Northeast Fisheries Science Center Reference Document 25-06

Monitoring the energy density of forage fishes from the NEFSC bottom trawl surveys: sampling, processing, and data protocols

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TABLE OF CONTENTS

EXECUTIVE SUMMARY/ABSTRACT 1
1.0 OVERVIEW 1
2.1 Sampling Design and Collection 3
2.2.1 Dry Weights 5
2.2.2 Proximate Composition Analysis and Estimation of Energy Density 6
3.0 DATA PROCESSING 7
3.1 Importing Additional Data and Updating Predictive Models 7
3.1.1 Importing Historical Data or Proximate Composition Analysis and Bomb Calorimetry Data 8
3.1.2 Incorporation of Additional Proximate Composition Analysis Data to Increase Predictive Range of Regressions 8
3.2 Reports 9
3.3 Data Auditing 10
4.0 DATABASE VIEWS and ACCESS 10
5.0 SUMMARY/CONCLUSIONS 11
6.0 ACKNOWLEDGEMENTS 12
7.0 TABLES AND FIGURES 12
Table 1 12
Figure 1 14
Figure 2 15
Figure 3 16
Figure 4 17
Figure 5 18
Figure 6 19
Figure 7 20
Figure 8 21
Figure 9 22
Figure 10 22
Figure 11 23
Figure 12 24
Figure 13 25
Figure 14 26

Figure 15 27
Figure 16 28
Figure 17 29
8.0 REFERENCES CITED 30
9.0 APPENDICES 34
A.Sample request protocol for Fish Energetics 34
B.Balance settings in Forage Fish 39
C. Percent dry weight (%DW) - energy density regressions and ranges in %DW for each species 40
D. Data import template examples (Proximate Composition and Historical Data) 42

EXECUTIVE SUMMARY/ABSTRACT

This reference document describes methodology for estimating forage fish energy density from Northeast Fisheries Science Center spring and fall bottom trawl surveys. We provide rationale for monitoring forage fish energy, explain our approach, and detail the complete workflow-including sample collection and processing, data acquisition, quality assurance, and data access protocols. The aim is to standardize these procedures and provide analysts with necessary detail to understand, access, and use these data. For relevant ecosystem and population analyses, we recommend using the audited values in the PREDICTED_ED_CURRENT_KJ_PER_G_WET_WEIGHT column located in the FSCS2 schema > FF_ENERGY_DENSITY view.

1.0 OVERVIEW

Many fish and squid are referred to as forage species and serve as mid trophic level links between primary producers and higher-level predators (Albo-Puigserver et al. 2017). The amount of energy (measured in calories or Joules) contained in forage species is a product of their environment (e.g., temperature, primary production), ontogeny, and other factors controlling their intake of energy and expenditures for growth and metabolism (Breck 2014). Forage species are of particular interest because of their importance to larger predators and higher trophic levels and their short life span means they can serve as useful indicators of integrated environmental productivity over relatively short time periods (i.e., several months) (Spitz et al. 2010; Albo-Puigserver et al. 2017; Price et al. 2024; Wuenschel et al. 2024). The pulsed seasonal productivity of cold, high latitude systems often contains high lipid and high energy forage species that accumulate and store energy during periods of seasonal productivity for later use (Copeman et al. 2022). Since fish energy content (kilojoules; kJ) is partially a function of the habitats they live in, as individual species shift habitats or range, they may be replaced by other species with different energy content. Also, changes in habitat quality for a given species, may result in a corresponding, quantifiable change to its energetic condition before a distribution shift is evident.

The total energy content and energy density (ED; kJ/g wet weight) are both variable across species, and sizes (i.e., not all forage has the same nutritional value; Hermann et al. 2025). In addition, ED may vary seasonally, annually, or over longer time periods (e.g., ‘regimes’, Renkawitz et al. 2015), however, time series of data to resolve these variations is typically lacking. Increasingly, ecosystem approaches to fisheries management and energy transfer models are seeking specific biological information on key forage species, as this impacts important (managed and/or protected) higher trophic species (Dickey-Collas et al. 2014; Pikitch et al. 2014; Dawson et al. 2020). Available data on energy content of forage species in the Northeast US Continental Shelf was outdated and limited in terms of samples per species, size ranges, and seasons (Steimle and Terranova 1985). To address this data gap, targeted sampling of forage species collected on Northeast Fisheries Science Center (NEFSC) spring and fall bottom trawl surveys was initiated in 2017.

Starting in 2017, the Population Biology Branch's Fish Reproduction and Condition program partnered with University of Massachusetts (UMASS) Dartmouth to study forage fish energy. Samples collected from the NEFSC bottom trawl surveys were processed at the NEFSC Woods Hole laboratory and UMASS Dartmouth. Notable seasonal, spatial, and ontogenetic variation in fish energy content was documented for several species (Bean 2020; Wuenschel et al. 2024). In some cases, this variation deviated from the limited historical estimates. For example, Atlantic herring showed a 45% reduction in ED from estimates in the 1980s (Steimle and Terranova 1985), while other forage species (including Atlantic mackerel, Northern sand lance, butterfish, silver hake, alewife, shortfin and longfin squid) had little or no change over the same period. Interestingly, in the 1980s, Atlantic herring ED was 1.6 times greater than the other prey species mentioned, but recent estimates for herring are similar to or even lower than the other species. A recent comparison of the intra-annual ED cycles of spring- and fall-spawning Atlantic herring indicates wide swings in ED with a peak in summer (Warren et al. *In press*). Therefore, estimates derived from samples collected during spring and fall bottom trawl surveys may underestimate maximum ED. Given the limited sample sizes and spatiotemporal coverage of the prior estimates, it is unclear whether differences reflect true changes in ED of Atlantic herring or are an artifact of sampling month and location differences between studies. Such a major reduction in the ED would have implications for Atlantic herring, as well as the predators that feed on them.

Current ecosystem models do not typically incorporate variation in the ED of prey, which could lead to significant miscalculation of forage energy available to support predators. Monitoring forage fish ED has continued beyond the 3-year period analyzed by Wuenschel et al. (2024). The time series runs from 2017 to present, with incomplete sampling in 2020 due to survey gaps during the COVID-19 pandemic. The time series of ED data for selected key forage species is reported in the annual State of the Ecosystem reports prepared for both the Mid-Atlantic and Northeast Fisheries Management Councils which have each expressed interest in these data.

Prior studies have identified the percent dry weight (%DW; 100*Dry weight/Wet weight) as an accurate predictor of ED of whole fish and fish tissues (Rand et al. 1994; Hartman and Brandt 1995; Scherekenbach et al. 2001; Breck 2014; Johnson et al. 2017). The strength of this relation results from the negative correlation between lipid content and water; the long established ‘fat-water’ line (Shulman and Love 1999). In practice, the strong correlation between %DW and ED makes it possible to reliably estimate the ED when both fresh (wet) weight and the dry weight are known. Therefore, a two-part approach can be used to estimate ED for a large number of samples with minimal additional effort. First, individual sample dry weights (and %DW) are measured. Second, individual ED is estimated using a species-specific linear regression. These regressions are established with %DW and a direct measurement of ED.

Determination of wet weight is straightforward; however, one may need to account for any changes in weight due to preservation and/or storage (Crane et al. 2016; Baltasar et al. 2021; Hobbs et al. 2025). Measurement of dry weight requires removal of all water from the sample, either through freeze drying or drying in an oven at a constant temperature. The temperature

used for drying is important, with higher temperatures potentially leading to 'burning off' non-water (i.e., volatilizing lipids) (Lantry and O'Gorman 2007). Most studies on fish energetics use a temperature of 60 °C to dry samples as recommended by Lantry and O'Gormon (2007). Dry weight measurement by either method takes time, and typically multiple weights are measured over many days and weeks showing declines in weight as water is removed until reaching a 'stable' dry weight, at which point further changes in mass are negligible. Although the method is time consuming, it is relatively easy and requires minimal laboratory equipment as compared to estimating ED directly via proximate composition analysis (PCA) or bomb calorimetry methods. The small size of forage species also makes them more convenient to study (freeze, transport, and dry to a stable weight in the laboratory).

This document outlines the sampling, sample processing, data entry, data auditing processes, and predictive regressions for this time series of forage fish energy data that began in 2017. We explain the methods used to calculate ED from measured quantities of water, lipid, and protein, and detail the sample sources, preservation and storage, laboratory processing and data entry, as well as quality assurance and quality control (QA/QC) measures developed. The sampling and processing protocols have evolved somewhat over the time series with notable transitions from simple spreadsheet data entry to an NEFSC-developed software application with relational database in 2022, and complete audit and upload of historical data to the database in 2025. We also provide information on how to access and use the database of audited ED data for further analysis.

2.0 SAMPLE SOURCE AND PROCESSING

The NEFSC spring and fall bottom trawls surveys are ideal platforms to sample forage species for energy content analysis. Specifically, the seasonal surveys cover a broad geographic range, use gear that effectively captures small fishes, and the FSVs H. B. Bigelow and Pisces are equipped to flash freeze and store samples during research cruises. The bottom trawl surveys cover 4 regions (Gulf of Maine [GOM], Georges Bank [GB], Southern New England [SNE], and the Middle-Atlantic Bight [MAB]) along the Northeastern Continental Shelf of the United States. Many fish in the region undergo seasonal migrations, and the spring and fall surveys capture seasonal distributions across minimum and maximum annual water temperatures. As such, the spring survey provides information on energetic condition following winter, and the fall survey provides data following summer feeding, including for young of the year for many species that spawn in the spring. The surveys use a stratified random sampling design and a standardized bottom trawl with a rock hopper sweep (Politis et al. 2014).

2.1 Sampling Design and Collection

Sampling requests were originally designed to collect 100 to 200 specimens of each target forage species per survey over a broad spatial extent. The following 8 species were initially selected based on relative importance in the ecosystem, frequency in the food habits database of stomachs sampled (Smith and Link 2010), and availability during NEFSC bottom trawl surveys: Atlantic

herring (*Clupea harengus*), Atlantic mackerel (*Scomber scombrus*), butterfish (*Peprilus triacanthus*), silver hake (*Merluccius bilinearis*), alewife (*Alosa pseudoharengus*), northern sand lance[1] (*Ammodytes dubius*), northern shortfin squid (*Illex illecebrosus)*, and longfin squid (*Loligo pealeii*). Additionally, several less-common species were included to obtain baseline data as they may increase in abundance or importance in the future—Spanish sardine (*Sardinella aurita*), round herring (*Etrumeus teres*), and chub mackerel (*Scomber japonicus)*. Starting in 2025, Atlantic menhaden (*Brevoortia tyrannus*) and Atlantic saury (*Scomberesox saurus*) were sampled. This array of forage fish includes species federally-managed by the Mid-Atlantic and New England Fishery Management Councils.

Sampling protocols programmed into the Fisheries Scientific Computing System (FSCS) vary by species (see Appendix A - sample request protocol from Fall 2024), with minor changes since sampling started. Generally, a maximum of 3 to 4 specimens (over a range in size) per species per tow are requested to be saved for analysis, but the maximum number saved per tow is set higher (5 to 6) for some species (e.g., Atlantic herring, northern sand lance, round herring, Spanish sardine) that are encountered less frequently. The squid species occur frequently, so only two specimens per tow are collected to maintain spatial coverage. A maximum number of samples collected from each of the four regions (MAB, SNE, GB, GOM) was implemented due to the freezer space limitations of the research vessels. The sampling for this request generates about 750 to 1200 samples (~12 to 15 boxes) per survey for subsequent analysis in the laboratory. As the number of observations grows for the continuing time series, we can evaluate adjusting the sampling level for some of the species once we have a better understanding of ontogenetic and spatiotemporal variability. In limited instances, additional samples were collected from some tows on an ad hoc basis to support specific research projects.

During catch processing at each survey station, samples (multiple specimens of a species per bag with a single FSCS label) are double-bagged to retain moisture using polyethylene resealable bags and immediately frozen in the –80 °C freezer. After rapid freezing and storage in the –80 ° C for hours to days, samples are transferred to the –20 °C walk-in freezer on-board and eventually transported to the –20 °C walk-in freezer at the NEFSC Woods Hole laboratory after completion of the survey. From 2017 to 2019, a subset of samples for each species were taken to UMASS Dartmouth and processed using PCA (described in section 2.2.2) to determine total energy content and ED.

The requirement for initial freezing in the –80 °C freezer was evaluated in a controlled experiment on land, using mummichogs (*Fundulus heteroclitus*) (Hobbs et al. 2025) to better understand the effect of different freezing treatments (both temperature and duration) on measured wet weights which may bias estimates of %DW. In each of the freezer treatments evaluated, the post-thaw wet weights of mummichogs were lower than the initial wet weights indicating some water loss. While measurable, the loss only had a significant effect on the %DW estimates for samples frozen and stored for 3 months at –20 °C. In contrast, samples stored at

[1] Two species of sand lance occur in the region, however we assumed all of our samples to be *Ammodytes dubius*, based on the depth of capture as described in Nizinski et al. (1990) and Nizinski (2002).

–80 °C showed minimal loss, likely due to the formation of smaller ice crystals and less leakage when thawed. The samples initially frozen at -80 °C and stored at -20 °C retained this insignificant change in %DW even after 4 months of total storage. It should be noted that the experiment by Hobbs et al. (2025) used fish that were smaller (<10 cm) than most of the samples analyzed from NEFSC bottom trawl surveys (8 to 35 cm). The effects of freezing on subsequent wet and dry estimates should be lower for larger fish as water loss due to freezing decreases as the surface area-to-volume ratio decreases. While some water loss likely occurs during our freezing and storage protocol, we consider this to have a negligible effect on subsequent determination of %DW and ED.

2.2 Sample Processing

Species-specific relationships between the %DW and ED tend to be strong and are often used to predict fish ED (Hartman and Brandt 1995; Breck 2008; Johnson et al. 2017; Morley et al. 2012; Wuenschel et al. 2024). Monitoring ED over time is feasible with these predictive relationships that can reliably estimate the ED of forage fish samples once they are dried to a constant weight. From 2017 to 2021, sample processing followed what is described below and in Wuenschel et al. (2024), but all the data was recorded in spreadsheets. Below, we outline the standardized procedures used by the Reproduction and Condition Program since 2022 with the NEFSC-developed software application Forage Fish (FF).

2.2.1 Dry Weights

In the laboratory, frozen samples are thawed until they are able to be manipulated for accurate length determination. For each sample, the FSCS barcode label is scanned, which automatically populates the following fields from tables in the FSCS2 schema: cruise (denoted as the 6-digit cruise6; 4-digit year plus 2-digit code for season [02 for spring or 04 for fall]), station, and species. Then, FF records the in-lab workup date, generates a unique pan ID# and asks the user if a FF label should be printed (Figure 1, section A). Specimens that show signs of damage that could affect weight are excluded from further analysis, and marked as omitted (Figure 2). For intact (non-omitted) samples, a FF label that includes the cruise, station, sample ID, and barcode is printed on an adhesive label that gets affixed to the bottom of an aluminum drying pan (Figure 3). Archival quality labels with polyester resin that can withstand high temperatures are used. There was no change in weight for FF labels after several months at 60 °C. The unique barcode on the FF label provides a means to quickly scan the pan using an upward facing scanner to open that individual sample record in FF during subsequent sample processing. After scanning the FF label, all of the recorded data associated with an individual organism is displayed, facilitating subsequent data entry, and general sample tracking.

