ICES/PROBYFISH WORKSHOP ON IDENTIFICATION OF TARGET AND BYCATCH SPECIES (WKTARGET)

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ICES/PROBYFISH WORKSHOP ON IDENTIFICATION OF TARGET AND BYCATCH SPECIES (WKTARGET)

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ICES
CIEM

International Council for
the Exploration of the Sea

Conseil International pour
l'Exploration de la Mer

Contents

i Executive summary

This ICES workshop was planned and arranged in collaboration with the EU project ProByFish, from the EASME tender EASME/EMFF/2017/022.

"Target species" and "bycatch species" are common denominations in fisheries. However, while these concepts make qualitative sense for describing mixed fisheries, they are difficult to define quantitatively and the allocation of one species into one or another category remain largely subjective, and may vary from fisheries to fisheries, or even from trip to trip. There are no established and standardized method to define these concepts objectively.

The objective of the workshop was thus to provide a scientifically based categorization of the different species in the catch according to the degree to which they are targeted by the fishery ("target", "hybrid", "valued bycatch" and "collateral bycatch") and to provide a tool which can be used to provide a quick overview of the importance of a given species as target, valued bycatch and collateral bycatch in different fleets.

The necessary analysis is based on catch data (including wanted and unwanted catches i.e. former landings and discards) as most of the collateral bycatch does not appear in the landings statistics. The analyses are performed at the finest possible scale to avoid any false technical interaction created by data aggregation.

The Workshop focused on developing methods, based on trip data, to identify "target", "hybrid", "valued bycatch" and "collateral bycatch" for each of the areas Bay of Biscay, Celtic Sea, English Channel, and North Sea, and the degree to which these stocks are concentrated across fleets, métier's, subareas and seasons.

ii Expert group information

Expert group name	ICES/Probyfish Workshop on identification of target and bycatch species (WKTARGET)
Expert group cycle	Annual
Year cycle started	2019
Reporting year in cycle	1/1
Chair	Youen Vermard, France
Meeting venue and dates	10–11 January 2019, Nantes, France (13 participants)

iii Term of reference

Term of reference	Addressed in this report
a) Assess data from observer trips and on catches by métier as available in the RDBES and their possible use in the following analyses.	Yes
b) Apply common procedures based on RDBES formats to assign stocks to the four catch categories target, valuable bycatch, collateral bycatch and hybrid species in each métier and integrate this to a status at fleet level.	Yes
c) Apply common procedures to assess the annual proportion landed of each stock at métier and fleet level.	Yes
d) Develop a method to visualize data on the distribution of stocks across catch categories within métier, fleets and management area.	Yes

1 Methods to classify species either "target", "valued bycatch", and "collateral bycatch"

1.1 Introduction

The entire analysis is based on input data containing information on catch composition in weight, value, and effort, formatted according to the RDB format http://www.ices.dk/marine-data/Documents/RDB/RDB%20Exchange%20Format.pdf. The analyses were though not applied directly on the RDB database, but were run individually by the scientists from the various member states on their national data, and only the outcomes were shared for conveying global patterns and trends.

Three types of categories were defined, with simple and intuitive separation of concepts:

- **Target species** would represent species that are valuable for the fishery. They would likely be seldom discarded over the minimum landing size and would represent a large share of the landings value.
- **"Collateral bycatch"** would mean species that have no importance for the fisheries. They are almost systematically discarded
- **"Valued bycatch"** would **represent** species in between these two categories. They might still be discarded frequently (at least more frequently than a target species) but may still represent a non-negligible share of the landings value

Several assumptions are however made when formulating the definitions as above.

1. These definitions do not take into account the dynamics of catch over the year. For instance, a target species can be discarded (or not sold) as soon as the TAC for that species is reached.
2. We assume a discarding behaviour at the scale of the fishing operation, that weakly accounts for highgrading.
3. Species are considered independent and no link with other caught species is taken into account in this definition

These definitions are based on discards and landing in value at the scale of the fishing operation (haul or net setting). Discard observations are not available in logbooks data and furthermore declarations in logbooks (when no e-logbook is available) are grouped at the scale of the fishing sequence (a sequence of fishing operations). Consequently, the only suitable dataset to identify the category of a species is catch observations collected by observers in board.

The main drawbacks of onboard observations are 1) the small number of observed trips leading to a limited spatial and seasonal coverage of catch dynamics and 2) possible bias in discarding behavior (volunteer vessels and observers onboard), which may not be representative of the .

1.2 Data

Sampling design for observing discards is theoretically stratified by métier Level 5 (gear-target species group-area) and operated by fishing trip during which at least one third of fishing operations is observed. For each fishing operation observed onboard, catches per species are reported into two parts, catches that are landed and sold, and catches that are discarded. In each part, catches are sampled and total catches estimated by length class in weight and in number.

The dataset includes 2013–2018 observer data by country in the standardized RGDB format (REF).

To compute landings in value, prices per kilo for each species are extracted from the sale dataset.

Given the available data, species-category can be defined at the scale of the métier for each region. Countries share a common definition of métiers at DCF level 5. However, catches are rather heterogeneous within a métier in a region, and for operational management reasons, it is more suitable to look at data by métiers according to their gear and mesh-size only (Level 4).

The exchange format used throughout the analysis is a table T_1 by country, by DCF level 4 métier and by ICES division, with a species observation at the scale of the fishing operation in row, and in columns several descriptors (vessel, trip, date, geographical position, landed catch, discarded catch…).

1.3 Method

A four-step method is proposed to derive a category for each species caught by each métier for each country in a region (Figure 1.1). The statistical unit considered in this analysis is the observation of species catch at the scale of the fishing operation (species-fishing operation, *SFO*).

First, an exploratory analysis of this dataset is performed to identify species that are systematically discarded and never landed. These species are therefore directly classified in the collateral species.

Second, a set of metrics are computed for the remaining species. These have been identified as potential descriptors for separating the three catch categories, according to the postulated definitions above.

The list of metrics is:

- proportion of the species catch in the total catch: $Pc_{i,j} = \frac{L_{i,j}+D_{i,j}}{\sum_{i=1}^{n} L_{i,j}+D_{i,j}}$,
- proportion of the species discard in the total catch: $Pd_{i,j} = \frac{D_{i,j}}{\sum_{i=1}^{n} L_{i,j}+D_{i,j}}$,
- proportion of the species discard in the total discards: $Pdd_{i,j} = \frac{D_{i,j}}{\sum_{i=1}^{n} D_{i,j}}$,
- proportion of the species landing in the total catch: $Pl_{i,j} = \frac{L_{i,j}}{\sum_{i=1}^{n} L+L_{i,j}+D_{i,j}}$
- proportion of the species landing in the total landings: $Pll_{i,j} = \frac{L_{i,j}}{\sum_{i=1}^{n} L_{i,j}}$
- proportion of the species landings in the total landings in value: $Pv_{i,j} = \frac{Lv_{i,j}}{\sum_{i=1}^{n} Lv_{i,j}}$
- proportion of the landings in this species catches: $Pll_{i,j} = \frac{L_{i,j}}{\sum_{j=1}^{m} L_{i,j}+D_{i,j}}$
- proportion of the discards in this species catches: $Pll_{i,j} = \frac{D_{i,j}}{\sum_{j=1}^{m} L_{i,j}+D_{i,j}}$
- the species $i \in [[1; n]]$ in the haul $j \in [[1; m]]$,
- $L_{i,j}$ the landing weight of the species i in the haul j,
- $V_{i,j}$ the landing value (in euro) of the species i in the haul j,
- $D_{i,j}$ the discard weight of the species i in the haul j,

A new table T_2 is derived with a species observation at the scale of the fishing operation in row, and in columns the computed metrics.

Third, these metrics are used to group species observations at the scale of the fishing operation. A Principal Component Analysis (PCA) followed by a Hierarchical Agglomerative Clustering (HAC) as in (Deporte *et al.*, 2012; Pelletier and Ferraris, 2000) are carried out on T_2. The PCA aims at building orthogonal linear combinations of the metrics maximizing the variance of species observations. Given the small number of metrics this step is not essential, but it allows i) characterizing correlation between species observations and exploring redundancies between metrics and ii) plotting the species observations in a 2 or 3 dimensions space. The HAC groups species observations by iterative pairwise agglomeration based on the Ward minimum variance

criterium (Ward, 1963). The number of clusters (3) was imposed by the question (three categories: target, Valued, Collateral). However, this fixed number is compared to the recommended number of clusters derived by statistical criteria based on successive gains in clustering variance to assess the quality of the clustering in the three groups. For each cluster, we compute the mean and the variance of each metric.

The identification of the cluster category name is performed assuming that the largest the metric "landings in value" is, the more targeted the species is. The cluster with the largest mean value of landings in value corresponds thus to the "target" *SFO* group of, the cluster with the intermediate mean value corresponds to the "valued bycatch" *SFO* group; and the cluster with the lowest mean value corresponds to the "collateral bycatch" *SFO* group. At the end of this step, a new column "cluster name" is added to table T_2 depicting the cluster in which the *SFO* has been assigned.

In the fourth step, the frequency of occurrence of each species in each cluster is computed. Ultimately, most species would occur in more than one cluster, so arbitrary thresholds must be used to finally categorize a species in one of the three categories. Let us denote t_{target} the threshold of frequency above, which a species is, defined as target and t_{valued} the one below, which a species is defined collateral bycatch.

At this stage of the analysis, the category of a species is known for a DCF level 4 métier and a country in the region. If several métiers catching this species are practised in the region and if several countries catch this species in this region, another rule is needed to define the category of this species in the region.
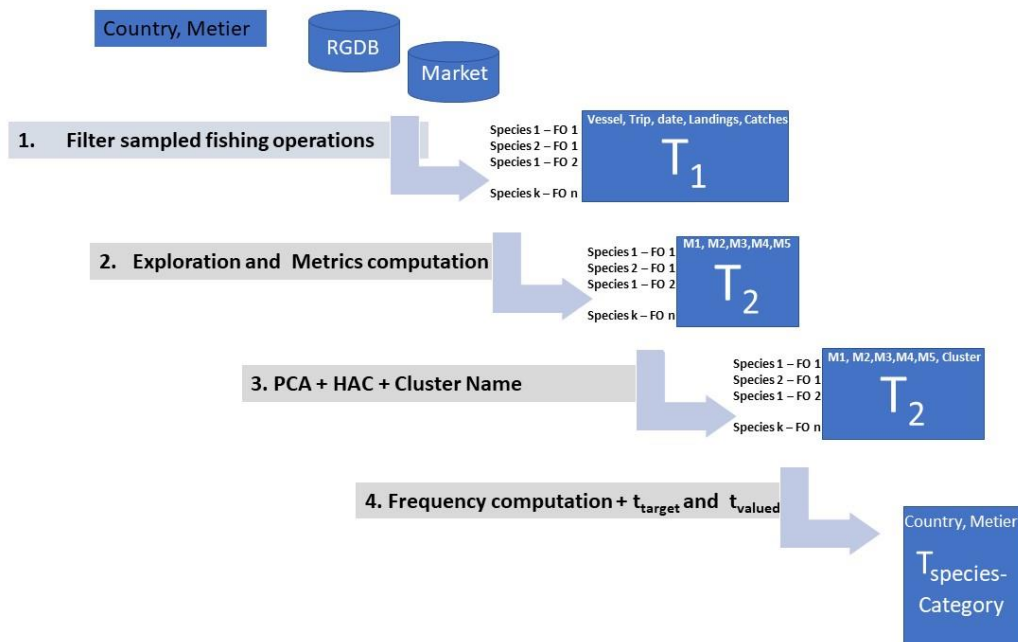

Figure 1.1. The four steps of the analysis to get the category of each species caught by métier.

2   Case studies

The purpose of the workshop was to assess the pertinence of the described methodology on different countries fishing in several areas with different gears.

To do so, scientists from the seven countries attending the workshop selected a subset of their observers' data to run the analysis on.

The analyses were run by "métiers" (gear*mesh size) for a number of combinations of countries, regions and years. The table 1 summarizes the analyses done.

Table 2.1. Summary of the analyses done during WKTARGET.

Country	numberRegion	numberYears	numberMetier
BE	6	9	1
IRL	1	5	2
DK	3	8	3
FRA	8	5	37
UK	6	5	2
GE	4	5	3
NLD	2	6	4

Table 1.1. Number of species observed during the observer trips.

region	Country	numberSpecies
3a	DK	94
4a	FRA	82
4a	GE	78
4a	UK	63
4b	BE	44
4b	DK	95
4b	NLD	56
4b	FRA	82
4b	GE	78
4b	UK	63
4c	BE	44
4c	DK	95
4c	NLD	56
4c	FRA	82
4c	GE	78
4c	UK	51
6a	FRA	124
6a	GE	23
7a	BE	48
7d	BE	51
7d	FRA	114
7d	UK	51
7e	FRA	147
7e	UK	88
7fghjk	BE	54
7fghjk	IRL	98
7fghjk	FRA	159
7fghjk	UK	88
8ab	BE	43
8ab	FRA	262

Once the method was applied to these individual cases (country, region, year, métier), the results were brought together into a single dataset. A number of visualization tools were developed in the shiny R application, for the analysis and interpretation of the results (see section 5).

