Population Viability Analyses

- PVA's are SIMULATION models of likely trajectory of population in question into the future, based on the BEST current <u>ESTIMATES</u> of demography & environmental impacts. Therefore, by definition, they are only best GUESSES
- BUT PVA's can be VERY useful to conservation biologists, especially if properly constructed AND interpreted.

Overview of Population Viability Analyses

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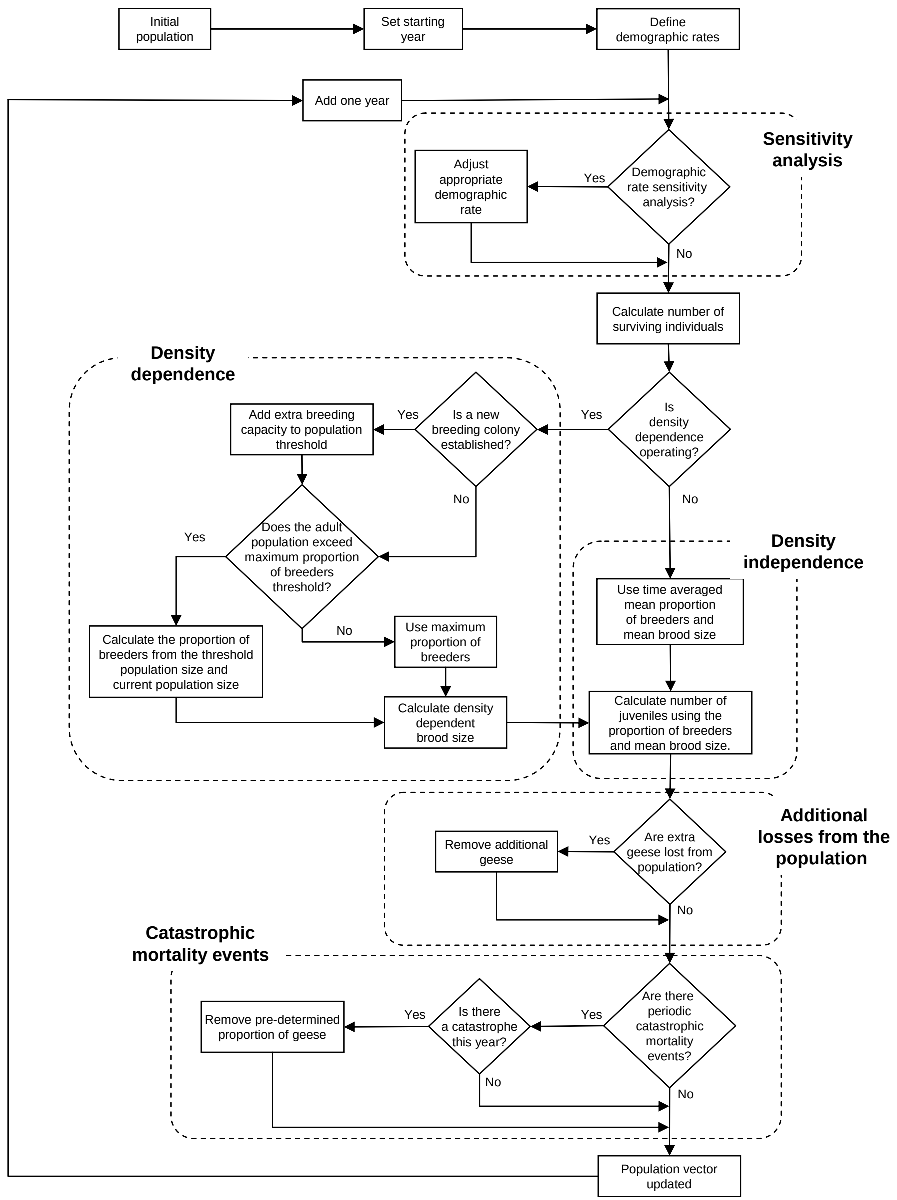
Example PVA Black box



Appendix 3. Flow chart describing the density dependent, stochastic population model for the Svalbard barnacle goose.

Population Viability Analyses

It should always be borne in mind that population viability analysis is essentially an exercise in *probability*. Figures produced by population viability analysis are the *probabilities* of given population trajectories over given time scales; the decision on *how certain a population's persistence* must be, and over what *time scale*, before it is classified as safe, remains *largely subjective*.

What PVA’s are NOT

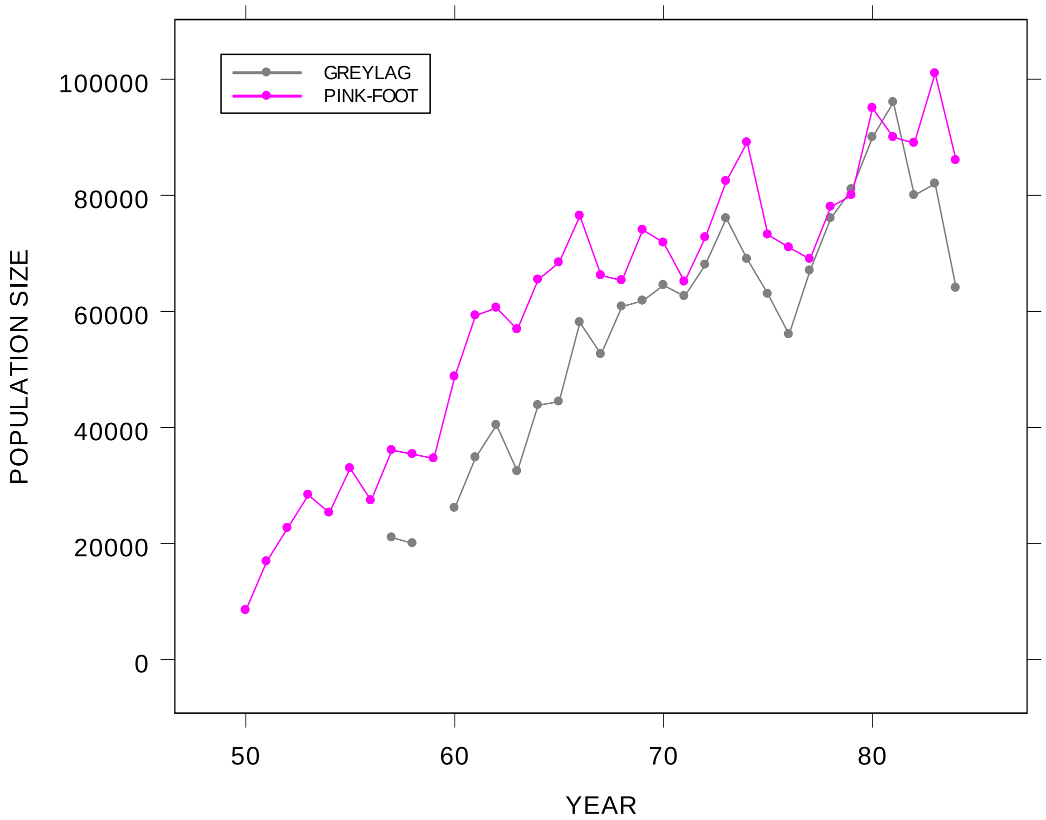
- PVA’s do NOT give certainty to predictions into the future
- PVA’s only give PROBABILISTIC behaviour into the future: NOT absolute numbers
- ONLY as good as the data on which they are based: GARBAGE IN; GARBAGE OUT

What PVA's CANNOT DO

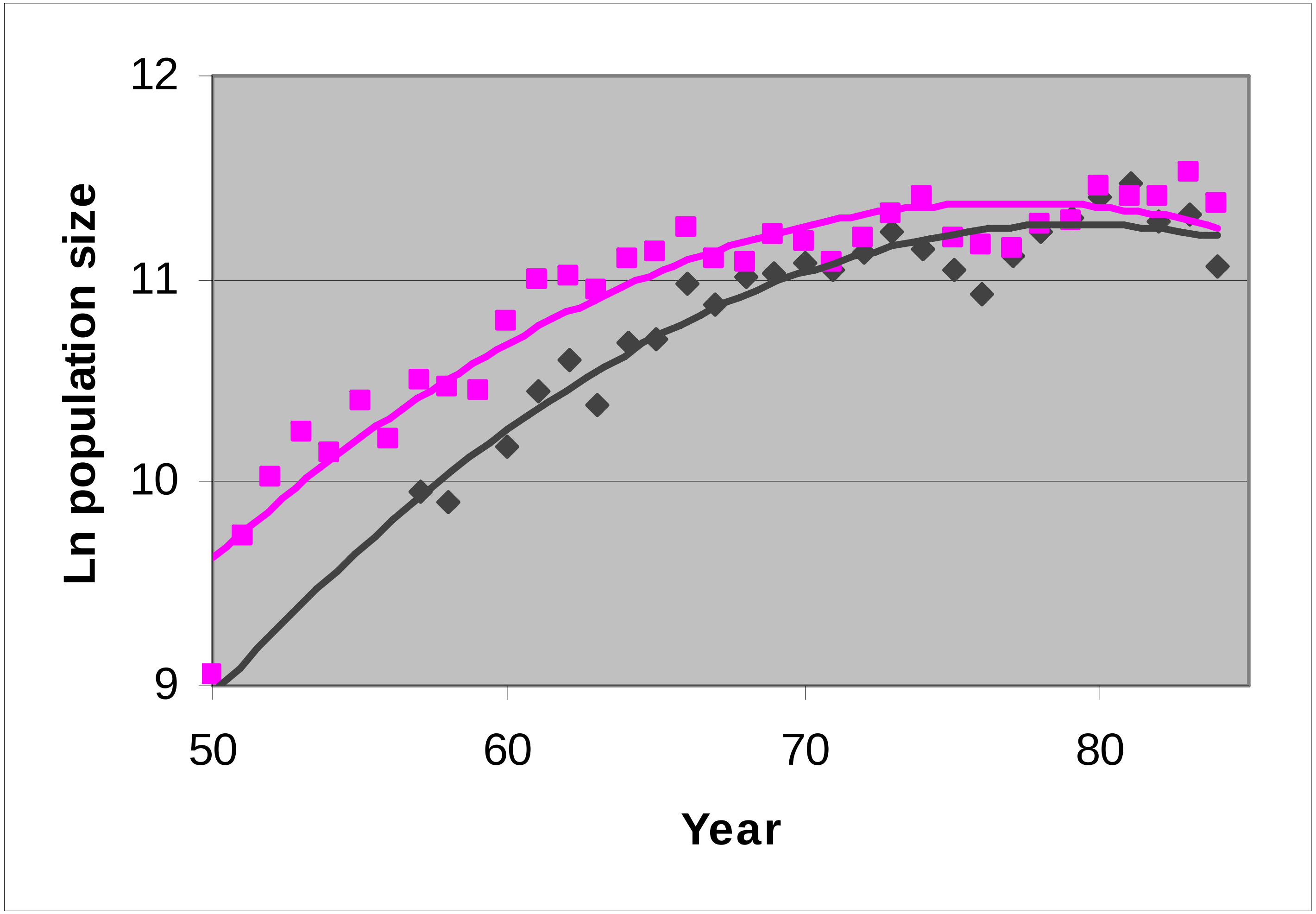
- They CANNOT tell you what $N_{(t+100)}$ will be UNLESS ASSUMPTIONS (ie environment & demography) remain IDENTICAL to those assumed in model
- VERY unlikely they can tell one anything about population behaviour too far into the future: THEREFORE PVA's need frequent updating (5 yrs) using the LATEST information available

