Spatial and Temporal Changes in Benthic Invertebrates Prey Availability on Dumbarton Shoals, San Francisco Bay



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USGS CMG: Bruce Jaffe, Amy Foxgrover, David Finlayson, Rob Kayen

Why Invertebrates?

Diversity of Life

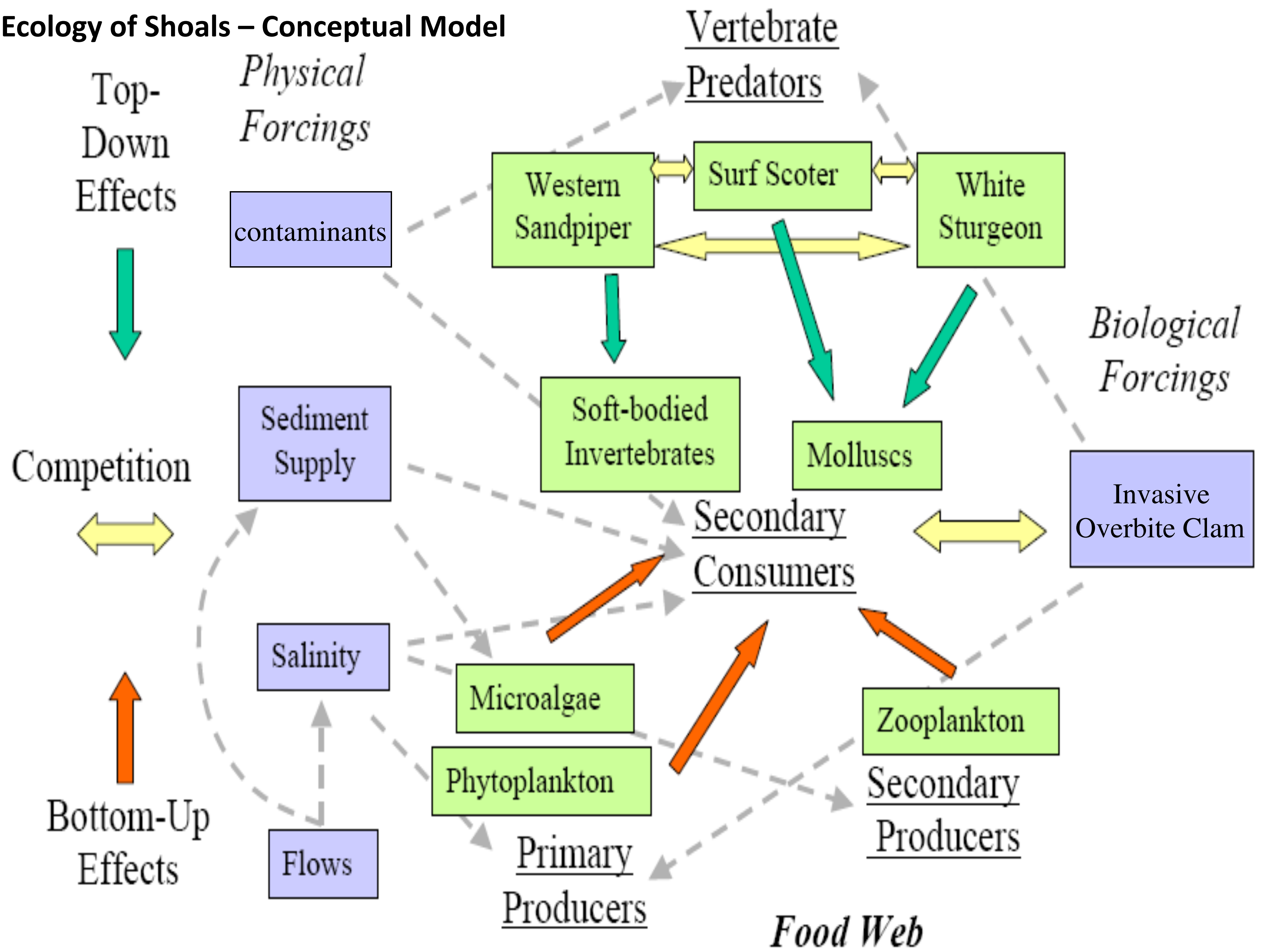
- 98% of Animals are invertebrates

The Gale Group

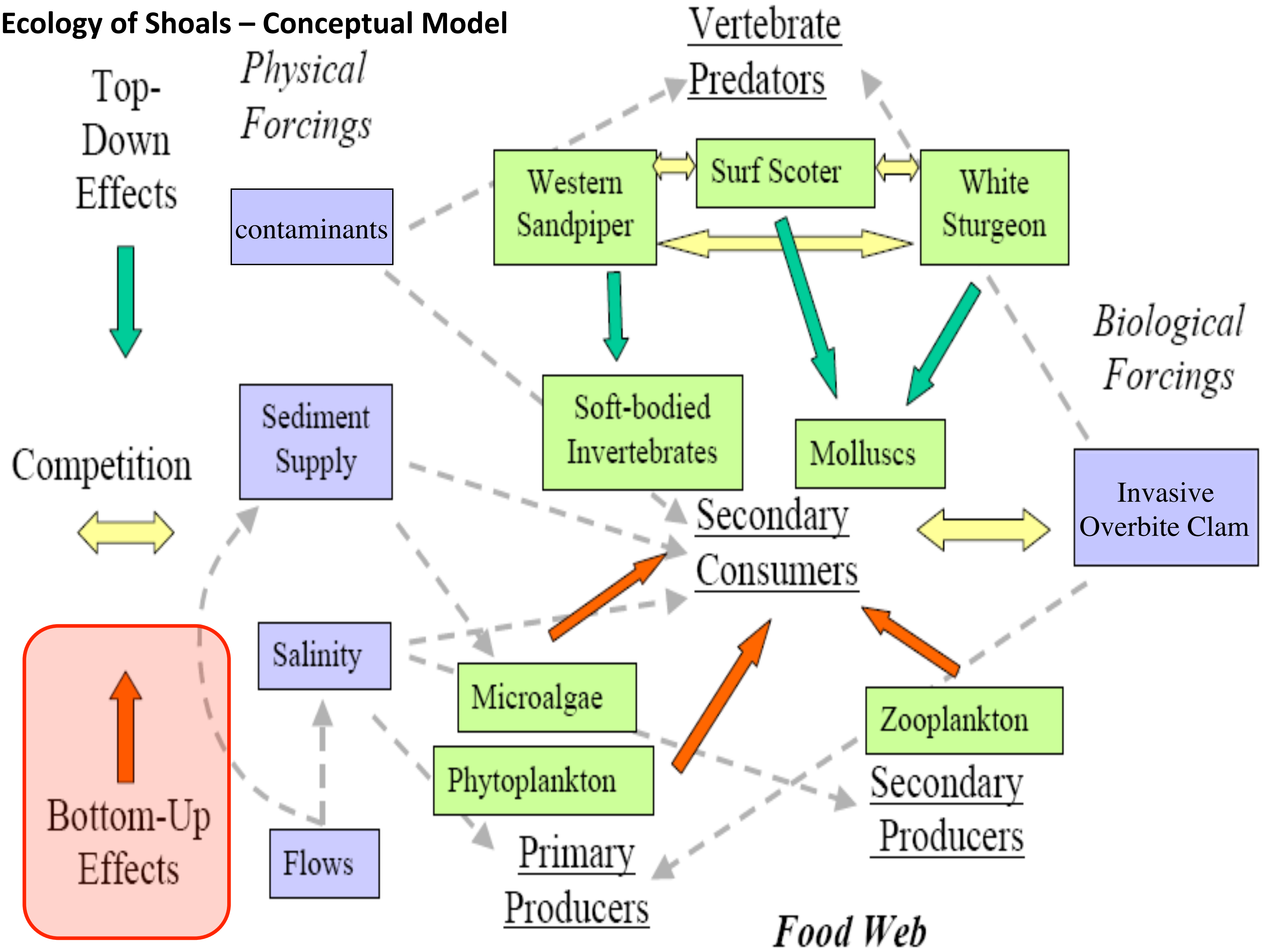
Why Invertebrates?

- Have specific physical tolerances (i.e. salinity) and foraging guilds
  - Indicator species for water quality
  - Indicator of habitat or habitat change
- Can cause bio-turbation of mudflat
- Important prey resource for
  - Fish species
  - Shorebirds and diving benthivores
    - San Francisco Bay is a site of Hemispheric Importance for Shorebirds
    - Important in wintering/staging areas for birds to "fuel up" before migration

Ecology of Shoals – Conceptual Model

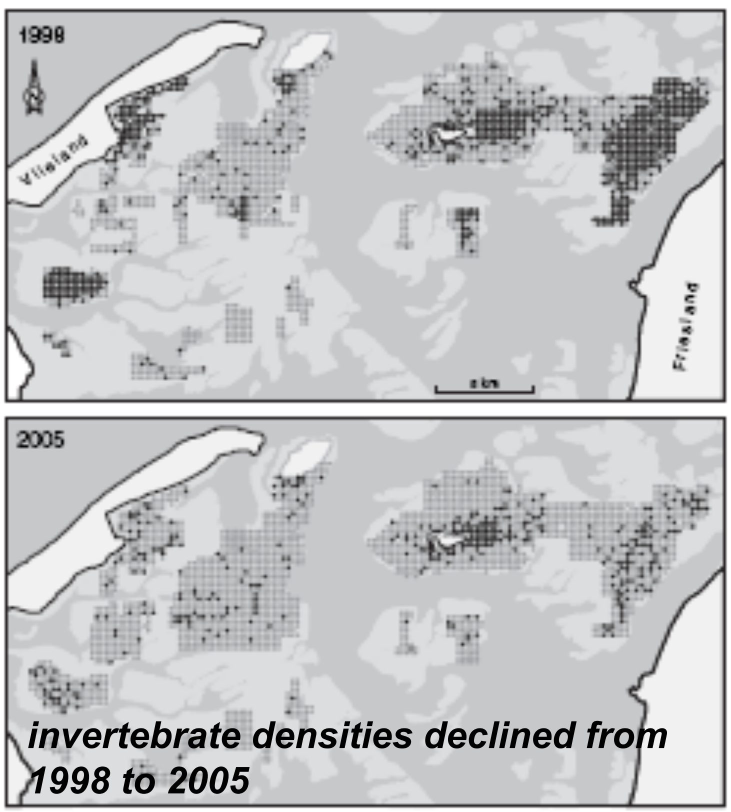


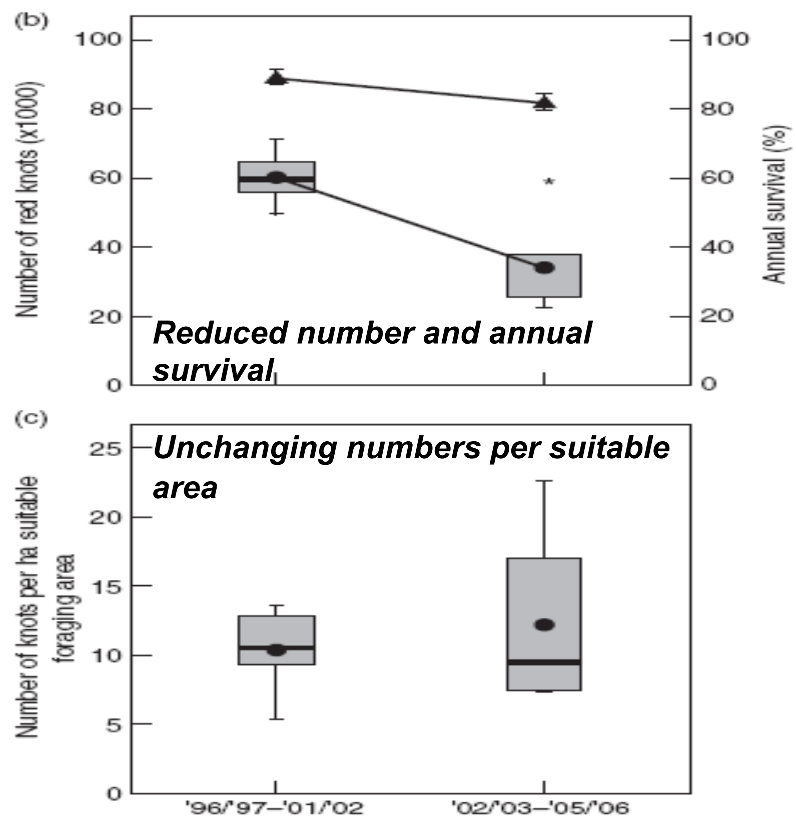
Ecology of Shoals – Conceptual Model



Landscape-scale experiment demonstrates that Wadden Sea intertidal flats are used to capacity by molluscivore migrant shorebirds (Kraan etal. 2009. J. Animal Ecology)

Effects of declining food on mud flats (cockle harvest) was tested for Red Knots based on yearly benthic mapping, colour-ringing, and bird-counts, 1996-2005. Suitable foraging area, spatial predictability of food, and survival were estimated.



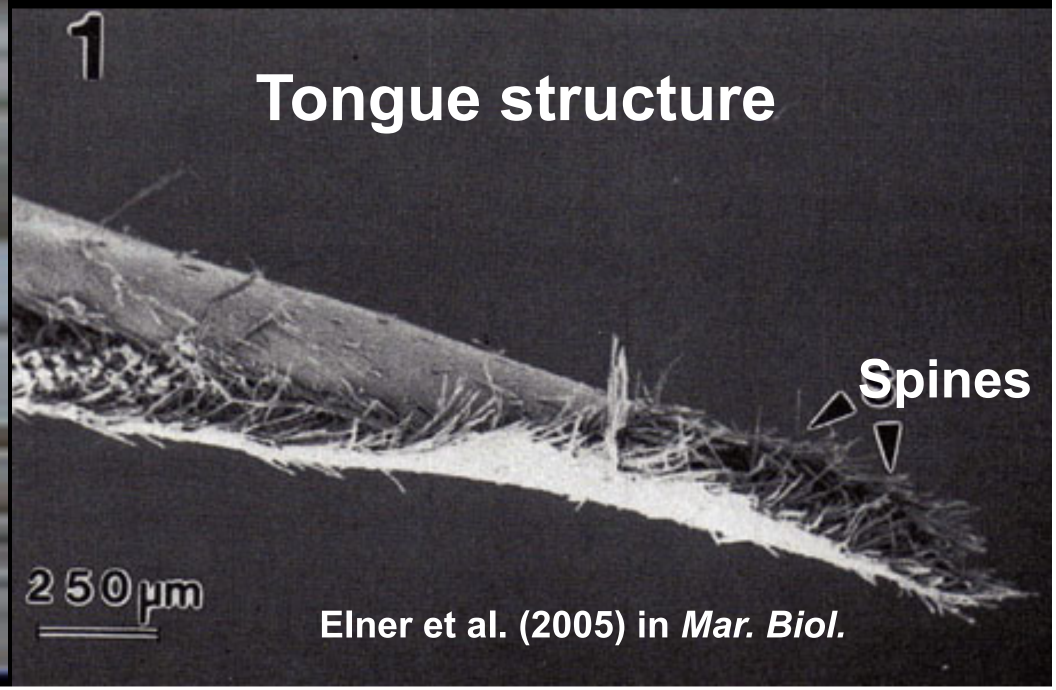


Red Knots lost 55% of their foraging area, decreased 42% in numbers, and .....Survival declined 82-89% accounting for half of the decline; others emigrated.

Evidence from foraging behavior (Kuwae 2010; Slow-motion video replay)

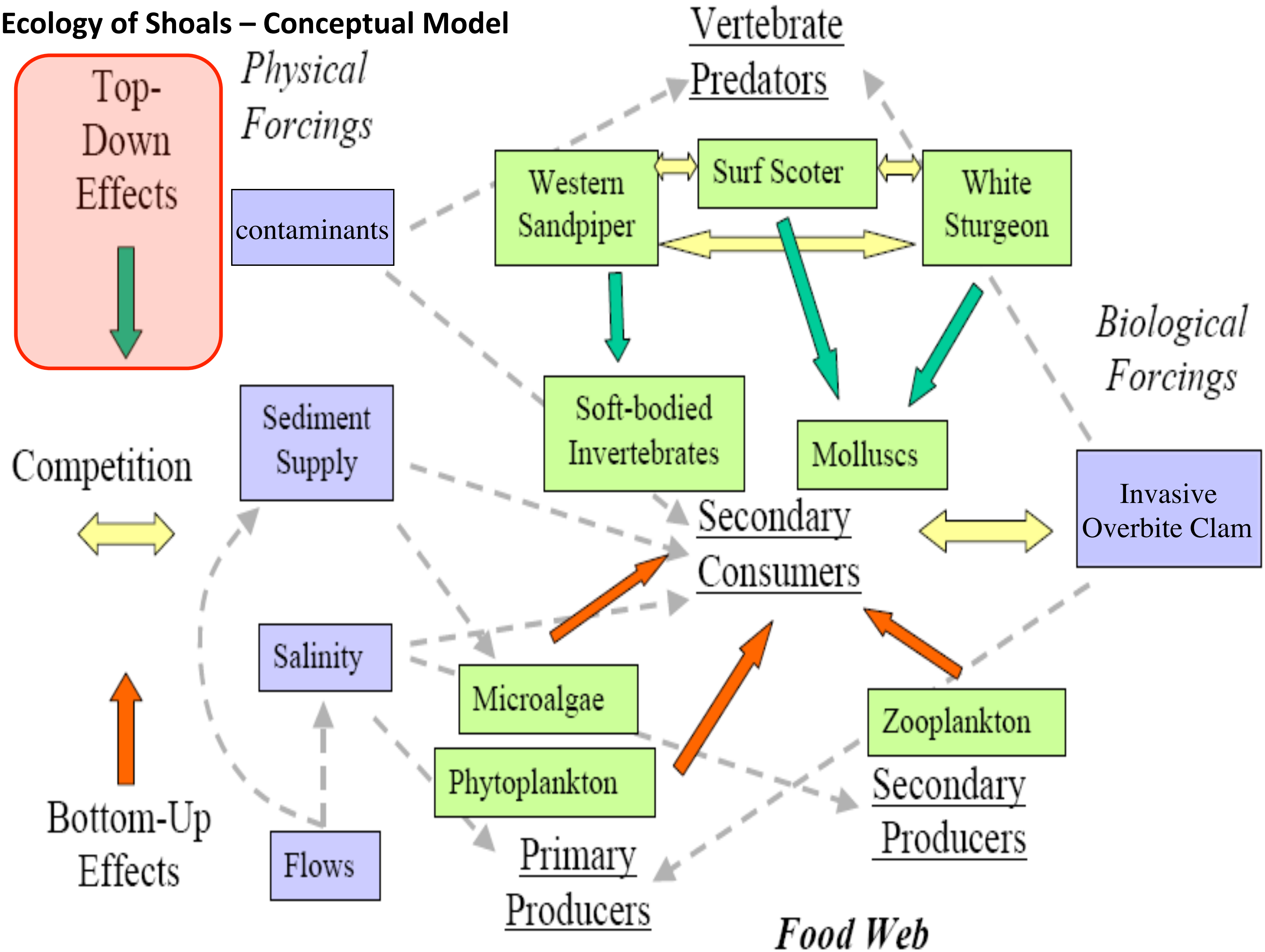
1. Sediment fluid held in between bills
2. Fluid moving back and forth by wiggling bills, as if seiving
3. Tongue structure with spines

