



NOAA Technical Memorandum NMFS-XXX-##

CPS Acoustic Classification

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Northwest Fisheries Science Center



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Welcome

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[[[enter cool image of CPS survey]]]

West Coast coastal pelagic species play an important role in the California Current ecosystem. They're food sources for marine mammals, sea birds, and larger fish, and they support commercial and recreational fisheries. The biomass and abundance estimates derived from this project are used in stock assessment models to support sustainable fisheries.

Document Objective:

This resource will serve as a tutorial to demonstrate how the SWFSC uses acoustic data generate biomass estimates of Coastal Pelagic Species from Baja, Mexico to Vancouver, Canada.

As part of our commitment to open science, reproducibility, and transparency, we provide this metadata guide to compliment our public-domain data.

Please consider this resource to be a **Living Document**. The code in this repository is regularly being updated and improved.

Do not hesitate to reach out (to us at either alice.beittel@noaa.gov or GitHub issues, especially if you find discrepancies in the data or want to suggest improvements to infrastructure. Thank you in advance for your collaboration and partnership with us as we develop our future data universe.

User Resources

Cite This Data

[enter text on how to do this]

NOAA README

This repository is a scientific product and is not official communication of the National Oceanic and Atmospheric Administration, or the United States Department of Commerce. All NOAA GitHub project code is provided on an 'as is' basis and the user assumes responsibility for its use. Any claims against the Department of Commerce or Department of Commerce bureaus stemming from the use of this GitHub project will be governed by all applicable Federal law. Any reference to specific commercial products, processes, or services by service mark, trademark, manufacturer, or otherwise, does not constitute or imply their endorsement, recommendation or favoring by the Department of Commerce. The Department of Commerce seal and logo, or the seal and logo of a DOC bureau, shall not be used in any manner to imply endorsement of any commercial product or activity by DOC or the United States Government.

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1 Survey Background

1.1 Who conducts the survey?

The California Current Ecosystem Survey is conducted by researchers at the NOAA Southwest Fisheries Science Center from the Fisheries Resources Division. The survey is also made possible by volunteers from additional NOAA line offices and science centers, universities, international partners, NOAA interns, and inter-agency employees.

1.2 Where does the survey take place?

1.3 Research objectives:

1. Acoustically map the distributions, measure the species compositions and size-frequency distributions, and estimate the abundances and biomasses of CPS present in the survey area, e.g., Pacific Sardine *Sardinops sagax*, Northern Anchovy (*Engraulis mordax*), Pacific Herring (*Clupea pallasii*), Round Herring (*Etrumeus acuminatus*), Pacific Mackerel (*Scomber japonicus*), and Jack Mackerel (*Trachurus symmetricus*)
2. Characterize and investigate linkages to their biotic and abiotic environments
3. Gather information regarding their life histories
4. Compare the species composition and size distributions of trawls and near shore vessel purse seine sets.

1.4 Survey History:

The SWFSC's ATM surveys of CPS in the CCE began in 2006 with a focus on the northern stock of Pacific Sardine. Since then, they have expanded in scope and objectives to

