A data-driven approach to planning river barrier decisions on the Penobscot River

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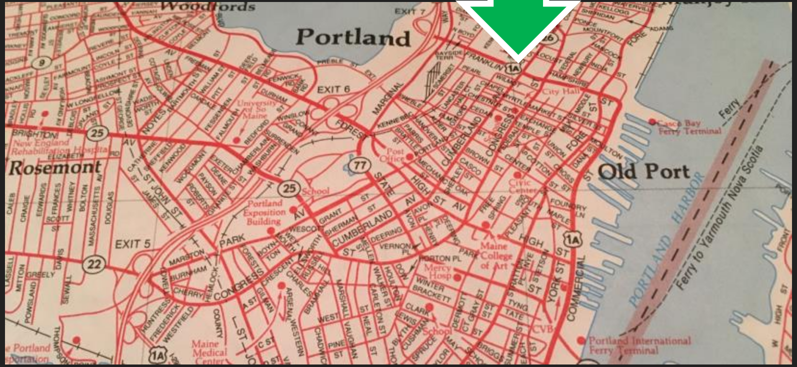
Why river barriers?
Dams and culverts provide benefits at the cost of others

Electricity

Potable Water

Ecosystem health

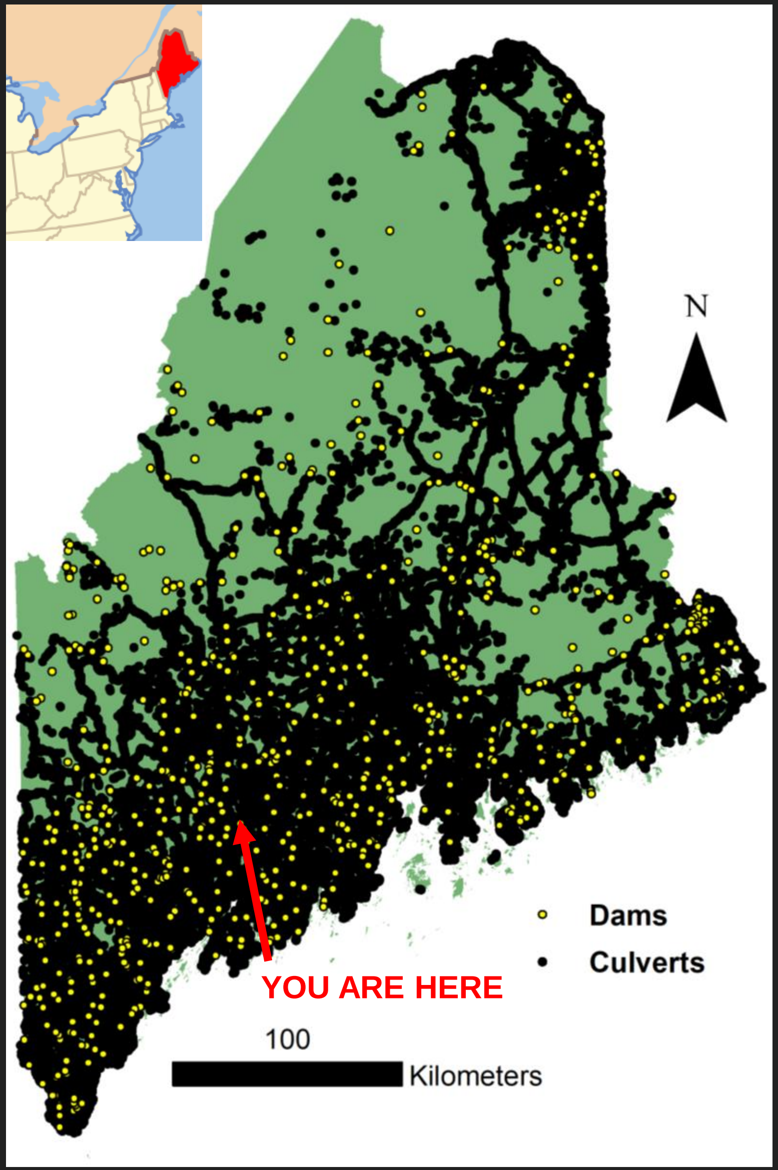


Transportation

Why river barriers?

- Degrading infrastructure
- Growing climate-related stress
- Expensive decisions

Why river barriers?

