

Making figures for Fisk- och skaldjursöversikt i hav och sötvatten - resursöversikt in R

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Contents

1	Introduction	1
1.1	Why R?	1
1.2	Basic prerequisites	1
1.3	What do these scripts do?	2
1.4	How do I use this for my species?	2
2	Preparation	2
2.1	Load libraries	2
2.2	Load example data and clean it up!	3
2.3	Define <i>ggplot</i> theme	4
3	Let's start making figures!	5
3.1	Fig. 1. Single series	5
3.2	Fig. 2. Multiple series	6
3.3	Fig. 3. Multiple series, two y-axes	10
3.4	Fig. 4. Landings by country	12

1 Introduction

First, this is a first draft and a work in progress so any feedback on this document or the figures are highly appreciated! This document has been put together by Max Lindmark (K-lab), with code and input from Massimiliano Cardinale massimiliano.cardinale@slu.se (H-lab) and Martin Ogonowski martin.ogonowski@slu.se (Sö-lab). We are also the R-contact-persons for RoM work, so please send any questions to your corresponding lab-contact. And if it's a general R-question, please do also email the R-mailing list Aqua r-users aqua-r-users@slu.se.

These code snippets are aimed to be as generic as possible. However, because almost all non-assessed species have different data, there is no guarantee that the code will work straight from pdf with your species. Do give it a try if you feel adventurous, but if you get stuck don't hesitate contacting us!

1.1 Why R?

The main argument for using code to create RoM figures is to standardize them across species and to do so while limiting repetitive work (you only need to write a script once!).

1.2 Basic prerequisites

It is an advantage if you know some basic R. I strongly recommend using R-studio and working in a so called R-studio project (but it is not needed to reproduce this code). To create a project, open R-studio, click

File/New Project/New Directory and specify where you want to save it. Open the “*your_project_name*”.Rproj and click File/New Script and save that in your project folder. And that’s it! The best thing is that now all your search paths are relative and not absolute. If you want to read in data, put the data inside the project folder and you don’t have to specify the full search path (“C:/R/RoM/data-file.csv” or whatever), it’s enough you give the name of the file only (more on that below!). Another benefit with a relative search path is that I don’t have to worry about setting the working directory and changing the directory each time I try to rerun anyone elses script.

Lastly, this is an R Markdown document. This means R-code is text with grey background. You can copy these chunks of code to a new R-script in your R-studio project and run it from there.

1.3 What do these scripts do?

These scripts give an example of how you can use R to create standardized figures for RoM, and save them in a predefined, ready to be used without further editing.

I have chosen data for freshwater pike (*Esox lucious*) and Baltic turbot (*Scophthalmus maximus*) to illustrate how you can use this code, because it has all potential data for a RoM species (recreational, multiple areas, error bars, landings-by-country etc.). These data have been uploaded on github.

1.4 How do I use this for my species?

Most basic RoM figures that all species have in some form can be grouped into different categories. Each category will have its own script. Once you identify the best category for your species you should not have to modify the actual plotting code that much, as a minimum you only have to:

(1) Pre-define your variables (set y-axis names), (2) Prepare your data in the right format (see examples below and do the same for your species), (3) If a multi-series plot: put hash tags in front of stuff you don’t need! E.g. if you don’t have points to plot, make sure to put a hash tag before the `geom_point()`-function, which plots points. But do not worry! Instructions for how to do that will be in the described below!

The categories are:

- Fig. 1. Single series
- Fig. 2. Multiple series
- Fig. 3. Multiple series and y-axes
- Fig. 4. Landings-by-country

Once you know which plot-type you want, make sure you follow how the data should be structured in your csv-file, and load the theme (see “*Define ggplot theme*”).

