

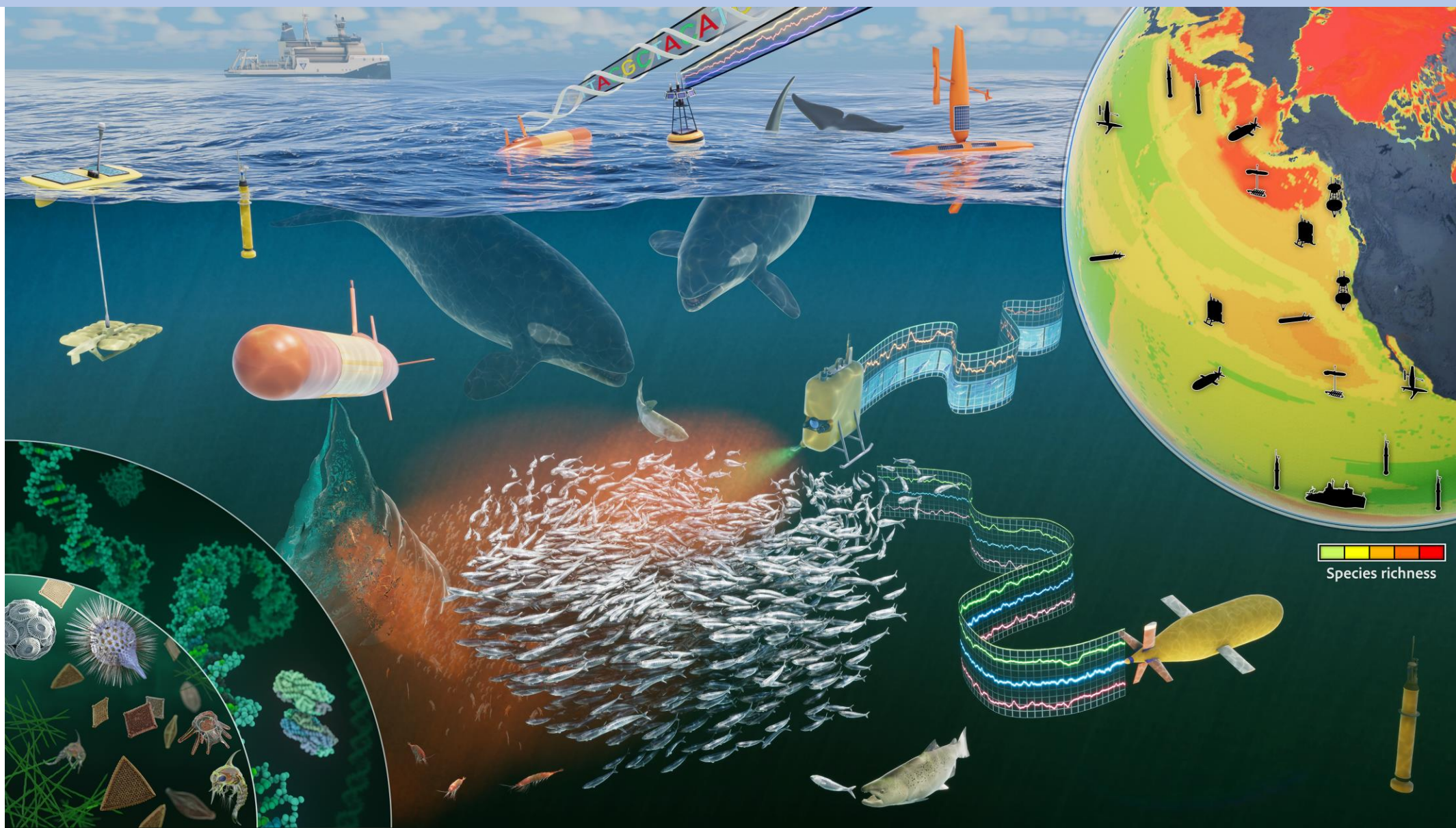
A photograph of two humpback whales breaching the ocean surface. The whales are dark, with visible white patches and barnacles on their backs. In the background, a large, long building with a grey roof and many windows is visible. Several birds are flying in the sky above the building.

FIDO: An Innovative Autonomous Instrument for Environmental DNA Sampling

Kevan Yamahara, Scott Jensen, Adam Sepulveda, Enoch Nicholson, James Birch

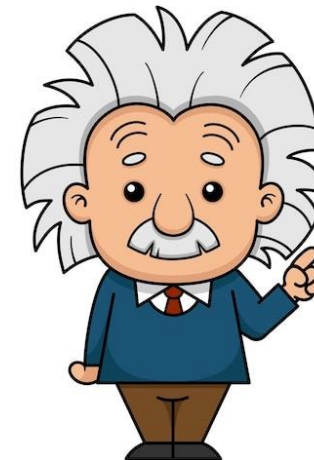
2nd Australian & New Zealand Environmental DNA Conference
February 20th, 2025

Conceptualizing is easy.....



