Aquatic Applications of Embedded Networked Sensors

1. Challenges

2. Designs and Constructs

3. Approach: Success and/or Lessons Learned

4. Looking Forward

Major Collaborators:
- USC (Sukhatme, Caron, Jones)
- UCLA (Estrin, Ho)
- CalTech (Tai)
- SCCWRP (Howard, Weisberg)
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The Venue:
Monitoring & Ecological Studies of Harmful Algal Blooms (HABs) in Coastal Ecosystems.

The Science Questions:
(1) What are the distributions of these events in time and space?
(2) What are the environmental drivers of their dynamics?
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The Approach:
Networked Aquatic Microbial Observing & Sensing (NAMOS)
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I. Challenges

Issues of Scale (Science)
- Time scales: minutes to years
- Spatial scales: micro- to regional

Collaboration Across Disciplines
- Jargon, the language barrier
- Identifying mutually interesting projects

Robustness and Autonomy of Systems (Technology)
- Making it work twice (or more)
- Decision making and the ‘human’ factor
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2. Designs and Constructs

Lake Fulmor (Small-scale microalgal dynamics)

3. The Approach

Sense everywhere, all the time.
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2. Designs and Constructs

Lake Fulmor (Small-scale microalgal dynamics)

3. The Lesson Learned

“You can sense some of the places all of the time, and all of the places some of the time, but you can’t sense all of the places all of the time”
(apologies to Abraham Lincoln)

For effective use of available resources, it is essential to critically evaluate the most important variables/scales, and focus effort on those.
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Lake Fulmor: Multiple modes of sensing (complementary arrays of spatially-scarce but temporally-dense sampling)
NB: The specific design for any given environment is completely dependent on the scientific question.

3. The Success

Insights into small-scale processes influencing the large-scale distribution of microalgae in the water.
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2. Designs and Constructs

King Harbor of Redondo Beach, Southern California Bight
(long-term, large-scale monitoring to decide how/when to sample ephemeral events such as harmful algal blooms)

3. The Approach

Let the network do all the work.
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2. Designs and Constructs

King Harbor of Redondo Beach, Southern California Bight
(long-term, large-scale monitoring to decide how/when to sample ephemeral events such as harmful algal blooms)

3. The Lesson

(some) Humans are smarter than they look.
(...or... sensor networks aren't as smart as we'd like)
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3. The Success

Data assimilation (from autonomous vehicles, sensor buoys, ocean models) to predict movement and enable and enhance (human) decision making in order to redirect vehicles and thereby assist adaptive sensing, sampling, and experimentation by humans (embedded intelligence).

Projection of a bloom from October 2007.
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4. Looking Forward

Rich Space for Future Research/Applications (and potential sources of funding)

- ‘Sentinel’ activities (Municipal, County, State, NOAA, EPA, USFWS, etc.)
  Swimming and/or drinking water quality (HABs, phytotoxins, pathogens)
  Monitoring marinas/harbors/fresh water (NOAA, Foundations)
    (dissolved oxygen, contaminants, ship ballast water)
  Aquaculture (State, Private)
  MPAs (NOAA)
  Climate change & ocean acidification initiatives (NOAA, NSF)

- Characterizing discharges (river outflow, outfall discharge, etc.)
  (Municipal, County, State)
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‘New’ Collaborators Established thru CENS:

UCSC (Kudela)
MBARI (Rajan, Ryan, Scholin)
MLML (Smith)
SCOOS, CeNCOOS
UCLA (Shipe)
UCSD (Carter, McGowan)
CalPoly (Moline)
UCSB (Brzezinski)

New sensor development

‘Lab-on-a-chip’ for interrogation of cultured algae (Tai laboratory, CalTech)

Electrochemical method for toxin detection (Ho laboratory, UCLA)

Enhancement of Ocean Observing Capabilities and Pier Monitoring
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4. Looking Forward

**Education and Outreach:**
- Redondo Beach Open House
- HAB Watch
- Student course involvement (Lake Arrowhead)

**Knowledge Transfer and Partnerships:**
- Redondo Beach, Marina Del Rey, Lake Arrowhead Association
- Desalination and algal blooms
  - West Basin Municipal Water District
  - Long Beach Water Department
- Water Managers
- Southern California Coastal Water Research Project
- CA Department of Public Health: Toxin monitoring