2006 Canopy-forming Kelp Inventory in the Western San Juan Archipelago: Data Collection and Processing Report
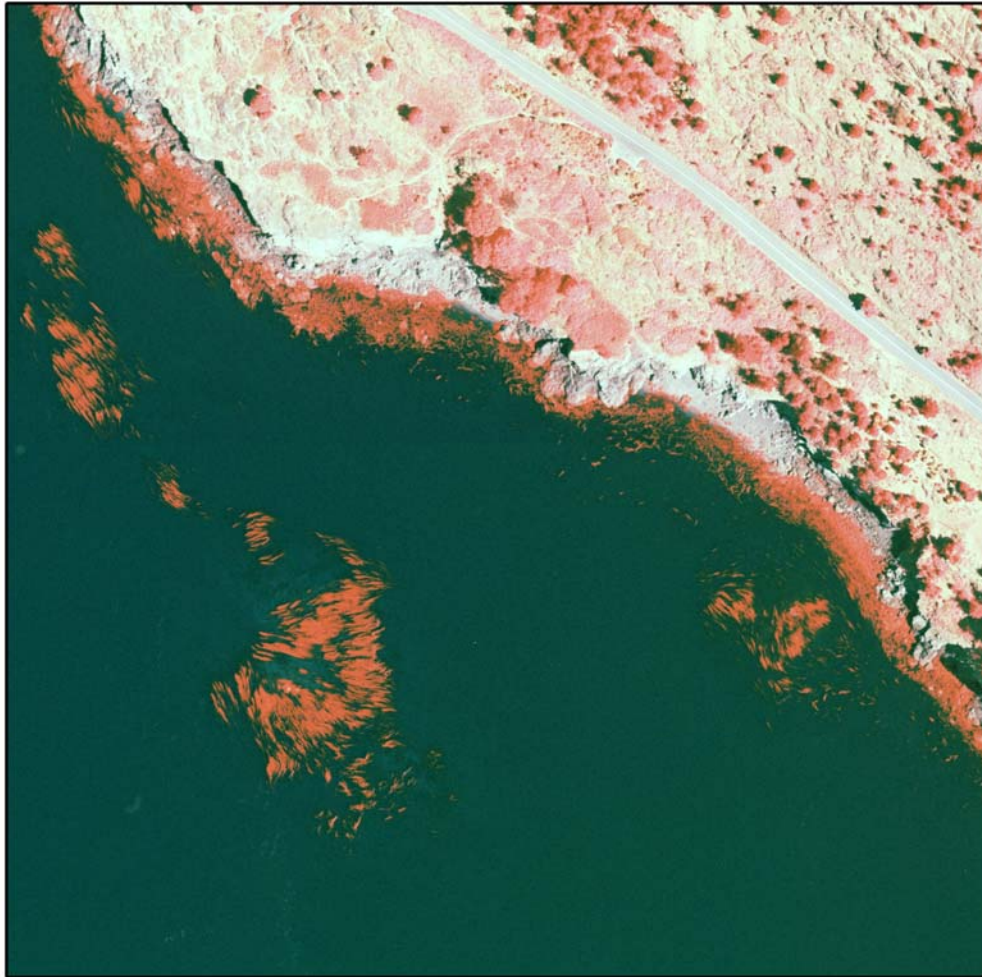

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1. Introduction

The Nearshore Habitat Program (NHP) of Washington Department of Natural Resources (WDNR) inventories and monitors vegetation and other resources in Washington State. The NHP and the FRIENDS of the San Juans (FOSJ) agreed to work cooperatively to produce digital maps of canopy-forming kelp in the western portion of the San Juan Archipelago (Cooperative Agreement 06-274). The project includes several objectives:

- Utilize kelp mapping protocols used by NHP for mapping the eastern San Juan Archipelago in 2004.
- Produce kelp maps for all saltwater shorelines of San Juan County that were not mapped in 2004.
- Deliver two products for local management in the San Juans: orthophotographs and a classified digital data on the location of canopy-forming kelp beds.

