



Spatial assessment of mariculture suitability along Oregon's coast



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Image attributions

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Acronyms

AI	artificial intelligence
AIS	Automatic Identification System
AOA	Aquaculture Opportunity Area
CMECS	Coastal and Marine Ecological Classification Standard
CUDM	Continuously Updated Digital Elevation Model
DEM	digital elevation model
FARM	Farm Aquaculture Resource Management
FVCOM	Finite Volume Community Ocean Model
GIS	geographic information system
LISA	Local Indicators of Spatial Association
MACMODS	MacroAlgal Cultivation MODeling System
MHW	mean high water
MLLW	mean lower low water
NAVD	North American Vertical Datum
NOAA	National Oceanic and Atmospheric Administration
OCMC	Oregon Coastal Mariculture Collaborative
OCMP	Oregon Coastal Management Program
ODA	Oregon Department of Agriculture
ODFW	Oregon Department of Fish and Wildlife
PNNL	Pacific Northwest National Laboratory
ROMS	Regional Ocean Modeling System
SMF	S membership function
SSCOFS	Salish Sea and Columbia River Operational Forecast System
SWAN	Simulating Waves Nearshore
TNC	The Nature Conservancy
TOPSIS	Technique for Order of Preference by Similarity to Ideal Solution
USFWS	U.S. Fish and Wildlife Service
VIIRS	Visible Infrared Imaging Radiometer Suite
WCOFS	West Coast Operational Forecast System
ZMF	Z membership function

1. Introduction

Sustainable growth of marine aquaculture (hereafter mariculture) has increasingly emerged as a priority at both national and state levels (Considine et al., 2023; Ehrhart & Doerr, 2022; National Oceanic and Atmospheric Administration [NOAA], 2021). The development of mariculture—particularly shellfish and seaweed farming—offers a dual opportunity: (1) supporting the recovery and resilience of marine ecosystems through the ecosystem services these species provide and (2) driving economic growth through job creation, the revitalization of working waterfronts, and expanded domestic seafood production and exports (NOAA, 2021; Theuerkauf et al., 2021). These benefits align with current U.S. administration goals to reduce the seafood trade deficit by boosting domestic seafood production (Executive Order No. 14,276, 2025). In Oregon, approximately 90% of seafood is sourced from outside the state (Hurt, 2023). Mariculture presents a compelling opportunity to enhance local seafood self-sufficiency and foster a more sustainable, resilient seafood system (Ehrhart & Doerr, 2022).

Regional marine spatial planning efforts enable a strategic evaluation of mariculture and its relative compatibility with existing and emerging ocean uses (Lester et al., 2018). These efforts are particularly important, as the economic value and ecosystem services of mariculture are increasingly recognized as priorities within the broader framework of blue economic growth (NOAA, 2021). By guiding the responsible siting of mariculture, these planning initiatives help minimize the potential impact of mariculture development on existing coastal ecosystem uses and natural resources—such as reducing habitat conflicts, operational interference, and water quality impacts—thereby contributing to the more balanced and orderly development of mariculture operations (Lester et al., 2018).

Furthermore, recent studies have indicated that well-sited and responsibly managed mariculture operations can generate a wide range of positive ecological interactions at local and ecosystem scales (Alleway et al., 2019; Gentry et al., 2020; Liu et al., 2024; Smaal & Van Duren, 2019). For example, at the ecosystem scale, water filtration by bivalve shellfish or nutrient

removal by seaweed (i.e., macroalgae) could improve water clarity, thereby increasing the overall distribution of submerged aquatic vegetation (Filgueira et al., 2015; Theuerkauf et al., 2021). Importantly, advancing our understanding of how shellfish and seaweed mariculture can be intentionally designed to enhance ecosystem goods and services is critical to achieving integrated ecological, social, and economic objectives of coastal management (Alleway et al., 2019; Chopin & Tacon, 2021).

The Oregon Coastal Mariculture Collaborative (OCMC)—a partnership among Ecotrust, the Oregon Aquaculture Association, the Oregon Kelp Alliance, Oregon Sea Grant, and The Nature Conservancy of Oregon (TNC)—works collectively to advance responsibly sited, restorative mariculture along Oregon's coast by supporting the expansion of native shellfish, seaweed, and aquatic plant cultivation in ways that strengthen ecological, cultural, and economic outcomes. Rooted in a shared vision to increase sustainable seafood and biomass production while delivering ecosystem services such as nutrient removal and habitat enhancement (Alleway et al., 2019; Chopin & Tacon, 2021; Gentry et al., 2017; Theuerkauf et al., 2021), the OCMC is addressing key barriers, particularly the need for rigorous spatial analyses to guide siting decisions identified in TNC's 2023 *Situation Analysis for Oregon's Emergent Seaweed Aquaculture Industry* (Considine et al., 2023). Through coordinated research, stakeholder engagement, and a "learn while doing" approach, the OCMC is building the foundation for an environmentally responsible, community-supported, and economically viable mariculture sector.

1.1. Oregon mariculture context

Commercial in-water mariculture in Oregon state waters currently occurs in six estuaries: Tillamook Bay, Netarts Bay, Yaquina Bay, Umpqua River (aka the Umpqua River and Triangle), Coos Bay, and Port Orford. However, commercial tank mariculture occurs only in Tillamook Bay (Garibaldi) and the Coquille River estuary (Bandon). See Figure 1 and Table 1. These estuarine systems support a diverse but relatively small mariculture industry dominated by oyster farming, with supplemental production of clams, urchins, and seaweeds (Ehrhart & Doerr, 2022).

Figure 1. Overview of commercial mariculture in Oregon based on the Commercial Shellfish Plats 2021 (Oregon Department of Agriculture [ODA], 2021) and known commercial and research tank-based operations for Pacific dulse and purple sea urchins.

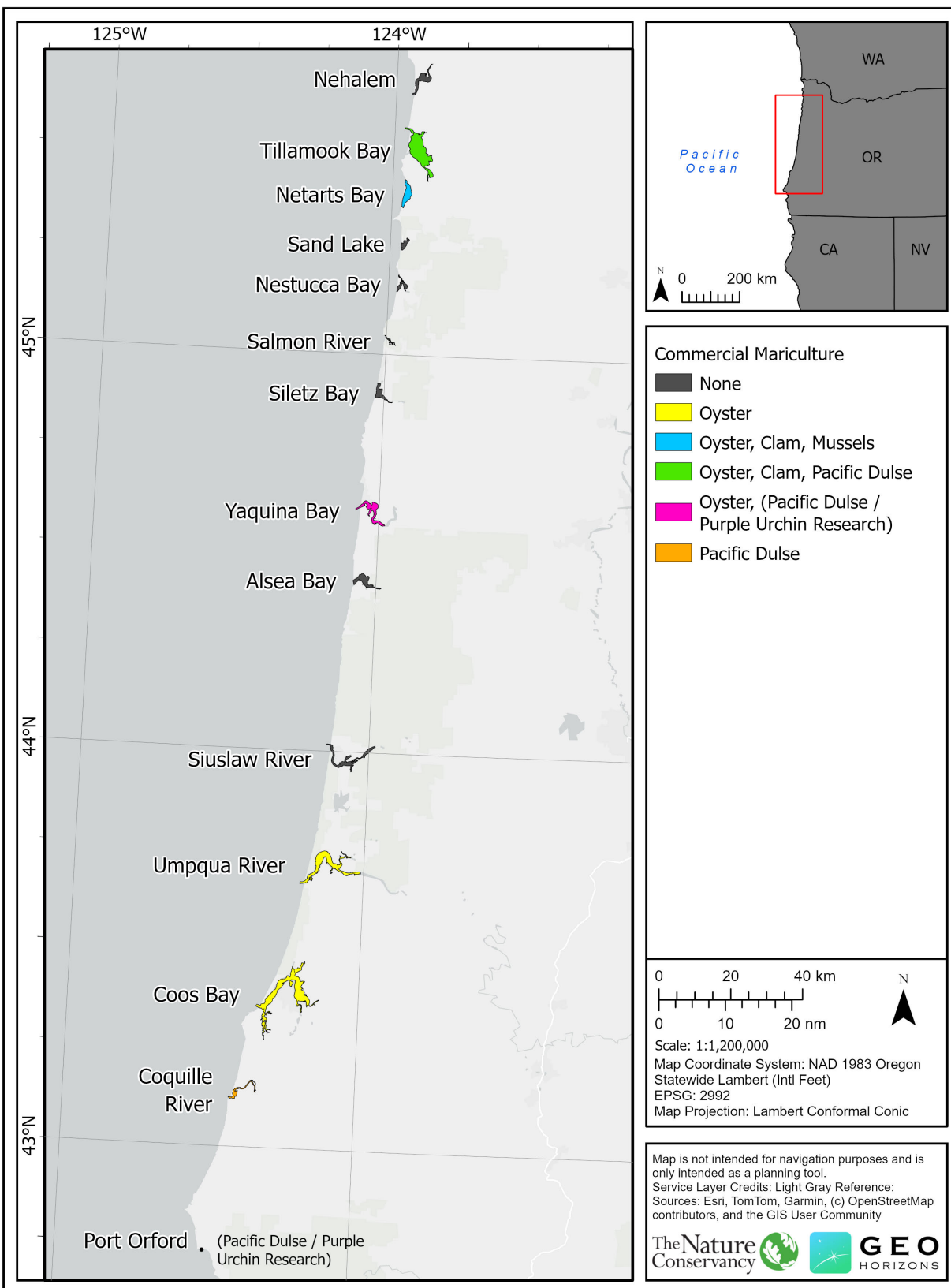


Table 1. Commercial shellfish mariculture for each estuary based on the Commercial Shellfish Plats 2021 (ODA, 2021) and commercial and research tank-based Pacific dulse and urchin mariculture.

Estuary	Mariculture species	Gear
Tillamook Bay	<i>Crassostrea gigas</i> (Pacific oyster)	Bottom or ground culture, trays, stakes, longline, horizontal line, semi-floating, rack, raft
Tillamook Bay	<i>Mercenaria mercenaria</i> (hard clam)	Bottom or ground
Tillamook (Garibaldi)	<i>Devaleraea mollis</i> (syn. <i>Palmaria mollis</i> ; Pacific dulse - commercial)	Tank
Netarts Bay	<i>C. gigas</i> & <i>C. sikamea</i> (oysters)	Bottom, stake, longline, float bags, hatchery
Netarts Bay	<i>Mytilus</i> spp. (mussels)	Longline
Netarts Bay	<i>M. mercenaria</i> (hard clam)	Bottom
Yaquina Bay	<i>C. gigas</i> , <i>Ostrea lurida</i> , <i>C. ariakensis</i> , & <i>C. sikamea</i> (oysters)	Bottom, tray, rack, longline, stake
Yaquina (Newport)	<i>D. mollis</i> (syn. <i>P. mollis</i>) / <i>Strongylocentrotus purpuratus</i> (research co-culture of Pacific dulse and purple sea urchin)	Tank
Umpqua River	<i>C. gigas</i> (Pacific oyster)	Longline, trays, bags, lines
Coos Bay (Upper)	<i>C. gigas</i> (Pacific oyster)	Bottom
Coos Bay (South Slough)	<i>C. gigas</i> (Pacific oyster)	Bottom, stake, longline, raft
Coquille (Bandon)	<i>D. mollis</i> (syn. <i>P. mollis</i> ; Pacific dulse - commercial)	Tank
Port Orford	<i>D. mollis</i> (syn. <i>P. mollis</i>) / <i>S. purpuratus</i> (research co-culture of Pacific dulse and purple sea urchin)	Tank

Note. The listed mariculture species and associated gear may not have been used or may not be actively used.

1.1.1. Oyster species and production methods

Oysters are the backbone of Oregon's mariculture sector. Production primarily involves three species:

Pacific oyster (*Crassostrea gigas*) – By far the most widely farmed species statewide and the cornerstone of Oregon's shellfish aquaculture industry. It was first introduced from Japan in the early 1900s to replace the overharvested native Olympia oyster (*Ostrea lurida*). *C. gigas* dominates commercial leases due to its rapid growth and high salinity tolerance (Barton et al., 2012; Ehrhart & Doerr, 2022).

Kumamoto oyster (*Crassostrea sikamea*) – Cultivated in smaller quantities where its slower growth and deep-cupped shell are valued for premium half-shell markets. It was initially introduced accidentally with *C. gigas* seed

but has become an established niche crop in Oregon and Washington (Hedgecock et al., 1993).

Olympia oyster (*Ostrea lurida*) – Oregon's only native oyster species. Once commercially harvested, it is now the focus of restoration efforts via mariculture methods due to major population declines. Restoration programs led by the Oregon Department of Fish and Wildlife (ODFW) and partners have reestablished small natural populations that contribute to ecosystem services such as filtration and habitat provision (Groth & Rumrill, 2009; Native Olympia Oyster Collaborative, n.d.).

Across estuaries, farmers employ a range of gear types—including bottom culture, trays, stakes, longlines, racks, rafts, and floating bags—tailored to the salinity, sediment, and hydrodynamic conditions of each system.

1.1.2. Seaweed and emerging multitrophic systems

Oregon also hosts four Pacific dulse (*Devaleraea mollis*; syn. *Palmaria mollis*) operations—two commercial (Garibaldi and Bandon) and two research (Newport and Port Orford). They are all conducted in land-based tanks supplied with tidal seawater (Considine et al., 2023). The Pacific dulse *D. mollis* is cultivated for human consumption and specialty applications and is also being used experimentally to feed purple sea urchins (*Strongylocentrotus purpuratus*) in co-culture systems that generate marketable “uni” while contributing to kelp-forest recovery.

No in-water seaweed farms currently operate in Oregon’s marine waters, yet the state’s coastal ecosystems have been identified as a top North American region for restorative aquaculture due to favorable environmental, social, and economic conditions (Theuerkauf et al., 2019). Research and pilot testing are exploring the feasibility of cultivating native kelps such as bull kelp (*Nereocystis luetkeana*), ribbon/winged kelp (*Alaria marginata*), and sugar kelp (*Saccharina latissima*), all of which are well suited to Oregon’s high-energy coastal environment and could enhance biodiversity and carbon sequestration if farmed responsibly (O’Shea et al., 2019; Theuerkauf et al., 2021).

1.2. Project goals and objectives

This project and report support a spatial assessment of estuarine and nearshore coastal ocean areas along the Oregon Coast for potential future seaweed and shellfish mariculture development. Using innovative, peer-reviewed spatial modeling techniques within a hierarchical geographic information system (GIS) framework, the assessment offered a robust evaluation of mariculture opportunities. It accounted for current and competing estuarine and ocean uses, as well as a broad spectrum of environmental and biophysical conditions necessary for the successful siting, operation, and cultivation of new mariculture ventures.

This spatial assessment used a multistage spatial modeling approach (Figure 2) within a study area defined in coordination with the OCMC (Figure 3). First, an Exclusion Model identified and removed from further consideration ocean space incompatible with mariculture

(e.g., maintained channel). Second, an Opportunity Model assessed the feasibility of cultivating various shellfish and seaweed species within the remaining ocean space. Third, a Suitability Model identified optimal locations for specific species based on environmental and operational factors. Finally, a Ranking Model prioritized the top areas for potential development of shellfish and seaweed mariculture. This study has contributed to a broader effort to support and promote the sustainable growth of Oregon’s mariculture industry.

Objectives of this study were to:

- **Identify suitable areas for shellfish and seaweed mariculture** using spatial modeling that accounts for compatibility factors concerning the environment, operation, and use.
- **Support sustainable seafood production** in Oregon by providing sound spatial planning to facilitate the expansion of domestic mariculture.
- **Facilitate the restoration of ecosystem health**, focusing on mariculture species and practices that provide services like nutrient removal, water filtration, and fish and invertebrate habitats.
- **Inform future policy and investment decisions** through science-based, stakeholder-informed spatial analysis to advance resilient coastal economies and ecosystems for Oregon.

Figure 2. Definition of model types used in this spatial analysis.

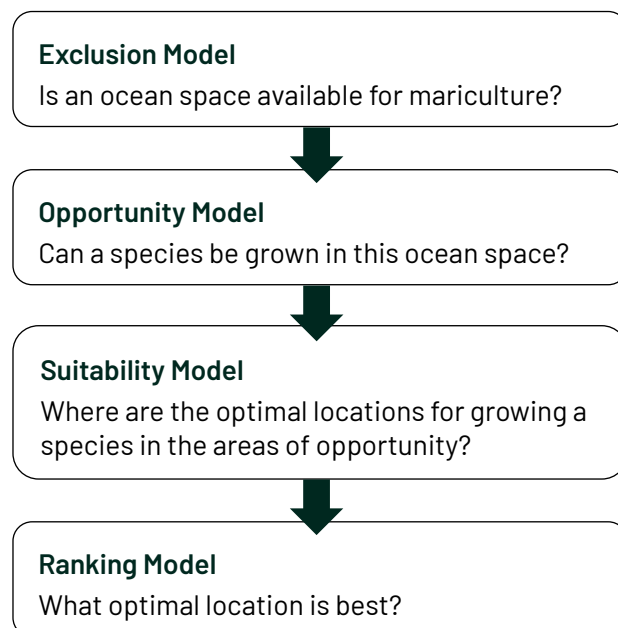
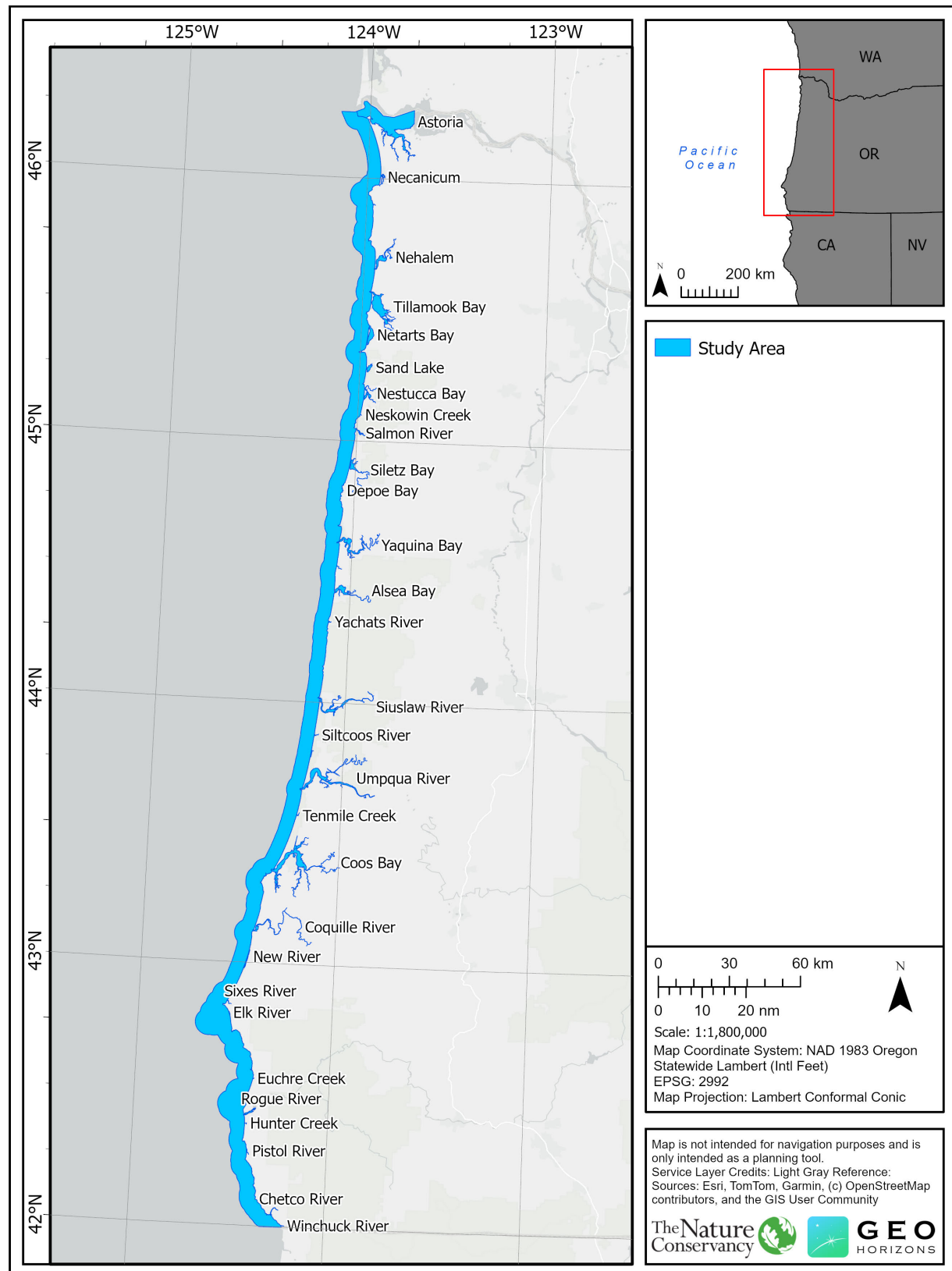


Figure 3. Project study area defined as including estuarine and state coastal ocean waters.



Note. The study area was developed using the Oregon Continually Updated Shoreline Product and the Oregon Coastal Zone Boundary (Oregon GEOHub, 2024a, 2024b).

2. Methods and approach

2.1. Project oversight

TNC and OCMC partners oversaw all work completed under this study; partners included staff from Oregon Sea Grant, Ecotrust, the Oregon Kelp Alliance, and the Oregon Aquaculture Association. Throughout the study, Geo Horizons met regularly with the OCMC Spatial Assessment Advisory Committee (hereafter “Advisory Committee”) to review and discuss all aspects of the methods, including data selection, data scoring, exclusion criteria, modeling framework, submodel layers and scoring, opportunity modeling, and suitability assessments for species and gear combinations. Over 10 meetings were held from November 2024 through 2025 to complete the study.

2.2. Overview

This study utilized the following spatial analytical workflow:

1. Define a focal study area encompassing Oregon’s estuarine and coastal ocean waters.
2. Identify shellfish and seaweed species of interest to be included in the spatial analysis.
3. Acquire, process, organize, and prepare relevant, best available spatial data for the analysis.
4. Develop an Exclusion Model to identify and remove from further consideration ocean space that is incompatible with mariculture (e.g., navigation channels, protected areas).
5. Construct an Opportunity Model to assess the feasibility of cultivating various shellfish and seaweed species in the remaining ocean space.
6. Develop a Suitability Model to identify optimal locations for specific species based on environmental and operational factors, further utilizing a Local Indicators of Spatial Association (LISA) analysis to refine results.
7. Construct a Ranking Model to prioritize the top areas for potential development of shellfish and seaweed mariculture.
8. Interpret and characterize model results to maximize the value of insights gleaned from the spatial analyses.
9. Develop recommendations and study conclusions that translate the study’s findings into actionable information to guide siting and further planning for shellfish and seaweed mariculture.
10. Develop a georeferenced, high-resolution spatial geodatabase with well-documented metadata to support current and future planning needs.

2.3. Study area

The study area (Figure 3) consists of 897,492 ac (3,632.0 km²) of Oregon’s coastal ocean waters (803,612 ac or 3,252.1 km²), including estuarine waters (93,880 ac or 379.9 km²) where data were available. The study area was formed using the Oregon Continually Updated Shoreline Product (Oregon GEOHub, 2024b) and the Oregon Coastal Zone Boundary (Oregon GEOHub, 2024a) to create a shapefile for subsequent analyses. Due to the different gear types, logistical considerations, data availability, and species tolerances in coastal ocean versus estuarine waters, two subareas (Coastal and Estuary) were developed within the study area for subsequent analysis. In addition, coastal ocean zones were developed using Thiessen polygons of port or estuary inlets with active fishing ports and infrastructure (Figure 4). The coastal ocean zones were used to summarize results in the Coastal subarea, while the individual estuaries were used to summarize results in the Estuary subarea.

2.4. Candidate shellfish and seaweed species selection

In coordination with the Advisory Committee, priority shellfish and seaweed species were identified for spatial analyses (Table 2). These included species currently cultivated in Oregon waters or considered for future cultivation. Non-native species such as the Pacific oyster (*C. gigas*), though widely farmed, were excluded. Purple laver (*Porphyra* spp.) and sea cabbage/sweet kombu (*Hedophyllum sessile*) were identified as priority species but could not be modeled due to insufficient data on environmental tolerances. Giant kelp (*Macrocystis pyrifera*; syn. *M. integrifolia*)—not considered a priority by the Committee—was modeled because adequate tolerance data were

available. Additionally, given the high uncertainty and data limitations within estuarine environments, a species-specific kelp model was infeasible. Instead, a generalized “kelp species” model was developed using representative environmental tolerance values applicable across multiple kelp taxa.

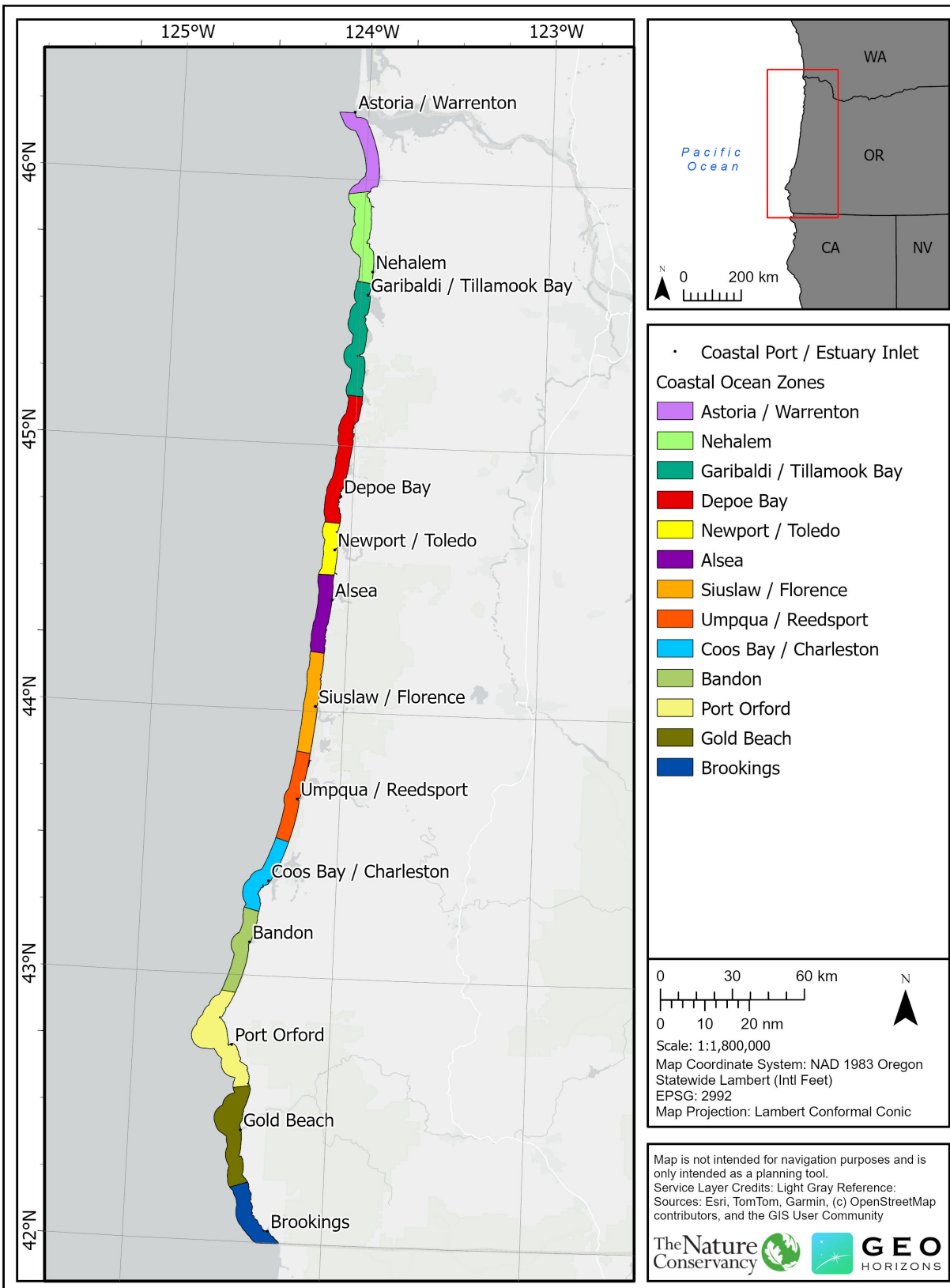
The analysis included commonly used cultivation gear associated with shellfish and seaweed mariculture. Given species diversity, site conditions, and localized operational practices, gear was represented using generalized categories: subtidal gear (floating or suspended cultivation systems deployed below

the water surface), tank culture (land-based mariculture operations using tanks), line or raft culture (floating rafts with vertically suspended lines), line culture systems, and planted-on-bottom approaches, in which seaweed are affixed to natural or artificial substrates and allowed to grow in situ for commercial cultivation or restoration purposes. Various intertidal gears are commonly used for oyster mariculture; due to high uncertainty in the intertidal zone caused by the dynamic nature of estuaries, all specific gear types were included under the term “subtidal” for this study.

Table 2. Mariculture species and associated gear evaluated.

Study area	Species	Gear
Estuary	Olympia oyster (<i>Ostrea lurida</i>)	Subtidal gear
Estuary	Purple sea urchin (<i>Strongylocentrotus purpuratus</i>)	Tank culture
Estuary	Pacific blue mussel (<i>Mytilus trossulus</i>)	Line culture
Estuary	Pacific dulse (<i>Devaleraea mollis</i> ; syn. <i>Palmaria mollis</i>)	Tank culture
Estuary	Kelp species	Line culture
Coastal	Red abalone or flat abalone (<i>Haliotis rufescens</i> or <i>H. walallensis</i>)	Tank culture
Coastal	Pacific blue mussel (<i>M. trossulus</i>)	Line culture
Coastal	California mussel (<i>Mytilus californianus</i>)	Line culture
Coastal	Bull kelp (<i>Nereocystis luetkeana</i>)	Line culture
Coastal	Bull kelp (<i>N. luetkeana</i>)	Planted on bottom
Coastal	Sugar kelp (<i>Saccharina latissima</i>)	Line culture
Coastal	Ribbon/winged kelp (<i>Alaria marginata</i>)	Line culture
Coastal	Giant kelp (<i>Macrocystis pyrifera</i> ; syn. <i>M. integrifolia</i>)	Line culture

Figure 4. Coastal ocean zones created using Thiessen polygons of port or estuary inlets with active fishing ports and infrastructure along the Oregon Coast.



Note. These zones were used to summarize results.

2.5. Data acquisition, processing, organization, and preparation

Geospatial analysis and marine spatial planning require the acquisition and balanced consideration of multiple, often disparate datasets (Longdill et al., 2008). Acquisition of the best available spatial data representing key factors (e.g., vessel traffic, sensitive habitats, biophysical conditions that control productivity) is an essential underpinning of effective spatial analysis. Data categorization and schemas are often used to organize relationships among groups of data for suitability modeling (Lightsom et al., 2015).

For this study, data were discovered and acquired from a variety of publicly available sources presented in Table 3, with some data provided by the Advisory Committee. Spatial data were organized into general categories and were reviewed by the Advisory Committee. All spatial data used were projected using the Oregon-state standard, Oregon Lambert Projected Coordinate System (EPSG:2992), as described by Oregon Geospatial Enterprise

Operations (n.d.). The best available data (i.e., most complete, highest-resolution) were prioritized for use in subsequent spatial analyses. Notably, several datasets representing the best available data had important limitations, as discussed further within Section 4, [Caveats, Limitations, and Discussion](#).

After preparing all relevant data for modeling, select datasets were used in the subsequent spatial analyses. Table 4 provides an overview of the datasets used in the Opportunity Models developed as part of this study. As described further in the following sections, certain data (e.g., logistics factors like the presence of shellfish distributors, cold storage, and seafood processors) were used in later stages of the spatial analysis (e.g., Suitability and Ranking Models) to further narrow down to the most suitable areas. Many of these data added value in characterizing and providing fine-level detail for each area identified as optimal by the Ranking Model.

Multiple geodatabases were created to organize all spatial data used for this study. See [Appendix A](#) for a complete list of the data reviewed for this study.

Table 3. Online resources and repositories where data were acquired.

Online resource	URL	Description
Bio-ORACLE	www.bio-oracle.org	Global environmental datasets (e.g., temperature, salinity, chlorophyll) designed for species distribution and marine ecological modeling.
Kelpwatch	kelpwatch.org	Monitoring platform providing satellite-derived kelp canopy extent and trends along the U.S. West Coast.
Marine Cadastre	hub.marinecadastre.gov	Federal geospatial data on ocean uses, boundaries, energy siting, and marine planning.
National Oceanic and Atmospheric Administration (NOAA) National Centers for Environmental Information	www.ncei.noaa.gov	Comprehensive archive of oceanographic, atmospheric, and geophysical data.
NOAA Tides and Currents	tidesandcurrents.noaa.gov	Tide, current, and sea level observations, forecasts, and modeling products.
Oregon GEOHub	geohub.oregon.gov	Statewide geospatial data portal, including shoreline, land use, and coastal boundary datasets.

Online resource	URL	Description
Oregon Explorer	hub.oregonexplorer.info	Natural resource and land use information portal with regional and statewide datasets.
Oregon Seafood Prospector	storymaps.arcgis.com/stories/49730646c69c4cecae4b7dc4aaf09b31	Interactive tool for exploring seafood industry and mariculture siting information in Oregon.
OROWindMap	offshorewind.westcoastoceans.org/visualize	Offshore wind energy data viewer with environmental, ocean use, and planning layers.
Pacific Marine & Estuarine Fish Habitat Partnership	www.pacificfishhabitat.org	Habitat data, maps, and regional assessments for estuarine and nearshore fish habitats on the U.S. West Coast.

Table 4. Summary of datasets for the Biophysical variable used within the Opportunity and Suitability Models, with the associated spatial resolution, dataset source, and link to the dataset.

Model	Variable	Resolution	Source	URLs to data
All	Water Temperature	Variable / ~5 km	NOAA Salish Sea and Columbia River Operational Forecast System (SSCOFS) / West Coast Operational Forecast System (WCOFS)	tidesandcurrents.noaa.gov/ofs/dev/sscofs/sscofs_info.html tidesandcurrents.noaa.gov/ofs/dev/wcofs/wcofs.html
All	Digital Elevation Models (DEMs)	3–10 m	NOAA	www.ncei.noaa.gov/maps/bathymetry
Coastal and Estuary	Current Speed	Variable / ~5 km	NOAA SSCOFS / WCOFS	tidesandcurrents.noaa.gov/ofs/dev/sscofs/sscofs_info.html tidesandcurrents.noaa.gov/ofs/dev/wcofs/wcofs.html
Coastal	Salinity	Variable / ~5 km	NOAA SSCOFS / WCOFS	tidesandcurrents.noaa.gov/ofs/dev/sscofs/sscofs_info.html tidesandcurrents.noaa.gov/ofs/dev/wcofs/wcofs.html
Coastal	Significant Wave Height	Variable	Pacific Northwest National Laboratory (PNNL)	Contact PNNL
Coastal	Light Availability	750 m	NOAA Visible Infrared Imaging Radiometer Suite (VIIRS)	coastwatch.noaa.gov/erddap/griddap/noaacwnppVIIRSkdPARSectorWZDaily.html
Coastal	Nitrate Concentration	~4 km	Bio-Oracle	bio-oracle.org/downloads-to-email.php
Coastal	Phosphate Concentration	~4 km	Bio-Oracle	bio-oracle.org/downloads-to-email.php
Coastal	Iron Concentration	~4 km	Bio-Oracle	bio-oracle.org/downloads-to-email.php

2.5.1. Data processing and preparation

While many datasets were incorporated directly into the analyses without modification, several required additional processing to ensure compatibility with the modeling frameworks. For these datasets, we summarize below the key steps undertaken to transform them into formats suitable for analysis and provide some additional rationale. [Appendix A](#) has all datasets with links or information on the data source.

2.5.2. Physical environment

Bathymetry

Multiple bathymetric digital elevation models (DEMs) were integrated and used, including 1/9 arc-second (~3 m) Continuously Updated Digital Elevation Models (CUDEMs) and 1/3 arc-second (~10 m) DEMs (Table 5). Each DEM's vertical datum was referenced to mean lower low water (MLLW)—the assumed start of the subtidal zone—using NOAA's VDatum software (vdatum.noaa.gov). Where datasets overlapped, the higher-resolution DEM was retained.

Table 5. Bathymetry datasets with links to data used in this study.

Bathymetry dataset	URL to data
Astoria, Oregon 1/3 arc-second MHW [Mean High Water] Coastal Digital Elevation Model	www.ncei.noaa.gov/access/metadata/landing-page/bin/iso?id=gov.noaa.ngdc.mgg.dem:5490
Central Oregon Coastal Digital Elevation Model NAVD 88 [North American Vertical Datum 88]	www.ncei.noaa.gov/metadata/geoportal/rest/metadata/item/gov.noaa.ngdc.mgg.dem:11500/html
Continuously Updated Digital Elevation Model (CUDEM) - 1/9 arc-second Resolution Bathymetric-Topographic Tiles	www.ncei.noaa.gov/maps/bathymetry/
Crescent City, California 1/3 arc-second MHW Coastal Digital Elevation Model	www.ncei.noaa.gov/metadata/geoportal/rest/metadata/item/gov.noaa.ngdc.mgg.dem:693/html
Garibaldi, Oregon 1/3 arc-second MHW Coastal Digital Elevation Model	www.ncei.noaa.gov/metadata/geoportal/rest/metadata/item/gov.noaa.ngdc.mgg.dem:4752/html
Port Orford, Oregon 1/3 arc-second MHW Coastal Digital Elevation Model	www.ncei.noaa.gov/metadata/geoportal/rest/metadata/item/gov.noaa.ngdc.mgg.dem:410/html

Current speed

The Salish Sea and Columbia River Operational Forecast System (SSCOFS) and the West Coast Operational Forecast System (WCOFS) were used to estimate current speed. Data from February 16, 2024, through February 28, 2025 (379 days) were downloaded and processed from both models. The higher-resolution SSCOFS model (Finite Volume Community Ocean Model [FVCOM]) covered only the northern portion of the Oregon Coast; therefore, the lower-resolution WCOFS model (Regional Ocean Modeling System [ROMS]) was applied to the southern portion. Hourly *u* (east–west) and *v* (north–south) surface vectors were used to calculate current speed. In areas of overlap between the two models, the higher-resolution SSCOFS outputs were prioritized. For all estuaries south of Alsea, where no high-

resolution hydrodynamic models were available, current speeds were assumed to be suitable.

Wave climate / site accessibility

Simulating Waves Nearshore (SWAN) model outputs, providing hourly significant wave height data, were obtained from the Pacific Northwest National Laboratory (PNNL) and the National Renewable Energy Laboratory. These data were used to estimate the frequency of site accessibility across locations. Instead of relying on the maximum significant wave height from the 2011–2020 time series, we developed a climatology centered on accessibility. For each data point, we calculated the number of days when the maximum significant wave height was less than or equal to 2 m. Locations with a greater

number of such days were considered more accessible than those with fewer.

Light availability

Light availability at 1 m in depth was derived from KdPAR estimates based on satellite observations from NOAA's Visible Infrared Imaging Radiometer Suite (VIIRS). The dataset represents a 14-year average (2009–2023) at a 750-m spatial resolution. Monthly values were calculated as the average of daily maximum light availability, corresponding to peak solar radiation hours (typically between 12:00 and 14:00 local time). Results were reported as average photosynthetically active radiation ($\mu\text{E m}^{-2} \text{s}^{-1}$) at 1 m in depth.

Temperature

SSCOFS and WCOFS were used to obtain water temperature data. Data from February 16, 2024, through February 28, 2025 (379 days) were downloaded and processed for both models. The higher-resolution SSCOFS model (FVCOM) covered only the northern half of the Oregon Coast; therefore, the lower-resolution WCOFS model (ROMS) was applied to the southern half. Hourly surface water temperature values were extracted, and daily maximum and minimum temperatures were summarized for each data point. For estuaries south of Alsea, where no high-resolution hydrodynamic models were available, water temperatures were assumed to be suitable.

Salinity

SSCOFS and WCOFS were used for salinity. Data from February 16, 2024, through February 28, 2025 (379 days) were downloaded and processed for both models. However, accurate high-resolution salinity data with sufficient temporal and spatial coverage were unavailable for most estuaries. Where SSCOFS salinity outputs were available, they did not

incorporate freshwater inputs and therefore did not adequately represent observed conditions (NOAA, n.d.). To address this gap, we used NOAA's Estuarine Salinity Zones dataset (Nelson, 2015) and the State of Oregon's salinity maps (Oregon Department of State Lands, n.d.). These products delineate three salinity zones: seawater (≥ 25 ppt), mixing (0.5–25 ppt), and tidal fresh (0–0.5 ppt), which were used to estimate opportunity for all Estuary models (Figure 5 and Figure 6).

Nutrients

Nutrient data were obtained from the Bio-ORACLE database and included surface nitrate (annual minimum), surface phosphate (annual mean), and surface iron (annual mean). Values represent the 2010–2020 climatology and were used in this analysis (Assis et al., 2024). The Advisory Committee recommended using the minimum value for nitrate.

2.5.3. Biological resources

Combined kelp distribution

Grid-based data representing the extent of kelp presence from Kelpwatch (Bell et al., 2025) were converted to polygons and merged with ODFW kelp canopy data to create a dataset reflecting the combined maximum extent of kelp. This maximum extent was used instead of the current presence to avoid excluding areas suitable for kelp restoration where kelp has historically occurred.

Pinniped haul-outs

Survey data for California sea lions (*Zalophus californianus*) and Pacific harbor seals (*Phoca vitulina richardii*) were used to identify pinniped haul-out sites. Any survey track where individuals of either species were observed was classified as an active haul-out location.

Figure 5. NOAA's Estuarine Salinity Zones (Nelson, 2015) and digitized salinity zones from the Oregon Department of State Lands (n.d.) for northern estuaries along Oregon's coast.

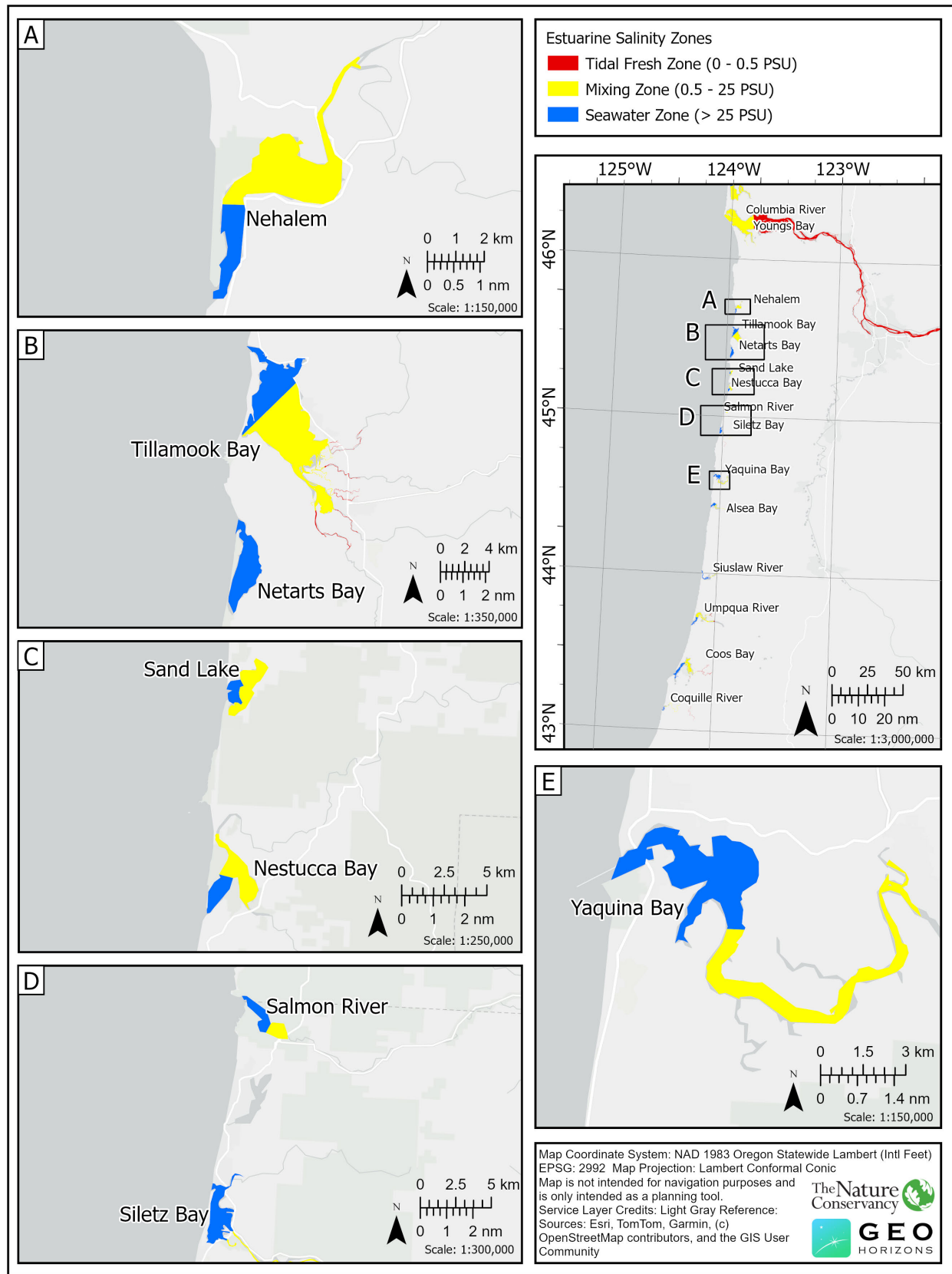
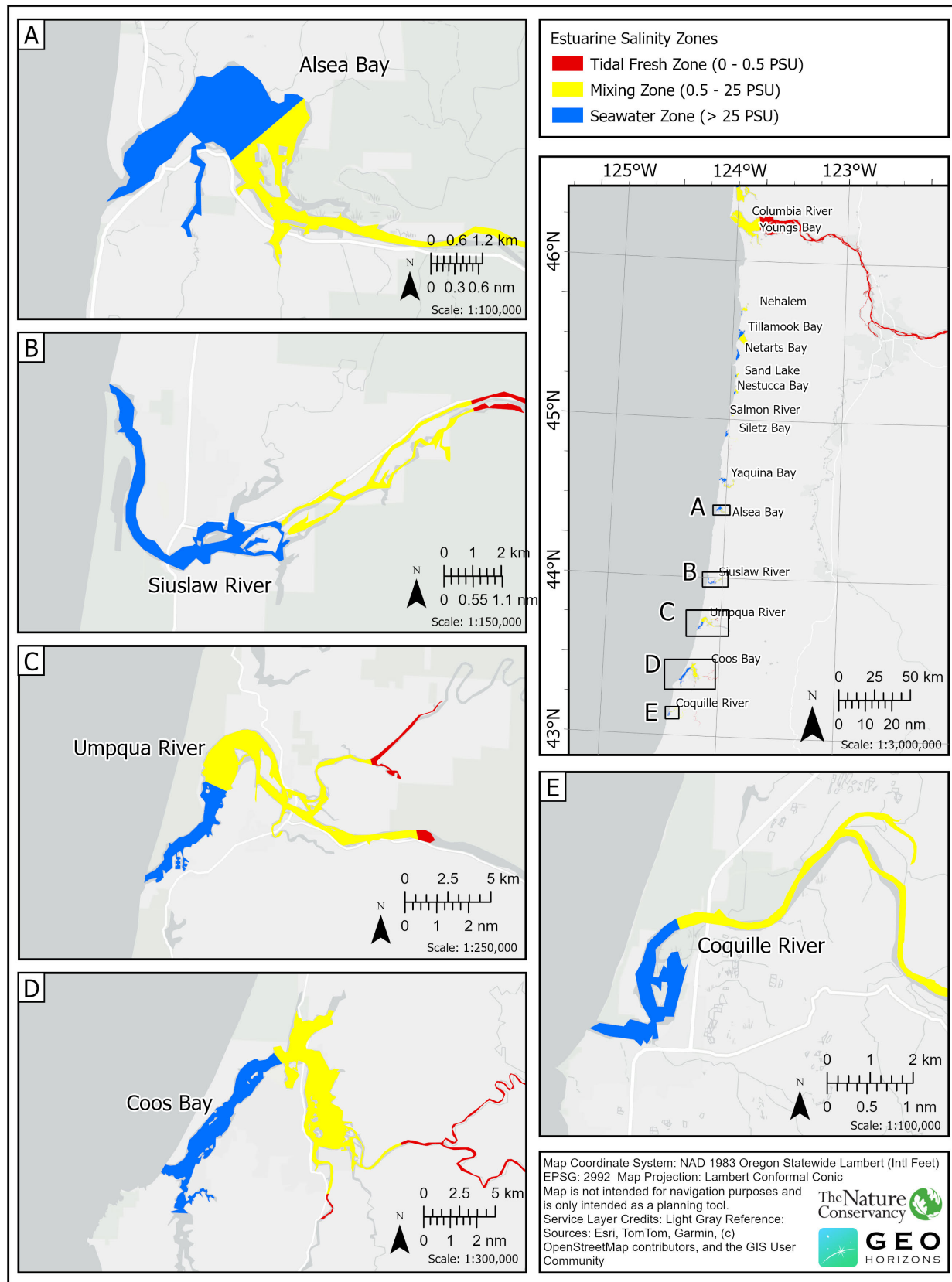


Figure 6. NOAA's Estuarine Salinity Zones (Nelson, 2015) and digitized salinity zones from the Oregon Department of State Lands (n.d.) for southern estuaries along Oregon's coast.



2.5.4. Human use and pressure

Fishing effort

Ecotrust provided fishing data and guidance on its application in the Suitability Model (Ecotrust, 2010). Key datasets included commercial and recreational Dungeness crab (*Metacarcinus magister*) importance by port, as well as recreational rockfish importance by port, derived from fisher surveys. Because these data were collected in 2010 and 2012, they may not fully reflect more recent shifts in fishery distribution and effort. For each port sector, areas of importance were identified and normalized to a 0–1 scale. Importance maps across port sectors were then merged into a single layer, with the maximum value retained in areas of overlap. The result was a single composite layer for each fishery, representing relative importance across the entire Oregon Coast. Data are available through the West Coast Ocean Data Portal's catalog (n.d.).

Vessel transits

Automatic Identification System (AIS) vessel tracklines from 2019–2023 were obtained from Marine Cadastre (n.d.). At the time of analysis, 2024 data were not yet available. Tracklines were categorized by vessel type: Cargo, Fishing, Not Available, Other, Passenger, Pleasure Craft/Sailing, Tanker, and Tug/Tow. To prepare the data for analysis, tracklines were converted to raster format using ArcGIS Pro Track Builder Pro 1.0. A resolution of 50 m by 50 m was selected to account for uncertainty associated with vessel deviations and movements not captured by straight-line interpolation between AIS points. Annual mean transit densities were then calculated separately for fishing vessels and for all non-fishing vessels.

2.5.5. Infrastructure and access

Bridges (road / train)

Data from the Oregon Department of Transportation were used to select road and railroad bridges crossing water. The line files were clipped by the estuaries, and a 500-ft (152-m) setback distance was applied.

Marina, dock, and boat ramp

Shoreline data developed in 2018 under the Coastal and Marine Ecological Classification Standard (CMECS) framework, together with visual assessments from recent satellite imagery (ArcGIS, n.d.), were used to identify the locations of marinas, docks, and boat ramps.

2.5.6. Management and planning context

Commercial shellfish management areas

Commercial shellfish management areas are defined in six estuaries and are approved for shellfish mariculture for human consumption. All other estuaries outside the certified areas were given a score of 0.5 to reflect uncertainty, and not necessarily any water quality or pollution sources. Similarly, the Columbia River, Nehalem Bay, Siletz River, Alsea Bay, Siuslaw River, and Coquille River are currently prohibited for commercial shellfish mariculture because they have not been evaluated by ODA and were given a score of 0.5. Prohibited areas were given a score of 0.25, rather than excluding these areas, as future monitoring may change the status of these areas.

Estuary planning and management zones

As part of Oregon's Statewide Planning Goal 16, estuaries are classified into different management units that characterize activities permissible in each estuary. Mariculture is allowed in all management units, but scoring was applied to give preference to estuaries classed as Deep and Shallow Draft Development (1.0), as existing infrastructure and development are already in place. Conservation estuaries received the second-highest score in the Suitability and Ranking Models (0.5), as these areas have already been altered. Natural estuaries received the lowest score (0.25); these areas have little to no development or existing infrastructure, and there is a desire to preserve the natural resources in these estuaries.

Estuary Aquaculture Screening 2021

The Oregon Coastal Management Program (OCMP) hosts a data layer, Estuary Aquaculture Screening 2021, that screens areas within estuaries throughout Oregon to determine the status of mariculture.

This data layer is somewhat redundant with the Commercial Shellfish Management Areas; however, additional areas within some estuaries were classified within this dataset, with any area that permits aquaculture outright receiving the most preference via a score of 1. Conditional areas received a score of 0.75, while areas requiring further consultation received a score of 0.5. In this case, if an estuary was not approved, it received the lower score of 0.25.

Zoned areas

Coastal lands were also explored to identify opportunities for expanding tank-based mariculture. To

identify potential land-based sites suitable for tank systems, only areas zoned for commercial or industrial use were considered. Residential and natural areas (e.g., state parks, estuaries) were excluded as unsuitable for tank operations. The Oregon statewide zoning layer served as the primary dataset, supplemented by local city or county zoning maps where available (Table 6). An additional 12,071 ac (48.8 km²) of land-based locations were identified for tank culture.

Table 6. Zoning information used to identify land-based opportunity for tank culture.

Zoning source	Zone description(s) selected	URL to data / zoning map
Oregon Statewide Zoning Layer	Combo Equal Emphasis	geohub.oregon.gov/datasets/oregon-geo::zoning/about
	Commercial – Central	
	Commercial – General	
	Commercial Neighborhood	
	Future Urban Development	
	Industrial – Heavy	
	Industrial – Light	
	Mixed-Use Com. & Res. High	
	Mixed-Use Com. & Res. Low	
	Mixed-Use Com. & Res. Med-high	
	Mixed-Use Com. & Res. Medium	
	Rural Commercial	
	Rural Industrial	
Bandon Zoning Map	Marine Commercial	www.bandon-or.gov/media/20401
Waldport Zoning Map	Commercial	www.waldportoregon.gov/planning-zoning/pages/maps
Coos County Zoning Map	Commercial	co.coos.or.us/coos-bay-estuary-management-plan-maps

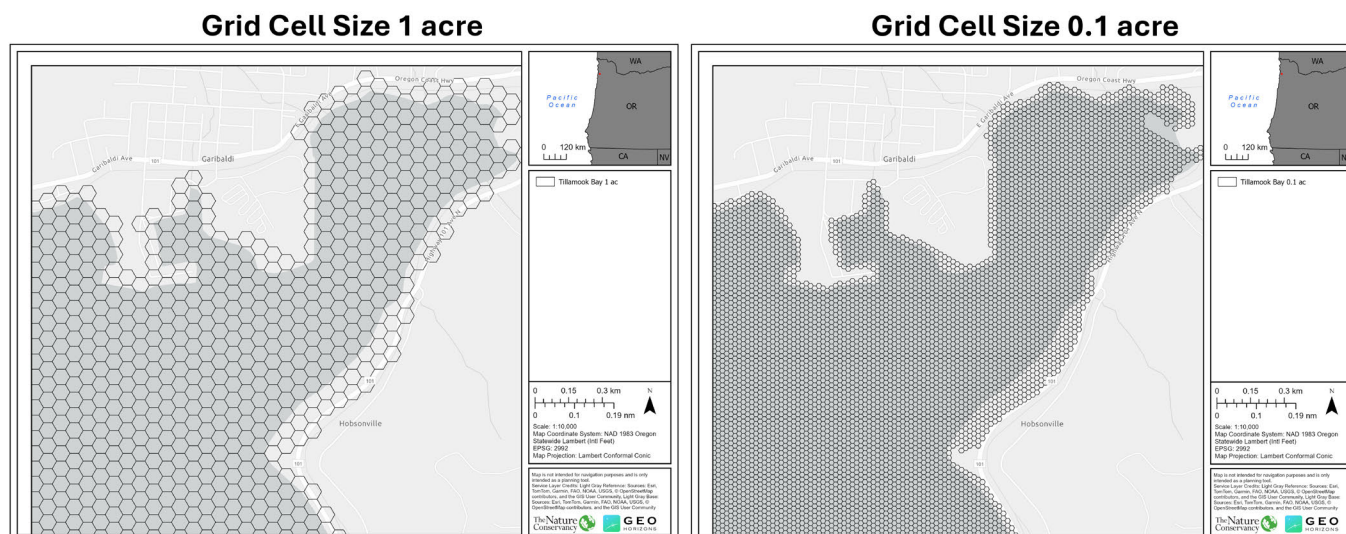
Note. Listed zone descriptions selected from the zoning maps were considered to have the potential for supporting land-based tank mariculture.

2.6. Modeling framework – gridded overlay

To ensure compatibility across different spatial datasets, a gridded overlay was created to translate all data into a common framework. Within the Oregon coastal study area, two subareas were delineated: Coastal and Estuary. For each subarea, a hexagonal grid was developed, with cell (pixel) size determined by both the overall extent of the subarea and the spatial resolution of available datasets (Birch et al., 2007; Hengl, 2006). These grids were applied in the

Exclusion, Opportunity, and Suitability Models. A consistent hexagonal grid was used across all three models; however, not all cells used in the Estuary Exclusion Model were carried forward into the other Estuary models due to identified incompatibilities and lack of data. The coastal ocean grid used a 1-acre cell size, while the estuarine grid used a finer 0.1-acre cell size, providing higher resolution for estuarine waters (Figure 7). In total, the coastal ocean grid comprised 814,504 cells, while the estuarine grid contained 1,001,419 cells.

Figure 7. Example of the gridded overlay used for modeling.



Note. Coastal ocean waters were modeled with a 1-acre grid cell size, while estuarine waters were modeled with a 0.1-acre grid cell size.