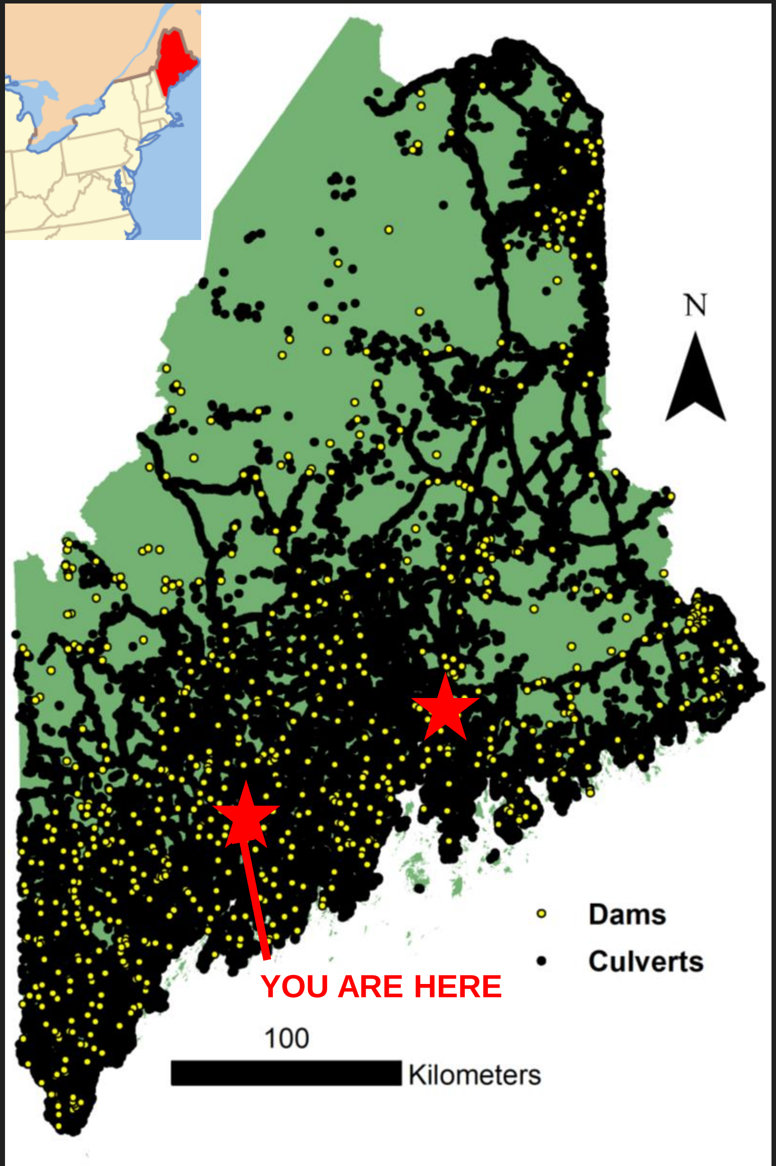


Potentially many pending decisions in Maine:

- >750 dams
- >45,000 culverts

Coordinating these decisions can lead to better overall outcomes

Examples from Maine



Coordinated barrier decisions:

- Four dams removed and many modified from 1999-2016:
  - Mainstem dams removed
  - Fish passage installation
  - Turbine power capacity improvements

- Result:
- +<u>5.1 million</u> sea-run fish
- No net loss in hydropower capacity

(Opperman et al. 2011)

Outline

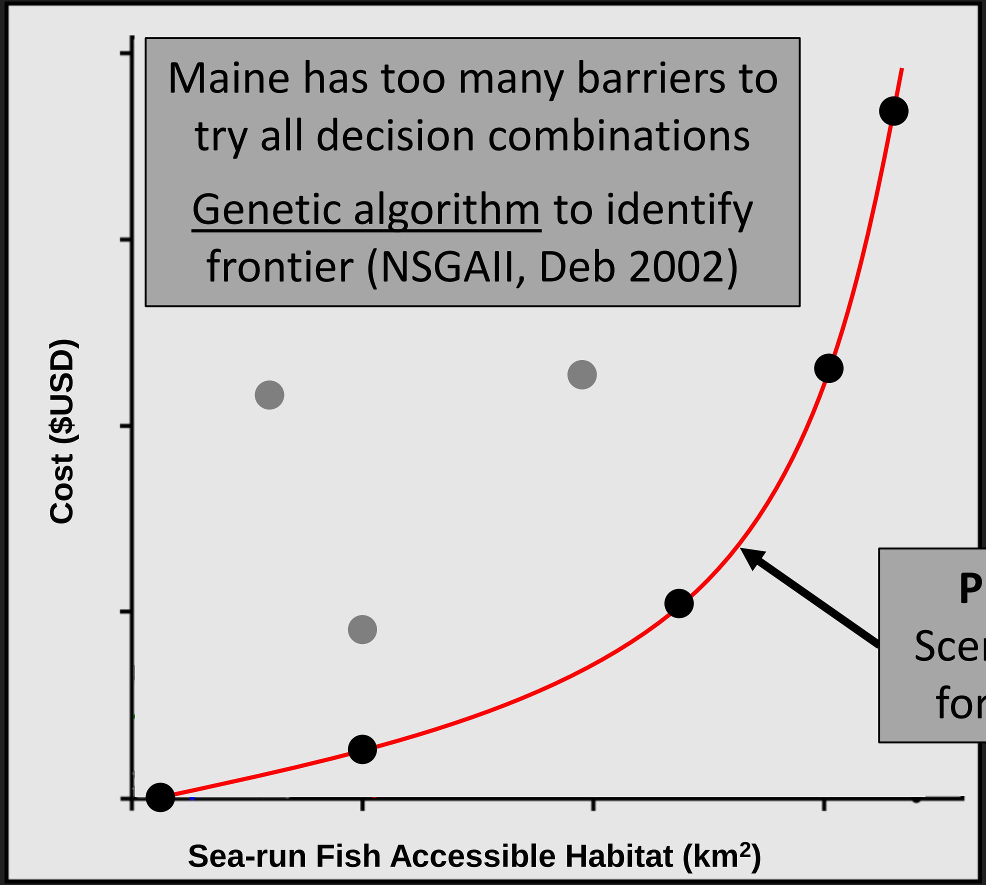
Explore coordinated barrier decisions and trade-offs among:

- Ecosystem connectivity
- Transportation network
- Cost of decisions
- Dam utilities

