Kelp Monitoring Methods & Technologies Webinar
June 6th, 2018 – 10:00 am – 12:30 pm

Intro
Webinar Objectives

- Learn from guest speakers – various efforts to survey kelp beds using diff methods/technologies, challenges of remote sensing/aerial mapping & ways to address them
- Discuss implications for our region – what seems the most promising and effective? What could be applied in our region to better understand kelp dynamics?
- Begin crafting monitoring recommendations

Agenda
Each presentation will be 10-20 minutes long, with 5 minutes at the end of each talk for questions, group discussion at the end
CDFW update
Speaker intros

- Rebecca Flores Miller, CDFW – environmental scientist, lead for marine algae management, "CDFW Aerial Kelp Surveys"
- Tom Bell, UCSB – postdoc researcher w/UCLA, "Remote Estimation of Kelp Canopy Density along the California Coast"
- Meredith McPherson, UCSC – 3rd year ocean sciences PhD student in Kudela lab, "Re-thinking our approach to observation and monitoring of bull kelp after large-scale ecological and environmental perturbations on the North Coast"
- Maycira Costa, UVic – Professor, coordinator of the remote sensing laboratory in dep of Geography, "Detection of bull Kelp in the Salish Sea Using High Resolution Satellite Imagery"
- Helen Berry, WA DNR - Marine ecologist, maps and monitors nearshore habitat, "An Overview of Floating Kelp Trends and Issues in Washington State"

Cynthia Catton, Kelp Recovery WG co-chair – Update for CDFW

- At beginning of May, was able to attend the International Abalone Symposium in China, interacted w/folks from international community who are dealing w/same issues as we are on the north coast that are thinking about impacts to ecosystems & economic interests. What we are doing here will be looked at more broadly that just here in our region. What we are doing is very important and will have implications for our area and beyond.
- Recreational harvesting event in Ocean Cove over Memorial Day weekend; gathered a lot of data, it was a very successful event, 100 divers participated over the weekend, estimated that they got 7,500 lbs of urchins from that cove (5 acres). Approximately equivalent to 15 commercial diving days. Really shows can be accomplished & benefit to using multiple approaches & utilizing all our resources.
- Another working group meeting last week for concerns state-wide, considering ecosystem management, identifying major threats & impacts of climate change.
- What we are doing here is fitting in very well with what is happening more broadly

Rebecca Flores Miller - "CDFW Aerial Kelp Surveys"

- Environmental scientist w/CDFW
- Outline: background of surveys, data accessibility, uses of dataset, north coast survey results, value & limitations

- Background – surveys performed along US mainland from Mexico border up through Oregon + Channel Islands, digital images collected have a 2 meter spatial resolutions & are multispectral w/infrared band to pick up kelp. The images are processed & geoprocessed, classified to distinguish kelp, giant & bull kelp are surveyed.
    - First survey in 1989 by contractor, then 1999 by compilation of surveys by CDFW and two other contractors, 2002-2007 done in-house, then contracted out 2008-2016
    - Although CDFW strives for a coast-wide survey, this has not always occurred b/c of weather, malfunctioning equipment, lack of funding impact surveys. CDFW can sometimes get data from other organizations, but it tends to be patchy & limited
- Data Accessiblity
    - GIS Shapefiles – ftp://ftp.dfg.ca.gov/R7_MR/BIOLOGICAL/Kelp/
    - MarineBIOS – http://www.wildlife.ca.gov/Conservation/Marine/GIS/MarineBIOS
    - Metadata available; all data includes surface canopy, starting in 2008 some data includes subsurface kelp
- CDFW Use of Dataset
    - MPA planning process, CalCOFI Status of the California Current
    - T14, Section 165.5
        - Admin kelp bed descriptions, kelp bed lease advance payment
    - Data review to inform kelp bed lease & harvest plan review as well as for abalone & urchin management
- Other entities use of dataset
    - NOAA, NPS, Scripps, UCSB, also incorporated into CeNCOOS Data Portal
- Aerial Kelp Surveys
    - Graph 1 Marin - Del Norte counties: vertical axis is sq km of kelp canopy, horiz is year. Does not include all years mentioned earlier, omits years that don't have a complete dataset (2009, 2010 don't provide coverage for entire north coast, not surveyed at all in 2011-2012, 2013 didn't have complete survey). 2008 was a very good kelp year, 2014 was a very poor kelp year
    - Graph 2 – Sonoma: More years of data than previous. 1989, 2002, 2008, 2009 were all good kelp growth years in Sonoma county, not surveyed in 2011/2012, 2013 did not include all of Sonoma. In 2014 we can see the drop in kelp coverage, then 2015 had a historic low in kelp coverage.
    - Graph 3 – Mendocino: 1989 & 2008 were good kelp years, partial surveys conducted in 2009/2010, no surveys in 2011-2013. 2014-2016 depicted low canopy.
- Value/Limitations
    - Value: 2 m spatial resolution, giant & bull kelp, long-term, used for multiple projects
    - Limitations: doesn't provide biomass, they are annual so they don't reflect seasonal different, admin – some years surveys were not performed due to lack of funding or staffing, or difficulty with contracting (costs have increased), CDFW does not have a kelp survey scheduled for this year and it was not done last year. CDFW continues to discuss alternative technology such as satellites/drones.
- Contact: Rebecca.floresmill@wildlife.ca.gov, 831-649-2835
- Questions
    - What error is associated with the canopy cover estimates? (Steve Lonhart)
        - A: We don't have that information; run through a classification process and then a visual eval.
    - What is the status of the drone-derived data? (Steve Lonhart)

