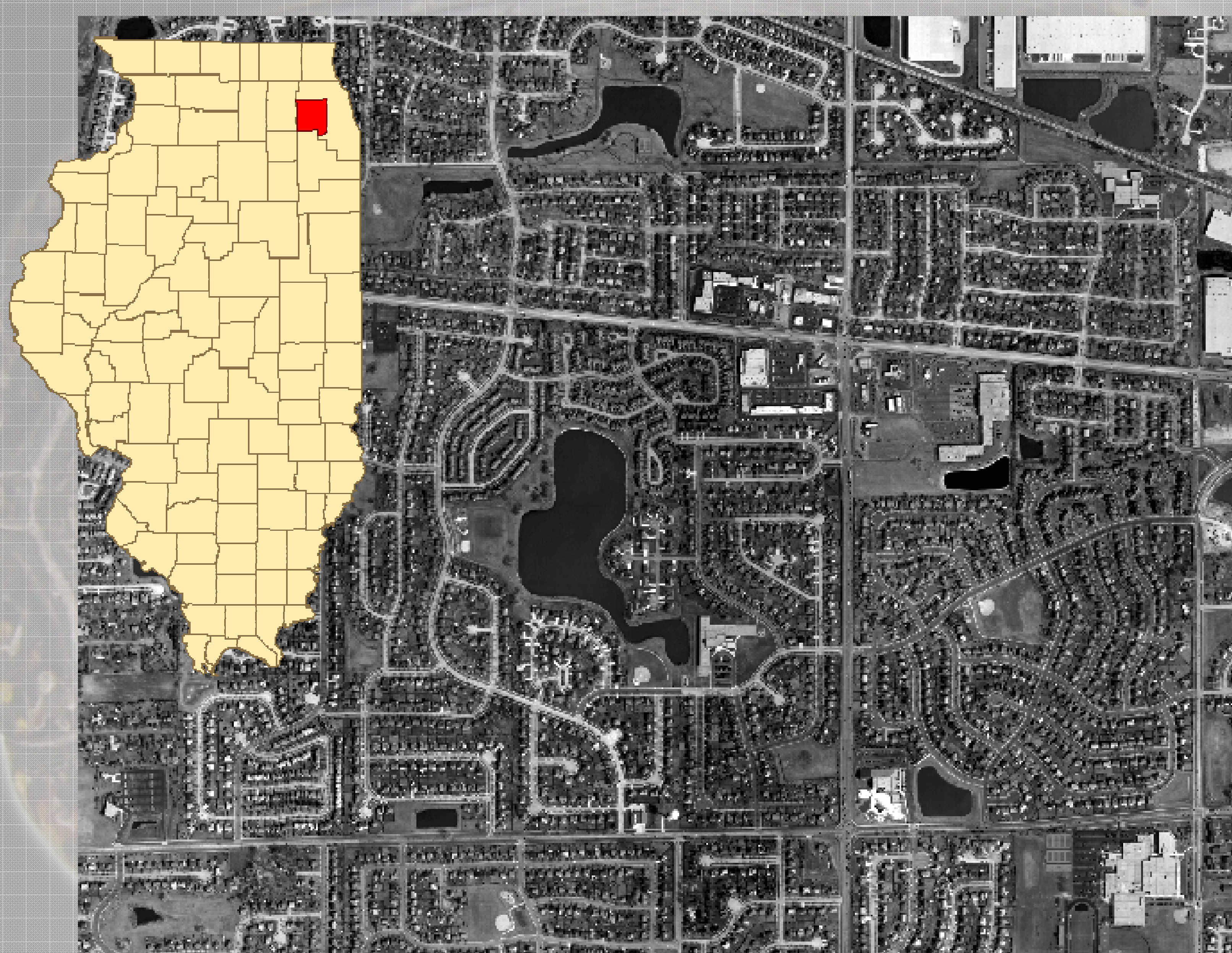
Population Viability Analysis

- VORTEX computer software (Lacy 1993a) for population viability analysis
- Input Parameters-mostly taken using data taken from Congdon et al. 1993 work at University of Michigan's E. S. George Reserve supplemented with limited DuPage County data

Input Parameters

Carrying capacity for healthy populations range from 2.5-22.3 per acre

DuPage County populations were estimated at 0.1 per acre


1954
2003

Model assumes 74% natural nest mortality

Hatchling success is estimated at 26% for survival through one year of age

Model Predictions

Release of less than 100 turtles seems to provide little benefit

With 80% juvenile annual survivorship less than 3% of the released turtles would be expected to survive to breeding age

