

Low-altitude sensing for detecting  
long-term changes  
in *Nereocystis luetkeana* (Bull Kelp)  
abundance

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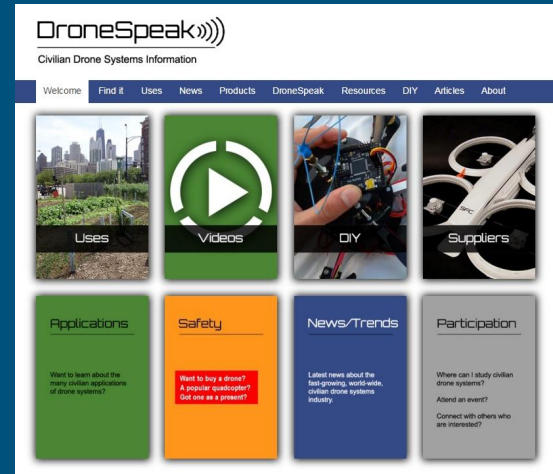
Preparation for a Near Term Action (NTA) Proposal  
to the Puget Sound Partnership

John Githens  
dronespeak1@gmail.com



# Background about the NTA proposal developer

- 10 years in electronic product design and manufacturing engineering
- 1 key year in Systems Engineering Methods, Boeing Commercial Airplanes
- 27 years in Boeing Information Technology (Sr. Business Systems Architect)
- 2012 moved to South Whidbey; Sea kayaker for 25+ years
- 2012 began posting on DIYdrones.com; custom flying robots
- 2013 founded DroneSpeak<sup>TM</sup>.com, a public service website
- 2015 Media Partner for InterDrone 2015 in Las Vegas, NV



# Why should we monitor kelp?

- We need to **protect and increase kelp** that provides habitat (food, shelter and other ecosystem services) for rockfish (critical habitat), herring, salmon and other sea life.
- There is evidence that kelp **is decreasing** across Puget Sound.
- Overall, **we don't know** how kelp is changing in **most** of Puget Sound.

# Surveying kelp in Washington State

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- Surveys of kelp species in Washington State started in the late 1800s.
  - There has been variation in survey methods, timing, consistency and areas covered.
  - The longest continuing aerial survey began in 1989 for the outer coast and Straits, **not including Puget Sound areas East, South, North of Port Townsend** (Van Wagenen 2015).
- Survey methods and techniques have included:
  - Boats, airplanes, SCUBA divers and sea kayakers.
  - Aerial film (visible and infrared) and digital images; GPS devices; in-water collection devices.
  - Professionals (many organizations) and volunteers.
- To fill the gaps for Puget Sound, the Northwest Straits Commission sponsored development of [A boat-based survey protocol for Bull Kelp in Puget Sound](#) for use by volunteer kayakers starting Summer 2015 (Bishop 2014).



Photo credit: Northwest Straits Initiative

# Identifying kelp beds and counting bulbs (2015)



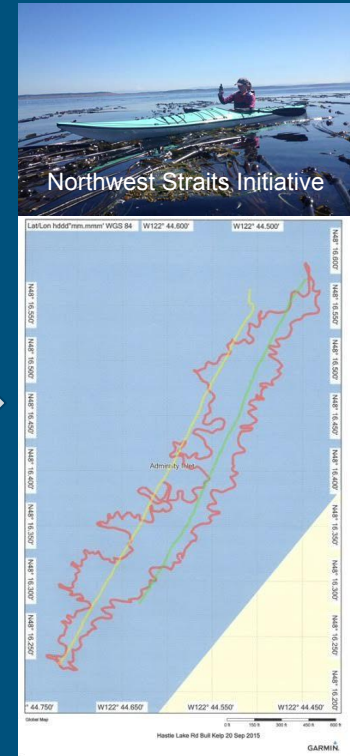
Photo from airplane with outlined kelp beds (G.Ridder)

## 1. Determining *kelp bed perimeter*

- Initial kelp bed perimeter identified using aerial photos taken by an MRC volunteer with a private airplane.
- Volunteer kayaker records many GPS points to specify the current bed perimeter.
- Subsequent bed perimeters likely to vary from current GPS points (measured area; position).

## 2. Determining *kelp bulb density*

- Kayaker positions their kayak near a GPS point at one end of the bed.
- Kayaker tries to paddle in a straight line (a transect) across the kelp plants.
- Kayaker counts kelp bulbs within an estimated rectangle along the kayak.
- Transects were altered by water current speed and direction, and other factors.
- Bulb counts were subject to the observer.



