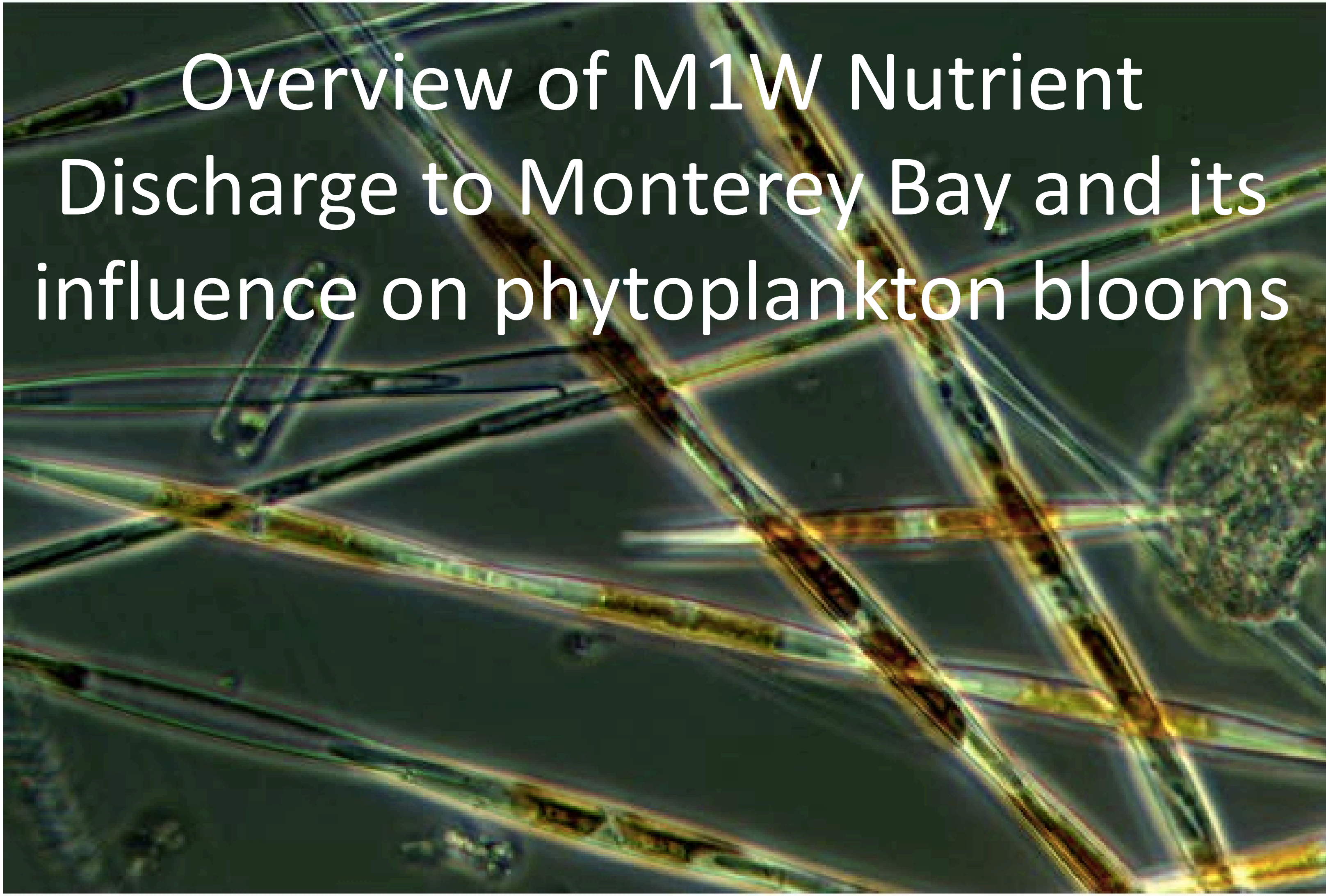
Overview of M1W Nutrient Discharge to Monterey Bay and its influence on phytoplankton blooms



