Downscaling AquaMaps

v01: blue whale, GEBCO SoCal

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## 0.1 Overview

**Goal**: Downscale [AquaMaps.org](https://aquamaps.org) species distributions (Kaschner et al. 2023; Ready et al. 2010) from 0.5 decimal degrees to 15 arc seconds (111.11 km to 0.46 km at the equator), using the R package [aquamapsdata](https://raquamaps.github.io/aquamapsdata/index.html) and the the General Bathymetric Chart of the Oceans [GEBCO](https://www.gebco.net/).

We start with the “Blue Whale” ([*Balaenoptera musculus*](https://aquamaps.org/preMap2.php?cache=1&SpecID=ITS-Mam-180528)) and Southern California.

Later we’ll iterate over species and expand to global, which will require large raster handling techniques using Cloud-Optimized GeoTIFFS (COGs; see [cogeo.org](https://www.cogeo.org)).

All code and files (except the large global GEBCO grid) are found in this repository:

* [github.com/marinebon/aquamaps-downscaled](https://github.com/marinebon/aquamaps-downscaled)

## 0.2 Species map (blue whale)

|  |
| --- |
| Figure 1: Map of blue whale (*Balaenoptera musculus*) distribution from AquaMaps. |

### 0.2.1 Zoom to SoCal

Notice the very large pixels, far bigger than useful for smaller planning purposes, such as for Sanctuaries or BOEM Wind Energy Areas.

|  |
| --- |
| Figure 2: Map of blue whale (*Balaenoptera musculus*) distribution from AquaMaps zoomed into Southern California. Notice the very large pixels, far bigger than useful for smaller planning purposes, such as for Sanctuaries or BOEM Wind Energy Areas. |

## 0.3 Environmental preferences

Here are the environmental preferences for the species in the database.

Table 1: Table of blue whale (*Balaenoptera musculus*) environmental suitability parameters from Aquamaps.

| name | value |
| --- | --- |
| SpeciesID | ITS-Mam-180528 |
| Speccode | 69007 |
| LifeStage | adults |
| FAOAreas | 18, 21, 27, 31, 34, 41, 47, 48, 51, 57, 58, 61, 67, 71, 77, 81, 87, 88 |
| FAOComplete | NA |
| NMostLat | 90 |
| SMostLat | -90 |
| WMostLong | -180 |
| EMostLong | 180 |
| DepthYN | 1 |
| DepthMin | 0 |
| DepthPrefMin | 1000 |
| DepthPrefMax | 4000 |
| DepthMax | 8000 |
| MeanDepth | 1 |
| Pelagic | 0 |
| TempYN | 1 |
| TempMin | -1.8 |
| TempPrefMin | -1.3 |
| TempPrefMax | 27.87 |
| TempMax | 32.07 |
| SalinityYN | 1 |
| SalinityMin | 3.58 |
| SalinityPrefMin | 32.57 |
| SalinityPrefMax | 35.49 |
| SalinityMax | 38.84 |
| PrimProdYN | 1 |
| PrimProdMin | 0.1 |
| PrimProdPrefMin | 1.4 |
| PrimProdPrefMax | 16.07 |
| PrimProdMax | 119.58 |
| IceConYN | 1 |
| IceConMin | -0.88 |
| IceConPrefMin | 0 |
| IceConPrefMax | 0.49 |
| IceConMax | 0.96 |
| OxyYN | 0 |
| OxyMin | 1.1 |
| OxyPrefMin | 116.82 |
| OxyPrefMax | 275.01 |
| OxyMax | 408.48 |
| LandDistYN | 0 |
| LandDistMin | 0 |
| LandDistPrefMin | 17 |
| LandDistPrefMax | 733 |
| LandDistMax | 1740 |
| Remark | FAO areas,bounding box and/or pelagic flag based on last review. |
| DateCreated | 2019-08-07 00:00:00 |
| DateModified | NA |
| expert\_id | NA |
| DateExpert | NA |
| Layer | s |
| Rank | 1 |
| MapOpt | 1 |
| ExtnRuleYN | 1 |
| Reviewed | 1 |

Now let’s convert all variables having {Var}YN == 1 into the relative environmental suitability rhomboids (Kaschner et al. 2006).