3 Results for one métier

The analyses cluster the species caught in the different fishing operations based on their similarity given the approach described above. For each of the métiers, the programs return a full HTML report page (using a .Rmd script). This section present the full suite of results obtained for a single case (with some annotations removed or added for the purpose of this report), illustrated with the Danish otter trawlers using mesh sizes over 100 mm in the North Sea in 2018.

3.1 Selection

DNK, 2018, 27.4, OTB_>=120-0

```
Country <- params$country


area_select <- params$area


year_select <- params$year


gear_select <- params$gear


gear_name <- params$gear_out
```

3.2 Introduction

To define species status (target, discards, non-targeted but valued, hybrid) data from at sea sampling are gathered. Species indicators are then computed and species classified. Data format is the COST format (an old version of the Fishframe format).

3.3 Tools

R and packages are lovely loaded. Some of them are not available on CRAN, and other are totally useless for this report. The famous COST (COST 2006) R packages (COSTcore, COSTeda and COSTdbe) are available in the Rpackages directory of the ProByFish_WP1 GitLab depository.

```
#working directory have to be the directory where the Rmarkdown file is.
#setwd("~/ifremer/projet/probyfish/analyse")


data_dir <- "XXX" #removed for the report
data_dir_common <- "XXX" #removed for the report


#R general option:
options(stringsAsFactors = FALSE, scipen = 999)
#chunk option
knitr::opts_chunk$set(
  cache = F,
```

```
  echo = TRUE,
  warning = FALSE,
  message = FALSE,


  fig.height = 6,
  dev = 'png'
)
#package
#library(COSTcore)
#library(COSTdbe)
#library(COSTeda)
library(FactoMineR)
library(factoextra)
library(dplyr)
library(tidyr)
library(knitr)
library(sparkTable)
library(gridExtra)
library(GGally)
library(openxlsx)
library(reshape2)
#library(ggplot2)
#library(maps)
#library(mapdata)
#library(pander)
#library(ggrepel)
```

3.4 Data

Data are set to the right format in the first program.

subsetting of data - only selecting hauls where catReg == "All", sppReg == "All" and haulVal == "V"

```
#load the data
    CSr <- readRDS(file = paste(data_dir, "cs_dnk.rds", sep = ""))


## load spp correspondance names
    sppCorr    <-    as.tbl(read.xlsx(xlsxFile    =    paste(data_dir_common,
"sspCorresp.xlsx",  sep  =  ""),  sheet  =  "sspCorresp",  skipEmptyRows  =
FALSE))%>%select(FAO, spp)


## load data from the economic report to extract prices
    df1 <- as.tbl(read.xlsx(xlsxFile = paste(data_dir_common, "2018-07_STECF
18-07 - EU Fleet Economic and Transversal data_national level_final.xlsx", sep
= ""), sheet = "Transversal-Economic MS level", skipEmptyRows = FALSE))


  prices  <-  df1  %>%group_by(year,country_code,  species_namesc)    %>%
select(year,country_code,  species_namesc,species_name,variable_name,  value,
unit) %>% filter(variable_name %in% c("Live  weight  of  landings","Value  of
landings"))




  prices2                                                             <-
dcast(prices,year+country_code+species_namesc+species_name~variable_name+uni
t, mean, na.rm=T)
  colnames(prices2)[5] <- 'kg'
  colnames(prices2)[6] <- 'euros'


  prices2 <- as.tbl(prices2)%>%mutate(price=euros/kg) %>% subset(kg>0) %>%
mutate(spp=species_namesc)
  prices2 <- prices2%>%select(year, country_code,spp,species_name,price)
```

3.5 Subsetting and creating needed variables

3.5.1 Subsetting

Only selecting hauls where catReg == "All", sppReg == "All" and haulVal == "V"

3.5.2 Gear

The variable "gear" (merging the 3-letter code for the gear and the mesh size range) is created to reflect management

3.5.3 Species indicators

- To classify species, a set of indicators was built.
- Let
- the species $i\in[[1;n]]$ in the haul $j\in[[1;m]]$,
- $L_{i,j}$ the landing weight of the species i in the haul j,
- $V_{i,j}$ the landing value (in euro) of the species i in the haul j,
- $D_{i,j}$ the discard weight of the species i in the haul j,

The indicators are, for now, 5:

- proportion of the species catch in the total catch: $Pc_{i,j}=\dfrac{L_{i,j}+D_{i,j}}{\sum_{i=1}^{n}L_{i,j}+D_{i,j}}$,
- proportion of the species discard in the total catch: $Pd_{i,j}=\dfrac{D_{i,j}}{\sum_{i=1}^{n}L_{i,j}+D_{i,j}}$,
- proportion of the species landing in the total catch: $Pl_{i,j}=\dfrac{L_{i,j}}{\sum_{i=1}^{n}L_{i,j}+D_{i,j}}$,
- proportion of the species discard in the total discards: $Pdd_{i,j}=\dfrac{D_{i,j}}{\sum_{i=1}^{n}D_{i,j}}$,
- proportion of the species landing in the total landings: $Pll_{i,j}=\dfrac{L_{i,j}}{\sum_{i=1}^{n}L_{i,j}+D_{i,j}}$,
- proportion of the landings in this species catches: $Plsp_{i,j}=\dfrac{L_{i,j}}{D_{i,j}+L_{i,j}}$,
- proportion of the discards in this species catches: $Pdsp_{i,j}=\dfrac{D_{i,j}}{D_{i,j}+L_{i,j}}$,
- landing value: $V_{i,j}$.
- proportion of the species landings in the total landings in value: $Pv_{i,j}=\dfrac{Lv_{i,j}}{\sum_{i=1}^{n}Lv_{i,j}}$,

```
  #CSr indicator
spp0 <-
  CSr@sl %>% filter(sampType == "S") %>% group_by(landCtry, vslFlgCtry, year,
proj, trpCode, staNum, catchCat, spp) %>% summarise(w = sum(wt, na.rm = T))
%>% distinct()


spp1 <- tidyr::spread(spp0, catchCat, w, fill = 0)

spp1 <- tidyr::spread(spp0, catchCat, w, fill = 0)

spp2 <-

spp1 %>% group_by(landCtry, vslFlgCtry, year, proj, trpCode, staNum, trpCode,
staNum) %>% mutate(totLAN = sum(LAN, na.rm = T),

                                        totDIS = sum(DIS, na.rm = T))
```

```r
# compute indicators on catch, landings and discards
spp3 <- spp2 %>% mutate(
  Pc = (DIS + LAN) / (totLAN + totDIS),
  Pd = DIS / (totLAN + totDIS),
  Pdd = ifelse(totDIS > 0, DIS / totDIS, 0),
  Pl = LAN / (totLAN + totDIS),
  Pll = ifelse(totLAN > 0, LAN / totLAN, 0),
  Pdspp = DIS / (LAN + DIS),
  Plspp = LAN / (LAN + DIS)
)


# get the infos about the trip
hh <- CSr@hh %>% filter(sampType == "S" & catReg == "All" & sppReg == "All" &
foVal == "V") %>% transmute(landCtry, vslFlgCtry, year, proj, trpCode, staNum,
date, area, rect, foCatEu6, sppReg, foDur) %>% distinct()


# Group the North Sea


hh <- mutate(hh, area = ifelse(area %in% c("27.4.a", "27.4.b", "27.4.c"),
"27.4", area))


tr <- CSr@tr %>% filter(sampType == "S") %>% transmute(landCtry, vslFlgCtry,
year, proj, trpCode,vslLen,vslPwr,harbour) %>% distinct()


spp4 <- spp3 %>% inner_join(hh) %>% inner_join(tr)
spp5 <- spp4 %>% mutate(month = substr(date, 6, 7)) %>% ungroup() %>%
mutate(year =

as.numeric(year))


# extrac the prices from the STECF economic data
prices2 <- prices2 %>% subset(country_code == Country)


spp6 <- left_join(spp5, prices2)
dim(spp6[is.na(spp6$price), ]) / dim(spp6)
## [1] 0.4446331 1.0000000
### fill the missing prices
### fill with the average price by species over the periode


spp6 <-
  spp6 %>% group_by(spp, year) %>% mutate(meanPrice = mean(price, na.rm =
```

```
                                                         T))            %>%
  ungroup()

  spp6 <- spp6 %>% mutate(price = ifelse(is.na(price), meanPrice, price))


  dim(spp6[is.na(spp6$price), ]) / dim(spp6)
## [1] 0.4446331 1.0000000
### fill the missing prices
### fill with the average price over the periode
  spp6 <-
    spp6 %>% group_by(spp) %>% mutate(meanPriceOverSpecies = mean(price, na.rm
=
                                                       T)) %>%
    mutate(price = ifelse(is.na(price), meanPriceOverSpecies, price))
  dim(spp6[is.na(spp6$price), ]) / dim(spp6)
## [1] 0.1241797 1.0000000
#### if price never recorded, set to 0!?
  spp6 <- spp6 %>% mutate(price = ifelse(is.na(price), 0, price))
  dim(spp6[is.na(spp6$price), ]) / dim(spp6)
## [1] 0 1
### compute landing prop in value
  spp6 <- spp6 %>% mutate(value = price * LAN / 1000)
  spp6 <- spp6 %>% mutate(value = price * LAN / 1000)
  spp6 <-
    spp6 %>% group_by(trpCode, staNum) %>% mutate(totVal = sum(value, na.rm =
T))
  spp6 <- spp6 %>% mutate(Pv = ifelse(totVal > 0, value / totVal, 0))



## create met level 5
  spp6$foCatEu5 <- substr(spp6$foCatEu6, 1, 7)
## create a combinaition of gear and mesh size used for management
  met <-
    as.tbl(colsplit(
      spp6$foCatEu6,
      "_",
      c("Gear", "target", "mesh1", "mesh2", "selec")
    ))
  met <-
    met %>% mutate(gear = ifelse(
      is.na(selec),
```

```
    paste(Gear, mesh1, sep = '_'),
    paste(Gear, paste(mesh1, mesh2, sep =
                      '-'), sep = '_')
  ))


spp6$gear <- met$gear



## get FAO names
spp6 <- left_join(spp6, sppCorr)
spp6 <- spp6 %>% mutate(FAO = ifelse(is.na(FAO), spp, FAO))
```

3.6   Focus on one métier

The final idea is to run the analyses on all métiers that seem to have enough sampling. But this script will focus on a specic gear. To be changed depending on your interest

This part of the code allows for checking the catch/landing/discard profiles and if they change over time

The species are grouped in the graphs. If they represent less than 1% of respectively catch/landing/discard they are renamed to "<1%". Then the graphs are divided between time-series of catch/landing/discard of species that represent more or less than 5% of the yearly catch/landing/discard.