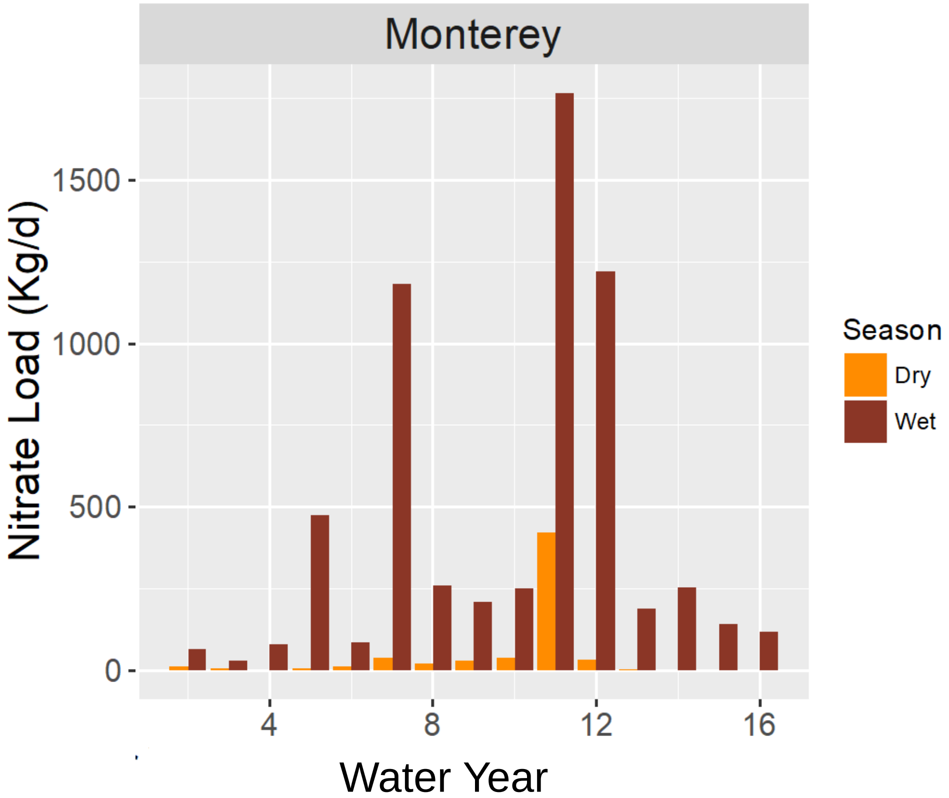
MINE BERG

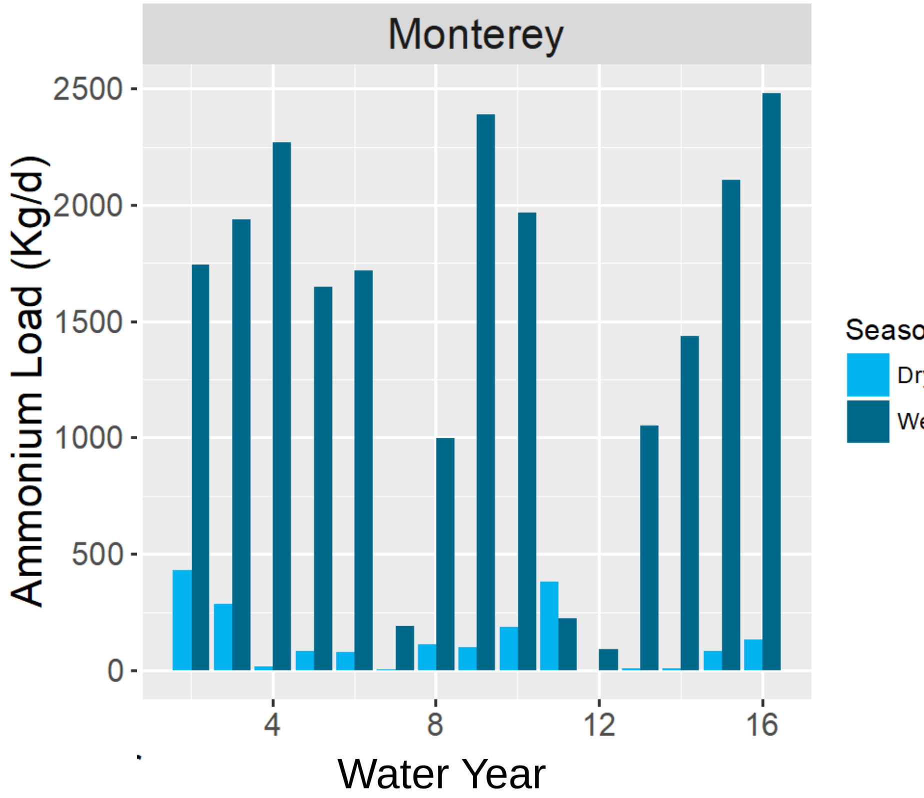
APPLIED marine SCIENCES

Topics covered

- Nitrogen Discharge by M1W
- Nitrogen sources and concentrations in MB
- Upwelling and circulation patterns in MB
- Phytoplankton Blooms in MB
  - Bloom initiation inside and outside MB
  - Factors influencing initiation vs proliferation of blooms
  - Mass of nutrients needed to sustain blooms

