Modelling Water Quality in Newfoundland Rivers from Data Obtained from the Real-Time Water Quality Monitoring Network.

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Overview

- An introduction to real time monitoring in Newfoundland
- Models for predicting water temperature
- Models for predicting dissolved oxygen
- A novel approach to linking the models together
- Conclusion

The Need for Water Quality Monitoring

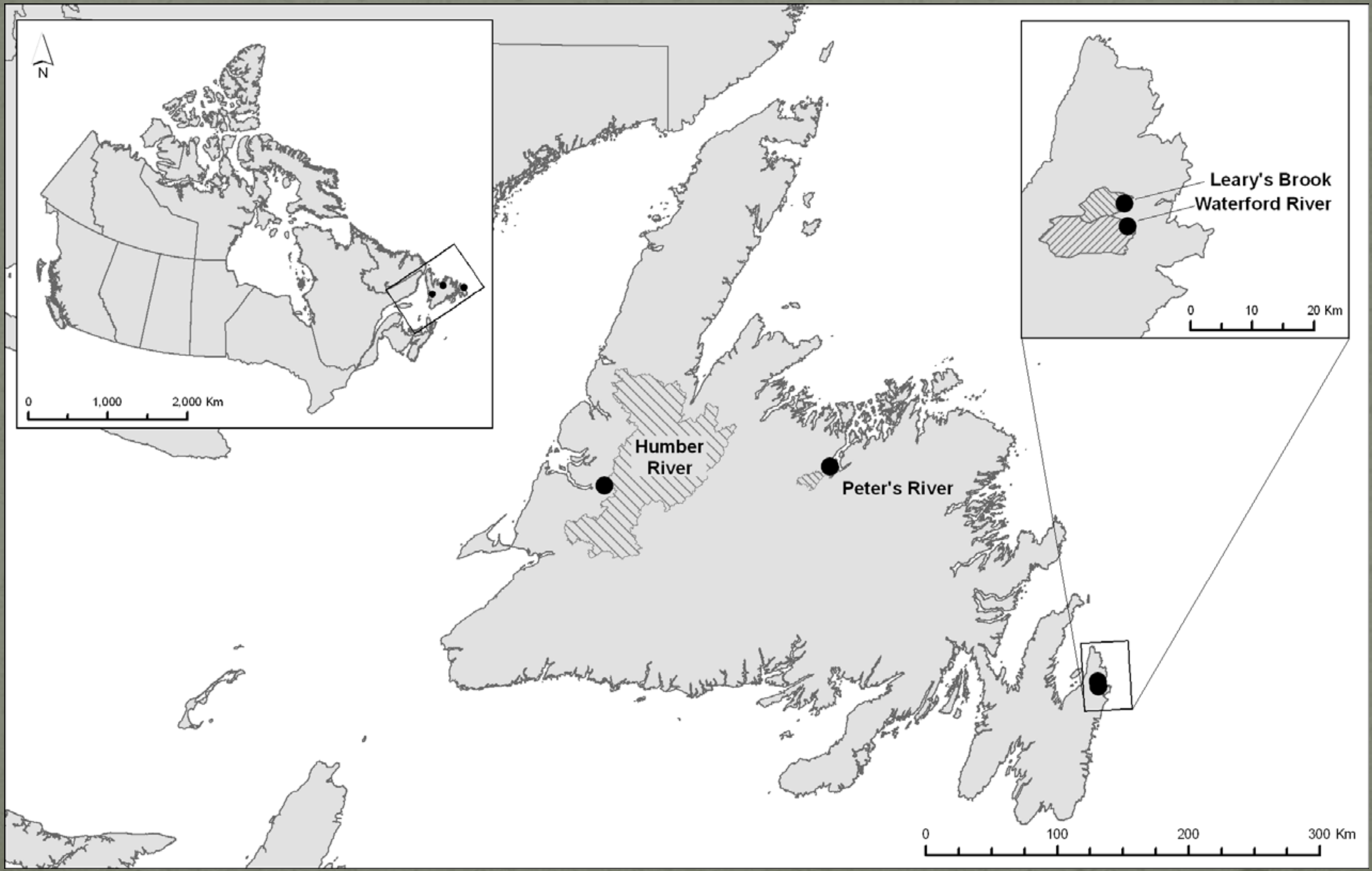
- Our global water resources are increasingly under threat from:
  - *Rapid human population growth*
  - *Increased industrialization*

- Monitoring programs use a variety of data collection methods to gain a complete understanding of the health of the water body being studied

The RTWQ Monitoring Network

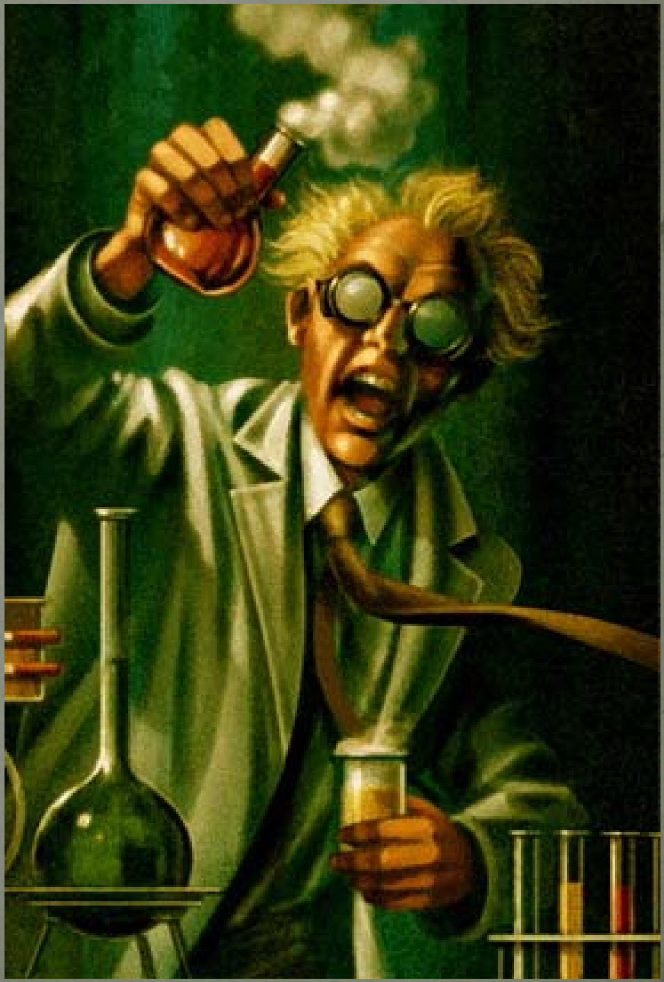
- Real Time Water Quality (RTWQ) monitoring network established in 2001
- Real time sensors placed in select rivers record water temperature, dissolved oxygen, specific conductance & turbidity
  - Once every hour in rural rivers
  - Once every 15 minutes in urban rivers
- Strict quality control/quality assurance measures in place to ensure the integrity of the data being collected

RTWQ Stations Used in This Research



The Need for New Research

- Real time monitoring still relatively new to resource managers in Canada
- Most research focuses on improving measurement techniques with very little research carried out that ensures data is being used effectively
- 2 recent areas of research:
  - *1. Can we predict water temperature?*
  - *2. Can we predict dissolved oxygen?*



Why Would We Model Water Temperature?