3.6.1   Catch profiles

```
# Select area
sppArea <- spp6%>%filter(area == area_select)


## select your gear of interest
#gearOfInterest <- "OTB_>=70"
gearOfInterest <- gear_select


tab <- sppArea %>% filter(gear%in%c(gearOfInterest))
tab <- tab %>% mutate(CATCH=DIS+LAN)


## landings profiles in kg
    ts1<-
tab%>%group_by(year,gear,FAO)%>%summarise(w=sum(LAN,na.rm=T)/1000)%>%

group_by(year)%>%mutate(wyear=sum(w),wperc=w/wyear,test1=wperc>=0.05,test2=w
perc>=0.01)%>%
            mutate(FAO=ifelse(test2,FAO,"<1%"),
                  condition=ifelse(test1,">5%","<5%"))
```
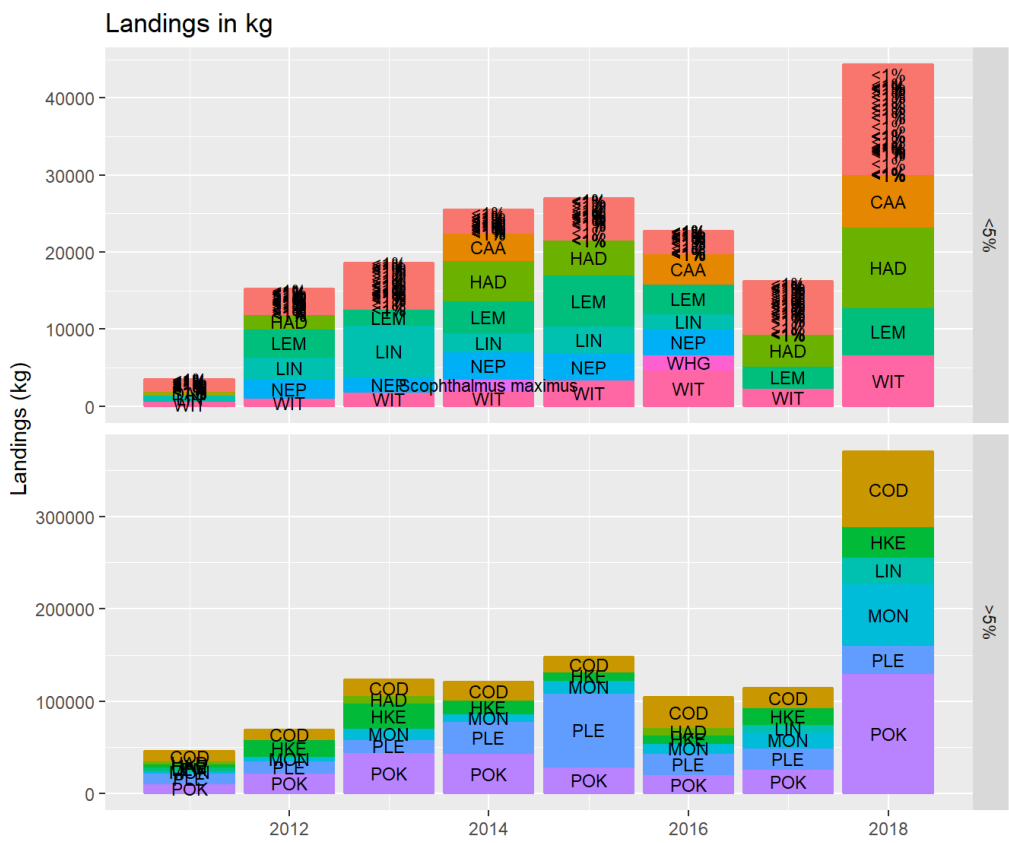
```
ts1plt<-ggplot(ts1,aes(x=year,y=w,colour=FAO,fill=FAO, label=FAO))+
geom_bar(stat="identity")+
facet_grid(condition~.,scale="free")+
xlab("")+ylab("Landings (kg)")+
ggtitle(paste0("Landings in kg"))+
geom_text(size = 3, position = position_stack(vjust = 0.5), col="black")+
theme(legend.position="none")

print(ts1plt)
```
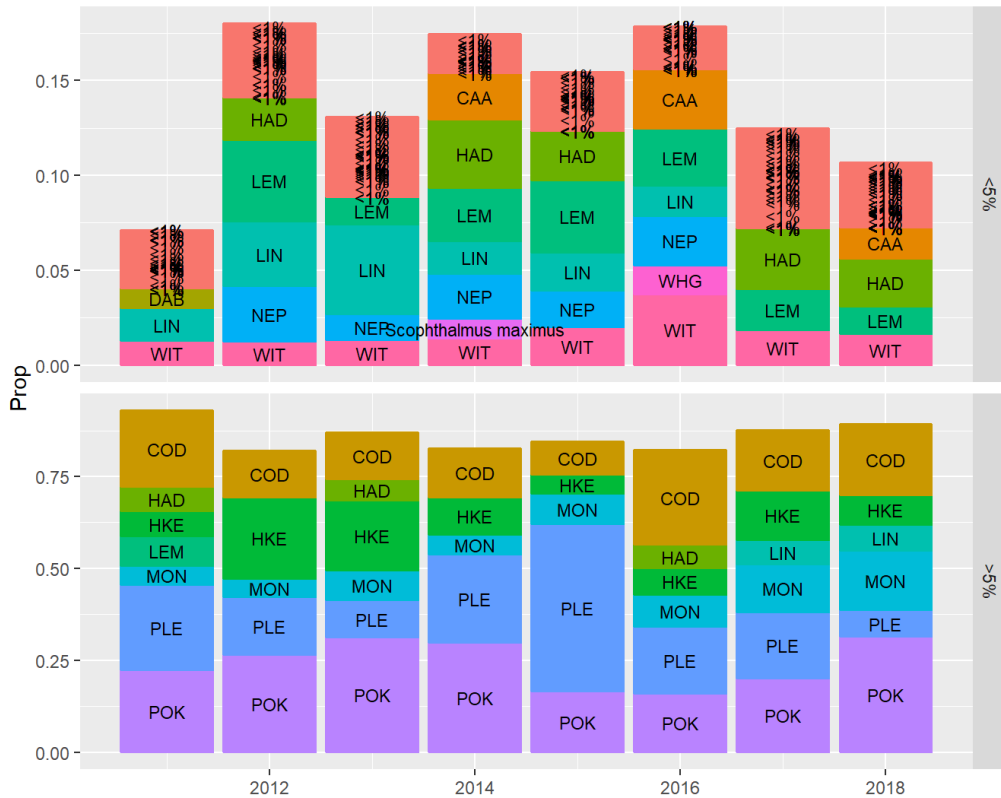

Landings in kg

```
## landings profiles in percentage


        ts1percplt<-ggplot(ts1,aes(x=year,y=wperc,colour=FAO,fill=FAO,
label=FAO))+

        geom_bar(stat="identity")+

        facet_grid(condition~.,scale="free")+

        xlab("")+ylab("Prop")+

        ggtitle(paste0("Landings  by  species  and  in  percentage  of  total
landings per year"))+

    geom_text(size = 3, position = position_stack(vjust = 0.5), col="black")+

        theme(legend.position="none")



        print(ts1percplt)
```

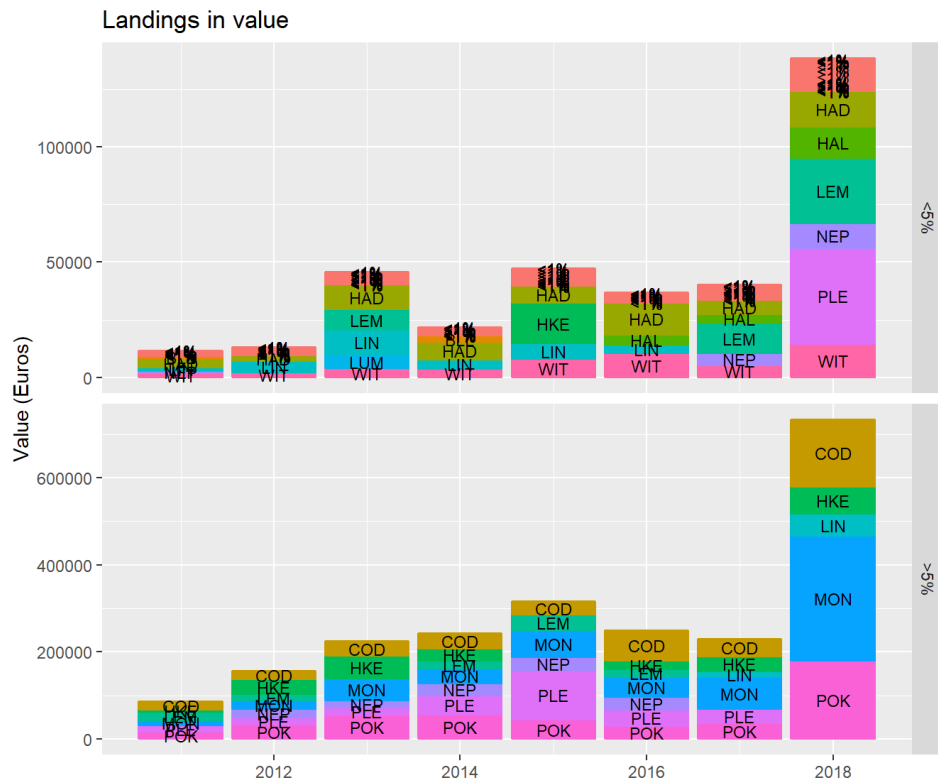Landings by species and in percentage of total landings per year

```r
## landings profiles in value


    ts1V<-tab%>%group_by(year,gear,FAO)%>%summarise(w=sum(value,na.rm=T))%>%

group_by(year)%>%mutate(wyear=sum(w),wperc=w/wyear,test1=wperc>=0.05,test2=w
perc>=0.01)%>%
          mutate(FAO=ifelse(test2,FAO,"<1%"),
                 condition=ifelse(test1,">5%","<5%"))


      ts1vplt<-ggplot(ts1V,aes(x=year,y=w,colour=FAO,fill=FAO, label=FAO))+
      geom_bar(stat="identity")+
      facet_grid(condition~.,scale="free")+
      xlab("")+ylab("Value (Euros)")+
      ggtitle(paste0("Landings in value"))+
    geom_text(size = 3, position = position_stack(vjust = 0.5), col="black")+
      theme(legend.position="none")



      print(ts1vplt)
```