1) M1W Nitrogen Discharge





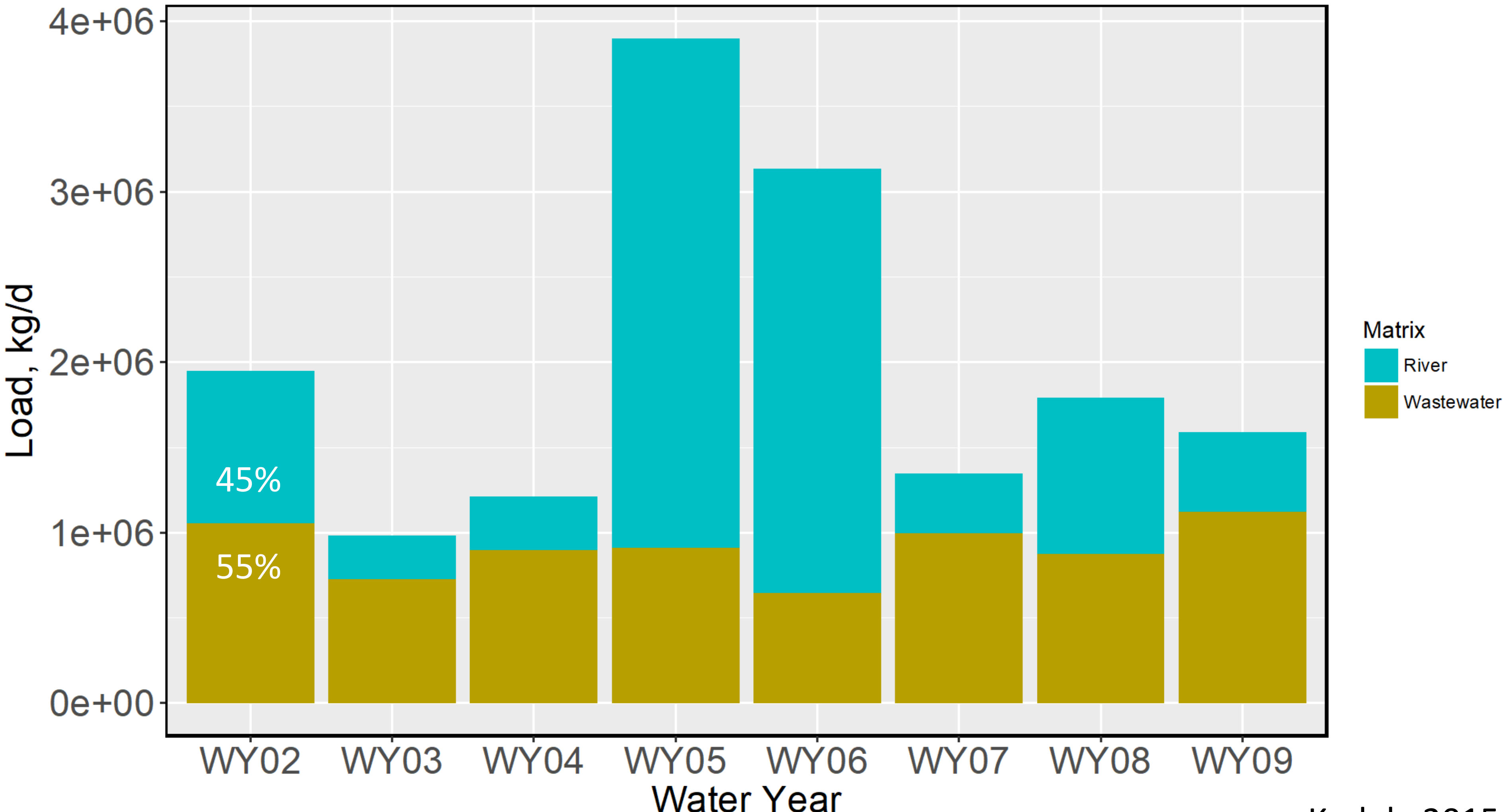
CCLEAN 2016

1) M1W Nitrogen Discharge

Nutrient	Mean Load[1] (kg/d)	Percent of Total Load[2] (%)	Permit Limit (kg/d)	Percent of Permit[3] (%)
NH_4^+	806.9	38.3	9798	10.6
NO_3^-	232.4	23.0		
PO_4^{3-}	69.7	17.5		

[1]Mean of annual loads (WY2-16) in units of kg/d.
[2]Total load is the sum load from Santa Cruz, Watsonville, M1W, and Carmel. In WY16, the dry season contribution to the NH_4^+ load by M1W was 15%, in the wet season it was 68% and the mean was 41%.
[3]Mean load (WY2-16) as a percent of load permitted; WY16 load was 14% of permitted load. Permit limit is 7.8×10^6 pounds/year.