1 Survey Background

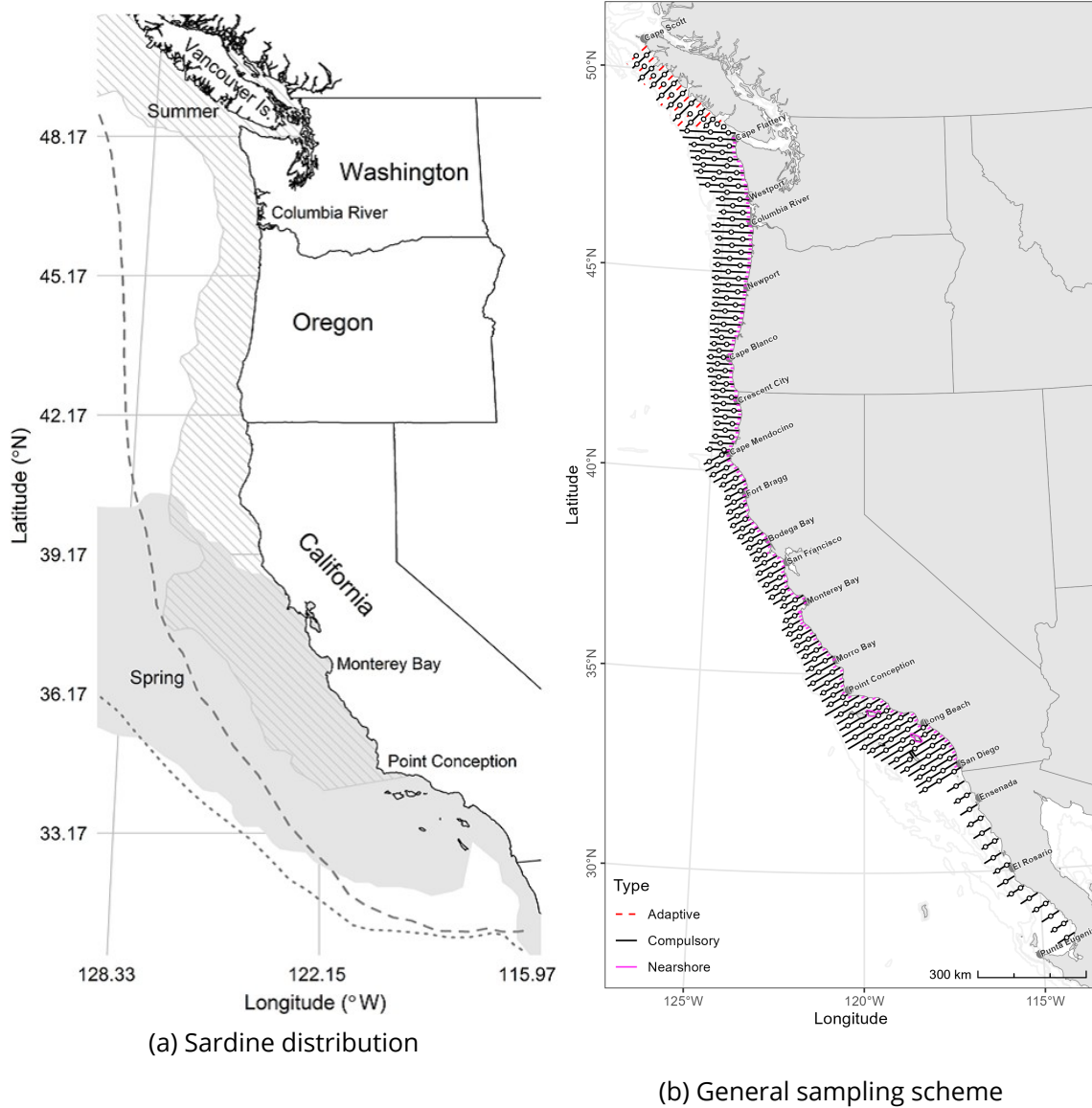


Figure 1.1: On left, a conceptual spring (shaded region) and summer (hashed region) distributions of potential habitat for the northern stock of Pacific Sardine along the west coasts of Mexico, the United States, and Canada. On right, the general sampling scheme of planned core-region (solid black lines), adaptive (dashed red lines), and nearshore lines (pink).

1 Survey Background

include the larger forage-fish assemblage and krill. This evolution, and the migratory behavior of Pacific Sardine, serve to explain the present survey region and design.

1.5 Code of Conduct

2 Data Acquisition

2.1 Survey Equipment

2.1.1 Acoustic Instruments

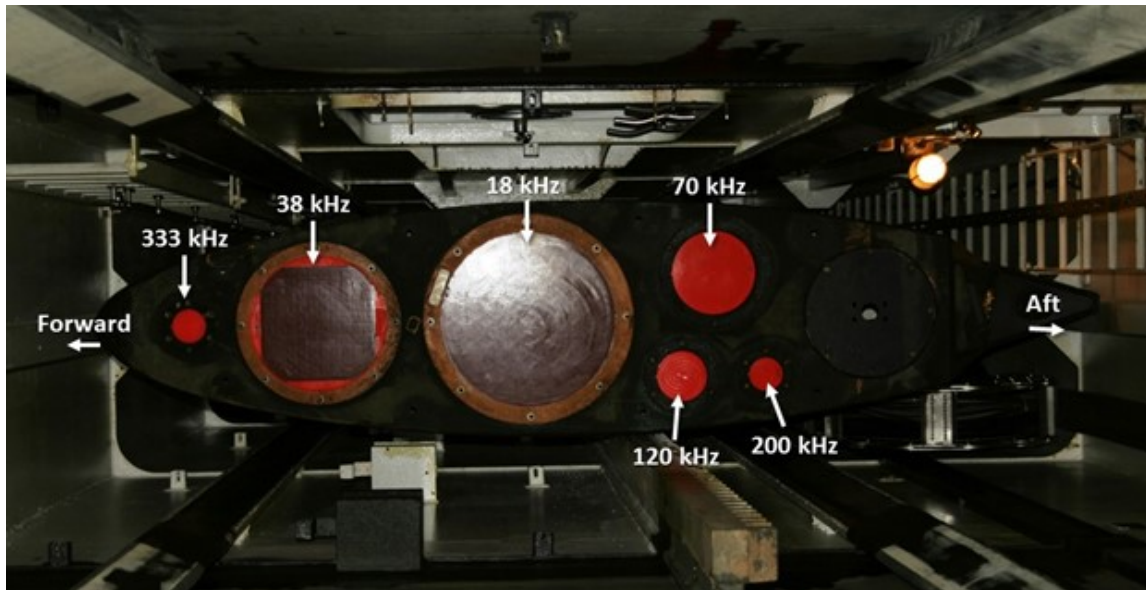


Figure 2.1: Transducer locations on the bottom of the centerboard aboard Lasker.

On *Lasker* and *Shimada*, multi-frequency Wideband Transceivers (Simrad EK80 WBTs; Kongsberg) were configured with split-beam transducers (Simrad ES18, ES38-7, ES70-7C, ES120-7C, ES200-7C, and ES333-7C on *Lasker* and ES18, ES38B, ES70-7C, ES120-7C, and ES200-7C on *Shimada*; Kongsberg). The transducers were mounted on the bottom of a retractable keel or “centerboard” (Figure 2.1). The keel was retracted (transducers ~5-m depth) during calibration, and extended to the intermediate position (transducers ~7-m depth) during the survey. Exceptions were made during shallow water operations, when the keel was retracted; or during times of heavy weather, when the keel was extended (transducers ~9-m depth) to provide extra stability and reduce the

2 Data Acquisition

effect of weather-generated noise. Transducer position and motion were measured at 5 Hz using an inertial motion unit (Applanix POS-MV; Trimble).