Landings in value


```
## landings profiles in value percenatge
        ts1vPercplt<-ggplot(ts1V,aes(x=year,y=wperc,colour=FAO,fill=FAO,
label=FAO))+
        geom_bar(stat="identity")+
        facet_grid(condition~.,scale="free")+
        xlab("")+ylab("Prop")+
        ggtitle(paste0("Landings by species and in percentage of total value
per year"))+
    geom_text(size = 3, position = position_stack(vjust = 0.5), col="black")+
        theme(legend.position="none")


        print(ts1vPercplt)
```
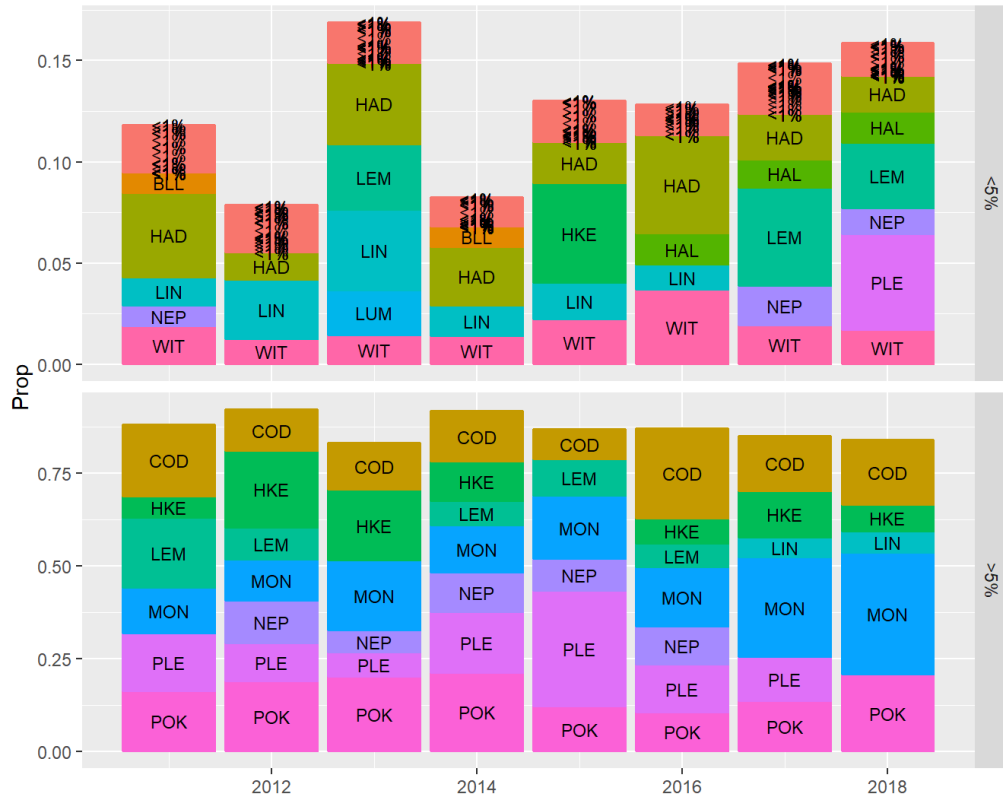
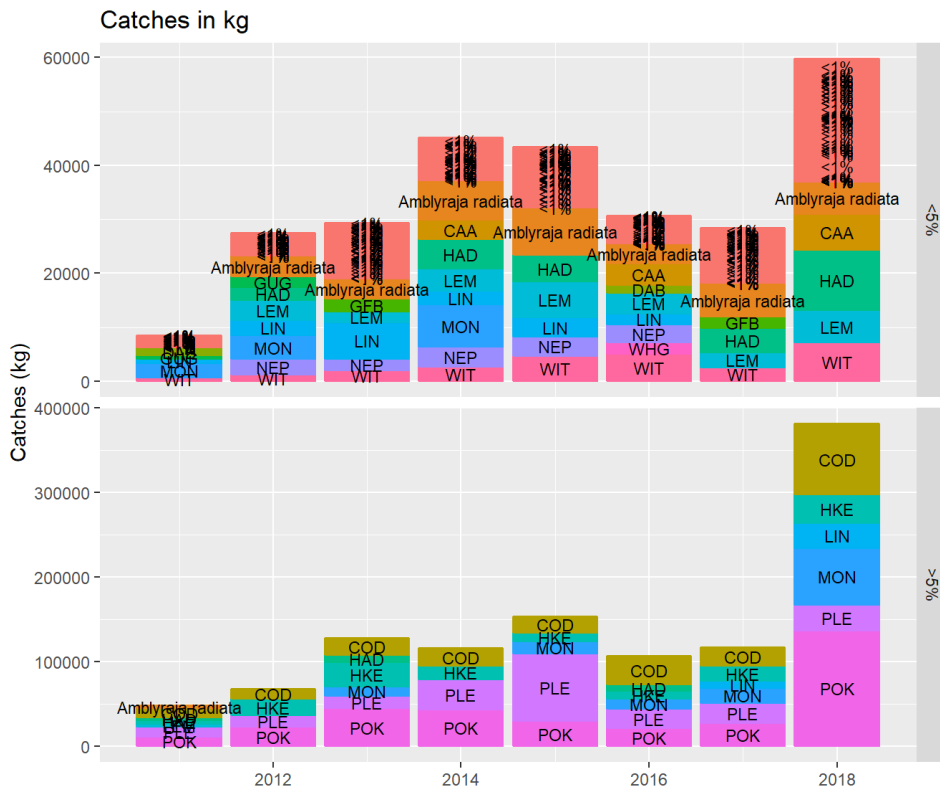Landings by species and in percentage of total value per year

```r
## catch profiles in kg


    ts2<-
tab%>%group_by(year,gear,FAO)%>%summarise(w=sum(CATCH,na.rm=T)/1000)%>%

group_by(year)%>%mutate(wyear=sum(w),wperc=w/wyear,test1=wperc>=0.05,test2=w
perc>=0.01)%>%
          mutate(FAO=ifelse(test2,FAO,"<1%"),
                condition=ifelse(test1,">5%","<5%"))

    ts2plt<-ggplot(ts2,aes(x=year,y=w,colour=FAO,fill=FAO, label=FAO))+
    geom_bar(stat="identity")+
    facet_grid(condition~.,scale="free")+
    xlab("")+ylab("Catches (kg)")+
    ggtitle(paste0("Catches in kg"))+
  geom_text(size = 3, position = position_stack(vjust = 0.5), col="black")+
    theme(legend.position="none")



    print(ts2plt)
```
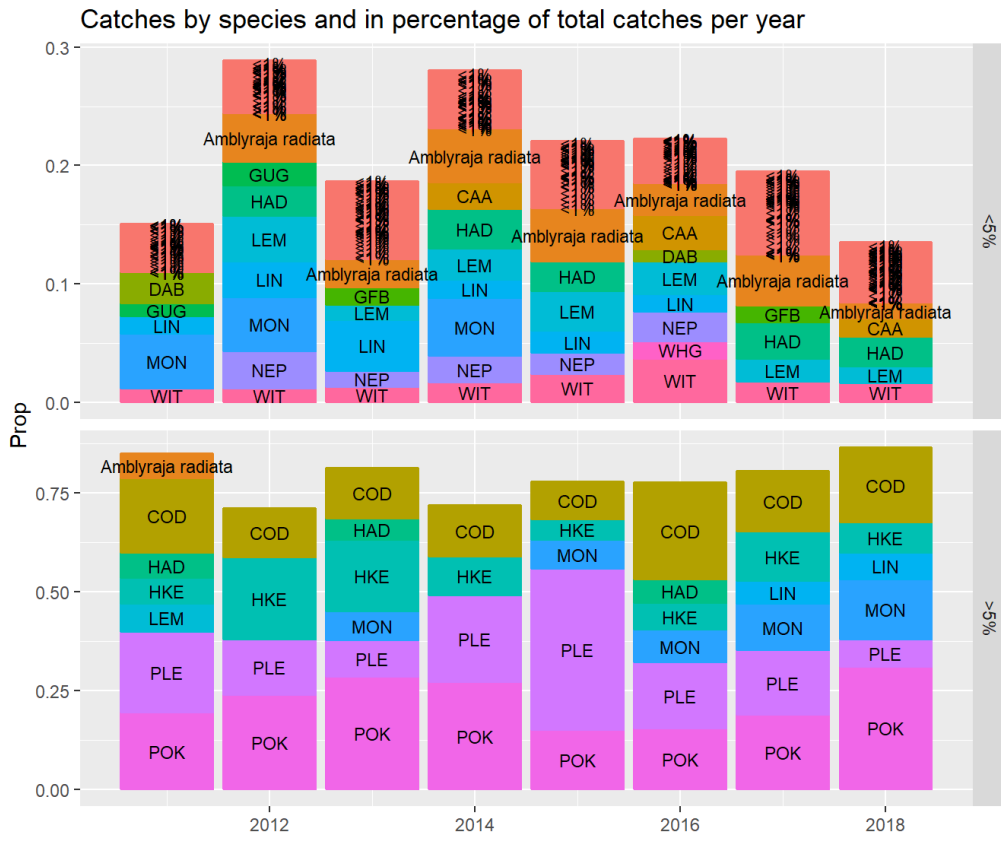
Catches in kg

```
## catch profiles in perc


        ts2Percplt<-ggplot(ts2,aes(x=year,y=wperc,colour=FAO,fill=FAO,
label=FAO))+

        geom_bar(stat="identity")+

        facet_grid(condition~.,scale="free")+

        xlab("")+ylab("Prop")+

        ggtitle(paste0("Catches by species and in percentage of total catches
per year "))+

    geom_text(size = 3, position = position_stack(vjust = 0.5), col="black")+

        theme(legend.position="none")



        print(ts2Percplt)
```

Catches by species and in percentage of total catches per year

```
## Discard profiles in kg


    ts3<-
tab%>%group_by(year,gear,FAO)%>%summarise(w=sum(DIS,na.rm=T)/1000)%>%

group_by(year)%>%mutate(wyear=sum(w),wperc=w/wyear,test1=wperc>=0.05,test2=w
perc>=0.01)%>%
          mutate(FAO=ifelse(test2,FAO,"<1%"),
                condition=ifelse(test1,">5%","<5%"))


    ts3plt<-ggplot(ts3,aes(x=year,y=w,colour=FAO,fill=FAO, label=FAO))+
    geom_bar(stat="identity")+
    facet_grid(condition~.,scale="free")+
    xlab("")+ylab("Discards (kg)")+
    ggtitle(paste0("Discards in kg"))+
  geom_text(size = 3, position = position_stack(vjust = 0.5), col="black")+
    theme(legend.position="none")



    print(ts3plt)
```
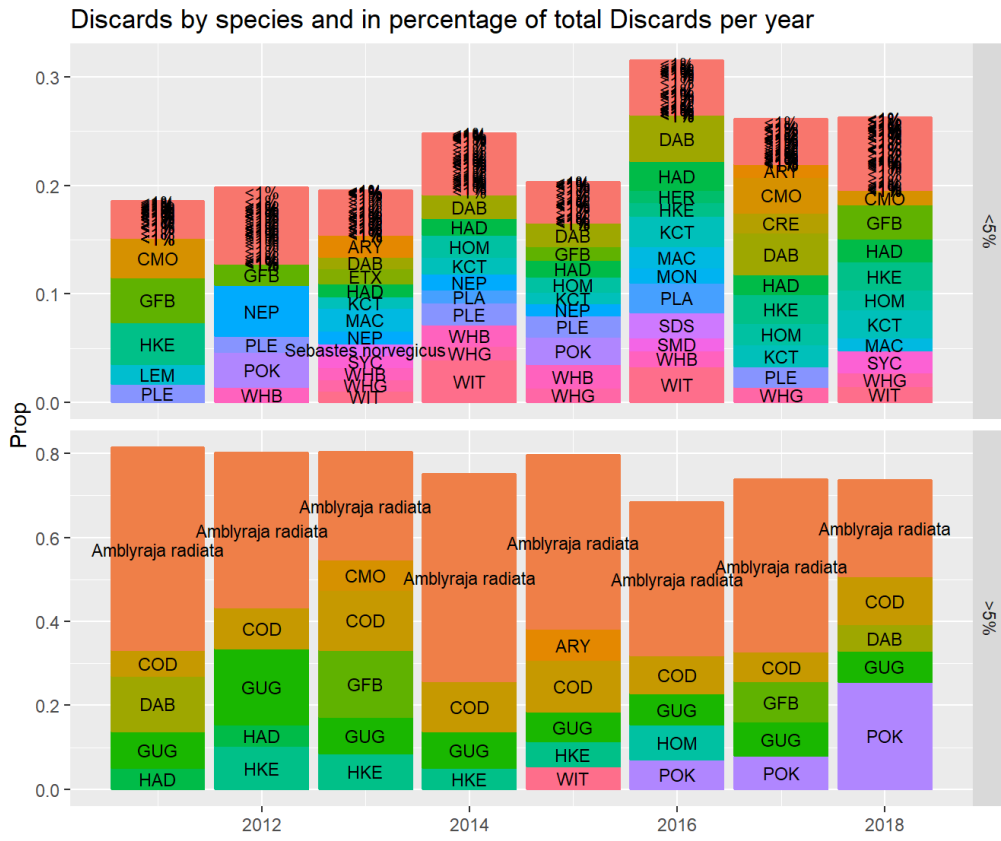
Discards in kg

```
## Discards profiles in perc


        ts3Percplt<-ggplot(ts3,aes(x=year,y=wperc,colour=FAO,fill=FAO,
label=FAO))+

        geom_bar(stat="identity")+

        facet_grid(condition~.,scale="free")+

        xlab("")+ylab("Prop")+

        ggtitle(paste0("Discards  by  species  and  in  percentage  of  total
Discards per year"))+

    geom_text(size = 3, position = position_stack(vjust = 0.5), col="black")+

        theme(legend.position="none")



        print(ts3Percplt)
```

Discards by species and in percentage of total Discards per year

```
##  create list of main species?


   sppVal <- ts1V%>%filter(condition==">5%")%>%select(FAO, year)
   sppCatch <- ts2%>%filter(condition==">5%")%>%select(FAO, year)
 sppLand <- ts1%>%filter(condition==">5%")%>%select(FAO, year)


   sppLandInf5 <- ts1%>%filter(condition=="<5%" & FAO!="<1%")%>%select(FAO,
year)
```

3.6.2   Always landed/discarded

List of species that are always landed or always discarded

```
### look every year what are the species always landed and always discarded
  tab <- sppArea %>% filter(gear%in%c(gearOfInterest))
  tab <- tab %>% mutate(CATCH=DIS+LAN)


  tab <- tab %>% group_by(year, FAO) %>% summarise(wL=sum(LAN,na.rm=T),
wD=sum(DIS, na.rm=T),

                                              wC=sum(CATCH, na.rm=T))


  AlwaysL <- tab%>%filter(wL==wC)
  AlwaysD <- tab%>%filter(wD==wC)


### look over the periode what are the species always landed and always
discarded

  tab <- sppArea %>% filter(gear%in%c(gearOfInterest))
  tab <- tab %>% mutate(CATCH=DIS+LAN)


  tab <- tab %>% group_by( FAO) %>% summarise(wL=sum(LAN,na.rm=T), wD=sum(DIS,
na.rm=T),

                                              wC=sum(CATCH, na.rm=T))


  AlwaysL <- tab%>%filter(wL==wC)%>%arrange(desc(wL))
  AlwaysD <- tab%>%filter(wD==wC)%>%arrange(desc(wD))


    kable(AlwaysL%>%select(FAO,wL), caption ="Species always landed and total
landings (in gr) over the period")
```

Species always landed and total landings (in gr) over the period

FAO	wL
GPT	82 600
SOL	78 086
GHL	51 840
LBE	2700

```
kable(AlwaysD%>%select(FAO,wD), caption ="Species always discarded and
total discards (in gr) over the period")
```

Species always discarded and total discards (in gr) over the period

FAO	wD
Amblyraja radiata	43 261 843
HOM	2 303 552
ARY	2 208 508
KCT	1 956 991
WHB	1 281 058
SYC	771 357
ETX	674 700
SHO	334 592
SDS	246 736
Leucoraja naevus	243 658
NOP	241 767
RJC	99 297
SYT	87 640
ARU	43 434
IOD	26 700
SFV	24 519
COE	20 640
ENC	18469
WHE	15 160
GDG	12 522

FAO	wD
POD	12 154
	11 000
RNG	8000
Dipturus oxyrinchus	7240
Myoxocephalus scorpius	6310
RJH	5980
Leucoraja fullonica	3300
GGU	3282
Lipophrys pholis	3270
LYY	1976
MUR	1174
Chelidonichthys cuculus	1100
ANE	1003
Labrus mixtus	800
Ammodytes marinus	496
GAR	400
BRF	320
Lycodes gracilis	254
Macropodia rostrata	250
AFT	178
Lophius Budegassa	134
Callionymus maculatus	35
MSF	34
BIB	25
MYG	25

