



**Automating kelp forest mapping using
deep learning for monitoring
spatiotemporal changes**

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Presented by: Luba Reshitnyk (Hakai Institute)

Taylor Denouden (Hakai Institute)

Hakai

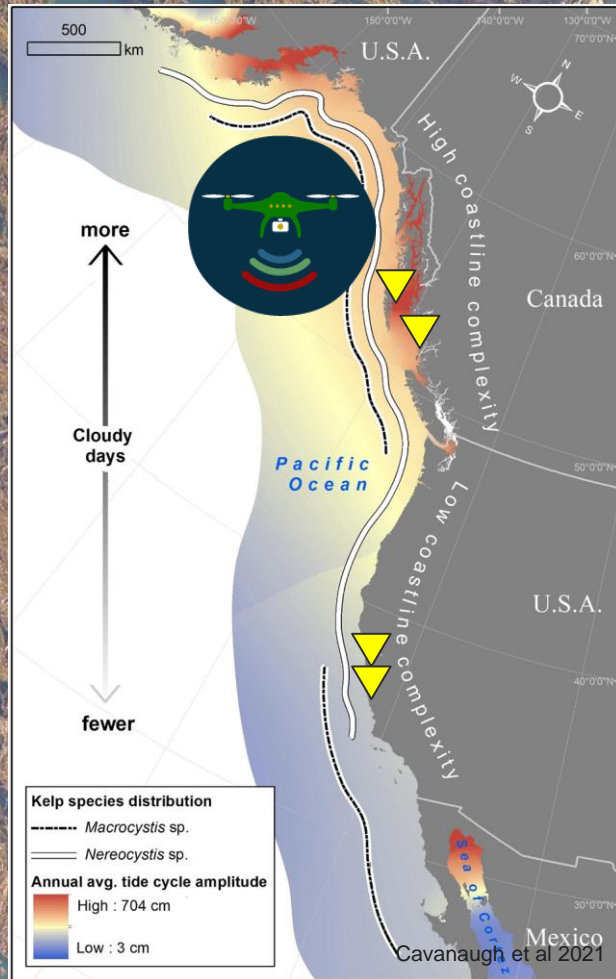
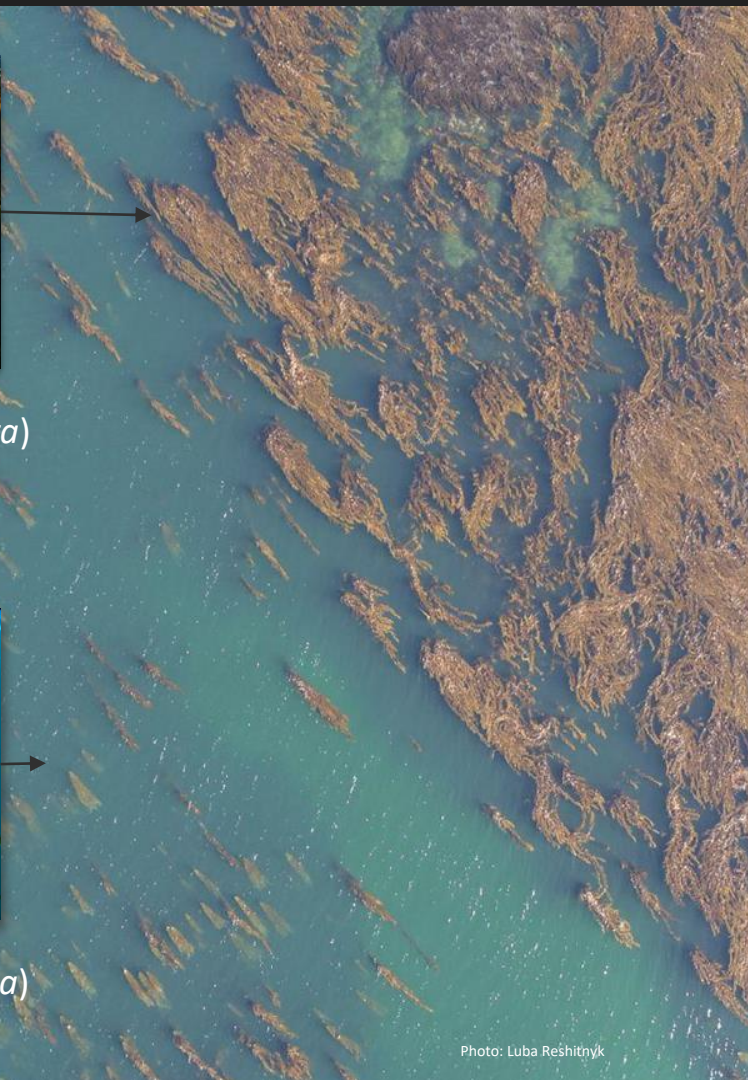


