Significant Lake Michigan Open Lake Nutrient Changes

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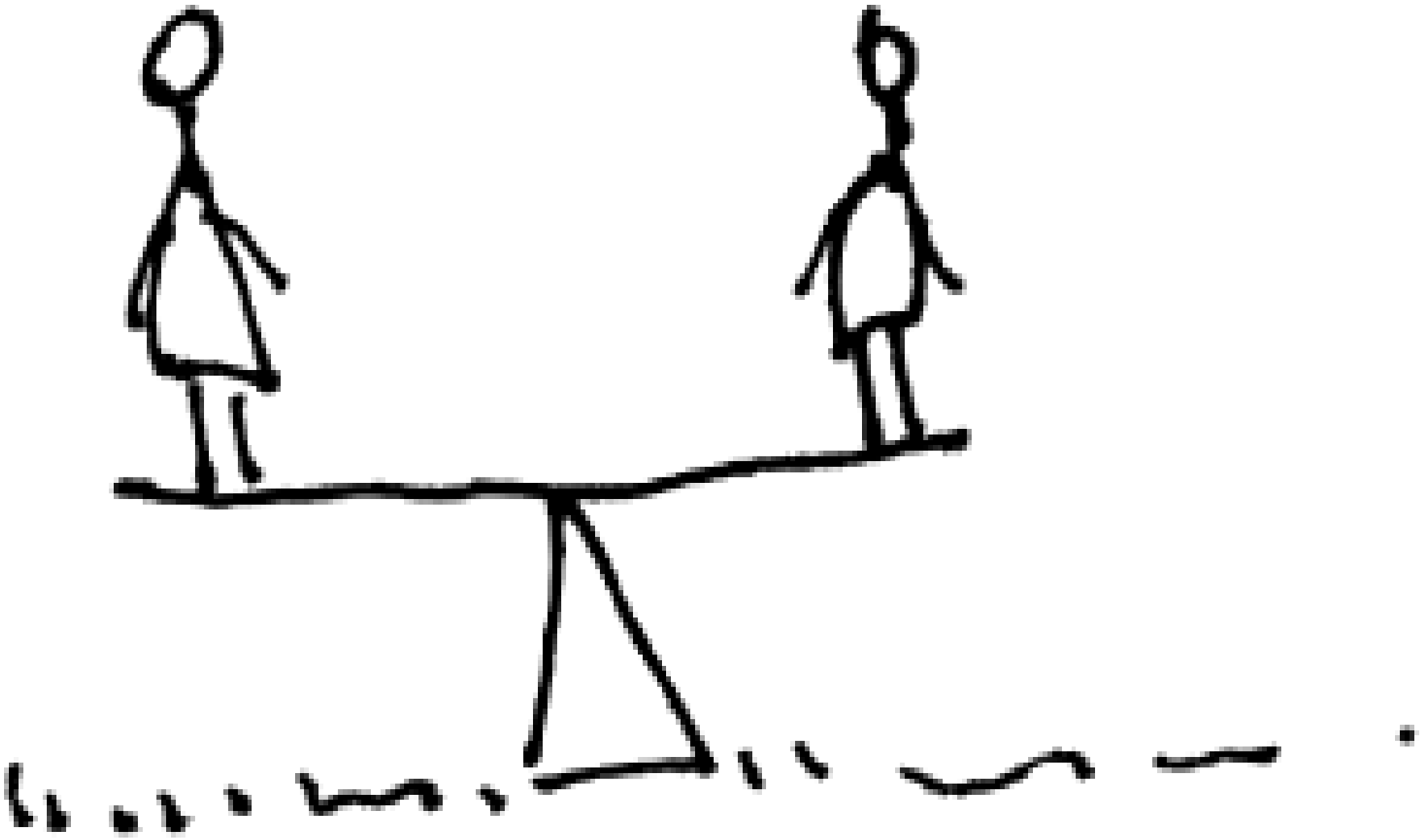
Starting with the effects

Is it top-down or bottom-up control?

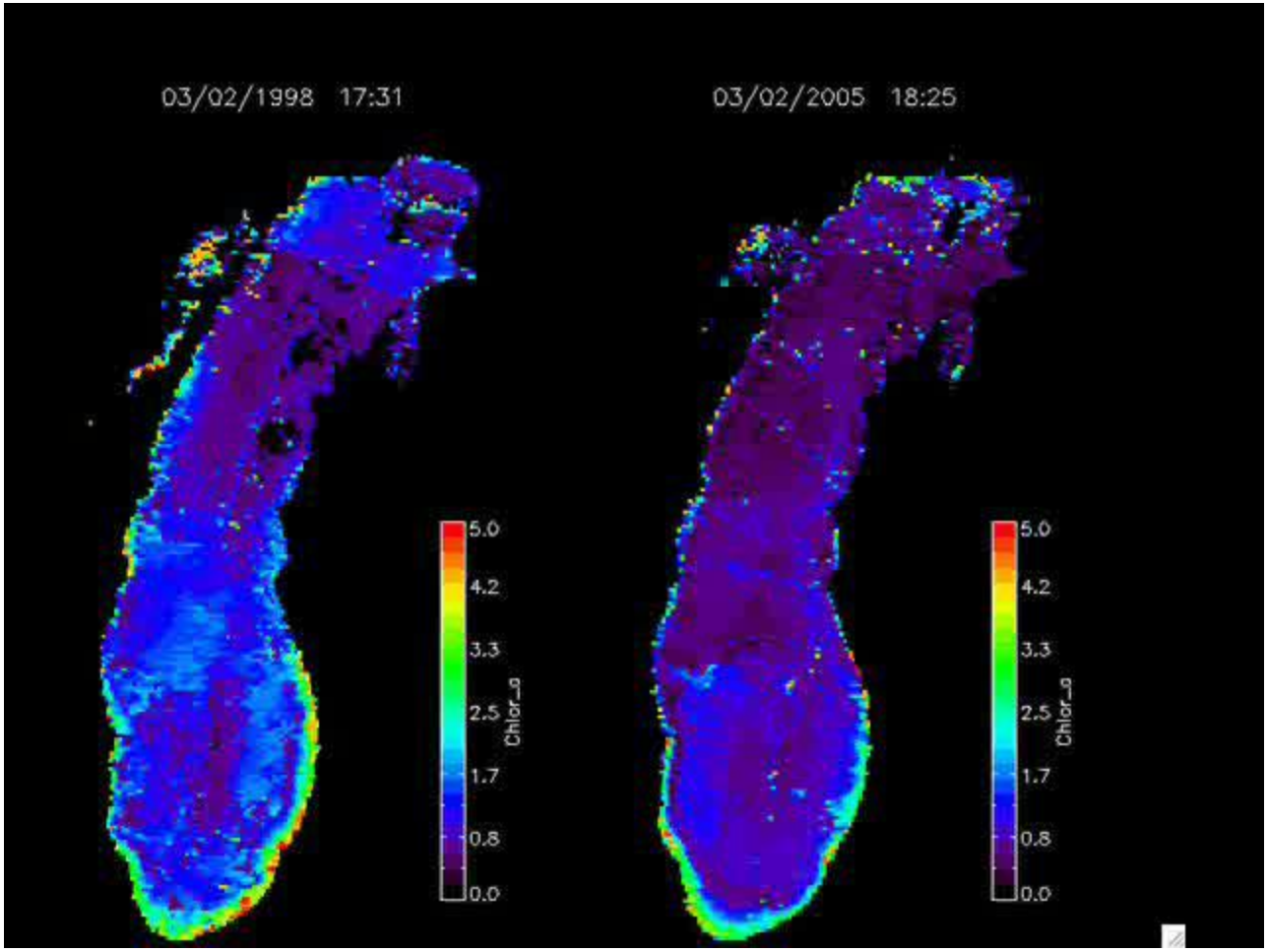


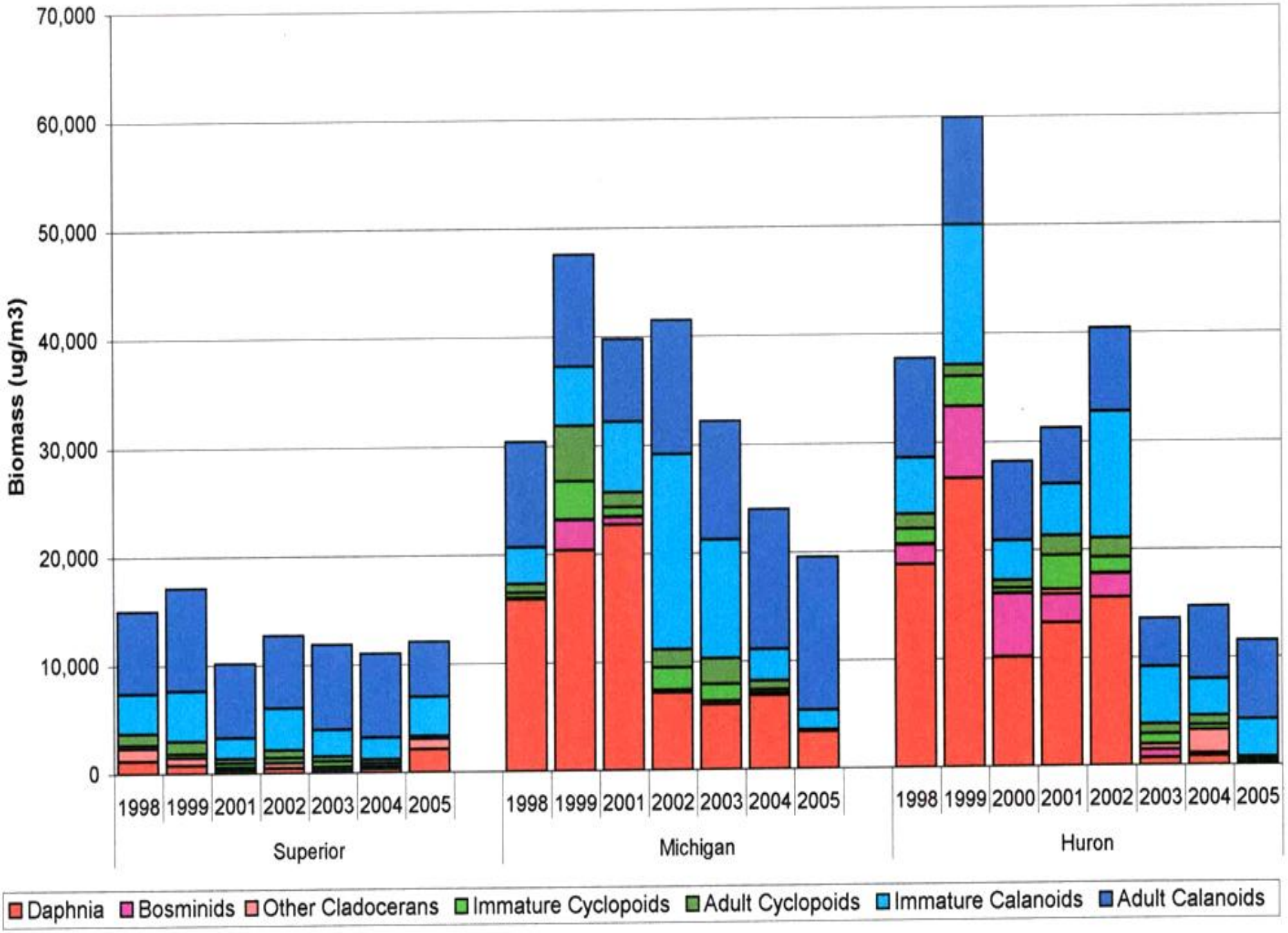
The case for nutrient control

Bottom-up

Phytoplankton to Fish

Barry Lesht


03/02/1998 17:31
03/02/2005 18:25
5.0
4.2
3.3
2.5
1.7
0.8
0.0
Chlor_a
5.0
4.2
3.3
2.5
1.7
0.8
0.0
Chlor_a