Large Challenges to Overcome

- Conventional wisdom of decades long traditional laboratory practices
- Fluid handling over 6 orders of magnitude (Liters to μL s)
- Diverse user needs, expectations and environments



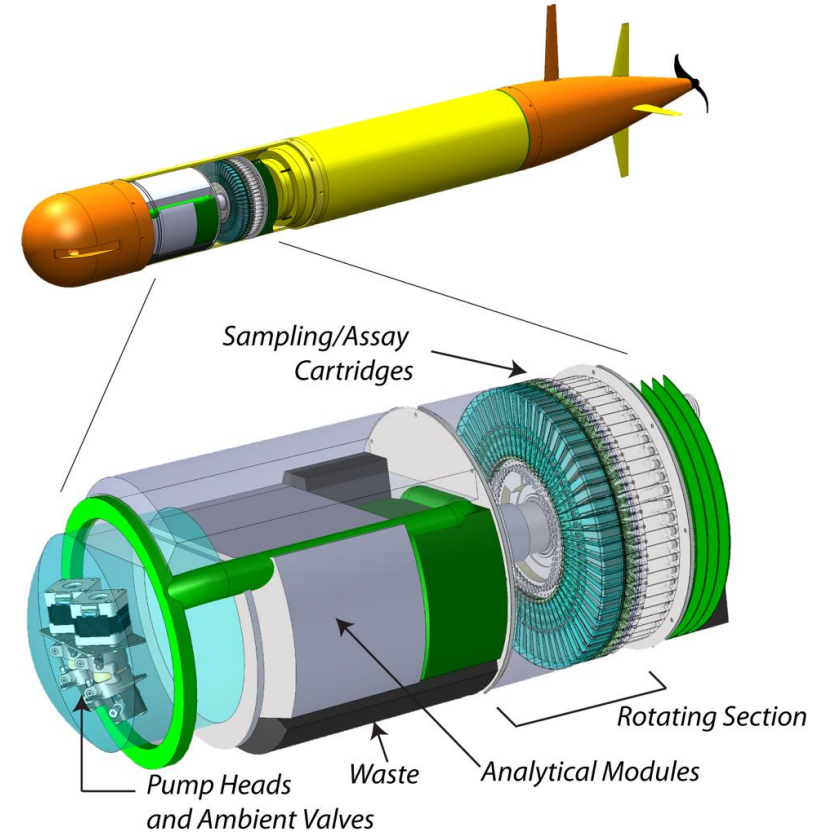
0.45 + 5.0 μm filters,
100 mL to 2L,
SHA arrays + PCR +
sequencing

Environmental Sample Processor

2nd Generation ESP



3rd Generation ESP



Specific design requirements:
Submerged or Autonomous Vehicle Deployments with *in situ* analysis

Sampling robots have enabled good science

Ottesen, E.A., et al. Metatranscriptomic analysis of autonomously collected and preserved marine bacterioplankton. 2011. ISME Journal 5: 1881-1895

The **ISME** Journal
Multidisciplinary Journal of Microbial Ecology

Saito, M.A., et al. 2011. Examination of microbial proteome preservation techniques applicable to autonomous environmental sample collection. Frontiers in Aquatic Microbiology. 2: 215.

 **frontiers**
in Microbiology

Nowinski, B., et al. Microdiversity and temporal dynamics of marine bacterial dimethylsulfoniopropionate genes. 2019. Environmental Microbiology 21(5): 1687-1701.

**environmental
microbiology**

Yamahara, K., et al. *In situ* autonomous acquisition and preservation of marine environmental DNA using an autonomous underwater vehicle. 2019. Frontiers in Marine Science. 6:373.

 **frontiers**
in Marine Science

Den Uyl, P., et al. Lake Erie field trials to advance autonomous monitoring of cyanobacterial harmful algal blooms. 2022. Frontiers in Marine Science. 9:1021952.

Sepulveda, A.J., et al. 2020. Robotic environmental DNA bio-surveillance of freshwater health. Scientific Reports 10:14389.

nature
SCIENTIFIC
REPORTS

**Science
Robotics**
AAAS

Zhang, Y., et al. A system of coordinated autonomous robots for Lagrangian studies of microbes in the oceanic deep chlorophyll maximum. 2021. Science Robotics 6: eabb9138.

Truelove, N.K., et al. 2022. Expanding the temporal and spatial scales of environmental DNA research with autonomous sampling. Environmental DNA. 4: 972-984.

Environmental DNA
Open Access
Dedicated to the study and use of environmental DNA for basic and applied sciences



Lessons learned from field demonstrations

- Every user/deployment has different requirements
- Many collaborators just want samples not analysis
- Collect samples over extended periods of time
- End Users want access and control of instrumentation
- Instruments need to be SIMPLE, CHEAPER & EASY to deploy



Freshwater Lotic Systems



ESP Sampler



- Terrestrial based deployments (non-submerged)
- Portable, easy to deploy and re-supply
- Minimum 160 samples
- Interactive communication and control