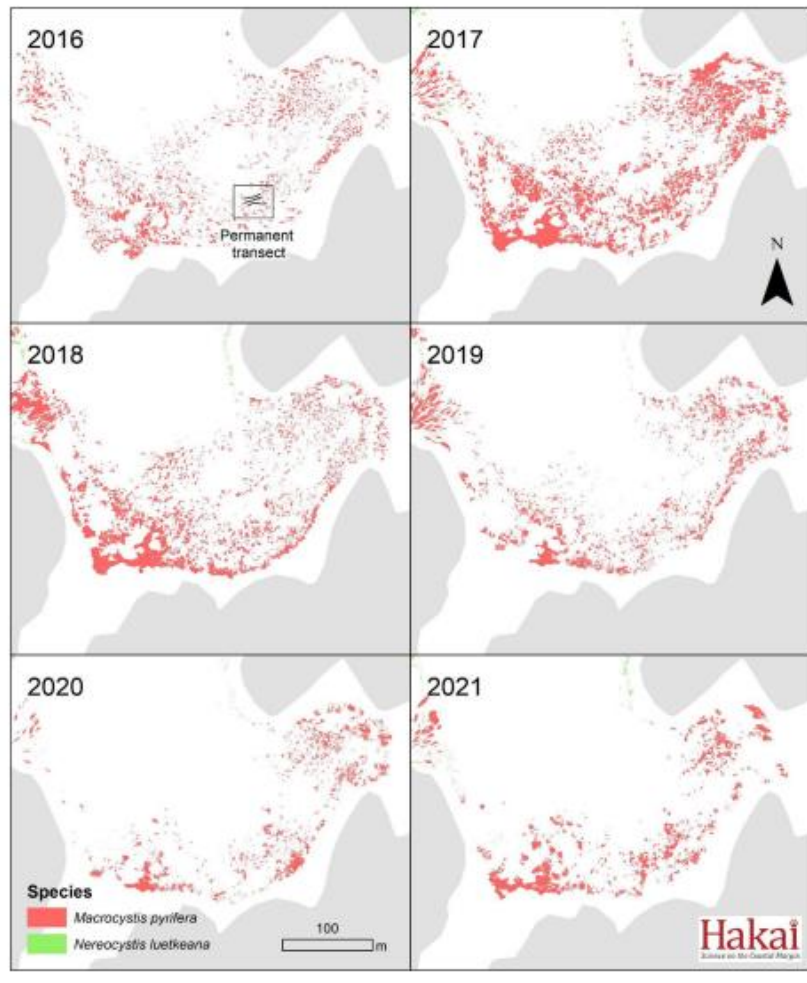
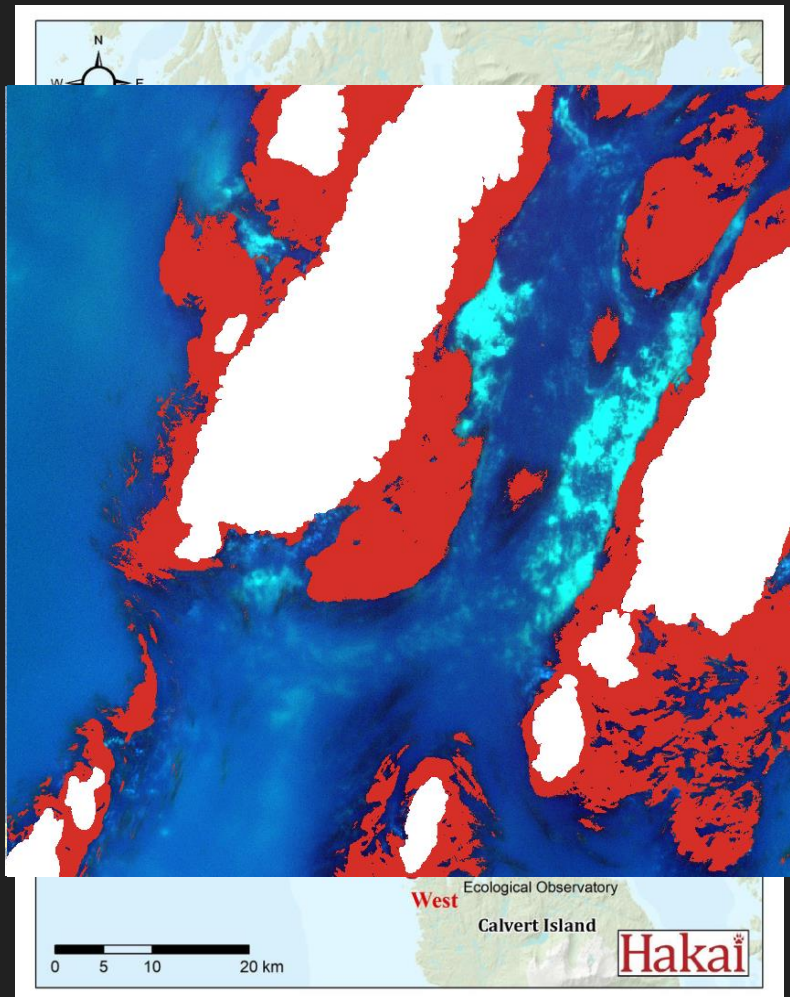
Giant kelp (*Macrocystis pyrifera*)



