FACT SHEET 5: AQUATIC ECOSYSTEMS – FISH HABITAT

New Hampshire's Changing Climate, Land Cover, and Ecosystems

With thousands of miles of rivers and streams and hundreds of lakes and ponds, New Hampshire offers aquatic habitat that support a rich fish population. However, some of our fish habitat is deteriorating due to elevated chloride concentrations, warmer water temperatures, and low flows during summer months. Projected changes in climate and land cover will lead to changes in these environmental variables in ways that will likely reduce fish habitat in the future, with increasing stream temperatures as the predominant problem.

WATER TEMPERATURES

WHAT HAVE WE SEEN SINCE 1995 FOR THE MERRIMACK RIVER?

- 70 river miles (~1% of the total NH river aquatic habitat) exceed an average weekly temperature tolerated by common indigenous fish species (84.6° F)

WHAT CAN WE EXPECT IN THE FUTURE?

- Warmer air temperatures and increased surface runoff in New Hampshire will result in elevations in stream and river water temperatures
- By mid-century, river miles with temperature impairment are expected to increase 4 to 19%
- By late-century, river miles with temperature impairment are expected to increase 4 to 62% (higher impact under the high emissions and backyard amenities scenarios)

CHLORIDE CONCENTRATIONS

WHAT HAVE WE SEEN SINCE 1995 FOR THE MERRIMACK RIVER?

- 27 river miles (<1% of total NH river aquatic habitat network) exceeds a chloride threshold of 140 mg chloride per litre that is protective of aquatic diversity

WHAT CAN WE EXPECT IN THE FUTURE?

- Given current land use, warmer winters could reduce impairment by 7 to 14% by mid-century or by 40% by late-century
- Increased impervious surfaces could increase chloride impairment up to 90% by the end of the century despite warmer winters

LOW FLOW

WHAT HAVE WE SEEN SINCE 1995 FOR THE MERRIMACK RIVER?

- 27 river miles (<1% of total NH river aquatic habitat network) experienced low flow (0.122 mm per day; described in methods on back)

WHAT CAN WE EXPECT IN THE FUTURE?

- Occurrences of low flow conditions are sensitive to both climate and land cover scenarios
- In a moderately warming climate (low emissions) with constant land cover, low flow occurrences decrease 40% by mid-century, but increase back to 30% of current values by late-century due to increased precipitation and maturing forest

NOTES

METHODS: Simulations use a linked terrestrial – aquatic model (PnET-FrAMES) tested against current conditions using a network of stream flow, temperature, and chemistry measurements. The temperature criteria is the average of weekly temperature tolerance of several local fish species. The chloride criteria protects diversity of organisms at the base of the aquatic food web. The low flow criteria used is the median 7-day 10th percentile flow, a common measure of protective in-stream flows, expressed as runoff (mm d^{-1}), for USGS gauging stations throughout the Merrimack and Piscataqua watersheds (0.122 mm d^{-1}) which applies to downstream (2nd order and larger) river reaches.

MODEL: Existing forest (PnET-CN) and river network (FrAMES) models were coupled to provide estimates of environmental condition under different scenarios. PnET-CN (Photosynthetic EvapoTranspiration with Carbon and Nitrogen), simulates forest water, carbon, and nitrogen dynamics. FrAMES (Framework for Aquatic Modeling in the Earth System), is a gridded model that represents land cover and land use to simulate runoff, water temperature, and chloride dynamics through watersheds. PnET-FrAMES represented the Merrimack and Piscataqua River Watersheds with grid a resolution of 1.5 km^2.

CONTEMPORARY VALIDATION: Testing of PnET-FrAMES under recent historical conditions used climate from NASA Modern Era-Retrospective Analysis for Research and Applications (MERRA) for the period of 1980-2014. Output corresponded well with station (gage) measurements for discharge (U.S. Geological Survey - USGS), specific conductance (Lotic Volunteers Temperature Electrical Conductance and Stage network – LoVoTECS; **ddc-lovotecs.sr.unh.edu**), and water temperature (USGS/ LoVoTECS).

LAND USE DATA: Two land cover scenarios encompass the widest divergence in land cover change: present-day land cover and Backyard Amenities, which prioritizes large building lots and increases impervious areas dramatically. More info at: **ddc-landcover.sr.unh.edu.**

FUTURE CLIMATE DATA: Future climate projections used statistically downscaled climate simulations derived from the Geophysical Fluid Dynamics Laboratory CM2.1 model (Hayhoe 2007). Two scenarios represent a wide range of potential future climate: lower emission (B1, 550 ppm CO_2 by 2100) and higher CO_2 emission (A1FI, 970 ppm CO_2 by 2100).

REFERENCES

Aber, JD and CT Driscoll (1997) Effects of land use, climate variation, and N deposition on N cycling and C storage in northern hardwood forests. Global Biogeochemical Cycles 11:639–648. doi:10.1029/97GB01366

Cañedo-Argüelles M and others (2013) Salinisation of rivers: An urgent ecological issue. Environmental Pollution 173:157–167.

Eaton JG and RM Scheller (1996) Effects of climate warming on fish thermal habitat in streams of the United States. Limnology and Oceanography 41(5):1109–1115.

Hayhoe K and others (2006) Past and future changes in climate and hydrological indicators in the US Northeast. Climate Dynamics 28(4):381–407.

Ollinger SV and others (2002) Interactive effects of nitrogen deposition, tropospheric ozone, elevated CO2 and land use history on the carbon dynamics of northern hardwood forests. Global Change Biology 8, 545–562.

Ollinger SV and others (2008) Potential effects of climate change and rising CO2 on ecosystem processes in northeastern U.S. forests, Mitigation and Adaptation Strategies for Global Change 13:467–485.

Rienecker MM and others (2011) MERRA: NASA's Modern-Era Retrospective Analysis for Research and Applications. Journal of Climate 24(14):3624–3648.

Samal, NR and others (In Review) Projections of coupled terrestrial and aquatic ecosystem change relevant to ecosystem service valuation at regional scales. Submitted to *Ecology and Society*.

Stewart, RJ and others (2013) Horizontal cooling towers: riverine ecosystem services and the fate of thermoelectric heat in the contemporary Northeast US. Environmental Research Letters 8(2):025010.

Tharme RE (2003) A global perspective on environmental flow assessment: emerging trends in the development and application of environmental flow methodologies for rivers. River Research and Applications 19(5-6):397–441.

Thorn, AM and others (In Review) New Hampshire Land Cover Scenarios, Part I: stakeholder engagement, scenario narratives, and land change simulation. Submitted to *Ecology and Society*.

Zhou, Z and others (In Review) Looking for the missing N sink in a northern hardwood forest by quantifying N gas losses: a model-based assessment. Submitted to *Ecological Modelling*.

Zuidema, S and others (In Review) Chloride impairment in a New England river network: current and projected conditions using a dynamic watershed transport model. Submitted to *Water Resources Research*.

ACCESS TO DATA: All three variables (water temperature, water chloride, and low flows) for multiple climate and land cover scenarios covering the time period 1995-2099 are available on the NH EPSCoR Data Discovery Center: **ddc.unh.edu.**

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