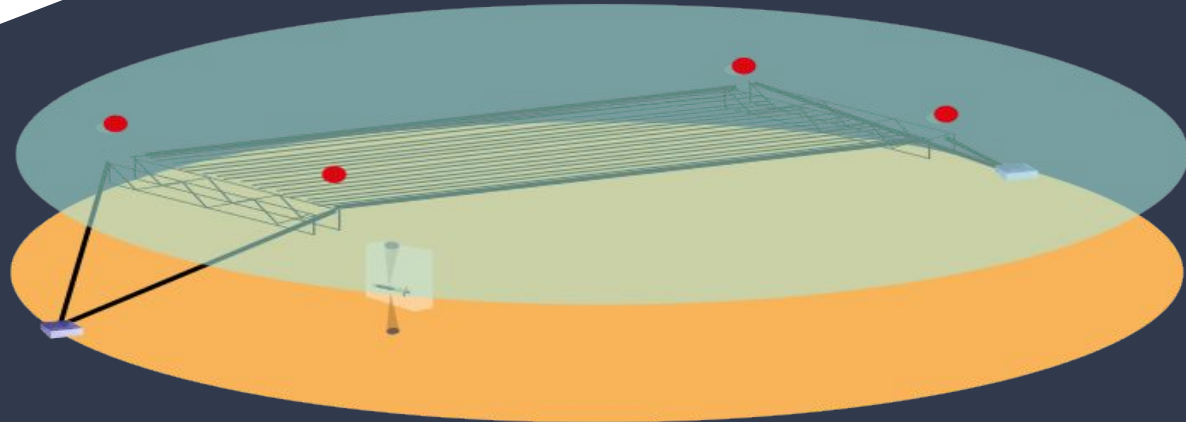
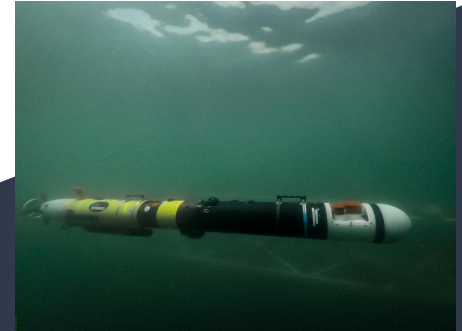
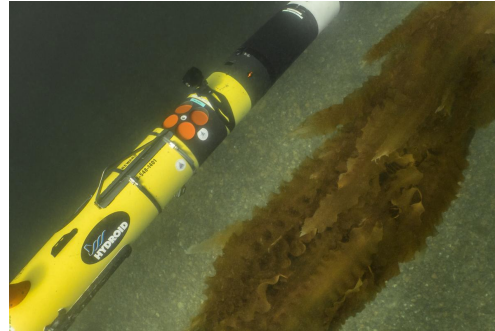


Autonomous underwater vehicle perception of infrastructure and growth for aquaculture

Erin Fischell, Daniel Gomez-Ibanez, Andone Lavery, Tim Stanton, Amy Kukulya

Woods Hole Oceanographic Institution



The Program: **ARPA-E MARINER**

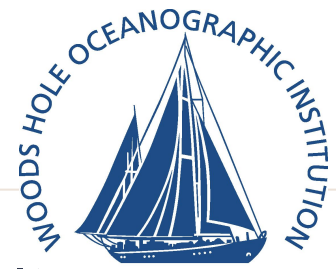


U.S. DOE Advanced Research Projects Agency-Energy (**ARPA-E**) Macroalgae Research Inspiring Novel Energy Resources (**MARINER**)

