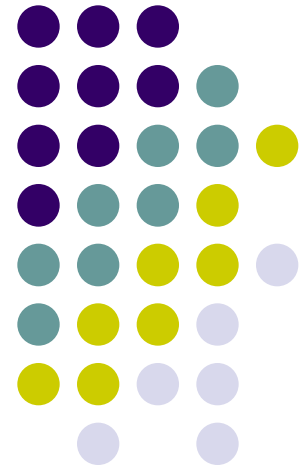


Tried and True versus Experimental Methods for Eurasian Watermilfoil Control: An Economic Analysis

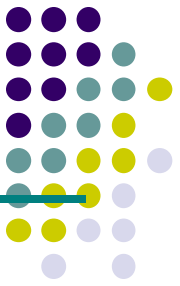
Frances Homans

Department of Applied Economics

Affiliated Faculty: NSF-IGERT on Introduced Species and Genotypes

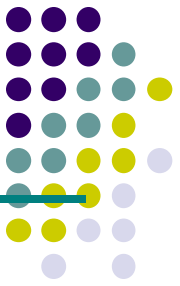


Background



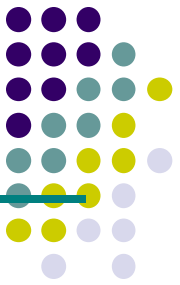
- Focus of IGERT Risk Analysis class
 - Risk Management Module
 - Ray Newman, David Ragsdale
- Effects of EWM
 - Reduces native plant diversity
 - Increases nutrient loading
 - Affects boating and swimming
- Problem in many lakes in MN and Wisconsin

Eurasian watermilfoil treatment options



1. Mechanical harvesting
2. Chemical treatments
 - Local
 - Whole lake
3. Biocontrol
 - Milfoil weevil
4. Water level manipulations
5. No control

Mechanical harvesting



- Out of pocket costs:
 - Per-hectare costs from \$500 per hectare to over \$2,500 per hectare (estimate for this presentation: \$1000)
 - plants usually grow back in 4-6 weeks
- Fragments on the shoreline can be distasteful
- Mechanical harvesting may accelerate growth

Before mechanical harvesting

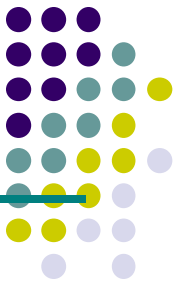


Photo: www.lakehopatcong.org/images

After mechanical harvesting

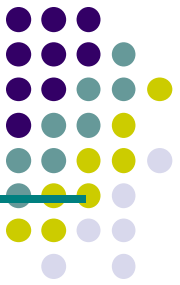
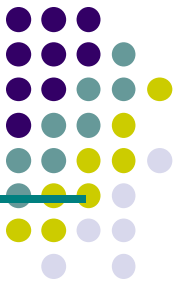


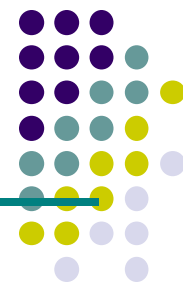
Photo: www.lakehopatcong.org/images

Biocontrol



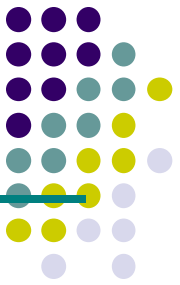
- Milfoil weevil (native to Northern U.S.)
- Larvae feed on stems, plants collapse, stored energy is reduced, and health in subsequent years is compromised
- Commercial firm (EnviroScience) provides weevils and pre- and post-stocking assessments for \$1000 per 1000 weevils (Madsen *et al.* 2000).
- Recommended density: 3000 weevils per hectare (Madsen *et al.* 2000, EnviroScience).
- Effectiveness enhanced by:
 - Self-sustaining weevil populations
 - Low predation by fish
 - Sufficient overwintering habitat
 - Healthy native plant communities to fill niche

Research Question



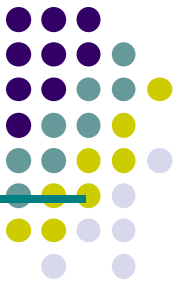
- Mechanical harvesting is a sure thing, and biocontrol is a risky strategy. Is it worth abandoning mechanical harvesting in favor of biocontrol?
- The two strategies are mutually exclusive because biocontrol agents live in the zone removed by mechanical harvesting.
- Basic idea can be applied to other management options that may be experimental.

