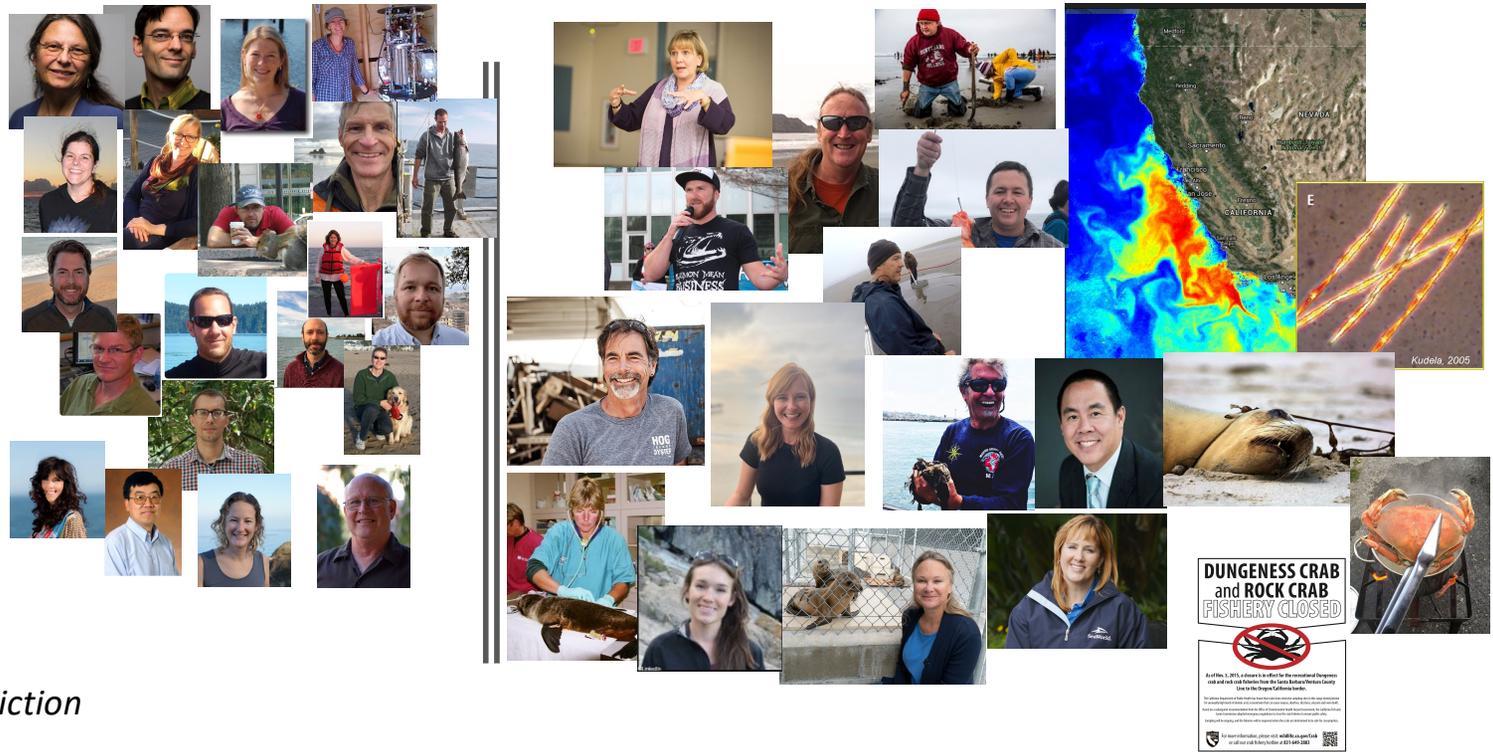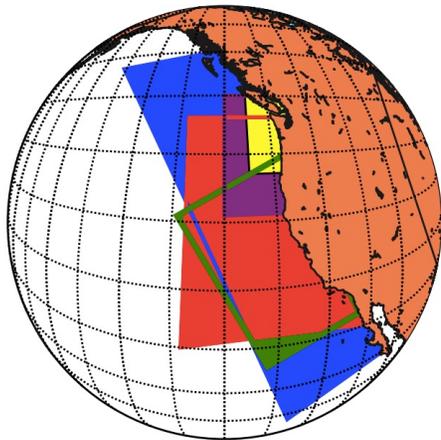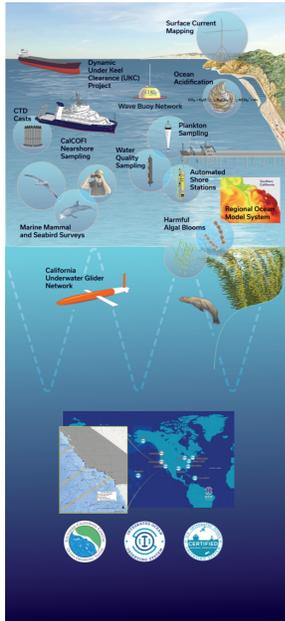# Developing a HAB Early Warning System for California
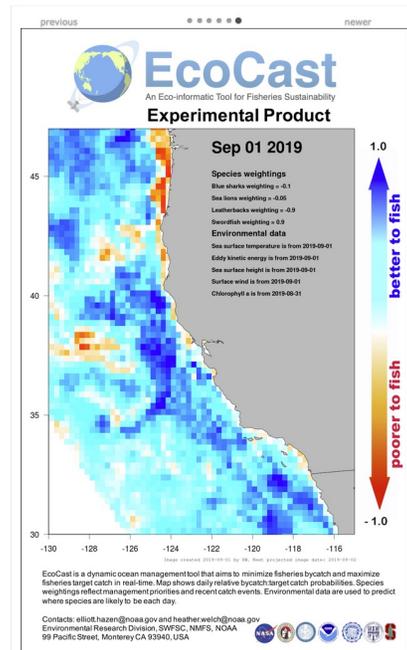
Raphael Kudela, Kasia Kenitz, Clarissa Anderson

