Using Remote Sensing For Pocket Estuary Mapping Within Puget Sound

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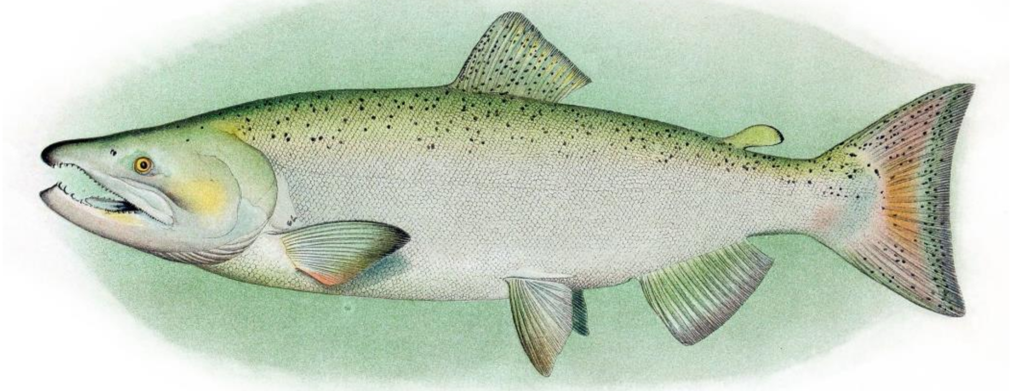
Pennsylvania State University | Advisor: Jarlath O'Neil-Dunne

Outline

- **Background**
  - Introduction
  - Problem
  - Solution
  - Pilot Project
- **Project Goals and Objectives**
- **Proposed Methodology**
  - Geographic Object-based Image Analysis
  - Habitat Classification Scheme
  - Project Workflow
- **Anticipated Results**
- **Project Timeline**

Introduction

- **Puget Sound basin**
  - Contains 16 large river systems and estuaries
  - Many small-scale pocket estuaries and independent streams
- **Pacific salmon**
  - Quintessential Puget Sound species
  - Provide major cultural, recreational, and economic value to the region
  - Chinook salmon listed as threatened under Endangered Species Act
- **Estuaries**
  - Are of great value for the endangered salmon
  - Majority lost due to degradation from agriculture and urbanization



