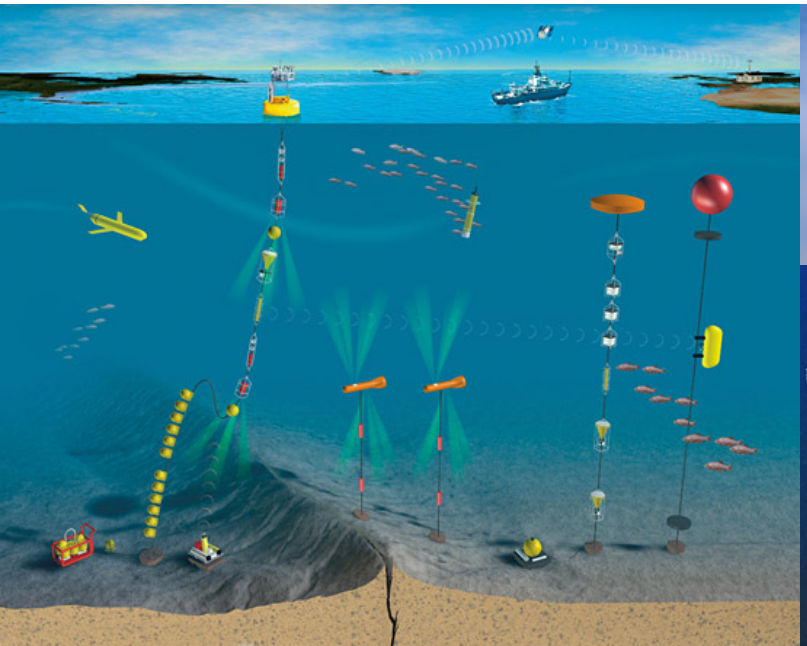
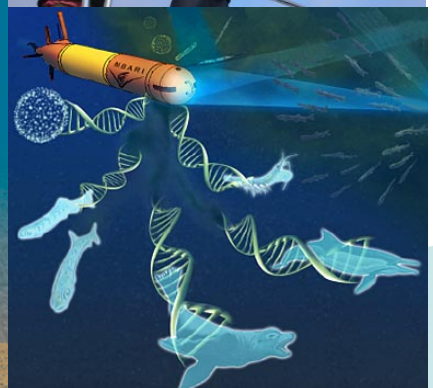
Science Enterprise Update

New research technologies, modeling, and other strategies in development to improve science and stock assessments





Cisco Werner, PhD
Director, Scientific Programs
and Chief Science Advisor

MAFAC
Portland, OR
June 26, 2018

Outline

- Implementation of new technologies to advance fisheries stock assessments is a major focus

- New survey designs
  - Combining surveys
  - Use of UAVs, drones

- Stock Assessment Improvement Plan (SAIP)
  - Methods
  - Schedules

- Fishing Effort Survey (FES)

- Science response on Resilience recommendations

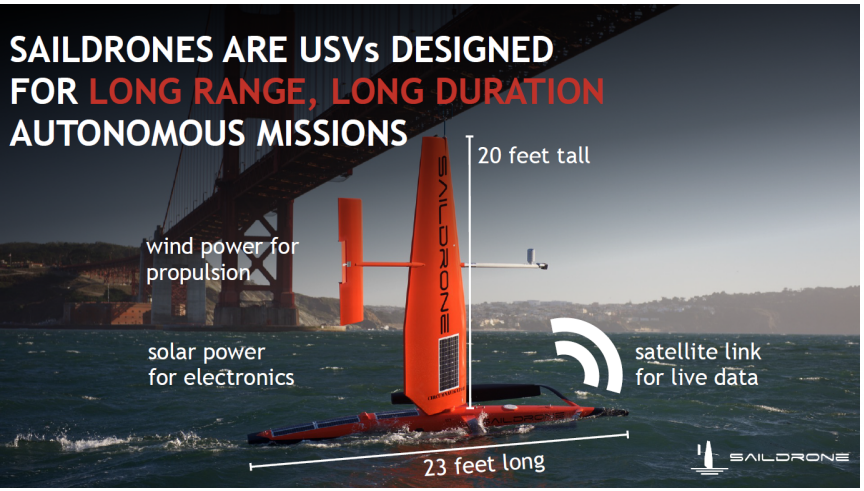
1. Robotic Vehicles & Autonomy

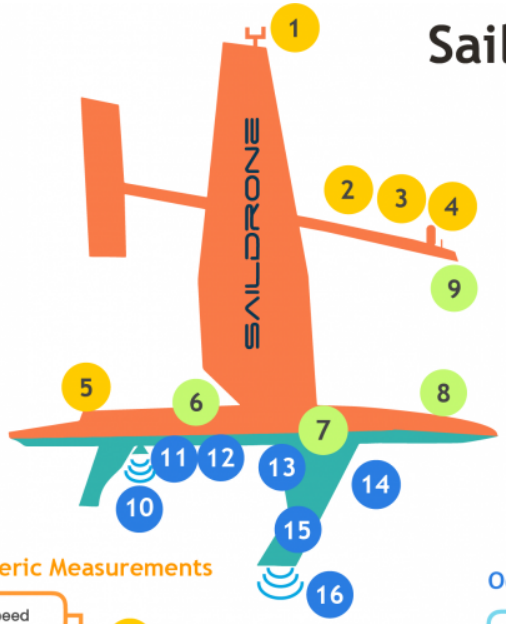
2. Automated Image Analysis & Artificial Intelligence

3. Aging and Growth

4. ’omics

Saildrone Sensor Suite





Specifications

Length: **7 m**
Height: **4.6 m (above water line)**
Draft: **2 m**
Weight: **545 kg (fully loaded)**
Speed: **Transit - 3 Kt, Max - 8 Kt**
Payload Power: **30 W (steady state)**
Payload Capacity: **100 kg**
Max Deployed Duration: **12 months**
Longest Voyage: **16,100 km**

Atmospheric Measurements

- Wind Speed, Wind Direction — 1 **Anemometer @ +4.5m** Gill WindMaster 3D Ultrasonic 20Hz
- Sunlight — 2 **Sunshine Pyrometer @ +2.2m** Delta-T Devices SPN1; 3 **Pyrometer +2.2m** Eppley PSP & PIR
- Air Temperature, Humidity — 4 **Meteorlogical Probe @+2.2m** Rotronic HC2 - S3 with rad shield
- Air Pressure — 5 **Digital Barometer @ +0.2m** Vaisala BAROCAP® PTB210

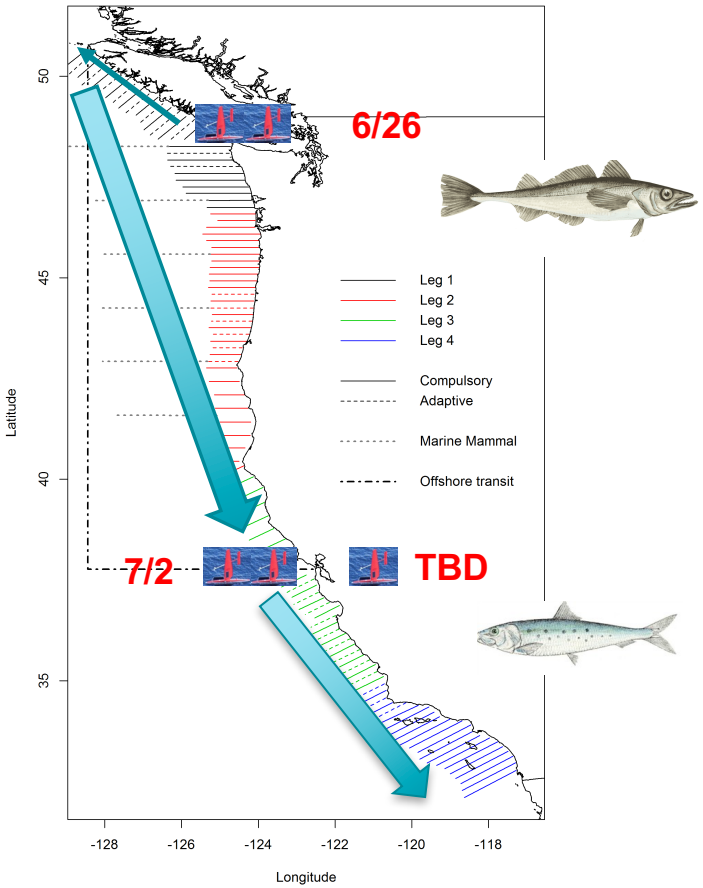
Oceanic Surface Measurements

- Wave Height & Period — 6 **Dual GPS & IMU** Vectornav / KVH
- pCO_2 — 7 **CO_2 System @ +0.3m** PMEL ASVCO$_2$
- Magnetic Field — 8 **Magnetometer @ 0m** Barrington MAG 648
- Skin Temperature — 9 **Pyrometer @ +2.2m** Heitronics KT15 II

Oceanic Subsurface Measurements

- Ocean Current — 10 **ADCP @ -0.2m** Teledyne RDI 300 kHz Workhorse Sentinel
- Chla, CDOM Concentration, Red Backscatter — 11 **Fluorometer** Sea-Bird Scientific WET Labs Eco Triplet
- Dissolved Oxygen — 12 **Oxygen Optode @ -0.5m** Aanderaa 4831
- pCO_2 — 13 **CO_2 System @ -0.5m** PMEL ASVCO$_2$ Sea-Bird Scientific SBE PRAWLER Honeywell Durafet
- Water Temperature, Salinity — 14 **Thermosalinograph CTD @ -0.5m** Teledyne RDI Citadel TS-NH
- Marine Mammal Presence — 15 **Passive Acoustic Recorder** Greenridge Sciences Inc. Acousonde
- Fish Biomass, Bathymetry — 16 **Scientific Echosounder @ -2.5 m** Simrad 38 kHz WBT-mini; **Multi-beam Sonar @ -2.5 m** Norbit iWBMS

2018 Summer Coast-wide Survey Using Unmanned Surface Vehicles (USVs)



5 Saildrones:

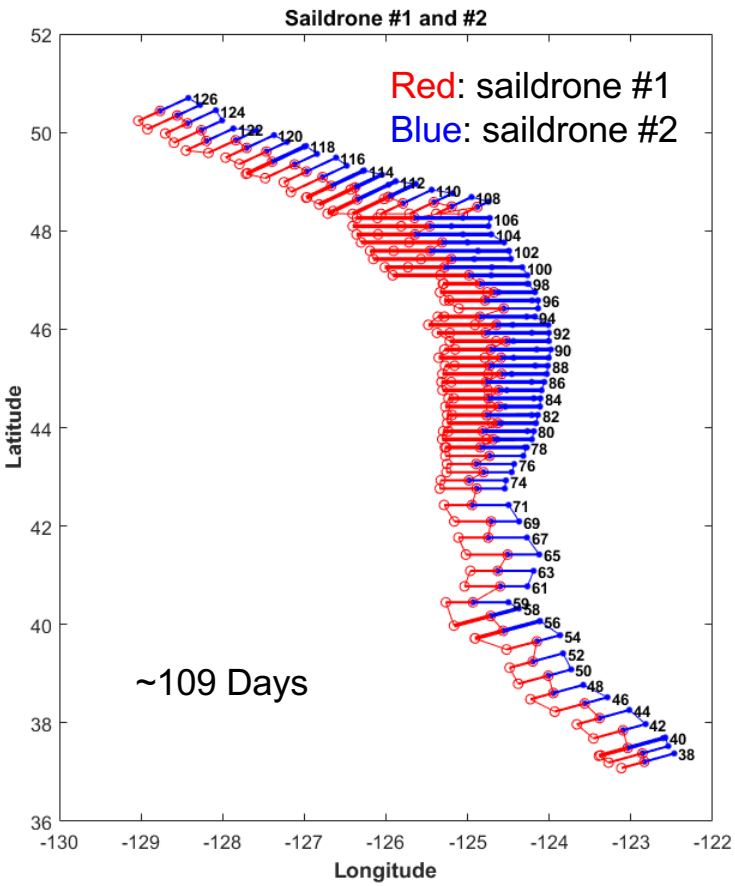
- 4 running transects (NWFSC)
  - 2 in a pair (North & South)
- 1 nearshore to 10 m bottom depth (SWFSC)

Same transects as Lasker:

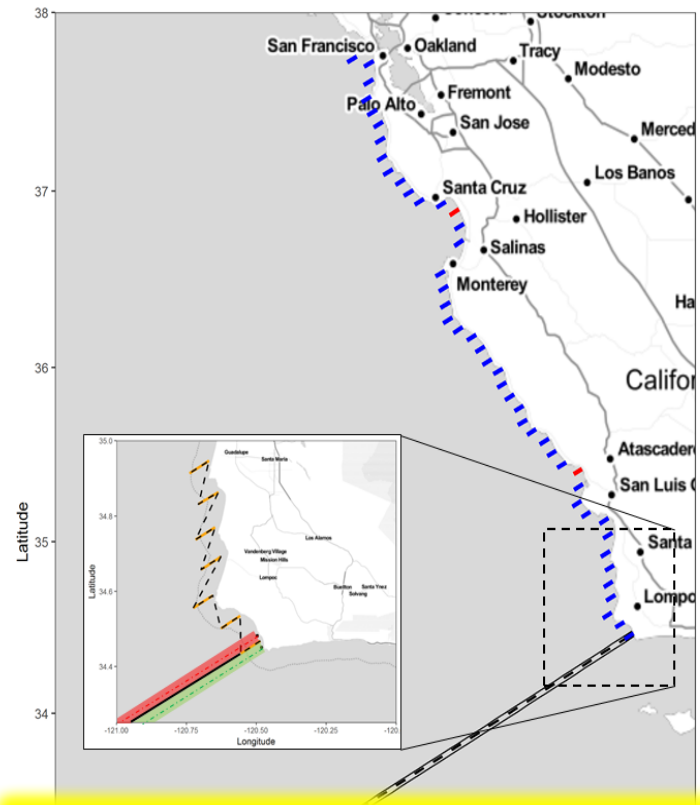
- Total transects: 110 (including adaptive)
- Total transect distance: ~5100mi mi (#1 - #4)
- 100 days or more until the mission is completed

NOAA FISHERIES PMEL Pêches et Océans Canada Fisheries and Oceans Canada SAILDRONE

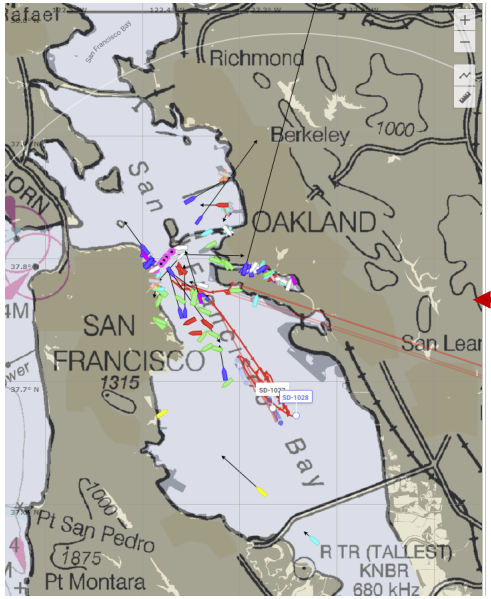
Operational Plan for Saildrones #1 thru #4 (offshore)

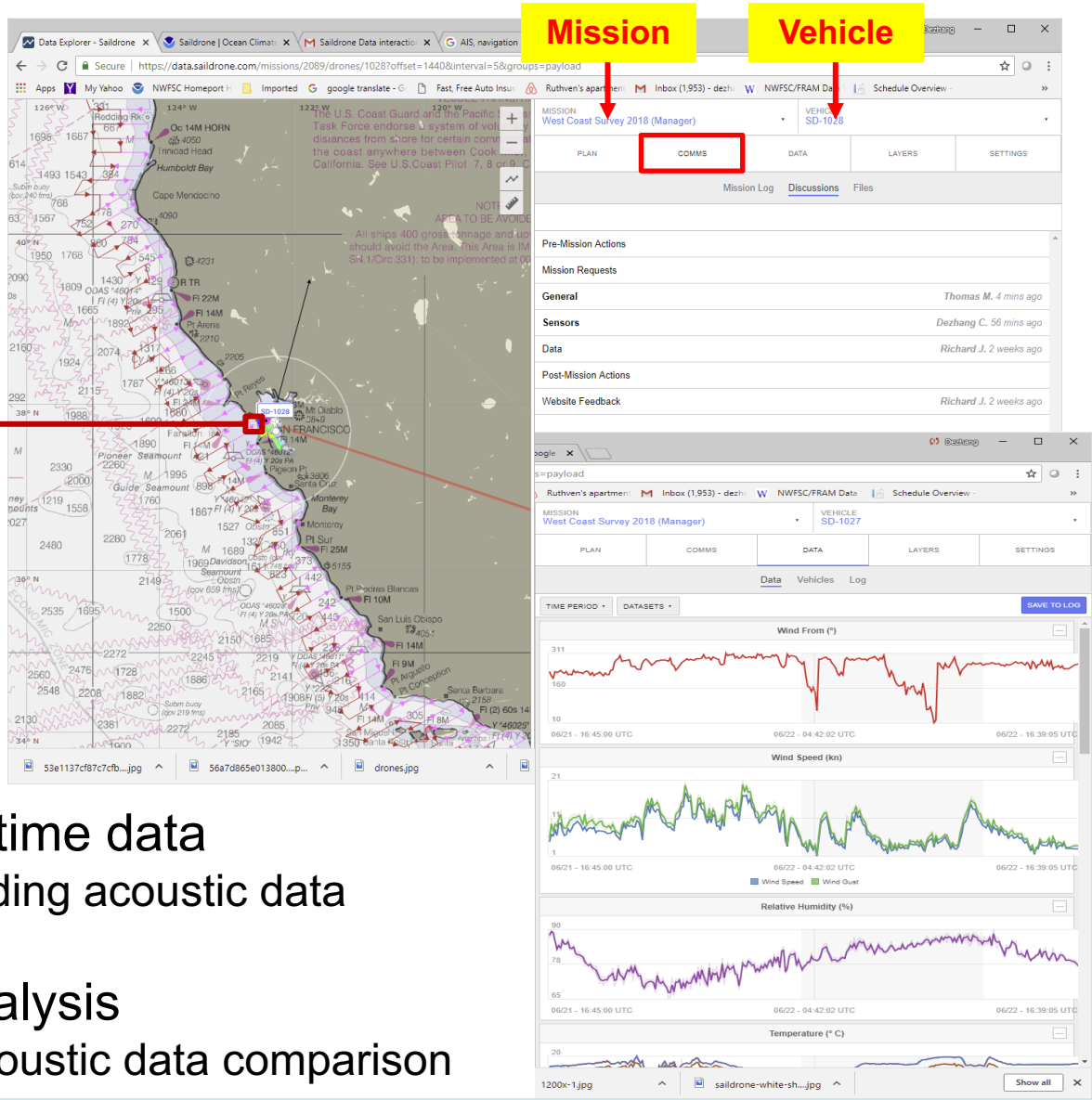


Operational Plan for Saildrone #5 (near shore)



Saildrone Data Interactive Portal
(https://data.saildrone.com)

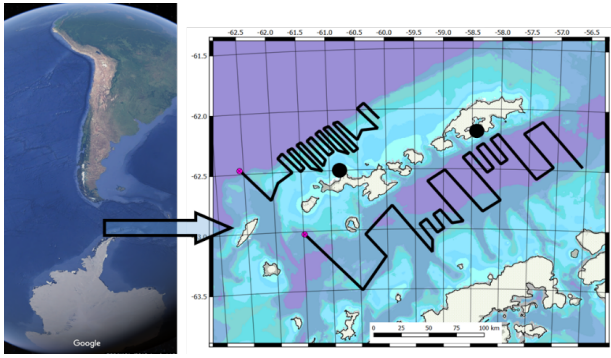




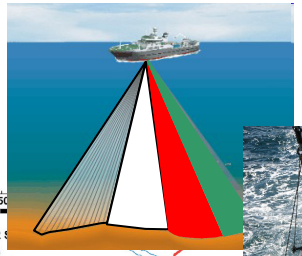
- Realtime or near realtime data
  - Downloadable including acoustic data
- Post mission data analysis
  - Lasker/Saildrone acoustic data comparison

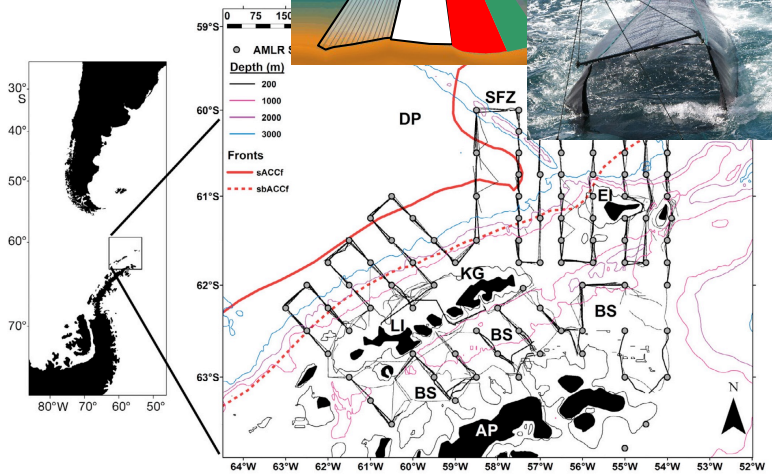
Antarctic Krill Biomass Estimation

Shift from ship-based to autonomous (glider and moorings) sampling



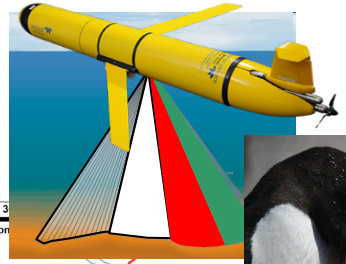
Traditionally

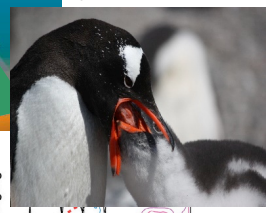


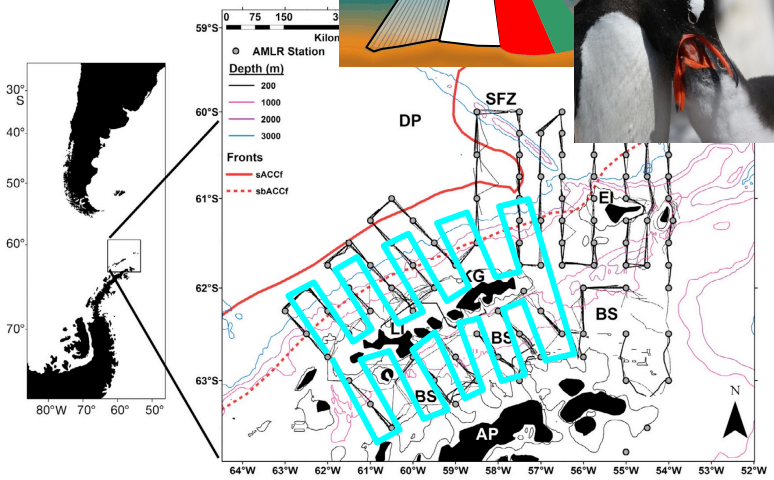


(e.g., Santora et al. 2010)

Autonomously







Test SoCal:
Summer 2018
Antarctic deployment:
Dec 2018-Mar 2019

NOAA FISHERIES

Joint/Integrated Surveys
[Marine Mammal (and Seabird) and Coastal Pelagics]

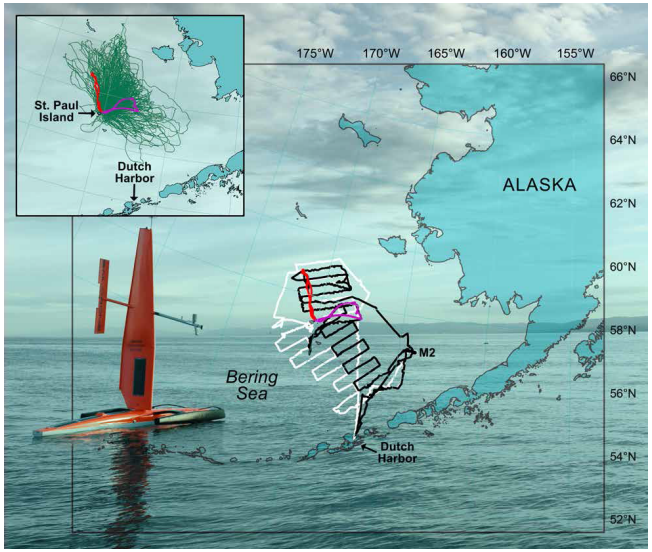
Advantages

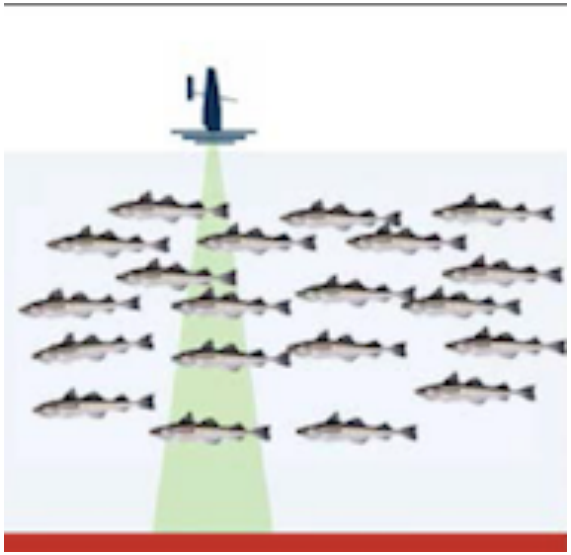
- Similar area/distribution
- Predator-prey association
- Same vessel

