

# Prioritizing-potential-aquaculture

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## 0.1 README.md Screenshot

# Prioritizing Potential Aquaculture on West Coast US

## About

In this repository you will find a geospatial analysis identifying optimal location for Marine Aquaculture development along the West Coast of the United States. To determine areas more suitable for Oyster farming and other marine aquaculture operations, we evaluated Exclusive Economic Zones (EEZs) based on species specific Sea Surface Temperature (SST) and Depth requirement.

### Objective for this assignment:

- Combining vector/raster data
- Resampling raster data
- Masking raster data
- Map algebra
- Creating a function

## Repository Structure

```
├── data
│   ├── average_annual_sst_2008.tif
│   ├── average_annual_sst_2009.tif
│   ├── average_annual_sst_2010.tif
│   ├── average_annual_sst_2011.tif
│   ├── average_annual_sst_2012.tif
│   ├── depth.tif
│   ├── wc_regions_clean.dbf
│   ├── wc_regions_clean.prj
│   ├── wc_regions_clean.shp
│   └── wc_regions_clean.shx
├── figs
├── HW4.pdf
├── HW4.qmd
└── LICENSE
└── Prioritizing-potential-aquaculture.Rproj
└── README.html
└── README.md
```

## About Data:

### Sea Surface Temperature

Use average annual sea surface temperature (SST) from the years 2008 to 2012 to characterize the average sea surface temperature within the region. The data was originally generated from NOAA's 5km Daily Global Satellite Sea Surface Temperature Anomaly v3.1.

### Bathymetry

For ocean depth characterization use the [General Bathymetric Chart of the Oceans \(GEBCO\)](#).<sup>3</sup>

## Exclusive Economic Zones

To designating maritime boundaries use Exclusive Economic Zones off of the west coast of US from [Marineregions.org](#).

## Course Information

Course Title: [EDS 223 - Geospatial Analysis & Remote Sensing](#) Term: Fall 2025 Program: [UCSB Masters in Environmental Data Science](#).

Teaching Team:

- Instructor: Annie Adams
- Teaching Assistant: Alessandra Vidal Meza
- Assignment: Homework 4 - Prioritizing Potential Aquaculture

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## References

Hall, S. J., Delaporte, A., Phillips, M. J., Beveridge, M. & O'Keefe, M. Blue Frontiers: Managing the Environmental Costs of Aquaculture (The WorldFish Center, Penang, Malaysia, 2011).

Gentry, R. R., Froehlich, H. E., Grimm, D., Kareiva, P., Parke, M., Rust, M., Gaines, S. D., & Halpern, B. S. Mapping the global potential for marine aquaculture. *Nature Ecology & Evolution*, 1, 1317-1324 (2017).

GEBCO Compilation Group (2022) GEBCO\_2022 Grid ([doi:10.5285/e0f0bb80-ab44-2739-e053-6c86abc0289c](https://doi.org/10.5285/e0f0bb80-ab44-2739-e053-6c86abc0289c))

What Exclusive Economic Zones (eez) on the west Coast of the US are best suited to developing marine aquaculture for several species of oysters and California datemussel.

# 1 Set-Up

```
# Load in Libraries
library(here)
library(testthat)
library(tidyverse)
library(sf)
library(kableExtra)
library(sp)
library(stars)
library(tmap)
library(terra)
library(viridisLite)

# Prepare Data

# Bathymetry
depth <- read_stars(here("data/depth.tif"))

# Exclusive Economic Zones (eez)
eez <- st_read(here("data/wc_regions_clean.shp"))

# Sea Surface Temperature (SST) load as a list of .tiff files
sst <- list.files(path= "data",
                  pattern= "average_annual", # file name matching pattern
                  full.names = TRUE) # Reference entire file name matching this pattern

# Stack all rasters files in folder using rast()
sst <- rast(sst)
names(sst) #checking list
```

