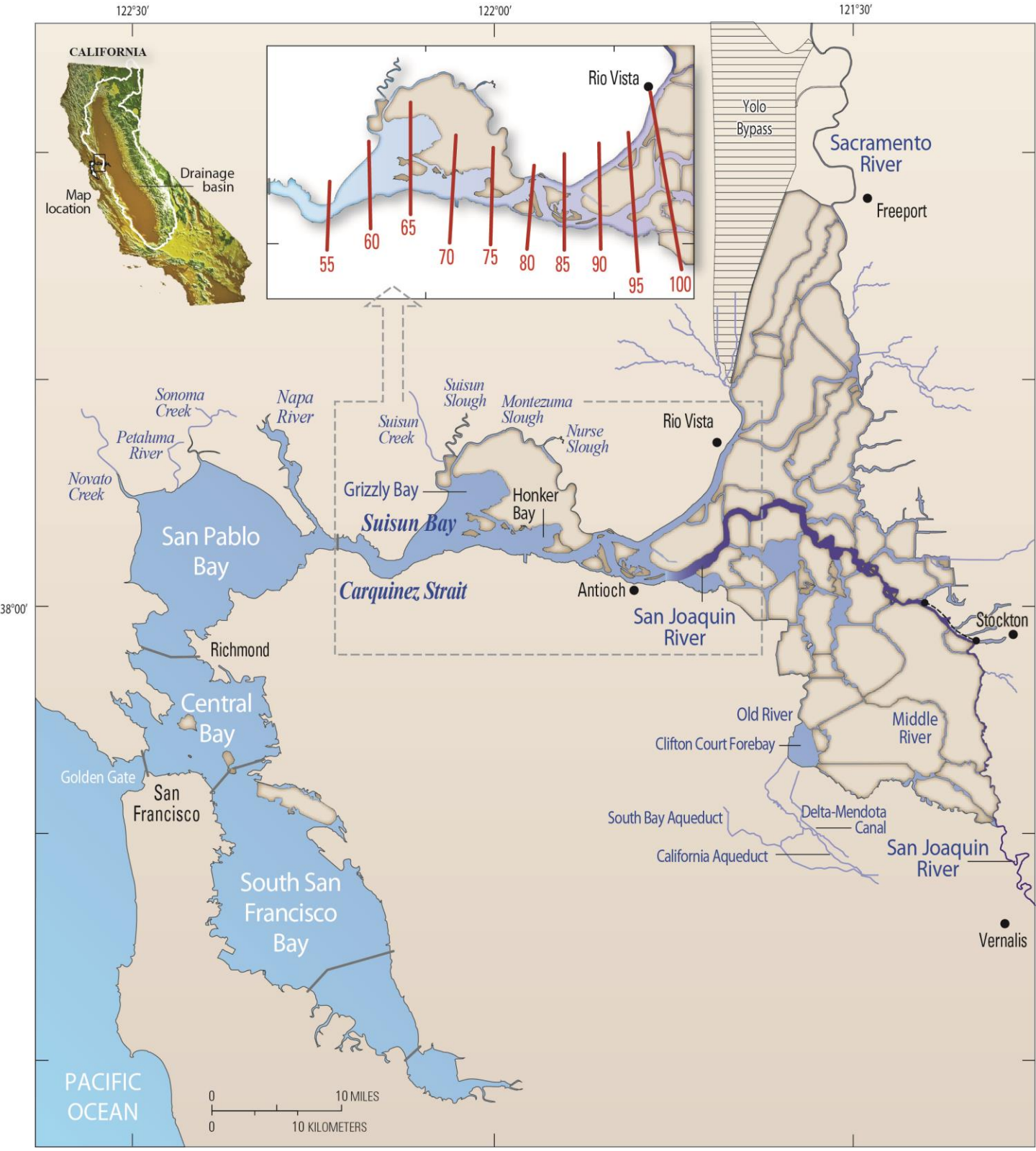
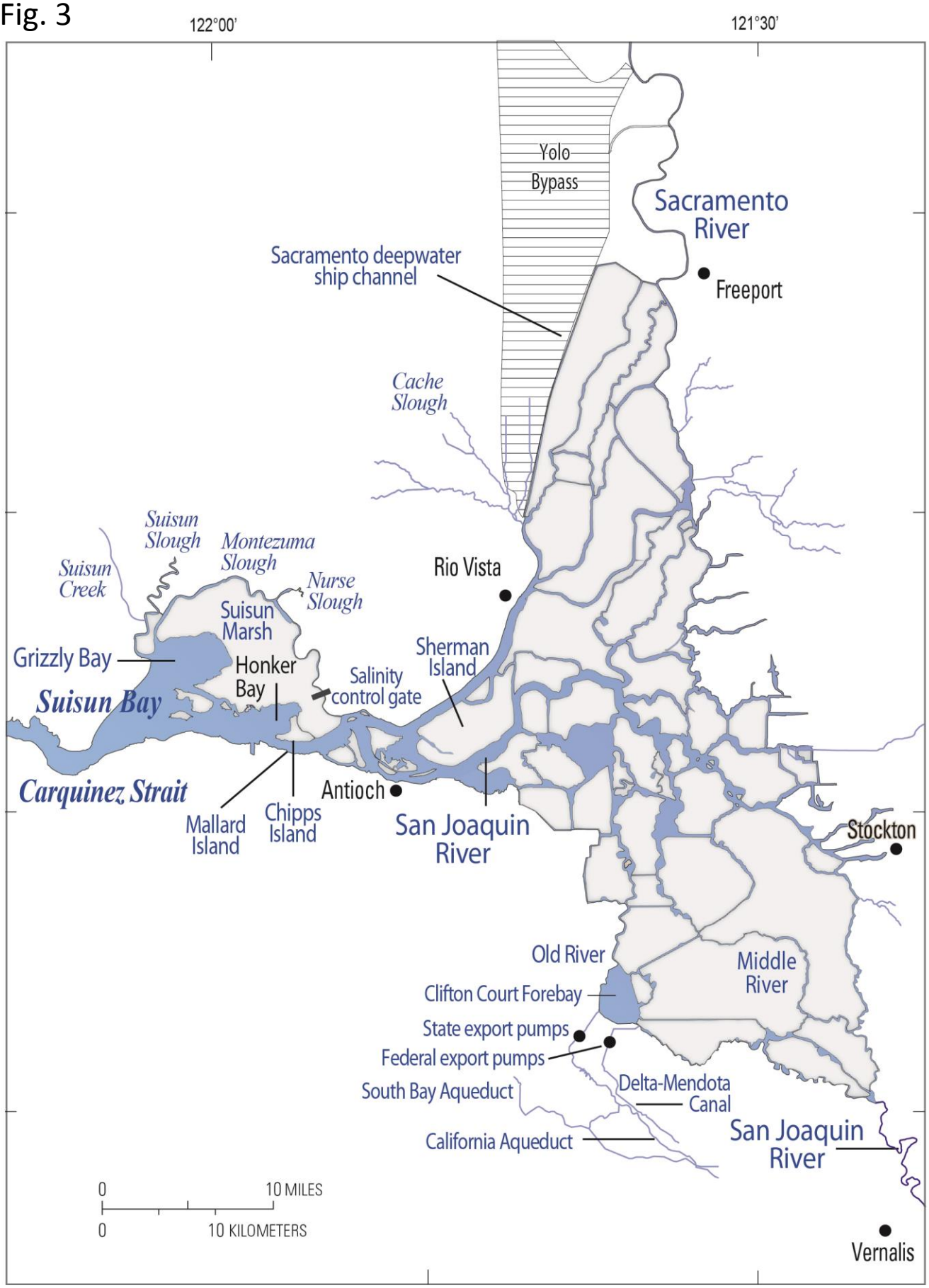
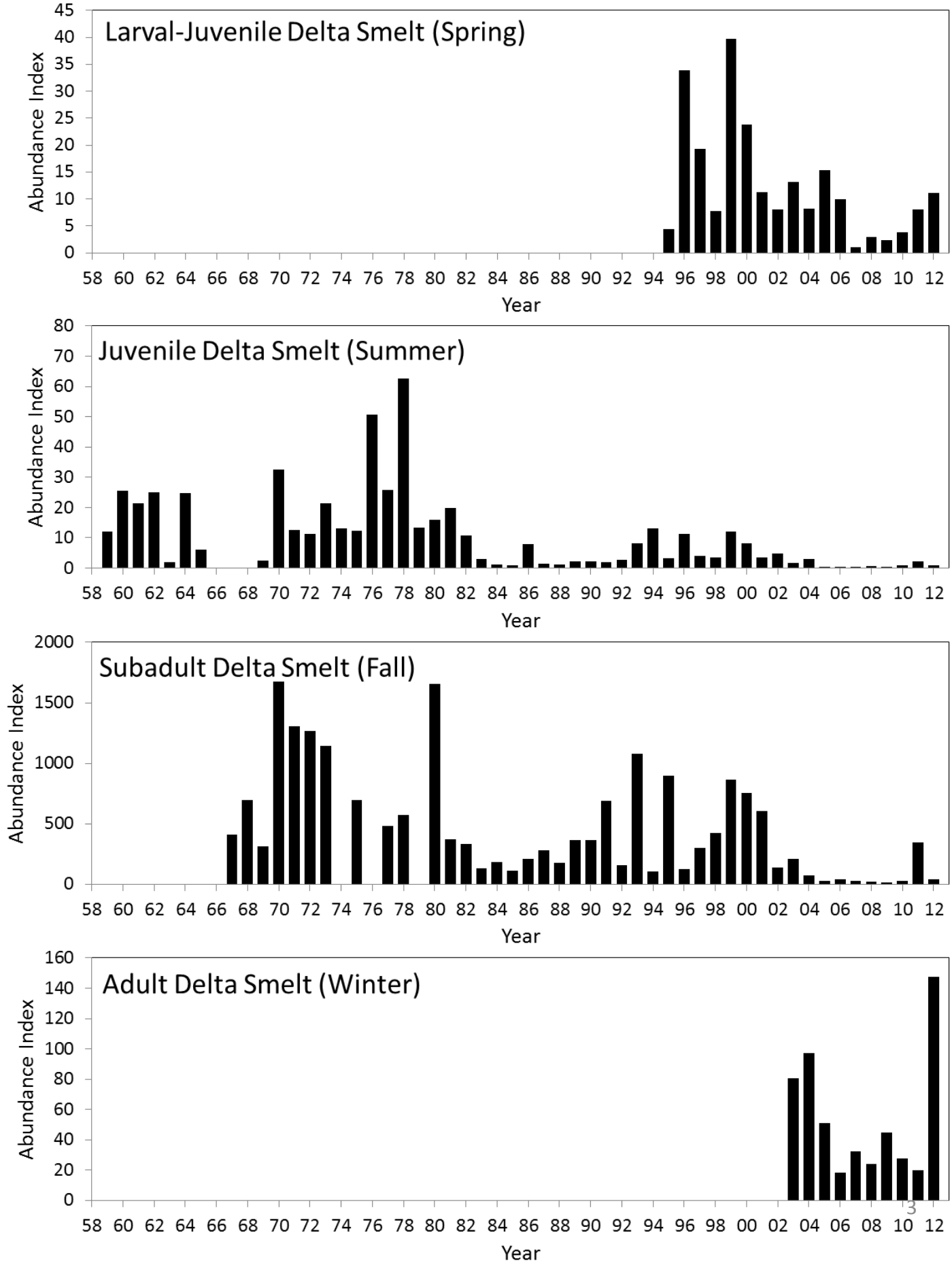

122°30′
122°00′
121°30′
38°00′
CALIFORNIA
Map location
Drainage basin
Rio Vista
55
60
65
70
75
80
85
90
95
100
Yolo Bypass
Sacramento River
Freeport
Sonoma Creek
Napa River
Suisun Slough
Montezuma Slough
Suisun Creek
Nurse Slough
Petaluma River
Novato Creek
Rio Vista
Grizzly Bay
Honker Bay
Suisun Bay
San Pablo Bay
Carquinez Strait
Antioch
San Joaquin River
Stockton
Richmond
Central Bay
Old River
Middle River
Clifton Court Forebay
Golden Gate
San Francisco
South Bay Aqueduct
Delta-Mendota Canal
California Aqueduct
San Joaquin River
South San Francisco Bay
Vernalis
PACIFIC OCEAN
0
10 MILES
0
10 KILOMETERS

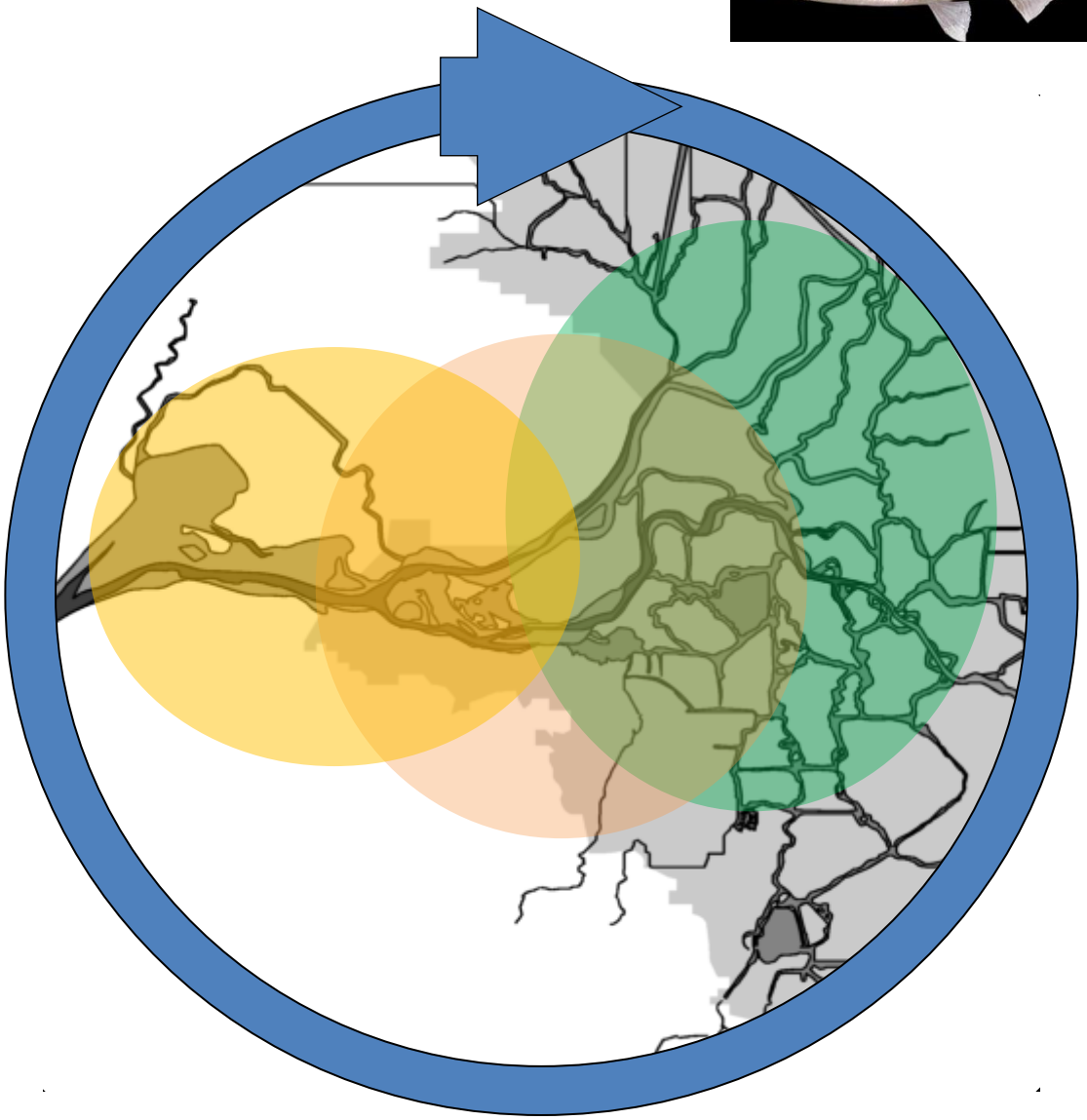
Fig. 3


122°00'
121°30'
38°00'
Yolo
Bypass
Sacramento
River
Freeport
Sacramento deepwater
ship channel
Cache
Slough
Suisun
Slough
Montezuma
Slough
Suisun
Creek
Nurse
Slough
Rio Vista
Suisun
Marsh
Grizzly Bay
Honker
Bay
Salinity
control gate
Sherman
Island
Suisun Bay
Carquinez Strait
Antioch
Mallard
Island
Chipps
Island
San Joaquin
River
Stockton
Old River
Middle
River
Clifton Court Forebay
State export pumps
Federal export pumps
South Bay Aqueduct
Delta-Mendota
Canal
California Aqueduct
San Joaquin
River
0
10 MILES
0
10 KILOMETERS
Vernalis


Larval-Juvenile Delta Smelt (Spring)
Abundance Index
Year
Juvenile Delta Smelt (Summer)
Abundance Index
Year
Subadult Delta Smelt (Fall)
Abundance Index
Year
Adult Delta Smelt (Winter)
Abundance Index
Year

Winter

Upstream migration after first flush



Fall

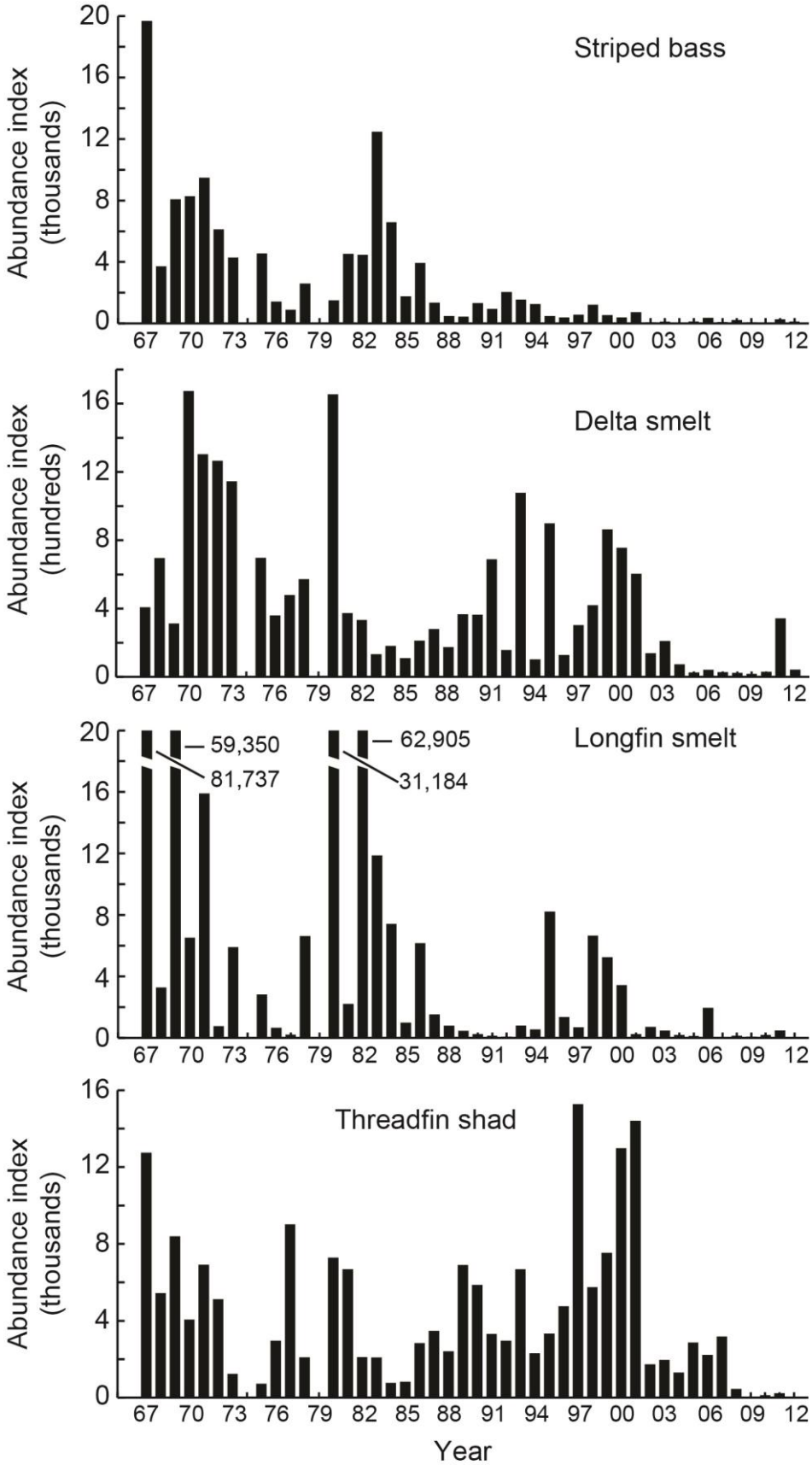
Maturation in low salinity zone

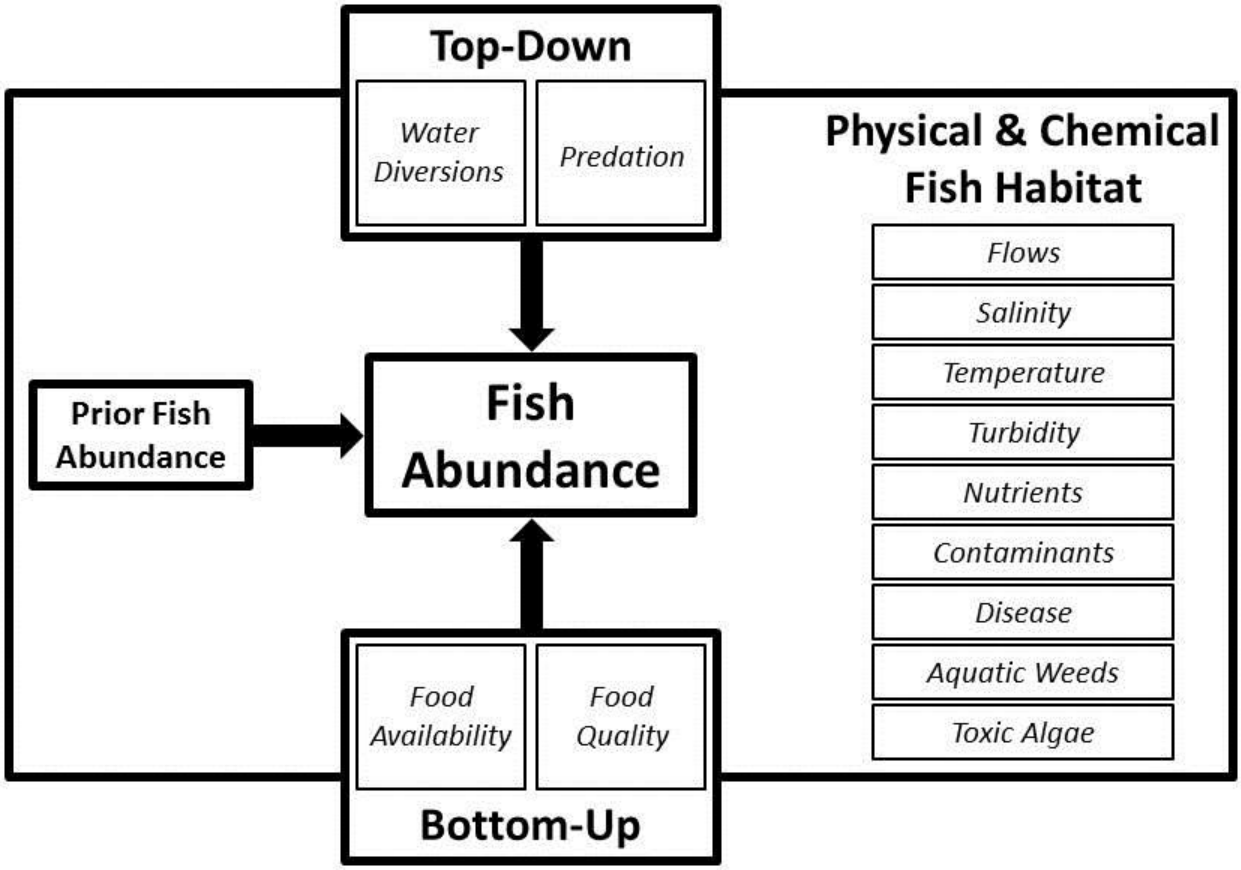
Spring

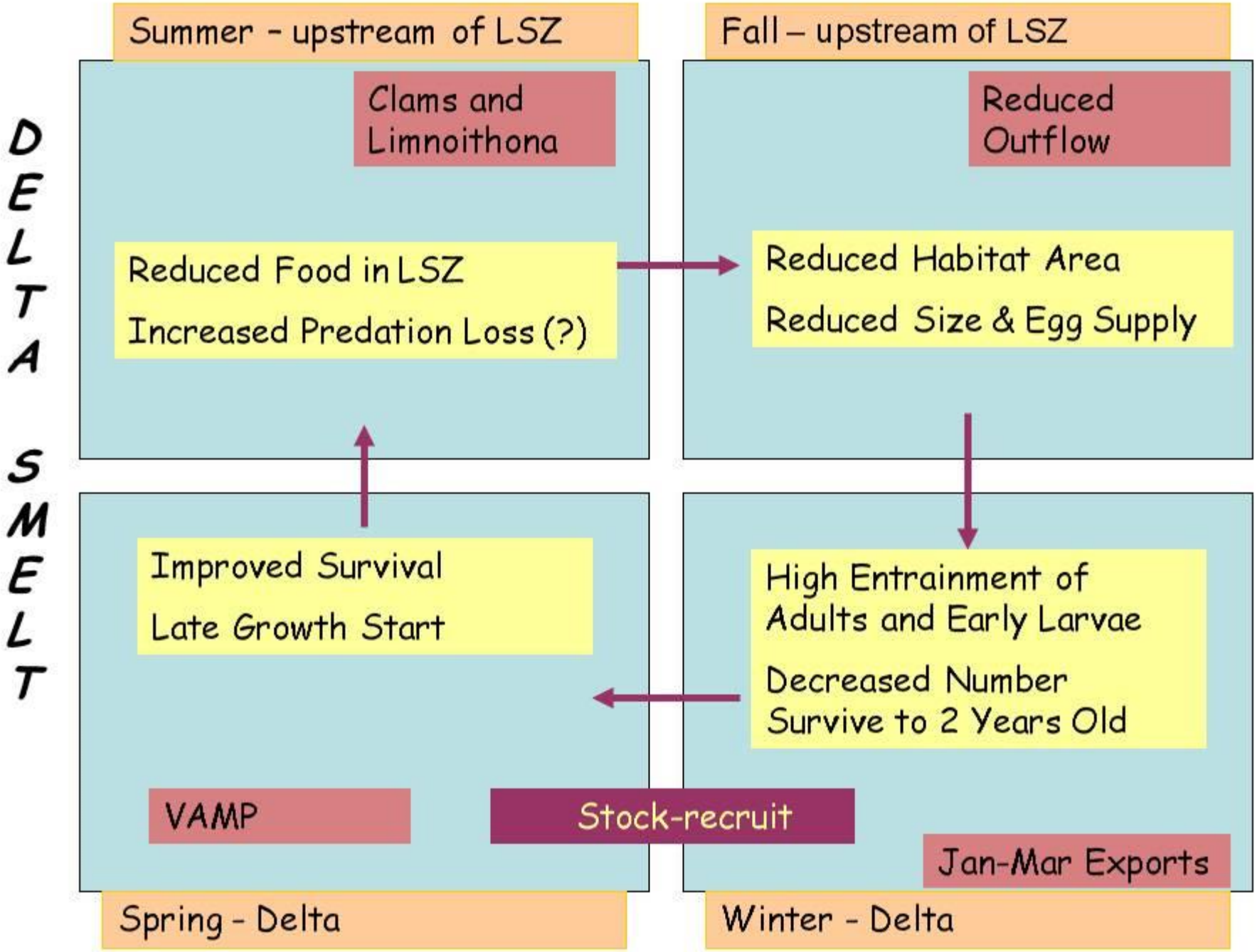
Spawning in fresh water

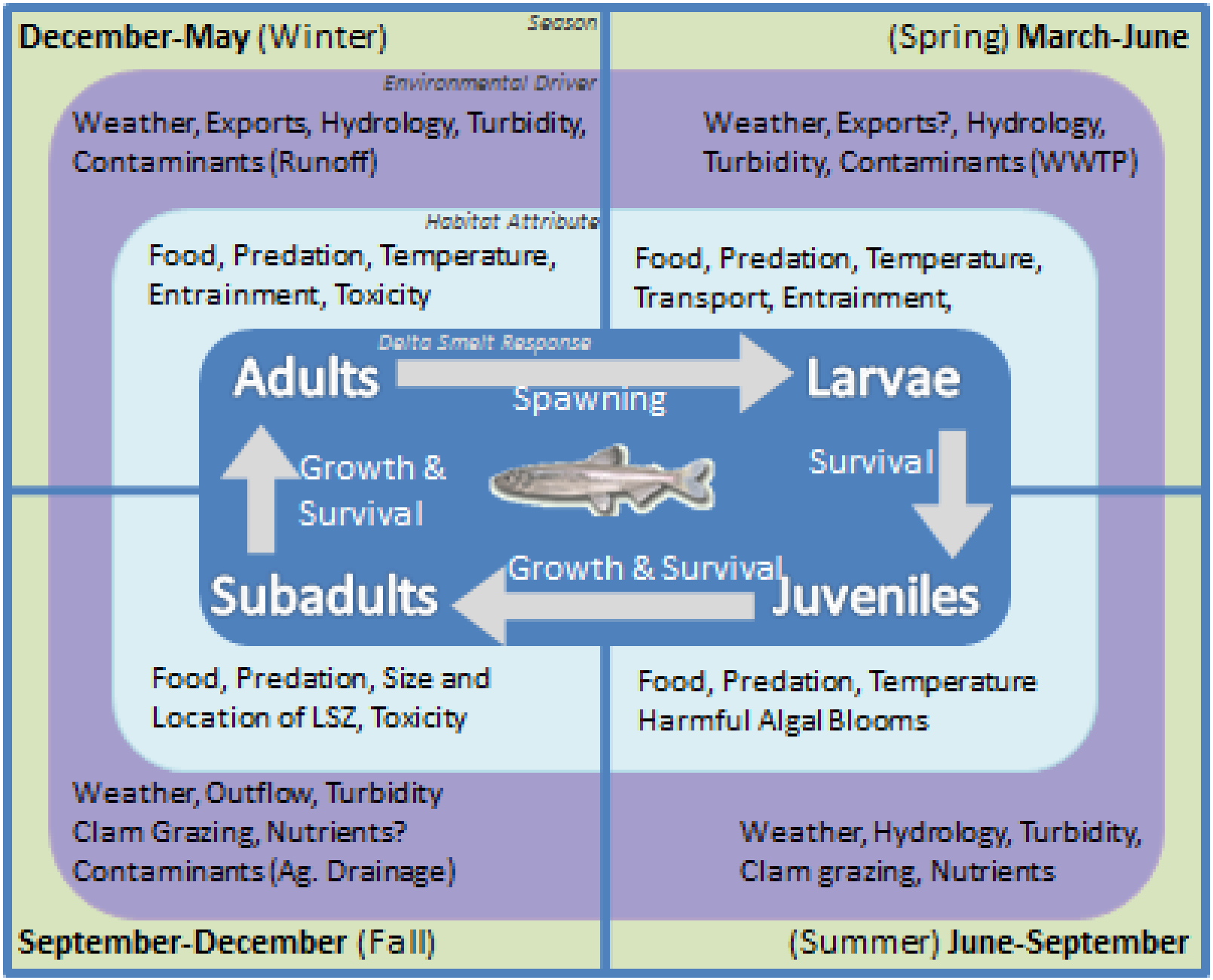
Summer

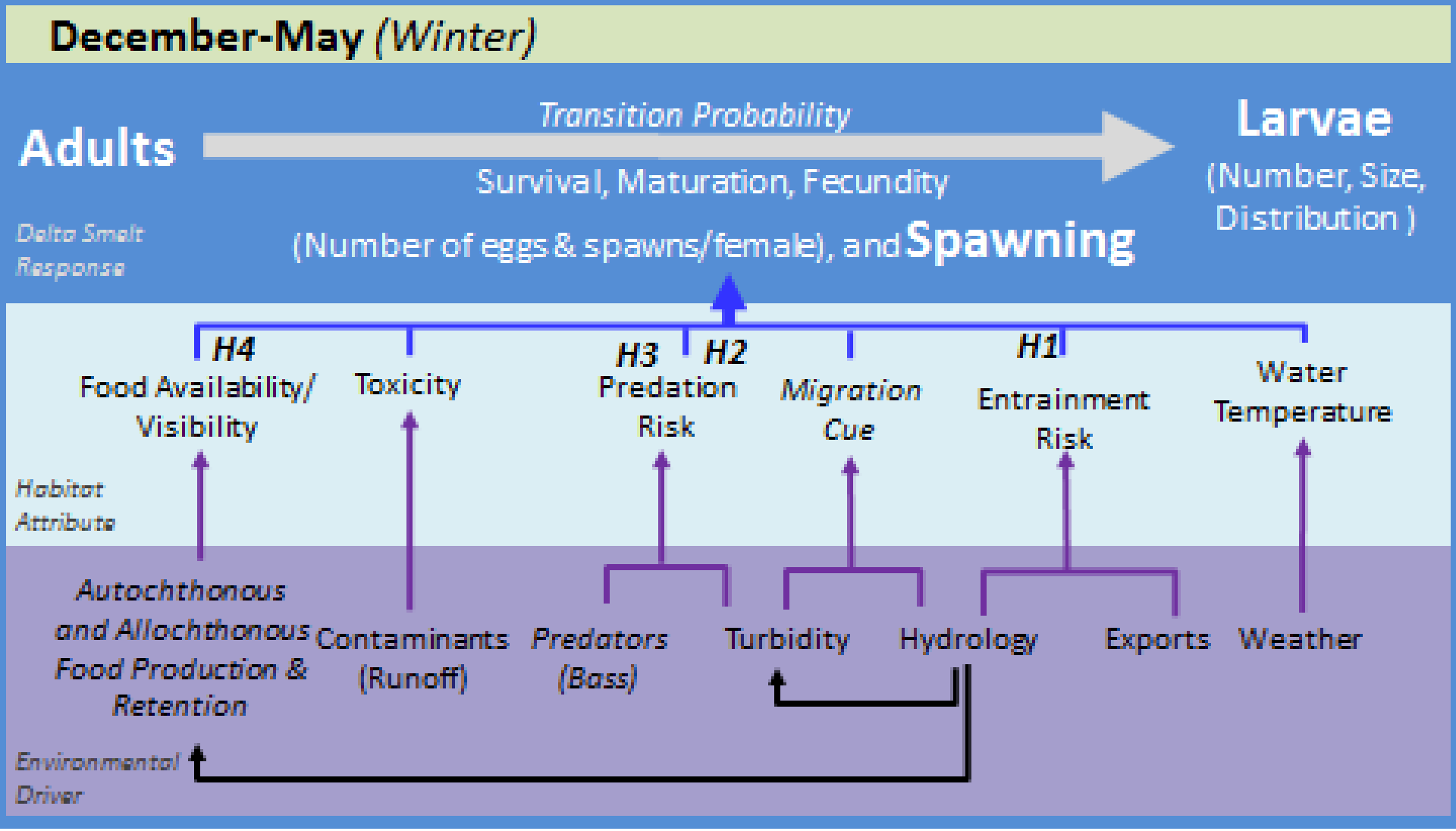
Migration to and rearing in low salinity zone