Printer Approach

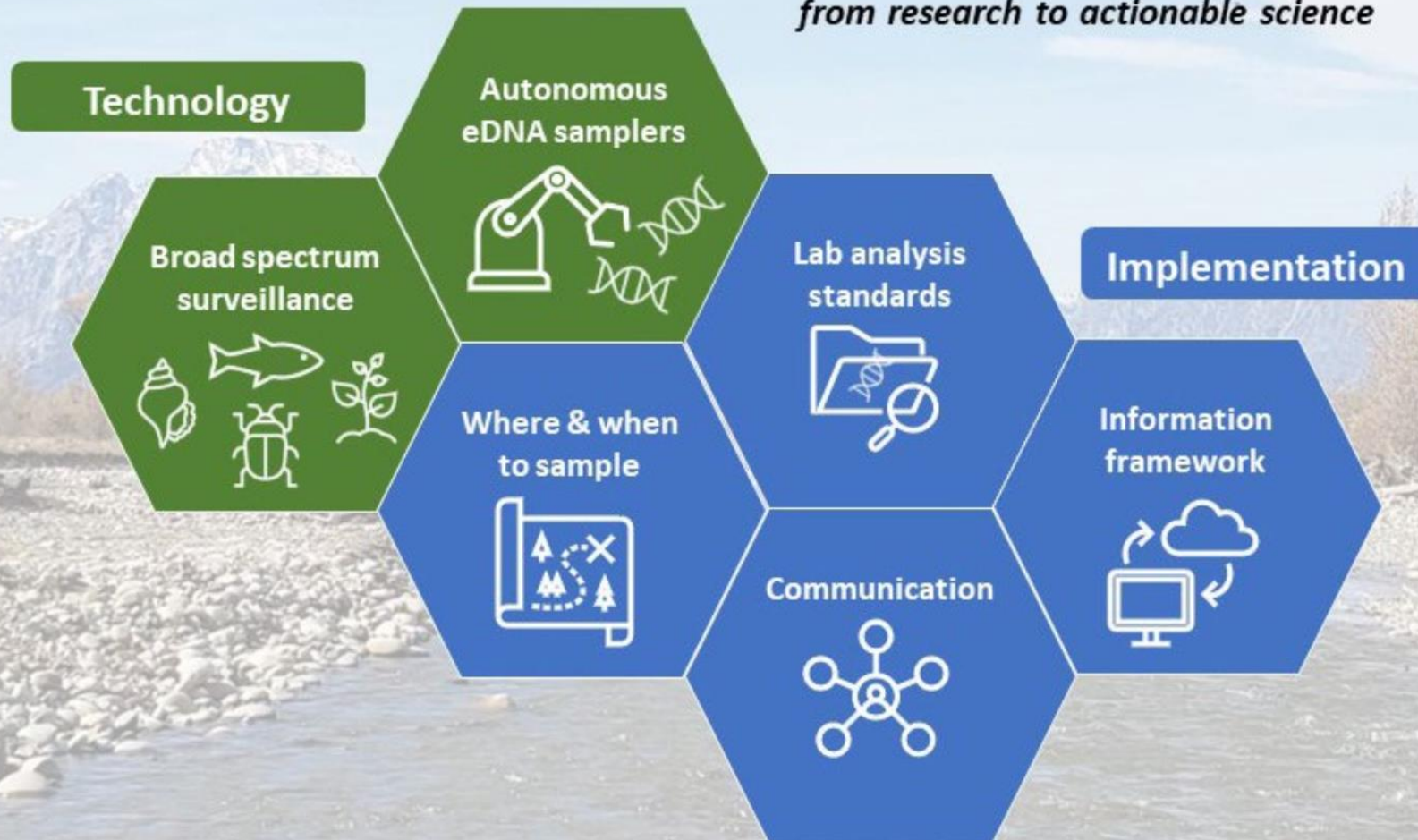
- Easy to Setup
- Easy to Use / Operate
- Easy to Maintain