Successful capture rate of visible small macrofauna is only 14 ± 11% (±SD)



Elner et al. (2005) in *Mar. Biol.*

Ecology of Shoals – Conceptual Model

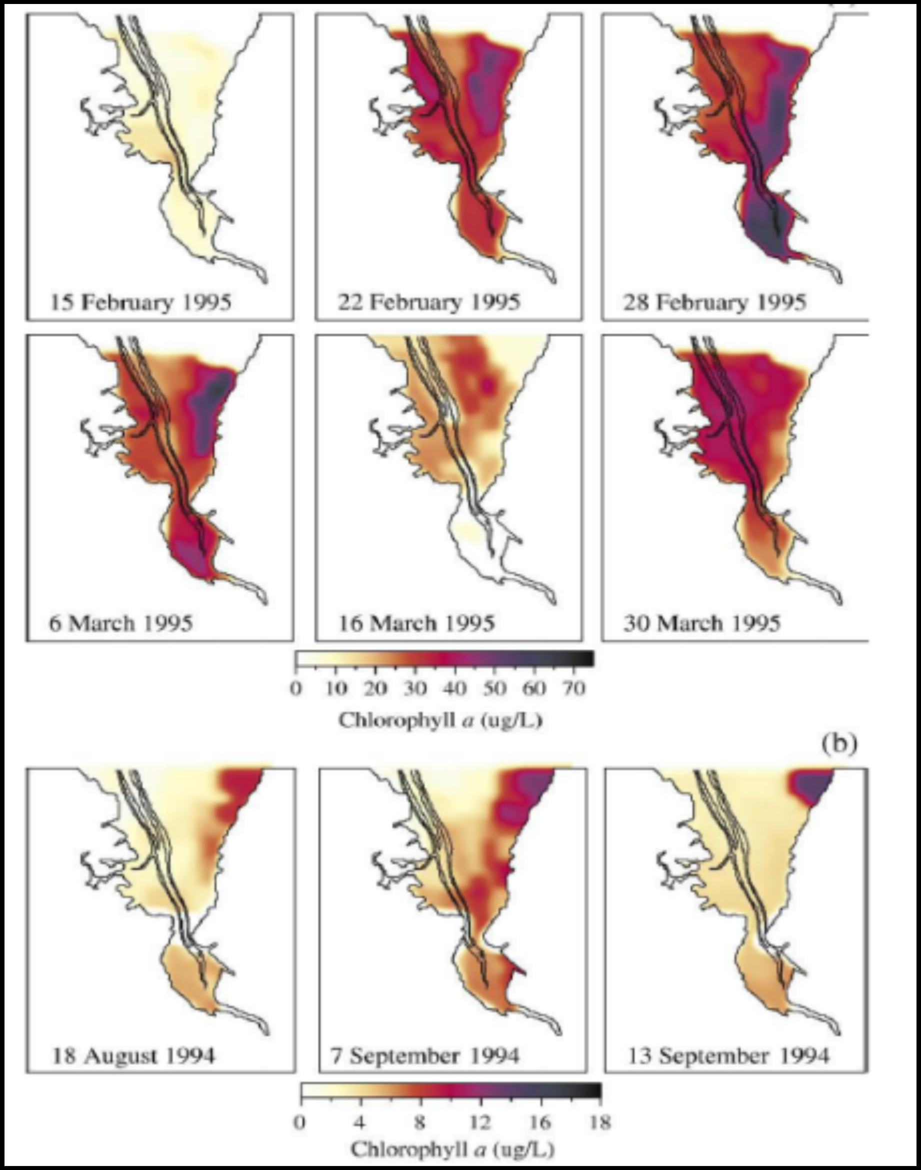


Shallow water processes govern system-wide phytoplankton bloom dynamics. (Thompson etal. 2008. J. Marine Systems; Lucas etal. 2009, J. Marine Systems)

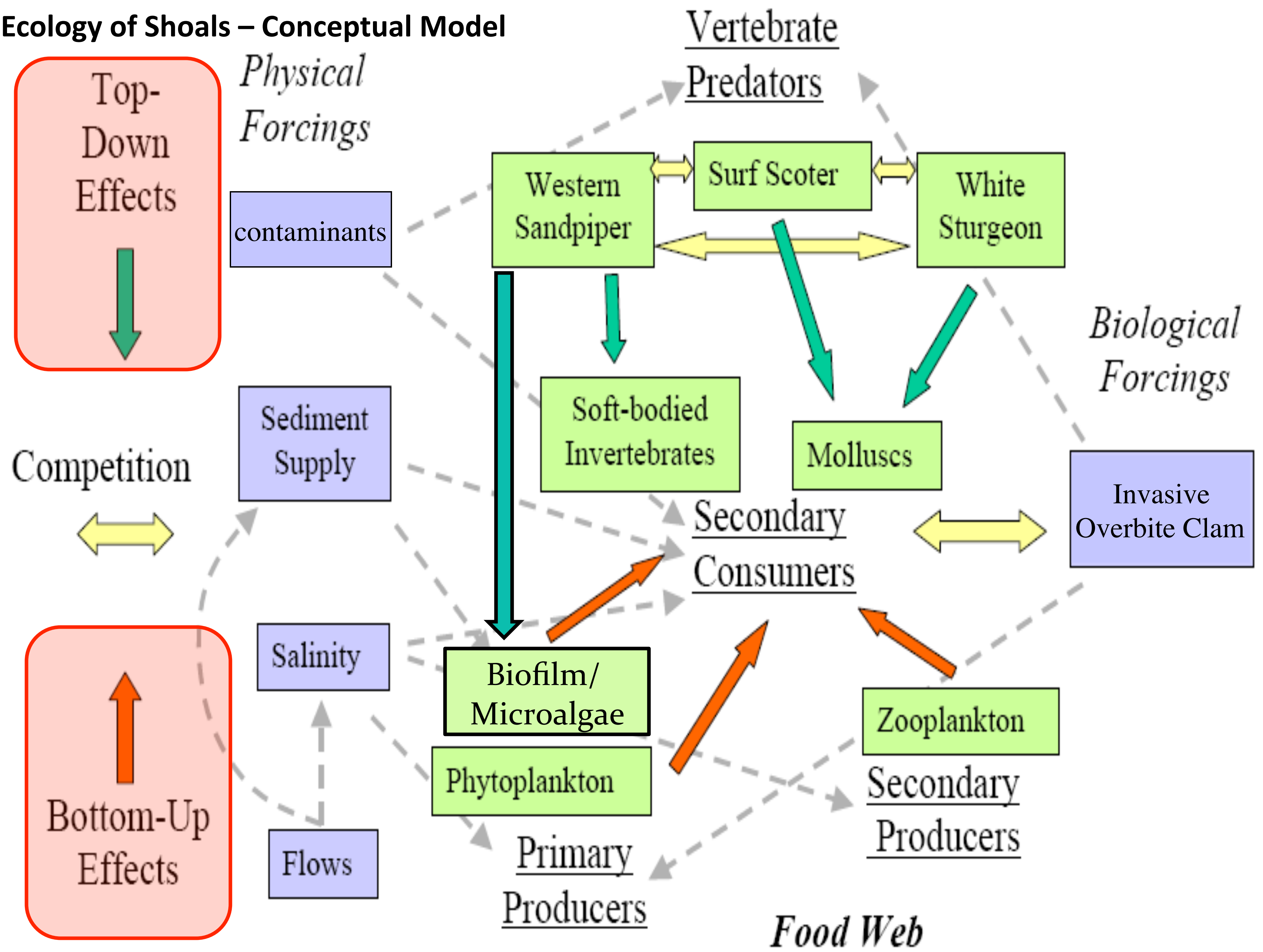
Grazing by bivalves determined phytoplankton blooms, and above a grazing threshold blooms ceased.

Bivalves, preyed upon by birds and fish in the fall and winter, disappear each year prior to the spring bloom.

Growth of phytoplankton depends on shallow water processes -- change in benthic filter-feeders or their predators has great potential to change the bloom dynamics.



Ecology of Shoals – Conceptual Model



South Bay Salt Pond Restoration

- Largest tidal wetland restoration on west coast
  - 16,500 acres of commercial salt ponds in South San Francisco Bay, 1,400 acres along Napa River in North Bay.
- South Bay Salt Pond Restoration Project will convert salt ponds into mosaic of tidal wetlands within an adaptive management framework

Restoration Uncertainties

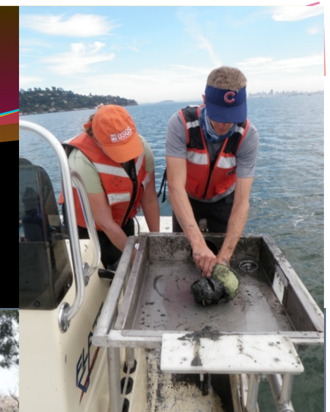
- A key uncertainty is how the restoration will affect the estuarine shoals that support the region's migratory birds and fishes.
- Ideal site to study hydrology, geomorphology, invertebrate-shorebird foodwebs

Dumbarton Shoals

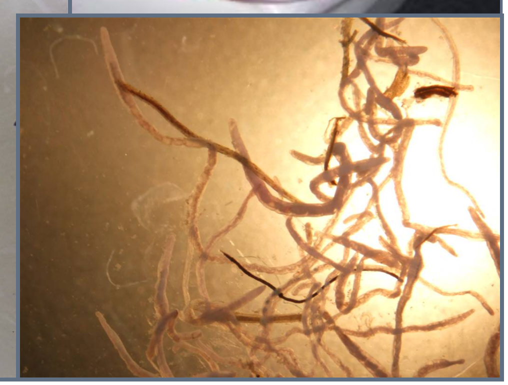
- 3 transects along elevation gradient
- 9 sampling locations
- 3 replicates for a total of 81 cores.
  - Subsample 1 core/ location
- Monthly sampling
- Biofilm, Oct 2010

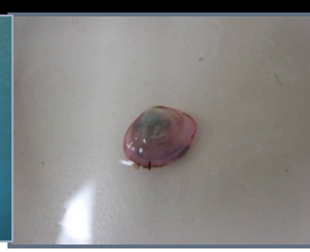
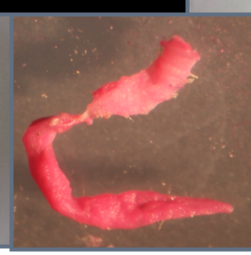
Methods

- Sieve through 0.5 mm screen
- Stained with Rose Bengal dye, preserved in 70% ethanol
- Sorted to lowest possible taxon
- Bivalves sorted by size class
- Biomass



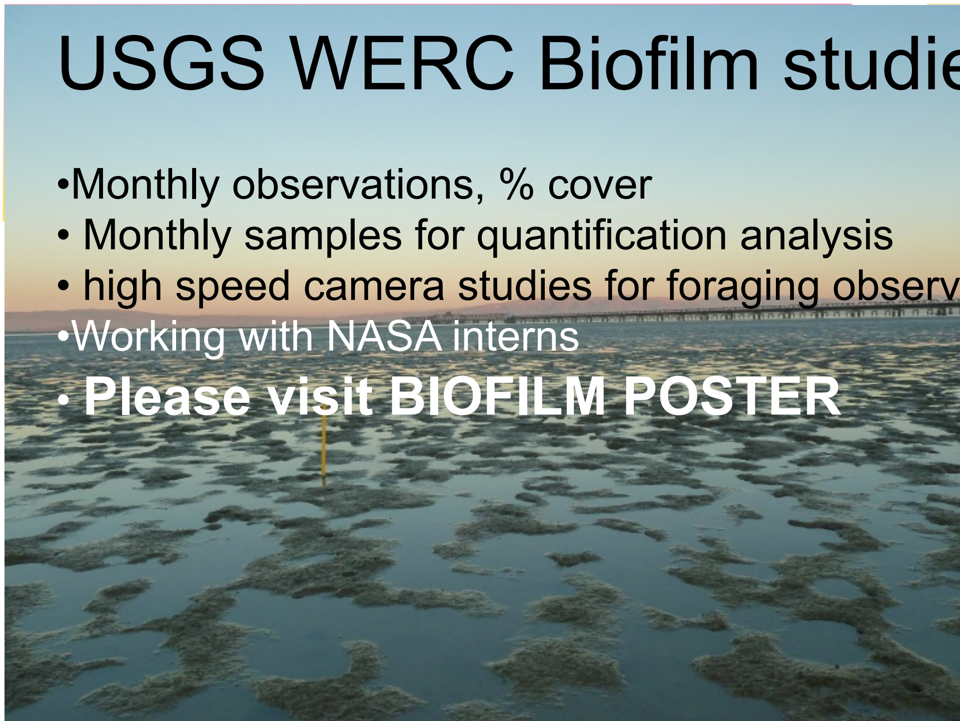


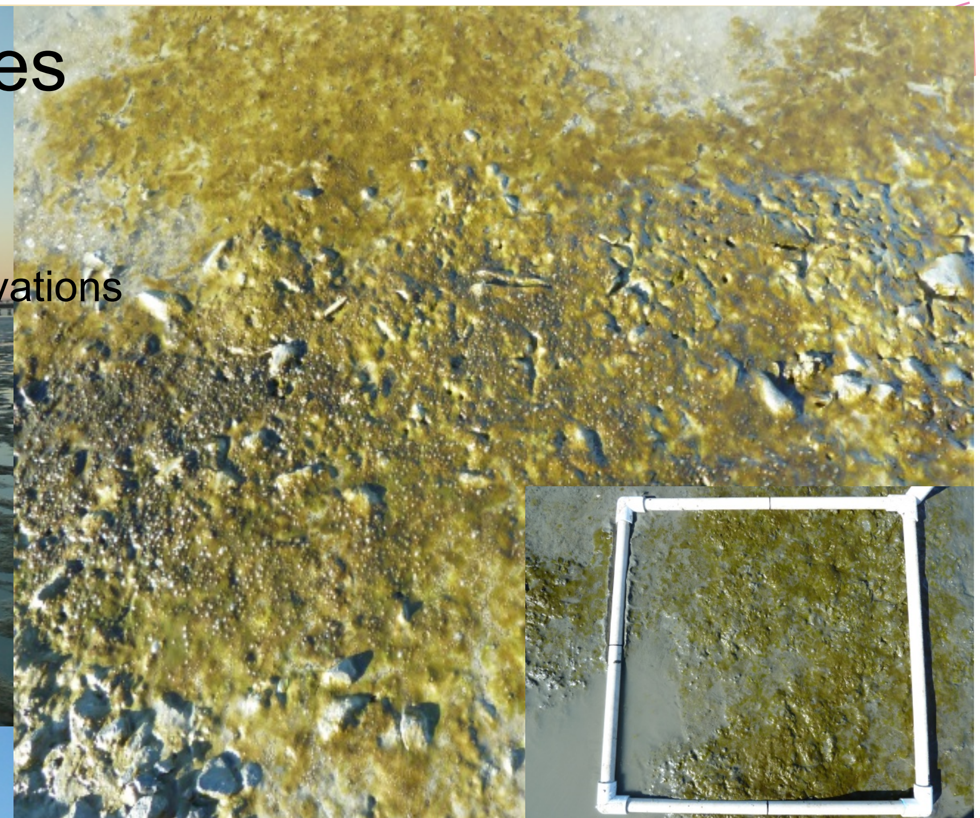



USGS WERC Biofilm studies

- Monthly observations, % cover
- Monthly samples for quantification analysis
- high speed camera studies for foraging observations
- Working with NASA interns
- **Please visit BIOFILM POSTER**