Check that the datasets have the same coordinate reference system

```
# Check and align CRS for multiple datasets
if (st_crs(depth) == st_crs(eez)) {
  print("Coordinate reference system match!")

} else{
  warning("CRS mismatch between depth and eez")
  # tranfgotm data to match
  depth <- st_transform(depth, st_crs(eez))

}
```

```
[1] "Coordinate reference system match!"
```

```
if (st_crs(eez)$wkt != crs(sst)) {
  warning("CRS mismatch between eez and sst")
  sst <- project(sst, st_crs(eez)$wkt)
}
```

```
Warning: CRS mismatch between eez and sst
```

## 2 Process data

- Find the mean SST from 2008-2012 (e.g. create single raster of average SST)
  - convert average SST from Kelvin to Celsius hint: subtract by 273.15
- crop depth raster to match the extent of the SST raster note:
  - the resolutions of the SST and depth data do not match resample the depth data to match the resolution of the SST data using the nearest neighbor approach
  - check that the depth and SST match in resolution, extent, and coordinate reference system

```
# Calculate the SST average
mean_sst <- app(sst[[c("average_annual_sst_2008",
  "average_annual_sst_2009",
  "average_annual_sst_2010",
  "average_annual_sst_2011",
  "average_annual_sst_2012")]],
  fun = mean, na.rm = TRUE)
```

```
# Convert average SST from Kelvin to Celsius
sst_mean_celsius <- mean_sst - 273.15
```

```
# First convert depth stars to SpatRaster
depth_rast <- rast(depth)
# crop depth to match SST  extent
depth_crop <- crop(depth_rast, sst_mean_celsius)

# Resample depth_crop to match SST resolution, use method near
depth_resample <- resample(depth_crop, sst_mean_celsius, method = "near")
```

```
#Check resolution match
if (all(dim(depth_resample) == dim(sst_mean_celsius)) &&
  isTRUE(all.equal(res(depth_resample), res(sst_mean_celsius))) &&
  crs(depth_resample) == crs(sst_mean_celsius) &&
  ext(depth_resample) == ext(sst_mean_celsius)) {
  cat(" All raster properties match!\n")
} else {
  cat(" Some properties do not match\n")
}
```

Some properties do not match

```
# Match depth and SST CRS's
crs(depth_resample) <- crs(sst_mean_celsius)

# Stack
ocean_stack <- c(sst_mean_celsius, depth_resample)
names(ocean_stack) <- c("sst", "depth")
cat(" Successfully stacked!\n")
```

Successfully stacked!

### 3 Find suitable locations for Oysters

To find suitable locations for marine aquaculture, we'll need to find locations that are suitable in terms of both SST and depth. **Oyster** research has show that oysters need the following conditions for optimal growth: - Sea surface Reclassify SST and depth data into locations that are suitable for oysters hint: set suitable values to 1 and unsuitable values to 0 find locations that satisfy both SST and depth conditions

```
# Reclassify SST (11-30°C suitable for oysters)
sst_suitable <- app(sst_mean_celsius, fun = function(x){
  ifelse(x >= 11 & x <= 30, 1, 0) # if temperate is between 11- 30 °C, return 1, else 0
})

# Reclassify Suitable depth range (0-70 meters for oysters)
depth_suitable <- app(depth_resample, fun = function(x){
  ifelse(x >= -70 & x <= 0, 1, 0) # select depths from 0 to 70 meters below surface.
})

# Suitable locations for both conditions
# Use lapp() to multiply the two suitability raster

suitable_locations <- lapp(c(sst_suitable, depth_suitable),
                           fun = function(sst, depth) {
                             sst * depth
                           })
```

### 4 Determine the most suitable EEZ

We want to determine the total suitable area within each EEZ in order to rank zones by priority. To do so, we need to find the total area of suitable locations within each EEZ.