        - A: We are not currently using drones; we want to look at satellite imagery/drones but it is only being discussed.
    - Do people harvest bull kelp in California? (Sara Hamilton)
        - A: Yes, people do harvest bull kelp in CA for food. In northern CA, all kelp beds are closed. A few are lease-only, so people have to apply to the commission. Majority of harvest is giant kelp in Monterey and further south for abalone aquaculture.
    - Are surveys done around the same time of year? (Steve Lonhart)
        - A: Yes, surveys are done between August and October, some years they've been done a little earlier. We've even had some surveys in early November. When we do surveys we strive to do coast-wide surveys, so if there are times when we were not able to do a particular area we'll do those areas in early Nov.
    - When you say "historic low", is that just for the years surveyed? (Cyndi Dawson)
        - A: Yes, historic low refers to the department's data included in presentation, and specific to north coast or counties in north coast.

Tom Bell – "Remote Estimation of Kelp Canopy Density along the California Coast"

- Outline:
    - Landsat estimates of giant kelp biomass in CA
    - Landsat estimates of bull kelp canopy in Oregon (collaboration w/Sara Hamilton)
    - UAV (drone) monitoring of kelp canopy
- Giant kelp – globally distributed marine macroalgae, considered a foundation species in that it supports an ecologically & economically important ecosystem.
- Landsat continuity – can estimate canopy density & biomass from Landsat satellites
    - Landsat 5 TM launched in 1984 & flew until 2011, continuous time series over the past 35 years, allowing us to look at kelp dynamics over time.
    - Landsat 7 & 8 flying now, we get an image every 8 days regardless of cloud cover, most areas of the CA coastline every month.
    - These allow us to look at kelp canopy on a 30 m x 30 m pixel scale, can also look at fractional cover within these images.
- Diver biomass estimates (Santa Barbara Coastal Long-Term Ecological Research Project
    - Time-series allows us to ground-truth images, started back in 2002. Researchers have developed an allometric relationship between the number and lengths of different frond segments to estimate biomass of giant kelp in several 40 m x 40 m plots in the Santa Barbara Channel.
- Focus is on area between US/Mexico border and just north of Santa Cruz CA. Includes Channel Islands, region where Macrocystis is the dominant canopy-forming kelp. This is about 1500 km of the coastline (8 landsat tiles)
    - Graphs: timeseries of kelp biomass at three sites as estimated by landsat
        - Top - shows extreme seasonality of kelp canopy that is typical of the Monterey peninsula & central coast.
        - Bottom - interannual patterns typical of areas around Orange county in San Diego.
        - Middle - Validation site, blue represents LTER surveys & red represents our Landsat surveys.
- Classification of kelp canopy
    - In the past, we've manually classified kelp canopy using near-infrared false color images. Red areas show areas of high infrared reflectance, which were then manually identified,

then canopy density was modeled using multiple endmember spectral mixture analysis (MESMA). Modeled each 30 m x 30 m pixel as a linear combination of a pure kelp spectral endmember and 30 seawater endmembers. This gives us an estimate of the fractional cover of kelp canopy in each pixel. We can see fractional cover using Landsat down to about 10% cover of that 900 sq m pixel.