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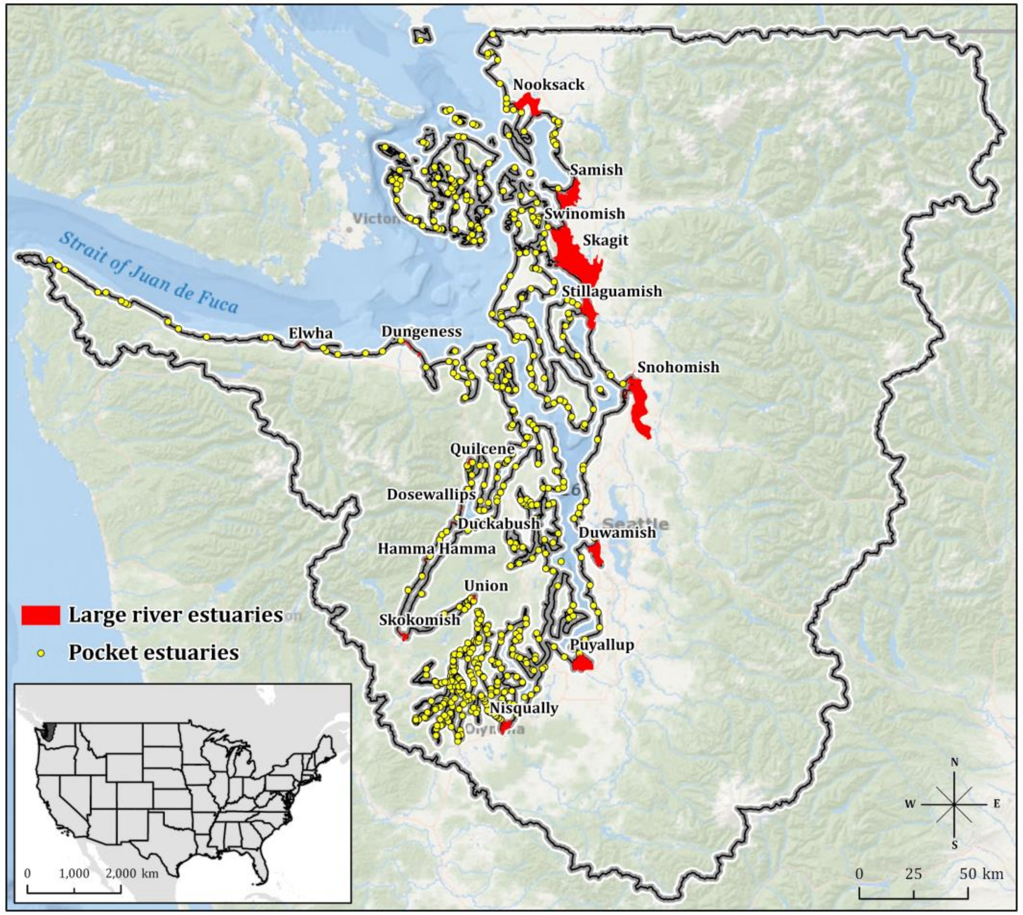
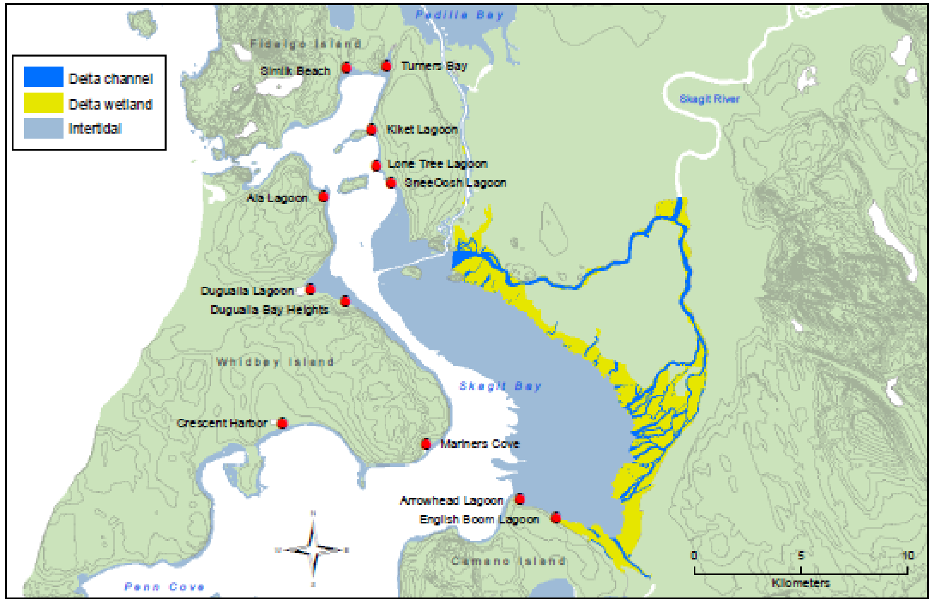
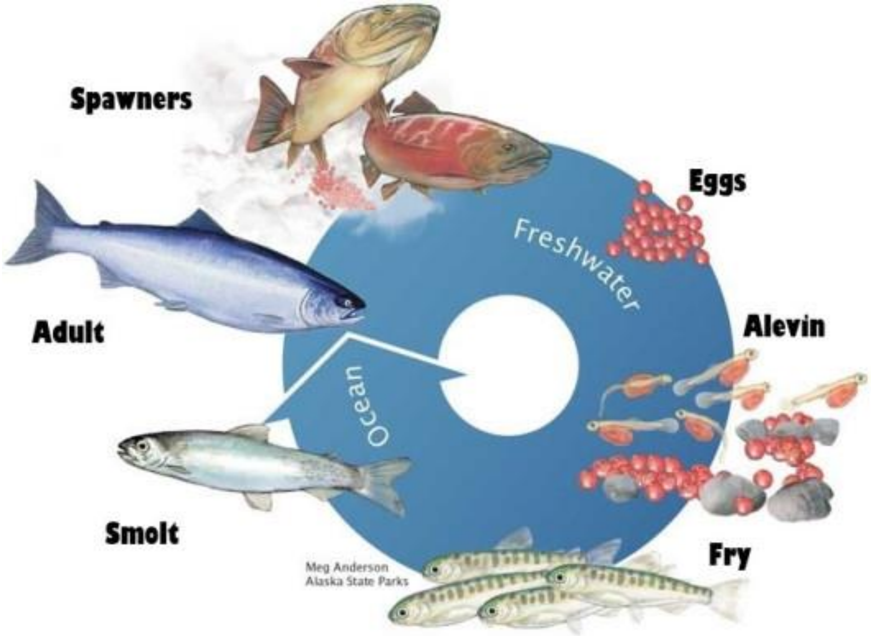


Pocket Estuaries

- **Barrier embayments**
  - Partially enclosed nearshore sub-estuaries
  - Have low energy habitat features
  - Potentially depressed salinity for part of the year
  - Form behind coastal accretion landforms or at small creek mouths
  - Typically characterized as tidal lagoons that contain fringing unvegetated flats, saltmarsh, and tidal channels
  - Non-natal rearing and refuge habitats
  - Utilized by juvenile Chinook salmon during migration from freshwater to saltwater



