Abundance projections

SSA 200

How do we assess future conditions for species with minimal demographic data?

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Abundance projections: in a nutshell

- Required elements:
  - Initial population size (N_0)
  - Growth rate (r) or change in population size (λ)
  - Specified time interval (t)
- Pros
  - Simple, minimal data required compared to matrix projections
  - Faster computation
- Cons
  - Limited opportunities for alternative models to address demographic/systemic uncertainties

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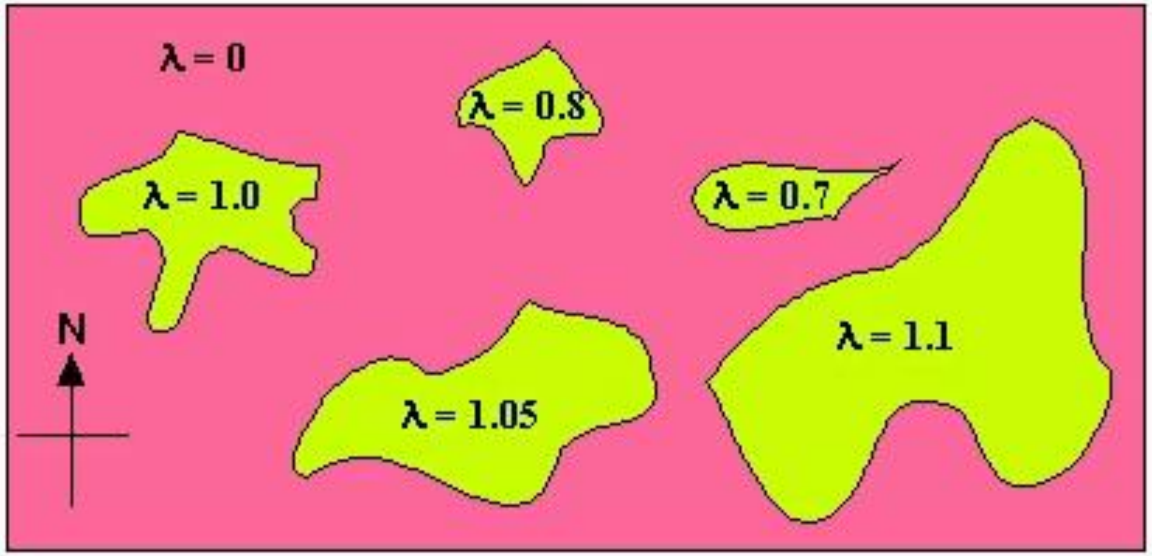
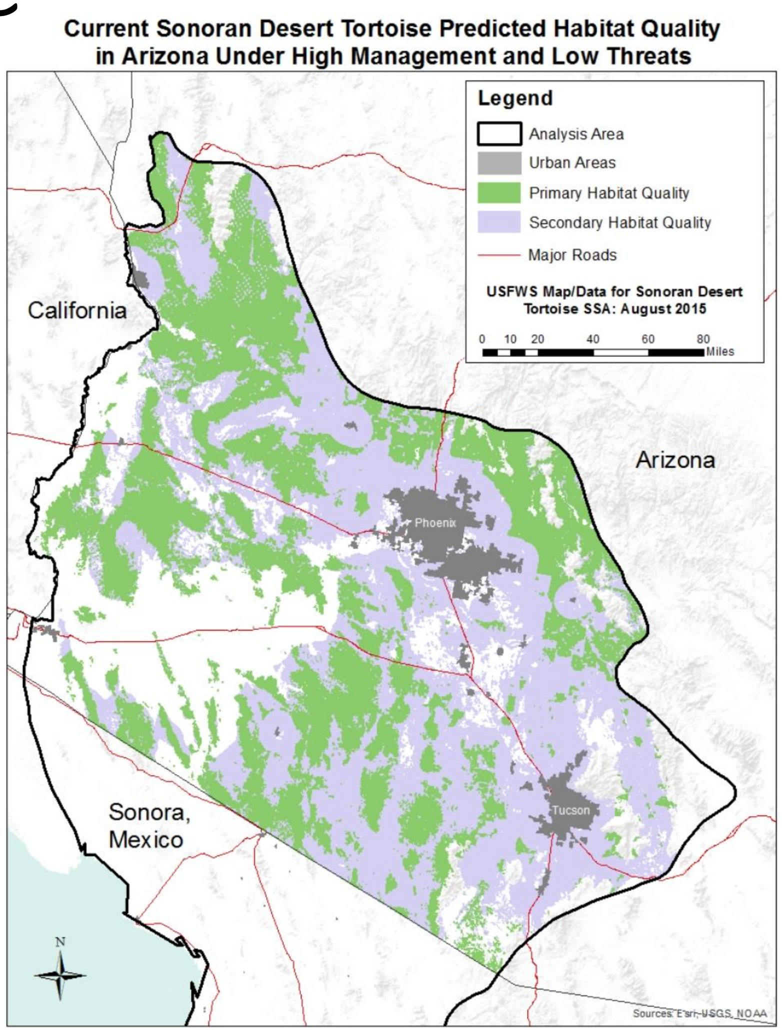
Population growth models - classic

Exponential growth curves are some of the foundations of metapopulation theory; minimum viable population





Exponential model assumption: unlimited resources in each patch.