- Using air temperature to predict water temperature can help us understand the influence of the surrounding environment on water quality

- Models that link these two parameters have been extensively studied in the literature but have never been developed for Newfoundland rivers

Datasets Used for Model Development

- Air temperatures from nearby Environment Canada meteorological stations :
  - Corner Brook for the Humber River station (15 km)
  - Badger for Peter's River (50 km)
  - St. John's airport for Leary's Brook (5 km) & Waterford River (10 km)

- Water temperature and dissolved oxygen from the RTWQ sensors

- Stage levels from nearby Environment Canada hydrometric monitoring stations

- Period of time covered by the historical records varied for each RTWQ station that was studied

Datasets Used for Model Development

- Historical records used to develop *monthly*, *weekly*, and *daily* datasets consisting of *mean*, *maximum* and *minimum* values:

Station Name	**Purpose of the Dataset**	**Time Frame**	**# of Observations**		
			Monthly	**Weekly**	**Daily**
Humber River	Model Development	Dec 03 – Dec 06	37	149	986
	Model Testing	Jan 07 – Apr 08	13	63	398
Peter's River	Model Development	July 05 – May 07	23	91	595
	Model Testing	July 07 – Feb 08	8	23	136
Leary's Brook	Model Development	Sept 04 – Dec 06	16	57	347
	Model Testing	May 07 – Dec 07	12	48	306
Waterford River	Model Development	July 05 – Mar 07	21	90	587
	Model Testing	Apr 07 – Mar 08	8	32	196

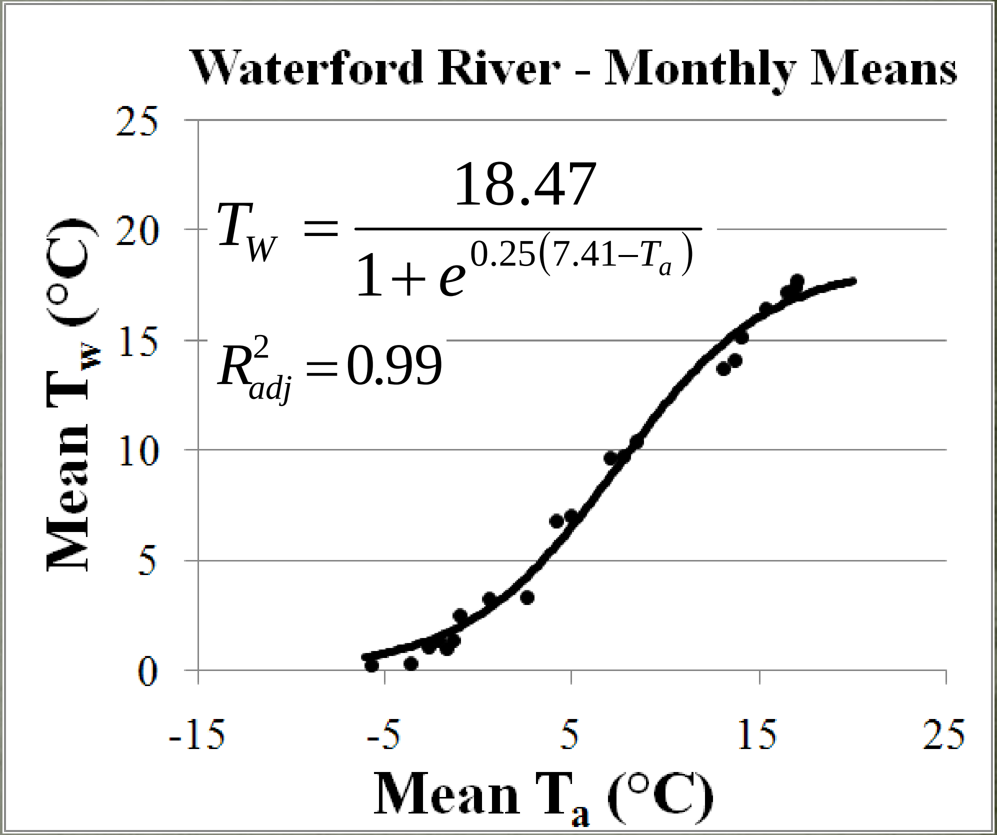
Empirical or Deterministic?

- Water temperature models are either empirical (regression-based) or deterministic (physical-based)
  - Deterministic models: obtaining the necessary inputs tends to be extraordinarily challenging.
  - Empirical models: develop regression equations that relate routinely monitored data to water temperature

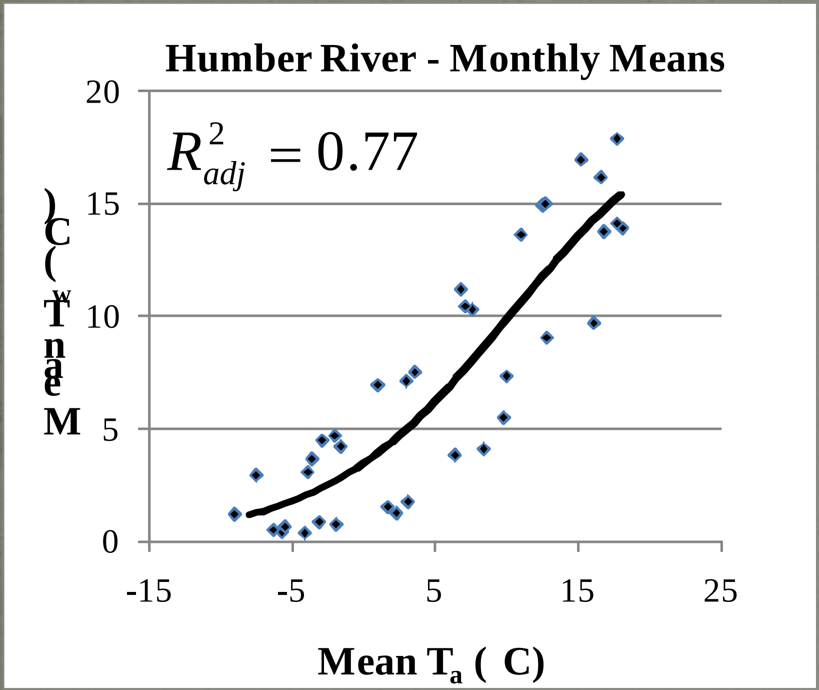
- The most commonly used regression models are:
  - **1. Linear:** traditional approach of using air temperature to predict water temperature in the rivers
  - **2. Nonlinear logistic:** describing an S-shaped relationship between air temperature and water temperature
  - **3. Multiple regression:** using air temperature and stage level

