Temperature Regime Characteristics of High-Quality Coldwater NH and MA Streams

November 20, 2009

Jennifer M. Jacobs and Gary Lemay
Environmental Research Group
Department of Civil Engineering
University of New Hampshire

In Partnership With
M. Carpenter, NHFG; T. Richards, MDFW

Acknowledgements
D. Neils, NHDES; W. Kimball, MADEP, R. Abele, USEPA Region I

USEPA TMDL and USGS WRI Funding

Project Goal

- Identify thermal regimes found in high quality coldwater streams in order to improve temperature monitoring and state temperature TMDL targets throughout New England.
  - NH and MA have ongoing stream temperature monitoring initiatives.
  - Significant database of stream water temperature, associated habitat and aquatic ecosystem characterization.

Thermal Regime and Fish

- Fish Species Preference
  - Coldwater
    NH Examples: **Brook Trout, Slimy Sculpin**, Brown Trout, Lake Chub, Longnose Sucker, Northern Redbelly Dace, Rainbow Trout
  - Eurythermal (tolerating a wide range of temperature)
    NH Examples: Common Shiner, Creek Chub, Eastern Blacknose Dace, Fallfish, Longnose dace, White Sucker

Pictures Credit:
NJ Freshwater Fish Identification

Thermal Regime and Water Quality

- Dissolved Oxygen
  - Inverse relationship between DO and temperature
  - Warm water may cause the fish's DO demand to increase.
- Photosynthesis
  - Cool waters slow the growth of bacteria and algae
  - Warm water enhances algal growth
- Water Chemistry
  - Increased plant growth can decease DO
  - Increasing temperature decreases pH
- Water Turbidity and Sediment Loads
- Aquatic Organisms
  - Species abundance and diversity
    Coldwater species include mayflies, caddisflies
  - Timing of reproduction, migration and aestivation

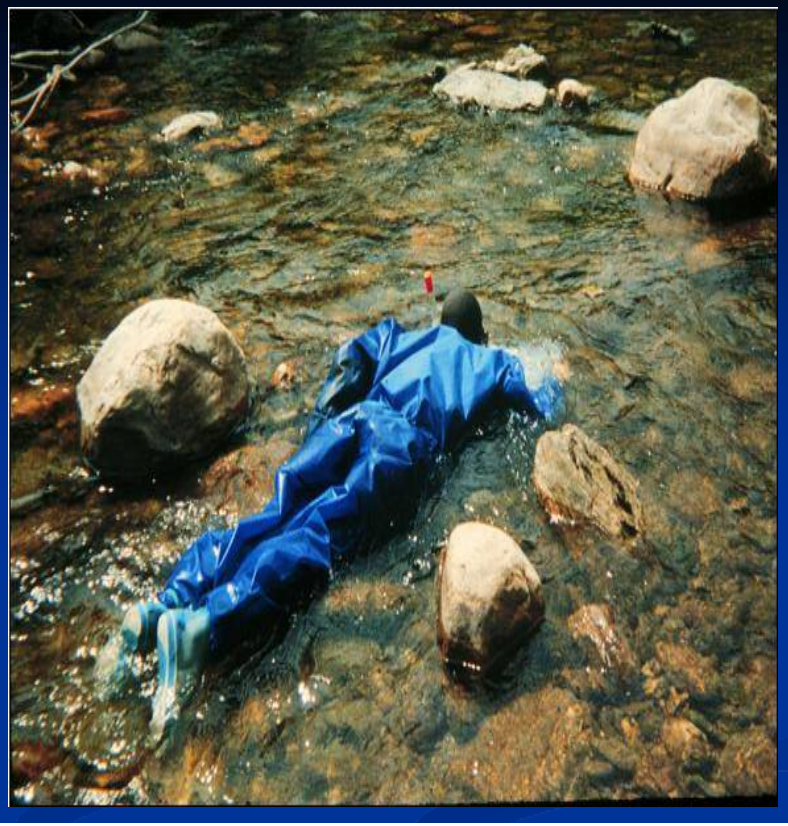
Pictures Credit: Bluegreen bloom, Upper Saranac Lake, 10/90 (source: R. Handler, MD)

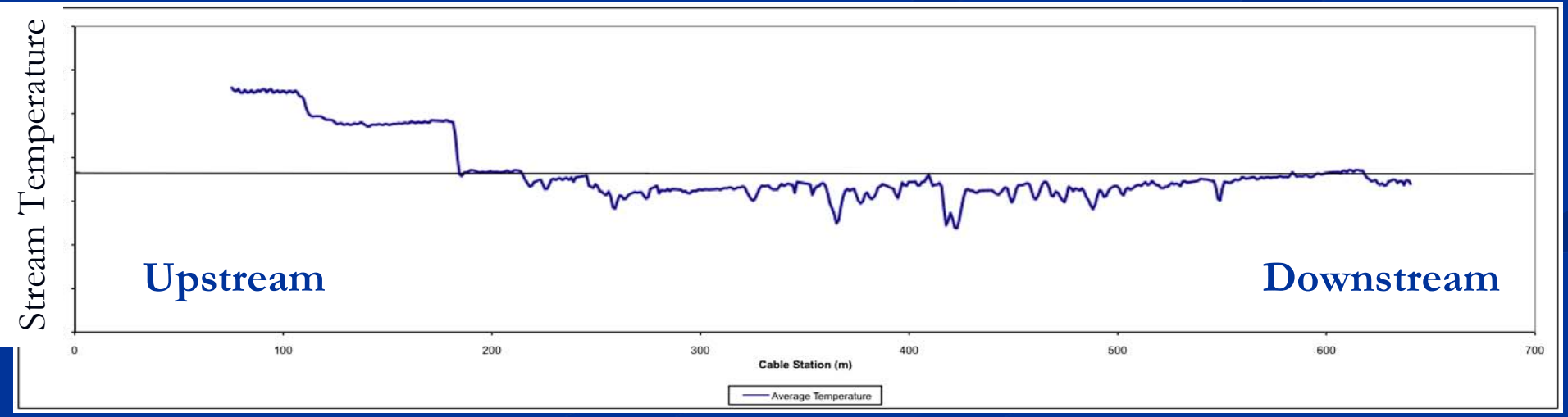
Why are coldwater streams cold? Regional Scale

- Geographic Position or Ecoregions
  - Coldwater fisheries in the Northeastern Highlands
  - Warm-water fisheries Northeastern Coastal Zone
- Topography
  - Cold-water fisheries had a minimum mean basin elevation of 190 ft; the maximum mean monthly temperature of streams at this elevation typically did not exceed 20°C.
- Size or Stream Order
  - Headwater streams often have low temperature and high dissolved oxygen

Why are coldwater streams cold? Finer scale

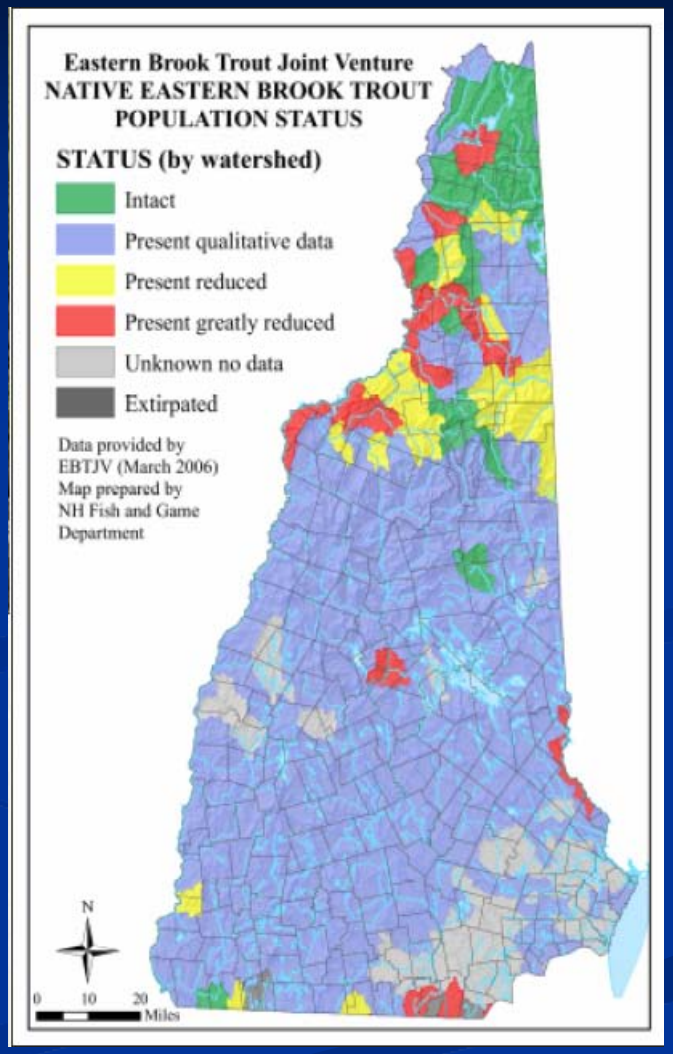
- Dense forest canopy
- Groundwater flow
- Hyporheic zone exchange





NH Cold Water Fisheries Threats

- Water withdrawals,
- suburban and urban development,
- poorly designed stream crossings,
- acid rain, and
- dams.



Source: State of New Hampshire Wildlife Journal, 2006

Regional Scale by Temperature

Max. Average Monthly Temp

- Coldwater: < 19 - 22°C (65-72°F)
  - 19°C (Chu et al. 2008, Carpenter NHF&G)
  - 22°C (Neumann et al., 2006)
  - 20°C (Massachusetts)
- Cool (Mixed) Water
- Warm Water: 22°C (72°F)
- Upper Lethal Temp 25-30°C (77-86°F)

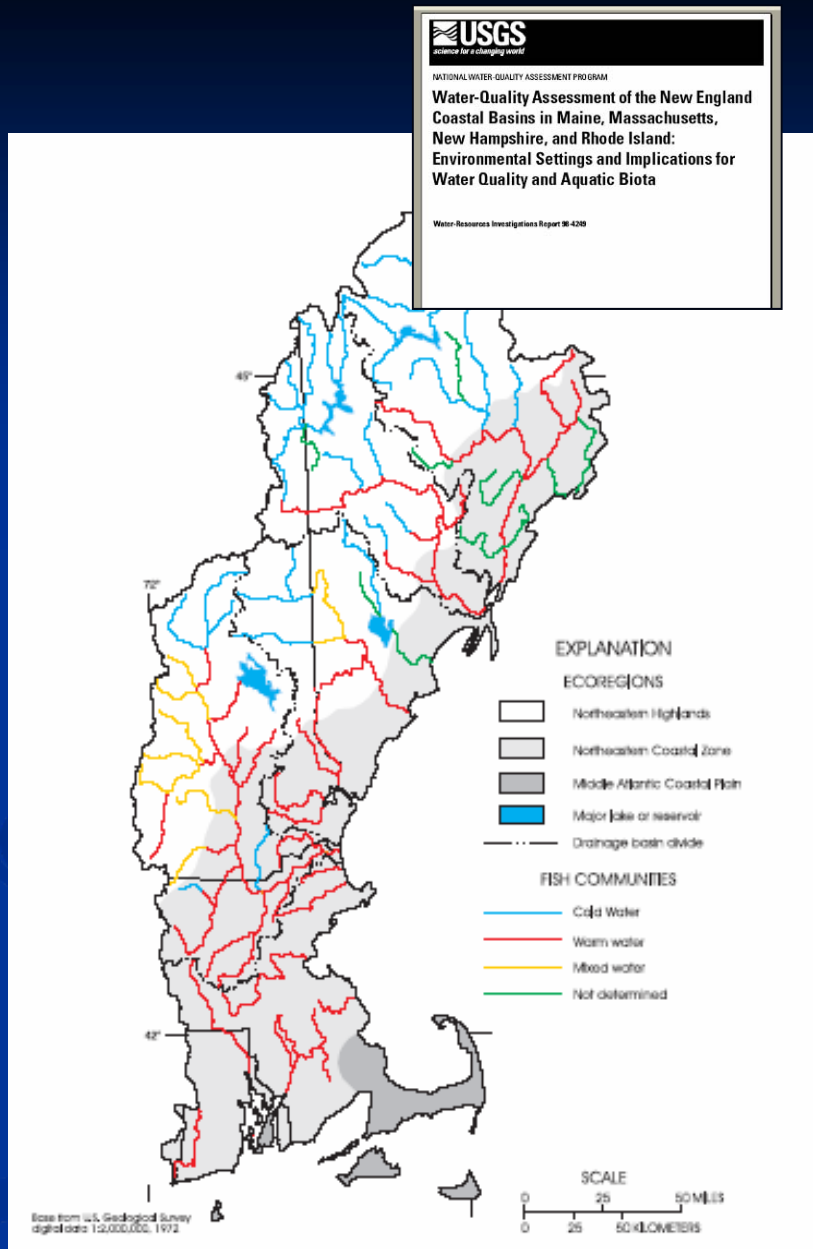
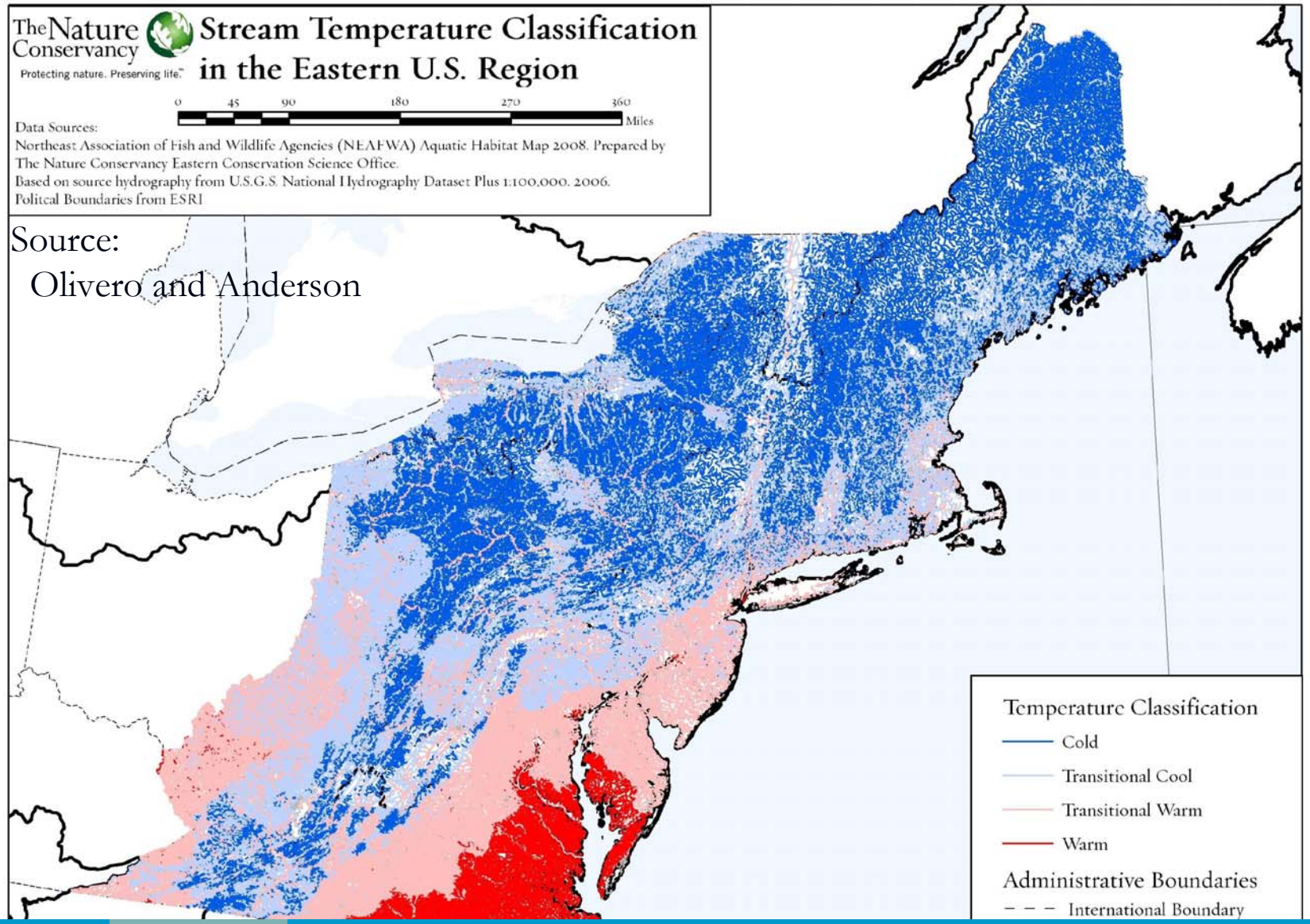


Figure 16. Ecoregions and fish communities in the New England Coastal Basins, in Maine, Massachusetts, New Hampshire, and Rhode Island.

