Accessing EMODnet Seabed Habitats' OGC services

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Document Control

Version	Date	Author	Comments
0.1	29-03-2021	Jordan Pinder	Initial documentation to access WFS services, basic data manipulation and visualisation
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Introduction

The European Marine Observation and Data Network (EMODnet) is a network of organisations supported by the EU's integrated maritime policy. These organisations work together to observe the sea, process the data according to international standards and make that information freely available as interoperable data layers and data products.

Seabed Habitats was one of seven themes of the EMODnet initiative. Since its inception in 2009, EMODnet Seabed Habitats developed, improved and gradually increased the coverage of a broad-scale seabed habitat map for Europe's seabed, also known as EUSeaMap. It also has a large library of benthic habitat maps from surveys, collections of benthic habitat point observations, composite data products such as Essential Ocean Variables and the OSPAR threatened and/or Declining Habitats database, and environmental data products such as light availability and energy at the seabed.

Seabed Habitats provides all of its spatial data through a series of web services in the Open Geospatial Consortitum (OGC) format, including:

- Web Mapping Services (WMS): access to pre-styled image layers as seen on the interactive mapper;
- Web Feature Services (WFS): access to "real" vectorised data formats including `geoJSON`, `ESRI Shapefile`, `GML`;

This tutorial is to serve as a guide for accessing `WFS` data from EMODnet Seabed Habitats.

Specific blogposts used during this tutorial were:

- `ows4R` - `R` interface for OGC web services. A good tutorial is here, GitHub repo is here.
- Drawing beautiful maps programatically with `R`, `sf`, and `ggplot2` - part one, part two, and part three.
- `xmltools` - useful tools for extracting `xml` based data in a tidy format, a good tutorial is here, GitHub repo is here.

Packages

Firstly we'll need to install and load our packages.

```
# install.packages(c('devtools', 'rgeos', 'janitor', 'httr',
# 'xml2', 'ows4R', 'tidyverse', 'dplyr', 'sf', 'ggrepel',
# 'glue', 'ggthemes', 'rnaturalearth', 'rnaturalearthdata'))

devtools::install_github("dantonnoriega/xmltools")

library(httr)
library(xml2)
library(xmltools)
library(ows4R)
library(tidyverse)
library(dplyr)
library(sf)
library(rvest)
library(tidygeocoder)
library(glue)
library(ggthemes)
library(ggrepel)
library(rnaturalearth)
library(rnaturalearthdata)
library(rgeos)
library(janitor)
library(kableExtra)
```

Accessing WFS data

URL endpoint

Get the URL of the web services. Below is the main one we'll be using, but see here for a full list of web services.

```
wfs_main <- "https://ows.emodnet-seabedhabitats.eu/emodnet_open/wfs"
```

Next, we append information to the URL address with the aid of `httr::parse_url` and `httr::build_url`. The former function parses an URL into a list for easier programmatic

addition of information to the URL. The latter function does the reverse and builds the URL from the list object.

The `url$query` slot is where you instruct the WFS what information it should return. It is constructed as a list with name-value pairs. For now, we only need to specify the `GetCapabilities` request. Other information such as `version` information (e.g. `version = 2.0.0`) can be added but is not required (by default, the latest version of the WFS service will be chosen).

```
url <- httr::parse_url(wfs_main)

url$query <- list(service = "wfs",
                  #version = "2.0.0", # facultative
                  request = "GetCapabilities"
                  )


request <- httr::build_url(url)
request
```

```
## [1] "https://ows.emodnet-seabedhabitats.eu/emodnet_open/wfs?service=wfs&request=GetCapabilities"
```

GetCapabilities

With `GetCapabilities`, we obtain a complete overview of all metadata for the web service.

To see all capabilities, you can visit the request in the webbrowser. For instance opening the page in the webbrowser and searching for `Filter_Capabilities` allows you to see all possible ways to filter the data from a WFS layer (e.g. restrict the downloaded data to a specified bounding box with `SpatialOperator name="BBOX"`).

Instead of searching the page on the web, there are several ways to access specific pieces of information programmatically. We will show here how to do this using functions in the `ows4R` package.

The first thing we need to do is generate a connection to the WFS with the aid of `WFSClient$new()`.

```
emodnet_client <- WFSClient$new(wfs_main, serviceVersion = "2.0.0")  # serviceVersion must be provided here

emodnet_client
```

Query layers

The features listed can be accessed using `$`. As a first example, the following code will list all available layers for that WFS which will return the layer name and title.

```
emodnet_client$getFeatureTypes(pretty = TRUE)
```

name	title
emodnet_open:art17_hab_1150	2013 Article 17 reporting gridded Annex I habitat distribution - Coastal lagoons (1150)
emodnet_open:art17_hab_1130	2013 Article 17 reporting gridded Annex I habitat distribution - Estuaries (1130)
emodnet_open:art17_hab_1160	2013 Article 17 reporting gridded Annex I habitat distribution - Large shallow inlets and bays (1160)
emodnet_open:art17_hab_1140	2013 Article 17 reporting gridded Annex I habitat distribution - Mudflats and sandflats not covered by seawater at low tide (1140)
emodnet_open:art17_hab_1120	2013 Article 17 reporting gridded Annex I habitat distribution - Posidonia beds (1120)
emodnet_open:art17_hab_1170	2013 Article 17 reporting gridded Annex I habitat distribution - Reefs (1170)
emodnet_open:art17_hab_1110	2013 Article 17 reporting gridded Annex I habitat distribution - Sandbanks (1110)
emodnet_open:art17_hab_1180	2013 Article 17 reporting gridded Annex I habitat distribution - Submarine structures made by leaking gases (1180)
emodnet_open:habitat_point_eunis	Collated EUNIS Habitat point data - public records
emodnet_open:habitat_point	Collated Habitat point data - All classification systems, public records
emodnet_open:eusm2019_bio_full	EUSeaMap (2019) Biozone habitat descriptor - full detail
emodnet_open:eusm2019_ene_full	EUSeaMap (2019) Energy Class habitat descriptor - full detail
emodnet_open:eusm2019_subs_full	EUSeaMap (2019) Substrate habitat descriptor - full detail
emodnet_open:eusm2019_regions	EUSeaMap 2019 Regions
emodnet_open:habitat_point_bboxes	Habitat point data - dataset bounding boxes
emodnet_open:ospar_points	OSPAR threatened and/or declining habitats - Points
emodnet_open:ospar_overview	OSPAR threatened and/or declining habitats - Polygon Overview

emodnet_open:ospar_poly	OSPAR threatened and/or declining habitats - Polygons
emodnet_open:eov_livecoral	[eov_livecoral] Areal Extent of Live Hard Coral (Essential Ocean Variable)
emodnet_open:eov_macroalgae	[eov_macroalgae] Areal Extent of Macroalgal Canopy (Essential Ocean Variable)
emodnet_open:eov_seagrass	[eov_seagrass] Areal Extent of Seagrass Meadows (Essential Ocean Variable)

This is an `R6` class object and the `$` can be used to chain together several functions, much in the same way as the pipe operator `%>%`.

There are a couple ways you can search the available feature types. The following searches for the `polygon` layer within the OSPAR Threatened & Declining Habitats database:

```
emodnet_client$getCapabilities()$findFeatureTypeByName("emodnet_open:ospar_poly")$getDescription() %>%
    map_chr(function(x) {
        x$getName()
    })
```

```
##  [1] "gui"          "recordkey"    "habtype"      "habsubtype"   "habstatus"
##  [6] "certainty"    "determiner"   "detdate"      "surveykey"    "startdate"
## [11] "enddate"      "datetype"     "placename"    "dataowner"    "accuracy"
## [16] "althabtype"   "althabclas"   "althabrel"    "shape_length" "shape_area"
## [21] "geom"
```

As alternative approach, this time searching for the `point` OSPAR data:

```
emodnet_client$describeFeatureType(typeName = "emodnet_open:ospar_points") %>%
    map_chr(function(x) {
        x$getName()
    })
```

```
##  [1] "gui"          "recordkey"    "habtype"      "habsubtype"   "habstatus"
##  [6] "certainty"    "determiner"   "detdate"      "surveykey"    "startdate"
## [11] "enddate"      "datetype"     "placename"    "dataowner"    "accuracy"
## [16] "latitude"     "longitude"    "althabtype"   "althabclass"  "althabrel"
## [21] "shape"
```

We can also search by other feature types such as the EUSeaMap regions:

```
emodnet_client$getCapabilities()$findFeatureTypeByName("emodnet_open:eusm2019
_regions")$getDescription() %>%
    map_chr(function(x) {
        x$getName()
    })
```

```
## [1] "euseamap_r" "shape_leng" "shape_area" "geom"
```

Or `point` data from the EUNIS habitat database:

```
emodnet_client$getCapabilities()$findFeatureTypeByName("emodnet_open:habitat_
point_eunis")$getDescription() %>%
    map_chr(function(x) {
        x$getName()
    })
```

```
##  [1] "objectid"                          "measurementid"
##  [3] "eventid"                           "datasetid"
##  [5] "shorttitle"                        "expectedcitation"
##  [7] "restriction"                       "contactpoints"
##  [9] "eventdate"                         "mindepth"
## [11] "maxdepth"                          "seabedclassificationsystem"
## [13] "seabedclassificationsystem_uri"    "seabedtype"
## [15] "seabedtype_uri"                    "seabedstatus"
## [17] "samplingmethod"                    "samplingmethod_uri"
## [19] "seabedtypedetermineddate"          "seabedtypedeterminedmethod"
## [21] "sourcehabitatoccurrenceid"         "relationshiptosourcehabitat"
## [23] "comments"                          "geom"
## [25] "eventenddate"                      "eunis_l3"
```

Now we've found some layers matching our search, we now want to extract them. First, let's see what operations are available using the WFS:

```
emodnet_client$getCapabilities()$getOperationsMetadata()$getOperations() %>%
    map_chr(function(x) {
        x$getName()
    })
```

```
## [1] "GetCapabilities"       "DescribeFeatureType"   "GetFeature"
## [4] "GetPropertyValue"      "ListStoredQueries"     "DescribeStoredQueries
"
## [7] "CreateStoredQuery"     "DropStoredQuery"
```

The next chunk shows how we can extract the available output formats. We will see later that `GetFeature` is the operation needed to read or download data from the WFS. The metadata for this operation has what we want and we can extract it with a combination of `purrr::map()` and `purrr::pluck()`.

```
emodnet_client$getCapabilities()$getOperationsMetadata()$getOperations() %>%
    map(function(x) {
        x$getParameters()
    }) %>%
```

```
    pluck(3, "outputFormat")
##  [1] "application/gml+xml; version=3.2"
##  [2] "GML2"
##  [3] "KML"
##  [4] "SHAPE-ZIP"
##  [5] "application/json"
##  [6] "application/vnd.google-earth.kml xml"
##  [7] "application/vnd.google-earth.kml+xml"
##  [8] "csv"
##  [9] "gml3"
## [10] "gml32"
## [11] "json"
## [12] "text/xml; subtype=gml/2.1.2"
## [13] "text/xml; subtype=gml/3.1.1"
## [14] "text/xml; subtype=gml/3.2"
```

