Do Drones Dream of Electric Sardines?

Exploring the use of Uncrewed Aerial Systems to Survey Coastal Pelagic Species

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Introduction: Since 2012, the California Department of Fish and Wildlife (CDFW) has conducted the California Coastal Pelagic Species Survey to document and estimate the biomass of Pacific Sardine and Northern Anchovy in nearshore waters. Currently, the survey uses an aircraft with an experienced spotter to locate fish schools, identify species, and estimate biomass. Due to increasing logistical challenges, in 2021 CDFW began exploring the feasibility of using uncrewed aerial systems (UAS) equipped with remote sensing technology and performing advanced image analyses to develop and apply a more repeatable biomass estimate calculation to ensure standardization of long-term datasets.

Goals: 1) Field – Locate and photograph schools of Pacific Sardine and Northern Anchovy.

2) Image Analyses – Use images captured by UAS in the field to calculate surface area and biomass of schools, delineate schools, and identify (ID) individual fish and species.

Methods – Field Deployment

Three field deployments in collaboration with **Oceans Unmanned (OU)**: Sept 27-30, 2021 (Ventura/Oxnard); March 21-23, 2022 (Los Angeles); May 25-26, 2022 (Monterey Bay)[1]

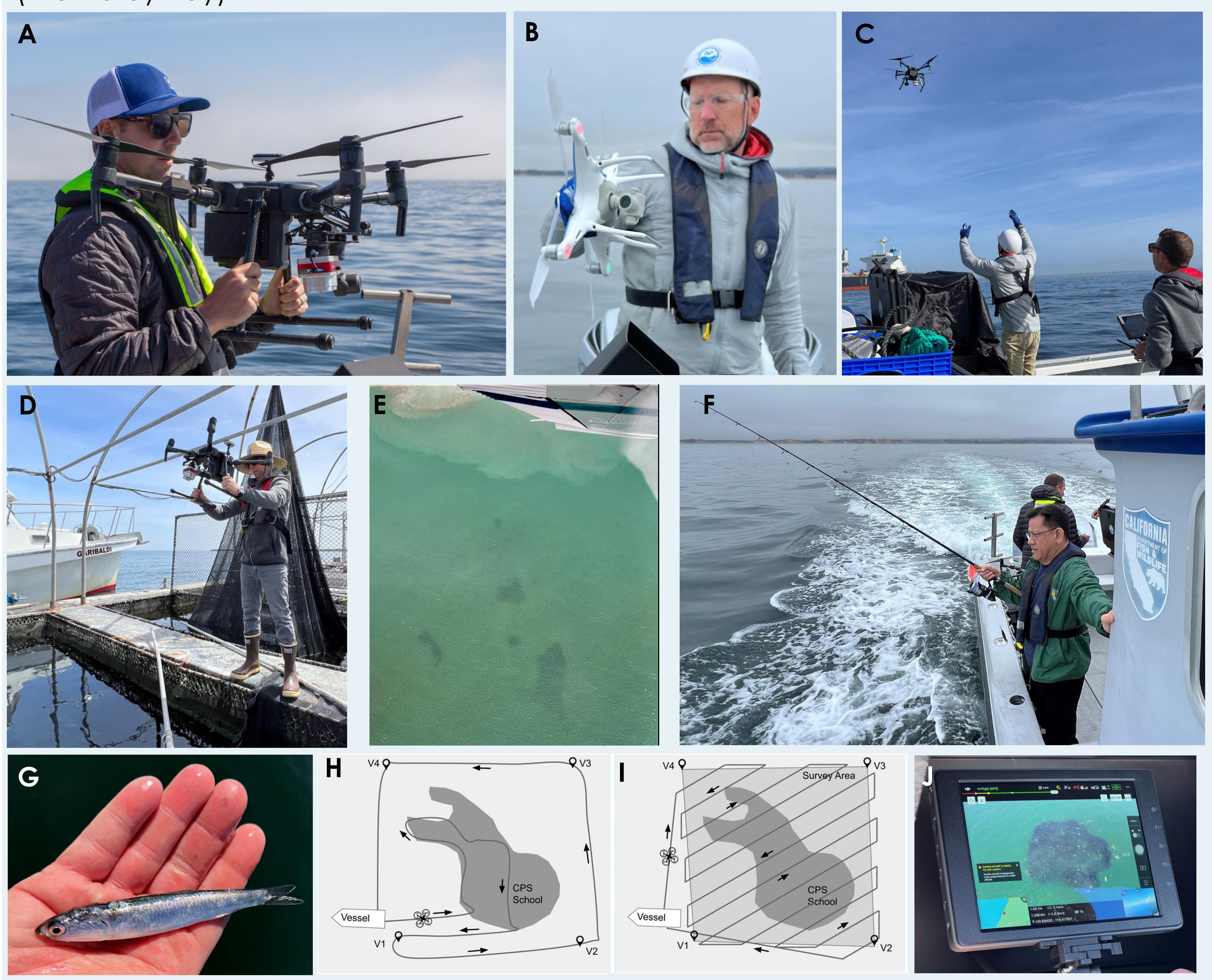


Fig 1. A) Primary UAS used was a DJI M210 equipped with the DJI X4S RGB camera, a 20MP 1-inch sensor with a 84°FOV; and the MicaSense Altum sensor capable of synchronized capture of multispectral, thermal, and RGB imagery, held by OU contractor Todd Van Epps during calibration; B) Smaller UAS, DJI Phantom 4, being calibrated by OU staff Matt Pickett, used for locating CPS; C)Matt recovering M210 as Todd