Comparison of Water Temperature within Groundwater versus Non-Groundwater Influenced Salmon Habitat in the Machias River Watershed.

Temperature loggers were located in mapped salmon rearing habitat within a groundwater influenced section of Old Stream below Rt 9 and a non groundwater influenced section of the Machias River below Rt. 9. Instantaneous water temperature was recorded twice per hour (0 and 30 minutes of each hour). Discharge data were obtained from USGS Gage 01021480 (Old Stream) and weather data from NCDC USC00179294 (Wesley).

Atlantic salmon parr feeding limits of 7.0 - 22.5 °C (Elliot 1991) were utilized to determine initial parr feeding dates and to assess the duration of non-feeding periods (>22.5 °C) during the spring and summer of 2011 and 2012.

In 2012, mean daily water temperature at both locations began to exceed 7 °C on April 13th (standard week 15, Julian day 104) when maximum and minimum daily air temperatures consistently exceeded 11 °C and 0 °C, respectively. See Figure1 and 3. The 2012 initial parr feeding date is 12 days earlier than 2011 (April 25th -standard week 17, Julian day 115) for both locations. Based on 2 years of water temperature data, it appears that groundwater influence in Old Stream does not affect initial springtime feeding dates for parr because high spring flows negate groundwater inputs.

In regard to high water temperature relating to non feeding periods (>22.5 °C), 2012 was warmer than 2011, especially in the Machias River. The groundwater influenced habitat in Old Stream did not experience non-feeding water temperatures in 2011 and only 1 hour (2@ 30 minute events) exceeded 22.5 °C in 2012. The mainstem Machias River (non groundwater influenced) elapsed 21 days (504 hours) of water temperatures >22.5 °C in 2011 and 33.9 days in 2012. See Table 1 and Figure 1.

Table 1. Summary of water temperature durations >22.5 °C below Rt 9 in Old Stream (groundwater influenced) and Machias River (non groundwater influenced) in 2011 and 2012.

Year	Old Stream >22.5C				Machias Rt 9 > 22.5C			
2011	0.0	hours	0.0	days	504.0	hours	21.0	days
2012	1.0	hours	0.0	days	812.5	hours	33.9	days

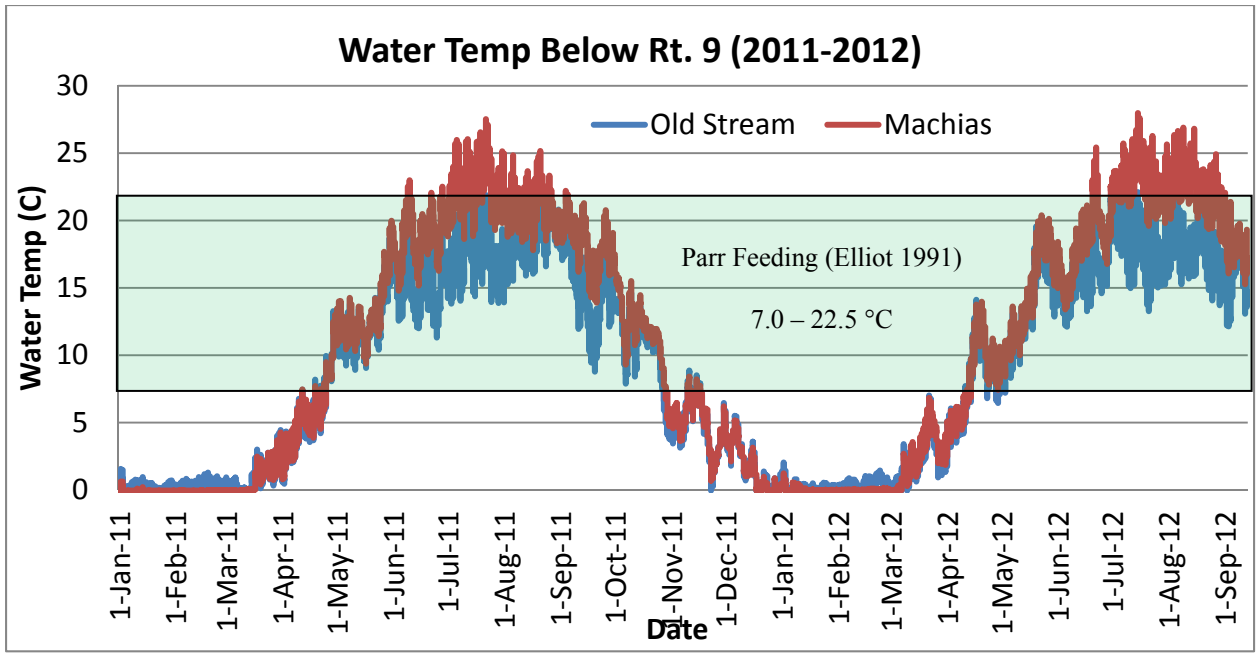


Figure 1. Plot of water temperature and zone of parr feeding (7.0 – 22.5 °C) for Old Stream and Machias River (2011- 2012).

