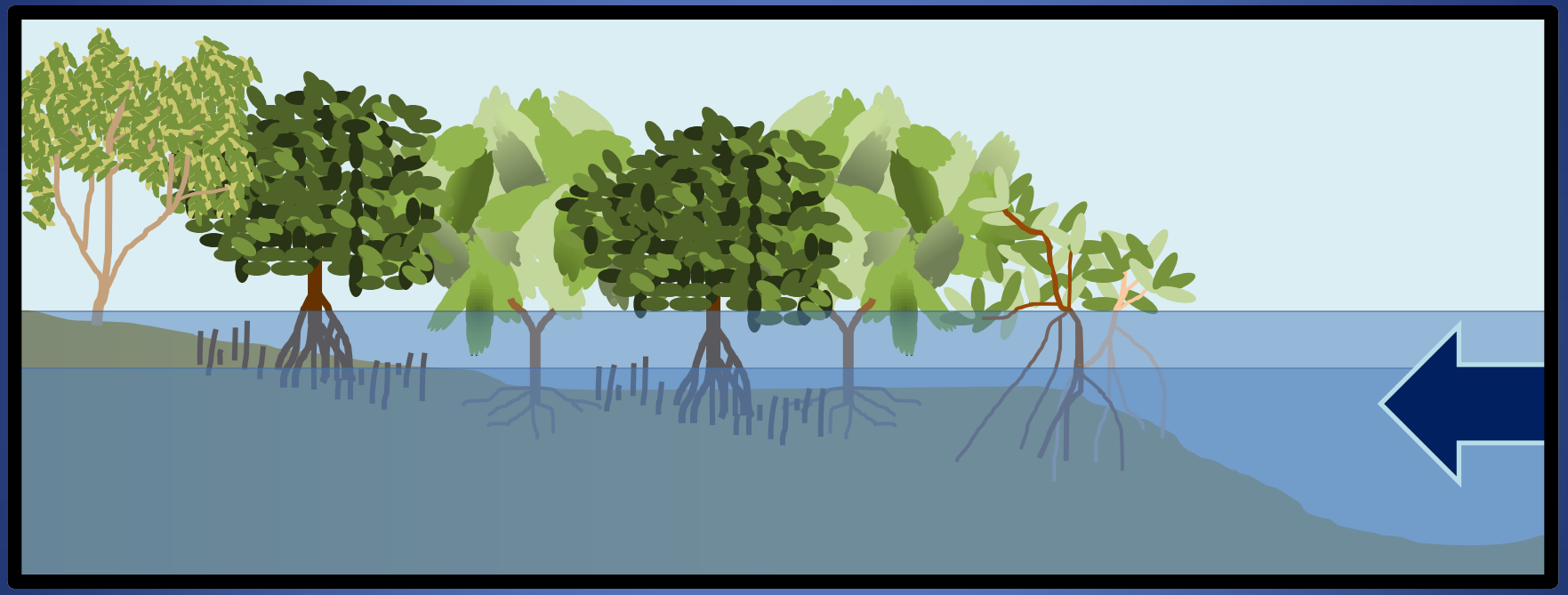
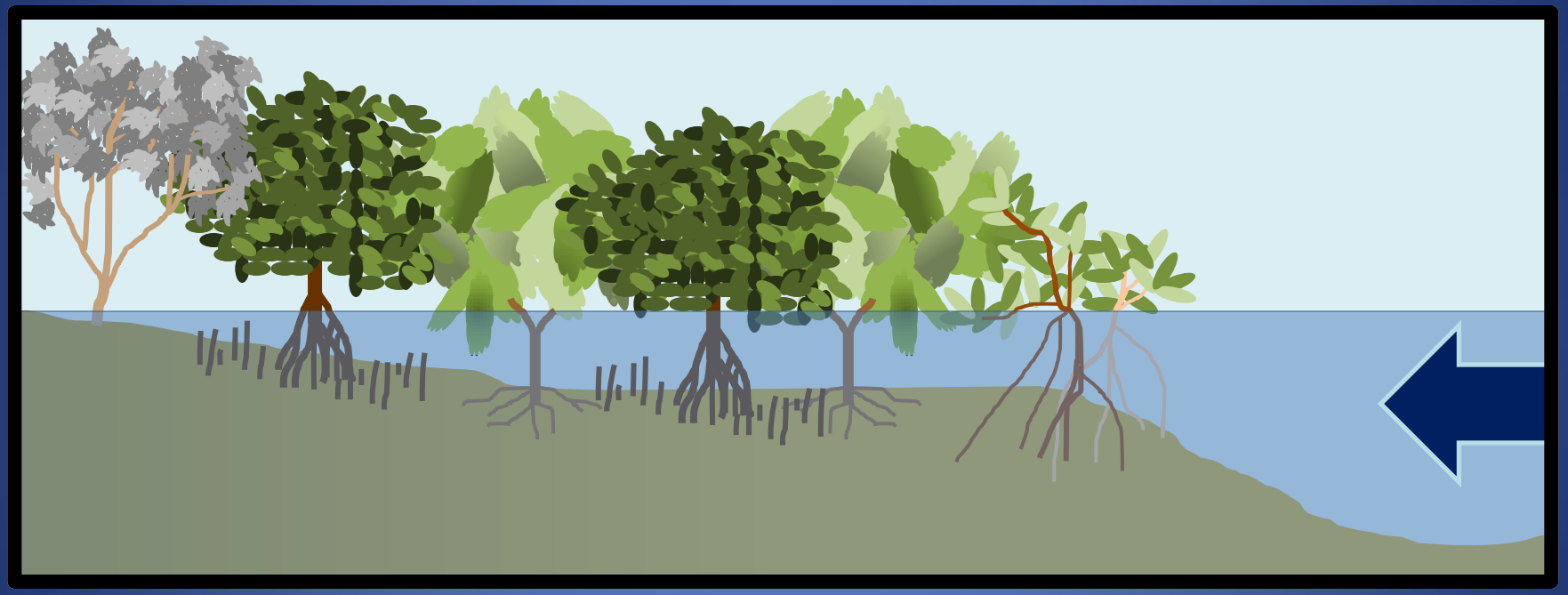
Hydropatterns and rainfall during the 2009-2010 hydrologic year (June to May) provide incite into how a restored Everglades might respond to sea level rise.

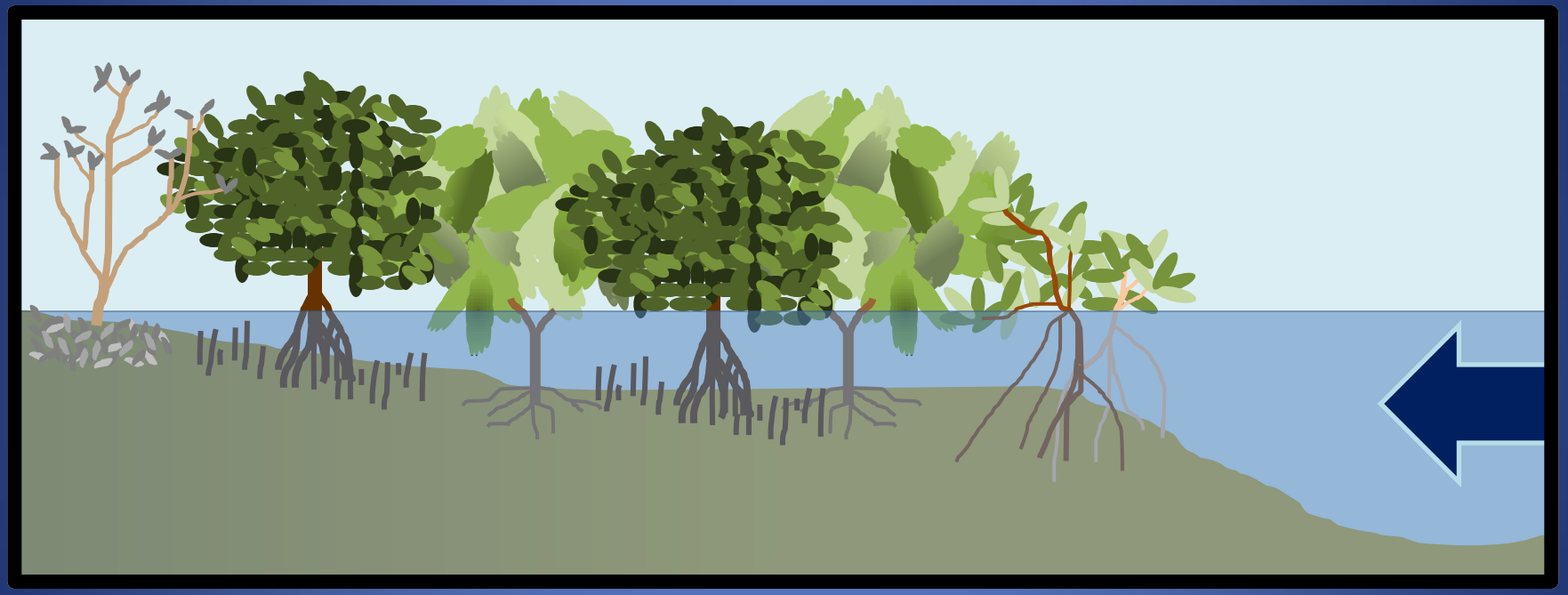
Jerome J. Lorenz, Peter E. Frezza and Michelle Robinson

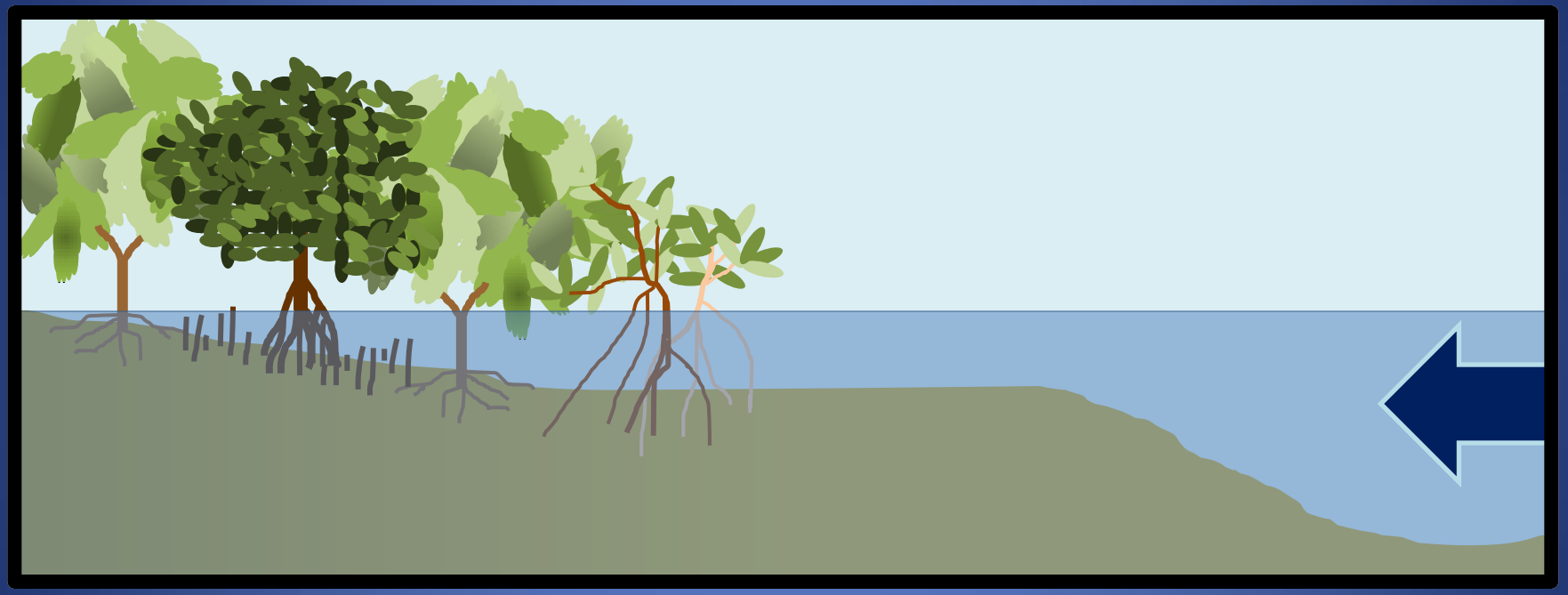
Audubon

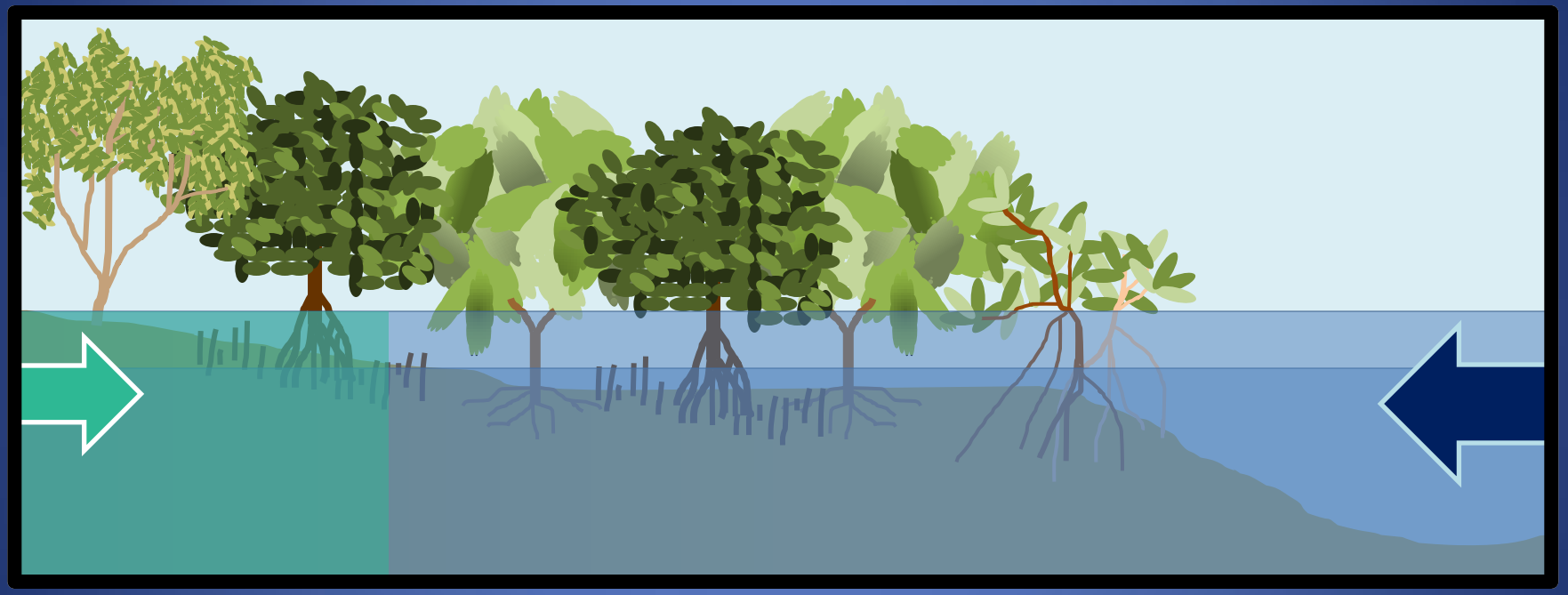
Tavernier Science Center

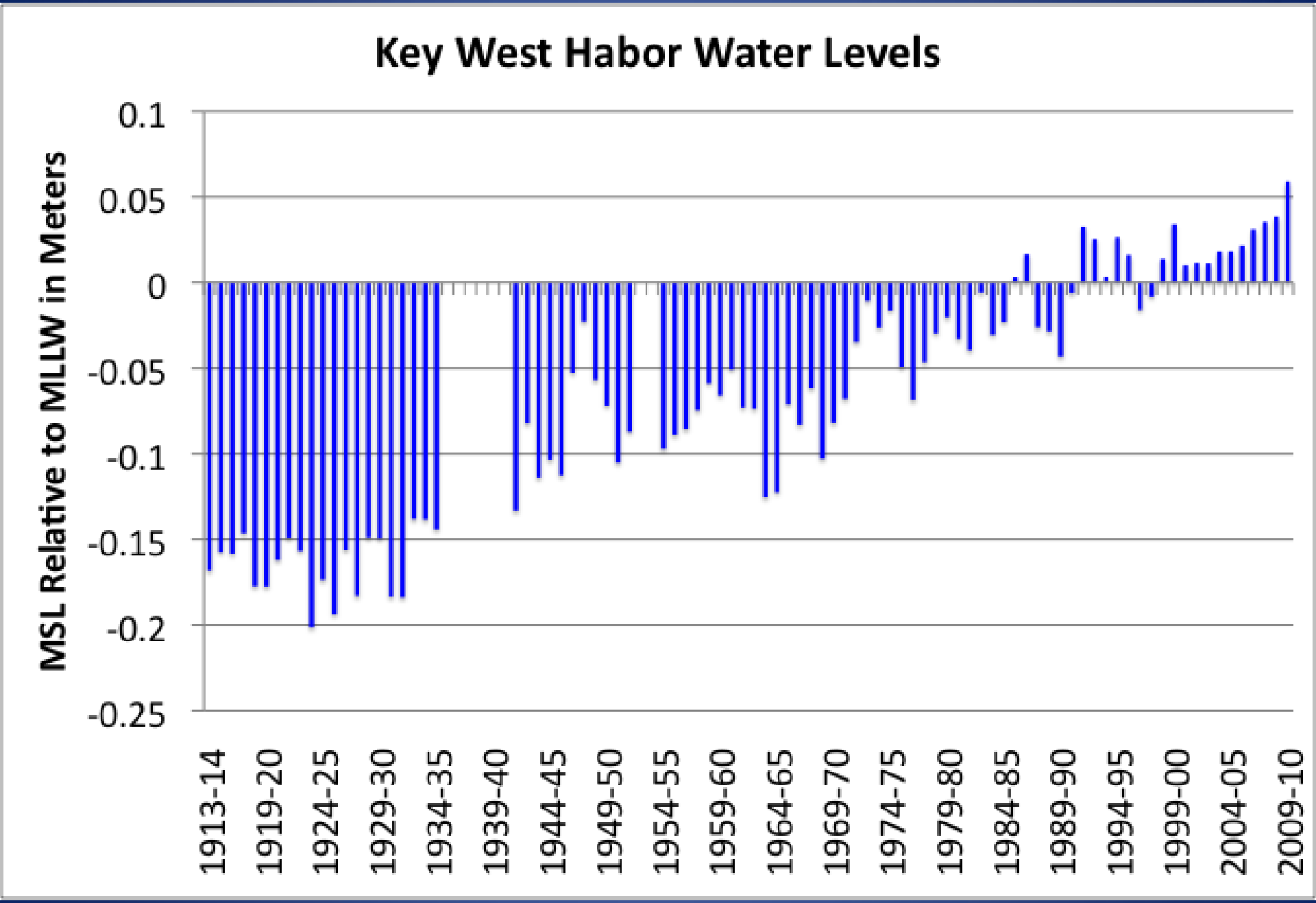




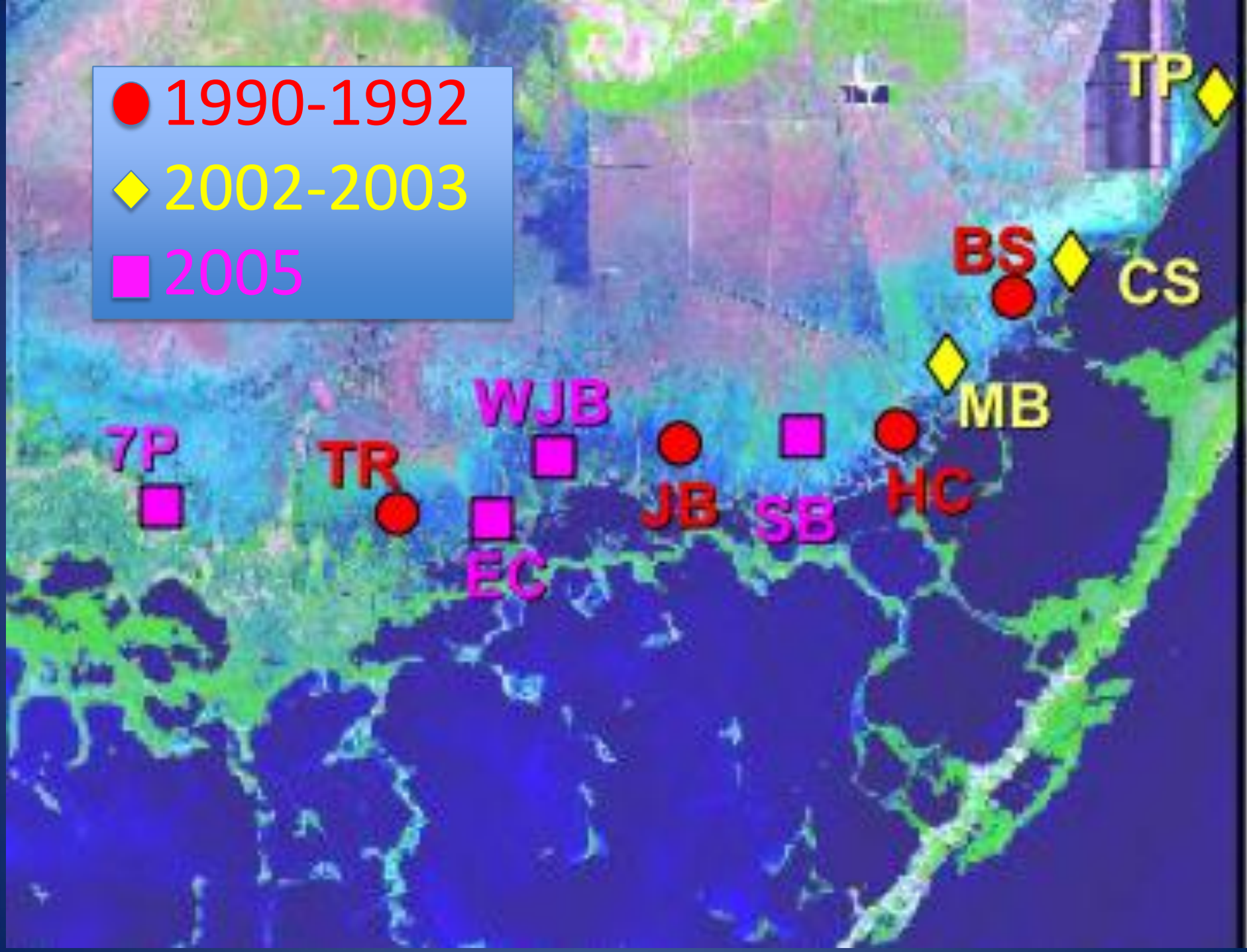







Key West Habor Water Levels
MSL Relative to MLLW in Meters
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
-0.25
1913-14
1919-20
1924-25
1929-30
1934-35
1939-40
1944-45
1949-50
1954-55
1959-60
1964-65
1969-70
1974-75
1979-80
1984-85
1989-90
1994-95
1999-00
2004-05
2009-10