Challenges

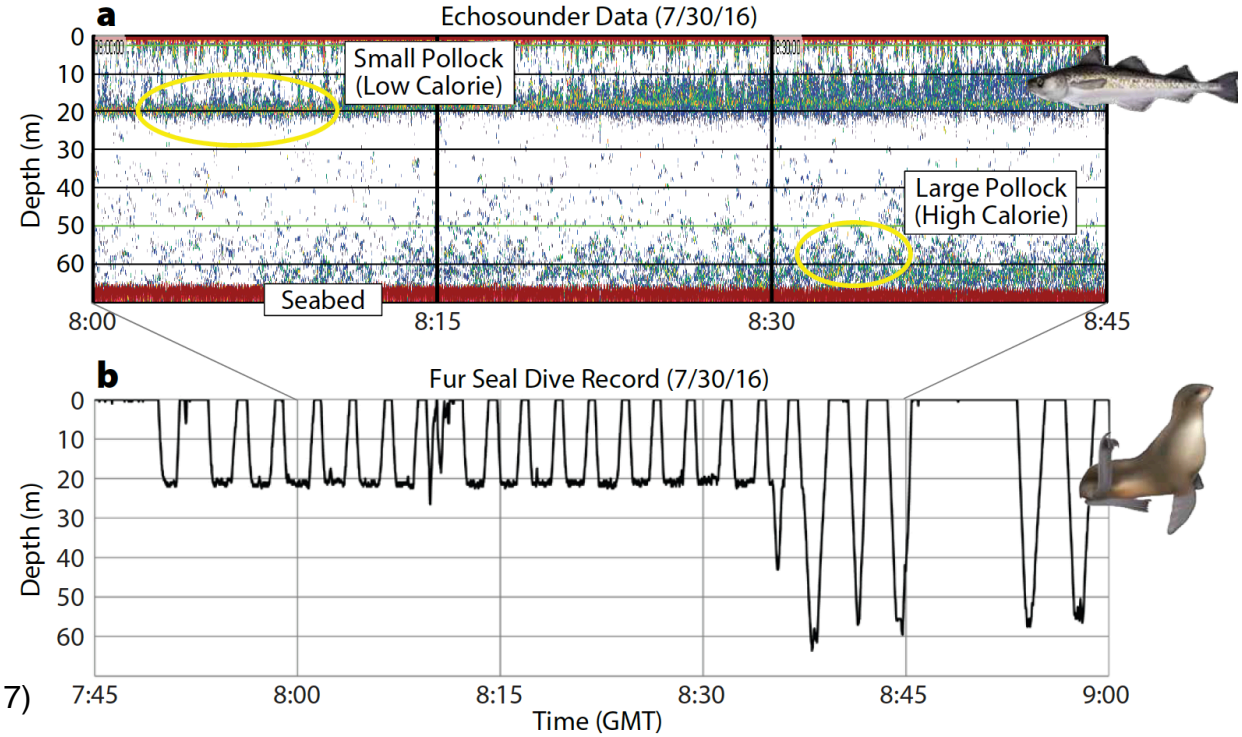
- Different sampling strategies (dictated by biology)
- Science crew size on ships

- 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.



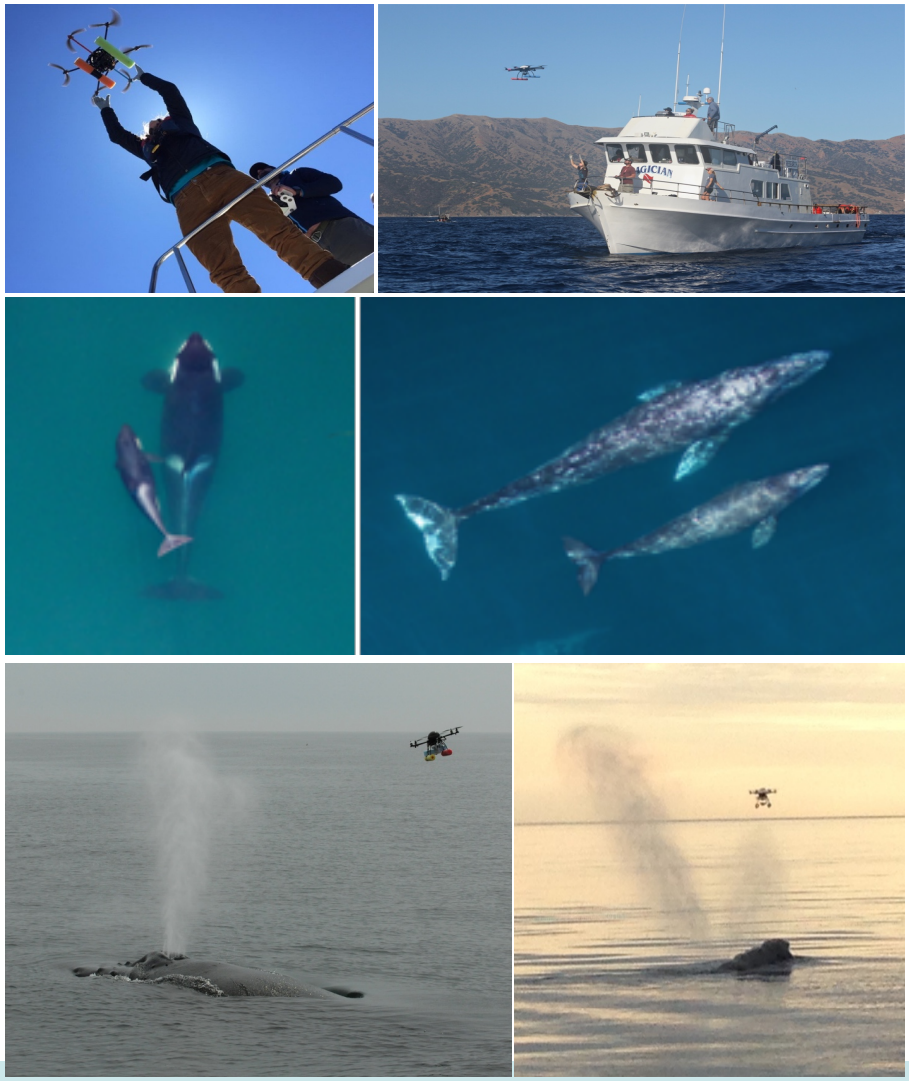
Mordy et al. (2017)

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)*.

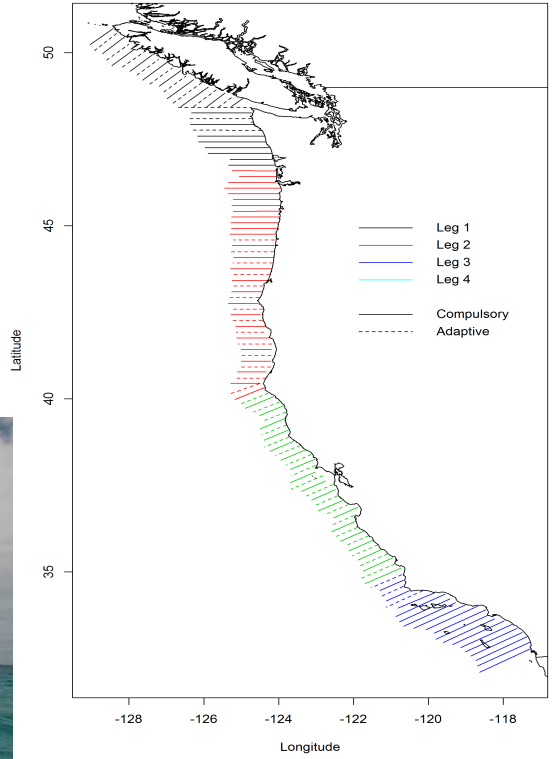
- For Southern Resident Killer Whales, a *"Species in the Spotlight"*, we are identifying whales in poor body condition and pregnancies that are not leading to successful births.

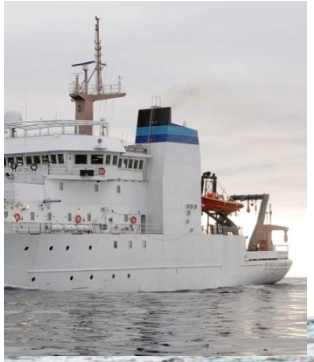


Unmanned Aerial Systems (sUAS) and extensions

- 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.



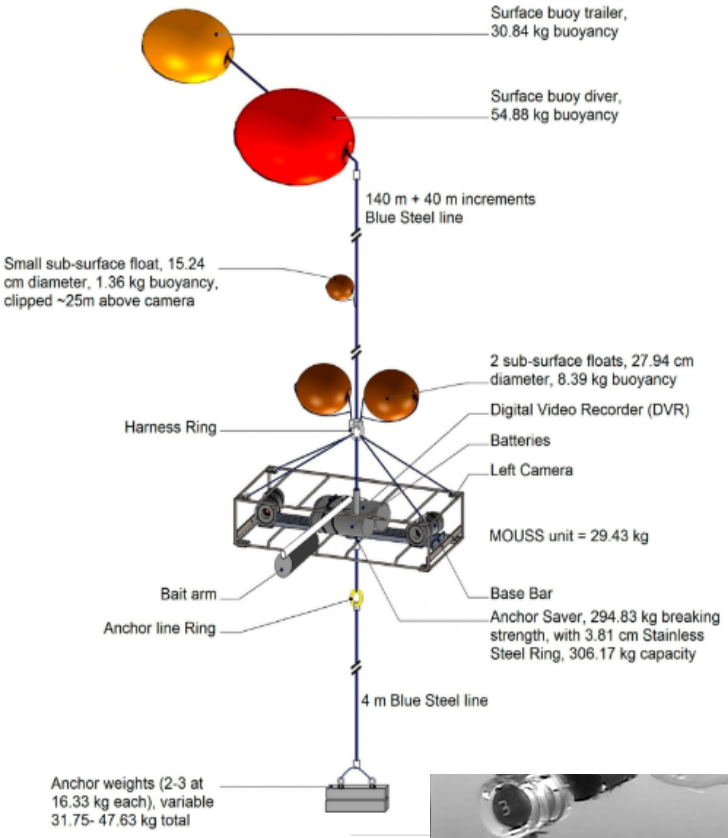


Imaging

- 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
- 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.



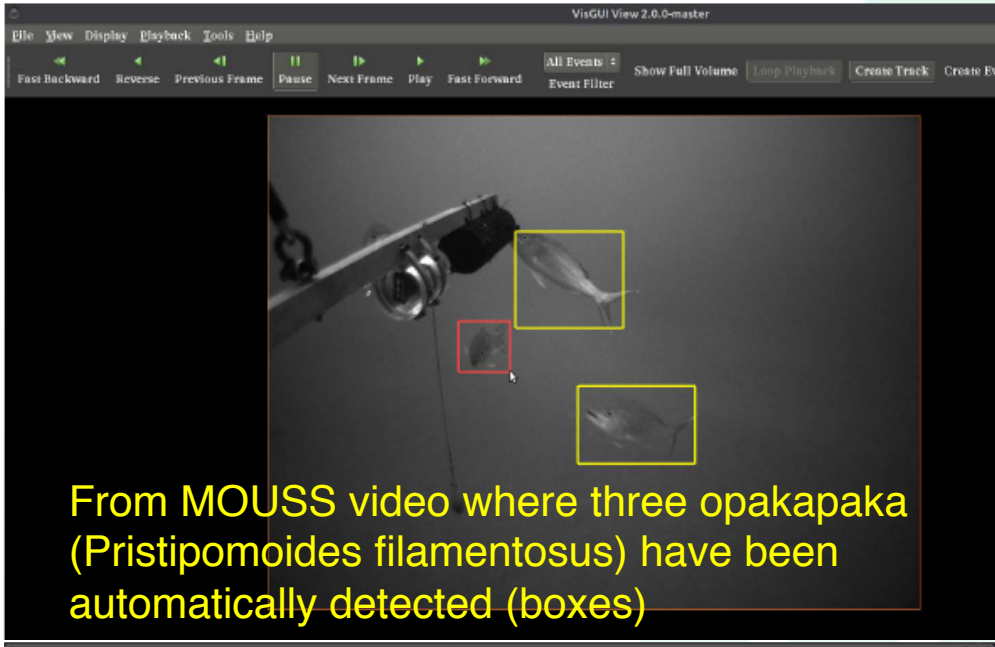
Automated Image Analysis & AI

- 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.