2 Preparation

2.1 Load libraries

If you haven’t done it already, you can now open a new script (*File->New Script*) and copy paste code chunks into that. The first thing to do is to install a few packages (this might take a moment!):

```
rm(list = ls()) # clear the workspace from objects

# Provide package names
pkgs <- c("devtools",
          "ggplot2",
          "RCurl",
```

```

      "RCurl",
      "tidyr",
      "dplyr",
      "scales",
      "png",
      "knitr")

# Install packages if not installed
if (length(setdiff(pkgs, rownames(installed.packages()))) > 0) {
  install.packages(setdiff(pkgs, rownames(installed.packages())))
}

# Load all packages
invisible(lapply(pkgs, function(x) require(x, character.only = T, quietly = T)))

```

2.2 Load example data and clean it up!

Now let's read in the example data (freshwater pike):

```

# Go to https://github.com/maxlindmark/ROM to view the data in the browser
dat <- read.csv(
  text = getURL("https://raw.githubusercontent.com/maxlindmark/ROM/master/pike.csv"),
  sep = ";")

```

For your own species, the code would typically look like this if you put the data inside your R Project folder:

```

#dat <- read.csv("pike.csv", sep = ";")

```

Inspect the data. It is important that you use the same column names as I do here. “Year” is Year, “error_plus” and “error_minus” are min and max of the confidence interval of the response variable - if you have any, otherwise just type NA. “Group” is our grouping variable, typically different areas and response_variable could be biomass, cpue or abundance. You will specify the unit before plotting, so that everyone can use the same base code, irrespective of which data the species have.

```
head(dat)
```

```
##   Year error_plus error_minus      Group Response_variable
## 1 1997         NA         NA Stora sj<f6>arna          115
## 2 1998         NA         NA Stora sj<f6>arna          114
## 3 1999         NA         NA Stora sj<f6>arna          149
## 4 2000         NA         NA Stora sj<f6>arna          145
## 5 2001         NA         NA Stora sj<f6>arna          121
## 6 2002         NA         NA Stora sj<f6>arna          145
```

```

# list(dat) # This function shows all the data,
# for you to see the levels in the Group column

```

Importing data in the right format is often non-trivial. Here I show you how you can rename the levels of the column Group (i.e. the lake-names in this case). We do this because the beauty of *ggplot* is that all important information in the plot will be inherited from the data.

```

levels(dat$Group) <- c("Fritidsfiske",
                      "Hjälmaren",
                      "Mälaren",
                      "Stora sjöarna",
                      "Vänern",

```

```

      "Vättern")
head(dat)

##   Year error_plus error_minus      Group Response_variable
## 1 1997         NA         NA Stora sjöarna             115
## 2 1998         NA         NA Stora sjöarna             114
## 3 1999         NA         NA Stora sjöarna             149
## 4 2000         NA         NA Stora sjöarna             145
## 5 2001         NA         NA Stora sjöarna             121
## 6 2002         NA         NA Stora sjöarna             145

tail(dat)

```

```

##   Year error_plus error_minus      Group Response_variable
## 121 2012         NA         NA Fritidsfiske             NA
## 122 2013         NA         NA Fritidsfiske             NA
## 123 2014        223         77 Fritidsfiske             150
## 124 2015        184         82 Fritidsfiske             133
## 125 2016         NA         NA Fritidsfiske             NA
## 126 2017         NA         NA Fritidsfiske             NA

```

There is one last thing you might need to do with the data before proceeding with plotting, and that is to change the order of the levels in the data. When plotting, *ggplot* sets the levels of the data in alphabetical order, but here we want a specific order: the first “level” should correspond to the total and the last to any special level, such as the recreational data. This is how you would do that, just replace the levels with your own names.

```

dat$Group <- factor(dat$Group,
  levels = c("Stora sjöarna",
             "Vänern",
             "Vättern",
             "Mälaren",
             "Hjälmaren",
             "Fritidsfiske"))

```

Now the data look much better! You might not need to do these modification on your own data. **But you need** to make sure it is structured in the same way, that is: **1 row = 1 observation (not multiple columns for different areas)**

2.3 Define *ggplot* theme

Now that you have loaded and cleaned up your or the example data, we can move on with general plotting settings. First the color palette:

```

pal <- c("#56B4E9", "#009E73", "#F0E442", "#0072B2", "#E69F00", "#D55E00")

