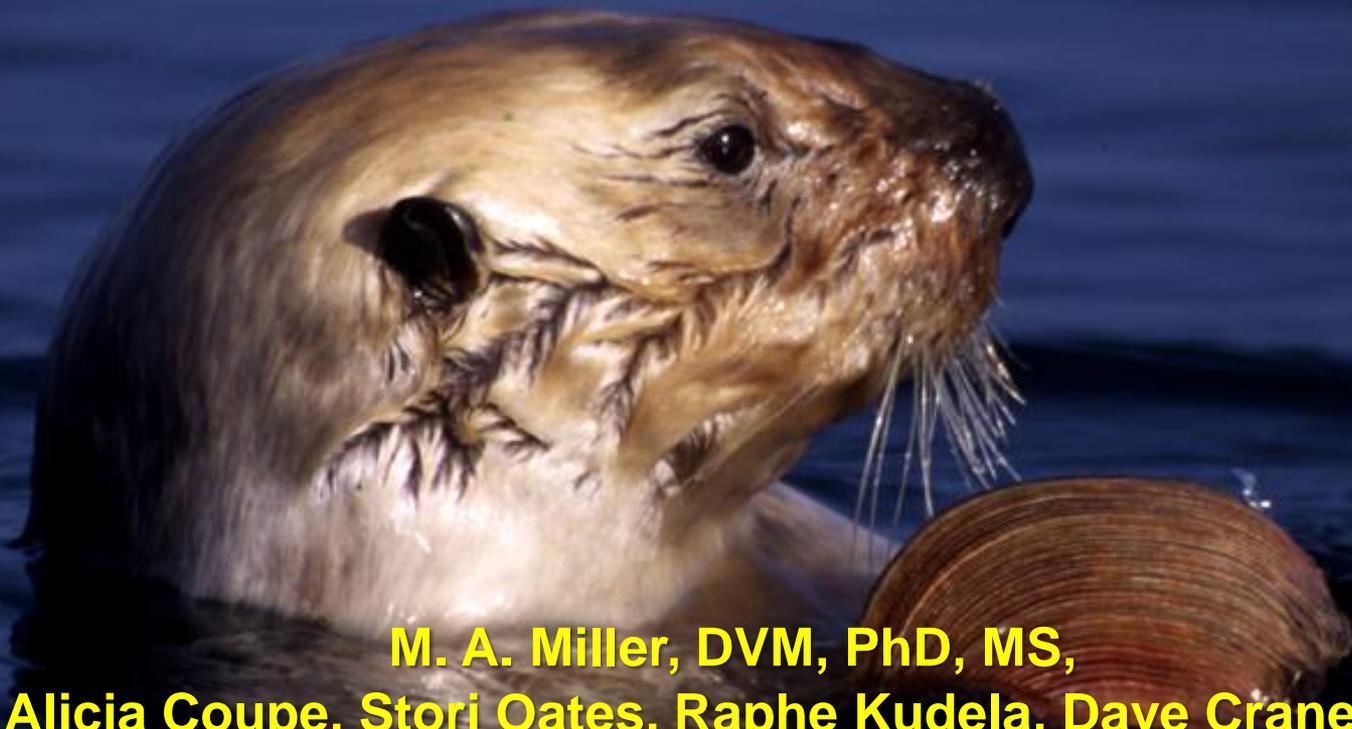


# Effects of cyanotoxins on California wildlife and the land-sea connection



**M. A. Miller, DVM, PhD, MS,  
Alicia Coupe, Stori Oates, Raphe Kudela, Dave Crane,  
Abdou Mekebri, Mike Murray, Tim Tinker,  
Karen Worcester, Kim Ward, Dominic  
Gregorio, Robert Ketley, Dave Paradies  
& many, many others!**



# Key cyanotoxins of California fresh & brackishwater systems

- **“Hepatotoxins”**: Microcystin, nodularin, others...
- **Neurotoxins**: Anatoxins, saxitoxin, others...
- **Pro-Inflammatory**: LPS, others...
  
- At present, what we know is far less than what we don't know
- Impact assessment hindered by communication obstacles, limited testing, limited understanding

# Why? Diverse routes & mechanisms of toxicity = diverse disease!

- **Routes:** Oral, inhalation, aspiration, dermal, IV, IP
- **Mechanisms:** Neurotoxicity, neurodegeneration, anticholinesterase, phosphatase inhibition, necrosis, apoptosis, oxidation, sensitization, inflammation, immunosuppression?, O<sub>2</sub> depletion, food web alteration, biomagnification, facilitation of botulism outbreaks?, synergy with other toxins/pathogens?, DNA damage, teratogen, tumor promotor

# **Additional challenges to estimating cyanotoxin impacts:**

- **DVMs & MDs: Minimal training re cyanotoxins!**
- **Taught that there is no Tx for this condition**
- **Existing descriptions: Experimental (rodents) & individual acute, severe cases**
- **Diverse toxins + varying production/ exposure/ duration = Spectrum of disease**
- **Result: Most cases are missed, including by top-notch veterinarians & doctors! → Few cases examined or tested → Fewer published**  
**= Disease prevalence greatly underestimated**  
**& numerous animals die without Tx**

# Monterey Bay: At least 4 sets of unexplained dog illness/death from acute liver Dz following water contact since 2007, including 2 dogs owned by DVMs! No dogs examined postmortem, none tested for cyanos!