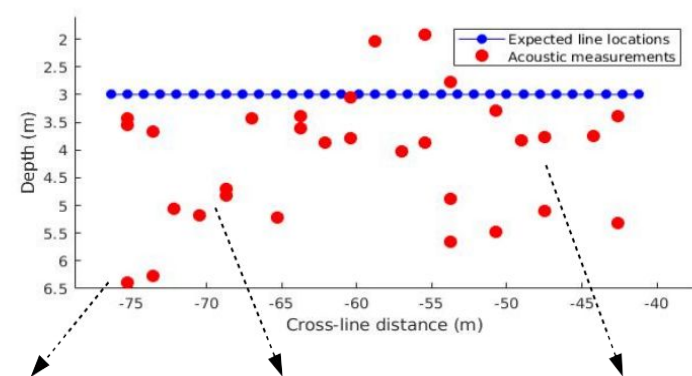
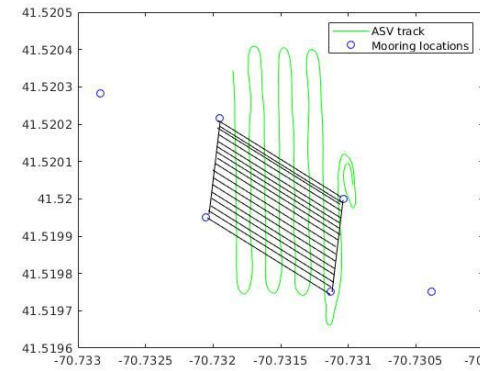
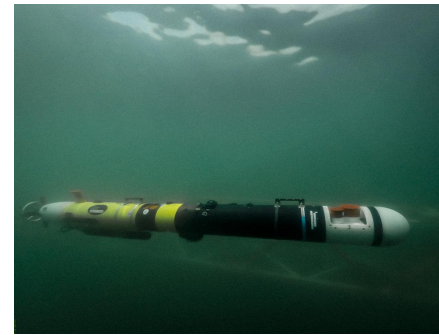
Objective: Fund technology development required for seaweed aquaculture to become a viable fuel source through off-shore aquaculture, including:

1. Farming offshore at scale
2. Harvest
3. Modelling
- 4. Monitoring**
5. Breeding

The Project: Cat. 4

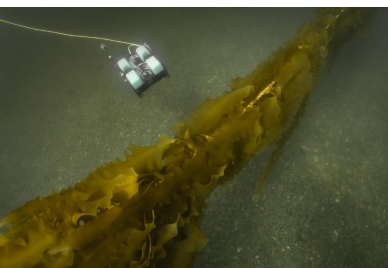
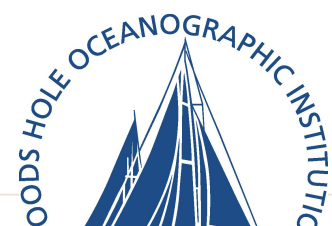


Develop autonomous monitoring tools for aquaculture.



Manual inspection to autonomous inspection and mapping

Sensors and Vehicles



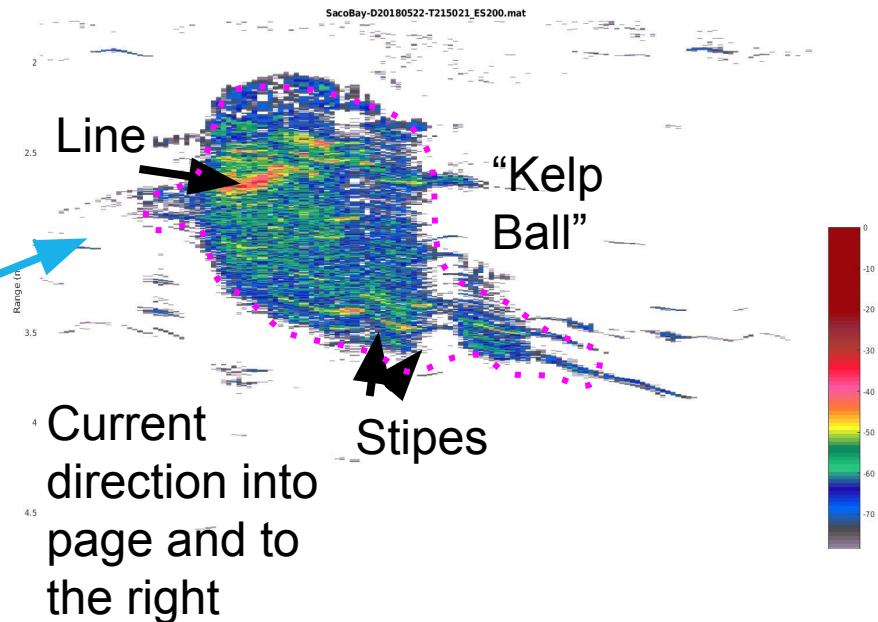
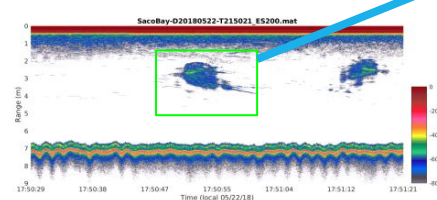
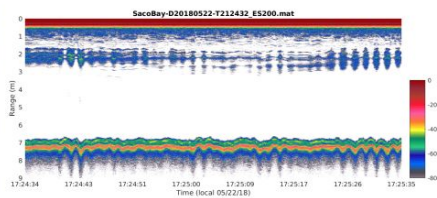
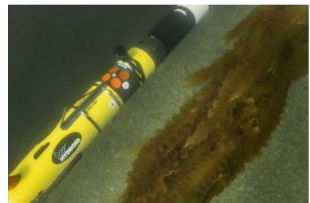
Sensor	Use	Vehicles
Up/Down ADCP, 600 kHz	Current estimation, navigation	Snoopy, Darter
INS	Navigation	Snoopy, Darter
NBOSI CT	Temperature, salinity	Snoopy, Darter
Optode O2	Dissolved oxygen	Snoopy, Darter
PAR	Light	Snoopy, Darter
Ecopuck triplet	Biological productivity	Snoopy
Suna V2 Nitrate	Dissolved N2	Snoopy
KelpCam	360 camera system	Darter
Low-cost sonars	Comparison with EK80 for kelp	JetYak
EK80 WBT-Mini	Split-beam 200 kHz, single-beam 333 kHz, broadband	Snoopy, JetYak