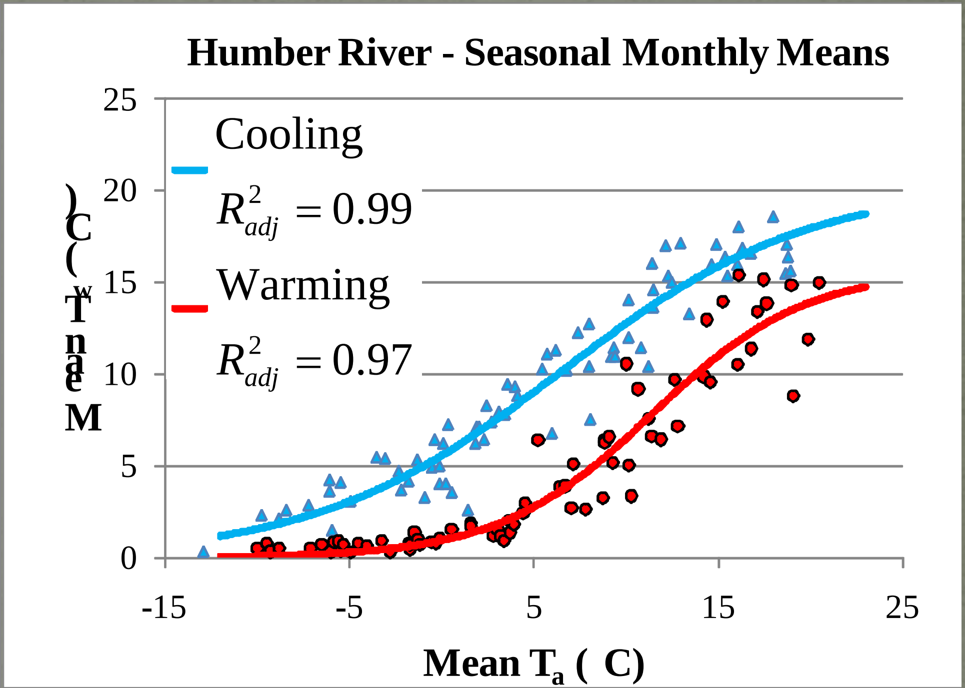
Modeling Results: Linearty vs. Nonlinearity?

- Simple linear model does not accurately describe the relationship between air and water temperature
- Logistic best describes the S-shaped relationship
  - At high air temperatures the relationship levels off due to evaporative cooling & back radiation from the water
  - When air temperatures drop below 0 °C the relationship levels off again as the river reaches a minimum temperature above 0 °C.



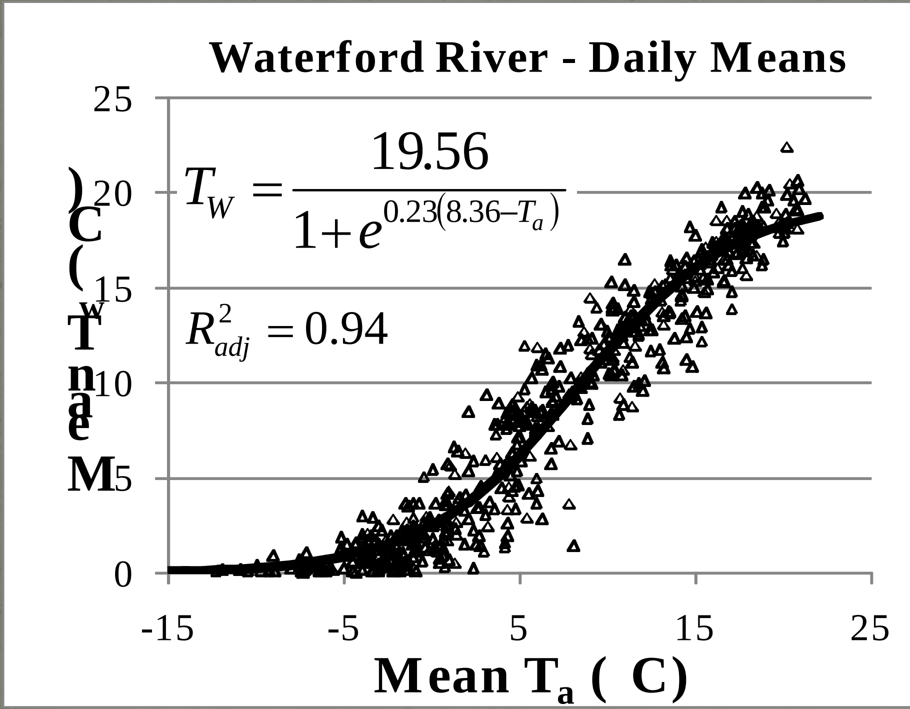
Modeling Results: Accounting for Hysteresis