2) Nitrogen sources to MB -coastal N inputs

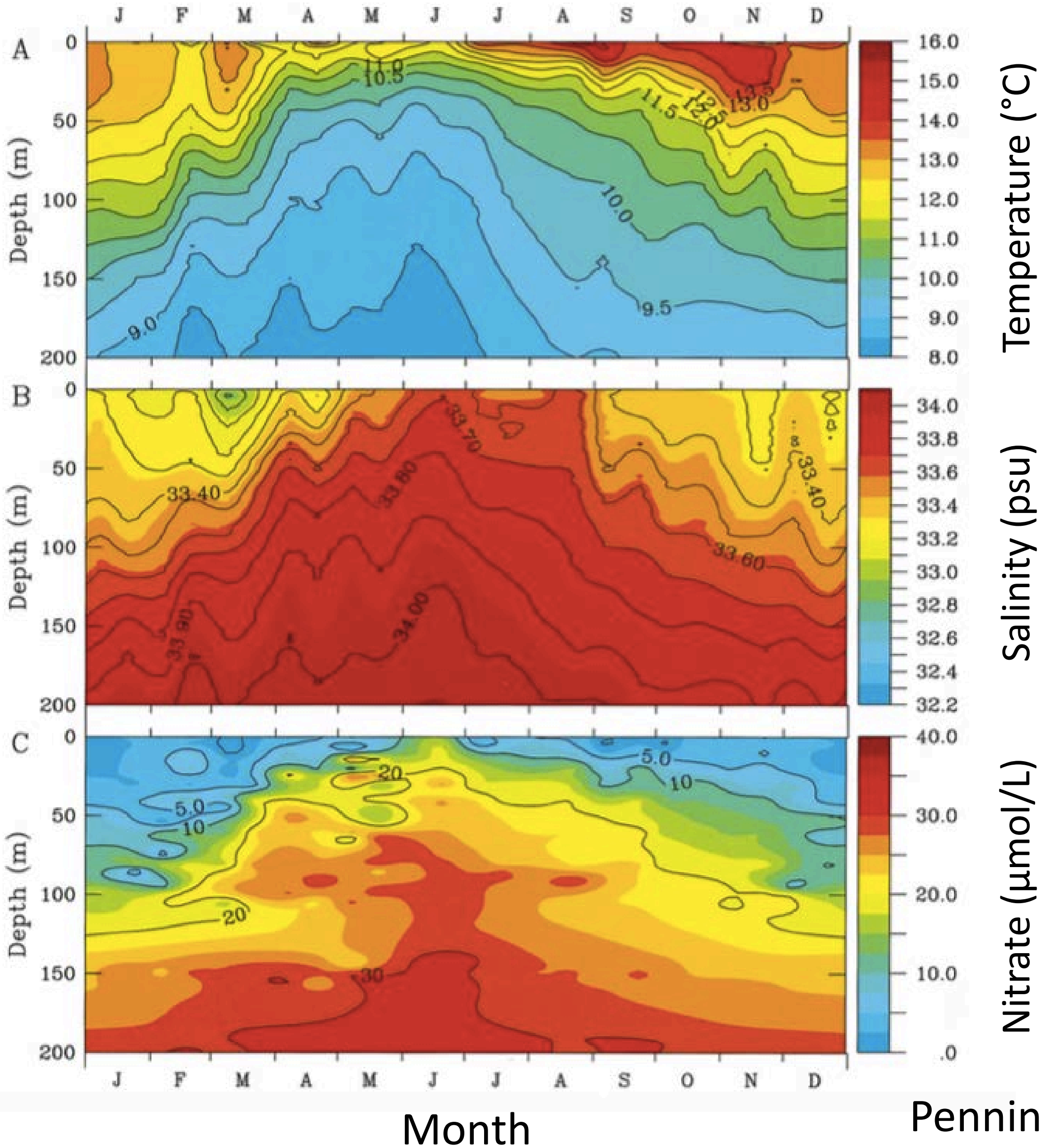


Kudela 2015

2) Nitrogen sources to MB -total N inputs

N source	Load (kg N/y)	Percent (%)
Upwelling	5.00E+08	99.60
Rivers	1.00E+06	0.20
Wastewater	1.01E+06	0.20

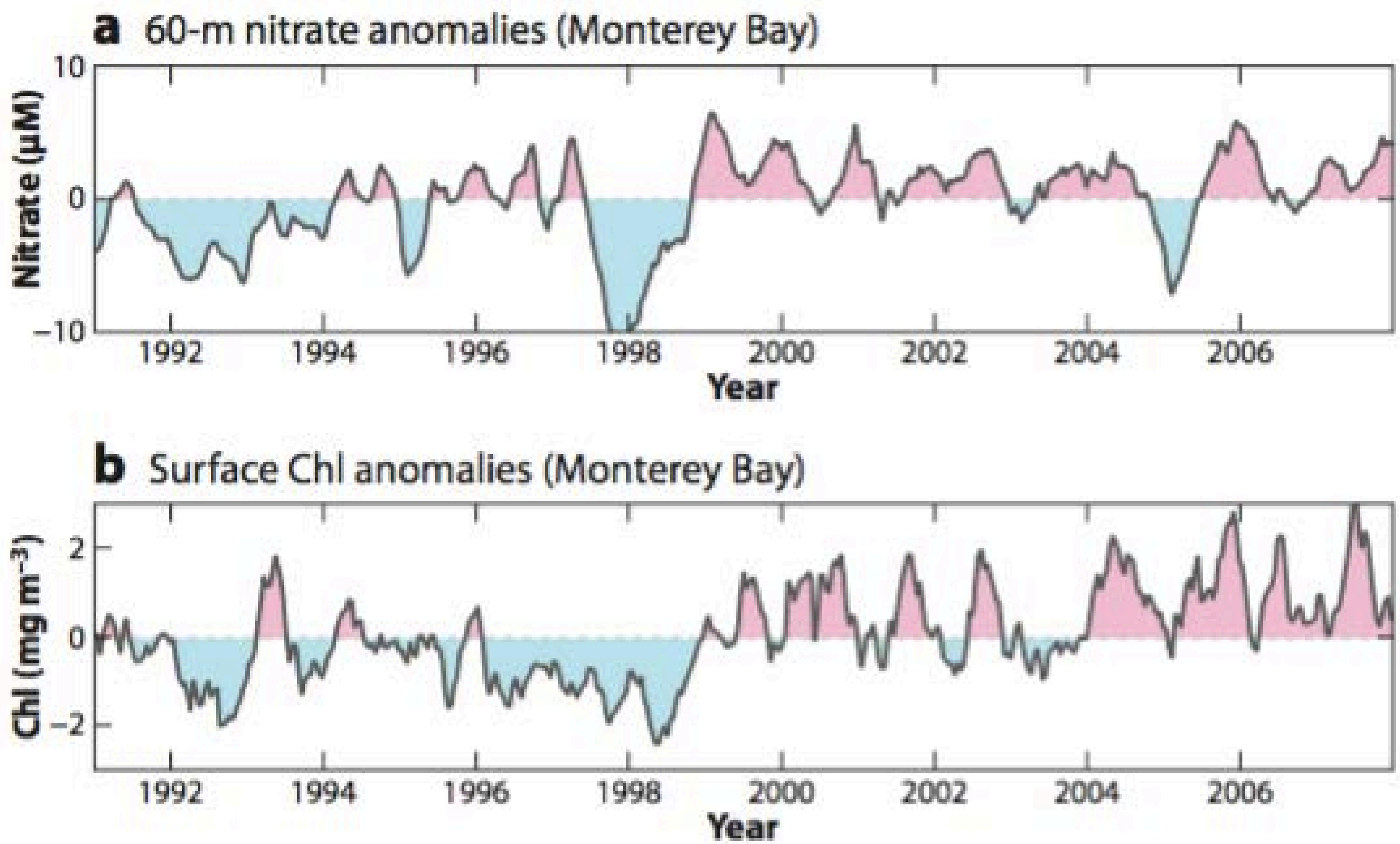
2) Nitrogen concentrations in MB -seasonal pattern



