



Kelson Marine Co.  
2 Portland Fish Pier, Ste. 210  
Portland, Maine, USA 04074

T +1 207-747-2090  
KelsonMarine.com  
Service@KelsonMarine.com

# **De-Risking Investments in Alaskan Aquatic Farming through Validated Regional Ocean and Wave Simulations Integrated with Model-Based Engineering and Techno-Economic Analysis: Interim Report**

September 22, 2025

For: Alaska Fisheries Development Foundation

<b>Version</b>	<b>Date</b>	<b>Originator</b>	<b>Checker</b>	<b>Approver</b>	<b>Description</b>
1.0	9/22/2025	Rickerich, Moscicki, Dewhurst	Dewhurst	Dewhurst	Interim report

### **Information class: Standard**

This document is issued for the party which commissioned it and for specific purposes connected with the specified project. It should not be relied upon by any other party or used for any other purpose.

We accept no responsibility for the consequences of this document being relied upon by any other party, or being used for any other purpose, or containing any error or omission which is due to an error or omission in data supplied to us by other parties.

This document contains confidential information and proprietary intellectual property. It should not be shown to other parties without consent from us or from the party which commissioned it.

## Executive Summary

**WHAT?** Kelson Marine and collaborators are de-risking investments in the Alaskan Mariculture industry by (1) characterizing operational and extreme oceanographic and wave environment conditions in data-sparse regions of the Gulf of Alaska and (2) specifying representative farm designs and the associated cost of production for cultivated seaweeds and oysters.

**WHY?** Alaska presently lacks operational and extreme surface wind, current, wave, and ocean biogeochemistry data at relevant length and time scales for informed use in the Alaskan mariculture industry across sites in Southwest, South Central, and Southeast coastal waters. Furthermore, synthesizing data into meaningful insights requires specialized tools and knowledge and effort. The sparse nature of actionable data in coastal Alaska is hindering quality site selection and reliable gear right-sizing, slowing the growth of safe, economically viable mariculture in the state.

**HOW?** Funded by Alaska Fisheries Development Foundation, Kelson Marine is creating new resources for the Alaskan mariculture industry's site selection and farm design process through the sequential application of validated ocean-wave (regional to coastal scale), hydro-/structural-dynamic (farm scale), and technoeconomic analysis (TEA) modeling methods to generate:

1. Maps and datasets of environmental factors affected mariculture, including (a) typical and extreme 1-hr near surface currents, water levels, wind, wave environments and (b) representative monthly temperature, salinity, turbidity, photosynthetically available radiation, and chlorophyll-a down to the sub-estuary/fjord scale.
2. Component specifications for selected sites through validated hydro-/structural dynamic model-based engineering of select oyster and seaweed cultivation structures.
3. Maps of estimated cost-of-production for seaweed and oysters through TEA as a function of site characteristics.

**WHEN?** These deliverables will be publicly available in reports and web maps by September 2026, providing actionable intelligence to safely accelerate the growth of Alaska's mariculture industry.

## 1 Regional Characterization of Currents, Waves, and Biogeochemistry

Alaska presently lacks operational and extreme surface wind, current, wave, and ocean biogeochemistry data at relevant length and time scales for informed use in the Alaskan mariculture industry across sites in Southwest, South Central, and Southeast coastal waters. Currently, valuable insights into these areas are made available through tools and resources like the AOOS's Mariculture Map, NOAA NCCOOS and BOEM's OceanReports, NOAA NCCOS Aquaculture Opportunity Areas, Greenwave's Regenerative Ocean Farming Hub. However, there exists a lack of comprehensive operational and extreme surface wind, current, wave, and ocean biogeochemistry data at relevant length and time scales for informed use in the Alaskan Mariculture industry across sites in Southwest, South Central, and Southeast coastal waters. Where data does exist, deriving meaningful insights can pose a barrier. A key aspect of this project is working towards breaking down data availability and access barriers to the mariculture industry through the characterization of ocean currents and waves, and biogeochemistry<sup>1</sup> by generating high resolution, high fidelity (a) ocean-wave numerical model hindcast and (b) satellite remote sensing datasets.

The ocean-wave numerical model hindcast is using the Semi-implicit Cross-scale Hydroscience Integrated System Model (SCHISM; Y. Zhang & Baptista, 2008; Y. J. Zhang et al., 2015, 2016) and the Wind Wave Model III (WWM; Roland, 2008) over an unstructured horizontal mesh resolving spatial resolutions on the order of 100 m (farm scale) to 5000 m (open waters) with location specific terrain following vertical sigma coordinates. The SCHISM-WWM model of Gulf of Alaska waters is forced at its boundaries by static bathymetry and time and space varying tidal, ocean, wave, atmospheric, and riverine conditions defined by the best available regional and data products. Internally, the ocean model resolves 3D processes and over time at the resolution of the mesh and parameterizes sub-mesh scale processes (e.g. turbulence, wetting and drying, bottom friction, air-sea exchange). The third-generation spectral wave model captures wind-wave generation, propagation (e.g. nonlinear wave-wave interactions, diffraction), and dissipation (e.g. whitecapping, depth-induced breaking, bottom friction). Ocean and wave model components are two-way coupled—meaning that models exchange information with each other over time to account for dynamic interactions between the wave environment, currents, and water levels.

