Mean Spectral Signatures of Salt Marsh and Seaweed Species from the Coast of Maine

Stefan Claesson, Hannah Webber, Matthew Duckett, and Christopher Shipley
October 2024

Contents

Coastal Ecosystem Spectral Library (CESL)

The Coastal Ecosystem Spectral Library (CESL) is an open-access warehouse used to explore and manage spectroscopy data collected from a variety of intertidal vegetation, seagrasses, marsh plants, and substrates. CESL stores not only spectra, but also biological or sediment/substrate data associated with spectra (e.g., species, wet weight, percent cover, grain size, TOC, etc.). The library may be used to upload and store spectra, perform data query, plotting, and download of spectral signatures and associated metadata.

Introduction

CESL was enhanced further by a grant from the Maine Community Foundation awarded to Schoodic Institute at Acadia National Park in 2022. Fieldwork and destructive sampling of vegetation and macroalgae in salt marshes and intertidal zones along the coast of Maine was performed by Schoodic Institute to collect representative samples of these plant and algal species. Subsequently, Nearview measured spectra for each of the samples collected by Schoodic Institute using a Spectra Vista (SVC) 1024i spectroradiometer fitted with a fiber-optic light guide and the SVC LC-RC PRO (i.e., leaf clip). This provided a full spectral range (350 – 2500 nm) mitigating atmospheric factors and noise that would otherwise be apparent using a standard foreoptic lens. Concurrently, multispectral and hyperspectral Uncrewed Aerial System (UAS) imagery was collected at each site.

The resulting data is being used to build a comprehensive spectral library for the Gulf of Maine's coastal vegetation habitats, and will be used to train machine and deep-learning models that can be used to automate coastal mapping efforts. High-resolution UAS imagery coupled with ground-truthed data from hand-held sensors will create the opportunity to assess, with high accuracy and confidence, the abundance and composition of salt marsh, eelgrass, and seaweed habitats. The resulting UAS tools, spectral libraries, and machine learning models may be built upon, re-trained, and commercialized to support monitoring and management of any variety of natural resources within and beyond the State of Maine.

Extraction of $\boldsymbol{\alpha}$ —Trimmed Means for Representative Spectral Signatures

The spectral signature for a plant sample can be thought of as a univariate function, where the spectral reflectance exhibited depends on the wavelength position along the light spectrum. CESL contains numerous samples from a variety of different plant and algae species. We wish to identify a representative spectral signature for each species represented in the spectral library. Given a collection of spectra, one can calculate a mean function by simply averaging the reflectance recorded at each discretized wavelength value in the domain. Smoothing methods may be applied if there is excessive noise in the measurements or the spectral curves are observed on different sets of points within the domain.

In univariate data sets, a mean calculation is heavily influenced by outliers. This is also true in functional data setting. When the presence of outliers is expected, it is often preferable to choose a statistically robust measure of central tendency. For univariate data, it is common to favor the median over the mean for heavily skewed data or an α-trimmed mean for symmetric data with outliers. To obtain an α-trimmed mean for univariate data containing n cases, one first orders the data and then $n\alpha$ of cases are removed from the tails of the distribution before calculating a mean of the central $n(1-\alpha)$ cases. However, when dealing with multivariate data, notions of data ordering become a little more complex. To calculate an α-trimmed mean for multi-variate data, one must first decide on a notion of depth. Depth refers to how deeply embedded a single multi-dimensional point is within a cloud of points. The more centrally located a point is, the larger its depth, and the deepest point of a single variable distribution always corresponds to the median. The calculation of a depth-based α-trimmed mean then involves removal of the $n\alpha$ points with the lowest depth values before calculating the mean. Essentially, the most extreme and outlying cases are prohibited from contributing to the mean calculation which makes the calculation robust against the inclusion of extreme outliers. Functional data analysis can be viewed as an infinite-dimension extension of multivariate data analysis and the notions of depth and α-trimmed means may be applied when the data consists of curves.

In one dimension, the depth of a given point x drawn from a probability distribution F_X can be defined by $D_1(x, F_X) = \min\{F_X(x), 1 - F_X(x)\}$. Many notions of depth exist for multivariate and functional data. Tukey depth (also known as halfspace depth) has been shown to be very effective when compared to alternative methods (Cuesta-Albertos and Nieto-Reyes 2008). The Tukey depth of point $x \in \mathbb{R}^d$ drawn from a probability distribution F_X is calculated by finding the infimum of 1-dimensional depth calculations across all possible 1-dimensional projections of x onto a marginal distribution of F_X. While effective, Tukey's depth carries a large computational cost due to the possibility for a large set of projections. Cuesta-Albertos and Nieto-Reyes (2008) showed that, in practice, Tukey Depth can be reasonably approximated by using a finite random sample of projections. The application of Tukey Depth via Random Projections to functional data can be implemented using the R package **fda.usc** via the function *depth.RP().*

To extract trimmed means for each species in the spectral library, spectral signatures were extracted for all algae and salt marsh cases through the CESL API (https://speclib.nearview.net). Salt marsh cases were further separated into two classes: leaf/stem and head/flower. Within each plant class, cases were then sorted by individual species. All signatures consist of reflectance values recorded on the same grid of irregularly spaced increments along the light spectrum ranging from 339.2 nm to 2506 nm, with 993 grid points total. The spectral data was converted to functional data using the *fdata()* function found in the **fda.usc** package. For each species, the within species depths were calculated using *depth.RP()* with the α parameter set to 0.2. The 0.2-trimmed means for each species were then extracted from the output. For any species with less than 5 cases, the standard functional mean is returned as no cases are trimmed.

This mean or master set of spectral signatures may be downloaded from CESL at https://speclib.nearview.net/news_page_001, as a zipped file in ENVI spectral library format (.sli), or as ascii text files (.txt). Mean spectral signatures of seaweed and salt marsh species are visualized and graphed in the following appendices.

References:

J.A. Cuesta-Albertos, A. Nieto-Reyes (2008). “The random Tukey depth.” Computational Statistics & Data Analysis, Volume 52, Issue 11, Pages 4979-4988, ISSN 0167-9473. https://doi.org/10.1016/j.csda.2008.04.021.

