Monitoring and Assessment Tool: Solid Phase Adsorption Toxin Tracking (SPATT)

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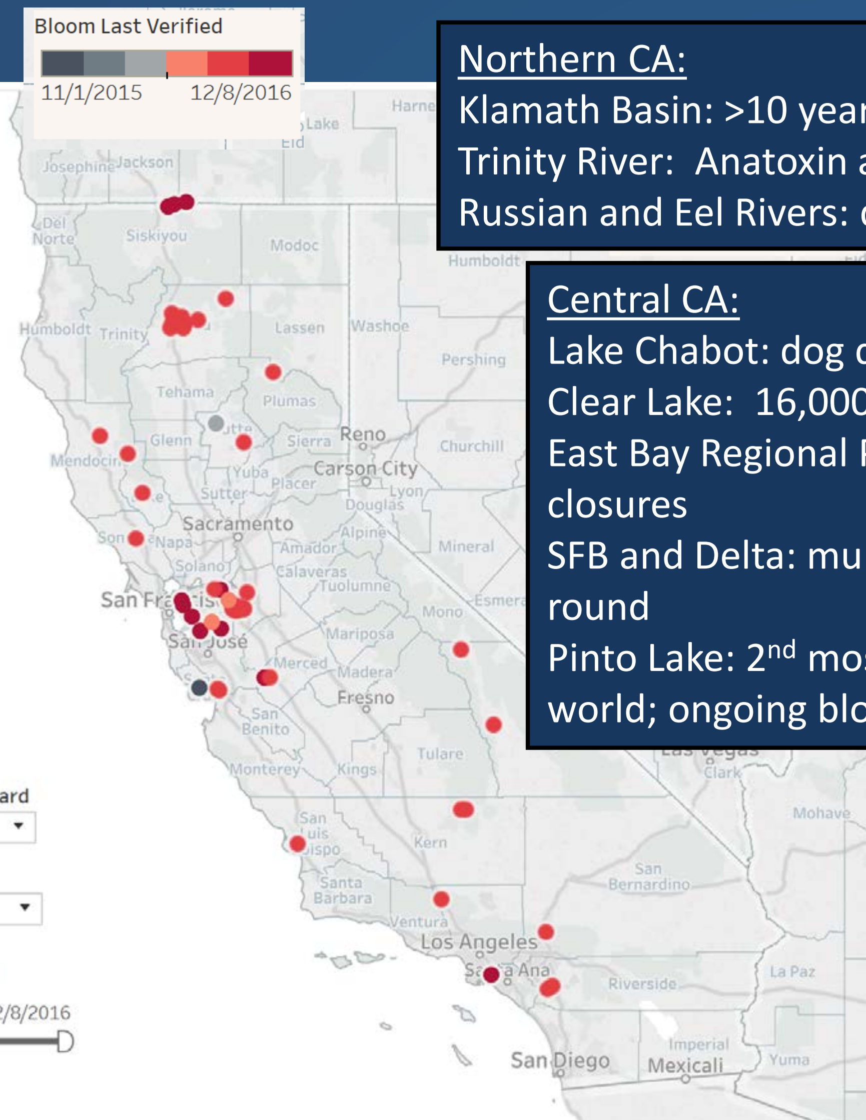
Recurrent Known Blooms and Cyanotoxin Hotspots in California Prior to 2011

Record Breaking Years 2014 - 2016

- Record high microcystin concentrations detected
- Record number of lakes closed for recreation
- Several dog deaths attributed to cyanotoxins
- Multiple toxins detected simultaneously
- Fish kills caused by *Pyrmnesium parvum*



Northern CA:
Klamath Basin: >10 years
Trinity River: Anatoxin and Microcystins
Russian and Eel Rivers: dog deaths

Central CA:
Lake Chabot: dog deaths
Clear Lake: 16,000 **μg/L**
East Bay Regional Parks: multiple lake closures
SFB and Delta: multiple toxins ~year-round
Pinto Lake: 2nd most toxic lake in the world; ongoing blooms; 1st closure

Southern CA:
Lake Elsinore: Multiple toxins > health thresholds
San Joaquin Marsh, 33,500 μg/L
Canyon Lake: multiple toxins >health thresholds
Suspected deer and mountain lion deaths
Fish kills from *P. parvum* at multiple lakes

A Tour of California Hotspots

Lake Elsinore—5,000 µg/L
Scum: MCY 95,000 µg/L; CYL 181 µg/L; ANA 18.5 µg/L

Lake Chabot—11,000 µg/L;
800,000 µg/L scum

Pinto Lake—1,000 µg/L annually;
2.9 million µg/L scum

San Joaquin Marsh—33,500 µg/L

A Tour of California Hotspots

Wadeable Streams:

Microcystin—33%

Lyngbyatoxin—21%

Saxitoxin—7%

Anatoxin-a—3%

Eel River algal mats:

Anatoxin-a—42%

Microcystins—15%

Both—5%

ATX ~ 10x > MCY

Data Sources: Fetscher et al. *Harmful Algae* 49: 105-116

Bouma-Gregson & Higgins, Eel River Recovery Project Report 2015

WADING INTO DANGER

Growth of toxic algae could make California's lakes unsafe

Extent of public health effects 'unknown'

NEWS

LAKE ELSINORE: Harmful blue-green algae forces area closure

All recreation is suspended on what is Southern California's largest natural freshwater body.

G+1 Like Share Tweet Email Share

By MICHAEL J. WILLIAMS / STAFF WRITER

Published: July 28, 2016 Updated: July 29, 2016 7:56 a.m.

SAN GABRIEL VALLEY TRIBUNE

ALGAL BLOOMS

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Home News Algal blooms

People got sick at Pyramid Lake before the state reported toxic algae bloom. Could it have been avoided?

SFGATE NEWS SPORTS BUSINESS A&E FOOD LIVING TRAVEL REAL ESTATE CAR

After dog dies, Labor Day revelers may have to avoid Russian River

By Henry K. Lee Updated 9:05 am, Friday, September 4, 2015

Photo: Brant Ward, The Chronicle

Stephanie K. Baer (Southern California News Group)
http://projects.sgvtribune.com/blue-green-algae/

Solid Phase Adsorption Toxin Tracking

"A simple and sensitive *in situ* (monitoring) method… involves the passive adsorption of biotoxins onto porous synthetic resin filled sachets (SPATT bags) and their subsequent extraction and analysis."

MacKenzie et al. (2004) Toxicon

K Borchers / San Jose Mercury News

M Roddam / UCSC

M Roddam / UCSC

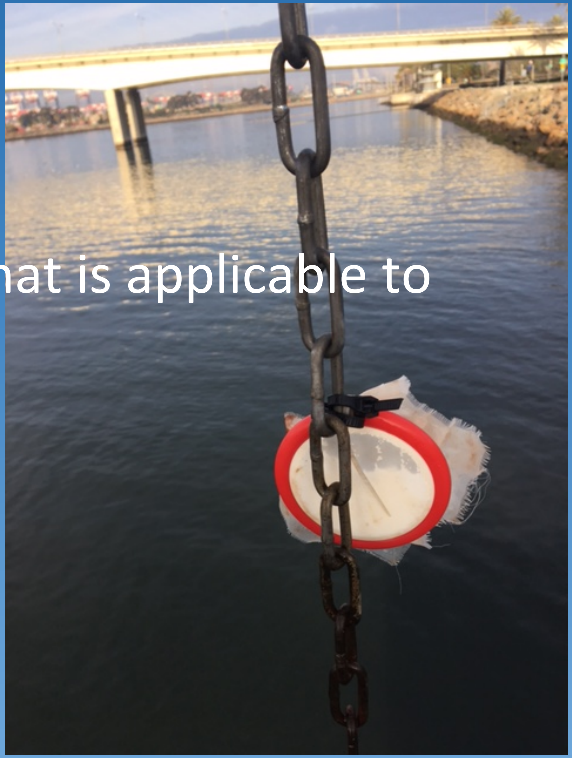
Solid Phase Adsorption Toxin Tracking (SPATT)

- Has been used in many areas of the world for the monitoring of dissolved algal toxins
  - Anatoxins (Wood et al 2011)
  - Azaspiracids (Fu et al 2009)
  - Dinophysistoxins (Fu et al 2008, 2009, Pizarro et al 2013)
  - Domoic acid (Lane et al 2010)
  - Microcystins (Kudela 2011)
  - Okadaic acid (MacKenzie et al 2004, Fu et al 2008, 2009)
  - Pectenotoxins (MacKenzie et al 2004, Fu et al 2009)
  - Saxitoxin (Lane et al 2010)
  - Spirolide toxins (Fu et al 2009)
  - Yessotoxins (MacKenzie et al 2004, Fu et al 2009)

Why Use SPATT?

Advantages:

- Passive Sampler that is time-integrative
- Provides continuous toxin detection to capture ephemeral events that discrete samples can miss
  - Enhanced sensitivity at low ambient concentrations
- Applicable in all waterbody types and for many different toxins
- Low cost, simple and easy to deploy/recover

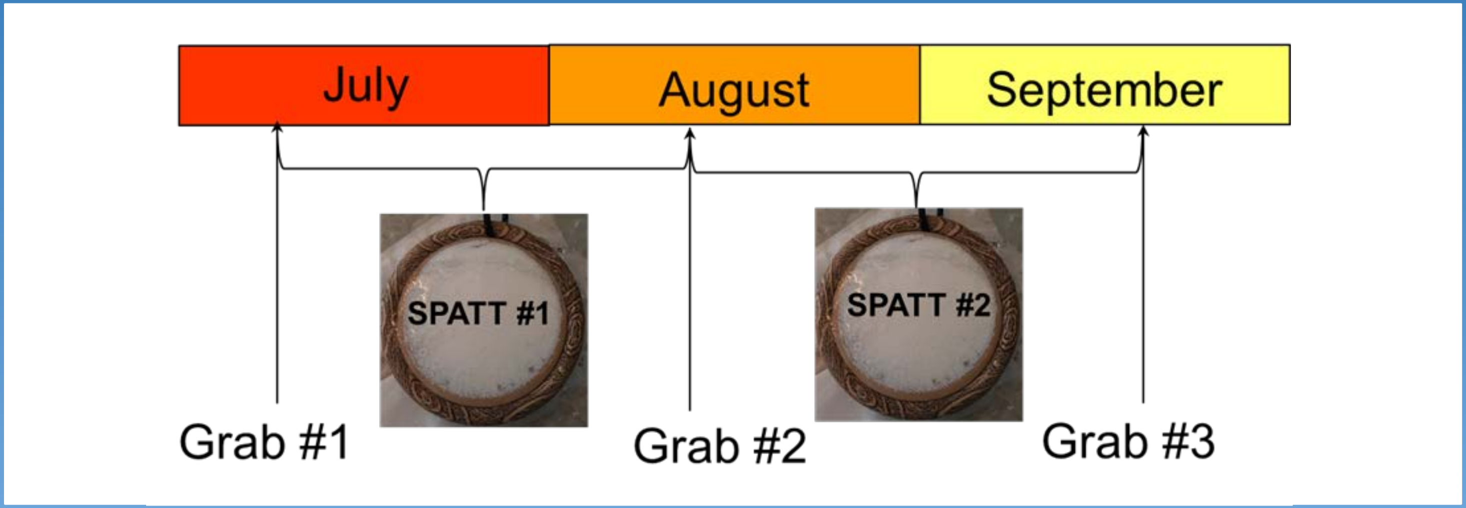


Disadvantages:

- SPATT will not provide a concentration of toxin that is applicable to health advisory thresholds (ng/g)
- Only measures dissolved toxins not total toxins

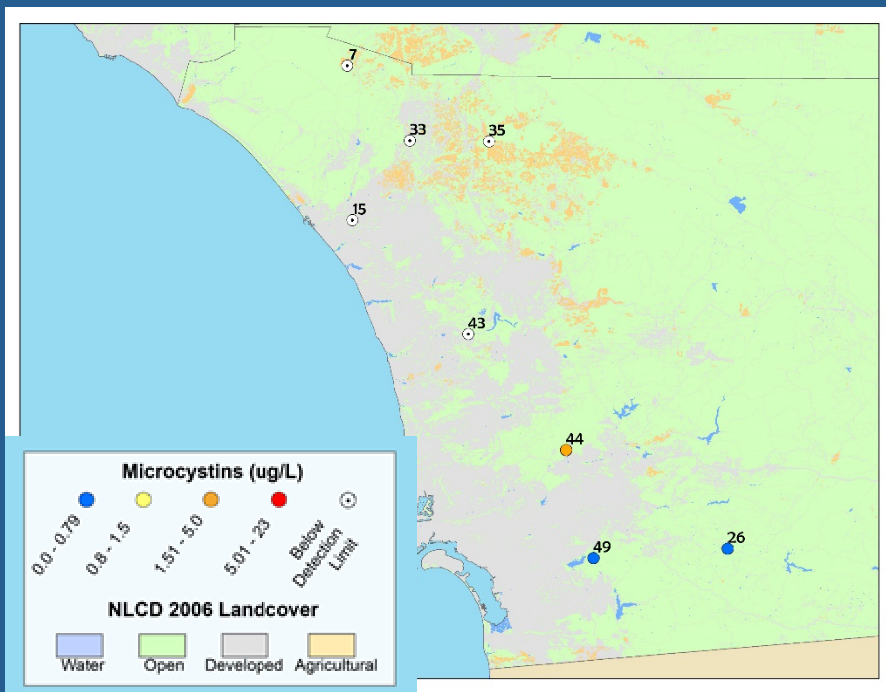
Why Use SPATT?
Determine Toxin *Prevalence*

- Condition assessments and screening studies
- Waterbodies with little to no HAB data
- Determine the prevalence of toxin across a region
  - Depressional wetlands assessment (probabilistic design)
  - Lakes, estuaries and reservoirs (targeted design)