2.7. Exclusion Model

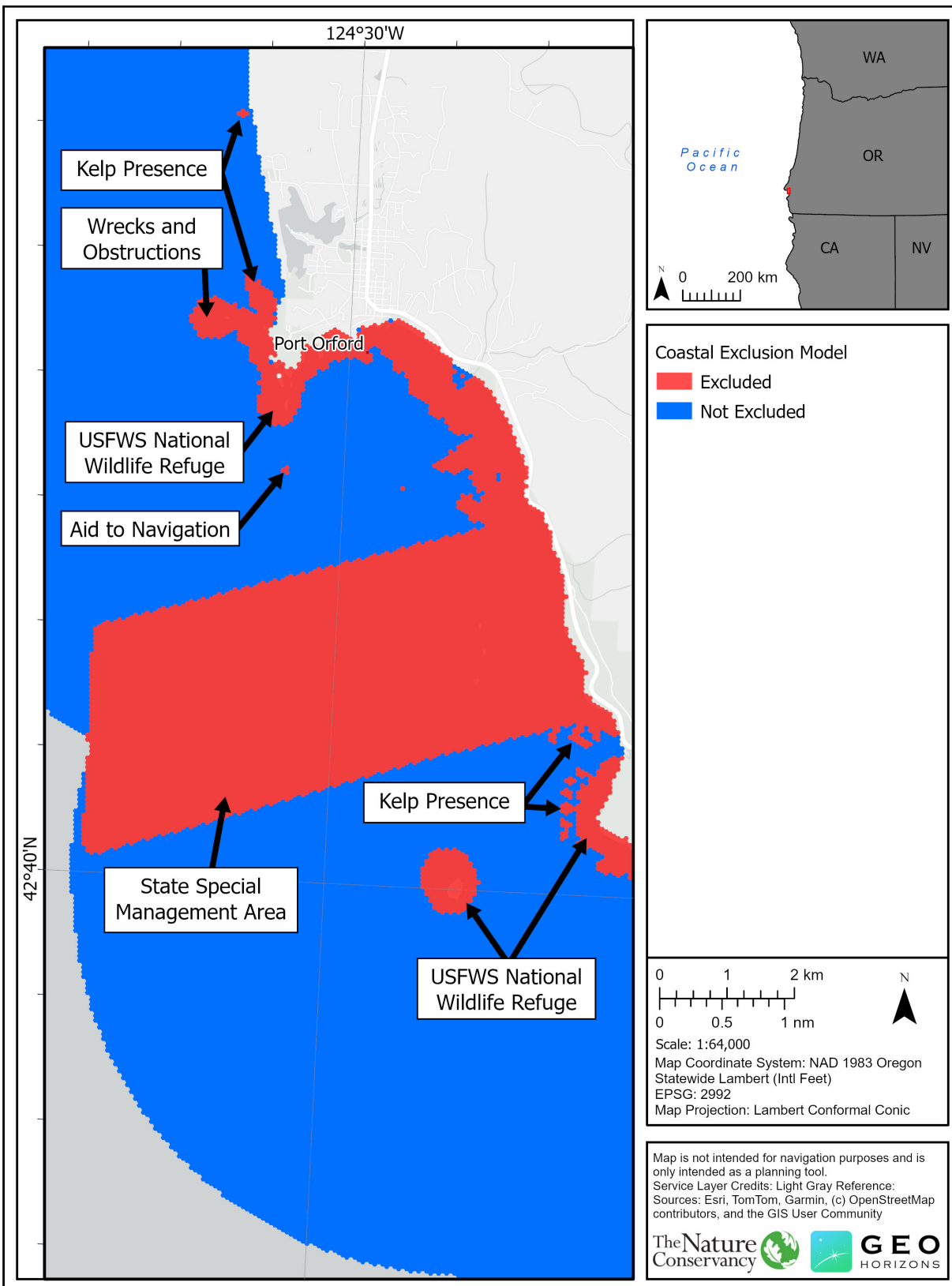
An exclusion model is used to eliminate areas where conflicts with other resources or uses preclude the siting of mariculture activities (Malczewski, 2006). This binary approach assigns a score of 0 (i.e., zero) to grid cells that intersect with features deemed incompatible with mariculture—such as existing immovable infrastructure, sensitive habitats, or regulated vessel traffic corridors—effectively removing them from further consideration. All other areas receive a score of 1 (i.e., one). In this analysis, any grid cell overlapping a feature classified as wholly incompatible with mariculture was assigned a 0, ensuring that such areas were excluded from subsequent planning steps. Relevant datasets were reviewed to identify features warranting exclusion, and appropriate setback distances were applied based on regulatory guidance, literature, or expert input.

Twenty-one data layers were identified for this study's Exclusion Model, developed for both coastal

ocean and estuarine waters (i.e., for the Coastal Exclusion Model and the Estuary Exclusion Model). This model included all in-water forms of shellfish and seaweed mariculture (i.e., line culture and subtidal gear; Figure 8 and Table 7). These layers were selected based on known conflicts with mariculture as seen in literature, as well as through discussions with local experts (Landuci et al., 2020; Morris et al., 2021; Riley et al., 2021; Wickliffe et al., 2019).

A separate model was created for the Coastal Tank Exclusion Model and the Estuary Tank Exclusion Model to assess land-based tank culture in ocean and estuarine waters. This model included 14 data layers. A data layer defining the zoned area with the potential for developing tank culture was the only addition (Table 7). Specifically, eligible areas were restricted to within 250 m in estuaries and 1 km along the coast of land zoned for commercial or industrial use.

Figure 8. Example of features considered within the Exclusion Model for this study (red-colored areas).



Note. Red-colored areas were assigned a score of 0 (i.e., zero) in the Exclusion Model, which removed those areas from further consideration for mariculture. USFWS = U.S. Fish and Wildlife Service.

Table 7. Exclusion Model data layers and their applicable Exclusion Model(s), as well as setback distances and data sources.

Data layer	Applicable Exclusion Model(s)	Setback distance	Data source	Notes
Active Ocean Disposal Sites	Coastal, Coastal Tank	-	Marine Cadastre / U.S. Environmental Protection Agency	Avoid these areas. Typically used for dredged material disposal.
Aids to Navigation	Coastal, Estuary	100 ft (30 m)	Marine Cadastre	Buoys may move with tide/currents. Using a 100-ft buffer provides additional risk mitigation.
Airports (Coos Bay / Astoria)	Estuary, Estuary Tank	1,640 ft (500 m)	Federal Aviation Administration / Geo Horizons	Mariculture may conflict with airports through lighted buoys or bird attraction.
Anchorage	Estuary, Estuary Tank	-	Marine Cadastre	Actively used by vessels for anchoring or mooring.
Bathymetry > 150 m	Coastal, Coastal Tank	-	National Oceanic and Atmospheric Administration (NOAA) National Centers for Environmental Information	Depths greater than 150 m were considered impractical for mariculture.
Bridges (Road / Rail)	Coastal, Estuary	500 ft (152 m)	Oregon Dept. of Transportation	Reduces risks near bridges and allows for maintenance access.
Clam Beds	Estuary, Estuary Tank	-	Oregon Coastal Management Program (OCMP)	Avoid conflicts with known clam bed habitats. Data collected according to the Coastal and Marine Ecological Classification Standard (CMECS).
Coastal Zoned Potential for Tank Mariculture	Coastal Tank	3,281 ft (1,000 m)	State of Oregon	Locations greater than 3,281 ft along the coast from shore-based infrastructure are unsuitable for tank culture.
Danger and Restricted Areas	Coastal, Coastal Tank	-	Marine Cadastre	Military, security, or hazardous use zones. A setback distance is generally built into delineated area.
Eelgrass Maximum Extent	Coastal, Coastal Tank, Estuary, Estuary Tank	-	Pacific Marine & Estuarine Fish Habitat Partnership	Avoid conflicts with this Essential Fish Habitat. Historic maximum extent used.

Data layer	Applicable Exclusion Model(s)	Setback distance	Data source	Notes
Environmental Sensor Buoys	Coastal, Estuary	100 ft (30 m)	National Data Buoy Center	Protects buoy equipment and data integrity (e.g., current speed readings).
Estuary Zoned Potential for Tank Mariculture	Estuary Tank	820 ft (250 m)	State of Oregon	Locations greater than 820 ft within estuaries from shore-based infrastructure are unsuitable for tank culture.
Kelp Bed Maximum Extent	Coastal, Coastal Tank	-	Kelpwatch / Oregon Department of Fish and Wildlife (ODFW)	Avoids conflicts with this Essential Fish Habitat.
Maintained Channels	Coastal, Estuary	-	NOAA / U.S. Army Corps of Engineers	Channel widths vary by channel and are regularly dredged and traversed by vessels.
Marinas, Docks, Boat Ramps	Coastal, Estuary	100 ft (30 m)	Satellite Imagery / CMECS	Excluded to avoid conflicts with vessel use and infrastructure.
Native Oyster Habitat	Estuary, Estuary Tank	-	CMECS	Avoid conflicts with known native oyster populations.
Pinniped Haul-Outs	Coastal, Coastal Tank, Estuary, Estuary Tank	150 ft (45 m)	OCMP	NOAA recommends 150-ft buffer for small marine mammals; includes California sea lions and harbor seals.
Recreational Shellfish Harvest Areas	Estuary	-	ODFW	Identified by ODFW surveys and local input as key recreational harvest zones.
South Slough National Estuarine Research Reserve	Estuary, Estuary Tank	500 ft (152 m)	NOAA	Reserve designated under the Coastal Zone Management Act.
State Special Management Areas	Coastal, Coastal Tank, Estuary, Estuary Tank	500 ft (152 m)	ODFW	Avoid conflicts with marine protected areas, reserves, and seabird protection areas.
Submarine Cable Areas	Coastal, Estuary	328 ft (100 m)	Marine Cadastre	Accounts for shifting cables and reduces interference risk.
U.S. Fish and Wildlife Service (USFWS) National Wildlife Refuges	Coastal, Coastal Tank, Estuary, Estuary Tank	100 ft (30 m); 500 ft (152 m)	USFWS	100-ft setback used generally; 500-ft setback applied for Oregon Islands National Wildlife Refuge to protect wildlife.

Data layer	Applicable Exclusion Model(s)	Setback distance	Data source	Notes
Wrecks and Obstructions	Coastal, Estuary	500 ft (152 m)	NOAA Electronic Navigational Charts / Marine Cadastre	Accounts for wreck movement and preserves use of wrecks (e.g., habitat, recreation).

Note. The Exclusion Model(s) used for a given data layer could include Coastal, Coastal Tank, Estuary, or Estuary Tank, as noted in the table. The “Notes” column explains the rationale behind using the layer as an exclusion or for the setback distance chosen.

2.8. Opportunity Model

The Opportunity Model was this study’s spatial modeling approach used to identify areas in Oregon waters potentially compatible with specific mariculture species and cultivation gear types. The purpose was to map the full geographic extent where a given species and gear could persist, even if conditions may not support optimal growth or performance.

The model applied minimum and maximum thresholds across key environmental variables (e.g., depth, salinity) to delineate broad opportunity zones. Thresholds were derived from relevant literature (i.e., regional and non-regional literature), as well as from data on ecologically similar species. These initial values were then refined through expert input (Table 8 and Table 9).

For each species, multiple environmental thresholds (e.g., temperature, salinity, current speed) were

summarized at the grid-cell level. ArcGIS Pro’s Spatial Join tool was used to assign environmental values to grid cells using the “closest” match option, meaning each cell was assigned the value of the nearest data point. Any grid cell with values outside a species’ tolerance range for any parameter was excluded from the opportunity area. This process was repeated for each species under assessment. For an example of this study’s Opportunity Model results, see Figure 9.

Environmental variables with uncertain thresholds (e.g., significant wave height, light availability) or with coarse spatial and temporal resolution (e.g., nutrients) were excluded from the Opportunity Model. However, these variables were incorporated into the subsequent Suitability Model (see Section 2.9, [Suitability Model](#)).

Table 8. Threshold values for variables used in each Estuary subarea’s Opportunity Model, developed for specific species and gear combinations.

Species / gear	Variable	Threshold	Literature and notes
Olympia oyster (<i>Ostrea lurida</i>) Subtidal gear	Water Temperature	4–38 °C	Davis, 1955; Wasson et al., 2015
	Water Salinity	≥ 8 PSU	Pritchard et al., 2015
	Current Magnitude	≤ 1 m/s	Kapetsky & Aguilar-Manjarrez, 2013
	Depth (mean lower low water [MLLW])	≥ 2 m	Most floating and suspended systems require several feet of continuous subtidal depth, with greater depths improving vessel access, reducing the risk of gear grounding, and minimizing interaction with the benthic environment (Forrest et al., 2009; Shumway et al., 2003). Deployment in waters shallower than 2 m may be feasible in some settings but is associated with increased risk of benthic disturbance, wave-induced gear contact, and

Species / gear	Variable	Threshold	Literature and notes
			infrastructure damage, particularly in dynamic nearshore environments (Forrest et al., 2009).
	Growing Season / Harvest	Year-round	
Pacific blue mussels (<i>Mytilus trossulus</i>) Line culture	Water Temperature	-1–28 °C	Braby & Somero, 2006; Hatcher et al., 1997; Hofmann & Somero 1995
	Water Salinity	10–32 PSU	LaBarre et al., 2023
	Current Magnitude	≤ 1.2 m/s	Nielsen & Vismann, 2014
	Depth (MLLW)	≥ 3 m	
	Growing Season / Harvest	Year-round	
Kelp species Line culture	Water Temperature	≤ 19 °C	O'Clair & Lindstrom, 2000; Simonson et al., 2015
	Water Salinity	≥ 13	Boderskov et al., 2021; Lind, 2016; Mumford, 2007
	Current Magnitude	≤ 1.0 m/s	Buckner et al., 2023
	Depth (MLLW)	≥ 3 m	
	Growing Season / Harvest	Varies	Year-round used.
Purple sea urchin (<i>Strongylocentrotus purpuratus</i>) Tank culture	Water Temperature	4–20 °C	Hammond & Hofmann, 2010; Morris et al., 1980
	Water Salinity	≥ 21 PSU	100% mortality at < 17 PSU; high mortality at 20.9 PSU (Burnett et al., 2002). Approved by the Advisory Committee in 2025.
	Depth (MLLW)	> 0 m	Intake pipe would need to be submerged.
	Growing Season / Harvest	Year-round	
Pacific dulse (<i>Devaleraea mollis</i> ; syn. <i>Palmaria mollis</i>) Tank culture	Water Temperature	≤ 18 °C	Demetropoulos & Langdon, 2004
	Water Salinity	30 – 35 PSU	Demetropoulos & Langdon (2004). 30–32 PSU is optimal.
	Depth (MLLW)	> 0 m	The pipe intake would need to be submerged.
	Growing Season / Harvest	Year-round	

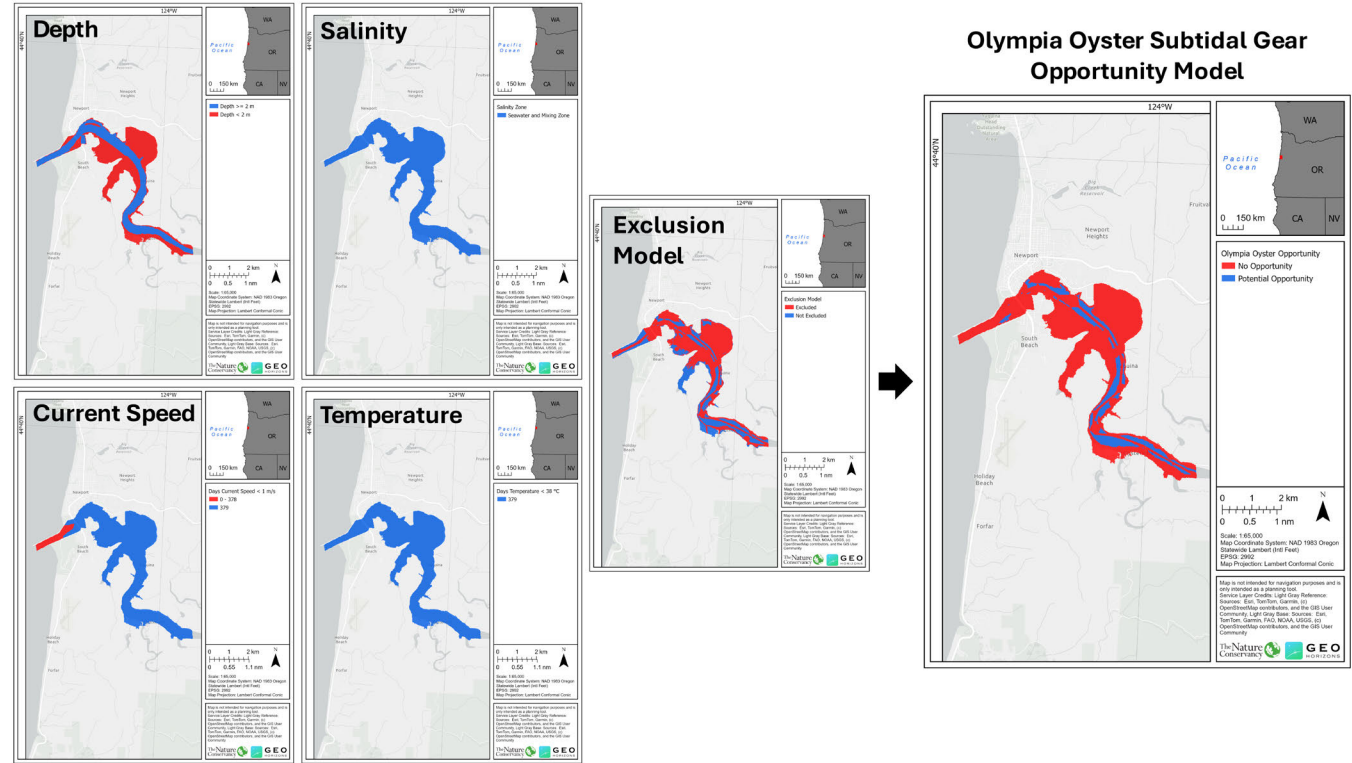
Table 9. Threshold values for variables used in each Coastal subarea's Opportunity Model, developed for specific species and gear combinations.

Species / gear	Variable	Threshold	Literature and notes
Bull kelp (<i>Nereocystis luetkeana</i>) Line culture	Water Temperature	≤ 18 °C	Maxell & Miller, 1996; Muth et al., 2019
	Water Salinity	> 26 PSU	Lind, 2016; Maxell & Miller, 1996; Mumford, 2007
	Current Magnitude	≤ 1.0 m/s	Buckner et al., 2023
	Depth (mean lower low water [MLLW])	≥ 5 m	
	Growing Season / Harvest	May–Sept	Pontier et al., 2024

Species / gear	Variable	Threshold	Literature and notes
Bull kelp (<i>N. luetkeana</i>) Planted on bottom	Water Temperature	≤ 18 °C	Maxell & Miller, 1996; Muth et al., 2019
	Water Salinity	> 26 PSU	Lind, 2016; Maxell & Miller, 1996; Mumford, 2007
	Current Magnitude	≤ 1.0 m/s	Buckner et al., 2023
	Depth (MLLW)	3–17 m	Mumford, 2007
	Growing Season / Harvest	Year-round	Advisory Committee, personal communication, 2025
Ribbon/winged kelp (<i>Alaria marginata</i>) Line culture	Water Temperature	≤ 18 °C	Muth et al., 2019; O'Clair & Lindstrom, 2000
	Water Salinity	≥ 24 PSU	General criteria – Buckner et al., 2023
	Current Magnitude	≤ 1.0 m/s	Buckner et al., 2023
	Depth (MLLW)	≥ 5 m	
	Growing Season / Harvest	Feb–July / Oct	Blasco, 2012; McConnico & Foster, 2005
Sugar kelp (<i>Saccharina latissima</i>) Line culture	Water Temperature	≤ 19 °C	O'Clair & Lindstrom, 2000; Simonson et al., 2015
	Water Salinity	≥ 13	Borderskov et al., 2021; Lind, 2016; Mumford, 2007
	Current Magnitude	≤ 1.0 m/s	Buckner et al., 2023
	Depth (MLLW)	≥ 5 m	Blasco, 2012; Bruhn et al., 2016; Peteiro & Freire, 2013
	Growing Season / Harvest	Nov–May	Buckner et al., 2023
Giant kelp (<i>Macrocystis pyrifera</i> ; syn. <i>M. integrifolia</i>) Line culture	Water Temperature	≤ 21 °C	Becheler et al., 2022; Rothäusler et al., 2009
	Water Salinity	≥ 24 PSU	Buschmann et al., 2004; Druehl, 1978
	Current Magnitude	≤ 1.0 m/s	Kregting et al., 2016
	Depth (MLLW)	≥ 5 m	
	Growing Season / Harvest	Year-round	
Red abalone or flat abalone (<i>Haliotis rufescens</i> or <i>H. walallensis</i>) Tank culture	Water Temperature	< 27.5 °C	Diaz et al. (2000). < 18 °C optimal: Rogers-Bennett et al. (2010).
	Water Salinity	25–40 PSU	Creencia & Noro (2018) pertaining to ragworm (<i>Hediste diversicolor</i>). Le Page (2005).
	Growing Season / Harvest	Year-round	
Pacific blue mussel (<i>Mytilus trossulus</i>) Line culture	Water Temperature	–1–28 °C	Braby & Somero, 2006; Hatcher et al., 1997; Hofmann & Somero, 1995
	Water Salinity	10–32 PSU	LaBarre et al., 2023
	Current Magnitude	≤ 1.2 m/s	Nielsen & Vismann, 2014
	Depth (MLLW)	≥ 5 m	Alma et al., 2023
	Growing Season / Harvest	Year-round	
	Water Temperature	7–28 °C	Coe & Fox (1942) pertaining to when feeding occurs. Range is likely larger for survival.

Species / gear	Variable	Threshold	Literature and notes
California mussel (<i>Mytilus californianus</i>) Line culture	Water Salinity	≥ 20 PSU	
	Current Magnitude	≤ 1.2 m/s	Nielsen & Vismann, 2014
	Depth (MLLW)	≥ 5 m	Alma et al., 2023
	Growing Season / Harvest	Year-round	

Figure 9. Example (for Olympia oyster) of how Opportunity Model inputs—tuned to the specific gear and biophysical thresholds for a species—were integrated with Exclusion Model results to identify potential mariculture opportunity areas.



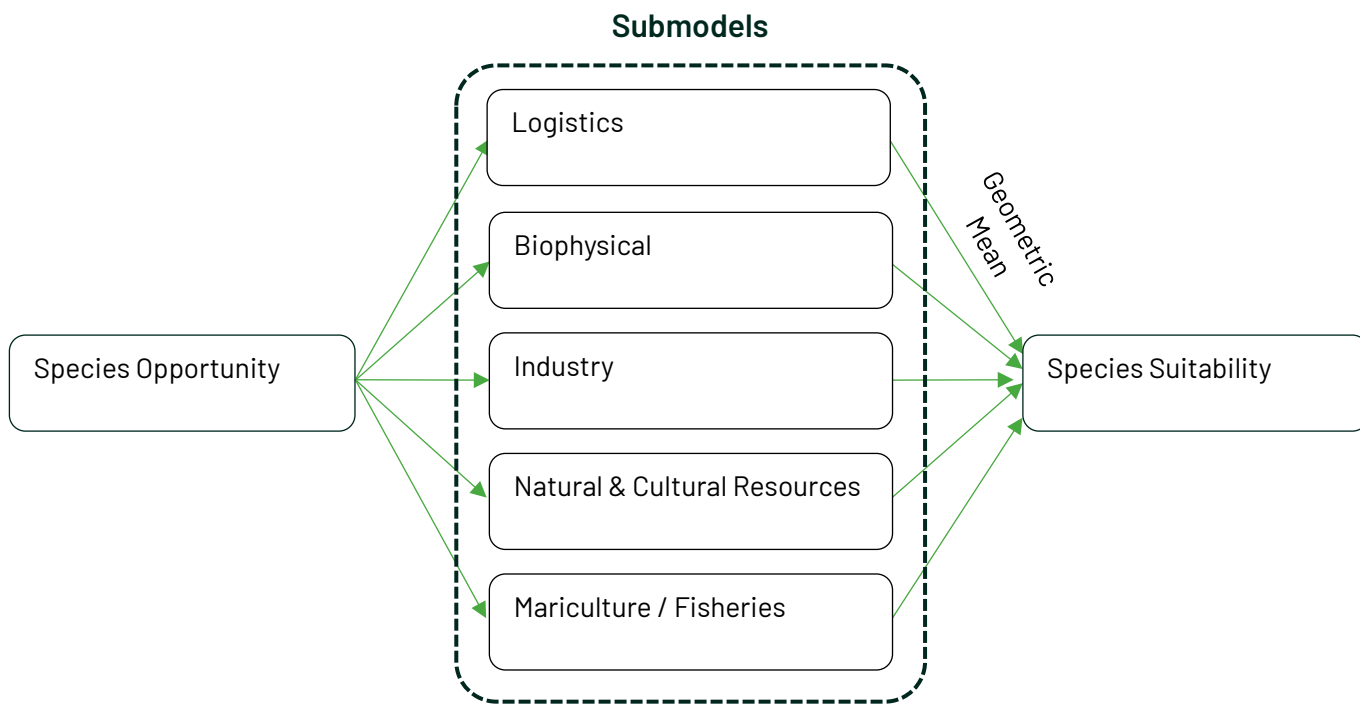
2.9. Suitability Model

The Suitability Model was the spatial modeling technique used in this study to identify the most appropriate areas for cultivating specific mariculture species and gear types. Building upon the Opportunity Model, which defined the broader geographic extent where a species or gear could potentially survive, suitability modeling refined this geographic extent by highlighting the more or less favorable portions of that area of cultivation. Suitability modeling is a form of Multi-Criteria Decision Analysis that integrates diverse factors to guide siting recommendations for mariculture (Landuci et al., 2020; Longdill et al., 2008; Silva et al., 2011).

The analysis involves a composite spatial model consisting of multiple submodels (Figure 10). The submodels are equally weighted (Longdill et al., 2008; Silva et al., 2011) and address different categories of considerations, including the following:

- **Negotiable use and resource conflicts** (e.g., fisheries, industrial activity, cultural and natural resources)
- **Practical siting factors** (e.g., logistical feasibility, economic viability)
- **Species- and gear-specific requirements** (e.g., light availability or nutrient levels for seaweed)

Figure 10. Example workflow for suitability modeling, in which broad opportunity zones are refined through a Suitability Model incorporating multiple factors to identify locations more or less favorable for mariculture operations.



2.9.1. Submodel approach

Logistics Submodel – Captures the physical, infrastructural, and operational feasibility of mariculture development by evaluating proximity to ports and processing facilities, water depth and wave exposure, substrate type, zoning and permitting context, and access to supporting infrastructure.

Biophysical Submodel – Characterizes the natural environmental conditions that determine species suitability and performance, such as light availability, nutrient concentrations, and substrate quality, to identify areas with optimal biophysical conditions for culture.

Industry Submodel – Represents the broader industrial context influencing mariculture siting, including enterprise and development zones, vessel traffic intensity, and other indicators of economic opportunity or potential spatial conflict with existing maritime activities.

Natural and Cultural Resources Submodel – Incorporates management designations, conservation priorities, and cultural resource protections to ensure proposed mariculture development aligns with ecological stewardship and coastal planning goals.

Mariculture / Fisheries Submodel – Evaluates spatial overlap and potential conflicts or compatibilities with commercial and recreational fishing activities and other existing aquaculture operations to inform sustainable multiuse planning. The Estuary Suitability Models used only mariculture-focused layers, as no data were available to represent fishing effort within estuaries. Conversely, the Coastal Suitability Models used only fisheries-focused layers, given the absence of active mariculture in the coastal areas.

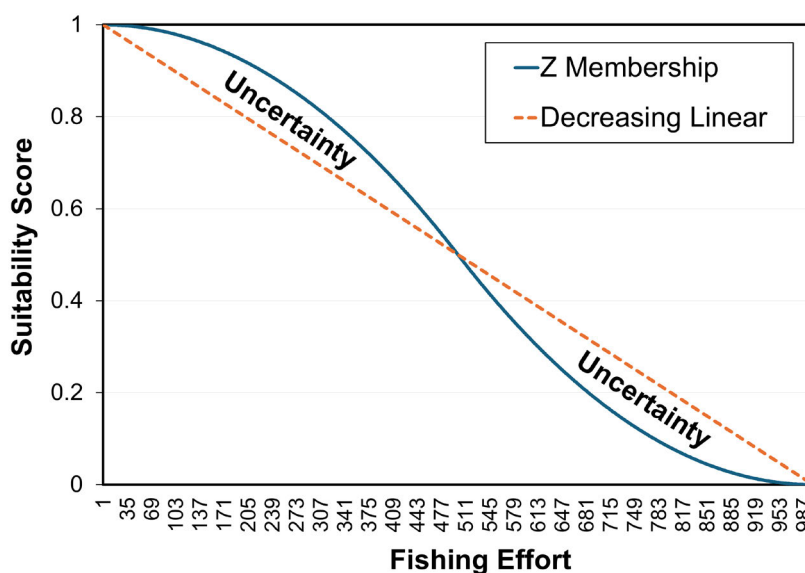
Each of the study's submodel included one or more data layers, scored along a gradient of relative suitability (i.e., between 0 and 1). Scoring for individual data layers was determined from relevant literature and, where literature was unavailable, expert input. Two types of criteria were used to assign datasets:

- **Categorical datasets** were assigned discrete suitability scores (e.g., 0 for incompatible, 0.5 for uncertain, 1 for compatible).

- **Continuous datasets** were re-scaled using four functions to represent suitability gradients, including (1) increasing linear, (2) decreasing linear, (3) fuzzy logic S membership function (SMF), and (4) fuzzy logic Z membership function (ZMF). For instance, high fishing effort may have been scored as low suitability (approaching 0), while low fishing effort was scored higher (approaching 1). Example functions are shown in Figure 11.

Model configurations developed for this study are presented in Table 10 through Table 13. As with the Opportunity Model, these Suitability Models used the labels Coastal, Estuary, Coastal Tank, and Estuary Tank (e.g., Estuary Tank Suitability Model).

Figure 11. Example of a decreasing linear function and a fuzzy logic Z membership function (ZMF).



Note. Both functions are similar, but the ZMF incorporates additional uncertainty into the scoring.

Table 10. Coastal Suitability Model framework and data layers, with rescale method and scoring for all non-estuary species.

Submodel	Data layer	Rescale method	Score range
Logistics	Distance to Commercial Ports	Decreasing linear function	0–1
Logistics	Depth	Depth ≤ 60 m = 1 Depth > 60 and ≤ 150 = decreasing linear function	0–1
Logistics	Significant Wave Height Days ≤ 2 m	S membership function (SMF)	0–1
Logistics	Benthic Habitat *	Fine sediment = 1 Coarser sediment = 0.5 Very coarse sediment = 0.1	0–1
Industry	Automatic Identification System (AIS) Vessel Traffic (No Fishing)	Z membership function (ZMF)	0–1
Natural and Cultural Resources	Whale Habitat	Depth > 30 m = 0.5 Depth ≤ 30 m = 1	0–1
Biophysical ⁺	Light Availability ⁺	SMF	0–1
Biophysical ⁺	Nitrate ⁺	SMF	0–1
Biophysical ⁺	Phosphate ⁺	SMF	0–1
Biophysical ⁺	Iron ⁺	SMF	0–1
Fisheries	AIS Fishing Vessel Transits	ZMF	0–1
Fisheries	Commercial Dungeness Crab	ZMF	0–1

Submodel	Data layer	Rescale method	Score range
Fisheries	Recreational Dungeness Crab	ZMF	0-1
Fisheries	Recreational Rockfish	ZMF	0-1

Note. A single Suitability Model was used for all species and gear. Each data layer was rescaled for each species grid where opportunity existed. Grids varied by species.

* For planted-on-bottom culture, fine and coarser sediment = 0.1, and very coarse sediment = 1.

+ Not used for mussel line culture Suitability Models.

Table 11. Coastal Tank Suitability Model framework and data layers, with rescale method and scoring, for red abalone or flat abalone.

Submodel	Data layer	Rescale method	Score range
Logistics	Permits Required at City Level	Presence = 0.5 / absence = 1	0 - 1
Logistics	Port Owned Lands	Presence = 1 / absence = 0.5	0 - 1
Logistics	Distance From Kelp	Decreasing linear function	0 - 1
Logistics	Distance to Area Within 1 km of Zoned Area - with potential for development of shoreline infrastructure	Decreasing linear function	0 - 1
Industry	Enterprise Zones - includes land intersecting with zoned area, with potential for development of shoreline infrastructure	Presence = 1 / absence = 0.5	0 - 1

Table 12. Estuary Suitability Model framework and data layers, with rescale method and scoring, for Olympia oysters, Pacific blue mussels, and kelp species.

Submodel	Data layer	Rescale method	Score range
Logistics *	Presence of Shellfish Shucker Packers *	Presence = 1 / absence = 0.5	0 - 1
Logistics *	Presence of Shellfish Distributors *	Presence = 1 / absence = 0.5	0 - 1
Logistics	Presence of Seafood Processors	Presence = 1 / absence = 0.5	0 - 1
Logistics	Presence of Cold Food Storage Warehouses	Presence = 1 / absence = 0.5	0 - 1
Logistics	Port Owned Lands	Presence = 1 / absence = 0.5	0 - 1
Logistics	Permits Required at City Level	Presence = 0.5 / absence = 1	0 - 1
Biophysical *	Commercial Shellfish Management Areas *	Approved area = 1 Conditionally approved = 0.5 Not specified = 0.5 Prohibited = 0.25	0 - 1
Biophysical *	Shellfish Plats 2021 *	Presence = 1 / absence = 0.5	0 - 1
Industry	Enterprise Zones	Presence = 1 / absence = 0.5	0 - 1

Industry	Automatic Identification System (AIS) Vessel Traffic (No Fishing)	Z membership function (ZMF)	0 - 1
Natural and Cultural Resources	Estuary Planning and Management Zones	Deep draft development = 1.0 Shallow draft development = 1.0 Conservation = 0.5 Natural = 0.25	0 - 1
Mariculture / Fisheries	Estuary Aquaculture Screening 2021	Land use permits – aquaculture outright = 1 Land use permits – aquaculture conditional = 0.75 Consult planning staff = 0.5 Estuary not approved by the Oregon Dept. of Ag. = 0.25	0 - 1
Mariculture / Fisheries	AIS Fishing Vessel Traffic	ZMF	0 - 1

* Not used in the kelp species Suitability Model.

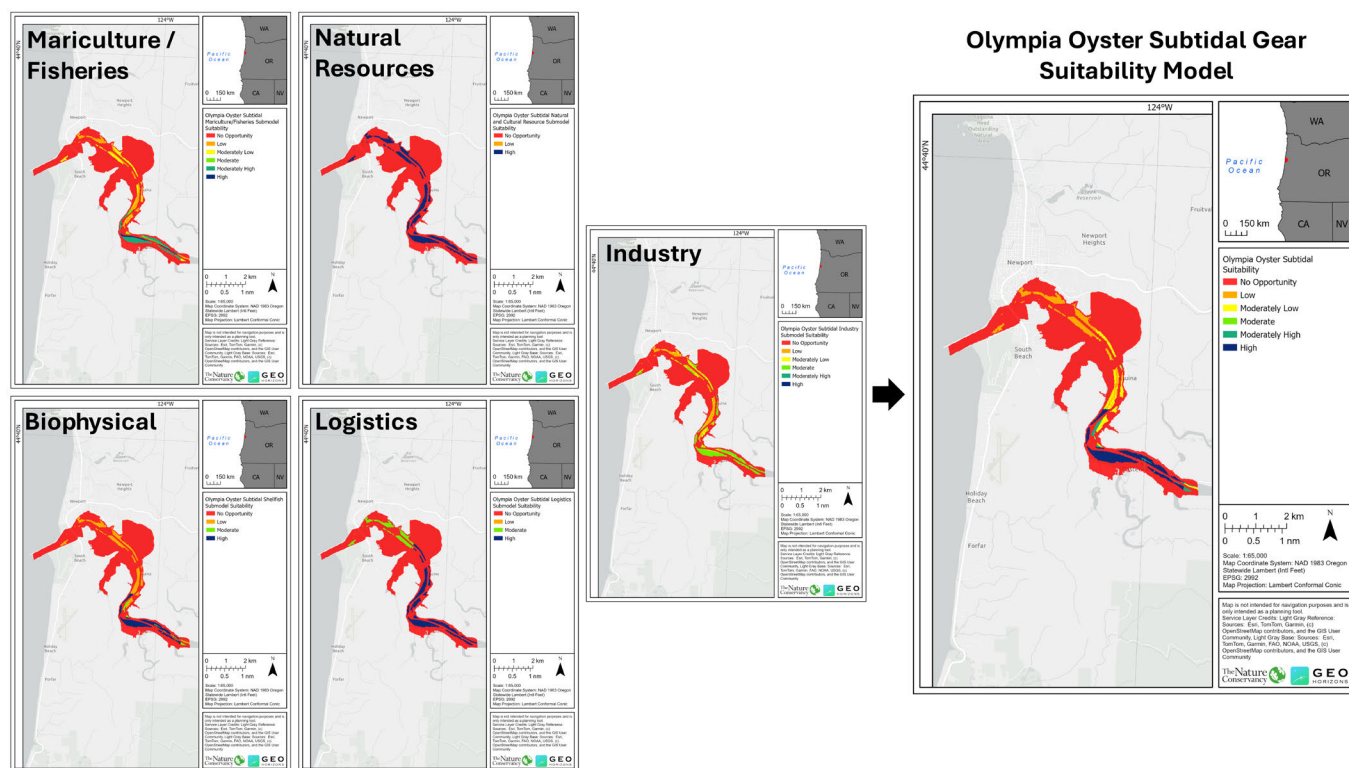
Table 13. Estuary Tank Suitability Model framework and data layers, with rescale method and scoring.

Submodel	Data layer	Rescale method	Score range
Logistics	Presence of Seafood Processors	Presence = 1 / absence = 0.5	0 - 1
Logistics	Presence of Cold Food Storage Warehouses	Presence = 1 / absence = 0.5	0 - 1
Logistics	Permits Required at City Level	Presence = 0.5 / absence = 1	0 - 1
Logistics	Port Owned Lands - includes land intersecting with zoned area, with potential for development of shoreside infrastructure	Presence = 1 / absence = 0.5	0 - 1
Logistics	Area Within 250 m of Zoned Area - with potential for development of shoreside infrastructure	Decreasing linear function	0 - 1
Industry	Enterprise Zones - includes land intersecting with zoned area, with potential for development of shoreside infrastructure	Presence = 1 / absence = 0.5	0 - 1
Natural and Cultural Resources	Estuary Planning and Management Zones	Deep draft development = 1.0 Shallow draft development = 1.0 Conservation = 0.5 Natural = 0.25	0 - 1

The submodels are integrated into a final composite Suitability Model unique to each species and gear combination, producing a spatially explicit surface of relative suitability. A range of mathematical approaches can be used to calculate the final score (e.g., arithmetic mean, product method); however, the geometric mean is often preferred. The geometric mean allows for a balanced integration of

submodels wherein each is given equal consideration, with low suitability in one category being offset by higher suitability in others, making the approach moderately resistant to outliers and reflective of overall central tendencies (Muñoz-Mas et al., 2012). An example Suitability Model for the Olympia oyster—composed of five individual submodels—is presented in Figure 12.

Figure 12. Example (for Olympia oyster) of how the geometric mean of the scores from the five different submodels—tuned to each species and gear—was used to calculate a final suitability score.

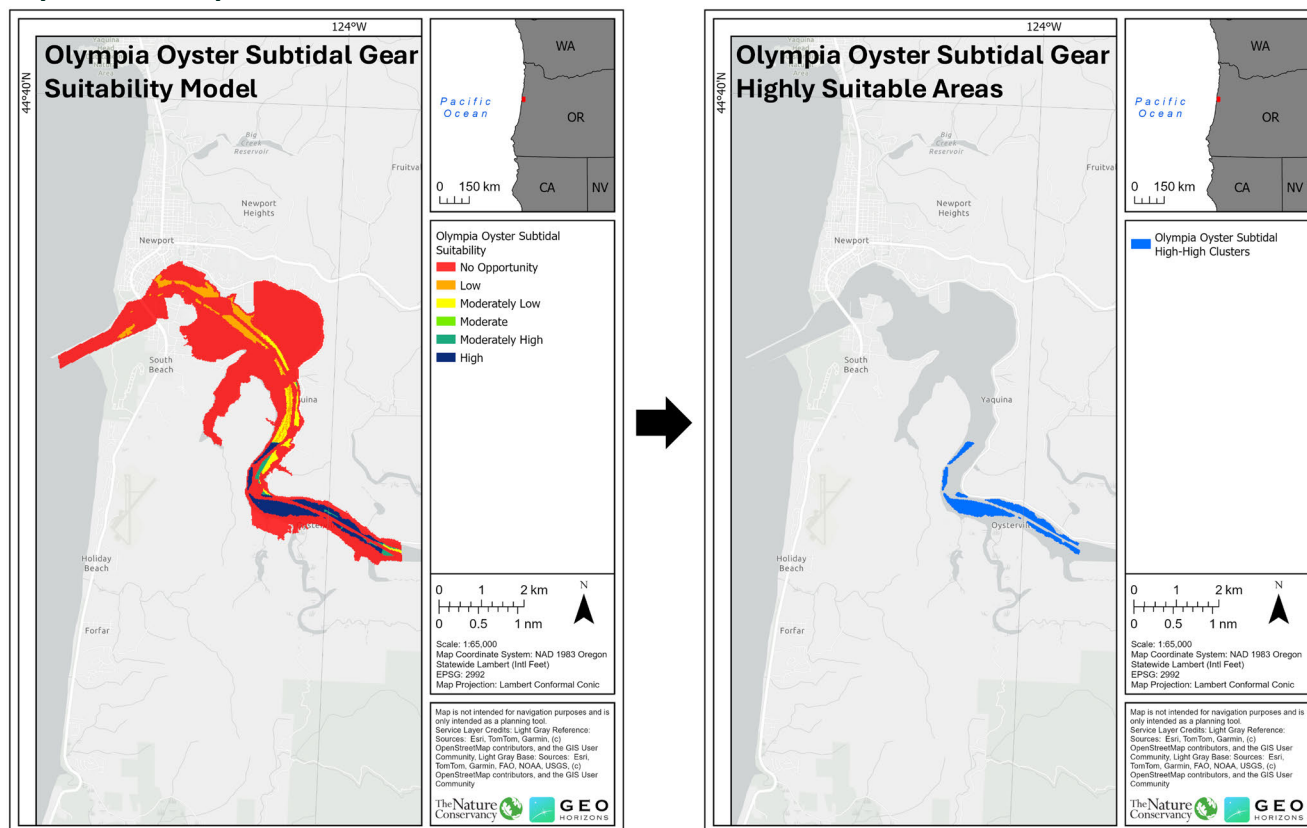


Following the completion of the suitability modeling, an LISA analysis was conducted to identify statistically significant areas of high suitability (Aneslin, 1995). This analysis specifically identifies where the most promising areas are for specific types of mariculture development. ArcGIS Pro's Cluster and Outlier Analysis tool was used (Esri, n.d.-a). A fixed distance band conceptualization was selected to focus on localized clustering of areas of high suitability, with a 300-ft (91-m) search distance applied in the coastal ocean waters model (1-acre cells) and a 100-ft (30-m) search distance applied in the estuarine waters model (0.1-acre cells). These distances were chosen to limit neighborhood calculations to immediately adjacent cells, producing more localized and conservative results.

The analysis applied a 95% confidence interval to identify the most suitable cells and systematically

detect spatially contiguous neighborhoods of high-scoring grid cells (Figure 13). This quantitative evaluation of the suitability surface highlights statistically significant high-high clusters—areas where high suitability scores are spatially correlated. These clusters delineate concentrated zones of high suitability and provide a spatially explicit foundation for precision siting of mariculture operations, tailored to the biophysical and operational characteristics of each area. The resulting high-high clusters are intended to highlight areas that possess more suitability based on the input variables. Throughout this report, these areas are referred to as *highly suitable areas*. However, areas not identified as high-high clusters or highly suitable areas may also be able to support a mariculture operation.

Figure 13. Example application of the Cluster and Outlier Analysis using the overall suitability scores from the Olympia oyster Suitability Model.



Note. Subsequent to applying the Cluster and Outlier Analysis tool, high-high clusters were selected and identified as highly suitable areas.

2.10. Ranking Model

To further refine the identification of optimal mariculture locations, Ranking Models were developed using the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS; Hwang & Yoon, 1981). While many methods are available, Díaz and Soares (2021) compared approaches for wind farm siting and found minimal differences in outcomes across methods. TOPSIS was selected for this study due to its practicality, simplicity, and ease of interpretation. The method ranks alternatives by identifying those closest to the “best” solution and closest to the “worst”—in this case, the most and least favorable mariculture locations.

The Ranking Analysis variables were the submodel composite scores using the geometric mean, similar to the Suitability Analysis submodels, with some minor modifications. Notably, the amount of highly suitable area was added as an industry consideration (i.e., part of the “Industry” variable), under the rationale that a greater area provides more scalability and opportunity

for mariculture. Conversely, wave height, depth, and distance to port were excluded from the Ranking Model due to the large contrasts in the amounts of area within the coastal ocean zones. For example, the Gold Beach zone contained 35,440 ac (143 km²) of highly suitable area for bull-kelp line culture; the Coos Bay zone contained 2,948 ac (12 km²). In such cases, averaging wave height or using a single closest distance to port would not adequately represent conditions across the full zone.

Ranking Model configurations developed for this study are presented in Table 14 through Table 16. As with the Opportunity and Suitability Models, the terms Coastal and Estuary pertain to the Ranking Models focused on these waters; the term Estuary Tank pertains to the model for land-based tank culture. No Coastal Tank Ranking Model was run due to high uncertainty with commercially and industrially zoned areas and the lack of variables. Essentially, a Ranking Model would have ranked sites solely by the size of the area available.

Table 14. Coastal Ranking Model variables and data layers, with rescale method and scoring.

Variable	Data layer	Rescale Method	Score Range
Industry	Highly Suitable Area Present	Increasing linear function	0-1
Biophysical *	Light Availability *	S membership function (SMF)	0-1
Biophysical *	Nitrate *	SMF	0-1
Biophysical *	Phosphate *	SMF	0-1
Biophysical *	Iron *	SMF	0-1
Fisheries	Automatic Identification System (AIS) Fishing Vessel Transits / Area	Z membership function (ZMF)	0-1
Fisheries	Commercial Dungeness Crab	ZMF	0-1
Fisheries	Recreational Dungeness Crab	ZMF	0-1
Fisheries	Recreational Rockfish	ZMF	0-1

Note. Data layers were summarized to the highly suitable area associated with each coastal ocean zone. The mean was calculated for environmental variables and fishery importance; the sum ÷ area was calculated for vessel transits.

* Not used for mussel line culture Ranking Models.

Table 15. Estuary Ranking Model variables and data layers, with rescale method and scoring.

Variable	Data Layer	Rescale Method	Score Range
Logistics *	Presence of Shellfish Shucker Packers *	Presence = 1 / absence = 0.5	0-1
Logistics *	Presence of Shellfish Distributors *	Presence = 1 / absence = 0.5	0-1
Logistics	Presence of Seafood Processors	Presence = 1 / absence = 0.5	0-1
Logistics	Presence of Cold Food Storage Warehouses	Presence = 1 / absence = 0.5	0-1
Logistics	Permits Required at City Level	Presence = 0.5 / absence = 1	0-1
Logistics	Port Owned Lands	Presence = 1 / Absence = 0.5	0-1
Industry	Highly Suitable Area Present	Increasing linear function	0-1
Industry	Enterprise Zones	Presence = 1 / absence = 0.5	0-1
Biophysical *	Commercial Shellfish Management Areas *	Approved area = 1 Conditionally approved = 0.5 Not specified = 0.5 Prohibited = 0.25	0-1
Biophysical *	Shellfish Plats 2021 *	Presence = 1 / absence = 0.5	0-1

* Not used in the kelp species Ranking Model.

Table 16. Estuary Tank Ranking Model variables and data layers, with rescale method and scoring.

Variable	Data layer	Rescale method	Score range
Logistics	Presence of Seafood Processors	Presence = 1 / absence = 0.5	0-1
Logistics	Presence of Cold Food Storage Warehouses	Presence = 1 / absence = 0.5	0-1
Logistics	Permits Required at City Level	Presence = 0.5 / absence = 1	0-1
Logistics	Port Owned Lands	Presence = 1 / absence = 0.5	0-1
Industry	Enterprise Zones	Presence = 1 / absence = 0.5	0-1
Industry	Highly Suitable Area Present	Increasing linear function	0-1

2.11. Characterization

Select mariculture species—Olympia oyster, purple sea urchin, and bull kelp—were further examined to identify key drivers and relevant considerations to mariculture planning. This process included reviewing data overlays from the Exclusion, Opportunity, and Suitability Models, helping highlight critical variables and potential limitations that may not have been immediately evident in the modeled results. Additional considerations are discussed in Section 4, [Caveats, Limitations, and Discussion](#).

2.12. Geodatabase development

All datasets and derived products were stored and organized within geodatabases to ensure consistency, accessibility, and long-term usability. These geodatabases provided a centralized framework for managing spatial data, allowing users to efficiently access, query, and interact with the information used throughout the analysis. In addition to raw and processed datasets, the geodatabases include metadata and standardized attribute fields to support reproducibility and facilitate integration with future analyses.

Data are available for viewing and download via the Oregon Coastal Atlas (coastalatlas.net/MaricultureSuitability). The atlas is maintained by the Oregon Department of Land Conservation and Development.

3. Results and characterization

3.1. Exclusion Analysis

The Advisory Committee provided input on a range of datasets to include within the Exclusion Analysis. Table 7 provides an overview of the datasets, including any associated setback distances applied, the original data source for the dataset, as well as any specific comments on the dataset and applied setback distance. Each species- and gear-specific spatial analysis that followed used the same underlying Exclusion Analysis described below to remove incompatible areas from further consideration for mariculture siting.

In total, the Exclusion Analysis removed a total of 36,013 ac (146 km²) within the estuarine subarea (36.0% of total area; Table 17, Table 18, Figure 14, and Figure 15) and 144,128 ac (583 km²) within the Coastal subarea (17.7% of total area; Table 17, Table 19, and Figure 17). For the Estuary Tank Exclusion Model, 92,676 ac (375 km²) were removed from the Estuary subarea (92.5% of total area; Table 17, Table 18, Figure 18, and Figure 19), while for the Coastal Tank Exclusion Model, 797,581 ac (3,228 km²) were removed (97.9% of total area; Table 17, Table 19, and Figure 20).

Table 17. Exclusion layers with number of cells excluded and percentage of cells excluded for the Coastal, Estuary, Coastal Tank, and Estuary Tank Exclusion Models.

Exclusion data layer	Grid cells excluded (%)			
	Coastal	Estuary	Coastal Tank	Estuary Tank
Active Ocean Disposal Sites	7,358 (0.9%)	–	7,358 (0.9%)	–
Aids to Navigation	167 (0.02%)	3,578 (0.4%)	–	–
Airports (Coos Bay / Astoria)	–	10,242 (1.0%)	–	10,242 (1.0%)
Anchorage	–	13,274 (1.3%)	–	13,274 (1.3%)
Bathymetry > 150 m	704 (0.09%)	–	704 (0.09%)	–
Bridges (Road / Train)	58 (0.01%)	42,390 (4.2%)	–	–
Clam Beds	–	41,232 (4.1%)	–	41,232 (4.1%)
Danger and Restricted Areas	8,470 (1.0%)	–	8,470 (1.0%)	–

Exclusion data layer	Grid cells excluded (%)			
	Coastal	Estuary	Coastal Tank	Estuary Tank
Eelgrass Maximum Extent	3 (< 0.01%)	118,534 (11.8%)	3 (< 0.01%)	118,534 (11.8%)
Environmental Sensor Buoys	8 (< 0.01%)	29 (< 0.01%)	–	–
Kelp Maximum Extent	14,837 (1.8%)	–	14,837 (1.8%)	–
Maintained Channels	1,485 (0.2%)	46,100 (4.6%)	–	–
Marina, Dock, Boat Ramp	4 (< 0.01%)	10,394 (1.0%)	–	–
Native Oyster Habitat	–	6,630 (0.7%)	–	6,630 (0.7%)
Pinniped Haul-Outs	1,567 (0.2%)	6,952 (0.7%)	1,567 (0.2%)	6,952 (0.7%)
Recreational Shellfish Harvest	–	74,163 (7.4%)	–	–
South Slough National Estuarine Research Reserve	–	7,296 (0.7%)	–	7,296 (0.7%)
State Special Management Areas	84,383 (10.4%)	7,488 (0.7%)	84,383 (10.4%)	7,488 (0.7%)
Submarine Cable Areas	12,142 (1.5%)	59,401 (5.9%)	–	–
U.S. Fish and Wildlife Service National Wildlife Refuges	21,669 (2.7%)	10,056 (1.0%)	21,669 (2.7%)	10,056 (1.0%)
Wrecks and Obstructions	11,483 (1.4%)	17,074 (1.7%)	–	17,074 (0.0%)
Tank Shoreside Zones	–	–	785,731 (96.5%)	904,464 (90.3%)
Total exclusions	144,128 (17.7%)	360,130 (36.0%)	797,581 (97.9%)	926,764 (92.5%)

Note. Coastal model cells were 1 ac, and Estuary model cells were 0.1 ac. Summing the values in each column will produce different totals than those shown because some of the exclusion areas overlap (e.g., some navigation areas may overlap fishing areas).

Table 18. All estuaries examined along Oregon’s coast, with the total area examined and the amount of area removed in the Estuary and Estuary Tank Exclusion Models.

Estuary (north to south)	Total area, acres	Area excluded by Estuary Model, acres (%)	Area excluded by Estuary Tank Model, acres (%)
Astoria	33,816	8,235 (24.4%)	32,468 (96.0%)
Youngs Bay	4,758	1,370 (28.8%)	4,758 (100%)
Necanicum *	398	71 (17.9%)	311 (78.0%)
Nehalem	2,871	1,020 (35.5%)	2,389 (83.2%)
Tillamook Bay	10,183	5,353 (52.6%)	9,774 (96.0%)
Netarts Bay	2,439	1,856 (76.1%)	2,359 (96.0%)
Sand Lake	863	140 (16.2%)	863 (100 %)
Nestucca Bay	1,248	433 (34.7%)	1,159 (92.5%)
Neskowin Creek *	13	4 (33.1%)	13 (100%)
Salmon River	345	41 (11.9%)	326 (94.3%)

Estuary (north to south)	Total area, acres	Area excluded by Estuary Model, acres (%)	Area excluded by Estuary Tank Model, acres (%)
Siletz Bay	2,236	831 (37.2%)	2,185 (97.7%)
Depoe Bay *	15	14 (92.7%)	14.6 (97.3%)
Yaquina Bay	4,873	2,754 (56.5%)	4,505 (92.4%)
Alsea Bay	2,927	1,087 (37.1%)	2,788 (95.2%)
Yachats River *	58	44 (75.7%)	58 (100%)
Siuslaw River	4,241	1,329 (31.3%)	3,716 (87.6%)
Siltcoos River *	72	9 (12.2%)	72 (100%)
Umpqua River	9,454	3,116 (33.0%)	8,644 (91.4%)
Tenmile Creek *	53	3 (4.7%)	53 (100%)
Coos Bay	13,950	7,517 (53.9%)	12,462 (89.3%)
Coquille River	2,348	453 (19.3%)	2,270 (96.7%)
New River *	225	0 (0.0%)	225 (100%)
Elk River *	48	0 (0.0%)	48 (99.0%)
Sixes River *	94	4 (4.5%)	94 (100%)
Euchre Creek *	20	8 (40.5%)	20 (98.5%)
Rogue River *	715	163 (22.8%)	612 (85.6%)
Hunter Creek *	27	11 (41.9%)	2 (5.9%)
Pistol River *	79	43 (54.7%)	79 (100%)
Chetco River *	250	87 (34.8%)	157 (62.6%)
Winchuck River *	33	18 (54.2%)	12 (35.2%)

* These estuaries were not considered further, primarily due to their small size or lack of data for these estuaries.

Figure 14. Estuary Exclusion Model results for northern Oregon estuaries based on data layers known to conflict with mariculture.

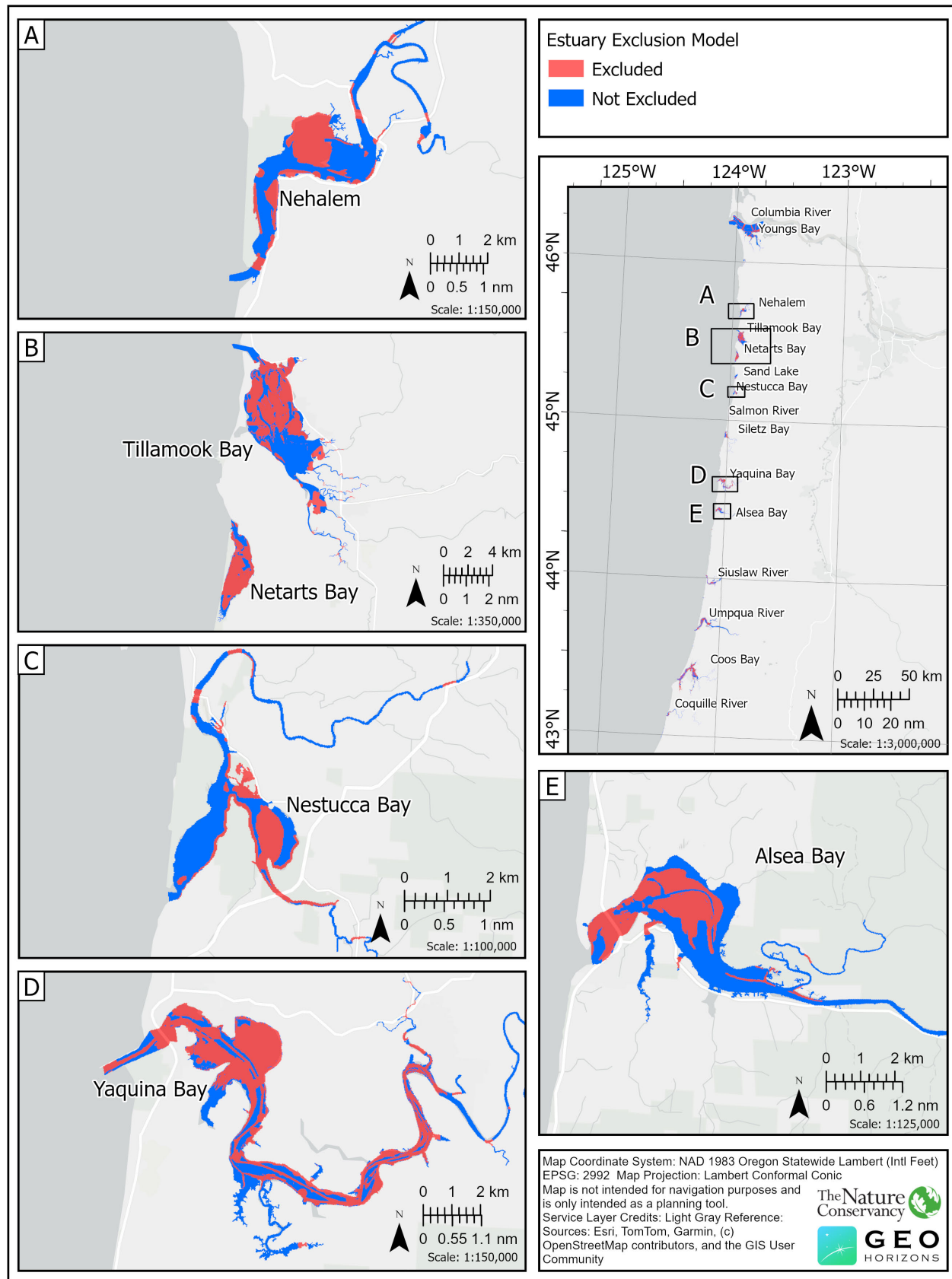


Figure 15. Estuary Exclusion Model results for southern Oregon estuaries based on data layers known to conflict with mariculture.