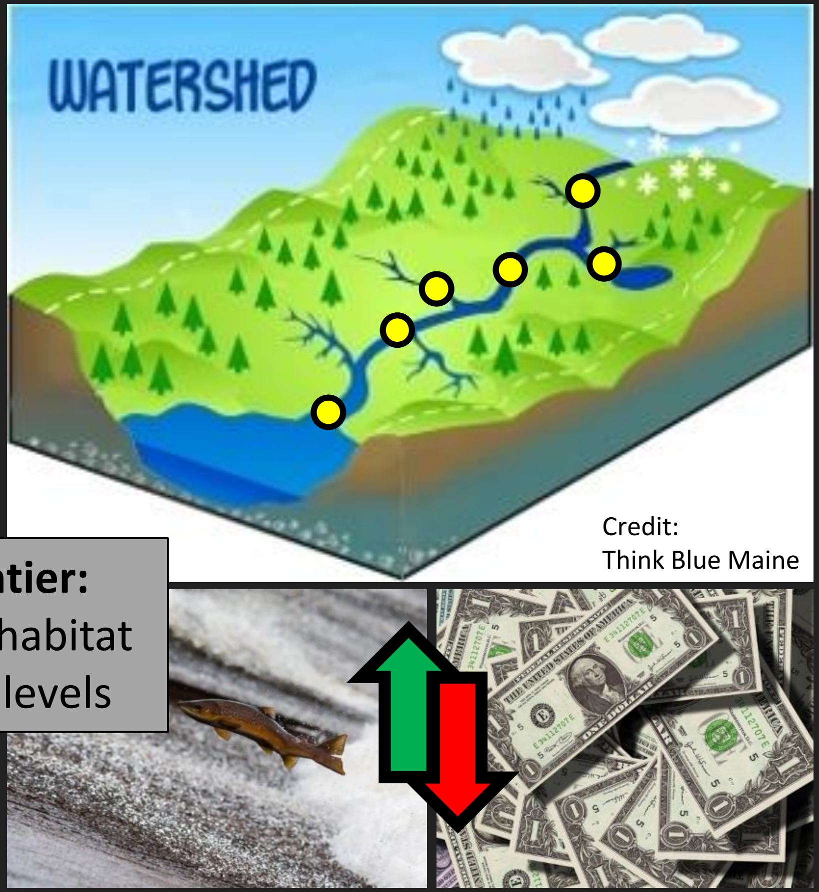
Potential partnerships for barrier Removal

