# Underwater video datasets and the VIAME open-source framework for fisheries stock assessment


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# Agenda

- NOAA Datasets
- Underwater video challenge dataset
- Open source toolkit: Video and Imagery Analytics for the Marine Environment

# Kitware

- **25+ team members**
- **12 PhDs**
- **Founded in 2007**
- **35+ contracts**

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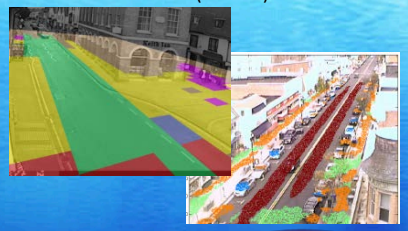
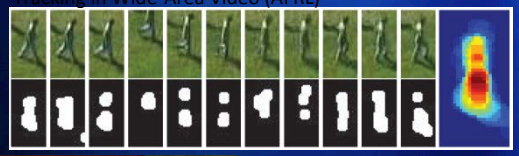
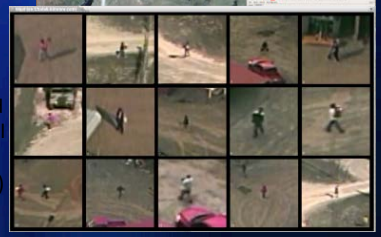
Human Activity Detection (OSD, CTTSO) and Tracking in Wide-Area Video (AFRL)



Object and Building Recognition by Function (DARPA)

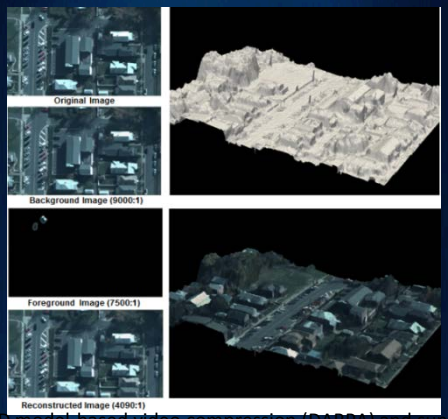

Threat Detection in Video (DARPA)



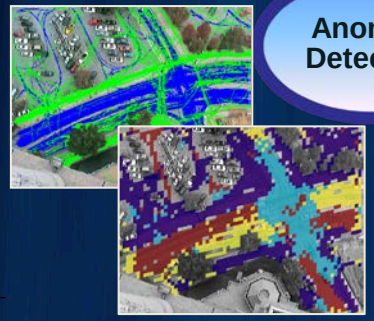


Content-based Video Retrieval by Actions (DARPA VIRAT)

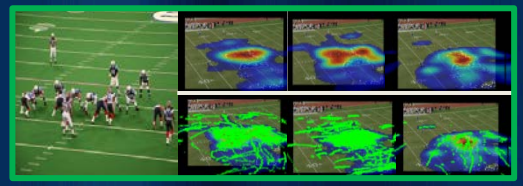
Complex Event Recognition in Internet Videos (GENIE)


3D model-based video compression (DARPA) and super-resolved 3D reconstruction (DARPA)



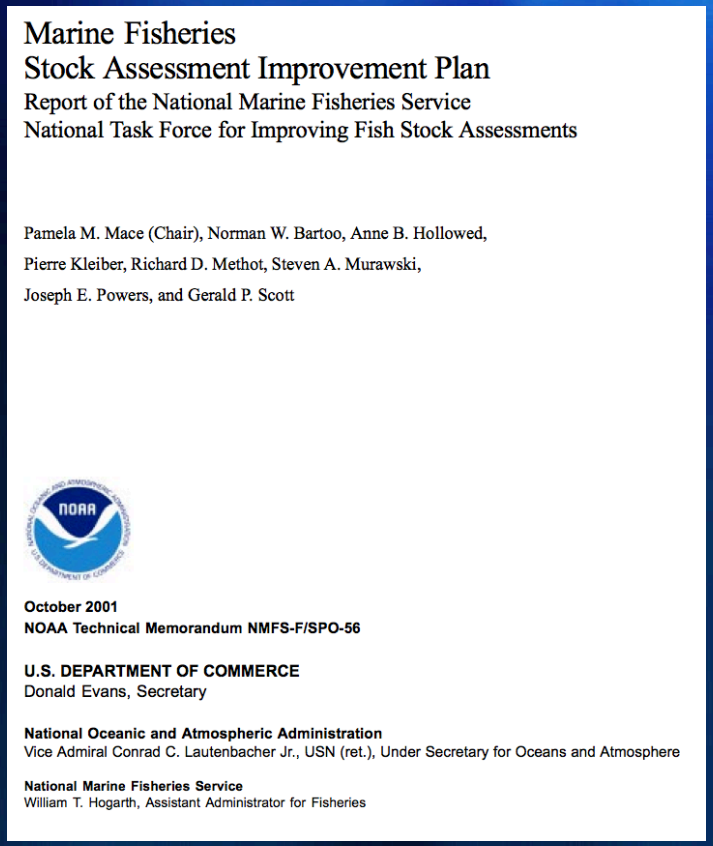
Normalcy Modeling and Anomaly Detection (DARPA PANDA and PerSEAS)



Football Play Recognition (DARPA CARVE)

Wide-Area Motion Imagery Event, Anomaly and Activity Detection (OSD Data to Decisions, DARPA PerSEAS)

# Stock Assessment Data Needs



Marine Fisheries
Stock Assessment Improvement Plan
Report of the National Marine Fisheries Service
National Task Force for Improving Fish Stock Assessments

Pamela M. Mace (Chair), Norman W. Bartoo, Anne B. Hollowed,
Pierre Kleiber, Richard D. Methot, Steven A. Murawski,
Joseph E. Powers, and Gerald P. Scott

October 2001
NOAA Technical Memorandum NMFS-F/SPO-56

U.S. DEPARTMENT OF COMMERCE
Donald Evans, Secretary

National Oceanic and Atmospheric Administration
Vice Admiral Conrad C. Lautenbacher Jr., USN (ret.), Under Secretary for Oceans and Atmosphere

National Marine Fisheries Service
William T. Hogarth, Assistant Administrator for Fisheries

Mace et al. 2001

- Accurate and precise estimates of species-specific size-structured abundance

  Numbers – species – length

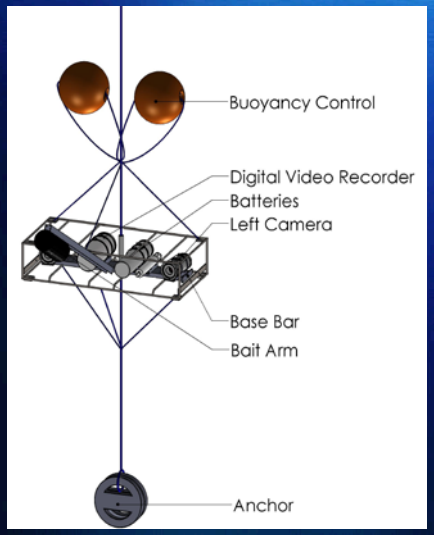
- "Greatest impediment to producing accurate, precise, and credible stock assessments is the lack of adequate input data"
- No index of abundance for 40% of stocks in 1999 Status of Fisheries Report
- Improved technologies to:
  - sample, survey, or experiment with species of interest in situ,
  - decrease sampling error,
  - increase sampling intensity,
  - increase the area or number of species covered.

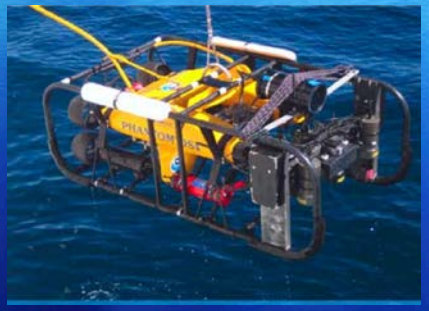
# NMFS Strategic Initiative on Automated Image Analysis

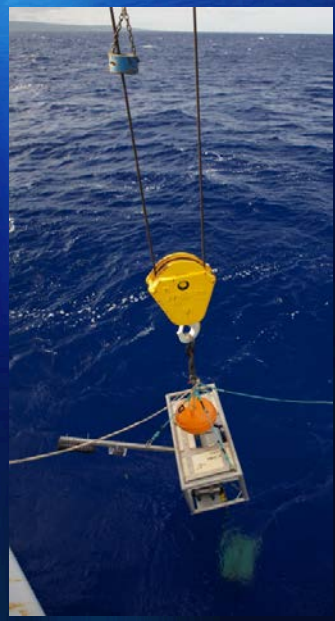
- Mission
  - Develop guidelines, set priorities, and fund projects to develop broad-scale, standardized, and efficient automated analysis of still and video imagery for use in stock assessment

- Benjamin Richards *(chair)*
  *NOAA Pacific Islands Fisheries Science Center*
- Alexandra Branzan Albu
  *University of Victoria*
- *Elizabeth Clarke*
  *NOAA Northwest Fisheries Science Center*
- George "Randy" Cutter
  *NOAA Southwest Fisheries Science Center*
- Duane Edgington
  *Monterey Bay Aquarium Research Institute*
- Dvora Hart
  *NOAA Northeast Fisheries Science Center*
- Anthony Hoogs
  *Kitware, Inc.*
- David Kriegman
  *University of California, San Diego*
- *Clay Kunz*
  *Google*
- Michael Piacentino
  *SRI International*
- Lakshman Prasad
  *Los Alamos National Laboratory*
- Charles Thompson
  *NOAA Southeast Fisheries Science Center*
- Kresimir Williams
  *NOAA Alaska Fisheries Science Center*

# Example Data Collectors



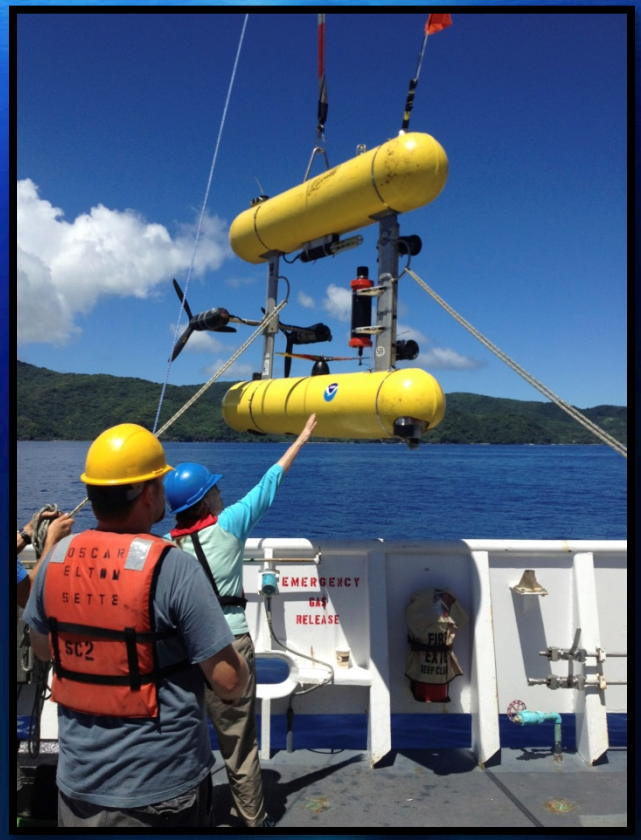





- Data streams exceed capabilities of human analysts
  - 100,000 - millions of images in a matter of days
- Automated tools must be developed to increase speed of analysis, reduce costs, improve assessments