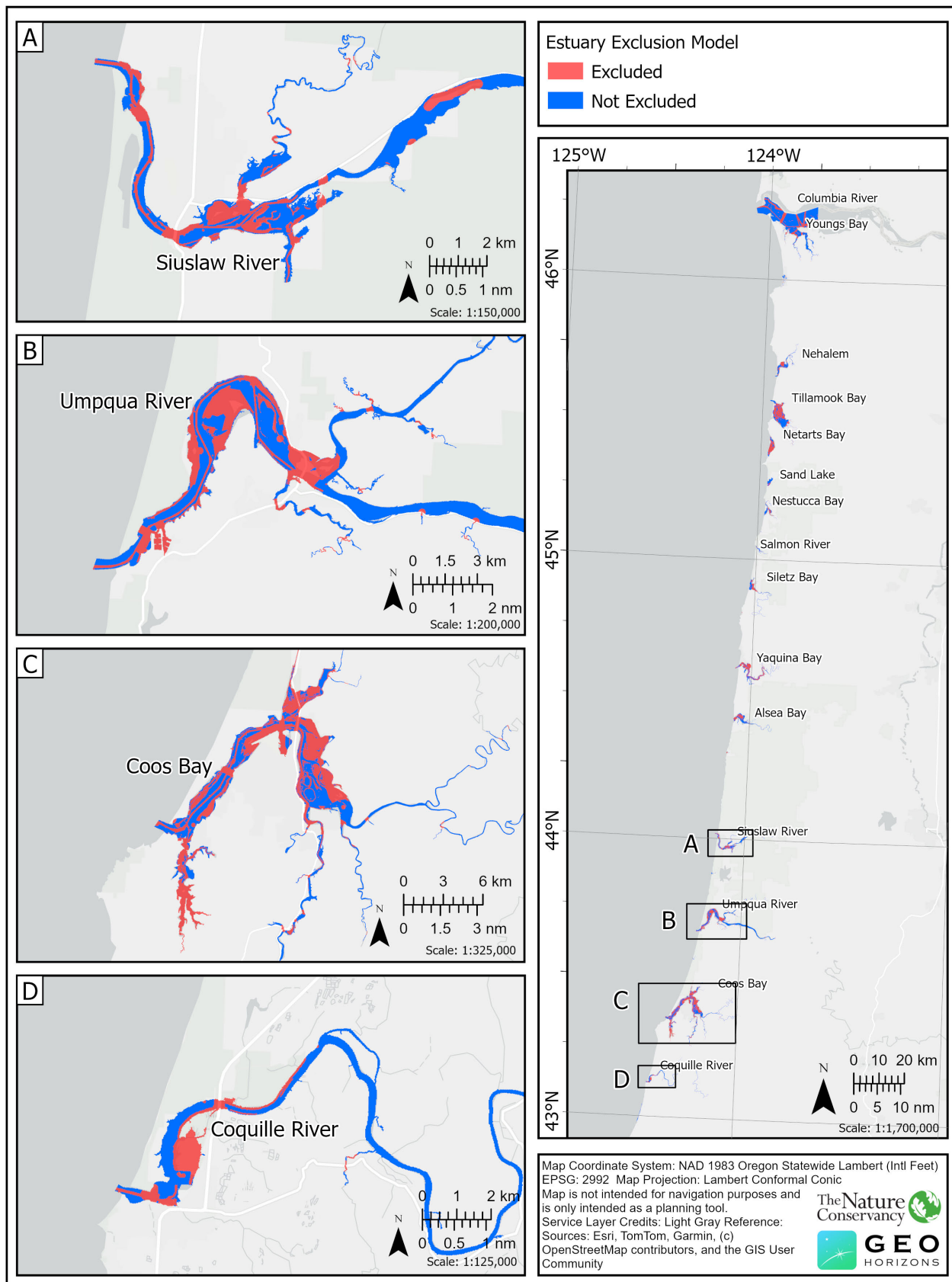


Table 19. Oregon’s coastal ocean zones examined in this analysis, with the total area examined and the amount of area removed in the Coastal and Coastal Tank Exclusion Models.

Coastal ocean zones (north to south)	Total area, acres	Area excluded by Coastal Model, acres (%)	Area excluded by Coastal Tank Model, acres (%)
Astoria / Warrenton	57,577	10,494 (18.2%)	56,588 (98.3%)
Nehalem	65,084	17,315 (26.6%)	62,653 (96.3%)
Garibaldi / Tillamook Bay	79,488	5,470 (6.9%)	77,326 (97.3%)
Depoe Bay	80,858	25,875 (32.0%)	78,817 (97.5%)
Newport / Toledo	33,257	2,105 (6.3%)	30,713 (92.4%)
Alsea	48,182	20,382 (42.3%)	46,469 (96.4%)
Siuslaw / Florence	60,661	21,348 (35.2%)	60,235 (99.3%)
Umpqua / Reedsport	54,558	1,634 (3.0%)	54,558 (100.0%)
Coos Bay / Charleston	51,323	6,440 (12.5%)	51,323 (100.0%)
Bandon	53,913	3,188 (5.9%)	53,460 (99.2%)
Port Orford	99,981	15,548 (15.6%)	99,012 (99.0%)
Gold Beach	82,183	7,926 (9.6%)	79,719 (97.0%)
Brookings	47,439	6,403 (13.5%)	46,708 (98.5%)

Figure 16. Kelp beds adjacent to Crook Point at the Oregon Islands National Wildlife Refuge. [Photo](#) by David B. Ledig, USFWS. [CC BY 2.0](#).



Figure 17. Coastal Exclusion Model results for Oregon's coast based on data layers known to conflict with mariculture.

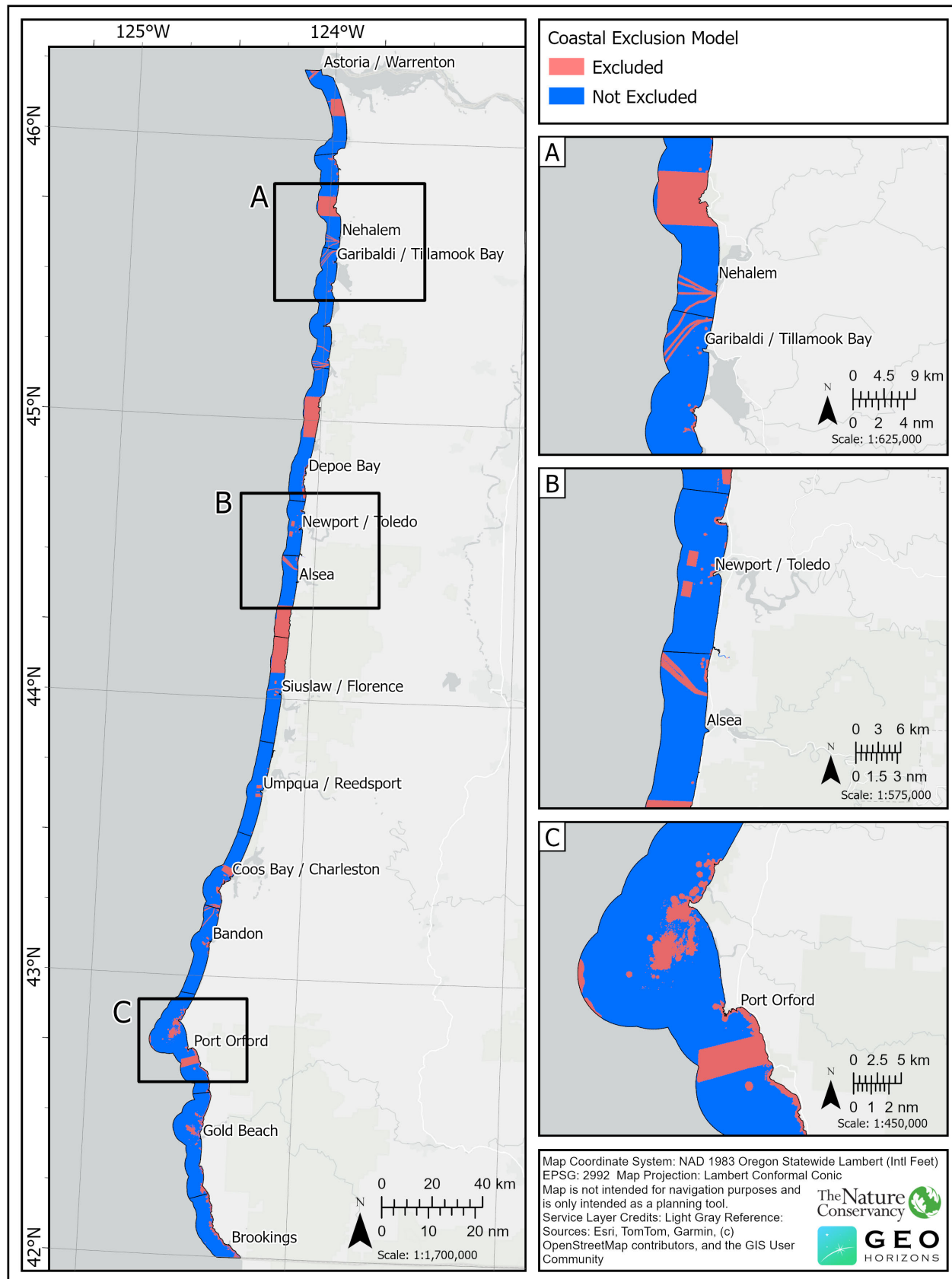


Figure 18. Estuary Tank Exclusion Model results for northern Oregon estuaries based on data layers known to conflict with tank mariculture, as well as limitations of potentially available land-based infrastructure.

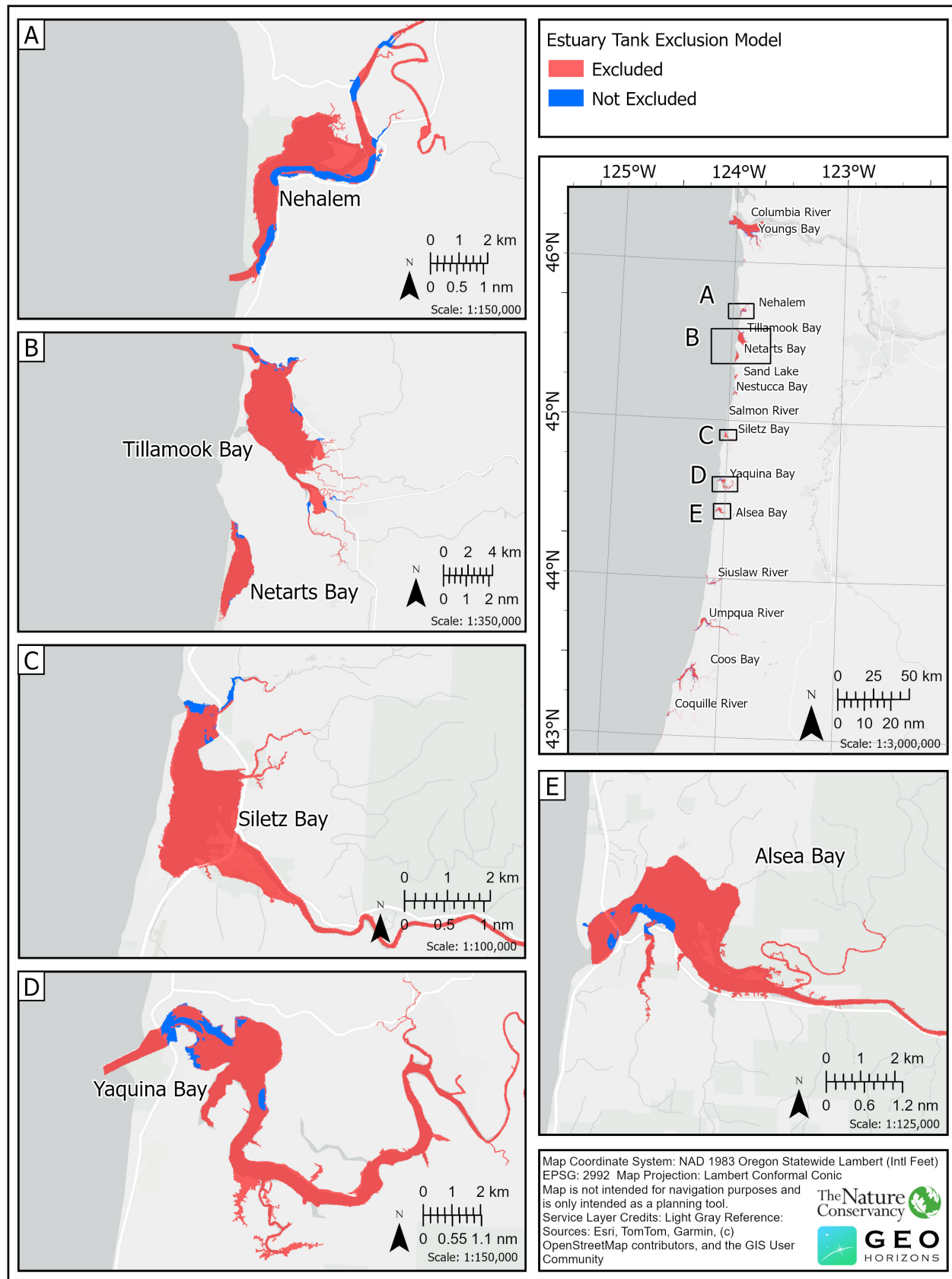


Figure 19. Estuary Tank Exclusion Model results for southern Oregon estuaries based on data layers known to conflict with tank mariculture, as well as limitations of potentially available land-based infrastructure.

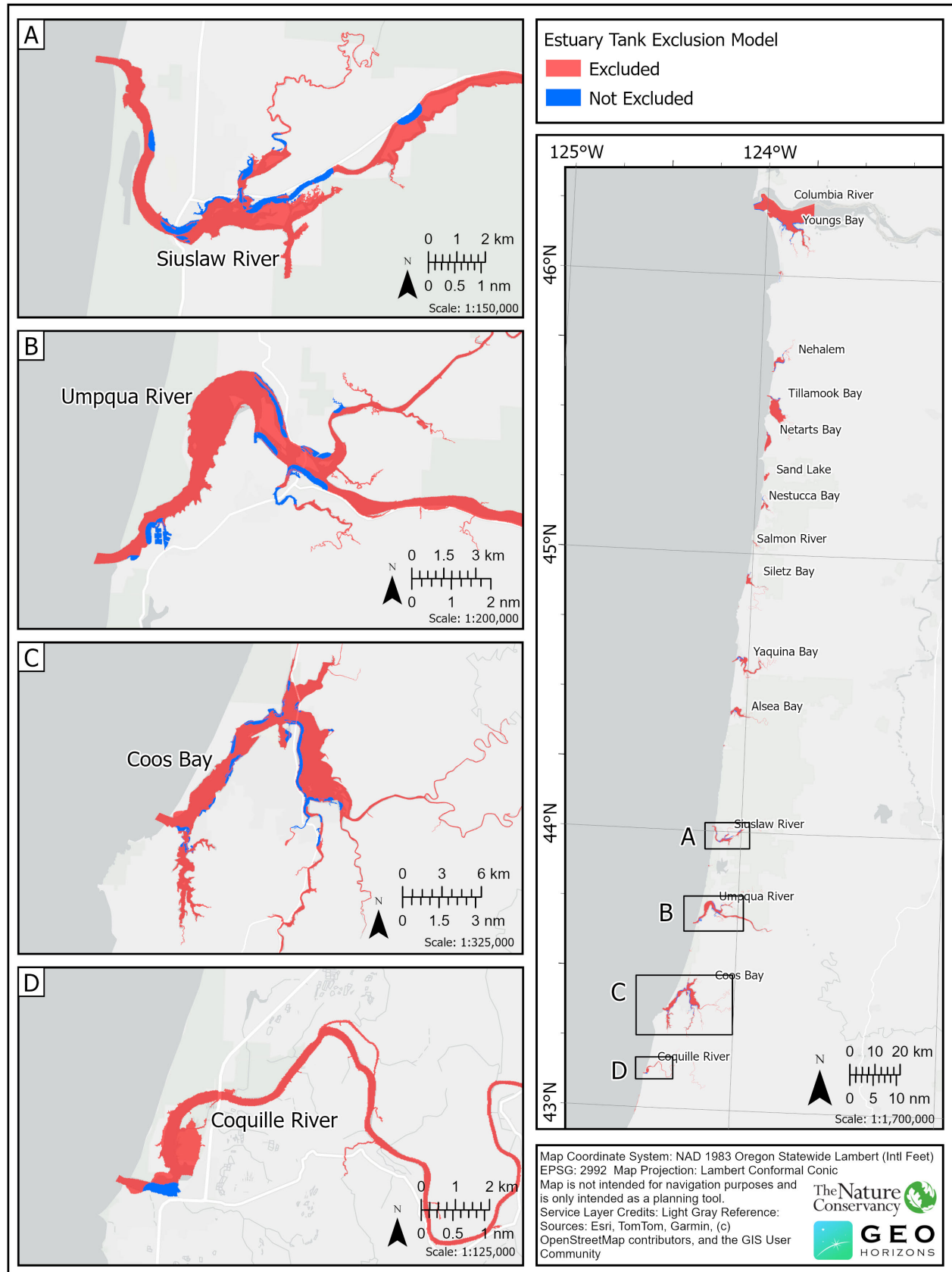
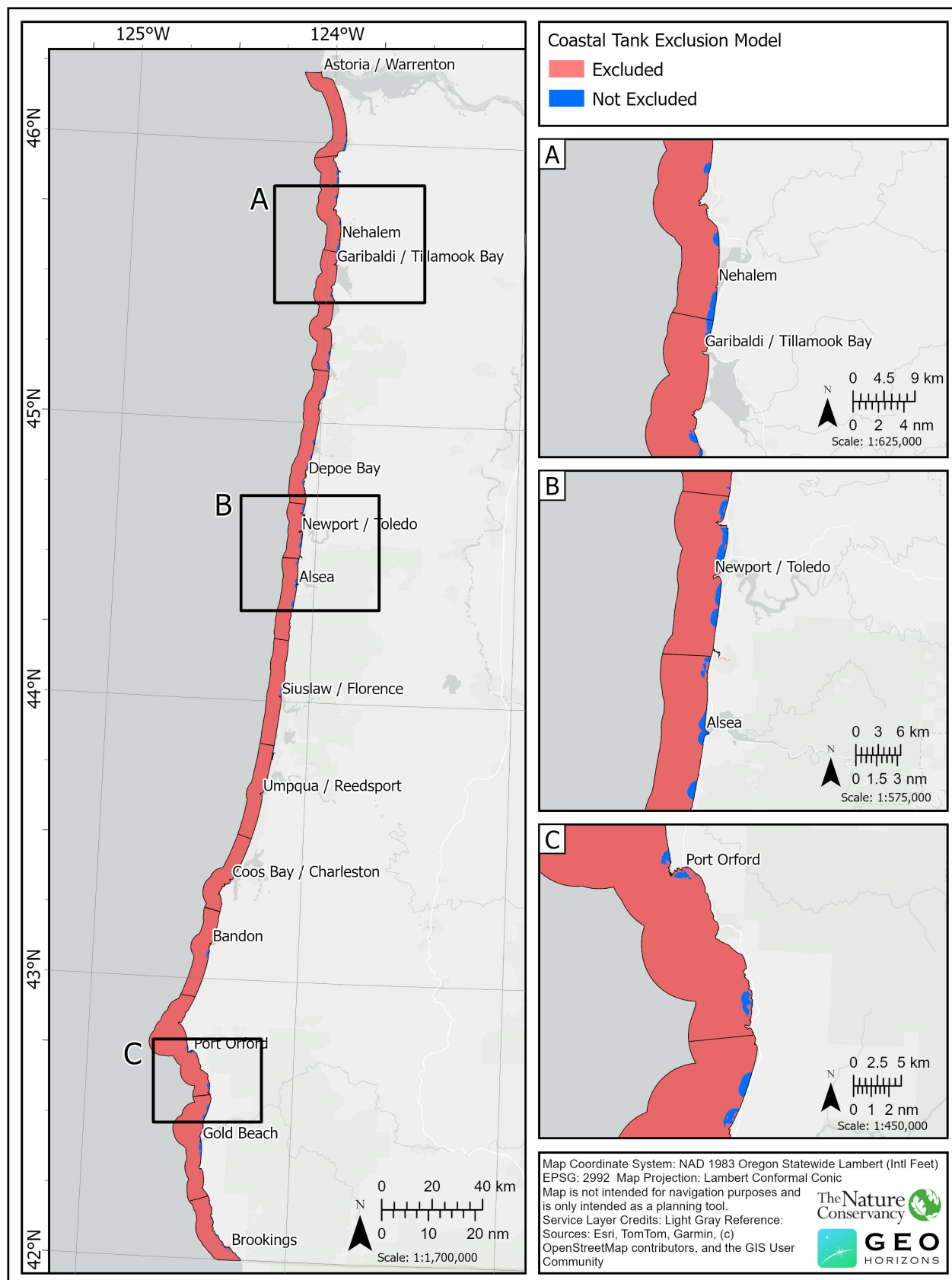


Figure 20. Coastal Tank Exclusion Model results for Oregon's coast based on data layers known to conflict with tank mariculture, as well as limitations of potentially available land-based infrastructure.



3.2. Opportunity Analysis

The Opportunity Analysis helped identify broad areas where a species-gear combination might have been feasible per defined minimum or maximum criteria or parameter thresholds (e.g., falling within a species' salinity tolerance range). These outputs did not imply site optimality or guarantee mariculture

success. They indicated sites that met baseline feasibility thresholds for the Biophysical variable—derived from peer-reviewed literature, expert judgment, and best available data. The upcoming species-specific sections ([Section 3.3.1](#) to [Section 3.3.4](#), as well as [Appendix B](#)) provide details and maps of model outputs. High-level results are presented in Table 20 through Table 22.

Table 20. Total area of opportunity (acres) for each mariculture species-gear combination evaluated under the Estuary and Coastal Models.

Model	Mariculture species	Gear	Area (ac)
Estuary	Olympia oyster (<i>Ostrea lurida</i>)	Subtidal gear	5,450
Estuary	Pacific blue mussel (<i>Mytilus trossulus</i>)	Line culture	4,004
Estuary	Kelp species	Line culture	2,375
Estuary	Pacific dulse (<i>Devaleraea mollis</i> ; syn. <i>Palmaria mollis</i>)	Tank culture	1,363
Estuary	Purple sea urchin (<i>Strongylocentrotus purpuratus</i>)	Tank culture	1,395
Coastal	Bull kelp (<i>Nereocystis luetkeana</i>)	Planted on bottom	58,599
Coastal	Bull kelp (<i>N. luetkeana</i>)	Line culture	373,186
Coastal	Giant kelp (<i>Macrocystis pyrifera</i> ; syn. <i>M. integrifolia</i>)	Line culture	451,278
Coastal	Ribbon/winged kelp (<i>Alaria marginata</i>)	Line culture	386,263
Coastal	Sugar kelp (<i>Saccharina latissima</i>)	Line culture	521,834
Coastal	Pacific blue mussel (<i>M. trossulus</i>)	Line culture	598,453
Coastal	California mussel (<i>Mytilus californianus</i>)	Line culture	543,863
Coastal	Red abalone or flat abalone (<i>Haliotis rufescens</i> or <i>H. walallensis</i>)	Tank culture	13,681

Table 21. Total area of opportunity (acres) for each species-gear combination within each estuary, from north to south along the Oregon Coast.

Estuary (north to south)	Area (ac)				
	Olympia oyster Subtidal gear	Pacific blue mussel Line culture	Kelp species Line culture	Pacific dulse Tank culture	Purple sea urchin Tank culture
Columbia River	0	0	0	0	0
Youngs Bay	0	0	0	0	0
Nehalem	307	176	47	94	93
Tillamook Bay	225	117	91	173	173
Netarts Bay	49	28	26	43	75
Sand Lake	0	0	0	0	0
Nestucca Bay	69	4	4	0	0
Salmon River	0	0	0	0	0
Siletz Bay	1	0	0	25	25
Yaquina Bay	514	355	206	287	287
Alsea Bay	23	10	5	114	114
Siuslaw River	281	210	210	81	81
Umpqua River	1,956	1,521	602	182	182
Coos Bay	1,871	1,512	1,137	306	307
Coquille River	155	71	47	58	58
Total area	5,450	4,004	2,375	1,363	1,395

Table 22. Total area of opportunity (acres) for each species-gear combination within each coastal ocean zone, as well as total area values for all kelp line culture and mussel line culture opportunities.

Coastal ocean zones (north to south)	Area (ac)									
	Bull kelp Planted on bottom	Bull kelp Line culture	Giant kelp Line culture	Ribbon/ winged kelp Line culture	Sugar kelp Line culture	All kelp Line culture	Pacific blue mussel Line culture	California mussel Line culture	All mussel Line culture	Red or flat abalone Tank culture
Astoria / Warrenton	0	0	0	5	21,089	21,094	28,342	1,609	28,342	0
Nehalem	288	120	10,380	10,510	32,614	32,745	34,748	32,719	34,748	1,177
Garibaldi / Tillamook Bay	1,400	1,608	35,379	7,103	42,085	42,201	69,135	58,199	69,135	2,183
Depoe Bay	1,474	2,603	41,004	2,603	41,004	41,013	53,078	46,109	53,078	1,798
Newport / Toledo	7,649	22,445	27,786	22,445	27,786	28,436	28,449	26,129	28,449	2,544
Alsea	5,163	25,215	25,209	25,215	25,209	25,215	25,215	25,017	25,215	1,710
Siuslaw / Florence	7,131	35,793	35,793	35,793	35,973	35,793	35,793	35,793	35,793	426
Umpqua / Reedsport	8,362	48,629	48,718	48,629	48,718	48,718	48,718	48,718	48,718	0
Coos Bay / Charleston	6,173	42,481	36,980	42,481	36,980	42,486	42,486	42,486	42,486	0
Bandon	7,530	47,515	47,515	47,515	47,515	47,515	47,515	44,564	47,515	453
Port Orford	2,739	52,453	52,333	49,691	65,661	68,423	82,568	79,913	82,568	965
Gold Beach	10,315	71,760	66,620	71,760	67,295	72,435	72,434	72,434	72,434	2,294
Brookings	507	23,233	24,363	23,233	31,071	31,071	31,069	31,069	31,069	152
Total area	58,599	373,186	451,278	386,263	521,834	536,159	598,453	543,863	598,453	13,681

Note. Grid cells that intersect multiple areas are counted in each applicable area; therefore, summing all listed area values in a column will slightly exceed the total area shown. Also, because the area of opportunity for one species is likely to share grids with the area of opportunity for another species, summing the values in a row will yield different values than those shown in the “all kelp / line culture” and “all mussel / line culture” totals.

3.3. Suitability and Local Indicators of Spatial Association (LISA) analysis

This study's Suitability Analyses assigned relative scores on a 0–1 scale to indicate areas where conditions were more favorable and where conflicts were lower for each species–gear combination, based on the input data and scoring framework. Scores were relative and not comparable across species or gear types; accordingly, results were classified into five categories using ArcGIS Pro quantiles (“Low,” “Moderately Low,” “Moderate,” “Moderately High,” and “High”; Esri, n.d.–b).

To identify the most suitable areas, a LISA analysis was applied to identify high–high clusters, representing areas of concentrated high suitability. The total areas of these high–high clusters, referred to as *highly suitable areas*, are presented in the next few paragraphs. These results do not guarantee suitability for mariculture operations; rather, they indicate areas that were found to be relatively more suitable than others evaluated, given the available data and scoring assumptions.

Multiple Suitability Models were developed for a range of species–gear combinations. Detailed written results are provided in [Section 3.3.1](#) to

[Section 3.3.4](#) for the Olympia oyster, purple sea urchin, and bull kelp (line culture, plus planted on bottom). Results for additional species are summarized in Table 23 through Table 25, with corresponding maps presented in [Appendix B](#).

Estuary Model results: Olympia oyster mariculture using subtidal gear exhibited the largest extent of highly suitable area among the species–gear combinations evaluated, totaling 1,485 ac (6 km²; Table 23). The greatest concentrations of highly suitable area were identified in Coos Bay (634 ac [3 km²]) and the Umpqua River (479 ac [2 km²]; Table 24).

Suitability modeling for purple sea urchin mariculture using tank culture identified 503 ac (2 km²) of highly suitable estuarine area (Table 23), with the largest areas located in Yaquina Bay (175 ac [1 km²]) and Coos Bay (156 ac [1 km²]; Table 24).

Coastal Model results: A total of 78,526 ac (318 km²) of highly suitable coastal ocean area was identified for bull kelp mariculture using line culture, along with 13,649 ac (55 km²) of highly suitable area for planted-on-bottom cultivation (Table 23). Gold Beach contained the largest extent of highly suitable area for both line culture (35,440 ac [143 km²]) and planted cultivation (9,187 ac [37 km²]; Table 25).

Table 23. Total amount of highly suitable area (acres) for both the Estuary and Coastal Models for each mariculture species–gear combination.

Model	Mariculture species	Gear	Area (ac)
Estuary	Olympia oyster (<i>Ostrea lurida</i>)	Subtidal gear	1,485
Estuary	Pacific blue mussel (<i>Mytilus trossulus</i>)	Line culture	1,132
Estuary	Kelp species	Line culture	521
Estuary	Pacific dulse (<i>Devaleraea mollis</i> ; syn. <i>Palmaria mollis</i>)	Tank culture	488
Estuary	Purple sea urchin (<i>Strongylocentrotus purpuratus</i>)	Tank culture	503
Coastal	Bull kelp (<i>Nereocystis luetkeana</i>)	Planted on bottom	13,649
Coastal	Bull kelp (<i>N. luetkeana</i>)	Line culture	78,526
Coastal	Giant kelp (<i>Macrocystis pyrifera</i> ; syn. <i>M. integrifolia</i>)	Line culture	111,337
Coastal	Ribbon/winged kelp (<i>Alaria marginata</i>)	Line culture	90,651
Coastal	Sugar kelp (<i>Saccharina latissima</i>)	Line culture	125,952

Model	Mariculture species	Gear	Area (ac)
Coastal	Pacific blue mussel (<i>M. trossulus</i>)	Line culture	137,785
Coastal	California mussel (<i>Mytilus californianus</i>)	Line culture	133,582
Coastal	Red abalone or flat abalone (<i>Haliotis rufescens</i> or <i>H. walallensis</i>)	Tank culture	3,691

Table 24. Total amount of highly suitable area (acres) for each species-gear combination within each estuary, from north to south along the Oregon Coast.

Estuary (north to south)	Area (ac)				
	Olympia oyster Subtidal gear	Pacific blue mussel Line culture	Kelp species Line culture	Pacific dulse Tank culture	Purple sea urchin Tank culture
Columbia River	0	0	0	0	0
Youngs Bay	0	0	0	0	0
Nehalem	0	0	0	0	0
Tillamook Bay	155	89	16	52	54
Netarts Bay	6	5	0	0	0
Sand Lake	0	0	0	0	0
Nestucca Bay	0	0	0	0	0
Salmon River	0	0	0	0	0
Siletz Bay	0	0	0	0	0
Yaquina Bay	211	85	0	169	175
Alsea Bay	0	0	0	0	0
Siuslaw River	0	0	0	0	0
Umpqua River	479	425	132	116	118
Coos Bay	634	528	373	151	156
Coquille River	0	0	0	0	0
Total area	1,485	1,132	521	488	503

Table 25. Total amount of highly suitable area (acres) for each species-gear combination within each coastal ocean zone, listed from north to south along the Oregon Coast, as well as total area values for all kelp line culture and mussel line culture.

Coastal ocean zones (north to south)	Area (ac)									
	Bull kelp Planted on bottom	Bull kelp Line culture	Giant kelp Line culture	Ribbon/ winged kelp Line culture	Sugar kelp Line culture	All kelp Line culture	Pacific blue mussel Line culture	California mussel Line culture	All mussel Line culture	Red or flat abalone Tank culture
Astoria / Warrenton	0	0	0	0	4,870	4,870	2,519	0	2,519	0
Nehalem	0	0	0	0	1,696	1,696	4,062	6,038	7,115	543
Garibaldi / Tillamook Bay	0	0	0	0	1,177	1,177	11,450	5,592	13,321	244
Depoe Bay	1	0	162	627	2,696	2,698	13,114	9,678	13,977	268
Newport / Toledo	8	0	381	1,043	1,748	1,852	6,772	7,311	8,453	785
Alsea	0	0	57	287	1,266	1,266	7,707	7,974	8,166	480
Siuslaw / Florence	0	0	3	5	103	103	11,638	12,318	12,318	0
Umpqua / Reedsport	34	881	3,375	7,809	9,769	9,785	14,218	14,774	14,774	0
Coos Bay / Charleston	40	2,948	4,746	7,943	8,430	9,809	12,304	13,687	13,687	0
Bandon	1,963	11,253	14,601	15,775	19,502	19,569	14,320	13,564	14,941	0
Port Orford	1,956	15,475	15,404	7,304	14,855	24,431	17,405	17,151	19,429	371
Gold Beach	9,187	35,440	49,596	38,688	41,238	57,369	18,444	20,707	20,707	873
Brookings	481	12,630	23,219	11,326	18,844	28,928	4,065	4,985	4,985	144
Total area	13,649	78,526	111,337	90,651	125,952	163,250	137,785	133,582	154,151	3,691

Note. Grid cells that intersect multiple areas are counted in each applicable area; therefore, summing all listed area values in a column will slightly exceed the total area reported. Also, because the highly suitable area for one species is likely to share grids with the highly suitable area for another species, summing the values in a row will yield different values than those shown in the “all kelp / line culture” and “all mussel / line culture” totals.

3.3.1. Olympia oyster – subtidal gear – modeling results

Opportunity Analysis

Opportunity for Olympia oyster mariculture using subtidal gear was identified in 11 of the 15 estuaries evaluated (Figure 21 and Figure 22). The largest areas of opportunity occurred in the Umpqua River and Coos Bay, while Netarts Bay, Nestucca Bay, Siletz Bay, and Alsea Bay exhibited the smallest areas of opportunity (Table 21). Highly suitable areas were identified in only five estuaries, with the greatest extents occurring in the Umpqua River and Coos Bay and the smallest extent in Netarts Bay (Table 24). Coos Bay ranked highest overall, driven in large part by its high Industry score; in addition to having the largest extent of highly suitable area, portions of these areas also overlapped designated enterprise zones. Netarts Bay and Tillamook Bay ranked lowest, with identical TOPSIS scores (Table 26).

Only 306.2 ac (1.2 km²) of Olympia oyster opportunity overlapped with the Commercial Shellfish Plats 2021 (ODA; Figure 21 and Figure 22). This limited overlap is largely attributable to the application of a minimum depth constraint (≥ 2 m) and the conservative exclusion of the maximum historical extent of eelgrass

habitat (Figure 23 to Figure 25). The results indicate a potential opportunity for the expansion of Olympia oyster mariculture into additional estuaries, including Nehalem Bay, Nestucca Bay, Alsea Bay, the Siuslaw River, and the Coquille River. However, due to data limitations, as well as the high interannual variability of water quality and eelgrass habitat, additional site-specific monitoring and review would be required to confirm actual feasibility in these areas.

Suitability Analysis

All highly suitable areas identified by the Suitability Model occurred in estuaries where oyster mariculture is already present (Figure 26 to Figure 29), although much of the modeled highly suitable area lies outside existing shellfish plats per the 2021 data (ODA, 2021), which tend to occur in shallower depths and are currently limited to six Estuary subareas. This pattern suggests either potential room for expansion or limitations in the available input data that may be influencing model outputs. In either case, further evaluation of these areas could help clarify why they are not currently utilized and assess whether they could support Olympia oyster mariculture operations.

Table 26. Estuaries ranked from more to less optimal for Olympia oyster mariculture using subtidal gear.

Estuary	Rank	Highly suitable area (ac)	Logistics	Industry	Biophysical	Distance positive	Distance negative	TOPSIS score
Coos Bay	1	633.8	0.87	0.95	0.50	0.51	0.95	0.65
Umpqua River	2	479.2	1.00	0.61	0.51	0.60	0.63	0.51
Yaquina Bay	3	210.4	1.00	0.40	0.70	0.62	0.47	0.43
Netarts Bay	4	6.1	0.87	< 0.01	1.00	0.96	0.50	0.34
Tillamook Bay	5	155.3	1.00	0.34	0.58	0.74	0.38	0.34

Note. The analysis employed the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS). The variables used in the analysis—Logistics, Industry, and Biophysical—ranged from 0 to 1, with 0 being less optimal and 1 being more optimal for mariculture. Distance from the positive solution and distance from the negative solution are provided in this table, with lower values being closer to and higher values being farther from each solution. The TOPSIS score was used for ranking, with a score of 1 being the most ideal solution and a score of 0 being the least ideal solution.

Figure 21. Opportunity Analysis results for Olympia oyster mariculture using subtidal gear in northern Oregon estuaries, with Commercial Shellfish Plats 2021 (ODA, 2021) overlaid.

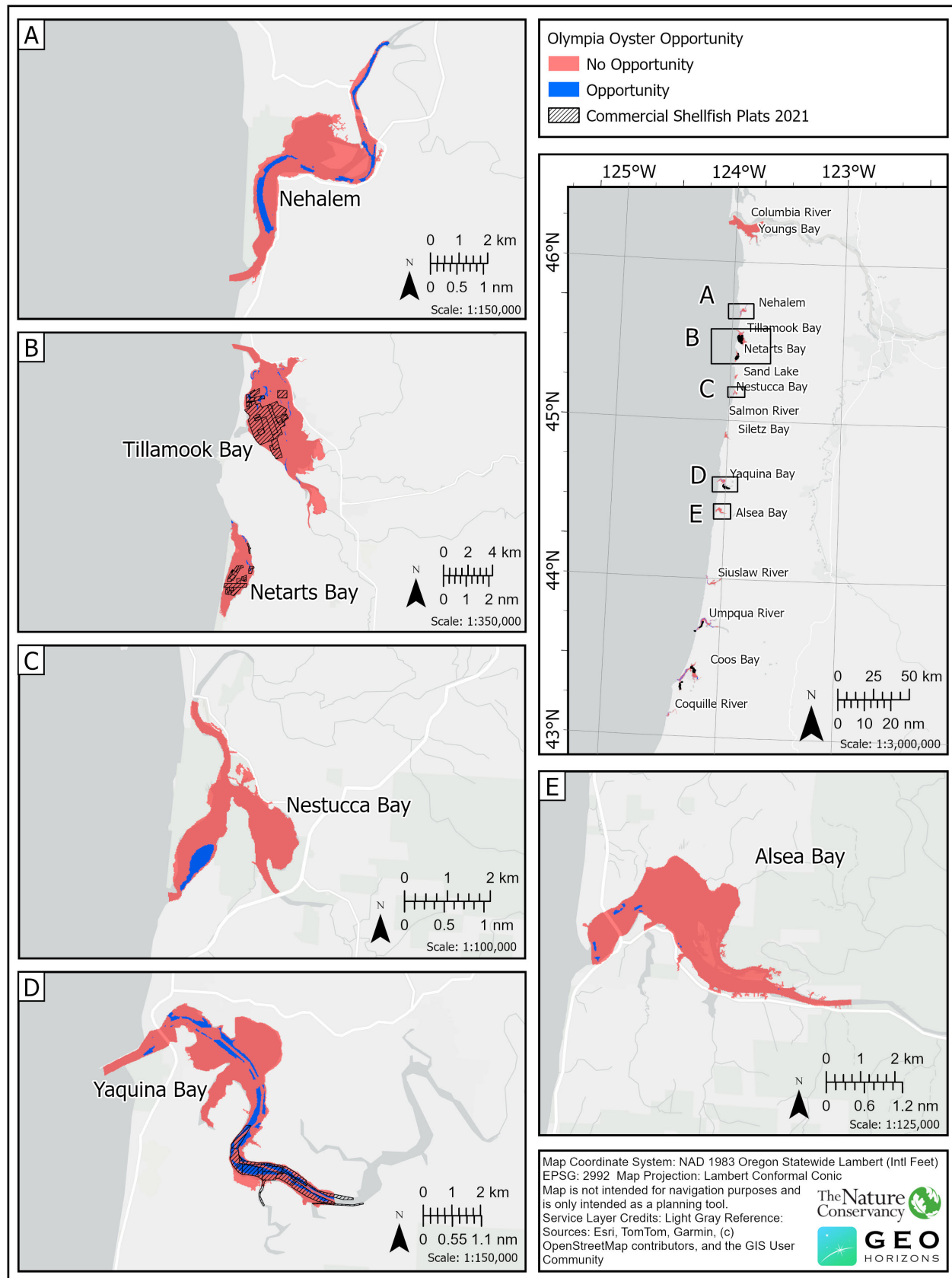


Figure 22. Opportunity Analysis results for Olympia oyster mariculture using subtidal gear in southern Oregon estuaries, with Commercial Shellfish Plats 2021 (ODA, 2021) overlaid.

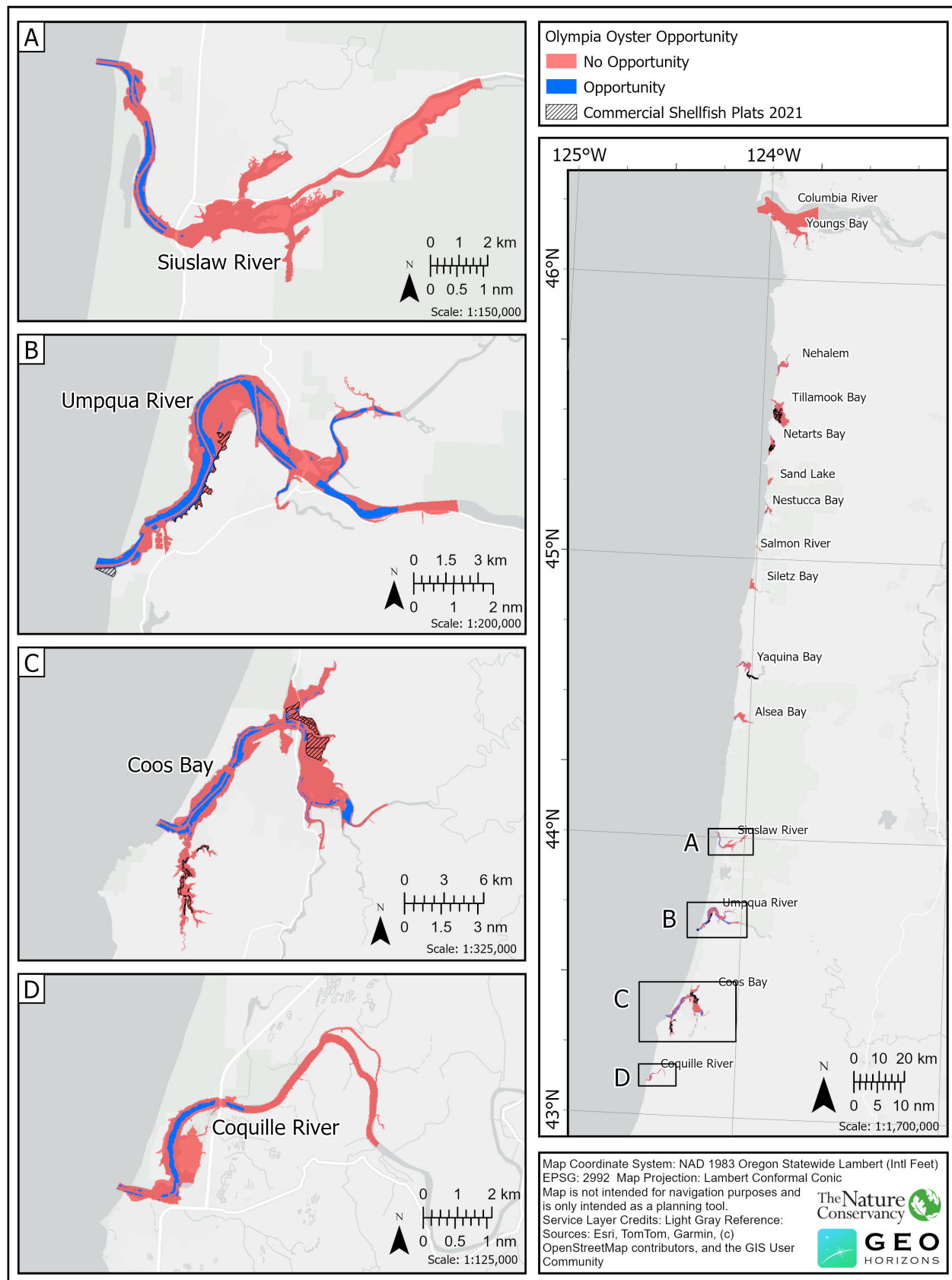


Figure 23. Example (Tillamook Bay) of spatial overlap between depth bins and Commercial Shellfish Plats 2021 (ODA, 2021). The “Depth ≥ 2 m” bin was an opportunity area for Olympia oyster mariculture using subtidal gear.

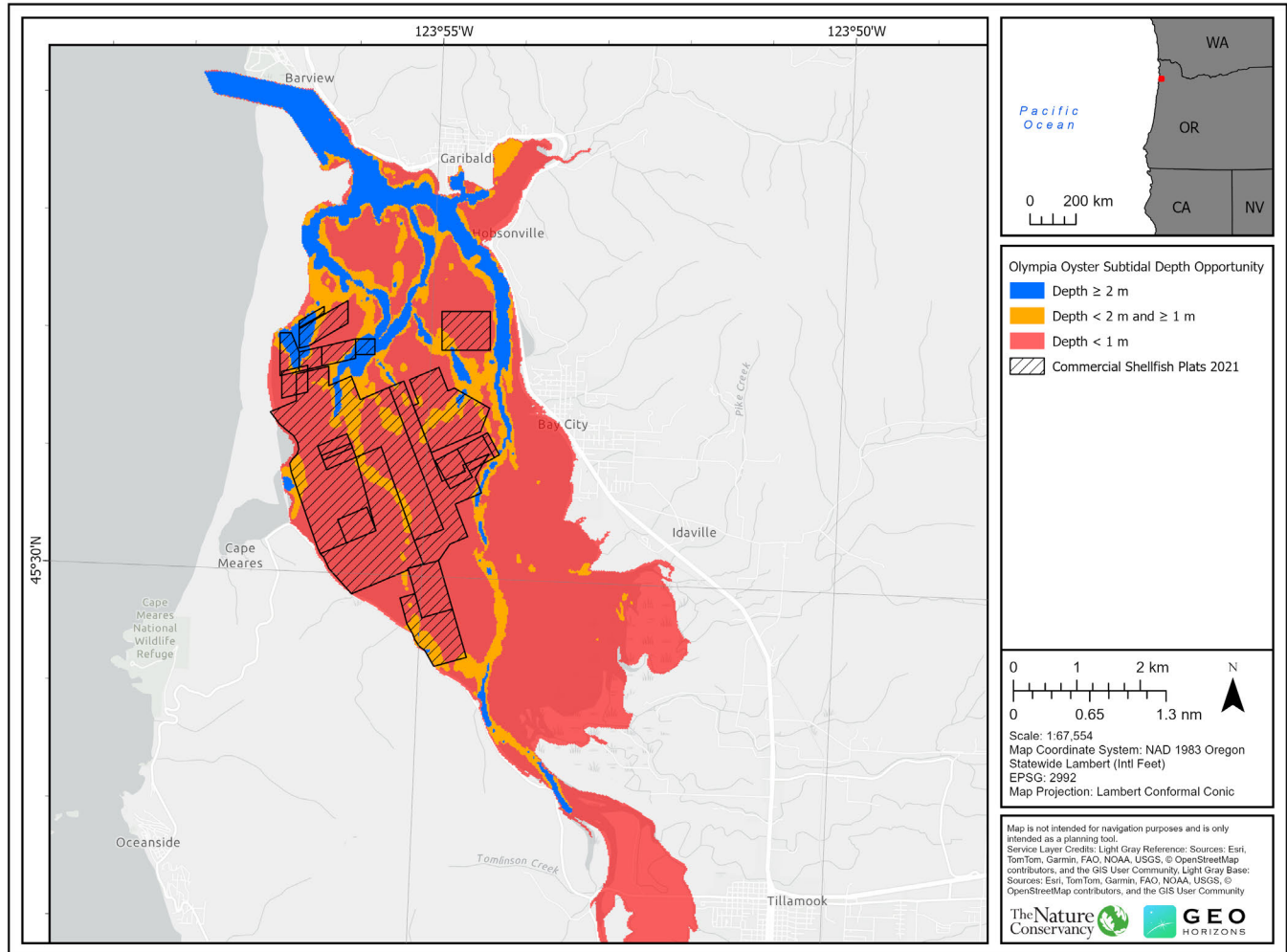


Figure 24. Tillamook Bay, along the Oregon Coast, with identified highly suitable areas for Olympia oyster mariculture shown alongside the maximum observed historical extent of eelgrass overlaid with Commercial Shellfish Plats 2021 (ODA, 2021).

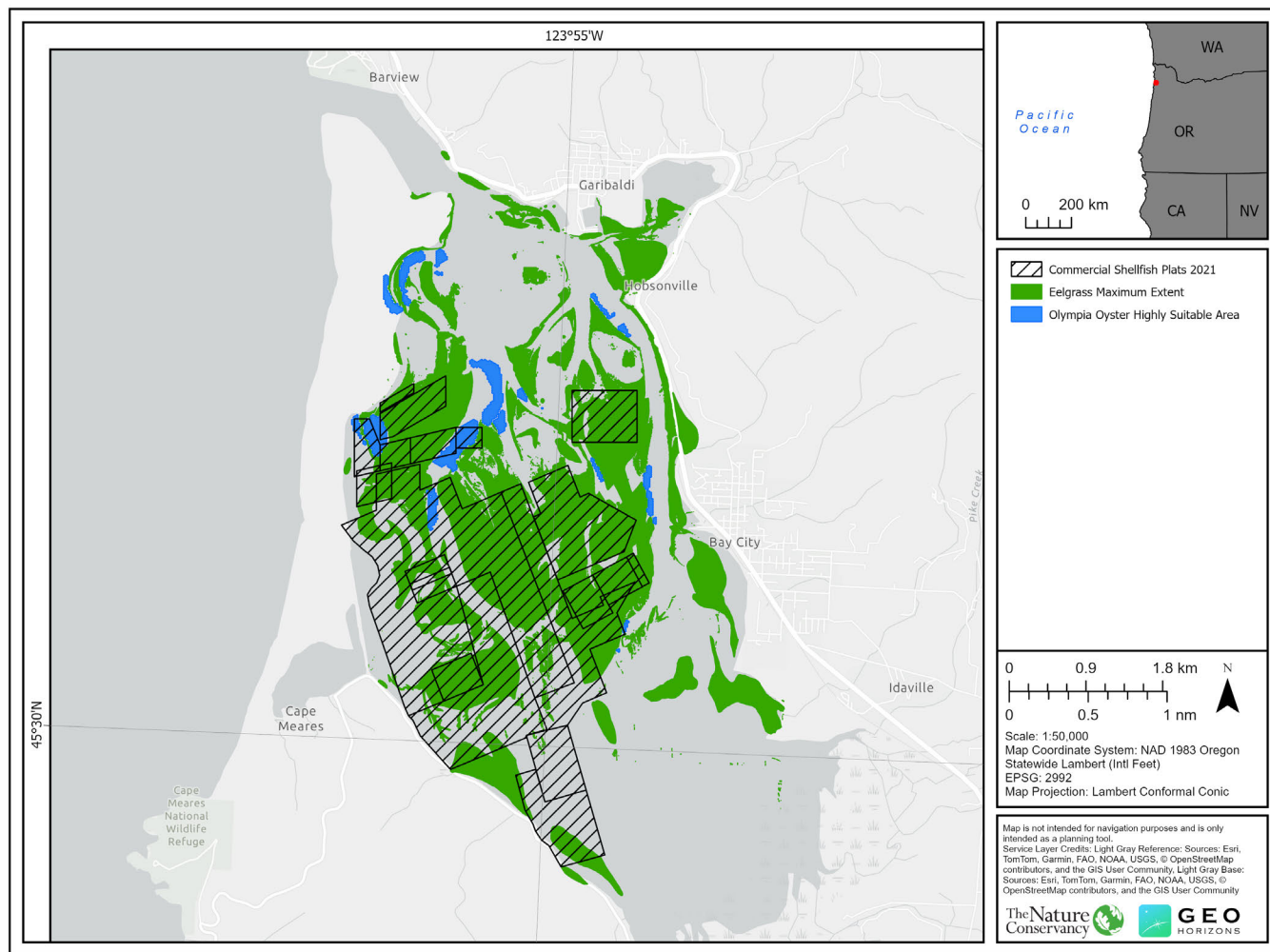


Figure 25. Estuaries along the Oregon Coast, with identified highly suitable areas for Olympia oyster mariculture shown alongside the maximum observed historical extent of eelgrass overlaid with Commercial Shellfish Plats 2021 (ODA, 2021).

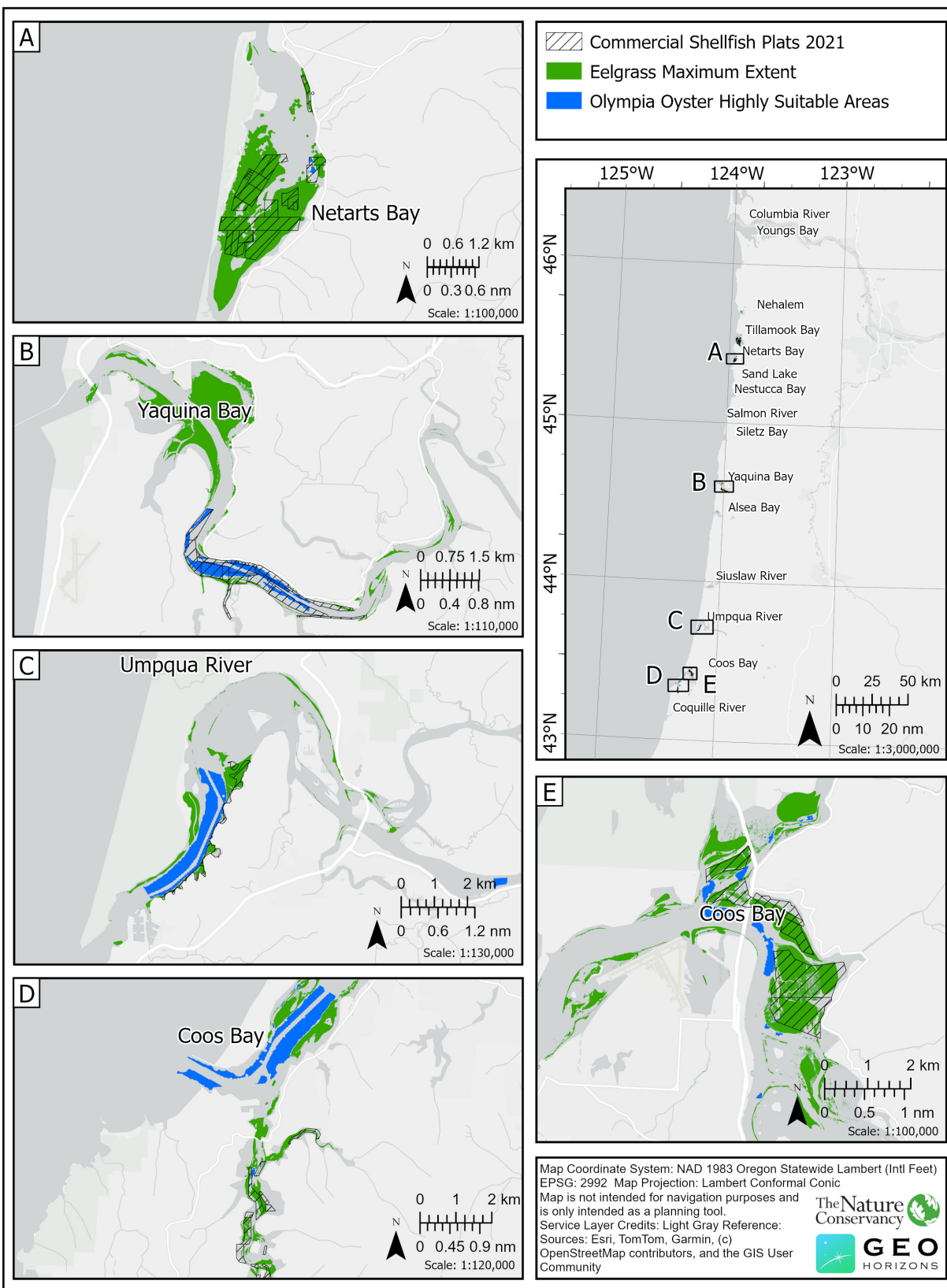


Figure 26. Suitability Analysis results for Olympia oyster mariculture using subtidal gear for northern Oregon estuaries.

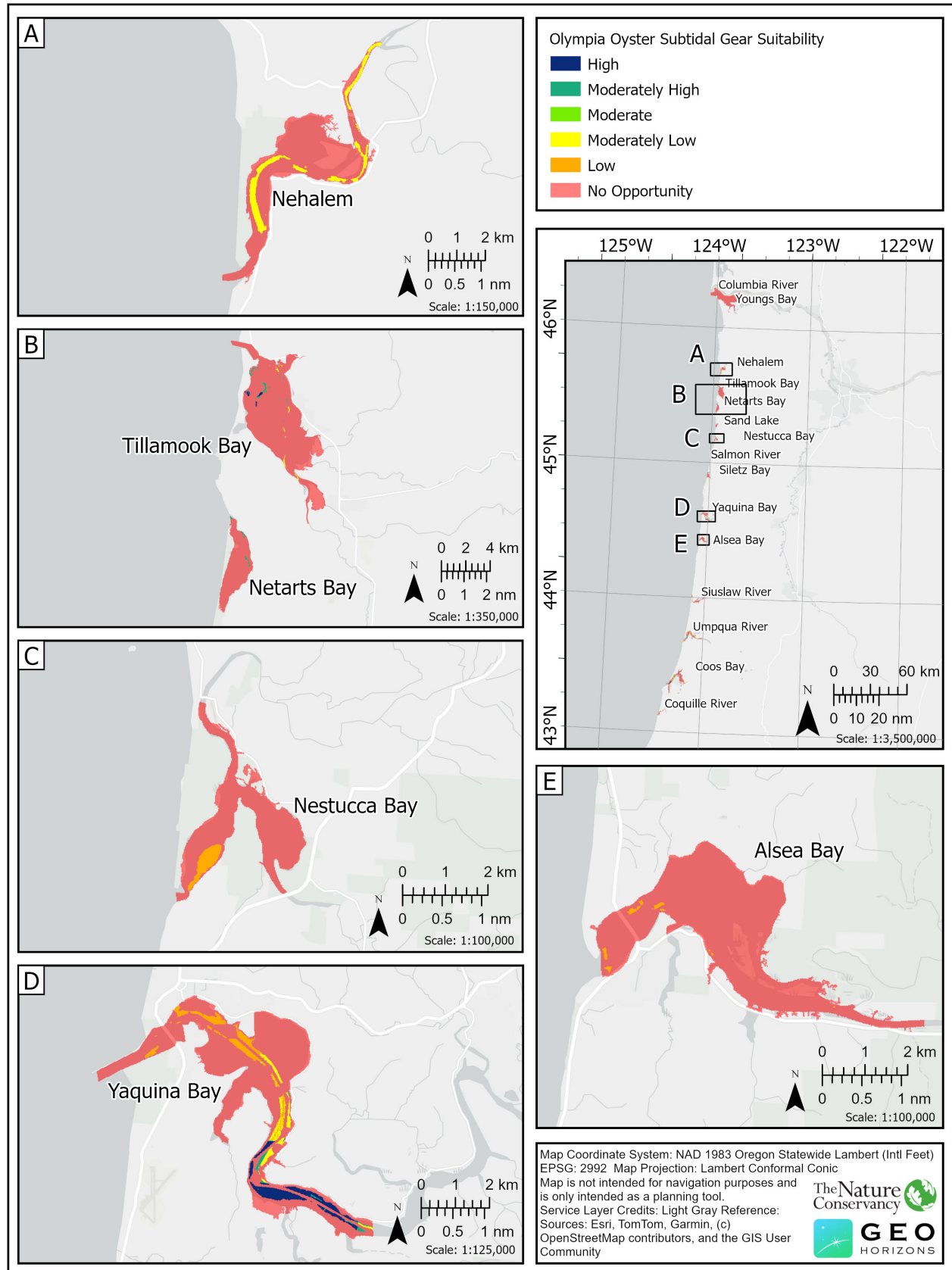


Figure 27. Suitability Analysis results for Olympia oyster mariculture using subtidal gear for southern Oregon estuaries.