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When could you use a ‘simple’ growth curve?

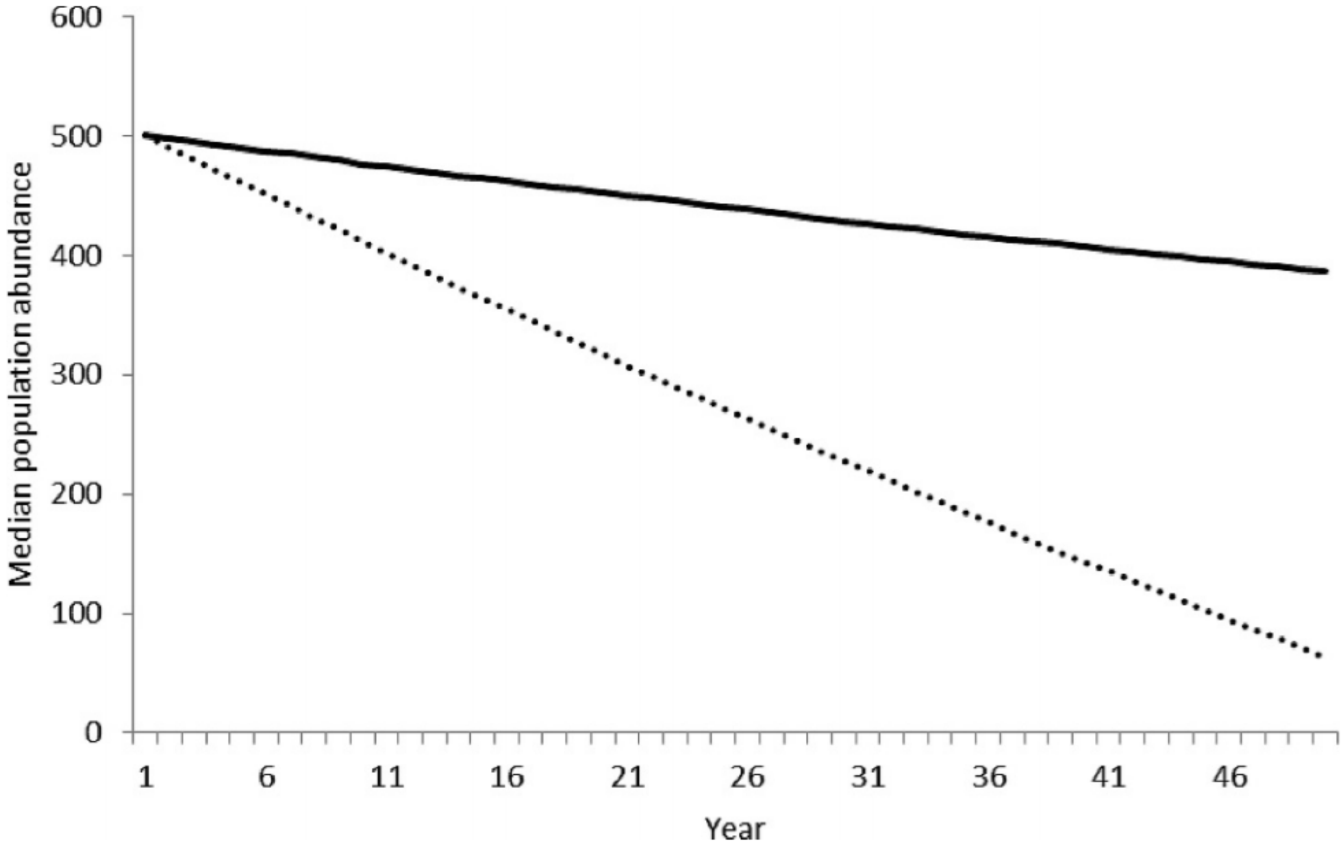


Figure 1. Comparison of the simulated median population abundance trajectories for a hypothetical endangered species with (dotted line) and without (solid line) incidental take 50 y into the future.

- SSA Current condition
- SSA Future condition
- SSA Scenario building
- Sec. 7 consultation
- Biological opinions

McGowan and Ryan 2010. JFWM.

