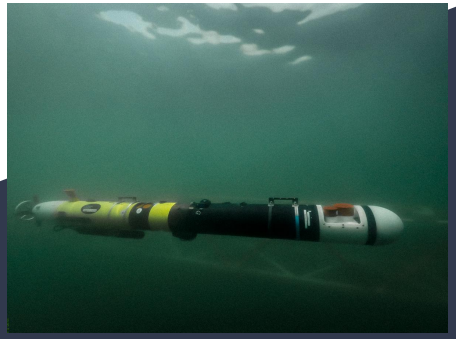
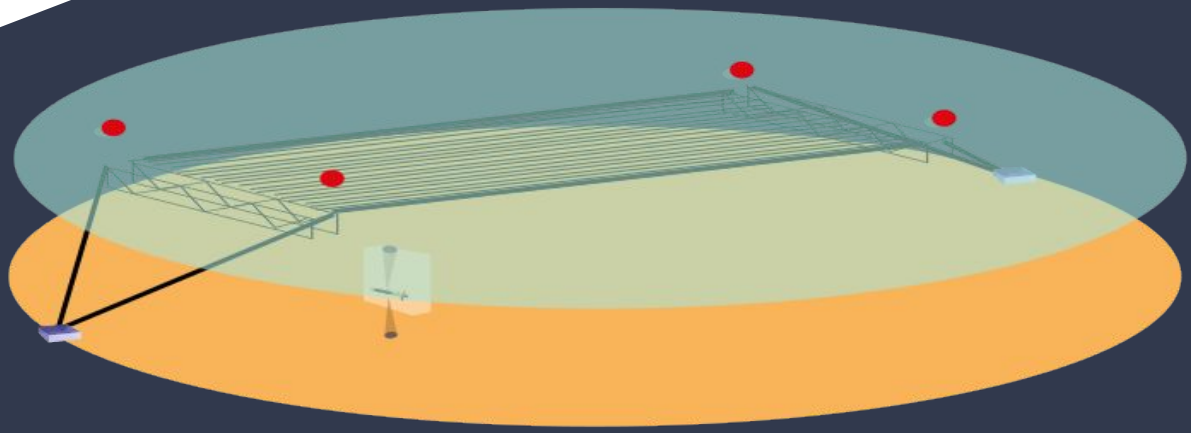
Autonomous underwater vehicle perception of infrastructure and growth for aquaculture

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

Woods Hole Oceanographic Institution





The Program: ARPA-E MARINER

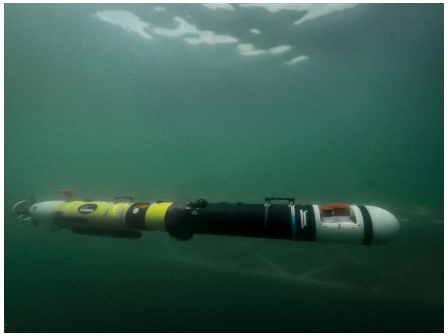
U.S. DOE Advanced Research Projects Agency-Energy (***ARPA-E***) Macroalgae Research Inspiring Novel Energy Resources (**MARINER**)

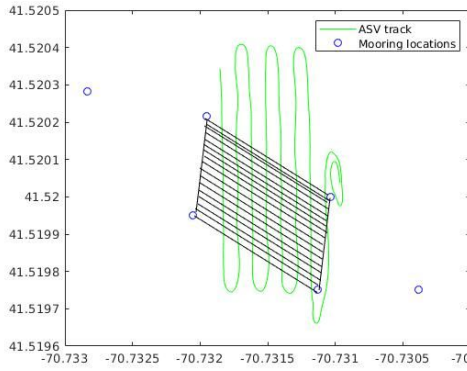
Objective: Fund technology development required for seaweed aquaculture to become a viable fuel source through off-shore aquaculture, including:

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

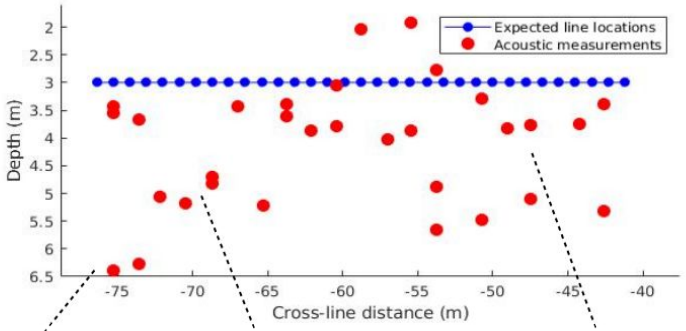
The Project: Cat. 4

Develop autonomous monitoring tools for aquaculture.