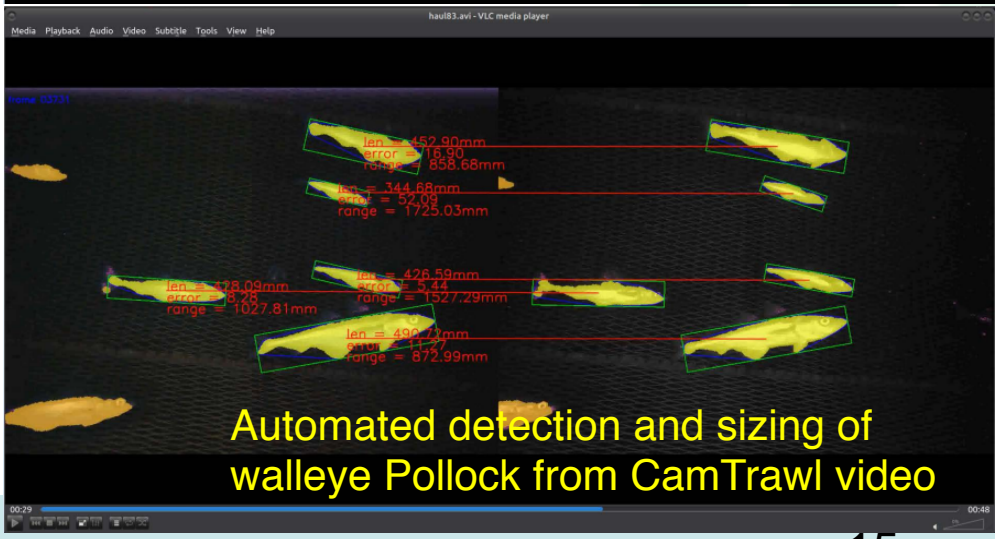
- The goal was to *create an end-to-end open source software toolkit* allowing for the automated analysis of optical data.

- 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.



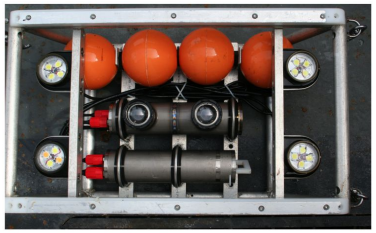
From MOUSS video where three opakapaka (Pristipomoides filamentosus) have been automatically detected (boxes)



Automated detection and sizing of walleye Pollock from CamTrawl video

Automated Image Analysis & AI

a



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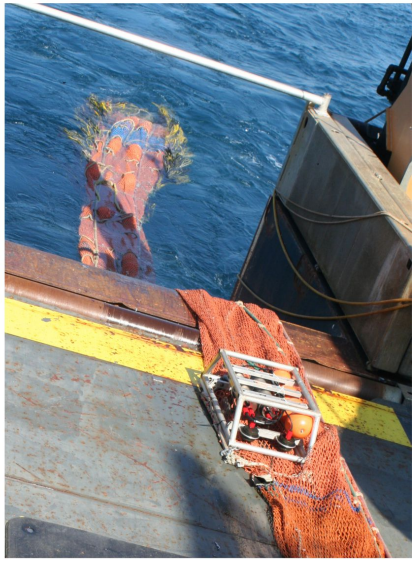
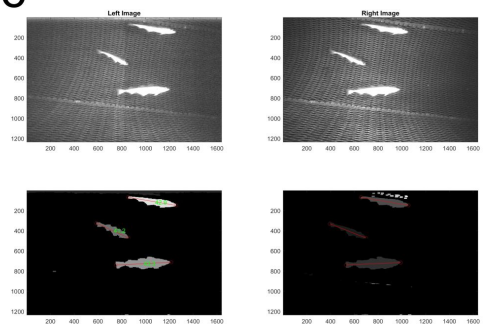
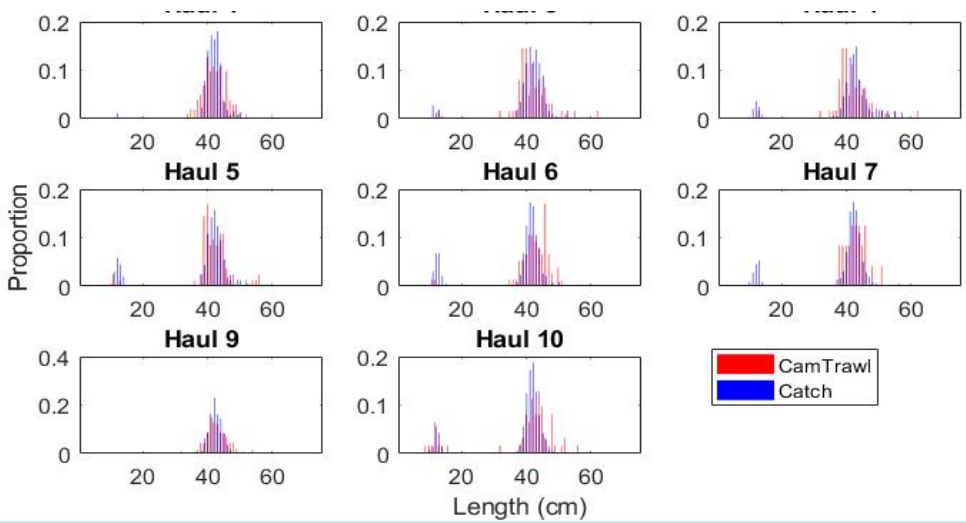


c





- CamTrawl involves placement of a *stereo camera package inside a large midwater trawl*.
- The camera-trawl system provides:
  - *time/depth-specific species and size composition*
  - *finer resolution than possible when traditional trawl sampling* methods.
- Image analysis software *automatically* processes CamTrawl data on the vessel during acoustic-trawl surveys, and *length measurements by species are entered into a database* alongside bio-physical measurements.

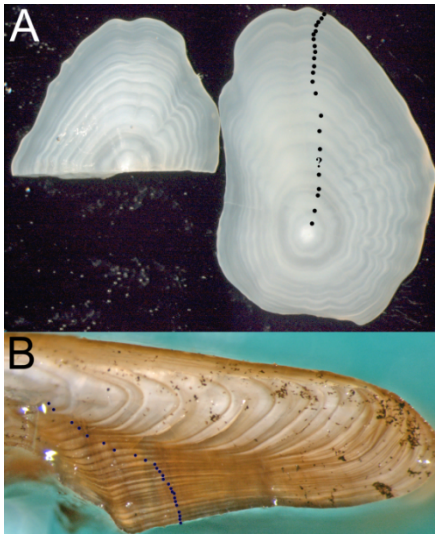
Fourier Transform-Near Infrared Spectroscopy of Otoliths to Estimate Age

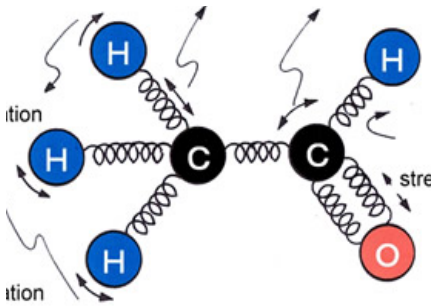
- **In fish otoliths, which contain protein, more vibrational energy produced from C-H, N-H and O-H bonds equates to older fish**
- Fourier transformed-near infrared spectroscopy (FT-NIRS) is a method of measuring vibrational energy changes (spectra) from excited molecules in organic substances

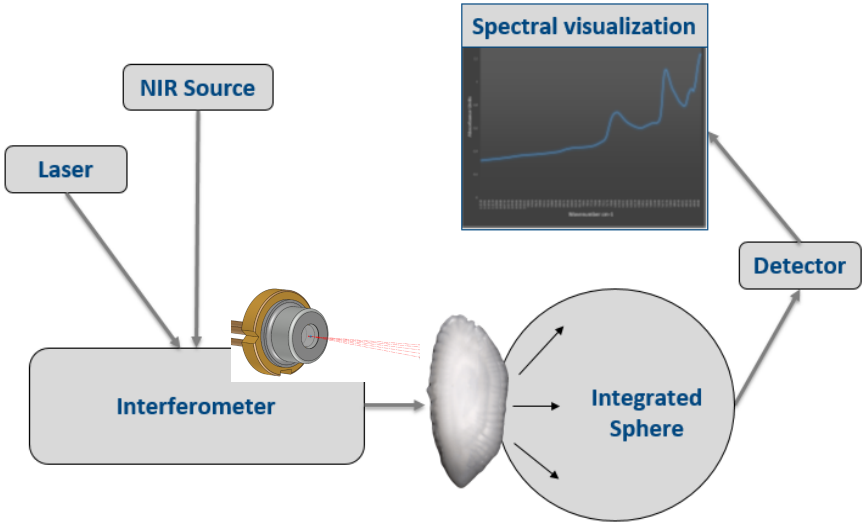
- FT-NIRS provides rapid age estimation with good precision, and greater than **800% efficiency compared to traditional methods**. Subjectivity is reduced and repeatability increased

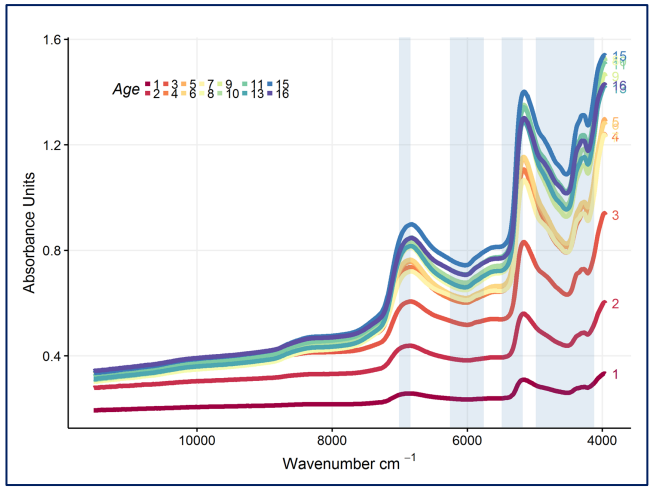
Tom Helser et al., AFSC

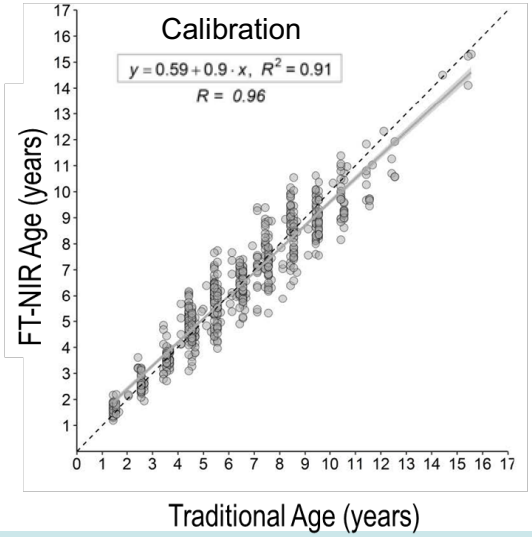
Fourier Transform-Near Infrared Spectroscopy of Otoliths to Estimate Age

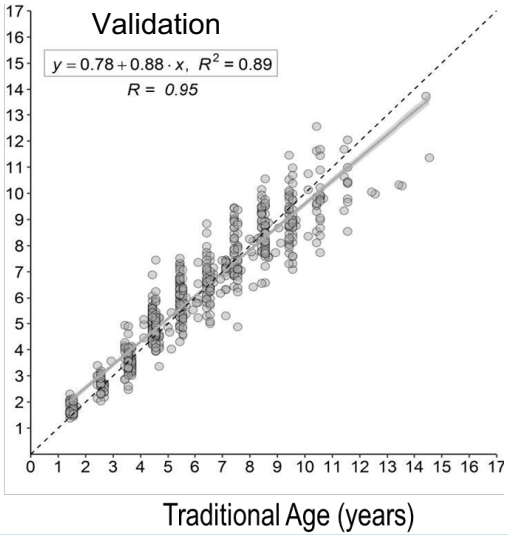












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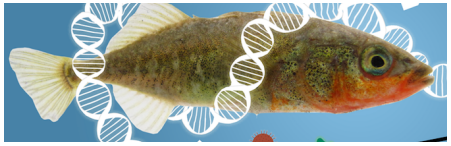
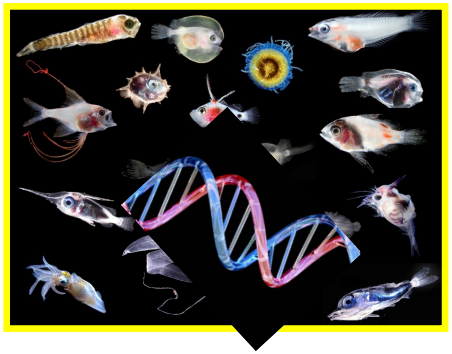
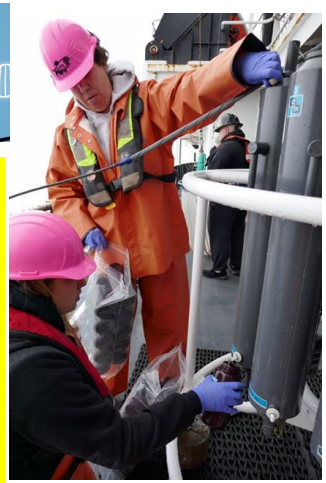
‘omics