USGS READI-NET PROGRAM

Rapid eDNA Assessment and Deployment Initiative & Network

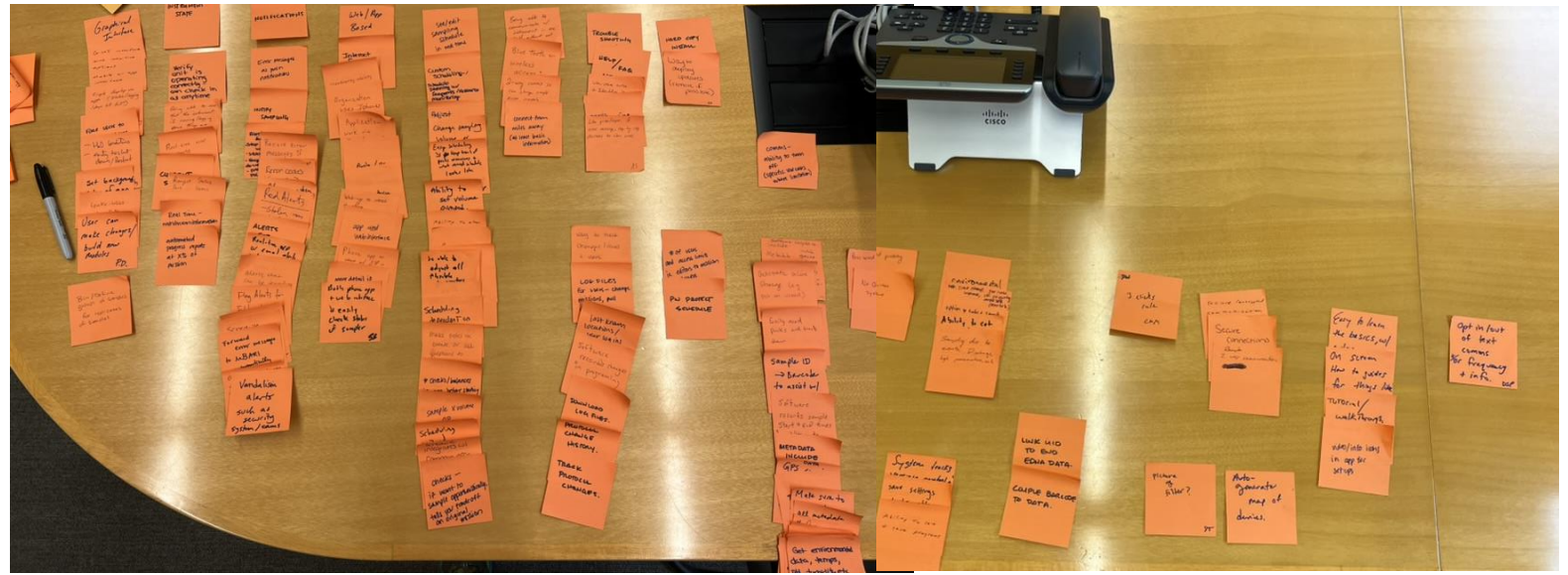
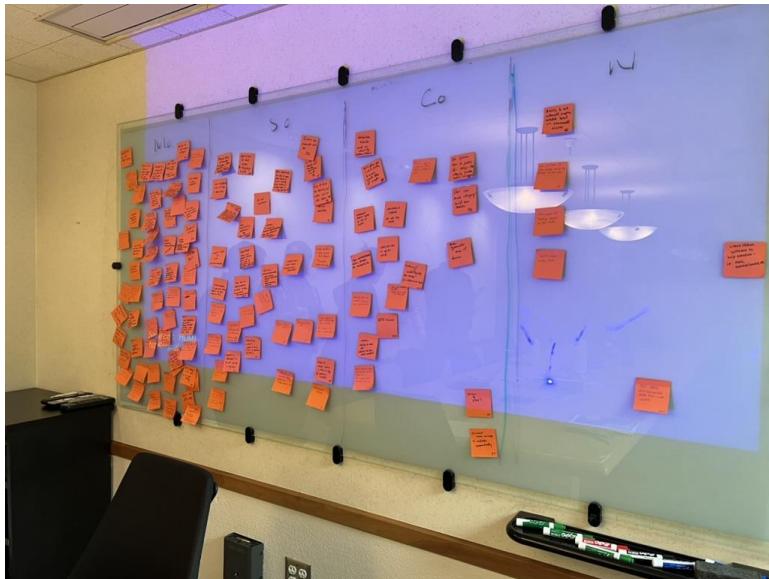
*transitioning eDNA biomonitoring
from research to actionable science*