2.1.2 Underway CTD

On *Lasker* and *Shimada*, conductivity and temperature profiles were measured down to 300 m using calibrated sensors on a probe cast from the vessel while underway (UnderwayCTD, or UCTD; Teledyne Ocean- science). Casts were typically conducted between two to four times along each transect. These data indicate the depth of the surface mixed layer, above which most pelagic CPS reside during the day. These data were also used to estimate the time-averaged sound speed (Demer, 2004), for estimating ranges to the sound scatterers, and frequency-specific sound absorption coefficients, for compensating signal attenuation of the sound pulse between the transducer and scatterers (Simmonds and MacLennan, 2005).

2.2 Software

2.2.1 Echosounder Software

EK80

2.2.2 NetTime

On *Lasker* and *Shimada*, the computer clocks were synchronized with the GPS clock (UTC) using a synchronization software called NetTime.

2.2.3 EAL

The 38-, 70-, 120-, 200-, and 333-kHz echosounders were controlled by the EK80 Adaptive Logger (EAL2, Renfree and Demer, 2016). The EAL optimizes the pulse interval based on the seabed depth, while avoiding aliased seabed echoes, and was programmed such that once an hour the echosounders would record three pings in passive mode, for obtaining estimates of the background noise level.

2 Data Acquisition

2.2.4 K Sync

To minimize acoustic interference on *Lasker* and *Shimada*, transmit pulses from the EK80s, acoustic Doppler current profiler and echosounder (Simrad-Kongsberg EC150-3C), multibeam echosounder (Simrad-Kongsberg ME70), imaging sonar (Simrad-Kongsberg MS70), scanning sonar (Simrad-Kongsberg SX90), and a separate acoustic Doppler current profiler (Teledyne RD Instruments OS75 ADCP) were triggered using a synchronization system (Simrad K-Sync; Kongsberg). The K-Sync trigger rate, and thus the echosounder ping interval, was modulated by the EAL using the 18-kHz seabed depth provided by the Scientific Computing System (SCS).

2.3 Raw Acoustic Data Format

Measurements of volume backscattering strength (S_v ; dB re 1 m² m⁻³) and target strength (TS ; dB re 1 m²), indexed by time and geographic positions provided by GPS receivers, were stored in Simrad-Kongsberg .raw format with a 1-GB maximum file size. During daytime, the echosounders operated in CW mode and logged to 60 m beyond the detected seabed range or to a maximum range of 500, 500, 500, 300, and 150 m for 38, 70, 120, 200, and 333 kHz, respectively. During nighttime, the echosounders operated in FM mode and logged to 100 m. For each acoustic instrument, the prefix for each file name is a concatenation of the survey name (e.g., 2307RL), the operational mode (CW or FM), and the logging commencement date and time from the EK80 software (v21.15.1). For example, a file generated by the Simrad-Kongsberg EK80 software for a WBT operated in CW mode is named 2307RL_CW-D20220826-T155651.raw.

3 Data Processing

After data acquisition, we identify acoustic echos of schooling CPS using a semi-automated data processing algorithm using Echoview software and in-house `Posit` code in the `estimATM` repository. With Echoview, we extract the backscatter of swim bladder fish and process using soundspeed and echosounder calibration values housed inside an Echoview Calibration Supplement (`.ecs`) file. The Echoview filters and thresholds were based on a sub-sample of echoes from randomly selected CPS schools. We complete the processing with the `estimATM` package in `extract_CPS_NASC.R`, where we further refine the backscatter selection to extract only CPS. Here we will cover the Echoview and `estimATM` semi-automated processing workflow.