Key West to Northeastern Florida Bay

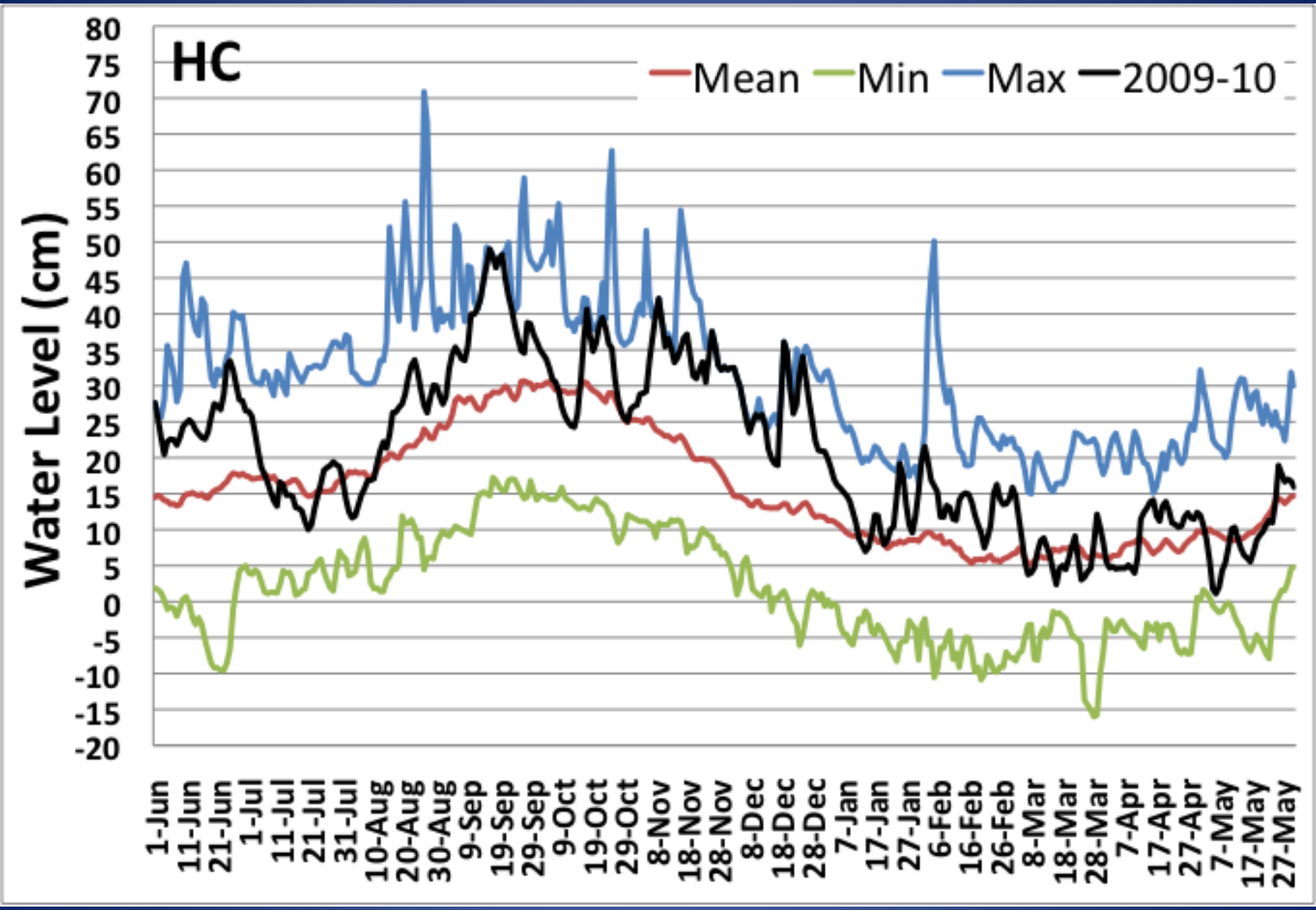

1990-1992
2002-2003
2005
TP
BS
CS
MB
WJB
7P
TR
JB
SB
HC
EC

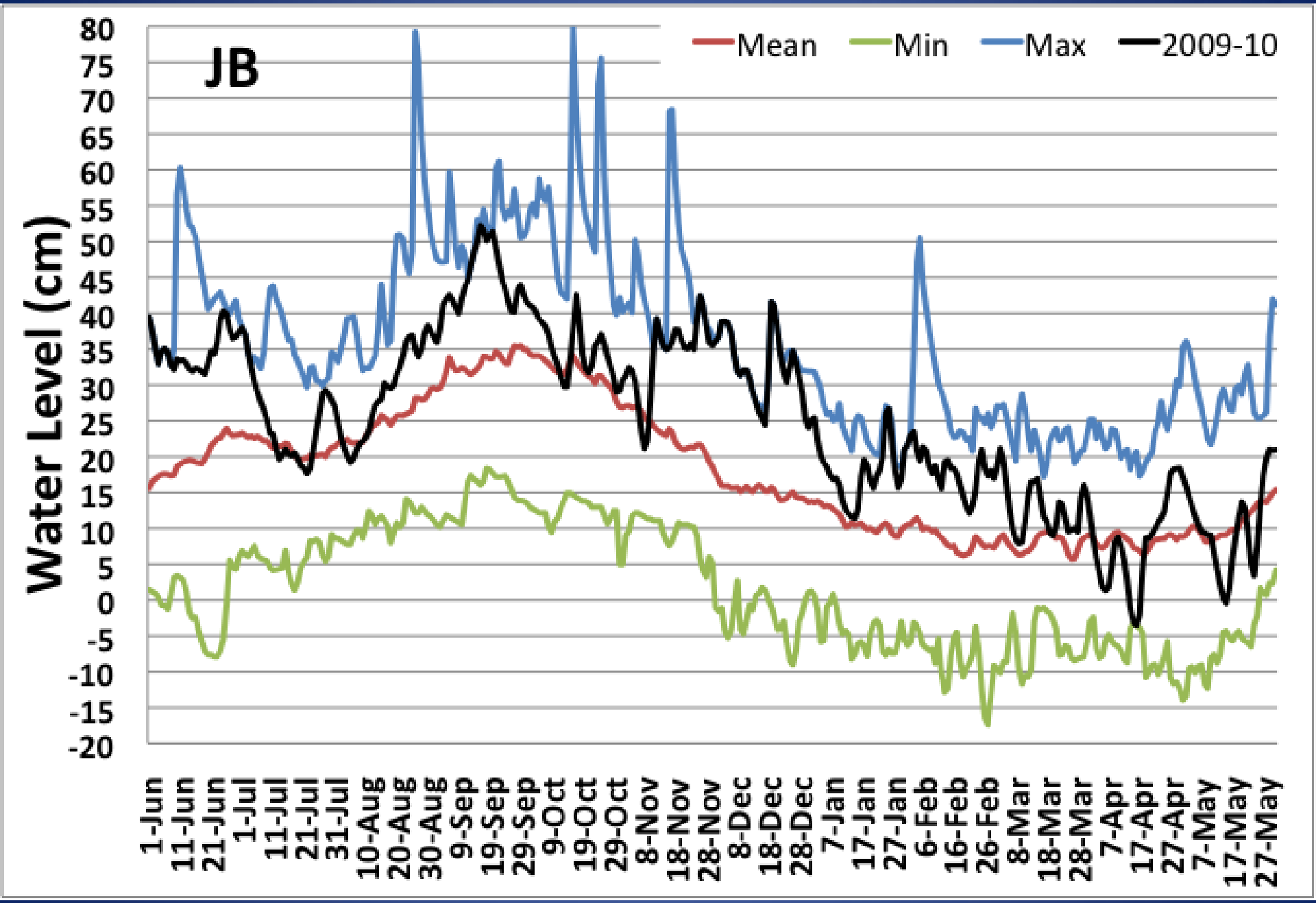
Long Term Sites

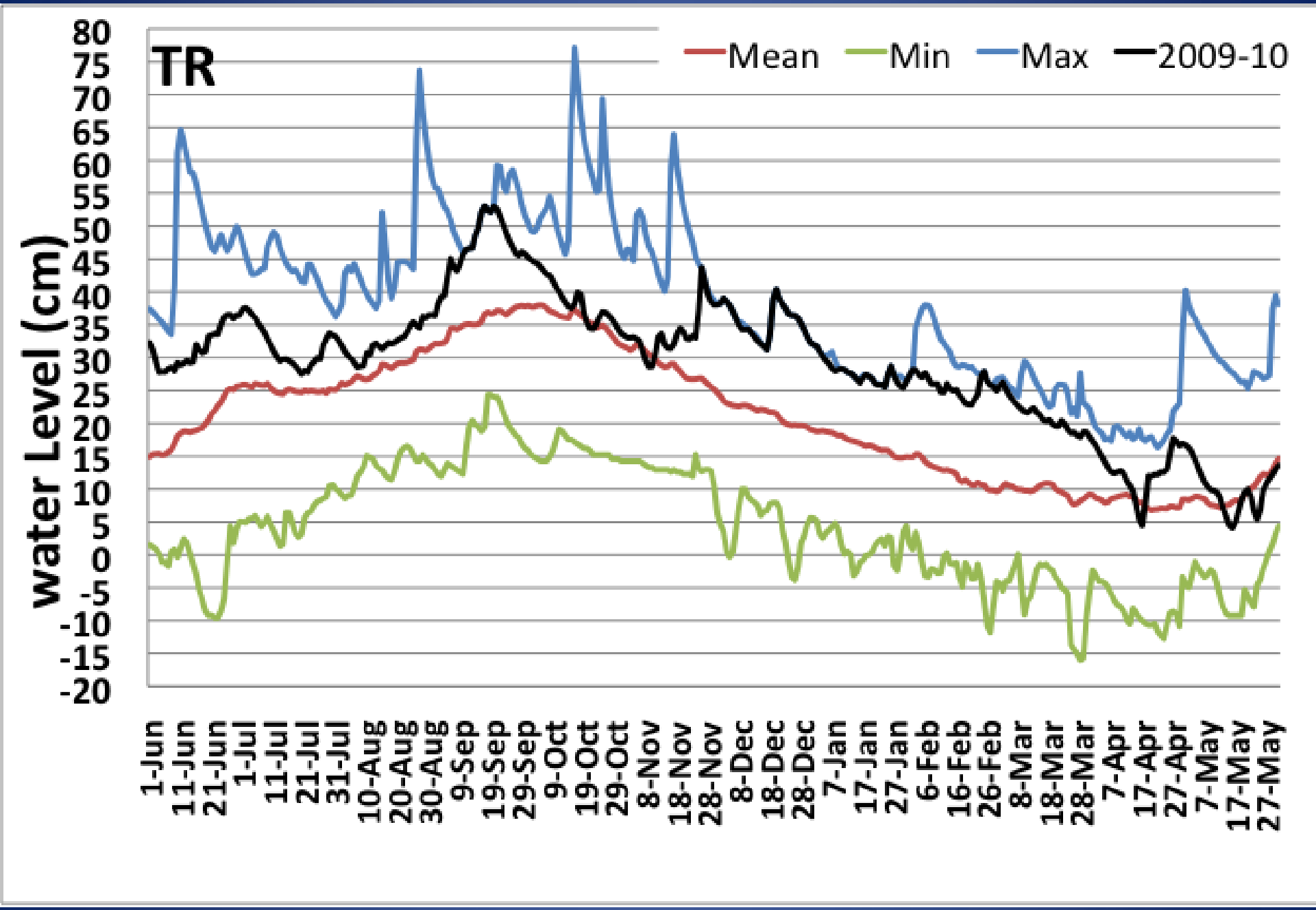
- TR (most influenced by Everglades fw flow)
- JB
- HC
- BS (most influenced by marine inflows)

Definitions

- Wet Season: June to November
- Dry Season December to May
- Hydro-year begins with wet season (June) and ends with dry season (May)


HC
Mean
Min
Max
2009-10
Water Level (cm)
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
-5
-10
-15
-20
1-Jun
11-Jun
21-Jun
1-Jul
11-Jul
21-Jul
31-Jul
10-Aug
20-Aug
30-Aug
9-Sep
19-Sep
29-Sep
9-Oct
19-Oct
29-Oct
8-Nov
18-Nov
28-Nov
8-Dec
18-Dec
28-Dec
7-Jan
17-Jan
27-Jan
6-Feb
16-Feb
26-Feb
8-Mar
18-Mar
28-Mar
7-Apr
17-Apr
27-Apr
7-May
17-May
27-May


JB
Mean
Min
Max
2009-10
Water Level (cm)
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
-5
-10
-15
-20
1-Jun
11-Jun
21-Jun
1-Jul
11-Jul
21-Jul
31-Jul
10-Aug
20-Aug
30-Aug
9-Sep
19-Sep
29-Sep
9-Oct
19-Oct
29-Oct
8-Nov
18-Nov
28-Nov
8-Dec
18-Dec
28-Dec
7-Jan
17-Jan
27-Jan
6-Feb
16-Feb
26-Feb
8-Mar
18-Mar
28-Mar
7-Apr
17-Apr
27-Apr
7-May
17-May
27-May

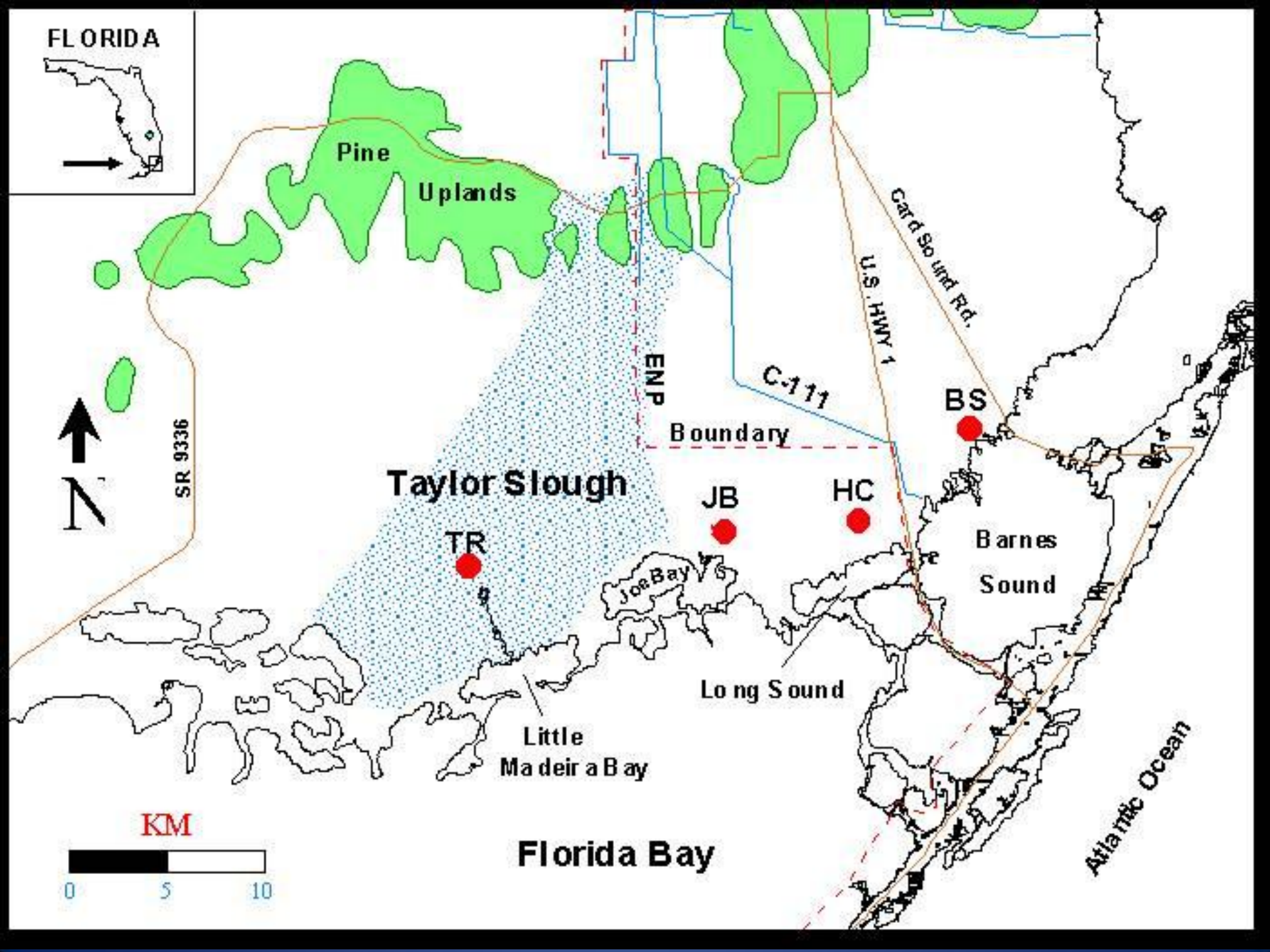

TR
Mean
Min
Max
2009-10
water Level (cm)
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
-5
-10
-15
-20
1-Jun
11-Jun
21-Jun
1-Jul
11-Jul
21-Jul
31-Jul
10-Aug
20-Aug
30-Aug
9-Sep
19-Sep
29-Sep
9-Oct
19-Oct
29-Oct
8-Nov
18-Nov
28-Nov
8-Dec
18-Dec
28-Dec
7-Jan
17-Jan
27-Jan
6-Feb
16-Feb
26-Feb
8-Mar
18-Mar
28-Mar
7-Apr
17-Apr
27-Apr
7-May
17-May
27-May

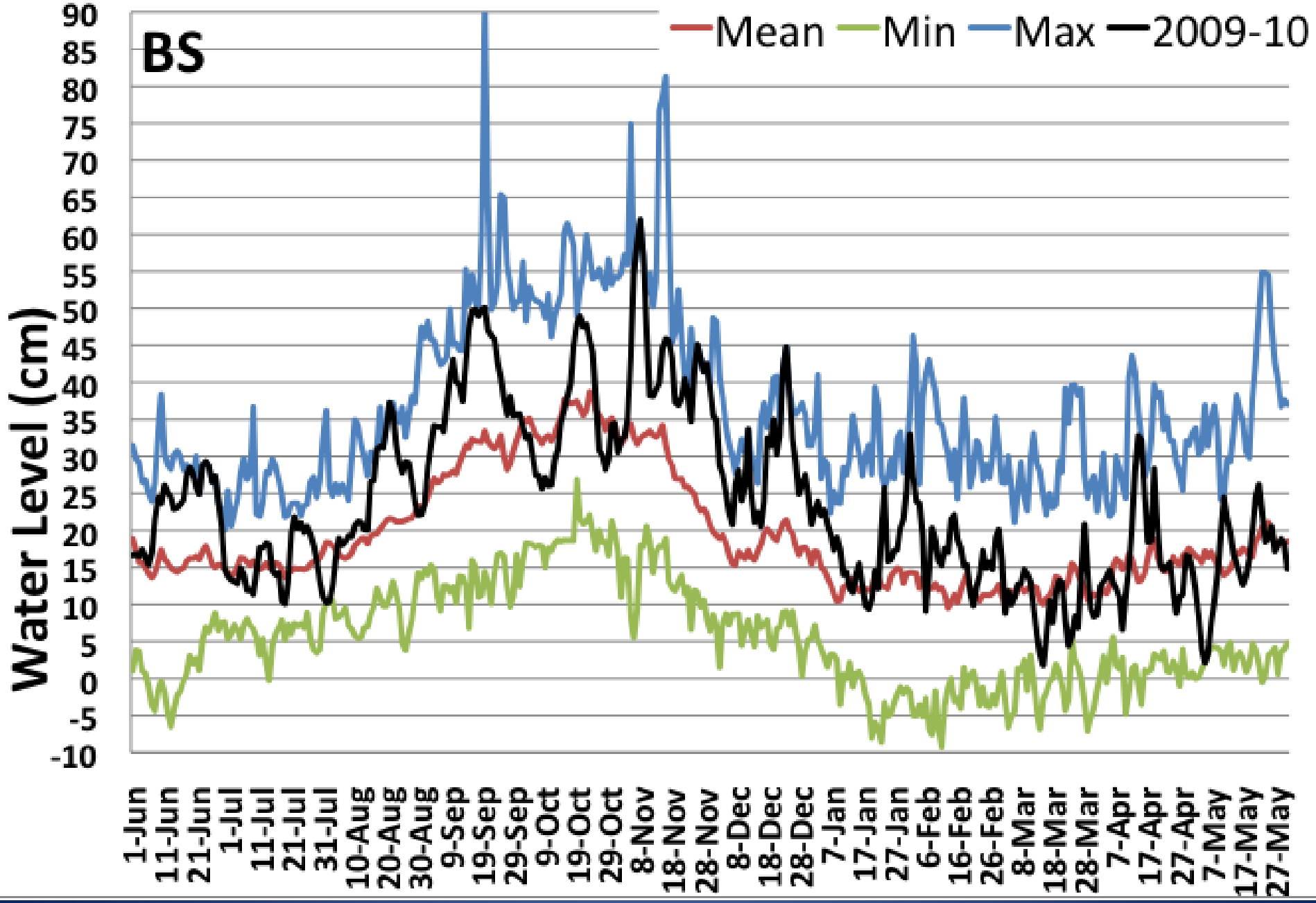
Record high water events occurred from August to February

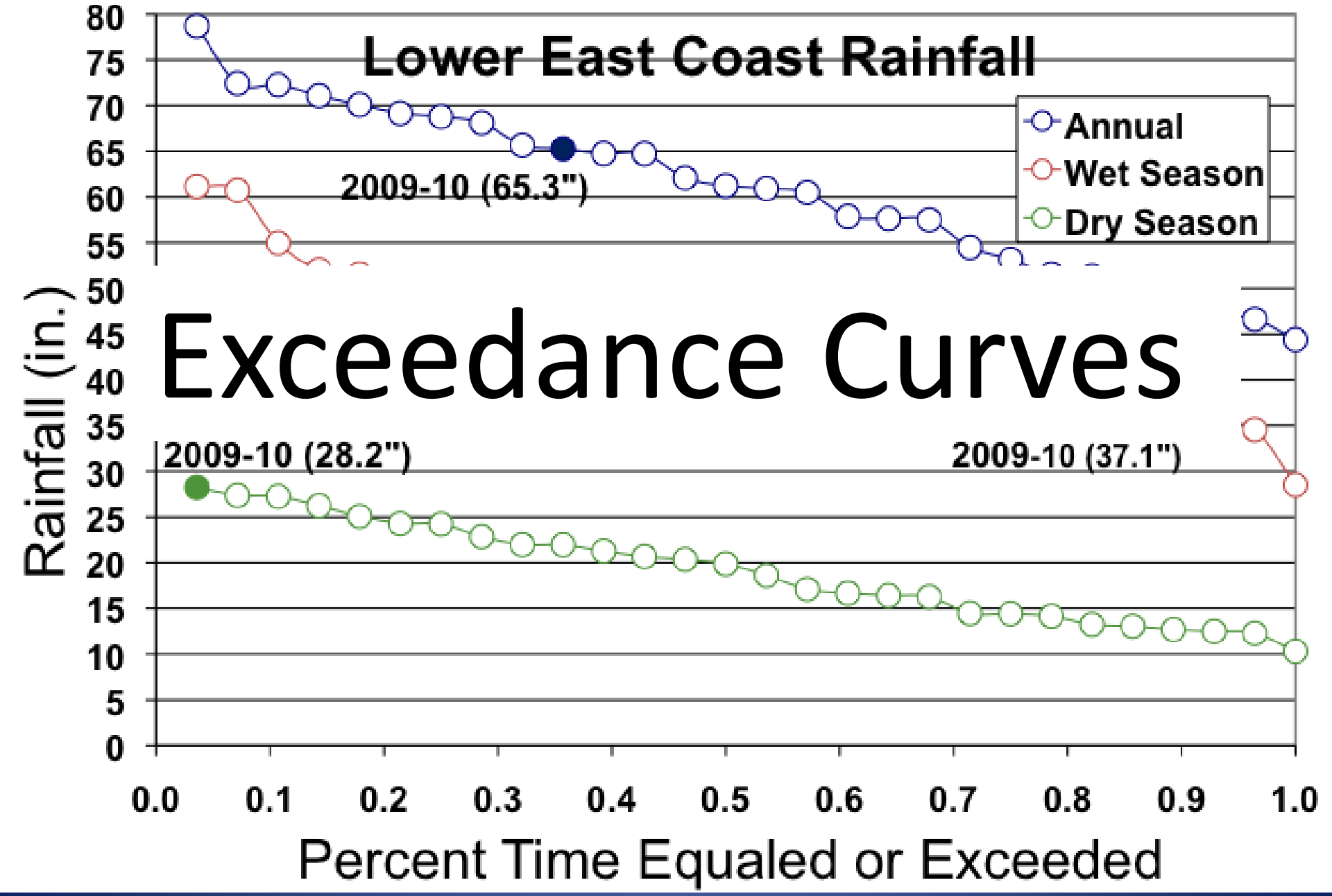
- Peak of the wet season to the middle of the dry season