Biomass (ug/m3)
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
1998 1999 2001 2002 2003 2004 2005
Superior
1998 1999 2001 2002 2003 2004 2005
Michigan
1998 1999 2000 2001 2002 2003 2004 2005
Huron
Daphnia
Bosminids
Other Cladocerans
Immature Cyclopoids
Adult Cyclopoids
Immature Calanoids
Adult Calanoids

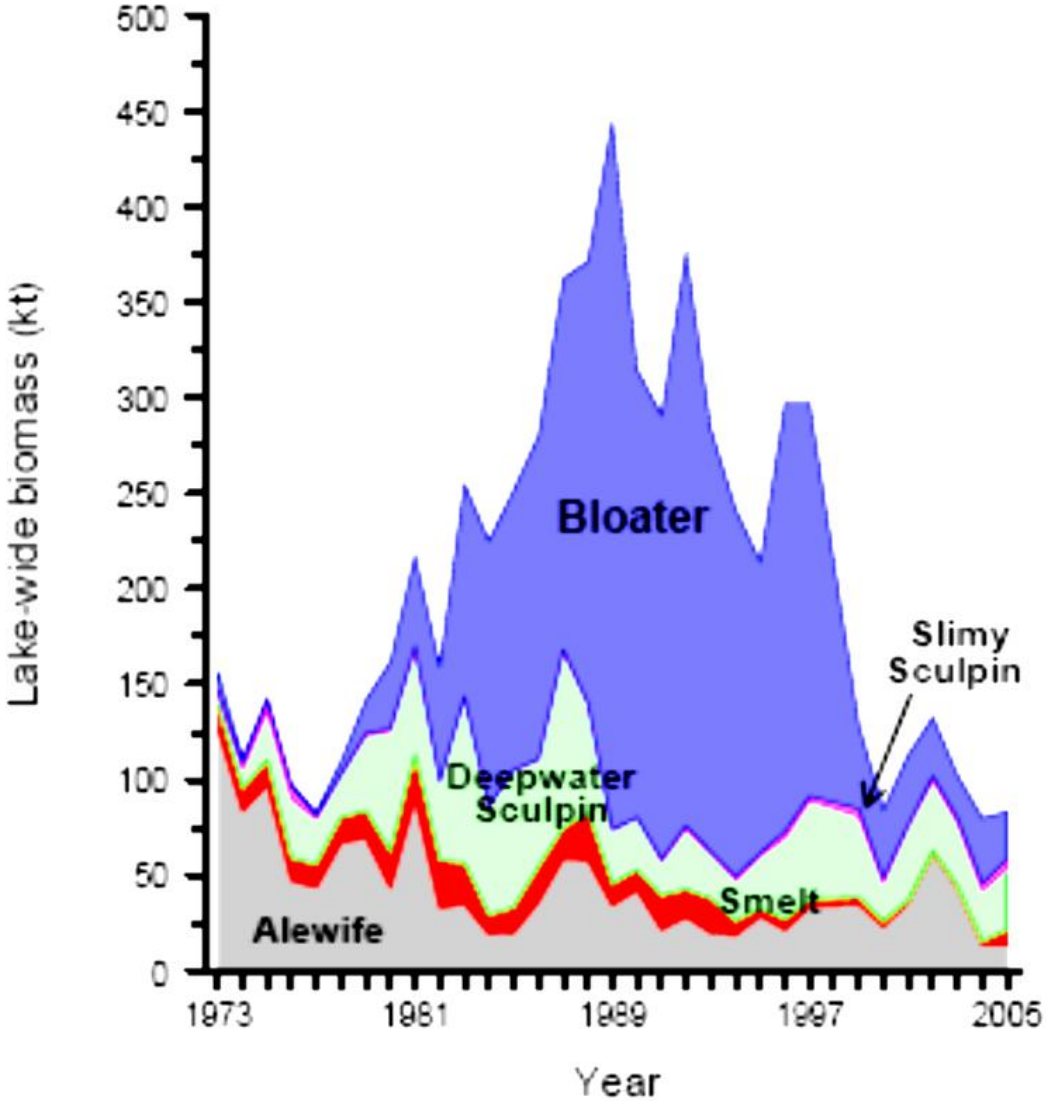
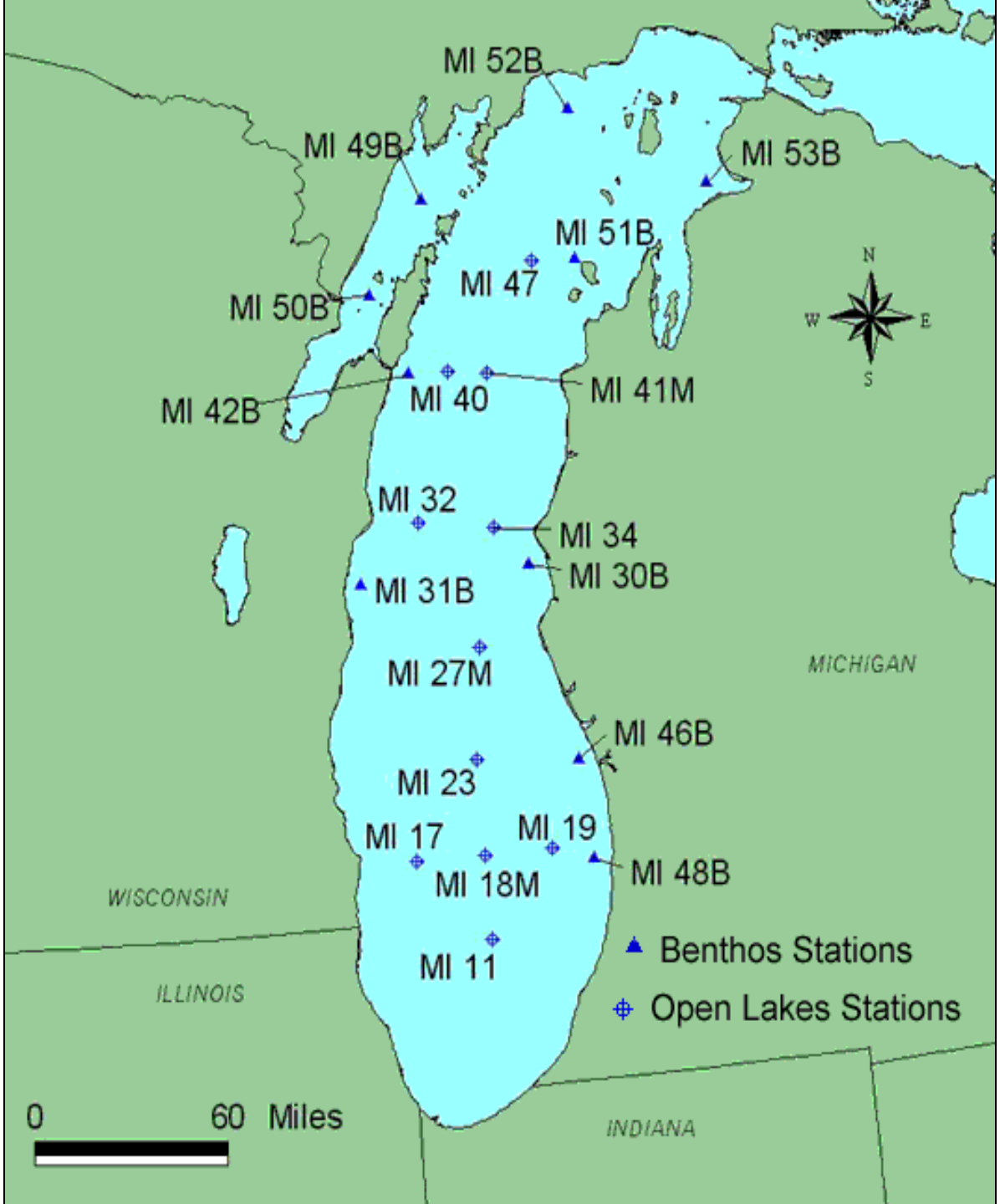
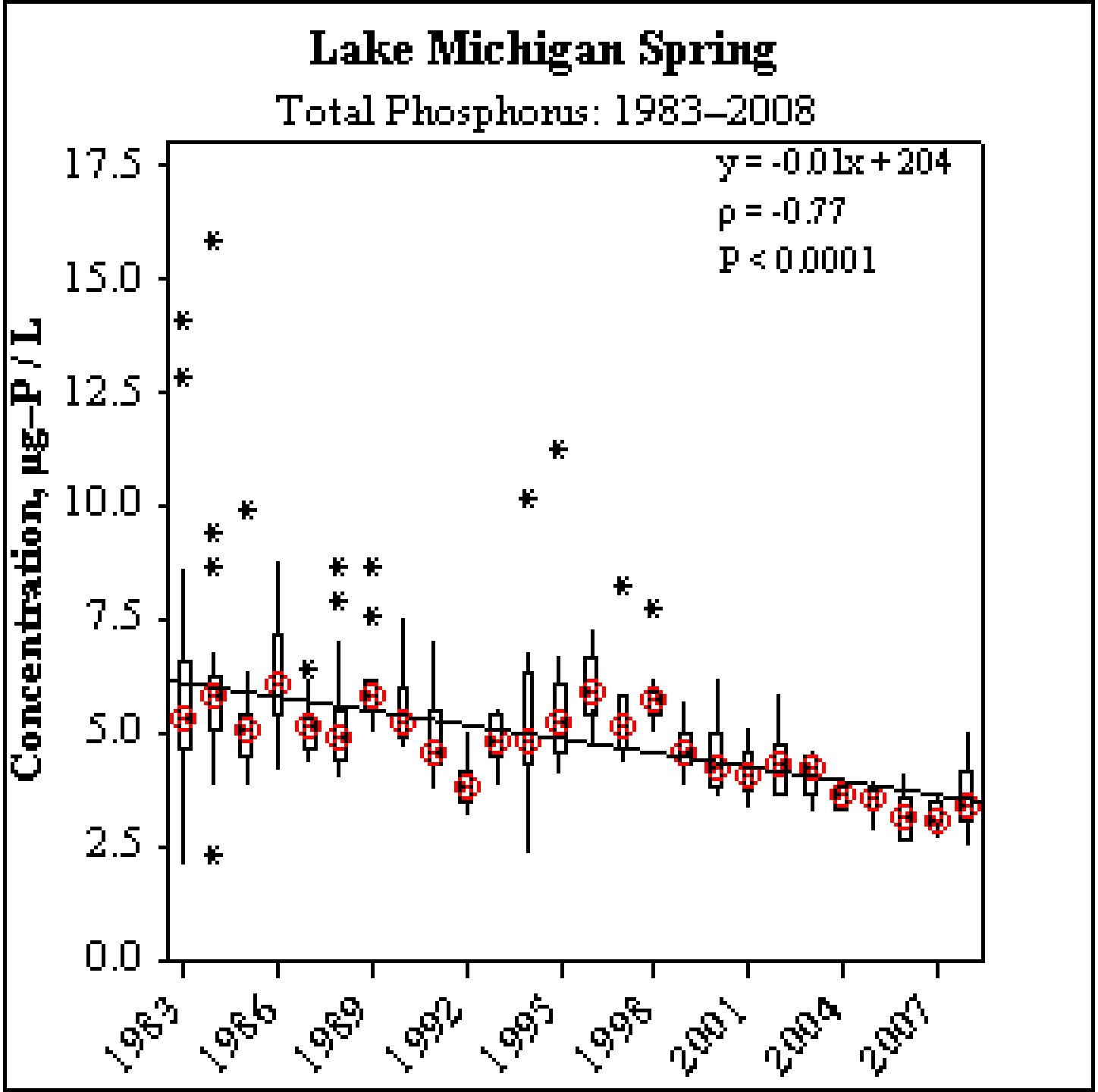
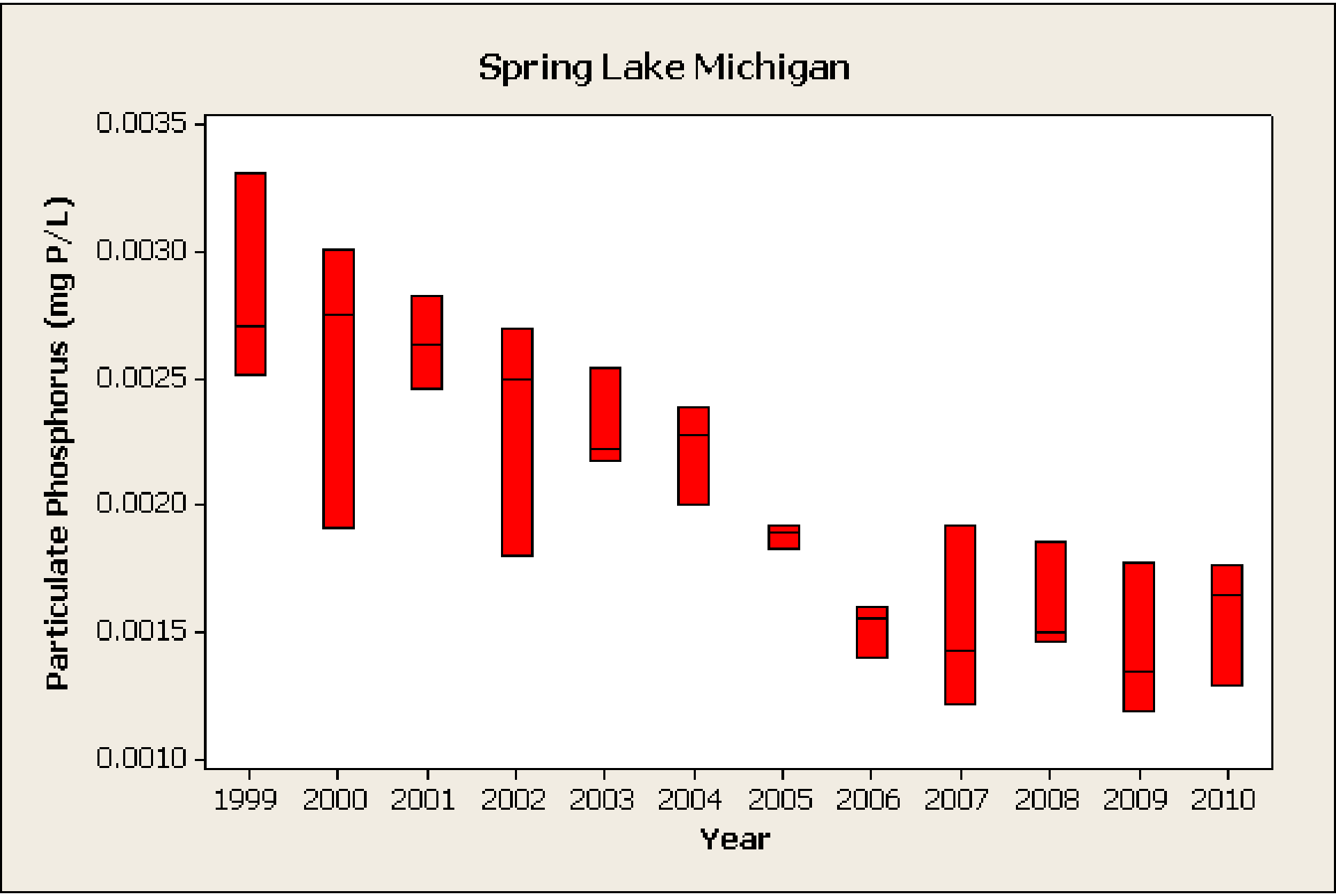