NASA DEVELOP interns at Dumbarton Shoals collecting spectral reflectance data

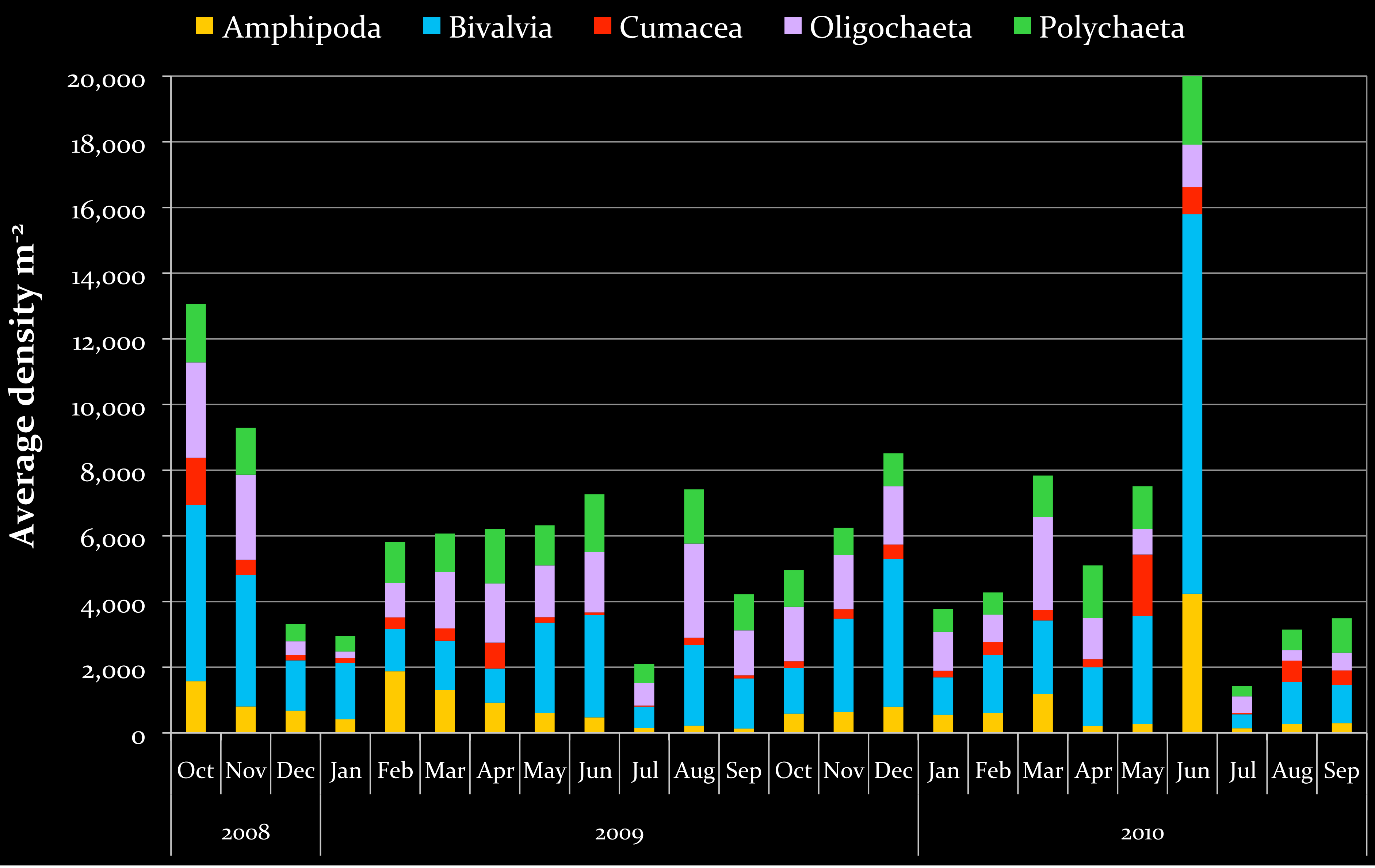
Results

- Invertebrate Density:
  - temporal and spatial variation
- Biomass
  - Ash Free Dry Weight maps, depletion?
- Available Foraging Times for invertebrate predation
- Patterns in Bivalve Size Class
  - Vary by elevation position and time

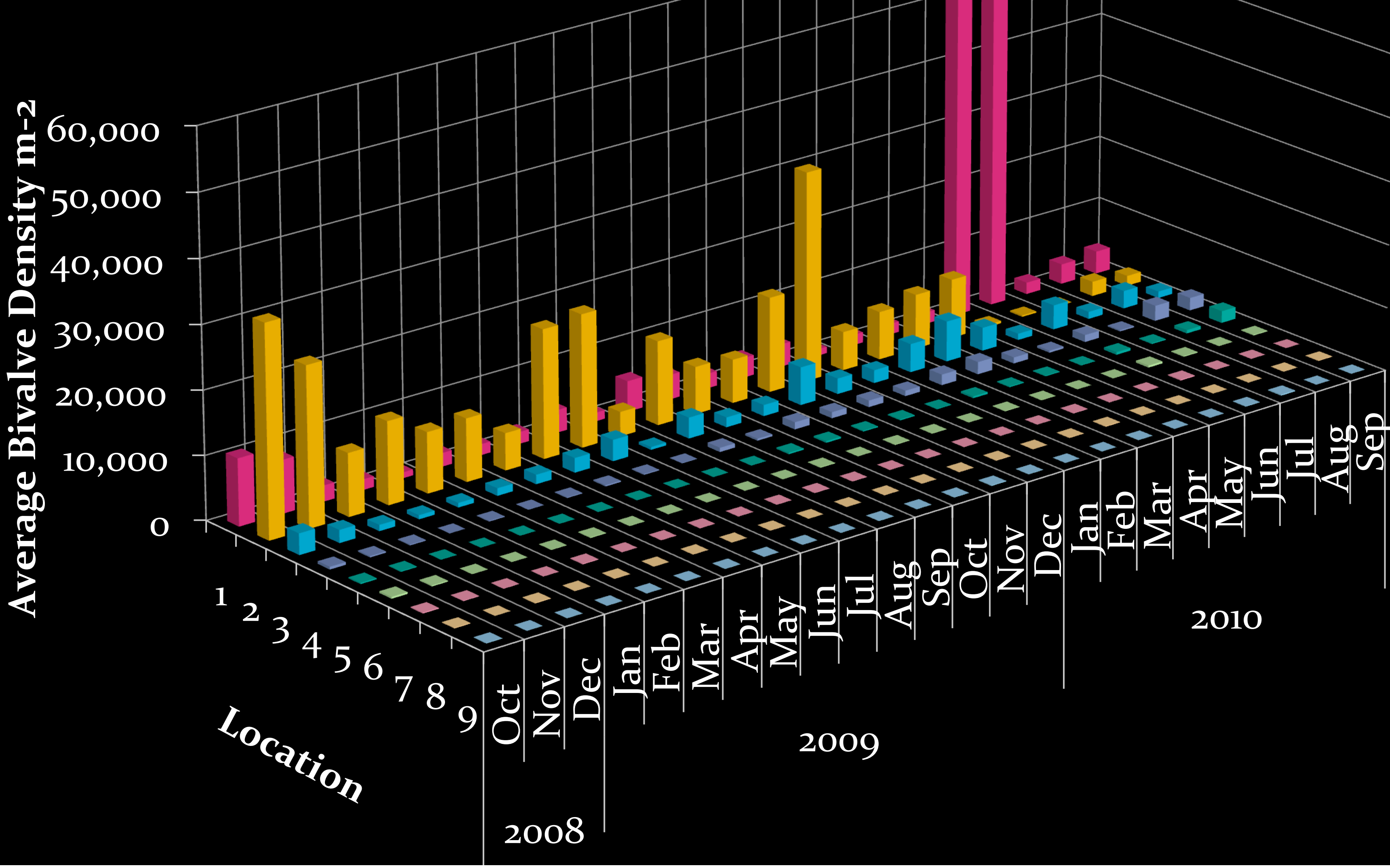
Results

- Invertebrate Density:
  - temporal and spatial variation

Taxa densities varied over time

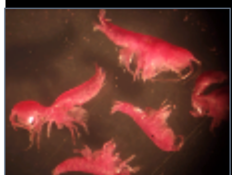


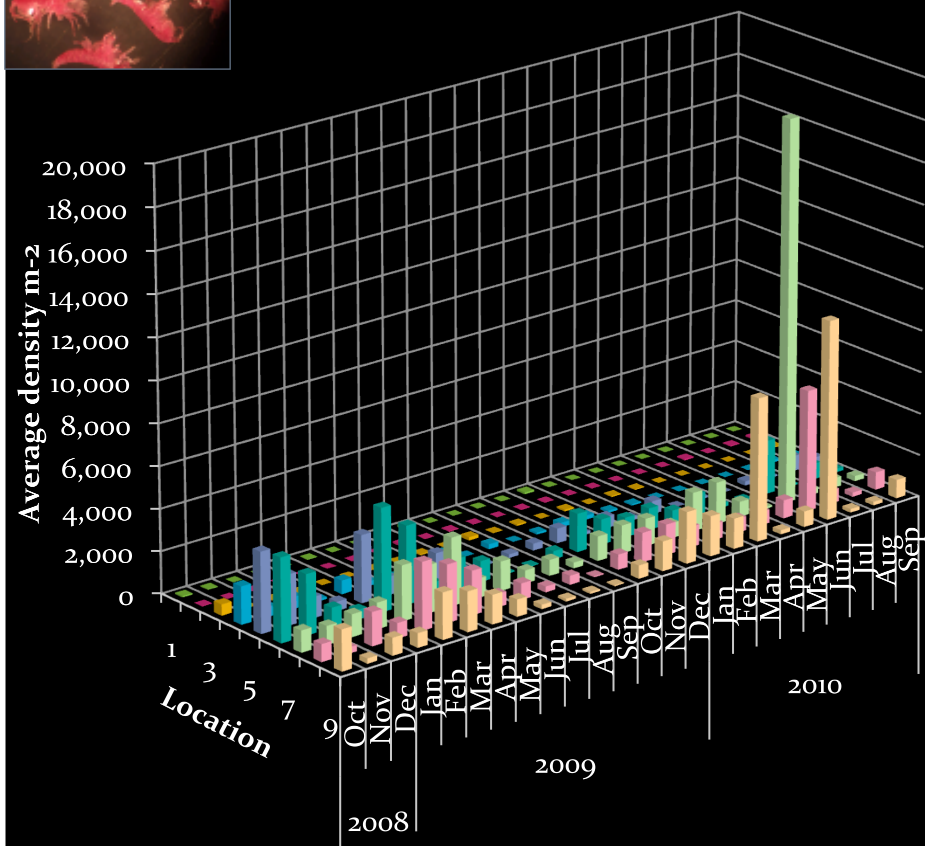
Bivalve density varied by month and location



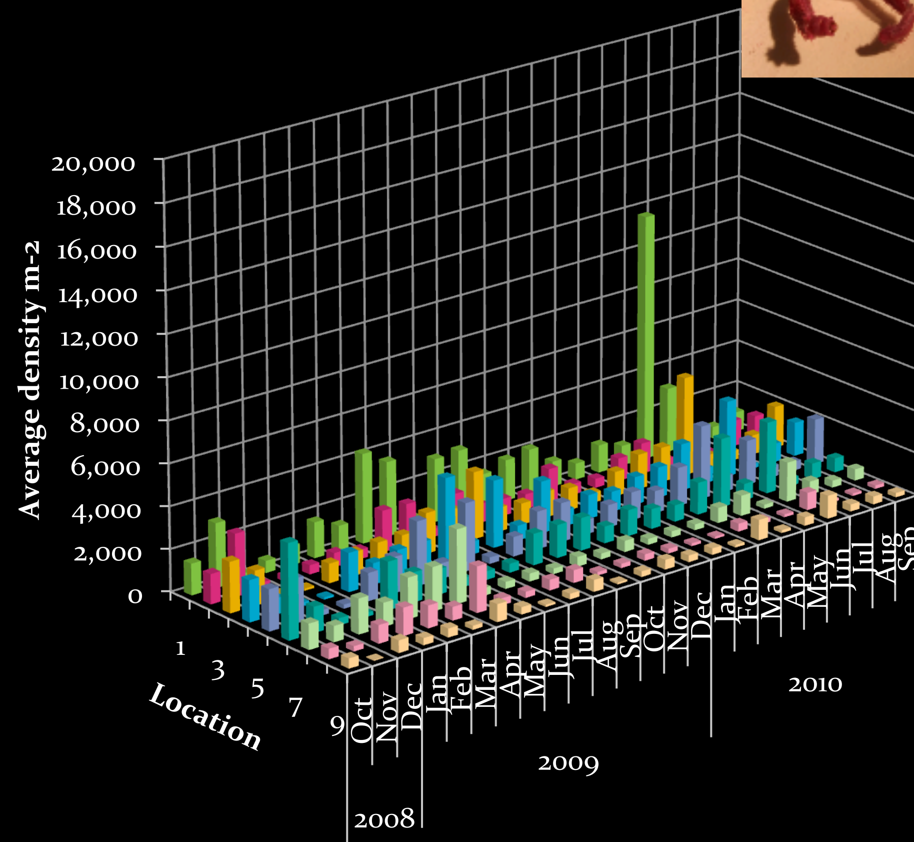
Spatial and temporal distribution varies by taxa

