Downscaling AquaMaps

v01: blue whale, GEBCO SoCal

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## 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)

# packages ----  
if (!"librarian" %in% installed.packages())  
 install.packages("librarian")  
if (!"rcrypt" %in% installed.packages())  
 devtools::install\_bitbucket("bklamer/rcrypt") # dependency for aquamapsdata  
librarian::shelf(  
 bklamer/rcrypt,  
 raquamaps/aquamapsdata,  
 dplyr, ggplot2, glue, here, knitr, leaflet,   
 # TODO: migrate raster to terra  
 # terra,   
 raster, rnaturalearth, sf, stringr, tidyr,  
 quiet = T)  
select = dplyr::select  
  
# initial run-once step required to install remote db locally  
# download\_db(force = TRUE)  
  
# aquamaps database ----  
am\_db <- default\_db("sqlite")  
  
# paths ----  
dir\_big <- "/Users/bbest/big"  
gebco\_nc <- glue("{dir\_big}/gebco\_2022\_sub\_ice\_topo/GEBCO\_2022\_sub\_ice\_topo.nc")  
gebco\_socal\_tif <- here("data/gebco\_socal.tif")  
land\_socal\_geo <- here("data/land\_socal.geojson")  
  
# custom functions ----  
add\_ocean\_basemap <- function(m){  
 # m: leaflet() map  
   
 m |>  
 # add base: blue bathymetry and light brown/green topography  
 addProviderTiles(  
 "Esri.OceanBasemap",  
 options = providerTileOptions(  
 variant = "Ocean/World\_Ocean\_Base")) |>  
 # add reference: placename labels and borders  
 addProviderTiles(  
 "Esri.OceanBasemap",  
 options = providerTileOptions(  
 variant = "Ocean/World\_Ocean\_Reference"))  
}  
  
add\_am\_raster <- function(  
 m,   
 r,  
 title,  
 cols = c("#FEB24C", "#FD8D3C", "#FC4E2A", "#E31A1C", "#B10026"),  
 truncate\_to\_zero = T){  
 # m: leaflet() map  
 # r: raster   
 # TODO: migrate to terra::rast()  
   
 # r = r\_gebco\_bb  
 # title = "GEBCO depth (m)"  
 # cols = RColorBrewer::brewer.pal(7, "Blues")  
   
 r <- leaflet::projectRasterForLeaflet(r, method = "bilinear")  
   
 # truncate to 0 to prevent negative values   
 # that were generated by projecting the raster   
 # from geographic projection (decimal degrees) to Web Mercator (meters)  
 if (truncate\_to\_zero){  
 v <- values(r)  
 v[v<0] <- 0  
 values(r) <- v  
 }  
   
 pal <- leaflet::colorBin(  
 cols, na.omit(unique(values(r))),   
 bins = length(cols), pretty = TRUE, na.color = "#00000000")  
   
 e <- raster::extent(r) |>   
 sf::st\_bbox() |>   
 st\_as\_sfc() |>   
 st\_as\_sf(crs=3857) |>   
 st\_transform(4326) |>   
 st\_bbox()  
   
 m |>   
 leaflet::addRasterImage(  
 r, project = F, colors = pal, opacity = 0.8) |>   
 addLegend(  
 values = raster::values(r),   
 title = title, pal = pal) |>   
 leaflet::fitBounds(  
 lng1 = e[["xmin"]],   
 lat1 = e[["ymin"]],   
 lng2 = e[["xmax"]],   
 lat2 = e[["ymax"]])  
}

## 2 Species map (blue whale)

# fuzzy search allows full text search operators AND, OR, NOT and +  
# see https://www.sqlitetutorial.net/sqlite-full-text-search/  
sp\_term <- "blue whale"  
key <- am\_search\_fuzzy(search\_term = sp\_term) |>   
 pull(key) # "ITS-Mam-180528"  
  
# get the identifier for the species  
r <- am\_raster(key)  
  
# show the native habitat map  
m <- leaflet() |>   
 add\_ocean\_basemap() |>   
 add\_am\_raster(r, title = sp\_term)  
m