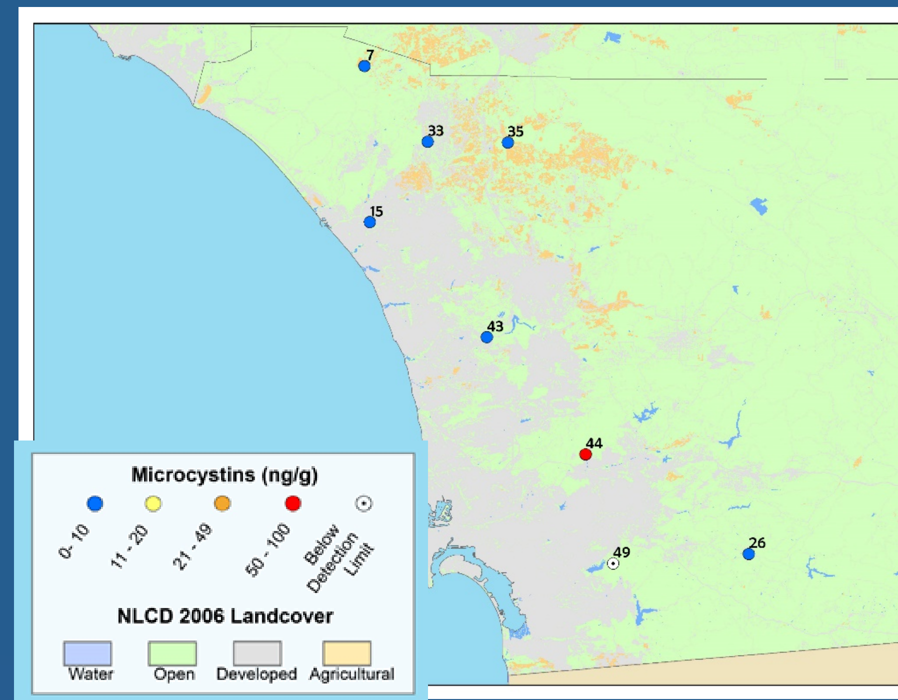


Microcystin Prevalence Underestimated From Grab Samples By ~50%

Grab Samples



SPATT Samples



% of Toxic Sites: Depressional Wetlands

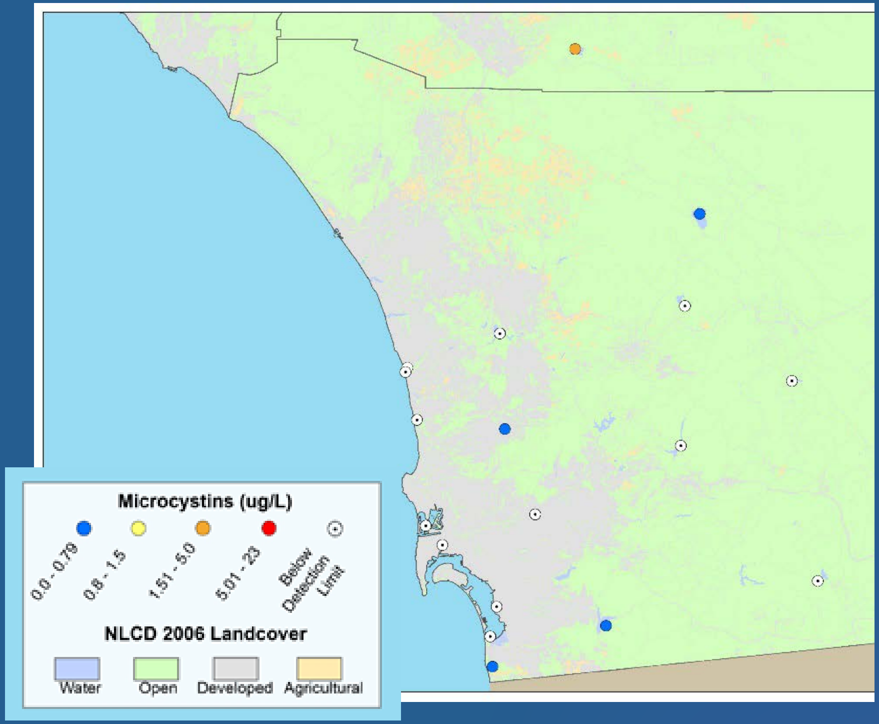
Grab Samples	29%
SPATT Samples	83%

Howard et al., submitted

Microcystins Detected at Every Site Sampled

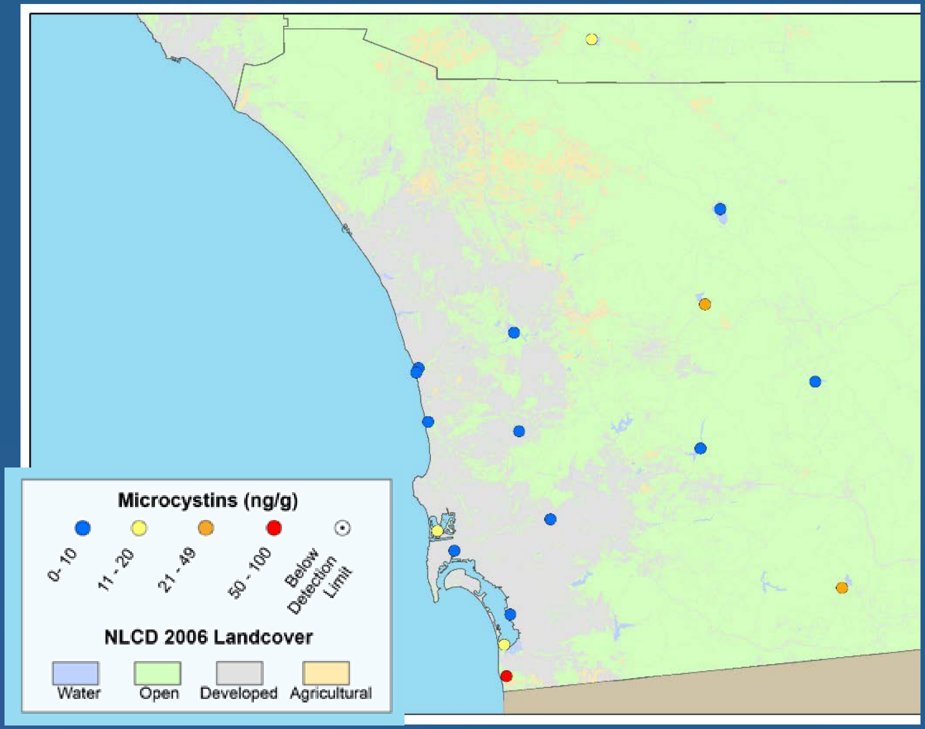
San Diego County: Lakes, Reservoirs, Estuaries and Coastal Lagoons

Grab Sample Results



SPATT Sample Results:

All sites toxic



Howard et al., submitted



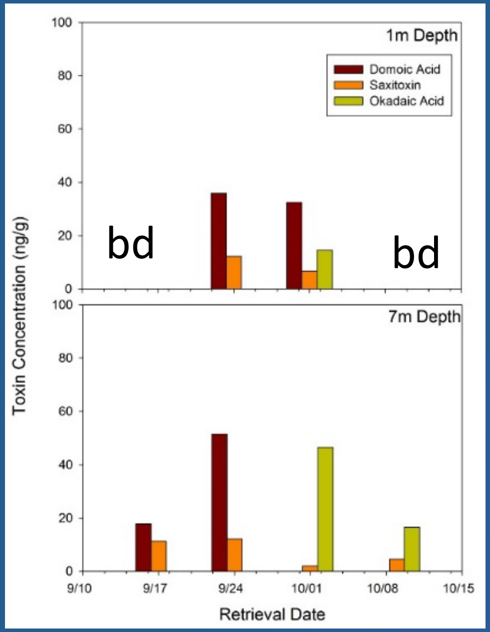



Why Use SPATT?
Deploy In Areas with Limited Sampling

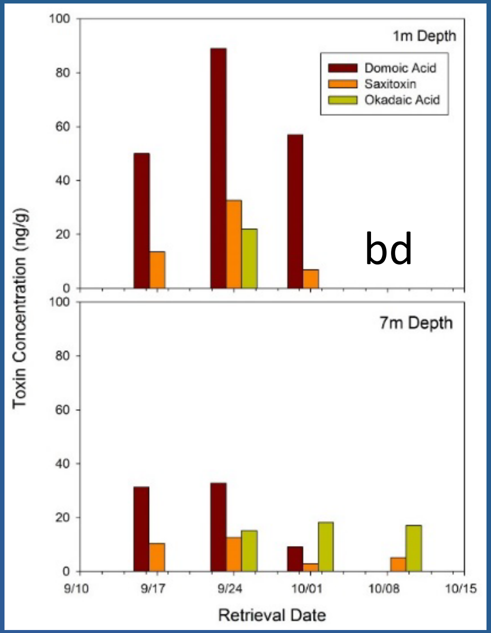
1 meter depth

7 meter depth

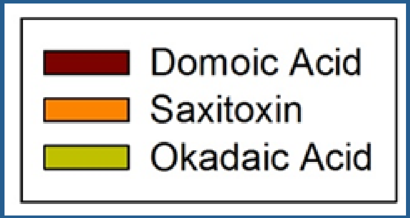
Site A



Site B

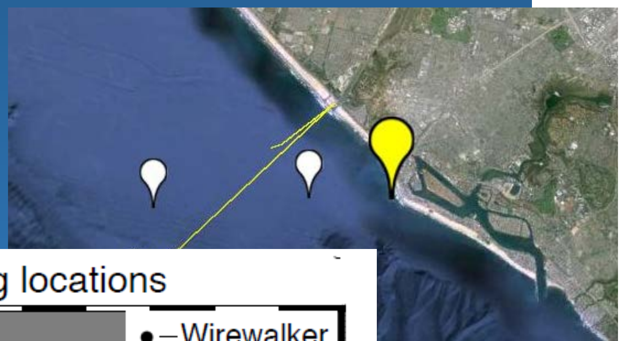


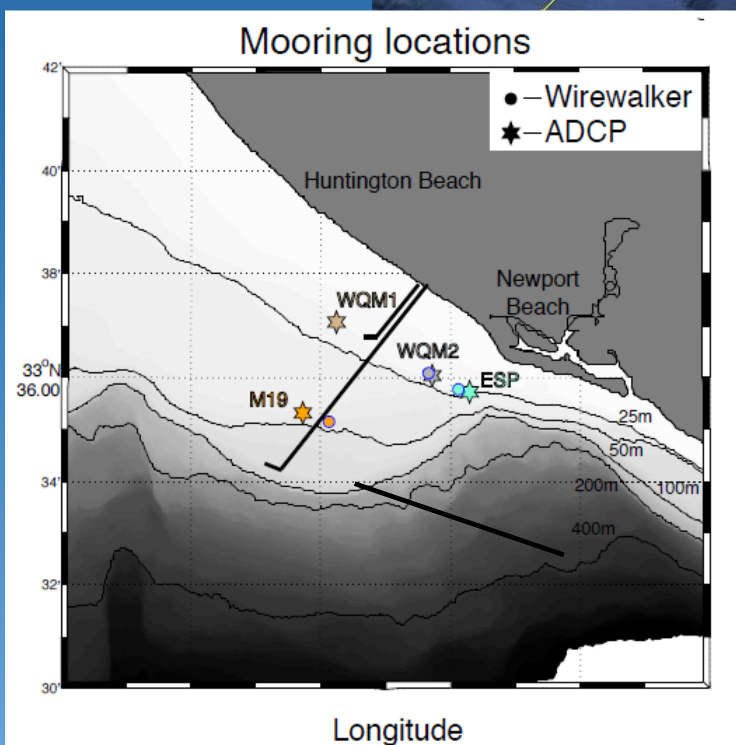
Pier:
DA below detection

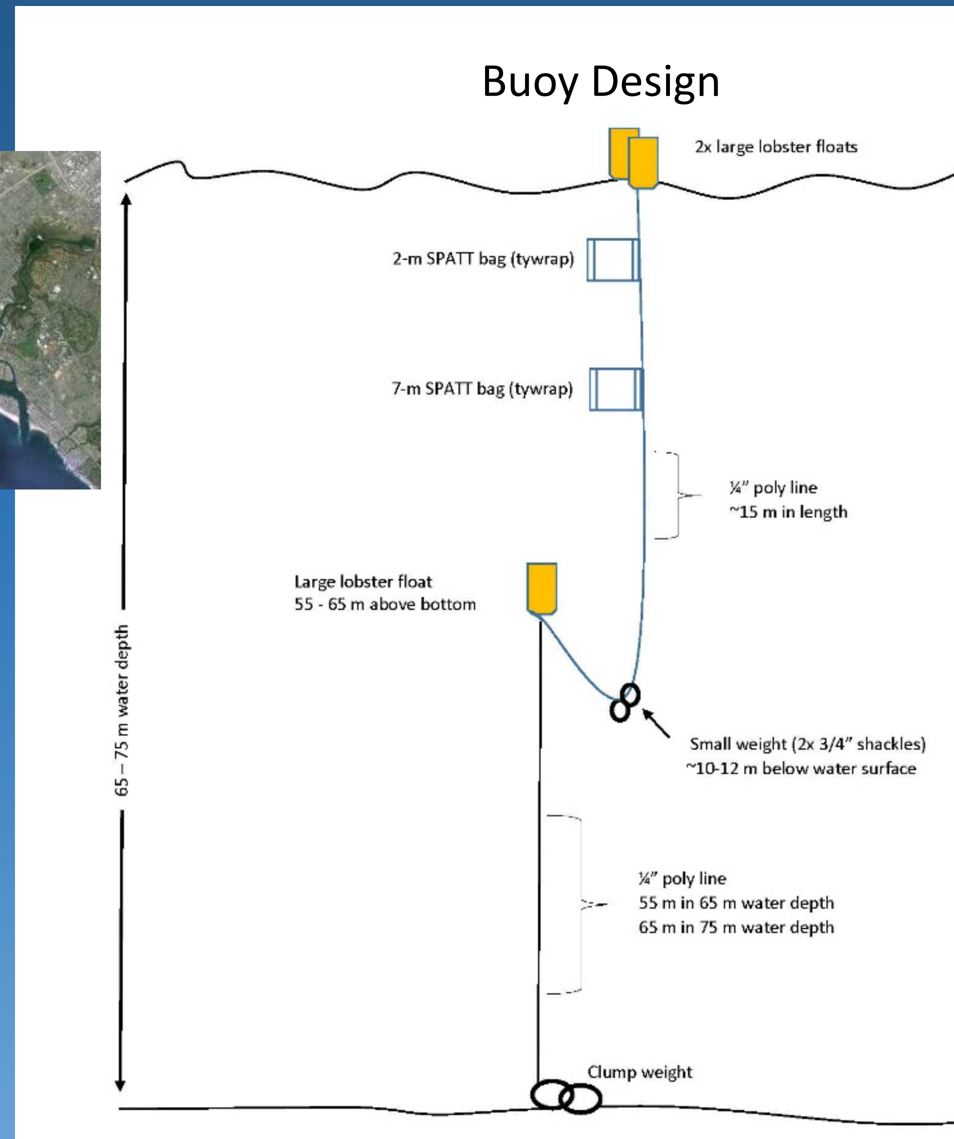


Slide and data provided by Erica Seubert

SPATT Deployment: Buoy and Mooring

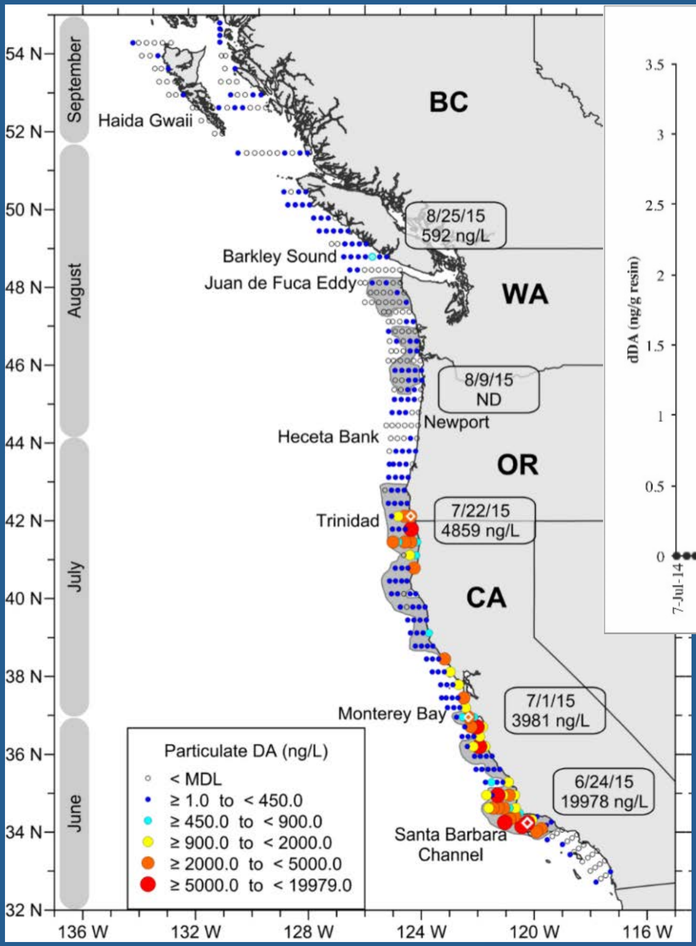




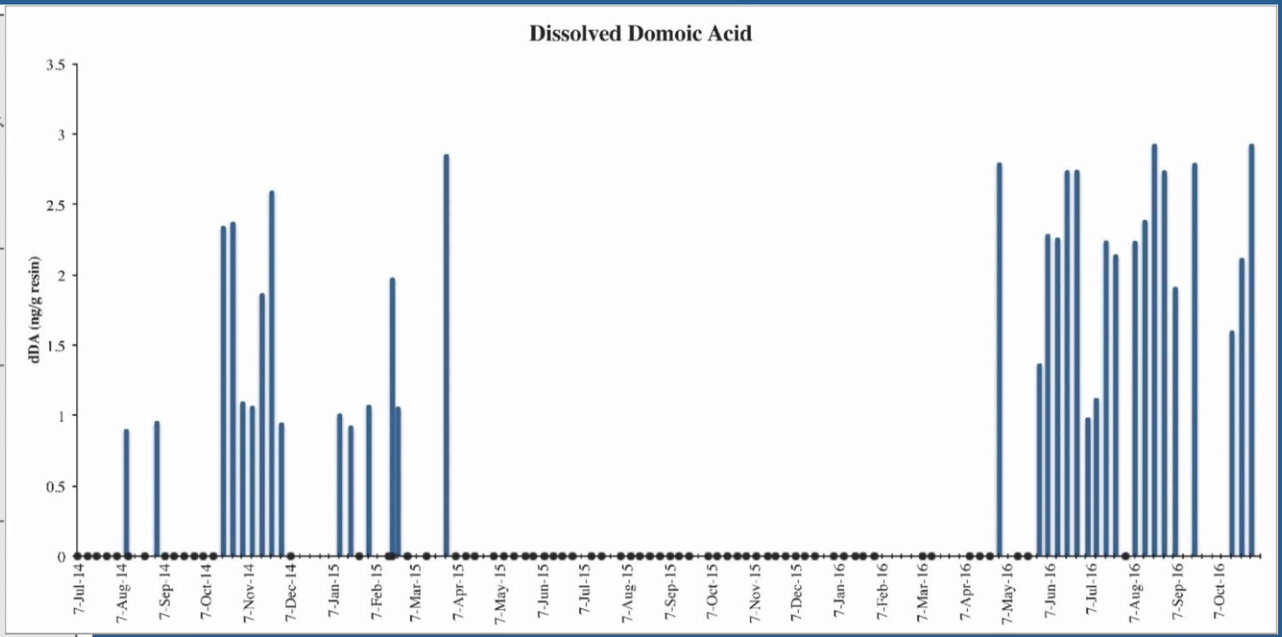


Map: Lucas and Kudela 2017; Buoy design George Robertson, Orange County Sanitation District