Modeling, Observations, Prediction
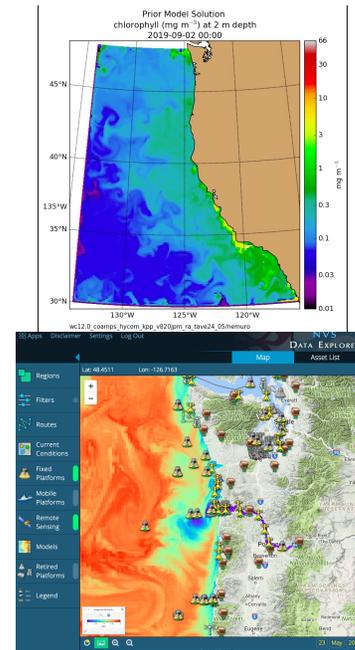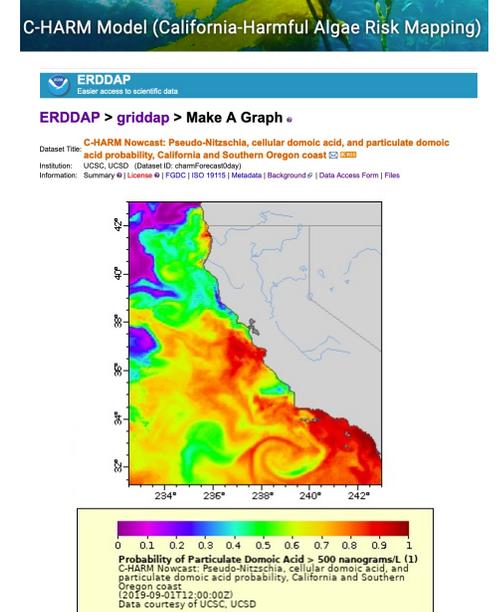
Observational Impacts in Data Assimilation

Fisheries Habitat

Ocean Acidification & Hypoxia
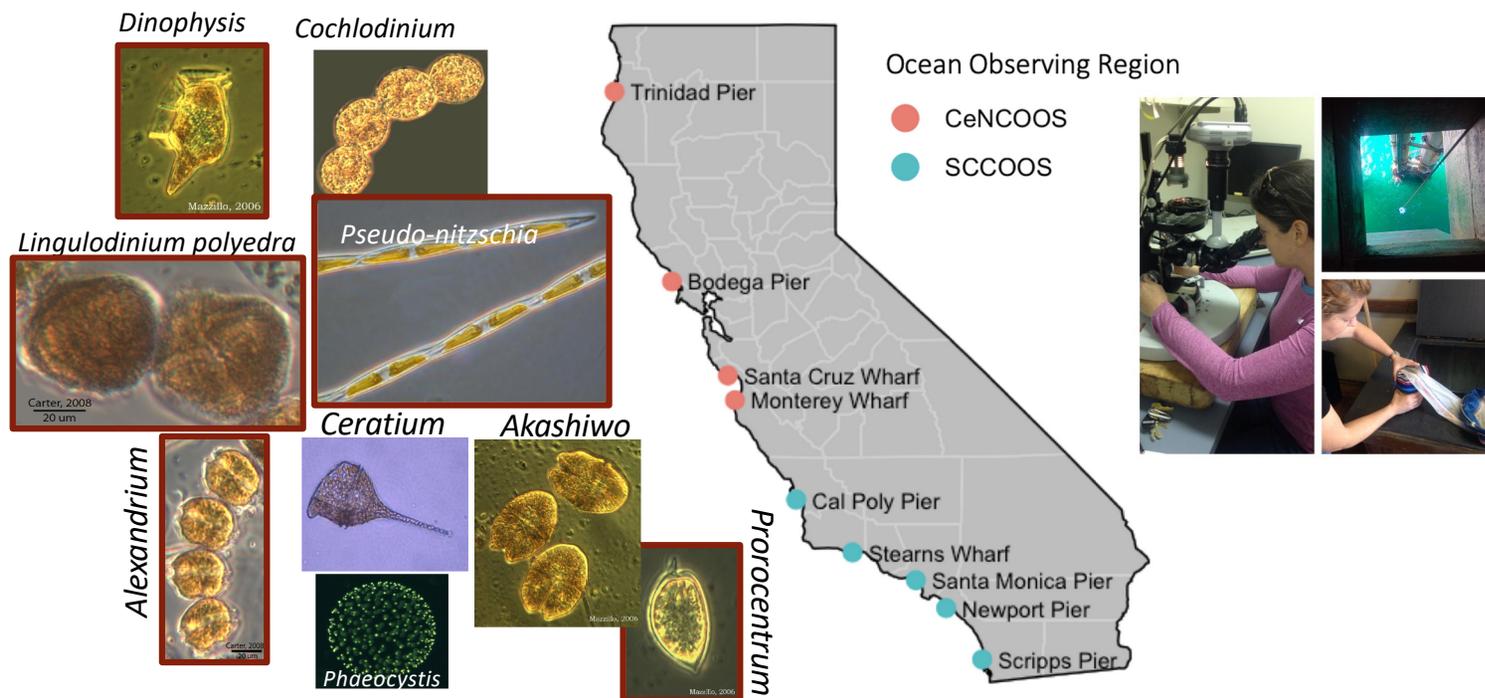

Harmful Algal Blooms

WC-COMT Stakeholder Workshop – Priority Themes

Broad participation of end-users and technical practitioners from the entire West Coast