Acoustic sensors and data



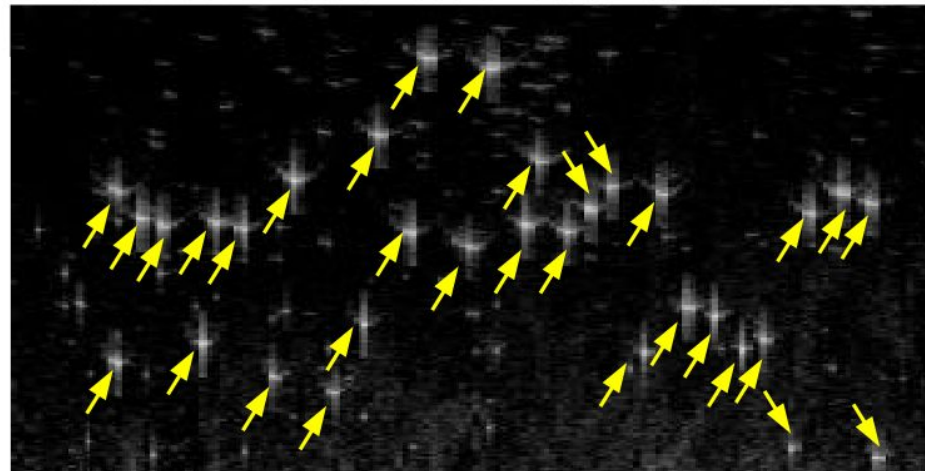
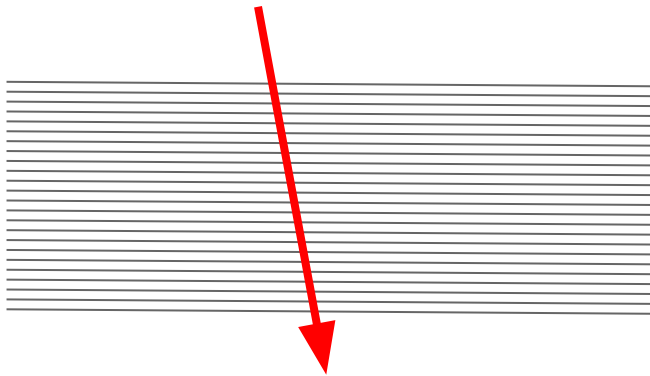
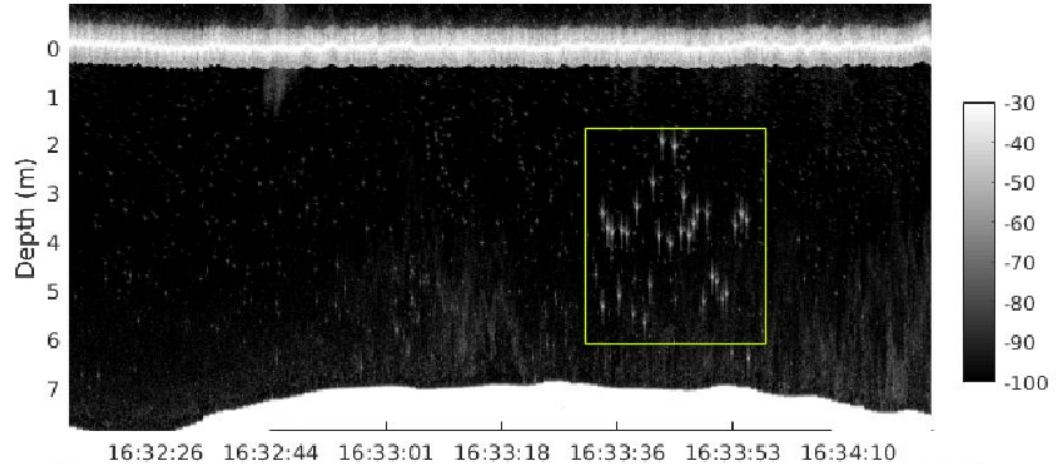
- ▶ EK80 WBT-Mini on AUVs, EK80 WBT-Mini + BlueROV ping on JetYak
- ▶ Used for detection/mapping of kelp, infrastructure, fish