Amphipods



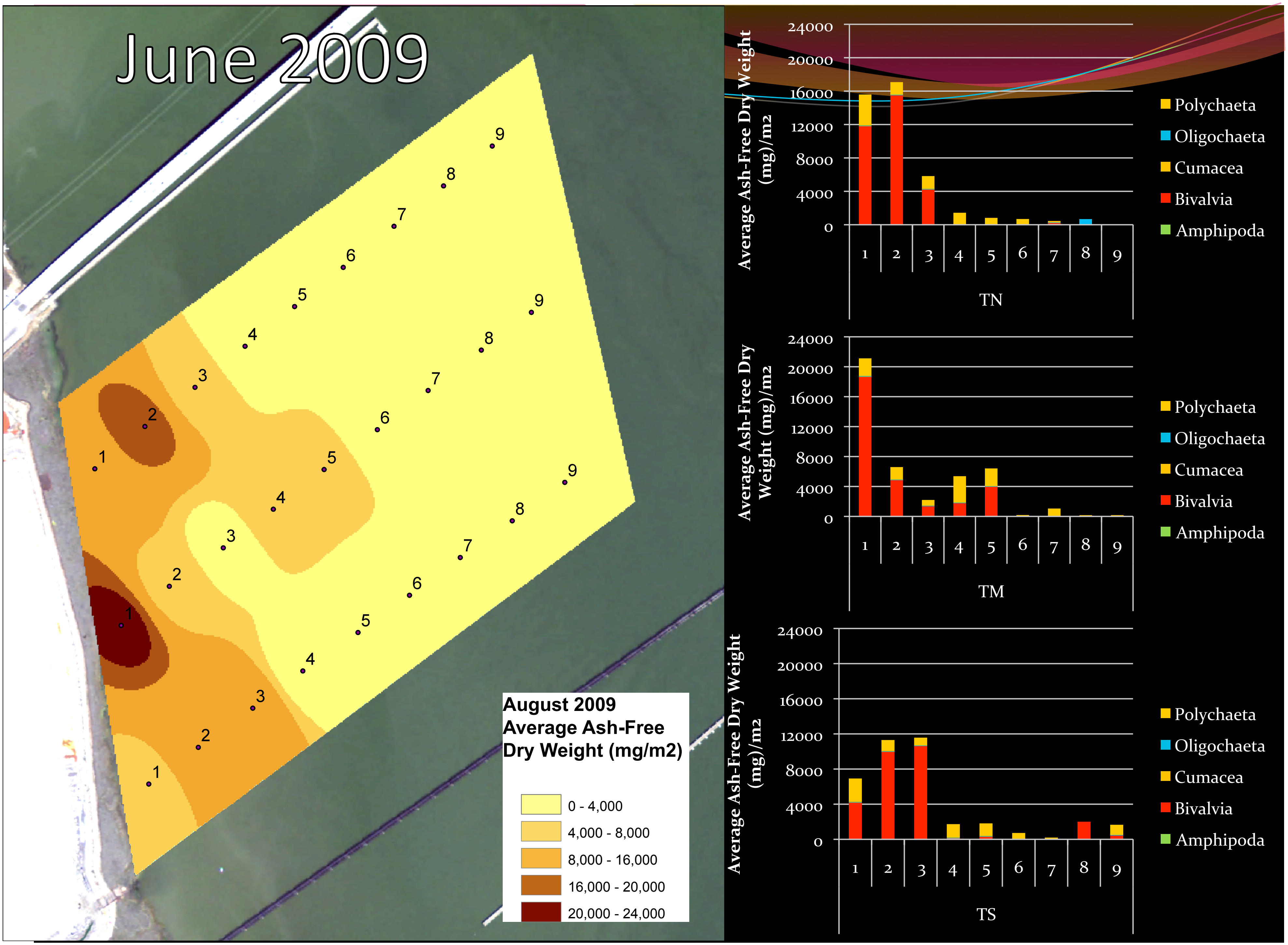


Polychaetes

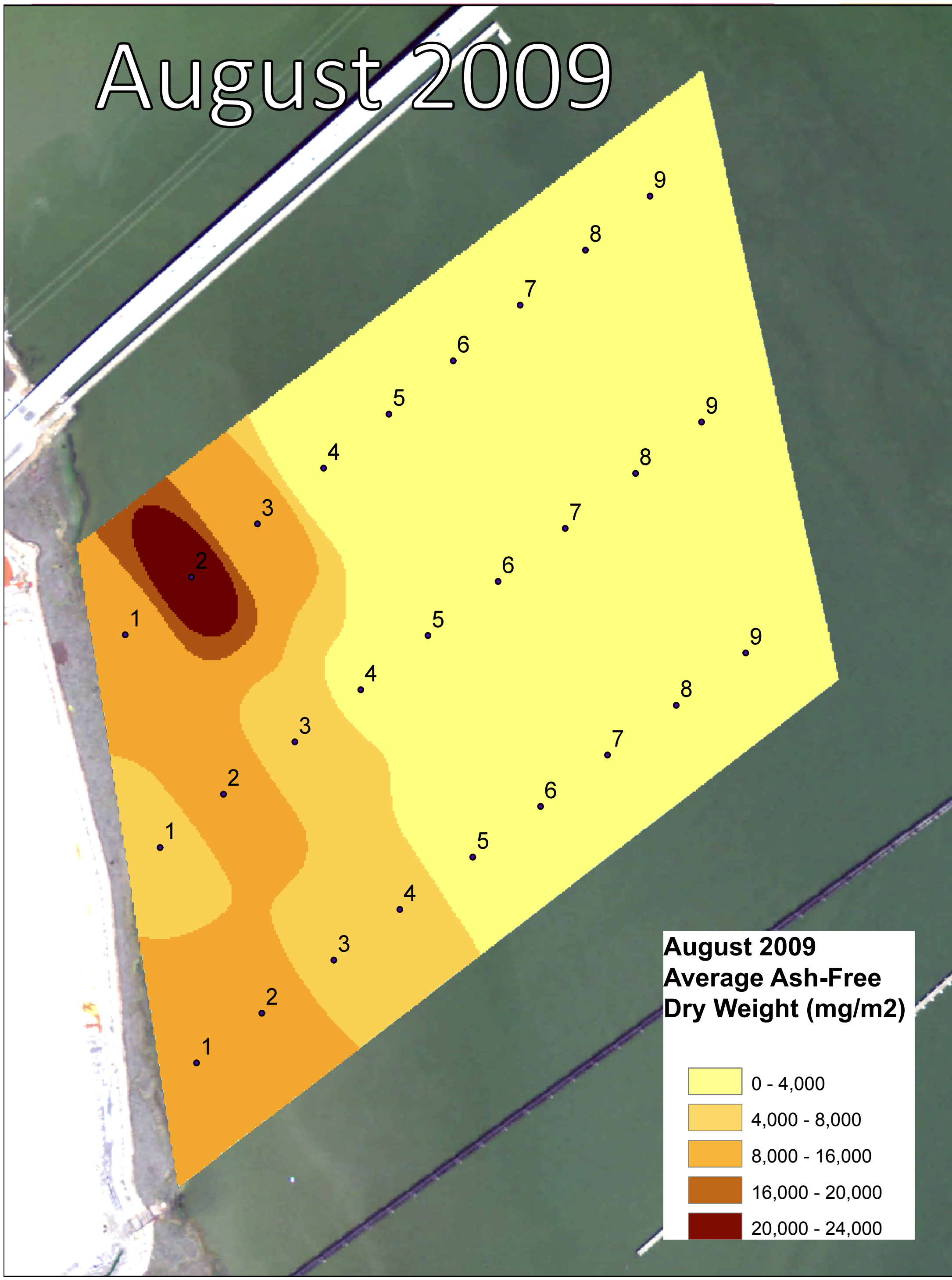


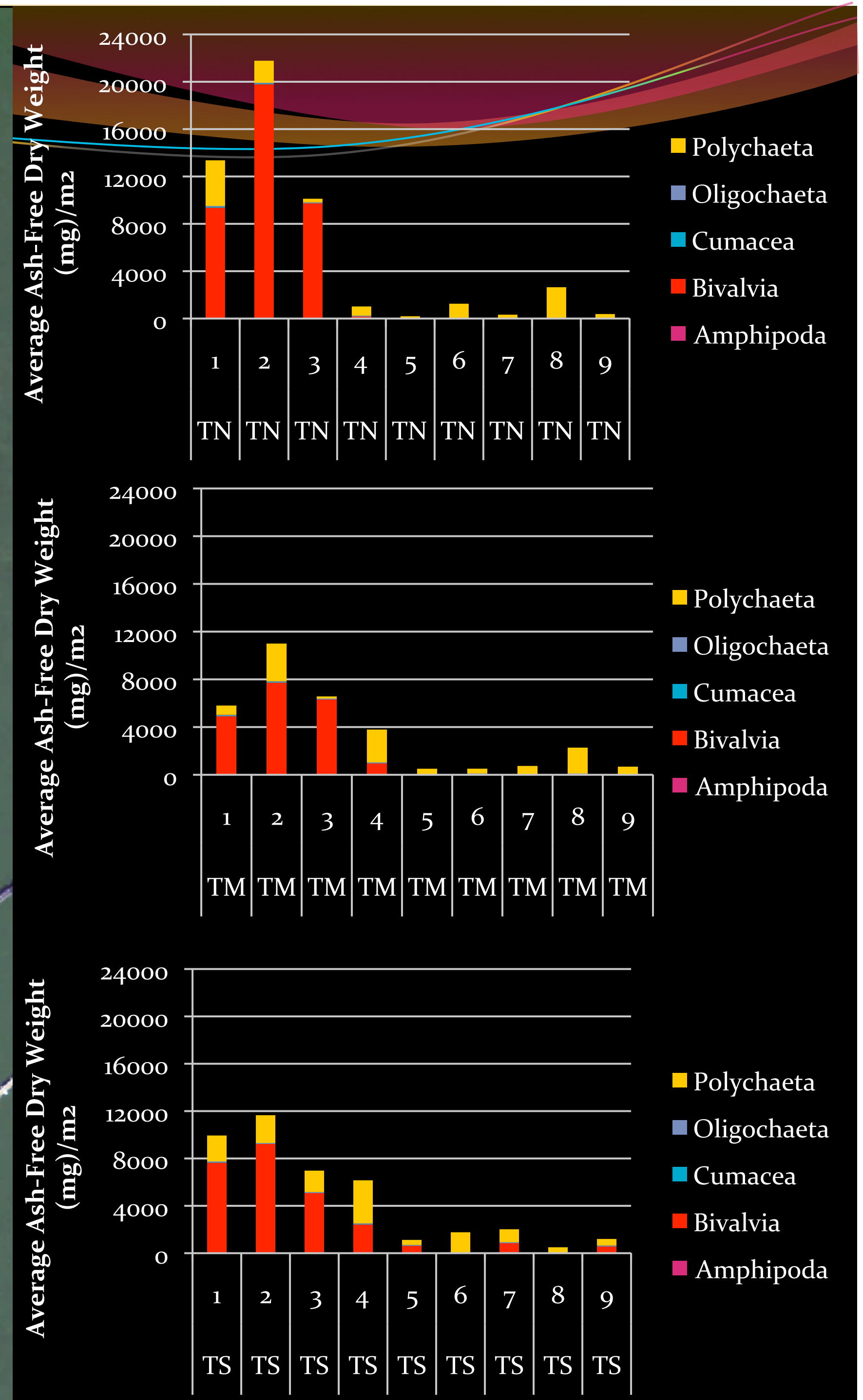
Results

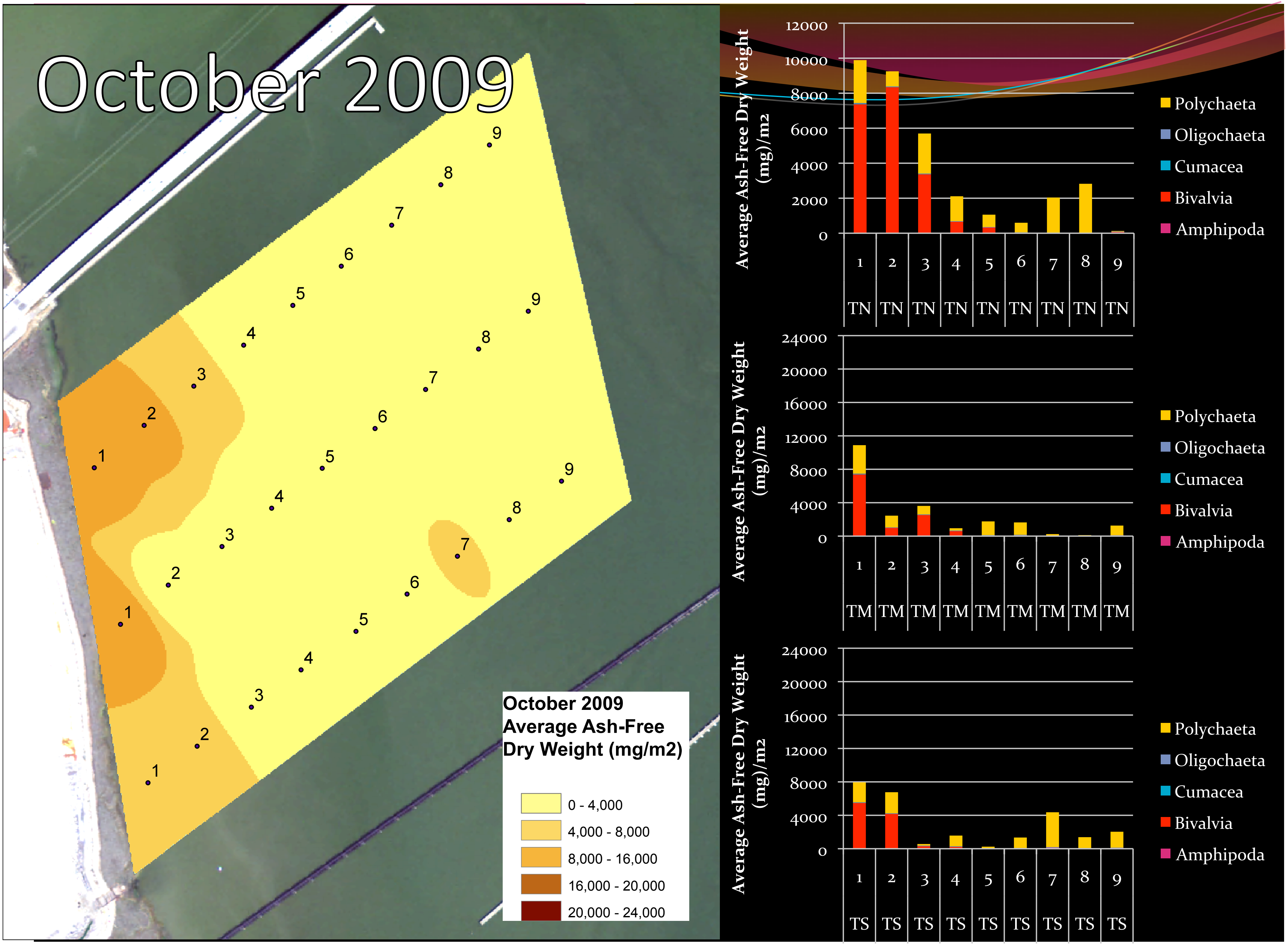
- Invertebrate Density:
  - temporal and spatial variation
- Biomass
  - Ash Free Dry Weight maps, depletion?



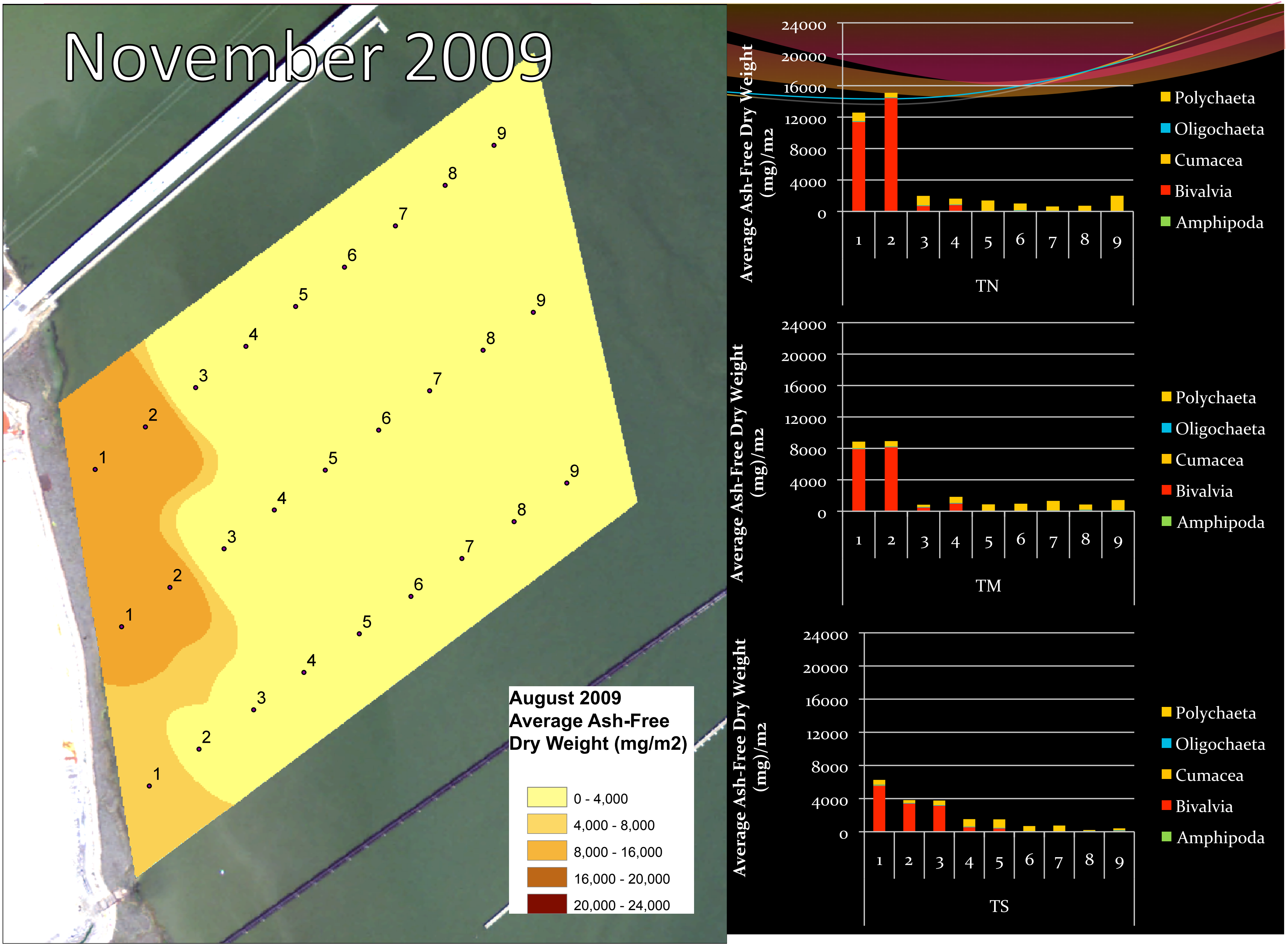
June 2009
August 2009
Average Ash-Free
Dry Weight (mg/m2)
0 - 4,000
4,000 - 8,000
8,000 - 16,000
16,000 - 20,000
20,000 - 24,000
Average Ash-Free Dry Weight (mg)/m2
TN
Average Ash-Free Dry Weight (mg)/m2
TM
Average Ash-Free Dry Weight (mg)/m2
TS
Polychaeta
Oligochaeta
Cumacea
Bivalvia
Amphipoda

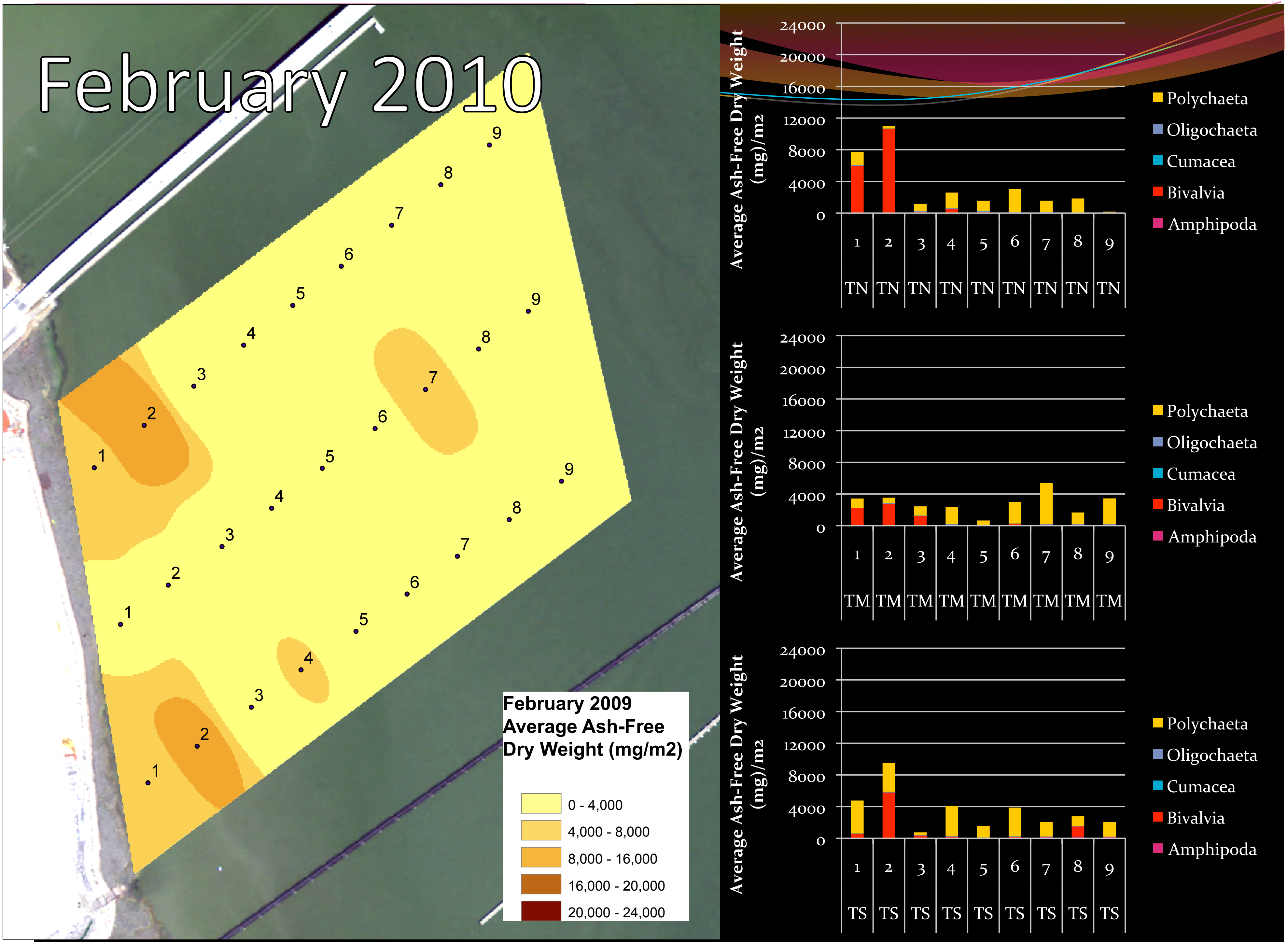

August 2009
1
2
3
4
5
6
7
8
9
August 2009
Average Ash-Free
Dry Weight (mg/m2)
0 - 4,000
4,000 - 8,000
8,000 - 16,000
16,000 - 20,000
20,000 - 24,000


Average Ash-Free Dry Weight (mg)/m2
24000
20000
16000
12000
8000
4000
0
1 2 3 4 5 6 7 8 9
TN TN TN TN TN TN TN TN TN
Polychaeta
Oligochaeta
Cumacea
Bivalvia
Amphipoda
Average Ash-Free Dry Weight (mg)/m2
1 2 3 4 5 6 7 8 9
TM TM TM TM TM TM TM TM TM
Average Ash-Free Dry Weight (mg)/m2
1 2 3 4 5 6 7 8 9
TS TS TS TS TS TS TS TS TS



October 2009
October 2009 Average Ash-Free Dry Weight (mg/m2)
0 - 4,000
4,000 - 8,000
8,000 - 16,000
16,000 - 20,000
20,000 - 24,000
Average Ash-Free Dry Weight (mg)/m2
Polychaeta
Oligochaeta
Cumacea
Bivalvia
Amphipoda
TN
TM
TS