Figure 11. Estimated lake-wide biomass of prey fishes in Lake Michigan, 1973-2005, based on bottom trawl surveys (between 5-m and 114-m depth contours).

Nutrients and Particles


MI 52B
MI 49B
MI 53B
MI 51B
MI 47
MI 50B
MI 42B
MI 40
MI 41M
MI 32
MI 34
MI 30B
MI 31B
MI 27M
MI 46B
MI 23
MI 17
MI 19
MI 18M
MI 48B
MI 11
N
W
E
S
MICHIGAN
WISCONSIN
ILLINOIS
INDIANA
Benthos Stations
Open Lakes Stations
0
60 Miles


Lake Michigan Spring
Total Phosphorus: 1983–2008
y = -0.01x + 204
ρ = -0.77
P < 0.0001
Concentration, µg–P / L
17.5
15.0
12.5
10.0
7.5
5.0
2.5
0.0
1983
1986
1989
1992
1995
1998
2001
2004
2007

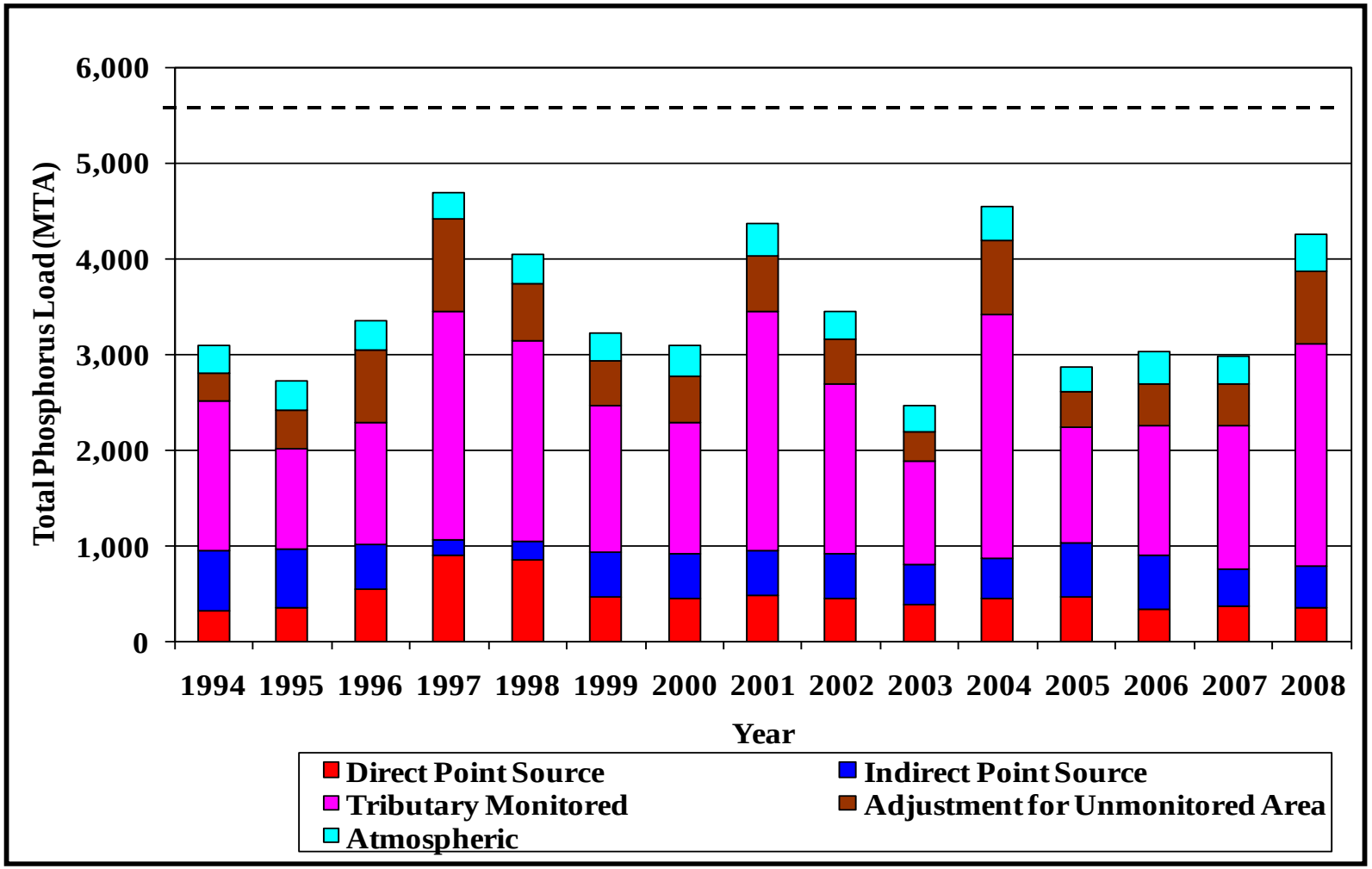

Spring Lake Michigan
Particulate Phosphorus (mg P/L)
0.0035
0.0030
0.0025
0.0020
0.0015
0.0010
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
Year

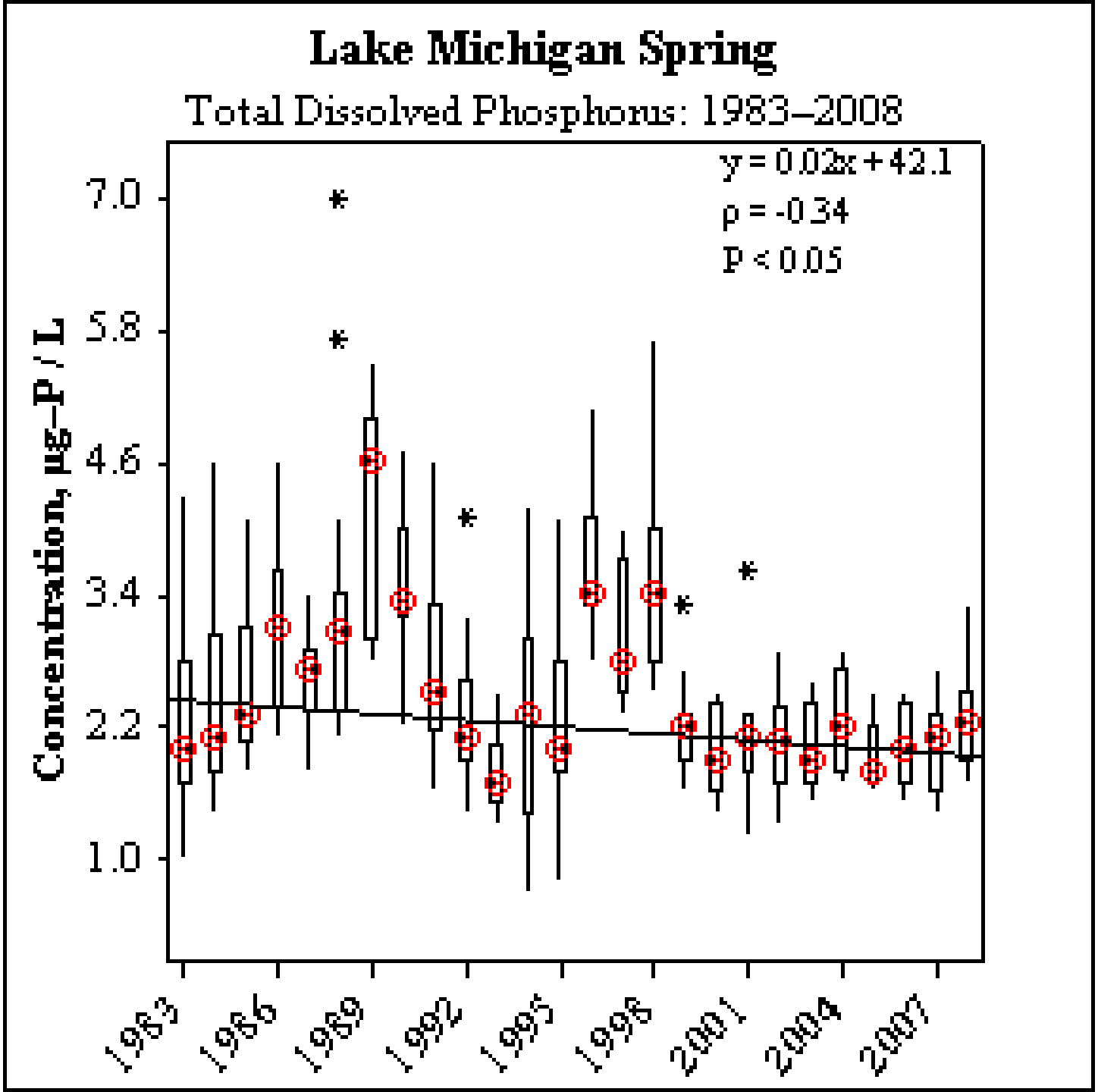
Lake Michigan Total Phosphorus Loadings 1994-2008

