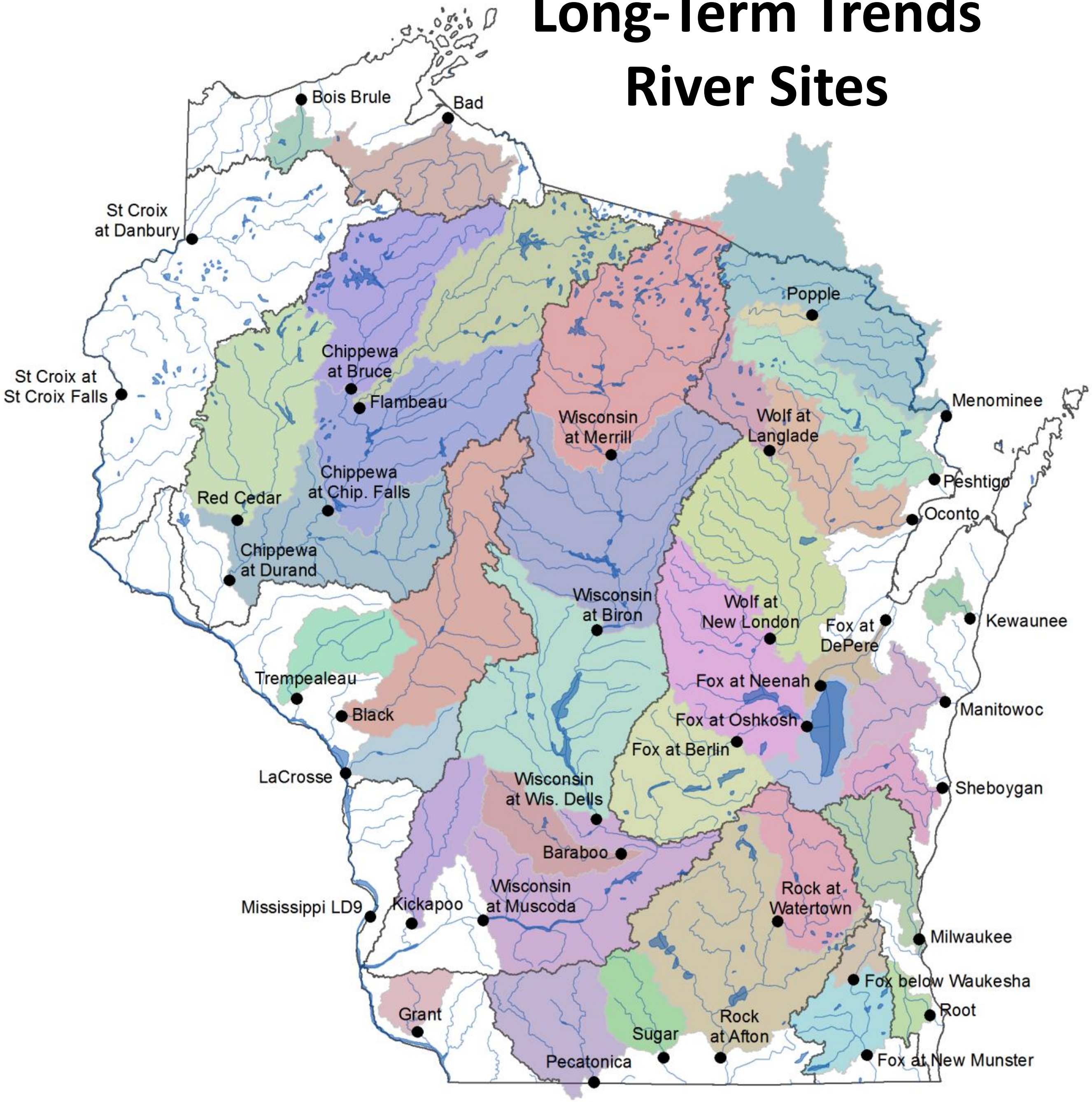
Long-Term Water Quality Trends in Wisconsin Rivers

Matthew Diebel
Wisconsin Department of Natural Resources

Long-Term Trends River Sites



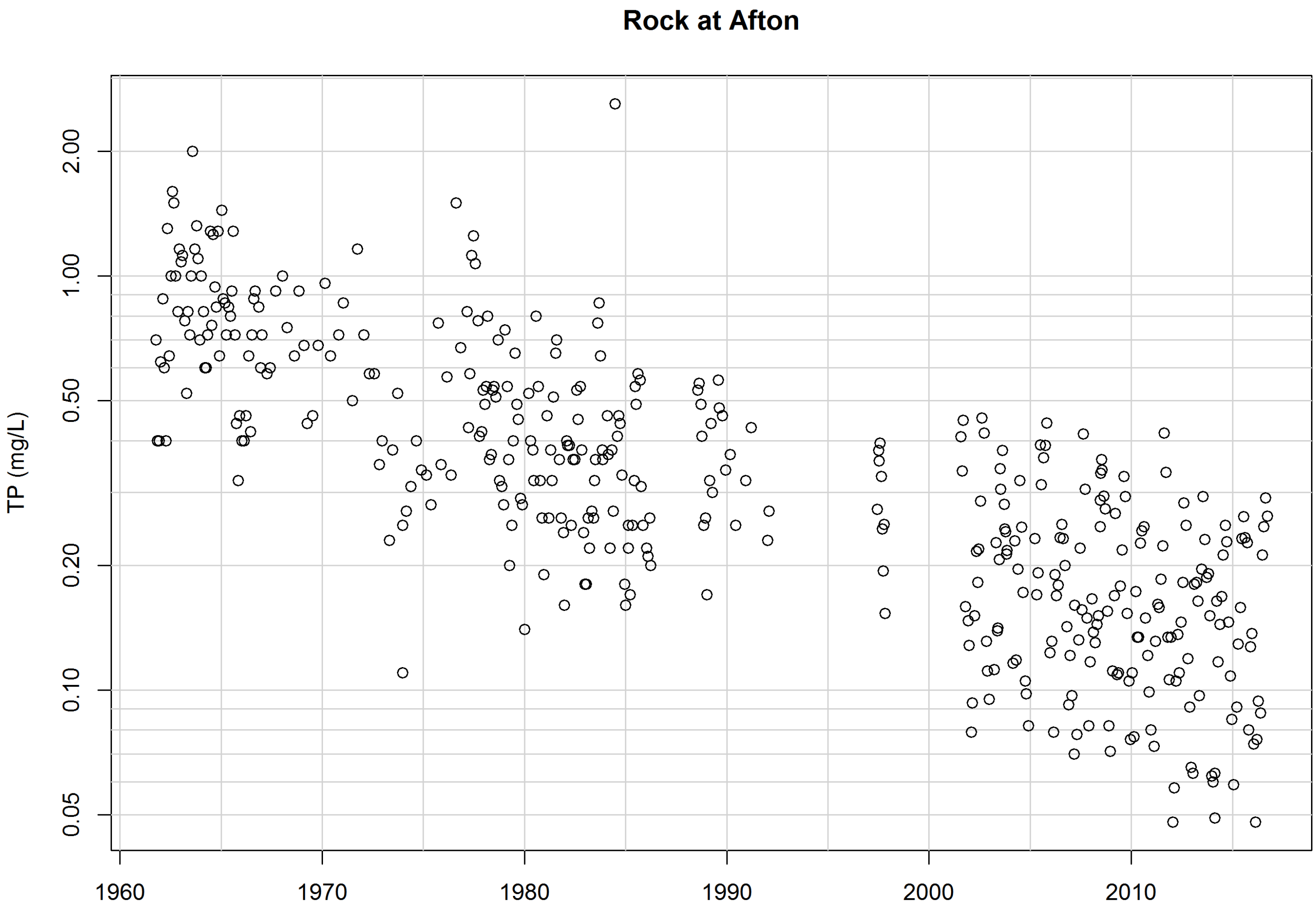
Data

- Started with 5 sites in 1961; now 41 sites
- Monthly or quarterly samples
- Phosphorus, nitrogen, suspended solids, chloride

Questions

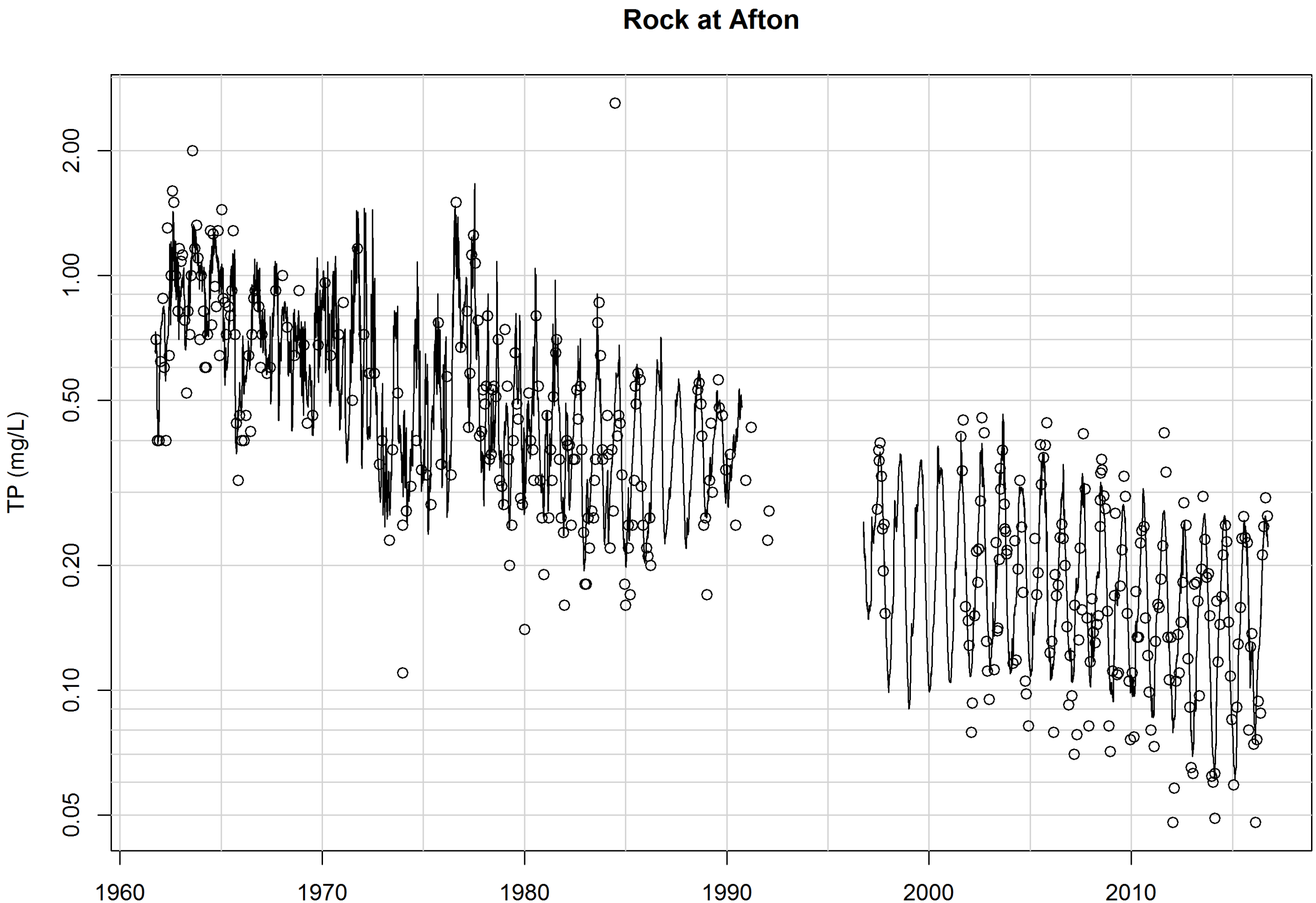
- Have policies and practices aimed at improving water quality worked?
- Which water quality parameters have changed the most?
- Which areas of the state have seen the biggest improvements or declines?
- Can we identify and head off worsening trends before they become critical?

Weighted Regressions on Time, Discharge, and Season



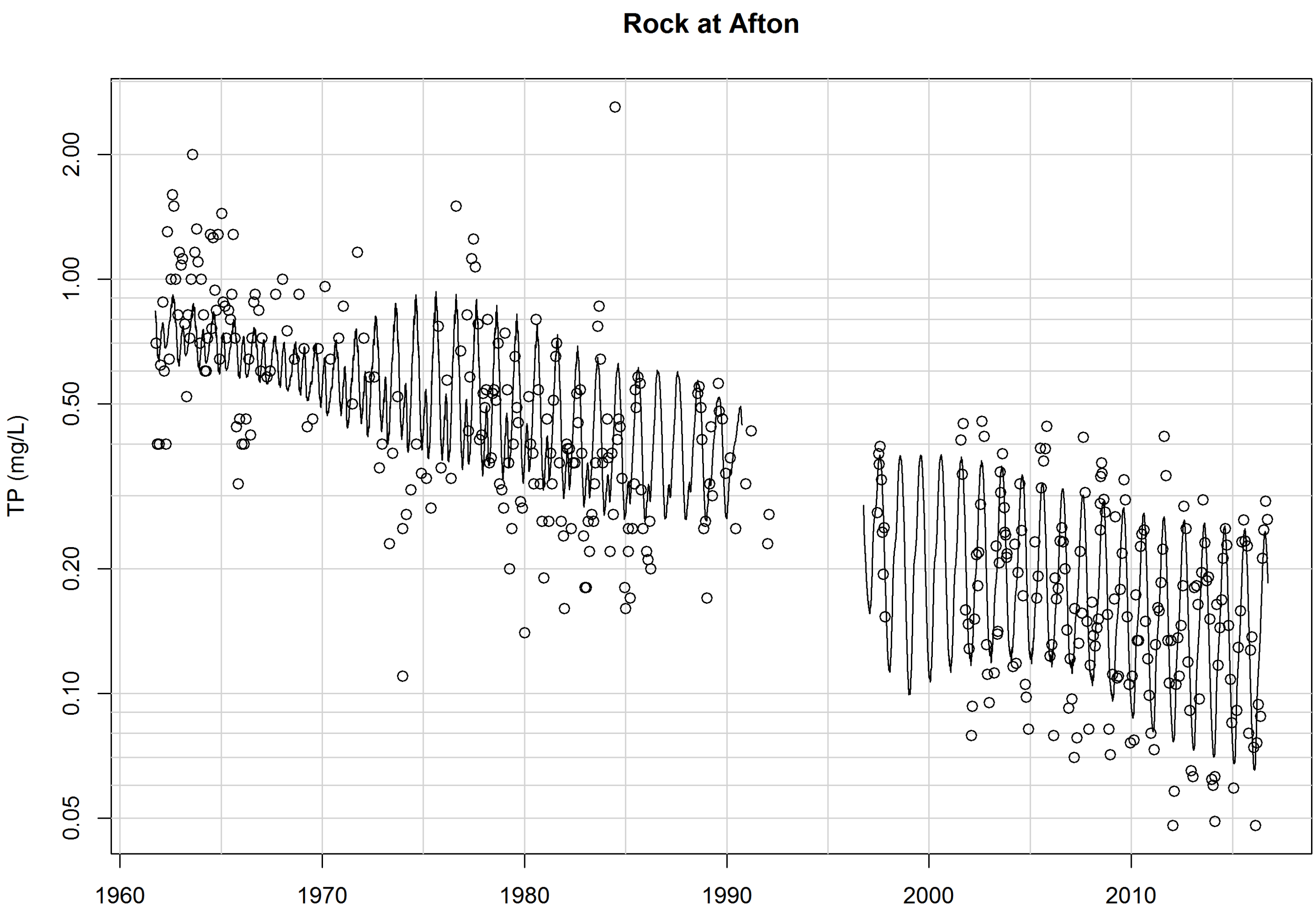
Hirsch, Robert M., Douglas L. Moyer, and Stacey A. Archfield, 2010. Weighted Regressions on Time, Discharge, and Season (WRTDS), With an Application to Chesapeake Bay River Inputs. Journal of the American Water Resources Association (JAWRA) 46(5):857-880.