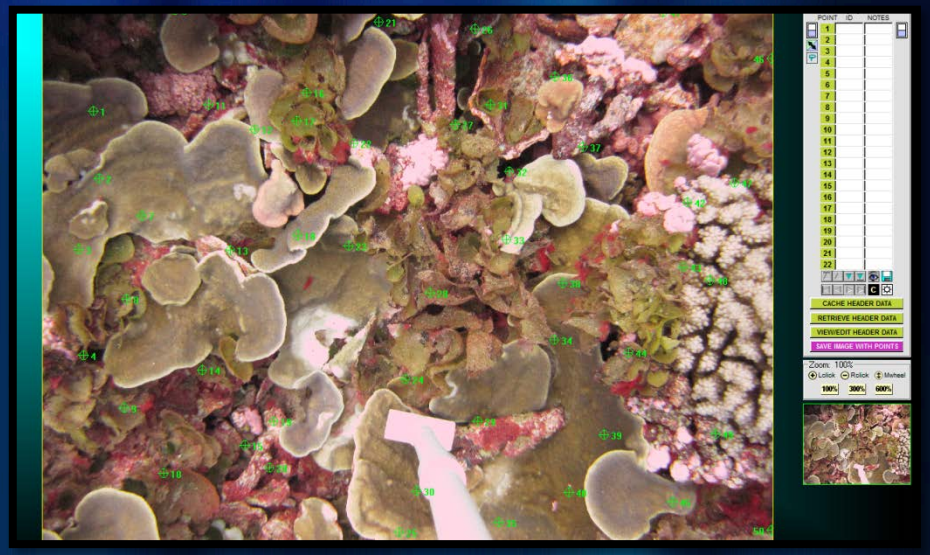
# Example Data Streams

- Single Camera Still Imagery
  - Aerial Photography – Seals
- Stereo Still Imagery
  - AUVs - Groundfish
- Single Camera Video
  - Towed Camera Systems – Scallops
  - ROVs – West Coast Groundfish
- Stereo-Video
  - Fixed Camera Systems – Reef and Hawaii Bottomfish
  - Trawl nets – Alaska Pollock
  - AUVs – Hawaii Bottomfish
  - Submersibles – West Coast Groundfish



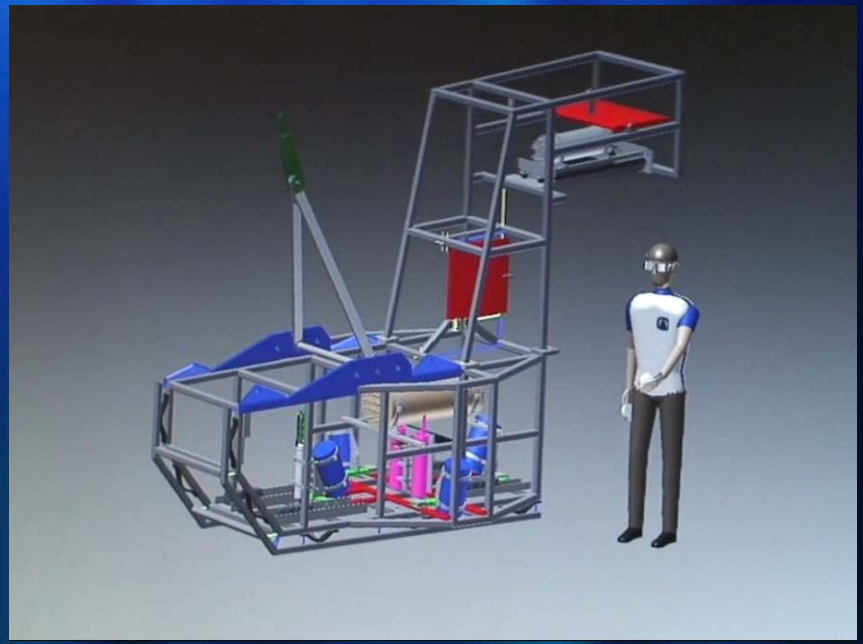
# Towed-Diver Benthic Surveys

- Williams et al. (PIFSC)
- Cameras
  - Digital, Mono, Still, Color, Downward-Facing
  - Canon EOS 50D
  - Frame Rate: 1 image/15 sec
- Lighting: Ikelite DS50
- Background: Moving, Complex
- Target: Benthic Cover
- Survey Speed: <1 kt
- Height above bottom: ~1 m
- Yearly Acquisition
  - Missions: 1-2
  - Still Images: 60,000
- Data Archive:
  - Still images: 600,000
- Human analysts: 5



# Towed Camera Benthic Surveys

- HabCam (Hart et al. NEFSC)
  - Cameras
    - Digital, Stereo, Still, Color, Downward-Facing
    - Model: Prosilica 1380C
    - Frame Rate: 6 fps
    - Baseline: 22 cm
  - Lighting: VIGI-Lux
  - Background: Moving, Complex
  - Target: Scallops, Benthic Inverts, Fish
  - Survey Speed: 5-7 kt
  - Height above bottom: 1-3 m
  - Yearly Acquisition
    - Missions: 3-4
    - Image Pairs: 6 million
  - Data Archive:
    - Image Pairs: 15 million
  - Human analysts: ~10
    - crowd-sourcing (http://www.seafloorexplorer.org)



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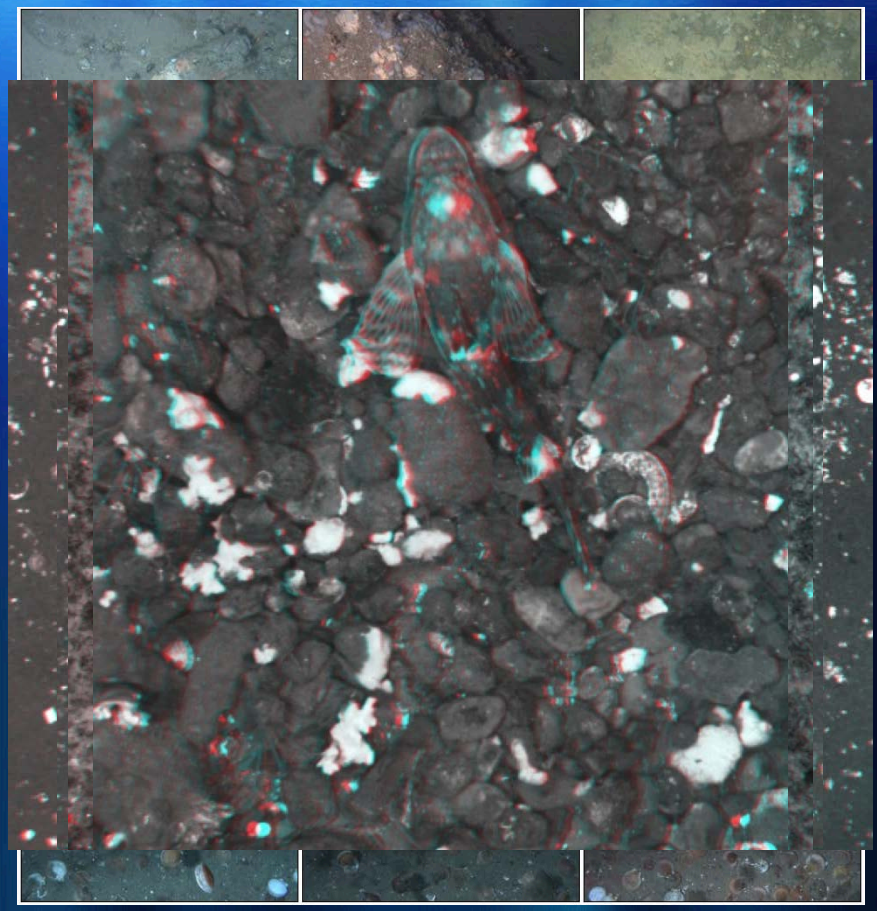

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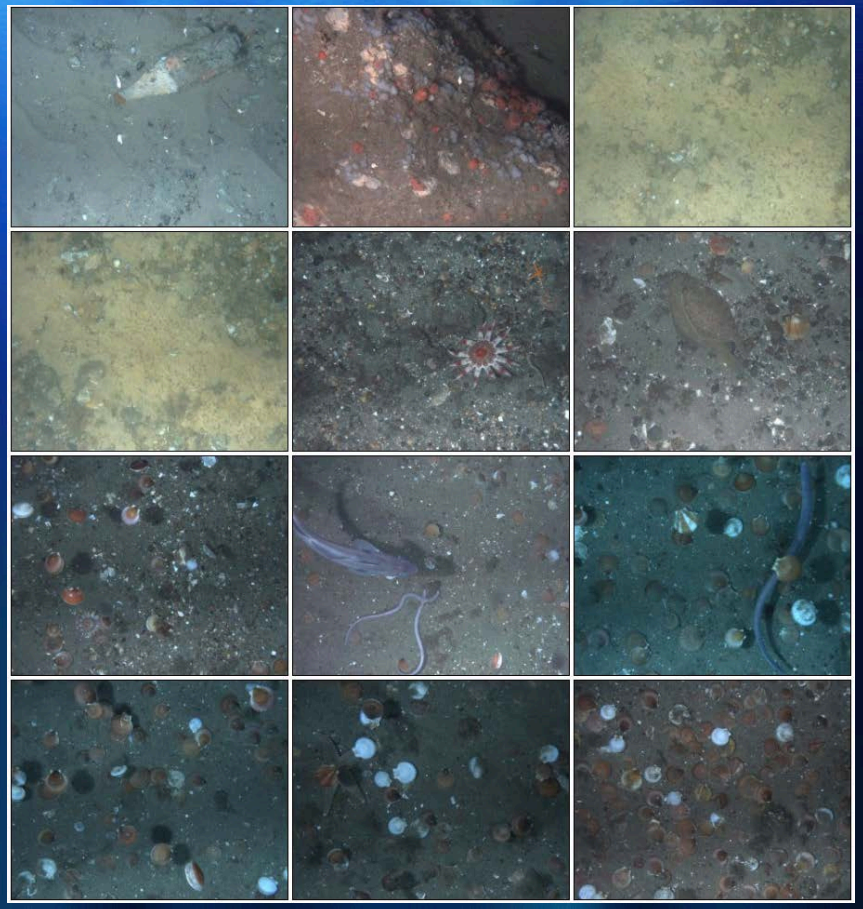
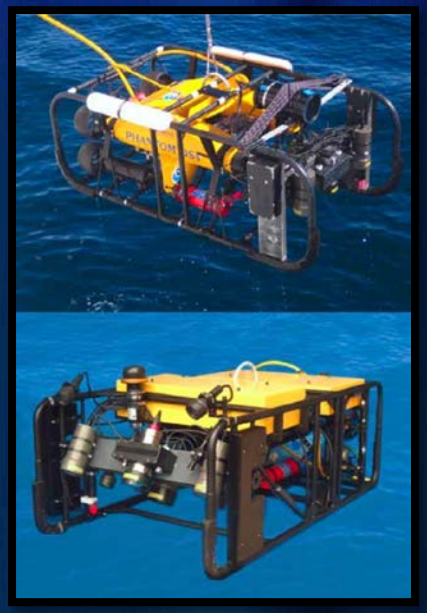


