National Park Service
U.S. Department of the Interior

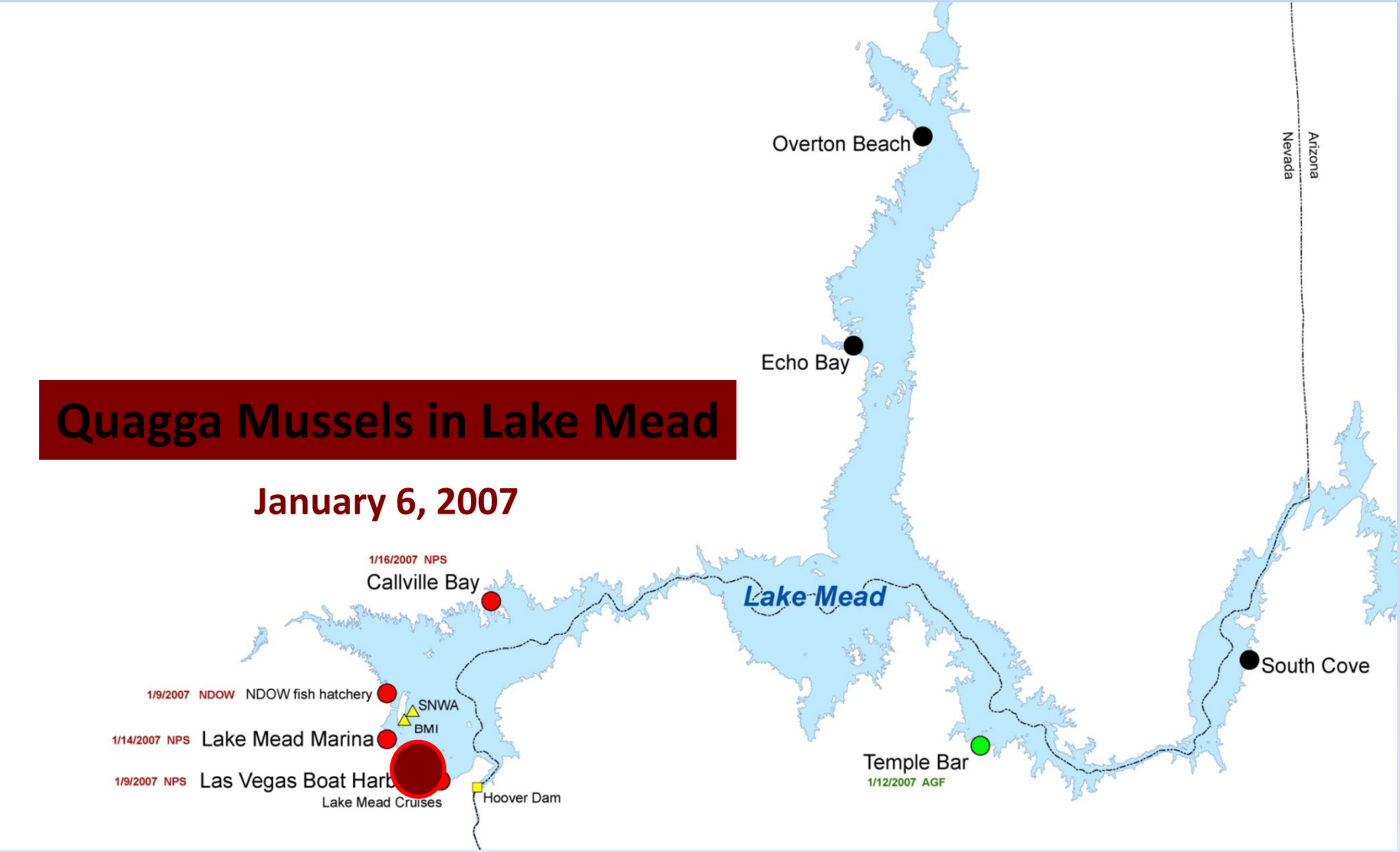
Lake Mead National Recreation Area
Resource Management Division

Interagency Monitoring Action Plan (I-MAP): Quagga Mussels in the Lower Colorado River Basin

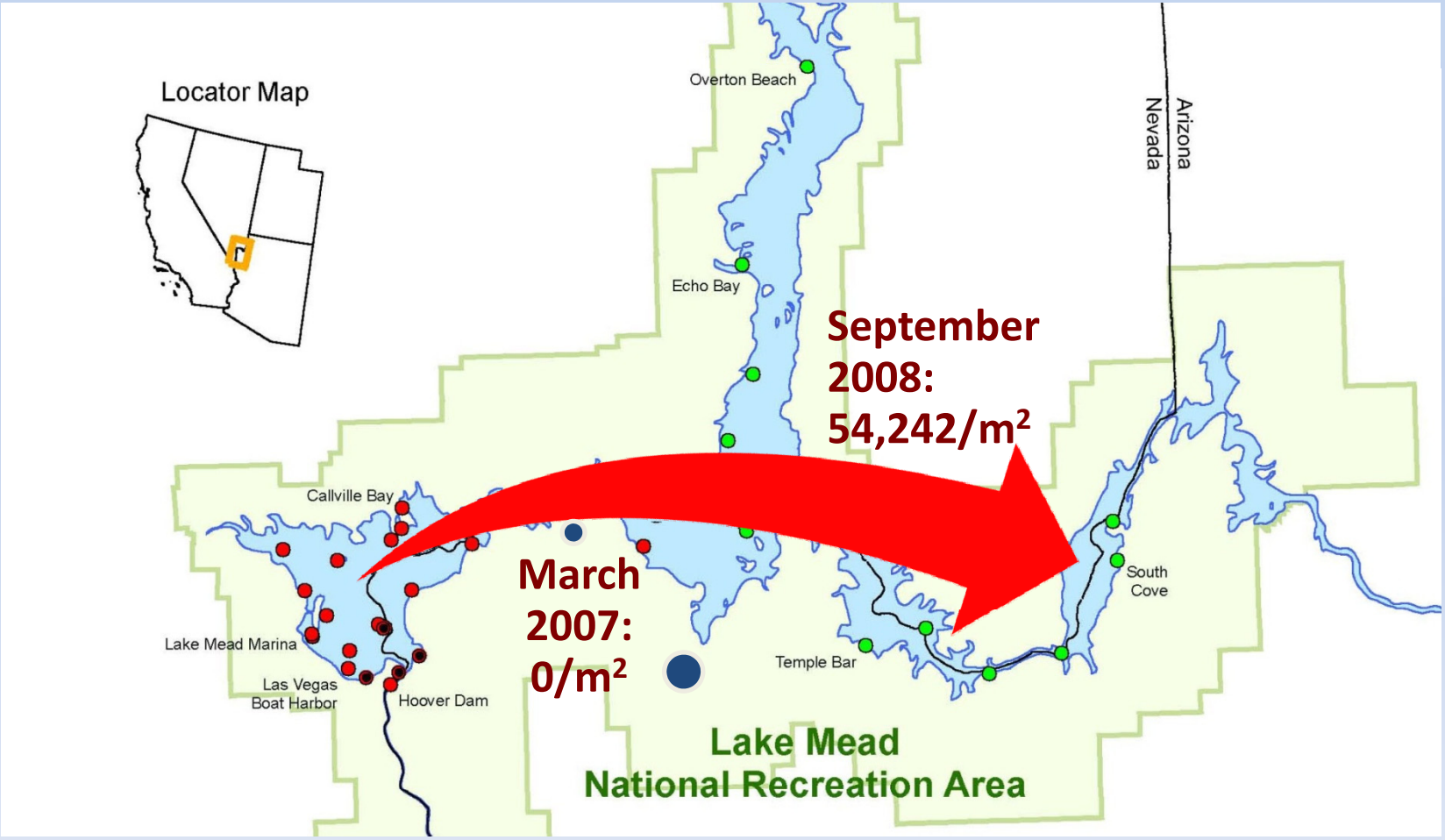
David Wong: UNLV
Ashlie Watters: NPS/GBI

May 24, 2012

Introduction: I-MAP Background



Quagga Mussels Spread Quickly



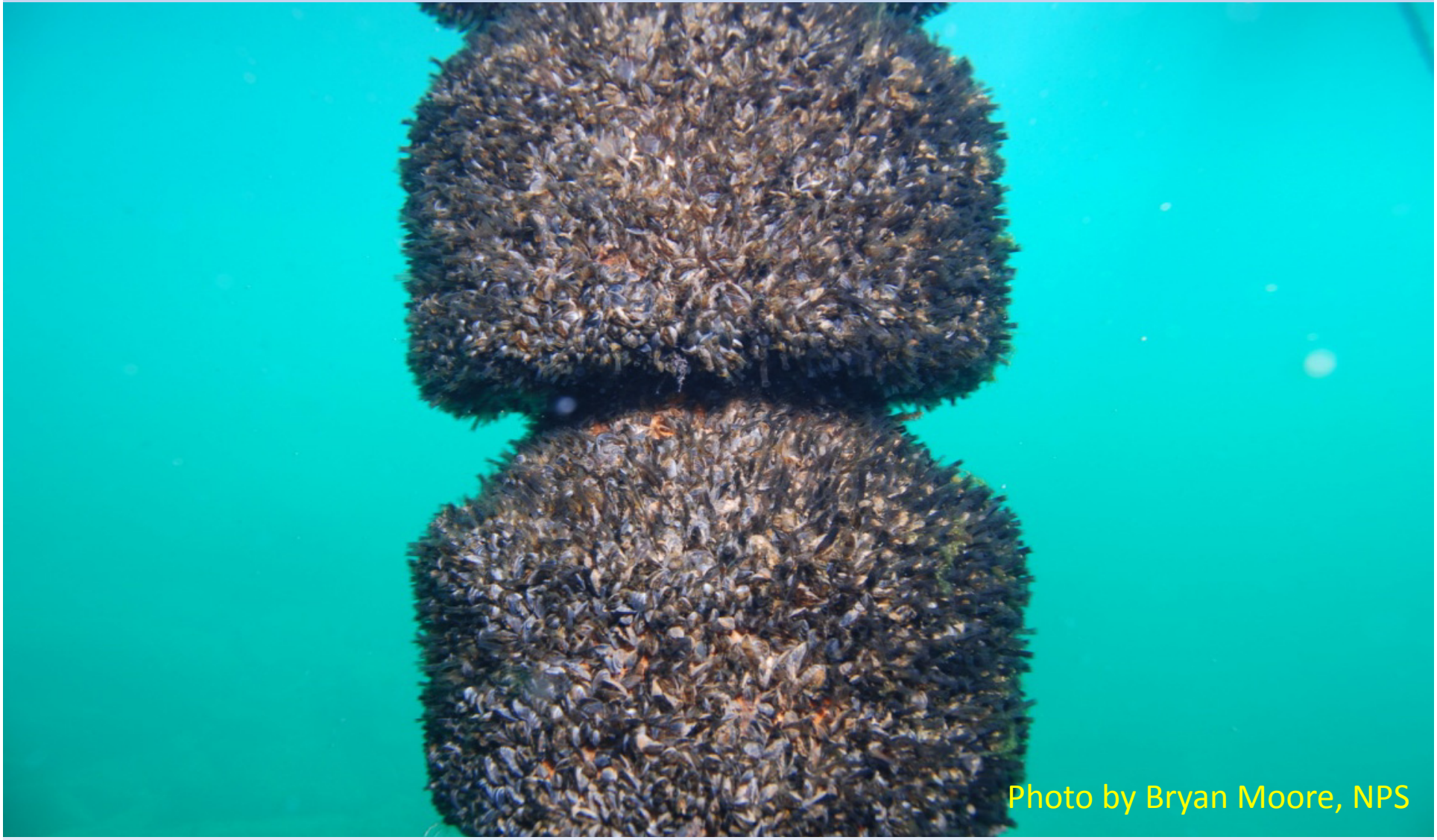
quagga mussels
high water mark
Boulder Basin
Photo courtesy of USBR/Becky Blasius and Janet Kirsch

Mussel Bed at Lake Bottom

Hoover Dam Water Intake

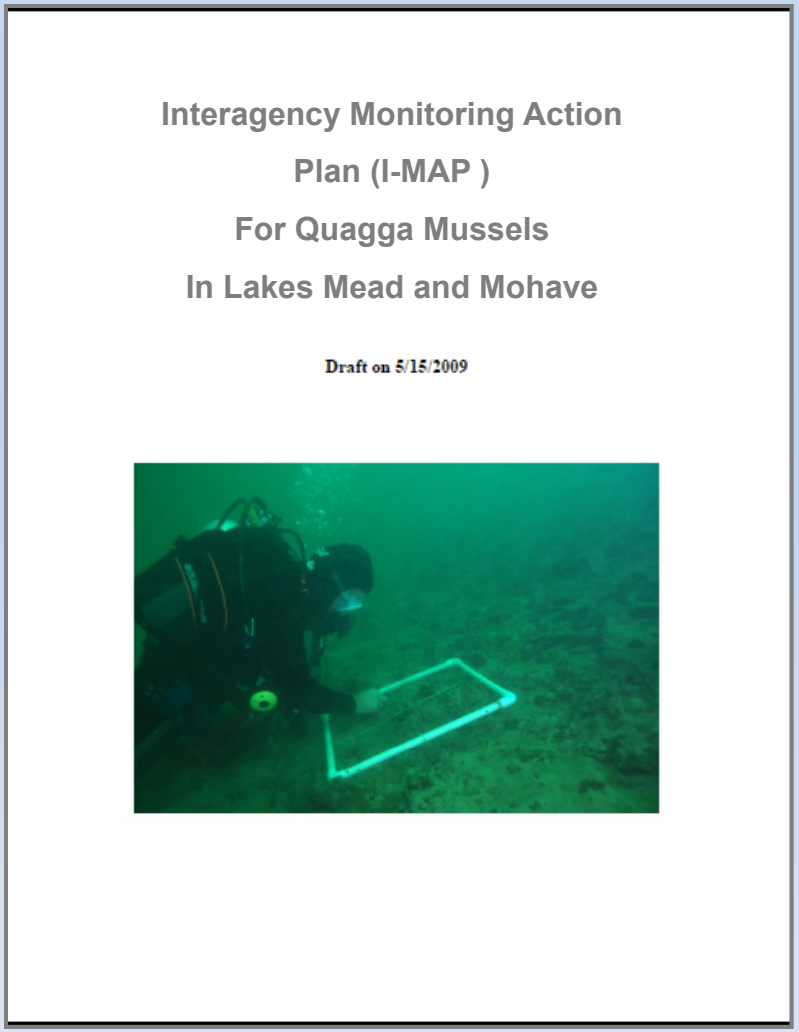
SNWA Water Intake

NPS Water Intake



Interagency Monitoring Action Plan (I-MAP)

1. I-MAP Members
2. Monitoring Programs



Interagency Monitoring Action

Plan (I-MAP)

For Quagga Mussels

In Lakes Mead and Mohave

Draft on 5/15/2009

Interagency Monitoring on Quagga Mussels

I-MAP Programs and Participants

Monitoring	Participating Agencies
1. Quagga Mussels (adults, juveniles, and veligers)	CWC NDOW NPS SNWA UNLV USBR
2. Water Quality	CWC NPS SNWA USBR USGS
3. Fish and Invertebrates	NDOW NPS UNLV UNR
4. Infrastructure Maintenance and Public Education	NDOW NPS SNWA UNLV USBR