3 Data Processing

3.0.1 Data Processing Overview

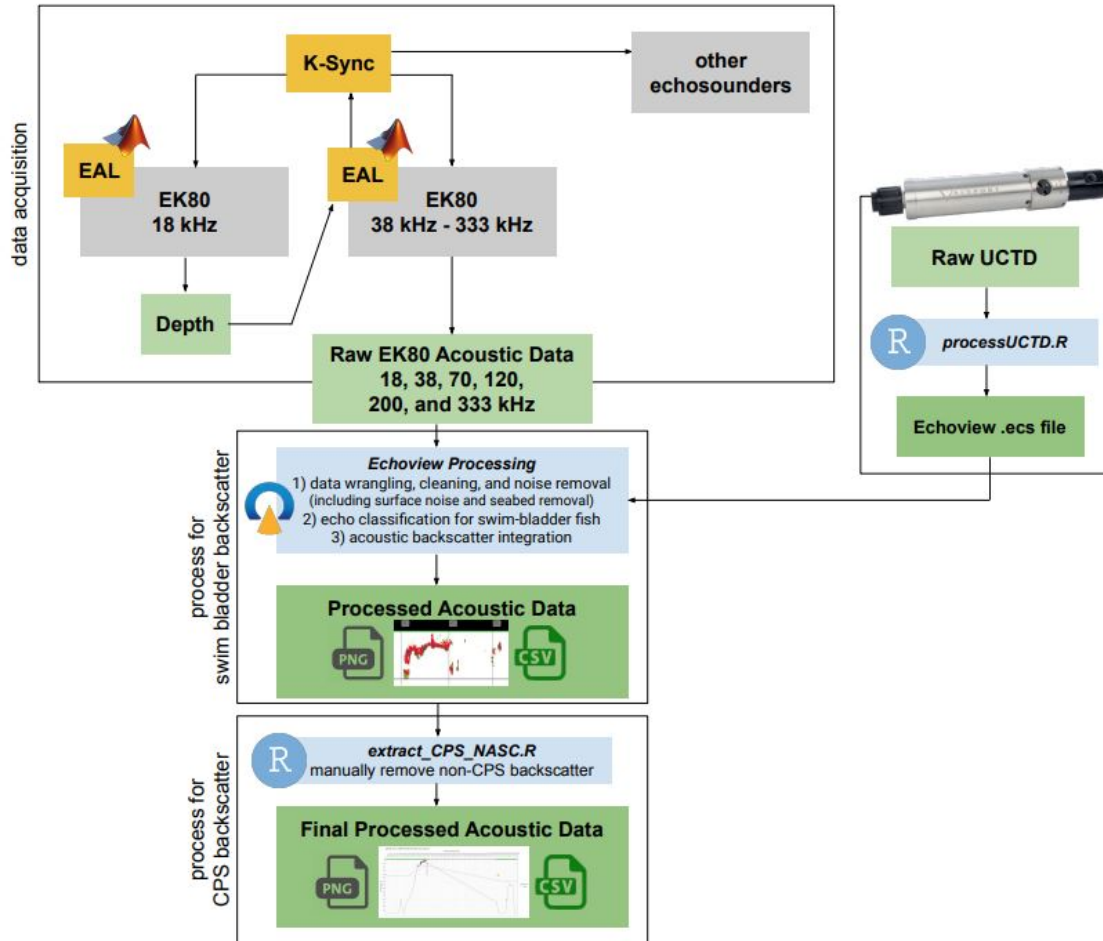


Figure 3.1: Overview of CPS Acoustic Processing. Vessel position and attitude data is used from the POS MV (not shown).

3.0.2 Echoview Processing Workflow

In Echoview, we organize, clean, and extract acoustic backscatter of swim bladder fish. There are three key steps to this process: 1) Data wrangling, cleaning, and noise

3 Data Processing

removal (including surface noise and seabed removal), 2) Echo classification for swim-bladdered fish, and 3) Acoustic Backscatter Integration. The aim of the filter criteria is to retain at least 95% of the noise-free backscatter from CPS while rejecting at least 95% of the non-CPS backscatter.

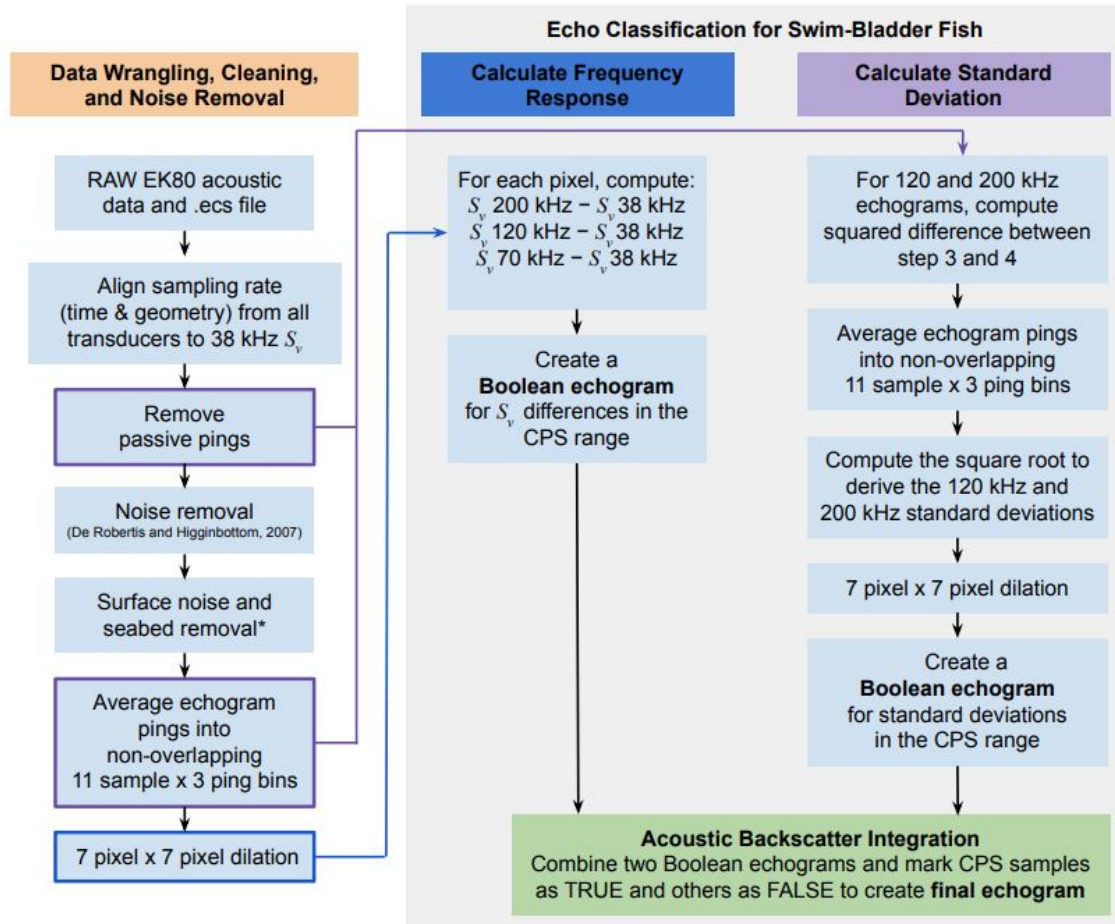


Figure 3.2: Simplified dataflow of processing in Echoview. *Surface noise and seabed removal relies on two manual inputs: the Integration Start and Integration Stop lines (not pictured, see step 5).