## The Carmel Pine Cone

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YOUR SOURCE FOR LOCAL NEWS, ARTS AND OPINION SINCE 1915

### Nothing plain about these artists



PHOTOS BY CHRIS COUNTS

The Carmel Art Festival got under way Thursday, when a bevy of plein air painters began working on the canvases they'll enter into the festival's competition. At left, Patris paints at Carmel Beach, while Pan Yan Chou renders fields and farm worker cabins (above). See page 13A.

### Bulldogs poisoned on beach outing

■ One dies, another gravely ill

By CHRIS COUNTS

A STROLL along Asilomar Beach by a Carmel Valley couple turned tragic Tuesday afternoon when Lulu — one of their two French bulldogs — died shortly after ingesting something in the sand. Their other dog, Hula, also fell gravely ill but survived.

Brenton Sanders decided to share his story so others are aware of the risks that could exist for dogs on Asilomar Beach — or on any other stretch of local sand.

"I don't want anybody else to go through what we had to deal with," said Sanders, whose wife, Sarah, owns and operates the Om Oasis yoga studio in Monterey. "If this brings any awareness, that's enough."

Sanders described Lulu as a dog "who would put anything in her mouth."

"She was playing on the beach and had a mouthful of sand," he recalled. "Two hours later, she was dead."

See POISON page 27A

### Man arrested for running over CHS student

■ DUI alleged; victim is son of River School principal

By MARY BROWNFIELD

PACIFIC GROVE resident Timothy Petrick, 25, was jailed for felony drunken driving early last Sunday morning after allegedly driving over Carmel High School student Ryan Marden with his pickup truck while trying to get up a hill. The teen, who is the son of Carmel River School principal Jay Marden, and a friend had been sleeping under the stars at a Corral de Tierra property when the accident occurred, according

"He had some passengers with him and ran over this kid, who was in his sleeping bag," he said. "He was unaware he had run over the victim until the passengers in his vehicle started yelling at him."

Lehman did not know what connection Petrick and his friends had with the



### Police crack down on rule-breaking dog owners

By MARY BROWNFIELD

CARMEL-BY-THE-SEA MAY market itself as being dog friendly — "but that doesn't mean no rules," animal control officer Cindi Mitchell said Monday, as the Carmel Police Department embarked on a renewed effort to convince residents and visitors to keep their canines out of trouble. An increasing number of complaints involving out-of-control dogs prompted the decision to crack down — albeit gently, at first — on people violating the rules.

"From a public safety view, we are trying to reach out and educate the public, so we don't have to take other drastic means," said Cmdr. Mike Calhoun.

Detection is highest where surveillance is greatest: Pets, livestock, T & E spp., mortality events, aquaculture, mariculture





# What can sea otters teach us about microcystin?

## High-risk habits in a polluted world

- Nearshore-dwellers w/strong site fidelity
- Often congregate near bays, harbors, river mouths
- Consume **25-30%** of body weight/day
- Primary prey = filter-feeding inverts (clams, mussels, worms.....)
- Filter-feeders remove both biological and chemical pollutants from contaminated water



**Many sea otters die following exposure to land-based pollutants**



# 2007: We begin noticing stranded, bright yellow otters



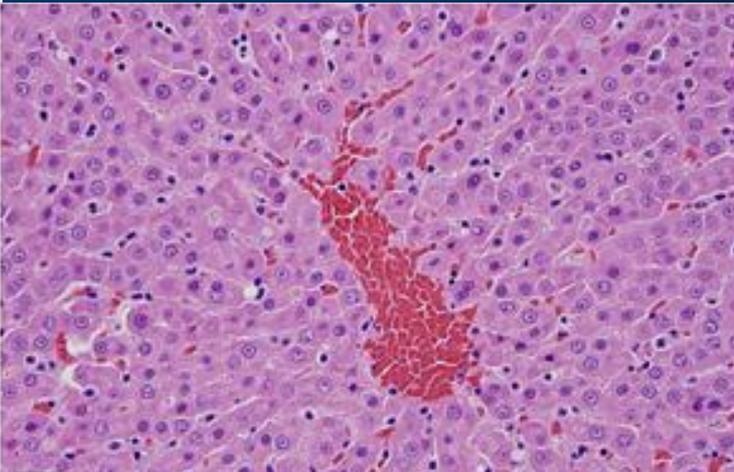
Icterus (jaundice): Oral mucosa and rib cartilage



