Automated Fish Analysis in the Northeast Groundfish Fishery: *Building a Library for Image Processing and Machine Learning to Support Electronic Monitoring Programs*

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What Do We Mean by EM?

- **Electronic Monitoring (EM)** refers to the use of cameras and other sensors to monitor fishing activities
- Increase of the efficiency of fisheries monitoring
  - Reduced cost
  - Increased flexibility for fishers
  - More rapid data transmission
- Can generate large volumes of video data
- Natural fit for machine learning and automated image processing

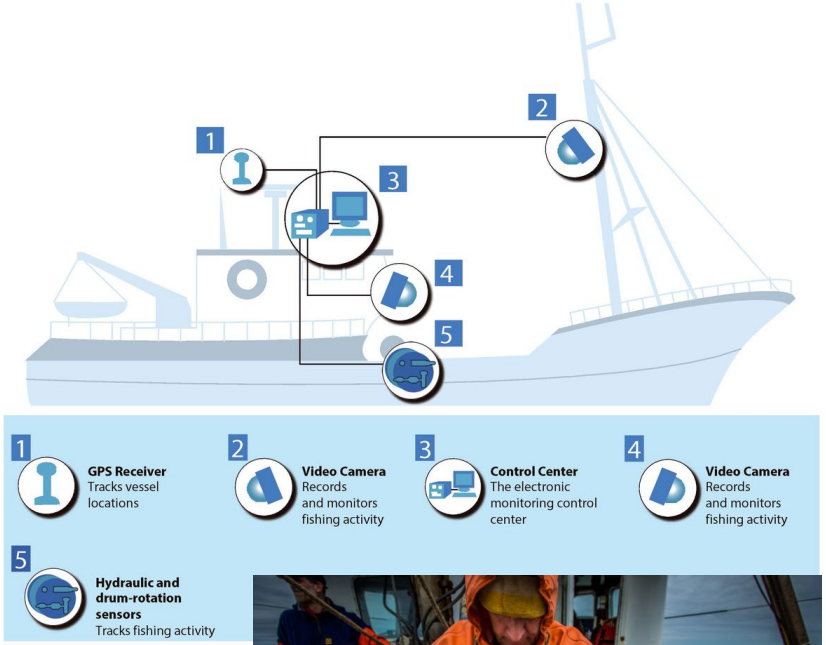
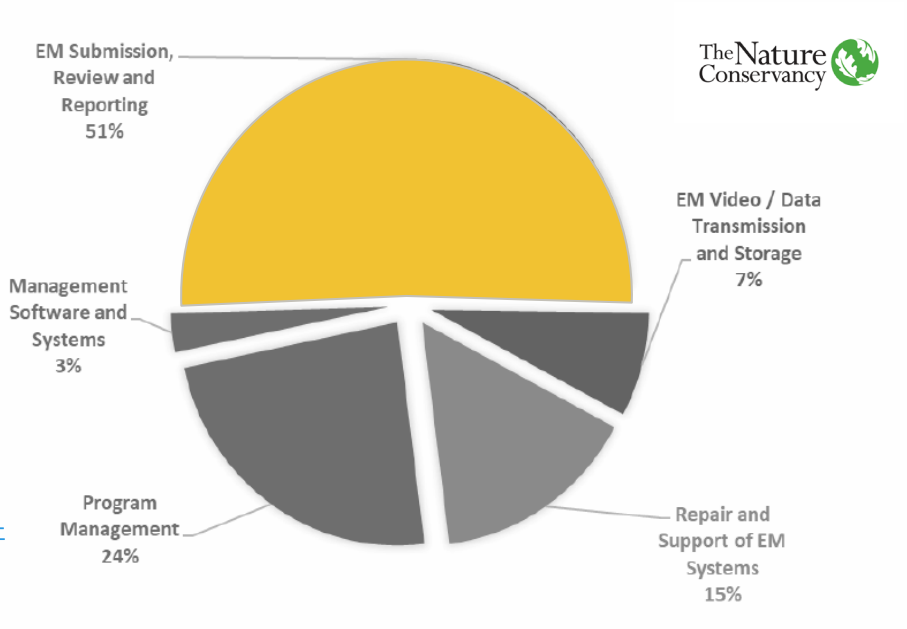