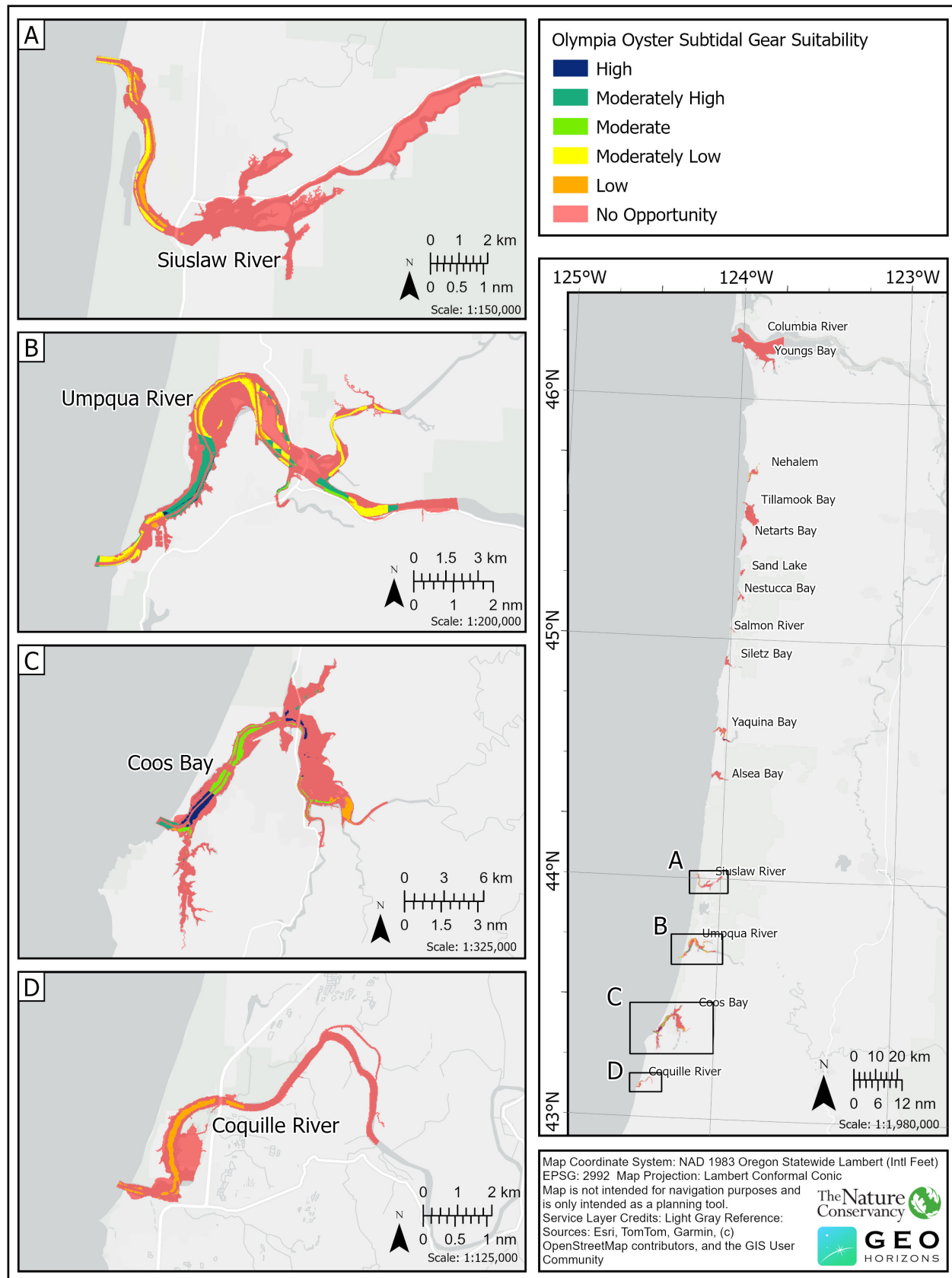


Figure 28. Highly suitable areas in northern Oregon estuaries for Olympia oyster mariculture using subtidal gear, as indicated by the LISA analysis.

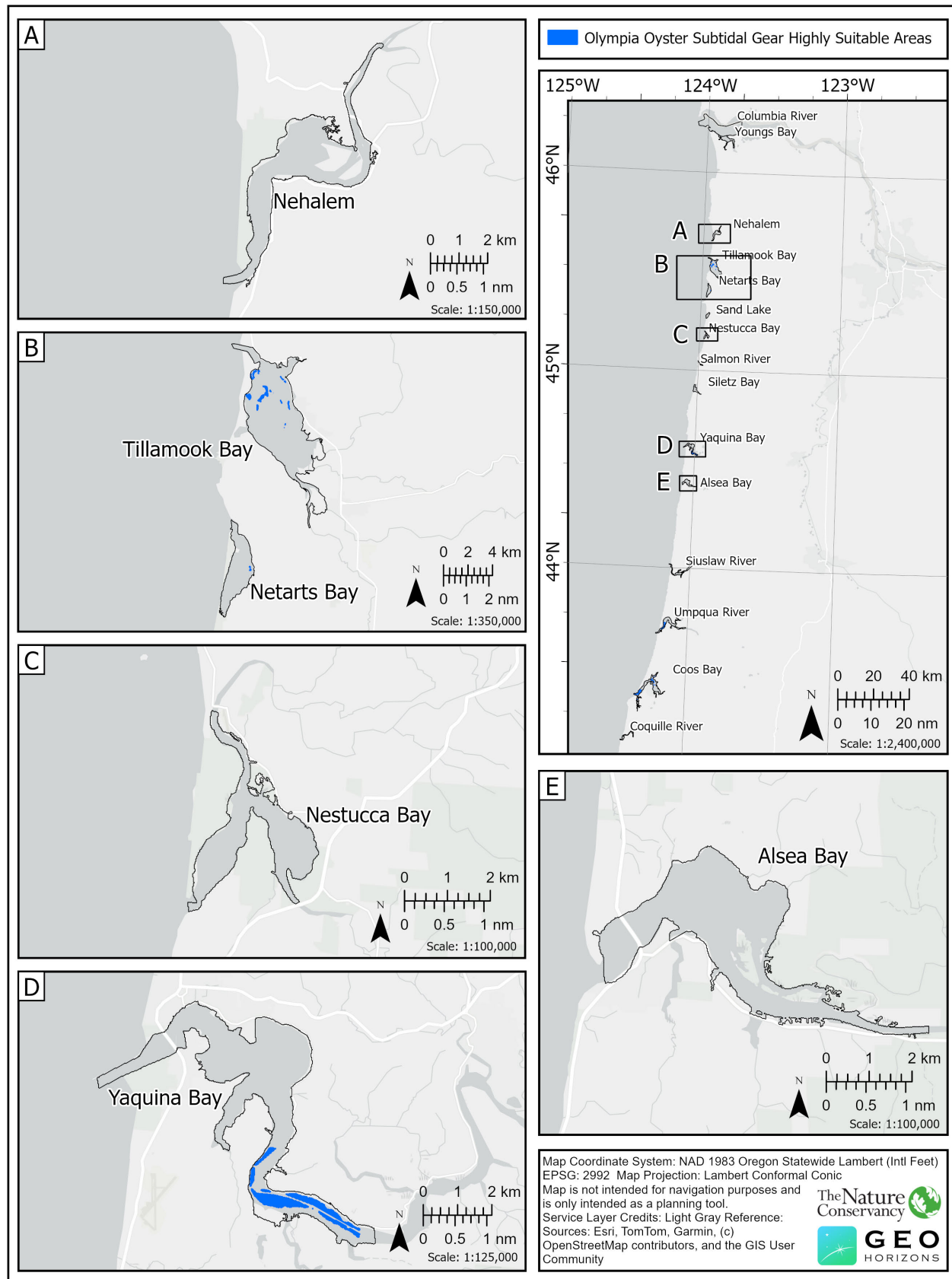
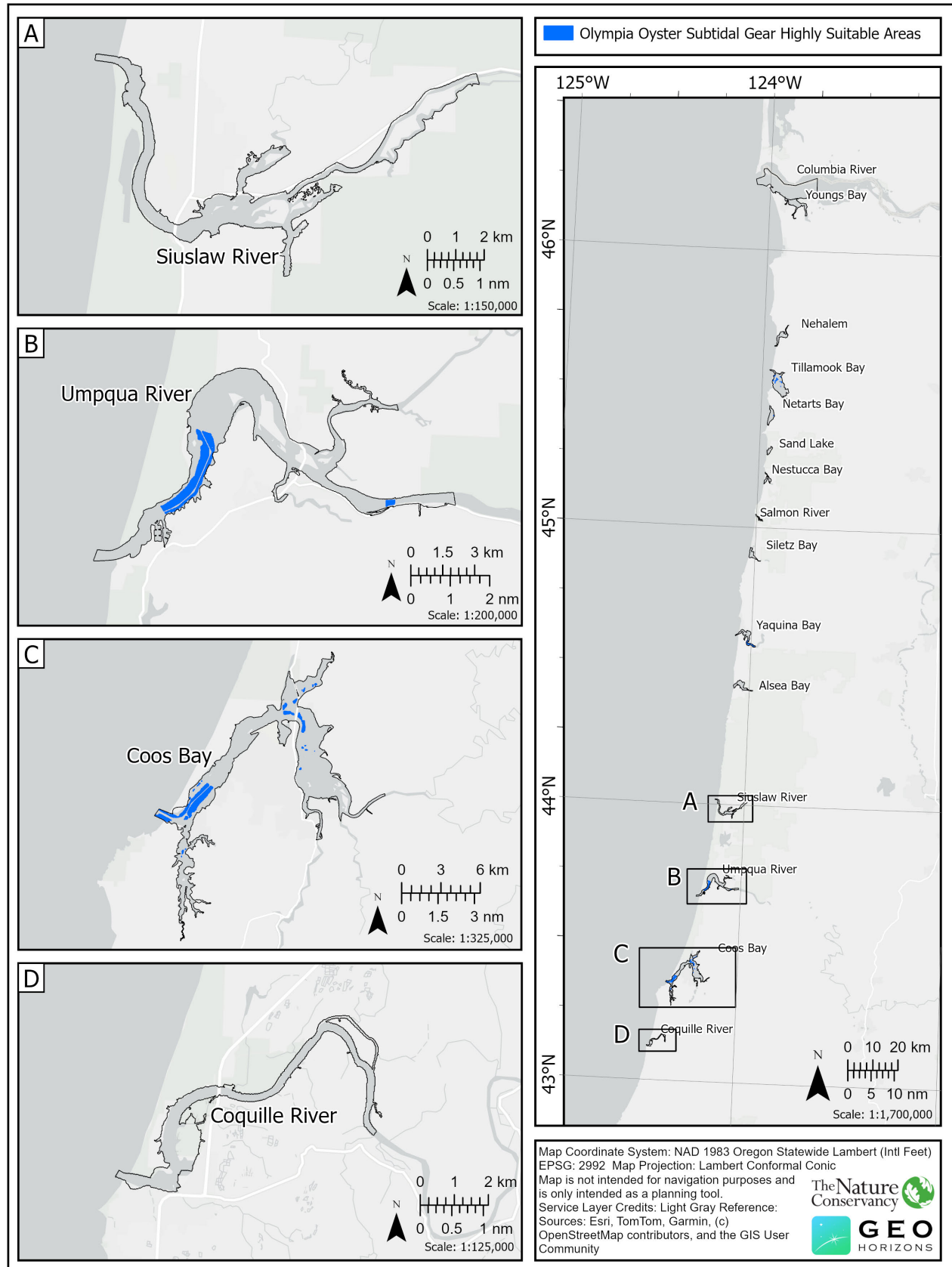


Figure 29. Highly suitable areas in southern Oregon estuaries for Olympia oyster mariculture using subtidal gear, as indicated by the LISA analysis.



3.3.2. Purple sea urchin – tank culture – modeling results

Opportunity Analysis

Opportunity for purple sea urchin mariculture using tank culture was identified in 10 of the 15 estuaries evaluated (Figure 30 and Figure 31). The largest areas of opportunity occurred in Coos Bay and Yaquina Bay, while Siletz Bay, Netarts Bay, and the Coquille River exhibited the smallest areas of opportunity (Table 21).

The Opportunity Model suggested substantial potential for expanding purple sea urchin mariculture into additional estuaries; however, significant uncertainty remains, particularly related to the availability, suitability, and cost of land-based infrastructure. Each candidate parcel would require a detailed, site-specific evaluation to determine whether viable opportunities exist. In addition, higher-resolution water quality data would improve confidence in identifying locations with consistently saline source waters suitable for land-based tank operations. In general, areas closer to estuary entrances are expected to be more suitable than upstream locations, although during winter months—when freshwater inputs are elevated—this gradient may be less pronounced.

Finally, eelgrass habitat was retained as an exclusion layer in this analysis, reflecting the assumption that intake infrastructure could disturb sensitive

habitats. While mitigation measures may allow for siting within or adjacent to eelgrass under certain conditions, this analysis assumed complete avoidance where feasible.

Suitability Analysis

Highly suitable areas for purple sea urchin mariculture identified by the Suitability Model were present in four estuaries, with only one—Tillamook Bay—currently supporting an active commercial purple sea urchin tank mariculture operation (Table 24 and Figure 32 to Figure 35). Notably, Bandon, located within the Coquille River estuary, currently hosts a commercial purple sea urchin mariculture operation but was not identified as highly suitable by the model. This discrepancy is largely attributable to limited supporting infrastructure, including the absence of nearby seafood processing facilities and cold storage, which reduced the overall suitability score for the Coquille River.

As noted previously, substantial uncertainty remains regarding the availability and feasibility of land-based parcels, and further site-specific evaluation could clarify whether additional locations could realistically support purple sea urchin mariculture operations. When comparing TOPSIS rankings (Table 27), Coos Bay and Yaquina Bay ranked highest overall, with the Umpqua River close behind. Tillamook Bay received the lowest rank, primarily due to the limited extent of highly suitable areas.

Table 27. Estuaries ranked from more to less optimal for purple sea urchin mariculture using tank culture.

Estuary	Rank	Highly suitable area (ac)	Logistics	Industry	Distance positive	Distance negative	TOPSIS score
Coos Bay	1	155.7	0.99	0.92	0.08	0.92	0.92
Yaquina Bay	2	175.1	0.85	1.00	0.14	0.99	0.87
Umpqua River	3	118.2	0.84	0.73	0.31	0.72	0.70
Tillamook Bay	4	54.0	0.85	0.01	1.00	0.01	0.01

Note. The analysis employed the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS). The variables used in the analysis—Logistics and Industry—ranged from 0 to 1, with 0 being less optimal and 1 being more optimal for mariculture. Distance from the positive solution and distance from the negative solution are provided in this table, with lower values being closer to and higher values being farther from each solution. The TOPSIS score was used for ranking, with a score of 1 being the most ideal solution and a score of 0 being the least ideal solution.

Figure 30. Opportunity Analysis results for purple sea urchin mariculture using tank culture in northern Oregon estuaries.

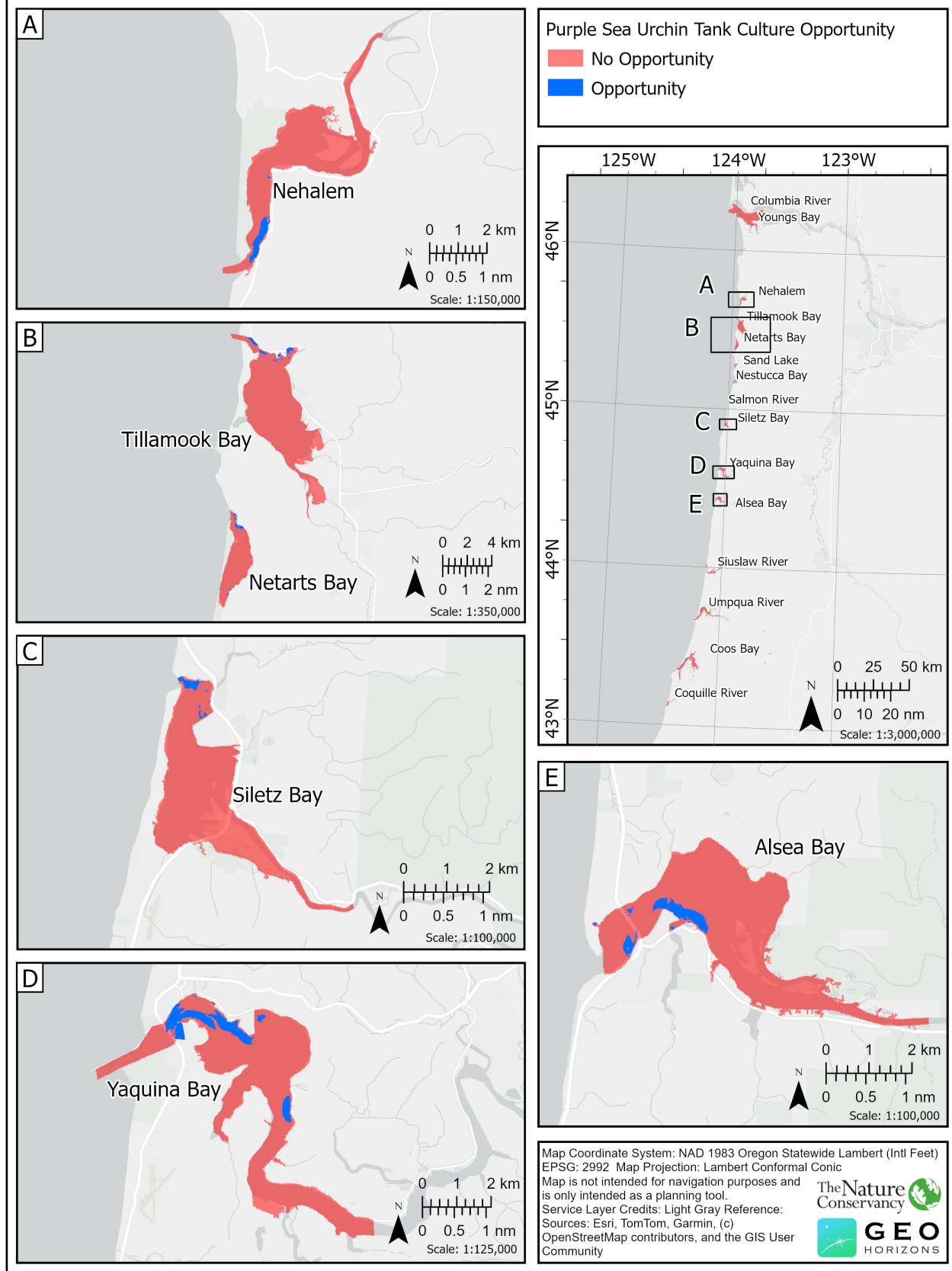


Figure 31. Opportunity Analysis results for purple sea urchin mariculture using tank culture in southern Oregon estuaries.

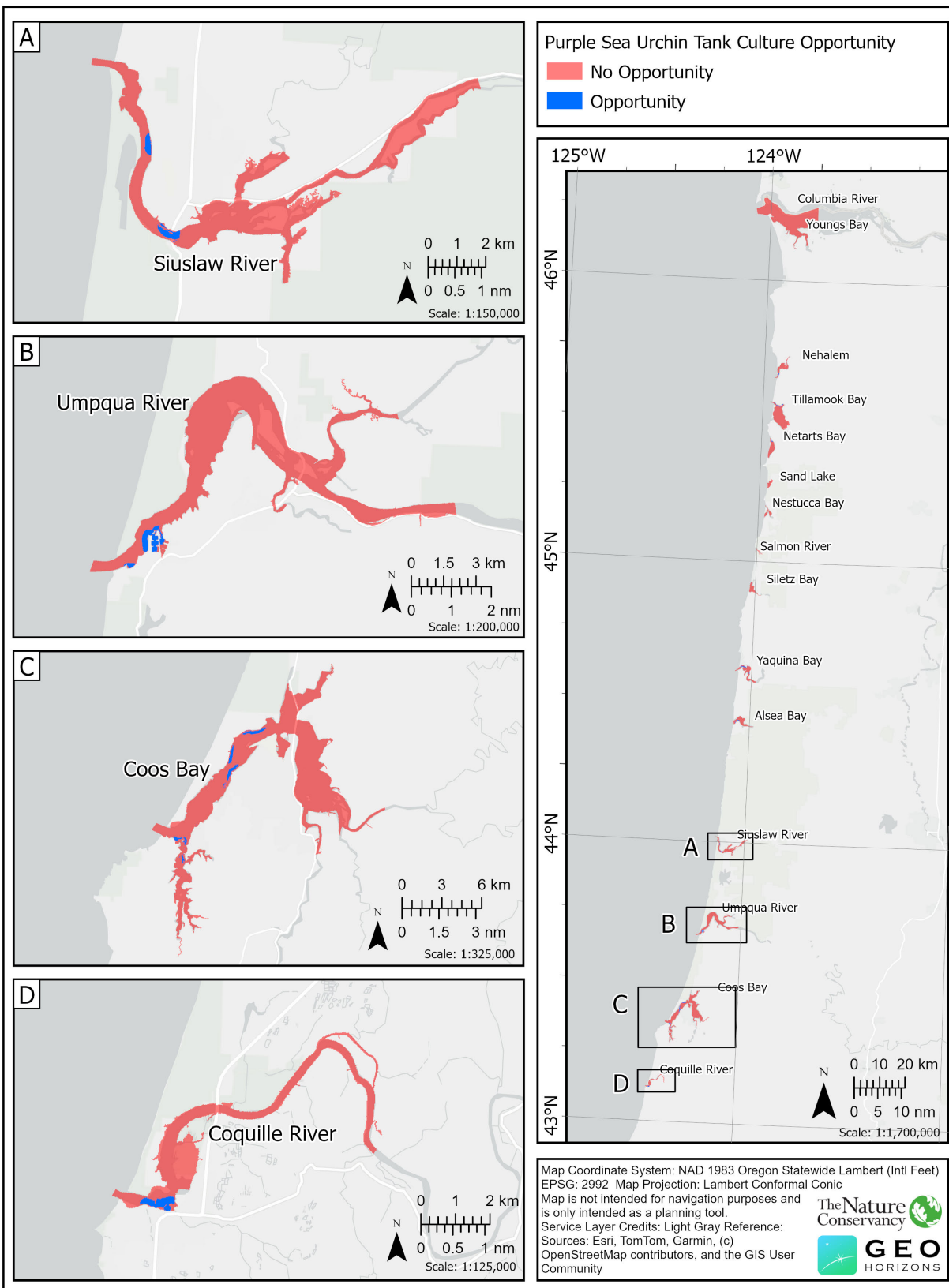


Figure 32. Suitability Analysis results for purple sea urchin mariculture using tank culture for northern Oregon estuaries.

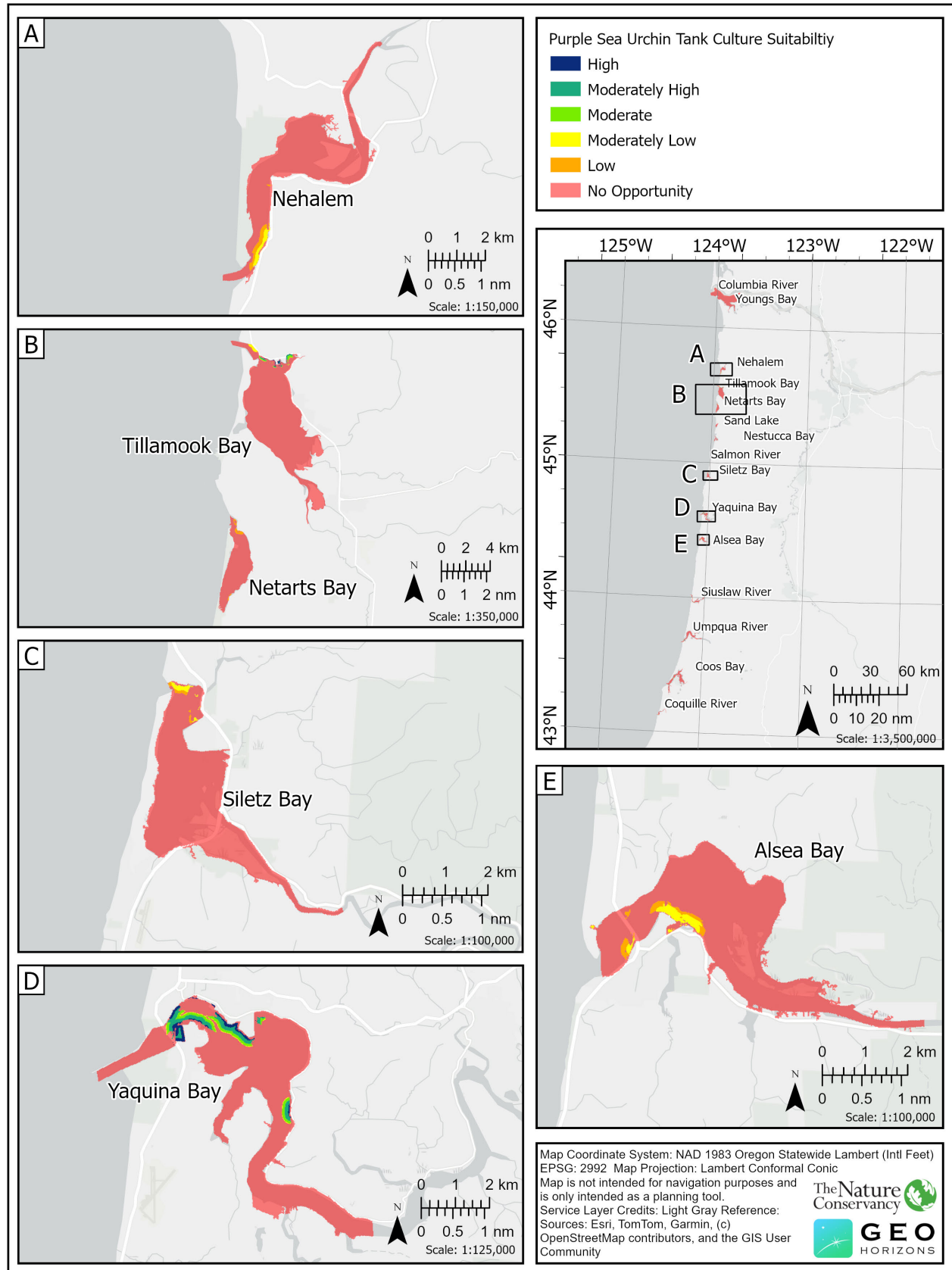


Figure 33. Suitability Analysis results for purple sea urchin mariculture using tank culture for southern Oregon estuaries.

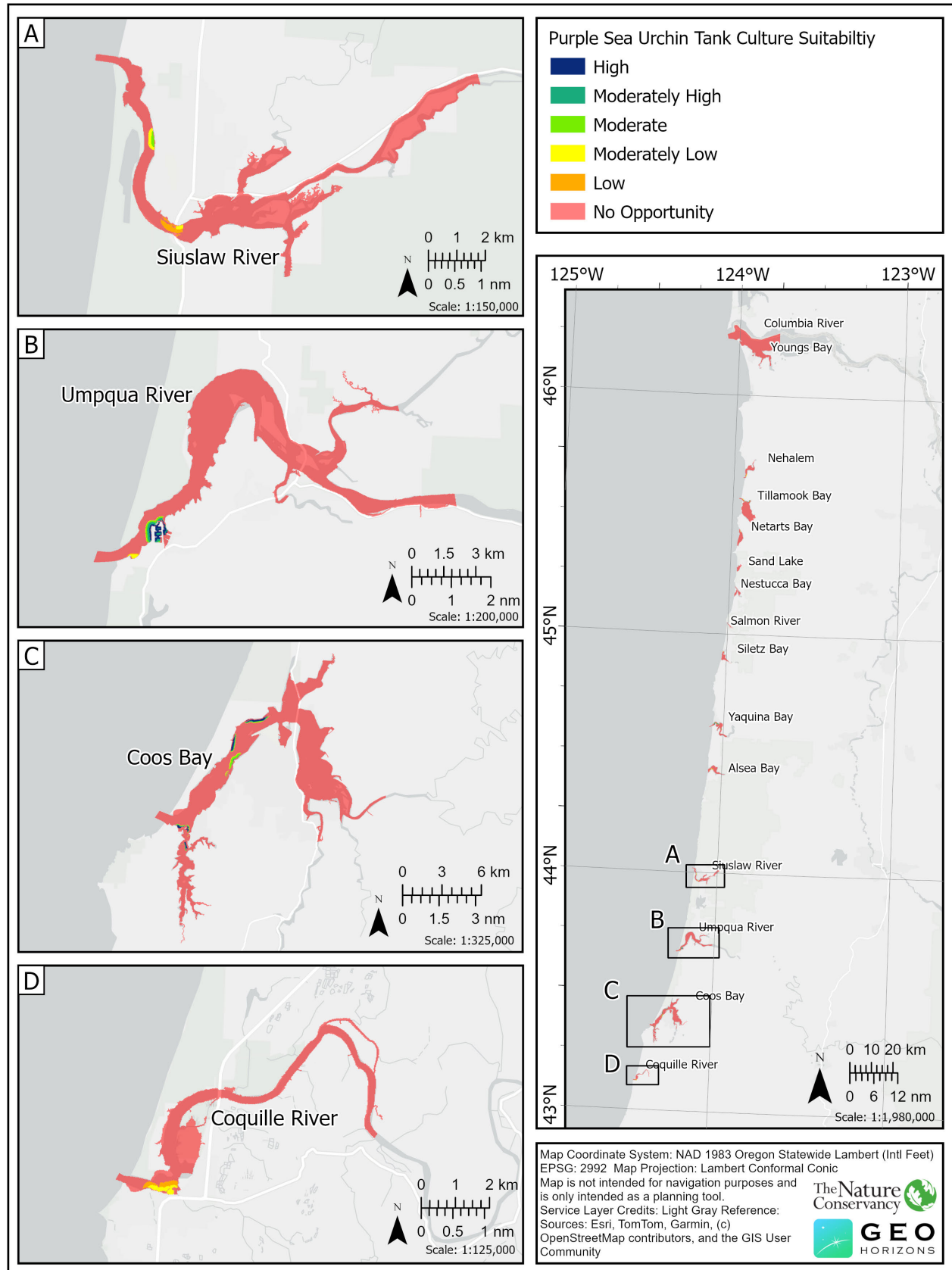


Figure 34. Highly suitable areas in northern Oregon estuaries for purple sea urchin tank mariculture, as indicated by the LISA analysis.

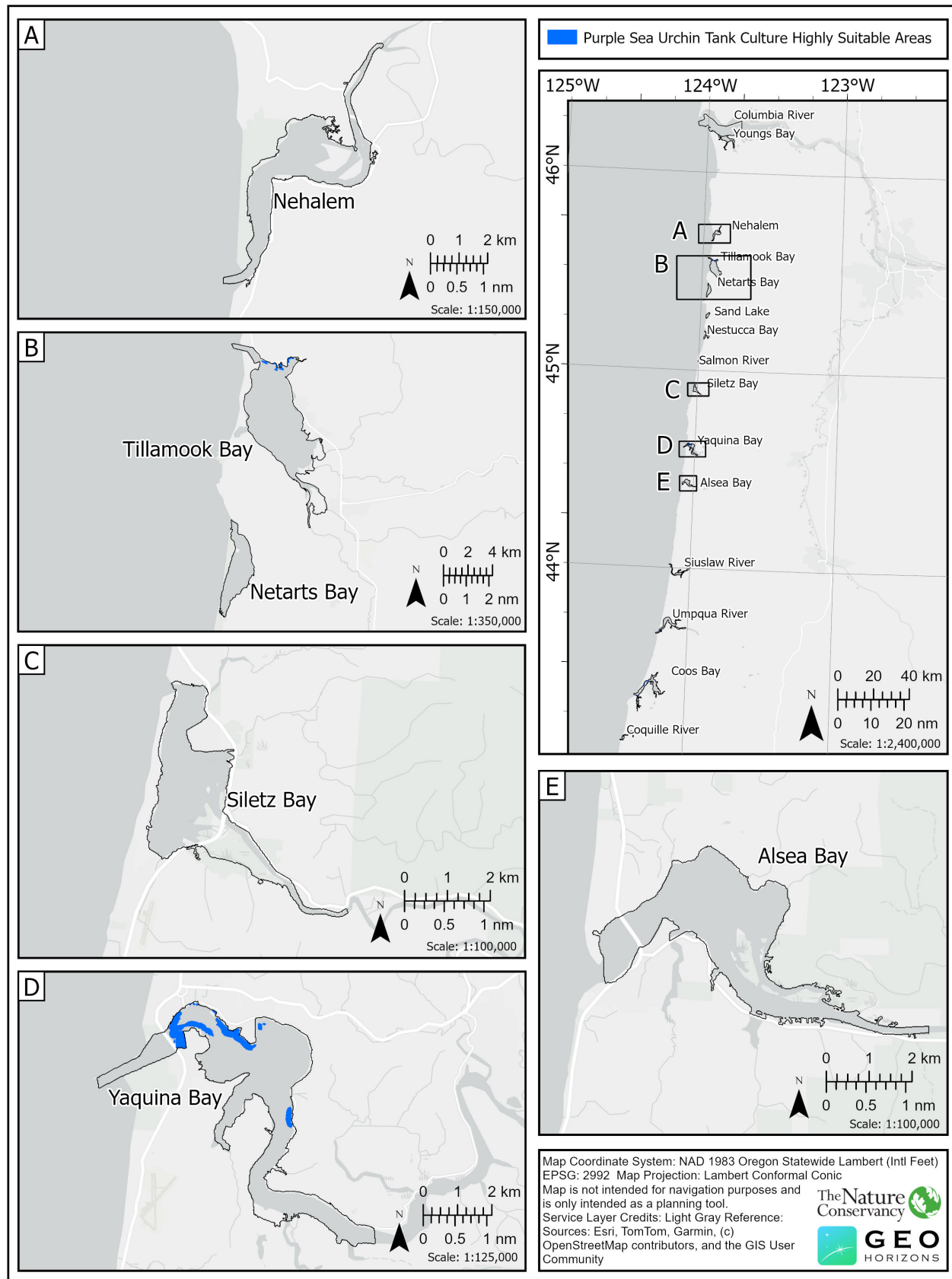
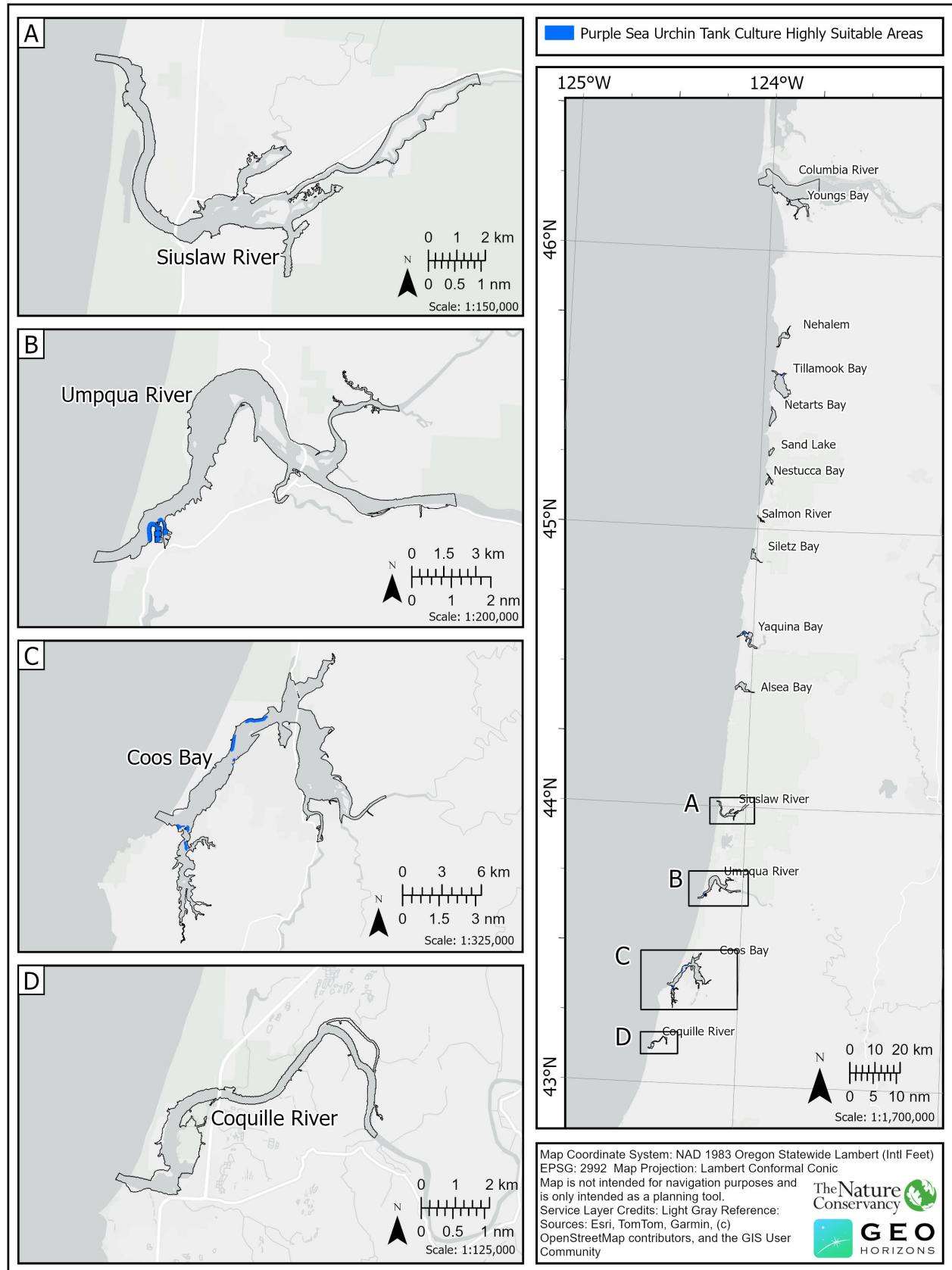


Figure 35. Highly suitable areas in southern Oregon estuaries for purple sea urchin tank mariculture, as indicated by the LISA analysis.



3.3.3. Bull kelp – line culture – modeling results

Opportunity Analysis

Opportunity for bull kelp mariculture using line culture was identified across 12 of the 13 coastal ocean zones evaluated, with only the northernmost area—Astoria/Warrenton—showing no opportunity (Figure 36 and Table 22). The greatest extents of opportunity occurred along the southern Oregon Coast, while coastal areas in the north exhibited progressively smaller suitable areas. Spatial differences in opportunity appear to be strongly influenced by the Columbia River plume, with lower salinity likely contributing to the limited suitability for bull kelp mariculture along Oregon’s northern coast (Figure 37).

Suitability Analysis

Highly suitable areas were identified across the six southernmost coastal ocean zones, driven primarily by more favorable conditions per the Biophysical variable for bull kelp mariculture (Figure 38 and Figure 39). Port Orford ranked highest overall (Table 28), despite having lower Biophysical suitability relative to other southern zones, due to its relatively large extent of highly suitable area with minimal interaction with Fisheries, and consequently a higher overall composite score. In contrast, Gold Beach and Brookings exhibited stronger Biophysical suitability but experienced substantially greater interaction with Fisheries, which reduced their overall rankings (Figure 40 to Figure 45).

Table 28. Coastal ocean zones ranked from more to less optimal for bull kelp mariculture using line culture.

Coastal ocean zone	Rank	Highly suitable area (ac)	Industry	Biophysical	Fisheries	Distance positive	Distance negative	TOPSIS score
Port Orford	1	15,475	0.42	0.01	0.91	0.90	1.00	0.53
Gold Beach	2	35,440	1.00	0.28	0.01	0.99	1.04	0.51
Bandon	3	11,253	0.30	0.07	0.84	0.94	0.89	0.49
Brookings	4	12,630	0.34	0.70	< 0.01	1.12	0.77	0.41
Coos Bay / Charleston	5	2,948	0.06	0.01	0.79	1.17	0.79	0.40
Umpqua / Reedsport	6	881	< 0.01	< 0.01	0.01	1.51	0.01	0.01

Note. The analysis employed the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS). The variables used in the analysis—Industry, Biophysical, and Fisheries—ranged from 0 to 1, with 0 being less optimal and 1 being more optimal for mariculture. Distance from the positive solution and distance from the negative solution are provided in this table, with lower values being closer to and higher values being farther from each solution. The TOPSIS score was used for ranking, with a score of 1 being the most ideal solution and a score of 0 being the least ideal solution.

Figure 36. Opportunity Analysis results for bull kelp mariculture using line culture along Oregon’s coast.

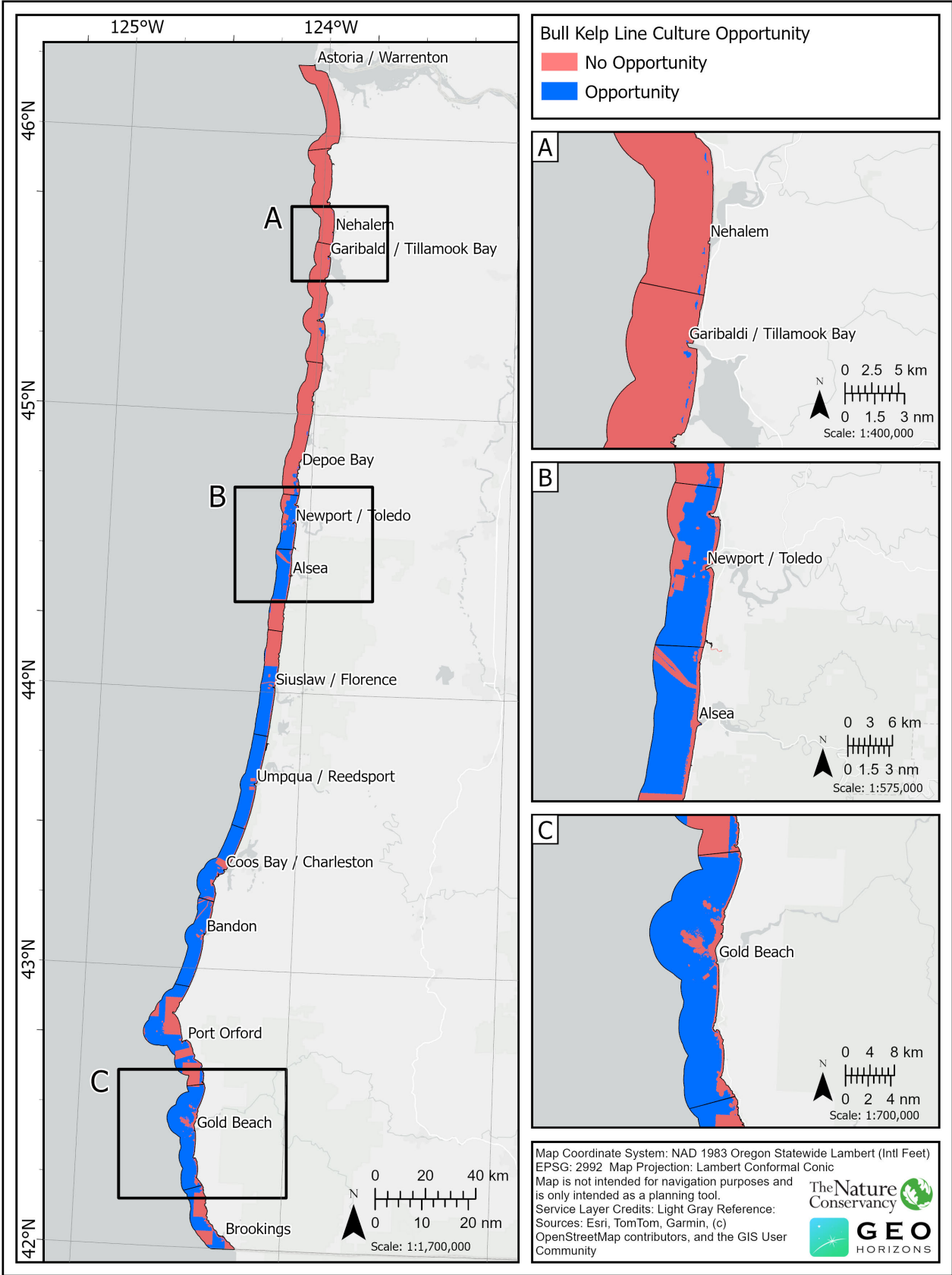
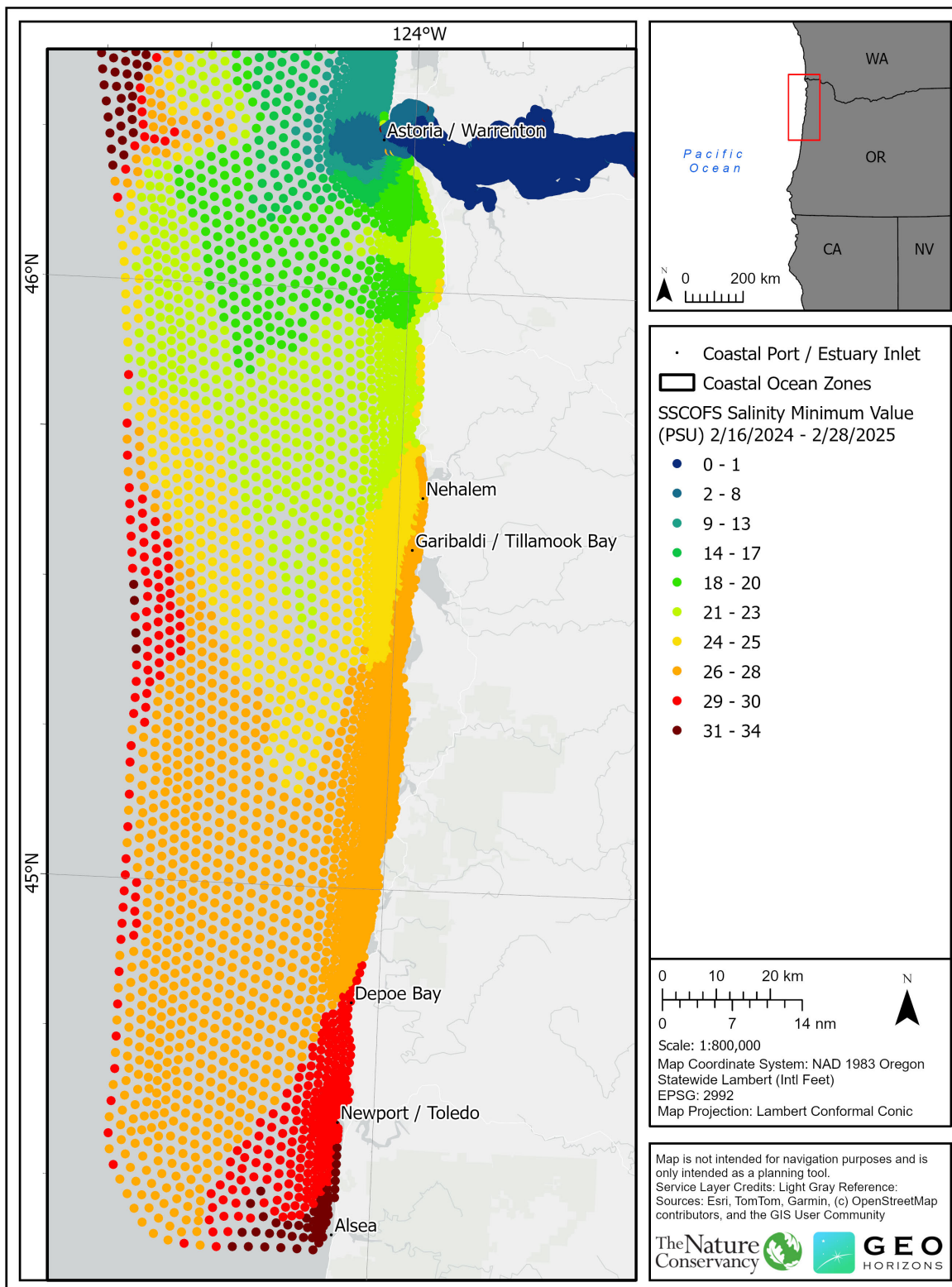


Figure 37. Northern Oregon Coast minimum hourly salinity value from SSCOFS model from Feb. 16, 2024, through Feb. 28, 2025.



Note. The Columbia River plume and its associated freshwater pulse are consistent with the literature and seasonally move south in the summer and north in the winter (Fiedler & Laurs, 1990). Interannual variations also occur (Burla et al., 2010). SSCOFS = Salish Sea and Columbia River Operational Forecast System.

Figure 38. Suitability Analysis results for bull kelp mariculture using line culture along Oregon's coast.

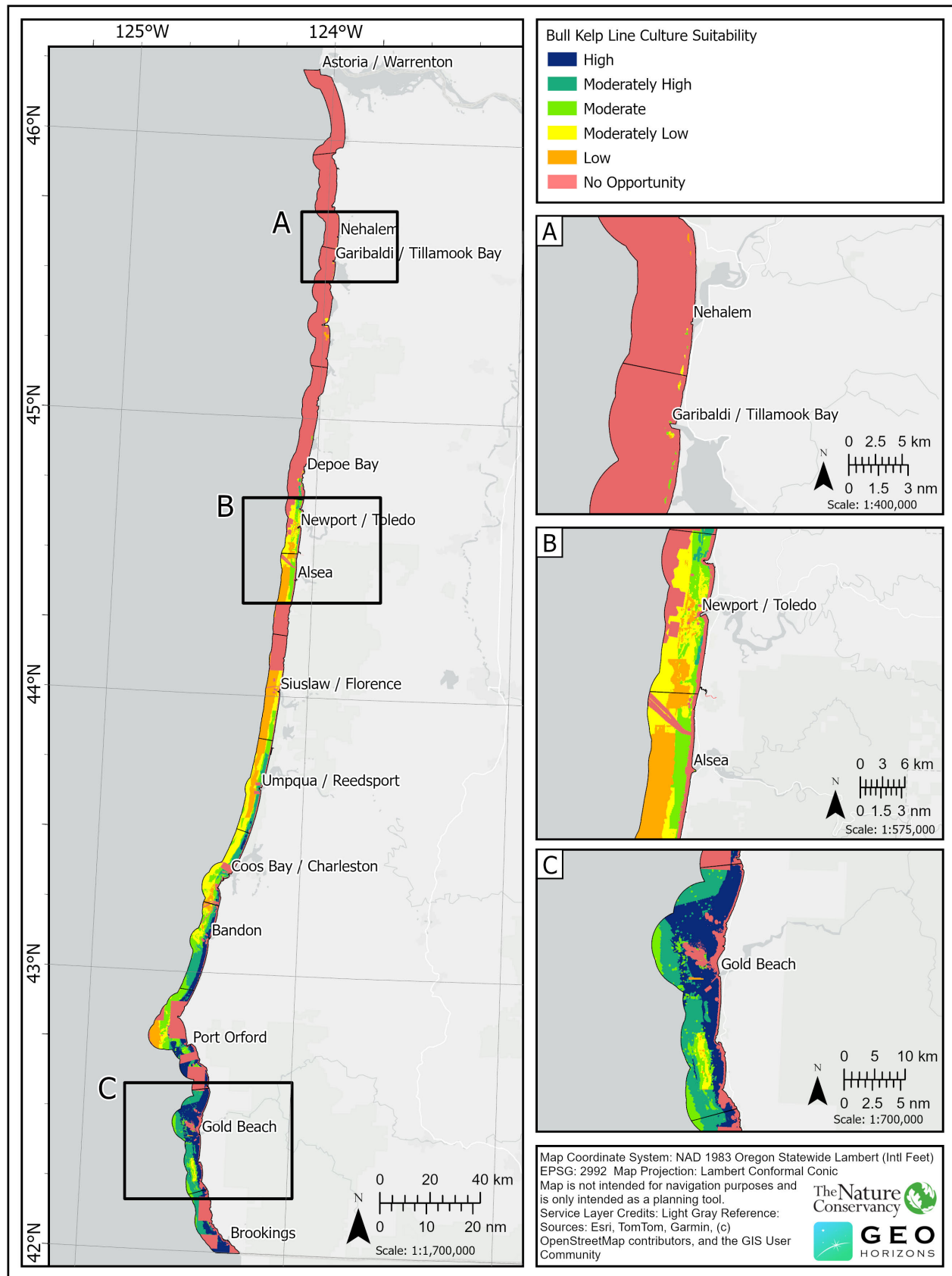


Figure 39. Highly suitable areas along Oregon’s coast for bull kelp mariculture using line culture, as indicated by the LISA analysis.

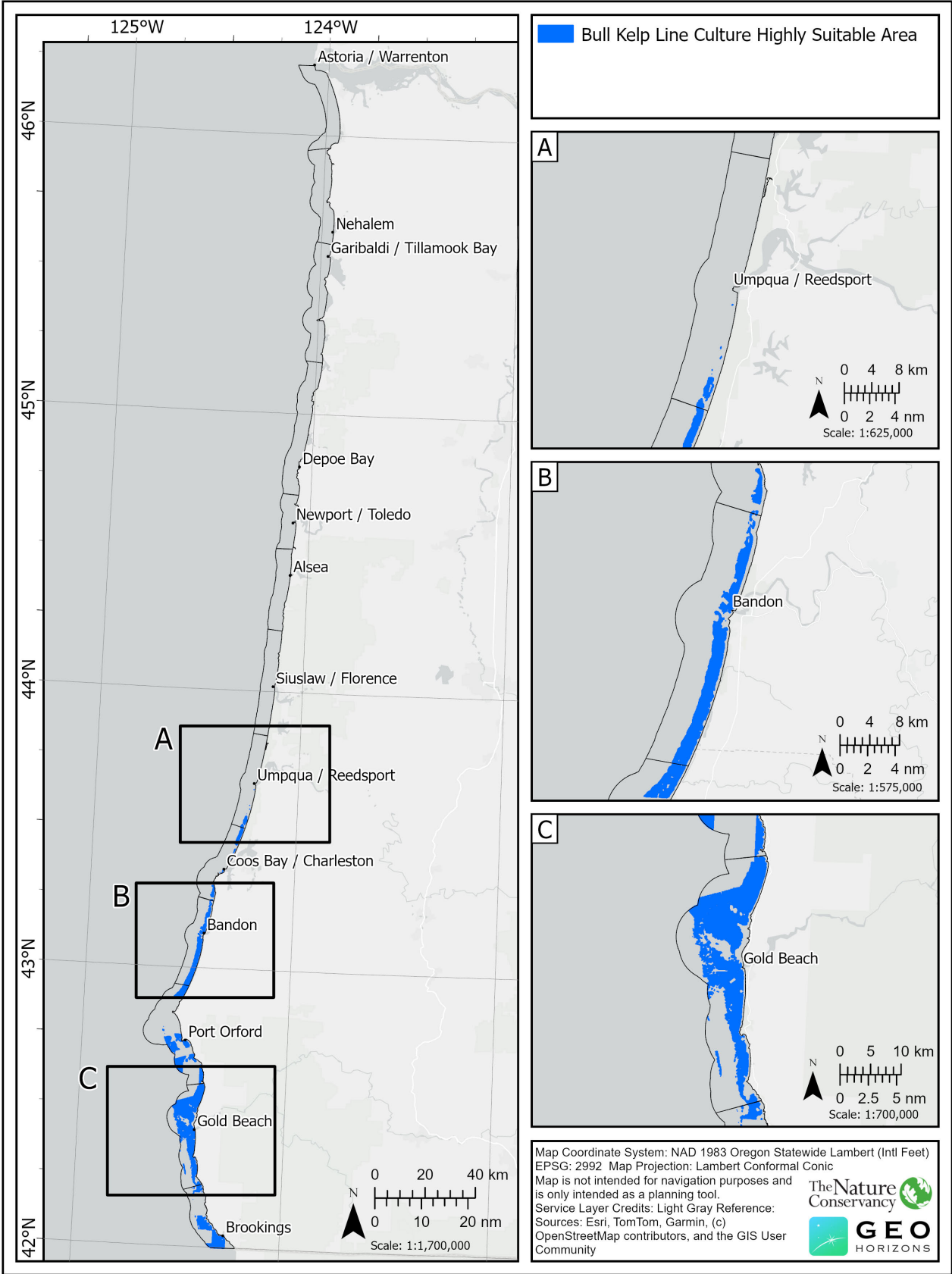


Figure 40. Logistics Submodel suitability for bull kelp mariculture using line culture.

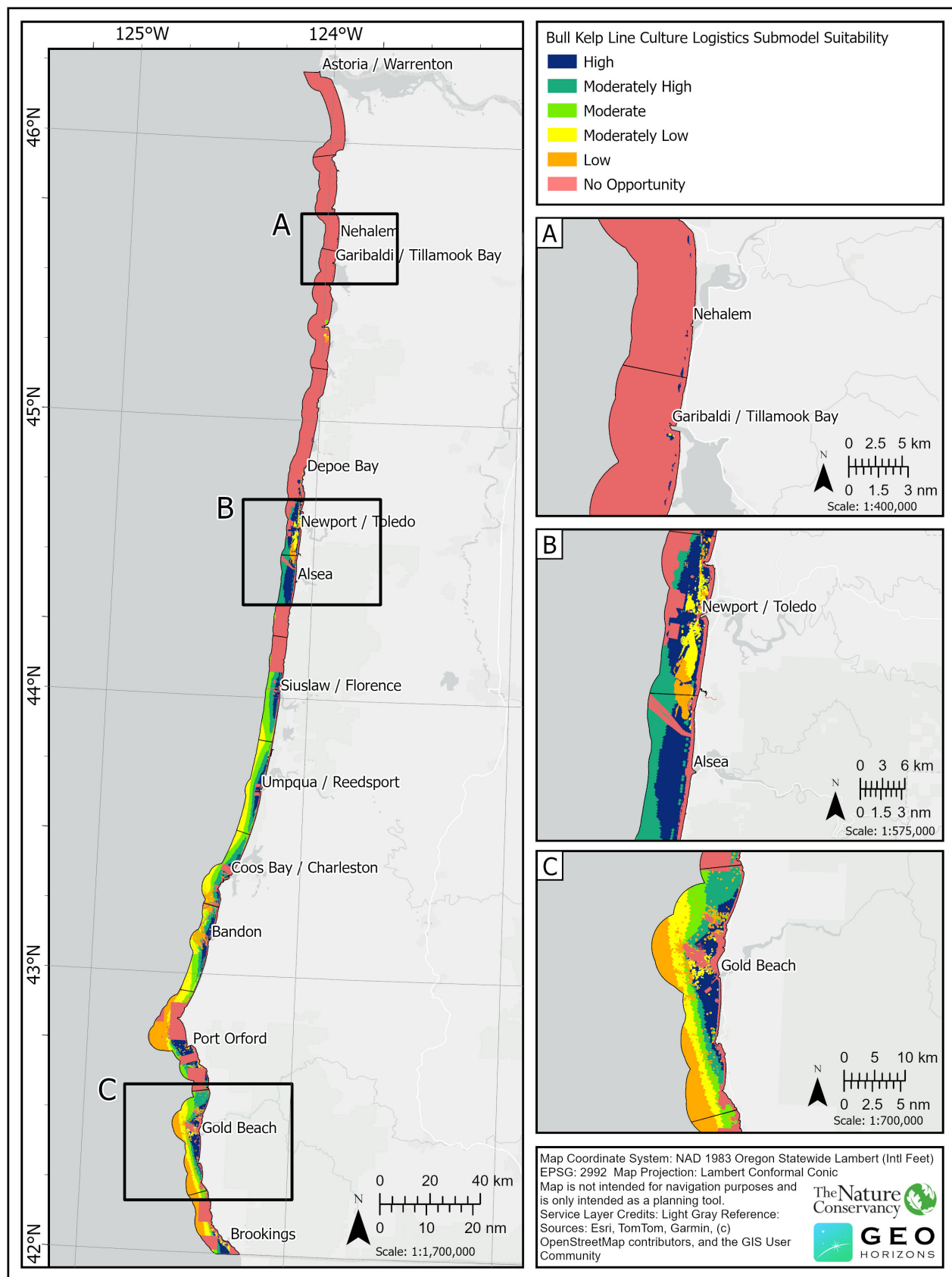


Figure 41. Biophysical Submodel suitability for bull kelp mariculture using line culture.