November 2009
1
2
3
4
5
6
7
8
9
August 2009
Average Ash-Free
Dry Weight (mg/m2)
0 - 4,000
4,000 - 8,000
8,000 - 16,000
16,000 - 20,000
20,000 - 24,000
Average Ash-Free Dry Weight (mg)/m2
0
4000
8000
12000
16000
20000
24000
TN
TM
TS
Polychaeta
Oligochaeta
Cumacea
Bivalvia
Amphipoda


February 2010
February 2009
Average Ash-Free
Dry Weight (mg/m2)
0 - 4,000
4,000 - 8,000
8,000 - 16,000
16,000 - 20,000
20,000 - 24,000
Average Ash-Free Dry Weight (mg)/m2
24000
20000
16000
12000
8000
4000
0
1 2 3 4 5 6 7 8 9
TN TN TN TN TN TN TN TN TN
TM TM TM TM TM TM TM TM TM
TS TS TS TS TS TS TS TS TS
Polychaeta
Oligochaeta
Cumacea
Bivalvia
Amphipoda

Results

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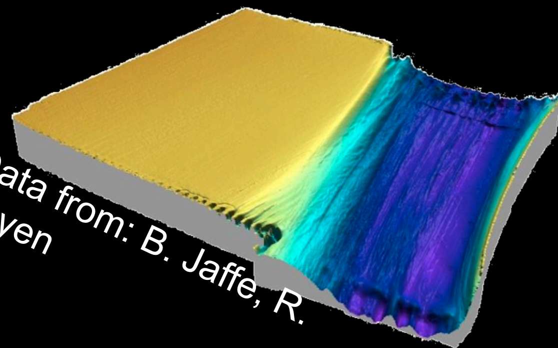
- Biomass
  - Ash Free Dry Weight maps, depletion?
- Available Foraging Times for invertebrate predation

Habitat availability for foraging



Data from: B. Jaffe, R. Kayen

Topography/ bathymetry

Data from: D. Schoelhamer, G. Shellenbarger

Water Levels

Foraging depths

Foraging depths in water and sediment vary by species (m)

.02
.04
.10
.50
1
10

Least Sandpiper

Snowy Plover
Western Sandpiper
Dunlin

Black-necked Stilt
American Avocet
Marbled Godwit

Northern Shoveler
Northern Pintail
Mallard

Lesser Scaup
Ruddy Duck
Eared Grebe
Least Tern

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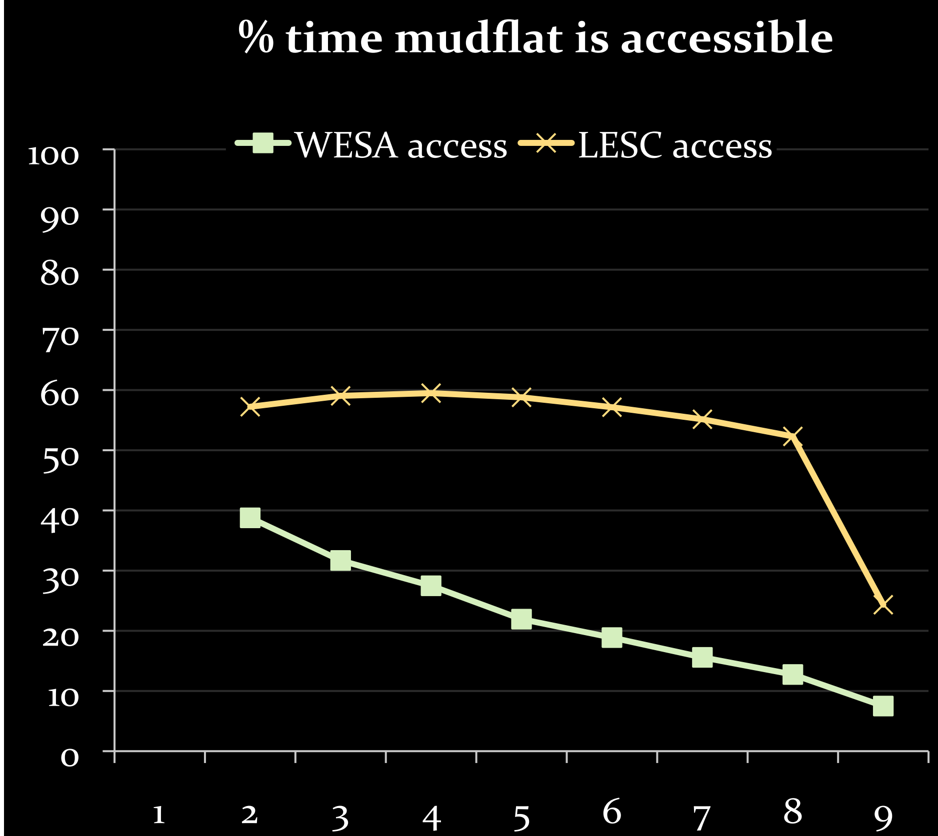
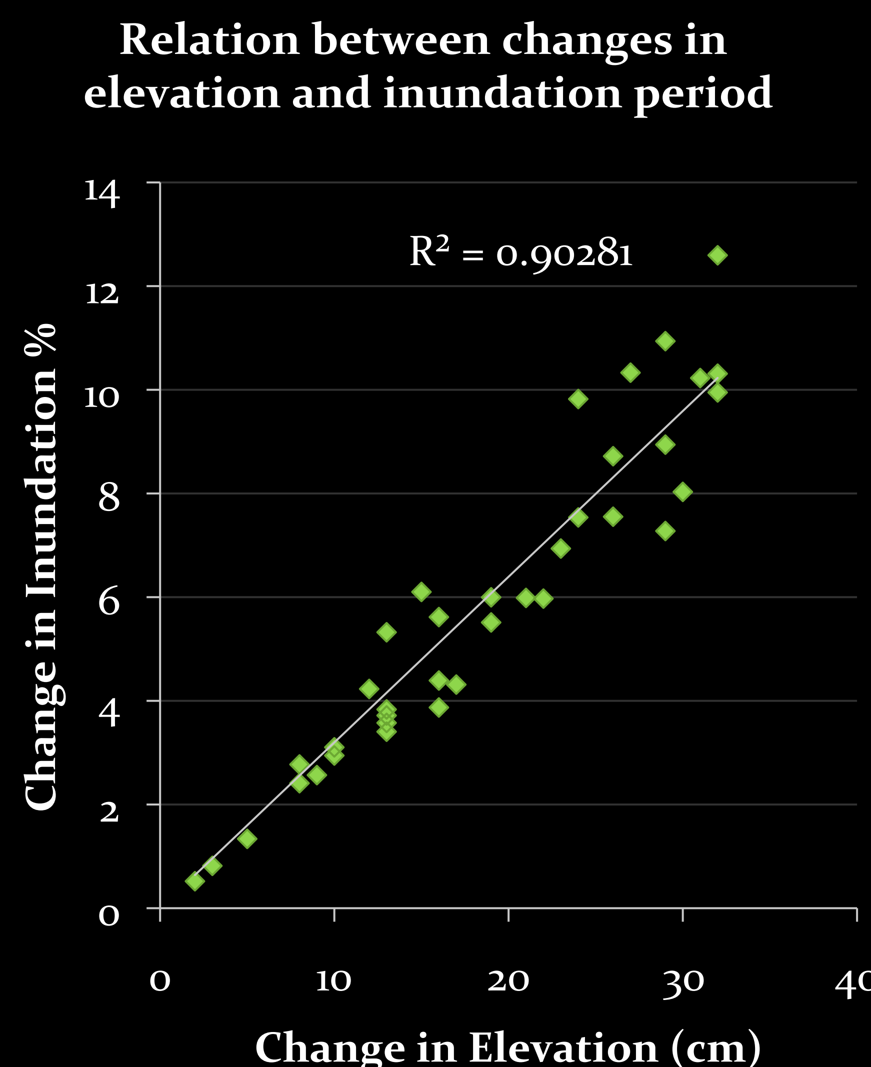
Accessible habitat for predation





Results

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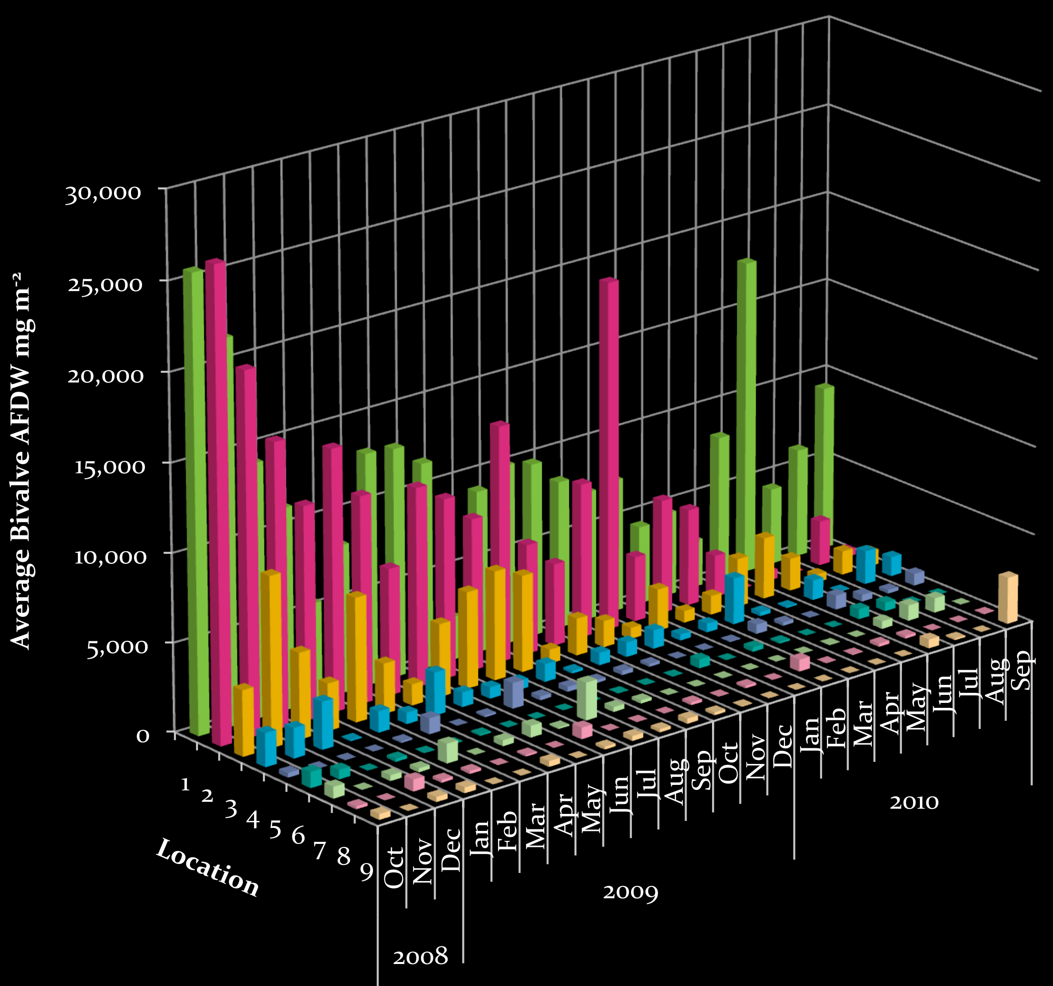
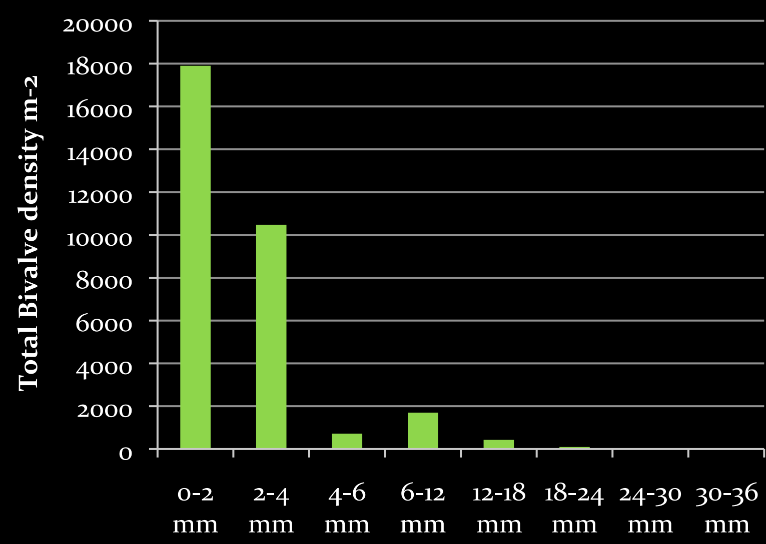
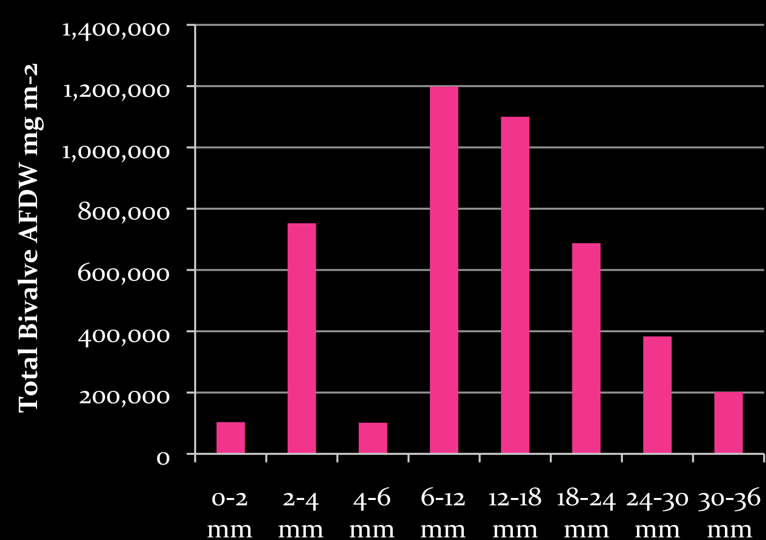
- Patterns in Bivalve Size Class
  - Vary by elevation position and time

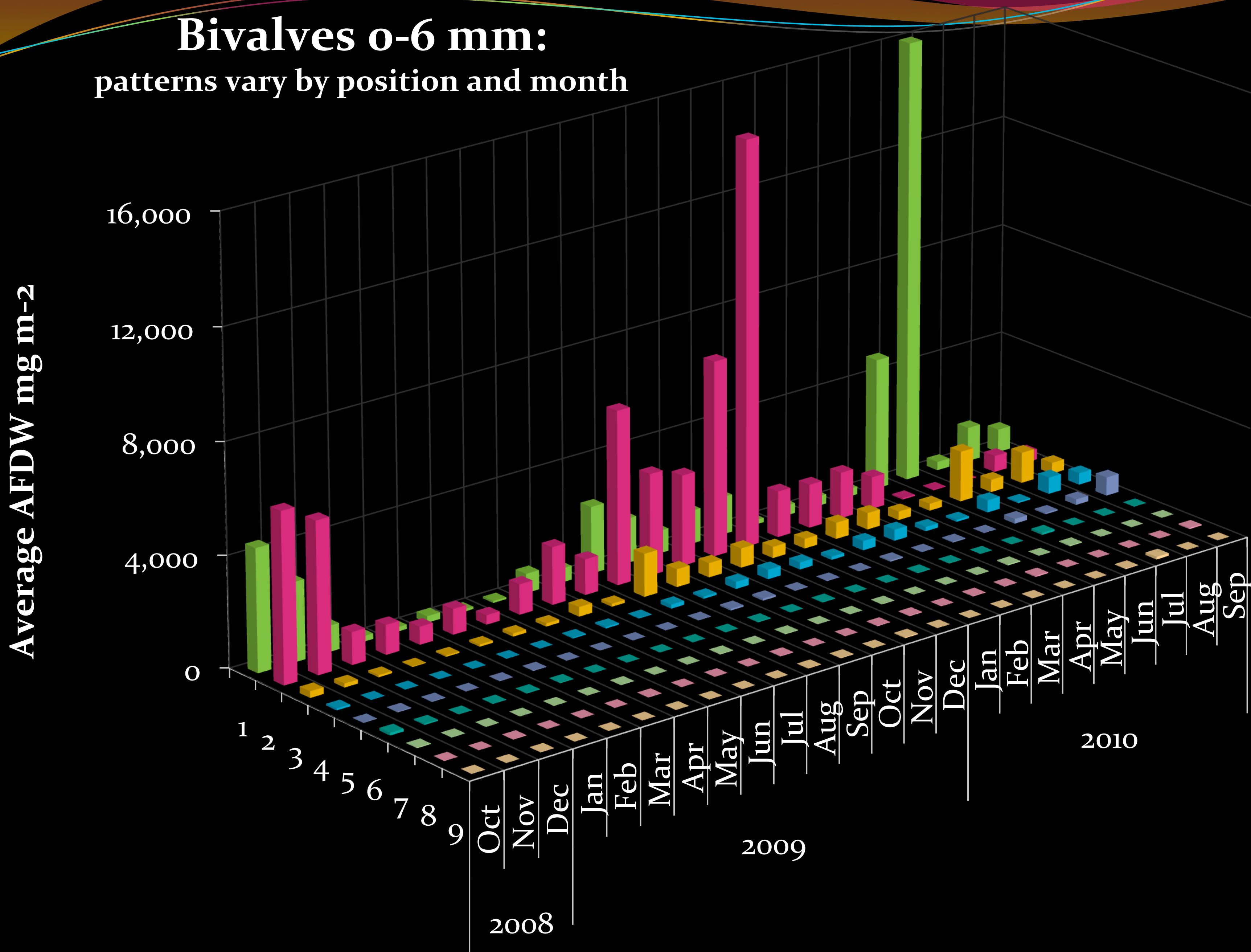
Bivalve biomass is primarily in shallow shoals