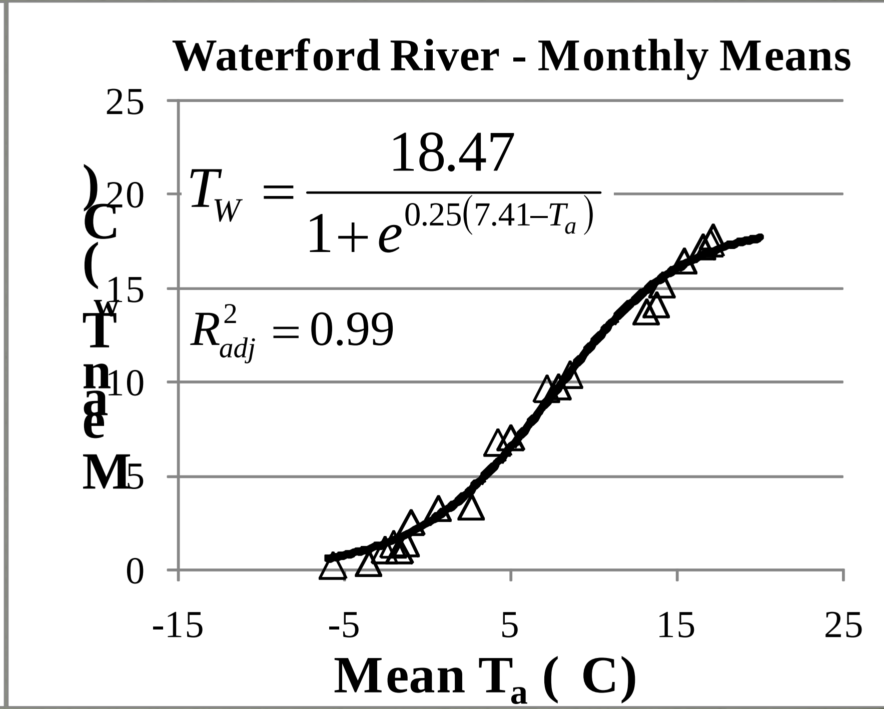




- Goodness-of-fit significantly improved after divisions were made to account for seasonal hysteresis in the Humber River dataset
  - Warming season (February to July – water temperatures lower)
  - Cooling season (August to January – water temperatures higher)
- No evidence of hysteresis in the other smaller rivers

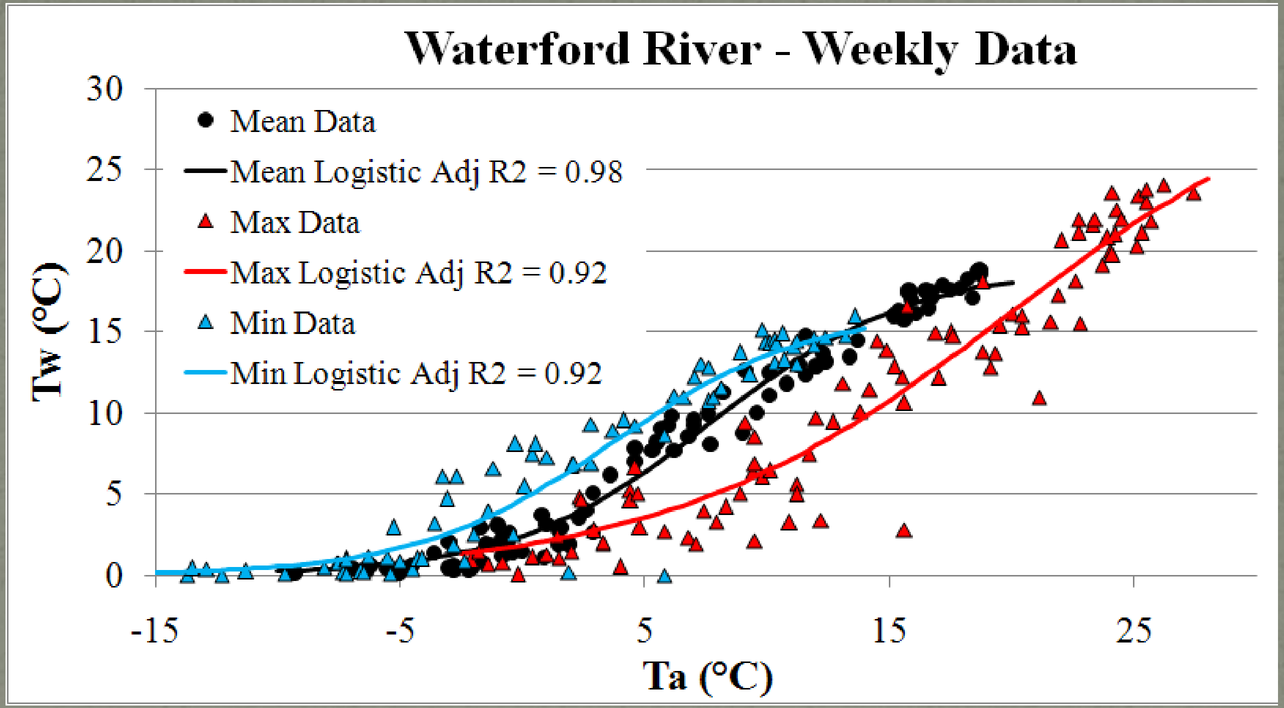
Modeling Results: The Influence of Timescale