Select suitable cells within West Coast EEZ's find area of grid cells find the total suitable area within each EEZ hint: it might be helpful to rasterize the EEZ data

```
# Rasterize the EEZ data (creates zone IDs)
eez_raster <- rasterize(eez, suitable_locations, field = "rgn")

# Mask suitable locations to EEZ boundaries
suitable_eez <- mask(suitable_locations, eez) # keep only raster cells that fall within the EEZ po

#Calculate cell area with cellSize()
cell_area_km2 <- cellSize(suitable_locations, unit = "km") # calculate actual area of each raster

# Calculate suitable area per cell
suitable_area <- suitable_eez * cell_area_km2

# Sum suitable are by EEZ zonal statistics
eez_suitable_area <- zonal(suitable_area, eez_raster, fun = "sum", na.rm = TRUE)
colnames(eez_suitable_area) <- c("eez_id", "suitable_area_km2")

# join with eez data
eez$suitable_area_km2 <- eez_suitable_area$suitable_area_km2[match(eez$rgn, eez_suitable_area$eez_]

# Rank EEZ data
eez_ranked <- eez[order(-eez$suitable_area_km2), ]
```

```

summary_table <- data.frame(
  Rank = 1:nrow(eez_ranked),
  EEZ_Name = eez_ranked$rgn_key,
  Suitable_Area_km2 = round(eez_ranked$suitable_area_km2, 2),
  Percent_of_Total = round(100 * eez_ranked$suitable_area_km2 /
                            sum(eez_ranked$suitable_area_km2), 1)
)

eez_table <- kable(summary_table,
  caption = "EEZ Rankings by Suitable Aquaculture Area",
  col.names = c("Rank", "EEZ Region", "Suitable Area (km2)", "% of Total"),
  align = c("c", "l", "r", "r")) %>%
kable_styling(bootstrap_options = c("striped", "hold_position"),
              full_width = FALSE) %>%
row_spec(0, bold = TRUE, background = "#4CAF50", color = "white") %>%
row_spec(1, bold = TRUE, background = "#E8F5E9") # Highlight top rank

eez_table

```

Table 1: EEZ Rankings by Suitable Aquaculture Area

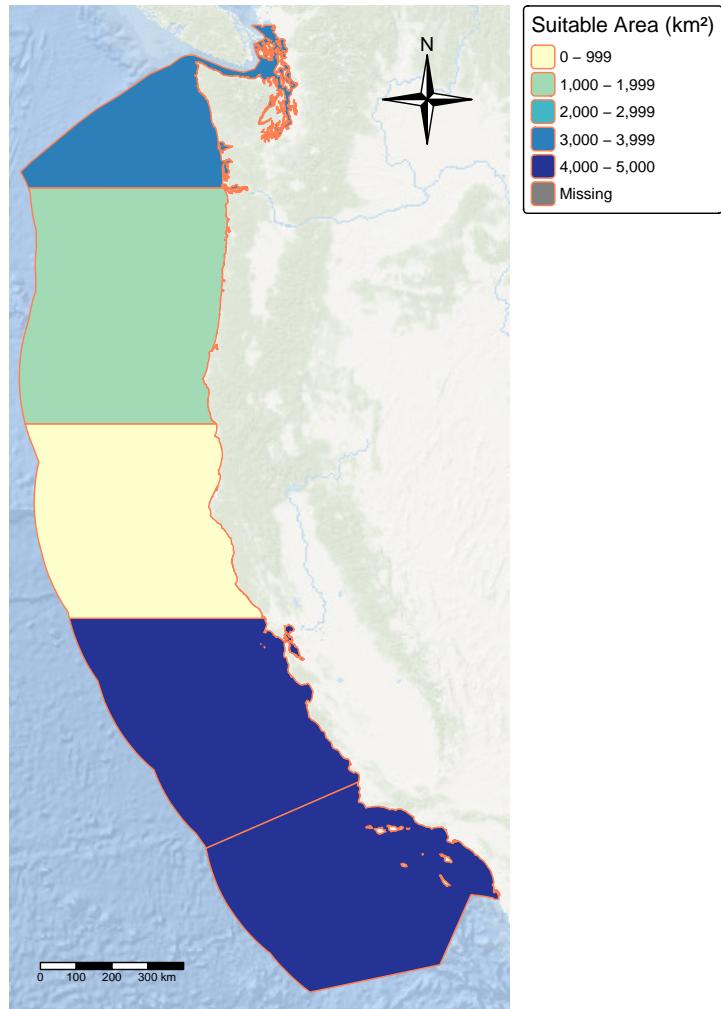
Rank	EEZ Region	Suitable Area (km <sup>2</sup> )	% of Total
1	CA-C	4940.04	34.1
2	CA-S	4221.39	29.1
3	WA	3313.16	22.8
4	OR	1578.97	10.9
5	CA-N	454.30	3.1

```

# Map with tmap basic
tm_basemap("Esri.OceanBasemap", alpha = 0.7) +
tm_shape(eez_ranked) +
tm_polygons("suitable_area_km2",
            palette = "YlGnBu",
            title = "Suitable Area (km2)",
            border.col = "coral",
            border.lwd = 0.5) +
tm_layout(main.title = "Suitable Oyster Aquaculture Area by EEZ",
          main.title.size = 1.2,
          legend.outsides = TRUE,
          frame = FALSE) +
tm_compass(type = "4star", position = c("right", "top")) +
tm_scalebar(position = c("left", "bottom"))