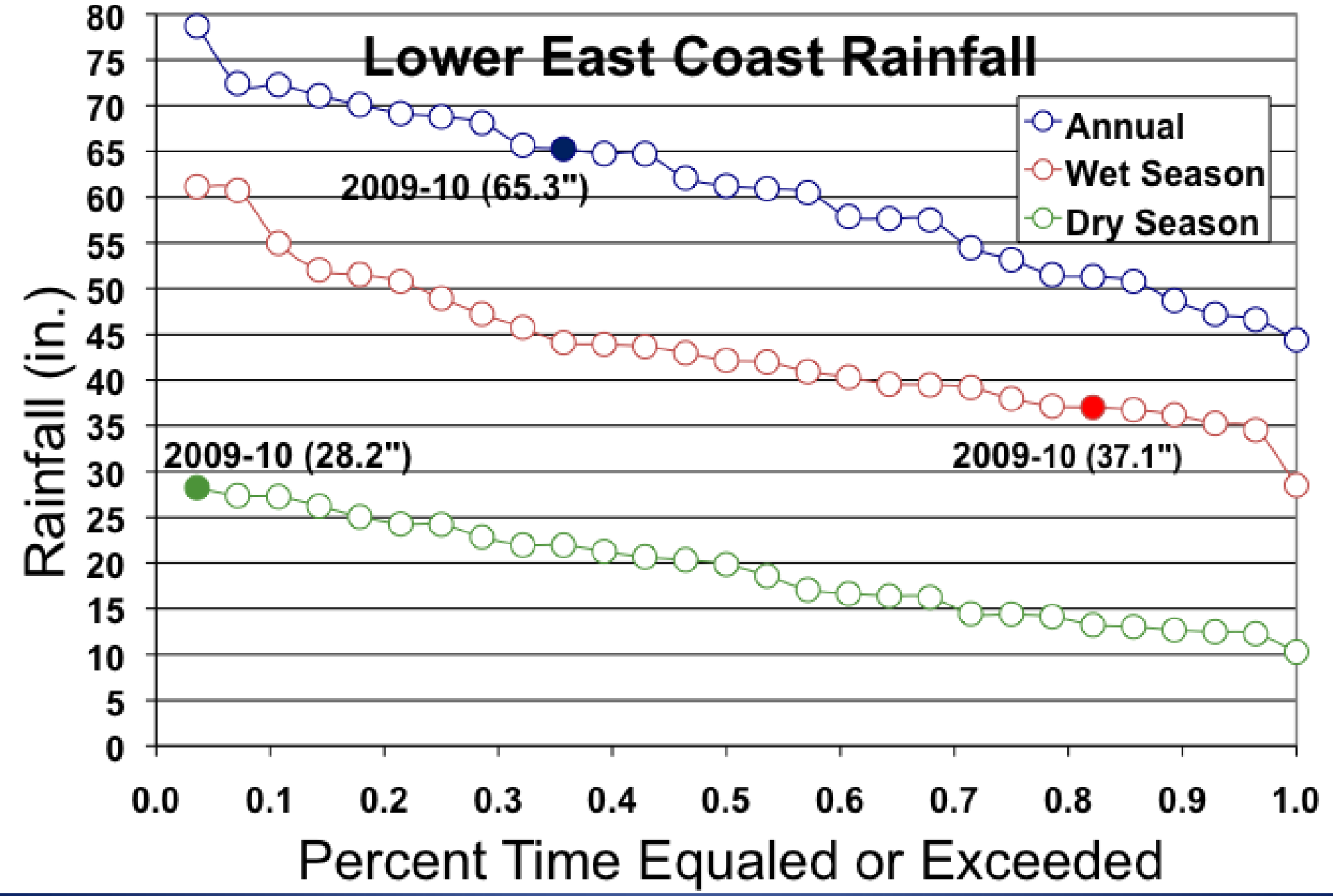
High water levels at these sites can be caused by 3 things

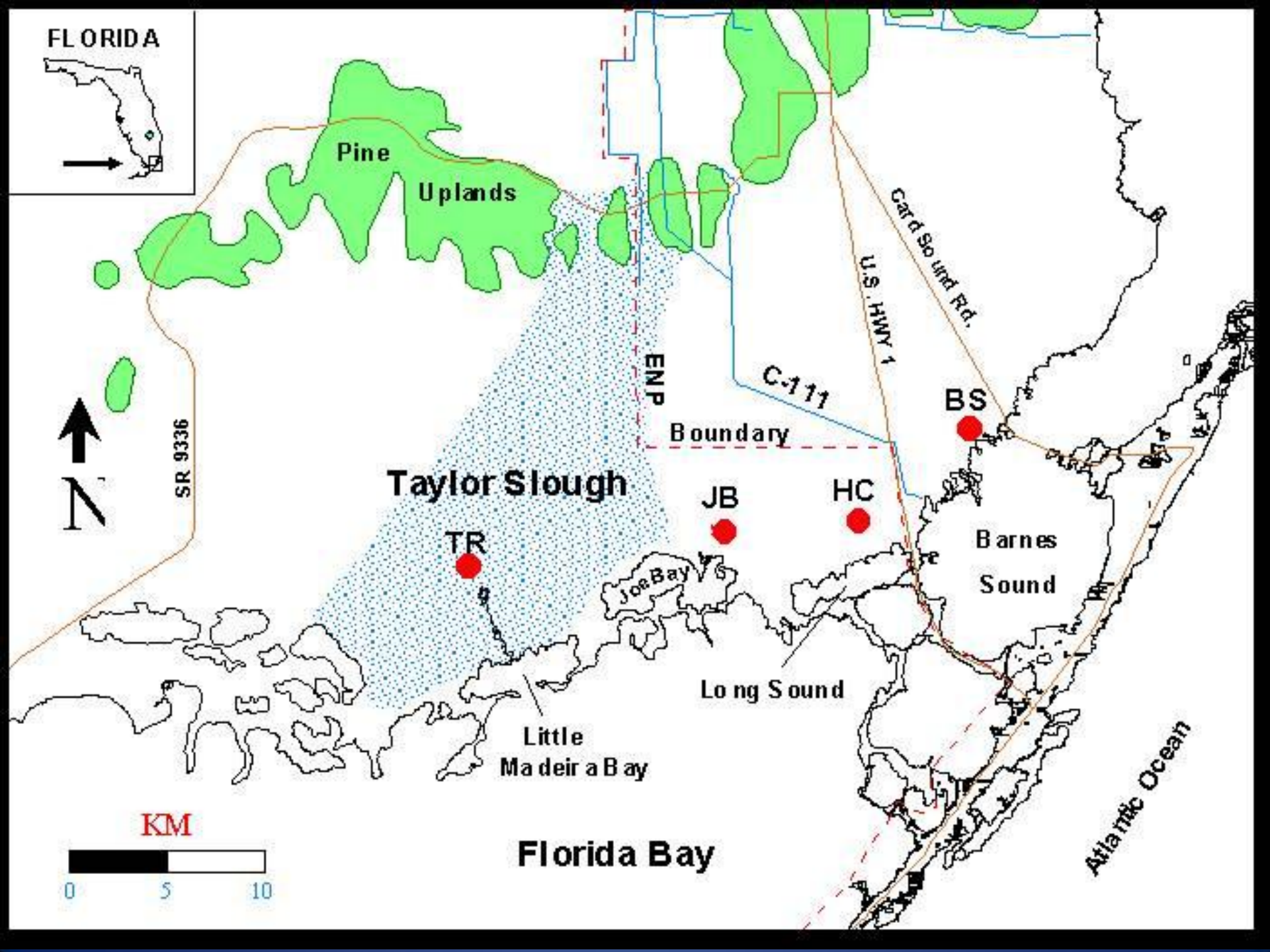
- Water management practices
- High rainfall and accompanying sheet flow
- High water conditions in the marine environment

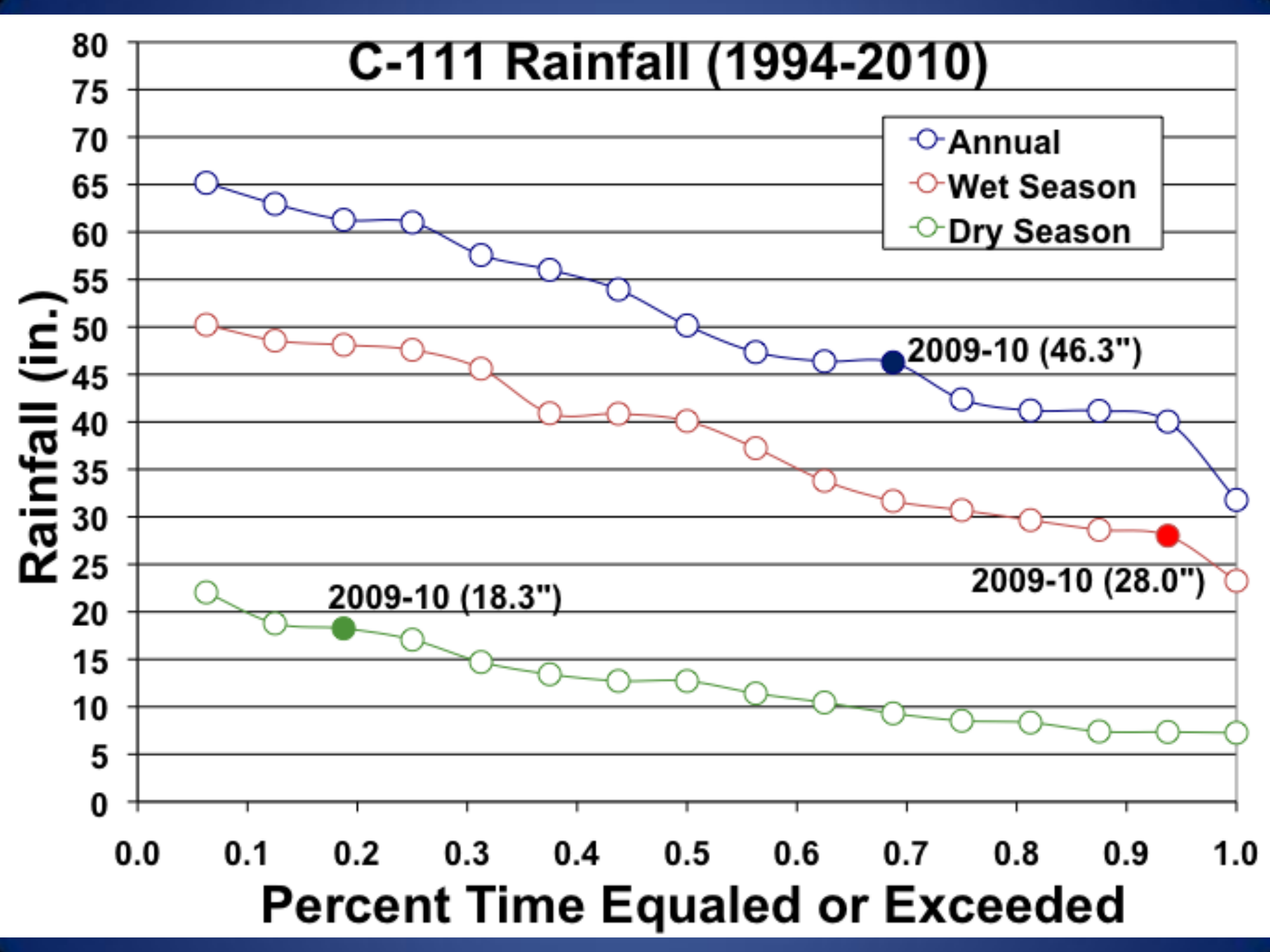

FLORIDA
Pine
Uplands
SR 9336
ENP
Boundary
C-111
U.S. HWY 1
Card Sound Rd.
BS
HC
JB
TR
Taylor Slough
Joe Bay
Barnes
Sound
Long Sound
Little
Madeira Bay
Florida Bay
Atlantic Ocean
N
KM
0
5
10

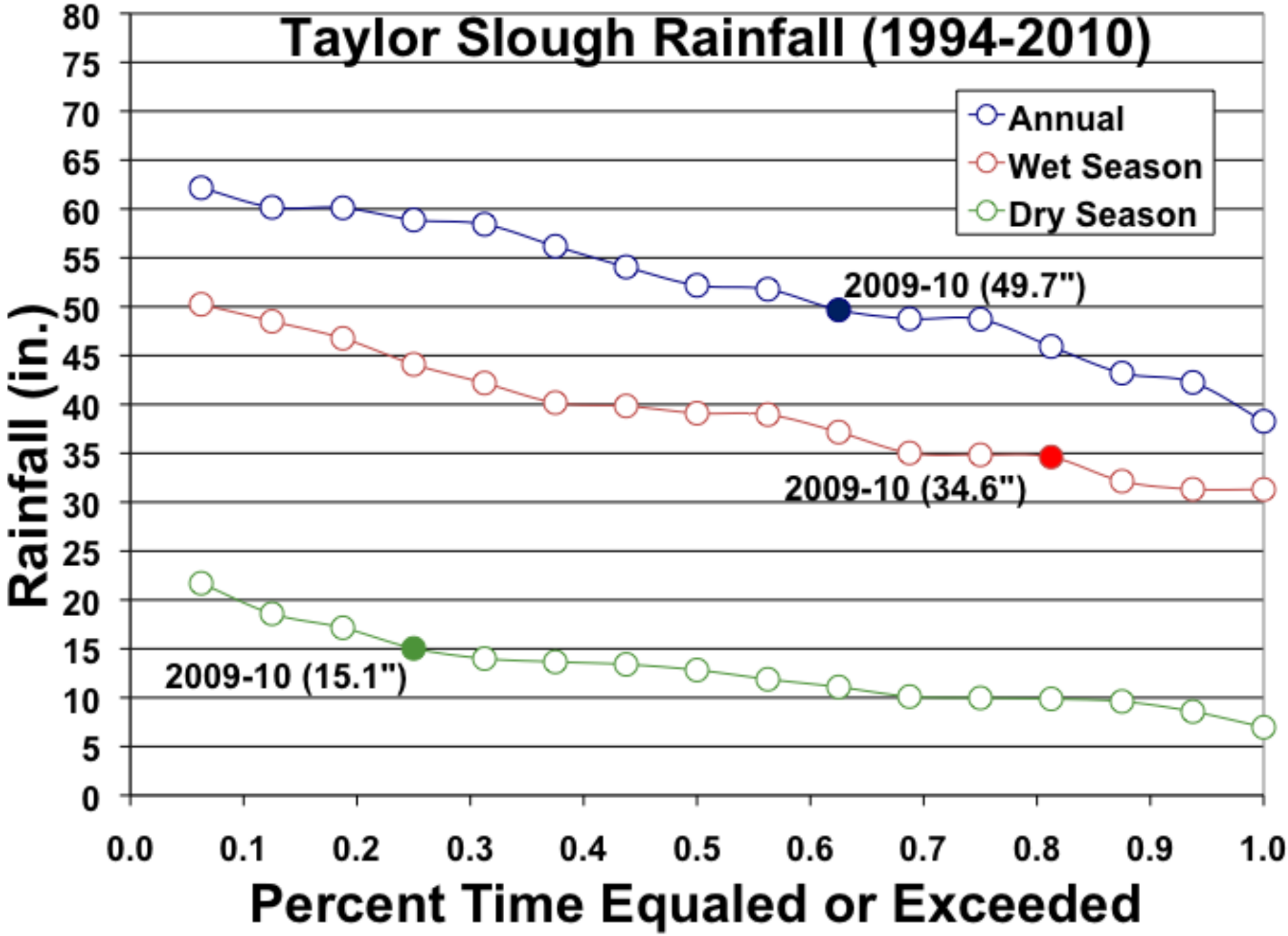

BS
Mean
Min
Max
2009-10
Water Level (cm)
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
-5
-10
1-Jun
11-Jun
21-Jun
1-Jul
11-Jul
21-Jul
31-Jul
10-Aug
20-Aug
30-Aug
9-Sep
19-Sep
29-Sep
9-Oct
19-Oct
29-Oct
8-Nov
18-Nov
28-Nov
8-Dec
18-Dec
28-Dec
7-Jan
17-Jan
27-Jan
6-Feb
16-Feb
26-Feb
8-Mar
18-Mar
28-Mar
7-Apr
17-Apr
27-Apr
7-May
17-May
27-May


Lower East Coast Rainfall
Annual
Wet Season
Dry Season
2009-10 (65.3")
Exceedance Curves
2009-10 (28.2")
2009-10 (37.1")
Rainfall (in.)
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Percent Time Equaled or Exceeded

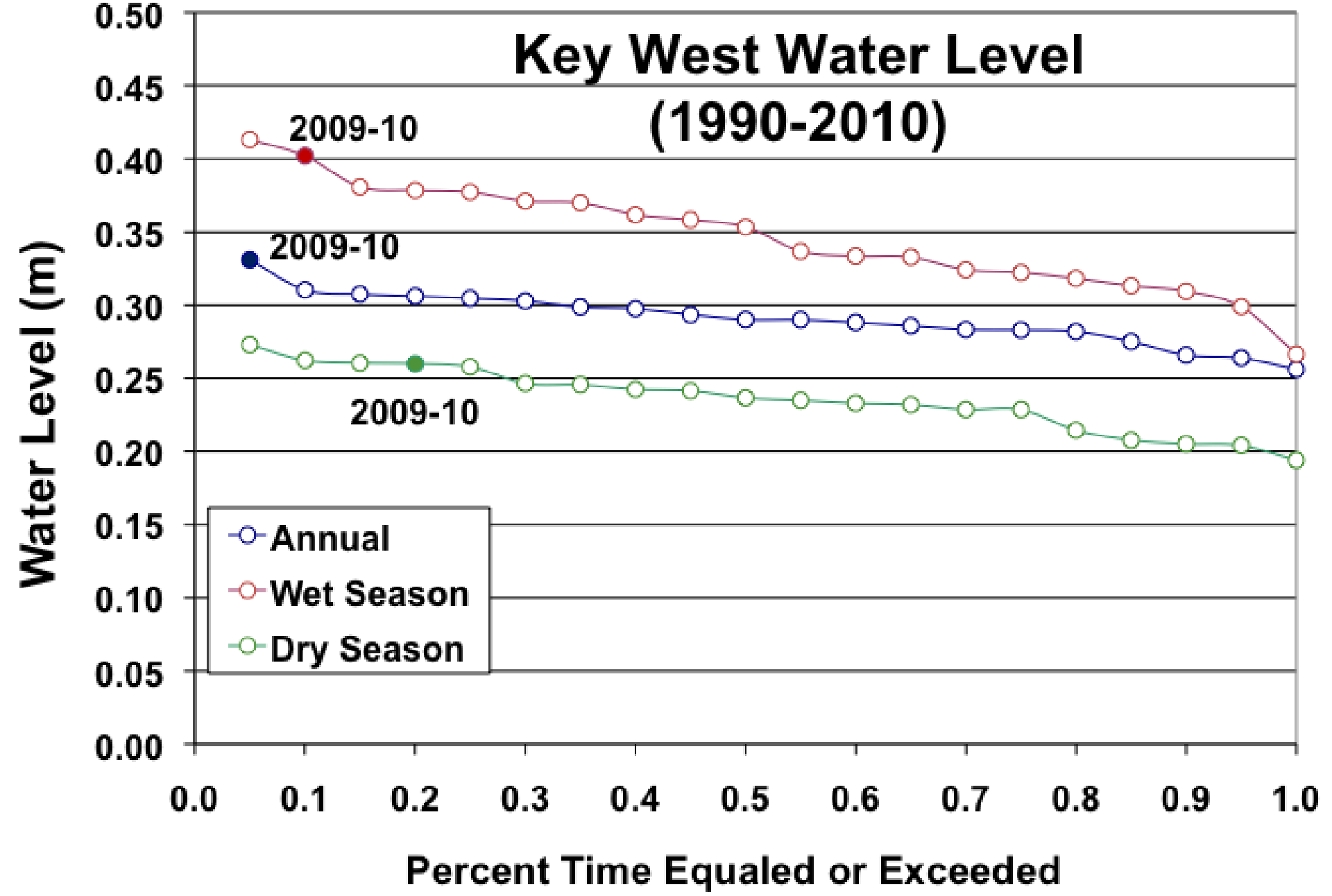

Lower East Coast Rainfall
Annual
Wet Season
Dry Season
2009-10 (65.3")
2009-10 (28.2")
2009-10 (37.1")
Rainfall (in.)
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Percent Time Equaled or Exceeded

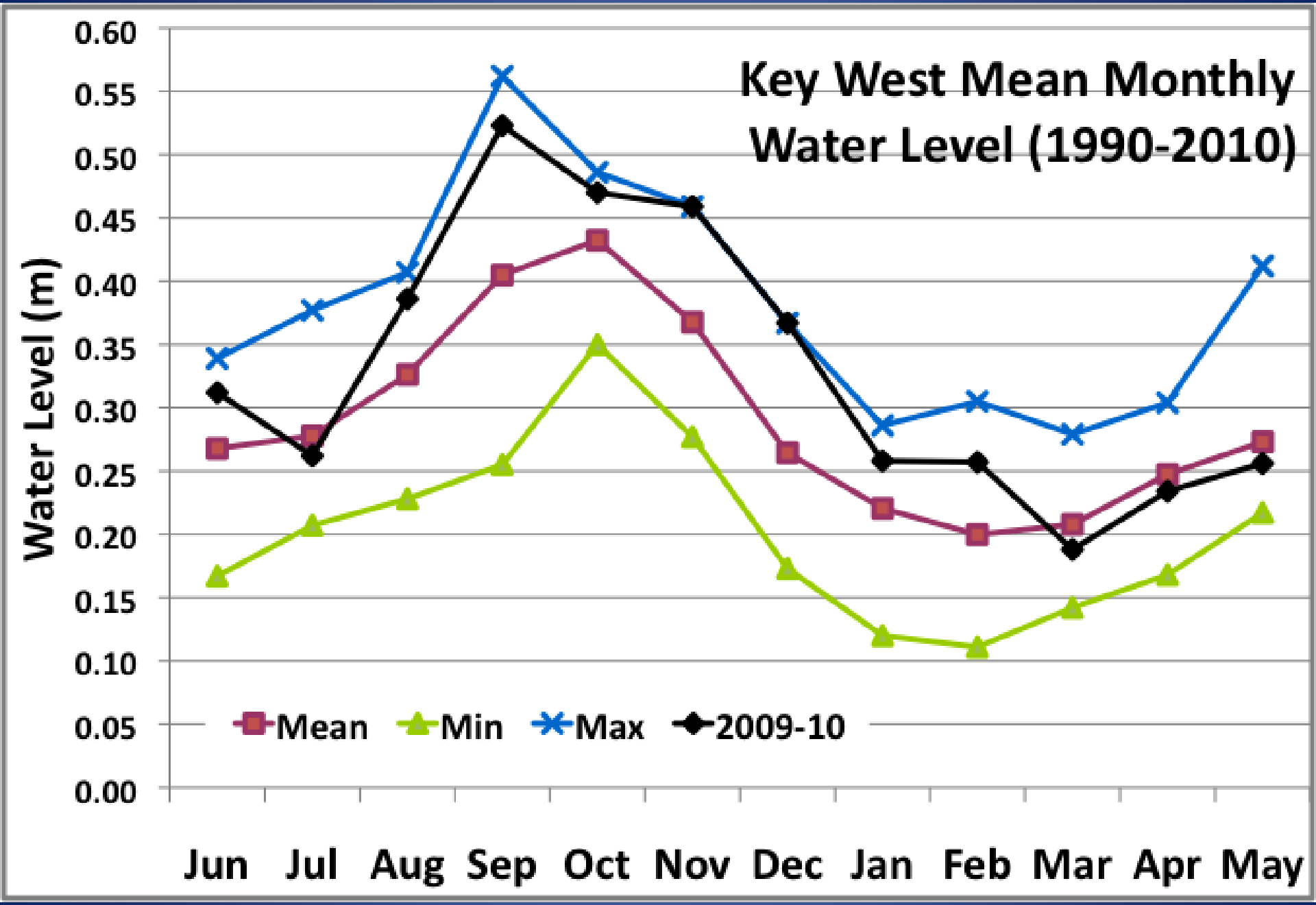

FLORIDA
Pine
Uplands
SR 9336
ENP
Boundary
C-111
U.S. HWY 1
Card Sound Rd.
BS
HC
JB
TR
Taylor Slough
Joe Bay
Barnes
Sound
Long Sound
Little
Madeira Bay
Florida Bay
Atlantic Ocean
N
KM
0
5
10