Why Use SPATT?
Continuous measurement of toxin

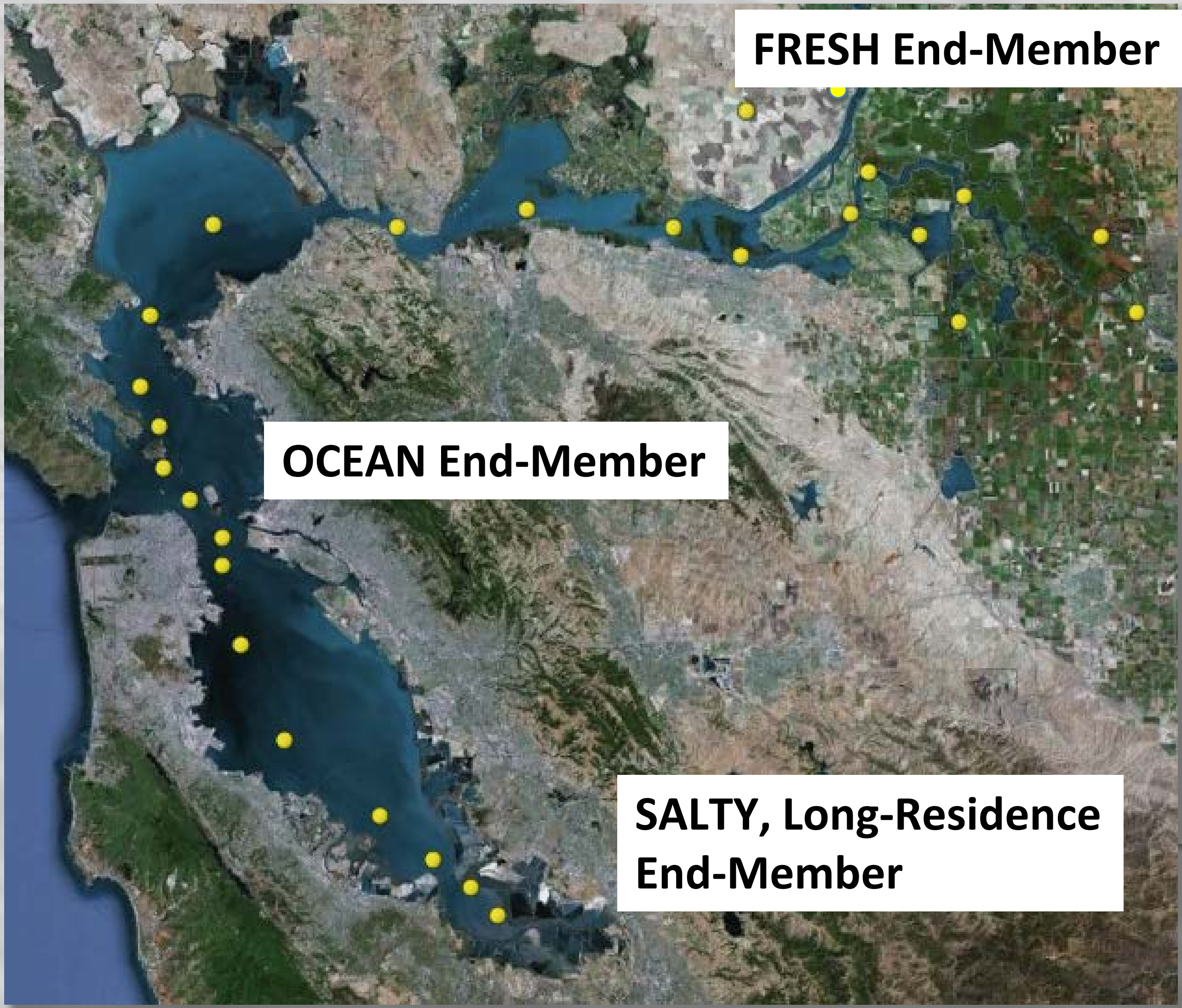


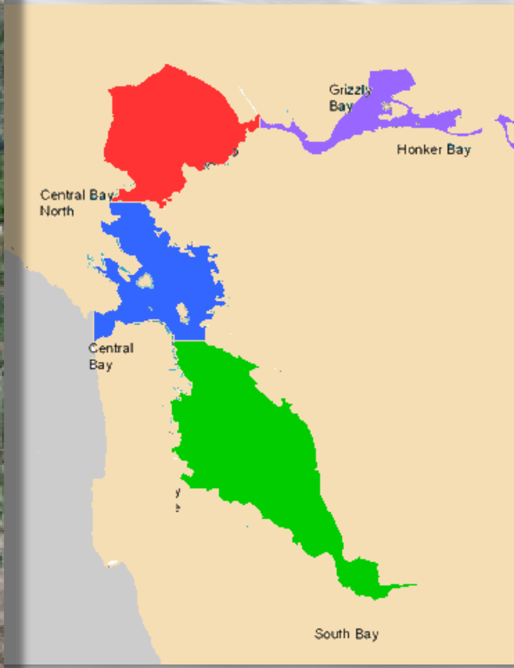
McCabe et al., 2016



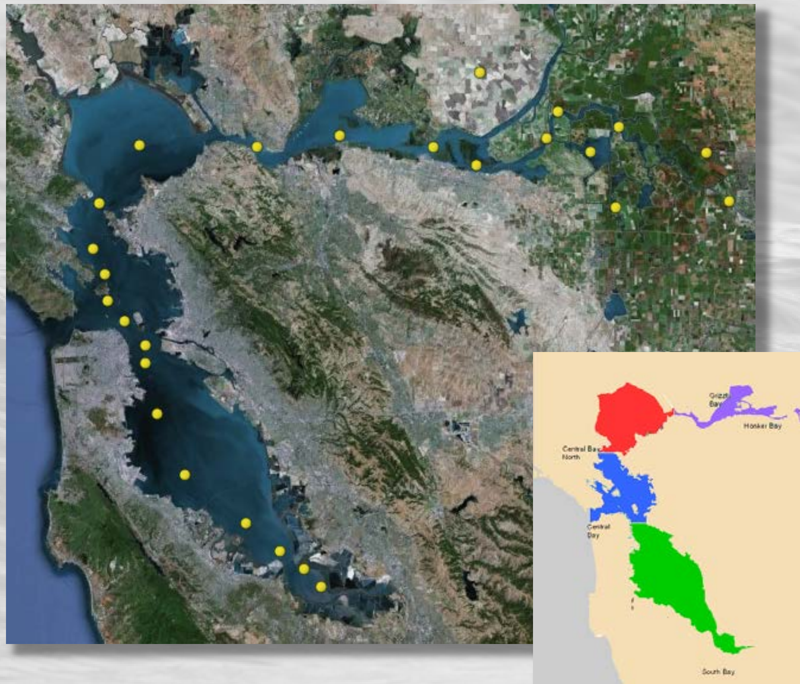
SPATT data provided by Jayme Smith and Dave Caron

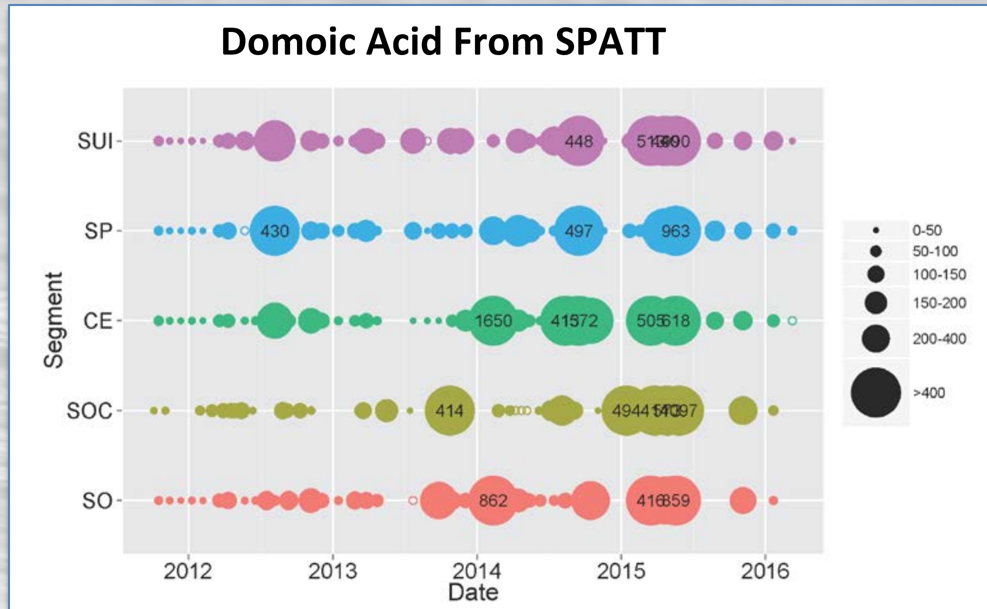
Why Use SPATT?
Uncovering Ubiquitous and Year Round Toxins
2011-2016: USGS Deployment of SPATT

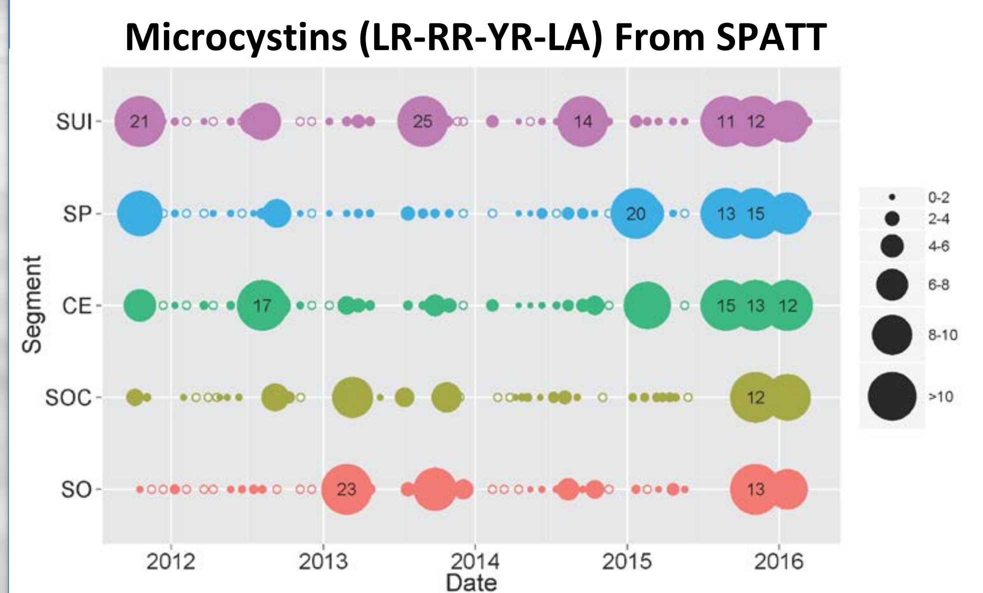




San Francisco Bay





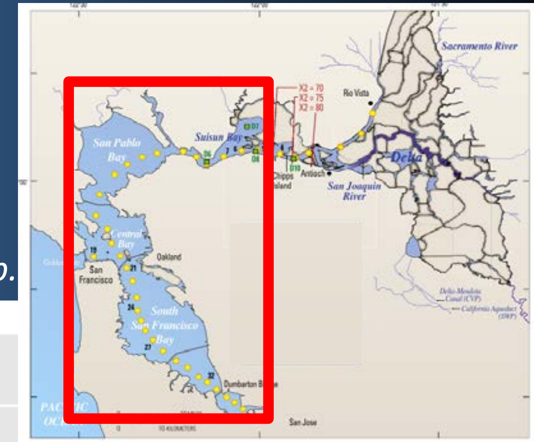


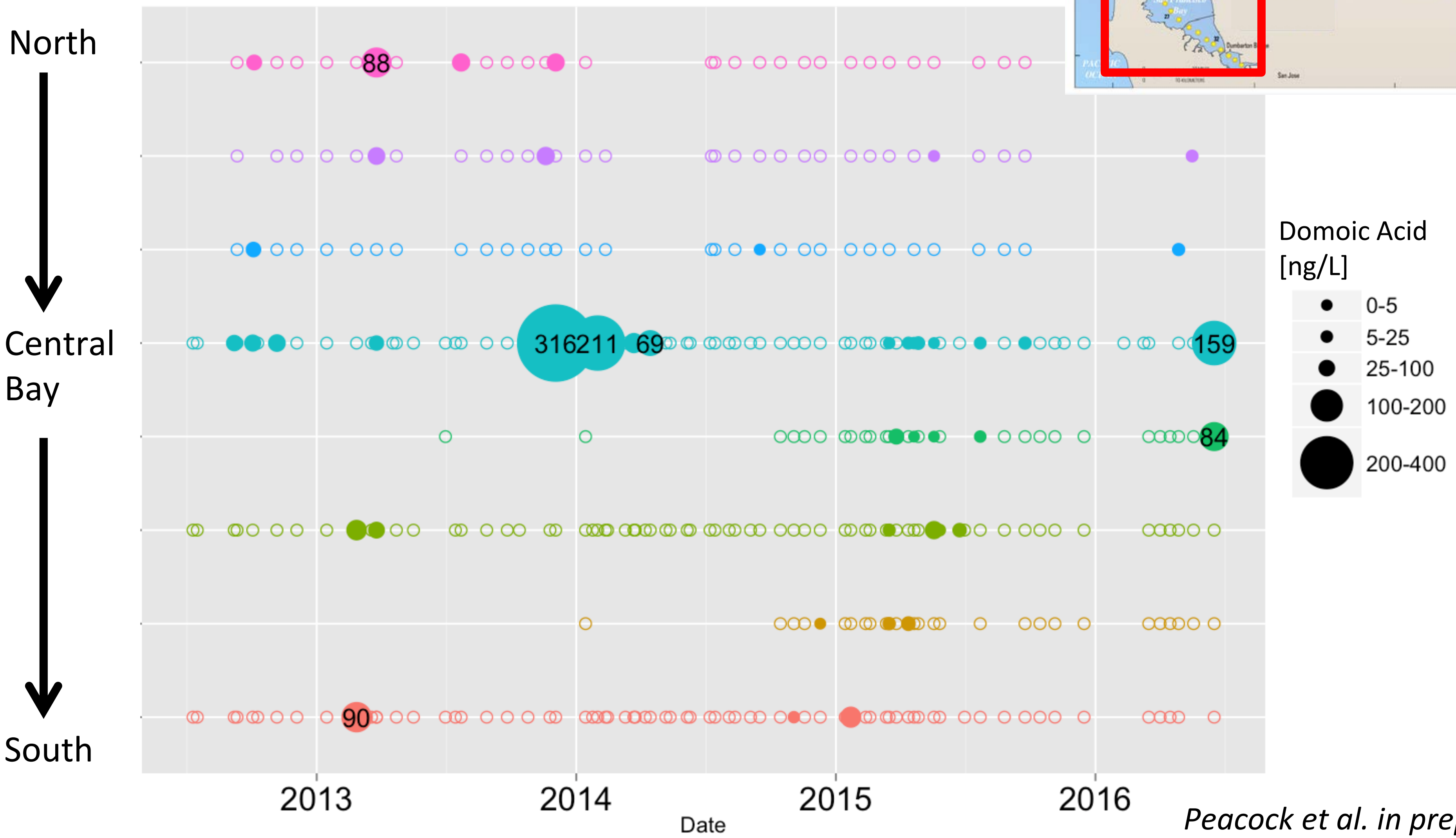
Focusing on SF Bay, we know that several algal toxins are nearly ubiquitous in the Bay.