Beamer et al. 2005



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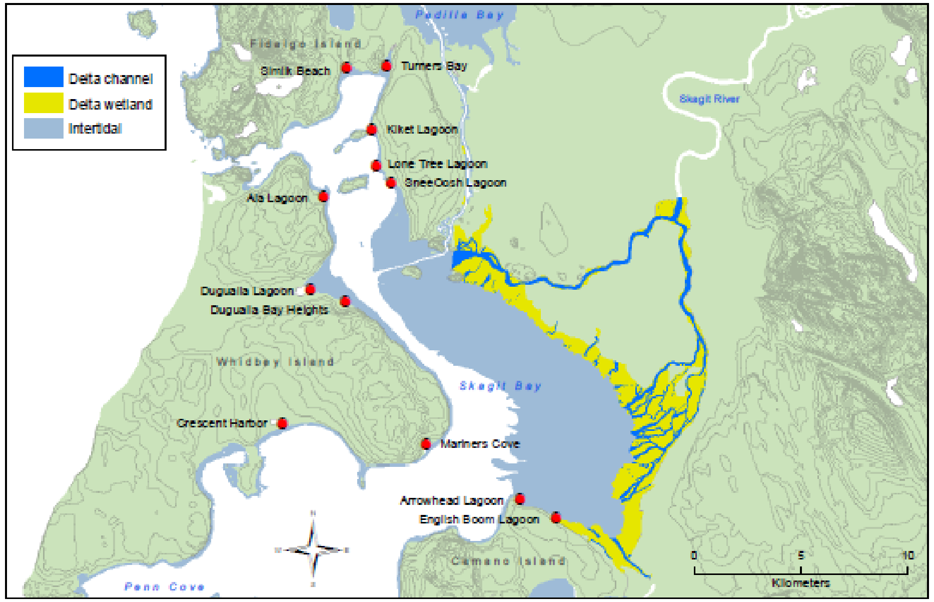
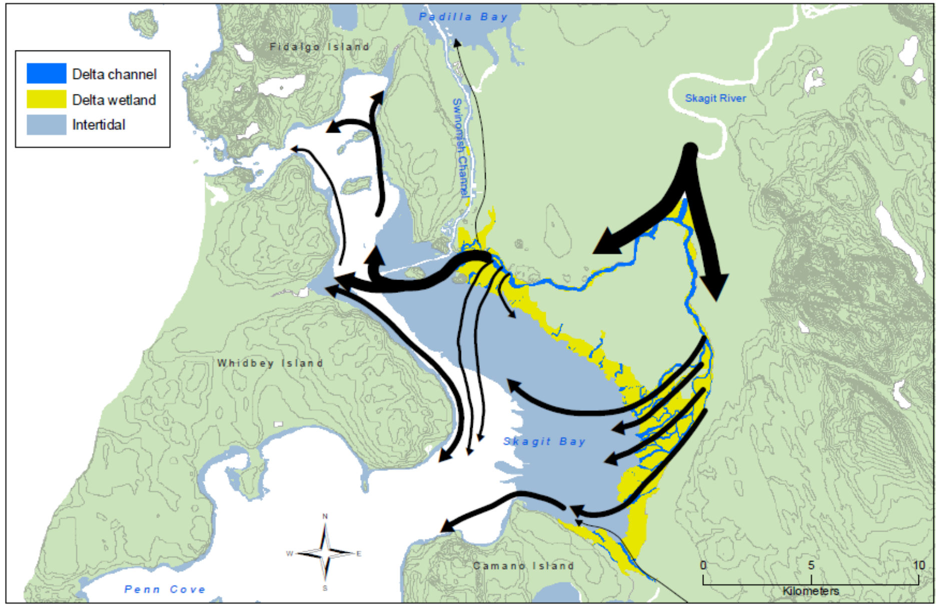
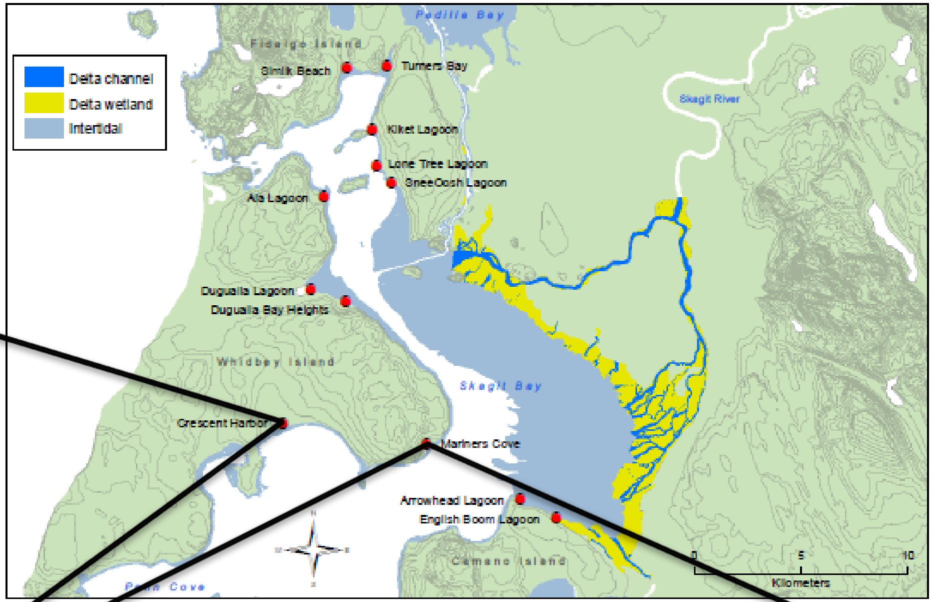




Beamer et al. 2005

Pocket Estuaries



Beamer et al. 2005

Problem

- Need for restoration and protection of pocket estuaries is well recognized by federal, state, and local entities
- Habitat monitoring is imperative in assessing change from degradation or restoration
- Habitat has not been mapped on a consistent basis at the Puget Sound scale