1. Monitoring Quagga Mussels

Adults

NPS/UNLV

7 transects: Quarterly

5 transects: Annual

Veligers

SNWA: 7 weekly stations

USBR: 23 monthly stations

UNLV: 1 weekly station

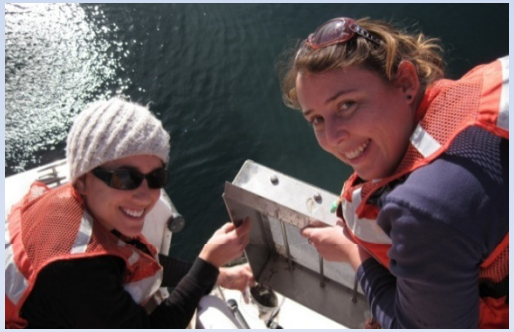
Contaminants

NPS/NDOW/UNLV: contaminants in quagga mussels, fish, and ducks

Substrates

NPS: Wen Baldwin

UNLV: six substrates

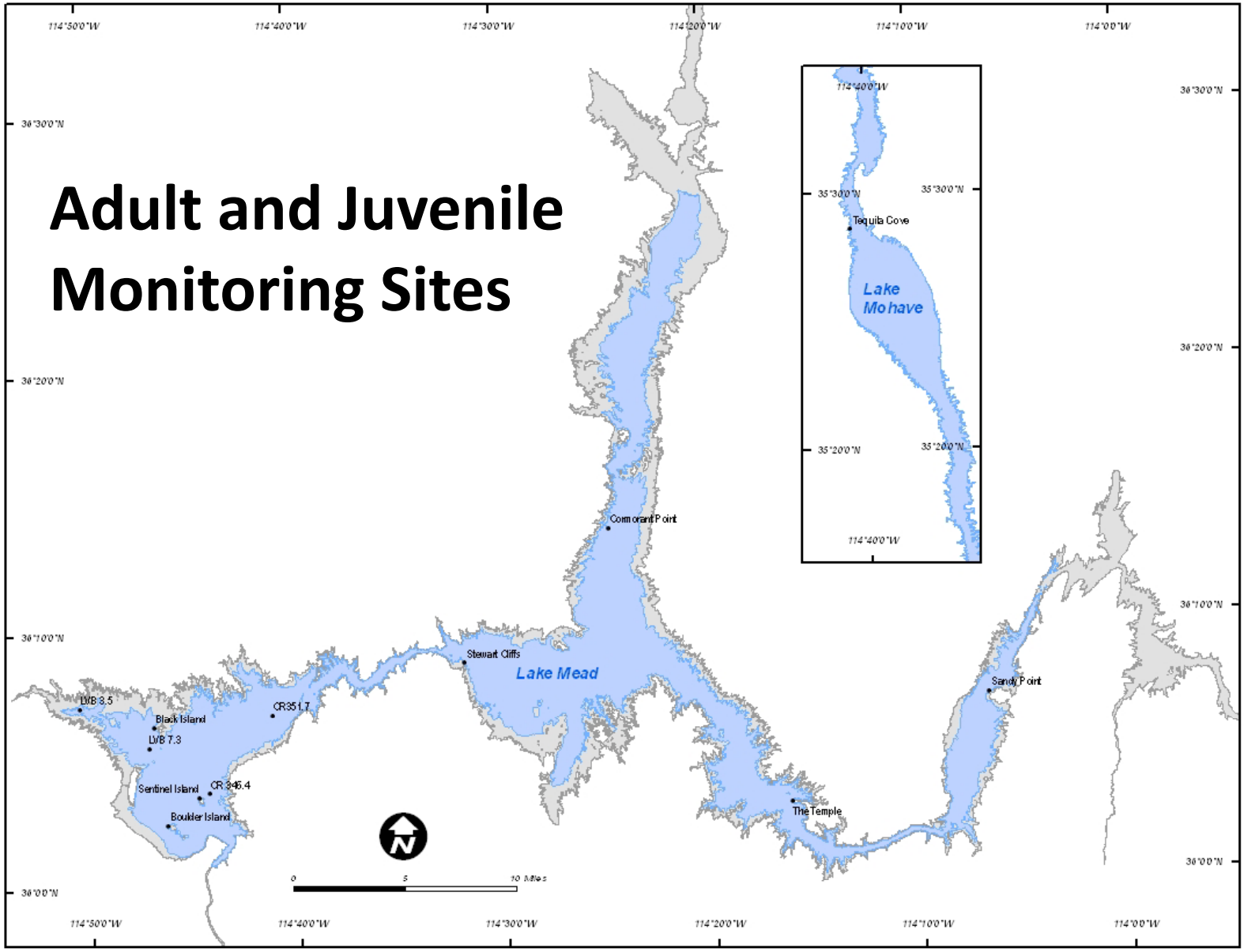


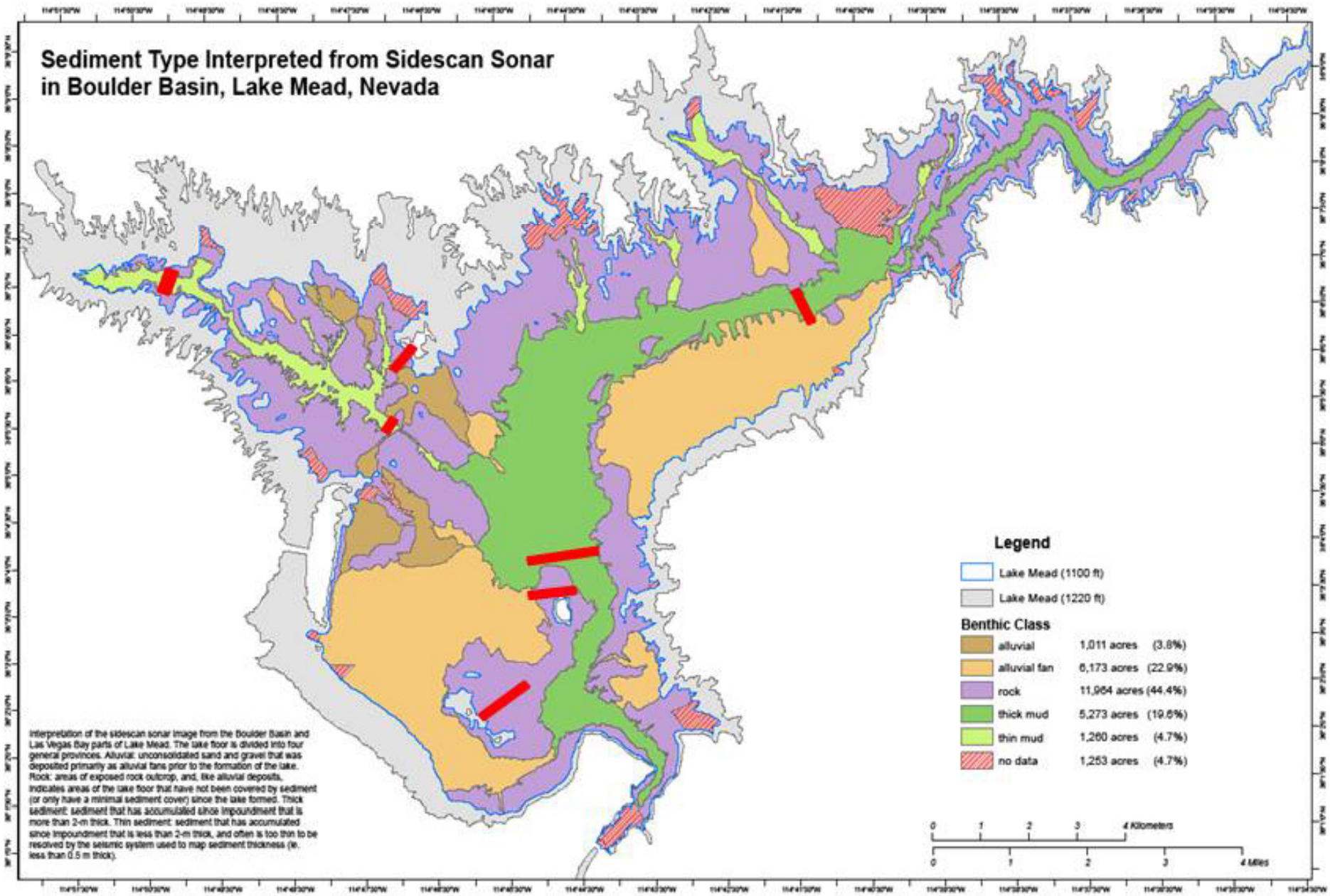
Adult and Juvenile Quagga Mussel Sampling Locations and Frequency

Transect	Station Name	Latitude	Longitude	Substrate	Sampling	Frequency
1	CR 346.4	36° 03' 42" N	114° 44' 21" W	Soft	Grab	Quarterly
2	LVB 7.3	36° 05' 29" N	114° 47' 15" W	Soft	Grab	Quarterly
3	LVB 3.5	36° 07' 05" N	114° 50' 30" W	Soft	Grab	Quarterly
4	CR351.7	36° 06' 42" N	114° 41' 14" W	Soft	Grab	Quarterly
5	Sentinel Island	36° 03' 34" N	114° 44' 48" W	Hard	Diving	Quarterly
6	Black Island	36° 06' 18" N	114° 46' 56" W	Hard	Diving	Quarterly
7	Boulder Island	36° 02' 30" N	114° 46' 20" W	Hard	Diving	Quarterly
8	Stewart Cliffs	36° 05' 09" N	114° 19' 10" W	Hard	Diving	Annual
9	Cormorant Point	36° 08' 14" N	114° 14' 53" W	Hard	Diving	Annual
10	The Temple	36° 01' 43" N	114° 09' 46" W	Hard	Diving	Annual
11	Sandy Point	36° 06' 58" N	114° 06' 41" W	Hard	Diving	Annual
12	Tequila Cove	35° 17' 08" N	114° 24' 26" W	Hard	Diving	Annual

Lakes Mead and Mohave

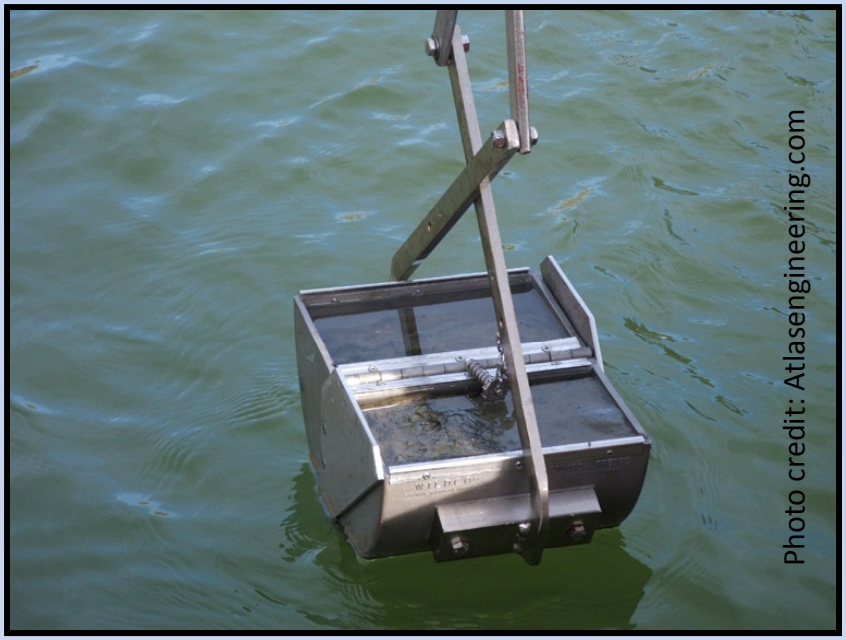
Adult and Juvenile Monitoring Sites




Sediment Type Interpreted from Sidescan Sonar
in Boulder Basin, Lake Mead, Nevada
Legend
Lake Mead (1100 ft)
Lake Mead (1220 ft)
Benthic Class
alluvial 1,011 acres (3.8%)
alluvial fan 6,173 acres (22.9%)
rock 11,964 acres (44.4%)
thick mud 5,273 acres (19.6%)
thin mud 1,260 acres (4.7%)
no data 1,263 acres (4.7%)
0 1 2 3 4 Kilometers
0 1 2 3 4 Miles
Interpretation of the sidescan sonar image from the Boulder Basin and Las Vegas Bay parts of Lake Mead. The lake floor is divided into four general provinces. Alluvial: unconsolidated sand and gravel that was deposited primarily as alluvial fans prior to the formation of the lake. Rock: areas of exposed rock outcrop, and, like alluvial deposits, indicates areas of the lake floor that have not been covered by sediment (or only have a minimal sediment cover) since the lake formed. Thick sediment: sediment that has accumulated since impoundment that is more than 2-m thick. Thin sediment: sediment that has accumulated since impoundment that is less than 2-m thick, and often is too thin to be resolved by the seismic system used to map sediment thickness (ie. less than 0.5 m thick).

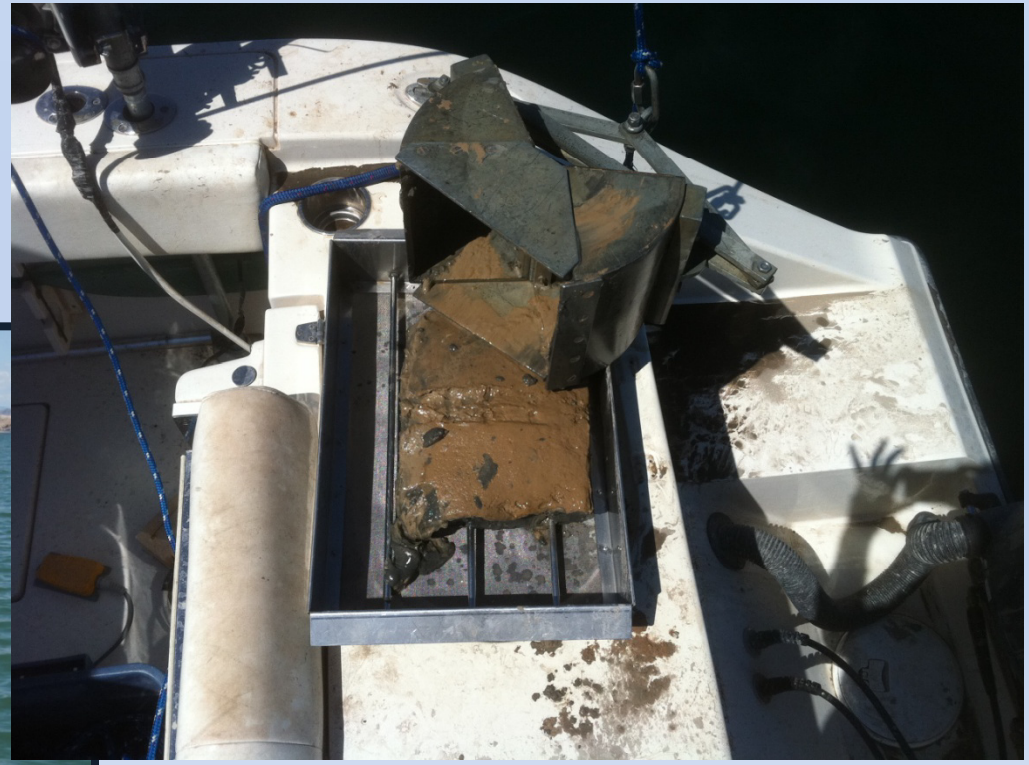
Ponar Grabs

- Sampling occurs quarterly at the following locations:



Transect	Station Name	Latitude	Longitude	Substrate	Frequency
1	CR 346.4	36° 03’ 42”N	114° 44’21” W	Soft	Quarterly
2	LVB 7.3	36° 05’ 29” N	114° 47’15” W	Soft	Quarterly
3	LVB 3.5	36° 07’ 05” N	114° 50’30” W	Soft	Quarterly
4	CR351.7	36° 06’ 42” N	114° 41’14” W	Soft	Quarterly

Ponar Grab



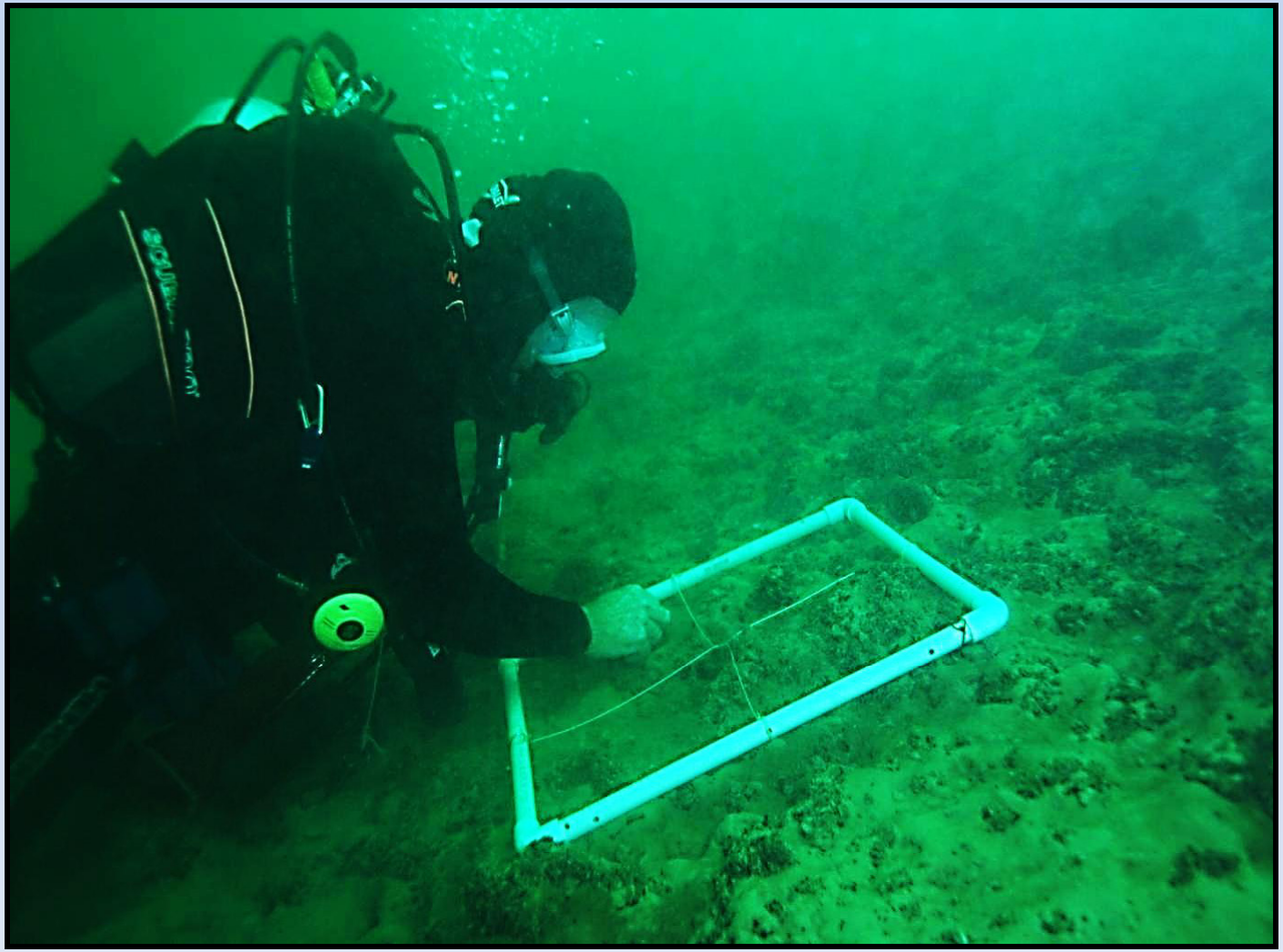
Ponar Grab

Boulder Basin Quagga Mussel Transects

Dive transects in Boulder Basin were conducted on a quarterly basis beginning in 2007 at the following sites:

Transect	Station Name	Latitude	Longitude	Substrate	Frequency
5	Sentinel Island	36° 03’ 34” N	114° 44’ 48” W	Hard	Quarterly
6	Black Island	36° 06’ 18” N	114° 46’ 56” W	Hard	Quarterly
7	Boulder Island	36° 02’ 30” N	114° 46’ 20” W	Hard	Quarterly