```

Suitable Oyster Aquaculture Area by EEZ



## 5 Workflow for other species using a function

```
find_suitable_aquaculture <- function(sst_raster, depth_raster, eez_sf,
                                         sst_min, sst_max,
                                         depth_min, depth_max,
                                         species_name = "Species") {

  # Reclassify SST
  sst_suitable <- app(sst_raster, fun = function(x) {
    ifelse(x >= sst_min & x <= sst_max, 1, 0)
  })

  # Reclassify depth
  depth_suitable <- app(depth_raster, fun = function(x) {
    ifelse(x >= depth_min & x <= depth_max, 1, 0)
  })

  # Find suitable locations (both conditions)
  suitable_locations <- sst_suitable * depth_suitable

  # Mask to EEZ
  suitable_in_eez <- mask(suitable_locations, eez_sf)
```

```

# Rasterize EEZ
eez_raster <- rasterize(eez_sf, suitable_locations, field = "rgn")

# Calculate cell areas
cell_area_km2 <- cellSize(suitable_locations, unit = "km")

# Calculate suitable area per cell
suitable_area <- suitable_in_eez * cell_area_km2

# Sum by EEZ zone
eez_suitable_area <- zonal(suitable_area, eez_raster, fun = "sum", na.rm = TRUE)
colnames(eez_suitable_area) <- c("EEZ_ID", "Suitable_Area_km2")

# Join with EEZ data and rank
eez_sf$suitable_area_km2 <- eez_suitable_area$Suitable_Area_km2[
  match(eez_sf$rgn, eez_suitable_area$EEZ_ID)
]
eez_ranked <- eez_sf[order(-eez_sf$suitable_area_km2), ]

# Create summary table
summary_table <- data.frame(
  Rank = 1:nrow(eez_ranked),
  EEZ = eez_ranked$rgn_key,
  Suitable_Area_km2 = round(eez_ranked$suitable_area_km2, 2)
)

# Return results as a list
results <- list(
  species = species_name,
  sst_suitable = sst_suitable,
  depth_suitable = depth_suitable,
  suitable_locations = suitable_locations,
  suitable_in_eez = suitable_in_eez,
  eez_ranked = eez_ranked,
  summary_table = summary_table
)
return(results)
}

```

## 6 Apply function to species of choice

### 6.1 *Adula californiensis* (Philippi, 1847)

- Common Name: California datemussel
- Low Fishing Vulnerability
  - Depth range: 0-20 meters
  - Temperature: 9.1-18.6 C
- Source: SeaLifeBase

```

# Mussels (different requirements)
mussel_results <- find_suitable_aquaculture(
  sst_raster = sst_mean_celsius,

```

```

depth_raster = depth_resample,
eez_sf = eez,
sst_min = 9.1,
sst_max = 18.6,
depth_min = 0,
depth_max = 20,
species_name = "California Datemussel"
)

# Access results
kable(mussel_results$summary_table)