Photo © Ayla Fox for The Nature Conservancy

Need for Means to Increase Efficiency

- Currently video review is the largest component of EM program costs
- Much of this involves simple species identification and length estimate generation
- Video review is an area project partners expect efficiencies can be developed

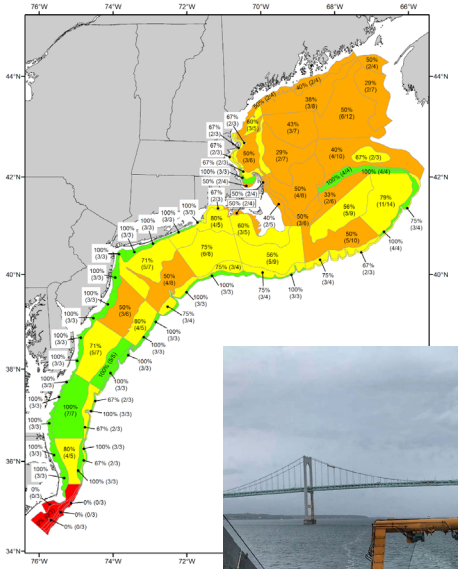
Chart 1: % of Annual Costs by Budget Category (Year 3 of Program)

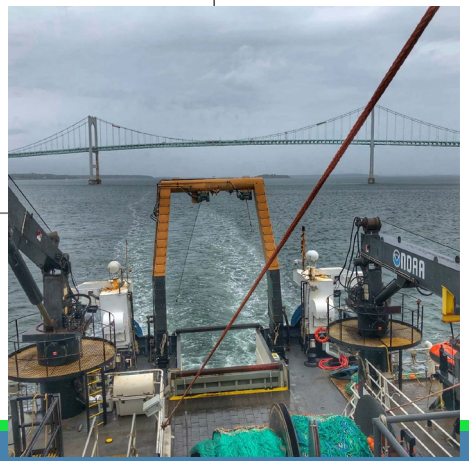


https://eminformation.com/wp-content/uploads/2019/04/TNC-EM-Cost-Assessment-Report-Submission-to-NEFMC-4_10_19.clean_.pdf
Cap Logg Group LLC & The Nature Conservancy

Northeast Fisheries Science Center Trawl Survey

- Fall: 1963-present
- Spring: 1968-present
- R/V Bigelow: 2018 - present
- Continuous sampling of: surface temperature, salinity, pCO2, water column currents (ADCP), fisheries acoustics along survey track
- 20 m depth to shelf edge
- Bottom trawl at ≈350 stations