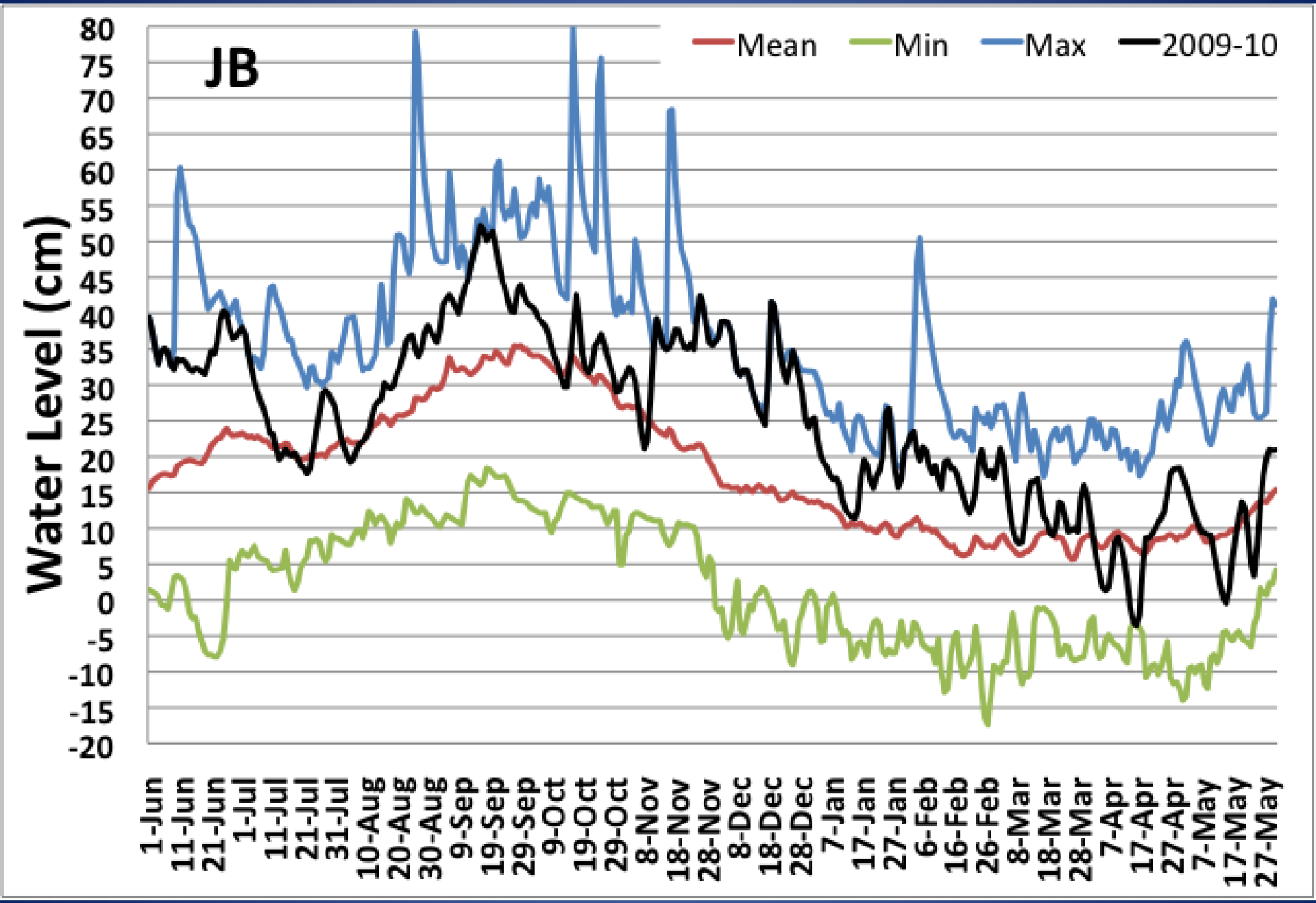

C-111 Rainfall (1994-2010)
Annual
Wet Season
Dry Season
2009-10 (46.3")
2009-10 (28.0")
2009-10 (18.3")
Rainfall (in.)
Percent Time Equaled or Exceeded
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0


Taylor Slough Rainfall (1994-2010)
Annual
Wet Season
Dry Season
2009-10 (49.7")
2009-10 (34.6")
2009-10 (15.1")
Rainfall (in.)
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Percent Time Equaled or Exceeded

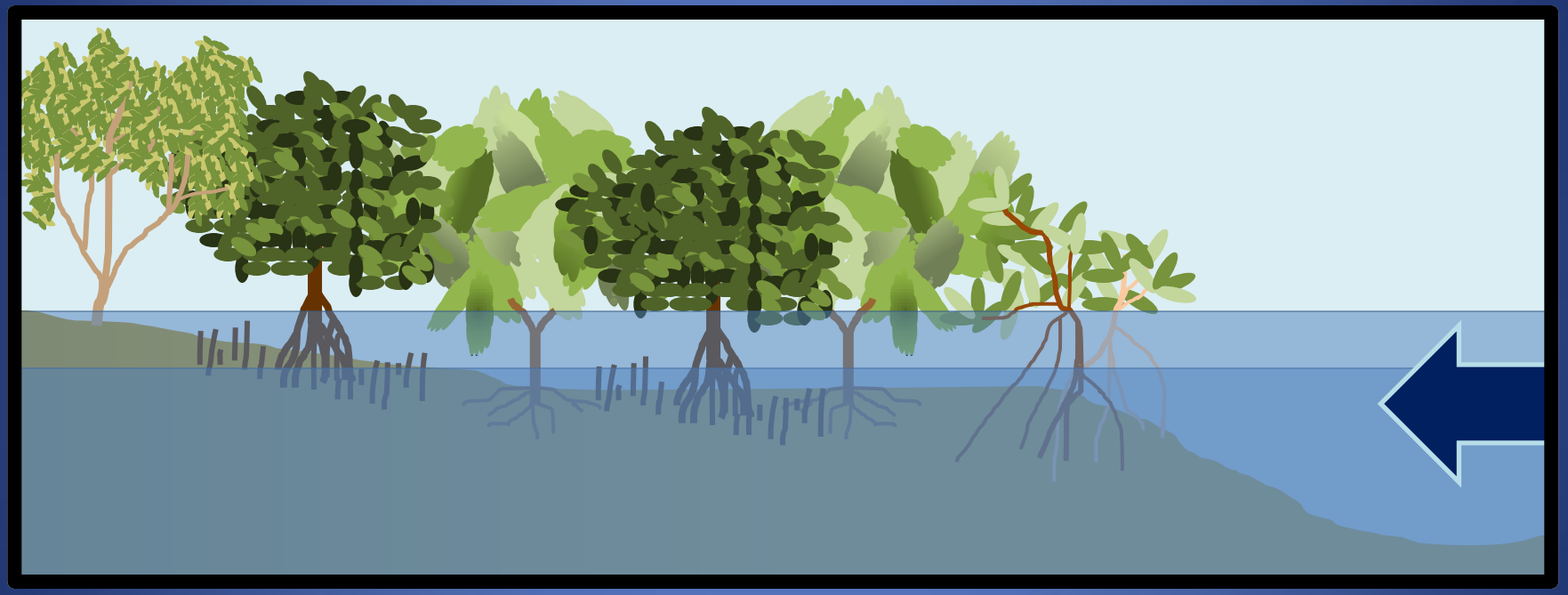
Not Water Management
Not Rainfall

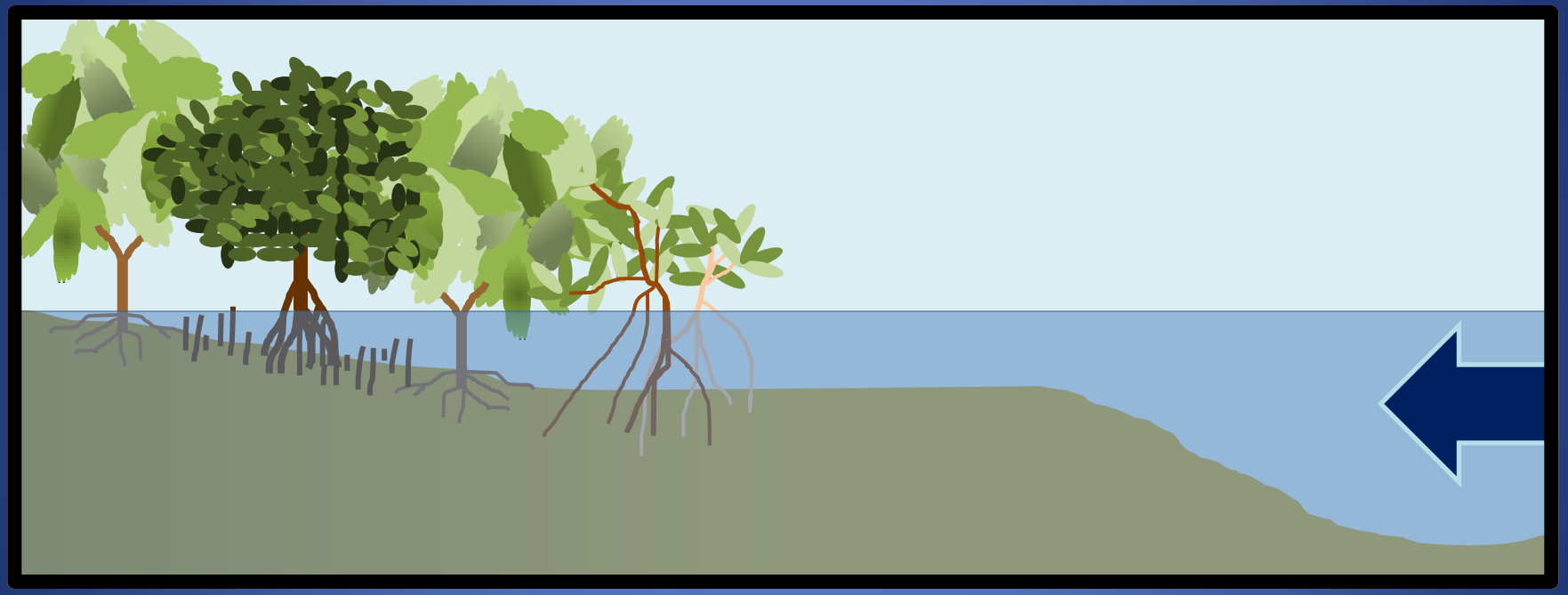

Key West Water Level
(1990-2010)
2009-10
2009-10
2009-10
Annual
Wet Season
Dry Season
Water Level (m)
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Percent Time Equaled or Exceeded

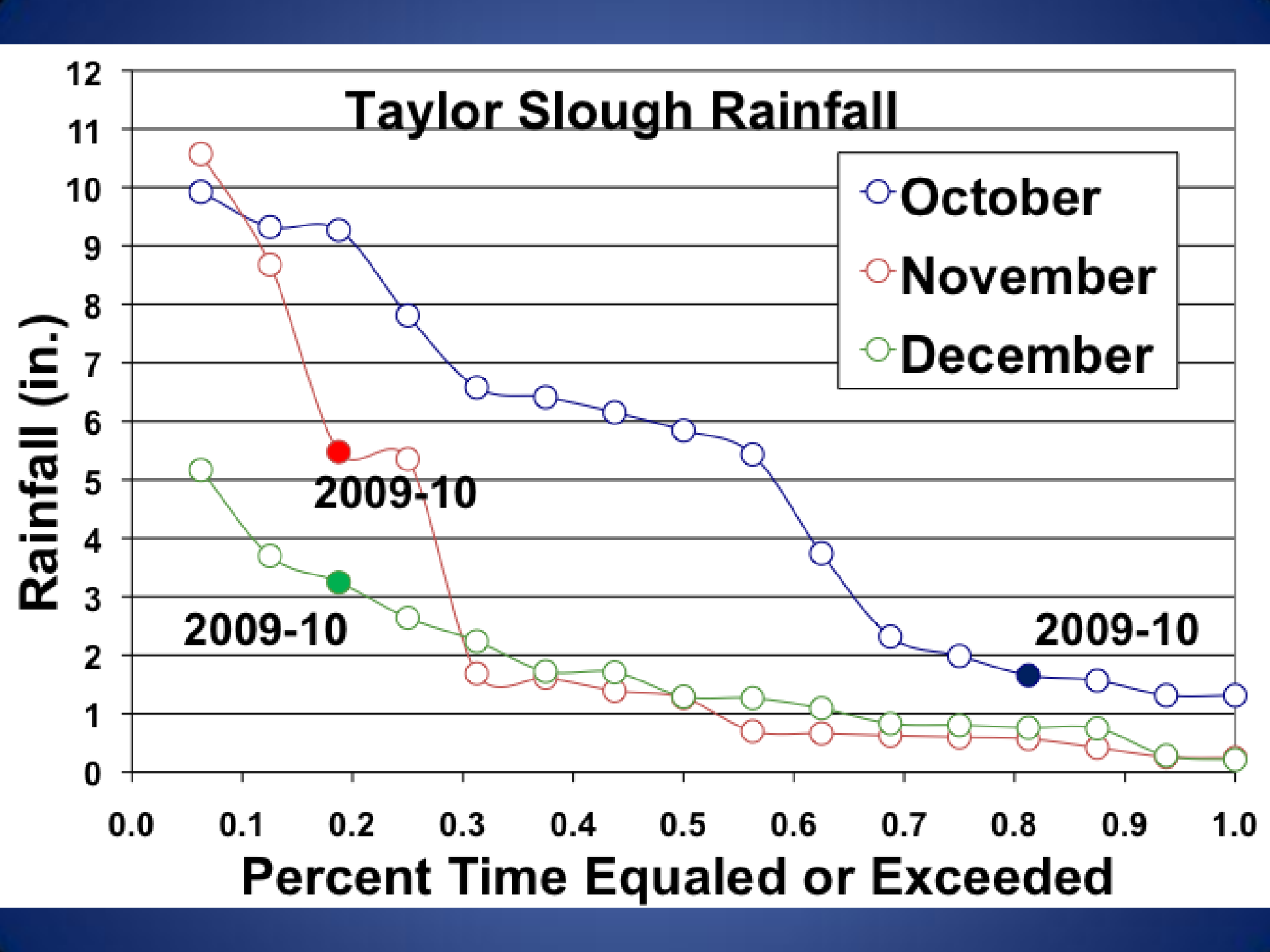

Key West Mean Monthly Water Level (1990-2010)
Water Level (m)
0.60
0.55
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
Mean
Min
Max
2009-10
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May

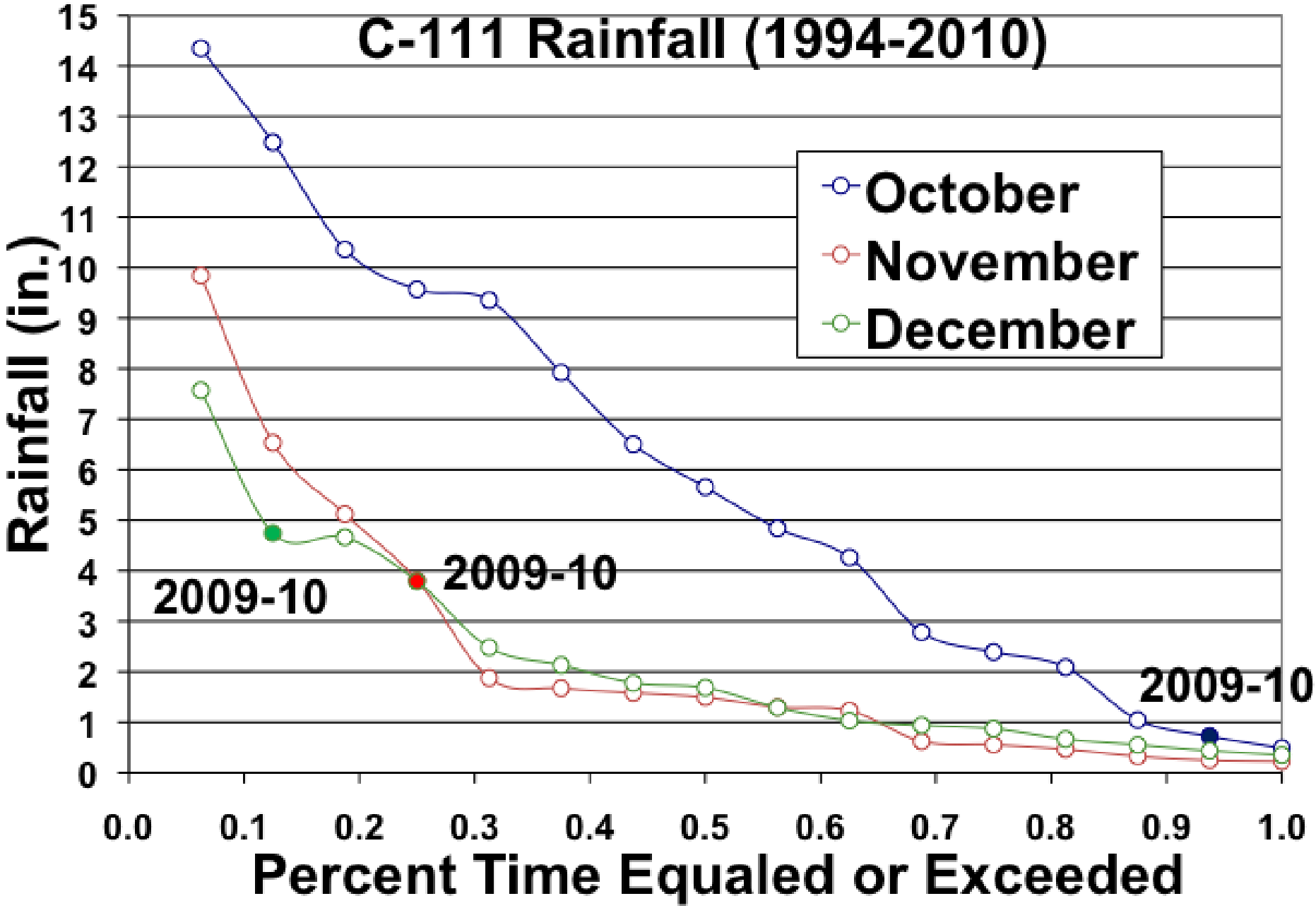

JB
Mean
Min
Max
2009-10
Water Level (cm)
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
-5
-10
-15
-20
1-Jun
11-Jun
21-Jun
1-Jul
11-Jul
21-Jul
31-Jul
10-Aug
20-Aug
30-Aug
9-Sep
19-Sep
29-Sep
9-Oct
19-Oct
29-Oct
8-Nov
18-Nov
28-Nov
8-Dec
18-Dec
28-Dec
7-Jan
17-Jan
27-Jan
6-Feb
16-Feb
26-Feb
8-Mar
18-Mar
28-Mar
7-Apr
17-Apr
27-Apr
7-May
17-May
27-May

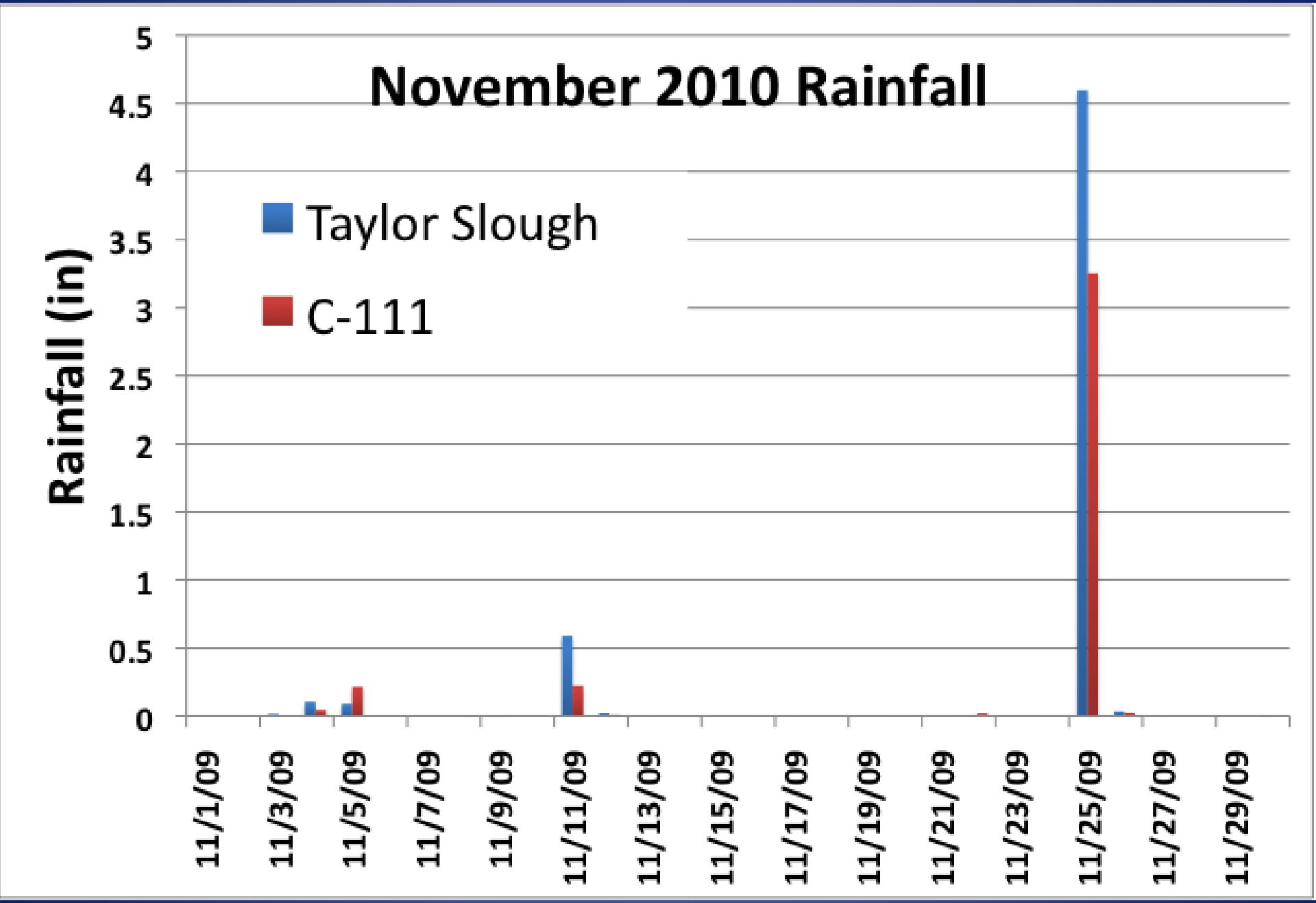
High water levels in the surrounding marine environment most likely explanation for the high water levels in the mangrove wetlands






Taylor Slough Rainfall
October
November
December
2009-10
2009-10
2009-10
Rainfall (in.)
Percent Time Equaled or Exceeded
0
1
2
3
4
5
6
7
8
9
10
11
12
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0


C-111 Rainfall (1994-2010)
Rainfall (in.)
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
October
November
December
2009-10
2009-10
2009-10
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Percent Time Equaled or Exceeded