NOAA FISHERIES PUGET SOUND PARTNERSHIP SKAGIT RIVER SYSTEM COOPERATIVE

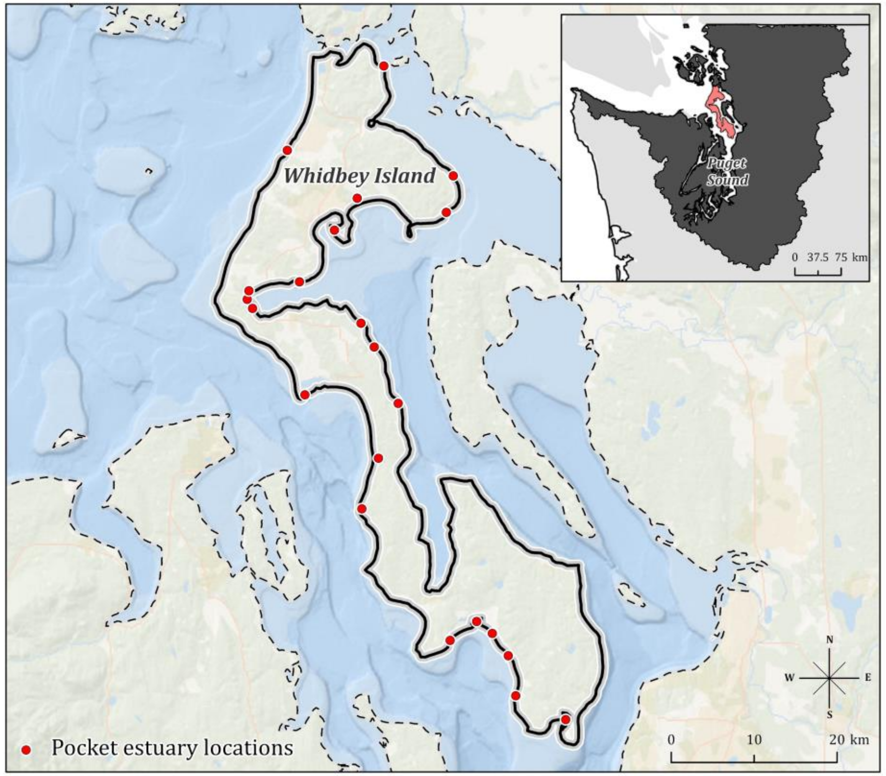
Solution

- **Remote sensing of estuarine habitats is a valuable and effective tool**
- **Resulting data products aid stakeholders in conservation and restoration**
- **Manual imagery interpretation**
  - Monitoring pocket estuary habitat at the sub-basin scale (SRSC)
  - Monitoring large river estuary habitat at the regional scale (NOAA)
  - Can be time-consuming, cost-inefficient, and inconsistent
- **Automated remote sensing approach is better suited and could be more cost-efficient for consistent assessment of estuarine habitat**

Pilot Project

- Substantial efforts of SRSC in assessment of pocket estuary habitat provide excellent benchmark in comparison of an automated method to manual approach
- Pilot project to test viability of new method
- Focusing on Whidbey Island
- If successful could expand to Puget Sound

SKAGIT RIVER SYSTEM
COOPERATIVE

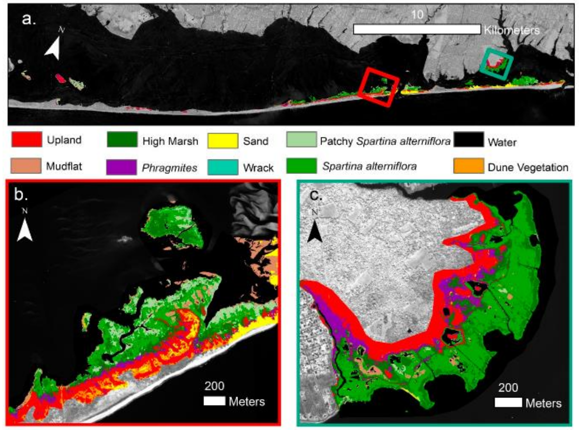


Project Goals and Objectives

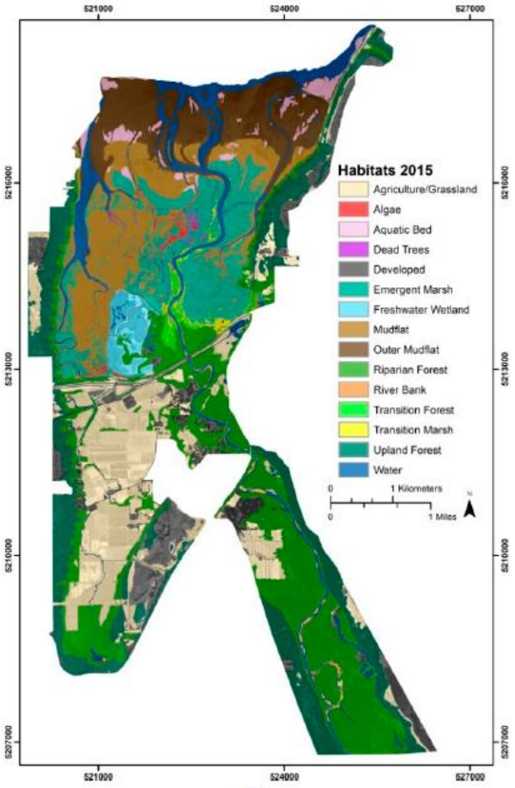
- **Project Goals**
  - Improve consistency and efficiency of pocket estuary habitat mapping within Puget Sound by developing a comprehensive geographic object-based analysis methodology.
  - Build on and contribute to the body of research on the application of remote sensing techniques in wetland habitat management.
- **Project Objectives**
  - Evaluate the availability and suitability of remotely sensed and ancillary data.
  - Develop protocols and prepare the acquired datasets for analysis.
  - Perform geographic object-based image analysis using a hierarchical rule-based system for classification of pocket estuary habitat features.
  - Evaluate the resulting accuracy of classified pocket estuary habitat features.