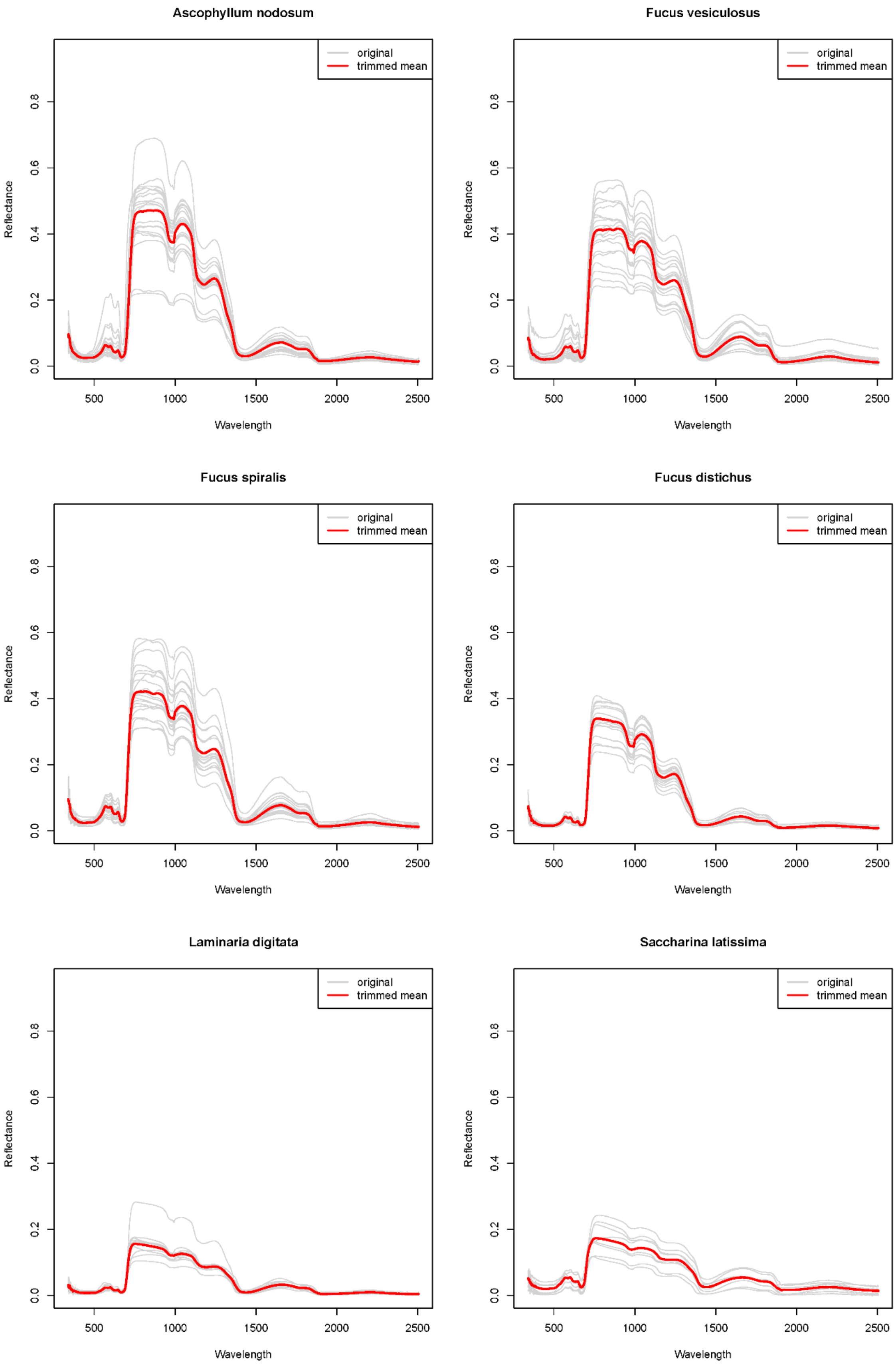
Febrero-Bande M, Oviedo de la Fuente M (2012). “Statistical Computing in Functional Data Analysis: The R Package fda.usc.” Journal of Statistical Software, 51(4), 1–28. https://www.jstatsoft.org/v51/i04/.

How to cite this paper:

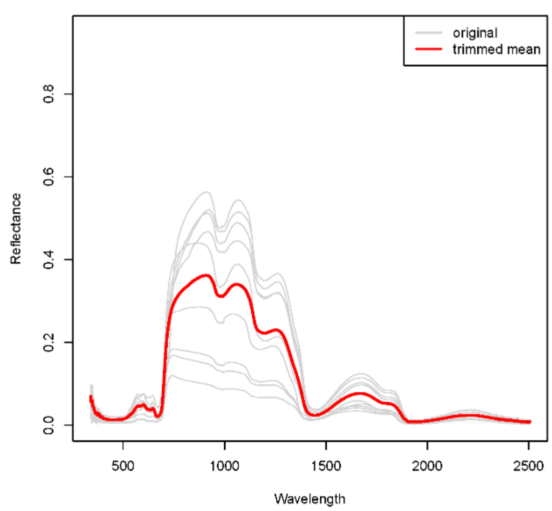
Claesson, S., Webber, H., Duckett, M., and Shipley, C. (2024). Mean Spectral Signatures of Salt Marsh and Seaweed Species from the Coast of Maine [White paper]. Nearview. https://speclib.nearview.net/static/news_001/mean-spectral-signatures.pdf.

Authors may be contacted at support@nearview.net.