+++ **38 Participants** +++ Across Five Major End-User Sectors

Weekly measurements:
- **HAB spp. (8-9 taxa)**
- Chl-a, Temp, Salinity, **Nutrients**
- **Domoic Acid + SPATT toxins**
- Weekly alerts to HABMAP listserv
- Monthly QC'd data now served via ERDDAP
- Synthesis with models: **CA HAB Bulletin**

- **10 academic institutions**

Dinophysis
Cochlodinium
Lingulodinium polyedra
Pseudo-nitzschia
Alexandrium
Ceratium
Akashiwo
Phaeocystis
Prorocentrum

Mazzillo, 2006
Carter, 2008 20 um
Carter, 2008
Mazzillo, 2006
Mazzillo, 2006

Ocean Observing Region
- CeNCOOS
- SCCOOS

Trinidad Pier
Bodega Pier
Santa Cruz Wharf
Monterey Wharf
Cal Poly Pier
Stearns Wharf
Santa Monica Pier
Newport Pier
Scripps Pier

SOUTHERN CALIFORNIA COASTAL OCEAN OBSERVING SYSTEM
CENTRAL & NORTHERN CALIFORNIA OCEAN OBSERVING SYSTEM

HARMFUL ALGAL BLOOM MONITORING & ALERT PROGRAM
Grass-roots origin in 2008; now fully supported by SCCOOS + CeNCOOS

Limitations: Only provides a weekly snapshots of a highly dynamic system; $$$ prohibitive to do daily monitoring; toxins and nutrients not even close to real-time; users want forewarning!

CA IFCB Network

- Close to having 9 IFCBs running in real-time, most at stations with full hydrological sampling suites

- OPC funding phasing out by 2024

- O&M now covered via IOOS/NCCOS support to SCCOOS and CeNCOOS (US HABON Pilot Projects) – *funds Melissa Carter & Kasia Kenitz to coordinate operations and data analysis for entire team*
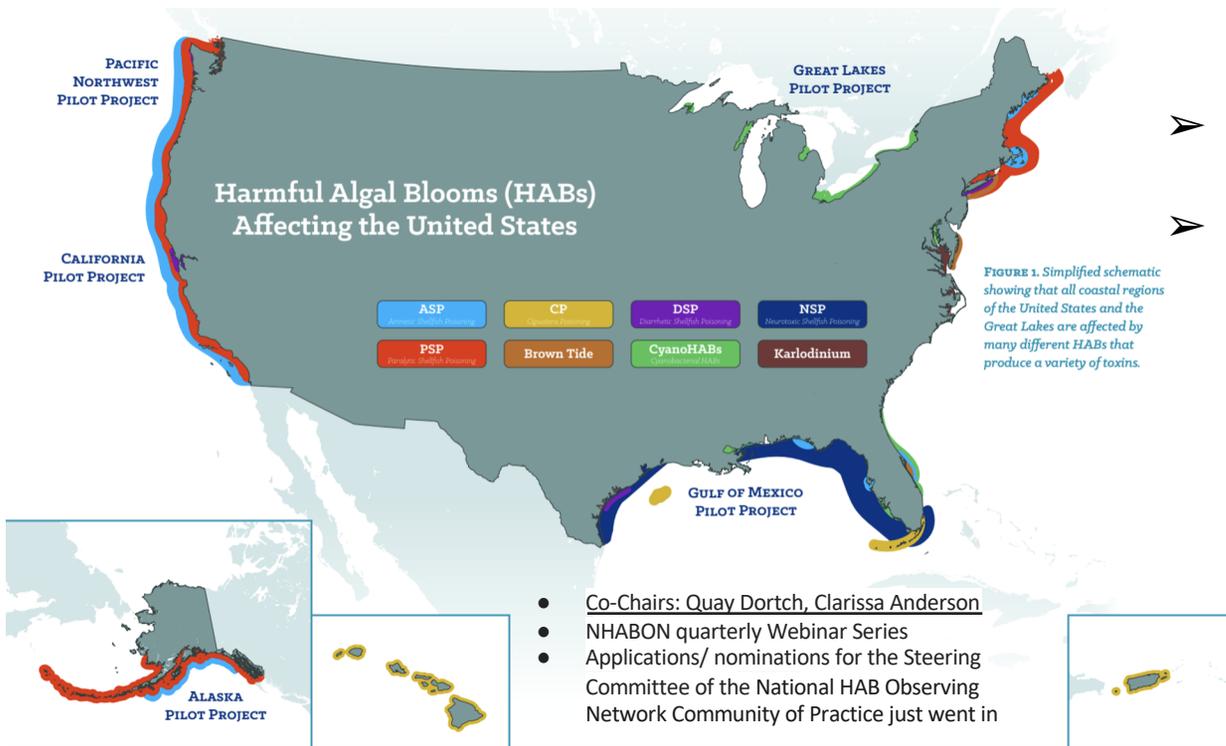
Left: IFCBs being built in McLane labs. **Middle**: OPC signage on Scripps Pier. **Right**: IFCB deployed on Scripps Pier in all its glory

Hog Island

HUMBOLDT STATE UNIVERSITY NOAA FISHERIES

Bodega Marine Lab — UC DAVIS UNIVERSITY OF CALIFORNIA

San Francisco Pier 17

UNIVERSITY OF CALIFORNIA SANTA CRUZ

Santa Cruz Municipal Wharf
Power Buoy

MBARI CENTRAL & NORTHERN CALIFORNIA OCEAN OBSERVING SYSTEM

UC SANTA BARBARA

Stearns Wharf

USC University of Southern California
OC SAN ORANGE COUNTY SANITATION DISTRICT
SCCWRP

Newport Pier

SCRIPPS INSTITUTION OF OCEANOGRAPHY UC San Diego SOUTHERN CALIFORNIA COASTAL OCEAN OBSERVING SYSTEM

Del Mar Mooring
Scripps Pier

CA IFCB Network

OCEAN PROTECTION COUNCIL

➤ *Ocean Protection Council Proposition 1 Infrastructure Project*
➤ *Transitioned to NHABON funds from IOOS and NCCOS*

NOAA NCCOS

IOOS Integrated Ocean Observing System

Harmful Algal Blooms (HABs) Affecting the United States

- PACIFIC NORTHWEST PILOT PROJECT
- GREAT LAKES PILOT PROJECT
- CALIFORNIA PILOT PROJECT
- GULF OF MEXICO PILOT PROJECT
- ALASKA PILOT PROJECT

| ASP | CP | DSP | NSP |
| PSP | Brown Tide | CyanoHABs | Karlodinium |

FIGURE 1. Simplified schematic showing that all coastal regions of the United States and the Great Lakes are affected by many different HABs that produce a variety of toxins.

