Hunting an Endangered Species?

Applying Scientific Methods to Harvest of Idaho Greater Sage Grouse Populations

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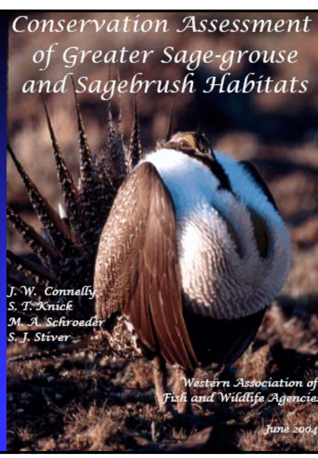
Overview

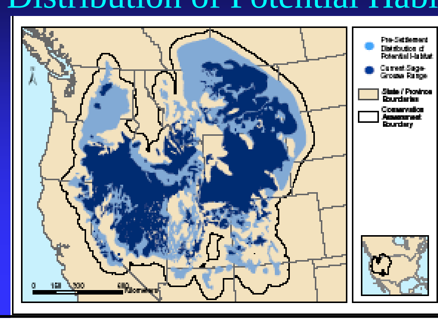
- Introduction and Background
- Conceptual Model of Grouse Populations
- A Neat Harvest Experiment
- Complex Analysis to Assess Sustainability
- Results
- Implications and Questions

ESA Petitions vs. Harvests

- 3+ petitions to list Greater Sage Grouse (*Centrocercus urophasianus*) under ESA beginning in early 90's
- Harvested in 10 states
- Status and trends?



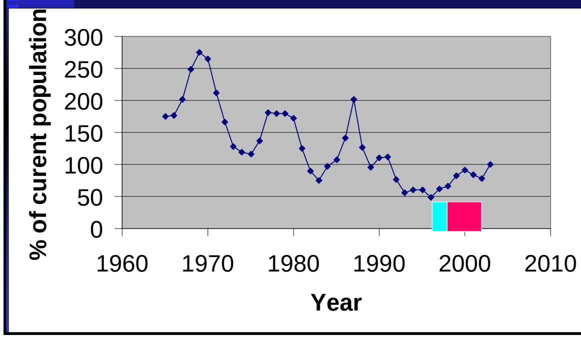
Current Distribution of Sage-Grouse and Pre-Settlement Distribution of Potential Habitat

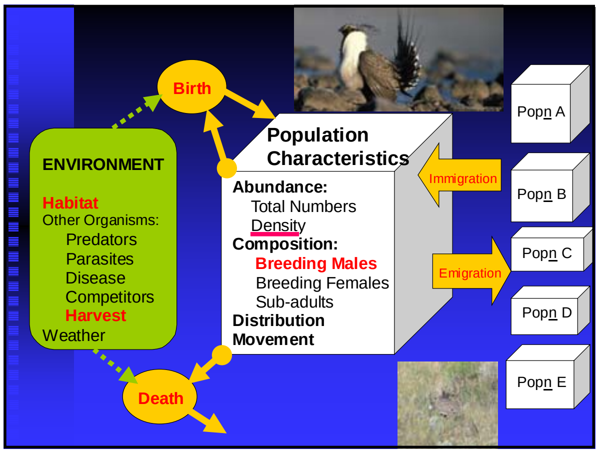


Species Assessment for WAFWA

- Sagebrush dominated area in Western US has declined from 1.2 M km^2 to current 0.6 M km^2 from
  - Urban-/suburbanization, agriculture, grazing, fire, exotic plants & energy development
- Population trend = 3.5% decline per year 1965-85
  = 0.4% decline per year 1986-2003
- Density-dependence in rates of change

Greater sage-grouse population index in Idaho



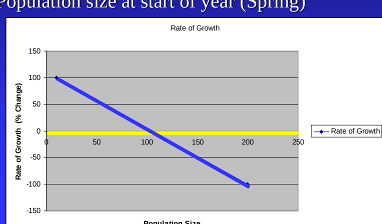


Harvest Effects

- Additive or compensatory? (Anderson 1974)?
- Compensatory effects are seen when inverse density dependence in population growth rate occurs.
- Inverse density dependence occurs when rate of population growth increases as size of population decreases (Bolen and Robinson 2003).

Inverse Density Dependent Rate of Change

- Rate of change of population = N_{2001} / N_{2000} =
  (Survivors + Recruits at end of winter)
  Population size at start of year (Spring)



Sustainable Harvest

- Sutherland (2001:132) proposed 10 fundamental principles/problems of sustainable exploitation:
  - 2. Inverse density dependence is essential.
  - 3. Quantifying density dependence is exceedingly difficult.
  - 5. Population growth rate is usually mis-measured.
  - 7. It is better to monitor the population than the harvest.

Sustainable Harvest

- Definition: Sustainable harvest requires a management system that yields long-term harvests with low chance of reducing populations to such low numbers that management interventions[1] will be required to prevent the population from becoming a small population[2].