PINK-FOOTED & GREYLAGS

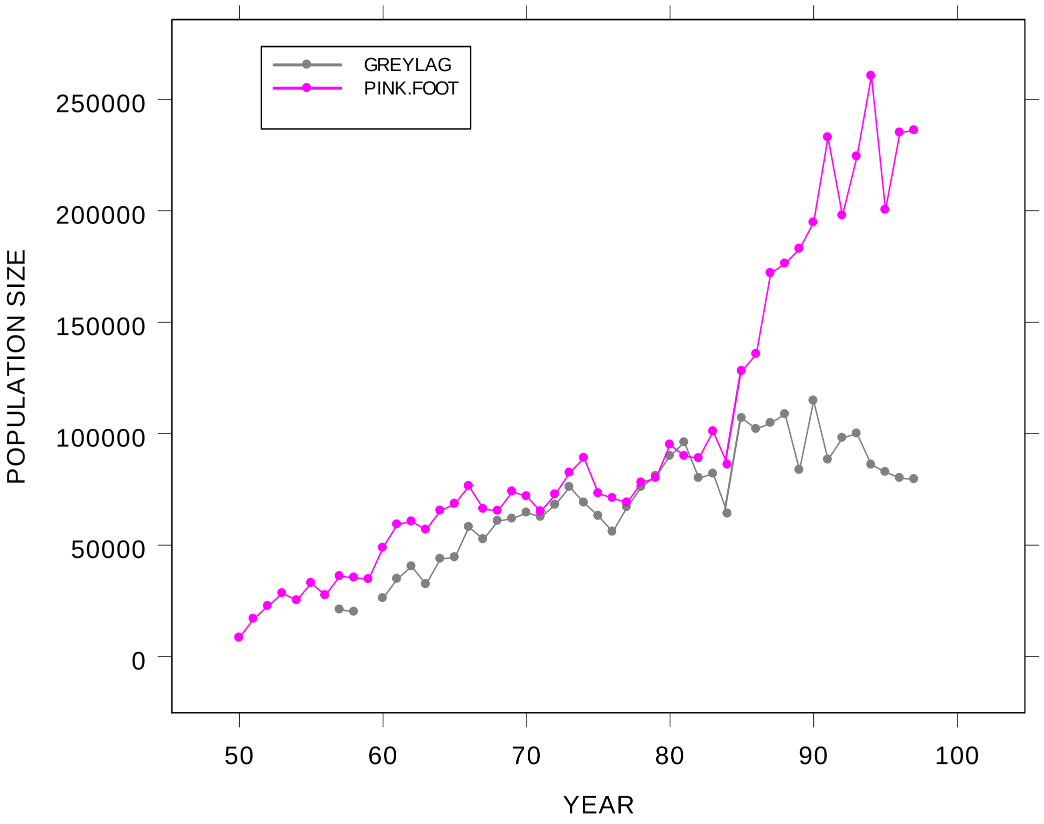
PINK-FOOTED & GREYLAG GEESE POPULATIONS TO 1984



Ln Population size with time ie *r*



PINK-FOOTED & GREYLAG GEESE POPULATIONS INTO LATE 1990s



How good are the data?

- REMEMBER: GARBAGE IN, GARBAGE OUT

BUT HERE WE HAD

- 30+ yrs of “good” population estimates
- Reasonable estimates of demography
- No evidence to suggest sudden change in population behaviour

How good are the data?

- Many published PVA’s & PVA’s used for “conservation” are based on:
- Short time series
- Poor population estimates (rare or cryptic or wide-ranging etc)
- Often poor demographic data with very small sample sizes
- Survival estimates often non-existent

Why use PVA's

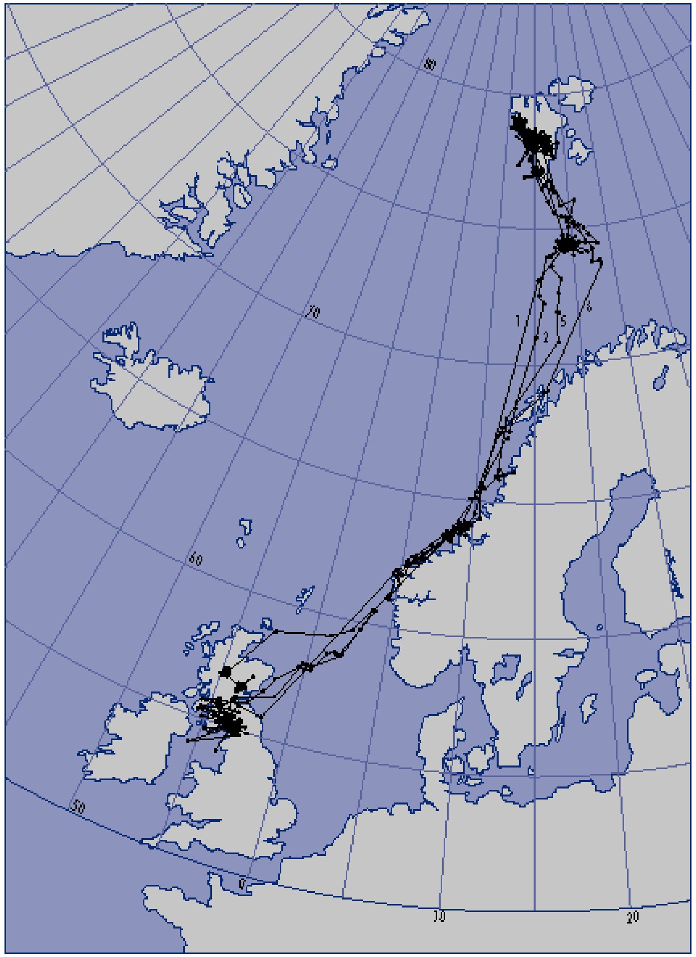
- Population estimates into the future obtained from PVA's are MODELS, not GOSPEL TRUTH

BUT

- PVA's useful in exploring WHAT IF? scenarios, either +'ve or –'ve
- Sensitivity analyses (elasticities) very informative
- Ultimately, should be used to inform WHAT further data are needed, & WHERE conservation action should be targetted

Svalbard Barnacle Goose

Svalbard Barnacle Goose



Svalbard Barnacle Goose

- Demography:
- What we can measure:
- Total Population Size: **(N_t)**
- Brood size: **(B_t)**
- Proportion of young: **(P_{jt})**