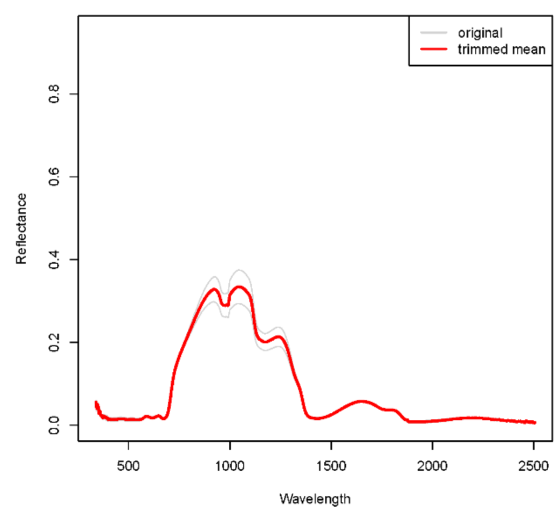
Appendix A: Mean Spectral Signatures of Seaweed


Ascophyllum nodosum
Fucus vesiculosus
Fucus spiralis
Fucus distichus
Laminaria digitata
Saccharina latissima
original
trimmed mean
Reflectance
Wavelength
0.0
0.2
0.4
0.6
0.8
500
1000
1500
2000
2500

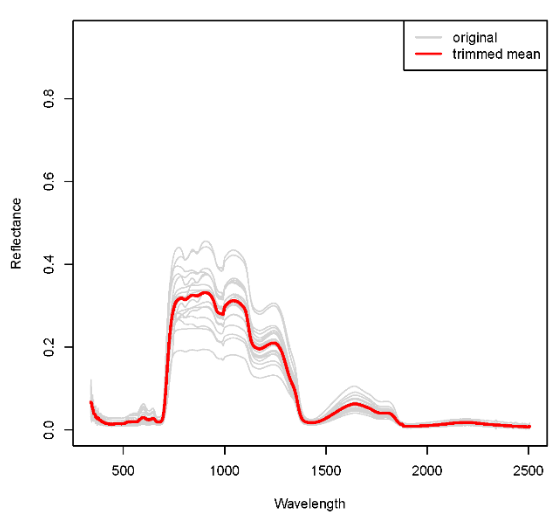
Alaria esculenta



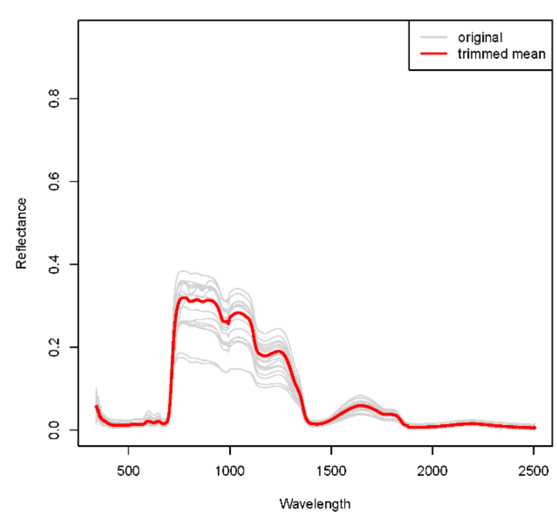
Polysiphonia spp.