Geographic Object-based Image Analysis

- **Traditional pixel-oriented approach**
  - Classification applied to pixels
  - Does not include contextual information regarding neighboring pixels
  - Suffers from “salt and pepper” effect caused by high heterogeneity between neighboring pixels
- **Object-based approach**
  - Classification applied to objects that are formed by grouping pixels based on spectral homogeneity
  - Has ability to utilize a fusion of various data sets, such as elevation
  - Can significantly increase the classification accuracy of wetland habitat features



Campbell and Wang, 2019

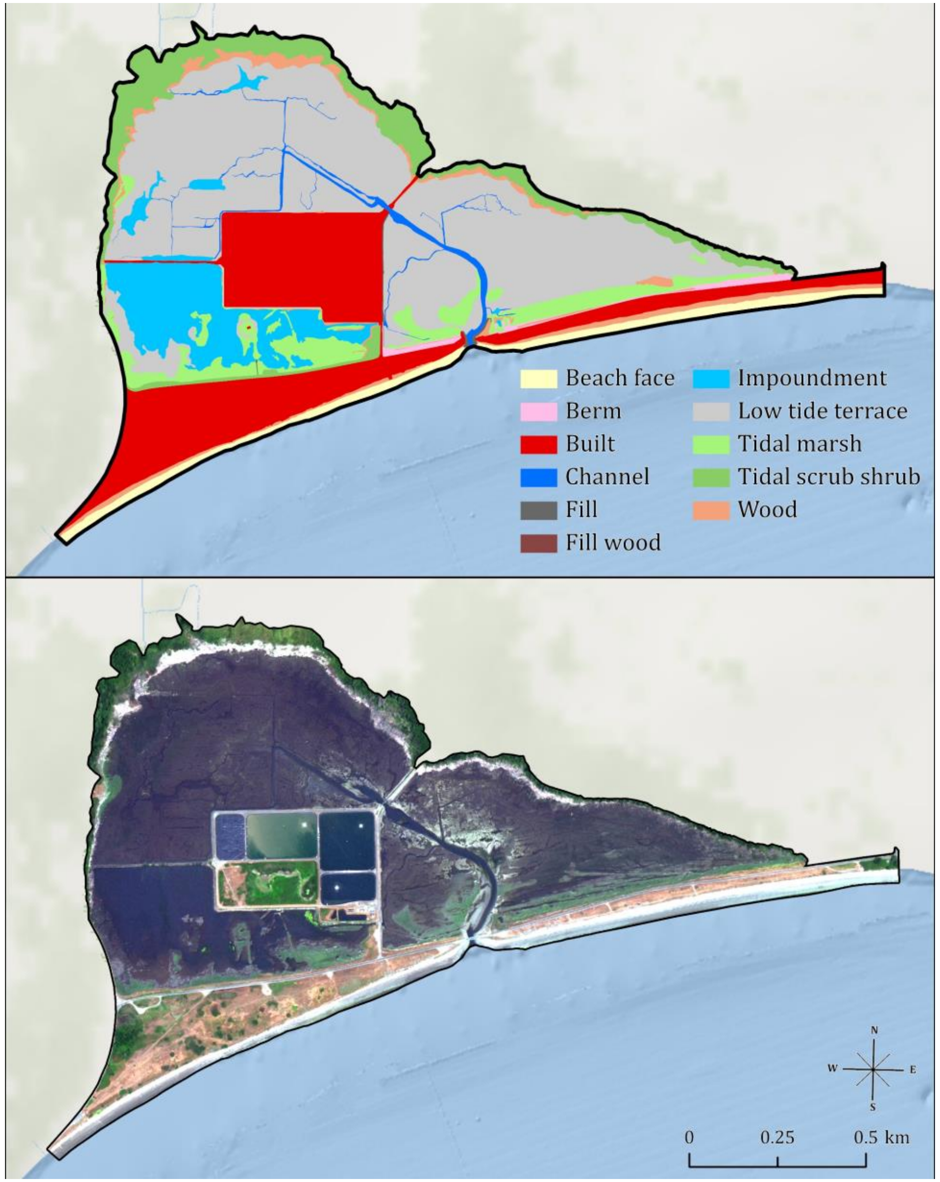


(b)