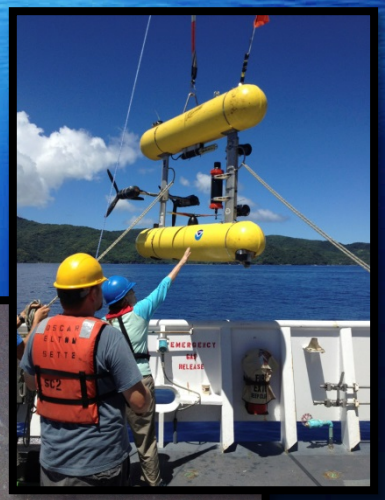
# ROV Fish Surveys

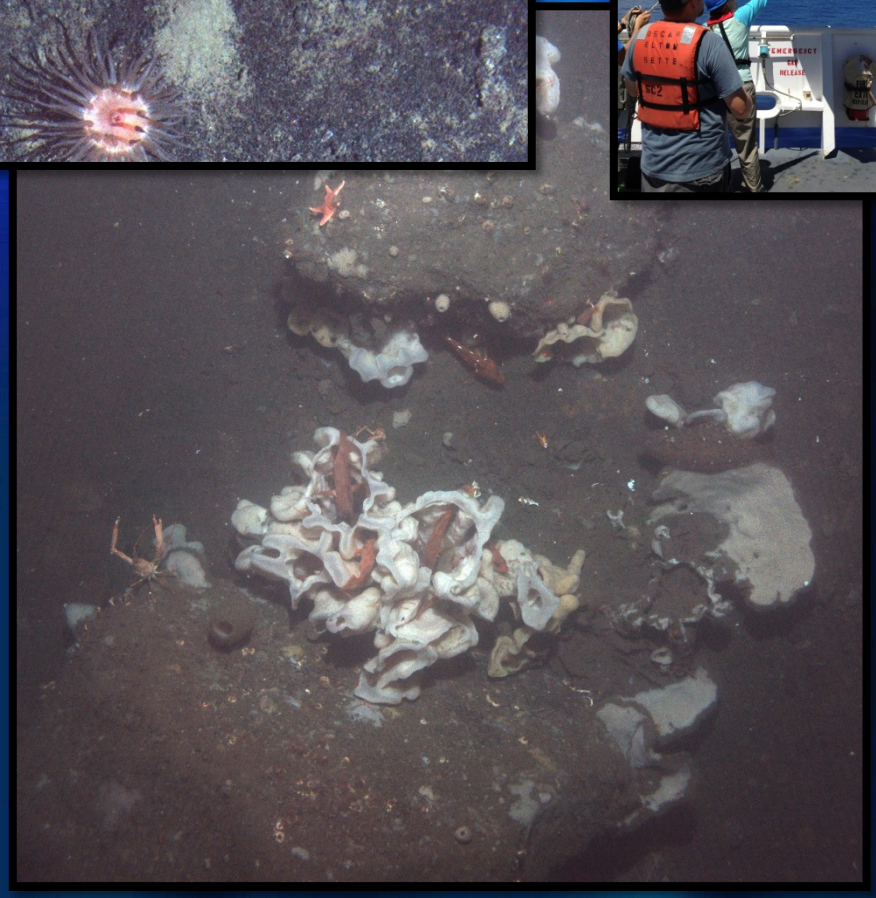
- Phantom DS4 & Custom (Yoklavich & Cutter, SWFSC)
  - Cameras
    - Video:
      - Insite Pacific NTSC (520x480)
      - Insite Pacific Zeus (1080)
      - Frame Rate: 29.97
      - Background: Moving, Complex
    - Still:
      - Insite Pacific Scorpio Plus (Nikon Coolpix 3mpx)
      - Background: Moving, Complex
  - Lighting: DSPL Multi Sea Light & Multi-SeaLite Matrix
  - Target: Demersal Fishes
  - Survey Speed: <1 kt
  - Height above bottom: <3 m
  - Yearly Acquisition
    - Missions: 1-5
    - Video: 150
    - Still Images: 8000
  - Data Archive:
    - Video: 1,100 hrs
    - Still images: 49,000
  - Human analysts: 3




# Demersal Fish AUV Surveys

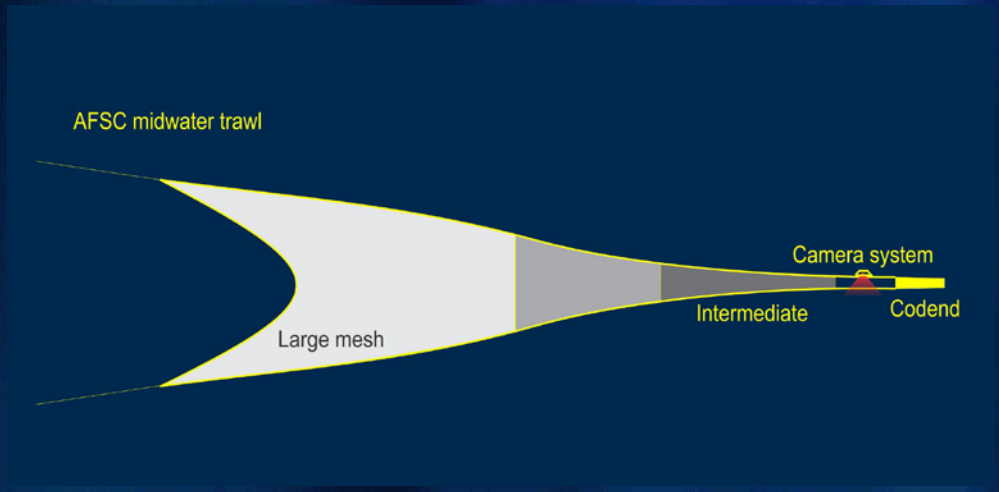
- SeaBED AUV (Clarke et al. NWFSC)
  - Cameras
    - Digital, Stereo, Still, Color, Downward-Facing
    - Model: Prosilica GC2450c (5pmx) & GE4000c (11mpx)
    - Frame Rate: 1 per 7 sec
    - Baseline: 10 cm
  - Lighting: White light Xenon DSLR strobe
  - Background: Moving, Complex
  - Target: Rockfish
  - Survey Speed: 0.25 mps
  - Height above bottom: 3 m
  - Yearly Acquisition
    - Missions: 2-3
    - Still images: 100,000
  - Data Archive:
    - Still images: 350,000
  - Human analysts: 1





# Net Camera Platforms

- CamTrawl (Williams et al. AFSC)
  - Cameras
    - Digital, Stereo, Still, Monochrome, Side-Facing
    - Model: JAI RM4200 GigE (4mpx)
    - Frame Rate: 5fps
    - Baseline: 28 cm
  - Lighting: 4 BridgeLux LED arrays
  - Background: Static, Simple
  - Target: Walleye Pollock
  - Yearly Acquisition
    - Missions: 3-4
    - Image Pairs: 3-4 million
  - Data Archive:
    - Image Pairs: 8.2 million
    - Human analysts: 2

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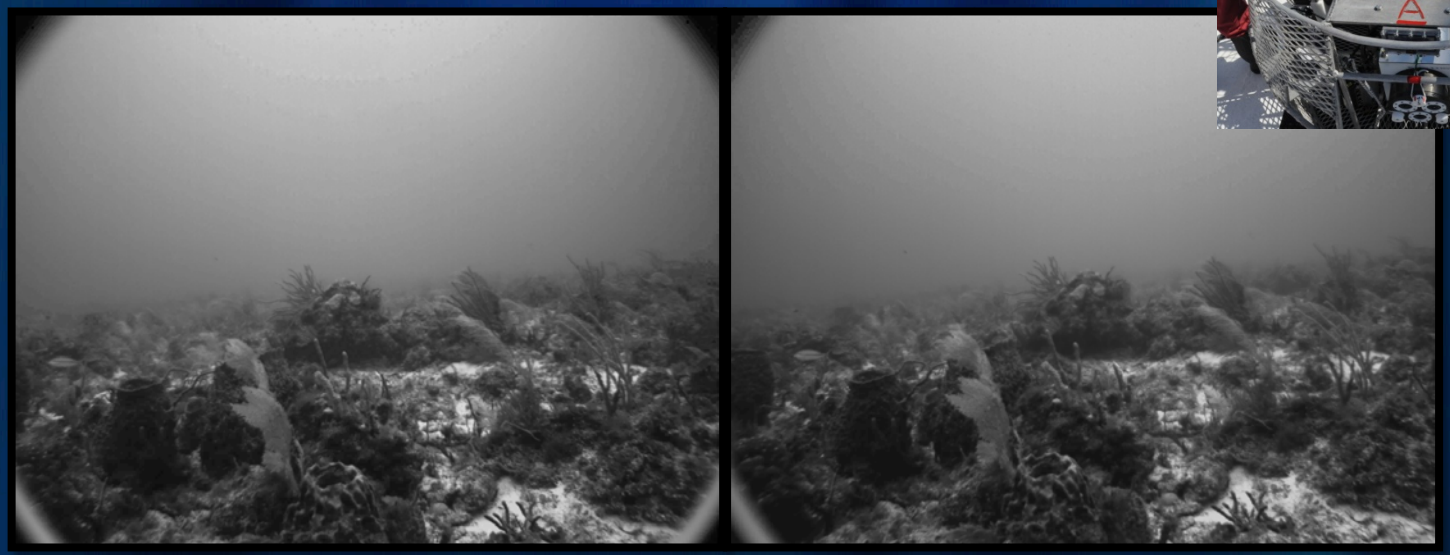
  - Yearly Acquisition
    - Missions: 3-4
    - Image Pairs: 3-4 million
  - Data Archive:
    - Image Pairs: 8.2 million
    - Human analysts: 2

# Stereo-Camera Platforms: Reef Fish

- QuadCam (Thompson et al. SEFSC)
- Camera
  - 4 camera still/stereo-video combination
  - Orthogonal positioning for 270° non-overlapping field of view
  - Video
    - Color
  - Still
    - Monochrome
    - Frame Rate: 1.2 fps
    - Baseline: 9 cm
  - Lighting: Ambient
  - Background: Moving, Complex
  - Target: Reef Fish
  - Height above bottom: 0 m
  - Yearly Acquisition
    - Missions: 4
    - Video: 1,200 hours
    - Still Images: 13.7 million
  - Data Archive:
    - Video: 15,000 hrs (7,000 digital)
    - Still images: 83 million
  - Human analysts: 4



