The ecological effects of sub-daily flow variability on riverine fishes

Sustainability in Hydropower 2023
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Acknowledgements

Energy Flexibility-Environment Tradeoff Toolkit core team

US Department of Energy Water Power Technologies Office

Hydropower flexibility

- Decarbonize power sector; increase renewable contribution to energy portfolio
- Variable solar and wind energy potentially supported by dispatchable hydroelectric power production (HPP)
- Flexible hydropower operation…
  - meets short-term grid demands
  - creates unpredictable flow regimes with high sub-daily flow variability (SDFV)

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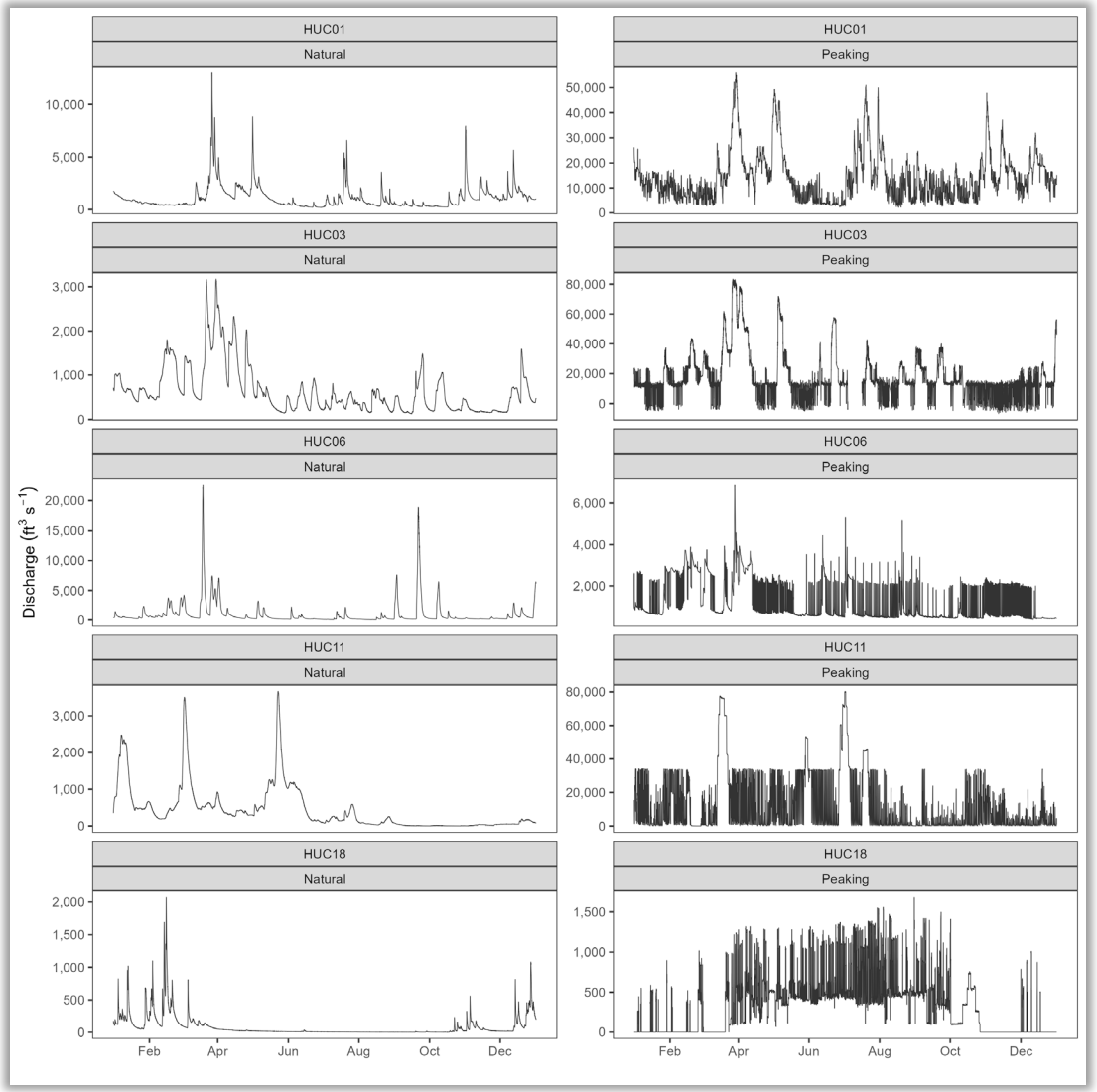

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Sub-daily flow variability (SDFV)

