Models and Ecological Data

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Mt Rundle Hike

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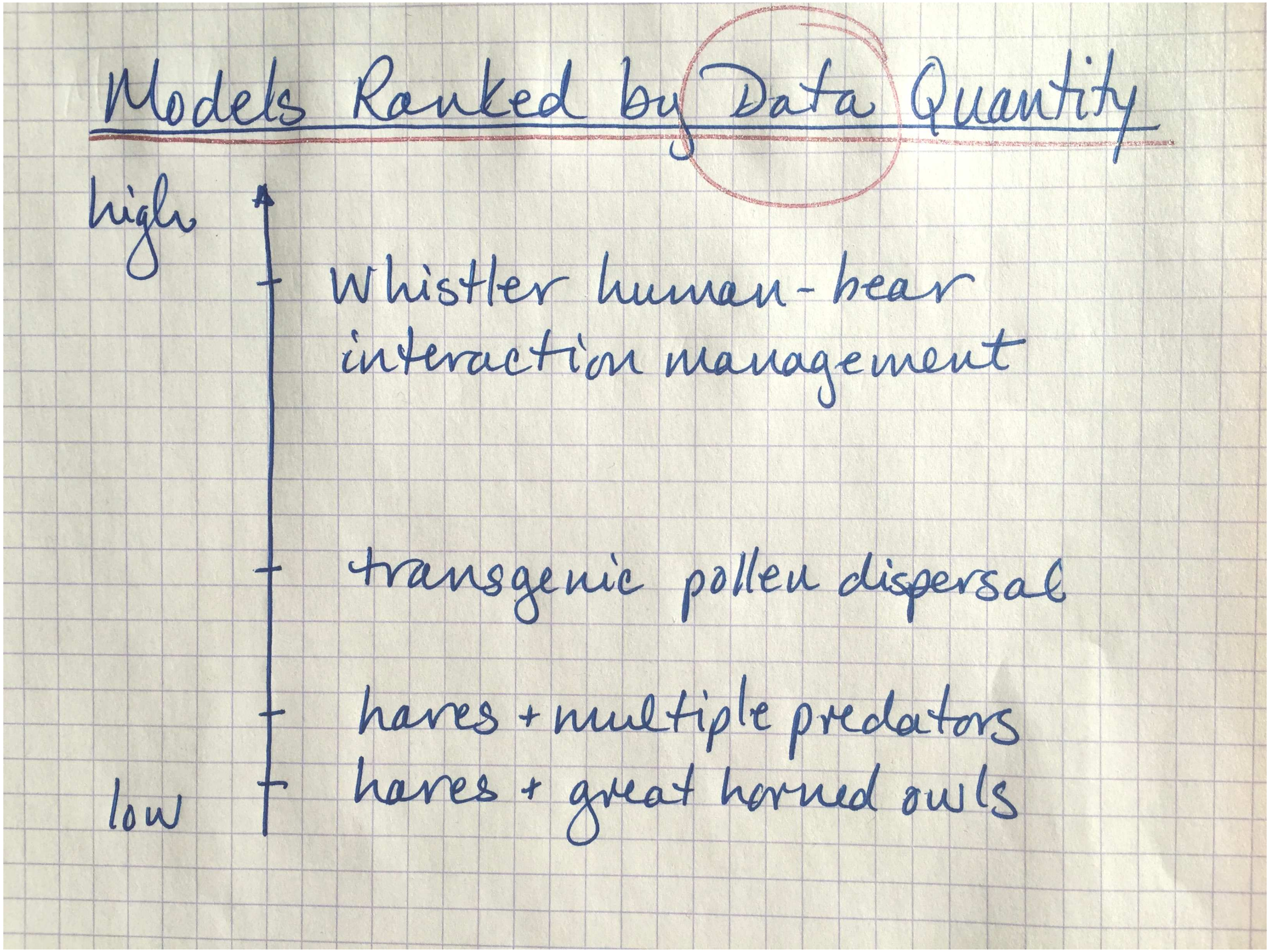
Models Ranked by Data



1. Whistler HBI Management

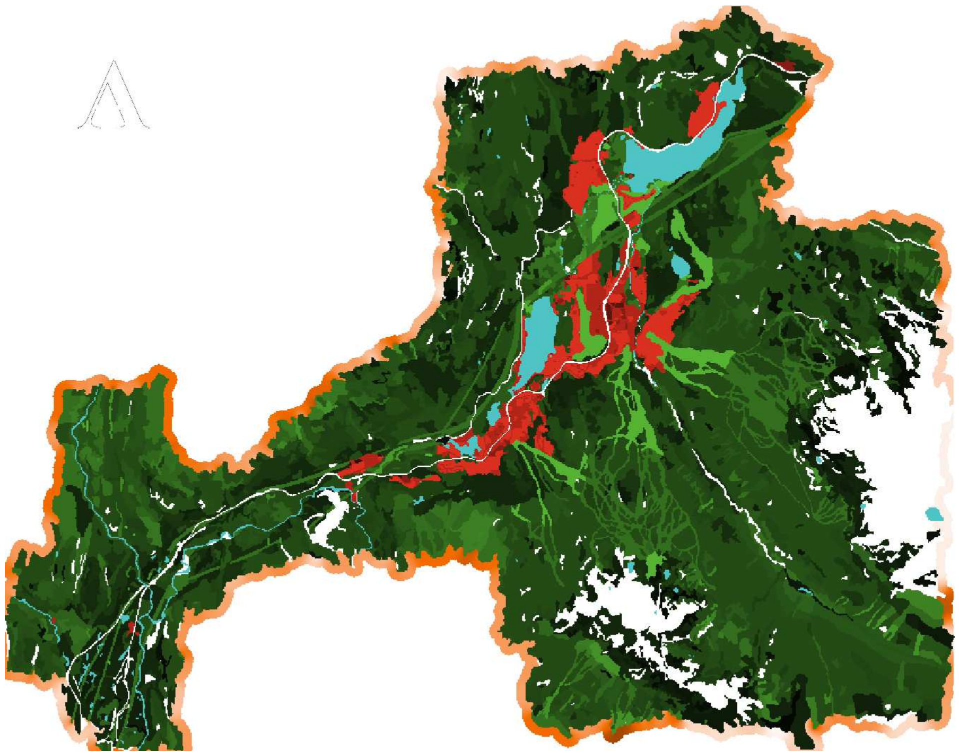
Research Question: Which management options will have the greatest effect at reducing HBI in Whistler?