Dave Dolan & Steve Chapra

University of Wisconsin Green Bay

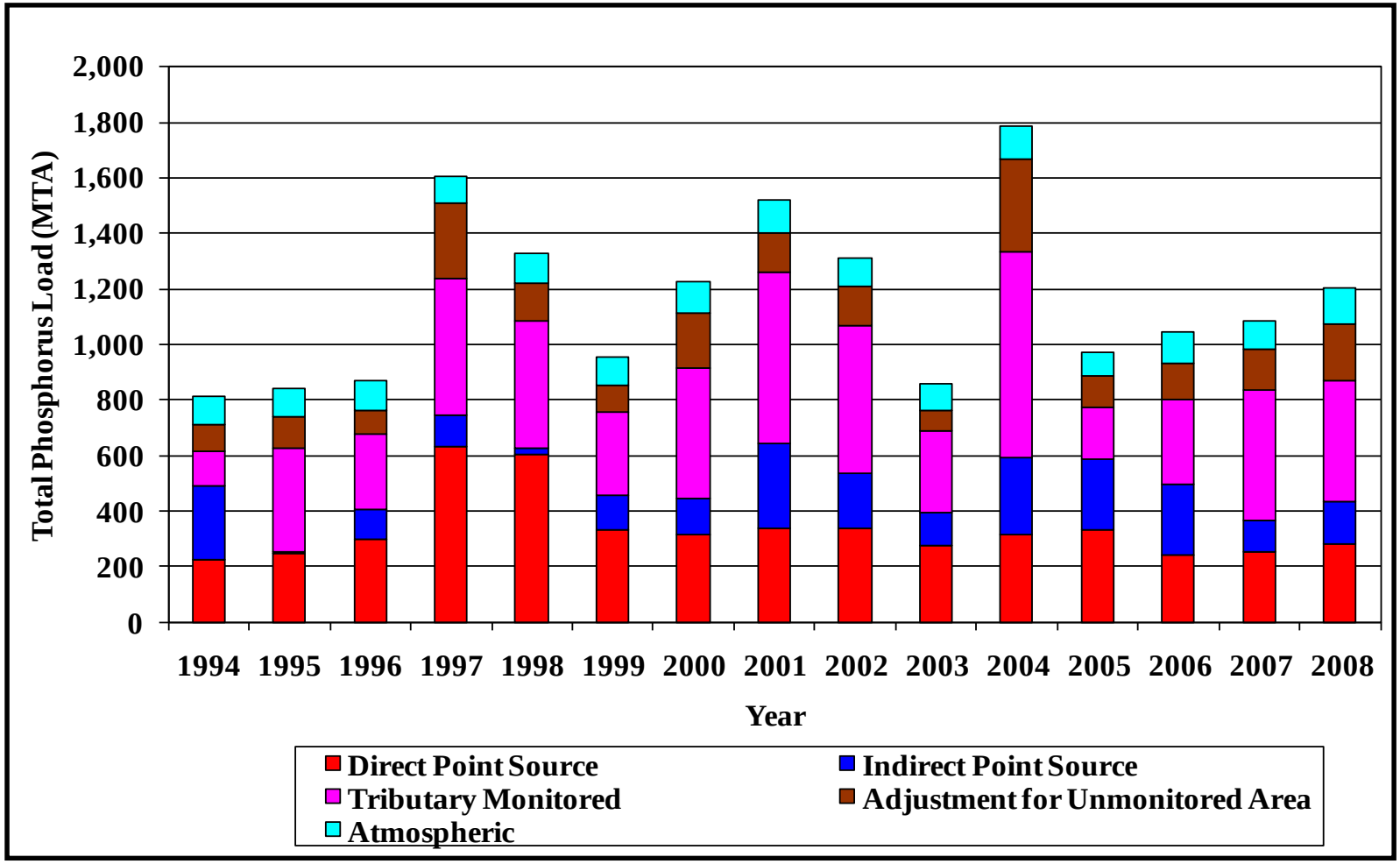
Tufts University

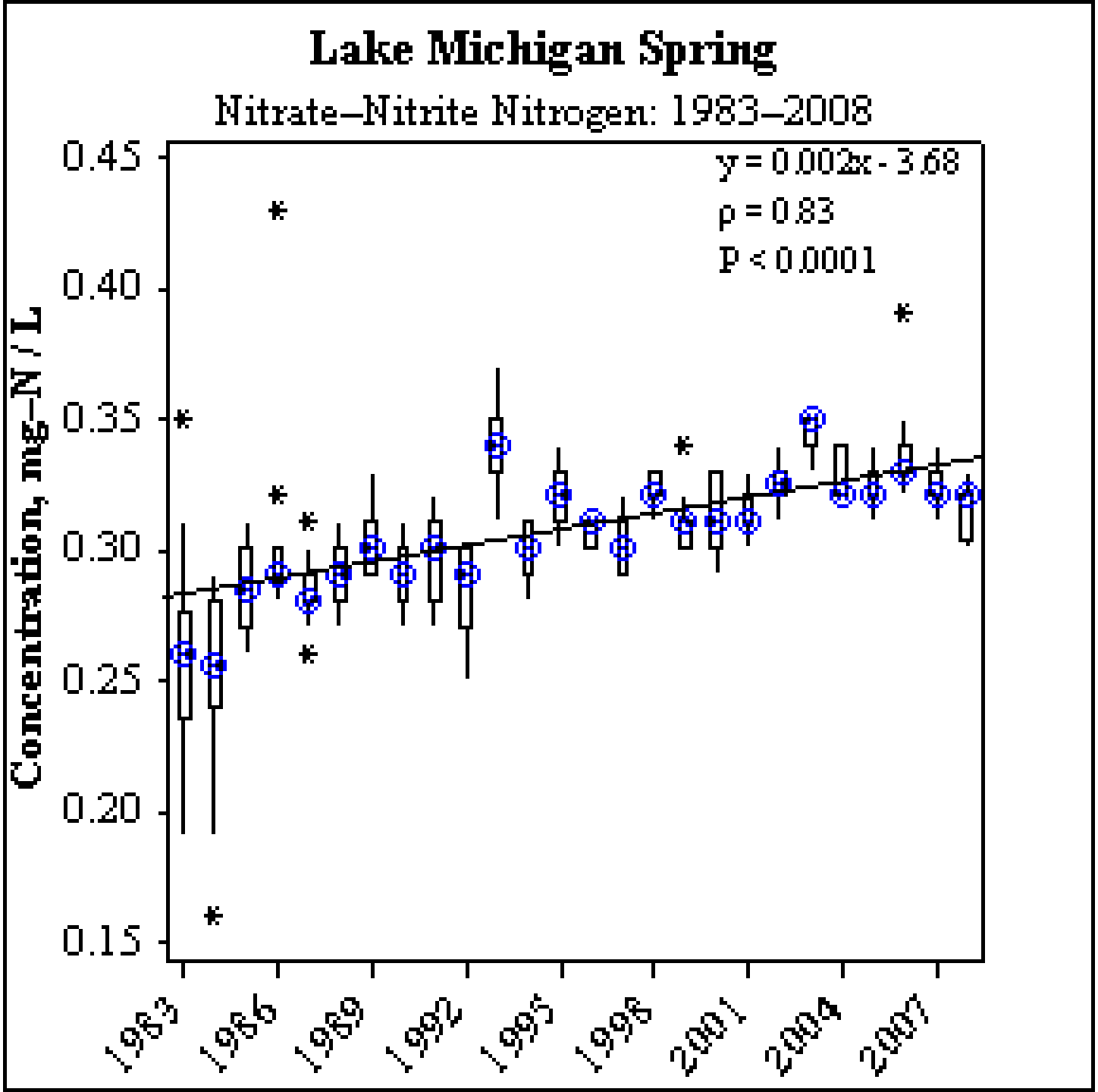


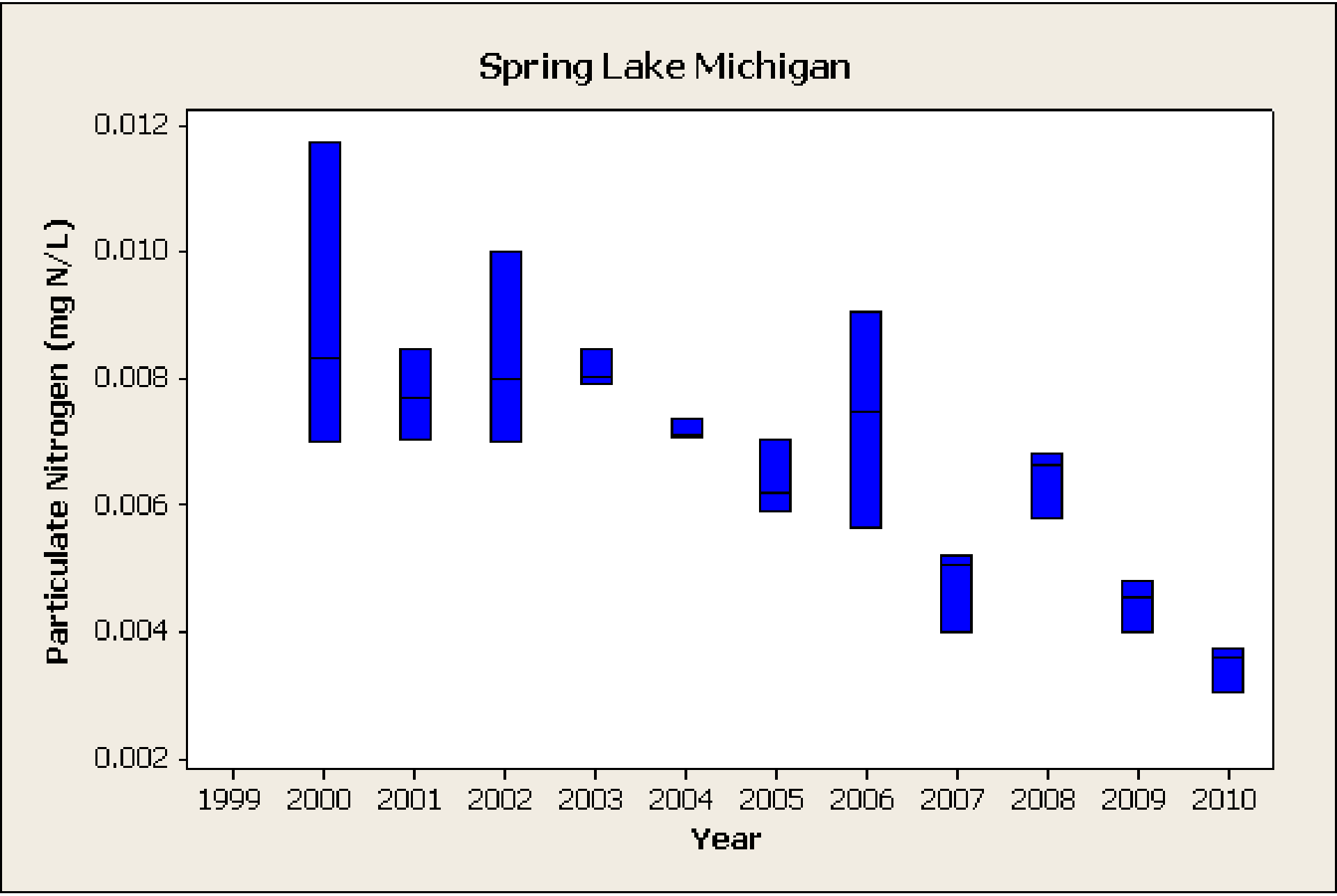

Lake Michigan Spring
Total Dissolved Phosphorus: 1983–2008
y = 0.02x + 42.1
ρ = -0.34
P < 0.05
Concentration, µg–P / L
7.0
5.8
4.6
3.4
2.2
1.0
1983
1986
1989
1992
1995
1998
2001
2004
2007