```

Second, we define the theme we will use for all plots. This is made to match as closely as possible to the RoM style. This applies to all figures styles.

```

theme_rom <- function(base_size = 12, base_family = "") {
  theme_bw(base_size = 12, base_family = "") +
    theme(
      axis.text = element_text(size = 8),
      axis.title = element_text(size = 8),
      axis.ticks.length = unit(0.05, "cm"),
      axis.line = element_line(colour = "black",

```

```

        size = 0.3),
text = element_text(family = "sans"),
panel.grid.major = element_blank(),
panel.grid.minor = element_blank(),
panel.border = element_blank(),
plot.title = element_text(hjust = 0.5,
                           margin = margin(b = -3),
                           size = 9.6,
                           face = "bold"),
legend.position = "bottom",
legend.text = element_text(size = 8),
legend.background = element_rect(fill = "transparent"),
legend.key = element_rect(fill = "transparent"),
legend.box.margin = margin(-25,-25,-25,-25),
aspect.ratio = 1,
plot.margin = unit(c(5.5, 5.5, 20, 5.5),
                    "points")
)
}

# And also replace points with commas in the plot
options(OutDec= ",")

```

You can also source the theme-function directly from github. That way you'll always have the latest version!

```

u<-c("https://raw.githubusercontent.com/maxlindmark/scaling/master/R/raincloud_plot.R")
script <- getURL(u, ssl.verifypeer = FALSE)

eval(parse(text = script))

```

3 Let's start making figures!

3.1 Fig. 1. Single series

For illustration purposes, we will now pretend our example pike data set only is a single series, by filtering it to only contain the area "Stora Sjöarna". If you have a "Fig.1 situation", your data might look something like this, with one column for year, one for area and one for tonnes.

```

dat1 <- dat %>%
  select(Year, Response_variable, Group) %>%
  filter(Group == "Stora sjöarna")

head(dat1)

```

```

##   Year Response_variable      Group
## 1 1997             115 Stora sjöarna
## 2 1998             114 Stora sjöarna
## 3 1999             149 Stora sjöarna
## 4 2000             145 Stora sjöarna
## 5 2001             121 Stora sjöarna
## 6 2002             145 Stora sjöarna

```

We now need to specify the **y-axis title**. For the pike data we can set them as:

```
y_axis <- c("Landningar (ton)")
```

Now go ahead and create the plot:

```
p1 <- ggplot(dat1, aes(Year, Response_variable)) +
  geom_bar(data = dat1,
    aes(x = Year, y = Response_variable),
    stat = "identity", color = pal[1], fill = pal[1],
    width = 0.6) +
  labs(x = "", y = y_axis) + # here's where the axis title is called
  guides(color = FALSE) +
  scale_x_continuous(expand = c(0, 0), breaks = scales::pretty_breaks(n = 6)) +
  scale_y_continuous(expand = c(0, 0), breaks = scales::pretty_breaks(n = 5)) +
  theme_rom() # here we call our predefined theme
```

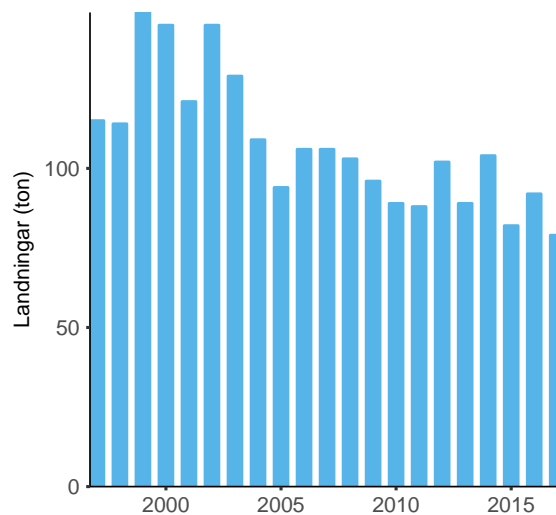


Figure 1: Gädde in the "Great Lakes" - example of a single-series plot using R

Save the file (to your working directory)

```
ggsave("Fig_1.tiff", plot = p1, dpi = 300, width = 8, height = 8, units = "cm")
```