pilots; D) Calibration of multispectral sensor by Todd holding M210 over a sardine bait barge; E) CPS observed from CDFW aircraft; F) CDFW Biologist Kirk Lynn catches CPS to validate UAS imagery; G) Northern Anchovy; H) Grid mission recon flight for school extent; I) Grid flight of school; J) M210 photographing entire school of CPS; *Photos by Trung Nguyen*

Conclusions and Future Research

- Use of UAS to survey CPS is a viable test bed for evaluating sensors and developing data collection and processing techniques; however, due to current regulatory and technical constraints it is not possible to solely use UAS for statewide surveys. Therefore, we are exploring how to apply the sensors and image analysis methods used with the UAS for use with a crewed fixed wing aircraft.
- Single-image photogrammetry is a cost-effective and promising method for calculating surface area of a single school. More data are required to develop variables for deriving volume from calculated surface area such as bathymetry, and further ground truthing via a spotter pilot and fishing vessels is needed. We are also exploring the feasibility of using historical imagery with known spotter biomass estimates to infer a biomass calculation from surface area.
- Multispectral image analysis successfully determined the presence of fish and delineated fish schools. Further research includes analyzing the costs and benefits of multispectral imagery versus RGB imagery and feasibility of scaling up multispectral analyses to larger datasets.
- AI demonstrated some ability to correctly detect individual fish and further exploration holds promise to develop software systems capable of turning large amounts of aerial imagery into useable data for species ID, individual fish ID, and school detection[3].