Data:

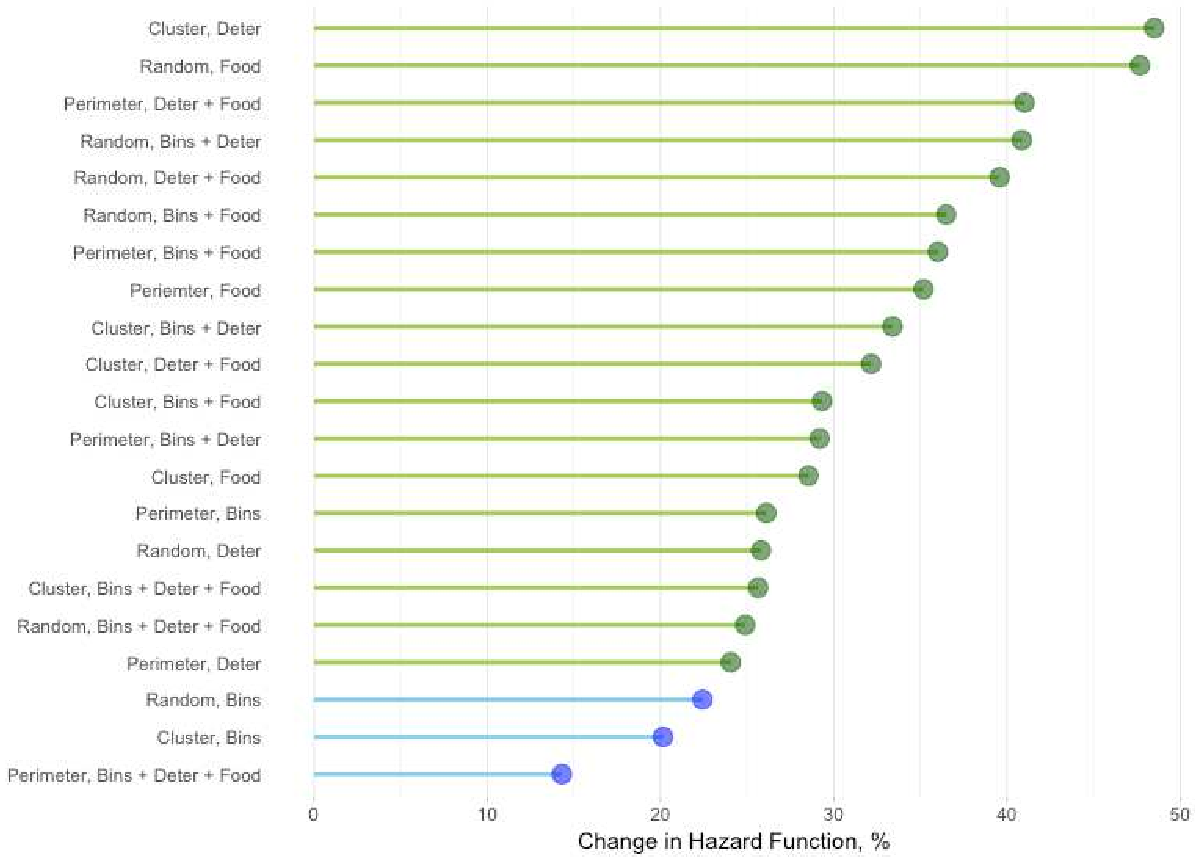
- GPS data from 9 collared bears
- vegetation maps
- urban zoning maps

Model:

- ABM



Results



Impact: new approach → proof of concept

Marley et al (2019) Ecological Modelling

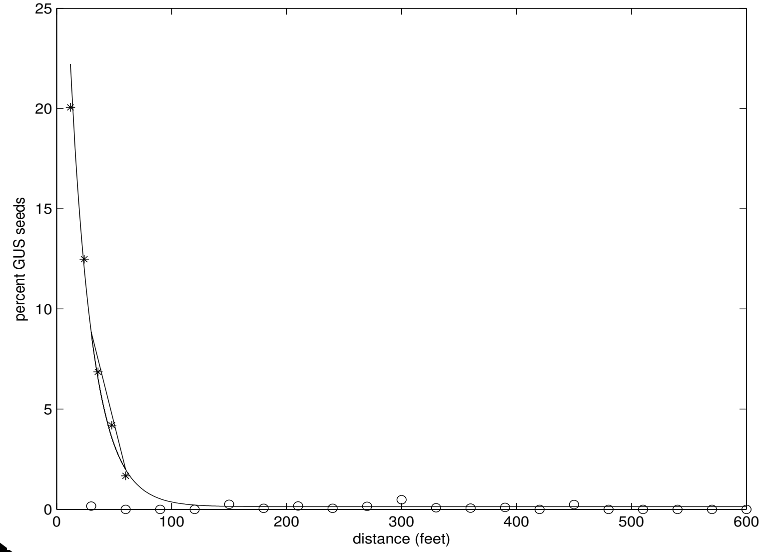
2. Transgenic Pollen Dispersal

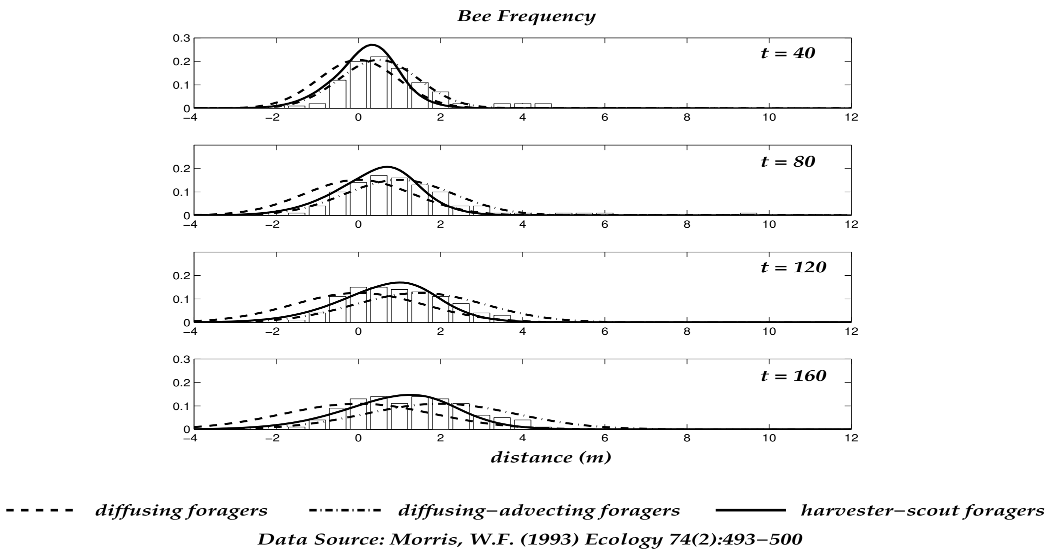
Research Question: How far will bee-transported transgenic pollen disperse?