3.2 Fig. 2. Multiple series

We now need to specify y-axis title, and in addition we need to define how many levels we have! For the pike data we can set them as:

```
y_axis <- c("Landningar (ton)")
main_series <- c("Stora sjöarna") # This is the sum of all other series
n_lev <- length(unique(dat$Group)) # Number of unique lakes
special_series <- c("Fritidsfiske") # This series must be drawn with points, so we need to
# separate it from the rest.
```

Note that we in this example use multiple data series, and that one of them is recreational fisheries that in turn has error bars. These need to be in columns, so that we have a high (error_plus) and

a low (error_minuss) column. Note also that they are NA when the Group is not equal to recreational fisheries

```
head(dat)
```

```
##   Year error_plus error_minus      Group Response_variable
## 1 1997         NA         NA Stora sjöarna             115
## 2 1998         NA         NA Stora sjöarna             114
## 3 1999         NA         NA Stora sjöarna             149
## 4 2000         NA         NA Stora sjöarna             145
## 5 2001         NA         NA Stora sjöarna             121
## 6 2002         NA         NA Stora sjöarna             145
```

```
tail(dat)
```

```
##   Year error_plus error_minus      Group Response_variable
## 121 2012         NA         NA Fritidsfiske             NA
## 122 2013         NA         NA Fritidsfiske             NA
## 123 2014        223         77 Fritidsfiske             150
## 124 2015        184         82 Fritidsfiske             133
## 125 2016         NA         NA Fritidsfiske             NA
## 126 2017         NA         NA Fritidsfiske             NA
```

And with that set, we can make the second figure, with multiple levels. The key to have a single legend is to have a layer that has all Groups. In this case it's the line. But we don't want all series to have lines (not the point or bar series). We can overcome this by setting those series to have full transparency. We control that in the `scale_alpha_manual()`-function. 0 means transparent and 1 is normal. The `override.aes` part in `guides()` makes sure this transparency is not inherited in the legend!

```
p2 <- ggplot(dat, aes(Year, Response_variable, color = Group)) +
  geom_bar(data = subset(dat, Group == main_series),
    aes(x = Year, y = Response_variable),
    stat = "identity", color = pal[1], fill = pal[1],
    width = 0.6) +
  geom_line(data = dat, aes(Year, Response_variable, color = Group, alpha = Group),
    size = 1) +
  geom_point(data = subset(dat, Group == special_series), # here we set our special series
    aes(Year, Response_variable, fill = Group),
    size = 2, color = pal[max(n_lev)]) +
  # above the number of level enters (max(n_lev))
  geom_errorbar(data = dat, aes(x = Year, ymin = error_minus, ymax = error_plus,
    color = Group),
    show.legend = FALSE, width = 1) +
  scale_alpha_manual(values = c(0, rep(1, (n_lev-2)), 0)) +
  scale_color_manual(values = pal[seq(1, n_lev)]) +
  # above we set the line between rec fisheries transparent
  labs(x = "", y = y_axis) +
  guides(fill = FALSE,
    alpha = FALSE,
    color = guide_legend(nrow = 3,
      title = "",
      override.aes = list(size = 1.3,
        color = pal[seq(1, n_lev)]),
      keywidth = 0.3,
      keyheight = 0.1,
      default.unit = "inch")) +
```

```
scale_x_continuous(expand = c(0, 0), breaks = scales::pretty_breaks(n = 6)) +
scale_y_continuous(expand = c(0, 0), breaks = scales::pretty_breaks(n = 5)) +
theme_rom()
```