Separate from ocean-wave numerical modeling in the coastal GOA waters, the characterization of regional ocean surface biogeochemistry facilitated by the processing and synthesis of satellite remote sensing data. In this process, estimates of Chlorophyll-a, Turbidity, Particulate Organic Matter, and Suspended Particulate Matter are derived from Level 1 satellite data through processing with location specific atmospheric correction and masking and parameter specific algorithms. Due to the overpass frequency of satellites, characterization of representative conditions reflects the parameters variability on a monthly timescale.

---

<sup>1</sup> In this context, “biogeochemistry” parameters include temperature, salinity, turbidity, photosynthetically available radiation, and chlorophyll-a.

Estimates of ocean, wave, and atmospheric variables derived from ocean-wave modeling and satellite data analysis are then compared to historical in situ datasets to assess the performance of data generation methods and to correct for bias. Post processing of ocean-wave model and satellite derived data products will yield maps accessible to the Alaskan mariculture industry through web-applications and self-descriptive CF-compliant NetCDF files.

Table 1. Expected High Resolution Maps of Environmental Variables by Statistic

Variable	Operational	Operational Statistic*	Extreme	Extreme Statistic**
Near surface current speed	Yes	1-hr Percentile Value	Yes	1-hr N-year Return Value
Sea surface height	Yes	1-hr Percentile Value	Yes	1-hr N-year Return Value
Significant wave height and associated peak wave period	Yes	1-hr Percentile Value	Yes	1-hr N-year Return Value
10 m wind speed	Yes	1-hr Percentile Value	Yes	1-hr N-year Return Value
Sea surface salinity	Yes	Monthly Climatology	No	N/A
Sea surface temperature	Yes	Monthly Climatology	No	N/A
Chlorophyll-a Concentration	Yes	Monthly Climatology	No	N/A
Photosynthetically Available Radiation	Yes	Monthly Climatology	No	N/A
Turbidity	Yes	Monthly Climatology	No	N/A
Particulate Organic Matter	Yes	Monthly Climatology	No	N/A
Suspended Particulate Matter	Yes	Monthly Climatology	No	N/A

\*e.g. 1<sup>st</sup>, 5<sup>th</sup>, 10<sup>th</sup>, 25<sup>th</sup>, 50<sup>th</sup>, 75<sup>th</sup>, 90<sup>th</sup>, 95<sup>th</sup>, and 99<sup>th</sup> percentile statistics

\*\*e.g. 10-year and 50-year return values derived from Extreme Value Analysis

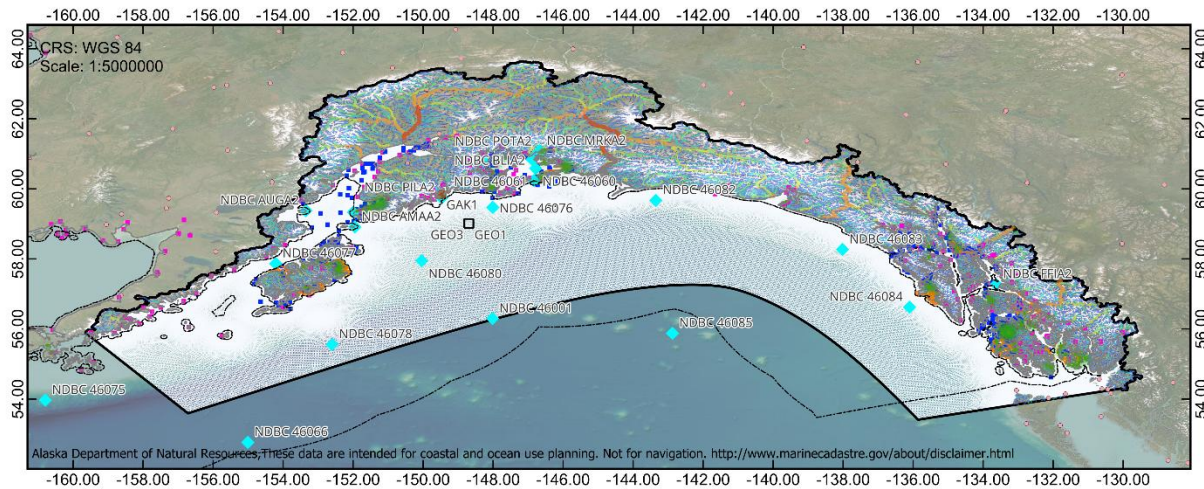


Figure 1. Draft Horizontal Mesh of the GOA Model Composed of Triangular Elements

## Performance Assessment

A critical step in all of Kelson’s model-based processes is validation against real-world data. PWS model performance assessment is facilitated by NOAA COOPS and NDBC in-situ observations shown in Figure 2.