Dive Sampling Sites



Quagga mussel veliger monitoring stations in Lake Mead

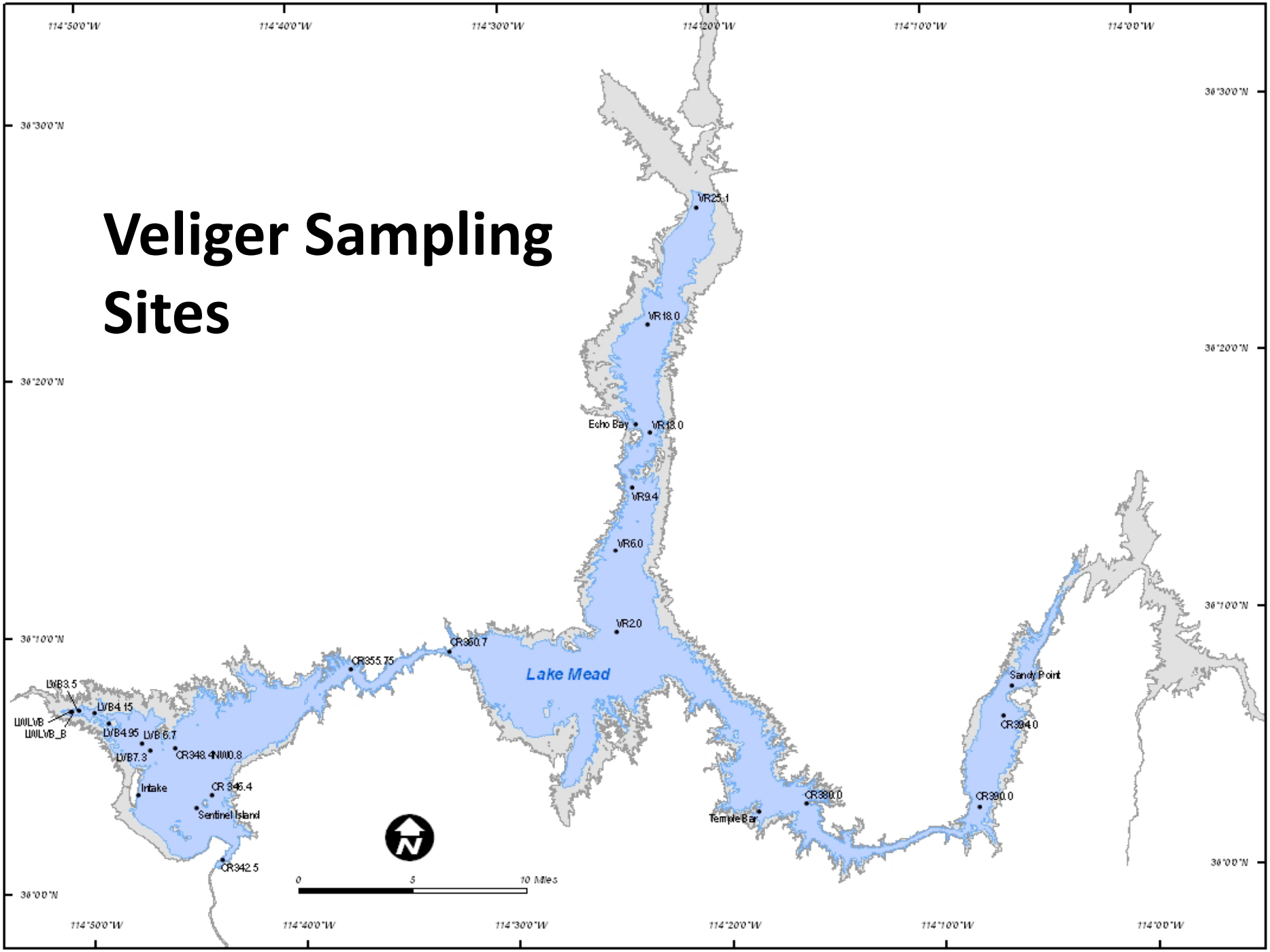
Station	Station Name	Latitude	Longitude	Agency	Smpling Frequency	Sampling Mode
1	LWLVB	36° 07' 04.19" N	114° 50' 56.65" W	BOR/SNWA	Weekly	Zooplankton
2	LWLVB_B	36° 07'0 3.58" N	114° 50' 51.25" W	SNWA	Weekly	Zooplankton
3	LVB4.15	36° 07' 00.82" N	114° 49' 49.50" W	BOR/SNWA	Weekly	Zooplankton
4	LVB 6.7	36° 05' 46.03" N	114° 47' 35.27" W	SNWA	Weekly	Zooplankton
5	INTAKE	36° 03' 47.05" N	114° 47' 51.32" W	SNWA	Weekly	Zooplankton
6	CR 346.4	36° 03' 41.96" N	114° 44' 20.88" W	BOR/SNWA	Weekly	Zooplankton
7	CR348.4NW0.8	36° 05' 34.85" N	114° 46' 03.97" W	SNWA	Weekly	Zooplankton
8	LVB3.5	36° 07' 04.92" N	114° 50' 33.42" W	BOR	Monthly	Zooplankton
9	LVB4.95	36° 06' 34.42" N	114° 49' 10.66" W	BOR	Monthly	Zooplankton
10	LVB7.3	36° 05' 29.39" N	114° 47' 14.76" W	BOR	Monthly	Zooplankton
11	CR342.5	36° 01' 09.78" N	114° 43' 57.59" W	BOR	Monthly	Veliger/Zooplankton*
12	VRLM	Variable		BOR	Monthly	Zooplankton**
13	MRLM	Variable		BOR	Monthly	Zooplankton**
14	VR25.1	36° 26' 06.90" N	114° 20' 48.07" W	BOR	Monthly	Zooplankton
15	VR18.0	36° 21' 36.09" N	114° 23' 15.15" W	BOR	Monthly	Zooplankton
16	VR13.0	36° 17' 23.74" N	114° 23' 17.07" W	BOR	Monthly	Zooplankton
17	VR9.4	36° 15' 18.17" N	114° 24' 13.20" W	BOR	Monthly	Zooplankton
18	VR6.0	36° 12' 50.34" N	114° 25' 03.28" W	BOR	Monthly	Zooplankton
19	VR2.0	36° 09' 41.01" N	114° 25' 08.83" W	BOR	Monthly	Zooplankton
20	CRLM_A	Variable		BOR	Monthly	Zooplankton
21	CR394.0	36° 06' 00.70" N	114° 07' 00.51" W	BOR	Monthly	Zooplankton
22	CR390.0	36° 02' 29.59" N	114° 08' 17.24" W	BOR	Monthly	Zooplankton
23	CR380.0	36° 02' 48.30" N	114° 16' 24.09" W	BOR	Monthly	Zooplankton
24	CR360.7	36° 09' 05.11" N	114° 33' 02.48" W	BOR	Monthly	Zooplankton
25	CR355.75	36° 08' 28.97" N	114° 37' 41.66" W	BOR	Monthly	Zooplankton
26	Eco Bay	36° 17' 44.30" N	114° 23' 58.78" W	BOR	Monthly	Veliger
27	Temple Bar	36° 02' 33.36" N	114° 18' 38.34" W	BOR	Monthly	Veliger
28	Sandy Point	36° 07' 10.02" N	114° 06' 33.37" W	BOR	Monthly	Veliger
29	Sentinel Island	36° 03' 14.50" N	114° 45' 05.40" W	UNLV	Weekly	Veliger***

*Apart from regular zooplankton sampling, extra samples from 0-10 m and 0-30 m are collected for veliger counting only;

** These two sites are being monitored but these two will be combined as one if water level falls below approximately 1110 ft;

* **Multiple depths will be smapled at different depth (surface water, 0-5 m, 5-10 m, 10-20 m, 20-30 m, 30-40 m, 40-50 m, 50-60 m);

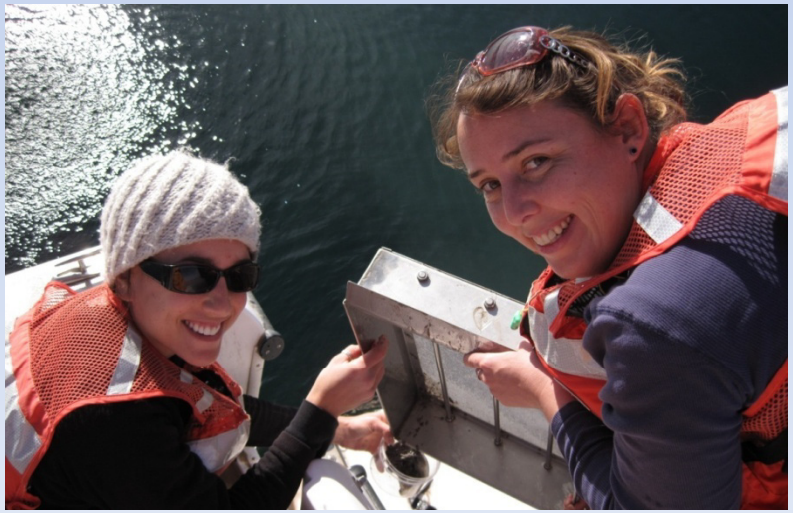
Veliger Sampling Sites



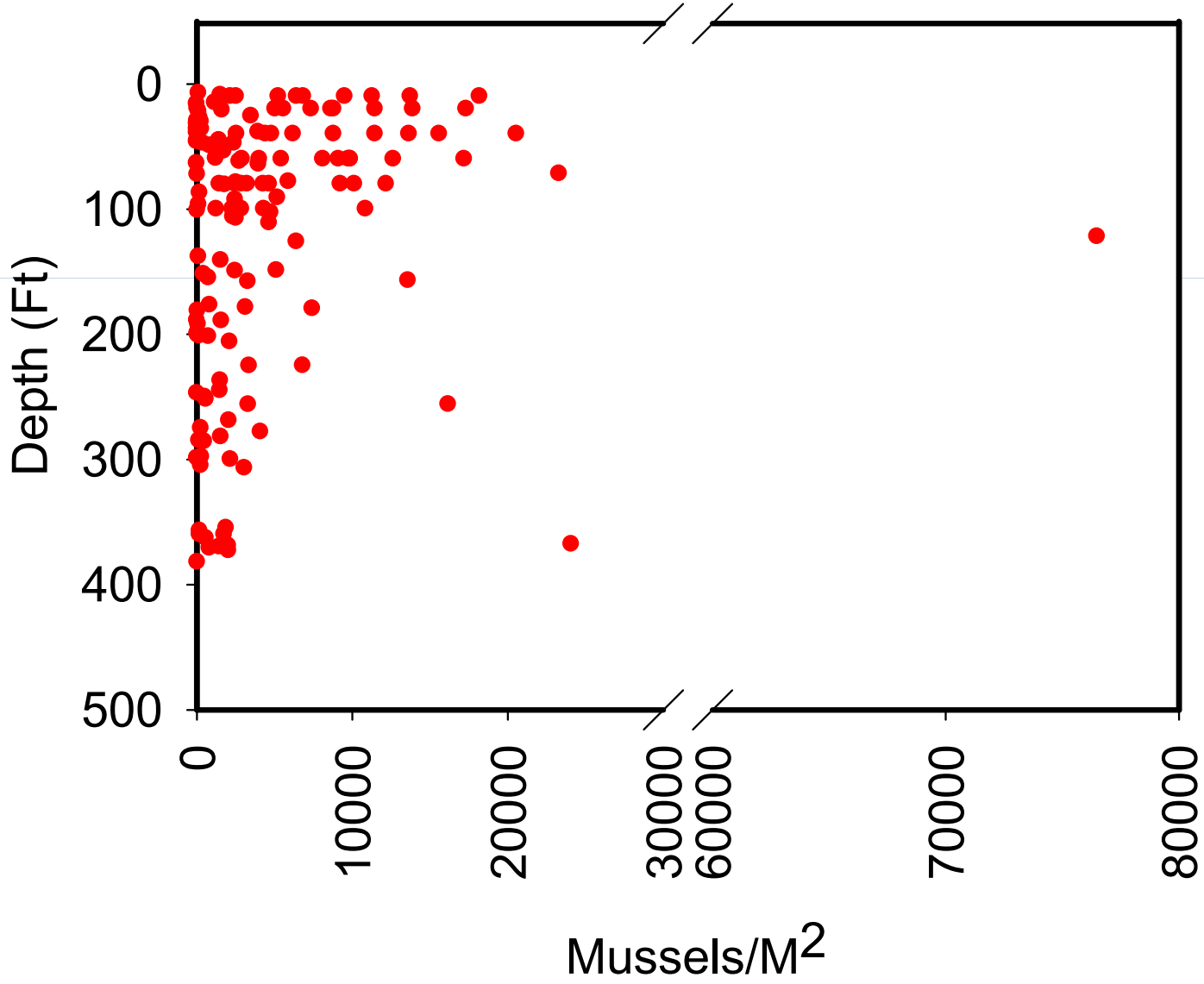
Results

Hard Substrates

Soft Substrates



Adult and Juvenile Quagga Mussels in Lake Mead (Fall 2009- Fall 2010)



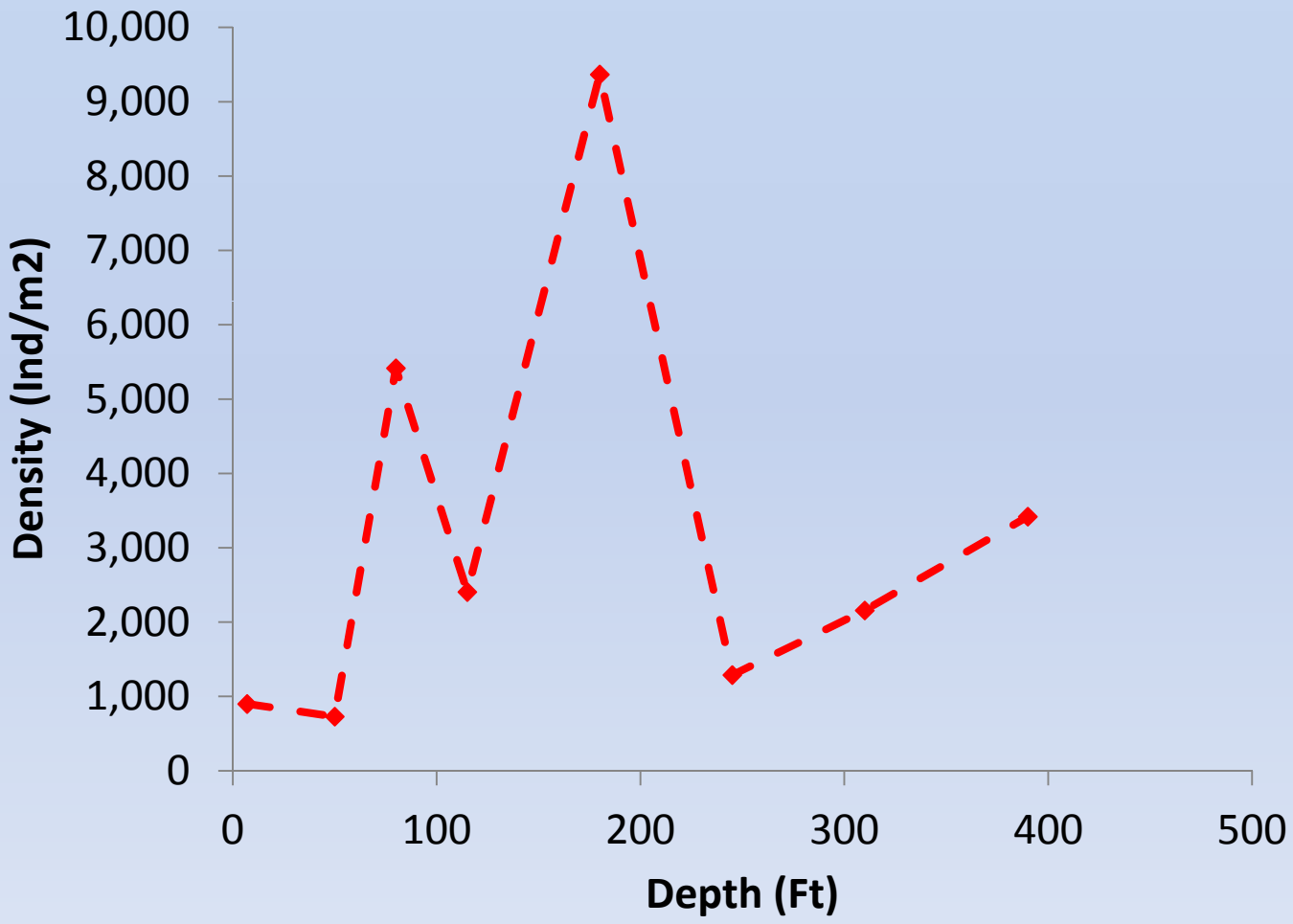
Data Analysis of I-MAP Adults: from Fall 2009 to Fall 2010

- **Density:**
  - hard substrate **8,078** mussels/m^2
  - soft sediment **3,014** mussels/m^2
- **No difference…**
  - among seasons
  - among epliminion, metalimnion, or hypolimnion
  - among basins

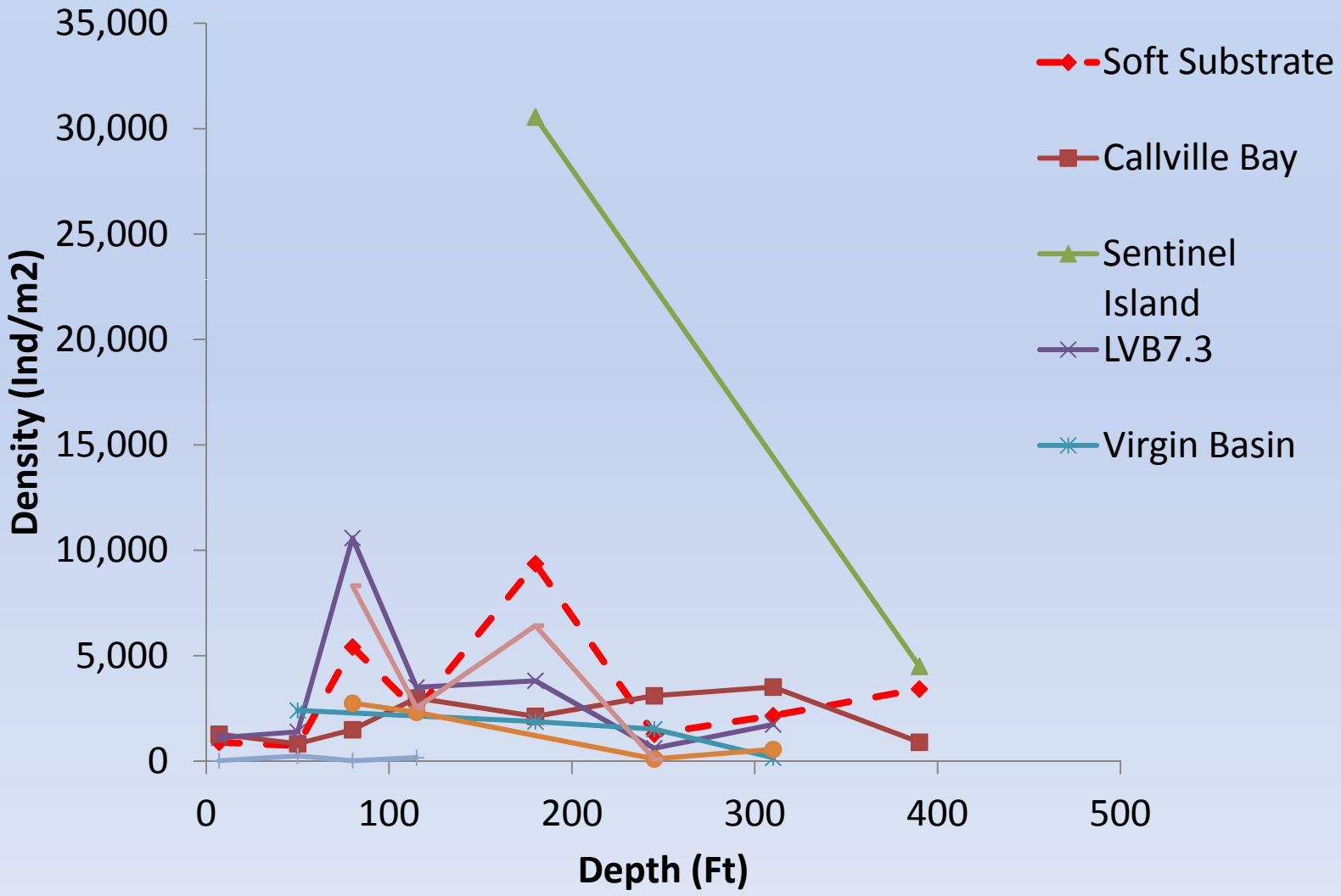
Abundance of adult/juvenile mussels in Lake Mead