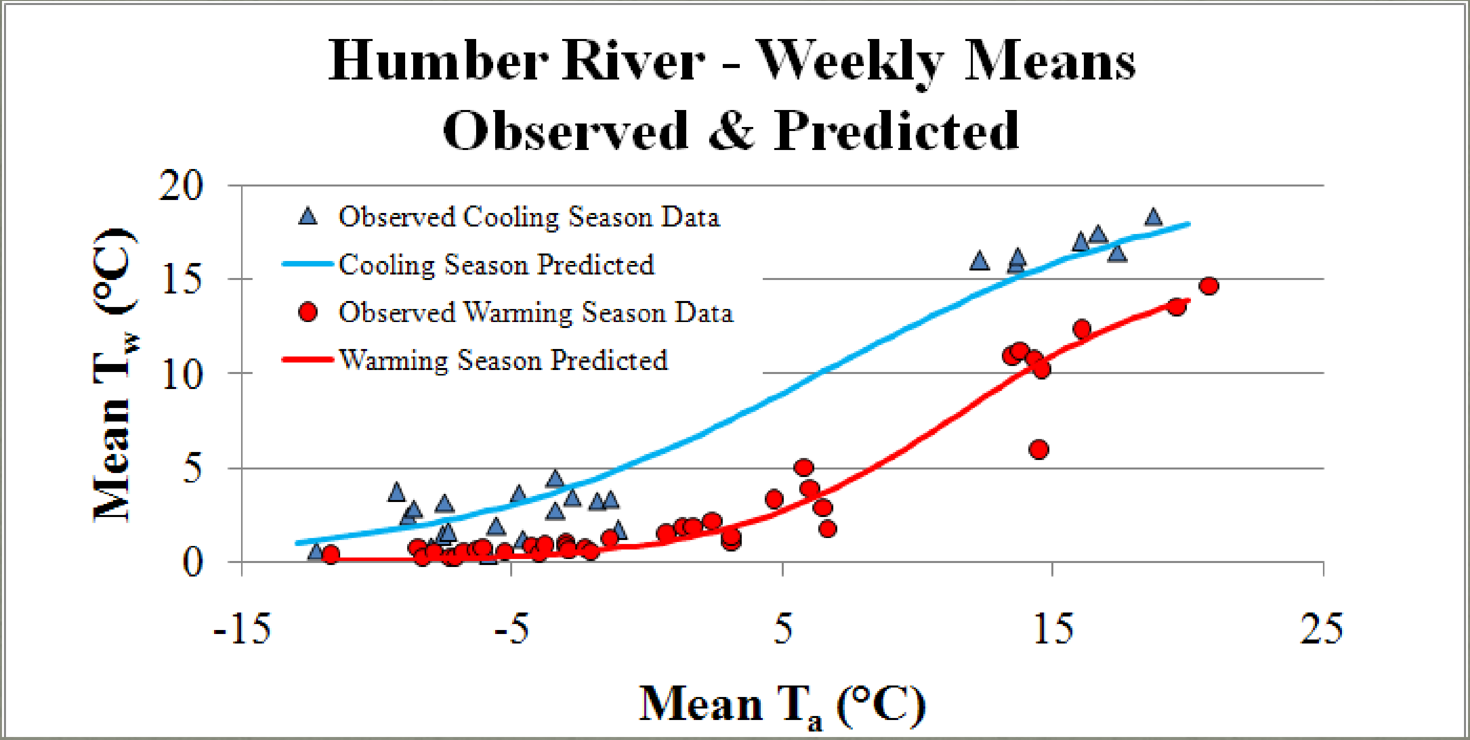
- Strength of the relationship strongest as the time scale was extended from daily observations to monthly observations
  - Monthly mean observations (R^2_{adj} range for the stations: 0.96-0.99)
  - Weekly mean observations (R^2_{adj} range for the stations: 0.91-0.98)
  - Daily mean observations (R^2_{adj} range for the stations: 0.83-0.94)

Modeling Results: Mean, Maximum & Minimum



- Accurate logistic regression models were developed for each RTWQ station for mean, maximum and minimum observations
  - Mean models tend to be the best fitting (less scatter in the data)
  - More scatter for maximum and minimum observations

Verification of the Developed Models



- Developed models proved to be capable of accurately predicting water temperature at the various timescales.
- Mean value of |Predicted – Observed| for weekly means:

Humber Cooling = 1.14 Humber Warming = 0.63

Peter's River = 1.21 Leary's Brook = 0.84 Waterford River = 1.21

Modeling Dissolved Oxygen

- So things worked out quite well for modeling water temperature, but can accurate models be developed for dissolved oxygen?

- Dissolved oxygen concentrations largely influence river health:
  - Low levels (0 – 8 mg/L) – fish kills
  - Healthy levels (8 – 12 mg/L)
  - High levels (12 – 20 mg/L) – algal growth

- Models using water temperature to predict DO would be useful for investigating the impact of changing water temperature on water quality

Modeling Dissolved Oxygen

- While DO models are not commonly found in the literature, there is a strong physical relationship between water temperature and dissolved oxygen (i.e. when temperatures go up, DO goes down)

- Three models investigated in this research:
  - **1. Linear :** using water temperature
  - **2. Multiple:** using water temperature and stage level
  - **3. Nonlinear exponential:** using water temperature

- The same monthly, weekly and daily datasets used in developing the water temperature models were used for these DO models

Modeling Results – Linearity vs. Nonlinearity

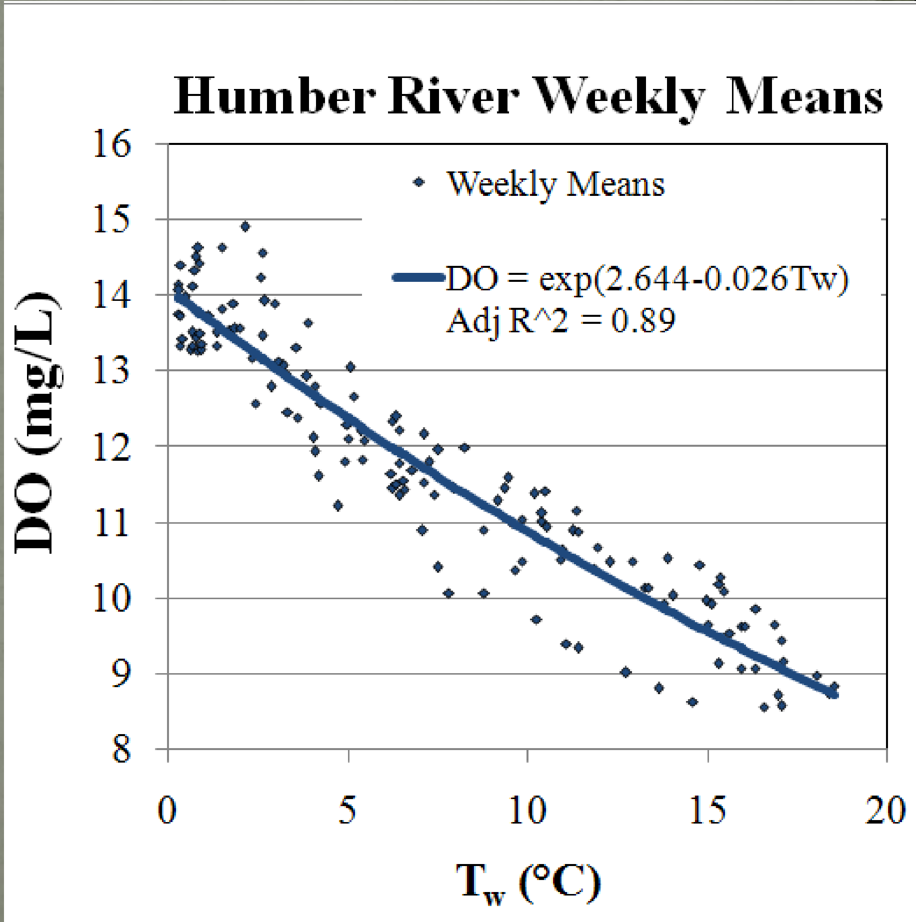
- Exponential models found to be slightly better fitting than simple linear models for DO
- Adj R^2 (monthly – weekly - daily)