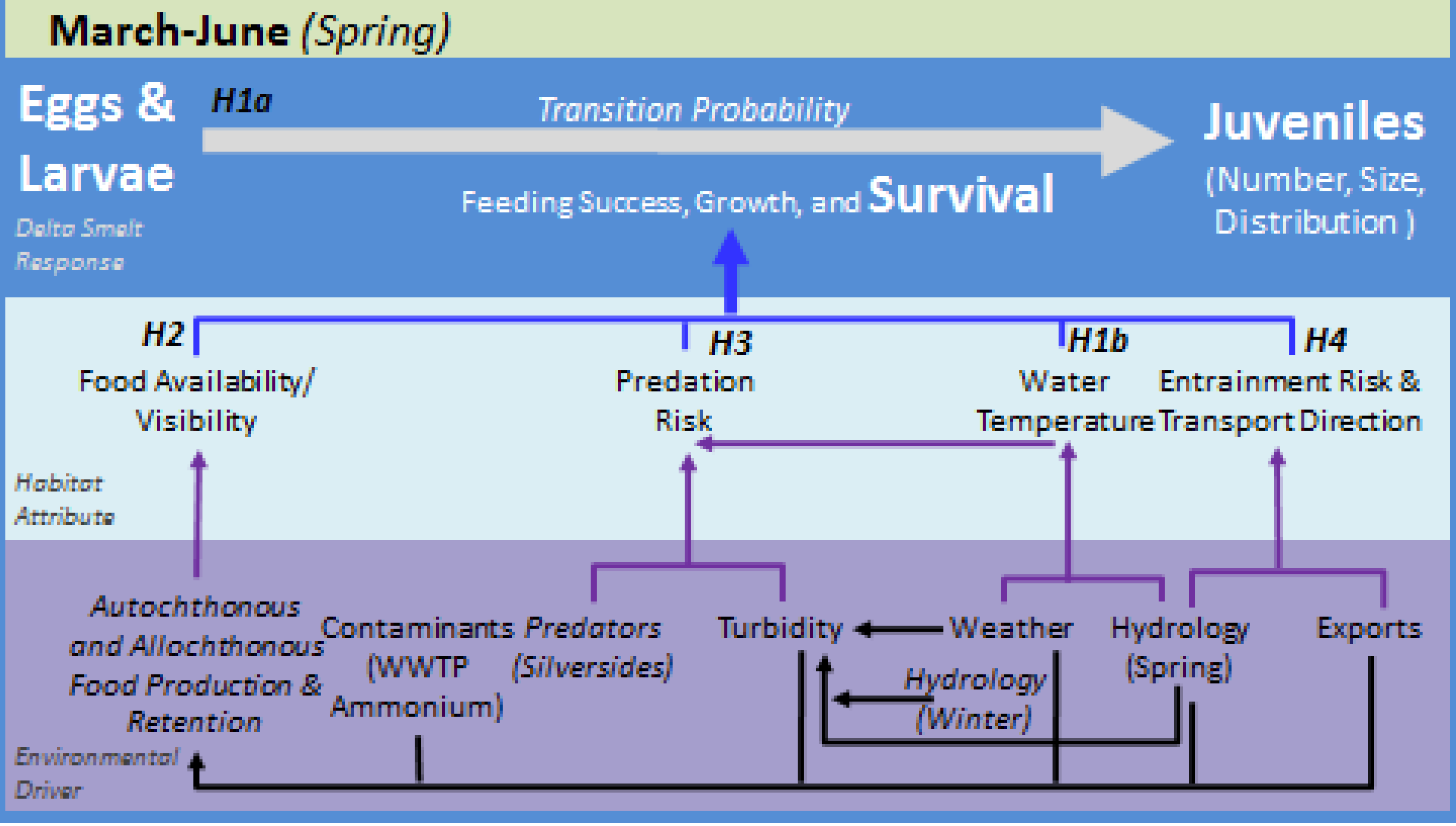

Striped bass
Abundance index (thousands)
Delta smelt
Abundance index (hundreds)
Longfin smelt
59,350
81,737
62,905
31,184
Abundance index (thousands)
Threadfin shad
Abundance index (thousands)
Year

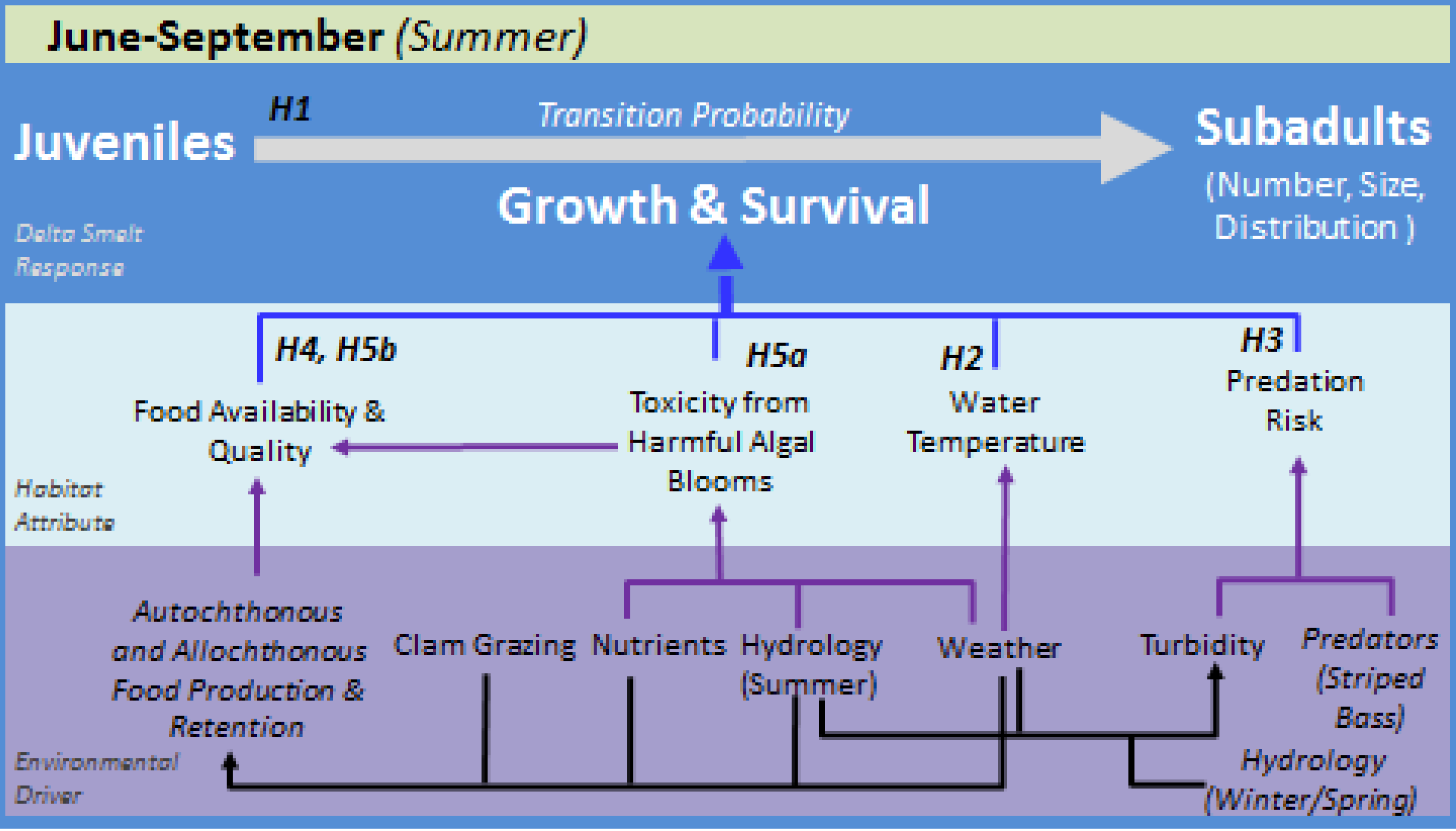

Top-Down
Water Diversions
Predation
Physical & Chemical Fish Habitat
Flows
Salinity
Temperature
Turbidity
Nutrients
Contaminants
Disease
Aquatic Weeds
Toxic Algae
Prior Fish Abundance
Fish Abundance
Food Availability
Food Quality
Bottom-Up

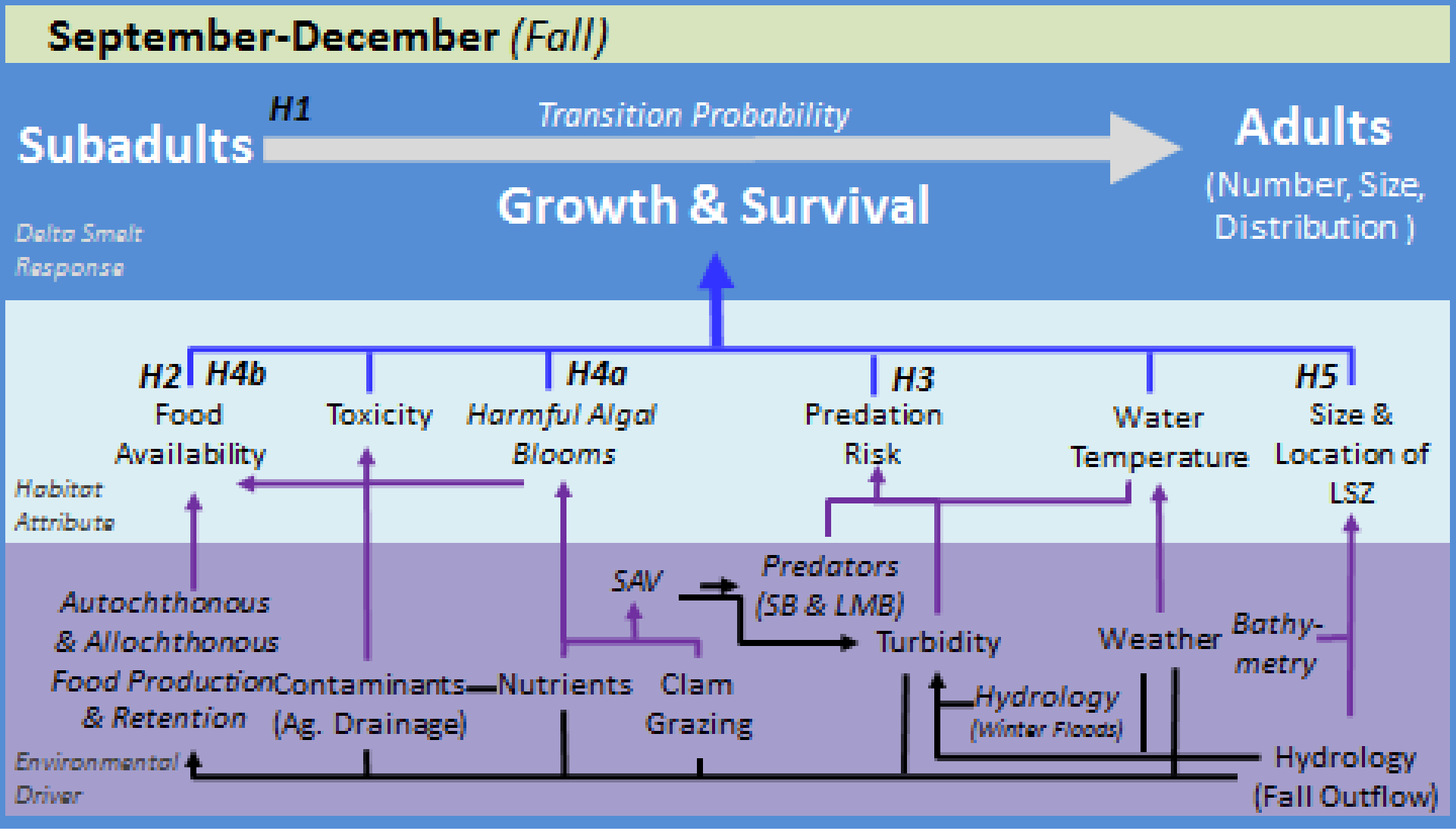

DELTA SMELT
Summer - upstream of LSZ
Clams and Limnoithona
Reduced Food in LSZ
Increased Predation Loss (?)
Fall – upstream of LSZ
Reduced Outflow
Reduced Habitat Area
Reduced Size & Egg Supply
High Entrainment of Adults and Early Larvae
Decreased Number Survive to 2 Years Old
Jan-Mar Exports
Winter - Delta
Stock-recruit
Spring - Delta
Improved Survival
Late Growth Start
VAMP

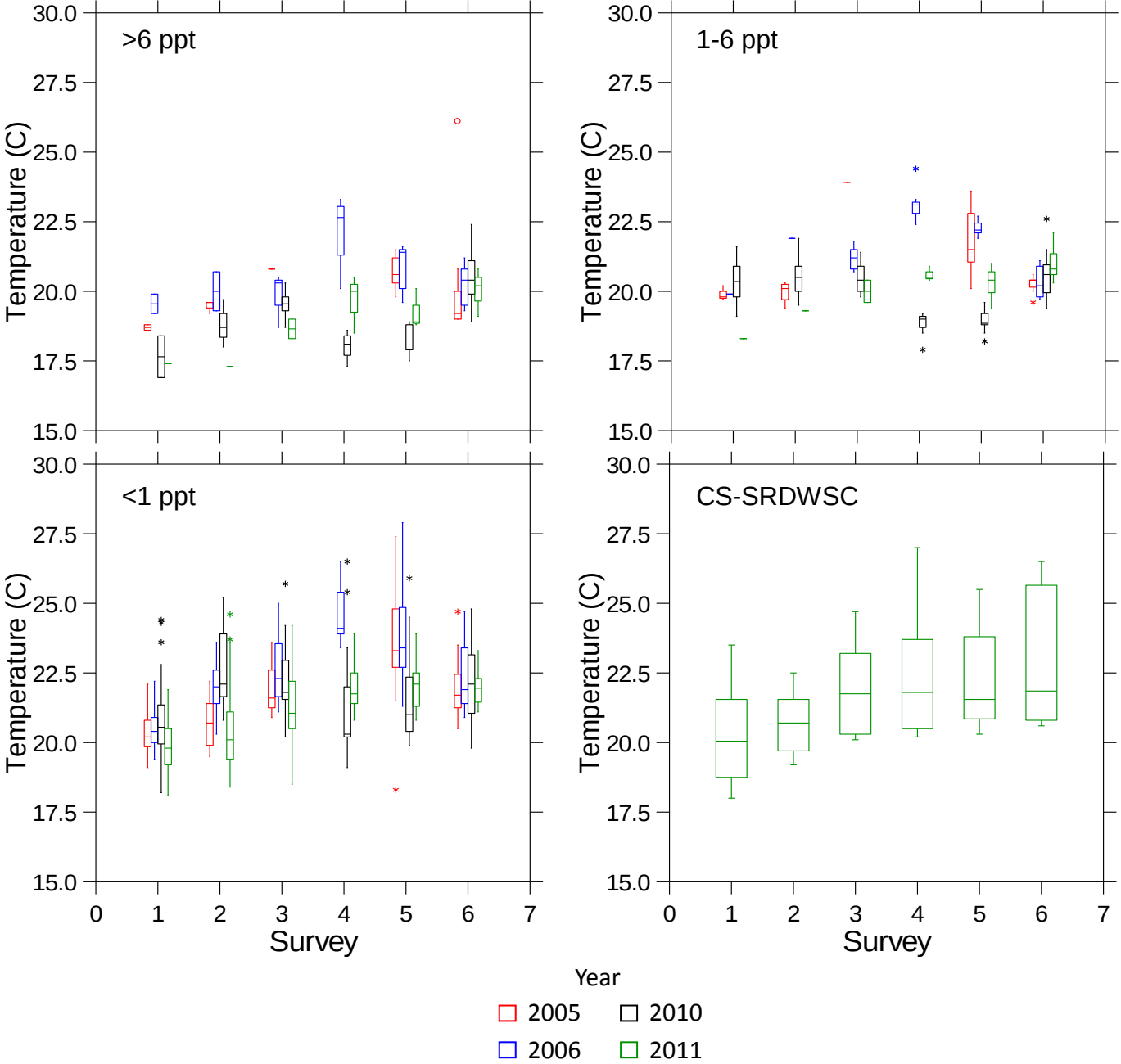

Season
December-May (Winter)
(Spring) March-June
Environmental Driver
Weather, Exports, Hydrology, Turbidity, Contaminants (Runoff)
Weather, Exports?, Hydrology, Turbidity, Contaminants (WWTP)
Habitat Attribute
Food, Predation, Temperature, Entrainment, Toxicity
Food, Predation, Temperature, Transport, Entrainment,
Delta Smelt Response
Adults
Spawning
Larvae
Growth & Survival
Survival
Growth & Survival
Subadults
Juveniles
Food, Predation, Size and Location of LSZ, Toxicity
Food, Predation, Temperature Harmful Algal Blooms
Weather, Outflow, Turbidity Clam Grazing, Nutrients? Contaminants (Ag. Drainage)
Weather, Hydrology, Turbidity, Clam grazing, Nutrients
September-December (Fall)
(Summer) June-September

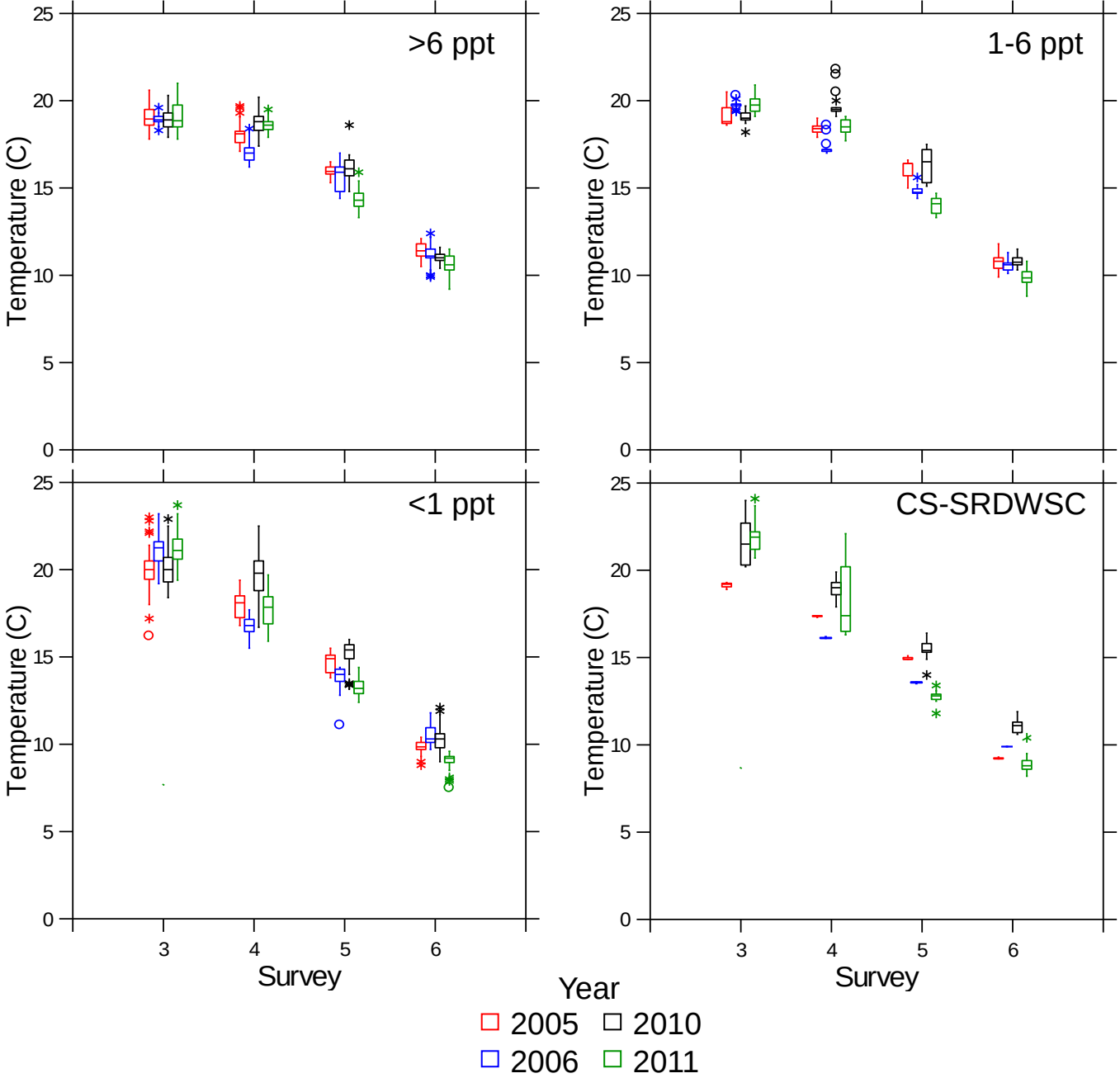

December-May (Winter)
Adults
Transition Probability
Survival, Maturation, Fecundity
(Number of eggs & spawns/female), and Spawning
Larvae
(Number, Size, Distribution)
Delta Smelt Response
H4
Food Availability/ Visibility
Toxicity
H3
H2
Predation Risk
Migration Cue
H1
Entrainment Risk
Water Temperature
Habitat Attribute
Autochthonous and Allochthonous Food Production & Retention
Contaminants (Runoff)
Predators (Bass)
Turbidity
Hydrology
Exports
Weather
Environmental Driver

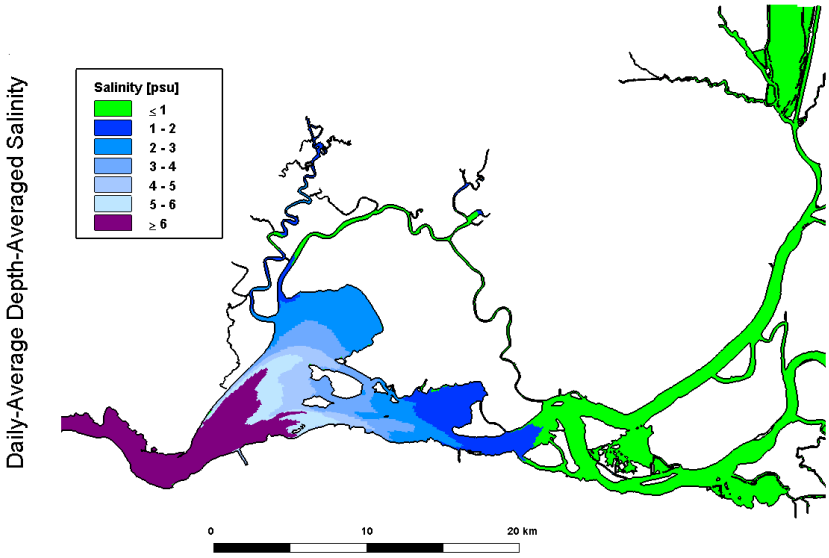

March-June (Spring)
Eggs & Larvae
Delta Smelt Response
H1a
Transition Probability
Juveniles
(Number, Size, Distribution)
Feeding Success, Growth, and Survival
H2
Food Availability/ Visibility
H3
Predation Risk
H1b
Water Temperature
H4
Entrainment Risk & Transport Direction
Habitat Attribute
Autochthonous and Allochthonous Food Production & Retention
Contaminants (WWTP Ammonium)
Predators (Silversides)
Turbidity
Weather
Hydrology (Winter)
Hydrology (Spring)
Exports
Environmental Driver

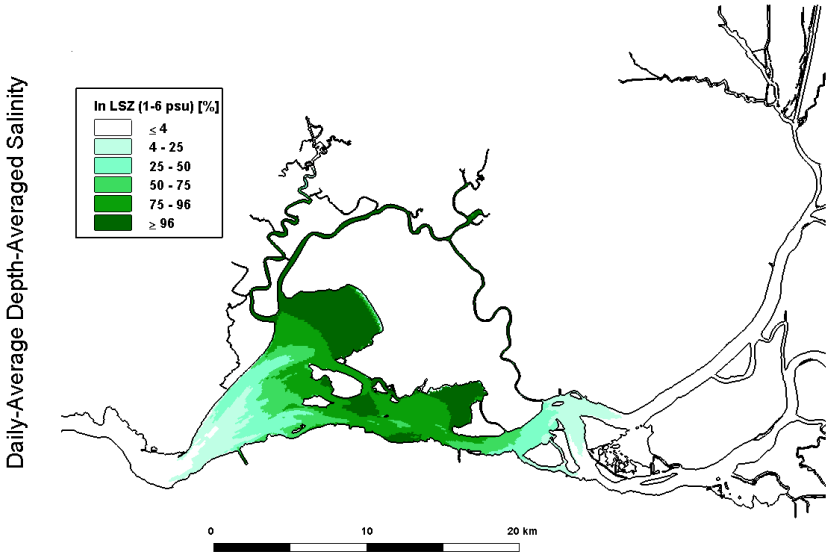

June-September (Summer)
Juveniles
H1
Transition Probability
Subadults
(Number, Size, Distribution)
Growth & Survival
Delta Smelt Response
H4, H5b
H5a
H2
H3
Food Availability & Quality
Toxicity from Harmful Algal Blooms
Water Temperature
Predation Risk
Habitat Attribute
Autochthonous and Allochthonous Food Production & Retention
Clam Grazing
Nutrients
Hydrology (Summer)
Weather
Turbidity
Predators (Striped Bass)
Hydrology (Winter/Spring)
Environmental Driver


September-December (Fall)
Subadults
H1
Transition Probability
Adults
(Number, Size, Distribution)
Growth & Survival
Delta Smelt Response
H2
H4b
Food Availability
Toxicity
H4a
Harmful Algal Blooms
H3
Predation Risk
Water Temperature
H5
Size & Location of LSZ
Habitat Attribute
Autochthonous & Allochthonous Food Production & Retention
Contaminants (Ag. Drainage)
Nutrients
SAV
Clam Grazing
Predators (SB & LMB)
Turbidity
Hydrology (Winter Floods)
Weather
Bathy-metry
Hydrology (Fall Outflow)
Environmental Driver


>6 ppt
1-6 ppt
<1 ppt
CS-SRDWSC
Temperature (C)
Survey
30.0
27.5
25.0
22.5
20.0
17.5
15.0
0
1
2
3
4
5
6
7
Year
2005
2010
2006
2011

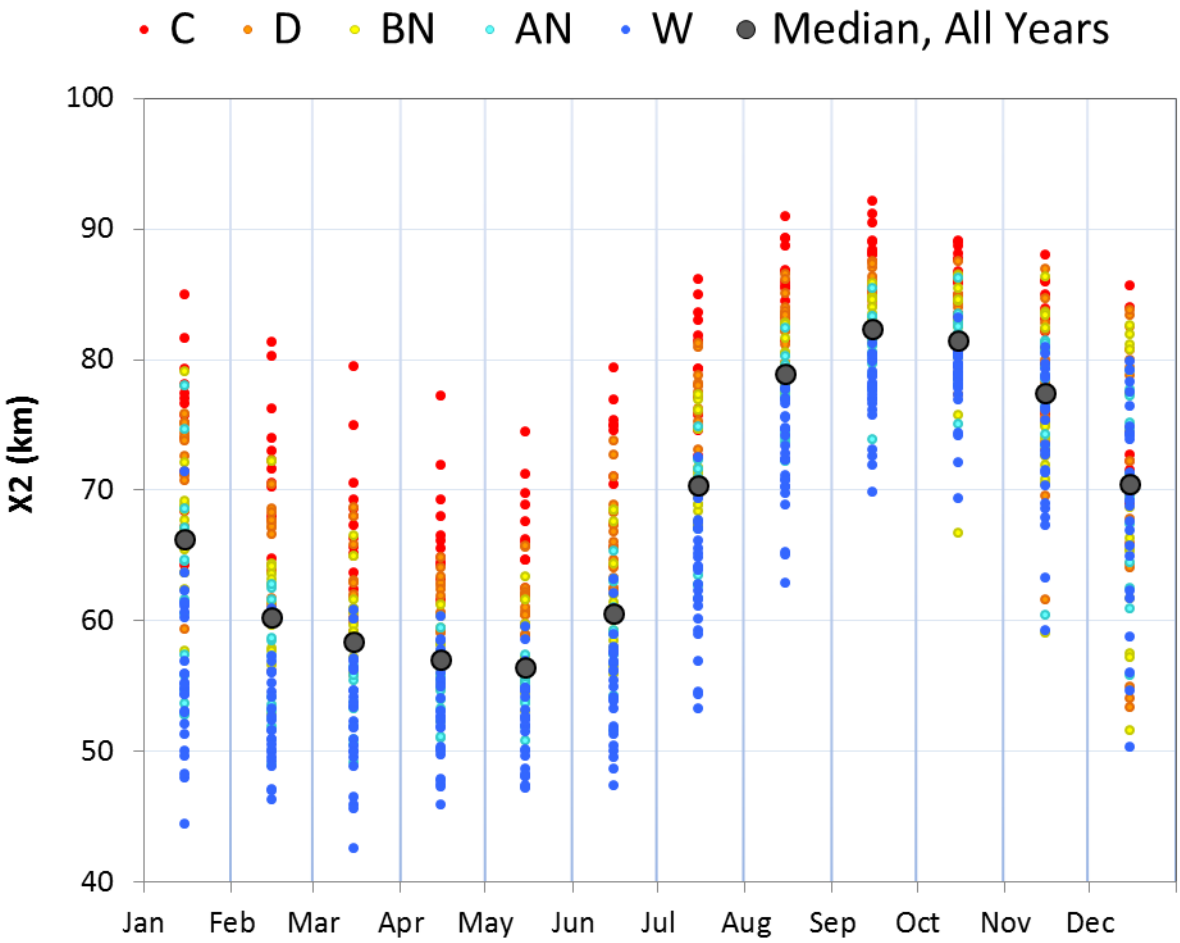

>6 ppt
1-6 ppt
<1 ppt
CS-SRDWSC
Temperature (C)
Survey
Year
2005
2006
2010
2011

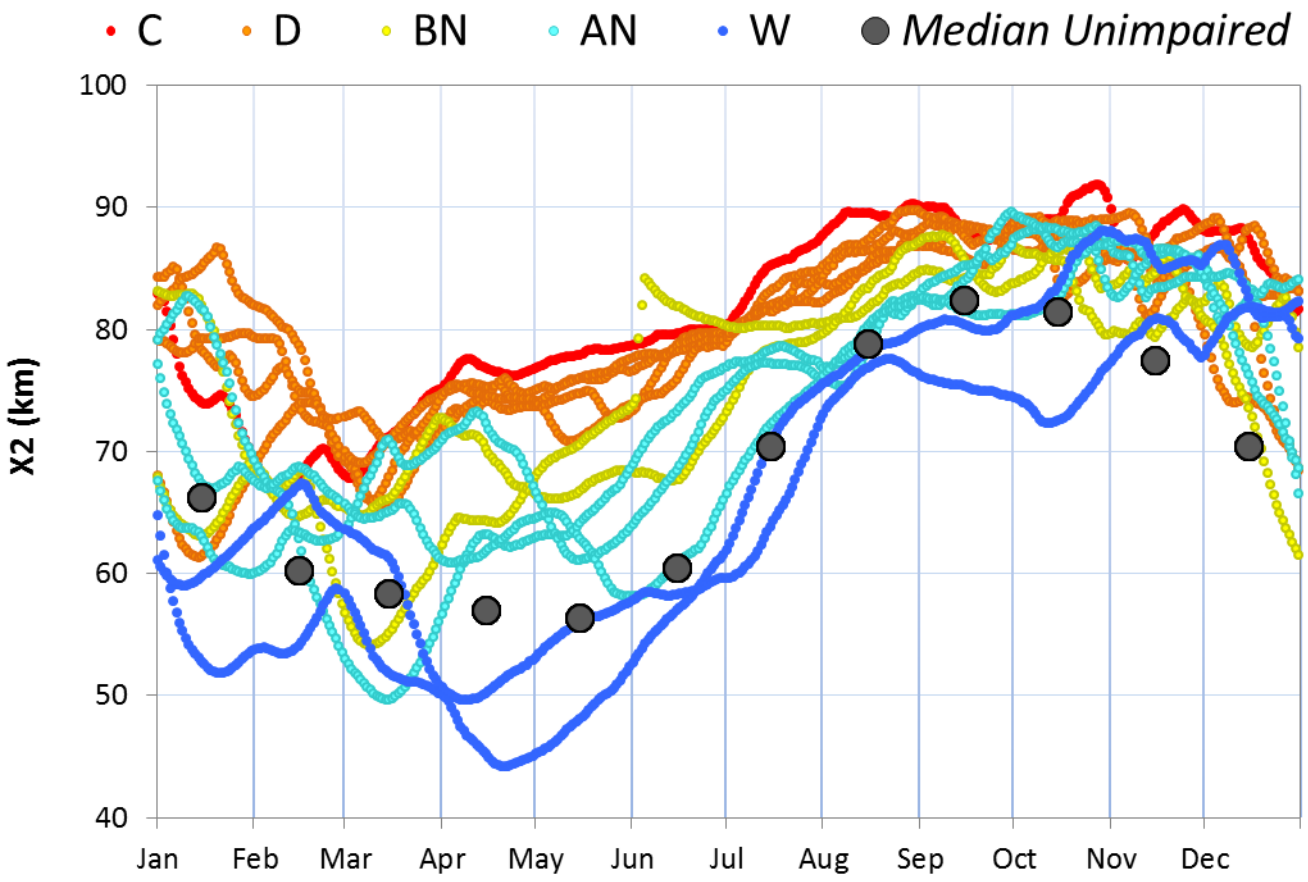

Daily-Average Depth-Averaged Salinity
Salinity [psu]
≤ 1
1 - 2
2 - 3
3 - 4
4 - 5
5 - 6
≥ 6
0
10
20 km