Some extra examples include: extracting the bounding boxes for all layers.

```
emodnet_client$getCapabilities()$getFeatureTypes() %>%
    map(function(x) {
        x$getBoundingBox()
    })
## [[1]]
##         min      max
## x -47.58017 41.95249
## y  24.81188 66.48150
##
## [[2]]
##         min      max
## x -24.26399 41.77421
## y  34.65221 66.48619
##
## [[3]]
##         min      max
## x -47.68894 42.30771
## y  26.94096 66.48399
##
## [[4]]
##         min      max
## x -37.06373 41.77421
## y  29.97137 66.44175
##
## [[5]]
##         min      max
## x -7.186059 37.02481
## y 32.452611 45.67816
##
## [[6]]
##         min      max
## x -51.12328 52.33401
```

```
## y  23.41187 66.33389
##
## [[7]]
##         min      max
## x -57.48689 59.53411
## y  23.10754 71.02764
##
## [[8]]
##         min      max
## x -34.14763 12.72759
## y  27.55606 60.78477
##
## [[9]]
##         min      max
## x -15.84686 29.59930
## y  34.89477 60.86076
##
## [[10]]
##         min      max
## x -15.84686 30.96407
## y  34.89477 60.86076
##
## [[11]]
##         min      max
## x -36.39353 43.10083
## y  22.06430 80.20107
##
## [[12]]
##         min      max
## x -25.34000 43.34000
## y  24.61456 81.09517
##
## [[13]]
##         min      max
## x -35.77074 41.40184
## y  27.94162 78.51768
##
## [[14]]
##         min      max
## x -36.39500 43.39500
## y  21.91587 81.09744
##
## [[15]]
##         min      max
## x -16.33373 31.51347
## y  36.21518 71.55264
##
## [[16]]
##         min      max
## x -26.15375 20.72628
```

```
## y  39.97409 70.23447
##
## [[17]]
##   min  max
## x -18 23.0
## y  36 72.5
##
## [[18]]
##         min      max
## x -14.11575 12.25857
## y  47.30682 60.87880
##
## [[19]]
##              min          max
## x  0.0003220005 0.0006506793
## y -0.0001562665 0.0001543668
##
## [[20]]
##              min          max
## x  3.234128e-04 0.0006328213
## y -9.500185e-05 0.0001869170
##
## [[21]]
##              min          max
## x  0.0002489462 0.0006332609
## y -0.0001554837 0.0003063432
```

Or, extracting the abstracts for each layer so that you can read the contents of the layer.

```
emodnet_client$getCapabilities()$getFeatureTypes() %>%
    map_chr(function(x) {
        x$getAbstract()
    })
##  [1] "Gridded distribution map for Annex I Coastal lagoons as reported by
EU member states for 2013 Habitats Directive Article 17 reporting. Available
from the European Environment Agency website at: https://www.eea.europa.eu/da
ta-and-maps/data/article-17-database-habitats-directive-92-43-eec-1#tab-metad
ata"
##  [2] "Gridded distribution map for Annex I Estuaries as reported by EU mem
ber states for 2013 Habitats Directive Article 17 reporting. Available from t
he European Environment Agency website at: https://www.eea.europa.eu/data-and
-maps/data/article-17-database-habitats-directive-92-43-eec-1#tab-metadata"
##  [3] "Gridded distribution map for Annex I Large shallow inlets and bays a
s reported by EU member states for 2013 Habitats Directive Article 17 reporti
ng. Available from the European Environment Agency website at: https://www.ee
a.europa.eu/data-and-maps/data/article-17-database-habitats-directive-92-43-e
ec-1#tab-metadata"
##  [4] "Gridded distribution map for Annex I Mudflats and sandflats not cove
red by seawater at low tide as reported by EU member states for 2013 Habitats
Directive Article 17 reporting. Available from the European Environment Agenc
```

```
y website at: https://www.eea.europa.eu/data-and-maps/data/article-17-database-habitats-directive-92-43-eec-1#tab-metadata"
##  [5] "Gridded distribution map for Annex I Posidonia beds as reported by EU member states for 2013 Habitats Directive Article 17 reporting. Available from the European Environment Agency website at: https://www.eea.europa.eu/data-and-maps/data/article-17-database-habitats-directive-92-43-eec-1#tab-metadata"
##  [6] "Gridded distribution map for Annex I Reefs as reported by EU member states for 2013 Habitats Directive Article 17 reporting. Available from the European Environment Agency website at: https://www.eea.europa.eu/data-and-maps/data/article-17-database-habitats-directive-92-43-eec-1#tab-metadata"
##  [7] "Gridded distribution map for Annex I sandbanks as reported by EU member states for 2013 Habitats Directive Article 17 reporting. \r\n\r\nAvailable from the European Environment Agency website at: https://www.eea.europa.eu/data-and-maps/data/article-17-database-habitats-directive-92-43-eec-1#tab-metadata"
##  [8] "Gridded distribution map for Annex I Submarine structures made by leaking gases as reported by EU member states for 2013 Habitats Directive Article 17 reporting. Available from the European Environment Agency website at: https://www.eea.europa.eu/data-and-maps/data/article-17-database-habitats-directive-92-43-eec-1#tab-metadata"
##  [9] "Fully open-access habitat point data from EMODnet Seabed Habitats collated point data where presented within the EUNIS habitat classification system.\r\n\r\nData can be filtered by EUNIS habitat in the \"seabedtype\" field, or using the web service vendor parameter \"hab_type\"."
## [10] "All downloadable habitat point data collated by EMODnet Seabed Habitats, presented per measurement with relevant sample method joined where possible."
## [11] "Biological zone at the seabed for various sea basins in Europe. Used as a habitat descriptor in the creation of the EMODnet broad-scale seabed habitat for Europe (EUSeaMap) 2019, as part of EMODnet Seabed Habitats. \r\n\r\n The extent of the mapped area includes the Mediterranean Sea, Black Sea, Baltic Sea, and areas of the North Eastern Atlantic extending from the Canary Islands in the south to the Barents Sea in the north.\r\n\r\nThe map was produced using a \"top-down\" modelling approach using classified habitat descriptors to determine a final output habitat.\r\n\r\nHabitat descriptors differ per region but include:\r\nBiological zone\r\nEnergy class\r\nOxygen regime\r\nSalinity regime\r\nSeabed substrate\r\nRiverine input\r\n\r\nHabitat descriptors (excepting Substrate) are calculated using underlying physical data and thresholds derived from statistical analyses or expert judgement on known conditions.\r\n\r\nThe model is produced using R and Arc Model Builder (10.1). \r\n \r\nThe model was created using raster input layers with a cell size of 0.00104dd (roughly 100 metres). The model includes the sublittoral zone only; due to the high variability of the littoral zone, a lack of detailed substrate data and the resolution of the model, it is difficult to predict littoral habitats at this scale.\r\n\r\nThis map follows the EUNIS 2007-11 classification system where it is appropriate. It has also been classified according to MSFD Benthic Broad Habitat types.\r\n\r\nThis report details the methods used in the previous version (v2016) - a new report is in progress:\r\nPopulus J. And Vasquez M. (Eds), 2017. EUSeaMap, a European broad-scale seabed habitat map.
```

Ifremer\r\nAvailable from: http://archimer.ifremer.fr/doc/00388/49975/"
[12] "Energy class at the seabed for various sea basins in Europe. Used as a habitat descriptor in the creation of the EMODnet broad-scale seabed habitat for Europe (EUSeaMap) 2019, as part of EMODnet Seabed Habitats. \r\n\r\nThe extent of the mapped area includes the Mediterranean Sea, Black Sea, Baltic Sea, and areas of the North Eastern Atlantic extending from the Canary Islands in the south to the Barents Sea in the north.\r\n\r\nThe map was produced using a \"top-down\" modelling approach using classified habitat descriptors to determine a final output habitat.\r\n\r\nHabitat descriptors differ per region but include:\r\nBiological zone\r\nEnergy class\r\nOxygen regime\r\nSalinity regime\r\nSeabed substrate\r\nRiverine input\r\n\r\nHabitat descriptors (excepting Substrate) are calculated using underlying physical data and thresholds derived from statistical analyses or expert judgement on known conditions. \r\n\r\nThe model is produced using R and Arc Model Builder (10.1). \r\n\r\nThe model was created using raster input layers with a cell size of 0.00104dd (roughly 100 metres). The model includes the sublittoral zone only; due to the high variability of the littoral zone, a lack of detailed substrate data and the resolution of the model, it is difficult to predict littoral habitats at this scale.\r\n\r\nThis map follows the EUNIS 2007-11 classification system where it is appropriate. It has also been classified according to MSFD Benthic Broad Habitat types.\r\n\r\nThis report details the methods used in the previous version (v2016) - a new report is in progress:\r\nPopulus J. And Vasquez M. (Eds), 2017. EUSeaMap, a European broad-scale seabed habitat map. Ifremer\r\nAvailable from: http://archimer.ifremer.fr/doc/00388/49975/"
[13] "Seabed substrate for various sea basins in Europe. Used as a habitat descriptor in the creation of the EMODnet broad-scale seabed habitat for Europe (EUSeaMap) 2019, as part of EMODnet Seabed Habitats. \r\n\r\nThe extent of the mapped area includes the Mediterranean Sea, Black Sea, Baltic Sea, and areas of the North Eastern Atlantic extending from the Canary Islands in the south to the Barents Sea in the north.\r\n\r\nThe map was produced using a \"top-down\" modelling approach using classified habitat descriptors to determine a final output habitat.\r\n\r\nHabitat descriptors differ per region but include:\r\nBiological zone\r\nEnergy class\r\nOxygen regime\r\nSalinity regime\r\nSeabed substrate\r\nRiverine input\r\n\r\nHabitat descriptors (excepting Substrate) are calculated using underlying physical data and thresholds derived from statistical analyses or expert judgement on known conditions.\r\n\r\nThe model is produced using R and Arc Model Builder (10.1). \r\n\r\nThe model was created using raster input layers with a cell size of 0.00104dd (roughly 100 metres). The model includes the sublittoral zone only; due to the high variability of the littoral zone, a lack of detailed substrate data and the resolution of the model, it is difficult to predict littoral habitats at this scale. \r\n\r\nThis map follows the EUNIS 2007-11 classification system where it is appropriate. It has also been classified according to MSFD Benthic Broad Habitat types.\r\n\r\nThis report details the methods used in the previous version (v2016) - a new report is in progress:\r\nPopulus J. And Vasquez M. (Eds), 2017. EUSeaMap, a European broad-scale seabed habitat map. Ifremer\r\nAvailable from: http://archimer.ifremer.fr/doc/00388/49975/"
[14] "The regions boundary layer shows the basins used to subset the modelling process used in the creation of the 2019 version of EMODnet broad-scale seabed habitat map for Europe (EUSeaMap 2019)."

```
## [15] "Bounding boxes for datasets within EMODnet Seabed Habitats' point da
ta collation."
## [16] "Points data from the 2018 OSPAR database of threatened and/or declin
ing habitats, compiled from OSPAR (Oslo Paris Convention) contracting parties
submission of listed habitats. For more information,, see https://www.ospar.o
rg/work-areas/bdc/species-habitats/mapping-habitats-on-the-ospar-list-of-thre
atened-or-declining-species-and-habitats."
## [17] "Overview grid (based on ICES sea squares) for the OSPAR polygon laye
r to show location of potentially small polygons at low zoom levels."
## [18] "Polygon data from the 2018 OSPAR database of threatened and/or decli
ning habitats, compiled from OSPAR (Oslo Paris Convention) contracting partie
s submission of listed habitats. For more information,, see https://www.ospar
.org/work-areas/bdc/species-habitats/mapping-habitats-on-the-ospar-list-of-th
reatened-or-declining-species-and-habitats."
## [19] "This layer shows the current known extent of Live Hard Coral in Euro
pean waters, collated by EMODnet Seabed Habitats. Lophelia pertusa and Coral
gardens are both on the OSPAR List of threatened and/or declining species and
habitats. The relevant habitats were extracted from the library of maps on th
e EMODnet Seabed Habitats portal and collated into one standardised shapefile
. This data product should be considered a work in progress and is not an off
icial product."
## [20] "This layer shows the current known extent of macroalgal forests in E
uropean waters, collated by EMODnet Seabed Habitats. Kelp and fucoid brown al
gae are the dominant species that comprise macroalgal forests. The relevant h
abitats were extracted from the library of maps on the EMODnet Seabed Habitat
s portal and collated into one standardised shapefile.  This data product sho
uld be considered a work in progress and is not an official product."
## [21] "This layer shows the current known extent of Seagrass meadows in Eur
opean waters, collated by EMODnet Seabed Habitats. Seagrasses provide essenti
al habitat and nursery areas for many marine fauna. There are approximately 7
2 seagrass species that belong to four major groups: Zosteraceae, Hydrocharit
aceae, Posidoniaceae and Cymodoceaceae. Zostera beds and Cymodecea meadows ar
e named on the OSPAR Threatened or Declining Habitats list. Posidonia beds ar
e protected under Annex I of the EU Habitats Directive. This data product sho
uld be considered a work in progress and is not an official product."
```

Read vector data

Now that we've queried the `WFS` metadata and seen what layers are available, we now want to extract a specific layer.