Instantaneous growth models

- Exponential growth, when growth in continuous across time

$$\frac{dN}{dt} = rN$$ Rate of change

- $$N_t = N_0 e^{rt}$$ Calculating population size by integration

Initial number

Natural log base

- r is the growth rate of the population over time interval t

The future condition: understanding how populations *increase and decrease* is imperative for decision-making

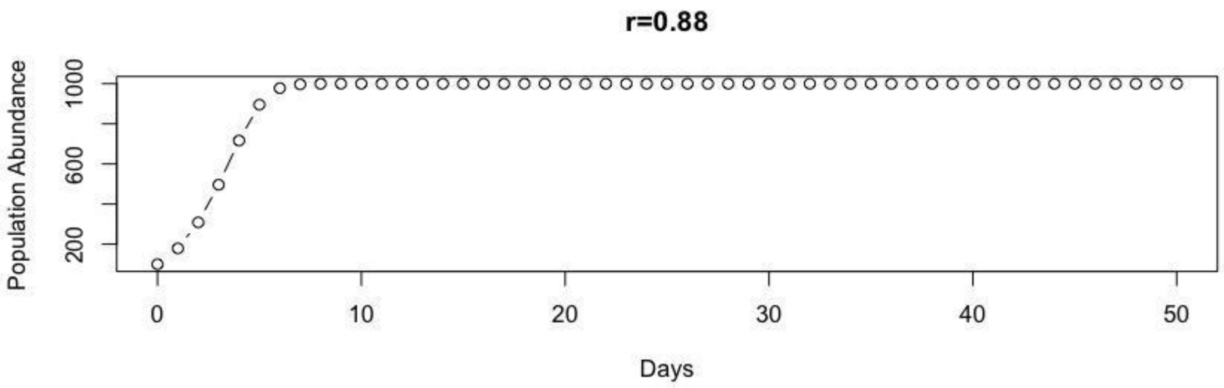
Define terms

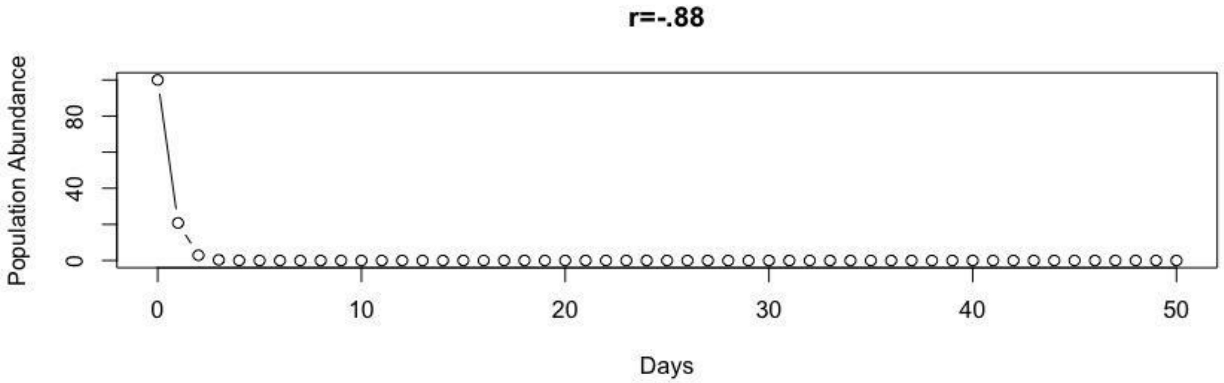
N - abundance

K - carrying capacity (resource limitation)

r - intrinsic growth rate (births - deaths)

λ - discrete growth rate





Instataneous growth model										
	mean	sd								
r	0.002	0.0005								
Ni	532									
	time									
rep	1	2	3	4	5	6	7	8	9	10
1	532	534.1933	537.1846	542.1613	547.1685	551.5168	564.4958	573.2466	587.6685	602.8219
2	532	534.4635	538.0165	543.0892	547.8497	556.143	565.3953	577.5968	587.7866	600.8106
3	532	533.4512	536.6816	540.4131	545.7366	552.4363	561.0846	571.3322	583.3235	593.9199
4	532	534.4324	536.995	541.0812	547.4015	553.4093	561.7927	569.9459	578.8499	590.5672
5	532	533.9433	537.0707	541.3321	546.1179	554.135	560.4183	564.5373	575.4371	587.1178
6	532	534.0625	537.0234	540.3732	546.0459	550.736	559.8343	565.4011	574.9834	588.3792
7	532	534.577	538.9243	544.9311	550.436	557.8599	566.7399	572.8351	580.8414	593.3201
8	532	534.9349	537.6218	539.2983	544.7012	551.5834	557.1969	568.0021	582.2625	597.1687
9	532	534.5787	537.8375	541.6961	547.014	553.2033	561.9015	574.8486	582.3822	597.0212
10	532	534.4032	536.9716	541.6232	546.7182	553.3649	557.7523	566.9441	575.7879	585.4111

$$N_t = N_0 e^{rt}$$

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Discrete population growth models

- Population growth happens in discrete time steps, i.e., birth pulses, so you use the rate of increase from year to year – lambda (λ)

Measure: $\lambda_t = N_{t+1} / N_t$

Mean estimate: $\bar{\lambda} = \sqrt[y]{\lambda_{t=1} \times \lambda_{t=2} \times \cdots \lambda_{t=y}}$