Hastie Lake GPS kelp bed perimeter, transects (L.Corin)

## Another way

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- **Robotic** drones are a low risk, affordable way to **consistently** monitor kelp, when compared to using kayaks, airplanes or satellites.
- **Volunteers participate** as the Pilot In Charge or as a Survey Area Monitor.
- On a survey date, the drone is **programmed** to fly a consistent pattern over a kelp area, recording images (visible, infrared) along the way.
- **During or soon after a flight**, the images are processed by an image “stitching” service to produce **a composite image** of the kelp area.
- **At the survey site**, the image is analyzed for kelp bulb density and other data.
- Data from that day’s survey is shared through the **SoundIQ Data System**.
- **Additional surveys** are completed as needed for long-term monitoring.

# Vision of a kelp monitoring system and process

1) Transport to survey location



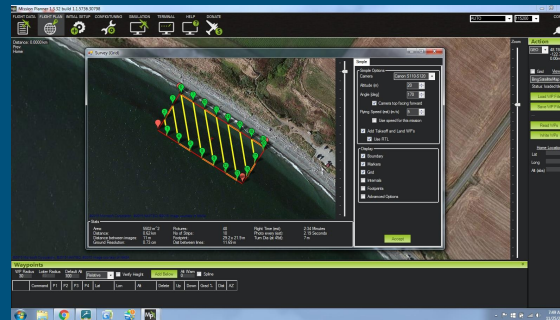
2) Prepare Ground Control Station



3) Prepare drone and cameras at launch/landing point



4) Program the drone auto-flight pattern



5) Launch drone to survey kelp area

6) Use cellular service to upload image files to cloud-based service<sup>4</sup> that generates one image/map file

7) Analyze<sup>5</sup> composite image file on laptop (kelp bulb density)

8) Files/data entered on Sound IQ System<sup>6</sup>

9) Pack up, leave site, evaluate/fix, store.



First four images by 3DR

Image by J.Githens



# Survey a kelp area along a shoreline

1. Using a computer with mission planning software and satellite images, select a launch/land location, and GPS points to specify a baseline area along a length of shoreline, extending from Low Water to depth of -35 ft. MLLW.
2. For efficiency, select a survey grid pattern for the selected camera, the camera's angle, and the drone's flight altitude. Save the flight plan.
3. Load the flight plan to the drone's autopilot to fly a consistent pattern that records overlapping images.
4. Post-process and analyze to develop a composite image and determine kelp bulb density.

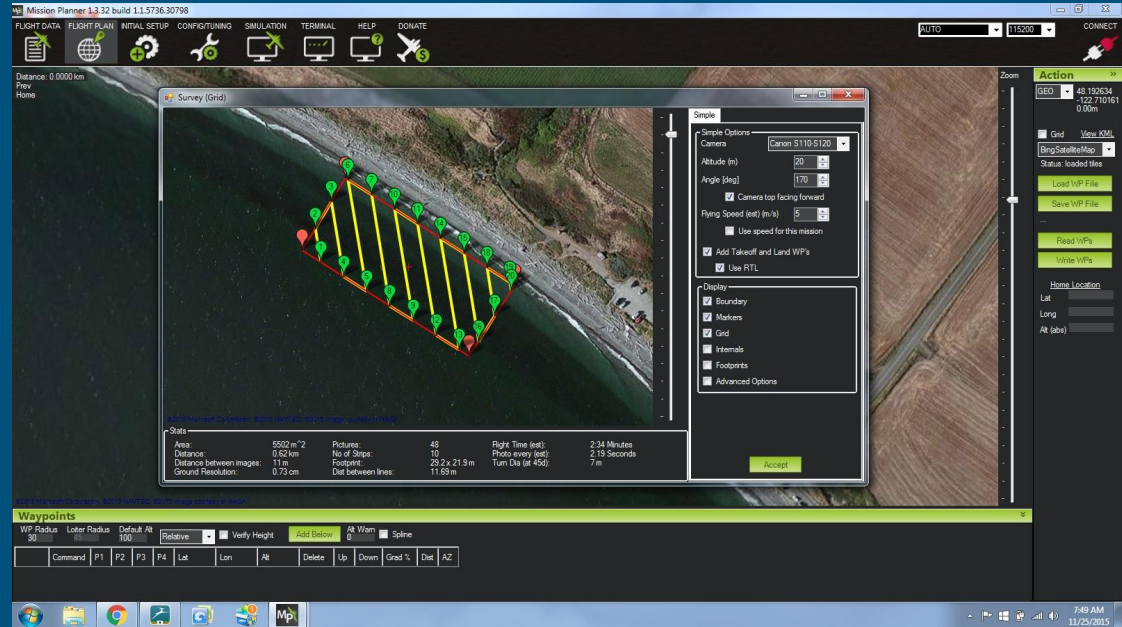


Image by J.Githens



# Areas of operation

## No Drone Zones for civilian drones

- NAS Whidbey Island, WA
- Paine Field, Everett, WA
- *Note 1: Several airports not shown.*
- *Note 2: Zones are wider than shown.*

