Assigning Watercraft Inspection Stations to Minnesota Lakes
An Operations Research Approach

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Watercraft Inspection Location Problem

- Where do we put inspection stations within a county?
- Objective: minimize the risk of zebra mussel moving into un-infested lakes
Data for Zebra Mussel

• Location of infested and uninfested lakes within counties

• Number of watercraft moving from infested lakes to uninfested lakes
  • Within the county
  • Within the county to outside
  • Outside the county to within the county
  • Observations aggregated over inspection period 2014-2017 and adjusted for non-uniform sample size

• Risk of establishment of AIS in un-infested lakes
Problem Formulation

Locate a fixed number of watercraft inspection stations to maximize the number of inspected watercraft that enter uninfested lakes

*Minnesota Waters*: DNR Level 1 inspectors checking underneath boat for aquatic vegetation
Problem Formulation

Infested lakes

1

2

3

4

20

20

30

10

Un-infested lakes

Minnesota Waters: DNR Level 1 inspectors checking underneath boat for aquatic vegetation
Minnesota Waters: DNR Level 1 inspectors checking underneath boat for aquatic vegetation

Problem Formulation

![Graph showing the number of infested and un-infested lakes with connections between them. The numbers represent the frequency of inspections.]
Problem Formulation

\[
\max_{x_i, y_j} Z = \sum_{j \in J} \sum_{i \in I} n_{ij} (a_{ij} + b_{ij})
\]

Subject to:

\[
a_{ij} \leq x_i \quad \forall i, j
\]

\[
b_{ij} \leq y_j \quad \forall i, j
\]

\[
a_{ij} + b_{ij} \leq 1 \quad \forall i, j
\]

\[
\sum_{i \in I} x_i + \sum_{j \in J} y_j \leq B
\]

\(x_i = 0\)-1 variable for whether station is located at lake \(i\)

\(y_j = 0\)-1 variable for whether station is located at lake \(j\)

\(a_{ij} = 0\)-1 variable for whether boats moving between lakes \(i\) and \(j\) are inspected as the leave lake \(i\)

\(b_{ij} = 0\)-1 variable for whether boats moving between lakes \(i\) and \(j\) are inspected as the enter lake \(j\)
Incoming boats from infested lakes (zebra mussel)

- 0 - 25
- 26 - 70
- 71 - 277
- 278 - 880
- 881 - 2,596

- 31 uninfested lakes
- 1 infested lake (Pleasant)
- 0 boats from infested lake in county to uninfected lakes in county
- 2,616 boats from infested lake in county to uninfected lakes outside county
- 3,216 boats from infested lakes outside county to uninfected lakes in county
Ramsey County

- 31 uninfested lakes
- 1 infested lake (Pleasant)

Washington County

Incoming boats from infested lakes (zebra mussel)

- 0 - 25
- 26 - 70
- 71 - 277
- 278 - 880
- 881 - 2,596
Ramsey County

• 31 uninfested lakes

• 1 infested lake (Pleasant)

• 0 boats from infested lake in county to uninfested lakes in county

• 2,616 boats from infested lake in county to uninfested lakes outside county

• 3,216 boats from infested lakes outside county to uninfested lakes in county
Ramsey County

Best solution with upper bound of 4 stations:

- 1 infested lake (Pleasant)
- 3 uninfested lakes (Turtle, Bald Eagle, Phalen)
Ramsey County

Best solution for a maximum of 4 stations:

- 1 infested lake (Pleasant)
- 3 uninfested lakes (Turtle, Bald Eagle, Phalen)
- 35 uninfested lakes
- 2 infested lakes (Forest, White Bear)

Incoming boats from infested lakes (zebra mussel):
- 0 - 25
- 26 - 70
- 71 - 277
- 278 - 880
- 881 - 2,596

- 0 boats from infested lake in county to uninfested lakes in county
- 2,616 boats from infested lake in county to uninfested lakes outside county
- 3,216 boats from infested lakes outside county to uninfested lakes in county
Incoming boats from infested lakes (zebra mussel)

- 0 - 25
- 26 - 70
- 71 - 277
- 278 - 880
- 881 - 2,596

Washington County

- 35 uninfested lakes
- 2 infested lakes (Forest, White Bear)
- 634 boats from infested lake in county to uninfested lakes in county
- 3,233 boats from infested lake in county to uninfested lakes outside county (693 to Ramsey County)
- 2,787 boats from infested lakes outside county to uninfested lakes in county
Incoming boats from infested lakes (zebra mussel)

- 0 - 25
- 26 - 70
- 71 - 277
- 278 - 880
- 881 - 2,596

Washington County

Best solution for upper bound of 4 stations:

- 2 infested lakes (Forest, White Bear)
- 2 uninfested lakes (Goose, Big Marine)
Incoming boats from infested lakes (zebra mussel)

Best solution for a maximum of 4 stations:
- 2 infested lakes (Forest, White Bear)
- 2 uninfested lakes (Goose, Big Marine)
Ramsey County

Best solution:
• 1 infested lake (Pleasant)
• 2 unininfested lakes (Turtle, Bald Eagle)

Washington County

Best solution:
• 2 infested lakes (Forest, White Bear)
• 3 unininfested lakes (Big Marine, Demontreville, Goose)
Ramsey County

Best solution:
- 1 infested lake (Pleasant)
- 2 uninfested lakes (Turtle, Bald Eagle)

Washington County

Best solution:
- 2 infested lakes (Forest, White Bear)
- 3 uninfested lakes (Big Marine, Demontreville, Goose)
Crow Wing County

- 23 infested lakes
- 134 uninfested lakes
Crow Wing County

- 23 infested lakes
- 134 uninfested lakes
- 5,272 boats from infested lakes in county to uninfested lakes in county
- 8,491 boats from infested lakes in county to uninfested lakes outside county
- 5,978 boats from infested lakes outside county to uninfested lakes in county
Crow Wing County

Best solution for upper bound of 10 stations:

• 7 infested lakes ●
  Edward, Pelican, Whitefish, North Long, Round, Little Rabbit

• 3 uninfested lakes ○
  Bay, Horseshoe, Emily
Crow Wing County

Best solution for a maximum of 10 stations:

- 7 infested lakes •
  Edward, Pelican, Whitefish, North Long, Round, Little Rabbit

- 3 uninfested lakes ○
  Bay, Horseshoe, Emily
Conclusions

• Knowing boat movement among lakes, we can set up quantitative measures for evaluating inspection strategies
• This is a work in progress
  • Inspection costs, potential losses (property value, recreation value)
  • Determine inspection locations to maximize expected net benefits (avoided loss minus cost of inspection)