- Co-Chairs: Quay Dortch, Clarissa Anderson
- NHABON quarterly Webinar Series
- Applications/ nominations for the Steering Committee of the National HAB Observing Network Community of Practice just went in

Regional Expansion

➢ National HAB Observing Network Implementation & Pilot Projects
➢ Work with regional pilots to assimilate data content, models, forecasts, and other products into the HAB DAC
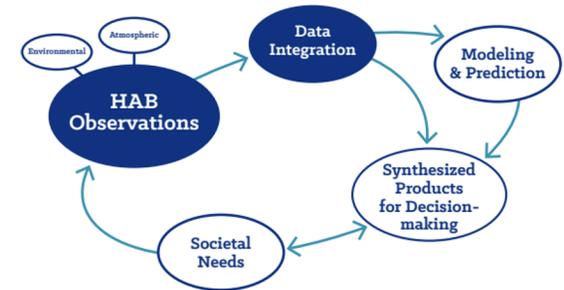
FIGURE 2. HAB observations support early warnings and forecasts that are key to keeping communities safe.
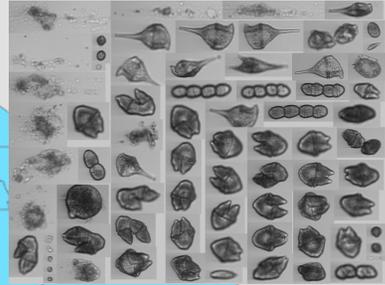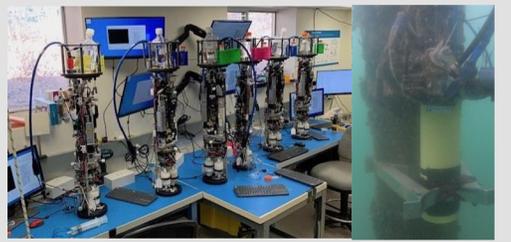
National HAB Observing Network - Community of Practice

NOAA IOOS and NCCOS funding us to establish a CA IFCB Network pilot project for national capacity development

CA IFCB Network—Progress
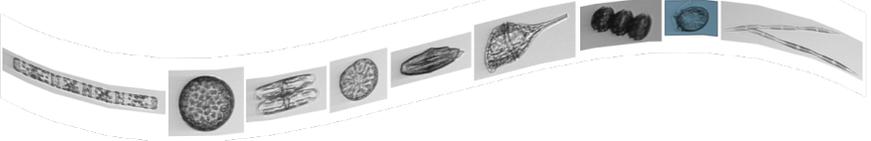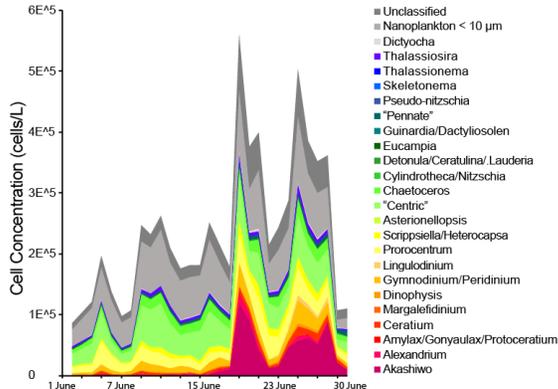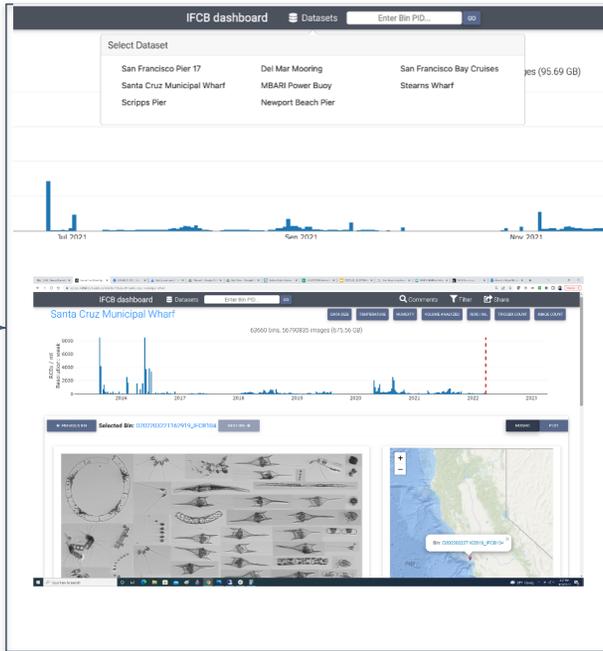

Kudela, Anderson, Ruhl, 2021, *Oceanography*

CA IFCB Network

➤ *Ocean Protection Council Proposition 1 Infrastructure Project*
➤ *Transitioned to NHABON funds from IOOS and NCCOS*

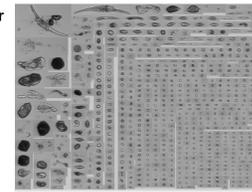# CA IFCB Data Management – instrument to dashboard

