Modeling Regional Dynamics of Human-Rangifer Systems: A Framework for Comparative Analysis

- **Matthew Berman**

- Institute of Social and Economic Research, University of Alaska Anchorage, Anchorage, AK, USA
- matthew.berman@uaa.alaska.edu

Similar sets of factors affect viability of both herding and hunting

- Environmental factors affecting forage quality, insects, snow and ice, etc.
- Environmental variability
- Geographic factors -- energetics of moving across landscape, summer-winter range
- Social factors: human population food needs, markets, culture, institutions

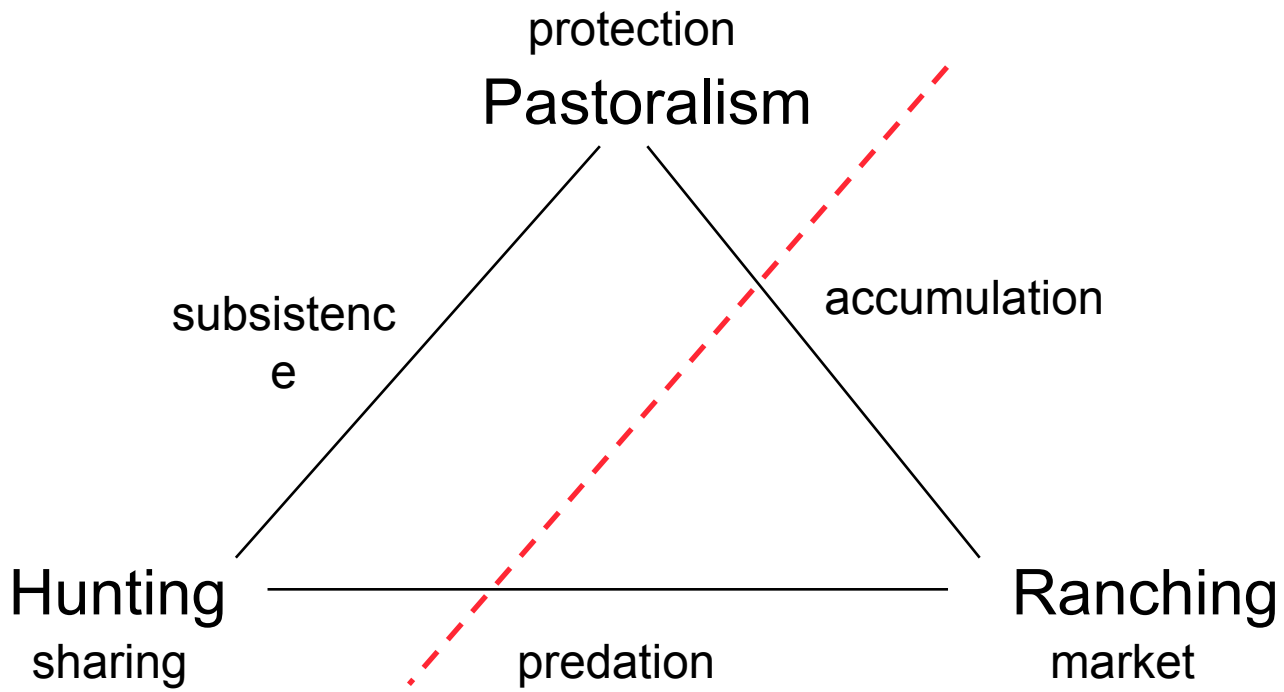
Wild and domestic herds are ecological competitors

- Forage limitations, overgrazing and trampling
- Parasite and disease vectors
- Loss of domestic animals to wild herds