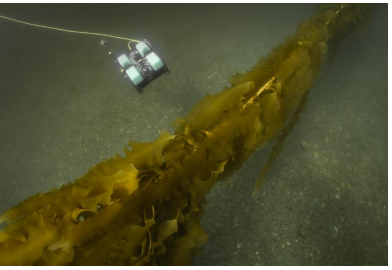




Manual inspection to autonomous inspection and mapping



Sensors and Vehicles

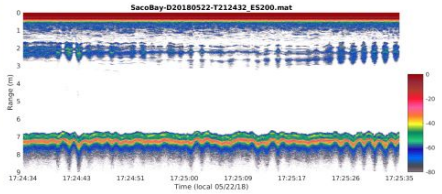


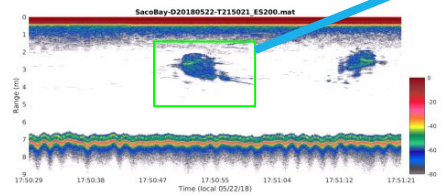
Sensor	Use	Vehicles
Up/Down ADCP, 600 kHz	Current estimation, navigation	Snoopy, Darter
INS	Navigation	Snoopy, Darter
NBOSI CT	Temperature, salinity	Snoopy, Darter
Optode O2	Dissolved oxygen	Snoopy, Darter
PAR	Light	Snoopy, Darter
Ecopuck triplet	Biological productivity	Snoopy
Suna V2 Nitrate	Dissolved 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