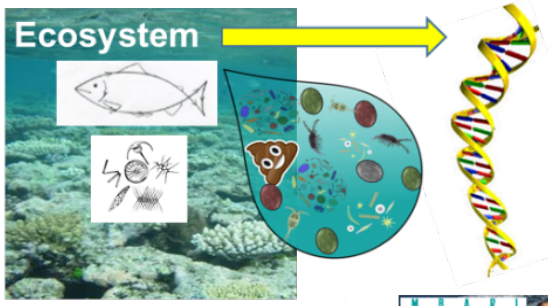
- ‘Omics and environmental DNA (eDNA) to characterize the microbiome
- Innovative techniques are being used to assess higher trophic levels (fish, turtles) from filtered seawater via capture of sloughed or excreted cells (eDNA)
- Current winter hake (Pacific whiting) survey to compare eDNA with trawl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







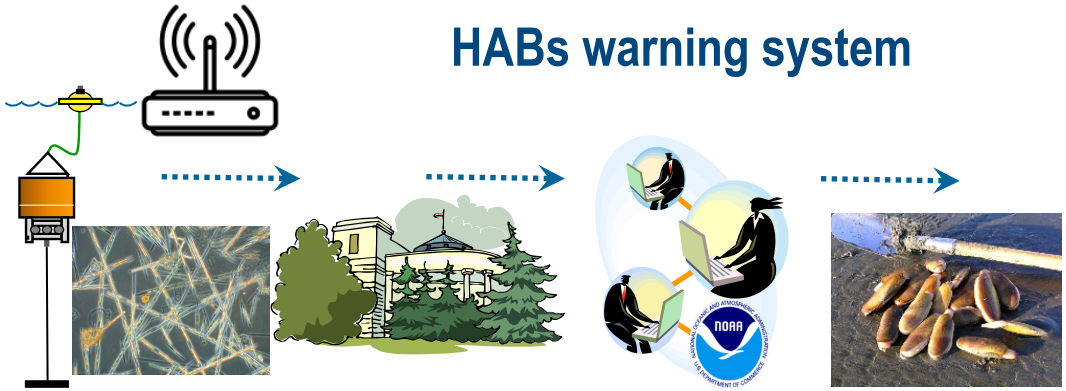
DNA analysis: promise for routine measurements



time and cost savings can increase throughput to data products

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

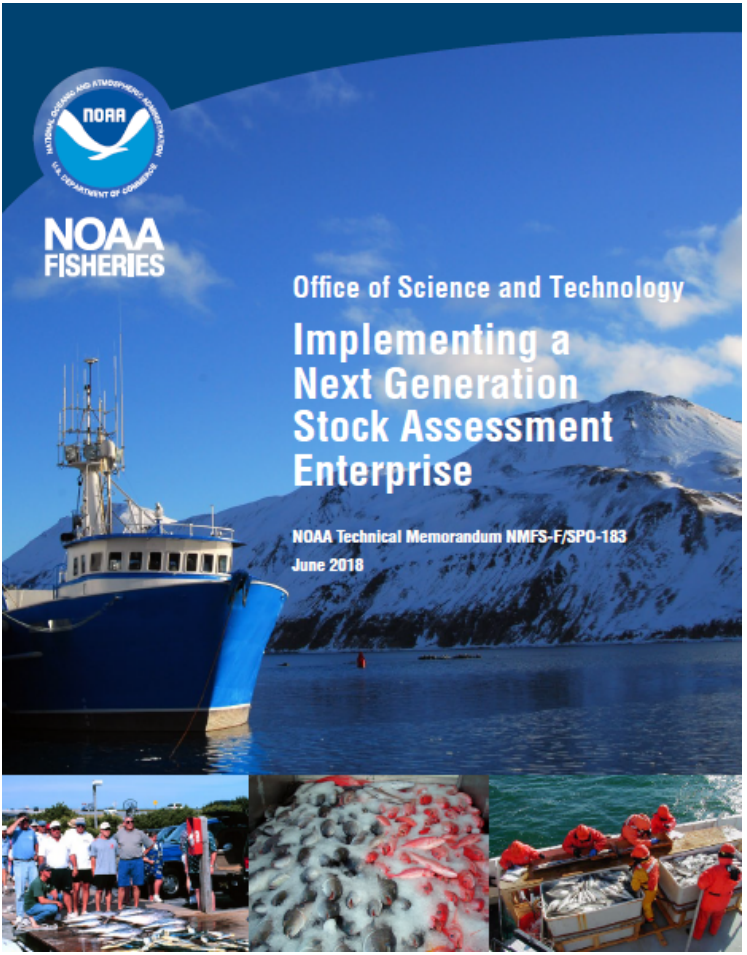
HABs warning system



Stock Assessment Improvement Plan

SAIP 2018

SAIP 2018



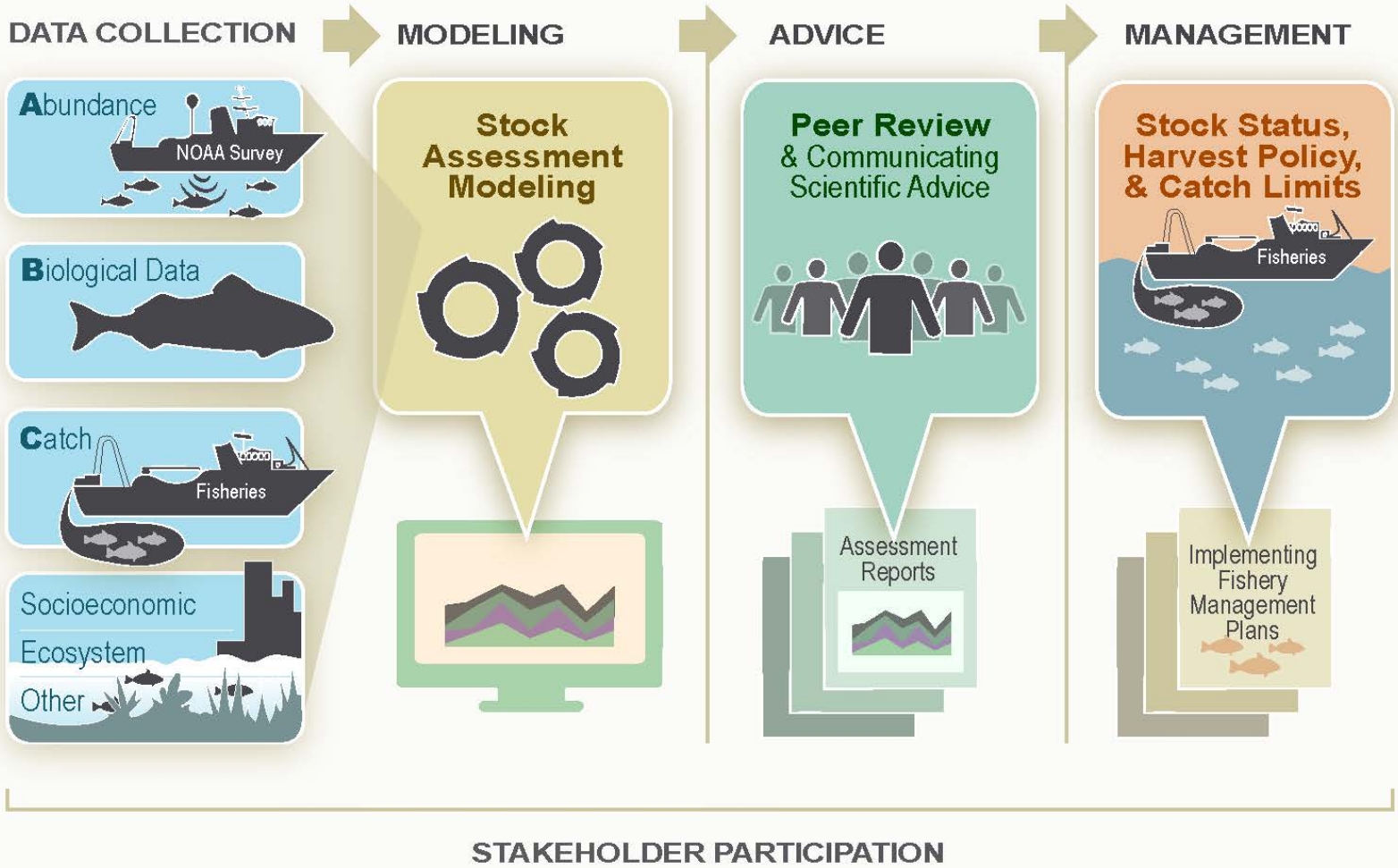
- Long version
  - Section 1: Intro
  - Section 2: Current status
  - Section 3: Next generation
  - Section 4: Recommendations
- Short version
  - Policymakers' summary

https://www.fisheries.noaa.gov/feature-story/updated-stock-assessment-improvement-plan-builds-past-success