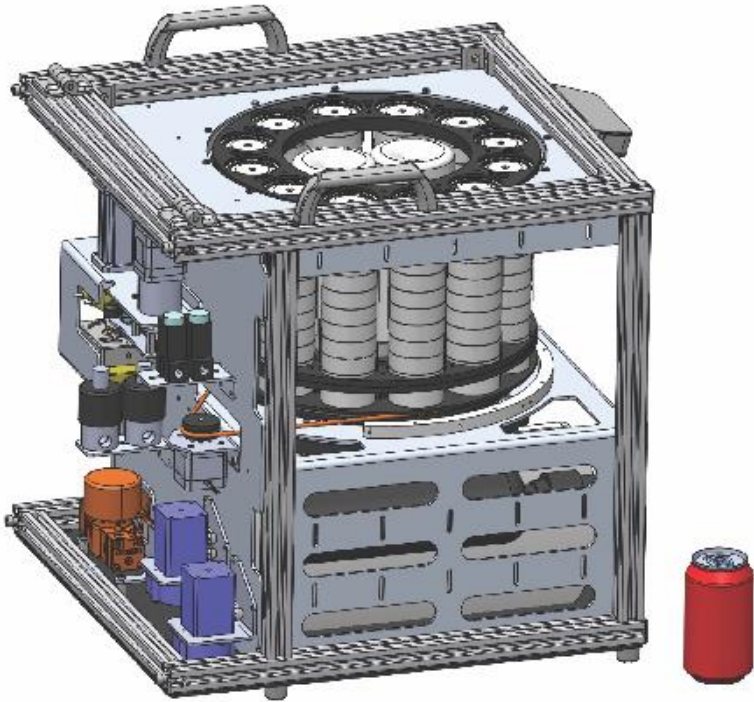
Courtesy of Adam Sepulveda - USGS

USGS READI-NET PROGRAM – MoSCoW

Must have, Should have, Could have or Won't have Prioritization

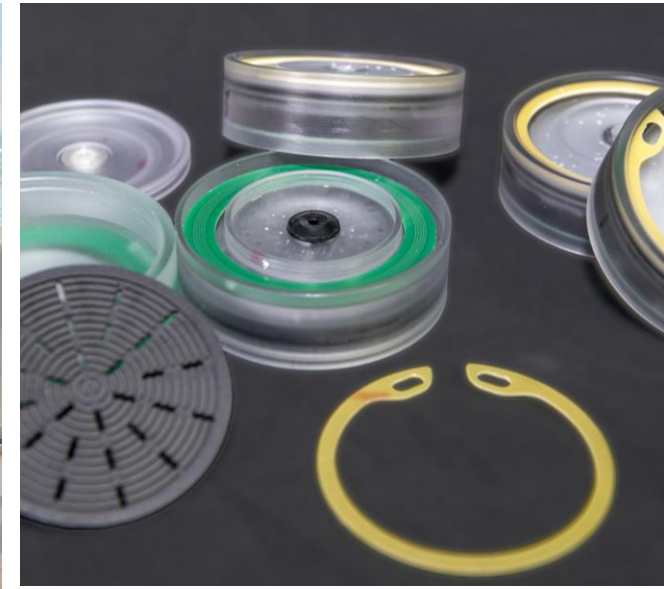
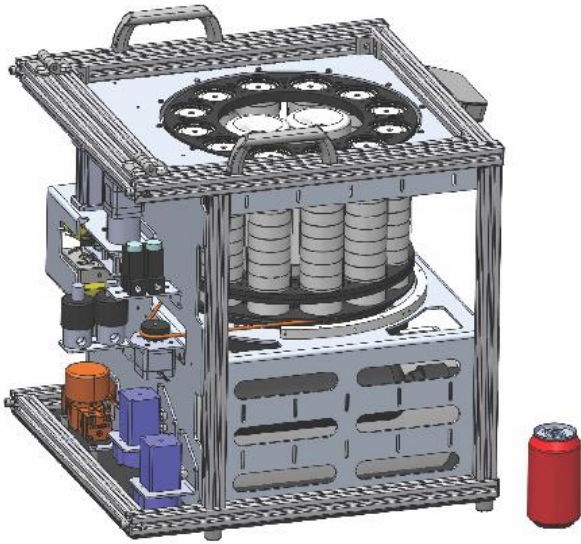


FIDO: Filtering Instrument for DNA Observations

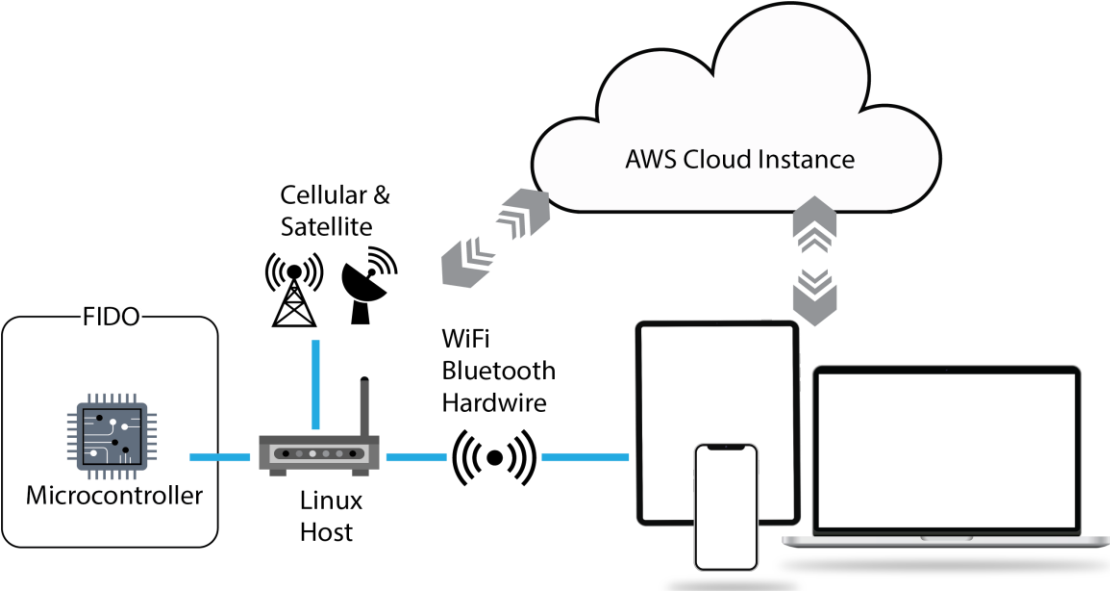


- 144 samples – 47mm Membranes
- Liquid Preservation
- Liquid Decontamination
- Remote Command & Control GUI
 - Wifi, Cellular and Satellite
- Sample metadata encoding
- Simple servicing and replenishment

FIDO: Filtering Instrument for DNA Observations



Communications and Web Interface



prod.readinet.org

Device 528d7af6

Device

Schedule

Management

Events

528d7af6

Device Status

Timezone
UTC

Number of Stocked Pucks
144

Device Health

Last Connectivity Ping Received
August 8, 2024 3:13 PM (Coordinated Universal Time UTC+00:00)