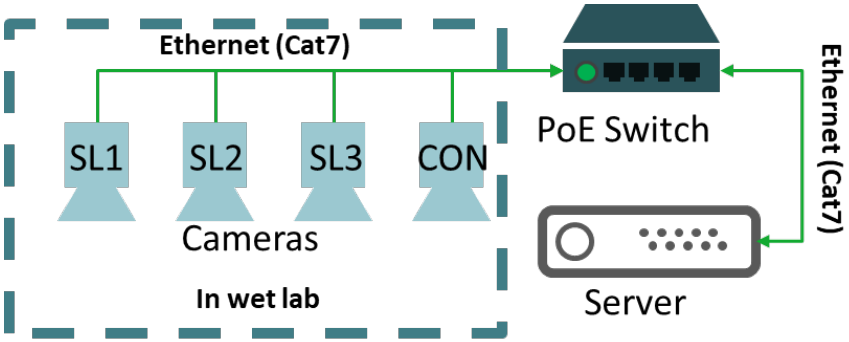




http://www.nefsc.noaa.gov/esb/

NEFSC Ecosystem survey branch

System Overview



Switch

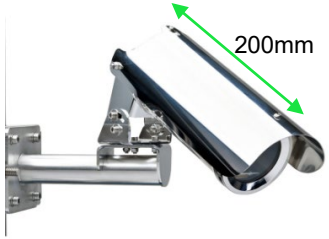
Server

10GigE ethernet
32 TB RAID 10
24 core AMD EPYC
32 GB RAM

Sensor

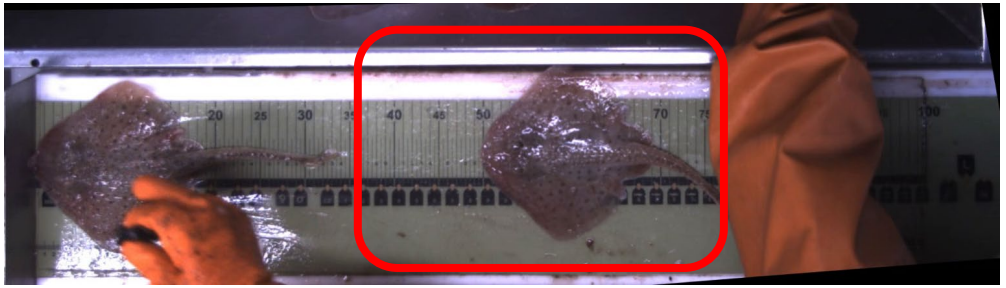
Lenses

Housing

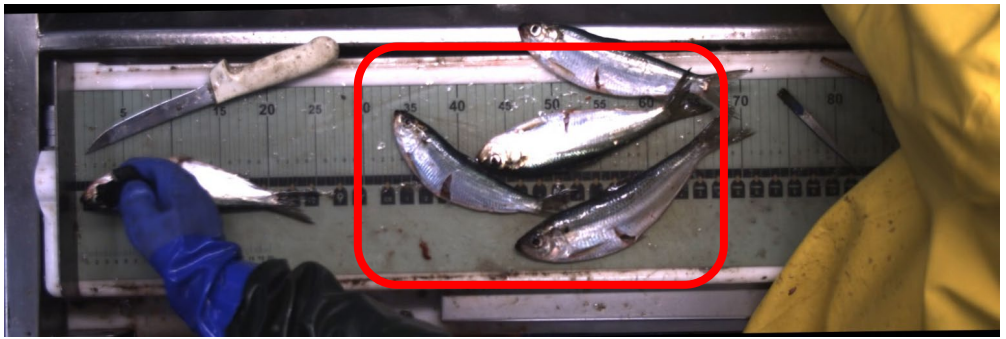


Capturing images on the boards

- Crew handling was **not** modified
- Two people at each station
- One person measuring and dissecting
- Another doing data entry
- Thus, for many individuals the clearest images are coming from the center of the of the board