HAB Data Assembly Center (DAC) Development
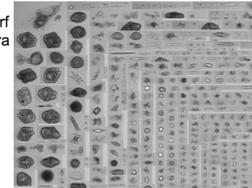
WHOI, PI Brosnahan, MERHAB
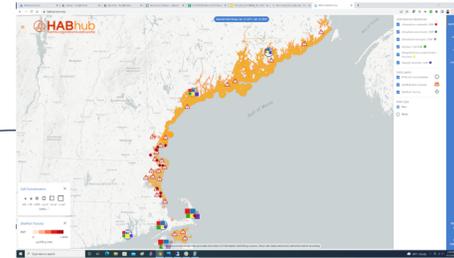
HABhub

IFCB Annotate

MACHINE LEARNING

PCMHAB 2020: Harmful Algal Bloom Community Technology Accelerator

NOAA NCCOS funding us to establish a national
HAB Data Assembly Center that uses the CA & GoM IFCB Networks as a prototype

UCSC Image Database

Akashiwo sanguinea
Ceratium spp.
Dinophysis spp.
Gymnodinium spp.
Margalefidinium spp.
Prorocentrum spp.

Scrippsiella, Heterocapsa spp.
Other dinoflagellates
Chaetoceros spp.
Detonula, Cerataulina, Lauderia spp.
Eucampia spp.
Guinardia, Dactyliosolen spp.

Pseudo-nitzschia spp.
Skeletonema spp.
Thalassiosira spp.
Centric diatoms
Pennate diatoms
Nanoplankton

J F M A M J J A S O N D

Fraction of total C

2018 2019 2020 2021 2022

DEL MAR
SIO
NEWPORT
MBARI M1
SANTA CRUZ
SAN FRANCISCO

WHOI

AXIOM

65M images at SCW, 1.85M images in SFB

Random Forest Model built with ~112,000 images
- 24 group/genus/species classes
- > 90% of total biomass
- Includes major HAB groups
- ~ 80% accurate

Total of 1,003,334 manual annotations:
➔ 97 genus/species classes
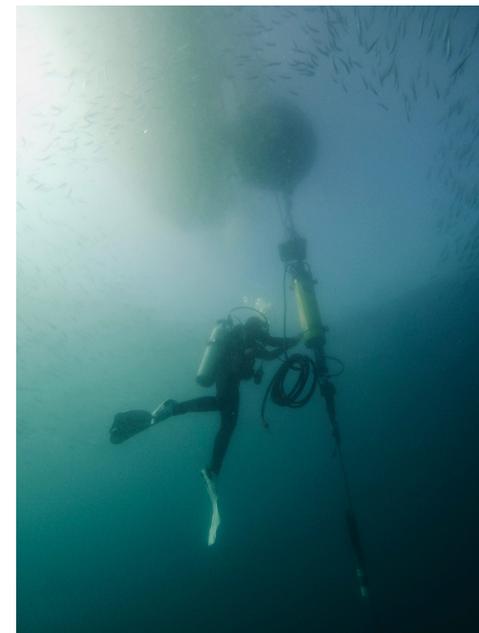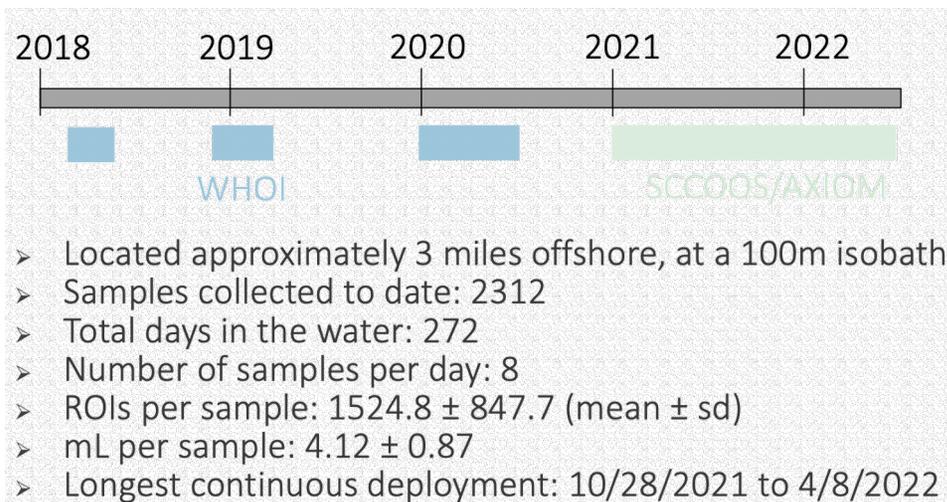➔ Several "super groups"
➔ Ash, cysts, detritus, etc.

Fischer et al. L&O 65: 2125-2141, 2020

Del Mar IFCB ("*Nelly*")