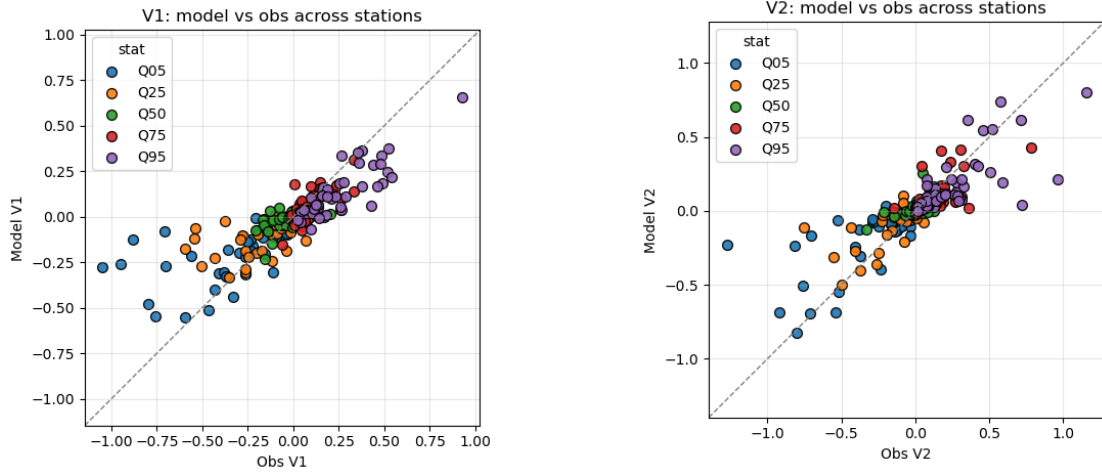


Figure 4: PWS simulated and observed near surface ocean current percentiles for (upper left) eastward velocity, (upper right) northward velocity. Note: observed near surface ocean currents do not overlap in time with simulated currents.

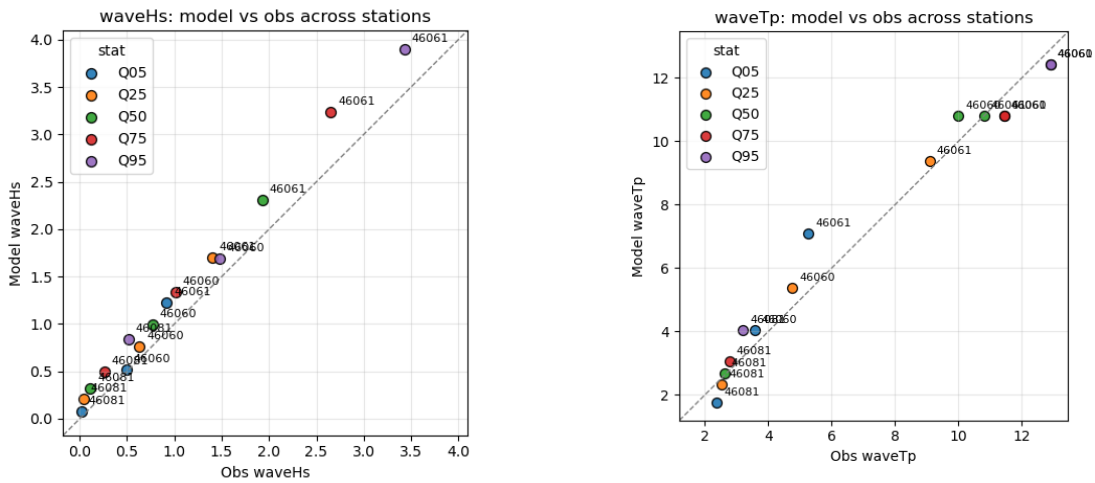


Figure 5: PWS simulated and observed bulk spectral wave parameter percentile statistics; (upper left) significant wave height, (upper right) peak wave period. Note: all observed wave parameters intersect in time with simulated wave parameters.