Weighted Regressions on Time, Discharge, and Season



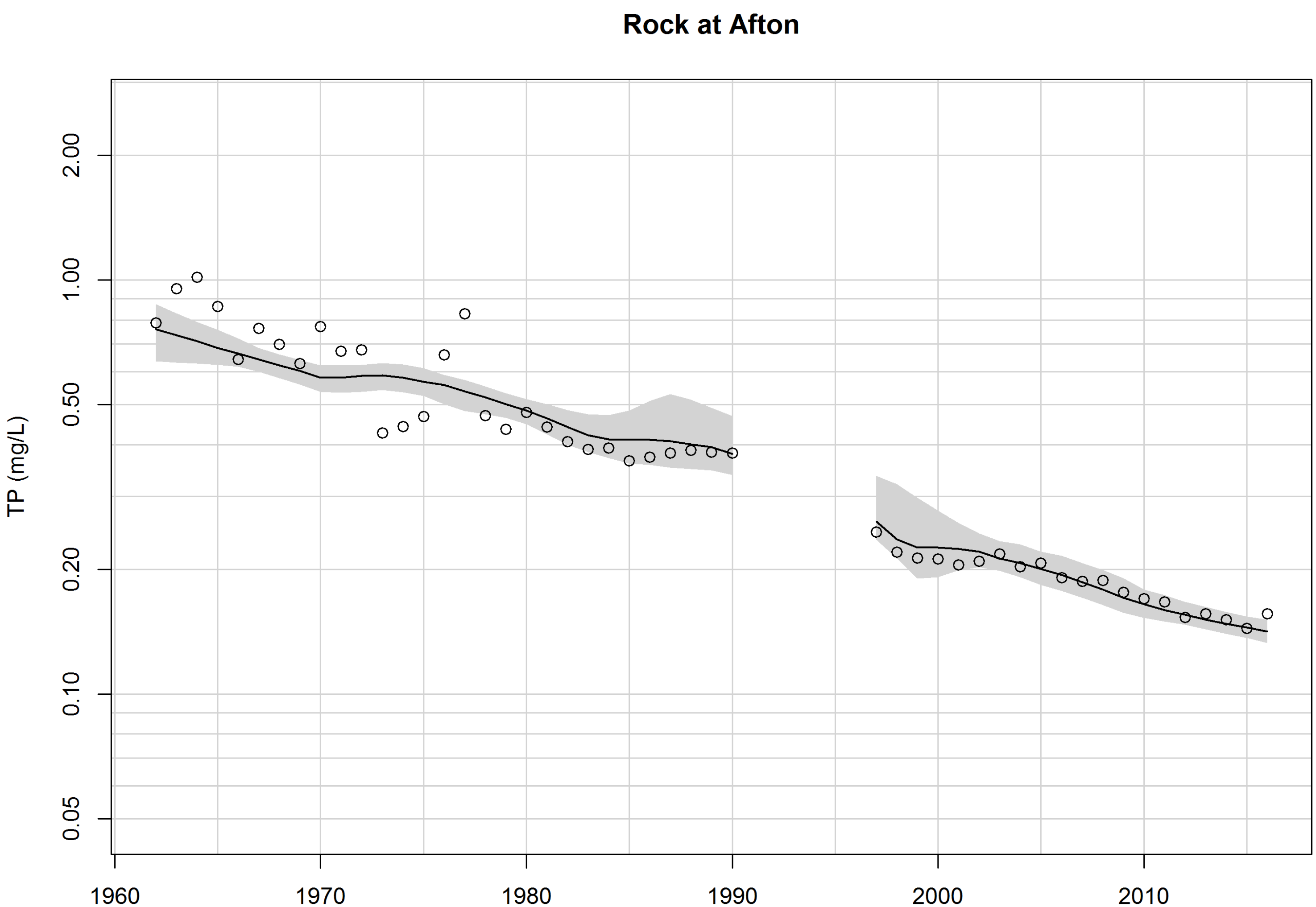
Hirsch, Robert M., Douglas L. Moyer, and Stacey A. Archfield, 2010. Weighted Regressions on Time, Discharge, and Season (WRTDS), With an Application to Chesapeake Bay River Inputs. Journal of the American Water Resources Association (JAWRA) 46(5):857-880.

Weighted Regressions on Time, Discharge, and Season



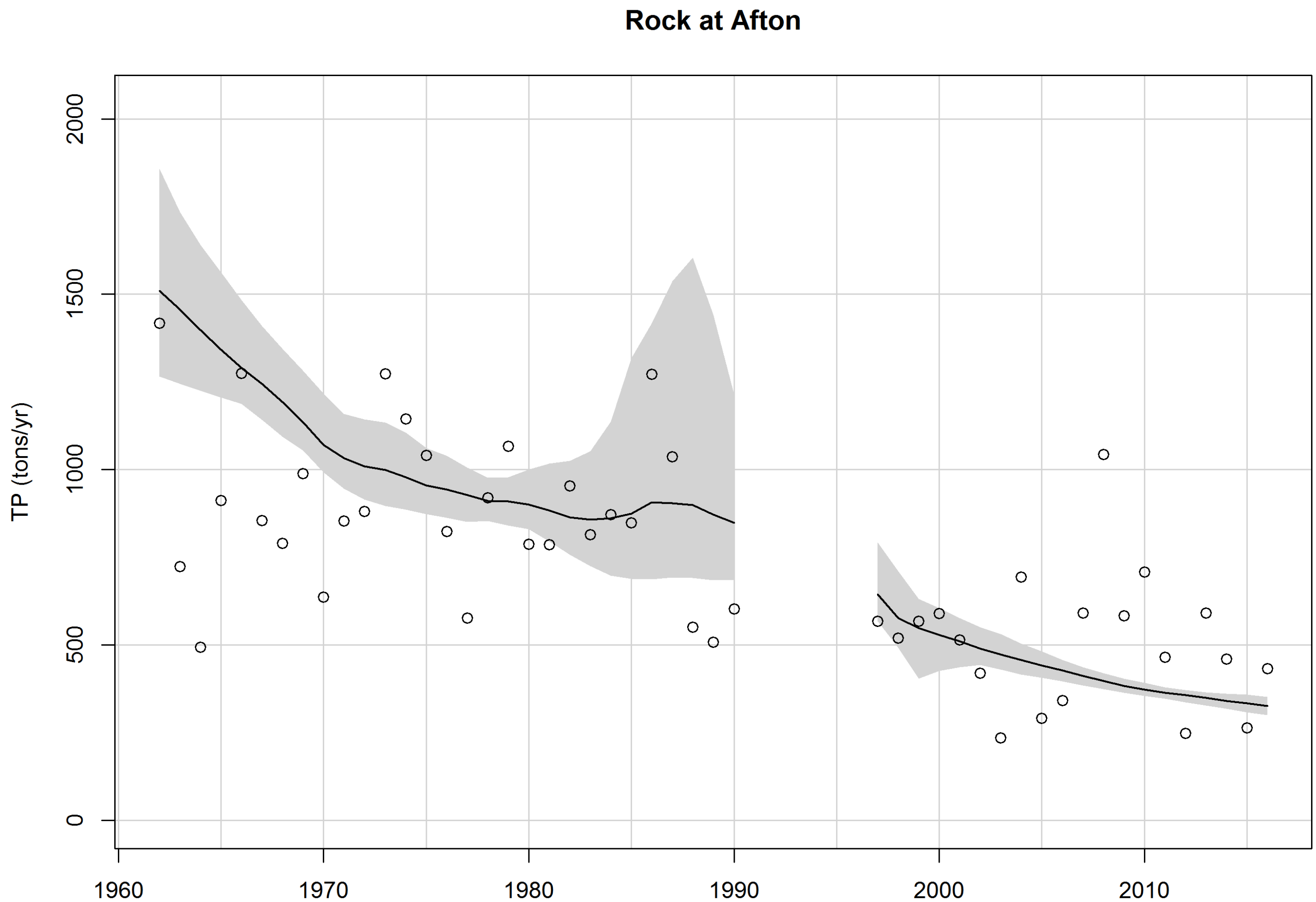
Hirsch, Robert M., Douglas L. Moyer, and Stacey A. Archfield, 2010. Weighted Regressions on Time, Discharge, and Season (WRTDS), With an Application to Chesapeake Bay River Inputs. Journal of the American Water Resources Association (JAWRA) 46(5):857-880.

Weighted Regressions on Time, Discharge, and Season



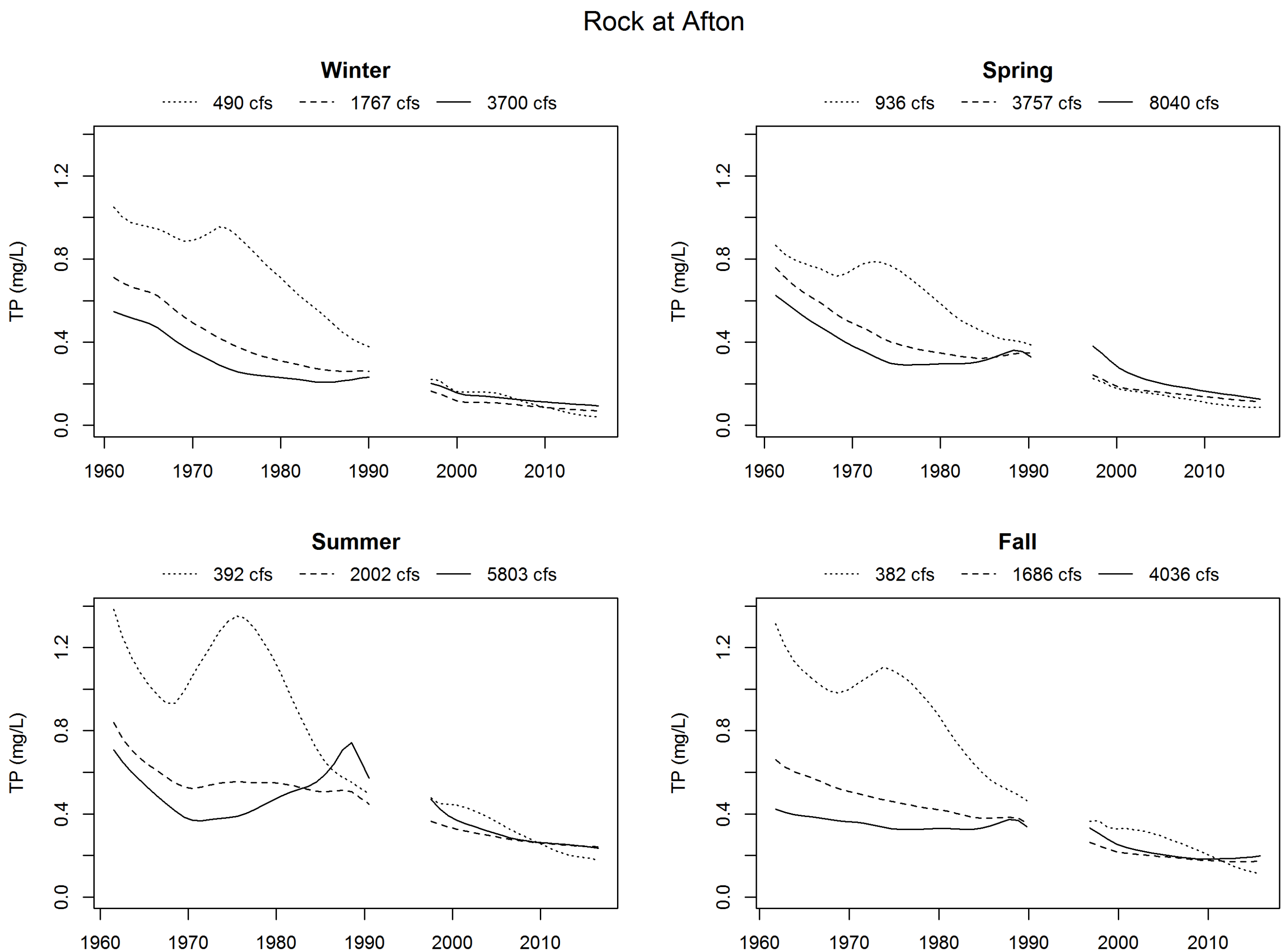
Hirsch, Robert M., Douglas L. Moyer, and Stacey A. Archfield, 2010. Weighted Regressions on Time, Discharge, and Season (WRTDS), With an Application to Chesapeake Bay River Inputs. Journal of the American Water Resources Association (JAWRA) 46(5):857-880.