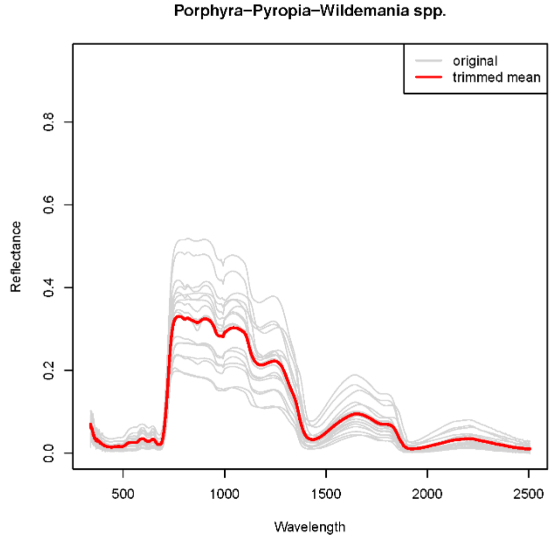
Mastocarpus stellatus



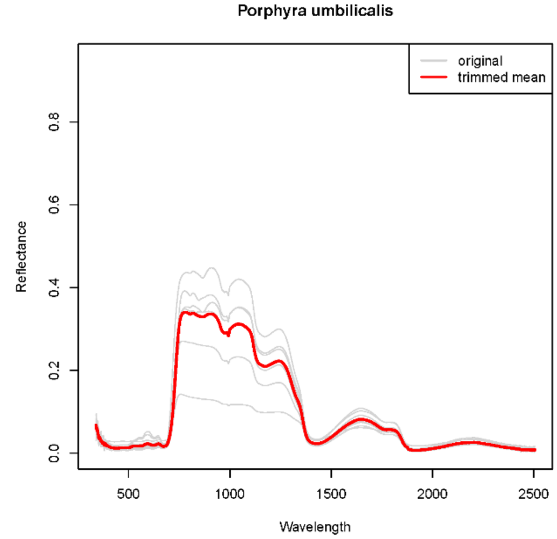
Chondrus crispus

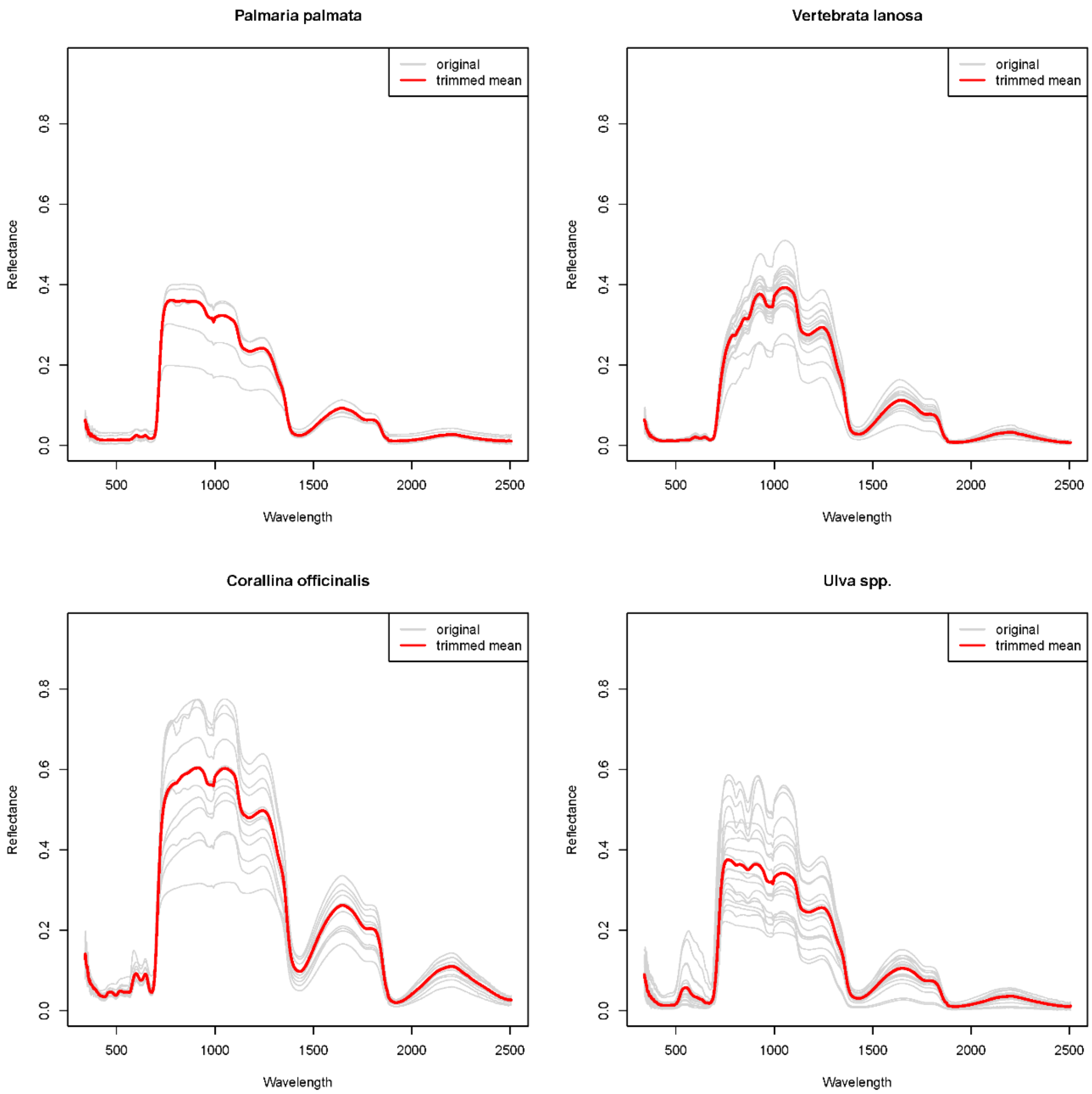


Porphyra–Pyropia–Wildemania spp.