3.0.2.1 Section 1) Data Wrangling, Cleaning, and Noise Removal:

1. Load RAW EK80 acoustic data and Echoview Calibration Supplement (.ecs)file into Echoview. The .ecs file contains soundspeed information calculated from

3 Data Processing

the nearest (temporally and spatially) Underway CTD cast and echosounder calibration parameters. This file is used at the very beginning to convert from power to S_v (volume-backscattering coefficient).

2. Align sampling rate (time and geometry) from all transducers to the 38 kHz S_v . Acousticians call this step 'matching geometry' of all S_v variables. Making sure pings are aligned from all echosounders is important for calculating the frequency response of backscatter in steps later on.
3. Remove passive-mode pings.
4. Noise removal: estimate and subtract background noise using the background noise removal function described in De Robertis and Higginbottom (2007).
5. **Surface noise and seabed removal** is completed by manually drawing an Integration Start and Integration Stop line in Echoview. The Integration Start line is drawn at the shallowest depth to include surface CPS schools but exclude transducer ring down and surface noise due to sea state (typically around 5 meters below the transducer face or ~10m depth). The Integration Stop line is drawn closest to the seabed to include bottom dwelling animals but exclude any non-living seabed features (typically 3 m above the estimated seabed (Demer et al. 2009) or to the maximum logging range (e.g., 350 m), whichever is shallowest). When drawing the lines, we set the color scale to a minimum S_v threshold of -60 dB which corresponds to a density of approximately three 20-cm-long Pacific Sardine per 100 m³). Doing this helps visually pick out schools from the seabed and from non-swim bladder animals that appear as diffuse scattering layers in the water column. The area of the water column between the two lines sets the depth range that will be integrated for swim bladder fish in steps later on.
6. Average the noise-free S_v echograms using non-overlapping 11-sample by 3-ping bins.
7. Expand the averaged, noise-reduced S_v echograms with a 7 pixel x 7 pixel dilation. This replaces each averaged datapoint from Step 6 with the maximum datapoint surrounding it in a 7x7 pixel region.

3.0.2.2 Section 2) Echo Classification for Swim Bladder Fish

3.0.2.2.1 Calculate Frequency Response:

3 Data Processing

1. For each dilated pixel, compute:

$$S_v 200\text{kHz} - S_v 38\text{kHz}$$

$$S_v 120\text{kHz} - S_v 38\text{kHz}$$

$$S_v 70\text{kHz} - S_v 38\text{kHz}$$

The difference between S_v values provides the frequency response for those pixels. Swim bladder fish have a unique frequency response which we can use to extract those acoustic returns in the next step. Acoustic returns that fall within the S_v ranges below are flagged as meeting the criteria for typical swim bladder fish, including CPS.

2. Create a Boolean echogram for S_v differences in the CPS range:

$$-13.85 < S_v 70\text{kHz} - S_v 38\text{kHz} < 9.89$$

$$-13.5 < S_v 120\text{kHz} - S_v 38\text{kHz} < 9.37$$

$$-13.51 < S_v 200\text{kHz} - S_v 38\text{kHz} < 12.53$$

3.0.2.2.2 Calculate Standard Deviation:

1. For 120 and 200 kHz, compute the squared difference between the noise-filtered S_v (remove passive pings) and averaged S_v (11-sample x 3 ping bin averages).
2. Average the results using an 11-sample by 3-ping window to derive variance.
3. Compute the square root to derive the 120- and 200-kHz standard deviations ($\sigma_{120\text{kHz}}$ and $\sigma_{200\text{kHz}}$, respectively).
4. Expand the standard deviation echograms with a 7 pixel x 7 pixel dilation (same step as Section 1, Step 7).
5. Create a Boolean echogram based on the standard deviations in the CPS range:

$$\sigma_{120\text{kHz}} > -65 \text{ dB}$$

$$\sigma_{200\text{kHz}} > -65 \text{ dB}$$

Diffuse backscattering layers have low σ (Zwolinski et al. 2010a) whereas fish schools have high σ . Intersect the two Boolean echograms to create an echogram with "TRUE" samples for candidate CPS schools and "FALSE" elsewhere. Mask the noise-reduced echograms using the CPS Boolean echogram.