- I) honey bee dispersal
- II) pollen dispersal

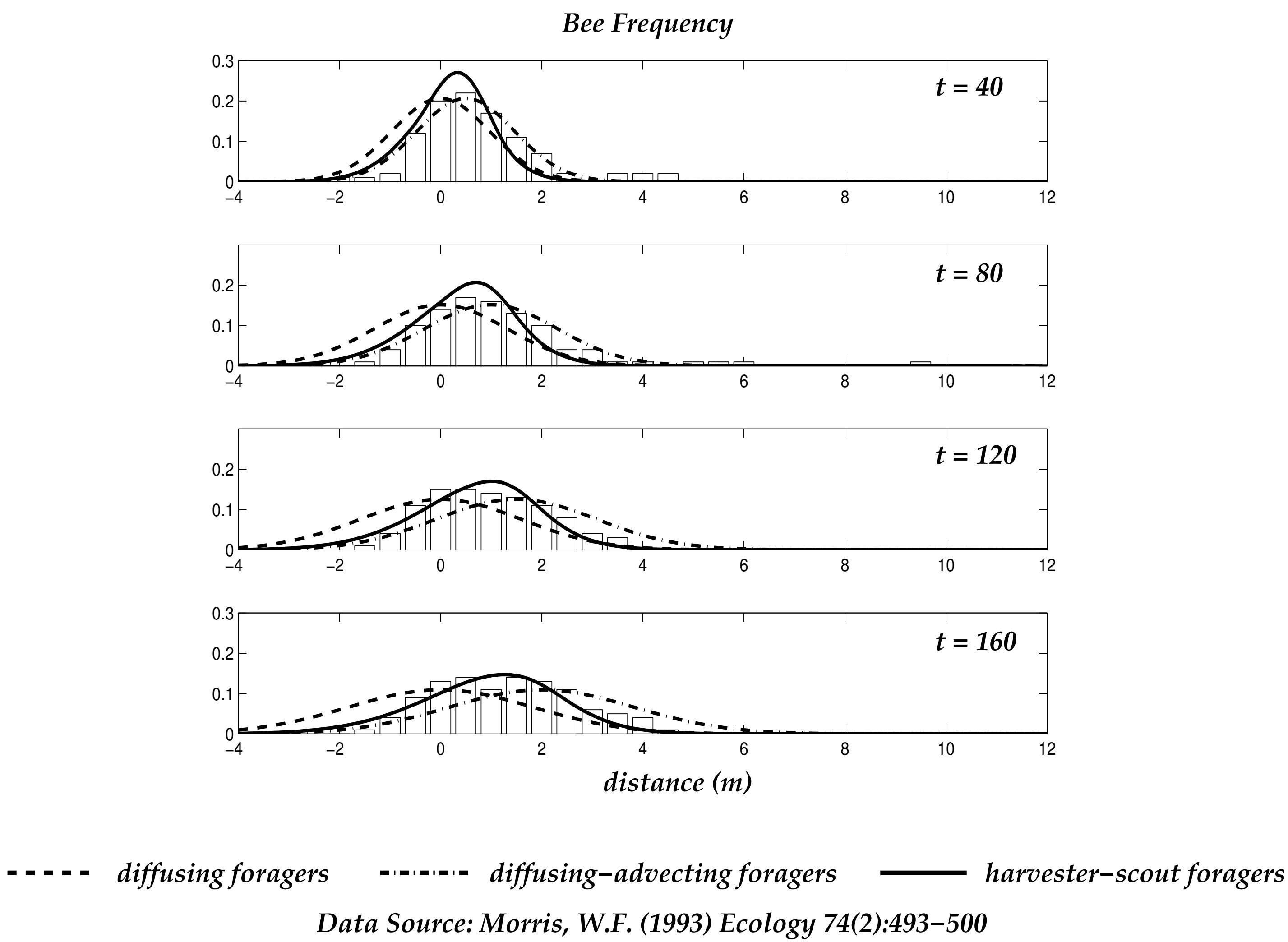
Data:

- percent transgenic seed as a function of distance
- honey bee dispersal over time
- flight speed