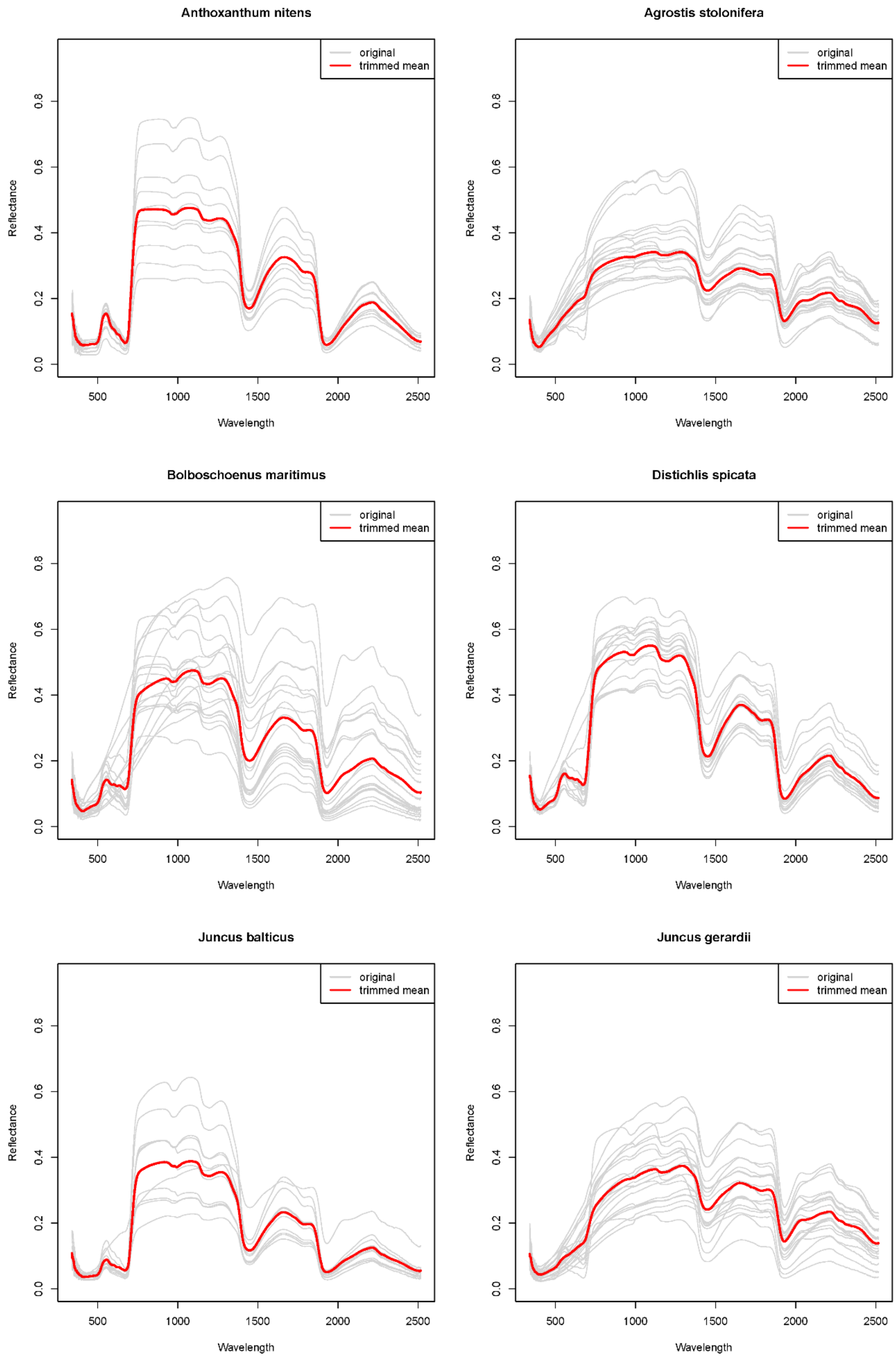


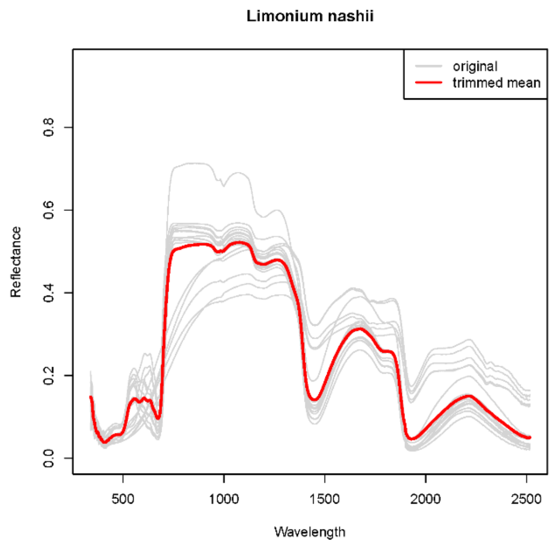
Porphyra umbilicalis

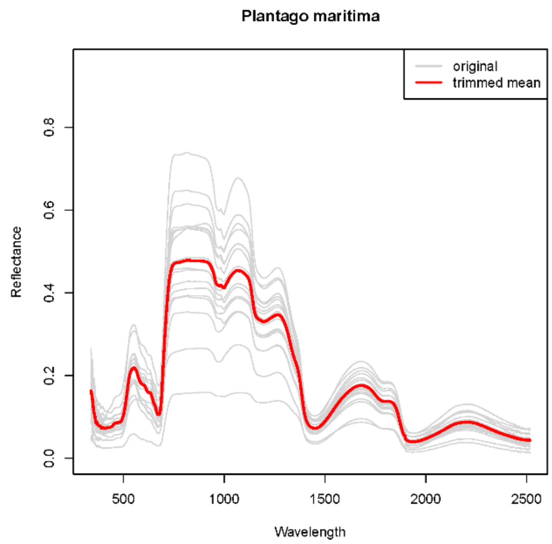


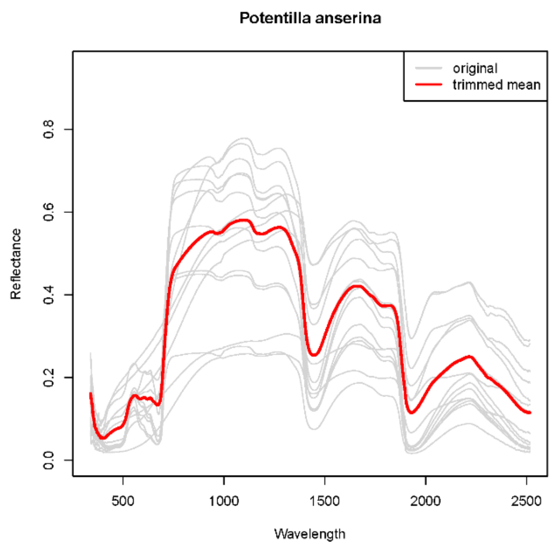

Palmaria palmata
Vertebrata lanosa
Corallina officinalis
Ulva spp.
original
trimmed mean
Reflectance
Wavelength
0.0
0.2
0.4
0.6
0.8
500
1000
1500
2000
2500

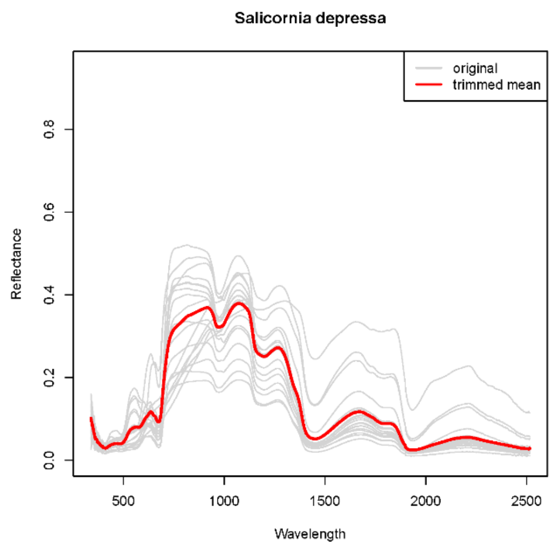
Appendix B: Mean Spectral Signatures of Salt Marsh Stem/Leaf

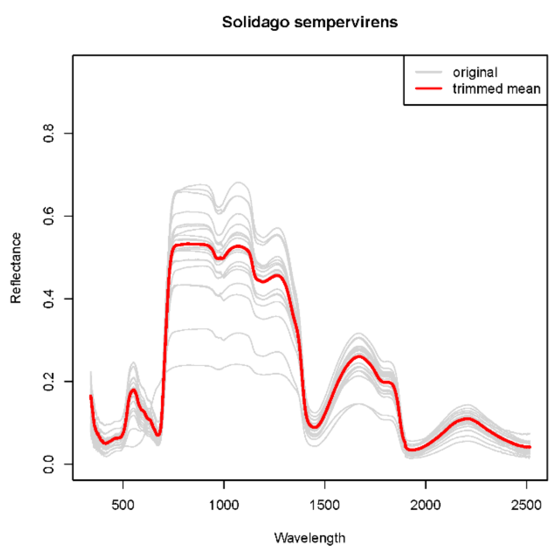

Anthoxanthum nitens
Agrostis stolonifera
Bolboschoenus maritimus
Distichlis spicata
Juncus balticus
Juncus gerardii
original
trimmed mean
Reflectance
Wavelength
0.0
0.2
0.4
0.6
0.8
500
1000
1500
2000
2500

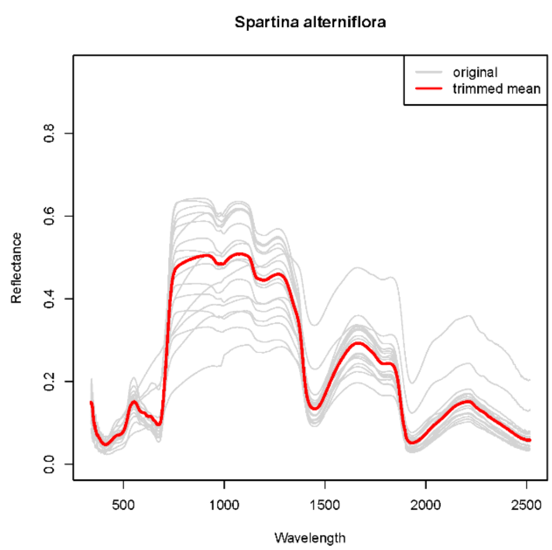

Limonium nashii
original
trimmed mean
Reflectance
0.0
0.2
0.4
0.6
0.8
500
1000
1500
2000
2500
Wavelength