The empty pan (with the attached FF label) weight (+/- 0.001 g) is transmitted directly into FF via a connected analytic balance (Figure 1, section B). Currently, FF is configured to accept weights from two connected balances (Sartorius, Mettler), and the communication settings are editable under the Settings > Balances option (see Appendix B for the configuration settings). Different sizes of pans, ranging from 60 mm diameter weigh pans, up to 22 cm x 11 cm x 6 cm

(2 lb) loaf pans are used depending on specimen size. Organism length is measured along the midline (fork or total length depending on tail shape for fishes or mantle length for squid species) to the nearest mm and entered manually. The fish is then placed in the pan, and the pan plus fish wet weight (+/- 0.001 g) is transmitted directly via the connected analytic balance (Figure 1, section B; Figure 3). Medium to larger-sized fish are cut into pieces to fit into the pans and facilitate drying. Pans containing individual samples are then placed in an oven and dried at 60 ° C.

An initial dry weight is recorded after 5 to 7 days in the oven at 60 °C depending on species and size. Subsequent dry weights are taken every 1 to 3 days until the change in weight per day between successive measurements is <0.101 g (for larger samples with initial wet weight >100 g) or <0.01g (for smaller samples with initial wet weight <100 g). These criteria are programmed into FF, and when met, the dry weight is considered stable and FF indicates the sample is considered "done" and the minimum dry weight is selected as the final dry weight by the user (Figure 1, section D; Figure 4). At this rate of weight change, further change in predicted %DW is < 0.1% and additional changes in the predicted ED of the sample is < 0.5%. Although minimal changes in dry weight may still occur if a sample is left to dry further, this criterion provides an objective measure for determining a final dry weight that balances accuracy with sample processing time and logistics.

2.2.2 Proximate Composition Analysis and Estimation of Energy Density

Once the final dry weight is determined, the %DW is calculated as:

%DW = 100* Final dry weight (g) / Wet weight (g)

The %DW can then be used to estimate the ED of a specimen using species-specific %DW–ED relationships. There are existing multi-species models at the family and order level (Hartman and Brandt 1995), but it is recommended that species-specific models be used whenever possible since body composition (relative amounts of bone, lipid, muscle, etc.) varies across species.

Species-specific predictive relationships between %DW and ED for the initial eight target species were estimated in Bean (2020) and developed further in Wuenschel et al. (2024) (See Appendix C for an example of the species-specific regression and range in %DW, both PCA and overall). In these studies, PCA results from a subset of samples covering the full range of observed %DW were used to develop species-specific %DW–ED relationships. This gravimetric method measures the water, lipid, protein, and ash fractions of a sample. The method is described in Bean (2020) and Wuenschel et al. (2024). In brief, after drying to remove all water, the dried samples are repeatedly rinsed in petroleum ether using a Soxhlet extractor to remove all lipid. The lean (now lipid-free sample) is re-dried overnight to remove any solvent and weighed again, with the amount of lipid lost calculated as the difference between the dry weight, and the lean (lipid-free, after Soxhlet) dry weight. To determine the protein content, the lean (lipid-free) sample is then placed into a muffle furnace, combusted at 600 °C, and re-weighed to determine the remaining inorganic (ash) weight. The weight lost from the lean sample during combustion is

assumed to be protein since fishes have very low amounts of carbohydrates (Craig 1977; Love 1980; Payne et al. 1999; Anthony et al. 2000; Breck 2008; Nurnadia et al. 2011; Sinclair et al. 2015). Energy is then calculated by converting the measured lipid and protein weights to energy units with the appropriate standard ED factors (39.54 kJ/g lipid, 23.64 kJ/g protein; Henken et al. 1986, Morley et al. 2012). The fractions water and ash do not have any energetic value, and are not used in calculating the total energy or ED. Alternatively, total energy and ED can be determined with the use of a bomb calorimeter, which measures heat generated from combusting a dried sample. This is a common approach that has been applied to a large number of studies (Hermann et al. 2025). Although we did not analyze any samples using bomb calorimetry, as a viable alternative it may be used in the future. Therefore, we include it as a possible data source in the upload options described in section 3.1.1.

With these established %DW–ED relationships, most sample processing ends when a final dry weight is reached, as an ED estimate can be generated from the species-specific %DW-ED regressions. However, FF stores the current %DW predictive range for each species (Figure 5) and if after the drying process, the calculated %DW falls outside of the existing range, the user is prompted to save the sample for subsequent PCA (Figure 6). When samples are saved for analysis, FF allows the user to record the organization and date sent and received for specific samples and accepts uploads of PCA or bomb calorimetry data provided by outside institutions (Figure 7). Saved samples are individually bagged and stored at –20 °C until further analysis (PCA or other). Real-time comparison of the observed %DW to the existing predictive range by FF allows for the improvement of the predictive range of %DW–ED relationships and prevents prediction outside of the range for the existing regression. To date, all direct measures of ED are from PCA done at UMASS Dartmouth, however other options may be utilized in the future.

3.0 DATA PROCESSING

All of the data associated with forage fish energy content resides in various tables within the FSCS2 schema on the NEFSC production database (NEFSC_DB_PROD). For example, the initial workup data (length, weight, cruise6, organism ID) is stored in the FF_PAN table, and subsequent dry weights are stored in the FF_DRY_RESULTS table. These support tables are not visible to general users, but are used by FF and Reproduction and Condition program to record data and generate reports. All of the audited and unaudited data is summarized in the FF_WORKING view, which displays measured and derived values in wide format with a single row per individual fish. The FF_WORKING view is continuously updated as data is collected, and this view is used to run various checks for QA/QC.

3.1 Importing Additional Data and Updating Predictive Models

Additional data, either prior (historical) wet and dry weight data, PCA data, or bomb calorimetry data for samples not processed using FF can be uploaded to the database. These data can then be reviewed and audited. Individual records of uploaded additional data can be searched and viewed

in the main FF window, but usually only the final dry weight was uploaded. The ability of FF to prompt a user to save samples that are outside the existing %DW range (for a species) allows for continued improvement (increased accuracy and/or precision) of ED estimates from %DW. The processes of uploading additional data, and incorporating it into improved regression models is described in more detail below.

3.1.1 Importing Historical Data or Proximate Composition Analysis and Bomb Calorimetry Data

In the FF file menu drop down there is an import data option that can be used to import historical and PCA data (Figure 8). For the purpose of data import, bomb calorimeter data is treated as a special case of PCA data where only the measured total energy is provided. As such, any bomb calorimetry data is referred to as PCA data within FF, but it would be identifiable as having only measured total energy, and no lipid and protein values. The import historical data feature is used for any samples that do not already exist in the database (i.e., they were processed outside of FF, either before the development of FF or at another laboratory by a collaborating organization). This feature was used to import the 5+ years of data collected before FF was in operation. A bulk of historical data (n = 8,054) for cruises 201702 to 202302 was imported on 04-18-2025, and shows that date as the initial workup date. The import historical data tool accepts .csv file format (see Appendix D for an example). Prior to import, historical and PCA data are audited. After incorporating new data, program staff can also revert the audit status of a cruise(s) and re-run the audit process (see section 3.3) to evaluate the imported data (alongside the existing data) for outliers.

When samples have been sent out for further analysis (PCA or bomb calorimetry), FF can import the additional data associated with samples already in the database (e.g., lipid, protein, ash, water from PCA, or measured total energy from bomb calorimeter). The upload PCA data tool accepts .csv file format (see Appendix D for an example). The import tool will identify any records that already have PCA data (Figure 9). This feature prevents unknowingly overwriting any existing PCA data. After evaluating any issues that are listed, once the ‘insert data’ option is selected the data is uploaded to the appropriate tables in the database and is viewable in FF (Figure 10).

3.1.2 Incorporation of Additional Proximate Composition Analysis Data to Increase Predictive Range of Regressions

When additional PCA data are obtained (as identified above for samples beyond the existing %DW range), this can increase the predictive range of the species-specific %DW – ED relationships that are used to predict ED. Potential changes in regression parameter values are evaluated when new MEASURED_ED_KJ_PER_G_WET_WEIGHT data (either from PCA or bomb calorimetry) is added to the database. The current regression (that uses the current PCA dataset) is compared to the updated regression (that includes the new data) using a linear model of the form:

$$ED \sim \%DW + Dataset + \%DW : Dataset$$

where ED is energy density, Dataset is either the previous PCA dataset or updated PCA dataset including the new values, and %DW : Dataset is an interaction term that allows the slope to vary by dataset to identify slope and intercept differences. QQ plots are examined to assess model assumptions and identify any problematic residual patterns in the updated PCA dataset. If the new models do not violate assumptions, the species-specific %DW range (minimum and/or maximum) and regression parameters are updated within FF (Figure 5). Prior estimates of ED for the species are re-predicted with the new, updated parameters and the PREDICTED_ED_CURRENT_KJ_PER_G_WET_WEIGHT column is re-calculated whenever new slope and intercept parameters are updated in FF (Table 1). Because this column uses the most recent regression parameters to estimate ED from %DW, it is considered to be the best available estimate of ED. All regression parameters are preserved and maintained in the FF_ED_REGRESSIONS table within the FSCS2 schema (Appendix C).

3.2 Reports

Several report functions in FF (under the Reports menu) provide information to assist and monitor sample processing. The Collected Samples Report queries FSCS2 tables by cruise for all samples collected under the fish energetics request and is filterable by species (Figure 11). The report provides a list of the samples collected with the following information: Cruise, Station, Species, Bag Count (number of sample bags for that species at that station), Fish Count (number of individuals saved), Processed (number of individuals processed in FF), and FSCS Barcodes (unique alphanumeric code associated with each sample bag(s)). The header also provides a summary: '# Organism(s) collected in # Bag(s), in # Pan(s)'. This allows program staff to quickly see how many samples were collected and how many have been processed so far in real-time. This indicates what remains to be processed and/or helps confirm all collected samples for a given survey have been processed before audit processes can begin. If necessary, the data can be exported as a .csv and filtered further.

The Processed Samples Report provides more detailed information for samples that have been scanned into FF and processed (Figure 12). Like the Collected Samples Report, the Processed Samples Report is filterable by cruise and species. This report includes samples that have been omitted, so that a full accounting of processed samples can be determined. The report displays the following information: Pan ID, Cruise, Station, Species, Length (mm), Pan Weight (g), Organism + Pan Weight (g), Final Dry + Pan Weight (g), Organism Weight (g), Final Dry Weight (g), Water Content (g), %Dry Weight, Initial Workup Date, Omitted, Audited, Saved, Organization, Date Sent, Date Received, and Comments. Double-clicking on an individual Pan ID in the first column, will open that Pan ID in the main window to review. The data can be exported as a .csv file to provide summaries (e.g., create a list of saved specimens for a specific organization).

The Active Pans Report provides a full accounting of samples that are currently being dried (Figure 13). This includes all non-omitted samples that have been scanned into FF, for which a pan was created, but a final dry weight has not been selected. This represents all of the samples currently drying in the oven. The report shows the following information: Cruise, Pan ID, Initial

Workup Date, Initial Pan Weight, Organism + Pan Weight, and Latest Dry Date. Double-clicking an individual Pan ID in the second column will open that Pan ID in the main window to review. This report indicates which samples need to be weighed on a given day and confirms all necessary dry weights have been recorded in FF. The active pans report is useful for daily lab management and processing.

3.3 Data Auditing

Audit procedures commence when all samples from a cruise have been processed (dried to a constant weight). During the audit, the auditor uses an R script to visualize and summarize FF data by species. The audit code directly accesses the FF_WORKING view to read FF data into R Studio (R Core Team 2024) and uses the AUDIT_STATUS column to differentiate the most recent, unaudited cruise data from previously audited records.

The *ggplot2* package is used to produce several plots for each species: Length vs. wet weight, length vs. dry weight, length vs. %DW, and wet weight vs. %DW scatter plots (Figure 14; Wickham 2016). To assist in the detection of outliers, the audit code utilizes the local outlier factor (lof) function within the *dbscan* package to produce a lof score for each data point (Hahsler et al. 2019). Each lof score represents how isolated a particular point is with respect to the surrounding neighborhood of points (e.g., using a MinPts value of 11; evaluates how outlying a point is in comparison to the 11 nearest neighbors). Currently, if a calculated lof score exceeds 5, the point is labeled with the Pan ID so that a user can investigate and appropriately address potential data entry errors within FF (Figure 14). Species-specific tables with summary statistics and distribution line plots are also automatically created to provide the auditor detail regarding potential ED changes over time (Figure 15; Iannone et al. 2024; Mock 2024).

Identified outliers may be corrected (in the event of an obvious data entry error), omitted (user is unable to deduce the data entry error), or left as is (true outlier). If any changes are made to a sample record, they are noted in the comment field (e.g., “Audit: Length changed from ___ to ___ on date by user initials). When the auditor has addressed all the issues evident in the initial audit, the audit script is re-run so that the plots can be re-generated to ensure the resolution of any issues within the recent cruise data. If the recent cruise data looks satisfactory, the auditor updates the audit status of the cruise within FF (Figure 16). All non-omitted records associated with audited cruises are available in the FF_ENERGY_DENSITY view within the FSCS2 schema.

4.0 DATABASE VIEWS and ACCESS

The final calculated values and data (excluding omitted samples) are accessible in the FF_ENERGY_DENSITY view in FSCS2 (Figure 17). This FF_ENERGY_DENSITY view is in a wide format like FF_WORKING, but with a reduced number of columns (Table 1, Figure 17). Access privilege to the FF_ENERGY_DENSITY view is provided to users under the SVDBS_USER role. Analysts interested in these data should request access from the PEMAD Data Manager. The PREDICTED_ED_CURRENT_KJ_PER_G_WET_WEIGHT uses the best

available prediction model. The PEMAD/PBB/Fish Reproduction and Condition program audits and updates this view.

5.0 SUMMARY/CONCLUSIONS

Forage species play a pivotal role in the transfer of energy from lower to higher trophic levels. The ED of forage species in the region is variable over seasonal, annual, and spatial scales (Wuenschel et al. 2024), which can have significant impacts on the productivity of these stocks as well as other fishes, birds, and mammals that feed on them. With continued monitoring of ED of key species since 2017, the now nearly 10-year time series provides useful data for analyses related to the forage species examined, and other stocks that feed on them. For example, egg production in many fishes is related to energetic condition, so forage stocks experiencing below average condition might be expected to produce below average fecundity (Marshall et al. 1999; McBride et al. 2015). Therefore, assessment of the managed species included in this database (Atlantic herring, Atlantic mackerel, butterfish, silver hake, longfin squid, and northern shortfin squid) should explore use of this ED time series to better understand patterns in observed condition, growth, and reproduction. Similarly, for predator species that feed heavily on the forage species analyzed, this data could be equally valuable. Both intra- and inter-specific changes in diet quality have been implicated in the productivity of higher trophic levels, such as Atlantic salmon (Renkawitz et al. 2015) and bluefin tuna (Golet et al. 2015; Nadeau et al. 2025). Since the value of forage species as prey is determined (in part) by the ED models of consumption will be more realistic if they are able to account for variation in prey quality in time and space. More broadly, since forage species serve as an integration of environmental production over relatively small spatial and temporal scales (weeks, months), the environmental drivers of forage ED should be explored at these scales. If such linkages can be established, it may be possible to use such environmental indices as proxies to extend the time series of forage ED for analyses over longer periods.