This report describes the methods used to meet these project objectives and the final products delivered to FOSJ.

2. Methods

The inventory was completed using methods employed by the Nearshore Habitat Program in 2004 for canopy-forming kelp inventory. The inventory was based on color-infrared 1:12,000 aerial photography, collected at low tide. Negative film was scanned, aerially triangulated and orthorectified. Canopy-forming kelp was classified by masking areas with kelp and then completing a supervised classification in ERDAS Imagine. The raster classification was then converted to vector shape files. Detailed methods associated with each step of the project are described below.

Following discussions with FOSJ about their ideal data products, WDNR completed several additional tasks:
- Created a mosaic of orthophoto sheets of the 2006 study area (in addition to individual orthophotos).
- Re-processed 2004 photography and created a mosaic of orthophoto sheets that is integrated with the 2006 mosaic.
- Re-processed 2004 kelp classification and created a seamless classification that is integrated with the orthophoto sheets and the 2006 classification.

Aerial Photography Collection
The Washington Department of Transportation collected aerial photography on July 24, 2006 during a window of low tide (below MLLW), no clouds and calm seas. Large format (9" x 9") negative color-infrared (CIR) film was collected in stereo coverage.

Flightlines were designed to integrate with aerial photography collected in 2004 in the eastern San Juan Archipelago (Figure 1) as part of WDNR's Puget Sound Assessment and Monitoring Program (PSAMP). A total of 521 images were collected, of which 138 were not required for complete coverage of nearshore areas, leaving a total of 383

delivered to FOSJ. The center coordinates of each photo were recorded with airborne differential GPS.

Figure 1. Map of 2004 and 2006 Kelp Inventory Flightlines

Negative Scanning
The 9" x 9" negative color-infrared film (CIR) was scanned at a resolution of 12.5 microns using a Leica DSW700 scanner. This produced a digital image with 0.5 foot resolution (pixel size). After scanning, images were color-balanced using Leica Image Equalizer v1.1 software and then dodged using Leica Dodger. The intended use of image Dodger software was to minimize light fall off common to most aerial negative images, to create a radiometrically balanced image that captures as much detail of the original negative film as possible and to create and image that visually looked as close as possible to images that were collected in the 2004 CIR project. A total of 521 images were collected and scanned.

Aerial Triangulation
Digital aerial triangulation was performed using BAE System's SOCET SET v5.3.0
software combined with Leica ORIMA v9.0a software. Images were controlled
horizontally using 1) airborne GPS data for each image; 2) existing photo-identified
resource grade ground positions; and 3) photo-identified positions photo from 1:32,000
imagery produced by the Washington State Orthophotography Partners. Images were
primarily controlled vertically using tidal heights at selected tidal stations. The
projection used was WA State Plane North zone, horizontal datum NAD83/91 (HARN),
vertical datum NAVD88, U.S. Survey Feet units. Absolute positional accuracy of the
aerial triangulation is estimated to be $\pm$5 feet. Positional accuracy was primarily
determined by the accuracy of the photo-identified, resource-grade ground positions. Of
the 521 images scanned, 138 images were not included in the aerial triangulation because
they contained no land (51) and all canopy-forming kelp was adequately captured in
adjacent images (87).

Orthophotograph Creation
Single orthophotographs were produced from the aerially triangulated images using
SOCET SET v5.3.0. The pixel size and projection were not changed during
orthophotograph production. Final digital images are in TIF Format with accompanying
world files. The orthophotographs have an absolute positional accuracy of approximately
$\pm$8 feet. Positional inaccuracies can be primarily attributed to two factors: inaccuracies
inherited from the aerial triangulation and from the Digital Elevation Model used to
generate the orthophotos. A total of 383 images were required for complete coverage of
all nearshore areas.