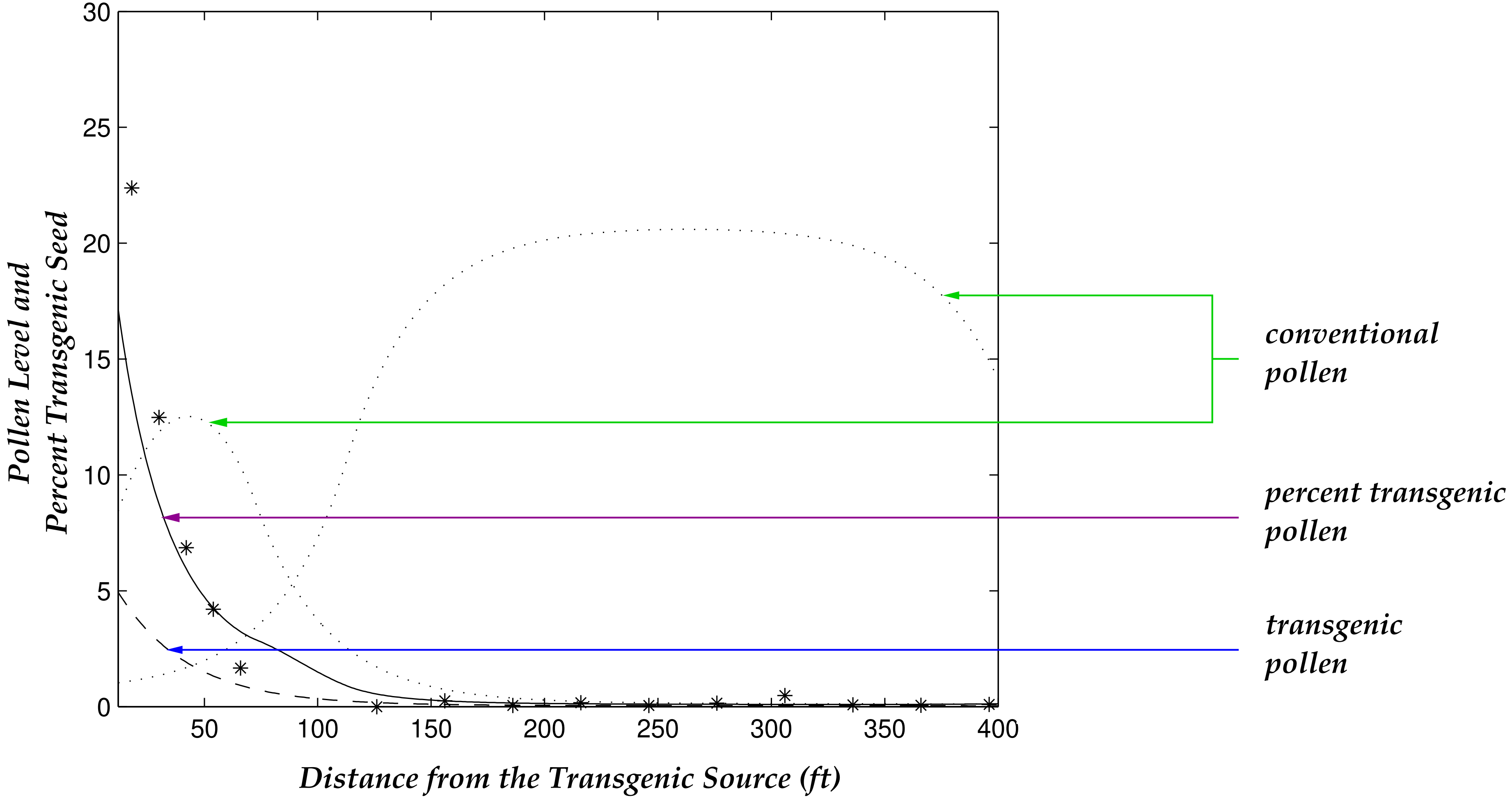
Validation



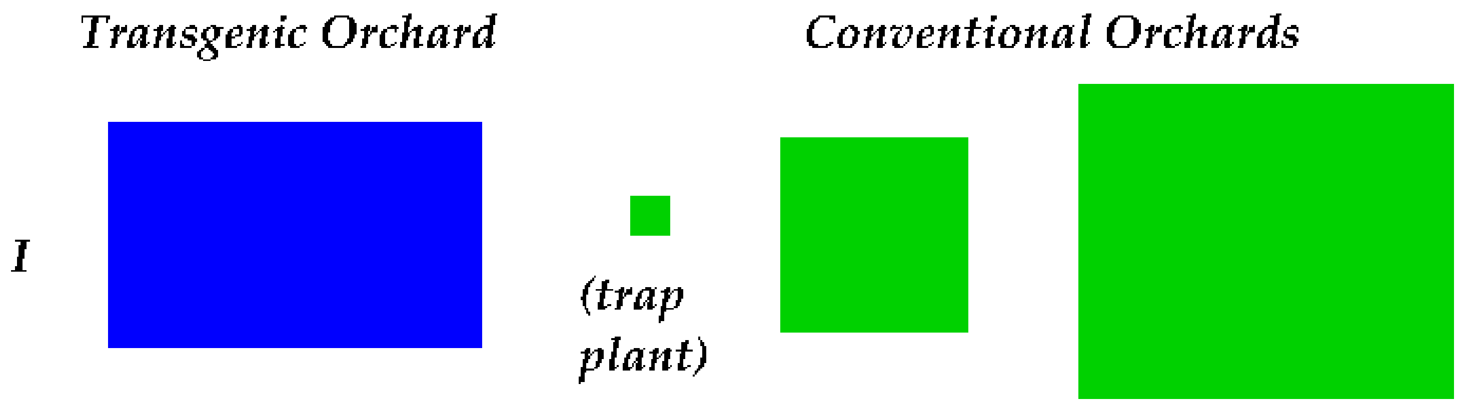
AIC used for formal validation

Tyson, Wilson & Lane, (2011) Theoretical Population Biology

Validation


Pollen Level and Percent Transgenic Seed
Distance from the Transgenic Source (ft)
0
5
10
15
20
25
30
50
100
150
200
250
300
350
400
conventional pollen
percent transgenic pollen
transgenic pollen

Results



Relative Size of Conventional Orchard	Isolation Distance Required (ft)	
	0.9% outcrossing	0.1% outcrossing
Trap	1829	3679
0.5	60	1510
1.0	50	1410
2.0	30	1320

Impact: GMO apple approved for planting in Canada

3. Hares + Multiple Specialists

Research Question: What drives the hare minima to the very low levels observed in the boreal forest? *Hypothesis: Multiple specialist predators.*

Data:

- Kluane study: 1 full cycle (1 data point per year)
  - parameter values
  - functional responses: lynx, coyote, great horned owl
- parameter values
- cycle properties (period, lag, max, min)

Model:

hare (prey):

$$\frac{dN}{dt} = rN\left(1 - \frac{N}{k}\right) - \sum_{i=1}^{n} \frac{\alpha_i N P_i}{N + \mu_i}$$

specialist predator:

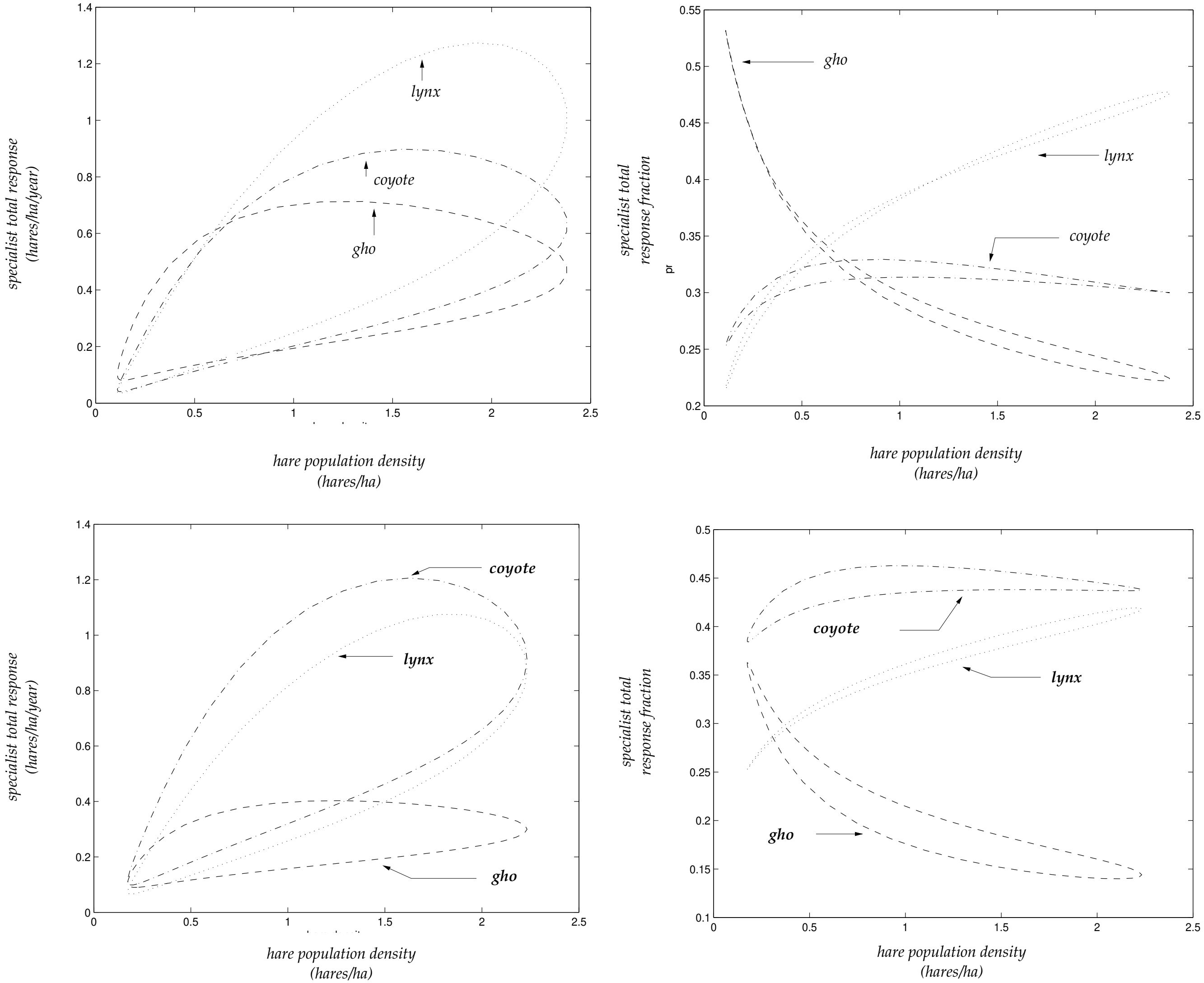
$$\frac{dP_i}{dt} = sP_i\left(1 - \frac{q_i}{N}P_i\right)$$