	2007	2010
Hard Substrate	624 mussels/m2	8,078 mussels/m2
Soft Sediment	80 mussels/m2	3,014 mussels/m2

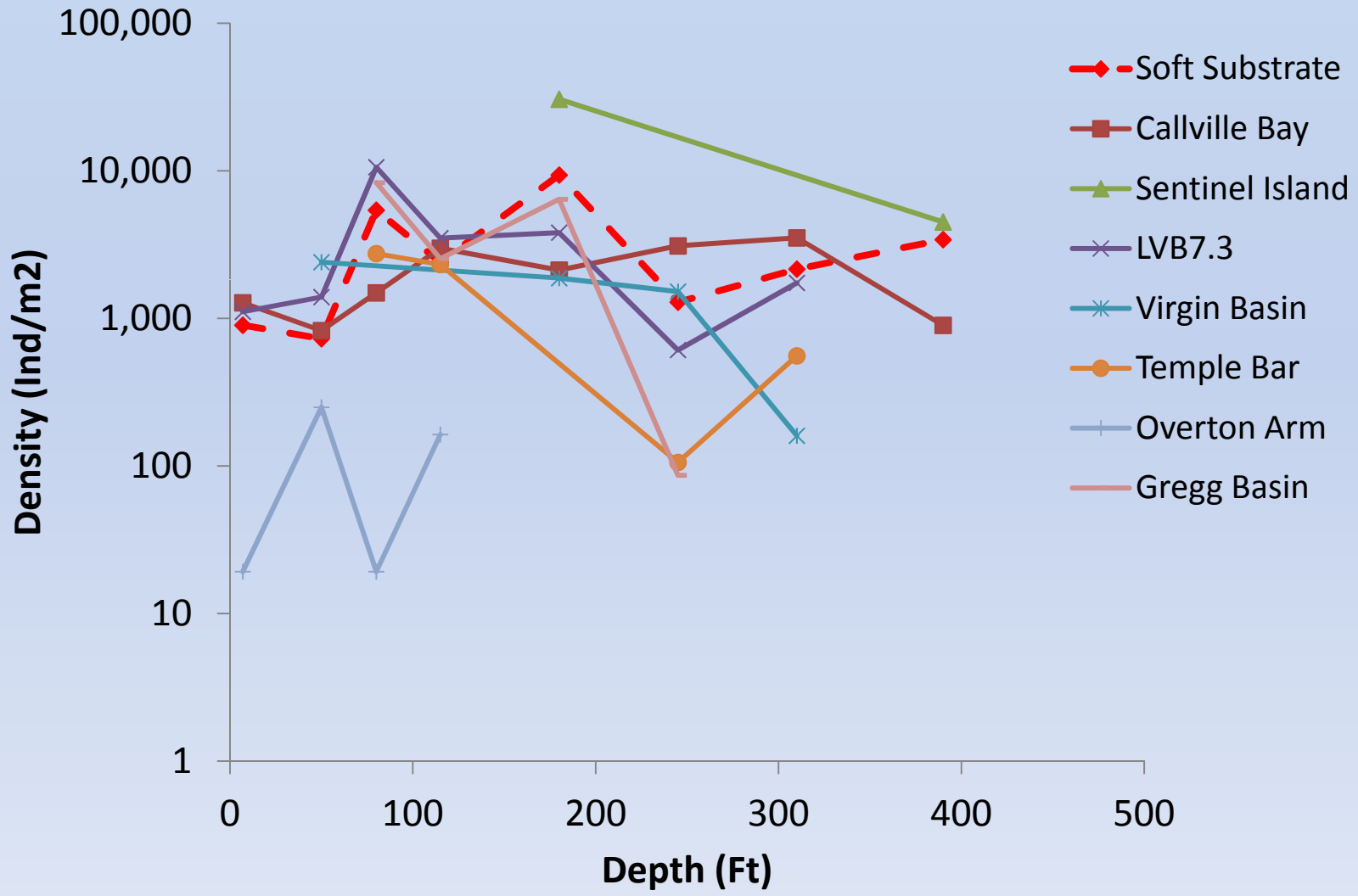
Soft Substrate Samples



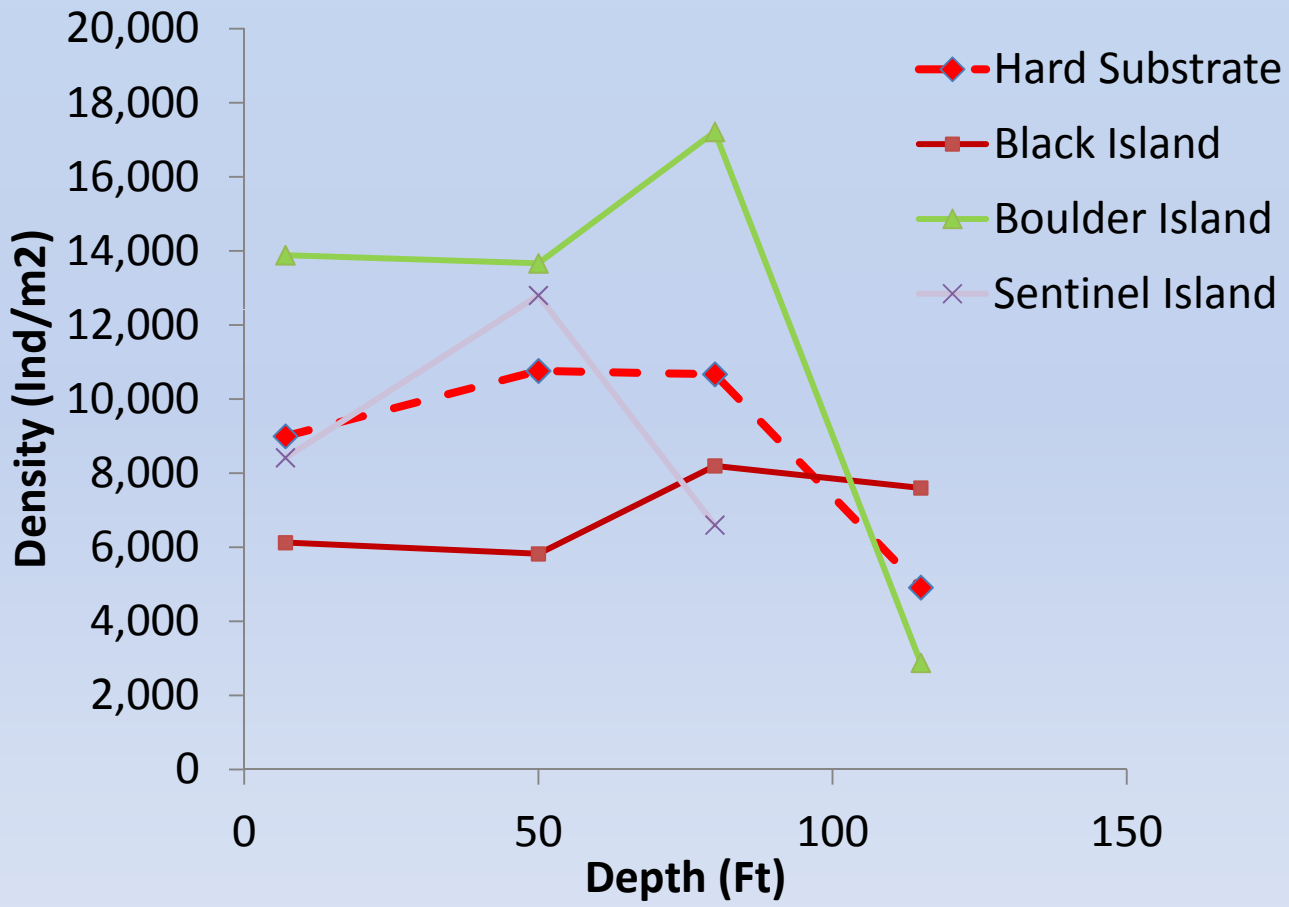
Soft Substrate Samples

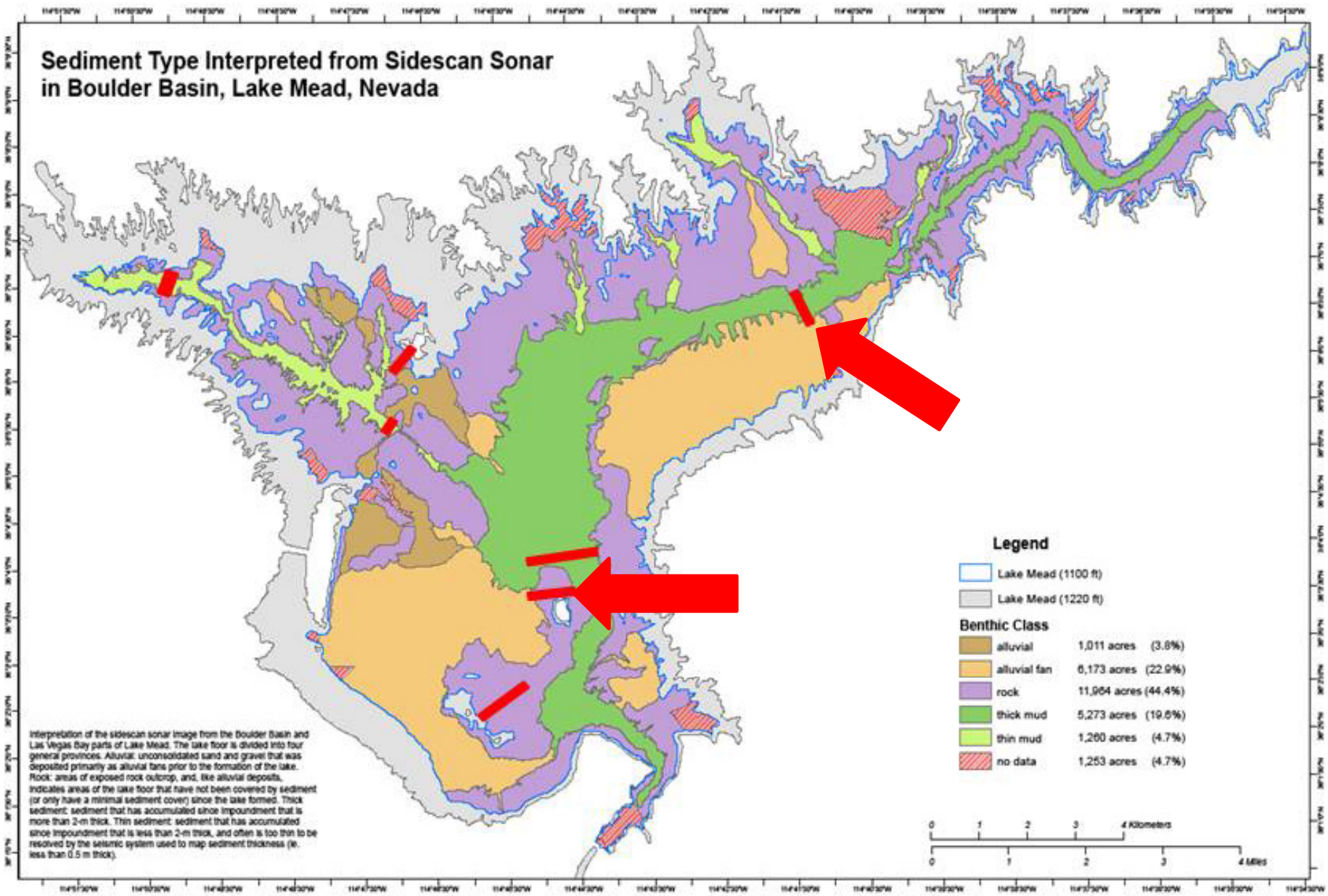


Soft Substrate Samples



Hard Substrate Samples

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Lake Mead (1220 ft)
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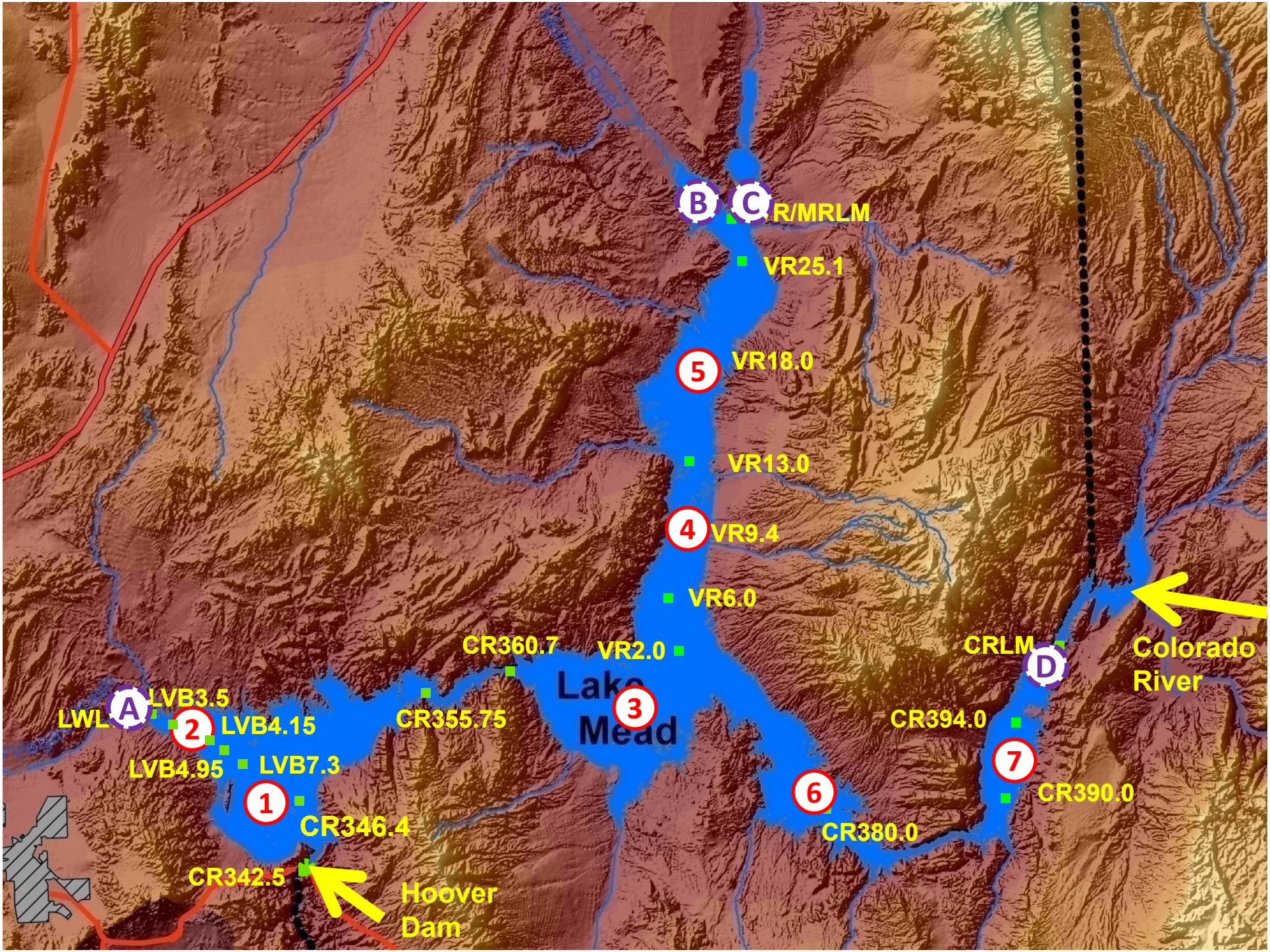
Standard Stratified Random Design

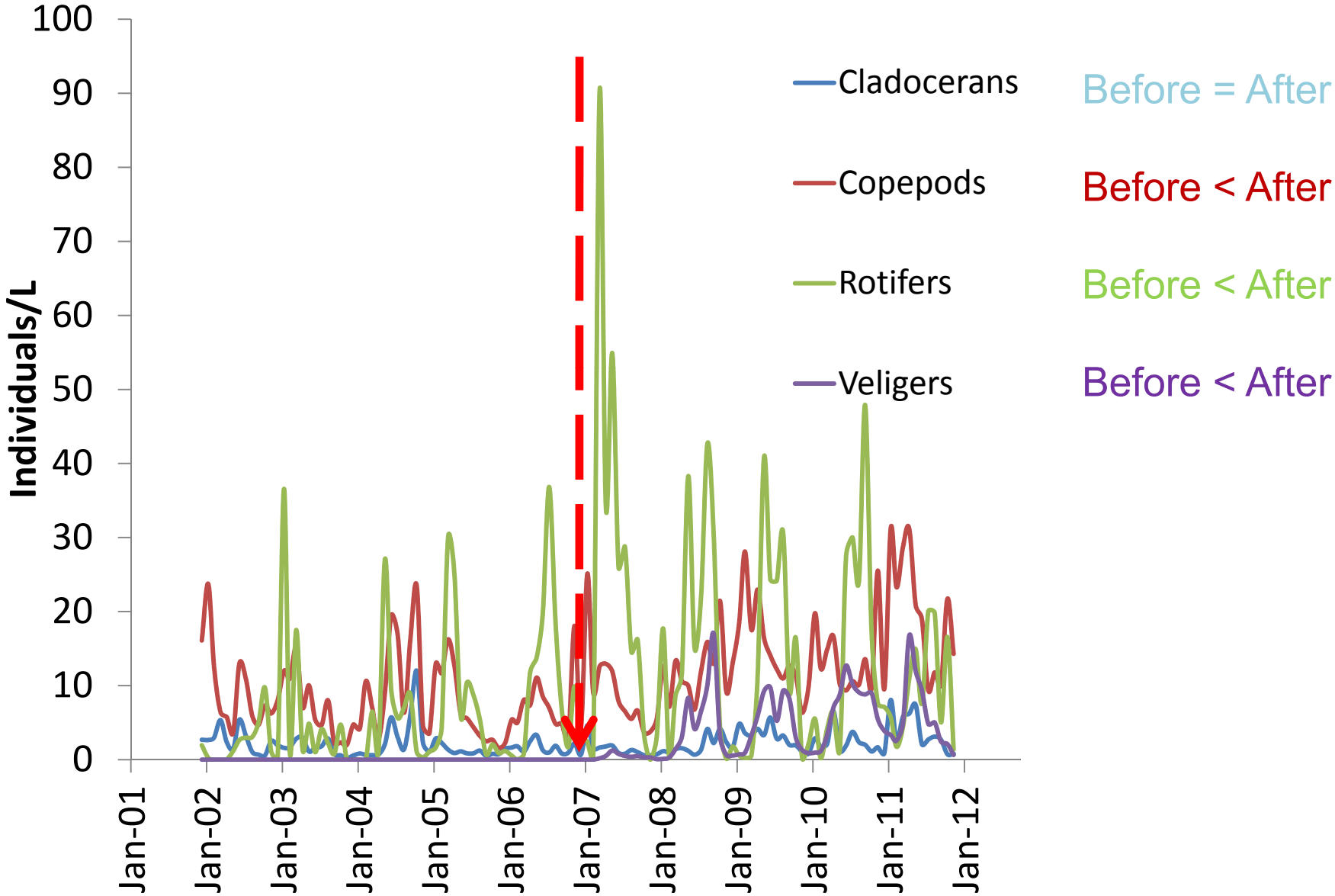
Hard Substrate	Sampling Sites
95%	11
98%	15
99%	18