For this section, we'll focus on the OSPAR Threatened and/or Declining Habitats data, specifically the `point` data - `emodnet_open:ospar_points`.

Example 1: read an entire layer

Firstly we'll read in the entire layer and transform the coordinate reference system (`CRS`) to the geographic World Geodetic Sytem (`WGS84`, `EPSG:4326`).

```
url <- parse_url(wfs_main)

url$query <- list(service = "wfs",
                  #version = "2.0.0", # optional
                  request = "GetFeature",
                  typename = "emodnet_open:ospar_points",
                  srsName = "EPSG:3857" # Web mercator system
                  )

request <- build_url(url)

ospar_points <- st_read(request) %>%
  st_transform(4326) # Transform to WGS84 for easier plotting
```

```
## Reading layer `ospar_points' from data source `https://ows.emodnet-seabedh
abitats.eu/emodnet_open/wfs?service=wfs&request=GetFeature&typename=emodnet_o
pen%3Aospar_points&srsName=EPSG%3A3857' using driver `GML'
## Simple feature collection with 44511 features and 21 fields
## Geometry type: POINT
## Dimension:     XY
## Bounding box:  xmin: -4657062 ymin: 4179747 xmax: 2962121 ymax: 20036570
## Projected CRS: WGS 84 / Pseudo-Mercator
```

We can inspect the first 5 rows of the data using `head()`.

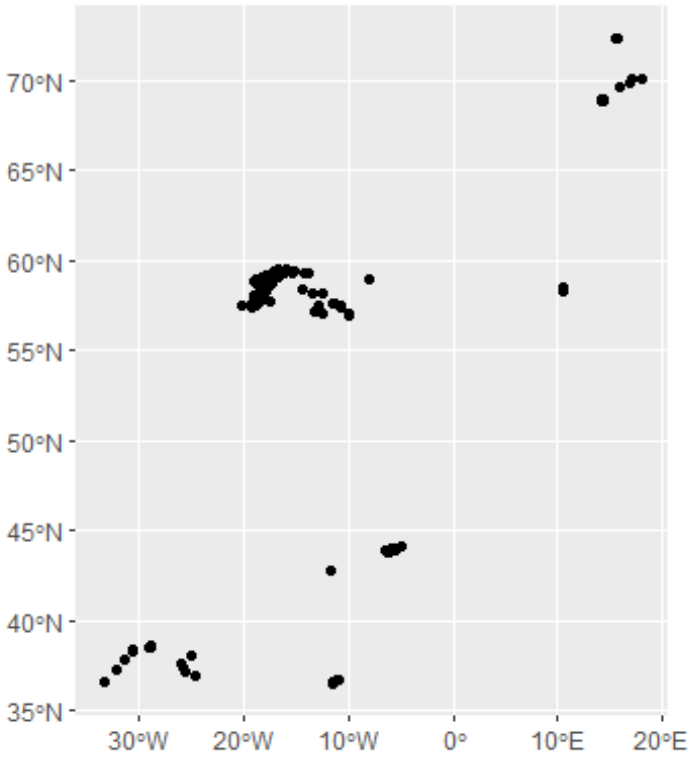
```
head(ospar_points)
```

gml_id	gui	recordkey	habtype	habsubtype	habstatus	certainty	determiner	detdate	survey key	start date
ospar_points.7	OSPARHab2010ES1v0	11000079	Lophelia pertusa reefs	Not applicable	Present	Uncertain	Max Wisshak & Andr, Freiwald / IPAL Erlangen	2006-01-01		
ospar_points.8	OSPARHab2010ES1v0	11000377	Lophelia pertusa reefs	Not applicable	Present	Uncertain	Max Wisshak & Andr, Freiwald / IPAL Erlangen	2006-01-01		1870-01-01
ospar_points.9	OSPARHab2010ES1v0	11000378	Lophelia pertusa reefs	Not applicable	Present	Uncertain	Max Wisshak & Andr, Freiwald / IPAL Erlangen	2006-01-01		1870-01-01
ospar_points.11	OSPARHab2010ES1v0	11000425	Lophelia pertusa reefs	Not applicable	Present	Uncertain	Max Wisshak & Andr, Freiwald / IPAL Erlangen	2006-01-01		1971-01-01
ospar_points.19	OSPARHab2010ES1v0	11001017	Lophelia pertusa reefs	Not applicable	Present	Uncertain	Max Wisshak & Andr, Freiwald / IPAL Erlangen	2006-01-01		1767-01-01
ospar_points.25	OSPARHab2010ES2v0	114	Lophelia pertusa reefs	Not applicable	Present	Uncertain				1967-01-01

end date	datetype	placename	dataowner	accuracy	latitude	longitude	althabtype	althabclass	althabrel	shape
	U				44	-5.57				c(-5.570799999899 67, 43.983300000219)
1870-12-31	Y	Iberian Shelf			36.5	-7.27				c(-7.266666999961 51, 36.483333000347 8)
1870-12-31	Y	Iberian Shelf			36.5	-7.27				c(-7.266666999961 51, 36.483333000347 8)
1971-12-31	Y	Iberian Shelf			36.3	-7.23				c(-7.231666999761 76, 36.288332999 8573)
1972-12-31	YY				43.6	-3.6				c(-3.600000000397 19, 43.596700000 0872)
1967-12-31	Y	T510	IFREMER		44	-6.98				c(-6.976666669651 42, 44.036666670 0299)

With the points read in, let's filter for any coral garden points and quickly visualise it using `ggplot2`:

```
ospar_points %>%
    filter(habtype %in% c("Coral gardens")) %>%
    ggplot() + geom_sf()
```



Example 2: filter by attributes

Whereas the previous example extracted a full layer from GeoServer, this example will add an attribute filter to return OSPAR habitats, specifically Coral Gardens, Seamounts and *Zostera* beds.

Filtering can be done using either the standard OGC filter specification or using a Common Query Language (CQL) filter. The OGC filtering approach is very verbose and prone to mistyping the filtering parameters. Hence, since EMODnet Seabed Habitats disseminates their data using GeoServer which supports CQL filtering, that's the approach we'll focus on.

In this example we also show how the previously used `R` code can be stitched together in a single command.

First let's remind ourselves what fields which we can filter by.

```
emodnet_client$getCapabilities()$findFeatureTypeByName("emodnet_open:ospar_po
ints")$getDescription() %>%
    map_chr(function(x) {
```

```
        x$getName()
    })
```

```
##  [1] "gui"         "recordkey"   "habtype"     "habsubtype"  "habstatus"
##  [6] "certainty"   "determiner"  "detdate"     "surveykey"   "startdate"
## [11] "enddate"     "datetype"    "placename"   "dataowner"   "accuracy"
## [16] "latitude"    "longitude"   "althabtype"  "althabclass" "althabrel"
## [21] "shape"
```

We can see that `habtype` field is the one we need to filter for our habitats of interest.

The CQL filter format is much more human readable and easier to code:

```
ospar_points_filtered <- wfs_main %>%
  parse_url() %>%
  list_merge(query = list(service = "wfs",
                          #version = "1.1.0", # optional
                          request = "GetFeature",
                          typeName = "emodnet_open:ospar_points",
                          srsName = "EPSG:3857",
                          cql_filter = glue::glue(
                            "habtype like 'Zos%'", # SQL-like wildcard filter
returning everything beginning with Zos (i.e. Zostera beds)
                          "or", # Add in the SQL `or` statement
                          "habtype like 'Coral%'", # wildcard filter returnin
g everything beginning with Coral
                          "or",
                          "habtype='Seamounts'",
                          .sep = " "
                          ))) %>%
  build_url() %>%
  read_sf() %>%
  st_transform(4326) #  Transform to same CRS

head(ospar_points_filtered)
```

gml_id	gui	recordkey	habtype	habsubtype	habstatus	certainty	determiner	detdate	survey key	start date
ospar_points.1318	OSPARHab2011ES1v1	111	Coral gardens	Not applicable	Present	Certain	Francisco Sanchez	2010-01-01	ES_1	2007-11-01
ospar_points.5008	OSPARHab2014ES1v2	1	Coral gardens	Not applicable	Present	Certain	IEO	2014-12-31	ES_ES1Surv1	2009-06-24
ospar_points.5009	OSPARHab2014ES1v2	10	Coral gardens	Not applicable	Present	Certain	IEO	2014-12-31	ES_ES1Surv1	2009-06-24
ospar_points.5010	OSPARHab2014ES1v2	11	Coral gardens	Not applicable	Present	Certain	IEO	2014-12-31	ES_ES1Surv1	2009-06-24
ospar_points.5011	OSPARHab2014ES1v2	12	Coral gardens	Not applicable	Present	Certain	IEO	2014-12-31	ES_ES1Surv1	2009-06-24
ospar_points.5012	OSPARHab2014ES1v2	13	Coral gardens	Not applicable	Present	Certain	IEO	2014-12-31	ES_ES1Surv1	2009-06-24

enddate	date type	placename	dataowner	accuracy	latitude	longitude	althab type	althab class	althab rel	shape
2009-12-31	Y	Cachucho Bank	Instituto Español de Oceanografía	50	44.1	-4.91				c(-4.9112000001444, 44.0811999998856)
2012-10-19	DD	Cañón de Avilés	IEO/FB	5	43.9	-6.45				c(-6.45019999986729, 43.9370999997054)
2012-10-19	DD	Cañón de Avilés	IEO/FB	5	43.7	-6.1				c(-6.09970000007428, 43.7316000002091)
2012-10-19	DD	Cañón de Avilés	IEO/FB	5	44	-5.91				c(-5.91340000038678, 44.0326000002397)
2012-10-19	DD	Cañón de Avilés	IEO/FB	5	43.9	-5.83				c(-5.82660000039447, 43.9450999998023)
2012-10-19	DD	Cañón de Avilés	IEO/FB	5	44	-5.83				c(-5.83134399981664, 43.9576799998068)

Note, you may find some datasets return the `geometry type` as a `MULTISURFACE` layer. This poses an issue for some `sf` functions, such as `st_buffer`, which do not work with this geometry. It's not necessarily an issue for what we're covering in this tutorial, but it's something to be aware of.

Example 3: bounding box filter

GeoServer is quite flexible in how it can provide data via `GetFeature` requests.

It is possible to query for features based on geometry. While there are limited options available in a GET request for spatial queries, filtering by bounding box (BBOX) is supported.

The BBOX parameter allows you to search for features that are contained (or partially contained) inside a box of user-defined coordinates. The format of the BBOX parameter is `bbox=x1,y1,x2,y2,[crs]` where `x1, y1, x2`, and `y2` represent the coordinate values. The optional `crs` parameter is used to name the CRS for the bbox coordinates (if they are different to the featureTypes native CRS.) The order of coordinates passed to the BBOX parameter depends on the coordinate system used.