NE Regional Scale Taxonomy

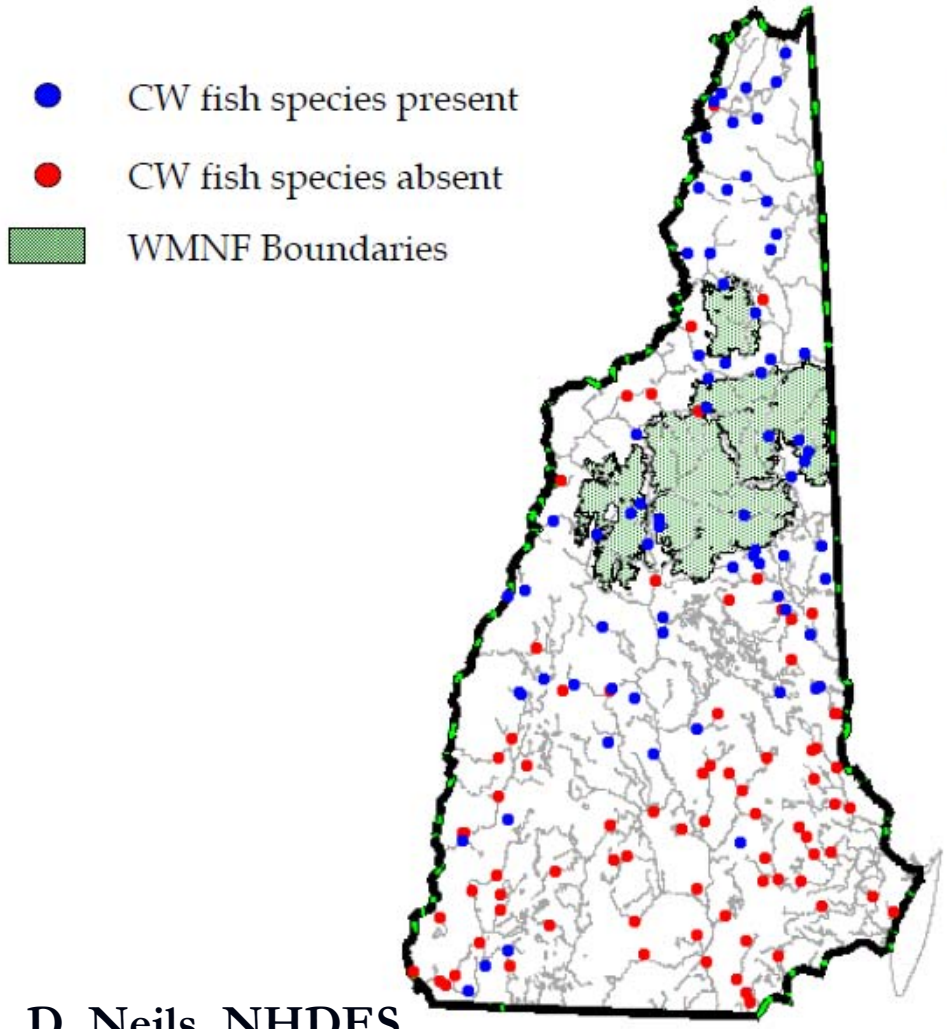
Northeast Aquatic Habitat Classification System 2008



Source:
Olivero and Anderson

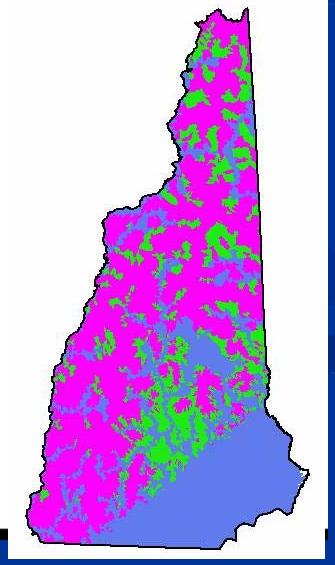
NHDES Regional Scale

Coldwater Fish Index of Biological Integrity



Northwest sites are exclusively coldwater and southeast sites are exclusively warmwater

Sites used to develop predictive model based on latitude, longitude, and upstream watershed area.



D. Neils, NHDES

EPA Water Quality Criteria

- The CWA Section 305(b) requires states to report to EPA on the quality of all surface waters every two years. Specifically, 305(b)(B) requires a report on the extent to which all surface waters support aquatic life and recreation.
- For any time of year, there are **two upper limiting temperatures** for a location (based on the important sensitive species found there at that time): (1) A **maximum temperature for short exposures** that is time dependent and is given by a species specific equation; (2) the second value is a limit on the **weekly average temperature** (see Gold Book).

Water Quality Criteria

- **NH**:
  - Class A - There shall be **no change in temperature** unless naturally occurring.
  - Class B- Any stream temperature increase associated with the discharge of treated sewage, waste or cooling water, water diversions, or releases shall not be such as to appreciably interfere with the uses assigned to this class. In prescribing minimum treatment provisions for thermal wastes discharged to interstate waters, the department shall adhere to the water quality requirements and recommendations of the NH Fish and Game Department, NEIWPCC, or the U.S. EPA.

- **MA**: Shall not exceed **68 degrees F in cold water fisheries**, nor **83 degrees F in warm water fisheries**, and the rise in temperature due to discharge shall **not exceed 1.5 (3 Class B) degrees F in** rivers and streams designated as cold water fisheries, nor 1.5 (5 Class B) degrees F in rivers and streams designated as warm water fisheries. **Natural seasonal and daily variations** shall be maintained. There shall be no changes from background that would impair any use assigned to this Class, including site-specific limits necessary to protect normal species diversity, successful migration, reproductive functions or growth of aquatic organisms.

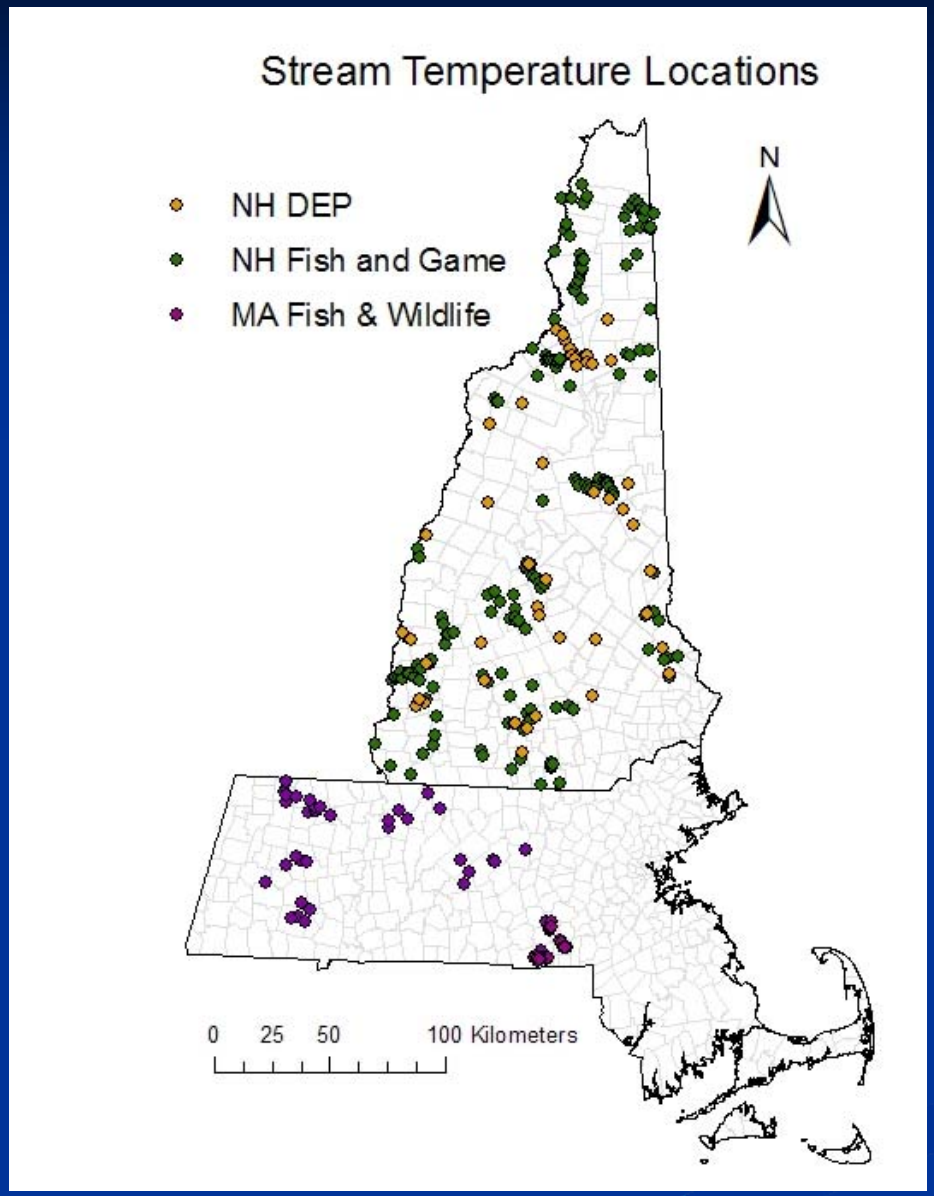
- **VT**: The change or rate of change in temperature, either upward or downward, shall be controlled to ensure full support of aquatic biota, wildlife, and aquatic habitat uses.
  - **Cold Water Habitat**: The increase from the ambient temperature due to all discharges/activities **shall not exceed 1.0 degree F**.

What's the temperature of a coldwater stream?

- Step 1: Develop a stream temperature database
- Step 2: Quantify stream temperature regimes

Magnitude
Frequency
Timing
Duration
Rate of Change

Available Data



More than 400 stream reaches have stream temperature datasets

Data Sources:

- NH Fish & Game
- MA Fish & Wildlife
- NH DES
- MA DEP

Measuring Water Temperature
Digital Temperature Loggers

- Hobo™ thermistor data loggers
  - Pro V2 ($120)
  - Pendant ($42)
- Tidbit temperature data loggers ($159)

Step 1: Develop a stream temperature database

- Reformat existing datasets
- Develop and apply QA/QC protocols
- Design database
- Populate database
- Transfer protocols
- Link to GIS and webservers

Stream Temperature Data

Name

2006_te

2006_te

Cold_Acworth_062806-092006_dn.xls

	A	B	C	D	E	F	G	H	I	J	K	L
1	Plot Title: 1000456											
2	#	Time, GMT-04:00	Temp, °C	month	Week_Nur	D_O_W	day_num	3_hr_runn	Daily_mea	Daily_med	max_3hr_	min_3hr_n
1682	1680	9/6/2006 8:00	14.625	4	11	4	71	14.6887				

2006_temp_sites.dbf

	A	B	C	D	E	
1	AU_ID	BASIN	TOWN	HDG_SCORE	HDG_CAT	SITE_
2	NHRIV801010806-06	Connecticut	JEFFERSON	5	D	98C-3
3	NHRIV600030601-08	Piscataqua	FARMINGTON	5	D	98P-4
4	NHRIV600030607-01	Piscataqua	BARRINGTON	12	M	98P-5
5	NHRIV801070202-02	Connecticut	ACWORTH	10	M	99C-3
6	NHRIV802010103-22	Connecticut	GILSUM	7	D	97C-1
7	NHRIV700030302-12	Merrimack	Bradford	9999	UNAVAIL	06m-1
8	NHRIV700060606-05	Merrimack	New Boston	9999	UNAVAIL	06m-0
9	NHRIV700060701-05	Merrimack	Hooksett	9999	UNAVAIL	06m-0
10	NHRIV801040401-05	Connecticut	Hanover	9999	UNAVAIL	06c-1
11	NHRIV801060701-12	Connecticut	Charlestown	9999	UNAVAIL	06c-1
12						
13						
14						

Stream Temperature Data

Date Modified

8/8/2006 8:50 AM
8/8/2006 9:00 AM
8/8/2006 9:17 AM

265341_Mill Brook Upper_08_06.xls

	A	B	C	D	E	F	G
1	Date/Time	Temperature	(*C)				
2	06/01						
3	06/01						
4	06/01						
5	06/01						
6	06/01						
7	06/01						
8	06/01						
9	06/01						
10	06/01						
11	06/01						
12	06/01						
13	06/01						
14	06/02						
15	06/02						
16	06/02						
17	06/02						
18	06/02						
19	06/02						
20	06/02						
21	06/02						
22	06/02						
23	06/02						
24	06/02						
25	06/02						
26	06/02						
27	06/02						
28	06/02						