Management interventions[1]

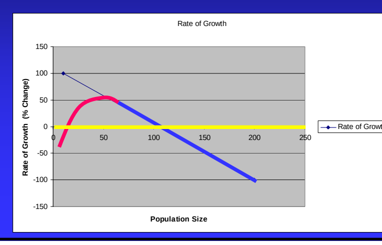
- Protection (eliminating all harvest or "takings" under US Endangered Species Act).
- Augmentation
- Habitat improvement or expansion

Small population[2]

- Small enough in numbers (density) that continued persistence is threatened by Allee effects or random effects of
  - demographic,
  - environmental, or
  - genetic processes.

Allee Effects

- Rate of change of population starts to **decline** if population reaches low enough densities!



Quantitative Model

- Conceptual model:
  - Annual rate of change of population = f(density , harvest, community)
- Ricker's model:
  - Measure annual rates of change as instantaneous annual rates:
  - $r_t = \ln (N_{t+1} / N_t)$

Expanded Ricker Model

- Discrete time stochastic logistic model incorporating harvest (H_t) and different habitat conditions (plant communities or ecoregions):
- $r_t = r_{max} - aN_t - bH_t + c_i + \sigma Z_t$
- Where
  - a = density-dependence coefficient
  - b = harvest coefficient
  - c_i = community (i) productivity coefficient
  - σZ_t = stochastic Normally distributed variance

$r_t = r_{max} - aN_t - bH_t + c_i + \sigma Z_t$

- Rate of change of population is equal to
- Maximum rate of increase of population
- minus any density dependent effect of limited resources
- minus a harvest effect
- plus a community (productivity) effect
- with some unexplained variation left over

Adaptive Harvest Management

- Idaho has pioneered Adaptive Harvest Management (Gratson et al. 1993) for big game which we applied in an analogous manner to sage grouse.
- In 1997 harvest was reduced on all sage grouse populations from the traditional 30-day seasons with 3-birds per day bag limit
- in order to do a harvest experiment intended to assess effects of harvest.

Experimental Unit

- Local sage grouse populations within GMUs
- Count males at leks along **lek routes**

Population Measurement

- Maximum count of males on each lek route each year.
- Percentage of average count for that population,
- e.g. N_t = 100 represents 100% of mean count over 8 years for that population.

Experimental Harvest Design

- Individual populations (lek routes within GMUs) randomly assigned to 3 treatment levels for a 5 year treatment period (1997-2002):
  - 7 popns = 2-birds per day, 23-day season
  - 6 popns = 1-bird per day, 7-day season
  - 4 popns + 2 INEEL = control (O harvest)

2-years pretreatment (1995-97) at historic harvest levels (3-bird bag, 30-day seasons) also incorporated into analyses.

Actual Experimental Design

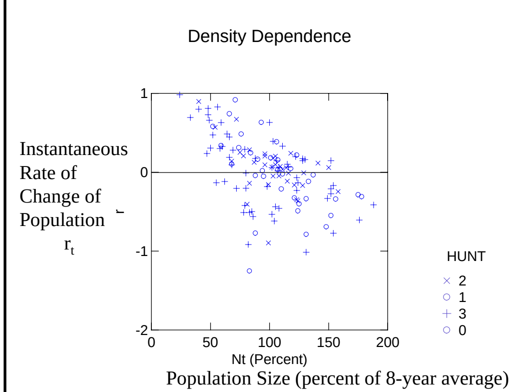
- Design not completely random as follows:
  - 4 control (no harvest) units interspersed intentionally amongst harvest units to
    - minimize movements between harvest units
    - interspersion of treatment and control units (Hurlbert's 1984)
  - 2 Idaho National Engineering Laboratory units (controls) never intentionally harvested

Analysis

- Frequentist (hypothesis testing) approach: tested a variety of competing hypotheses
- Model-building: build most parsimonious model using information theoretic methods applied to maximum likelihood estimates (Burnham and Anderson 2001).

Results

- Connelly et al. (2003) earlier analyses:
  - Higher harvest rates = faster rate of decline
- Sedinger and Rotella (2005) critique:
  - Failure to incorporate effects of density dependence



Testing for Density Dependence

- Regressed r_t on N_t
  - t-statistic testing for density dependence
  - Parametric bootstrap likelihood ratio procedure (PBLR) applied to t^2 (Dennis and Taper 1994)

Tests of Density Dependence

HUNT	n	r_{max}	a	t	Prob.
0	27	0.154	-0.256	-4.016	**0.02**
1	35	0.024	-0.280	-3.629	**<0.01**
2	35	0.064	-0.197	-3.524	**0.01**
3	34	-0.220	-0.363	-5.404	**<0.001**
All	**130**	**0.716**	**-0.007**	**-7.44**	**<0.001**