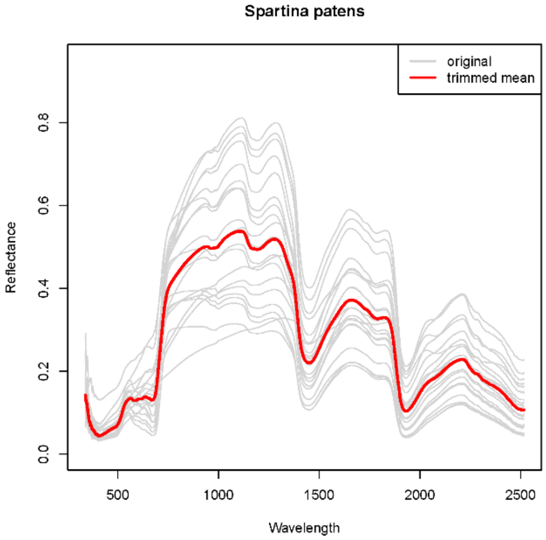

Plantago maritima
original
trimmed mean
Reflectance
0.0
0.2
0.4
0.6
0.8
500
1000
1500
2000
2500
Wavelength

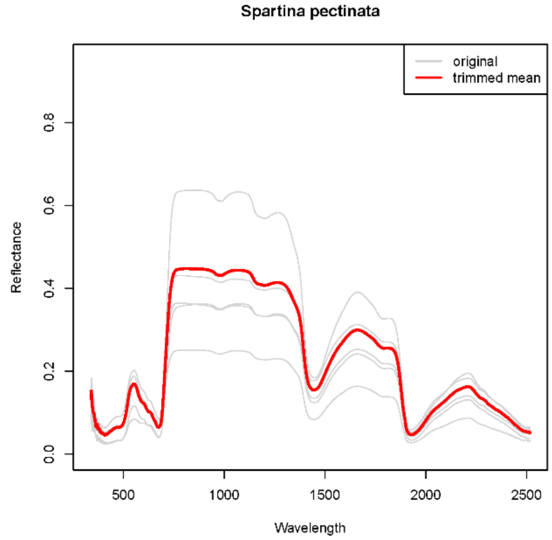

Potentilla anserina
original
trimmed mean
Reflectance
0.0
0.2
0.4
0.6
0.8
500
1000
1500
2000
2500
Wavelength

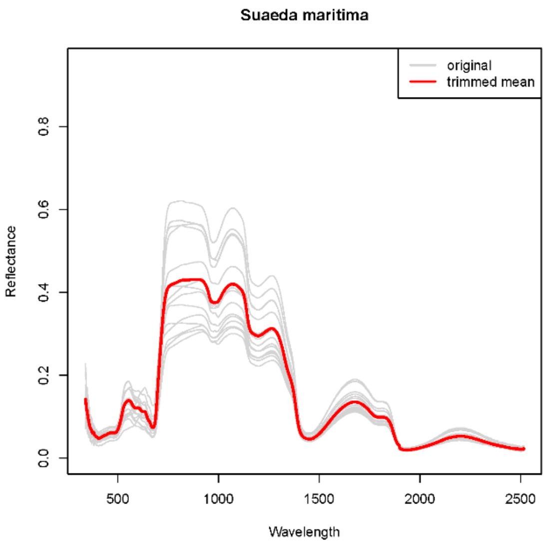

Salicornia depressa
original
trimmed mean
Reflectance
0.0
0.2
0.4
0.6
0.8
500
1000
1500
2000
2500
Wavelength

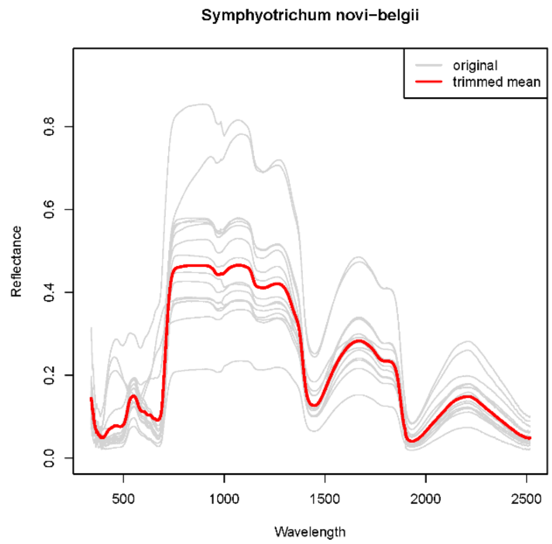

Solidago sempervirens
original
trimmed mean
Reflectance
0.0
0.2
0.4
0.6
0.8
500
1000
1500
2000
2500
Wavelength

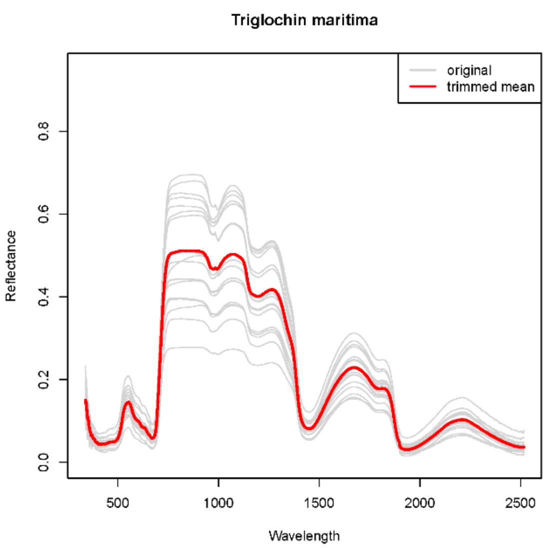

Spartina alterniflora
original
trimmed mean
Reflectance
0.0
0.2
0.4
0.6
0.8
500
1000
1500
2000
2500
Wavelength