Other Water Temperature Indices.

Stanley and Trial (1984) developed water temperature Habitat Suitability Index (HSI) curves for juvenile Atlantic salmon. HSI "V1"was calculated by taking the average of the daily maximum values from the warmest continuous 3 day period. Daily range or Δ (Max – Min) surrounding these HSI "V1" dates were also calculated. See Figure 2 for more detail.

Old Stream			
Dates	Max	Min	Daily Δ
7/1/2012	22.6	19.8	2.8
7/2/2012	22.4	19.6	2.8
7/3/2012	21.8	18.3	3.5
Mean- 3 Day	22.3	19.2	3.0
HSI 3 Day Max	89%		

Machias			
Dates	Max	Min	Daily Δ
7/14/2012	26.7	23.0	3.7
7/15/2012	28.0	23.7	4.3
7/16/2012	27.6	23.9	3.7
Mean- 3 Day	27.4	23.5	3.9
HSI 3 Day Max	13%		

7/11/2011	22.4	17.5	4.9
7/12/2011	22.4	18.6	3.8
7/13/2011	21.5	18.4	3.1
Mean- 3 Day	22.1	18.2	3.9
HSI 3 Day Max	90%		

7/22/2011	27.5	22.9	4.6
7/23/2011	27.1	23.9	3.2
7/24/2011	25.4	22.7	2.7
Mean- 3 Day	26.7	23.2	3.5
HSI 3 Day Max	17%		