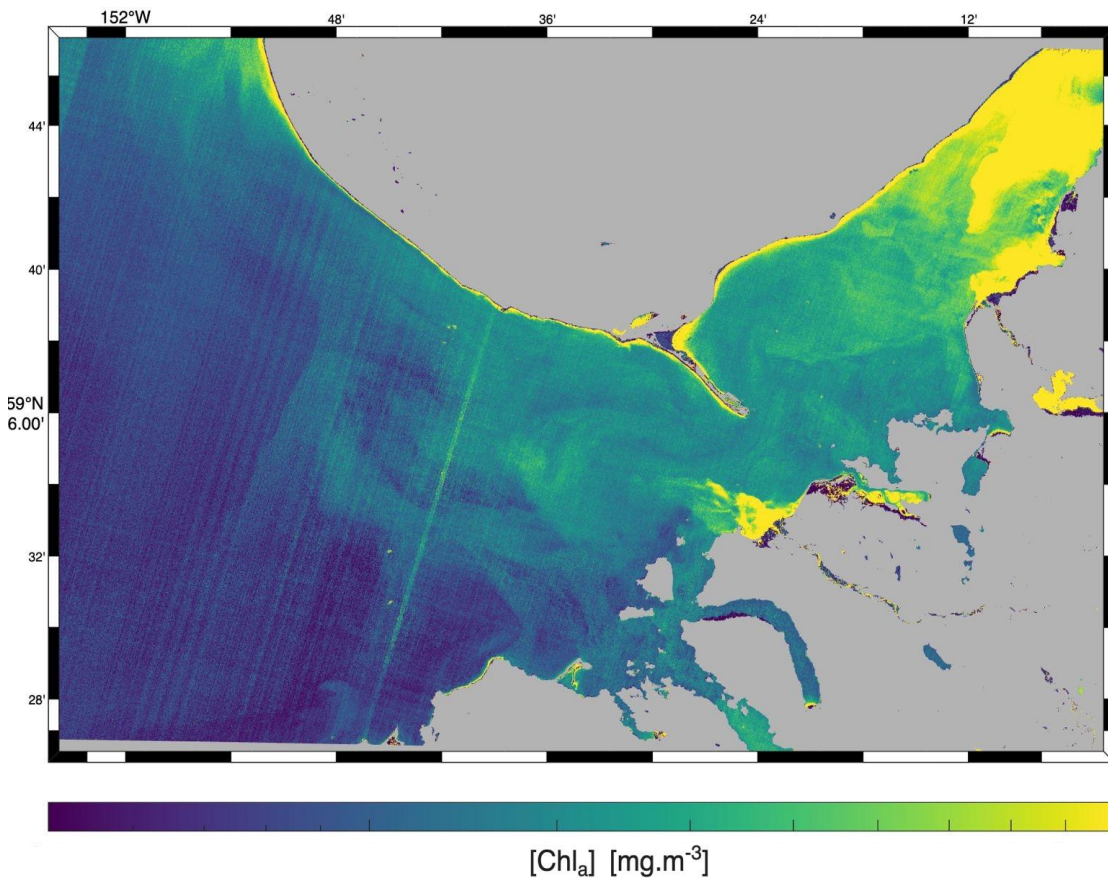
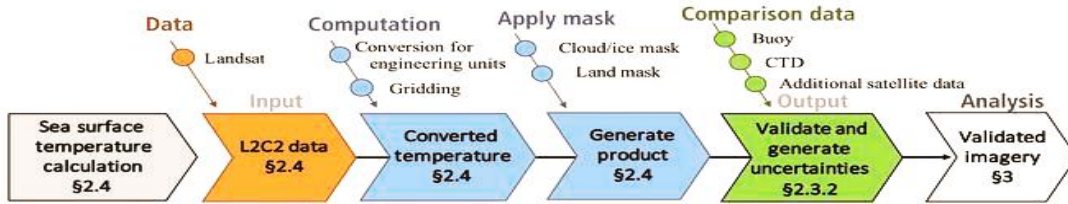
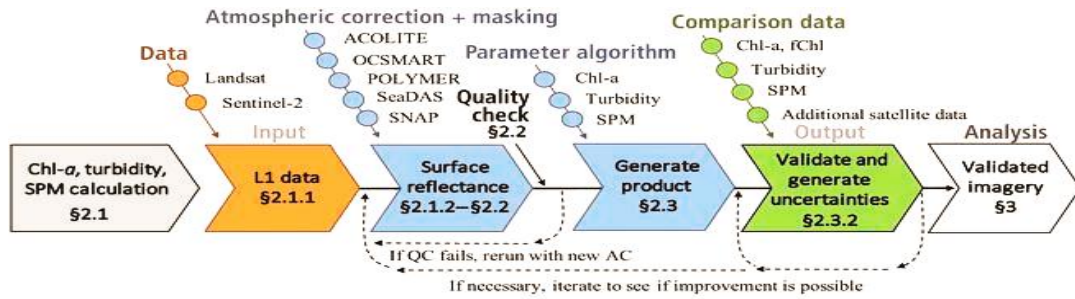


Figure 6: (Top) Process of generating satellite-derived water quality products (Tavora et al. 2023) and (Bottom) example satellite-derived Chl-a concentrations in mg/m<sup>3</sup> over Kechmak Bay.