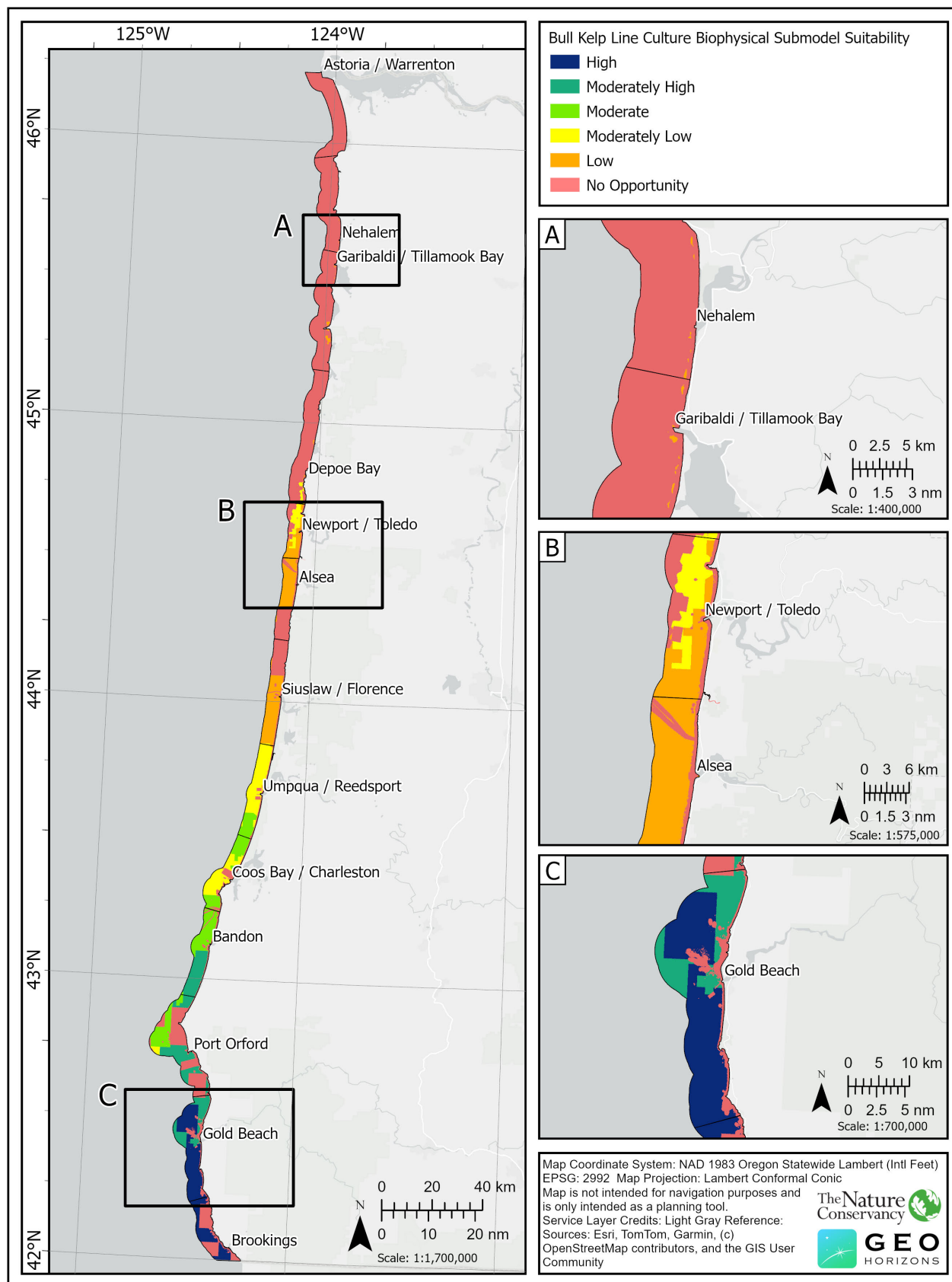


Figure 42. Overlap of highly suitable areas in Oregon for bull kelp line culture and AIS mean fishing vessel transits (2019–2023).

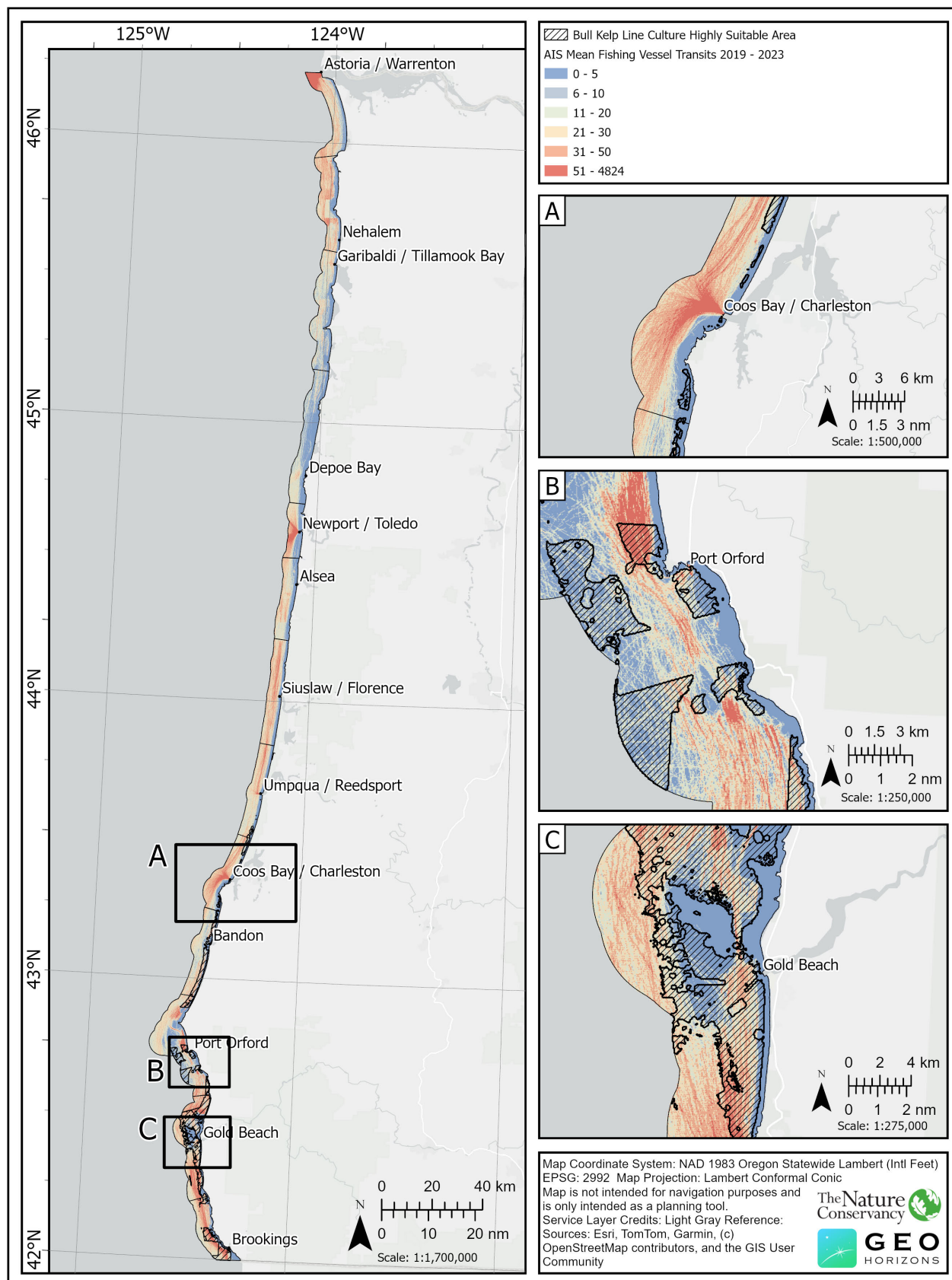


Figure 43. Overlap of highly suitable areas in Oregon for bull kelp line culture and Dungeness Crab Commercial Fishing Importance data (Ecotrust, 2010).

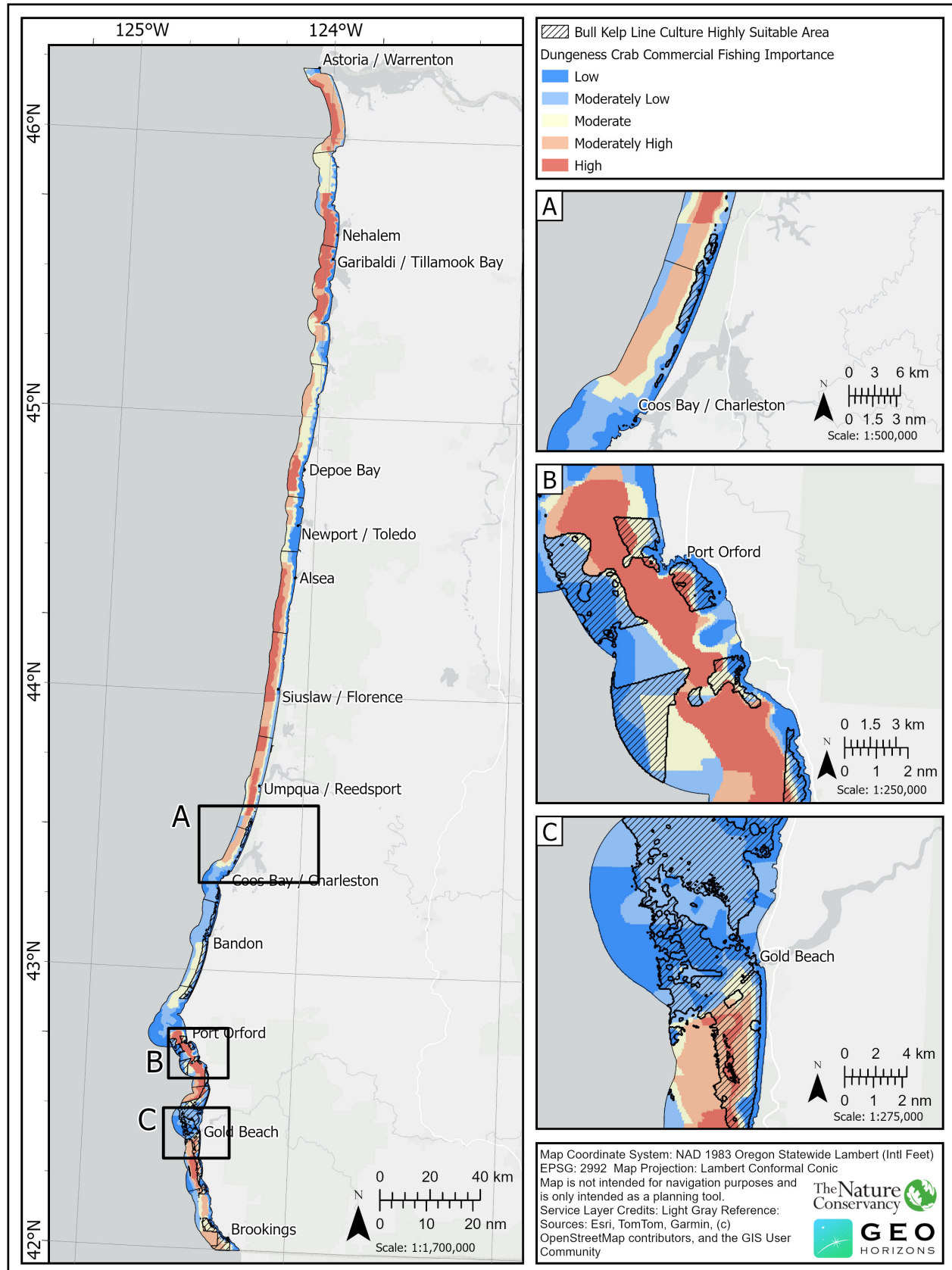


Figure 44. Overlap of highly suitable areas in Oregon for bull kelp line culture and Dungeness Crab Recreational Fishing Importance data (Ecotrust, 2010).

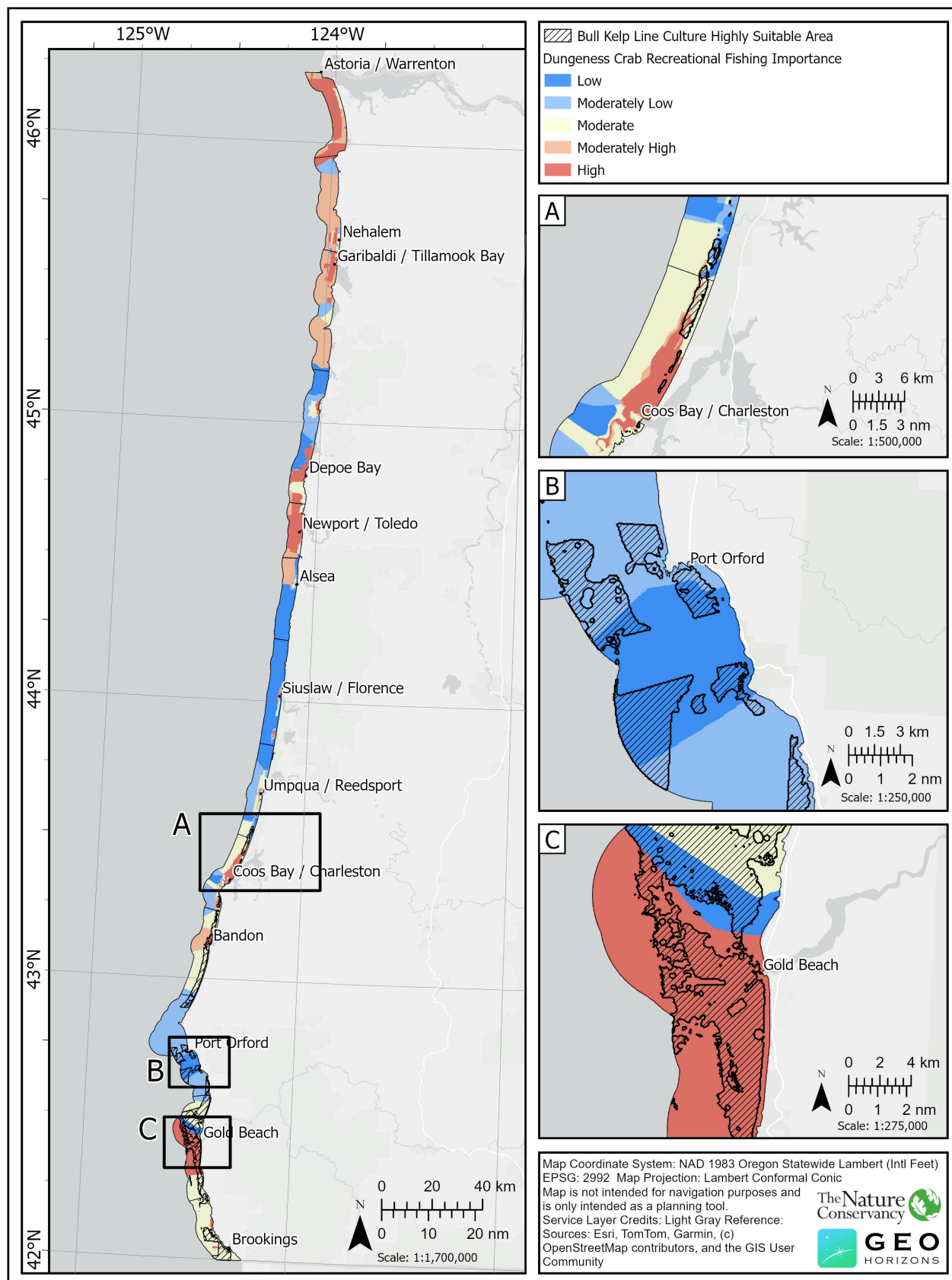
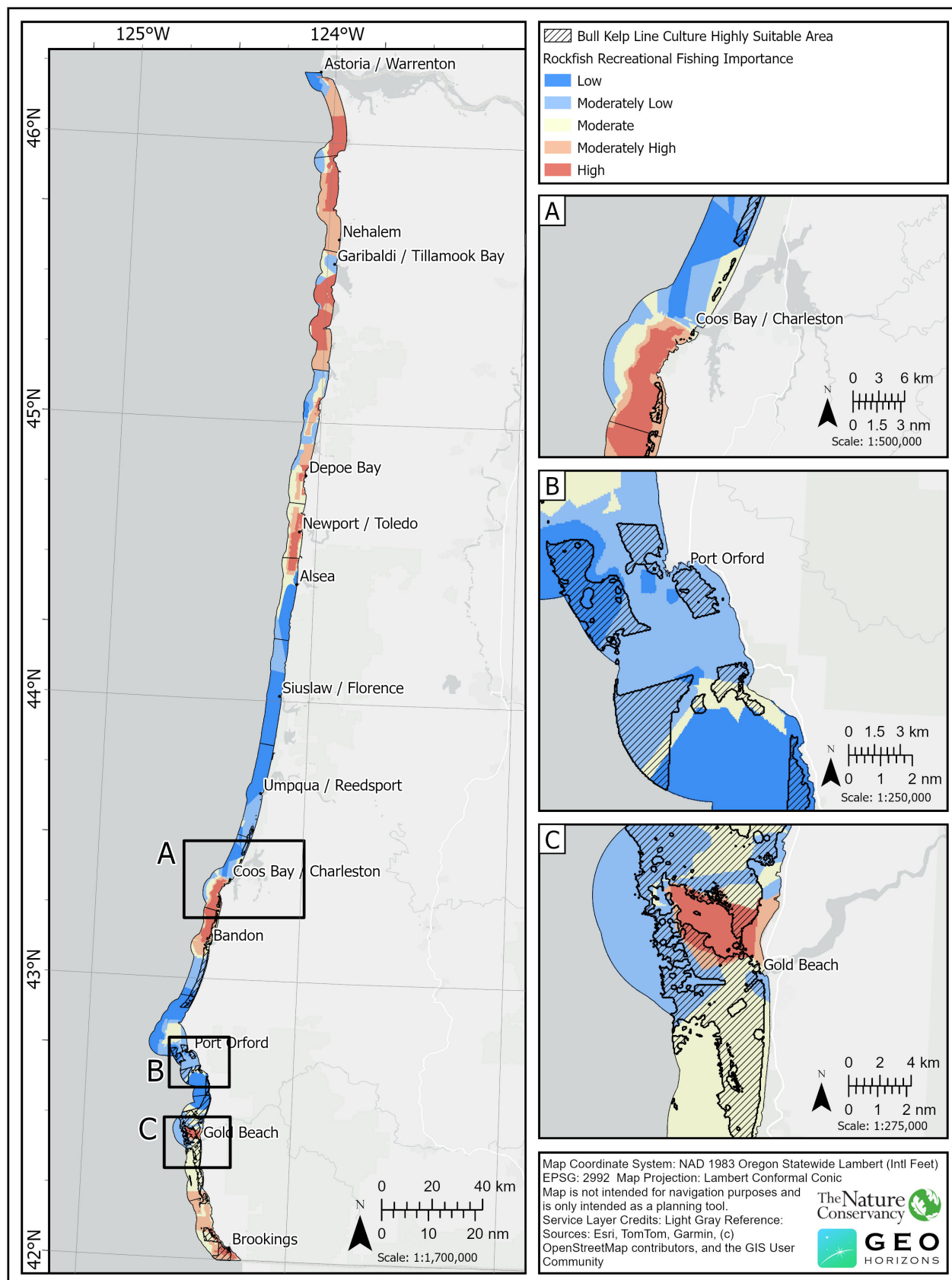


Figure 45. Overlap of highly suitable areas in Oregon for bull kelp line culture and Rockfish Recreational Fishing Importance data (Ecotrust, 2010).



3.3.4. Bull kelp – planted on bottom – modeling results

Opportunity Analysis

Similar to the above modeling evaluation of bull kelp line culture ([Section 3.3.3](#)), the opportunity for bull kelp planted-on-bottom culture was identified across 12 of the 13 coastal ocean zones evaluated. The northernmost coastal ocean zone—Astoria/Warrenton—showed no identified opportunity (Figure 46 and Table 22). However, the more restrictive depth requirements associated with the planted-on-bottom method resulted in a more even distribution of opportunity along the Oregon Coast relative to line culture. In addition, portions of the southern coast were excluded due to the use of existing kelp bed extent as an exclusion layer, further

influencing the spatial pattern of identified opportunity.

Suitability Analysis

The southernmost coastal ocean zones had the largest amounts of highly suitable area, and generally the higher ranks (Table 29, Figure 47, and Figure 48). These findings are primarily driven by the larger amounts of area available and higher scores for the Biophysical variable. The TOPSIS scores for Gold Beach, Brookings, and Bandon were all fairly similar. The primary reason Newport / Toledo was ranked above Port Orford was due to its lower interaction with the Fisheries variable. The three lowest-ranked coastal ocean zones all had low amounts of highly suitable area, lower Biophysical suitability, and higher interaction with fisheries.

Table 29. Coastal ocean zones ranked from more to less optimal for bull kelp planted-on-bottom mariculture.

Coastal ocean zone	Rank	Highly suitable area (ac)	Industry	Biophysical	Fisheries	Distance positive	Distance negative	TOPSIS score
Gold Beach	1	9,187	1.00	0.02	0.08	1.14	1.00	0.47
Brookings	2	481	0.05	0.91	0.00	1.24	0.91	0.42
Bandon	3	1,963	0.21	0.19	0.71	1.07	0.77	0.42
Newport / Toledo	4	8	< 0.01	< 0.01	0.80	1.35	0.80	0.37
Port Orford	5	1,956	0.21	0.10	0.60	1.15	0.64	0.36
Coos Bay / Charleston	6	40	< 0.01	0.04	0.01	1.55	0.04	0.02
Umpqua / Reedsport	7	34	< 0.01	< 0.01	0.01	1.56	0.01	0.01
Depoe Bay	8	1	< 0.01	< 0.01	0.01	1.57	0.01	0.01

Note. The analysis employed the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS). The variables used in the analysis—Industry, Biophysical, and Fisheries—ranged from 0 to 1, with 0 being less optimal and 1 being more optimal for mariculture. Distance from the positive solution and distance from the negative solution are provided in this table, with lower values being closer to and higher values being farther from each solution. The TOPSIS score was used for ranking, with a score of 1 being the most ideal solution and a score of 0 being the least ideal solution.

Figure 46. Opportunity Analysis results for bull kelp planted-on-bottom mariculture along Oregon’s coast.

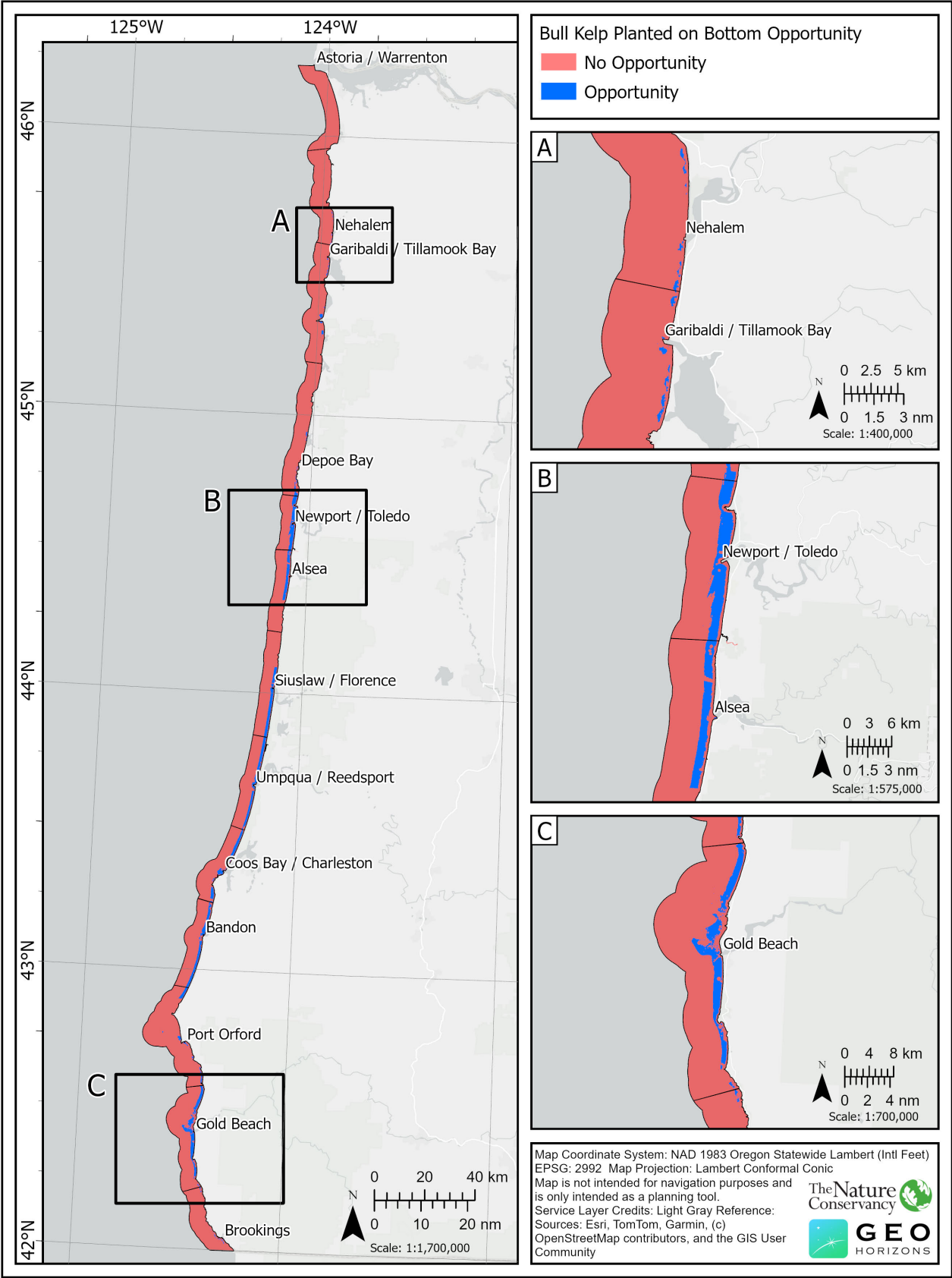


Figure 47. Suitability Analysis results for bull kelp planted-on-bottom mariculture along Oregon's coast.

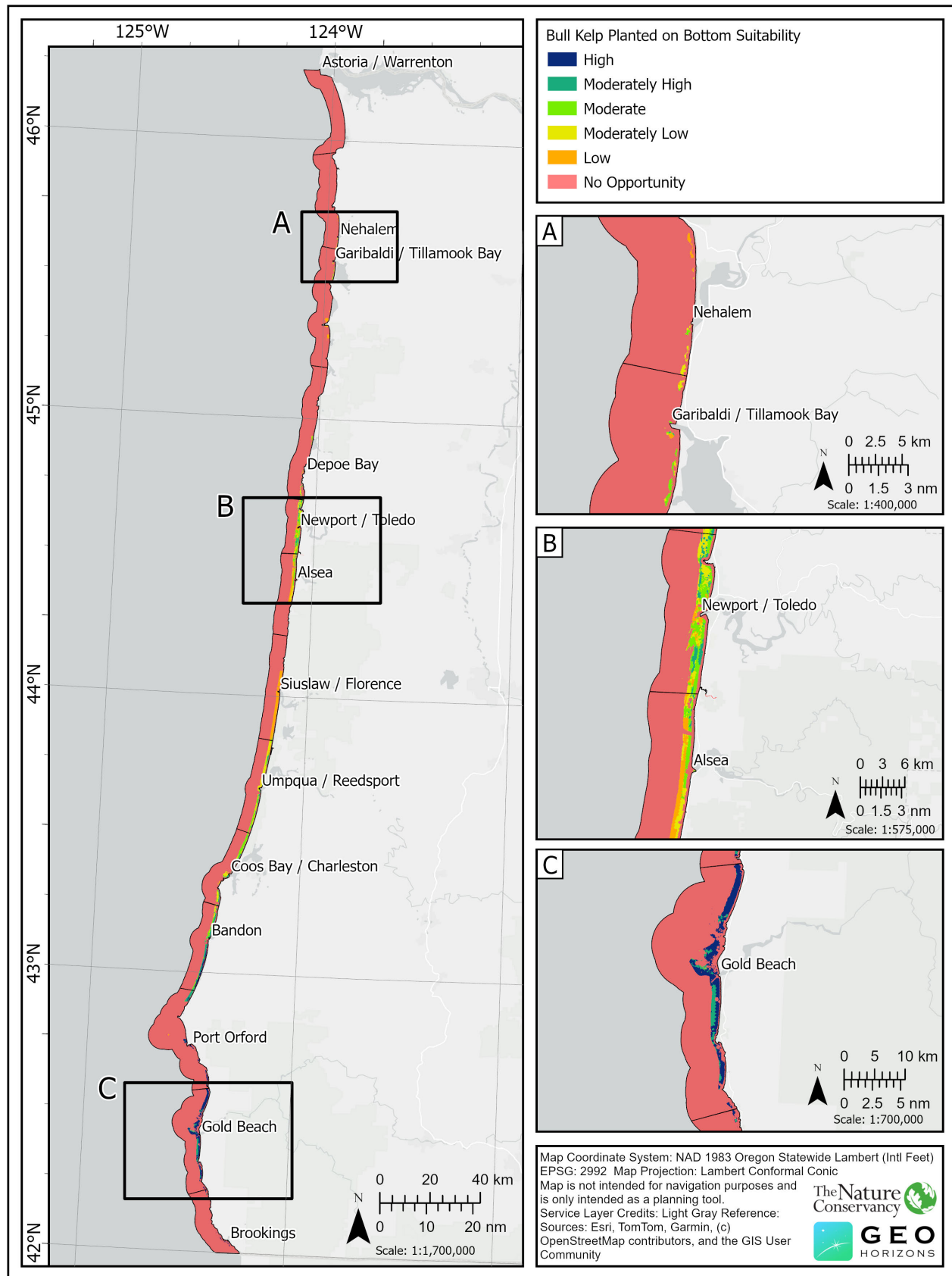
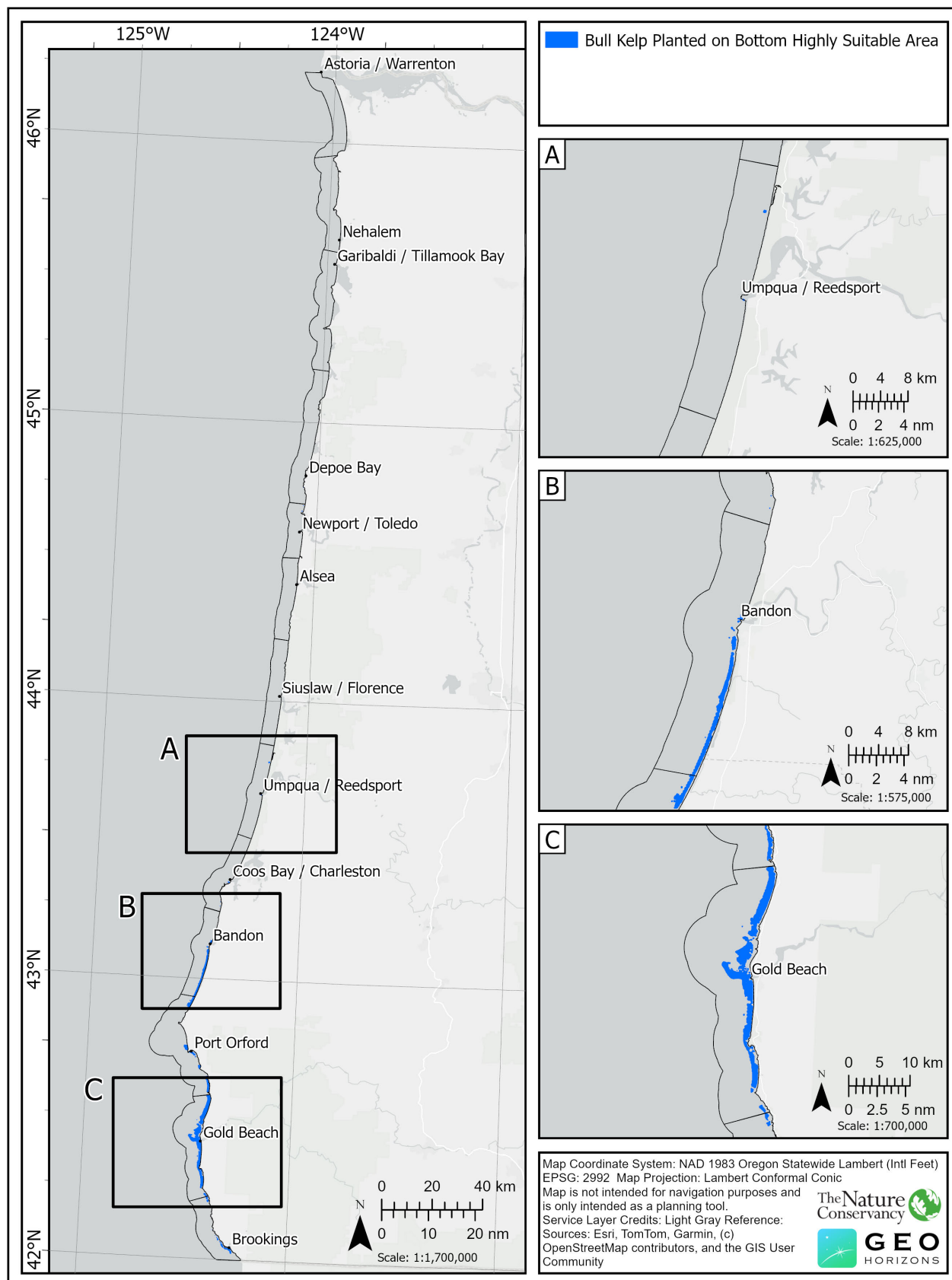


Figure 48. Highly suitable areas along Oregon's coast for bull kelp planted-on-bottom mariculture, as indicated by the LISA analysis.



3.4. Additional high-level analyses

Additional high-level spatial analyses were conducted to better understand potential locations best suited for the co-culture of seaweed and shellfish, and to rank the most opportune locations along the Oregon Coast for mariculture development. As previously mentioned, [Appendix B](#) provides the species-specific analyses not covered in this main text.

3.4.1. Seaweed and shellfish co-culture

The study included an assessment of co-culture mariculture involving all seaweed species evaluated (as listed in Table 2) and both mussel species (i.e., Pacific blue mussel and California mussel). The Bandon coastal ocean zone ranked the highest of all zones for co-culture, due to higher amounts of area available and relatively lower interaction with the

Fisheries variable (Table 30 and Figure 50). The coastal ocean zones ranked second through sixth had relatively similar TOPSIS scores but differed in their scores for the Industry, Biophysical, and Fisheries variables. For example, Gold Beach had the most area available but one of the highest interactions with Fisheries, while Alsea did not have much area available but the lowest interaction with Fisheries (Table 30). The lowest-ranked ocean zones were the three northernmost, due to low amounts of highly suitable area and lower scores for Fisheries.

Only three estuaries had highly suitable areas for kelp species line culture that could be co-sited with oyster or mussel mariculture (Table 31 and Figure 51). All estuaries had similar Logistics and Biophysical scores, which made the amount of highly suitable area available the primary driver of the ranking.

Table 30. Coastal ocean zones ranked from more to less optimal for co-culture mariculture involving seaweed (all species) and mussels (both species).

Coastal ocean zone	Rank	Highly suitable area (ac)	Industry	Biophysical	Fisheries	Distance positive	Distance negative	TOPSIS score
Bandon	1	14,472	0.70	< 0.01	0.66	0.54	0.96	0.64
Umpqua / Reedsport	2	9,785	0.47	0.03	0.73	0.65	0.87	0.57
Port Orford	3	9,494	0.46	< 0.01	0.61	0.73	0.76	0.51
Alsea	4	1,266	0.06	< 0.01	0.98	0.99	0.98	0.50
Gold Beach	5	20,707	1.00	0.01	0.01	1.02	1.00	0.50
Siuslaw / Florence	6	103	< 0.01	< 0.01	0.95	1.05	0.95	0.48
Depoe Bay	7	2,698	0.13	0.01	0.57	1.01	0.58	0.37
Newport / Toledo	8	1,852	0.08	0.01	0.51	1.07	0.51	0.32
Coos Bay / Charleston	9	9,809	0.47	0.04	0.14	1.03	0.49	0.32
Brookings	10	4,985	0.24	0.31	0.01	1.24	0.39	0.24
Garibaldi / Tillamook Bay	11	1,177	0.05	0.01	0.25	1.23	0.26	0.17
Nehalem	12	1,696	0.08	< 0.01	0.23	1.23	0.24	0.17
Astoria / Warrenton	13	1,679	0.08	0.01	< 0.01	1.38	0.08	0.05

Note. The analysis employed the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS). The variables used in the analysis—Industry, Biophysical, and Fisheries—ranged from 0 to 1, with 0 being less optimal and 1 being more optimal for mariculture. Distance from the positive solution and distance from the negative solution are provided in the table, with lower values being closer to and higher values being farther from each solution. The TOPSIS score was used for ranking, with a score of 1 being the most ideal solution and a score of 0 being the least ideal solution.

Table 31. Estuaries ranked from more to less optimal for co-culture mariculture for seaweed (all species) and mussels (both species).

Coastal ocean zone	Rank	Highly suitable area (ac)	Logistics	Industry	Biophysical	Distance positive	Distance negative	TOPSIS score
Coos Bay	1	371.4	0.79	0.99	0.50	0.14	0.98	0.87
Umpqua River	2	131.8	0.89	0.40	0.50	0.59	0.41	0.41
Tillamook Bay	3	15.9	0.89	0.01	0.60	0.98	0.14	0.13

Note. The analysis employed the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS). The variables used in the analysis—Logistics, Industry, and Biophysical—ranged from 0 to 1, with 0 being less optimal and 1 being more optimal for mariculture. Distance from the positive solution and distance from the negative solution are provided in the table, with lower values being closer to and higher values being farther from each solution. The TOPSIS score was used for ranking, with a score of 1 being the most ideal solution and a score of 0 being the least ideal solution.

Figure 49. Kelp and mussels. Photo by Zechariah Meunier, Oregon State University. CC BY-SA 2.0.



Figure 50. Highly suitable areas along Oregon's coast for the coastal co-culture modeling for seaweed (all species) and mussels (both species), as indicated by the LISA analysis.

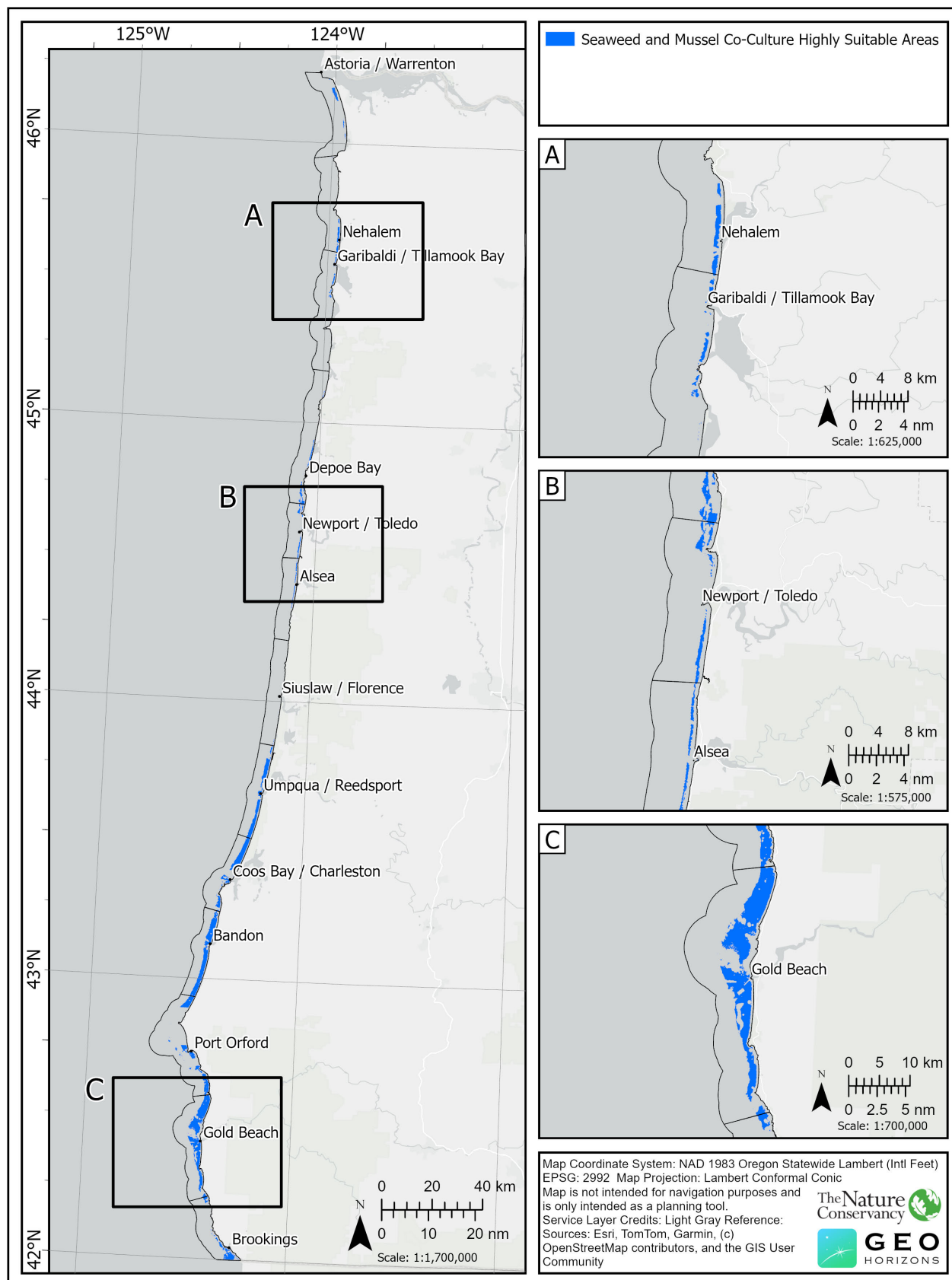
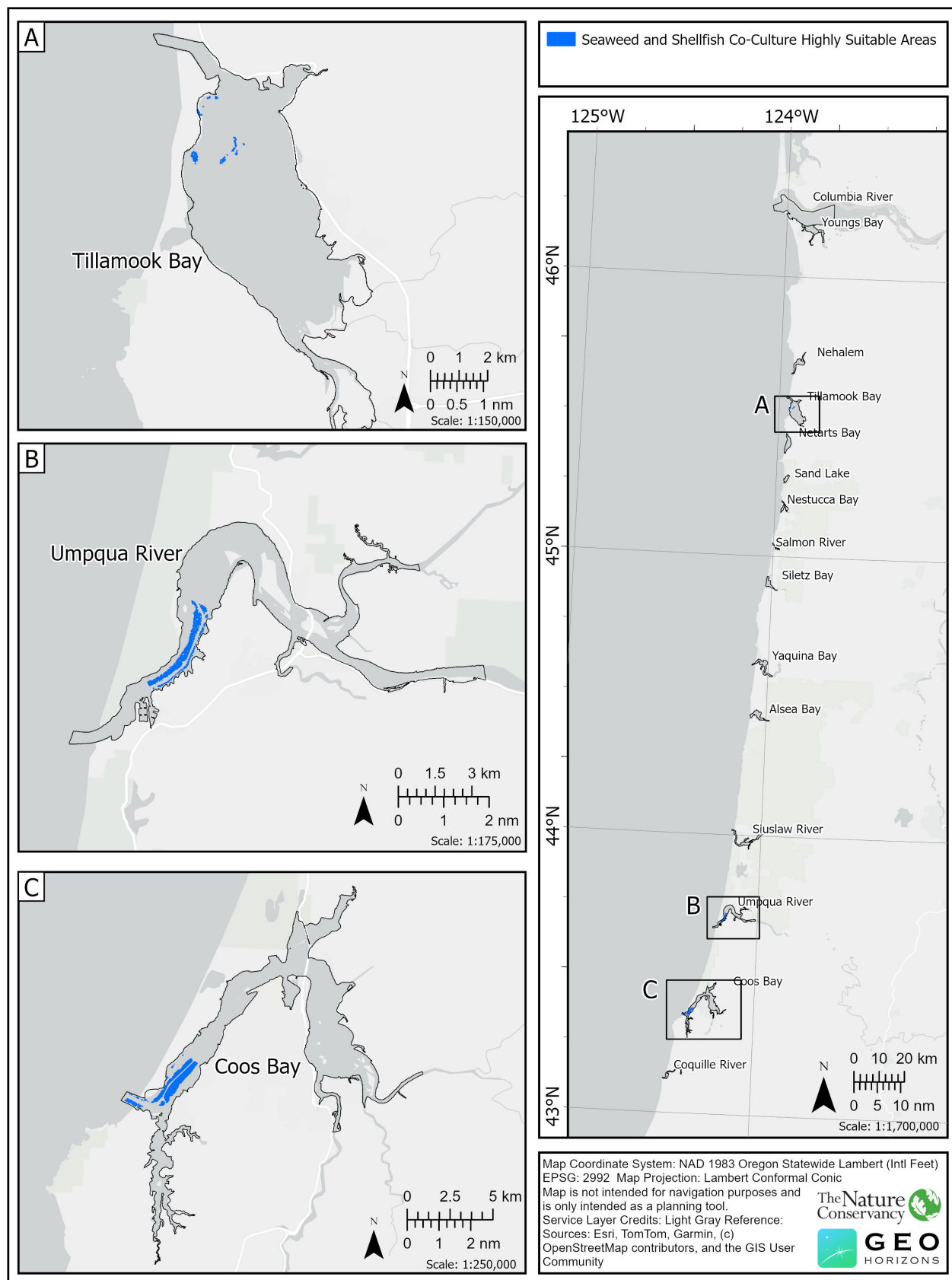


Figure 51. Highly suitable areas within three Oregon estuaries for the coastal co-culture model for seaweed (kelp species) and shellfish (Pacific blue mussel and Olympia oyster), as indicated by the LISA analysis.



3.4.2. Overall mariculture Ranking Model

Overall, Gold Beach ranked as the highest coastal ocean zone. Its ranking was driven by having the greatest extent of highly suitable area across all commercial mariculture types and the second-highest suitability score for the Biophysical variable, despite relatively higher interaction with Fisheries (Table 32). Port Orford ranked second, characterized by a large amount of highly suitable area available and lower interaction with Fisheries, though with comparatively lower Biophysical scores for seaweed cultivation. In contrast, the three

lowest-ranked coastal ocean areas—Newport/Toledo, Nehalem, and Astoria/Warrenton—were characterized by limited extents of highly suitable area, less favorable Biophysical conditions, and higher levels of interaction with Fisheries. It is important to note that classifications of high or low interaction with Fisheries reflect average conditions across each coastal zone and do not imply uniform interaction throughout the entire area. Therefore, site-specific evaluation would be required to fully assess potential interactions between proposed mariculture sites and existing fisheries within any given zone over time.

Table 32. Coastal ocean zones ranked from more to less optimal for overall coastal mariculture (not including planted-on-bottom bull kelp).

Coastal ocean zone	Rank	Highly suitable area (ac)												
		Bull kelp	Giant kelp	Ribbon/ winged kelp	Sugar kelp	Pacific blue mussel	California mussel	Red or flat abalone	Industry	Biophysical	Fisheries	Distance positive	Distance negative	TOPSIS score
Gold Beach	1	35,440	49,596	38,688	41,238	18,444	20,707	873	1.00	0.12	0.38	0.48	1.07	0.69
Port Orford	2	15,475	15,404	7,304	14,855	17,405	17,151	371	0.44	< 0.01	0.82	0.62	0.93	0.60
Bandon	3	11,253	14,601	15,775	19,502	14,320	13,564	0	0.14	0.05	0.81	0.89	0.82	0.48
Alsea	4	0	57	287	1,266	7,707	7,974	480	0.02	0.01	0.84	1.01	0.84	0.45
Umpqua / Reedsport	5	881	3,375	7,809	9,769	14,218	14,774	0	0.06	0.04	0.74	0.97	0.75	0.44
Depoe Bay	6	0	162	627	2,696	13,114	9,678	268	0.03	0.02	0.75	1.00	0.75	0.43
Brookings	7	12,630	23,219	11,326	18,844	4,065	4,985	144	0.26	0.26	0.42	0.85	0.56	0.40
Siuslaw / Florence	8	0	3	5	103	11,638	12,318	0	< 0.01	< 0.01	0.67	1.04	0.67	0.39
Coos Bay / Charleston	9	2,948	4,746	7,943	8,430	12,304	13,687	0	0.08	0.04	0.49	1.01	0.50	0.33
Garibaldi / Tillamook Bay	10	0	0	0	1,177	11,450	5,592	244	0.01	0.02	0.46	1.09	0.46	0.30
Newport / Toledo	11	0	381	1,043	1,748	6,772	7,311	785	0.04	0.02	0.01	1.29	0.04	0.03

Coastal ocean zone	Rank	Highly suitable area (ac)							Industry	Biophysical	Fisheries	Distance positive	Distance negative	TOPSIS score
		Bull kelp	Giant kelp	Ribbon/ winged kelp	Sugar kelp	Pacific blue mussel	California mussel	Red or flat abalone						
Nehalem	12	0	0	0	1,696	4,062	6,038	543	0.01	< 0.01	0.01	1.32	0.01	0.01
Astoria / Warrenton	13	0	0	0	4,870	2,519	0	0	< 0.01	< 0.01	< 0.01	1.33	< 0.01	< 0.01

Note. The highly suitable area for each species is provided for reference. The analysis employed the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS). The variables used in the analysis—Industry, Biophysical, and Fisheries—ranged from 0 to 1, with 0 being less optimal and 1 being more optimal for mariculture. Distance from the positive solution and distance from the negative solution are provided in the table, with lower values being closer to and higher values being farther from each solution. The TOPSIS score was used for ranking, with a score of 1 being the most ideal solution and a score of 0 being the least ideal solution.

Of the 15 estuaries evaluated, only five had highly suitable areas identified within them. Overall, the Logistics scores for all five estuaries were similar, and except for Netarts Bay, all the Biophysical scores were similar, other than Netarts Bay, which had the highest Biophysical score of 1.0 (Table 33). Therefore, the largest driver of the overall ranking was the highly suitable area and enterprise zones available for the five different species, with Coos Bay and Umpqua River having the

highest acreage and area in enterprise zones. Netarts Bay had the lowest amount of highly suitable area; however, it had the highest biophysical conditions for growing shellfish. Tillamook Bay and Yaquina Bay ranked the lowest due to lower Industry scores because of having less highly suitable area than the other estuaries, with both estuaries having substantial historical eelgrass coverage, which was removed from consideration during the Exclusion Analysis.

Table 33. Estuaries ranked from more to less optimal for overall estuary mariculture.

Estuary	Rank	Highly suitable area (ac)					Logistics	Industry	Biophysical	Distance positive	Distance negative	TOPSIS score
		Olympia oyster	Pacific blue mussels	Kelp species	Pacific dulse	Purple sea urchin						
Coos Bay	1	633.8	528.2	373.4	151.2	155.7	0.79	0.95	0.48	0.53	0.95	0.64
Umpqua River	2	479.2	424.6	131.8	116.3	118.2	0.89	0.62	0.48	0.62	0.63	0.51
Netarts Bay	3	6.1	5.6	0	0	0	0.79	< 0.01	1.00	0.95	0.52	0.35
Tillamook Bay	4	155.3	88.6	15.9	51.6	54	0.88	0.21	0.52	0.88	0.23	0.21
Yaquina Bay	5	210.4	84.8	0	169.3	175.1	0.86	0.12	0.54	0.95	0.15	0.14

Note. The highly suitable area for each species is provided for reference. The analysis employed the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS). The variables used in the analysis—Logistics, Industry, and Biophysical—ranged from 0 to 1, with 0 being less optimal and 1 being more optimal for mariculture. Distance from the positive solution and distance from the negative solution are provided in the table, with lower values being closer to and higher values being farther from each solution. The TOPSIS score was used for ranking, with a score of 1 being the most ideal solution and a score of 0 being the least ideal solution.

4. Caveats, limitations, and discussion

The results presented herein are based on the best available data at the time of analysis; however, as detailed in Section 2.5, [Data Acquisition, Processing, Organization, and Preparation](#), data coverage may be incomplete, spatially uneven, or outdated in certain locations. In addition, the thresholds applied within the Opportunity and Suitability Models were selected to reflect extreme bounds of suitability, rather than optimal conditions for production. As such, the results should be interpreted as a screening-level assessment. Any use of these outputs for siting purposes should be accompanied by site-specific monitoring, field verification, and regulatory review prior to initiating in-water or tank culture mariculture activities.

4.1. Suitability modeling

The highly suitable areas identified through the suitability modeling and LISA analyses represent locations that are comparatively more favorable relative to other areas evaluated based on the selected input datasets and scoring framework. These results do not guarantee technical feasibility, economic viability, or operational success of a mariculture operation. Additional site-specific analyses—including field surveys, hydrodynamic assessments, permitting considerations, and operational constraints—would be required to confirm feasibility within any identified area.

4.2. Nutrient data gaps

Nutrient variables (e.g., nitrate and phosphate) used in the coastal ocean modeling were sourced from Bio-ORACLE (Assis et al., 2024), which provides decadal-scale average concentrations. While these data offer a useful regional context, they do not capture seasonal or monthly variability. For species grown seasonally, such as kelp, site-specific nutrient monitoring or higher-resolution modeling would be needed to better characterize nutrient availability during the relevant growing periods.

4.3. Fisheries data gaps

The Ecotrust fisheries importance data are over 10 years old and may not reflect current fishing trends (Ecotrust, 2010). Additionally, only the fisheries importance data for Dungeness crab and rockfish were considered in this analysis. The AIS fishing vessel transits are not limited to any one fishery; however, not all fishing vessels carry an AIS transponder. Therefore, any area examined further for mariculture development should consult with local fishers and managers to mitigate potential conflict.

4.4. Endangered and protected species

Depths deeper than 30 m were given reduced suitability scores to avoid conflict with humpback whales (Buckner et al., 2023), and pinniped haul-outs were excluded. However, further review and consultation with local managers of other endangered or protected species is needed to ensure a mariculture site mitigates potential interaction.

4.5. Estuary data coverage

Many Oregon estuaries lack consistent satellite-derived remote sensing data, including chlorophyll a, light availability, and nutrient concentrations. Although some data exists for larger systems (e.g., Coos Bay), coverage is often limited spatially and temporally. Given the highly dynamic nature of estuarine environments, available values may not be fully representative of in situ conditions. Furthermore, comparative analyses across multiple estuaries require consistent data availability, which currently constrains cross-system evaluations.

4.6. Coastal oceanographic data gaps

Two oceanographic models were used in this analysis: the Salish Sea and Columbia River Operational Forecast System (SSCOFS) for Oregon's northern coast and the West Coast Operational Forecast System (WCOFS) for the southern coast. While both models were applied over the same period, from February 16, 2024, through February 28, 2025, they differ in spatial resolution, with SSCOFS providing higher resolution in the Columbia River outflow region. Ideally, a single, high-resolution, multiyear

model would be used for the entire coastline. However, rather than relying on a lower-resolution multi-year dataset coastwide, the decision was made to prioritize higher-resolution representation of key oceanographic features where available.

4.7. Estuary hydrodynamic modeling limitations

Available estuarine hydrodynamic models present additional limitations. For example, SSCOFs accounts for freshwater input from the Columbia River but does not incorporate inputs from smaller river systems, which can result in misleading salinity patterns for other estuaries. In addition, many smaller estuaries lack sufficient biophysical data to support robust hydrodynamic or ecological modeling, limiting confidence in model outputs for these systems. This is why the salinity zones, rather than the modeled salinity data, were used in the Opportunity Models.

4.8. Land-based tank mariculture infrastructure

The analysis assumes that all shoreside parcels zoned for commercial or industrial use could theoretically support land-based tank mariculture operations. In practice, many of these parcels are already developed or may be economically infeasible due to land values, infrastructure limitations, or competing uses. Further parcel-level evaluation would be necessary to determine whether suitable opportunities exist and whether such operations would be financially viable.

In the analysis, the selected zoned parcels were assumed to be suitable, while adjacent coastal and estuary waters were assumed to be unsuitable since they were subtidal and thus underwater.

4.9. Gear limitations

General gear thresholds were assumed for these analyses, with depth and current speed thresholds for gear used to exclude areas. In the case of depth, depths greater than 150 m were excluded as too costly. Also, operating a farm at depths greater than 150 m was assumed to be impractical. For kelp line

culture, a current speed of 1 m/s was used as a maximum threshold, per the general recommendation to stay under this threshold to prevent plant dislodgement and preserve gear integrity (Kawamata, 2001). Some kelp can withstand greater water velocities; however, the more turbulent the environment, the greater the engineering and gear costs, as well as the greater the risk. In the case of the mussel longlines, 1.2 m/s was related to mussel detachment and feeding (Nielsen & Vismann, 2014), not necessarily gear limits for mussel line culture (Sunny et al., 2024, 2025).

Many offshore mussel and kelp line culture designs are submerged to deep depths and engineered to withstand significant wave heights (Frieder et al., 2022; Sunny et al., 2024, 2025). Therefore, rather than attempting to exclude areas based on a significant wave height threshold, a data layer was created to reflect days a site would be accessible. This data layer counted the number of days the maximum significant wave height was less than or equal to 2 m. In these analyses, areas with fewer days accessible received lower suitability scores, while areas with more days accessible received higher suitability scores. Many additional considerations are needed to determine whether a site is safely accessible on a particular day, such as site wave exposure, wind speed, and vessel size, to name a few. After in-site monitoring and a review of the chosen gear design, some areas deemed highly suitable may prove not to be cost-effective due to engineering and gear requirements. For more information on potential types of gear, see NOAA's *Technical Guide to Marine Aquaculture Gear* (Feldman et al., 2025).

For Olympia oyster (*O. lurida*) mariculture using subtidal gear, a minimum depth threshold of 2 m was applied. Numerous subtidal oyster aquaculture systems are currently in use, including floating, suspended, and on-bottom gear. Most floating and suspended systems require several feet of continuous subtidal depth, with greater depths improving vessel access, reducing the risk of gear grounding, and minimizing interaction with the benthic environment (Forrest et al., 2009; Shumway et al., 2003). OysterGro floating systems, for example, are

designed to operate across a wide depth range (~2–1,500 ft [1–457 m]), but the manufacturer identifies depths of approximately 8–15 ft (~2–5 m) as optimal, supporting approximately 2 m as a conservative minimum depth threshold for floating gear deployment (OysterGro, 2024). Deployment in shallower waters may be feasible in some settings but is associated with increased risk of benthic disturbance, wave-induced gear contact, and infrastructure damage, particularly in dynamic nearshore environments (Forrest et al., 2009).

4.10. Kelp cultivation in estuarine environments

Sugar kelp (*S. latissima*) may be well suited for estuarine cultivation due to its relatively high tolerance for lower salinities and its tendency to grow closer to the surface (Flavin et al., 2013). In contrast, bull kelp (*N. luetkeana*) and giant kelp (*M. pyrifera*; syn. *M. integrifolia*) typically require higher salinities, greater depths, and different culture configurations. During winter months, Oregon estuaries experience increased freshwater input and reduced salinities, conditions that may limit the feasibility of some kelp species. Sugar kelp grown in higher-salinity zones of estuaries may tolerate episodic reductions in salinity and could benefit from increased light availability associated with near-surface growth, particularly during periods of elevated turbidity.