  Humber: 0.91 – 0.89 - 0.88

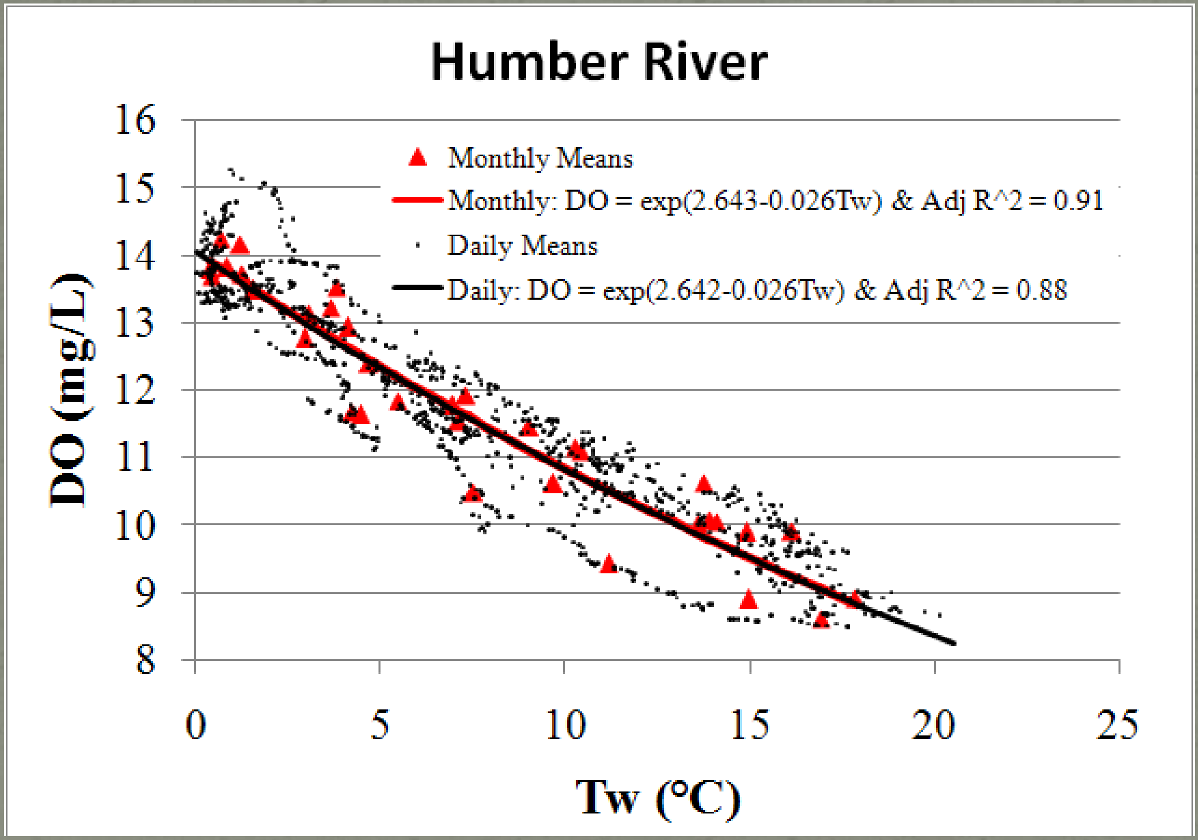
  Peter's River: 0.94 – 0.92 - 0.91

  Leary's Brook: 0.81 – 0.77 - 0.68

  Waterford River: 0.89 – 0.82 - 0.81

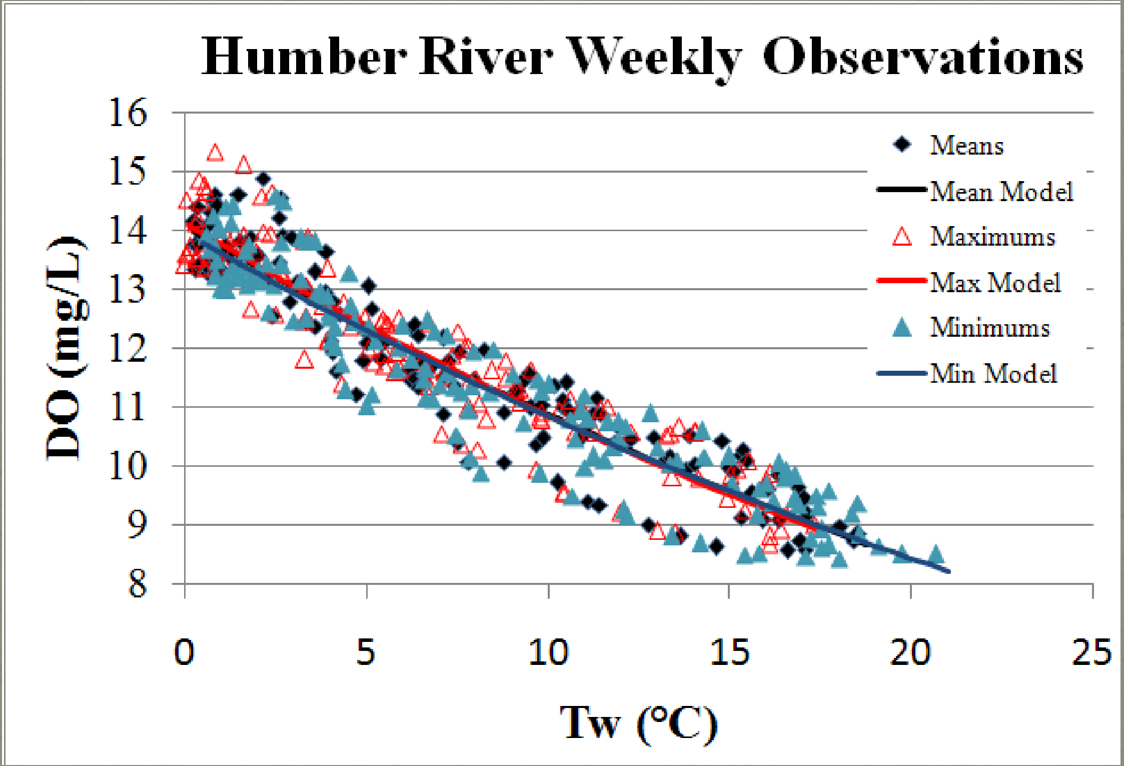


Modeling Results – The Effect of Timescale



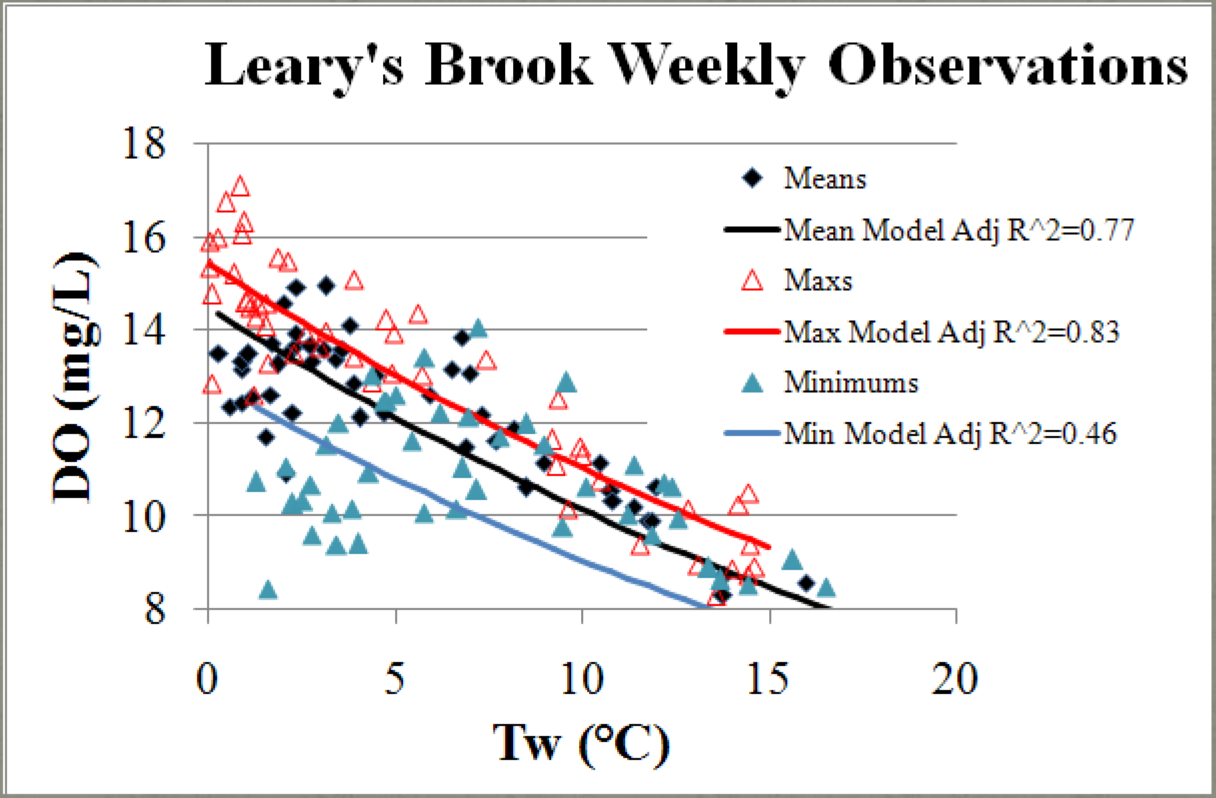
- Like the water temperature models, goodness of fit better at the monthly time scale than at the daily time scale
  - When dealing with mean DO data this decrease was usually less than 5%

Modeling Results – Mean vs. Max vs. Min



- For the two larger rivers (Humber River and Peter's River), there is little difference between the mean, maximum and minimum DO models
  - Only difference coming at colder temperatures, where maximum DO models suitably account for the higher DO values

Modeling Results – Mean vs. Max vs. Min