A framework for quantitative stakeholder negotiation

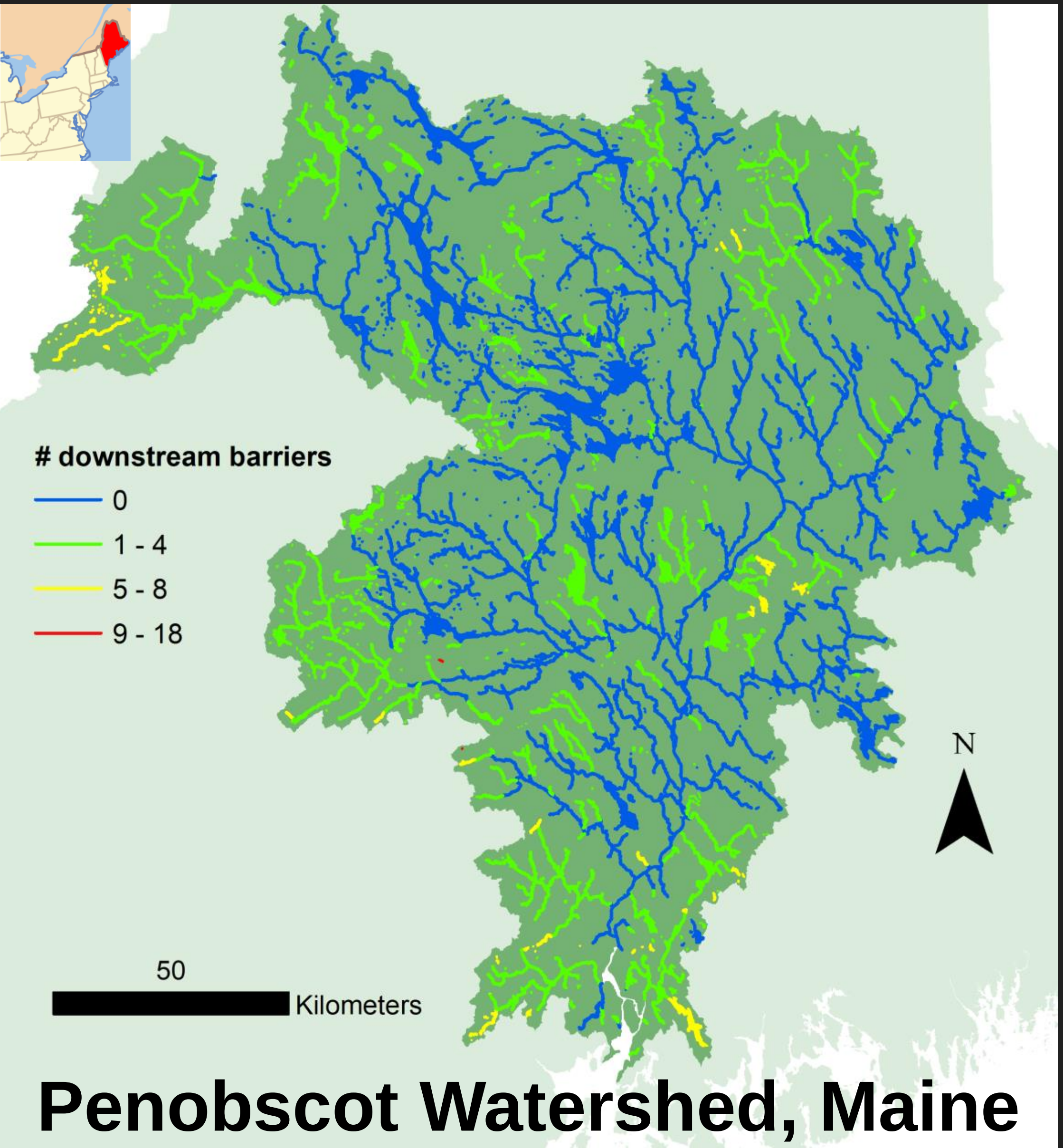
Multi-objective approach

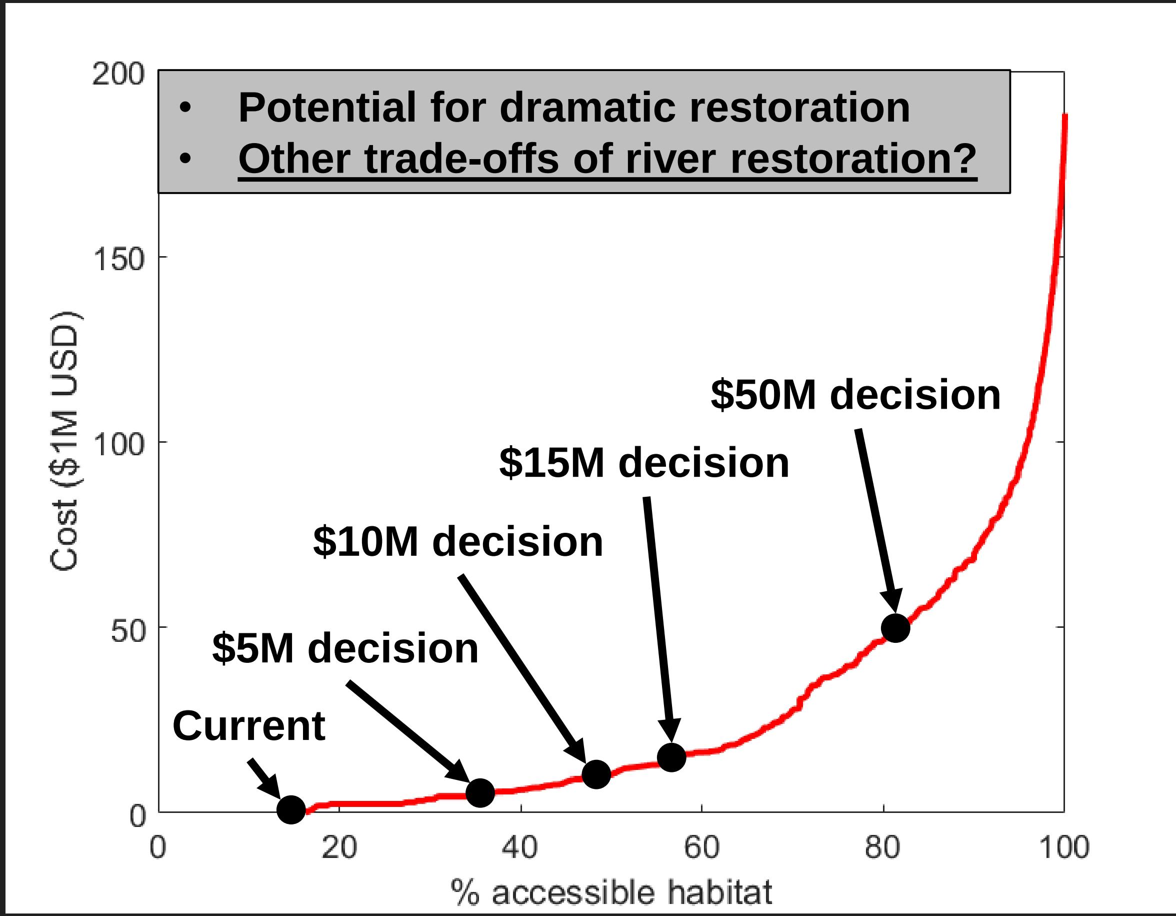


Production possibility Frontier:
Scenarios that maximize fish habitat for different minimized cost levels