Photo: Nick Norman

Bull kelp (*Nereocystis luetkeana*)

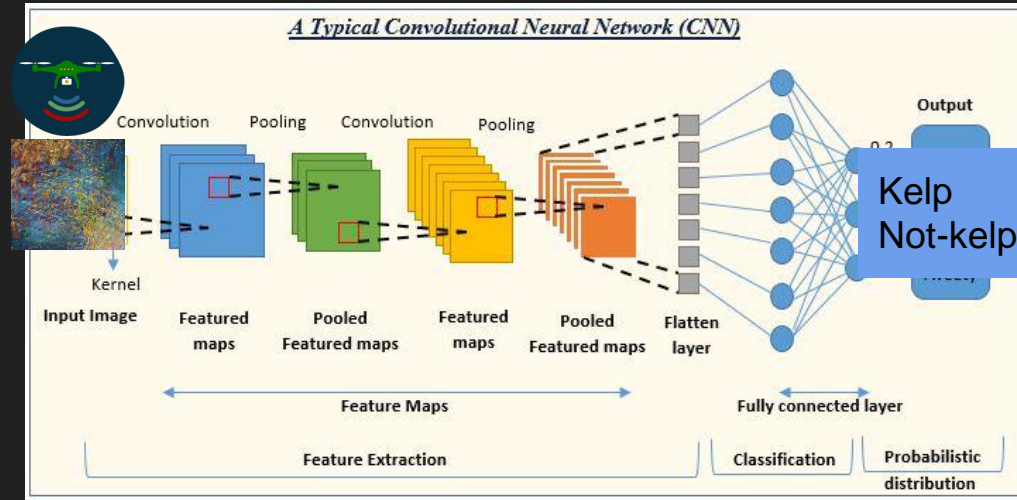




CNNs in ecological mapping

CNNs

- Used to identify biophysical components in high-res drone imagery (Brodrick et al. 2019)
- Leverage spatial context
- Good when ecological component has a distinct shape & texture



<https://www.analyticsvidhya.com/blog/2022/01/convolutional-neural-network-an-overview/>

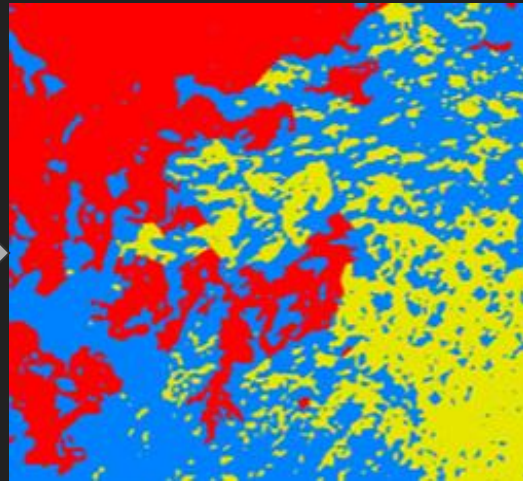
- Deep learning & drones review (Osco et al 20121)
 - CNN most common architecture
 - Mostly terrestrial applications
- Marine examples - seagrass dominant
 - McKenzie et al (2022) - seagrass cover
 - Tahara et al (2022) - differentiated 2 seagrass species

No current examples of CNN applied to landscape classification of kelp forests in drone/high res imagery

Objectives for the Kelp-O-Matic (KoM)

1. Train a semantic segmentation CNN to classify emergent (at sea surface) canopy kelp present in drone imagery (ie. presence/absence)
 - a. The CNN should be (ideally) as accurate and faster than the index-based methods
2. Train the CNN to differentiate between species (*Macrocystis pyrifera* & *Nereocystis luetkeana*)
3. Tool should be open source, easy to use

Input:
Drone image



Output:
Classified image
Red = *Macrocystis* sp.
Yellow = *Nereocystis* sp.
Blue = not kelp

Results: Presence/Absence

Quantitative

IoU (> 0.5 good)

- **0.78** overall mIoU
- **0.59** IoU for kelp

Fscore (combo of precision + recall)

- **0.86** overall F-score
- **0.69** F-score kelp

Overall accuracy

- 0.99

Qualitative

- Can classify complex scenes
 - Glint, waves, nearshore/shallow waters, multi species
- Small areas of misclassification on shorelines, easy to remove during QA/QC

Classify a scene (~2.5 GB) in < 5 min on a GPU,
average 2 - 5 min for single drone flight.