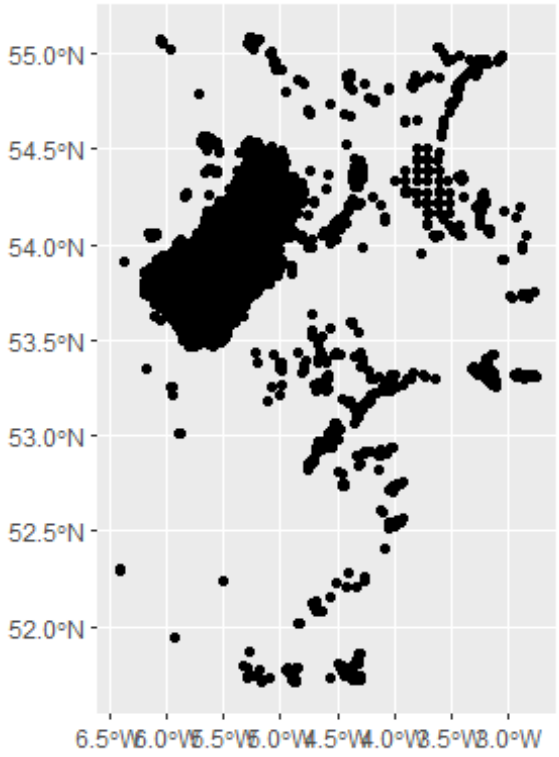
To specify the coordinate system for the returned features, append `srsName=CRS` to the WFS request, where CRS is the Coordinate Reference System you wish to use.

Below is an example request returning any points within the Irish Sea.

```
ospar_bbox_filter <- wfs_main %>%
  parse_url() %>%
  list_merge(query = list(service = "wfs",
                          #version = "1.1.0", # optional
                          request = "GetFeature",
                          typeName = "emodnet_open:ospar_points",
                          srsName = "EPSG:3857", # source CRS is projected, n
ot geographic
                          bbox = "-6.613770,51.713416,-2.746582,55.090944,EPS
G:4326" # bbox box with geographic CRS
                          )) %>%
  build_url() %>%
  read_sf() %>%
  st_transform(4326)
```

Now to quickly plot it.

```
ggplot(ospar_bbox_filter) + geom_sf()
```



This covers the majority of options applicable to EMODnet Seabed Habitats data, but for additional options to read in data from `WFS` services I would strongly recommend reading the previous tutorial listed above (here for reference)

Visualising data

Now that we've had a chance to read in some data let's make some nicer plots. This section will be using the `ospar_points_filtered` object we read in earlier, focusing on Coral Gardens, Seamounts & Zostera beds.

Read in global country data

To serve as reference points in our maps we'll need some country boundary data; this dataset is available from the `rnaturalearth` package. We'll extract the data and choose the appropriate scale. By default the function returns data of the `sp` class, but since we're working with `sf` data we'll specify this in one of the arguments.

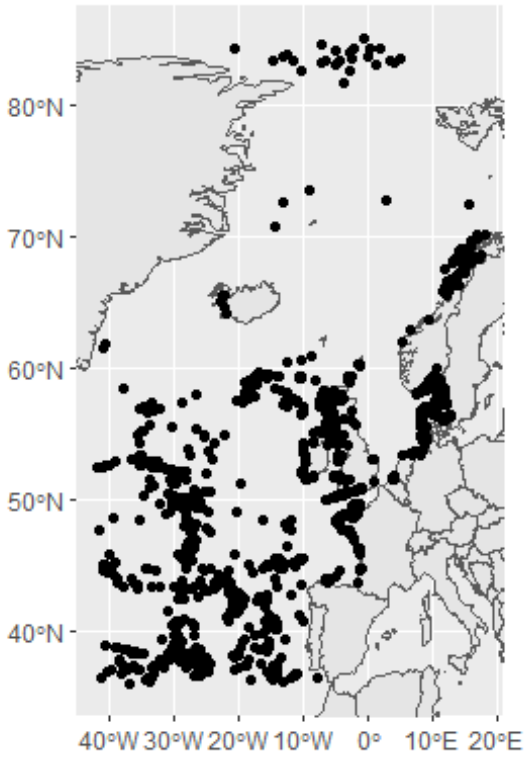
```
world <- ne_countries(scale = "medium", returnclass = "sf")

class(world)

## [1] "sf"         "data.frame"
```

Basic plot

Now we'll visualise our filtered OSPAR points alongside the world boundaries data. Since the extent of the map will by default show the entire world, we'll need to limit this

extent to the range of our OSPAR points. This can be done with the `coord_sf()` function, and we also set `expand = TRUE` to prevent the data and axes from overlapping.

```
ggplot() + geom_sf(data = world) + geom_sf(data = ospar_points_filtered) +
    coord_sf(xlim = st_bbox(ospar_points_filtered)[c(1, 3)],
        ylim = st_bbox(ospar_points_filtered)[c(2, 4)], expand = TRUE)
```



It's good to see that the points are plotting correctly, but since we didn't provided any map symbology (e.g. colours) it's difficult to tell where each habitat is.

Add symbologies

We'll now focus on how we can use the same map layer styles as the interactive mapper, therefore keeping any visualisations consistent with the EMODnet Seabed Habitats project. Here we'll extract the layer styles from GeoServer in an `xml` file format, which will be parsed using the `xmltools` package in a `tidy` format.

First, we'll need to set up a `url` request to the GeoServer `workspace` where all styles & symbologies are stored, which is on the Web Mapping Service `emodnet_view` workspace, or `WMS` for short.

Unfortunately, the `ows4R` package does not currently support `WMS` metadata harvesting, meaning we'll have to explore this manually. However, we can still build the `url` request:

```
wms_main <- "https://ows.emodnet-seabedhabitats.eu/emodnet_view/wms"

url <- parse_url(wms_main)
```

```
url$query <- list(service = "wms", version = "1.3.0", request = "GetCapabilit
ies")
request <- build_url(url)

request
```

```
## [1] "https://ows.emodnet-seabedhabitats.eu/emodnet_view/wms?service=wms&ve
rsion=1.3.0&request=GetCapabilities"
```

You can copy and paste the above `url` and enter it into your browser, or go directly to the `GetCapabilities` using this link. This will return a large `xml` data of all layers available on the `emodnet_view` workspace, their metadata, associated styles and so on.

To quickly find our layer style of interest, using `Ctrl + F` and search for `ospar_points`. We can see this brings up `4` results and is provided below.

```
htmltools::img(src = knitr::image_uri(here::here("figs", "ospar_getCapbilitie
s.PNG")))
```

Highlighted is information on the layer style, essentially the information we're need to capture. You can preview this style pasting the `xlink:href` attribute into your browser or by using this link.

So now we know the name of the style is `emodnet_view:ospar_points` (conveniently similar to our layer name!). We can download the style directly from the GeoServer instance using a `GetStyle` request. We'll store it as a temporary file.

```
tf <- tempfile(tmpdir = tdir <- tempdir(), fileext = ".xml")

download.file("https://ows.emodnet-seabedhabitats.eu/emodnet_view/wms?service
=wms&version=1.1.1&request=GetStyles&layers=emodnet_view:ospar_points",
    tf)
```

Let's read the `xml` file and view the `tree` structure.

```
doc <- xml2::read_xml(tf)

doc %>%
    xmltools::xml_view_tree()
```

```
## ++-- NamedLayer
##   +-- Name
##   ++-- UserStyle
##     +-- Name
##     +-- IsDefault
##     ++-- FeatureTypeStyle
##       +-- Name
##       +-- Rule
##         +-- Name
```

```
##         +-- Title
##         +-- Filter
##           ++-- PropertyIsEqualTo
##             +-- PropertyName
##             ++-- Literal
##         ++-- PointSymbolizer
##           ++-- Graphic
##             +-- Size
##             ++-- Mark
##               +-- WellKnownName
##               ++-- Fill
##                 ++-- CssParameter
##       +-- Rule
##         +-- Name
##         +-- Title
##         +-- Filter
##           ++-- PropertyIsEqualTo
##             +-- PropertyName
##             ++-- Literal
##         ++-- PointSymbolizer
##           ++-- Graphic
##             +-- Size
##             ++-- Mark
##               +-- WellKnownName
##               ++-- Fill
##                 ++-- CssParameter
##       +-- Rule
##         +-- Name
##         +-- Title
##         +-- Filter
##           ++-- PropertyIsEqualTo
##             +-- PropertyName
##             ++-- Literal
##         ++-- PointSymbolizer
##           ++-- Graphic
##             +-- Size
##             ++-- Mark
##               +-- WellKnownName
##               ++-- Fill
##                 ++-- CssParameter
##       +-- Rule
##         +-- Name
##         +-- Title
##         +-- Filter
##           ++-- PropertyIsEqualTo
##             +-- PropertyName
##             ++-- Literal
##         ++-- PointSymbolizer
##           ++-- Graphic
##             +-- Size
```

```
##             ++-- Mark
##               +-- WellKnownName
##               ++-- Fill
##                 ++-- CssParameter
##       +-- Rule
##         +-- Name
##         +-- Title
##         +-- Filter
##           ++-- PropertyIsEqualTo
##             +-- PropertyName
##             ++-- Literal
##         ++-- PointSymbolizer
##           ++-- Graphic
##             +-- Size
##             ++-- Mark
##               +-- WellKnownName
##               ++-- Fill
##                 ++-- CssParameter
##       +-- Rule
##         +-- Name
##         +-- Title
##         +-- Filter
##           ++-- PropertyIsEqualTo
##             +-- PropertyName
##             ++-- Literal
##         ++-- PointSymbolizer
##           ++-- Graphic
##             +-- Size
##             ++-- Mark
##               +-- WellKnownName
##               ++-- Fill
##                 ++-- CssParameter
##       +-- Rule
##         +-- Name
##         +-- Title
##         +-- Filter
##           ++-- PropertyIsEqualTo
##             +-- PropertyName
##             ++-- Literal
##         ++-- PointSymbolizer
##           ++-- Graphic
##             +-- Size
##             ++-- Mark
##               +-- WellKnownName
##               ++-- Fill
##                 ++-- CssParameter
##       +-- Rule
##         +-- Name
##         +-- Title
##         +-- Filter
```

```
##           ++-- PropertyIsEqualTo
##             +-- PropertyName
##             ++-- Literal
##         ++-- PointSymbolizer
##           ++-- Graphic
##             +-- Size
##             ++-- Mark
##               +-- WellKnownName
##               ++-- Fill
##                 ++-- CssParameter
##       +-- Rule
##         +-- Name
##         +-- Title
##         +-- Filter
##           ++-- PropertyIsEqualTo
##             +-- PropertyName
##             ++-- Literal
##         ++-- PointSymbolizer
##           ++-- Graphic
##             +-- Size
##             ++-- Mark
##               +-- WellKnownName
##               ++-- Fill
##                 ++-- CssParameter
##       +-- Rule
##         +-- Name
##         +-- Title
##         +-- Filter
##           ++-- PropertyIsEqualTo
##             +-- PropertyName
##             ++-- Literal
##         ++-- PointSymbolizer
##           ++-- Graphic
##             +-- Size
##             ++-- Mark
##               +-- WellKnownName
##               ++-- Fill
##                 ++-- CssParameter
##       +-- Rule
##         +-- Name
##         +-- Title
##         +-- Filter
##           ++-- PropertyIsEqualTo
##             +-- PropertyName
##             ++-- Literal
##         ++-- PointSymbolizer
##           ++-- Graphic
##             +-- Size
##             ++-- Mark
##               +-- WellKnownName
```

```
##                ++-- Fill
##                  ++-- CssParameter
##        +-- Rule
##          +-- Name
##          +-- Title
##          +-- Filter
##            ++-- PropertyIsEqualTo
##              +-- PropertyName
##              ++-- Literal
##          ++-- PointSymbolizer
##            ++-- Graphic
##              +-- Size
##              ++-- Mark
##                +-- WellKnownName
##                ++-- Fill
##                  ++-- CssParameter
##        +-- Rule
##          +-- Name
##          +-- Title
##          +-- Filter
##            ++-- PropertyIsEqualTo
##              +-- PropertyName
##              ++-- Literal
##          ++-- PointSymbolizer
##            ++-- Graphic
##              +-- Size
##              ++-- Mark
##                +-- WellKnownName
##                ++-- Fill
##                  ++-- CssParameter
##        +-- Rule
##          +-- Name
##          +-- Title
##          +-- Filter
##            ++-- PropertyIsEqualTo
##              +-- PropertyName
##              ++-- Literal
##          ++-- PointSymbolizer
##            ++-- Graphic
##              +-- Size
##              ++-- Mark
##                +-- WellKnownName
##                ++-- Fill
##                  ++-- CssParameter
##        ++-- Rule
##          +-- Name
##          +-- Title
##          +-- Filter
##            ++-- PropertyIsEqualTo
##              +-- PropertyName
```

```
##             ++-- Literal
##         ++-- PointSymbolizer
##           ++-- Graphic
##             +-- Size
##             ++-- Mark
##               +-- WellKnownName
##               ++-- Fill
##                 ++-- CssParameter
```

This gives a breakdown of the full tree structure, showing the attributes and elements used for styling an OSPAR record. We can see that the styling elements really begin at the `++-- FeatureTypeStyle` section of the tree, which is the 4th level of the tree.