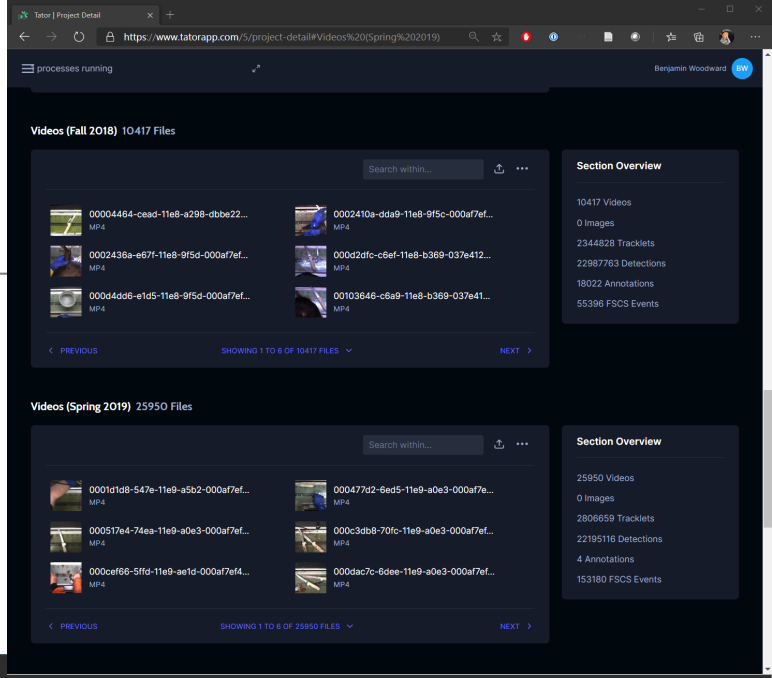


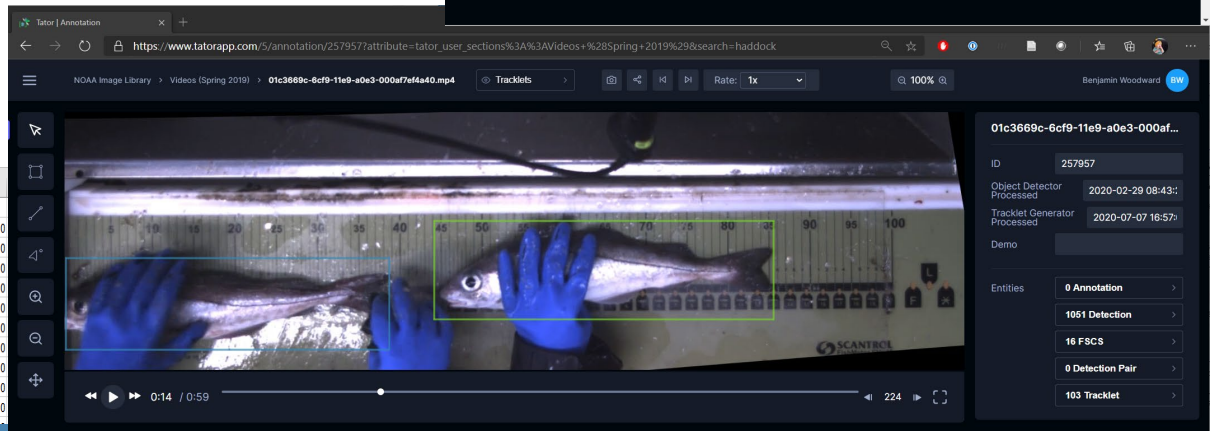
‘on deck’ position



Tator Online – Collaborative Annotation and Analysis of Image and Video

- Web based platform for video/imagery annotation and analysis
- Open source project supported by CVision, NGS, and NOAA SBIR (https://github.com/cvisionai/tator)
- Customizable metadata, including hierarchical taxonomies (e.g. WoRMS, ITIS)
- Automated summary reports
- Custom algorithm pipelines for automated analysis and review within platform
- Used to make contributing material for other image libraries
  - FathomNet – MIT/MBARI/CVision
  - Fishnet.ai - TNC

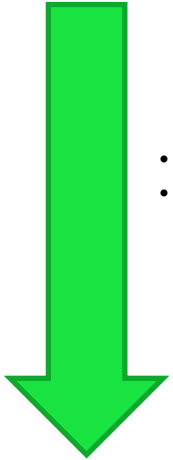




	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	section	media	thumbnai	id	user	frame	type	x	y	width	height	Notes	Tentative	Taxonomi	Species	MaxN
2	Solomon I	DOEX0015_20150111		7217014	Sarah Bingo	12275	box	0	0	934.5516	244.6917				Squalidae	0
3	Solomon I	DOEX0015_20150111		7217018	Sarah Bingo	15926	box	366.0237	12.99248	423.4179	367.0376				Squalidae	0
4	Solomon I	DOEX0015_20150111		7217019	Sarah Bingo	16541	box	538.2064	2.165414	525.2115	404.9323				Squalidae	0
5	Solomon I	DOEX0015_20150111		7217012	Sarah Bingo	9244	box	533.8748	0	210.0846	106.1053				Squalidae	0
6	Solomon I	DOEX0015_20150111		7217017	Sarah Bingo	15731	box	225.2453	0	1038.511	415.7594				Squalidae	0
7	Solomon I	DOEX0015_20150111		7217020	Sarah Bingo	16788	box	136.4467	28.15038	1012.521	395.188				Squalidae	0
8	Solomon I	DOEX0015_20150111		7217011	Sarah Bingo	9244	dot	663.824	58.46617	0	0				Selachii	0
9	Solomon I	DOEX0015_20150111		7217055	Sarah Bingo	9120	dot	492.7242	470.9774	0	0				Actinopterygii	0
10	Solomon I	DOEX0015_20150111		7217013	Sarah Bingo	12267	dot	468.9002	85.53383	0	0				Squalidae	0
11	Solomon I	DOEX0015_20150111		7217010	Sarah Bingo	0	dot	868.5037	55.01976	0	0	seafloor arrival; hard bottom			none	0