3.6.3 Landings/discards profiles for the species representing more than 5% of the landings for the selected gear

```
#
#
#    tab <- sppArea %>% filter(gear%in%c(gearOfInterest) & spp=="Nephrops
norvegicus")%>% mutate(percL=LAN/(LAN+DIS), percD=DIS/(LAN+DIS))
#
#
#   L <- ggplot(tab, aes(y=LAN/1000, x=as.character(year))) +
#     geom_boxplot()
#   D <- ggplot(tab, aes(y=DIS/1000, x=as.character(year))) +
#     geom_boxplot()
#
#   grid.arrange(L,D)
#
#   pL <- ggplot(tab, aes(y=percL, x=as.character(year))) +
#     geom_boxplot()
#
#   pD <- ggplot(tab, aes(y=percD, x=as.character(year))) +
#     geom_boxplot()
#
#   grid.arrange(pL,pD)




  sppLand <- sppLand%>%mutate(test=T)
  tab      <-     sppArea     %>%     filter(gear%in%c(gearOfInterest))%>%
mutate(percL=LAN/(LAN+DIS), percD=DIS/(LAN+DIS))
  tab2 <- left_join(tab, sppLand)%>%filter(test==T)


  pL <- ggplot(tab2, aes(y=percL, x=as.character(year),fill=FAO)) +
    geom_boxplot()


  pD <- ggplot(tab2, aes(y=percD, x=as.character(year),fill=FAO)) +
    geom_boxplot()


  grid.arrange(pL,pD)
```
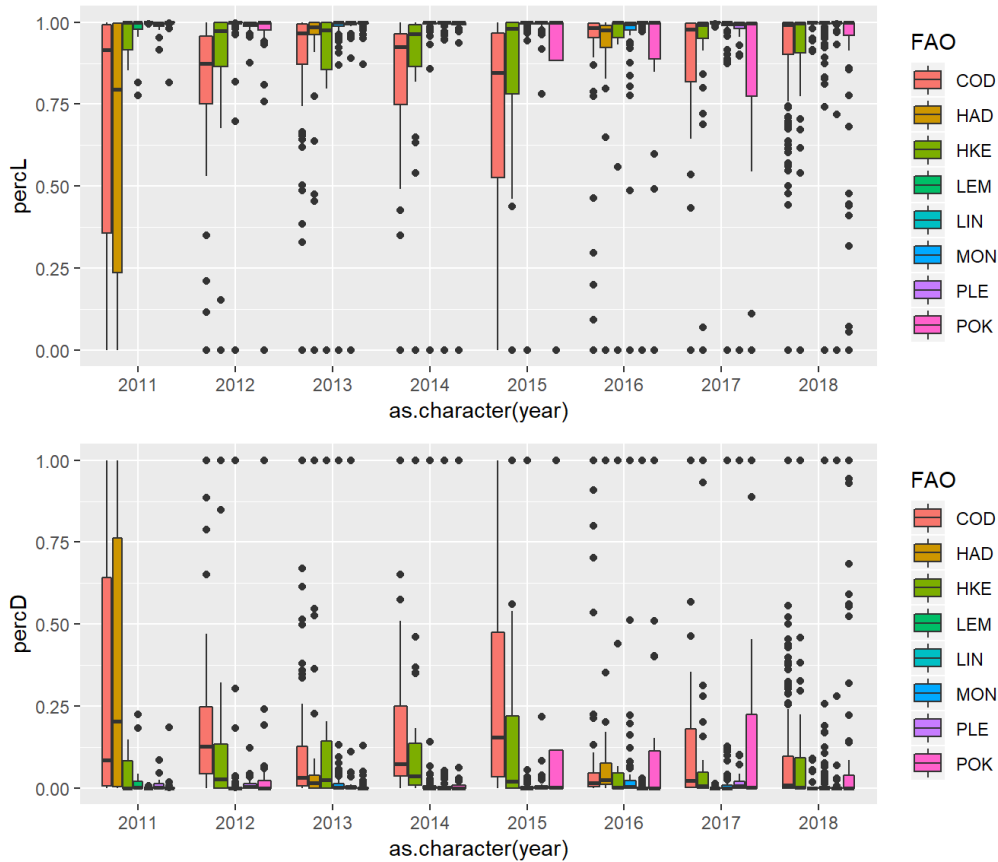
3.6.4 Data subsetting

This report focus on the ICES Subarea 27.4 and the gear OTB_>=120-0 Data are subsetted accordingly.

```
spp7 <-
  spp6 %>% filter(area == area_select &
                  gear == gearOfInterest) %>% ungroup()
```

3.7 Exploratory data analysis

Some basic data exploratory analyses to assess numerical links between indicators.

3.7.1 Pairs plot

```
#plot(spp6%>%select(DIS,LAN,totLAN,totDIS,Pc,Pd,Pdd,foDur,vslLen,month))

#ggpairs(spp7%>%select(DIS,LAN,totLAN,totDIS,Pc,Pd,Pdd,Pl,Pll,value,
Pv,foDur,vslLen,month))
```

3.7.2   Indicators PCA

```r
# library(ade4)
tmp <-
  spp7 %>% filter(year == year_select) %>% select(Pc, Pd, Pl, Pll, Pdd, Plspp,
Pdspp, Pv, price, foDur)

# rez<-dudi.pca(tmp,scannf=FALSE,nf=5,scale=T,center=T)
# library(factoextra)
# print(fviz_eig(rez))
# print(fviz_pca_ind(rez))
# print(fviz_pca_var(rez,col.var = "contrib"))

tmp[is.na(tmp)] <- 0

library(FactoMineR)
rez<-PCA(tmp)
```
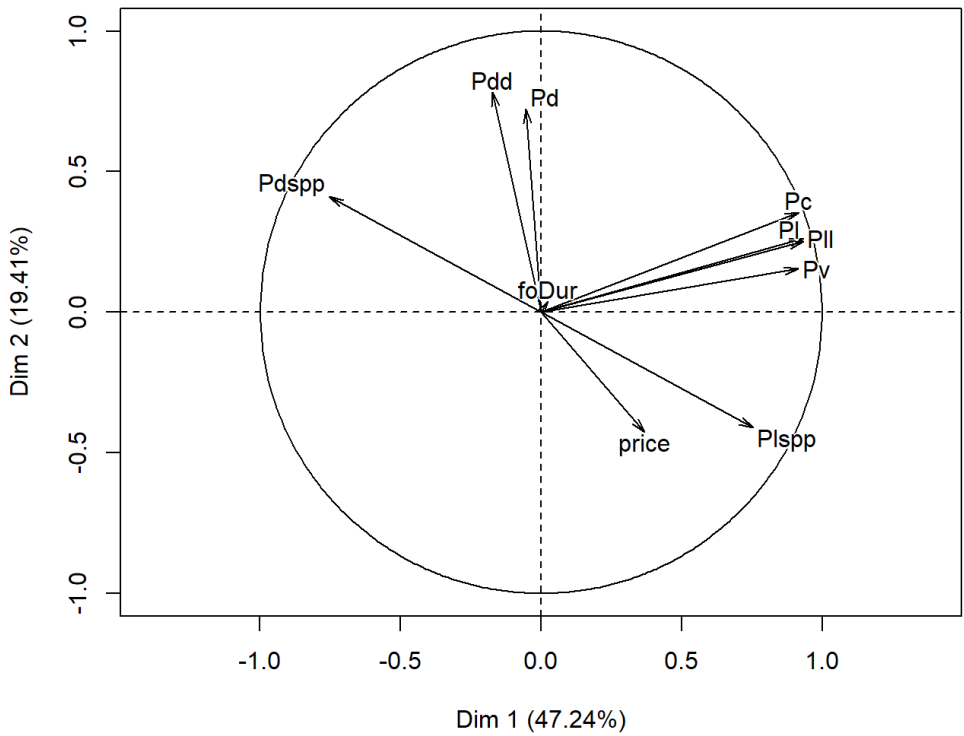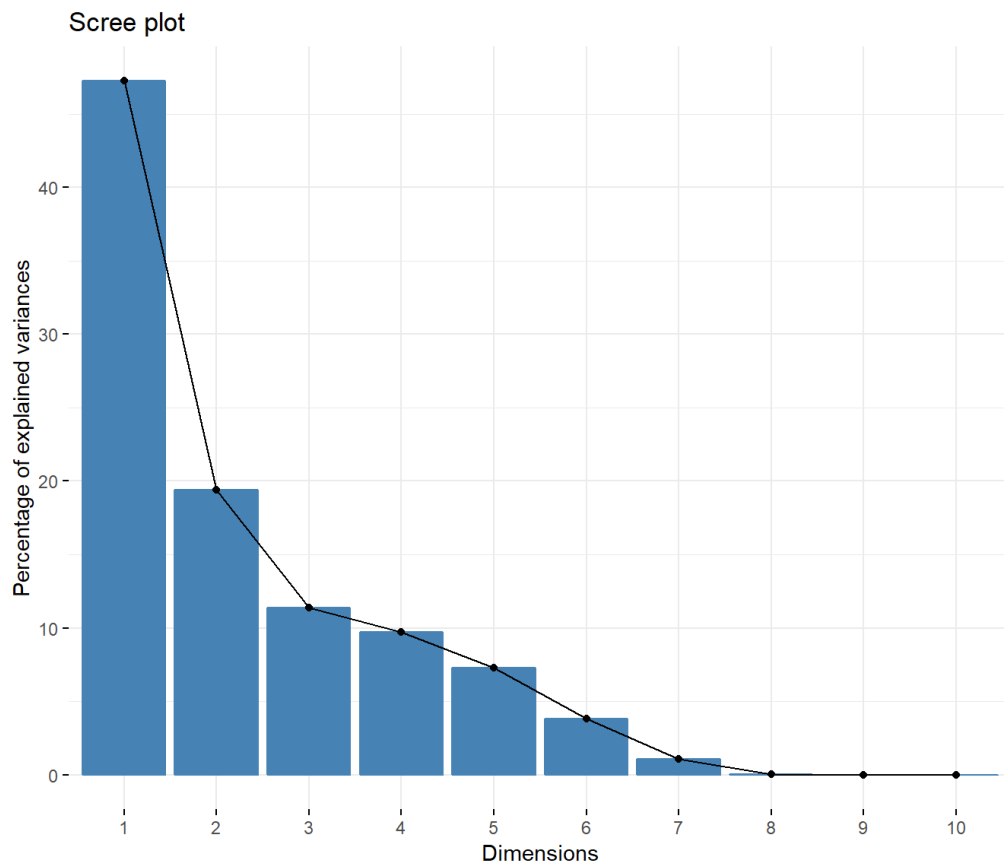
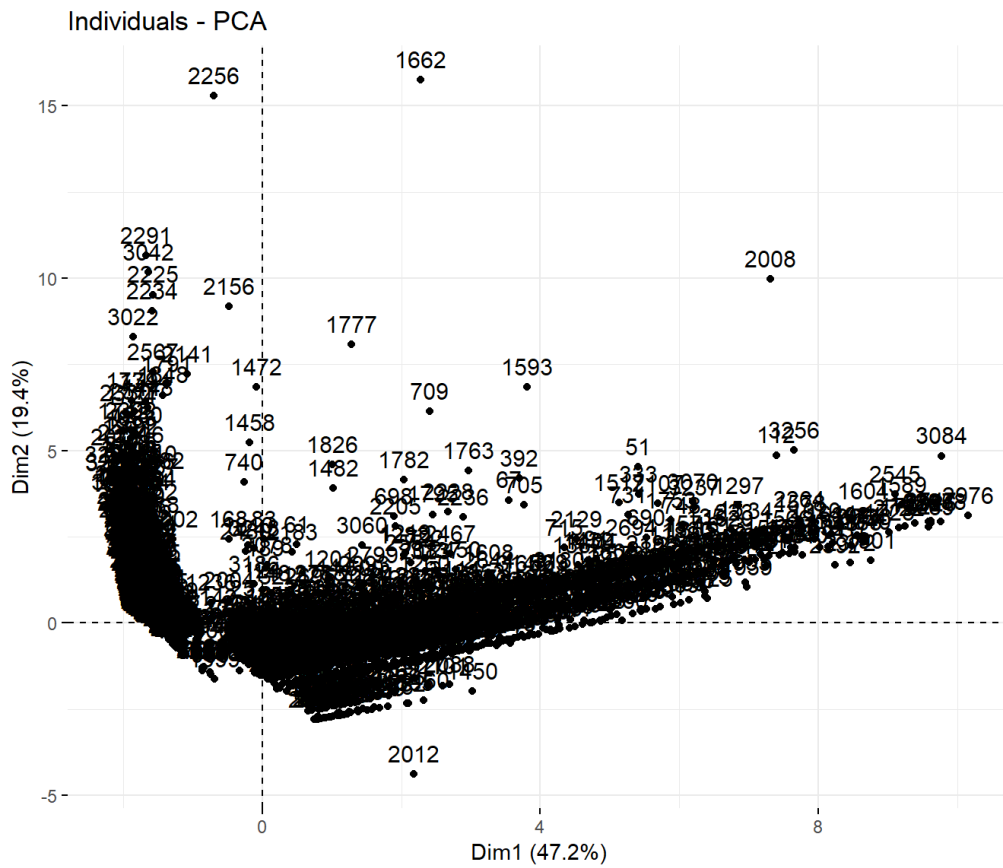**Individuals factor map (PCA)**
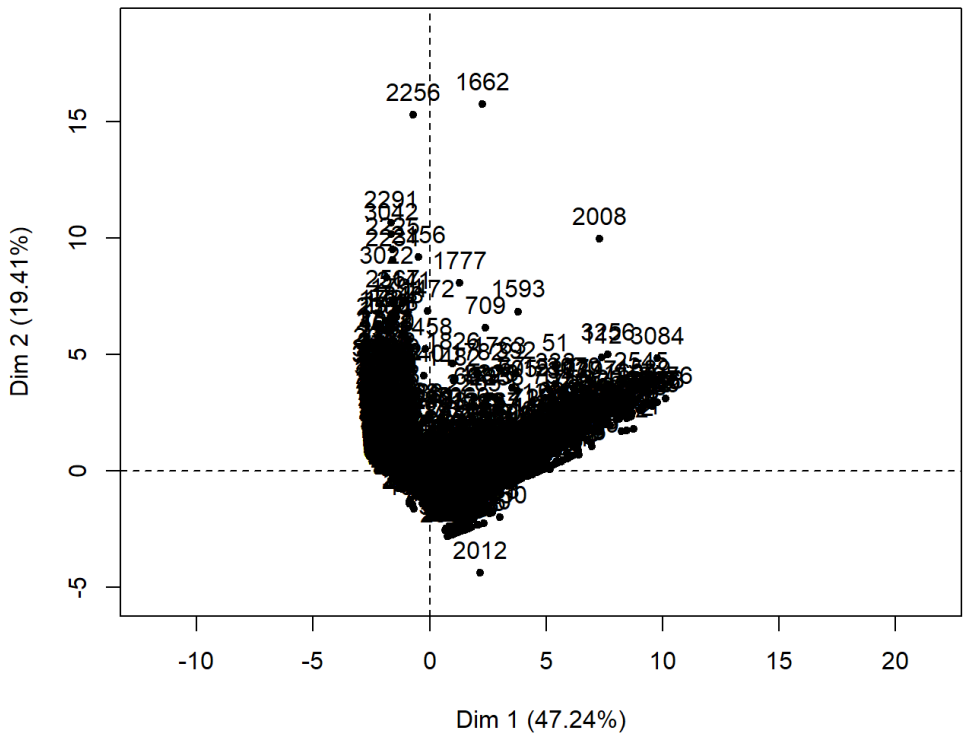
Variables factor map (PCA)

```r
library(factoextra)
print(fviz_eig(rez))
```


