EMERGING TECHNOLOGIES FOR NOAA OCEAN RESEARCH

A Response from NOAA to the Science Advisory Board's Report

10 April 2018

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Outline

- Purpose
  - respond to SAB's recommendations, and
  - provide status of ongoing activities
- Issue
  - Attention to, and implementation of, emerging technologies
- Need and action re NOAA's coordination
  - internally (across LOs), and
  - externally (e.g., private/academia)
- Desired Outcome
  - informational and continued input on ongoing activities, next steps and future opportunities

Purpose

Respond to SAB's recommendations[1] to

- *continue to invest in 'omics technologies…*
- *types and applications for unmanned robotic vehicles are exploding …*
- *Sophisticated imaging systems …*
- *Automated measurement systems …*
- *Passive acoustic sensors on moorings and mobile platforms … sensors for new orbital and suborbital platforms including ship-launched drones, aircraft and satellites*

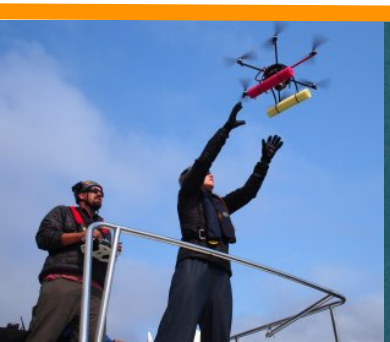
[1] https://www.sab.noaa.gov/ReportLibrary.aspx#11337161-ecosystem-sciences-and-management-working-group

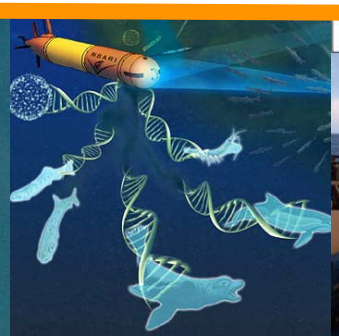
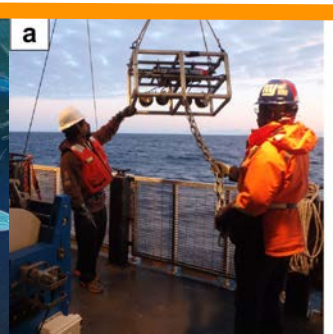
Response

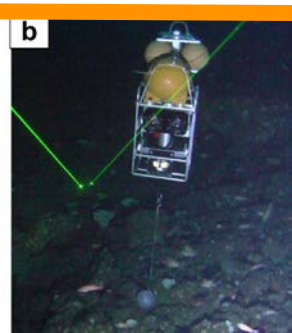
- We thank the SAB for its thoughtful comments and advice, and we support and concur with the SAB's report's recommendations.

- We add, as illustrated by the examples that follow, that NOAA is already making solid investments in the (rapidly evolving) identified technologies, and in several instances, their implementations are in advanced stages of R2O (research-to-operations).

- We underscore our concurrence with the SAB's recommendation that we need to invest in training the personnel required to extract the full extent of what these technologies offer.

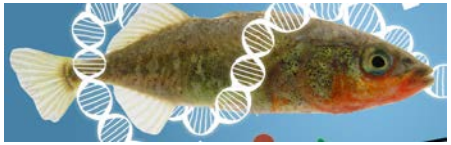


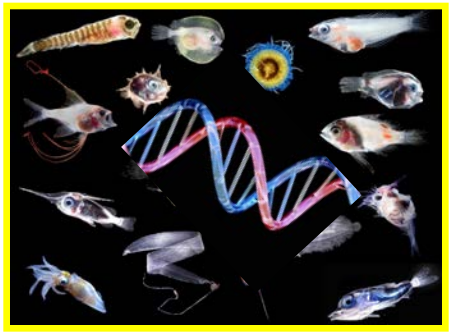



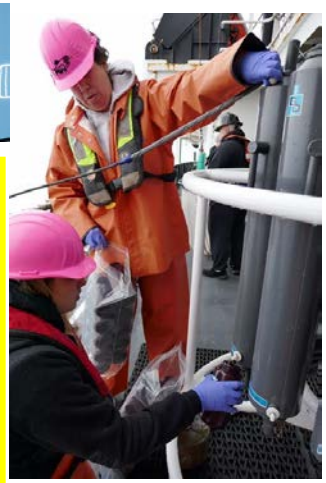


‘omics

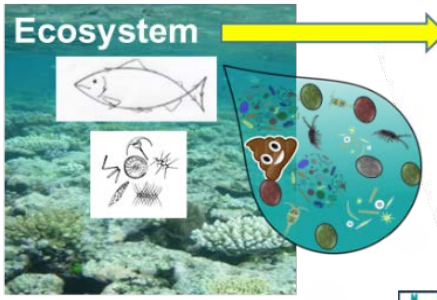
- ‘Omics and environmental DNA (eDNA) to characterize the microbiome
- Innovative techniques are being used to assess higher trophic levels (fish, turtles) from filtered seawater via capture of sloughed or excreted cells (eDNA)
- Current winter hake (Pacific whiting) survey to compare eDNA with trawl data (acoustic and fishing) to augment survey data for fisheries stock assessments.







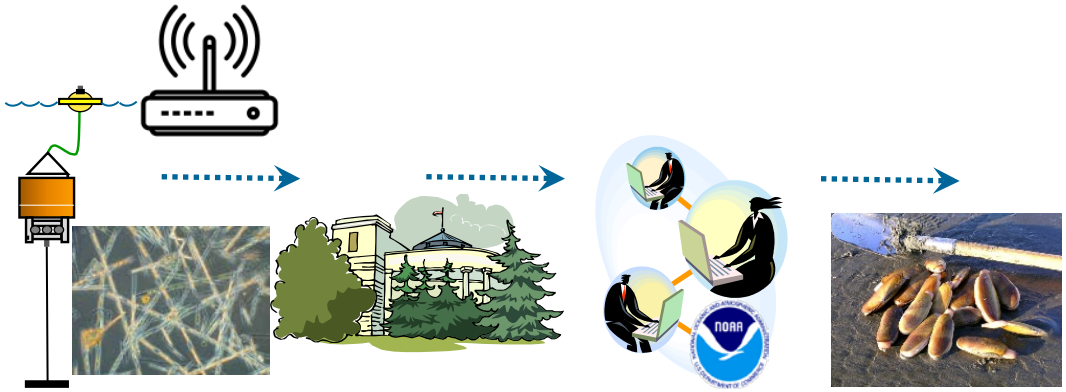
DNA analysis: promise for routine measurements



time and cost savings can increase throughput to data products

in-situ & mobile platforms can increase spatial & temporal coverage needed for models

- HABs warning system



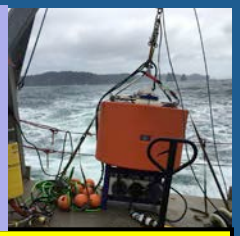
Environmental Sample Processor

ESP Progress at NWFSC: a transition success to HABs warning

- First ever deployment of an ESP in PNW
- Shore-based

- Archive deployment and technology transfer to NOAA FTEs
- Shore-based
- IOOS OTT award!!