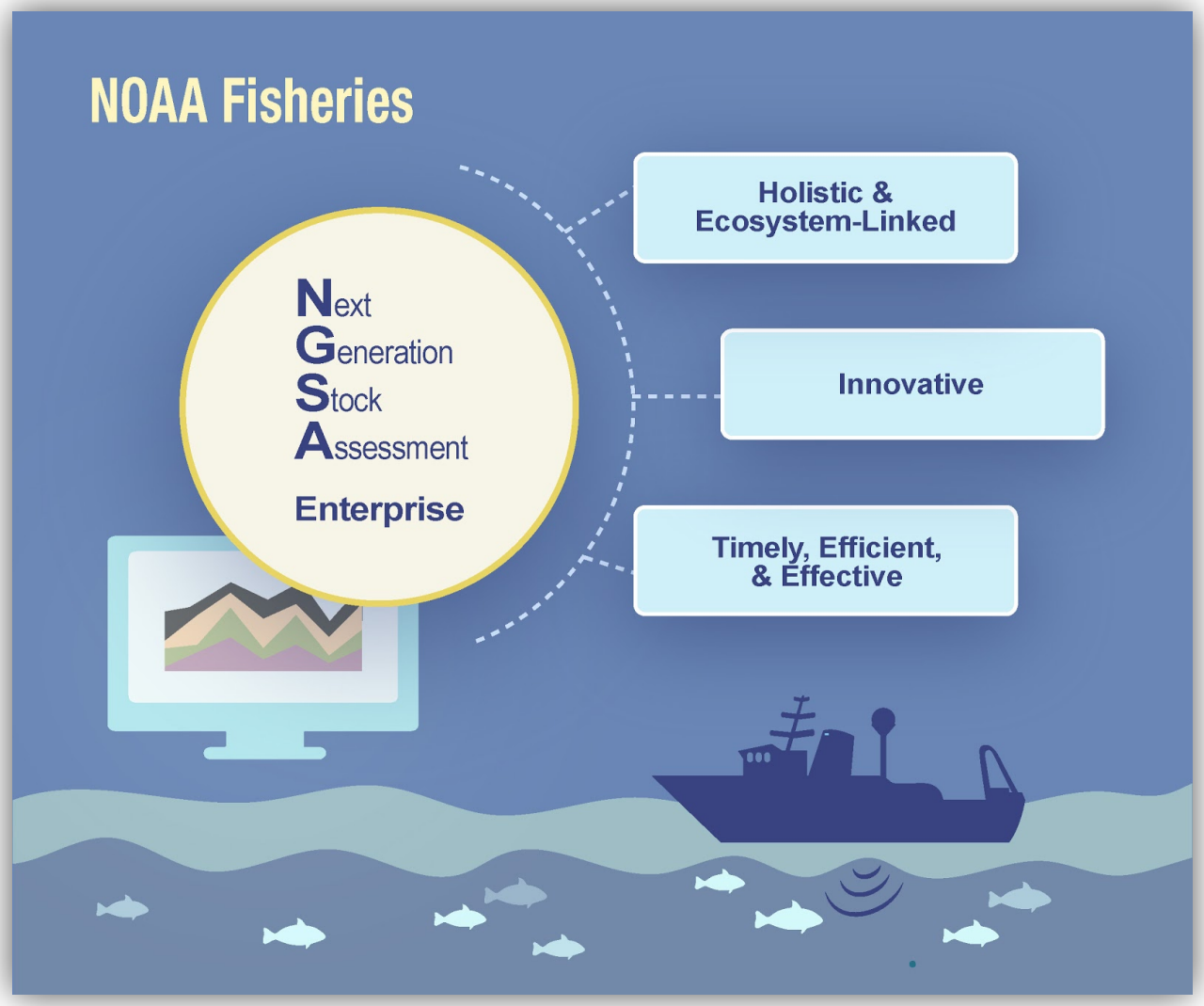
NOAA Fisheries Stock Assessment Process

The Science Behind Sustainable Fisheries Management

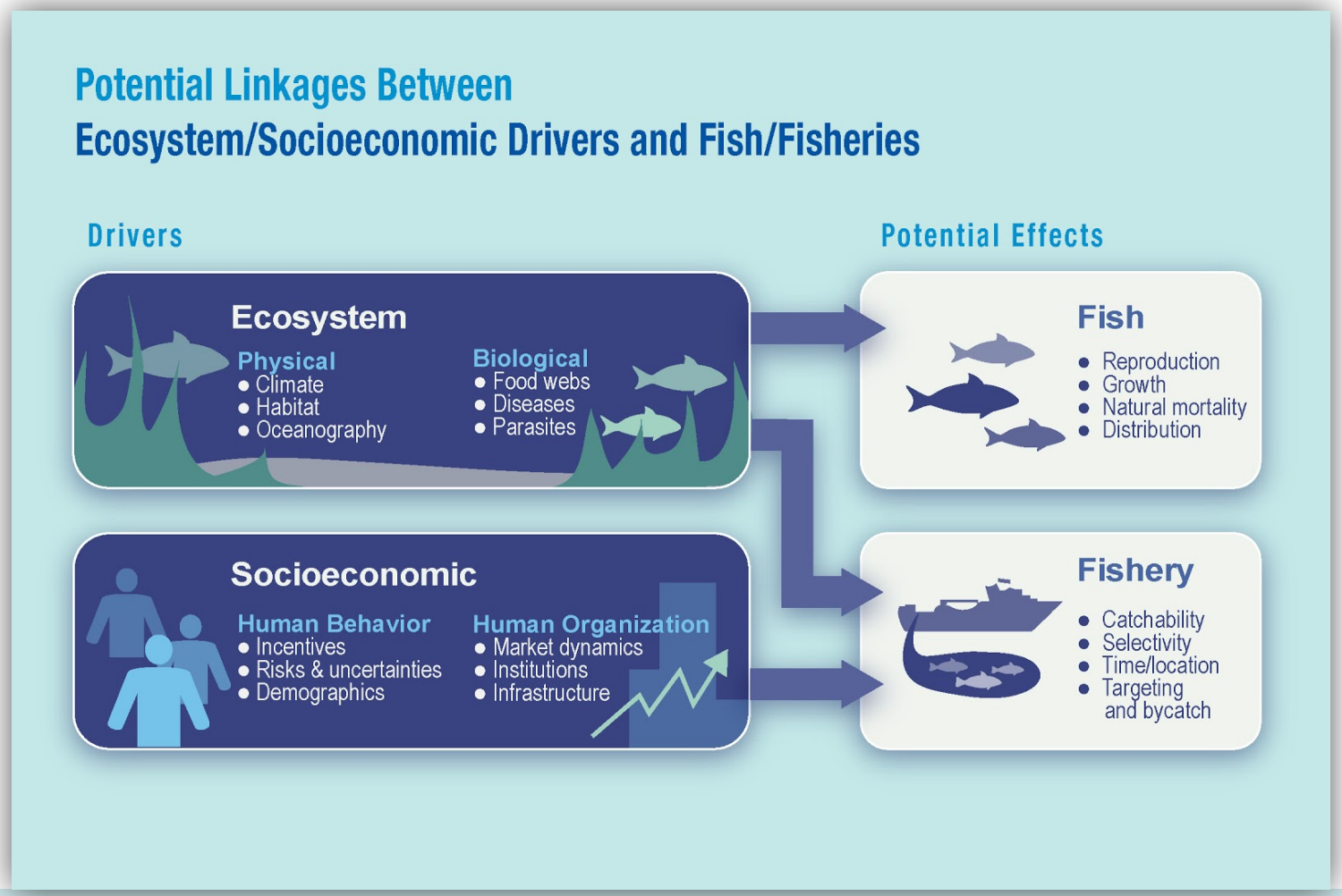
Healthy Fish Stocks
= Sustainable Jobs, Fisheries, and Food



Next Generation Stock Assessments



Holistic & Ecosystem-linked



Holistic & Ecosystem-linked

- Many assessments should expand in scope (use research track for analyzing new elements)
- Criteria and decision process for how to include or link data provided in SAIP
- Addressing issues/gaps among interdisciplinary teams highlighted as a priority

Pacific cod 2017 assessment

Importance of including ecosystem and environmental considerations

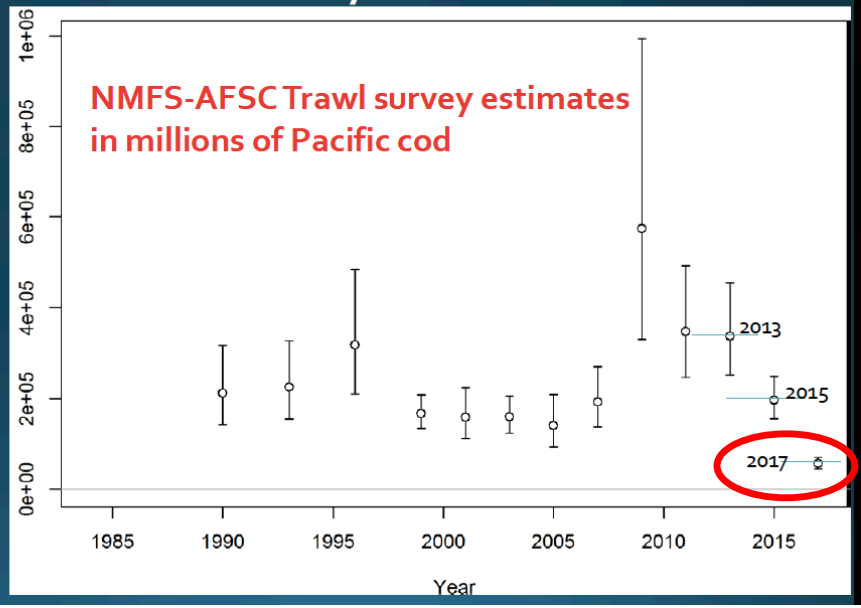
S. Barbeaux
https://npfmc.legistar.com/View.ashx?M=F&ID=5485956&GUID=CBE79CD6-801C-419A-89AF-B8F00B4788B7

2017 Bottom trawl survey

Lowest estimate
- 196 million fish and 107,324 t
- Precise (12% CV)

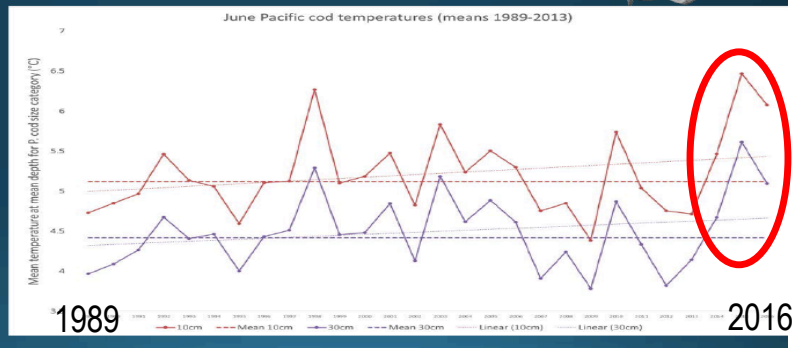
71% drop from 2015 estimate
- 83% drop from 2013

58% decline in biomass since 2015 (78% since 2013)



Anomalously warm waters for Pacific cod

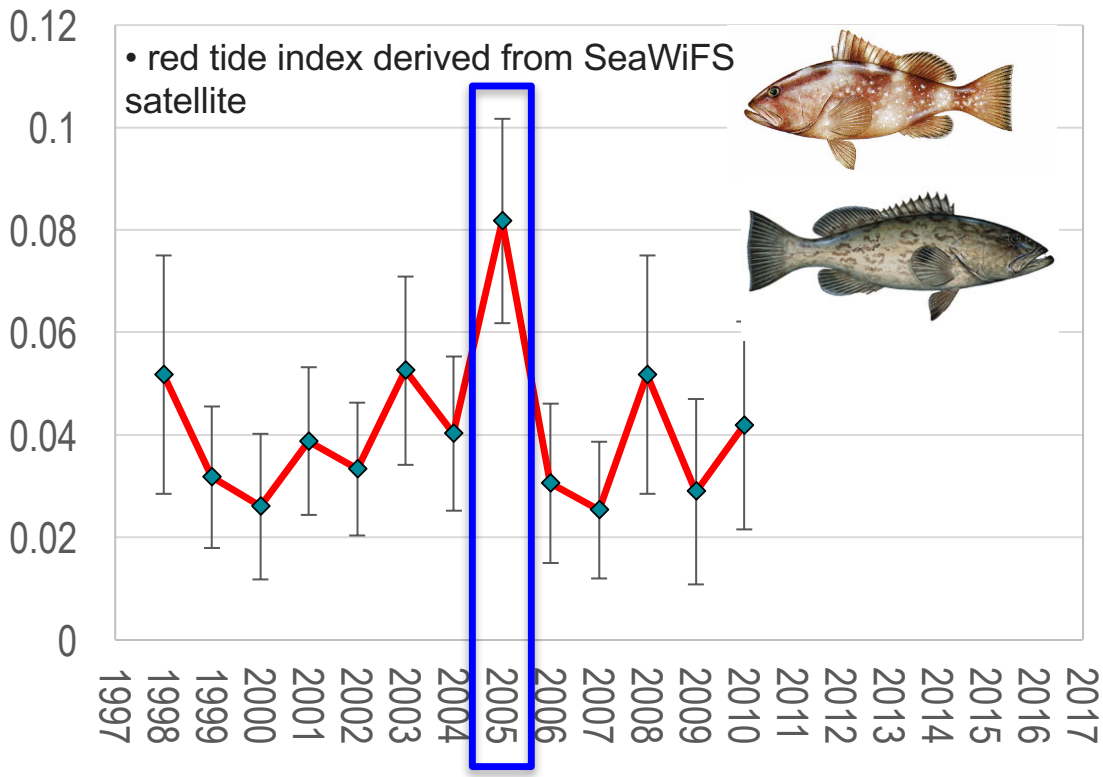
2014-2016 different in that temperatures were higher for entire year



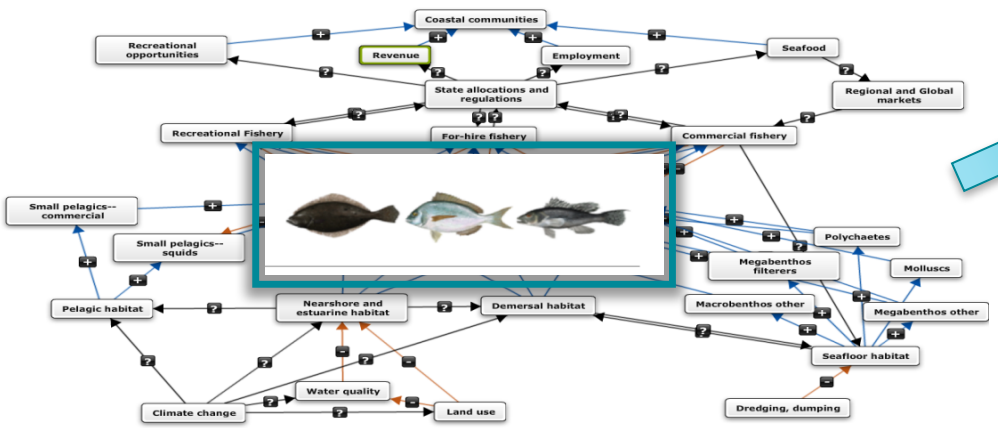
Pacific cod bio-energetics - Summary

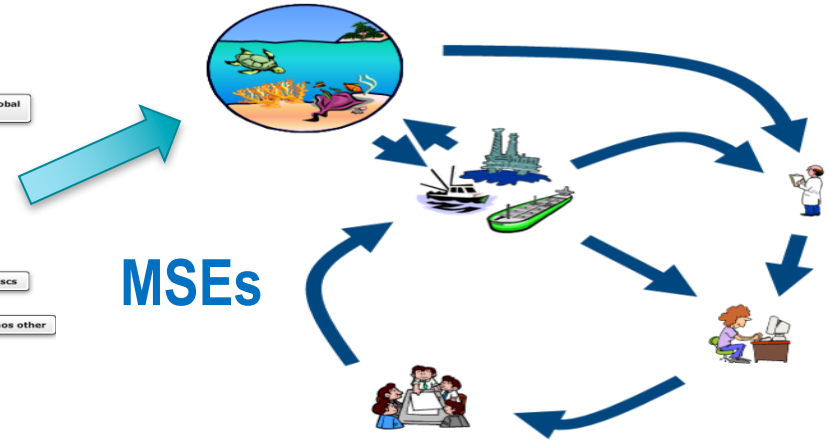
- Warmer temperatures were throughout the year and water column
- Higher metabolism in warmer temps lead to higher forage requirements
- Indications of lower forage amounts in 2015-2016
- Combination could have lead to higher natural mortality for these years for the 2012 year class.