Weighted Regressions on Time, Discharge, and Season



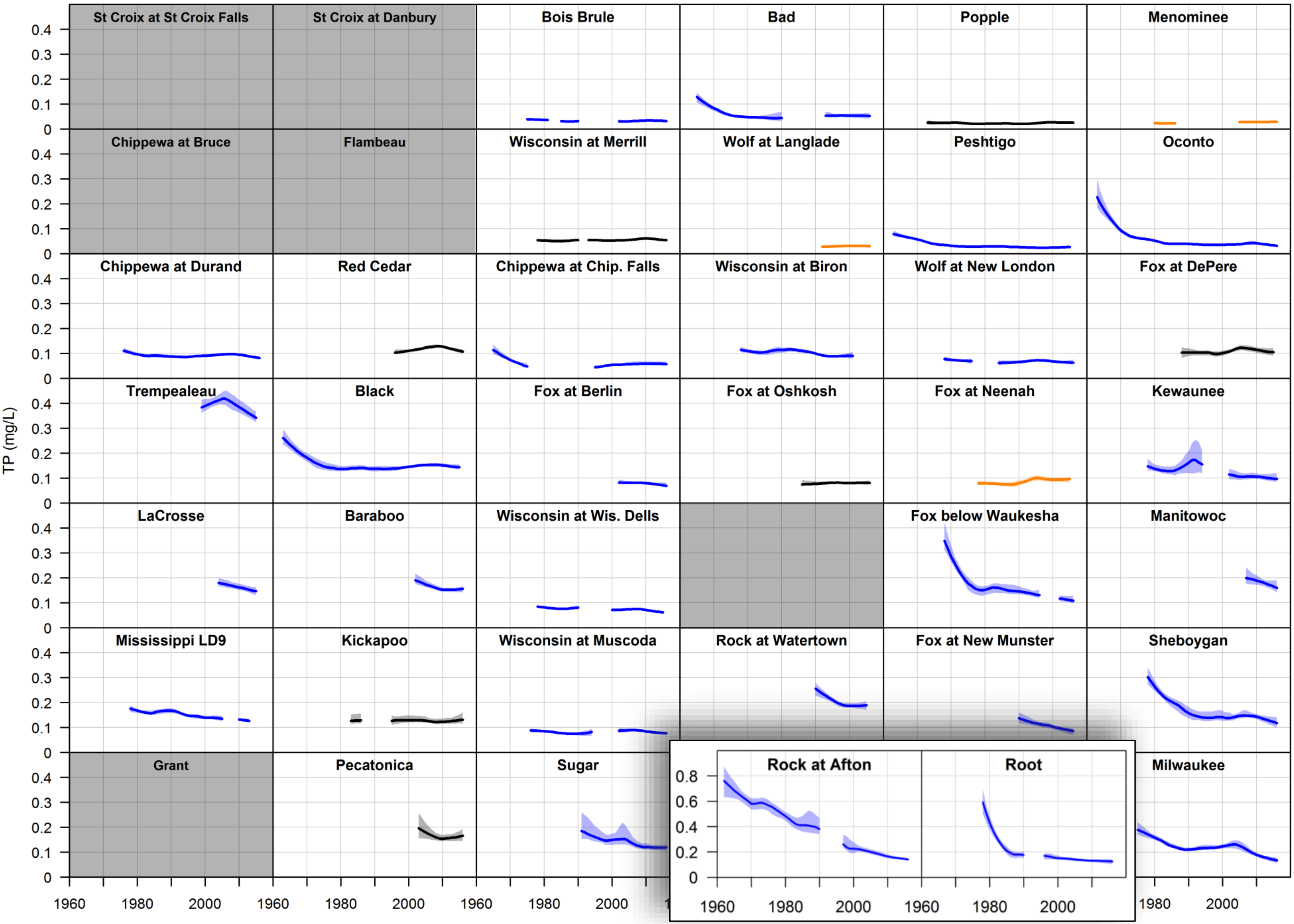
Hirsch, Robert M., Douglas L. Moyer, and Stacey A. Archfield, 2010. Weighted Regressions on Time, Discharge, and Season (WRTDS), With an Application to Chesapeake Bay River Inputs. Journal of the American Water Resources Association (JAWRA) 46(5):857-880.

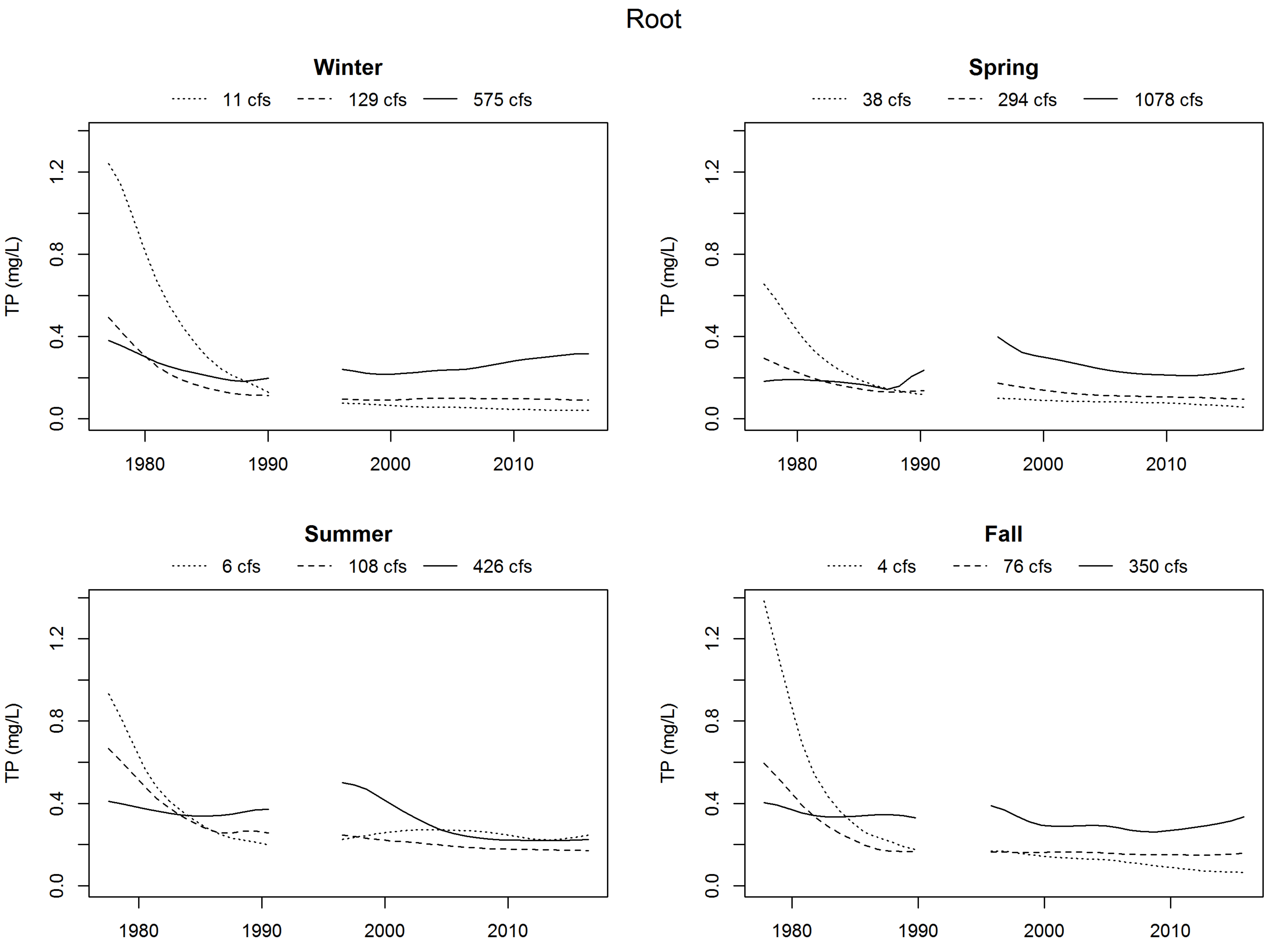
Weighted Regressions on Time, Discharge, and Season



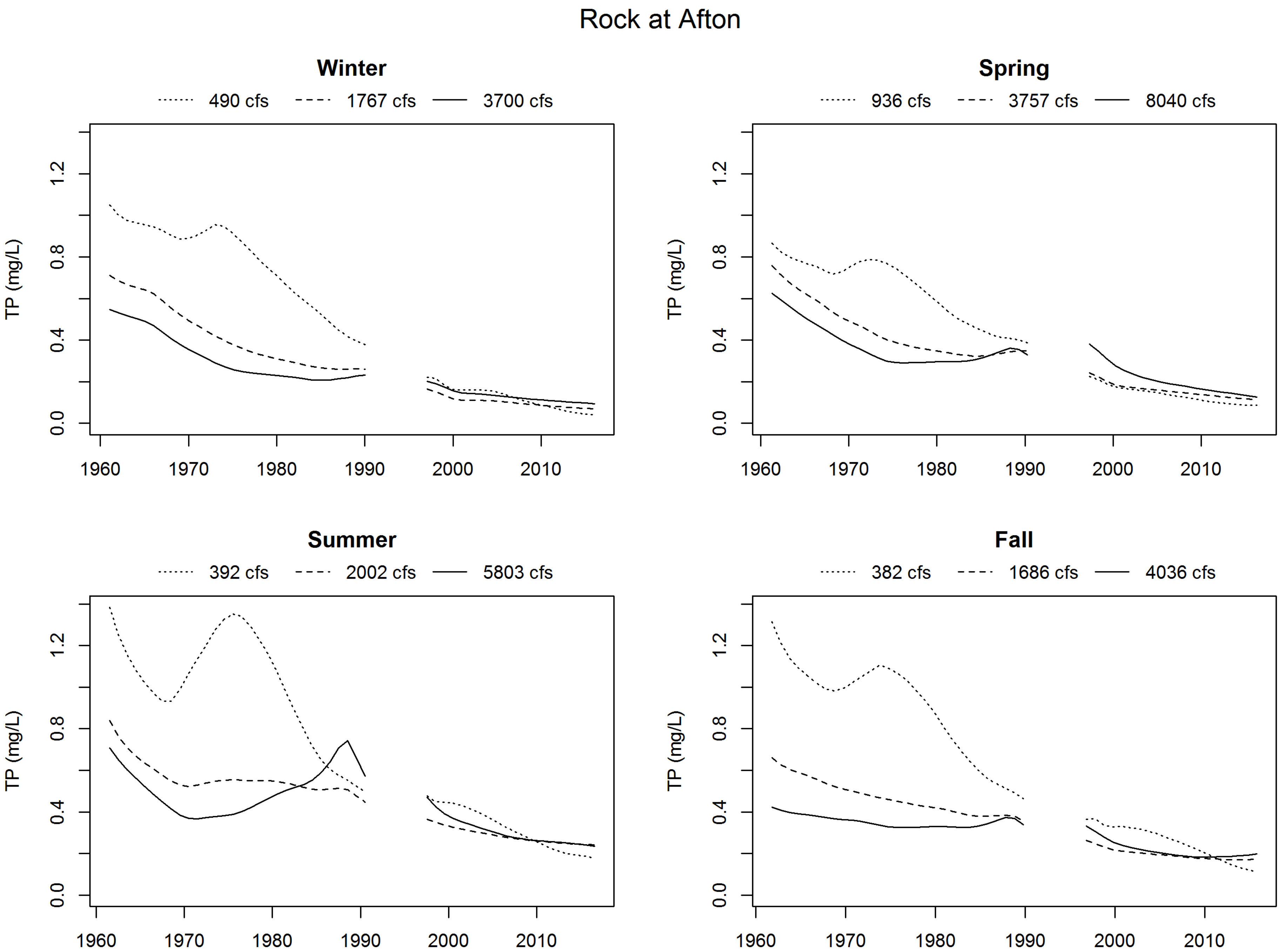
Hirsch, Robert M., Douglas L. Moyer, and Stacey A. Archfield, 2010. Weighted Regressions on Time, Discharge, and Season (WRTDS), With an Application to Chesapeake Bay River Inputs. Journal of the American Water Resources Association (JAWRA) 46(5):857-880.