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

### 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.

# Southern California  
bbox <- c(-121, 32, -117, 35)  
m |>  
 fitBounds(lng1 = bbox[1], lat1 = bbox[2], lng2 = bbox[3], lat2 = bbox[4])

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| 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. |

## 3 Environmental preferences

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

sp\_env <- am\_hspen() |>   
 filter(SpeciesID == key) |>   
 head(1) |>   
 collect()  
  
sp\_env |>   
 mutate(across(everything(), as.character)) |>   
 pivot\_longer(everything()) |>   
 kable()

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).

var <- "Depth"  
  
d\_probs <- tribble(  
 ~prob\_name, ~prob\_value,  
 "Min" , 0,  
 "PrefMin" , 1,  
 "PrefMax" , 1,  
 "Max" , 0)  
  
vars\_yes <- sp\_env |>   
 select(ends\_with("YN")) |>   
 pivot\_longer(  
 everything()) |>   
 filter(value == 1) |>   
 pull(name) |>   
 str\_replace("YN","")  
  
d <- sp\_env |>   
 select(starts\_with(vars\_yes)) |>  
 select(!ends\_with("YN")) |>   
 pivot\_longer(  
 everything(),  
 values\_to = "var\_value") |>   
 separate\_wider\_regex(  
 name,  
 c(var = paste(vars\_yes, collapse = "|"), # "",  
 prob\_name = paste(d\_probs$prob\_name, collapse = "|"))) |>   
 left\_join(  
 d\_probs,  
 by = "prob\_name")  
  
kable(d)

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 |

g <- ggplot(d, aes(var\_value, prob\_value)) +  
 geom\_area() +  
 theme\_light() +  
 facet\_wrap(  
 vars(var),   
 scales = "free") +  
 labs(  
 title = sp\_term,  
 subtitle = "environmental envelope",  
 x = NULL,  
 y = "probability of presence")  
g

|  |
| --- |
| 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). |

## 4 Depth (GEBCO) for SoCal

# limit to bounding box for now  
ply\_bb <- extent(  
 c(bbox[1], bbox[3], bbox[2], bbox[4])) |>   
 st\_bbox() |>   
 st\_as\_sfc() |>   
 st\_as\_sf(crs = 4326)  
  
# land  
if (!file.exists(land\_socal\_geo)){  
 ply\_land <- ne\_download(  
 scale = 10, # 110/50/10: high spatial resolution (10 m)  
 type = "land",   
 category = "physical",  
 returnclass = "sf")  
 # plot(ply\_land)  
 ply\_land\_bb <- ply\_land |>   
 st\_intersection(ply\_bb)  
 # plot(ply\_land\_bb)  
 write\_sf(ply\_land\_bb, land\_socal\_geo)  
}  
ply\_land\_bb <- read\_sf(land\_socal\_geo)  
# plot(ply\_land\_bb)  
  
if (!file.exists(gebco\_socal\_tif)){  
 # read large GEBCO netcdf file outside repo  
 r\_gebco <- raster(gebco\_nc)  
   
 # crop to SoCal bounding box  
 r\_gebco\_bb <- r\_gebco |>   
 crop(ply\_bb)  
   
 # mask out land, ie > 0   
 r\_gebco\_bb <- r\_gebco\_bb |>   
 mask(r\_gebco\_bb <= 0, maskvalue = 0) \* -1  
   
 # write to TIF  
 writeRaster(r\_gebco\_bb, gebco\_socal\_tif, overwrite = T)  
}  
r\_gebco\_bb <- raster(gebco\_socal\_tif)  
  
m <- leaflet() |>   
 add\_ocean\_basemap() |>   
 add\_am\_raster(  
 r = r\_gebco\_bb,   
 title = "GEBCO depth (m)",   
 cols = RColorBrewer::brewer.pal(7, "Blues"))  
m

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| --- |
| 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). |

## 5 TODO: Downscale AquaMaps with Depth

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## 6 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>.