EK80 data: Saco Bay



Acoustic sensors and data

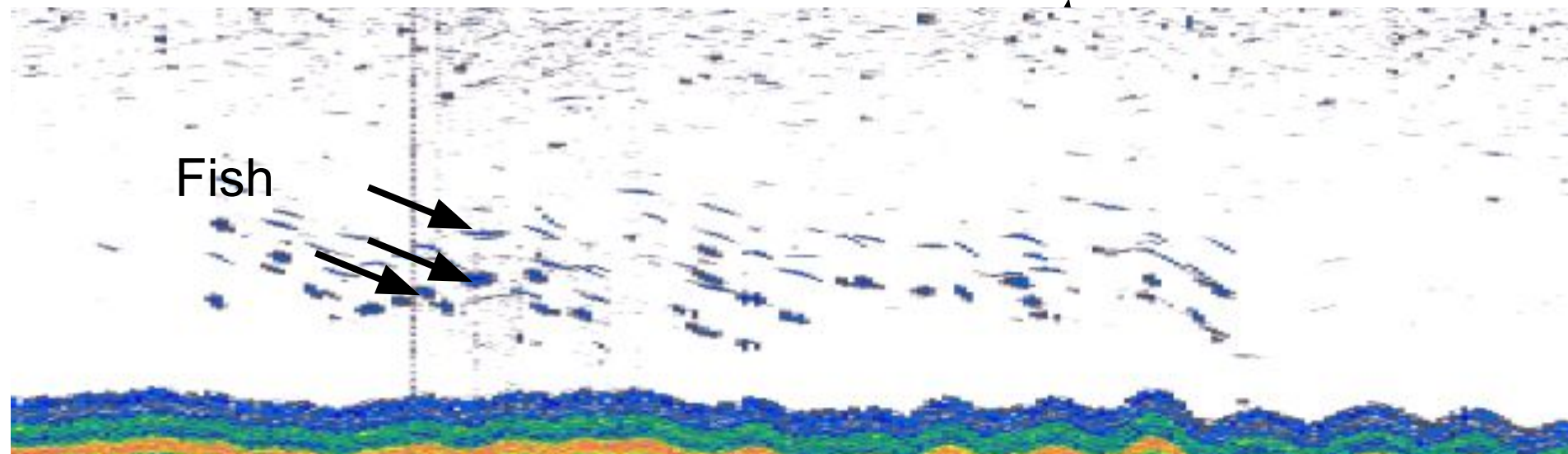
Acoustic scattering
from longline array



Acoustic sensors and data



Fish visible in Saco Bay data- possible processing task



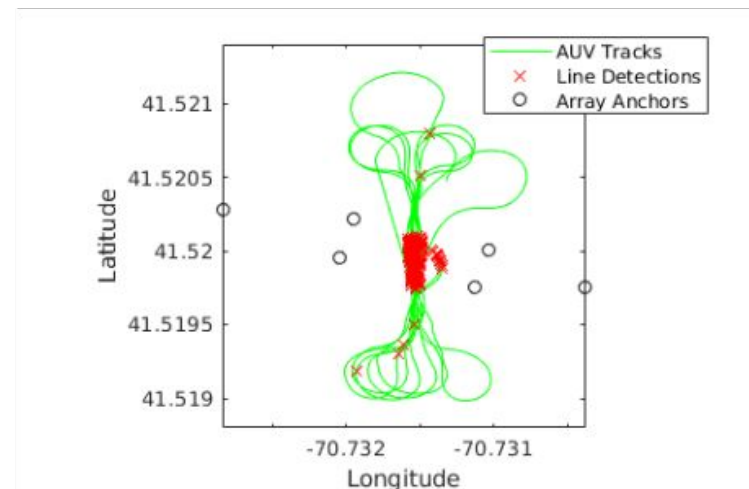
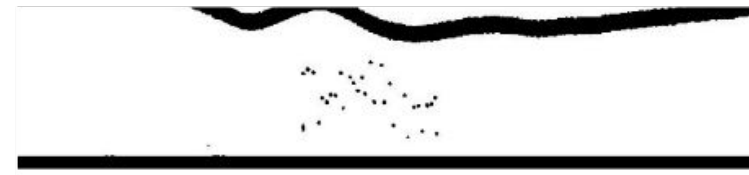