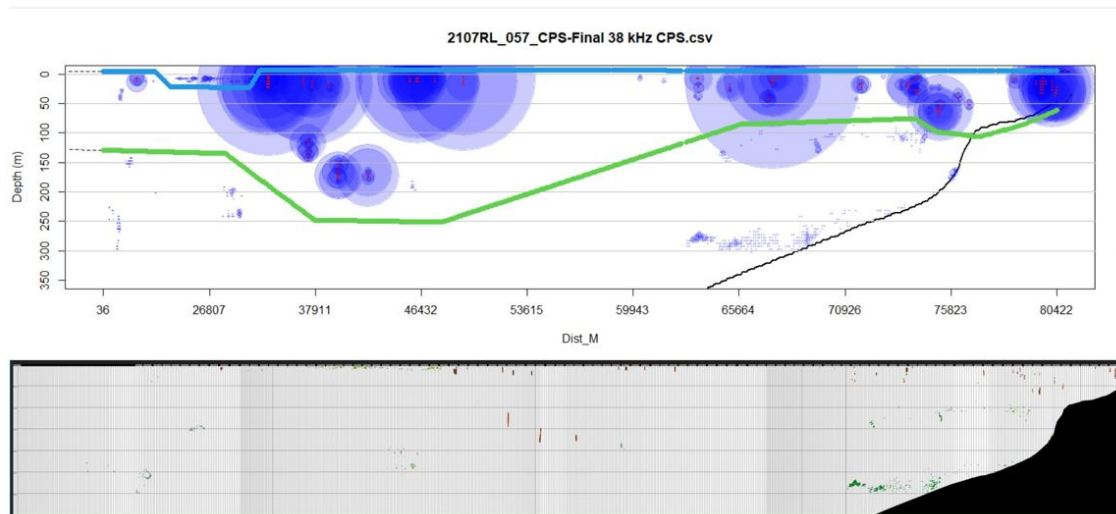
3 Data Processing

3.0.2.3 Section 3) Acoustic Backscatter Integration

1. Integrate the volume backscattering coefficients (SV , $m^2 m^{-3}$) attributed to CPS over 5-m depths and averaged over 100-m distances;
 2. Output the resulting nautical area scattering coefficients (sA ; $m^2 nmi^{-2}$) and associated information from each transect and frequency to comma-delimited text (.csv) files.
-

3.0.3 Posit Processing Workflow

The exported .csv file from Echoview contains all swim bladder backscatter which can include non-target species such as rockfish. In order to further refine the acoustic classification to retain only CPS backscatter, the processed .csv file proceeds to the final semi-automated processing step in Posit using `extract_CPS_NASC.R`, an R-based tool in the `estimATM` package.

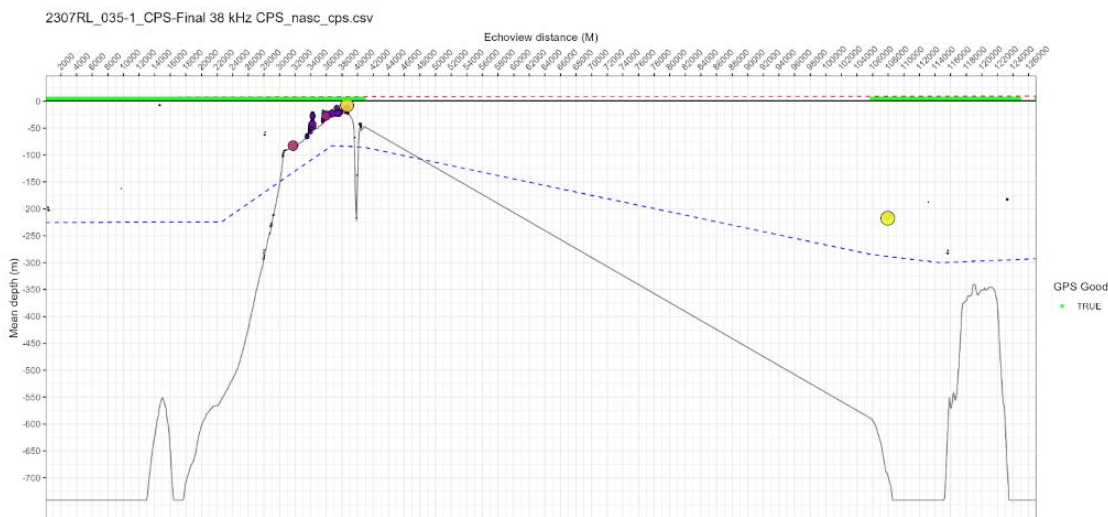


Echoes from fishes with swimbladders (blue points, scaled by backscatter intensity) along an example acoustic transect (top) and the corresponding Echoview echogram image (bottom). In this example, the upper (blue) and lower lines (green) indicate boundaries within which echoes were retained. When the lower boundary is deeper than the seabed (black line), echoes above the seabed are retained. Echoes from

3 Data Processing

deep, bottom-dwelling schools of non-CPS fishes with swimbladders, and from diffuse scatters near the surface are excluded.