Hierarchy of Video Analysis Automation

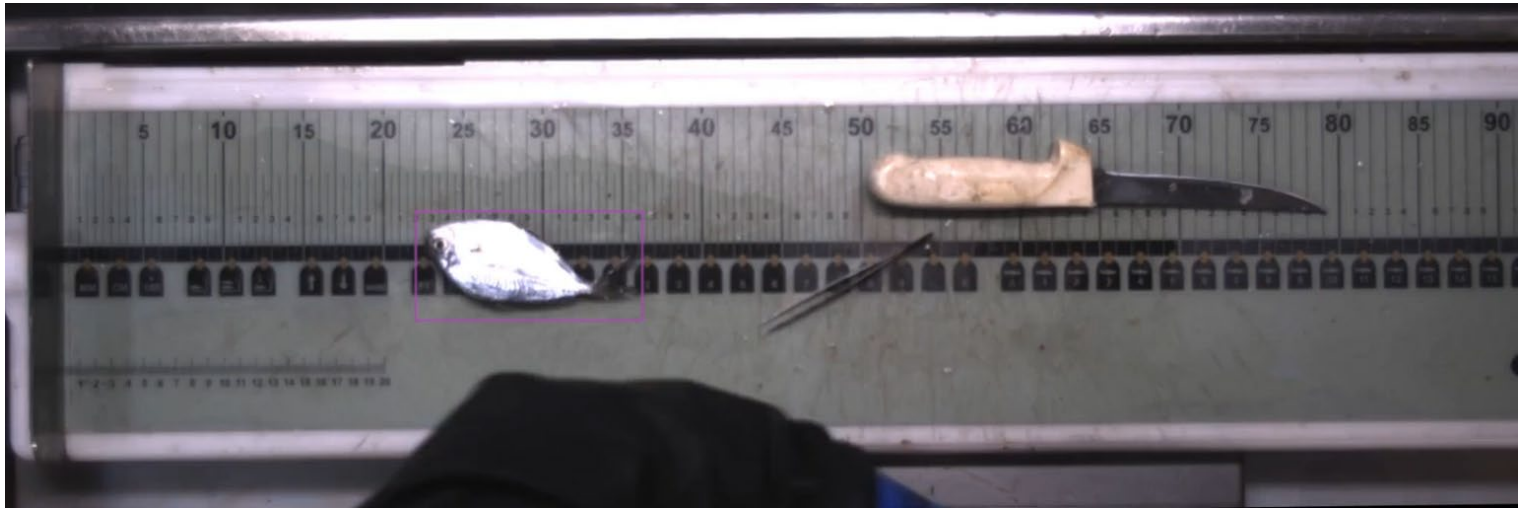
- Object Localization – I saw a fish here
  - Count of all fish in a frame
- Object Classification – I saw this kind of fish
  - Count of different types of fish in a frame
- Multi-Object Tracking – I saw this individual fish
  - Count of all fish of different species in a video



- Increasing Automation
- Increasing Difficulty

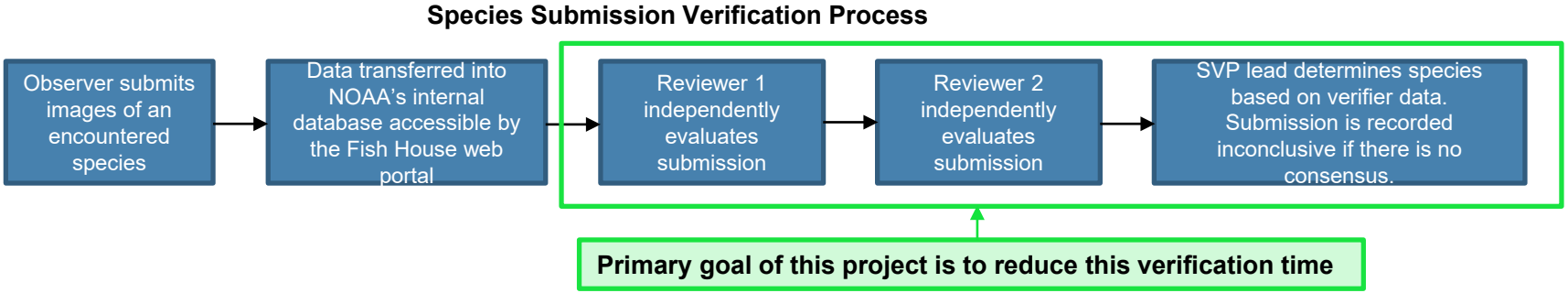
Every step in the hierarchy to be automated reduces the review burden on human analysts