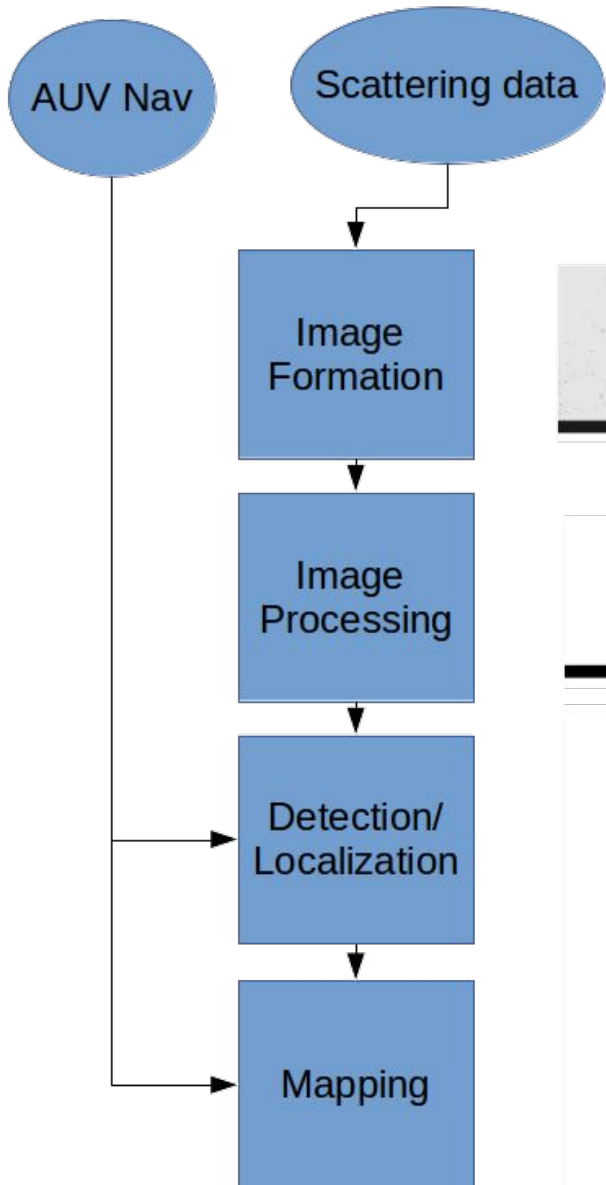
Acoustic processing



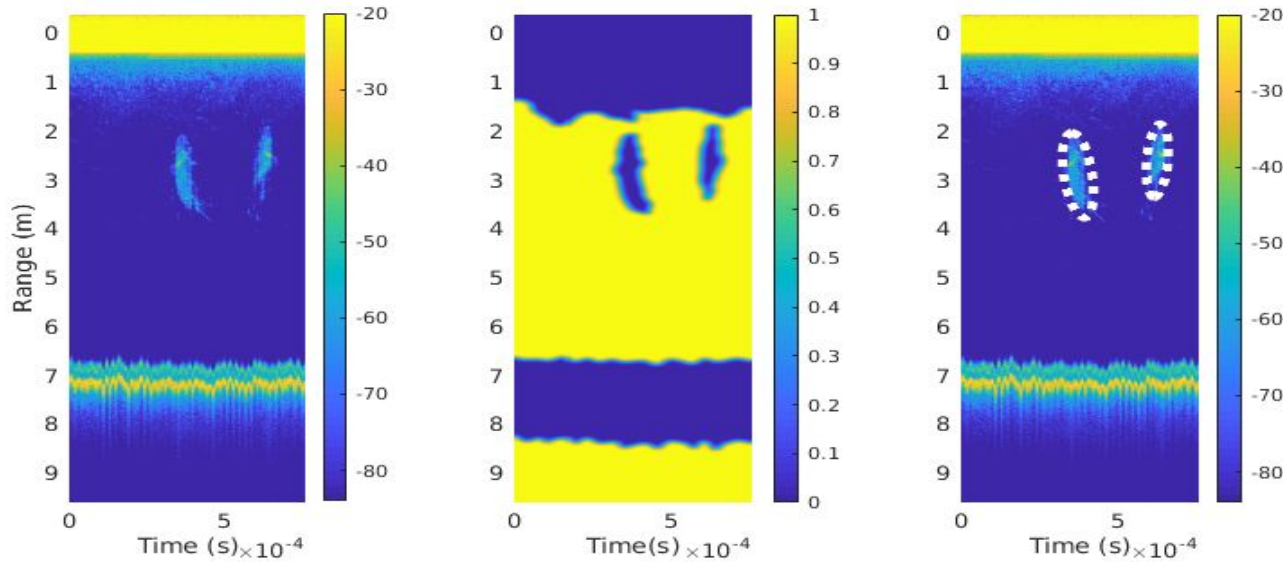
Objectives:

1. Map out infrastructure so we don't hit it.
2. Use map to improve acoustic data collection.
3. Provide farmer with site-wide data on infrastructure, kelp growth, and maybe local marine biology.