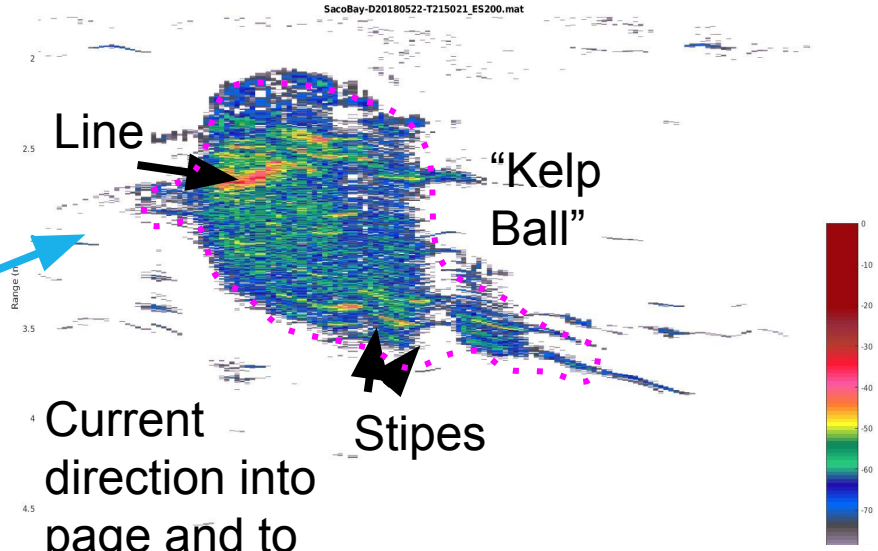
Acoustic sensors and data

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

EK80 data: Saco Bay

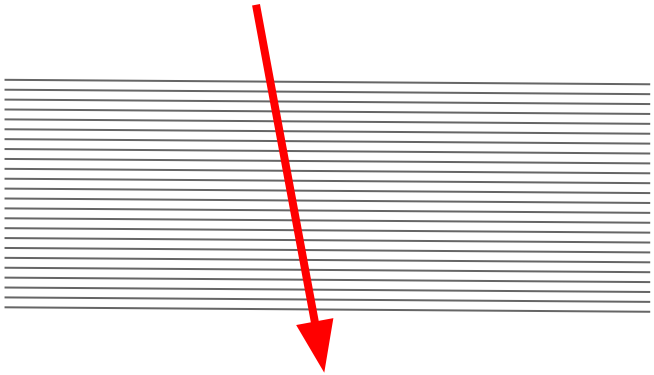


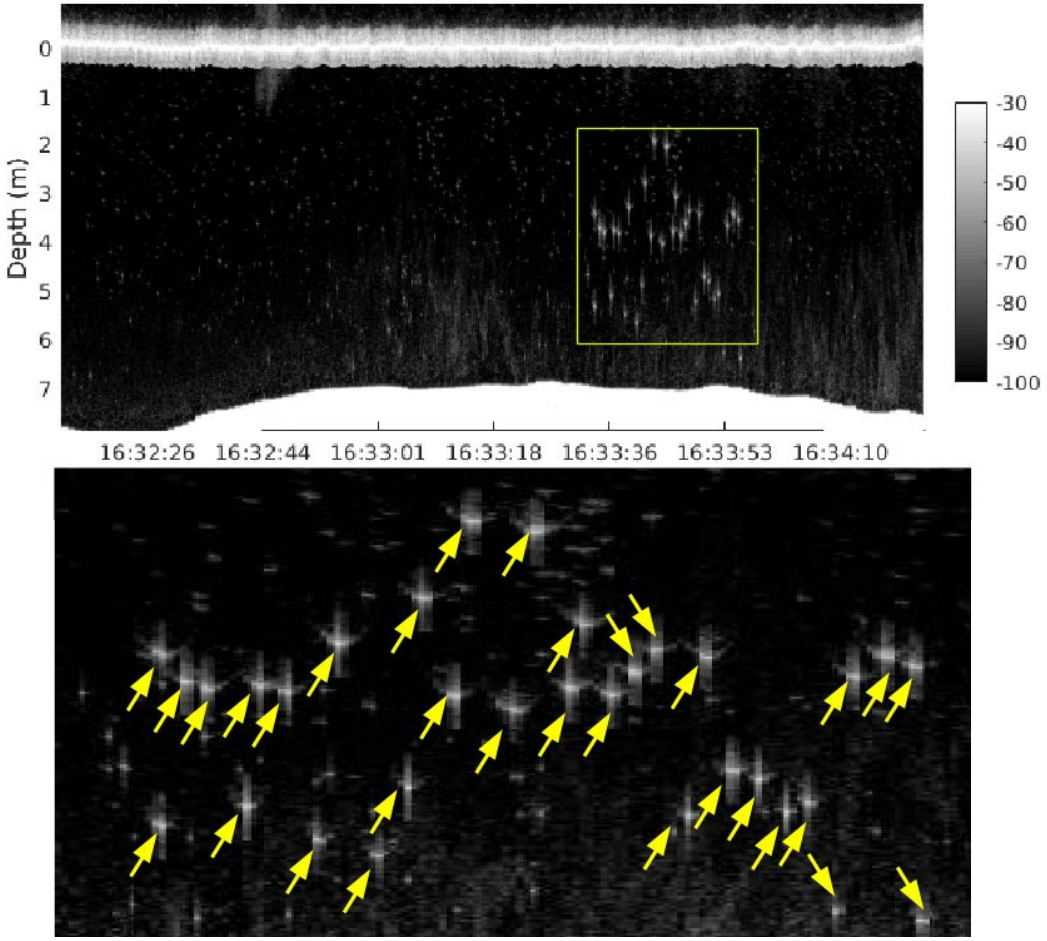




Acoustic sensors and data

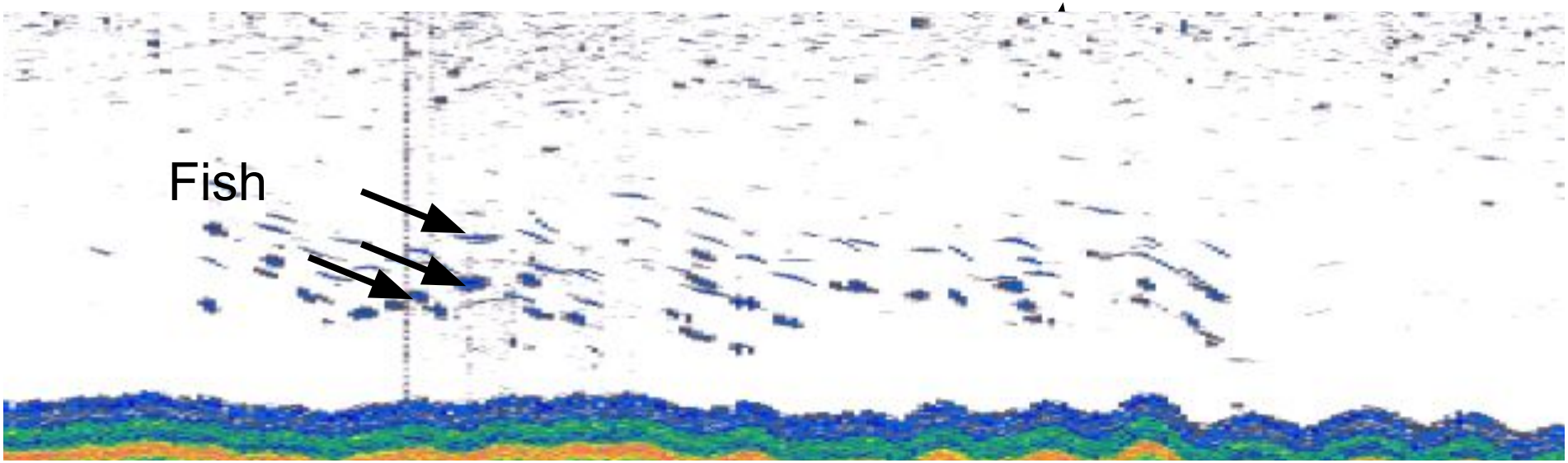
Acoustic scattering from longline array





Acoustic sensors and data

Fish visible in Saco Bay data- possible processing task