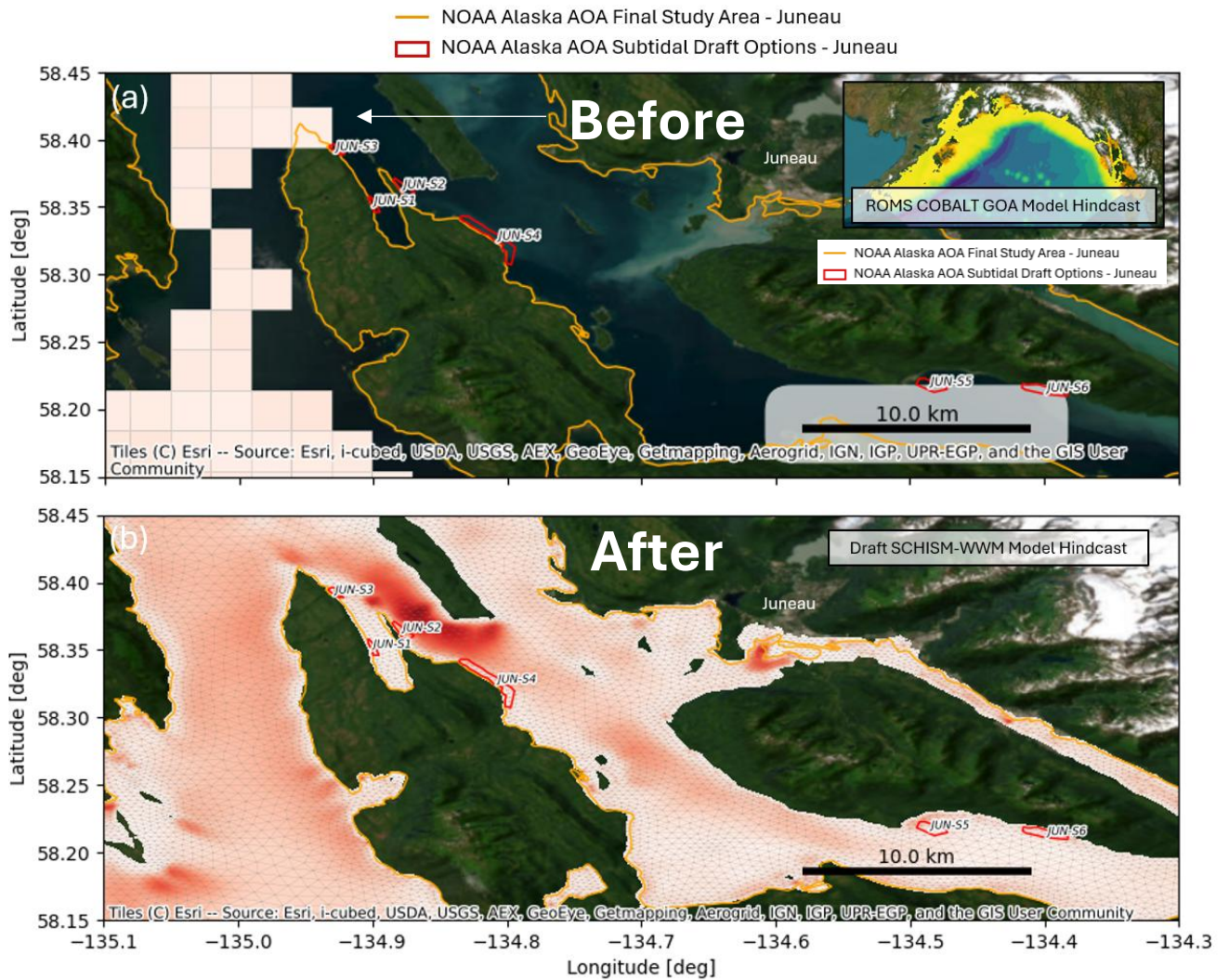


Figure 7. Spatial resolution of (a) existing data and (b) datasets being generated by Kelson Marine in the present project. Juneau, AK with NOAA Alaska draft AOAs. The (a) existing ROMS COBALT GOA Hindcast dataset provides insights into the regional scale dynamics and is not intended to describe nearshore oceanographic processes or variables. (b) Kelson's SCHISM-WWM ocean model provides high-resolution insights for coastal, fjord, and estuarine sites.

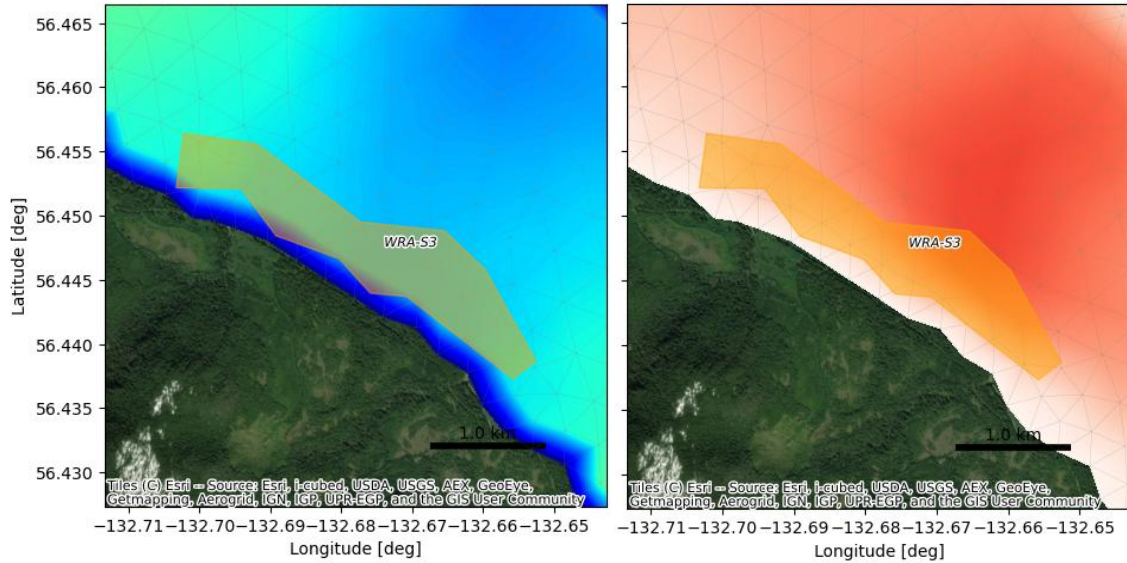


Figure 8. Example Resolution of Metocean Data Map Product: Operational (left) Significant Wave Height and (right) Current Speed near NOAA AOA Draft Subtidal Option Area WRA-S3

## 2 Informing Required Component Specification of Cultivation Structures for Selected Representative Sites

### 2.1 Select Representative and Suitable Sites

Kelson Marine is collaborating with NOAA NCCOS to identify representative and suitable sites. Kelson has advised on qualitative and quantitative input into wave, depth, and exposure parameters that increase a site's suitability for mariculture. NOAA NCCOS is sharing up-to-date revisions of its draft aquaculture opportunity areas, which Kelson is incorporating into its selection of representative sites for its right-sizing analysis. The final selection of representative sites will

combine AOAs, regions with active aquatic farming leases, and input from the project’s Alaskan mariculture industry advisory board.