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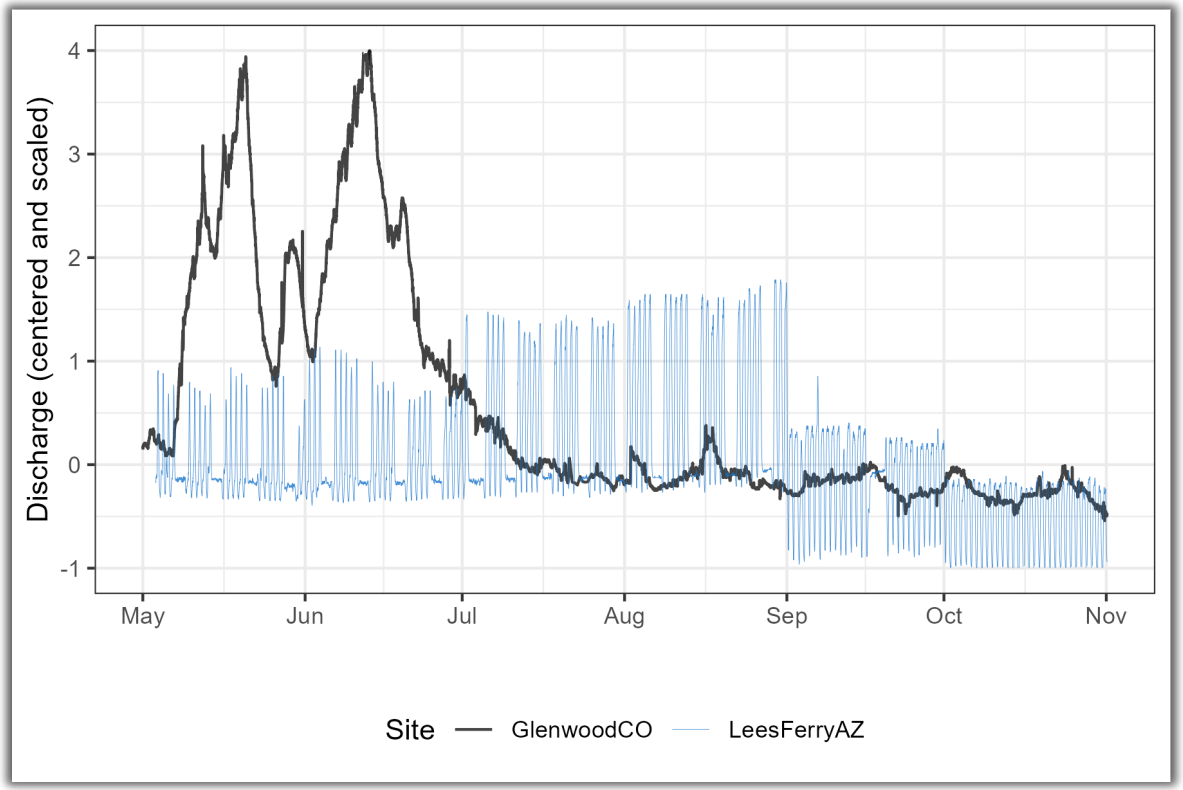
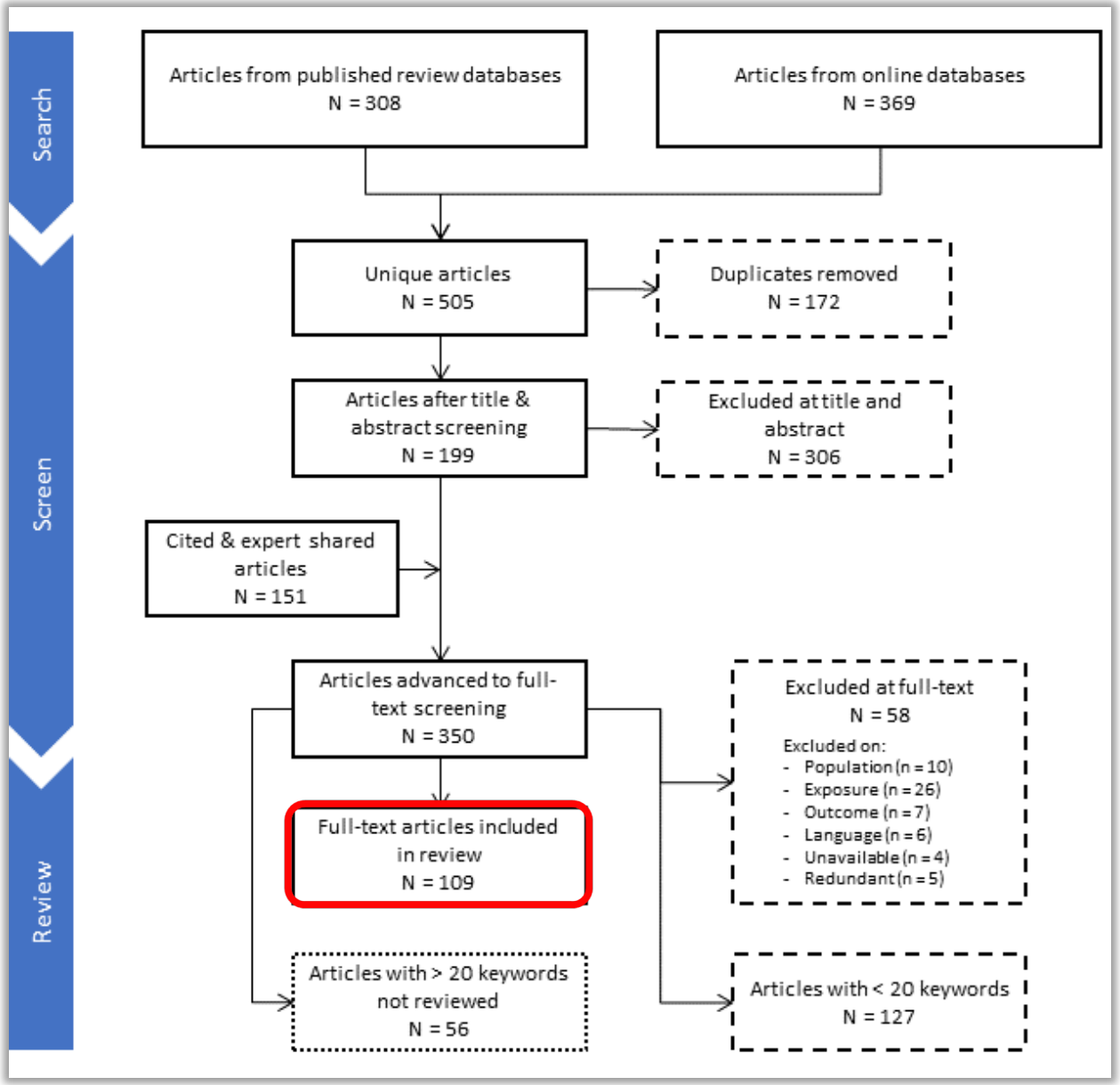
- Variable solar and wind energy potentially supported by dispatchable hydroelectric power production (HPP)
- Flexible hydropower operation…
  - meets short-term grid demands
  - creates unpredictable flow regimes with high sub-daily flow variability (SDFV)
- Understand how flow decisions impact power system *and* environmental outcomes



Systematic review

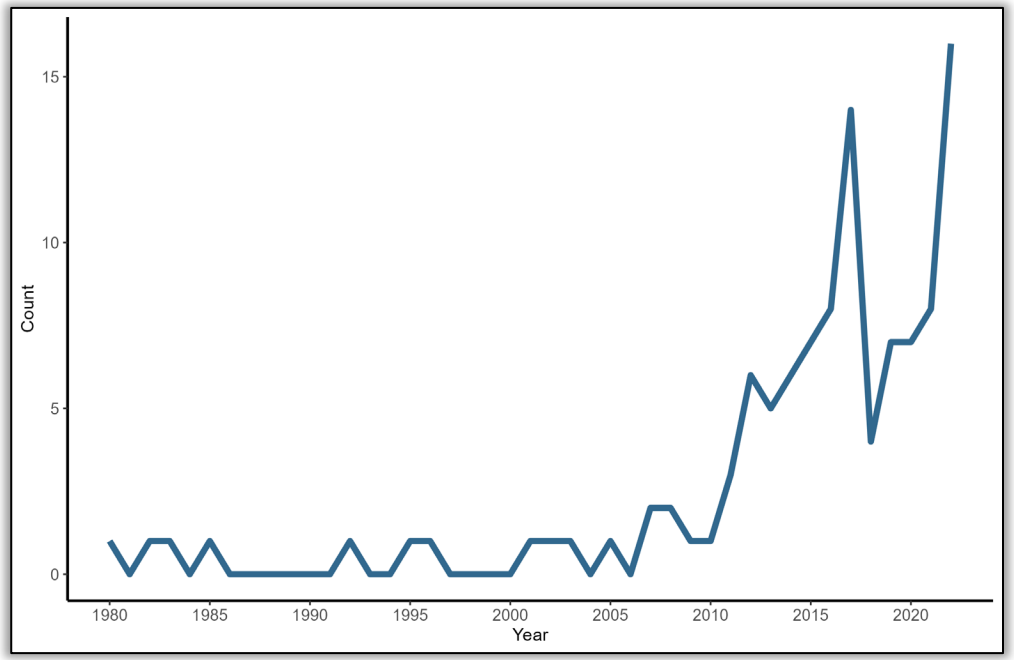
What are the ecological effects of sub-daily flow variability on riverine fish?

- Iterative search, filter, & review of articles from seven sources
- Identified 350 unique articles for review, prioritized by keyword frequency
- Reviewed 109 relevant articles for synthesis in manuscript