Predict: $N_t = N_0 \lambda^t$

- *In words*: Population size at some time (N_t) equals the initial populations size (N_0), multiplied by the discrete growth rate (λ), raised to the time interval length (t)
- **What assumption is this type of projection making?**

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Abundance projection in a lambda growth model

	mean	SD
Lambda	1.01	0.01
Ni	532	

rep	year										
	0	1	2	3	4	5	6	7	8	9	10
1	532	538	544	542	549	559	559	557	564	572	582
2	532	534	536	539	540	544	558	566	568	578	581
3	532	536	537	541	542	551	548	550	558	557	566
4	532	535	554	565	572	579	578	581	590	596	602
5	532	532	526	533	538	549	556	555	565	581	594
6	532	536	541	550	553	556	554	559	565	560	569
7	532	535	536	544	549	550	555	566	575	584	598
8	532	533	540	550	554	558	560	565	575	587	593
9	532	536	550	568	580	593	595	599	600	604	617
10	532	537	548	547	557	570	576	574	584	585	587

Logistic population growth

- At times, populations increase rapidly, but they also slow down because resources become limited; the environment has a **carrying capacity** (K) for a species population.

$$\frac{dN}{dt} = rN(1 - \frac{N}{K})$$

Instantaneous rate of change

$$N_t = \frac{K}{1 + \left(\frac{K - N_0}{N_0}\right) e^{rt}}$$

Calculate population size

In words: The individuals at some time (N_t) equals the intrinsic rate of increase (*r*) times the total new individuals, constrained by the carrying capacity (K) of the site.

Instataneous growth model										
	mean	sd								
r	0.02	0.0005								
Ni	532									
K	600									
				Nt=K/1+((K-No)/No)e^rt						
	time									
rep	1	2	3	4	5	6	7	8	9	10
1	532	534.4046	537.7867	542.2478	547.2419	552.5976	558.2903	564.034	569.6581	574.8667
2	532	534.356	537.7503	542.1378	547.1322	552.716	558.4814	564.1464	569.7271	575.0028
3	532	534.3463	537.7001	541.9215	546.9736	552.6733	558.6001	564.4515	569.91	575.2121
4	532	534.4412	537.9227	542.1183	547.2385	552.863	558.4698	564.223	569.7475	575.0958
5	532	534.3521	537.7204	541.8302	546.8932	552.5683	558.633	564.3609	570.081	575.0492
6	532	534.4012	538.026	542.2396	547.3727	552.7508	558.5511	564.4972	570.1008	575.5357
7	532	534.4739	537.9846	542.1709	547.1792	552.5167	558.3661	564.2434	569.8952	575.1494
8	532	534.3873	537.8363	542.1573	547.2281	552.9212	558.6698	564.42	570.1014	575.1003
9	532	534.441	537.8877	542.3224	547.3409	552.8331	558.5403	564.3753	569.9074	575.2646
10	532	534.3486	537.7364	542.0307	547.0645	552.6835	558.6609	564.4573	569.9638	575.136

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Instataneous growth model										
	mean	sd								
r	0.02	0.0005								
Ni	532									
K	1000									
				Nt=K/1+((K-No)/No)e^rt						
	time									
rep	1	2	3	4	5	6	7	8	9	10
1	532	542.0098	556.8495	577.0382	601.2207	630.2362	662.3778	696.4258	732.9002	770.4732
2	532	541.688	556.9368	576.9094	601.6556	630.8703	662.9592	698.8009	735.9887	773.1935
3	532	541.9707	556.6019	576.3665	599.5989	627.1836	659.5253	694.5599	731.7886	768.6715
4	532	542.2905	557.3721	577.0001	601.2147	630.2178	663.5854	698.6781	735.6124	773.5783
5	532	542.1335	556.3599	575.2854	598.4359	626.7221	658.4371	693.7409	731.5617	768.4635
6	532	541.6995	557.1531	576.0615	599.5344	629.4309	662.358	697.5744	733.2197	771.5943
7	532	541.7587	556.6224	576.3533	600.5331	628.6	659.8032	695.0104	731.5609	768.9046
8	532	541.7891	556.15	576.7433	601.3615	629.0955	660.35	695.0404	732.6421	769.1061
9	532	541.8267	556.7818	576.4356	601.3673	628.7733	660.9572	695.4473	732.9856	769.6054
10	532	541.8015	557.2801	576.5073	600.3131	629.4474	661.7704	696.4777	732.4749	771.2058