2018   2019   2020   2021   2022

WHOI

SCCOOS/AXIOM

- ➢ Located approximately 3 miles offshore, at a 100m isobath
- ➢ Samples collected to date: 2312
- ➢ Total days in the water: 272
- ➢ Number of samples per day: 8
- ➢ ROIs per sample: 1524.8 ± 847.7 (mean ± sd)
- ➢ mL per sample: 4.12 ± 0.87
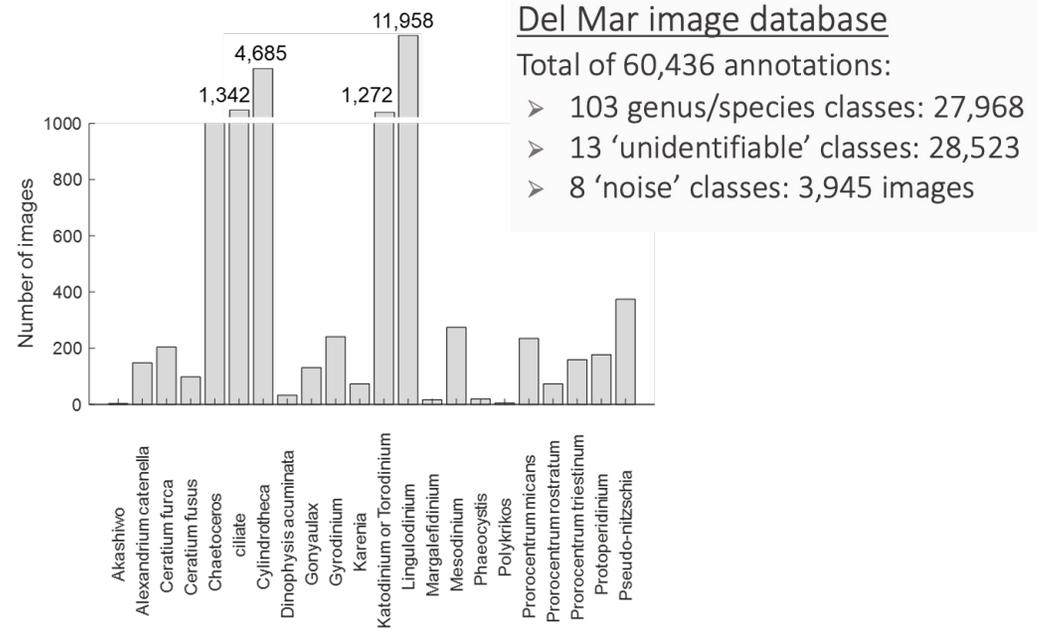- ➢ Longest continuous deployment: 10/28/2021 to 4/8/2022

Del Mar buoy

4 m   IFCB

PCMHAB 2020: Harmful Algal Bloom Community Technology Accelerator

NOAA NCCOS funding us to establish a national
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Del Mar image classification

NES classifier → Del Mar image database

Del Mar image database

Total of 60,436 annotations:

- 103 genus/species classes: 27,968
- 13 'unidentifiable' classes: 28,523
- 8 'noise' classes: 3,945 images

Bar chart — Number of images. Values labeled: 1,342 (Chaetoceros), 4,685 (ciliate), 11,958 (Lingulodinium), 1,272 (Katodinium or Torodinium).

X-axis categories: Akashiwo, Alexandrium catenella, Ceratium furca, Ceratium fusus, Chaetoceros, ciliate, Cylindrotheca, Dinophysis acuminata, Gonyaulax, Gyrodinium, Karenia, Katodinium or Torodinium, Lingulodinium, Margalefidinium, Mesodinium, Phaeocystis, Polykrikos, Prorocentrum micans, Prorocentrum rostratum, Prorocentrum triestinum, Protoperidinium, Pseudo-nitzschia

SCRIPPS INSTITUTION OF OCEANOGRAPHY — UC San Diego · WOODS HOLE OCEANOGRAPHIC INSTITUTION · Axiom DATA SCIENCE — A TETRA TECH COMPANY · UNIVERSITY OF CALIFORNIA SANTA CRUZ · CENTRAL & NORTHERN CALIFORNIA OCEAN OBSERVING SYSTEM
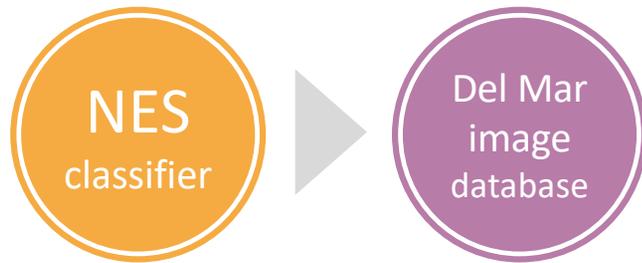
PCMHAB 2020: Harmful Algal Bloom Community Technology Accelerator

