Environmental Conditions and the Shenandoah River Fish Kills

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What is a fish kill?

The sudden death of large numbers of fish

- **Causes:**
  - **Lack of Oxygen:** High Biochemical Oxygen Demand (BOD) from increased organic matter and other factors that decrease DO levels
  - **Fish Disease and Parasites:** Fish are constantly exposed to disease-causing viruses, bacteria, fungi and parasites
  - **Pollutants:** Pesticides, chlorine, gasoline, fuel oil, ammonia fertilizer, acids and other toxic chemicals
  - **Naturally toxic water:** Acid-sulphate soils and aluminum toxicity
  - **Thermal Pollution:** Power plants

Virginia Tech: Virginia Cooperative Extension. “Fish Kills: Their Causes and Prevention.” 2000


Old Picture

VA Tech DVM Report on South Fork Shenandoah fish deaths

- **2005 fish samples:**
  - **Fish died from secondary bacterial and fungal skin infections due to immune suppression** (Smith 2005)
  - **"as a result of fluctuating environmental and water temperatures."** (Smith 2005)

- **Immune Suppression can be caused by a variety of stressors** (UF 2002):
  - **Biological:** Population density, pathogenic and non-pathogenic microorganisms, internal and external parasites
  - **Chemical:** Low DO, changes in pH, chemical pollution, diet composition, accumulation of ammonia or nitrite, dissolved gases
  - **Physical:** Temperature, light, sounds
  - **Procedural:** Handling, shipping, disease treatment

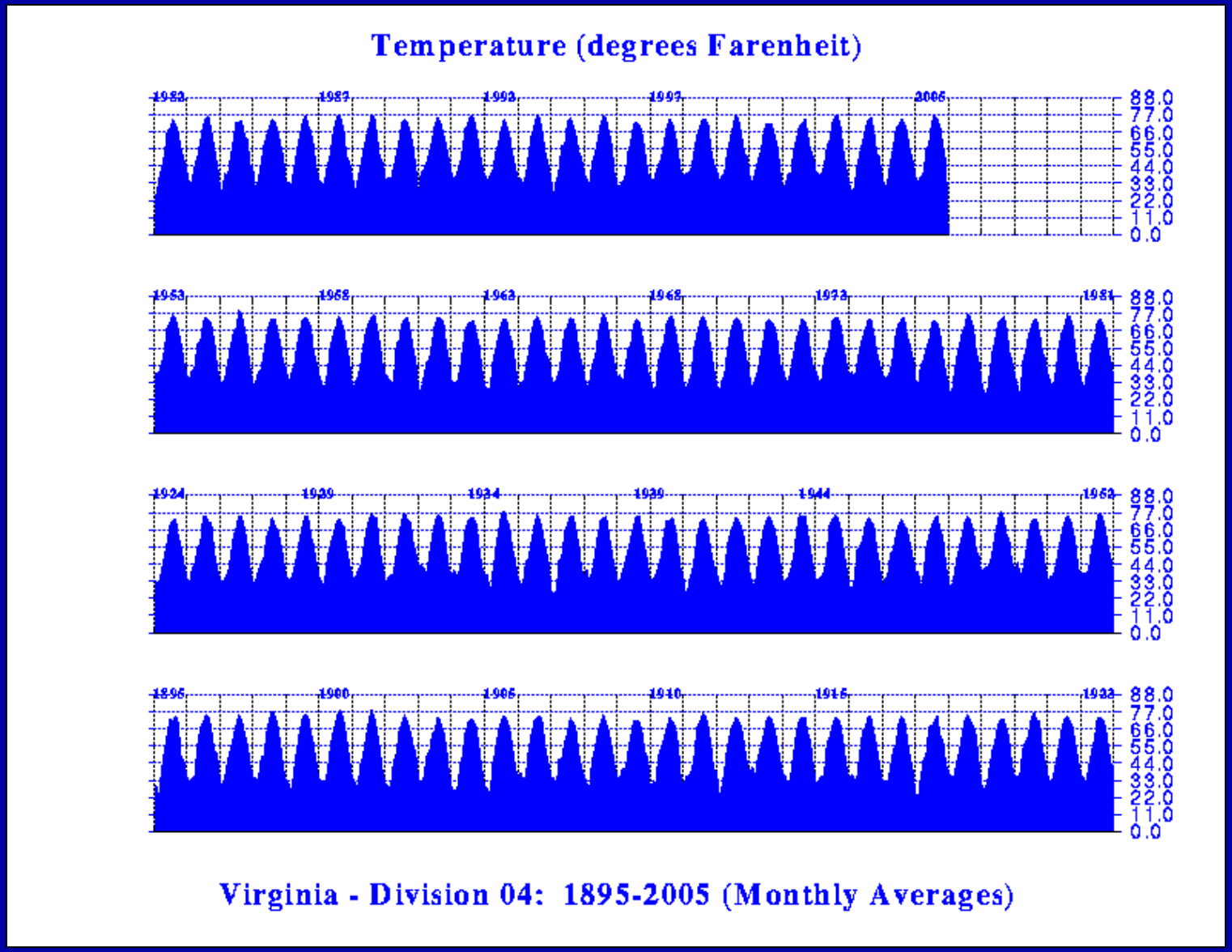
- **JMU Project:**
  - Establish a knowledge and understanding of environmental conditions before, during and after the fish kills
  - Study meteorological data including rainfall and runoff, discharge data, air temperature, and water temperature
- **Flow quantity and variability:**
  - Discharge data available from several U.S. Geological Survey (USGS) gaging stations
- **Air temperature data and summaries:**
  - Meteorological info including air temperature data available in abundance: VA State Climatology Office, National Climate Data Center & other databases
- **Water Temperature data:**
  - Discharge data have been collected for many years; but long term water temperature data are unavailable
  - Municipal water treatment plants - ???

Climate Trends in Virginia

- **Air Temperature:**
  - 1985 to present has been warmer than the period of 1960 to 1985
  - The mid-1960s was the coolest period since the beginning of the century
  - The hottest decade on record is still the 1930s
  - An identifiable trend for VA air temperature has **not** been observed
- **Precipitation:**
  - National precipitation averages have increased by 10% over the last century
  - In Virginia there has been **no** annual trend in precipitation
  - The last few decades have had notably dry summers
- **The recurring themes are:**
  - Natural climate variability is great
  - Although global temperature and national precipitation levels may be increasing, there is **no** definitive evidence in Virginia that supports either observation

http://climate.virginia.edu/vca/vca23_1/nature_change.html

Lower Shenandoah Valley Average Monthly Air Temperature (all stations)

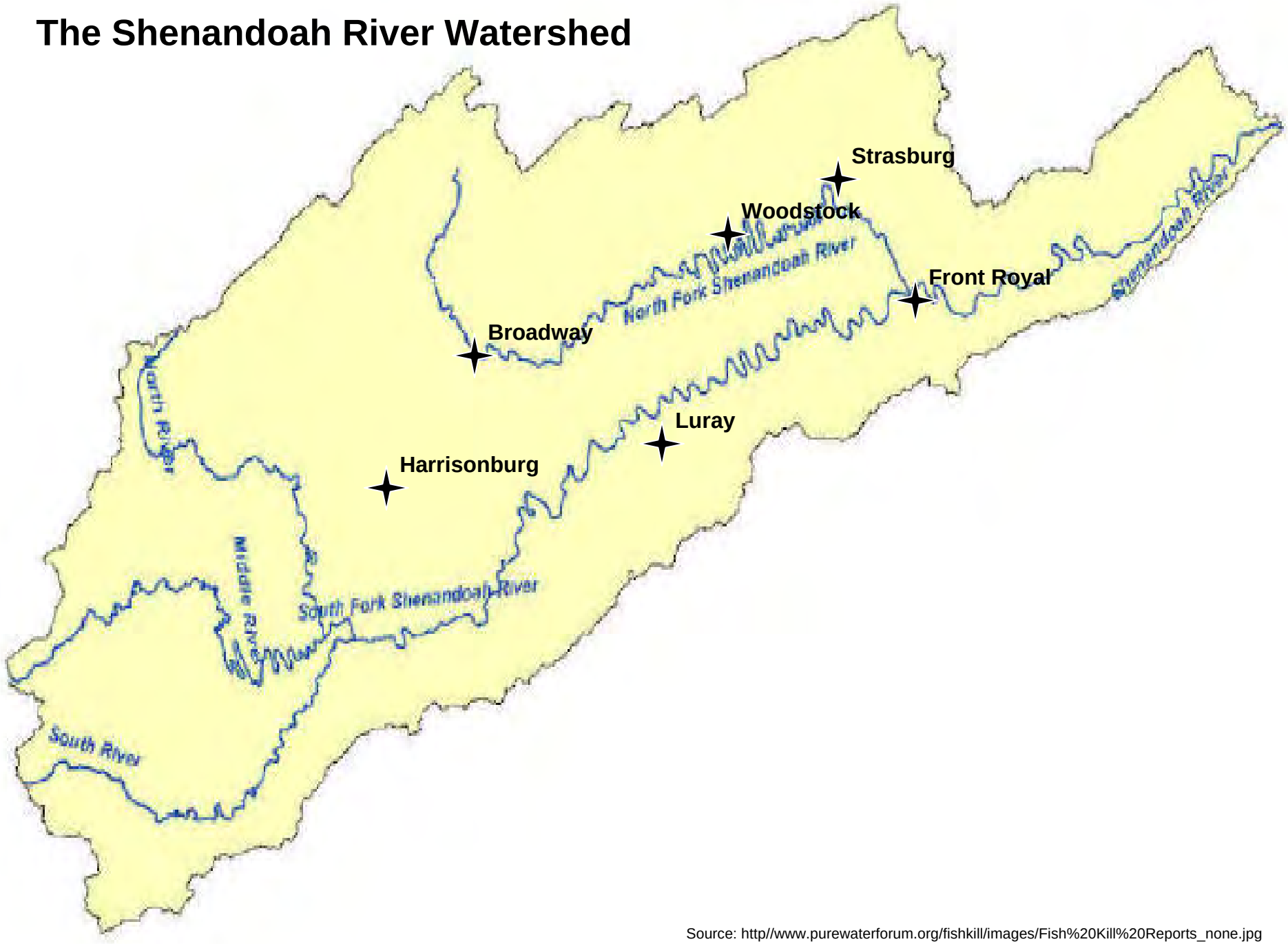


http://lwf.ncdc.noaa.gov/oa/climate/onlineprod/drought/xmgr.html

Sources of Water Temperature Data

Site Name	Latitude Longitude	River System	Elevation (Feet above sea level)
Front Royal WTP	38° 54′ N 78° 10′ W	Shenandoah: South Fork	468
Strasburg WTP	38° 59′ N 78° 22′ W	Shenandoah: North Fork	520
Woodstock WTP	38° 51′ N 78° 30′ W	Shenandoah: North Fork	760
Broadway WTP	38° 37′ N 78° 47′ W	Shenandoah: North Fork	1020
Moorefield, WV WTP	39°02 ′ N 78° 57′ W	South Branch Potomac: South Fork	834

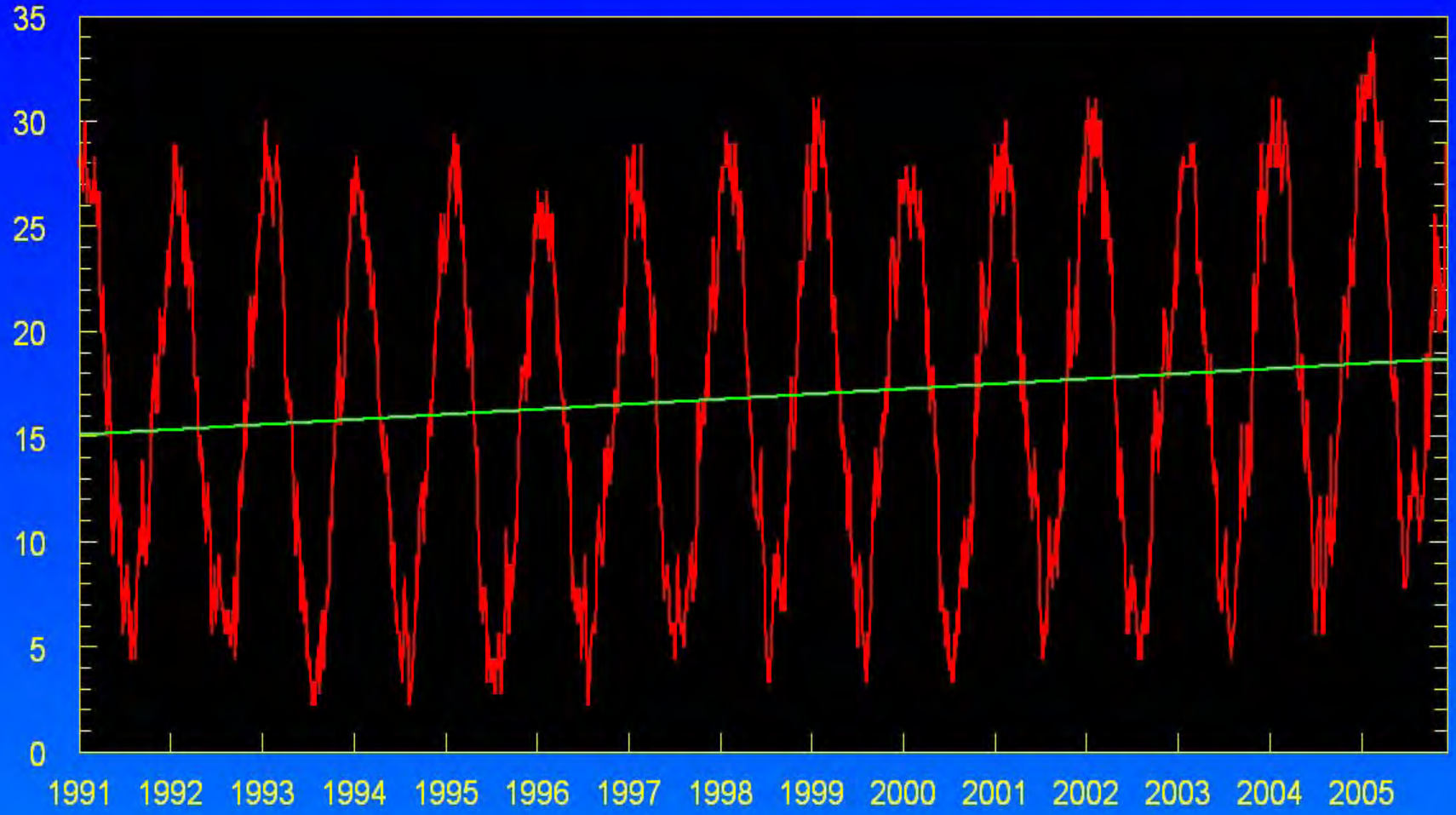
The Shenandoah River Watershed



Source: http//www.purewaterforum.org/fishkill/images/Fish%20Kill%20Reports_none.jpg