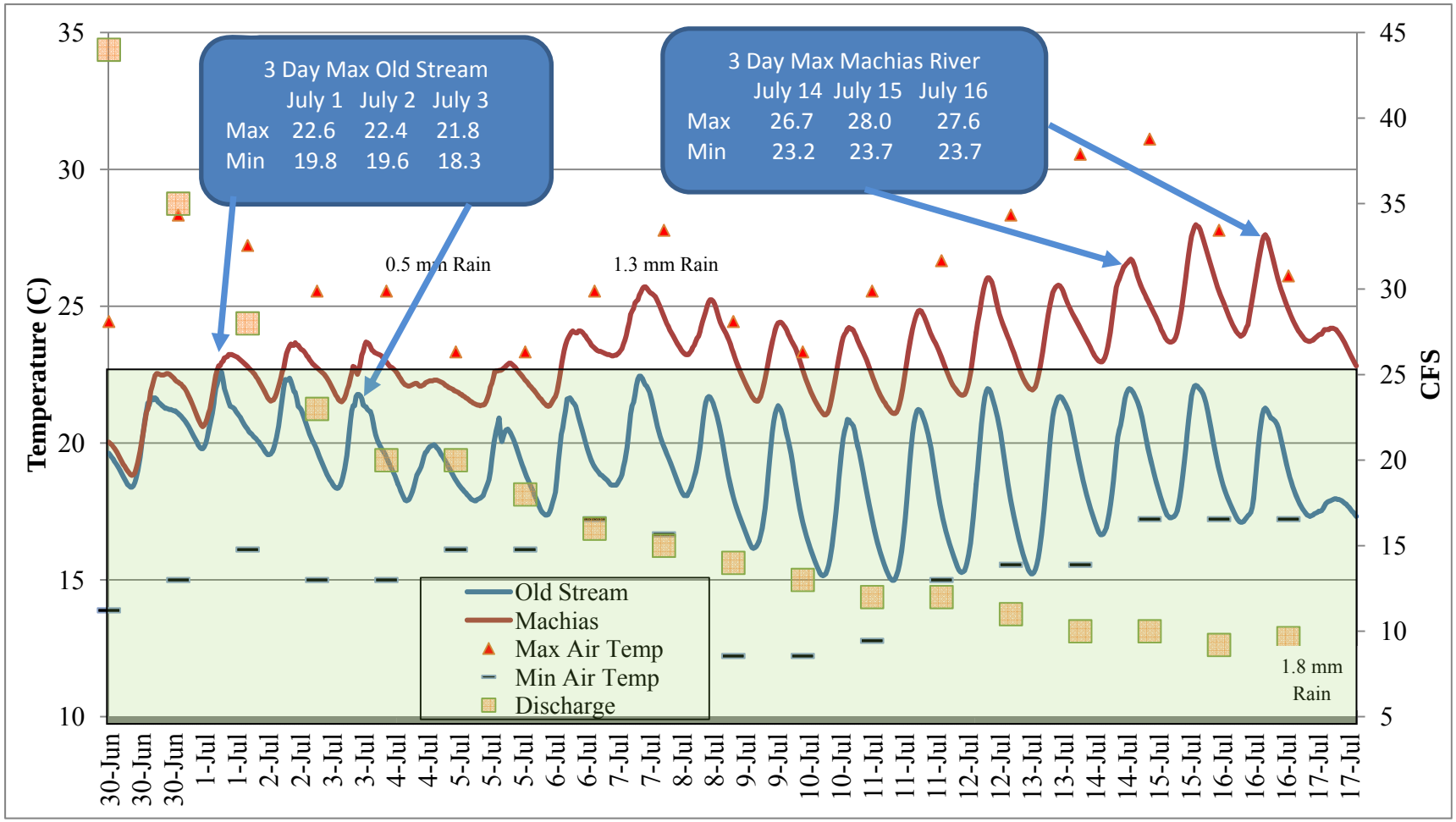


Figure 2. Water and air temperatures in Old Stream and Machias River during warmest 3 day period in 2012. Discharge (2nd axis) shows the minimum daily flow at the Old Stream Gage.

Water quality component "V2" in Stanley and Trial (1984) refers to mean water temperatures over the "growing season or summer". Two HSI "V2" metrics were calculated.

1) Mean water temperature from onset of daily mean water temperatures >7 °C to fall season period when <7 °C.

2) Summer defined as the time period from June 15 to Aug. 15.

Old Stream	
Dates Temps >7C - <7C	Apr 25- Oct 28 2011
Mean Temp	14.8
HSI Growing Season	100%

Machias	
Dates Temps >7C - <7C	Apr 25- Oct 29 2011
Mean Temp	17.4
HSI Growing Season	100%

		Old Stream	Machias
	Year	Mean Temp	
Jun 15 to Aug 15	2012	17.8	23.0
	2011	16.9	21.2

HSI Summer	2012	100%	2%
	2011	100%	38%

Comparing the two water HSI scores from the actual growing season versus a defined summer period of Jun 15 – Aug 15 clearly indicates the later is a better estimator of thermal habitat suitability.

The 7 day mean maximum weekly average maximum temperature (MWMT) that is described by Dunham et al. (1995) as the highest average temperature summarized over a continuous 7 days during the summer. Standard weeks utilized by the Maine salmon database were utilized for defining time periods.

	Old Stream		Machias	
Year	Std. Week	MWMT (C)	Std. Week	MWMT (C)
2012	27	19.7	28	23.8
2011	35	19.7	29	23.7