NOAA NCCOS funding us to establish a national HAB Data Assembly Center that uses the CA & GoM IFCB Networks as a prototype
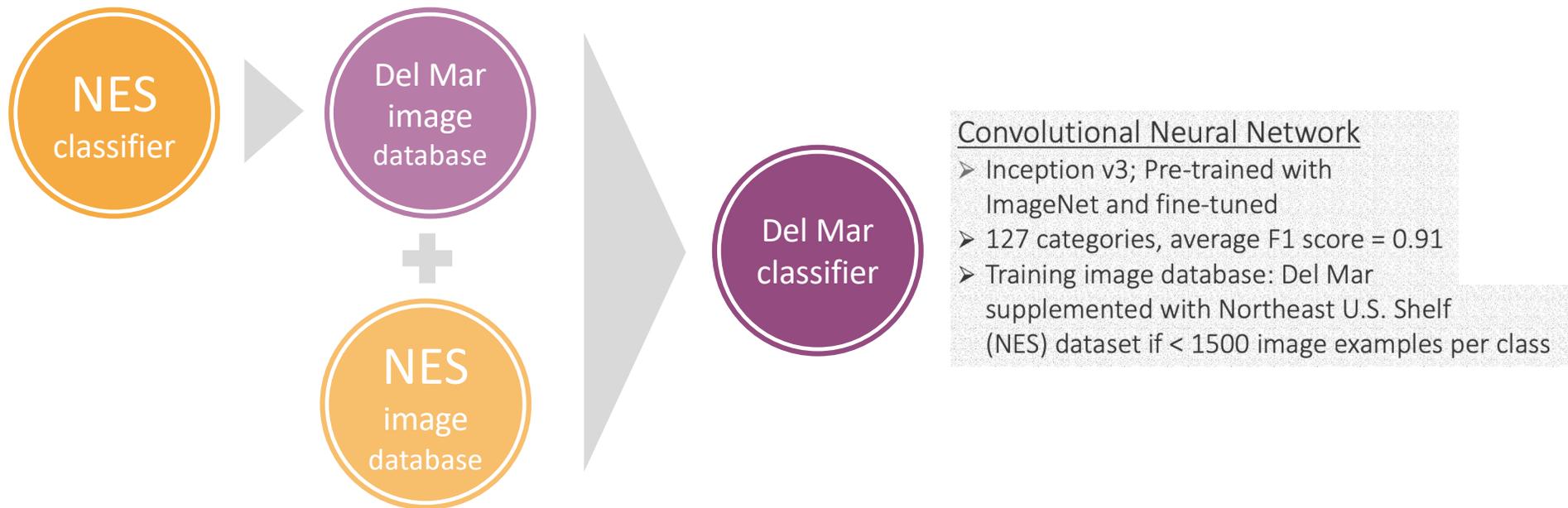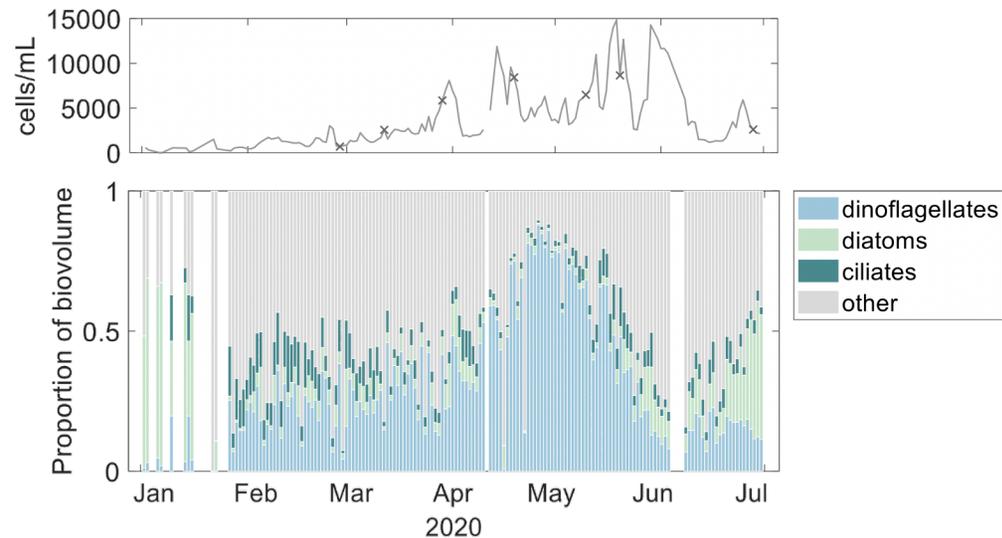
Del Mar image classification

NES classifier → Del Mar image database

+

NES image database

→ Del Mar classifier

Convolutional Neural Network
- Inception v3; Pre-trained with ImageNet and fine-tuned
- 127 categories, average F1 score = 0.91
- Training image database: Del Mar supplemented with Northeast U.S. Shelf (NES) dataset if < 1500 image examples per class

Del Mar community structure

PCMHAB 2020: Harmful Algal Bloom Community Technology Accelerator
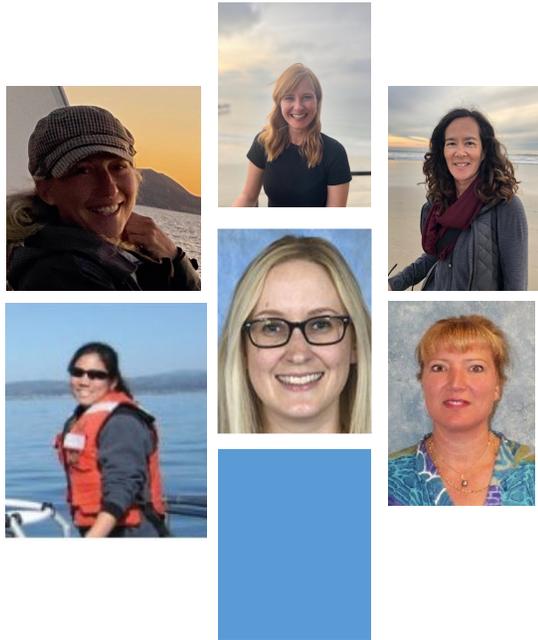
NOAA NCCOS funding us to establish a national
HAB Data Assembly Center that uses the CA & GoM IFCB Networks as a prototype

Del Mar community structure
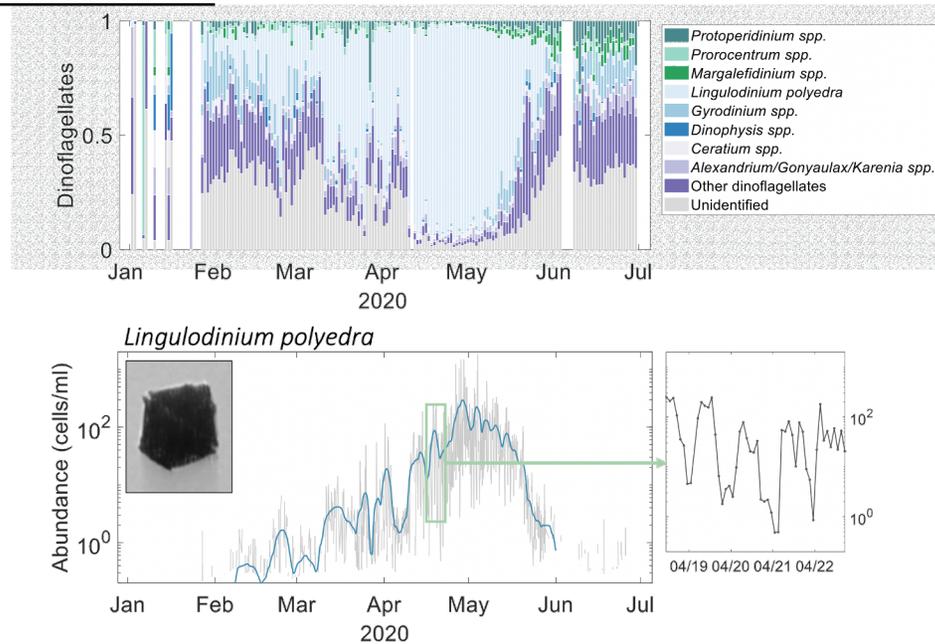
Lingulodinium polyedra