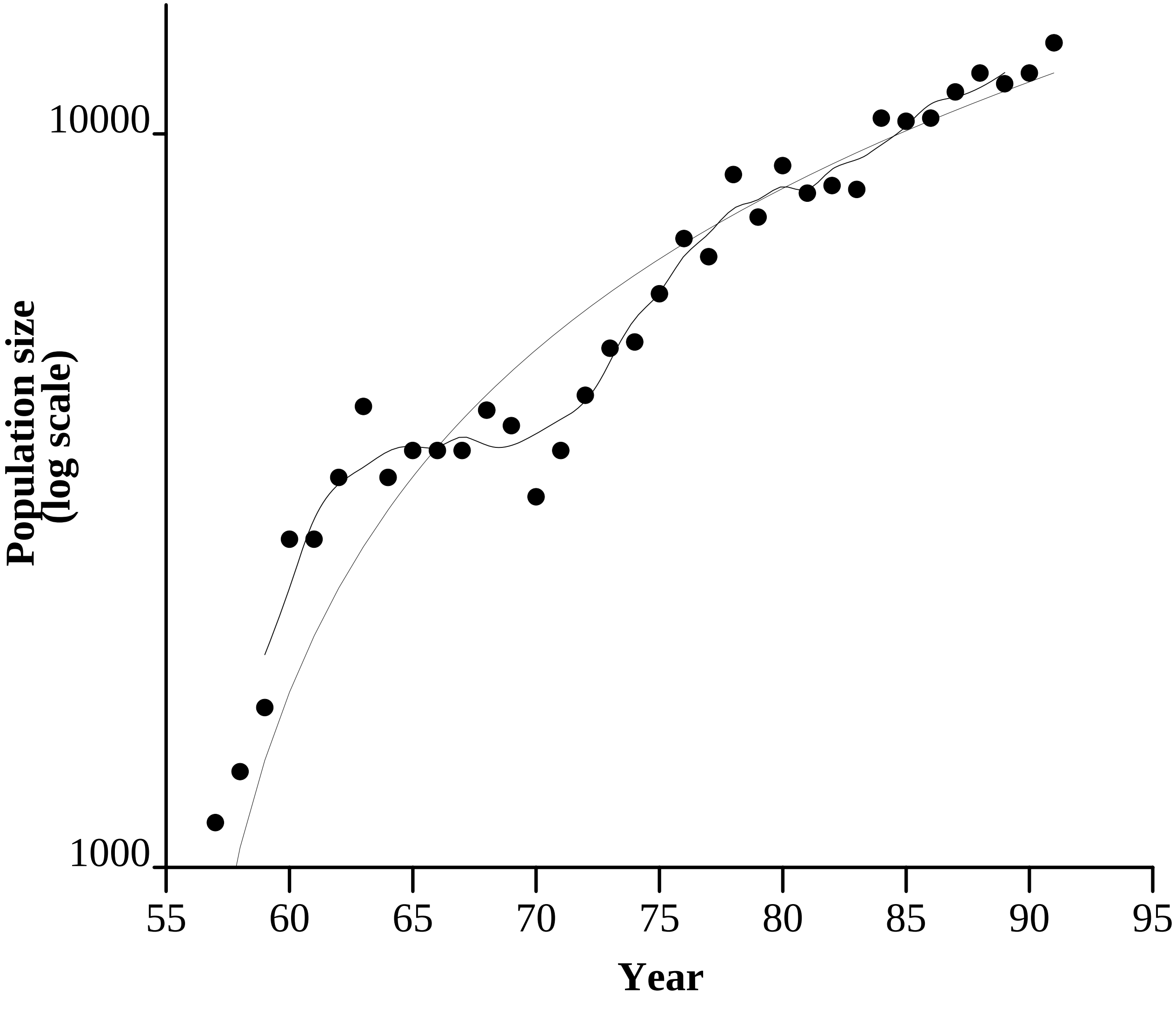
Svalbard Barnacle Goose

Demography: We know: (N_t), (B_t), (P_{jt})

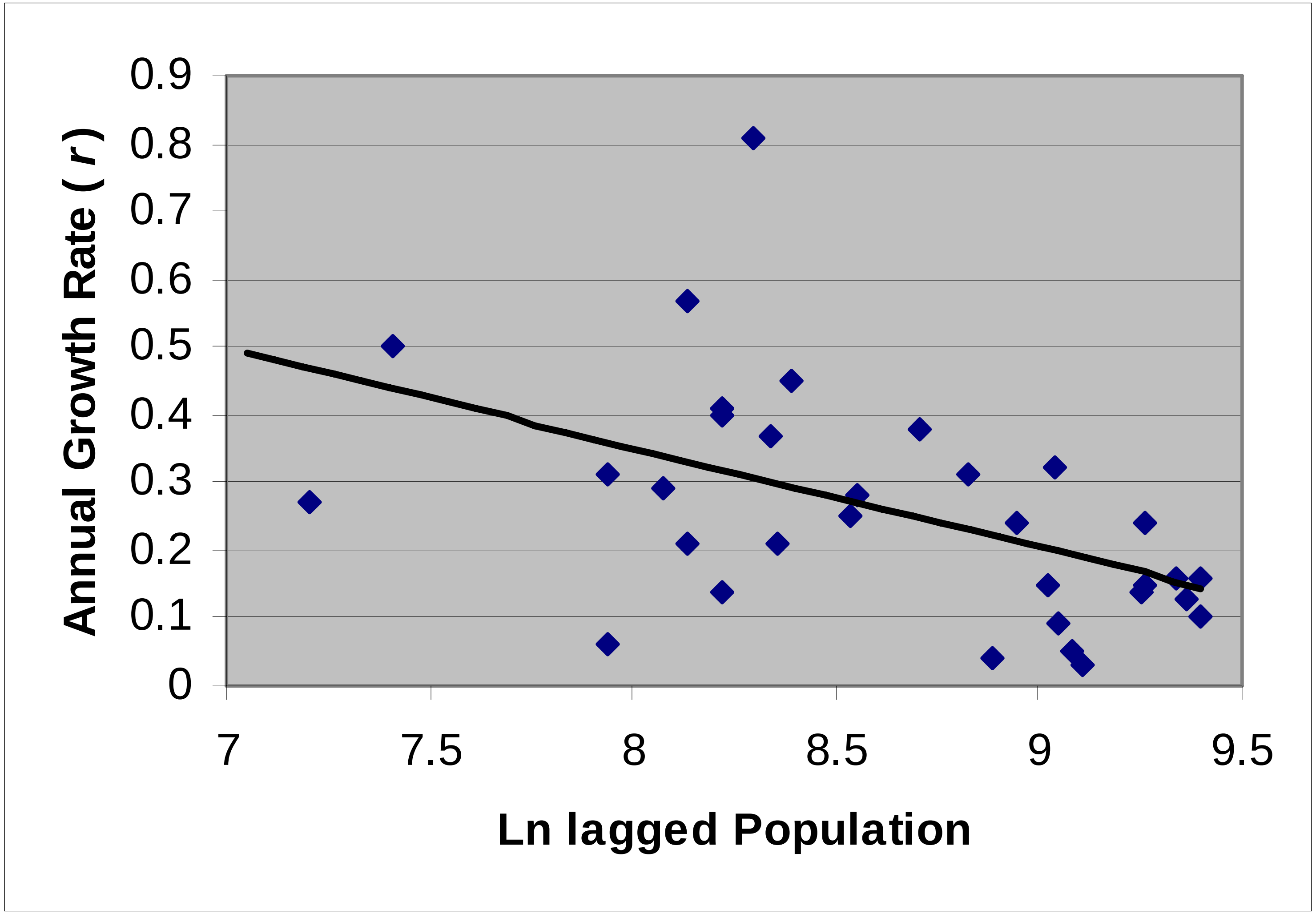
We can infer:

- Number of Juveniles $(J_t) = (N_t)*(P_{jt})$
- Successfully Breeding Adults $(A_{bt}) = 2*[(J_t)/(B_t)]$
- Number of 2nd yr birds $(I_t) = (J_{t-1})*(S_{t-1})$
- Potential breeding adults $(A_{pt}) = (N_t) - (J_t) - (I_t)$
- Breeding Ratio $(R_t) = (A_{bt})/(A_{pt})$
- Productivity $(F_t) = (J_t)/(A_{pt})$
- Survival Rates $(S_t) = [(N_{t+1}) - (J_{t+1})]/(N_t)$