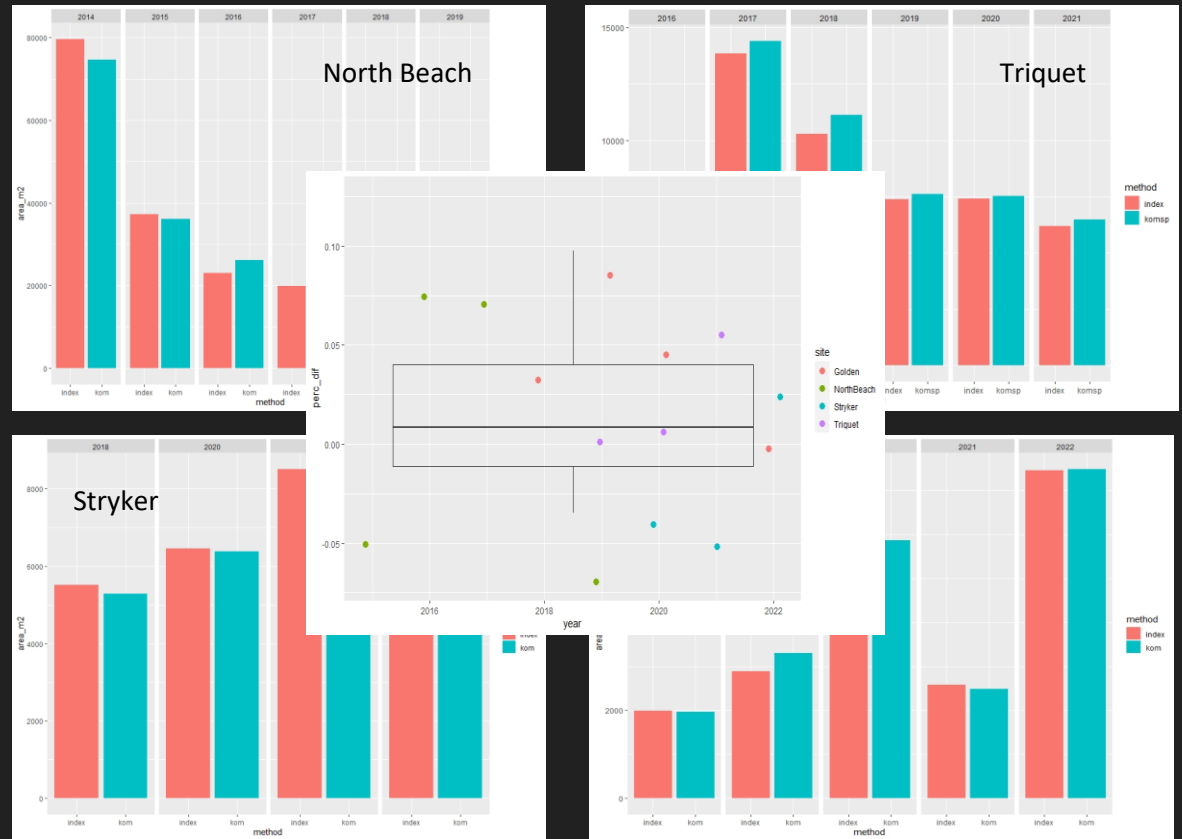


KoM-Index comparison

Compared raw KoM outputs to index-derived (clean) outputs for 4 sites (n=16 comparisons)

- Average ~2.5% overprediction
- Absolute mean dif. In extent mapped was ~4%

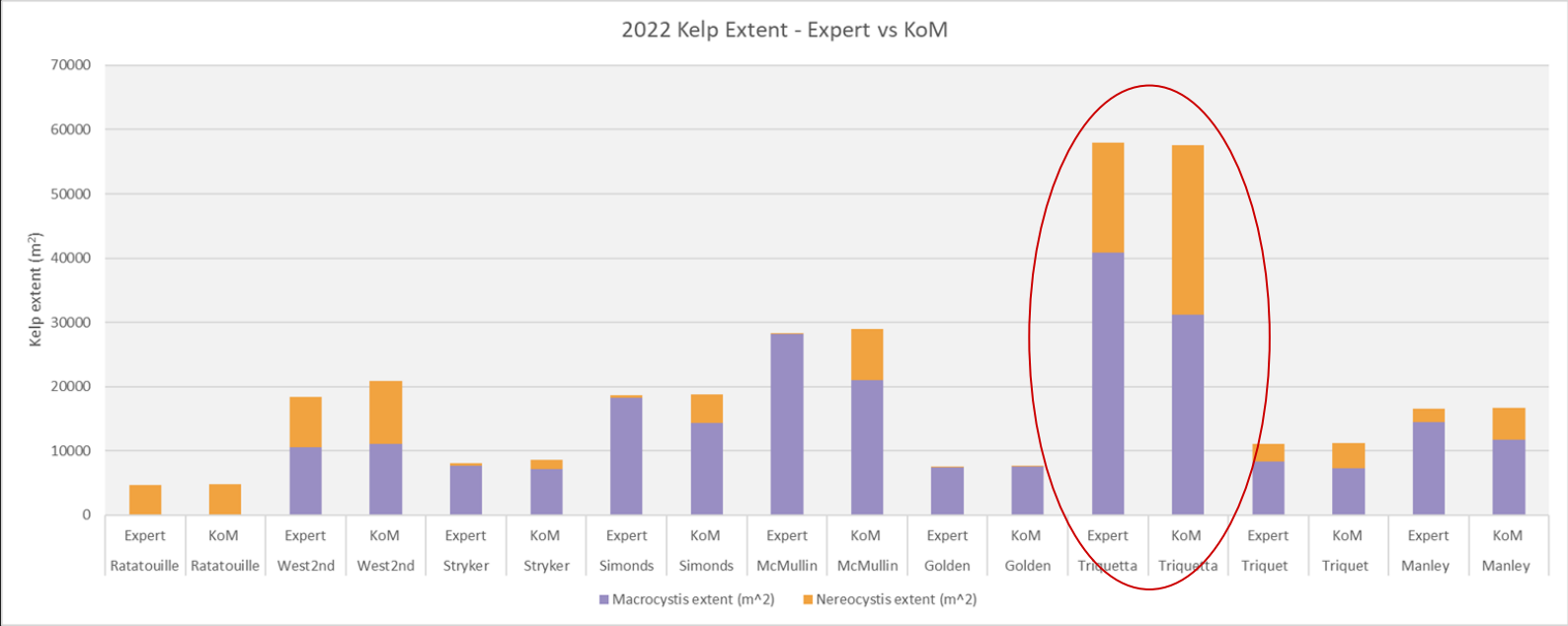
Capture magnitude and direction of trends in kelp forest extent