PCMHAB 2020: Harmful Algal Bloom Community Technology Accelerator

NOAA NCCOS funding us to establish a national
HAB Data Assembly Center that uses the CA & GoM IFCB Networks as a prototype

IFCB Network annotation effort

➢ Standardized annotation and classification workflow across all sites

➢ Image database available for sites without taxonomic expertise

➢ Centralized automated classification of plankton images for the network

IFCB Annotate
Created at Woods Hole Oceanographic Institution

SCRIPPS INSTITUTION OF OCEANOGRAPHY
UC San Diego

WOODS HOLE OCEANOGRAPHIC INSTITUTION

Axiom DATA SCIENCE
A TETRA TECH COMPANY

UNIVERSITY OF CALIFORNIA SANTA CRUZ

CENTRAL & NORTHERN CALIFORNIA OCEAN OBSERVING SYSTEM

PCMHAB 2020: Harmful Algal Bloom Community Technology Accelerator

NOAA NCCOS funding us to establish a national
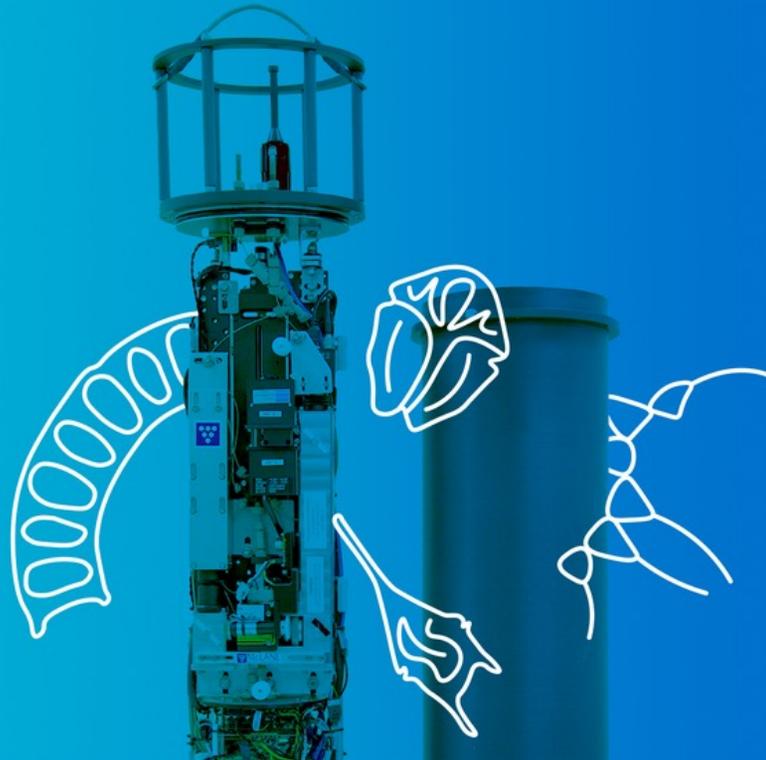*HAB Data Assembly Center that uses the CA & GoM IFCB Networks as a prototype*

- Web-based (Python, Docker, PostGres)
- Designed to support community annotation
- Backward compatible with MATLAB (WHOI) toolboxes

IFCB Network Image Annotation

Manual Classifications

SCW ⌄	2022 ⌄	08-16 ⌄	T19:58:42Z ⌄	Target...	HIDE NOTES	HIDE INFO
Time Series	*Year*	*Day*	*File*	*Jump to Target*		

08-16

JAN   FEB

Opening D20220816T195842_IFCB104.mat   ✕

You have chosen to open:

D20220816T195842_IFCB104.mat

which is: mat File (24.8 KB)
from: http://odontella.oceandatacenter.ucsc.edu:8000

What should Firefox do with this file?

○ Open with   [Browse...]

● Save File

☐ Do this automatically for files like this from now on.

[Cancel]   [OK]

Analysis

SEARCH

Find any image or collection of images with the help of classification filtering, file look-up, and more.

Start

DOWNLOAD BY CLASS

Download a ZIP file containing all, or a desired subset of, images classified as a particular species.

Start

ANALYZE COMMUNITY DATA

Check over community scientist classifications, review completion statuses, and download their datasets.

Start

ANALYZE LAB DATA

Review lab classification files and download the datasets.

Start

Notebook

🔍

AUTHOR +   FILE +   TIMESERIES +   IFCB +

SCW, D20220316T000858

jamiewalton 2022-05-02

Test note

Reply

IFCB104, D20220316T000858

AMcG 2022-03-17

Check on pseudos

Reply

Target 00072

Target 00072
IFCB104, D20210807T000613

jamiewalton 2021-08-10 🏳

Does anyone know how this one should be classified? It looks closest to being a noctiluca to me, but I can't tell if that's correct.

Reply

> **AMcG** 2021-10-21
>
> I think this is called Spatulodinium pseudonoctiluca, and I put it in Noctiluca (didn't realize it was a different thing until recently!)
>
> *Reply*

Thank you

kudela@ucsc.edu
kkenitz@ucsd.edu
clrander@ucsd.edu