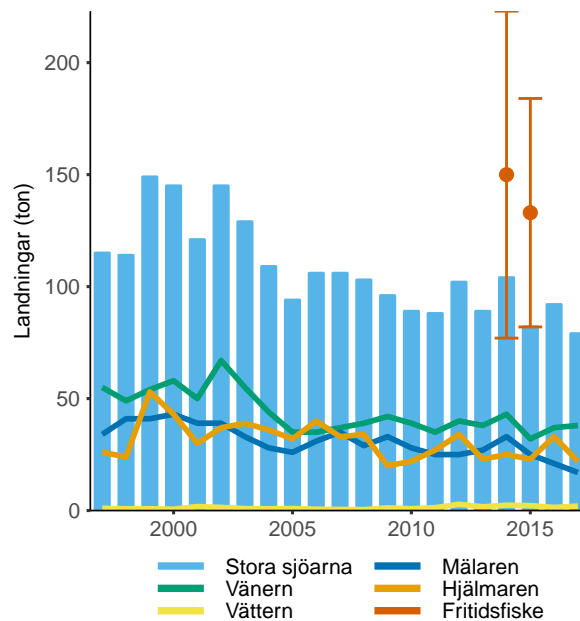


Figure 2: Gädda in the Great Lakes - example of a multiple-series plot using R

Now save the file (to your working directory)

```
ggsave("Fig_2.tiff", plot = p2, dpi = 300, width = 8, height = 8, units = "cm")
```

Let's say that you have 3 different areas and no special series and no error bars. Then you simply need to hash tag the code the plots those features. We subset the full data to select only the total and lake Mälaren as an example:

```
dat2 <- dat %>%
  select(Year, Response_variable, Group) %>%
  filter(Group %in% c("Stora sjöarna", "Mälaren"))
```

We now need to update the number of levels in the data:

```
n_lev <- length(unique(dat2$Group))
```

Repeat the general Fig. 2 plot, but remove the points and error bars using hashtags. (see also changes to `scale_alpha_manual(!)`)

```
p2a <- ggplot(dat2, aes(Year, Response_variable, color = Group)) +
  geom_bar(data = subset(dat2, Group == main_series),
```



```

    aes(x = Year, y = Response_variable),
    stat = "identity", color = pal[1], fill = pal[1],
    width = 0.6) +
  geom_line(data = dat2, aes(Year, Response_variable, color = Group, alpha = Group), # remove alpha = G
    size = 1) +
  #geom_point(data = subset(dat, Group == special_series), # here we define our special series
  #    aes(Year, Response_variable, fill = Group), size = 2, color = pal[max(n_lev)]) +
  #geom_errorbar(data = dat, aes(x = Year, ymin = error_minus, ymax = error_plus,
  #    color = Group),
  #
  #    show.legend = FALSE, width = 1) +
  scale_alpha_manual(values = c(0, 1)) +
  scale_color_manual(values = pal[seq(1, n_lev)]) +
  labs(x = "", y = y_axis) +
  guides(fill = FALSE,
    alpha = FALSE,
    color = guide_legend(nrow = 3,
      title = "",
      override.aes = list(size = 1.3,
        color = pal[seq(1, n_lev)]),
      keywidth = 0.3,
      keyheight = 0.1,
      default.unit = "inch")) +
  scale_x_continuous(expand = c(0, 0), breaks = scales::pretty_breaks(n = 6)) +
  scale_y_continuous(expand = c(0, 0), breaks = scales::pretty_breaks(n = 5)) +
  theme_rom()