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    - Frame Rate: 1.2 fps
    - Baseline: 9 cm
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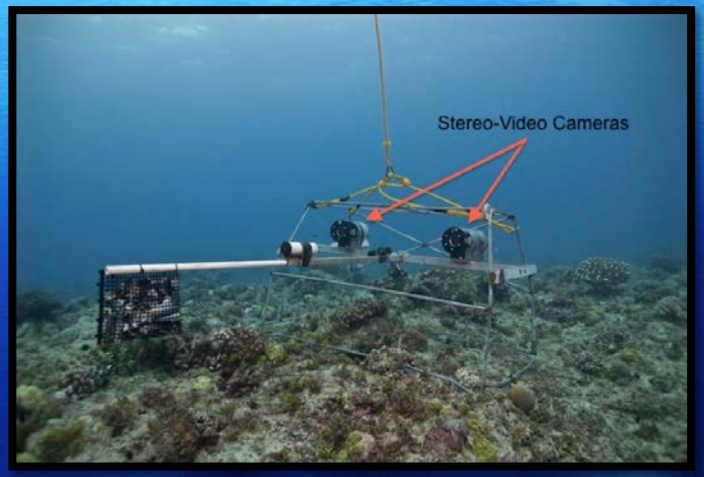
  - Background: Moving, Complex
  - Target: Reef Fish
  - Height above bottom: 0 m
  - Yearly Acquisition
    - Missions: 4
    - Video: 1,200 hours
    - Still Images: 13.7 million
  - Data Archive:
    - Video: 15,000 hrs (7,000 digital)
    - Still images: 83 million
  - Human analysts: 4

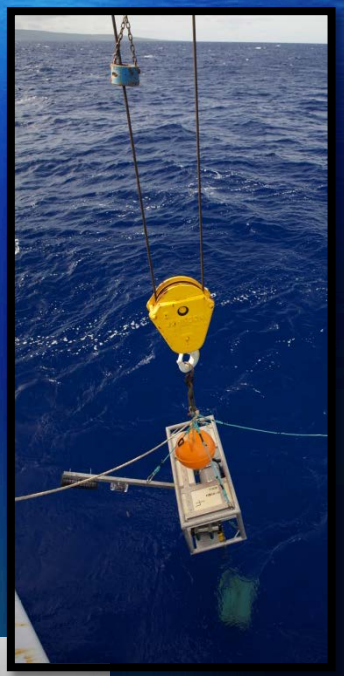
# Stereo-Camera Platforms: Reef Fish

- BRUVS (Asher et al. PIFSC/UWA)
  - Cameras
    - Digital, Stereo, Video, Color, Forward-Facing
    - Sony CX12
    - Frame Rate: 29.97
    - Baseline: 75 cm
  - Lighting: Ambient
  - Background: Moving, Complex
  - Target: Reef Fish
  - Height above bottom: 0 m
  - Yearly Acquisition
    - Missions: 1-3
    - Video: 100 - 600 hrs
  - Data Archive:
    - Video: 1,200 hrs
  - Human analysts: 1




# Stereo-Camera Platforms: Bottomfish

- BotCam (Richards et al. PIFSC UH)
  - Cameras
    - Analogue, Stereo, Video, Monochrome, Forward-Facing
    - ROS Navigator
    - Frame Rate: 29.97
    - Baseline: 75 cm
  - Lighting: Ambient
  - Background: Moving, Complex
  - Target: Bottomfish
  - Height above bottom: 5 m
  - Yearly Acquisition
    - Missions: 3
    - Video: 100 hrs
  - Data Archive:
    - Video: 1,500 hrs
  - Human analysts: 3

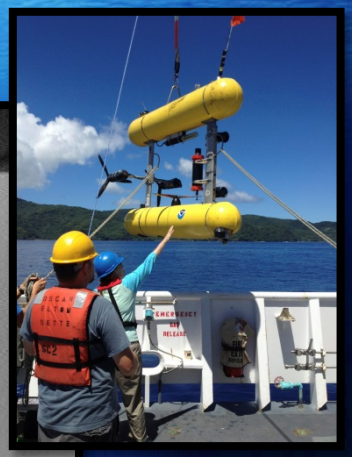


# Towed-Diver Fish Surveys

- Williams et al. PIFSC
- Cameras
  - Analogue, Video, Color, Mono, Forward-Facing
  - Model: Canon Vixia HF S21
  - Frame Rate: 29.97
- Lighting: Ambient
- Background: Moving, Complex
- Target: Reef Fish
- Survey Speed: ~1.5 kt
- Height above bottom: <3 m
- Yearly Acquisition
  - Missions: 1-2
  - Video: 250 hrs
- Data Archive:
  - Video: 2,300 hrs
- Human analysts: 2

# Bottomfish AUV Surveys

- SeaBED AUV (Richards et al. PIFSC)
  - Cameras
    - Analogue, Video, Stereo, Monochrome, Forward-Facing
    - ROS Navigator
    - Frame Rate: 29.97
    - Baseline: 50 cm
  - Lighting: Ambient
  - Background: Moving, Complex
  - Target: Bottomfish
  - Survey Speed: 0.25 mps
  - Height above bottom: <10 m
  - Yearly Acquisition
    - Missions: 2-4
    - Video: 100 hrs
  - Data Archive:
    - Video: 1,100 hrs
  - Human analysts: 2



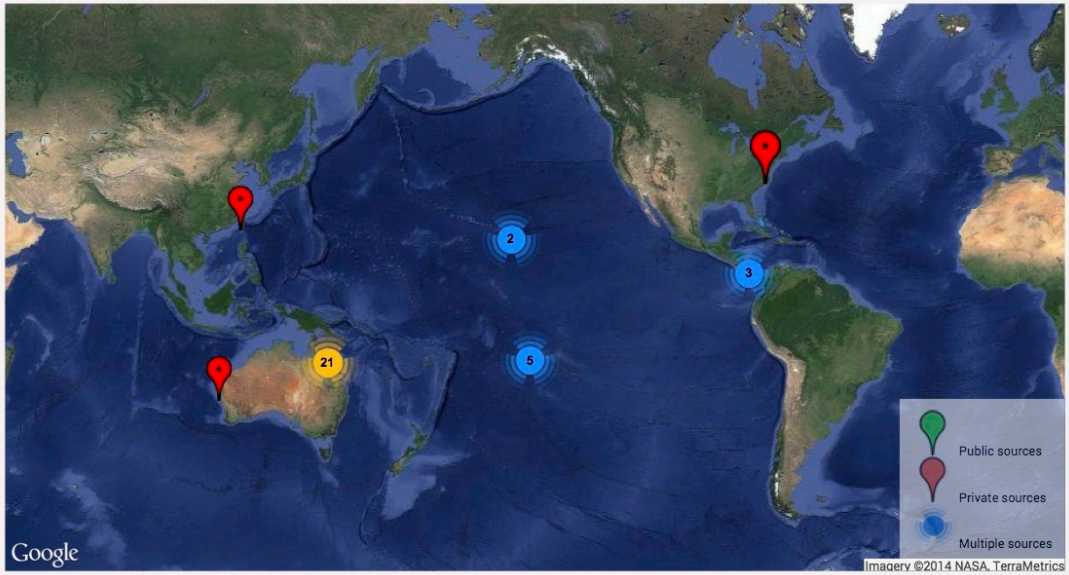
# Benthic Habitat Classification

**CORALNET** ALPHA

**A WEB SOLUTION FOR CORAL REEF ANALYSIS**

Upload coral reef images, organize and annotate images, and view annotation statistics.

Sign In  Sign Up  What is CoralNet?

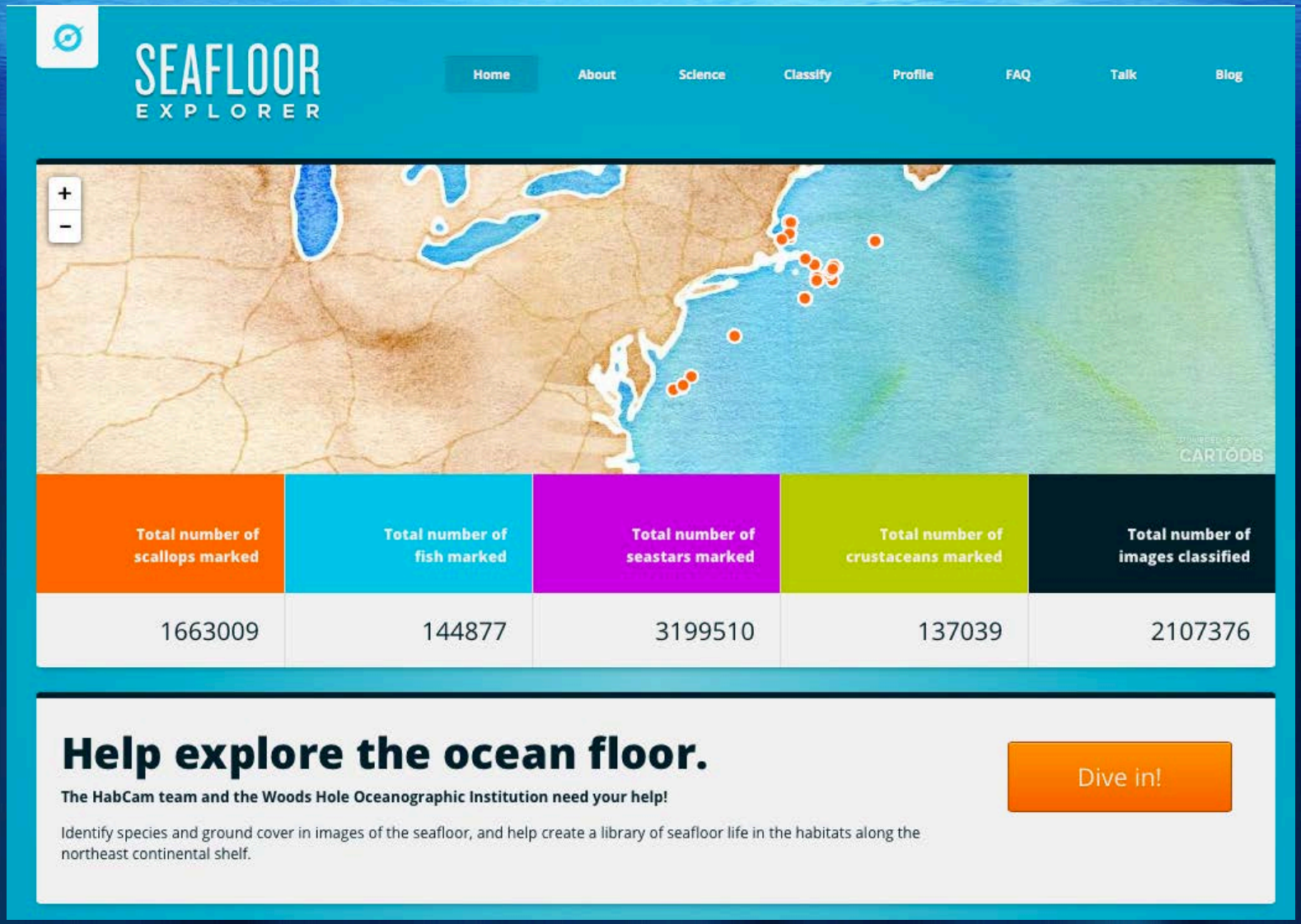



Visit data sources from around the world by clicking on public sources to explore images, labels, and coverage statistics.