High Count Matching

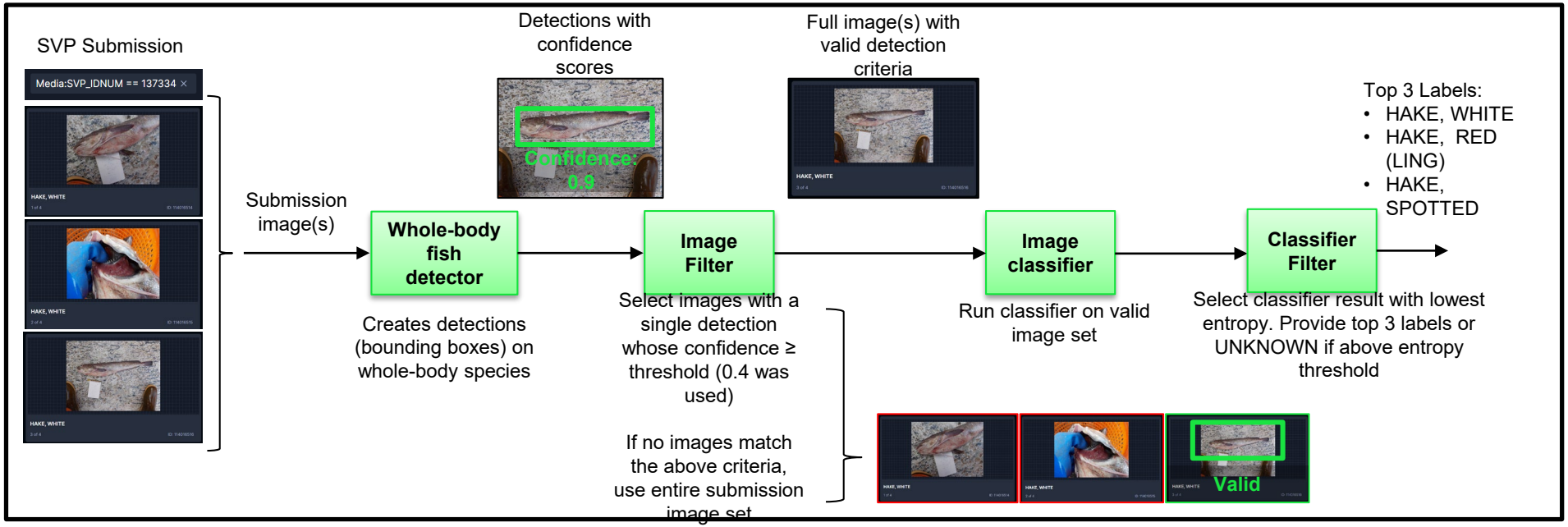


Species Verification Project

- Northeast Fisheries Observer Program (NEFOP) observers required to submit species encountered on fishing operations
  - Fisheries Sampling Branch (FSB) observer programs utilizes this accurate and near real-time data collection for quota and population monitoring
- Species Verification Program (SVP) goals:
  - Ensure high levels of species identification accuracy by verifying submissions of observed species
  - Inform observers about identification issues and improve training methods



Algorithm pipeline



Object Detector Performance

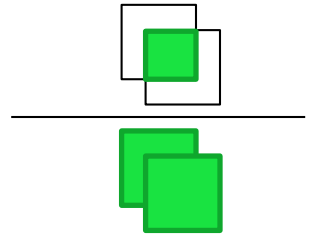
- Performance reported in HTML report
- Whole-body vs partial-body image:
  - If detector created 0 detections, assume partial-body image
  - Otherwise, assume a whole-body image
- Metrics based on whole-body vs partial-body image identification
  - Precision
    - How often does the detector incorrectly predict a partial-body image as a whole-body image
  - Recall
    - How often does the detector incorrectly predict a whole-body image as a partial-body image
  - Intersection over union
    - How well does the detector's bounding box compare with the annotated truth