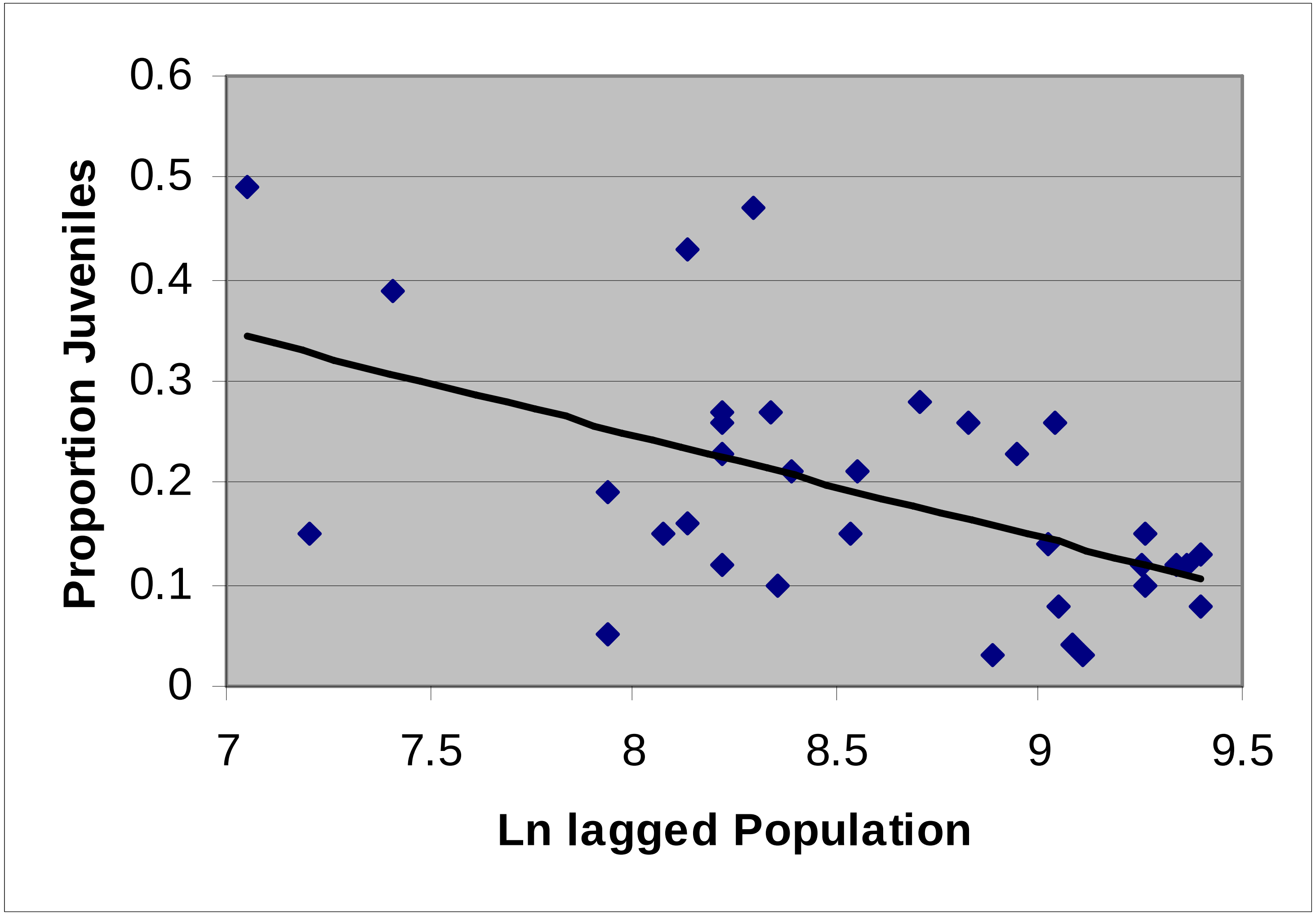
SvBG – Population Growth



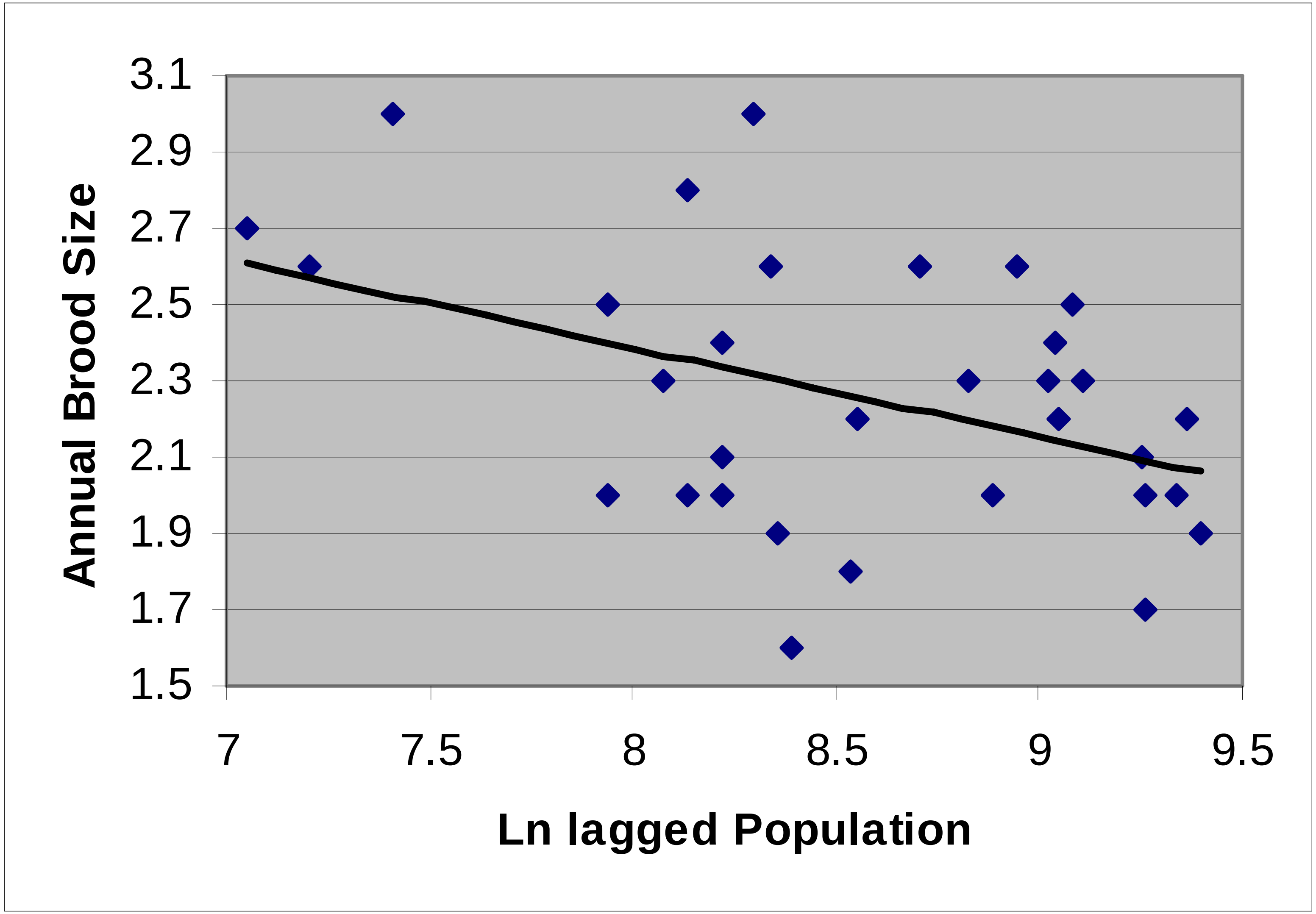
SvBG – annual growth rate *r*



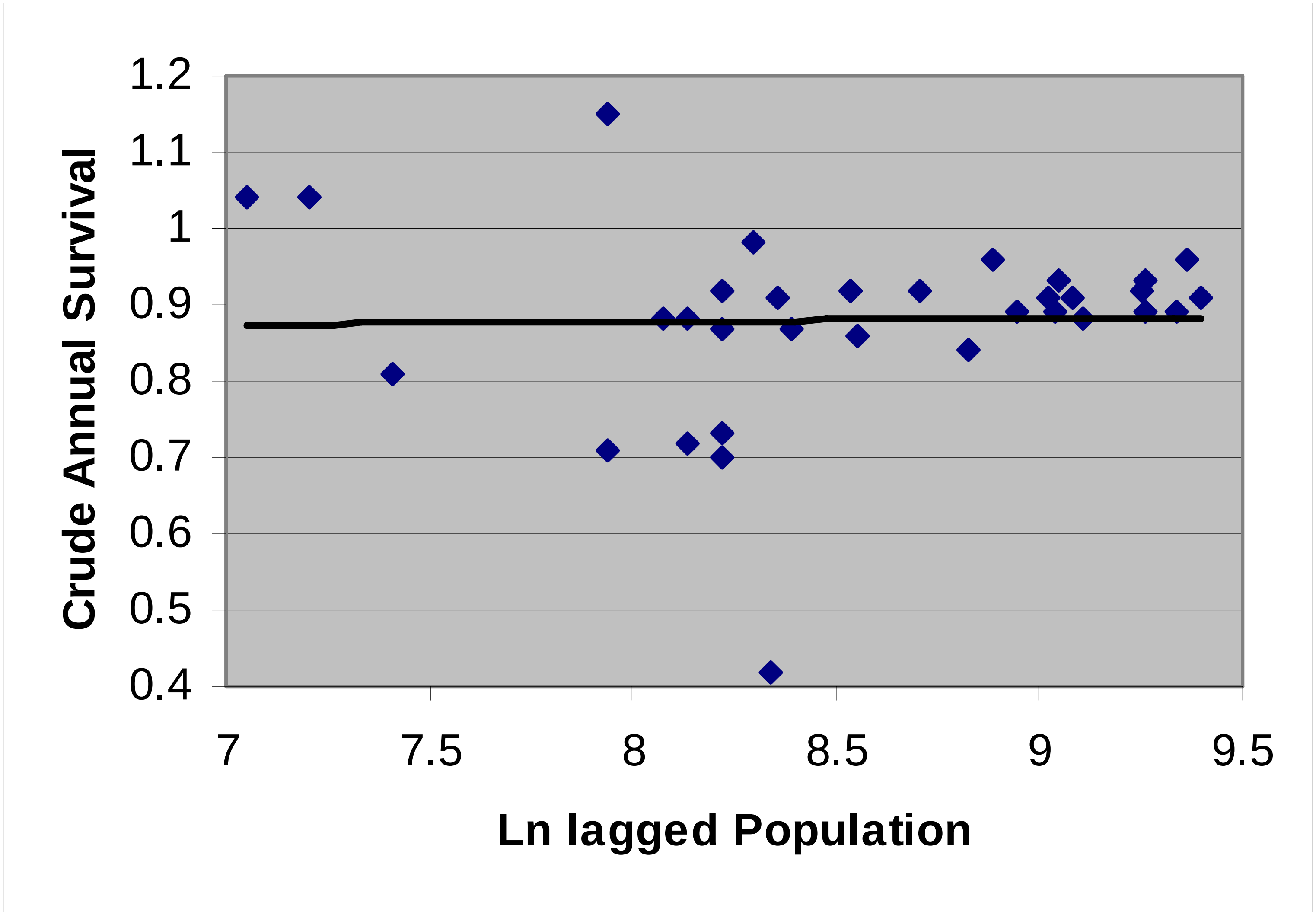
SvBG – density dependence?



SvBG – density dependence?



SvBG – density dependence?



SvBG – density dependence?