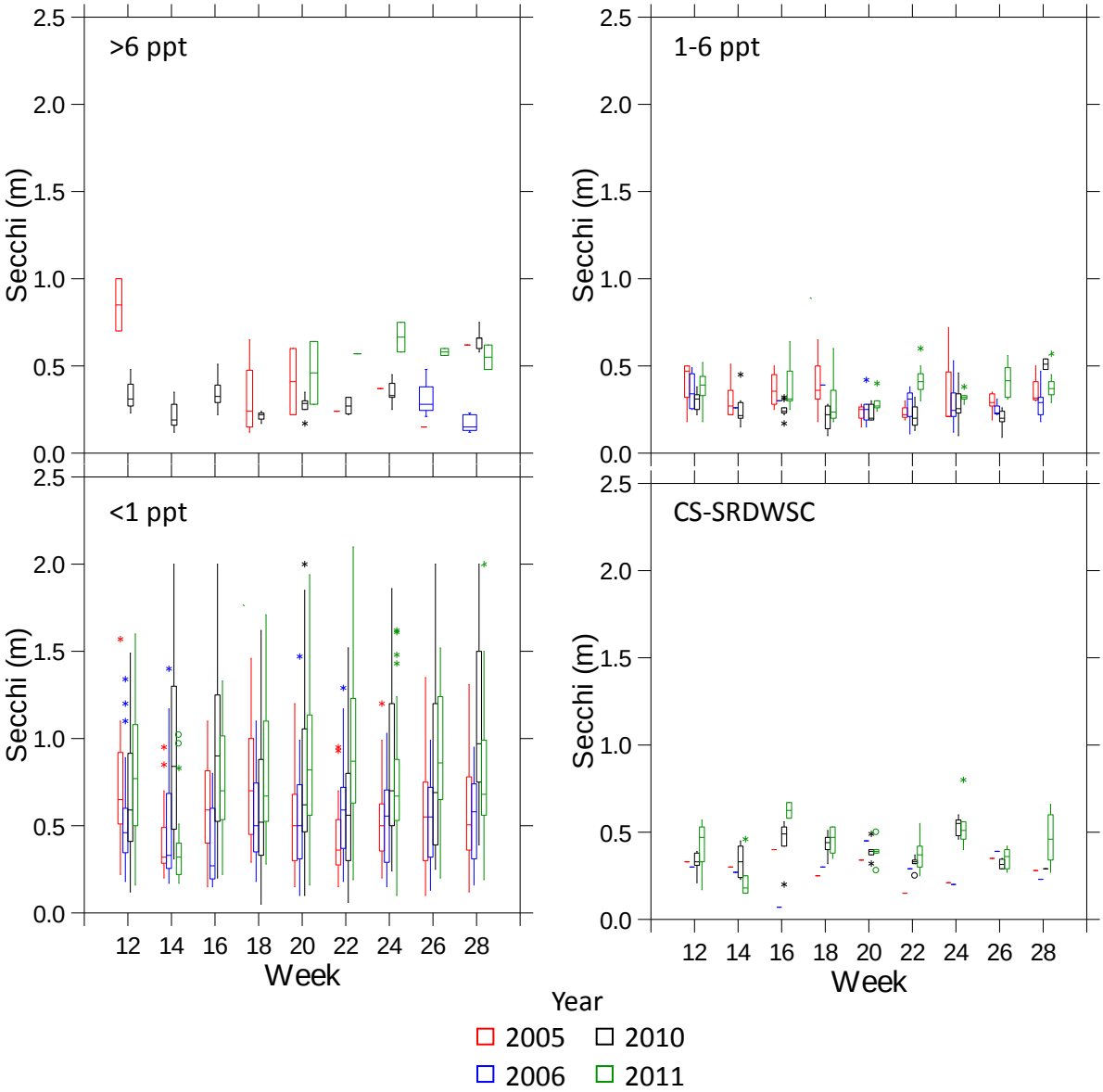

Daily-Average Depth-Averaged Salinity
In LSZ (1-6 psu) [%]
≤ 4
4 - 25
25 - 50
50 - 75
75 - 96
≥ 96
0
10
20 km

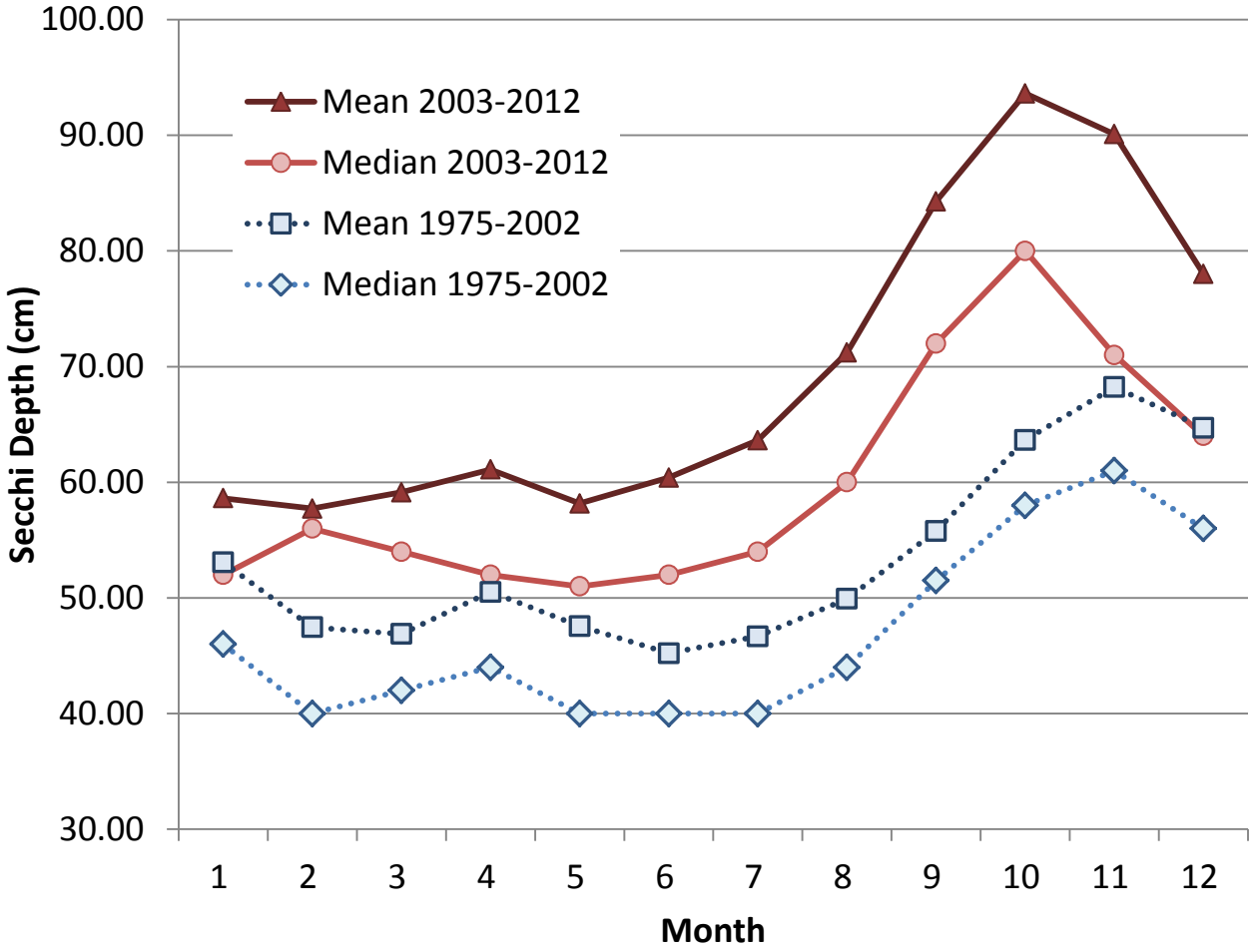
Daily-Average Depth-Averaged Salinity

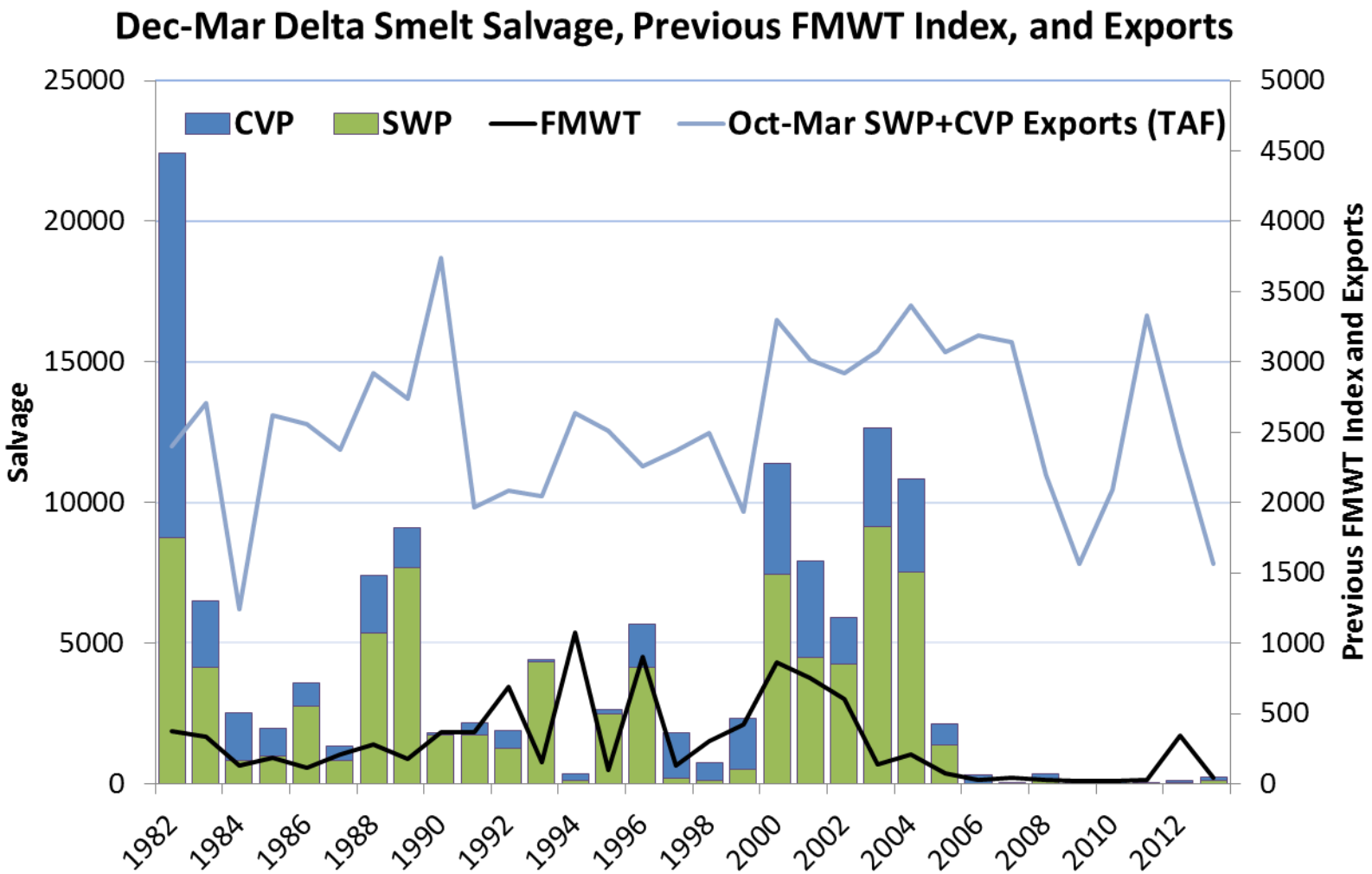
Daily-Average Depth-Averaged Salinity

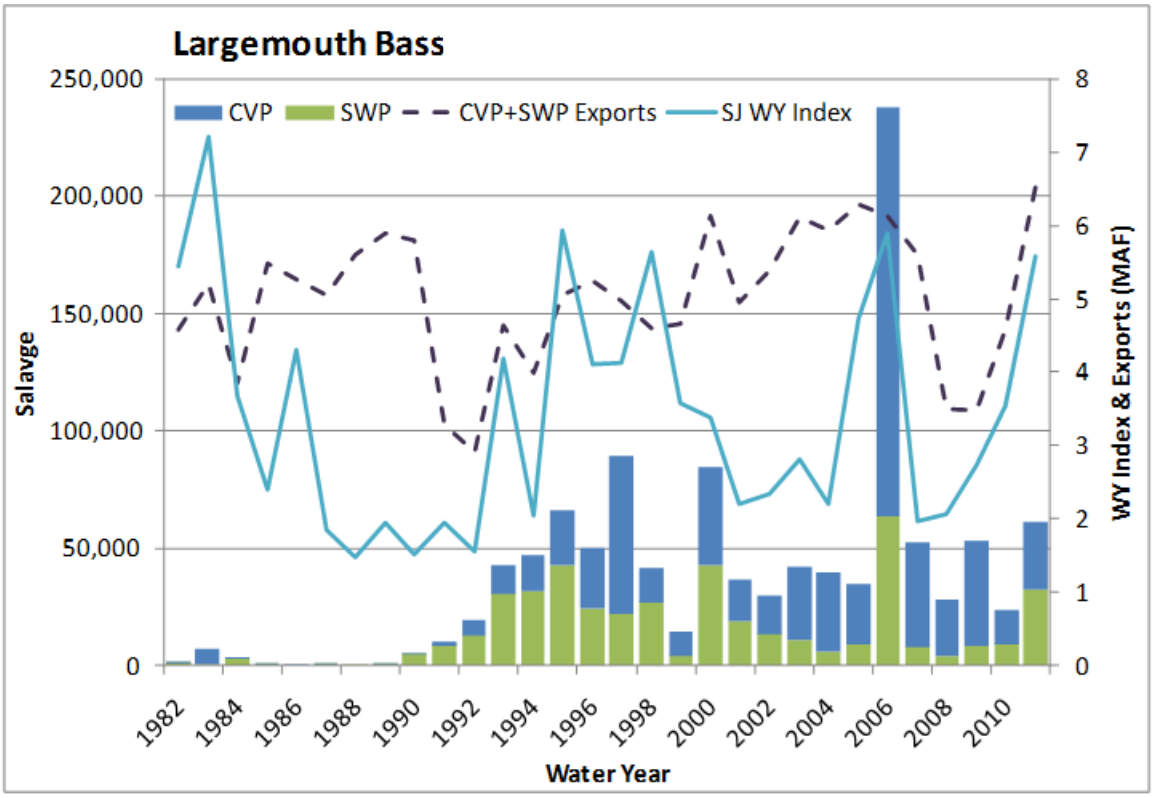

C
D
BN
AN
W
Median, All Years
X2 (km)
100
90
80
70
60
50
40
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

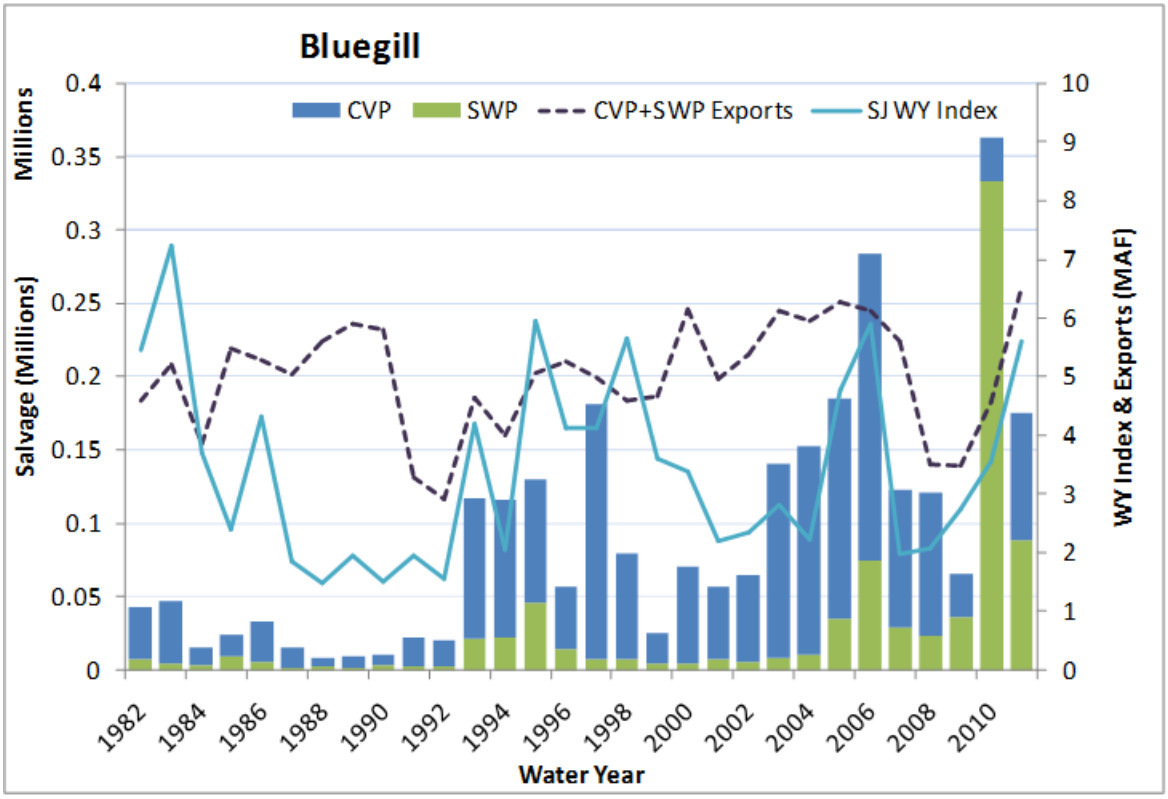

C
D
BN
AN
W
Median Unimpaired
X2 (km)
100
90
80
70
60
50
40
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

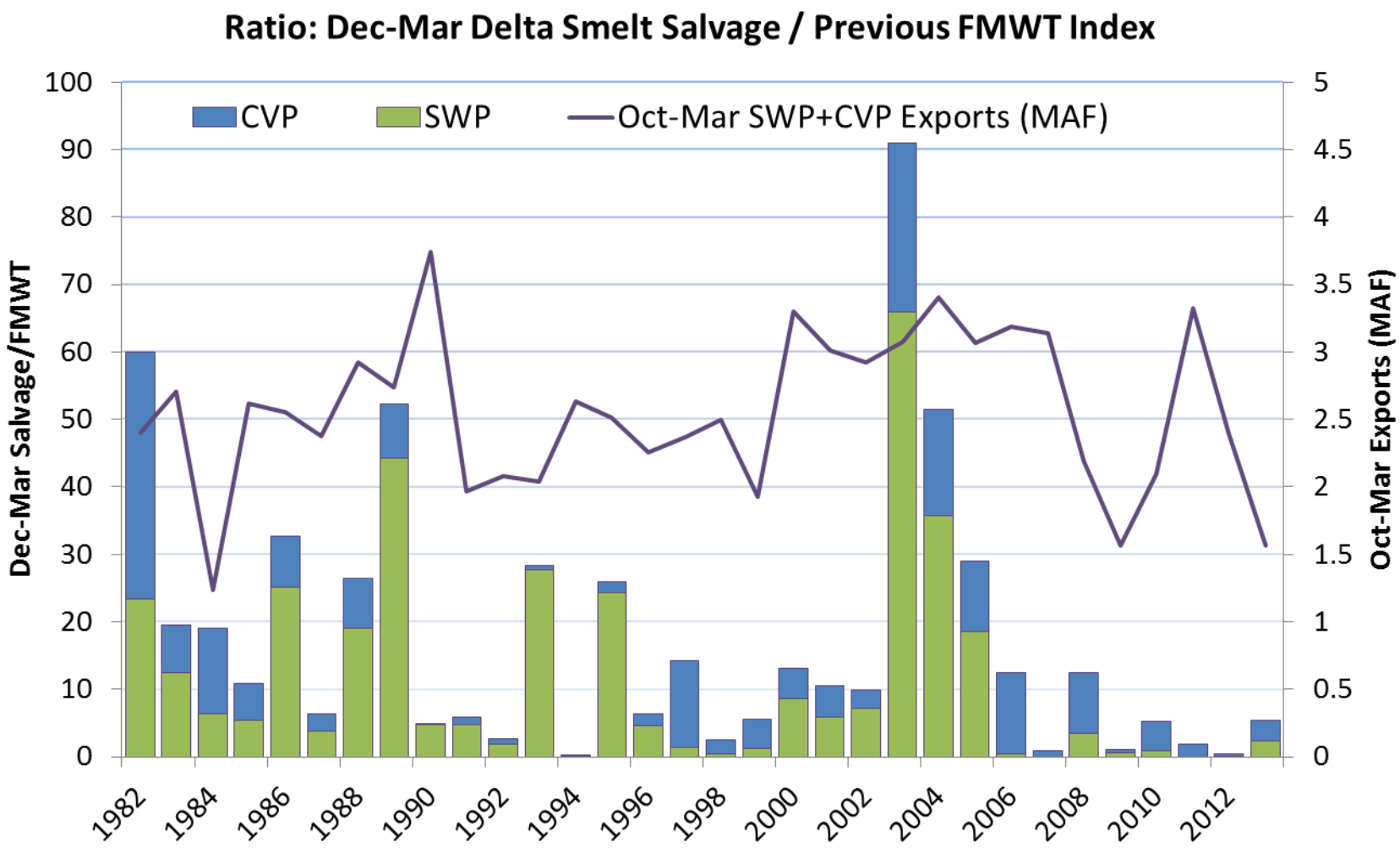

>6 ppt
1-6 ppt
<1 ppt
CS-SRDWSC
Secchi (m)
Week
Year
2005
2010
2006
2011

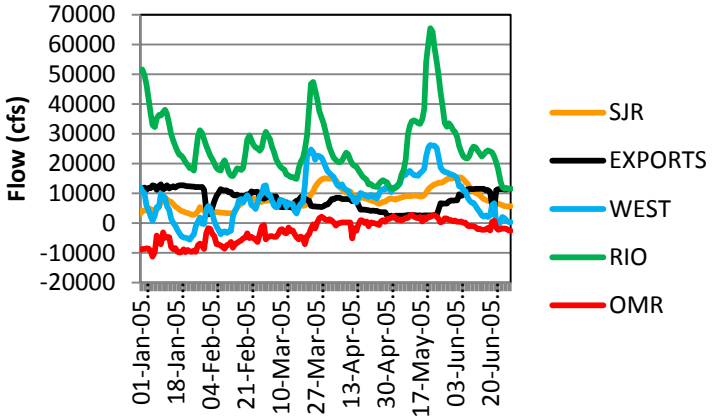

100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
Secchi Depth (cm)
Mean 2003-2012
Median 2003-2012
Mean 1975-2002
Median 1975-2002
1
2
3
4
5
6
7
8
9
10
11
12
Month

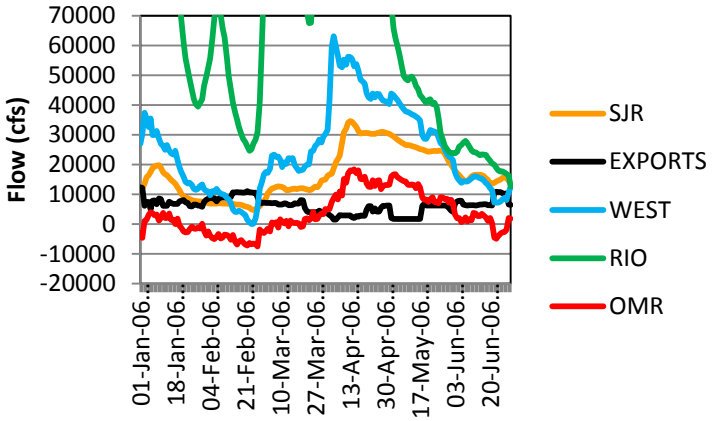

Dec-Mar Delta Smelt Salvage, Previous FMWT Index, and Exports
CVP
SWP
FMWT
Oct-Mar SWP+CVP Exports (TAF)
Salvage
Previous FMWT Index and Exports
25000
20000
15000
10000
5000
0
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012

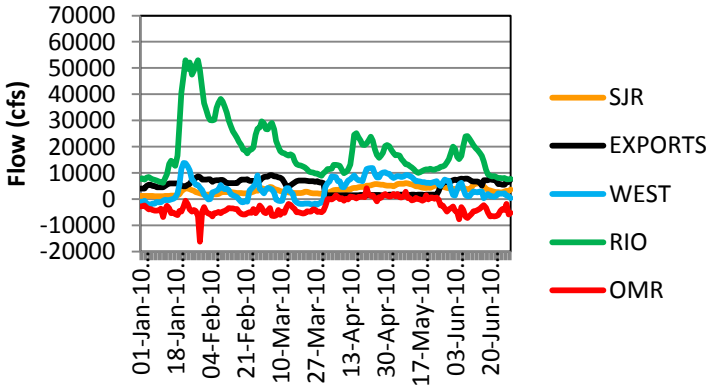

Largemouth Bass
CVP
SWP
CVP+SWP Exports
SJ WY Index
Salavge
WY Index & Exports (MAF)
Water Year
250,000
200,000
150,000
100,000
50,000
0
8
7
6
5
4
3
2
1
0
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010

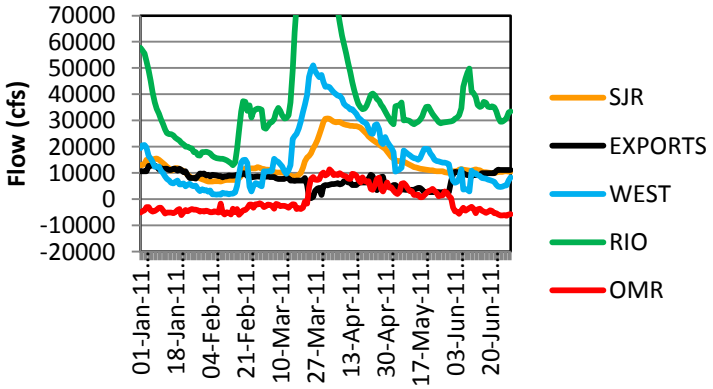

Bluegill
CVP
SWP
CVP+SWP Exports
SJ WY Index
Millions
Salvage (Millions)
WY Index & Exports (MAF)
Water Year
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
10
9
8
7
6
5
4
3
2
1
0
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010

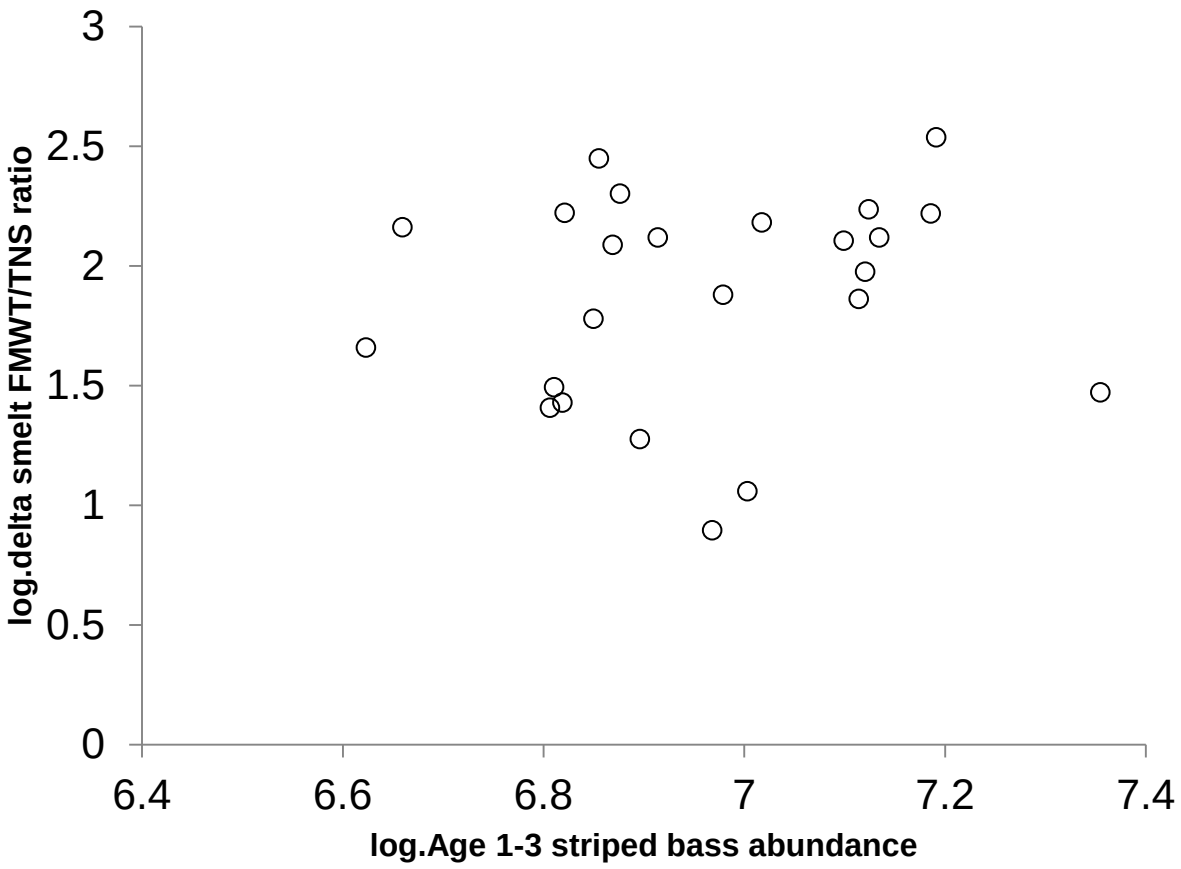

Ratio: Dec-Mar Delta Smelt Salvage / Previous FMWT Index
CVP
SWP
Oct-Mar SWP+CVP Exports (MAF)
Dec-Mar Salvage/FMWT
Oct-Mar Exports (MAF)
100
90
80
70
60
50
40
30
20
10
0
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012

