Modeling the Risks and Damages from a "Potential" Invasive Plant Species: Yellow Starthistle (*Centaurea solstitialis*)

Sergey Tsynkevych and Duncan Knowler
School of Resource and Environmental Management
Simon Fraser University

Mitacs Accelerate Program

- Funded by Mitacs Accelerate Program & the British Columbia Cattlemen's Association (BCCA)
- Partner and beneficiary: BCCA
- Deliverables include:
  - *Invasive damage estimates*
  - *Land mgmt recommendations*
  - *ENGO involvement*

Yellow Starthistle (YST) - A Dangerous Invader

- Characteristics:
  - *Long germination season*
  - *High seed productivity (75-100k)*
  - *Deep taproot*
  - *Establishes and disperses best in human-disturbed areas*

Fig. 1 – Unpalatable to cattle

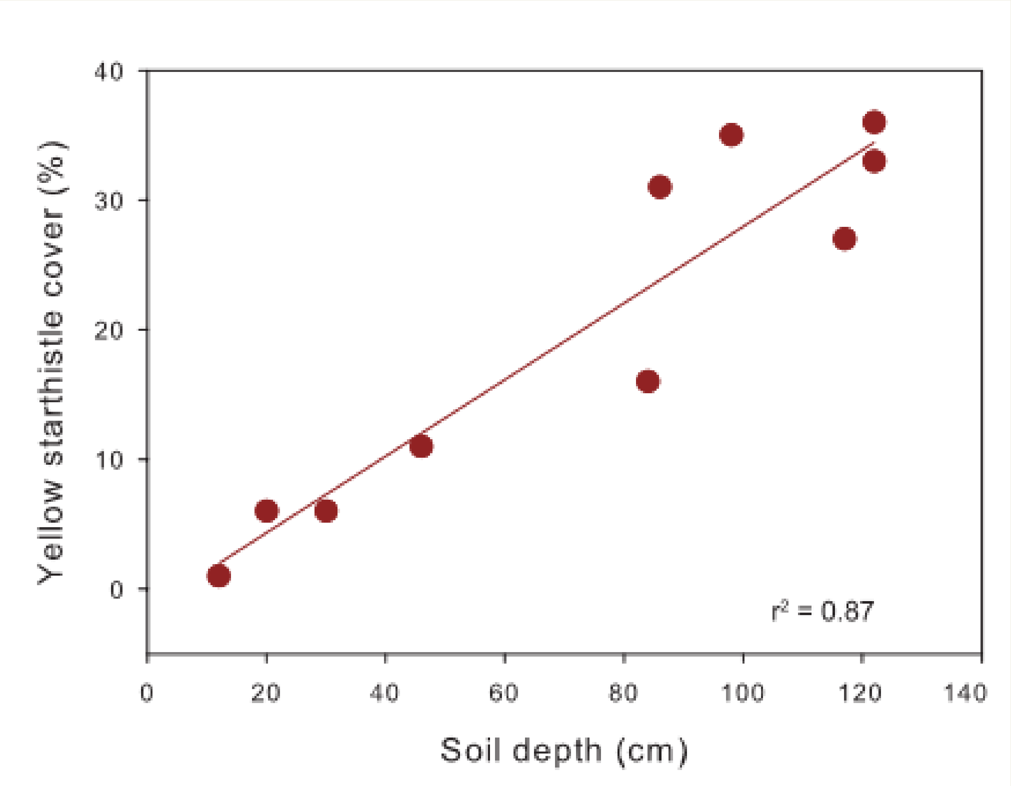
Known Effects

- Direct effects:
  - *Ranching (unpalatable to cows)*
  - *food crops*
- Indirect effects:
  - *biodiversity loss*
  - *tourism & recreation*