What we need to do is extract the the `terminal nodes`, which are `elements` which do not have any `children`. These nodes contain the information we generally want to extract into a tidy dataframe.

To do this, we'll use the `xml_get_paths` function to find all feasible `xpaths` within the `xml` structure.

```
## we can find all feasible paths then collapse
## what we really want is the parent node of terminal nodes.
## use the `only_terminal_parent = TRUE` to do this

terminal_parent <- doc %>% ## get all xpaths to parents of parent node
  xml_get_paths(only_terminal_parent = TRUE)

terminal_xpaths <- terminal_parent %>% ## collapse xpaths to unique only
  unlist() %>%
  unique()

terminal_nodesets <- lapply(terminal_xpaths, xml2::xml_find_all, x = doc)
```

Now we have the nodesets, we can now extract the `xml` file to a tidy dataframe. As mentioned when we viewed the tree structure, we know that the nodes we are interested begin at the 4th level, so we'll extract from there until the last (8th) level..

```
ospar_styling <- terminal_nodesets[c(4:8)] %>%
    purrr::map(xml_dig_df) %>%
    purrr::map(dplyr::bind_rows) %>%
    dplyr::bind_cols() %>%
    janitor::clean_names() %>%
    dplyr::select(title:css_parameter)

head(ospar_styling)
```

title	property_name	literal	size	well_known_name	css_parameter

Carbonate mounds	habtype	Carbonate mounds	4	circle	#d3d3d3
Coral gardens	habtype	Coral gardens	7	star	#2ba67d
Deep-sea sponge aggregations	habtype	Deep-sea sponge aggregations	4	circle	#00ff00
Intertidal Mytilus edulis beds on mixed and sandy sediments	habtype	Intertidal Mytilus edulis beds on mixed and sandy sediments	4	circle	#49c2e2
Intertidal mudflats	habtype	Intertidal mudflats	4	circle	#b2393b
Littoral chalk communities	habtype	Littoral chalk communities	4	circle	#f3c4eb

Voila! We now have all the styling information we need for the `ospar_points` layer. A breakdown of the table attributes is below:

- `title` - the value which is displayed in the legend;
- `property_name` - the field name of the GeoSever layer relevant for setting the style (*Note*, we used this field earlier when we extracted the OSPAR data);
- `literal` - the literal `habtype` value that each style will be applied to;
- `size` - denotes the symbol size to be used when plotting;
- `well_known_name` - the specific symbol to be used when plotting;
- `css_parameter` - the hex value specifying the colour to use.

We'll now join this style to our filtered OSPAR points dataset that we read in earlier, giving us a single tidy `sf` object. We'll join the two objects by the `habtype` and `literal` column, which contain the exact free-text match of the OSPAR habitat.

```
ospar_points_complete <- ospar_points_filtered %>%
    left_join(ospar_styling, by = c(habtype = "literal"))

names(ospar_points_complete)
```

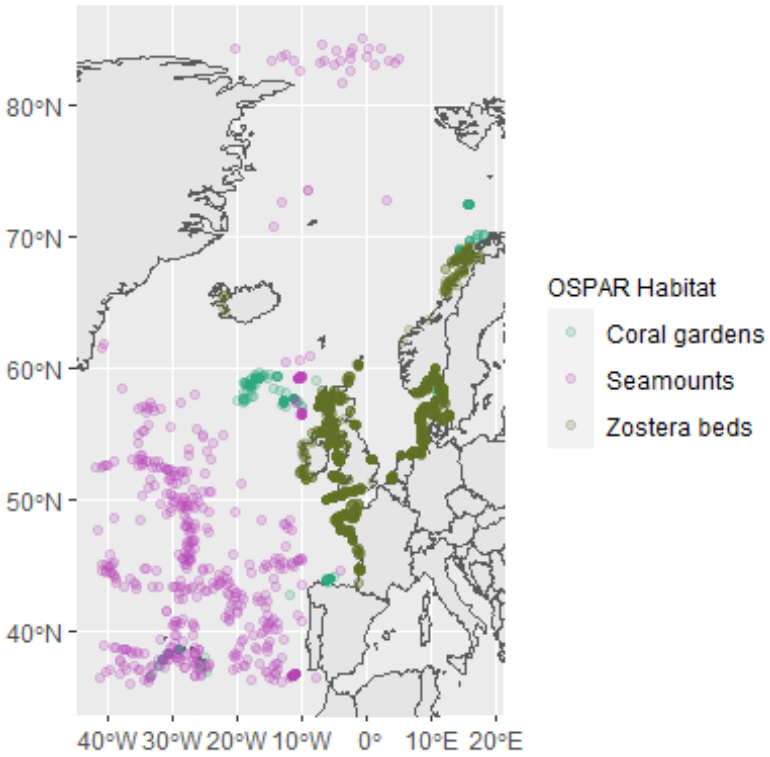
```
##  [1] "gml_id"          "gui"             "recordkey"       "habtype"
##  [5] "habsubtype"      "habstatus"       "certainty"       "determiner"
##  [9] "detdate"         "surveykey"       "startdate"       "enddate"
## [13] "datetype"        "placename"       "dataowner"       "accuracy"
## [17] "latitude"        "longitude"       "althabtype"      "althabclass"
```

```
## [21] "althabrel"       "shape"           "title"           "property_name"
## [25] "size"            "well_known_name" "css_parameter"
```

We can see that the styling columns have been appended to our `sf` object.

Now, let's visualise the points again with the correct stlying applied.

```
col_group <- as.character(ospar_points_complete$css_parameter) # Assign colou
r values to vector
names(col_group) <- as.character(ospar_points_complete$habtype) # Assign grou
ping names to vector

ggplot(data = world) +
  geom_sf() +
  geom_sf(data = ospar_points_complete,              # OSPAR points
          aes(color = habtype),
          alpha = 0.2) +                            # Legend item, point trans
parency
  scale_colour_manual(name = "OSPAR Habitat",        # Legend name
    values = col_group) +
  coord_sf(xlim = st_bbox(ospar_points_complete)[c(1, 3)],
           ylim = st_bbox(ospar_points_complete)[c(2, 4)],
           expand = TRUE) +
  theme(legend.title = element_text(size = 9))
```

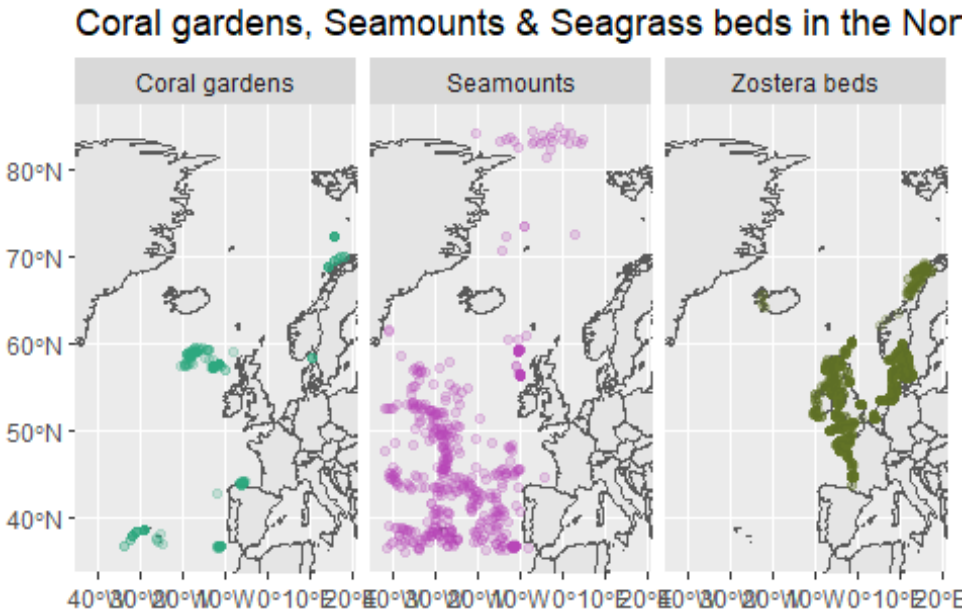


That's the colour sorted, and by adding a `alpha` argument to change the transparency this helps us to visualise clusters of points. However the map is still pretty busy and doesn't tell us much, so how can we improve this?

Facet maps

One way is to simply add in the `facet_wrap` argument, which will create a plot for each habitat using the same extents.

```
colour_scheme <- as.character(ospar_points_complete$css_parameter) # Assign c
olour values to vector
names(colour_scheme) <- as.character(ospar_points_complete$habtype) # Assign
grouping names to vector

ggplot() +
  geom_sf(data = world) +
  geom_sf(data = ospar_points_complete,
          aes(color = habtype),
          alpha = 0.2) +
  scale_colour_manual(values = colour_scheme) + # Specify OSPAR colour scale
  facet_wrap(~habtype) + # Create individual panel by habtype
  coord_sf(xlim = st_bbox(ospar_points_complete)[c(1, 3)],
          ylim = st_bbox(ospar_points_complete)[c(2, 4)],
          expand = TRUE) +
  ggtitle("Coral gardens, Seamounts & Seagrass beds in the Northeast Atlantic
") + # Add title
  guides(colour=FALSE) # Remove legend as not needed for this plot
```



We can see where there are clusters of each habitat. To provide more context we will create a series of inset maps for each habitat.

Inset maps

An inset map is a smaller map featured on the same page as the main map. Traditionally, inset maps are shown at a larger scale (smaller area) than the main map. Often, an inset map is used as a locator map that shows the area of the main map in a broader, more familiar geographical frame of reference.

Coastline data

The world coastlines from the `rnaturalearth::ne_countries()` dataset are very coarse and are only suitable for viewing at lower geographic scales. For the inset plots we will use a higher resolution coastline provided by the European Environment Agency.

```
temp_download <- tempfile()
temp_files <- tempfile()

# URL for coastline download saved into 'temp_download'
download.file("https://www.eea.europa.eu/data-and-maps/data/eea-coastline-for
-analysis-1/gis-data/europe-coastline-shapefile/at_download/file",
    temp_download, mode = "wb")

# unzip the contents in 'temp' and save unzipped content in
# 'temp_files'
unzip(zipfile = temp_download, exdir = temp_files)

# Find the filepath for the polygon dataset (i.e. 'poly.shp$'
# will string match that file)
coastline_file <- list.files(temp_files, pattern = "poly.shp$",
    full.names = TRUE)

# read to sf object and transform to WGS84
eu_coast_detailed <- sf::st_read(coastline_file) %>%
    st_transform(4326)
```