## 2016-17 survey areas

- Hastie Lake
- Libbey Beach
- Ebey's Landing

## Outdoor areas for training and outreach events (to be identified)

- On Whidbey Island
- Near Marine Resources Committees
- Near Local Integrating Organizations
- Near other organizations



# Initial *Kelp Monitoring System (KMS)* components



MAPIR  
'Infrared'  
Camera<sup>7</sup>



MAPIR  
'Visible'  
Camera<sup>8</sup>



MAPIR  
Dual  
Mount<sup>9</sup>



3DR Solo  
Drone &  
Controller<sup>10</sup>



3DR Solo  
Drone, Controller,  
Gimbal, GoPro<sup>11</sup>



Survey  
Participant  
Vest

- 3DR Solo Backpack (x2)
- Micro SD Cards (x5)
- Camera lens protectors (x2)
- Batteries (Camera, Drone, GCS)
- Battery chargers
- Replacement propellers
- Other replacement parts
- Long Range GCS Antenna
- Cellular dongle and service
- VHF radio for airport contact

- Perimeter warning signs
- Whistles
- Walkie-talkies
- Tripod; lightweight stand
- Ground tarps (launch/land)
- **Operation, maintenance, repair documentation**



Laptop  
Computer



mapper  
pro  
Pix4D  
Software  
License<sup>5</sup>

# Aerial remote-sensing alternatives as of 1 Dec 2015

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## A. An airplane camera flown more often, at lower altitudes

- Images have been obtained by a volunteer pilot, with a private airplane and mounted camera, at ~2500 feet.
- Image resolution without sun glare, sufficient for kelp bulb counting? Do more frequent, lower altitude flights?
- Would more frequent, lower-altitude flights impact local homeowners (noise or privacy issues)?

## B. Consumer quadcopter with GoPro camera (DJI Phantom 3 Pro)

- September 7, 2015: Requires a skilled pilot to visually guide the drone to first record the waypoints for a future flight pattern.
- Alternative: Video from one or more overlapping transects. Use sequential frames/images to stitch a composite image.
- Alternative: Time-lapsed still images from one or more overlapping transects. Stitch to generate a composite image.

## C. Commercial quadcopter package for aerial mapping of terrain/objects

- Looked for suppliers experienced with robotic drone technology (programmed agricultural or infrastructure surveying).
- Looked for suppliers with a large base of professional users providing frequent feedback to developers and manufacturers.
- (Industry research suggests multi-rotor rather than fixed-wing drones for initial kelp area survey efforts.)

# Proposed Near Term Action (NTA) purpose and scope

- Purpose

- Develop, test and maintain a portable **system** and a documented **process**, including a **robotic drone**, for long-term monitoring of changes in *Nereocystis luetkeana* (Bull Kelp).
- Plan and schedule **field survey events** to get quality images from low-altitude drone flights.
- Complete surveys **with volunteers**, while recording data during the peak kelp growing season.
- Demonstrate/present survey capability to organizations **within and outside of Island County**.

- Scope

- Two year project. Guided by an advisory group. Insured. Financially accountable.
- **Three (3) kelp areas/beds along the West side of Whidbey Island, WA.**
- MRC volunteers participate in field survey events, **compliant with FAA, state and local laws.**
- **Survey data gathered June - October, 2016-17, and stored in the Sound IQ Data System.**<sup>6</sup>
- Additional **systems** may be deployed, depending on funding and volunteer capacity.