- Took delivery of ESPeddie [NOAA IOOS]



- 3rd off-shore deployment in May
- 4th off-shore deployment in Sep
- **Sophisticated near-real time data dissemination via NANOOS application "*Realtime HABs*"**

2011 **2012** **2013** **2014** **2015** **2016** **2017**

- Took delivery of ESPfriday [NOAA OHHI]

- Coordinated deployment of 4 ESPs [NOAA Office of Aquaculture]
- Expanded detection capability
- Shore-based with near-real time data dissemination

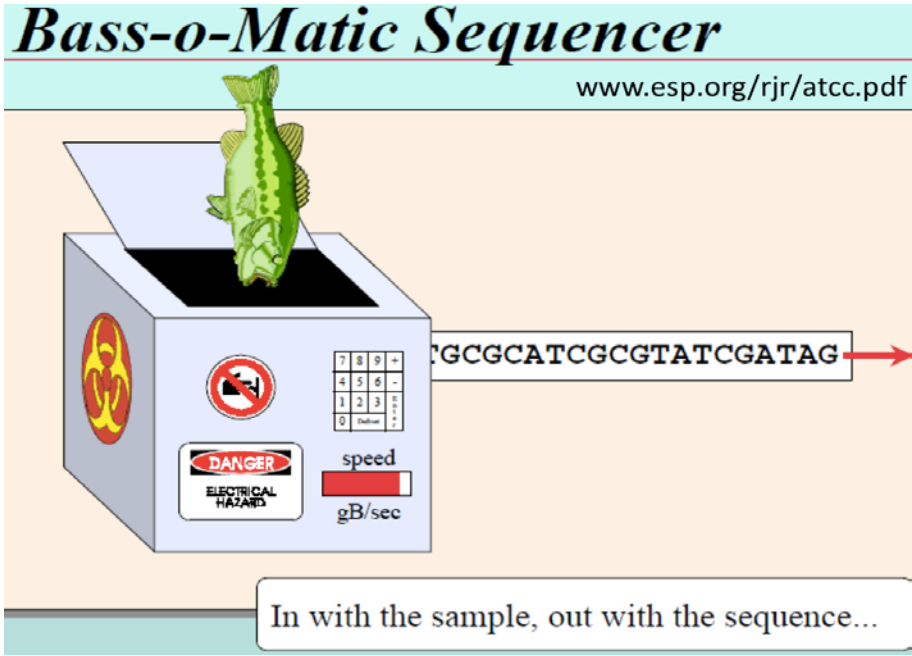
- Underwater deployment on a new mooring design
- Expanded detection capability for **domoic acid** (Doucette, NOS)

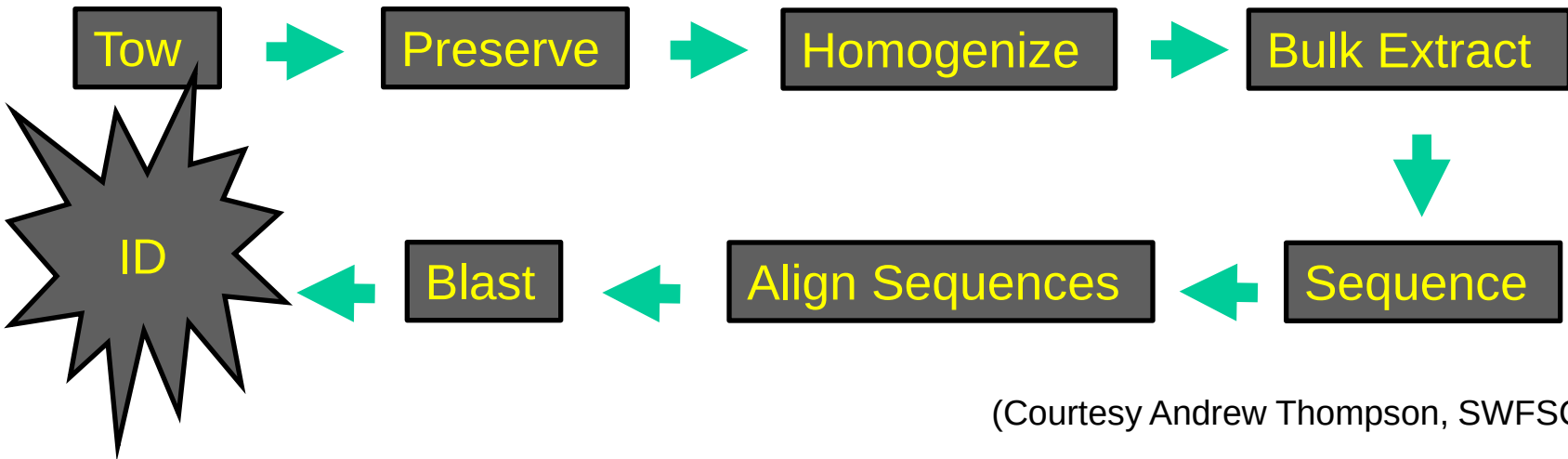
- 1st off-shore deployment (WA coast) May-Jul
- 2nd off-shore deployment Sep-Oct
- **Early warning of toxic HABs** [NOAA IOOS]

Meta-barcoding

- Common in microbial studies
- Becoming more common for eukaryotes

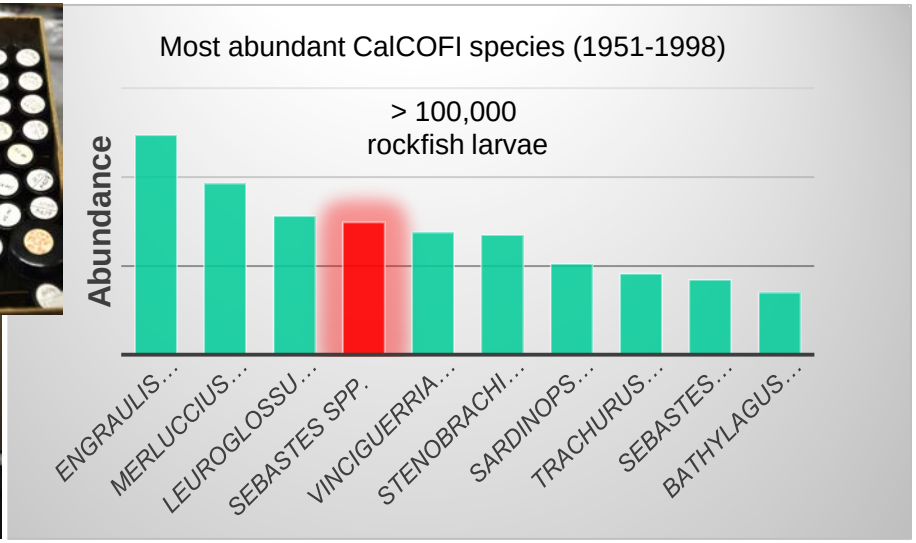
Goal: Develop a robust framework for incorporating metabarcoding in fisheries surveys



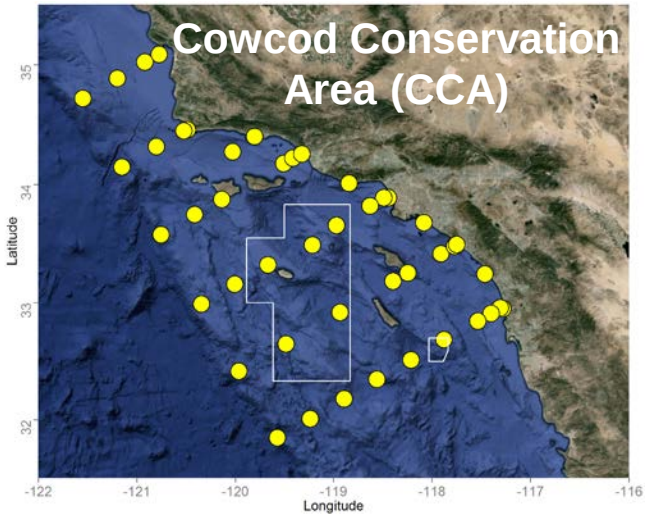


(Courtesy Andrew Thompson, SWFSC)

Example: CalCOFI and MPAs (CCA) Cowcod Conservation Area



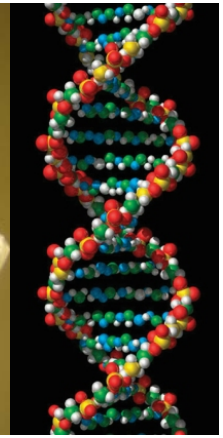
- Unfortunately, most larval rockfishes cannot be IDed to species based on morphology.
- Sequence cytochrome b gene from 6919 larvae in winter b/w 1998 and 2013