Information on ED of forage species represents ‘value-added’ data for samples collected during routine NEFSC spring and fall bottom trawl surveys. Recent advances in the software application (FF) and protocols described here allow for efficient sample processing, data auditing, and data storage and access in an enterprise database. Samples can be tracked completely throughout the process from the initial specimen obtained at sea to the conclusion of sample processing in the laboratory. The use of barcode scanning at all steps improves efficiency and data quality by reducing any manual data entry errors related to the sample ID. In addition, since the data tables and views reside in the FSCS2 schema, they can be easily linked and merged with other relevant data (e.g., station location, depth, temperature etc.) by analysts. Updated summaries of ED data for selected key forage species is reported in the annual State of the Ecosystem reports prepared for both the Mid-Atlantic and Northeast Fisheries Management Councils.

The emerging time series of forage fish ED provides enhanced observations of ocean resources to improve management advice. Continued monitoring of energetic status will enable researchers to evaluate mechanistic linkages between forage fish ED and the environmental variables that influence productivity. Similarly, this information may improve our understanding of the

downstream effects of forage fish ED on recruitment and growth of these important keystone species and the many, commercially valuable predators that depend upon them.

6.0 ACKNOWLEDGEMENTS

We thank staff of the NOAA Ecosystems Surveys Branch for their efforts on the bottom trawl survey and the work of the captains and crews of the NOAA ships Henry B. Bigelow and Pisces. J. Kircun and M. Bergman assisted with at-sea sampling protocols. Many useful discussions with P. Kostovick helped scope the data work flows and database structure. K. Bean, E. Hobbs, Y. Press, K. Oliveira, and A. Bourget assisted with dry weight and PCA determinations. T. Sheehan provided constructive comments that improved the manuscript. Mention of a commercial product or trademarked names does not imply an endorsement by the National Marine Fisheries Service or NOAA. This work was supported in part through funding from NEFSC Research and Development Funds (in support of the Northeast Regional Action Plan and the Regional Ecosystem-Based Fishery Management Implementation Plan) and from the Cooperative Institute for the North Atlantic Region.

7.0 TABLES AND FIGURES

Table 1. Column name, field descriptions, and units for the FF_ENERGY_DENSITY view within the NEFSC production database (FSCS2.FF_ENERGY_DENSITY). Proximate composition analysis (PCA) was performed on a subset of samples so LIPID_CONTENT_G, PROTEIN_CONTENT_G, and ASH_CONTENT_G information is not available for every record. There are a few, omitted records (due to missing Cruise and Station data), which are included in the appropriate species-specific percent dry weight (%DW) – energy density (ED) regressions because they have associated PCA data. The PREDICTED_ED_CURRENT_KJ_PER _G_WET_WEIGHT uses the most recent regression parameters to estimate ED from %DW and is considered to be the best available estimate of ED.

COLUMN_NAME	FIELD DESCRIPTION	UNITS
PAN_ID	Unique sample identification number	##### #
CRUISE_ID	NEFSC cruise identification number	######
STATION	Survey station associated with sample	###
SPECIES	Genus species (common name)	
LENGTH_MM	Fork, total, or mantle length (for squid species)	mm
ORGANISM_WEIGHT_G	Wet weight of sample	g
FINAL_DRY_WEIGHT_G	Weight value when successive weight measurements are less than 0.101 g (for larger samples with a >100 g wet weight) or less than 0.01 g (for smaller samples with <100 g wet weight).	g
WATER_CONTENT_G	Equal to the difference between the wet weight and final dry weight of a sample	g

COLUMN_NAME	FIELD DESCRIPTION	UNITS
PERCENT_DRY_WEIGHT	Equal to final dry weight divided by wet weight times 100	%
LIPID_CONTENT_G	Lipid weight measured by gravimetric PCA	g
PROTEIN_CONTENT_G	Protein weight measured by gravimetric PCA	g
ASH_CONTENT_G	Ash weight measured by gravimetric PCA	g
TOTAL_ENERGY_KJ	Lipid weight * 39.54 kJ/g + protein weight * 23.64 kJ/g	kJ
MEASURED_ED_KJ_PER_G_WET_WEIGHT	Total energy / wet weight	kJ/g
PARAMETER_SLOPE	Current slope parameter from the species-specific %DW – ED linear regression equation	
PARAMETER_INTERCEPT	Current intercept parameter from the species-specific %DW – ED linear regression equation	
PREDICTED_ED_ORIGINAL_KJ_PER_G_WET_WEIGHT	Original ED estimate using the appropriate, cruise and species-specific %DW–ED regression equation. This serves as a record of historical ED values used to create earlier reports.	kJ/g
PREDICTED_ED_CURRENT_KJ_PER_G_WET_WEIGHT	Estimated ED that uses the current, species-specific %DW–ED equation. This is the estimated energy density to be used in analyses.	kJ/g
COMMENTS	Sample-specific comments	
AUDIT_STATUS	Y/N indicates whether or not a record has been audited	Y/N

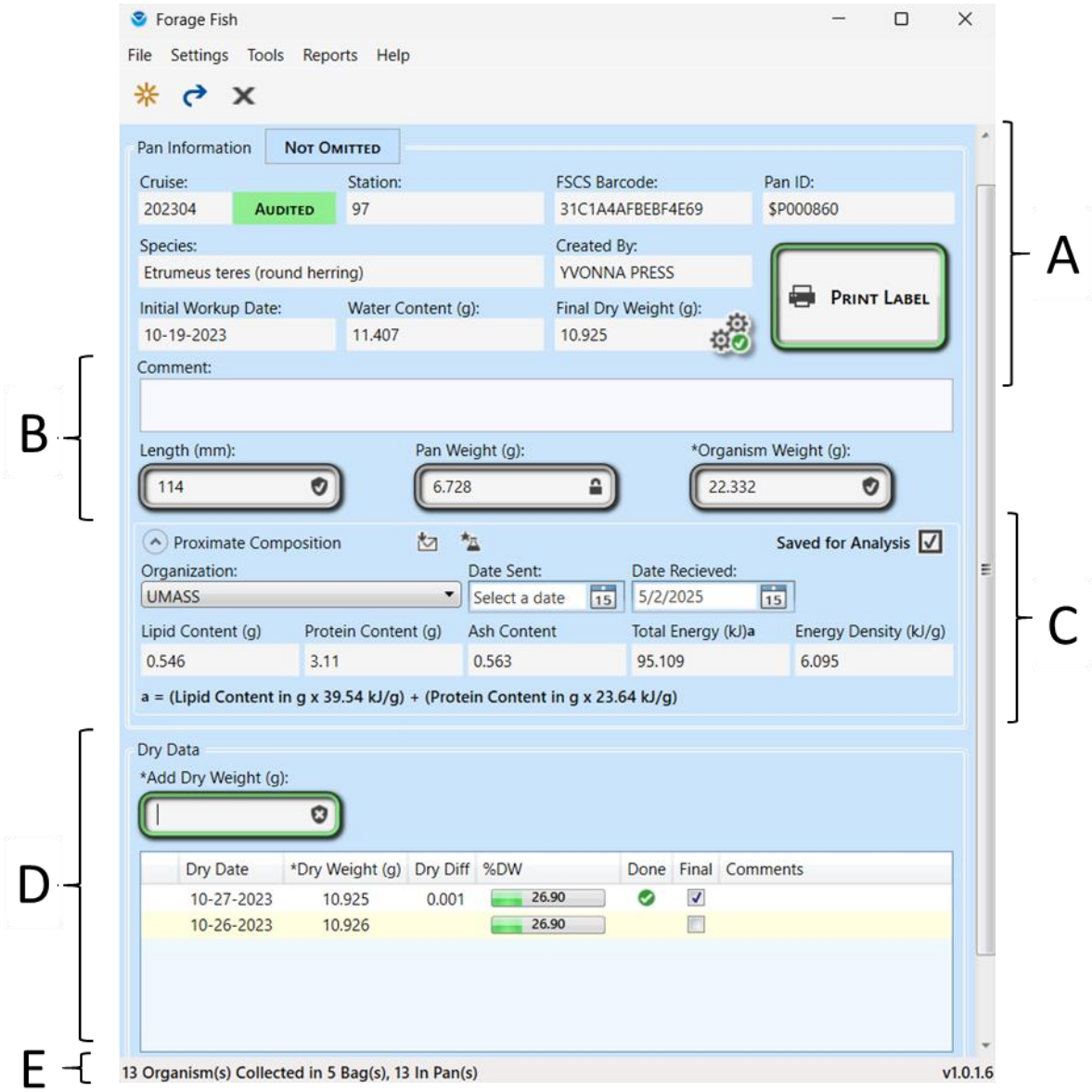


Figure 1. Forage Fish data entry screen. Section A includes the omit/not omitted button and audit status as well as the attributes that are auto-populated after scanning a Fisheries Scientific Computer System (FSCS) barcode. Section B shows the data collected during the initial workup. Section C includes proximate composition analysis and tracking information for samples that are saved for further analysis. Section D displays subsequent measurement dates and dry weight(s) with the most the recent listed at the top, and percent dry weight calculated for each dry weight. Based on the change in weight thresholds described in the text (section 2.2.1), if the sample is considered "done" based on the change in weight between two last records, the green circle checkmark icon appears in the Done column. Section E denotes the number of samples ("13 organisms collected") and bags ("5 bags") for that species and cruise as well as the number that have been worked up in the laboratory ("13 in pans").

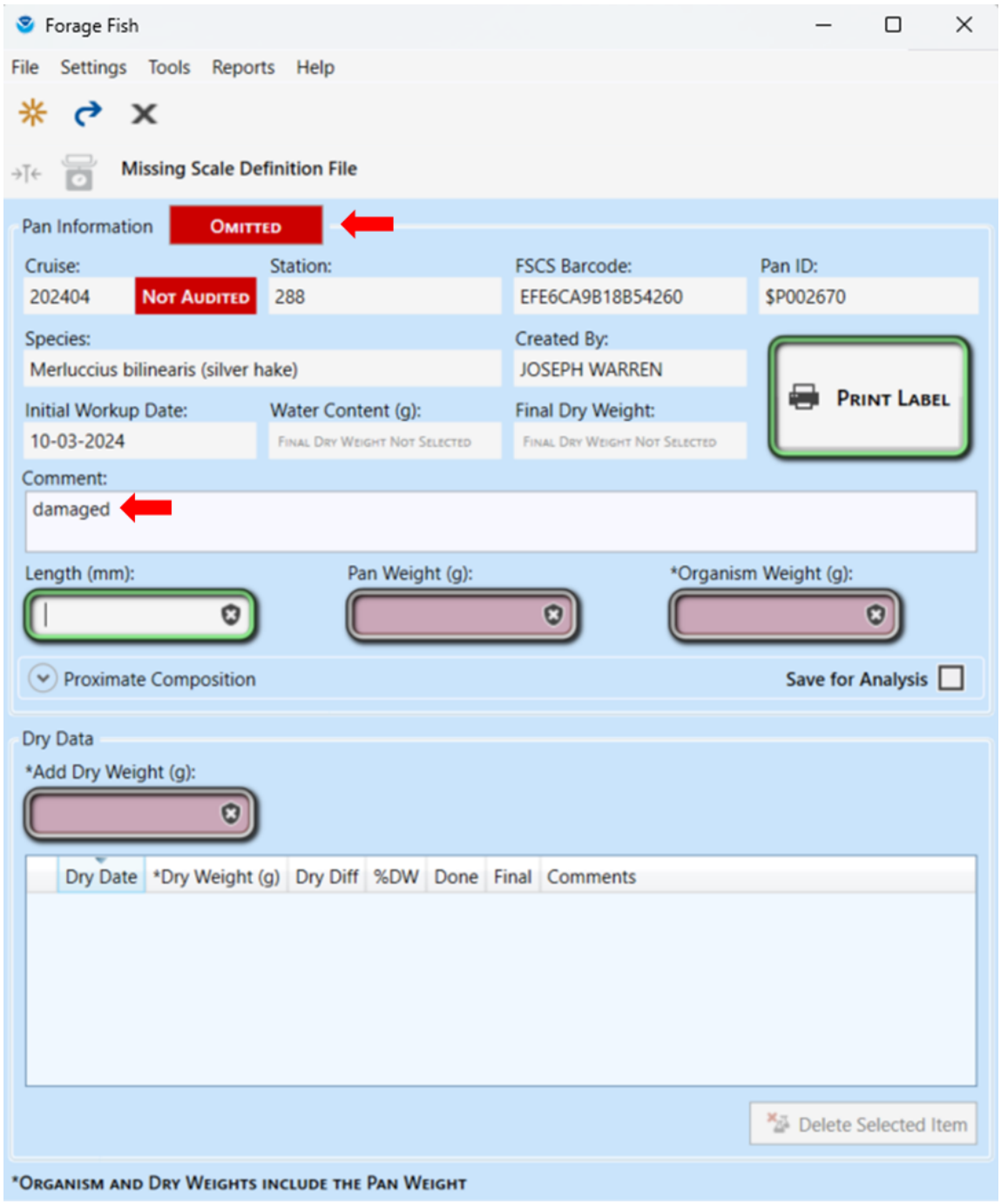


Figure 2. Forage Fish window for an individual sample. Users can omit an individual fish by clicking on the "omitted" button and provide a comment with the omission rationale.

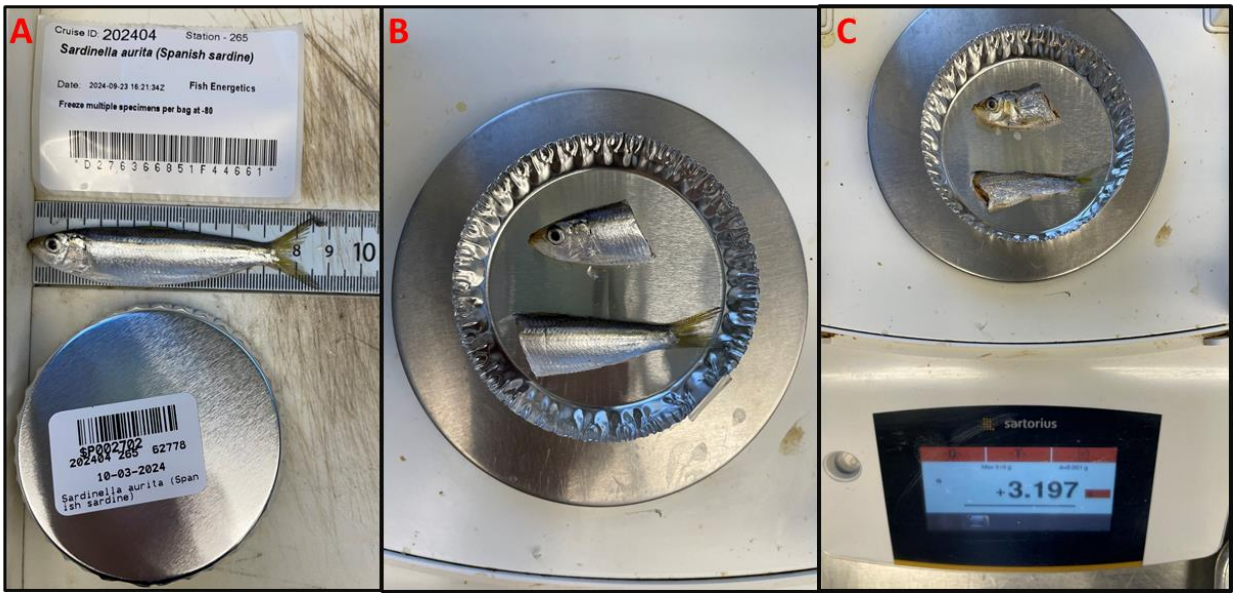


Figure 3. Typical sample processing of collected forage fishes. Panel A: The fork length measurement and the Fisheries Scientific Computer System (FSCS) label that was generated at sea is scanned to create a label with a unique Pan ID (and barcode) that is affixed to the bottom of the pan. Panel B: After the initial weight of the empty pan with label is recoded, the weight of the pan plus fish wet weight are recorded. The sample is then placed in the drying oven. Panel C: The measurement of the first dry weight after 7 days in the drying oven.