Orthophotograph Mosaic Sheet Creation
A mosaic of orthophotograph sheets was produced from the aerially triangulated images
using SOCET SET v5.3.0. The size of individual sheets was developed based on two
goals: 1) to minimize the number of sheets; and 2) to maintain manageable file sizes.
Final digital images are in ERDAS Imagine IMG format. Image pixel size and projection
were not changed during mosaic sheet production.

Image Classification
For the purpose of this study, canopy-forming kelp was defined to include bull kelp,
Nereocystis luetkeana. Areas with canopy-forming kelp were manually identified and
delineated using photo interpretation and a variety of data sources, including:
- Field data describing canopy-forming kelp presence, collected using GPS and
  photo-annotation during 5 days of boat-based field work between August 8 and
  August 21, 2006. All data was collected during periods of tides below +1 foot
  (MLLW).
- Canopy-forming kelp inventory in The Washington State ShoreZone Inventory.
  (Nearshore Habitat Program 2001).
- Multiple historical kelp inventories, compiled in Thom and Hallum (1990).

Because vegetation species could not be differentiated using spectral values, canopy-forming kelp was differentiated from other vegetation types during the masking process using photo-interpretation cues, including shape, texture, and habitat context.

We classified canopy-forming kelp on the orthophoto mosaic sheets. Within the masked portion of each sheet, we completed a supervised image classification using ERDAS Imagine v8.7 to identify canopy-forming kelp at the pixel-scale. Training sites throughout the study area were used to identify spectral signatures of canopy-forming kelp within the red (representing infrared) and blue spectral bands. In each band, brightness ranged from 0-255. Combinations of brightness in the red (representing infrared) and blue bands were identified that were predominantly associated with canopy-forming kelp (Figure 2). A single set of spectral signature criteria was applied to the entire study area.
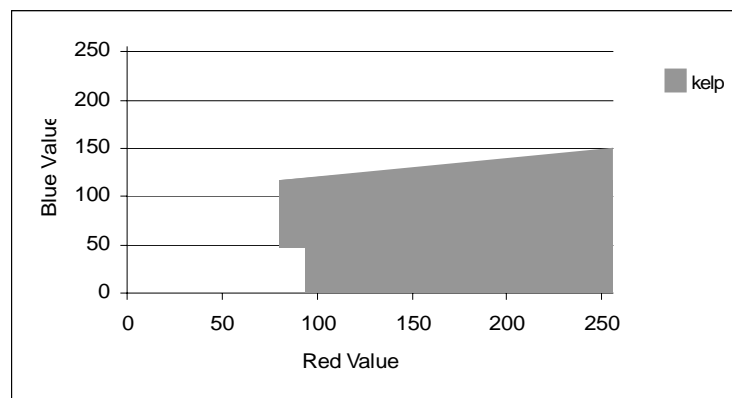
Figure 2. Supervised Canopy-forming kelp Classification, Shown in Feature Space

Our criteria for defining the spectral signature was to capture the greatest amount of kelp canopy while minimizing false-positive identifications. Features that posed the greatest degree of classification confusion included:

- The feature most often confused with kelp was glare on the water surface, especially in areas with surface roughness or waves. Glare was most extreme in the northeast portion of the study area, which was flown later in the day.
- Submerged portions of canopy-forming kelp plants are often visible as dark, linear forms. These features are not included in the canopy-forming kelp classification because it is easy to confuse these features with other submerged vegetation and rocks.
- Logs and other debris often collect in kelp canopies. The classification was fine-tuned to minimize inclusion of these features.

One classified kelp raster was created for each color infrared raster image sheet processed. Each raster sheet was then converted to a polygon shape file using ESRI's ARC/GIS v 9.1 and then mosaiced into a single shapefile. The shapefile was then reviewed and edited to maximize consistency in photo-interpretation procedures and to minimize erroneous classifications associated with factors such as glare.