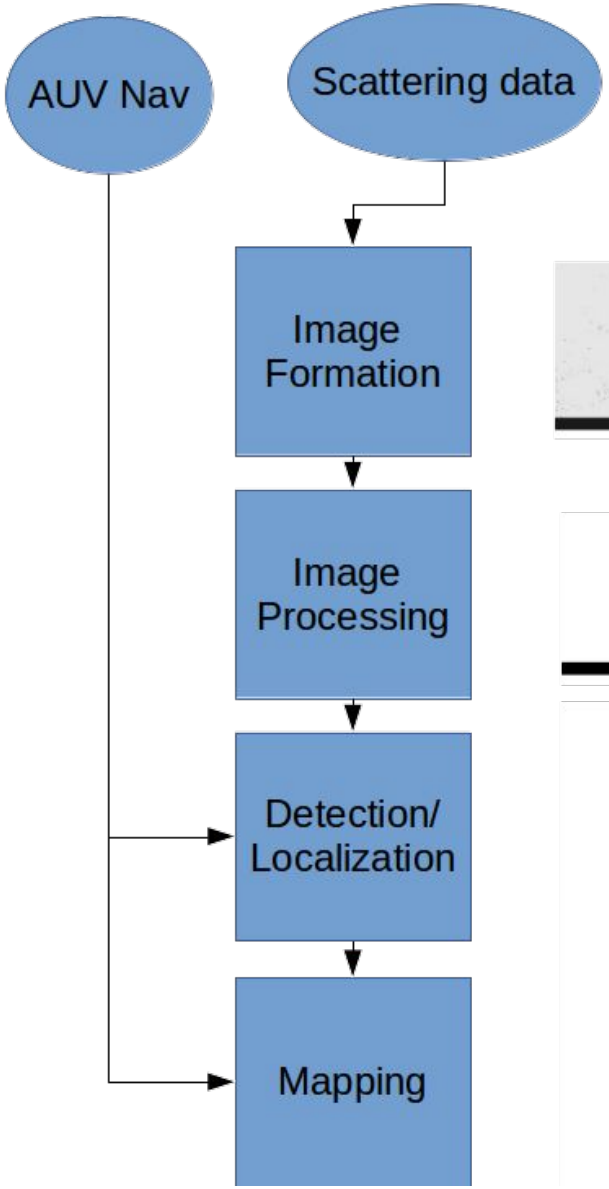


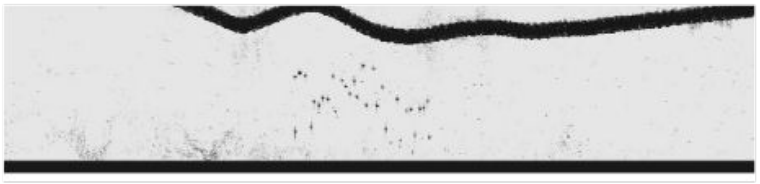
Acoustic processing

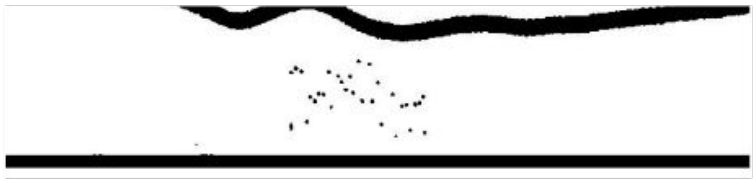
Objectives:

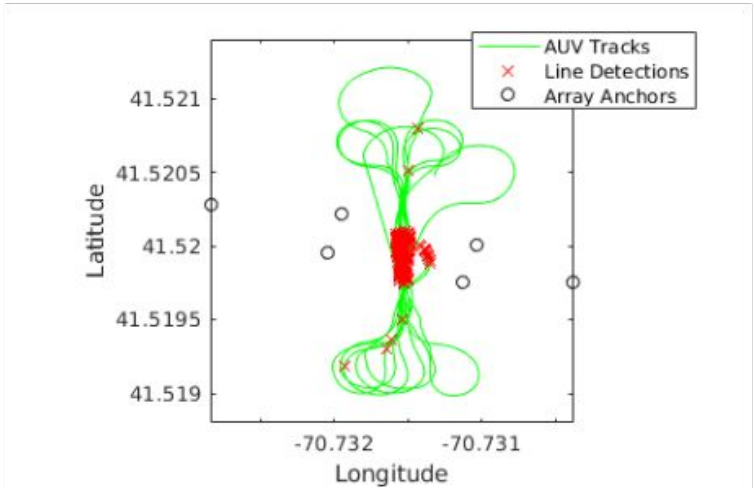
1. Map out infrastructure so we don’t hit it.
2. Use map to improve acoustic data collection.
3. Provide farmer with site-wide data on infrastructure, kelp growth, and maybe local marine biology.