... but social complements

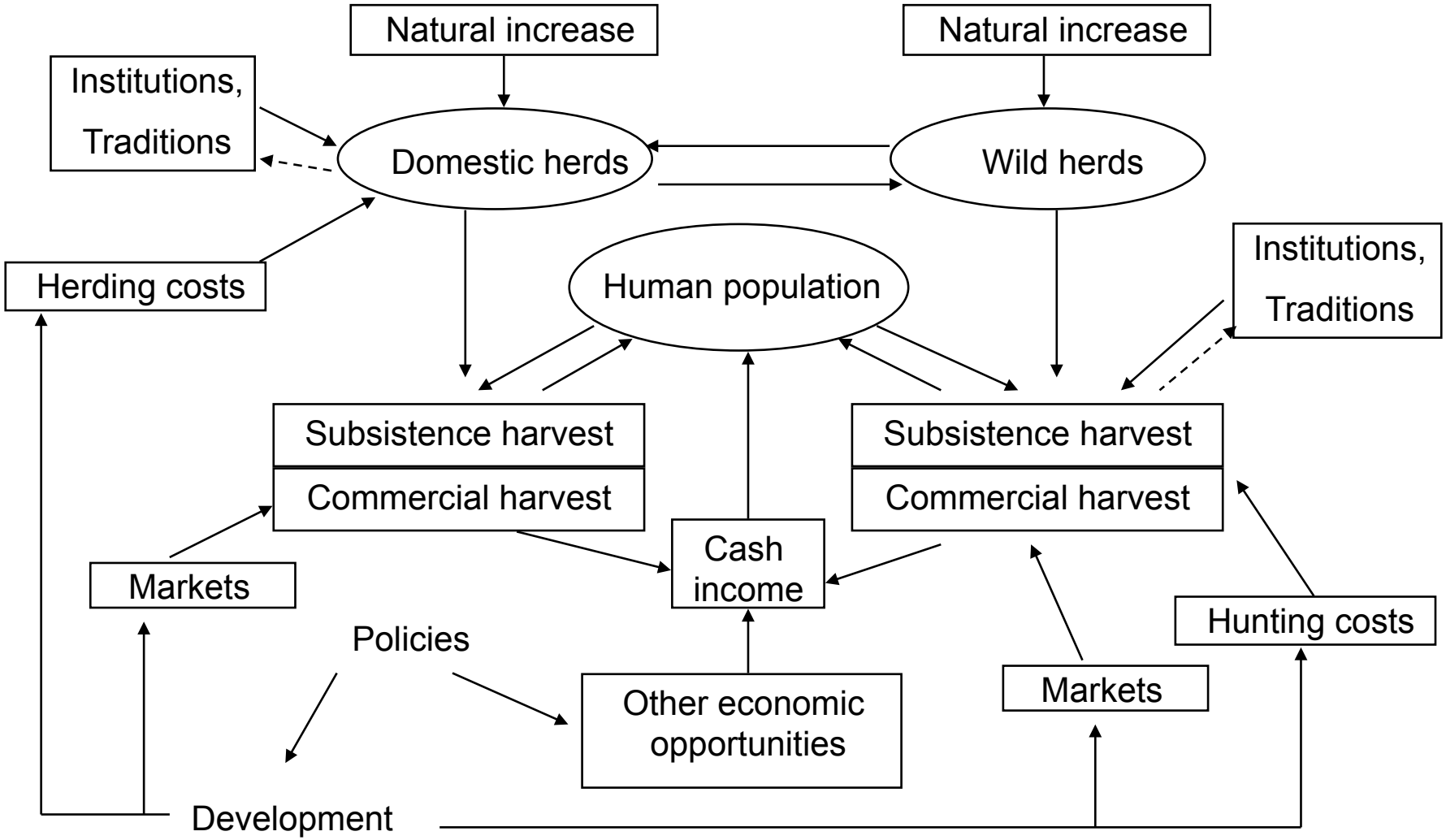
- Substitutes for subsistence -- human predation
- Market economies of scale -- large wild herds lower threshold for viability of commercial herding
- Domestic herds may provide transportation for hunters