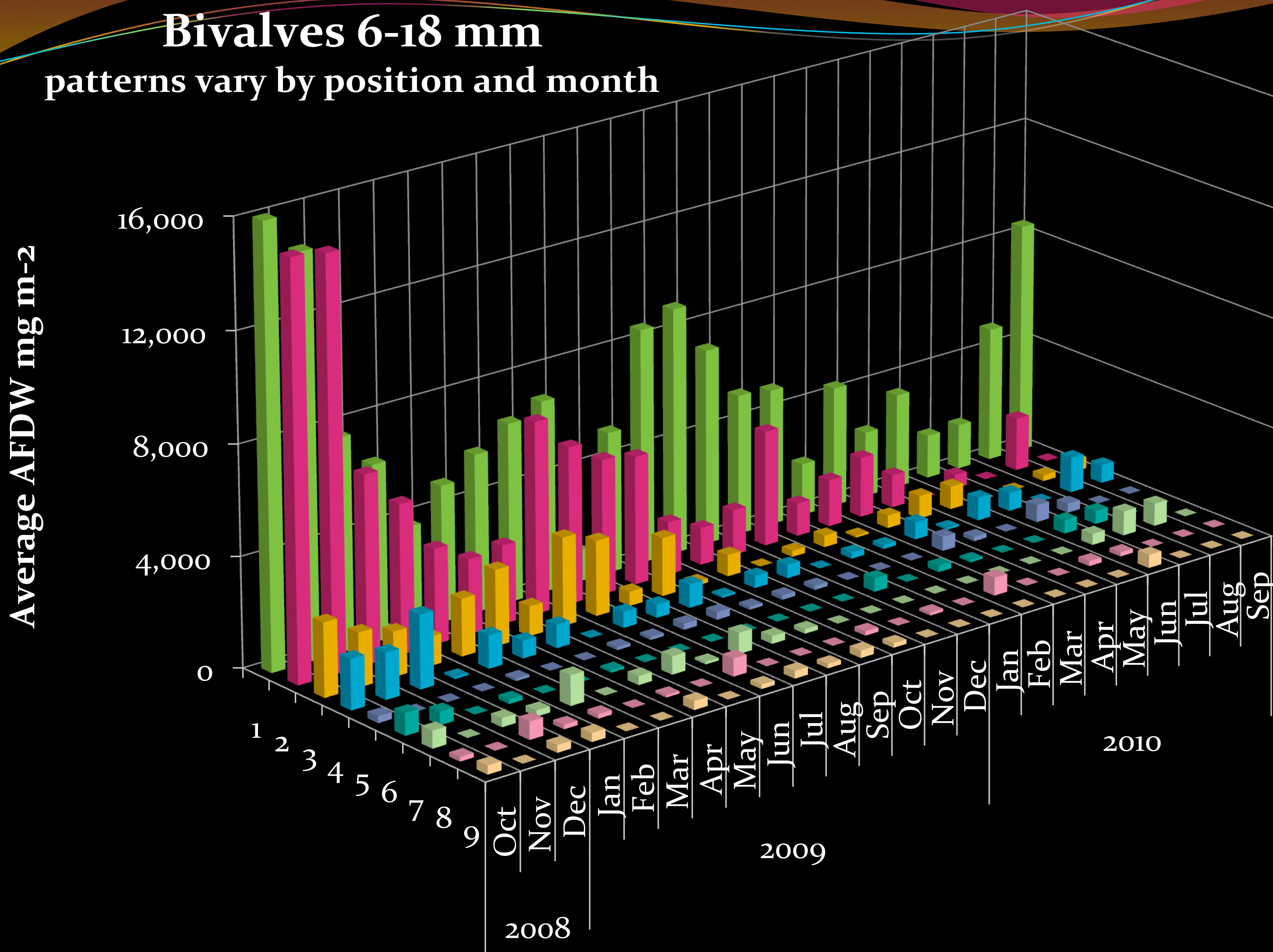


Bivalves 0-6 mm:
patterns vary by position and month

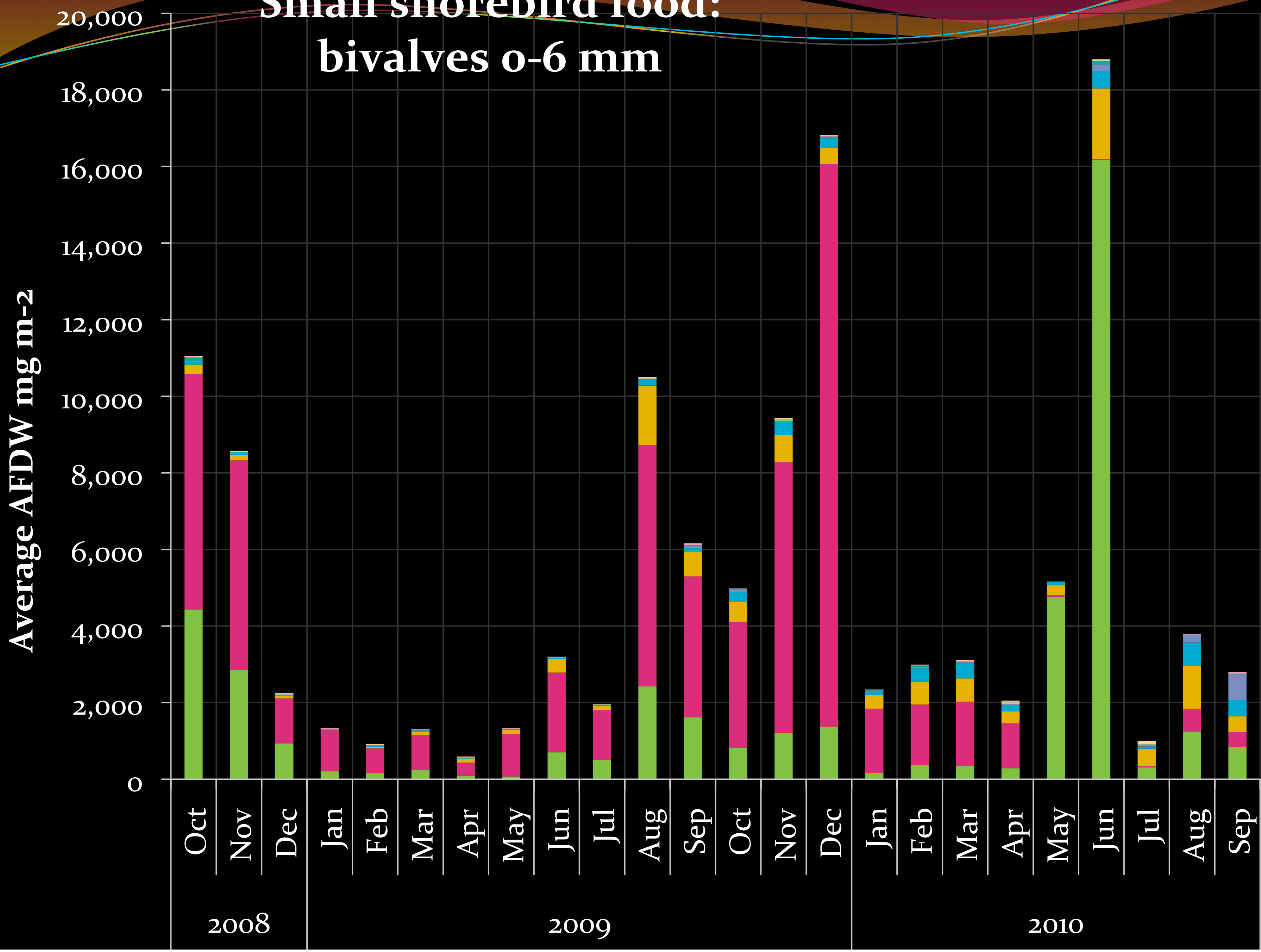


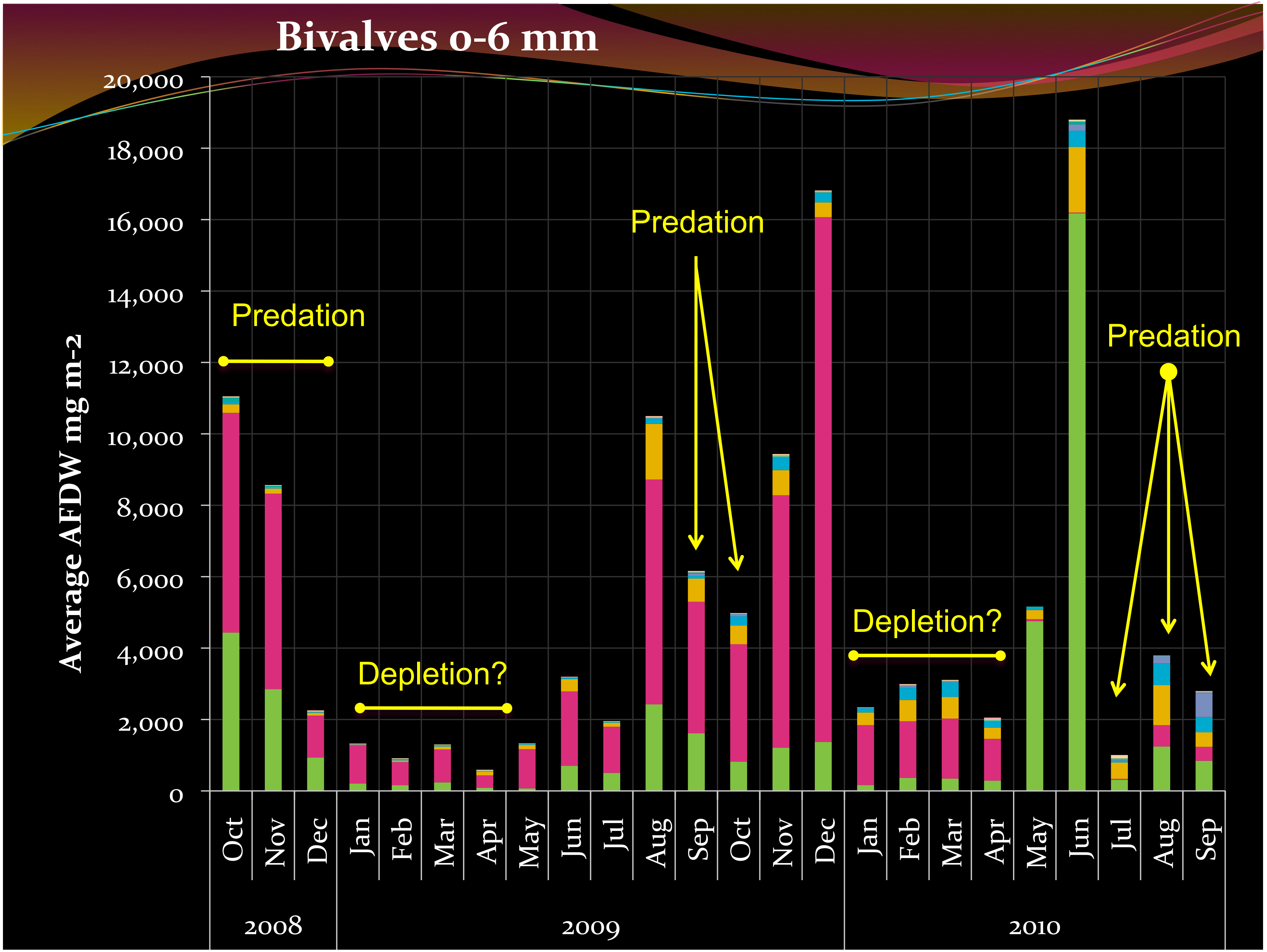
Bivalves 6-18 mm

patterns vary by position and month



Small shorebird food: bivalves 0-6 mm




Bivalves 0-6 mm
Average AFDW mg m-2
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
Predation
Depletion?
Predation
Depletion?
Predation
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
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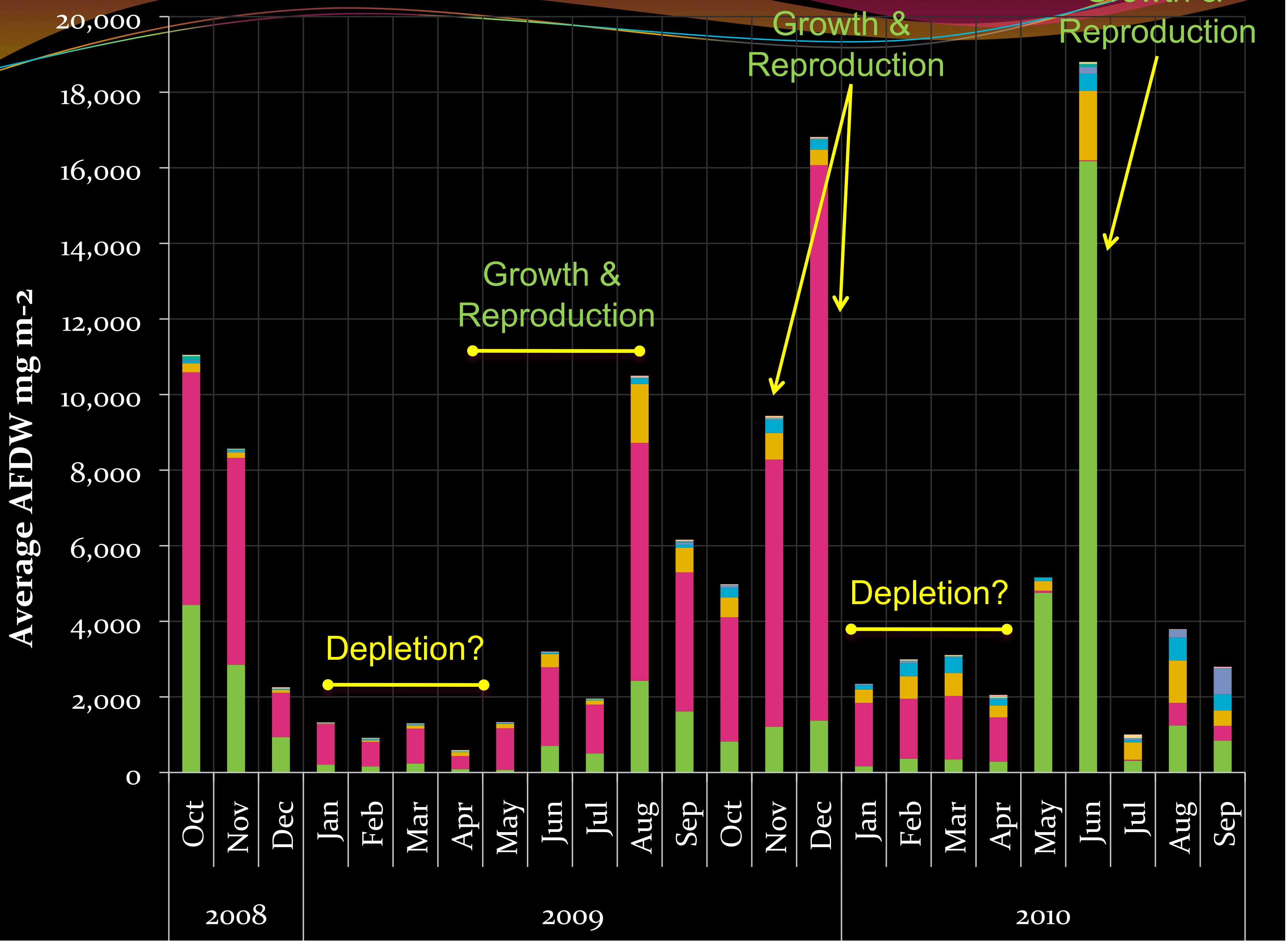
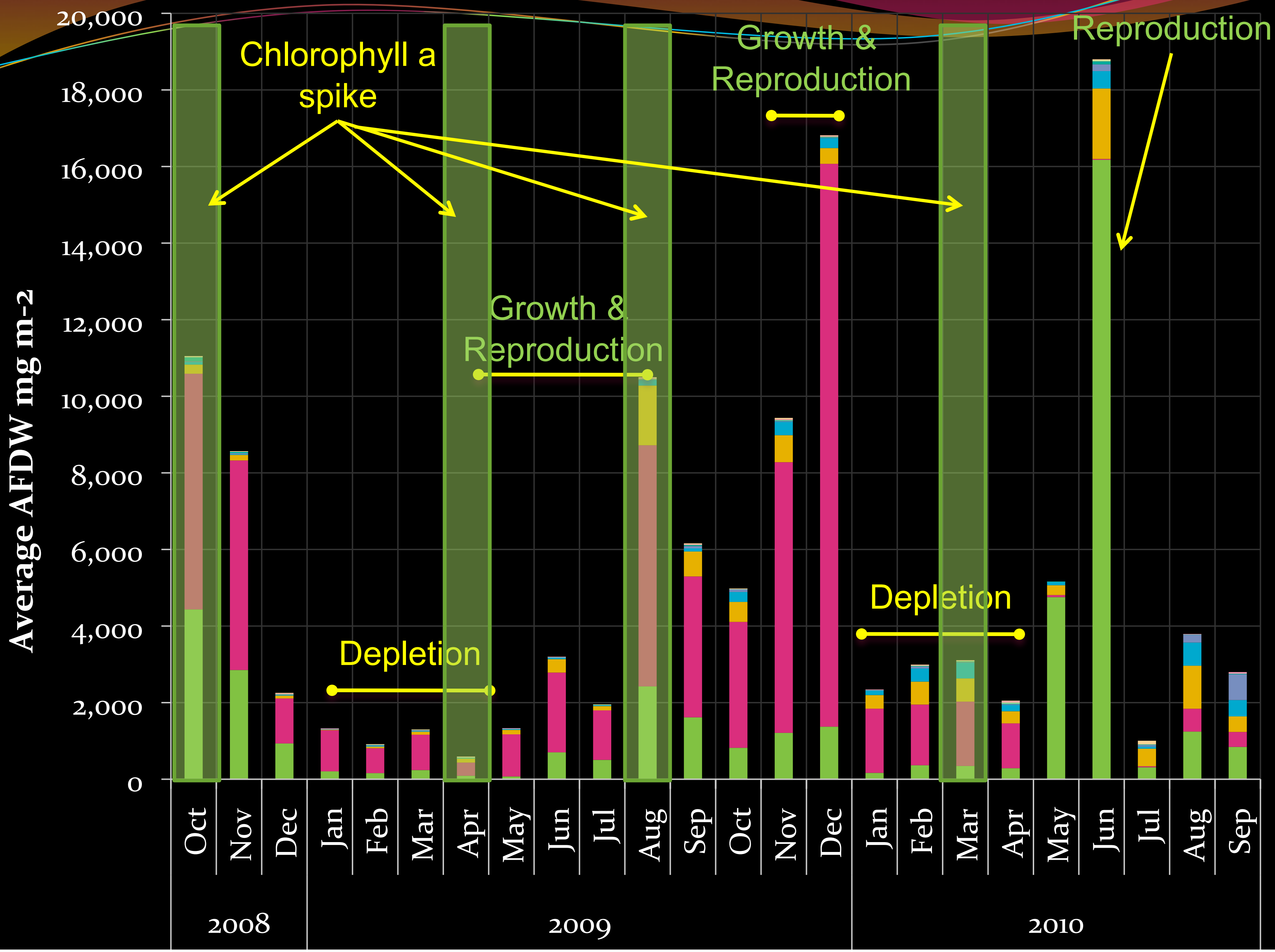
Sep
2008
2009
2010