Scree plot

```r
print(fviz_pca_ind(rez, axes=c(1,2)))
```

```
print(fviz_pca_ind(rez, axes=c(1,3)))
```
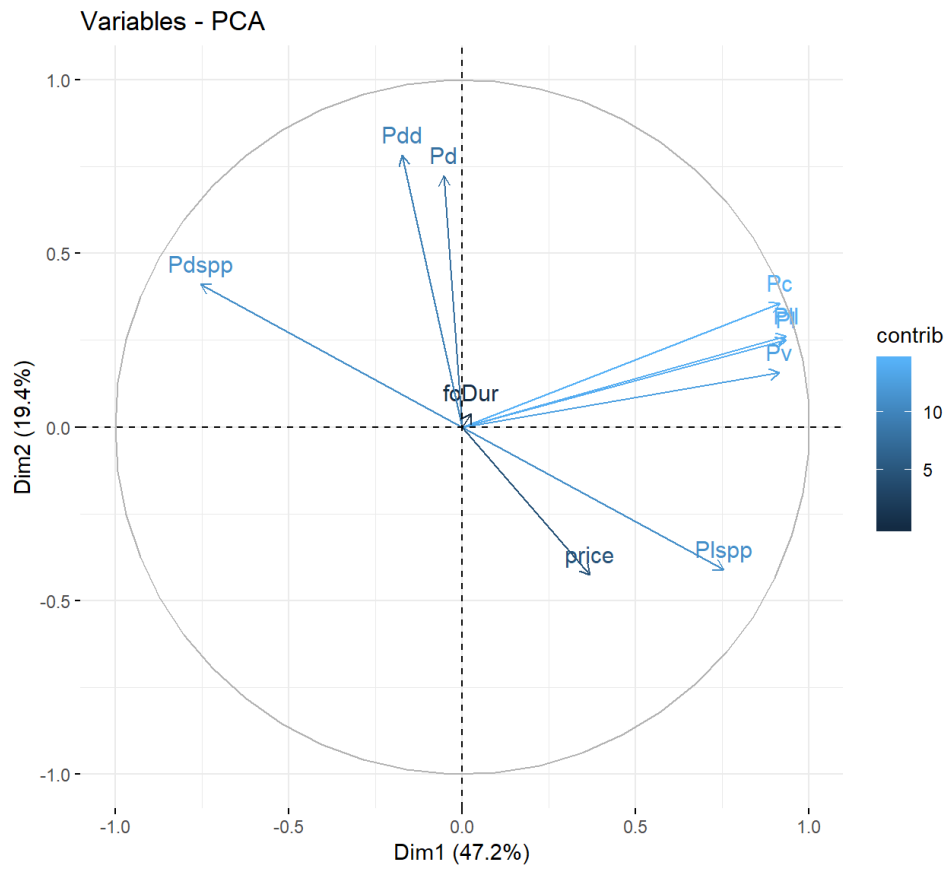
Individuals - PCA

```
print(fviz_pca_ind(rez, axes=c(2,3)))
```

```
print(fviz_pca_var(rez,col.var = "contrib", axes=c(1,2)))
```
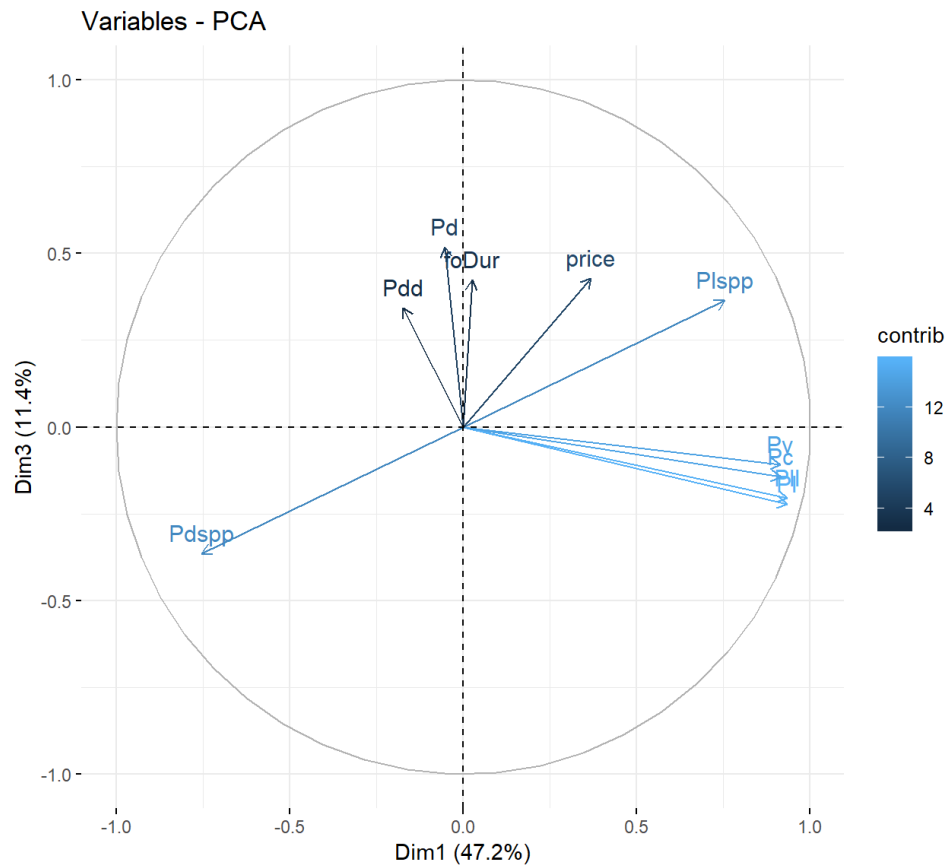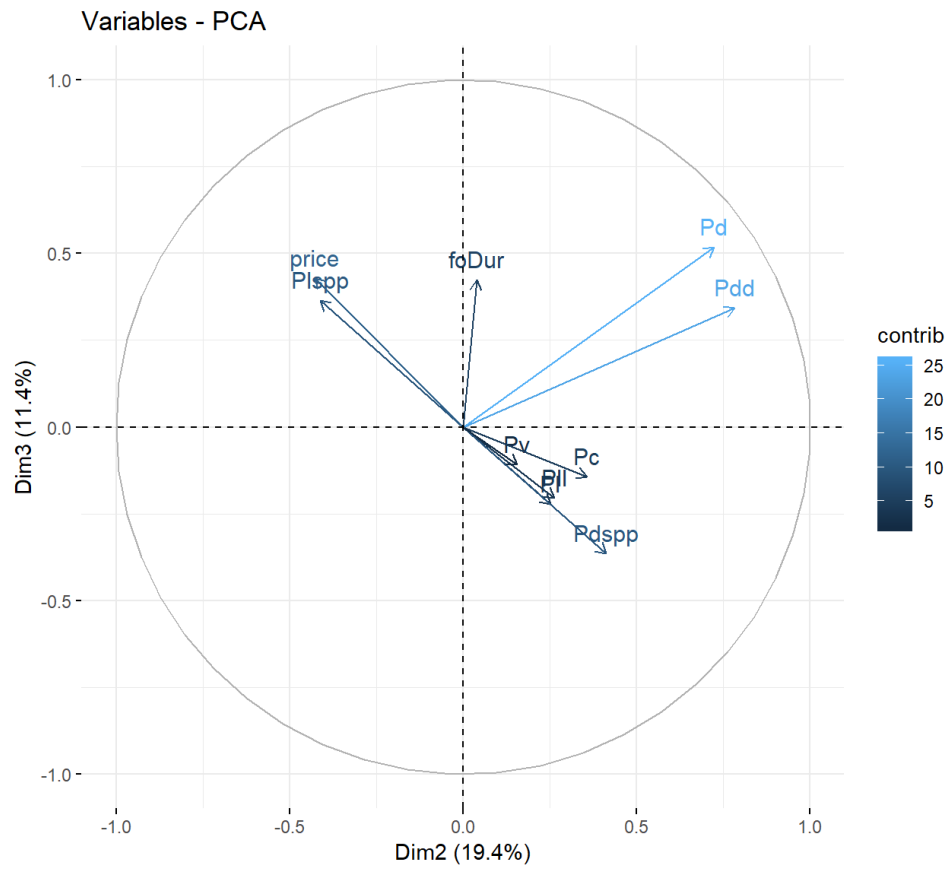
Variables - PCA

```
print(fviz_pca_var(rez,col.var = "contrib", axes=c(1,3)))
```
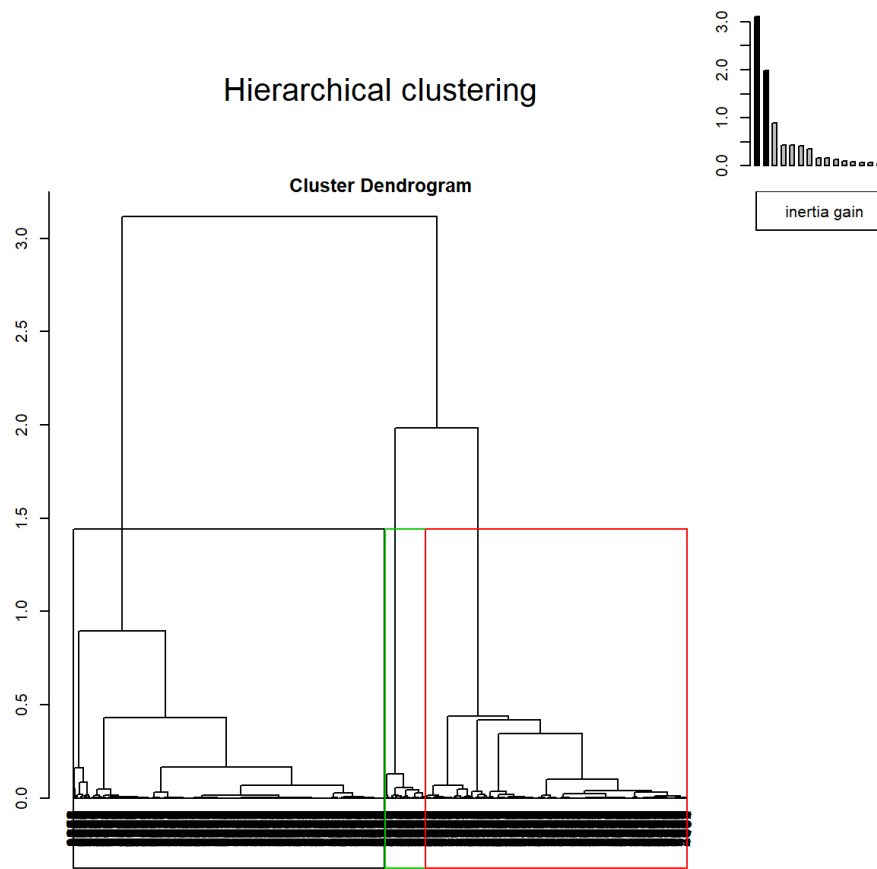
```
print(fviz_pca_var(rez,col.var = "contrib", axes=c(2,3)))
```
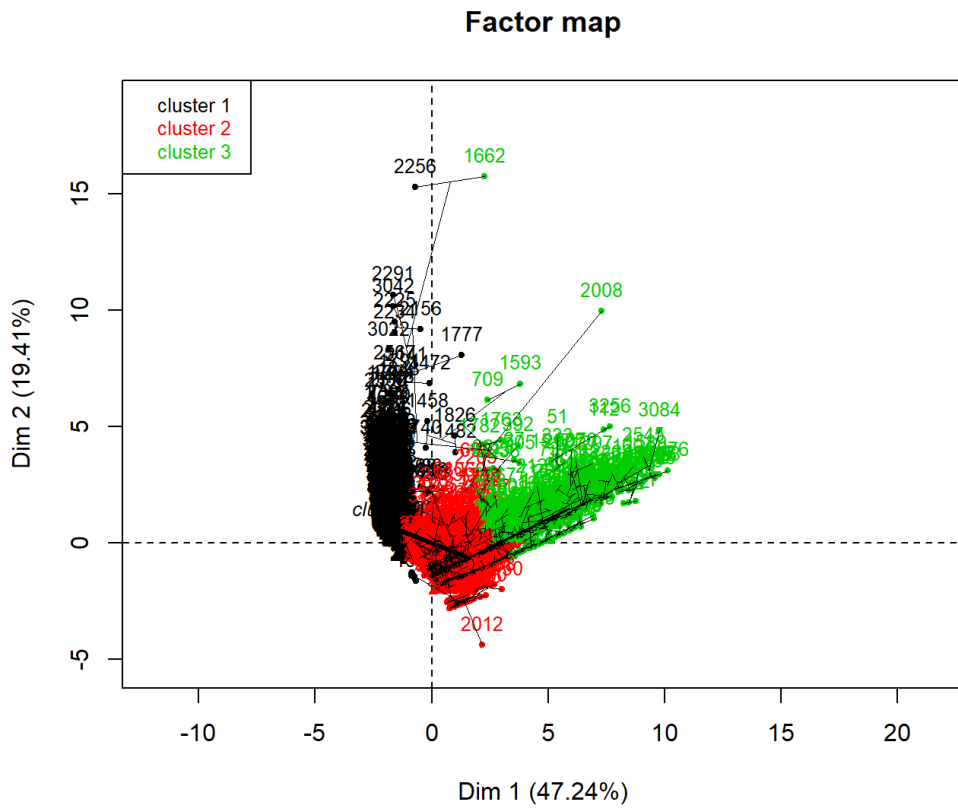
Variables - PCA
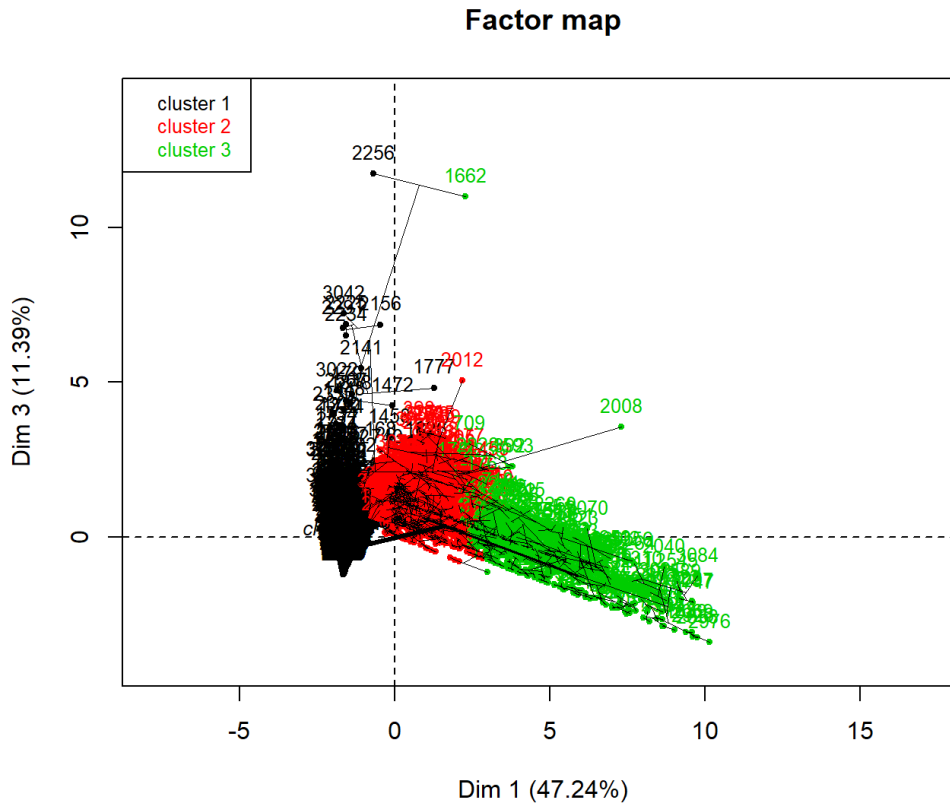
```
cah <- HCPC(rez, nb.clust= 3, graph = FALSE)
plot(cah, choice = "tree")
```