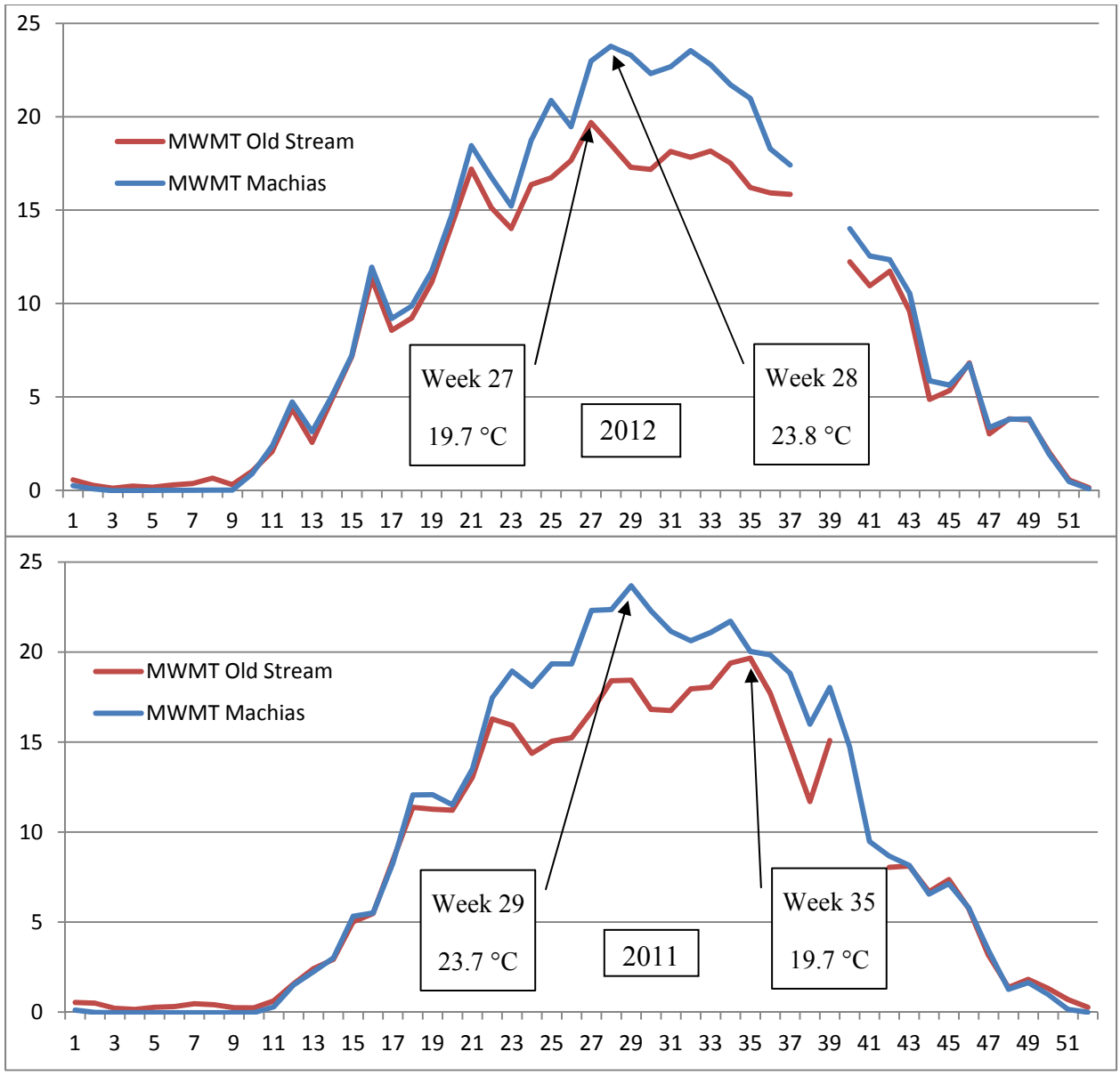


Figure 3. Maximum weekly average maximum temperature (MWMT) for 2012 and 2011 by standard week. For Old Stream and Machias River.

Daily mean water temperature was utilized to calculate egg development to the fry feeding stage. Developmental Index (D.I.) was calculated by the methods of Kane (1988) where 58.3% equates to eggs hatching and 100% is initial fry feeding. Starting dates were selected when daily mean water temperatures dropped below 10 °C.

If natural in-stream incubation temperatures mimic the same temperature regime as data loggers, it appears there is minimal difference (≤3 days) in the timing (onset of water temperatures <10 °C), hatching and initial feeding of fry in Old Stream and the Machias River.

Although water temperatures in Old Stream are consistently warmer in the winter (groundwater inputs), the Machias River's warmer temperatures in early spring minimize cumulative D.I. differences prior to initial feeding (100% D.I.). See Figure 4.

Annual temporal differences in developmental rates of hatching (16-19 days) and initial feeding (9-11 days) were earlier in 2011-2012 versus 2010-2011.

Warmer winter water temperatures at Craig Brook National Fish Hatchery increase developmental rates by 4-10 days over natural river conditions as calculated from the primary egg take date of Machias River captive reared salmon in the last two years.