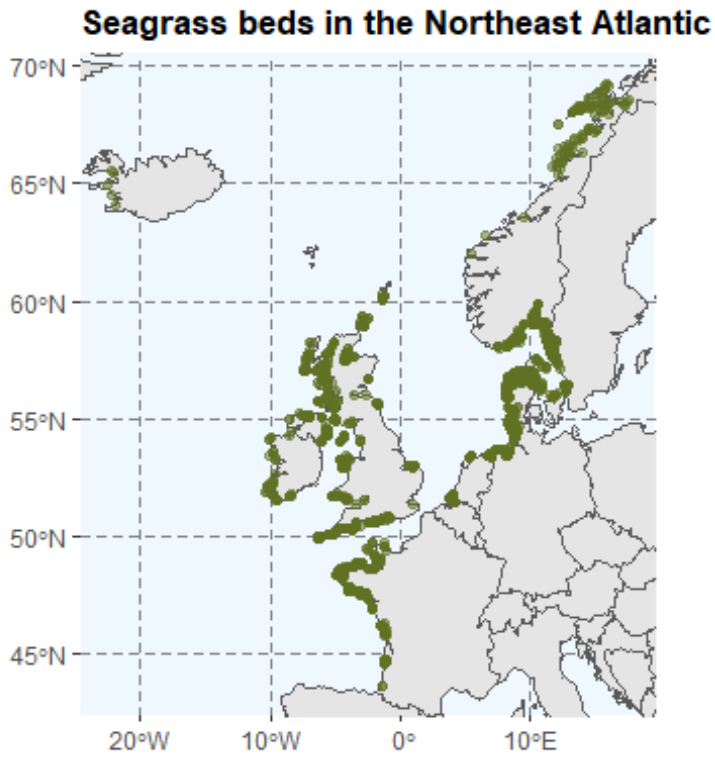
```
## Reading layer `Europe_coastline_poly' from data source `C:\Users\Harriet.A
llen\AppData\Local\Temp\RtmpQ9mWLY\file8706b2995f\Europe_coastline_poly.shp'
using driver `ESRI Shapefile'
## Simple feature collection with 71520 features and 1 field
## Geometry type: POLYGON
## Dimension:     XY
## Bounding box:  xmin: 943609.8 ymin: -375446 xmax: 7601958 ymax: 6825119
## Projected CRS: ETRS89-extended / LAEA Europe
```

Zostera basemap

Now with the extra data gathered, we'll now create the basemap map of *Zostera* beds observations, this is essentially the previous plot filtered for *Zostera* beds. In this example, we'll also make some changes the map background in the `theme()` function;

we'll change graticule lines to `dashed` and the background to `aliceblue` to show the marine areas.

```
# Create a zostera-only variable to use in mapping to the correct extent
ospar_zostera <- ospar_points_complete %>%
      filter(str_detect(habtype, "Zostera")) # Wildcard search for Zostera

zostera_colour <- as.character(ospar_zostera$css_parameter) # Assign colour v
alues to vector
names(zostera_colour) <- as.character(ospar_zostera$habtype) # Assign groupin
g names to vector

(gg_zostera <- ggplot() +
  geom_sf(data = world) + # Note: we use the world coastline data for broad v
isualisation
  geom_sf(data = ospar_zostera,
          aes(color = habtype),
          alpha = 0.5) +
  scale_colour_manual(values = zostera_colour) +
  coord_sf(xlim = st_bbox(ospar_zostera)[c(1, 3)],
          ylim = st_bbox(ospar_zostera)[c(2, 4)],
          expand = TRUE) +
    ggtitle("Seagrass beds in the Northeast Atlantic") + # Add title
  theme(plot.title = element_text(size = 13, face = "bold"),
        legend.position = "none", # Remove legend as it's not needed for thes
e plots
        panel.grid.major = element_line(color = gray(0.5), # Setting graticul
e lines to dashed
                                        linetype = "dashed",
                                        size = 0.5),
        panel.background = element_rect(fill = "aliceblue"))) # Background fi
ll is blue
```



From the above map, we can see that some interesting study areas could be:

- Isle of Arran, UK
- The Gulf of Morbihan, France
- Kattegat Straits

Location data

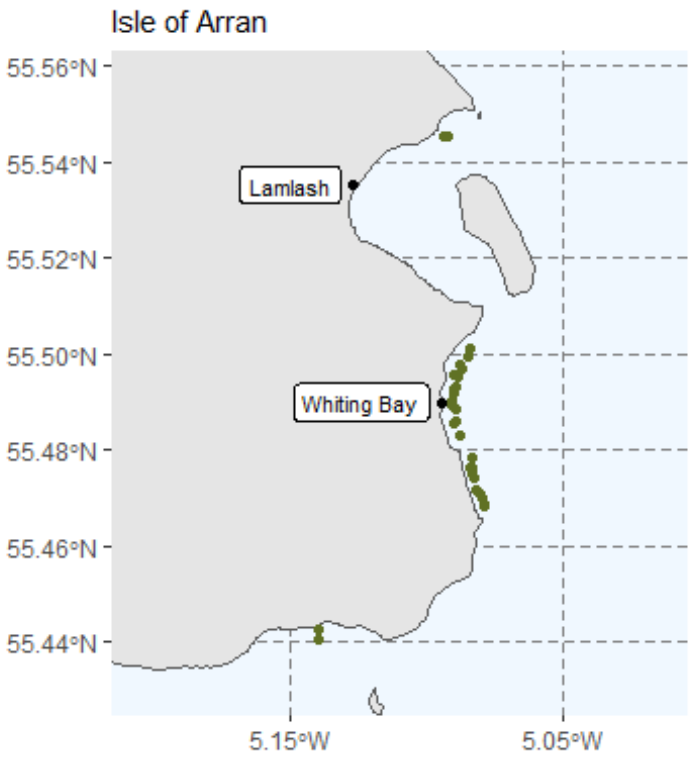
For study areas, we'll collate the coordinates of some nearby towns/cities to provide additional reference in the plots. This is done using the `geocode()` function from the `tidygeocoder` package. In this example we already know the locations so we can pass these directly to the function.

```
location_data <- tibble(location = c("Lamlash", "Whiting Bay", # Isle of Arra
n
                                     "Vannes", # Gulf of Morbihan locations
                                     "Gothenburg")) # Skagerrak locations

locations_sf <- location_data %>%
  tidygeocoder::geocode(city = location,
                        method = 'osm') %>%
  st_as_sf(coords = c("long", "lat"), crs = 4326) %>%
  mutate(lon = unlist(purrr::map(.$geometry, 1)), # Keep coords as explicit c
olumns
         lat = unlist(purrr::map(.$geometry, 2)))
```

Zostera inset maps

We'll focus on the Isle of Arran inset map first. To do this, we'll need to manually pass the lat/lon extents to the `coord_sf` function. We'll also add a title the plot denoting the region, provide the town/cities location as reference points via `ggrepel::geom_label_repel()` and use the `st_crop()` function on the EU coastline to speed up plotting.

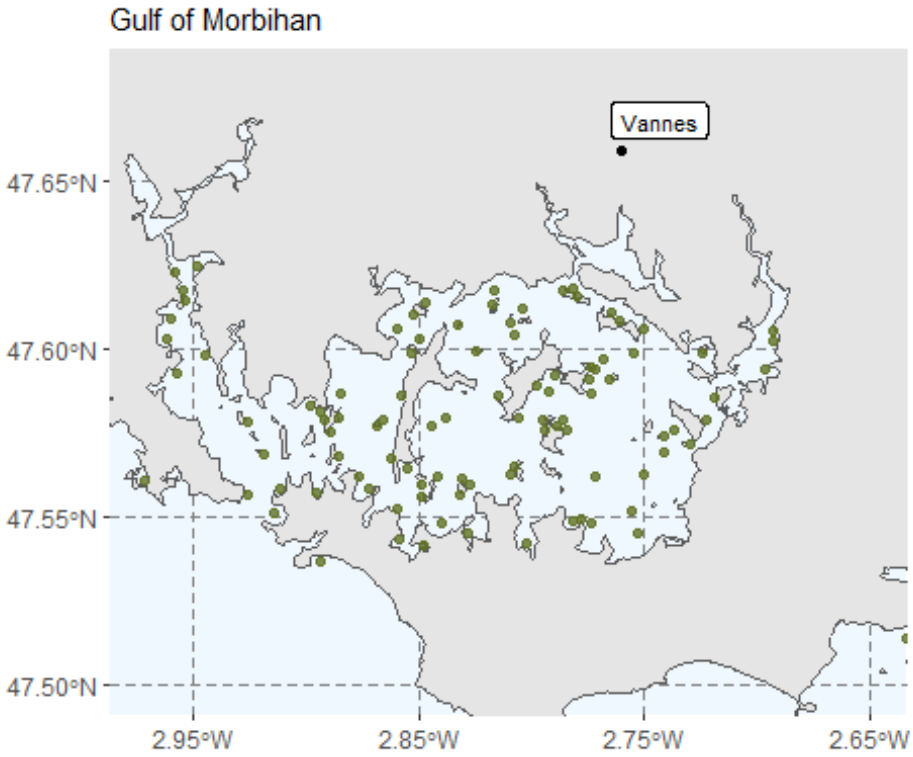
```
(gg_arran <- ggplot() +
    geom_sf(data = st_crop(eu_coast_detailed, # Speed up plotting
                           xmin = -6, ymin = 54,
                           xmax = -4, ymax = 57)) +
    geom_sf(data = ospar_zostera, aes(color = habtype), alpha = 1) + # Add Zo
stera points
    scale_colour_manual(values = zostera_colour) + # Add colour
    geom_sf(data = locations_sf %>% # Town point data
              filter(location %in% c("Lamlash", "Whiting Bay"))) +
    geom_label_repel(data = locations_sf %>% # Town labels
                       filter(location %in% c("Lamlash", "Whiting Bay")),
                     aes(x = lon, y = lat,
                         label = location),
                     size = 3,
                     fontface = "plain",
                     nudge_x = c(-0.02, -0.02), # Move along the x axis
                     nudge_y = c(0, 0)) + # Move along the y axis
    coord_sf(xlim = c(-5.206146, -5.013885),
             ylim = c(55.430962, 55.556602), expand = TRUE) +
    scale_x_continuous(breaks = c(-5.15, -5.05)) + # Set longitude breaks
    scale_y_continuous(breaks = c(55.44, 55.46, 55.48,
                                  55.50, 55.52, 55.54, 55.56)) + # Set latitu
de breaks
    ggtitle("Isle of Arran") +
    theme(legend.position = "none",
          plot.title = element_text(size = 11),
          axis.title.x  = element_blank(),
          axis.title.y = element_blank(),
          panel.grid.major = element_line(color = gray(0.5),
                                          linetype = "dashed",
                                          size = 0.5),
          panel.background = element_rect(fill = "aliceblue")))
```



Now repeat for the Gulf of Morbihan plot.

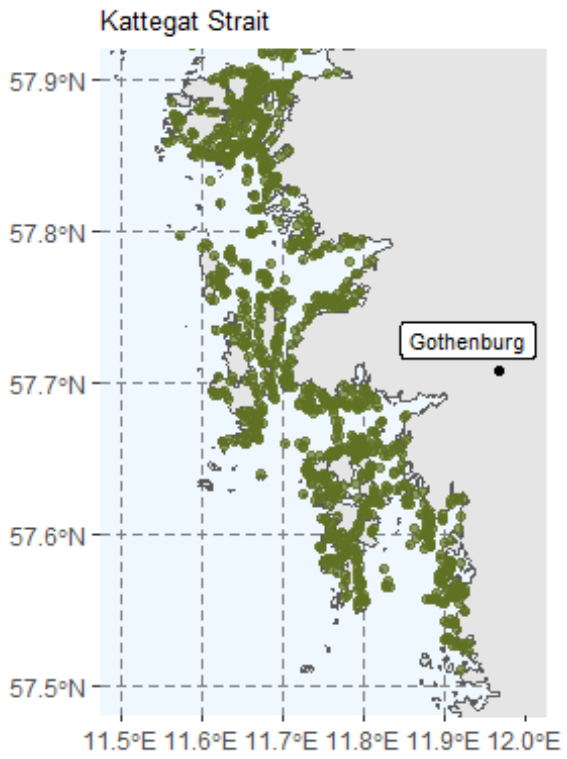
```
(gg_morbihan <- ggplot() +
    geom_sf(data = st_crop(eu_coast_detailed,
                           xmin = -5, ymin = 45,
                           xmax = -0, ymax = 49)) +
    geom_sf(data = ospar_zostera, aes(color = habtype), alpha = 0.8) +
    scale_colour_manual(values = zostera_colour) +
    geom_sf(data = locations_sf %>%
              filter(location %in% c("Vannes"))) +
    geom_label_repel(data = locations_sf %>%
                       filter(location %in% c("Vannes")),
                     aes(x = lon, y = lat,
                         label = location),
                     size = 3,
                     fontface = "plain",
                     nudge_x = c(0),
                     nudge_y = c(0)) +
    coord_sf(xlim = c(-2.97, -2.65), ylim = c(47.5, 47.68), expand = TRUE) +
    scale_x_continuous(breaks = c(-2.95, -2.85, -2.75, -2.65)) + # Set longit
ude breaks
    ggtitle("Gulf of Morbihan") +
    theme(legend.position = "none",
          plot.title = element_text(size = 11),
          axis.title.x  = element_blank(),
          axis.title.y = element_blank(),
          panel.grid.major = element_line(color = gray(0.5),
```

```
                                          linetype = "dashed",
                                          size = 0.5),
        panel.background = element_rect(fill = "aliceblue")))
```