Summary statistics

- >85% articles published since 2010



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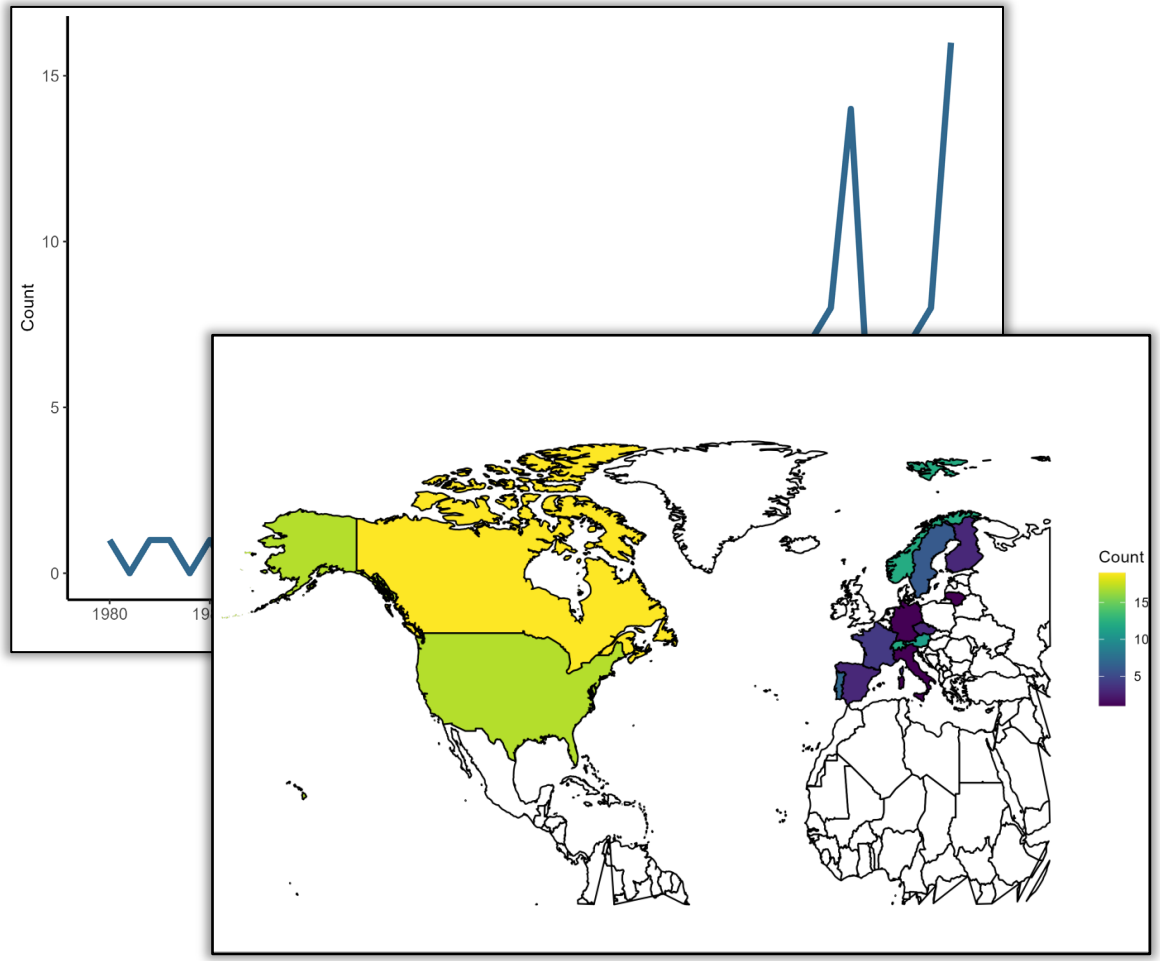

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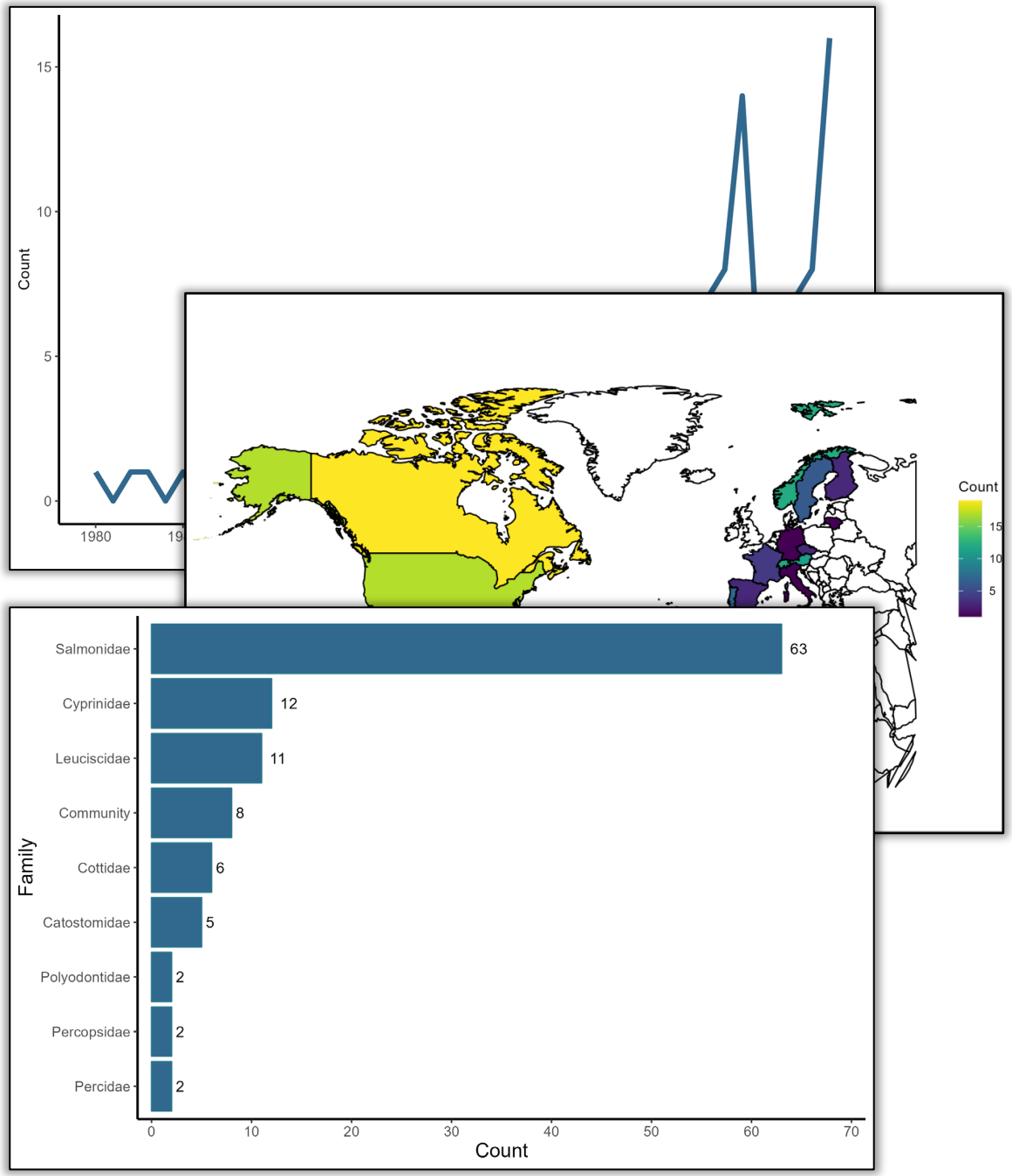