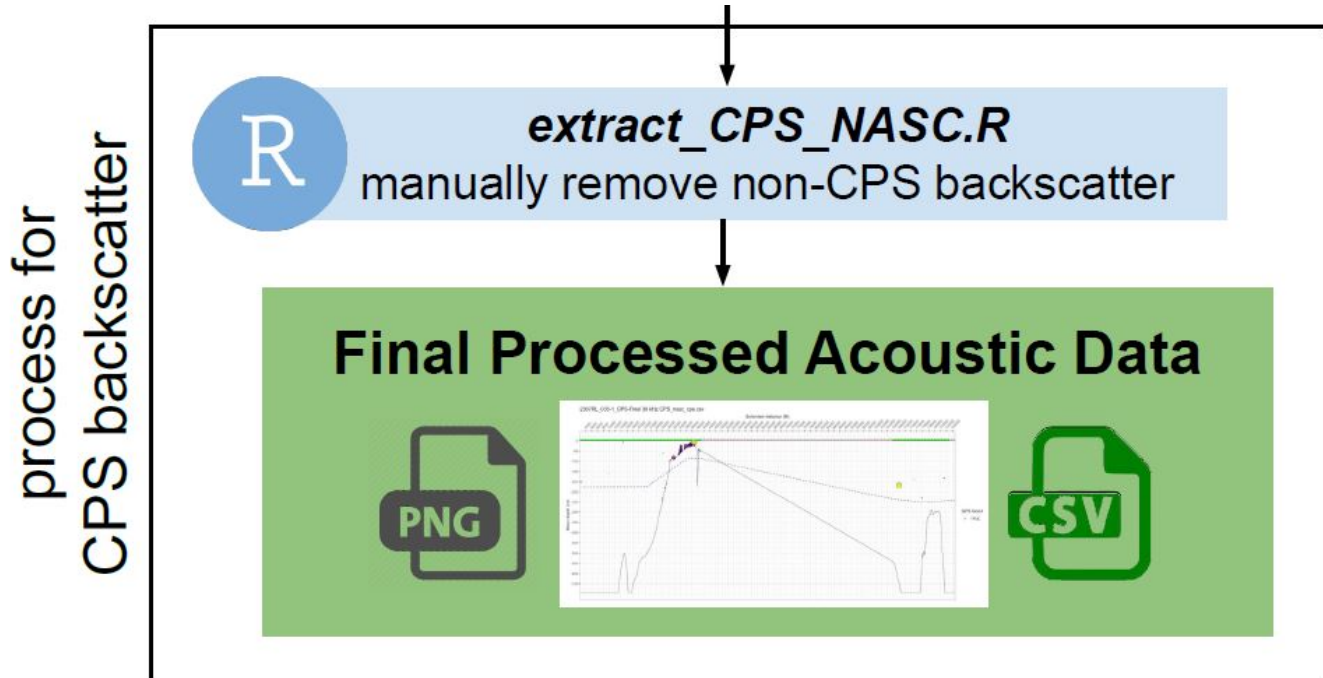
The script will open a plot (top) where the acoustics technician can draw new integration start line (blue) and stop line (green). Blue points that fall below the stop line will be excluded while blue points below the start line will be included from the resulting .csv file. The goal is to visually review the Echoview exported echogram image (bottom) and remove backscatter that you believe are not CPS (e.g., rockfishes, hake), possibly contain accidental seabed, or any surface noise and diffuse scattering layers. The process of picking out CPS from other swim-bladder fish can be tricky as CPS can have a range of characteristics. The Backscatter Identification section goes into detail on this process.



Once you are happy with the two lines, an image will appear showing the results of your editing. If the backscatter needs to be removed, or put back, you can re-run the script and the results will be replaced.

The result is a final .csv with only backscatter information for CPS targets.

4 Backscatter Identification



When performing the final step in CPS backscatter processing, there are several assumptions and acoustic characteristics about CPS that allow us to refine our classification. This process aims to distinguish CPS from non-target species from mid-water, demersal, and benthic swim bladder fishes.

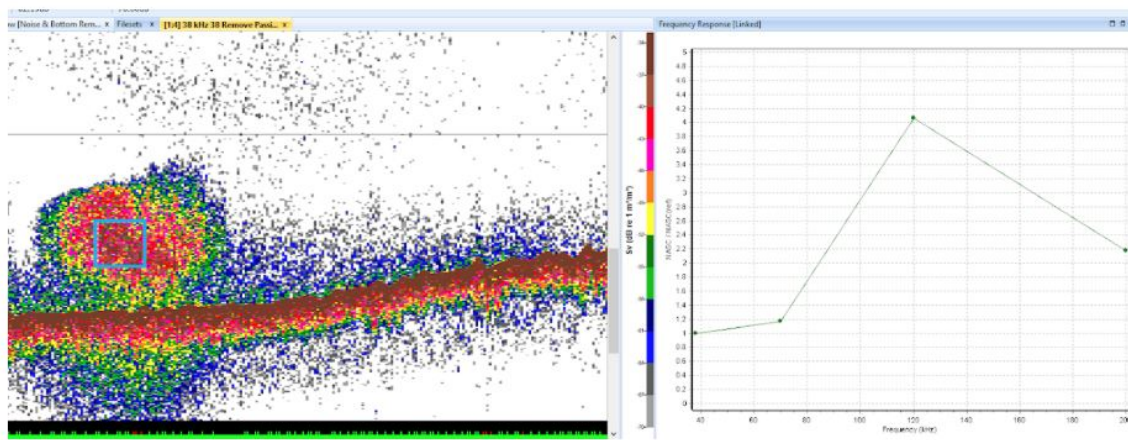
4.0.0.1 Acoustic Characteristics of CPS

While the acoustic properties of swimbladder fish depends on several factors, the most important are the acoustic wavelength, swimbladder size, and swimbladder orientation to the incident sound pulse. We use 39, 70, 120, and 200kHz to capture a range of swimbladder sizes and orientations. We estimate the dorsal surface area of a swimbladder (swimbladder size) based on a function of fish lengths sampled from

4 Backscatter Identification

nightly trawl catches. Knowing the approximate dorsal surface area of a swimbladder allows us to calculate an acoustic backscattering coefficient and derive a target strength for each CPS species. For this survey we calculate target strength as a logarithmic function of frequency and species-specific parameters obtained theoretically or experimentally and fish total length from trawl samples. Full details on species-specific target strength parameters can be found in the survey biomass report here.

When looking at Echoview echograms of acoustic transects, visually we look for how the volume backscattering strength (S_v) changes over each frequency. We refer to this as the frequency response. Swimbladder fish are expected to have a flat or decreasing frequency response across 38kHz, 70kHz, 120kHz, and 200kHz (cite image).