Lake Michigan Total Dissolved Phosphorus Loadings 1994-2008

Dave Dolan & Steve Chapra

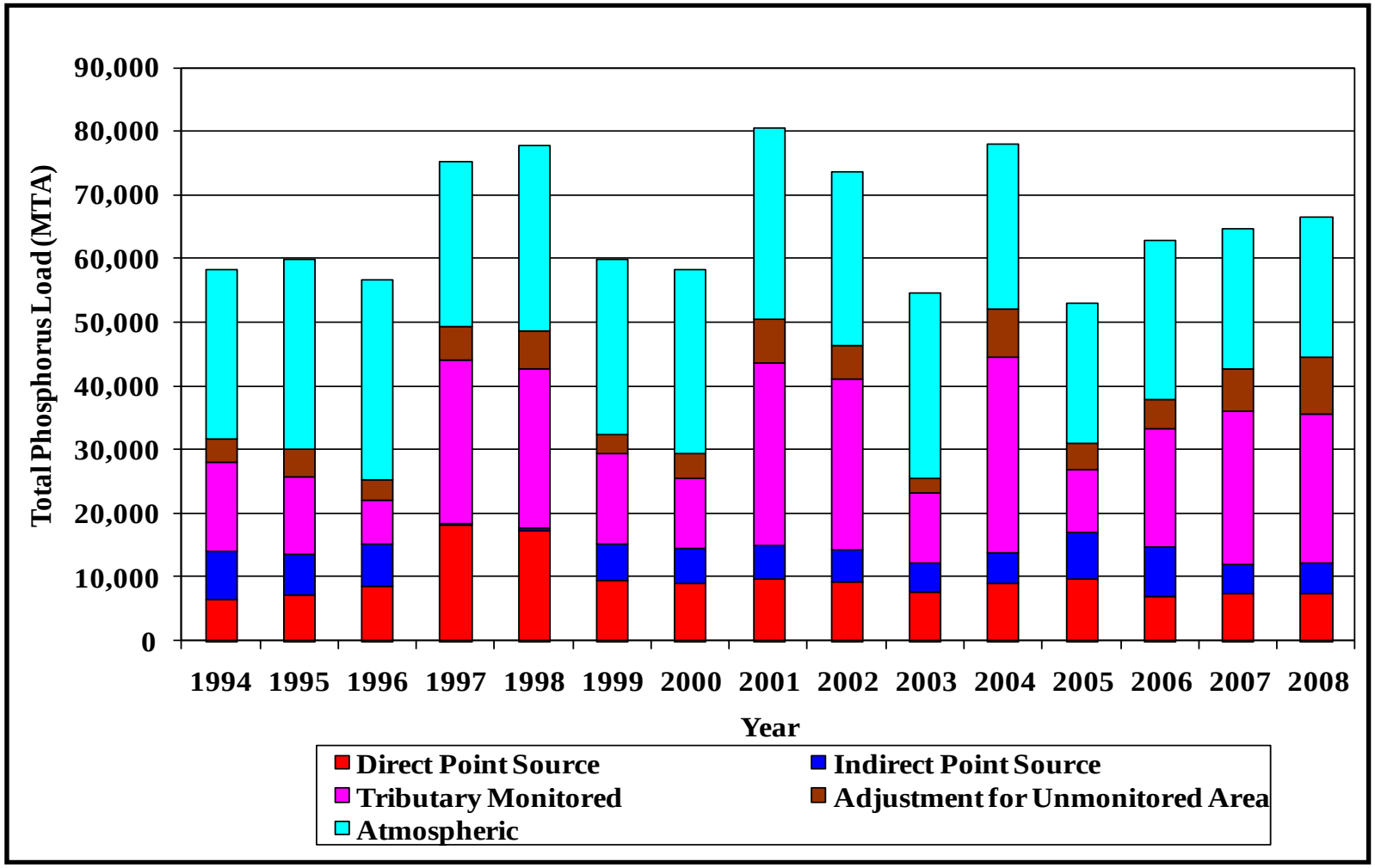


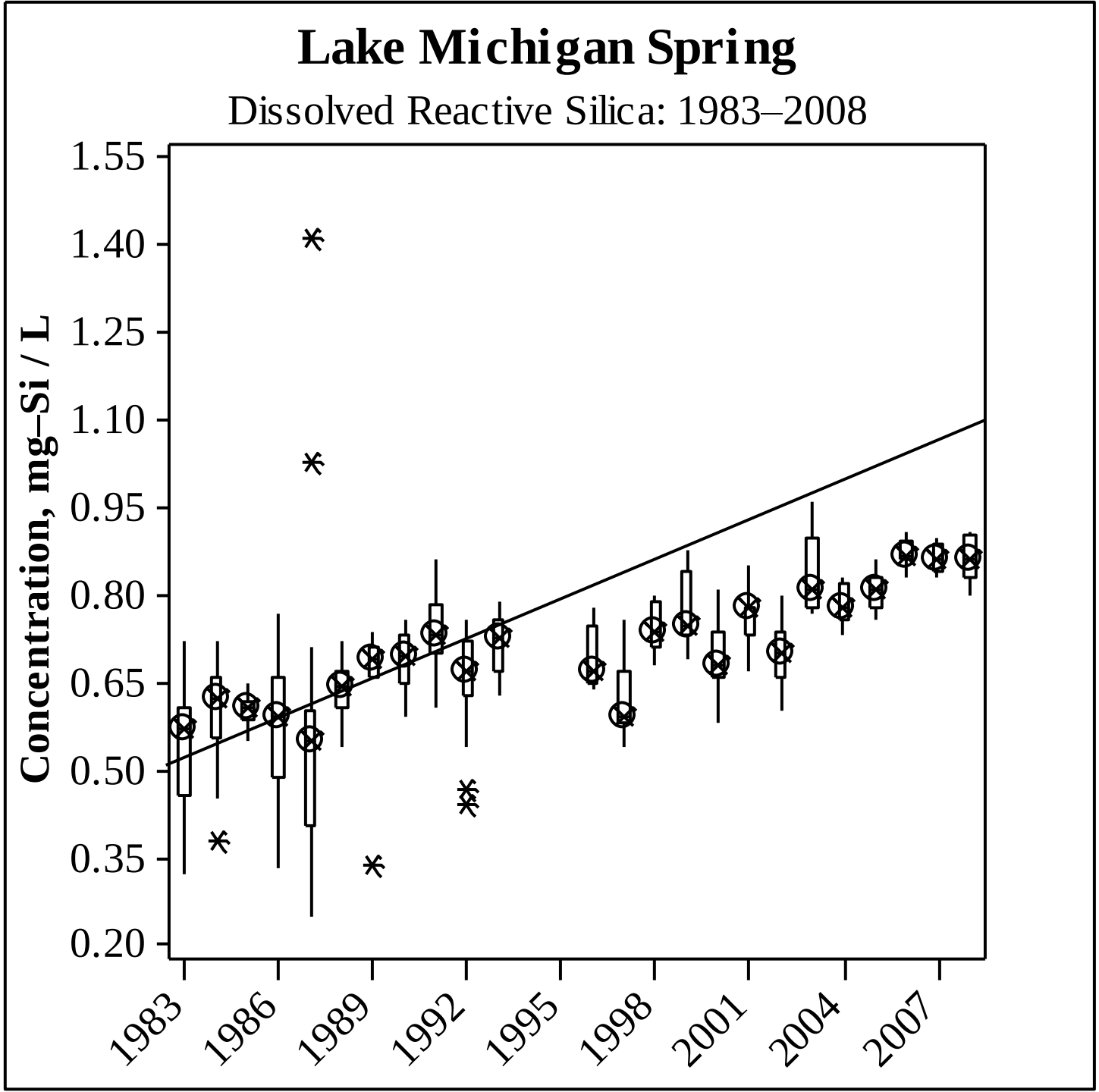

Lake Michigan Spring
Nitrate–Nitrite Nitrogen: 1983–2008
y = 0.002x - 3.68
ρ = 0.83
P < 0.0001
Concentration, mg–N / L
0.45
0.40
0.35
0.30
0.25
0.20
0.15
1983
1986
1989
1992
1995
1998
2001
2004
2007