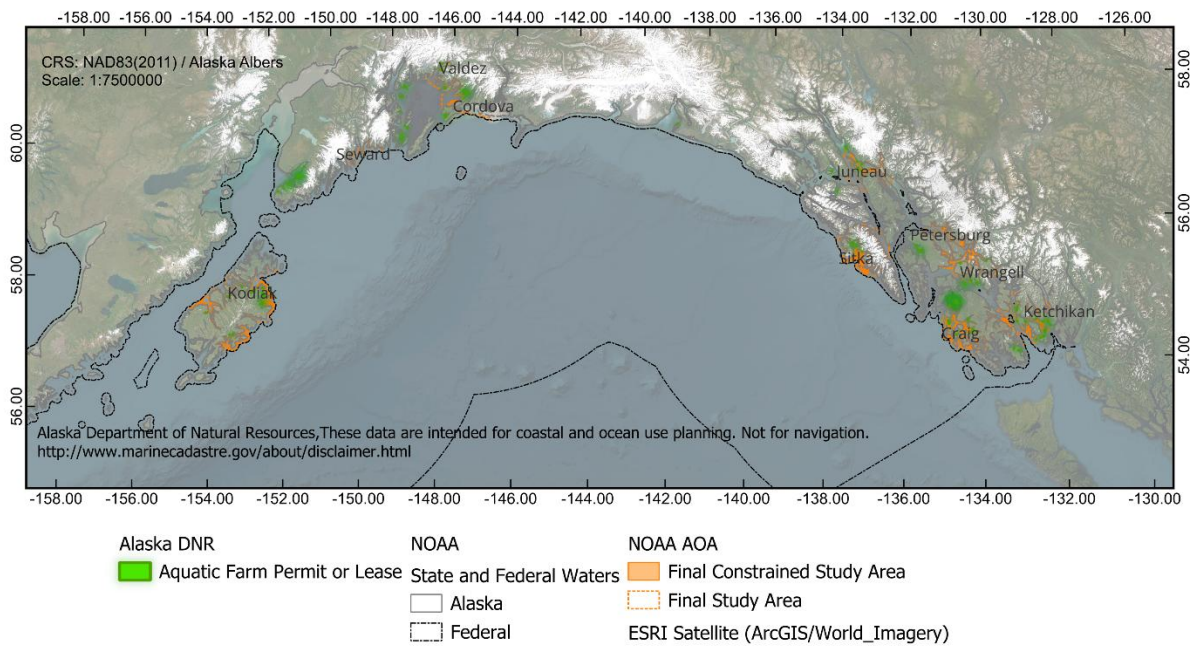
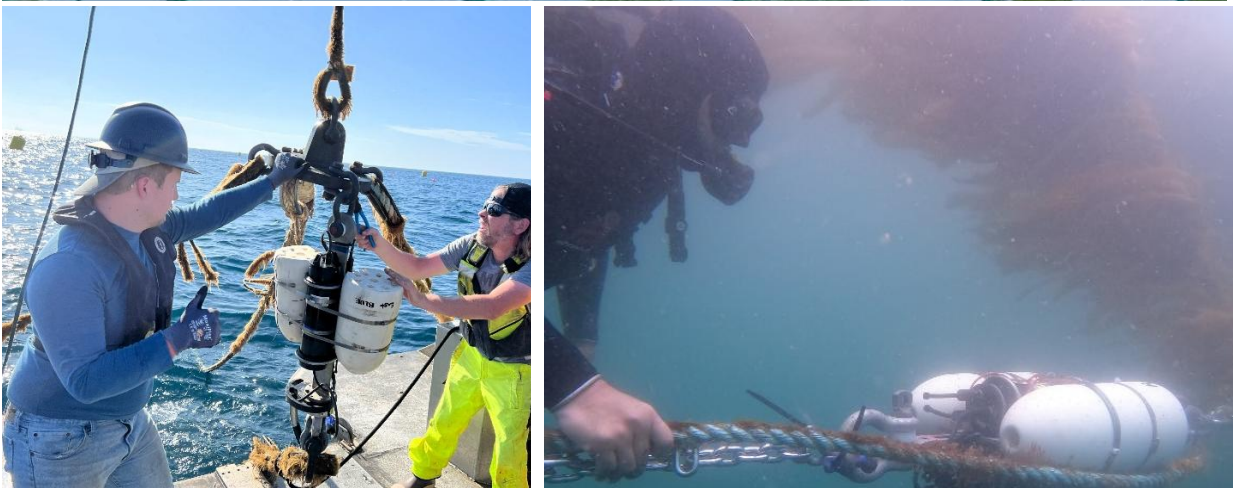
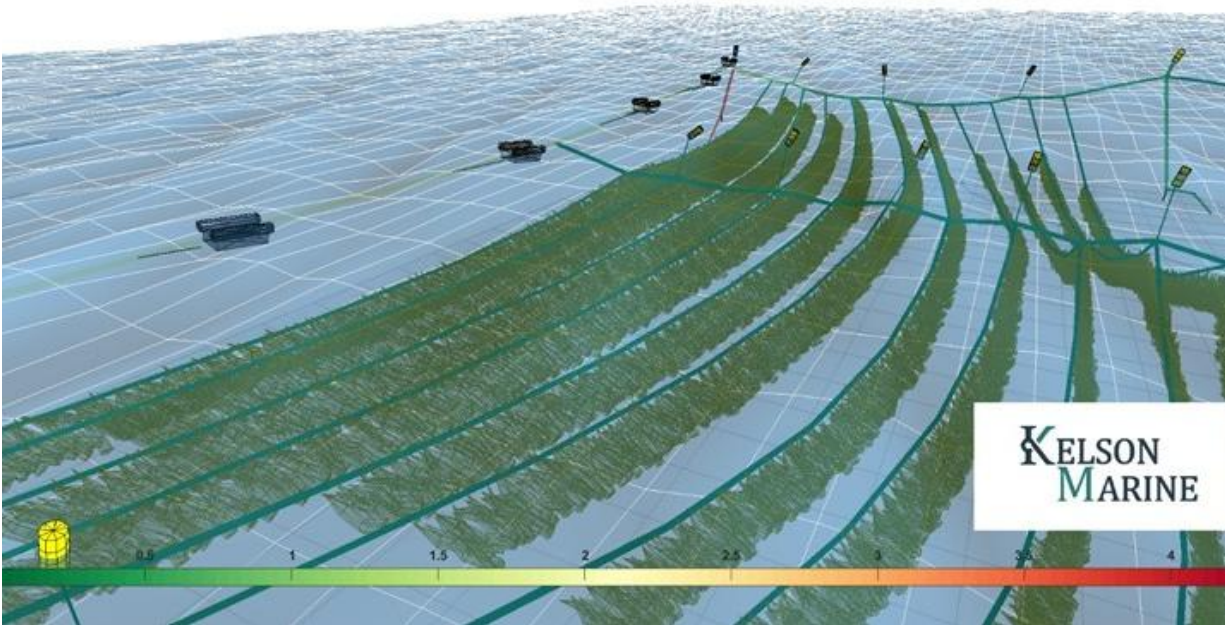