Total Phosphorus

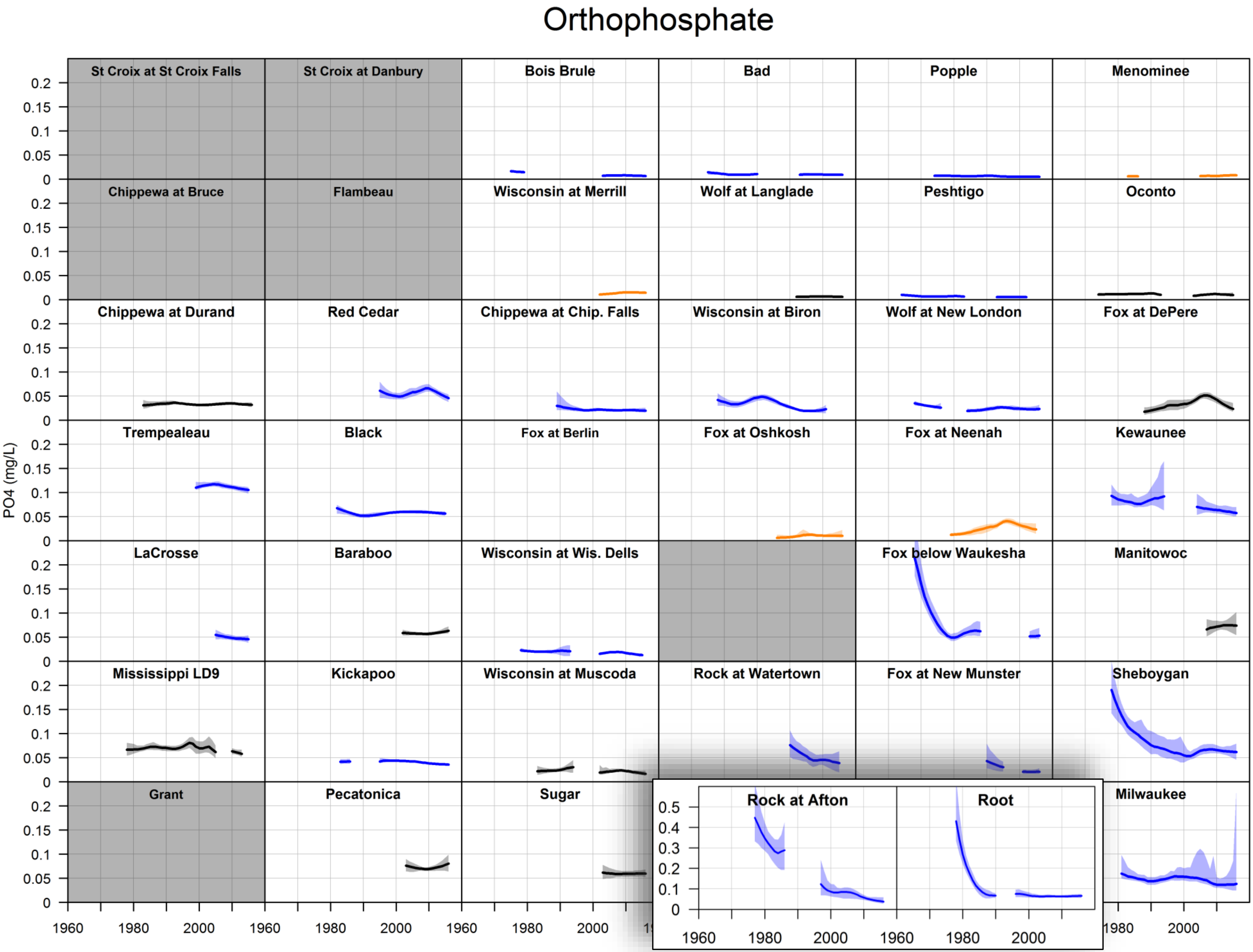




Root
Winter
11 cfs
129 cfs
575 cfs
Spring
38 cfs
294 cfs
1078 cfs
Summer
6 cfs
108 cfs
426 cfs
Fall
4 cfs
76 cfs
350 cfs
TP (mg/L)
0.0
0.4
0.8
1.2
1980
1990
2000
2010

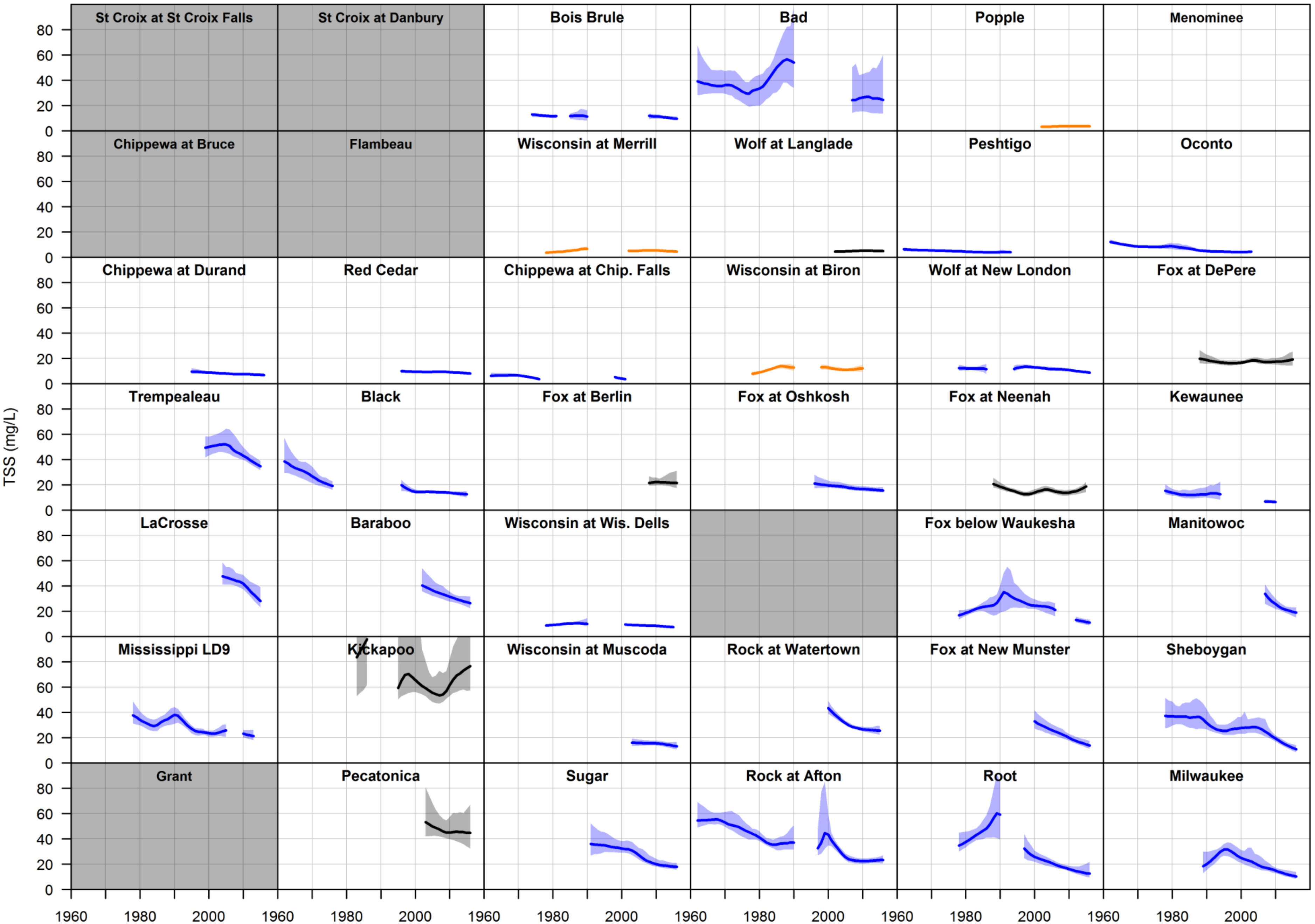


Rock at Afton
Winter
490 cfs
1767 cfs
3700 cfs
Spring
936 cfs
3757 cfs
8040 cfs
Summer
392 cfs
2002 cfs
5803 cfs
Fall
382 cfs
1686 cfs
4036 cfs
TP (mg/L)
0.0
0.4
0.8
1.2
1960
1970
1980
1990
2000
2010

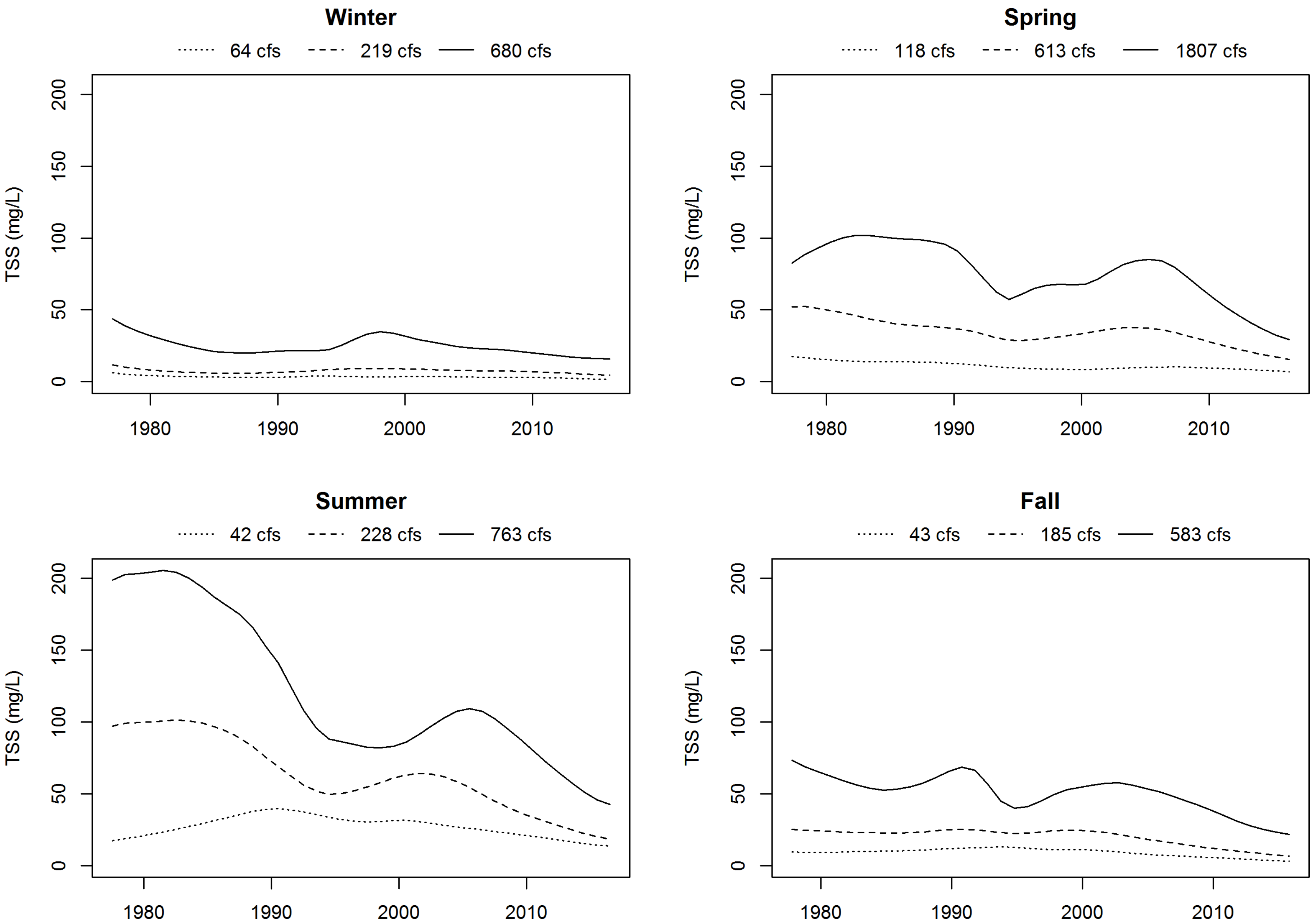


Orthophosphate
PO4 (mg/L)
St Croix at St Croix Falls
St Croix at Danbury
Bois Brule
Bad
Popple
Menominee
Chippewa at Bruce
Flambeau
Wisconsin at Merrill
Wolf at Langlade
Peshtigo
Oconto
Chippewa at Durand
Red Cedar
Chippewa at Chip. Falls
Wisconsin at Biron
Wolf at New London
Fox at DePere
Trempealeau
Black
Fox at Berlin
Fox at Oshkosh
Fox at Neenah
Kewaunee
LaCrosse
Baraboo
Wisconsin at Wis. Dells
Fox below Waukesha
Manitowoc
Mississippi LD9
Kickapoo
Wisconsin at Muscoda
Rock at Watertown
Fox at New Munster
Sheboygan
Grant
Pecatonica
Sugar
Rock at Afton
Root
Milwaukee
0
0.05
0.1
0.15
0.2
0.3
0.4
0.5
1960
1980
2000