Cost-benefit: barrier decisions for river restoration

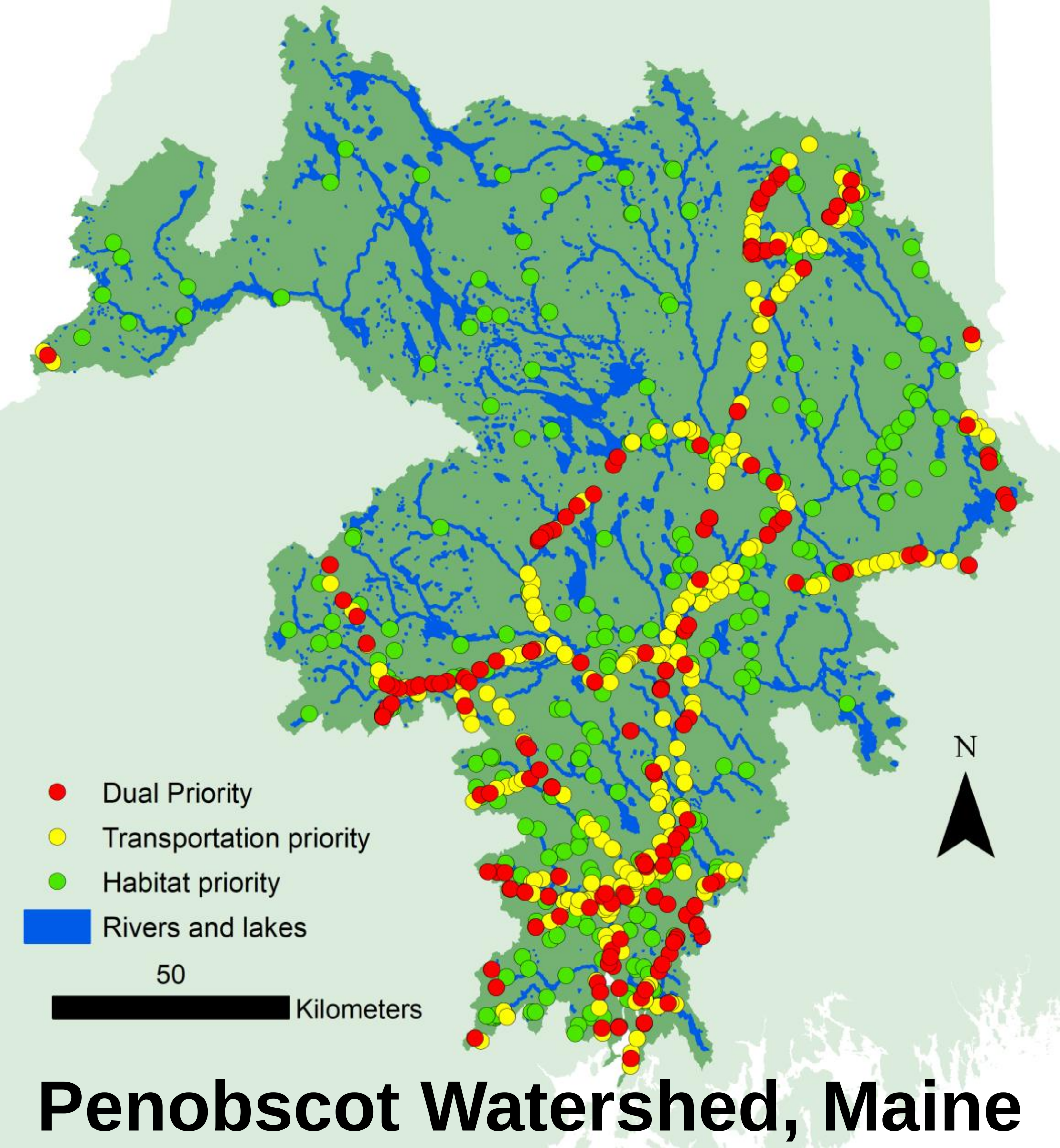


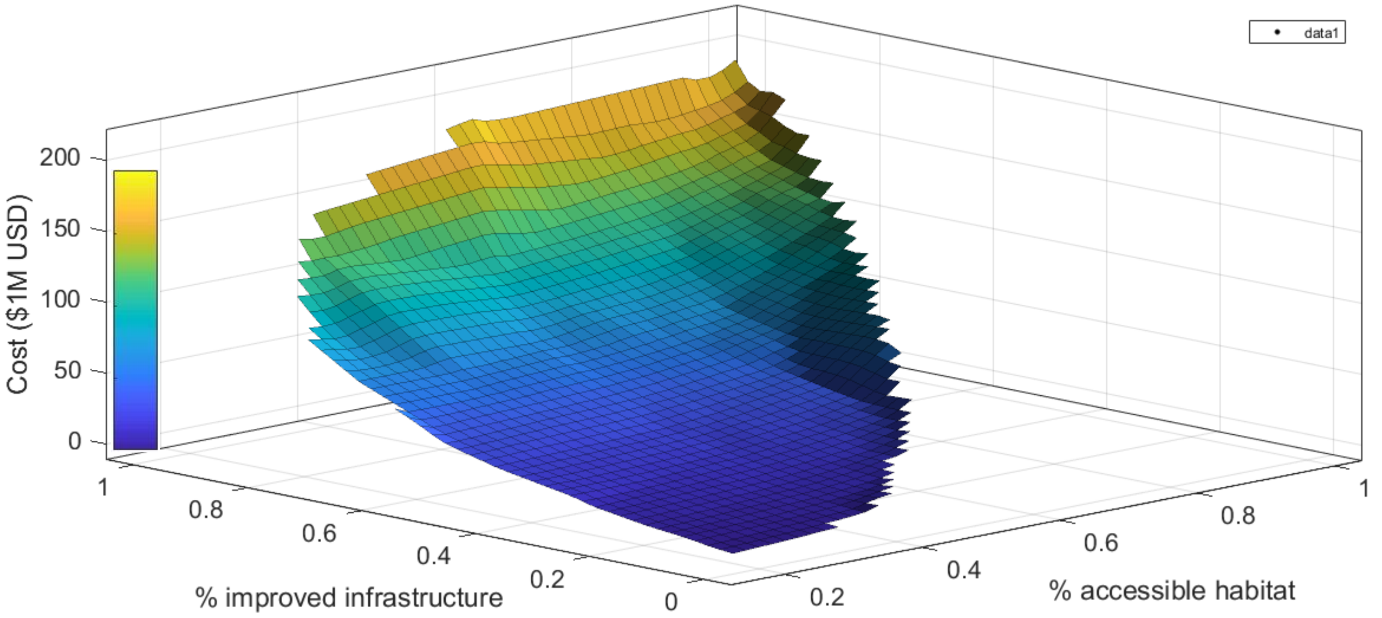


Pooling resources: different priorities, same decisions

- Culvert replacement to:
  - Connect freshwater habitat