Model



- Eurasian watermilfoil is a binary variable
 - $S=1$ (milfoil is a problem)
 - $S=0$ (milfoil is not a problem)
- Damage caused by watermilfoil is a linear function of S :
 - $\text{Damage Cost} = d \cdot S$
- Control cost per hectare:
 - $\text{Mechanical harvesting} = c_1 \cdot \text{MH}$
 - $\text{MH} = 1$ if mechanical harvesting is undertaken
 - Biocontrol: $c_2 \cdot \varkappa$
 - $\varkappa$ is the stocking rate per square meter

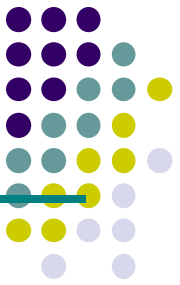
Effects of Control Options



- Mechanical harvesting
 - Eliminates damage at a cost of $c_1 = \$2,000$ per hectare per season
- Biocontrol
 - If a population establishes successfully, Eurasian watermilfoil is suppressed permanently.
 - Probability of Successful establishment and control of milfoil in the subsequent year, with x as the stocking rate:

$$P(S_{t+1} = 0 | S_t = 1, x_t) = \frac{e^{-x_t}}{1 - e^{-x_t}}$$

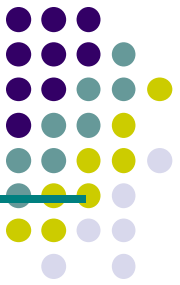
Dynamic Programming Approach



- Choose x_t (stocking rate) to minimize expected costs over time:

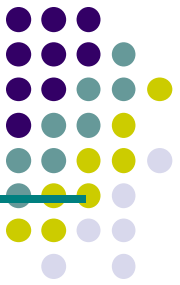
$$\min_{x_t} V(S_t, x_t) = c_1 S_t - c_2 x_t + \frac{1}{1+r} (P(S_{t+1}=0 | x_t, S_t) * V(0, t+1) - P(S_{t+1}=1 | x_t, S_t) * V(1, t+1))$$

Parameter Values



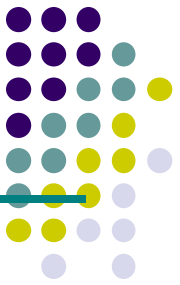
- $c_2 = \$1$
- $r = 0.05$
- d , α and β to be estimated
- $d = \$3,000$
- α : Without stocking, what is the $P(\text{success})$?
 - $P(\text{success}) = 0.1$, $\alpha = -2.3$
 - $P(\text{success}) = 0.5$, $\alpha = 0$

Parameter Values



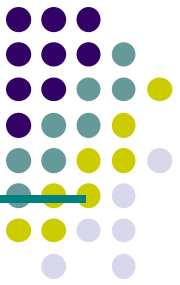
- β to be estimated
 - EnviroScience recommends 0.3 weevils/sq meter
- If $\alpha = -2.3$
 - If 0.3 weevils/sq meter is 29% effective, $\beta = 4.62$
 - If 0.3 weevils/sq meter is 60% effective, $\beta = 9$
 - If 0.3 weevils/sq meter is 80% effective, $\beta = 12.3$
- If $\alpha = 0$,
 - If 0.3 weevils/sq meter is 60% effective, $\beta = 1.35$
 - If 0.3 weevils/sq meter is 80% effective, $\beta = 4.62$

Solution Procedure



- Determine the date of the last decision, T
 - Final costs will be incurred in Period $T+1$
- Choose x_T to minimize costs in period T plus expected costs in period $T+1$. Calculate $V(T)$, given that $S_T=1$. ($V(T)=0$ if $S_T=0$)
- Go back to period $T-1$, solve for the best x_{T-1} , calculate $V(T-1)$, etc. Repeat.
- At some point, the decision date no longer matters and you have the solution for an infinite horizon problem.

Mechanical Harvesting Costs

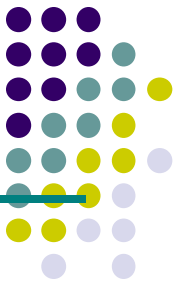


- What is the present value of incurring the cost of mechanical harvesting for the relevant time horizon?

- PV(mechanical harvesting)=

$$\sum_{t=i}^{T+1} \frac{C_1}{(1+r)^{t-i}}$$

Results

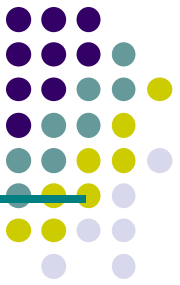


- With: $\alpha = -2.3$, $\beta = 4.63$ (so that $P(\text{success}) = 29\%$ if $x = .3$)

Time	$V(t)$	$x^*(t)$	$c \cdot x^*(t)$	$P(\text{success}/x=x^*(t))$	PV(mech harvesting)
T	\$10,744	0.558	\$ 5,579	0.569	\$3,905

- At date T, it's better to continue with mechanical harvesting because the expected present value of the cost of biocontrol (\$10,744) exceeds the cost of mechanical harvesting (\$3,905).