Tyson, Haines, & Hodges (2010) Theoretical Ecology

Fit to the Data

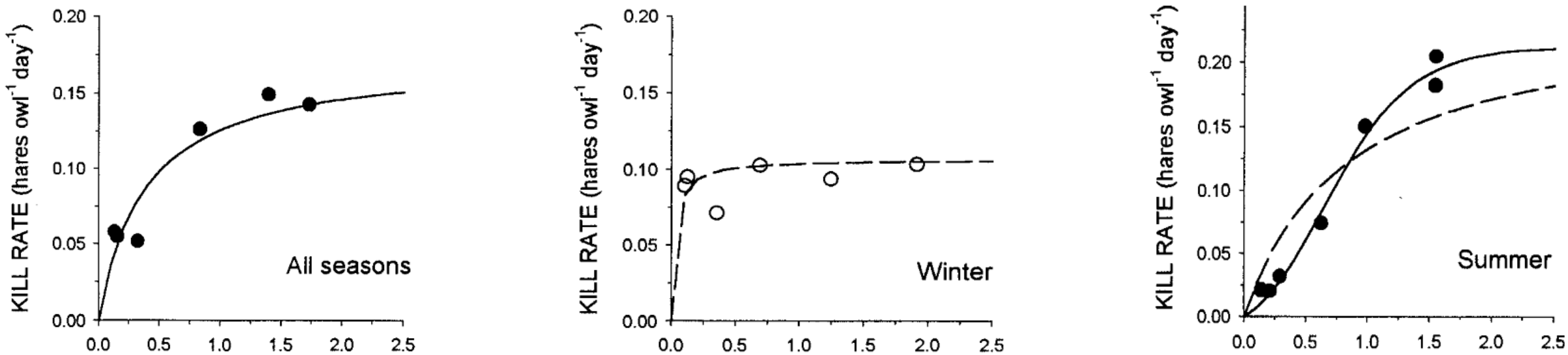
Probe		*Basic* Model				*LC & LG* Models		*LCG* Model
		l	l:c	l:g	l:c:g	l&c	l&g	l,c&g
hare density	max	√	√	×	√	√	√	√
(/ha)	min	×	×	×	×	×	×	√
pred. complex	max	–	×	×	√	–	–	–
density (/100 km^2)	min	–	×	×	√	–	–	–
lynx density	max	×	–	–	–	×	×	√
(/100 km^2)	min	×	–	–	–	×	×	√
coyote density	max	–	–	–	–	×	–	√
(/100 km^2)	min	–	–	–	–	×	–	√
owl density	max	–	–	–	–	–	√	√
(/100 km^2)	min	–	–	–	–	–	√	√
predator lag	l	√	√	√	√	√	√	√
(years)	c	–	–	–	–	√	–	√
	g	–	–	–	–	–	√	√
period (years)		√	√	√	√	√	√	√