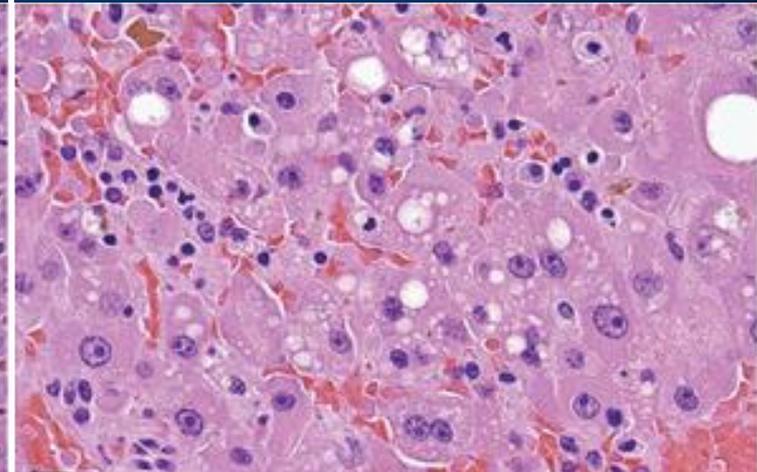
Normal sea otter liver



Liver from sick sea otter



Normal liver (microscopic view)



Liver from sick otter (microscopic view)