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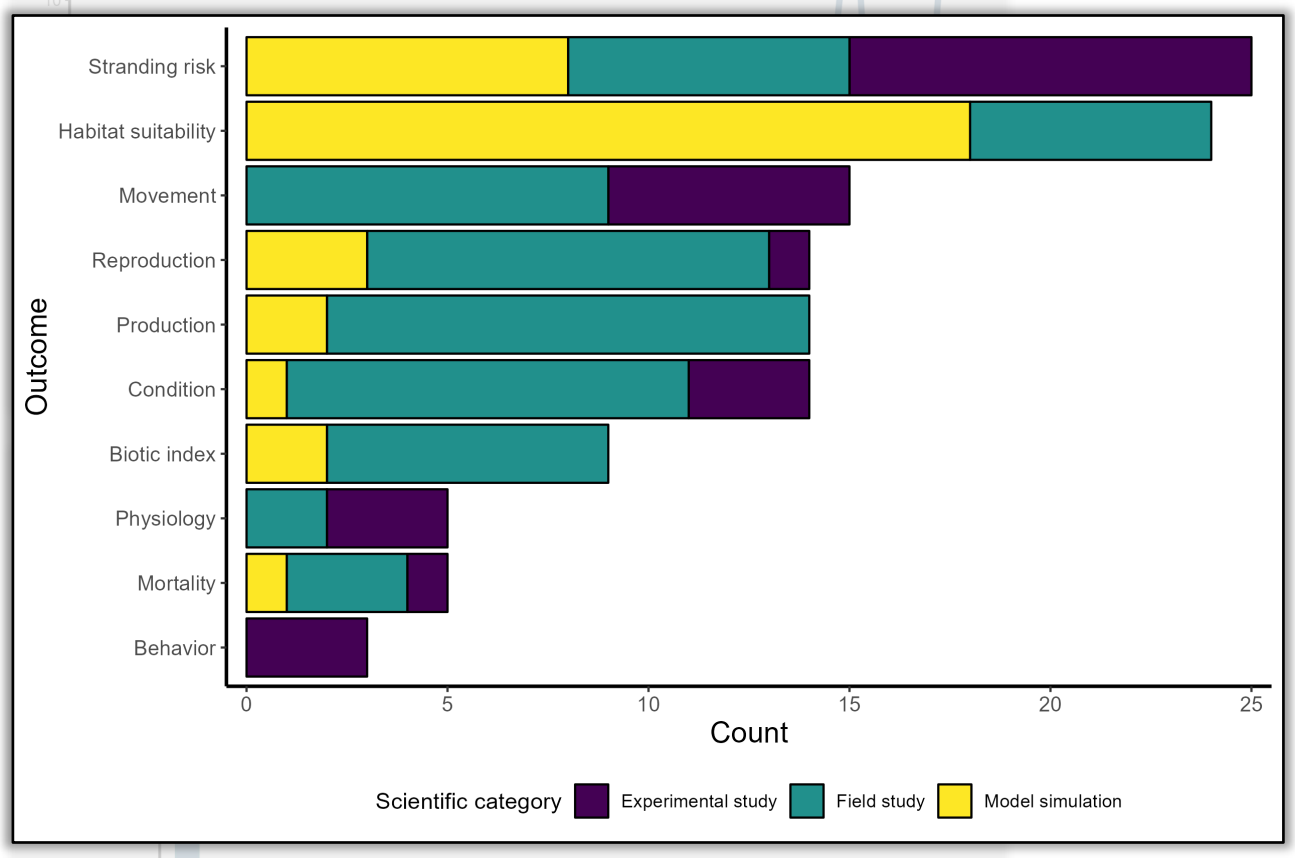
- Classified articles into 10 ecological outcome categories and 3 methods of scientific inquiry



Outcomes in space and time

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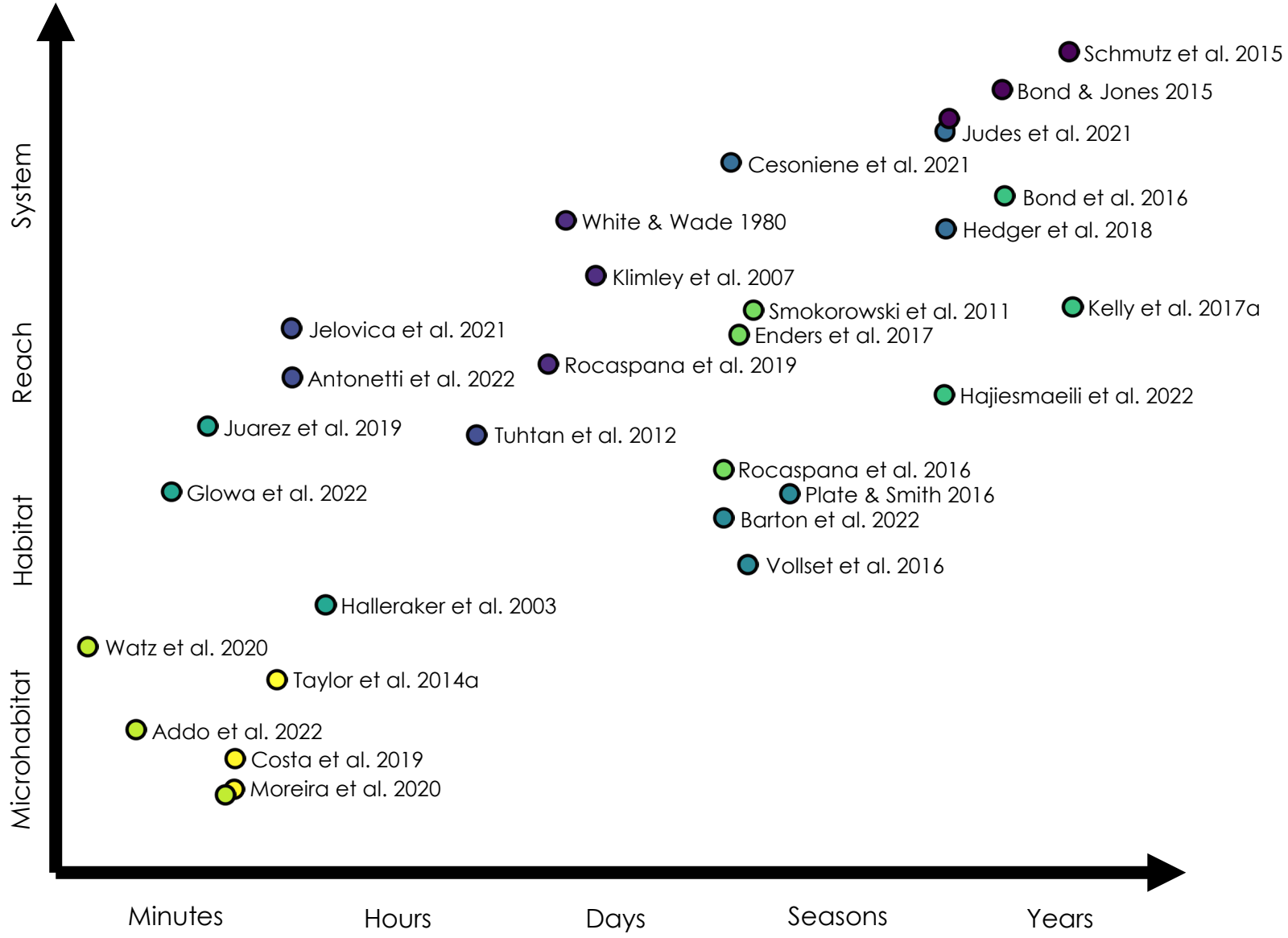
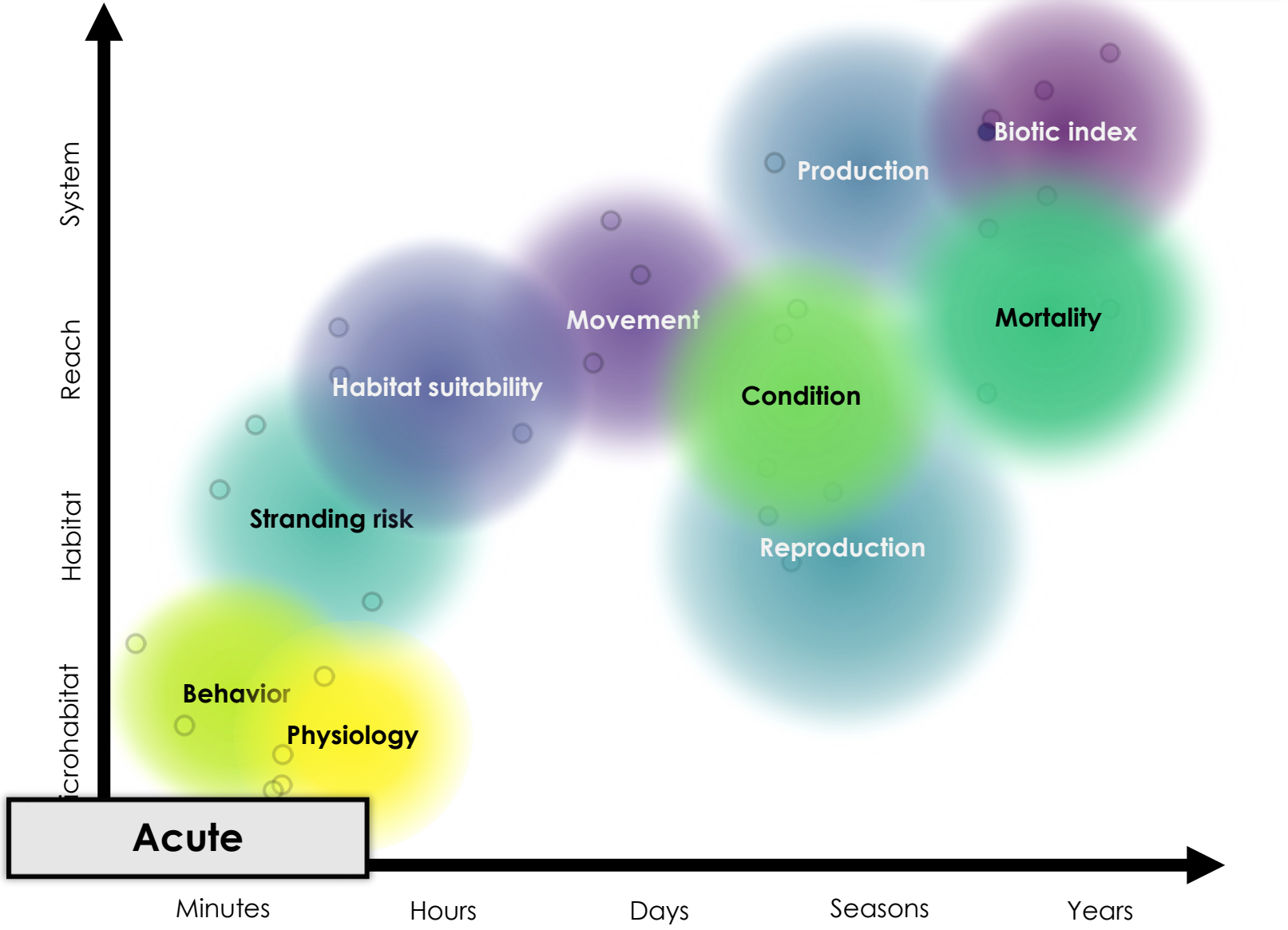