There are currently 71 sources on CoralNet, with a combined total of 31197 images. Out of all the annotations on the site, 1325658 are human annotated, 1565039 are machine annotated, with a total of 2890697 annotations.

http://coralnet.ucsd.edu, D. Kreigman, UCSD

# Classification of Benthic Fauna




http://www.seafloorexplorer.org

# Classification of Benthic Fauna

Lightfield & color correction

Substrate classifiication

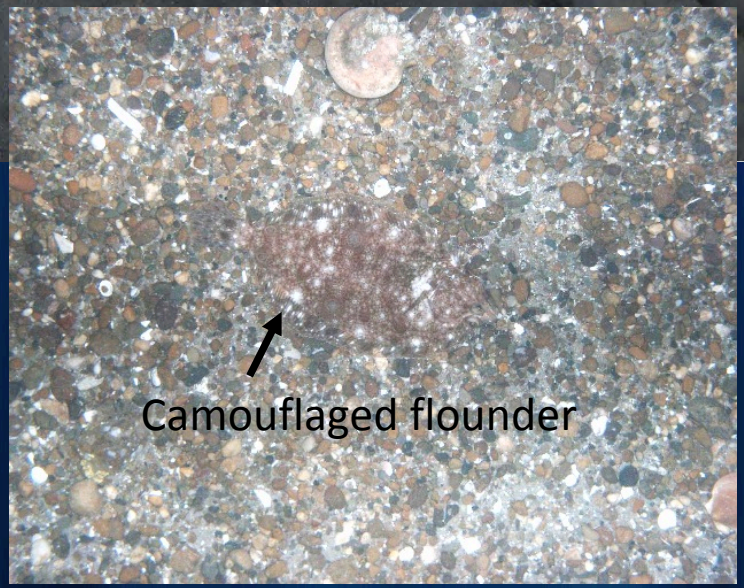
Stereo rectification

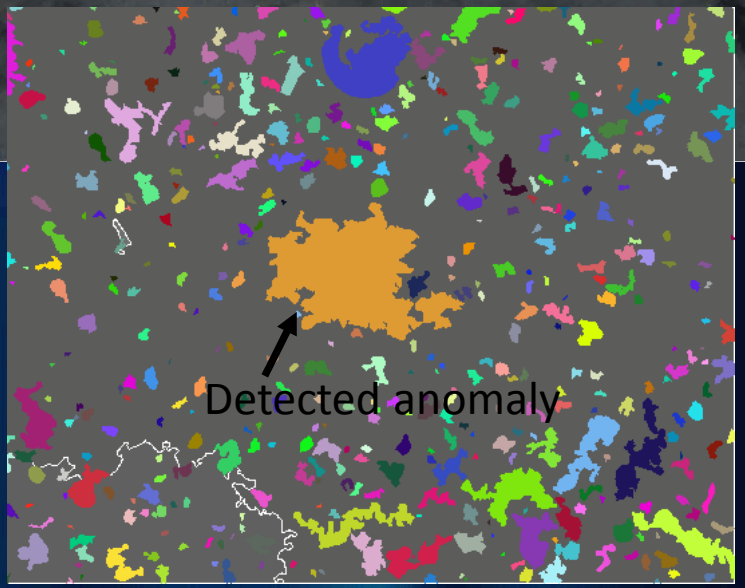
Stereo depth map

Geomorphology
*Rugosity
*Slope
*Gradient

Original image with 2 scallops

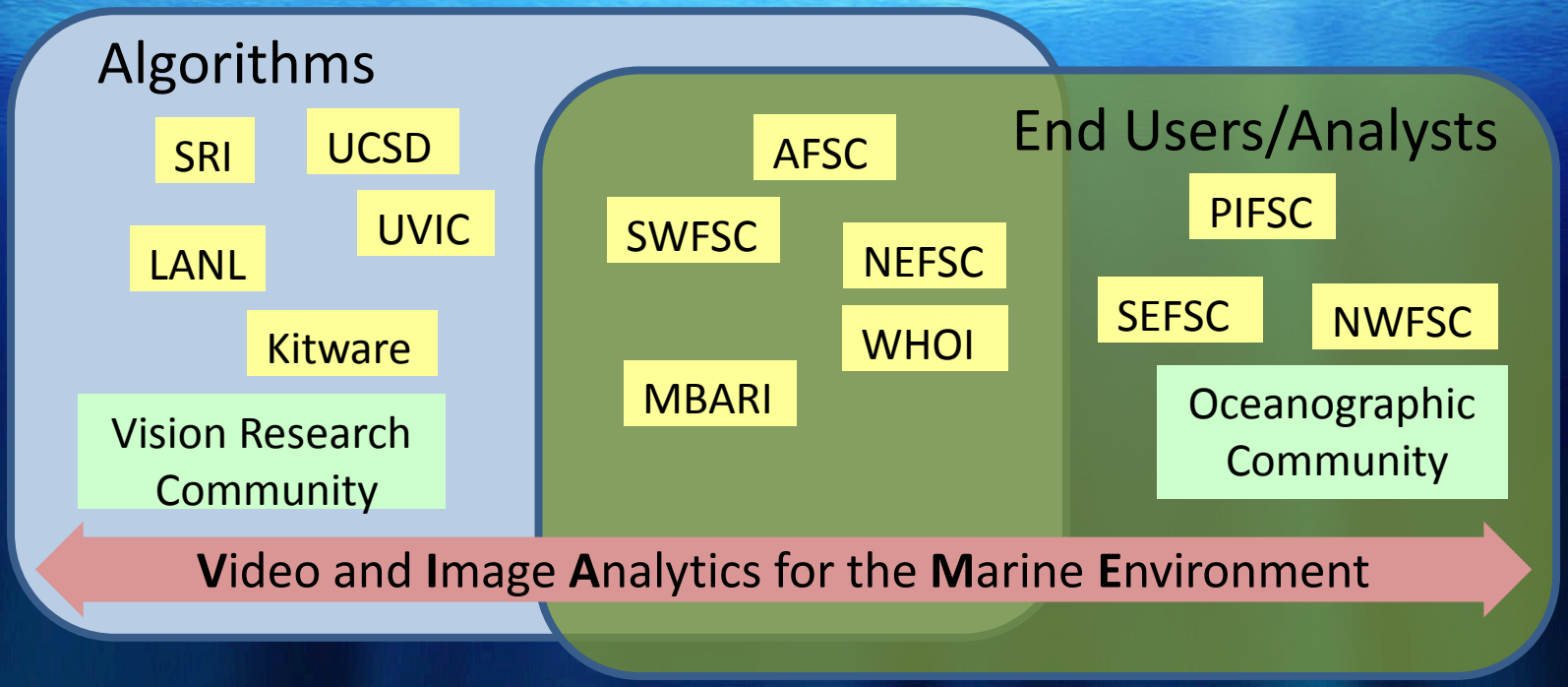
Triangulated image with detected scallops (red)




Images courtesy of D. Hart & S. Gallager, NEFSC/WHOI, HabCam

# Lots of Data, Analytics and Users





NOAA Fisheries Science Centers involved in AIASI

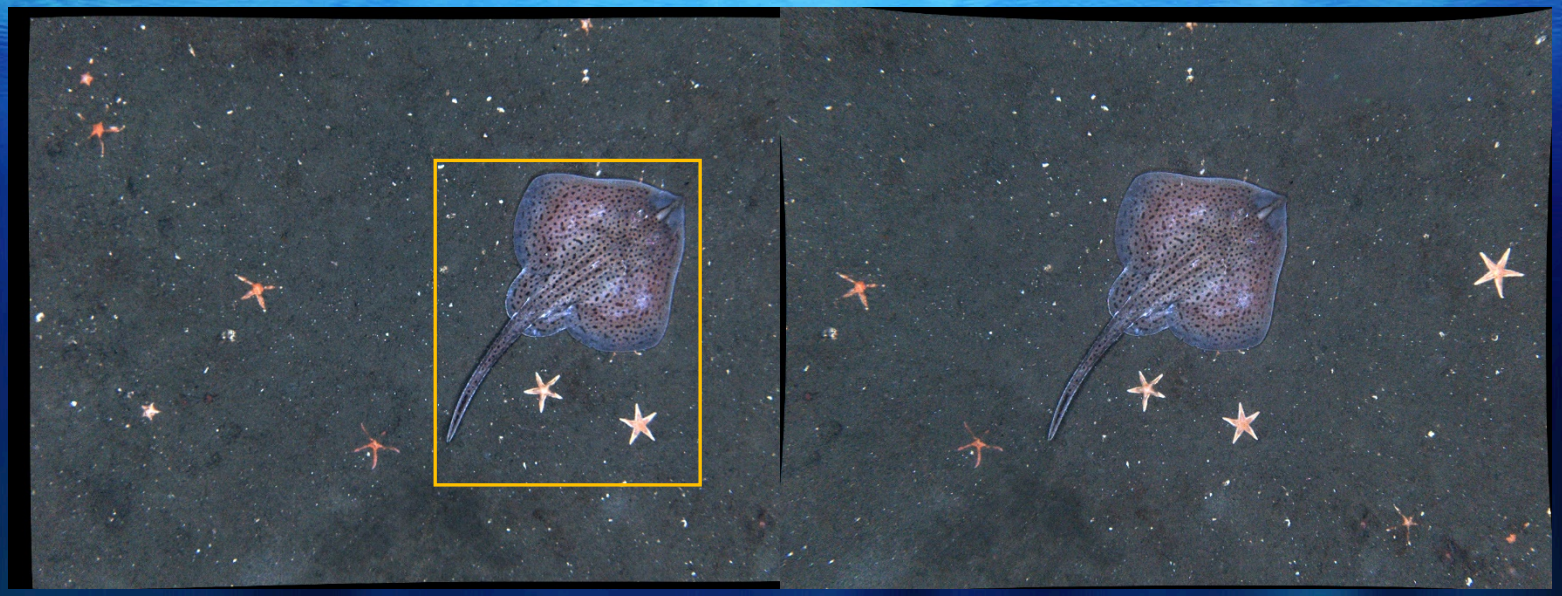
# Agenda

- NOAA Datasets
- Underwater video challenge dataset
- Open source toolkit: Video and Imagery Analytics for the Marine Environment

# Underwater Video Challenge Dataset

- Challenge workshop proposal for CVPR 2018
  - Automated Analysis of Marine Video for Environmental Monitoring
- Fish detection in images
  - Horizontal imagery
  - Down-looking imagery
- Fish classification
- Annotations for training and testing
- Software for scoring, visualization, baseline algorithms
- Schedule
  - Dataset and annotations released in January
  - Results due end of March
  - Top performers  present at workshop
  - Cash prize (pending approval)