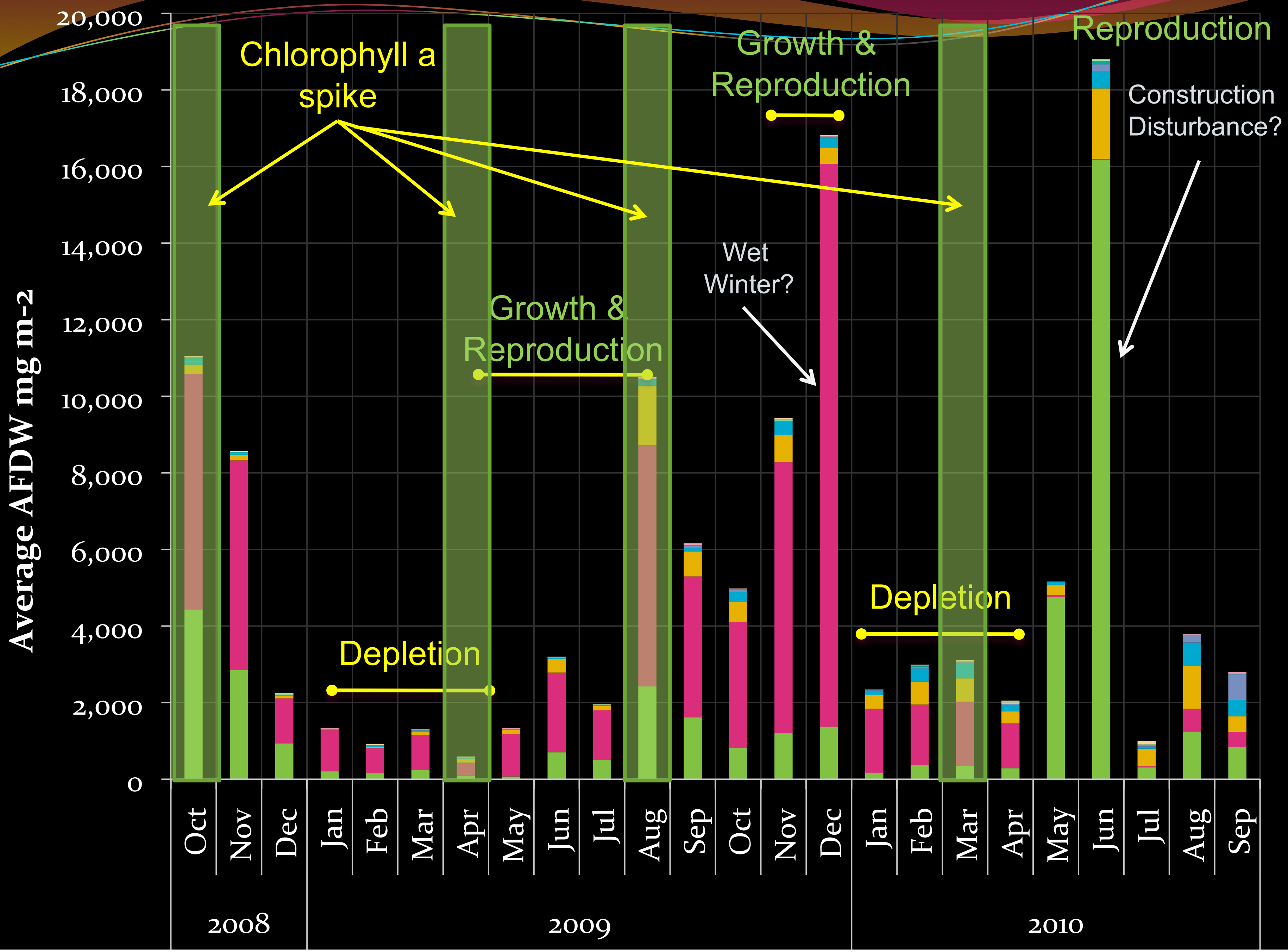
Small shorebird food: bivalves 0-6 mm



Small shorebird food: bivalves 0-6 mm



Small shorebird food: bivalves 0-6 mm



Conclusions

- Benthic invertebrates show distinct monthly and elevation patterns.
  - Patterns are complex and vary by size class, elevation, and season and may reflect a combination of bottom-up and top-down controls
- Are invertebrate prey resources limiting? This may exert a bottom-up control on foraging birds (as in Kraan et al. 2009)
  - What is the carrying capacity of this site? See A. Rowan Poster
  - biofilm may contribute to shorebird diet: see J. Takekawa et al. Biofilm Poster
- Shorebirds may exhibit top-down control on mud flat invertebrate communities, especially bivalves
  - Bivalves exert control on phytoplankton (Cloern 1982, Thompson et al. 2009, Lucas et al 2009); such that *"…change in benthic filter-feeders or their predators has great potential to change the bloom dynamics."*
- Predation depends on site accessibility which is determined by elevation and tides and size class

Acknowledgments

Funding: USGS

Access and support:
FWS-DESFBNWR

Invertebrate collection and processing: Andrew Bibian, Andrew Perry, Alex Westhoff, Brian Hess, Brittany Stieg, Carmen Daggett, Chris Potter, Derek Drolette, Daniel Porton, Erin Flynn, Elana Garfinkle, Eric Palm, Heather Robinson, Harlan Vaska, Jonathan Felis, Jeff Leicthy, Joel Shinn, Kristin Brailsford, Kristin Hirsch, Katherine Powelson, Laura Hollander, Monica Iglesia, Margaret Schaap, Maria Villagrana, Polly Gibson, Stephanie Bishop, Seth Dallmann, Seth Lanning, Stacy Moskal, Sara Piotter, Sylvia Major, Tanya Graham, Tony Henner, Tina Mathews, and Toby Rohmer

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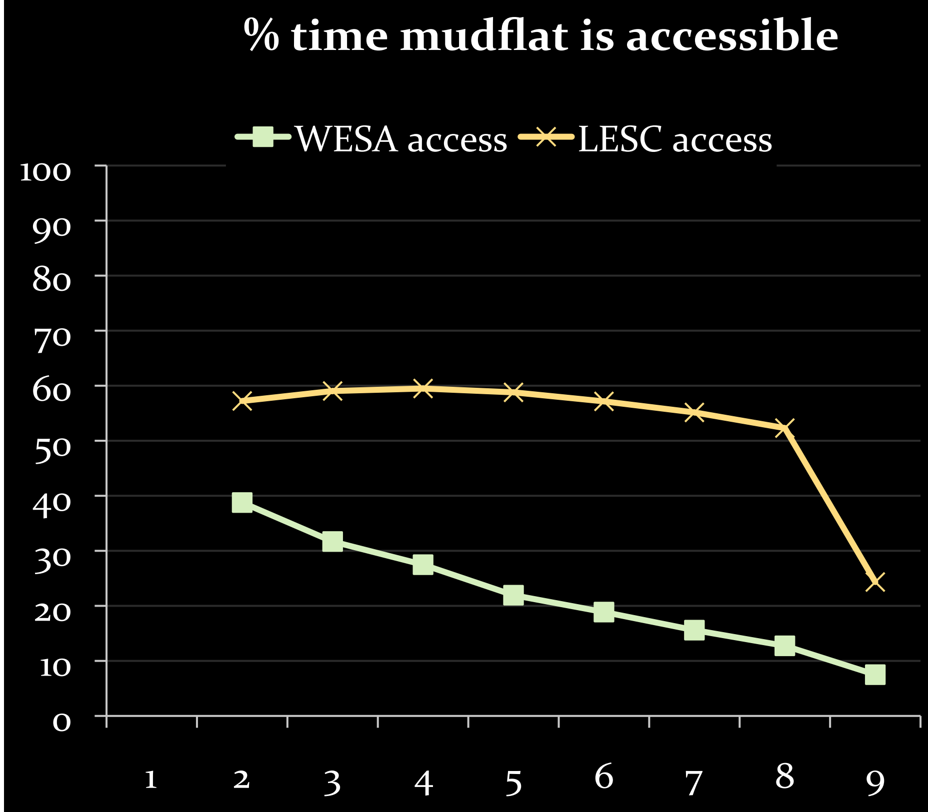
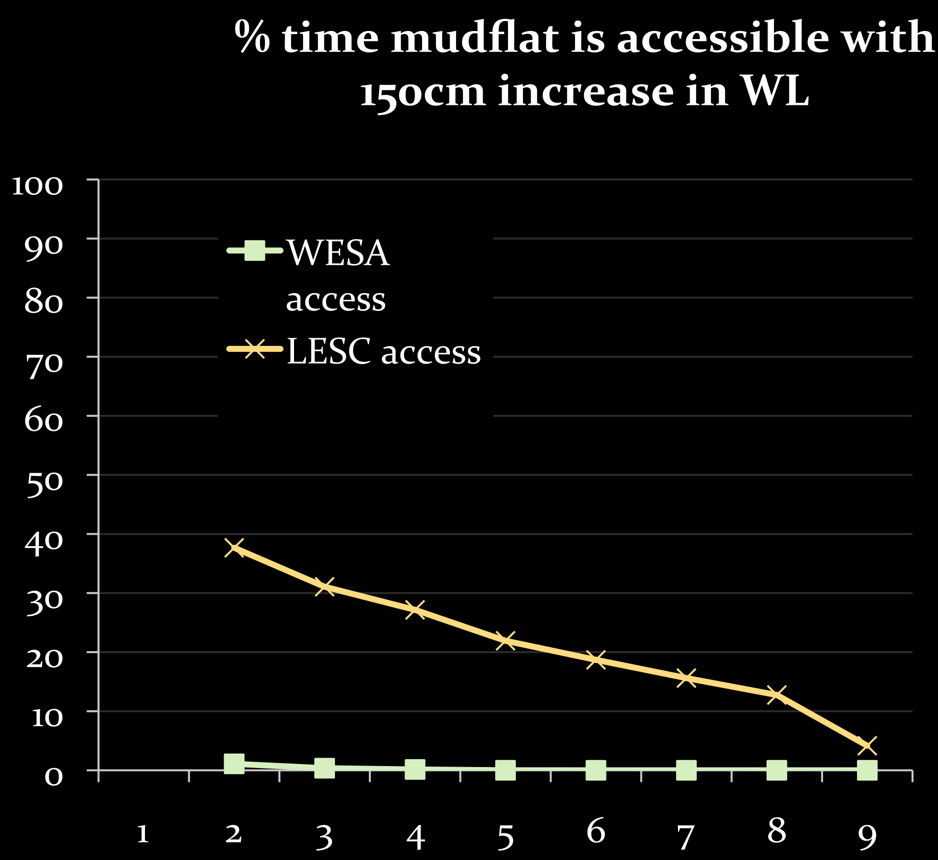
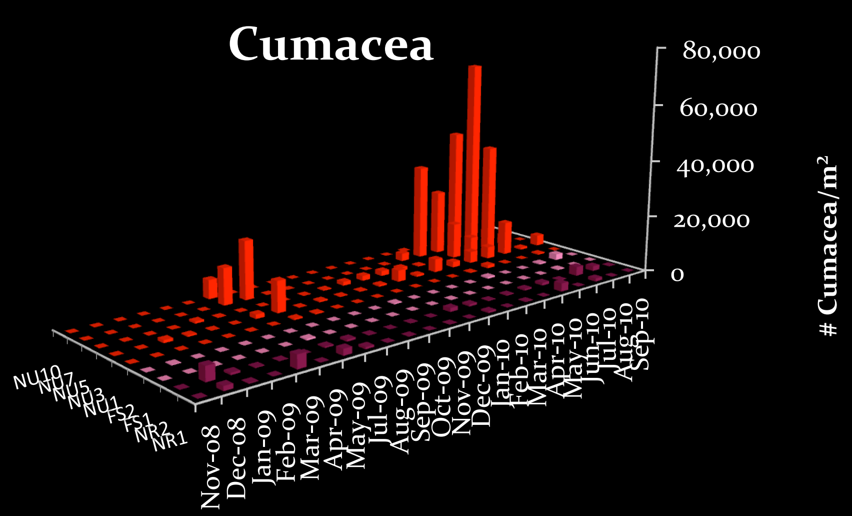
With increased Water Levels, available foraging habitat decreases

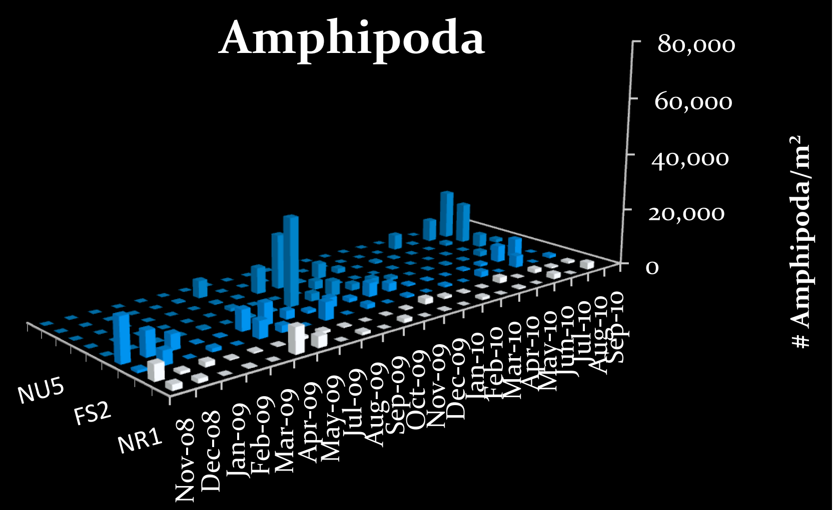
Given static mudflat elevations

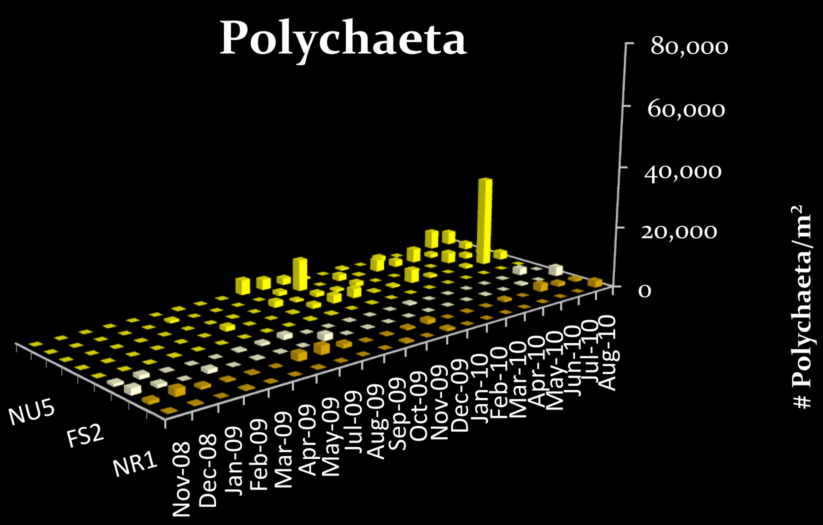


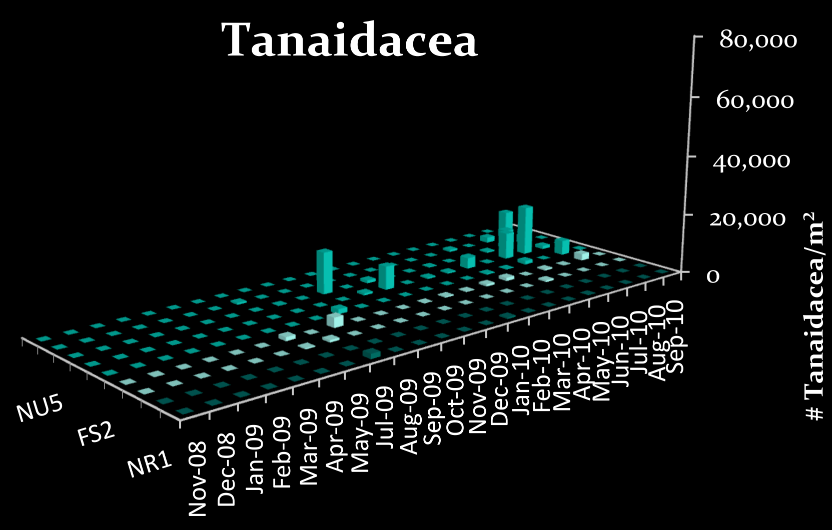


Spatial and temporal trends in most abundant NU taxa









Restoration Uncertainties

- A key uncertainty is how the restoration will affect the estuarine shoals that support the region's migratory birds and fishes.
- How does climate change scenarios influence wetland restoration processes and outcomes?