- Landsat continuity
    - While the Landsat sensors (5 TM, 7 ETM, 8 OLI) represent an un-interrupted time series, there are important differences between them.
        - Increases in signal to noise ratio as we move through time and a quantization of data. Ex: sensors from 7 & 5 were 8 bit, so we see reflectance in 256 different digital members, but Landsat 8 has a 12 bit sensor.
    - Spectral differences between sensors:
        - Infrared band in Landsat 8 is significantly thinner than near infrared bands in 5 or 7, did this to avoid absorption feature from water vapor.
        - To correct for these differences, we simulated 5/7/8 imagery from a hyperspectral image that was taken of kelp canopy from the SB channel taken in 2013. This allowed us to generate kelp fraction estimates as if the kelp forest was measured by the three Landsat sensors simultaneously. We see there was an under-estimation of kelp canopy fraction by Landsat 8 compared to 5 & 7 and we were able to correct for this.
    - Landsat kelp fraction vs. canopy biomass
        - Compared kelp fraction estimates from MESMA to canopy biomass estimated from divers at our validation sites for each sensor and for all sensors together. Transformed kelp canopy estimates to kelp canopy biomass from Landsat.
- Landsat kelp biomass automation procedure - now have a manuscript in revision which describes how we automated this process and took away the manual step. This process allows us to transform a Landsat image into estimates of biomass of kelp canopy biomass in just about a minute, which used to take about an hour to do manually.
    - Overview of automated process
        - Start w/level 2 reflectance product from USGS which has six different bands stacked across color and near infrared and short wave infrared; then mask out land using an elevation model from the ASTER satellite sensor; then we used binary decision trees to classify each pixel as seawater, cloud or kelp canopy; this step removes any need for manual classification. We then use MESMA to estimate the fractional cover of kelp in each pixel identified as kelp canopy through the decision tree process and we apply our empirical relationship with the diver data to transform those pixel fractions to canopy biomass.
    - Confusion matrices between our manual and automated classification processes
        - The process does well for each sensor
    - Comparison of automated and manually classified biomass
        - Time series in SB channel; manual process is in blue, automated in red; they match up well.
        - Slight underestimation in automated protocol vs manual, likely because in manual surveys sometimes intertidal surfgrass or algae or waves are identified as kelp, which are not identified by the automated process, so we are fairly confident that the automated process actually does a bit better than the manual process.
    - Landsat 7 ETM+ scan line corrector error - black lines caused by mechanical failure

        - Validation of kelp canopy biomass gapfilling: kelp canopy is going to vary through time more similarly in beds which are closer together than farther apart; since the scan line/error lines move from image to image, we can fill them using pixels from known biomass relationships between the missing pixel and nearby pixel lines not covered by the missing lines.
        - Synchrony gapfilling validation does well on the pixel scale and very well when pixels are aggregated to a patch scale.
    - Effect of tide on kelp canopy estimates - will be a problem using any aerial or satellite image
        - Compared Landsat 5 to 7 biomass estimates from three Landsat times in SoCal from 1999-2003, taken 8 days apart, sometimes one showed greater biomass than the other. Due to tidal cycles linking up with the 8 day offset between sensors, controlled which one was seeing more than the other; can correct for this by looking at a seasonal average.
    - Public dataset - used automated protocol to develop a seasonal time series of every giant kelp pixel in the range of dominance in CA, public dataset through the SBC LTER portant will be updated to automated protocol w/publication of the new paper.
- Oregon bull kelp canopy density from Landsat (w/Sara Hamilton)
    - Looked at Oregon DFW aerial photography and compared it to the Landsat estimated kelp canopy fraction for *Nereocystis*
    - Found that there is a fairly strong relationship between the two, so we are moving ahead w/making a time series for OR using the automated protocol, would like to do the same for northern CA. Also working on a time series for southeast Alaska.
- Landsat continuity - can look back through time at any site we want in the US
- Using UAVs (drones) to image kelp canopy
    - Drone flights in Alaska last summer where there is both giant and bull kelp; a lot of potential for this moving forward
- Contact: tbell@ucsb.edu, tomwbell.net
- Questions:
    - Are there restrictions to crosswalking this for bull kelp (meaning biomass as it's related to depth)? How do you account for depth? (Tom Ford)
        - A: We only look at canopy, no depth. There are limitations for bull kelp, as there is less surface canopy, might be more subject to tides and currents. Not really many biomass surveys done for bull kelp for validation. For OR we are looking at canopy density, the validation we are using the the higher spatial resolution overflights that were done by ODFW.
    - Why doesn't aerial versus Landsat relationship for bull kelp go through origin? (Mark Carr)
        - A: It doesn't because there is, at very low canopy densities, there is a lot of error on whether or not we can detect bull kelp at all; when we get to 5% of the pixel of bull kelp we have trouble observing it at all. We would also want to test our kelp endmember, here we just use our general brown kelp endmember. Spectrally bull kelp and macro look almost the same but we'd probably want to try to look at a bull kelp endmember taking from Landsat imagery or from the lab.
    - Have you estimated the threshold of bed sizes that the Landsat imagery captures? (Helen Berry)