Methods & Results - Image Analyses

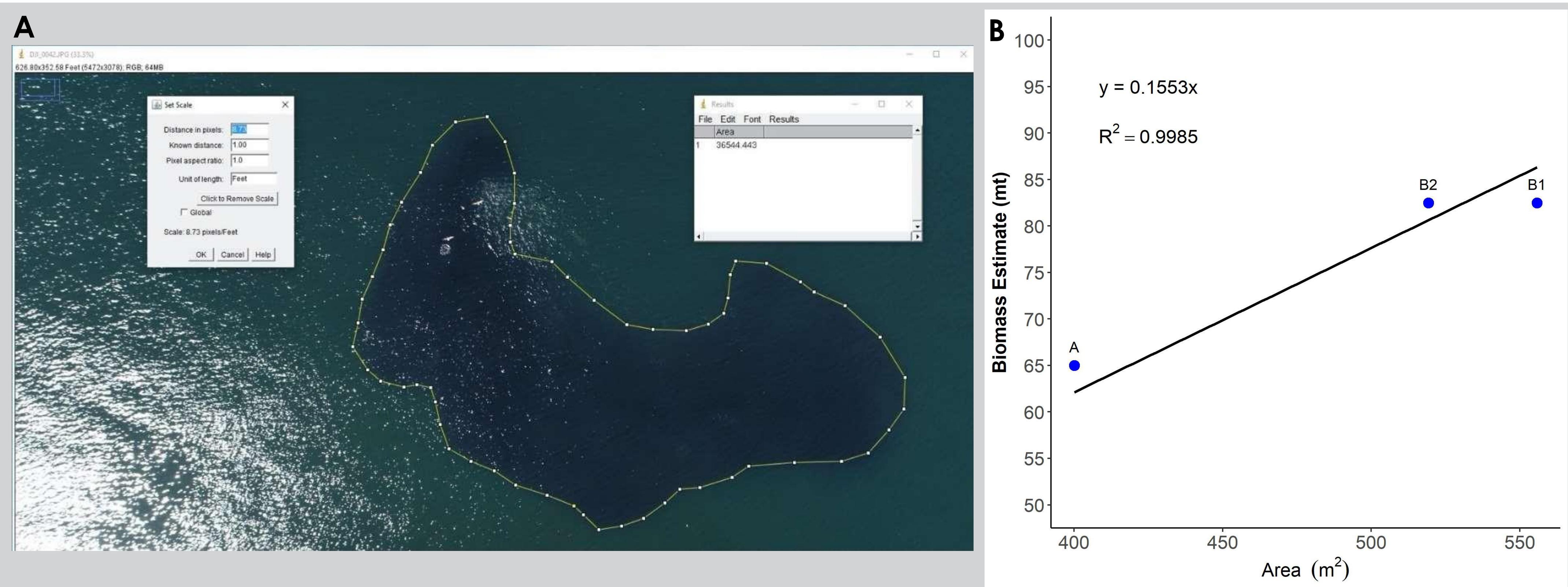


Fig 2. A) Images of schools were photographed at nadir (-90° from horizon) when possible. An error correction factor was used for non-nadir images to calculate GSD; B) correlation between calculated surface area and spotter estimated biomass of two schools (A and B); school B was seen twice.

Single-image Photogrammetry

- Surface area was measured in ImageJ for 9 images of individual schools using each images' Ground Sampling Distance (GSD) for scale (Fig 2A).
- Biomass estimates by a trained spotter were captured for two schools. Surface area estimates from UAS imagery show promise in demonstrating school biomass (Fig 2B).