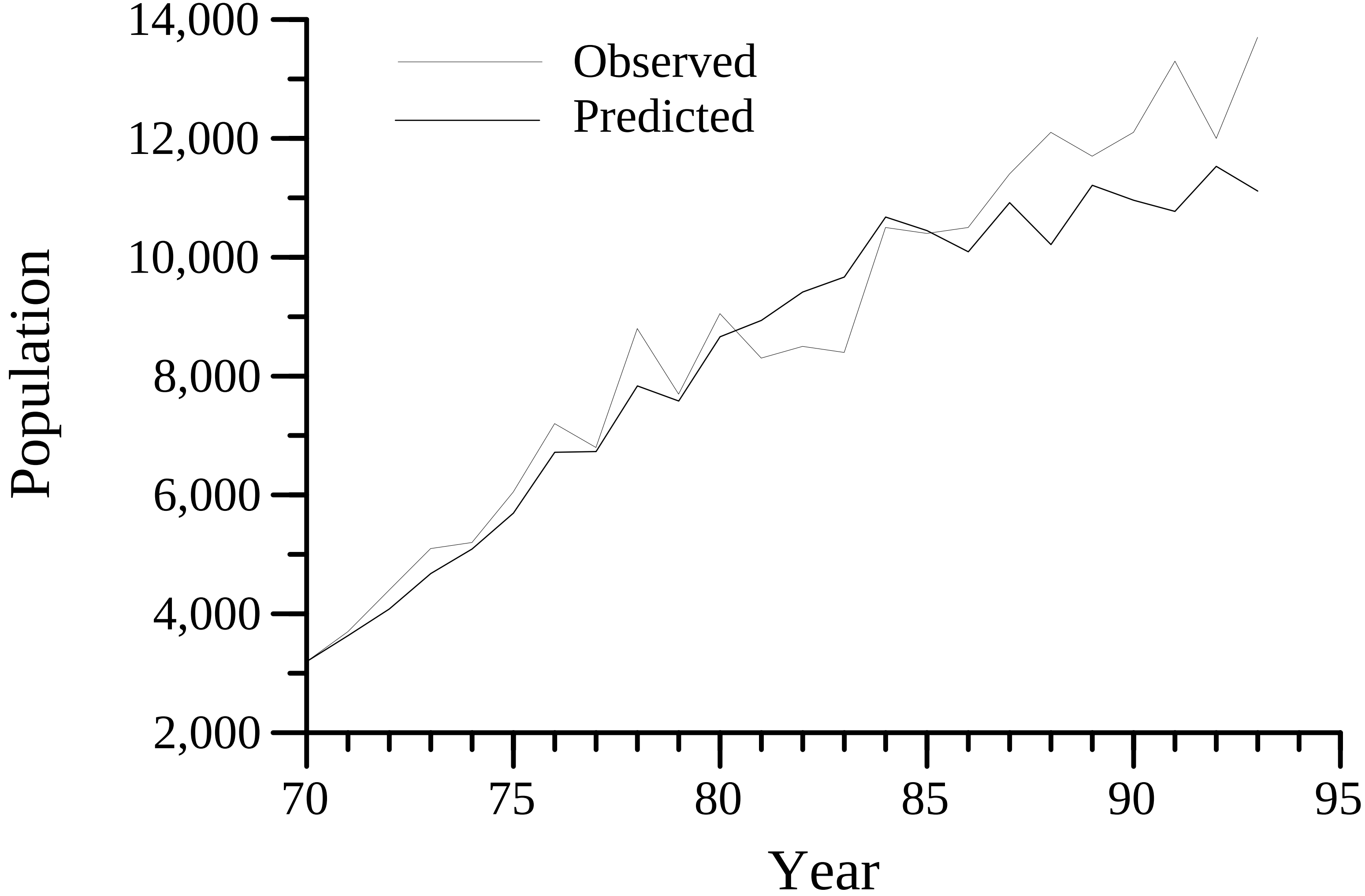
- DD apparent in key demographic breeding parameters
- Substantiated by analysing ringing data
- Also Pollard’s & other DD tests
- BUT no DD in crude annual survival estimates
- Similarly, no evidence from MARK (CMR) analyses of ringed birds

SVBG PVA from data 1952 - 1992

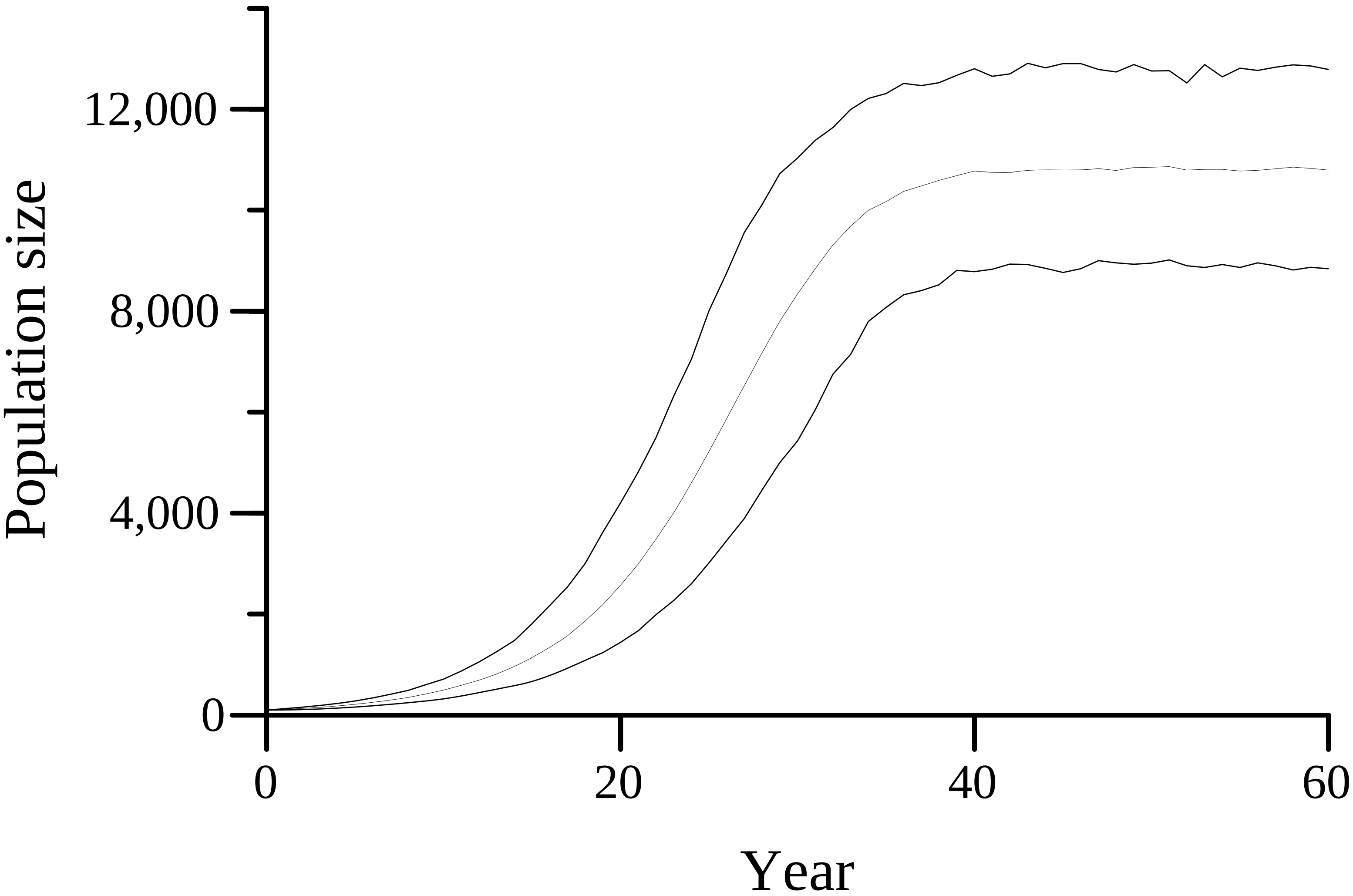
The BLACK BOX:

- Stochastic Leslie matrix model but modified to account for seasonal variation in mortality (from ringing data)
- Stage-structured (from ringing data)
- Incorporates density dependence
- Incorporates effects of environmental factors

SVBG PVA from data 1952 - 1992



SVBG PVA from data 1952 - 1992



SVBG PVA from data 1952 - 1992

- Long-time series
- Good annual data on demographic parameters
- Good knowledge of environmental factors
- All parameterisation supported by intensive statistical analyses of over 3,000 birds ringed and 50,000 resightings
- **Text book example of how to do a PVA**

SVBG PVA from data 1952 - 1992

Wrong

WRONG

WRONG!!!!