# Beginning the investigation at the Pajaro River mouth



Pinto Lake Park

- Launch Ramp
- Picnic Areas
- Boat rentals
- Fishing



X- Sick sea otter

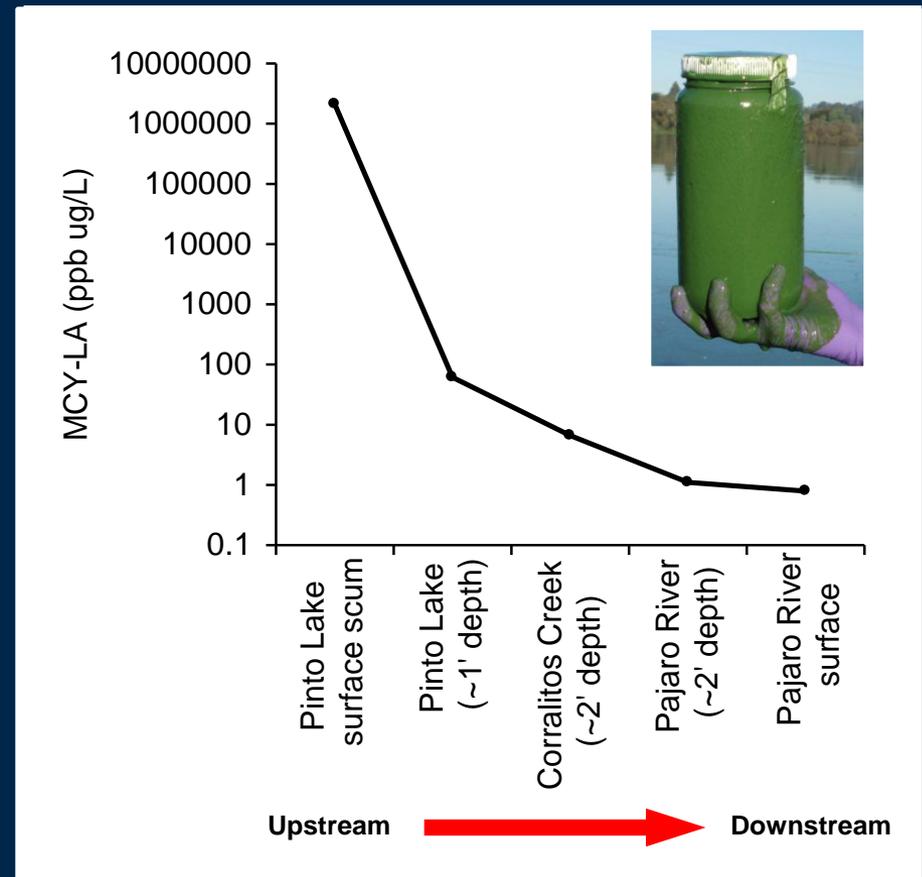
Monterey Bay



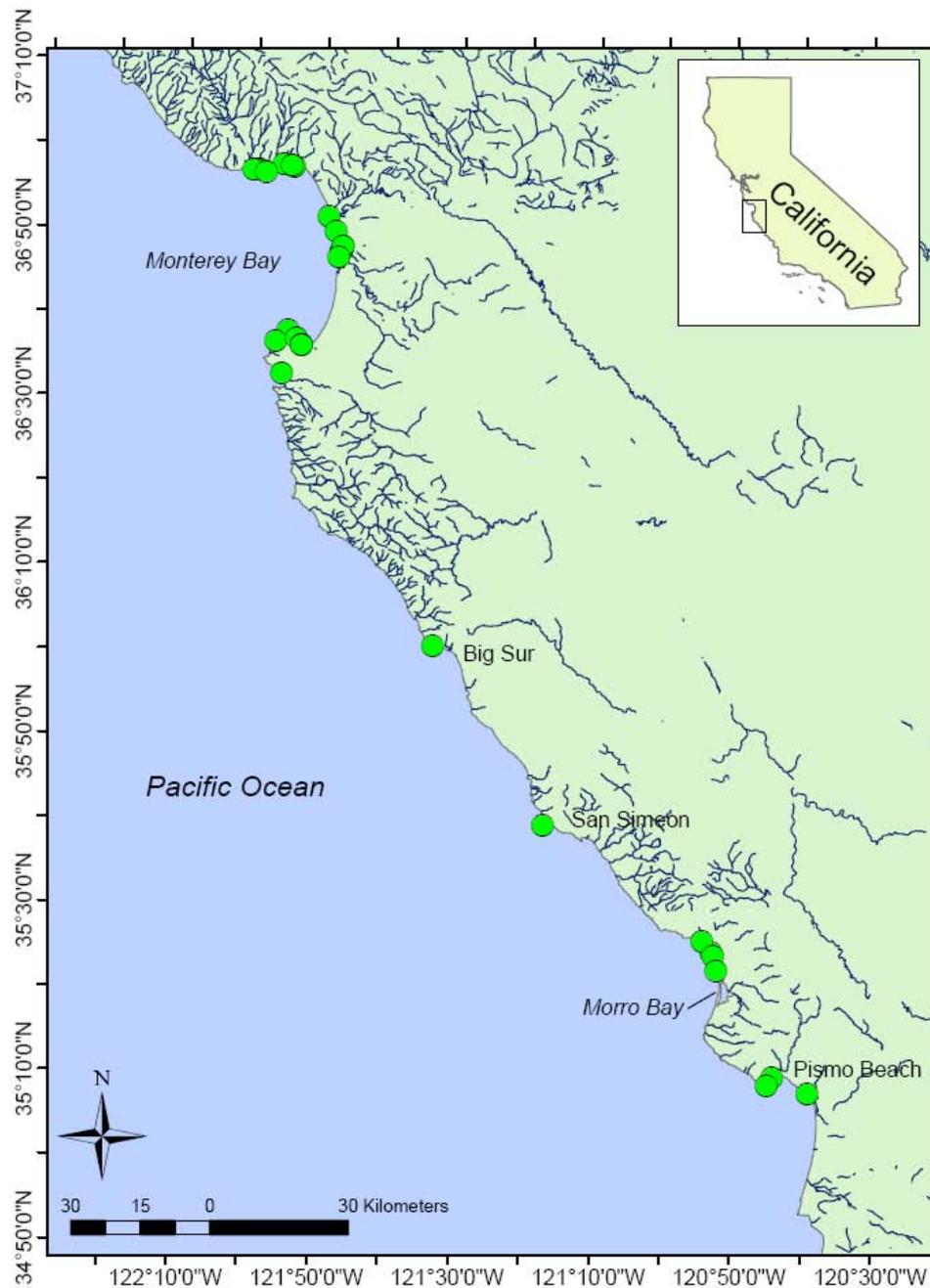
# Stepwise sampling from Pinto Lake to the ocean, fall 2007

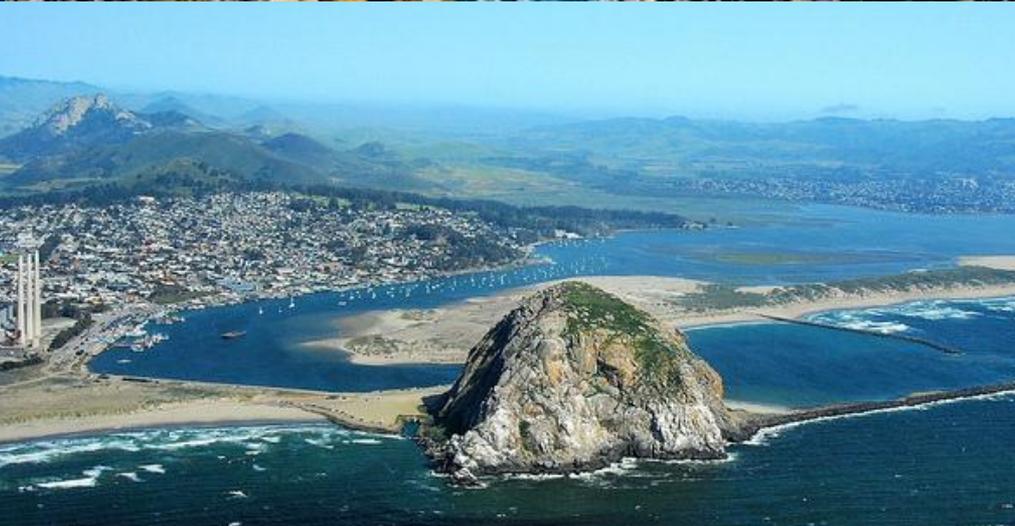


- Pinto Lake surface scum: 2,900 ppm
- Corralitos Creek also +
- Pajaro River + within 1 km of the ocean