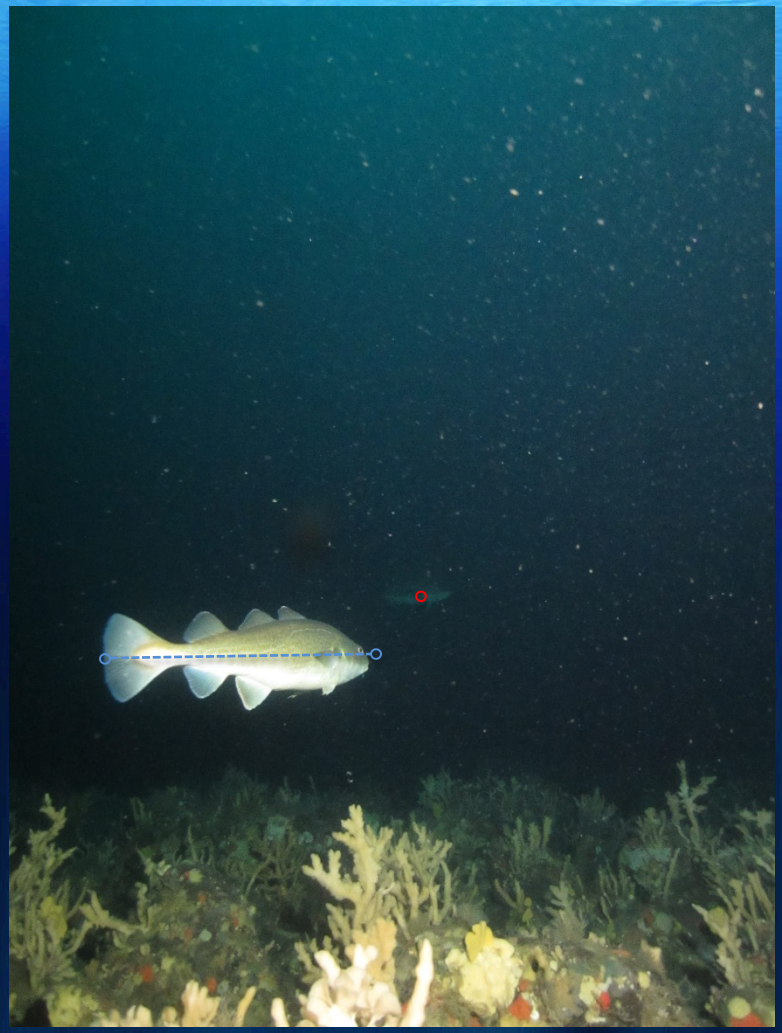
# Dataset: HabCam 2015 Stereo Collect



**119463 Images**
**38566 Total Annotations (Boxes, Lines, Points)**

- Crabs - 1423
- Live Scallops - 8864
- Dead Scallops - 456
- Skates, Other Fish - 2538
- Other - 25285

# Dataset: AFSC Dropcam

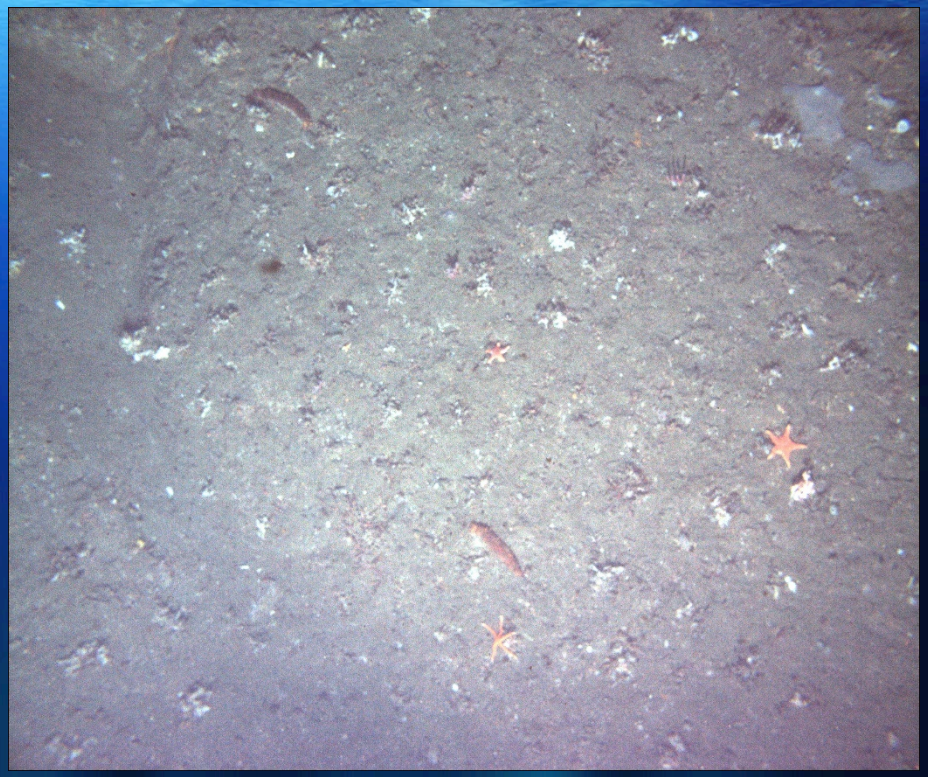


| Class | Quantity |
|---|---|
| Northern Rockfish | 1473 |
| Rockfish Unid. | 2675 |
| Flatfish Unid. | 778 |
| Pacific Ocean Perch | 823 |
| Pacific Cod | 675 |
| Pacific Halibut | 287 |
| Fish Unid. | 1587 |
| Dusky Rockfish | 269 |
| Searcher | 190 |
| Pollock | 189 |
| Harlequin Rockfish | 399 |
| Irish Lord | 182 |
| Sculpin Unid. | 157 |
| Poacher Unid. | 119 |
| Flathead Sole | 47 |
| Rex Sole | 48 |
| Atka Mackerel | 43 |
| Arrowtooth Flounder | 31 |
| Rock Sole Unid. | 22 |
| Sharpchin Rockfish | 32 |
| Black Rockfish | 19 |
| Skate Unid. | 26 |
| Dover Sole | 6 |
| Prickleback | 36 |
| Ronquil Unid. | 86 |
| Silvergray Rockfish | 20 |

**3343 Images**

**Mix of Point and Line Annotations**

# Dataset: NWFSC AUV



**3313 Images**

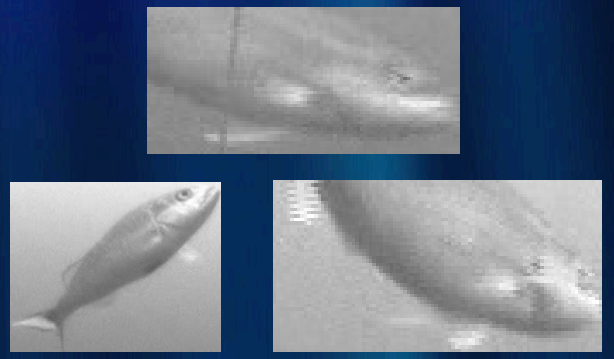
**1546 Annotations: Rockfish, Flatfish, Other**