Table 2: Table environmental suitability parameters from Aquamaps that are applicable to blue whale (*Balaenoptera musculus*), i.e. {Var}YN == 1 in [Table 1](#tbl-blue_whale_env).

| var | prob\_name | var\_value | prob\_value |
| --- | --- | --- | --- |
| Depth | Min | 0.00 | 0 |
| Depth | PrefMin | 1000.00 | 1 |
| Depth | PrefMax | 4000.00 | 1 |
| Depth | Max | 8000.00 | 0 |
| Temp | Min | -1.80 | 0 |
| Temp | PrefMin | -1.30 | 1 |
| Temp | PrefMax | 27.87 | 1 |
| Temp | Max | 32.07 | 0 |
| Salinity | Min | 3.58 | 0 |
| Salinity | PrefMin | 32.57 | 1 |
| Salinity | PrefMax | 35.49 | 1 |
| Salinity | Max | 38.84 | 0 |
| PrimProd | Min | 0.10 | 0 |
| PrimProd | PrefMin | 1.40 | 1 |
| PrimProd | PrefMax | 16.07 | 1 |
| PrimProd | Max | 119.58 | 0 |
| IceCon | Min | -0.88 | 0 |
| IceCon | PrefMin | 0.00 | 1 |
| IceCon | PrefMax | 0.49 | 1 |
| IceCon | Max | 0.96 | 0 |

|  |
| --- |
| Figure 3: Plots of environmental suitability parameters from Aquamaps that are applicable to blue whale (*Balaenoptera musculus*) from [Table 2](#tbl-blue_whale_env_yes). |

## 0.4 Depth (GEBCO) for SoCal

|  |
| --- |
| Figure 4: Map of depth from GEBCO zoomed into Southern California. Notice the much higher resolution compared to [Figure 2](#fig-blue_whale_map_socal). |

## 0.5 Ramp depth with species preference

### 0.5.1 Create ramp\_env() function

|  |
| --- |
| Figure 5: Plot of original depth preferences for 4 points (black circles) and interpolated values (red asterisks) using new ramp\_env() function. |

### 0.5.2 Apply to SoCal

Apply the ramp\_env() function to the SoCal depth using blue whale preferences.

|  |
| --- |
| Figure 6: Map of depth preference for r sp\_term applied to SoCal depth with the ramp\_env() function. |

## 0.6 sdmpredictors

|  | dataset\_code | terrestrial | marine | url | description | citation |
| --- | --- | --- | --- | --- | --- | --- |
| 2 | Bio-ORACLE | FALSE | TRUE | https://bio-oracle.org/ | Bio-ORACLE is a set of GIS rasters providing geophysical, biotic and environmental data for surface and benthic marine realms at a spatial resolution 5 arcmin (9.2 km) in the ESRI ascii and tif format. | Tyberghein L., Verbruggen H., Pauly K., Troupin C., Mineur F. & De Clerck O. Bio-ORACLE: a global environmental dataset for marine species distribution modeling. Global Ecology and Biogeography. doi: 10.1111/j.1466-8238.2011.00656.x |
| 3 | MARSPEC | FALSE | TRUE | http://marspec.org/ | MARSPEC is a set of high resolution climatic and geophysical GIS data layers for the world ocean. Seven geophysical variables were derived from the SRTM30\_PLUS high resolution bathymetry dataset. These layers characterize the horizontal orientation (aspect), slope, and curvature of the seafloor and the distance from shore. Ten “bioclimatic” variables were derived from NOAA’s World Ocean Atlas and NASA’s MODIS satellite imagery and characterize the inter-annual means, extremes, and variances in sea surface temperature and salinity. These variables will be useful to those interested in the spatial ecology of marine shallow-water and surface-associated pelagic organisms across the globe. Note that, in contrary to the original MARSPEC, all layers have unscaled values. | Sbrocco, EJ and Barber, PH (2013) MARSPEC: Ocean climate layers for marine spatial ecology. Ecology 94: 979. doi: 10.1890/12-1358.1 |