Collect plankton

Sort fish larvae

Visually ID larvae to genus



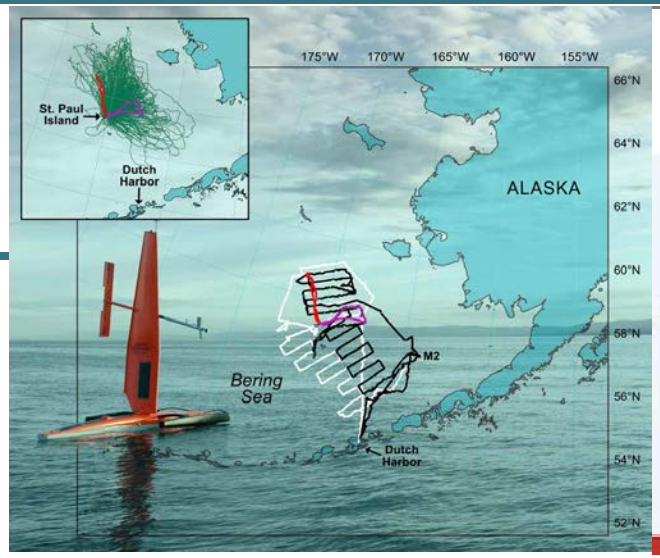
Genetically ID larvae

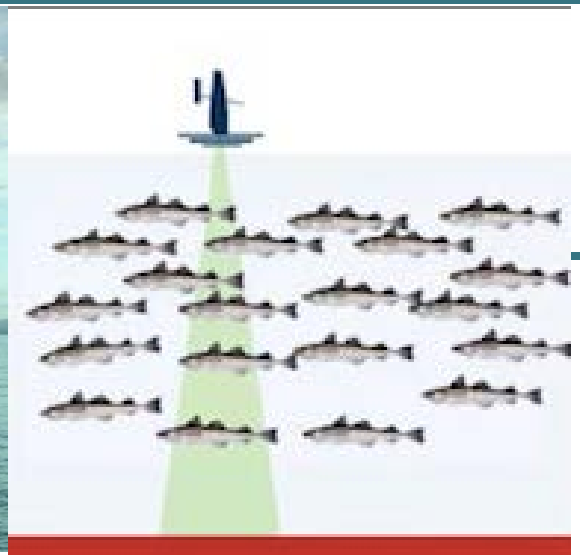
- Most targeted species increasing faster in than out of CCA
- Indicates that CCAs are helping increase production of overfished rockfishes

(Courtesy Andrew Thompson, SWFSC)

Robotic Vehicles, Autonomy and Artificial Intelligence

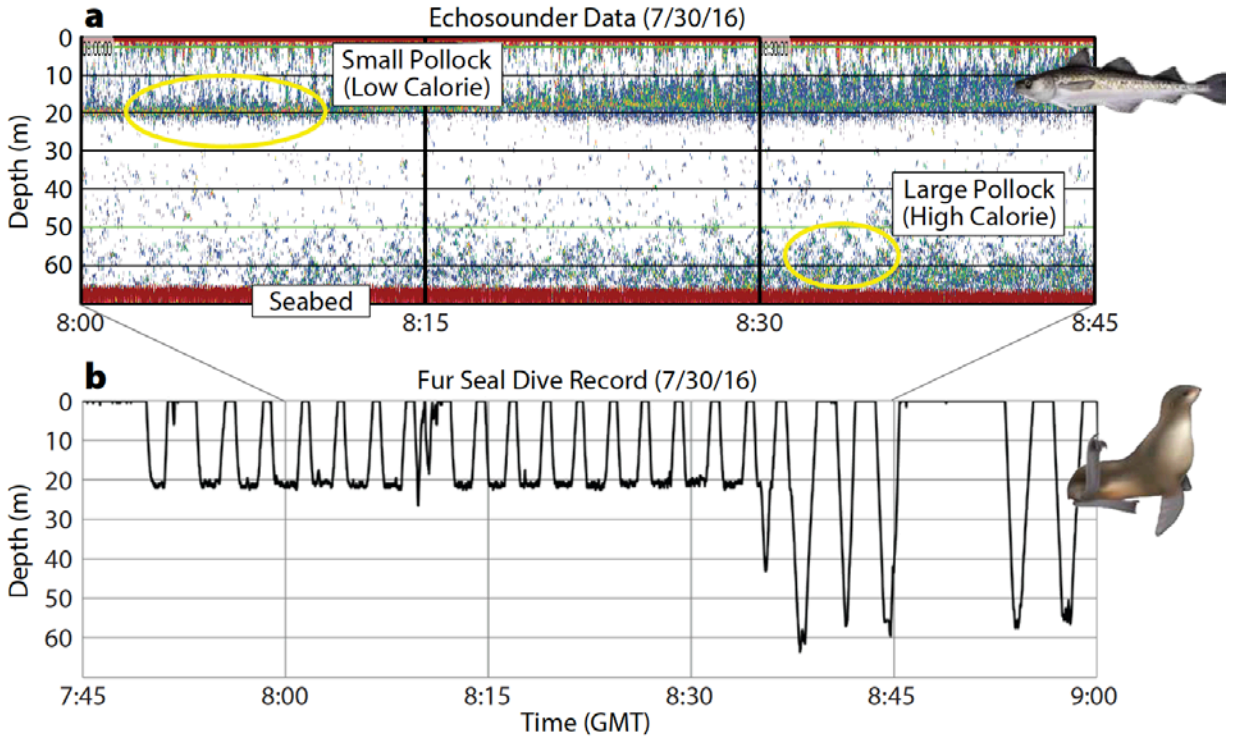
- Saildrones:
  - in Alaska
  - along the U.S. West Coast
- Gliders & moorings in the Western Antarctic Peninsula
- Small Unmanned Aerial Systems (sUAS)



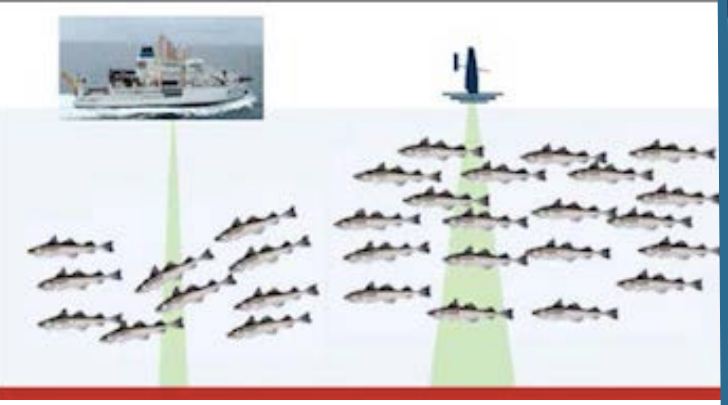


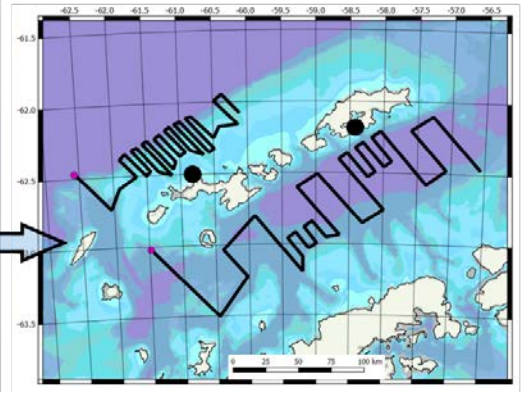
- Saildrone echosounder showing (a) backscatter from small pollock at ~10–20 m depth and larger pollock near the bottom, and (b) a dive profile from a northern fur seal.

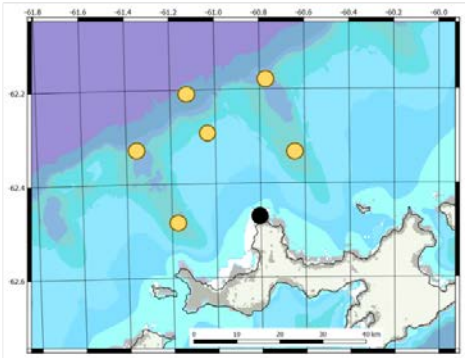
- This fur seal spent time diving to ~20 m depth and then switched to deeper dives. The dive pattern suggests the seal was initially foraging on smaller pollock and then switched to targeting the larger pollock near the bottom.