        - A: We think for giant kelp we can go down to about 10% of the pixel. As long as there's about 90 sq m of kelp canopy inside of a 900 sq m Landsat pixel, we should be able to detect it. Should probably be about the same for bull kelp.
    - Could you discuss the costs of obtaining the satellite imagery? (Rebecca Flores Miller)
        - A: The satellite imagery it is free. With the automated process it takes a lot less time to do it. Would be happy to work with the state and make these data more publically available.

Meredith McPherson - "Re-thinking our approach to observation and monitoring of bull kelp after large-scale ecological and environmental perturbations on the North Coast"

- Differences between species influence the way we study bull kelp
    - Remote sensing studies of bull kelp remain largely missing from the literature; bull kelp is annual so we only see canopy during August-Nov, giant is perennial and can be detected year round, even though the seasonal max is in summer/fall. bull kelp has biomass concentrated in the canopy, where giant has biomass distributed throughout the water column. Response to climate change might be different.
- Paper - Extreme warming challenges sentinel status of kelp forests as indicators of climate change
    - Found that there wasn't really an impact of temperature anomaly on giant kelp biomass, but they did see significant impacts to sessile inverts such as urchins/sea stars.
    - But we know that there has been a dramatic response by bull kelp in northern CA to some combination of environmental drivers.
- Using remote sensing as a tool to monitor bull kelp
    - Primary focus of my research is to understand whether the impacts of spatial resolution impact our ability to measure bull kelp after the die off.
    - Slide image: 30 x 30 m pixel depicts landsat; great tool for detecting relatively large kelp beds (giant kelp). Bull kelp after the die-off - diameters of the beds were reduced to very small patch sizes, so it is unclear whether or not Landsat can be used as a tool to detect these small patches.
- Looking at satellites w/higher spatial resolution (5 x 5 m)
    - Increases likelihood of small patches being detected
- Using remote sensing as a tool
    - Landsat - good historical record, but can it accurately measure bull kelp?
    - Some other sensors that have higher spatial resolution
    - How will spatial resolution influence our ability to measure bull kelp canopy and biomass? We need to assess this; it is important to accurately measure impacts of multiple stressors. Increasing resolution will also allow us to use remote sensing platforms to go beyond monitoring canopy area (to biomass & physiology)
- Sensor comparison:
    - Compared RapidEye (commercial satellite, 5 m resolution), Landsat (5 & 8) 30 m res) & CDFW aerial surveys. Specially looked at Van Damme.
    - The three sensors are spectrally similar, but RapidEye does have one additional band in the red edge of the brown kelp spectra that Landsat doesn't have.
- RapidEye (RE):
    - Run by Planet Labs, commercial, continuous from 2009 onward
    - Provides 10,000 sq km free imagery per month, has a 5 m spatial resolution
- Landsat (LS) 5/7/8
    - Run by USGS/NASA, non-commercial, continuous from 1984 onward