Instataneous growth model										
	mean	sd								
r	0.02	0.0005								
Ni	532									
K	400									
				Nt=K/1+((K-No)/No)e^rt						
	time									
rep	1	2	3	4	5	6	7	8	9	10
1	532	524.8808	515.3739	504.385	491.8645	479.3719	467.0685	455.5342	445.1895	436.1488
2	532	525.3243	515.8505	504.0572	491.8372	479.2566	467.3068	455.7776	445.5638	436.3576
3	532	525.0764	516.0861	505.558	493.29	480.6671	468.4075	456.8222	446.1356	436.9943
4	532	525.416	516.1603	505.6013	492.4378	479.8059	467.6598	456.3241	445.9151	436.7696
5	532	524.9775	515.9426	505.1804	492.7584	480.5406	467.9384	456.4616	445.8873	436.8747
6	532	525.1101	515.8014	504.7385	492.7476	480.1744	467.8782	456.0774	445.8651	437.1244
7	532	524.927	515.4769	504.5151	492.438	479.6792	467.6099	456.3341	445.8835	436.6092
8	532	525.4705	516.246	504.765	492.3454	479.1073	467.4019	456.2821	446.1679	436.7122
9	532	525.2117	515.6984	504.6383	492.0637	479.3867	467.2212	456.107	445.837	436.8707
10	532	525.3032	515.8431	504.2268	492.2777	479.7028	467.5072	456.5548	446.2779	437.1779

REAL example. How do you interpret this analysis for your SSA?

Lambda Calculations

We calculated annual population growth rates from aerial censuses as $\lambda = (N_t/N_0)^{(1/t)}$, where N was the population estimate, and t was the interval (i.e., no. years) between estimates (Caughley 1977). We corrected survey estimates for sightability using program NOREMARK (White 1996) by correcting for missed animals (Wittmer et al. 2005*a*) unless snow conditions allowed for high sightability (i.e., >300 cm snow depth equating to >90% sightability of marked animals; Supplementary Appendix A), in which case we adjusted numbers positively by 10% as the Provincial standard (Supplementary Appendix A). We did not use census data if there were an insufficient number of radio-collars (<10) to provide a mark-resight estimate when snow depth was <300 cm (Supplementary Appendix A). Additional census details are provided in Wittmer et al. (2005*a*).

We calculated λ from the R-M equation as $\lambda = S/(1 - R)$, where S is the annual survival rate and R is the recruitment rate. DeCesare et al. (2012) presented an adjustment to this equation to account for the proportion of females in the population by estimating the ratio of juvenile females to the number of juvenile + adult females as a component of recruitment. This adjustment was appropriate because λ was

Serrouya et al. 2016. JWM.

What type of model is this?

Exponential model!
$N_t = N_0 e^{\wedge rt}$

What assumptions are the authors making with this type of model?

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Application: Lambda growth models to assess take

McGowan and Ryan. JFWM. 2010.

Doak (2002). The equation to predict future population size simply multiples current population size by the estimated population growth rate to predict the population size at the next time step:

$$N_{t+1} = N_t \lambda \qquad (1)$$

where N is the population abundance, t is time, and λ is

Consider a case where a wind power company wants to build a wind farm facility in an area where an endangered bird species lives. Based on other wind farm projects, they estimate that their actions will likely take between 5 and 10 adult breeding birds of the endangered species each year. Using our simple model described above, applying this take is simply a matter of subtracting the annual take from the projection equation:

$$N_{t+1} = (N_t - T_t)\lambda_t \qquad (5)$$

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Alternative incidental take scenarios