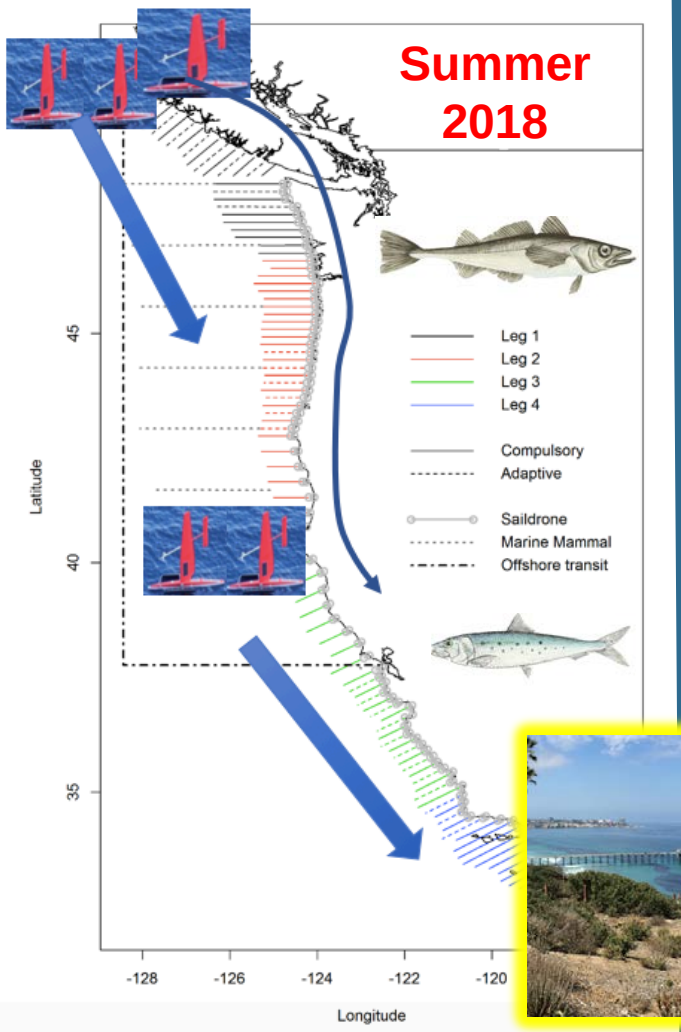


Mordy et al. (2017)



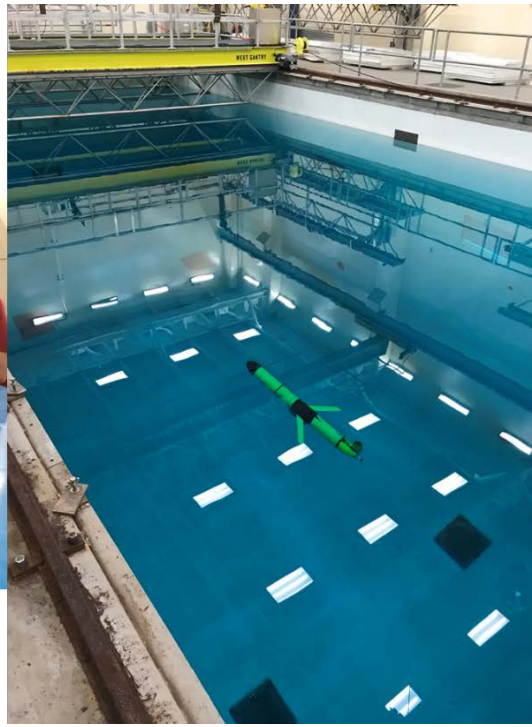






Test SoCal: summer 2018

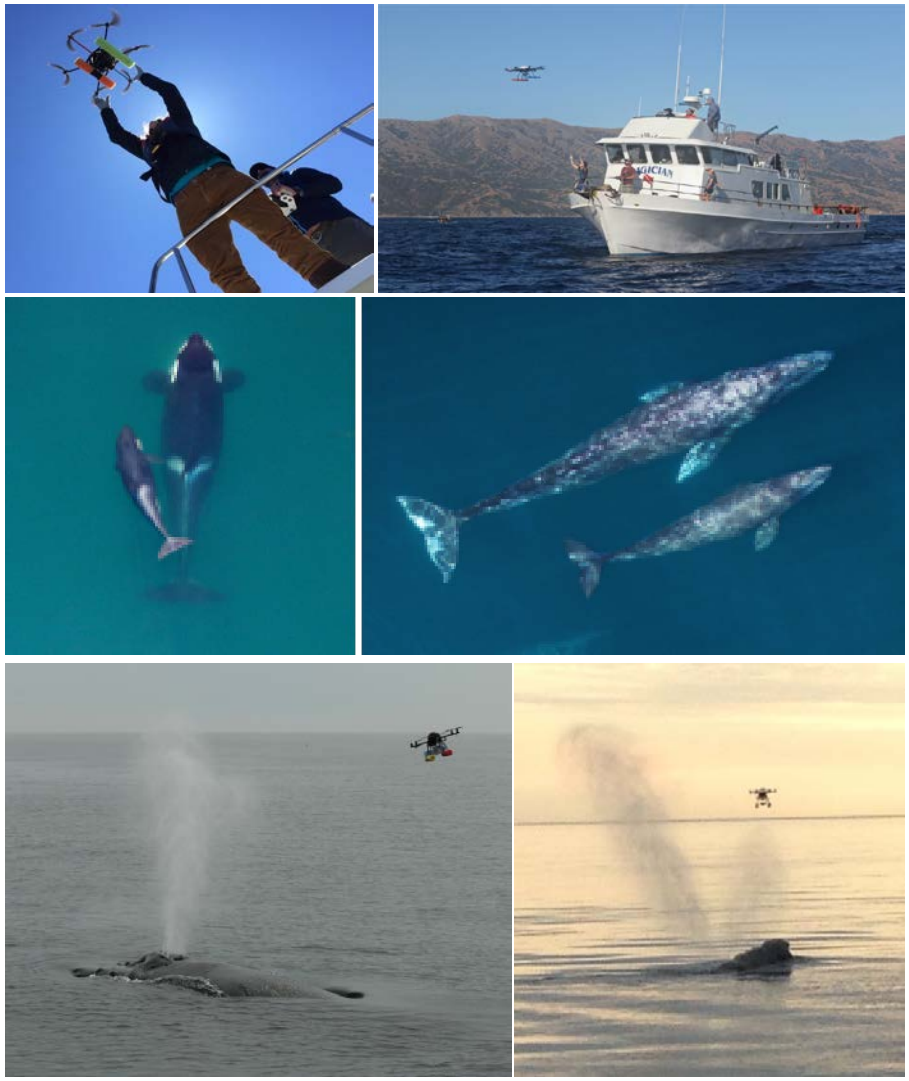
Antarctic deployment: Dec 2018-Mar 2019



Small Unmanned Aerial Systems (sUAS)

- We have now completed *thousands of successful flights* with small multi-rotor UAS platforms launched from a variety of boat and ship platforms, and from shore, in marine habitats ranging *from the tropics to the poles in three ocean basins*.