Point Annotations

# Dataset: PIFSC MOUSS/BotCam

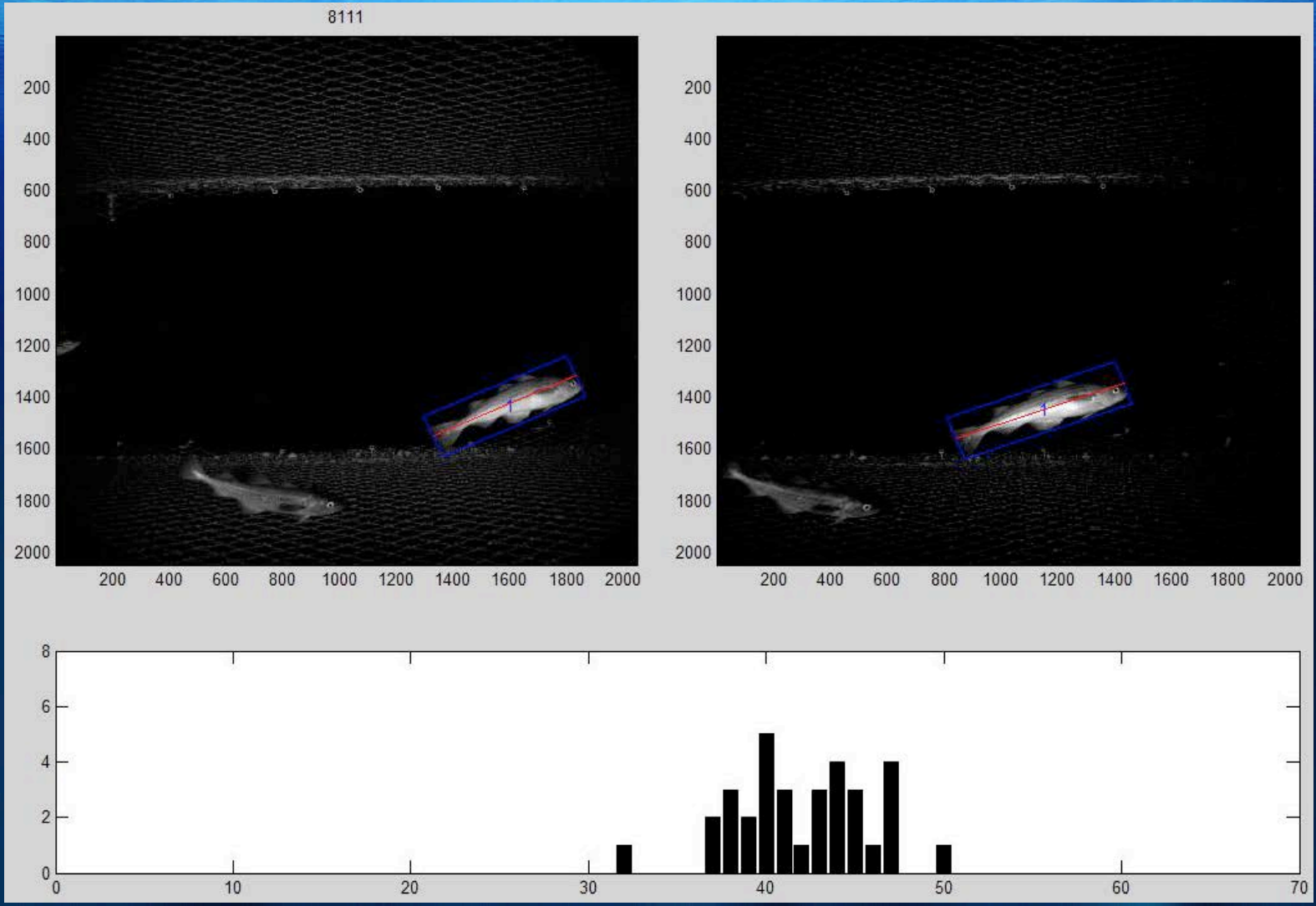
**Kale Kale**

**Opakapaka**



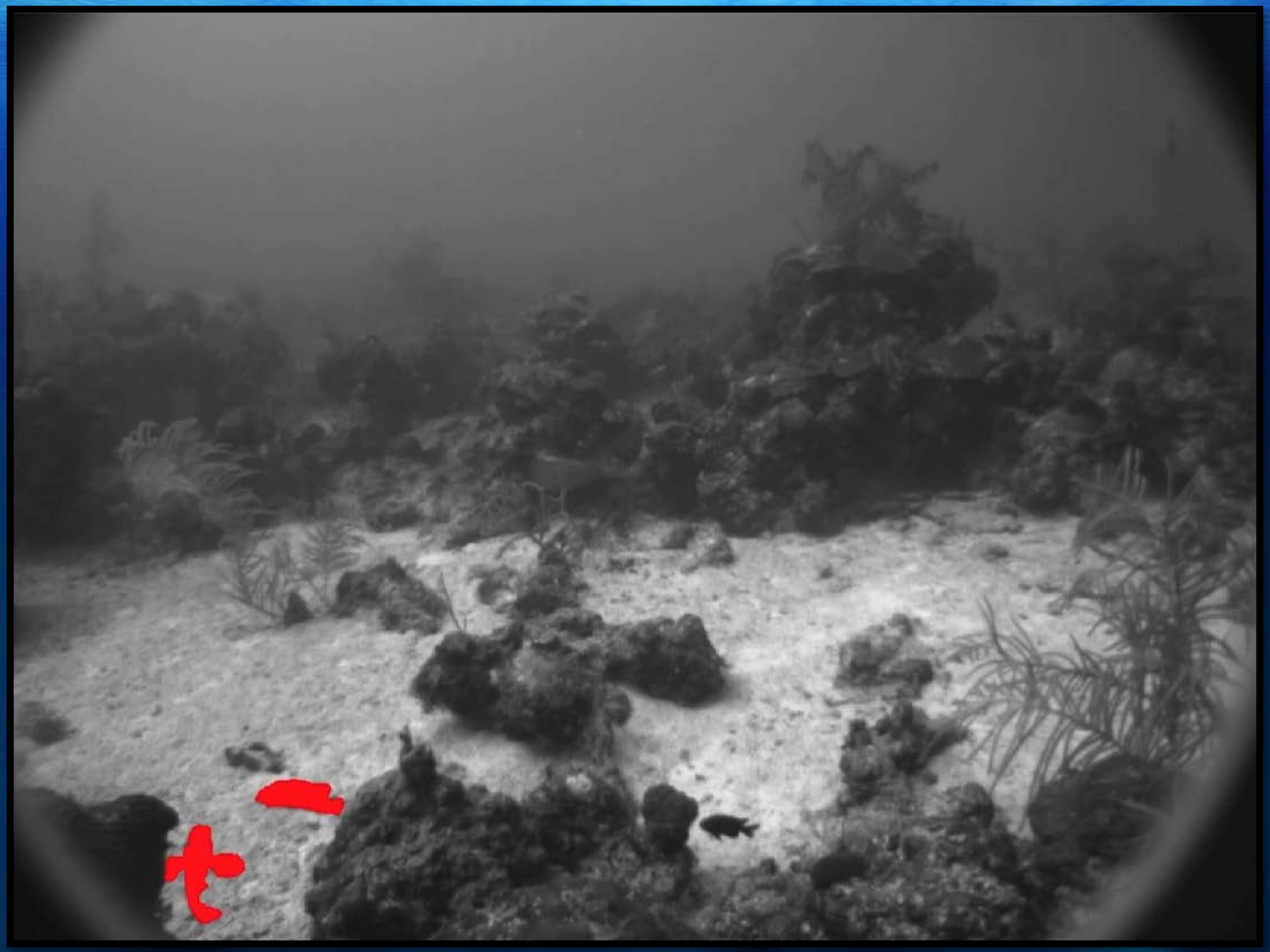
~1200 Chip Annotations
Currently Updating

# Automated Fish Detection




Video sequences courtesy of K. Williams (AFSC) from CamTrawl

# Automated Fish Detection



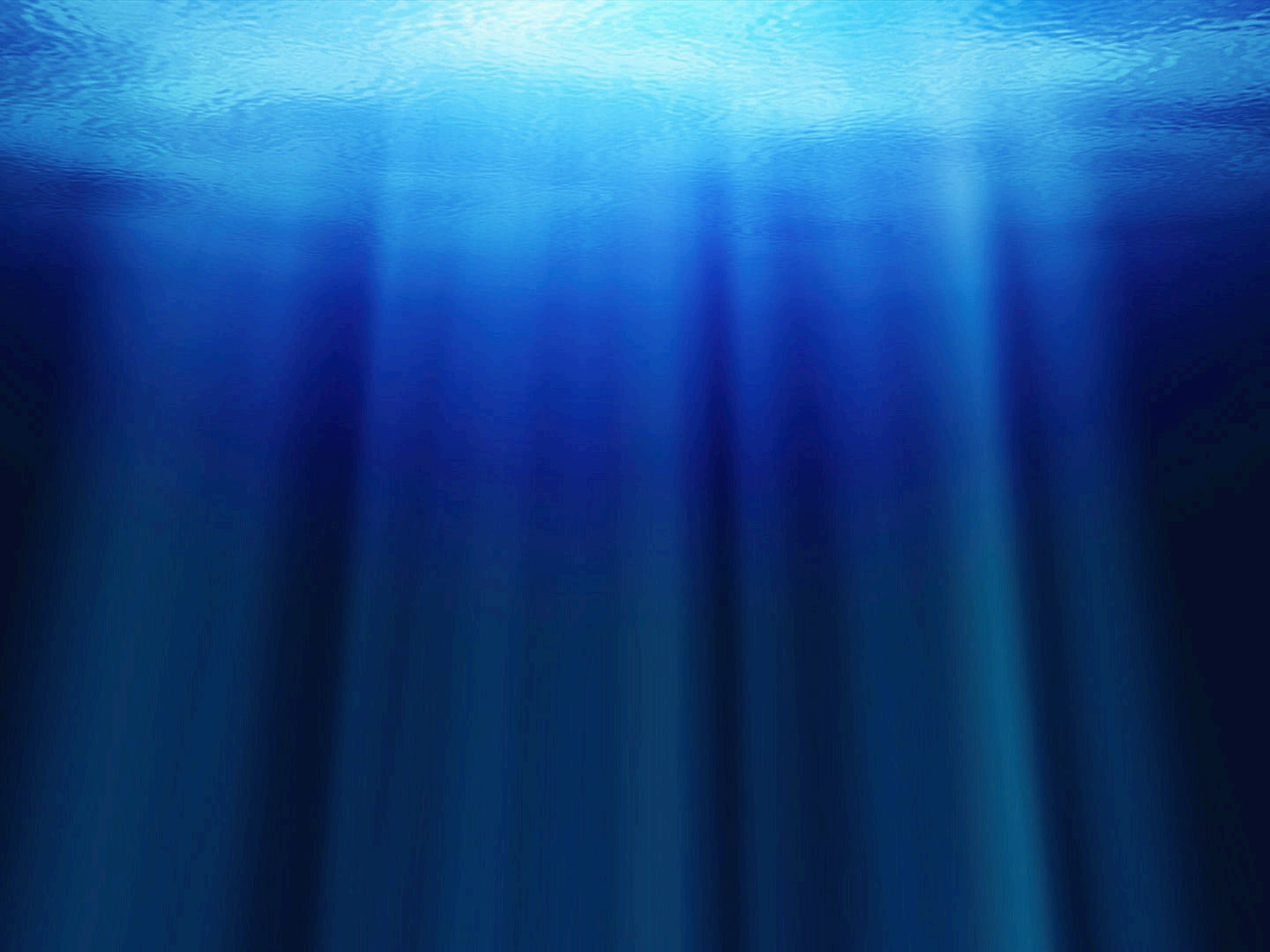
Video sequences courtesy of C. Thompson (SEFSC) & L. Prasad (LANL) using RADIUS target detection algorithms

# Stay Tuned!

- Announcement on tutorial page and VIAME home page, viametoolkit.org, when dataset is released
- Initial challenge will be detection and classification on images
- Future additions will include
  - Tracking
  - Length measurement using stereo video
  - Behavior recognition
  - Anomaly detection

# Agenda

- NOAA Datasets
- Underwater video challenge dataset
- Open source toolkit: Video and Imagery Analytics for the Marine Environment

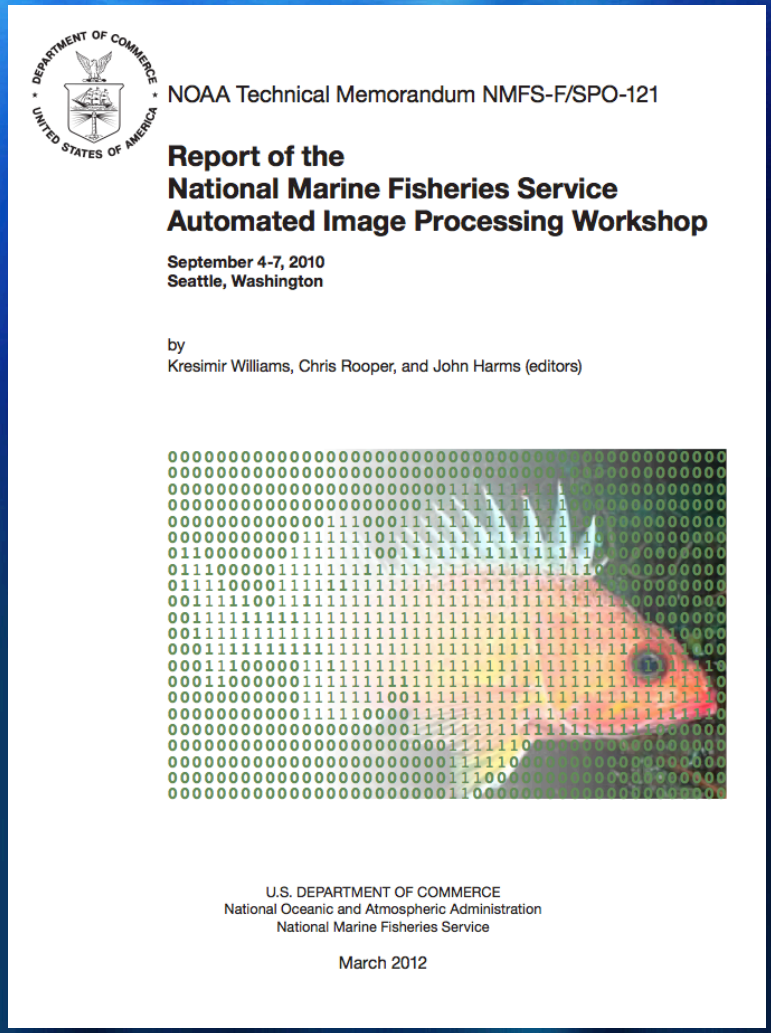


# Challenges

- Data streams exceed capabilities of human analysts
  - 100,000 - millions of images in a matter of days
- Data products not available quickly enough for use in stock assessments
- Automated tools must be developed to increase speed of analysis, reduce costs, improve assessments

# NMFS Workshop on Automated Image Processing (2014)

- Recommendations
  - Inter-disciplinary collaboration
  - Create international forum or working group for automated analysis of images from marine image-based sampling systems
  - Development of a database to facilitate in feature recognition for marine organisms
    - Shared image bank
  - Optimal allocation of automation in analysis
    - Easy vs Hard problems
    - Partial automation
  - **Modular approach with medium for exchange**