Detector Performance Metrics

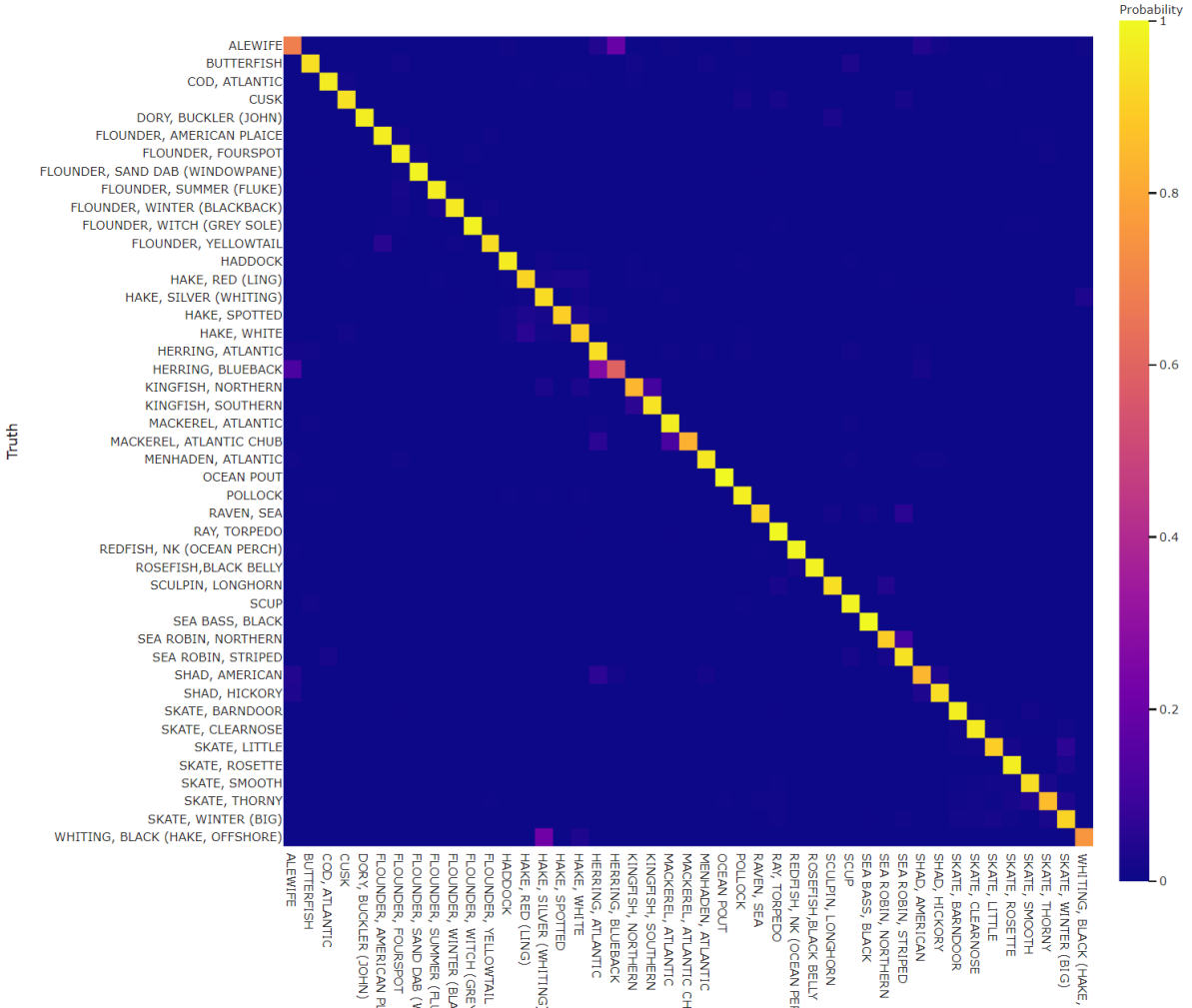
$$Precision = \frac{\#\ of\ correct\ whole\ body\ predictions}{\#\ of\ correct\ whole\ body\ predictions + \#\ of\ incorrect\ partial\ predictions}$$

$$Recall = \frac{\#\ of\ correct\ whole\ body\ predictions}{\#\ of\ correct\ whole\ body\ predictions + \#\ of\ incorrect\ whole\ body\ predictions}$$