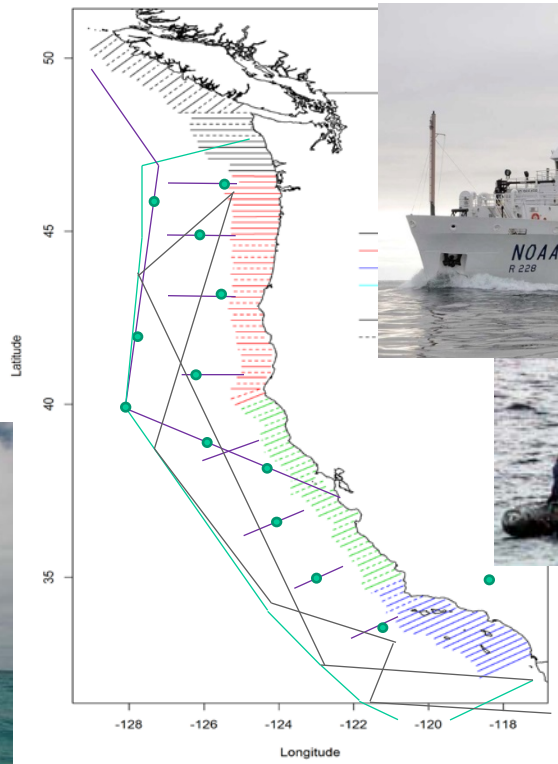
- Example: ID individual whales based on natural markings and *track their health and reproductive history (rather than just monitor at the population level)*. For Southern Resident Killer Whales, a *"Species in the Spotlight"*, we are identifying whales in poor body condition and pregnancies that are not leading to successful births.

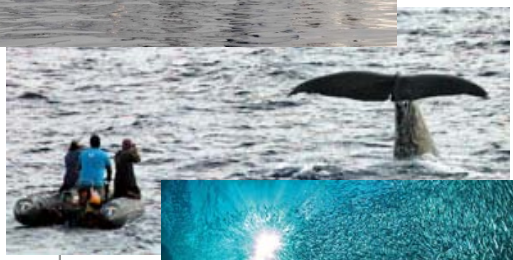


Unmanned Aerial Systems (sUAS) and extensions

- Now using hexacopters to collect imagery to assess Steller sea lion abundance and pup production. Short-range, within line-of-sight UAS operations have provided outstanding mission-critical imagery of pinniped and cetaceans.

- Long-range, beyond line-of-sight UAS surveys are experimental. Transitioning to new long-range UAS platforms will require additional work and resources.



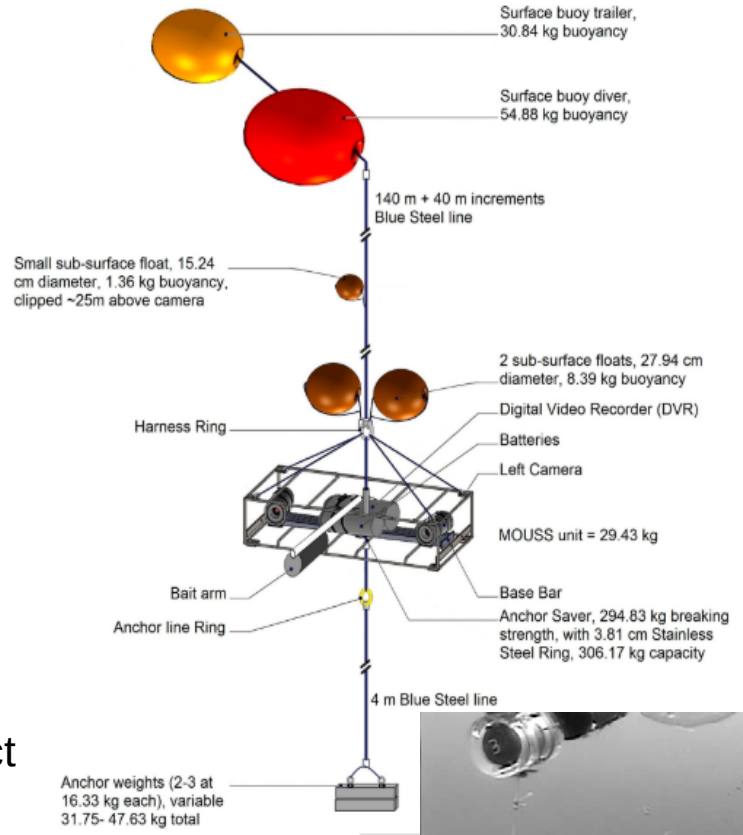


Imaging

- Robotic imaging (MOUSS) and machine learning (AI) systems
- Stereo camera systems to address fisheries stock assessment needs:
  - CamTrawl
  - Lowered stereo-cameras (LSC)
- Towed camera systems to address fisheries stock assessment needs: NEFSC's HabCam
- Steller Watch: An online crowdsourcing project to analyze Steller sea lion images
- Multi-spectral imaging for surveys of seals in the Arctic

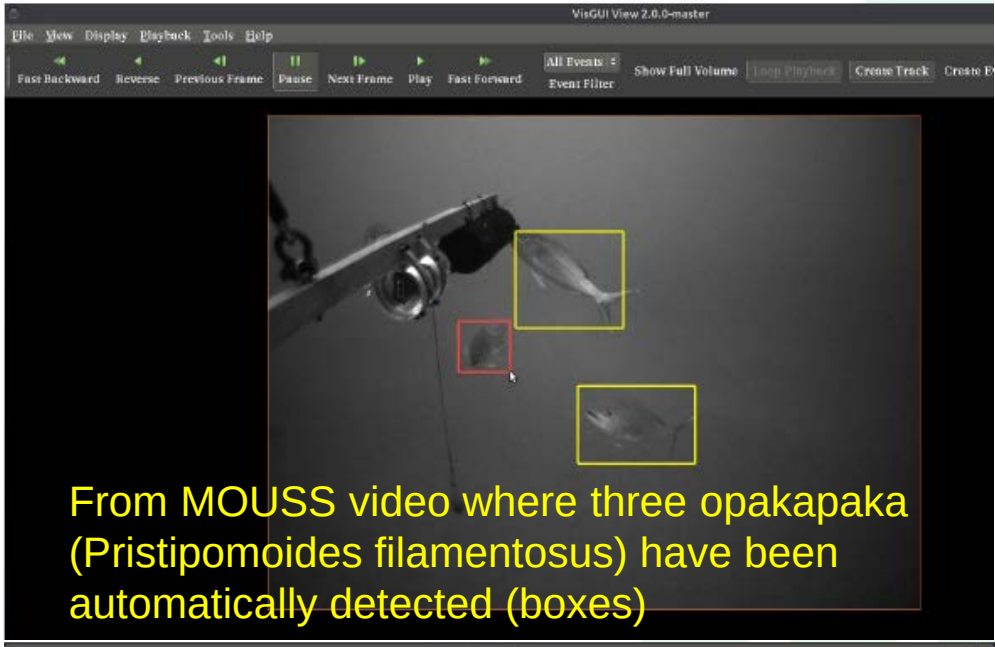
MOUSS (Modular Optical Underwater Survey System)

- MOUSS used to study abundance and identify juvenile habitat for deep-water snappers and generate fishery-independent, species-specific, size-structured abundance estimates of the “Deep-7” bottomfish stock.
- *These data were incorporated into the 2018 Bottomfish Stock Assessment.*
- These ssp. are susceptible to overfishing, making non-extractive surveying methodologies ideal in MPAs.
- MOUSS is a modular, low-light, stereo-video camera system designed to collect species-specific, size-structured abundance data using ambient light.
- MOUSS has been tested from vessels as small as 19’ LOA and can operate to a depth of 250m in Hawaiian waters.