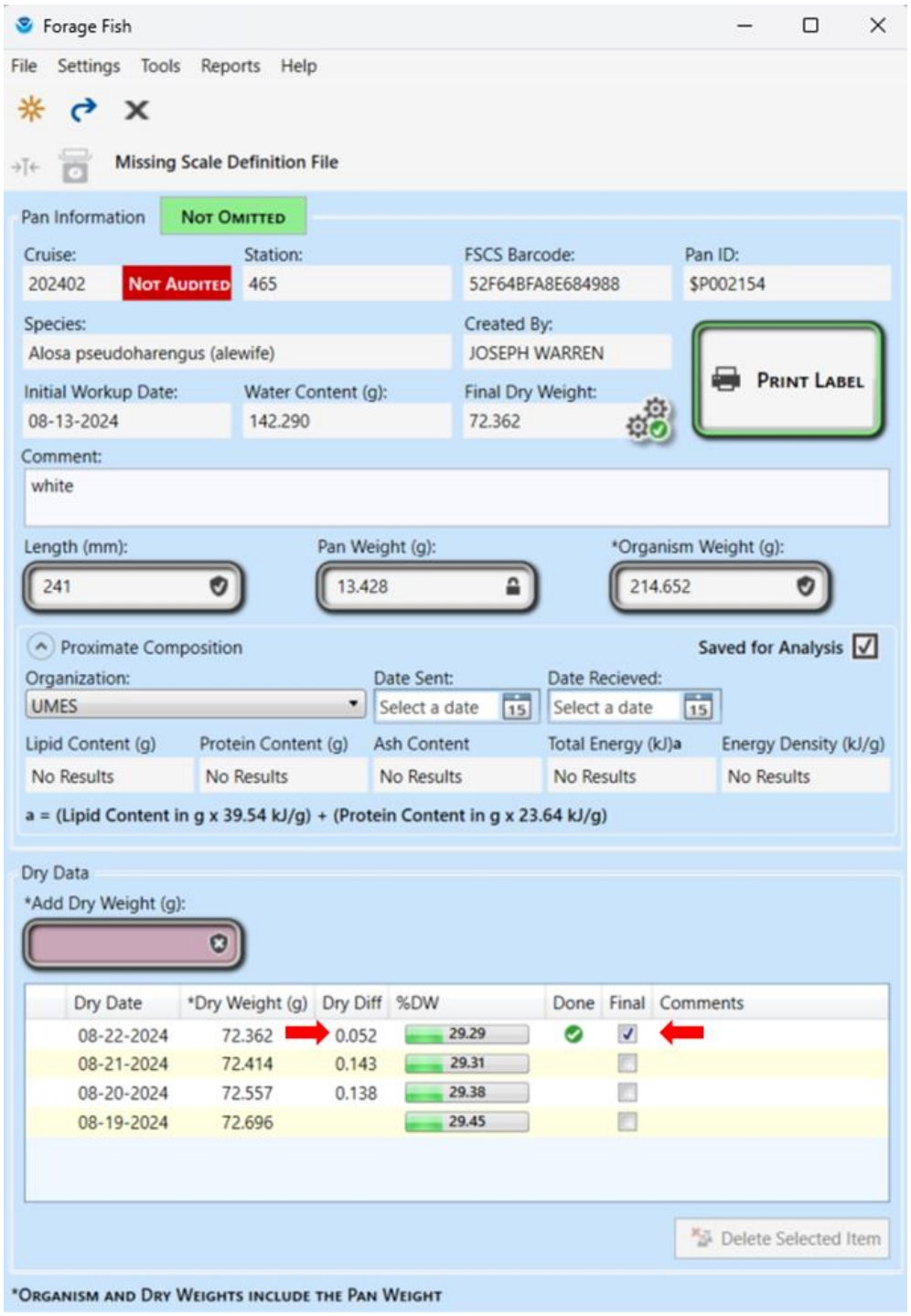


Figure 4. Example of Forage Fish alerting the user that a sample is "done" or dried to a stable weight. For this 201.224 g Alewife, *Alosa pseudoharengus*, (Organism Weight – Pan Weight), the last two dry weight measurements differ by less than 0.101 g, which results in the appearance of the green circle checkmark icon and the user manually checking the "Final" dry weight box.

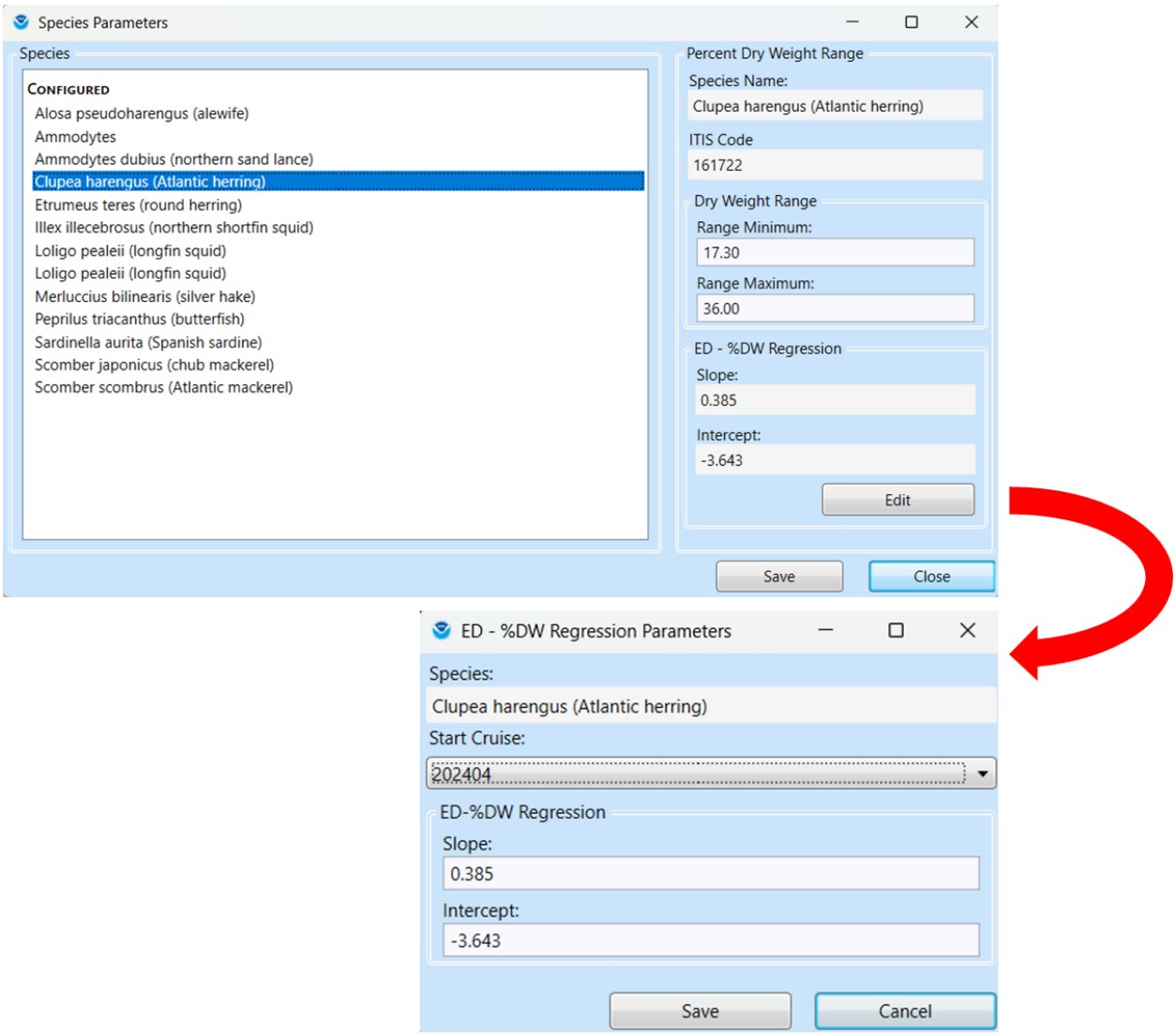


Figure 5. From the settings menu of Forage Fish, the Species Parameters allows for updates to the percent dry weight (%DW) range (minimum and maximum) and regression parameters for energy density (ED) as a function of the %DW when new proximate composition analysis data is available. When updating regression parameters, the user must select the start cruise when the parameters go into effect.

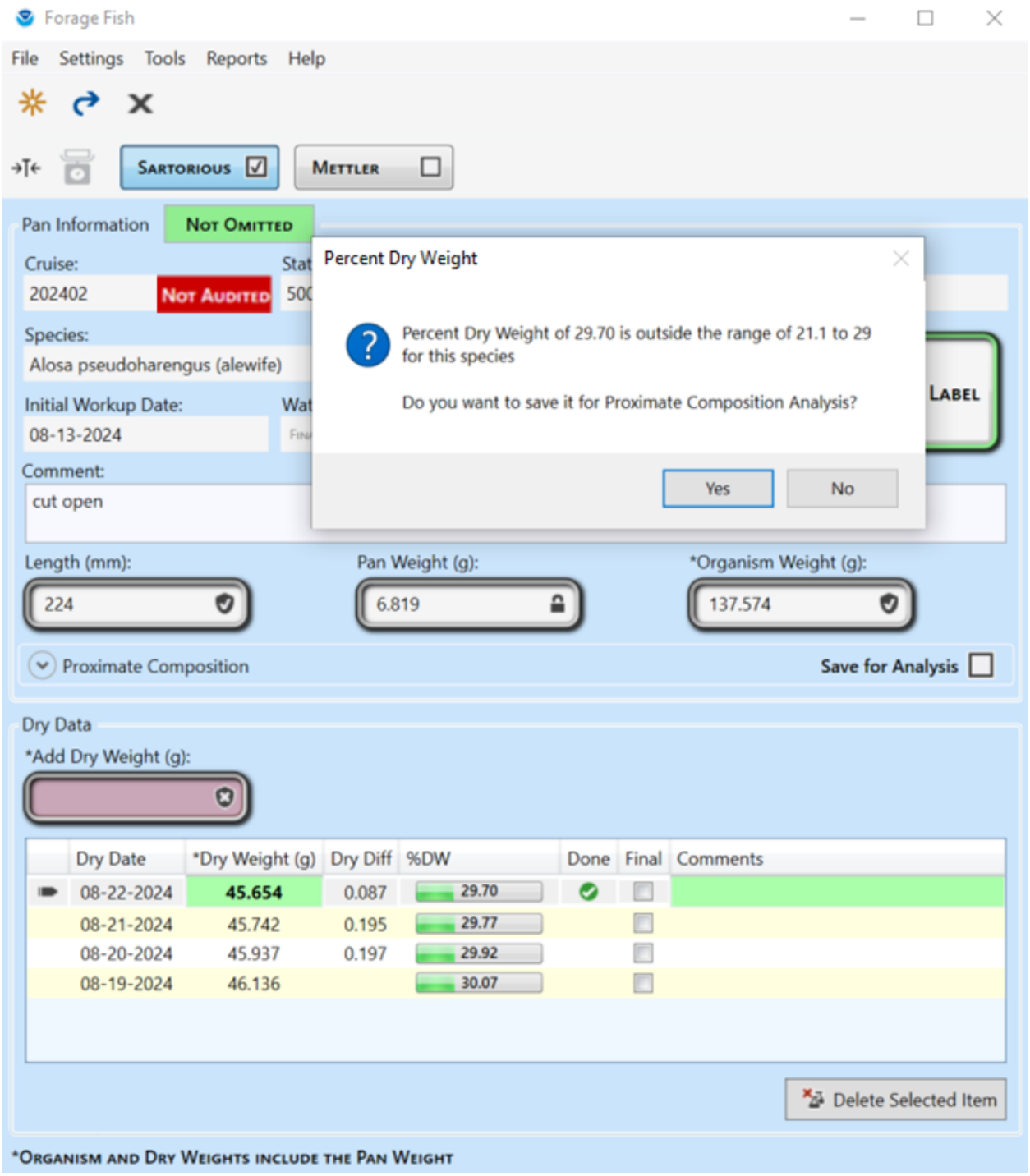


Figure 6. Forage Fish prompt (pop-up) that appears after a sample meets the "done" criteria (consecutive dry weights are <0.101 g for samples with initial wet weight >100 g or <0.01g for samples with initial wet weight <100 g) and the resulting percent dry weight (%DW) falls outside the existing %DW range of samples with proximate composition analysis measurements of energy density.

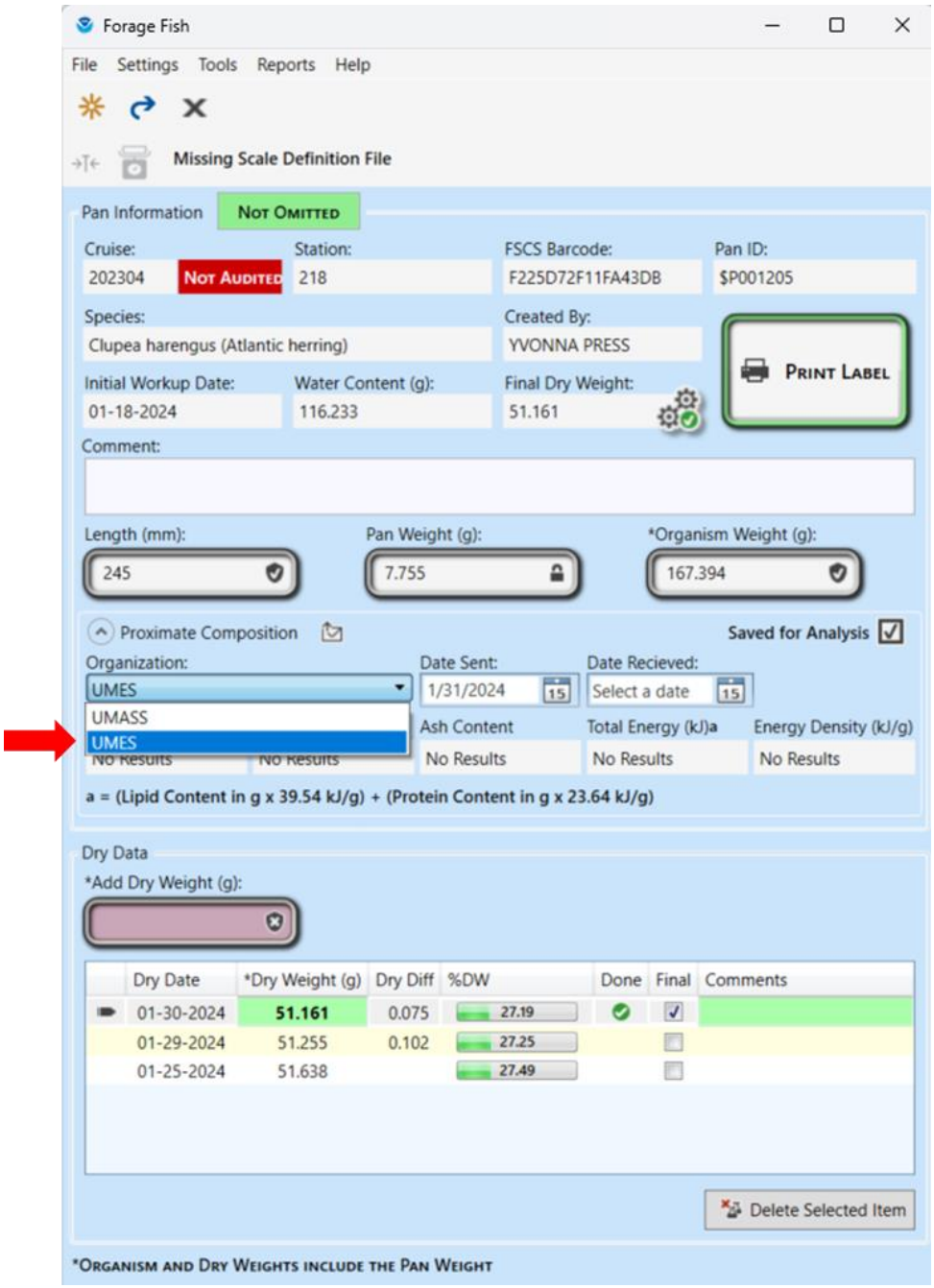


Figure 7. If a sample is saved for further analysis, this is recorded within Forage Fish by selecting the appropriate organization with the option to record the date sent and/or received. Organizations are editable via the Settings > Organization Management.