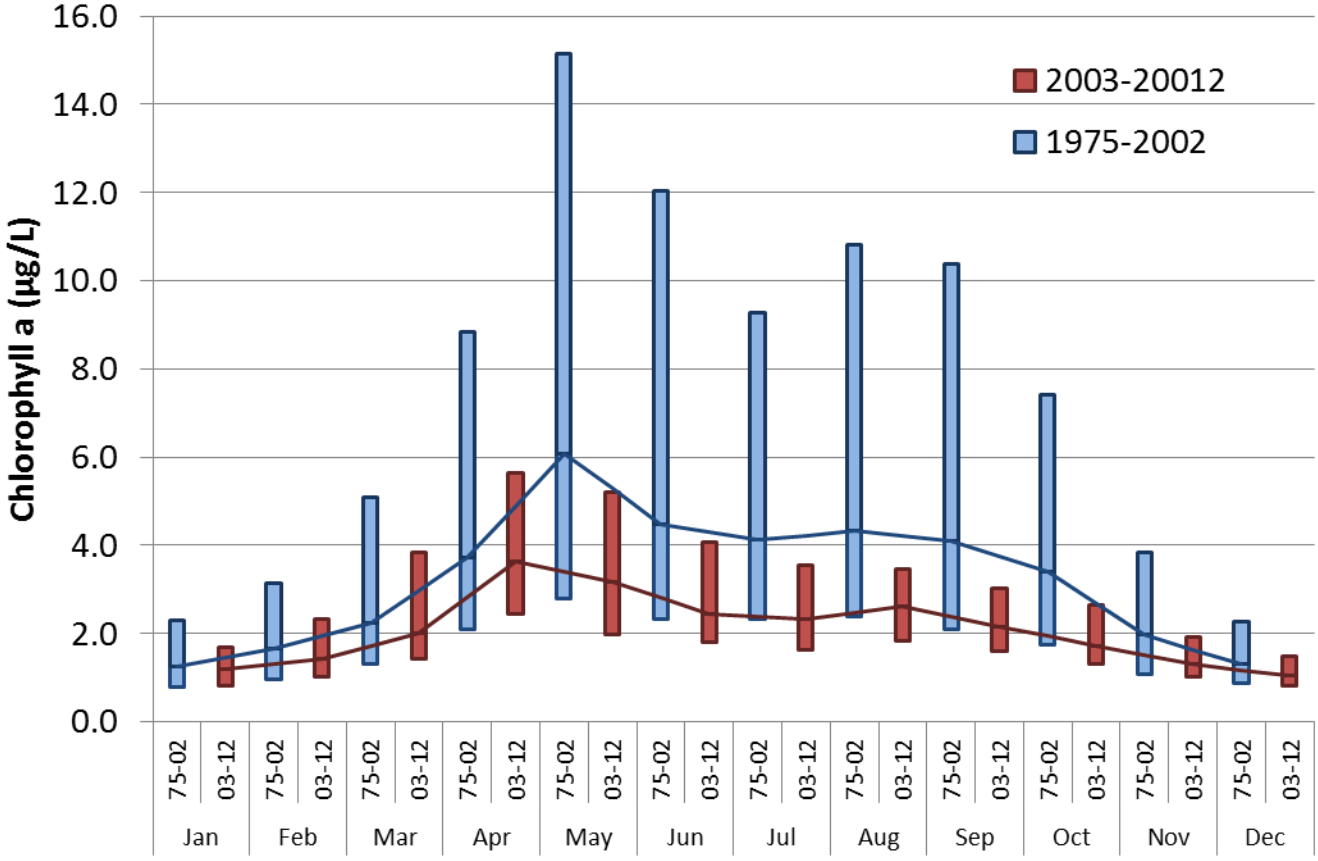

Flow (cfs)
70000
60000
50000
40000
30000
20000
10000
0
-10000
-20000
01-Jan-05
18-Jan-05
04-Feb-05
21-Feb-05
10-Mar-05
27-Mar-05
13-Apr-05
30-Apr-05
17-May-05
03-Jun-05
20-Jun-05
SJR
EXPORTS
WEST
RIO
OMR

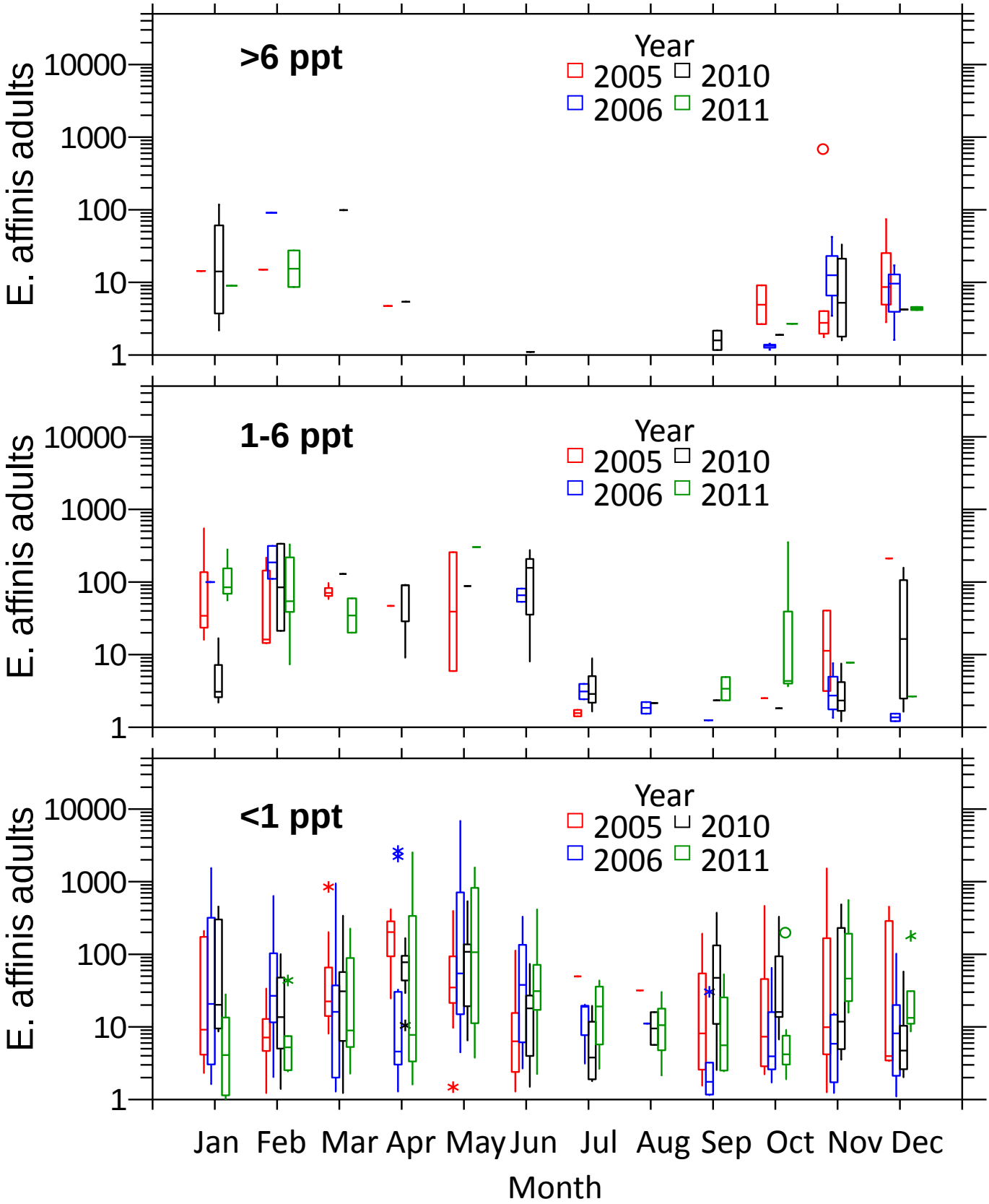

Flow (cfs)
70000
60000
50000
40000
30000
20000
10000
0
-10000
-20000
01-Jan-06
18-Jan-06
04-Feb-06
21-Feb-06
10-Mar-06
27-Mar-06
13-Apr-06
30-Apr-06
17-May-06
03-Jun-06
20-Jun-06
SJR
EXPORTS
WEST
RIO
OMR

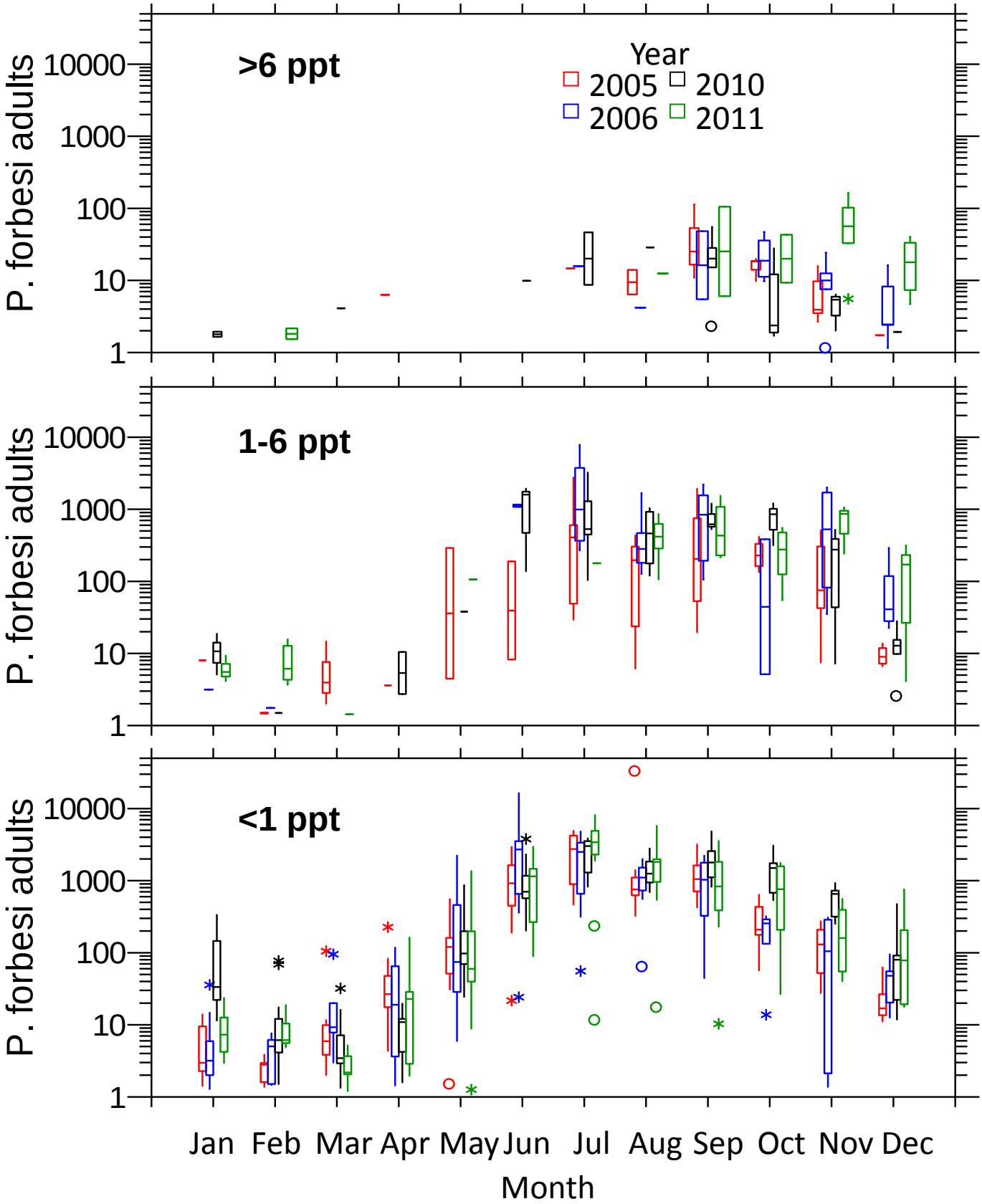

Flow (cfs)
70000
60000
50000
40000
30000
20000
10000
0
-10000
-20000
01-Jan-10
18-Jan-10
04-Feb-10
21-Feb-10
10-Mar-10
27-Mar-10
13-Apr-10
30-Apr-10
17-May-10
03-Jun-10
20-Jun-10
SJR
EXPORTS
WEST
RIO
OMR

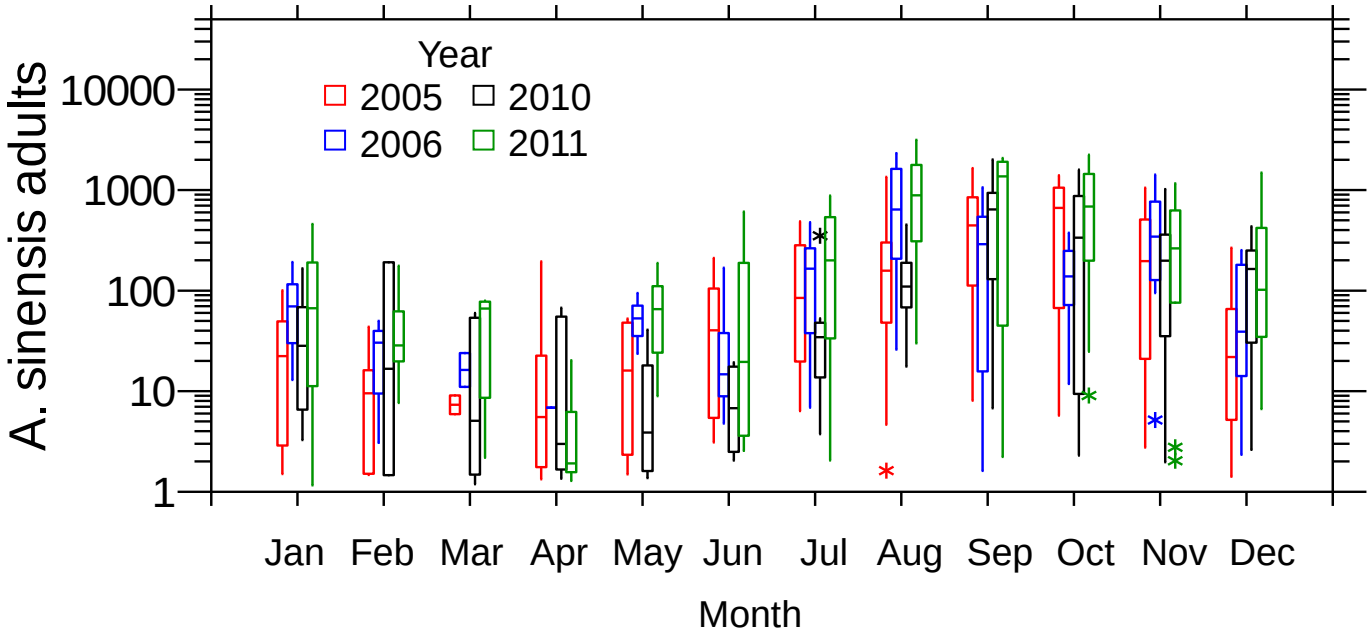

Flow (cfs)
70000
60000
50000
40000
30000
20000
10000
0
-10000
-20000
01-Jan-11
18-Jan-11
04-Feb-11
21-Feb-11
10-Mar-11
27-Mar-11
13-Apr-11
30-Apr-11
17-May-11
03-Jun-11
20-Jun-11
SJR
EXPORTS
WEST
RIO
OMR

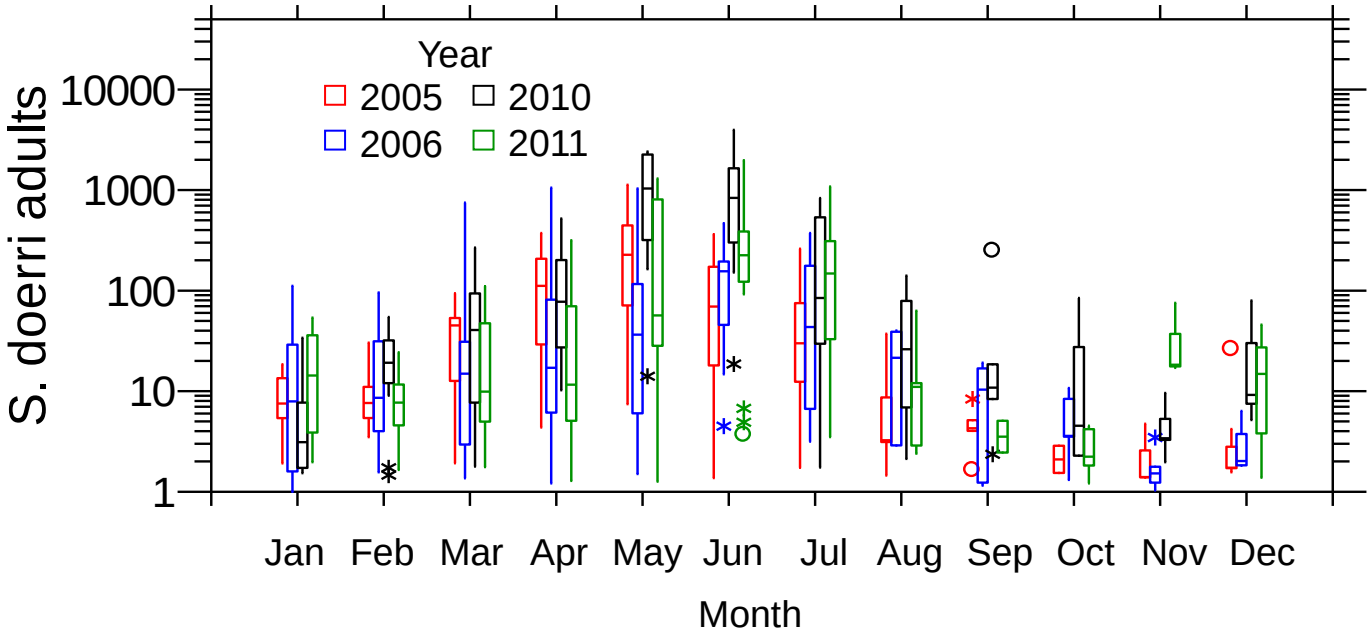

3
2.5
2
1.5
1
0.5
0
log.delta smelt FMWT/TNS ratio
6.4
6.6
6.8
7
7.2
7.4
log.Age 1-3 striped bass abundance

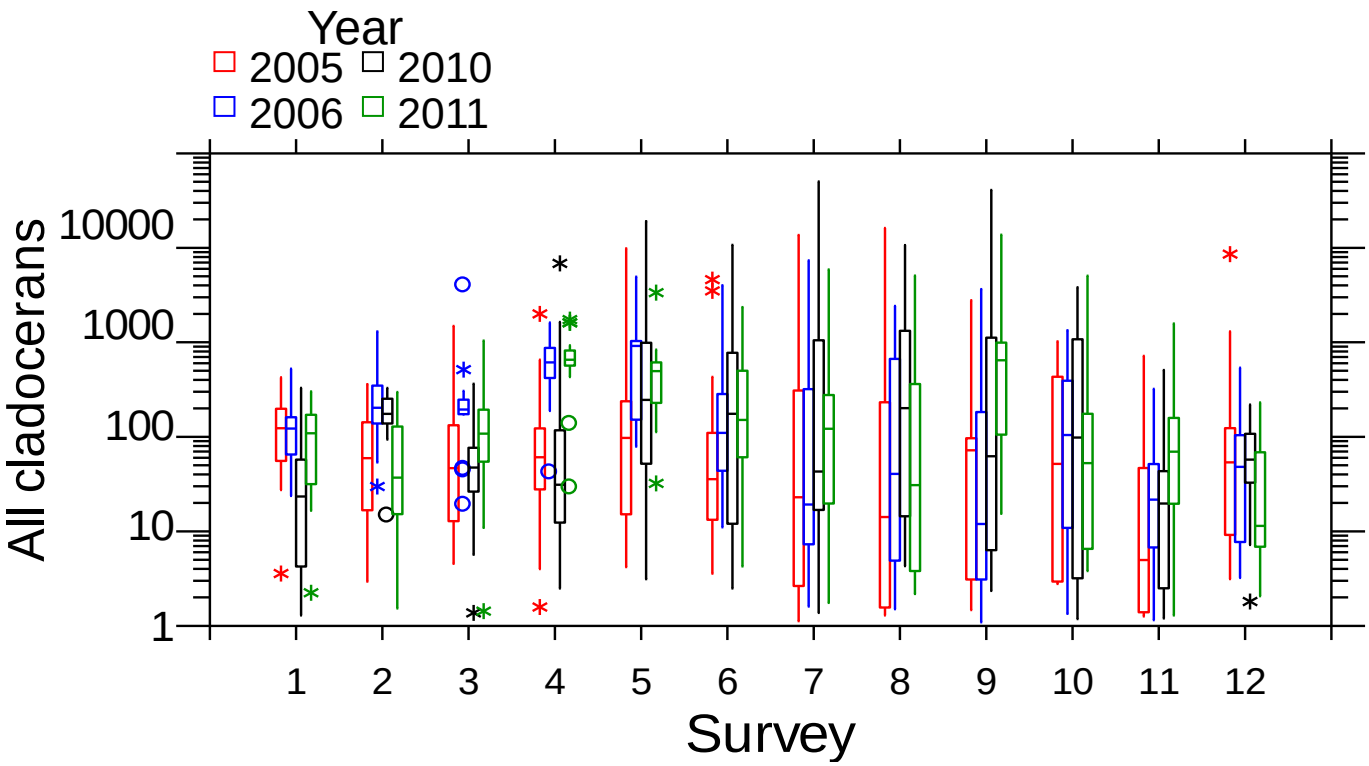

16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
Chlorophyll a (µg/L)
2003-20012
1975-2002
75-02
03-12
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

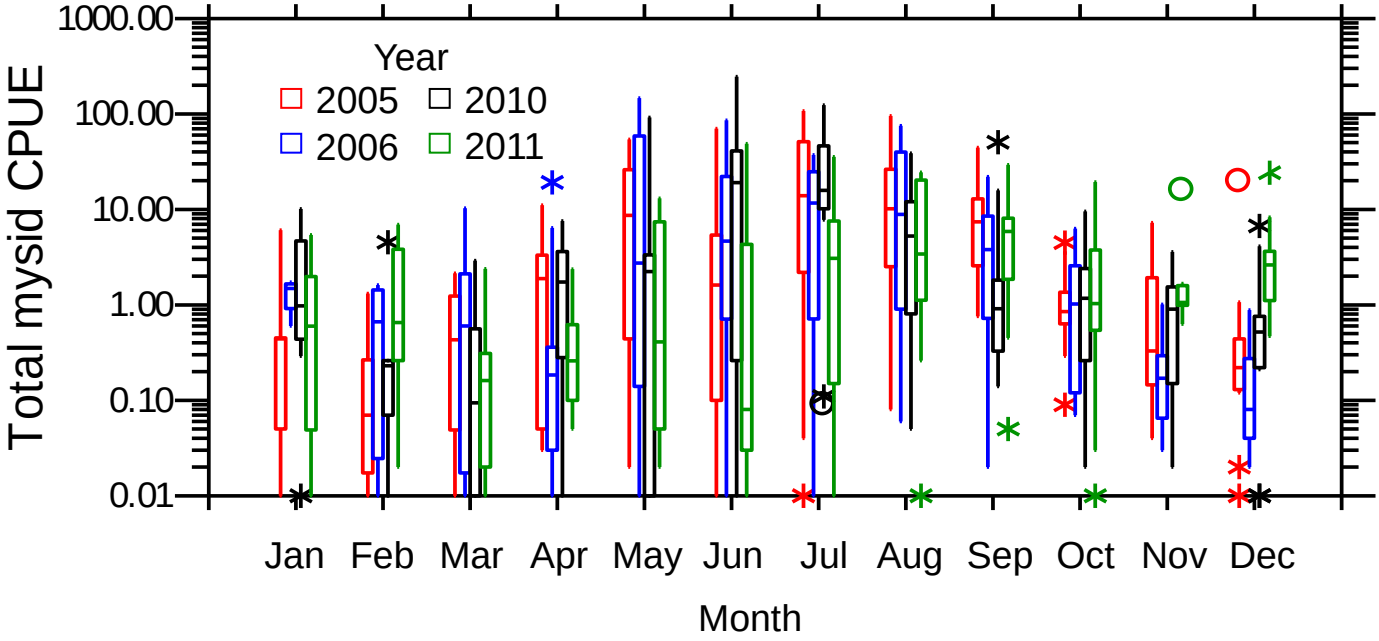

>6 ppt
1-6 ppt
<1 ppt
Year
2005
2006
2010
2011
E. affinis adults
10000
1000
100
10
1
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month

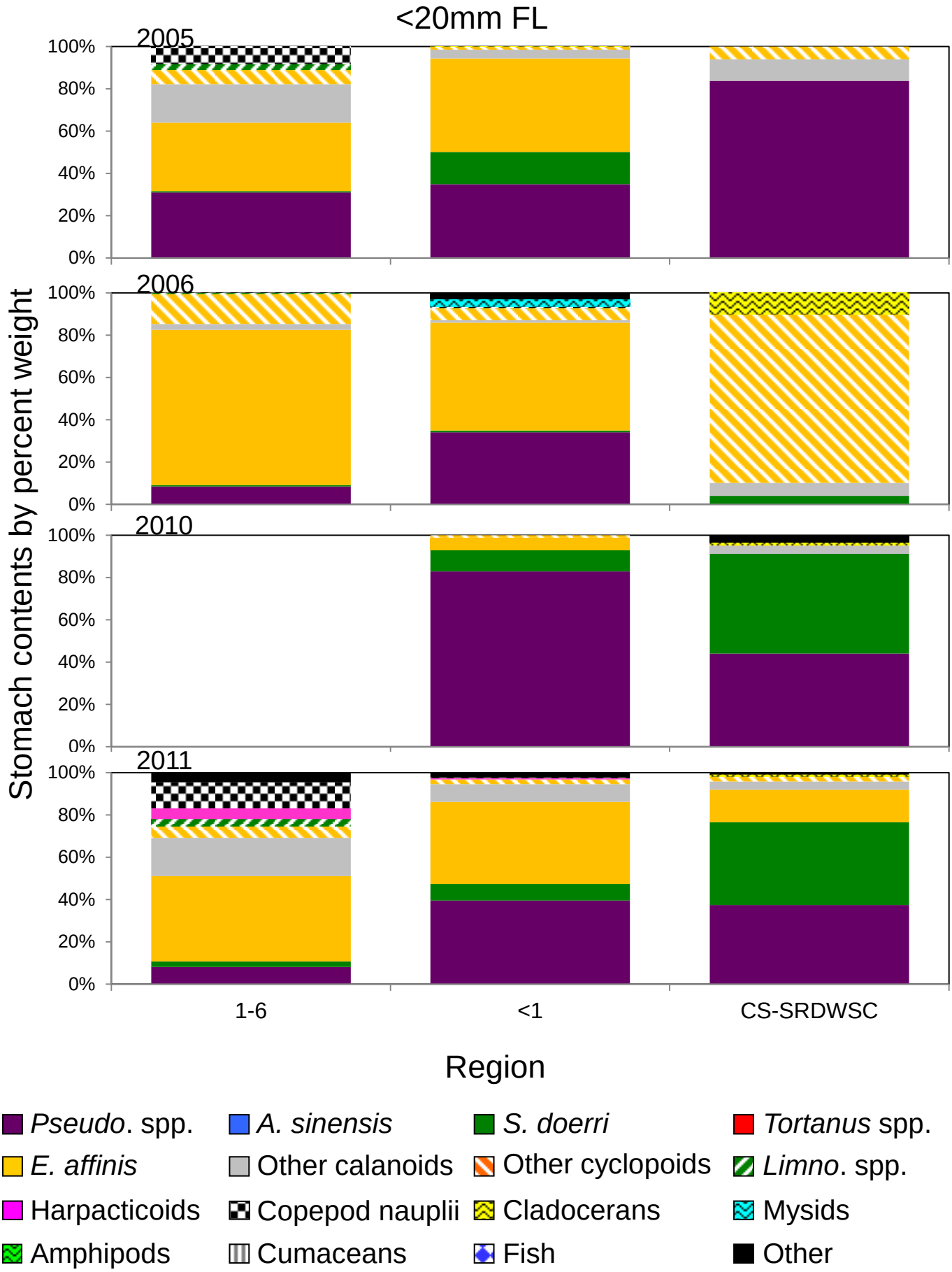

>6 ppt
1-6 ppt
<1 ppt
Year
2005
2006
2010
2011
P. forbesi adults
10000
1000
100
10
1
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month

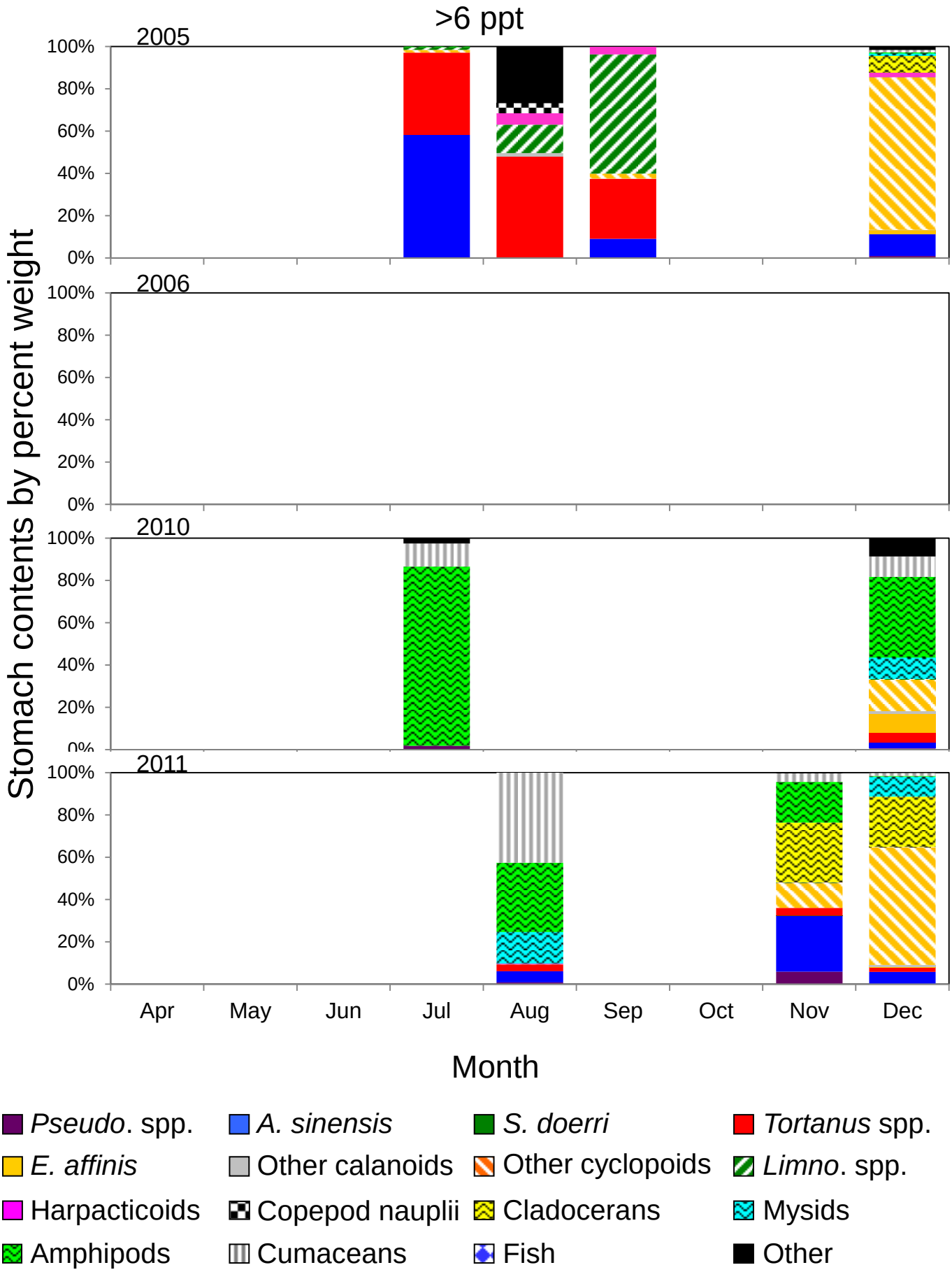

Year
2005
2006
2010
2011
A. sinensis adults
10000
1000
100
10
1
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month

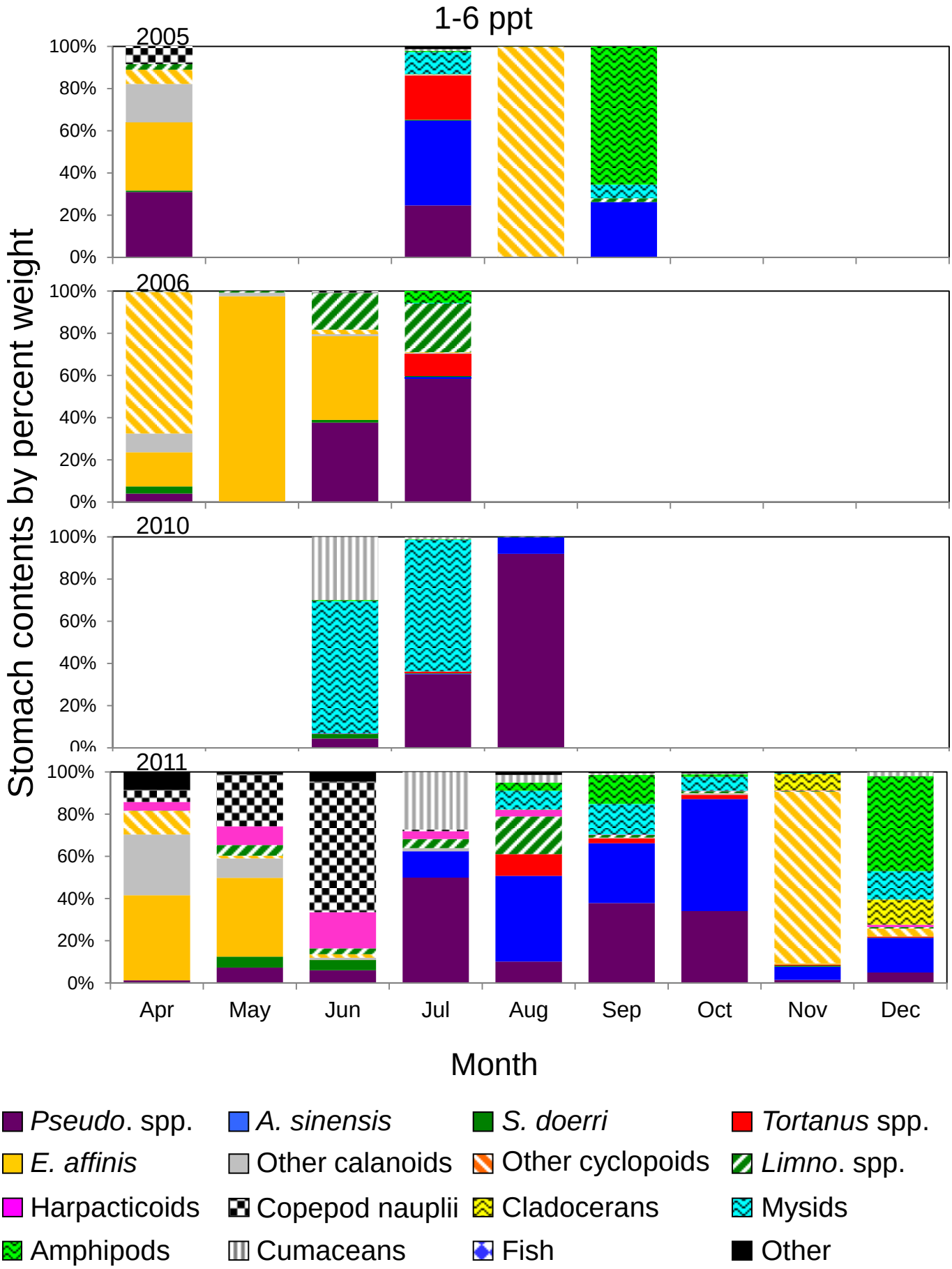

Year
2005
2010
2006
2011
S. doerri adults
10000
1000
100
10
1
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month