November 2010 Rainfall
Taylor Slough
C-111
Rainfall (in)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
11/1/09
11/3/09
11/5/09
11/7/09
11/9/09
11/11/09
11/13/09
11/15/09
11/17/09
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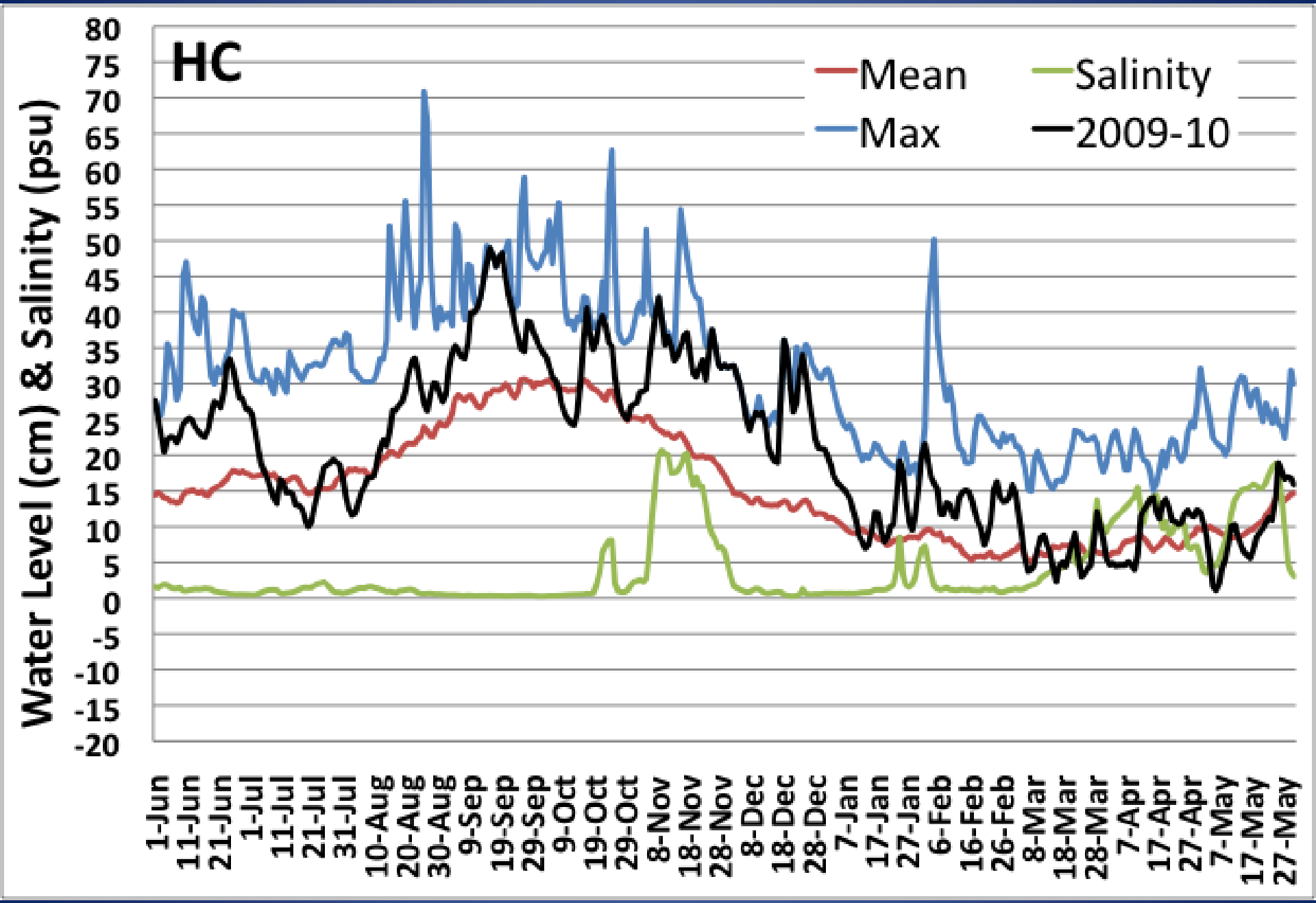
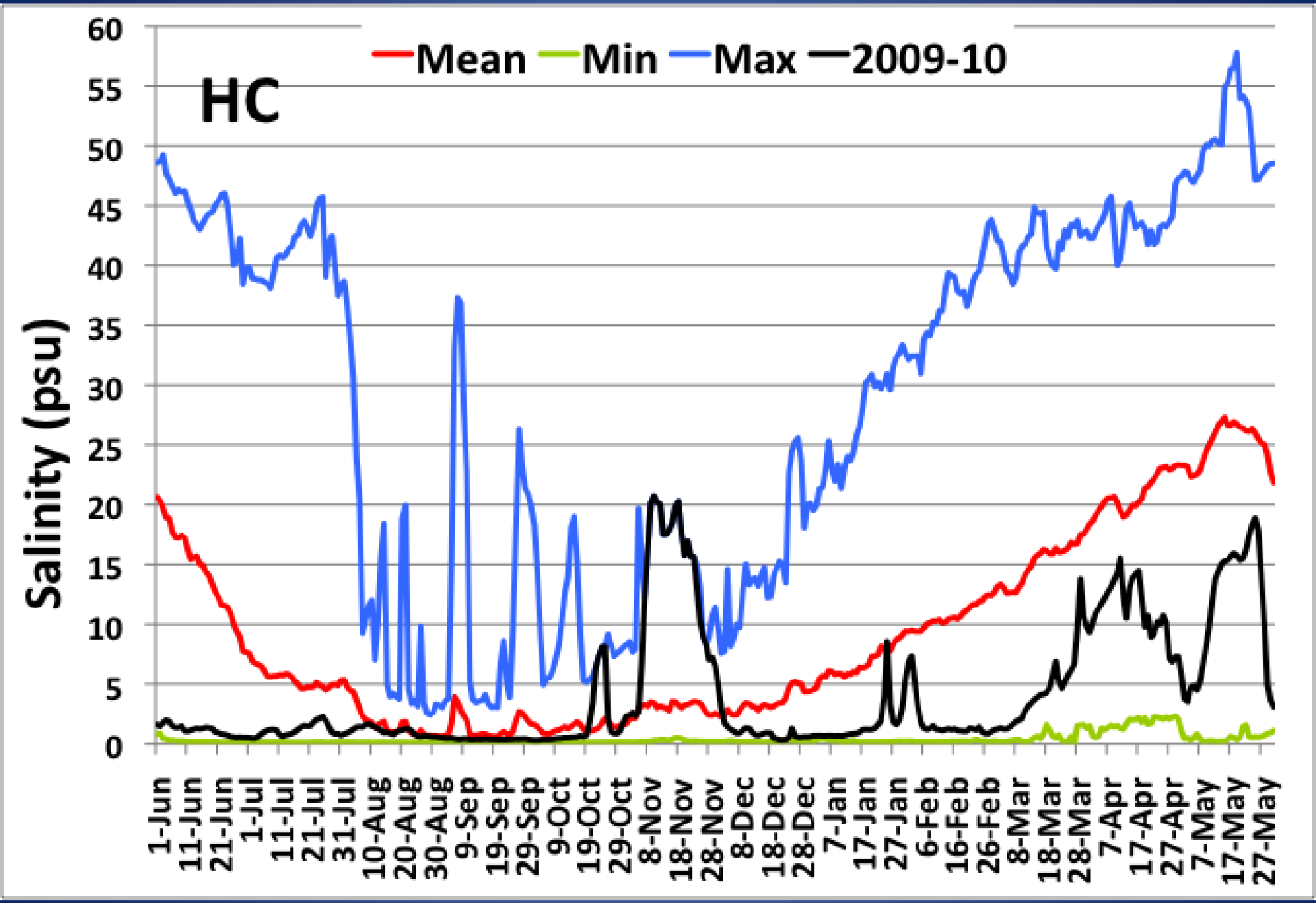
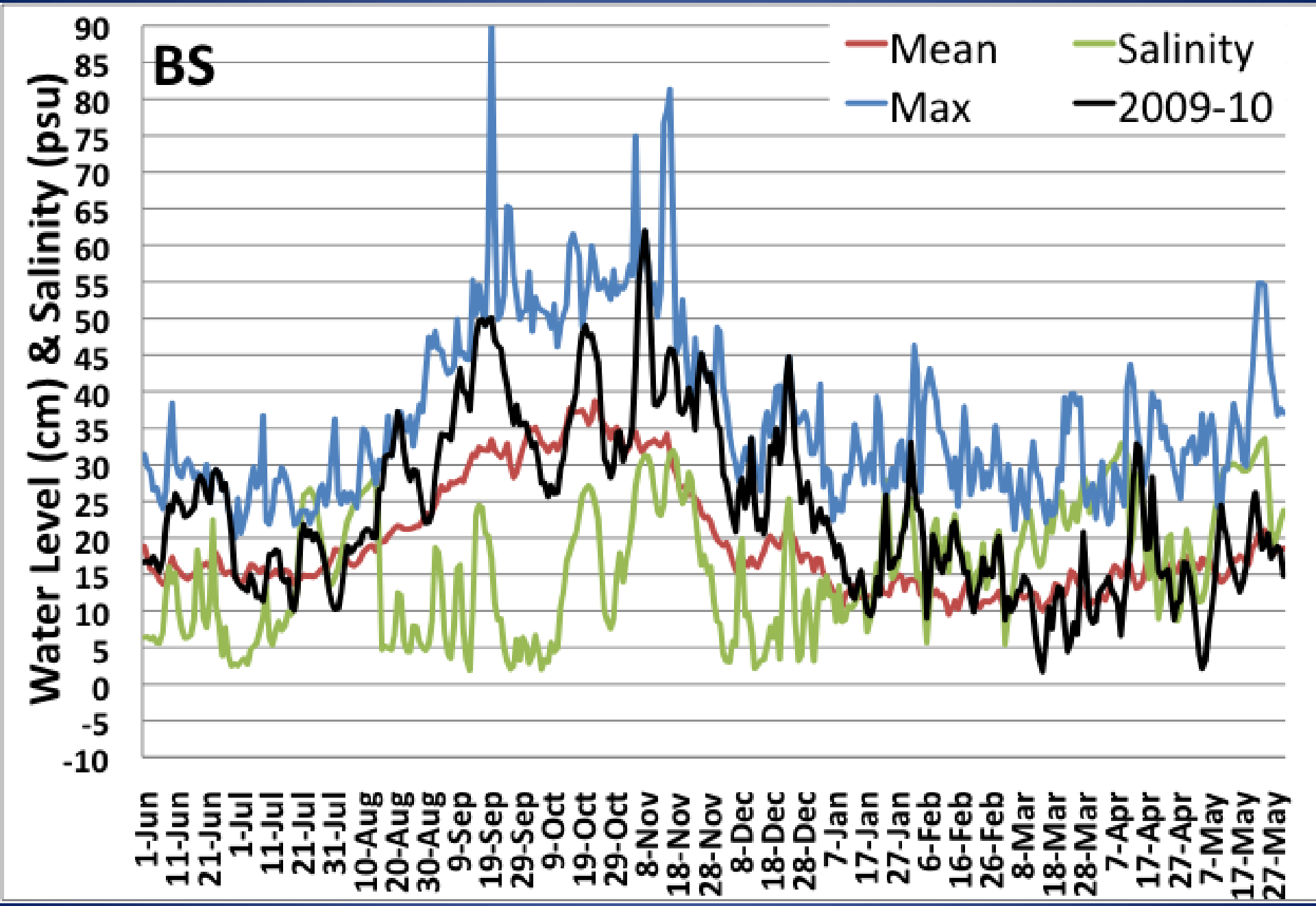
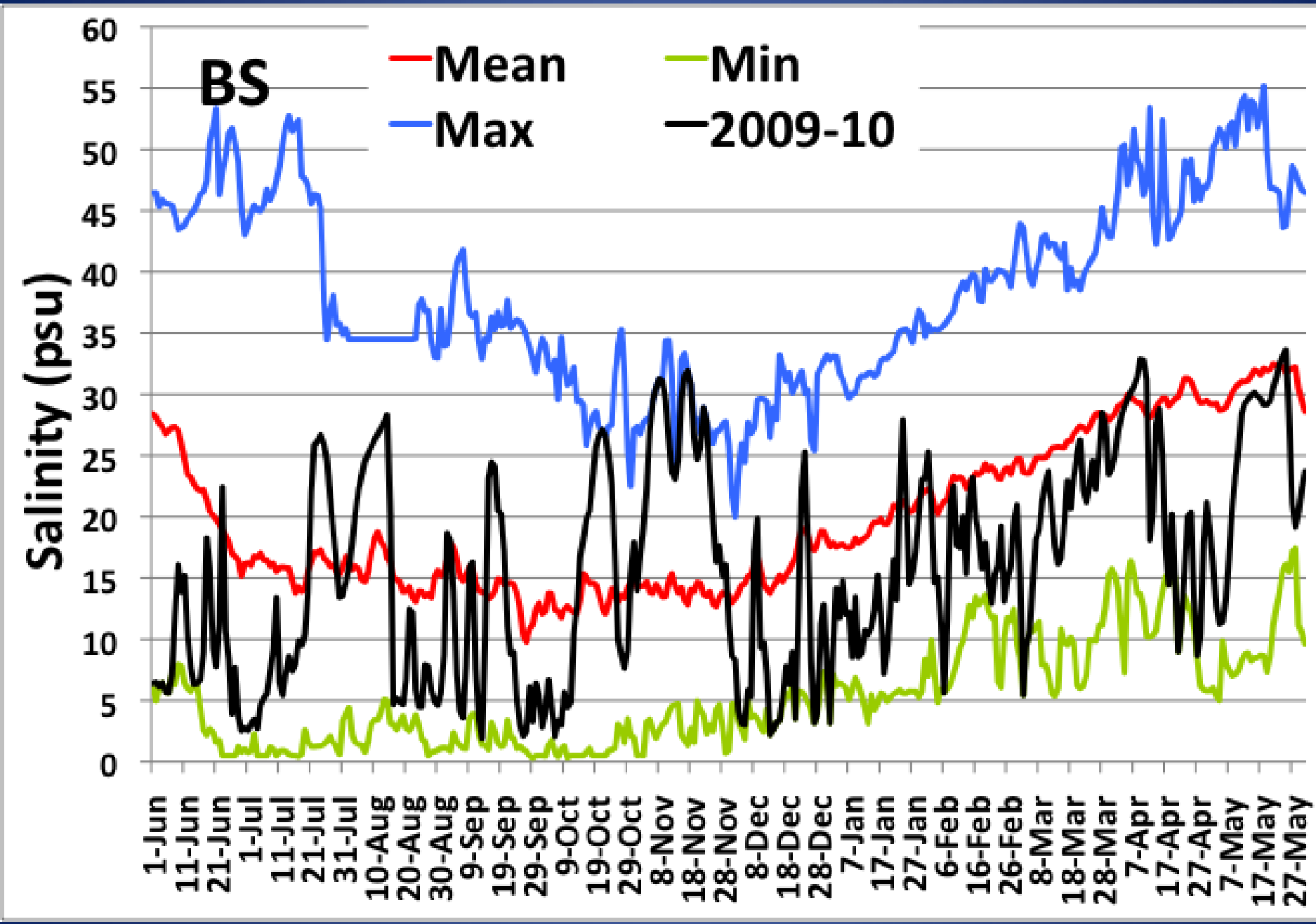
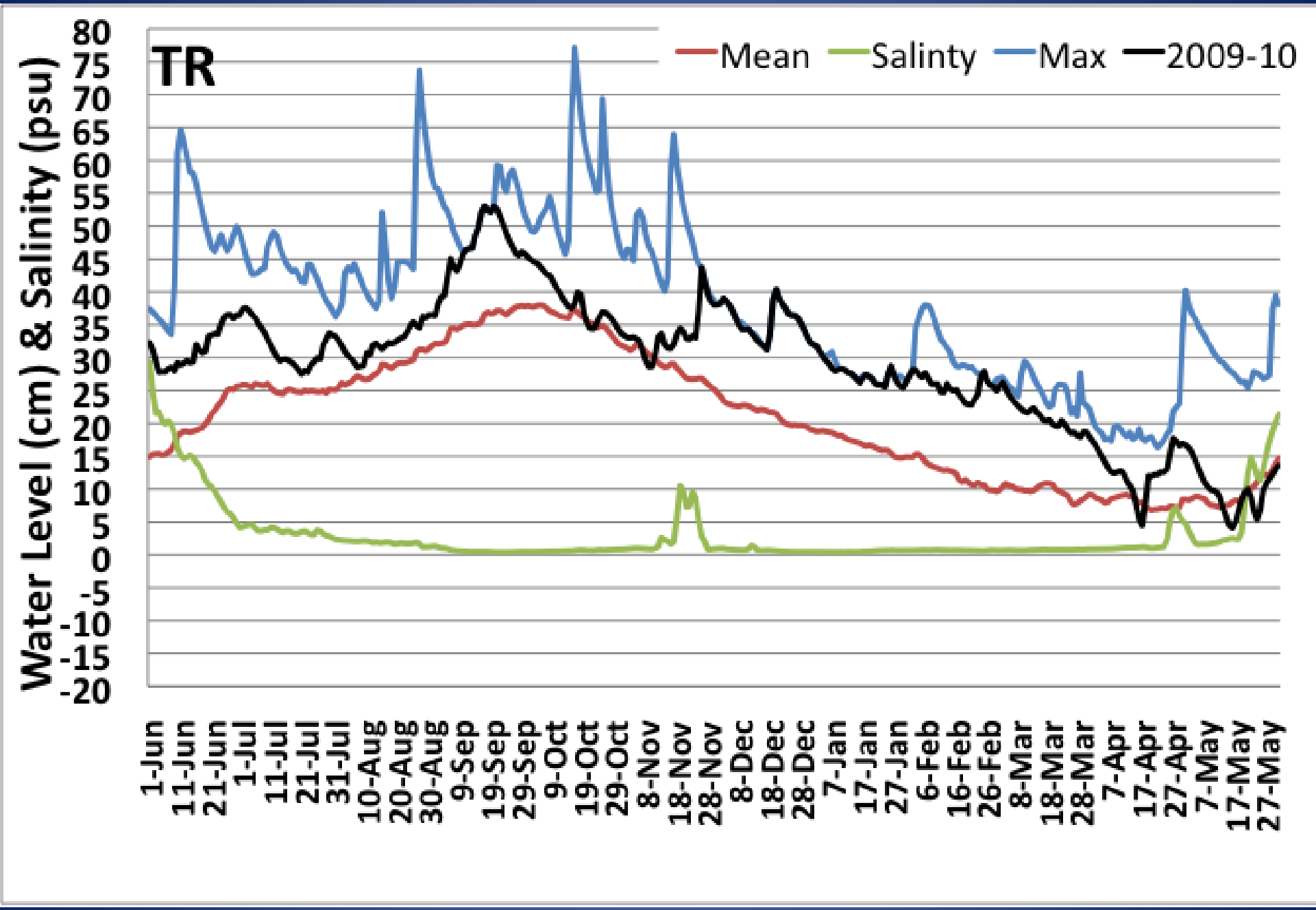
11/21/09
11/23/09
11/25/09
11/27/09
11/29/09

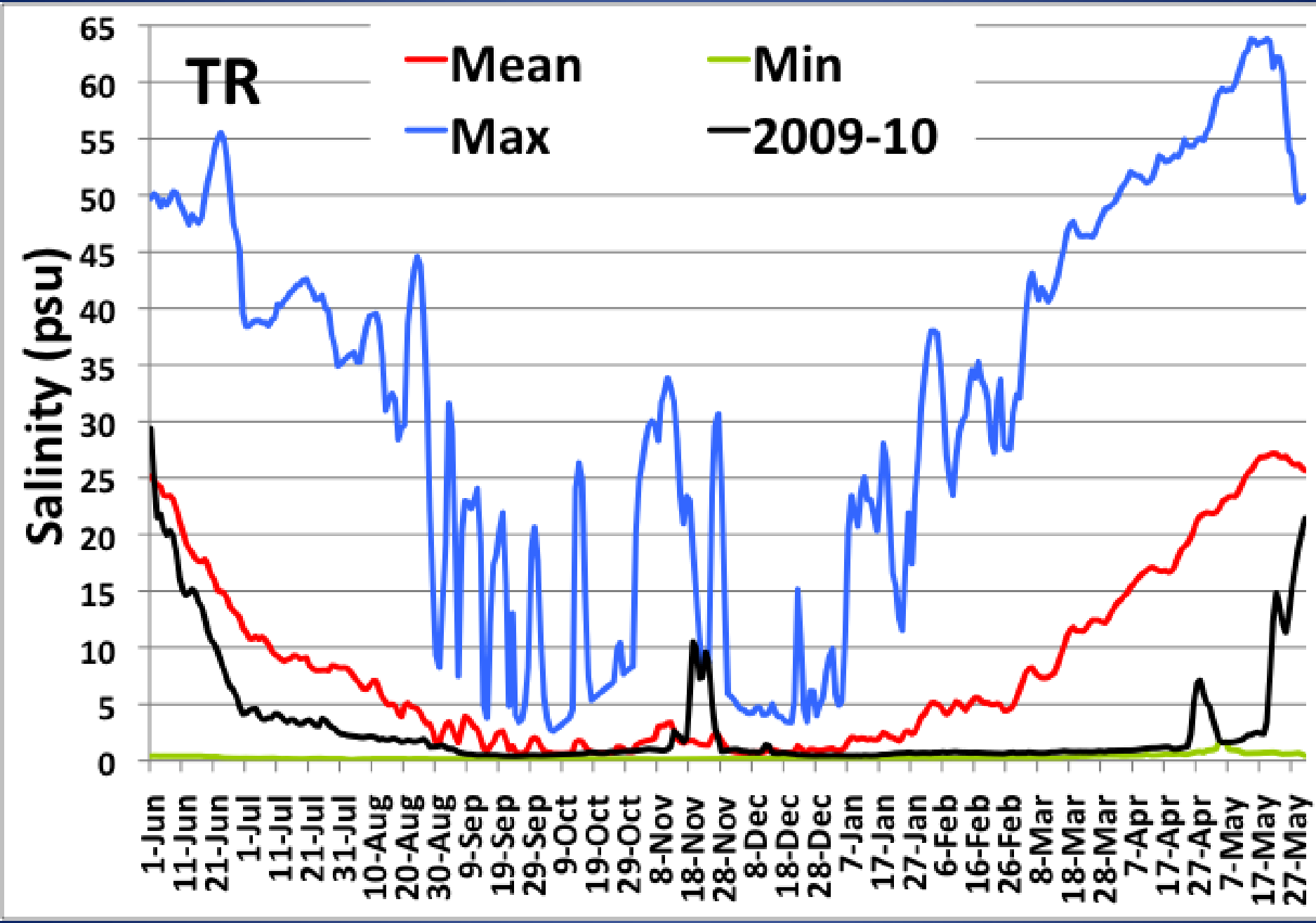

HC
Mean
Salinity
Max
2009-10
Water Level (cm) & Salinity (psu)
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
-5
-10
-15
-20
1-Jun
11-Jun
21-Jun
1-Jul
11-Jul
21-Jul
31-Jul
10-Aug
20-Aug
30-Aug
9-Sep
19-Sep
29-Sep
9-Oct
19-Oct
29-Oct
8-Nov
18-Nov
28-Nov
8-Dec
18-Dec
28-Dec
7-Jan
17-Jan
27-Jan
6-Feb
16-Feb
26-Feb
8-Mar
18-Mar
28-Mar
7-Apr
17-Apr
27-Apr
7-May
17-May
27-May

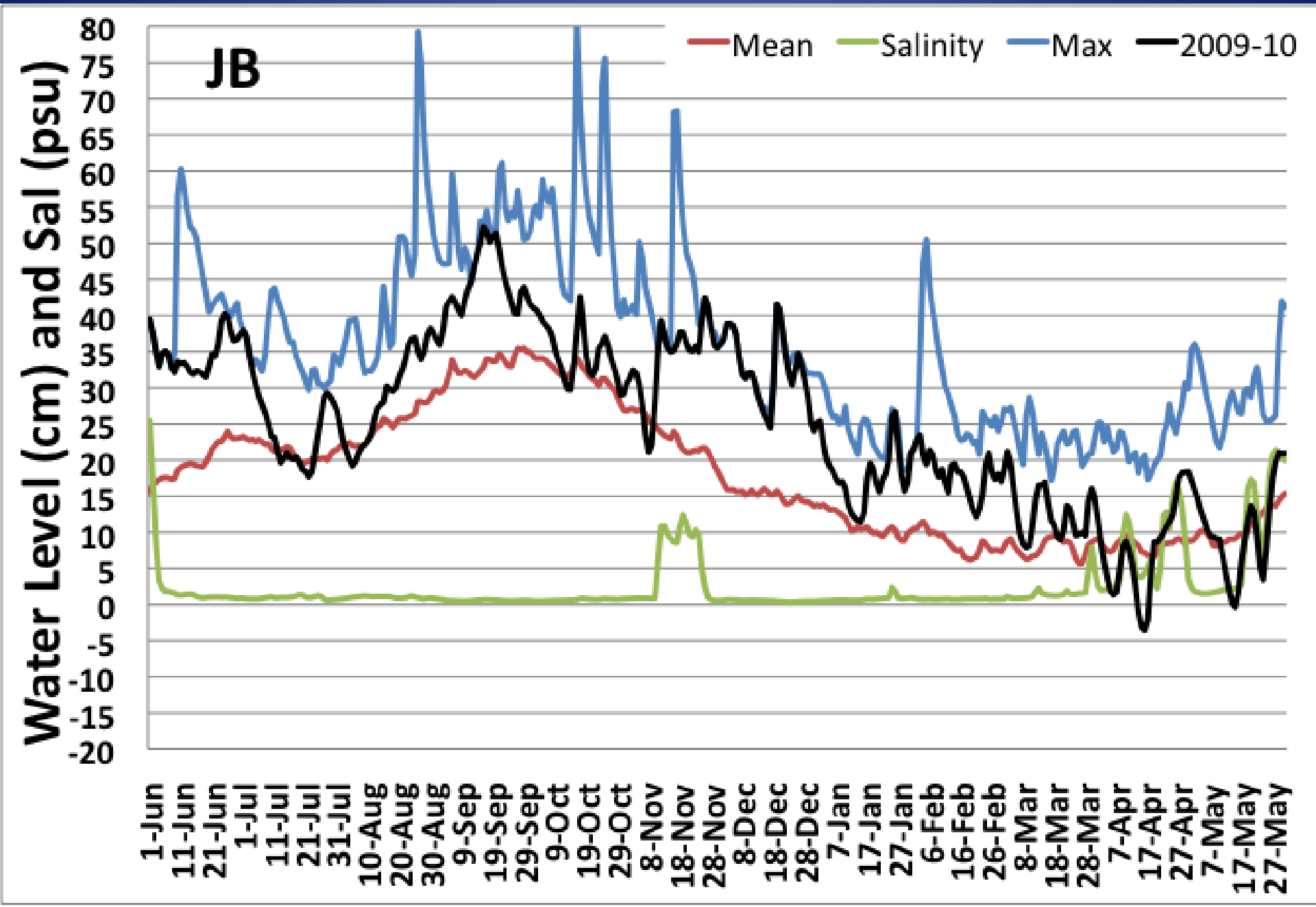

HC
Mean
Min
Max
2009-10
Salinity (psu)
60
55
50
45
40
35
30
25
20
15
10
5
0
1-Jun
11-Jun
21-Jun
1-Jul
11-Jul
21-Jul
31-Jul
10-Aug
20-Aug
30-Aug
9-Sep
19-Sep
29-Sep
9-Oct
19-Oct
29-Oct
8-Nov
18-Nov
28-Nov
8-Dec
18-Dec
28-Dec
7-Jan
17-Jan
27-Jan
6-Feb
16-Feb
26-Feb
8-Mar
18-Mar
28-Mar
7-Apr
17-Apr
27-Apr
7-May
17-May
27-May