Temp_Loc_Data.xls

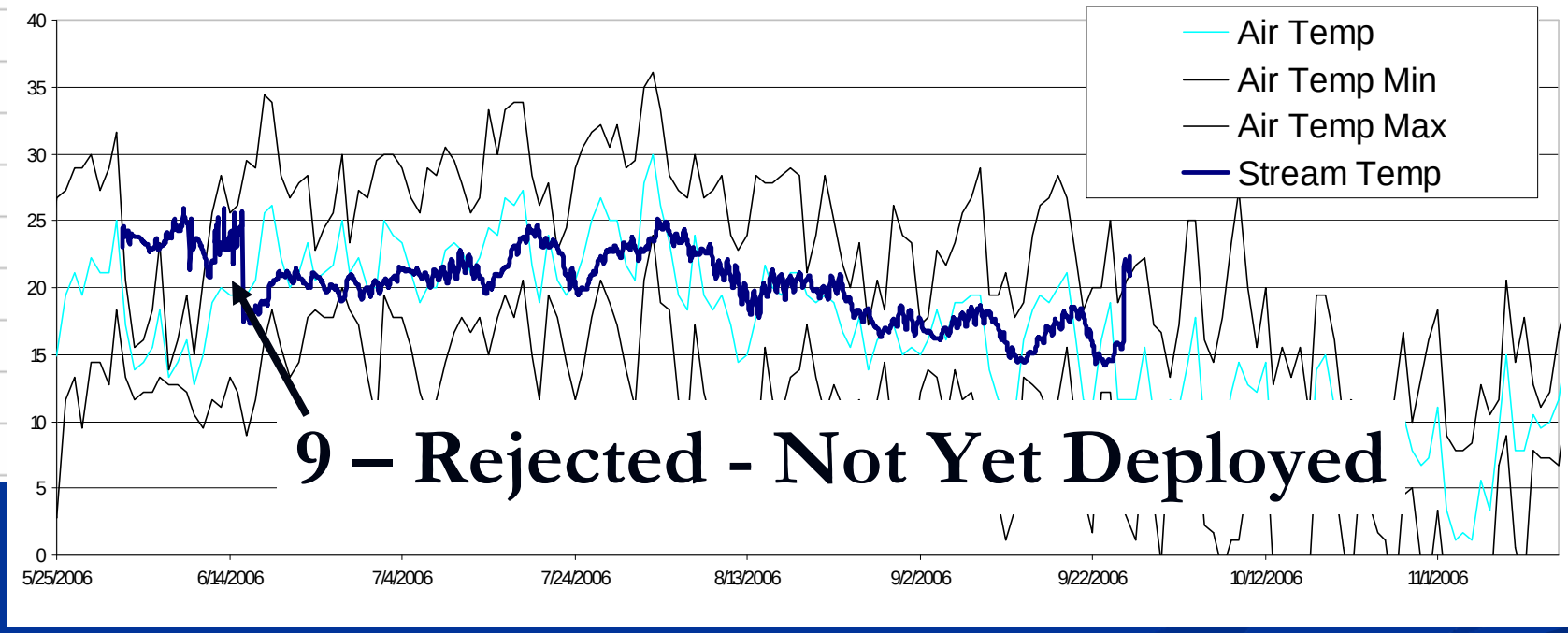
	A	B	C
1	REGION	Act ID	Act ID
352	4	2006-345117-Warren Brook Lower	2006-345117-WAR-Warren Brook Lower
353	4	2006-34514-Cold River	2006-34514-COLD-Cold River
354	1	2006-345091-Dead Diamond Two	2006-345091-DDW-Dead Diamond Two
355	3	2007-265338-Piscassic River	2007-265338-LRW-Piscassic River
356	3	2007-265343-UpperOyster River	2007-265343-ORW-UpperOyster River
357	3	2007-345115-Exeter River	2007-345115-ERW-Exeter River
358	3	2007-345108-North Branch River	2007-345108-LRW-North Branch River
359	3	2007-265357-North Branch River	2007-265357-LRW-North Branch River
360	3	2007-265342-North Branch River	2007-265342-LRW-North Branch River
361	3	2007-265341-North Branch River	2007-265341-LRW-North Branch River
362	3	2007-345113-North Branch River	2007-345113-LRW-North Branch River
363	3	2007-845847-North Branch River	2007-845847-LRW-North Branch River
364	3	2007-845665-North Branch River	2007-845665-LRW-North Branch River
365	3	2007-845848-North Branch River Trib	2007-845848-LRW-North Branch River Trib
366	3	2007-845850-North Branch River Trib	2007-845850-LRW-North Branch River Trib
367	3	2007-845852-North Branch River Trib	2007-845852-LRW-North Branch River Trib
368	3	2007-845853-No	
369	3	2007-854849-No	
370	3	2007-845846-No	
371		2007-345110-No	
372		2007-345117-No	ranch River
373		2007-345109-Unknown Trib to North Branch River	2007-345109--Unknown Trib to North Branch River
374		2007-265349-North Branch River	2007-265349--North Branch River
375		2007-265358-North Branch River	2007-265358--North Branch River
376	1	2007-854666-Peabody River	2007-854666-ANDRO-Peabody River

NH Fish & Game

Stream Temperature QAPP

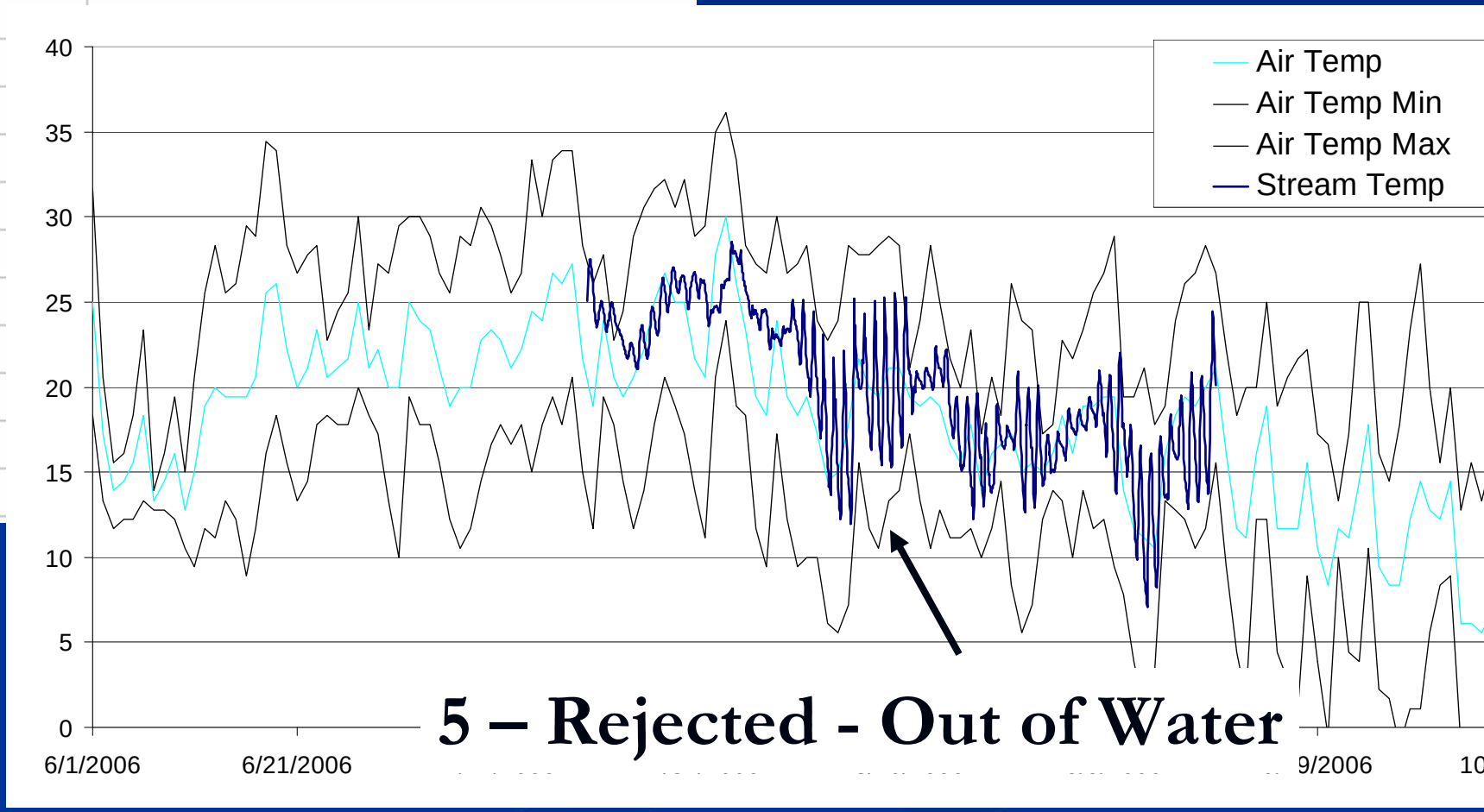
Quality Assurance Project Plan

QAQC Code	Description
0	Not reviewed
1	Accepted



Stream Temperature QAPP

QAQC Code	Description



Stream Temperature Database

Microsoft Access

File Edit View Insert Format Records Tools Window Help

StreamTemperature_2009-11-13 : Database (Access 2002 - 2003 file format)

NE Temp : Table

ID	Site ID	Date	Time	Temp (°C)	Light Intensity	Hobo Serial #	QAQC	Adj Temp (°C)
540844	NH Blck02	7/19/2006	11:25:11 PM	23.785	0	845853	1	
542362	NH Chel01	7/19/2006	11:18:51 PM	21.437	0	845849	1	0

Str Loc Master 11_14_09 : Table

SiteID	Watershed	Stream	Location	Town	Latitude (N)	Longitude (W)	Agency	Agency ID	EBT
NH Blck02		Blackwater Rive	1st site above d	Webster	43.3221	-71.72902	NHFG	2006-845853-Bl	A
NH Chel01		Chelsey Brook	Rte 155 A to Pa	Lee	43.13332	-70.9708	NHFG	2006-845849-C	P
NH Cnch01		Cocheco River	80 - 10 m down	Dover	43.21284	-70.92178	NHFG	2006-845852-C	A
NH Farr01		Farrer Brook		Stark	44.6489	-71.47	NHFG	2006-854674-Fa	P
NH MPis01		M. Branch Pisc	Take 1st right o	New Boston	43.01234	-71.70429	NHFG	2006-265349-M	A
NH Mill01		Mill Brook Lowe	Rte 127 to Warr	Salisbury	43.3548	-71.7921	NHFG	2006-845848-M	P
NH Mill02		Mill Brook Uppe	Up stream ~ 15	Salisbury	43.3633	-71.8144	NHFG	2006-265341-B	P
NH Scat01		Scataquag Broc	August data onl	Lyndeborough	42.9339	-71.74107	NHFG	2006-265357-S	P
NH Slid01		Slide Brook	~ 60' upstream	Stark	44.6653	-71.4574	NHFG	2006-345104-Sl	P
NH Swft01		Swift River	Up stream ~ 15	Tamworth	43.89244	-71.2979	NHFG	2006-265358-S	P
NH Thay01		Thayer Brook	undercut bank u	Acworth	43.1719	-72.3017	NHFG	2006-345115-Th	P
NH Wrrn01		Warren Brook L	150-200' upstre	Alstead	43.15188	-72.34938	NHFG	2006-345117-W	A
NH Wrrn02		Warren Brook M	150-200' downs	Alstead	43.13697	-72.32301	NHFG	2006-345113-W	A
NH Wrrn03		Warren Brook u	~200'upsteam fr	Alstead	43.125	-72.2989	NHFG	2006-345110-W	A
NH Isrl01	ISRAEL RIVER	Isreal River		JEFFERSON	44.412534	-71.498855	NHDES	98C-36	A
NH Mad01	COCHECO RIV	Mad River		FARMINGTON	43.385216	-71.084132	NHDES	98P-48	A
NH Isgl01	COCHECO RIV	Isinglass River		BARRINGTON	43.247274	-71.005655	NHDES	98P-54	A
NH Cold01	COLD RIVER	Cold River		ACWORTH	43.18762	-72.255749	NHDES	99C-38	A
NH Ashl01	UPPER ASHUE	ASHUELOT		GILSUM	43.060079	-72.230919	NHDES	97C-169	A
NH Wwrn01	WARNER RIVE	West Branch W		Bradford	43.26778	-71.9674	NHDES	06m-11	A
NH Pstq01	PISCATAQUOG	S. Br. Piscataqu		New Boston	42.98237	-71.6824	NHDES	06m-09	A