Human-Rangifer Systems: Modes of Production



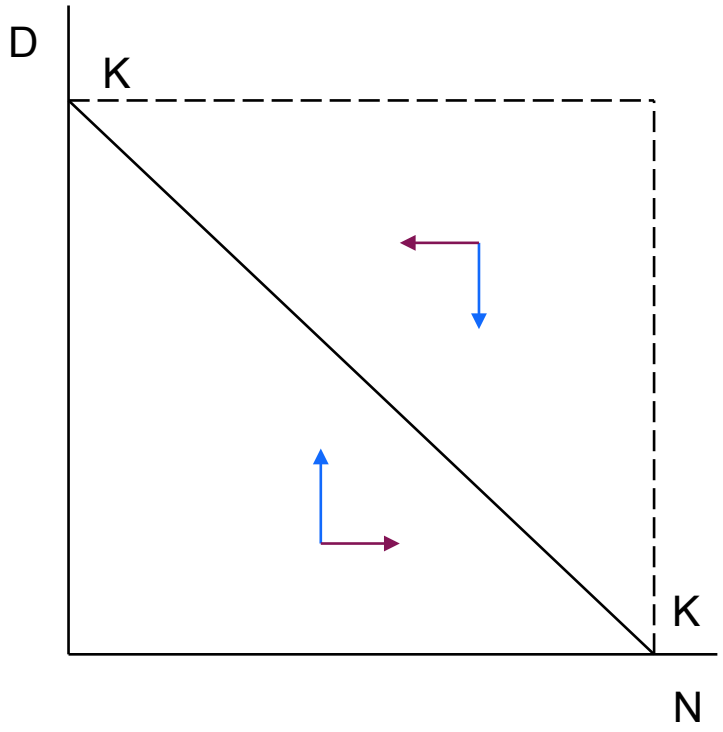
Source: Ingold (1980), p. 4.

Conceptual Socio-Economic Model of the Human-Rangifer System



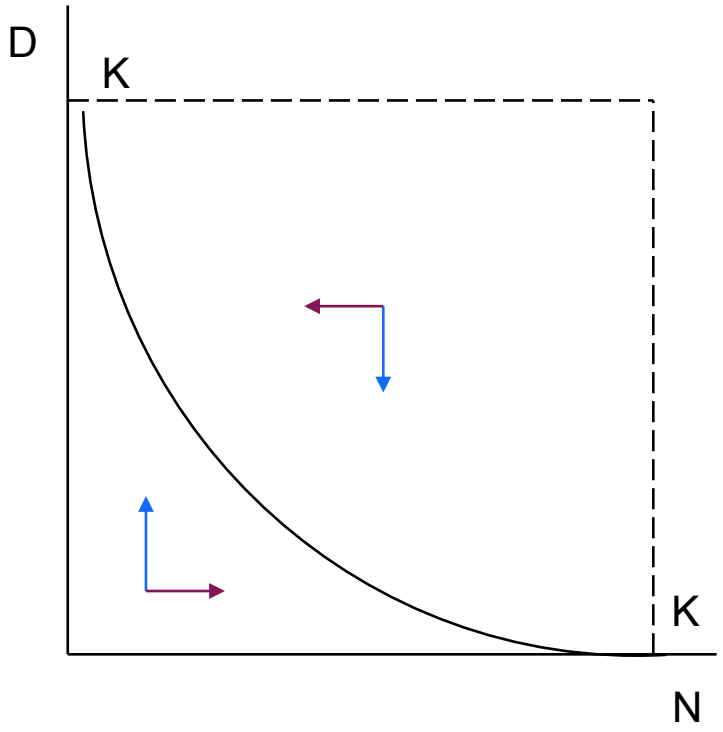
Simple density-dependent models of interaction