Acoustic processing

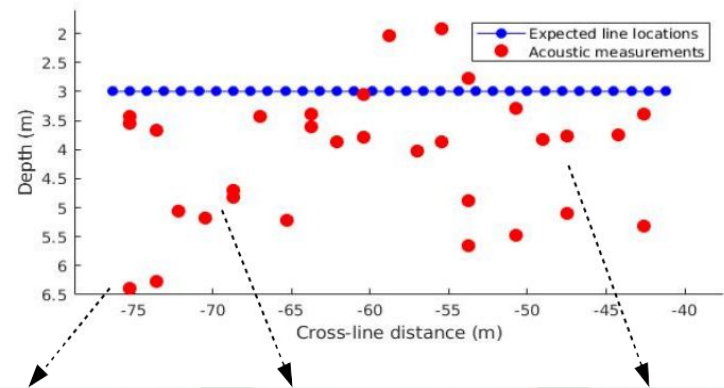


Acoustic processing



Kelp scattering estimation (above)

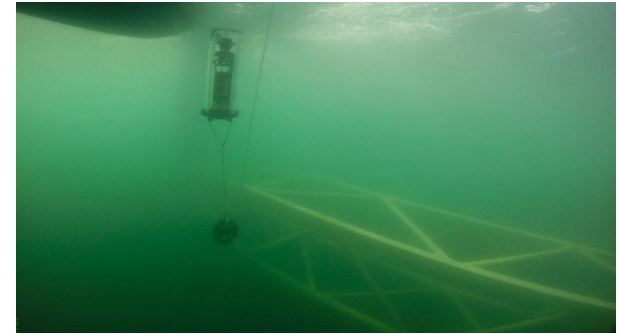
Mapping of longline locations to image data (right)



Kelpcam



- 360 degree photogrammetry system
- Uses include detailed inspection of infrastructure, macroalgae imaging.



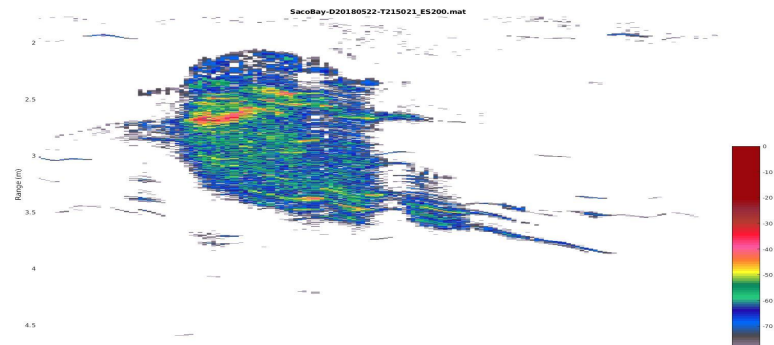
Camera processing



- Processing for edges, organic shape, “interestingness” for labeling and mapping.
- Advantage: easily understood data.
- Disadvantage: turbidity, limited range, qualitative.



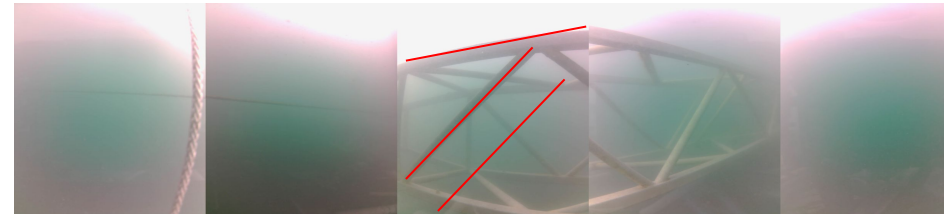
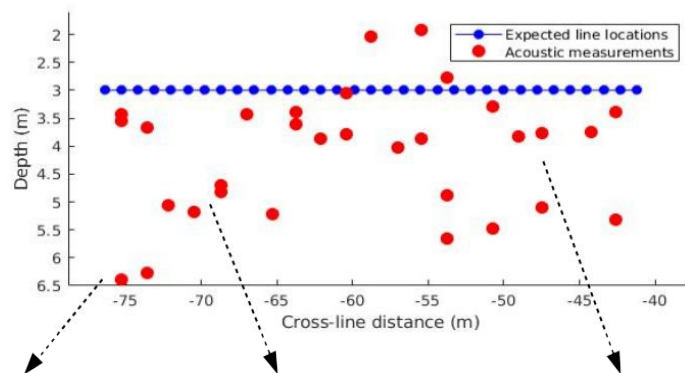
v.