Bull kelp may also be a potential candidate for estuarine line culture, given its May–November growing season, which largely avoids winter freshwater pulses. Provided turbidity levels are not excessive, there may be limited opportunities for estuarine bull kelp cultivation. Overall, while estuarine kelp line culture shows potential, it would be necessary to obtain substantially higher-resolution spatial and temporal data, along with site-specific monitoring, before pursuing this approach as a feasible commercial option.

4.11. Economic considerations

Market and financial factors are critical to the viability of any mariculture operation. In the models developed within this study, these considerations were represented both directly and indirectly through a

range of logistical and industry-related variables. For example, distance to port influences travel time, fuel use, and associated operating costs, while site depth can affect capital and maintenance costs by necessitating additional or more robust gear and anchoring systems, particularly at greater depths. Enterprise zones were weighted favorably due to the potential for tax incentives and other economic benefits. Likewise, proximity to seafood processors, cold storage facilities, and other supply-chain infrastructure can reduce handling, transportation, and transaction costs.

Several important factors were not explicitly accounted for in the modeling and beyond the scope of this study. Once a candidate site is selected, however, these elements can be evaluated in greater detail. Gear costs can be more accurately estimated based on site-specific engineering requirements for installation and maintenance under local environmental conditions, and carrying capacity can be used to estimate total yield and production potential. Together, these considerations would support a more refined assessment of the overall economic viability of a proposed mariculture operation.

4.12. Existing mariculture

Data layers reflective of existing mariculture were scored higher in the Suitability Analysis and Ranking Analysis. These areas are being utilized and managed and have been proven suitable for shellfish mariculture, in addition to having existing infrastructure and community acceptance. By giving preference to existing mariculture, the Suitability and Ranking Models may have overlooked areas that may be as suitable yet lack existing mariculture. However, reviewing the Opportunity Models could provide insight into future monitoring and review by ODA. For example, Nehalem, Siuslaw, and Umpqua estuaries have high Olympia oyster opportunity.

4.13. Columbia River plume and estuary

The Columbia River and Youngs Bay estuaries were considered in the analysis; however, due to the high freshwater input (low salinity) observed, both were considered to have no opportunity for any of the

mariculture species (Figure 37). Additionally, the Columbia River plume reduced the area of opportunity along the northern Oregon Coast for all the different kelp species, except for sugar kelp, which has a lower salinity tolerance. The Columbia River plume varies seasonally, with a southward direction during the summer months and a northward direction during the winter months (Fiedler & Laurs, 1990). In addition, the Columbia River plume extent varies interannually (Burla et al., 2010). Any mariculture operation along the mid to northern coast of Oregon should evaluate any potential impacts from the Columbia River plume.

4.14. Eelgrass exclusion

Eelgrass maximum extent across a multiyear period was used to exclude areas from consideration. Given the inherently dynamic and interannually variable nature of eelgrass distribution, this conservative approach was adopted to minimize the risk of impacts to existing eelgrass habitat, as well as to areas where eelgrass has been documented historically but may not be present in all survey years. As such, this screening approach was intentionally precautionary and was not expected to represent the current eelgrass extent.

Potential impacts of mariculture activities on eelgrass include shading by surface or suspended gear, physical disturbance associated with anchoring and installation, and localized changes in sediment conditions (Theuerkauf et al., 2021; Ward et al., 2024). However, documented interactions are context-dependent. Some studies have reported co-occurring benefits, such as improved water clarity via shellfish filtration, increased biodiversity, localized protection of eelgrass, and potential amelioration of ocean acidification. These have been reported alongside localized negative effects, including competition for light or space, disturbance during mechanical harvest, and increased nutrient or sulfide accumulation in sediments (Ward et al., 2024).

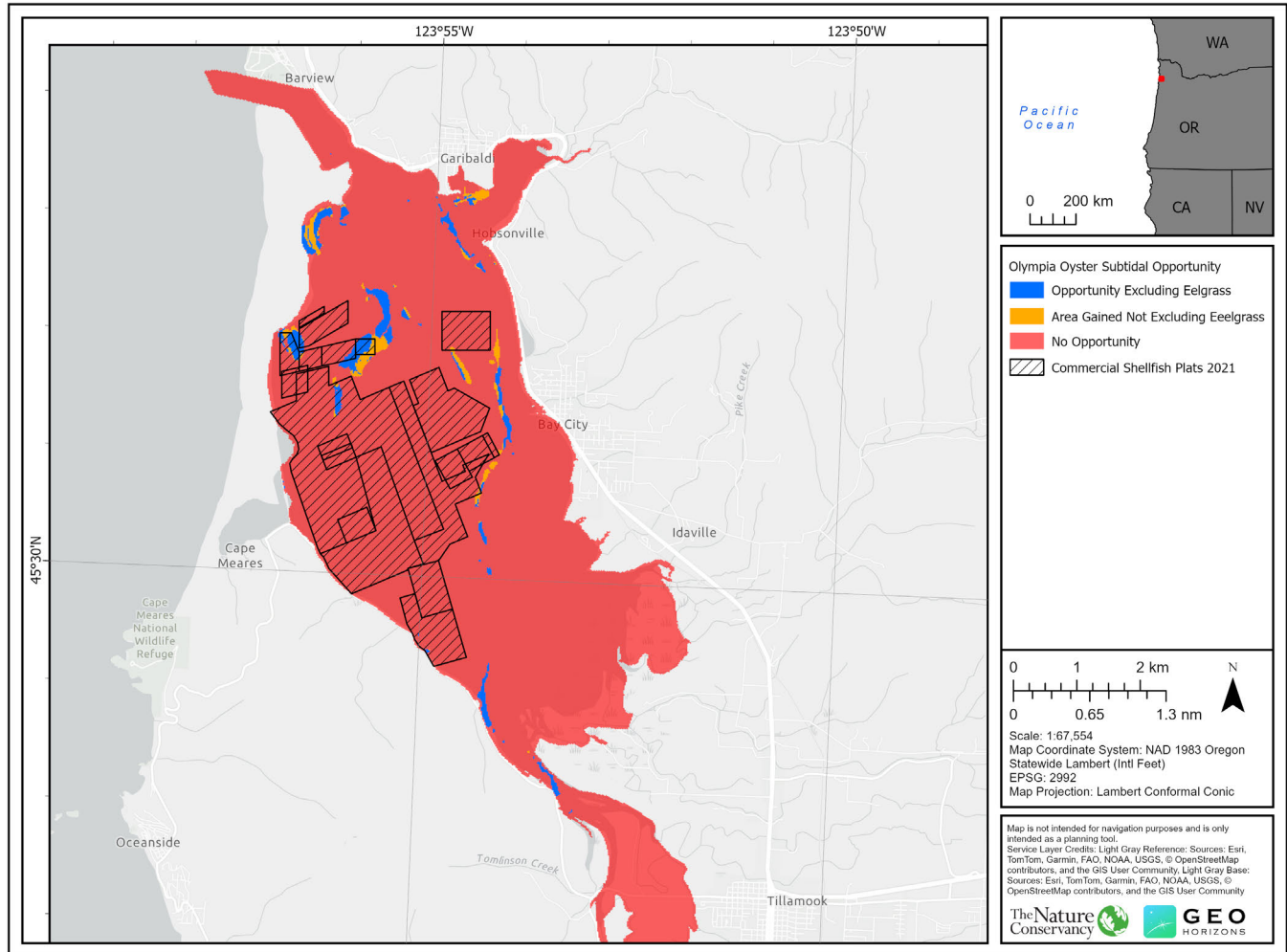
Overall, application of the eelgrass exclusion removed 488 ac (2.0 km²) from consideration (Table 34 and Figure 52). In cases where a mariculture operation may overlap with eelgrass habitat, there may be opportunities to mitigate disruptive interactions. These could include avoiding areas of dense eelgrass coverage, minimizing or eliminating anchoring within eelgrass beds, and reducing trampling or disturbance during maintenance and harvest activities.

Table 34. Olympia oyster opportunity by estuary, evaluated under two scenarios: (1) with eelgrass maximum extent incorporated as an exclusion layer and (2) without eelgrass applied as an exclusion.

Estuary (north to south)	Olympia oyster opportunity Area (ac) when eelgrass excluded	Olympia oyster opportunity Area (ac) when eelgrass <i>not</i> excluded	Area gained (ac)
Columbia River	0	0	0
Youngs Bay	0	0	0
Nehalem	307	312	+5
Tillamook Bay	225	337	+112
Netarts Bay	49	53	+4
Sand Lake	0	0	0
Nestucca Bay	69	75	+6
Salmon River	0	0	0
Siletz Bay	1	1	0
Yaquina Bay	514	565	+51
Alsea Bay	23	31	+8
Siuslaw River	281	282	+1
Umpqua River	1,956	2,034	+78
Coos Bay	1,871	2,092	+221
Coquille River	155	157	+2
Total area	5,450	5,938	+488

Note. Calculated for each estuary is the additional area made available when eelgrass is not used as an exclusion.

Figure 52. Opportunity for Olympia oyster mariculture using subtidal gear within Tillamook Bay, with eelgrass used as an exclusion, plus the area gained with eelgrass not used as an exclusion.



Note. The Commercial Shellfish Plats 2021(ODA, 2021) are overlaid to provide additional context.

5. Conclusions and next steps

This study has provided a baseline assessment of mariculture opportunities in Oregon's estuarine and coastal ocean waters, identifying areas suitable for specific species and gear types. Using a hierarchical spatial modeling framework—from broad compatibility screening (Exclusion Analysis) to the identification of highly suitable areas—the analysis has established a robust basis for estimating mariculture development potential. The study relied on best available, high-resolution, quality-controlled datasets, strengthening Oregon's spatial planning capacity and supporting long-term sustainable development of the mariculture sector. Farm-specific siting factors were clearly defined, enabling transparent determination of where and to what extent mariculture development would be most appropriate to develop in Oregon's coastal waters.

Results from this work directly support production and ecological carrying capacity modeling for seaweed and shellfish mariculture at both farm and ecosystem scales. Total carrying capacity represents a key endpoint, and the identified prospective farm sites provide the spatial inputs needed to estimate maximum sustainable production levels prior to adverse ecosystem impacts. Once optimal sites are defined under each scenario, established models—such as the MacroAlgal Cultivation MODELing System (MACMODS) for seaweed (Frieder et al., 2022) and the Farm Aquaculture Resource Management (FARM) model for shellfish (Ferreira et al., 2009)—can be applied to quantify farm-scale production, ecosystem-level carrying capacity, and conditions for sustainable mariculture development along the Oregon Coast.

This study has established a strong foundation for spatial planning to guide sustainable mariculture development in Oregon. Targeted technical analyses can further refine these results, enhance ecological and management benefits, and support application in other regions. Key areas for continued advancement include those described in the following subsections.

5.1. Sustaining web map viewers

As part of this study, the spatial analysts and Advisory Committee developed an interactive web map viewer that enables users to explore and engage directly with the study's results. As mentioned earlier in this report, data are available for viewing and download via the Oregon Coastal Atlas (coastalatlases.net/MaricultureSuitability), maintained by the Oregon Department of Land Conservation and Development.

Prior research indicates that such tools substantially increase the uptake and practical application of complex spatial analyses by a broad range of stakeholders (Wickliffe et al., 2019). However, maintaining these tools—across software platforms, underlying datasets, and modeling frameworks—requires sustained technical and financial resources to ensure continued functionality, relevance, and accuracy over time.

Benefits:

- Sustained, interactive access to modeling results, allowing users to explore suitability outputs, assumptions, and scenarios without requiring specialized technical expertise.
- Greater flexibility to support adaptive planning, including the ability to update datasets, revise assumptions, incorporate new regulatory or environmental constraints, and evaluate alternative scenarios as conditions, policies, or management priorities evolve.
- Improved uptake and real-world application of results, translating complex spatial analyses into actionable information that can directly inform planning, permitting, and decision-making processes.

5.2. Precision siting

Fine-scale spatial modeling to determine optimal farm size, configuration (e.g., gear spacing, orientation relative to prevailing winds), co-culture, and other site-specific parameters critical for informed mariculture siting decisions.

Benefits:

- Reduces risk and lowers barriers to entry for prospective mariculture operators.
- Increases permitting efficiency and regulatory confidence by providing clear, data-driven guidance.
- Aligns farm placement with conservation priorities (TNC, 2021), ensuring mariculture growth supports conservation objectives.

5.3. Farm-scale modeling

High-resolution modeling of mariculture productivity and environmental interactions at the farm level.

Benefits:

- Strengthens business planning and investment readiness for new operations.
- Enhances the scientific rigor of permitting applications by addressing likely environmental questions (e.g., nutrient cycling, ecosystem-scale impacts).
- Quantifies potential environmental benefits of mariculture, such as nutrient removal, improved water clarity, and habitat provisioning.

5.4. Ecosystem recovery optimization modeling

Shellfish and seaweed aquaculture can deliver measurable ecosystem service benefits, including nutrient uptake and habitat restoration. Prior global-scale work—led by TNC and NOAA and spearheaded by Geo Horizons team member Dr. Seth Theuerkauf—has developed the Restorative Aquaculture Opportunity Index to identify ecoregions where mariculture development could best advance ecosystem recovery goals (Theuerkauf et al., 2019).

This framework could be refined and applied to the Oregon Coast to prioritize areas where restorative shellfish and seaweed mariculture would be most impactful, by considering the following:

- Locations with the greatest historical loss of shellfish and seaweed habitats.
- Areas facing persistent nutrient pollution challenges.
- Regions where development and fishing pressure have degraded benthic habitats, increasing the need for ecological recovery.

Benefit:

- Complements this study's focus on biophysical and existing use and resource potential by identifying where mariculture could deliver the greatest ecosystem benefits, thereby supporting more strategic, conservation-aligned development.

5.5. Support for Alaska mariculture planning

NOAA Fisheries is advancing the identification of Aquaculture Opportunity Areas (AOAs) in Alaska's state waters for shellfish and seaweed farming (NOAA, 2025). The potential is strong to extend the approaches developed in the Oregon study—including the potential development of the above-described complementary resources—to support Alaska's planning goals and maximize conservation outcomes of future mariculture development.

Benefit:

- Ensures consistent, science-based decision support across regions, while tailoring analyses to regional conservation and development priorities.

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Appendix A: Table of data compiled for the spatial analysis

Data category	Data layer	URL to data
Bathymetry	Astoria, Oregon 1/3 arc-second MHW [Mean High Water] Coastal Digital Elevation Model	https://www.ncei.noaa.gov/access/metadata/landing-page/bin/iso?id=gov.noaa.ngdc.mgg.dem:5490
Bathymetry	Central Oregon Coastal Digital Elevation Model NAVD 88 [North American Vertical Datum 88]	https://www.ncei.noaa.gov/metadata/geoportal/rest/metadata/item/gov.noaa.ngdc.mgg.dem:11500/html
Bathymetry	Continuously Updated Digital Elevation Model (CUDEM) - 1/9 arc-second Resolution Bathymetric-Topographic Tiles	https://www.ncei.noaa.gov/maps/bathymetry/
Bathymetry	Crescent City, California 1/3 arc-second MHW Coastal Digital Elevation Model	https://www.ncei.noaa.gov/access/metadata/landing-page/bin/iso?id=gov.noaa.ngdc.mgg.dem:693
Bathymetry	Garibaldi, Oregon 1/3 arc-second MHW Coastal Digital Elevation Model	https://www.ncei.noaa.gov/metadata/geoportal/rest/metadata/item/gov.noaa.ngdc.mgg.dem:4752/html
Bathymetry	Port Orford, Oregon 1/3 arc-second MHW Coastal Digital Elevation Model	https://www.ncei.noaa.gov/metadata/geoportal/rest/metadata/item/gov.noaa.ngdc.mgg.dem:410/html
Bathymetry	U.S. Coastal Relief Model Vol. 8 - Northwest Pacific	https://www.ncei.noaa.gov/metadata/geoportal/rest/metadata/item/gov.noaa.ngdc.mgg.dem:288/html
Benthic	Biotic Component Estuary	https://gis.lcd.state.or.us/server/rest/services/Framework/Bioscience_CoastalMarineEcologicalSystems/MapServer/7
Benthic	Geoform Component Estuary	https://gis.lcd.state.or.us/server/rest/services/Framework/Bioscience_CoastalMarineEcologicalSystems/MapServer/10
Benthic	Substrate Component Estuary	https://gis.lcd.state.or.us/server/rest/services/Framework/Bioscience_CoastalMarineEcologicalSystems/MapServer/15
Benthic	Substrate Component Intertidal	https://gis.lcd.state.or.us/server/rest/services/Framework/Bioscience_CoastalMarineEcologicalSystems/MapServer/19
Benthic	West Coast USA Nearshore Coastal and Marine Ecological Classification Standard (CMECS) Substrate Habitat	https://www.pacificfishhabitat.org/data/nearshore-cmeecs-substrate-habitat/
Boundary	Bandon Zoning Map	https://www.bandon-or.gov/media/20401
Boundary	Coos County Zoning Map	https://co.coos.or.us/coos-bay-estuary-management-plan-maps

Data category	Data layer	URL to data
Industry	Vessel Transits – Passenger 2019-2023	https://hub.marinecadastre.gov/pages/vesseltraffic
Industry	Vessel Transits – Pleasure Sailing 2019-2023	https://hub.marinecadastre.gov/pages/vesseltraffic
Industry	Vessel Transits – Tanker 2019-2023	https://hub.marinecadastre.gov/pages/vesseltraffic
Industry	Vessel Transits – Tug and Tow 2019-2023	https://hub.marinecadastre.gov/pages/vesseltraffic
Mariculture	Cold Food Storage Warehouse	https://www.arcgis.com/apps/dashboards/f9e78cec171543e0b402abf909f0ada7
Mariculture	Estuary Aquaculture Screening 2021	https://gis.lcd.state.or.us/server/rest/services/Projects/OCMP_Aquaculture/MapServer/11
Mariculture	Estuary Planning Management Zones	https://www.oregon.gov/lcd/ocmp/pages/estuary-planning.aspx
Mariculture	Oregon Commercial Shellfish Management Areas 2021	https://gis.lcd.state.or.us/server/rest/services/Projects/OCMP_Aquaculture/MapServer/2
Mariculture	Oregon Commercial Shellfish Plats 2021	https://gis.lcd.state.or.us/server/rest/services/Projects/OCMP_Aquaculture/MapServer/1
Mariculture	Oregon Fish Hatcheries	https://nrimp.dfw.state.or.us/DataClearinghouse/default.aspx?p=202&XMLname=1116.xml
Mariculture	Oregon Recreational Shellfish Harvest Productive Areas 2014	https://gis.lcd.state.or.us/server/rest/services/Projects/OCMP_Aquaculture/MapServer/0
Mariculture	Permit Required by City	https://gis.lcd.state.or.us/server/rest/services/Projects/OCMP_Aquaculture/MapServer/7
Mariculture	Port Owned Lands	Not posted online; contact the Oregon Coastal Mariculture Collaborative (OCMC) for access.
Mariculture	Seafood Processors	https://www.arcgis.com/apps/dashboards/f9e78cec171543e0b402abf909f0ada7
Mariculture	Shellfish Distributors	https://www.arcgis.com/apps/dashboards/f9e78cec171543e0b402abf909f0ada7
Mariculture	Shellfish Shucker and Packer	https://www.arcgis.com/apps/dashboards/f9e78cec171543e0b402abf909f0ada7
National Security	Danger Zones and Restricted Areas	https://hub.marinecadastre.gov/datasets/noaa::danger-zones-and-restricted-areas-1/about
National Security	Military Operating Areas	https://hub.marinecadastre.gov/datasets/noaa::military-operating-areas/about
National Security	Military Regulated Airspace	https://hub.marinecadastre.gov/datasets/noaa::military-regulated-airspace/about
National Security	Military Special Use Airspace	https://hub.marinecadastre.gov/datasets/noaa::military-special-use-airspace/about

Data category	Data layer	URL to data
National Security	Munitions and Explosives of Concern	https://hub.marin cadastre.gov/datasets/noaa::munitions-and-explosives-of-concern/about
Natural and Cultural Resources	California Sea Lion Haul-Out Counts Oregon Department of Fish and Wildlife (ODFW) 2011	https://gis.lcd.state.or.us/server/rest/services/Projects/OCMP_SeaSketch_Biological/MapServer/3
Natural and Cultural Resources	Clam Beds CMECS 2018	https://gis.lcd.state.or.us/server/rest/services/Projects/OCMP_Aquaculture/MapServer/6
Natural and Cultural Resources	Critical Habitats West Coast Region	https://www.fisheries.noaa.gov/resource/map/critical-habitat-maps-and-gis-data-west-coast-region
Natural and Cultural Resources	Eelgrass Beds	https://gis.lcd.state.or.us/server/rest/services/Projects/OCMP_SpecialHabitatViewer/MapServer/6
Natural and Cultural Resources	Eelgrass Habitat West Coast	https://www.pacificfishhabitat.org/data/west-coast-usa-eelgrass-habitat/
Natural and Cultural Resources	Ghost Shrimp Beds CMECS 2018	https://gis.lcd.state.or.us/server/rest/services/Projects/OCMP_Aquaculture/MapServer/5
Natural and Cultural Resources	Kelp Beds	https://www.arcgis.com/home/item.html?id=24760dc16a4a4dcb9b3360d3ad6659ae
Natural and Cultural Resources	Kelp Presence – Kelpwatch	https://kelpwatch.org/
Natural and Cultural Resources	Mud Shrimp Beds CMECS 2018	https://gis.lcd.state.or.us/server/rest/services/Projects/OCMP_Aquaculture/MapServer/4
Natural and Cultural Resources	Native Oyster Habitat	https://gis.lcd.state.or.us/server/rest/services/Projects/OCMP_SpecialHabitatViewer/MapServer/7
Natural and Cultural Resources	Oregon State Special Management Areas	https://gis.lcd.state.or.us/server/rest/services/Projects/OCMP_SpecialHabitatViewer/MapServer/1
Natural and Cultural Resources	Pacific Harbor Seal Haul-Out Counts ODFW 2011	https://gis.lcd.state.or.us/server/rest/services/Projects/OCMP_SeaSketch_Biological/MapServer/10
Natural and Cultural Resources	U.S. Fish and Wildlife Service (USFWS) National Wildlife Refuges	https://www.arcgis.com/home/item.html?id=5e92f2e0930848faa40480bcb4fdc44e#overview
Navigation	Aids to Navigation	https://hub.marin cadastre.gov/datasets/noaa::aids-to-navigation-2/about
Navigation	Anchorage	https://hub.marin cadastre.gov/datasets/noaa::anchorage/about
Navigation	Maintained Channels	https://www.fisheries.noaa.gov/inport/item/39972
Navigation	Shipping Lanes	https://www.fisheries.noaa.gov/inport/item/39986

Data category	Data layer	URL to data
Navigation	Wrecks and Obstructions	https://encdirect.noaa.gov/
Oceanographic	Chlorophyll <i>a</i>	https://oceandata.sci.gsfc.nasa.gov/l3/
Oceanographic	Iron Concentration	https://www.bio-oracle.org/downloads-to-email.php
Oceanographic	Light Availability	Light availability at 1-m depth based on KdPAR Visible Infrared Imaging Radiometer Suite (VIIRS) data
Oceanographic	Nitrate Concentration	https://www.bio-oracle.org/downloads-to-email.php
Oceanographic	National Oceanic and Atmospheric Administration (NOAA) Estuarine Salinity Zones	https://coastalscience.noaa.gov/data_reports/estuarine-salinity-zones-in-us-east-coast-gulf-of-mexico-and-us-west-coast-from-1999-01-01-to-1999-12-31-ncei-accession-0127396/
Oceanographic	Oregon Salinity Maps	https://www.oregon.gov/dsl/wetlands-waters/Documents/salinity_maps.pdf
Oceanographic	Phosphate Concentration	https://www.bio-oracle.org/downloads-to-email.php
Oceanographic	Significant Wave Height	https://tidesandcurrents.noaa.gov/ofs/dev/wcofs/wcofs.html
Oceanographic	Salish Sea and Columbia River Operational Forecast System (SSCOFS) Model – Salinity	https://tidesandcurrents.noaa.gov/ofs/dev/sscofs/sscofs_info.html
Oceanographic	SSCOFS Model – u	https://tidesandcurrents.noaa.gov/ofs/dev/sscofs/sscofs_info.html
Oceanographic	SSCOFS Model – v	https://tidesandcurrents.noaa.gov/ofs/dev/sscofs/sscofs_info.html
Oceanographic	SSCOFS Model – Water Temperature	https://tidesandcurrents.noaa.gov/ofs/dev/sscofs/sscofs_info.html
Oceanographic	West Coast Operational Forecast System (WCOFS) Model – Salinity	https://tidesandcurrents.noaa.gov/ofs/dev/wcofs/wcofs.html
Oceanographic	WCOFS Model – u	https://tidesandcurrents.noaa.gov/ofs/dev/wcofs/wcofs.html
Oceanographic	WCOFS Model – v	https://tidesandcurrents.noaa.gov/ofs/dev/wcofs/wcofs.html
Oceanographic	WCOFS Model – Water Temperature	https://tidesandcurrents.noaa.gov/ofs/dev/wcofs/wcofs.html

Note. Not all datasets presented in this table were used in the analysis.

Appendix B: Species-specific modeling results

Species-specific modeling results are presented for the species-gear combinations listed in the following overview table:

Appendix B Overview Table. Species-gear combinations and where their modeling results are presented in this report.

Species	Gear	Subarea	Report location *
Olympia oyster	Subtidal gear	Estuary	3.3.1
Purple sea urchin	Tank	Estuary	3.3.2
Bull kelp	Line	Coastal	3.3.3
Bull kelp	Planted on bottom	Coastal	3.3.4
Pacific blue mussel	Line	Estuary	B.1
Kelp species	Line	Estuary	B.2
Pacific dulse	Tank	Estuary	B.3
Red abalone or flat abalone	Tank	Coastal	B.4
Sugar kelp	Line	Coastal	B.5
Ribbon/winged kelp	Line	Coastal	B.6
Giant kelp	Line	Coastal	B.7
Pacific blue mussel	Line	Coastal	B.8
California mussel	Line	Coastal	B.9

* The first four rows (with decimal numbers) point to locations in the main body of this report. The remaining rows (with “B” before a number) point to locations in this appendix. Click on the hyperlinked location to jump to the relevant modeling results.

B.1. Pacific blue mussel – line culture – modeling results

Table B1. Estuaries ranked from more to less optimal for Pacific blue mussel mariculture using line culture.

Estuary	Rank	Highly suitable area (ac)	Logistics	Industry	Biophysical	Distance positive	Distance negative	TOPSIS score
Coos Bay	1	528.2	0.79	0.96	0.5	0.54	0.95	0.64
Umpqua River	2	424.6	1.00	0.63	0.51	0.59	0.66	0.53
Yaquina Bay	3	84.8	1.00	0.28	0.7	0.74	0.39	0.35
Netarts Bay	4	5.6	0.79	0.01	1.00	0.97	0.5	0.34
Tillamook Bay	5	88.6	1.00	0.28	0.58	0.79	0.35	0.31

Note. The highly suitable area in acres is provided for reference. The analysis employed the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS). The variables used in the analysis—Logistics, Industry, and Biophysical—ranged from 0 to 1, with 0 being less optimal and 1 being more optimal for mariculture. Distance from the positive solution and distance from the negative solution are provided in this table, with lower values being closer to and higher values being farther from each solution. The TOPSIS score was used for ranking, with a score of 1 being the most ideal solution and a score of 0 being the least ideal solution.

Figure B1. Opportunity Analysis results for Pacific blue mussel mariculture using line culture for northern Oregon estuaries.

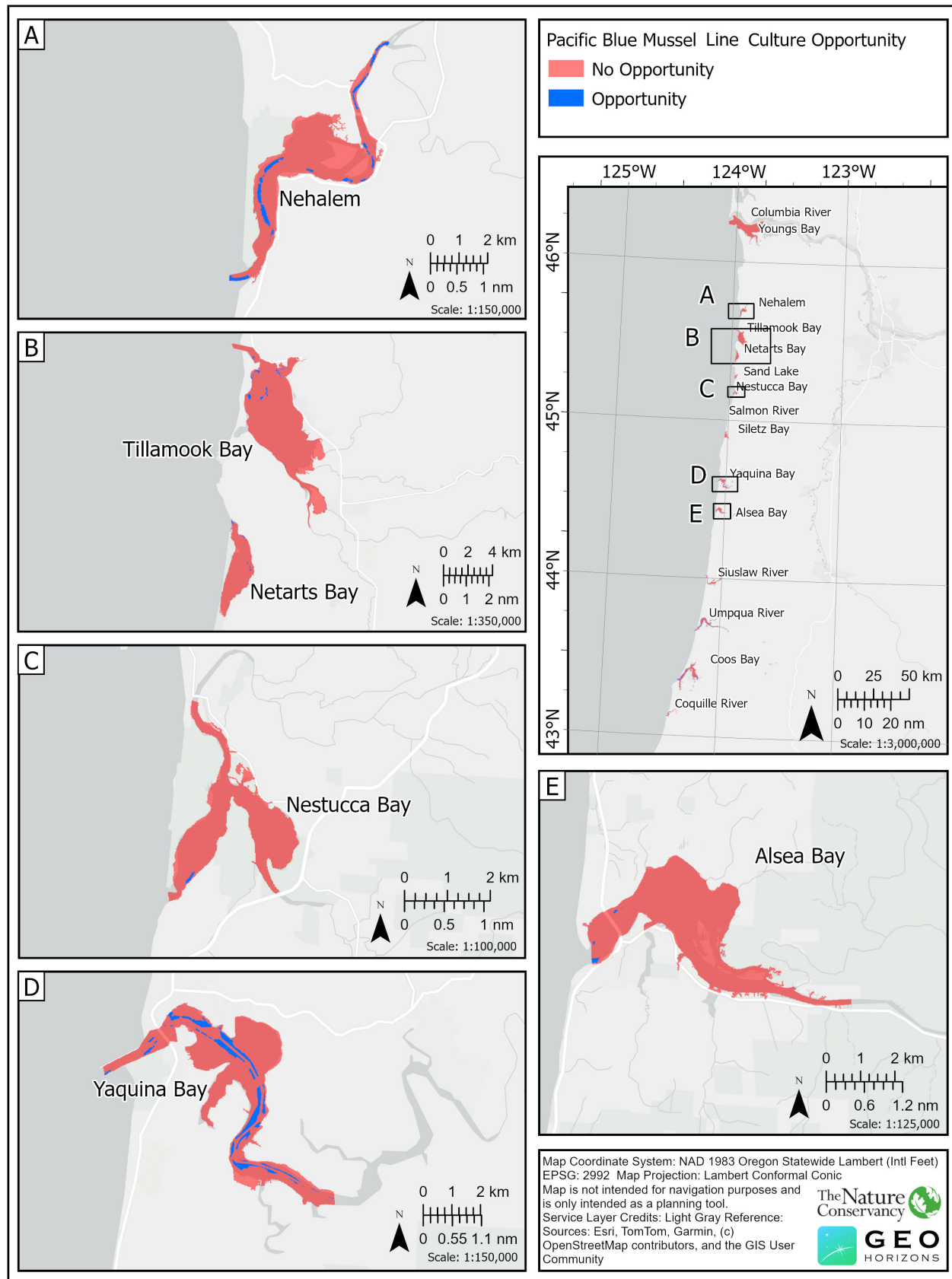


Figure B2. Opportunity Analysis results for Pacific blue mussel mariculture using line culture for southern Oregon estuaries.

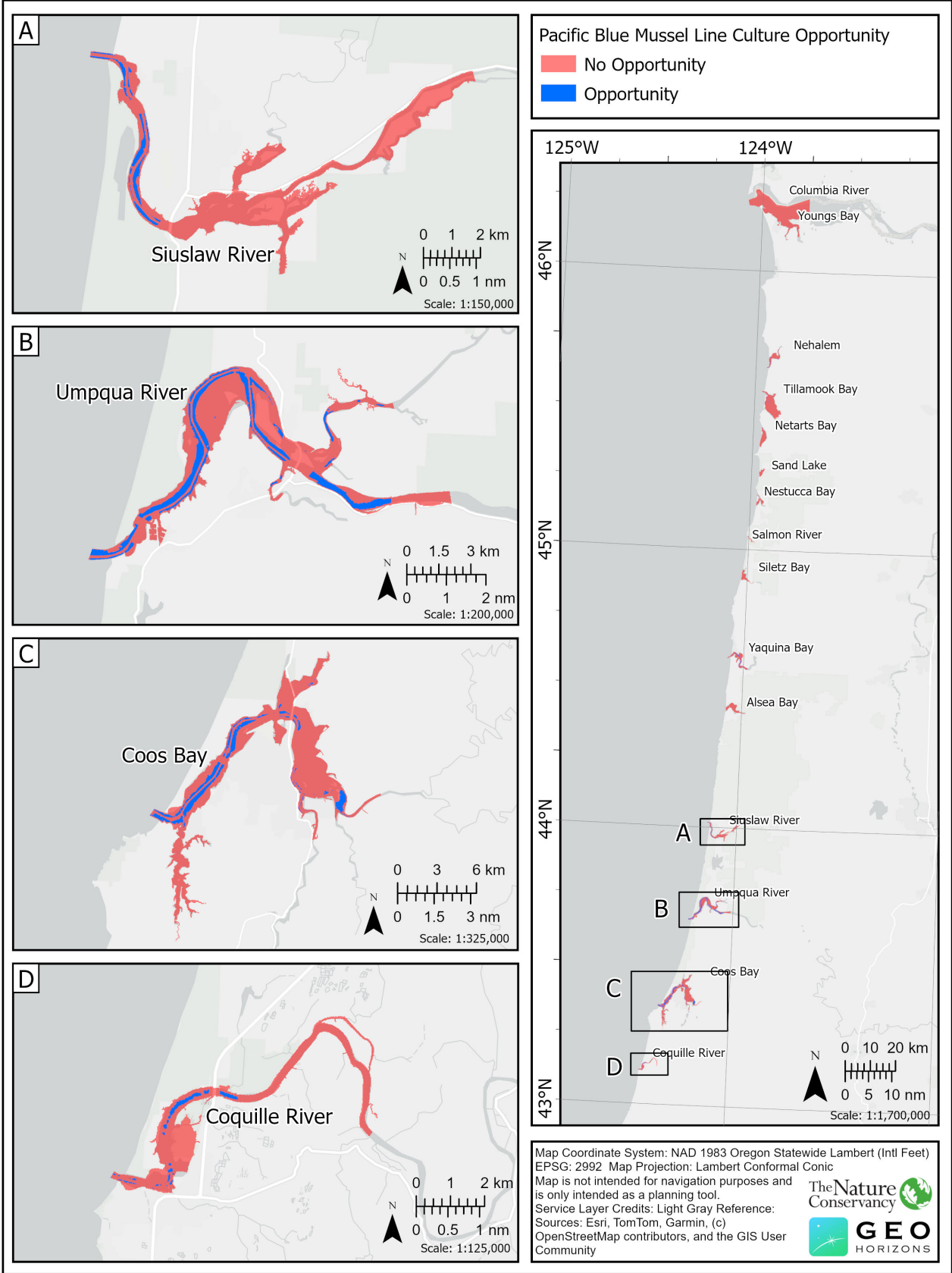


Figure B3. Suitability Analysis results for Pacific blue mussel mariculture using line culture for northern Oregon estuaries.

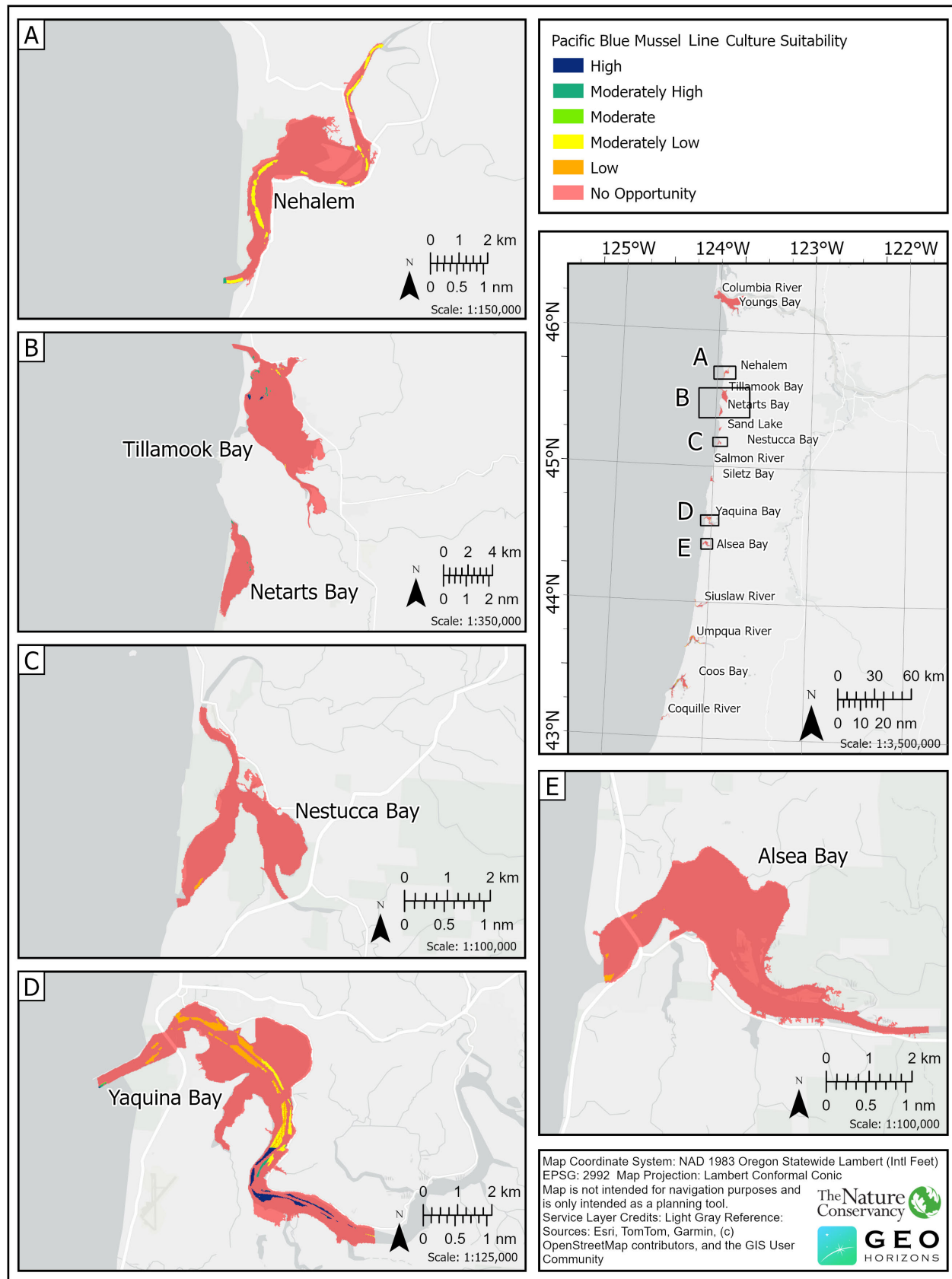


Figure B4. Suitability Analysis results for Pacific blue mussel mariculture using line culture for southern Oregon estuaries.

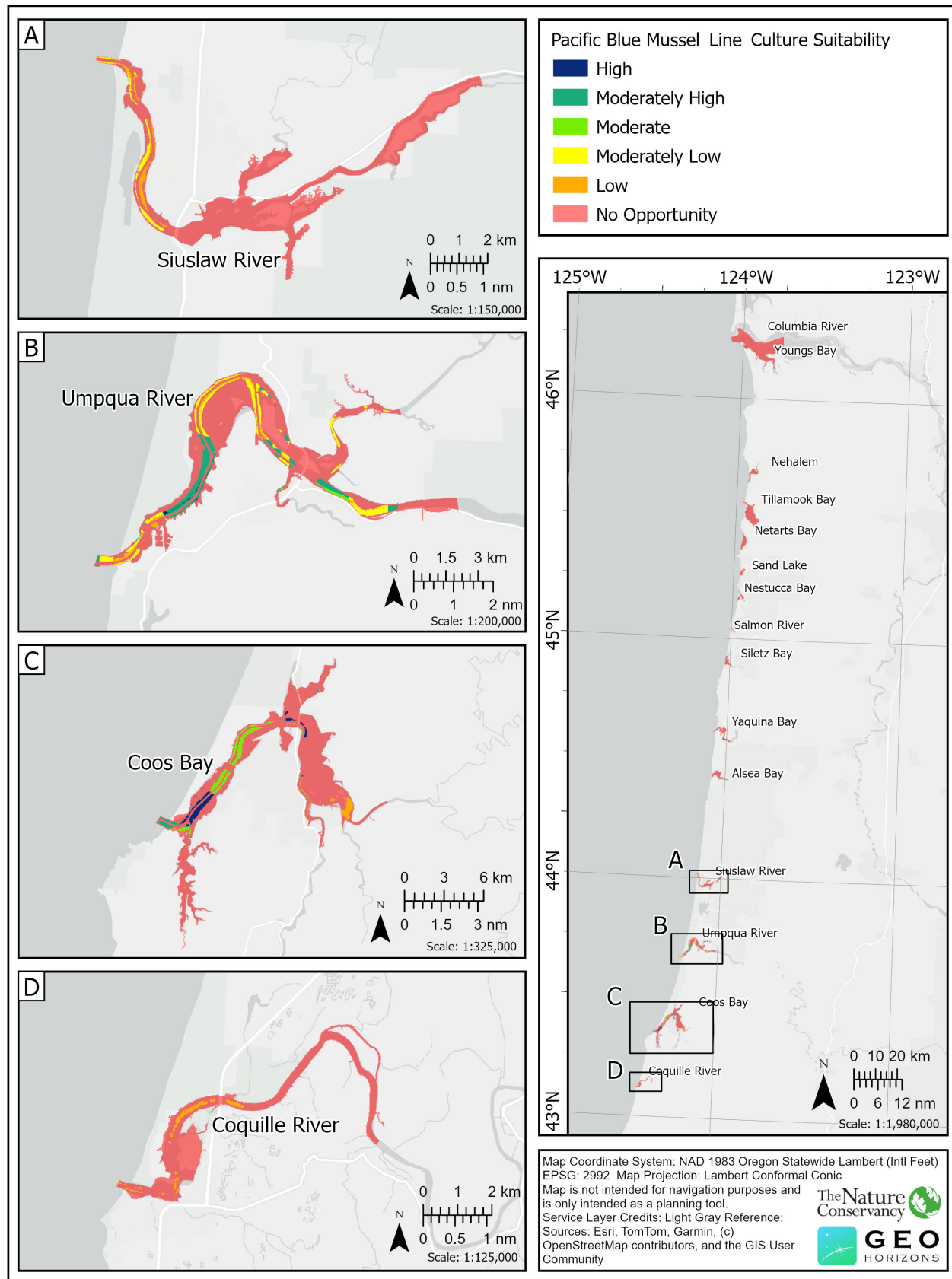


Figure B5. Highly suitable areas in northern Oregon estuaries for Pacific blue mussel line culture, as indicated by the LISA analysis.

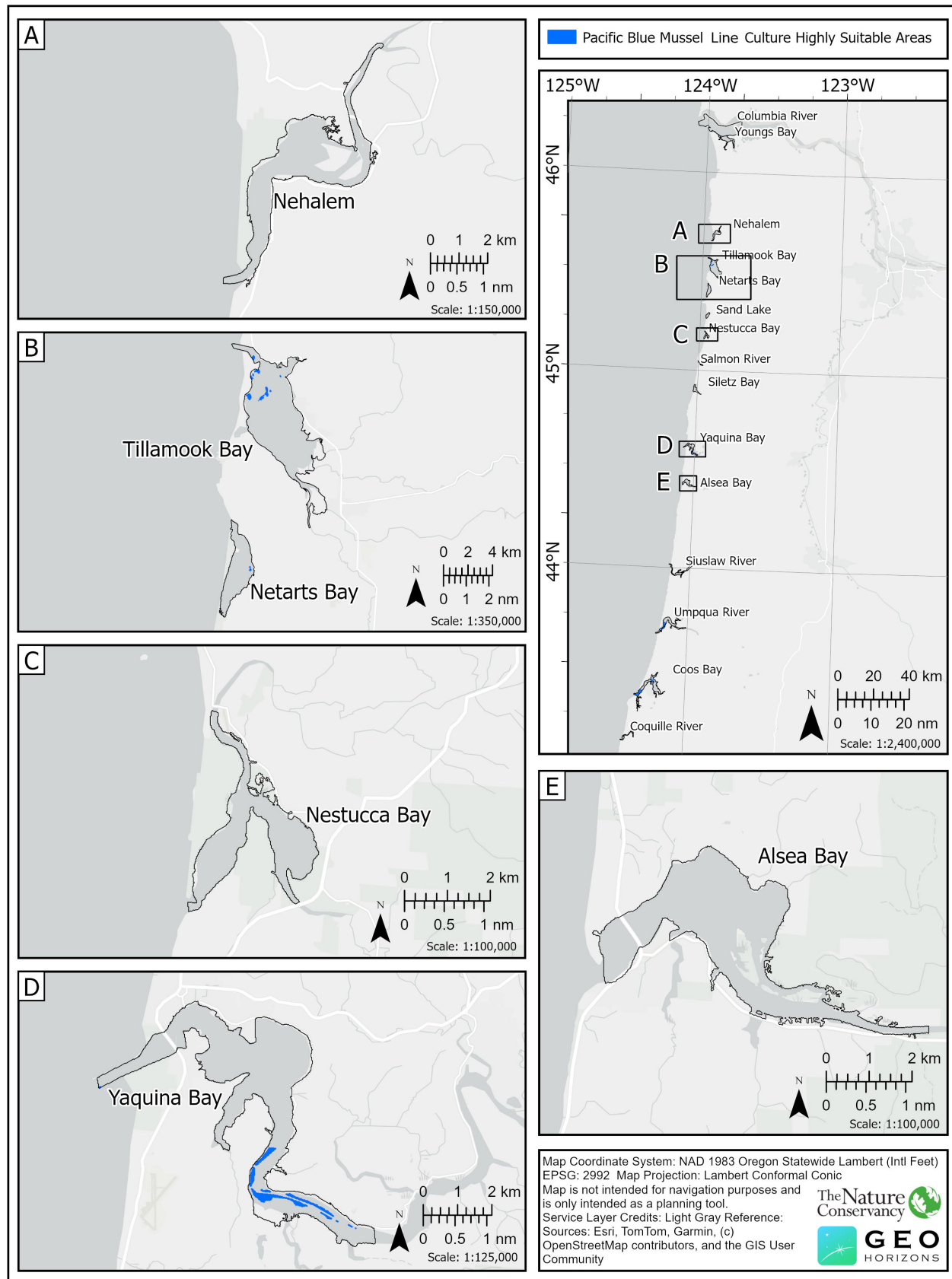
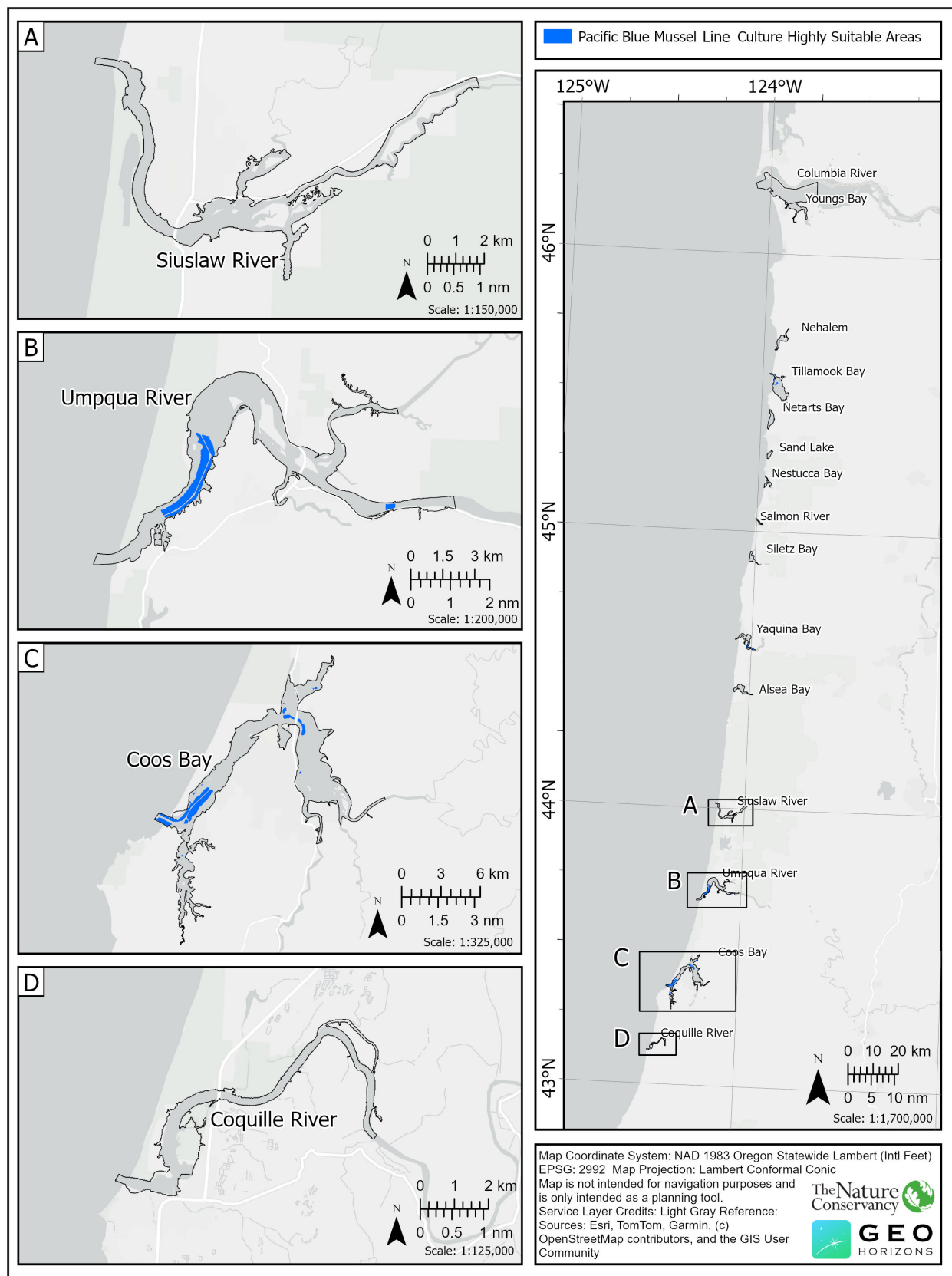


Figure B6. Highly suitable areas in southern Oregon estuaries for Pacific Blue mussel line culture, as indicated by the LISA analysis.



B.2. Kelp species – line culture – modeling results

Table B2. Estuaries ranked from more to less optimal for kelp species mariculture using line culture.

Estuary	Rank	Highly suitable area (ac)	Logistics	Industry	Distance positive	Distance negative	TOPSIS score
Coos Bay	1	373.4	0.84	0.99	0.00	0.98	1.00
Umpqua River	2	131.8	0.84	0.37	0.61	0.37	0.38
Tillamook Bay	3	15.9	0.84	< 0.01	0.98	< 0.01	< 0.01

Note. The highly suitable area for each species is provided for reference. The analysis employed the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS). The variables used in the analysis—Logistics and Industry—ranged from 0 to 1, with 0 being less optimal and 1 being more optimal for mariculture. Distance from the positive solution and distance from the negative solution are provided in this table, with lower values being closer to and higher values being farther from each solution. The TOPSIS score was used for ranking, with a score of 1 being the most ideal solution and a score of 0 being the least ideal solution.

Figure B7. Opportunity Analysis results for kelp species mariculture using line culture for northern Oregon estuaries.

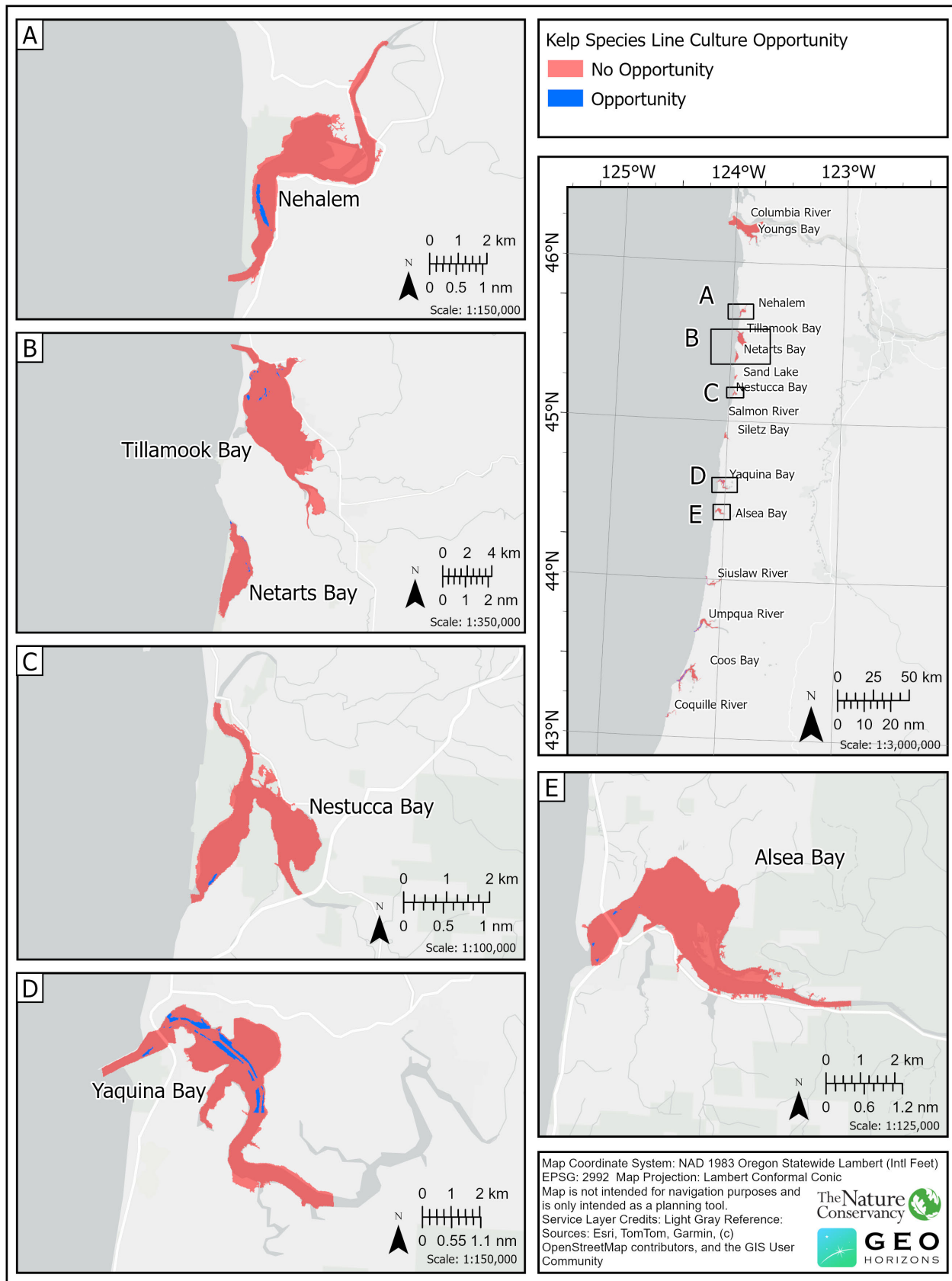


Figure B8. Opportunity Analysis results for kelp species mariculture using line culture for southern Oregon estuaries.

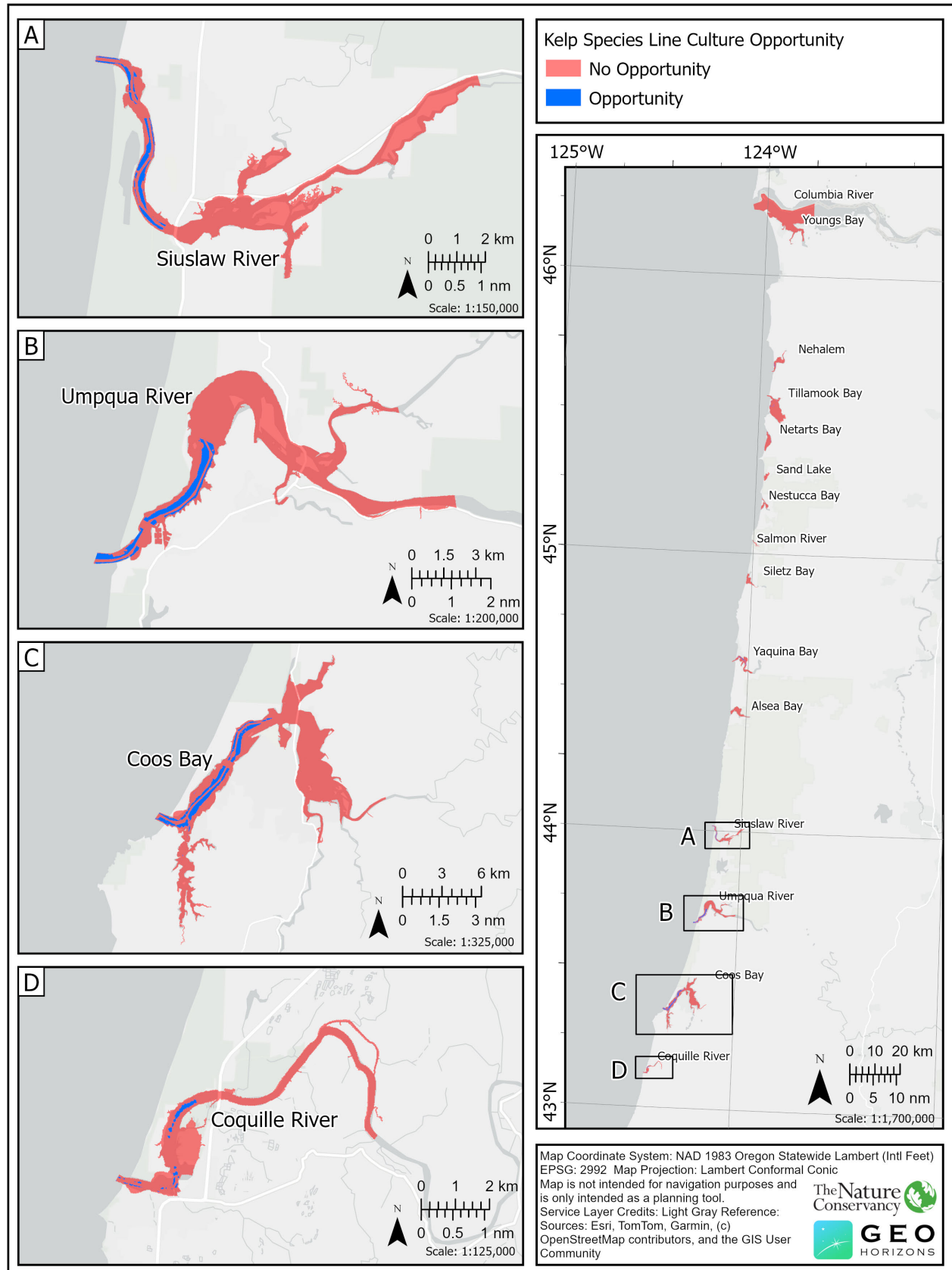


Figure B9. Suitability Analysis results for kelp species mariculture using line culture for northern Oregon estuaries.