# Uncertainties, risks, and mitigations (1 of 3)

- A) **Time** for Federal Aviation Administration (FAA) to grant a Section 333 Exemption
  - Risk of kelp survey delay. Submit the exemption request as soon as possible.
- B) **Time** for acceptance by Washington State, County or municipality officials
  - Risk of political pressure. Emphasize compliance with FAA regulations, and the use of quick, low-altitude flights primarily over kelp (minimizes risk of harm or reduced privacy).
- C) **Perceptions** of drone use, if negative and expressed by property owners or beach/bluff walkers
  - Risk of formal complaints to authorities. Place temporary warning signs. Volunteer monitors explain the project's purpose, emphasizing compliance with FAA safety regulations.
- D) **Physical access** to beach or bluff for drone launches/landings
  - Risk of damage to equipment while reaching or leaving a beach or bluff. Use backpacks.
  - Risk of insufficient communications from bluff launch/land point. Buy longer-range equipment.
- E) **Cellular system service** in field locations
  - Risk of delay in accessing the cloud service that creates a composite image from multiple camera images. Walk or drive to a better location to initiate transfers of images stored by the drone's camera.



# Uncertainties, risks, and mitigations (2 of 3)

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## F) **Volunteer hours** per the schedule of training and survey events

- Risk of insufficient number of trained volunteers to fulfill the operations roles (FAA-certified Pilot in Command (PIC); Survey Area Monitors). Publish the training and survey event schedule 1-2 months ahead. Obtain commitments. Maintain a list of backup volunteers in case of illness.

## G) **Competency** of the system operator and volunteers

- Risk of camera preparation failure, ground control station failure, or drone crash due to failure of operator or PIC to follow all steps and checklists for each flight plan and flight. Maintain complete, easy-to-use system and process documentation. Maintain agreements and VHF communications with local airports.
- Risk of survey area intrusion by people or animals. Place temporary warning signs. Volunteer monitors to wear labeled, reflective vests, while asking walkers to wait a few minutes until the drone flight is complete.

## H) **Weather conditions**

- Risk of system component damage due to high wind or rain. Cancel event if conditions are excessive.

## I) **Project resources**

- Risk of inadequate funds, volunteer hours or partner hours to achieve all NTA objectives, outcomes and outputs. Quarterly reviews with an Advisory Council and the Island County Marine Resources Committee.



# Uncertainties, risks, and mitigations (3 of 3)

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## J) Image quality

- Risk of excessive sun glare from water surfaces. Adjust the drone's flight pattern to minimize glare.
- Risk of digital anomalies in the composite images of kelp areas. Buy camera(s) with sufficient resolution from the anticipated drone altitude. Maintain constant speed and altitude during flight to maintain focus on kelp. Ensure sufficient overlap in source images. Optionally, use RAW images.

## K) Liability insurance

- Risk of legal action due to an incident or accident that results in harm to people or property. Operator to carry sufficient insurance, paid by project funds. Volunteers covered by personal insurance policies(?).

## L) Property management

- Risk of property harm due to handling of components of the Kelp Monitoring System. Train volunteers in proper handling of components. After field use, return all items to designated storage locations, followed by evaluation, maintenance or repairs per documented practices. Avoid harmful weather conditions.
- Risk of loss of components during operation of the Kelp Monitoring System (example: drone crash on land or in water). Provide sufficient system training and operation opportunities for the operator and volunteers. Purchase additional drones, batteries and repair parts.

# NTA Owning Organization? Partners?

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The NTA proposal must be submitted by **10AM, 31 December 2015**.

Current assumptions about 'Owner Organization' and 'Partners':

- A. Partners are supposed to “materially contribute” to the project.
- B. 'DroneSpeak LLC', a company licensed in Washington State, is currently the designated 'Owner Organization', with 'John Githens' as the Owner Organization's Point of Contact.
- C. 'Island County Marine Resources Committee' is a 'Partner' because the ICMRC asks volunteers to participate in kelp surveys. Point of Contact is Anna Toledo (cc: Frances Wood).
- D. 'Northwest Straits Commission' is a 'Partner' because of leadership for kelp surveys across the seven-county area, and sponsorship of the SoundIQ System. Point of Contact is Dr. Lucas Hart.
- E. 'Northwest Straits Foundation' is a 'Partner' as a significant advocate for funding for the project. Point of Contact is Caroline Gibson, Executive Director.
- F. *As an alternative to the above*, could the ICMRC (or another organization) be the 'Owner Organization', with 'DroneSpeak LLC' as a 'Partner' ('John Githens' as Point of Contact)?