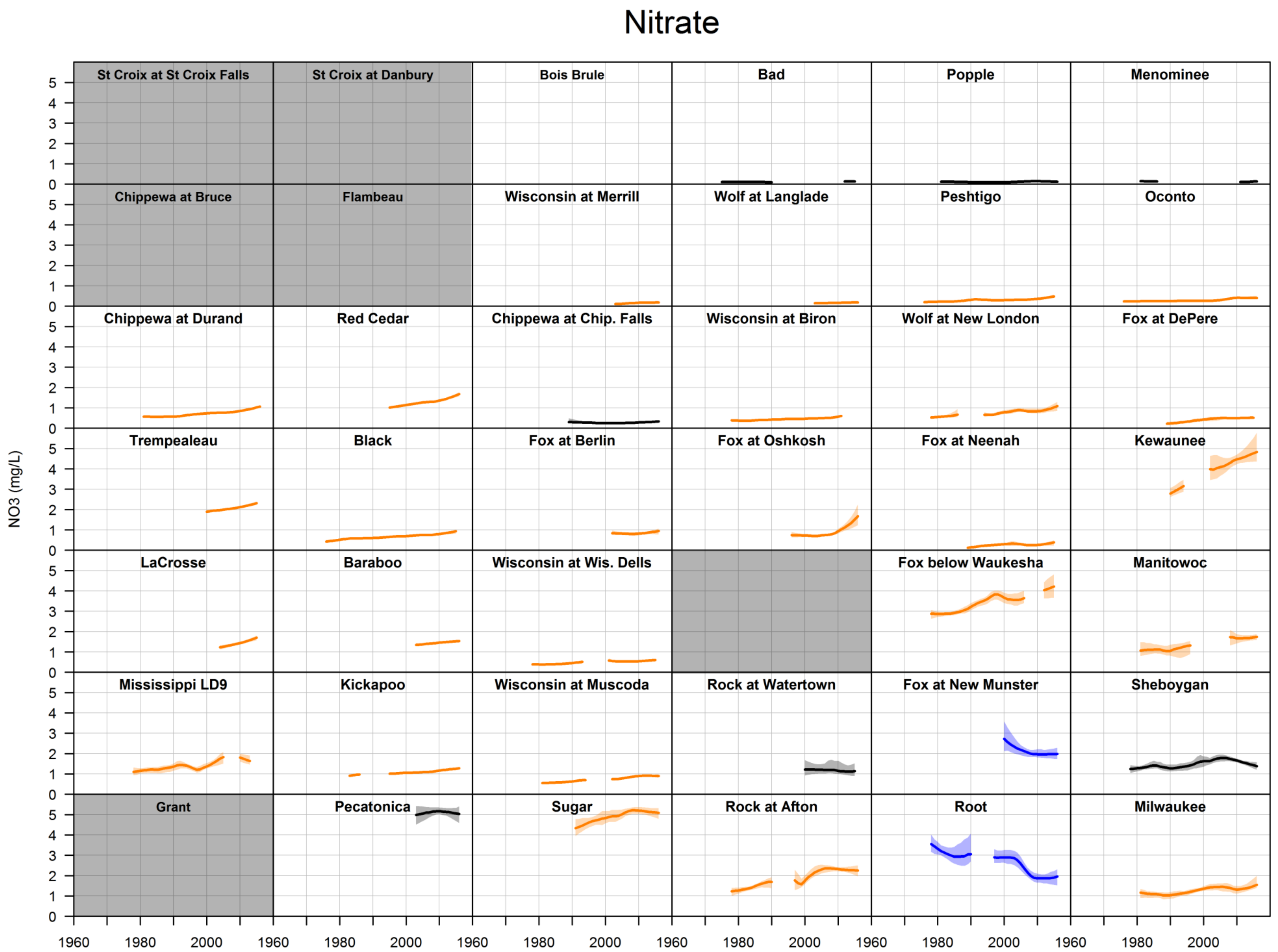
Total Suspended Solids



Sheboygan

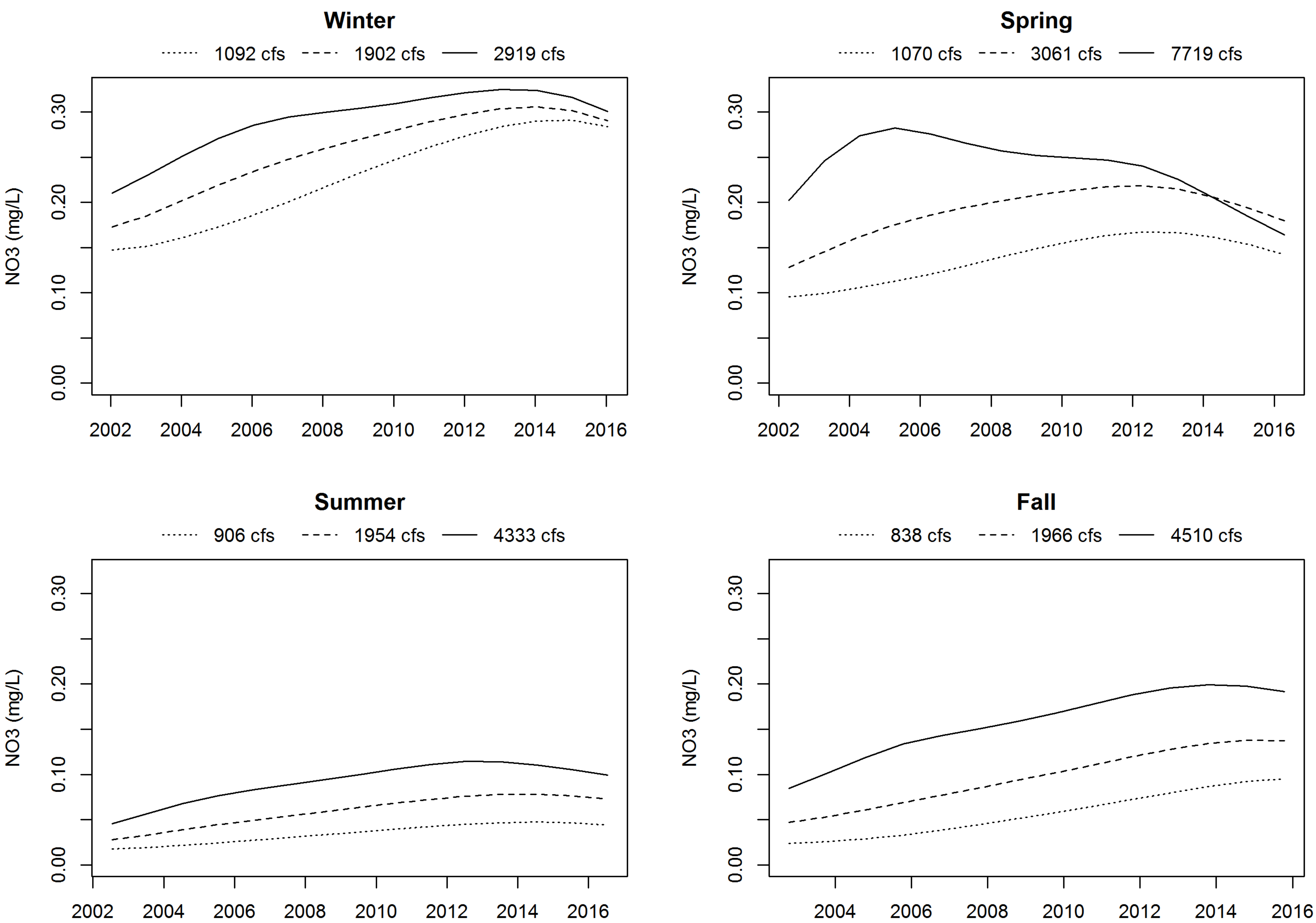


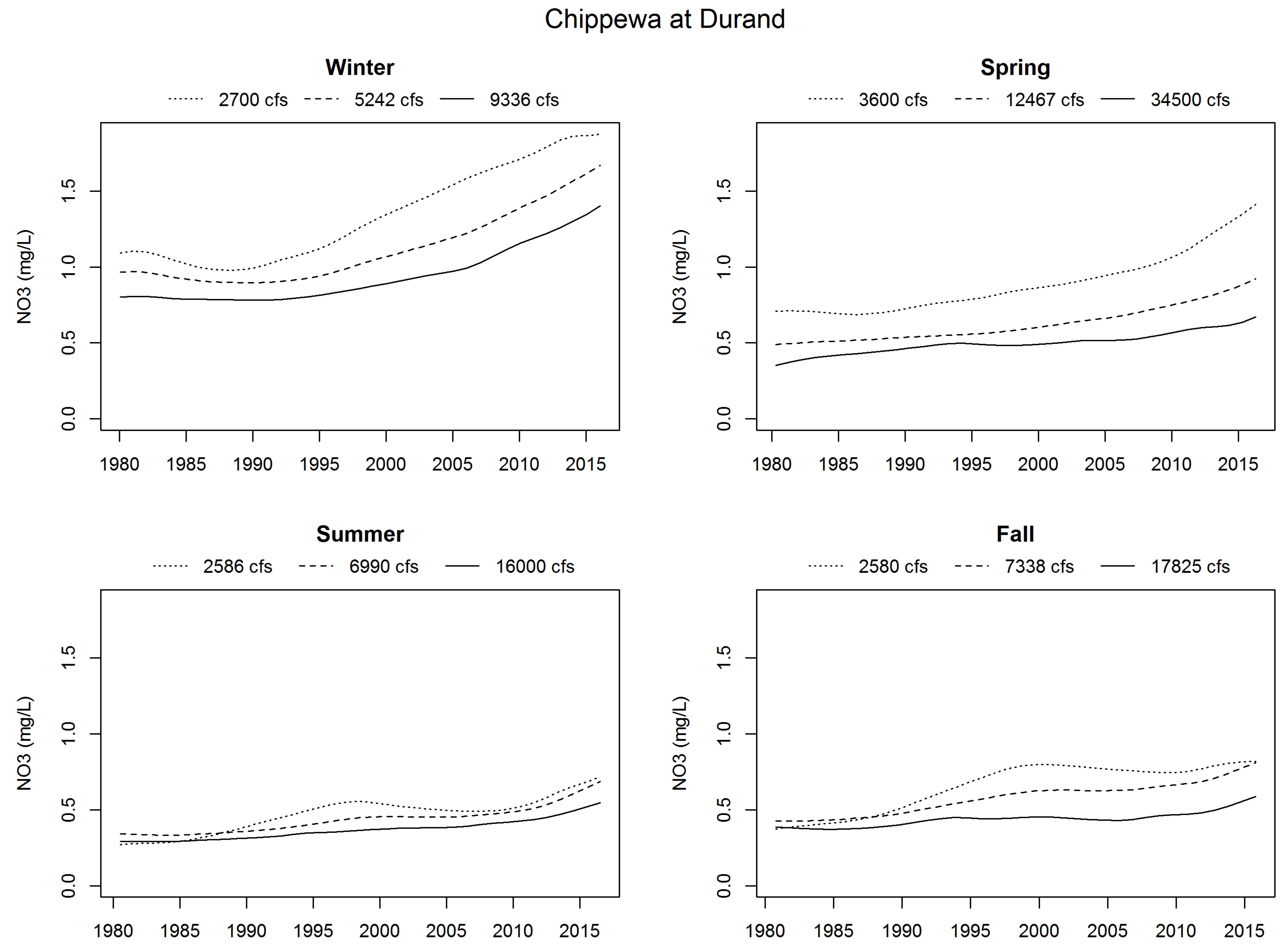
Winter
64 cfs
219 cfs
680 cfs
TSS (mg/L)
0
50
100
150
200
1980
1990
2000
2010
Spring
118 cfs
613 cfs
1807 cfs
Summer
42 cfs
228 cfs
763 cfs
Fall
43 cfs
185 cfs
583 cfs



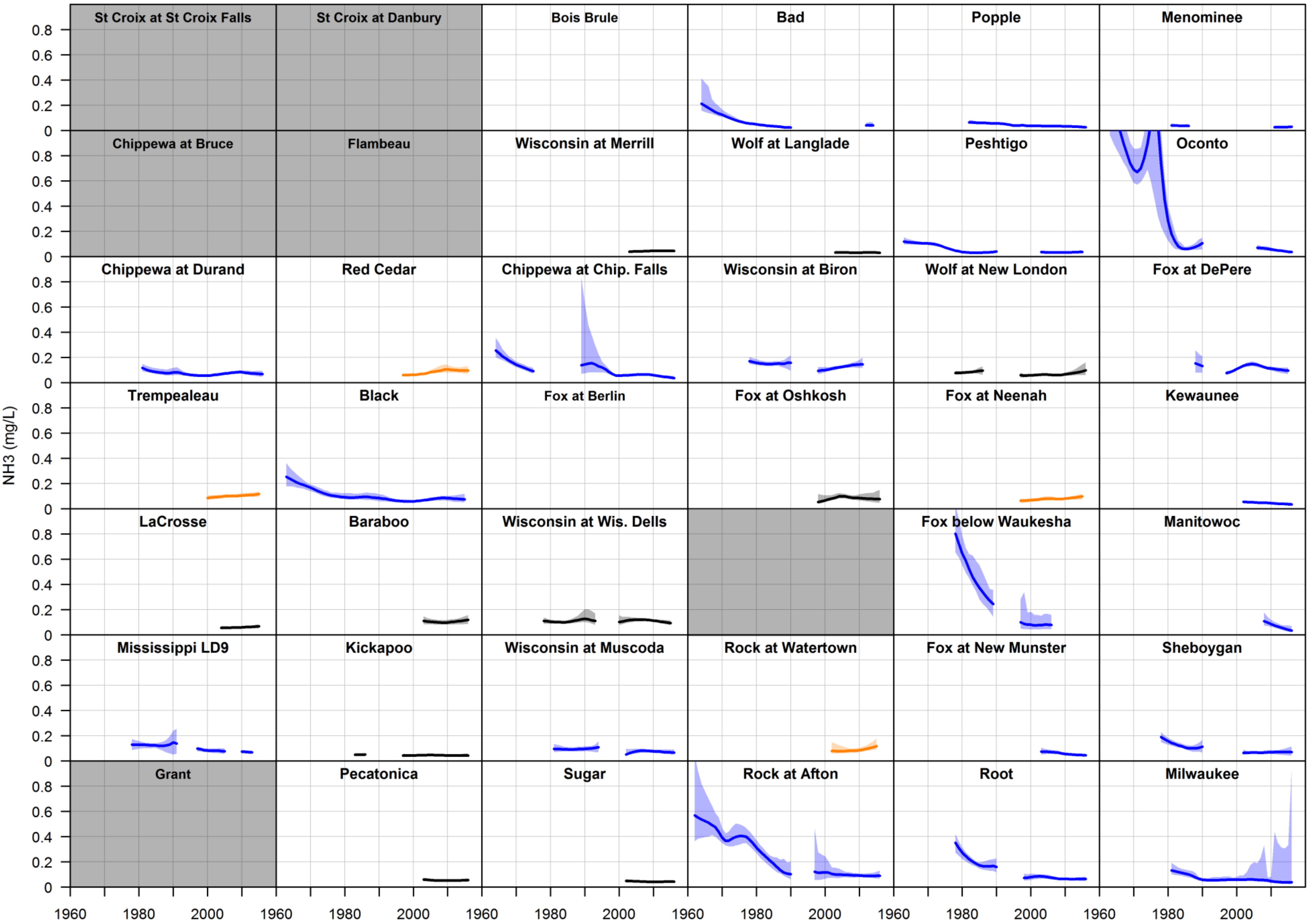
Nitrate
NO3 (mg/L)
St Croix at St Croix Falls
St Croix at Danbury
Bois Brule
Bad
Popple
Menominee
Chippewa at Bruce
Flambeau
Wisconsin at Merrill
Wolf at Langlade
Peshtigo
Oconto
Chippewa at Durand
Red Cedar
Chippewa at Chip. Falls
Wisconsin at Biron
Wolf at New London
Fox at DePere
Trempealeau
Black
Fox at Berlin
Fox at Oshkosh
Fox at Neenah
Kewaunee
LaCrosse
Baraboo
Wisconsin at Wis. Dells
Fox below Waukesha
Manitowoc
Mississippi LD9
Kickapoo
Wisconsin at Muscoda
Rock at Watertown
Fox at New Munster
Sheboygan
Grant
Pecatonica
Sugar
Rock at Afton
Root
Milwaukee
0
1
2
3
4
5
1960
1980
2000