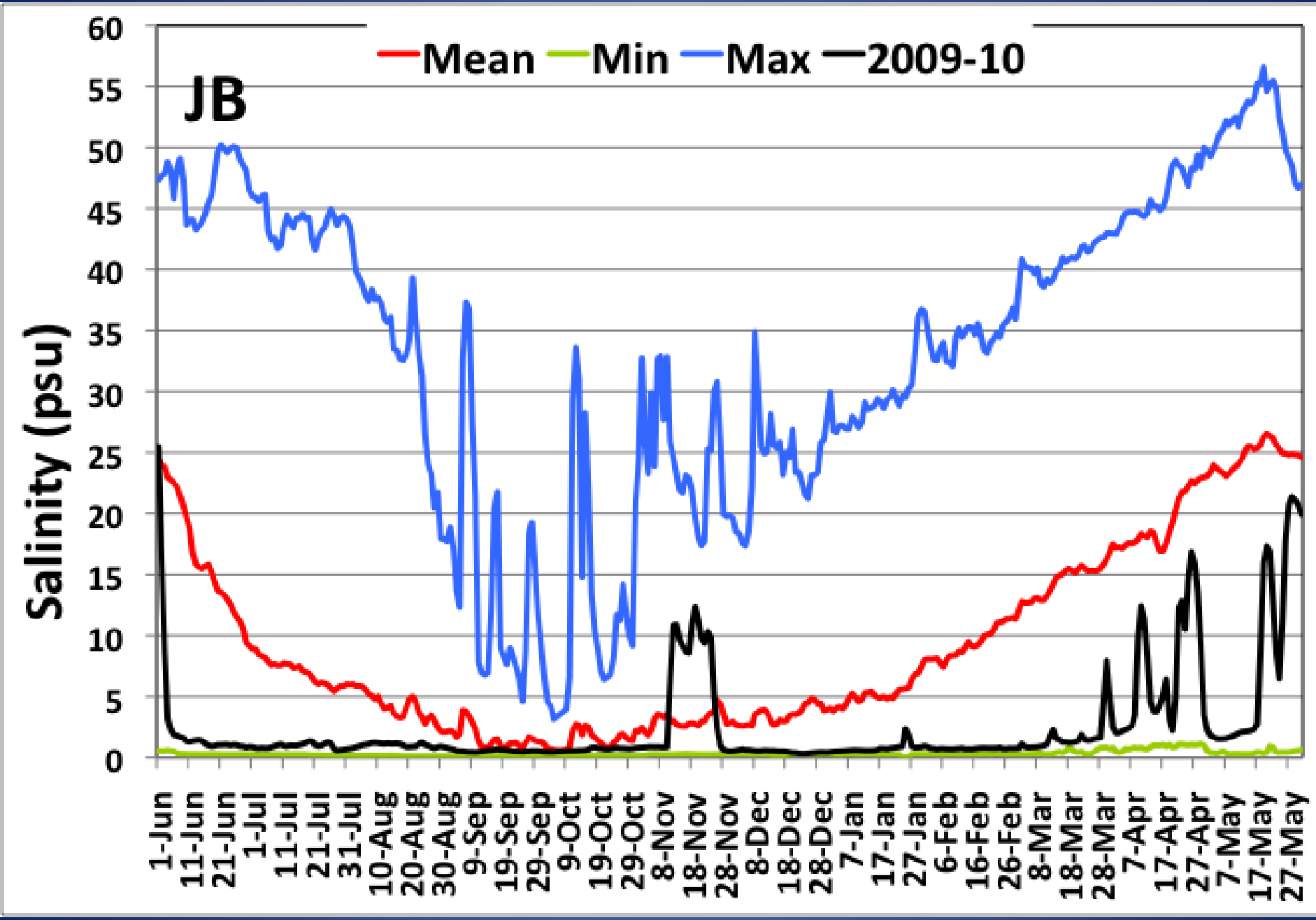

BS
Mean
Salinity
Max
2009-10
Water Level (cm) & Salinity (psu)
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
-5
-10
1-Jun
11-Jun
21-Jun
1-Jul
11-Jul
21-Jul
31-Jul
10-Aug
20-Aug
30-Aug
9-Sep
19-Sep
29-Sep
9-Oct
19-Oct
29-Oct
8-Nov
18-Nov
28-Nov
8-Dec
18-Dec
28-Dec
7-Jan
17-Jan
27-Jan
6-Feb
16-Feb
26-Feb
8-Mar
18-Mar
28-Mar
7-Apr
17-Apr
27-Apr
7-May
17-May
27-May


BS
Mean
Min
Max
2009-10
Salinity (psu)
60
55
50
45
40
35
30
25
20
15
10
5
0
1-Jun
11-Jun
21-Jun
1-Jul
11-Jul
21-Jul
31-Jul
10-Aug
20-Aug
30-Aug
9-Sep
19-Sep
29-Sep
9-Oct
19-Oct
29-Oct
8-Nov
18-Nov
28-Nov
8-Dec
18-Dec
28-Dec
7-Jan
17-Jan
27-Jan
6-Feb
16-Feb
26-Feb
8-Mar
18-Mar
28-Mar
7-Apr
17-Apr
27-Apr
7-May
17-May
27-May


TR
Mean
Salinty
Max
2009-10
Water Level (cm) & Salinity (psu)
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
-5
-10
-15
-20
1-Jun
11-Jun
21-Jun
1-Jul
11-Jul
21-Jul
31-Jul
10-Aug
20-Aug
30-Aug
9-Sep
19-Sep
29-Sep
9-Oct
19-Oct
29-Oct
8-Nov
18-Nov
28-Nov
8-Dec
18-Dec
28-Dec
7-Jan
17-Jan
27-Jan
6-Feb
16-Feb
26-Feb
8-Mar
18-Mar
28-Mar
7-Apr
17-Apr
27-Apr
7-May
17-May
27-May

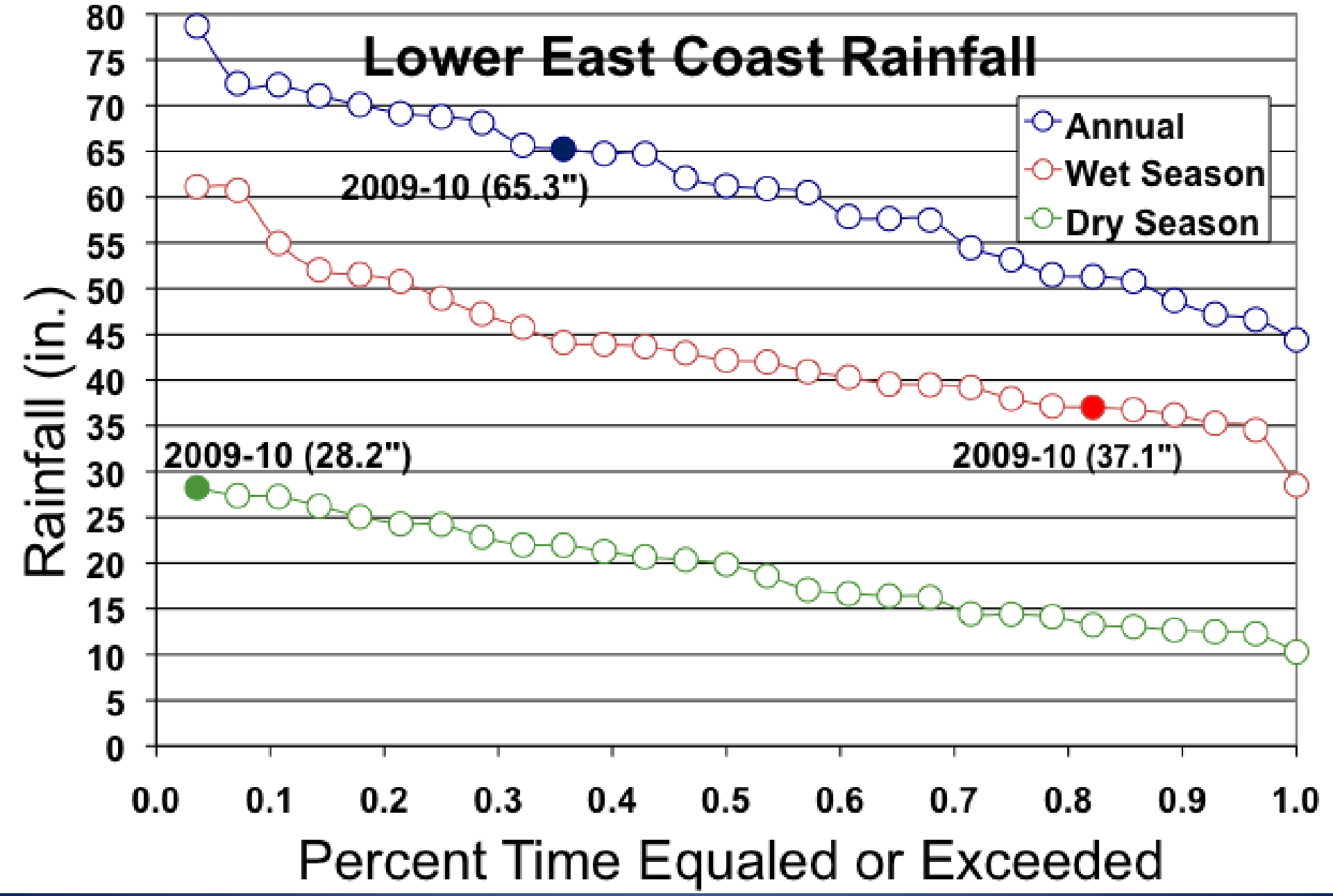

TR
Mean
Min
Max
2009-10
Salinity (psu)
65
60
55
50
45
40
35
30
25
20
15
10
5
0
1-Jun
11-Jun
21-Jun
1-Jul
11-Jul
21-Jul
31-Jul
10-Aug
20-Aug
30-Aug
9-Sep
19-Sep
29-Sep
9-Oct
19-Oct
29-Oct
8-Nov
18-Nov
28-Nov
8-Dec
18-Dec
28-Dec
7-Jan
17-Jan
27-Jan
6-Feb
16-Feb
26-Feb
8-Mar
18-Mar
28-Mar
7-Apr
17-Apr
27-Apr
7-May
17-May
27-May

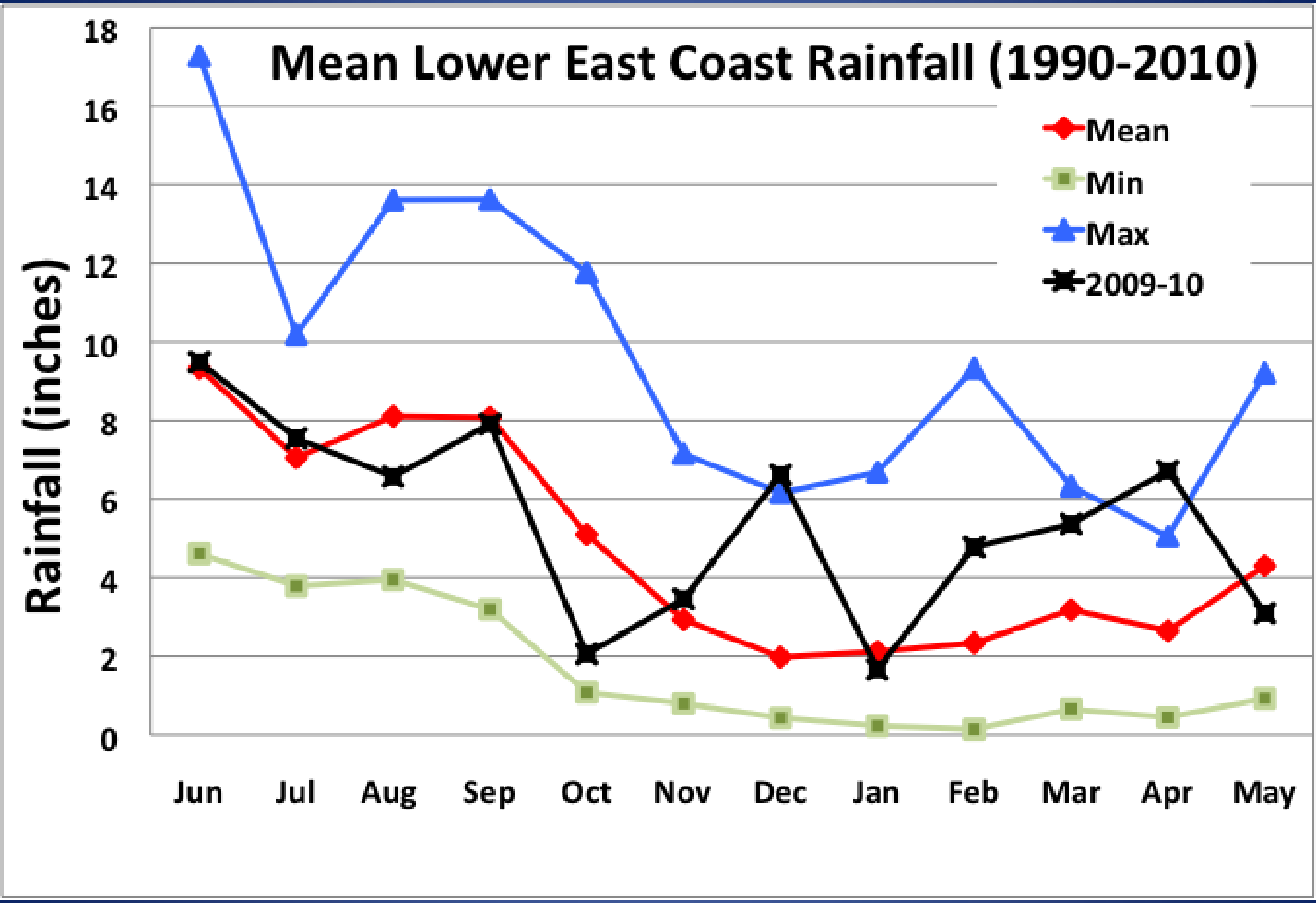

JB
Mean
Salinity
Max
2009-10
Water Level (cm) and Sal (psu)
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
-5
-10
-15
-20
1-Jun
11-Jun
21-Jun
1-Jul
11-Jul
21-Jul
31-Jul
10-Aug
20-Aug
30-Aug
9-Sep
19-Sep
29-Sep
9-Oct
19-Oct
29-Oct
8-Nov
18-Nov
28-Nov
8-Dec
18-Dec
28-Dec
7-Jan
17-Jan
27-Jan
6-Feb
16-Feb
26-Feb
8-Mar
18-Mar
28-Mar
7-Apr
17-Apr
27-Apr
7-May
17-May
27-May

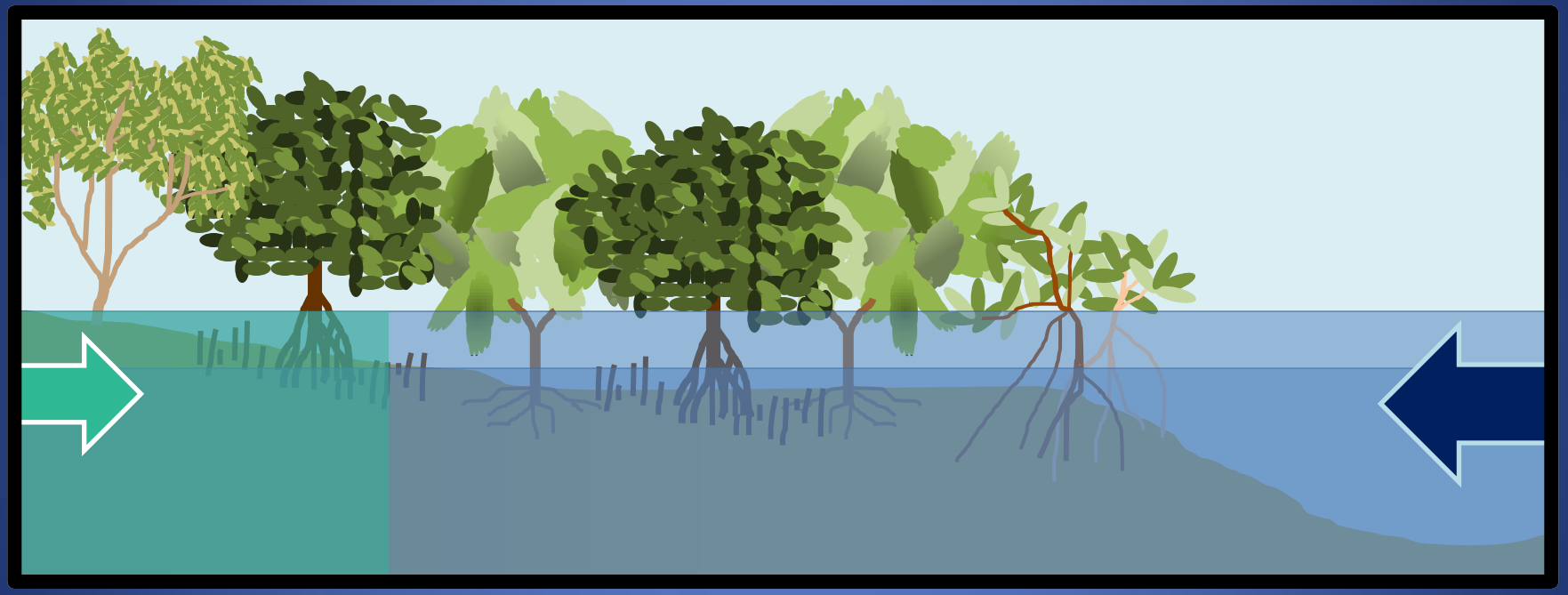

JB
Mean
Min
Max
2009-10
Salinity (psu)
60
55
50
45
40
35
30
25
20
15
10
5
0
1-Jun
11-Jun
21-Jun
1-Jul
11-Jul
21-Jul
31-Jul
10-Aug
20-Aug
30-Aug
9-Sep
19-Sep
29-Sep
9-Oct
19-Oct
29-Oct
8-Nov
18-Nov
28-Nov
8-Dec
18-Dec
28-Dec
7-Jan
17-Jan
27-Jan
6-Feb
16-Feb
26-Feb
8-Mar
18-Mar
28-Mar
7-Apr
17-Apr
27-Apr
7-May
17-May
27-May

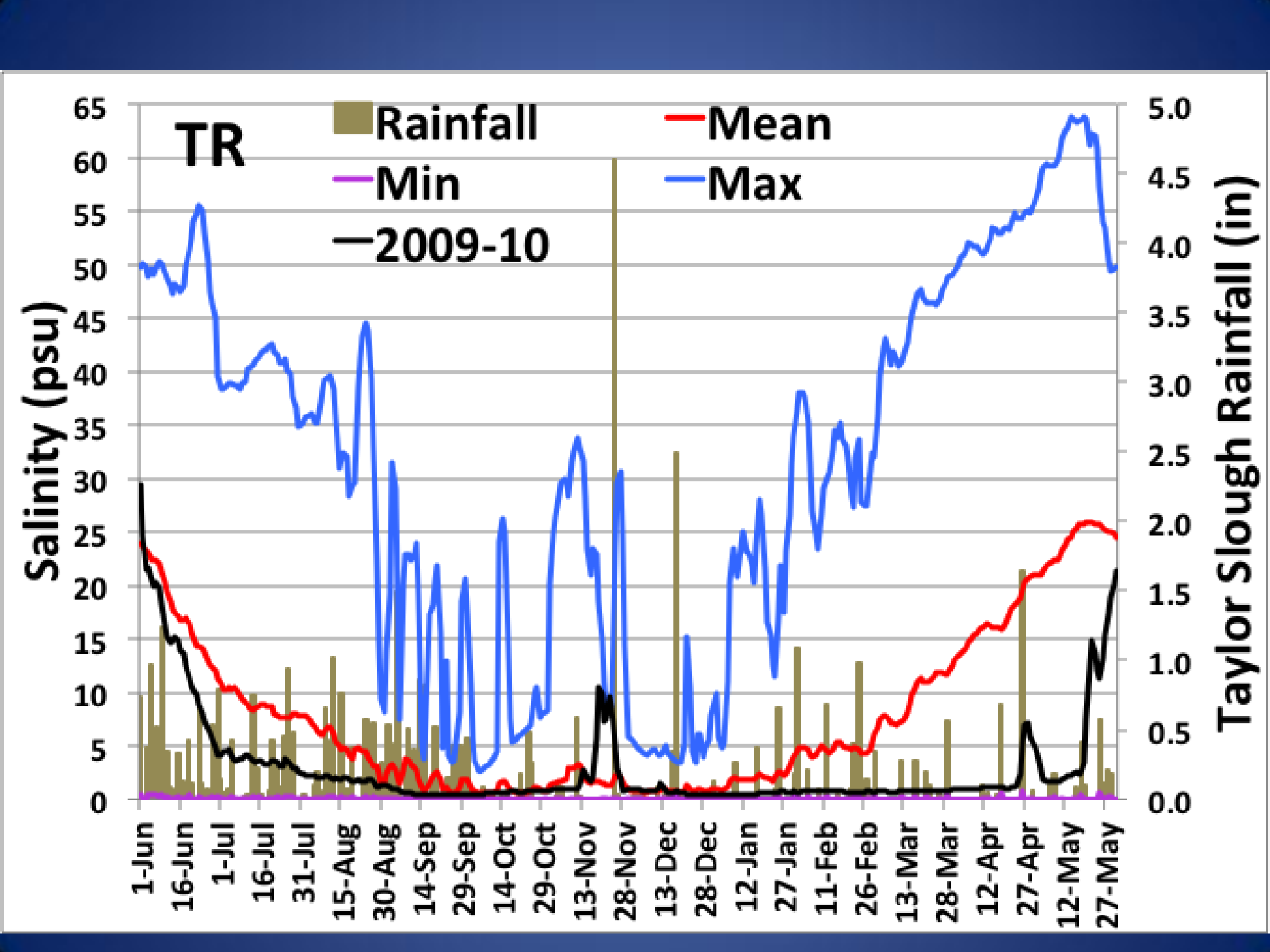
Summary of Events Oct-Nov 2010

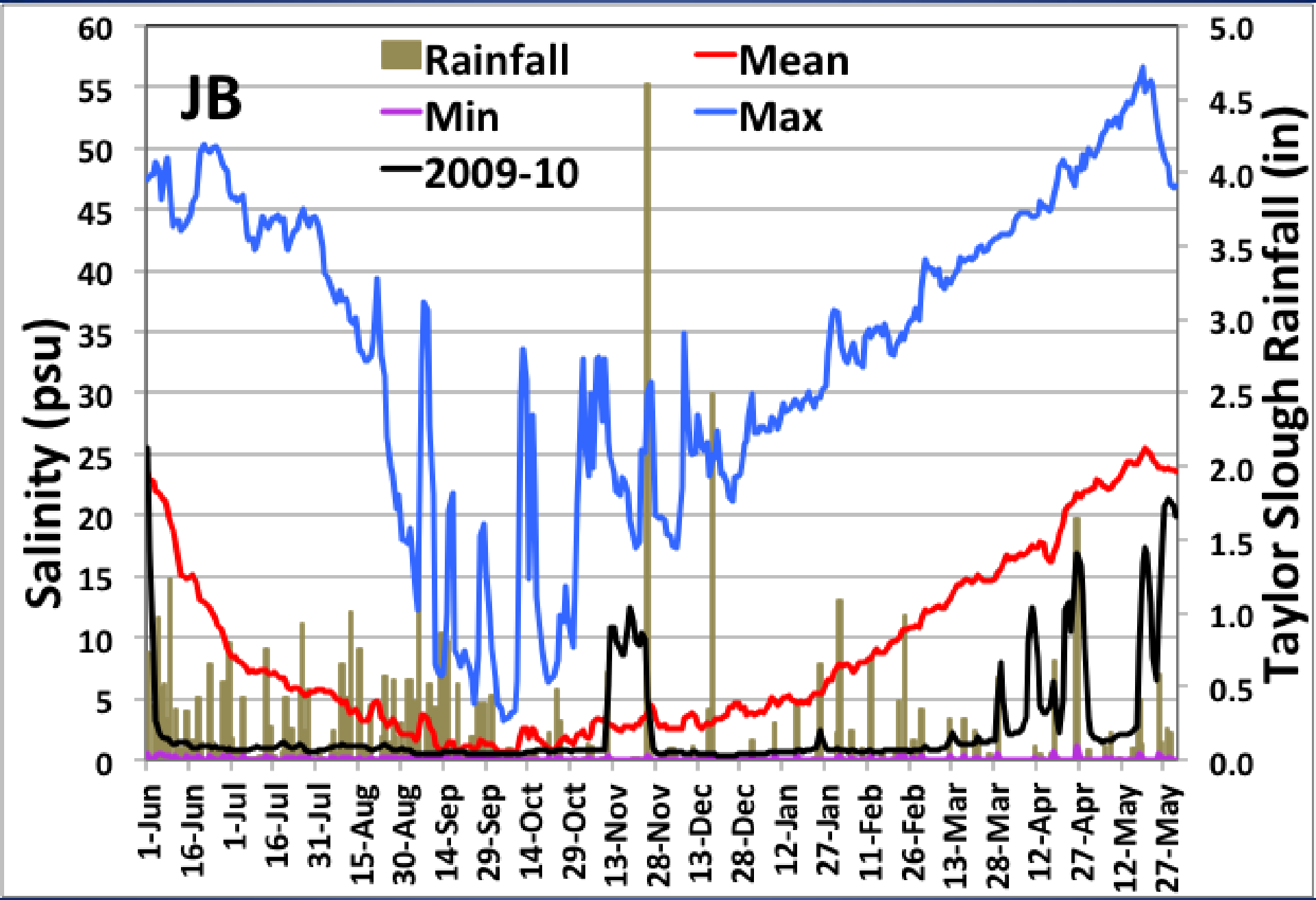
- Record high water levels in surrounding marine environment
- Record high water levels in mangrove wetlands
- Unusually low rainfall
- Record high salinity