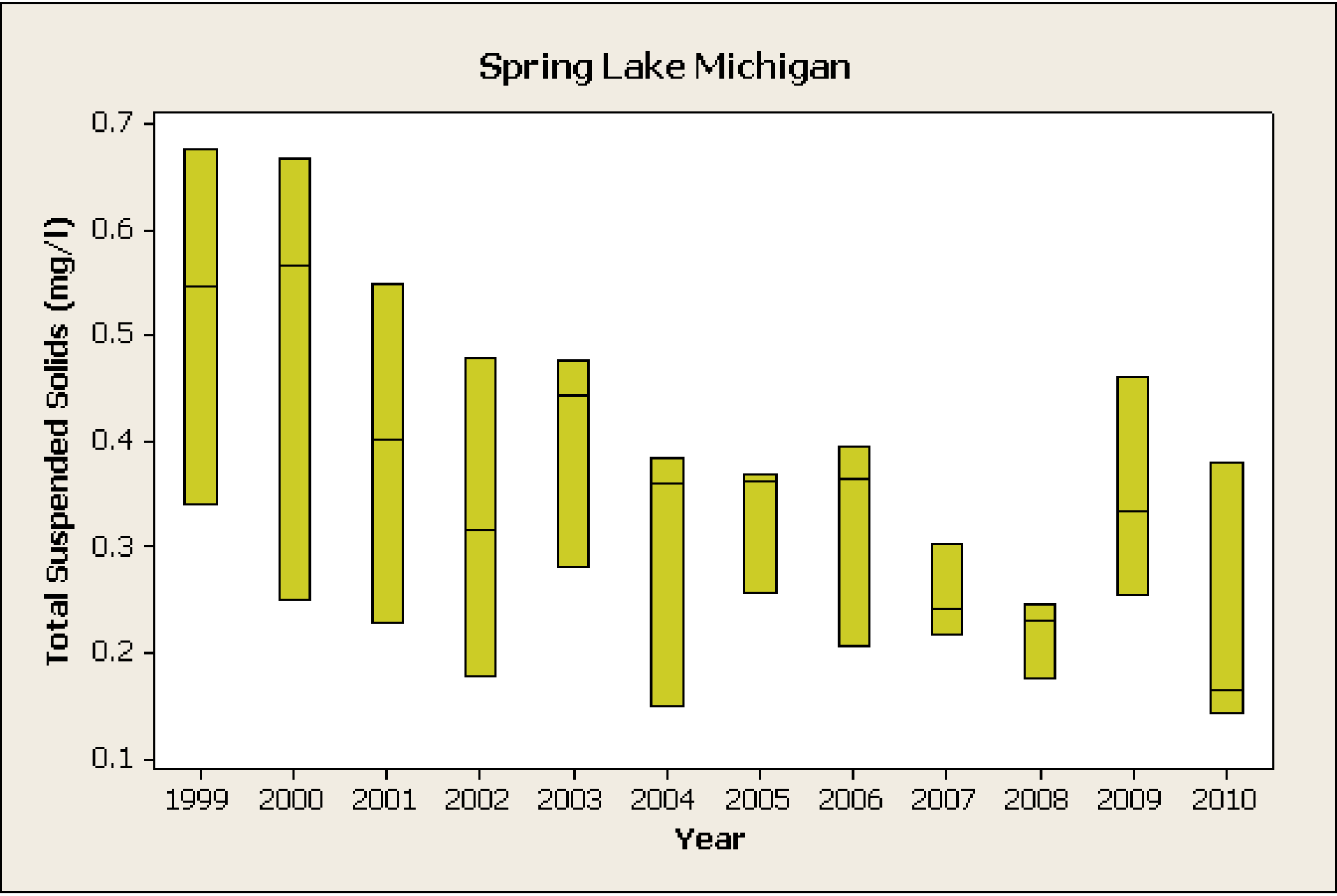

Spring Lake Michigan
Particulate Nitrogen (mg N/L)
0.012
0.010
0.008
0.006
0.004
0.002
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
Year

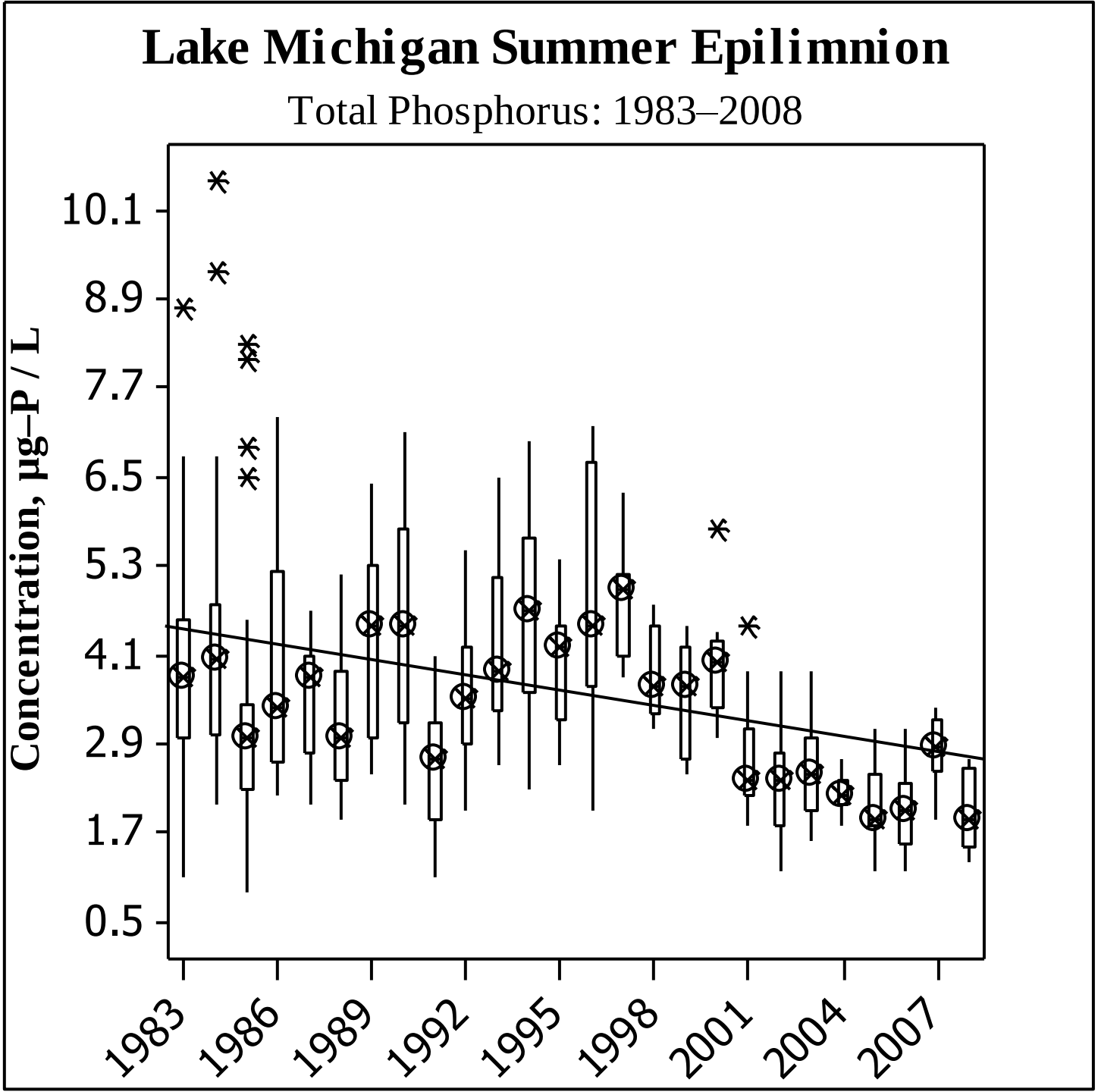
Lake Michigan Nitrate Loadings 1994-2008