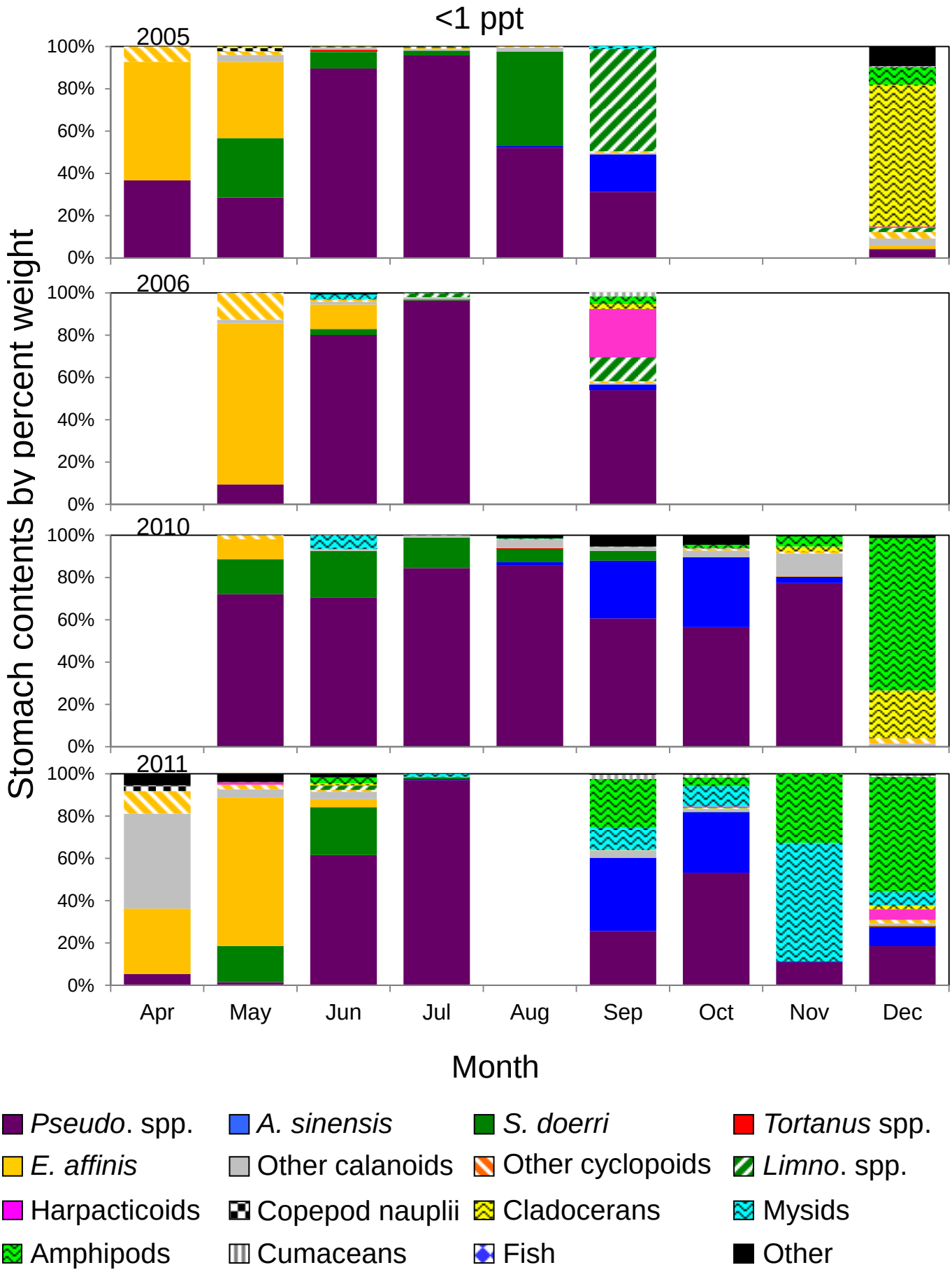

Year
2005
2010
2006
2011
All cladocerans
10000
1000
100
10
1
1
2
3
4
5
6
7
8
9
10
11
12
Survey

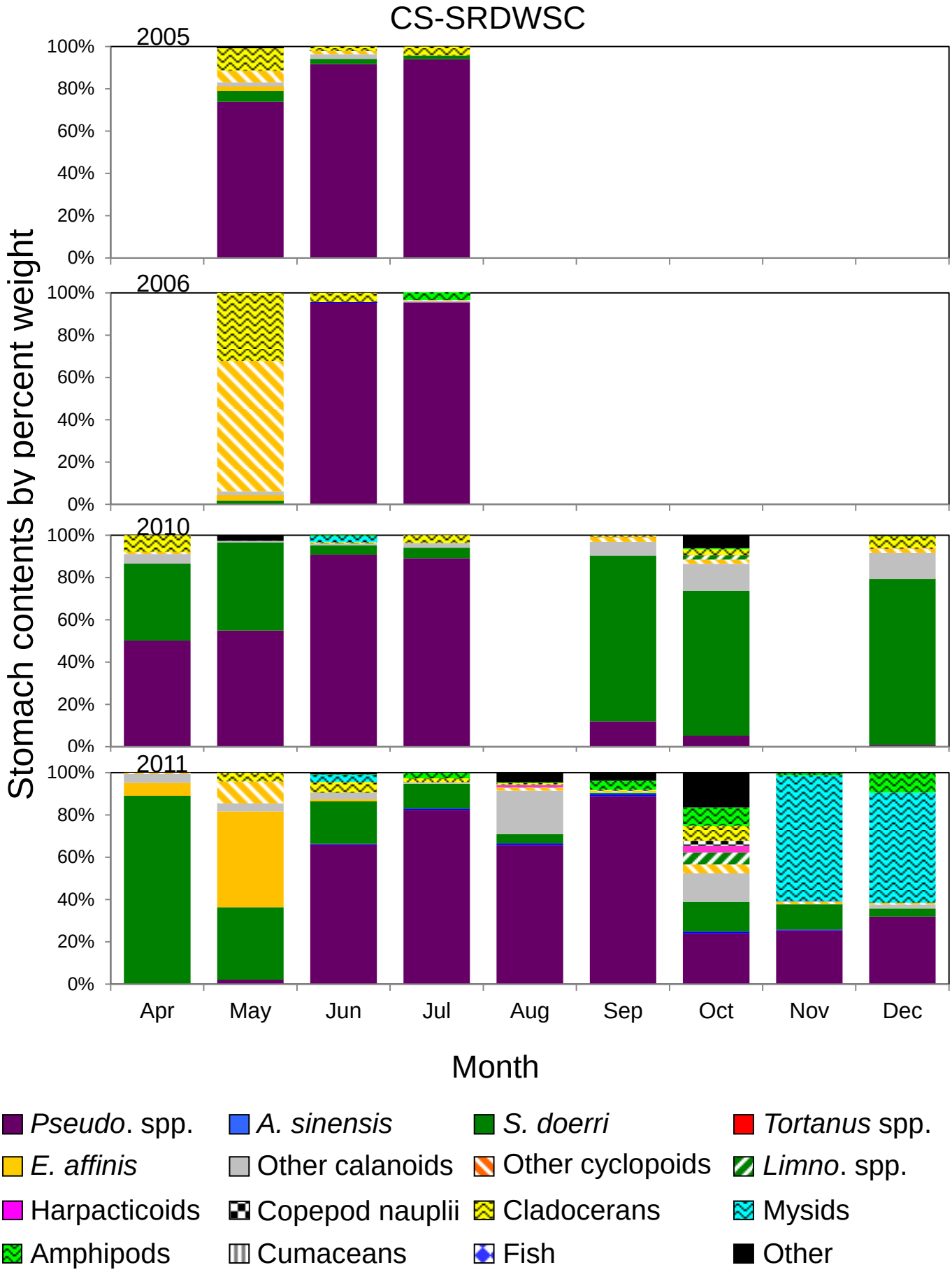

Total mysid CPUE
1000.00
100.00
10.00
1.00
0.10
0.01
Year
2005
2010
2006
2011
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month

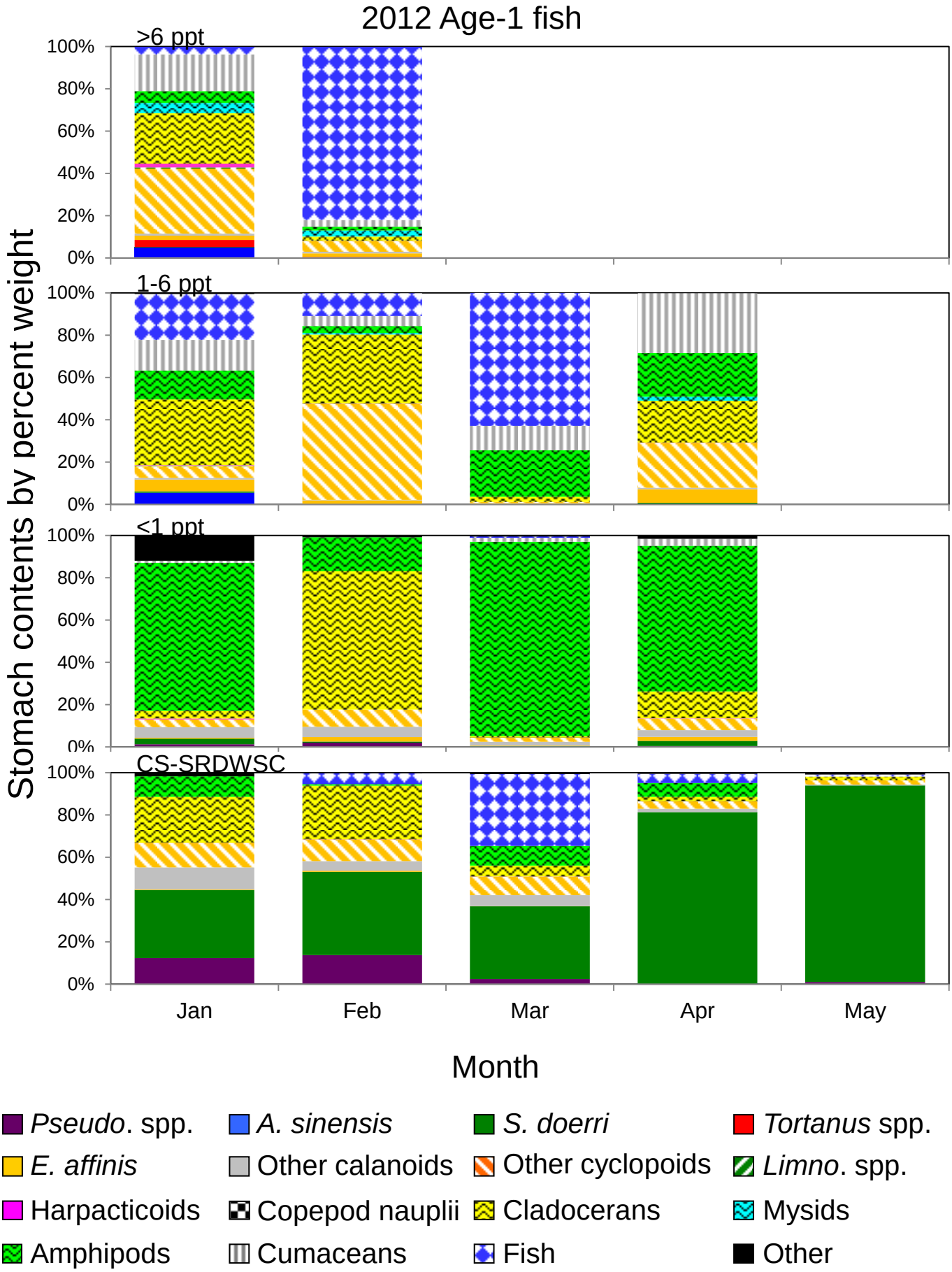

<20mm FL
2005
2006
2010
2011
100%
80%
60%
40%
20%
0%
Stomach contents by percent weight
1-6
<1
CS-SRDWSC
Region
Pseudo. spp.
A. sinensis
S. doerri
Tortanus spp.
E. affinis
Other calanoids
Other cyclopoids
Limno. spp.
Harpacticoids
Copepod nauplii
Cladocerans
Mysids
Amphipods
Cumaceans
Fish
Other

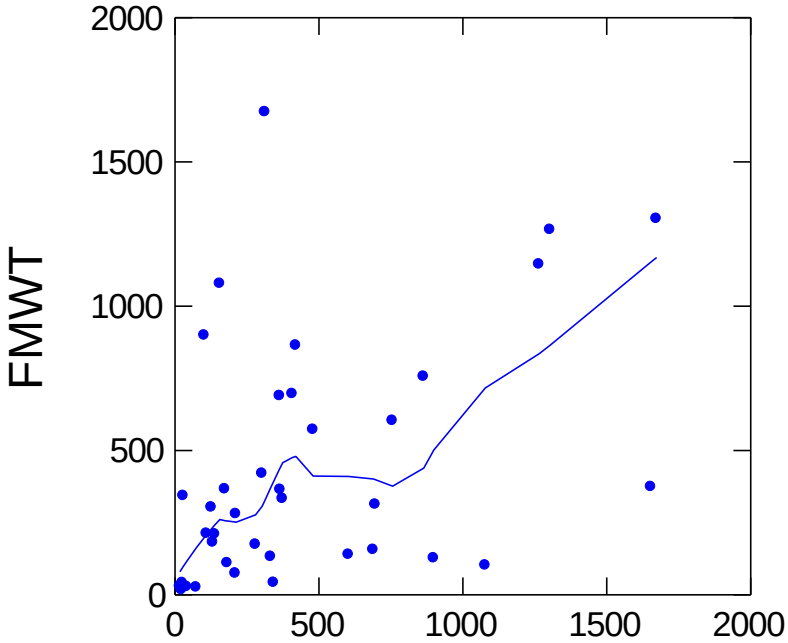

>6 ppt
2005
2006
2010
2011
100%
80%
60%
40%
20%
0%
Stomach contents by percent weight
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month
Pseudo. spp.
A. sinensis
S. doerri
Tortanus spp.
E. affinis
Other calanoids
Other cyclopoids
Limno. spp.
Harpacticoids
Copepod nauplii
Cladocerans
Mysids
Amphipods
Cumaceans
Fish
Other

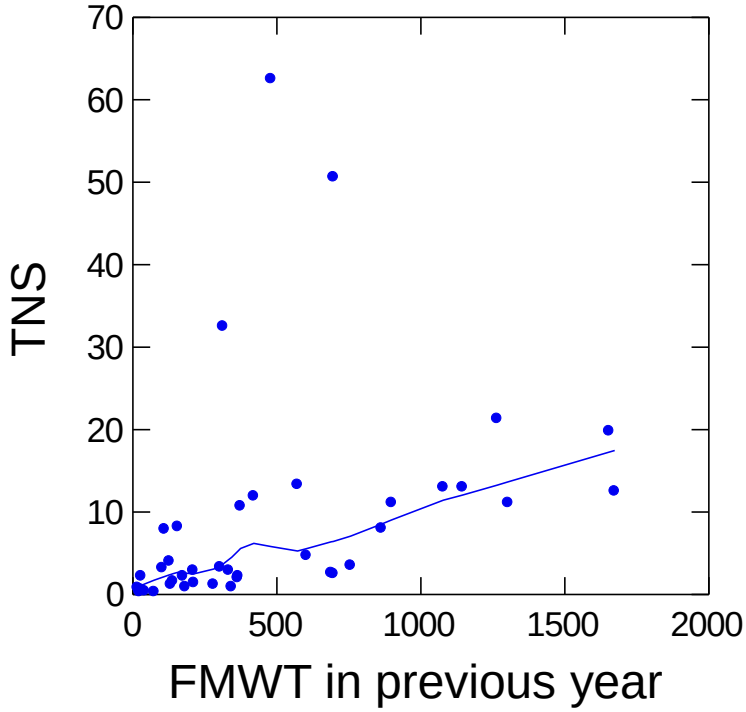

1-6 ppt
2005
2006
2010
2011
100%
80%
60%
40%
20%
0%
Stomach contents by percent weight
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month
Pseudo. spp.
A. sinensis
S. doerri
Tortanus spp.
E. affinis
Other calanoids
Other cyclopoids
Limno. spp.
Harpacticoids
Copepod nauplii
Cladocerans
Mysids
Amphipods
Cumaceans
Fish
Other

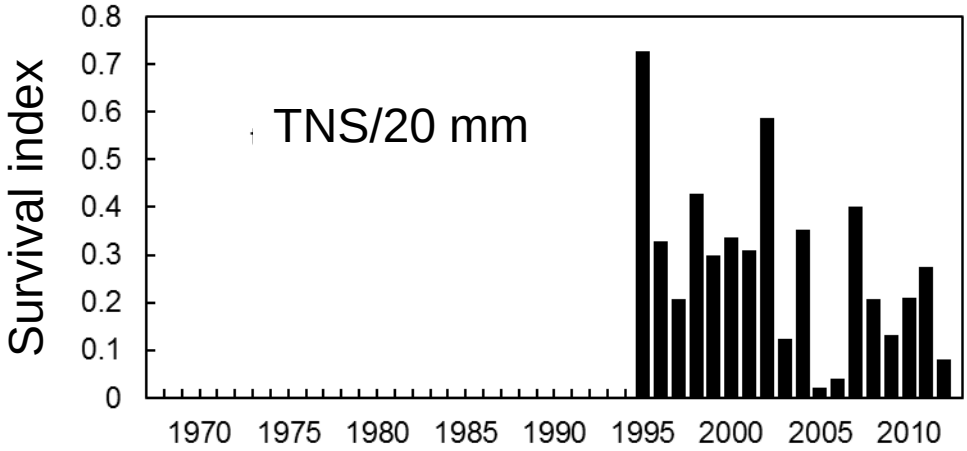

<1 ppt
2005
2006
2010
2011
100%
80%
60%
40%
20%
0%
Stomach contents by percent weight
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month
Pseudo. spp.
A. sinensis
S. doerri
Tortanus spp.
E. affinis
Other calanoids
Other cyclopoids
Limno. spp.
Harpacticoids
Copepod nauplii
Cladocerans
Mysids
Amphipods
Cumaceans
Fish
Other

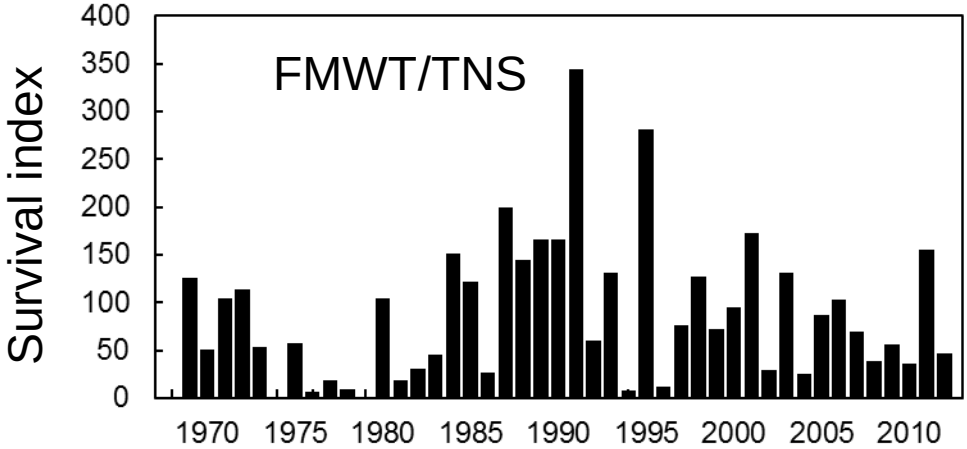

CS-SRDWSC
2005
2006
2010
2011
100%
80%
60%
40%
20%
0%
Stomach contents by percent weight
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month
Pseudo. spp.
A. sinensis
S. doerri
Tortanus spp.
E. affinis
Other calanoids
Other cyclopoids
Limno. spp.
Harpacticoids
Copepod nauplii
Cladocerans
Mysids
Amphipods
Cumaceans
Fish
Other

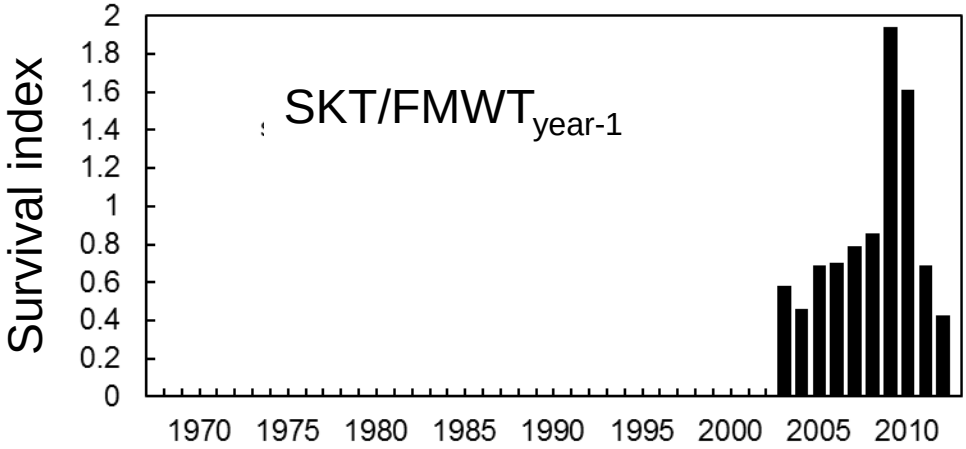

2012 Age-1 fish
>6 ppt
1-6 ppt
<1 ppt
CS-SRDWSC
100%
80%
60%
40%
20%
0%
Stomach contents by percent weight
Jan
Feb
Mar
Apr
May
Month
Pseudo. spp.
A. sinensis
S. doerri
Tortanus spp.
E. affinis
Other calanoids
Other cyclopoids
Limno. spp.
Harpacticoids
Copepod nauplii
Cladocerans
Mysids
Amphipods
Cumaceans
Fish
Other

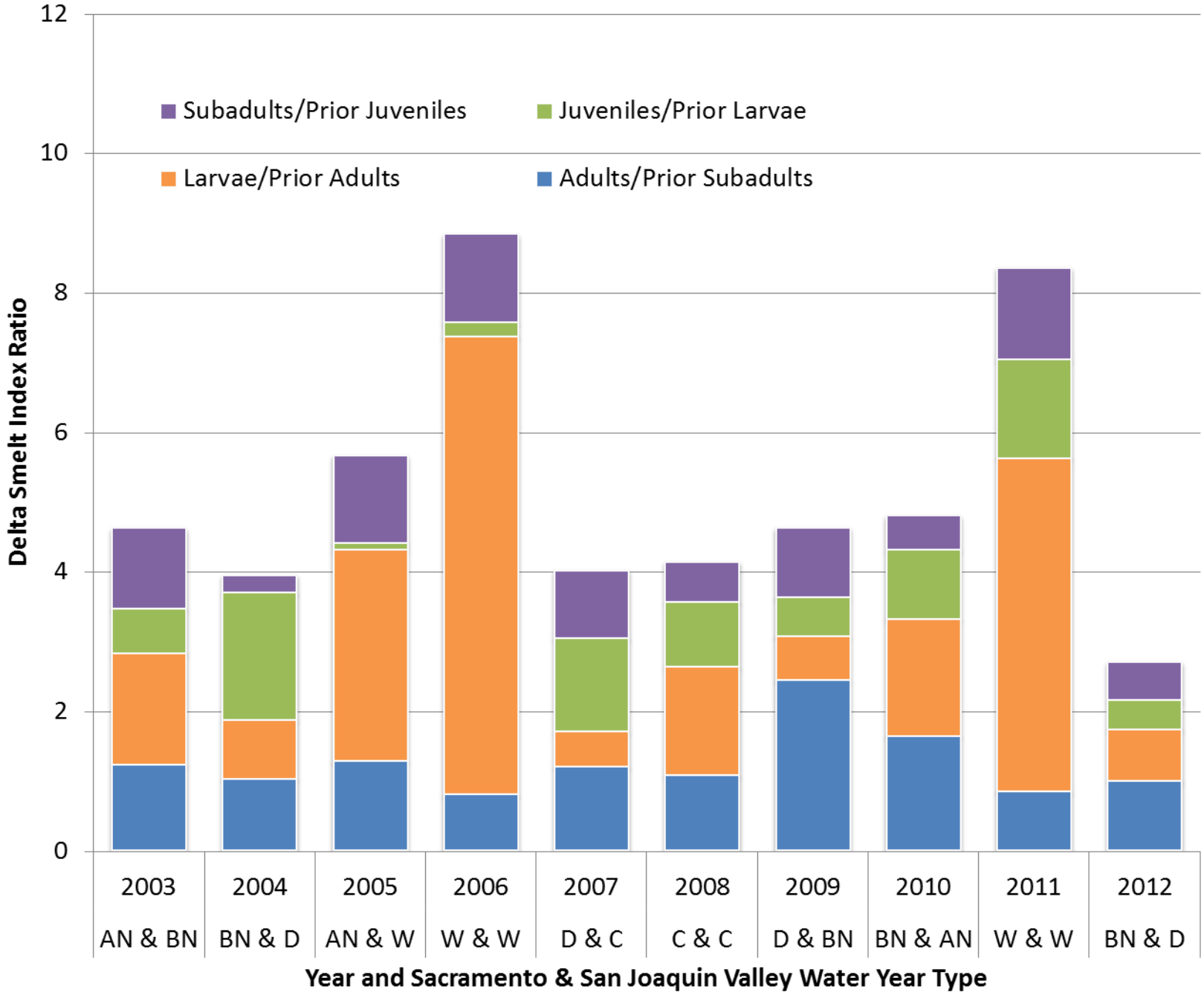

FMWT
2000
1500
1000
500
0
0
500
1000
1500
2000

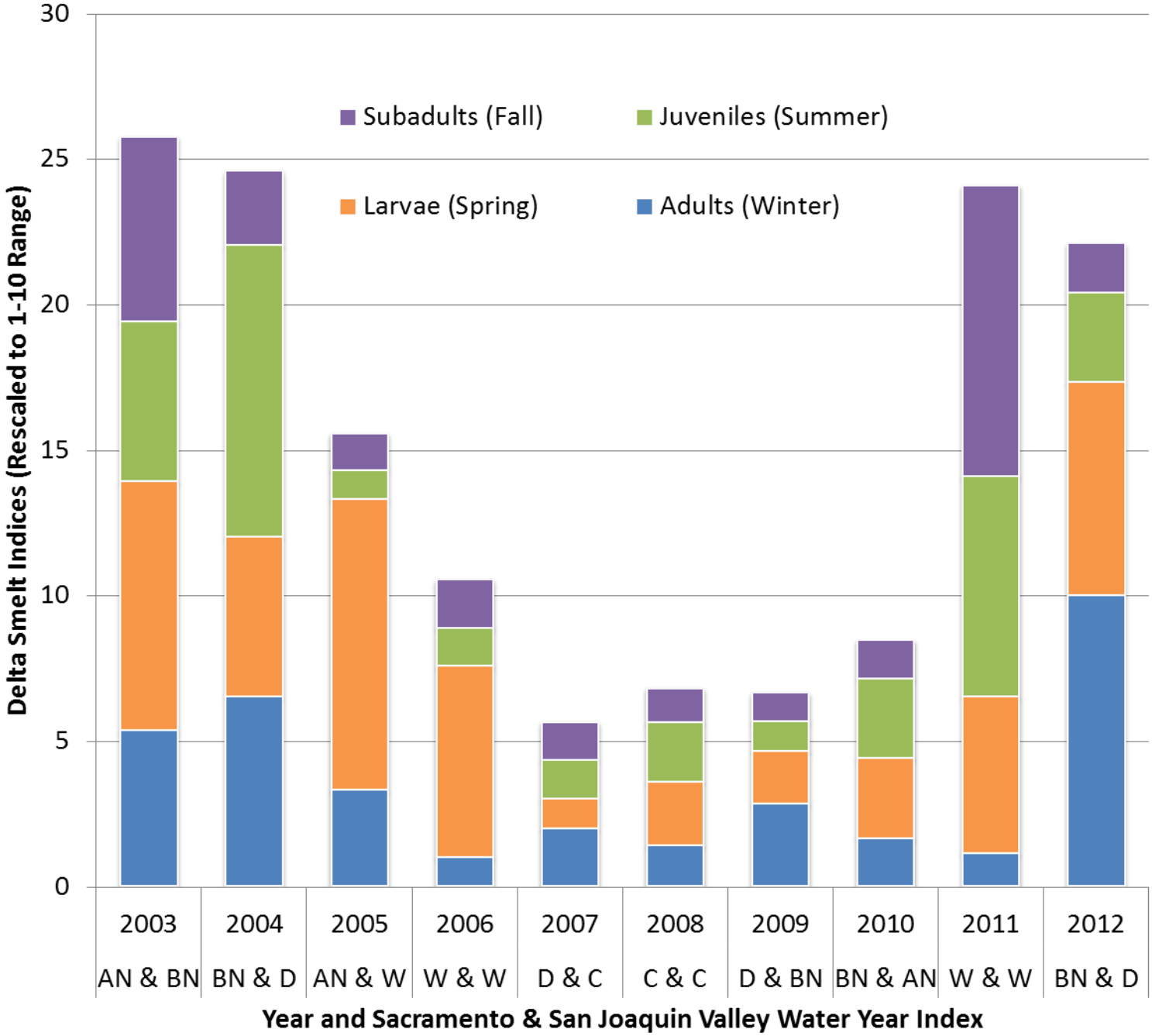

TNS
70
60
50
40
30
20
10
0
0
500
1000
1500
2000
FMWT in previous year

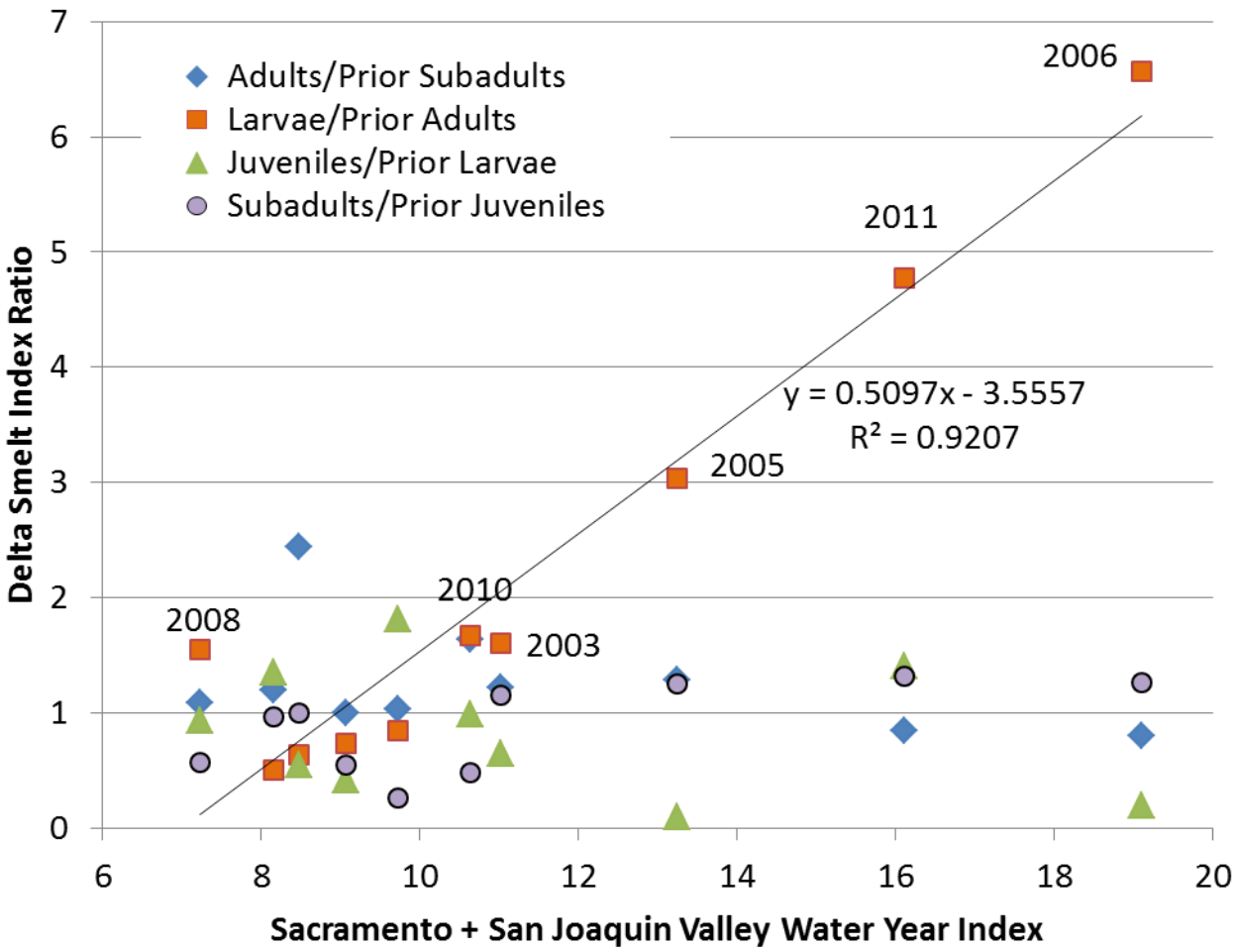

Survival index
TNS/20 mm
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1970
1975
1980
1985
1990
1995
2000
2005
2010