Figure 9. NOAA Alaska AOA data layers in relation to Alaska DNR existing Aquatic Farming Permits or Leases across the GOA.

## 2.2 Right-size Equipment for Selected Sites

Shellfish and seaweed cultivation equipment will be right-sized for the selected sites using the environmental forcing parameters derived under Objective 1 and Kelson’s in-house mariculture engineering tools. For each selected site and species, Kelson is designing multiple farms (i.e. individual longlines and tension-balanced arrays). Kelson has specifically developed and validated engineering tools and methods for accurately and efficiently designing and de-risking large-scale kelp farms for high-energy sites. To quantify the structural response and performance, Kelson is applying its validated dynamic HS-DFEA modeling approach driven by site-specific load cases to quantify the performance of various farm design alternatives and specify the required capacities of the farm mooring components. The Kelson team will translate these HS-DFEA results into material requirements (i.e. diameter, breaking strength, stiffness) for components within the prescribed farm designs for oysters and seaweed at the selected sites of interest. Representative farm sizes are being determined in coordination with the industry advisory board.



*Figure 10. Top: Kelson’s HS-DFEA modeling applied to right-sizing and derisking components of a combined oyster and macroalgae farm in coastal waters. Bottom: These models have been validated against simultaneous measurements of waves and currents and mooring line loads in full-scale ocean farms.*

## 2.3 Map Mariculture Cost of Production

### 2.3.1 Approach

Cost of Production for a given cultivated species is estimated using a comprehensive techno-economic analysis in which key linkages between structure, biological growth and operations are incorporated into a model that resolves implications for the economic “bottom-line”. The model resolves all distinct operational tasks, biological growth, structural components and the relationship between these such that direct structural costs, labor costs, vessel costs, equipment



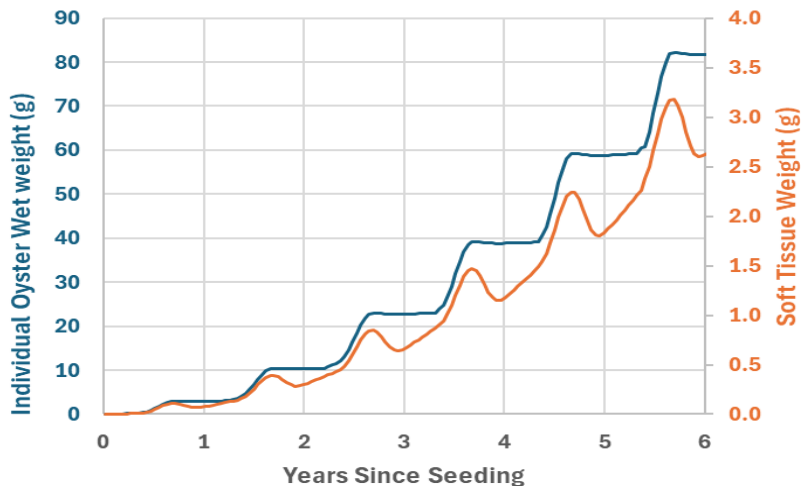


Figure 13. Average weight of an individual oyster introduced to the farm as a 0.09 g seed oyster in January as predicted by the Hawkins et al. growth model. Both the total weight (including soft tissue and shell weight) and the soft tissue weight alone are shown. The wintertime loss in soft tissue weight is apparent.

We resolve daily fresh kelp frond weight as a function of water temperature, current speed, nutrient concentration, and light available to the algae. Kelp yield is then estimated using the expected number of fronds per length of cultivation line.