    - Free unlimited imagery for anyone with an account, 30 m spatial resolution
- Prelimary results: Sensor comparison for kelp canopy coverage
    - Landsat & CDFW match up well, but RapidEye does not; also RE overestimates for years where we have overlapping in 2015/2016.
    - Don't want to discount RE just yet
- Moving forward w/imagery
    - Results show challenges w/RE imagery, require us to focus on certain image processing tools - atmospheric correction (none exists for RE, so we are correcting them ourselves), signal-to-noise ratio (decreases, which may impact ability to measure kelp), computational expense (for every LS pixel there are 36 RE pixels, much more time to process)
    - Look at refining detection of kelp w/RE imagery
    - Plan to include other sensors such as sentinel 2A (10 m res) & WorldView-2 (2 m res)
- Biomass estimates:
    - Will be doing them this summer
    - Less of a tidal impact in satellite imagery for giant kelp since the biomass is more even/distributed throughout water column; for each pixel, the fraction of water to bull kelp is much different than for giant kelp.
- Empirical relationship for bull kelp canopy biomass
    - Only one study in Alaska for estimation of bull kelp
    - Methods: sample a 30 x 30 m plot to correspond to a Landsat pixel, in water measurements of morphology (longest blade length, bulb diameter, sub-bulb diameter); end of season (late Sept) - entire canopy weight to correlate.
    - Relating biomass back to the satellite
    - Measuring kelp health - building on work that Tom Bell did; take in-situ measurements on chlorophyll & carbon and develop relationship in which they could be detected from a remote sensing platform; plan is to optimize this for a multispectral sensor and put it on a drone to monitor kelp health at a very high spatial resolution.
- Conclusions
    - Hopeful that we can learn as much about bull kelp systems as we have about giant kelp systems in southern CA using these techniques
    - Should consider higher resolution commercial satellites (don't put all our eggs into the Landsat bucket yet
    - Can drones help us monitor supplement satellites and measure high spatial/temporal resolution of kelp health?
- Questions:
    - Is there is information about latitudinal variation in bull kelp biomass? Context: has noticed that Nereo up north and into Washington is much less robust than Big Sur. (Steve Lonhart)
        - A: It isn't common for people to take these measurements. The only study I know of is the one I mentioned in Alaska. I don't know of any published study that shows a trend in biomass along the coastline.
    - Steckoll found that biomass ground-truthing is very extensive and there was significant variation by location. How do you plan to address this - having lots of different locations? (Helen Berry)
        - A: Will be doing a lot of work with Cynthia & Laura up in Sonoma/Mendocino county, will be visiting several sites along the coast to get a large spatial

variation of biomass across the two counties and CDFW sites which we can correlate to specific locations back to the satellite imagery.

Maycira Costa - “Detection of bull Kelp in the Salish Sea Using High Resolution Satellite Imagery”

- Context of research - large collaborative project looking at decline of chinook & coho salmon, including kelp
- Most of data comes from satellites (MODIS, VIIRS, Sentinel-3, WV, SPOT), also from sensors from ferries, research vessels, citizens
- Ocean productivity - the ferries have sensors which continuously detect light coming from the water and use it as validation of atmospheric correction
- Coastal biogeochemical domains - BC and SE Alaska
    - Chlorophyll concentration maps used to define biogeochemical domains along the migration route of juvenile salmon; data can be associated with zooplankton biodiversity & abundance
- Eelgrass - spatiotemporal changes: aerial photography/UAV to look at spatial/temporal distribution of eelgrass along the coast from 1932 until 2016. Also associates declines with shoreline development.
- Kelp & juvenile salmon survey:
    - Looking at presence of salmon in kelp beds
- Kelp detection with satellites:
    - Depends on kelp structure (density, exposure), environmental characteristics (tide height, time of year, water surface), satellite characteristics (spatial & spectral resolution)
    - Kelp structure - not much is above the water that can be detected by satellite, would really only see a small part of the entire structure
    - Environmental characteristics: tides, good below 1.2, bad above 1.2 (no kelp seen)
    - Time of year - max growth and extent are in July/August
    - Proximity to coastline - can be a problem when it comes to pixels on the satellite; pixel-mixing can happen at 30 m spatial resolution, so kelp can get mixed up with rocks/vegetation/water and it’s not easy to detangle the spectral signal from each of these things; very important for BC because of how close bull kelp grows to the coastline, causing a lot of error
    - Water surface - glint: sunlight reflecting off of water at the same angle that a satellite views can obscure kelp; can be very difficult to correct
    - Kelp - satellite characteristics: spectral resolution & kelp reflectance
        - Kelp reflectance: looked at different densities in different kelp beds (reflectance % vs wavelength nm); water has very low reflectance; kelp has very high reflectance in infrared spectrum
- WorldView-3 - 1.2 m resolution - time series 2004-2016 (600 km orbit)
    - Form a spectral fingerprint, or kelp print, to use for classification; have to process data properly first
    - Preprocessing - need to correct for spatial inaccuracies & create geographically accurate image; correct for effects of atmosphere & glint; do a temporal analysis to normalize historical images to corrected image; and mask land/deep water based on reflectance & bathymetry
    - Atmospheric correction - spectral profile show dramatic change in spectra after removal of atmospheric attenuation
    - Glint removal