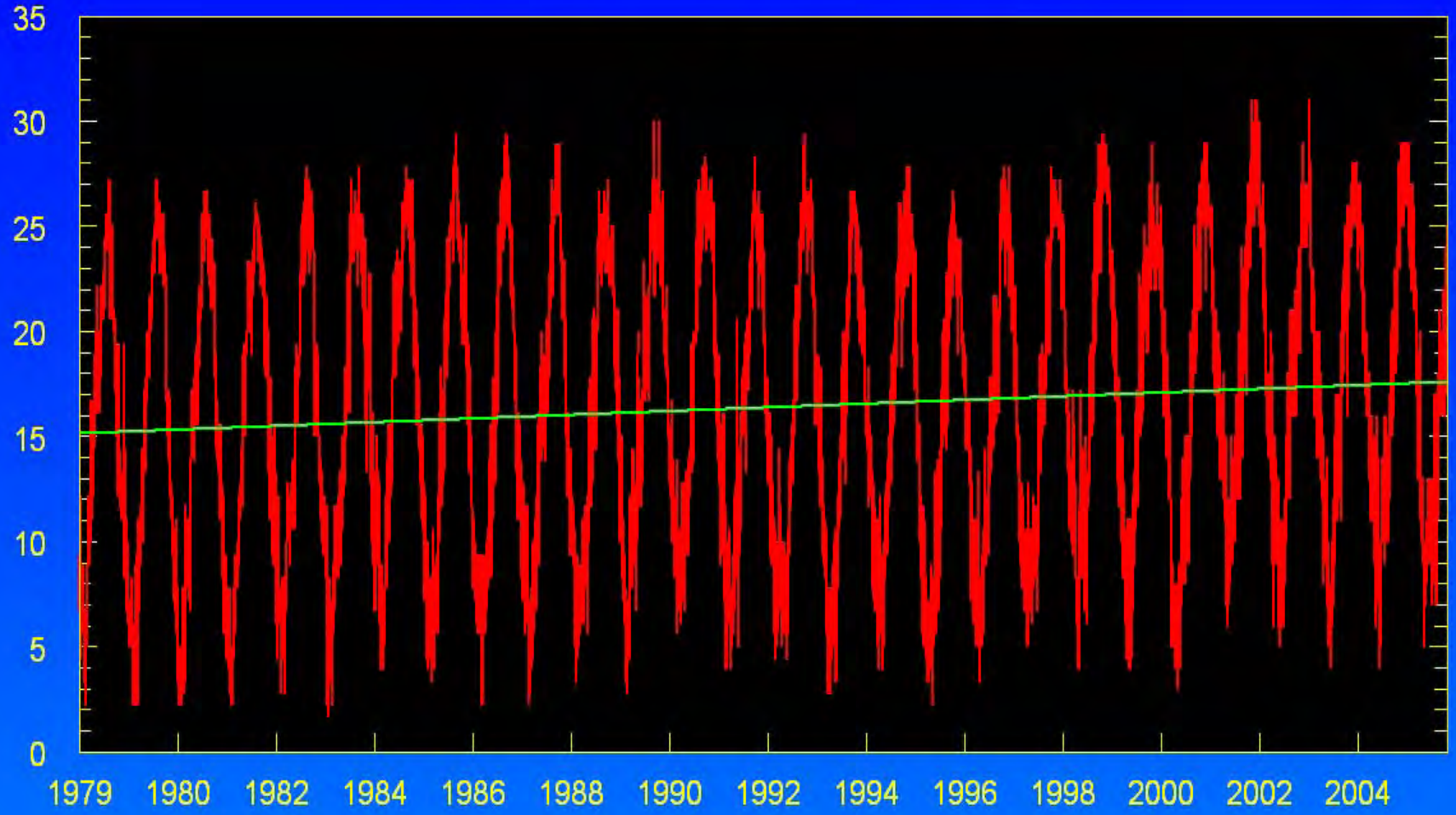
Daily Water Temperature Values

Front Royal: SF Shenandoah River

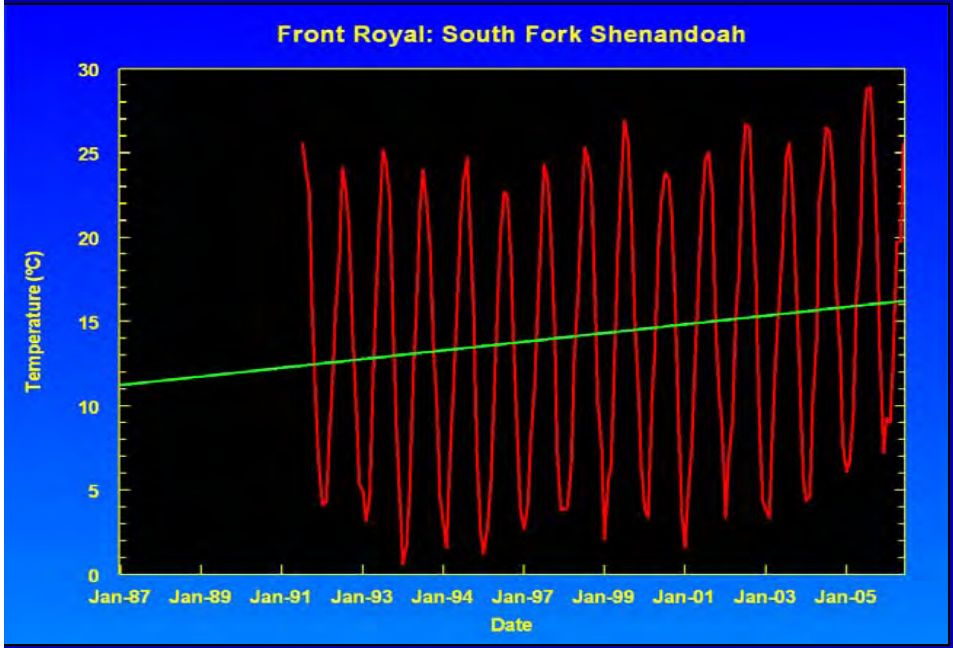


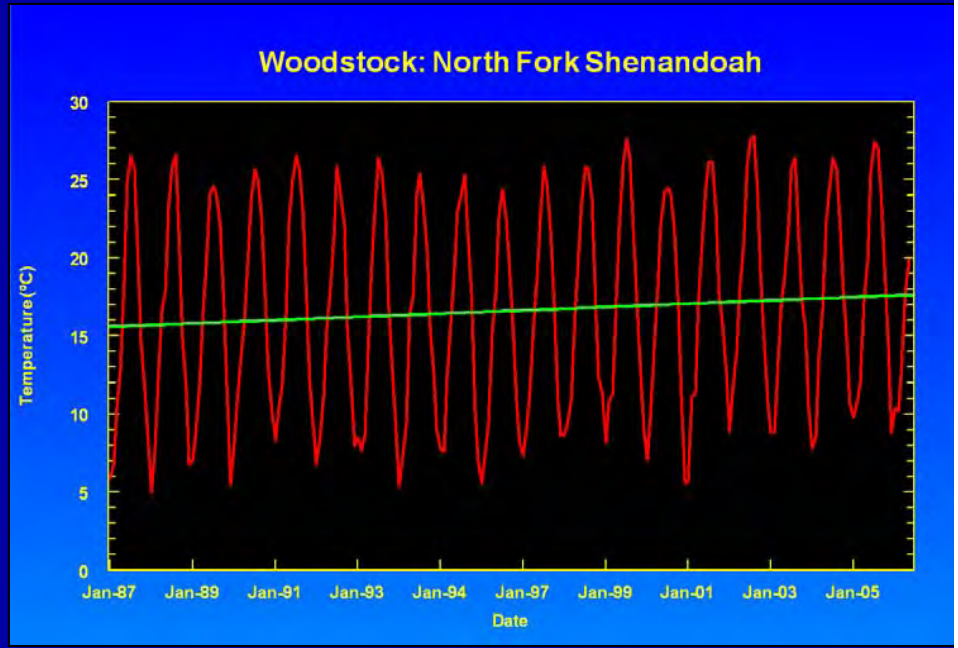
Daily Water Temperature Values

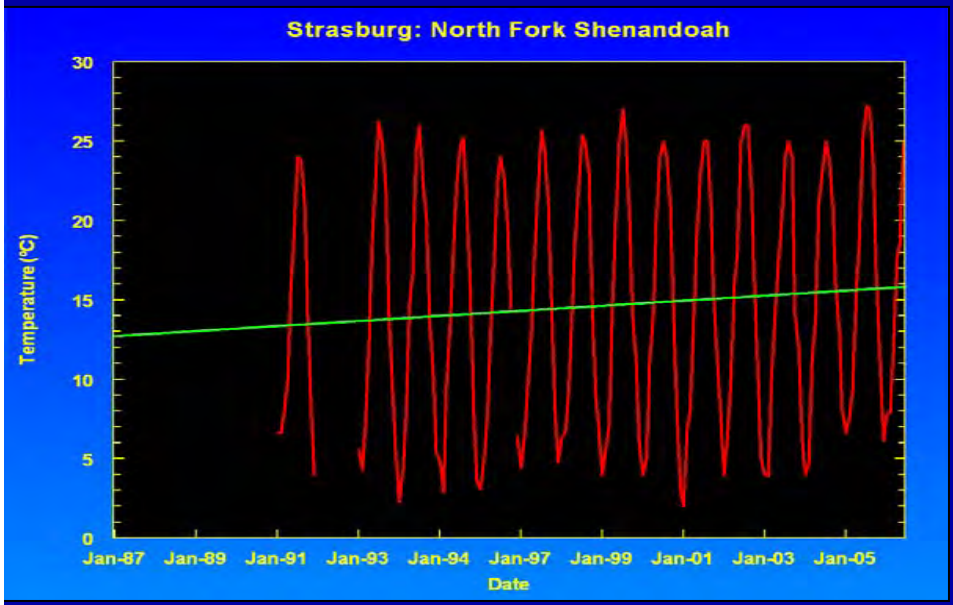
Woodstock: NF Shenandoah River

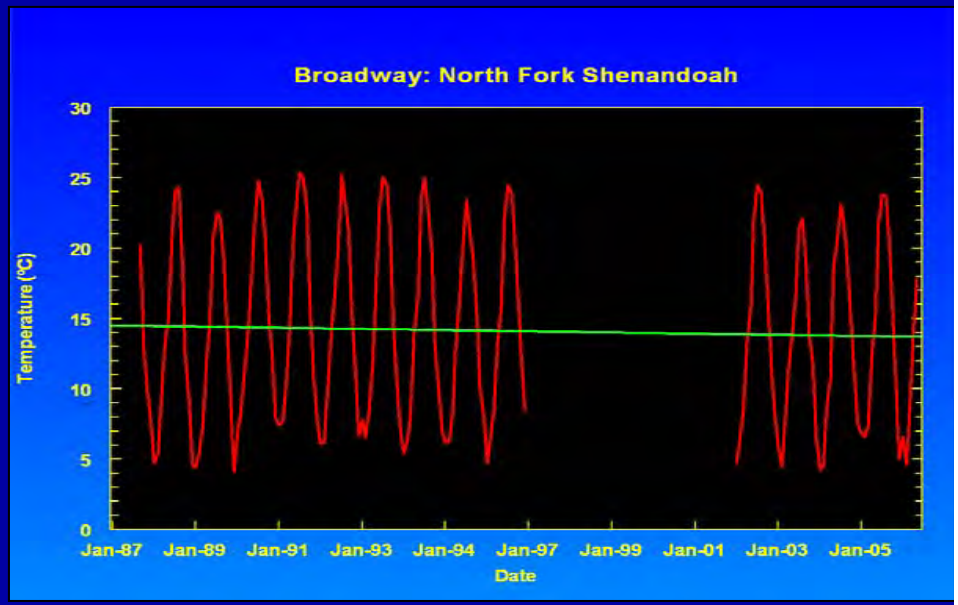


Monthly Average Water Temperatures at M&I Intake Stations



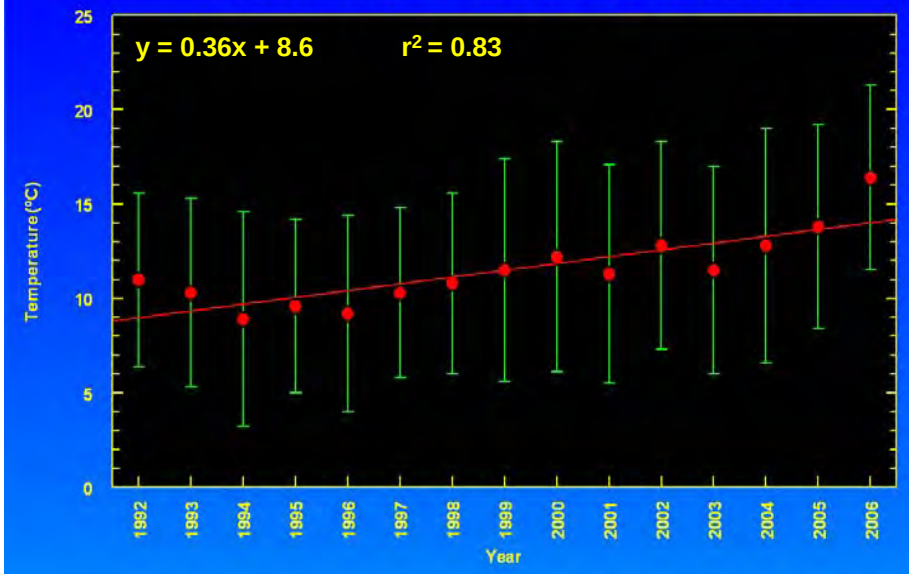




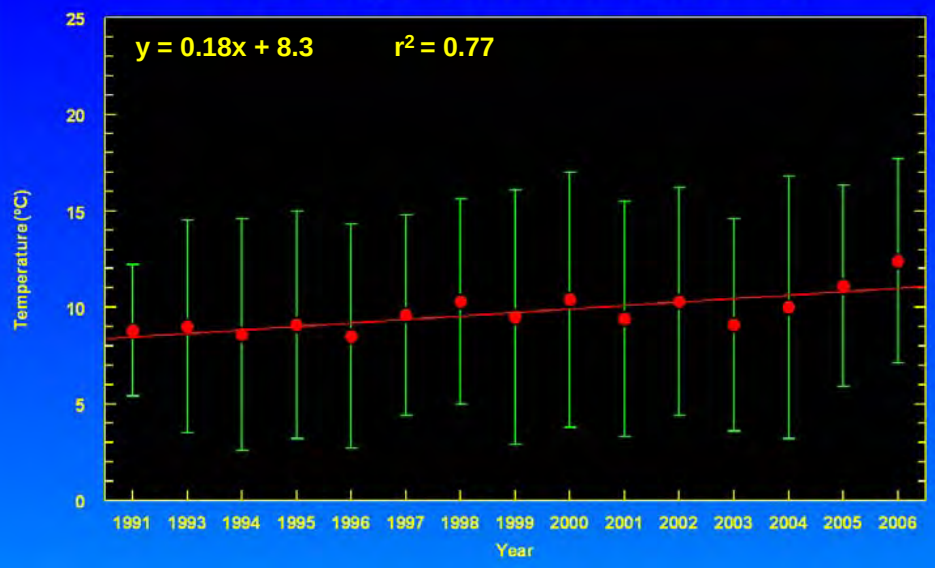


20 Week Temperature Averages at M&I Intake Stations

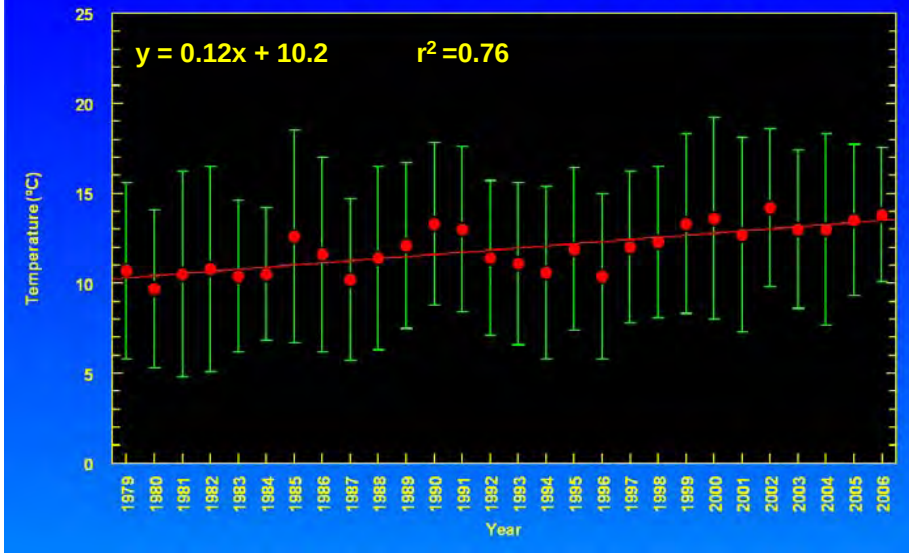
Front Royal: South Fork Shenandoah



Strasburg: North Fork Shenandoah



Woodstock: North Fork Shenandoah



Broadway: North Fork Shenandoah

January to June Water Temperature Analysis

Site Name	Years of Comparison	Average Temp. (C)	Standard Deviation	P value
Front Royal WTP	2004 - 2006 1992 - 1994	16.7 12.8	7.2 7.0	< 0.001
Strasburg WTP	2004 - 2006 1991, 1993, 1994	13.9 11.5	7.1 6.7	< 0.001
Woodstock WTP	2004 - 2006 1992-1994	15.3 13.5	6.1 6.2	< 0.001
Woodstock WTP	2004 - 2006 1979 - 1981	15.3 12.7	6.1 6.4	< 0.001