Acoustic processing

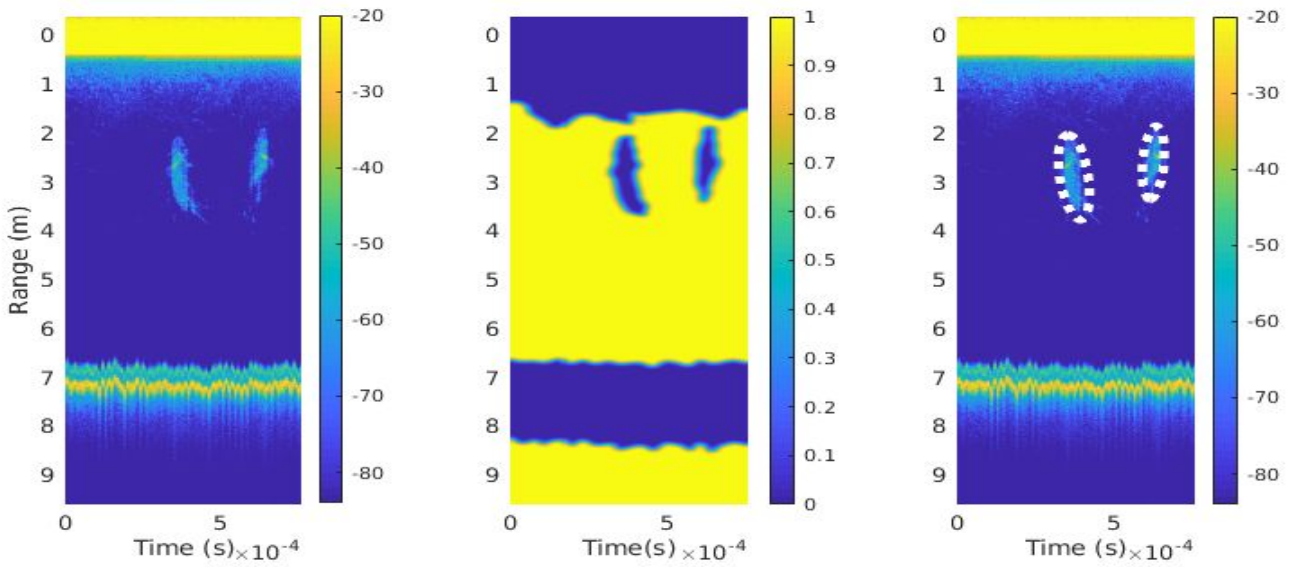






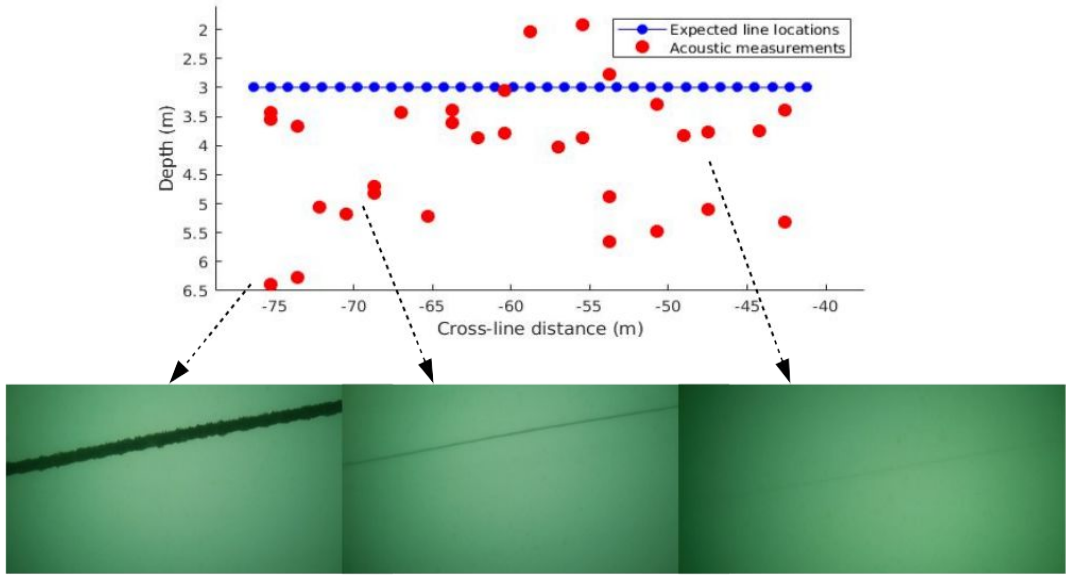


Acoustic processing



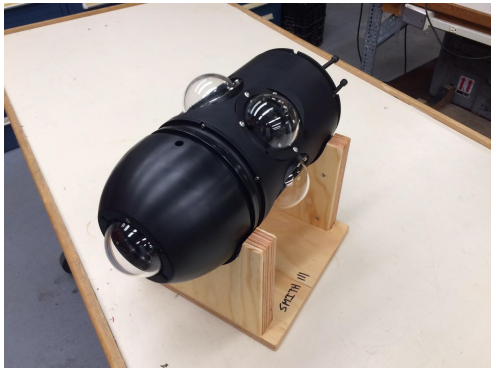
Kelp scattering estimation (above)

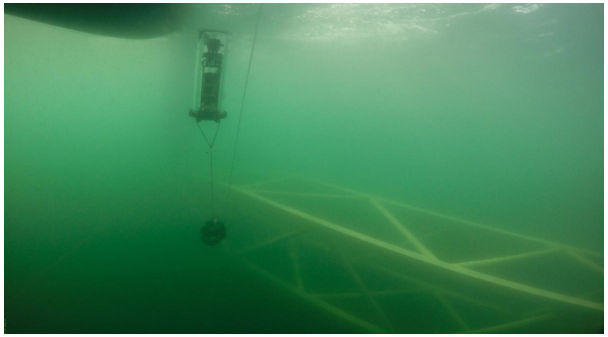
Mapping of longline locations to image data (right)