Record: 96 of 96

Step 2: Quantify stream temperature 2006 Dataset

Magnitude

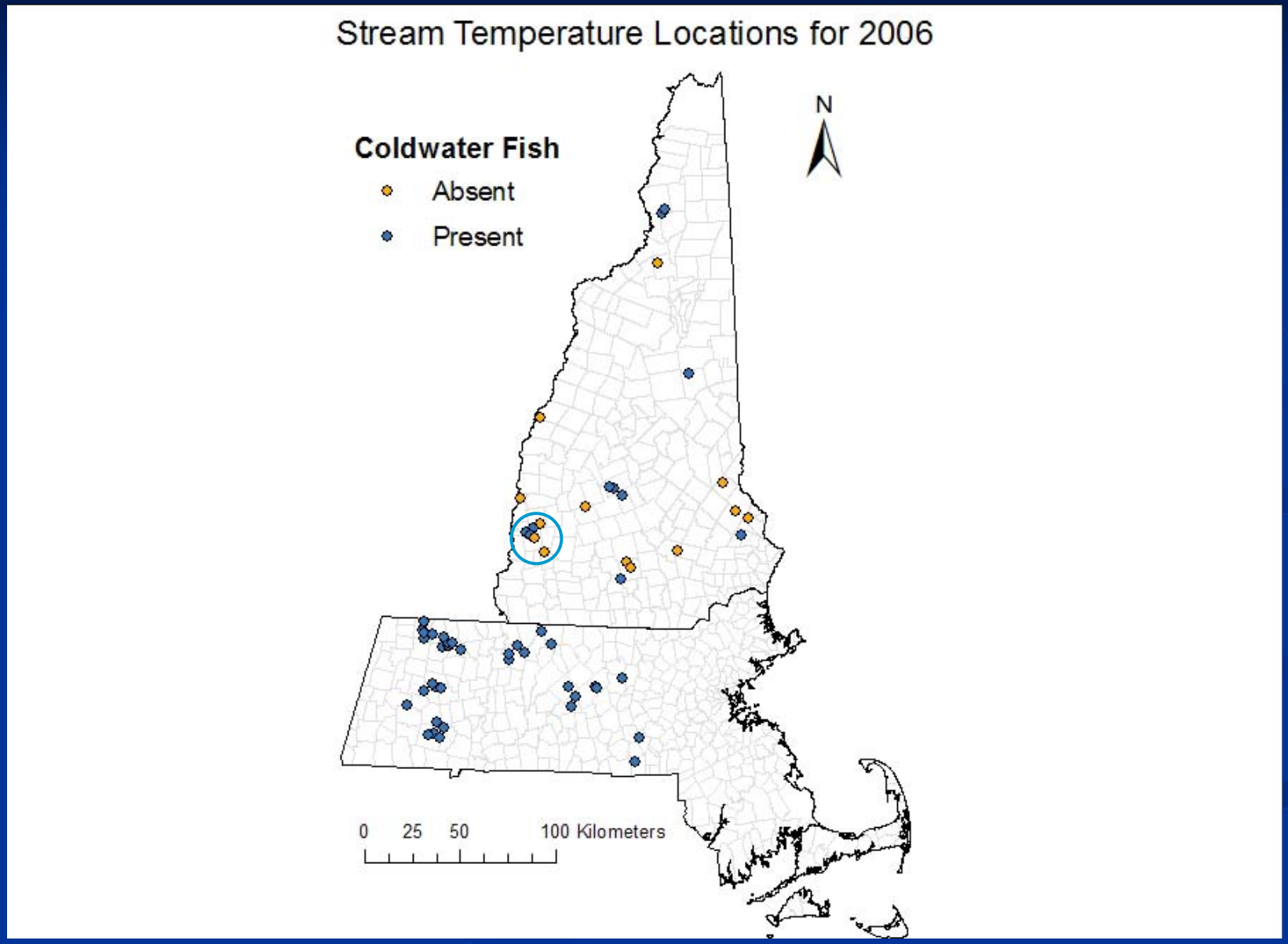
Frequency

Timing

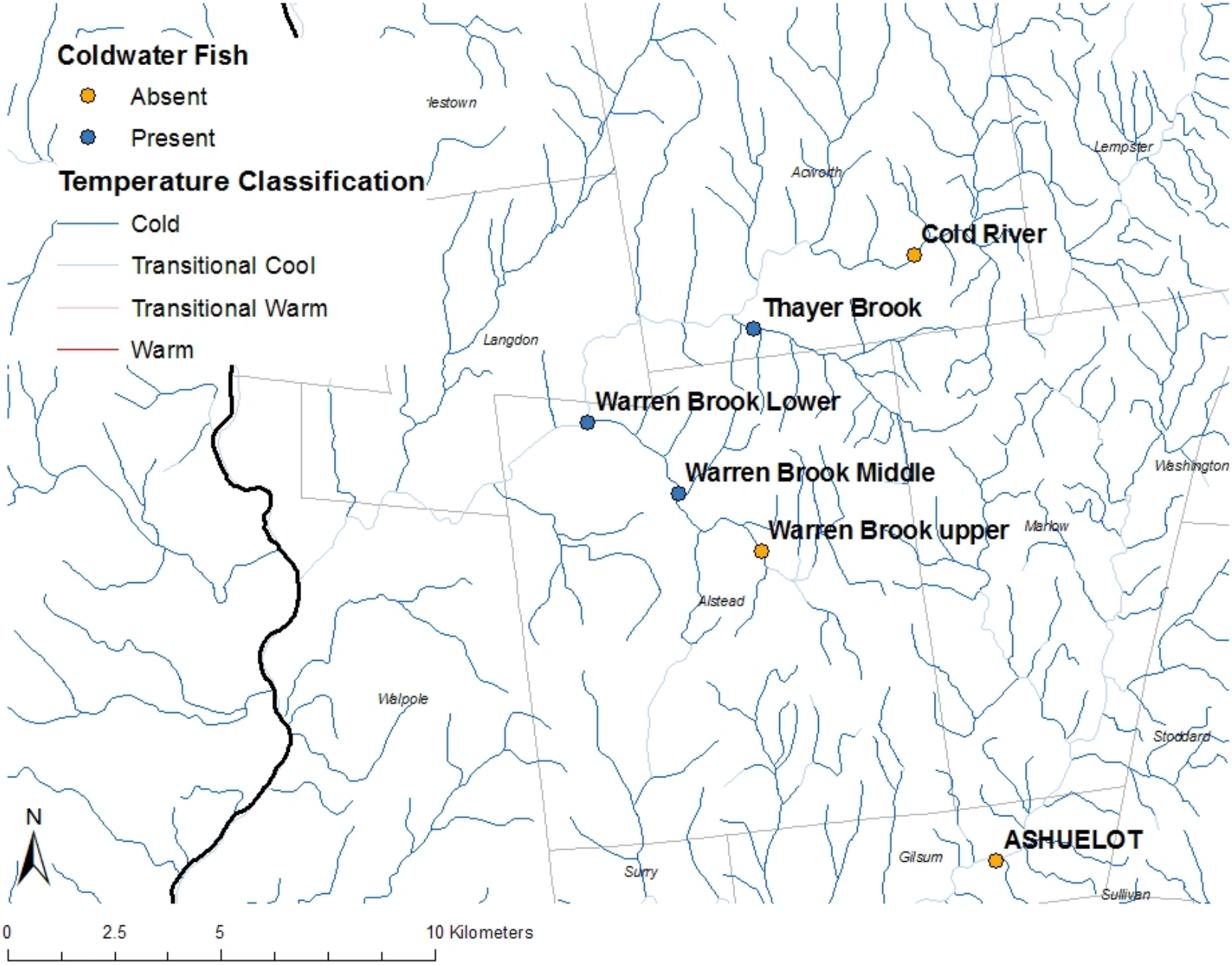
Duration

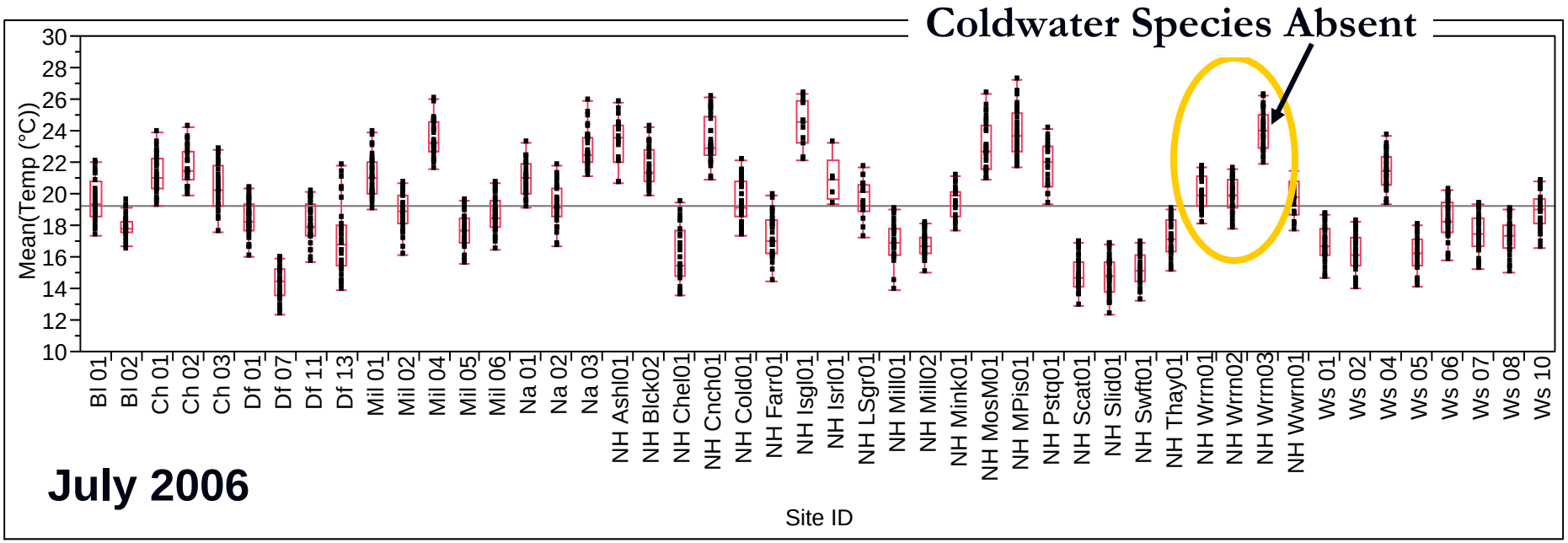
Rate of Change

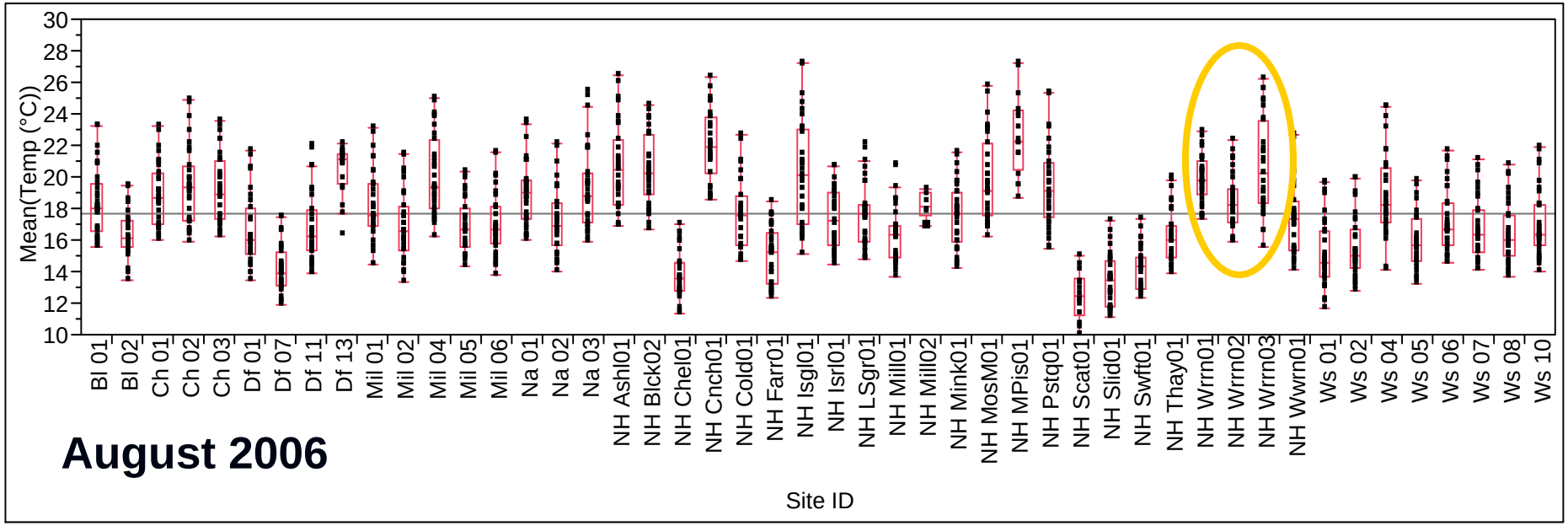
Step 2: Quantify stream temperature



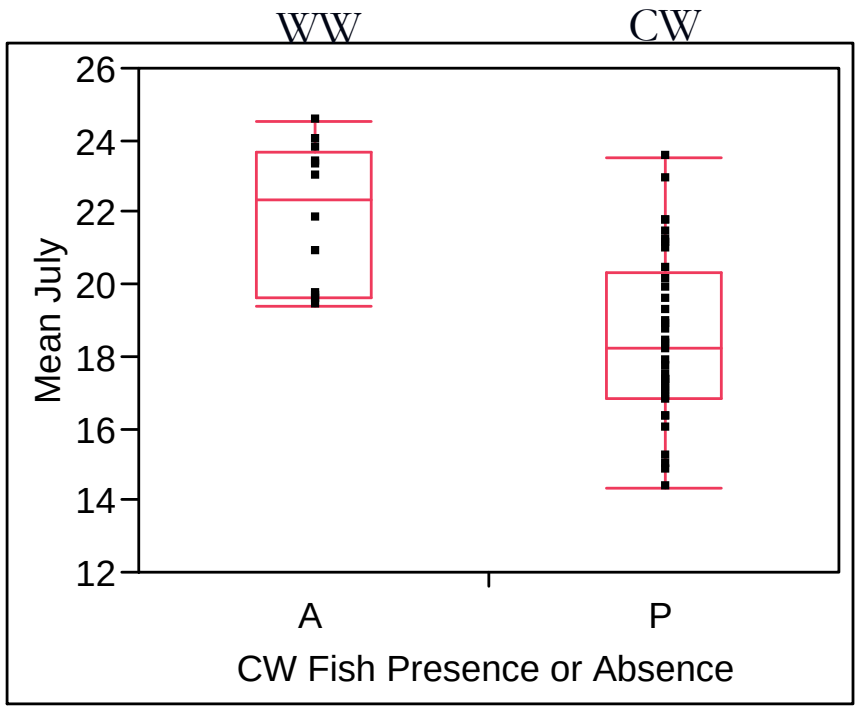
Warren Brook Site Map

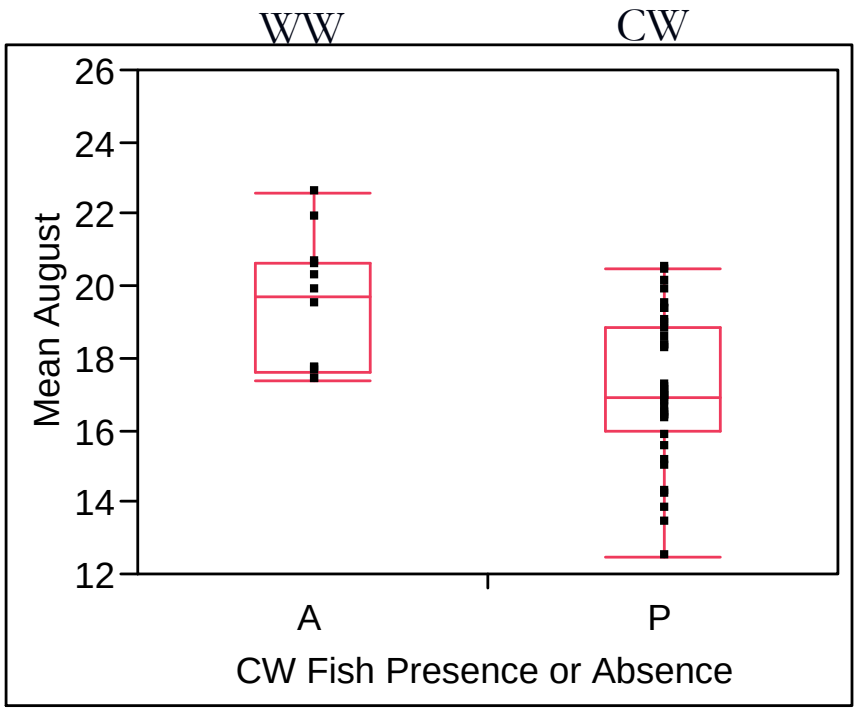



Coldwater Species Absent
Mean(Temp (°C))
30
28
26
24
22
20
18
16
14
12
10
Bl 01
Bl 02
Ch 01
Ch 02
Ch 03
Df 01
Df 07
Df 11
Df 13
Mil 01
Mil 02
Mil 04
Mil 05
Mil 06
Na 01
Na 02
Na 03
NH Ashl01
NH Blck02
NH Chel01
NH Cnch01
NH Cold01
NH Farr01
NH Isgl01
NH Isrl01
NH LSgr01
NH Mill01
NH Mill02
NH Mink01
NH MosM01
NH MPis01
NH Pstq01
NH Scat01
NH Slid01
NH Swft01
NH Thay01
NH Wrrn01
NH Wrrn02
NH Wrrn03
NH Wwrn01
Ws 01
Ws 02
Ws 04
Ws 05
Ws 06
Ws 07
Ws 08
Ws 10
July 2006
Site ID