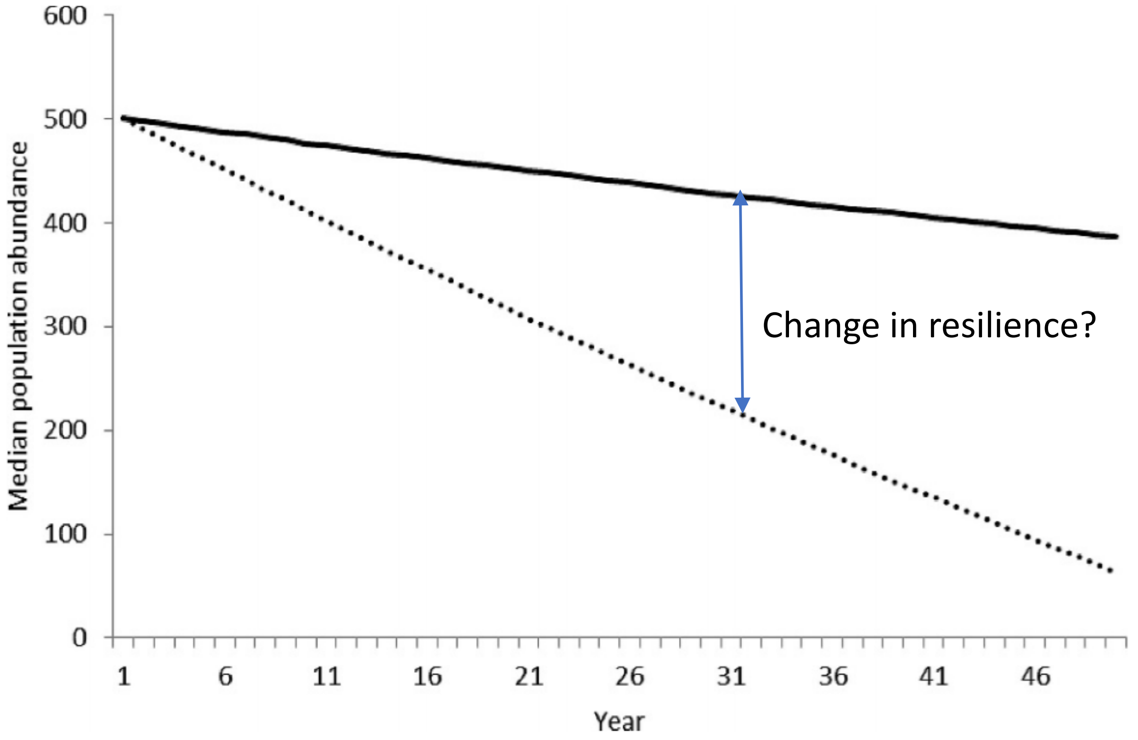


Figure 1. Comparison of the simulated median population abundance trajectories for a hypothetical endangered species with (dotted line) and without (solid line) incidental take 50 y into the future.

- Alternative "Take" scenarios
- Solid line: "no take"

  $N_{t+1} = N_t \lambda_t$
- Dotted line: "5-10 animals killed by wind farm annually"

  $N_{t+1} = (N_t - T_t) \lambda_t$

McGowan and Ryan 2010. JFWM.

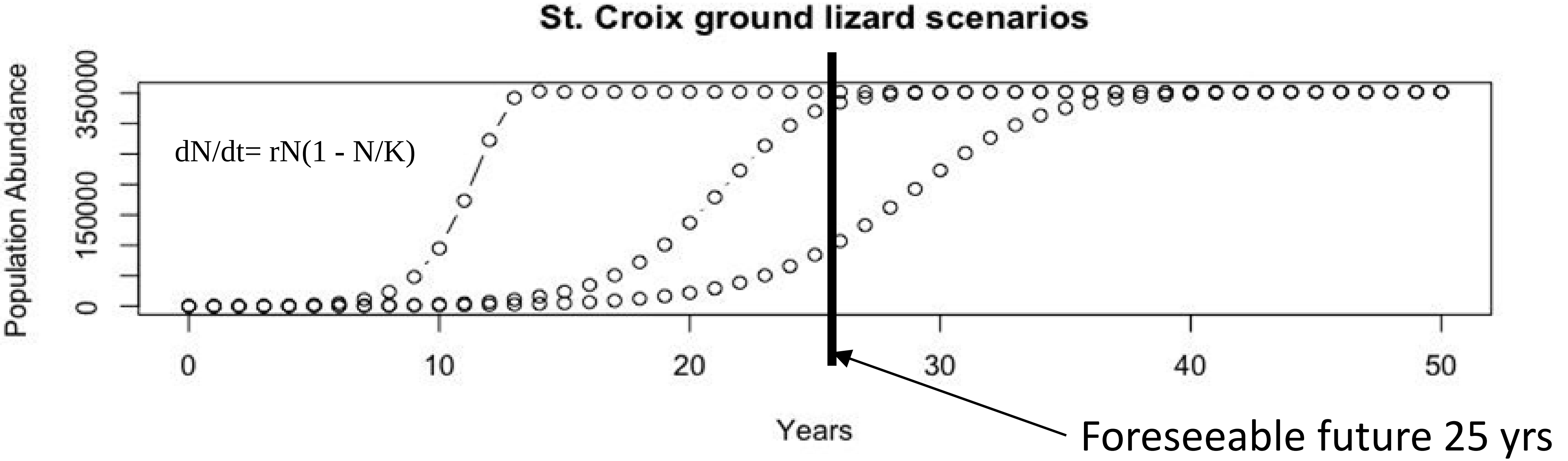
Application - St. Croix ground lizard population growth

Sec. 7 consultation - if rats are introduced and lizard mortality increases, what will happen to the population?

- All three scenarios begin with 57 individuals, carrying capacity (K) = 3,520,000

Attribute	**Scenario 1** 	**Scenario 2** 	**Scenario 3**  
Intrinsic growth rate (r)	1.13	0.5	0.35
Mortality	Fixed: 12%	Random: 20-50%	Random: 50-66%

Application - St. Croix ground lizard growth



Attribute	**S1**	**S2**	**S3**
Intrinsic growth rate (r)	1.13	0.5	0.35
Mortality	Fixed: 12%	Random: 20-50%	Random: 50-66%