Ballanti et al. 2017

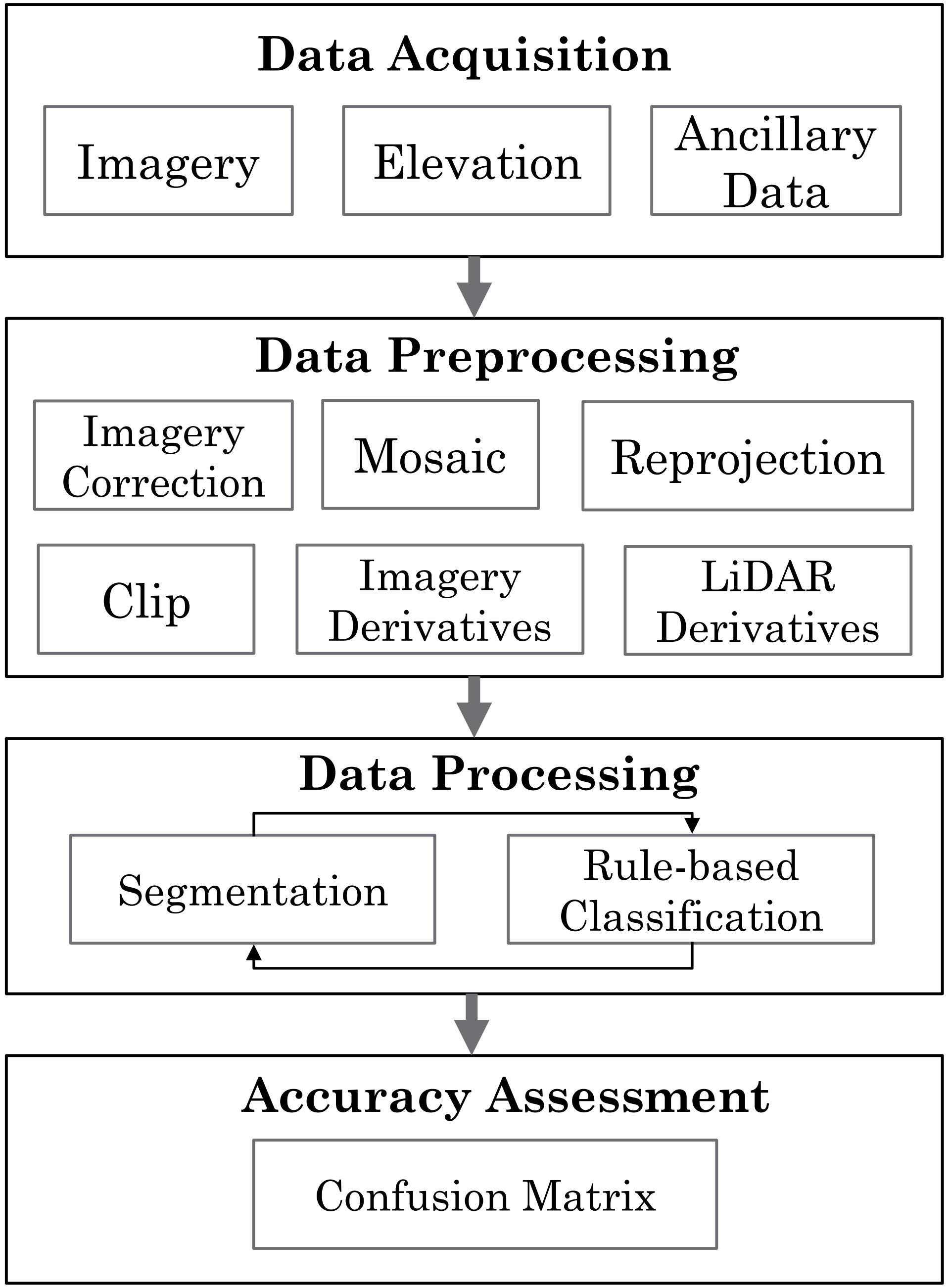
Habitat Classification Scheme

- Recovery and Implementation Technical Team Common Framework classification scheme
- Developed to provide a formal monitoring framework for assessing Puget Sound Chinook recovery
    - Berm
    - Built
    - Beach face
    - Channel
    - Fill
    - Fill wood
    - Impoundment
    - Low tide terrace
    - Rocky beach
    - Tidal marsh
    - Tidal scrub shrub
    - Tidal forest
    - Wood



Project Workflow

- **Four phases**
  - Data Acquisition
  - Data Preprocessing
  - Data Processing
  - Accuracy Assessment
- **Software**
  - ArcGIS Pro
  - ENVI
  - eCognition



Data Acquisition

- **Imagery**
  - National Agriculture Imagery Program – United States Department of Agriculture
  - WorldView-2 – DigitalGlobe through NextView License Agreement
- **Elevation Data**
  - Island County LiDAR Point Cloud – Washington State Department of Natural Resources
  - National Elevation Dataset Digital Elevation Model – United States Geologic Survey
- **Ancillary Data**
  - Whidbey Basin Pocket Estuary Classification Layer – Skagit River System Cooperative
  - Road Layer – Island County

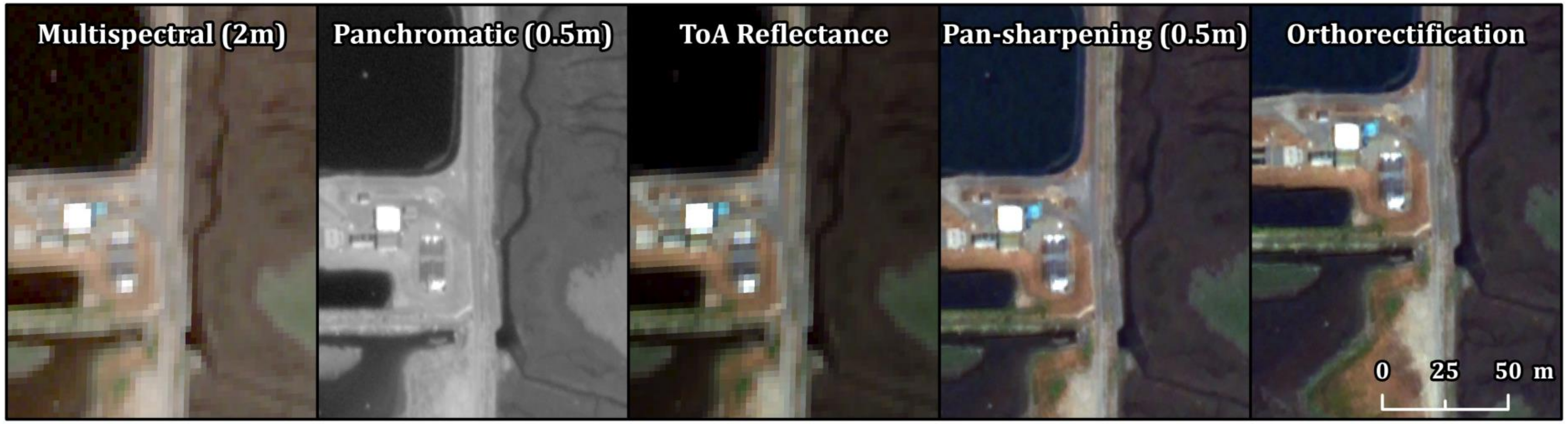
Imagery

- **Tidal stage at or near Mean Low Water is imperative**
- **NAIP aerial**
  - 2019
  - 60 cm
  - 4-bands
  - Requires minimal preprocessing
  - Acquired at high tidal stage for some locations
- **WorldView-2 satellite**
  - 2016-2018
  - 50 cm
  - 8-bands
  - Requires substantial preprocessing
  - Acquired at lower tidal stage