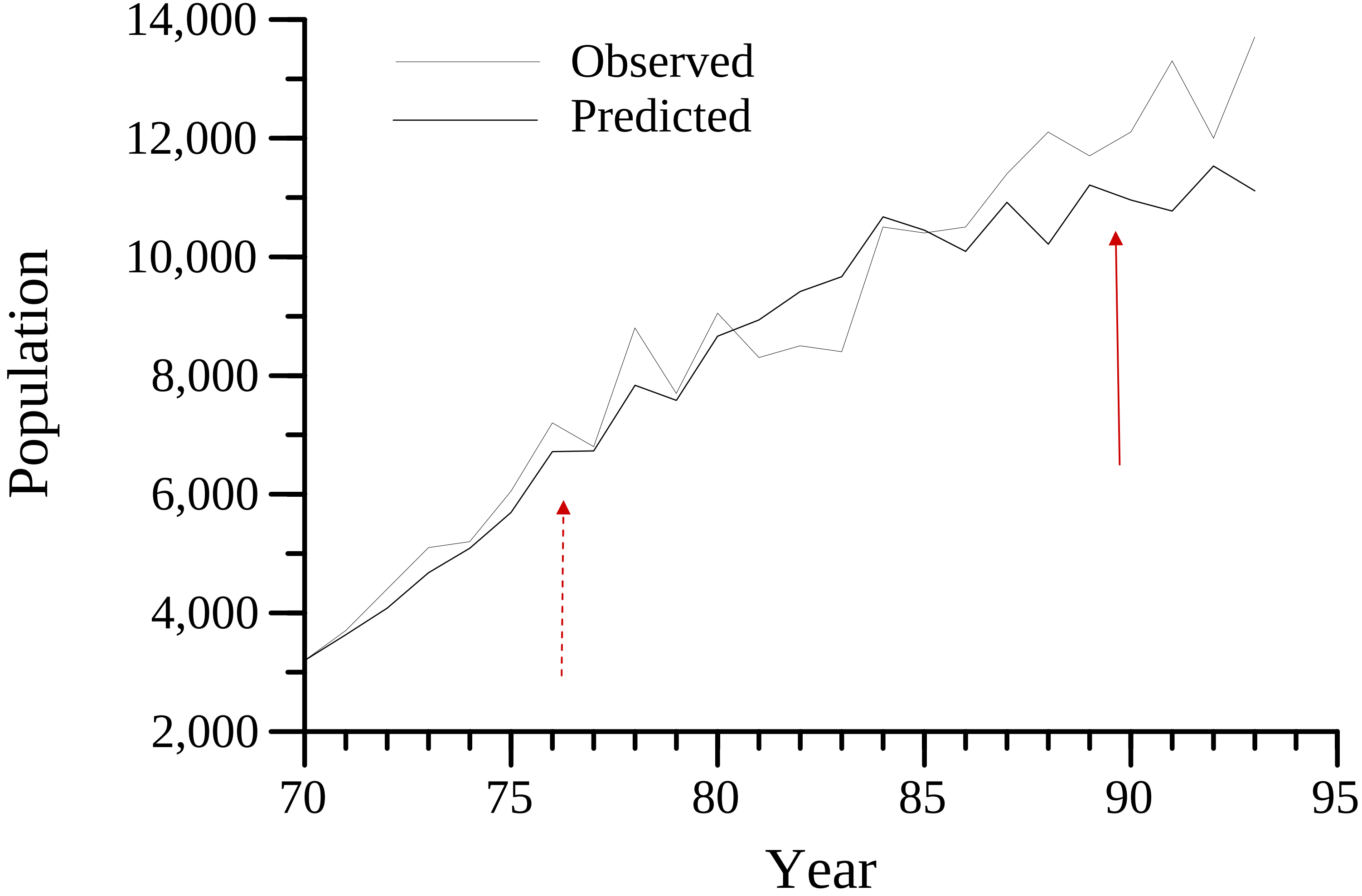
Why did we get it so wrong?

- 1) Research on Svalbard difficult logistically (& expensive): therefore established colonies with previous research history studied
- 2) These colonies are the oldest, & dd on breeding most pronounced
- 3) New colonies being established, but their contribution unknown

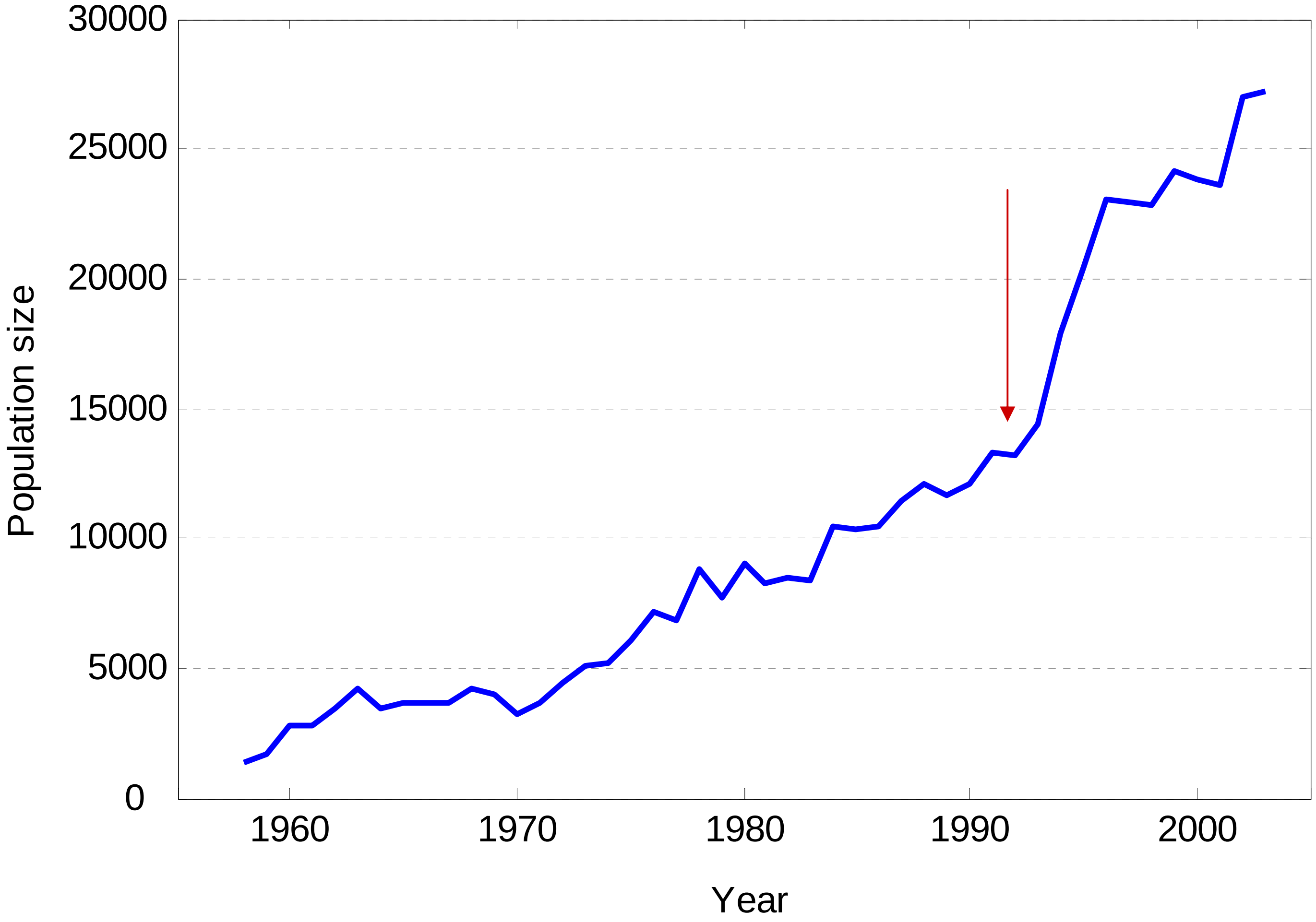
Why did we get it so wrong? (2)

- 4) Barnacle Goose Management Scheme came into affect in 1994, just as our initial work finished (1992)
- 5) Currently much greater mobility of winter flocks than previously established
- 6) Since mid-90’s, also changed spring & autumn staging posts, increasing survival.
- *i.e.* SvBG behaviour changed in ways UNPREDICTED from *30+ years previous intensive study!!*

SVBG PVA from data 1952 - 1992



SvBG Population Growth 1958 - 2003



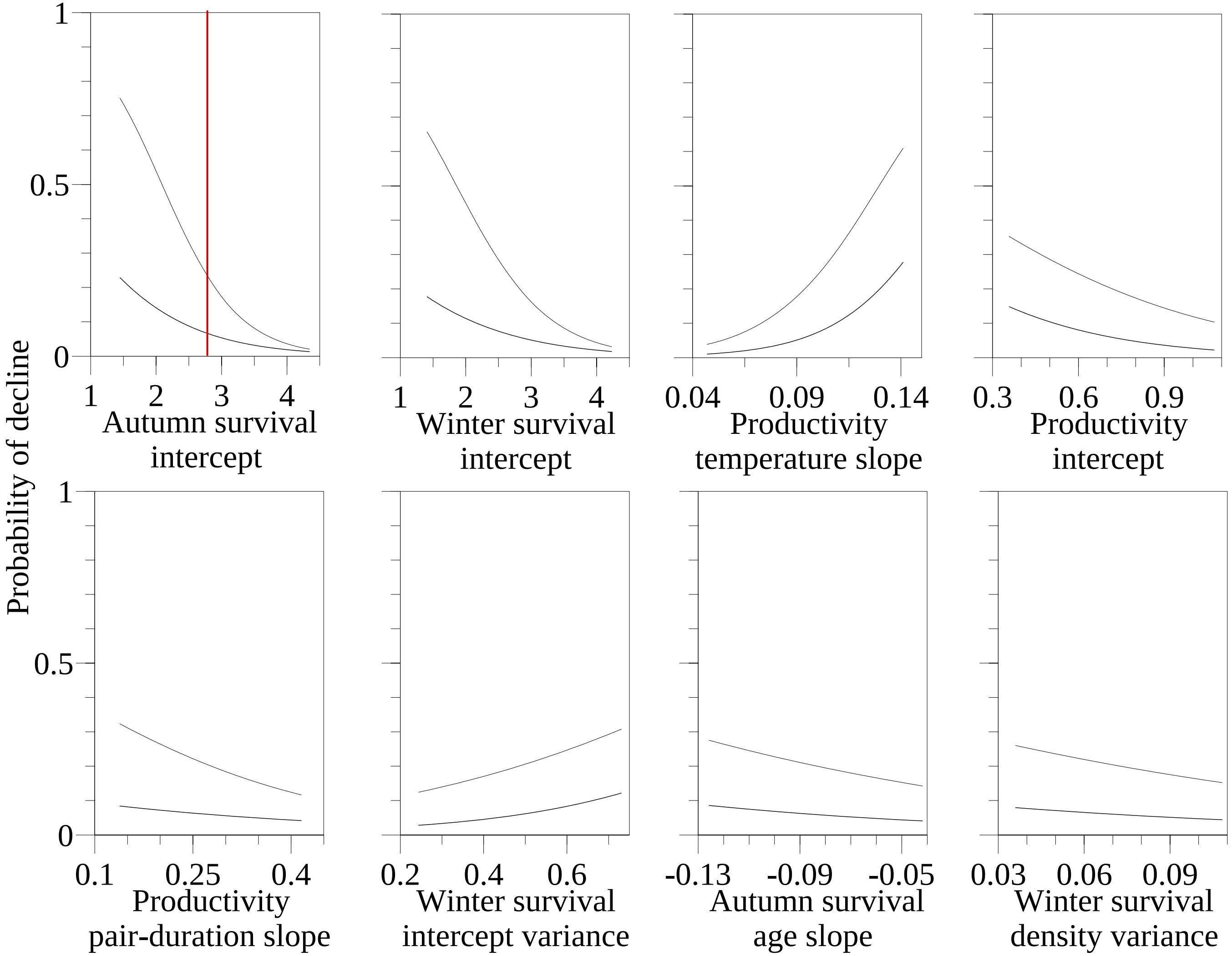
However, all is not lost!!