```

Rank	EEZ	Suitable_Area_km2
1	WA	260.91
2	CA-S	124.68
3	CA-C	103.50
4	OR	76.65
5	CA-N	33.36

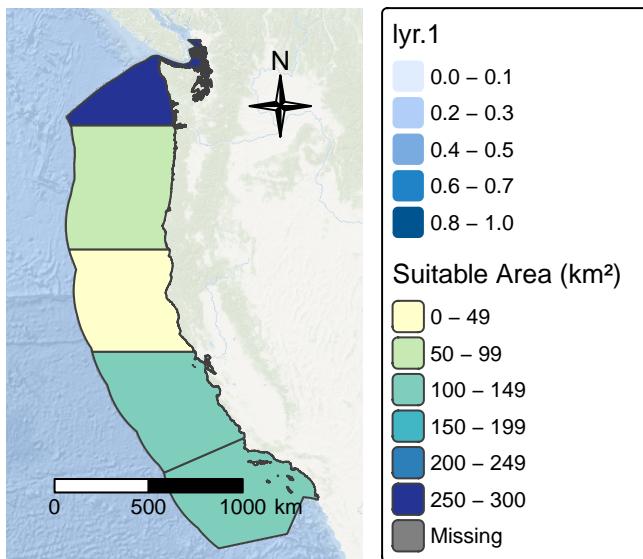
```

# Plot Mussel EEZ
#| fig.width: 10
#| fig.height: 8

tm_basemap("Esri.OceanBasemap", alpha = 0.7) +
tm_shape(mussel_results$suitable_in_eez) +
tm_raster() +
tm_shape(mussel_results$eez_ranked) +
tm_polygons("suitable_area_km2",
            palette = "YlGnBu",
            title = "Suitable Area (km2)", boarder.col = "black",
            border.lwd = 0.5) +
tm_layout(main.title ="Suitable Mussel Aquaculture Area by EEZ",main.title.size =1.2,legend.out
tm_compass(type = "4star",
            position = c("right", "top"),
            size = 2) +
tm_scale_bar(position = c("left", "bottom"),
             text.size = 0.7)

```

Suitable Mussel Aquaculture Area by EEZ



## 7 Reflections

Reflections must be clear, accurate, and demonstrate a deep understanding of the analysis performed

This analysis identified suitable locations for oyster aquaculture along the West Coast EEZs by integrating sea surface temperature (SST) and bathymetric data. The workflow demonstrated how geospatial analysis can support marine resource management decisions by combining environmental constraints with jurisdictional boundaries. In the analysis we found that 2.3% (based on cellsize) of the West Coast EEZ area meets the suitability criteria for oyster cultivation (11-30°C SST, 0-70m depth). CA-C (Central California) ranked highest with 4940.04 km<sup>2</sup> of suitable area, suggesting it as the priority zone for aquaculture development.

## 8 Cite

Hall, S. J., Delaporte, A., Phillips, M. J., Beveridge, M. & O'Keefe, M. Blue Frontiers: Managing the Environmental Costs of Aquaculture (The WorldFish Center, Penang, Malaysia, 2011).

Gentry, R. R., Froehlich, H. E., Grimm, D., Kareiva, P., Parke, M., Rust, M., Gaines, S. D., & Halpern, B. S. Mapping the global potential for marine aquaculture. *Nature Ecology & Evolution*, 1, 1317-1324 (2017).

GEBCO Compilation Group (2022) GEBCO\_2022 Grid (doi:10.5285/e0f0bb80-ab44-2739-e053-6c86abc0289c)

Commercially Important Species Occurring in United States (contiguous states). (2025). Sealifebase.ca. [https://www.sealifebase.ca/country/CountryChecklist.php?c\\_code=840&vhabitat=commercial](https://www.sealifebase.ca/country/CountryChecklist.php?c_code=840&vhabitat=commercial)

Oliver, R. (2025, November 25). Homework Assignment 4. Github.io. <https://eds-223-geospatial.github.io/assignments>