Hierarchical clustering


```
plot(cah, choice = "map")
```

Factor map


```
plot(cah, axes=c(1,3),choice = "map")
```

Factor map


```
meanCluster <- cah$data.clust %>% group_by(clust) %>% summarise_all(mean)

varCluster <- cah$data.clust %>%  group_by(clust) %>% summarise_all(var)


test   <-   cah$data.clust%>%mutate(toto=1:dim(cah$data.clust)[1])%>%select(-
c(foDur,price))

test                                                                      <-
reshape(test,idvar=c("clust","toto"),varying=list(1:8),v.names="Value",direc
tion="long")

graphtest <- ggplot(data=test, aes(x=as.character(time),y=Value,fill=clust))
+         geom_boxplot()          +          scale_x_discrete("",labels=
dimnames(cah$data.clust)[[2]][1:8])

graphtest
```
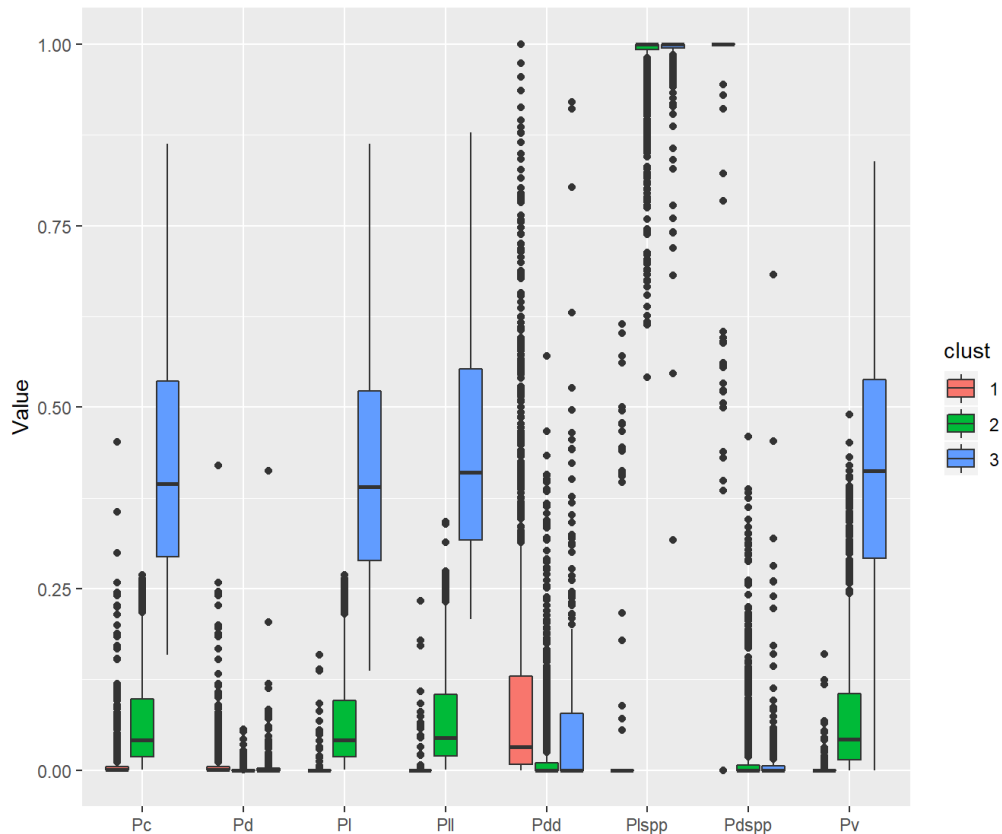
```
results <- cbind( spp7%>%filter(year==year_select)%>%select(FAO, year, area,
gear, vslFlgCtry), cah$data.clust)


saveRDS(results, paste(data_dir, "results_", Country, "_", year_select, "_",
area_select, "_", gear_name, ".rds", sep = ""))



sppClust      <-      results      %>%      group_by(FAO,      clust)      %>%
summarise(sumClust=length(clust))                                        %>%
mutate(percClust=sumClust/sum(sumClust))%>%            ungroup()         %>%
mutate(clust=as.integer(clust) %>% arrange(desc(clust),desc(percClust)) %>%
mutate(FAO=factor(FAO,levels=unique(as.character(FAO))))%>%
mutate(clust=factor(clust,levels=as.character(3:1)))




perc     <-     ggplot(sppClust,     aes(x=FAO,y=percClust,     fill=clust))     +
geom_bar(stat="identity")    +    theme(axis.text.x    =   element_text(size=5,
angle=45))

perc
```
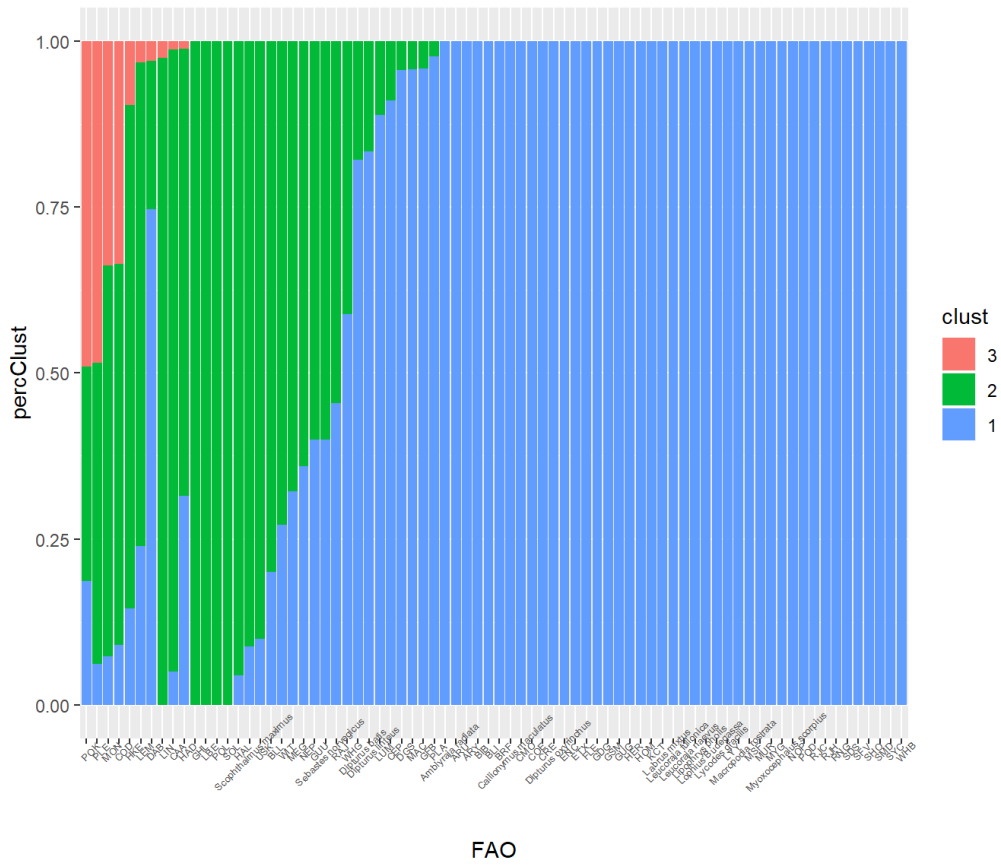
```
table(results$FAO, results$clust)
##
##                            1    2    3
##   Amblyraja radiata      182    0    0
##   ARU                     31    0    0
##   ARY                     19    0    0
##   BIB                      1    0    0
##   BLI                      6    0    0
##   BLL                      1    4    0
##   BRF                      2    0    0
##   CAA                      4   74    1
##   Callionymus maculatus    2    0    0
##   CEP                     51    5    0
##   CMO                     23    0    0
##   COD                     21  133   78
##   COE                      1    0    0
##   CRE                     29    0    0
##   DAB                     50   15    2
##   DGS                     22    1    0
##   Dipturus batis          23    5    0
```

```
## Dipturus linteus              5   1   0
## Dipturus oxyrinchus           3   0   0
## ENC                           7   0   0
## ETX                          36   0   0
## FLE                           1   0   0
## GDG                           4   0   0
## GFB                          70   3   0
## GHL                           0   1   0
## GSM                           1   0   0
## GUG                         193   0   0
## GUU                           4   6   0
## HAD                          52 111   2
## HAL                           2  43   0
## HER                          37   0   0
## HKE                          24 125  16
## HOM                          53   0   0
## KCT                         118   0   0
## Labrus mixtus                 1   0   0
## LBE                           0   1   0
## LEM                          22  67   3
## Leucoraja fullonica           2   0   0
## Leucoraja naevus             18   0   0
## LIN                           0 150   4
## Lipophrys pholis              2   0   0
## Lophius Budegassa             1   0   0
## LUM                           8   1   0
## Lycodes gracilis              2   0   0
## LYY                           1   0   0
## MAC                          68   3   0
## Macropodia rostrata           1   0   0
## MEG                          18  38   0
## MON                          17 136  78
## MSF                           1   0   0
## MUR                           2   0   0
## MYG                           1   0   0
## Myoxocephalus scorpius        1   0   0
## NEP                          14  25   0
## NOP                          23   0   0
## PLA                          85   2   0
```

```
##    PLE                 6  44  47
##    POD                12   0   0
##    POK                37  64  97
##    POL                 0  20   0
##    RAJ                 5   6   0
##    RJC                 5   0   0
##    RJH                 3   0   0
##    RNG                 1   0   0
##    Scophthalmus maximus  3  31   0
##    SDS                 3   0   0
##    Sebastes norvegicus   2   3   0
##    SFV                 7   0   0
##    SHO                40   0   0
##    SMD                 5   0   0
##    SOL                 0   1   0
##    SYC                48   0   0
##    USK                 1   9   0
##    WHB                27   0   0
##    WHG                73  51   0
##    WIT                47 126   0
```