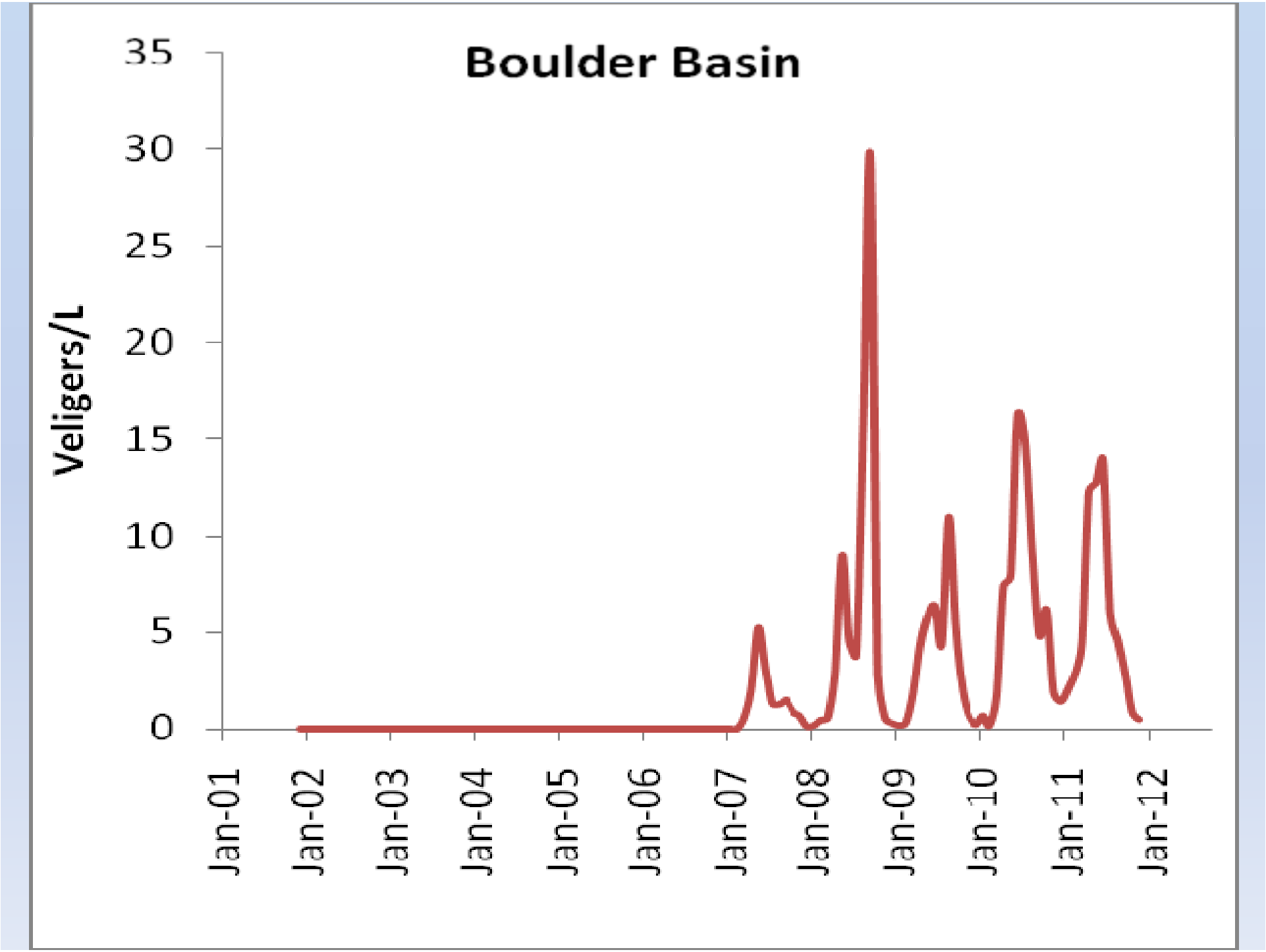
Veliger Abundance – Zooplankton Monitoring

Data courtesy of
Chris Holdren (Reclamation)


B
C
R/MRLM
VR25.1
5
VR18.0
VR13.0
4
VR9.4
VR6.0
CR360.7
VR2.0
Lake
Mead
3
CRLM
D
Colorado
River
LWL
A
LVB3.5
2
LVB4.15
CR355.75
CR394.0
LVB4.95
LVB7.3
7
1
6
CR390.0
CR346.4
CR380.0
CR342.5
Hoover
Dam