The Bay seems to act as a mixing bowl for both freshwater and marine toxins…

Particulate Domoic Acid

Pseudo-nitzschia spp.

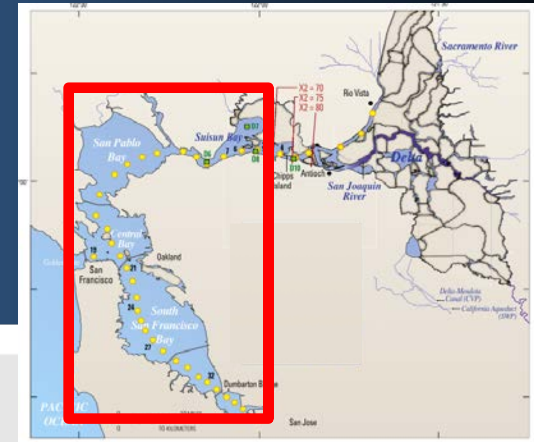


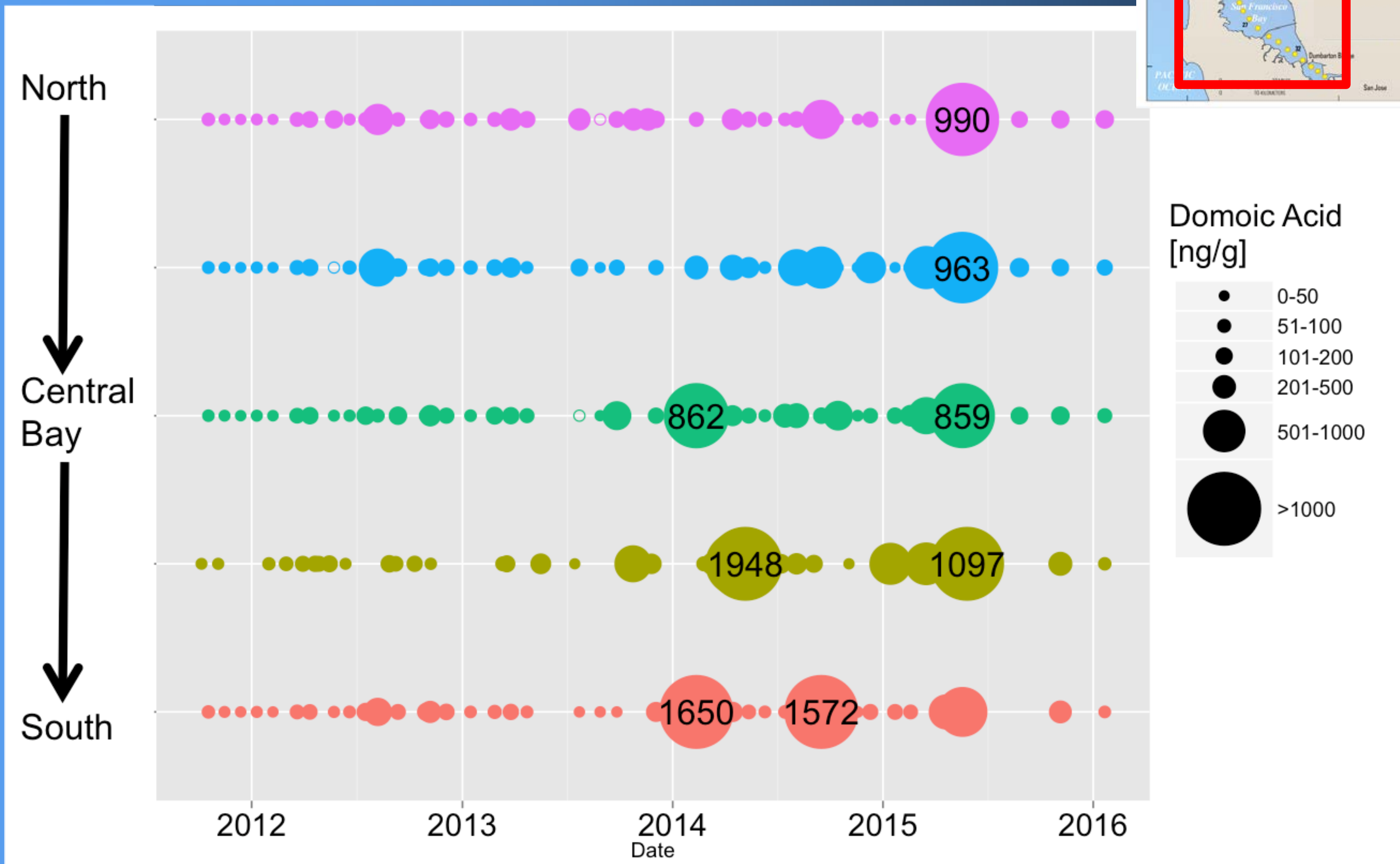


Peacock et al. in prep

Dissolved Domoic Acid From SPATT

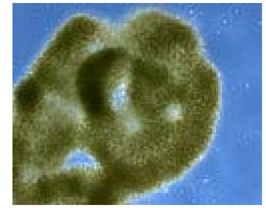
Pseudo-nitzschia spp.





Peacock et al. in prep

Particulate Microcystin

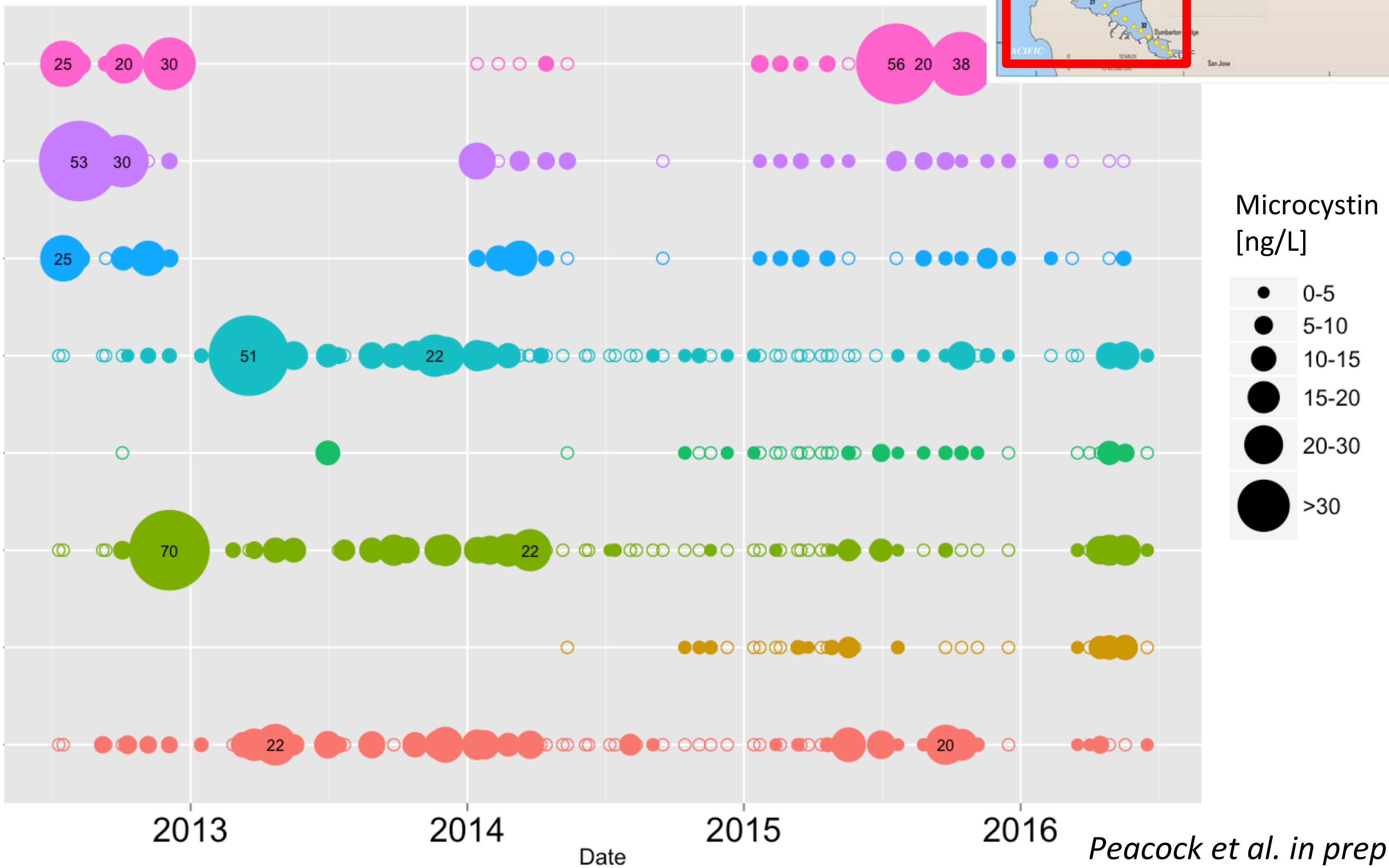


Microcystis spp.

North

Central Bay

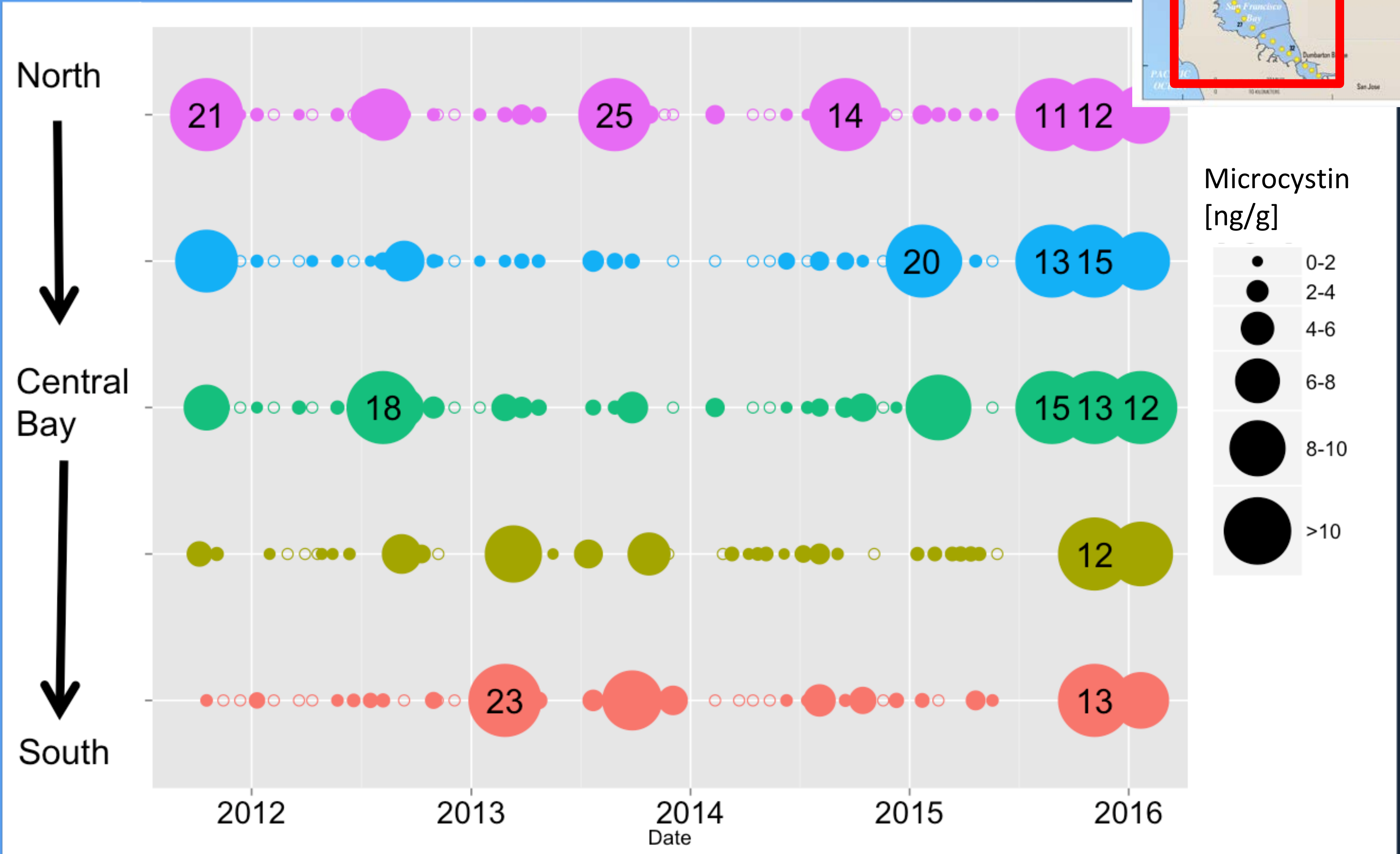
South



Peacock et al. in prep

Dissolved Microcystin From SPATT

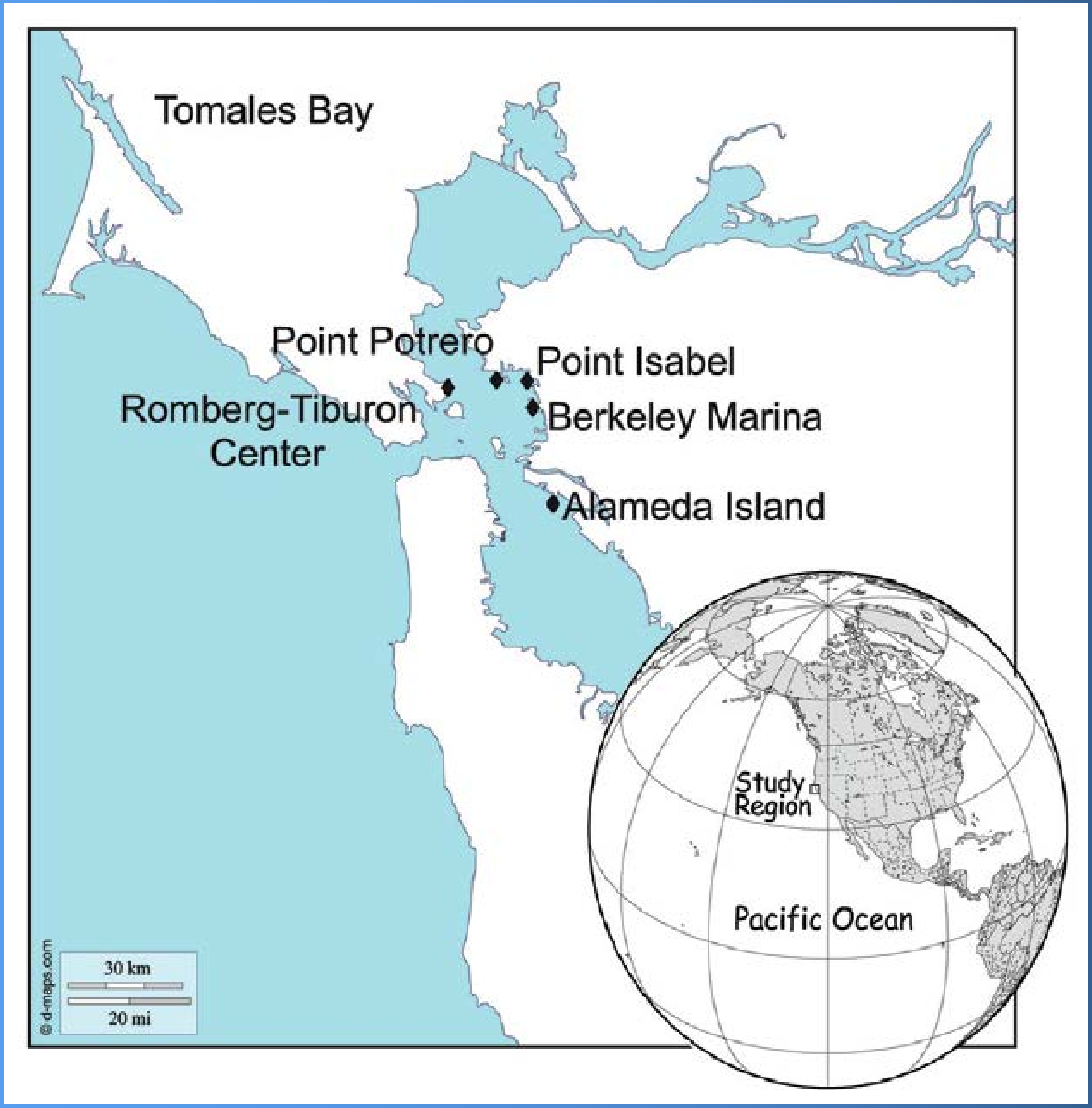
Microcystis spp.