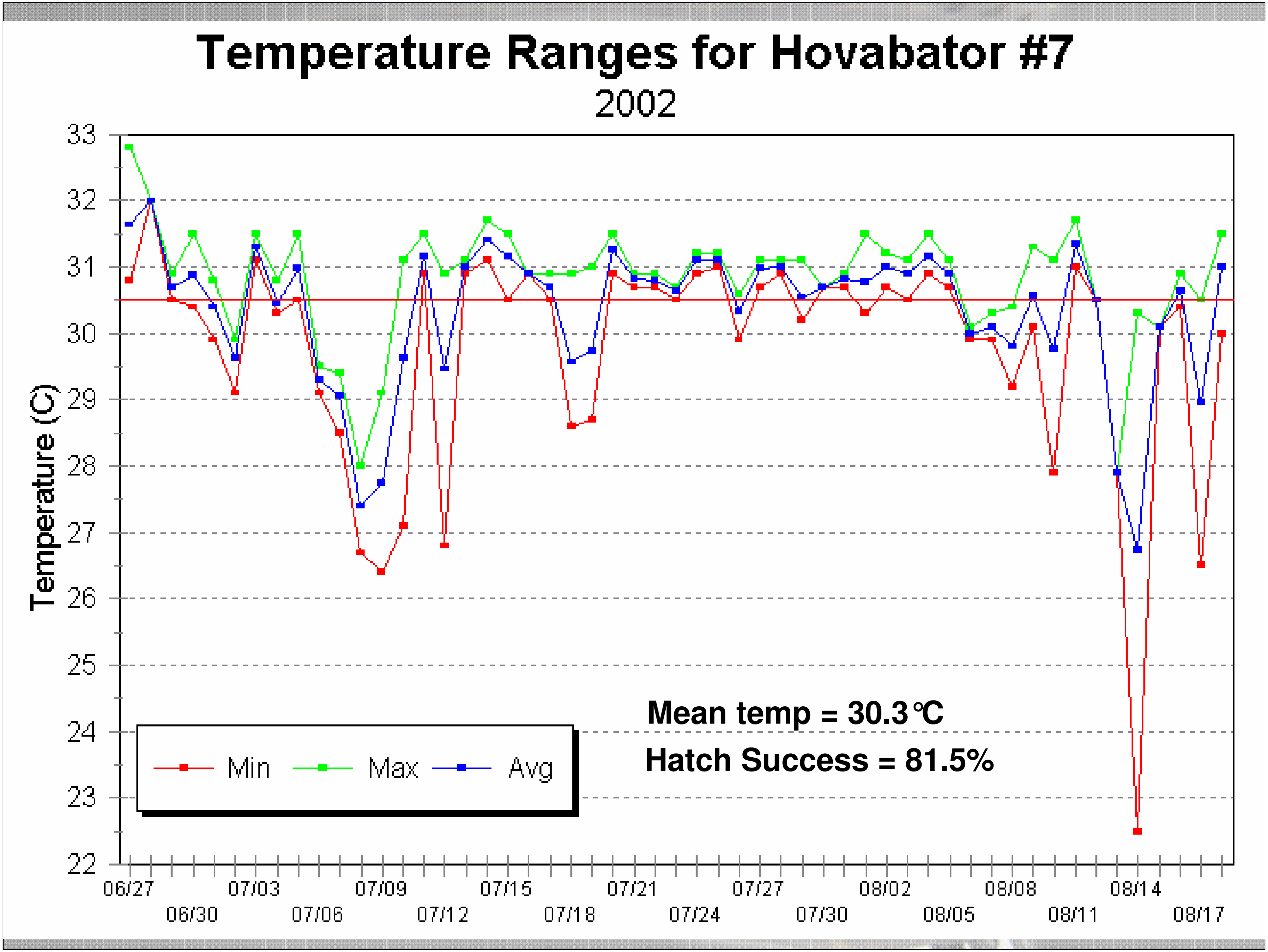
Genetics

- Ruben et al. 2001 Chicago region populations isolated and may be genetically depauperate, although currently do not exhibit significant differentiation

- To maintain more genetic diversity and reduce inbreeding is to combine presently isolated populations (and prevent any further fragmentation) Transferring head started juveniles can mutually reinforce each population

Predators

Incubation Sex Ratio


Temperature Ranges for Hovabator #7
2002
Temperature (C)
33
32
31
30
29
28
27
26
25
24
23
22
06/27
06/30
07/03
07/06
07/09
07/12
07/15
07/18
07/21
07/24
07/27
07/30
08/02
08/05
08/08
08/11
08/14
08/17
Min
Max
Avg
Mean temp = 30.3℃
Hatch Success = 81.5%

Hatchling success reached 95% in 2006

Human Pressures

Husbandry Issues

- Habituation
- Loss of instinctual fear of predators
- Disease and Parasites *Entamoeba invadans*
- Nutritional requirements
- Natural rate of development

Release Techniques

Various ages and size

Mainly Fall release = Soft release

Some supplemental Spring release

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Illinois Department of Natural Resources
Dr. Daniel R. Ludwig

Dr. Justin Congdon; *Professor Emeritus, University of Georgia*

University of Illinois
Cory Ruben, MS

Values

- Spiritual
- Aesthetic
- Intrinsic
- Transformative
- Biophilic
- Social amenity
- Economic
- Ecological
- Scientific

[see D. Takacs, 1996]