Date	Spectral Resolution (nm)	Type	Spatial Resolution (m)	Tidal Stage (MLW)
3 March 2016	CB (400–450), B (450–510), G (510–580), Y (585–625), R (630–690), RE (705–745), NIR1 (770–895), NIR2 (860–1040)	WorldView-2	0.5	**0.48 m**
25 May 2017	CB (400–450), B (450–510), G (510–580), Y (585–625), R (630–690), RE (705–745), NIR1 (770–895), NIR2 (860–1040)	WorldView-2	0.5	**-1.09 m**
26 August 2017	CB (400–450), B (450–510), G (510–580), Y (585–625), R (630–690), RE (705–745), NIR1 (770–895), NIR2 (860–1040)	WorldView-2	0.5	**0.17 m**
16 July 2018	CB (400–450), B (450–510), G (510–580), Y (585–625), R (630–690), RE (705–745), NIR1 (770–895), NIR2 (860–1040)	WorldView-2	0.5	**-1.17 m**
22 July 2018	CB (400–450), B (450–510), G (510–580), Y (585–625), R (630–690), RE (705–745), NIR1 (770–895), NIR2 (860–1040)	WorldView-2	0.5	**0.58 m**
6 August 2019	R (619–651), G (525–585), B (435–495), NIR (808–882)	Leica SH-100 (NAIP)	0.6	**1.11 m**
10 October 2019	R (619–651), G (525–585), B (435–495), NIR (808–882)	Leica SH-100 (NAIP)	0.6	**0.68 m**
11 October 2019	R (619–651), G (525–585), B (435–495), NIR (808–882)	Leica SH-100 (NAIP)	0.6	**0.28 m**

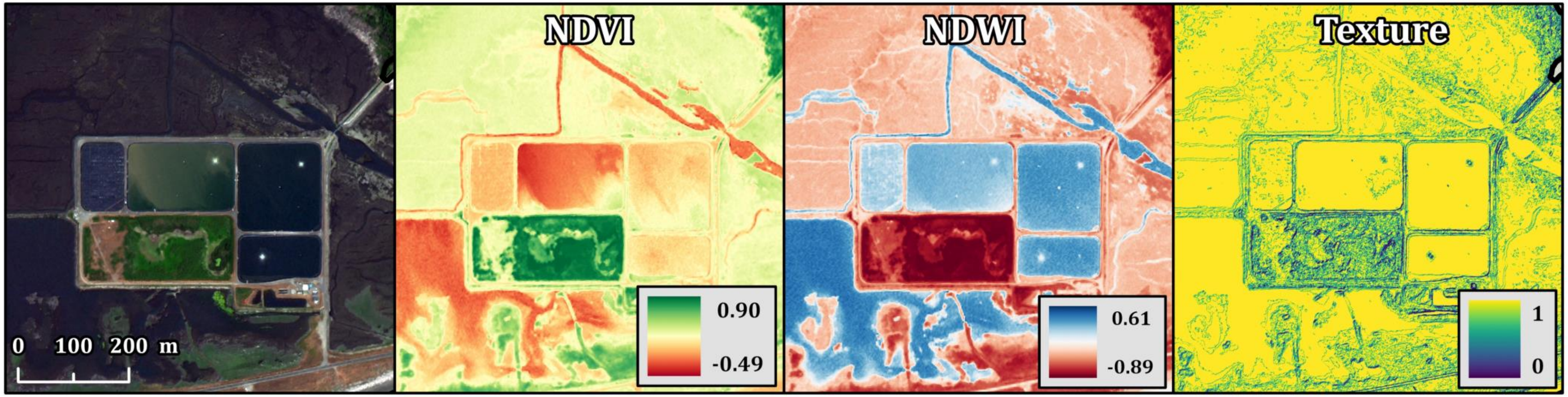
WorldView-2 Imagery Correction

- **Preprocessing is an important step in satellite data analysis**
- **Radiometric Calibration**
  - Normalizes images across dates by converting Digital Numbers to Top-of-Atmosphere Reflectance
- **Pan-sharpening**
  - Sharpens multispectral bands (2 m) to panchromatic band (0.5 m) resolution
- **Orthorectification using reference image and topography**
  - Removes topographic distortions due to systematic geometry errors