Nitrate=0-5 µmol/L year round except in June

Pennington and Chavez 2000

2) Nitrogen concentrations in MB -trend over time



Chavez et al. 2011

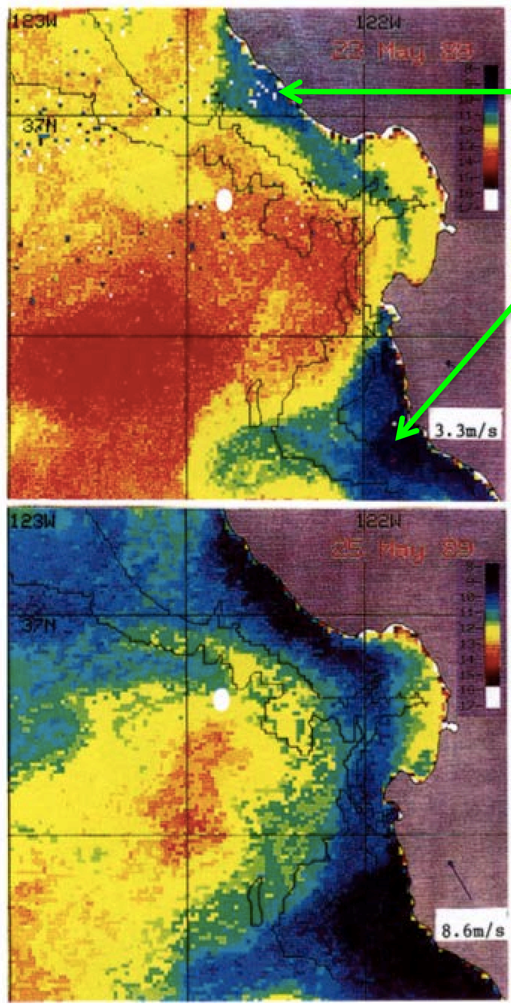
3) Flow of water in MB due to upwelling

Upwelling Mode

(Feb-July; peak April-June)

a) Weak winds

b) Strong winds



Upwelling Loci (Ano nuevo & Point Sur)

Flow of surface water is typically offshore

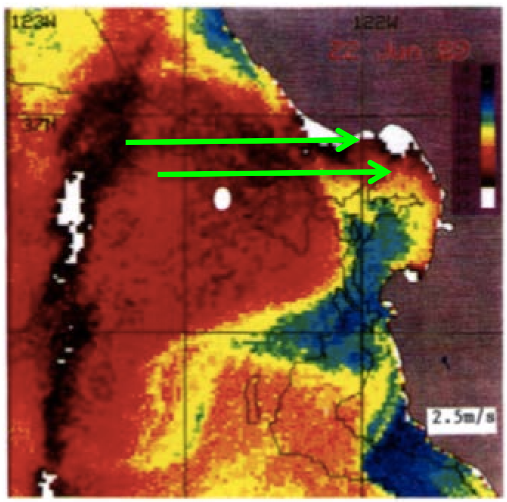
Blue=cold water

Red=warm water

Rosenfeld 1994

3) Flow of water in MB due to upwelling

Relaxation Mode
(July-December)



Warmer water is advected onshore into the north corner of MB; water column stratifies and surface water is separated from deeper water

Blue=cold water
Red=warm water

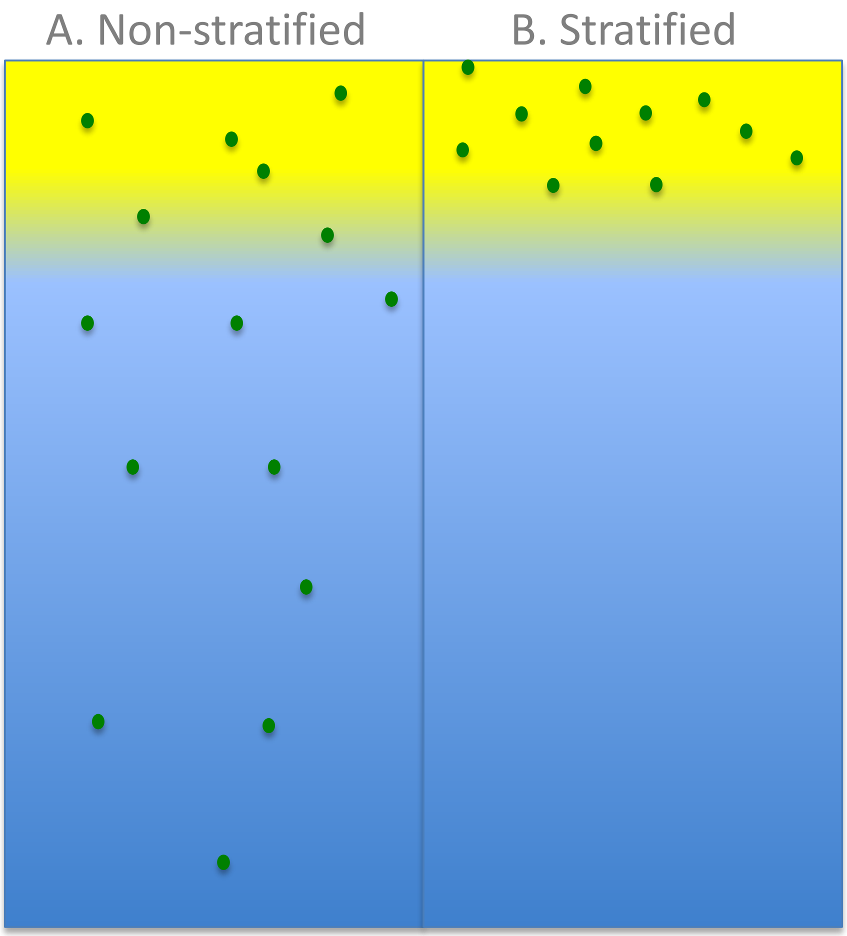
Rosenfeld 1994

4) Phytoplankton blooms

- Factors controlling initiation vs proliferation of blooms
- Initiation inside MB
- Initiation outside MB
- Harmful algal bloom frequency and seasonality
- Mass of nutrients needed to sustain blooms