Last Sampler Self Check Performed
August 8, 2024 3:10 PM (Coordinated Universal Time UTC+00:00)

Upcoming Events

- No Events Scheduled

Latest Log Messages

```
[Errno 2] could not open port /dev/ttyUSB0: [Errno 2] No such file or directory: '/dev/ttyUSB0'  
[Errno 2] could not open port /dev/ttyUSB0: [Errno 2] No such file or directory: '/dev/ttyUSB0'  
[Errno 2] could not open port /dev/ttyUSB0: [Errno 2] No such file or directory: '/dev/ttyUSB0'  
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[Errno 2] could not open port /dev/ttyUSB0: [Errno 2] No such file or directory: '/dev/ttyUSB0'  
[Errno 2] could not open port /dev/ttyUSB0: [Errno 2] No such file or directory: '/dev/ttyUSB0'
```

See all events

Current Location: 36.802151, -121.788162

Rock Pi Software Version
readinet-server (02a9149)

GUI Management and Scheduler

Device 528d7af6

Device

Schedule

Management

Events

Management

Sensor Management

Default Volume

1.0

Liters

Default Filter Porosity

0.5

µLiter

Scheduled Events

Enabled

☒ Next Scheduled: February 13, 2025 5:30 AM (Coordinated Universal Time UTC+00:00)

Sensor Actions

Take Sample Now

Restock Sampler

Cancel Sample

Truncate Sampler

Decontaminate

Reset Sampler

Location

Latitude

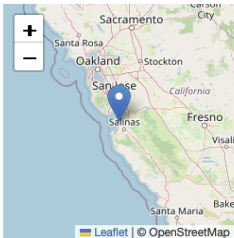
36.802151

Longitude

-121.788162

Notes

Internal notes



Device Management

Device Name

528d7af6

Device Timezone

UTC

Local WiFi SSID

readinet-528d7af6

Local WiFi Password

readinet

Uplink Internet

Uplink Type

WiFi/Hotspot

Uplink Wifi SSID

MBARI-Guest

Uplink Wifi Password

vampsqu1d

Remote Management

Adopted to Cloud Management

Adopt to New Organization

Rock Pi Software Version
readinet-server (02a9149)