# 1. manual upload with retry

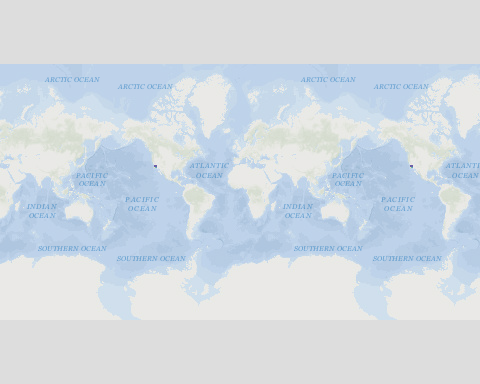
* [problems here possibly in version 0.6-1 of stars](https://github.com/r-spatial/stars/commit/b70735ac26c58155ecc6b137d2dcdde586b03f4b#diff-51920e95310ebfbc1ae31709f3b95f89afffbf4f1a6e38e8b2b406e2fb6197eaR3) > # version 0.6-1 > \* [<-.stars\_proxy() clones environment, so that after r[r > 100]<-NA we don’t get infinite recursion when realizing r
* [General Bathymetric Chart of the Oceans (GEBCO) - awesome-gee-community-catalog](https://gee-community-catalog.org/projects/gebco/)
* [Resampling and Reducing Resolution | Google Earth Engine | Google for Developers](https://developers.google.com/earth-engine/guides/resample)

Generate from ramps in GEE with:

* [ee.Algorithms.If()](https://developers.google.com/earth-engine/guides/ic_mapping)
  + [Computations using Images | Google Earth Engine | Google for Developers](https://developers.google.com/earth-engine/tutorials/tutorial_api_03)
  + [javascript - Google Earth Engine: Apply scaling function to band values of image - Geographic Information Systems Stack Exchange](https://gis.stackexchange.com/questions/368016/google-earth-engine-apply-scaling-function-to-band-values-of-image)
  + [Applying Raster Calculation to Image Collection in Google Earth Engine - Geographic Information Systems Stack Exchange](https://gis.stackexchange.com/questions/370706/applying-raster-calculation-to-image-collection-in-google-earth-engine)
* [Image.unitScale(low, high)](https://developers.google.com/earth-engine/apidocs/ee-image-unitscale)
  + [google earth engine - Rescale NDVI [-1,1] to 0-255 using GEE - Geographic Information Systems Stack Exchange](https://gis.stackexchange.com/questions/418562/rescale-ndvi-1-1-to-0-255-using-gee)

## 1.1 Try COG

* [GEE: export\_depth](https://code.earthengine.google.com/?scriptPath=users%2Fben-ecoquants%2Faquamaps-downscaled%3Aexport_depth)



* [How do I set up CORS for my Google Cloud Storage Bucket?](https://developer.bitmovin.com/encoding/docs/how-do-i-set-up-cors-for-my-google-cloud-storage-bucket)

echo '[{"origin": ["\*"],"responseHeader": ["\*"],"method": ["GET", "HEAD"],"maxAgeSeconds": 3600}]' > cors-config.json  
  
echo '[{"origin": ["\*"],"method": ["\*"]}]' > cors-config.json  
  
gsutil cors set cors-config.json gs://offhab\_lyrs  
  
gsutil cors get gs://offhab\_lyrs

## 1.2 Next Steps

Goal: Downscale global AquaMaps with all env preferences

TODO:

* ☐ Gather finer resolution global data based on yes/no parameters (\*YN):
  + ☒ Depth: [GEBCO](https://gee-community-catalog.org/projects/gebco/)
  + ☒ Temp: BO22\_tempmean\_ss
  + ☒ Salinity: BO22\_salinitymean\_ss
  + ☒ PrimProd: BO22\_ppmean\_ss
  + ☒ IceCon: BO22\_icecovermean\_ss
  + ☐ Oxy:
  + ☐ LandDist:
  + ☐ ExtnRule:
    - Note: “BO22\_” refers to Bio-Oracle version 2.2 from sdmpredictors
* ☐ Work out rest of individual species workflow
  + ☐ Apply ramp\_env() to each environmental parameter applicable to the species (ie {var}YN ==1)
  + ☐ Average all environmental parameter grids for the species
  + ☐ Clip to NMostLat, SMostLat, WMostLong, EMostLong
  + ☒ Mask to FAOAreas
  + ☐ Figure out unknown fields: ExtnRuleYN, MapOpt, …
* ☐ Repeat for workflow for ALL species
* ☐ Render maps from anywhere
  + ☐ Store in COG with each species as a separate layer; or try individual layer COGs
  + ☐ Upload COG to Google Cloud Storage
  + ☐ Install [TiTiler](https://developmentseed.org/titiler) on MarineBON.app server
  + ☐ Render map layers from COG using TiTiler in new function(s) borrowing from [offhabr](https://offshorewindhabitat.info/offhabr/index.html) functions like [oh\_map\_cog\_lyr()](https://offshorewindhabitat.info/offhabr/reference/oh_map_cog_lyr.html)
* ☐ Build Shiny app
  + ☐ Render map of selected species from dropdown
  + ☐ Summarize species from drawn area
  + ☐ Summarize species from selected area from existing:
    - ☐ EEZ
    - ☐ LME
    - ☐ Sanctuary
    - ☐ BOEM Wind Energy Area
    - ☐ …
* ☐ Calculate biodiversity metrics
  + ☐ Richness
  + ☐ Abundance
  + ☐ Extinction Risk
  + ☐ Endemism
  + ☐ Foundation Species
  + ☐ …