		Year	
		2011-2012	2010-2011
Old Stream	Start Date	26-Oct-11	30-Oct-10
	Hatching (D.I. 58.3%)	26-Mar-12	11-Apr-11
	Initial Feed (D.I. 100%)	10-May-12	19-May-11
Machias River	Start Date	27-Oct-11	30-Oct-10
	Hatching (D.I. 58.3%)	26-Mar-12	14-Apr-11
	Initial Feed (D.I. 100%)	8-May-12	19-May-11
CBNFH Machias River	Start Date	16-Nov-11	5-Nov-10
	Hatching (D.I. 58.3%)	14-Mar-12	8-Mar-11
	Initial Feed (D.I. 100%)	4-May-12	9-May-11

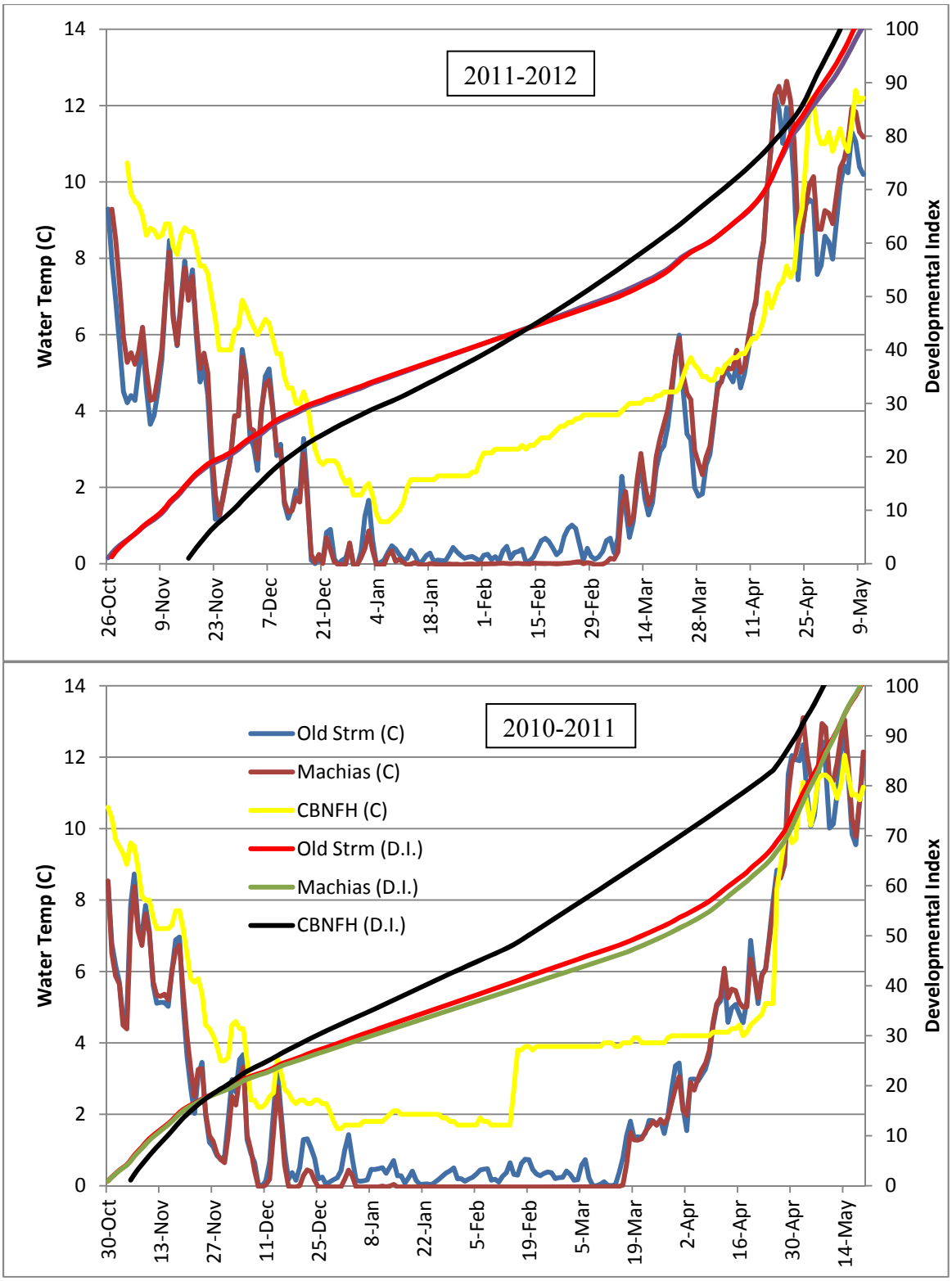


Figure 4. Cumulative developmental index scores and daily mean water temperature for Old Stream, Machias River and primary Machias River egg take at Craig Brook National Fish Hatchery in 2011-12 and 2010-2011.

Summary of Old Stream Discharge during Summer 2012 Rearing Period.