Factors controlling initiation vs proliferation of blooms

Initiation

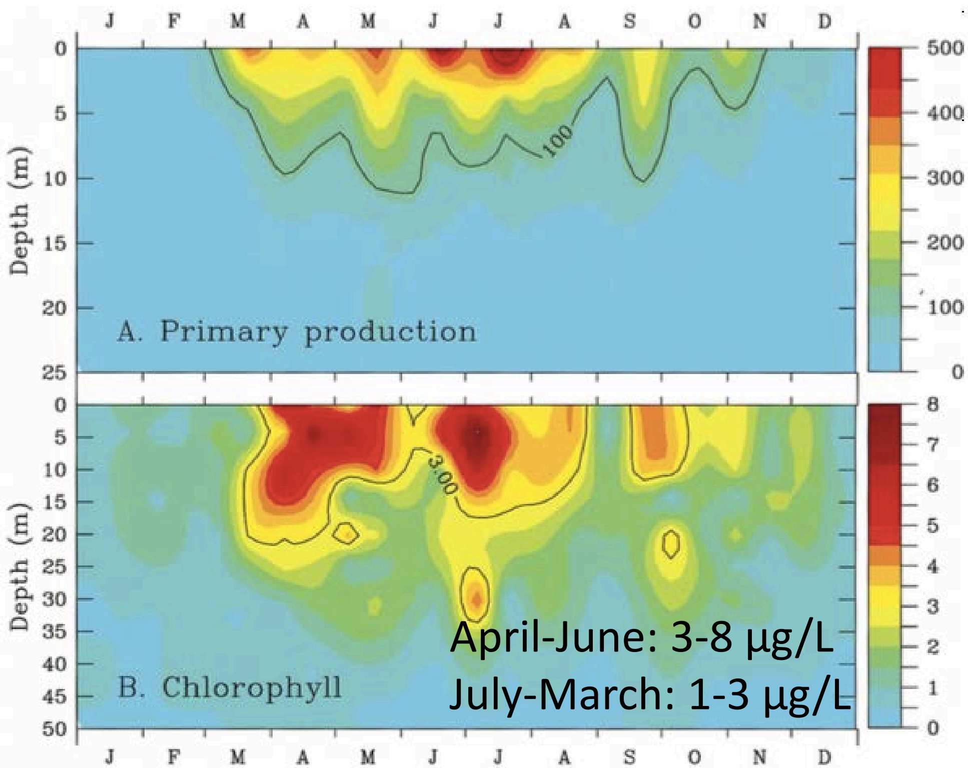


Proliferation

- Continued water column stratification
- Sufficient nutrient concentration in euphotic zone