    - Apply image transformations: “spectral kelpprint” - take samples from classes of interest and compare which bands are best for separability
    - Kelpprint: combo of different spectral indices - areas of pink/red correspond to kelp
    - Classification: supervised (82%) & unsupervised (80%); very good match for validation, but slight difference in timing needs to be considered
    - Historical data - 2004, 2012, 2015, 2016
    - Spatial temporal trend analysis - looking at presence/absence, not area; not much change in the distribution of kelp over a period of 10 years
    - British 1905 - would draw kelp, we are working on digitizing it to help form a baseline; also
- Contact: maycira@uvic.ca, sbc@uvic.ca

Helen Berry - “An Overview of Floating Kelp Trends and Issues in Washington State”

- Kelp in Washington State: >20 species, about 10% of kelp in the area is on the rocky outer coast, but the majority of kelp is present throughout Puget Sound - fjord system with large tides, strong currents and estuarine circulation; this is where most of the human development is located
    - environmental context for kelp & stressors are very regionally distinct
    - Kelp found around marine shoreline both on the outer coast and within PG, even the inner basins; there is a lot more understory kelp rather than floating
    - Widespread concern about losses in kelp, especially bull kelp
    - NOAA is funding a kelp recovery plan for PG, offshoot of ESA mandated rockfish recovery plan (phase 1 - literature review, phase 2 - outline actions to be taken)
- Two species of floating kelp - bull and giant kelp
    - Important to remember that kelp canopy surveys are not highly precise, esp in PG where there are extreme tides, currents & weather conditions; giant kelp is only present on the outer coast
- Annual monitoring of floating kelp canopy area along straight and outer coast (1989-present)
    - Have used many different methods: aerial photography, airborne multispectral, kayaks, small boats, underwater videography, etc. Will talk about the longest dataset we have that uses consistent methods, because that’s where we are learning about trends
    - Aerial photography, color infrared photography, mapped at 1-12,000, collected annually in late summer at low tide & low current
    - Kelp canopy area - stable, yet highly variable; abundance of both species is positively correlated (they do compete at smaller spatial scales); extreme lows in kelp abundance during extreme high temperatures (1997 & 2014).
- Kelp ecologists have long attributed much of the variation we see in kelp to climate; we recently quantified the links between canopy area & climate using ARIMA models as we finally have a long enough dataset to do it;
    - Saw significant correlations with all three oceans with the indices we tested; kelp abundance greater during cool nutrient rich phases = positive correlation w/NPGO, negative correlation w/ONI & PDO
    - This confirmed that kelp abundance is linked to climate
- Floating kelp area along the strait over a century
    - We are really interested in how kelp abundance has changed over time; compared long-term dataset to detailed maps created by Rigg in 1911-1912 to identify kelp beds for harvesting for fertilizer
    - Compared area between the two time periods

    - Kelp canopy generally stable in strait at a broad scale over the long term, except at eastern boundary (closest to development, farthest from ocean)
- Changes in bull kelp distribution in south PG
    - Compiled all observations from about 30 data sources from about 1855 to present
    - Most sites absent recently in west and central
    - Simplified analysis - divided up all the stretches of shoreline where bull kelp has been noted into 29 sites, only presence or absence at every site; it's a rough approach, but it allows us to incorporate data sets that are not comprehensive & to only use narrative descriptions
    - Pattern of decreased persistence in west and central regions in recent years
    - After 1980, proportion of observations with bull kelp lower in west and central
        - Can roll up all these dots and just look at what proportion of observations saw bull kelp present or absent; before 1980, there was a relatively high proportion of observations with bull kelp present; after 1980, the median in west and central is zero. Area with strong mixing showed higher persistence, possibly protected from stressor in other areas.
- Concern over losses in Salish Sea, especially in inner basins
    - Candidate stressors: elevated temps, urbanization, anthropogenic nutrients, sedimentation, overfishing, community shifts, grazing - mostly kelp crabs, sargassum
- Recent trends - short-term: major canopy losses in 2014 - spatially complex recovery 2015 to 2017
    - Observed kelp along coast and the strait declined dramatically in 2014; but unlike California, these areas rebounded in 2015
    - Fairly spatially complex pattern; other areas within PG decreased as well, but recovery was delayed; could be linked to temperature
- Elevated SST in 2015/2016 in Salish Sea
    - There is high temp variability within PG; the strait is fairly well-mixed, but areas further within PG stayed warm
- Have a lot of volunteer kayakers to validate DNR aerial photography; many sites as of 2017 are stable, but there are still declining beds in the inner basins where temps are higher
- Lessons learned from aerial methods
    - Aerial imagery is effective but not precise, consistency is critical; satellite imagery has been problematic in WA because of narrow data collection windows & narrow beds in many areas; major limitation - only captures canopy forming kelp, a small fraction of the community
- Experimenting with large areas using underwater videography - documented massive effects of sedimentation following Elwha River dam removal
    - One year after dams were removed, observed massive losses right by the mouth of the river