Wisconsin at Merrill

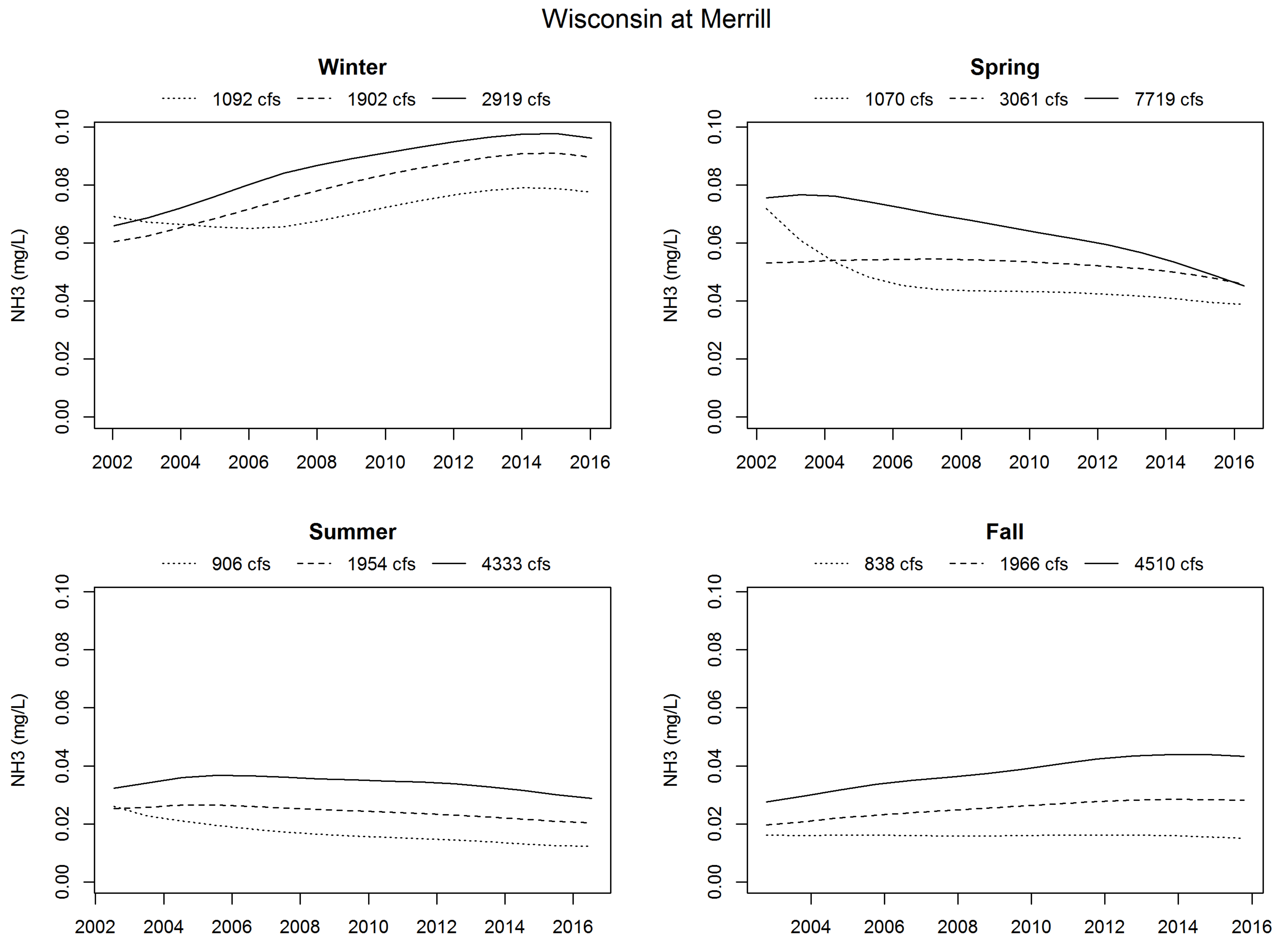



Chippewa at Durand
Winter
2700 cfs
5242 cfs
9336 cfs
Spring
3600 cfs
12467 cfs
34500 cfs
Summer
2586 cfs
6990 cfs
16000 cfs
Fall
2580 cfs
7338 cfs
17825 cfs
NO3 (mg/L)
0.0
0.5
1.0
1.5
1980
1985
1990
1995
2000
2005
2010
2015

Ammonia

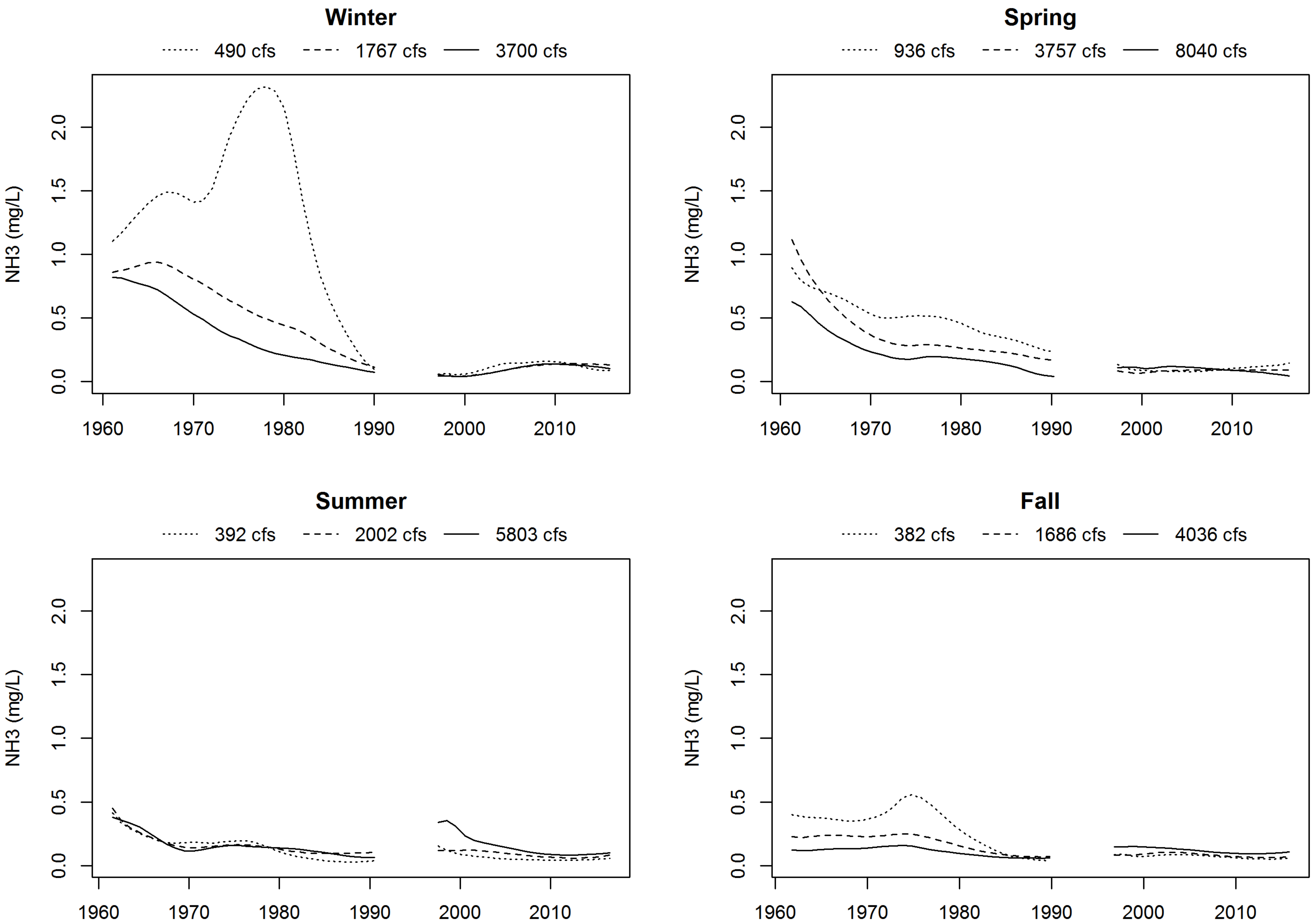


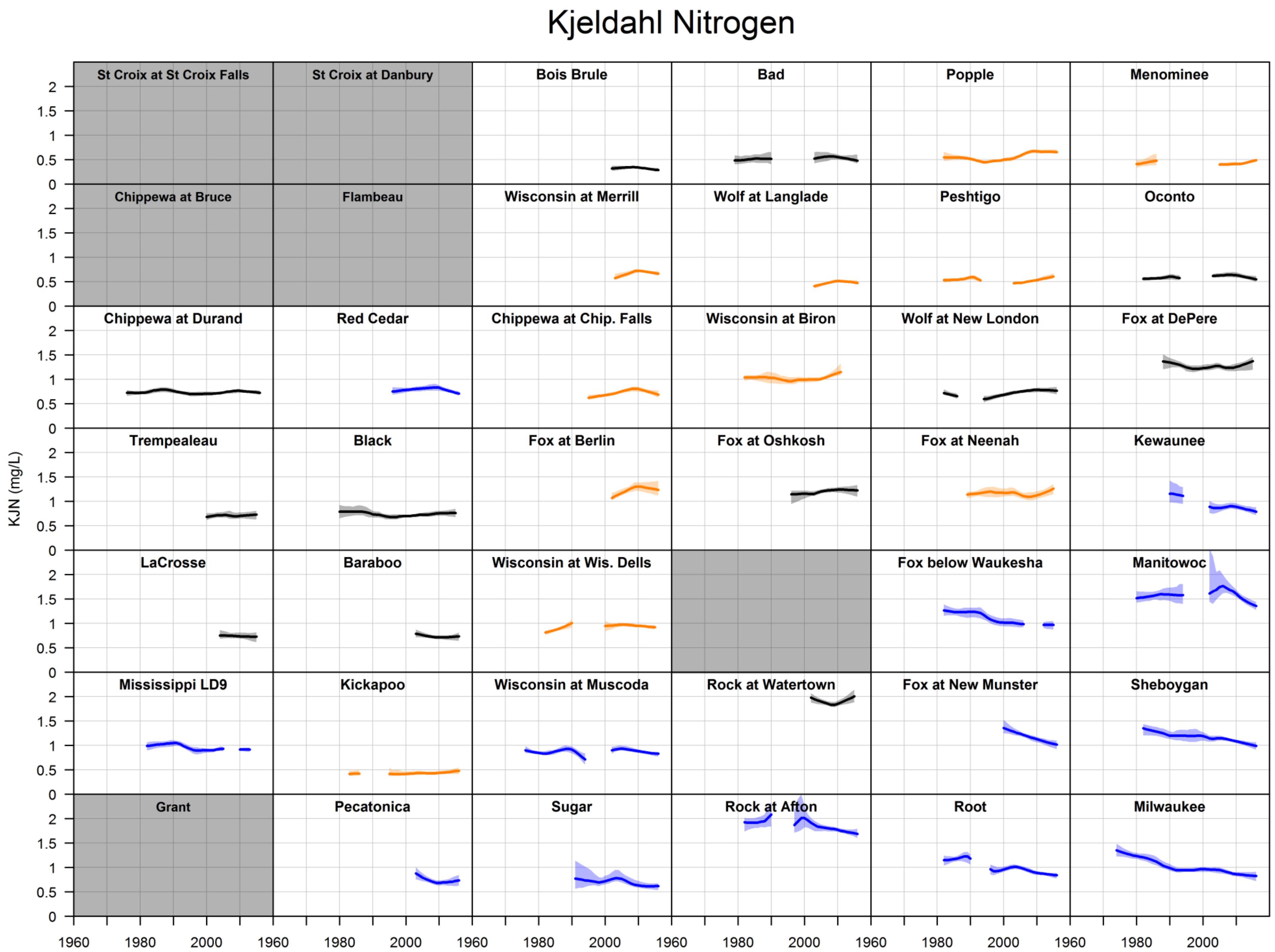
St Croix at St Croix Falls
St Croix at Danbury
Bois Brule
Bad
Popple
Menominee
Chippewa at Bruce
Flambeau
Wisconsin at Merrill
Wolf at Langlade
Peshtigo
Oconto
Chippewa at Durand
Red Cedar
Chippewa at Chip. Falls
Wisconsin at Biron
Wolf at New London
Fox at DePere
Trempealeau
Black
Fox at Berlin
Fox at Oshkosh
Fox at Neenah
Kewaunee
LaCrosse
Baraboo
Wisconsin at Wis. Dells
Fox below Waukesha
Manitowoc
Mississippi LD9
Kickapoo
Wisconsin at Muscoda
Rock at Watertown
Fox at New Munster
Sheboygan
Grant
Pecatonica
Sugar
Rock at Afton
Root
Milwaukee
NH3 (mg/L)
0
0.2
0.4
0.6
0.8
1960
1980
2000

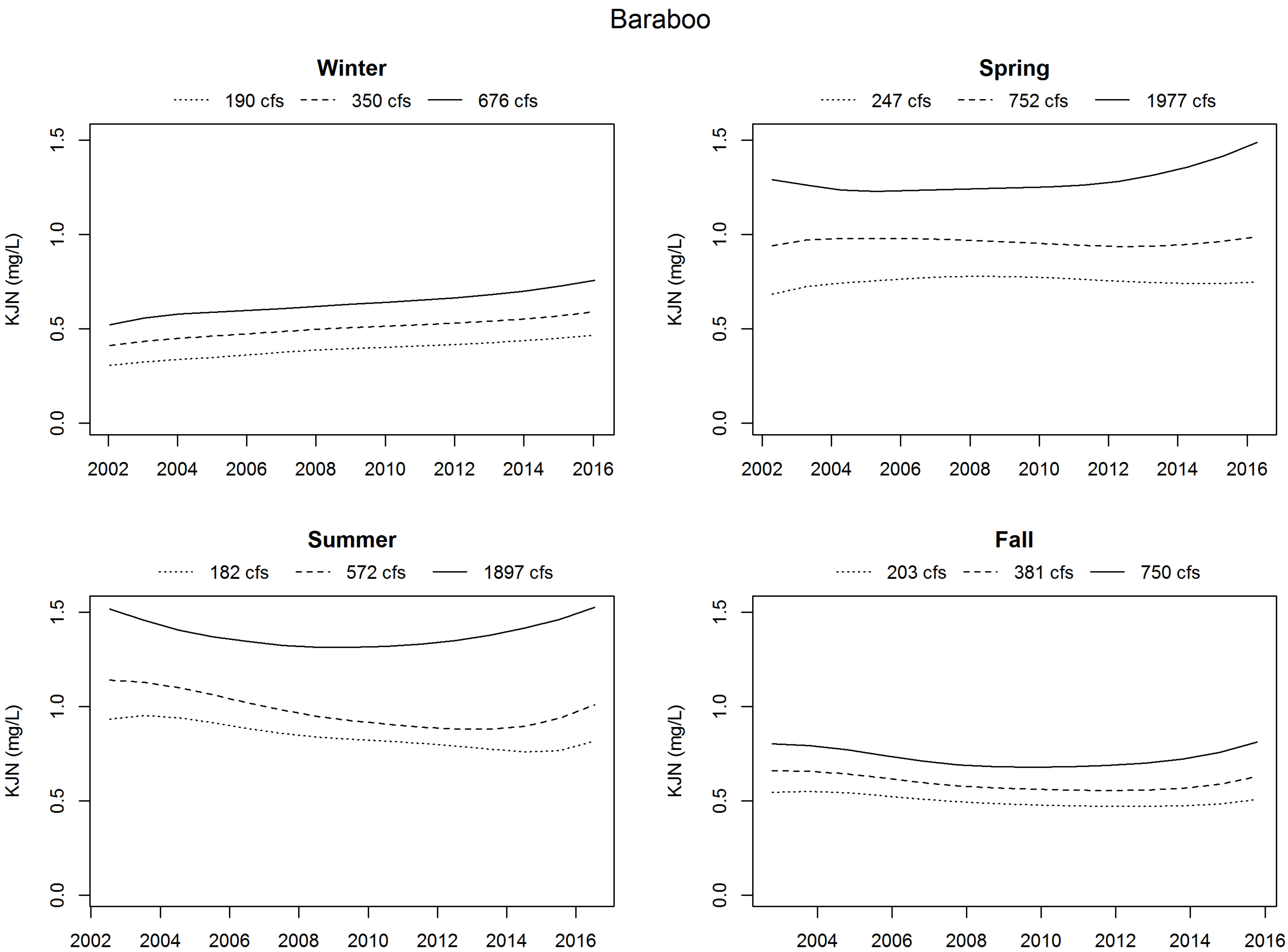


Wisconsin at Merrill
Winter
1092 cfs
1902 cfs
2919 cfs
Spring
1070 cfs
3061 cfs
7719 cfs
Summer
906 cfs
1954 cfs
4333 cfs
Fall
838 cfs
1966 cfs
4510 cfs
NH3 (mg/L)
0.00
0.02
0.04
0.06
0.08
0.10
2002
2004
2006
2008
2010
2012
2014
2016