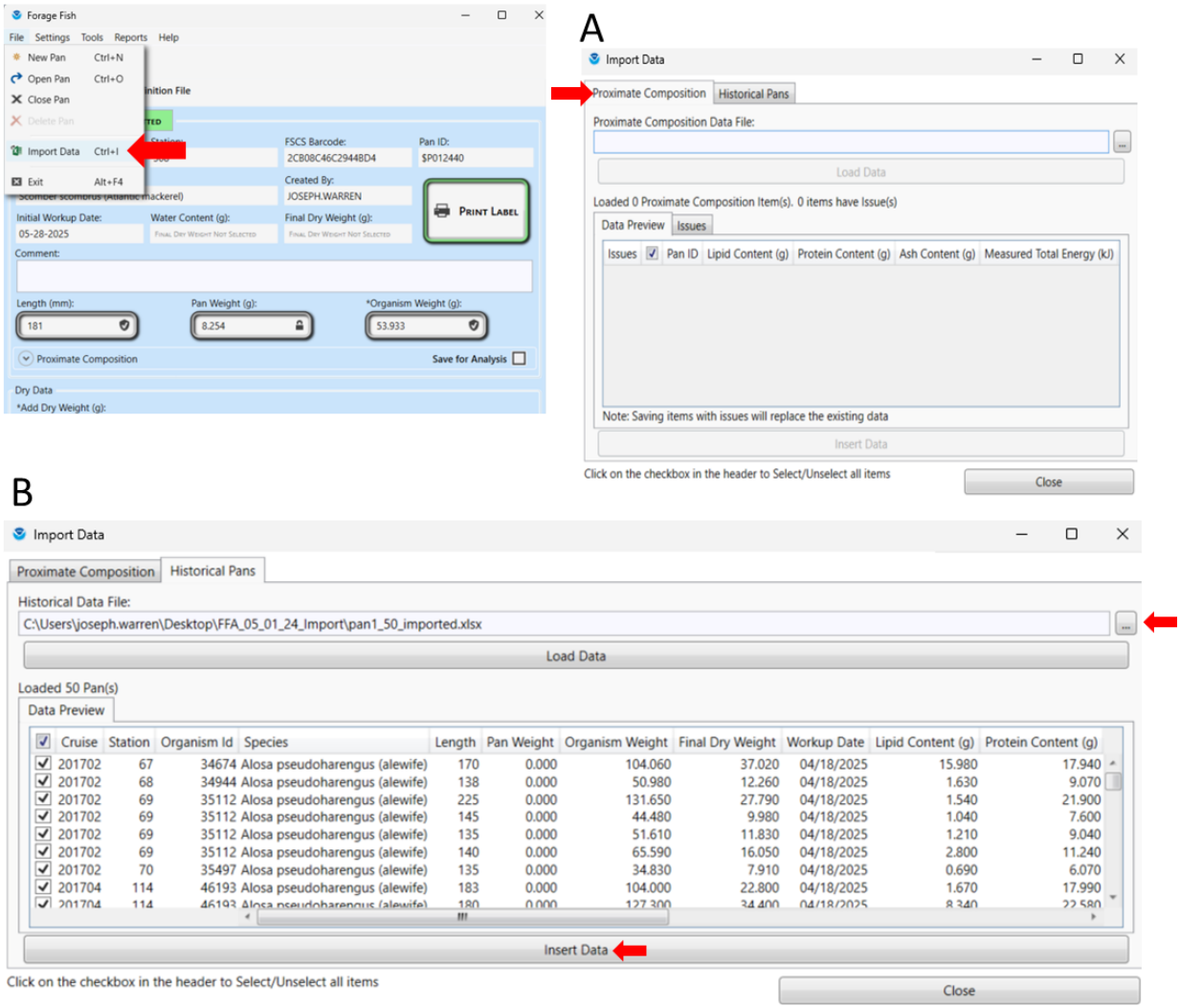


Figure 8. Historical and proximate composition analysis data can be imported into Forage Fish (FF) by navigating to Import Data within the File menu. An import data screen will open and the user can select the appropriate tab (Proximate Composition or Historical Pans; A). The user can then upload the appropriate .csv file (B). FF will generate a data preview and allow the user to verify the records slated for import. Clicking Insert Data will complete the data import to FF.

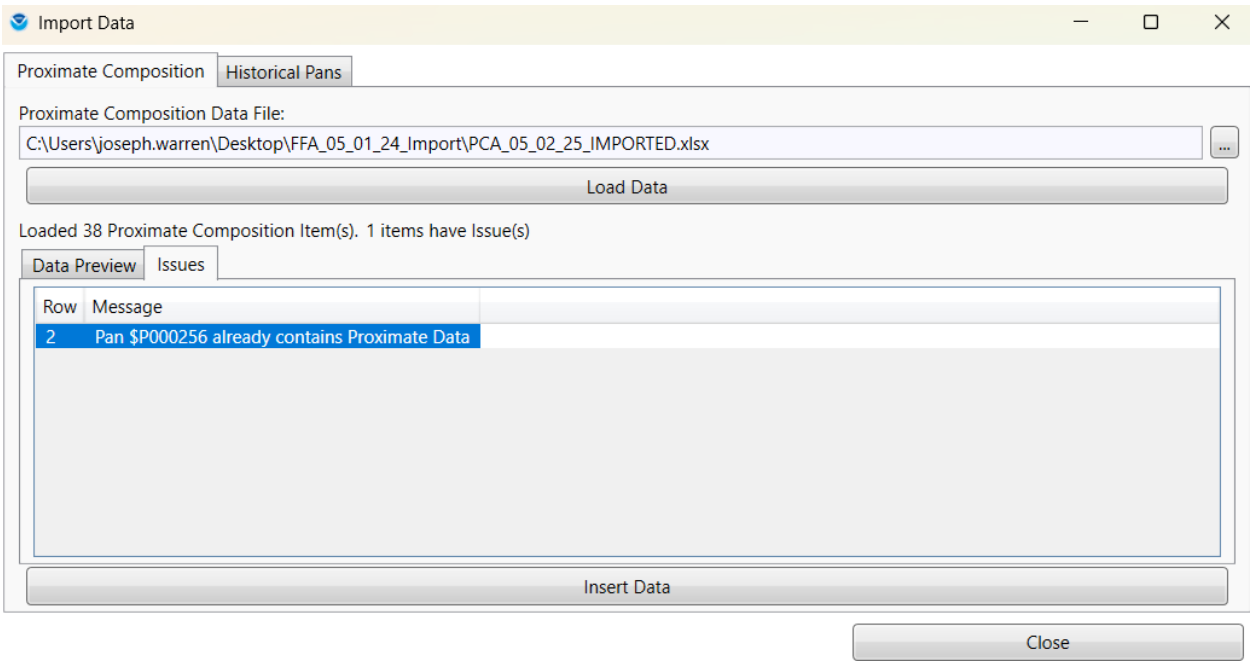


Figure 9. Before uploading proximate composition analysis (PCA) data to the database, Forage Fish identifies any records that already have PCA data in the issues tab. This alerts users to any data that would be overwritten so potential issues can be addressed.

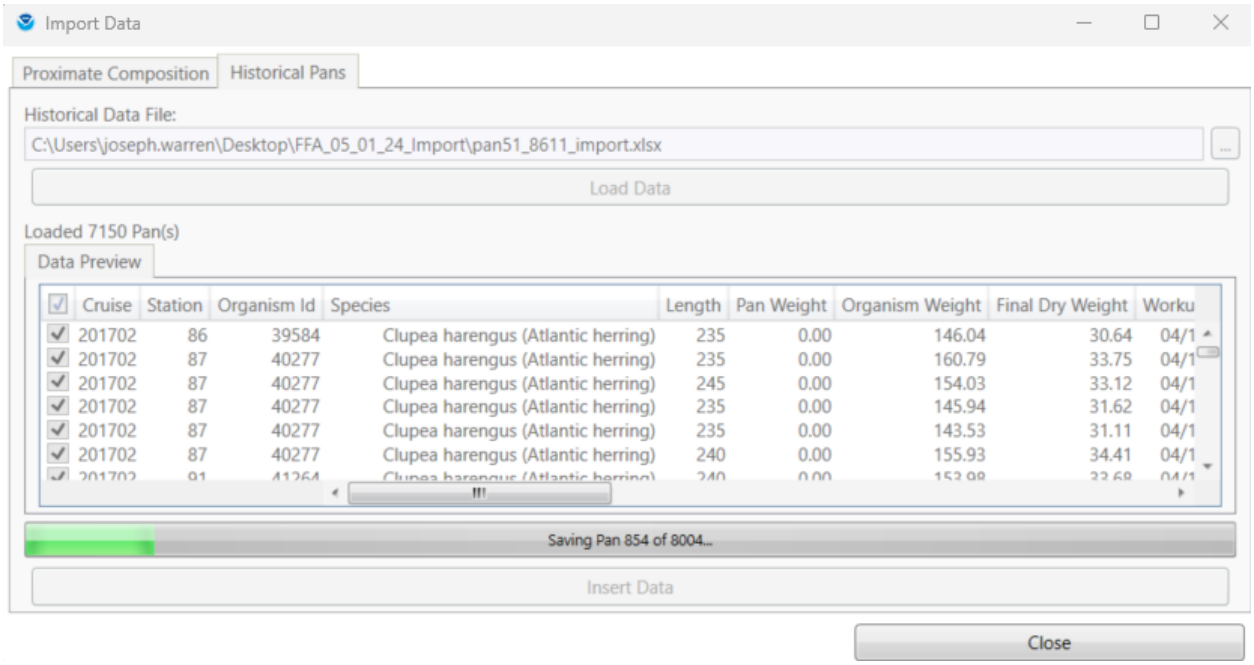


Figure 10. After the user clicks “Insert Data” the records are imported by Forage Fish and uploaded to the appropriate tables in the database.

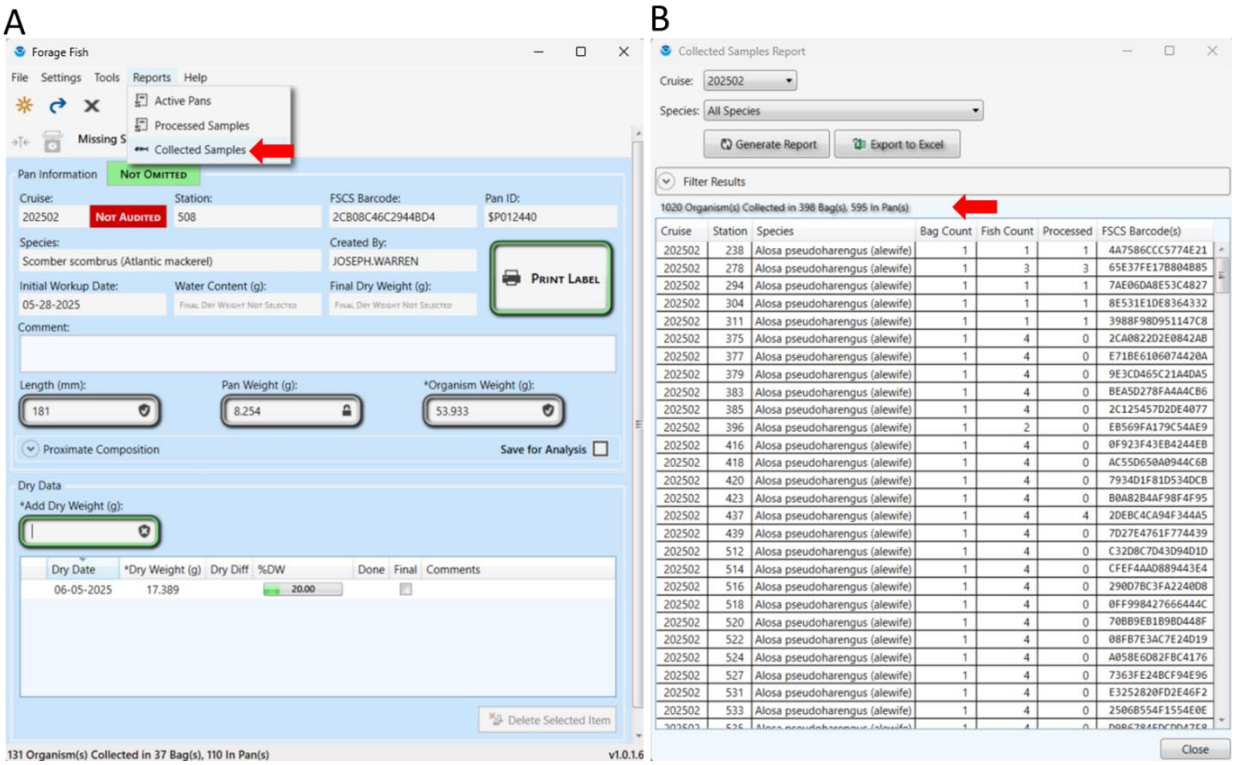
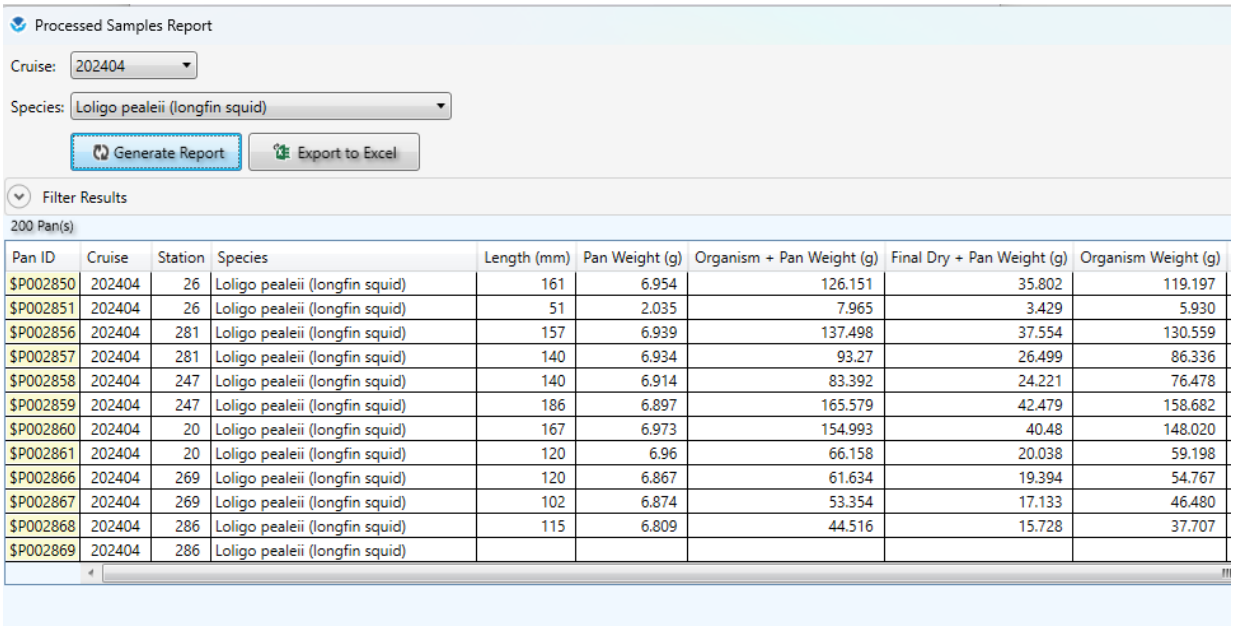
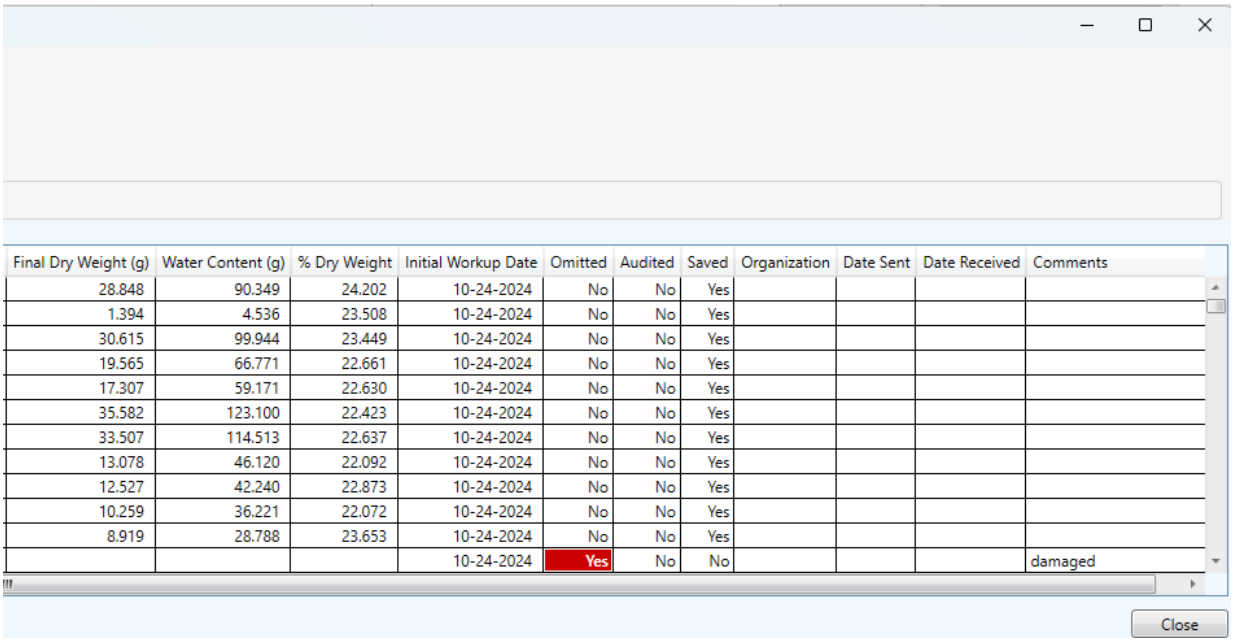