```

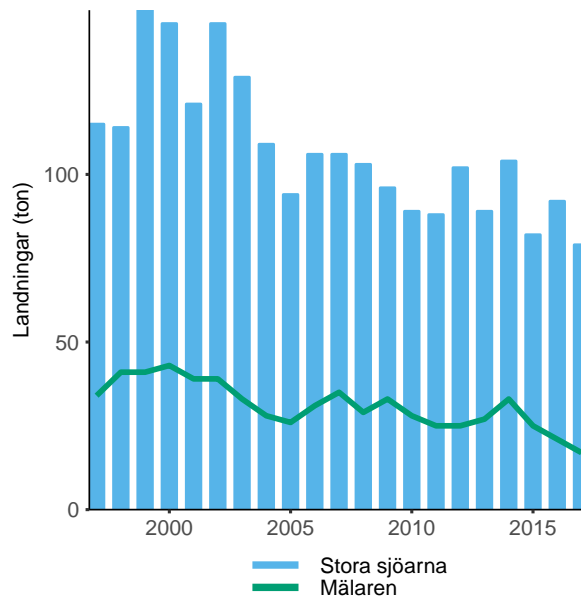


Figure 3: Gädda in the Great Lakes - example of a multiple-series plot using R

3.3 Fig. 3. Multiple series, two y-axes

In some cases, you may be forced to plot different series on two different axes, e.g. when you have things in different units (landings and an index perhaps). Using the pike-data set, we will invent such a scenario treating the “Fritidsfiske” as if on a different unit.

```
## Increase the value of Fritidsfiske:
dat3 <- dat
dat3$Response_variable <- ifelse(dat3$Group == "Fritidsfiske",
                                dat3$Response_variable * 100,
                                dat3$Response_variable)

## And the errorbars...
dat3$error_minus <- dat3$error_minus * 100
dat3$error_plus <- dat3$error_plus * 100

# Define plot settings again
y_axis <- c("Landningar (ton)")
y_axis2 <- c("Fångst per ansträngning (antal/timme)") # 2nd axis title
main_series <- c("Stora sjöarna") # This is the sum of all other series
n_lev <- length(unique(dat3$Group)) # Number of unique lakes
special_series <- c("Fritidsfiske") # This series must be drawn with points, so we need to
# separate it from the rest.
```

```
# Define temporary maximum of primary y-axis
max_yax <- max(na.omit(subset(dat3, Group == main_series))$Response_variable,
               na.omit(subset(dat3, Group == special_series))$error_plus/100)*1.1
```

And with that set, we can make the second figure, with multiple levels. Hashtag `geom_point` and `geom_errorbar` as these are no longer on the same scale.

```
p3 <- ggplot(dat3, aes(Year, Response_variable, color = Group)) +
  geom_bar(data = subset(dat3, Group == main_series),
           aes(x = Year, y = Response_variable), stat = "identity",
           color = pal[1], fill = pal[1],
           width = 0.6) +
  geom_line(data = dat3, aes(Year, Response_variable, color = Group, alpha = Group),
           size = 1) +
#geom_point(data = subset(dat, Group == special_series), # here we set our special series
#           aes(Year, Response_variable, fill = Group), size = 2, color = pal[max(n_lev)]) +
#geom_errorbar(data = dat, aes(x = Year, ymin = error_minus, ymax = error_plus,
#                           color = Group),
#           show.legend = FALSE, width = 1) +
  scale_alpha_manual(values = c(0, rep(1, (n_lev-2)), 0)) +
  scale_color_manual(values = pal[seq(1, n_lev)]) +
  labs(x = "", y = y_axis) +
  guides(fill = FALSE,
         alpha = FALSE,
         color = guide_legend(nrow = 3,
                              title = "",
                              override.aes = list(size = 1.3,
                                                    color = pal[seq(1, n_lev)]),
                              keywidth = 0.3,
                              keyheight = 0.1,
                              default.unit = "inch")) +
  scale_x_continuous(expand = c(0, 0), breaks = scales::pretty_breaks(n = 6)) +
  scale_y_continuous(expand = c(0, 0),
                    limits = c(0, max_yax), breaks = scales::pretty_breaks(n = 5)) +
  theme_roman()
```