Peacock et al. in prep

Deploy SPATT Using Ship Flow-Through System

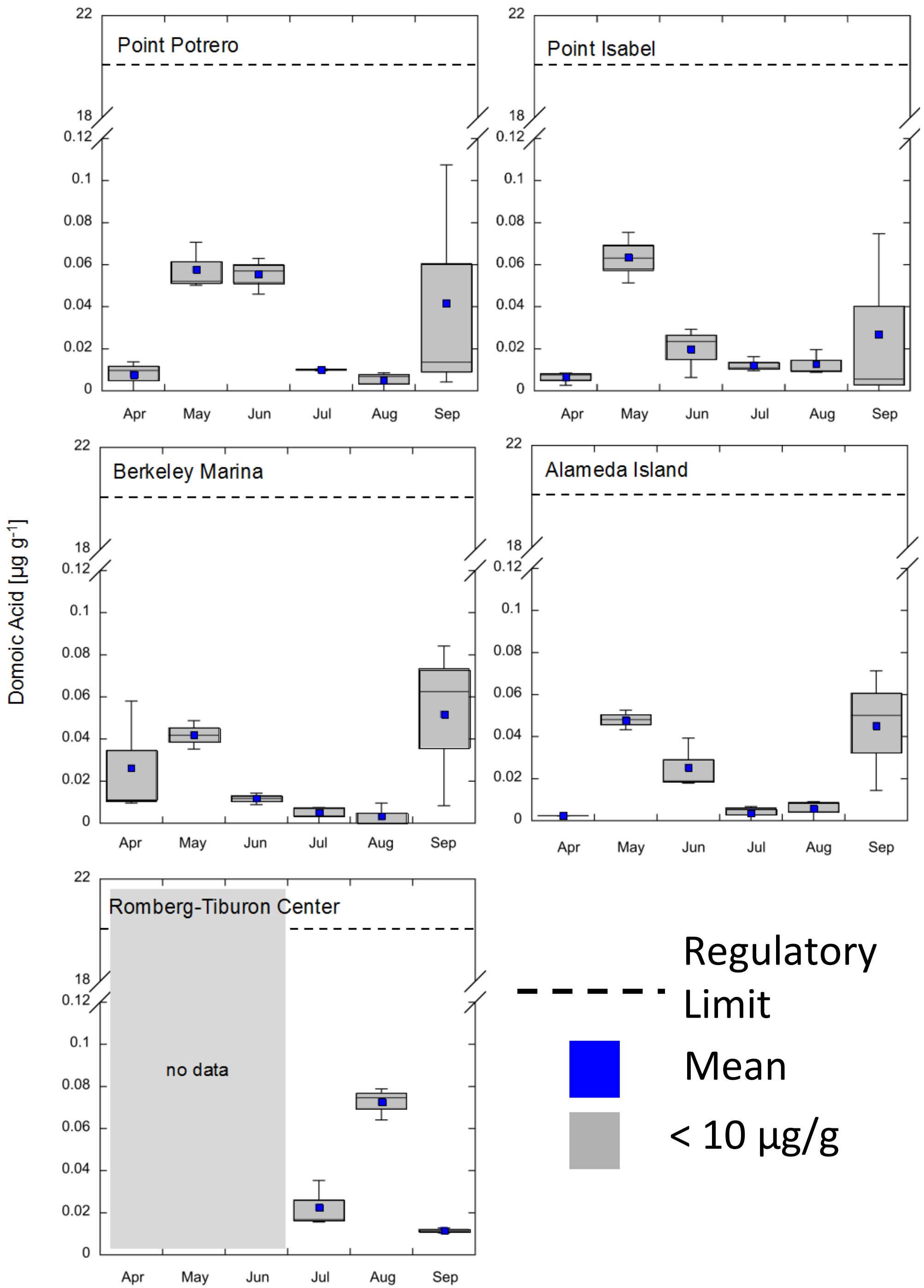
Mussel Collection

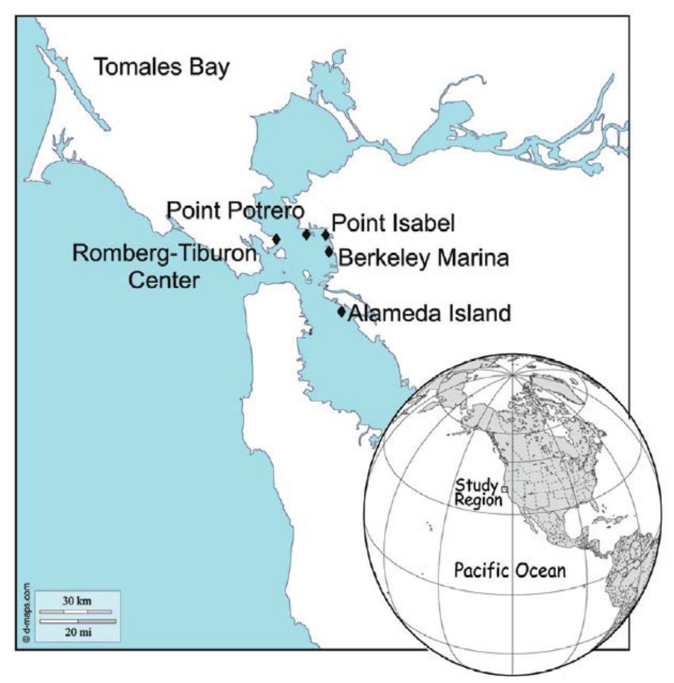


- Environmental mussel samples
- 5 locations, 1x per month
- April – September 2015
- Each mussel tested for Domoic Acid, Microcystin, PST, Okadaic Acid and DTX-2

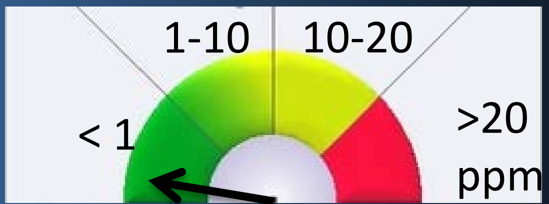
California Mussel

Domoic Acid in Mussels



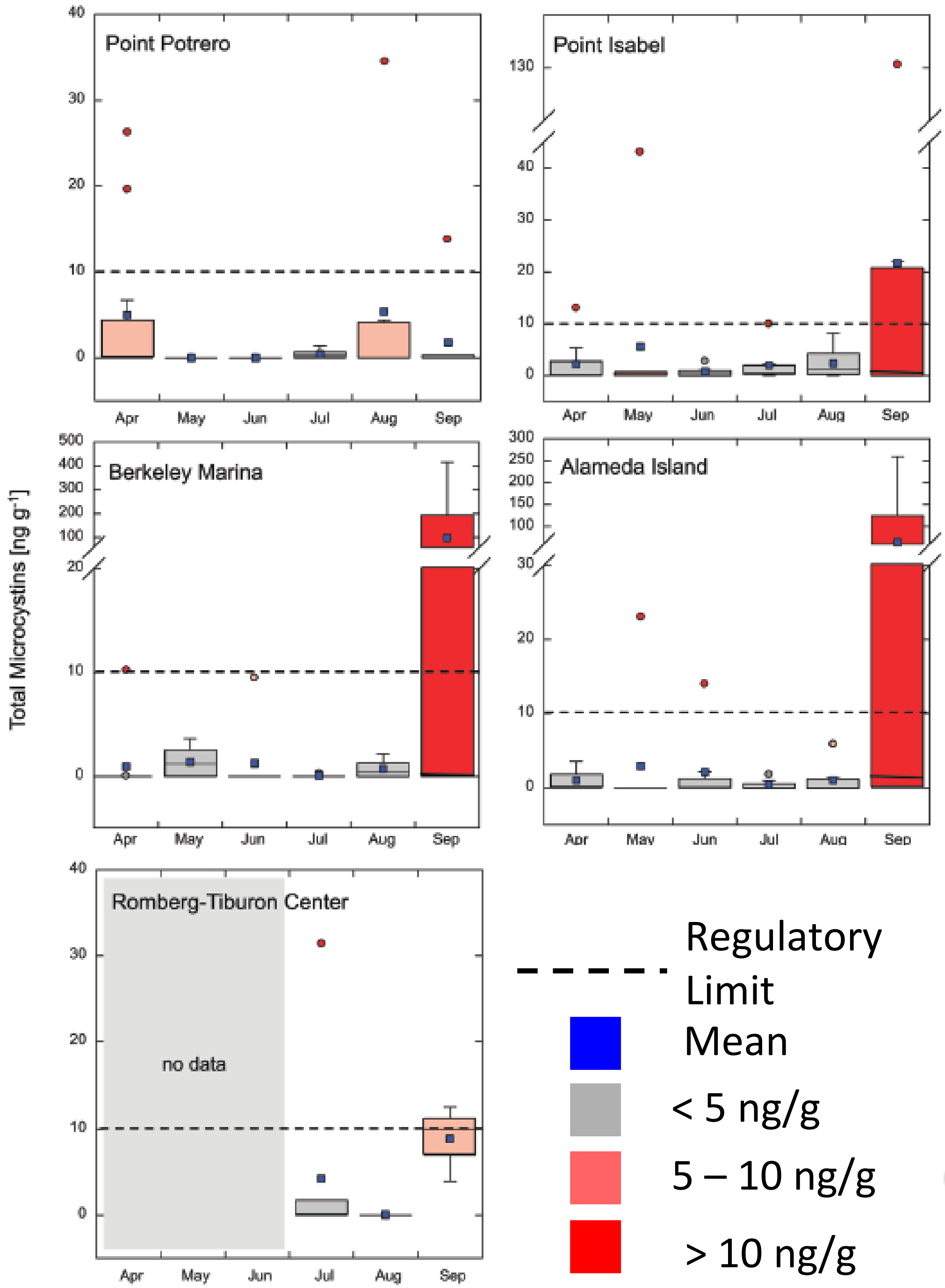


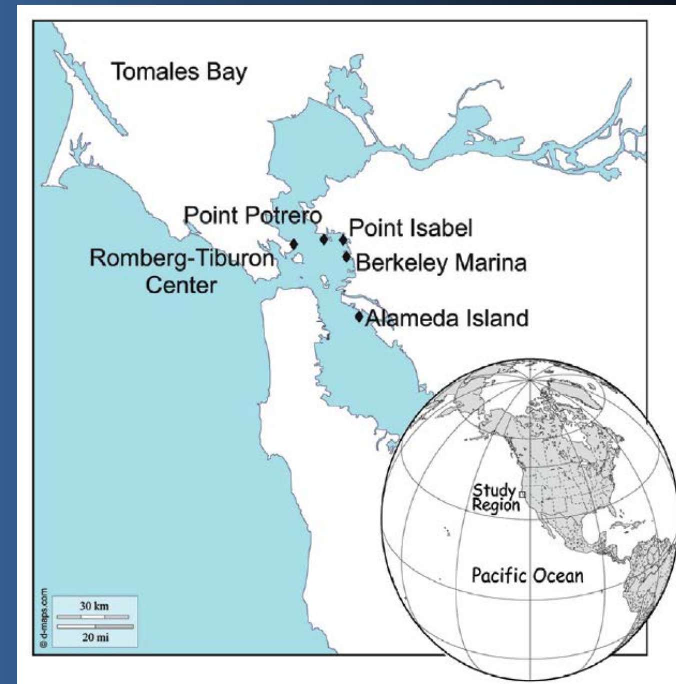
- Low but measurable DA
- Followed the trend of West Coast bloom
- But NOT the magnitude



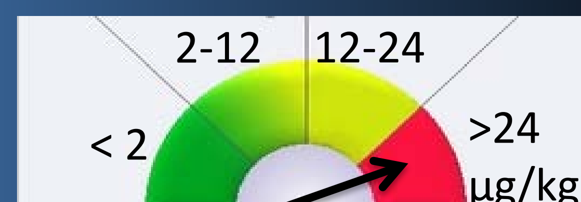
Peacock et al. in prep

Microcystins in Mussels



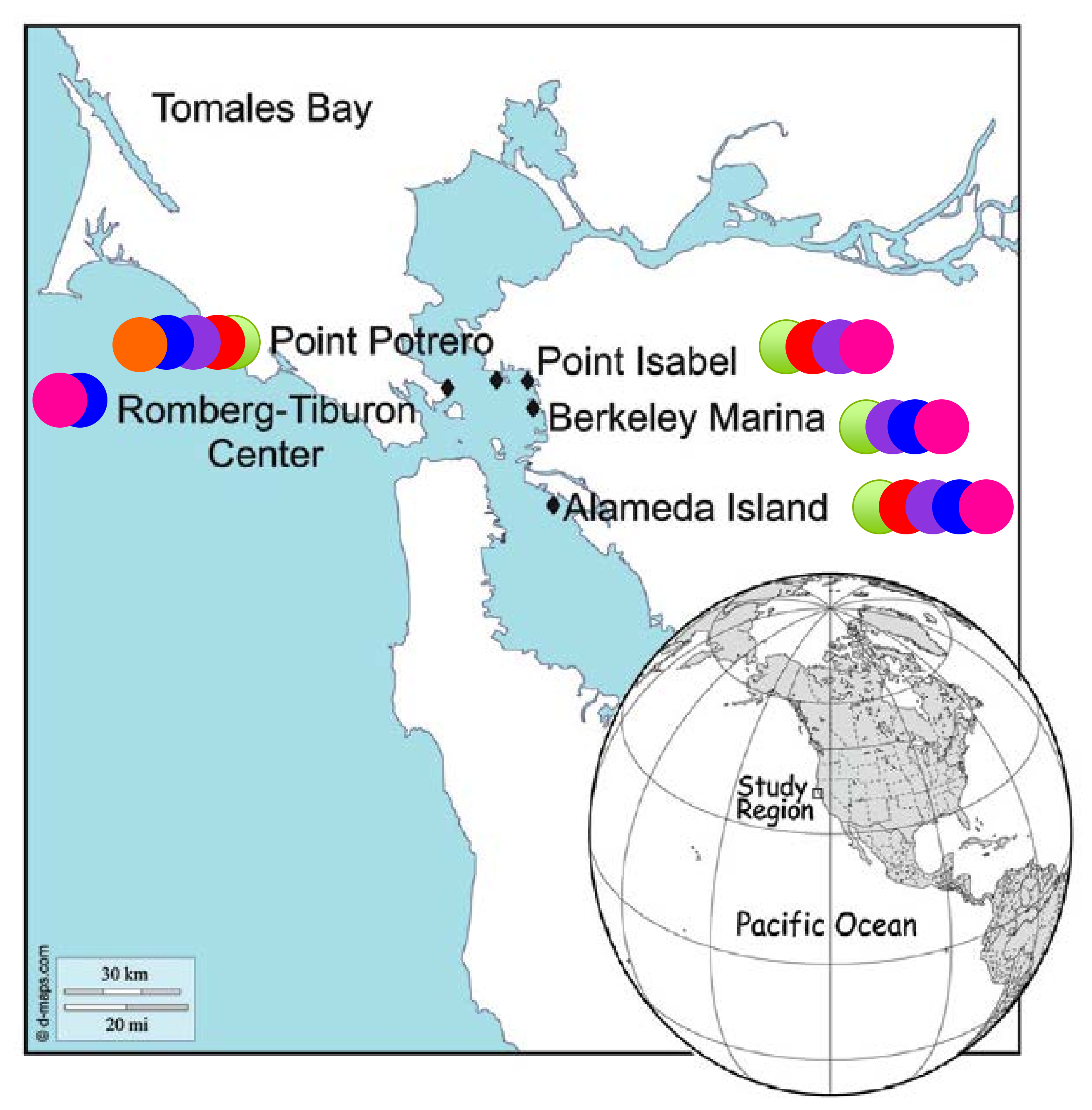


- Sometimes **HIGH** microcystin
- Variability
- No regulatory limit
- Are **NOT** monitored for