Additional Data Sets Requested by FOSJ
In addition to the above data sets, FOSJ requested that WDNR identify areas where canopy-forming kelp may have escaped detection due to environmental conditions. The purpose of this task was to identify areas where FOSJ might conduct additional field work and then incorporate the results into a generalized digital shape file of canopy-forming kelp for managers. WDNR delineated areas in an ARC/GIS shape file (field_work_priorities.shp). Three common environmental conditions may have led to mis-representation: 1) shading by adjacent cliffs, 2) glare, and 3) species confusion. WDNR prioritized areas based on the likelihood that additional information on canopy-forming kelp might change a generalized inventory of canopy-forming kelp occurrence.

Related Research by WDNR
In addition to the kelp inventory, WDNR collected photography from one stretch of shoreline 5 times during a single low tide window in order to assess the effects of currents and tides on measured kelp canopy. This data was processed using the same methods as the kelp inventory. Analysis of this time series data is ongoing.

3. Data Usage Considerations
All data sets have usage limitations that are related to data collection methodology. General data usage considerations for the orthophotographs include:
- The orthophotographs have resource-grade positional accuracy. They are not appropriate for survey-grade applications.
- While positional accuracy is estimated to be ± 8 feet, lower positional accuracy may be apparent in areas with steep cliffs when viewing images at scales larger than 1:24,000. This artifact is due to Digital Elevation Model (DEM) induced errors. The DEM is lower accuracy than the orthophotos, however, it is the only DEM available.
- The two orthophotograph formats provide different benefits:
    - The mosaic sheets provide a single, synoptic coverage that agrees positionally with the kelp classification. Users who want a single edgematched image will prefer the mosaic sheets.
    - The individual orthophotgraphs have substantial overlap and vary slightly in image characteristics and location of moving features such as kelp. Users who want the best possible image of a particular area or feature may prefer one of the individual orthophotos due to image quality issues such as glare and darkness/brightness.

General data usage considerations for the canopy-forming kelp inventory include:
- While extreme care was used to produce this inventory, it has inherent limitations. The inventory is a snapshot in time of a large spatial area. It is a valuable screening tool, but it cannot replace site-specific surveys.
- Photo interpretation was used to identify canopy-forming kelp. As photo interpretation is an interpretive science, the ability to differentiate between canopy-forming kelp and other vegetation types is limited by visual

characteristics. Canopy-forming kelp is most likely to be confused with *Sargassum muticum*, a canopy-forming brown alga that occurs in shallow subtidal areas in the study area in similar habitat types as canopy-forming kelp. There are also many other species of canopy-forming and understory algae in the region that could be confused with canopy-forming kelp. Field work and contextual cues were used to the greatest extent possible to minimize confusion among species.

- While the inventory reliably identifies canopy-forming kelp beds, it does not reliably identify isolated stipes of canopy-forming kelp or small clusters of plants.
- The kelp inventory data has the greatest spatial agreement with the orthophoto mosaic sheet imagery. There is sometimes an offset between the single orthophotos and the kelp classification due to kelp movement associated with waves and currents or due to small differences in relative spatial location of the image (within the accuracy threshold).
- The measured surface extent of kelp canopies is known to vary based on environmental conditions, including tides and currents (Britton-Simmons et al, 2005), and water and light conditions.

4. Personnel

Work was completed by two groups within WDNR. Within the Resource Mapping Section, Richard Petermann completed scanning, aerial triangulation, orthophoto mosaic sheet creation, imagery masking. Michael Wellander produced individual orthophotos. Terry Curtis consulted on project methods.

Within the Nearshore Habitat Program, Helen Berry oversaw all aspects of the project including flightline development, aerial photography collection window definition, imagery masking, supervised classification development, and product review. Lisa Ferrier performed image masking, classification and conversion to ARC/GIS. Betty Bookheim reviewed draft classification results. Pete Dowty provided technical consulting on project methods.

5. References

Britton-Simmons, K., D.O. Duggins, and J.E. Eckman. 2005. *Effect of Tidal Currents and Tidal Stage on Size Estimates of Nereocystis luetkeana Beds in Washington State.* Olympia, WA: Final Report to the Washington State Department of Natural Resources, Nearshore Habitat Program.