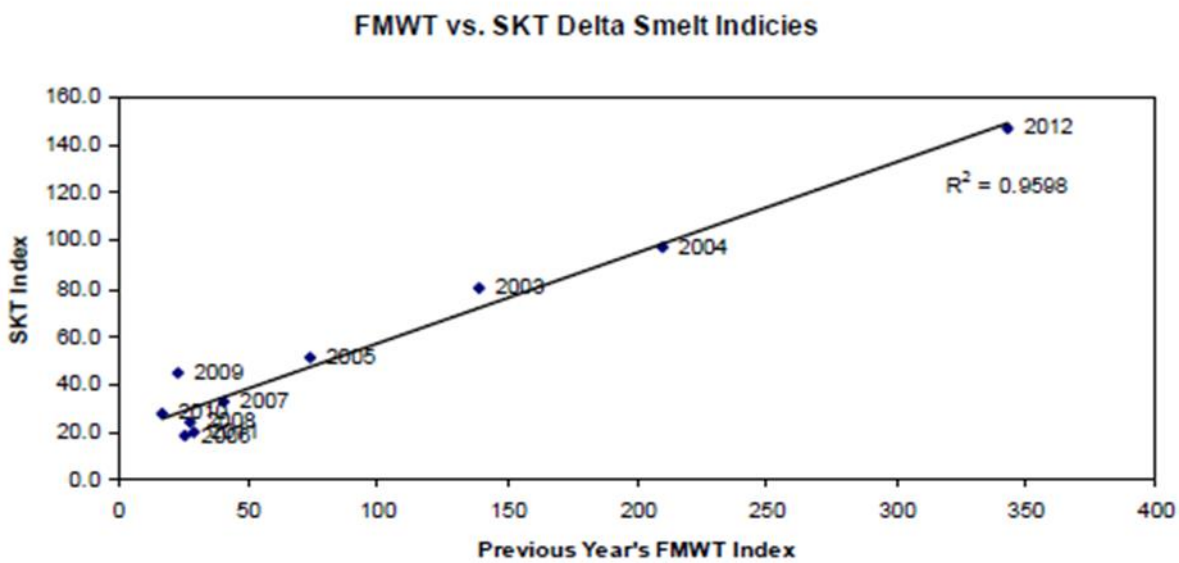

Survival index
FMWT/TNS
400
350
300
250
200
150
100
50
0
1970
1975
1980
1985
1990
1995
2000
2005
2010

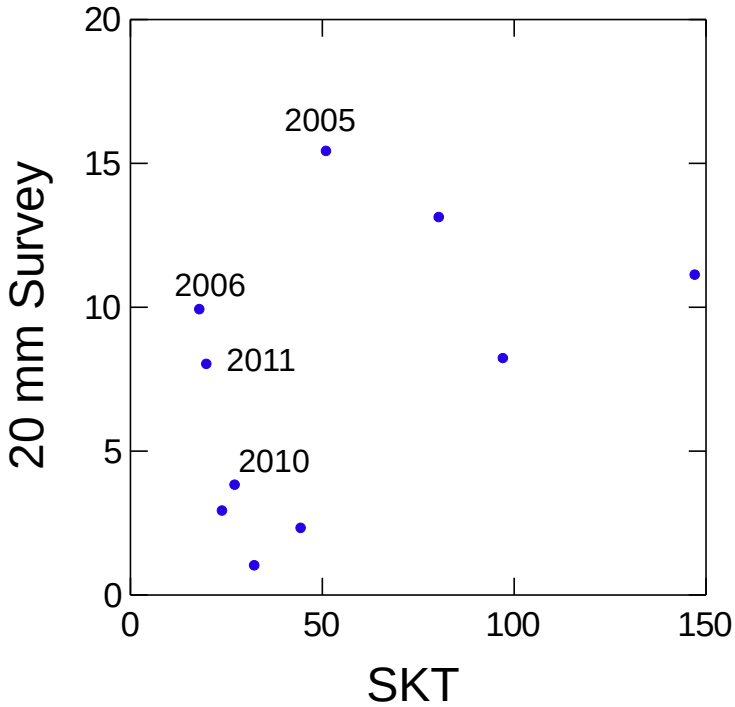

Survival index
SKT/FMWT year-1
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1970
1975
1980
1985
1990
1995
2000
2005
2010

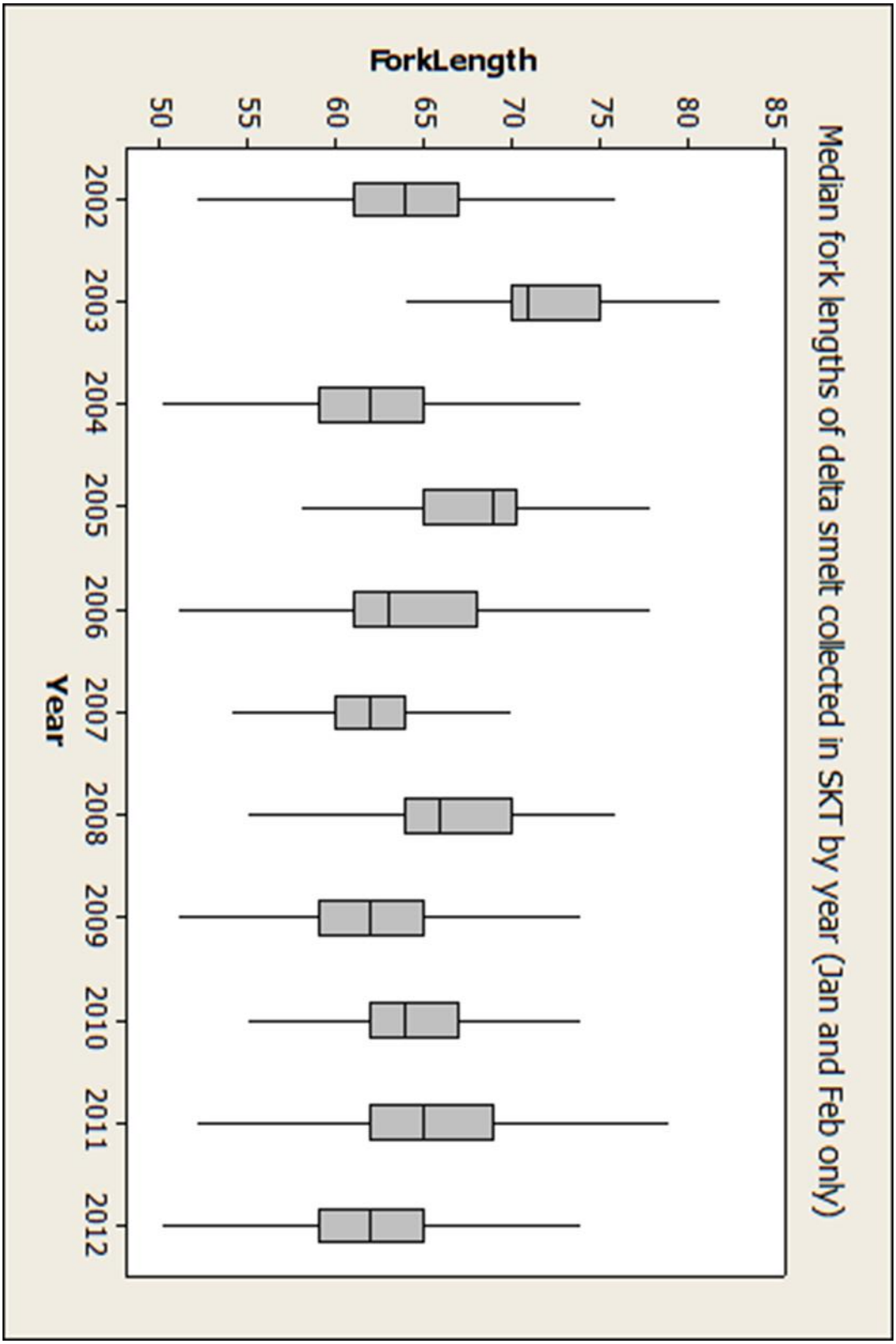

Subadults/Prior Juveniles
Juveniles/Prior Larvae
Larvae/Prior Adults
Adults/Prior Subadults
Delta Smelt Index Ratio
0
2
4
6
8
10
12
2003
AN & BN
2004
BN & D
2005
AN & W
2006
W & W
2007
D & C
2008
C & C
2009
D & BN
2010
BN & AN
2011
W & W
2012
BN & D
Year and Sacramento & San Joaquin Valley Water Year Type

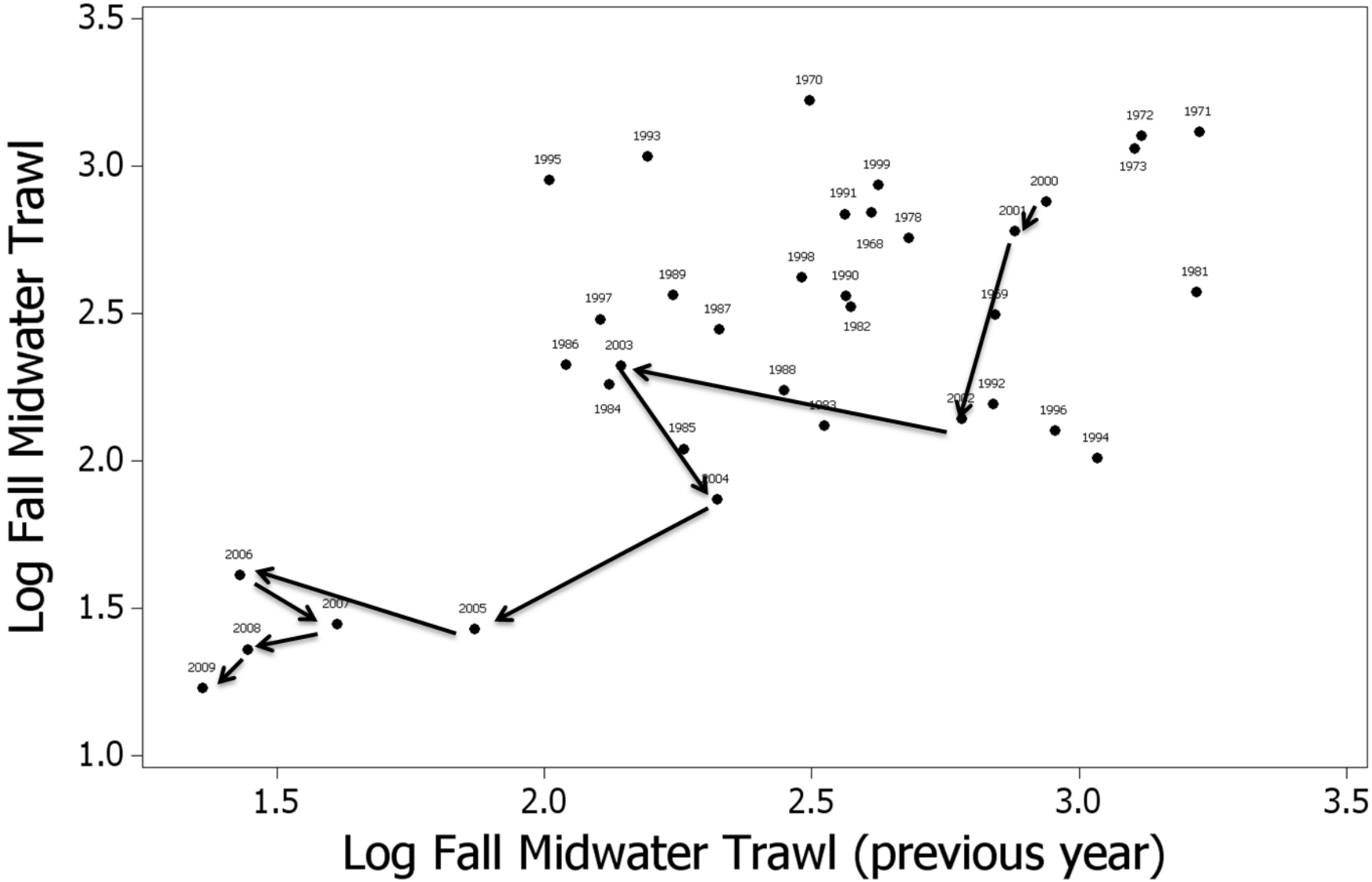

Subadults (Fall)
Juveniles (Summer)
Larvae (Spring)
Adults (Winter)
Delta Smelt Indices (Rescaled to 1-10 Range)
30
25
20
15
10
5
0
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
AN & BN
BN & D
AN & W
W & W
D & C
C & C
D & BN
BN & AN
W & W
BN & D
Year and Sacramento & San Joaquin Valley Water Year Index

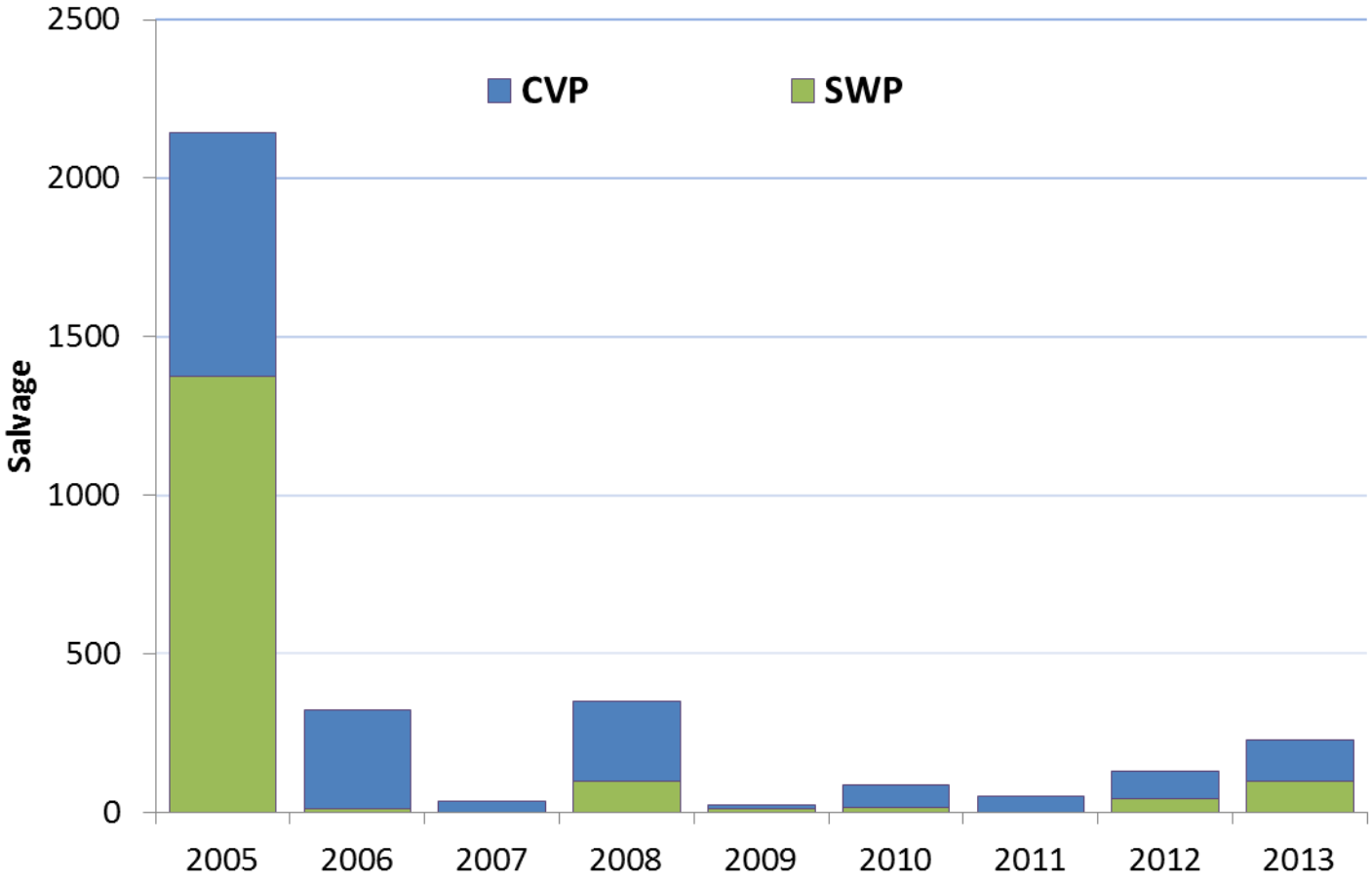

Adults/Prior Subadults
Larvae/Prior Adults
Juveniles/Prior Larvae
Subadults/Prior Juveniles
2006
2011
2005
2010
2008
2003
y = 0.5097x - 3.5557
R² = 0.9207
Delta Smelt Index Ratio
Sacramento + San Joaquin Valley Water Year Index
0
1
2
3
4
5
6
7
6
8
10
12
14
16
18
20

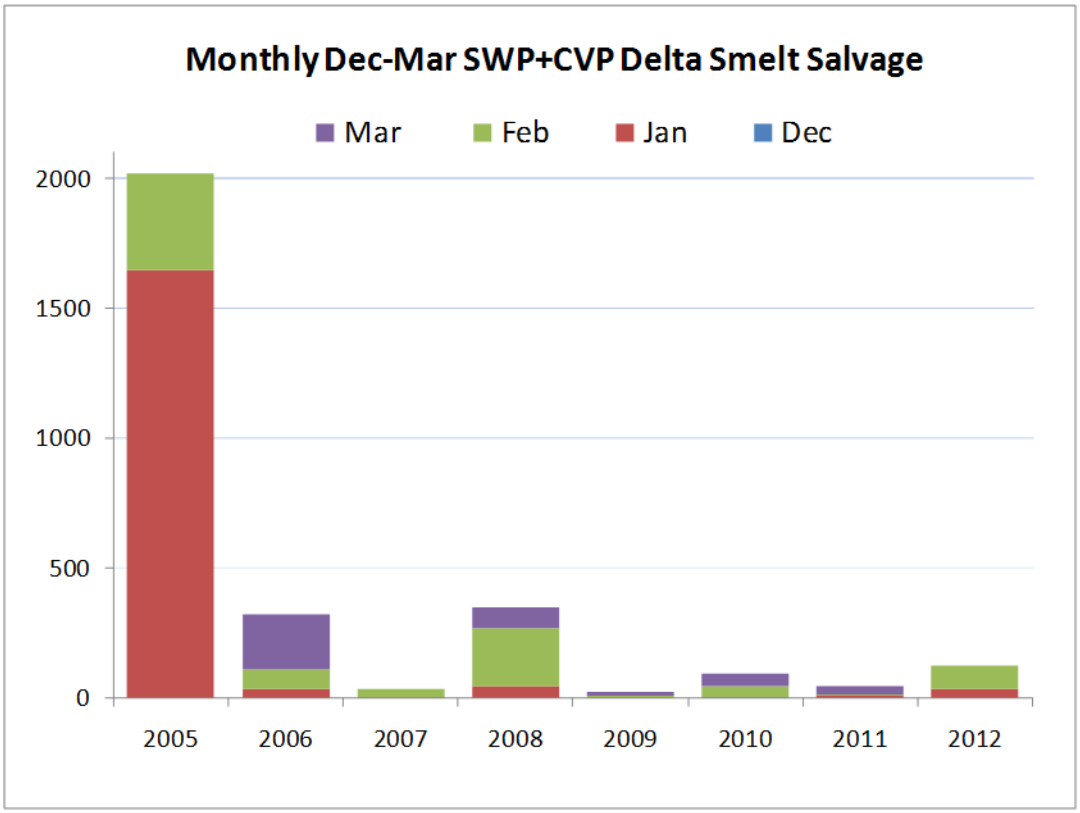

FMWT vs. SKT Delta Smelt Indicies
SKT Index
Previous Year's FMWT Index
160.0
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
0
50
100
150
200
250
300
350
400
2012
R^2 = 0.9598
2004
2003
2005
2009
2007
2010
2008
2006
2011

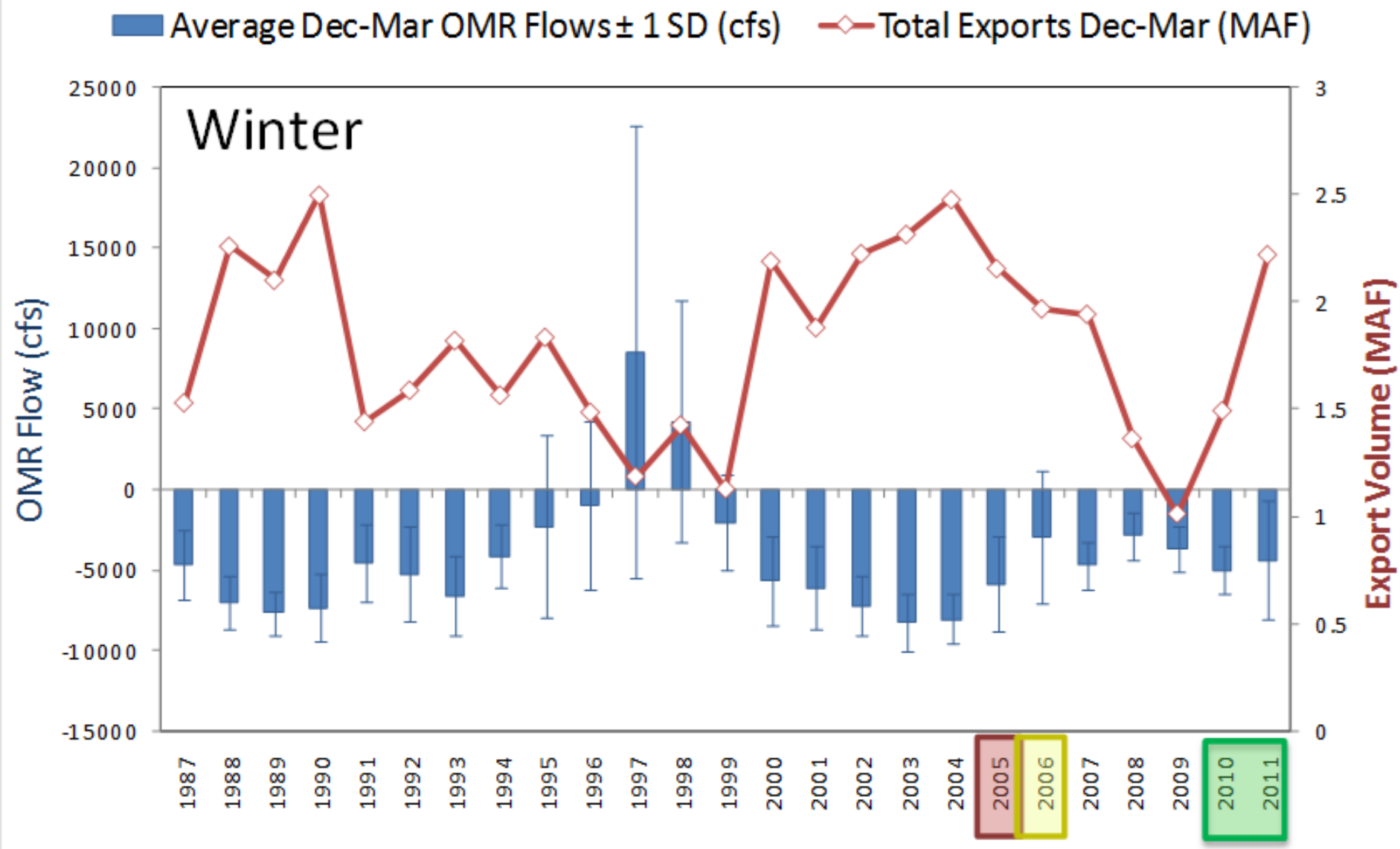

20
15
10
5
0
0
50
100
150
2005
2006
2011
2010
20 mm Survey
SKT

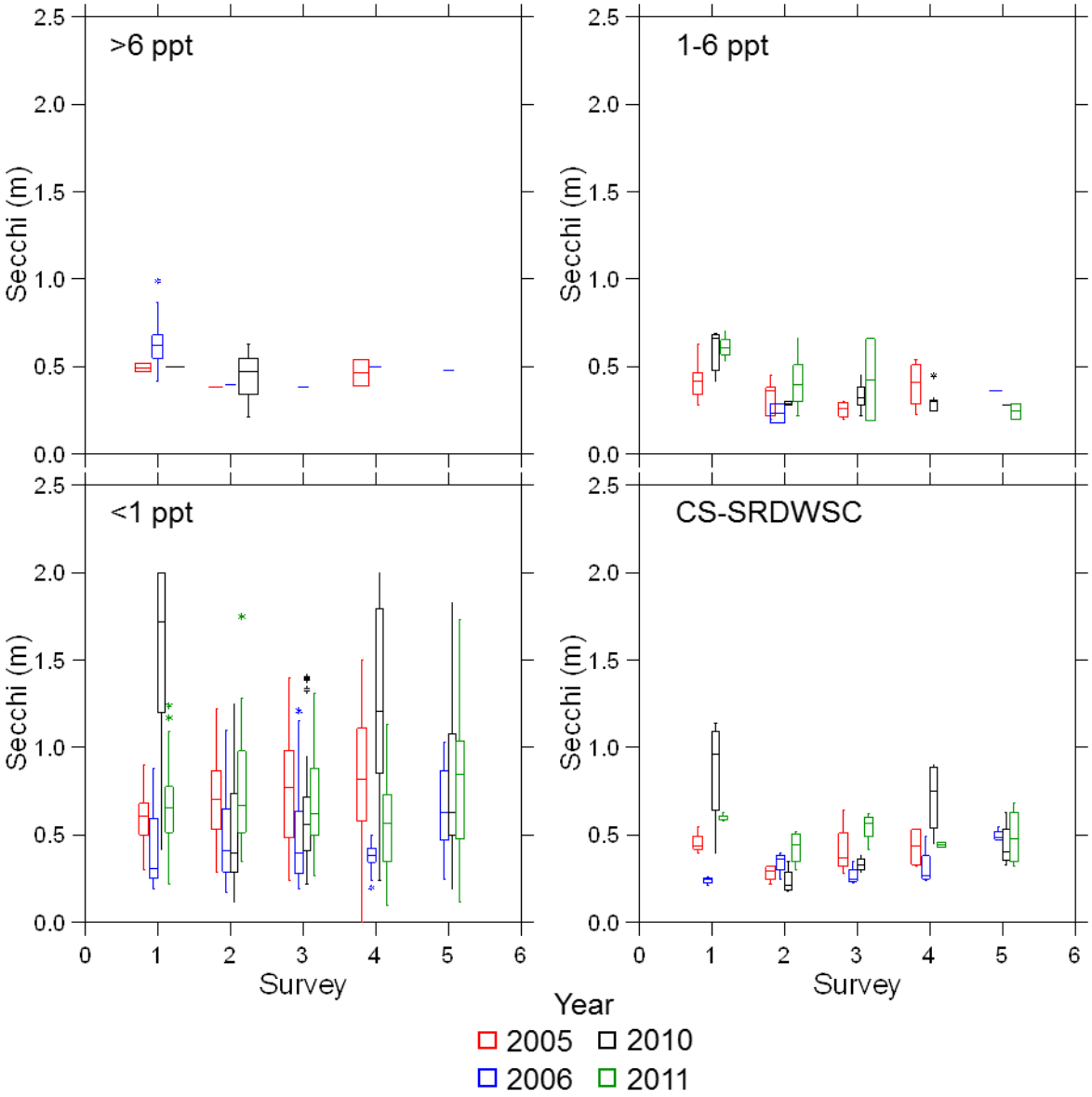

Median fork lengths of delta smelt collected in SKT by year (Jan and Feb only)
ForkLength
85
80
75
70
65
60
55
50
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
Year

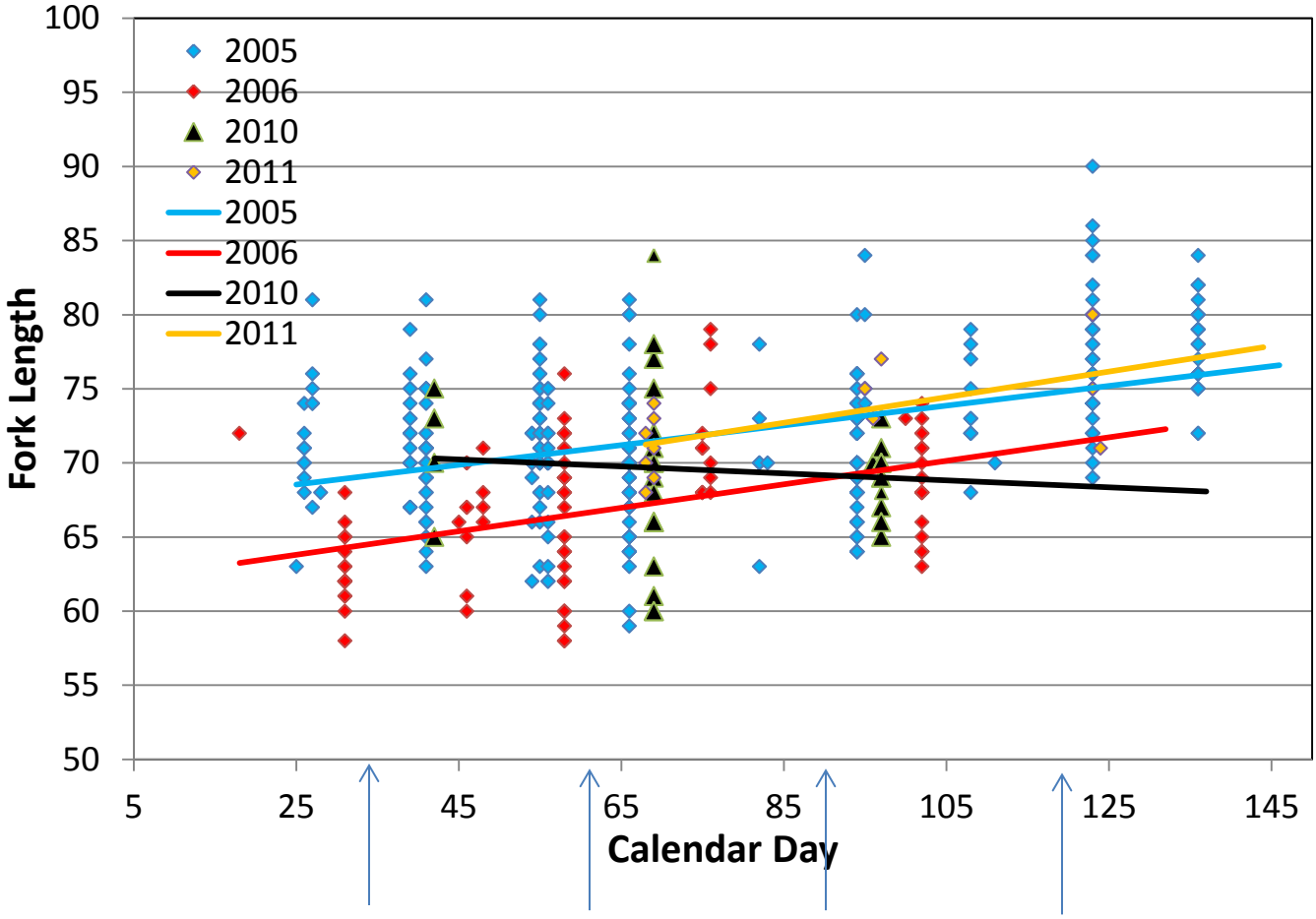

Log Fall Midwater Trawl
Log Fall Midwater Trawl (previous year)
3.5
3.0
2.5
2.0
1.5
1.0
1.5
2.0
2.5
3.0
3.5
1970
1972
1971
1993
1995
1999
1973
2000
1991
2001
1978
1968
1998
1989
1990
1981
1997
1987
1982
1986
2003
1988
1992
1984
1996
1985
1994
2004
2006
2007
2005
2008
2009