NOAA Technical Memorandum NMFS-F/SPO-121

**Report of the National Marine Fisheries Service Automated Image Processing Workshop**

**September 4-7, 2010**
**Seattle, Washington**

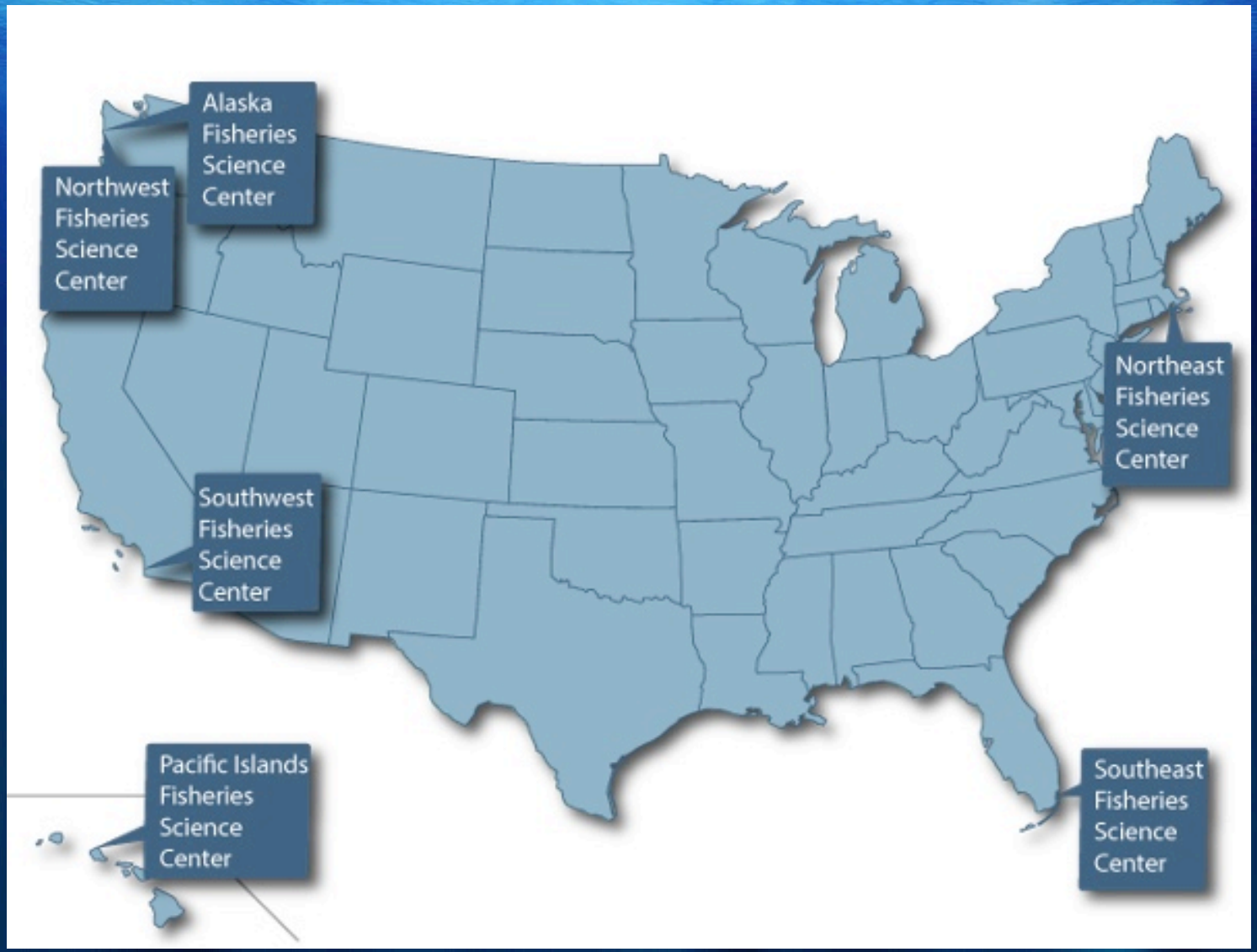
by
Kresimir Williams, Chris Rooper, and John Harms (editors)

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service

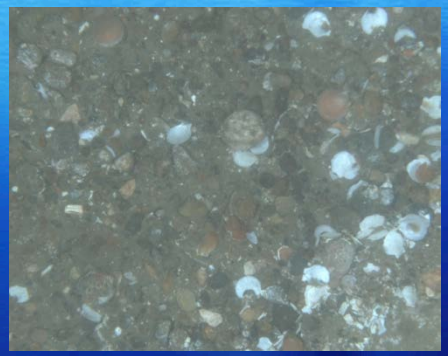
March 2012

Williams et al (2012)

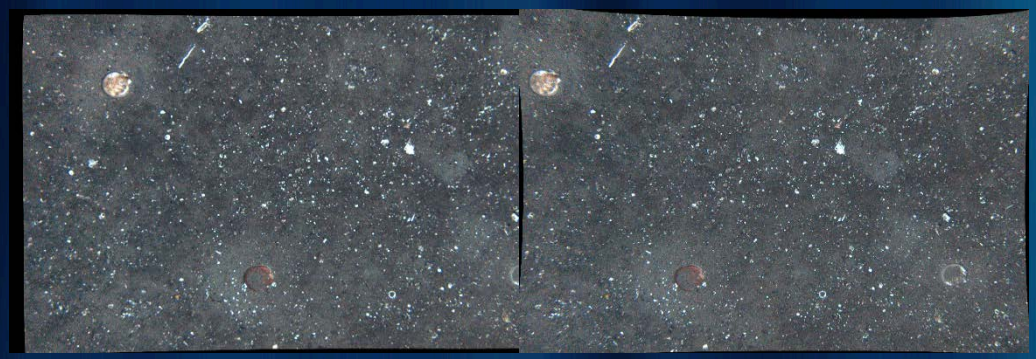
# NOAA FSC's Involved in AIASI



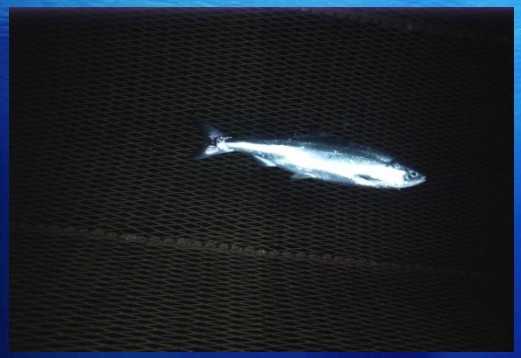
# Example Data Sources

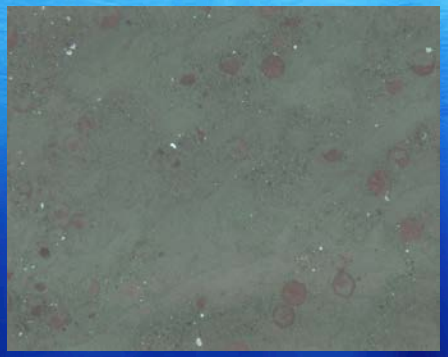



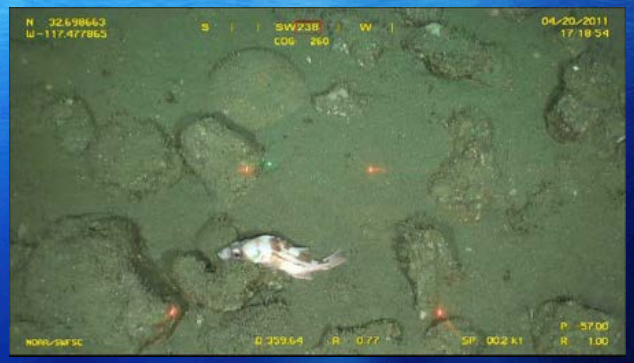


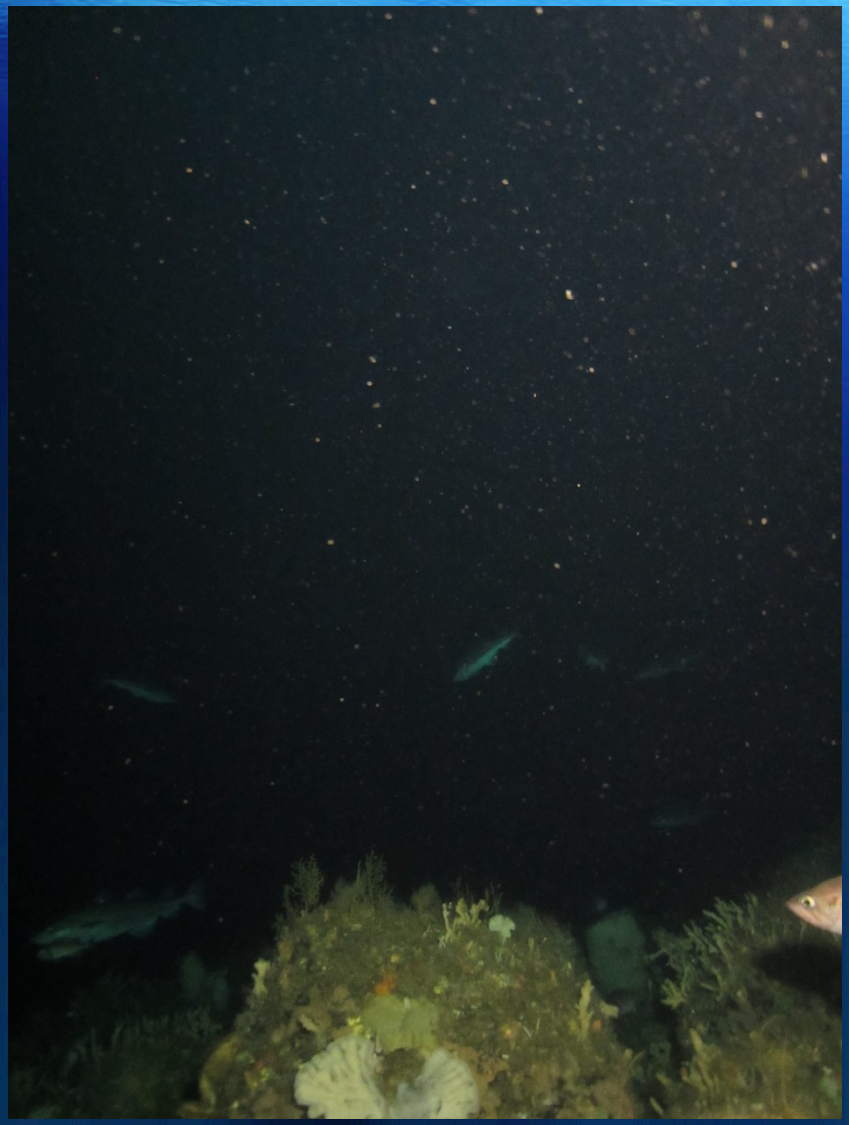
# Example Data Sources







# Dataset: AFSC Dropcam



# Dataset: Camtrawl Collect

Annotations currently in progress, refined from automatic detections

# Dataset: SWFSC ROV video

Only certain species annotated (not all fish in frame)