Mean(Temp (°C))
30
28
26
24
22
20
18
16
14
12
10
Bl 01
Bl 02
Ch 01
Ch 02
Ch 03
Df 01
Df 07
Df 11
Df 13
Mil 01
Mil 02
Mil 04
Mil 05
Mil 06
Na 01
Na 02
Na 03
NH Ashl01
NH Blck02
NH Chel01
NH Cnch01
NH Cold01
NH Farr01
NH Isgl01
NH Isrl01
NH LSgr01
NH Mill01
NH Mill02
NH Mink01
NH MosM01
NH MPis01
NH Pstq01
NH Scat01
NH Slid01
NH Swft01
NH Thay01
NH Wrrn01
NH Wrrn02
NH Wrrn03
NH Wwrn01
Ws 01
Ws 02
Ws 04
Ws 05
Ws 06
Ws 07
Ws 08
Ws 10
August 2006
Site ID

Mean Daily Temperature
July and August 2006

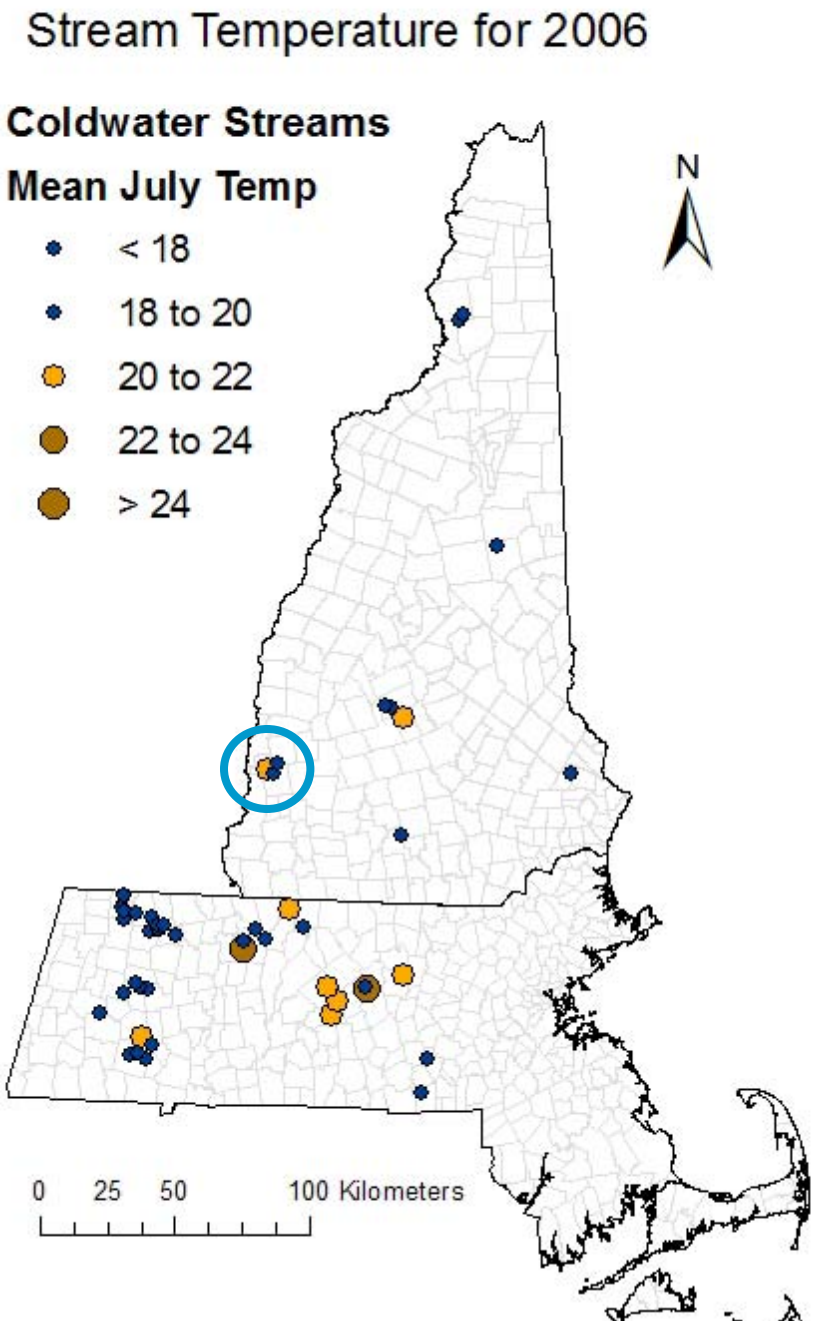


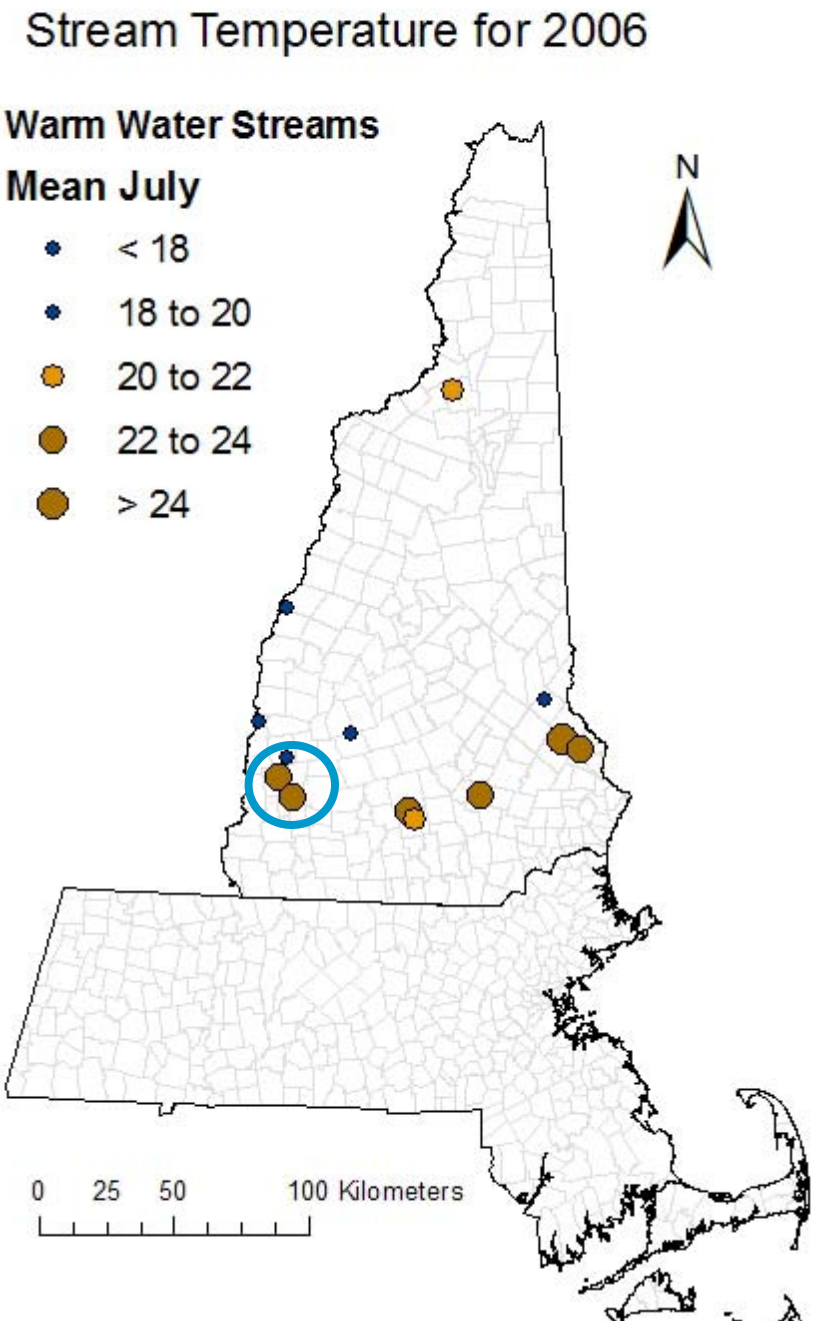