Device 528d7af6

Schedule

Management

Events

< today > UTC

Feb 9 – 15, 2025

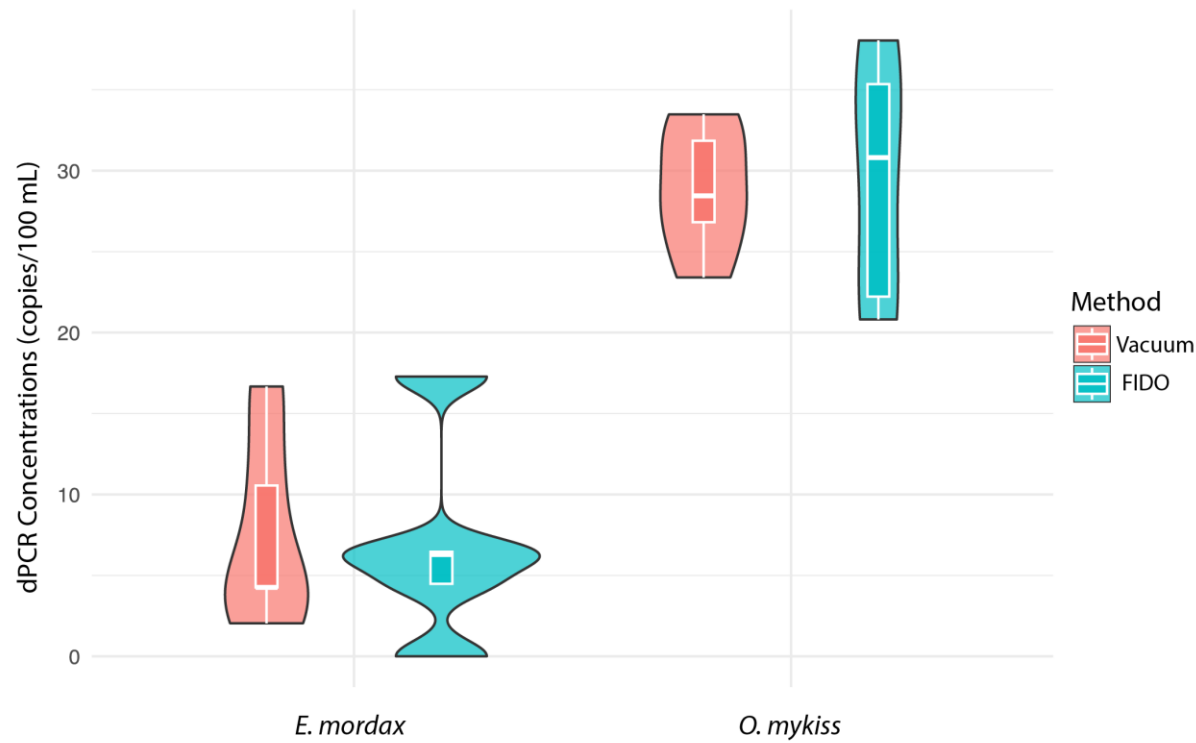
day week month

	Sun 2/9	Mon 2/10	Tue 2/11	Wed 2/12	Thu 2/13	Fri 2/14	Sat 2/15
3am							
4am							
5am							
6am					Scheduled Sample/Decon	Scheduled Sample/Decon	
7am							
8am							
9am							
10am							
11am							
12pm							
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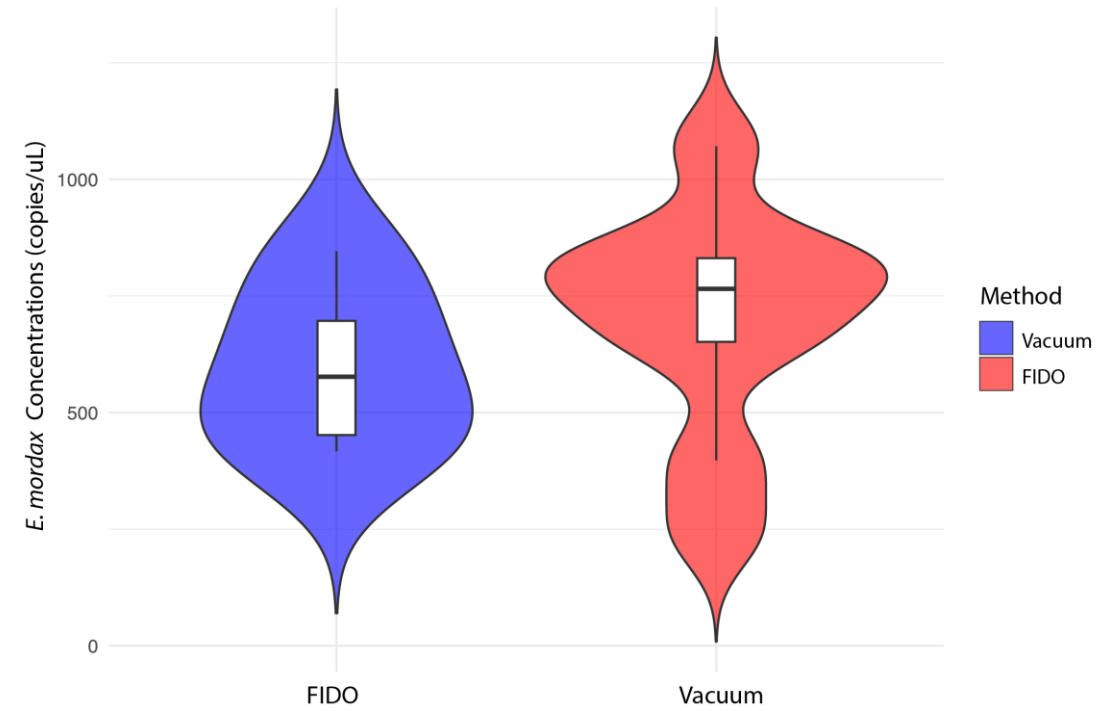
Rock Pi Software Version
readinet-server (02a9149)

FIDO dPCR and qPCR Validations

dPCR Anchovy and Rainbow Trout

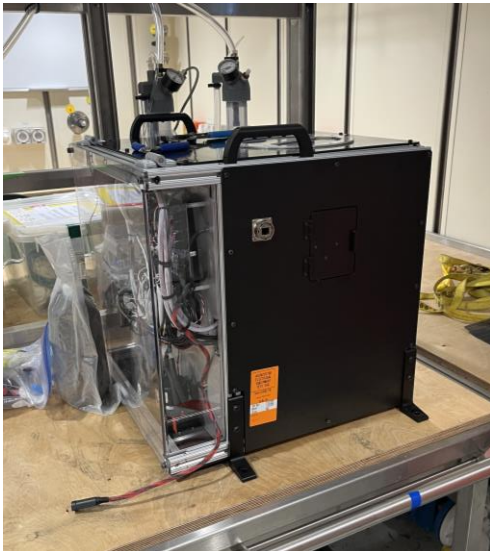
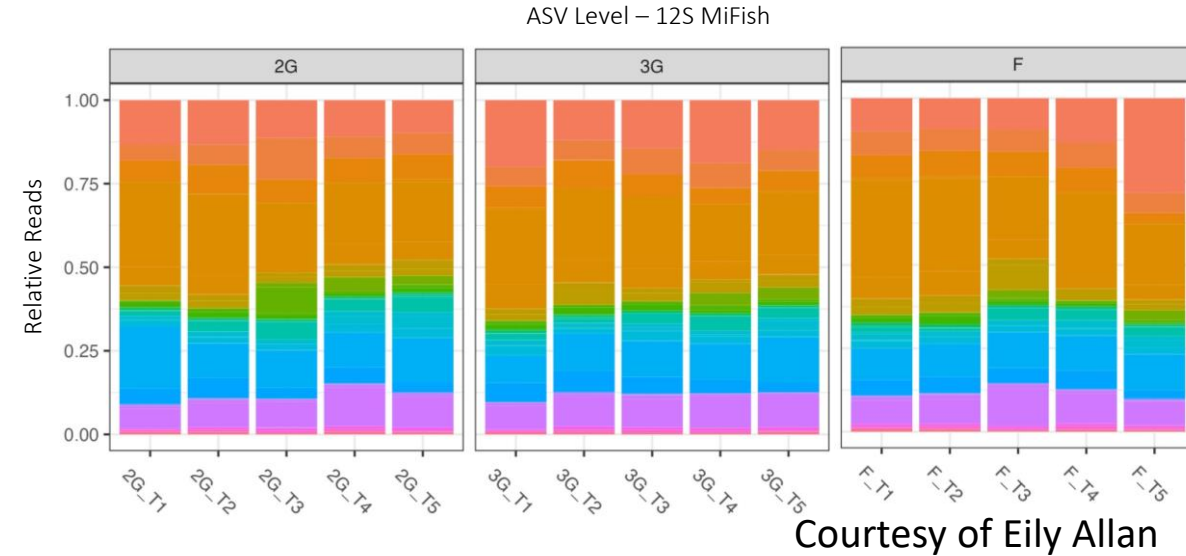