Broadway WTP	2004 – 2006 1992 - 1994	11.3 12.3	5.8 6.3	0.044
Moorefield, WV WTP	2004 - 2006 1992 - 1994	10.5 11.1	6.6 6.9	0.159

Spawning and Temperature

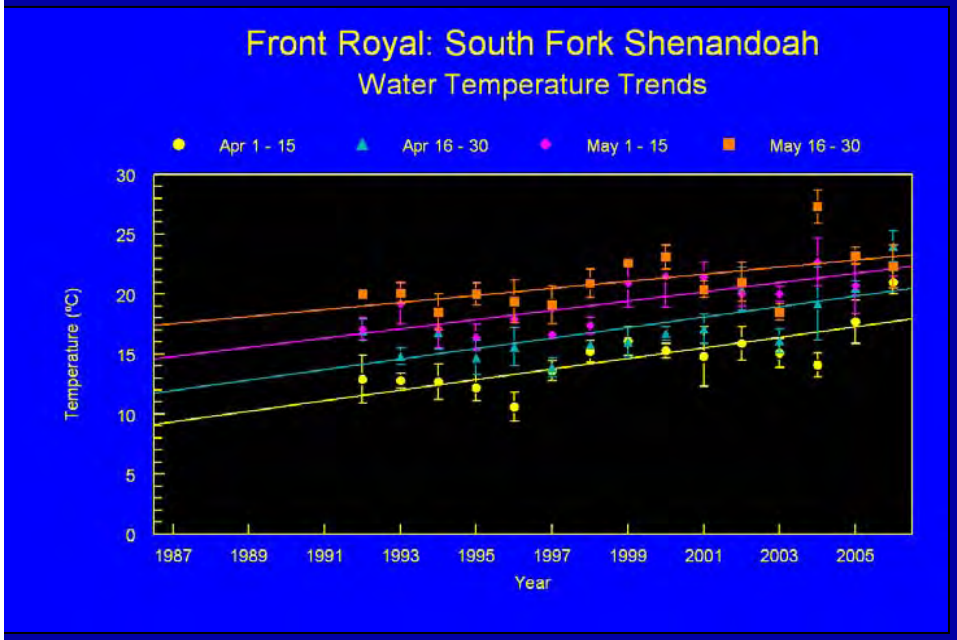
Smallmouth bass (*Micropterus dolomieu*)**:** Spawning occurs in 16 - 22^{o}C water, generally in mid-May “when the river clears and flows stabilized.” (Surber 1970)

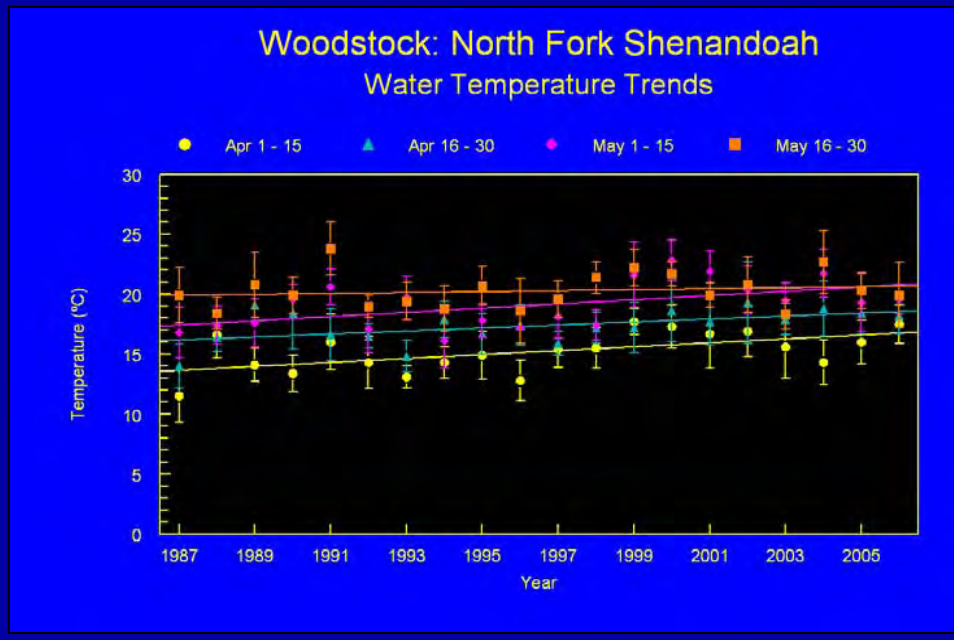
Redbreast sunfish (*Lepomis auritus*)**:** Water temperatures during breeding have been noted between 16 and 28^{o}C. Redbreasts have been observed guarding nests between May 13th and July. (Jenkins and Burkhead 1993)

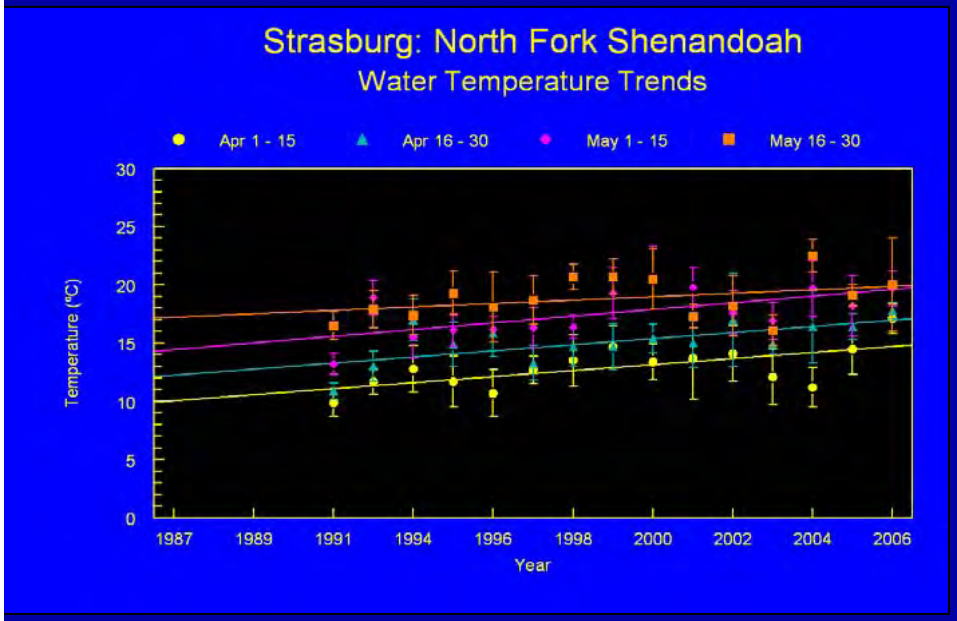
Northern hogsucker (*Hypentelium nigricans*)**:** Spawn in water between 11 and 23^{o}C during April and May; “…has an interesting reproductive repertoire that contrasts with that of other sucker genera.” (Jenkins and Burkhead 1993)

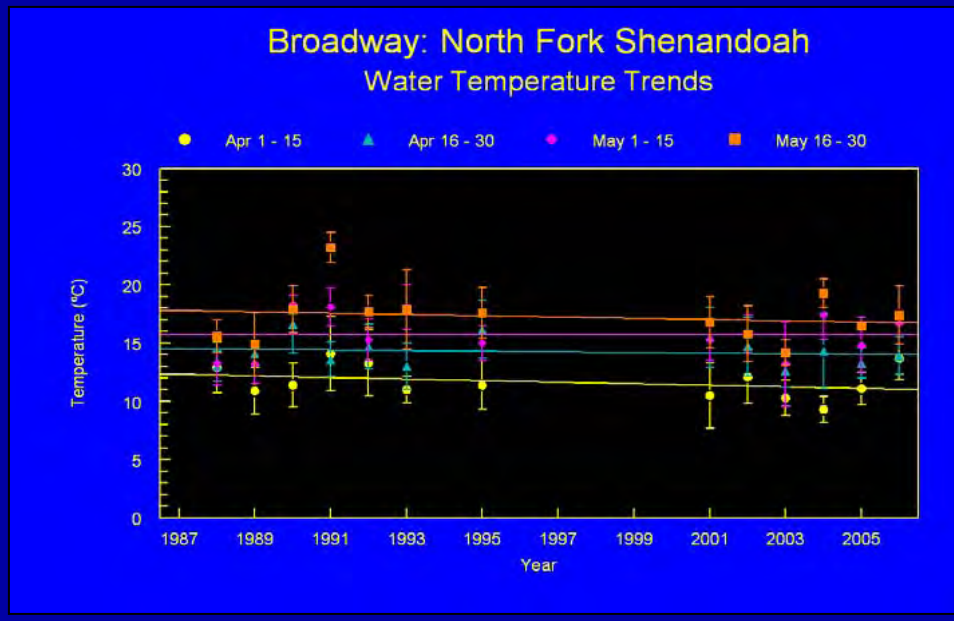
Largemouth bass (*Micropterus salmoides*)**:** Spawning occurs in 18 - 24^{o}C water (Carlander 1977); Normal spawning period in Virginia is May and June. (Jenkins and Burkhead 1993)