## 1.3 Links from GEE

TODO: - convert Bio-Oracle SDM predictors to same resolution - experiment with mosaic from for simple export \* [google earth engine - How to split the world in four quadrants as ee.Image - Geographic Information Systems Stack Exchange](https://gis.stackexchange.com/questions/445938/how-to-split-the-world-in-four-quadrants-as-ee-image) \* [Google Earth Engine Tutorial: Split Image By Grid and Export to Google Drive - YouTube](https://www.youtube.com/watch?v=3yqv5fZSdH4) \* [ee.ImageCollection.mosaic | Google Earth Engine | Google for Developers](https://developers.google.com/earth-engine/apidocs/ee-imagecollection-mosaic) \* [ee.ImageCollection.fromImages | Google Earth Engine | Google for Developers](https://developers.google.com/earth-engine/apidocs/ee-imagecollection-fromimages) \* [Image mosaic/composite creation for Landsat and Sentinel-2 in Google Earth Engine - openMRV](https://openmrv.org/web/guest/w/modules/mrv/modules_1/image-mosaic-composite-creation-for-landsat-and-sentinel-2-in-google-earth-engine)

### 1.3.1 NOTES

* try:
  + /Users/bbest/Github/offshorewindhabitat/scripts/offhab\_gee1.ipynb
  + geemap: see below
  + [zarr | IOOS](https://ioos.github.io/ioos_code_lab/content/code_gallery/data_management_notebooks/2023-03-20-Reading_and_writing_zarr.html)
  + [stars](https://r-spatial.github.io/stars/index.html)
    - [stars proxy objects](https://r-spatial.github.io/stars/articles/stars2.html#stars-proxy-objects)
    - [IPBES raster gdalcubes](https://ict.ipbes.net/ipbes-ict-guide/data-management/technical-guidelines/file-formats#b.-raster-data)
    - [Large data and cloud native | Ch. 9 Spatial Data Science](https://r-spatial.org/book/09-Large.html#very-large-data-cubes)
    - [Accessing data from large online rasters with Cloud-Optimized-Geotiff, GDAL, and terra R package | Francisco Rodríguez-Sánchez](https://frodriguezsanchez.net/post/accessing-data-from-large-online-rasters-with-cloud-optimized-geotiff-gdal-and-terra-r-package/)
    - [Cloud-based processing of satellite image collections in R using STAC, COGs, and on-demand data cubes](https://r-spatial.org/r/2021/04/23/cloud-based-cubes.html)
  + viz with leafem: seemed slow
    - [new addGeoRaster method · Issue #25 · r-spatial/leafem](https://github.com/r-spatial/leafem/issues/25)
    - [Add Cloud Optimised Geotiff (COG) to a leaflet map. — addCOG • leafem](https://r-spatial.github.io/leafem/reference/addCOG.html)
  + [gdalcubes](https://gdalcubes.github.io) again
    - [w/ rstac](https://gdalcubes.github.io/source/tutorials/vignettes/gc02_AWS_Sentinel2.html#finding-images-with-rstac)
* break up into smaller tiles
  + [2.2. Generate a Regional Composite Through Spatial Tiling](https://google-earth-engine.com/Advanced-Topics/Scaling-up-in-Earth-Engine/)
  + [Compositing, Masking, and Mosaicking | GEE](https://developers.google.com/earth-engine/tutorials/tutorial_api_05) By combining the concepts of image collections, logical operators, masking and compositing, you can achieve interesting cartographic results. For example, suppose you want an image in which land pixels are displayed in true-color and all the other pixels are displayed in blue
* other env predictors
  + distance from shore
    - [30-m global shorelin on GEE](https://gee-community-catalog.org/projects/shoreline/)
    - [ee.Image.distance | Google Earth Engine | Google for Developers](https://developers.google.com/earth-engine/apidocs/ee-image-distance)