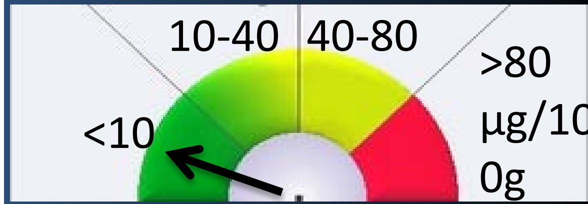


Gibble et al., 2016

PST in Mussels

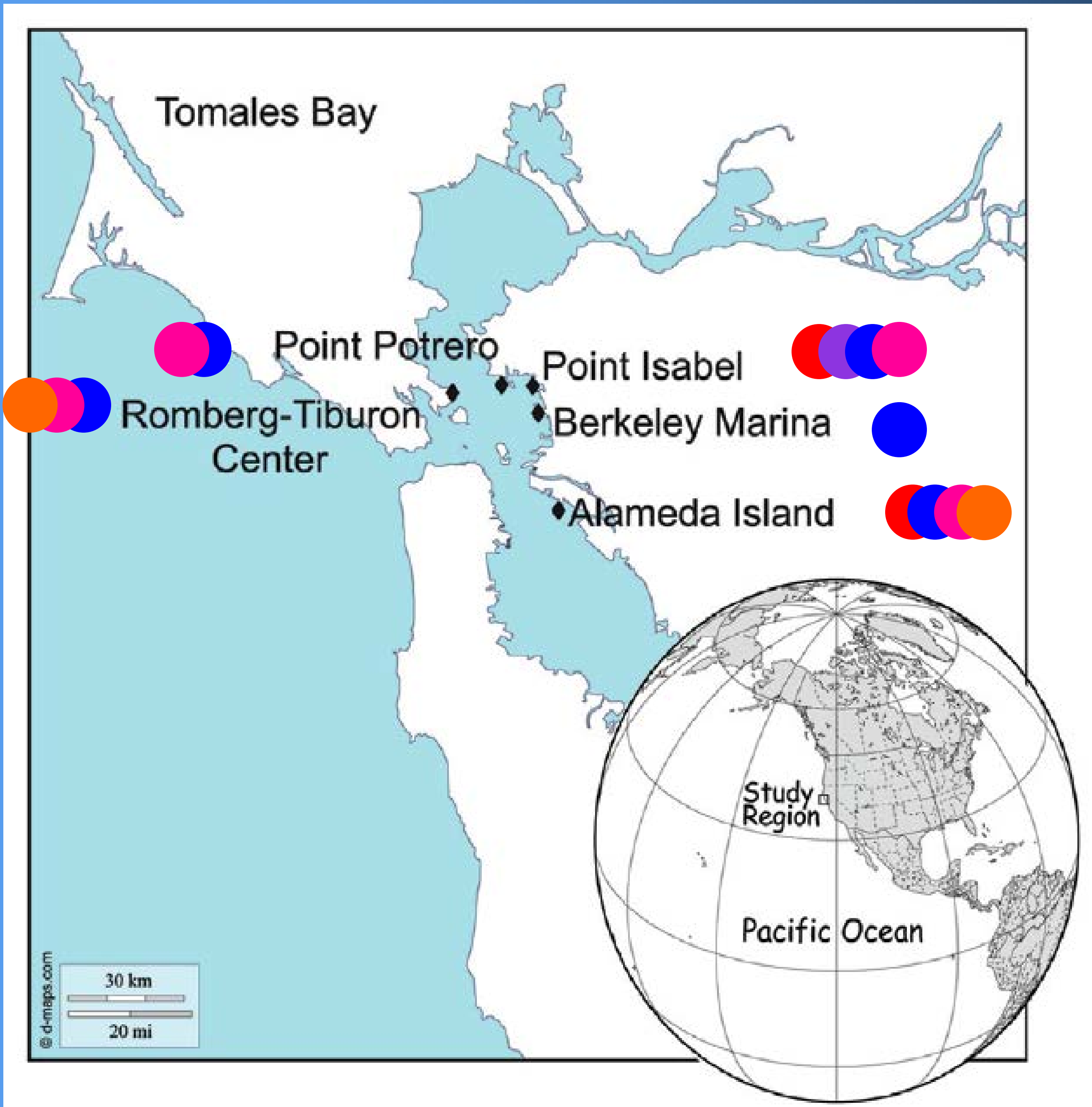


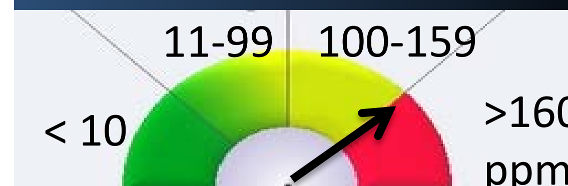
- Can be marine or freshwater toxins
- Low but measurable



Okadaic Acid and DTX-2 in Mussels

- Sometimes HIGH OA and DTX
- Variability





April

May

June

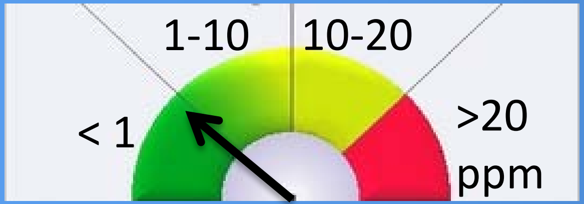
July

August

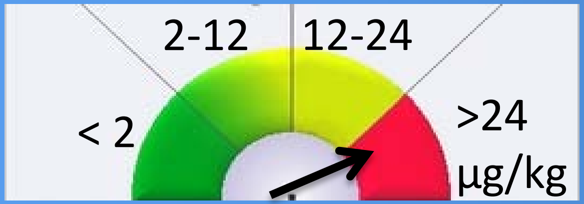
September

These toxins accumulate in the food web

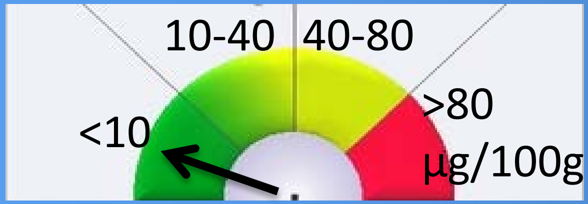
2012, 2014 RMP Caged Mussels



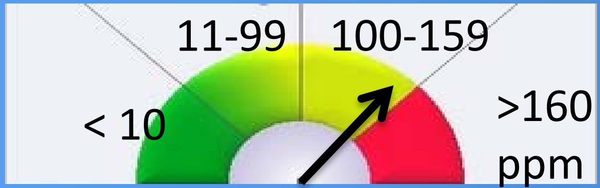
Domoic Acid
(100% of mussels contaminated)



Microcystins
(82% of mussels contaminated)



Paralytic Shellfish Toxins
(59% of mussels contaminated)



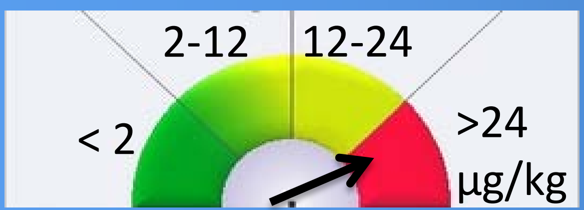
Okadaic Acid and DTX-2
(71% of mussels contaminated)

These toxins accumulate in the food web

~~2012, 2014 RMP Caged Mussels~~
Naturally occurring mussels, 2014-2016

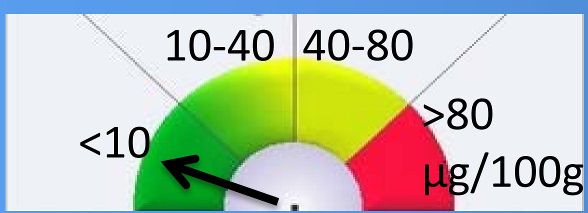
Domoic Acid

(*~~100%~~ of mussels contaminated)*
100%



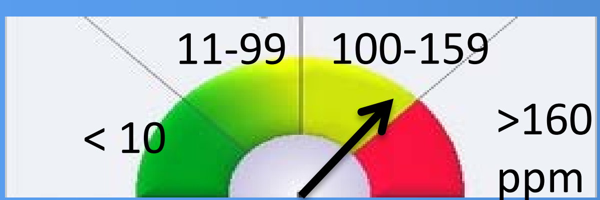
Microcystins

(*~~82%~~ of mussels contaminated)*
82%



Paralytic Shellfish Toxins

(*~~25%~~ of mussels contaminated)*
59%



Okadaic Acid and DTX-2

(*~~100%~~ of mussels contaminated)*
71%

Why Use SPATT?

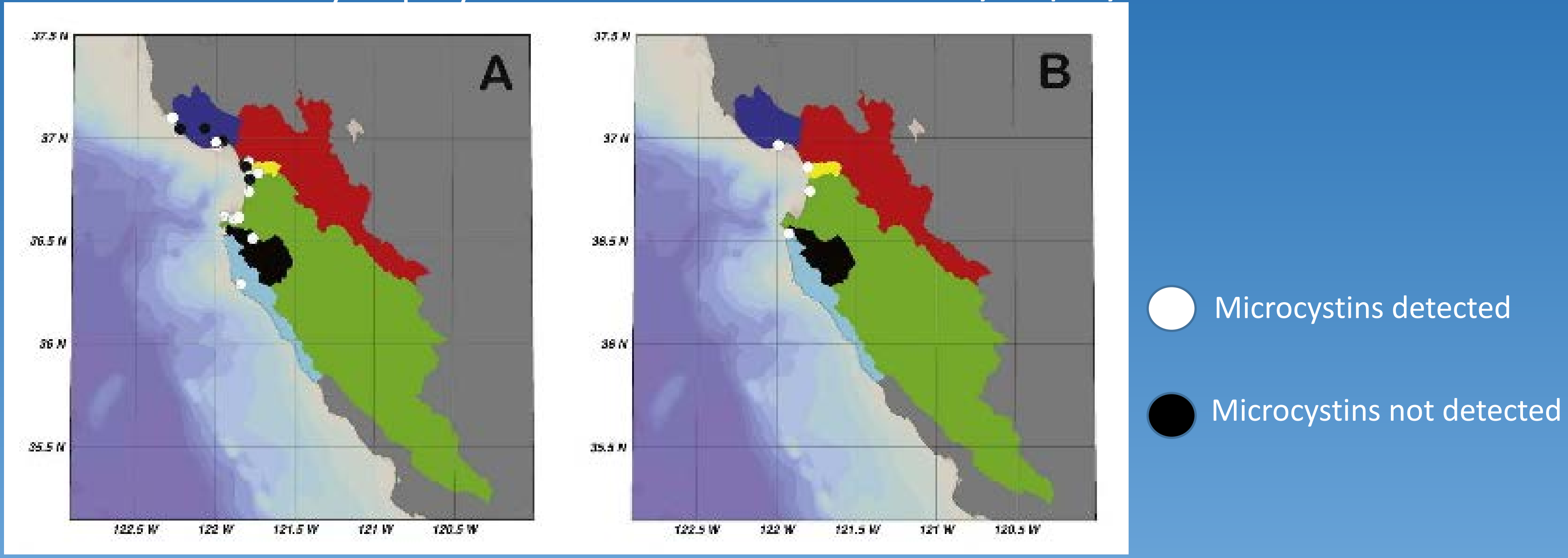
Persistence of cyanotoxins flowing into marine waters

Do microcystins persistently flow into Monterey Bay from surrounding watersheds?

Answer: YES! Microcystins were persistently present over several years.

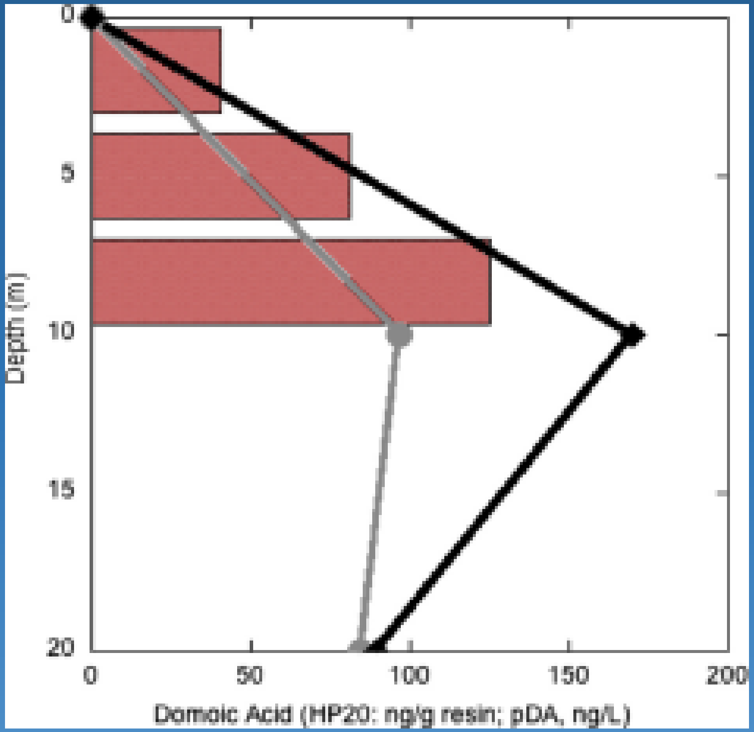
- Toxin peaks were in the spring and autumn seasons

2010-2011 Monthly deployments 2011-2013 Weekly deployments



Gibble and Kudela, 2014

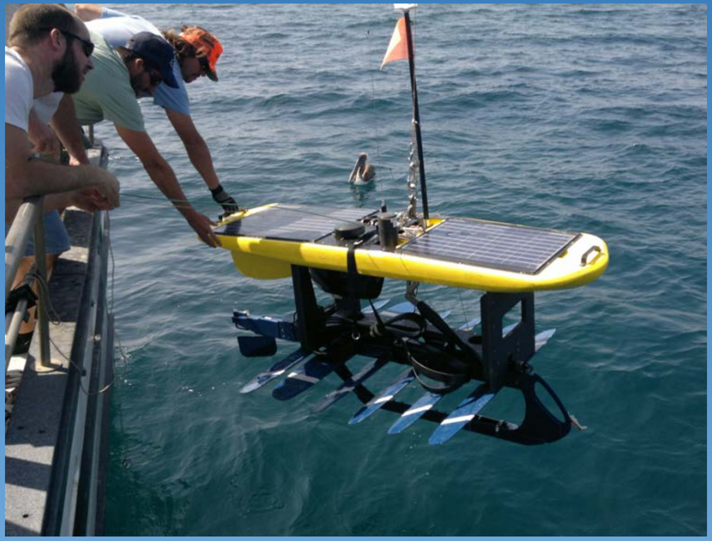
SPATT Deployment: AUVs



SPATT
Grab 25 Oct.
Grab 8 Nov.