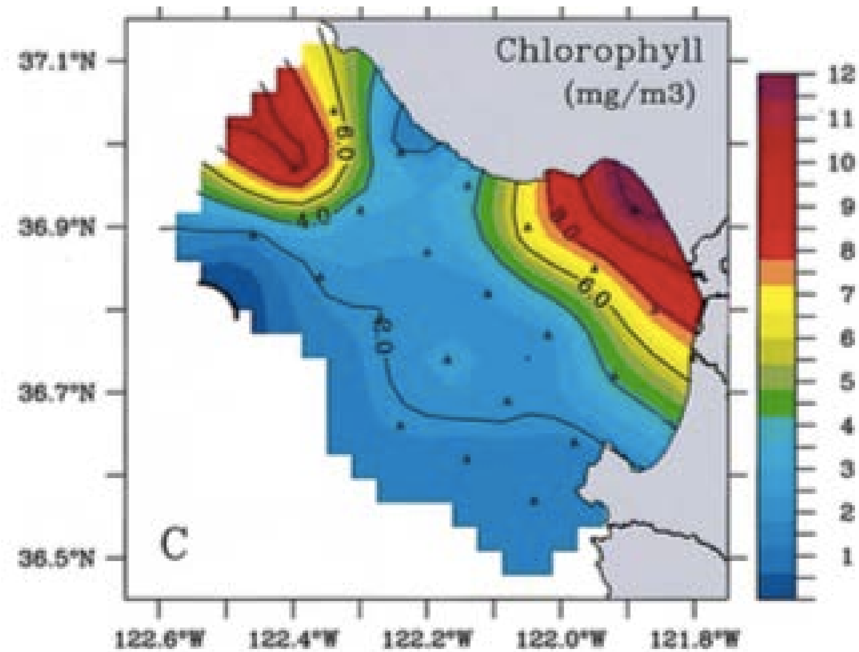
4) Blooms initiated within MB

Seasonally



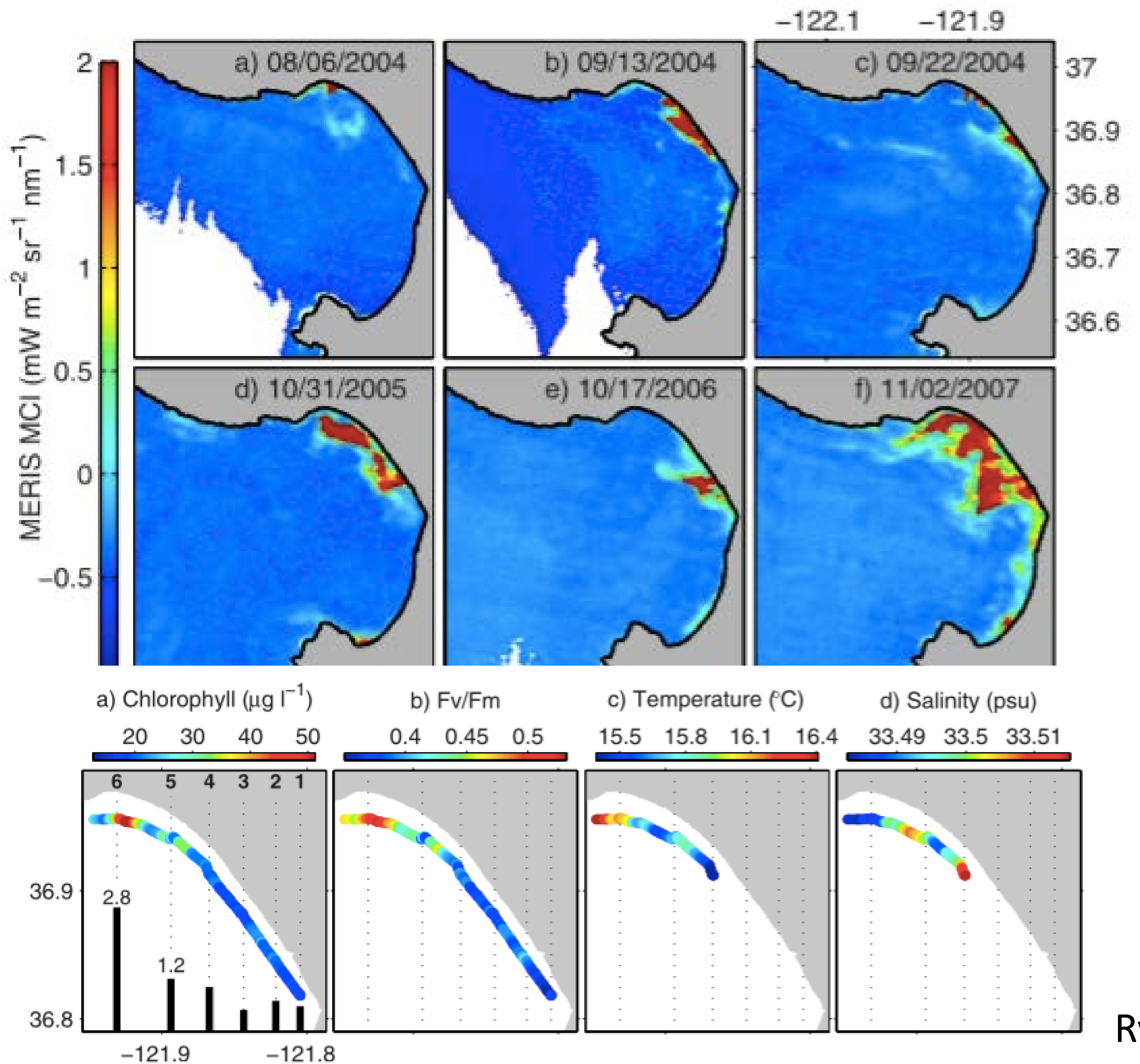
Month

Spatially



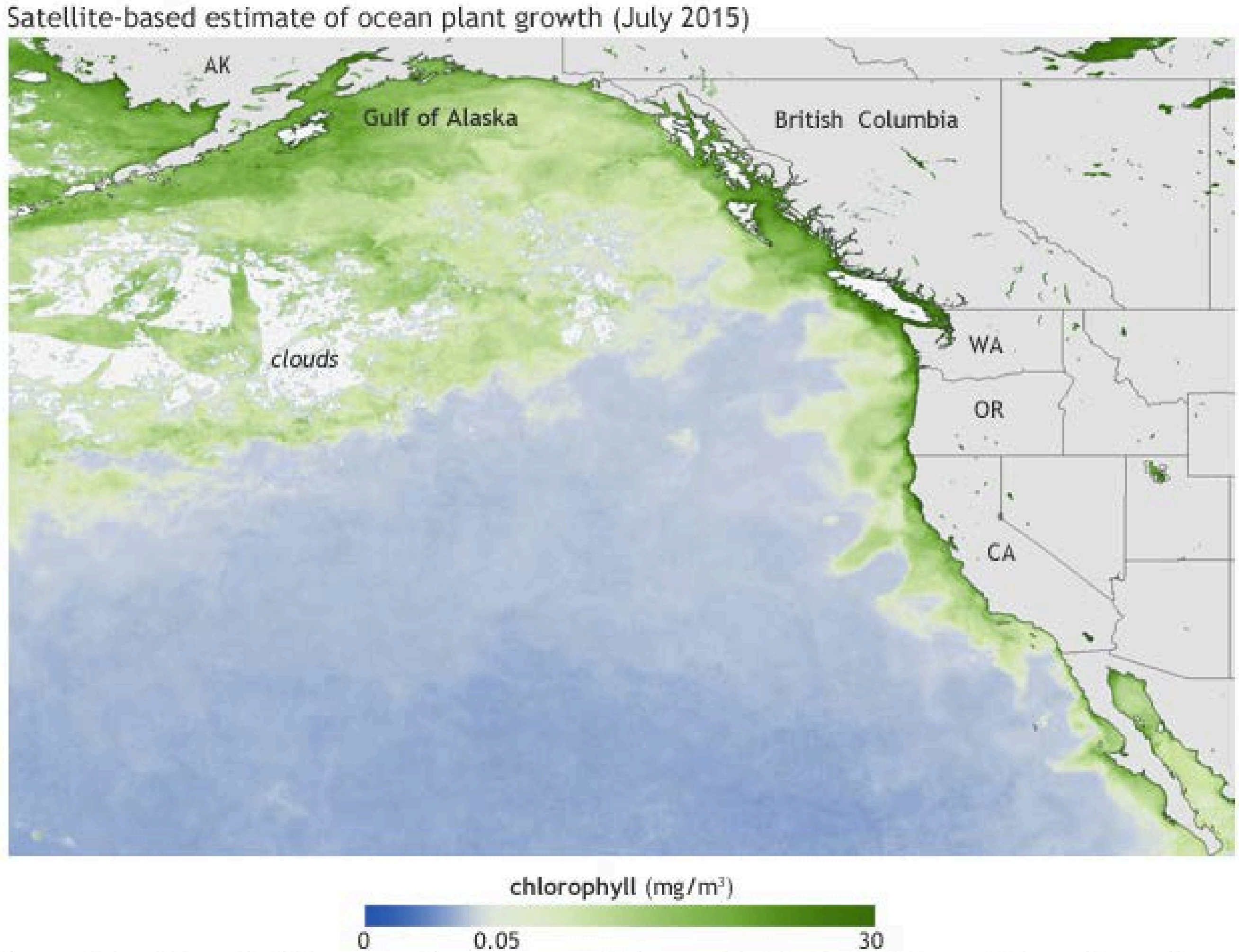
Pennington and Chavez 2000

4) Phytoplankton blooms start in north-east corner of MB



Ryan et al. 2008

4) Blooms initiated outside MB

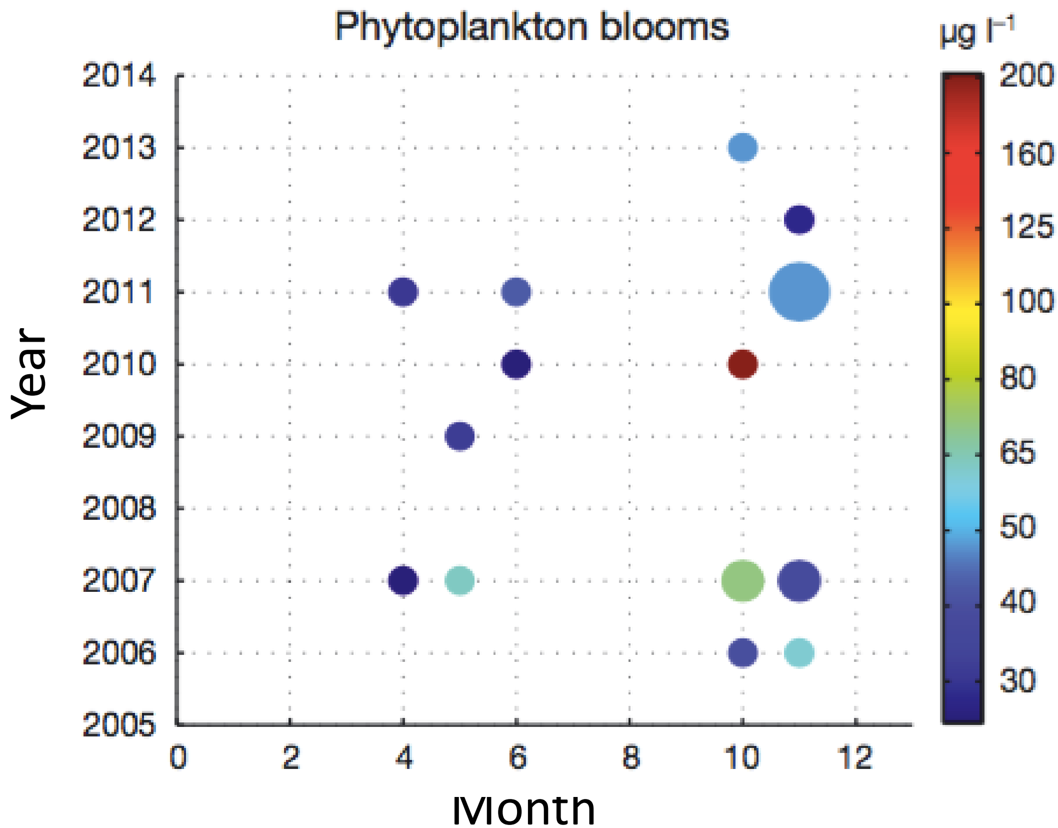


A record-breaking algal bloom continues to expand across the North Pacific reaching as far north a the Aleutian Islands and as far south as southern California. Coinciding with well above average sea surface temperatures across the North Pacific and West Coast of North America, the bloom is laced with some toxic species that have had far-reaching consequences for sea life and regional and local economies.

Du et al. 2016
McCabe et al. 2016

https://www.climate.gov/news-features/event-tracker/scientists-link-toxic-algal-blooms-along-us-west-coast-warm-waters

4) Harmful algal blooms in MB



- Two thirds occur in fall
- Are more intense than spring blooms
- Are dominated by dinoflagellates (>60% are toxic)
- Are started by a relaxation/stratification event
- Are sustained by: upwelling preceeding relaxation event; nutrients carried from Elkhorn slough via Davidson Current; canyon nutrient pumping