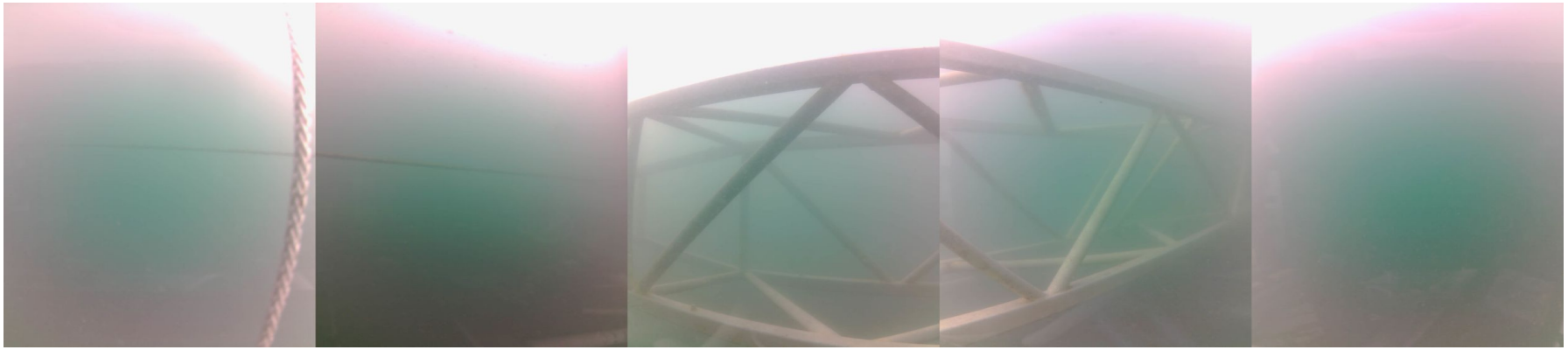


Kelpcam

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

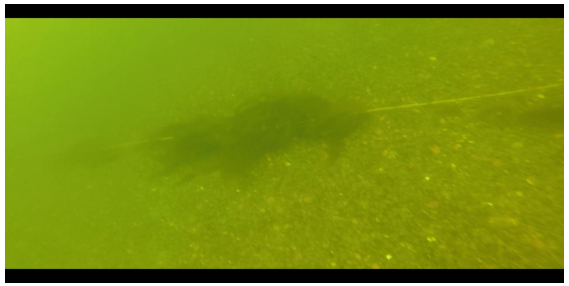






Camera processing

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



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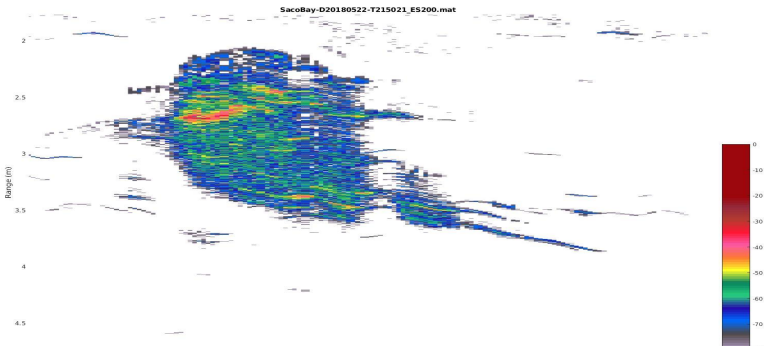
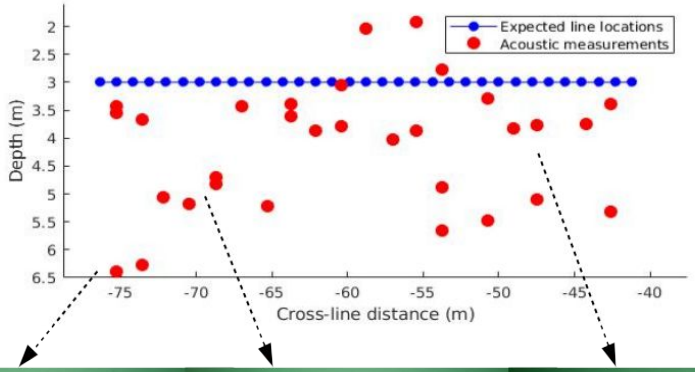
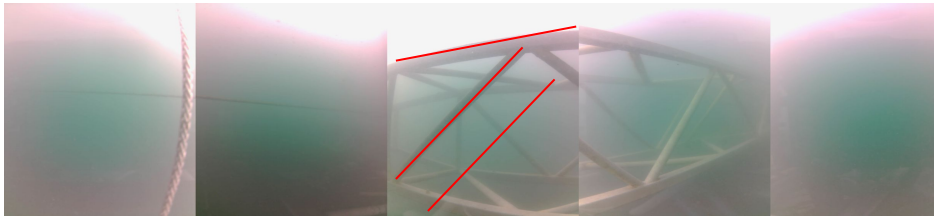


Perception

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.