April and May Water Temperatures at M&I Intake Stations



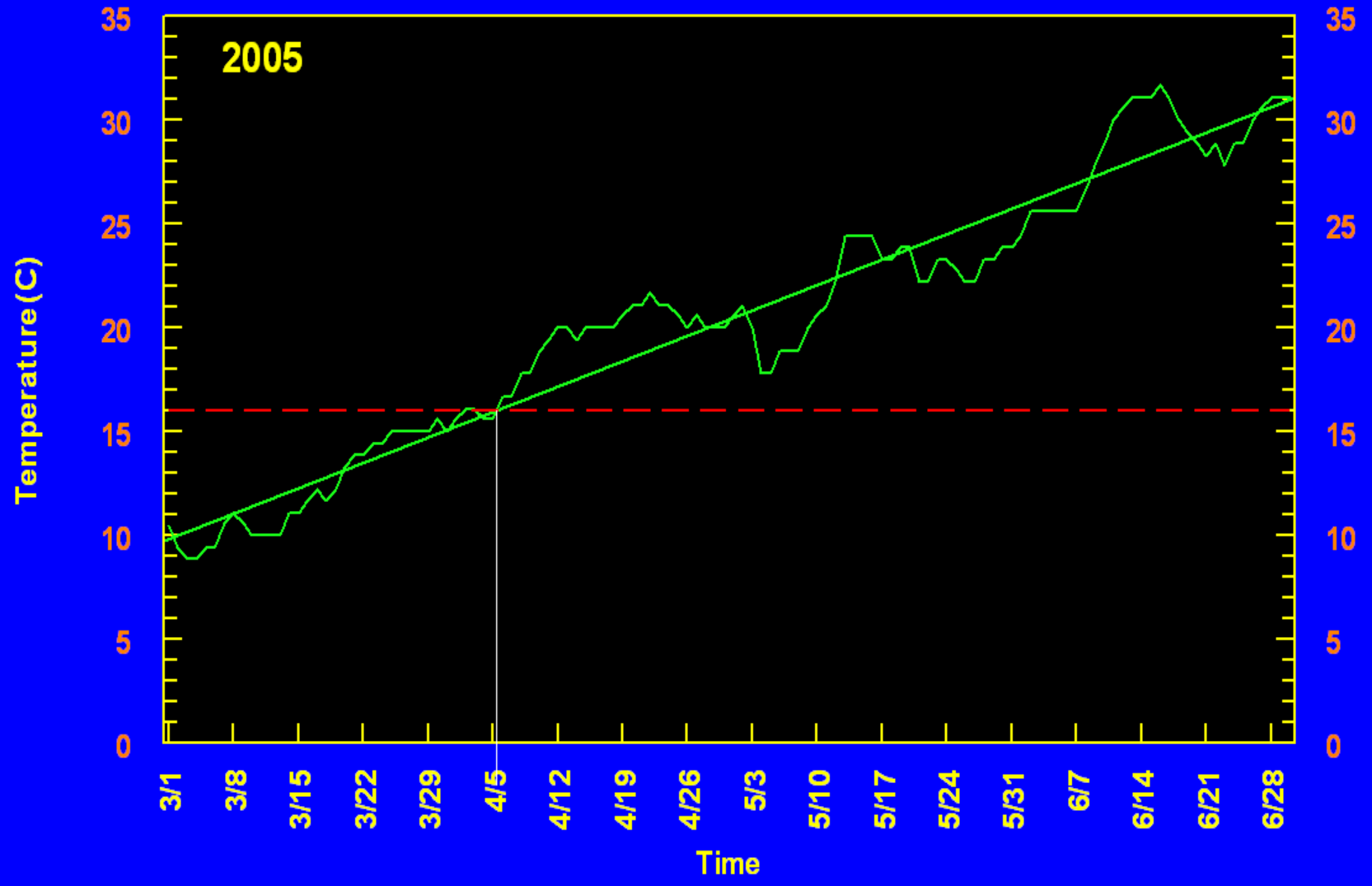






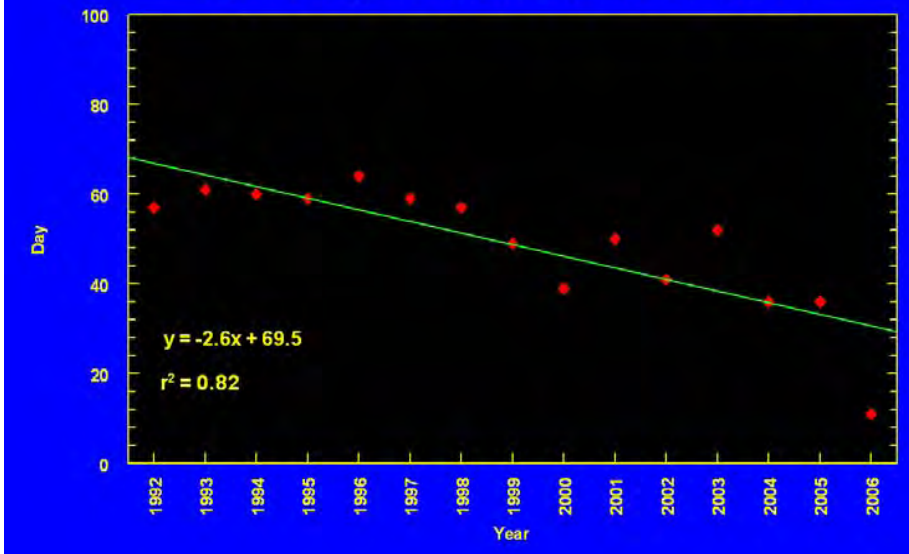
March to June Temperature

Front Royal - SF Shenandoah River

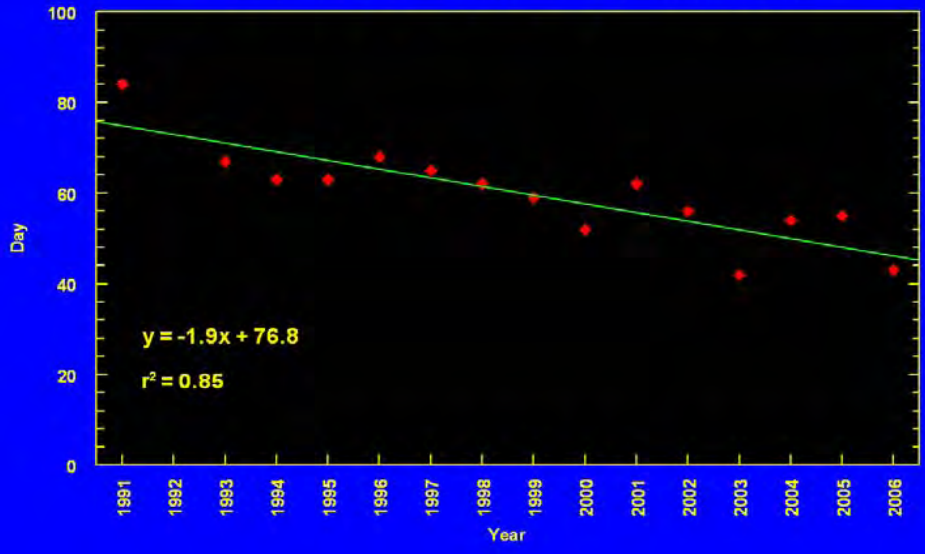


16° C : March 1 – June 30

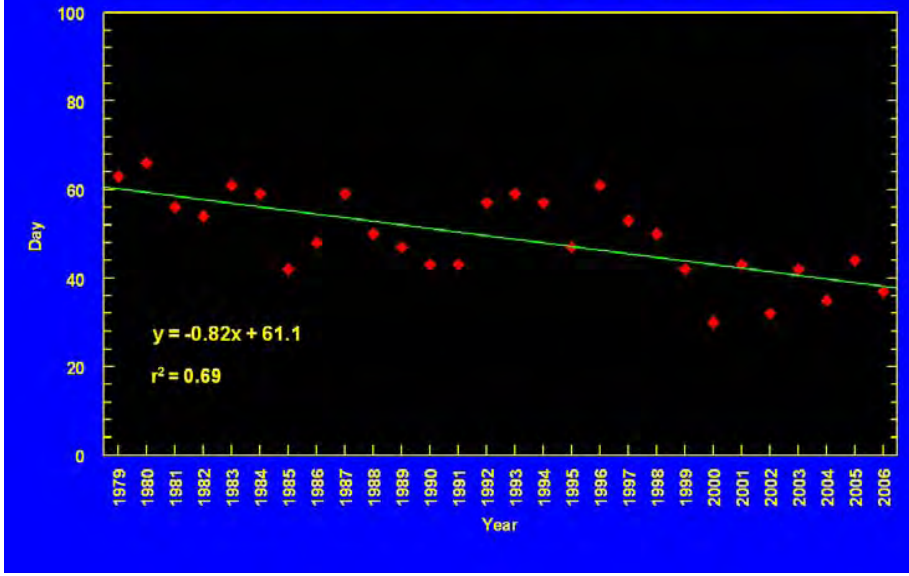
Front Royal: South Fork Shenandoah



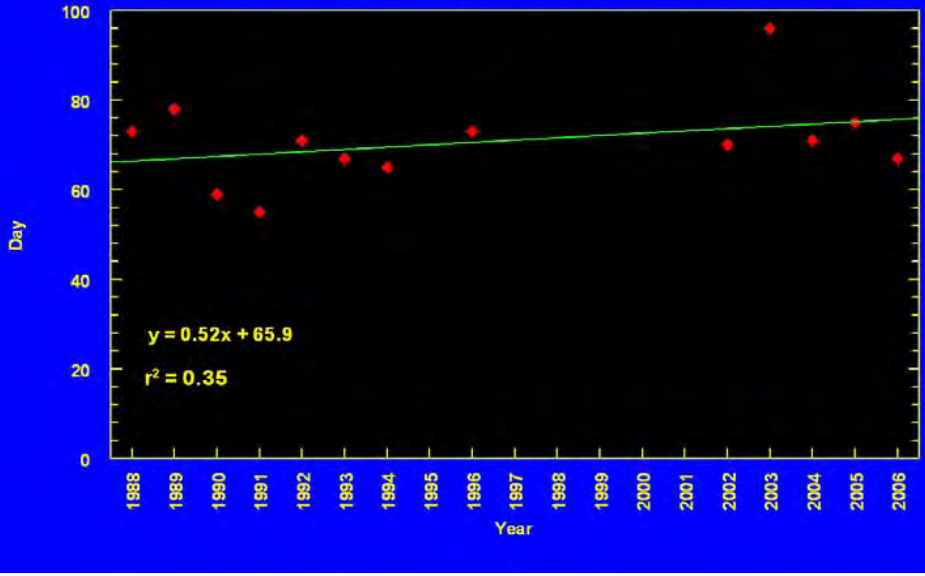
Strasburg: North Fork Shenandoah



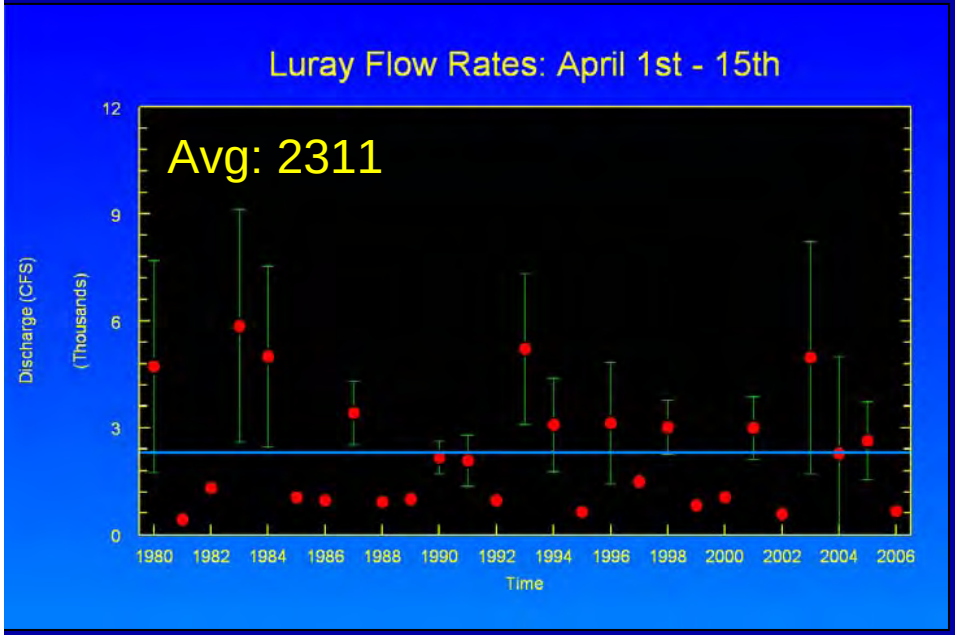
Woodstock: North Fork Shenandoah

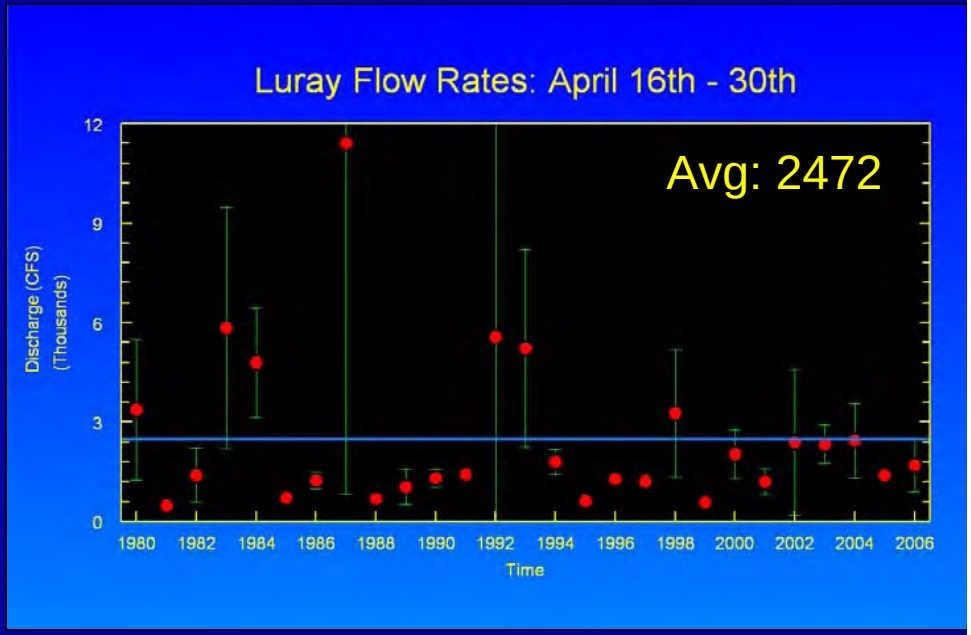


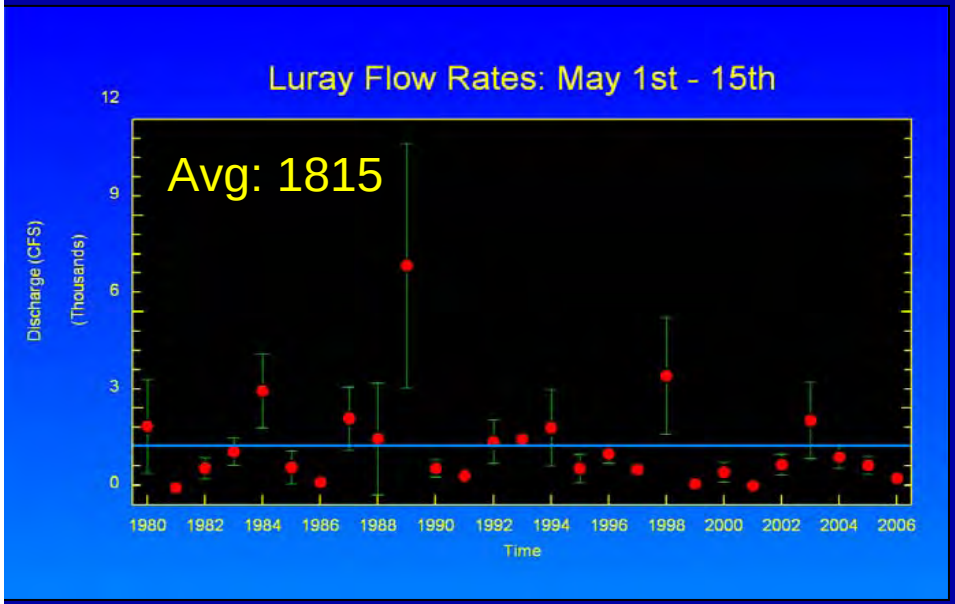
Broadway: North Fork Shenandoah

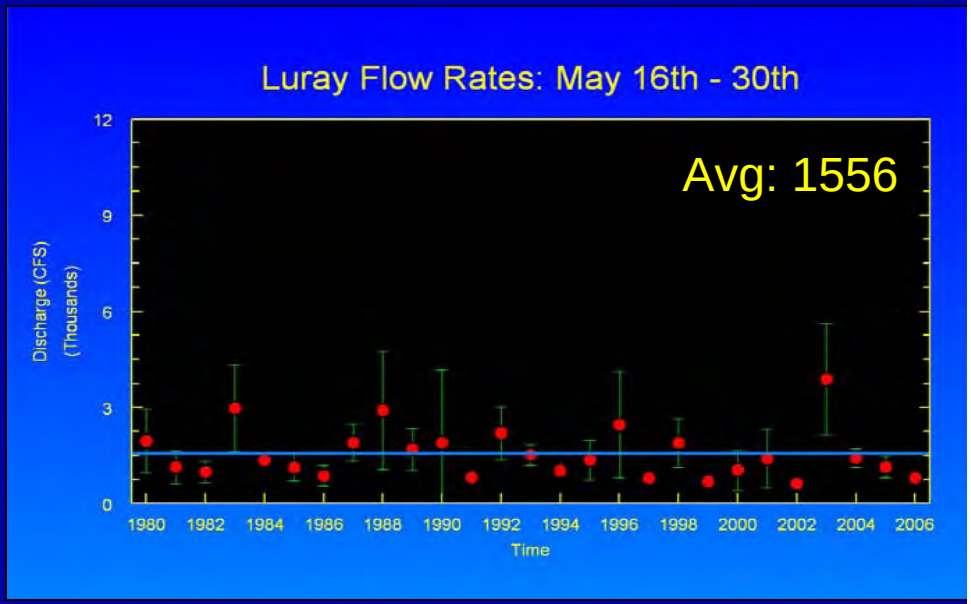


Luray Flow Rates: South Fork Shenandoah

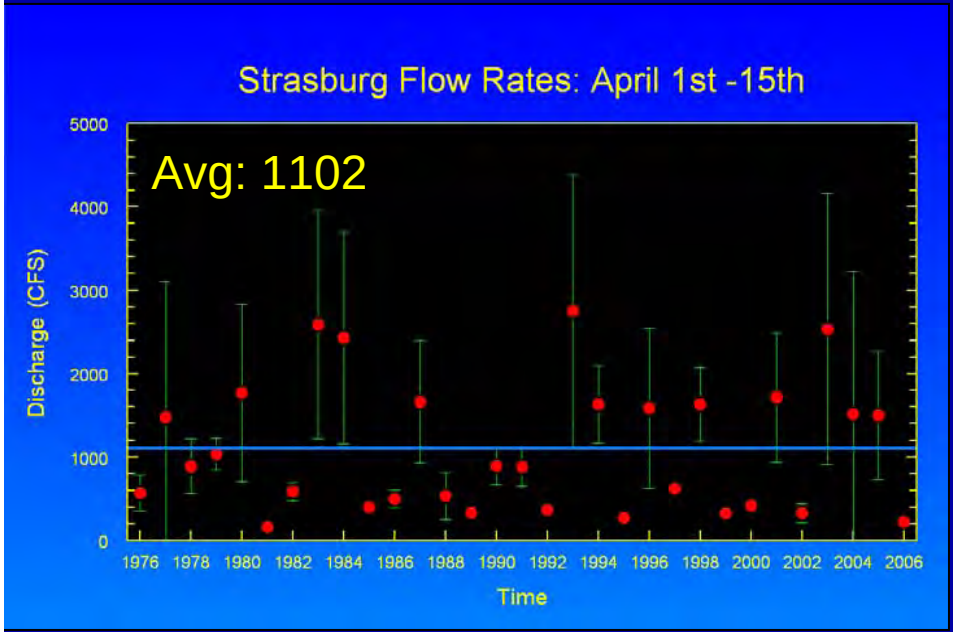


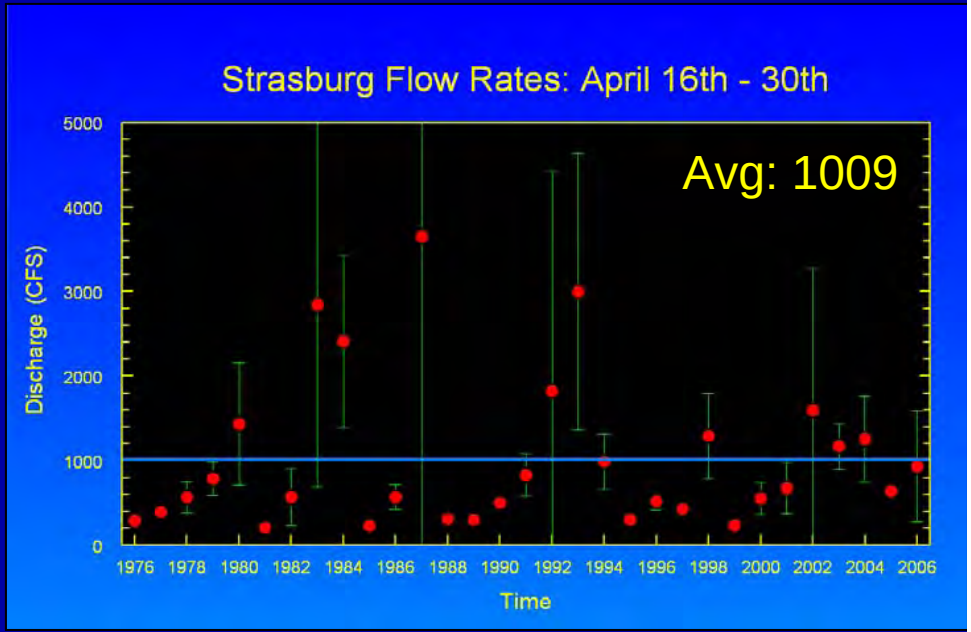


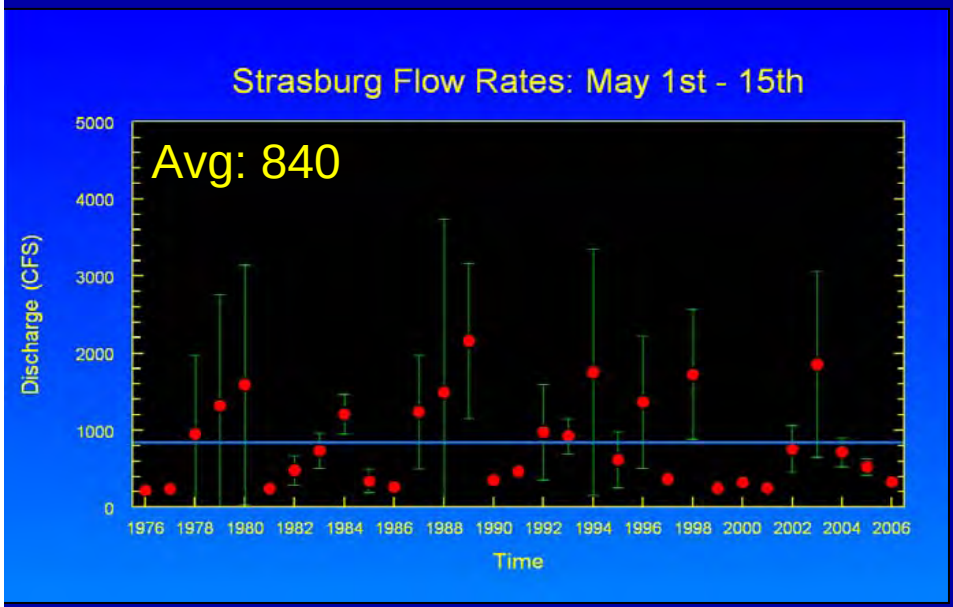


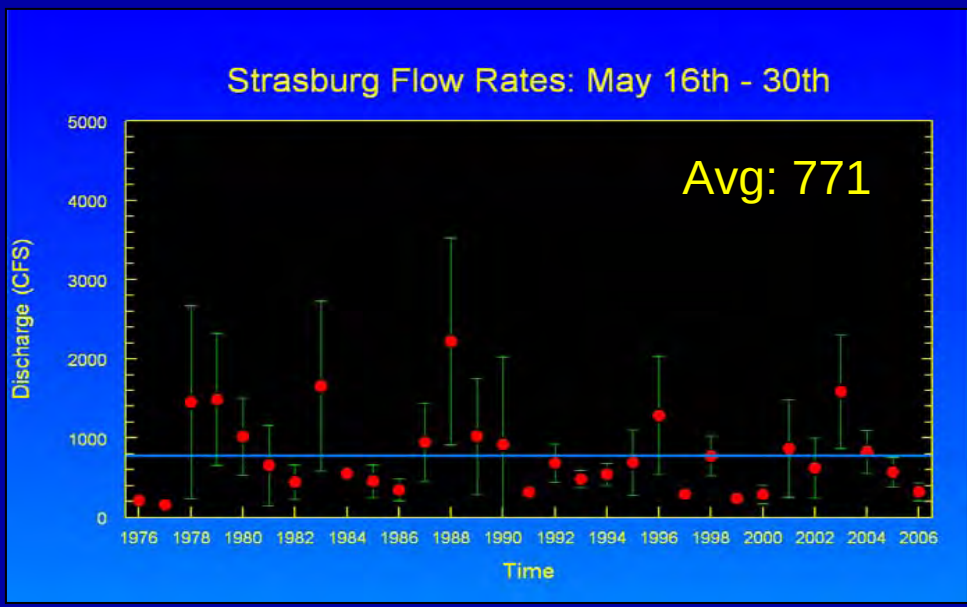


Strasburg Flow Rates: North Fork Shenandoah









Conclusions:

- There has been no observed trend in air temperatures coincident with the increase in river water temperatures
- When 2004, 2005, and 2006 data were compared to the earliest data set at Woodstock, Strasburg and Front Royal:
  - Annual water temperature averages increased by 1.5 to 2.9^{O}C
  - January to June temperature averages increased by 2.4 to 3.9^{O}C
  - Spawning temperatures occurred 3-4 weeks earlier
- Most fish kills occurred in the reach of the river system where temperature increases were observed
- No fish kills were officially reported upstream of Broadway, VA
- It is possible that (with the greater discharge and more dramatic fluctuations that typically occur in April of most years) fish that have historically spawned in mid-May are additionally stressed. The added stress may exacerbate their already weakened condition enough to cause mortality.