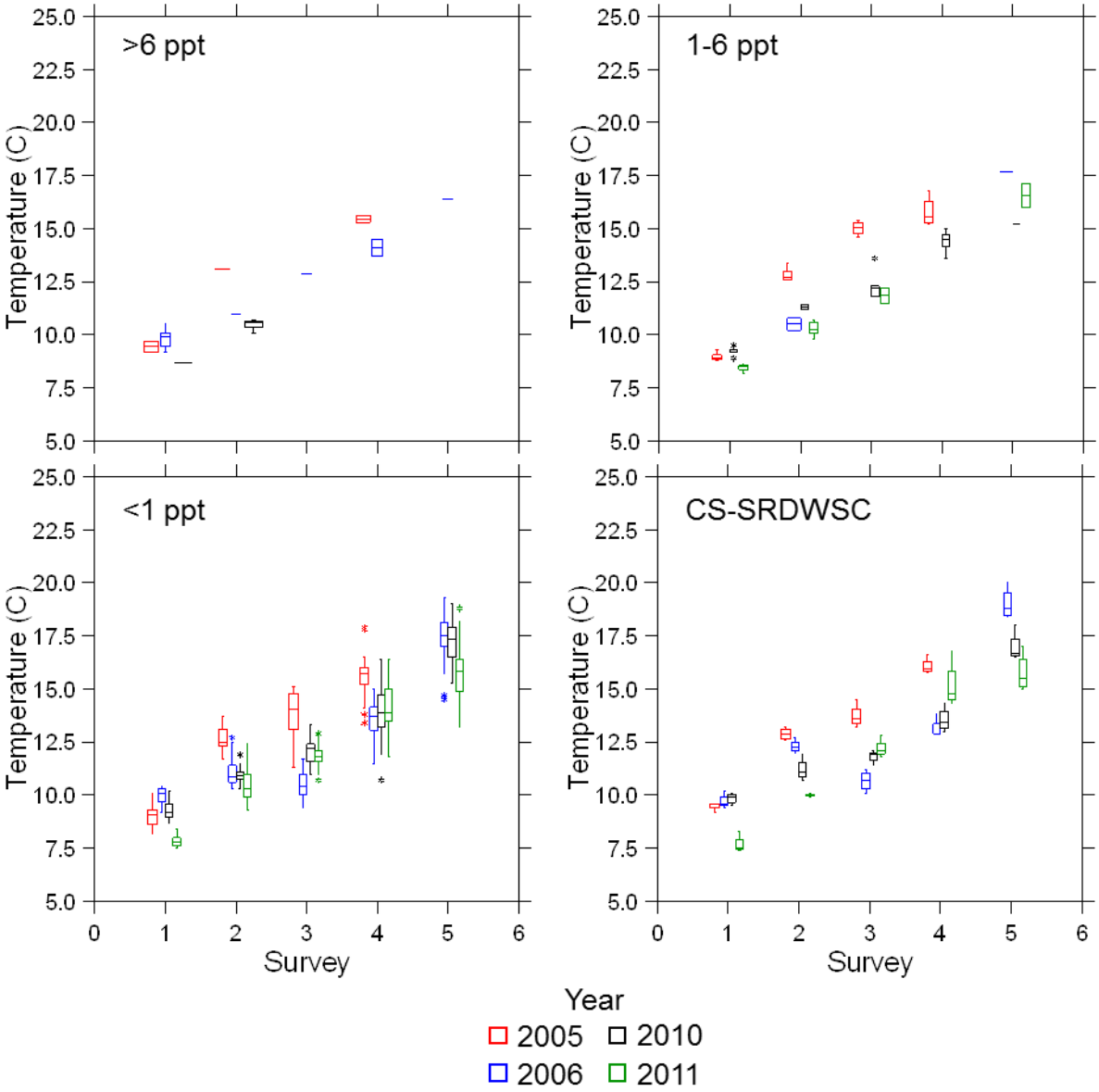

2500
2000
1500
1000
500
0
Salvage
CVP
SWP
2005
2006
2007
2008
2009
2010
2011
2012
2013

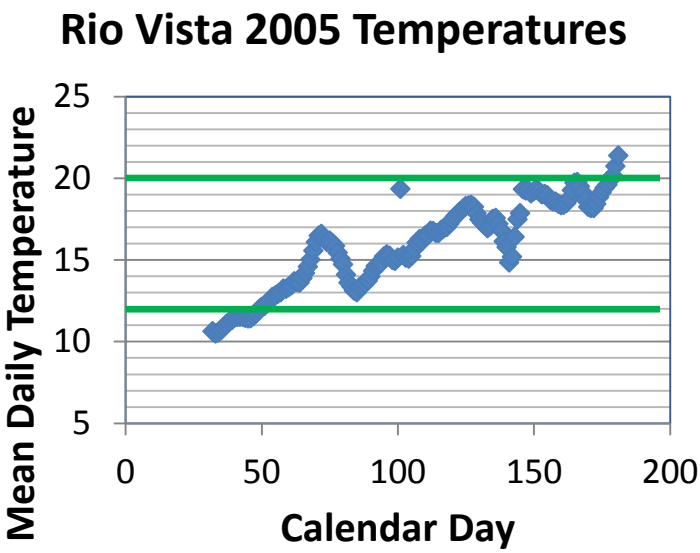

Monthly Dec-Mar SWP+CVP Delta Smelt Salvage
Mar
Feb
Jan
Dec
2000
1500
1000
500
0
2005
2006
2007
2008
2009
2010
2011
2012

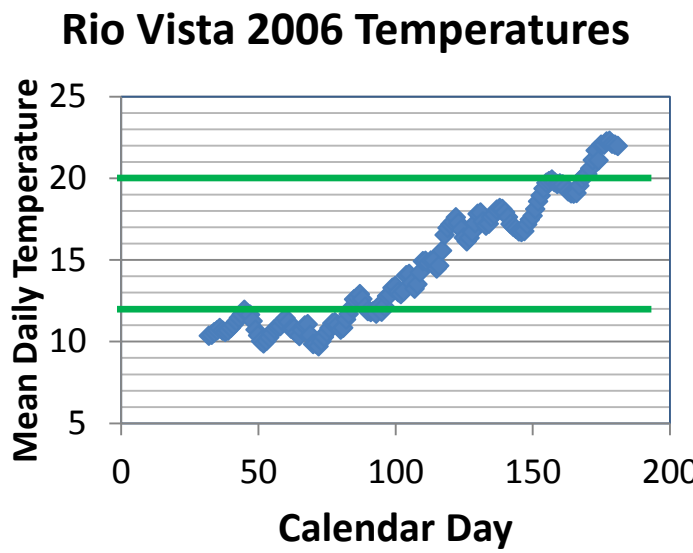

Average Dec-Mar OMR Flows ± 1 SD (cfs)
Total Exports Dec-Mar (MAF)
Winter
OMR Flow (cfs)
Export Volume (MAF)
25000
20000
15000
10000
5000
0
-5000
-10000
-15000
3
2.5
2
1.5
1
0.5
0
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011

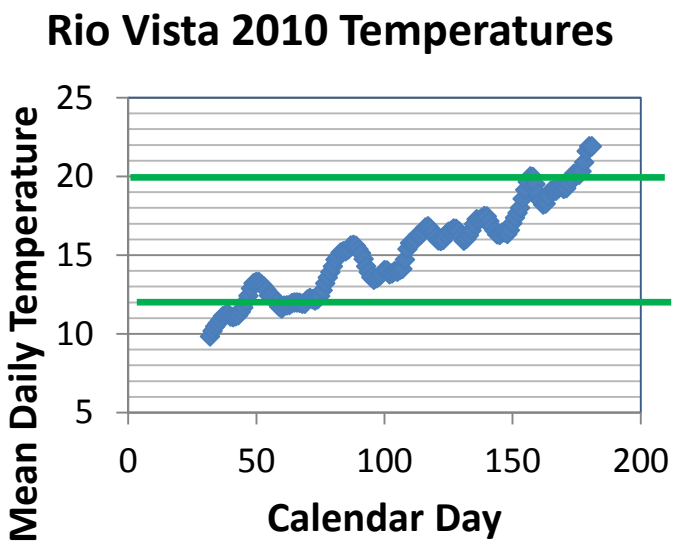

>6 ppt
1-6 ppt
<1 ppt
CS-SRDWSC
Secchi (m)
Survey
Year
2005
2010
2006
2011

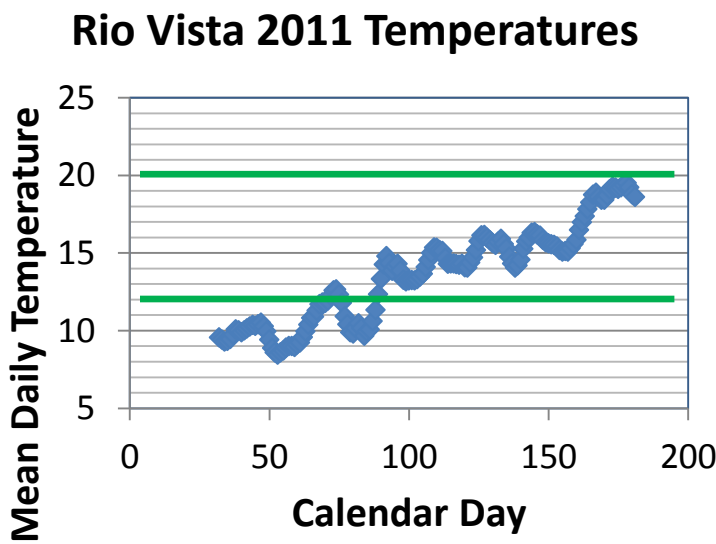

100
95
90
85
80
75
70
65
60
55
50
Fork Length
2005
2006
2010
2011
2005
2006
2010
2011
5
25
45
65
85
105
125
145
Calendar Day

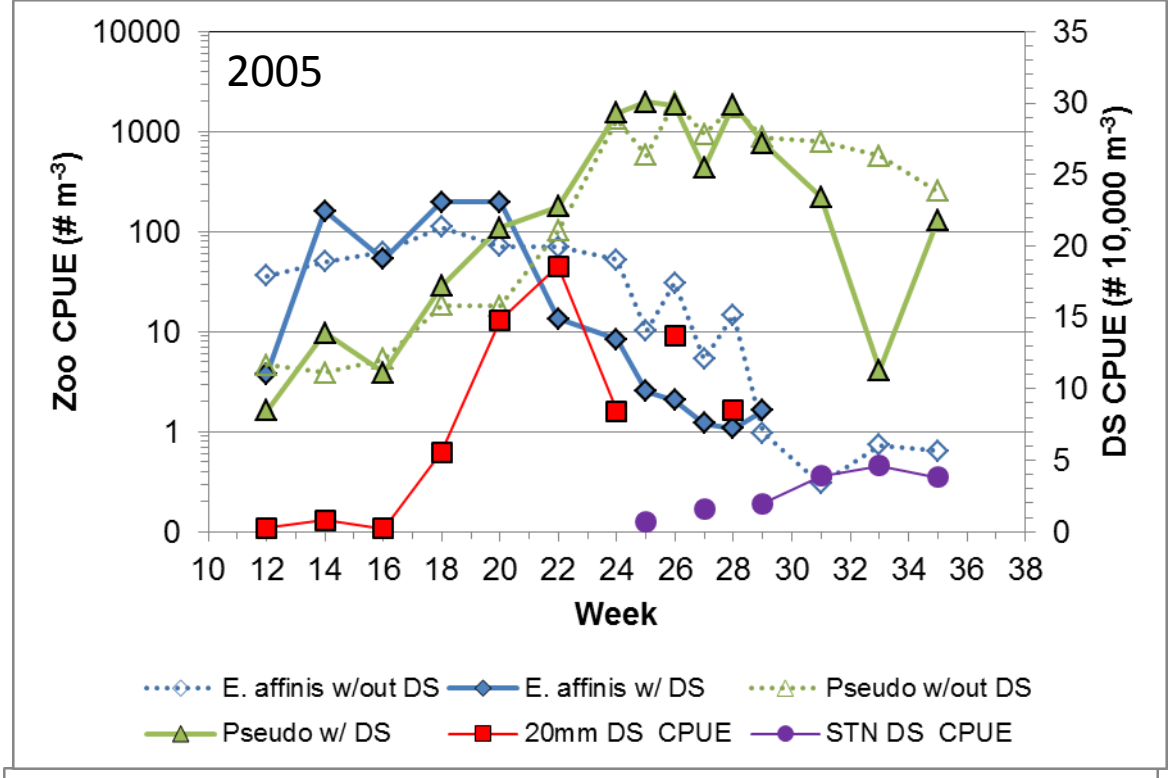

>6 ppt
1-6 ppt
<1 ppt
CS-SRDWSC
Temperature (C)
Survey
Year
2005
2010
2006
2011

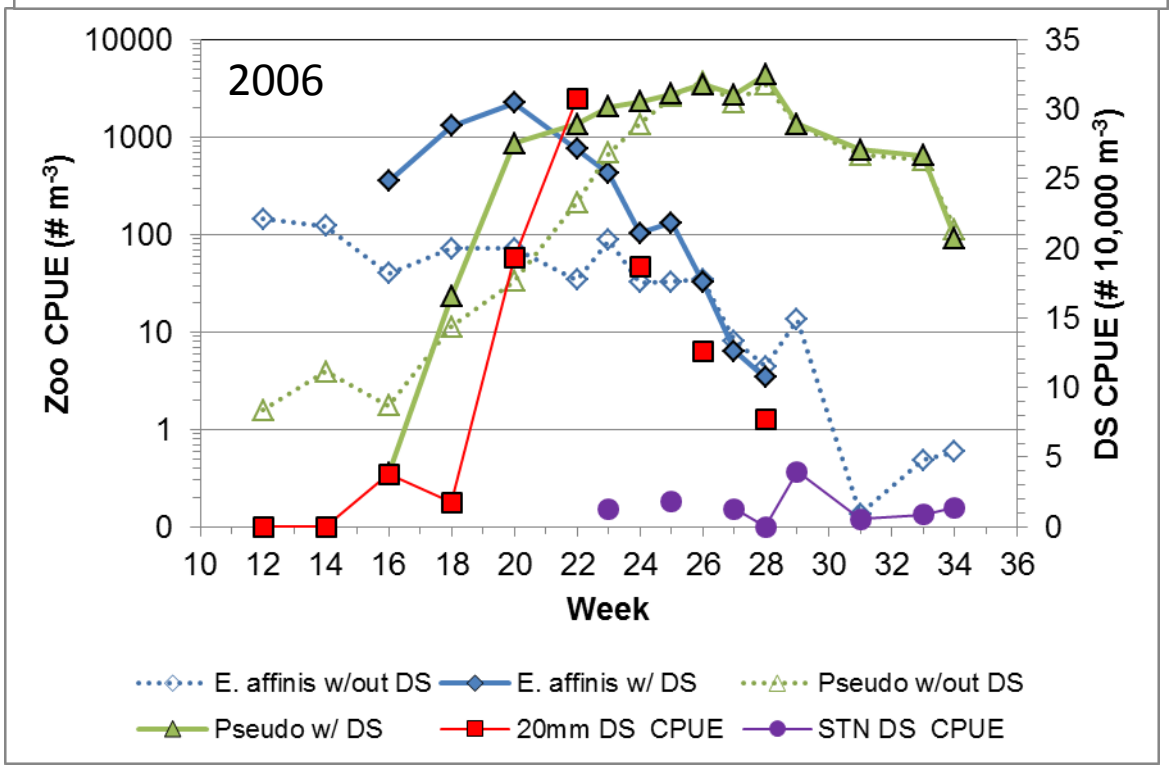

Rio Vista 2005 Temperatures
Mean Daily Temperature
25
20
15
10
5
0
50
100
150
200
Calendar Day

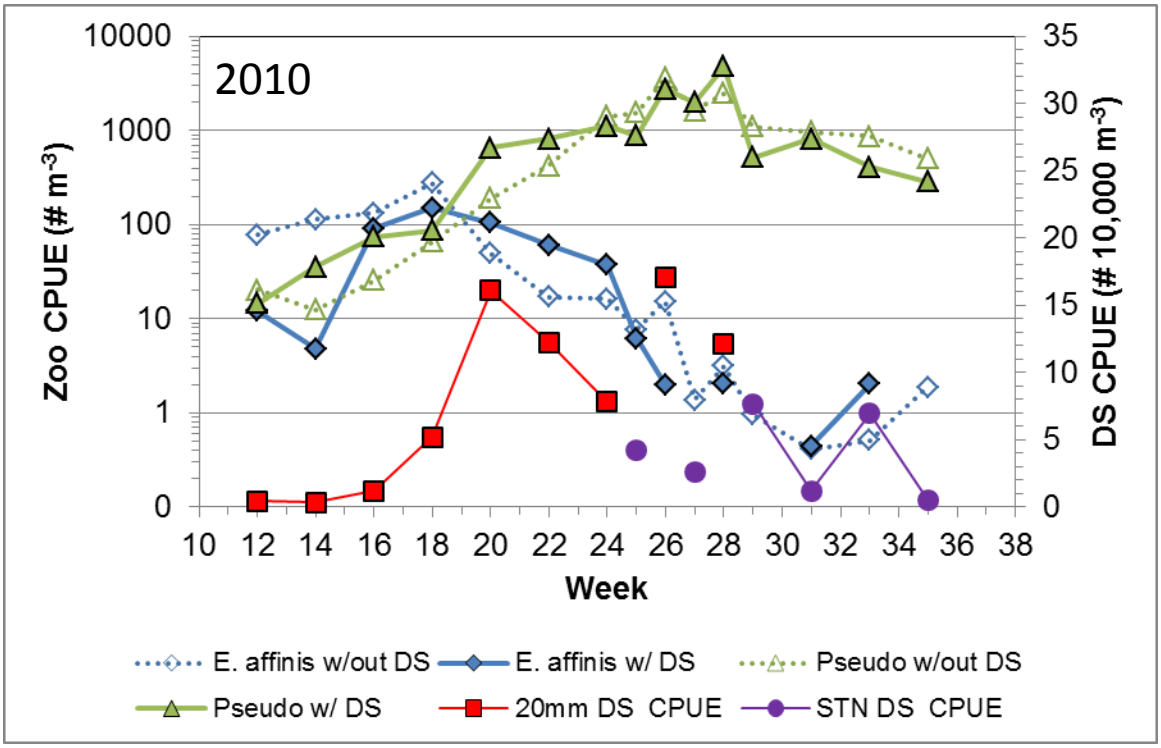

Rio Vista 2006 Temperatures
Mean Daily Temperature
25
20
15
10
5
0
50
100
150
200
Calendar Day

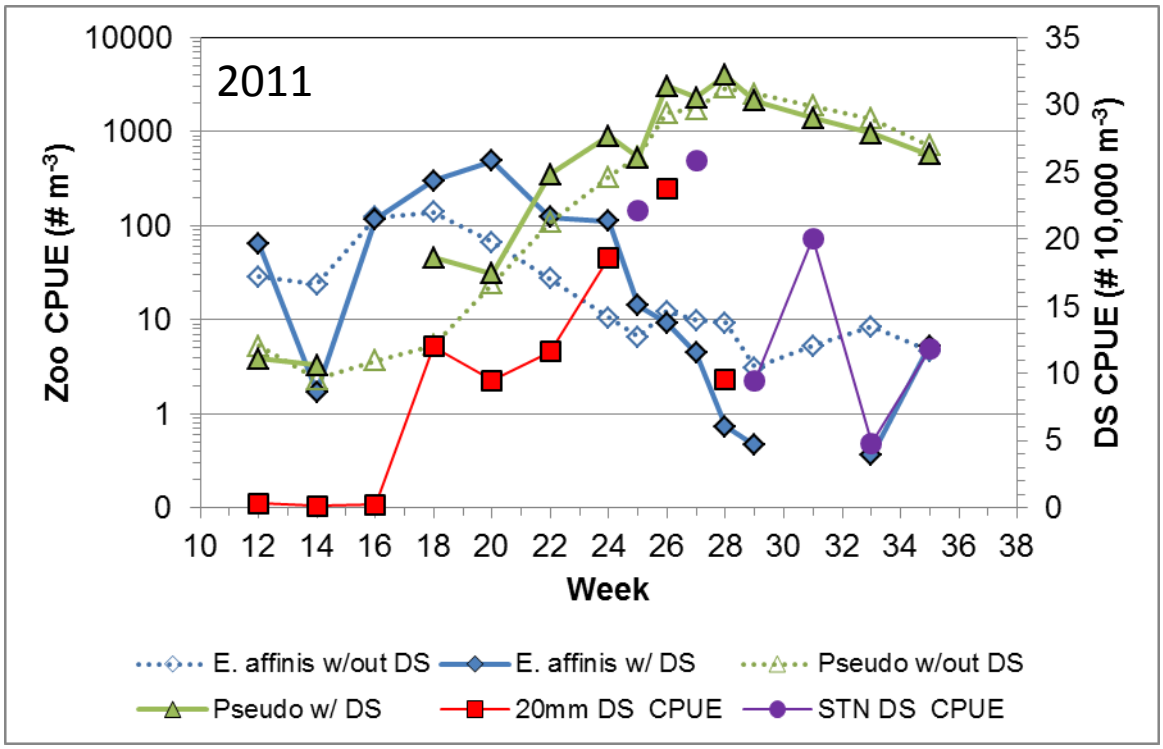

Rio Vista 2010 Temperatures
Mean Daily Temperature
25
20
15
10
5
0
50
100
150
200
Calendar Day

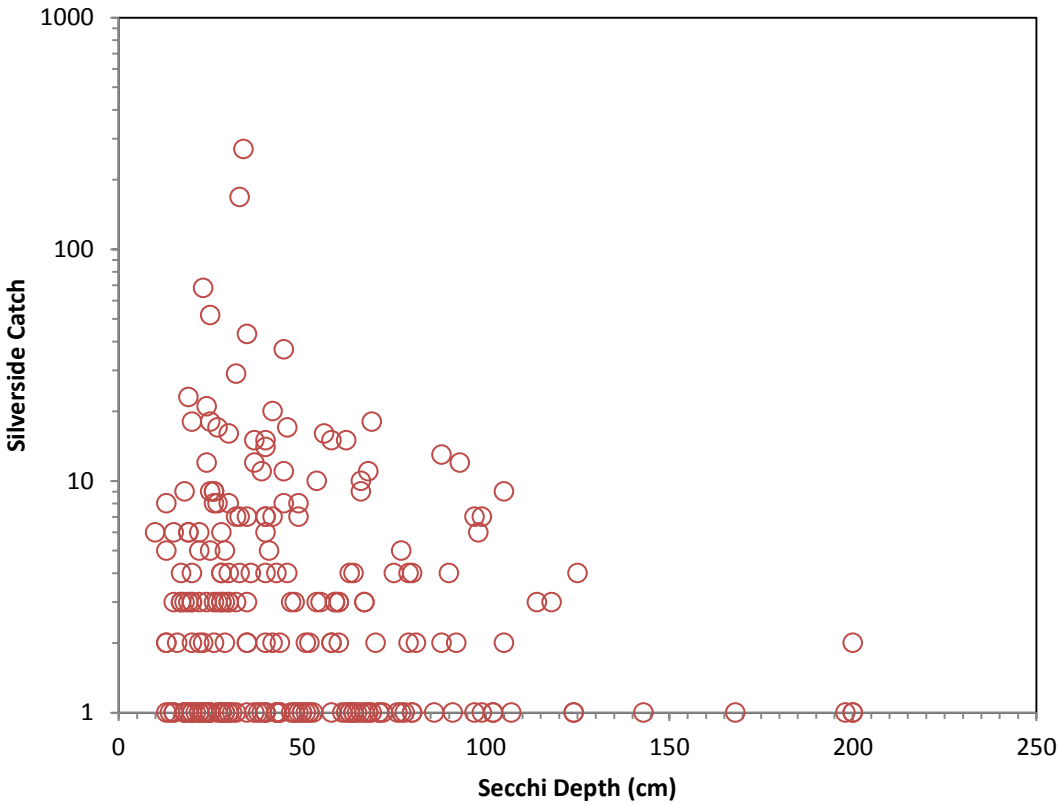

Rio Vista 2011 Temperatures
Mean Daily Temperature
25
20
15
10
5
0
50
100
150
200
Calendar Day

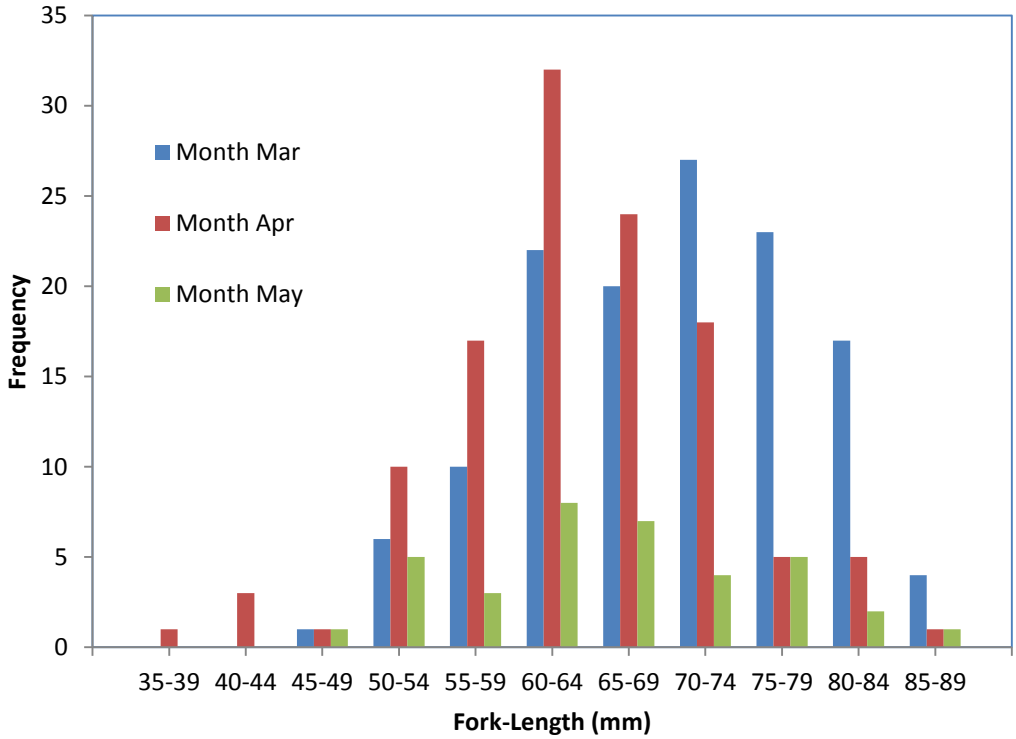

2005
Zoo CPUE (# m-3)
DS CPUE (# 10,000 m-3)
Week
E. affinis w/out DS
E. affinis w/ DS
Pseudo w/out DS
Pseudo w/ DS
20mm DS CPUE
STN DS CPUE

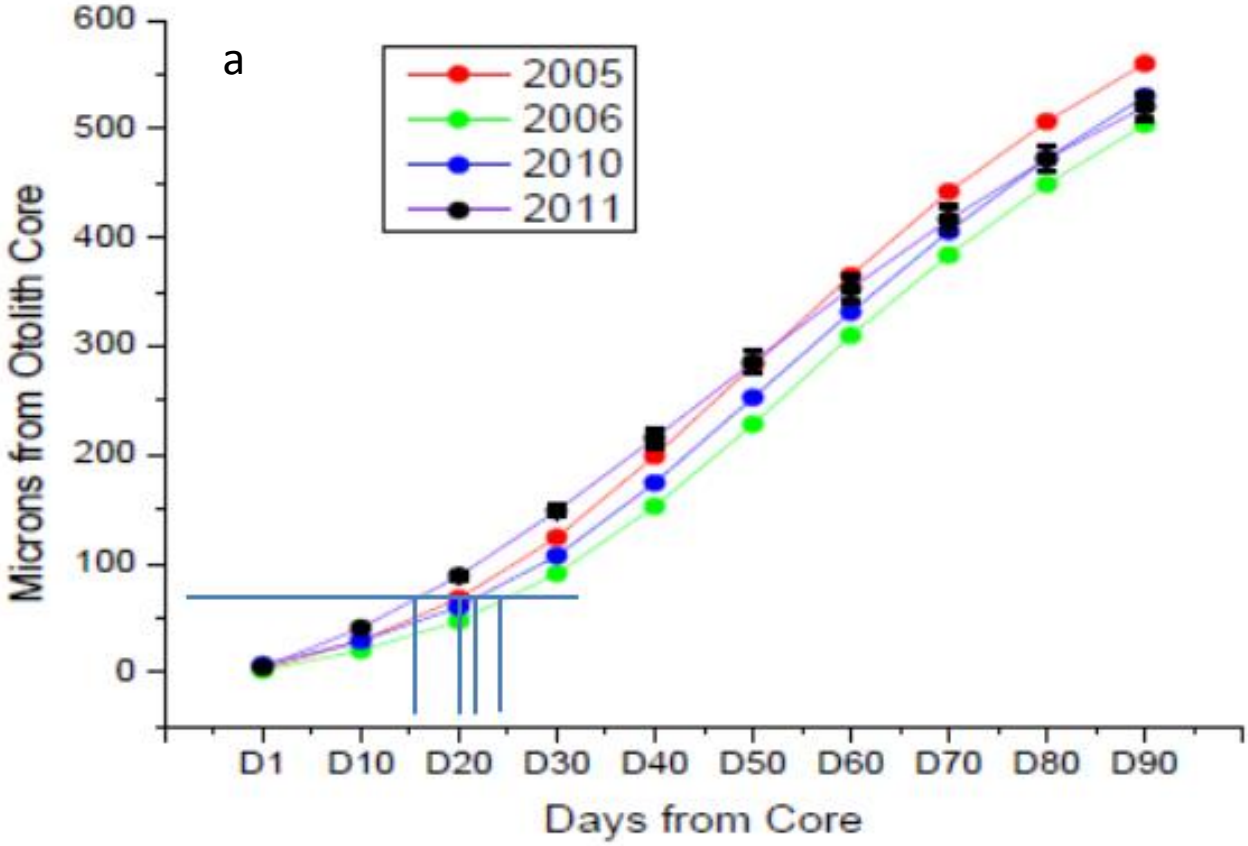

2006
Zoo CPUE (# m-3)
DS CPUE (# 10,000 m-3)
Week
E. affinis w/out DS
E. affinis w/ DS
Pseudo w/out DS
Pseudo w/ DS
20mm DS CPUE
STN DS CPUE

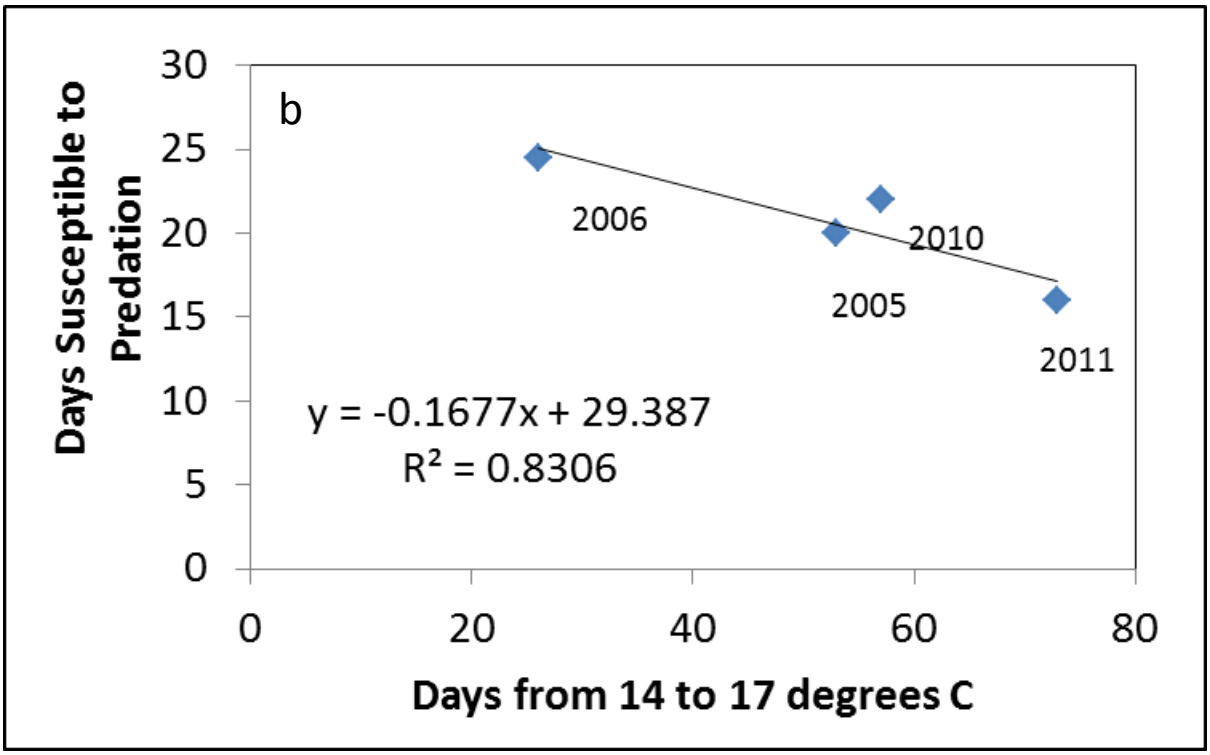

2010
Zoo CPUE (# m-3)
DS CPUE (# 10,000 m-3)
Week
E. affinis w/out DS
E. affinis w/ DS
Pseudo w/out DS
Pseudo w/ DS
20mm DS CPUE
STN DS CPUE