July Ave Air Temp = 22.7 °C

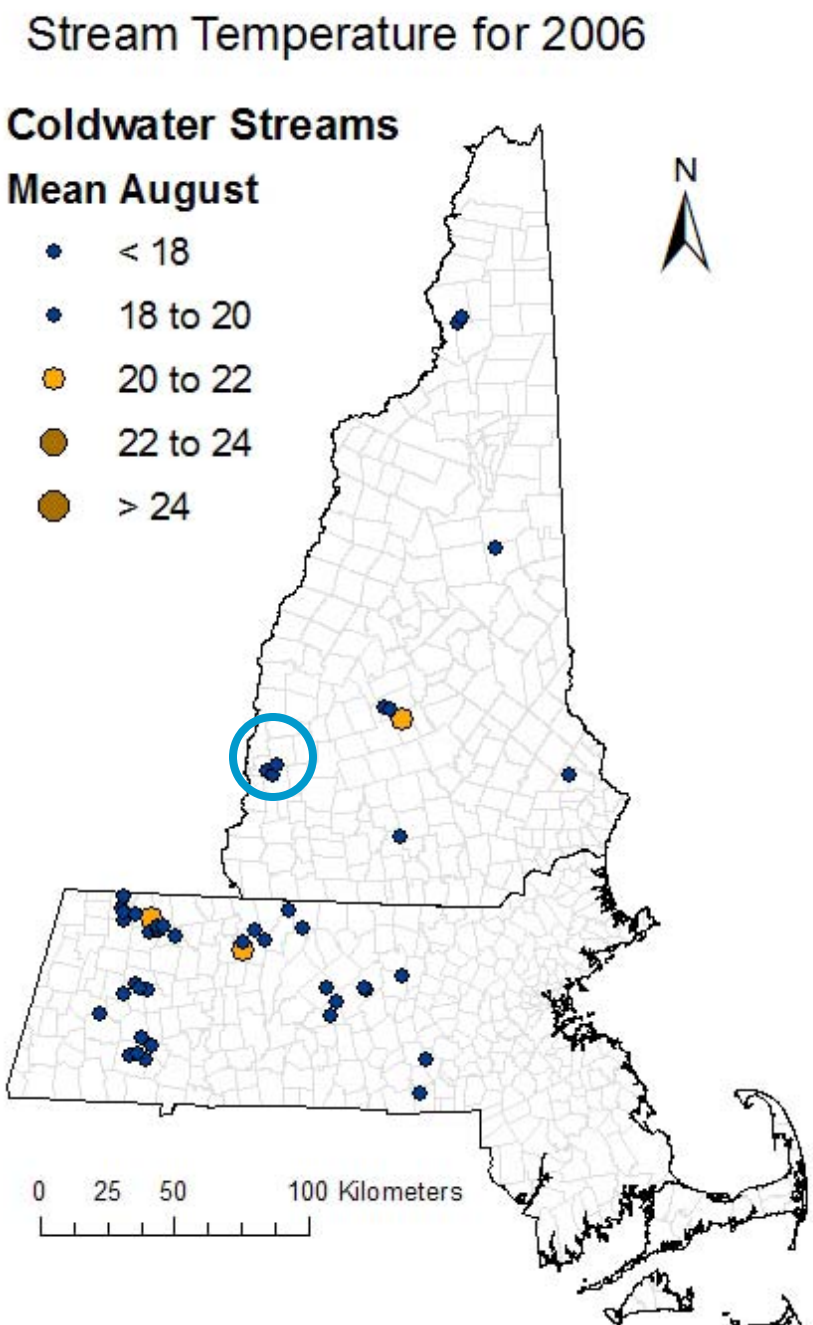
August Ave Air Temp = 19.3 °C

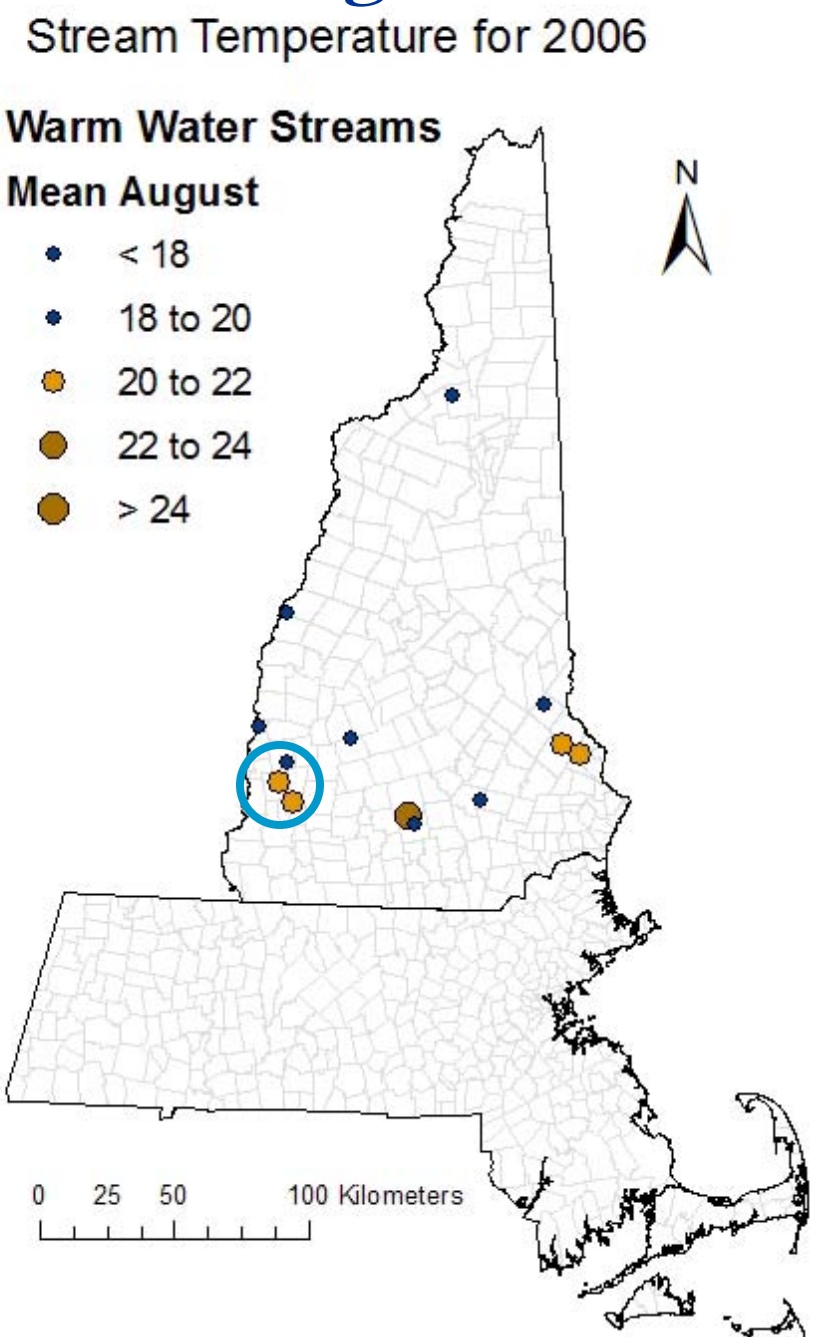
Mean Daily Temperature in July 2006

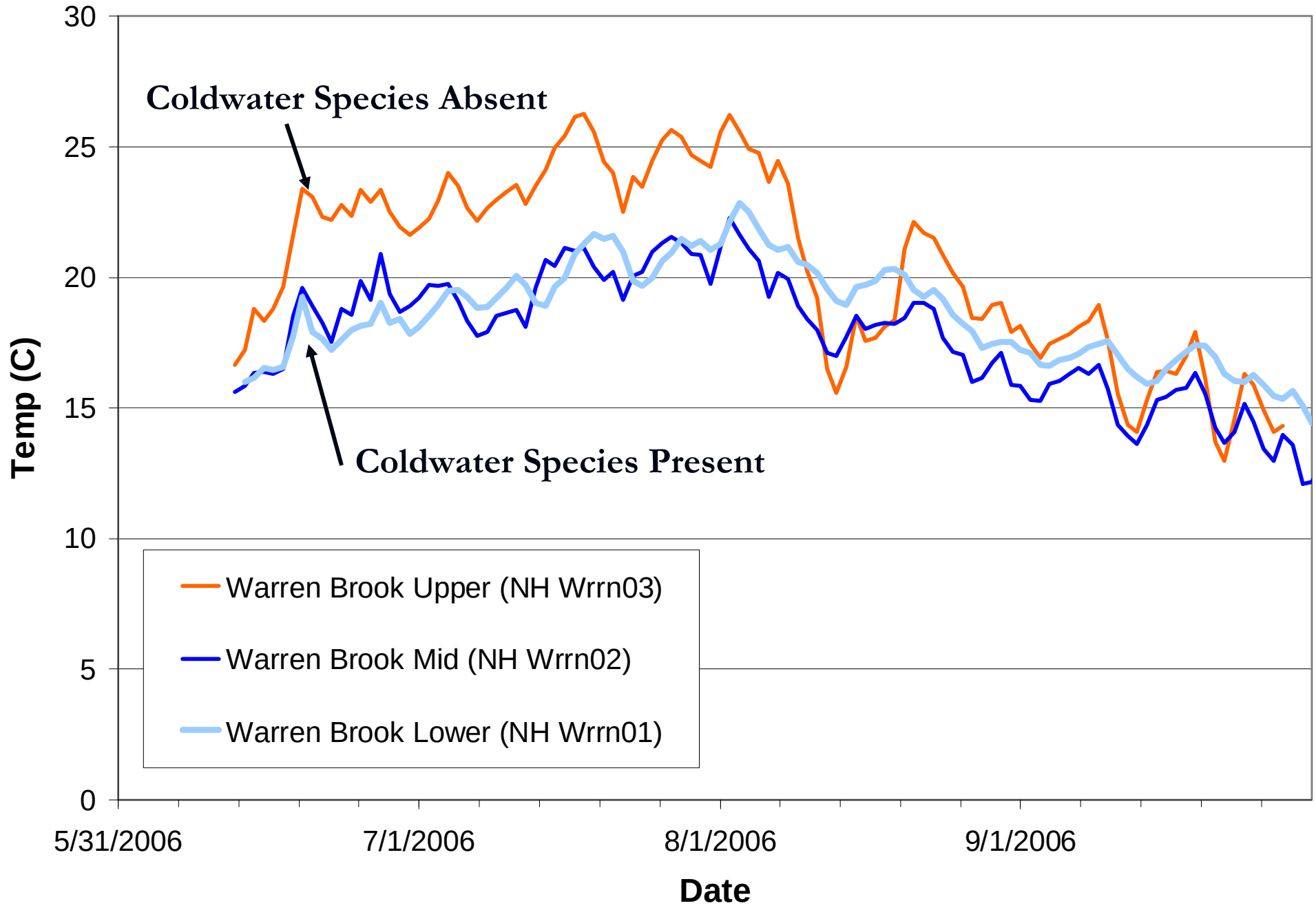




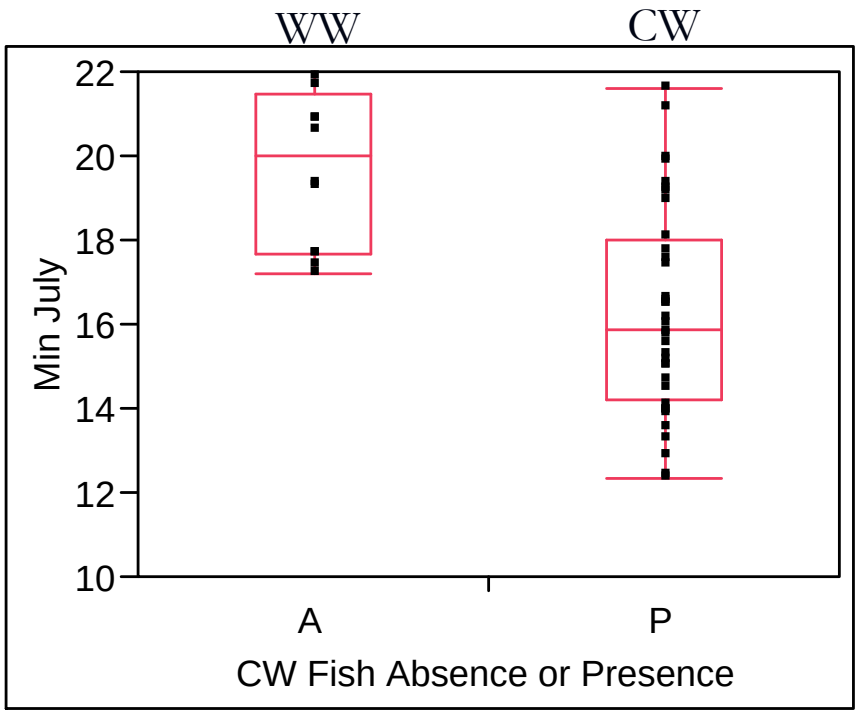
Mean Daily Temperature in August 2006

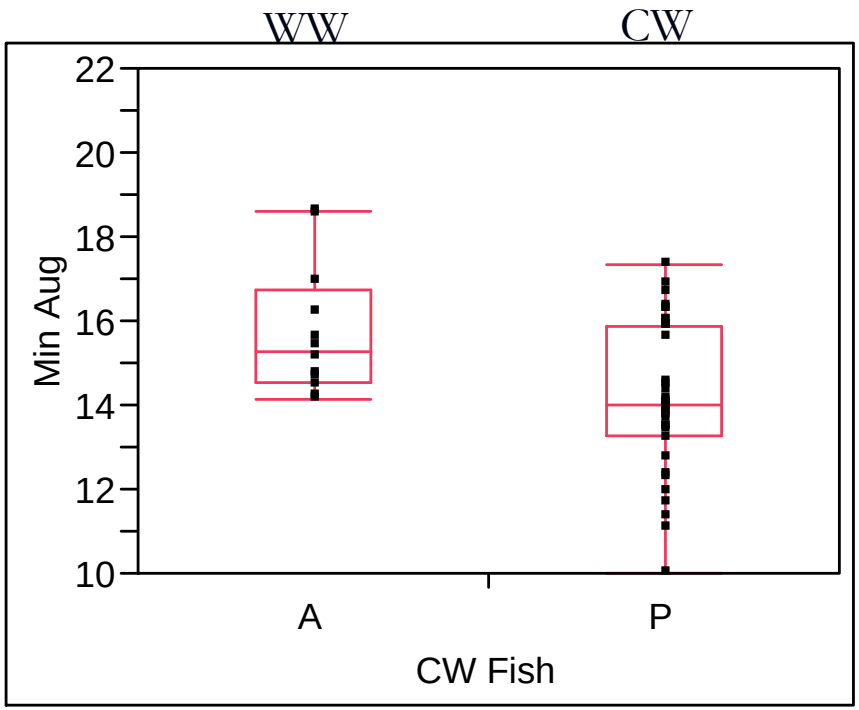





Coldwater Species Absent
Coldwater Species Present
Warren Brook Upper (NH Wrrn03)
Warren Brook Mid (NH Wrrn02)
Warren Brook Lower (NH Wrrn01)
Temp (C)
30
25
20
15
10
5
0
5/31/2006
7/1/2006
8/1/2006
9/1/2006
Date