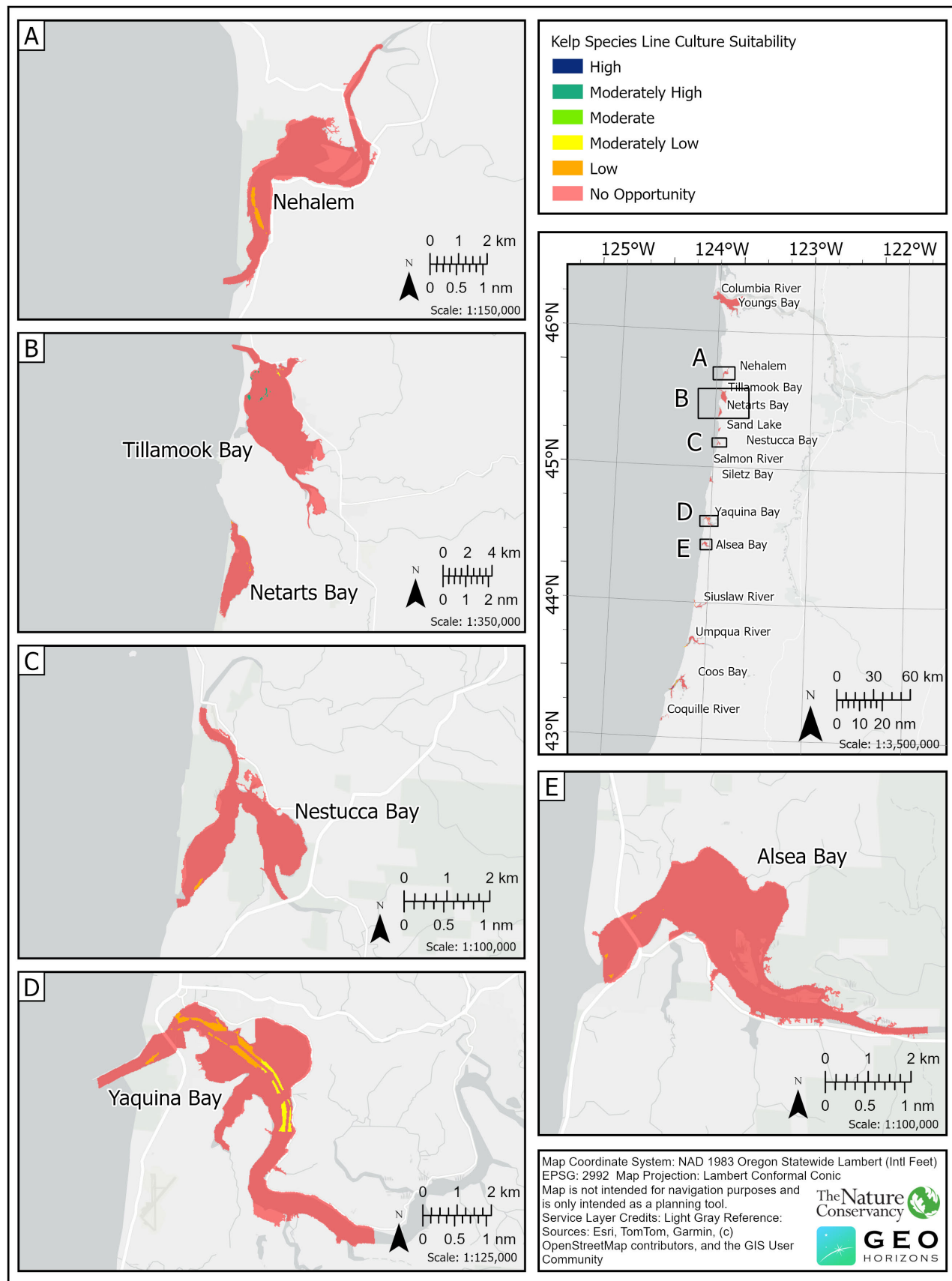


Figure B10. Suitability Analysis results for kelp species mariculture using line culture for southern Oregon estuaries.

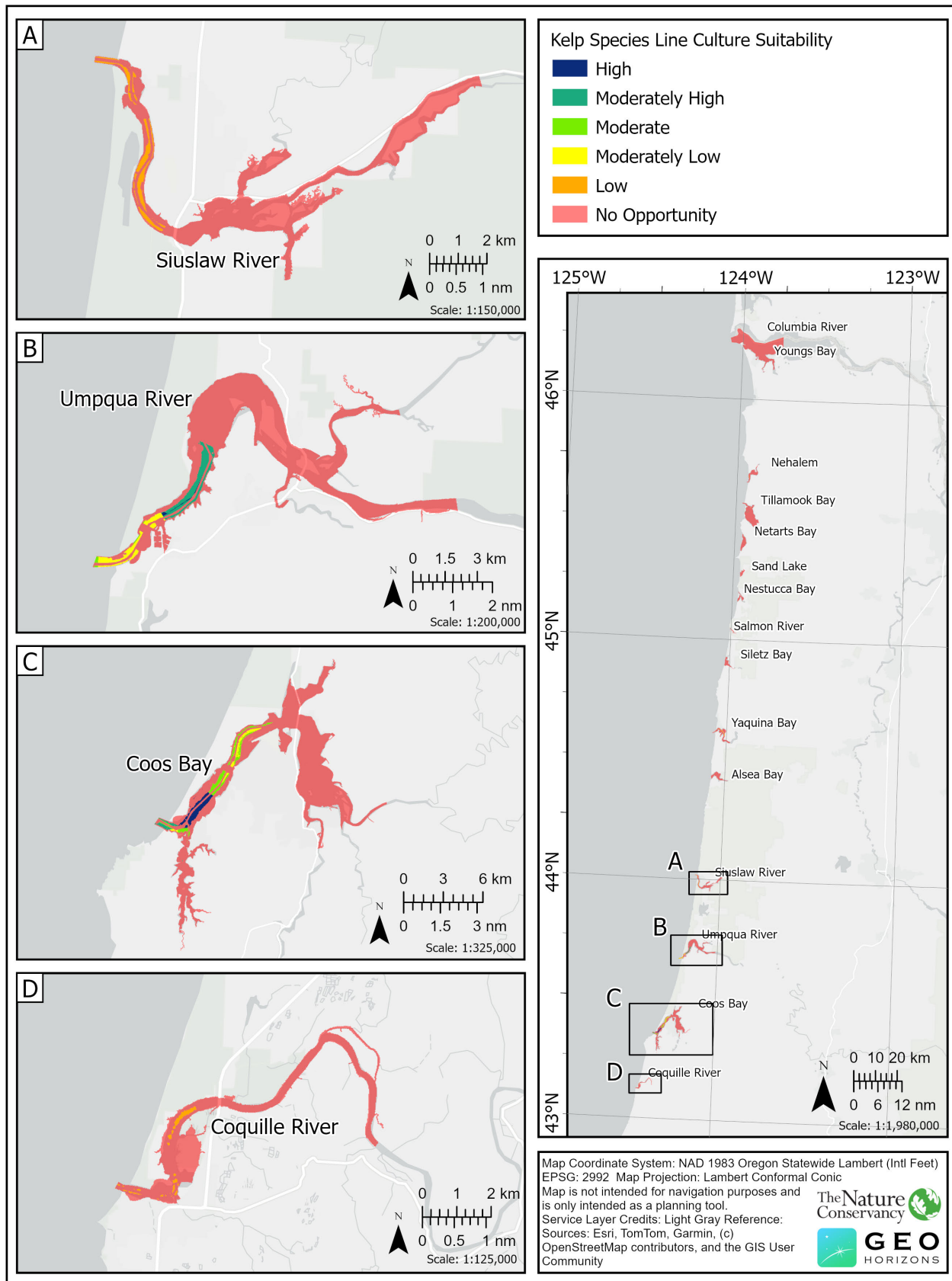


Figure B11. Highly suitable areas in northern Oregon estuaries for kelp species line culture, as indicated by the LISA analysis.

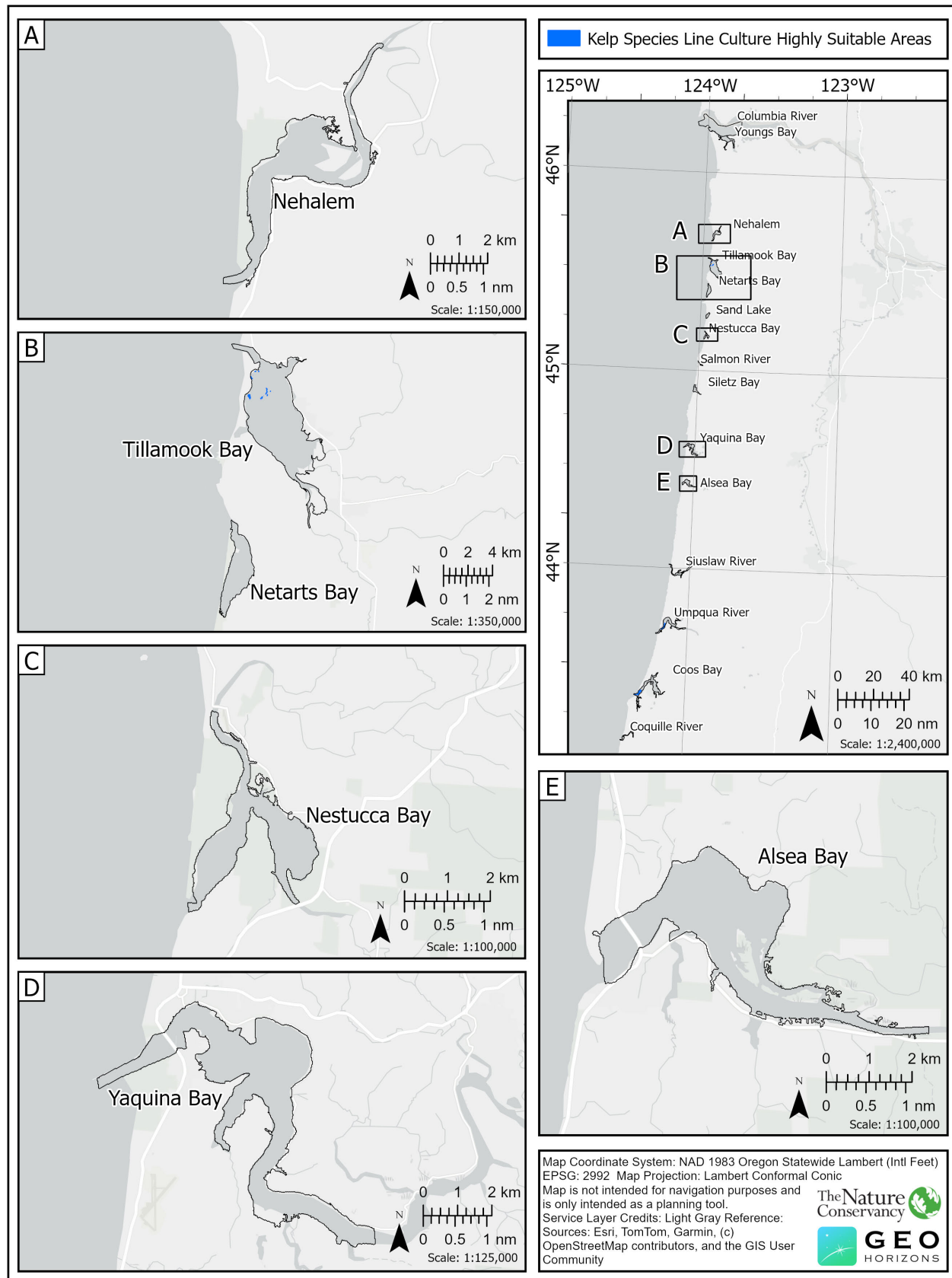
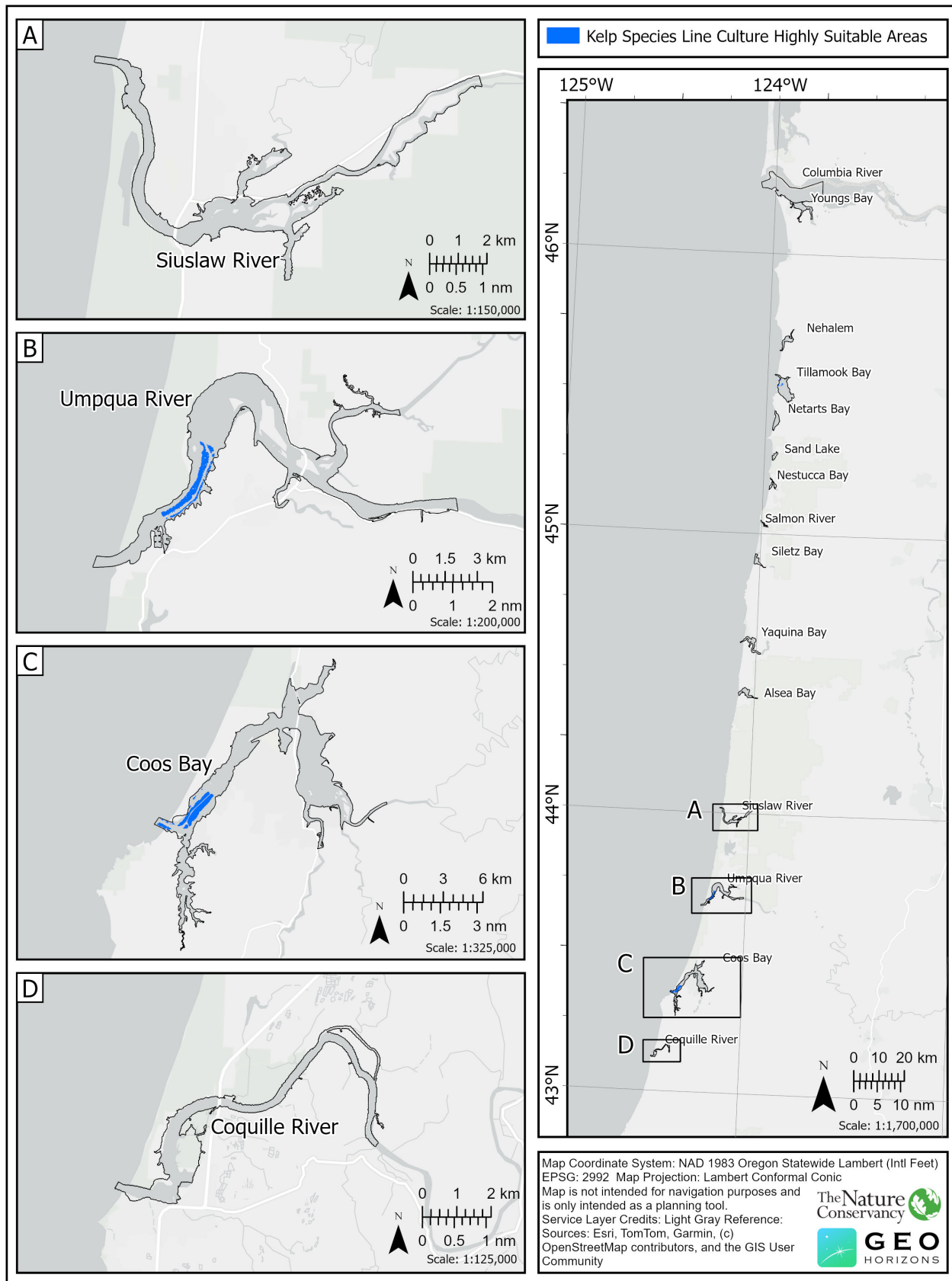


Figure B12. Highly suitable areas in southern Oregon estuaries for kelp species line culture, as indicated by the LISA analysis.



B.3. Pacific dulse – tank culture – modeling results

Table B3. Estuaries ranked from more to less optimal for Pacific dulse tank culture.

Estuary	Rank	Highly suitable area (ac)	Logistics	Industry	Distance positive	Distance negative	TOPSIS score
Coos Bay	1	155.7	0.99	0.84	0.16	0.89	0.85
Yaquina Bay	2	175.1	0.72	1.00	0.27	1.00	0.79
Umpqua River	3	118.2	0.71	0.53	0.55	0.53	0.49
Tillamook Bay	4	54	0.72	< 0.01	1.03	0.02	0.02

Note. The highly suitable area is provided for reference. The analysis employed the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS). The variables used in the analysis—Logistics and Industry—ranged from 0 to 1, with 0 being less optimal and 1 being more optimal for mariculture. Distance from the positive solution and distance from the negative solution are provided in this table, with lower values being closer to and higher values being farther from each solution. The TOPSIS score was used for ranking, with a score of 1 being the most ideal solution and a score of 0 being the least ideal solution.

Figure B13. Opportunity Analysis results for Pacific dulse tank culture for northern Oregon estuaries.

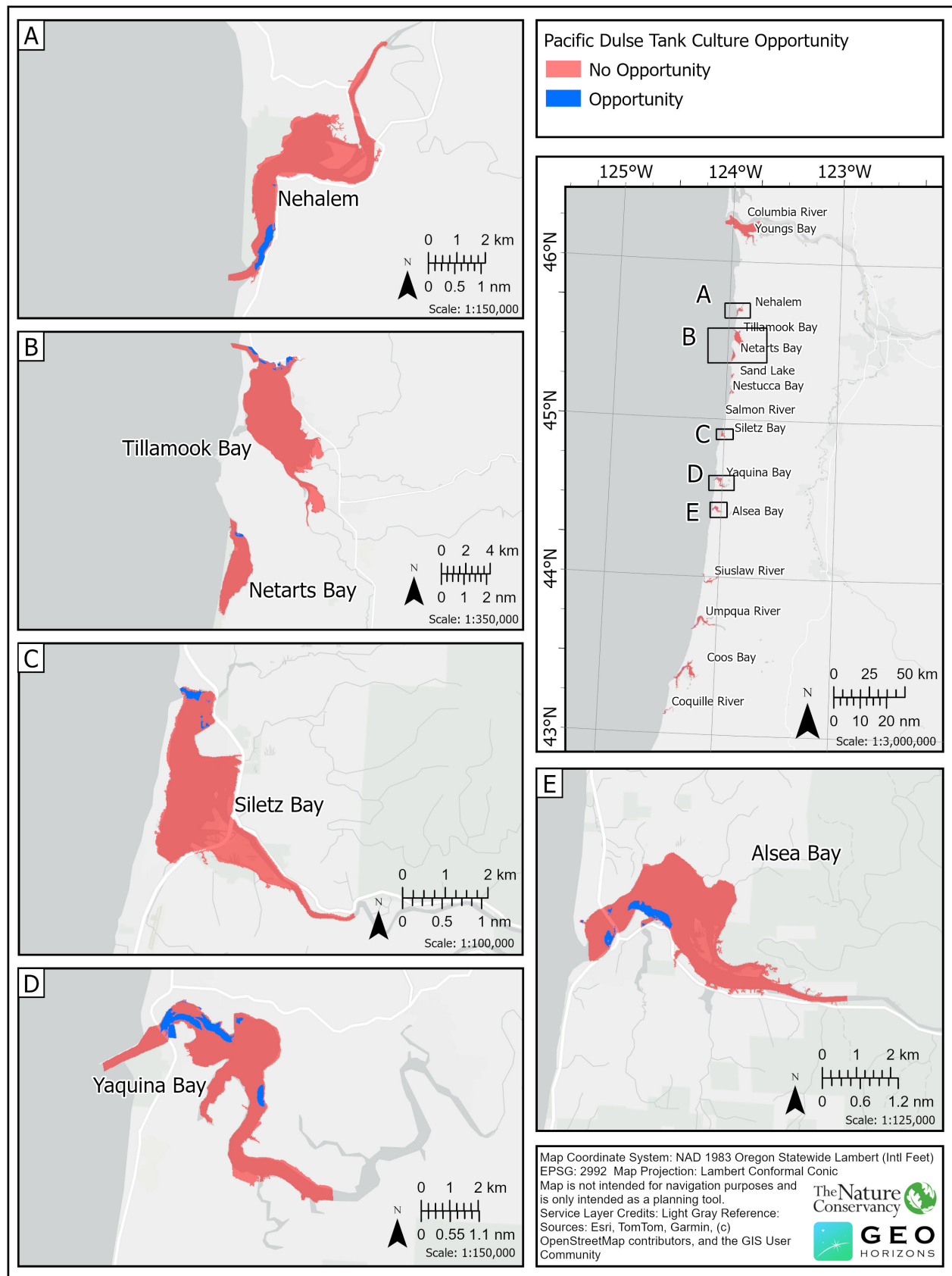


Figure B14. Opportunity Analysis results for Pacific dulse tank culture for southern Oregon estuaries.

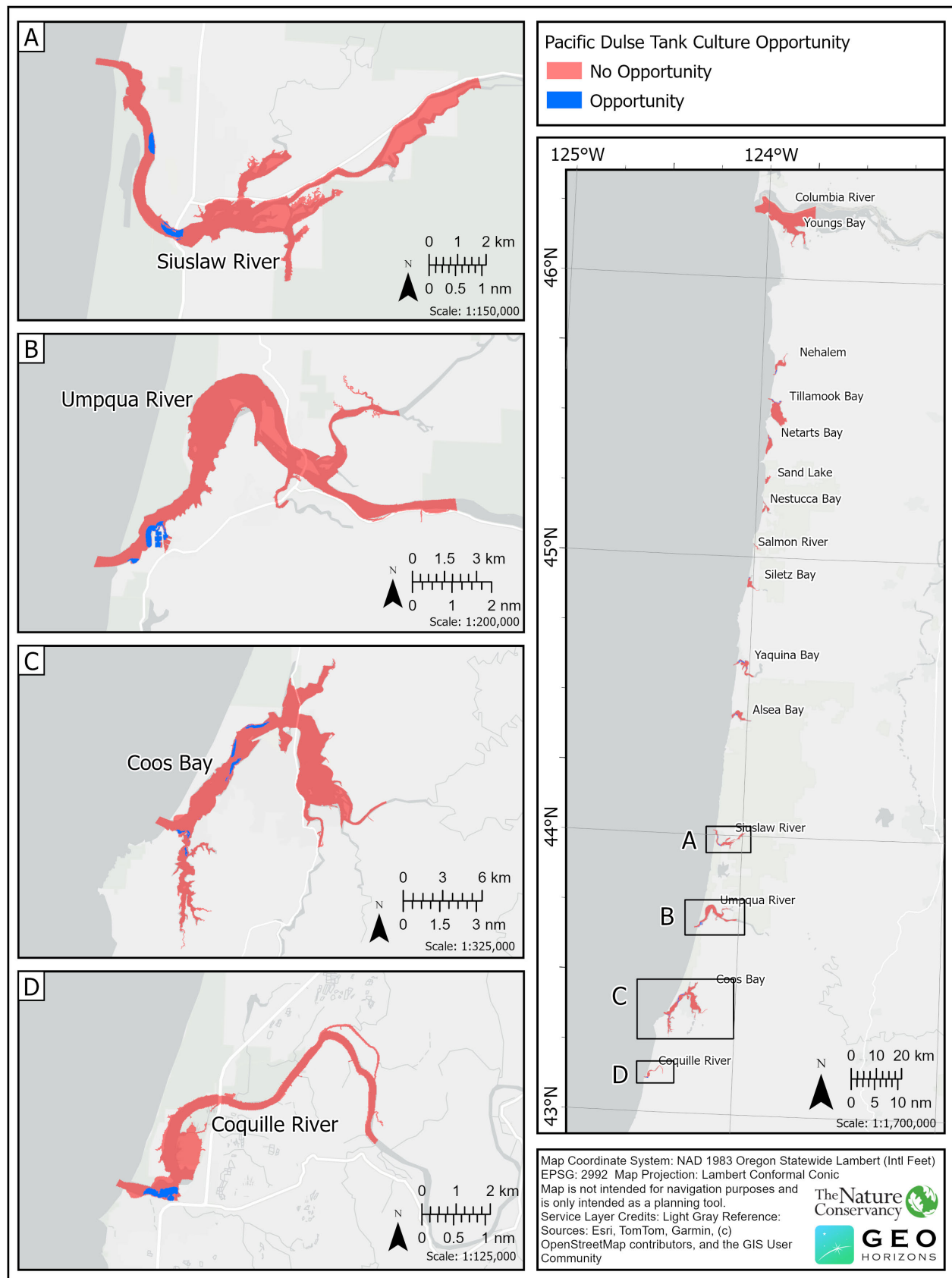


Figure B15. Suitability Analysis results for Pacific dulse tank culture for northern Oregon estuaries.

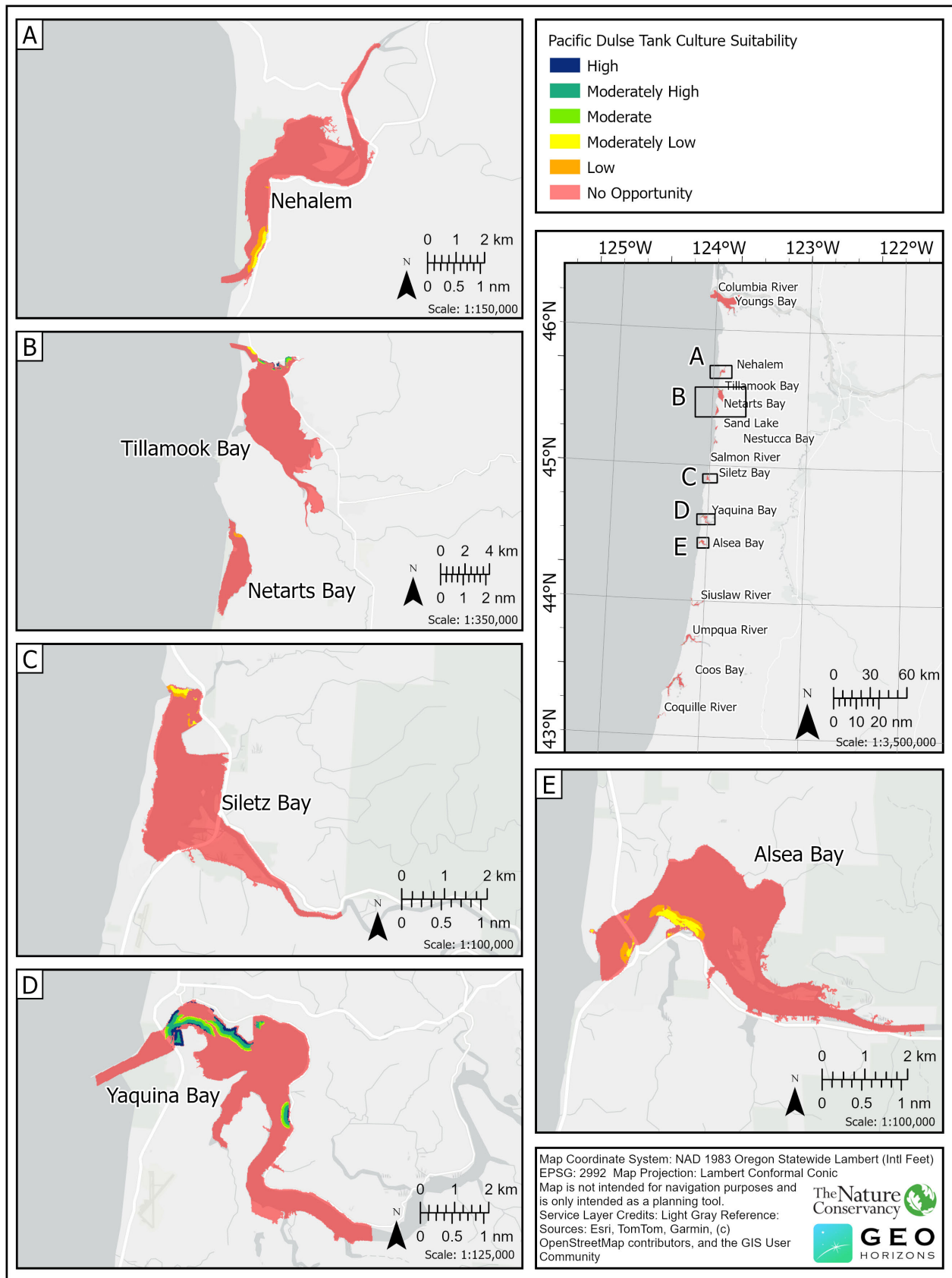


Figure B16. Suitability Analysis results for Pacific dulse tank culture for southern Oregon estuaries.

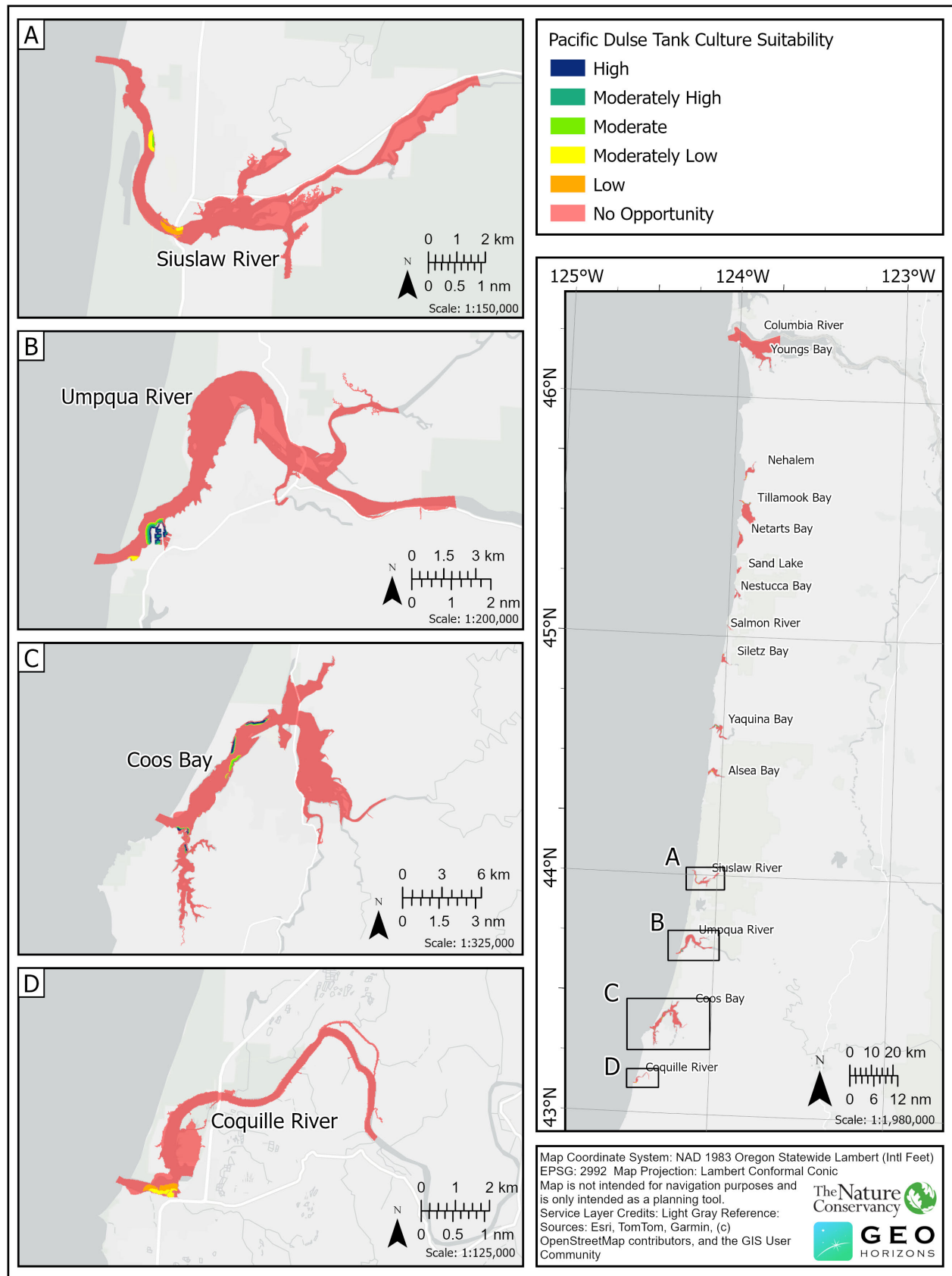


Figure B17. Highly suitable areas in northern Oregon estuaries for Pacific dulse tank culture, as indicated by the LISA analysis.

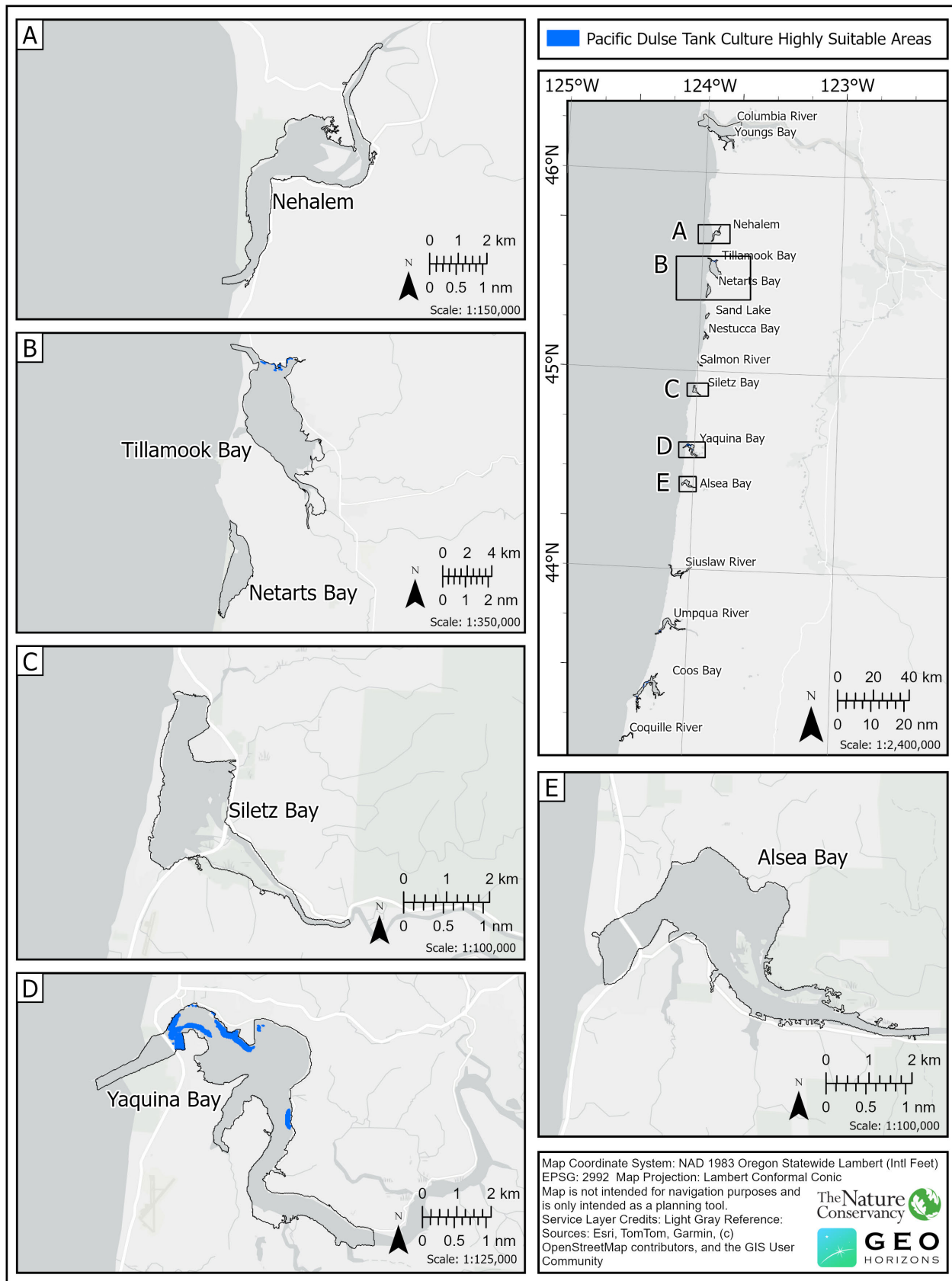
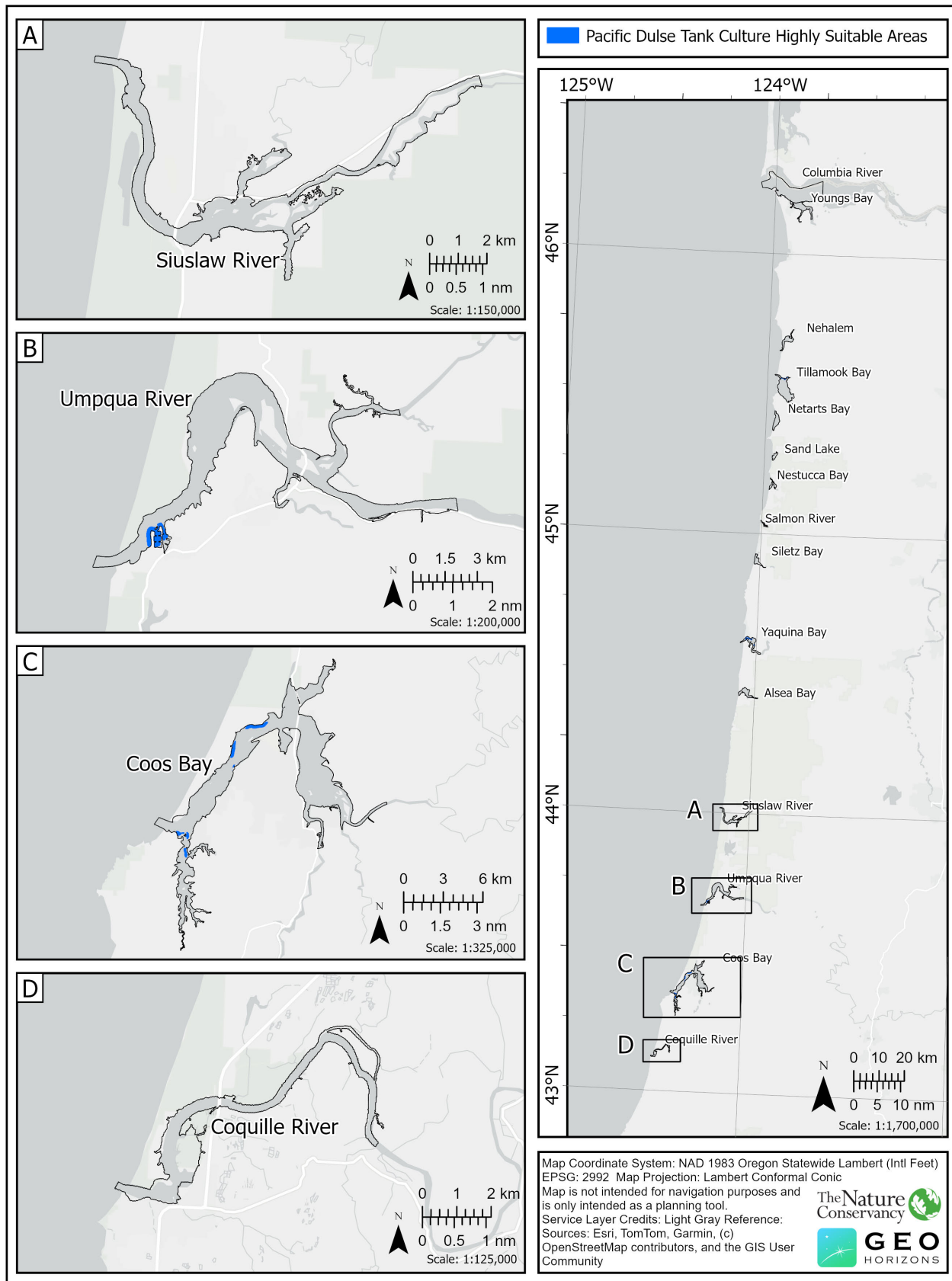


Figure B18. Highly suitable areas in southern Oregon estuaries for Pacific dulse tank culture, as indicated by the LISA analysis.



B.4. Red abalone or flat abalone – tank culture – modeling results

Due to high uncertainty with commercially and industrially zoned areas and the lack of variables, no Ranking Model was performed for red abalone or flat abalone tank culture. Essentially, a Ranking Model would rank by the size of the area available.

Table B4. Highly suitable areas by coastal ocean zone for red abalone or flat abalone mariculture using tank culture.

Coastal ocean zone (north to south)	Red or flat abalone tank culture area (ac)
Astoria / Warrenton	0
Nehalem	543
Garibaldi / Tillamook Bay	244
Depoe Bay	268
Newport / Toledo	785
Alsea	480
Siuslaw / Florence	0
Umpqua / Reedsport	0
Coos Bay / Charleston	0
Bandon	0
Port Orford	371
Gold Beach	873
Brookings	144

Figure B19. Opportunity Analysis results for red abalone or flat abalone mariculture using tank culture along Oregon's coast.

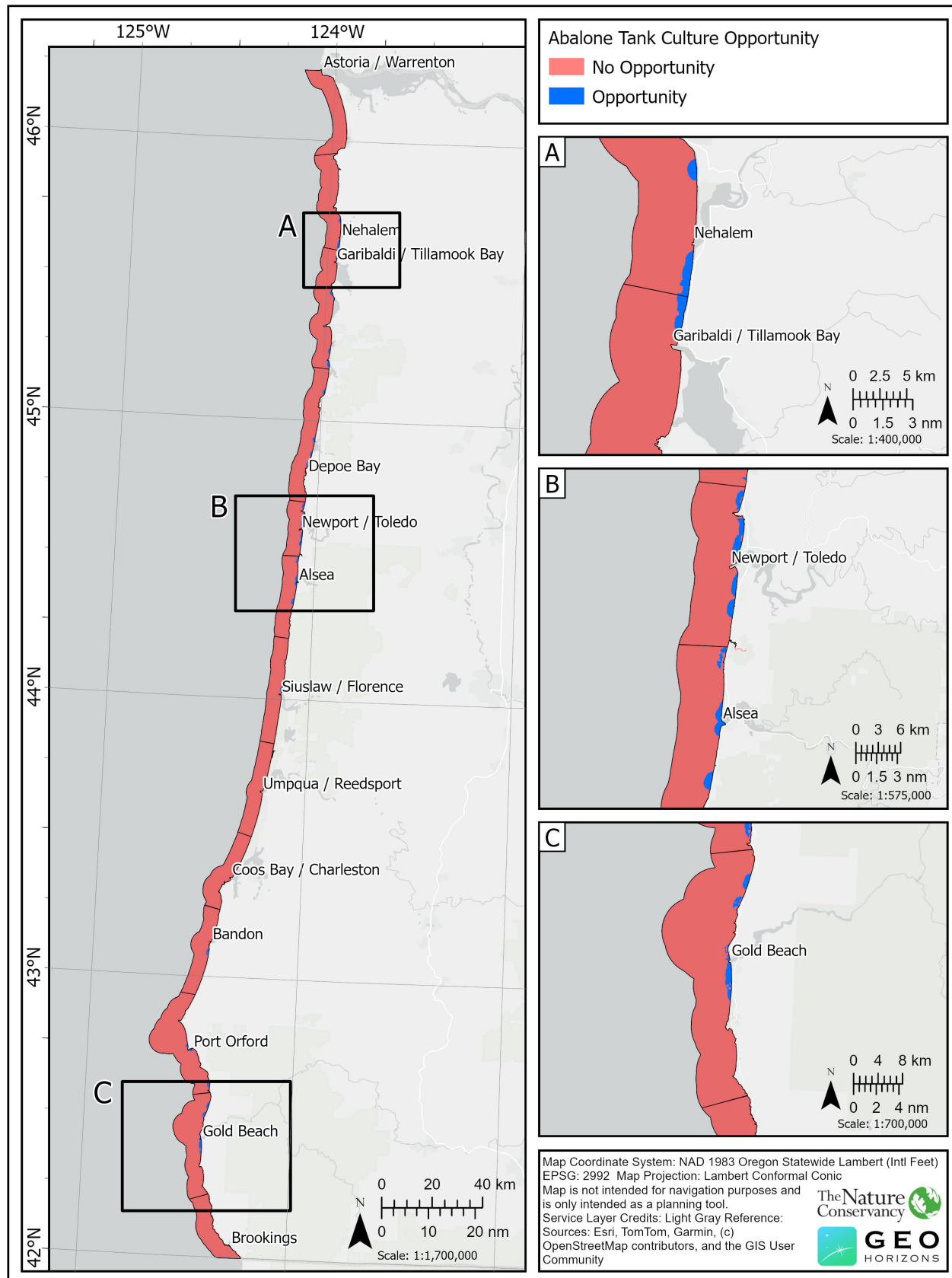


Figure B20. Suitability Analysis results for red abalone or flat abalone mariculture using tank culture along Oregon's coast.

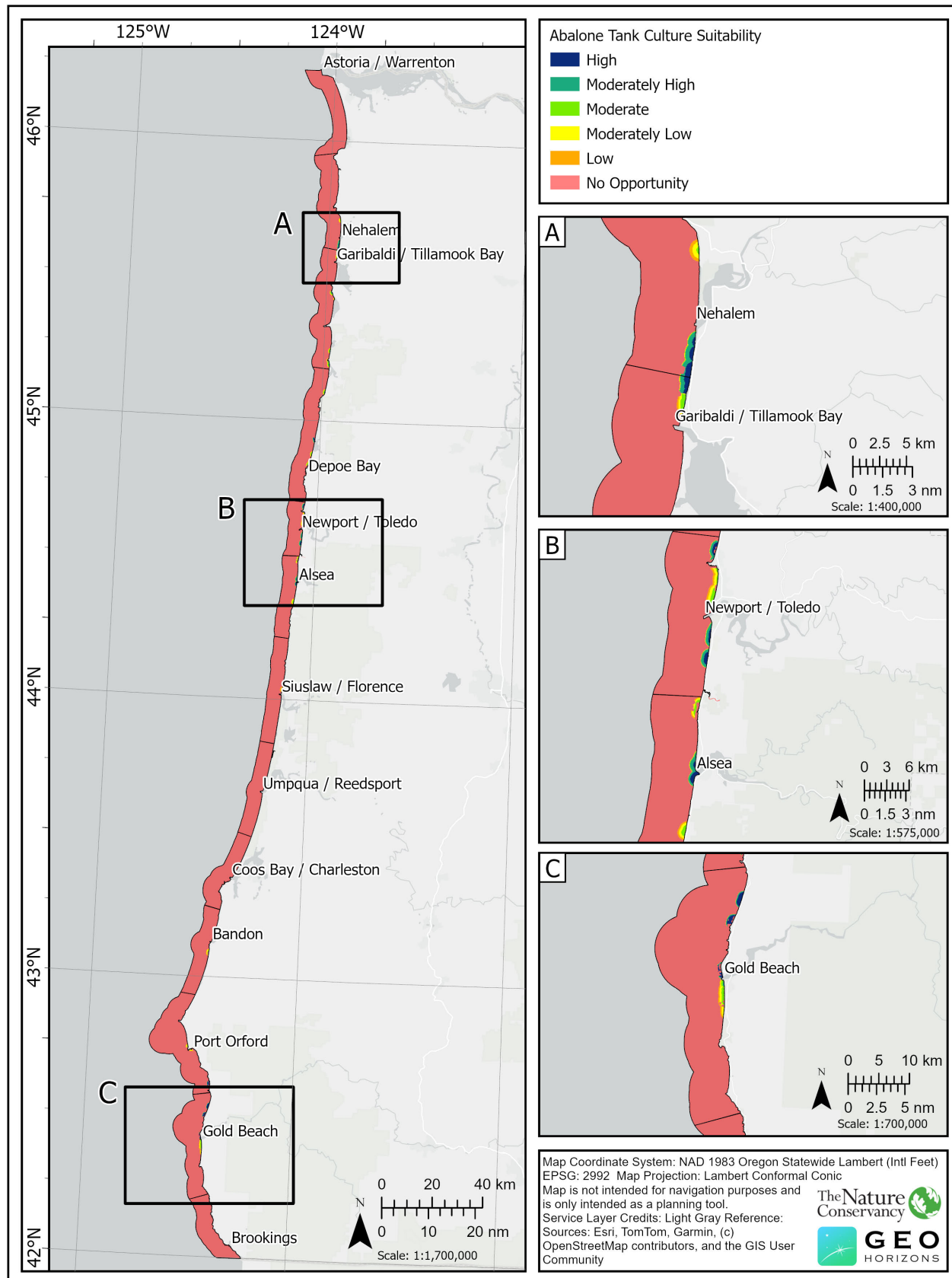
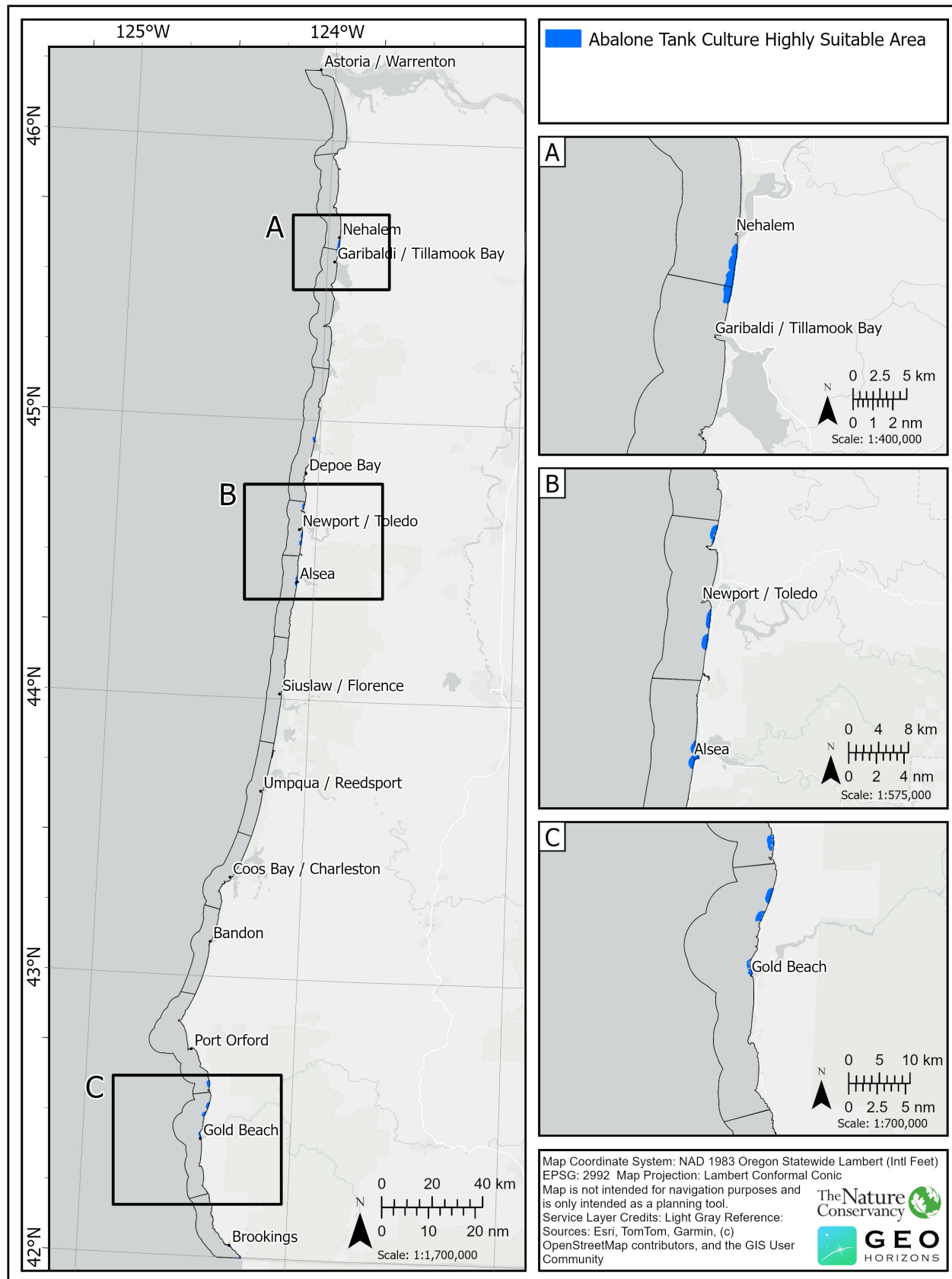


Figure B21. Highly suitable areas along Oregon's coast for red abalone or flat abalone mariculture using tank culture, as indicated by the LISA analysis.



B.5. Sugar kelp – line culture – modeling results

Table B5. Coastal ocean zones ranked from more to less optimal for sugar kelp mariculture using line culture.

Coastal ocean zone	Rank	Highly suitable area (ac)	Industry	Biophysical	Fisheries	Distance positive	Distance negative	TOPSIS score
Gold Beach	1	41,238	0.28	0.01	1.00	0.80	1.04	0.56
Bandon	2	19,502	0.74	< 0.01	0.47	0.70	0.88	0.56
Umpqua / Reedsport	3	9,769	0.80	0.05	0.23	0.86	0.83	0.49
Alsea	4	1,266	0.98	< 0.01	0.03	1.05	0.98	0.48
Siuslaw / Florence	5	103	0.97	< 0.01	< 0.01	1.08	0.97	0.47
Port Orford	6	14,855	0.49	< 0.01	0.36	0.90	0.61	0.40
Brookings	7	18,844	0.16	0.41	0.46	0.98	0.63	0.39
Depoe Bay	8	2,696	0.68	0.02	0.06	1.06	0.68	0.39
Newport / Toledo	9	1,748	0.63	0.02	0.04	1.09	0.63	0.37
Coos Bay / Charleston	10	8,430	0.35	0.08	0.20	1.07	0.41	0.28
Garibaldi / Tillamook Bay	11	1,177	0.31	0.01	0.03	1.25	0.31	0.20
Astoria / Warrenton	12	4,870	< 0.01	0.04	0.12	1.37	0.12	0.08
Nehalem	13	1,696	< 0.01	< 0.01	0.04	1.43	0.04	0.03

Note. The highly suitable area is provided for reference. The analysis employed the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS). The variables used in the analysis—Industry, Biophysical, and Fisheries—ranged from 0 to 1, with 0 being less optimal and 1 being more optimal for mariculture. Distance from the positive solution and distance from the negative solution are provided in this table, with lower values being closer to and higher values being farther from each solution. The TOPSIS score was used for ranking, with a score of 1 being the most ideal solution and a score of 0 being the least ideal solution.

Figure B22. Opportunity Analysis results for sugar kelp mariculture using line culture along Oregon's coast.

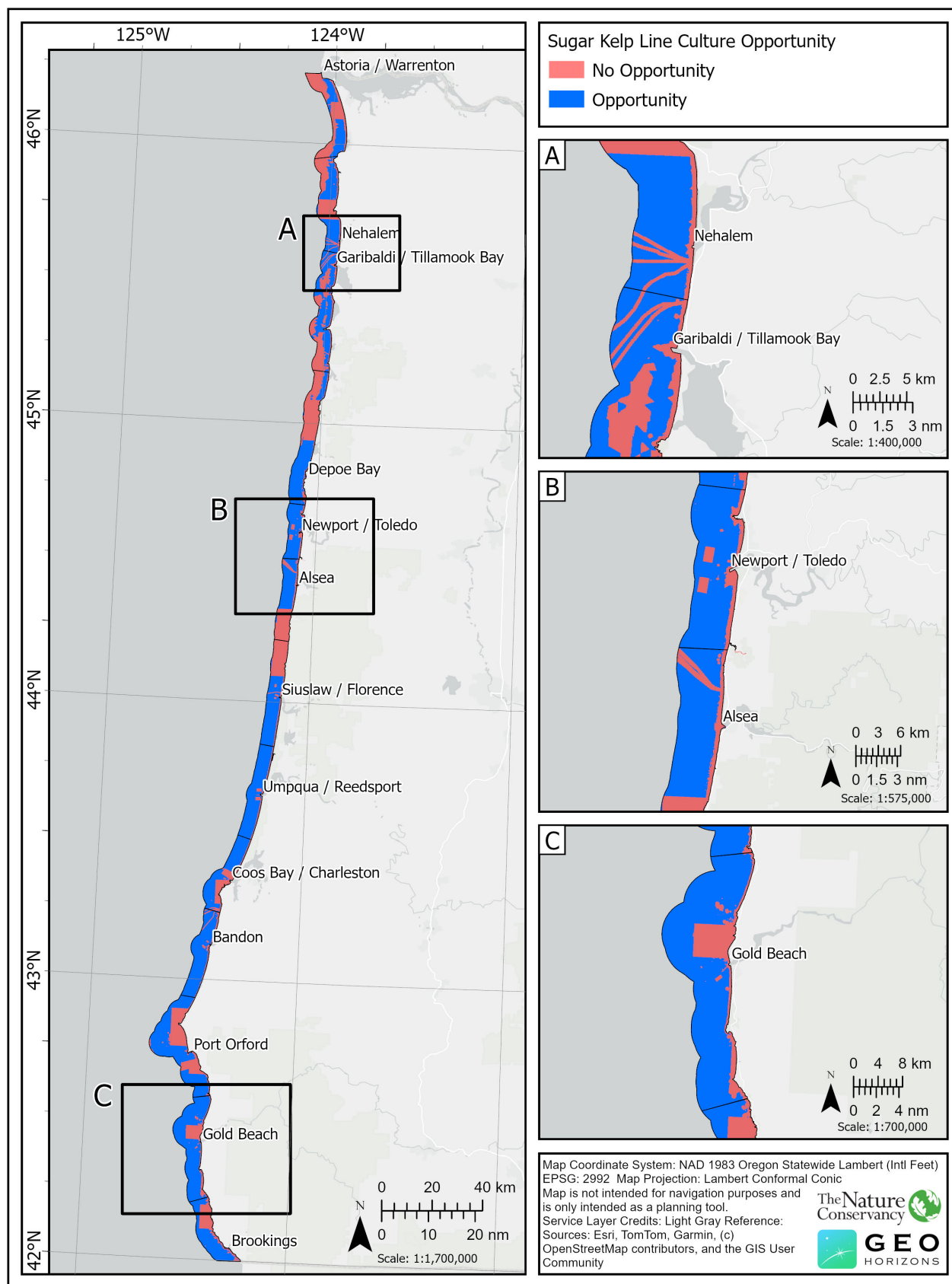


Figure B23. Suitability Analysis results for sugar kelp line culture along Oregon's coast.