Outcomes in space and time

1. Physiology
2. Behavior
3. Condition
4. Mortality
5. Stranding risk
6. Reproduction
7. Production
8. Habitat suitability
9. Movement
10. Biotic index



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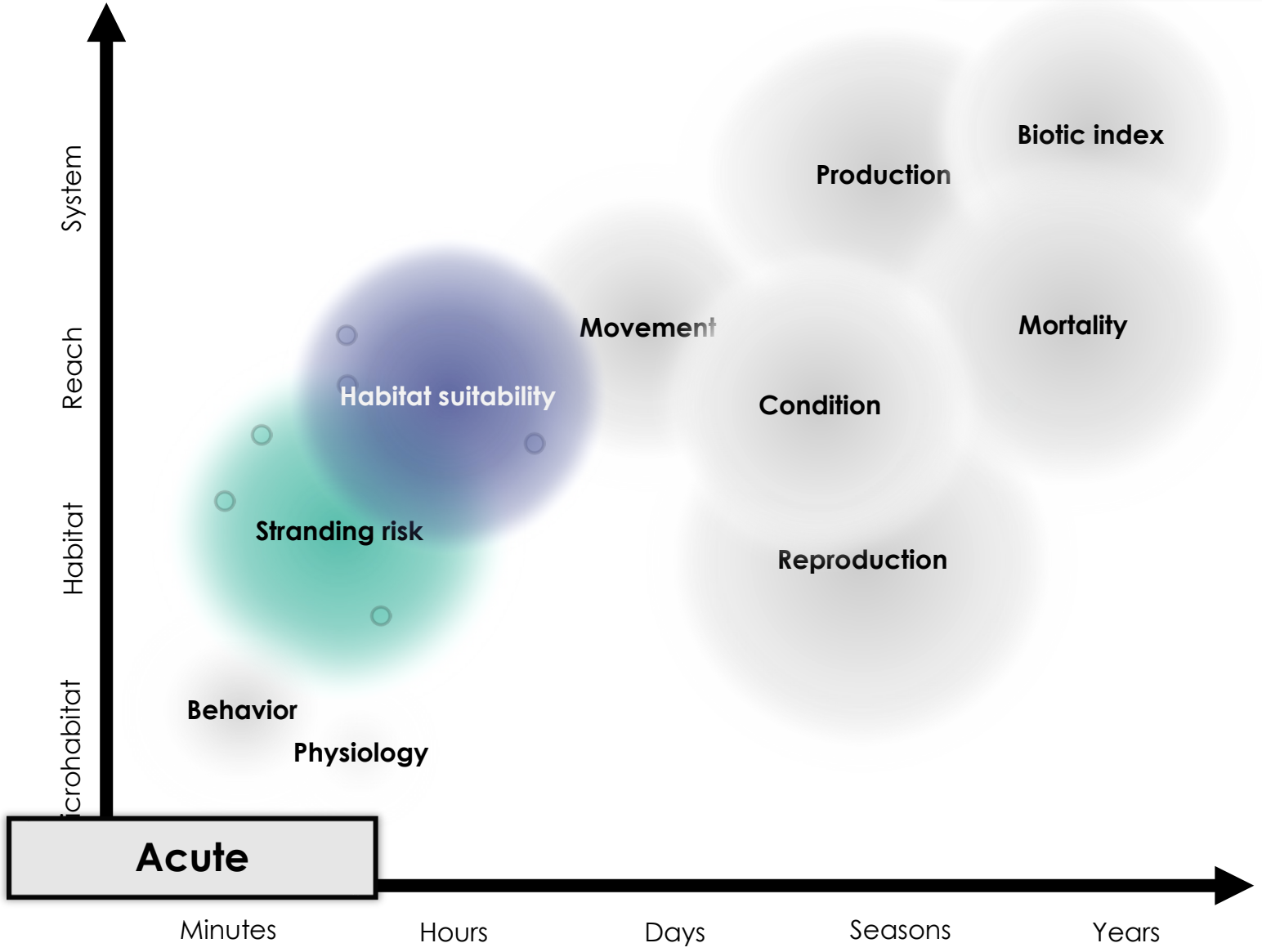