- Difference between mean, maximum and minimum models more noticeable for Leary's Brook and Waterford River
  - Shallower urban rivers with increased scatter when compared to the Humber River dataset, particularly for minimum DO observations

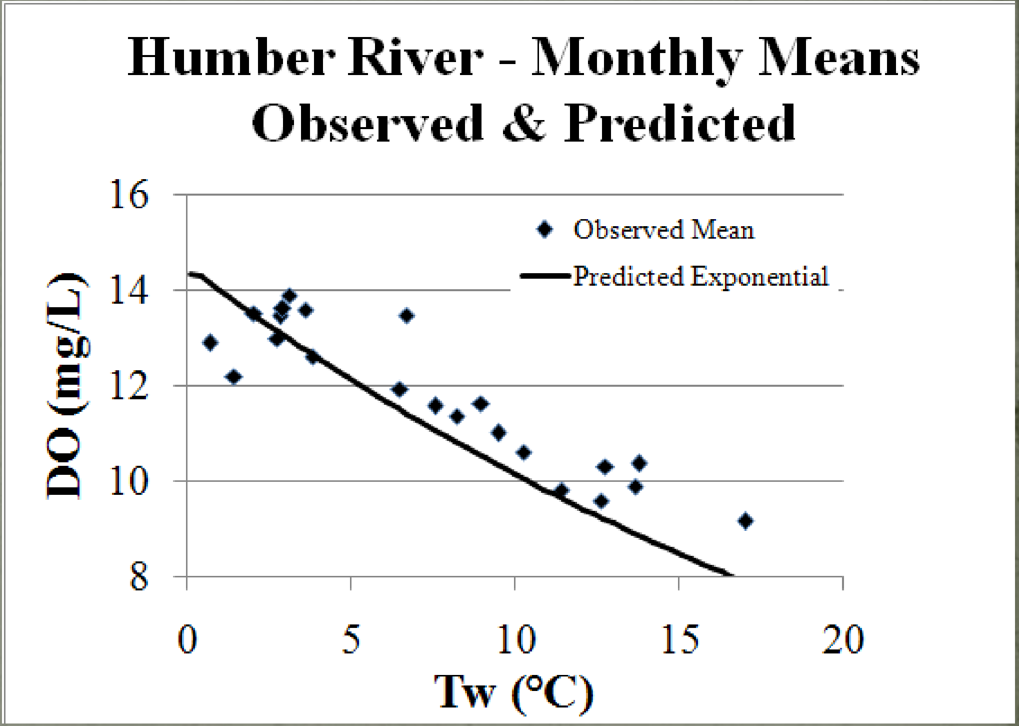
Modeling Results – Trouble with Leary's Brook

- DO Observations in Leary's Brook and Waterford River show more variation than those in the Humber River and Peter's River
- DO data collected in this research using Clark cell DO membrane technology (the only technology available at the time)
- Appears membranes in the urban rivers have been affected by some characteristic of the river that did not allow the membranes to properly function for the full length of their deployment
    - i.e. membrane covered in film or grease
- WRMD now use a luminescent DO technology in their urban streams and are no longer having issues with their DO measurements