Acknowledgements

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- Karen Anderson: Friends of the Shenandoah River
- Ross E. Clem: Town of Broadway WTP
- Robert Heavener: Harrisonburg-Rockingham Regional Sewer Authority
- Bill Henry: Town of Moorefield, WV WTP Don Kain: VDEQ
- William Kusar: Town of Front Royal WTP
- Christopher Ritenour: Town of Strasburg WTP
- Charles Weaver: Town of Woodstock WTP
- JMU - Chemistry Department
- VA State Climatology Office – Dr. Pat Michaels
- Steve Reeser: VDGIF

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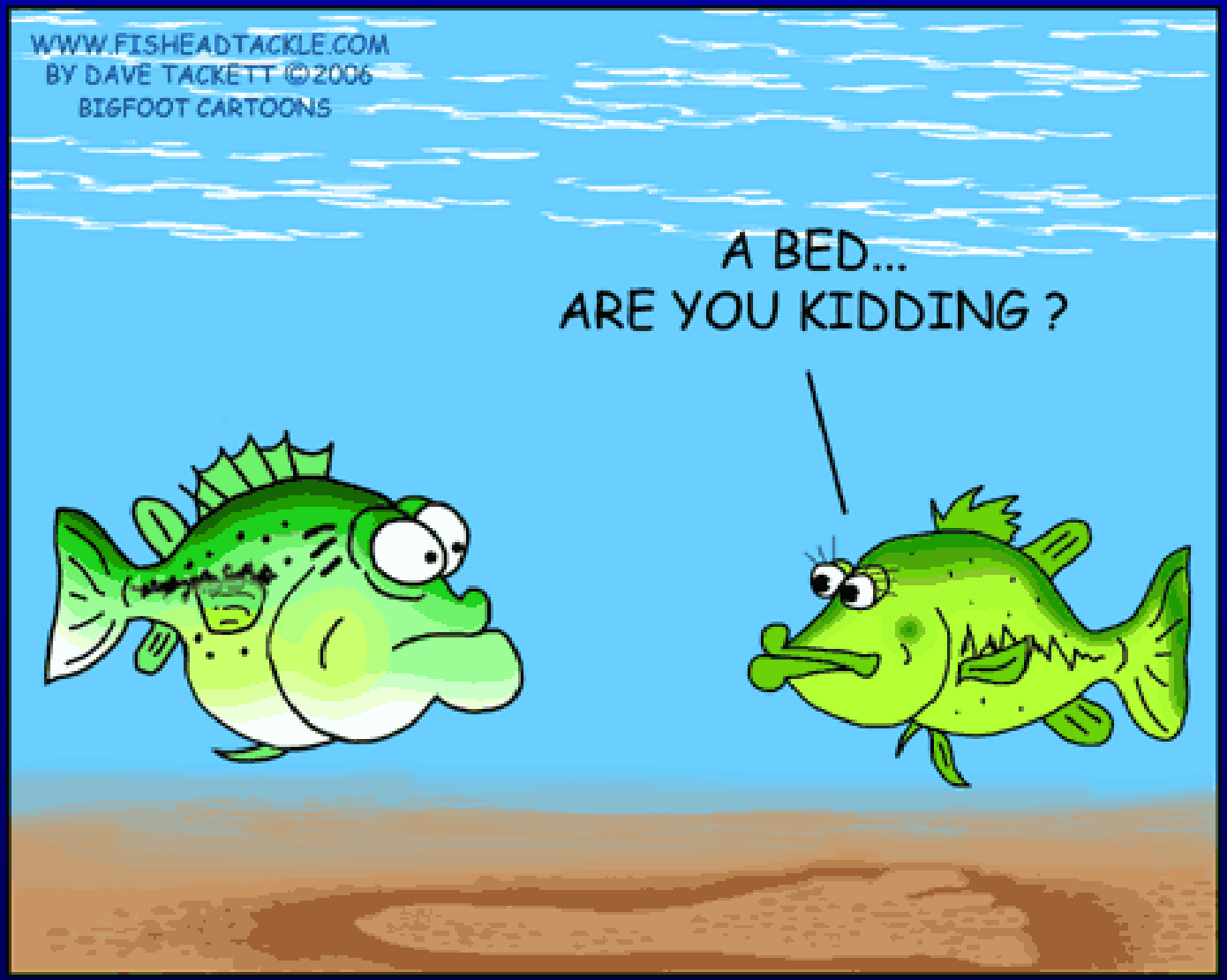
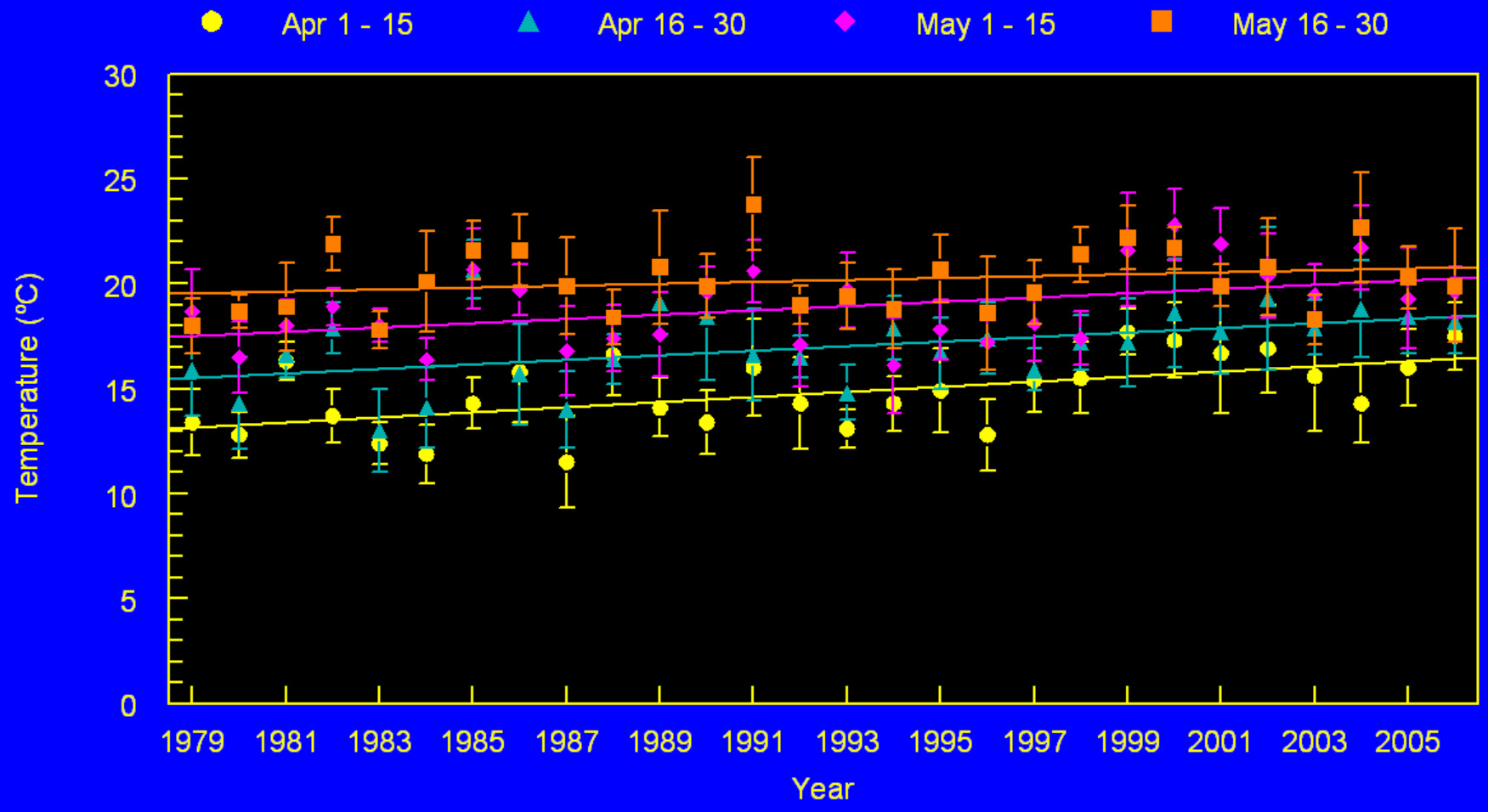
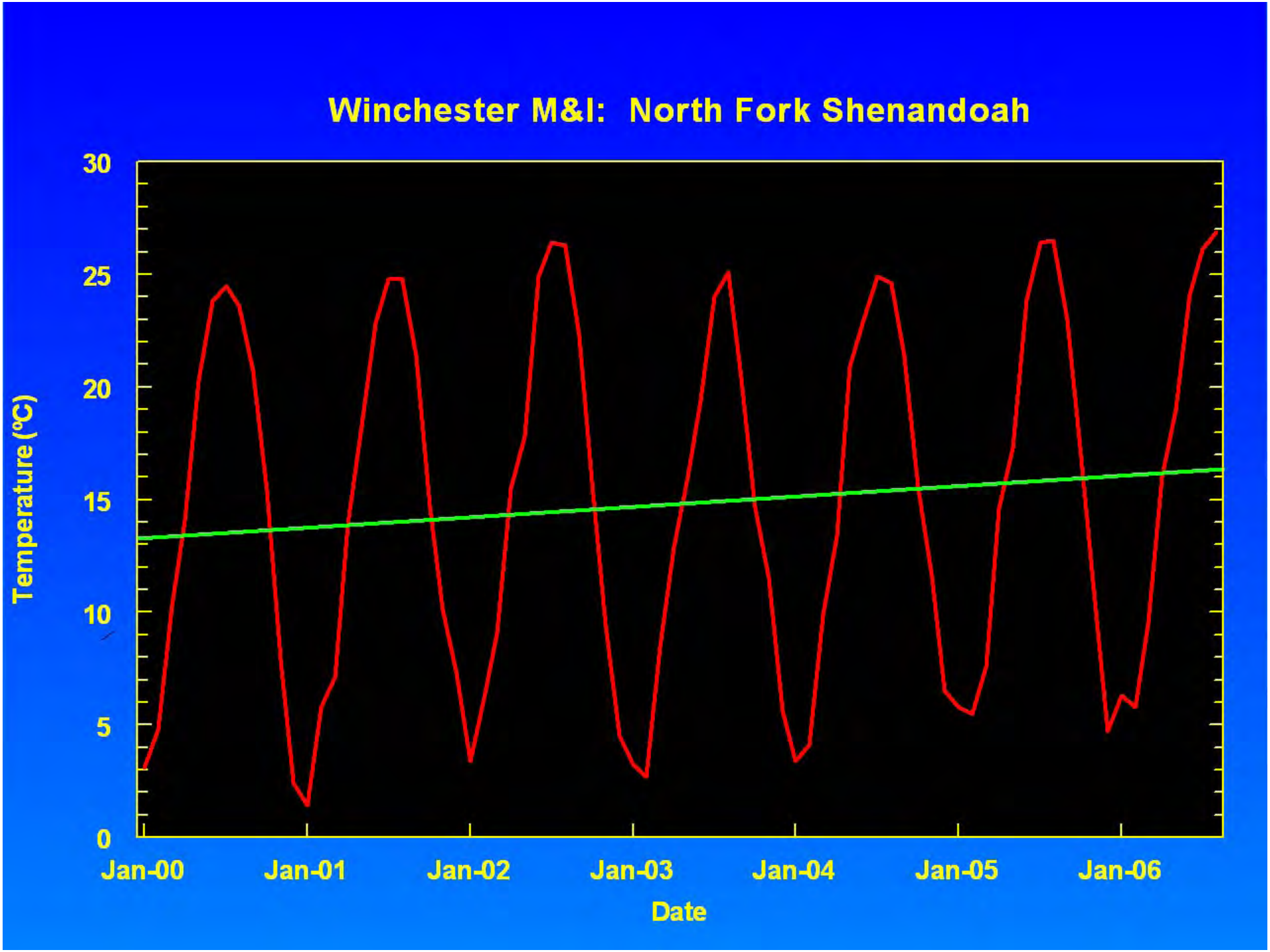


Any Questions ??