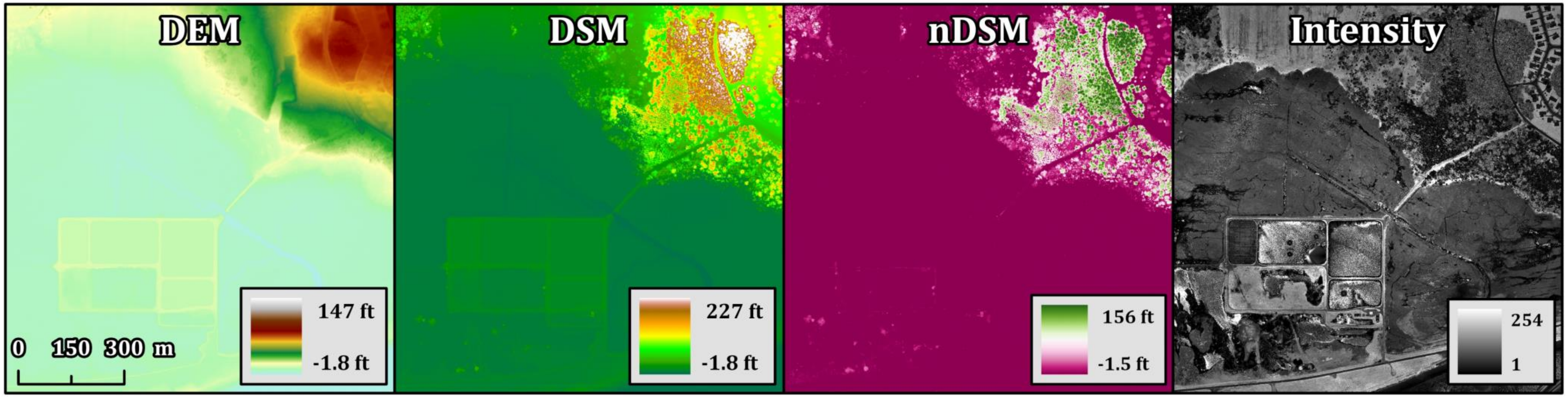
Imagery Derivatives

- **Derivatives based on image bands and their mathematical combinations and ratios**
  - Normalized Difference Vegetation Index
  - Normalized Difference Water Index
  - Visual brightness
  - Texture



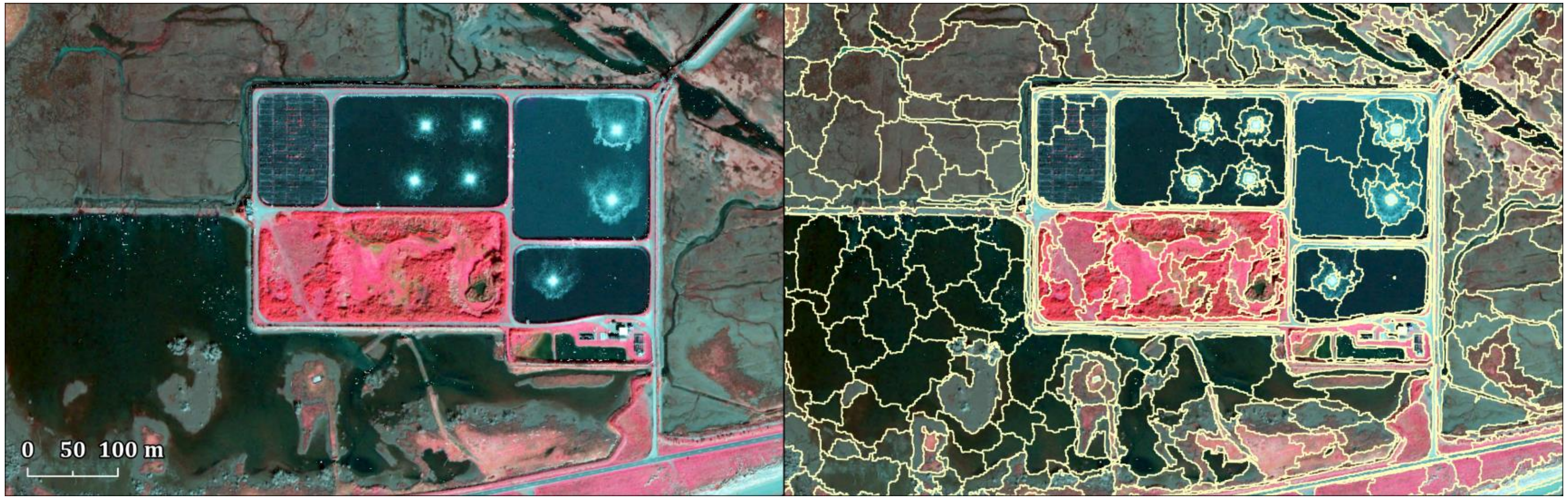
LiDAR Derivatives

- **Derivatives based on LiDAR returns**
  - Digital Elevation Model
  - Digital Surface Model
  - Normalized Digital Surface Model
  - Return Intensity



Segmentation and Classification

- **Iterative rule-based approach**
  - Alternating between image segmentation and threshold based classification applied to imagery, LiDAR derivatives, and ancillary data
- **Employing multi-resolution segmentation algorithm**
  - Grouping pixels into objects based on weighted spectral, brightness and textural elements



Accuracy Assessment

- **Classification results will be compared to the SRSC data set**
  - Number of assessment points will be determined based on Congalton and Green (2009)
  - Confusion matrix will be developed
    - Class accuracies and overall accuracy
    - Kappa coefficient calculated – a measure of how the classification results compare to values assigned by chance

	Berm	Built	Beach face	Channel	Fill	Fill wood	Impoundment	Low tide terrace	Rocky beach	Tidal marsh	Tidal scrub shrub	Tidal forest	Wood	Total	User Accuracy	Kappa
Berm																
Built																
Beach face																
Channel																
Fill																
Fill wood																
Impoundment																
Low tide terrace																
Rocky beach																
Tidal marsh																
Tidal scrub shrub																
Tidal forest																
Wood																
Total																
Producer Accuracy																
Kappa																

Anticipated Results

- **Project deliverables**
  - Data preprocessing protocols
  - eCognition rule-set of hierarchical classification of pocket estuary habitat
    - NAIP Aerial Imagery
    - WorldView-2 Satellite Imagery
  - Generated shapefiles of pocket estuary habitat classification
  - Article in a peer-reviewed journal that publishes about applications of remote sensing technology, such as Remote Sensing (ISSN 2072-4292)

Project Timeline

Task	Required Time	Timeframe
Project Proposal	3 Months	March 2020 - May 2020
Data Acquisition	0.5 Month	April 2020
Data Preprocessing	1 Month	May 2020
Data Processing	2 Months	June 2020 - August 2020
Accuracy Assessment	0.5 Month	August 2020
Manuscript Development	3 Months	September 2020 - December 2020
Journal Submission	1 Month	January 2020

Questions?

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