Figure 11. Forage Fish Collected Samples Report appears in the Reports tab (arrow, A). The report is filterable by cruise and species (B). The summary header (arrow, B) indicates the numbers of organisms collected, bags of samples, and how many have been or are currently being processed (dried and omitted).



Pan ID	Cruise	Station	Species	Length (mm)	Pan Weight (g)	Organism + Pan Weight (g)	Final Dry + Pan Weight (g)	Organism Weight (g)
$P002850	202404	26	Loligo pealeii (longfin squid)	161	6.954	126.151	35.802	119.197
$P002851	202404	26	Loligo pealeii (longfin squid)	51	2.035	7.965	3.429	5.930
$P002856	202404	281	Loligo pealeii (longfin squid)	157	6.939	137.498	37.554	130.559
$P002857	202404	281	Loligo pealeii (longfin squid)	140	6.934	93.27	26.499	86.336
$P002858	202404	247	Loligo pealeii (longfin squid)	140	6.914	83.392	24.221	76.478
$P002859	202404	247	Loligo pealeii (longfin squid)	186	6.897	165.579	42.479	158.682
$P002860	202404	20	Loligo pealeii (longfin squid)	167	6.973	154.993	40.48	148.020
$P002861	202404	20	Loligo pealeii (longfin squid)	120	6.96	66.158	20.038	59.198
$P002866	202404	269	Loligo pealeii (longfin squid)	120	6.867	61.634	19.394	54.767
$P002867	202404	269	Loligo pealeii (longfin squid)	102	6.874	53.354	17.133	46.480
$P002868	202404	286	Loligo pealeii (longfin squid)	115	6.809	44.516	15.728	37.707
$P002869	202404	286	Loligo pealeii (longfin squid)					

Continued…



Final Dry Weight (g)	Water Content (g)	% Dry Weight	Initial Workup Date	Omitted	Audited	Saved	Organization	Date Sent	Date Received	Comments
28.848	90.349	24.202	10-24-2024	No	No	Yes				
1.394	4.536	23.508	10-24-2024	No	No	Yes				
30.615	99.944	23.449	10-24-2024	No	No	Yes				
19.565	66.771	22.661	10-24-2024	No	No	Yes				
17.307	59.171	22.630	10-24-2024	No	No	Yes				
35.582	123.100	22.423	10-24-2024	No	No	Yes				
33.507	114.513	22.637	10-24-2024	No	No	Yes				
13.078	46.120	22.092	10-24-2024	No	No	Yes				
12.527	42.240	22.873	10-24-2024	No	No	Yes				
10.259	36.221	22.072	10-24-2024	No	No	Yes				
8.919	28.788	23.653	10-24-2024	No	No	Yes				
			10-24-2024	Yes	No	No				damaged

Figure 12. Forage Fish Processed Samples Report appears in the Reports tab. The report is filterable by cruise and species and has 20 columns (shown split here to improve legibility). The summary header (“200 Pans”) indicates the total number of organisms processed, including samples that were omitted.

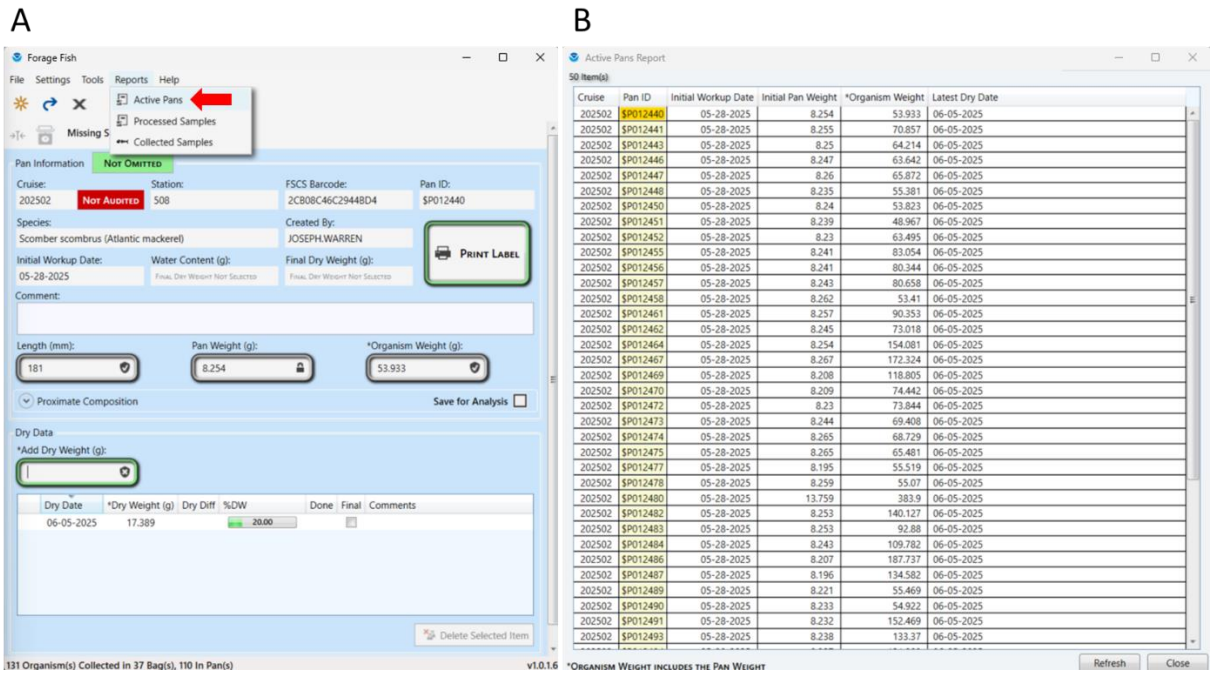


Figure 13. The Forage Fish Active Pans Report summarizes samples that are currently in-progress. When selected (A), this opens a window (B) that displays all Pan IDs that have been created and have an unchecked ‘final’ dry weight box. Specific organism data can be reviewed in the main window (A) by double-clicking on an individual Pan ID (B; highlighted yellow).

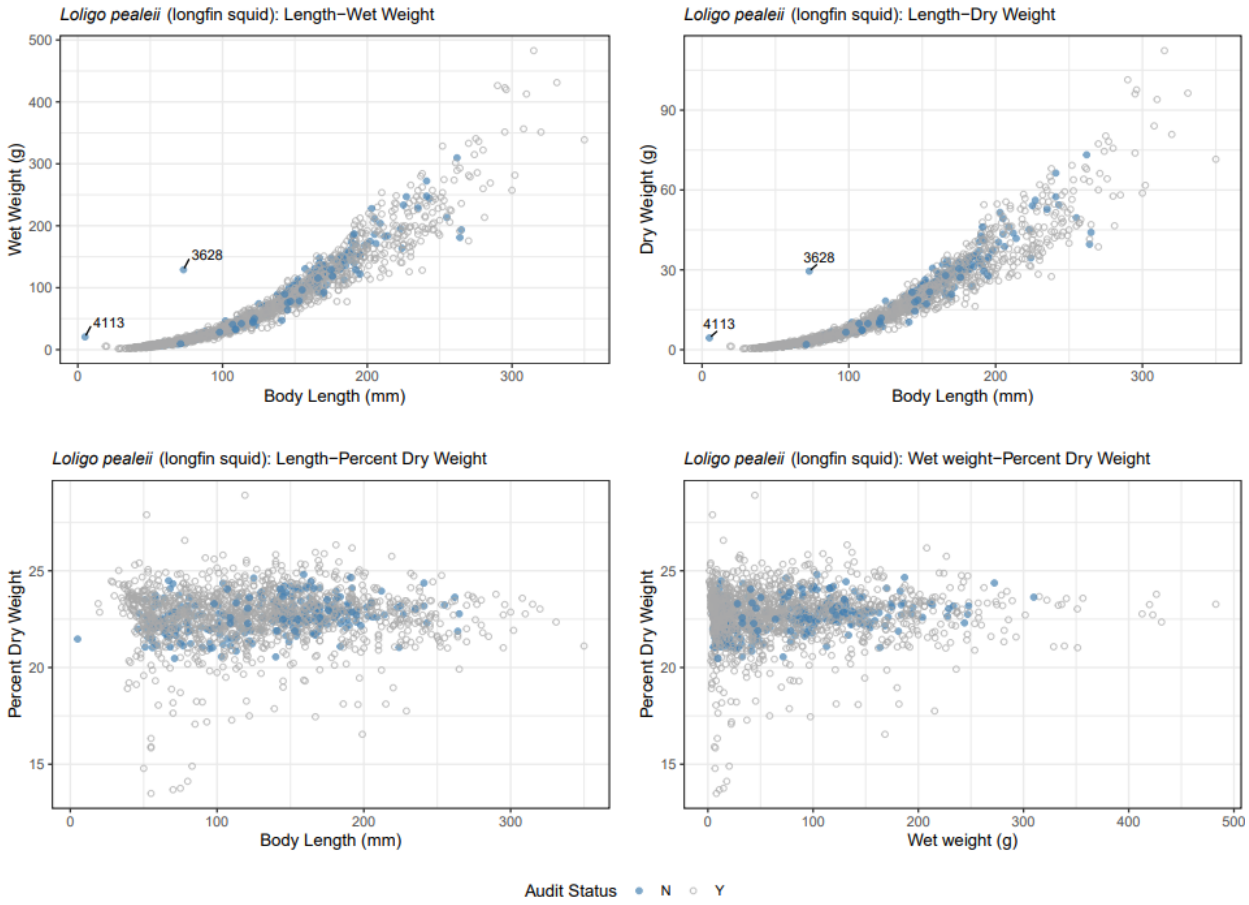


Figure 14. An example of various audit plots that assist with the detection of potential outliers in unaudited data (●) when compared to audited data (○). Samples with a local outlier function score > 5 are labeled so the user can investigate and address potential data entry errors within Forage Fish.

Species and Year	Season	N	Energy Density (ED)[1]	Standard Deviation of ED	ED Distribution
***Clupea harengus* (Atlantic herring)**					
2017	Spring	171	5.57	1.07	
2017	Fall	134	5.84	1.33	
2018	Spring	113	6.12	1.50	
2018	Fall	50	5.42	1.43	
2019	Spring	81	5.49	0.89	
2019	Fall	84	5.87	1.31	
2020	Spring	8	5.58	0.70	
2021	Spring	117	6.36	1.40	
2021	Fall	123	5.97	1.04	
2022	Spring	200	6.16	1.50	
2022	Fall	113	6.09	1.55	
2023	Spring	66	8.12	1.04	
2023	Fall	131	6.73	1.44	
2024	Spring	161	5.77	1.28	
2024	Fall	110	6.37	1.46	
2025	Spring	95	5.42	1.18	

[1] kilojoules per gram of wet weight

Figure 15. Example species-specific summary table with density distribution plots produced using the *gt* and *gtextras* packages.