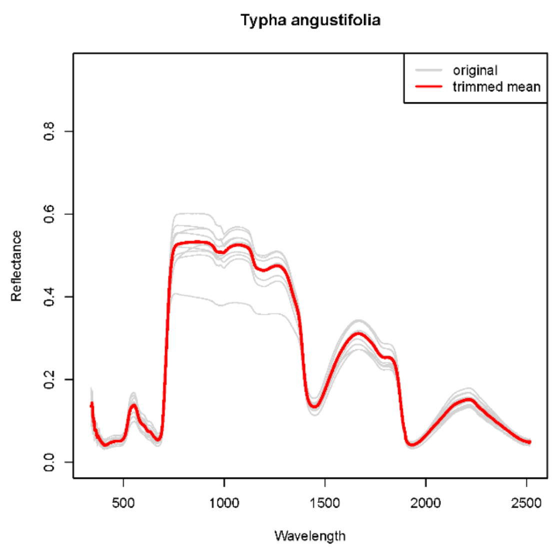

Spartina patens
original
trimmed mean
Reflectance
0.0
0.2
0.4
0.6
0.8
500
1000
1500
2000
2500
Wavelength


Spartina pectinata
original
trimmed mean
Reflectance
0.0
0.2
0.4
0.6
0.8
500
1000
1500
2000
2500
Wavelength

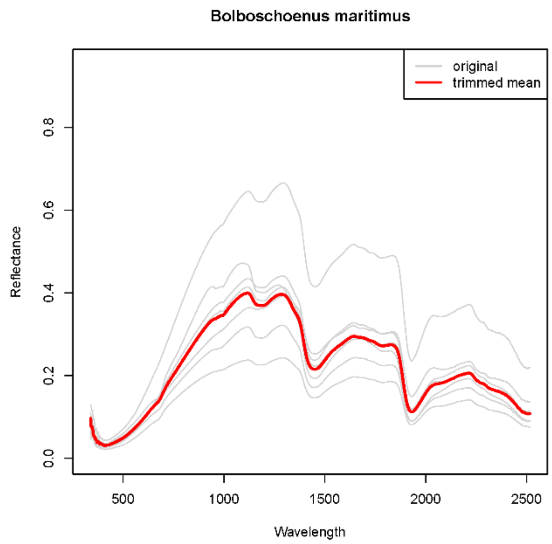

Suaeda maritima
original
trimmed mean
Reflectance
0.0
0.2
0.4
0.6
0.8
500
1000
1500
2000
2500
Wavelength

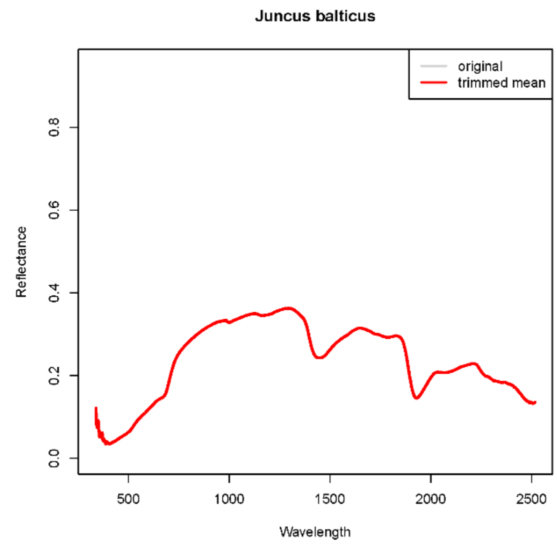

Symphyotrichum novi−belgii
original
trimmed mean
Reflectance
0.0
0.2
0.4
0.6
0.8
500
1000
1500
2000
2500
Wavelength

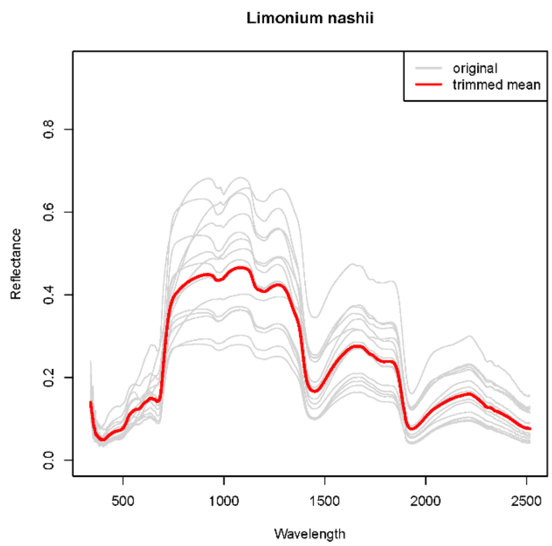

Triglochin maritima
original
trimmed mean
Reflectance
0.0
0.2
0.4
0.6
0.8
500
1000
1500
2000
2500
Wavelength

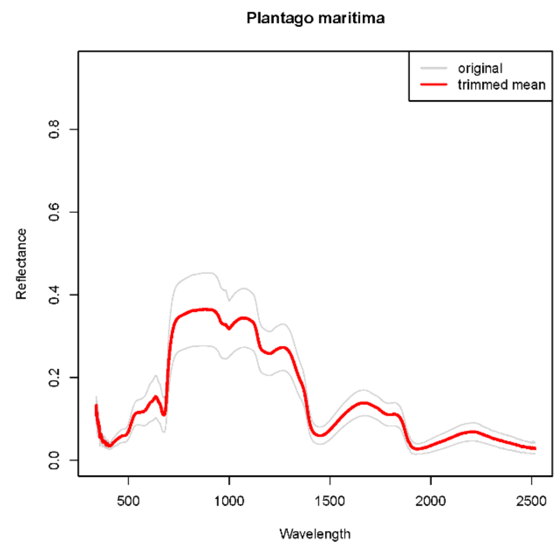

Typha angustifolia
original
trimmed mean
Reflectance
0.0
0.2
0.4
0.6
0.8
500
1000
1500
2000
2500
Wavelength