Results: Predator Comparison



Impact: Understanding the role of avian predators

4. Seasonal Specialist



Krebs, et al. *Ecosystem Dyamics of the Boreal Forest: The Kluane Project.* 2001

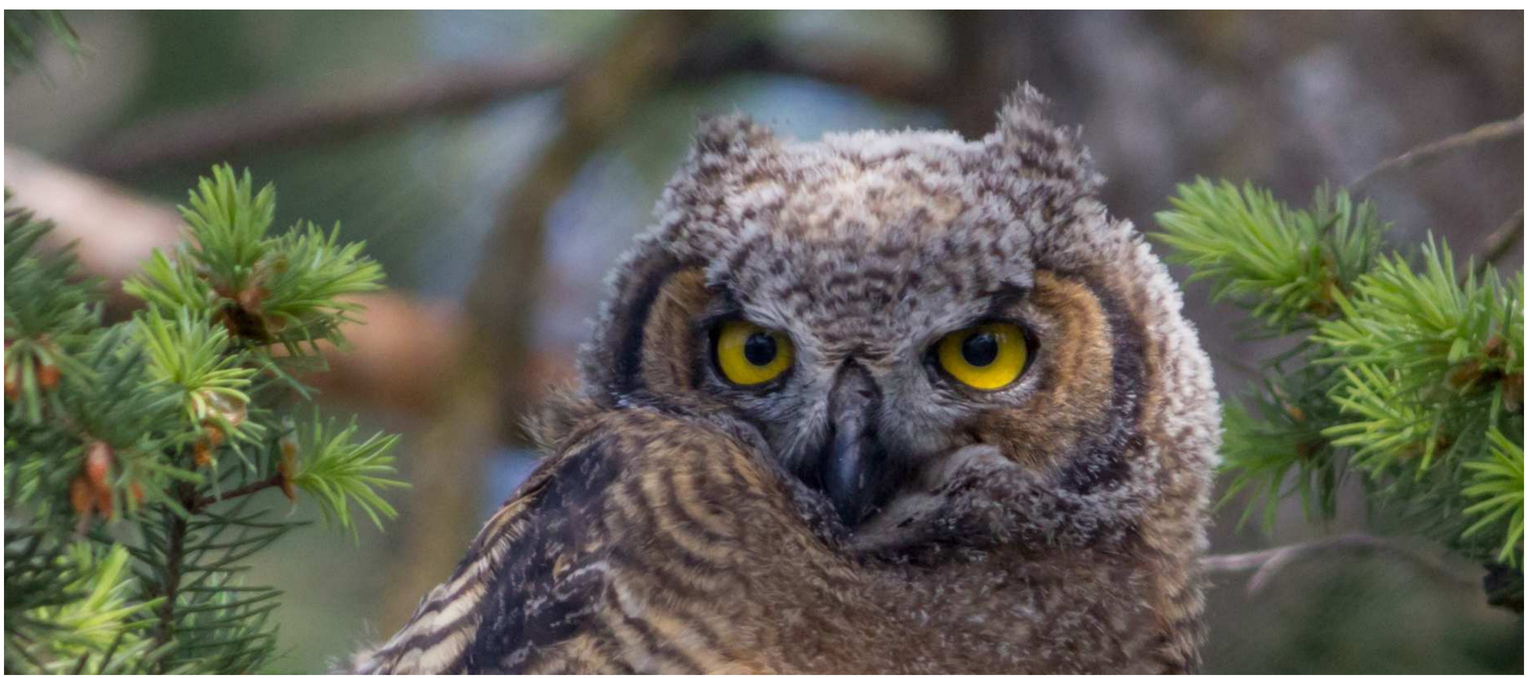


photo credit: R. Lalonde

Hare and Great Horned Owl

Research Question: If the predator functional response is generalist in one season and specialist in the other, what behaviours do we find in the predator-prey system?

Data:

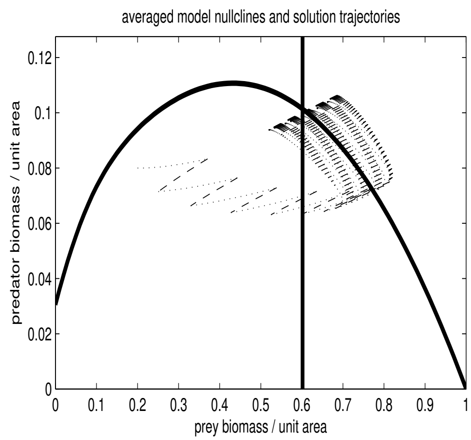
- Kluane study: 1 full cycle (2 data points per year)
  - parameter values
  - great horned owl summer and winter functional responses
- parameter values

Model: The averaged model worked well:

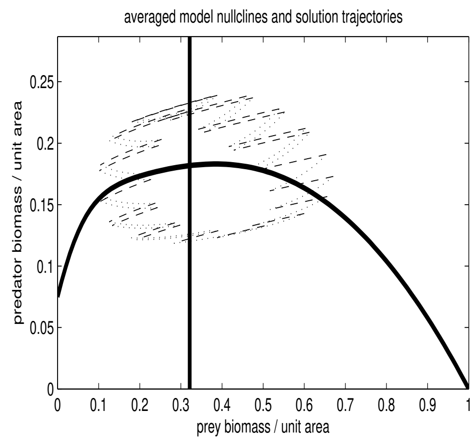
$$\begin{aligned}\frac{dn}{d\tau} &= T_s\left[n(1-n) - \frac{n^2 p}{b^2+n^2}\right] + (1-T_s)\left[-\frac{\alpha n p}{\beta + n}\right]\\ \frac{dp}{d\tau} &= T_s\left[\gamma\frac{n^2 p}{b^2+n^2} + s\frac{p}{1+\nu p} - mp\right] + (1-T_s)\left[\gamma\frac{\alpha n p}{\beta+n} - \mu p\right].\end{aligned}$$