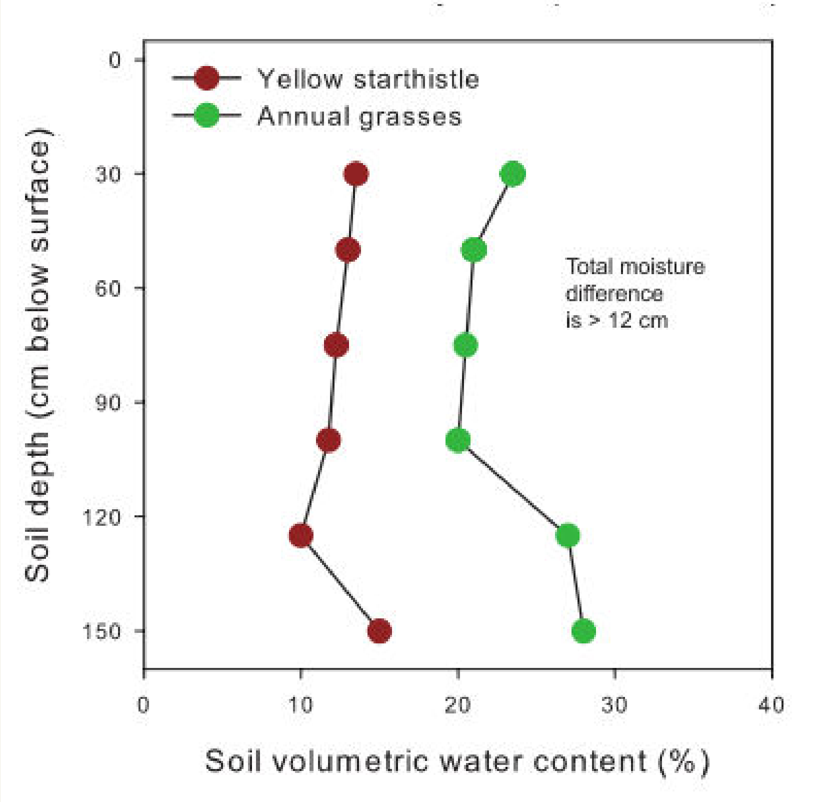
Fig. 2 - Dense Stands

Known Effects - Watersheds

- Significantly affects soil moisture content



Roche, 1994

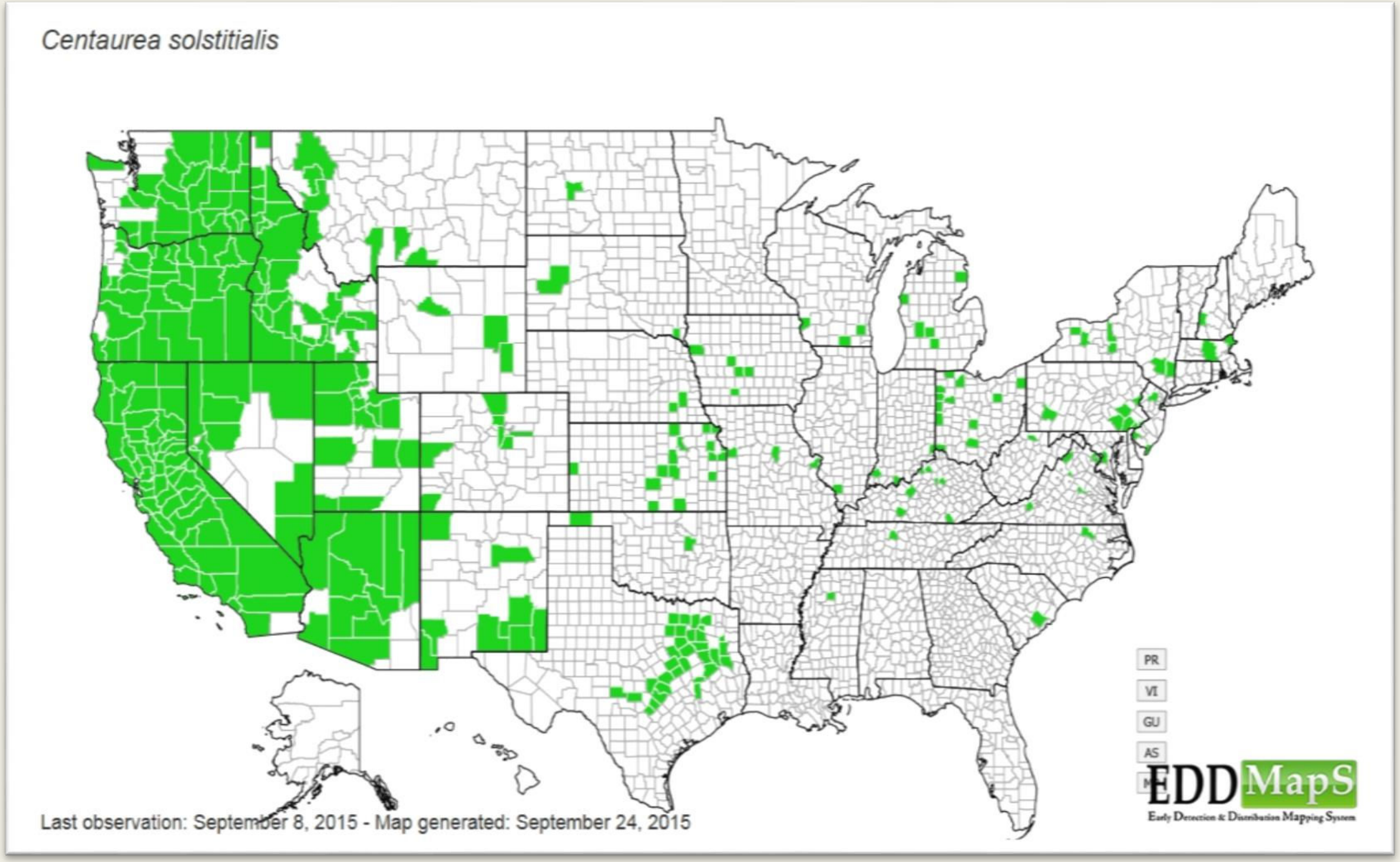


Gerlach, 2003

Risks for BC

- Well suited to Columbia Basin climate (Zouhar, 2002)
- Maximises its potential on blue bunch wheat grass and Idaho fescue (Ibid.)

YST dispersion in the USA



BC's Beef Cattle Industry

- Constitutes 5% of Canada's cattle population
- Mainly cow-calf operations
- Born and raised on rangeland
- $600M/year industry
- 8700 persons employed
- Land-stewardship

Research Questions

- What are the optimal levels of cattle stocking/offtake on ranch grasslands?
- What would be the difference in returns with or without the invasion?
- How sensitive are ranch-level returns to: stocking levels, forage growth rate, beef prices, levels of YST invasion?
- How can the above results inform management practices and therefore prevention?

Model Overview

- Bioeconomic optimal control (dynamic optimisation) model
- Variables subject to control are cattle offtake *(N)* or stocking rate *(H)*
- Integrates risk via a hazard function (Barbier et al. 2011)[1]
- Captures trade-off facing ranchers: whether to continue with current management or modify to reduce risk

[1] a hazard function is the probability something happens given it hasn't happened up till now