And then the Kattegat plot.

```
(gg_kattegat <- ggplot() + geom_sf(data = st_crop(eu_coast_detailed,
    xmin = 9, ymin = 55, xmax = 14, ymax = 60)) + geom_sf(data = ospar_zostera,
    aes(color = habtype), alpha = 0.7) + scale_colour_manual(values = zostera_colour) +
    geom_sf(data = locations_sf %>%
        filter(location %in% c("Gothenburg"))) + geom_label_repel(data = locations_sf %>%
    filter(location %in% c("Gothenburg")), aes(x = lon, y = lat,
    label = location), size = 3, fontface = "plain", nudge_x = c(0),
    nudge_y = c(0.02)) + coord_sf(xlim = c(11.5, 12), ylim = c(57.5,
    57.9), expand = TRUE) + ggtitle("Kattegat Strait") + theme(legend.position = "none",
    plot.title = element_text(size = 10), axis.title.x = element_blank(),
    axis.title.y = element_blank(), panel.grid.major = element_line(color = gray(0.5),
        linetype = "dashed", size = 0.5), panel.background = element_rect(fill = "aliceblue")))
```



Before creating the final map, we need to create the arrows to show the position of each inset map relative to the position in the main map.

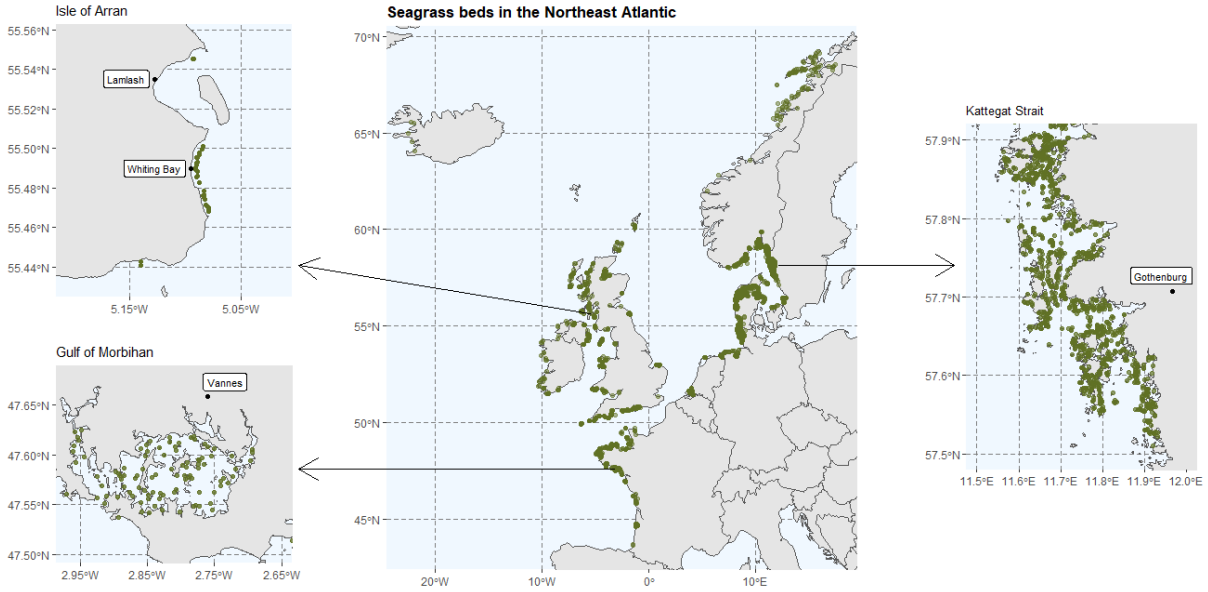
We can connect the three subplots to the main map using arrows which are passed through to the `geom_segment()` function. We'll create a `data.frame` storing the start and end point on the panel (`x1`, `x2` and `x3` on the x-axis, `y1`, `y2` and `y3` on the y-axis).

```
arran_arrow <- data.frame(x1 = 98, x2 = 50, y1 = 47, y2 = 55)

morbihan_arrow <- data.frame(x1 = 102, x2 = 50, y1 = 21.5, y2 = 21.5)

kattegat_arrow <- data.frame(x1 = 129, x2 = 158, y1 = 55, y2 = 55)
```

We can now create the final map. **Note** that we have set the background elements in the `theme()` argument to blank to ensure we only plot our `ggplot` objects.

```
ggplot() + coord_equal(xlim = c(0, 200), ylim = c(0, 100), expand = FALSE) +
    annotation_custom(ggplotGrob(gg_zostera), xmin = 31, xmax = 170,
        ymin = 1, ymax = 99) + annotation_custom(ggplotGrob(gg_arran),
    xmin = 1, xmax = 50, ymin = 45, ymax = 100) + annotation_custom(ggplotGro
b(gg_morbihan),
    xmin = 1, xmax = 50, ymin = 0, ymax = 45) + annotation_custom(ggplotGrob(
gg_kattegat),
    xmin = 152, xmax = 199, ymin = 0, ymax = 100) + geom_segment(aes(x = x1,
    y = y1, xend = x2, yend = y2), data = arran_arrow, arrow = arrow(),
    lineend = "round") + geom_segment(aes(x = x1, y = y1, xend = x2,
    yend = y2), data = morbihan_arrow, arrow = arrow(), lineend = "round") +
```

```
    geom_segment(aes(x = x1, y = y1, xend = x2, yend = y2), data = kattegat_a
rrow,
        arrow = arrow(), lineend = "round") + theme(axis.line = element_blank
(),
    axis.text.x = element_blank(), axis.text.y = element_blank(),
    axis.ticks = element_blank(), axis.title.x = element_blank(),
    axis.title.y = element_blank(), legend.position = "none",
    panel.background = element_blank(), panel.border = element_blank(),
    panel.grid.major = element_blank(), panel.grid.minor = element_blank(),
    plot.background = element_blank())
```



Further development

This was a first attempt at extracting EMODnet Seabed Habitats data. During the testing, some minor bugs were found.

Webscraping multiple city locations

The example provided in this tutorial focused on manually passing locations to the `tidygeocoder::geocode()` function. However, if you are wanting to gather coordinates for multiple locations, you can do so by scraping webpages and passing these to the `geocode()` function. Below is an example using the `rvest` and `purrr` packages, web scraping towns & cities for England, Sweden & Norway.

```
html.english_locations <- xml2::read_html("https://en.wikipedia.org/wiki/List
_of_cities_in_the_United_Kingdom")

df.english_locations <- html.english_locations %>% # Pass html file
  rvest::html_nodes("table") %>% # Extract table nodes
  .[c(1)] %>% # Tables of interest
```

```
  purrr::map_dfr(html_table) %>%
  filter(str_detect(`Nation/region`, "England")) %>% # Filter for cities in E
ngland only
  dplyr::select(1) %>%
  dplyr::mutate(`City[1]` =
                  stringr::str_replace_all(`City[1]`, # Some extra tidying us
ing regex to clean city name
                                           glue::glue("[:digit:]|", # Remove
all numbers
                                           "\\[|\\]|", # Remove square bracke
ts
                                           "\\s*\\([^\\)]+\\)"), # Remove all
text within parenthesis
                                           "")) %>%
  arrange(1) %>%
  drop_na()



html.swedish_locations <- xml2::read_html("https://en.wikipedia.org/wiki/List
_of_cities_in_Sweden")
df.swedish_locations <- html.swedish_locations %>%
  rvest::html_nodes("table") %>%
  .[c(2)] %>%
  purrr::map_dfr(html_table) %>%
  dplyr::select(1) %>%
    dplyr::mutate(`City` =
                  stringr::str_replace_all(`City`, # Some extra tidying using
regex to clean city name
                                           glue::glue("[:digit:]|", # Remove
all numbers
                                                      "\\[|\\]|", # Remove sq
uare brackets
                                                      "\\s*\\([^\\)]+\\)"), #
Remove all text within parenthesis
                                           "")) %>%
  arrange(1) %>%
  drop_na()

html.norwegian_locations <- xml2::read_html("https://en.wikipedia.org/wiki/Li
st_of_towns_and_cities_in_Norway")
df.norwegian_locations <- html.norwegian_locations %>%
  rvest::html_nodes("table") %>%
  .[c(1:3)] %>%
  purrr::map_dfr(html_table) %>%
  dplyr::select(1) %>%
  dplyr::mutate(`City/town` =
                  stringr::str_replace_all(`City/town`, # Some extra tidying
using regex to clean city name
                                           glue::glue("[:digit:]|", # Remove
```

```
all numbers
                                                    "\\[|\\]|", # Remove sq
uare brackets
                                                    "\\s*\\([^\\)]+\\)"), #
Remove all text within parenthesis
                                                "")) %>%
  arrange(1) %>%
  drop_na()

# Merge into single dataframe
webscraping_location_data <- list(df.english_locations,
                      df.swedish_locations,
                      df.norwegian_locations) %>%
  purrr::map(., setNames, "location") %>% # using purrr::map to set names of
dataframes to the same
  bind_rows() %>% # merge into a single object
  as_tibble()
```

With the locations in a single object, pass this to the `geocode()` function.

```
webscraping_locations_sf <- webscraping_location_data %>%
  tidygeocoder::geocode(city = location,
                        method = 'osm') %>%
  drop_na() %>%
  st_as_sf(coords = c("long", "lat"), crs = 4326) %>%
  mutate(lon = unlist(purrr::map(.$geometry, 1)), # Keep coords as explicit c
olumns
         lat = unlist(purrr::map(.$geometry, 2)))
```

We can now inspect the first 5 rows using `head()`.

```
head(webscraping_locations_sf)
```

location	geometry	lon	lat
Bath	c(-2.3596963, 51.3813864)	-2.36	51.4
Birmingham	c(-1.9026911, 52.4796992)	-1.9	52.5
Bradford	c(-1.7519186, 53.7944229)	-1.75	53.8
Bristol	c(-2.5972985, 51.4538022)	-2.6	51.5
Cambridge	c(0.139153737368744, 52.19758465)	0.139	52.2
Canterbury	c(1.0802533, 51.2800275)	1.08	51.3

And the last 5 rows using `tail()`.

```
tail(webscraping_locations_sf)
```

location	geometry	lon	lat
Tromsø	c(18.9543434, 69.649208)	19	69.6
Trondheim	c(10.3951929, 63.4305658)	10.4	63.4
Tønsberg	c(10.4080715, 59.2677363)	10.4	59.3
Vadsø	c(29.7827792993115, 70.22671985)	29.8	70.2
Vardø	c(30.9617519722659, 70.3308174)	31	70.3
Ålesund	c(6.1492684, 62.4728781)	6.15	62.5

You can now pass these coordinates to any plots similar to the above or perform additional analysis.

Extracting complex styles

Some styles, such as the Marine Strategy Framework Directive and Biozone habitat descriprtor, layers have specific polygon styles to make the features more distinguishable. These include polygons with strokes, graphic fills and hatching fills.