Zooplankton Abundance




Boulder Basin
Veligers/L
35
30
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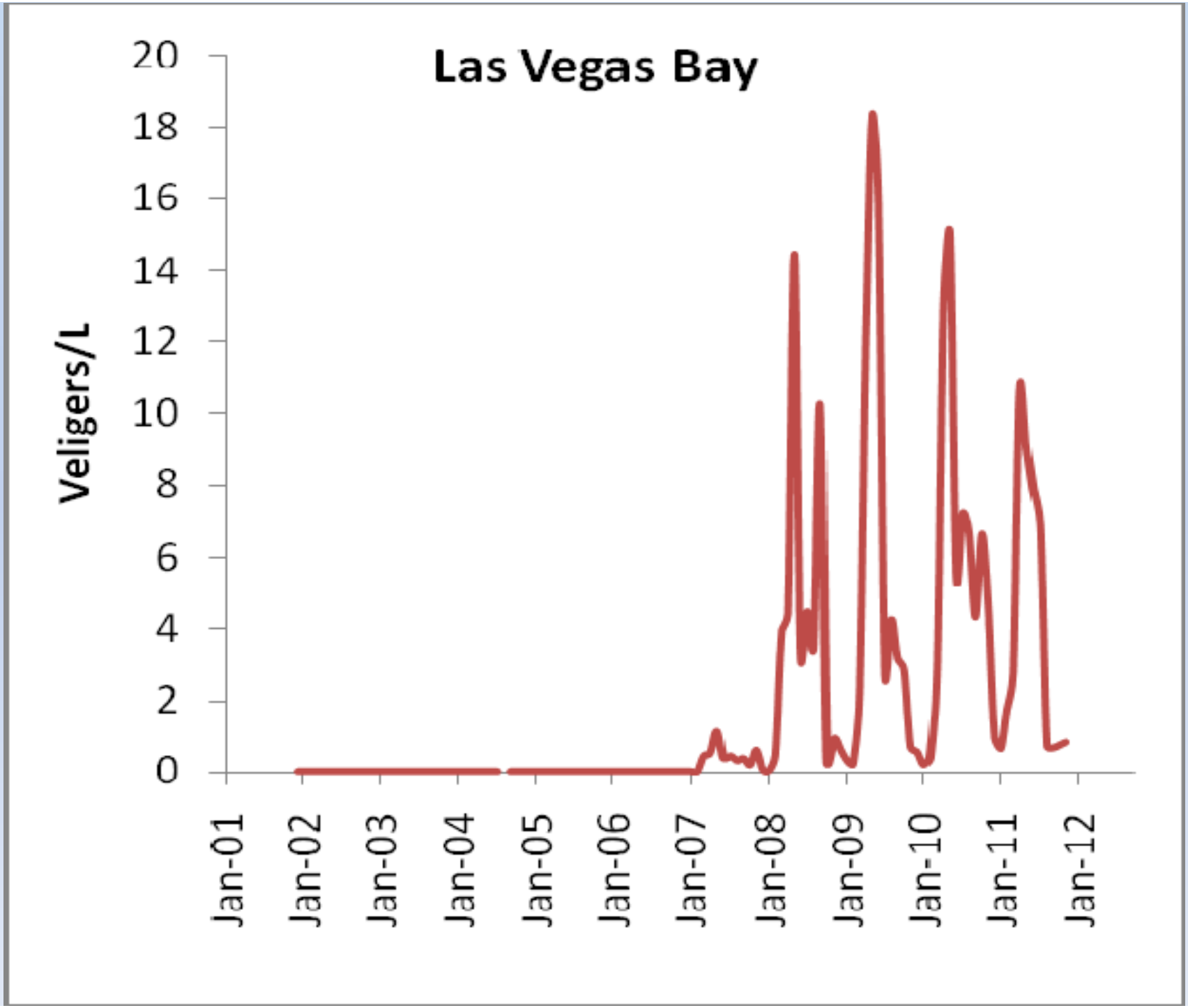
Las Vegas Bay
Veligers/L
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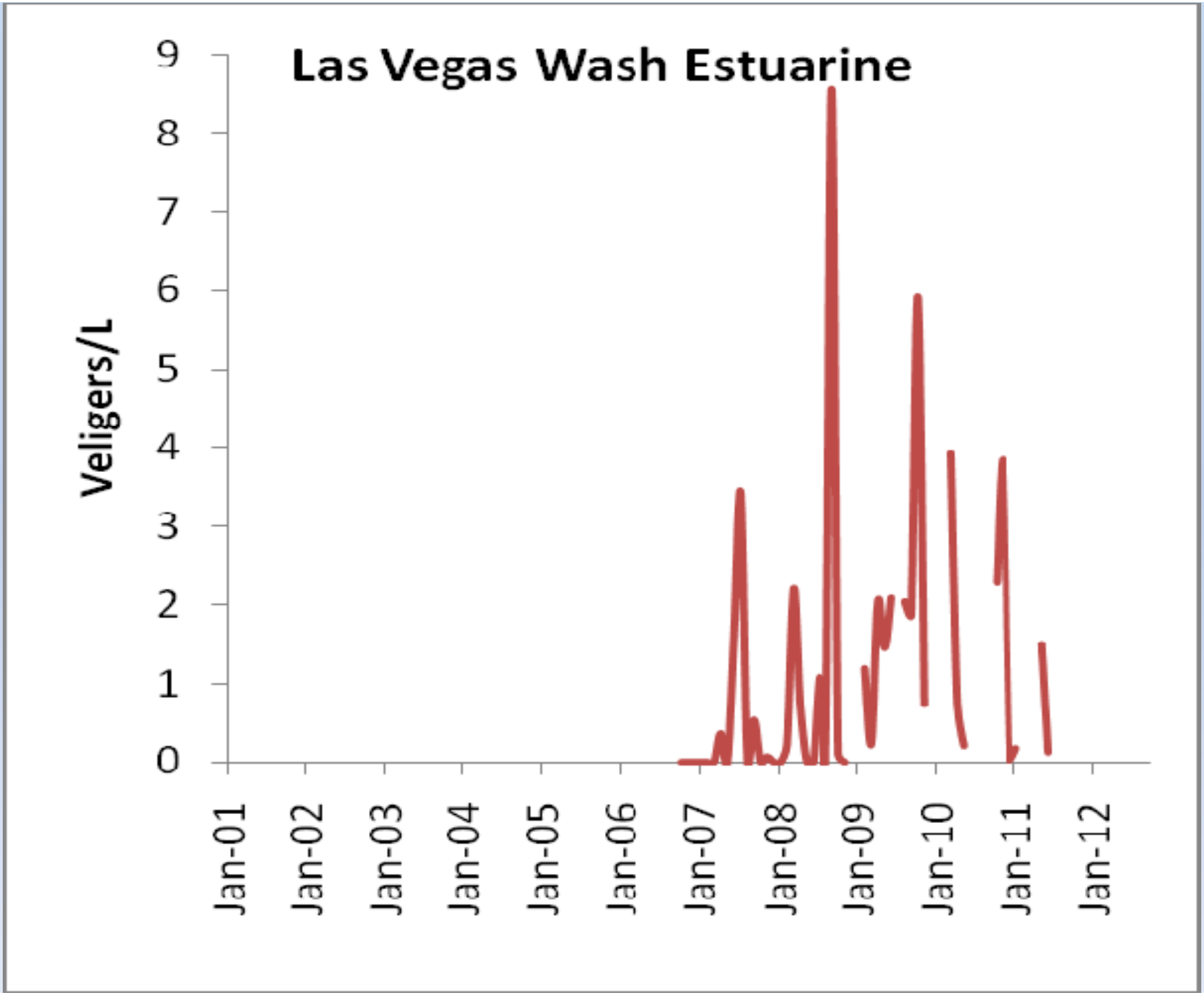
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Veligers/L
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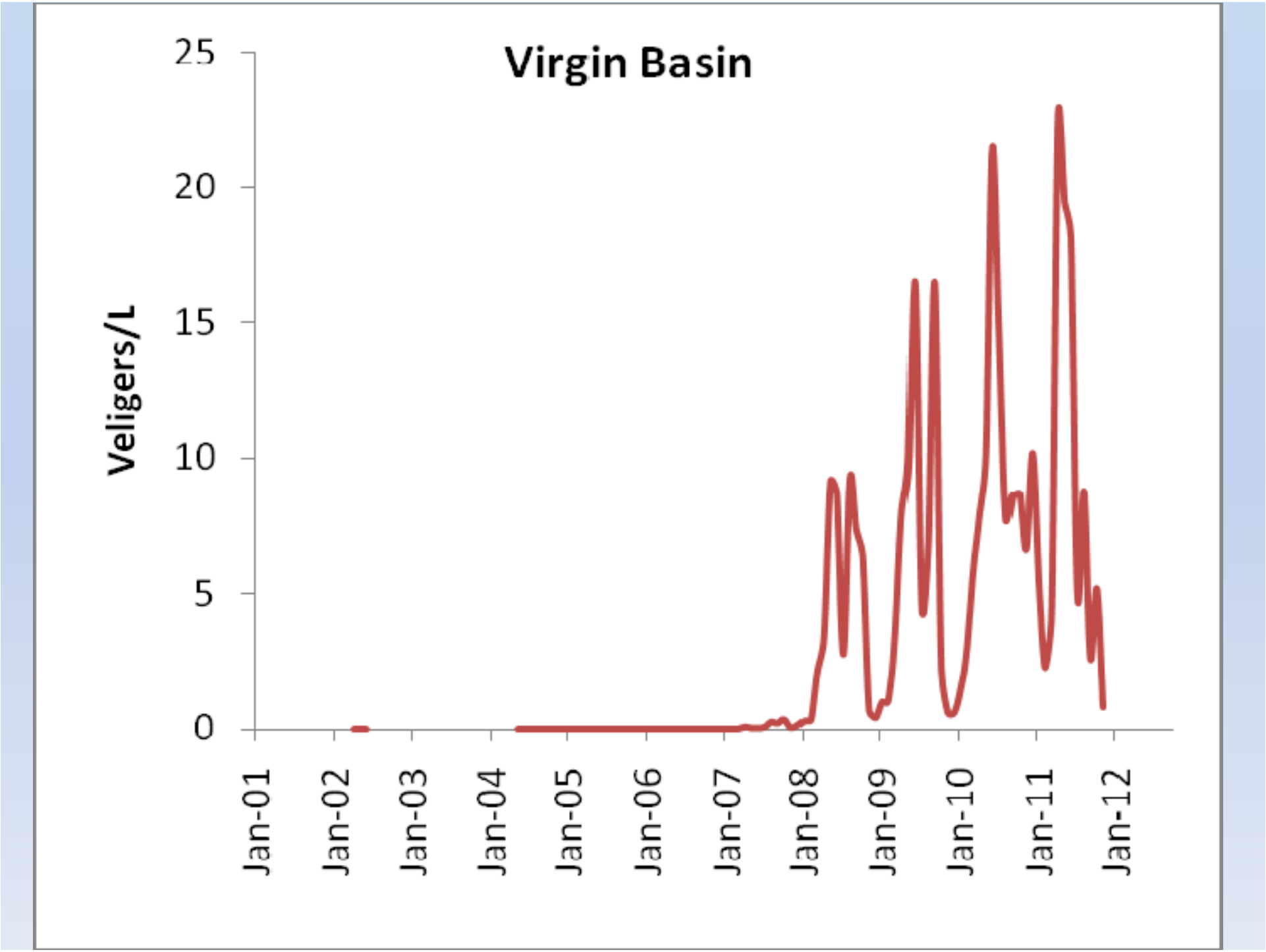
Virgin Basin
Veligers/L
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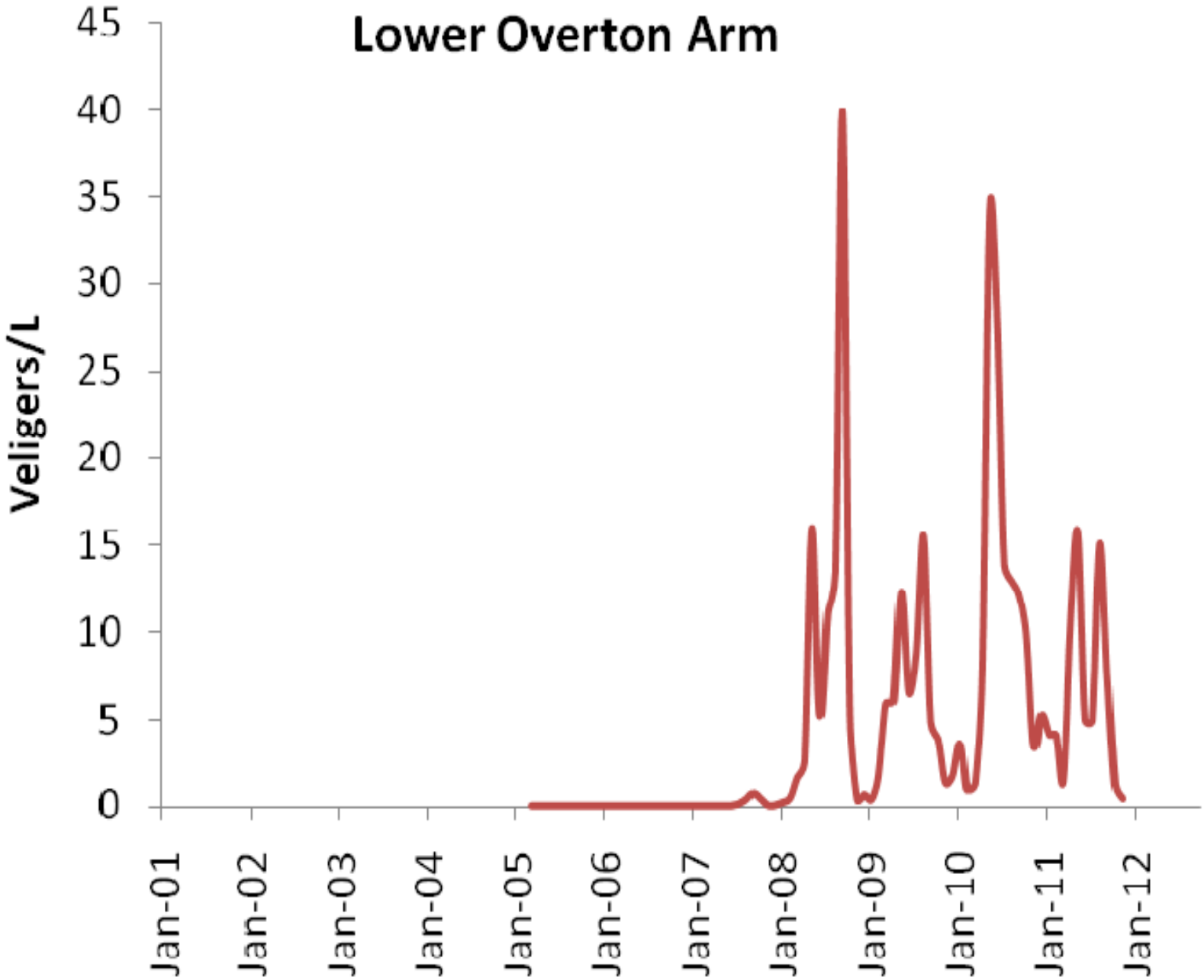
Lower Overton Arm
Veligers/L
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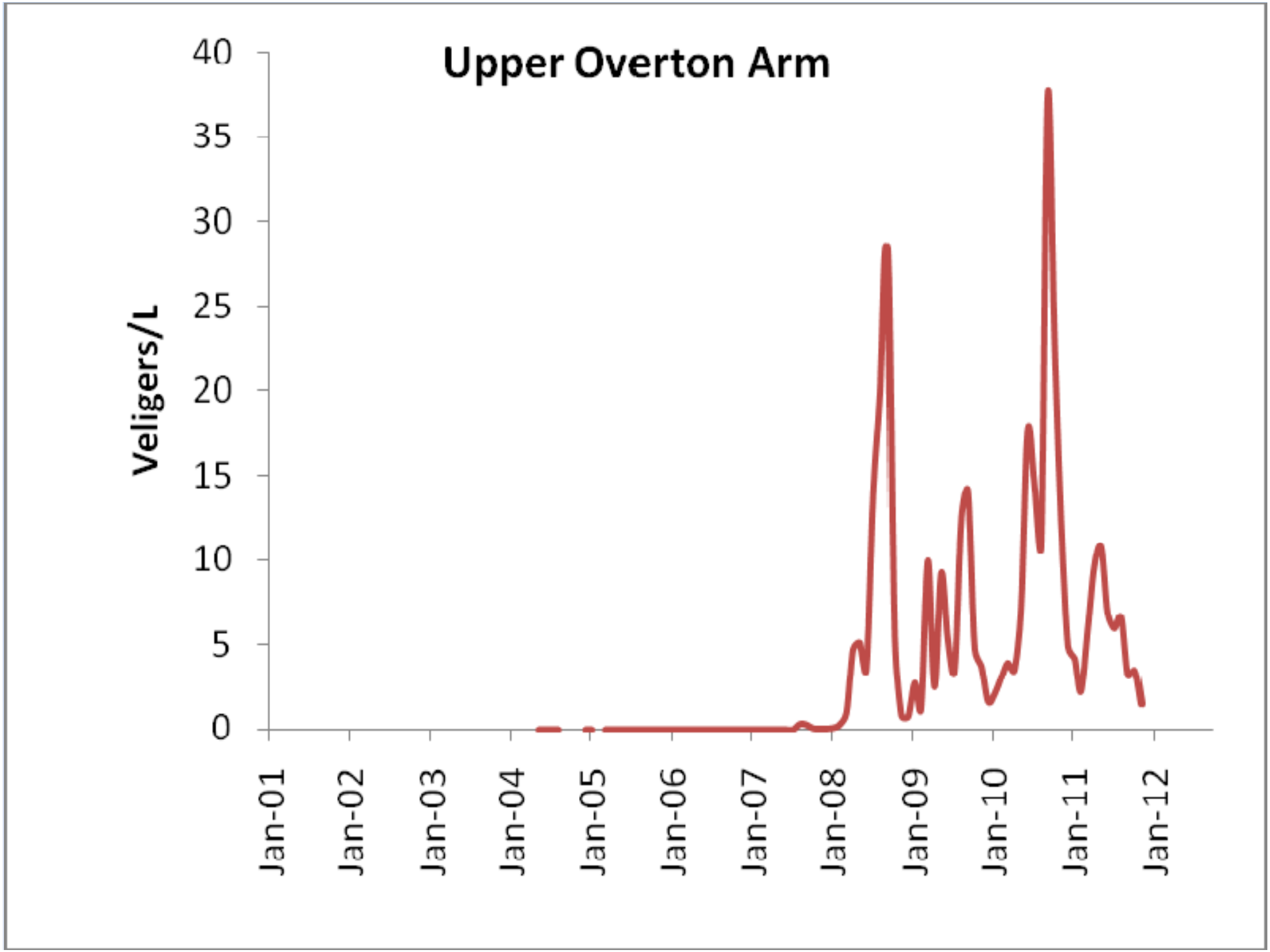
Upper Overton Arm
Veligers/L