# Current case distribution





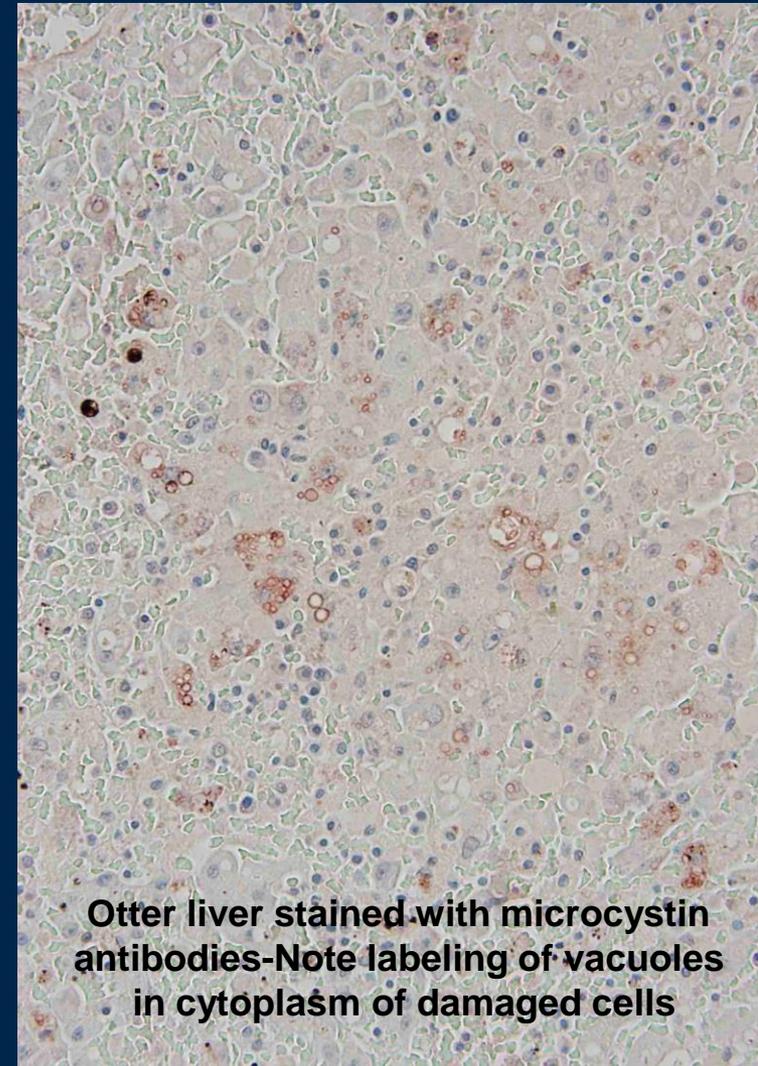
# How are sea otters getting exposed?

- ✓ **Rapid lysis:** *Microcystis* nearly 100% lysed >24h in seawater
- ✓ **Environmental persistence:** Freshwater microcystins stable in seawater (still easily detectable after 21d)
- ✓ **Endemic & commercial spp are excellent bioaccumulators:** clams, mussels, oysters & snails > crabs. Bivalve GI up to 107x > [microcystin] than seawater (up to 1,324 ppb ww)
- ✓ **Slow depuration:** Bivalve GI tissues strongly + 2 weeks PE, despite exposure to clean seawater >4d PE



# Although microcystin appears to be originating from freshwater sources in CA, intoxication is pretty common in sea otters