Results: Species

Quantitative

- **0.76 overall mIoU**
 - **0.71 IoU for macro**
 - **0.59 IoU for nereo**
- **0.85 overall F-score**
 - **0.83 macro**
 - **0.69 nereo**
- **0.99 OA**

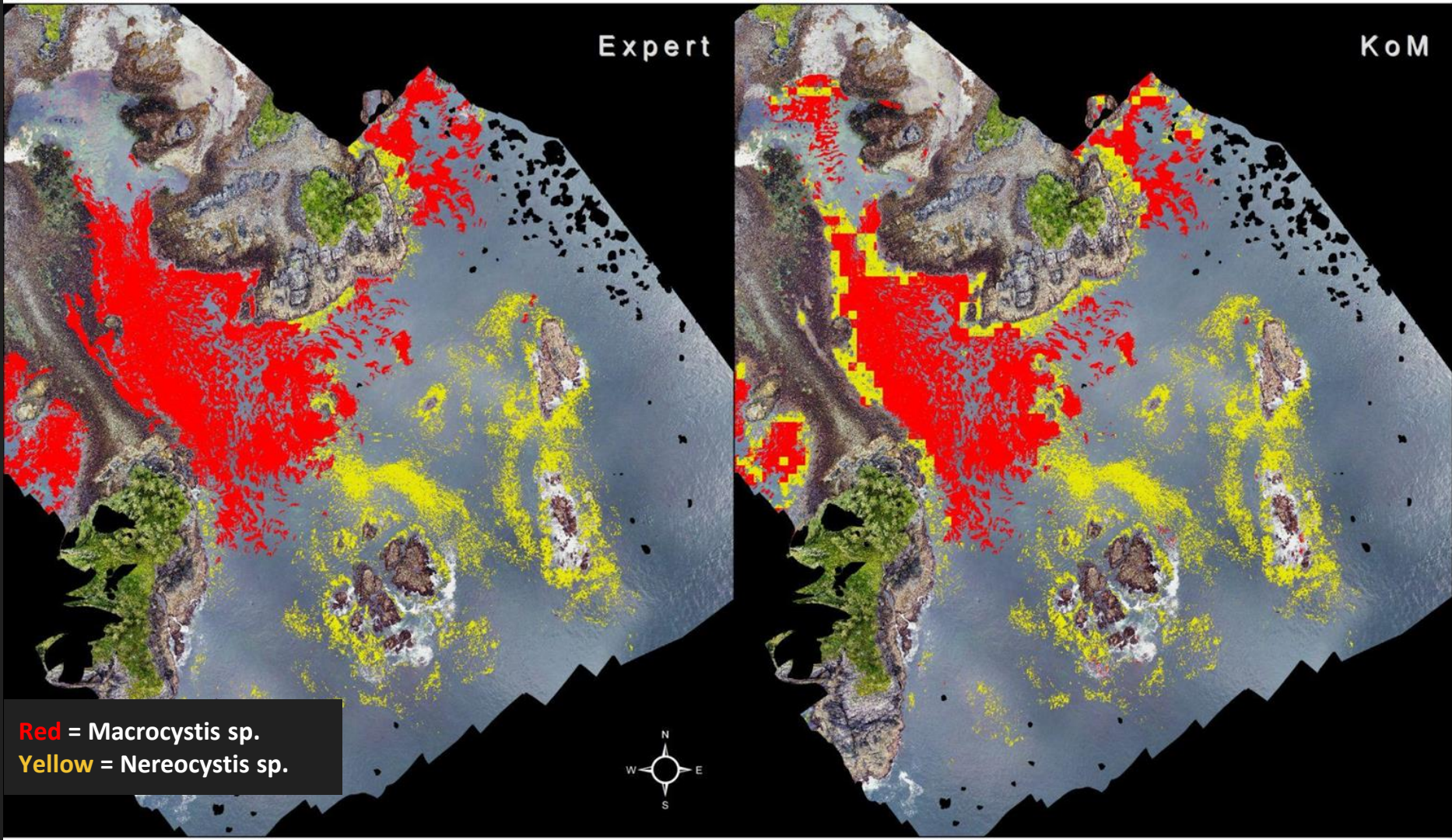


Expert

KoM

Red = *Macrocystis* sp.

Yellow = *Nereocystis* sp.



Using the KoM

- Beginner guide
 - Install Anaconda (Python/R distribution software for package management) and KoM packages
- 1 line of script
 - `kom find-kelp --species input.tif output.tif`
 - 1 = kelp
 - 2 = *Macrocystis pyrifera*
 - 3 = *Nereocystis luetkeana*

```
C:\WINDOWS\system32\cmd.exe - kom find-kelp --species H:\Internal\RS\UAV\Files\Patagonia\Imagery\YendegaiaE3_Orthomosaic_export_SatAug24153848.687001.tif

(DuckKoM) C:\Users\luba.reshitnyk>kom find-kelp --species H:\Internal\RS\UAV\Files\Patagonia\Imagery\YendegaiaE3_Orthomosaic_export_SatAug24153848.687001_komsp_output.tif
C:\Users\luba.reshitnyk\Anaconda3\envs\DuckKoM\lib\site-packages\hakai_segmentation\managers.py:110: UserWarning: Define the cell size raster to speed up processing.
  warnings.warn(
Processing: 37%|██████████| 2650/7140 [02:49<06:03, 12.35it/s]
```

KoM in the field

BC Summer 2022

- Surveyed 16 sites
- Analysis ready species-level data during field work (< 2 weeks)

Northern California

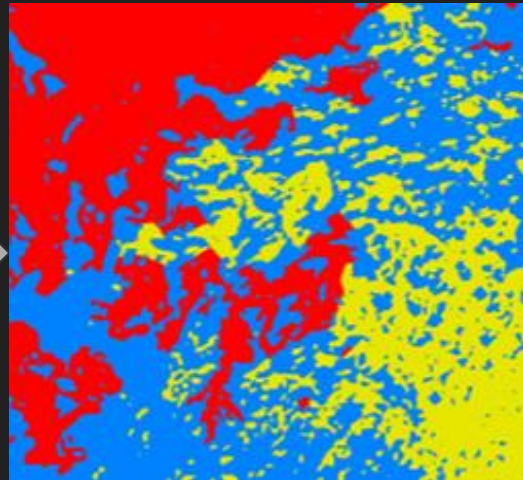
- Conducted surveys at kelp restoration sites in Northern California -> same day results