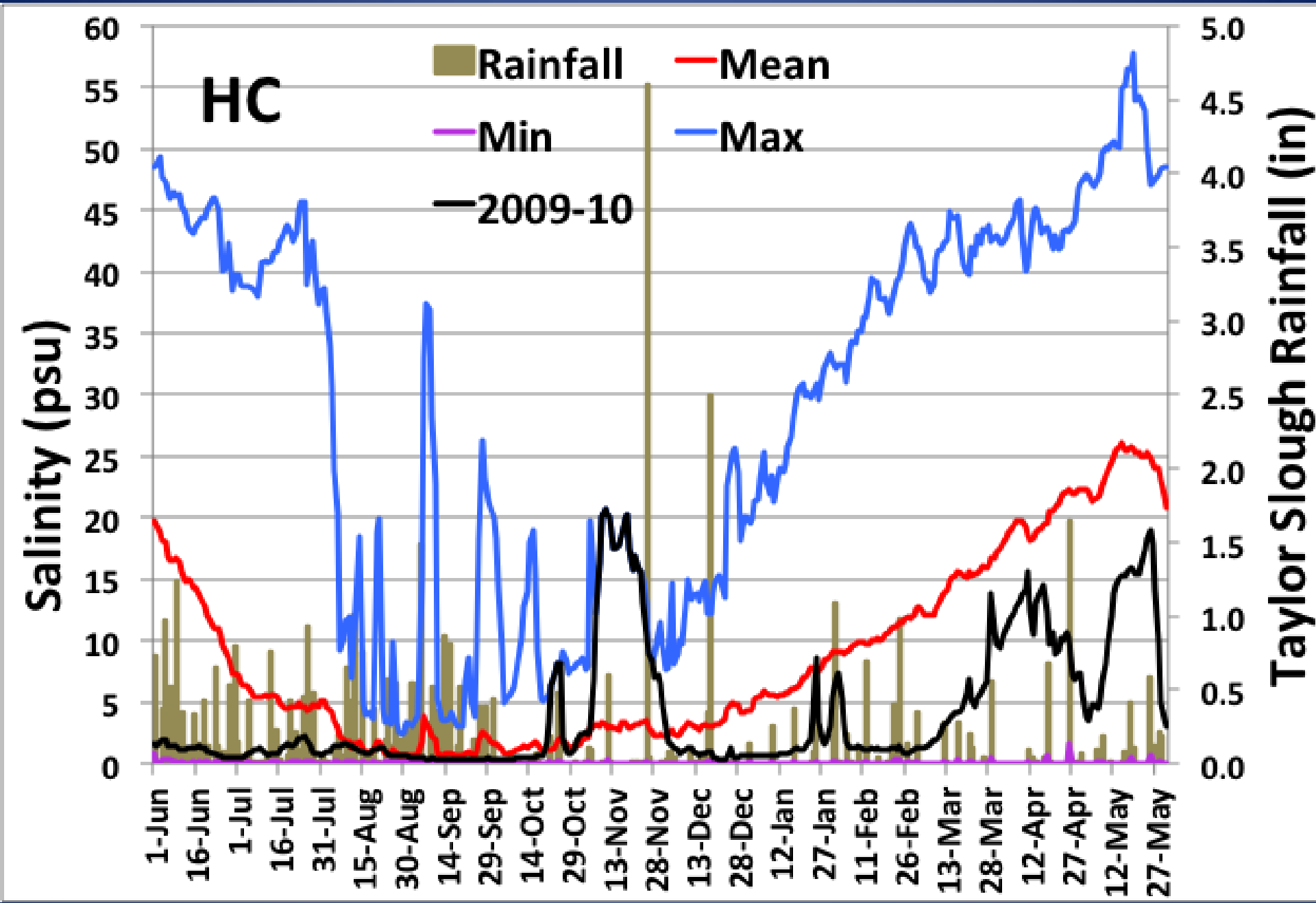

Lower East Coast Rainfall
Annual
Wet Season
Dry Season
2009-10 (65.3")
2009-10 (28.2")
2009-10 (37.1")
Rainfall (in.)
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Percent Time Equaled or Exceeded

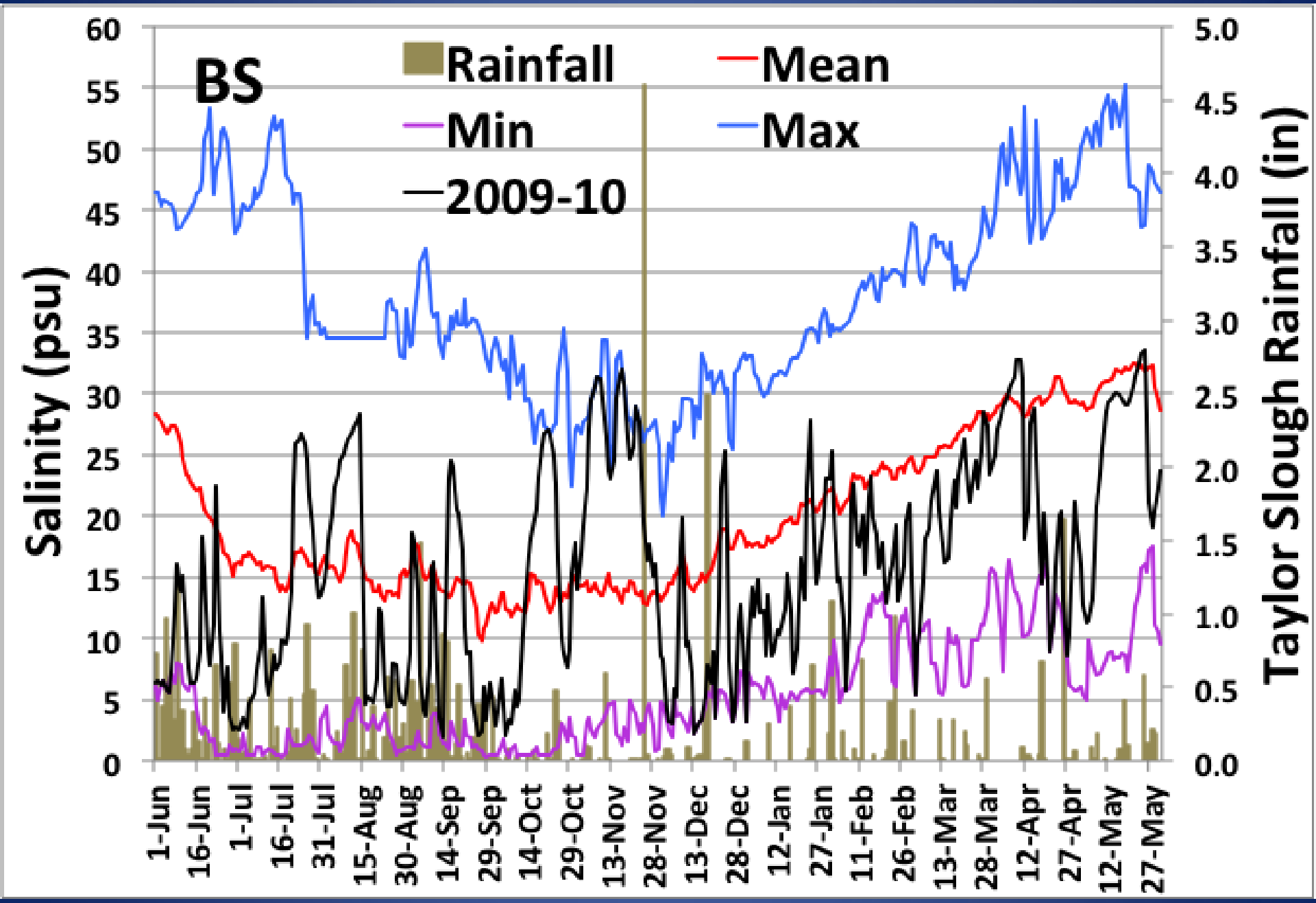

Mean Lower East Coast Rainfall (1990-2010)
Rainfall (inches)
18
16
14
12
10
8
6
4
2
0
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Mean
Min
Max
2009-10



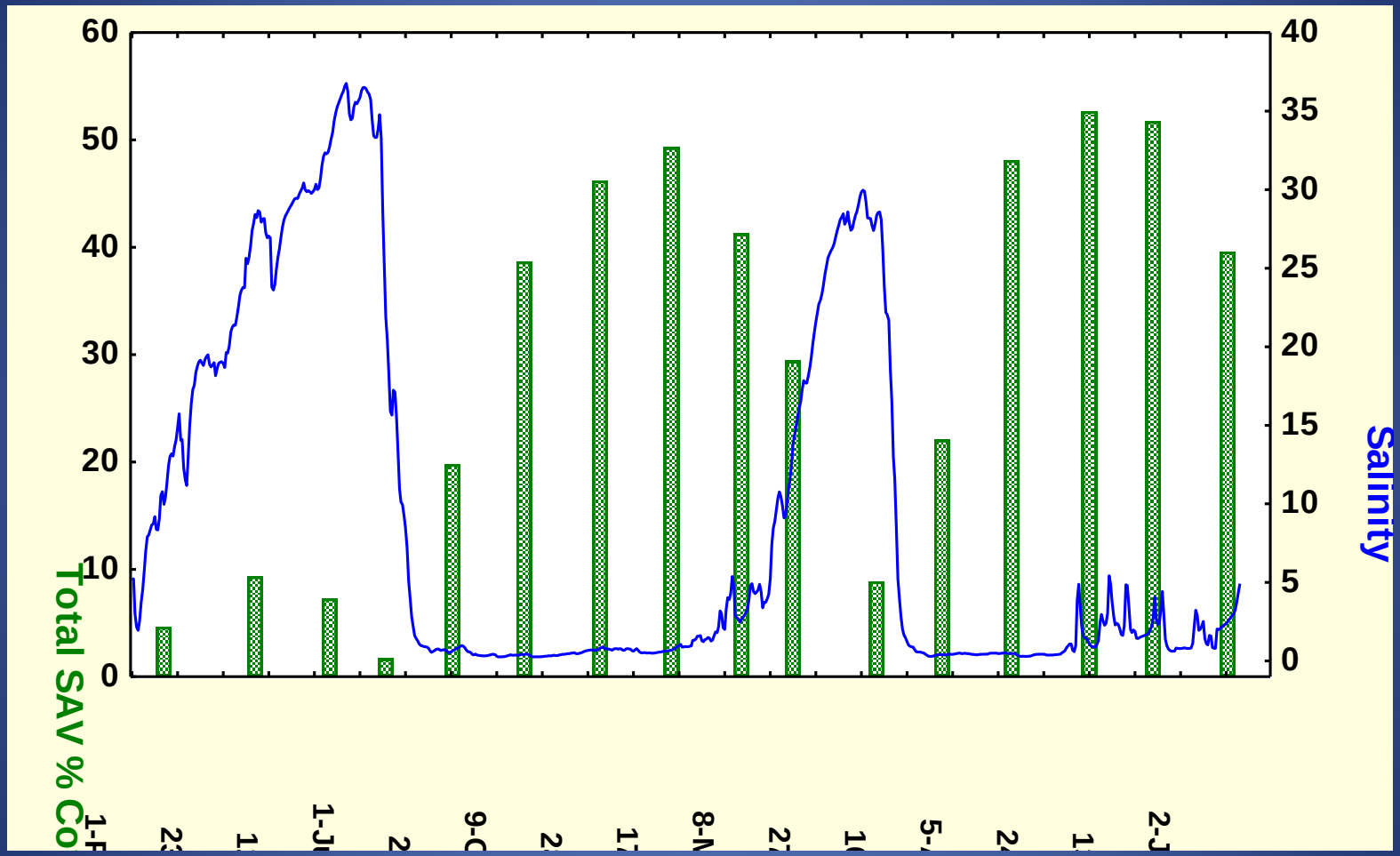

TR
Rainfall
Mean
Min
Max
2009-10
Salinity (psu)
Taylor Slough Rainfall (in)
65
60
55
50
45
40
35
30
25
20
15
10
5
0
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
1-Jun
16-Jun
1-Jul
16-Jul
31-Jul
15-Aug
30-Aug
14-Sep
29-Sep
14-Oct
29-Oct
13-Nov
28-Nov
13-Dec
28-Dec
12-Jan
27-Jan
11-Feb
26-Feb
13-Mar
28-Mar
12-Apr
27-Apr
12-May
27-May


JB
Rainfall
Mean
Min
Max
2009-10
Salinity (psu)
Taylor Slough Rainfall (in)
60
55
50
45
40
35
30
25
20
15
10
5
0
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
1-Jun
16-Jun
1-Jul
16-Jul
31-Jul
15-Aug
30-Aug
14-Sep
29-Sep
14-Oct
29-Oct
13-Nov
28-Nov
13-Dec
28-Dec
12-Jan
27-Jan
11-Feb
26-Feb
13-Mar
28-Mar
12-Apr
27-Apr
12-May
27-May

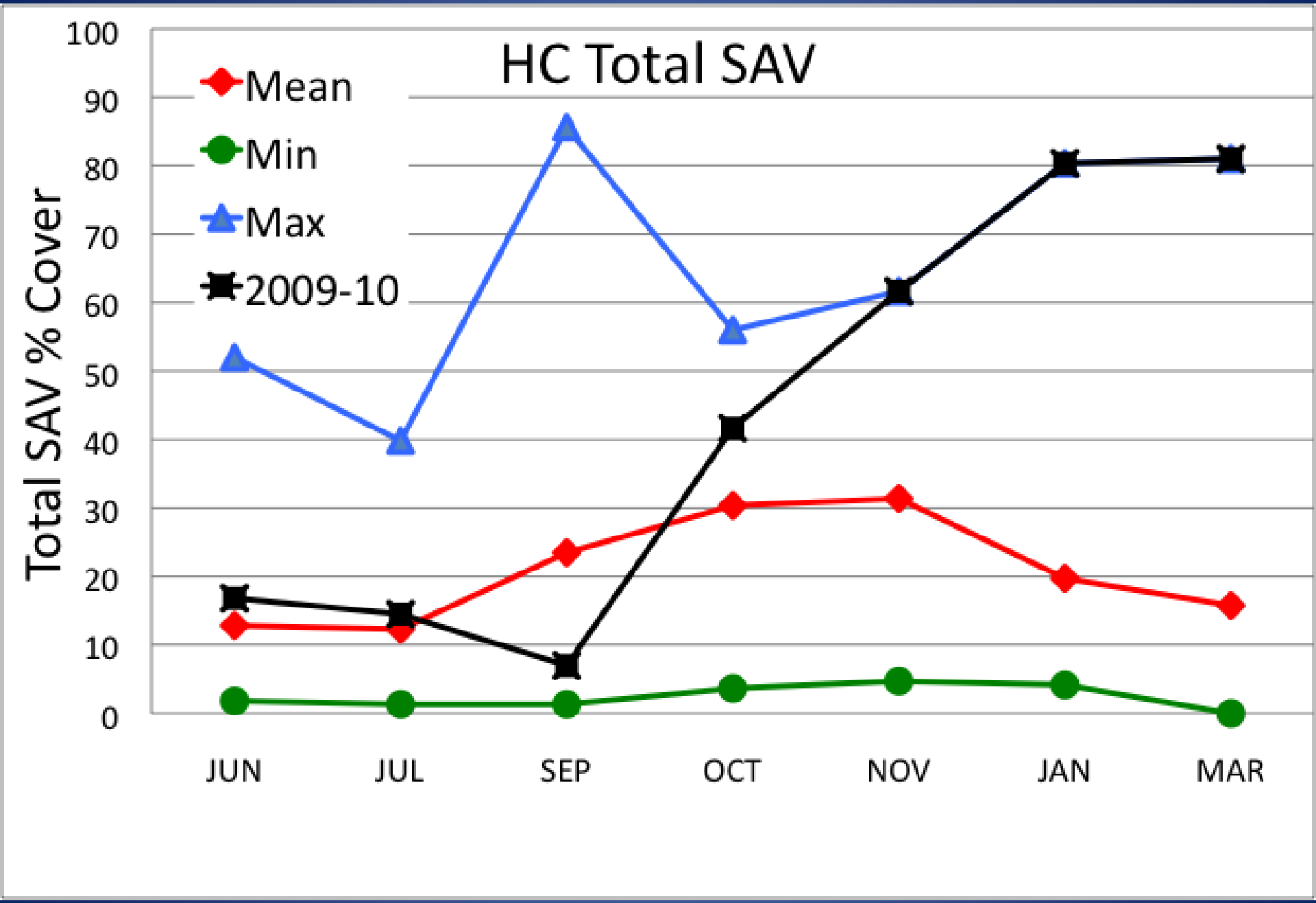

HC
Rainfall
Mean
Min
Max
2009-10
Salinity (psu)
Taylor Slough Rainfall (in)
60
55
50
45
40
35
30
25
20
15
10
5
0
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
1-Jun
16-Jun
1-Jul
16-Jul
31-Jul
15-Aug
30-Aug
14-Sep
29-Sep
14-Oct
29-Oct
13-Nov
28-Nov
13-Dec
28-Dec
12-Jan
27-Jan
11-Feb
26-Feb
13-Mar
28-Mar
12-Apr
27-Apr
12-May
27-May

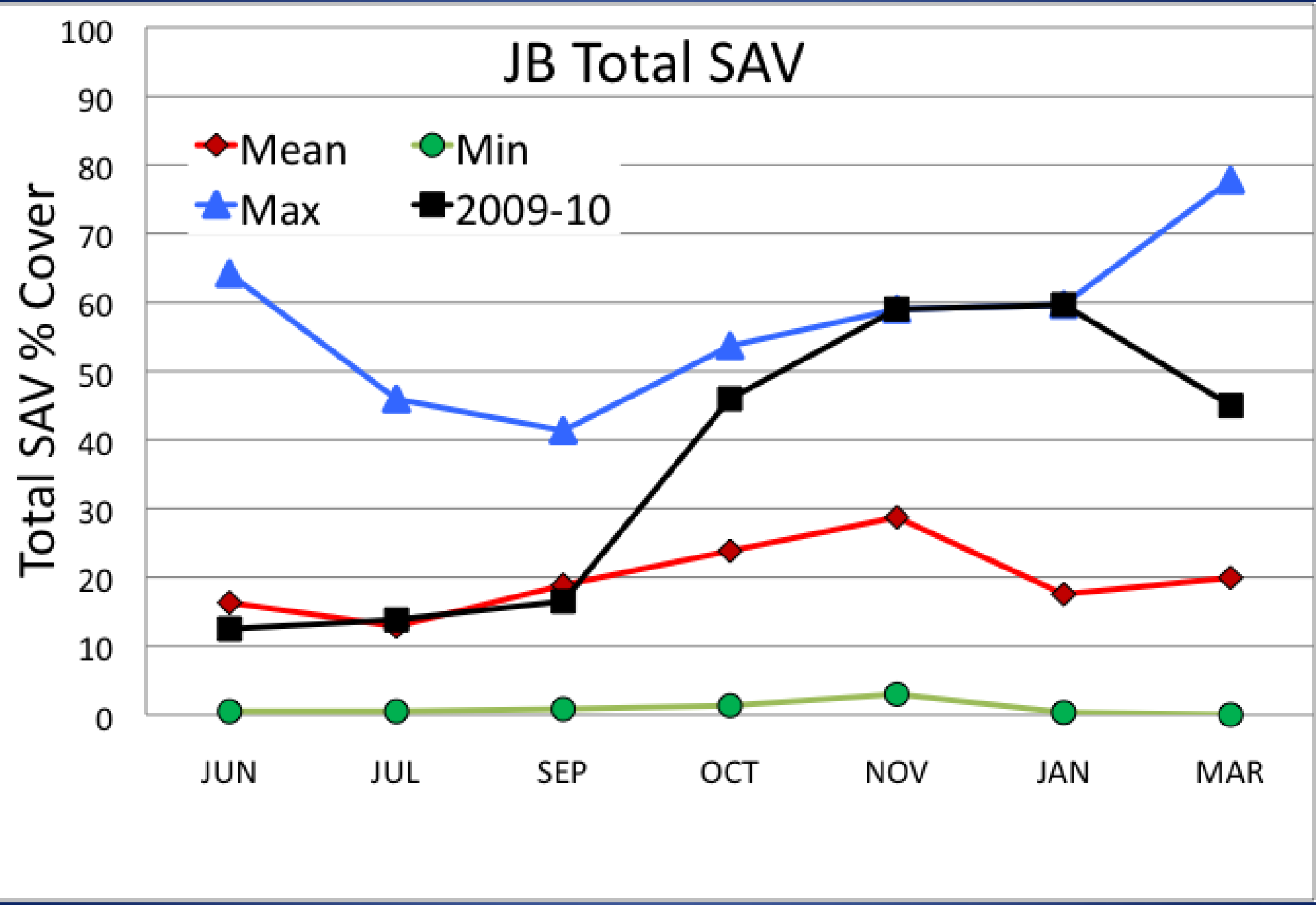

BS
Rainfall
Mean
Min
Max
2009-10
Salinity (psu)
Taylor Slough Rainfall (in)
60
55
50
45
40
35
30
25
20
15
10
5
0
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
1-Jun
16-Jun
1-Jul
16-Jul
31-Jul
15-Aug
30-Aug
14-Sep
29-Sep
14-Oct
29-Oct
13-Nov
28-Nov
13-Dec
28-Dec
12-Jan
27-Jan
11-Feb
26-Feb
13-Mar
28-Mar
12-Apr
27-Apr
12-May
27-May