Tyson & Lutscher (2016) American Naturalist

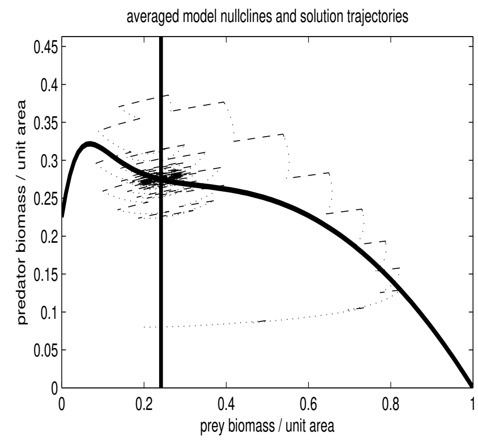
Results



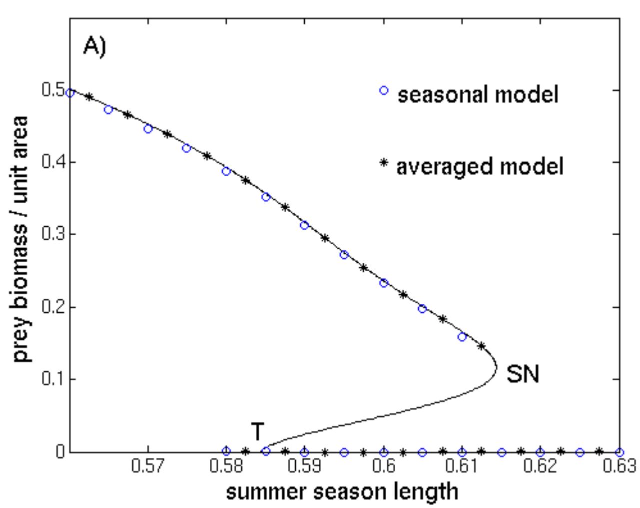
(a) Ts = 0.55

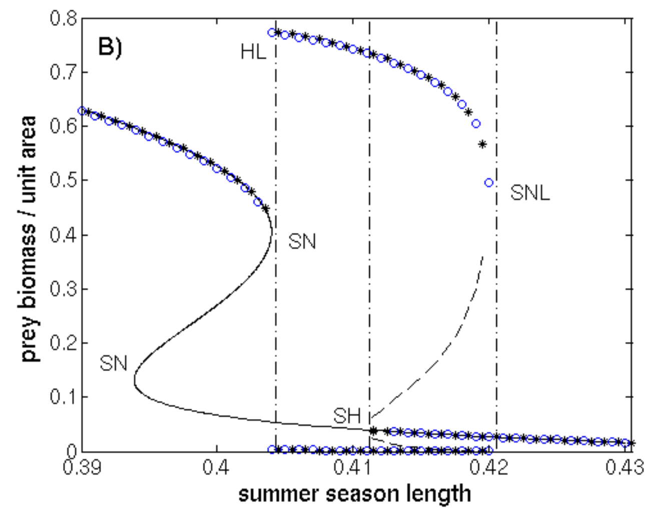


(a) Ts = 0.75



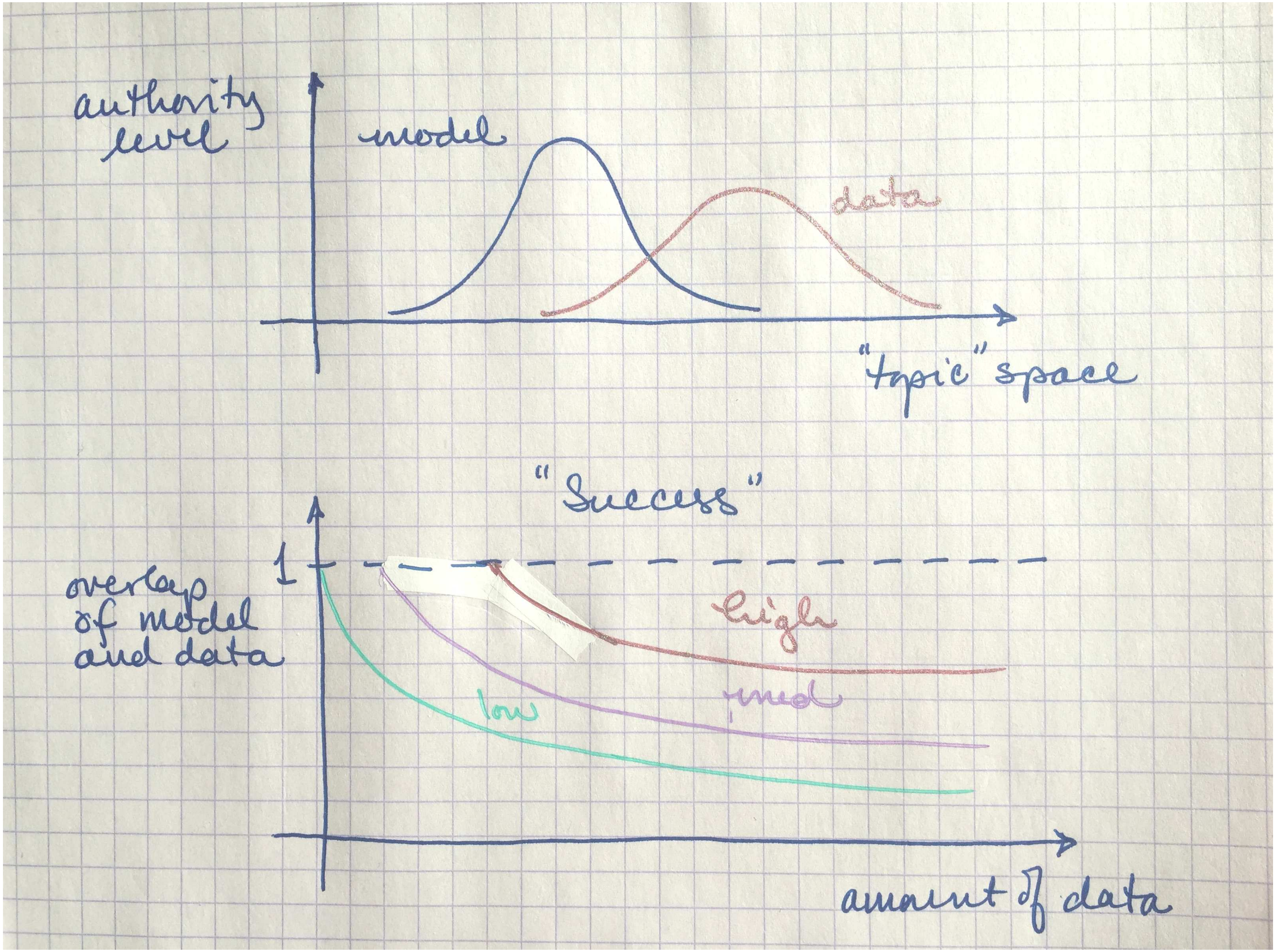
(a) Ts = 0.9





Impact: Theory - successful use of averaging, need for seasonal data for functional responses

Overlap of Models and Data



Many Thanks

- Researchers
  - Tony Hamilton
  - Susan E. Senger
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  - W. David Lane
  - Eric Deleersnider
  - Emmanuel Hanert
  - Karen Hodges
  - Frithjof Lutscher
- Students
  - Jessa Marley
  - Joseph Salkeld
  - J. Ben Wilson
  - Valentin Vallaeys
  - Sheena Haines

NSERC
CRSNG

Movement Model

$$\overbrace{\frac{\partial H}{\partial t}}^{\text{harvesters}} = \overbrace{D\frac{\partial^2 H}{\partial x^2}}^{\text{diffusion}} - \overbrace{\gamma_1 H}^{\text{switch to scouting}} + \overbrace{\gamma_2(S_l + S_r)}^{\text{switch from scouting}} \tag{1a}$$

$$\overbrace{\frac{\partial S_r}{\partial t}}^{\text{right-moving scouts}} = \overbrace{-v\frac{\partial S_r}{\partial x}}^{\text{advection}} + \overbrace{\gamma_1\left(\frac{H}{2}\right)}^{\text{switch from harvesting}} - \overbrace{\gamma_2 S_r}^{\text{switch to harvesting}} \tag{1b}$$

$$\overbrace{\frac{\partial S_l}{\partial t}}^{\text{left-moving scouts}} = \overbrace{v\frac{\partial S_l}{\partial x}}^{\text{advection}} + \overbrace{\gamma_1\left(\frac{H}{2}\right)}^{\text{switch from harvesting}} - \overbrace{\gamma_2 S_l}^{\text{switch to harvesting}} \tag{1c}$$

Tyson, Wilson & Lane, (2011) Theoretical Population Biology

Pollen Dispersal Model

$$\overbrace{\frac{\partial P_d}{\partial t}}^{\text{diffusing pollen}} = \overbrace{D\frac{\partial^2 P_d}{\partial x^2}}^{\text{diffusion}} + \boxed{\overbrace{\alpha F(x) - \beta P_d}^{\text{production \& decay}}} - \overbrace{\gamma(P_d - P_r - P_l)}^{\text{movement mode switching}} \tag{2a}$$

$$\overbrace{\frac{\partial P_r}{\partial t}}^{\text{right-moving pollen}} = \overbrace{-v\frac{\partial P_r}{\partial x}}^{\text{rightward advection}} + \overbrace{\gamma\left(\frac{P_d}{2} - P_r\right)}^{\text{movement mode switching}} \tag{2b}$$

$$\overbrace{\frac{\partial P_l}{\partial t}}^{\text{left-moving pollen}} = \overbrace{v\frac{\partial P_l}{\partial x}}^{\text{leftward advection}} + \overbrace{\gamma\left(\frac{P_d}{2} - P_l\right)}^{\text{movement mode switching}} \tag{2c}$$

$$\overbrace{\frac{\partial P_s}{\partial t}}^{\text{stationary pollen}} = \boxed{\overbrace{\beta P_d}^{\text{deposition}}} \tag{2d}$$