Berdalet et al., 2014

Liquid Robotics G5 surface wave glider

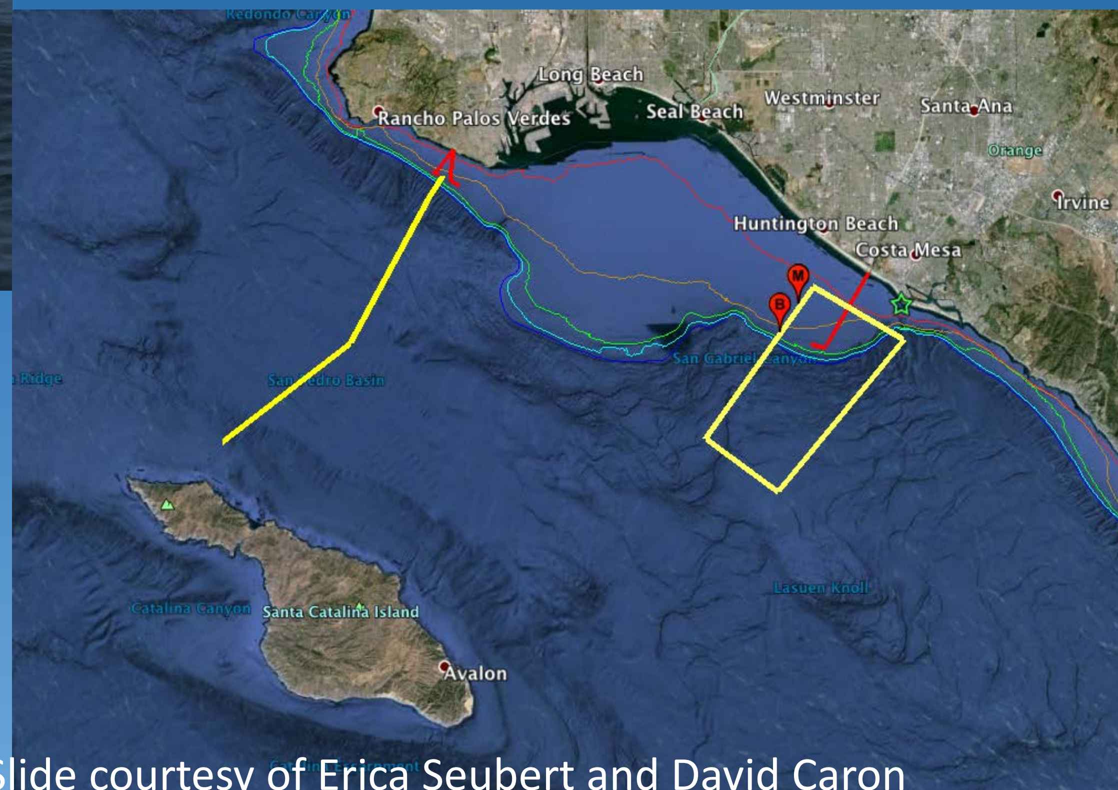


SPATT and Grab samples showed similar results: a persistent increase in DA

SPATT Deployment: AUVs

Teledyne Webb Slocum Gliders

SPATT detected domoic acid, saxitoxin; no okadaic acid detected



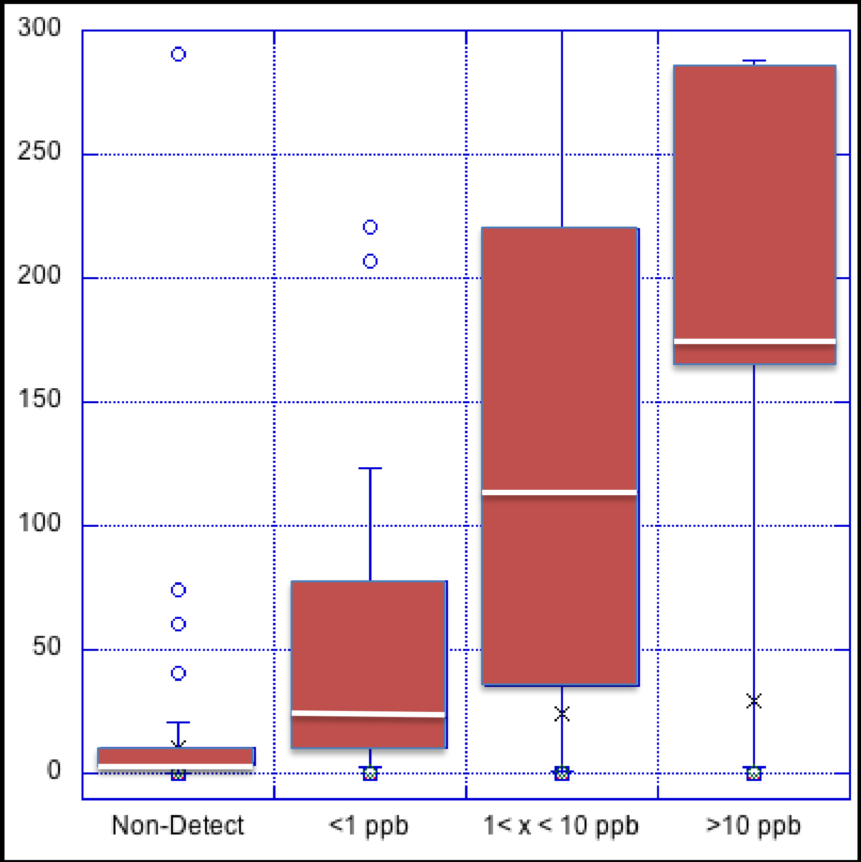
Slide courtesy of Erica Seubert and David Caron

Comparison of SPATT to Grab and Mussel Samples

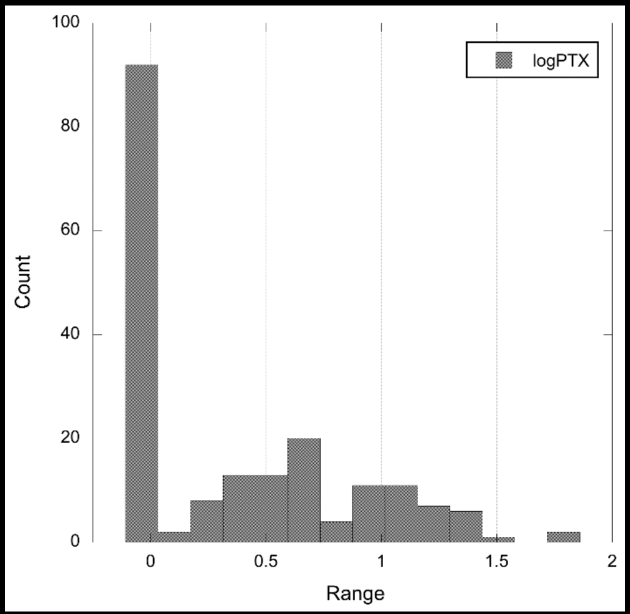
Values are reported as mass toxin per gram resin, for some period of time. Difficult to directly compare to regulatory limits, which are typically based on grab samples or contamination of food products.

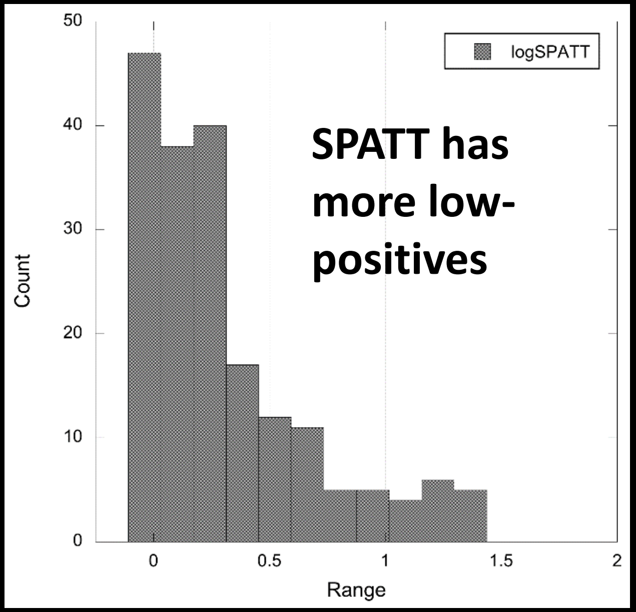
Microcystin Grab Sample (ppb)	SPATT (ng/g)
Non-Detect	5-13
< 1 ppb	10-50
1< x < 10 ppb	50-200
> 10 ppb	175-275

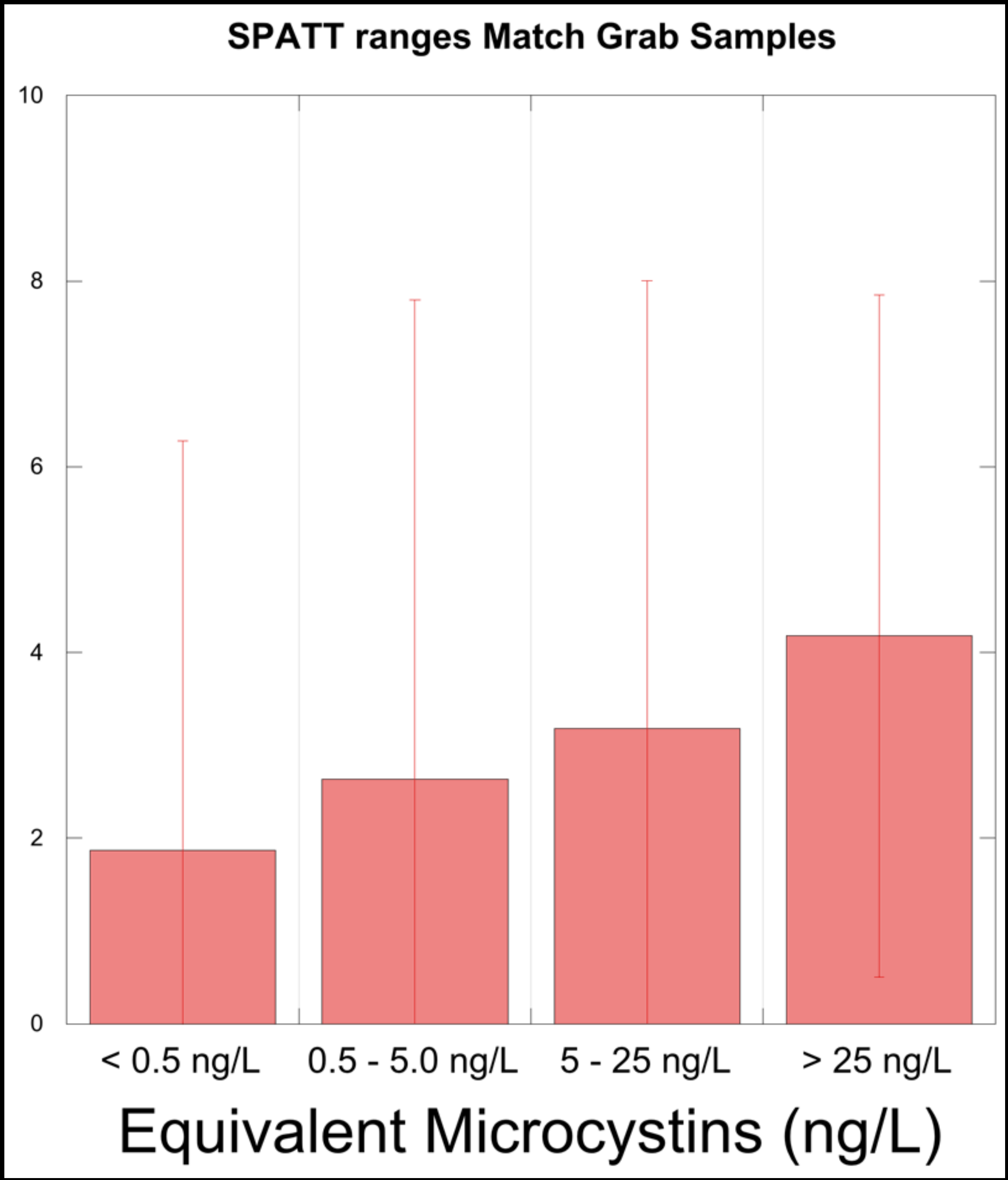
Domoic Acid Mussel (ppm)	SPATT (ng/g)
0-5 ppm	0-30
5-10 ppm	30-50
10-20 ppm	50-75
>20 ppm	>150



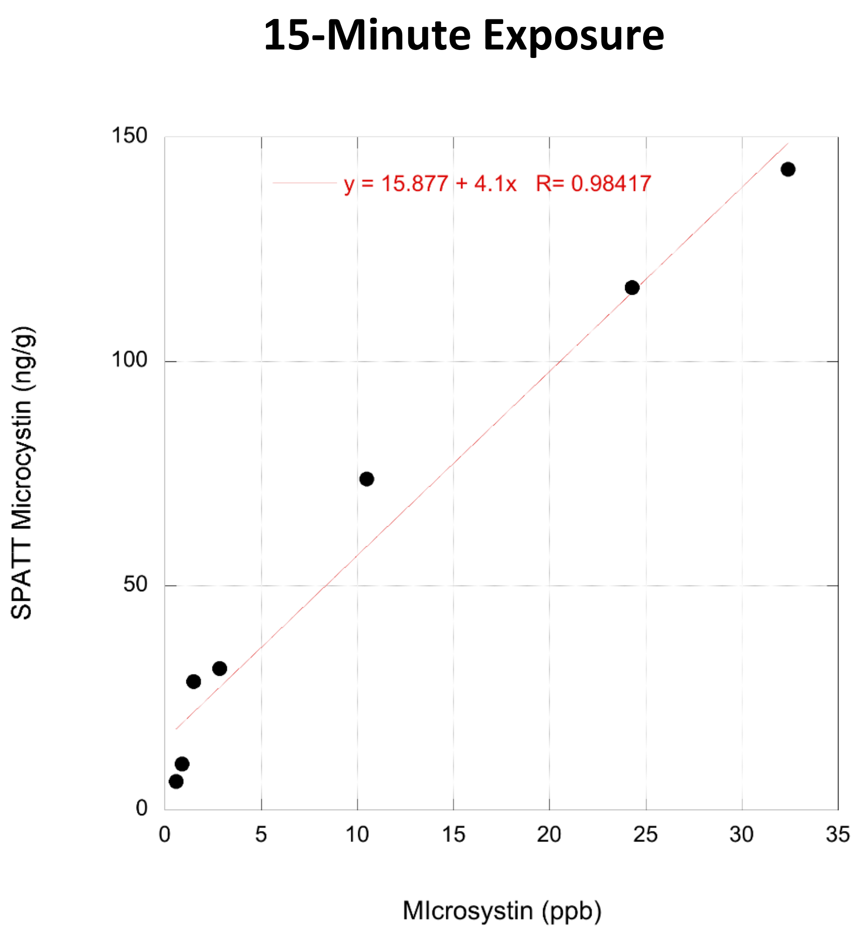
SPATT vs. Grab Samples San Francisco Bay