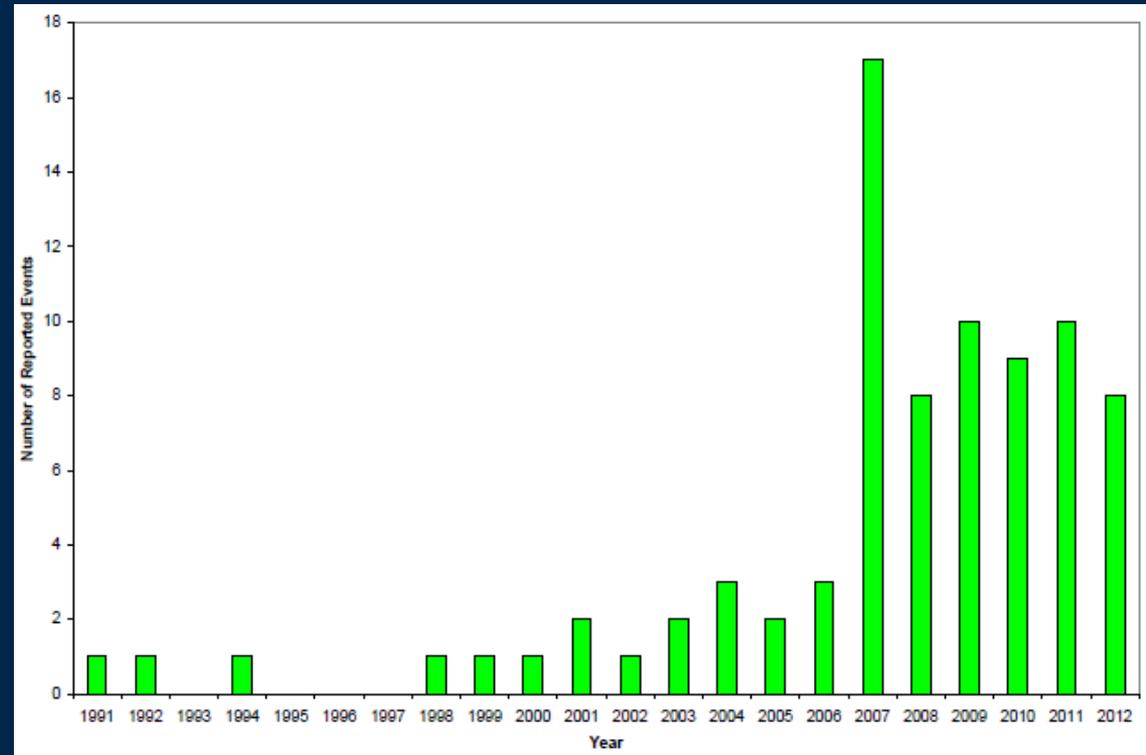
- 31 cases, 1999-2011: First report in any marine mammal
- All LCMS/MS + (Limited testing)
- Additional LCMS/MS- suspects (bound MC?, other cyanotoxin?)
- Equal proportion of males, females
- All age classes (~75% adults)



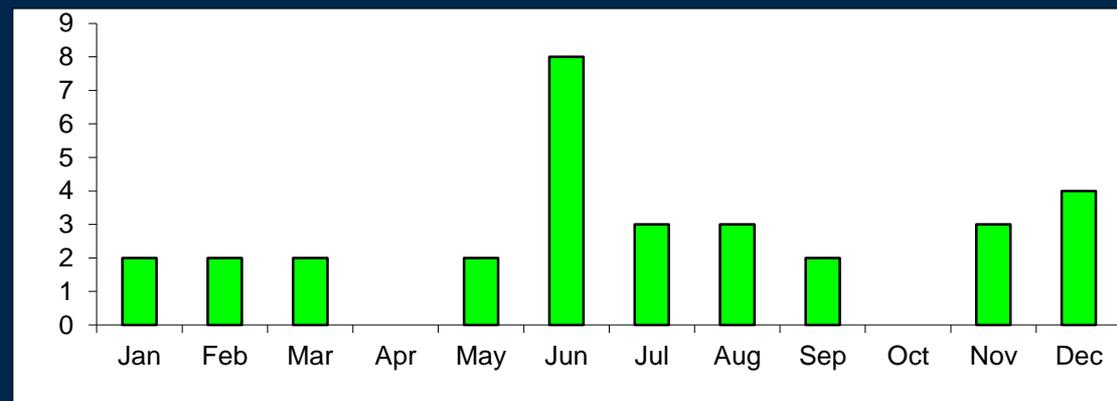
• Otter liver stained with microcystin antibodies-Note labeling of vacuoles in cytoplasm of damaged cells