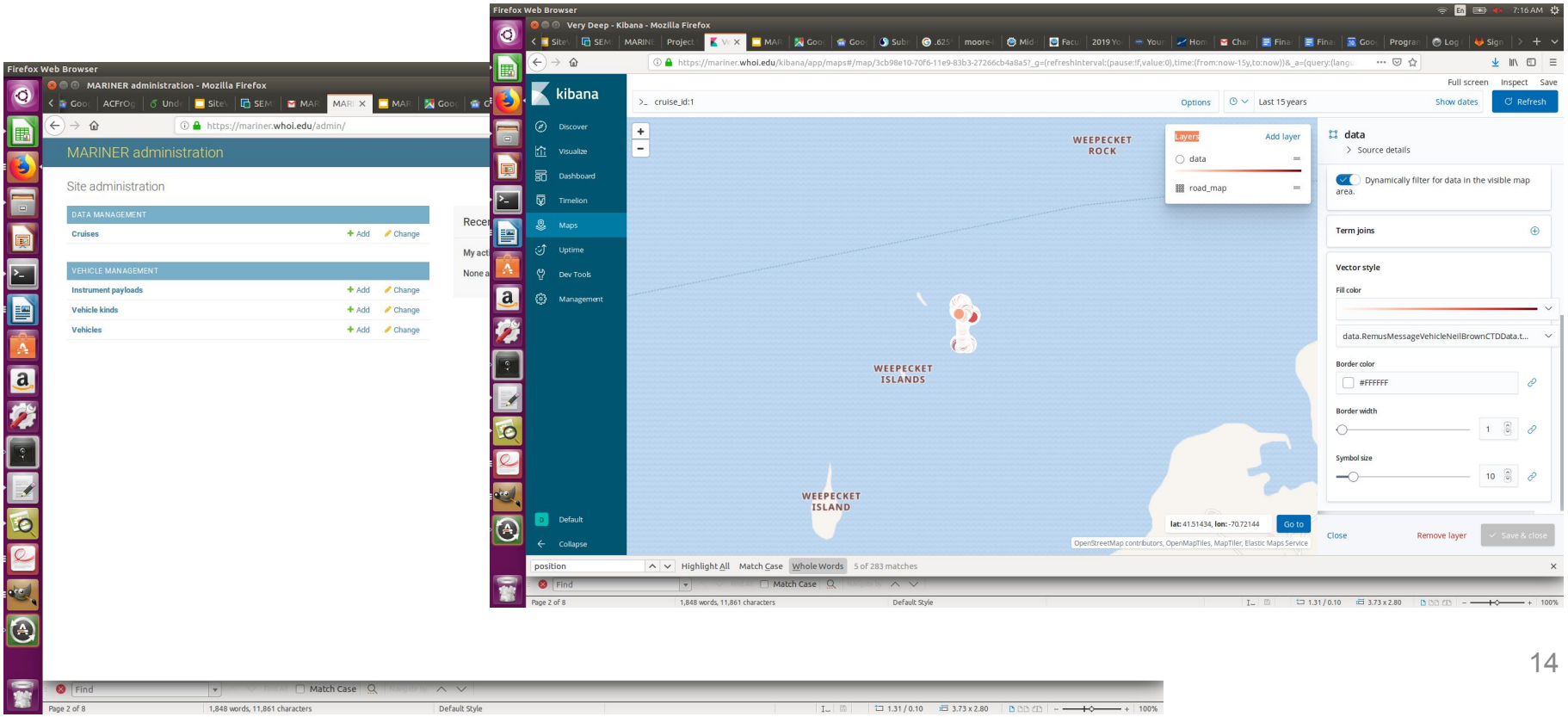




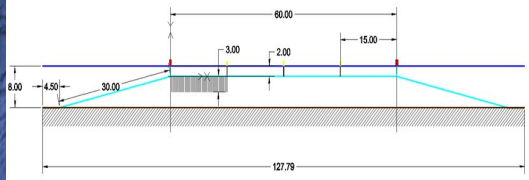
Data management

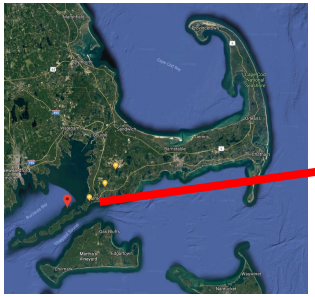
As of 5/1: database system is live!