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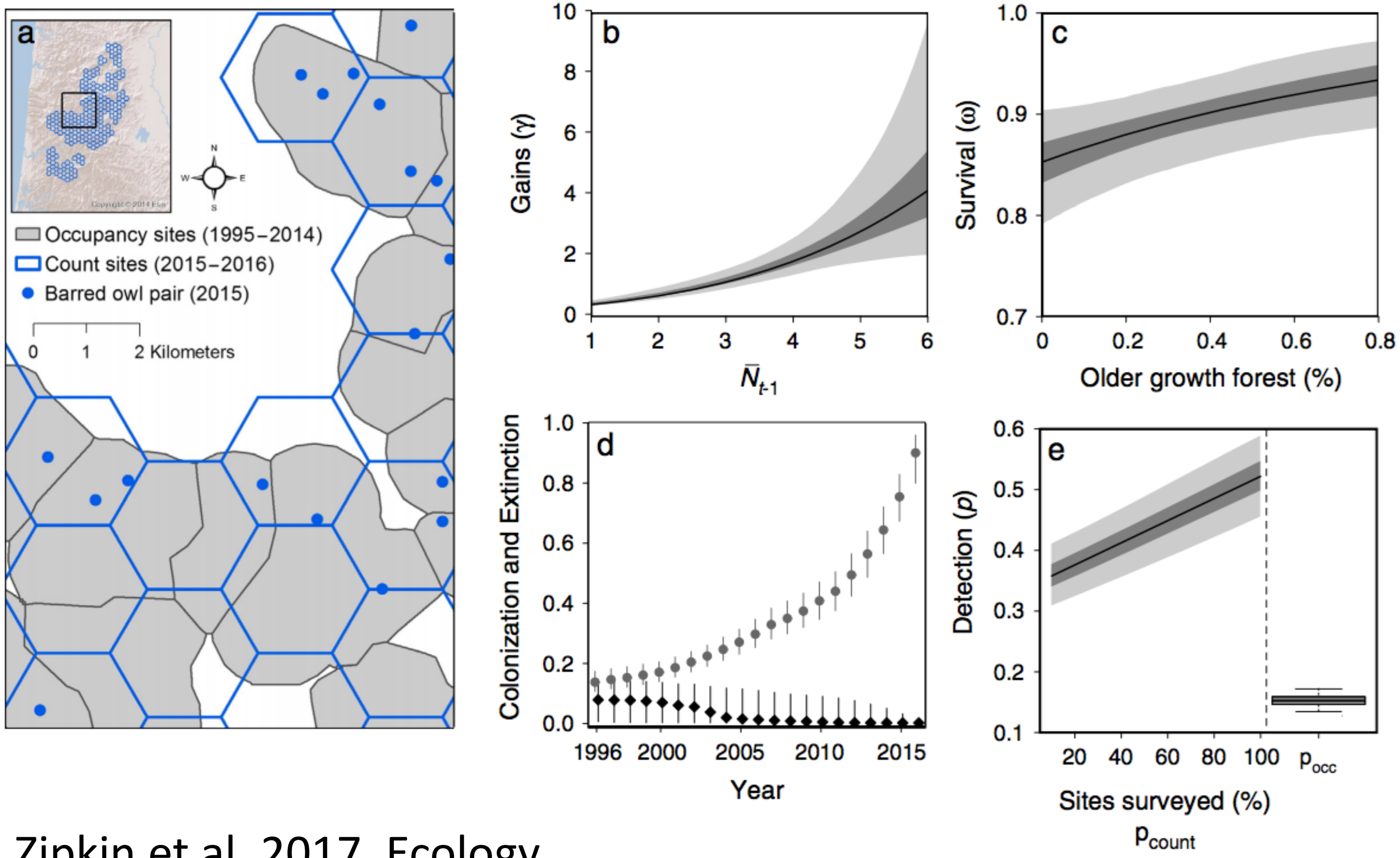
Population growth models –
Complex demographic projections can be useful for your SSA



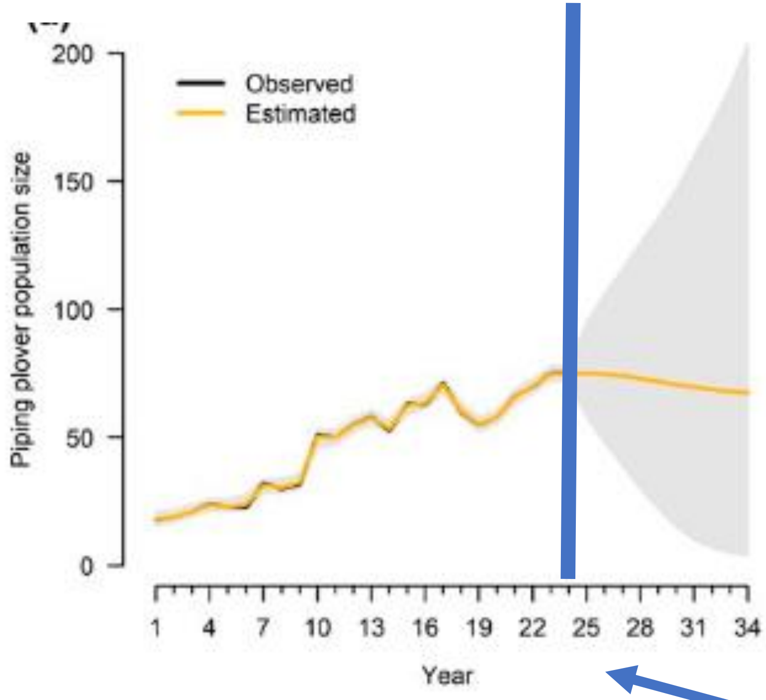
Historic and Current!

