Balancing cost and income in red deer management – a case study from Norway

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Background

- Recent large increases in deer population sizes both in Europe and North America
- Ecological key stone species
  - Vegetation and general ecosystem impact
- Increased potential hunting benefits
- Costs related to traffic incidents, damage to forestry, agriculture field damage


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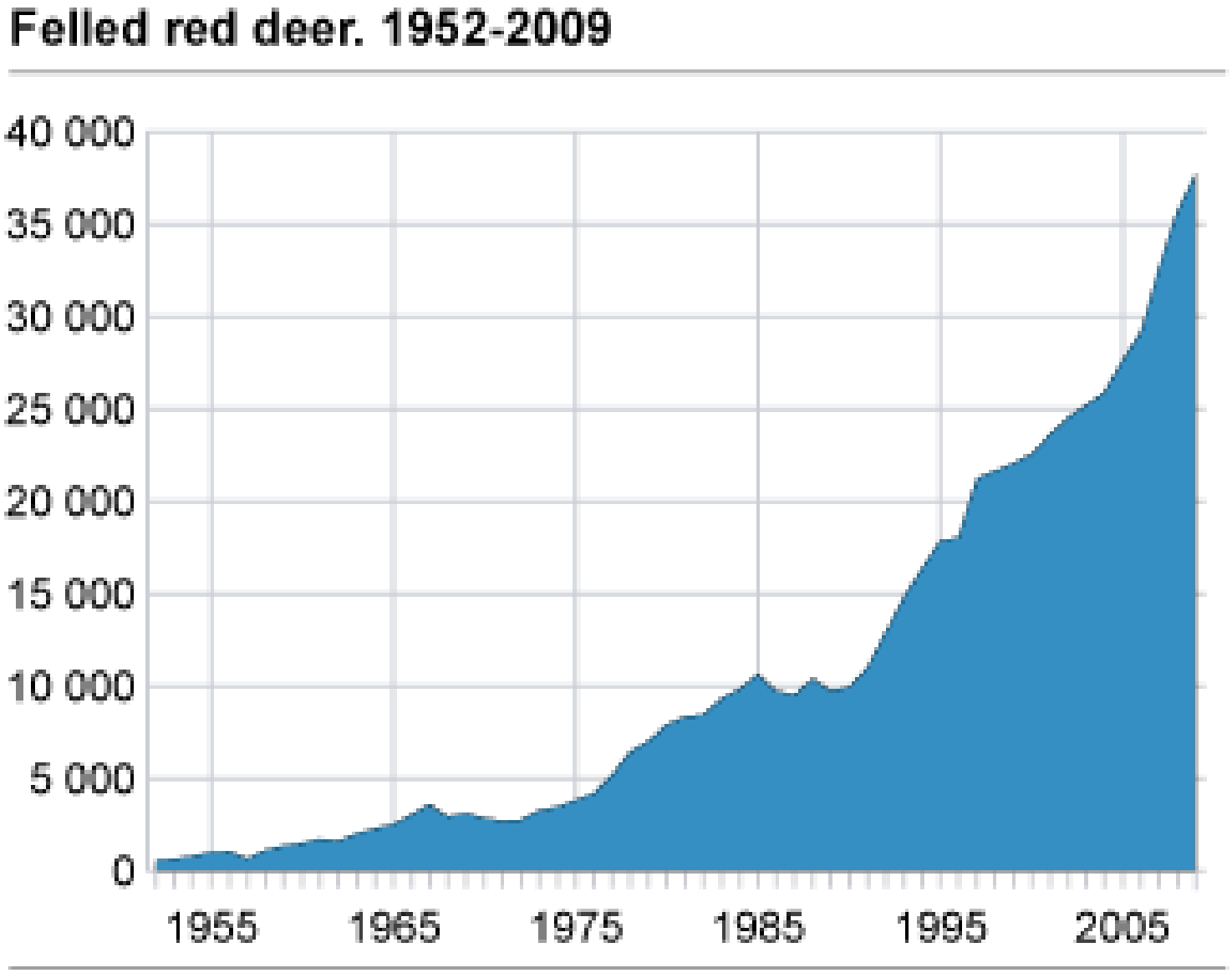
Norwegian red deer stock:



Two main reasons:

1. Selective harvesting
   - Harvest more bulls (stags), calves and yearlings, less females
2. Forestry practice
   - From selective logging to clear cutting

Motivation:

- Biological project to maximize meat production
- Economic considerations?
  - Stage structured harvesting
  - Overall red deer stock

Stage structured harvesting in general

- Calf harvesting:
  - Resistance among hunters
- Trophy hunting:
  - Trophy bulls very rare

Overall stock size in general:

- Grazing damage costs
- Traffic damage costs
  - material costs as well as road accident deaths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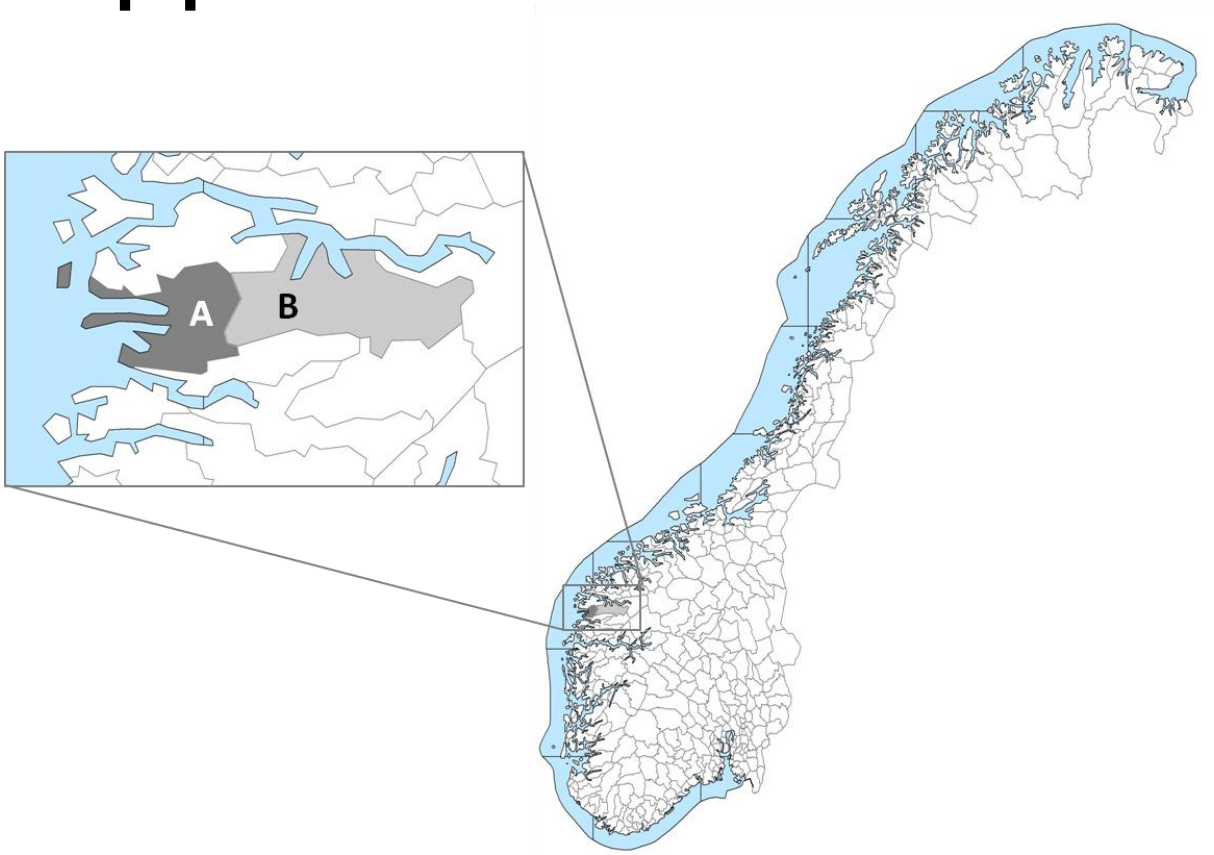
Map, study area: Flora and Gloppen



Landowner perspective:

- Case 1: Landowners maximising hunting value only: *V+B*
- Case 2: Landowners maximizing hunting value taking grazing damage costs into account: *V+B-D*

Ecological model

- five-stage model:
  - calves (X_c)
  - female yearling (X_{yf})
  - male yearlings (X_{ym})
  - adult females (X_f)
  - adult males (X_m)

Hunting

- Choosing harvest fractions (controls):

1) h_c: Harvest rate calves
2) h_{yf}: Harvest rate female yearlings
3) h_{ym}: Harvest rate male yearlings
4) h_f: Harvest rate females
5) h_m: Harvest rate males