1st phase: Ranch level optimisation

- Basic ranch level profit maximization formulation
- Derive basic steady-state solutions for optimal stock size X^* and offtake N^*
- Compare both “no-invasion” and “with-invasion” scenarios

$$\max_{N} \int_0^T e^{-\delta t}\left(pN - (p_m N + p_a L + p_h X)\right)dt$$

$$s.t. \quad \dot{X} = rX\left(1 - \frac{X}{aL}\right) - N$$

w/out YST

$$\max_{N,D} \int_0^T e^{-\delta t}\left(pN - (p_m N + p_a L + p_h X + wD)\right)dt$$

$$s.t. \quad \dot{X} = rX\left(1 - \frac{X}{aL}\right) - N$$

$$\dot{U} = yU\left(1 - \frac{U}{U_M}\right) - T(D)$$

YST Present

2^{nd} phase: Integrating YST Risk & Damages

- Use information about potential costs from YST invasion consisting of lost grazing and control costs
- Integrate a hazard function as in Reed & Heras (1992)
- Increases the risk and recognizes the potential shift to an invasion dominated system
- Highlights the trade off for ranchers: they can continue with current management but risk a shift to an invaded situation

More on Risk: Hazard function

- Determine invasion hazard risk as function of plant characteristics
- Baseline (average) hazard = 0.005
- Thus, probability of invasion by typical invader is 0.5%
- In contrast, YST hazard is 0.008 or 0.8%
- Due to YST having greater than average invasive characteristics