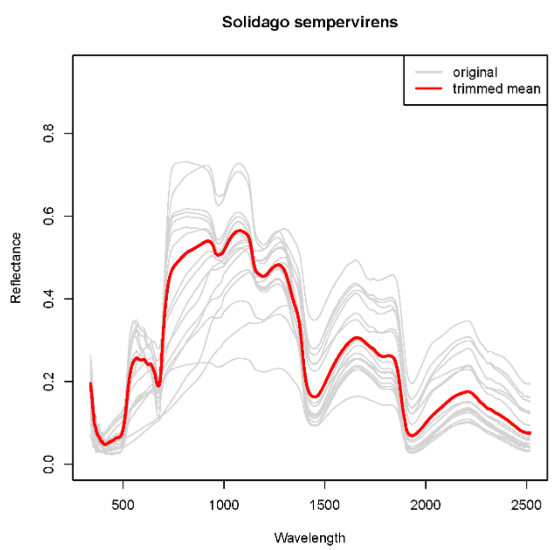
Appendix C: Mean Spectral Signatures of Salt Marsh Head/Flower

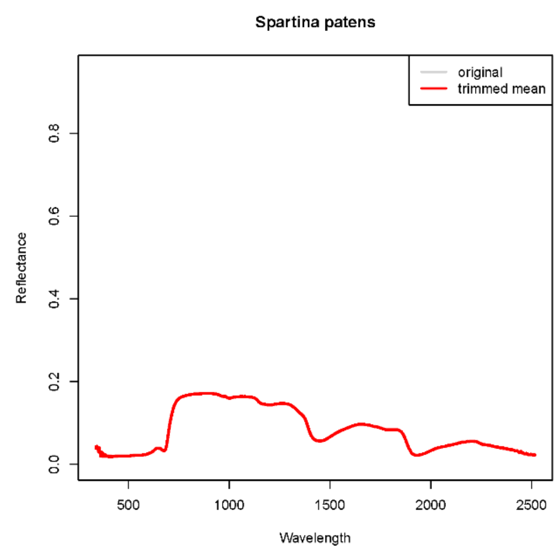

Bolboschoenus maritimus
original
trimmed mean
Reflectance
0.0
0.2
0.4
0.6
0.8
500
1000
1500
2000
2500
Wavelength

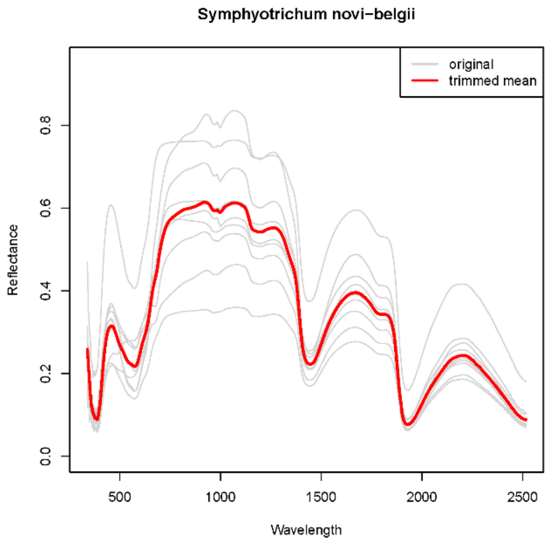

Juncus balticus
original
trimmed mean
Reflectance
0.0
0.2
0.4
0.6
0.8
500
1000
1500
2000
2500
Wavelength

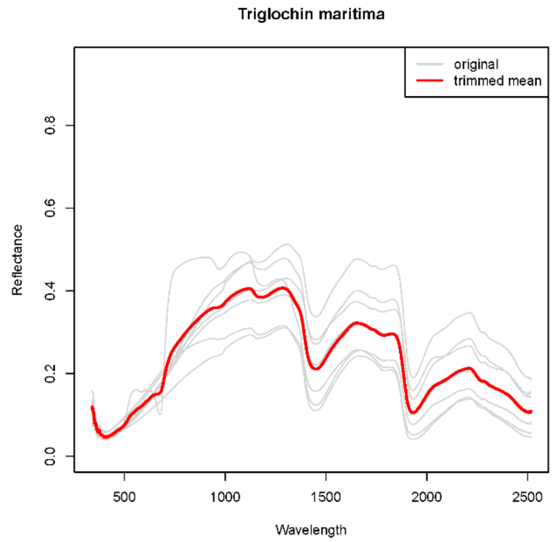

Limonium nashii
original
trimmed mean
Reflectance
0.0
0.2
0.4
0.6
0.8
500
1000
1500
2000
2500
Wavelength

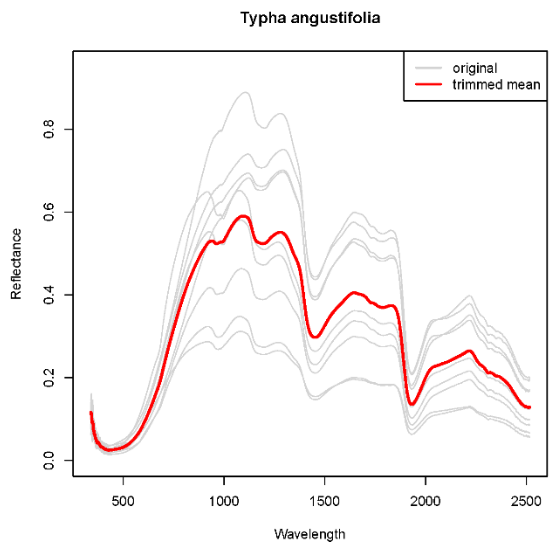

Plantago maritima
original
trimmed mean
Reflectance
0.0
0.2
0.4
0.6
0.8
500
1000
1500
2000
2500
Wavelength


Solidago sempervirens
original
trimmed mean
Reflectance
0.0
0.2
0.4
0.6
0.8
500
1000
1500
2000
2500
Wavelength


Spartina patens
original
trimmed mean
Reflectance
0.0
0.2
0.4
0.6
0.8
500
1000
1500
2000
2500
Wavelength


Symphyotrichum novi−belgii
original
trimmed mean
Reflectance
0.0
0.2
0.4
0.6
0.8
500
1000
1500
2000
2500
Wavelength


Triglochin maritima
original
trimmed mean
Reflectance
0.0
0.2
0.4
0.6
0.8
500
1000
1500
2000
2500
Wavelength


Typha angustifolia
original
trimmed mean
Reflectance
0.0
0.2
0.4
0.6
0.8
500
1000
1500
2000
2500
Wavelength