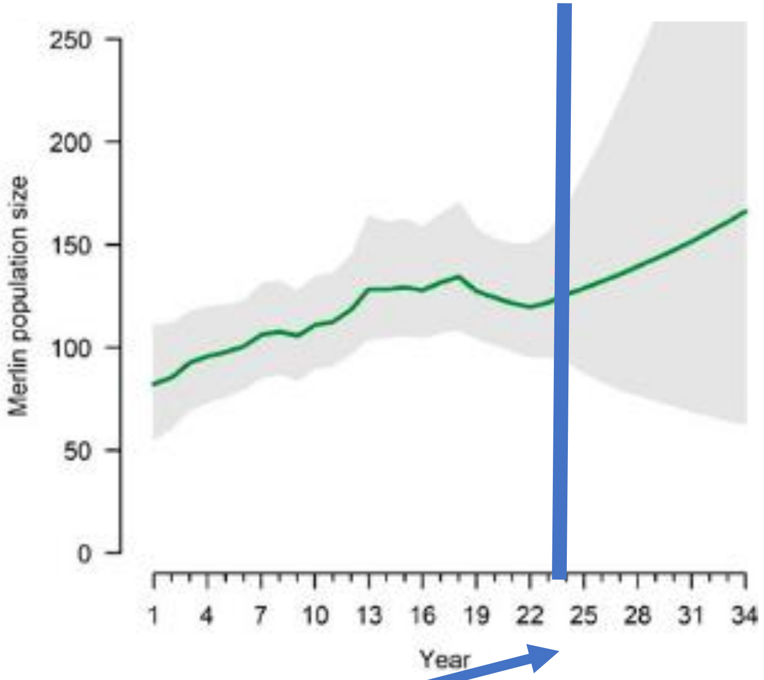
You could also use the trends to estimate the future condition!

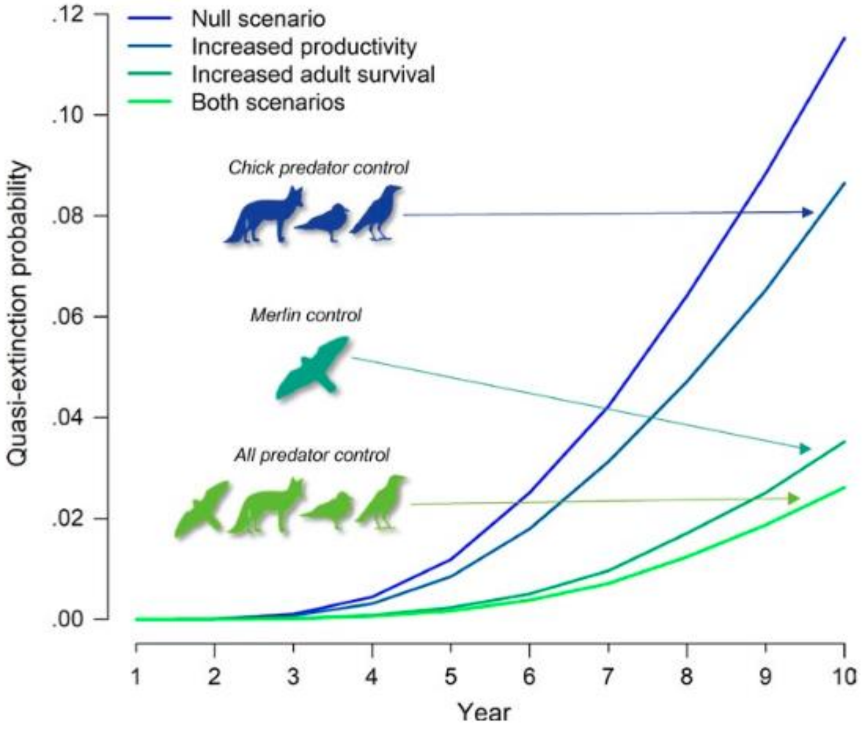
Zipkin et al. 2017. Ecology.

Application: Abundance projection with integrated population models (IPM)

Piping plover population viability under alternative management scenarios







Projection begins

Saunders et al. 2019. J. Applied Ecol.

Conclusions

- Straight-forward way to project abundance into the future
  - Minimal data required
  - Can include some threats (e.g., take) and conservation actions (e.g., head start)
- General strategy: start simple, add complexity
- Remember: the only constant is change
  - Environment all conditions
  - Genetics, morphology, distribution of species
  - Conservation actions

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