- FIRST, we recently revisited our 5 goose PVA’s done in mid-90’s against actual observed population growth: in 4/5 instances we had good agreement
- SECOND, we have rerun our models using updated info (especially wrt dd), & good overall agreement
- THIRD, our sensitivity analyses remained sound
- FOURTH, our early PVA’s redirected our research to specific Q’s & hypotheses.

Remember? Why use PVA's

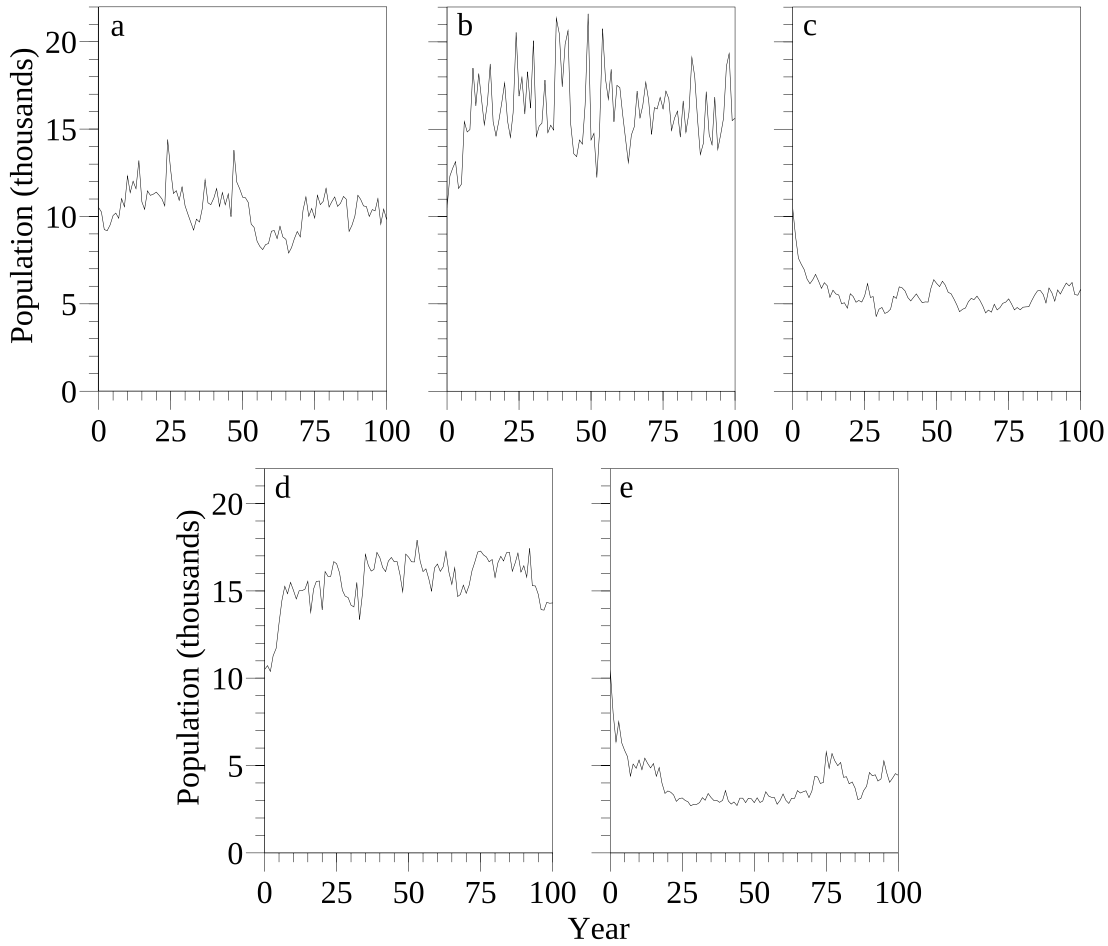
- 1) Population trajectories – hmmm…?
- 2) Elasticities – what demographic factors are driving the popn dynamics?
- 3) What "offtake" are populations capable of withstanding (assuming NO CHANGE in environment or demography)?
- 4) At what point should we be concerned with catastrophic but rare events?

ELASTICITIES i.e. population sensitivity to parameter change



Example population trajectories over 100 years

a) model parameters unchanged; b) no dd in productivity; c) dd in productivity x 5; d) autumn survival increased 2x; e) autumn survival decreased (40%).



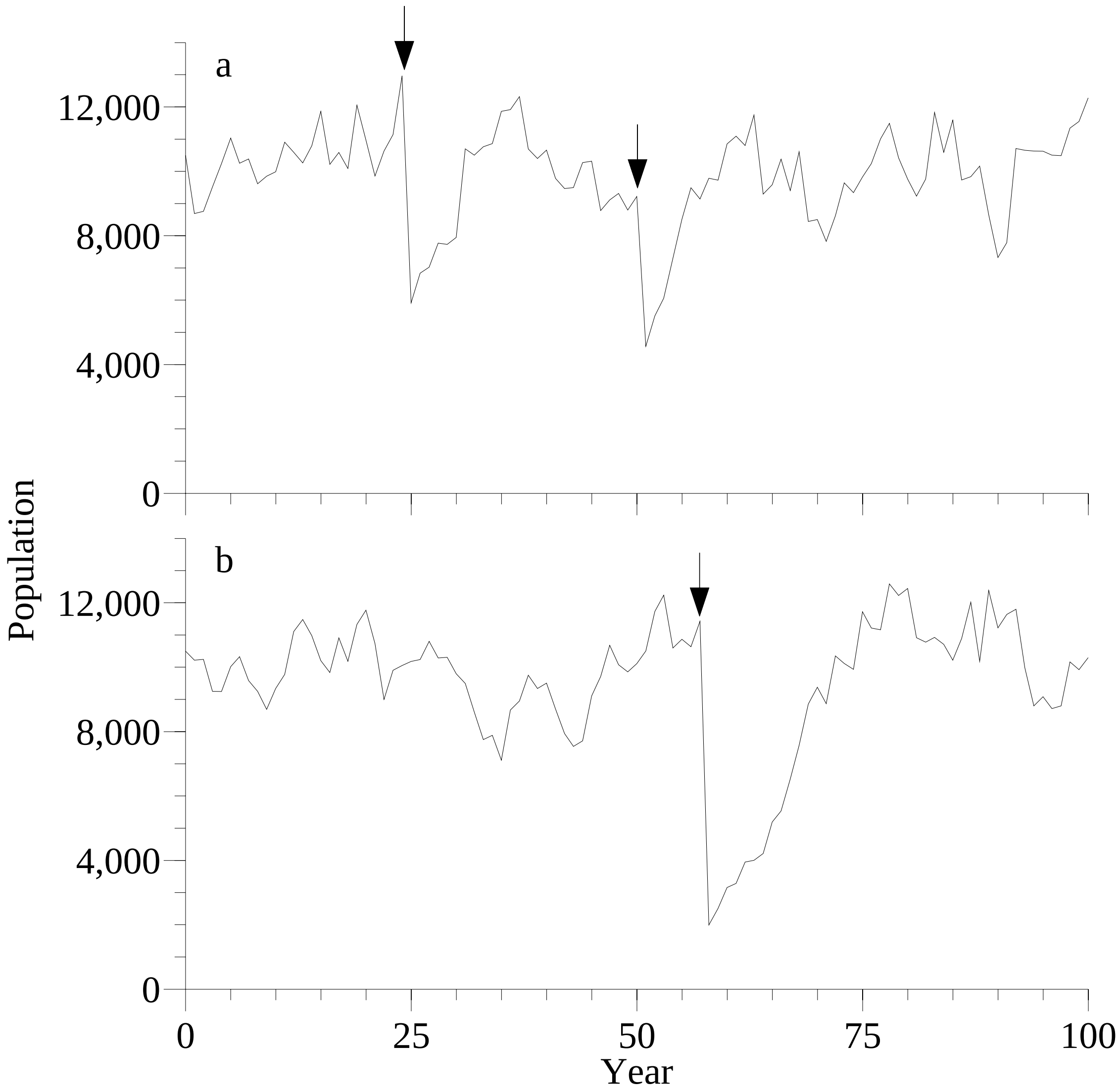
Sensitivity Rules of Thumb

- 1) In “K-selected” species, it is generally the annual survival of adults that is critical.
- 2) In “*r*-selected” species, it is generally annual recruitment that is critical.
- 3) Density <u>In</u>dependent trajectories tend to reach higher values, but generally more susceptible to random crashes
- 4) Density dependence regulates populations, offering “buffering” to crises
- 5) BUT dd CAN BE very hard to detect
- 6) Remember, dd can occur even in SMALL popns.