Nearshore Habitat Program. 2001. *The Washington State ShoreZone Inventory.* CD-ROM. Olympia, WA: Washington State Department of Natural Resources, Nearshore Habitat Program.

Thom, R.M, and L. Hallum. 1990. ***Long-term Changes in the Areal Extent of Tidal Marshes, Eelgrass Meadows and Kelp Forests of Puget Sound***. Seattle, WA: Final Report to the US Environmental Protection Agency, Office of Puget Sound, Region 10.

6. Data Files

Final data was provided to FOSJ on two LACIE hard drives (Table 1). The projection is WA State Plane North zone, datum NAD83/91 (HARN), U.S. Survey Feet units. The pixel size of all imagery is 0.5 feet.

The following data sets are recommended as a starting point for general use (a sample ARC/GIS .mxd file is provided):

- **2004, 2006, and combined orthophotograph mosaic sheets** – an exhaustive image backdrop for the San Juan Archipelago. The combined sheets include portions of 2004 and 2006 images in areas where the two study areas overlapped.
- **Combined orthophotograph sheet index** – a spatial index that identifies the name and spatial footprint of each mosaic image sheet for the 2004 and 2006 study areas.
- **2004 and 2006 kelp classification** – inventory of canopy-forming kelp throughout the area, divided into separate files for each study area.
- **2006 individual orthophotograph sheet index** – a spatial index that identifies the name and photo center of each individual orthophotograph.

Table 1. Kelp Inventory Data Delivered to FOSJ

Type	Description	Drive	Path and File Name
Orthophotography	Orthophoto mosaic sheets in 2006 study area. In ERDAS Imagine format	2	\ortho_sheets_2006\ 2006_ortho_#.img (files numbered sequentially)
	Orthophoto mosaic Sheets in 2004 study area. In ERDAS Imagine format.	2	\ortho_sheets_2004\ 2004_ortho_#.img (files numbered sequentially)
	Combined mosaic sheets composed of 2004 and 2006 imagery in areas where the two study areas overlap. In ERDAS Imagine format.	2	\ortho_sheets_combined\ comb_ortho_2006_#_2004_#.img (files numbered sequentially)
	Individual orthophotos from 2006 imagery, generated for each aerial photograph. In TIF format.	1	\kelp_2006_indiv_ortho\#.tif
	Combined orthophoto mosaic sheet index. Index to orthophoto mosaic sheets for entire San Juan Archipelago. Defines the boundaries of each sheet and lists sheet number. In ARC/GIS shapefile format.	2	\image_index\ 2004_2006_kelp_image_index.shp
Kelp Inventory	2004 kelp classification. Kelp presence in the 2006 study area. Attributes also include area (ft^2), acres, hectares. In ARC/GIS shapefile format.	2	\kelp_classification\ 2004_kelp
	2006 kelp classification, Kelp presence in the 2006 study area. Attributes also include area (ft^2), acres, hectares. In ARC/GIS shapefile format.	2	\kelp_classification\ 2006_kelp
Aerial Photography	2006 scanned images. Scanned, unrectified 9" x 9" aerial photographs.	1	\kelp_2006_images\#
	Photo centers describing the geographic location of each aerial photograph. Collected using airborne GPS. In ARC/GIS shapefile format.	2	\image_index\ 2006_indiv_ortho_center.shp
	Excel file containing airborne GPS data collected during aerial photography collection. Similar to photo center file, with additional fields.	2	\misc\ DOT_2006_airphoto_gps_files.xls
Miscellaneous	Project report. In PDF format.	2	\misc\ san_juan_kelp_report.pdf
	ARC/GIS map file. Includes the general use data sets outlined above.	2	\misc\ canopy_forming_kelp.mxd
	Prioritized identification of areas where FOSJ may want to complete field work prior to completing a generalized inventory. In ARC/GIS shapefile format.	2	\misc\ field_work_priorities.shp