    - Env. NGOs, agencies
  - Improve infrastructure resilience
    - Dept. transportation, municipalities, private owners
- Trade-off analysis identifies potential overlapping interests

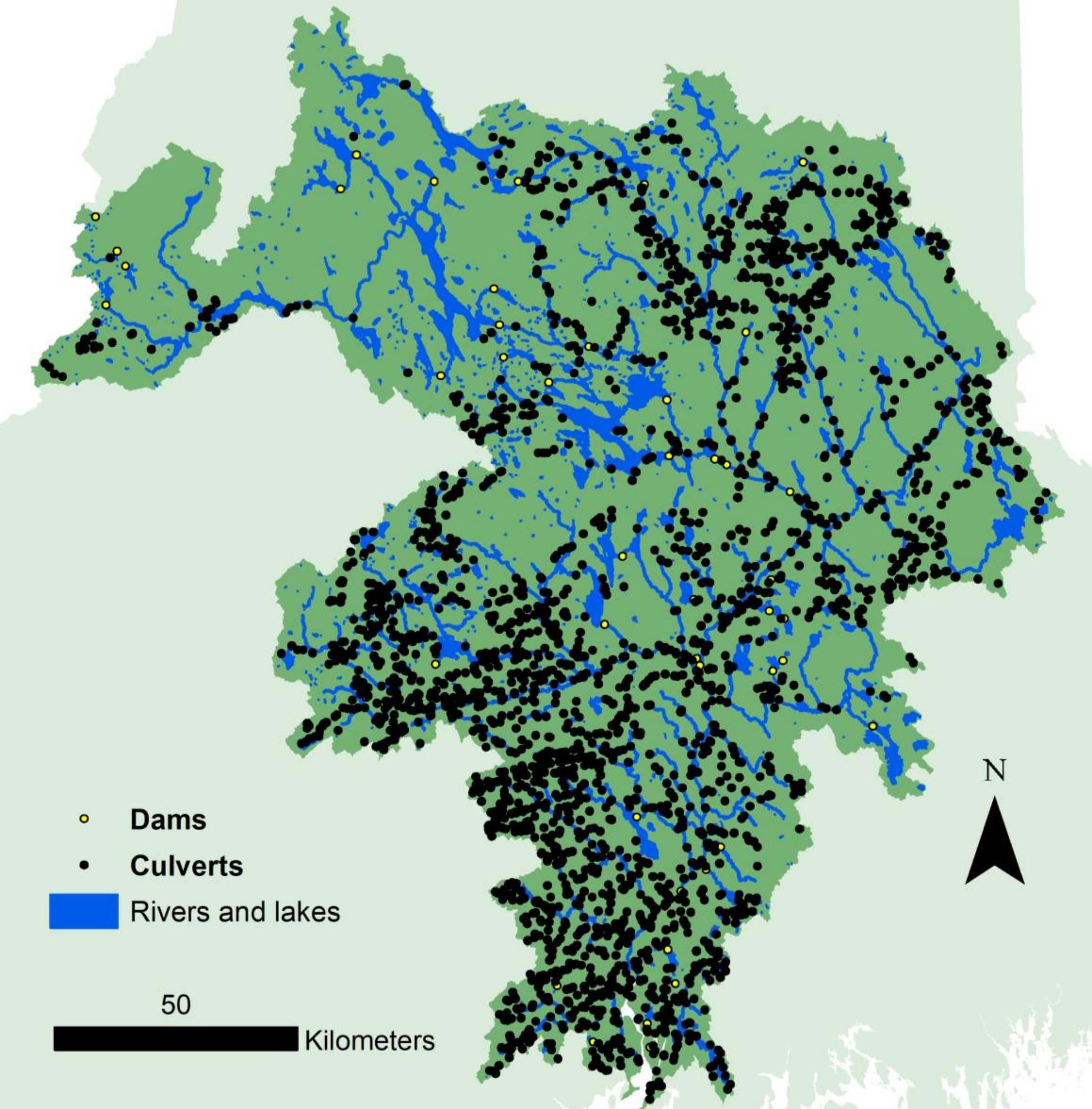
Pooling resources for ecology and infrastructure