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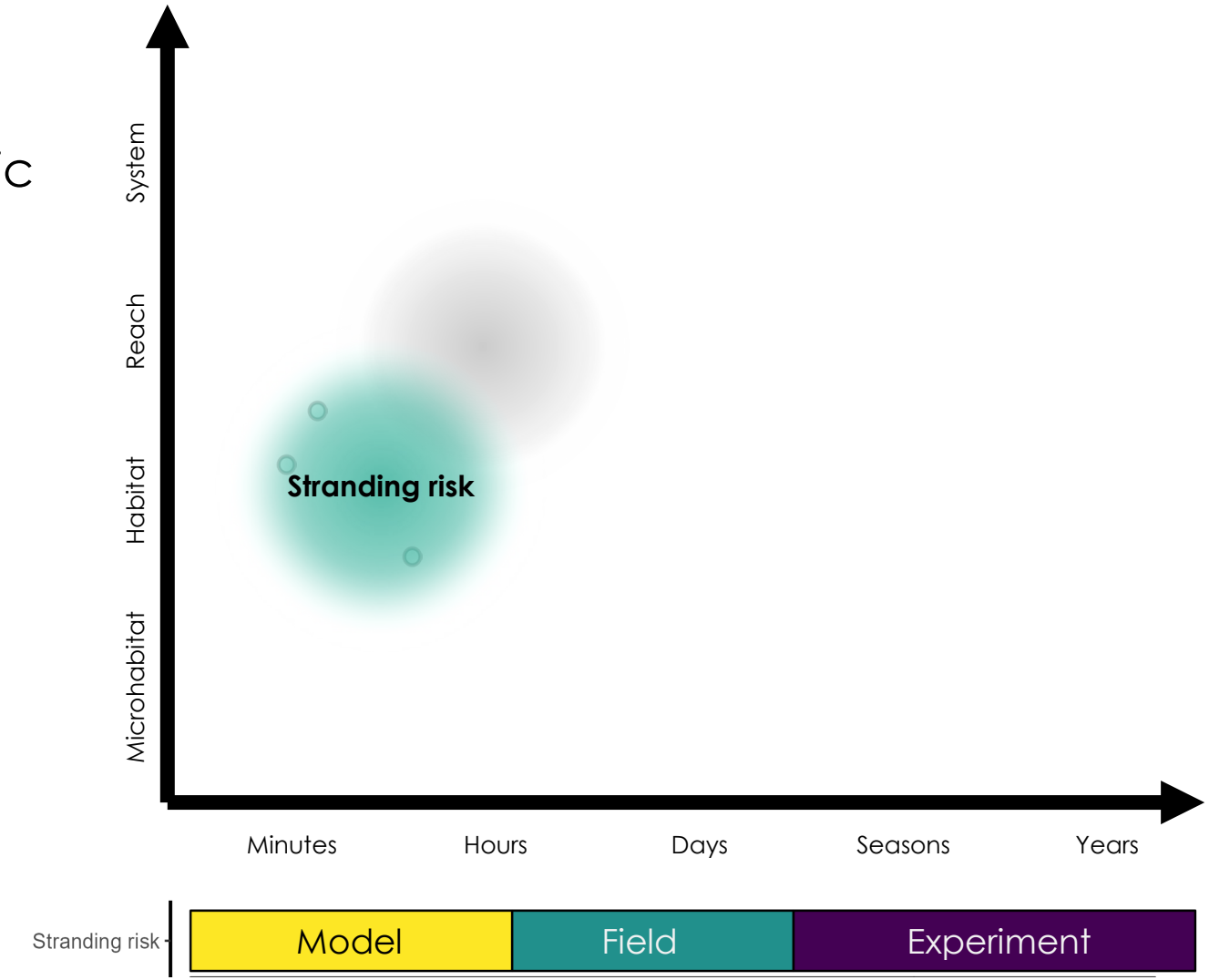
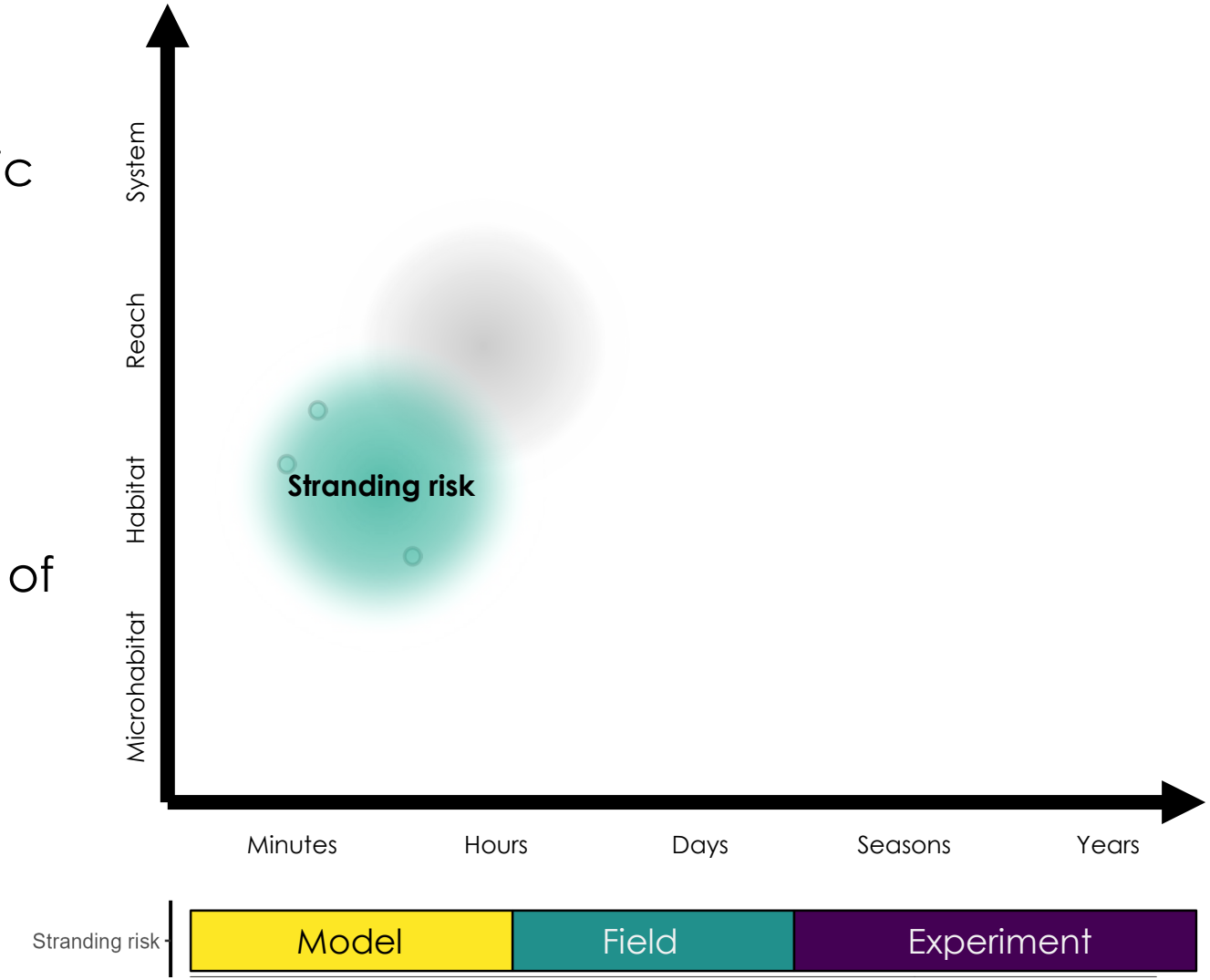
Stranding risk (N = 21)

- Juvenile fish are at risk of becoming stranded during down-ramping events due to a complex combination of biotic and abiotic factors