$$IoU = \frac{Intersection}{Union}$$

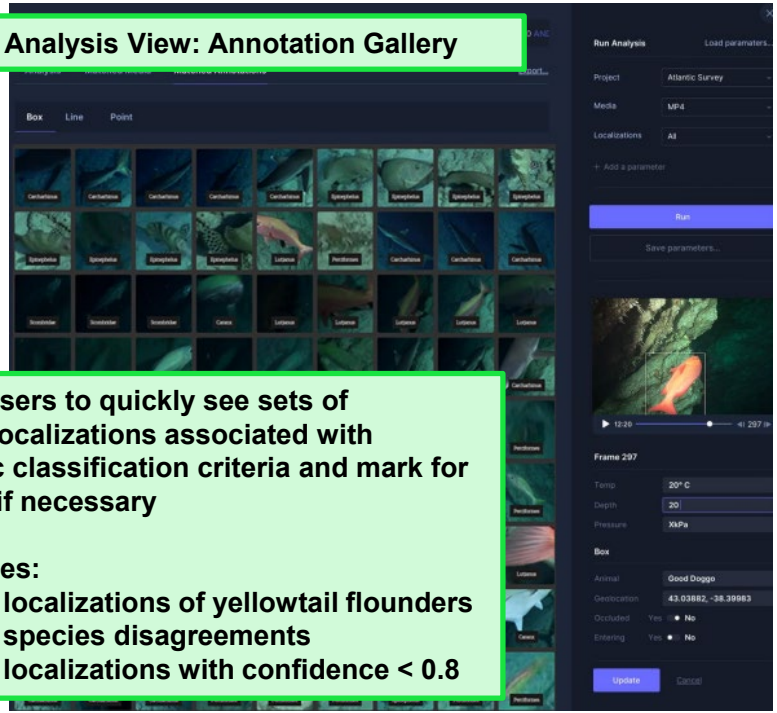


Confusion Matrix



Tator: Analysis View

Analysis View: Annotation Gallery

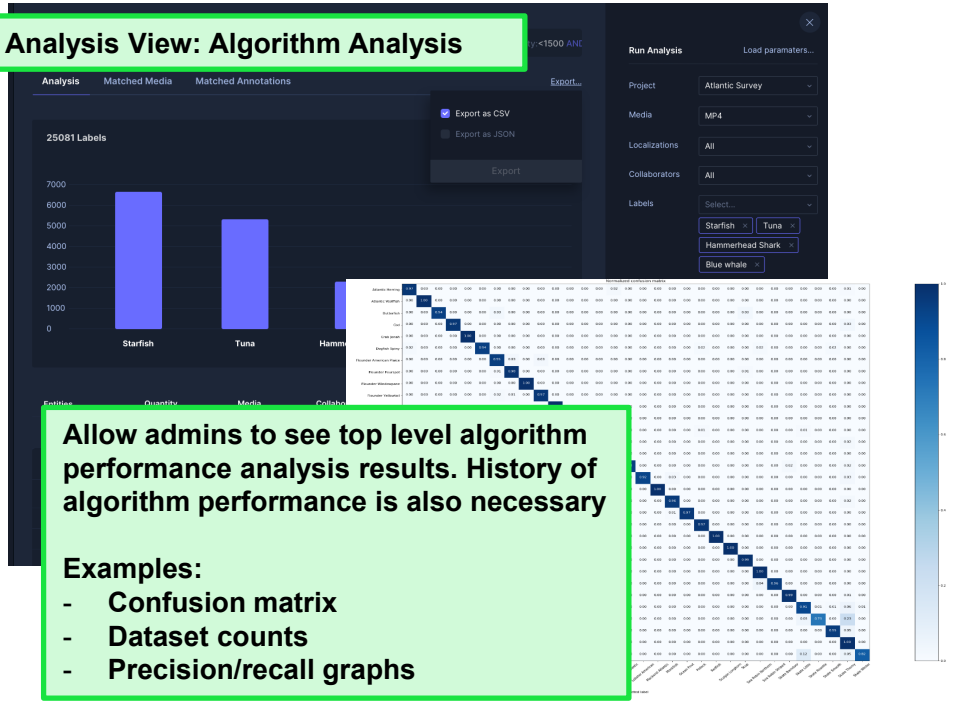


Allow users to quickly see sets of media/localizations associated with specific classification criteria and mark for review if necessary

Examples:

- **See localizations of yellowtail flounders**
- **See species disagreements**
- **See localizations with confidence < 0.8**

Analysis View: Algorithm Analysis



Allow admins to see top level algorithm performance analysis results. History of algorithm performance is also necessary

Examples:

- **Confusion matrix**
- **Dataset counts**
- **Precision/recall graphs**

Thank You! – Support From Many Sources Made These Projects A Success

- **Henry B. Bigelow crew** for support at sea
- **ESB Staff** supported work at sea and FSCS data requests
- **Brett Alger, Andy Jones, Glenn Chamberlain,** and **Chris McGuire** contributed ideas and advice
- The **FIS** and **NOP** provided funding for this project

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