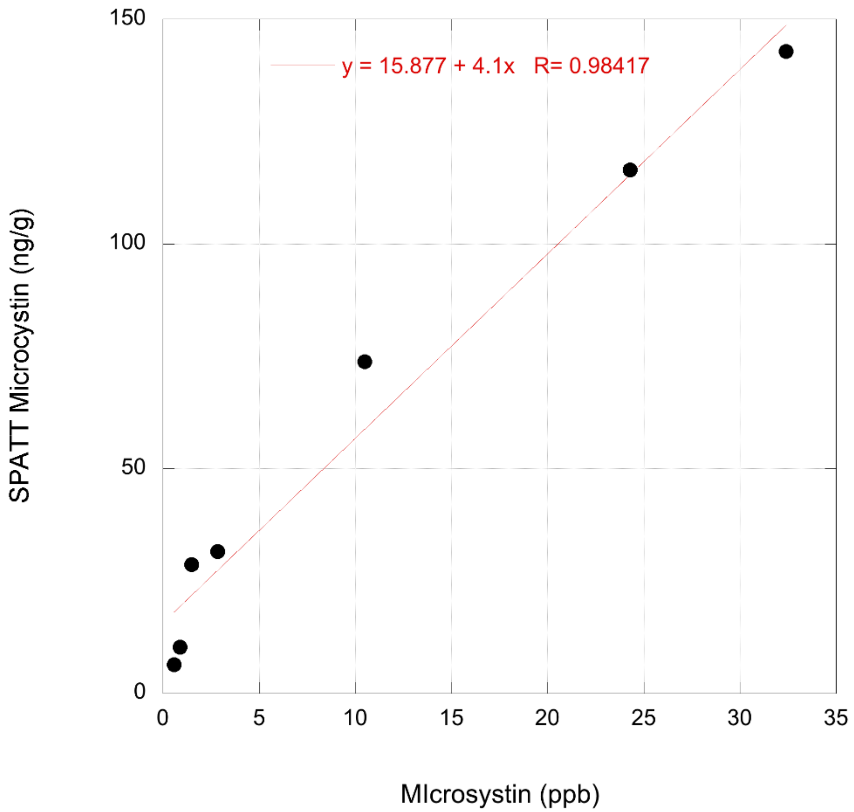


Adsorption Kinetics: Lab Trials

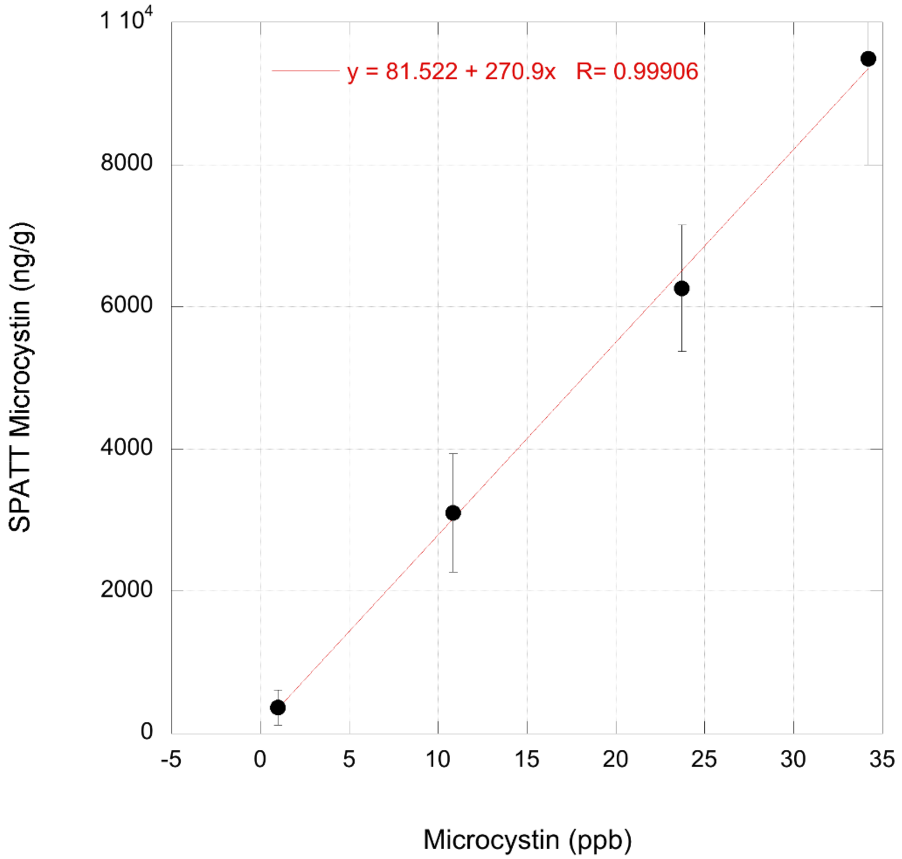


Microcystins (time)

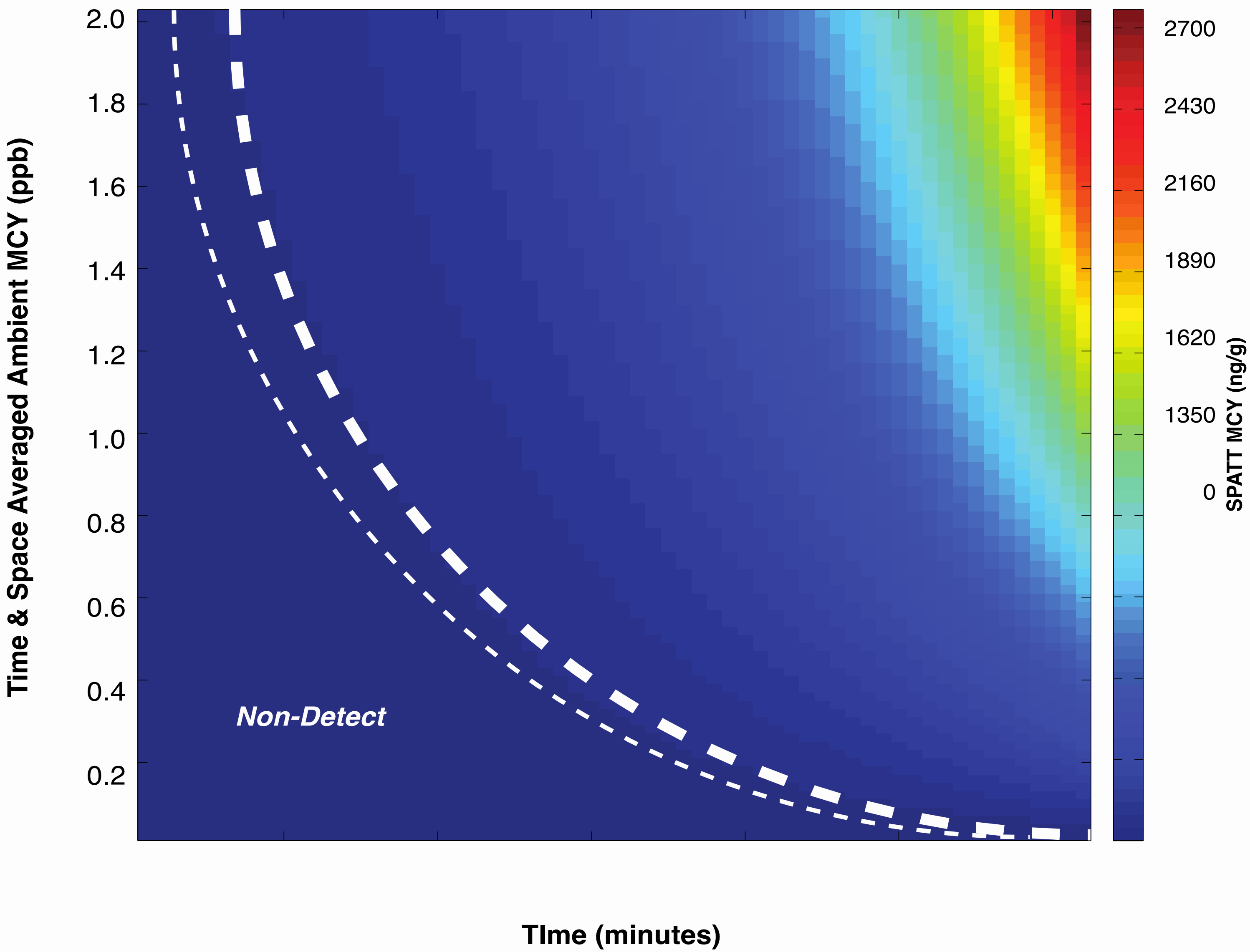
15 minute exposure



1 hour exposure

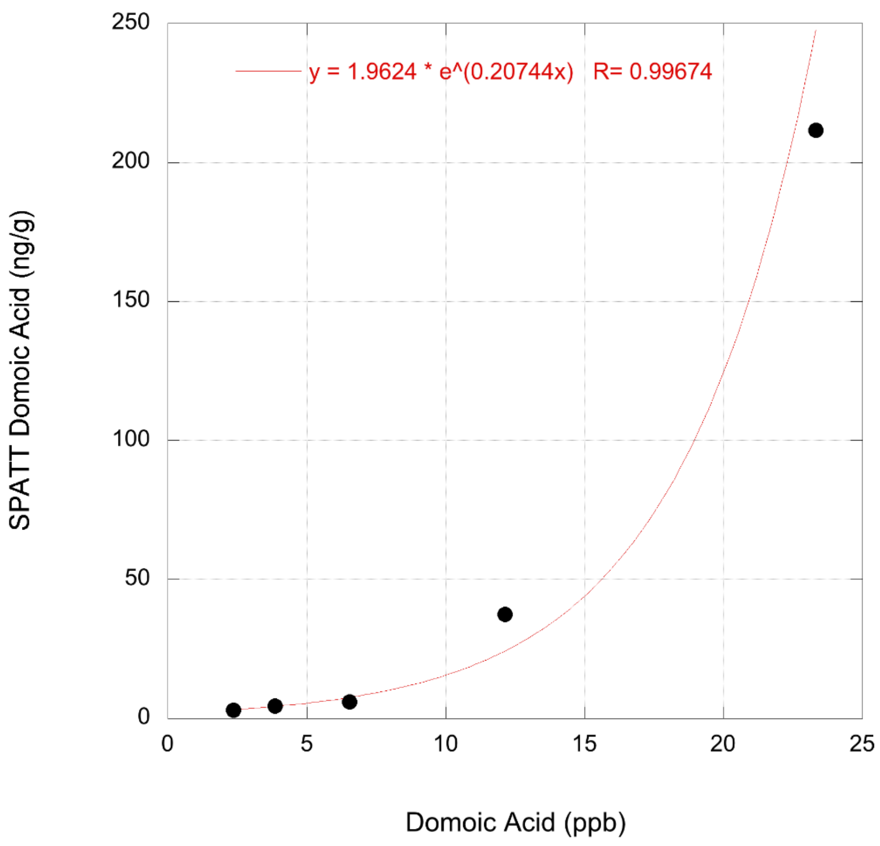


Because SPATT is time-averaging, increasing toxin (ng/g) is related to BOTH time of exposure and ambient concentration—it is helpful deploy SPATT *consistently*

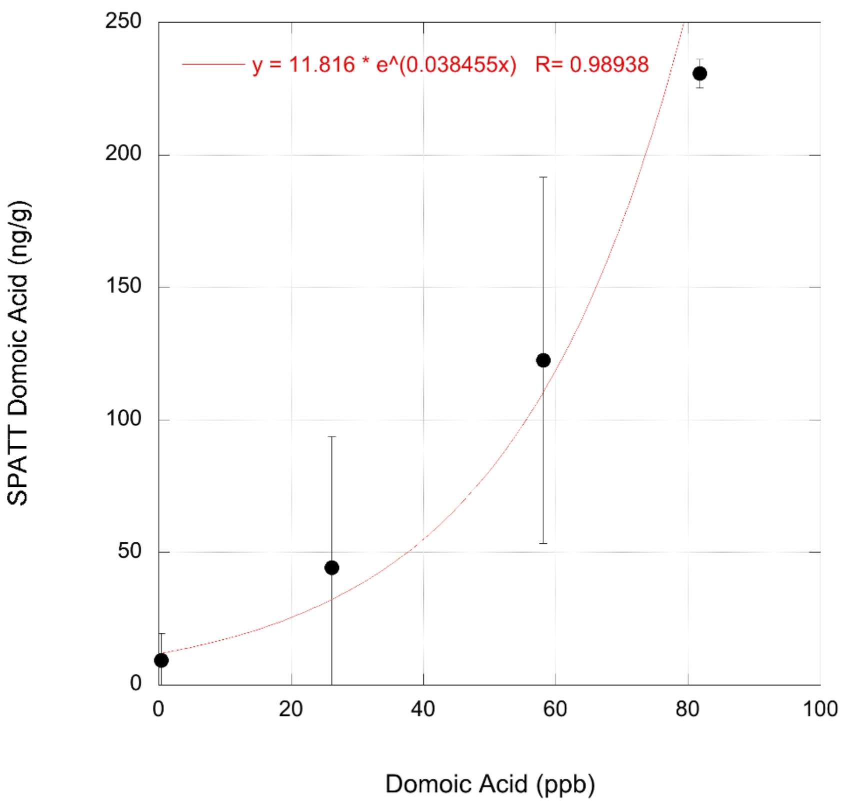


Domoic Acid
(not as linear as MCY for HP20 resin; other resins are more linear)

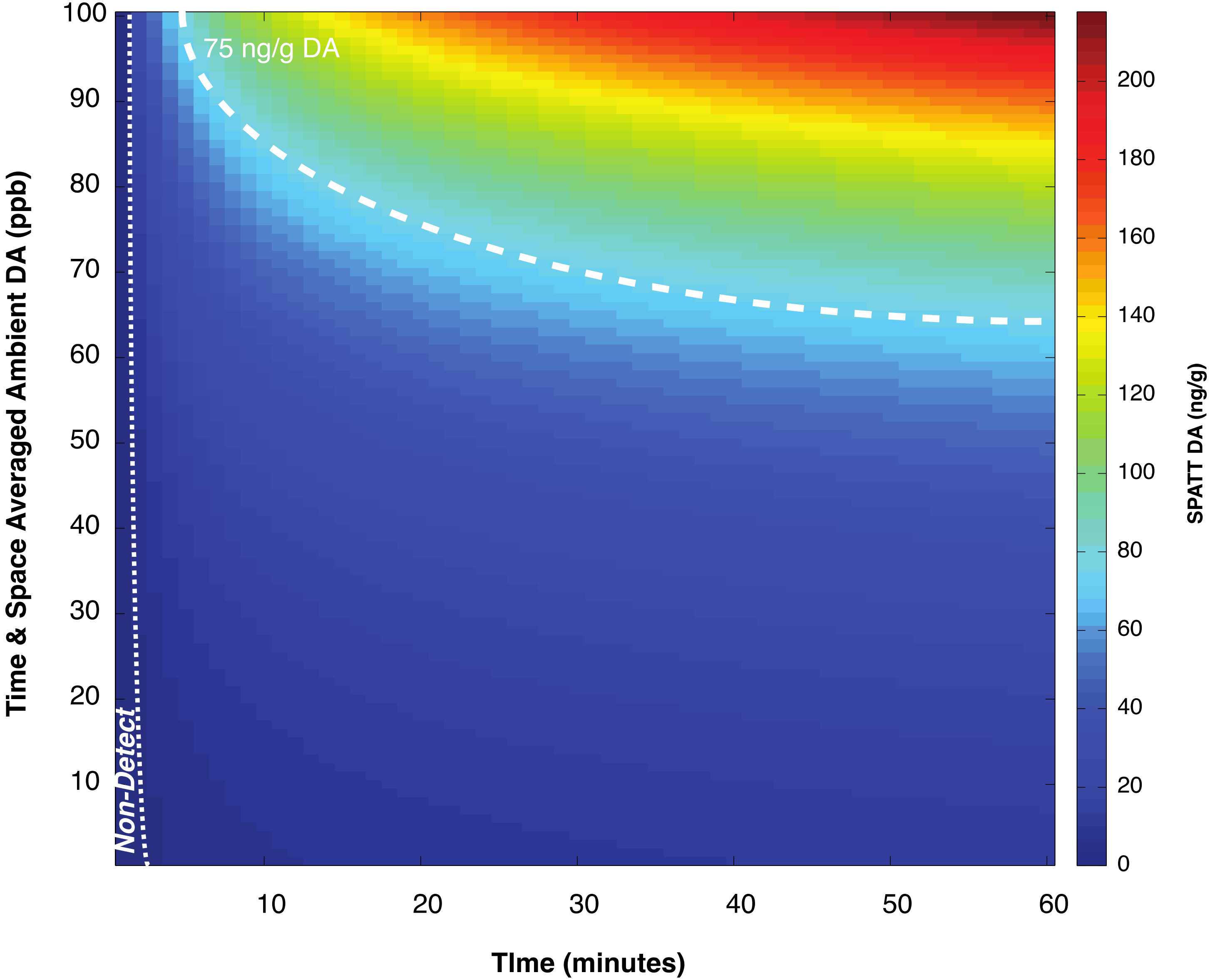
15 minutes



>20 hours



Because SPATT is time-averaging, increasing toxin (ng/g) is related to BOTH time of exposure and ambient concentration—it is helpful deploy SPATT *consistently*



SPATT Availability

- Currently NOT commercially available as a pre-made unit
- Easy to make in the laboratory:
  - Lane et al., 2010: Limnology & Oceanography: Methods, 8: 645-660
  - Lane et al., 2012: ICHA14 Conference Proceedings, Crete 2010
  - Kudela, 2011: Harmful Algae, 11: 117-125
- Most commonly used resin is DIAON HP20 (widely applicable for many toxins)
- Compatible with standard analytical methods (LCMS, ELISA)

Conclusions

- SPATT Advantages:
  - Low cost, easy to deploy tool
  - Applicable to marine, brackish and freshwater environments
  - Measures marine and freshwater toxins
  - Can be deployed in many different ways and in areas where there is limited sampling
  - More robust indicator of toxin prevalence compared to grab samples ('snapshots')

- Disadvantages:
  - Cannot be directly compared to health advisory thresholds
    - However, SPATT concentrations of DA/MCY corresponding to matching mussel/water samples have been established

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Central and Northern California Ocean Observing System
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Thank You!

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