Discussion/Q&A (facilitated by Francesca, KRWG Co-Chair)

- Mark Carr, question for Helen Berry: When you are looking at these spatial patterns for both loss and recovery of bull kelp, do you have data on urchin densities and urchin density trends over that time period?
    - A: We generally do not see very high urchin densities in many of these areas; far less than the thresholds. Here they are relatively low, except for the areas that are closed to urchin densities. Do we know of any urchin barrens in WA? We have not really come up with one that fits the criteria. We do have sea otters on the outer coast and human

harvesters starting within the strait. Perhaps they are controlling the population? There was very heavy harvest in the 1980/1990s and the population is considered a fraction of what it was.

- Cynthia, question for Helen: What do you think is driving the strong correlation with the one-year lagged NPGO? Do you think that is driven by the Macro or Nereo, or does that matter?
    - A: We did look at correlations by species as well. It is slightly higher for bull kelp, but for both species, the highest is the one-year previous lag. There was no significant correlation with temperature. Temperature is really spatially complex in the Puget Sound. With more spatially explicit temp data, I don't know if we would see a stronger correlation. Somehow the NPGO is synthesizing both the temperature and nutrient characteristics so that we do get a significant relationship between the two variables. In PG, the relationships between nutrients and kelp are empirical and they rely on temp in upwelling systems. We just don't know how consistent that relationship; it appears environmental conditions are leading indicator by one year, closer to three years for giant kelp in the area of California where Cavanough studied.
- Cynthia follow-up: Do you think that is pointing to spore production/previous year conditions/indices combine many different environmental factors, possibly even precipitation; do you think that indicates that we should be thinking about previous year's environmental conditions influencing production of either additional sites for Macro, or spore production, etc for the following year?
    - A: That is my supposition exactly. There two things happening - one that the environmental conditions are happening the year that they are occurring, and then you also have lead time for the conditions having an effect over multiple years
- Rebecca, question for Meredith: When you were comparing the RapidEye surveys with the CDFW and Landsat surveys, and found that the RapidEye was overestimating, can you expand upon why that might be the case?
    - A: We don't know exactly why right now. There is no atmospheric correction for RE like there is for Landsat, but I thought we could try to detect it without the correction. That is probably why it is overestimating. Now I'm working on the atmospheric correction for RE to see if that increases the signal of the kelp. Most of the atmospheric correction programs you have to purchase and is widely applied to satellite imagery, but I'm trying to do it the free way; it just takes time.
- Tom Bell, question for Meredith: Maybe try a dark object subtraction as an atmospheric correction for the RE. *Meredith has tried cloud and shadow, which did not work well, but dark pixel correction is on her radar*.
- Tom Bell - Kyle Cavanaugh in 2011 paper found that there was a three year lag with NPGO; we found in 2015, depending on the region of CA, that there was a 1-2 season lag with NPGO. If you're looking at an annual scale, that probably means more like a one-year lag. When you look at southern CA w/Macro the biomass follows the NPGO very closely. The NPGO may tell us processes that are going on that SST doesn't, such as a showing of the halocline or nutricline which could be flooding these shallow reefs with nutrients that we may not be seeing with SST alone, could lead to increased recruitment the following year. If you look at southern CA, the NPGO increases the strength of the CA current and sends a lot of cold water down into southern CA, which is why there might be a mismatch between what we see in the SB channel and southern CA. We also see a strong predictor of the NPGO in central CA as well, it's just there's a seasonal cycle with waves on top of that. It's complex; a new paper coming out does a complete analysis of the NPGO in CA and we really think it is driving a lot of the interannual patterns of canopy biomass.