# Cyanotoxin cases may be increasing through time in CA & can present any time of the year

Sea otters →  
dogs, cattle,  
horses, fish,  
birds, goats



Sea otters →

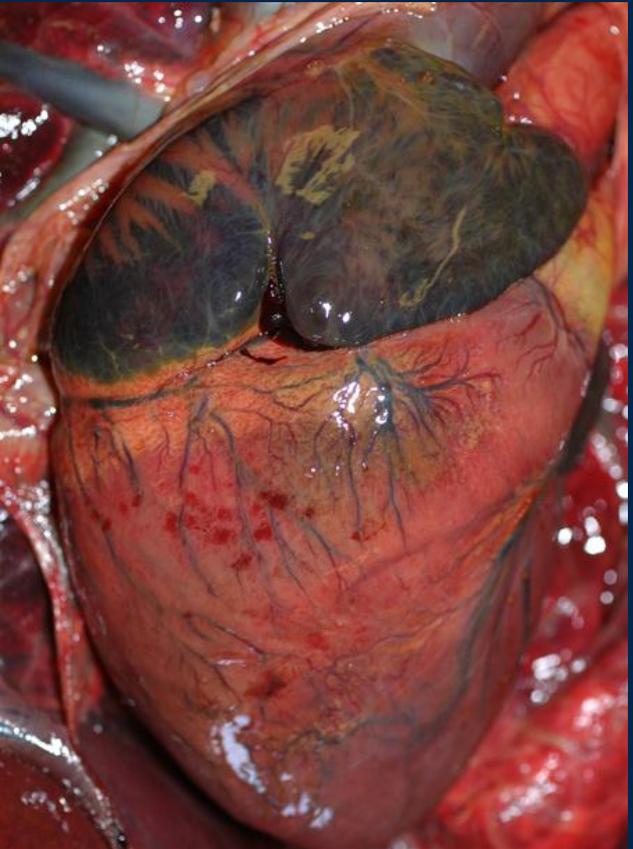


# Not all affected animals die acutely

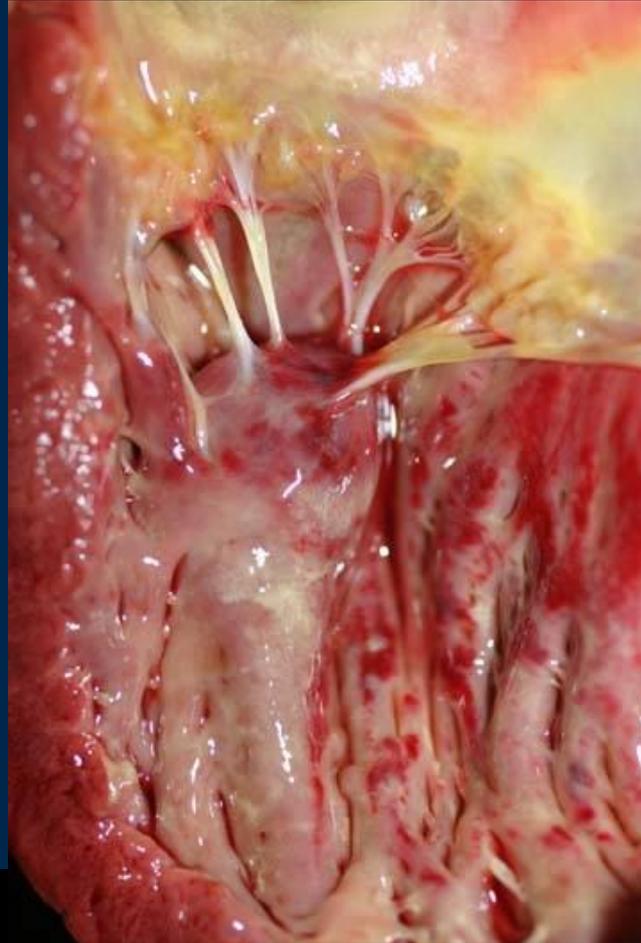
- 16 otters stranded alive
- 6 lived 4-70 days post-stranding → Still MC+!  
(Prolonged toxin retention D/T enterohep. recirc.)
- Clinical signs often vague (ADR) → Euthanized
- Few recognized clinically as microcystin cases
- Suspect foods: Clams, mussels, crabs, worms, milk



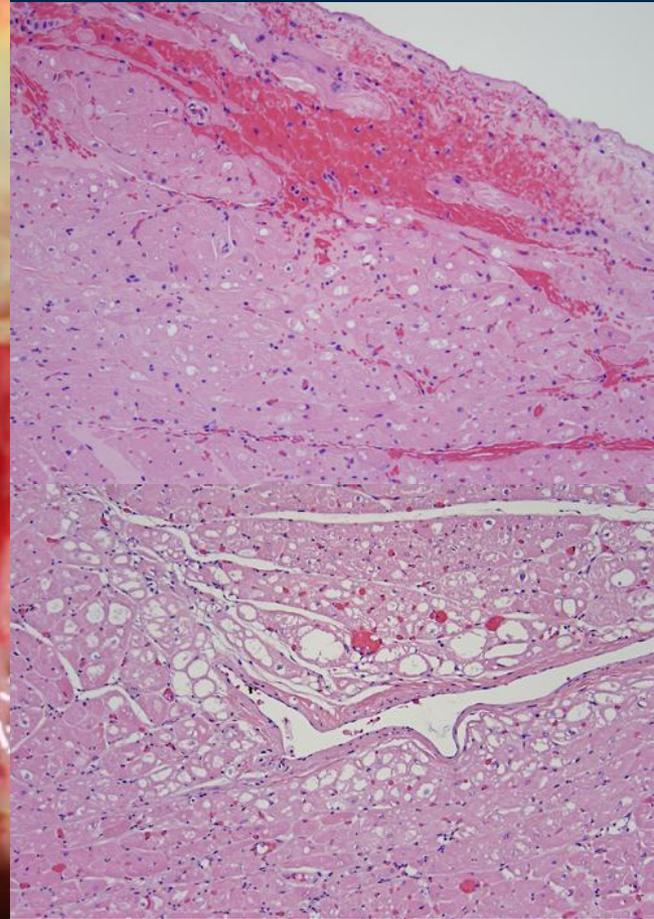
**It's not only about the liver!**  
**Phosphatases are present in most tissues!**  
(Additional targets: Brain, heart, kidney, BVs, etc.)



