Balancing use and sustainability of ecosystem services in dammed rivers: a trade-off assessment in New England

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Why dams?

- We receive benefits from rivers and lakes: *ecosystem services*
- Trade-offs: dams produce some ecosystem services at the cost of others
- Can coordinated dam decisions help improve all of these ecosystem services?
Why dams?

- Trade-off case study: Penobscot River Restoration
- Explore New England dam decision scenarios to balance ecosystem services
- Interpret significance of scale, criteria, preferences in decision-making

- We receive benefits from rivers and lakes: *ecosystem services*
- Trade-offs: dams produce some ecosystem services at the cost of others
- Can coordinated dam decisions help improve all of these ecosystem services?
Trade-off case study: Penobscot River Restoration

- Penobscot River Restoration Trust
- 2 dams removed, several modified (2012-2016)
- 100x increase in river herring population
- ~1% loss in hydroelectric generation

Penobscot River Restoration Trust (http://www.penobscotriver.org/content/4055/fish)
Trade-off case study: Penobscot River Restoration

- **Penobscot River Restoration Trust**
- 2 dams removed, several modified (2012-2016)
- Major historic river herring fishery
- 167.5 MW cumulative capacity

**Can we scale up multi-dam decisions?**

- Lose: ~1% total hydropower
- Gain: 100x more river herring

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**Fish population**

**Power (MW)**
Scaling up: New England

- >14,000 dams
- >14 million people
- 11 sea-run fish species
- >1.6 GW hydropower capacity
- Many old, obsolete dams
Coordinated dam decisions:

1. Trading off hydropower and sea-run fish

Power produced by flowing water harnessed and channeled through turbines (FERC)

Sea-run fish spend parts of their lives migrating through freshwater rivers/streams (FWS, USGS, TNC)
Coordinated dam decisions:
1. Trading off hydropower and sea-run fish

**Production possibility Frontier:**
Maximum production of one ecosystem service for every level of production for another ecosystem service

- **Sea run fish:** 4%
- **Hydropower:** 100%
- **Removal cost:** $0
Coordinated dam decisions:

1. Trading off hydropower and sea-run fish

Sea run fish: 38%
Hydropower: 100%
Removal cost: $1.56bn
Coordinated dam decisions:

1. Trading off hydropower and sea-run fish

Sea run fish: 88%
Hydropower: 87%
Removal cost: $2.02bn
Coordinated dam decisions:

1. Trading off hydropower and sea-run fish

Sea run fish: 99%
Hydropower: 62%
Removal cost: $2.54bn
Coordinated dam removal:

2. Significance of scale

“equal preference” trade-offs at large scale can lead to inequality at local scales...
Coordinated dam removal: 2. Significance of scale

Scaling up improves trade-offs, but can lead to local inequalities

What about other ecosystem services?
Coordinated dam removal: 3. Multiple Criteria

Criteria normalized to maximum values, assuming no additional dam construction

Criteria weighed based on hypothetical stakeholder preferences
Coordinated dam removal:

3. Multiple Criteria

- Hydropower
- Drinking water
- Sea-run fish biomass
- Dam breach safety
- Dam removal cost
- Properties impacted by removal
- Nutrient flux control
- Water storage

Criteria normalized to maximum values, assuming no additional dam construction.
Criteria weighed based on hypothetical stakeholder preferences.

Introduction
Trade-offs
Scenarios
Conclusions

New England: “Equal preference”

Connecticut: preserve dam services

Penobscot: restore fisheries, recreation, preserve lake-related dam services
3. Multiple Criteria

More criteria can be useful for diverse stakeholder engagement.

There can still be scale-dependent inequality.

New England: “Equal preference”

Connecticut: Preserve dam services

Penobscot: restore fisheries, recreation, preserve lake-related dam services

Properties impacted by removal

Nutrient flux control

Water storage

Hydropower

Drinking water

Sea-run fish biomass

Dam breach safety

Criteria normalized to maximum values, assuming no additional dam construction

Criteria weighed based on hypothetical stakeholder preferences.
Dam(n) conclusions

1. New England as a model for informed dam decision-making
2. Decision scale is critical:
   1. Narrow the gap between locally plausible and globally efficient scenarios
   2. Modular decision criteria: iteratively refine based on stakeholder values
3. It takes a village:
Questions?

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Optimized dam removal:

3. Multiple Criteria

Introduction Trade-offs Scenarios Conclusions

Hydropower
Drinking water
Recreation
Sea-run fish biomass

New England: “Eco-restoration”

Water storage
Nutrient flux control
Properties impacted by removal
Dam removal cost
Dam breach safety

Criteria normalized to maximum values, assuming no additional dam construction
Criteria weighed based on hypothetical stakeholder preferences
Optimized dam removal:
4. Multiple Alternatives in the Penobscot

Potential “win-win” scenarios

But, cost of alternatives often far exceed cost of dam removal
Optimized dam removal:

2. Significance of scale

"equal preference" trade-offs at large scale can lead to inequality at local scales...

...but pursuing "equal preference" at smaller scales leads to costlier trade-offs

50% restoration target

-16 MW
Region scale
-632 MW
Local scale

Trade-offs at large scale can lead to inequality at local scales…

but pursuing "equal preference" at smaller scales leads to costlier trade-offs
4. Stakeholder perceptions of dam decisions

Different stakeholders

Different perspectives

Different interests

Different objectives

Search for local/regional patterns in stakeholder perceptions to help fine-tune the decision making process

Access to dam decisions through news media
What about potential FERC-related decisions

**Fig 9:** Trade offs between hydropower capacity and Atlantic Salmon habitat for different combinations of decisions. Black lines: decision trees that highlight potential scenarios for renewal in the next 12 years. A: current conditions, B: removals only, C: removals and upgrades.
Optimized dam removal: 3. Multiple Criteria

New England: “Current conditions”

Criteria normalized to maximum values, assuming no additional dam construction.