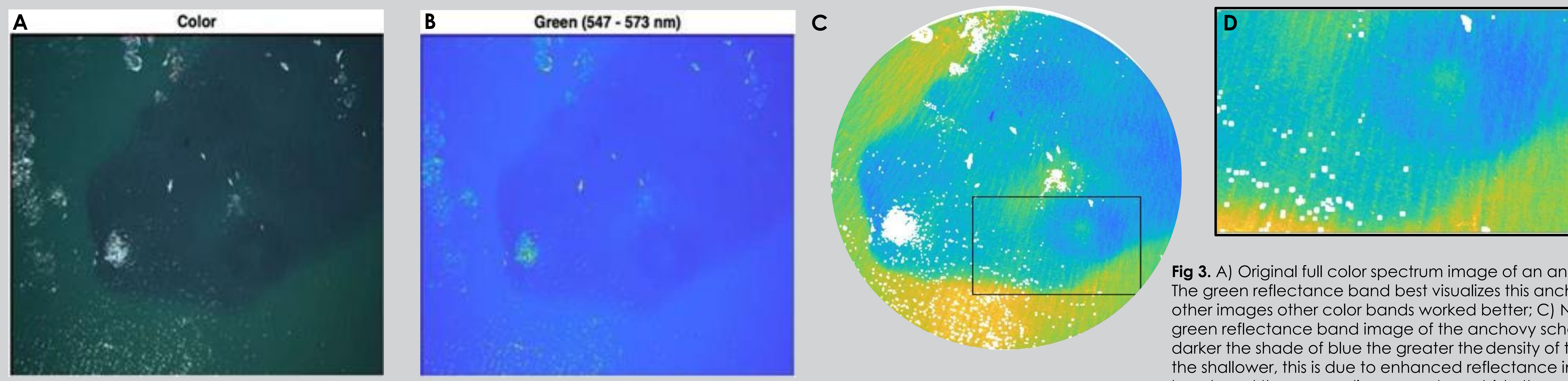


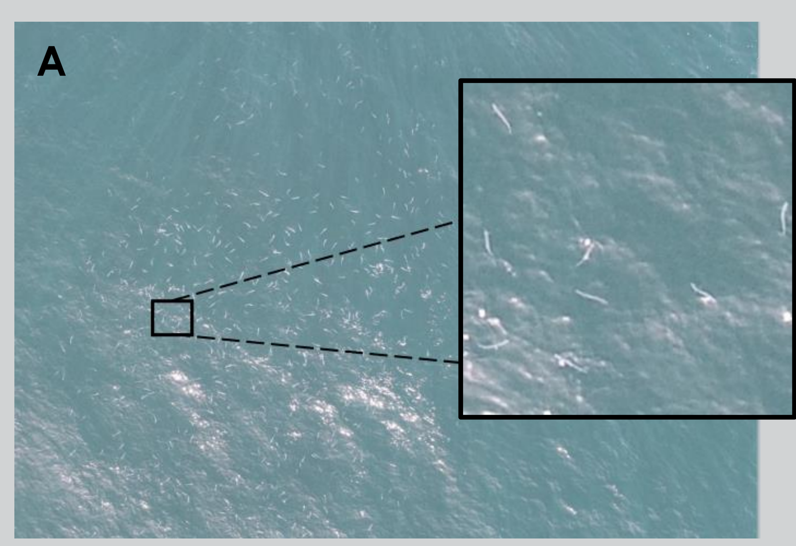
Fig 3. A) Original full color spectrum image of an anchovy school; B) The green reflectance band best visualizes this anchovy school, in other images other color bands worked better; C) NIR mask over green reflectance band image of the anchovy school; D) The darker the shade of blue the greater the density of the school and the shallower, this is due to enhanced reflectance in the blue/green bands and the surrounding seawater outside the school being blue.

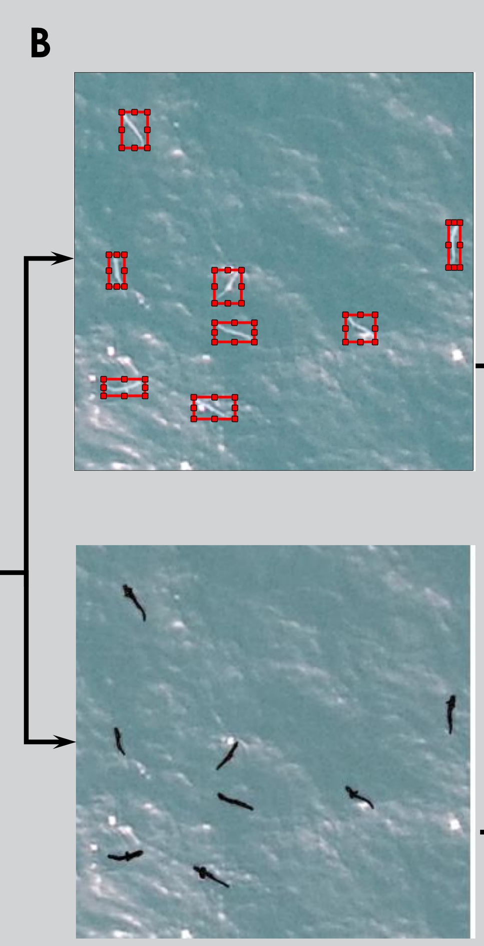
Multi-spectral Image Analysis

- Color images were created from the Red, Green, Blue, and Near Infrared bands (NIR) of the multispectral sensor (Fig 3A, B). Then an NIR derived mask is applied to the color image that best visualizes the school in order to remove visual noise such as glare. The depth of fish and the surrounding seawater conditions will affect the reflectance in different color bands and thus how density is assessed (Fig 3C, D).