Rock at Afton

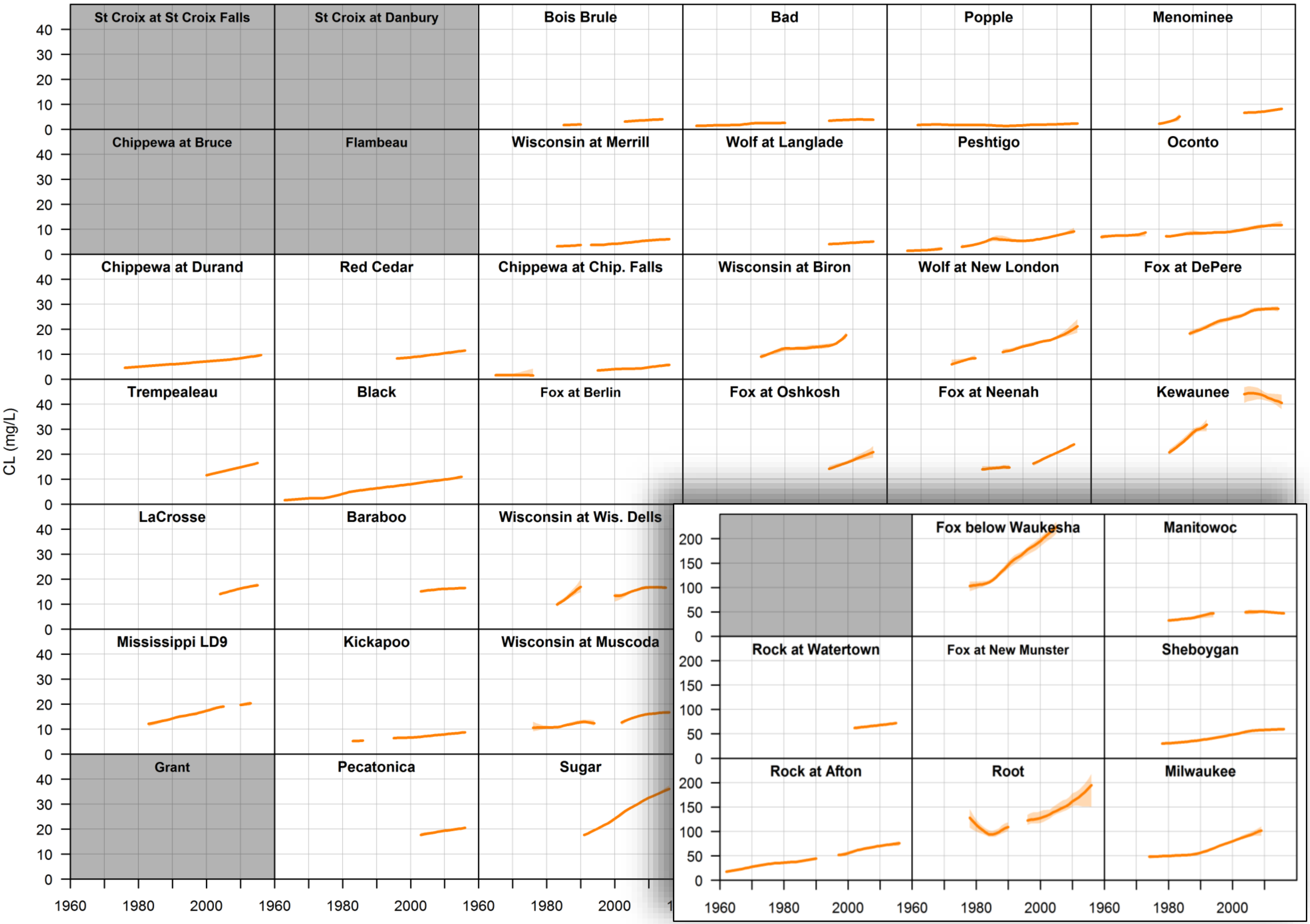


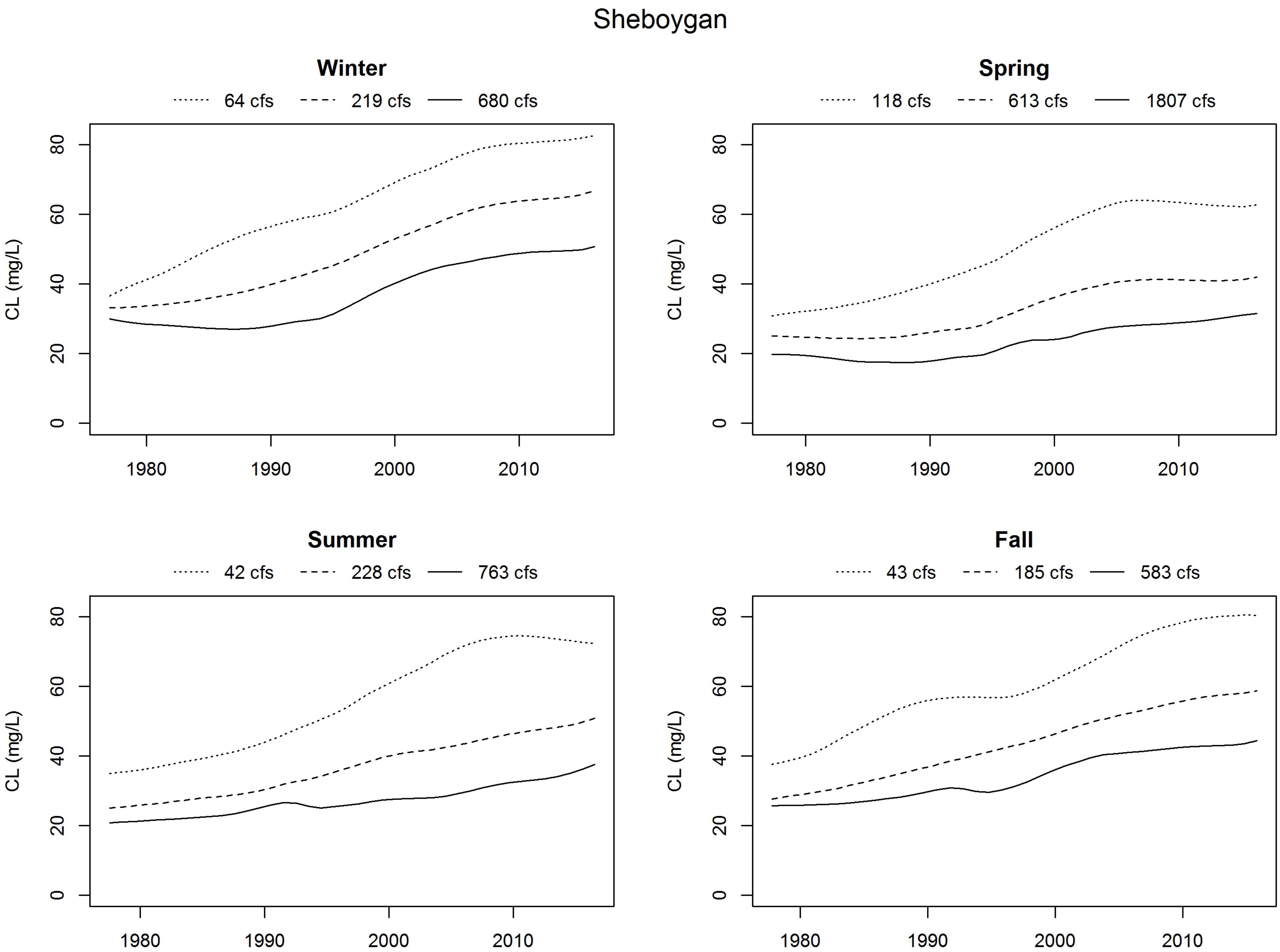

Kjeldahl Nitrogen
St Croix at St Croix Falls
St Croix at Danbury
Bois Brule
Bad
Popple
Menominee
Chippewa at Bruce
Flambeau
Wisconsin at Merrill
Wolf at Langlade
Peshtigo
Oconto
Chippewa at Durand
Red Cedar
Chippewa at Chip. Falls
Wisconsin at Biron
Wolf at New London
Fox at DePere
Trempealeau
Black
Fox at Berlin
Fox at Oshkosh
Fox at Neenah
Kewaunee
LaCrosse
Baraboo
Wisconsin at Wis. Dells
Fox below Waukesha
Manitowoc
Mississippi LD9
Kickapoo
Wisconsin at Muscoda
Rock at Watertown
Fox at New Munster
Sheboygan
Grant
Pecatonica
Sugar
Rock at Afton
Root
Milwaukee
KJN (mg/L)
0
0.5
1
1.5
2
1960
1980
2000



Baraboo
Winter
190 cfs
350 cfs
676 cfs
Spring
247 cfs
752 cfs
1977 cfs
Summer
182 cfs
572 cfs
1897 cfs
Fall
203 cfs
381 cfs
750 cfs
KJN (mg/L)
0.0
0.5
1.0
1.5
2002
2004
2006
2008
2010
2012
2014
2016

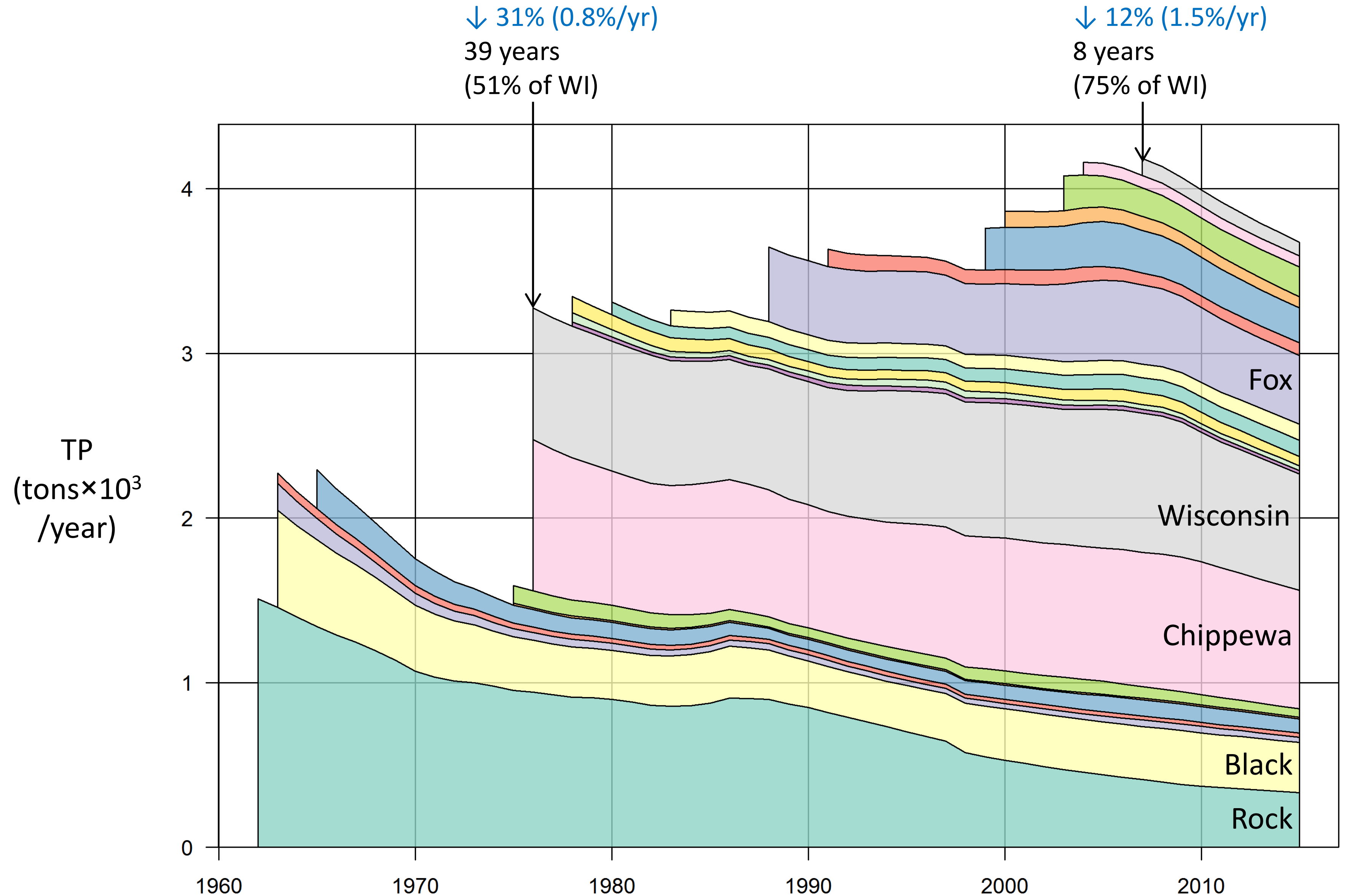
Chloride


CL (mg/L)
St Croix at St Croix Falls
St Croix at Danbury
Bois Brule
Bad
Popple
Menominee
Chippewa at Bruce
Flambeau
Wisconsin at Merrill
Wolf at Langlade
Peshtigo
Oconto
Chippewa at Durand
Red Cedar
Chippewa at Chip. Falls
Wisconsin at Biron
Wolf at New London
Fox at DePere
Trempealeau
Black
Fox at Berlin
Fox at Oshkosh
Fox at Neenah
Kewaunee
LaCrosse
Baraboo
Wisconsin at Wis. Dells
Mississippi LD9
Kickapoo
Wisconsin at Muscoda
Grant
Pecatonica
Sugar
Fox below Waukesha
Manitowoc
Rock at Watertown
Fox at New Munster
Sheboygan
Rock at Afton
Root
Milwaukee
0
10
20
30
40
50
100
150
200
1960
1980
2000