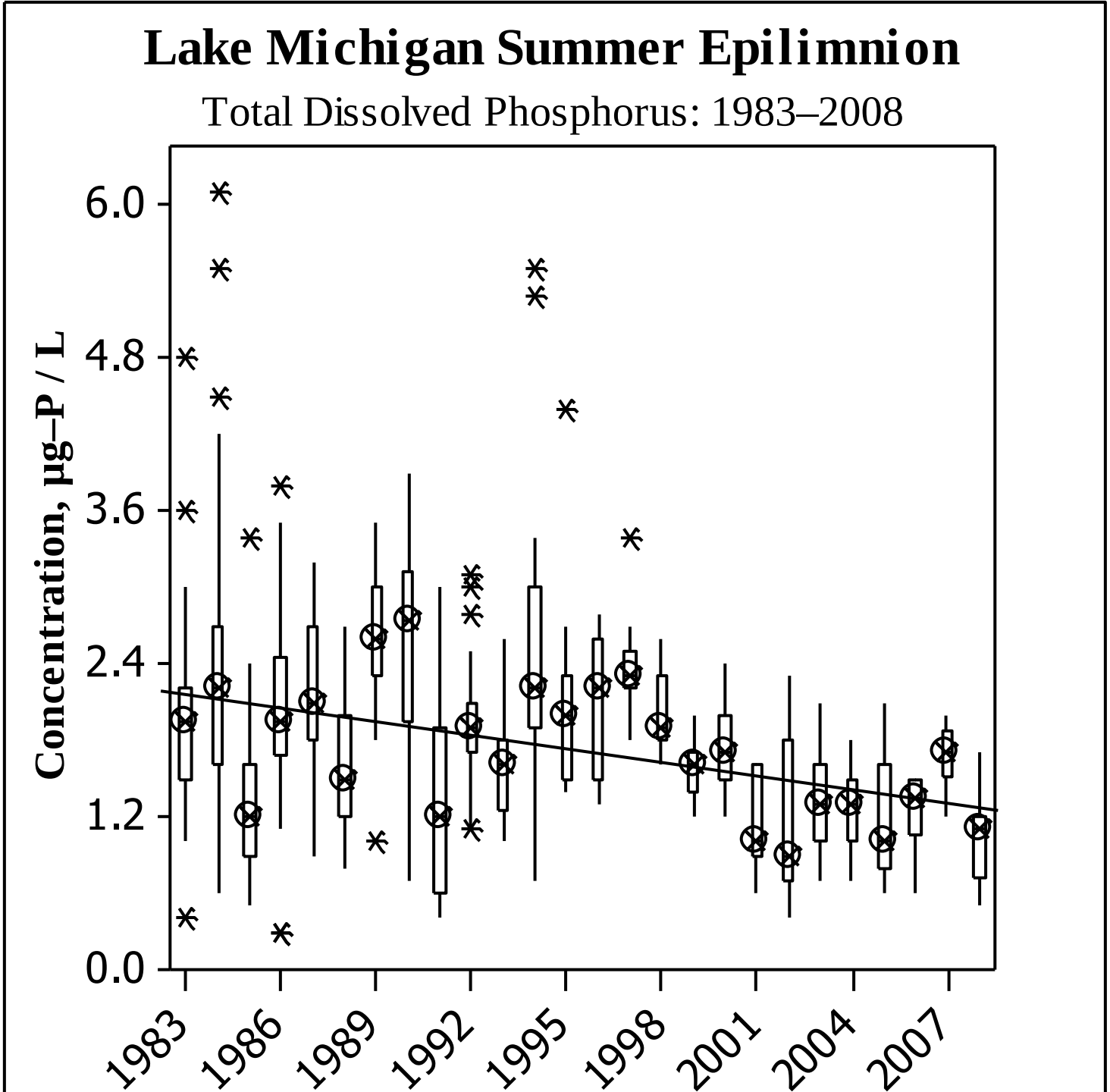
Dave Dolan & Steve Chapra

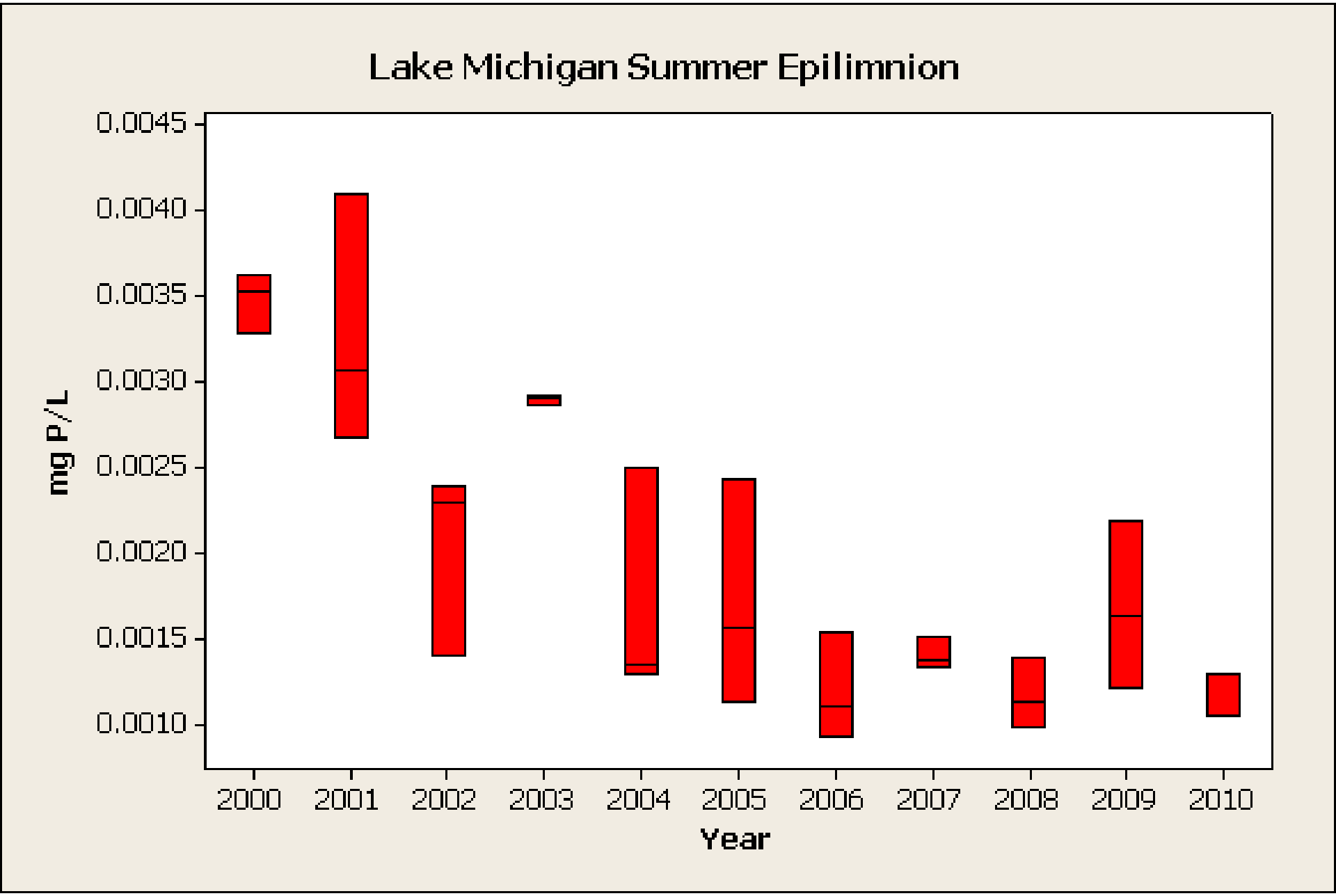


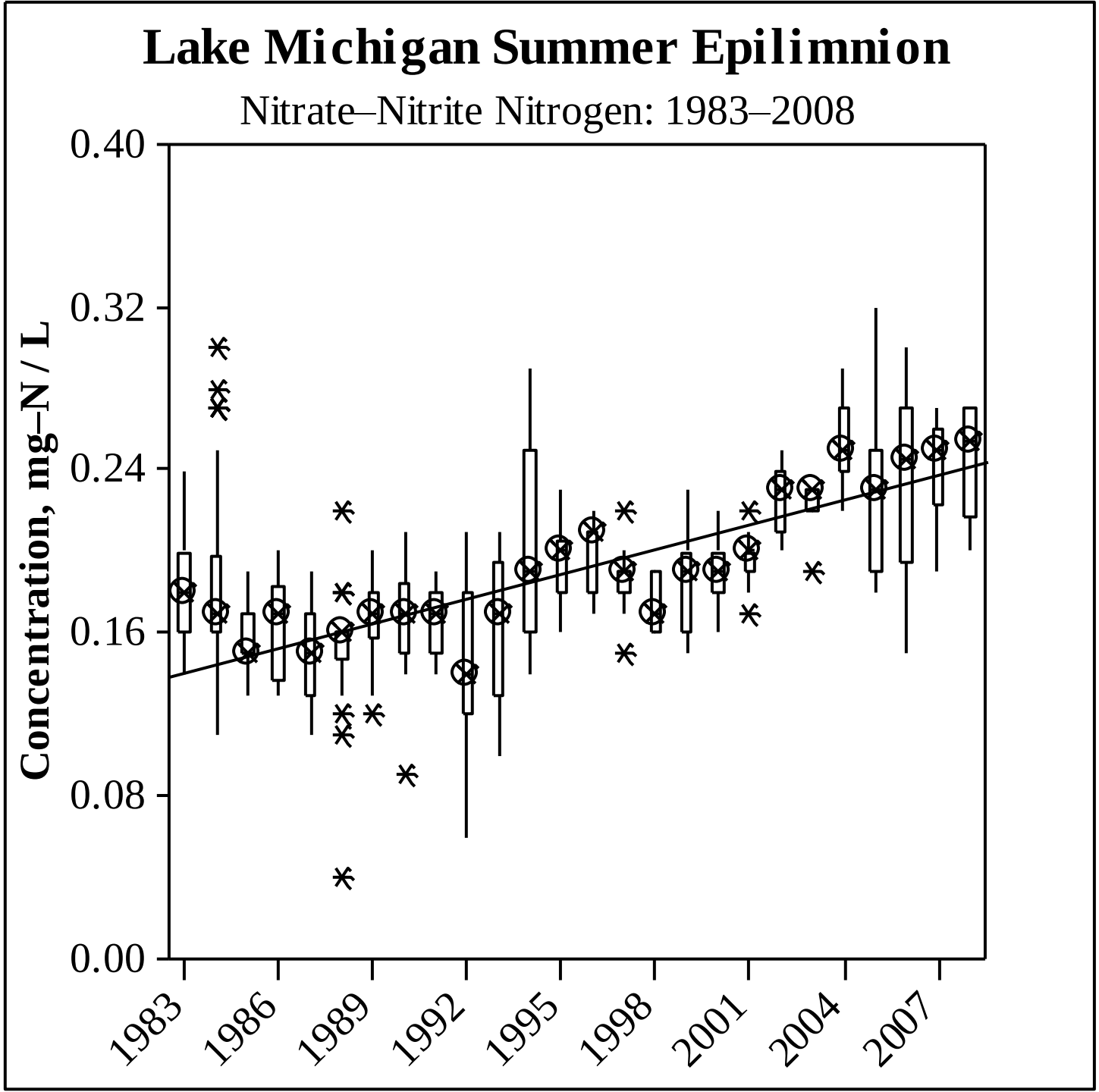

Lake Michigan Spring
Dissolved Reactive Silica: 1983–2008
Concentration, mg–Si / L
1.55
1.40
1.25
1.10
0.95
0.80
0.65
0.50
0.35
0.20
1983
1986
1989
1992
1995
1998
2001
2004
2007

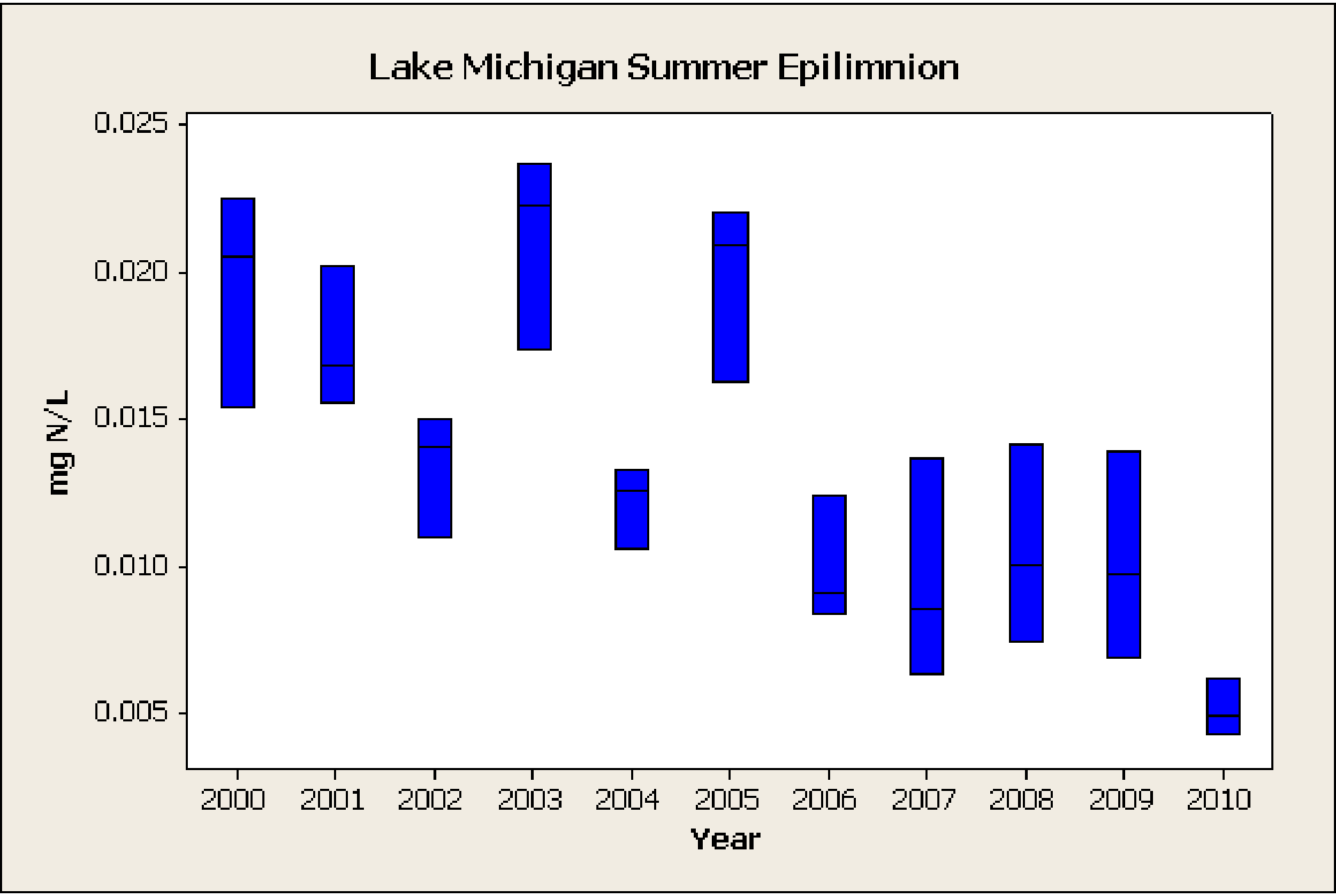

Spring Lake Michigan
Total Suspended Solids (mg/l)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
Year