- Francesca, question for Rebecca: With respect to the aerial surveys, has anyone reached out to Lighthawk? They have flight capacity and might be able to help.
    - A: When the department began contracting out surveys, we began to develop a request for proposals. Once folks submit a proposal, there is a bid associated with it. Any of the applicants that pass a certain scoring range, they are seen as a responsible bidder. Then the contract will go to the lowest bidder. So the department can't pick and choose who they want to do the survey. Interested in following up with Lighthawk.
- Mark Carr, question for Tom/Meredith/all others who are exploring both the remote versus drone-based survey methods. What are your thoughts for the north coast, given the weather conditions and unpredictability of being able to capture satellite imagery, with respect to exploring drones versus the remote sampling methods?
    - Tom Bell - we've been doing two drone-based operations. One in Santa Barbara doing simultaneous to Landsat overpasses and simultaneous to LTER biomass collection. We've also been doing it in Alaska from boats, mostly in southeast AL around Prince of Wales island. There are pluses and minuses to both. We do get a fair amount of Landsat coverage in northern CA, though it'll never be as good as southern. We do get 6-10 cloud-free images per year. If you have someone there in the area that can fly a drone, it represents a great way to take advantage of good conditions. Color camera drones are a lot cheaper than a multispectral unit, but we can still get kelp density. It is a great way forward; the spatial extent will be smaller but if you have someone on site that can go fly it when there is good weather, it's great.
    - Meredith - I think it depends on your question. It would be very labor intensive to get as much drone imagery as would cover just one Landsat image. It would be very interesting to use a drone to study changes at one site for example over time or over a season to get higher temporal resolution and much higher spatial resolution. If we're looking at larger scale dynamics and ocean processes, we'd have to use satellite imagery.
    - Mark - there are different types of drones that you've been thinking about doing, versus the larger drones that could fly the whole coast. It would be really interesting to explore the options and costs for what those different approaches would be with respect to how expensive they are, how reliable the data they are, and how often you can get reasonable satellite images. *Follow up to Meredith* - Maybe it's a blend of the two. There are benefits to both approaches at different spatial scales. Maybe the solution is to design a sampling program that uses both to compliment one another.
- Helen, follow up question to the last discussion - we are experimenting with small drones a little, but the site size is much, much smaller. It becomes a complementary technique rather than a substitute for satellite imagery. Have you thought about what that site size is for the drones?
    - Tom - for a phantom 4 drone, you are limited to 40 ha per flight (given good conditions), so that would be a big limitation, then you'd have to move site to site. Agrees that it will be a complementary method. Once FAA regulations relax on drones, it would be good to see if we can explore fixed wing options rather than quadcopter options where we can cover larger spatial areas, with drones that can fly larger portions of the coastline. Right now regulations require that you stay within line of site with your drone. Those may be relaxed in the near future.
- Rebecca - agrees that the beauty of drones is that you can perform those surveys more often. The CDFW surveys are only done once a year. Also we found that in our statewide surveys, there were some areas that had plenty of kelp, but then we went right around the bend and the kelp had dramatically decreased. One consideration about the drones is that they may not pick up on those little details.

- Steve Lonhart - What does a multi-spectral sensor on a drone cost?
    - Tom - The one we discussed earlier is around $4,500 and you can put it on a matrice 100 DJI drone which is another $2,500-$3,000, making the total around $7k-8k. Have heard of someone mounting that same sensor on a phantom DJI drone, which is about $1,500.

Josh Russo - Update (copied from email)
Watermen's Alliance Recreational Purple Urchin Removal Event

Total Volume of Whole Urchins: 2,200 gallons
Total Number of Recreational Diver Days: 126
Total Number of Individual Divers: 100

	Saturday	Sunday	Total
Total Catch (count)	38,651	21,882	60,533
Total Catch (lbs)	4,708	2,797	7,505

	Saturday	Sunday
Average Diameter (mm)	51	51
Weight / Bucket (lbs)	16.8	17.5
# Purps / Bucket	138.0	136.8
# Reds / Bucket	0.1	0
# Buckets Sampled	26	25

7500 lbs of purple urchins is ~15 commercial diver days of effort.

We had the Alameda County Dive Rescue Team filling tanks for free so divers could dive as much as they want.
We also had a state lifeguard on duty in the water on a jet ski for the event.
At the Raffle, one of the clubs organized we raised another $13,600 and were approved a $20,000 grant from Sonoma County Fish and Game for the commercial divers effort totalling approximately $120,000 raised by Watermen's Alliance and Sonoma County Abalone Network so far.

One very uplifting moment was after the first days collecting I asked how many would do it again and 100% said yes. I asked if they would only do Sonoma or if they're willing to go to Mendocino and 100% said they'd do it wherever we held the event. I asked how often they could commit to participating and they said every other month so we will be alternating future events every other month between Sonoma and Mendocino county.

Our next recreational removal event is July 21 and 22 at Albion/Schooners Landing in Mendocino.

Josh Russo
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