Ecological model

1) $$X_{c,t} = r_{yf}(X_{yf,t})X_{yf,t} + r_f(X_{f,t})X_{f,t}$$

2) $$X_{yf,t+1} = \psi s_c(1-h_{c,t})X_{c,t}$$

3) $$X_{ym,t+1} = (1-\psi)s_c(1-h_{c,t})X_{c,t}$$

4) $$X_{f,t+1} = s_{yf}(1-h_{yf,t})X_{yf,t} + s_f(1-h_{f,t})X_{f,t}$$

5) $$X_{m,t+1} = s_{ym}(1-h_{ym,t})X_{ym,t} + s_m(1-h_{m,t})X_{m,t}$$

Code of conduct restriction:

- Calves dependent on mother first winter:

$$h_c X_c \geq h_f X_f$$

Avoid extremely sex skewed sex ratio

- $h_{ym,t} \leq \bar{h}_{ym}$ and $h_{m,t} \leq \bar{h}_{m}$

- Or

$$X_{m,t} / X_{f,t} \geq \bar{x}$$

$$L=\sum_{t=0}^{\infty}\rho^{t}\left\{\left[p_c h_{c,t}[r_{yf}(X_{yf,t})X_{yf,t}+r_f(X_{f,t})X_{f,t}]+[p_{yf}h_{yf,t}+p_{ym}h_{ym,t}(1-\psi)/\psi)]X_{yf,t}+p_f h_{f,t}X_{,t}+p_m h_{m,t}X_{m,t})\right]\right.$$

$$+(z/\theta)(h_{c,t}+h_{yf,t}+h_{ym,t}+h_{f,t}+h_{m,t})-\rho\eta_{t+1}\left[X_{yf,t+1}-\psi s_c(1-h_{c,t})[r_{yf}(X_{yf,t})X_{yf,t}+r_f(X_{f,t})X_{f,t}]\right]$$

$$-\rho\lambda_{t+1}\left[X_{f,t+1}-s_{yf}(1-h_{yf,t})X_{yf,t}-s_f(1-h_{f,t})X_{f,t}\right]-\rho\mu_{t+1}\left[X_{m,t+1}-[s_{ym}(1-h_{ym,t})(1-\psi)/\psi]X_{yf,t}-s_m(1-h_{m,t})X_{m,t}\right]$$

$$\left.-\rho\omega_{t+1}[h_{f,t}X_{f,t}-h_{c,t}[r_{yf}(X_{yf,t})X_{yf,t}+r_f(X_{f,t})X_{f,t}]]-\rho\zeta_{t+1}(h_{m,t}-\bar{h}_m)\right\}$$

Kuhn-Tucker conditions

$$\frac{\partial L}{\partial h_{i,t}} \leq 0 \; ; \qquad 0 \leq h_{i,t} < 1 \qquad (i = c, yf, ym, f, m)$$

What can be shown analytically?

- Not much…
- Possible to say something about the harvest pattern when the recreational value is zero (or negligible)
- Especially if we ignore the code of conduct harvest restrictions as well….
- Without female-calf restriction: No calf harvest
- With the restriction, it is always binding
- All adult males should be harvested

Baseline results, biological

	Case 1	Case 2
h_c	0.11	0.12
h_{yf}	0.33	0.37
h_{ym}	0.55	0.55
h_f	0.08	0.11
h_m	0.55	0.55
H	752	682
X_c	1 176	1 021
X_{yf}	392	336
X_{ym}	392	336
X_f	1 720	1 137
X_m	264	227
X	**3 944**	**3 057**

Baseline results, economic

	Case 1	Case 2
Meat value (V)	3,016	2,700
Recreational value (B)	809	850
Hunting value (V+B)	3 825	3 550
Grazing cost (D)	2,099	1,594
Overall net benefit (R=V+B-D)	1,726	1,956
R/H	2.295	2.868
R/X	**0.438**	**0.640**

Optimal uniform harvest rate

- Case 1: (h=0.18), net benefit=NOK 693 (from 1,726)
- Case 2: (h=0.19), net benefit=NOK 752 (from 1,956) in Case 2.

Sensitivity analysis

- Economic results sensitive to the male harvest constraint
- Harvest pattern generally very stable to different parameter changes, except…
- High recreational value: More calf than female harvest (restriction does not bind!)

Concluding remarks

- Stage structured harvest pays off
- Recreational value crucial
- Grazing damage important
- Current red deer stock is to high
- Current harvest pattern is wrong