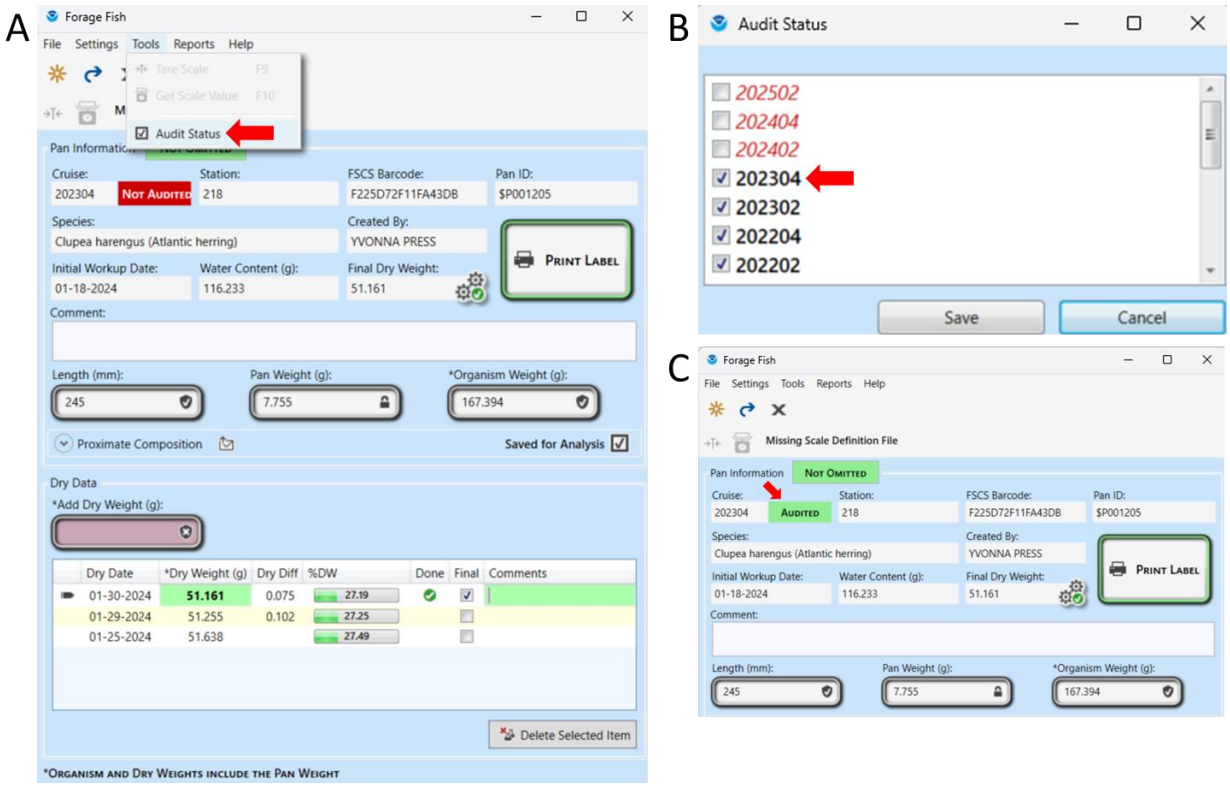


Figure 16. Following completion of a cruise audit, the user can update the audit status by navigating to "Audit Status" under the Tools menu (A) and select the audited cruise (B). After clicking save, all the samples associated with the selected cruise (in this example, 202304, 202302, 202204, and 202202) will show a green "AUDITED" icon (C) in FF. All audited records (that are not omitted) are available in the FF_ENERGY_DENSITY view within the FSCS2 schema.

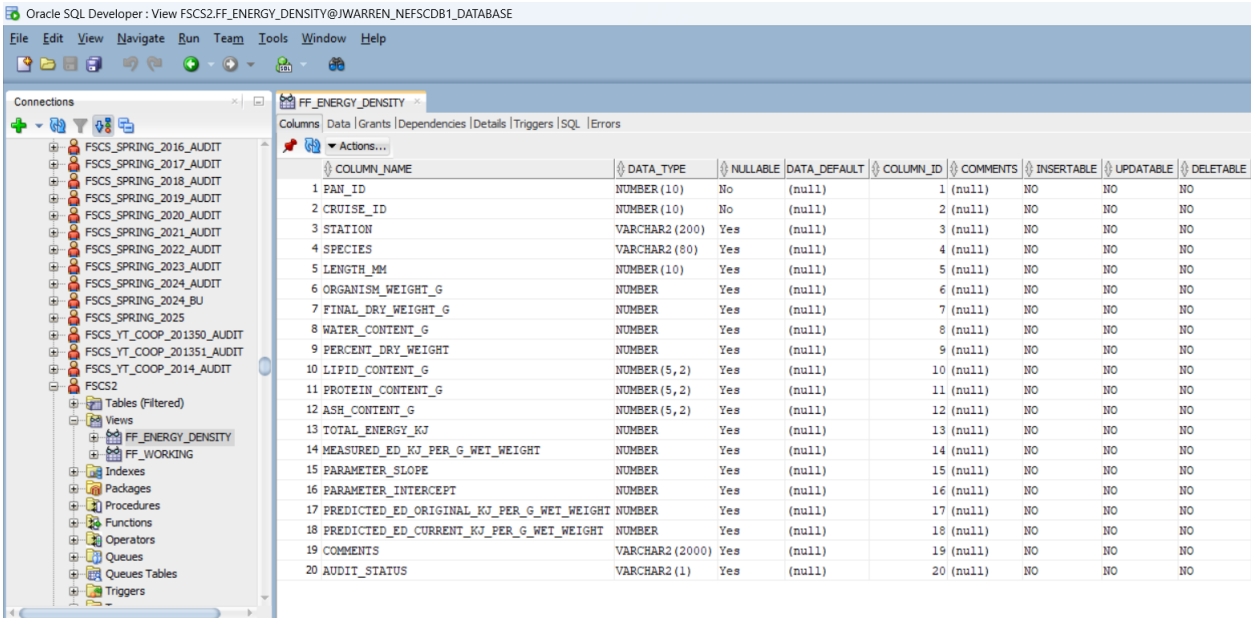


Figure 17. The FF_ENERGY_DENSITY view can be found by navigating to the FSCS2 user -> Views -> FF_ENERGY_DENSITY (FSCS2.FF_ENERGY_DENSITY).

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9.0 APPENDICES

A. Sample request protocol for Fish Energetics

Example 'Fish Energetics' sample request protocols from the Fall 2024 bottom trawl survey (202404). Additional notes and preservation detail include double-bagging and freezing at –80° C.

Year	Season	Cruise ID	Investigator ID	Scientific Name	Size Ranges	Specimen Totals	Locations
2024	FALL	202404	Fish Energetics	*Alosa pseudoharengus* (alewife)	Any	4 per station, 75 total	Georges Bank
2024	FALL	202404	Fish Energetics	*Alosa pseudoharengus* (alewife)	Any	4 per station, 75 total	Gulf of Maine
2024	FALL	202404	Fish Energetics	*Alosa pseudoharengus* (alewife)	Any	4 per station, 75 total	Mid Atlantic Bight
2024	FALL	202404	Fish Energetics	*Alosa pseudoharengus* (alewife)	Any	4 per station, 75 total	Southern New England
2024	FALL	202404	Fish Energetics	*Ammodytes dubius* (northern sand lance)	Any	6 per station, 75 total	Georges Bank
2024	FALL	202404	Fish Energetics	*Ammodytes dubius* (northern sand lance)	Any	6 per station, 75 total	Gulf of Maine
2024	FALL	202404	Fish Energetics	*Ammodytes dubius* (northern sand lance)	Any	6 per station, 75 total	Mid Atlantic Bight

Year	Season	Cruise ID	Investigator ID	Scientific Name	Size Ranges	Specimen Totals	Locations
2024	FALL	202404	Fish Energetics	*Ammodytes dubius* (northern sand lance)	Any	6 per station, 75 total	Southern New England
2024	FALL	202404	Fish Energetics	*Clupea harengus* (Atlantic herring)	Any	6 per station, 125 total	Georges Bank
2024	FALL	202404	Fish Energetics	*Clupea harengus* (Atlantic herring)	Any	6 per station, 125 total	Gulf of Maine
2024	FALL	202404	Fish Energetics	*Clupea harengus* (Atlantic herring)	Any	6 per station, 125 total	Mid Atlantic Bight
2024	FALL	202404	Fish Energetics	*Clupea harengus* (Atlantic herring)	Any	6 per station, 125 total	Southern New England
2024	FALL	202404	Fish Energetics	*Etrumeus teres* (round herring)	Any	5 per station, 75 total	Georges Bank
2024	FALL	202404	Fish Energetics	*Etrumeus teres* (round herring)	Any	5 per station, 75 total	Gulf of Maine
2024	FALL	202404	Fish Energetics	*Etrumeus teres* (round herring)	Any	5 per station, 75 total	Mid Atlantic Bight

Year	Season	Cruise ID	Investigator ID	Scientific Name	Size Ranges	Specimen Totals	Locations
2024	FALL	202404	Fish Energetics	*Etrumeus teres* (round herring)	Any	5 per station, 75 total	Southern New England
2024	FALL	202404	Fish Energetics	*Illex illecebrosus* (northern shortfin squid)	Any	2 per station, 50 total	Georges Bank
2024	FALL	202404	Fish Energetics	*Illex illecebrosus* (northern shortfin squid)	Any	2 per station, 50 total	Gulf of Maine
2024	FALL	202404	Fish Energetics	*Illex illecebrosus* (northern shortfin squid)	Any	2 per station, 50 total	Mid Atlantic Bight
2024	FALL	202404	Fish Energetics	*Illex illecebrosus* (northern shortfin squid)	Any	2 per station, 50 total	Southern New England
2024	FALL	202404	Fish Energetics	*Loligo pealeii* (longfin squid)	Any	2 per station, 50 total	Georges Bank
2024	FALL	202404	Fish Energetics	*Loligo pealeii* (longfin squid)	Any	2 per station, 50 total	Gulf of Maine
2024	FALL	202404	Fish Energetics	*Loligo pealeii* (longfin squid)	Any	2 per station, 50 total	Mid Atlantic Bight

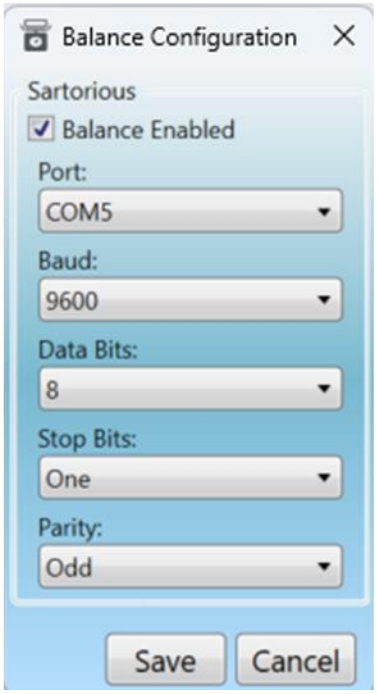
Year	Season	Cruise ID	Investigator ID	Scientific Name	Size Ranges	Specimen Totals	Locations
2024	FALL	202404	Fish Energetics	*Loligo pealeii* (longfin squid)	Any	2 per station, 50 total	Southern New England
2024	FALL	202404	Fish Energetics	*Merluccius bilinearis* (silver hake)	Any	3 per station, 50 total	Georges Bank
2024	FALL	202404	Fish Energetics	*Merluccius bilinearis* (silver hake)	Any	3 per station, 50 total	Gulf of Maine
2024	FALL	202404	Fish Energetics	*Merluccius bilinearis* (silver hake)	Any	3 per station, 50 total	Mid Atlantic Bight
2024	FALL	202404	Fish Energetics	*Merluccius bilinearis* (silver hake)	Any	3 per station, 50 total	Southern New England
2024	FALL	202404	Fish Energetics	*Peprilus triacanthus* (butterfish)	Any	3 per station, 50 total	Georges Bank
2024	FALL	202404	Fish Energetics	*Peprilus triacanthus* (butterfish)	Any	3 per station, 50 total	Gulf of Maine
2024	FALL	202404	Fish Energetics	*Peprilus triacanthus* (butterfish)	Any	3 per station, 50 total	Mid Atlantic Bight
2024	FALL	202404	Fish Energetics	*Peprilus triacanthus* (butterfish)	Any	3 per station, 50 total	Southern New England

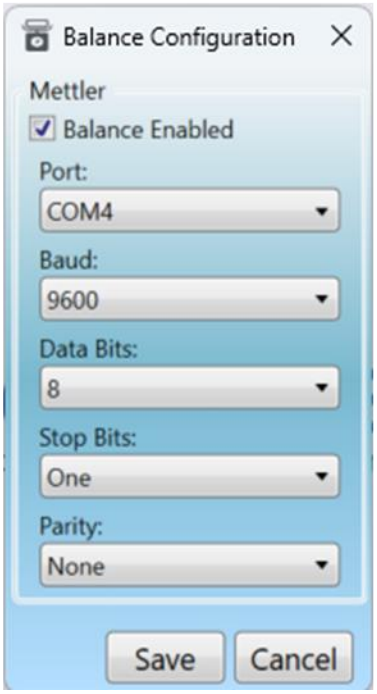
Year	Season	Cruise ID	Investigator ID	Scientific Name	Size Ranges	Specimen Totals	Locations
2024	FALL	202404	Fish Energetics	*Sardinella aurita* (Spanish sardine)	Any	5 per station, 50 total	Georges Bank
2024	FALL	202404	Fish Energetics	*Sardinella aurita* (Spanish sardine)	Any	5 per station, 50 total	Gulf of Maine
2024	FALL	202404	Fish Energetics	*Sardinella aurita* (Spanish sardine)	Any	5 per station, 50 total	Mid Atlantic Bight
2024	FALL	202404	Fish Energetics	*Sardinella aurita* (Spanish sardine)	Any	5 per station, 50 total	Southern New England
2024	FALL	202404	Fish Energetics	*Scomber scombrus* (Atlantic mackerel)	Any	4 per station, 75 total	Georges Bank
2024	FALL	202404	Fish Energetics	*Scomber scombrus* (Atlantic mackerel)	Any	4 per station, 75 total	Gulf of Maine
2024	FALL	202404	Fish Energetics	*Scomber scombrus* (Atlantic mackerel)	Any	4 per station, 75 total	Mid Atlantic Bight
2024	FALL	202404	Fish Energetics	*Scomber scombrus* (Atlantic mackerel)	Any	4 per station, 75 total	Southern New England

B. Balance settings in Forage Fish

Screenshots of the configuration parameter values for the connected balances. Top panel shows the navigation to the balance settings, and lower panels show the configuration settings currently used. Both balances are connected via serial to USB adapters, which get assigned COM Ports. The COM Ports on the PC may get reassigned; users can use the Device Manager in Windows to see which COM Ports are in use and adjust as necessary. When FF is being run from a laptop that is not connected to any balance, none will appear under the balances tab.