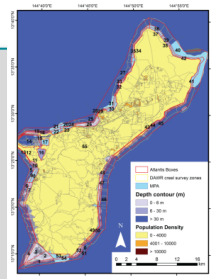
Gulf of Mexico red tide effects on fisheries



- Estimates probability of a red tide bloom
- Used in red and gag grouper and ecosystem assessments
- explained declines of **~8 million grouper** (gag and red combined) in 2005

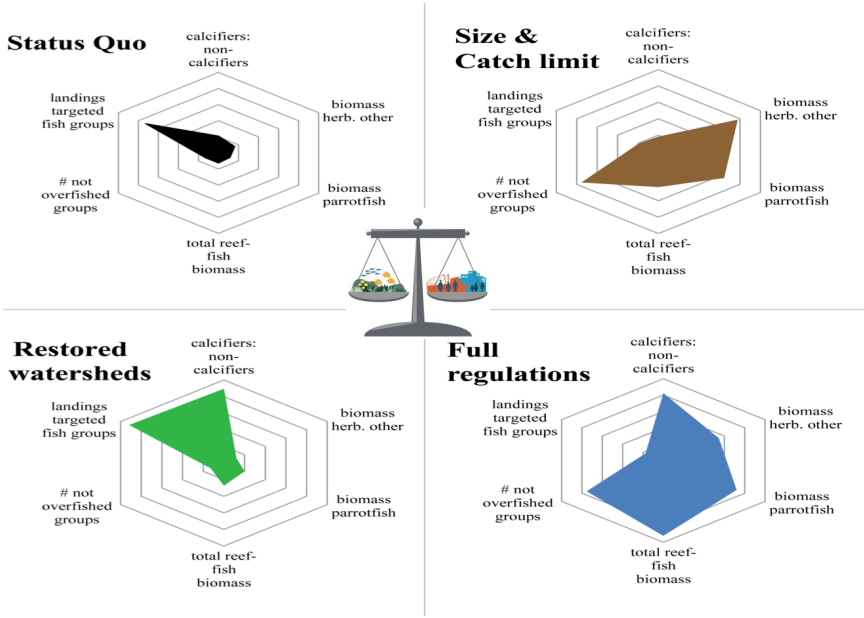






Council Decision Support:

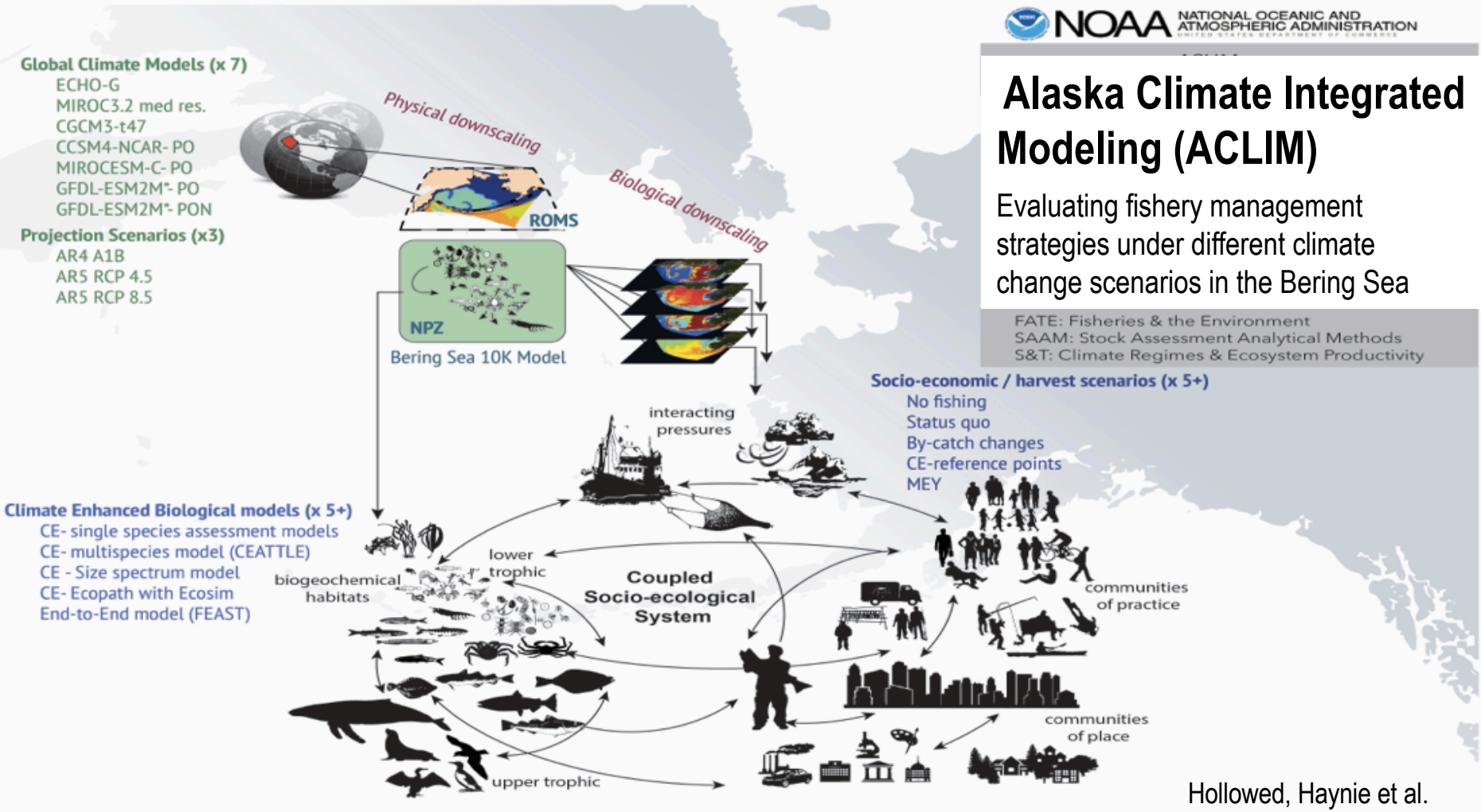
Visualize tradeoffs of alternative management strategies with regard to improved coral reef ecosystems status or improved fishery indicators.



Alaska Climate Integrated Modeling (ACLIM)

Evaluating fishery management strategies under different climate change scenarios in the Bering Sea

FATE: Fisheries & the Environment
SAAM: Stock Assessment Analytical Methods
S&T: Climate Regimes & Ecosystem Productivity



Hollowed, Haynie et al.

Next Generation Stock Assessments

The 4Ts of Assessment Demands

Throughput

Expectation
Conduct a high number of assessments each year to support development of annual catch limits.

Reality
There are many more stocks under NOAA's purview than can be assessed in a year with current capacity.

Solution
Objective prioritization to determine the stocks most needing assessment; conduct more routine update assessments.

Timeliness

Expectation
Utilize current information and rapidly develop advice for management decisions.

Reality
Regional approaches to processing and assembling data, modeling, and reviewing assessments vary substantially.

Solution
Standardized and right-sized data delivery, modeling options, and peer review.

Thoroughness

Expectation
Assessments should be comprehensive investiga-tions with fully-independent peer reviews.

Reality
Current data availability and assessment capacity do not facilitate comprehensive assessments for all stocks.

Solution
Objective prioritization to determine the stocks in need of comprehensive investigations.

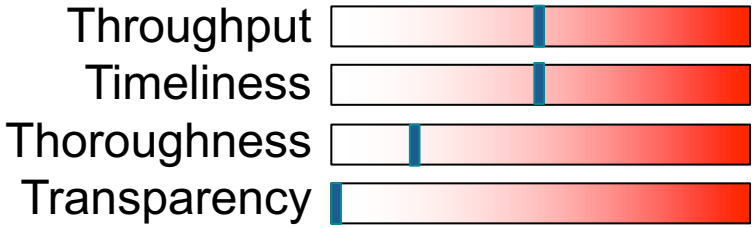
Transparency

Expectation
Results should be fully documented, clearly communicated, and accessible for public understanding.

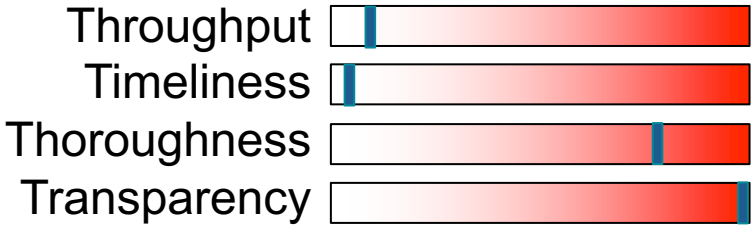
Reality
Assessments are complicated, produce numerous results, and a variety of communication formats are used.

Solution
Standardized and tiered reporting templates that summarize results at various levels of detail.

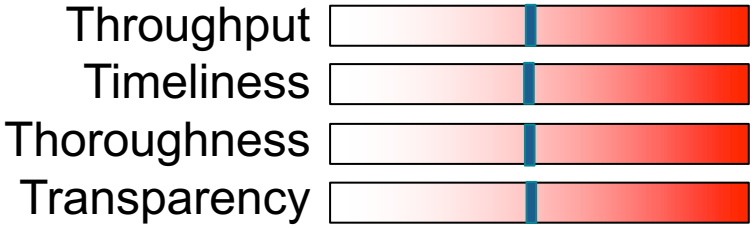
Evolution of the 4Ts



One person, one computer, one dark office

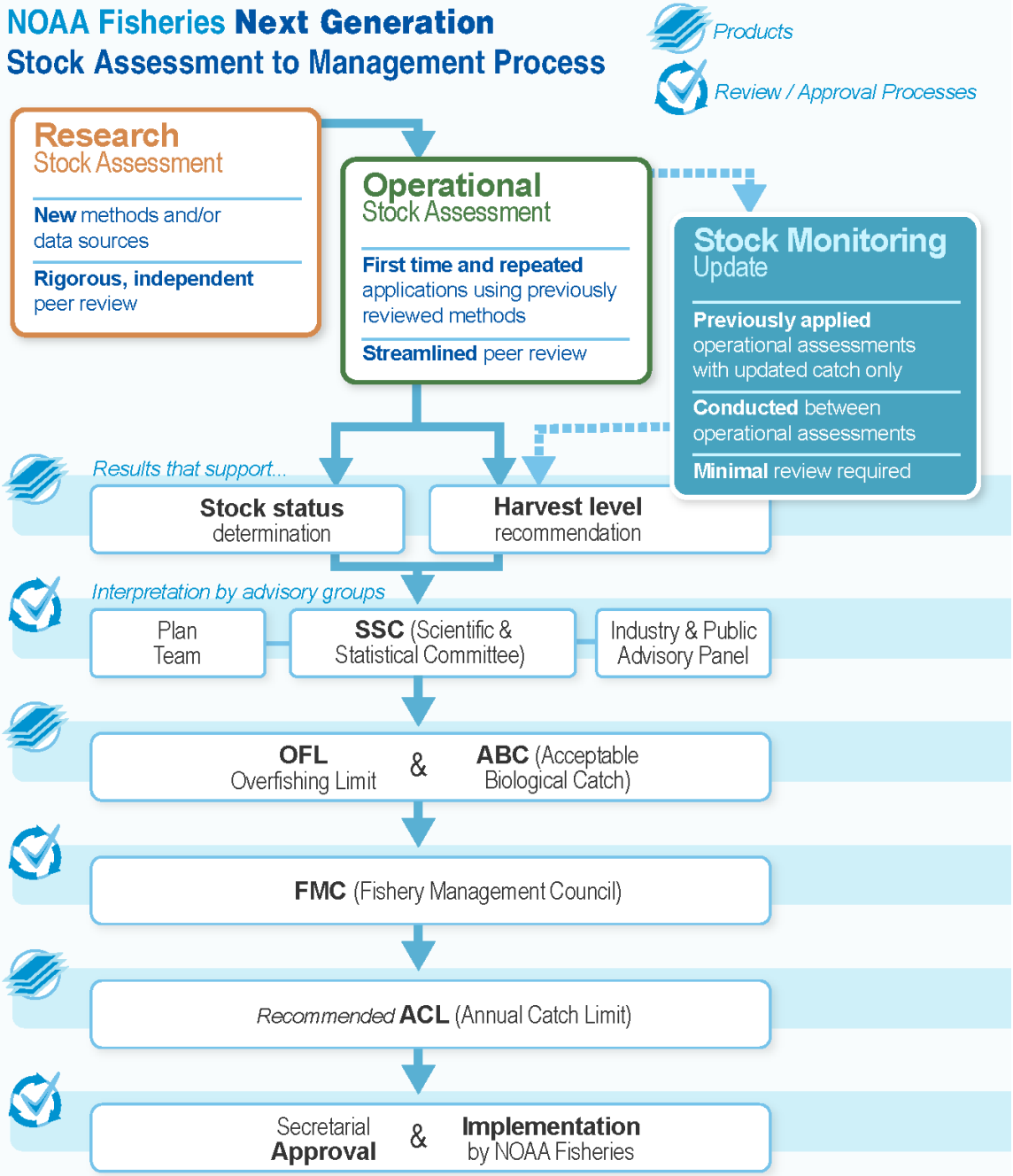


Maximum transparency, uncover every stone, can be painstakingly slow



Balanced, efficient, and prioritized

NOAA Fisheries **Next Generation** Stock Assessment to Management Process



Timely, efficient, & effective

Improve the assessment process

- Streamlined operational assessments to facilitate time for research and complete more assessments
- Parallel research track to address priorities in expanded assessments
- Tailor peer review to degree of new/novel aspects