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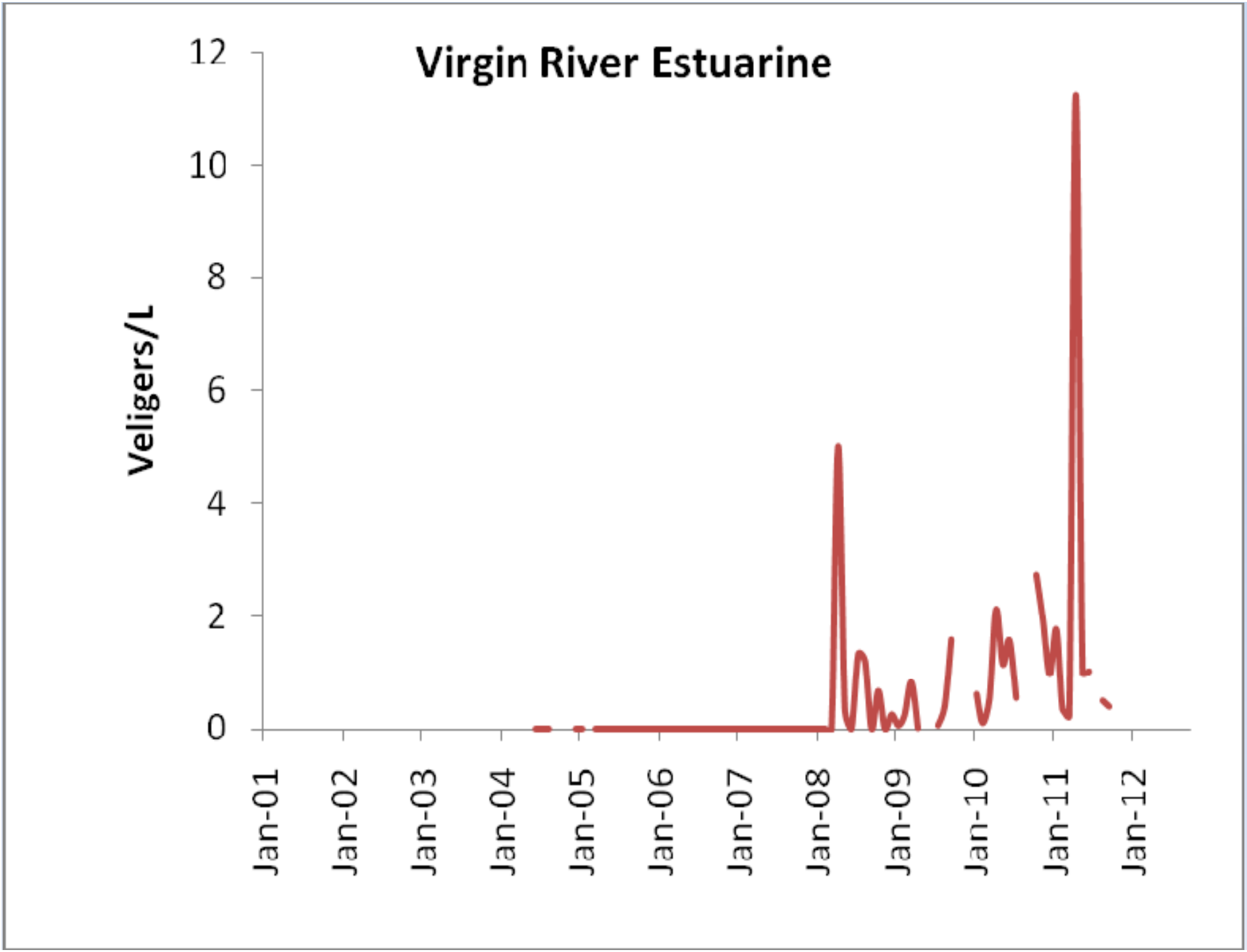
Virgin River Estuarine
Veligers/L
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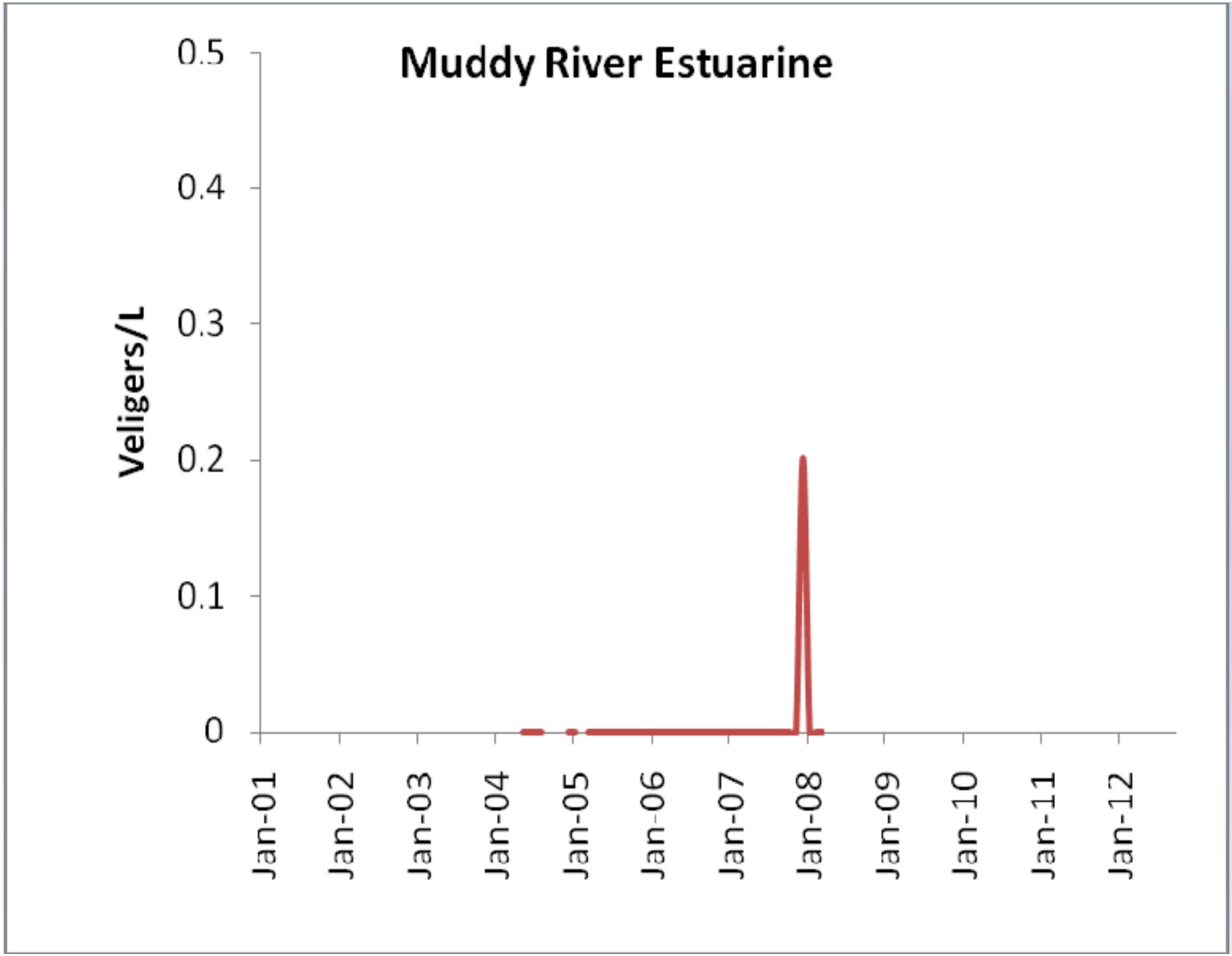
Muddy River Estuarine
Veligers/L
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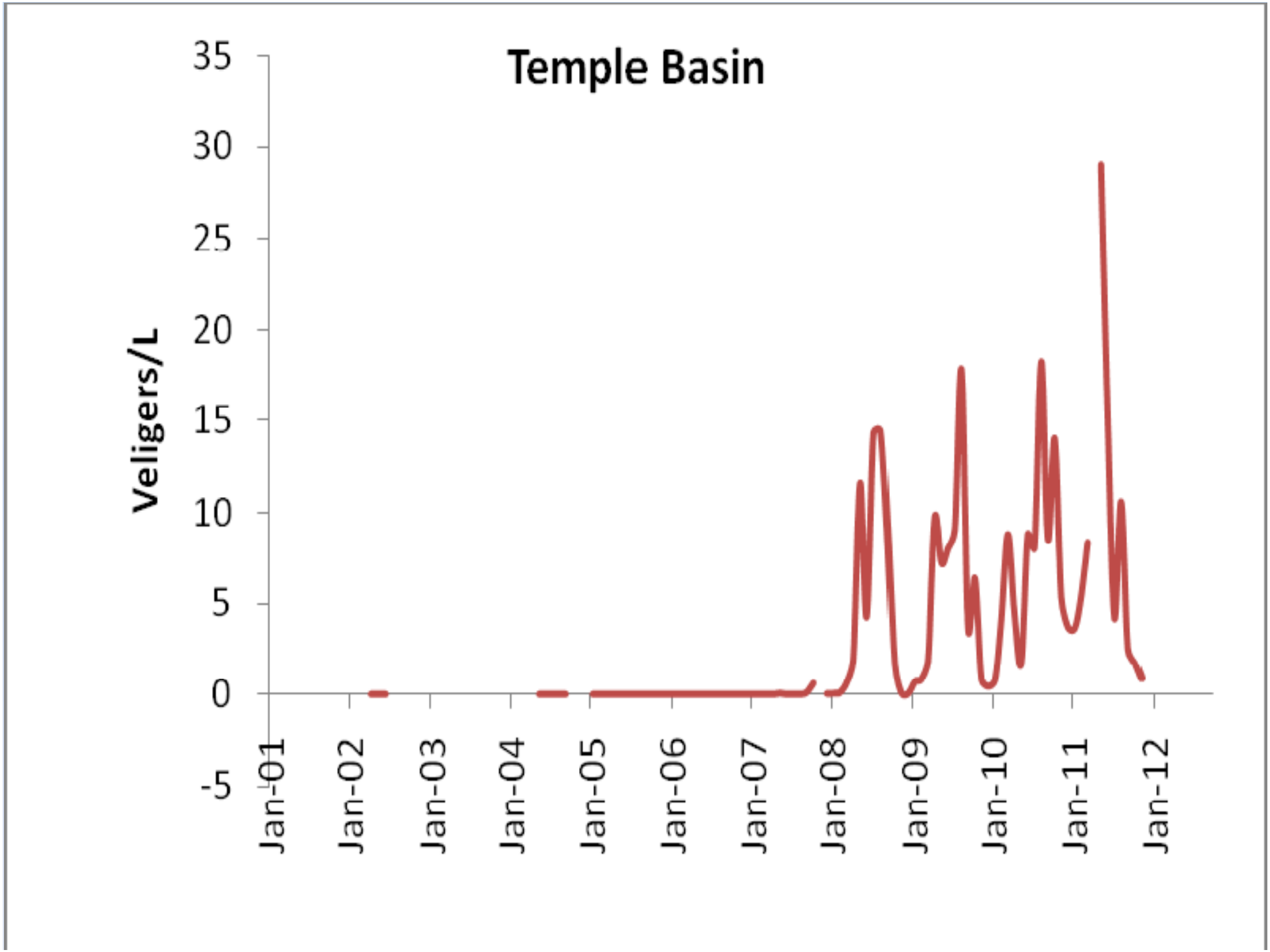
Temple Basin
Veligers/L
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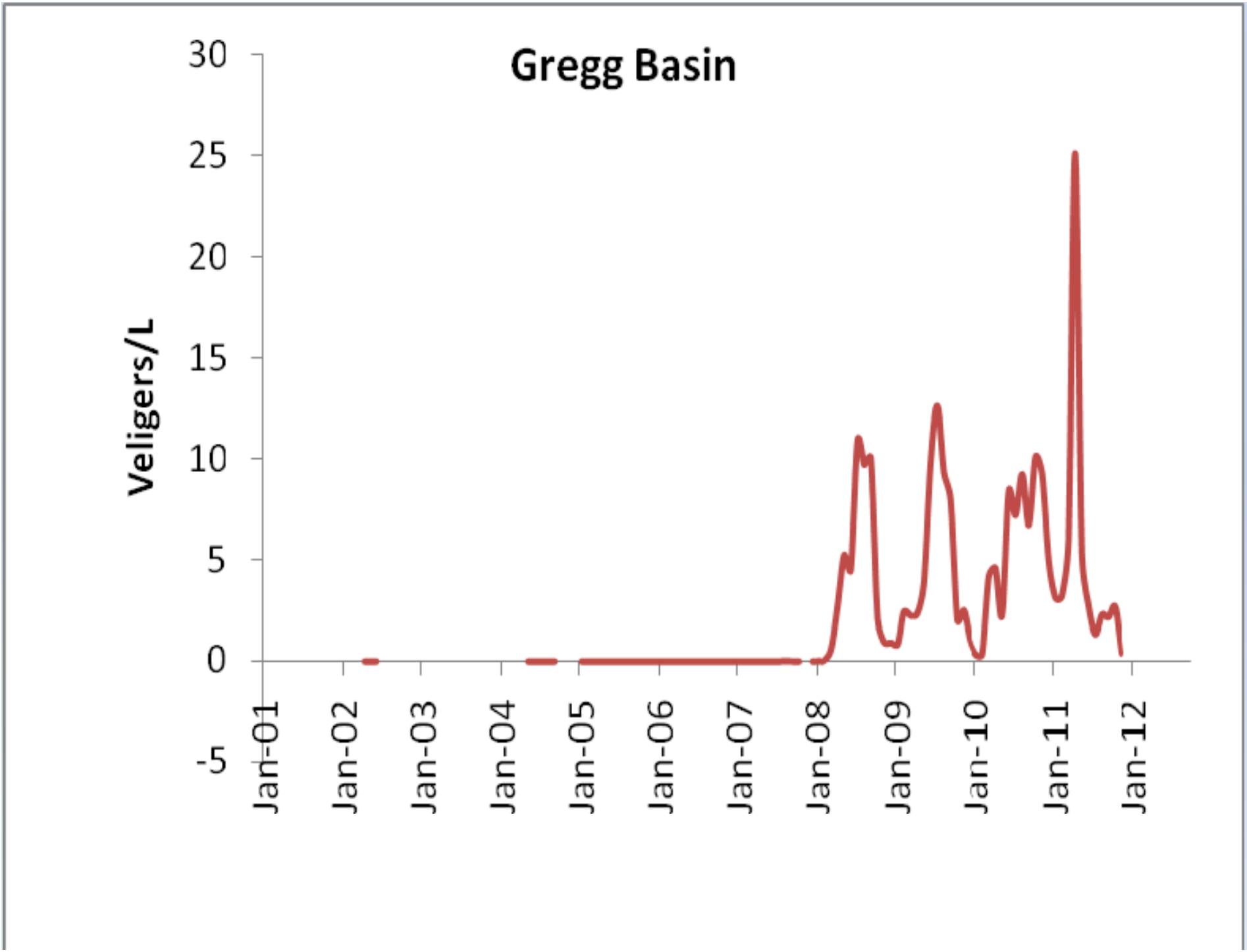
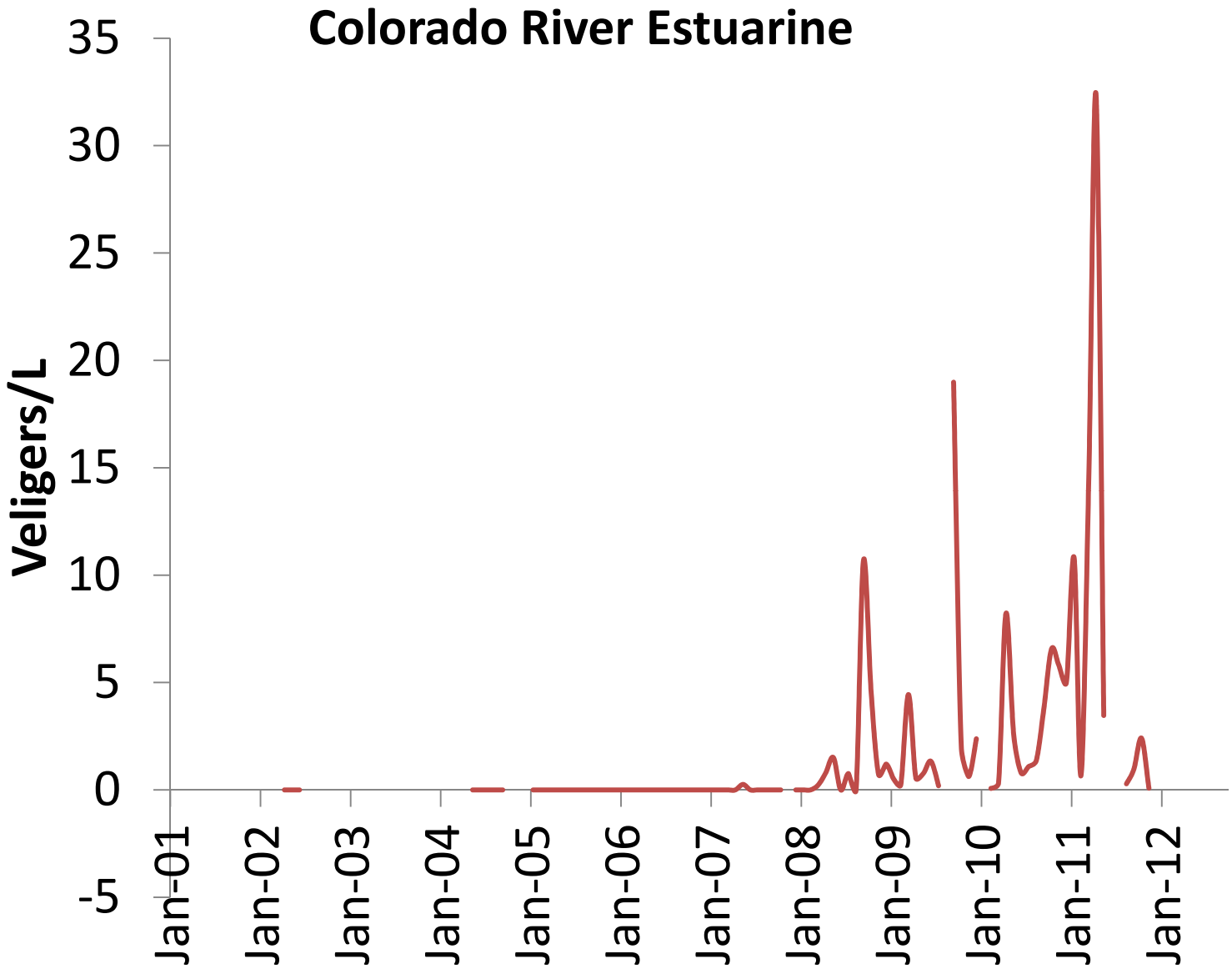
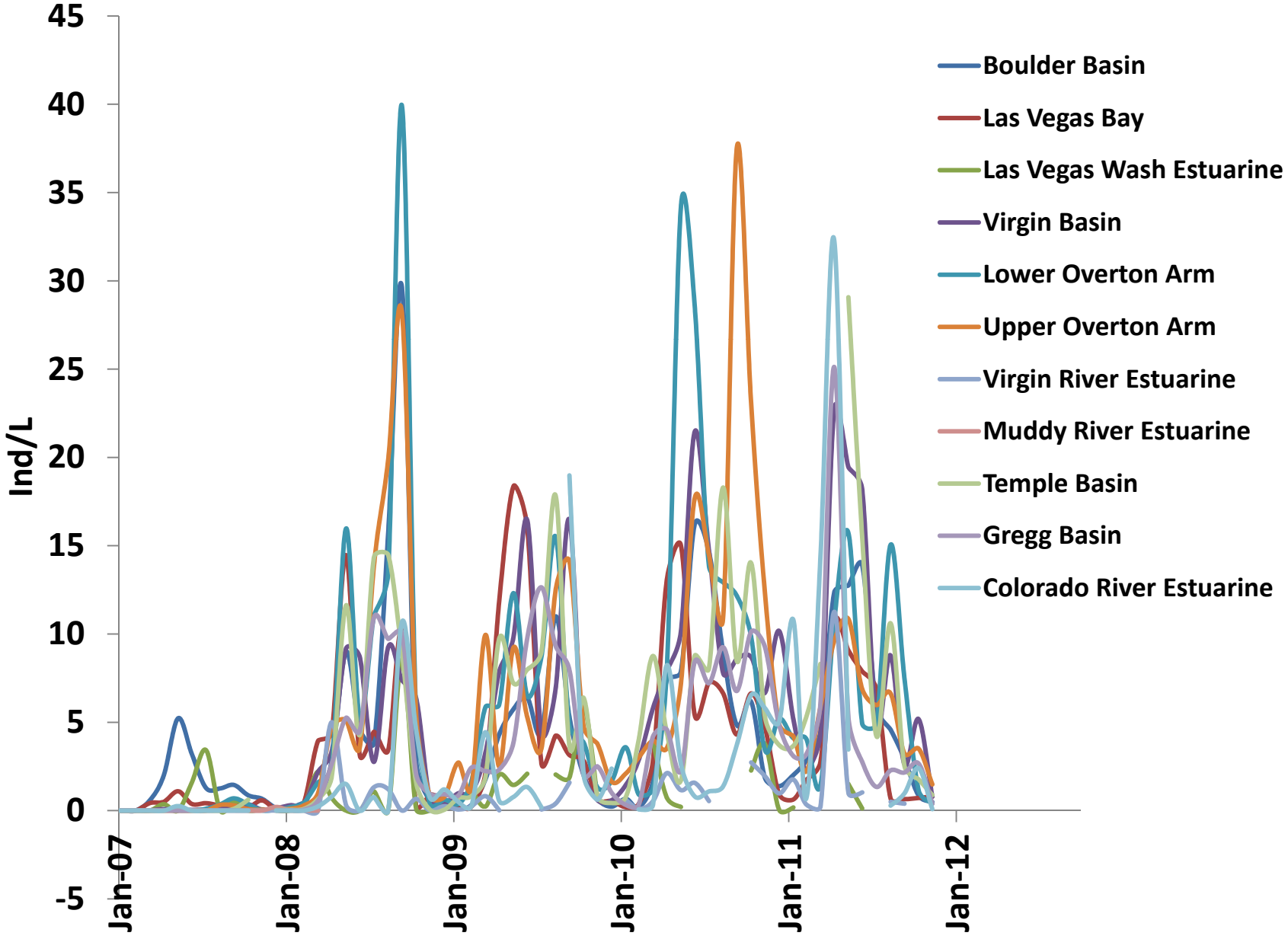
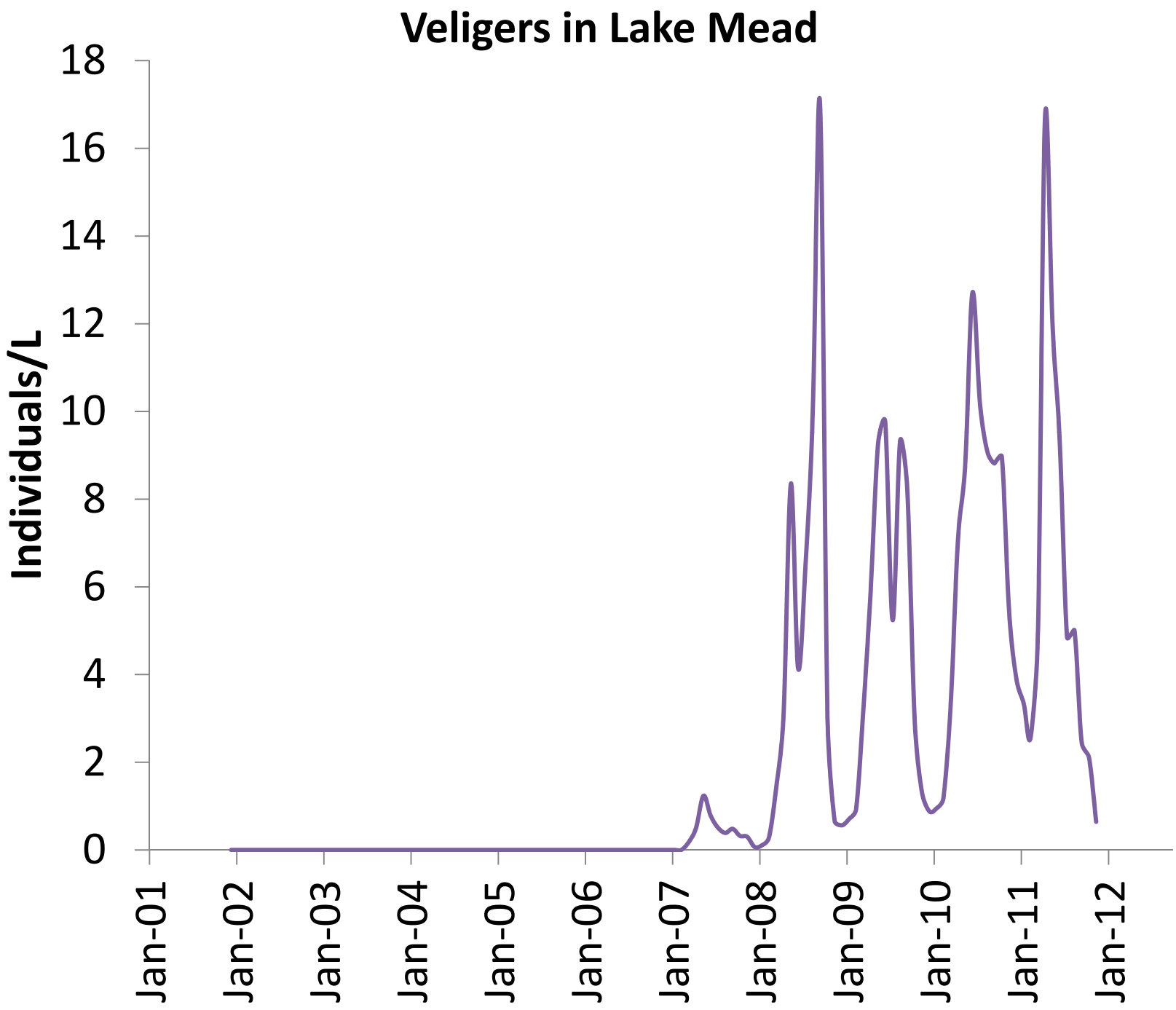
0
-5
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Jan-06
Jan-07
Jan-08
Jan-09
Jan-10
Jan-11
Jan-12