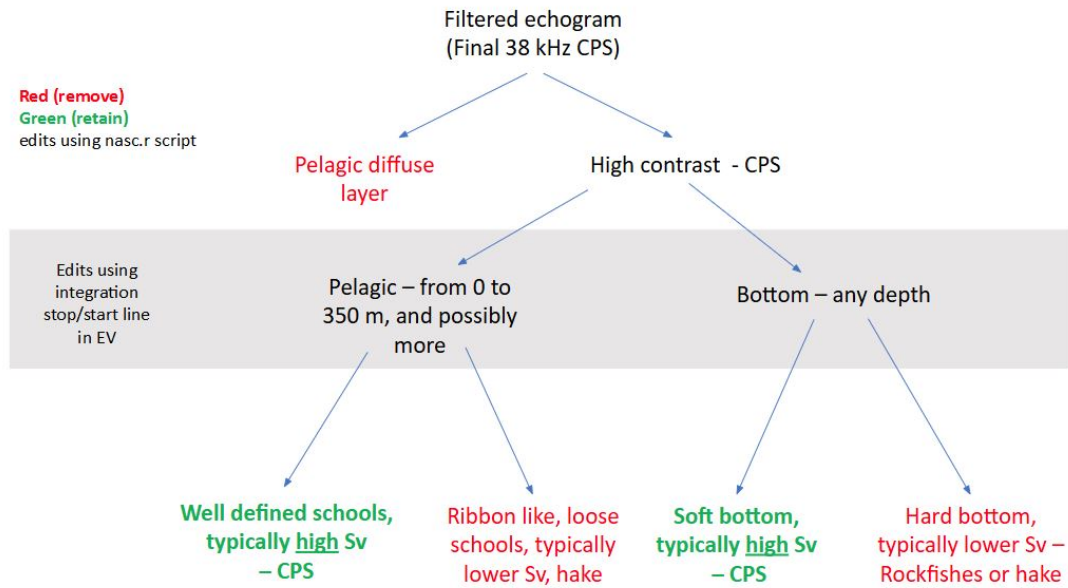


4.0.0.2 Biological Characteristics of CPS

- Temperature ranges from 8 deg C to 24 deg C and salinity from 30-38 psu (Zwolinski et al. 2010b)
- Diffuse schools observed offshore near the surface or deeper than ~250m
- Rockfish tend to be located in areas where the seabed is hard and rugged

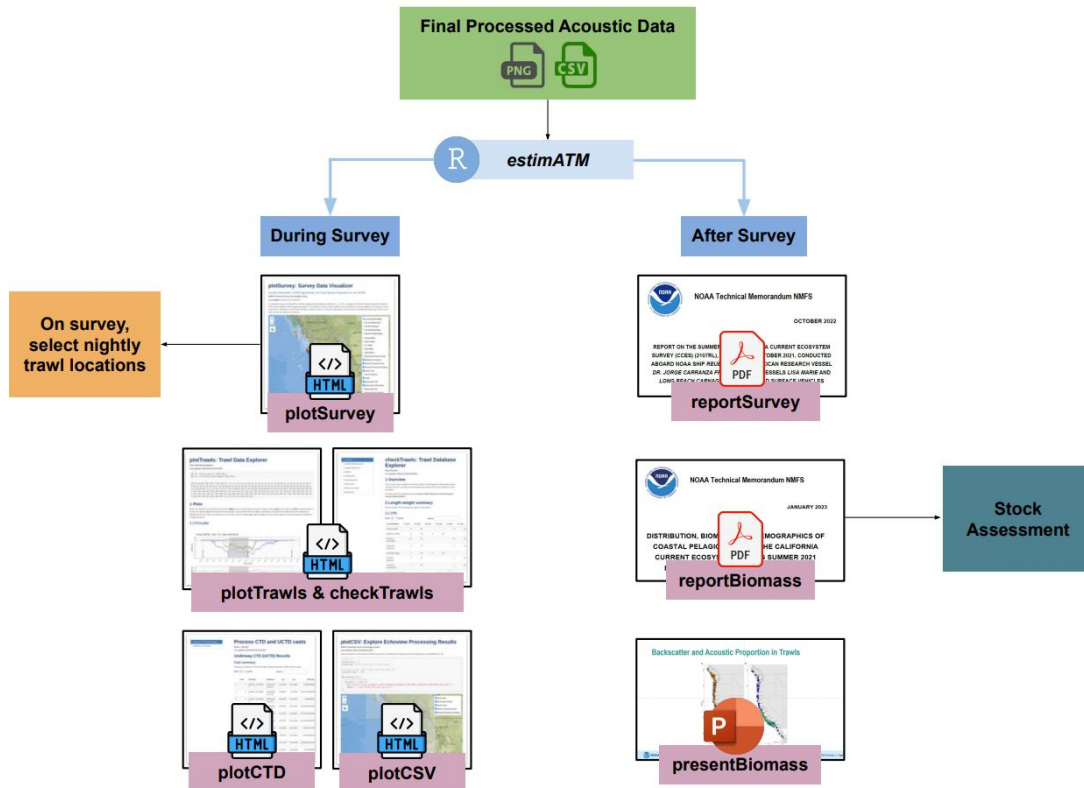
A picture guide for helping decipher tricky backscatter in the R script `extract_CPS_NASC.R` and Echoview processing.

4 Backscatter Identification



Build out from this google document.

5 Biomass Calculation



References

- De Robertis, Alex, and Ian Higginbottom. 2007. "A Post-Processing Technique to Estimate the Signal-to-Noise Ratio and Remove Echosounder Background Noise." *ICES Journal of Marine Science* 64 (6): 1282–91. <https://doi.org/10.1093/icesjms/fsm112>.
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- . 2010b. "Sardine Potential Habitat and Environmental Forcing Off Western Portugal." *ICES Journal of Marine Science* 67 (8): 1553–64. <https://doi.org/10.1093/icesjms/fsq068>.