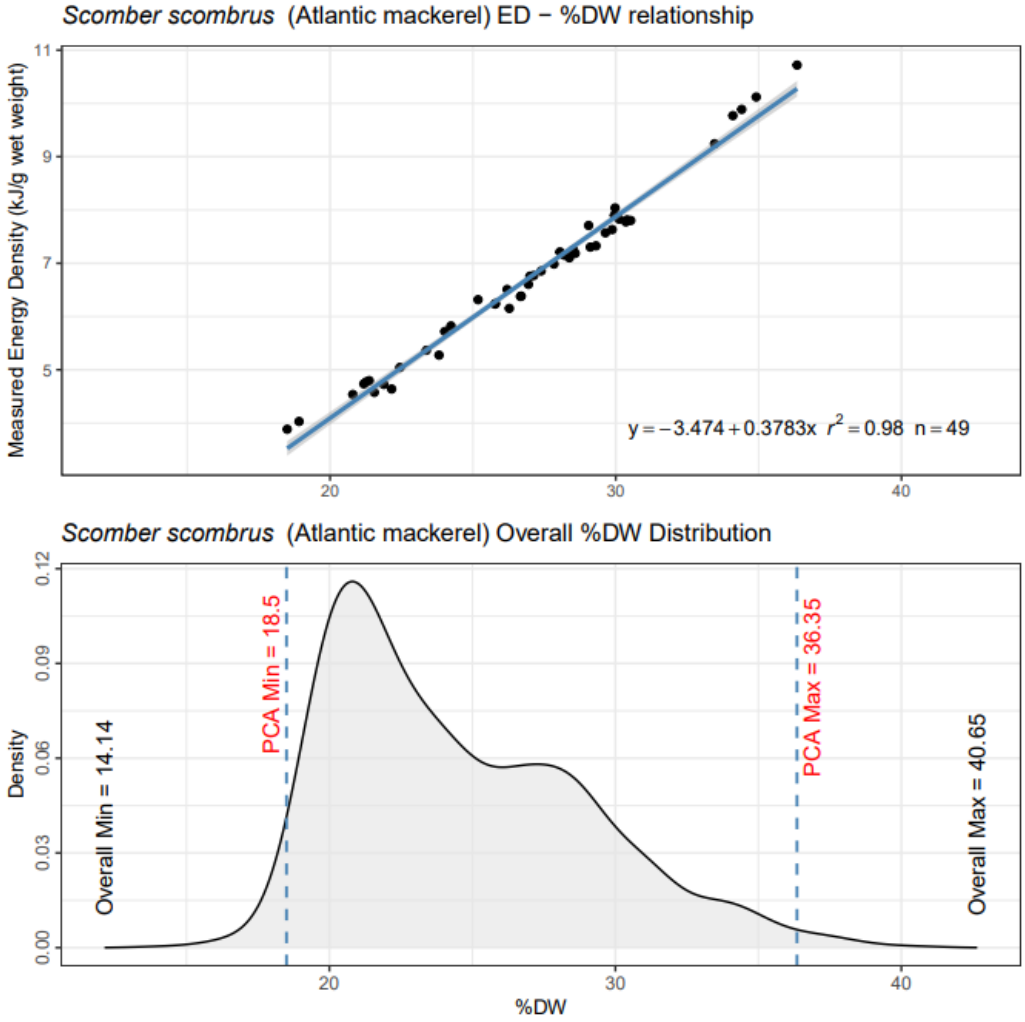




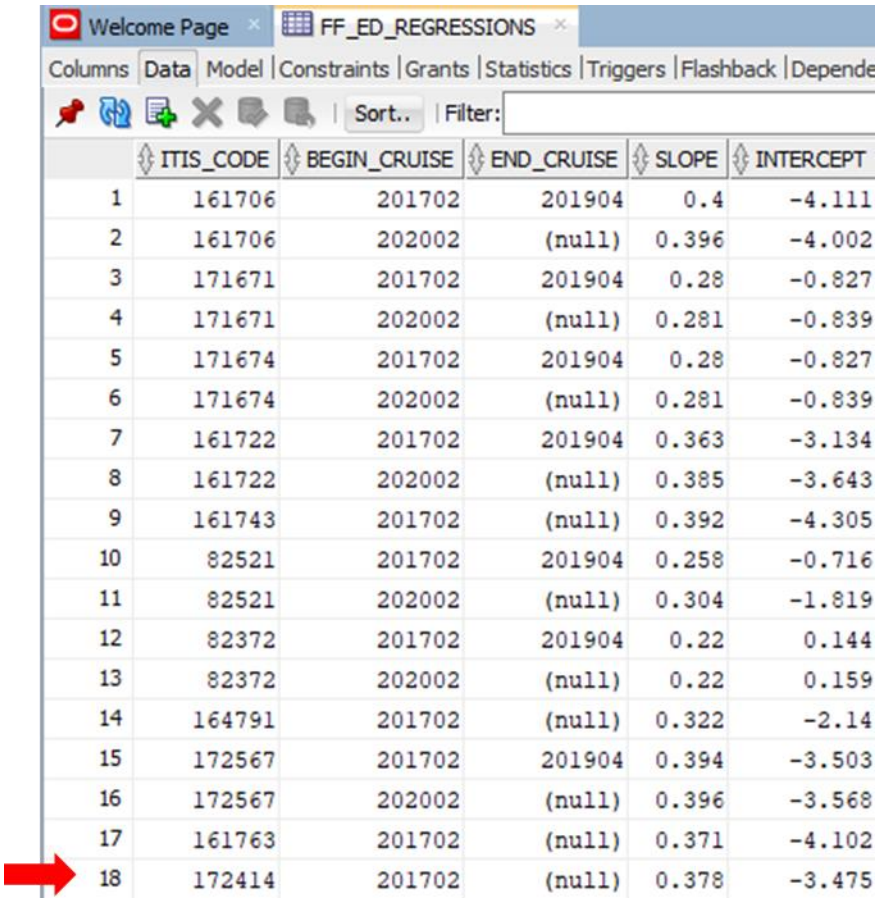


C. Percent dry weight (%DW) - energy density regressions and ranges in %DW for each species

Species-specific linear regressions of proximate composition analysis (PCA) determined energy density (ED) vs. percent dry weight (%DW), with distributions of %DW data and minimum and maximum %DW values for PCA samples shown. The example shown includes all records through cruise = 202502. Two plots are generated for each species; the top panel shows all PCA data and the fitted regression (equation, r^2, and number of observations shown), the bottom panel shows the overall distribution of %DW observations to date (and includes unaudited and audited records), with the minimum and maximum values for all samples in black and the minimum and maximum values of %DW for PCA samples (dashed blue line, red text). The paired plots for Atlantic mackerel are shown as an example.



Currently active and historical species-specific regression parameters are maintained in the FF_ED_REGRESSIONS table (organized by ITIS code) within the FSCS2 schema. The record for Atlantic mackerel is indicated by the red arrow.



Welcome Page | FF_ED_REGRESSIONS

Columns | Data | Model | Constraints | Grants | Statistics | Triggers | Flashback | Depende

Sort.. | Filter:

	ITIS_CODE	BEGIN_CRUISE	END_CRUISE	SLOPE	INTERCEPT
1	161706	201702	201904	0.4	-4.111
2	161706	202002	(null)	0.396	-4.002
3	171671	201702	201904	0.28	-0.827
4	171671	202002	(null)	0.281	-0.839
5	171674	201702	201904	0.28	-0.827
6	171674	202002	(null)	0.281	-0.839
7	161722	201702	201904	0.363	-3.134
8	161722	202002	(null)	0.385	-3.643
9	161743	201702	(null)	0.392	-4.305
10	82521	201702	201904	0.258	-0.716
11	82521	202002	(null)	0.304	-1.819
12	82372	201702	201904	0.22	0.144
13	82372	202002	(null)	0.22	0.159
14	164791	201702	(null)	0.322	-2.14
15	172567	201702	201904	0.394	-3.503
16	172567	202002	(null)	0.396	-3.568
17	161763	201702	(null)	0.371	-4.102
18	172414	201702	(null)	0.378	-3.475

D. Data import template examples (Proximate Composition and Historical Data)

Proximate Composition Analysis (PCA) data import template example. Note: the .csv worksheet must be labelled “PCA”. Bomb Calorimetry data can be imported using this template, with values only in the MEASURED_TOTAL_ENERGY_KJ column.

PAN_ID	CRUISE_ID	STATION	SPECIES	LIPID_CONTENT_G	PROTEIN_CONTENT_G	ASH_CONTENT_G	MEASURED_TOTAL_ENERGY_KJ
$P000256	202204	297	Alosa pseudoharengus (alewife)	12.499	22.326	3.862	
$P000258	202204	275	Alosa pseudoharengus (alewife)	27.608	32.767	5.674	
$P000268	202204	269	Alosa pseudoharengus (alewife)	34.593	42.834	4.702	
$P000269	202204	269	Alosa pseudoharengus (alewife)	29.83	36.665	6.441	
$P000270	202204	290	Alosa pseudoharengus (alewife)	7.621	19.318	3.202	
$P000271	202204	290	Alosa pseudoharengus (alewife)	21.732	31.085	4.648	
$P000272	202204	290	Alosa pseudoharengus (alewife)	32.003	33.036	6.288	
$P000277	202204	288	Alosa pseudoharengus (alewife)	36.086	58.32	7.118	
$P000279	202204	298	Alosa pseudoharengus (alewife)	25.565	34.484	5.251	
$P000284	202204	300	Alosa pseudoharengus (alewife)	23.185	34.983	6.518	
$P000286	202204	274	Alosa pseudoharengus (alewife)	23.859	28.761	4.442	
$P000288	202204	289	Alosa pseudoharengus (alewife)	18.54	27.61	4.795	
$P000289	202204	289	Alosa pseudoharengus (alewife)	21.627	32.916	6.196	
$P000290	202204	289	Alosa pseudoharengus (alewife)	20.997	29.99	5.534	
$P000294	202204	291	Alosa pseudoharengus (alewife)	16.182	26.56	4.309	
$P000296	202204	291	Alosa pseudoharengus (alewife)	25.902	34.178		
$P000298	202204	292	Alosa pseudoharengus (alewife)	36.384	43.893	7.01	
$P000304	202204	285	Alosa pseudoharengus (alewife)	26.021	29.578	5.178	
$P000305	202204	285	Alosa pseudoharengus (alewife)	27.532	27.931	4.996	
$P000856	202304	66	Etrumeus teres (round herring)	0.227	2.843	0.494	
$P000857	202304	66	Etrumeus teres (round herring)	0.477	1.934	0.417	
$P000859	202304	97	Etrumeus teres (round herring)	0.389	3.037	0.577	
$P000860	202304	97	Etrumeus teres (round herring)	0.546	3.11	0.563	
$P000861	202304	97	Etrumeus teres (round herring)	0.166	2.131	0.433	
$P000862	202304	65	Etrumeus teres (round herring)	3.129	9.184	1.47	
$P000863	202304	65	Etrumeus teres (round herring)	5.15	11.969	1.843	
$P000864	202304	65	Etrumeus teres (round herring)	4.875	12.047	1.976	
$P000866	202304	70	Etrumeus teres (round herring)	0.403	3.323	0.517	

PCA

Historical data import template example. Note: the .csv worksheet must be labelled “HISTORICAL”.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	GENERATED_PAN_ID	JW_PAN_ID	CRUISE_ID	STATION	SPECIES	ORGANISM_ID	INITIAL_WORKUP_DATE	LENGTH_MM	ORGANISM_WEIGHT_G	FINAL_DRY_WEIGHT_G	DRY_DATE	LIPID_CONTENT_G	PROTEIN_CONTENT_G	ASH_CONTENT_G
2	$P004247	PI000001	201702	67	Alosa pse	34674	18-Apr-25	170	104.06	37.02	18-Apr-25	15.98	17.94	
3	$P004248	PI000002	201702	68	Alosa pse	34944	18-Apr-25	138	50.98	12.26	18-Apr-25	1.63	9.07	
4	$P004249	PI000003	201702	69	Alosa pse	35112	18-Apr-25	225	131.65	27.79	18-Apr-25	1.54	21.9	
5	$P004250	PI000004	201702	69	Alosa pse	35112	18-Apr-25	145	44.48	9.98	18-Apr-25	1.04	7.6	
6	$P004251	PI000005	201702	69	Alosa pse	35112	18-Apr-25	135	51.61	11.83	18-Apr-25	1.21	9.04	
7	$P004252	PI000006	201702	69	Alosa pse	35112	18-Apr-25	140	65.59	16.05	18-Apr-25	2.8	11.24	
8	$P004253	PI000007	201702	70	Alosa pse	35497	18-Apr-25	135	34.83	7.91	18-Apr-25	0.69	6.07	
9	$P004254	PI000008	201704	114	Alosa pse	46193	18-Apr-25	183	104	22.8	18-Apr-25	1.67	17.99	
10	$P004255	PI000009	201704	114	Alosa pse	46193	18-Apr-25	180	127.3	34.4	18-Apr-25	8.34	22.58	
11	$P004256	PI000010	201704	114	Alosa pse	46193	18-Apr-25	180	112.6	31.2	18-Apr-25	8.81	19.04	
12	$P004257	PI000011	201704	72	Alosa pse	20748	18-Apr-25	212	98.678	21.897	18-Apr-25			
13	$P004258	PI000012	201704	72	Alosa pse	20748	18-Apr-25	200	175.2	49.1	18-Apr-25	7.43	36.65	
14	$P004259	PI000013	201702	73	Alosa pse	36214	18-Apr-25	171	41.405	14.633	18-Apr-25			
15	$P004260	PI000014	201702	73	Alosa pse	36214	18-Apr-25	125	31.89	7.13	18-Apr-25	0.52	5.57	
16	$P004261	PI000015	201704	114	Alosa pse	46193	18-Apr-25	190	157.7	41.9	18-Apr-25	8.75	28.84	
17	$P004262	PI000016	201704	114	Alosa pse	46193	18-Apr-25	178	127.7	34	18-Apr-25	7.65	22.74	
18	$P004263	PI000017	201704	114	Alosa pse	46193	18-Apr-25	225	240.3	67.9	18-Apr-25	19.32	41.71	
19	$P004264	PI000018	201704	114	Alosa pse	46193	18-Apr-25	170	83.8	18.3	18-Apr-25	1.31	14.35	
20	$P004265	PI000019	201704	114	Alosa pse	46193	18-Apr-25	200	162	46.5	18-Apr-25	12.45	29.17	
21	$P004266	PI000020	201702	77	Alosa pse	37495	18-Apr-25	165	105.4	25.42	18-Apr-25	6.69	15.33	
22	$P004267	PI000021	201702	81	Alosa pse	38838	18-Apr-25	240	228.41	67.88	18-Apr-25	17.39	44.16	
23	$P004268	PI000022	201702	92	Alosa pse	41722	18-Apr-25	220	157.81	38.66	18-Apr-25	6.31	27.12	
24	$P004269	PI000023	201702	96	Alosa pse	42165	18-Apr-25	195	116.66	29.58	18-Apr-25	5.44	20.53	
25	$P004270	PI000024	201702	96	Alosa pse	42165	18-Apr-25	210	142.19	36.76	18-Apr-25	7.57	24.22	
26	$P004271	PI000025	201702	96	Alosa pse	42165	18-Apr-25	175	85.32	21.97	18-Apr-25	4.34	15.06	
27	$P004272	PI000026	201702	96	Alosa pse	42165	18-Apr-25	195	115.83	29.65	18-Apr-25	6.43	20.05	
28	$P004273	PI000027	201702	97	Alosa pse	42603	18-Apr-25	165	90.45	31.37	18-Apr-25	13.01	15.64	
29	$P004274	PI000028	201702	98	Alosa pse	43002	18-Apr-25	185	87.21	19.84	18-Apr-25	2.14	15.02	
30	$P004275	PI000029	201702	98	Alosa pse	43002	18-Apr-25	188	89.37	22.02	18-Apr-25	2.98	16.31	
31	$P004276	PI000030	201702	99	Alosa pse	43508	18-Apr-25	210	168.22	66.51	18-Apr-25	32.51	29.47	
32	$P004277	PI000031	201702	107	Alosa pse	45466	18-Apr-25	175	63.838	16.132	18-Apr-25			
33	$P004278	PI000032	201702	107	Alosa pse	45466	18-Apr-25	177	63.698	15.574	18-Apr-25			
34	$P004279	PI000033	201702	107	Alosa pse	45466	18-Apr-25	178	64.695	14.448	18-Apr-25			
35	$P004280	PI000034	201702	107	Alosa pse	45466	18-Apr-25	182	75.449	20.559	18-Apr-25			
36	$P004281	PI000035	201702	107	Alosa pse	45466	18-Apr-25	183	73.235	17.875	18-Apr-25			

HISTORICAL

Historical Import Template fields continue below

O	P	Q	R	S	T	U	V
MEASURED_TOTAL_ENERGY_KJ	PAN_WEIGHT_G	OMITTED	SAVED	ORGANIZATION_NAME	DATE_SENT	DATE_RECEIVED	COMMENTS
	0	No					
	0	No					
	0	No					
	0	No					
	0	No					
	0	No					
	0	No					

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