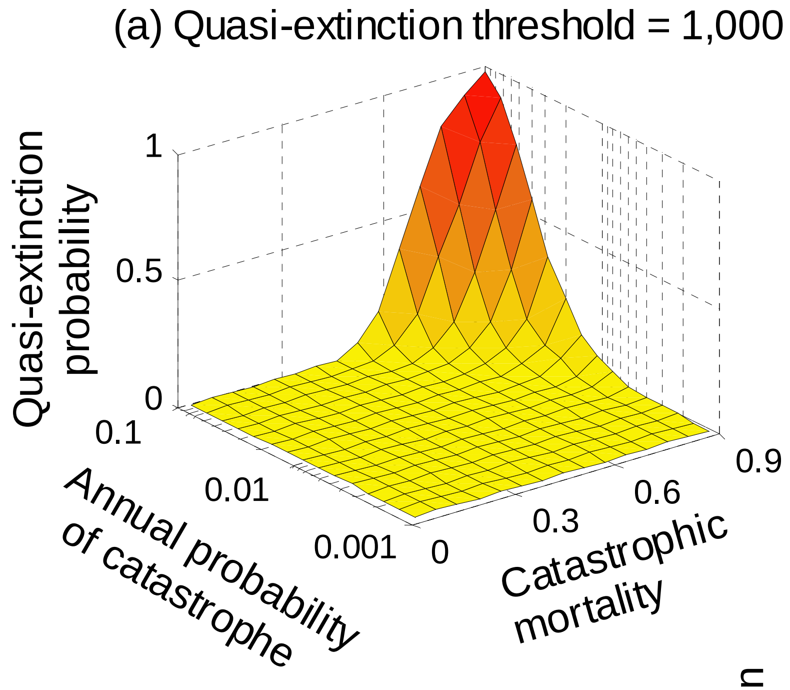
Quasi-extinction

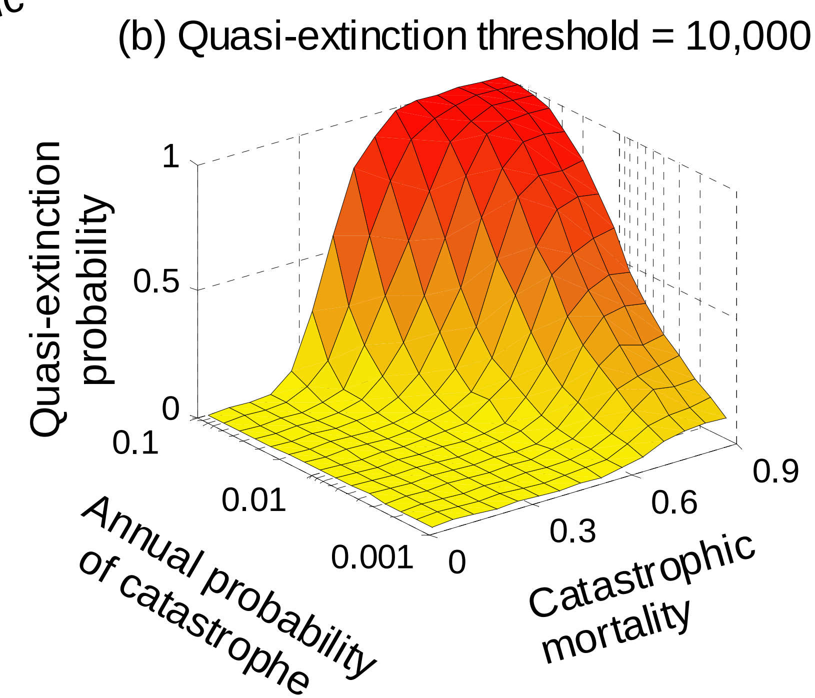
- Generally used when population size exceeds some subjective value e.g. look at risk of Sv Barnacle geese declining to 5 or 10,000 birds from 25,000, or Pink-feet (250,000+) declining to 100,000 birds.
- In other words, use values that are biologically meaningful, BOTH from a modelling perspective & in terms of conservation.

Example dd population trajectories over 100 years under a) 0.01 annual risk of 50% catastrophic mortality, and b) 0.01 annual risk of 80% mortality.

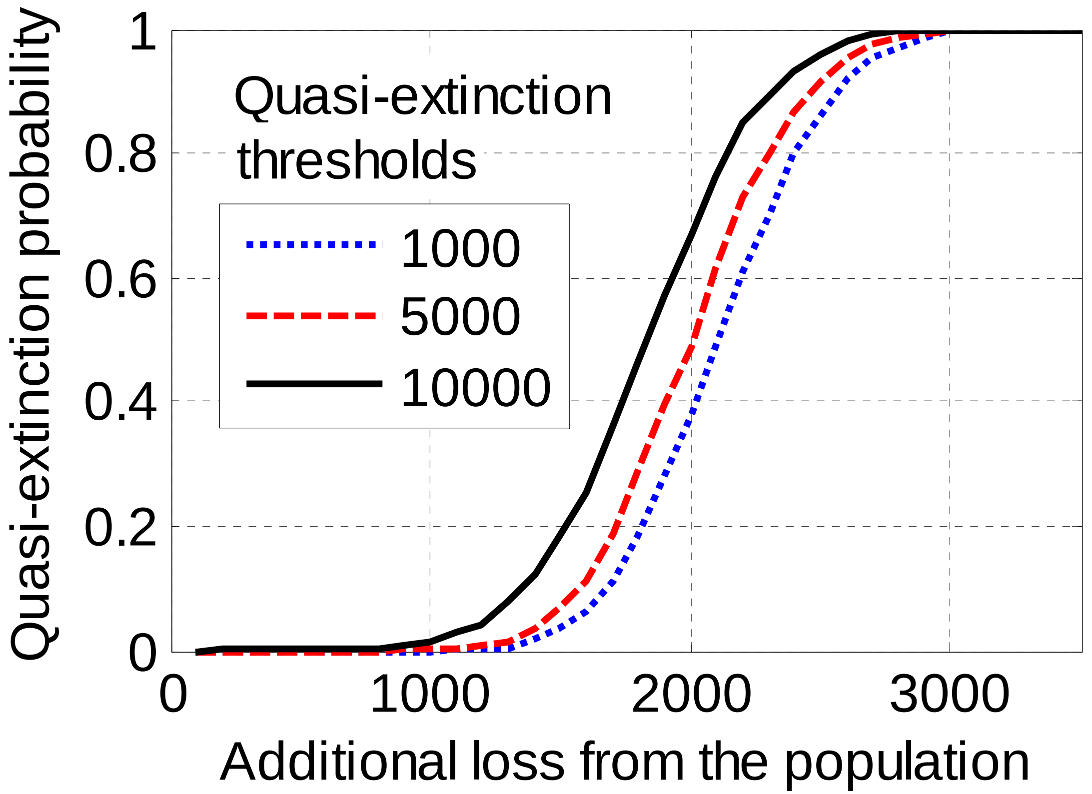


Quasi-extinction risk





Hunting offtake



Svalbard barnacle goose quasi-extinction probabilities within 25 years resulting from increasing levels of loss of individuals from the population in the presence of density dependent regulation.

The Previous Predictions - CAUTION

- 1) Assumes model assumptions persist into the future – as we've seen, this can be VERY unreliable
- 2) Need to exercise "PRECAUTIONARY PRINCIPLE"
- 3) The confidence intervals are wide, & get wider as time into future increases (i.e. greater uncertainty in predictions)

SUMMARY

At the heart of population viability analysis lies the interaction between environmental stochasticity and population demography. In the words of Soulé (1987), conservationists must grapple with the question: "What are the minimum conditions for the long-term persistence and adaptation of a species or population in a given place?". He goes on to state that "This is one of the most difficult and challenging intellectual problems in conservation biology. Arguably, it is the quintessential issue in population biology, because it requires a prediction based on a synthesis of *all the biotic and abiotic factors in the spatial-temporal continuum.*"

TAKE HOME MESSAGES (1)

- 1) Population trajectories into the future are filled with uncertainty: behaviour can change in unpredictable ways. Be VERY wary of categorical statements & assess QUALITY of data used
- 2) Density-dependence CAN be a fact of life in populations (even small ones) – detecting dd VERY difficult, but crucial for model behaviour

TAKE HOME MESSAGES (2)

- 3) Sensitivity analyses most “useful” aspect of PVA’s, but often neglected
- 4) Quasi-extinction risk gives insight into population behaviour *as formulated in model*
- 5) Modelling “catastrophic” events useful
- 6) Can give insight into “sustainable offtake” – but always phrase with sufficient cautions!!

TAKE HOME MESSAGES (3)

- 7) PVA's can help understand population dynamics & targetting of conservation / research action – above all, they are FUN!!
- 8) Finally, PVA's are not be all & end all of simulating population dynamics. Behavioural & evolutionary ecology can help a lot (IBM's & game-theory). *Above all, use your own common sense & ecological knowledge!!*