Perception



1. Use line detection mapping (real-time) to select depths, tracklines for kelp survey.
2. Use line detection mapping, estimate of turbidity (real-time) to select camera inspection behavior.
3. Anomaly detection in kelp scattering cross-section, infrastructure positioning for camera inspection.
4. Perception-in-the-loop autonomy development, simulation, and in-water testing.



Data management

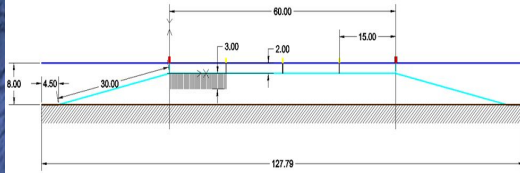


As of 5/1: database system is live!

- ▶ Upload files, automatically parsed and added to data
- ▶ Display tools auto-linked and built in

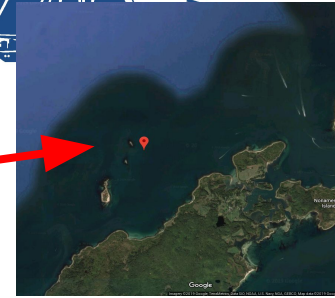
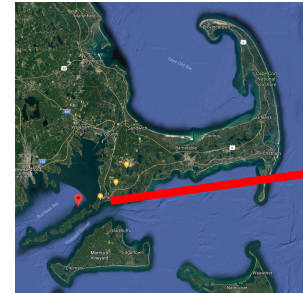
The screenshot shows a desktop environment with a Firefox browser window open to the MARINER administration site. The browser's address bar shows the URL "https://mariner.whoi.edu/admin/". The page content includes sections for "MARINER administration" and "Site administration", with sub-sections for "DATA MANAGEMENT" (Cruises), "VEHICLE MANAGEMENT" (Instrument payloads, Vehicle kinds, Vehicles), and "My actions". A sidebar on the left contains various application icons. In the background, a Kibana interface is visible, displaying a map of the WEEPECKET ISLANDS area. The Kibana interface includes a search bar with the query ">_ cruiseId:1", a "Layers" panel with "data" and "road_map" layers, and a "data" panel with "Source details" and "Dynamically filter for data in the visible map area" options. The Kibana interface also shows "Term joins", "Vector style" settings (Fill color, Border color, Border width, Symbol size), and a "Go to" button with coordinates "lat:41.51434, lon:-70.72144". The browser's status bar at the bottom shows "Page 2 of 8", "1,848 words, 11,861 characters", and "Default Style".

System deployments

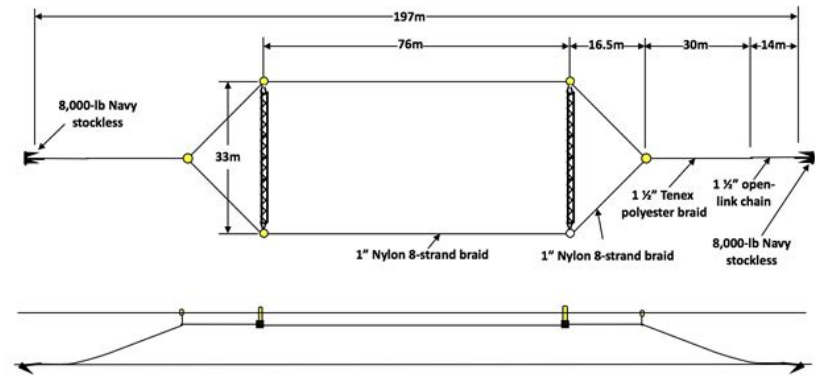


All Dimensions are in meters

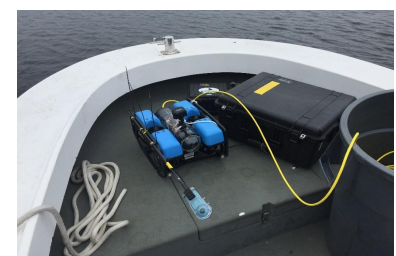
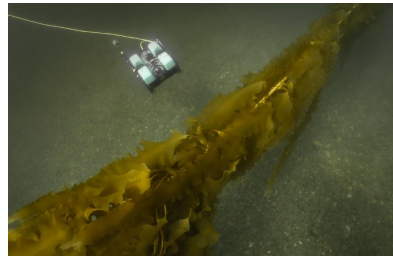
Saco Bay, ME (left): run by UNE
Buzzards Bay, MA (right): run by WHOI
Gulf of Maine (not shown): run by UNH