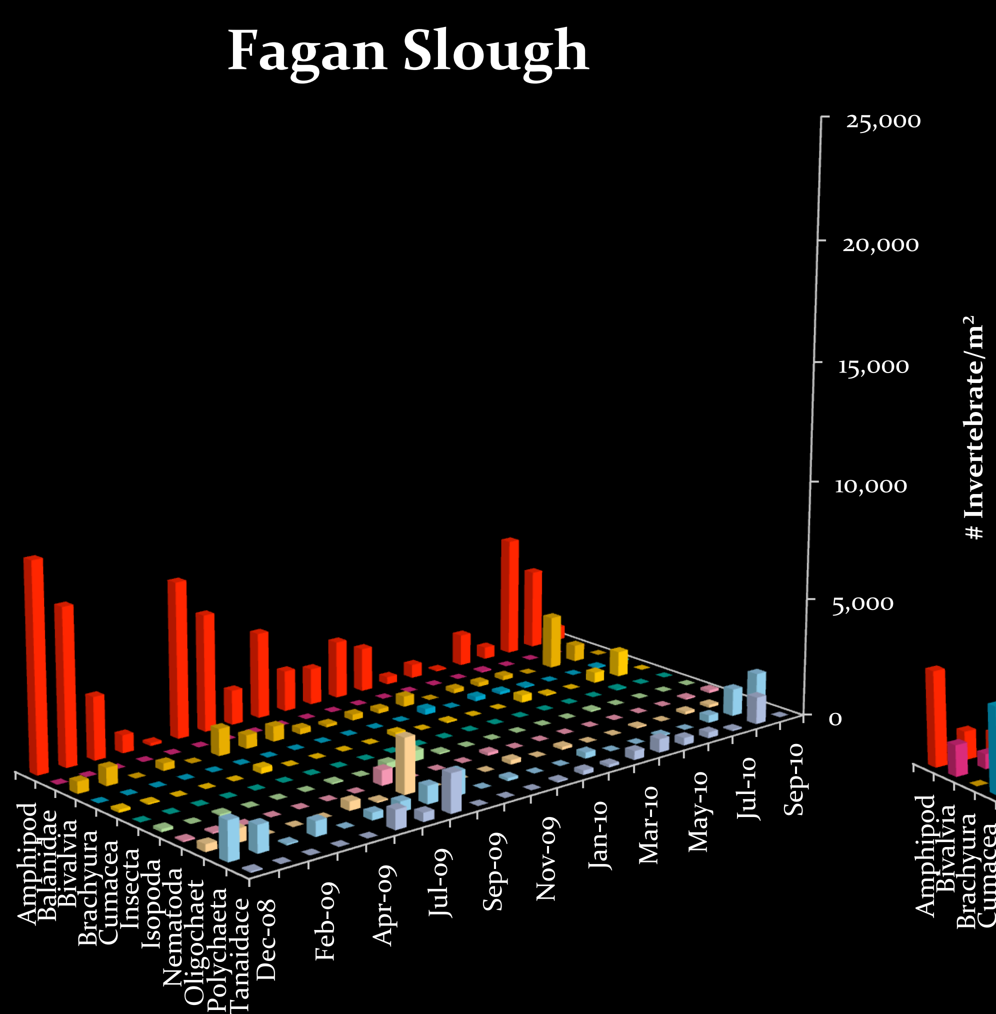
8113
8113
Salt Marsh Harvest

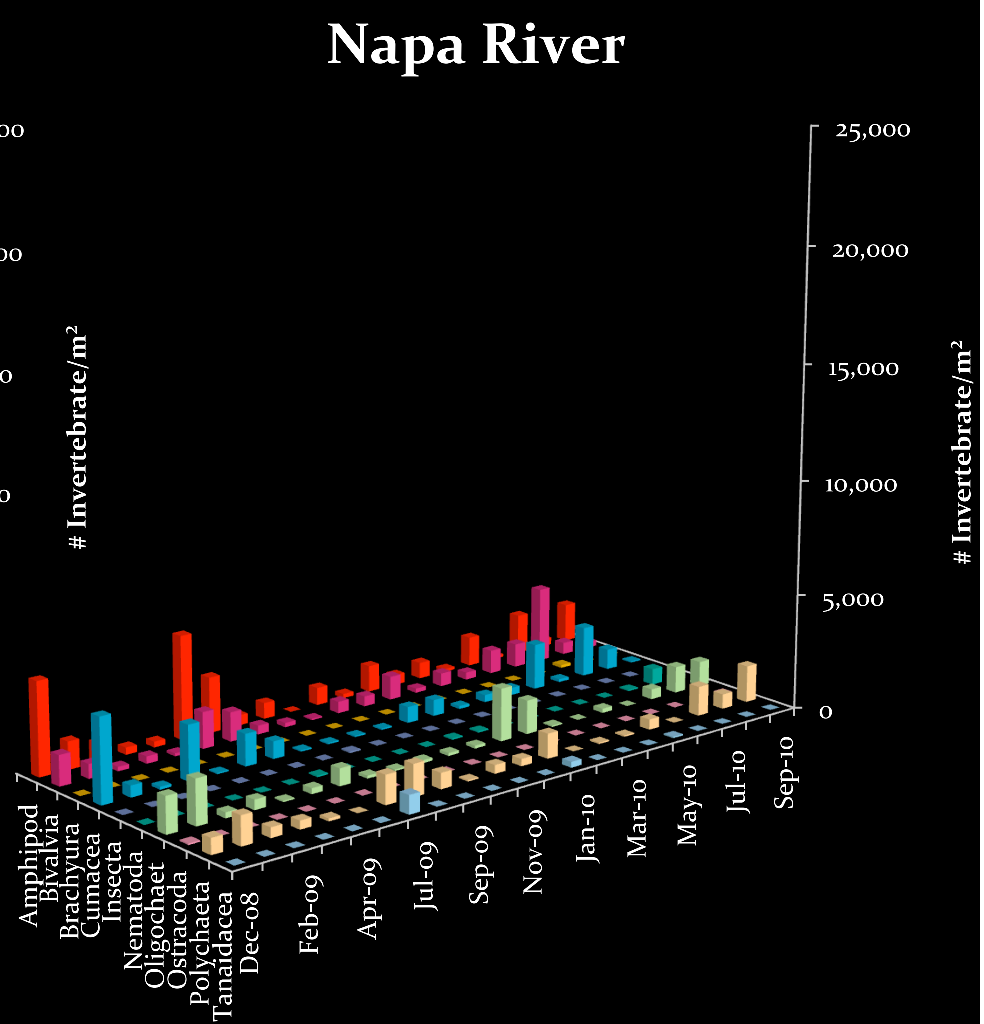
Lessons Learned from NBay

North Unit, Napa Plant Site

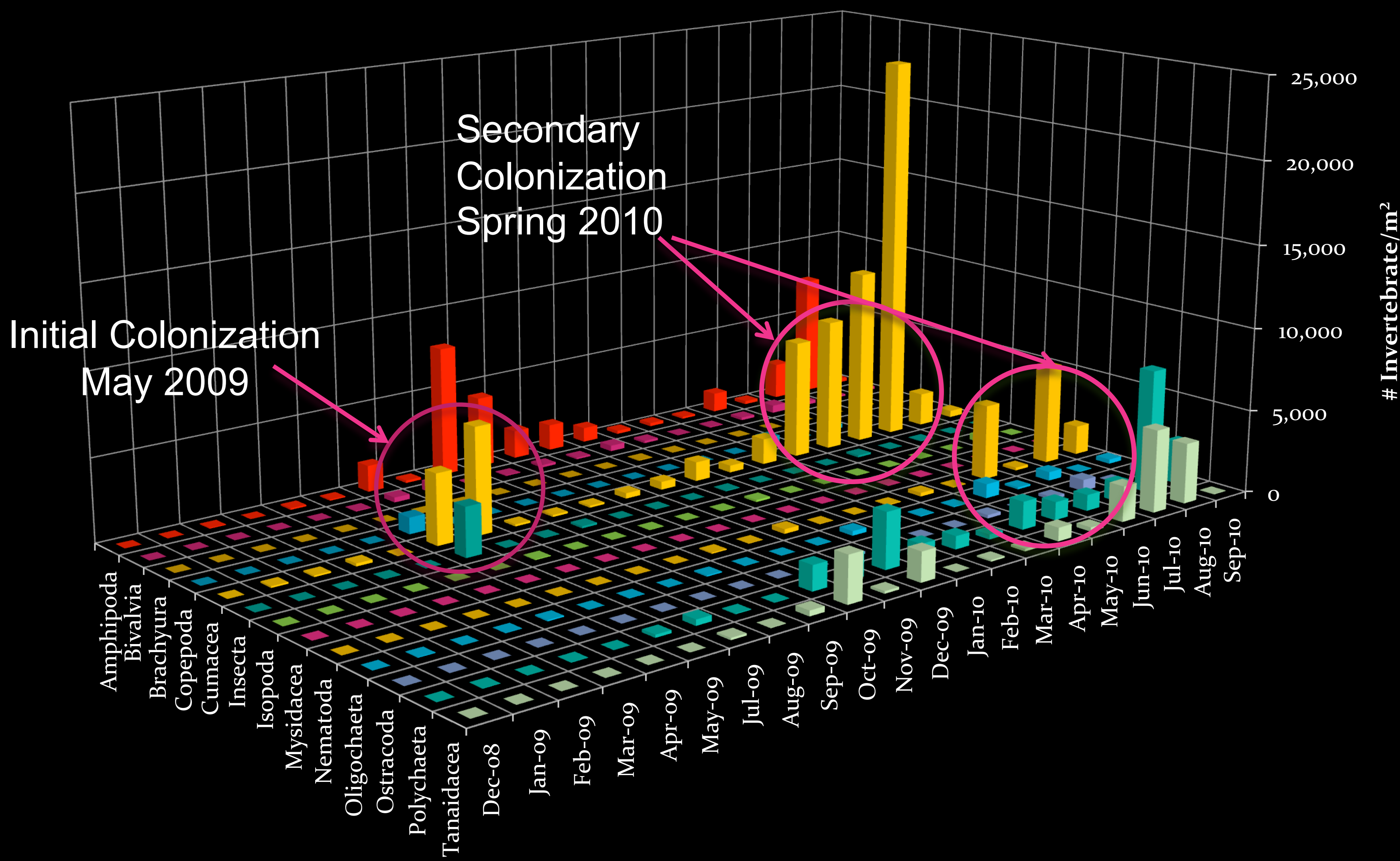
- Monthly collection at 10 North Unit sites, 2 Fagan Slough, and 2 Napa River
- 10 cm x 10 cm cylindrical cores
- Sieved with 0.5mm mesh
- Sorted and identified to taxonomic groups
- Dec 2008 – Sep 2010

Source Populations: Fagan Slough and Napa River

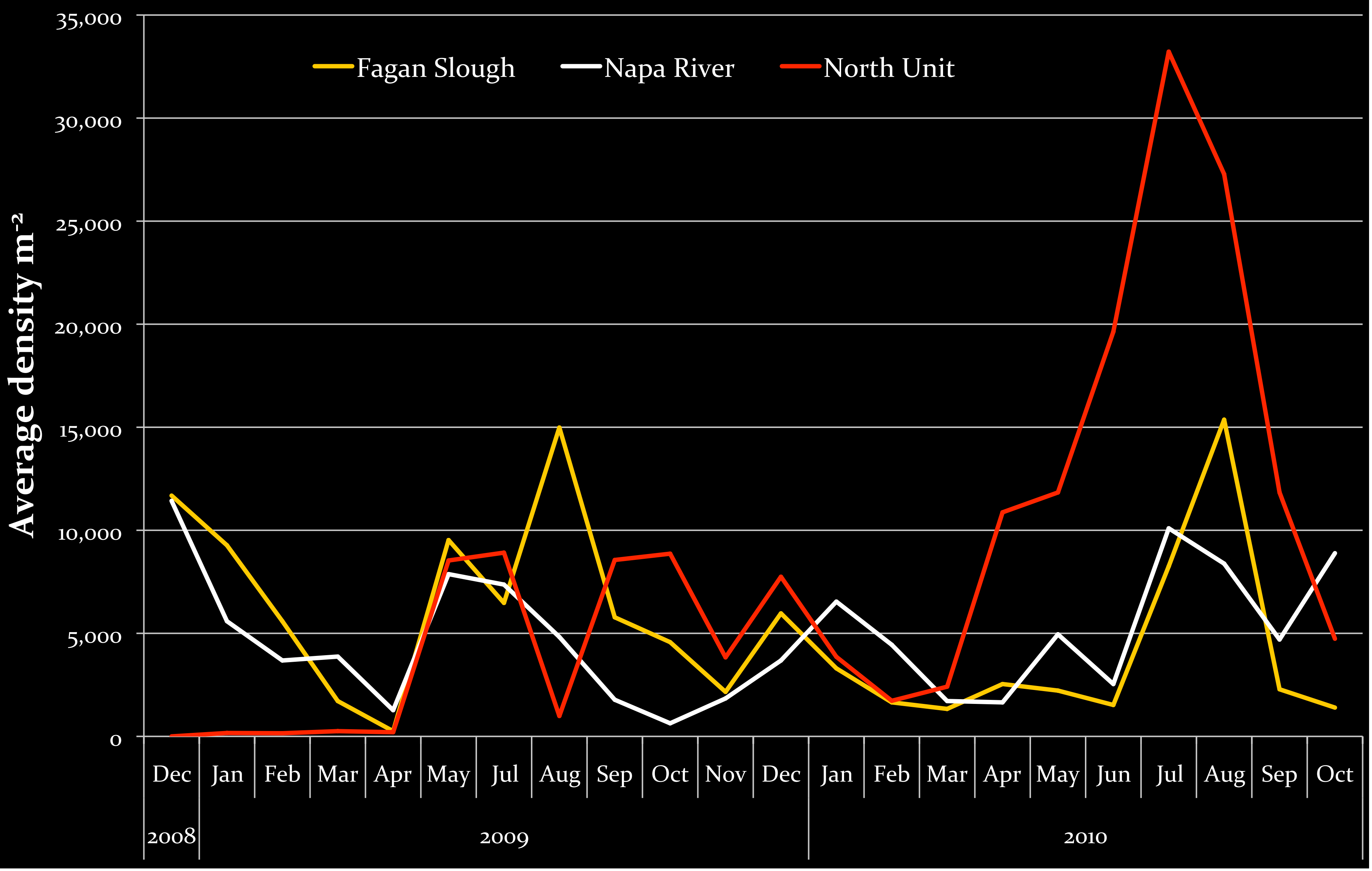




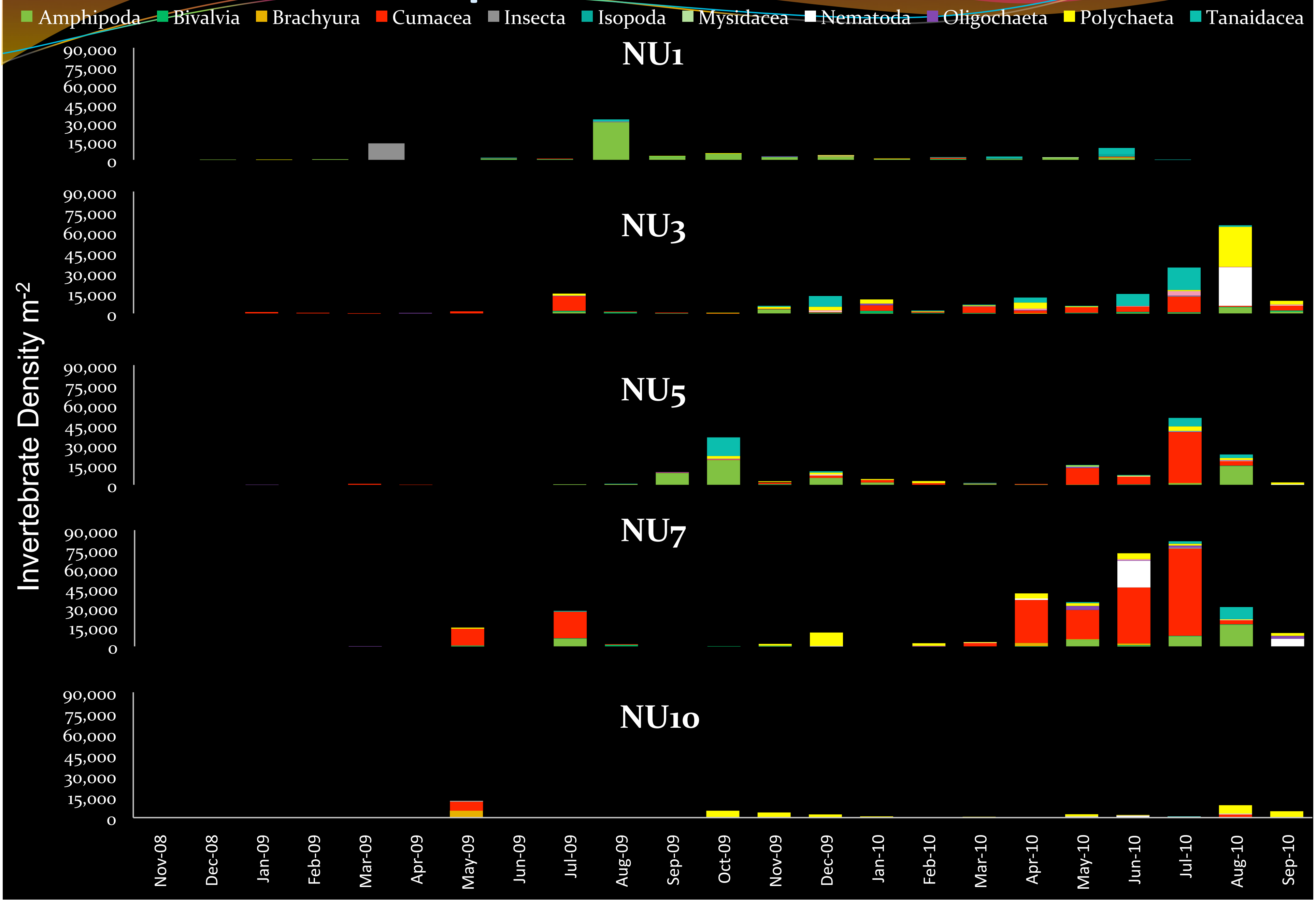
North Unit Colonization After Breach in October 2008



Seasonal trends in averaged total density



Spatial Trends



Overall Colonization Trends at Napa Plant Site

- Initial colonization after 6 months and robust detection after 18 months
- Restorations can provide relatively high invertebrate abundance compared to adjacent sloughs
- Initial colonizing taxa (found in low numbers in adjacent control sites) can become very abundant, but over time a more diverse and even community may emerge
- Seasonal patterns influence system-wide abundance and can help explain colonization patterns
- Colonization may not occur in a linear pattern, and different sites with a restoration area may support specific invertebrate populations