D = domestic herd size, N = wild herd size



Shared carrying capacity, K

$$\frac{d\ln(D)}{dt} = r\left[1-(D+N)/K\right]$$



Shared carrying capacity with competition

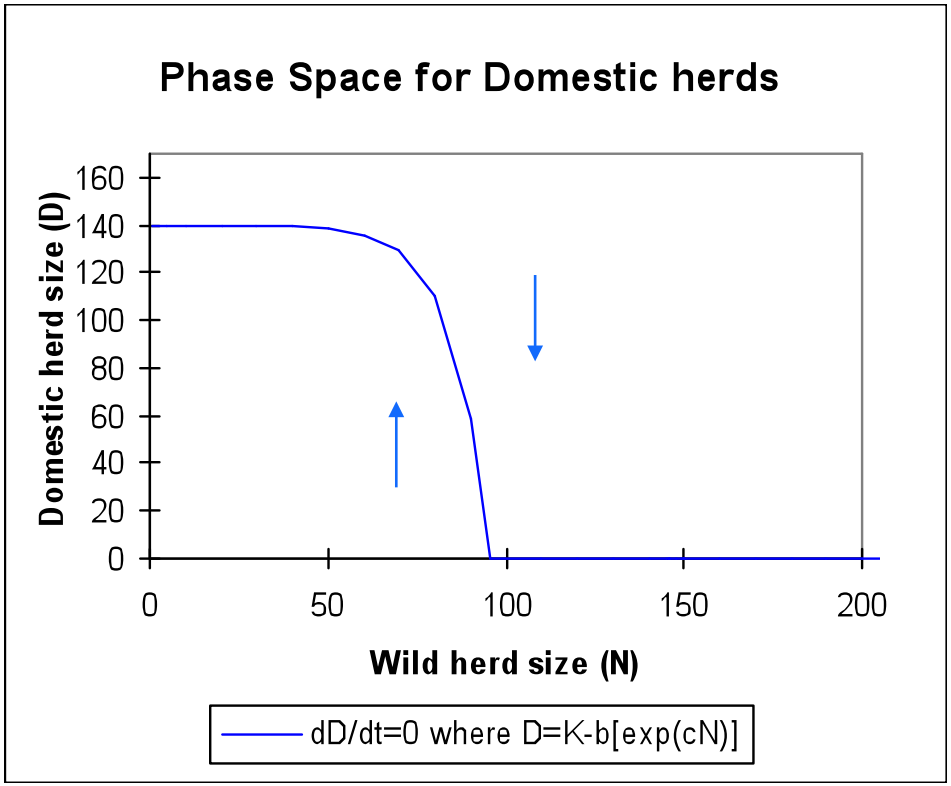
$$\frac{d\ln(D)}{dt} = r\left[1-(D+N+aDN)/K\right]$$

Differential effects of ecological competition suggest more complex interactions of domestic and wild stocks

- Loss of domestic animals to wild herds (affects domestic only)
- Wild herds better able to disperse to avoid overgrazing and trampling forage with higher population numbers
- Wild herds able to move long distances across difficult terrain better than domestic herds to exploit summer and winter ranges
- High-density herding increases parasite and disease problems
- Remnant wild herds may persist in reduced range, even with large domestic herds occupying most potential habitat
- Selective breeding, managed age-sex distribution, and predator control increases domestic recruitment rate for given harvest level

More complex density-dependent models of interaction

Domestic herds in competition with wild herds



$$\frac{d\ln(D)}{dt} = r\left[1-(be^{cN}+D)/K\right]$$

Parameters:

K (carrying capacity) = 140

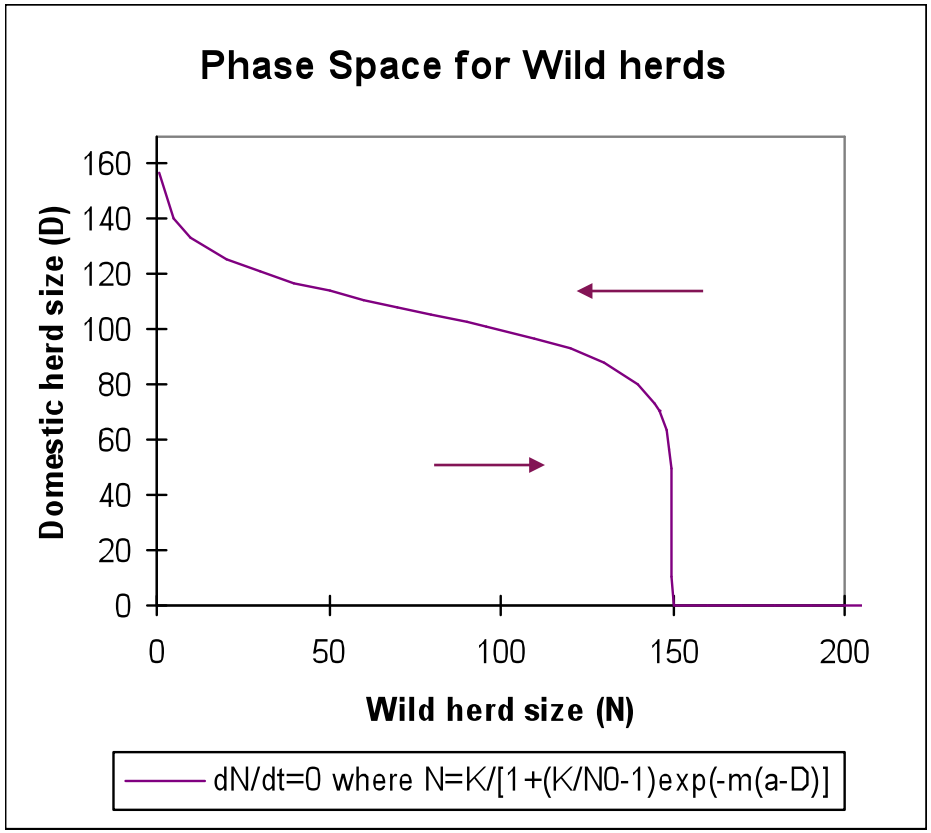
b (skew factor: b>0) = 0.01

c (wild-domestic compatibility factor, when combined with b: c > 0) = 0.1

K and r (growth rate) for domestic herds determined by social as well as ecological factors