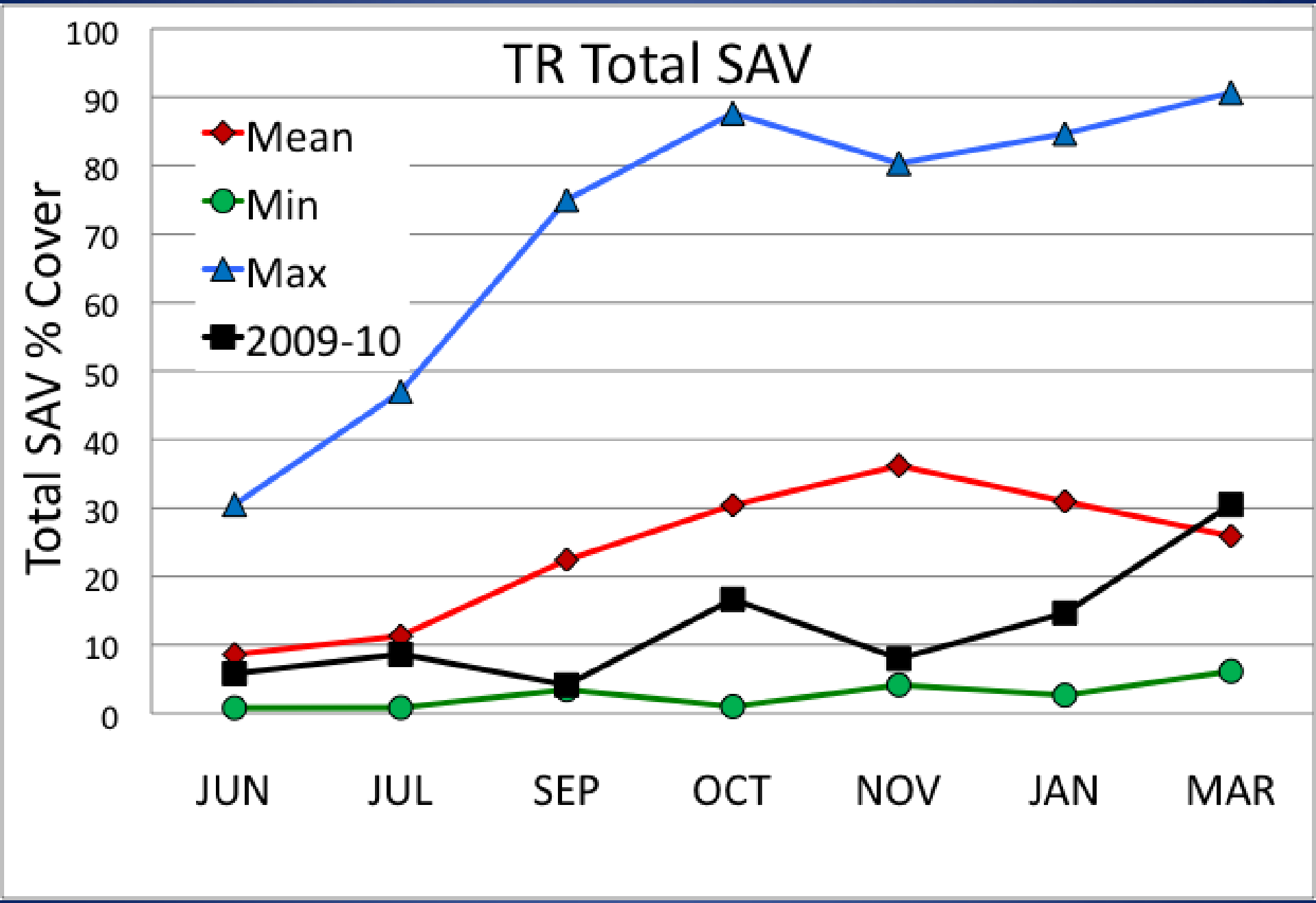
Ecological Consequence: Inverse relationship between SAV and salinity (Frezza et al. 2007)



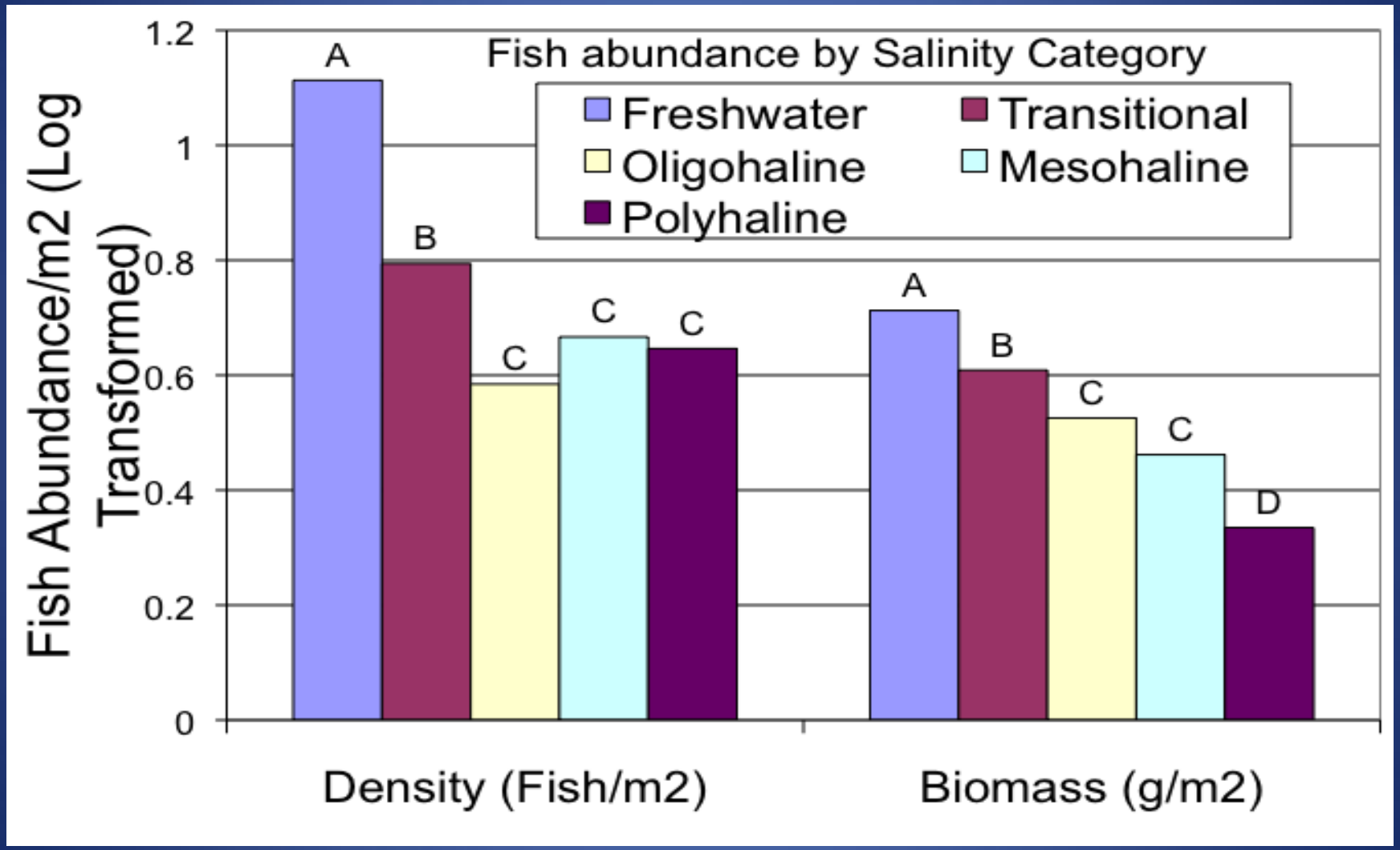
Frezza, P.E, L. Canedo and J.J. Lorenz. 2007. Relationships Between Submerged Aquatic Vegetation Abundance and Salinity Variability within the Coastal Mangrove Zone of Northeastern Florida Bay


HC Total SAV
Mean
Min
Max
2009-10
Total SAV % Cover
100
90
80
70
60
50
40
30
20
10
0
JUN
JUL
SEP
OCT
NOV
JAN
MAR

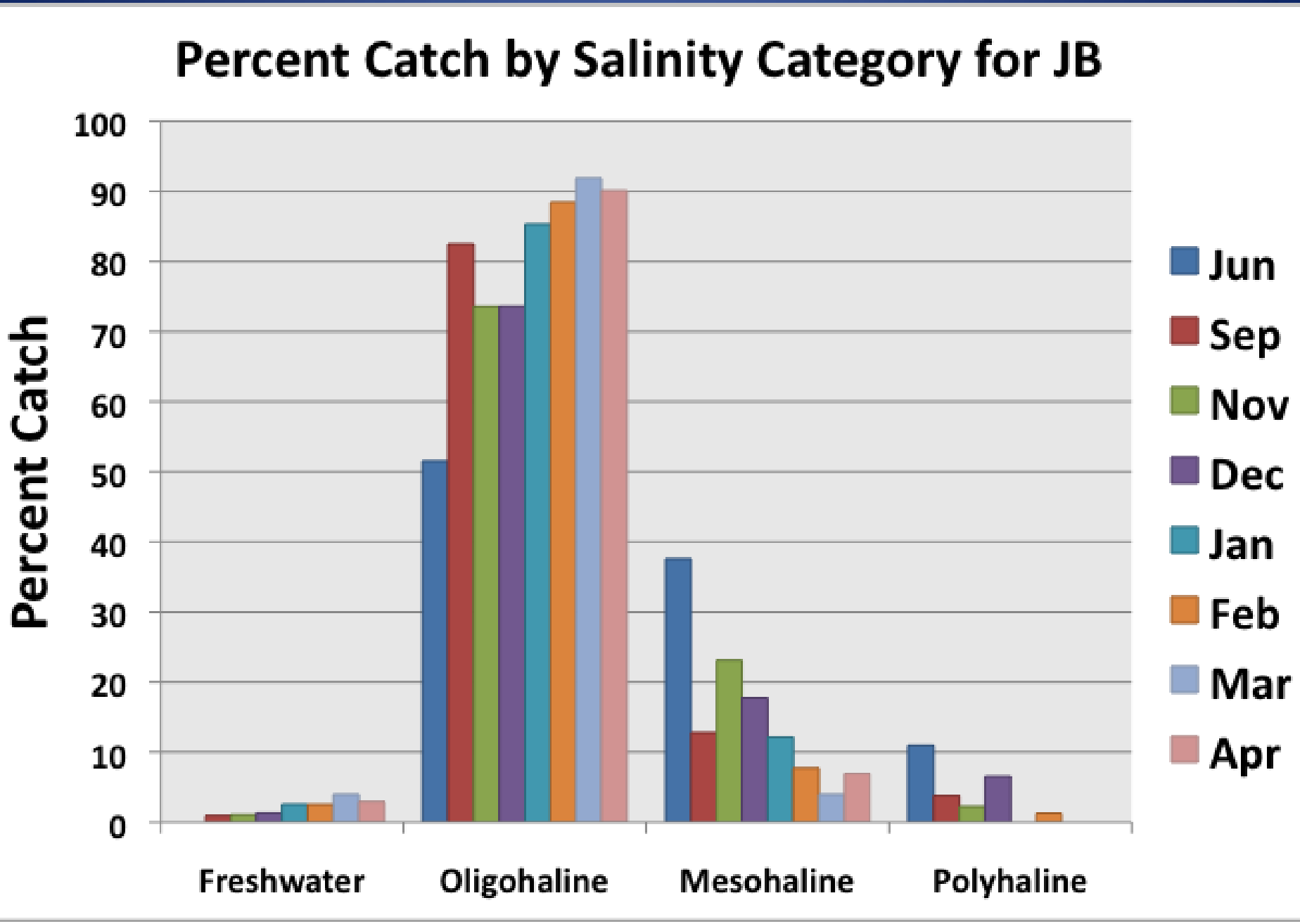

JB Total SAV
Mean
Min
Max
2009-10
Total SAV % Cover
100
90
80
70
60
50
40
30
20
10
0
JUN
JUL
SEP
OCT
NOV
JAN
MAR

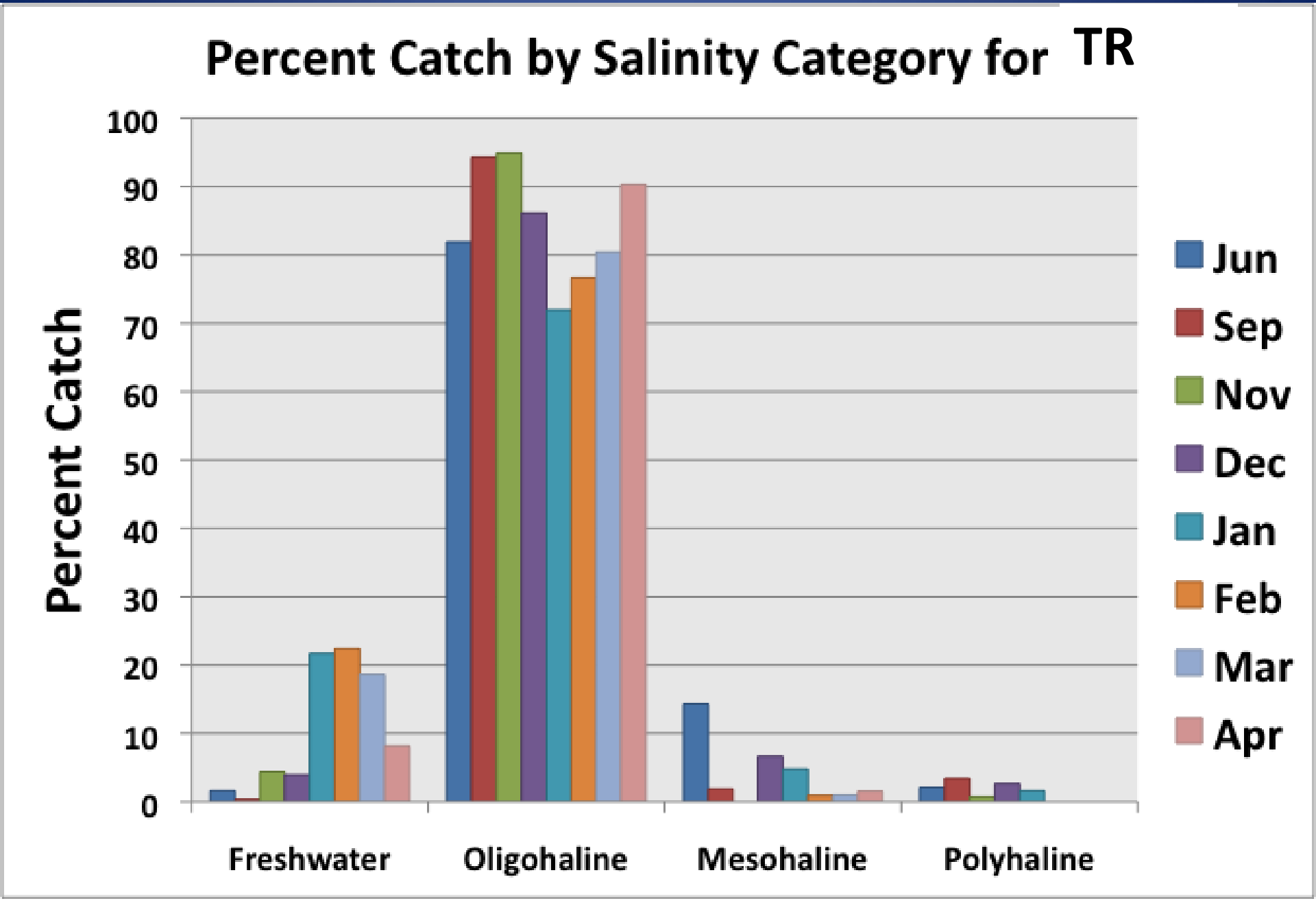

TR Total SAV
Total SAV % Cover
100
90
80
70
60
50
40
30
20
10
0
Mean
Min
Max
2009-10
JUN
JUL
SEP
OCT
NOV
JAN
MAR

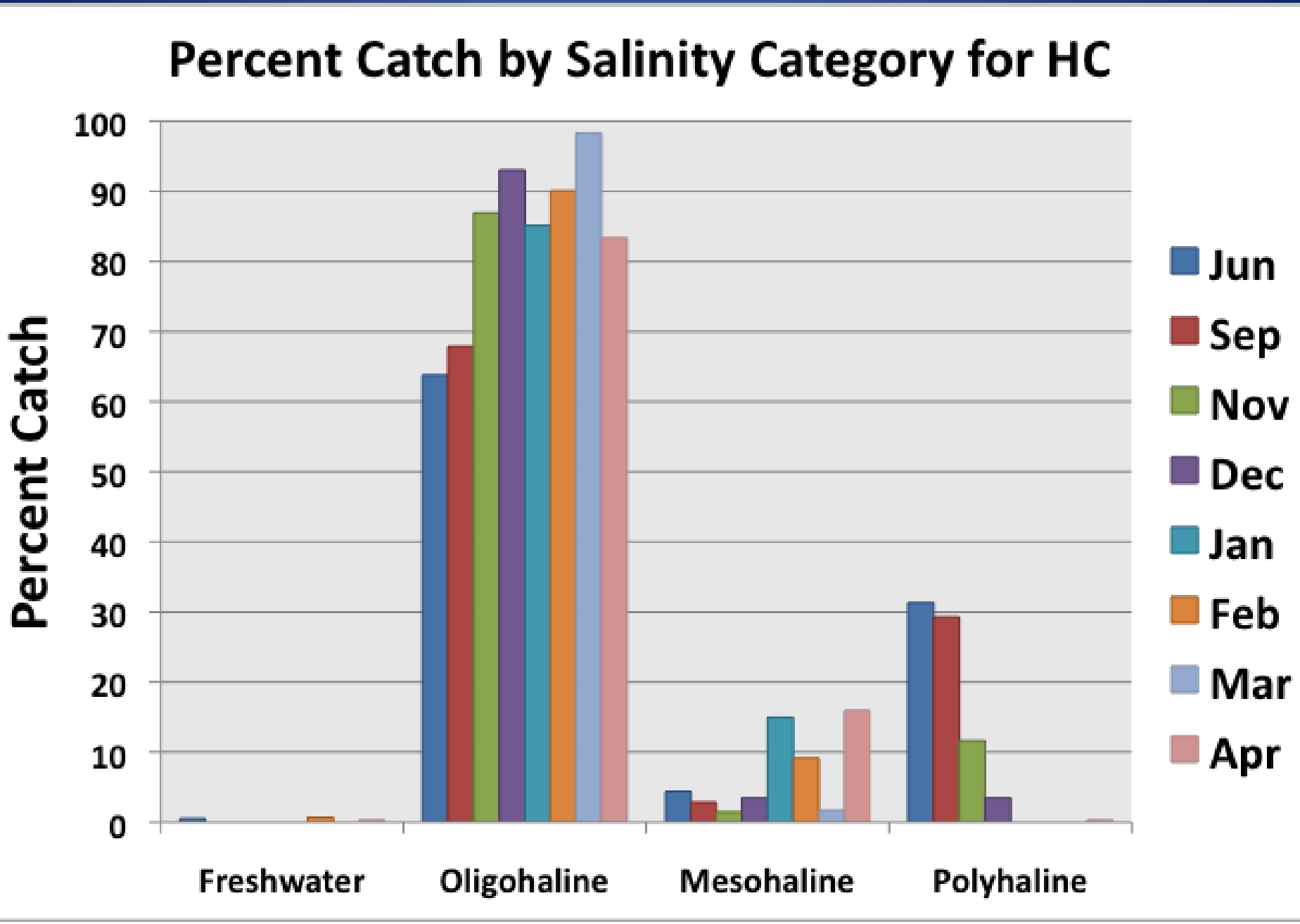
Ecological Consequence: Lower salinity results in a more productive prey fish community (Lorenz and Serafy 2006)

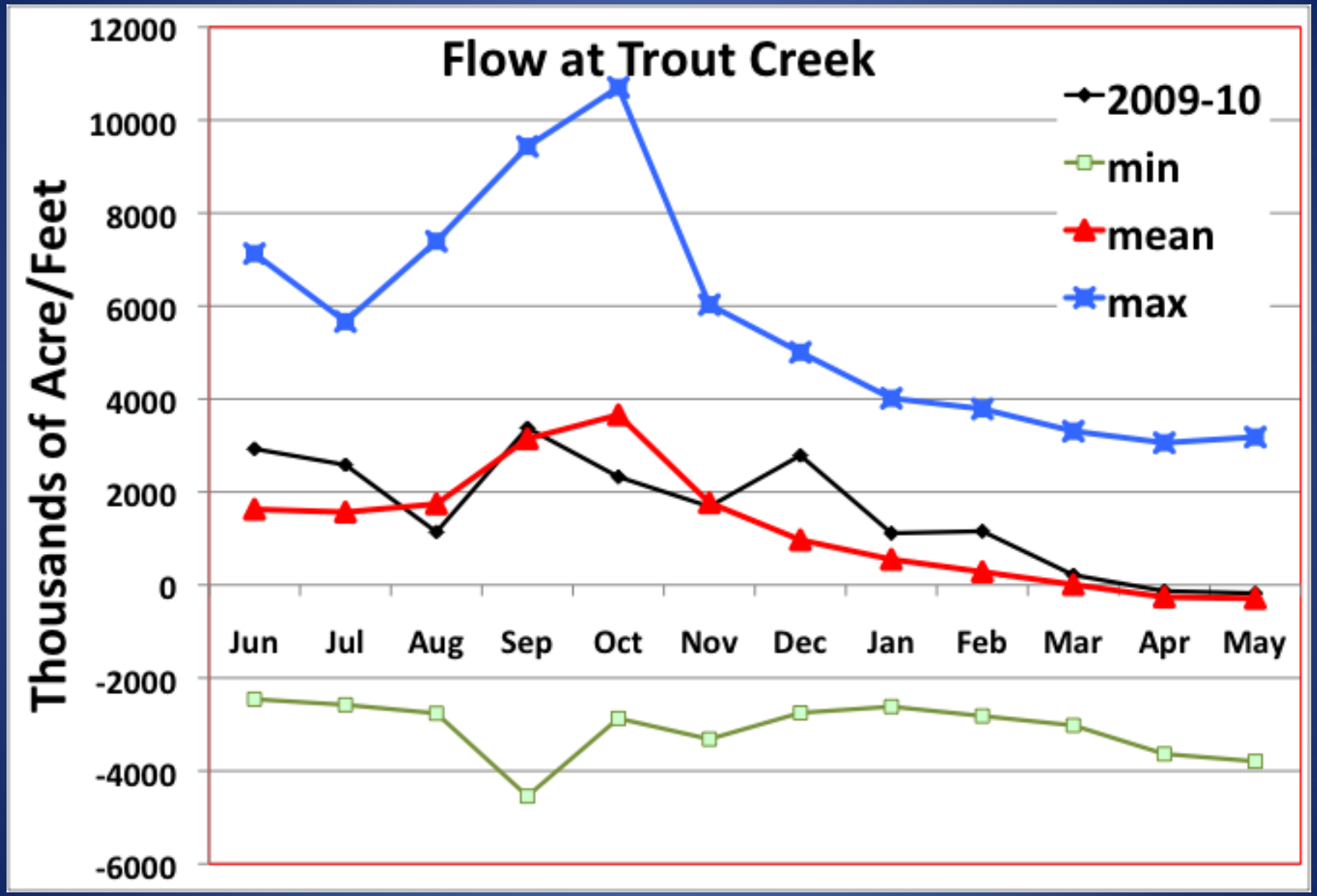


Lorenz, J.J. and J. E. Serafyt. 2006. **Subtropical wetland fish assemblages and changing salinity regimes: implications for Everglades restoration. Hydrobiologia 569:401–422**


Percent Catch by Salinity Category for JB
Percent Catch
100
90
80
70
60
50
40
30
20
10
0
Freshwater
Oligohaline
Mesohaline
Polyhaline
Jun
Sep
Nov
Dec
Jan
Feb
Mar
Apr


Percent Catch by Salinity Category for TR
Percent Catch
100
90
80
70
60
50
40
30
20
10
0
Freshwater
Oligohaline
Mesohaline
Polyhaline
Jun
Sep
Nov
Dec
Jan
Feb
Mar
Apr


Percent Catch by Salinity Category for HC
Percent Catch
100
90
80
70
60
50
40
30
20
10
0
Freshwater
Oligohaline
Mesohaline
Polyhaline
Jun
Sep
Nov
Dec
Jan
Feb
Mar
Apr


Flow at Trout Creek
2009-10
min
mean
max
Thousands of Acre/Feet
12000
10000
8000
6000
4000
2000
0
-2000
-4000
-6000
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May

Marshall et al. 2008 used models coupled with paleoecological to simulate pre-drainage conditions.

- Consevatively estiamted almost 4 times the freshwater flow from Taylor Slough compared to existing flows
- 2009-10 good representation of what would happen with restored Everglades and predicted SLR

Marshall III, F.E., G.L.Wingard and P. Pitts. 2008. A simulation of historic hydrology and salinity in Everglades National Park: coupling paleoecological assemblage data with regression models. Estuaries and Coasts


Questions?