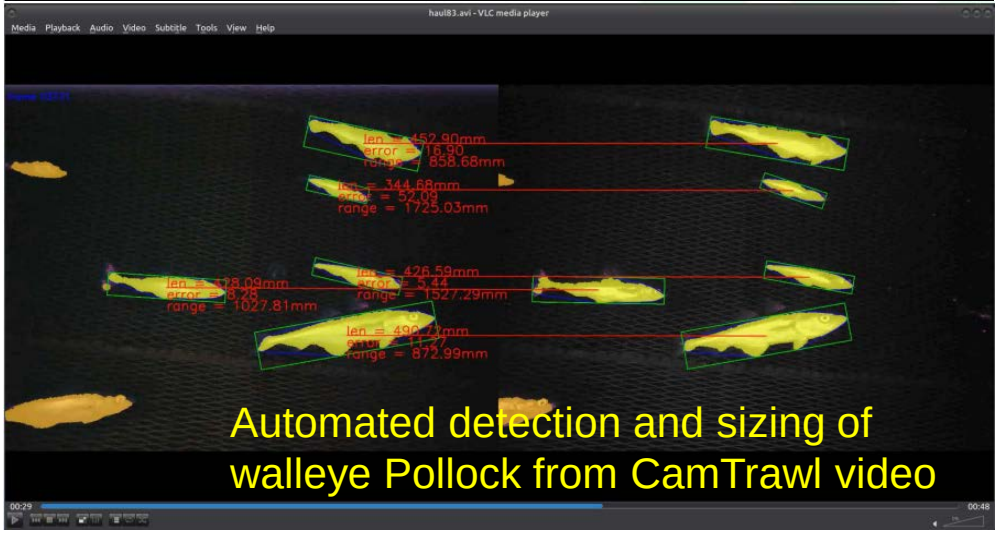


Automated Image Analysis & AI

- Robotic imaging systems (e.g., MOUSS, HabCam, CamTrawl) generate *large data volumes.* NOAA's *Automated Image Analysis Strategic* Initiative (AIASI) … develop broad-scale, standardized methods for automated analysis of still and video imagery.
- The goal was to *create an end-to-end open source software toolkit* allowing for the automated analysis of optical data.
- In 2018, the AIASI began roll-out of VIAME: The Video and Image Analytics for a Marine Environment toolkit (an *open-source software system for analysis of underwater video and imagery* that enables rapid, low-cost integration of new algorithmic modules, datasets and workflows).
- VIAME leverages *machine learning* from surveillance and biomedical fields, as well as DARPA funded *deep learning* research, to create automated analysis pipelines for processing of marine video data.

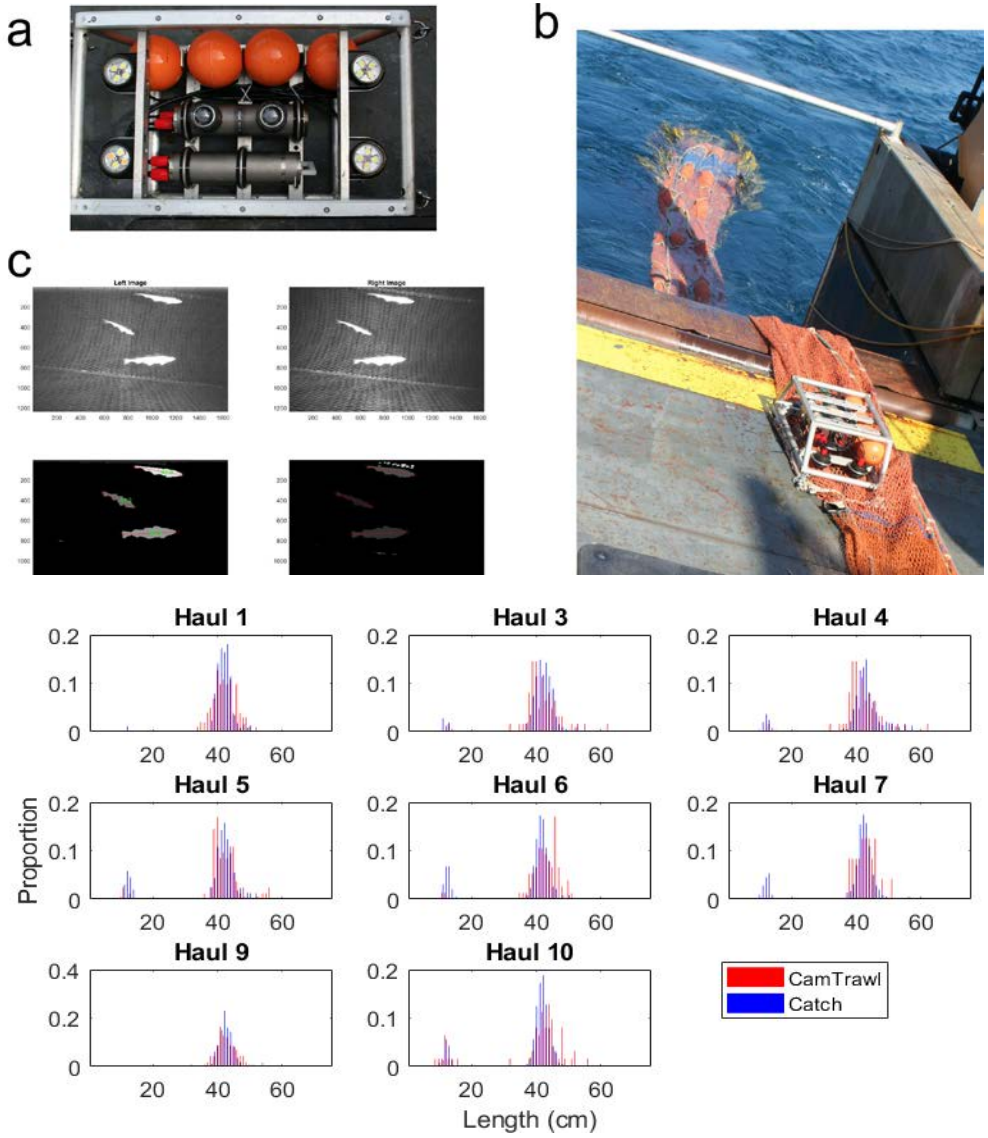


From MOUSS video where three opakapaka (Pristipomoides filamentosus) have been automatically detected (boxes)



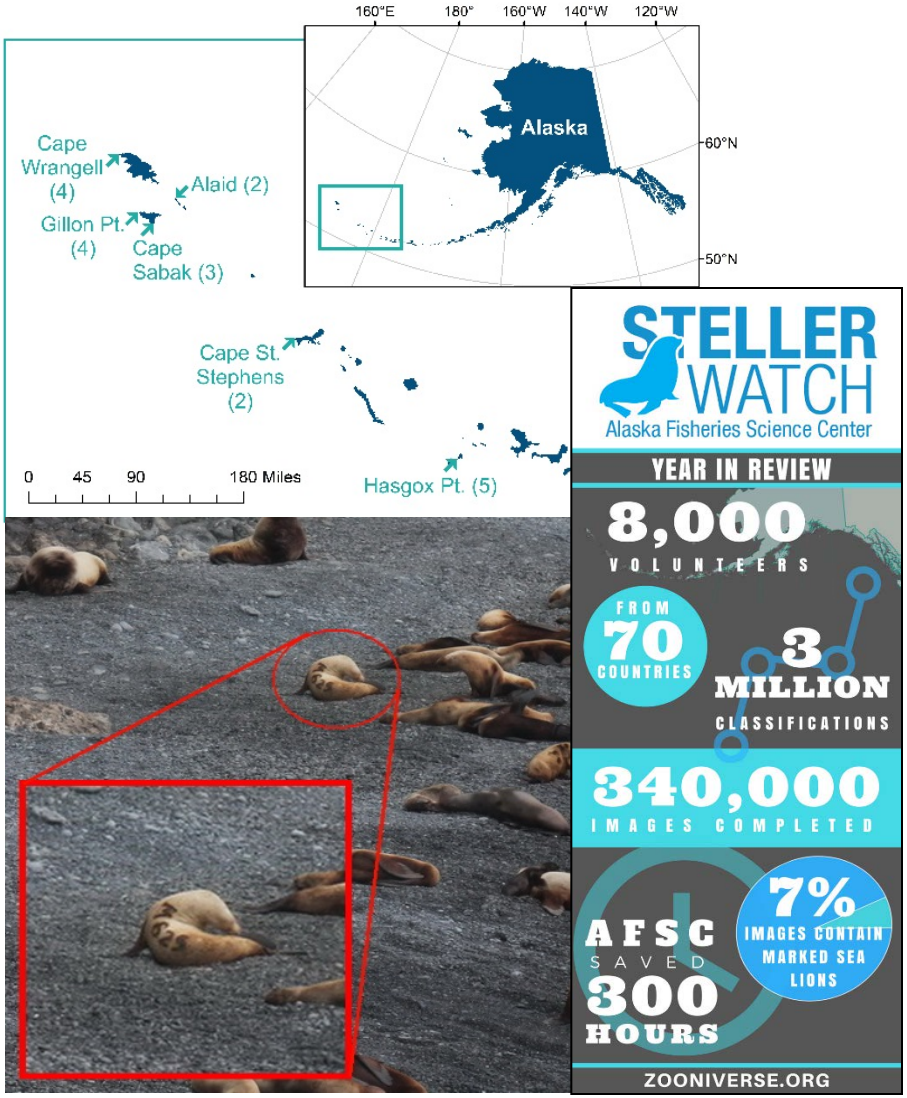
Automated detection and sizing of walleye Pollock from CamTrawl video