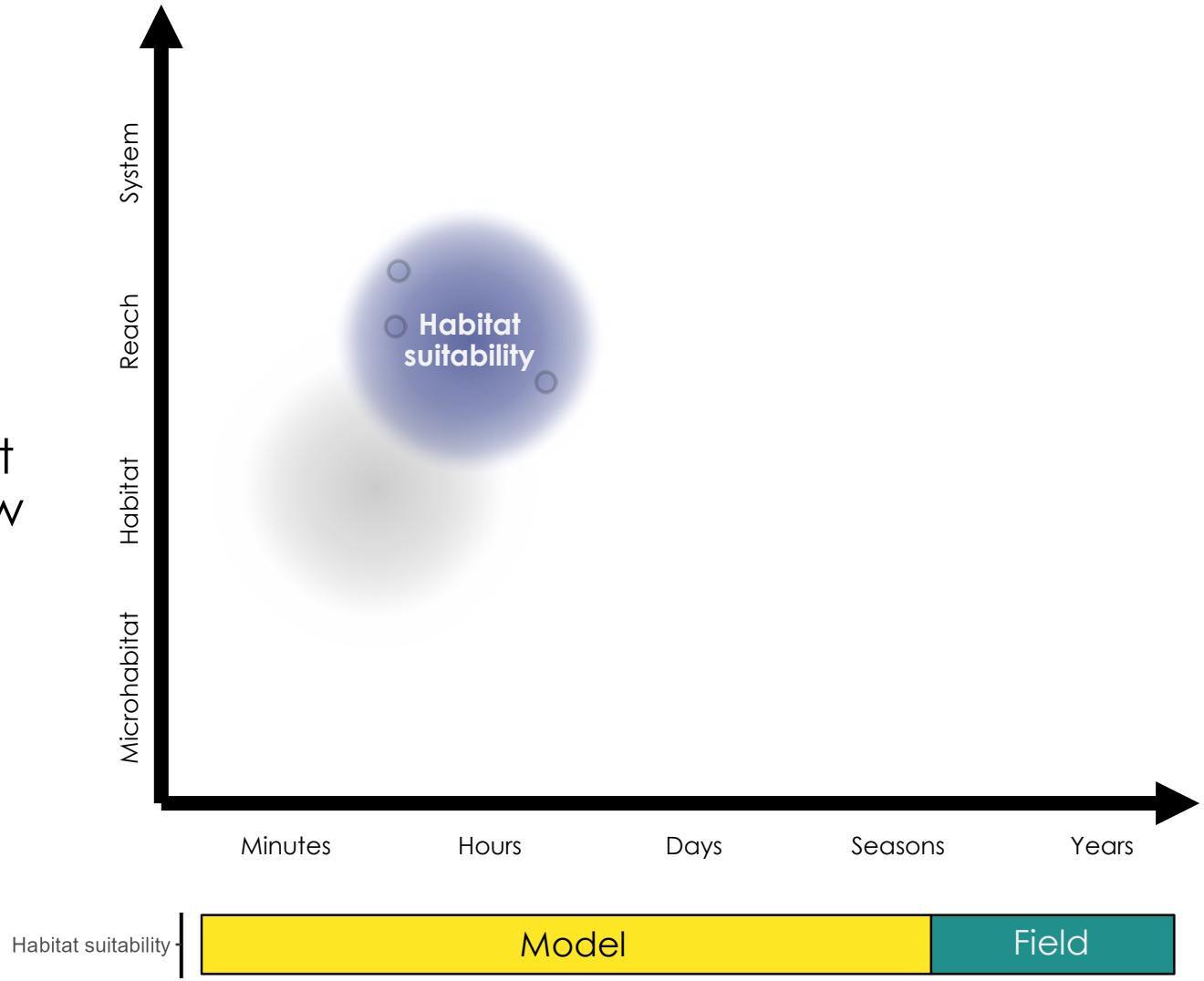
Stranding risk (N = 21)

- Juvenile fish are at risk of becoming stranded during down-ramping events due to a complex combination of biotic and abiotic factors
  - Time of day
  - Temperature/season
  - Channel morphology
  - Habitat heterogeneity
- Stranding risk is greatest during periods of lowest fish activity; exacerbated by shallow bank slopes and habitat complexity
- Down-ramping should be minimized during periods of known low activity, efficacy constrained by site



Habitat suitability (N = 20)

- SDFV destabilizes fish habitat by changing the quantity, quality, and arrangement of suitable habitat
  - Age class
  - Habitat heterogeneity
  - Distance from peaking facility
- Heterogeneity provides suitable habitat for multiple age classes, attenuates flow variability, increases stranding risk
- Habitat assessments must consider arrangement of suitable habitats for specific age classes, not just quantity



Big picture

Sub-daily flow variability due to hydroelectric power production…

- Increases stranding risk
- Destabilizes habitat
- Decreases diversity
- Decreases production
- Increases condition