Now the trick is to first transform the variable that is to be plotted on the second y-axis to a similar scale, and then reset the scale to the original values::

```
p3f <- p3 +
  geom_point(data = subset(dat3, Group == special_series),
            aes(Year, Response_variable/100), size = 1, color = pal[max(n_lev)]) +

  geom_errorbar(data = subset(dat3, Group == special_series),
               aes(x = Year, ymin = (error_minus/100), ymax = (error_plus/100),
                  color = Group), show.legend = FALSE, width = 1) +

  scale_y_continuous(sec.axis = sec_axis(~.*100, name = y_axis2),
                    expand = c(0, 0), breaks = scales::pretty_breaks(n = 5),
                    limits = c(0, max_yax)) +
  theme(axis.title.y.right = element_text(angle = 90)) # make direction of 2nd axis
```

```
## Scale for 'y' is already present. Adding another scale for 'y', which
## will replace the existing scale.
```

```
# title same as 1st!
```

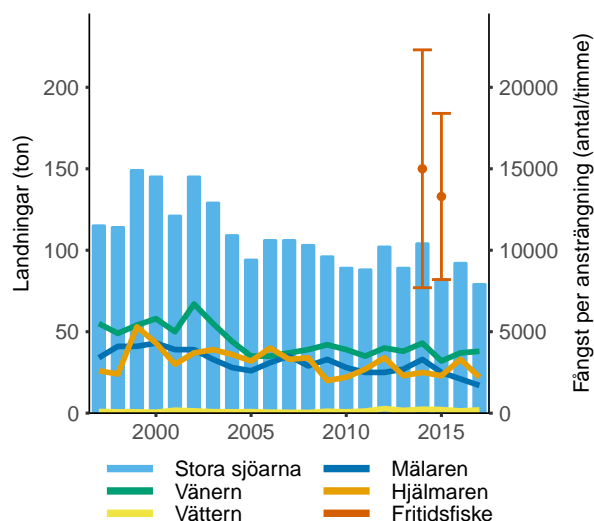


Figure 4: Gädda in the Great Lakes with secondary y-axes- example of a multiple-series plot using R

Now save the file (to your working directory)

```
ggsave("Fig_3.tiff", plot = p3f, dpi = 300, width = 8, height = 8, units = "cm")
tail(dat3)
```

This is not a very straightforward plot to make. First you need to manually find a value that scales the different units so they become close (see above when making p3f). When scaling back you need to verify all the data-points are within the plot range (which now is manual! By default it's based on your data but we need to bypass that). Also, in order to inherit the legend, we need at least one geom with all data we want in the legend. This is `geom_line` in the above case. In order to not get a gigantic primary y-axis, we set it manually and simply plot the series that is on a different scale outside the plot window. So, many things to keep in mind when/if adapting this code to your data!