More complex density-dependent models of interaction

Wild herds in competition with domestic herds



$$\frac{dN}{dt} = r\frac{N}{K}\left[\frac{K}{1+\left(K/N_0-1\right)e^{-m(a-D)}} - N\right]$$

Parameters:

K (carrying capacity) = 150

N_0 (minimum viable wild population) = 2

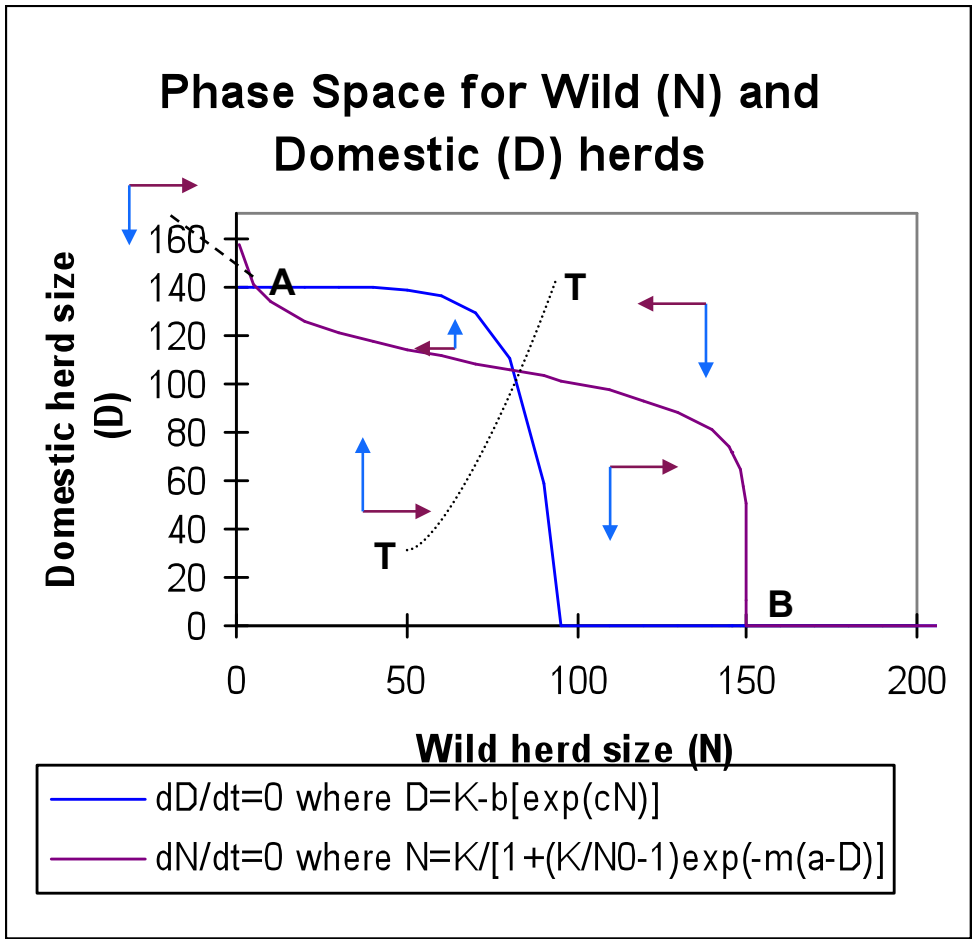
m (wild-domestic compatibility, determined by social as well as ecological factors) = 0.1

a (domestic herd threshold for extirpation of wild herds) = 150

K and r (growth rate) for wild herds determined by ecological factors

More complex density-dependent models of interaction

Wild and domestic herds in competition



Stable states and thresholds:

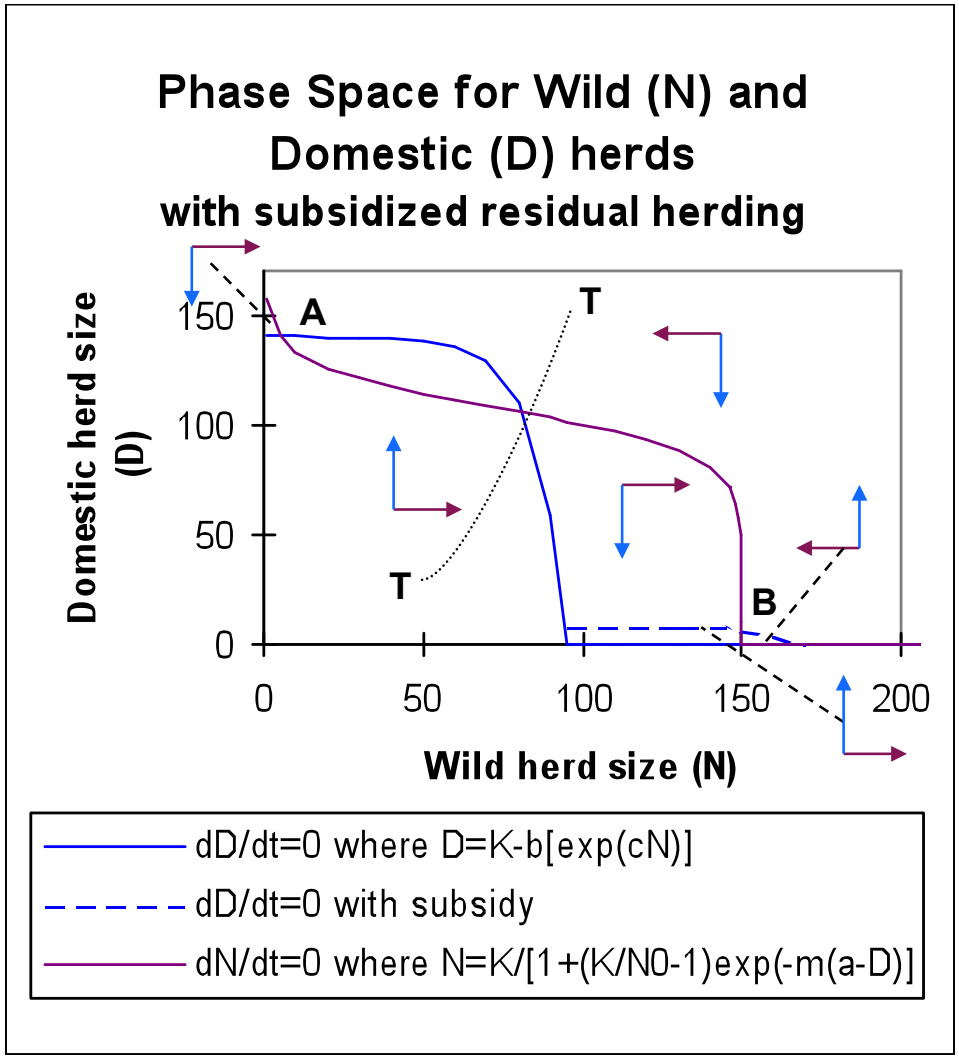
A - stable herding state with residual wild herd

B - stable hunting state, no herding

TT - state-change threshold

More complex density-dependent models of interaction

Wild and domestic herds in competition with subsidized residual herding or herding for transportation support to hunting



Stable states and thresholds:

A - stable herding state with residual wild herd

B - stable hunting state, residual subsidized herding or small herds to support hunting system

TT - state-change threshold

In this example, “subsidies” support a maximum herd size of 8. Large subsidies or state support for herding could raise the “subsidized” herding level equal to or even above domestic K.