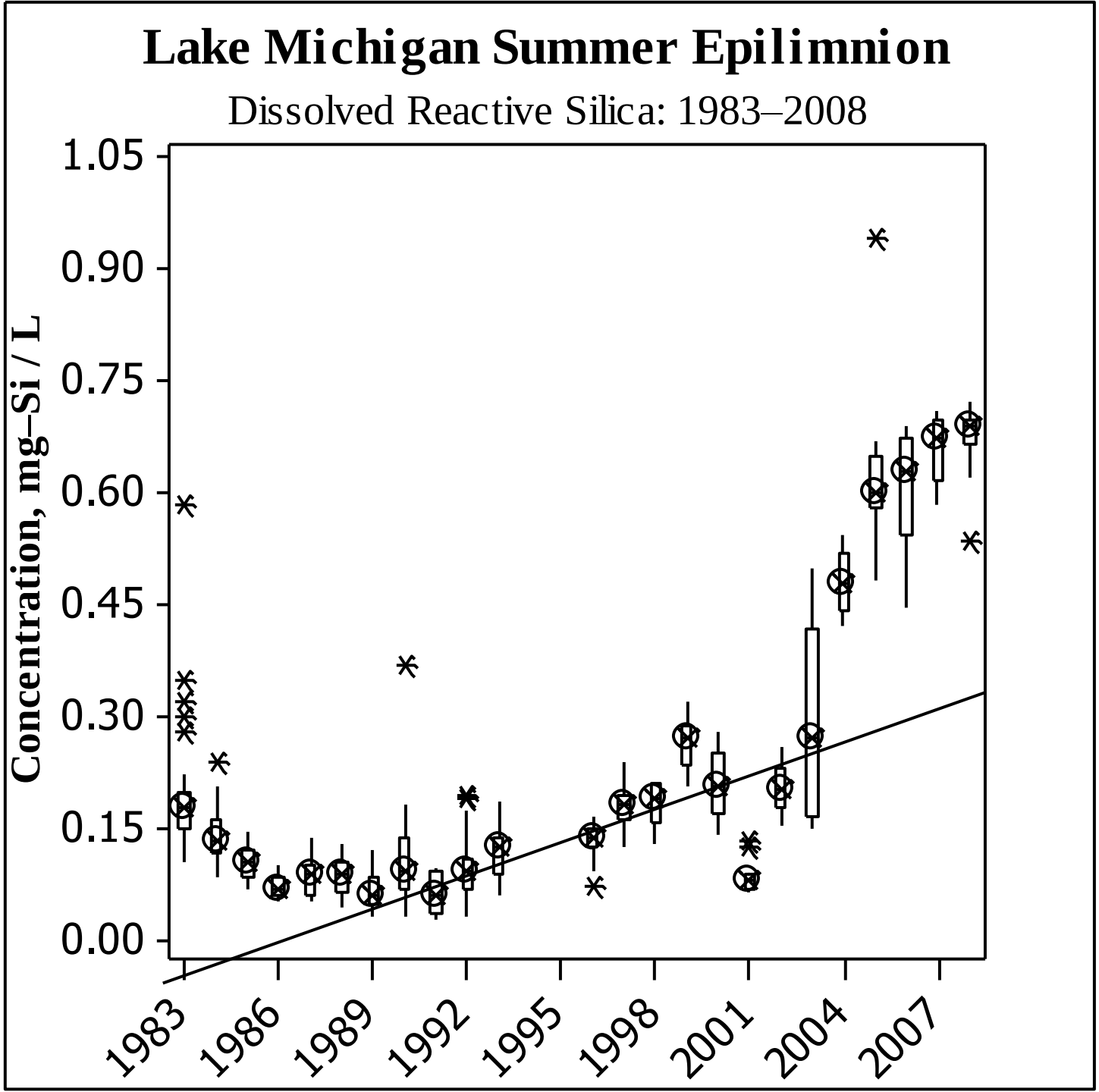

Lake Michigan Summer Epilimnion
Total Phosphorus: 1983–2008
Concentration, µg–P / L
10.1
8.9
7.7
6.5
5.3
4.1
2.9
1.7
0.5
1983
1986
1989
1992
1995
1998
2001
2004
2007

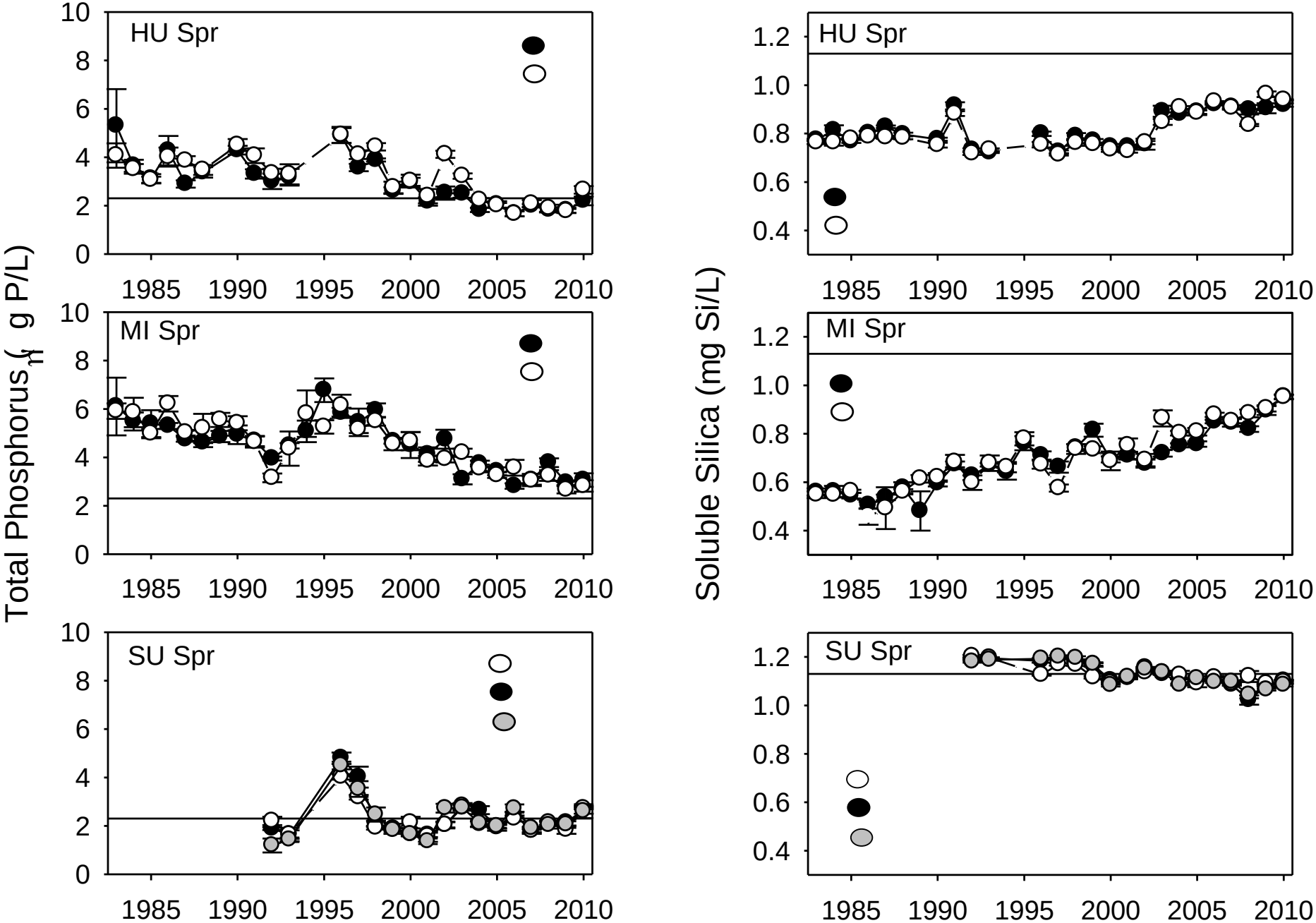

Lake Michigan Summer Epilimnion
Total Dissolved Phosphorus: 1983–2008
Concentration, µg–P / L
6.0
4.8
3.6
2.4
1.2
0.0
1983
1986
1989
1992
1995
1998
2001
2004
2007

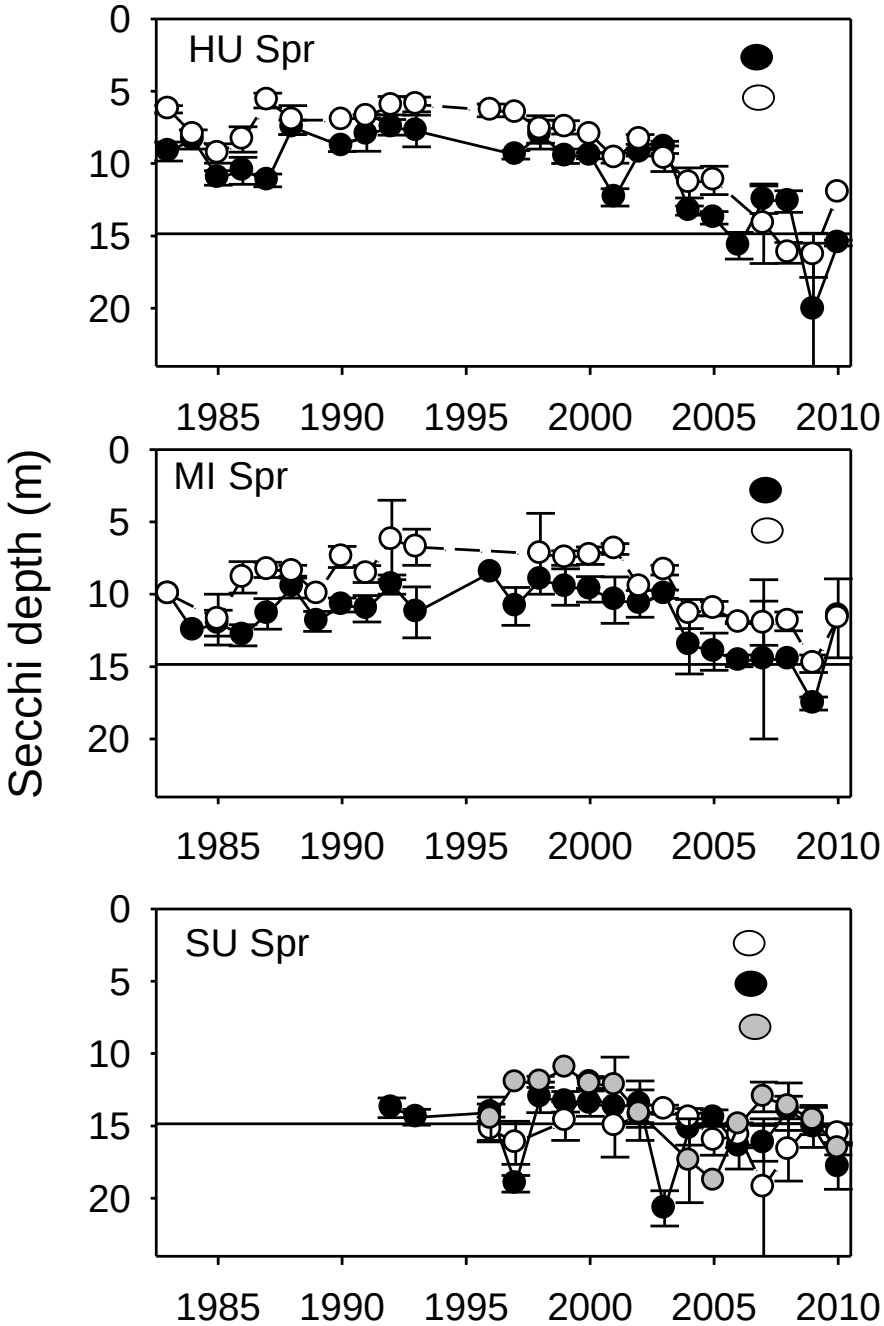

Lake Michigan Summer Epilimnion
0.0045
0.0040
0.0035
0.0030
0.0025
0.0020
0.0015
0.0010
mg P/L
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
Year


Lake Michigan Summer Epilimnion
Nitrate–Nitrite Nitrogen: 1983–2008
Concentration, mg–N / L
0.40
0.32
0.24
0.16
0.08
0.00
1983
1986
1989
1992
1995
1998
2001
2004
2007


Lake Michigan Summer Epilimnion
0.025
0.020
0.015
0.010
0.005
mg N/L
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
Year


Lake Michigan Summer Epilimnion
Dissolved Reactive Silica: 1983–2008
Concentration, mg–Si / L
1.05
0.90
0.75
0.60
0.45
0.30
0.15
0.00
1983
1986
1989
1992
1995
1998
2001
2004
2007


Total Phosphorus (µg P/L)
Soluble Silica (mg Si/L)
HU Spr
MI Spr
SU Spr
0
2
4
6
8
10
0.4
0.6
0.8
1.0
1.2
1985
1990
1995
2000
2005
2010


HU Spr
MI Spr
SU Spr
Secchi depth (m)
0
5
10
15
20
1985
1990
1995
2000
2005
2010