**Otter that died from  
microcystin intoxication**



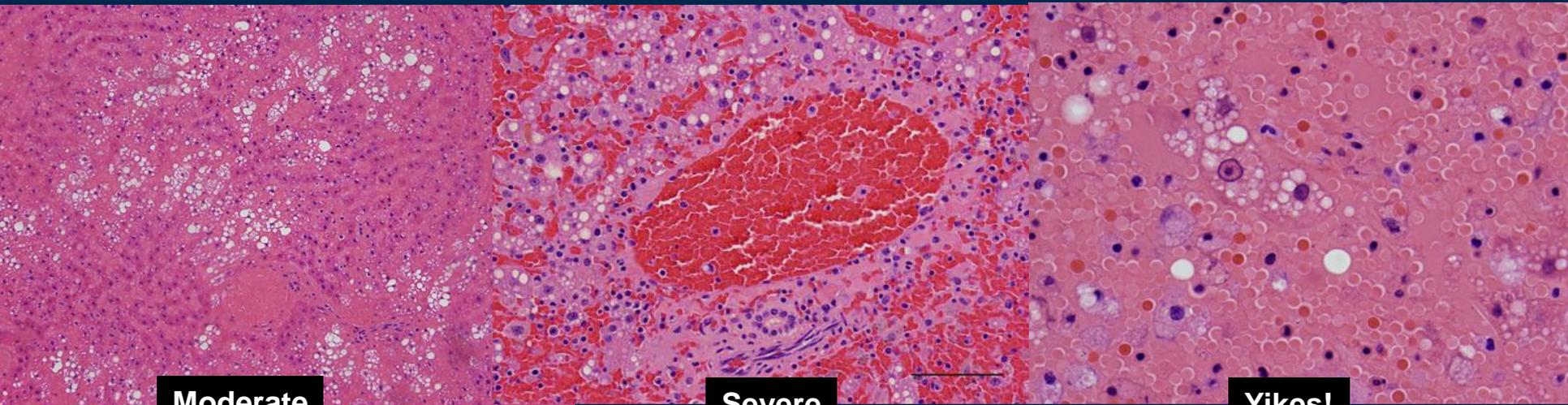
**Hemorrhage, internal  
heart wall**



**Hemorrhage &  
Vacuolation, heart muscle**

## Spectrum of disease (easy to miss), synergy with other toxins/ pathogens?

- < 1/2 were icteric (yellow)
- Nearly 1/3 had normal looking livers (grossly)
- 58% had evidence of abnormal blood clotting
- > 1/2 had gross cardiac lesions
- ~2/3 had gross brain lesions
- ~2/3 had significant bacterial infection
- Synergy with other biotoxins? (eg. cardiac Dz)



Moderate

Severe

Yikes!

On the microscope

# How can we optimize mitigation of cyanobacterial impacts in CA?

- Improved awareness (DVMs, MDs & the public)
- Organized reporting & mapping of suspect cases  
→ ID “High risk areas” for focused mitigation
- Match cyano testing & pathology
- ↑ test availability, ↓ cost, test validation & standardizat.
- Focused research on food web dynamics, high-risk spp., human health risks, disease spectrum

**SPATT: Bloom dynamics, locations, potential source(s), etc.**

**ANIMALS/ PEOPLE: ID high risk areas, food web dynamics, human health risks, case recognition, treatment, public notification**

# Benefits



- ↓ Health risks: Animals & humans
- Fewer animal deaths
- Problem-focused mitigation
- Improved water quality & food safety
- Ecosystem-wide wildlife benefits
- Conservation of T&E spp.
- “Take” of wildlife & T&E spp.-Illegal under state & federal law, including water pollution
- People care about this!

# Thank you!

CDFG, MBA, USGS, UCSC, UCD, TMMC, USFWS, TMMC, California State Water Quality Control Board, California Central Coast Water Quality Control Board, CDFG Water Pollution Control Laboratory, City of Watsonville, Applied Marine Science, CDPH



(Photo credit: Randy Wilder, Monterey Bay Aquarium)

**Courtesy of undergraduate student Jacob Badish  
& his Introduction to Ecology Class  
Santa Clara University  
November 13, 2012**