Cost-effective Management of Aquatic Invasive Species in the Pacific Northwest: The Case of New Zealand Mudsnails

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Invasive Species (IS) Are

- Introduced species that cause or may cause economic, environmental, or human health damages
- e.g. New Zealand mudsnails (NZMS) : high-speed dispersal, potential impacts on other invertebrates and nutrient levels in water, probable influence on primary producers, and effects on prey and predator relationship (USGS)

←NZMS from USGS website (Accessed April 04, 2011)

Photo: D. AcKinney → from mudsnails.com (Accessed March 06, 2011)

Ultimate Goal: Minimize Total Cost

- Prediction of relative IS risk
- Estimation of potential damages and management costs
- Comparison of alternative management actions
- → Total Cost Minimization

Spatial Bioinvasion Risk

- Risk of Invasive Species Introduction: unintentional transportation by humans is a key IS vector
  → Gravity model (boat flows)
- Risk of Invasive Species Establishment: IS may successfully establish in a recipient region, or may fail to establish based on environmental and biological factors
  → Maximum entropy method (habitat suitability)

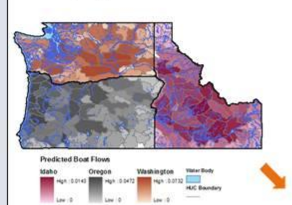
- The Relative Risk of Biological Invasion

$$R_j = \tau_j \times \pi(j)$$

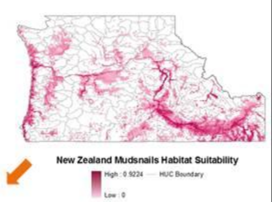
τ_j: the normalized boats movement from the gravity model

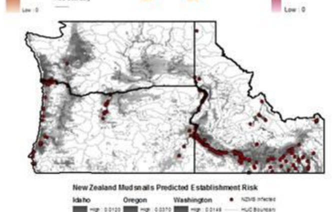
$\pi(j)$: the relative probability of species occurrence from maximum entropy method

Anthropogenic Introduction Risk



Habitat Suitability





Integrated Relative Risk

Invasive Species Damages

- Potential damages include recreational utility loss due to biodiversity loss, boat maintenance, and loss of hydroelectric power generation and drinking water treatment

1. Utility Loss of Anglers: biodiversity loss estimated as habitat quality by using Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST) + Random Utility Model

$$U_{nj} = (1 - No_j) \times (\beta_y Price_j + \beta_s \ln Water\ area_j + \beta_r Road\ density_j + \beta_o Ocean\ dummy_j + \beta_w Water\ Herfindahl_j + \beta_p Park\ Herfindahl_j + \beta_q Habitat\ quality_j) + \beta_{no} No_j + \varepsilon_{nj}$$

2. Hydroelectricity plant damage: $124,110/facility (Connelly et al., 2007; USEIA, 2010)
3. Water treatment plant damage: $726.5/facility (< 2MGD), $1453/facility (>= 2MGD) (Connelly et al., 2007; Idaho DEQ, Oregon DEQ, and Washington DOH)
4. Boat motor replacement: $118/boat (< 16 feet) or $235/boat (16-26 feet) (Recreational Boating Statistics 2010 & motor price web search)
5. Boat paint cost: $107/boat (< 16 feet) or $184/boat (16-26 feet) (Recreational Boating Statistics 2010 & motor price web search)

- Uncertainty of Bioinvasion

→ Expected Damages = Relative Risk X Potential Damages

Invasive Species Management Cost

- Prevention, early detection and rapid response (EDRR) with following eradication and containment, and Ex-post managing without EDRR

1. Using survey data about real IS management expense in Idaho, Oregon, and Washington during 2009-2010 and 2010-2011 fiscal years
   → ID; OR; WA State-wide prevention: $606,414; $396,103; $416,500; state-wide EDRR + others: $10,938,462; $13,492,907; $47,999,754; state-wide ex-post: $10,544,451; $13,492,907; $47,634,095 (Survey to IS managers)
2. Connelly et al. (2007) Zebra mussels management costs of hydroelectricity and drinking water treatment plants
3. Boat decontamination—chemical treatment by boaters
4. Prevention of hatcheries—hydrocyclone installation

Total Cost Minimization

- Trade-off between Damages & Management Costs
- IS Total cost = IS Damages ↓ + IS Management Costs ↑

- The Representative Resource Manager's Objective fn.

$$\min_{x \in \{x_j^{k,h}\}_+} \sum_j \left[\sum_h \left\{ ED_j^h exp\left(-\sum_k \theta^{k,h} x_j^{k,h} \right) + \sum_k x_j^{k,h} \right\} \right]$$

In a given region j (here, 6digit HUCs in each state),

ED_j^h = expected IS damage h

$x_j^{k,h}$ = management option of type k with respect to damage h

$\theta^{k,h}$ = efficacy of management option of type k with respect to damage h

→ Budget constraint

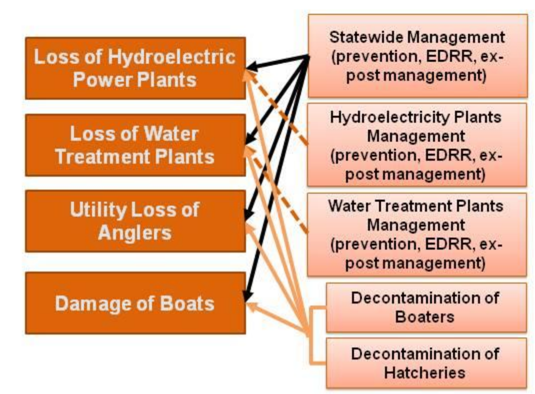
$$\sum_j \sum_h \sum_k x_j^{k,h} \le \overline{Budget\ Constraint}_{state}$$

→ Targeted expected damage constraint

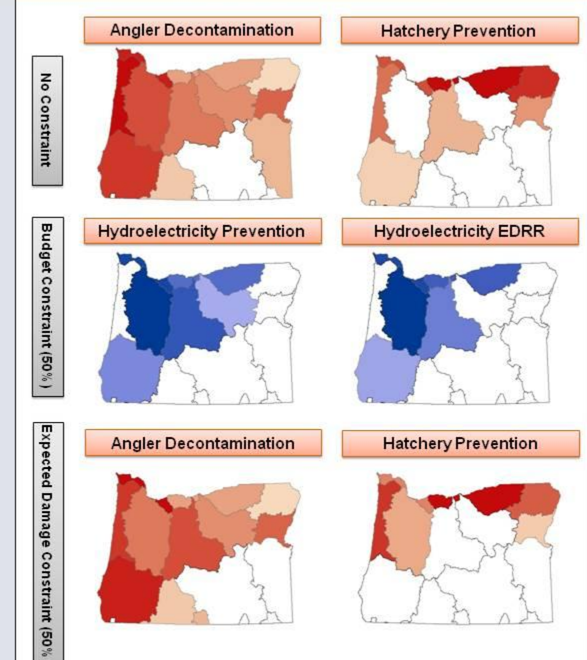
$$\sum_h \left\{ ED_j^h exp\left(-\sum_k \theta^{k,h} x_j^{k,h} \right) \right\} \le \overline{Expected\ Damage}_j, \forall j$$

Assumptions about Management

- Effectiveness
  - Prevention > EDRR + other management > Boater decontamination = Hatchery prevention > Ex-post management without EDRR
  - Local management (i.e. management of hydroelectricity plant & water treating plant) > Statewide management



Cost-Efficient Management in Oregon



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