The winter of 2011-2012 was warmer and drier than normal and this yielded stream flows far below the 14 year average up to April 23. On April 24 a 95.5 mm rain event yielded a 666 CFS event that equates to a 3.3 year flood return interval. See Figure 4.

Flows remained above the 14 year average until May 22 and during the periods of June 26 to July 7, Sept. 4- Sept. 15 and Sept. 29- Oct. 12. Low flows were moderate to extreme from Aug. 21 to Sept. 3rd with Gage values at or below the 50% percentile. Most 1st order streams in the area were either dry or largely intermittent with most 2nd order tributaries being intermittent (S. Craig USFWS Personal Observation). USGS provides annual water year summaries.

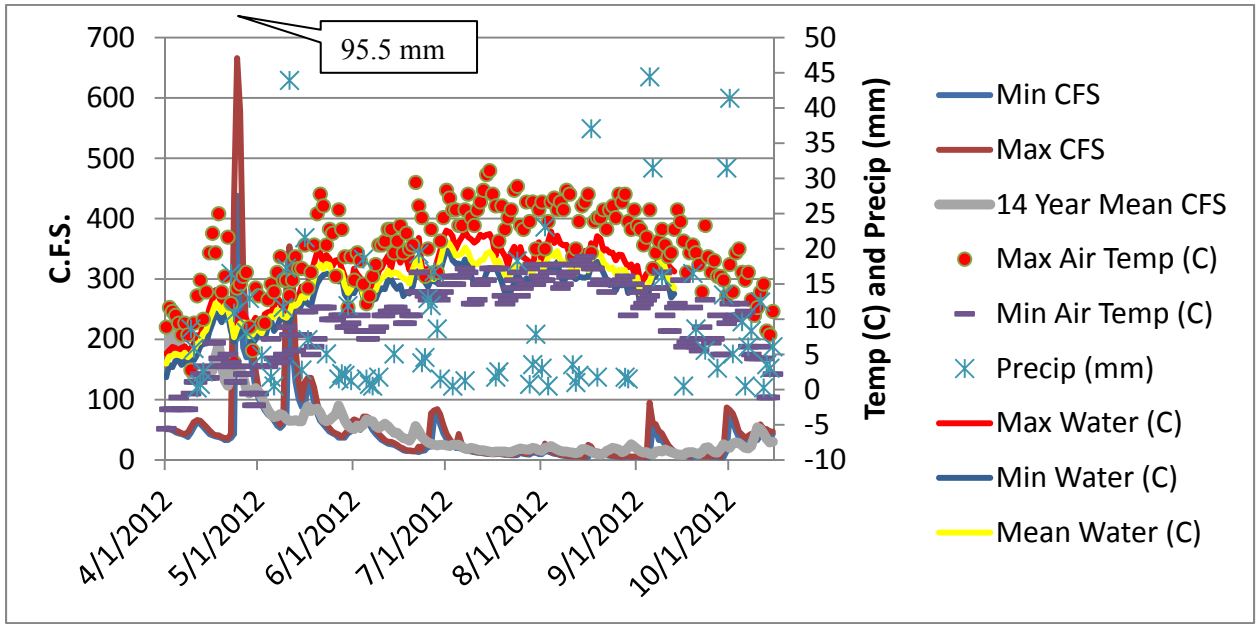


Figure 4. Summary of discharge, water and air temperature and precipitation in Old Stream nearly Wesley, Maine from April 1 to October 15 2012.