Complex polygon styling means the GeoServer styles have more nested layers and cannot be parsed easily.

```
# Download style files
## Make a temporary file (tf) and a temporary folder (tdir)
tf <- tempfile(tmpdir = tdir <- tempdir(), fileext = ".xml")

download.file("https://ows.emodnet-seabedhabitats.eu/emodnet_view/wms?service
=wms&version=1.1.1&request=GetStyles&layers=emodnet_view:eusm2019_bio_full",
              tf)

styles_doc <- xml2::read_xml(tf)

# Let's view the XML tree to understand the structure
styles_doc %>%
  xmltools::xml_view_tree()

## ++-- NamedLayer
##   +-- Name
##   +-- UserStyle
##     +-- Name
##     +-- IsDefault
##     ++-- FeatureTypeStyle
##       +-- Name
##       +-- Rule
```

```
##           +-- Name
##           +-- Title
##           +-- MaxScaleDenominator
##           +-- Filter
##             ++-- PropertyIsEqualTo
##               +-- PropertyName
##               ++-- Literal
##           ++-- PolygonSymbolizer
##             ++-- Fill
##               ++-- CssParameter
##         +-- Rule
##           +-- Name
##           +-- Title
##           +-- MaxScaleDenominator
##           +-- Filter
##             ++-- PropertyIsEqualTo
##               +-- PropertyName
##               ++-- Literal
##           ++-- PolygonSymbolizer
##             ++-- Fill
##               ++-- CssParameter
##         +-- Rule
##           +-- Name
##           +-- Title
##           +-- MaxScaleDenominator
##           +-- Filter
##             ++-- PropertyIsEqualTo
##               +-- PropertyName
##               ++-- Literal
##           ++-- PolygonSymbolizer
##             ++-- Fill
##               ++-- CssParameter
##         +-- Rule
##           +-- Name
##           +-- Title
##           +-- MaxScaleDenominator
##           +-- Filter
##             ++-- PropertyIsEqualTo
##               +-- PropertyName
##               ++-- Literal
##           ++-- PolygonSymbolizer
##             ++-- Fill
##               ++-- CssParameter
##         +-- Rule
##           +-- Name
##           +-- Title
##           +-- MaxScaleDenominator
##           +-- Filter
##             ++-- PropertyIsEqualTo
##               +-- PropertyName
```

```
##              ++-- Literal
##          ++-- PolygonSymbolizer
##            ++-- Fill
##              ++-- CssParameter
##        +-- Rule
##          +-- Name
##          +-- Title
##          +-- MaxScaleDenominator
##          +-- Filter
##            ++-- PropertyIsEqualTo
##              +-- PropertyName
##              ++-- Literal
##          ++-- PolygonSymbolizer
##            ++-- Fill
##              ++-- CssParameter
##        +-- Rule
##          +-- Name
##          +-- Title
##          +-- MaxScaleDenominator
##          +-- Filter
##            ++-- PropertyIsEqualTo
##              +-- PropertyName
##              ++-- Literal
##          ++-- PolygonSymbolizer
##            ++-- Fill
##              ++-- CssParameter
##        +-- Rule
##          +-- Name
##          +-- Title
##          +-- MaxScaleDenominator
##          +-- Filter
##            ++-- PropertyIsEqualTo
##              +-- PropertyName
##              ++-- Literal
##          ++-- PolygonSymbolizer
##            ++-- Fill
##              ++-- CssParameter
##        +-- Rule
##          +-- Name
##          +-- Title
##          +-- MaxScaleDenominator
##          +-- Filter
##            ++-- PropertyIsEqualTo
##              +-- PropertyName
##              ++-- Literal
##          ++-- PolygonSymbolizer
##            ++-- Fill
##              ++-- CssParameter
##        +-- Rule
##          +-- Name
```

```
##         +-- Title
##         +-- MaxScaleDenominator
##         +-- Filter
##           ++-- PropertyIsEqualTo
##             +-- PropertyName
##             ++-- Literal
##         ++-- PolygonSymbolizer
##           ++-- Fill
##             ++-- CssParameter
##       +-- Rule
##         +-- Name
##         +-- Title
##         +-- MaxScaleDenominator
##         +-- Filter
##           ++-- PropertyIsEqualTo
##             +-- PropertyName
##             ++-- Literal
##         ++-- PolygonSymbolizer
##           ++-- Fill
##             ++-- CssParameter
##       +-- Rule
##         +-- Name
##         +-- Title
##         +-- MaxScaleDenominator
##         +-- Filter
##           ++-- PropertyIsEqualTo
##             +-- PropertyName
##             ++-- Literal
##         ++-- PolygonSymbolizer
##           ++-- Fill
##             ++-- CssParameter
##       +-- Rule
##         +-- Name
##         +-- Title
##         +-- MaxScaleDenominator
##         +-- Filter
##           ++-- PropertyIsEqualTo
##             +-- PropertyName
##             ++-- Literal
##         ++-- PolygonSymbolizer
##           ++-- Fill
##             ++-- CssParameter
##       +-- Rule
##         +-- Name
##         +-- Title
##         +-- MaxScaleDenominator
##         +-- Filter
##           ++-- PropertyIsEqualTo
##             +-- PropertyName
##             ++-- Literal
```

```
##           ++-- PolygonSymbolizer
##             ++-- Fill
##               ++-- CssParameter
##         +-- Rule
##           +-- Name
##           +-- Title
##           +-- MaxScaleDenominator
##           +-- Filter
##             ++-- PropertyIsEqualTo
##               +-- PropertyName
##               ++-- Literal
##           ++-- PolygonSymbolizer
##             ++-- Fill
##               ++-- CssParameter
##         +-- Rule
##           +-- Name
##           +-- Title
##           +-- MaxScaleDenominator
##           +-- Filter
##             ++-- PropertyIsEqualTo
##               +-- PropertyName
##               ++-- Literal
##           ++-- PolygonSymbolizer
##             ++-- Fill
##               ++-- CssParameter
##         +-- Rule
##           +-- Name
##           +-- Title
##           +-- MaxScaleDenominator
##           +-- Filter
##             ++-- PropertyIsEqualTo
##               +-- PropertyName
##               ++-- Literal
##           ++-- PolygonSymbolizer
##             ++-- Fill
##               ++-- CssParameter
##         +-- Rule
##           +-- Name
##           +-- Title
##           +-- MaxScaleDenominator
##           +-- Filter
##             ++-- PropertyIsEqualTo
##               +-- PropertyName
##               ++-- Literal
##           ++-- PolygonSymbolizer
##             ++-- Fill
##               ++-- GraphicFill
##                 ++-- Graphic
##                   +-- Size
##                   ++-- Mark
```

```
## 10 +-- WellKnownName
## 10 ++-- Stroke
## 11 ++-- CssParameter
##       +-- Rule
##         +-- Name
##         +-- Title
##         +-- MaxScaleDenominator
##         +-- Filter
##           ++-- PropertyIsEqualTo
##             +-- PropertyName
##             ++-- Literal
##         ++-- PolygonSymbolizer
##           ++-- Fill
##             ++-- GraphicFill
##               ++-- Graphic
##                 +-- Size
##                 ++-- Mark
## 10 +-- WellKnownName
## 10 ++-- Stroke
## 11 ++-- CssParameter
##       +-- Rule
##         +-- Name
##         +-- Title
##         +-- MaxScaleDenominator
##         +-- Filter
##           ++-- PropertyIsEqualTo
##             +-- PropertyName
##             ++-- Literal
##         ++-- PolygonSymbolizer
##           ++-- Fill
##             ++-- GraphicFill
##               ++-- Graphic
##                 +-- Size
##                 ++-- Mark
## 10 +-- WellKnownName
## 10 ++-- Stroke
## 11 ++-- CssParameter
##       +-- Rule
##         +-- Name
##         +-- Title
##         +-- MaxScaleDenominator
##         +-- Filter
##           ++-- PropertyIsEqualTo
##             +-- PropertyName
##             ++-- Literal
##         ++-- PolygonSymbolizer
##           ++-- Fill
##             ++-- GraphicFill
##               ++-- Graphic
##                 +-- Size
```

```
##                 ++-- Mark
## 10 +-- WellKnownName
## 10 ++-- Stroke
## 11 ++-- CssParameter
##       +-- Rule
##         +-- Name
##         +-- Title
##         +-- MaxScaleDenominator
##         +-- Filter
##           ++-- PropertyIsEqualTo
##             +-- PropertyName
##             ++-- Literal
##         ++-- PolygonSymbolizer
##           ++-- Fill
##             ++-- GraphicFill
##               ++-- Graphic
##                 +-- Size
##                 ++-- Mark
## 10 +-- WellKnownName
## 10 ++-- Stroke
## 11 ++-- CssParameter
##       +-- Rule
##         +-- Name
##         +-- Title
##         +-- MaxScaleDenominator
##         +-- Filter
##           ++-- PropertyIsEqualTo
##             +-- PropertyName
##             ++-- Literal
##         ++-- PolygonSymbolizer
##           ++-- Fill
##             ++-- GraphicFill
##               ++-- Graphic
##                 +-- Size
##                 ++-- Mark
## 10 +-- WellKnownName
## 10 ++-- Stroke
## 11 ++-- CssParameter
##       +-- Rule
##         +-- Name
##         +-- Title
##         +-- MaxScaleDenominator
##         +-- Filter
##           ++-- PropertyIsEqualTo
##             +-- PropertyName
##             ++-- Literal
##         ++-- PolygonSymbolizer
##           ++-- Fill
##             ++-- GraphicFill
##               ++-- Graphic
```

```
##                 +-- Size
##                 ++-- Mark
## 10 +-- WellKnownName
## 10 ++-- Stroke
## 11 ++-- CssParameter
##       +-- Rule
##         +-- Name
##         +-- Title
##         +-- MaxScaleDenominator
##         +-- Filter
##           ++-- PropertyIsEqualTo
##             +-- PropertyName
##             ++-- Literal
##         ++-- PolygonSymbolizer
##           ++-- Fill
##             ++-- GraphicFill
##               ++-- Graphic
##                 +-- Size
##                 ++-- Mark
## 10 +-- WellKnownName
## 10 ++-- Stroke
## 11 ++-- CssParameter
##       ++-- Rule
##         +-- Name
##         +-- Title
##         +-- MaxScaleDenominator
##         +-- Filter
##           ++-- PropertyIsEqualTo
##             +-- PropertyName
##             ++-- Literal
##         ++-- PolygonSymbolizer
##           ++-- Fill
##             ++-- GraphicFill
##               ++-- Graphic
##                 +-- Size
##                 ++-- Mark
## 10 +-- WellKnownName
## 10 ++-- Stroke
##   ++-- UserStyle
##     +-- Name
##     +-- Title
##     +-- Abstract
##     ++-- FeatureTypeStyle
##       +-- Name
##       ++-- Rule
##         +-- Name
##         +-- Title
##         +-- Abstract
##         ++-- PolygonSymbolizer
##           +-- Stroke
```

```
##           ++-- Fill
##             ++-- CssParameter

styles_terminal_parent <- styles_doc %>% ## get all xpaths to parents of pare
nt node
  xml_get_paths(only_terminal_parent = TRUE)

styles_terminal_xpaths <- styles_terminal_parent %>% ## collapse xpaths to un
ique only
  unlist() %>%
  unique()
styles_terminal_nodesets <- lapply(styles_terminal_xpaths,
                           xml2::xml_find_all,
                           x = styles_doc)

# This code has been included for reference, but bugs have been found during
testing. Due to the more complex polygon styling of the GeoServer styles, sty
les_terminal_nodesets has nested layers of differing list lengths and cannot
be parsed easily. Some amendments to xml_dig_df and xml_to_df could address t
his issue.
biozone_parse <- styles_terminal_nodesets %>%
  purrr::map(xml_dig_df) %>% ## does not dig by default
  purrr::map(dplyr::bind_rows) %>%
  dplyr::bind_cols()

biozone_parse <- styles_terminal_nodesets[6][[1:17]] %>%   #select specifics
parts of the style
  purrr::map(xml_dig_df) %>% ## does not dig by default
  purrr::map(dplyr::bind_rows) %>%
  dplyr::bind_cols()
```