Trainer et al. 2000
Ryan et al. 2008
Ryan et al. 2010
Ryan et al. 2014
Fischer et al. 2014
Schulien et al. 2017

4) Mass of Nitrogen needed to sustain typical HAB in MB

Bloom Size (km^2)[#]	Mass of bloom (µg Chl a L^{-1})	Nitrogen requirement* (kg N d^{-1})	Contribution of M1W discharge to sustaining bloom (% d^{-1})
5	6.25×10^{12}	8.75×10^{4}	0.143
80	1.00×10^{14}	1.40×10^{6}	0.009

[#]Size data from Ryan et al. 2008

*Assumes that phytoplankton double once per day

Conclusions

Initiation of HABs and other algal blooms inside MB:

Blooms are initiated by water column stratification, resulting from changes in weather and hydrology

Blooms start in North-east corner of Monterey Bay

Bloom initiation sites are spatially separated from the M1W outfall

Blooms are fuelled by large nutrient infusions from upwelling, the Elkhorn Slough plume, and canyon nutrient pumping

Riverine and wastewater effluent discharge are typically not at a scale large enough to sustain blooms for very long

Initiation of HABs outside MB:

Blooms are initiated by by large-scale climate events leading to water column stratification

Blooms occur in spring, summer and fall

Blooms are fuelled by large nutrient infusions from upwelling

Blooms are advected into coastal bays through winds