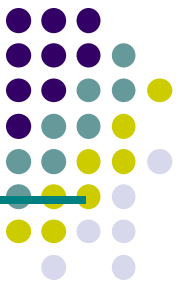
Results: $\alpha=-2.3$, $\beta=4.63$



Time	V(t)		$x^*(t)$	$c^*x^*(t)$	$P(\text{success}/x=x^*(t))$	PV(mech harvesting)
T	\$	10,744	0.558	\$ 5,579	0.569	\$ 3,905
T-1	\$	13,505	0.834	\$ 8,341	0.825	\$ 5,719
T-2	\$	14,000	0.884	\$ 8,836	0.856	\$ 7,446
T-3	\$	14,078	0.891	\$ 8,914	0.860	\$ 9,092
T-4	\$	14,090	0.893	\$ 8,926	0.861	\$ 10,659
T-5	\$	14,092	0.893	\$ 8,927	0.861	\$ 12,151
T-6	\$	14,092	0.893	\$ 8,928	0.861	\$ 13,573
T-7	\$	14,092	0.893	\$ 8,928	0.861	\$ 14,926
T-8	\$	14,092	0.893	\$ 8,926	0.861	\$ 16,216

- With 6-7 years in the planning horizon, it becomes optimal to try biocontrol.
- At $t=T-5$, optimal solution becomes invariant to remaining time

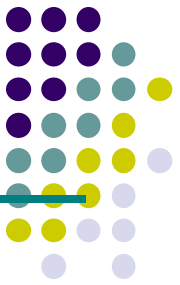
Results: $\alpha = -2.3$, $\beta = 9$



Probability of Success if $x=0.3$ is 0.6

Time	V(t)	$x^*(t)$	$c \cdot x^*(t)$	P(success/ $x=x^*(t)$)	PV(mech harvesting)
T	\$ 8,135	0.473	\$ 4,732	0.876	\$ 3,905
T-1	\$ 8,824	0.471	\$ 4,713	0.875	\$ 5,719
T-2	\$ 8,915	0.480	\$ 4,804	0.883	\$ 7,446
T-3	\$ 8,926	0.482	\$ 4,815	0.884	\$ 9,092
T-4	\$ 8,928	0.482	\$ 4,816	0.884	\$ 10,659
T-5	\$ 8,928	0.482	\$ 4,817	0.884	\$ 12,151

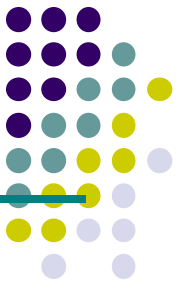
Results: $\alpha = -2.3$, $\beta = 12.3$



Probability of Success if $x=0.3$ is 0.8

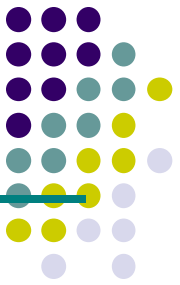
Time	V(t)		$x^*(t)$		$C^*x^*(t)$		P(success/ $x=x^*(t)$)		PV (mech harvesting)
T	\$	6,705	0.289	\$	2,892		0.778	\$	3,905
T-1	\$	7,359	0.355	\$	3,546		0.887	\$	5,719
T-2	\$	7,434	0.362	\$	3,621		0.896	\$	7,446
T-3	\$	7,443	0.363	\$	3,630		0.897	\$	9,092
T-4	\$	7,443	0.363	\$	3,630		0.897	\$	10,659
T-5	\$	7,444	0.363	\$	3,631		0.897	\$	12,151

Discussion



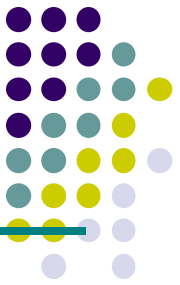
- Biocontrol becomes attractive relative to mechanical harvesting with a long time horizon.
 - Property owners may have to endure several seasons of milfoil effects for eventual eradication of the population.
 - Biocontrol offers the promise of permanent control, while mechanical harvesting guarantees that property owners will incur ongoing costs.

Discussion



- As β becomes smaller, a longer time horizon is required for biocontrol to be compare favorably to mechanical harvesting.
- A higher β leads to a lower optimal stocking rate, α , and a higher optimal probability of success in any particular try.
- Existing milfoil weevil populations may control Eurasian watermilfoil. A higher probability of control from existing populations (α) leads to lower optimal stocking rates

Model Refinements



- Learn about other factors influencing success

- Temperature
- Habitat
- Predators
- Availability of native plants

$$P(S_{t+1} = 0 | S_t = 1, x_t) = \frac{e^{-x_t}}{1 + e^{-x_t}}$$

- Include in the vector, x
- Learn about other parameters, e.g. damage per hectare from willingness to pay studies (e.g., studies done in Wisconsin, Florida)