Automated Image Analysis & AI



- CamTrawl involves placement of a *stereo camera package inside a large midwater trawl,* which is routinely used in traditional acoustic-trawl surveys.
- The camera-trawl system provides a *time/depth-specific species and size composition* of fish passing through the midwater trawl over the entire haul path.
- This makes CamTrawl valuable for identifying acoustically sampled layers at *finer resolution than possible when traditional trawl sampling* methods.
- Image analysis software has been developed to *automatically* process CamTrawl data aboard the vessel during acoustic-trawl surveyd, and *length measurements by species are entered into a database* alongside bio-physical measurements.

Crowdsourcing: Steller Watch

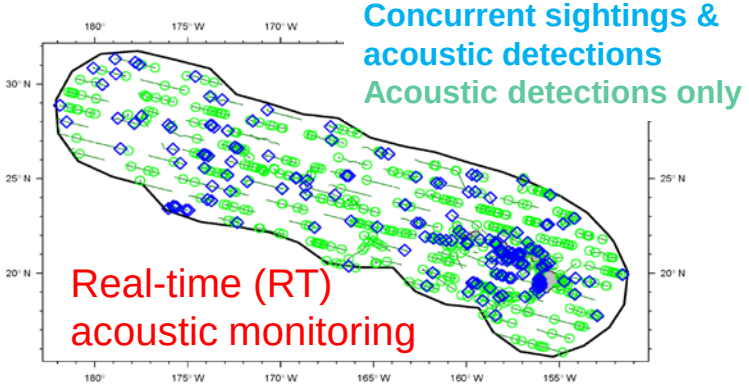


- Twenty-one cameras have been stationed at six known Steller sea lion sites in the western and central Aleutian Islands: capture images every 5-20 minutes year-round.
- Because of area's remoteness, we can only access these cameras once a year.
- Since in 2011, we have collected up to half a million photographic images per year.
- Crowdsourcing … Zooniverse's has a million registered citizen scientists:
  - Are there sea lions present?
  - Are there marked sea lions present?
- 8,000 volunteers from 70 countries participated in Steller Watch and conducted >3M classifications, completing almost 340K images, narrowing down hundreds of thousands of images to the 7% of highest priority images with sea lions present that have a readable mark.

Other: passive acoustics, drones, orbital platforms

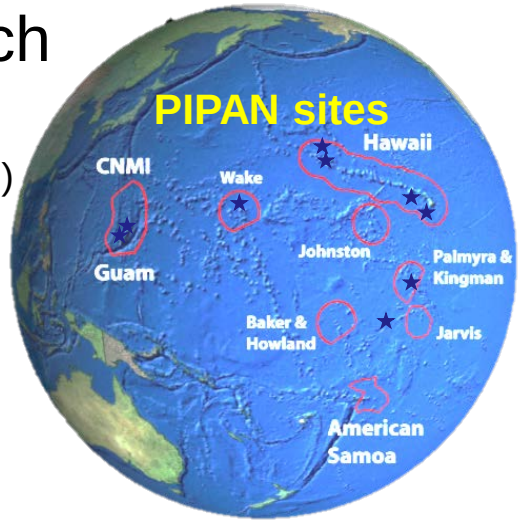
Passive Acoustic Tools for Cetacean Research

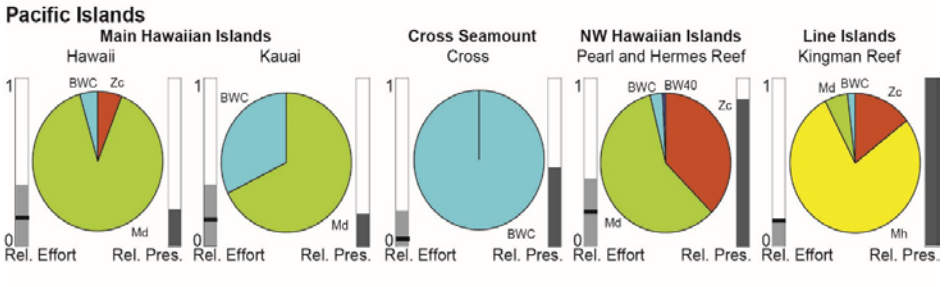
- Long-term autonomous recorders: days to years continuous recording to monitor cetacean, ambient, and human-caused noise at Pacific Island Passive Acoustic Network (PIPAN) sites.

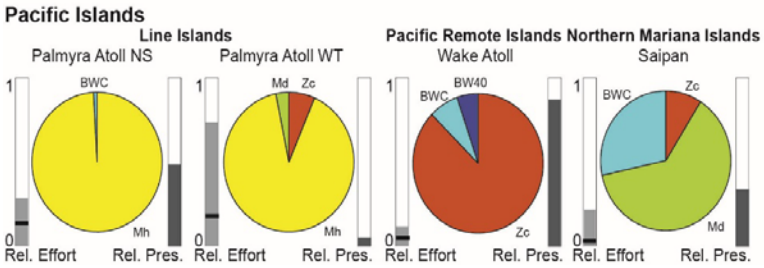


The Hawaiian Islands Cetacean and Ecosystem Assessment Survey (HICEAS) in 2017 included daytime RT monitoring (towed hydrophones). The real-time tracking system separated echolocation click and whistle detectors and classifiers to provide RT location information for tracking vocal groups at sea.

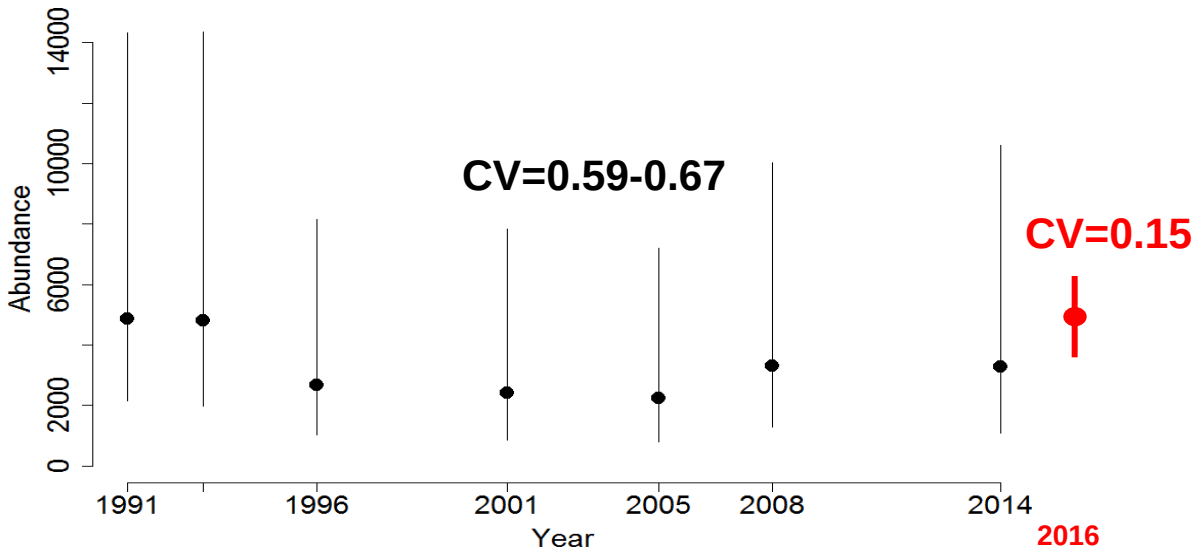
- Zc = Ziphius cavirostris (Cuvier's beaked whale)
- Md = Mesoplodon densirostris (Blainville's beaked whale)
- BWx = unidentified beaked whales