# NTA objectives, outcomes and outputs

- 1) Demonstrate the capability to measure three (3) *Nereocystis luetkeana* (Bull Kelp) areas in Puget Sound.
  - a) Portable, maintainable **Kelp Monitoring Systems (KMSs)**
    - i) Minimum of one (1) KMS for field use by March 31, 2016
    - ii) Minimum of one (1) improved KMS for field use by April 30, 2017
  - b) Documentation to enable a repeatable, objective **Kelp Monitoring Process (KMP)**
    - i) April 30, 2016
    - ii) April 30, 2017
  - c) **Trained volunteers** to perform KMP roles during operation of a KMS
    - i) May 31, 2016
    - ii) May 31, 2017
  - d) **Composite aerial images** and **kelp bulb density data** about three (3) kelp areas
    - i) June, July, August, September, October, 2016 (optimal tide, current and weather permitting)
    - ii) June, July, August, September, October, 2017 (optimal tide, current and weather permitting)
  - e) Image and kelp bulb density data entered in the **Sound IQ Data System**<sup>6</sup>
    - i) November 30, 2016
    - ii) November 30, 2017
- 2) Deliver information about the KMP and KMS to organizations within and outside of Island County
  - a) **Field demonstrations** to MRCs, LIOs and other organizations
    - i) Minimum of one (1) event in May, 2016; October, 2016; May, 2017; October, 2017
  - b) **Presentations** to MRCs, LIOs and other organizations
    - i) Minimum of one (1) presentation in May, October, November 2016 and 2017

# NTA planning and budgeting considerations

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## A. Most important **milestones**

- Acquisition of all **equipment, software and services** (April 2016)
- Completion of **training** of field survey volunteers (May 2016 and 2017)
- Completion of the **first** field survey event (June 2016 and 2017)
- Completion of the **last** survey event (October 2016 and 2017)
- **Survey data entered** in the Sound IQ Data System (November 2016 and 2017)
- Delivery of year-end **progress reports** (December 2016 and 2017)

## B. Most **limiting resources in 2016**

- Federal Aviation Administration (FAA) **flowtime to grant a Section 333 Exemption**
- Contractor hours to **develop and maintain** the initial system, documentation and training
- Volunteer hours for **training** and **participation** as Pilot-In-Charge or Survey Area Monitor
- Contractor hours to **deliver outreach presentations** or **field demonstrations**

## C. Most limiting resources in **2017**

- Contractor hours to **improve** the 2016 system, process documentation, and training plan
- Volunteer hours **on Whidbey Island** for **participation** as Pilot-In-Charge or Survey Area Monitor
- Contractor hours to deliver presentations, demonstrations, and training **beyond Whidbey Island**

# About estimating project cost for 2016-17

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- A. The commercial drone industry is growing rapidly, affecting the availability and prices of **products** and **services**.
- B. **2016**, the first of this two-year project, could be the most labor-intensive. However **2017** could be equally labor-intensive due to requests for more kinds of scientific data about kelp, more kelp areas to cover, essential system upgrades (multi-rotor > fixed-wing drone), and increasing requests for information.
- C. If the results during 2016 are positive, and there is interest in accelerating the adoption of this approach by other MRCs, then funding will need to be adjusted.
- D. As of Dec.1, 2015, the method or process is unclear for requesting additional funding **during an NTA**. Contingency funds may need to be included in the original proposal's estimates.

# Reference links

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1. [Washington Coast Kelp Resources, Port Townsend to the Columbia River, Summer 2014, Van Wagenen 2015](#)
2. [A boat-based survey protocol for Bull Kelp in Puget Sound \(Northwest Straits Commission, 2014\)](#)
3. [2016 Action Agenda Update: Near Term Action Proposals \(Puget Sound Partnership, 2015\)](#)
4. [DroneDeploy](#)
5. [Pix4D Mapper Pro](#)
6. [Sound IQ Data System](#)
7. [MAPIR Infrared, Green, or other Camera](#)
8. [MAPIR Visible Light \(RGB\) Camera](#)
9. [MAPIR Dual Static Mount](#)
10. [3D Robotics Solo Drone and Controller Package \(no GoPro\)](#)
11. [3D Robotics Solo Drone, Controller, Gimbal, GoPro Package](#)
12. [Kelp forest mapping by use of airborne hyperspectral imager \(Volent 2007\)](#)
13. [Remote monitoring of giant kelp biomass and physiological condition: An evaluation of the potential for the Hyperspectral Infrared Imager \(HyspIRI\) mission \(Bell 2015\)](#)
14. [FAA Section 333 Exemption](#)
15. [Puget Sound Partnership's Strategic Initiatives: Stormwater, Habitat, Shellfish, Crosscutting Substrategies](#)
16. [Puget Sound Partnership's Activity Types \(Categories\)](#)
17. [Puget Sound Vital Signs](#)