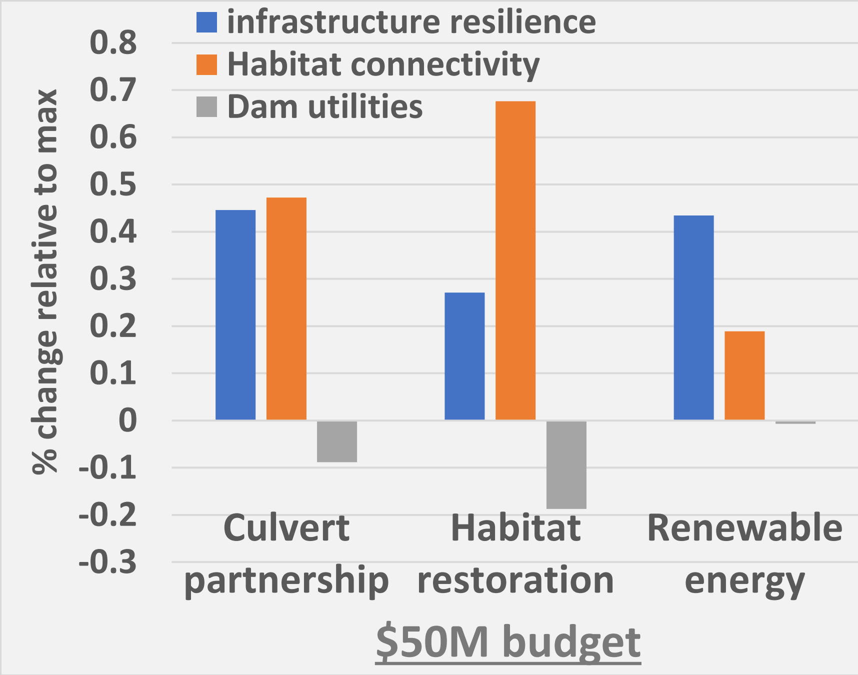


- >180 culverts with significant overlapping priority
- But coordinating these decisions for habitat connectivity will also impact dam utilities

Trade-offs: cost, habitat, infrastructure, dam utilities



Penobscot Watershed, Maine



- Trade-offs among 4 criteria:
  - Smaller individual gains
  - Greater overall gains
  - Opportunities to negotiate within estimated budget

Conclusions

- Coordinated decisions:
  - Efficient trade-offs, greater overall gains at lower cost
  - More stakeholders, varied/conflicting preferences
  - Provides a shortlist of decisions based on varied preferences
- Requires:
  - Substantial, modern geospatial datasets and computational techniques
  - Inclusive stakeholder engagement practices
  - An interface to combine the two

A multiscale approach to balance trade-offs among dam infrastructure, river restoration, and cost

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Aging infrastructure and growing interests in river restoration have led to a substantial rise in dam removals in the United States. However, the decision to remove a dam involves many complex trade-offs. The benefits of dam removal for hazard reduction and ecological restoration are potentially offset by the loss of hydroelectricity production, water supply, and other important services. We use a multiobjective approach to examine a wide array of trade-offs and synergies involved with strategic dam removal at three spatial scales in New England. We find that increasing the scale of decision-making improves the efficiency of trade-offs among ecosystem services, river safety, and economic costs resulting from dam removal, but this may lead to heterogeneous and less equitable local-scale outcomes. Our model may help facilitate multilateral funding, policy,

the constraints of dam ownership and regulation. For example, the Penobscot River experienced a dramatic increase in sea-run fish populations with a minimal impact on hydropower capacity through a restoration project combining the removal of two mainstem dams, hydropower improvements at tributary dams, and fish passage installations at an uncharacteristically broad scale (17, 18). The vast number of NE dams and rich diversity of ecosystem services make it a valuable location to quantify the range and scale-dependence of trade-offs. At least 14,000 dams have been constructed, modified, or rebuilt in this region in the last 3 centuries (6), ranging in height from <1 m to >80 m (*SI Appendix*, Fig. S3 and Table S1). More than 7,500 of these dams have a recorded upstream drainage area greater than 1 km^2 and are used in this analysis. More than 2,000