Minimum Daily Temperature July and August 2006

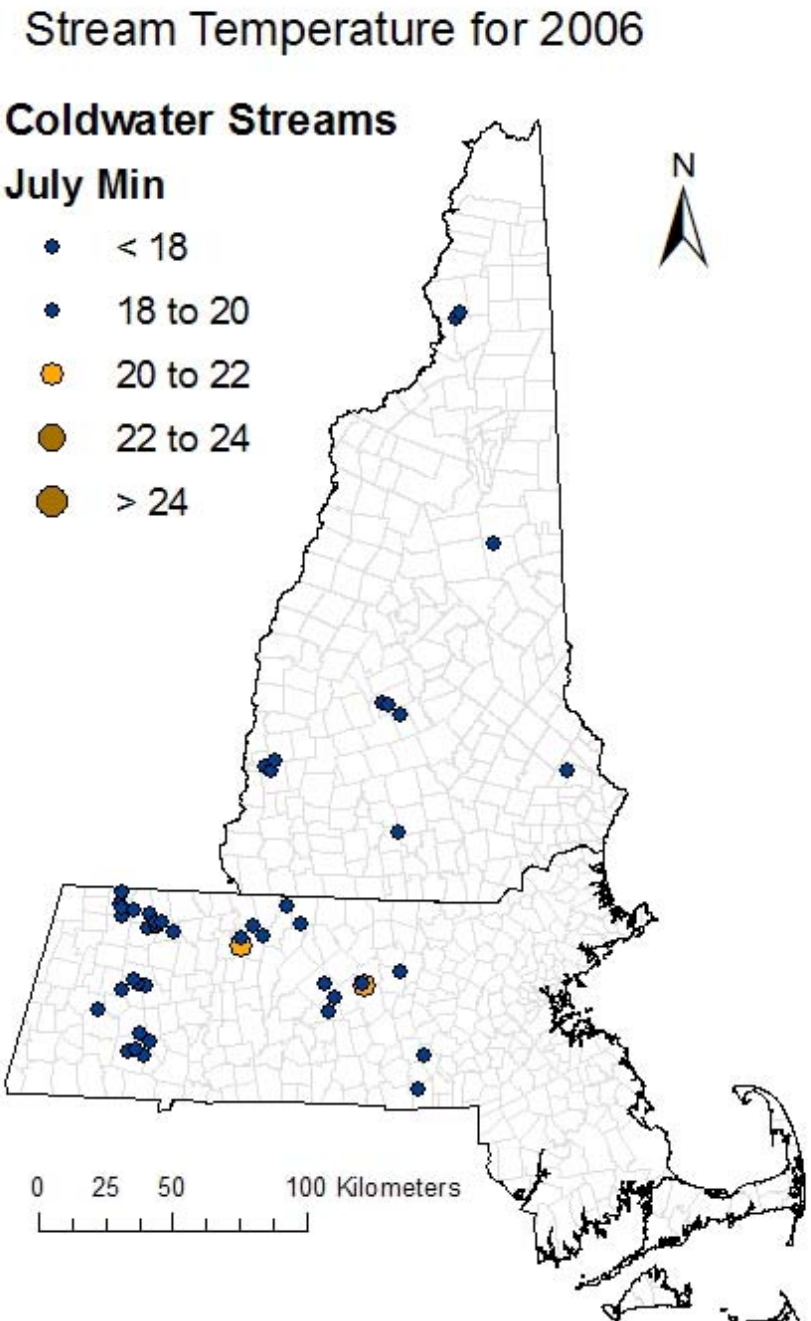


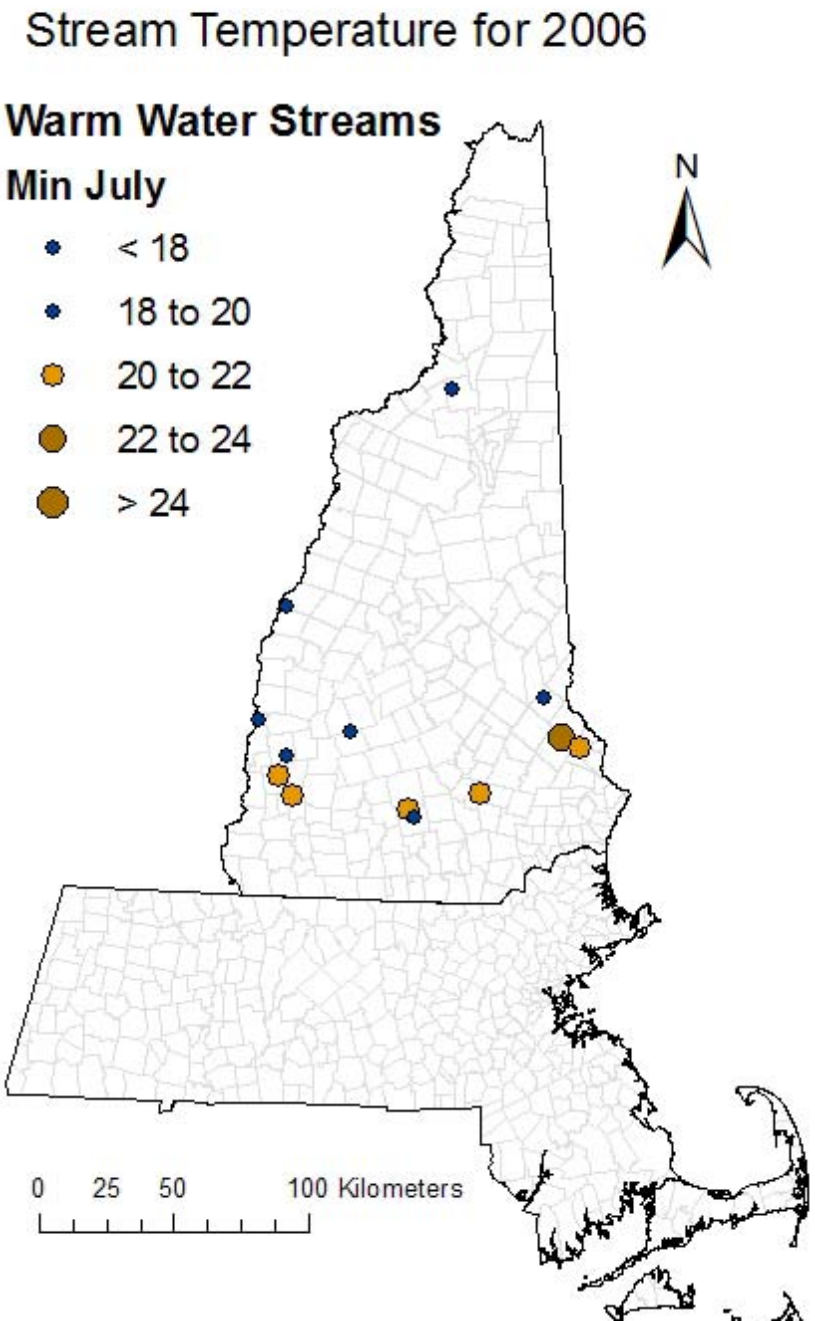


July Min Air Temp = 18.9 °C

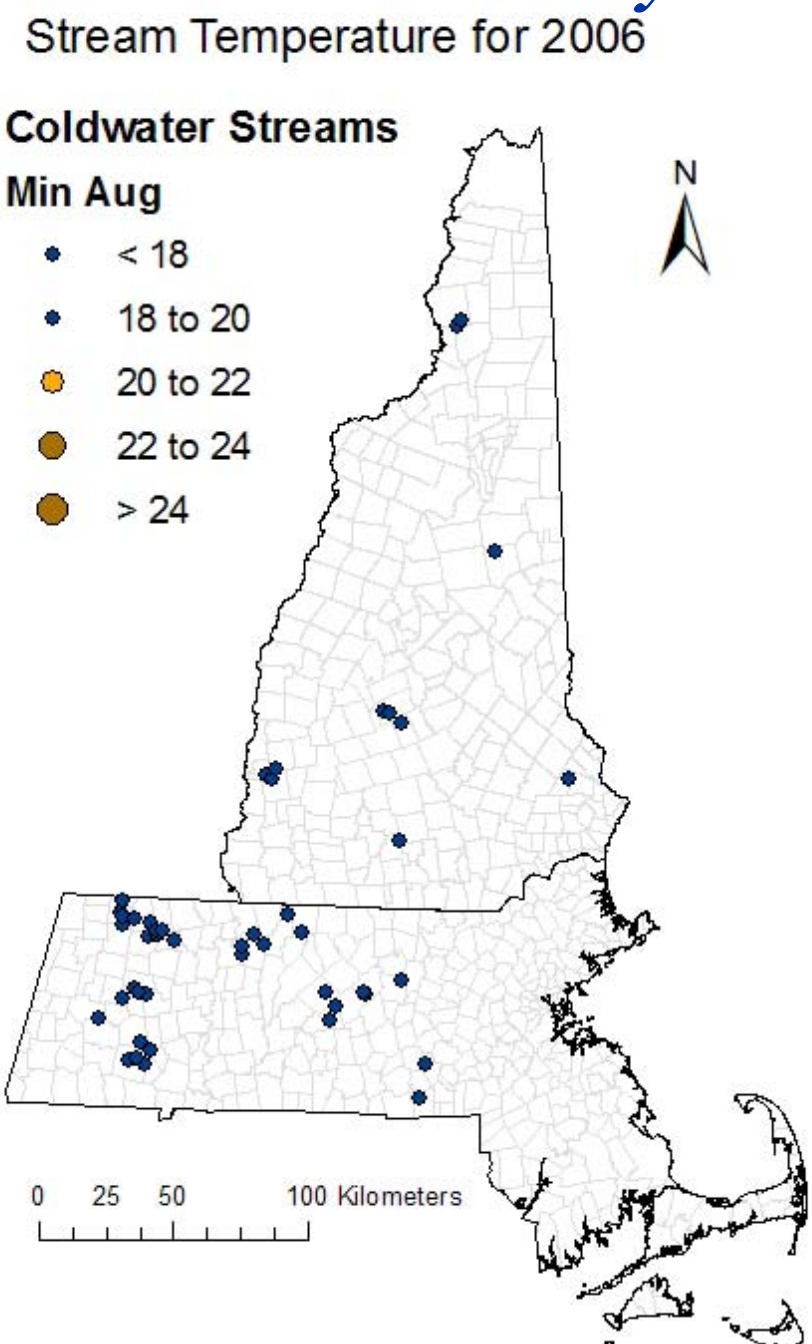
August Min Air Temp = 13.9 °C

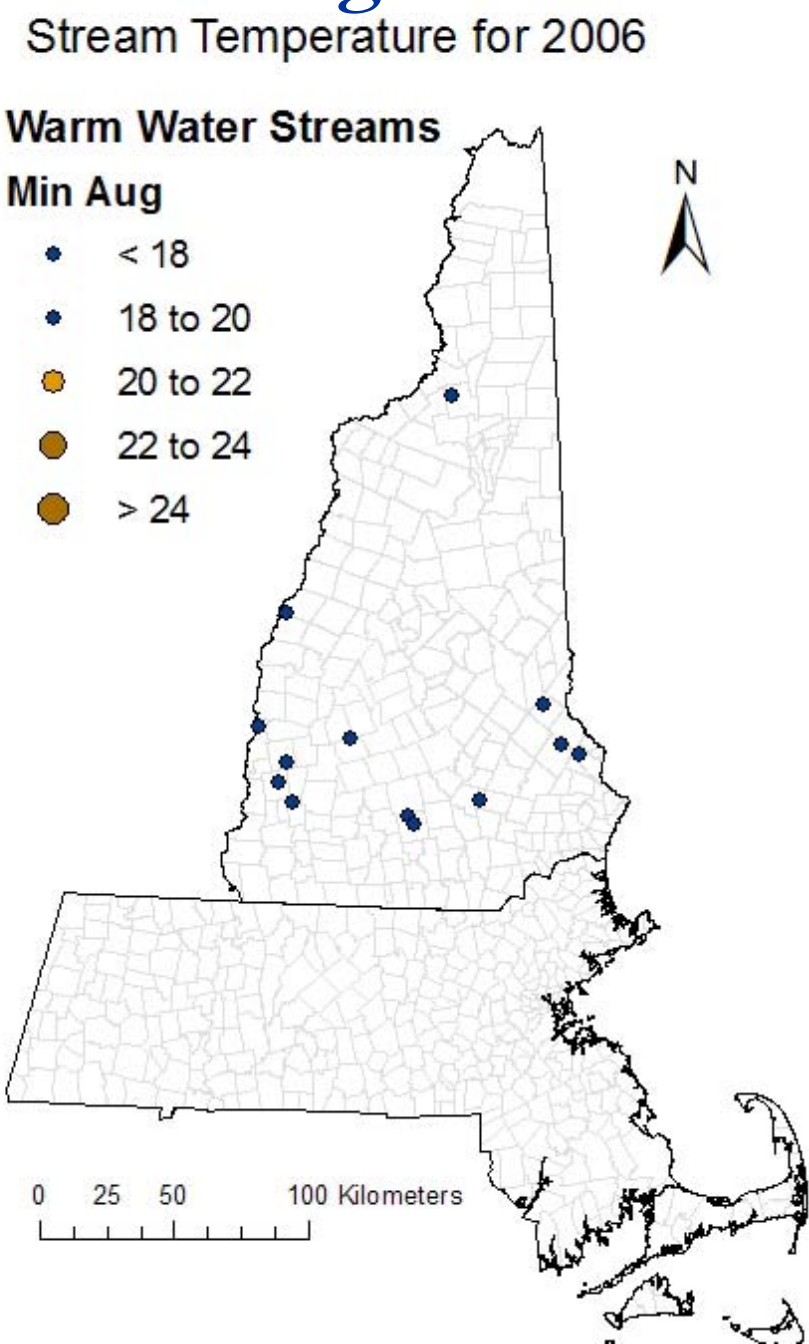
Minimum Daily Temperature in July 2006



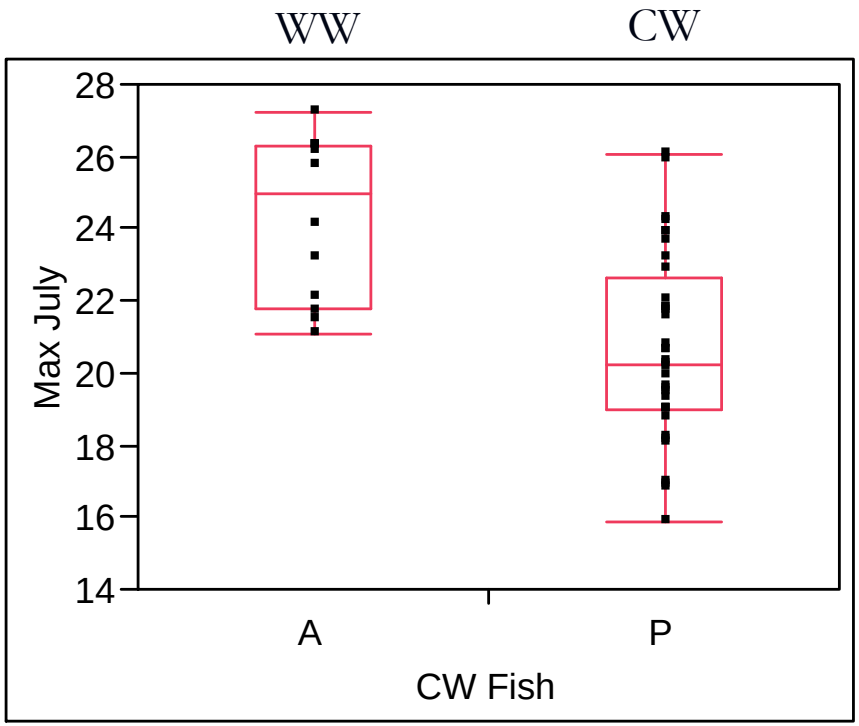


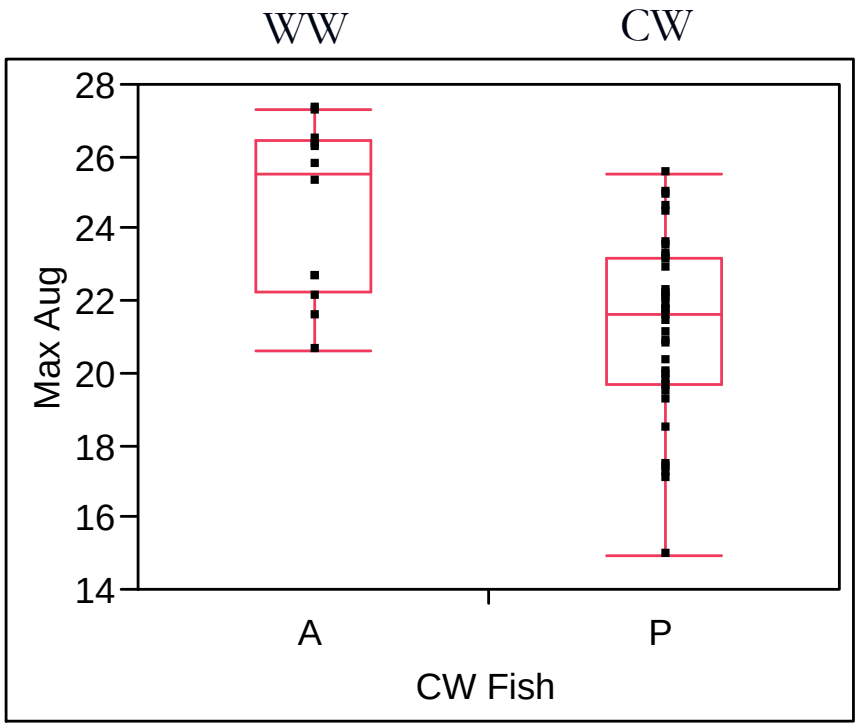
Minimum Daily Temperature in August 2006