Near-term Actions

Timely and efficient

- Begin working with councils and regional programs to implement process changes
- Initiate national data gap analysis and improved assessment summaries

Holistic and ecosystem linked

- Expand collaborations w/ecosystem & socioeconomic communities to prioritize and expand assessments

Innovative

- Invest in improvements w/available funds and cost-saving opportunities (industry partnerships, electronic technology)

Concluding remarks - challenges

- **Available new technologies:**
  - Training of scientists
  - Increased data management and analysis capabilities
  - Calibration

- **Development of new technologies:**
  - Establish collaboration with other LOs, academia and industry
  - New funding strategies/initiatives

- **Joint surveys:**
  - Differences in sampling protocols
  - Necessary ship crew
  - Calibration – return on investment (ROI)

- **Development of advanced analytics:**
  - Quantitative skill of staff
  - Uptake and review of newer models

Concluding remarks – linking science & management (R2O2M)

New capabilities, and the departure from established/legacy methods require new approaches not just in addressing the needed science capabilities but also in the translation of science advice that management can use:

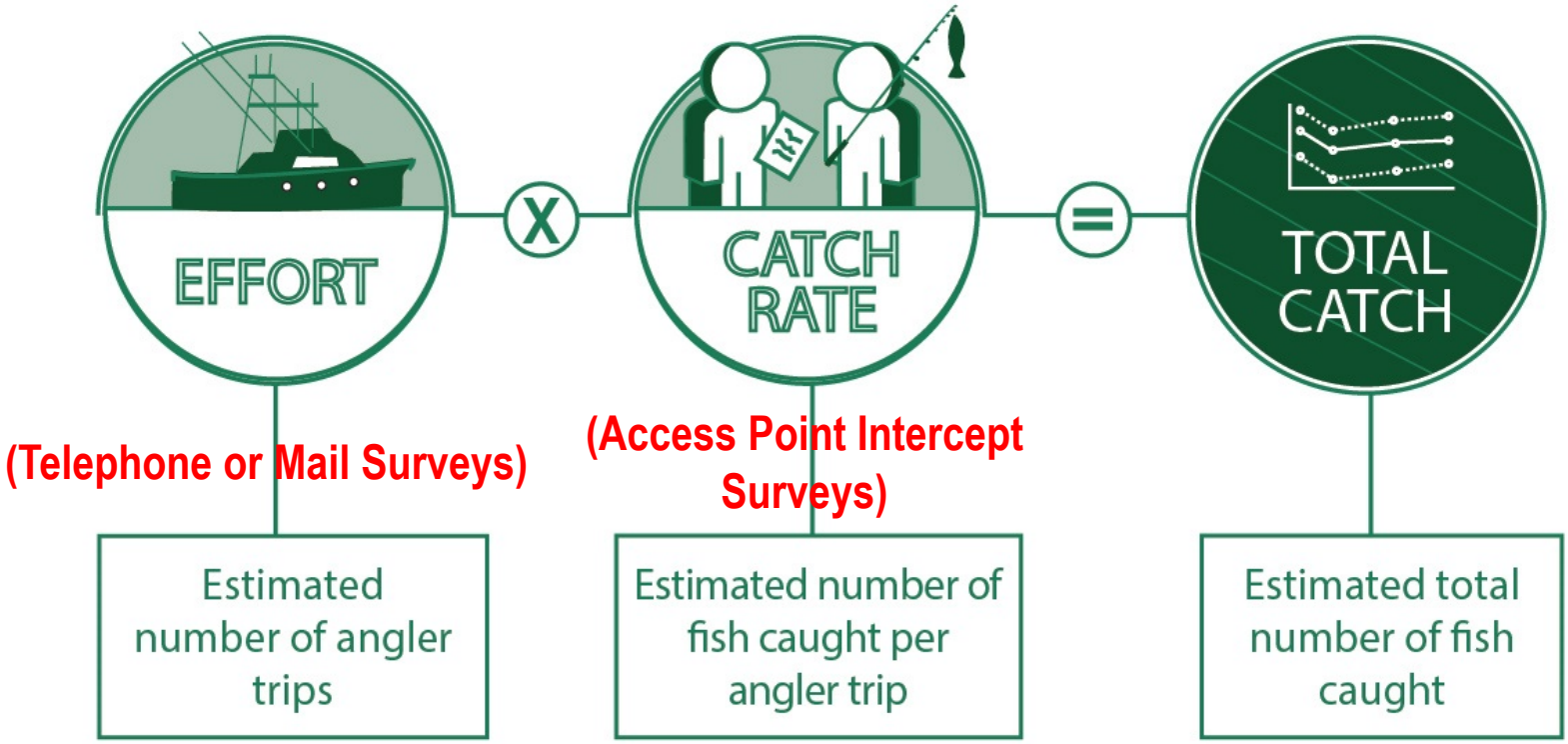
- More holistic assessments (e.g., multispecies)
- Better assessments (e.g., effects of environment on stocks – temperature, red tides, etc.)
- Ecosystem components (e.g., MSEs, trade-offs, etc.)

Marine Recreational Information Program

Transitioning to Improved Survey Designs

Fishing Effort Survey (FES)
[Status update]

Estimating Recreational Fishery Catch



Supporting NOAA's mission of ensuring productive, sustainable fisheries and vibrant fishing communities through science-based decision-making.

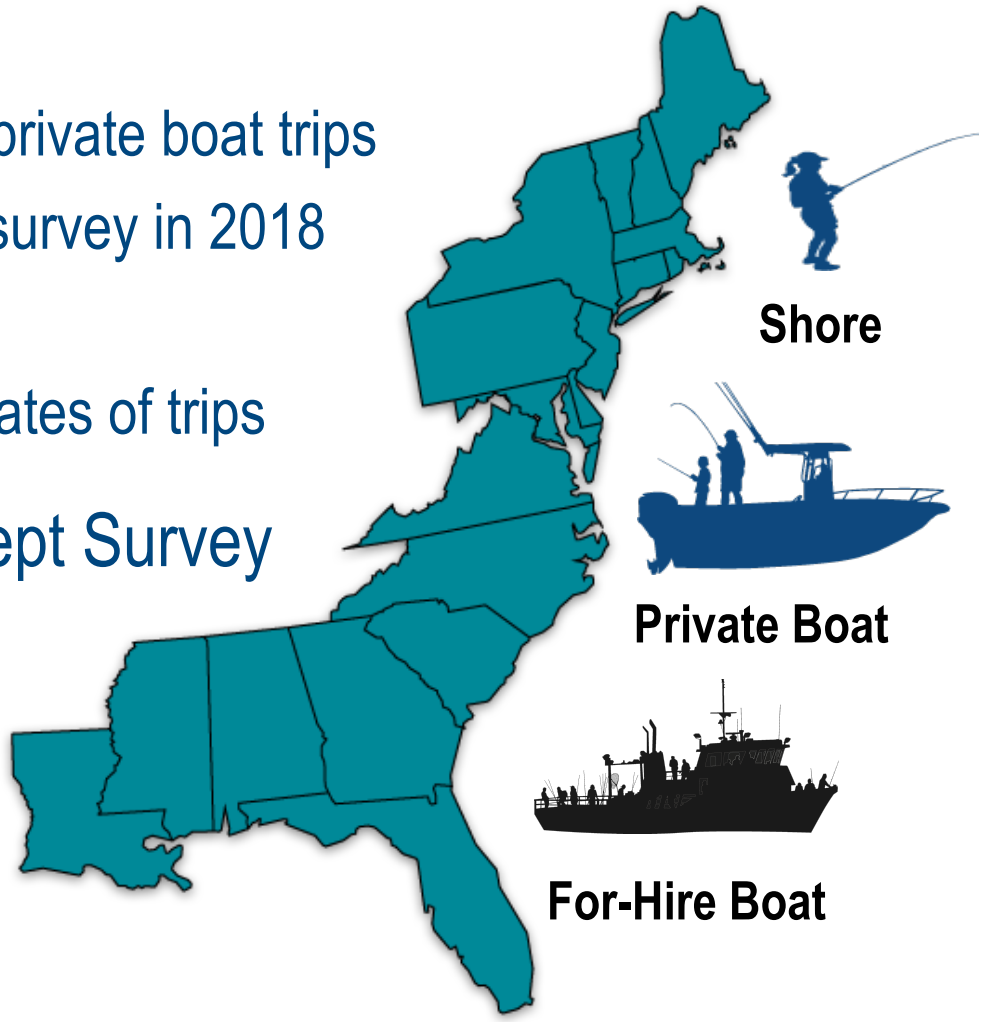
Improved Surveys

Fishing Effort Survey

- New mail survey of shore & private boat trips
- Replaced legacy telephone survey in 2018
- Tested and peer reviewed
- Higher, more accurate estimates of trips

Access Point Angler Intercept Survey

- New design for surveying catch in all fishing modes
- Implemented in 2013
- Better temporal coverage
- More statistically sound



Fishing Effort Survey

We're reaching more anglers.

Surveys get into the right hands.

Much higher response rate.

Improved questionnaire.

More complete answers.

National Academies 2017 Review of MRIP

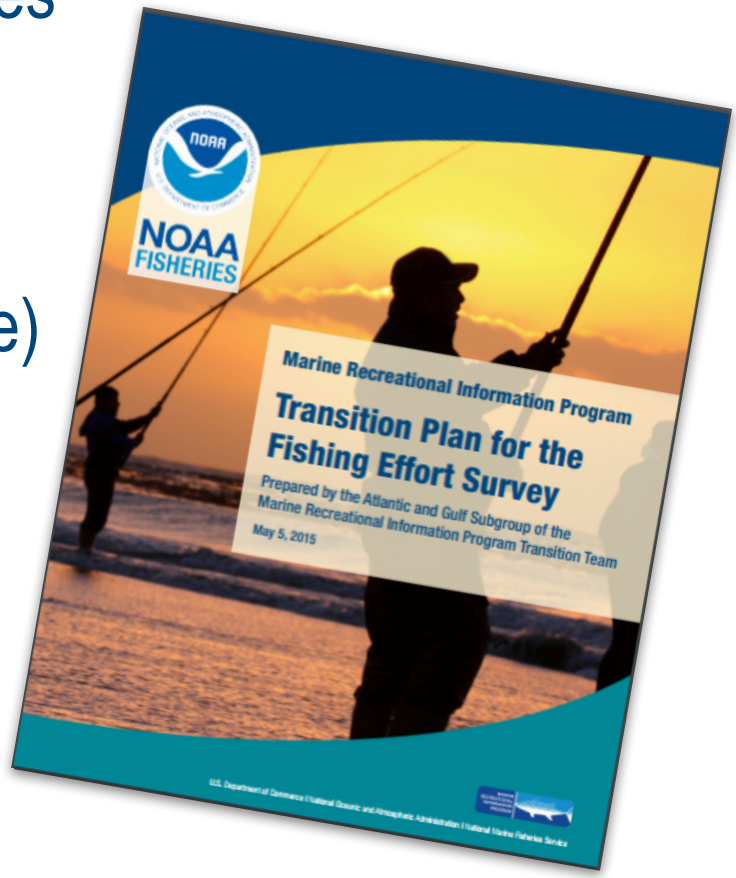
National Academies: “The methodologies, including the address-based sampling survey design, are major improvements from the original Coastal Household Telephone Survey that employed random-digit-dialing.”

Transition Plan

Survey changes can change estimates

Transition Plan developed by NOAA, states, councils, and commissions.

- Benchmarking (mail vs. phone)
- Calibration (old vs. new)
- Convert "old" estimates into "new" currency
  - Stock assessments
  - Management decisions



Questions & Discussion