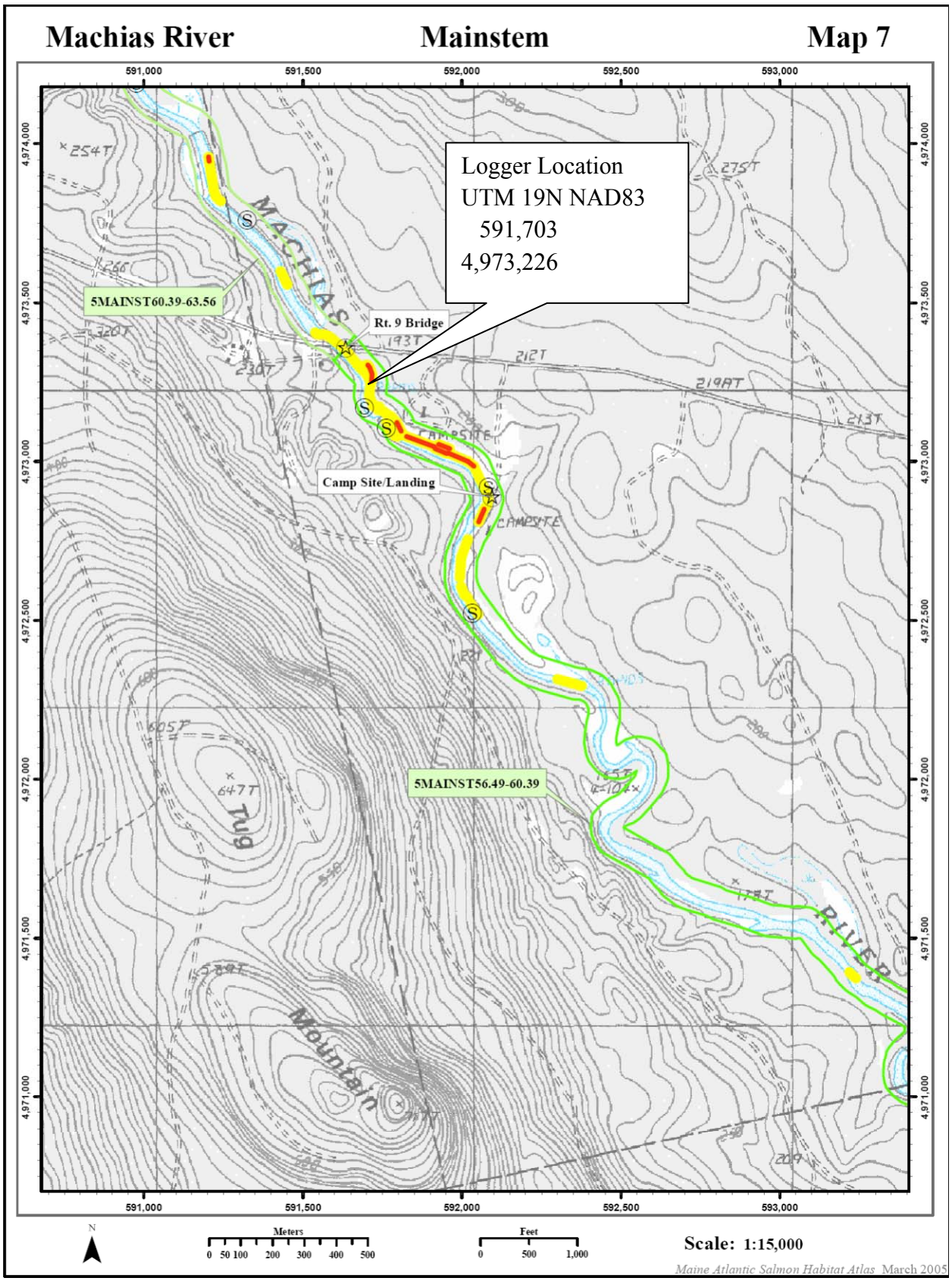
Literature Cited:

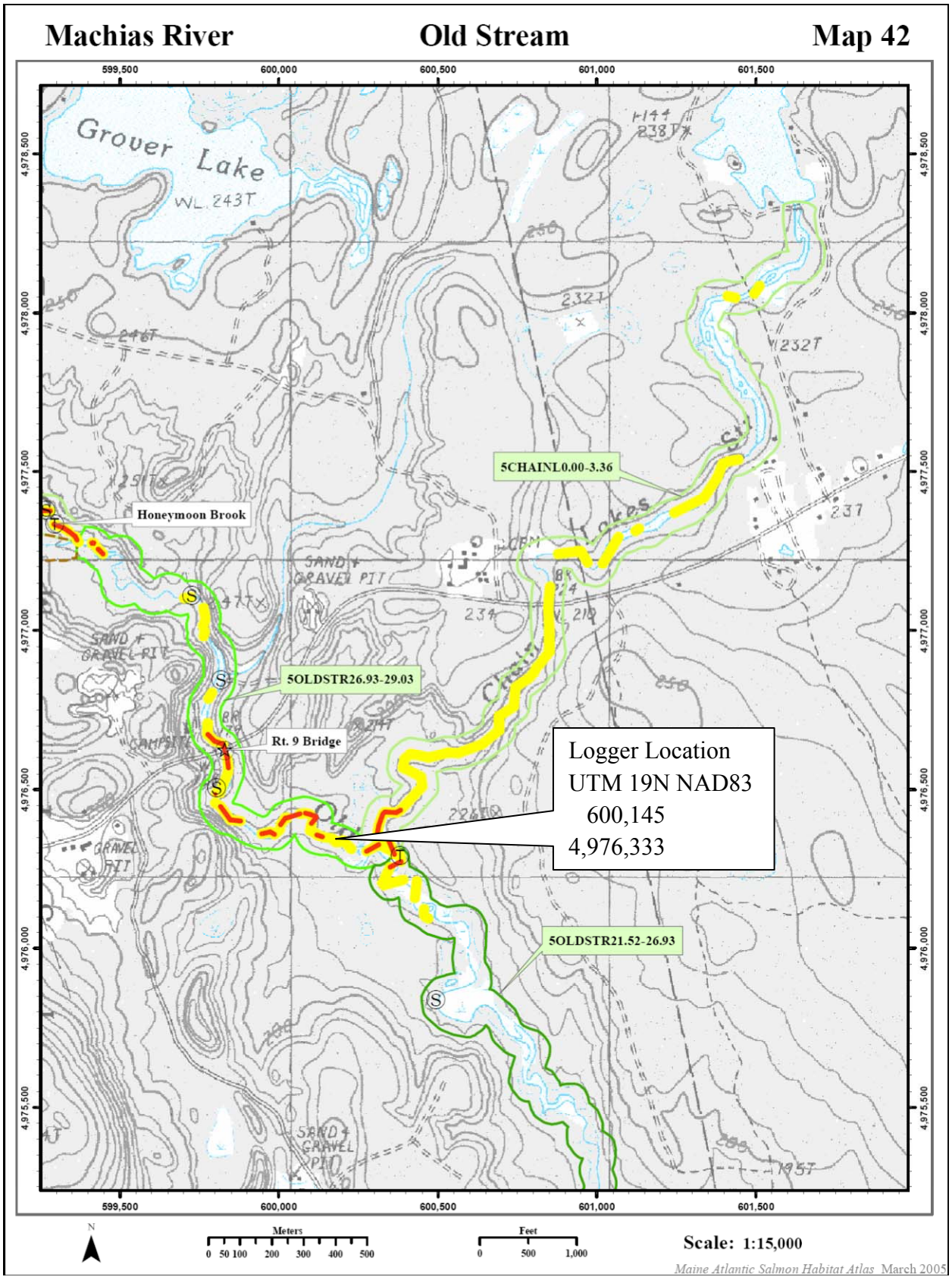
Dunham, J., et al. (2005). Measuring stream temperature with digital data loggers: a user's guide. Gen. Tech. Rep. RMRSGTR-150WWW. Fort Collins, CO. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 15 p.

Elliott, J. M. (1991). Tolerance and resistance to thermal stress in juvenile Atlantic salmon, *Salmo salar*. Freshwater biology 25(1): 61-70.

Kane, T. R. (1988). Relationship of Temperature and Time of Initial Feeding of Atlantic Salmon. The Progressive Fish Culturalist (50): 93-97.

Stanley, J. G. and J. G. Trial (1995). Habitat Suitability Index Models: Nonmigratory Freshwater Life Stages of Atlantic Salmon. Washington D.C., U.S. Department of the Interior. National Biological Service: 20 p.


Machias River
Mainstem
Map 7
Logger Location
UTM 19N NAD83
591,703
4,973,226
5MAINST60.39-63.56
Rt. 9 Bridge
Camp Site/Landing
5MAINST56.49-60.39
MACHIAS
RIVER
Tug
Mountain
CAMPSITE
591,000
591,500
592,000
592,500
593,000
4,974,000
4,973,500
4,973,000
4,972,500
4,972,000
4,971,500
4,971,000
N
Meters
0 50 100 200 300 400 500
Feet
0 500 1,000
Scale: 1:15,000
Maine Atlantic Salmon Habitat Atlas March 2005


Machias River
Old Stream
Map 42
Grover Lake
WL 243T
5CHAINL0.00-3.36
Honeymoon Brook
5OLDSTR26.93-29.03
Rt. 9 Bridge
Logger Location
UTM 19N NAD83
600,145
4,976,333
5OLDSTR21.52-26.93
599,500
600,000
600,500
601,000
601,500
4,978,500
4,978,000
4,977,500
4,977,000
4,976,500
4,976,000
4,975,500
N
Meters
0 50 100 200 300 400 500
Feet
0 500 1,000
Scale: 1:15,000
Maine Atlantic Salmon Habitat Atlas March 2005