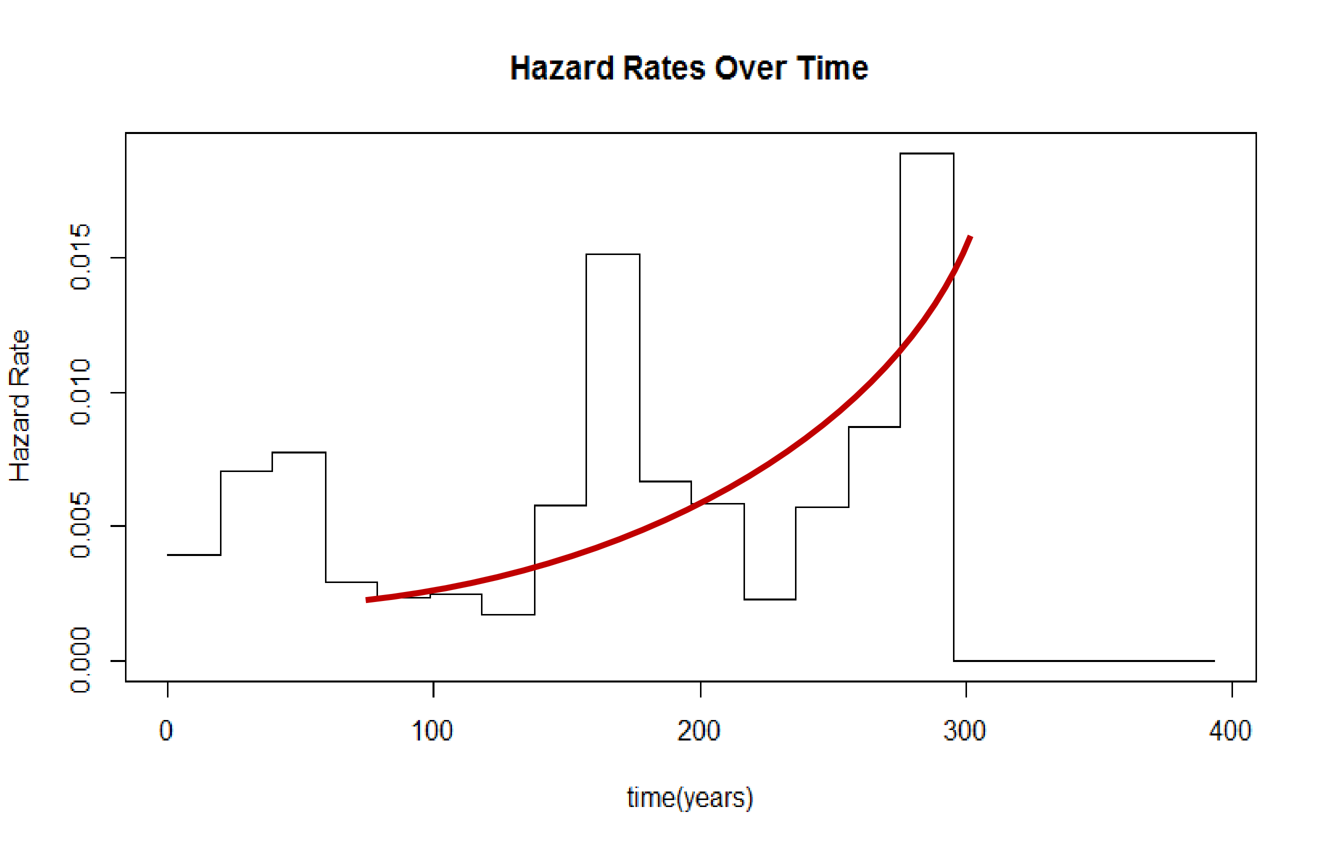


Fig. 3 – Cumulative Hazard function

3rd Phase: Managing for Potential Invasion

- But there is a tradeoff, e.g. lower stocking rates → lower profits.
- Formulate as a “decision problem” where rancher can continue with risk of YST invasion (as discussed above)
- Can assess if there is an optimal time to “switch” to modified management to reduce invasion risk

Significance & Policy Implications

- Will better inform policy-makers whether there is a need to establish targeted preventative programs
  - *"An ounce of prevention is worth a pound of cure." (Finnoff, 2007)*
- Can be updated as new data and research become available

Challenges & Limitation

- Under-representation of true damages (analysis from ranch profit-maximization perspective)
- Optimisation caveats (over-representing revenues and damages due to optimality conditions)
- Integrating the effects of climate change

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QUESTIONS & COMMENTS

Thank you

Acknowledgements:
SFU GSS Travel Grants
Mitacs Accelerate

And the following individuals: Dr. D. Knowler, S. Hrushowy