SUSTAINABILITY SCIENCE

NSF TRACK 2: IIA-1330641,1330691

Data/model sources

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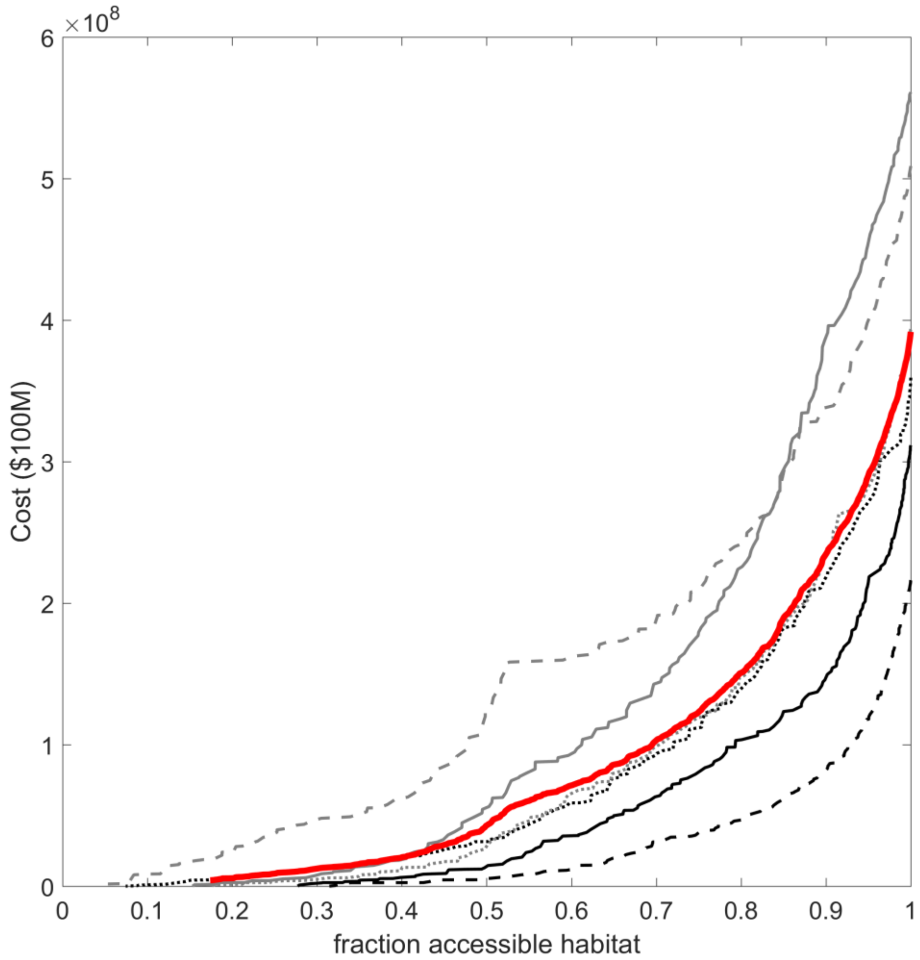
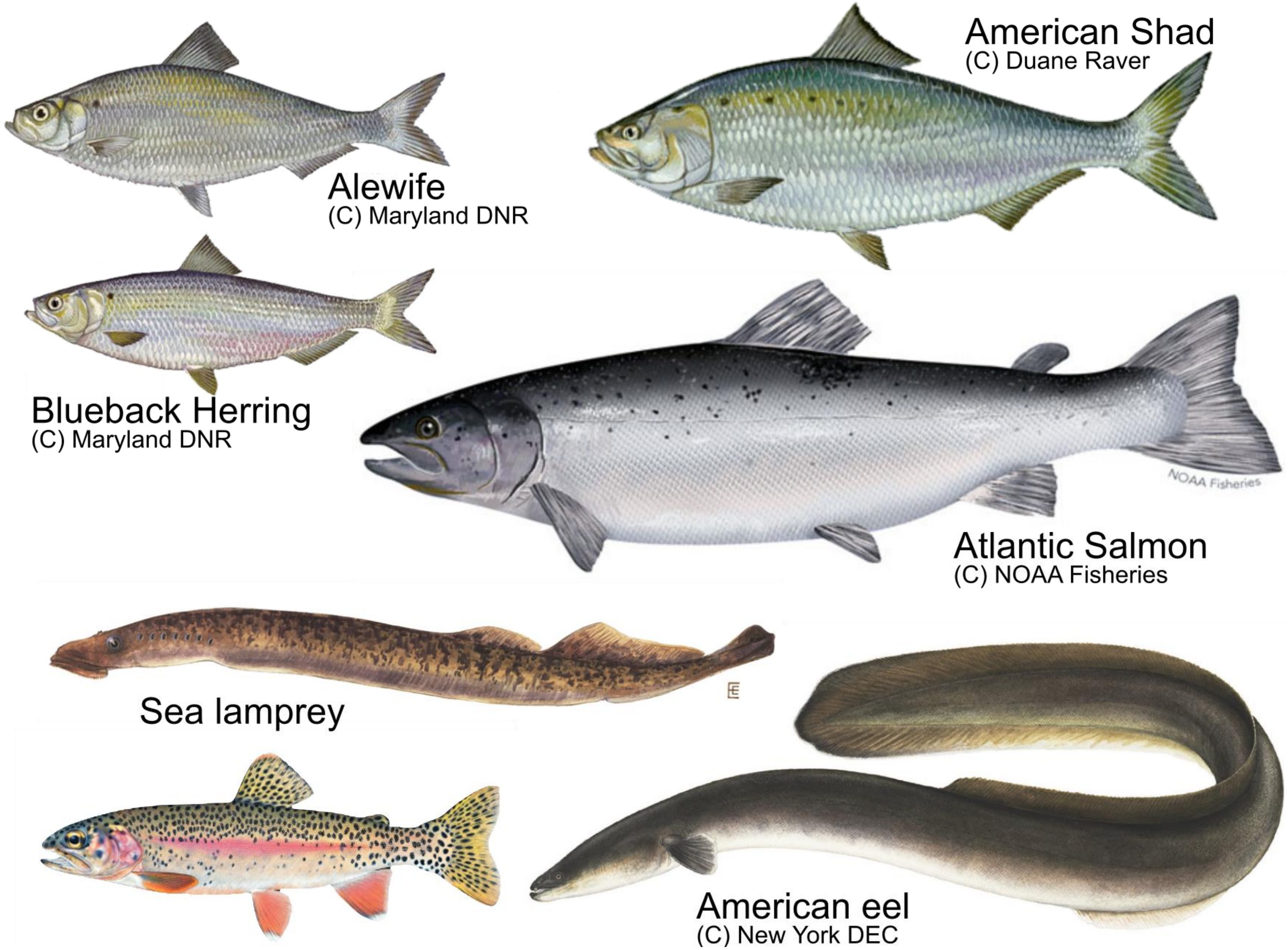

×10^8
6
5
4
3
2
1
0
Cost ($100M)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
fraction accessible habitat


Alewife
(C) Maryland DNR
American Shad
(C) Duane Raver
Blueback Herring
(C) Maryland DNR
NOAA Fisheries
Atlantic Salmon
(C) NOAA Fisheries
Sea lamprey
American eel
(C) New York DEC