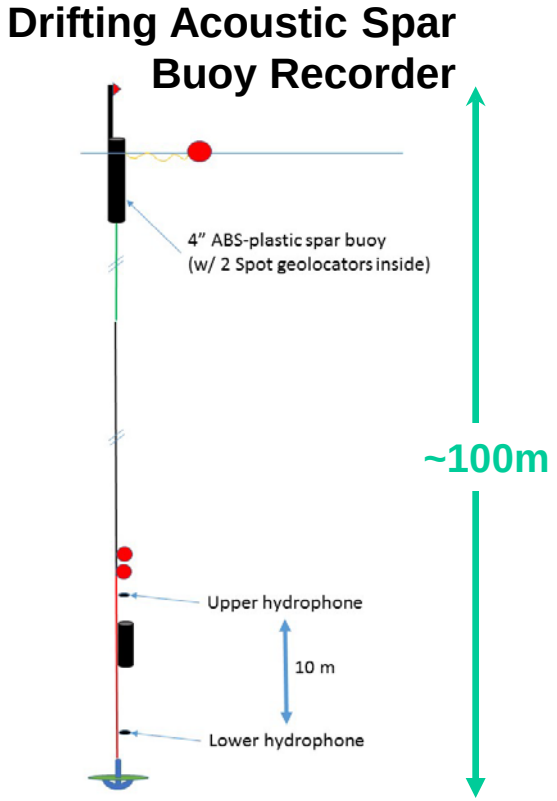






Acoustics vs. Visual Estimates of Beaked Whales Abundance



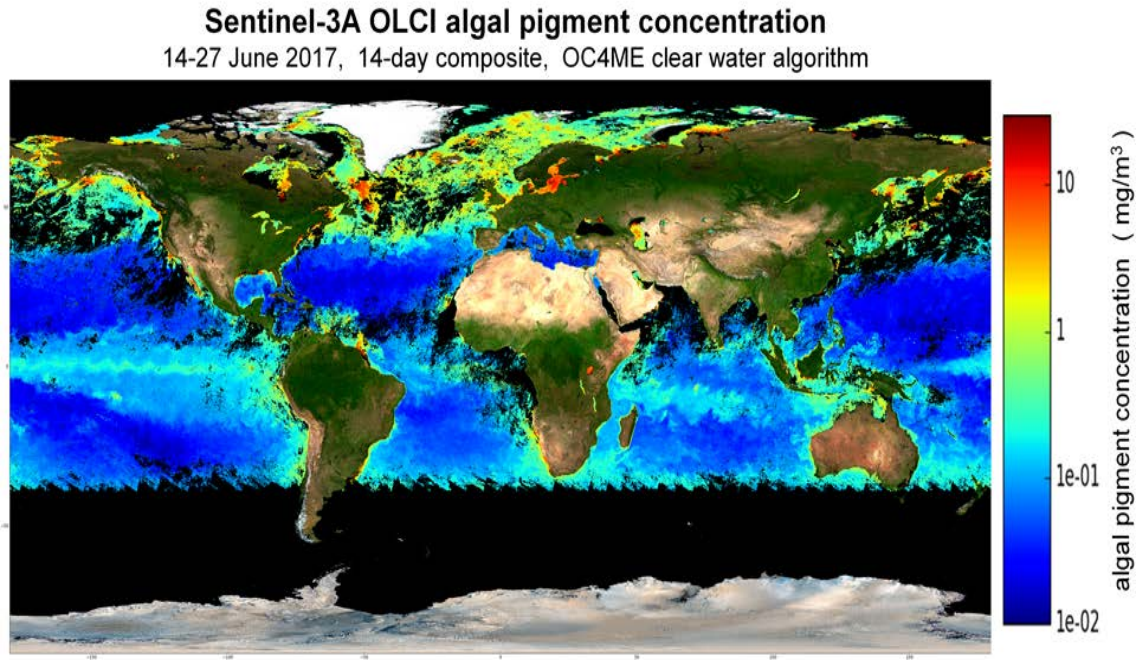


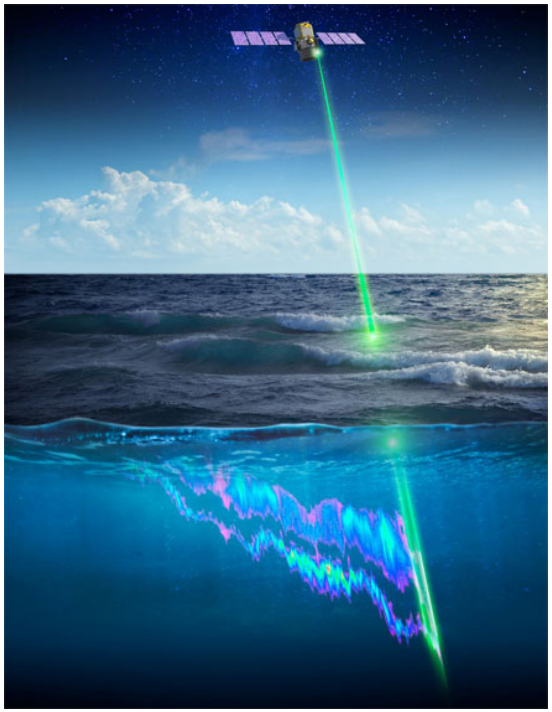
- An example of how passive acoustics can estimate abundance of a marine mammal (here a beaked whale)
- **Much better precision than visual line-transect surveys.**
- Still needs more information on depth distribution of clicking
- And incorporate temporal autocorrelation which would reduce the "effective" sample size.

Sentinel, Space-borne LIDAR

SENTINEL. Ocean topography and ocean color provided by the Sentinel 3A and Sentinel 3B satellites represent exciting developments. Ocean topography, the ability to derive convergence and diverge zones in the ocean, can help map areas of potentially high fisheries productivity. OLCI on the Sentinel series provides additional wavelengths to enable enhanced performance in coastal areas and presents the opportunity to identify specific plant pigments.

Space-borne LIDAR can offer better vertical resolution, more detection bands, and more laser emission wavelengths. A vertical resolution of 1-3 meters and deeper penetration in the water column, will improve estimates of primary productivity. More detection bands: additional phyto-plankton assemblage detail.





NOAA Coordination & Views

- Emerging technologies are necessary:
  - To sample more broadly, more quantitatively, more efficiently
  - Integrate across the components of the Earth System
- Challenges – resources needed for:
  - Laboratory development, engineering and sensor development, and testing in the field
  - Development/training of personnel
- Transition, including capitalization costs and understanding the relation between measurements from new technologies with instrumentation currently in use

NOAA Coordination & Views

- Ongoing coordination (can always build on)
  - within and across LOs, e.g., ‘omics, sUAS, gliders
  - with academic and private/commercial enterprise (e.g., Saildrone, MBARI, WHOI, Scripps, UW, etc.)
  - Internationally with Japan, Norway, China, Canada, etc.
- Methods of engagement/collaboration:
  - CRADAs
  - joint surveys
  - funded external projects

Desired Outcome

Informational briefing to provide feedback and facilitate a discussion on NOAA's response to the SAB's *Emerging Technologies Report* recommendations.

We thank the SAB for their thoughtful advice and we remain open to future input and recommendations on this important topic.