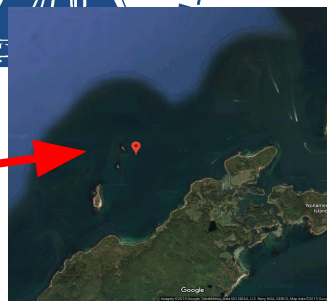
- Upload files, automatically parsed and added to data
- Display tools auto-linked and built in



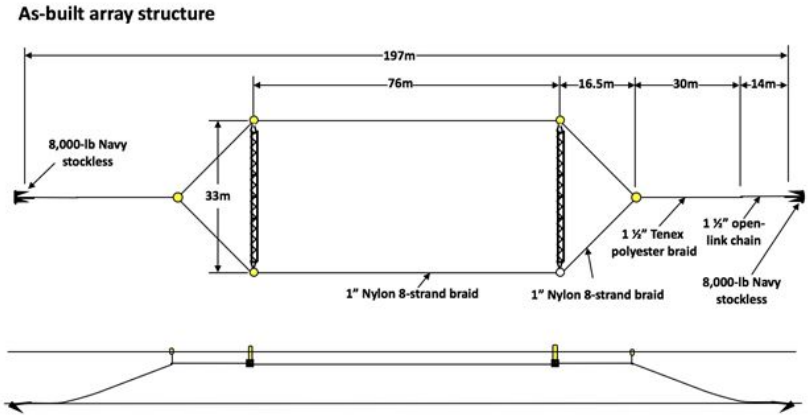
System deployments



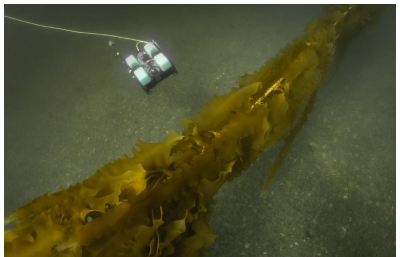


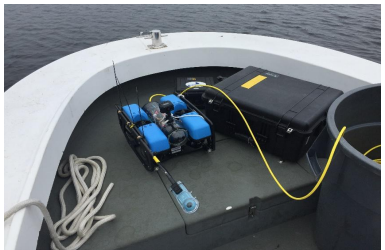


Saco Bay, ME (left): run by UNE
Buzzards Bay, MA (right): run by WHOI
Gulf of Maine (not shown): run by UNH



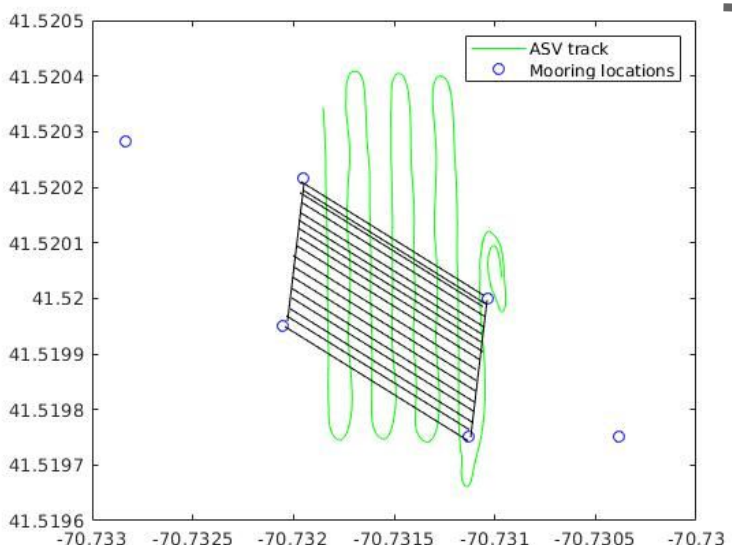
Spring 2019: surveys of UNE, UNH, Buzzards Bay farm site.

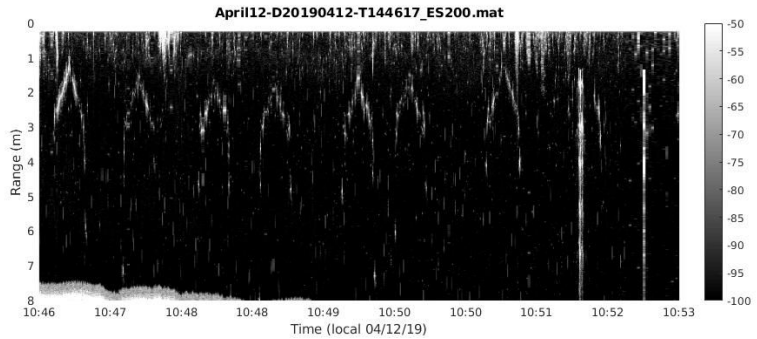




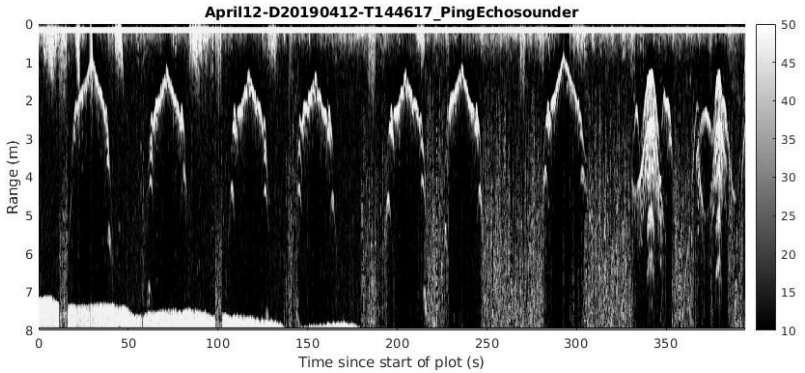
Exploring low-cost options

- 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!