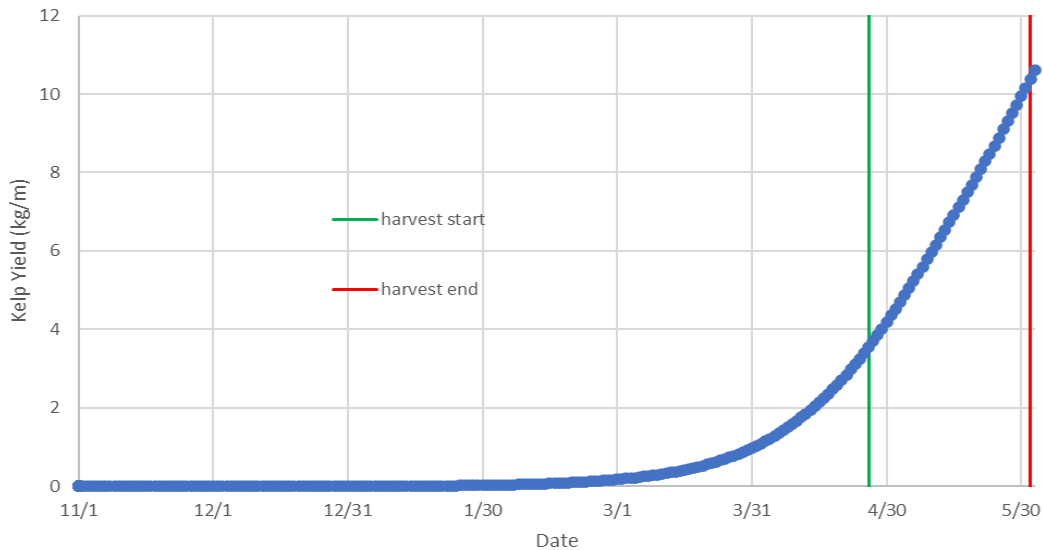


Figure 14. Sugar kelp yield estimated by the growth model as a function of days since seeding for an offshore site assuming typical 175 fronds per meter. The start and end of the typical harvest period is shown. The large difference in yield between the start and end of the harvesting period is evident. This change in yield is accounted for in our operational model, typically wrestling in less overall biomass harvested than if average yield were assumed for all cultivation substrate.

Growth of biofouling organisms is a particular concern for oyster farmers. Growth of unwanted encrusting organisms reduces water flow (and contained food and oxygen) to cultivated oysters, reducing growth, and in some cases lead to significant crop loss. To estimate how often cleaning of oyster cages is needed we estimate biofouling derived mesh occlusion thickness as a function of water temperature and container mesh dimensions and cleaning regimen.

### 2.3.3 Farm structure costs

Annualized cost of farm structural components such as anchors, ropes, chain, floats, cultivation containers or substrate are estimated as a function of component performance (e.g. strength, buoyancy, pressures rating, etc.), and expected lifetime. These requirements are resolved using the engineering procedures described in section 2.2. Self-interaction / tangling is also estimated / quantified using dynamic modelling results in which the structure, biomass and typical metocean characteristics for the site are resolved.

### 2.3.4 Startup Costs

Costs for site characterization, engineering, permitting, assembly and installation are explicitly accounted for based on site characteristics, farm size and structural design.

### 2.3.5 Operating Costs

All operations are resolved in terms of their labor, vessel, land-based infrastructure time and space requirements over the relevant time-frame. Labor and vessel costs are resolved with highest precision since these comprise the majority of operating costs. Operations are resolved as interactions with each component type or cultivated organism during discrete tasks within larger operations including: Assembly, Mooring installation, Cultivation system deployment, Seeding / planting / stocking, Maintenance, Cleaning, Sorting, Harvest, Decommissioning. Husbandry models resolve the required frequency and quantity of key farm tasks as a function of biological growth, cultivation structure characteristics and seasonality.



*Figure 15. Project key personnel Moscicki harvesting sugar kelp *Saccharina latissima* at an experimental deepwater farm for validating growth models.*

### 3 Results Synthesis

To maximize impact and accessibility, Kelson will:

- *Curate Geographic Information System Layers from Metocean Characterization*
- *Develop Webmap Application of Metocean Characterization and Exposure (For a low-resolution example with limited datasets, see <https://www.kelsonmarine.com/resources#exposure-index-calculator>).*
- *Report Objective 2 Findings Visually and in Tabulated Format*

Kelson will make our geographic information system (GIS) layers available to:

1. the **Alaska Ocean Observing System (AOOS)**
2. NOAA's **Marine Cadastre** for use in its **OceanReports** tool
3. Kelson's website for expedited release (**KelsonMarine.com/Resources**).

Furthermore, a public report will be published containing the extreme values, dimensioned drawings, and right-sized gear requirements for the selected representative sites. These deliverables will be publicly available in reports and web maps by September 2026, providing actionable intelligence to safely accelerate the growth of Alaska's mariculture industry.

## 4 References

- Moscicki, Z., St. Gelais, A.T., Coleman, S., Kinley, A., Dewhurst, T., Lindell, S., Fredriksson, D.W. and Brady, D.C., Comprehensive quantification of production costs for large-scale kelp aquaculture and cost reduction opportunities. *Algal Research*. In review
- Roland, A. (2008). *Development of WWM II: Spectral wave modelling on unstructured meshes* [Doctoral dissertation, Ph. D. thesis]. Institute of Hydraulic and Water Resources Engineering.
- Standards Norway. (2022). *NS 9415:2021 (en) Floating aquaculture farms Site survey, design, execution and use* (Issue 1.0, p. 140).
- Zhang, Y., & Baptista, A. M. (2008). SELFE: A semi-implicit Eulerian–Lagrangian finite-element model for cross-scale ocean circulation. *Ocean Modelling*, 21(3), 71–96.  
<https://doi.org/https://doi.org/10.1016/j.ocemod.2007.11.005>
- Zhang, Y. J., Ateljevich, E., Yu, H.-C., Wu, C. H., & Yu, J. C. S. (2015). A new vertical coordinate system for a 3D unstructured-grid model. *Ocean Modelling*, 85, 16–31.  
<https://doi.org/https://doi.org/10.1016/j.ocemod.2014.10.003>
- Zhang, Y. J., Ye, F., Stanev, E. V, & Grashorn, S. (2016). Seamless cross-scale modeling with SCHISM. *Ocean Modelling*, 102, 64–81.  
<https://doi.org/https://doi.org/10.1016/j.ocemod.2016.05.002>