Consensus

- Interrupts reproduction
- Increases mortality
- Prompts movement

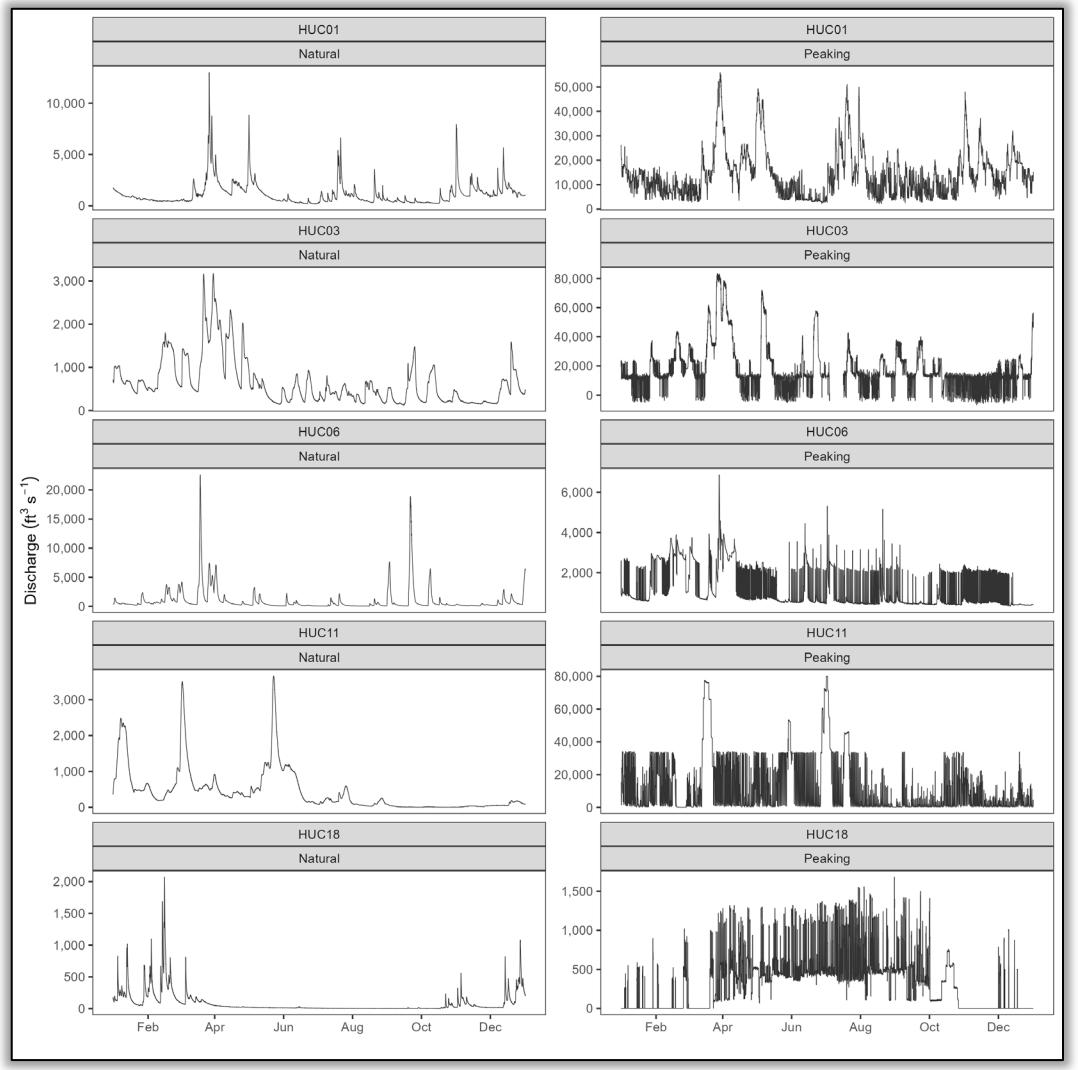
Moderate evidence

- Does not meaningfully or consistently impact physiology or behavior

Limited evidence

Looking forward

- Characterize hydropower operation modes under modern grid dynamics



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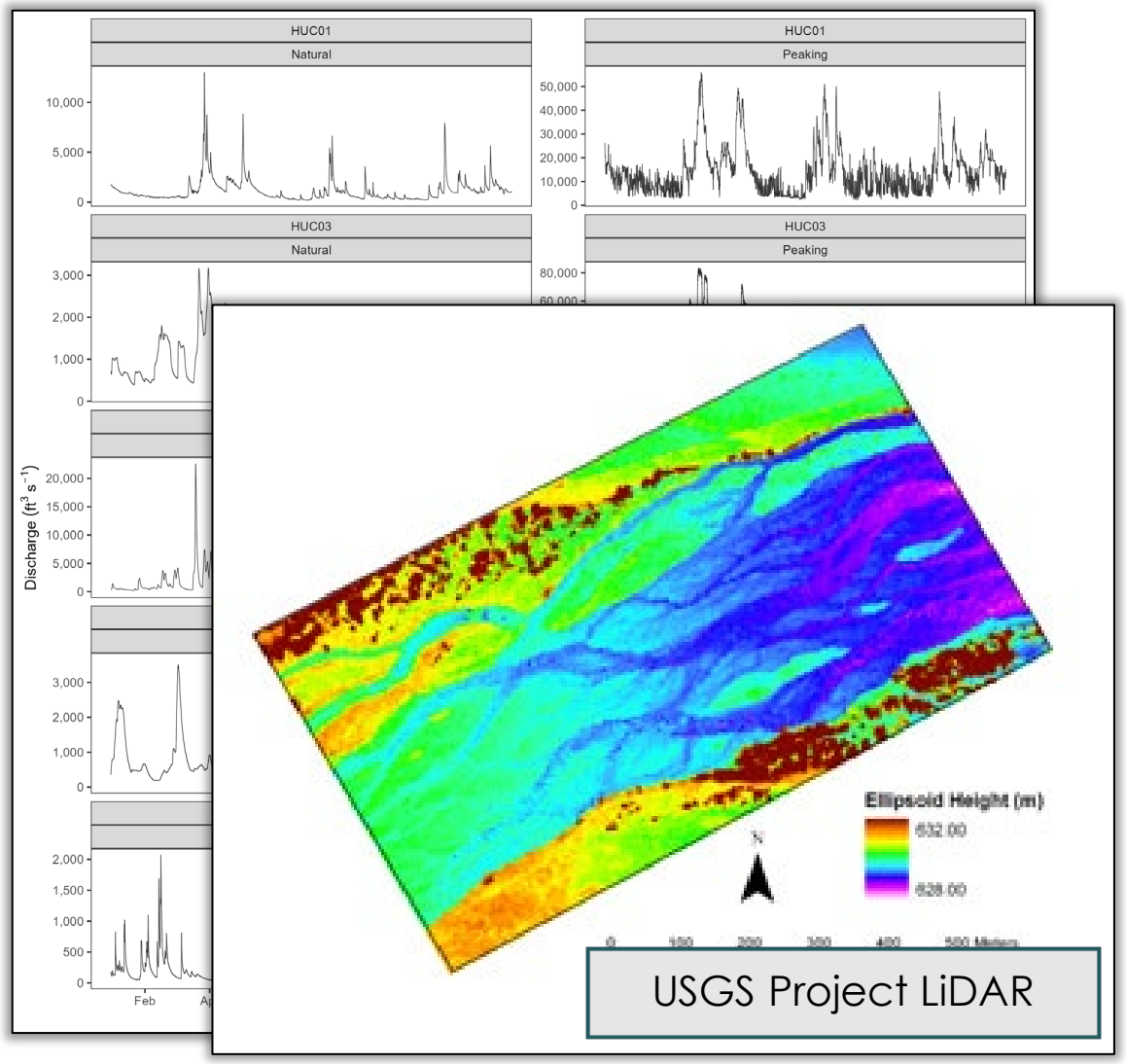

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Looking forward

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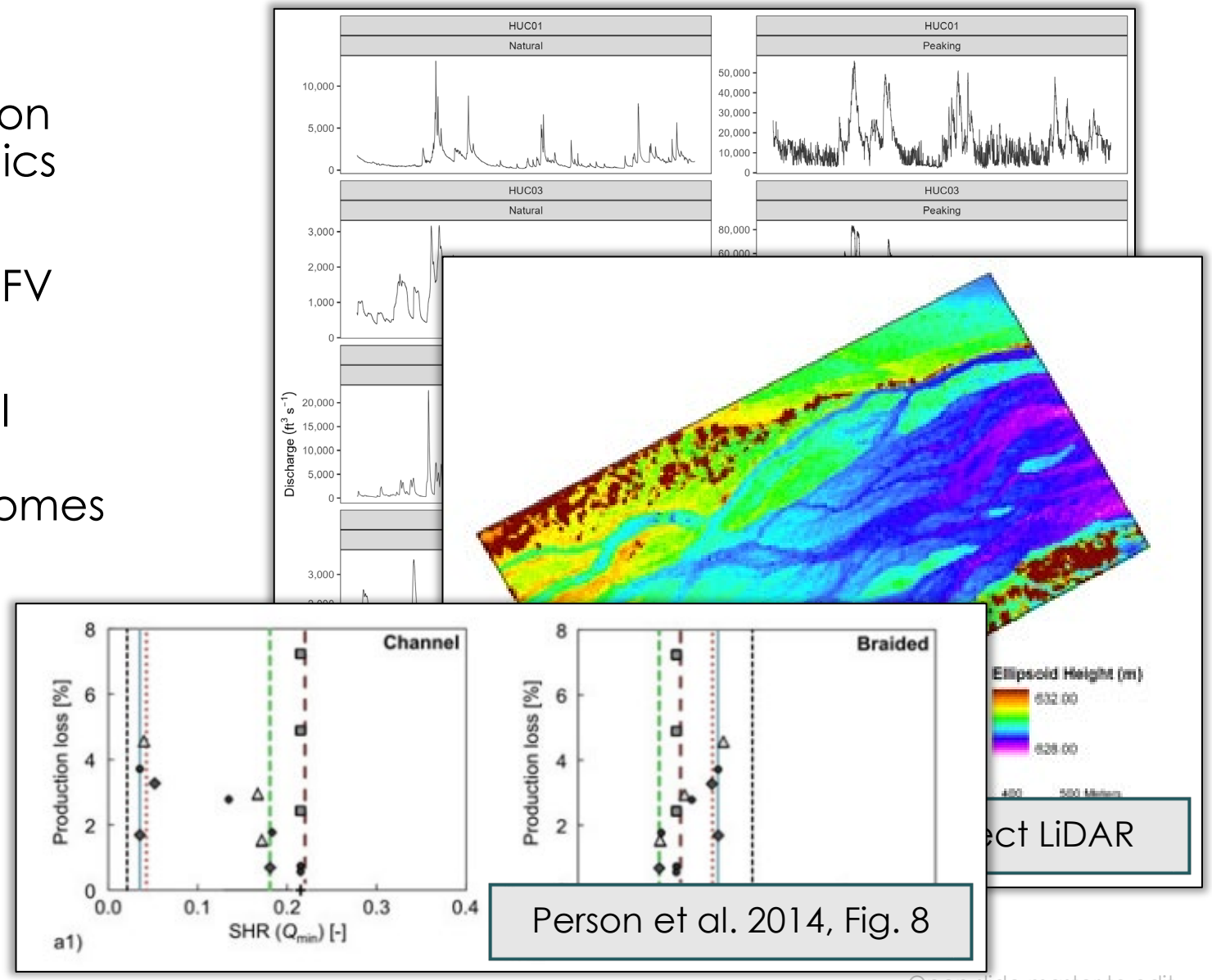
- Incorporate morphology and heterogeneity into longitudinal SDFV models
- Link economic and environmental models to evaluate anticipated commercial and ecological outcomes associated with flow decisions



Person et al. 2014, Fig. 8

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Argonne NATIONAL LABORATORY

NREL NATIONAL RENEWABLE ENERGY LABORATORY

INL Idaho National Laboratory

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