Artificial Intelligence (AI)

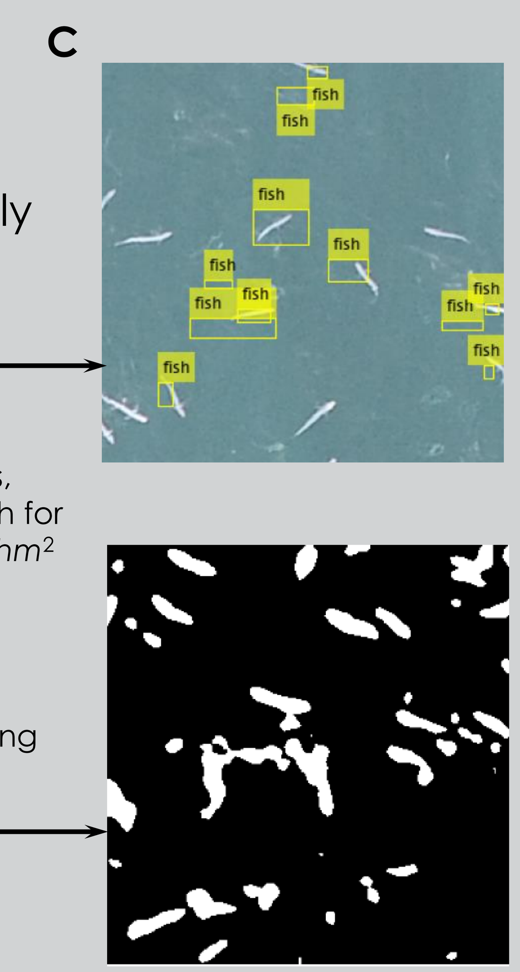
Step 1: Images were split into hundreds of small "tiles" (Fig 4A, right) that could be processed by the AI algorithms[2].





Step 2: A subset of tiles were selected for training each algorithm method and manually marked[2] (Fig 4B).

Fig 4. A) Full resolution images, >15 mil pixels, were split into tiles,100K pixels, B) Marking fish for Yolov4 (above) an *object detection algorithm*[2] and DeeplabV3 (below) is a *semantic segmentation* algorithm, which attempts to distinguish objects of interest from their background[2]; C) Performance of YoloV4 (above) and DeeplabV3 (below) in detecting fish.



Step 3: After training, the AI algorithms were each given a new set of tiles to determine if each method could successfully detect individual fish (YoloV4, Fig 4C, top) or distinguish individual fish from the background (DeeplabV3, Fig 4C, bottom)[2].

- **Overall**, the performance of both AI algorithms were limited by the small sample size available (20-30 tiles each)[2]. Glare and sunspots presented a challenge and impacted detection, particularly in the DeeplabV3 algorithm (Fig 4C).

References: 1) Oceans Unmanned. 2022. Using Remote Sensing via Unmanned Aerial Systems to Survey Marine Coastal Pelagic Species [P2070011]. Santa Barbara, CA. **2)** Collins, Gaemus. 2022. Artificial Intelligence (AI) for automatic detection of coastal pelagic species. Oceans Unmanned, Santa Barbara, CA. **3)** T. Kontzer. 2018. Whale of an Idea: Tapping AI to Keep Ships from Striking Endangered Sea Mammals. NVIDIA. [Online]. Available: https://blogs.nvidia.com/blog/2018/10/29/planck-ai-ships-strikesright-whales/.

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