Getting herding started in a hunting society

- Is domestication for transportation feasible and worth the effort?
  - Geographic features
    - Terrain complexity increases difficulty of controlling herds
    - Barriers to moving across the landscape with sleds (open water, wetlands, steep canyons, etc.)
    - Distance between summer and winter ranges
  - Availability and suitability of substitute technologies -- dogs, mechanized transport
  - Compatibility of herd movements with seasonal subsistence cycles (Ingold: taiga dwellers at tree line in better position to develop herding for transportation to support hunting than coastal tundra dwellers)
- Is herding for food feasible and worth the effort?
  - Rangifer dependence and food security -- availability of other food sources and vulnerability to food shortages from wild stock crashes (Krupnik hypothesis)
  - Availability of markets for products -- Russia, Seward Peninsula

Environmental Variability, Herd Cycling, and System State Changes

- Environmental variability – effects on recruitment rate r
  - Forage and other energetics effects on cow and calf body condition
  - Body condition affects calf survival and pregnancy rate
  - Effect on pregnancy rate leads to effect on next year's recruitment
  - Produces positive first-order autocorrelation of variable recruitment rate, r
  - May apply to domestic as well as wild herds?
- Frame size and herd cycling (Russell et al.)
  - K moves up or down over decadal scale, due to nutri
  - Wild herds only, due to controlled domestic breeding
- Large environmental shocks or large cycling effects may push a seemingly stable system past the threshold line and cause system to change states.
- Policy shifts, especially in combination with environment-caused cycling, may change domestic K enough to push the system across the state-change threshold.

Empirical strategies for estimating parameters of the model for use in comparative analyses across regions of the Arctic

- Expert knowledge
- Statistical methods
- Bayesian estimation – combining the two

RESILIENCE		Status in 1960-1970				Trends					Present			status
		Dom.R No	Wild R No	Pas tures	Reindeer Economy	Dom.R No	Wild R No	Pastures	Reindeer Economy		Dom.R No	Wild R No	Pas tures	Reindeer Economy
Yamal	Nenets (tundra)	H	L	O	Hd Co	↑	=	↓	≡		H	L	O	Hd Co
	Forest Nenets	M	L	U	Hd Co+Ht Sb	=	=	↓	≡		M	M	U	Hd Co+Ht Sb
	Khants	M	L	U	Hd Co	↓	=	↑	≡		L	L	U	Hd Sb
	Selkups	M	L	U	Hd Co	×	↑	=	Hd →Ht	Co →Sb	A	L	U	Ht Sb
Taimyr	Nenets	H	M	N	Hd Co	=	↑	=?	Hd → Hd +Ht		H	M	?	Hd Co+Ht Sb
	Evenks	M	L	N	Hd Co	↓	=	↓	≡	Co →Sb	L	L	?	Hd Sb
	Nganassan	H	H	N	Hd Co+Ht Sb	×	↑↑	↓	Hd →Ht	(Co →Sb)	A	H	?	Ht Co (Sb)
	Dolgans	M	H	U	Hd Co+Ht Sb	↓	↑↑	↓	Hd → Hd +Ht	Co →Sb	L	H	?	Ht Co+Hd Sb
N. Evenkia	Evenks	M	M	U	Hd Co	×	↑↑	?	Hd →Ht	Co →Sb	M	H	?	Ht Sb
	Yakuts	M	M	U	Hd Co	↓	↑↑	?	Hd → Hd +Ht	Co →Sb	M	M	?	Hd Sb+Ht Sb
Yakutia	North-West	H	L	N	Hd Co	↓	↑	?	Hd → Hd +Ht	Co →Sb	L	M	N?	Hd Sb+ Ht Sb
	North-East	H	L	N	Hd Co	↓	↑	↑	Hd → Hd +Ht	Co →Sb	L	M	N?	Hd Sb +Ht Sb
	South	M	L	U	Hd Co	↓	=	=	Hd → Hd +Ht	Co →Sb	L	L	U	Hd Sb+Ht Sb
Chukotka	North	H	L	O	Hd Co	↓	↑	↑	Hd → Hd +Ht	Co →Sb	L	M	U	Hd Co
	North-East	H	A	O	Hd Co	↓		↑	≡	Co →Sb	L	A	U	Hd Co
	Centre	H	L	O	Hd Co	↓	↑↑	↑	Hd → Hd +Ht	Co →Sb	M	H?	?	Hd Co
	West	M	L	N	Hd Co	×	↑	↑	Hd →Ht	Co →Sb	A	M?	U	Hd Co
	South	H	L	N	Hd Co	↓	↑	↑	Hd → Hd +Ht	Co →Sb	L	L?	U	Hd Co
	South-East	H	A	O	Hd Co	×		↑	×		A	A	U	Hd Co