Tyson, Wilson & Lane, (2011) Ecological Modelling

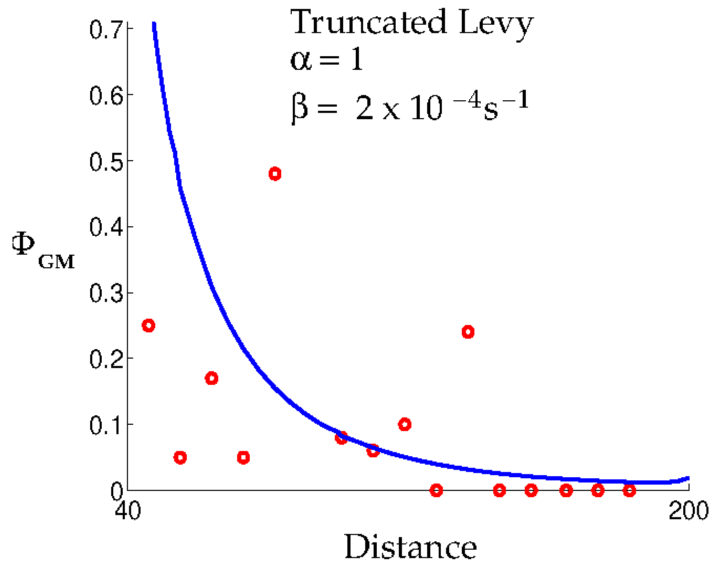
Another Approach

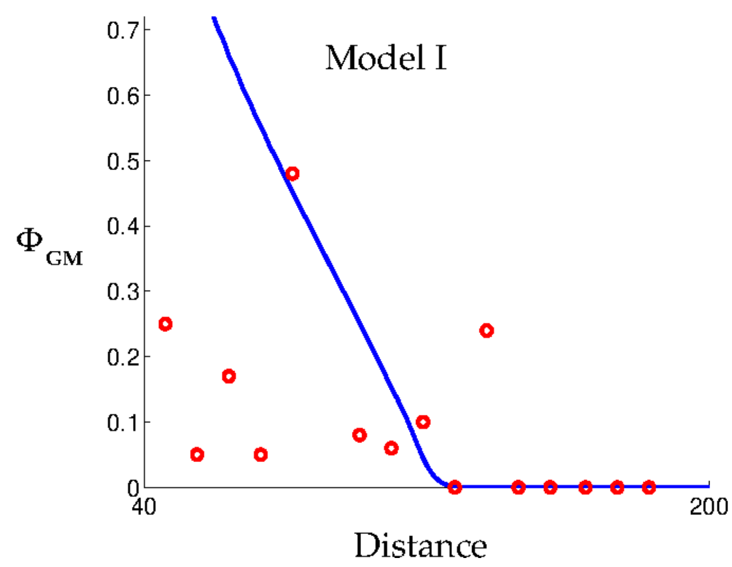
Truncated Levy *vs* Harvester-Scout (Model I)

motile pollen: $$\frac{\partial P_m}{\partial t}(x,t) = K_\alpha \partial_x^{\alpha,\lambda} P_m(x,t) + F(x,t) - \beta P_m(x,t)$$

stationary pollen: $$\frac{\partial P_s}{\partial t}(x,t) = \beta P_m(x,t)$$

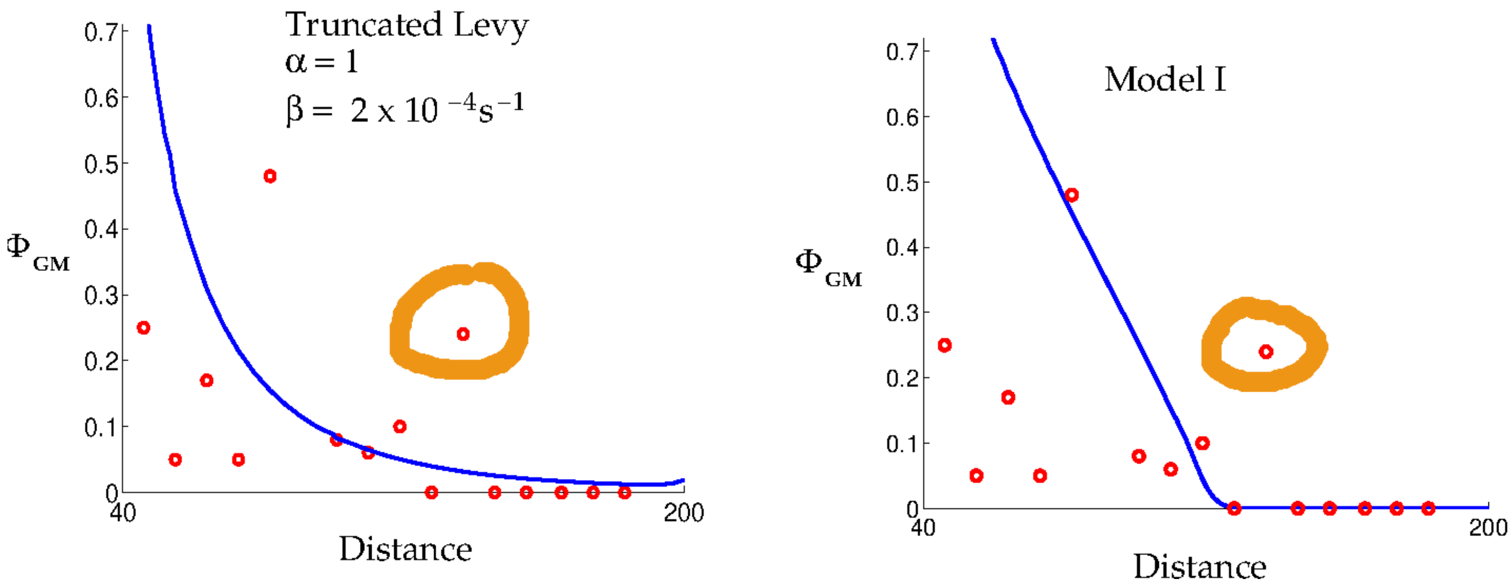
Fit to the Tail





Vallaeys et al. (2017) Royal Society Interface

Key Data in the Tail



Relative Size of Conventional Orchard	Isolation Distance Required (m)	
	Harvester-Scout	Truncated Levy
0.5	18	88
1.0	15	72
2.0	9	51

Results: Predator Comparison

Define

$$\text{Total Response}_i = TR_i = \frac{\alpha_i N P_i}{N + \mu_i}$$

$$\text{Total Response Fraction}_i = \Phi_i = \frac{\text{Total Response}_i}{\sum_{j=1}^{3} \text{Total Response}_j}$$

where

- Total Response$_i$ = density of hares killed per year by P_i
- Total Response Fraction$_i$ = fraction due to P_i of total density of hares killed