qPCR Anchovy



Next Steps

- Validation is continuing
 - qPCR and metabarcoding
- READi-net Implementation in 2025
 - 10 production units are currently being built

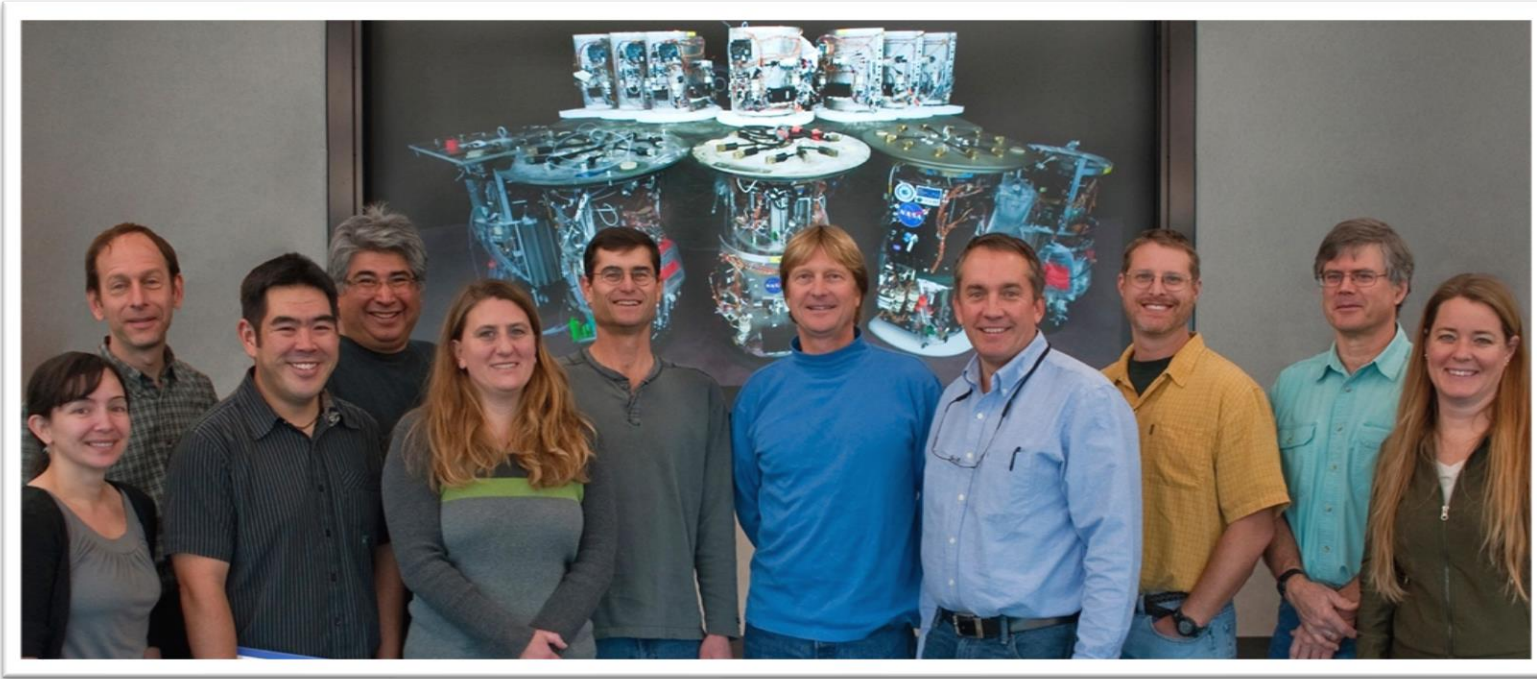


- Integration on-board research vessels

Take Aways

- There is no single “silver bullet” instrument for each application or use case
 - Each instrument is designed for an intended purpose with specific design requirements
- Instruments should be co-designed for intended use cases / applications
 - Or applications should be matched to appropriate instrumentation
- Proper validation build confidence in data and reduces operational risks

Acknowledgements



MBARI ESP Team



Adam Sepulveda