Objectives

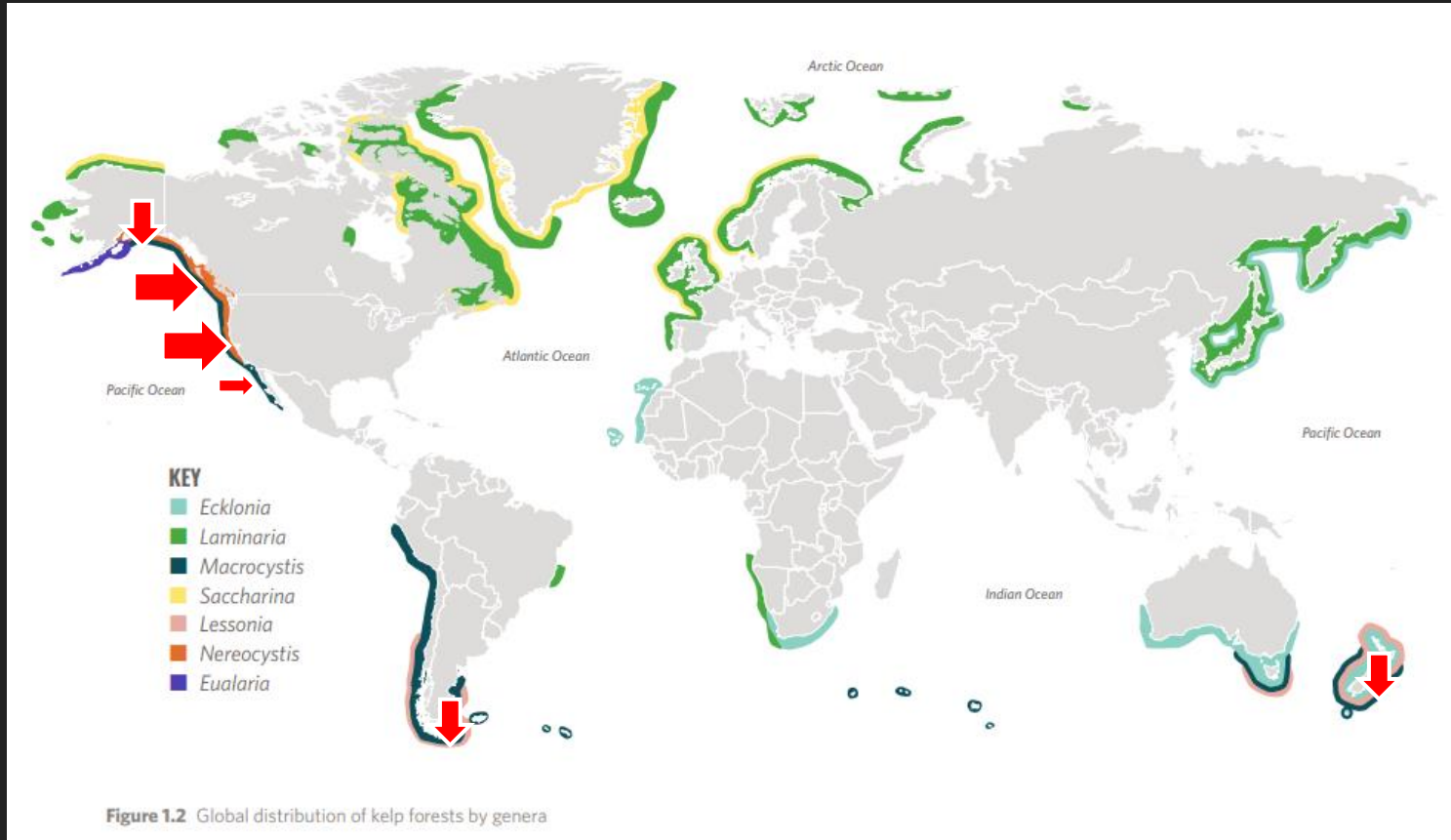
1. KelpOMatic can very accurately detect emergent canopy kelp present in drone imagery
2. KelpOMatic can accurately differentiate between species (*Macrocystis pyrifera* & *Nereocystis luetkeana*) but needs improvement more mixed species scenes
3. KoM is much more efficient compared to index-based methods while achieving very similar results
4. Tool is open source, easy to use

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Drone image



Output:
Classified image
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Blue = not kelp

Where else have we tested the KoM?