    - [ee.Image.fastDistanceTransform | Google Earth Engine | Google for Developers](https://developers.google.com/earth-engine/apidocs/ee-image-fastdistancetransform)
  + SST by month
    - [GEE: GSST 2002-2019](https://gee-community-catalog.org/projects/sstg/)
* model data products
  + https://www.ecco-group.org/
    - https://podaac.jpl.nasa.gov/dataset/ECCO\_L4\_TEMP\_SALINITY\_05DEG\_MONTHLY\_V4R4#
    - https://ecco-v4-python-tutorial.readthedocs.io/intro.html
* install titiler
  + https://github.com/developmentseed/titiler
* gee tricks
  + [client vs server | GEE](https://developers.google.com/earth-engine/guides/client_server)
  + [GFW use of GEE](https://globalfishingwatch.org/data/public-data-google-earth-engine/)
  + [Jenks natural breaks w/ SLD](https://developers.google.com/earth-engine/guides/image_visualization#styled-layer-descriptors)
* geemap
  + [11 export image](https://geemap.org/notebooks/11_export_image/#download-an-eeimagecollection)
  + [44 cog stac](https://geemap.org/notebooks/44_cog_stac/?h=cog#working-with-spatiotemporal-asset-catalog-stac)
  + [92 plotly - geemap](https://geemap.org/notebooks/92_plotly/?h=titiler)
  + [95 create cog](https://geemap.org/notebooks/95_create_cog/?query=cog)
  + [100 numpy to cog](https://geemap.org/notebooks/100_numpy_to_cog/?h=cog)
  + [103 split control](https://geemap.org/notebooks/103_split_control/?h=cog)
  + [plotlymap module add\_cog\_layer()](https://geemap.org/plotlymap/?h=cog#geemap.plotlymap.Map.add_cog_layer)
  + [plotlymap module add\_stac\_layer(](https://geemap.org/plotlymap/?h=cog#geemap.plotlymap.Map.add_stac_layer)
  + [foliumap module add\_cog\_layer()](https://geemap.org/foliumap/?h=#geemap.foliumap.Map.add_cog_layer)
  + [foliumap add\_stac\_layer()](https://geemap.org/foliumap/?h=#geemap.foliumap.Map.add_stac_layer)
* indicator portal
  + [Data Management Tutorials - IPBES ICT guide](https://ict.ipbes.net/ipbes-ict-guide/data-management/data-management-tutorials)
    - [Part 2 - Preparing and Mapping Data to IPBES Regions and Sub-regions - IPBES ICT guide](https://ict.ipbes.net/ipbes-ict-guide/data-management/technical-guidelines/preparing-and-mapping-data-to-ipbes-regions-and-sub-regions)
    - [Part 11 - How to Document an Indicator - IPBES ICT guide](https://ict.ipbes.net/ipbes-ict-guide/data-management/technical-guidelines/how-to-document-an-indicator)
* Map of Life: indicators, portal setup
  + [Map of Life | Map of Life](https://mol.org/)
  + [Map of Life - Indicators](https://mol.org/indicators/)
  + [Map of Life - Patterns](https://mol.org/patterns/)
  + [Discovery Potential](https://vertlife.org/data/discoverypotential/)

## 1.4 References

Kaschner, K., K. Kesner-Reyes, C. Garilao, J. Segschneider, J. Rius-Barile, T. Rees, and R. Froese. 2023. “AquaMaps: Predicted Range Maps for Aquatic Species. Retrieved from https://www.aquamaps.org.”

Kaschner, K., R. Watson, A. W. Trites, and D. Pauly. 2006. “Mapping World-Wide Distributions of Marine Mammal Species Using a Relative Environmental Suitability (RES) Model.” *Marine Ecology Progress Series* 316 (July): 285–310. <https://doi.org/10.3354/meps316285>.

Ready, Jonathan, Kristin Kaschner, Andy B. South, Paul D. Eastwood, Tony Rees, Josephine Rius, Eli Agbayani, Sven Kullander, and Rainer Froese. 2010. “Predicting the Distributions of Marine Organisms at the Global Scale.” *Ecological Modelling* 221 (3): 467–78. <https://doi.org/10.1016/j.ecolmodel.2009.10.025>.