Gregg Basin
Veligers/L
30
25
20
15
10
5
0
-5
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Jan-06
Jan-07
Jan-08
Jan-09
Jan-10
Jan-11
Jan-12


Colorado River Estuarine
Veligers/L
35
30
25
20
15
10
5
0
-5
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Jan-06
Jan-07
Jan-08
Jan-09
Jan-10
Jan-11
Jan-12

Lake Mead Veliger Abundance

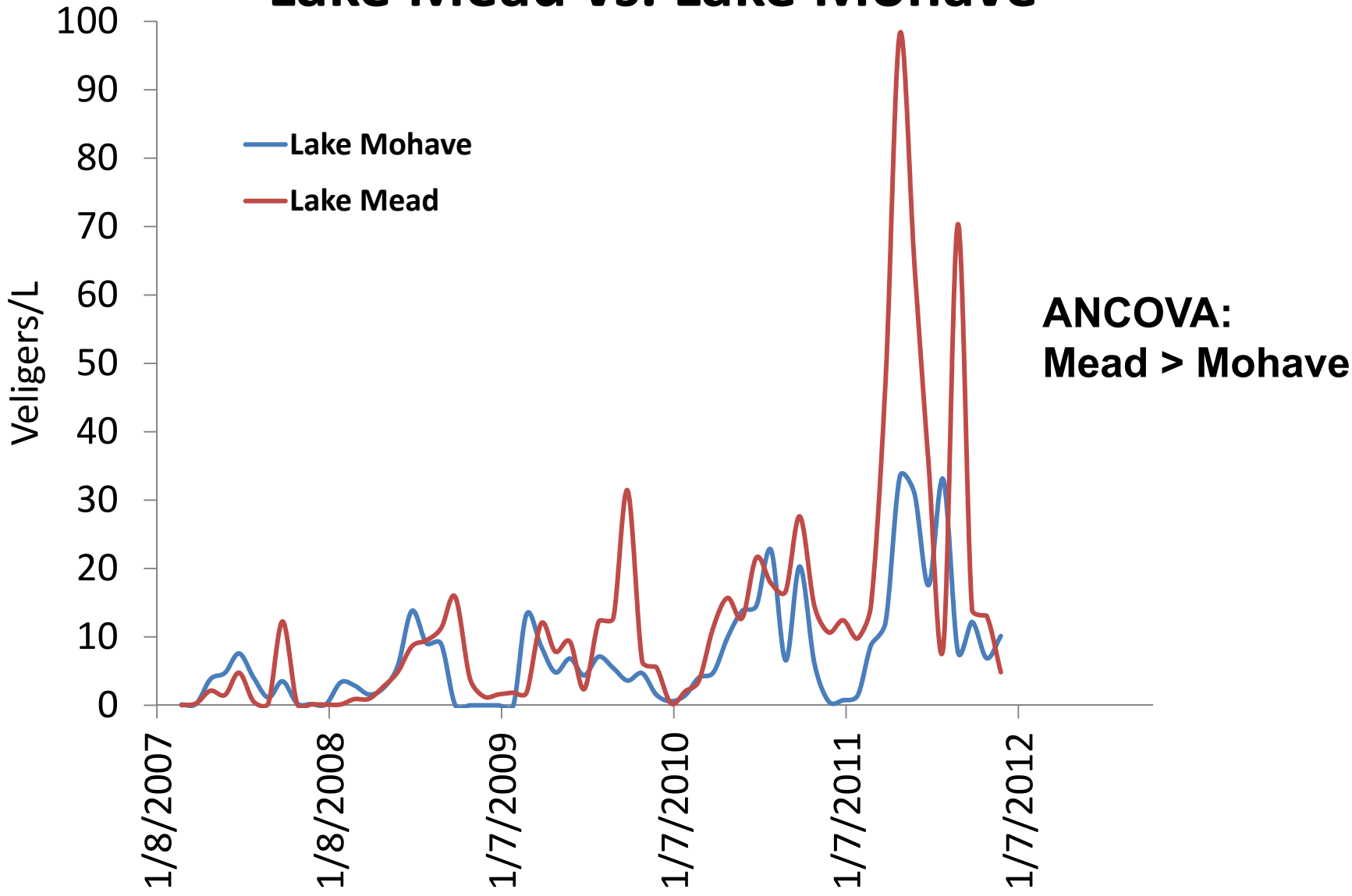


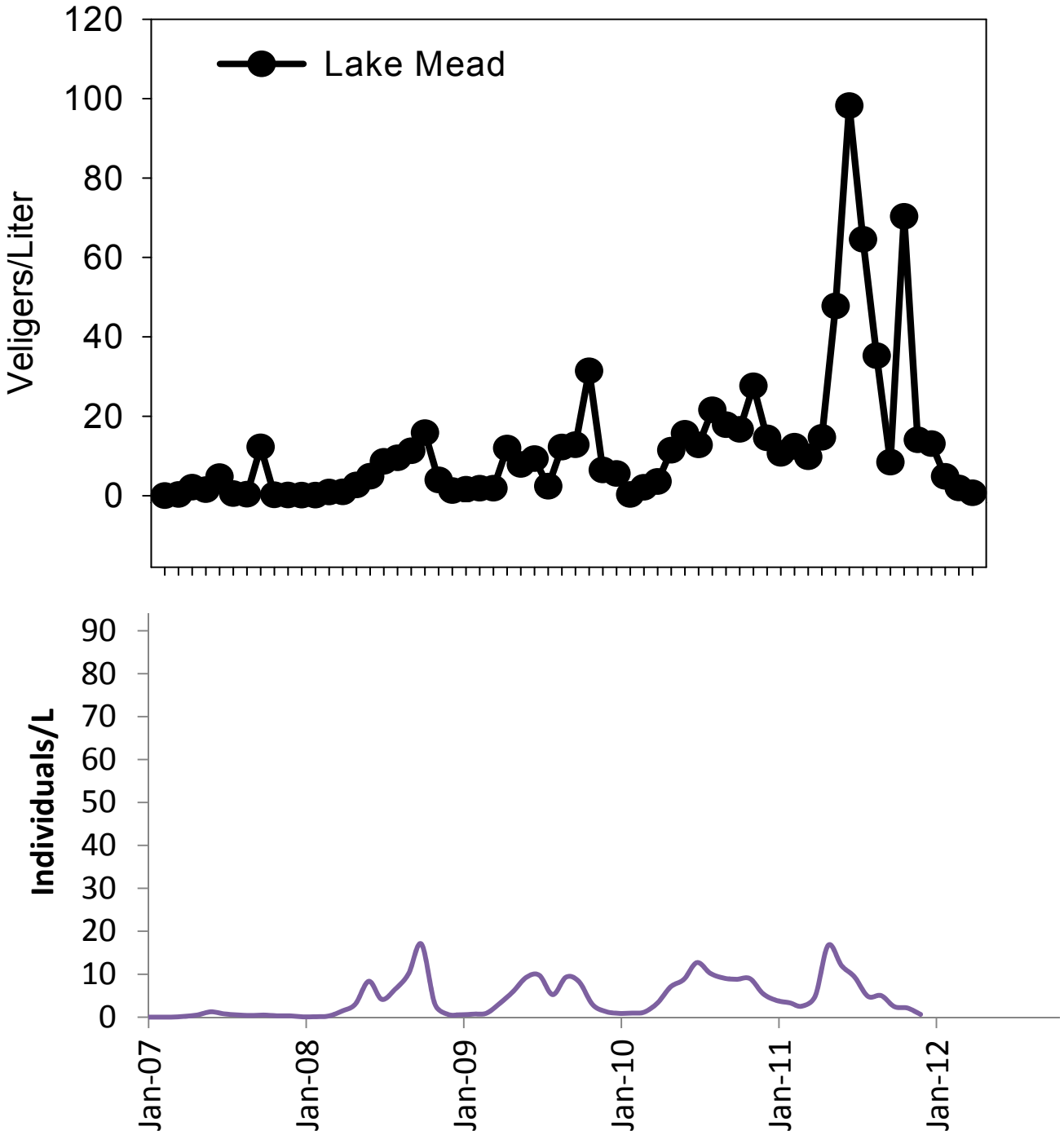

Veligers in Lake Mead
Individuals/L
18
16
14
12
10
8
6
4
2
0
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Jan-06
Jan-07
Jan-08
Jan-09
Jan-10
Jan-11
Jan-12

Veliger abundance in each basin/estuarine area of Lake Mead

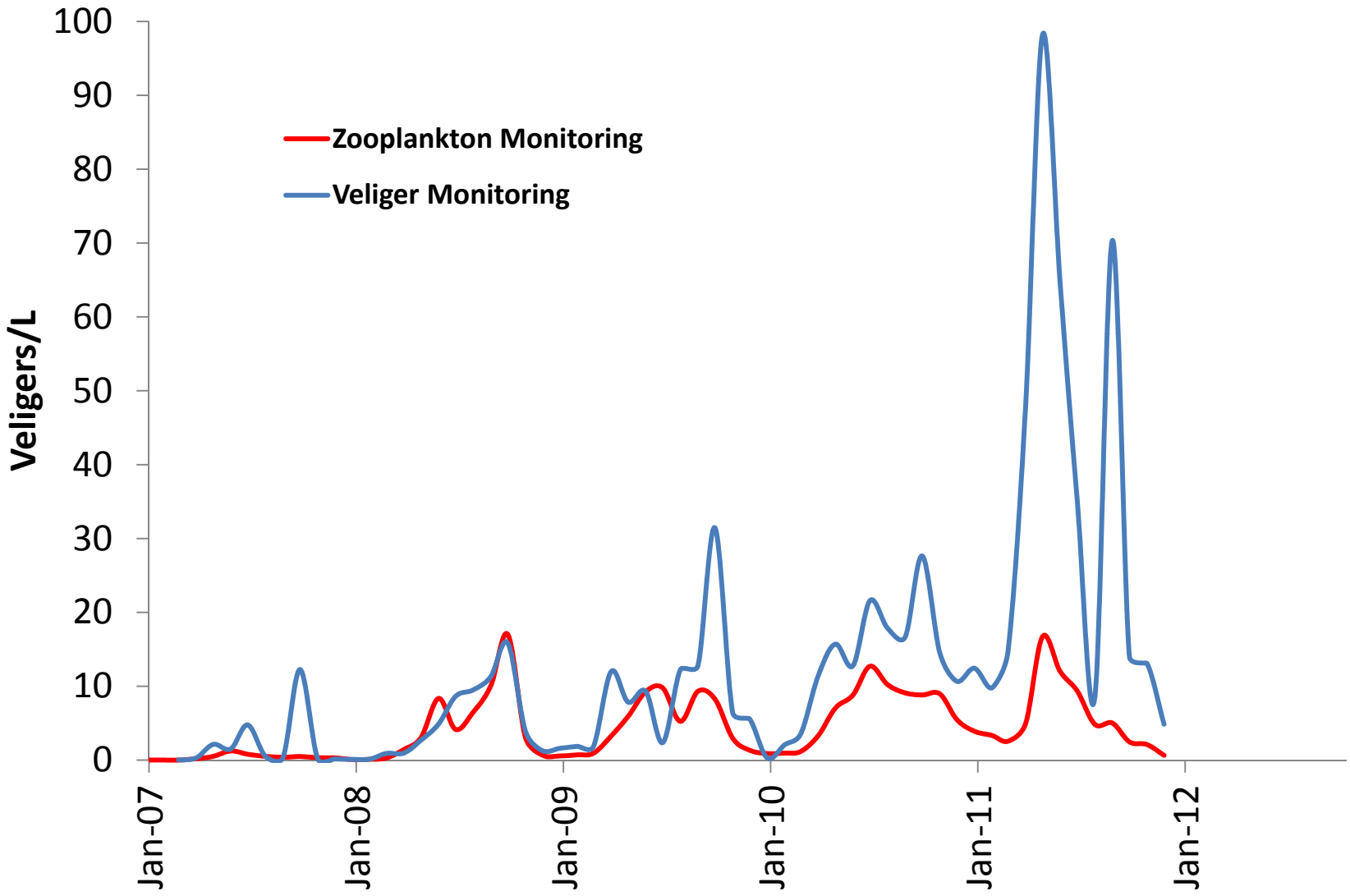
Basin		Mean	N		SNK Grouping			
Lower Overton Arm		4.57	162				A	
Virgin Basin		3.41	190		B		A	
Upper Overton Arm		3.32	256		B		A	
Temple Basin		2.88	102		B		A	C
Gregg Basin		2.46	182		B			C
Boulder Basin		2.31	457		B		D	C
Las Vegas Bay		1.77	367		B	E	D	C
Colorado River Estuarine		1.55	99		B	E	D	C
Las Vegas Wash Estuarine		1.05	47			E	D	C
Virgin River Estuarine		0.45	90			E	D	
Muddy River Estuarine		0.01	58			E		

Veliger Monitoring - Reclamation
Lake Mead vs. Lake Mohave



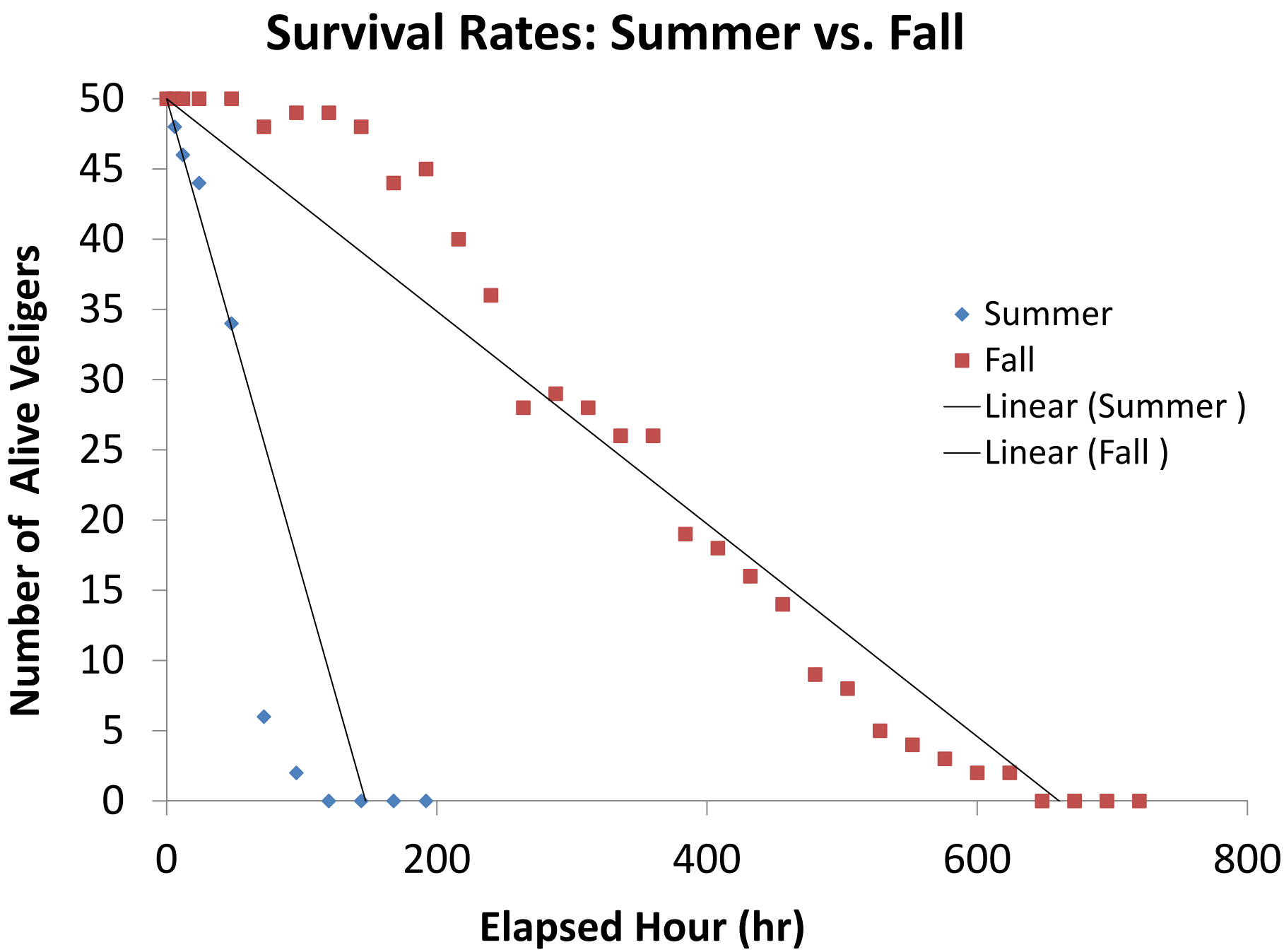

Lake Mead
Veligers/Liter
120
100
80
60
40
20
0
Individuals/L
90
80
70
60
50
40
30
20
10
0
Jan-07
Jan-08
Jan-09
Jan-10
Jan-11
Jan-12

Lake Mead

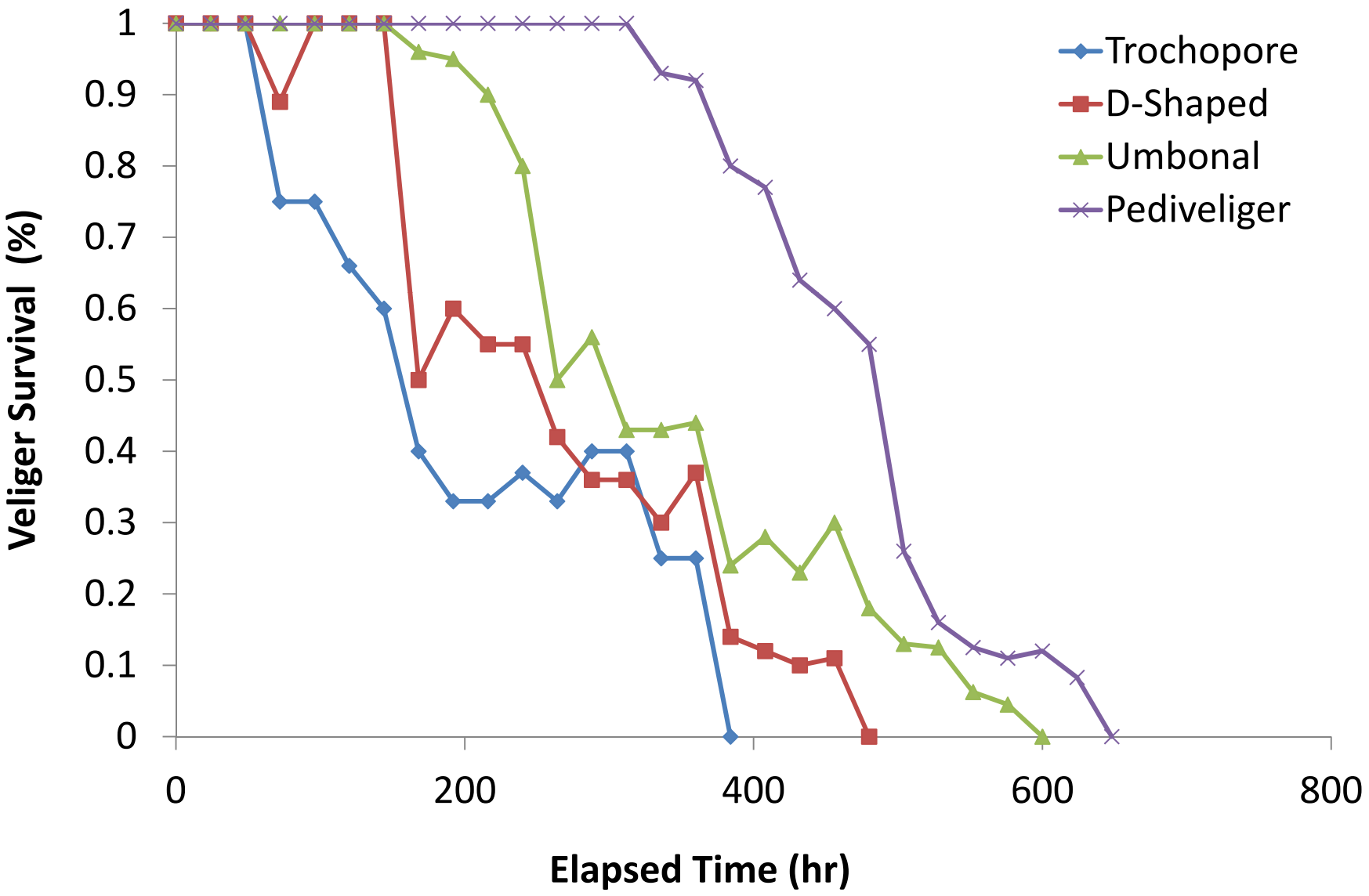

Zooplankton Monitoring
Veliger Monitoring
Veligers/L
100
90
80
70
60
50
40
30
20
10
0
Jan-07
Jan-08
Jan-09
Jan-10
Jan-11
Jan-12

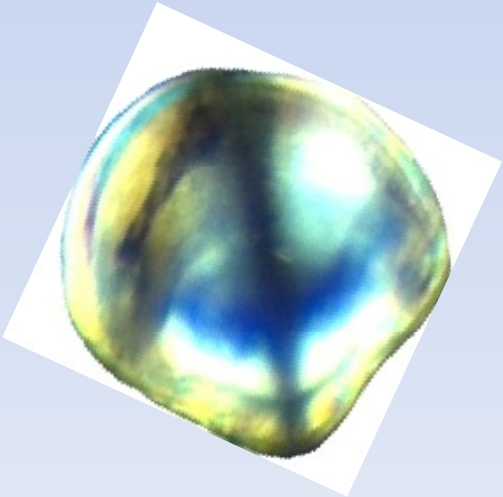
Abundance of veligers in Lake Mead

	2007	2011
1100 Ft	18,686,653,425,292	320,480,041,621,890


Survival Rates: Summer vs. Fall
Number of Alive Veligers
50
45
40
35
30
25
20
15
10
5
0
0
200
400
600
800
Elapsed Hour (hr)
Summer
Fall
Linear (Summer)
Linear (Fall)

Survival rates among the four veliger stages



Summary

- Quagga mussel density in Lake Mead increased significantly over the past 4-to-5 years (1.5 trillions of adults and 320 trillions of veligers)
- It is a challenge for stakeholders to manage quagga mussels: invasive, resilient, and collectively massive