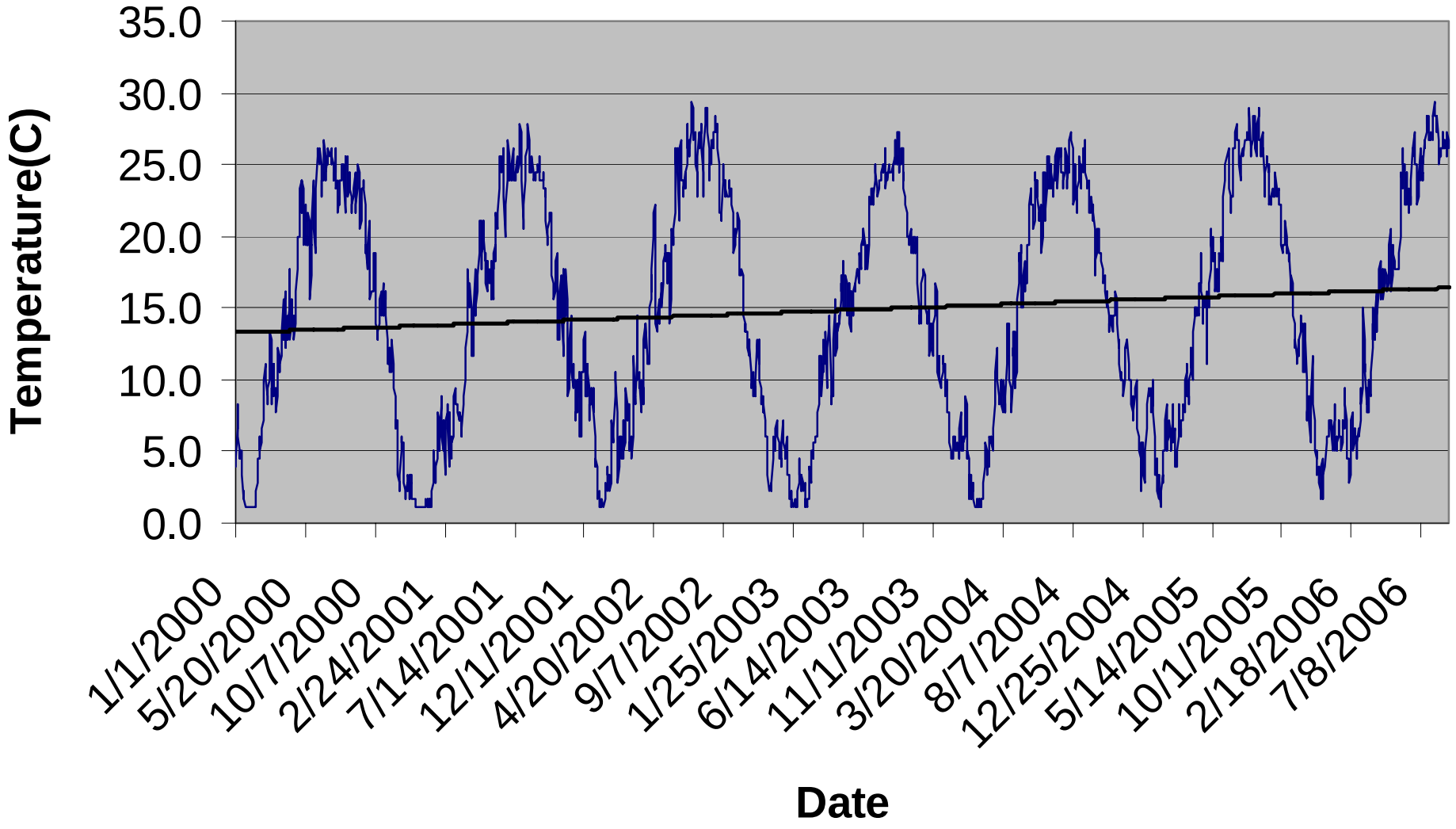
Woodstock: North Fork Shenandoah

Water Temperature Trends

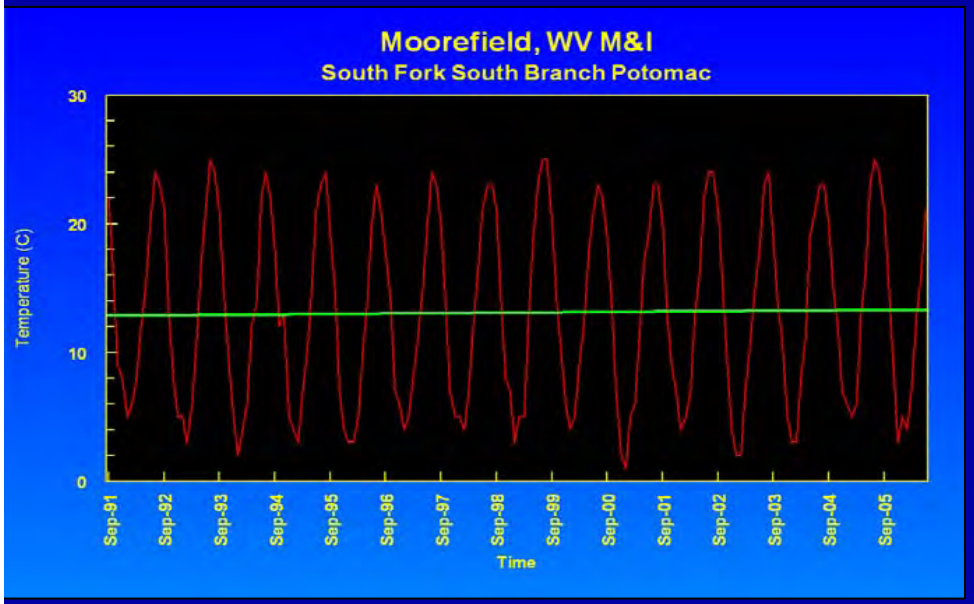


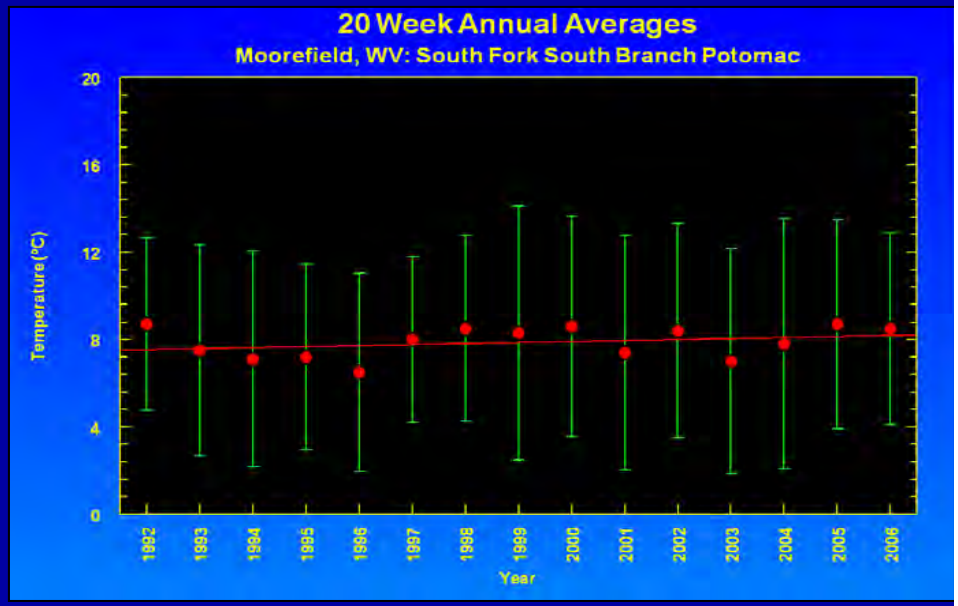

Winchester M&I: North Fork Shenandoah
30
25
20
15
10
5
0
Temperature (°C)
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Jan-06
Date