3.4 Fig. 4. Landings by country

For this example, we will use Baltic turbot data:

```
u<-c("https://raw.githubusercontent.com/maxlindmark/ROM/master/Landingsbycountry_Baltic_Turbot.csv")
tur <- read.csv(
  text = getURL(u),
  sep = ";")
```

```
head(tur)
```

```
##   Year Danmark Estland Finland Lettland Litauen Polen Sverige Tyskland
## 1 1965    0,001    0,001    0,001    0,001    0,001 0,001    0,001    42
## 2 1966   37,000    0,001    0,001    0,001    0,001 0,001    0,001    58
## 3 1967   34,000    0,001    0,001    0,001    0,001 0,001    0,001    17
## 4 1968   32,000    0,001    0,001    0,001    0,001 0,001    0,001    70
## 5 1969   26,000    0,001    0,001    0,001    0,001 0,001    0,001    61
## 6 1970   24,000    0,001    0,001    0,001    0,001 0,001    2,000    45
##   Ryssland Andra.l.e4.nder   FishStock   Swedishname
## 1    0,001              0,001 tur.27.22-32 Piggvar i <d6>stersj<f6>n
## 2    0,001              0,001 tur.27.22-32 Piggvar i <d6>stersj<f6>n
## 3    0,001              0,001 tur.27.22-32 Piggvar i <d6>stersj<f6>n
## 4    0,001              0,001 tur.27.22-32 Piggvar i <d6>stersj<f6>n
## 5    0,001              0,001 tur.27.22-32 Piggvar i <d6>stersj<f6>n
## 6    0,001              0,001 tur.27.22-32 Piggvar i <d6>stersj<f6>n
```

```
# Rename column
```

```
tur <- tur %>% rename("Andra länder" = "Andra.l.e4.nder")
```

```
# Make data long (1 row, 1 observation)
```

```
tur_l <- tur %>% gather(land, landningar, 2:11, na.rm = TRUE)
```

```
# Show total tonnes by country
```

```
tur_l %>%
  group_by(land) %>%
  summarize(tot_land = sum(landningar)) %>%
  arrange(desc(tot_land))
```

```
## # A tibble: 10 x 2
##   land      tot_land
##   <chr>      <dbl>
## 1 Danmark    7136.
## 2 Polen     5287.
## 3 Tyskland   3295
## 4 Sverige   2224.
## 5 Ryssland   649.
## 6 Litauen    466.
## 7 Lettland   365.
## 8 Andra länder 0.053
## 9 Estland    0.053
## 10 Finland   0.053
```

```
# We will only plot the top 5 countries and the total. Other countries will
# be regrouped to "Andra länder"
```

```
unique(tur_l$land)
```

```
## [1] "Danmark"      "Estland"      "Finland"      "Lettland"
## [5] "Litauen"      "Polen"        "Sverige"      "Tyskland"
## [9] "Ryssland"     "Andra länder"
```

```
tur_l$land <- ifelse(tur_l$land %in% c("Litauen",
                                       "Lettland",
                                       "Estland",
                                       "Finland"),
```

```

      "Andra länder",
      tur_l$land)

unique(tur_l$land)

## [1] "Danmark"      "Andra länder" "Polen"        "Sverige"
## [5] "Tyskland"     "Ryssland"

```

We now need to specify the **y-axis title**. For the turbot landings data we can set them as:

```
y_axis <- c("Landningar (1000 ton)")
```

Now go ahead and create the plot:

```

p4 <- ggplot(tur_l, aes(x = Year, y = landningar/1000, fill = land)) +
  geom_bar(stat = "identity") +
  labs(x = "", y = y_axis) +
  scale_fill_manual(values = pal) +
  labs(x = NULL) +
  scale_x_continuous(expand = c(0,0)) +
  scale_y_continuous(expand = c(0,0)) +
  guides(fill = guide_legend(nrow = 2,
                             title = "",
                             keywidth = 0.1,
                             keyheight = 0.03,
                             default.unit = "inch"))) +

  theme_rom() +
  theme(legend.box.margin = margin(-15,-15,-15,-15)) # Note we here overwrite
                                                    # the default in the RoM-theme

```

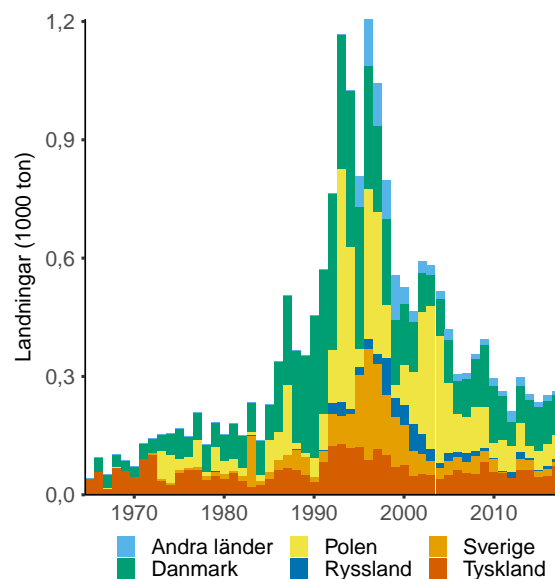


Figure 5: Landings of turbot in the Baltic Sea - example of a landings-by-country plot using R

Save the file (to your working directory)

```
ggsave("Fig_4.tiff", plot = p4, dpi = 300, width = 8, height = 8, units = "cm")
```