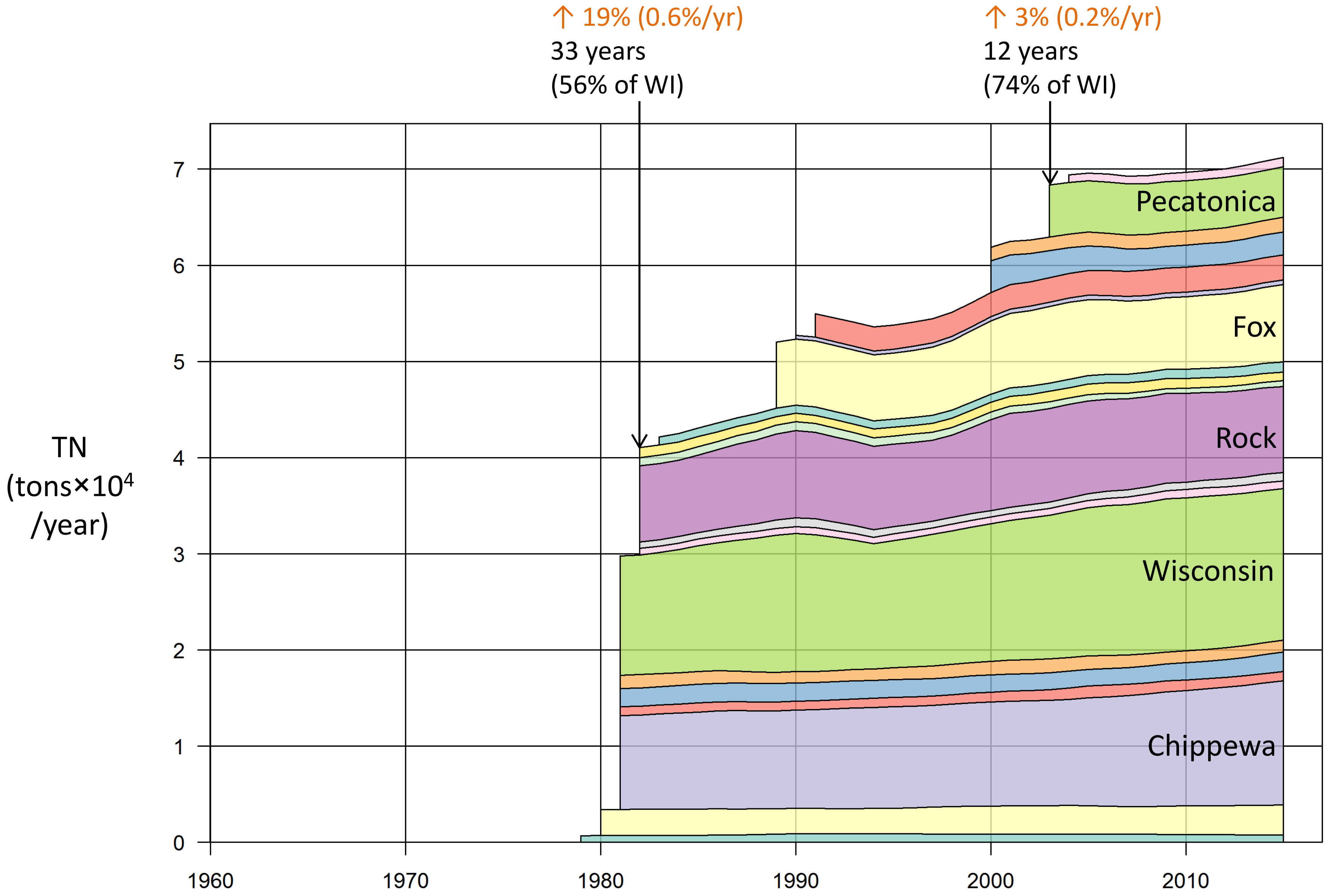


Sheboygan
Winter
64 cfs
219 cfs
680 cfs
Spring
118 cfs
613 cfs
1807 cfs
Summer
42 cfs
228 cfs
763 cfs
Fall
43 cfs
185 cfs
583 cfs
CL (mg/L)
0
20
40
60
80
1980
1990
2000
2010

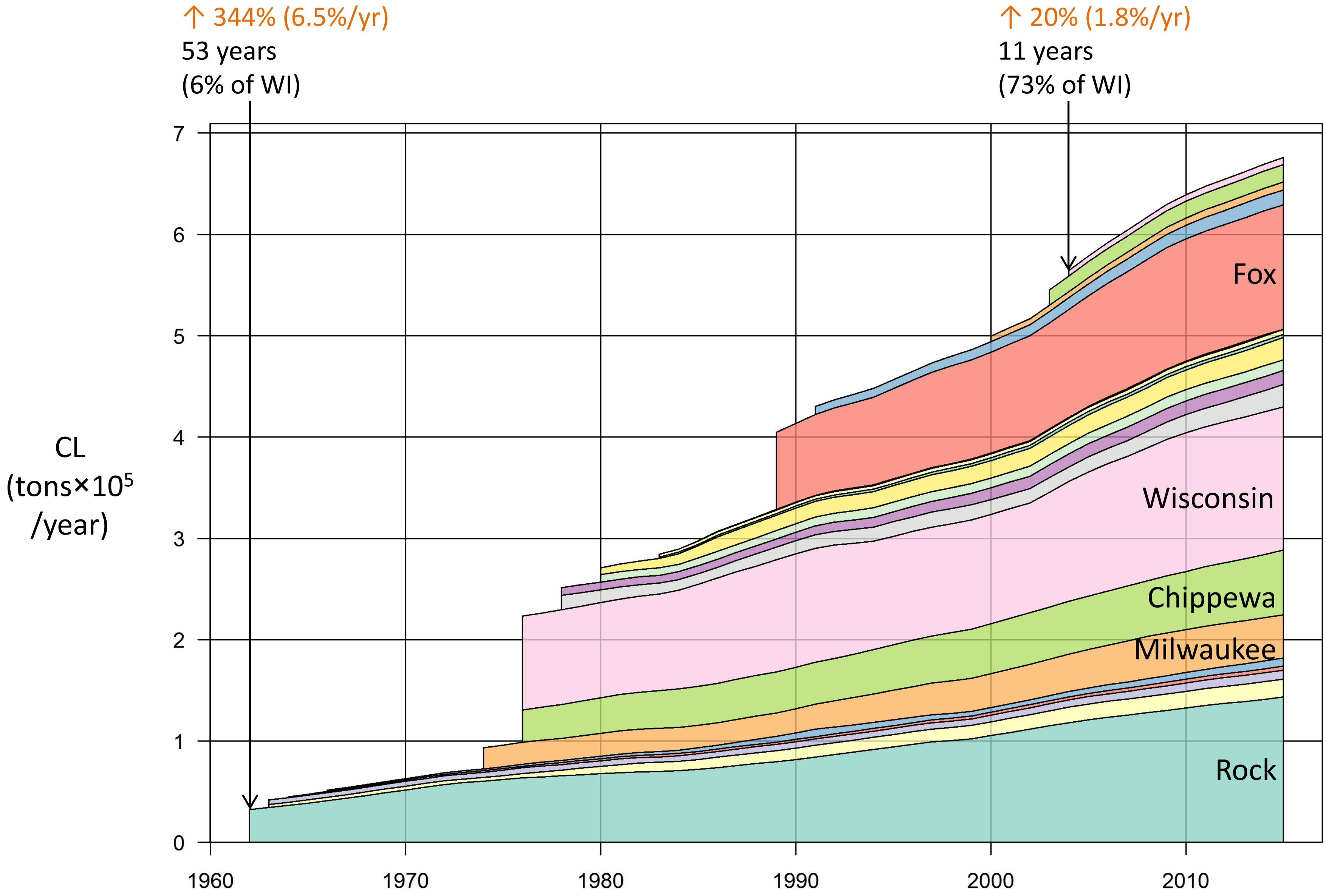
Total Phosphorus Flux



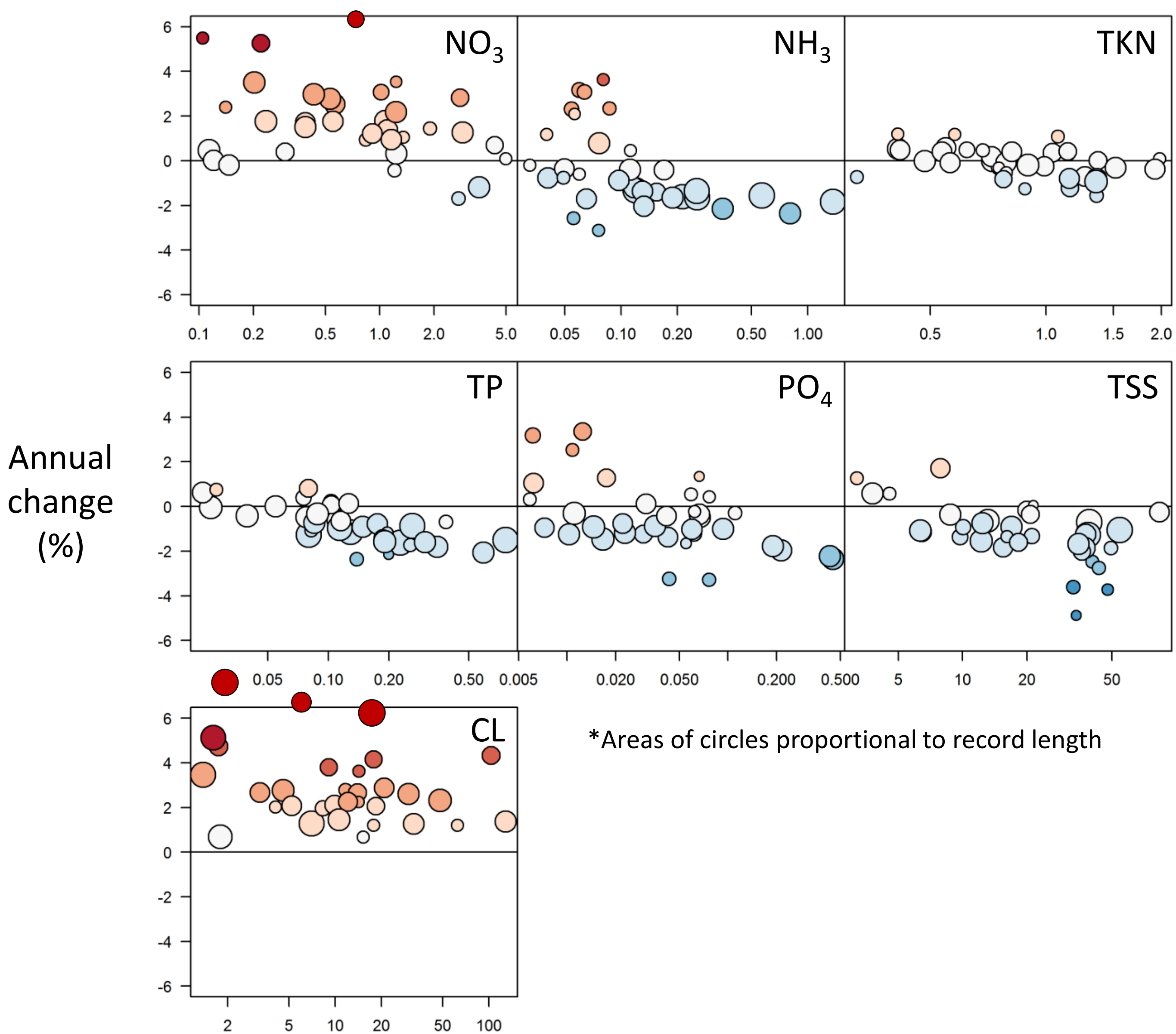
Total Nitrogen Flux



Chloride Flux



River Water Quality Trend Summary



*Areas of circles proportional to record length

River Water Quality Trend Summary

- Phosphorus, suspended solids, and ammonia have decreased in most rivers
  - The biggest improvements occurred in the 1960s-80s
  - Timing of decreases indicates wastewater improvements are the primary cause, but also some evidence of non-point reductions (TSS)
  - Recent drop in phosphorus coincident with numeric phosphorus criteria
  - Most rivers meet or are close to meeting phosphorus criteria
- Nitrate and chloride have increased in most rivers
  - Soluble chemicals move through groundwater pathways
  - Nitrate trends from increased fertilizer use and nitrification of ammonia in wastewater treatment
  - Chloride increases from road de-icing

Acknowledgments

- Those who had the foresight to start the long-term trend monitoring network, without necessarily knowing what they would find
- All of the DNR water quality biologists who continue to collect these valuable data
- Recent program champions John Sullivan and Ken Schreiber (DNR retired)
- Dale Robertson (USGS)