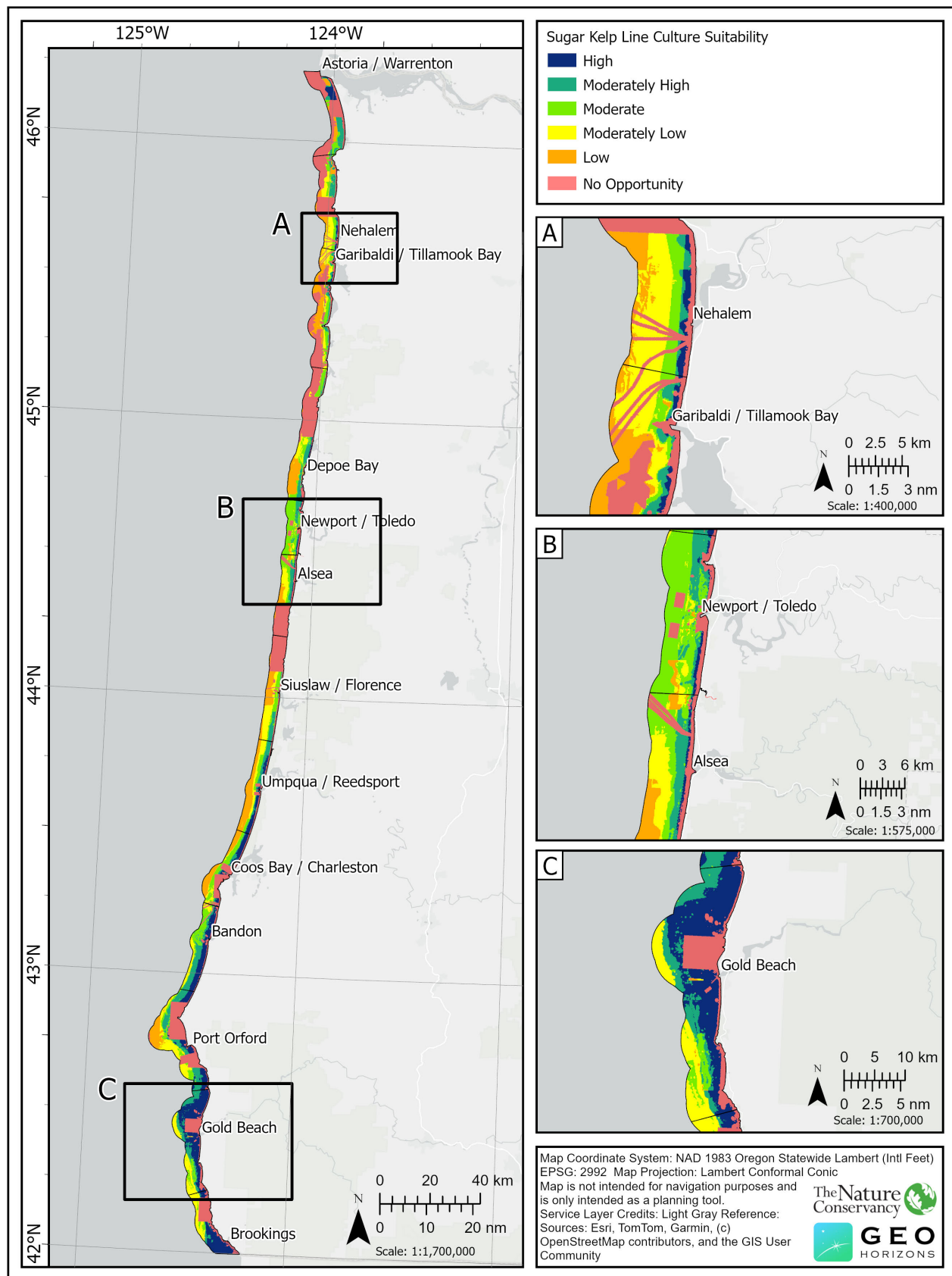
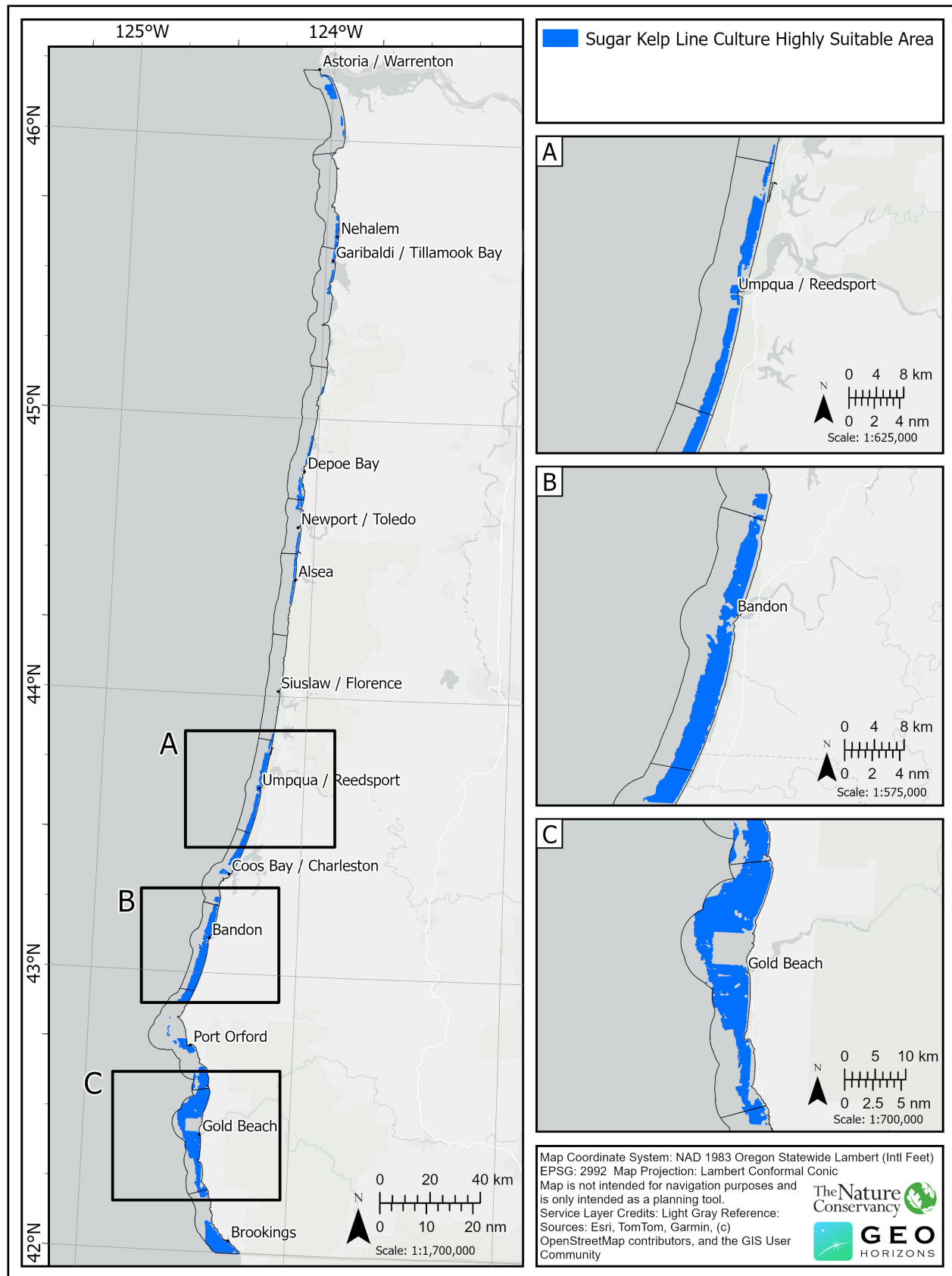


Figure B24. Highly suitable areas along Oregon's coast for sugar kelp line culture, as indicated by the LISA analysis.



B.6. Ribbon/winged kelp – line culture – modeling results

Table B6. Coastal ocean zones ranked from more to less optimal for ribbon/winged kelp mariculture using line culture.

Coastal ocean zone	Rank	Highly suitable area (ac)	Industry	Biophysical	Fisheries	Distance positive	Distance negative	TOPSIS score
Gold Beach	1	38,688	1.00	0.01	0.21	1.18	1.02	0.46
Brookings	2	11,326	0.29	< 0.01	0.91	1.19	0.95	0.44
Alsea	3	287	0.01	0.96	< 0.01	1.34	0.96	0.42
Siuslaw / Florence	4	5	< 0.01	0.90	0.005	1.35	0.90	0.40
Depoe Bay	5	627	0.02	0.86	< 0.01	1.34	0.86	0.39
Bandon	6	15,775	0.41	0.59	0.02	1.13	0.72	0.39
Umpqua / Reedsport	7	7,809	0.20	0.61	0.07	1.21	0.64	0.35
Newport / Toledo	8	1,043	0.03	0.46	0.01	1.41	0.46	0.25
Coos Bay / Charleston	9	7,943	0.21	0.33	0.11	1.29	0.41	0.24
Port Orford	10	7,304	0.19	0.11	0.02	1.48	0.22	0.13

Note. The highly suitable area is provided for reference. The analysis employed the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS). The variables used in the analysis—Industry, Biophysical, and Fisheries—ranged from 0 to 1, with 0 being less optimal and 1 being more optimal for mariculture. Distance from the positive solution and distance from the negative solution are provided in this table, with lower values being closer to and higher values being farther from each solution. The TOPSIS score was used for ranking, with a score of 1 being the most ideal solution and a score of 0 being the least ideal solution.

Figure B25. Opportunity Analysis results for ribbon/winged kelp mariculture using line culture along Oregon's coast.

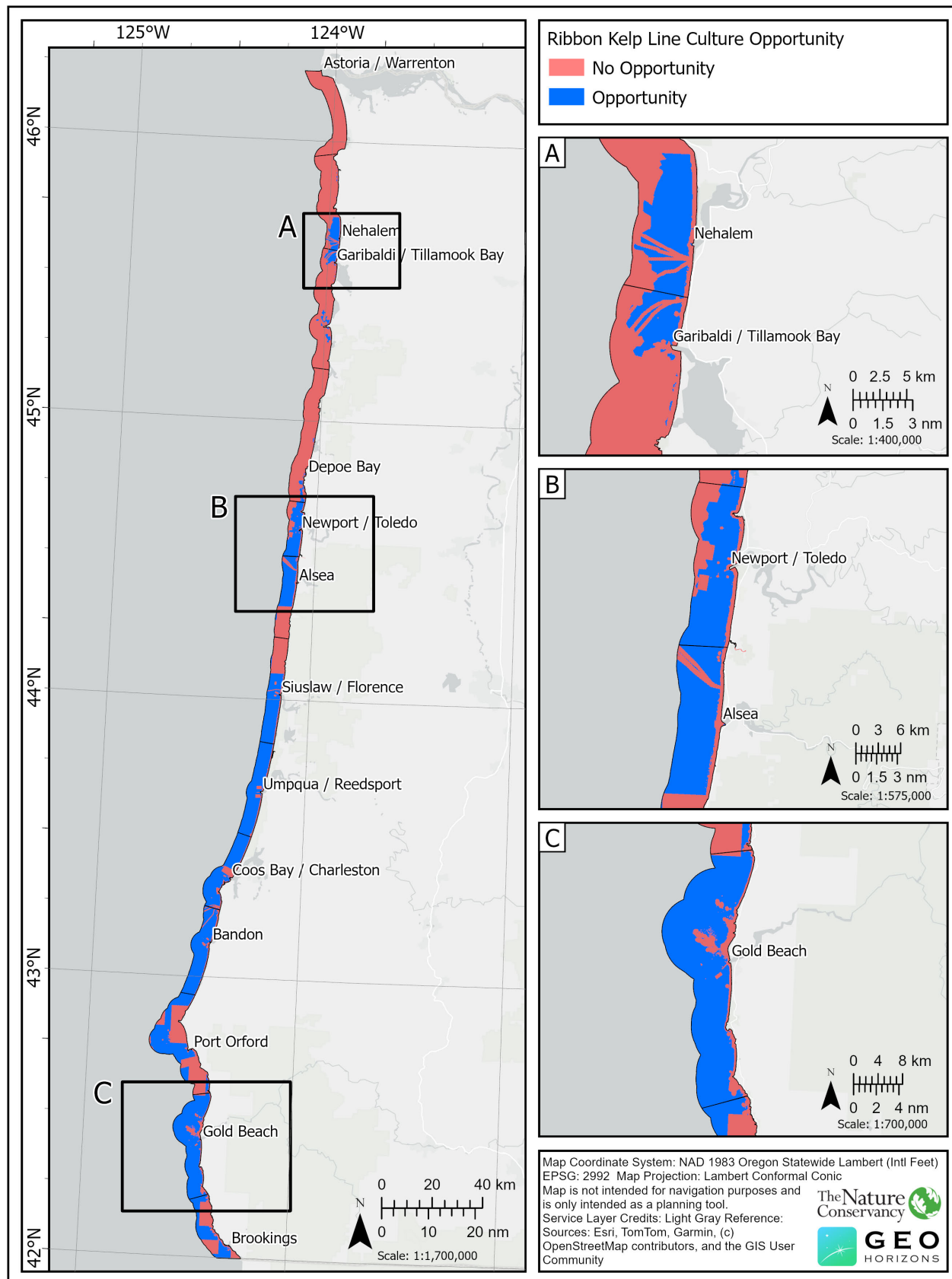


Figure B26. Suitability Analysis results for ribbon/winged kelp mariculture using line culture along Oregon's coast.

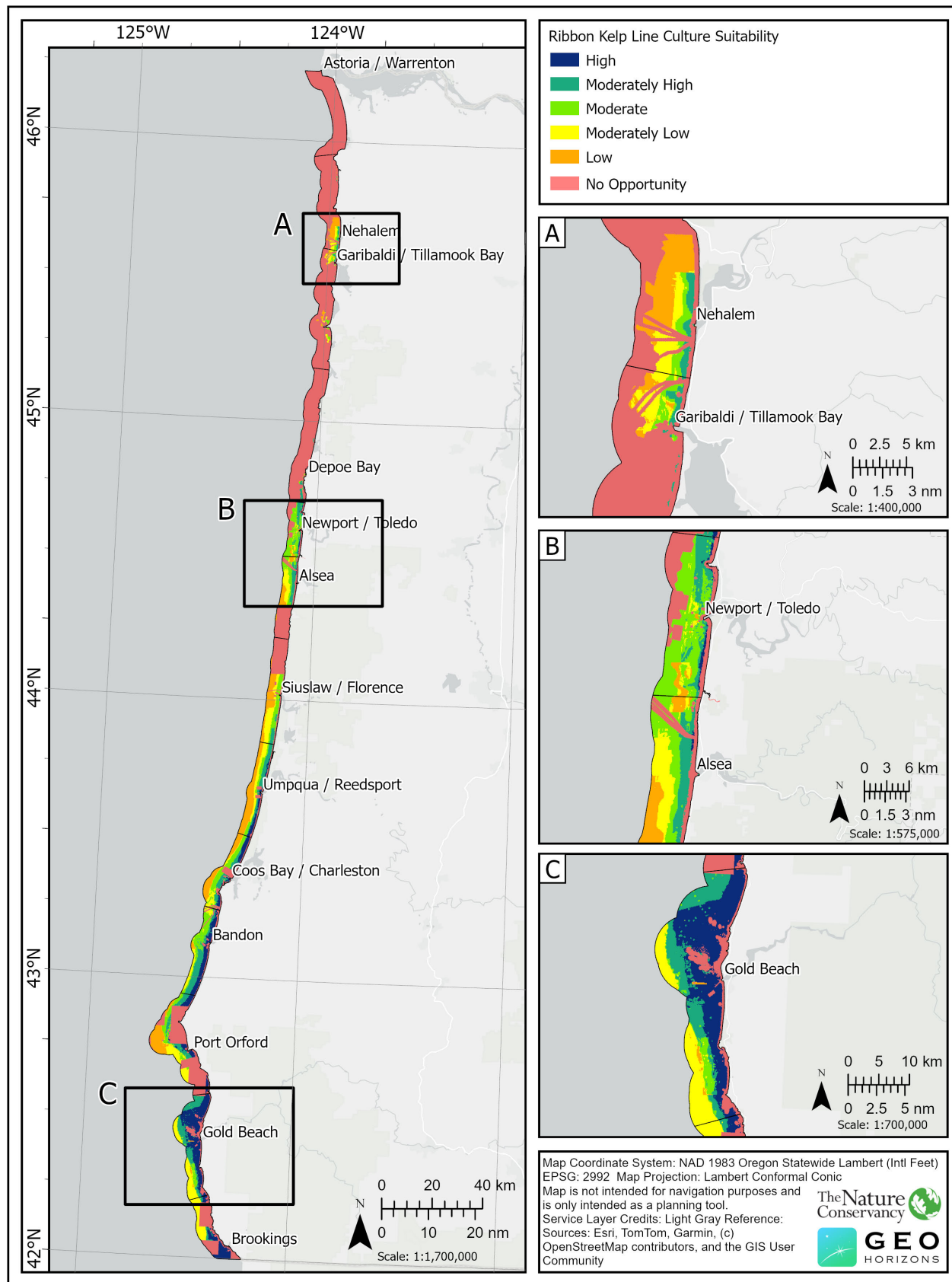
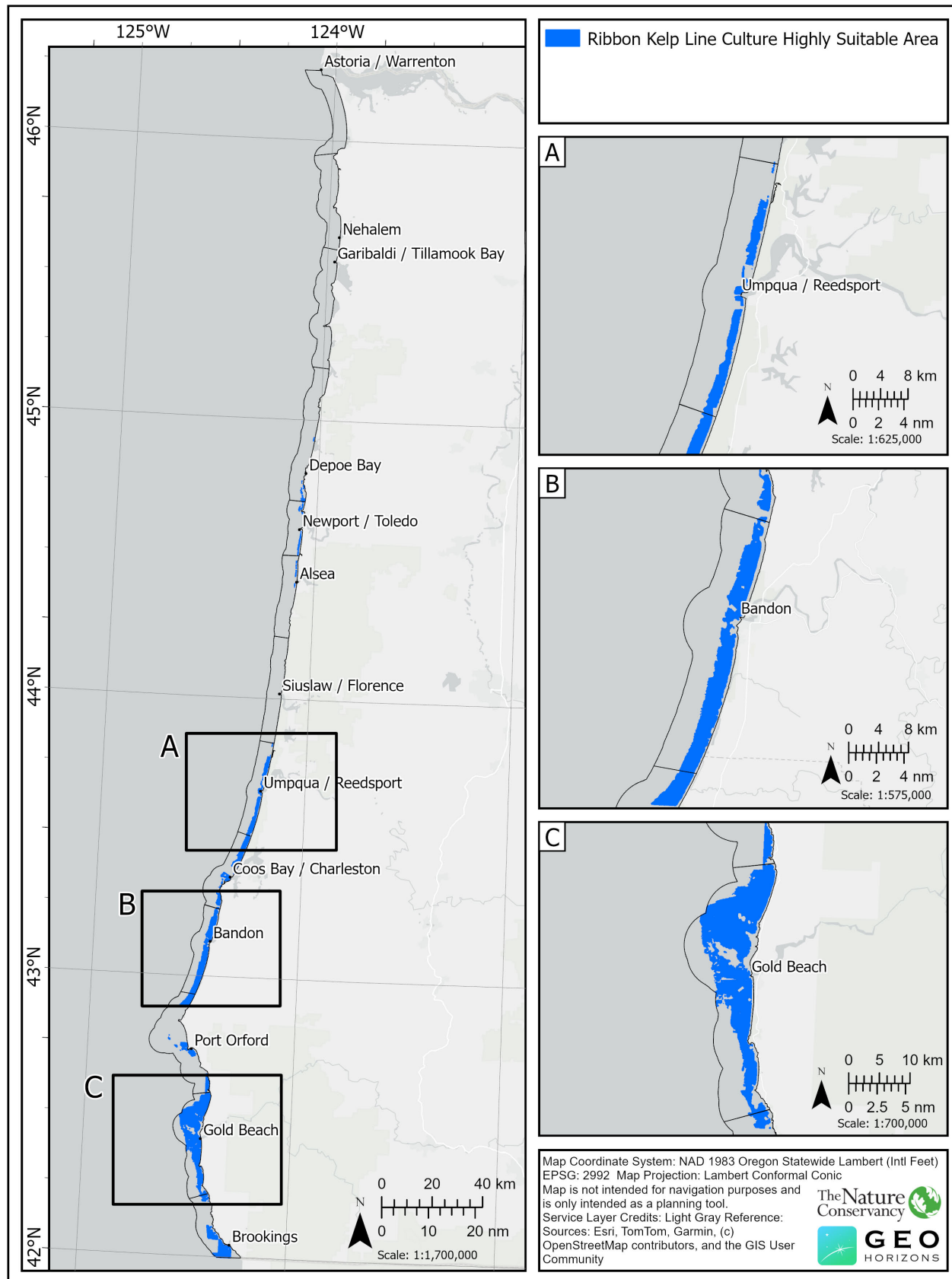


Figure B27. Highly suitable areas along Oregon's coast for ribbon/winged kelp mariculture using line culture, as indicated by the LISA analysis.



B.7. Giant kelp – line culture – modeling results

Table B7. Coastal ocean zones ranked from more to less optimal for giant kelp mariculture using line culture.

Coastal ocean zone	Rank	Highly suitable area (ac)	Industry	Biophysical	Fisheries	Distance positive	Distance negative	TOPSIS score
Gold Beach	1	49,596	1.00	0.37	< 0.01	1.11	1.07	0.49
Brookings	2	23,219	0.47	0.87	< 0.01	1.13	0.99	0.47
Alsea	3	57	< 0.01	< 0.01	1.00	1.32	1.00	0.43
Siuslaw / Florence	4	3	< 0.01	< 0.01	0.87	1.33	0.87	0.40
Port Orford	5	15,404	0.31	0.02	0.64	1.15	0.72	0.38
Depoe Bay	6	162	< 0.01	< 0.01	0.80	1.34	0.80	0.37
Bandon	7	14,601	0.29	0.16	0.53	1.10	0.63	0.36
Umpqua / Reedsport	8	3,375	0.07	0.09	0.35	1.38	0.36	0.21
Coos Bay / Charleston	9	4,746	0.10	0.13	0.32	1.35	0.36	0.21
Newport / Toledo	10	381	0.01	0.01	0.01	1.64	0.02	0.01

Note. The highly suitable area is provided for reference. The analysis employed the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS). The variables used in the analysis—Industry, Biophysical, and Fisheries—ranged from 0 to 1, with 0 being less optimal and 1 being more optimal for mariculture. Distance from the positive solution and distance from the negative solution are provided in this table, with lower values being closer to and higher values being farther from each solution. The TOPSIS score was used for ranking, with a score of 1 being the most ideal solution and a score of 0 being the least ideal solution.

Figure B28. Opportunity Analysis results for giant kelp mariculture using line culture along Oregon's coast.

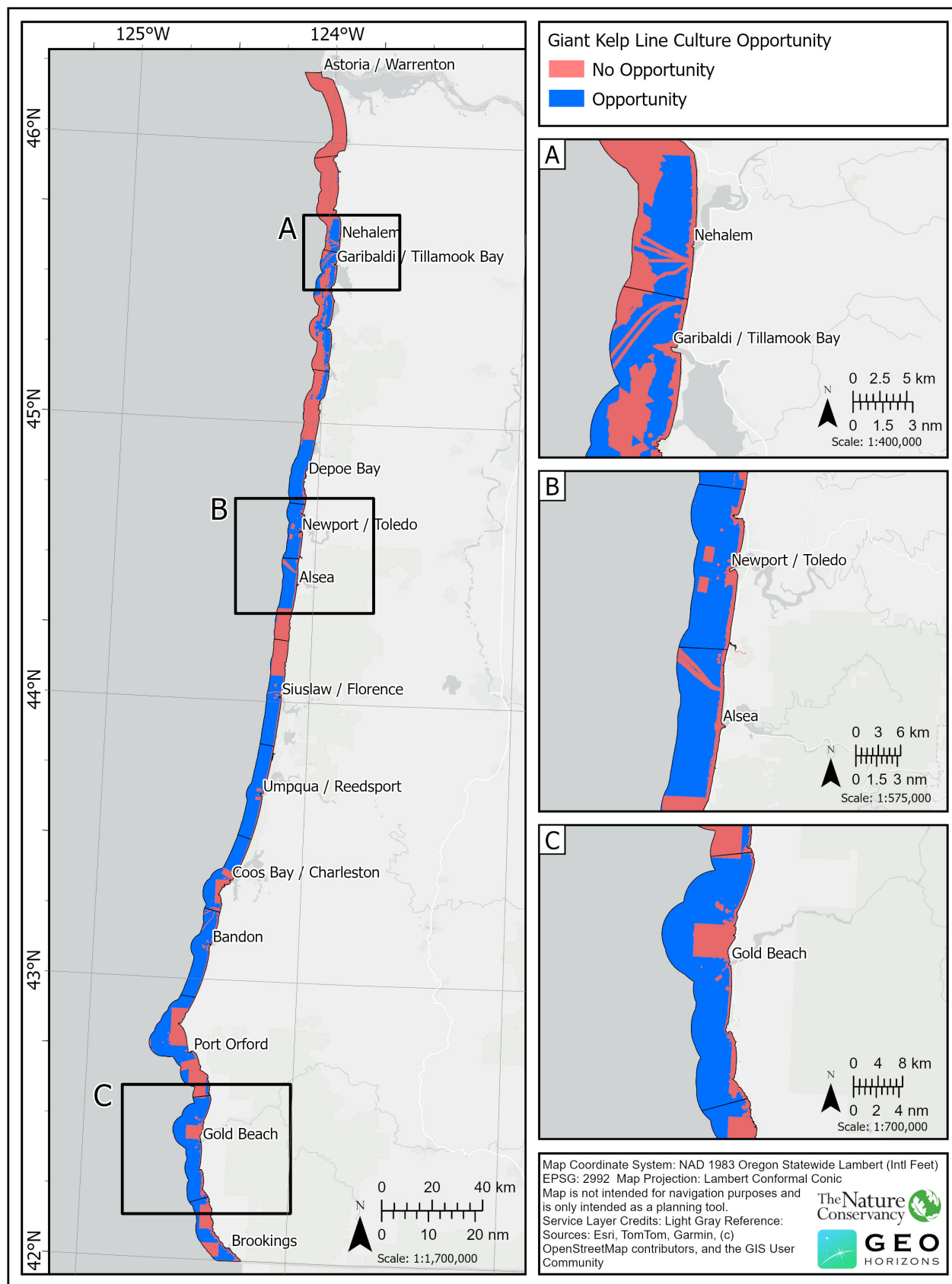


Figure B29. Suitability Analysis results for giant kelp line culture along Oregon's coast.

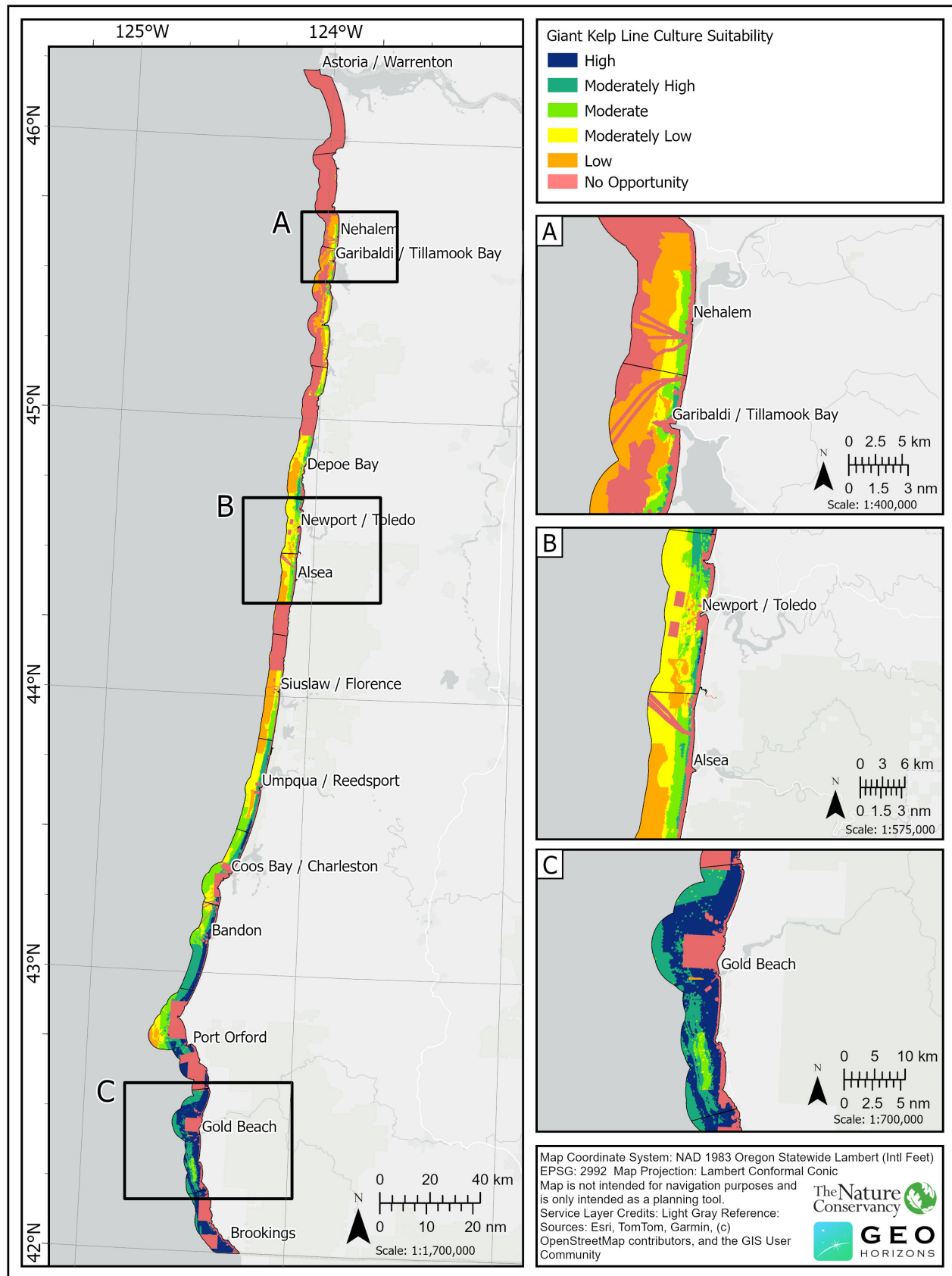
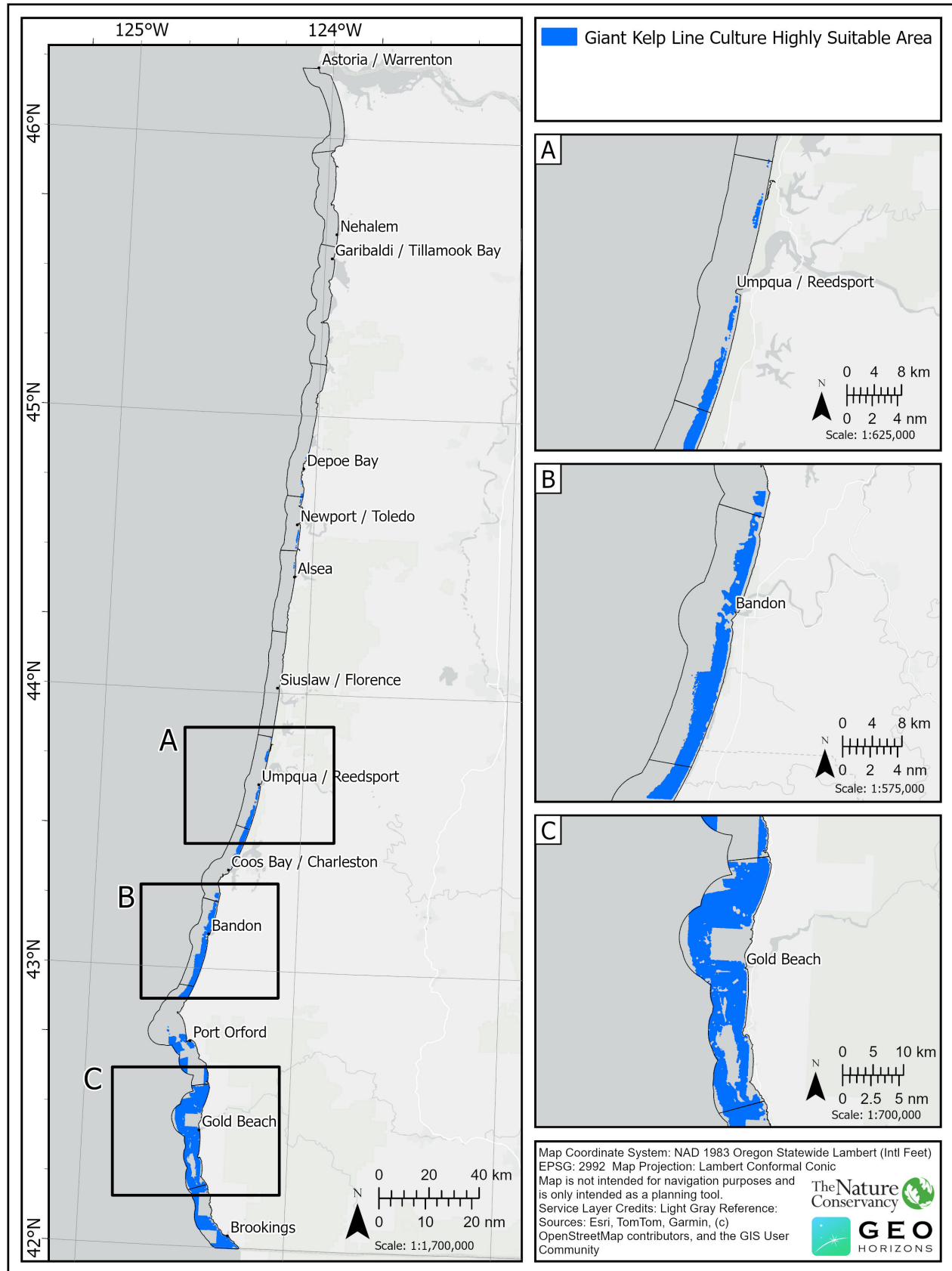


Figure B30. Highly suitable areas along Oregon's coast for giant kelp line culture, as indicated by the LISA analysis.



B.8. Pacific blue mussel – line culture – modeling results

Table B8. Coastal ocean zones ranked from more to less optimal for Pacific blue mussel mariculture using line culture.

Coastal Ocean Zones	Rank	Highly suitable area (ac)	Industry	Fisheries	Distance positive	Distance negative	TOPSIS score
Port Orford	1	17,405	0.93	0.83	0.07	1.25	0.95
Gold Beach	2	18,444	1.00	0.56	0.27	1.14	0.81
Bandon	3	14,320	0.74	0.75	0.27	1.06	0.80
Umpqua / Reedsport	4	14,218	0.73	0.64	0.33	0.97	0.75
Depoe Bay	5	13,114	0.67	0.70	0.36	0.97	0.73
Coos Bay / Charleston	6	12,304	0.61	0.54	0.48	0.81	0.63
Siuslaw / Florence	7	11,638	0.57	0.59	0.49	0.82	0.63
Alsea	8	7,707	0.33	0.72	0.68	0.79	0.54
Garibaldi / Tillamook Bay	9	11,450	0.56	0.35	0.65	0.66	0.50
Newport / Toledo	10	6,772	0.27	0.01	1.10	0.27	0.20
Nehalem	11	4,062	0.10	0.01	1.22	0.10	0.07
Brookings	12	4,065	0.10	< 0.01	1.22	0.10	0.07
Astoria / Warrenton	13	2,519	< 0.01	< 0.01	1.29	<0.01	<0.01

Note. The highly suitable area is provided for reference. The analysis employed the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS). The variables used in the analysis—Industry and Fisheries—ranged from 0 to 1, with 0 being less optimal and 1 being more optimal for mariculture. Distance from the positive solution and distance from the negative solution are provided in this table, with lower values being closer to and higher values being farther from each solution. The TOPSIS score was used for ranking, with a score of 1 being the most ideal solution and a score of 0 being the least ideal solution.

Figure B31. Opportunity Analysis results for Pacific blue mussel mariculture using line culture along Oregon’s coast.

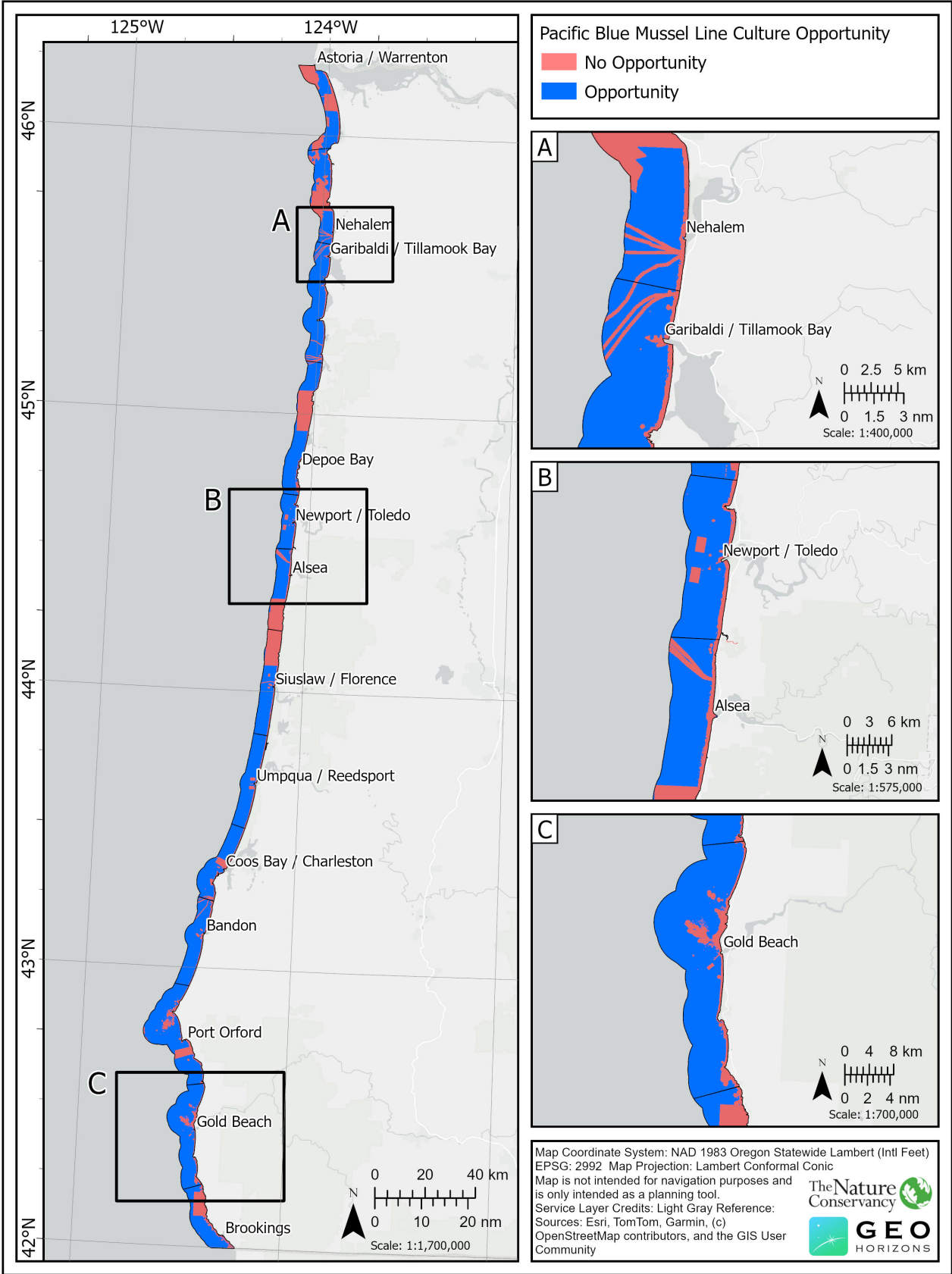


Figure B32. Suitability Analysis results for Pacific blue mussel line culture along Oregon’s coast.

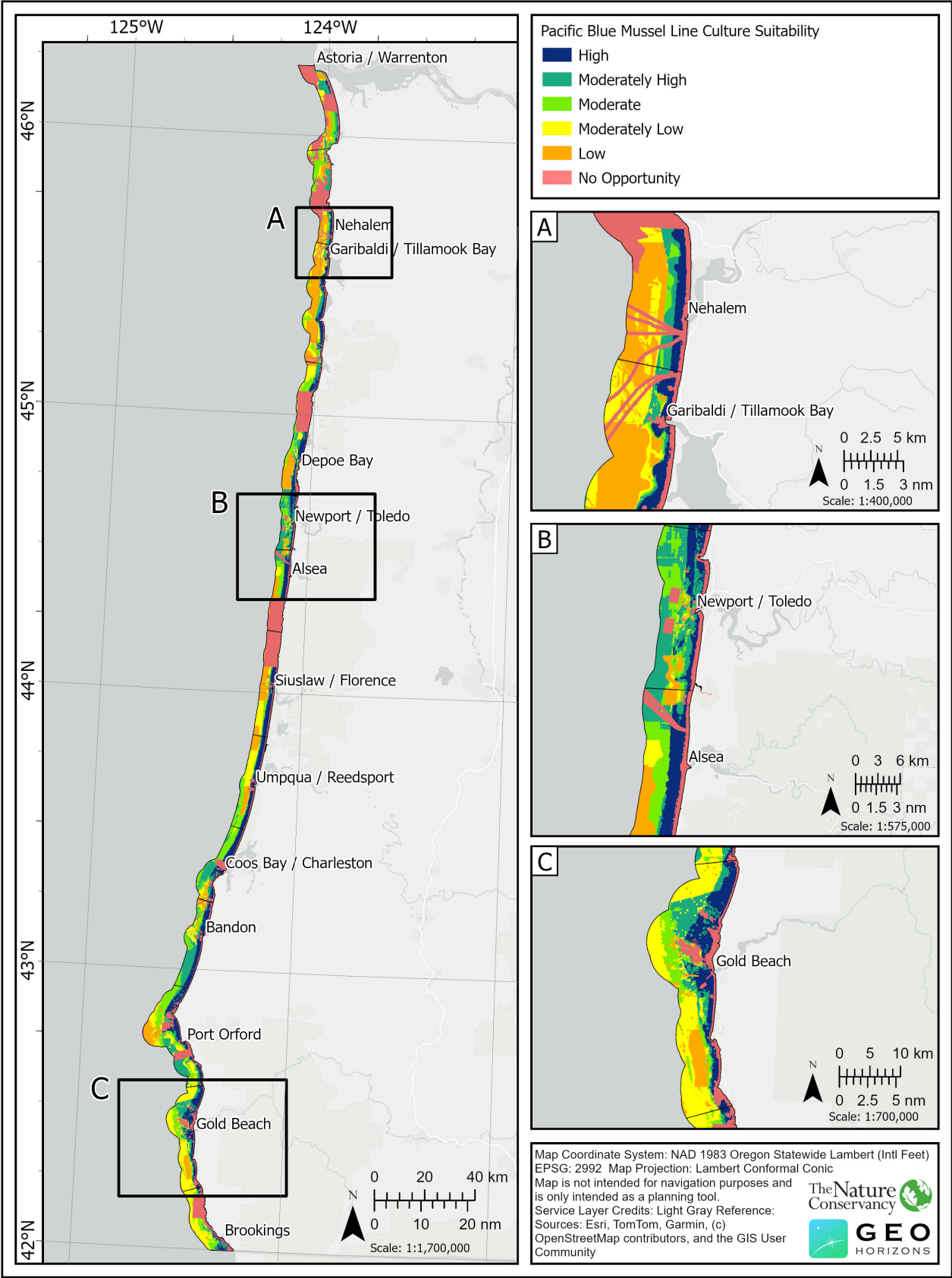
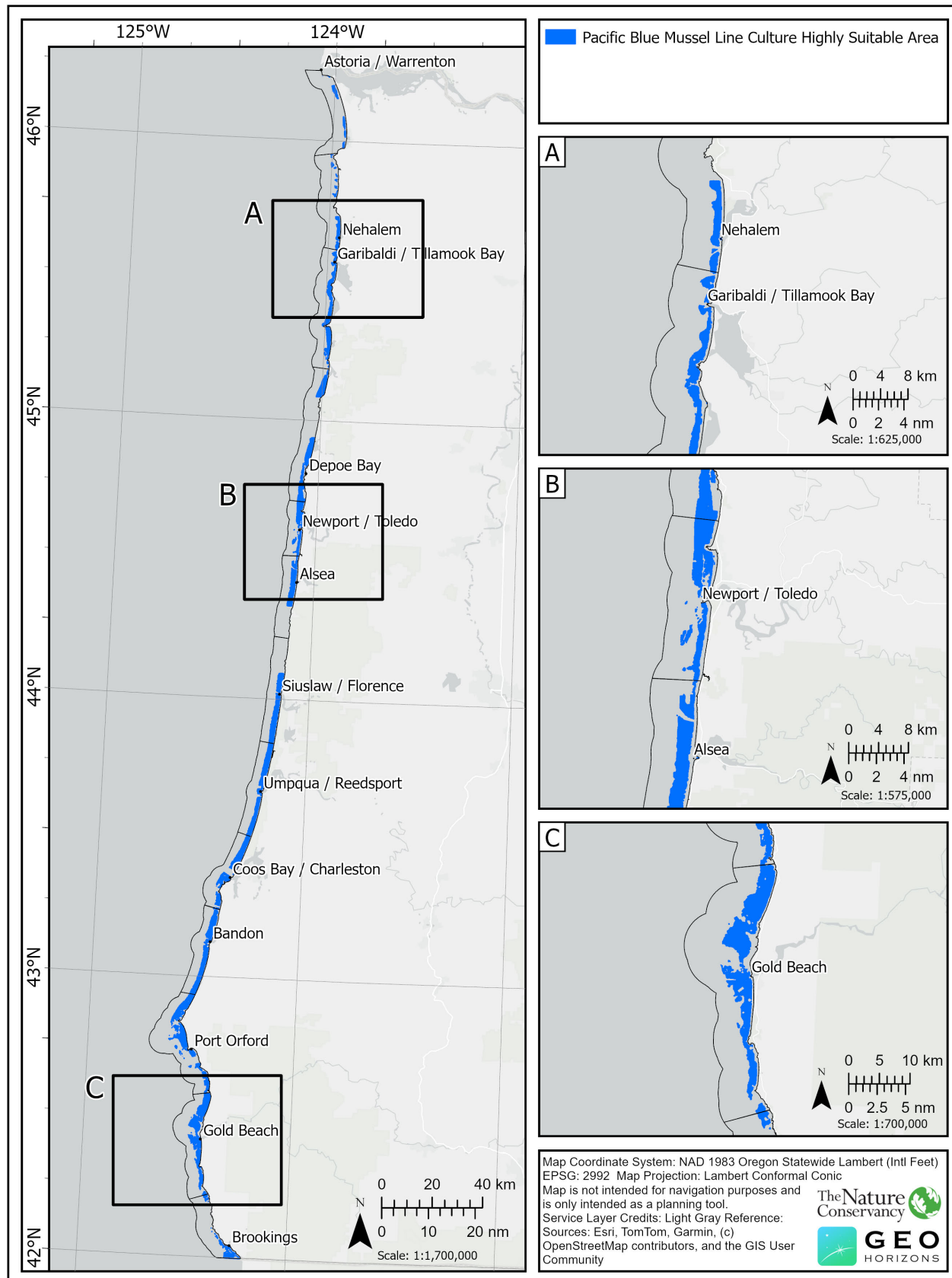


Figure B33. Highly suitable areas along Oregon's coast for Pacific blue mussel line culture, as indicated by the LISA analysis.



B.9. California mussel – line culture – modeling results

Table B9. Coastal ocean zones ranked from more to less optimal for California mussel mariculture using line culture.

Coastal Ocean Zones	Rank	Highly suitable area (ac)	Industry	Fisheries	Distance positive	Distance negative	TOPSIS score
Gold Beach	1	20,707	1.00	0.47	0.28	1.10	0.80
Port Orford	2	17,151	0.77	0.59	0.28	0.97	0.78
Bandon	3	13,564	0.55	0.75	0.45	0.92	0.67
Coos Bay / Charleston	4	13,687	0.55	0.55	0.49	0.78	0.62
Umpqua / Reedsport	5	14,774	0.62	0.29	0.59	0.69	0.54
Depoe Bay	6	9,678	0.30	0.57	0.72	0.64	0.47
Alsea	7	7,974	0.19	0.54	0.84	0.57	0.41
Siuslaw / Florence	8	12,318	0.47	0.02	0.90	0.47	0.34
Garibaldi / Tillamook Bay	9	5,592	0.04	0.16	1.13	0.16	0.12
Newport / Toledo	10	7,311	0.15	0.01	1.13	0.15	0.12
Nehalem	11	6,038	0.07	< 0.01	1.19	0.07	0.05
Brookings	12	4,985	< 0.01	< 0.01	1.25	< 0.01	< 0.01

Note. The highly suitable area is provided for reference. The analysis employed the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS). The variables used in the analysis—Industry and Fisheries—ranged from 0 to 1, with 0 being less optimal and 1 being more optimal for mariculture. Distance from the positive solution and distance from the negative solution are provided in this table, with lower values being closer to and higher values being farther from each solution. The TOPSIS score was used for ranking, with a score of 1 being the most ideal solution and a score of 0 being the least ideal solution.

Figure B34. Opportunity Analysis results for California mussel mariculture using line culture along Oregon's coast.

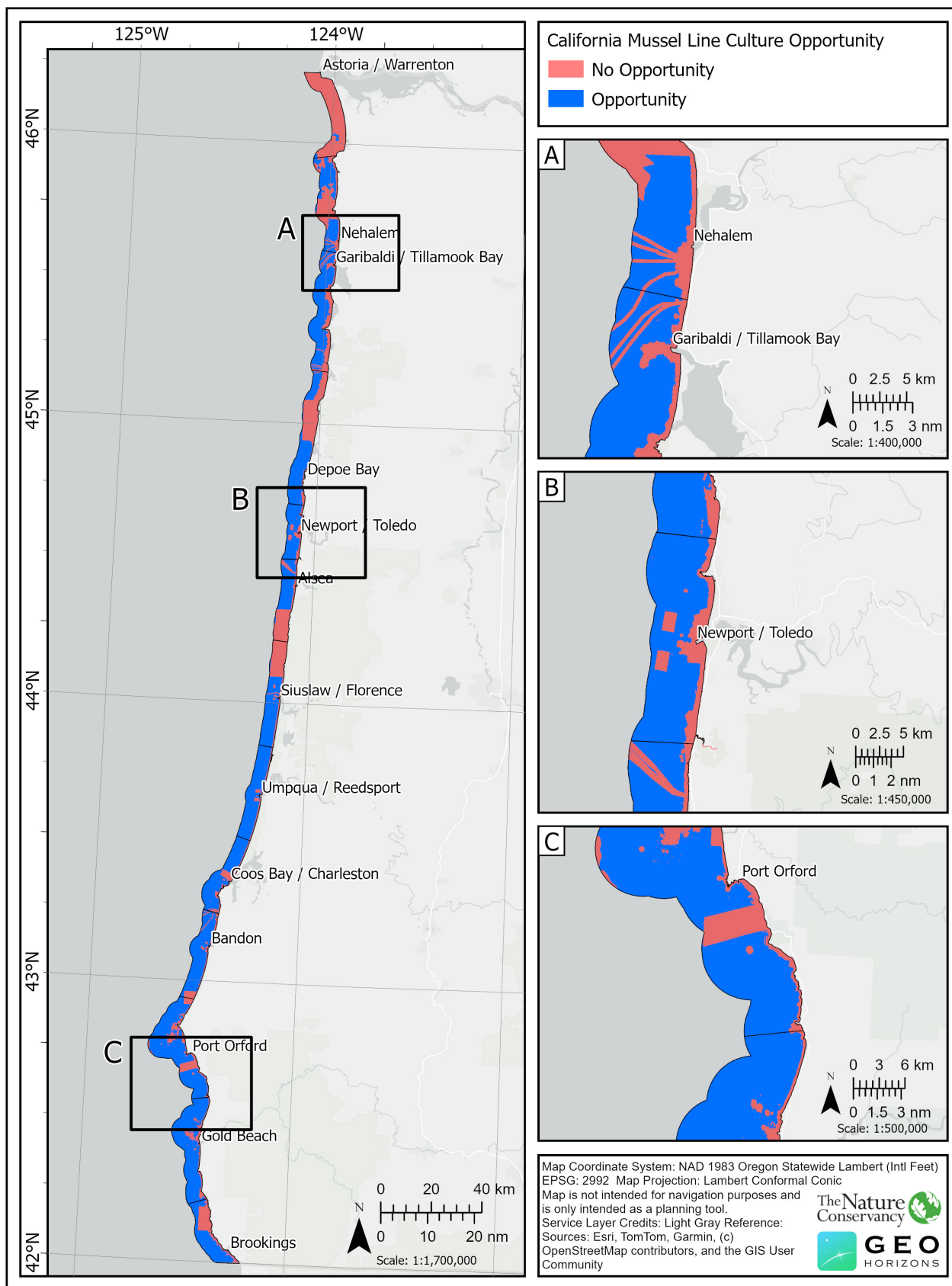


Figure B35. Suitability Analysis results for California mussel line culture along Oregon's coast.

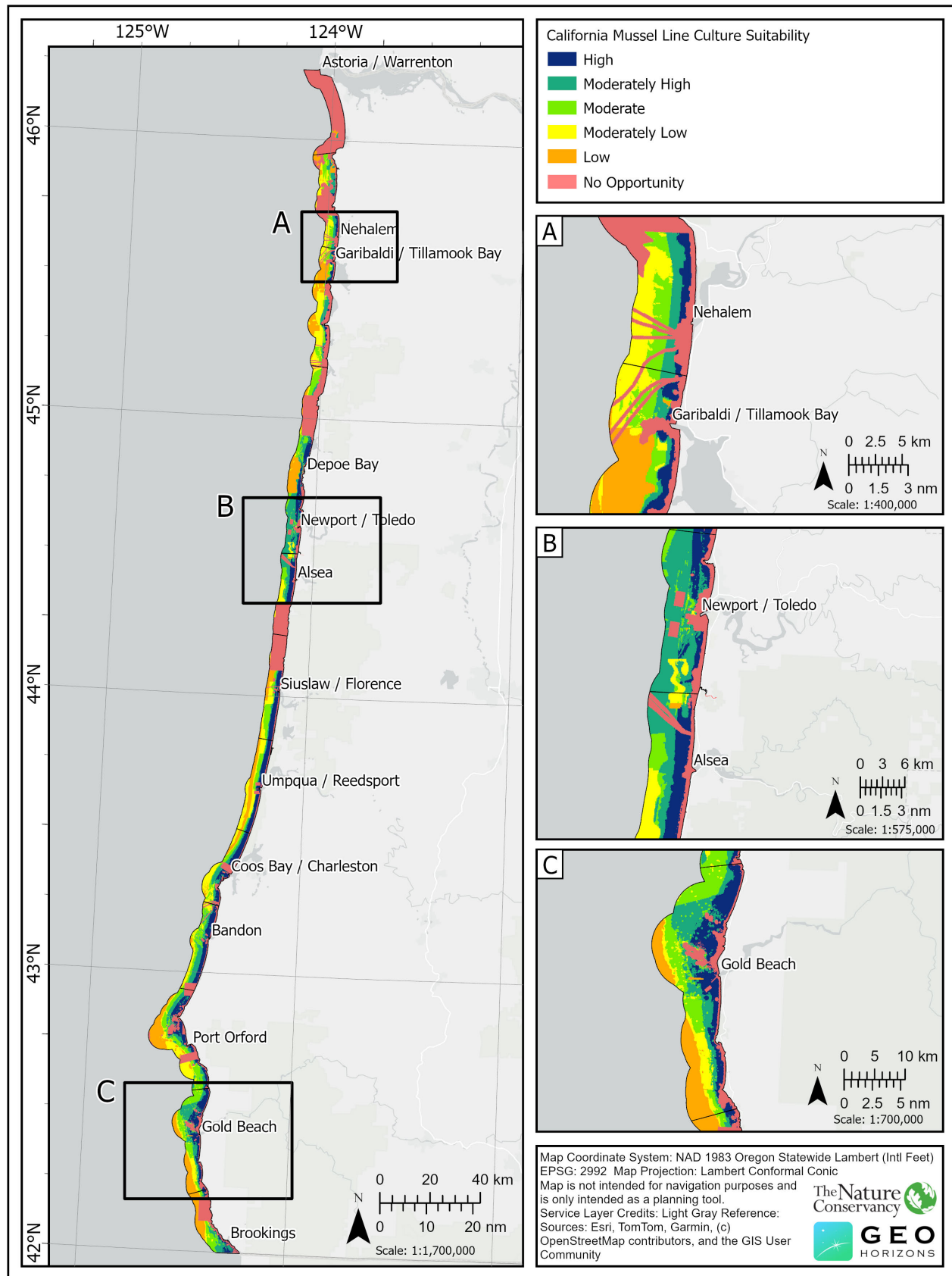
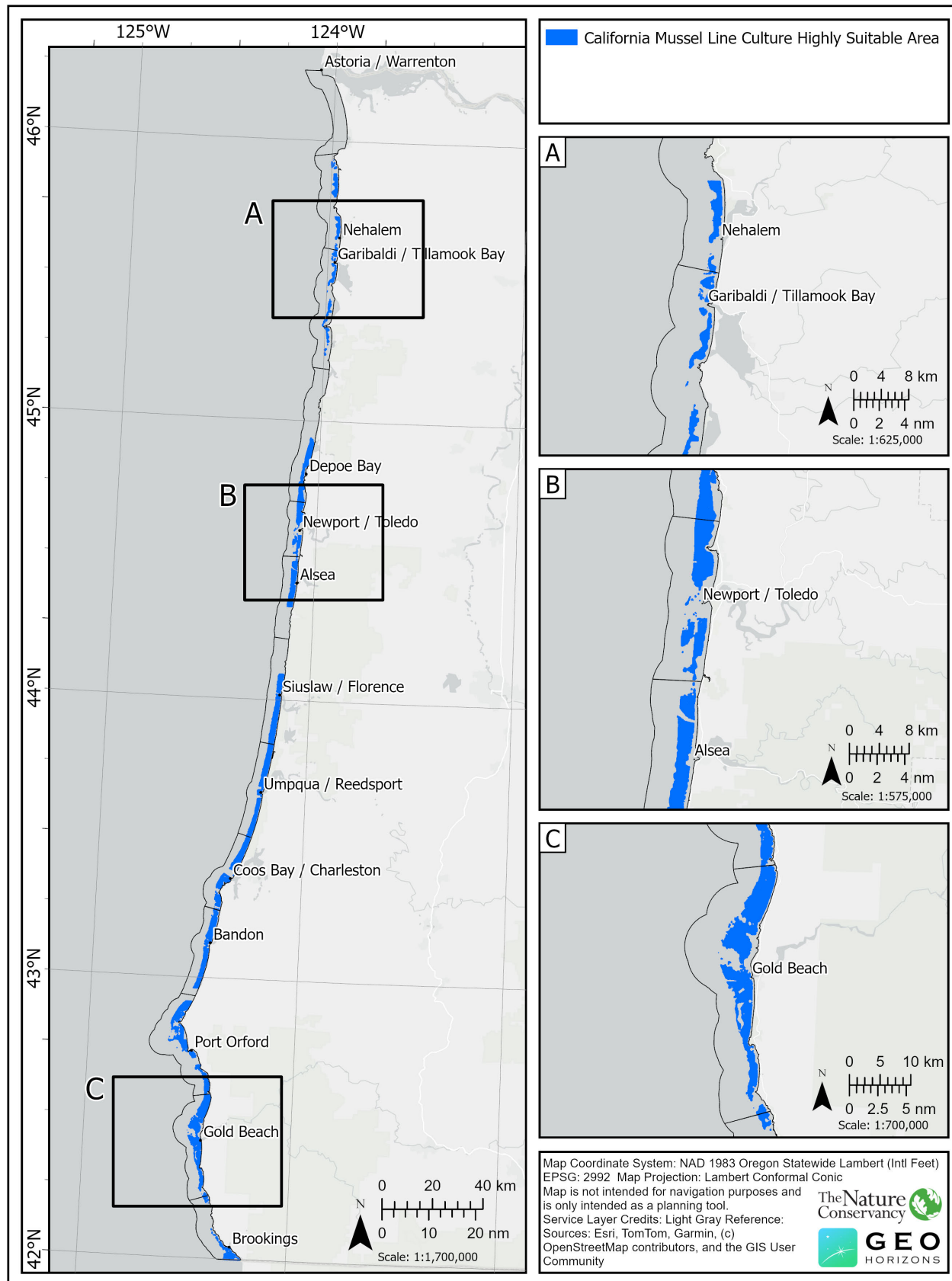


Figure B36. Highly suitable areas along Oregon's coast for California mussel line culture, as indicated by the LISA analysis.





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