As-built array structure



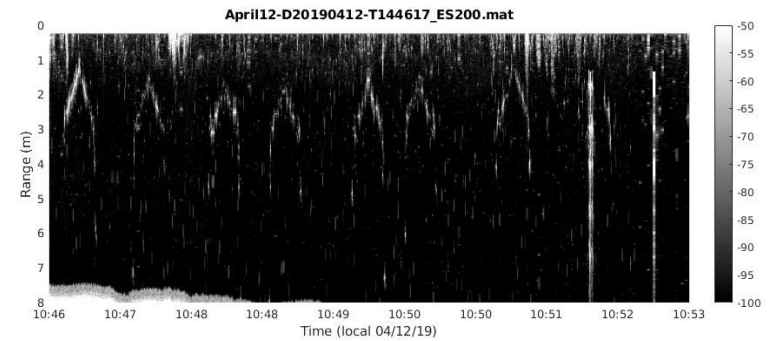
Spring 2019: surveys of UNE, UNH, Buzzards Bay farm site.



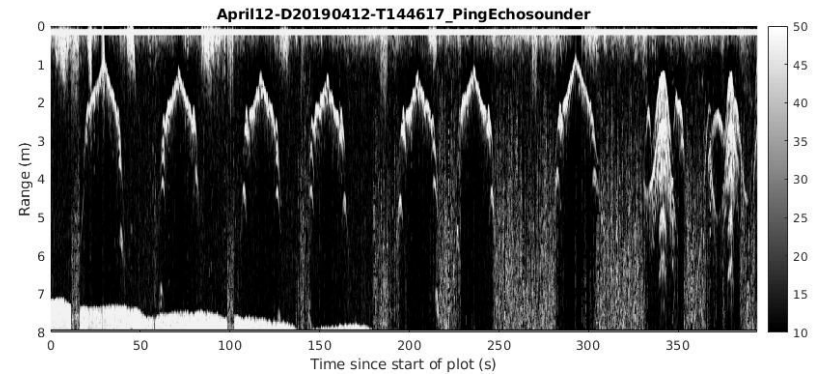
Exploring low-cost options



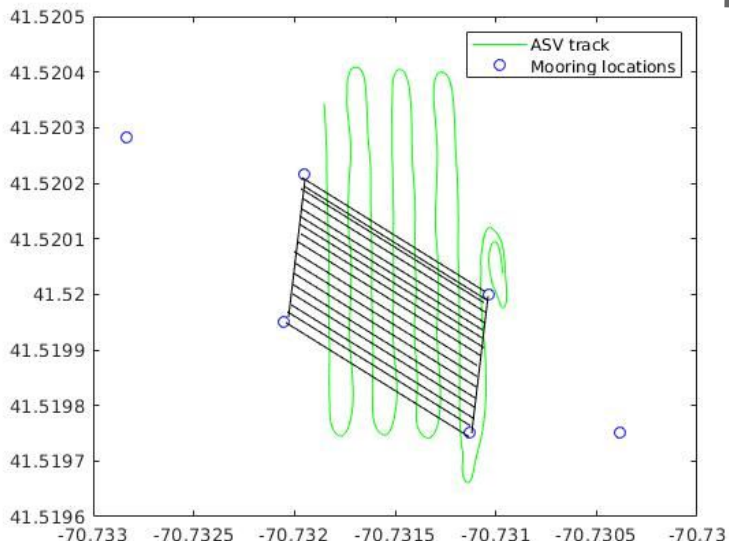
- ▶ Sensor comparison: low-cost works fine for infrastructure.



EK80 Data



Ping Data



What's next



- Data collection, hardware and software testing.
- Assess lower-cost sensors on lower-cost platforms (e.g. BlueRobotics Ping on WHOI JetYak).
- Development of real-time data assimilation, mapping, and autonomous adaptation.
- Advanced development on mapping tools to support management of kelp farms, answering questions such as:
 - Are longlines maintaining expected position and depth?
 - Is kelp growth uniform over the farm area?
 - Does extreme weather event affect kelp growth?
 - What is the optimal harvest date and sequence?
 - What is the impact of the kelp farm on

THANK YOU!