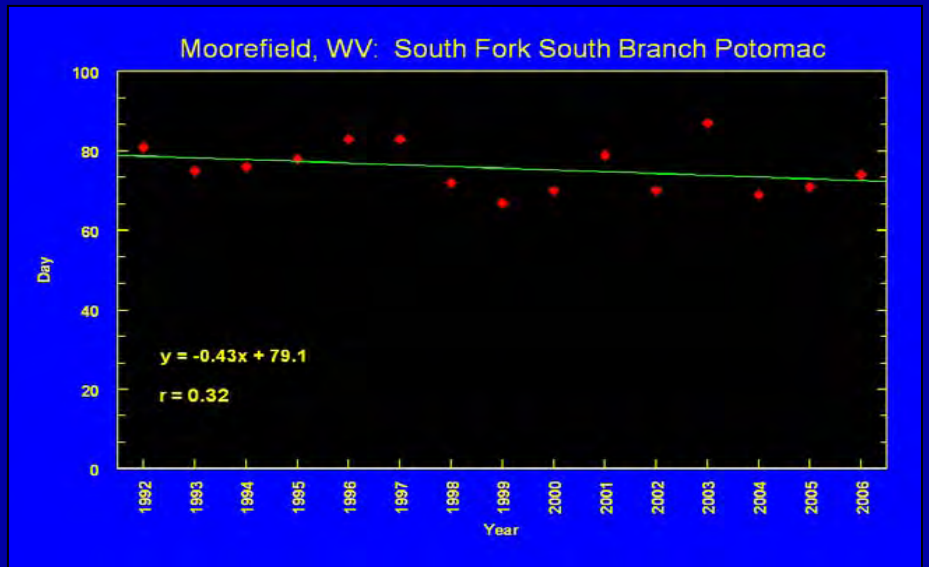
Winchester M&I: Daily Water Temperature

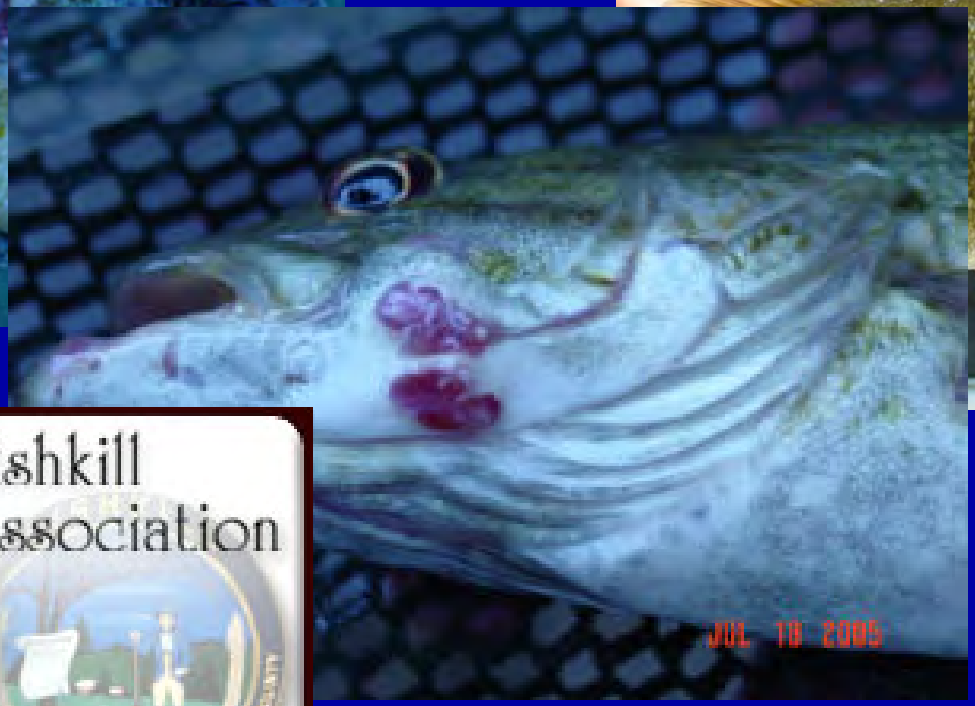


Moorefield, WV WTP: Average Annual, 20 Week and Calculated Spawning Temperatures









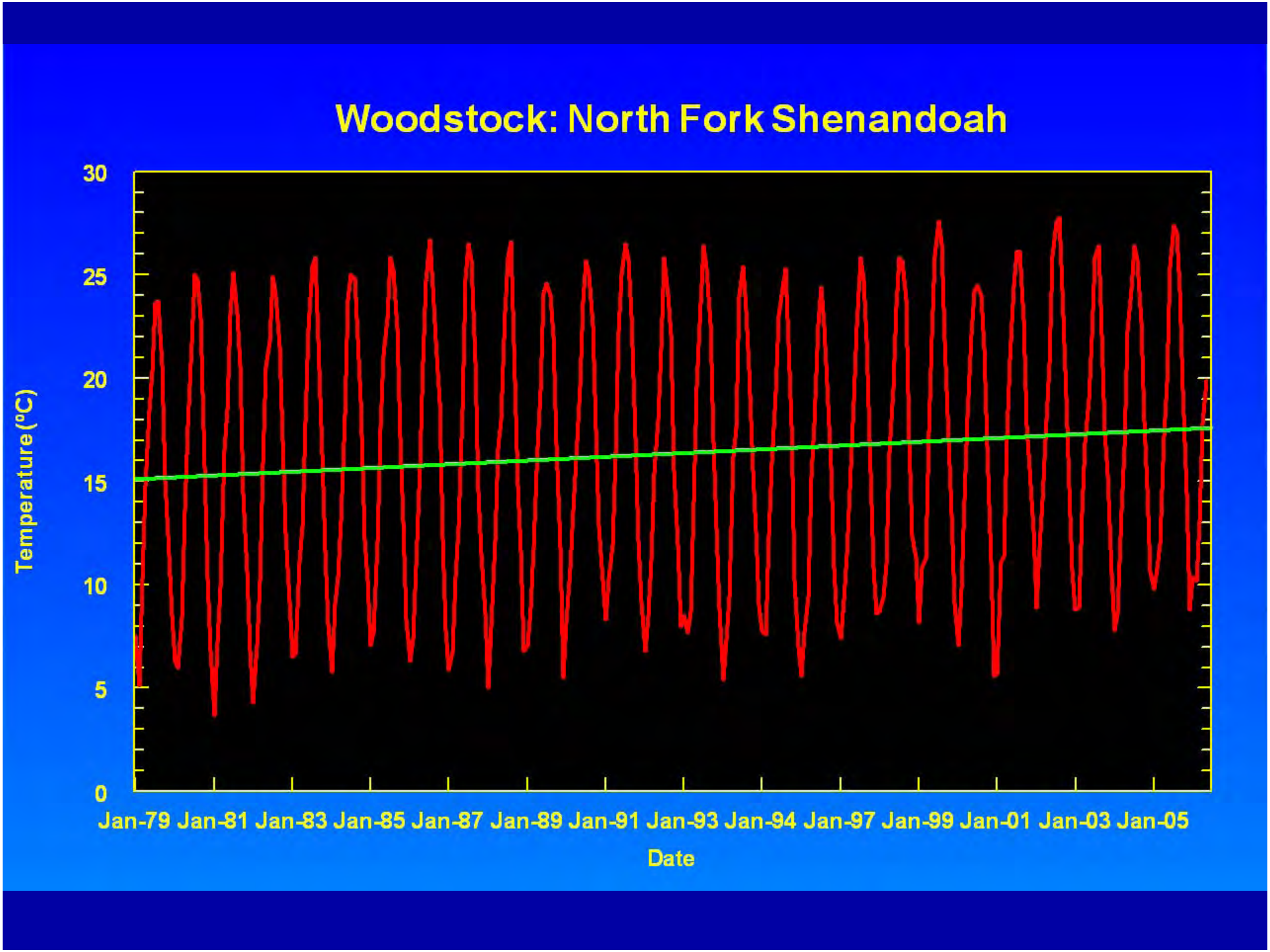
The Fishkill
Business Association

PO Box 353 845 896-1626

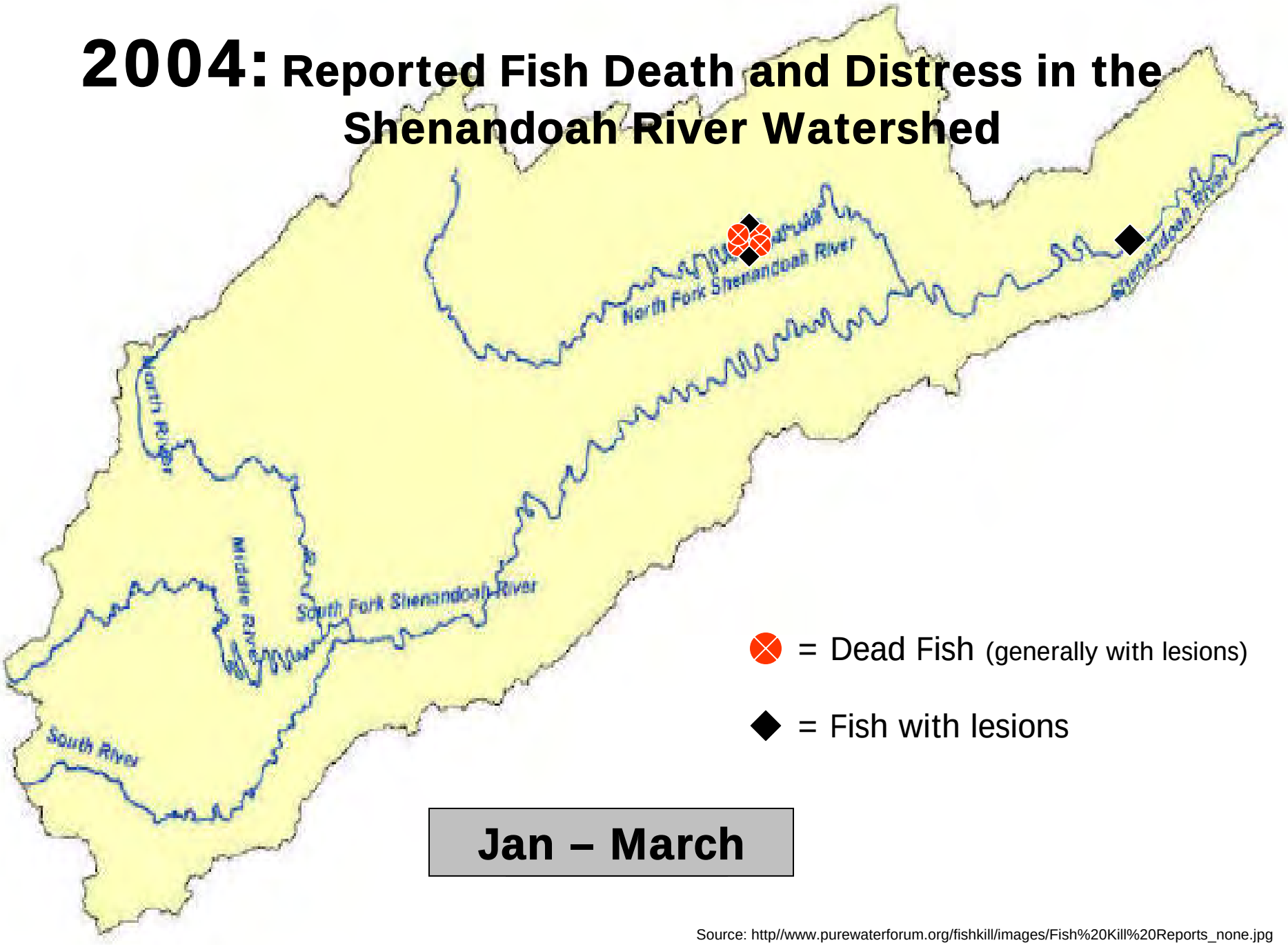
Shenandoah River Fish Kill Task Force

- Formed by VDEQ and VDGIF in July of 2005:
  - Includes representatives of state and federal agencies, riparian landowners, anglers, academia and other stakeholders
  - To evaluate potential factors resulting in fish lesions and mortality to identify the cause(s) of the fish kills and recommend corrective actions

- Specific studies include:
  - Water quality sampling by DEQ during storm events
  - Comprehensive fish health evaluation by USGS
  - USGS “around the clock” monitoring
  - Genomic DNA pathogen evaluation by VCU
  - Benthic invertebrate study by VA Tech
  - Climatological and hydrologic data assessment by JMU

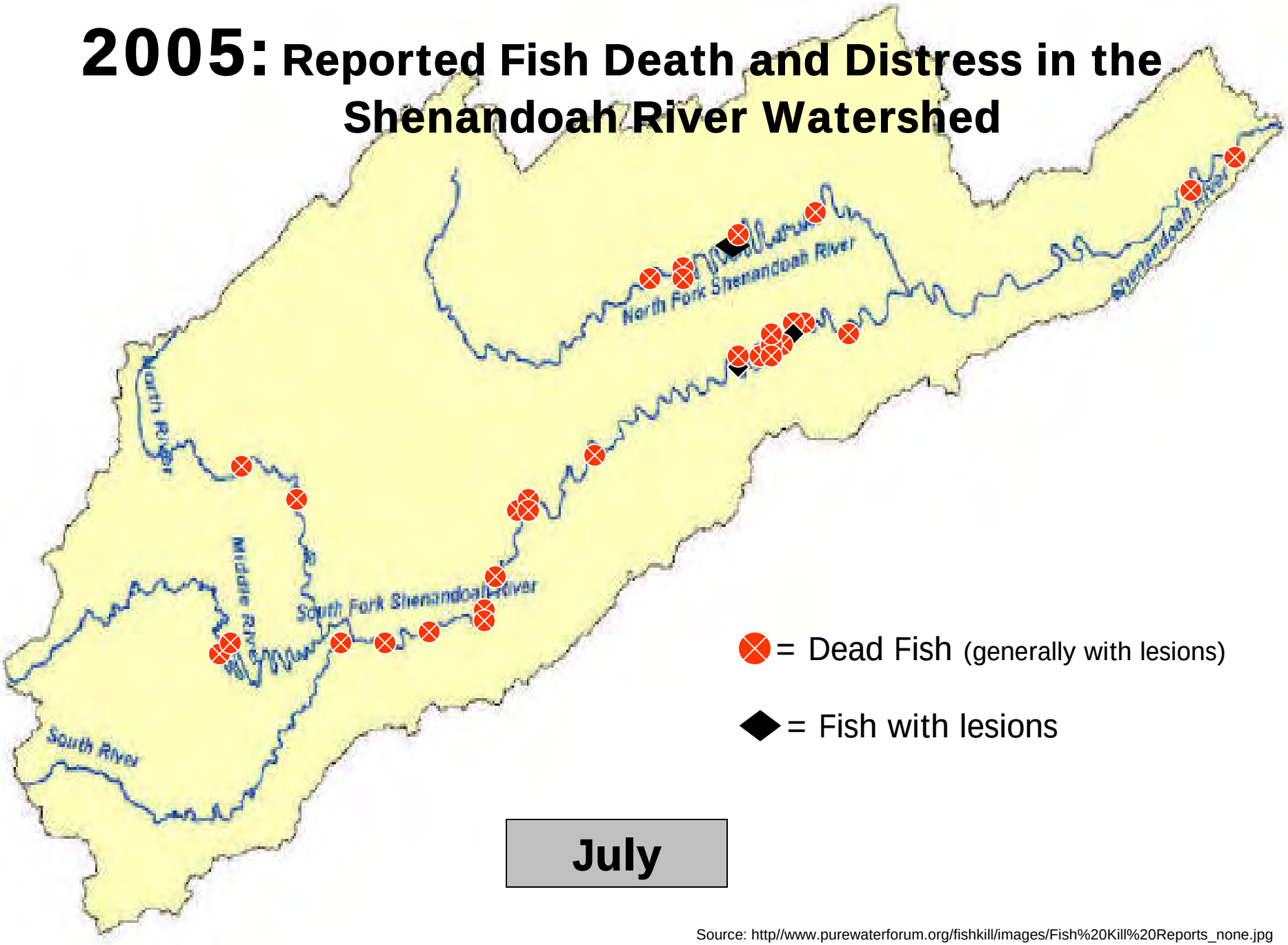

Woodstock: North Fork Shenandoah
Temperature (°C)
30
25
20
15
10
5
0
Jan-79 Jan-81 Jan-83 Jan-85 Jan-87 Jan-89 Jan-91 Jan-93 Jan-94 Jan-97 Jan-99 Jan-01 Jan-03 Jan-05
Date

2004: Reported Fish Death and Distress in the Shenandoah River Watershed



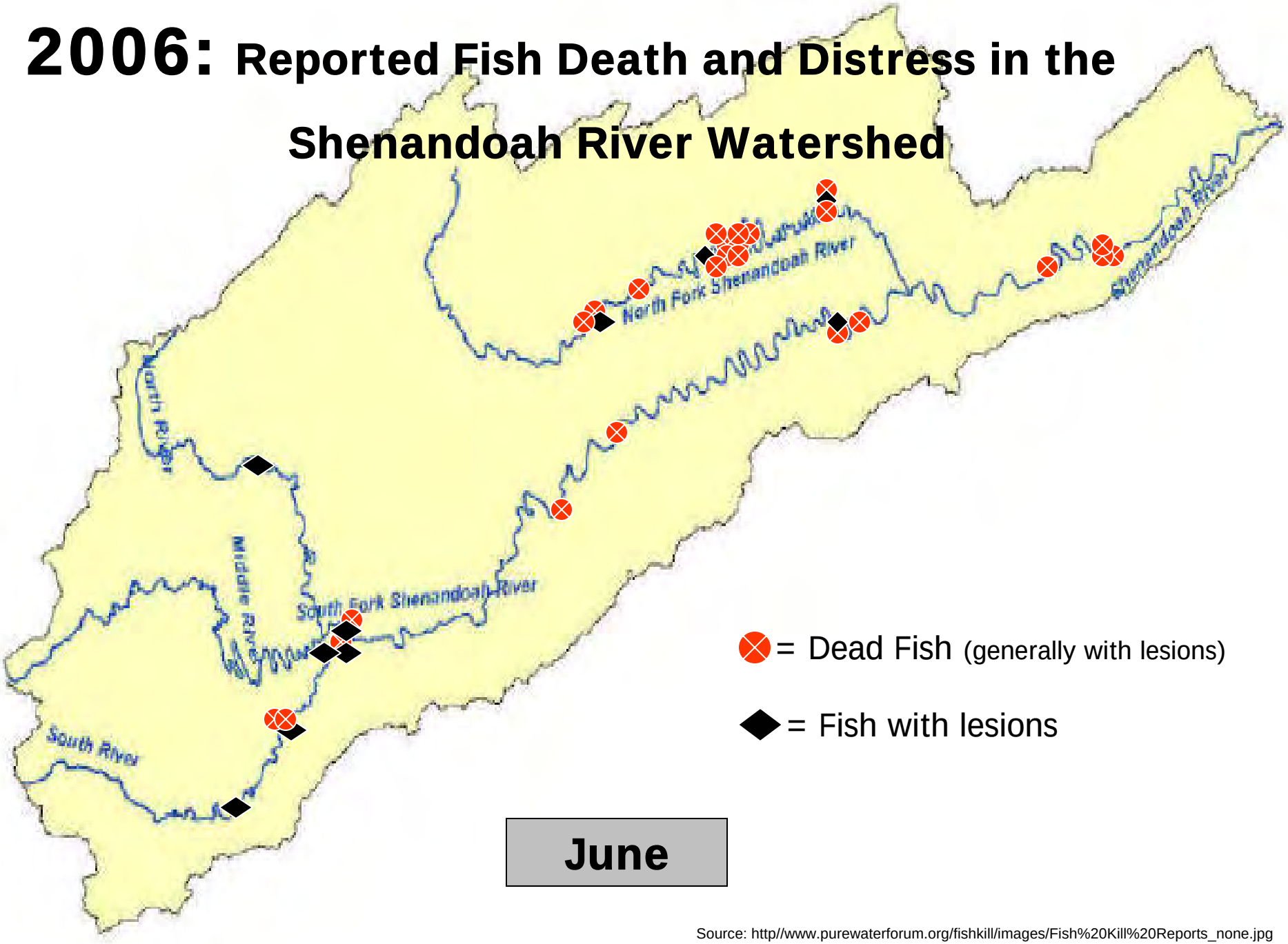
Source: http//www.purewaterforum.org/fishkill/images/Fish%20Kill%20Reports_none.jpg

2005: Reported Fish Death and Distress in the Shenandoah River Watershed



Source: http//www.purewaterforum.org/fishkill/images/Fish%20Kill%20Reports_none.jpg

2006: Reported Fish Death and Distress in the Shenandoah River Watershed



Source: http//www.purewaterforum.org/fishkill/images/Fish%20Kill%20Reports_none.jpg

There are three types of lies: "Lies - damned lies - and statistics."

Aphorism attributed to Benjamin Disraeli by Leonard Henry Courtney 1895