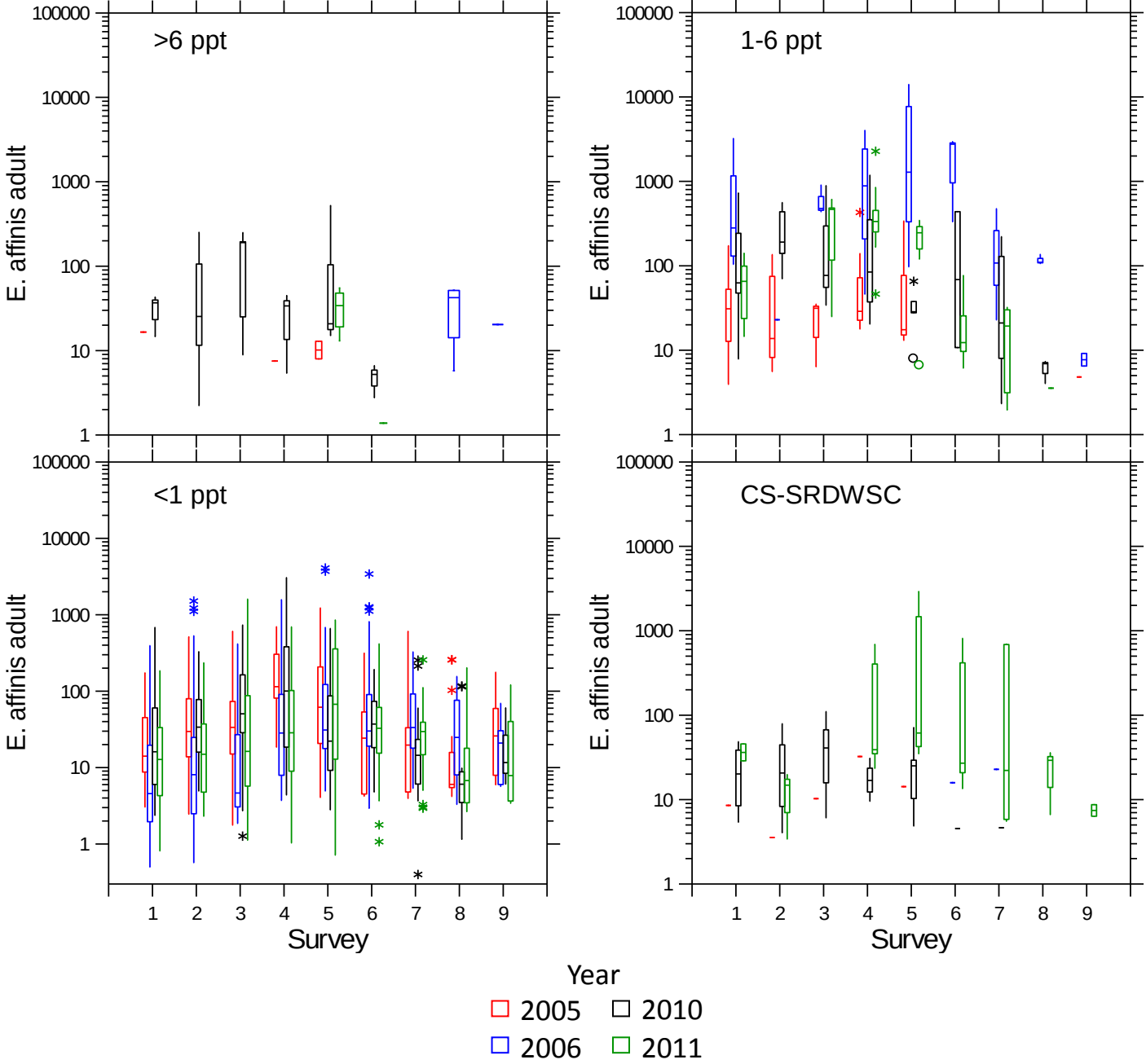

2011
Zoo CPUE (# m-3)
DS CPUE (# 10,000 m-3)
Week
E. affinis w/out DS
E. affinis w/ DS
Pseudo w/out DS
Pseudo w/ DS
20mm DS CPUE
STN DS CPUE

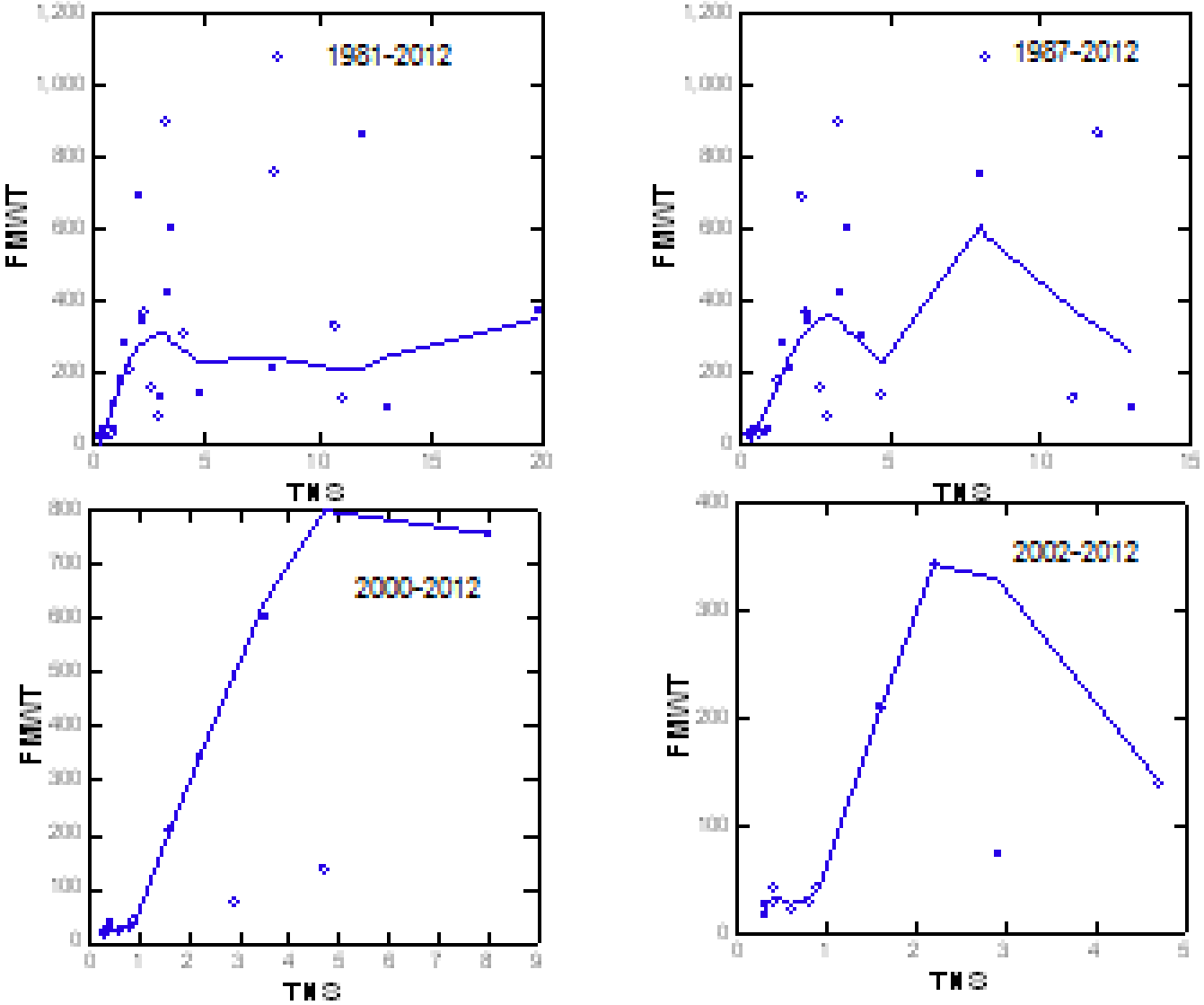

1000
100
10
1
Silverside Catch
0
50
100
150
200
250
Secchi Depth (cm)

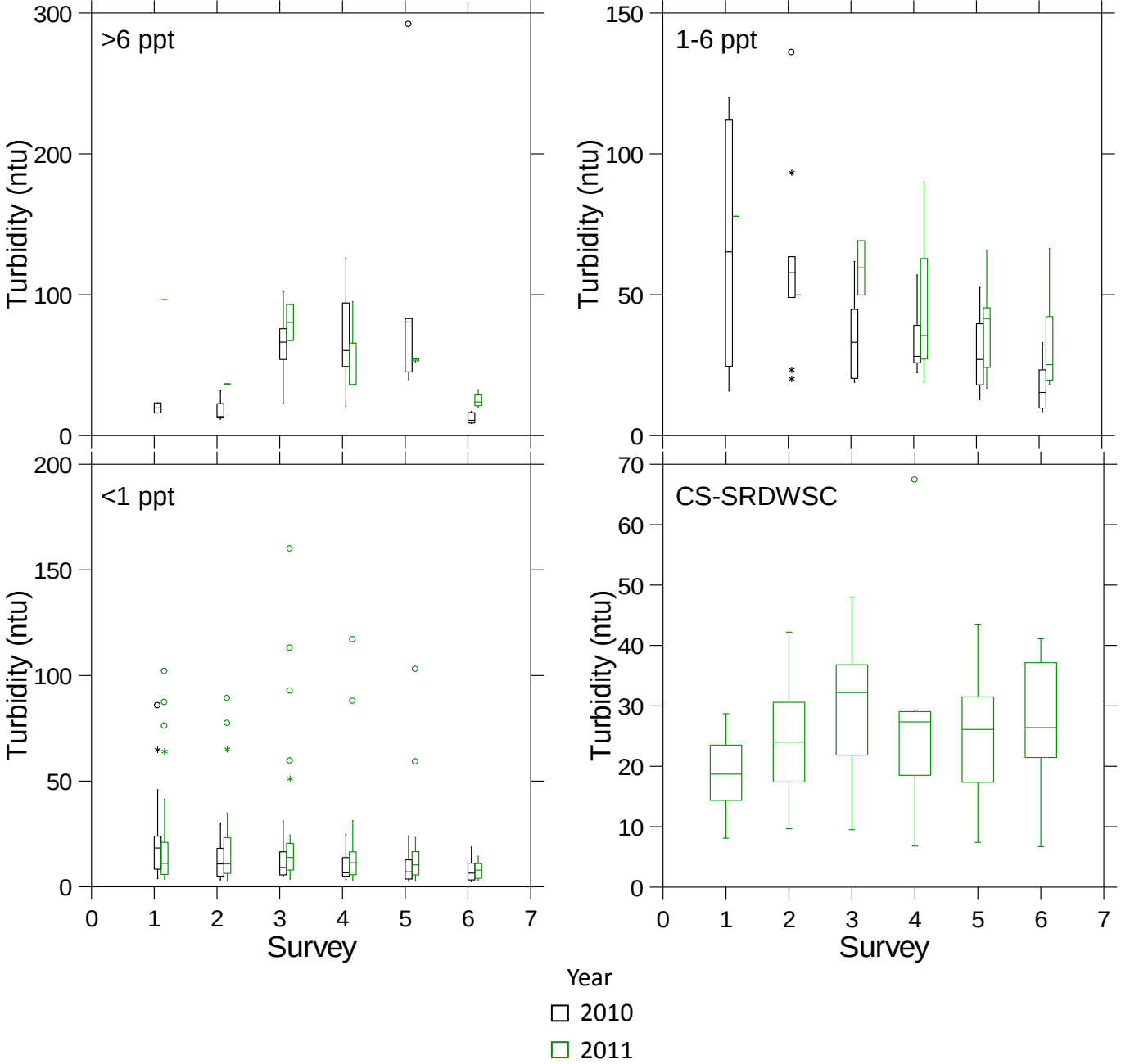

35
30
25
20
15
10
5
0
Frequency
Month Mar
Month Apr
Month May
35-39
40-44
45-49
50-54
55-59
60-64
65-69
70-74
75-79
80-84
85-89
Fork-Length (mm)

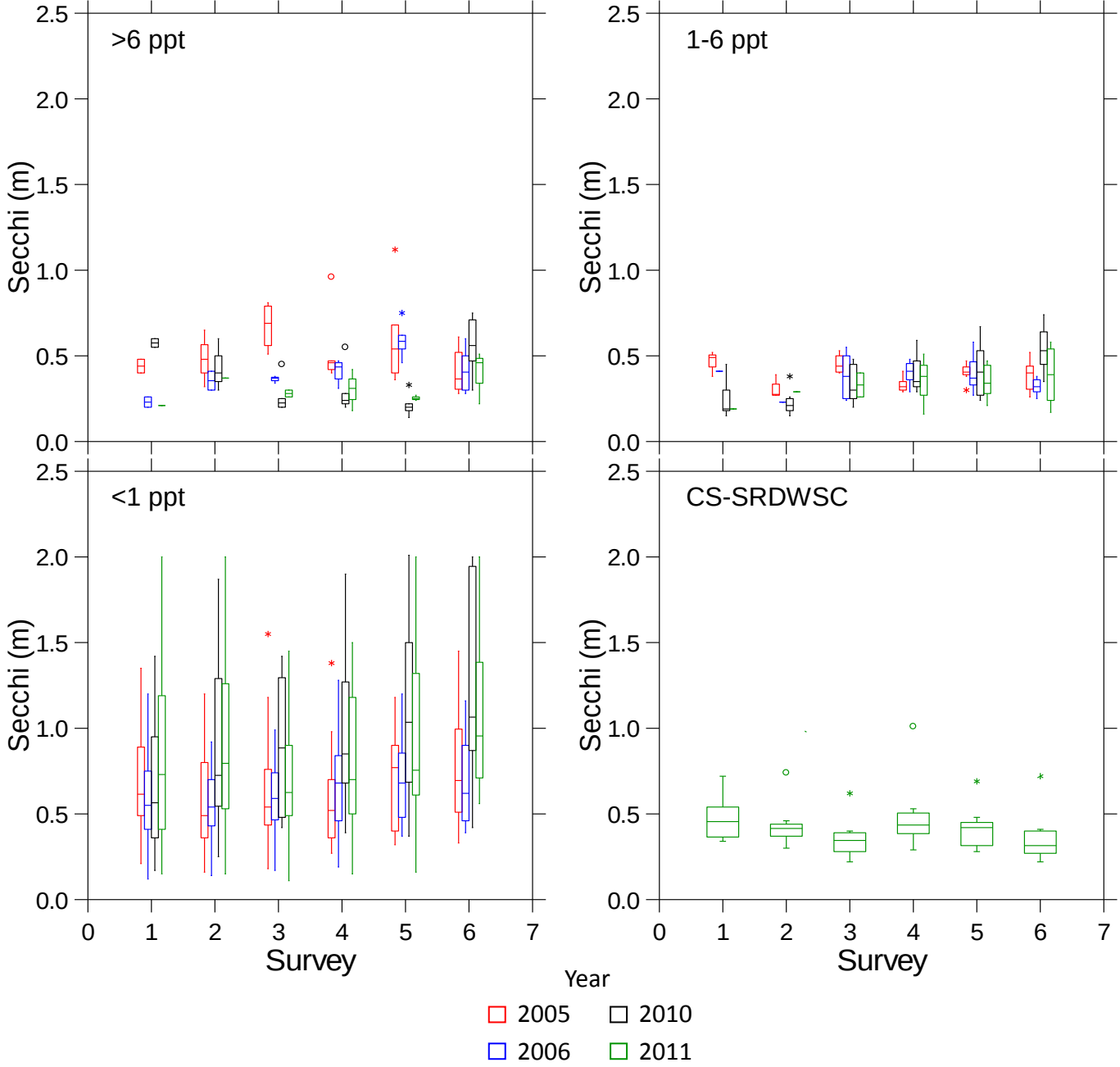

a
2005
2006
2010
2011
Microns from Otolith Core
600
500
400
300
200
100
0
D1
D10
D20
D30
D40
D50
D60
D70
D80
D90
Days from Core


b
Days Susceptible to Predation
30
25
20
15
10
5
0
2006
2010
2005
2011
y = -0.1677x + 29.387
R² = 0.8306
0
20
40
60
80
Days from 14 to 17 degrees C

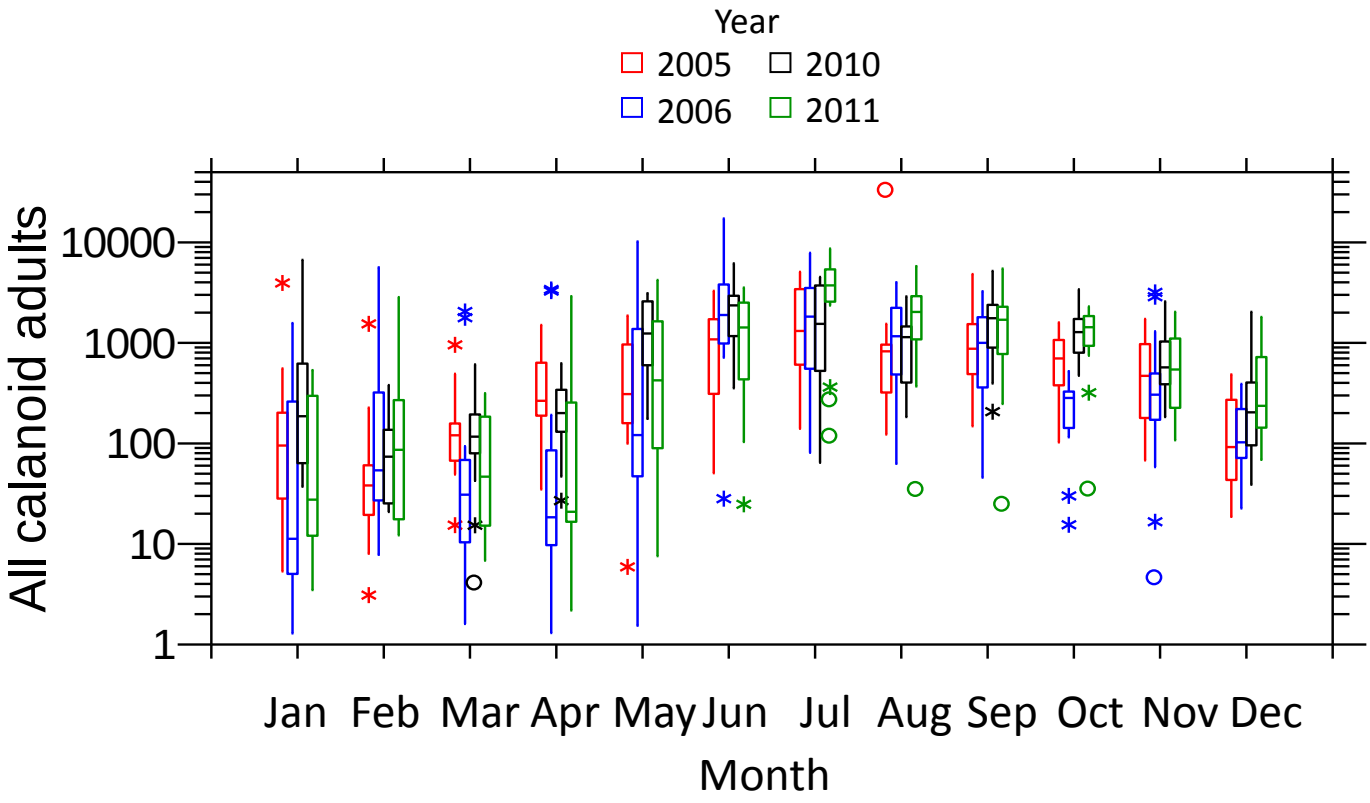

>6 ppt
1-6 ppt
<1 ppt
CS-SRDWSC
E. affinis adult
100000
10000
1000
100
10
1
1
2
3
4
5
6
7
8
9
Survey
Year
2005
2010
2006
2011

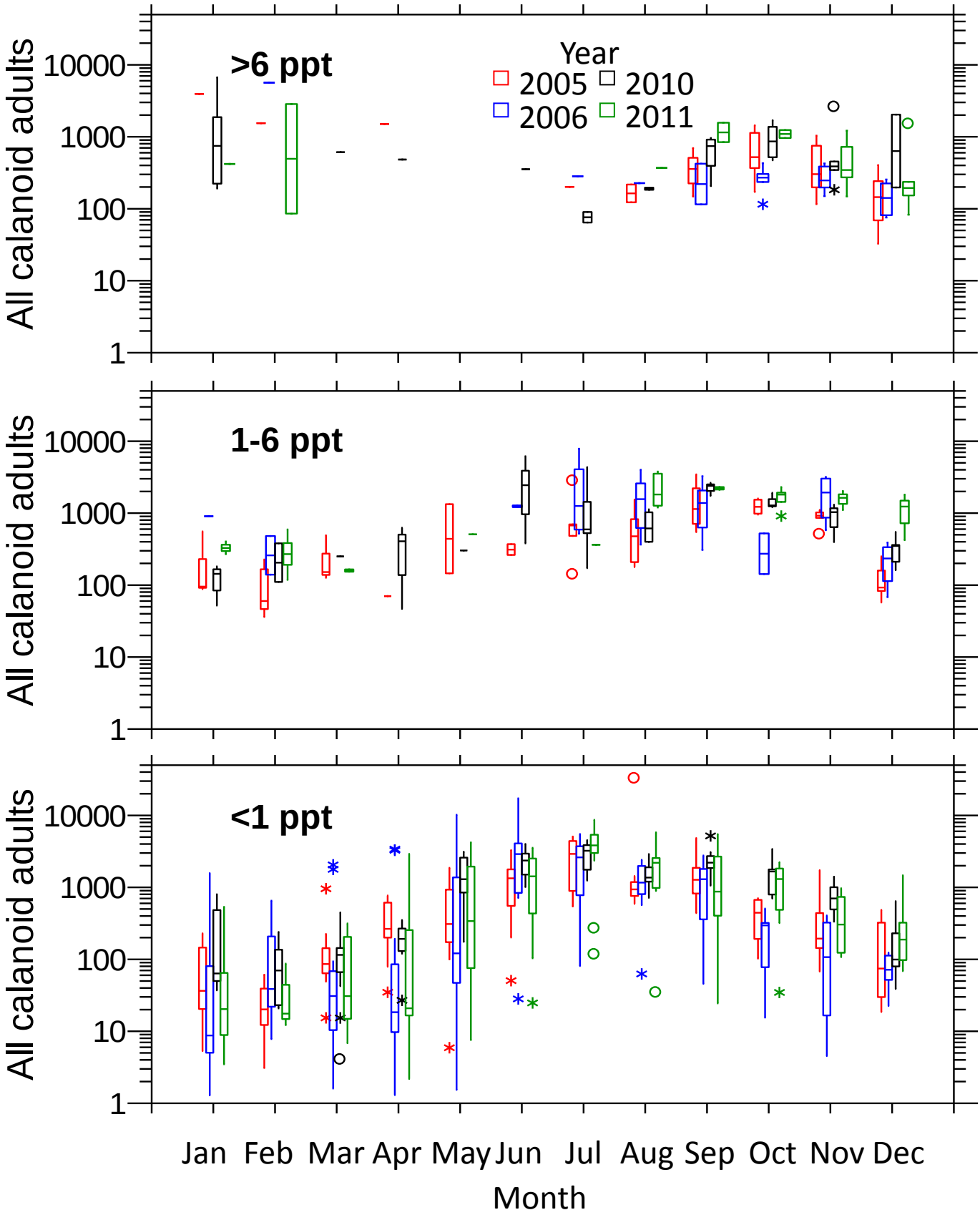

1981-2012
1987-2012
2000-2012
2002-2012
FMWT
TMS

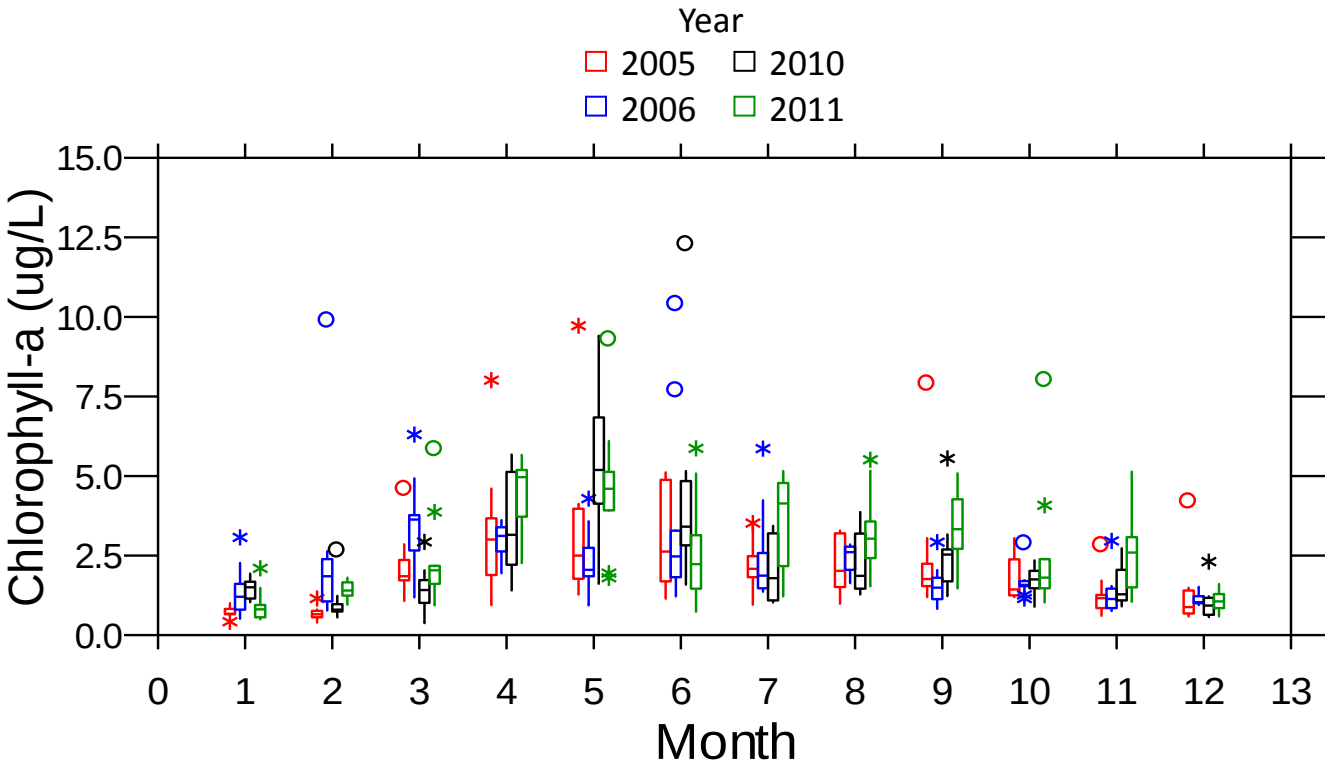

>6 ppt
1-6 ppt
<1 ppt
CS-SRDWSC
Turbidity (ntu)
Survey
Year
2010
2011

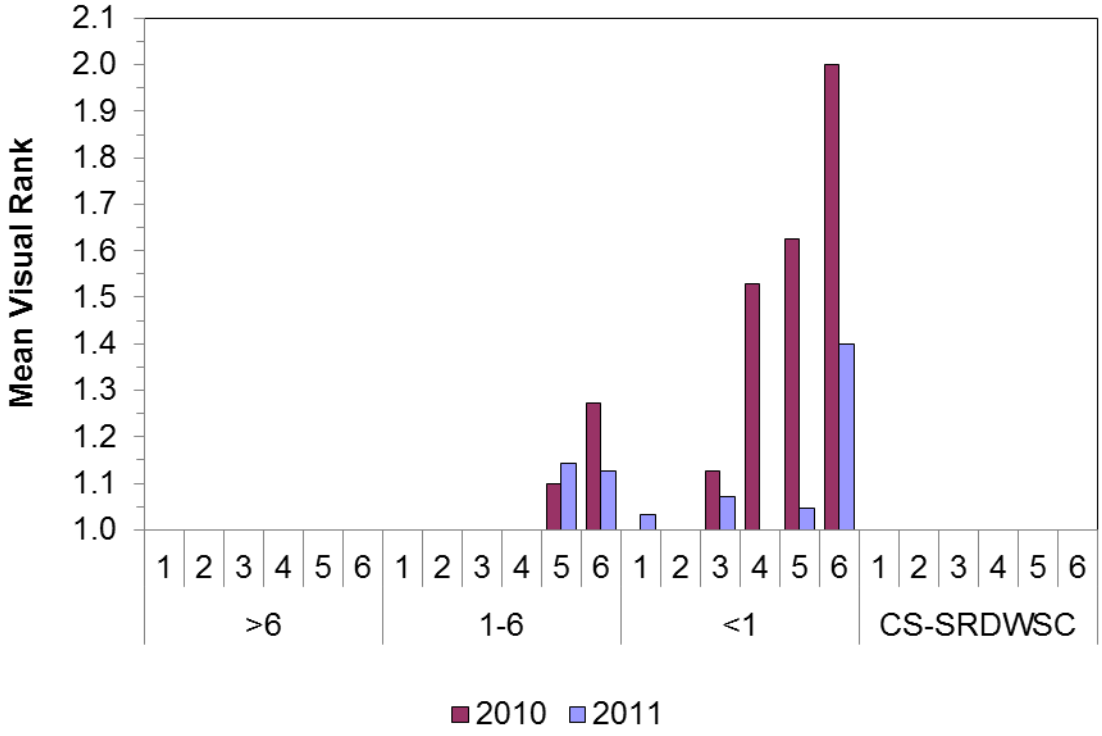


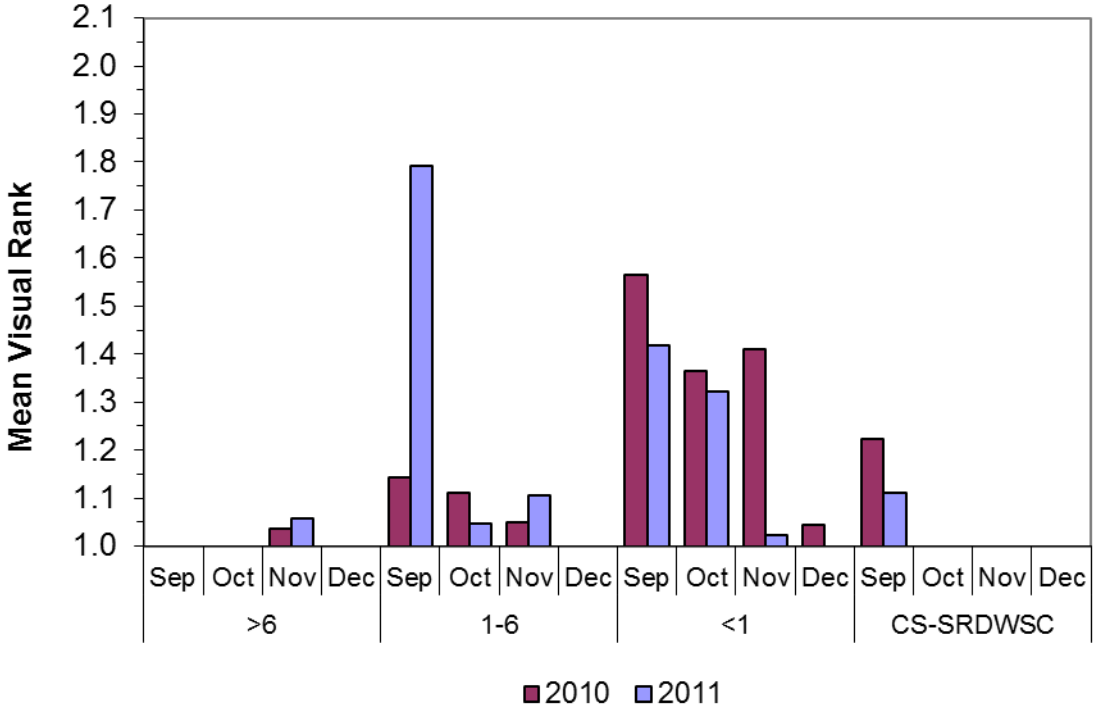
Secchi depth data collected during the Summer Townet Survey. Surveys are conducted biweekly June-August.


Year
2005
2010
2006
2011
All calanoid adults
10000
1000
100
10
1
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month


>6 ppt
1-6 ppt
<1 ppt
Year
2005
2006
2010
2011
All calanoid adults
10000
1000
100
10
1
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month


Year
2005
2010
2006
2011
Chlorophyll-a (ug/L)
15.0
12.5
10.0
7.5
5.0
2.5
0.0
0
1
2
3
4
5
6
7
8
9
10
11
12
13
Month


Mean Visual Rank
2.1
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
1 2 3 4 5 6 1 2 3 4 5 6 1 2 3 4 5 6 1 2 3 4 5 6
>6
1-6
<1
CS-SRDWSC
2010
2011


Mean Visual Rank
2.1
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
Sep
Oct
Nov
Dec
Sep
Oct
Nov
Dec
Sep
Oct
Nov
Dec
Sep
Oct
Nov
Dec
>6
1-6
<1
CS-SRDWSC
2010
2011