Model Verification

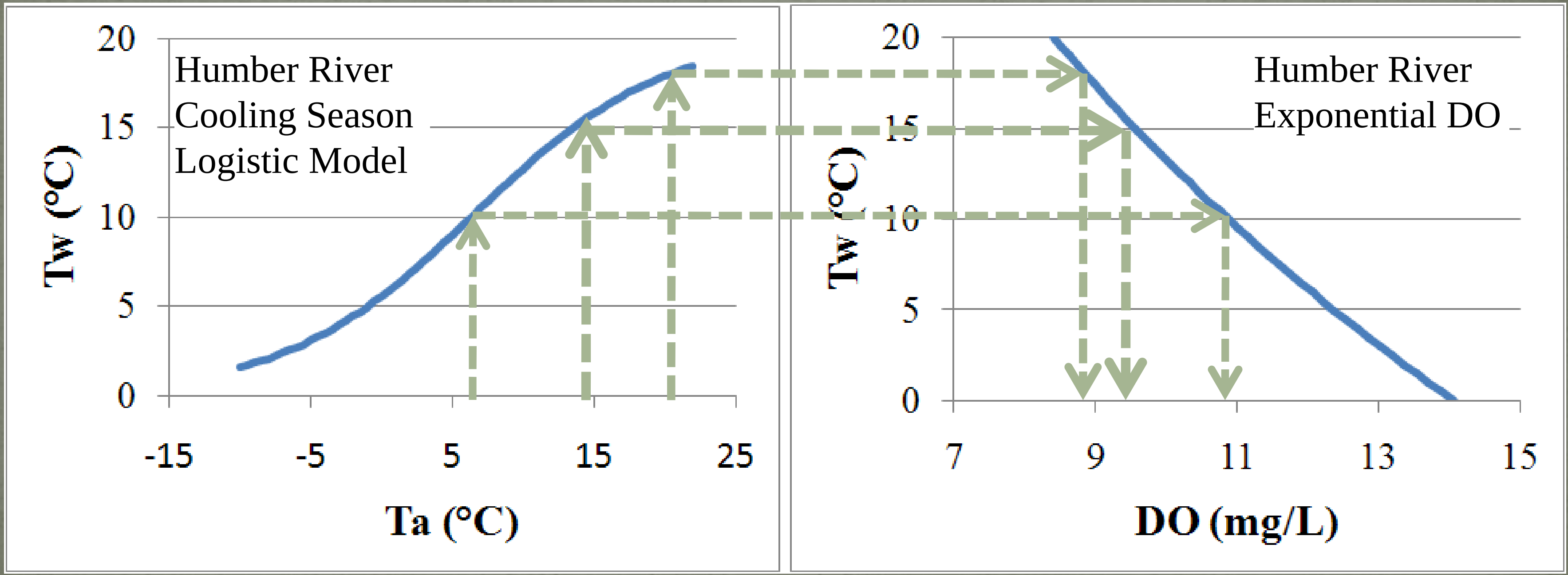
- Developed models proved to be capable of accurately predicting DO at the Humber River and Peter's River Stations.

- While models for predicting DO at Leary's Brook and Waterford River were less accurate due to significant data scatter, these models were still capable of accurately predicting monthly and weekly mean DO



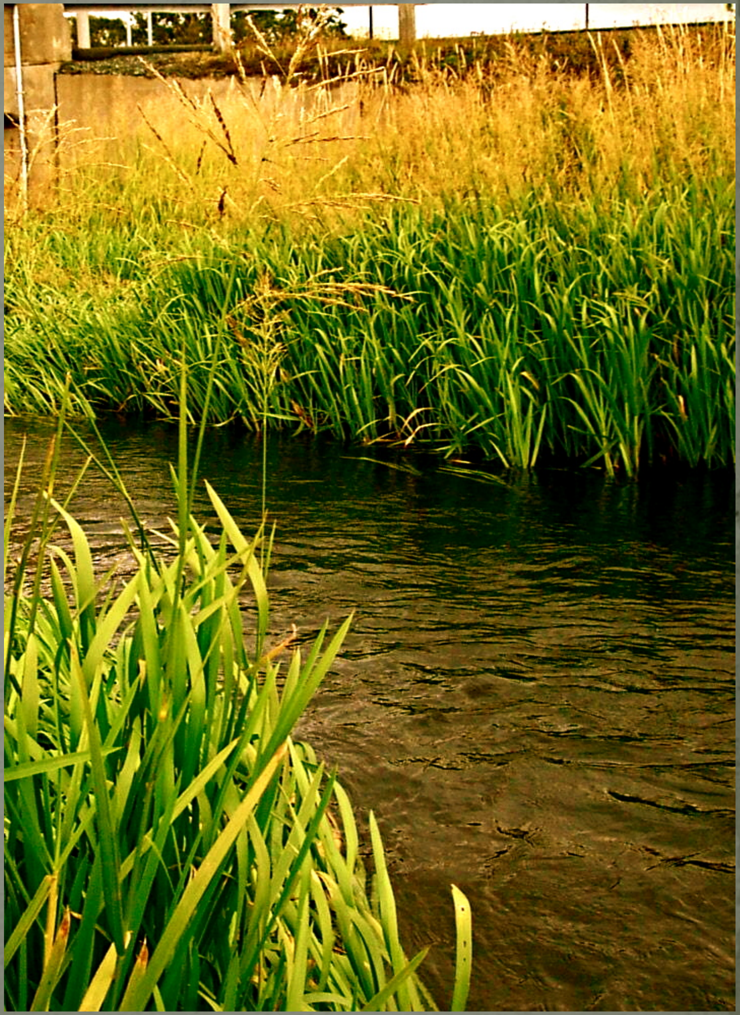
A New Approach to Linking the Models

- So accurate models have been developed for predicting water temperature and DO at the RTWQ stations, but no published research has ever taken the next step of visually linking the models together …



Conclusion

- Models have been developed for predicting water temperature and DO at Newfoundland RTWQ stations
- The logistic S-shaped model is best for predicting water temperature while an exponential model is best for predicting dissolved oxygen
- Models can be visually linked together through a novel approach
- Future research will explore model development for other RTWQ stations



Thank You

- Natural Sciences and Engineering Research Council of Canada
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- Water Resources Management Division, Newfoundland and Labrador Department of Environment and Conservation