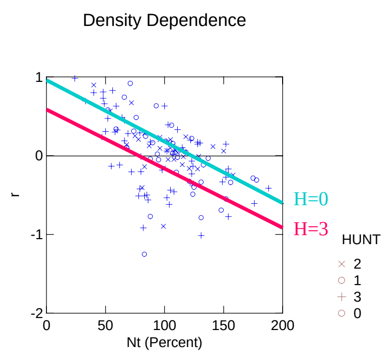
Testing Alternate Hypotheses

- Testing null hypothesis against 3 alternate hypotheses (after Dennis and Otten 2000):
  - H_1: a$\neq$0 & b=0, density dependence & no harvest effect, **P<0.001**
  - H_2: a=0 & b$\neq$0, no density dependence & harvest effect, P=0.45
  - H_3: a$\neq$0 & b$\neq$0, Strong evidence for both density dependence & harvest effects, **P=0.02**

Information Theoretic Modeling

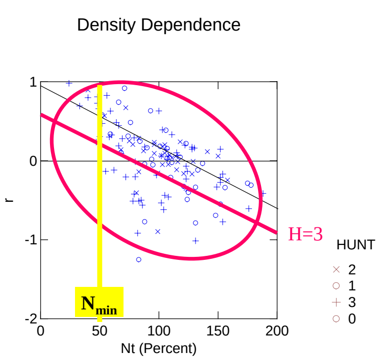
Model	AICc	ΔAIC
r_t = 0.946 – 0.00785 N_t – 0.092HUNT	**115.1**	**0**
r_t = 0.637 – 0.00802 N_t – HUNTc	115.8	0.7
r_t=0.61–0.008N_t–HUNTc+Community	117.8	2.7
r_t = 0.716 – 0.00701 N_t	119.7	4.5
r_t=0.81–0.008N_t–HUNTc+Dist30K	125.3	10.2
r_t=0.71–HUNTc	160.4	45.3

Instantaneous Rate of Change of Population r_t



Population Size (percent of 8-year average)

Instantaneous Rate of Change of Population r_t



Population Size (percent of 8-year average)

Sustainable Harvest

- Definition: Sustainable harvest requires a management system that yields long-term harvests with **low probability** of reducing populations to such **low numbers** that management interventions[1] will be required to prevent the population from becoming a small population[2].

Parametric bootstrap on minimum population size in 100 years

Harvest	Prob(N_{min}< 25% of long-term mean)	Prob(N_{min}< 33% of long-term mean)
0	0.9%	5%
1	1.5%	11%
2	4%	25%
3	**13%**	**60%**

Conclusions

- Strong evidence for inverse density dependence
- Strong evidence that harvest reduces the rate of change of the population.
- Both factors operate at same time.

Implications

- Best models suggest that all but highest level of harvest are sustainable and that the populations would fluctuate stochastically around different levels:
  - 0 Hunt => Popn 20% higher than ave.
  - 1 Hunt => Popn 9% higher
  - 2 Hunt => Popn 3% lower
  - 3 Hunt => Popn 15% lower

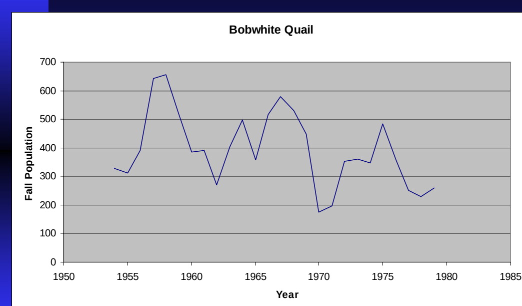
Implications

- Highest harvest level (traditional 3-birds per day, 30-day season) would increase the likelihood that population would reach a low enough population size that management intervention would be required to preserve the population.
- The highest harvest rate is not sustainable under this harvest system.

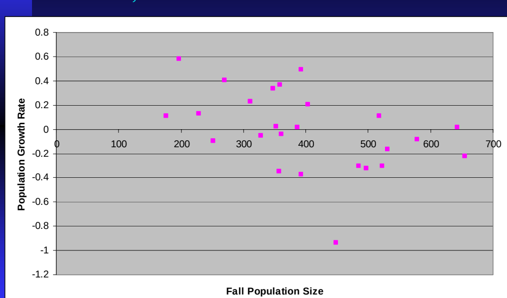
Inverse Density Dependence in Bobwhite Quail at Carbondale, Illinois

- Roseberry and Klimstra (1984) studied bobwhite quail population near Carbondale, Illinois for 26 years.
- They demonstrated a very complex pattern of population regulation including numerous inverse density dependent relationships between survival/reproduction and population size and rates in current or previous years.

Bobwhite Quail at Carbondale RA, Illinois



Density Dependence in Bobwhite Quail Population at Carbondale, Illinois



Tests of Density Dependence in Bobwhite Quail Population at Carbondale, Illinois

- Applying the same test to Roseberry and Klimstra's (1984) data:
- Model: $r_t = 0.442 - 0.00448\ N_t$
- Density dependence is significant ($P<0.05$)
- This population is more resistant to declines to low population sizes under harvest system in practice: Prob(N_{min}<33%) = 25%
  - Prob(N_{min}<25%) = 5%
  - Prob(N_{min}<10%) < 1%
- Note: Harvest was 31-49 day seasons (Ave. 49 gun hrs./ 100 ha/ season)


Questions