Maximum Daily Temperature July and August 2006

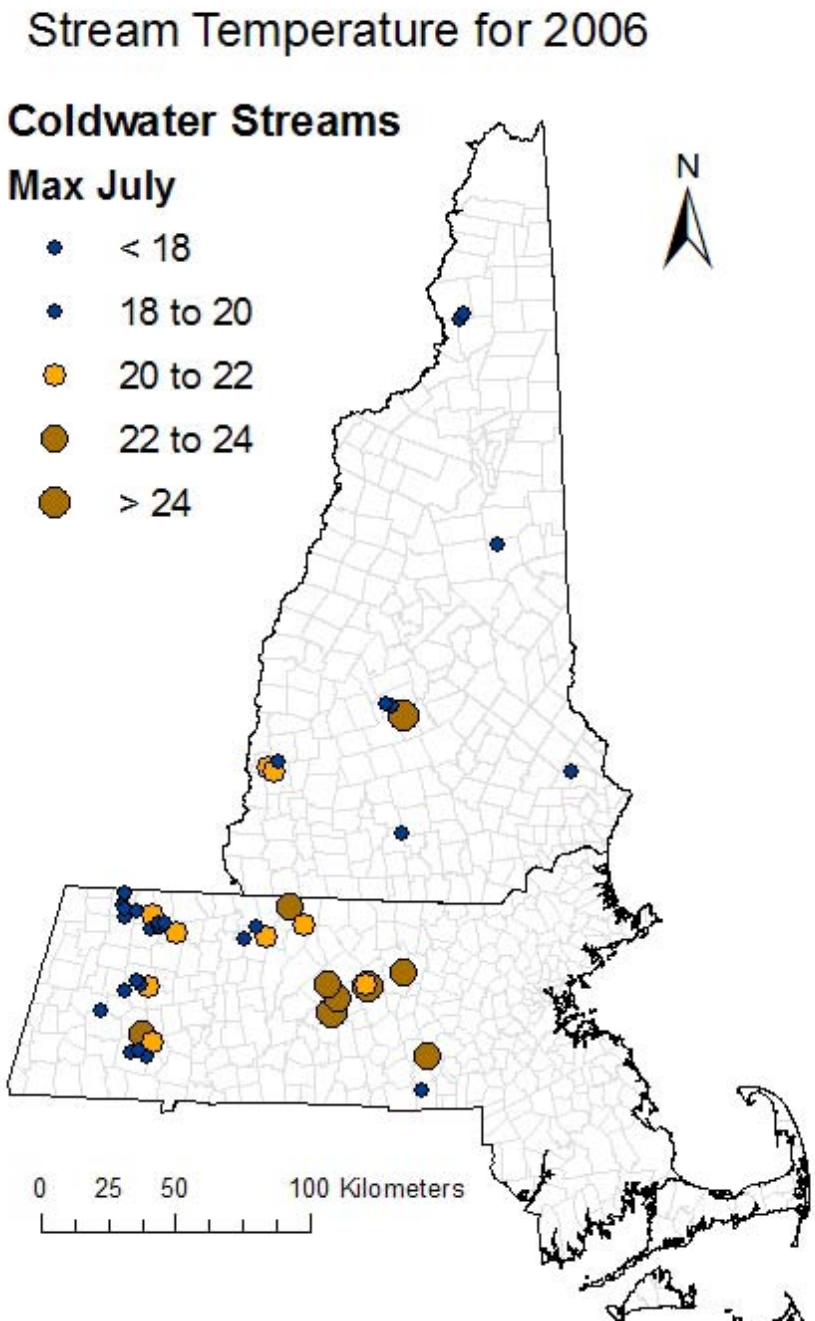


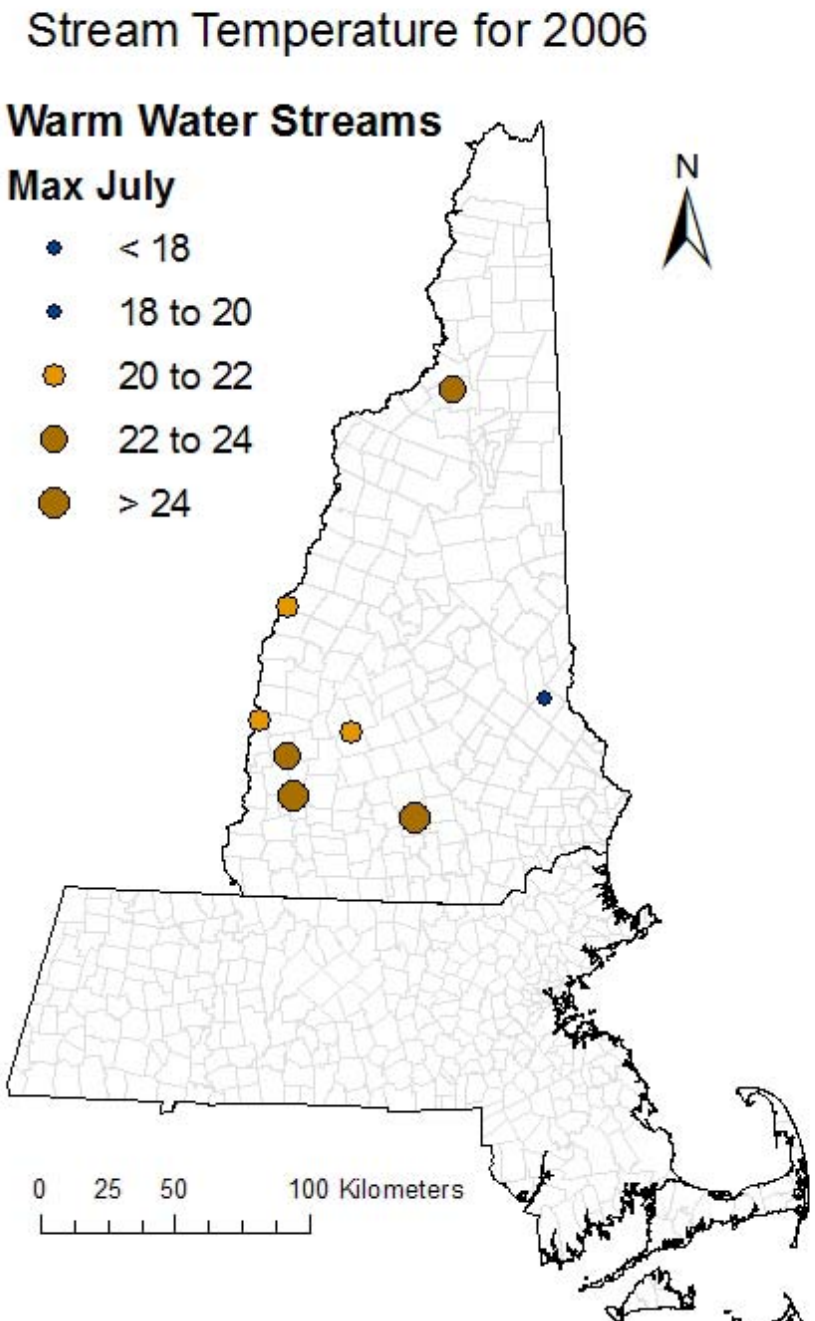


July Max Air Temp = 27.2°C

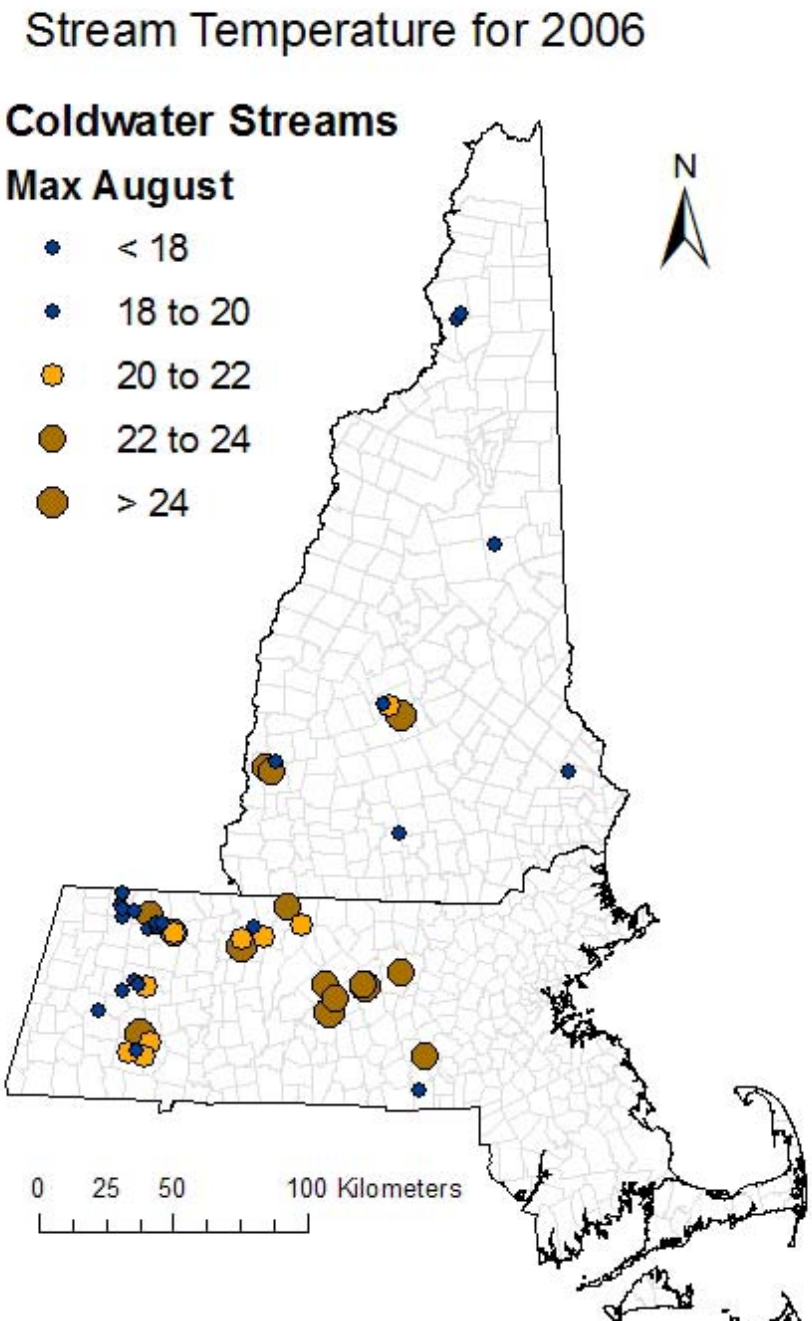
August Max Air Temp = 30.0°C

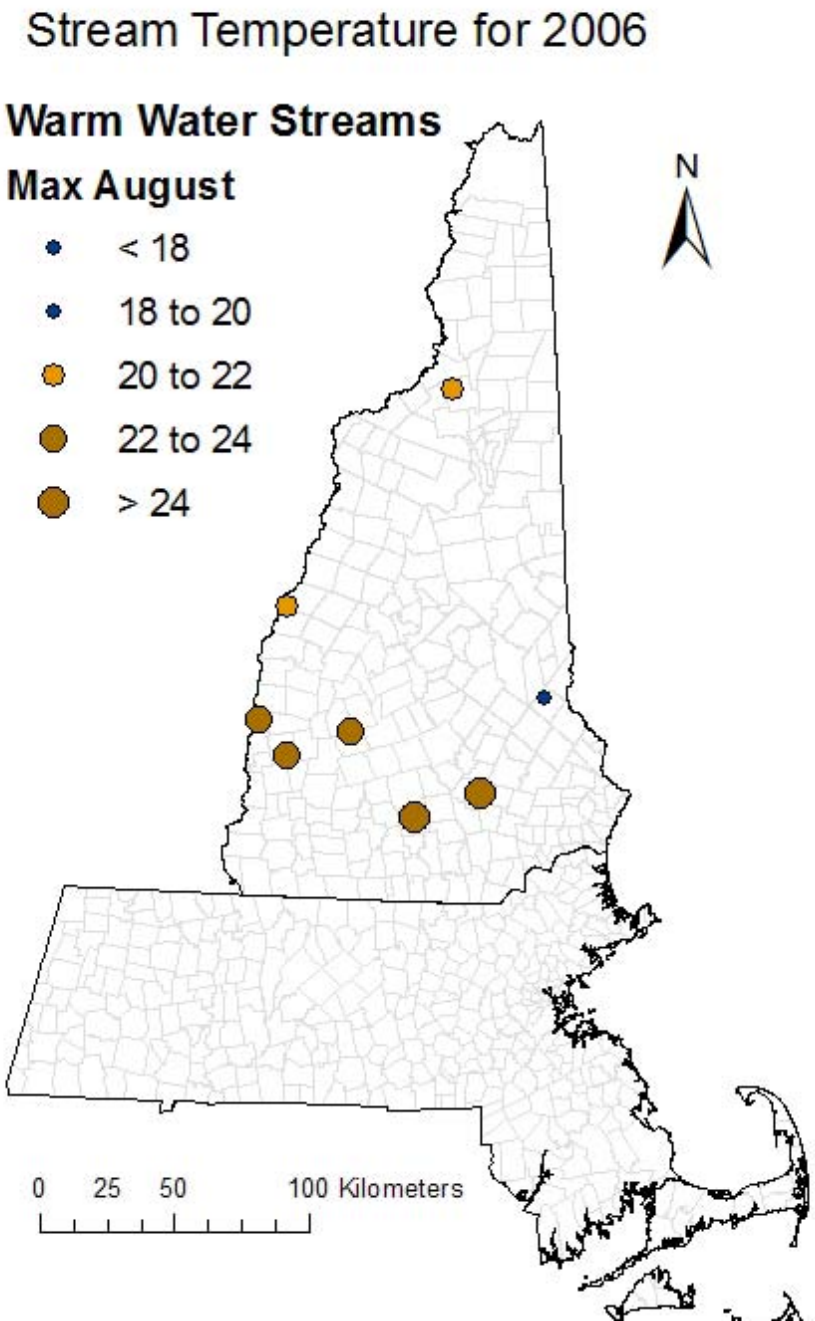
Maximum Daily Temperature in July 2006





Maximum Daily Temperature in August 2006



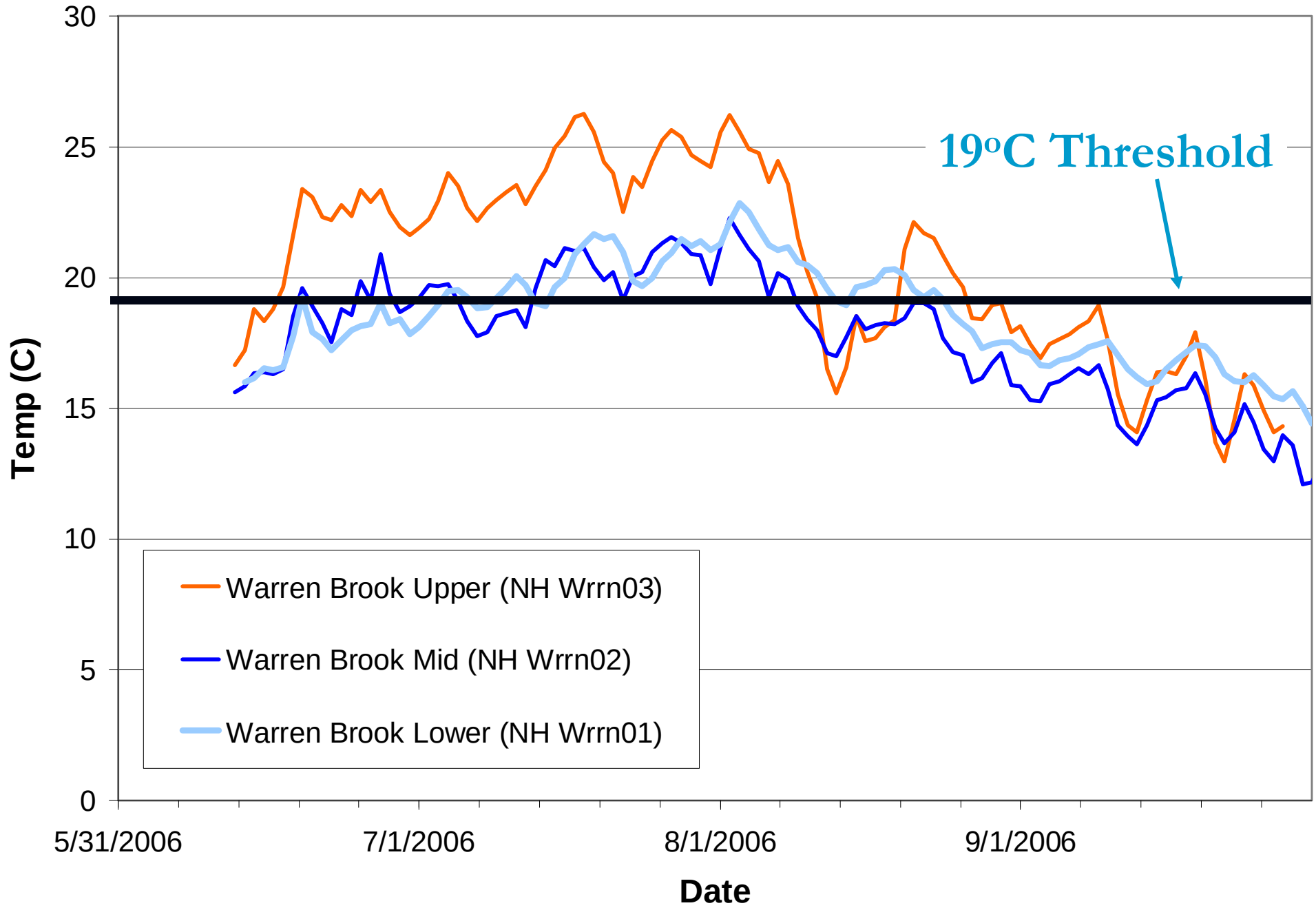


Stream Temperature Database

- Reformat existing datasets
- Develop and apply QA/QC protocols
- Design database
- Populate database
- Transfer protocols
- Link to GIS and webservers
- Provide guidance on data collection

Quantify Stream Temperature

- Expand Data Analysis
  - Add MA DEP
  - 2006-2009 Datasets
- Complete Analysis
  - Magnitude
  - Frequency
  - Timing
  - Duration
  - Rate of Change


19°C Threshold
Temp (C)
30
25
20
15
10
5
0
5/31/2006
7/1/2006
8/1/2006
9/1/2006
Date
Warren Brook Upper (NH Wrrn03)
Warren Brook Mid (NH Wrrn02)
Warren Brook Lower (NH Wrrn01)

Jennifer Jacobs
University of New Hampshire

jennifer.jacobs@unh.edu
603 862-0635

"Temperature is probably the most important, but least discussed, parameter in determining water quality"

Blakely (1966)