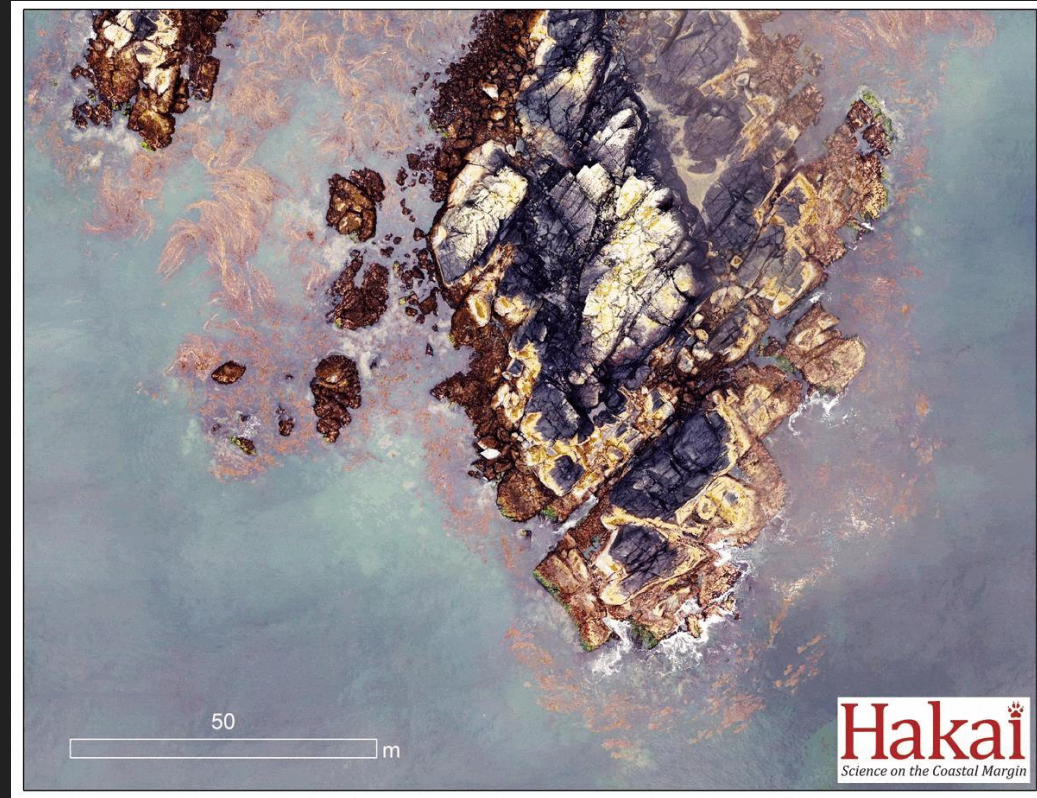


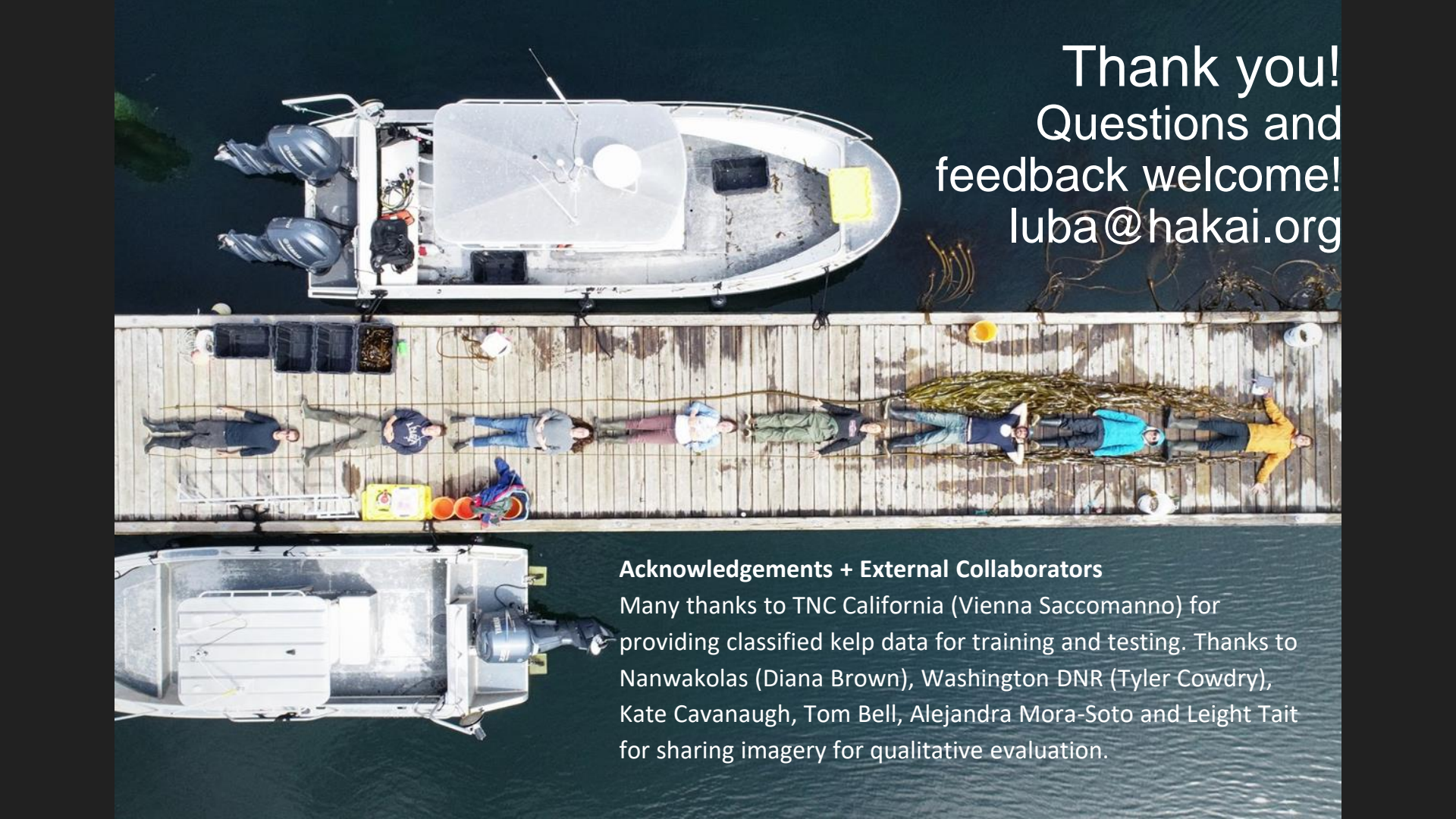
Future work

- Publication in prep
- Consider other CNN architectures
- Include more training data
- Applications to training aerial imagery

Collaborate on expand species and geographic applications!

2023 Kelp Mapper's Meeting - hosted by UVic + Hakai, TNC



An aerial photograph showing a white boat with two outboard motors on the left, a wooden dock in the center, and another white boat on the right. A group of about ten people are standing on the dock. There are various pieces of equipment, including a yellow container, orange buckets, and a large pile of seaweed on the dock. The background is a dark blue body of water.

Thank you!
Questions and
feedback welcome!
luba@hakai.org

Acknowledgements + External Collaborators

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