COST. 2006. "Studies and Pilot Projects for Carrying Out the Common Fisheries Policy Call for Proposal Ref : FISH/2006/15 – Lot 2 Project No :SI2.467814 Project Acronym :COST." EUROPEAN COMMISSION.

3.8   Summary

The results above demonstrated the flow of work for a given métier. The case shown here is fairly representative of a typical mixed fisheries, where a few species make most of the landings and of the value (8 species *, many species appear with low and variable levels in the landings and in the discards, and a great number of species are fully discarded and never appear in the landings.

The first 3 axes of the PCA explain 78% of the variance.

The final outcome for this métier is that no species is systematically considered a target in every single fishing operation. The main target species are saithe (POK) and plaice (PLE), considered target in around half of the observed fishing operations, and cod and monkfish (MON), in around one third, and hake (HKE) in 10% of the fishing operations.

4   Global analysis and visualization

All results above from the various countries, regions, years and métiers were combined together in a unique dataset, and a suite of visualization tools were developed using the R Shiny framework.

4.1   Choice of threshold levels

The analysis above demonstrated that most commercial species which could intuitively be considered as "target" are, in reality, targeted in some fishing operations (high value, low discards) and valued bycatch in others (medium value, medium discards).

In order to categorize a species as being rather a target or rather a valued bycatch, is this therefore necessary to fix a threshold. For example, "a given species is considered a target if it is considered a target in more than 70% of the fishing operations". The higher the target, the lower the number of target species.

The first visualization tool investigated thus the sensitivity of the target definition to the choice of threshold.

Putting all regions and gears together, the number of target species appear as linearly correlated to the threshold level for all regions, with no obvious "jumps" (Figure 4.1). For example, in the region 8.ab (Bay of Biscay) with the largest number of species observed, 31 species are recorded as target in 50% of the fishing operations, and 16 species if the threshold is at 75%, and 9 species if the threshold is at 95%.
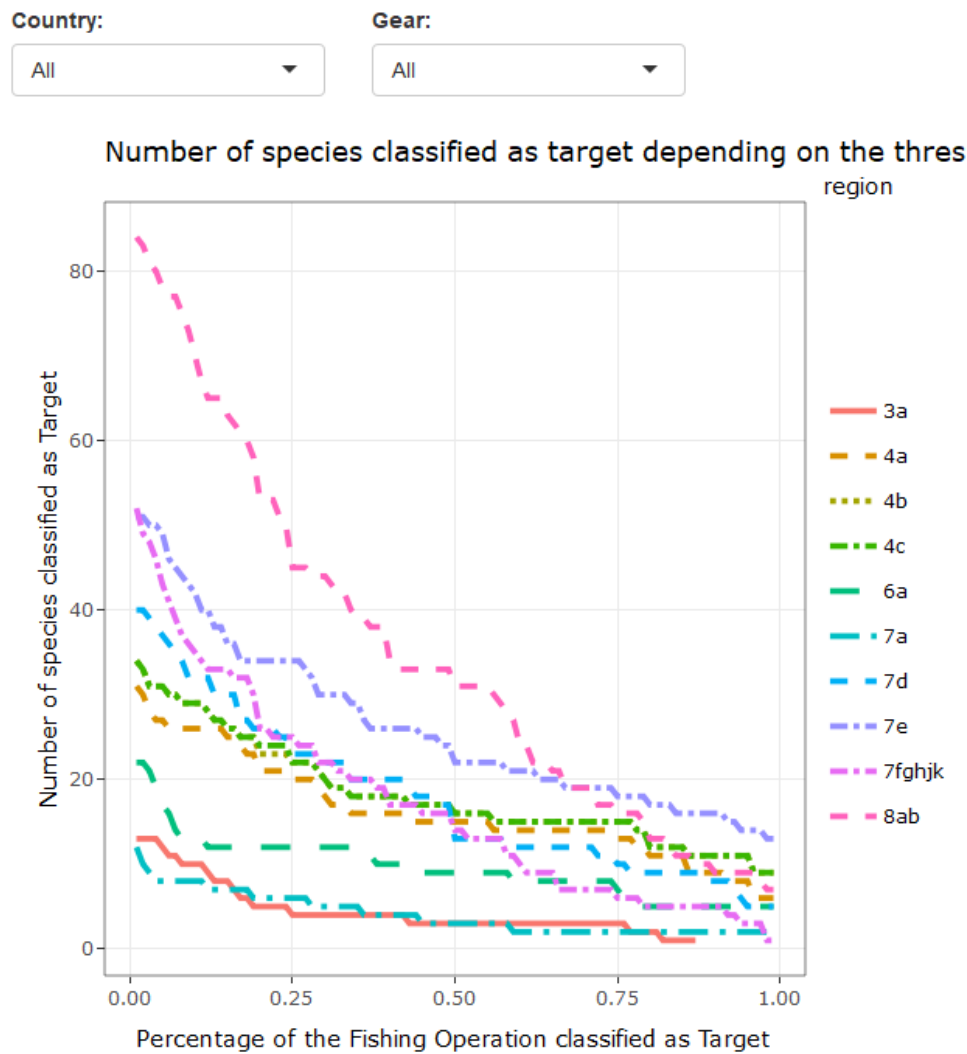
Figure 4.1. Number of species classified as target depending on the threshold level for all regions.

This gradual decrease is observed for many combinations of métiers and areas. However, when exploring the results in more details, some métiers would indeed show more pronounced patterns. For example, the seiners in the Bay of Biscay would only have six target species already above a 30% threshold (Figure 4.2).
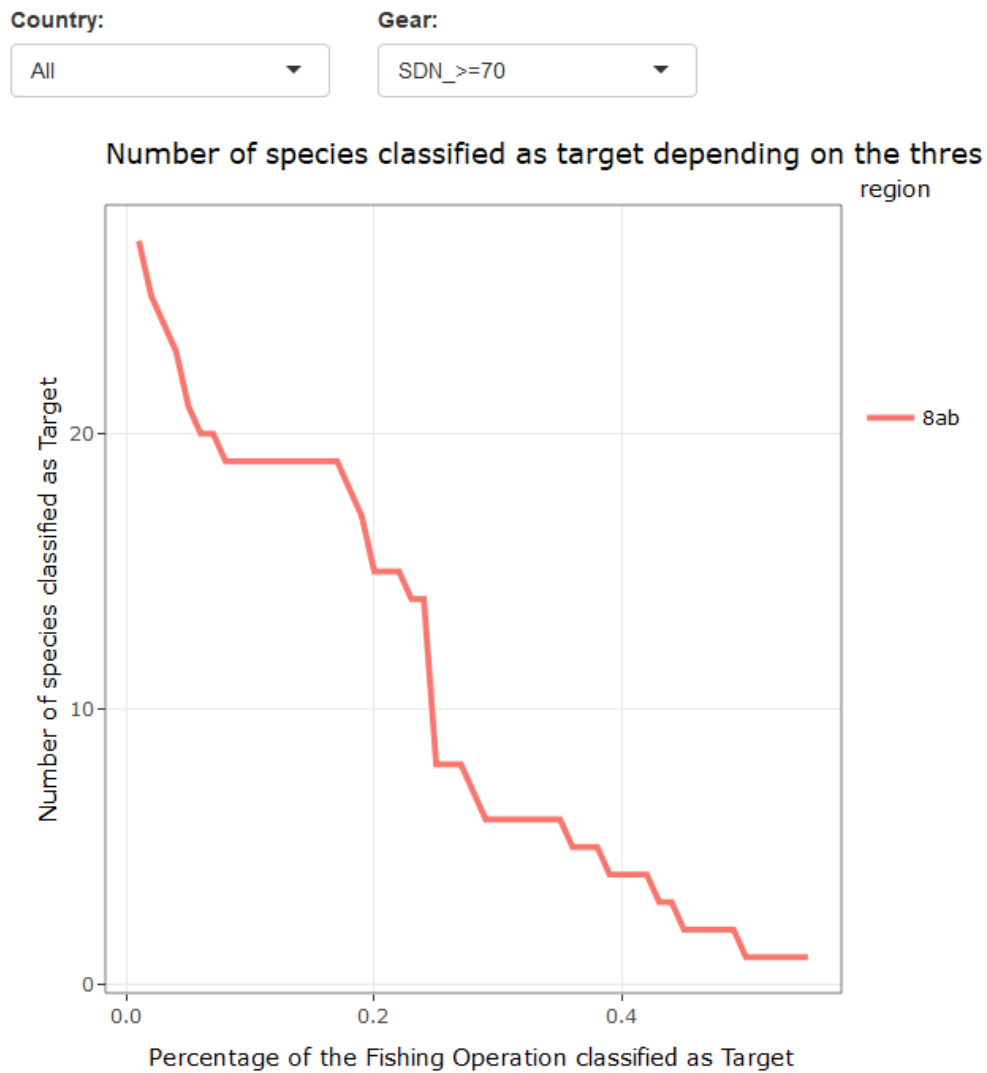
Figure 4.2. Number of species classified as target depending on the threshold level for 8ab (Bay of Biscay) only.

4.2   Target species by métier

The second visualization tool displays which are the species allocated to the various categories, for the selection of region and métier, and for a given threshold. Considering also that the allocation varies from year to year, the display how regular is the targeting analysis. The example below is for the Celtic Sea (ICES divisions 7.fg, 7.h–k), considering a threshold of 50% of the FOs in a given strata (country*metier*year) to be allocated as target species. There, it shows that monkfish (MON + ANF) is always considered a target for the trammelnets (GTR>=220) and the beam trawlers (TBB_70-99) [dark red colour means every year], but more irregularly for the trawlers and seiners métiers (yellow colour). The beam trawlers also target regularly sole and megrim, while the bottom trawlers and seiners do not have obvious target species at that level. Some species are classified as target, but not every year (yellow and orange colours). [Pale yellow means no target] (Figure 4.3)

Figure 4.3. Visualisation tool showing targeted/bycatch species by region and métier at a given threshold.

4.3 Target species by region

The third visualization tool focuses on the individual species, and maps its characterization across métiers over the different regions. (Figure 4.4) For example, the two figures below contrast the results obtained in 2015 for cod and monkfish respectively, and using a 30% target threshold (i.e. the species must be considered to be a target in at least 30% of the observed fishing operations of a métier in a given area and year in order to be considered a target species for that métier overall).

Monkfish is considered a valued bycatch in all métiers in the Bay of Biscay, North Sea, Skagerrak, and Eastern Channel, while it considered a target species in a number of métiers in the Western Channel and Celtic Sea (red fraction of the pie chart). On the other way, cod is mainly a valued bycatch in the Celtic Sea, while it is considered a target in a few métiers in the Eastern Channel, Northern North Sea and Skagerrak. Notably, cod is also considered a "collateral bycatch" in some métiers of the southern and central North Sea and in the Skagerrak.
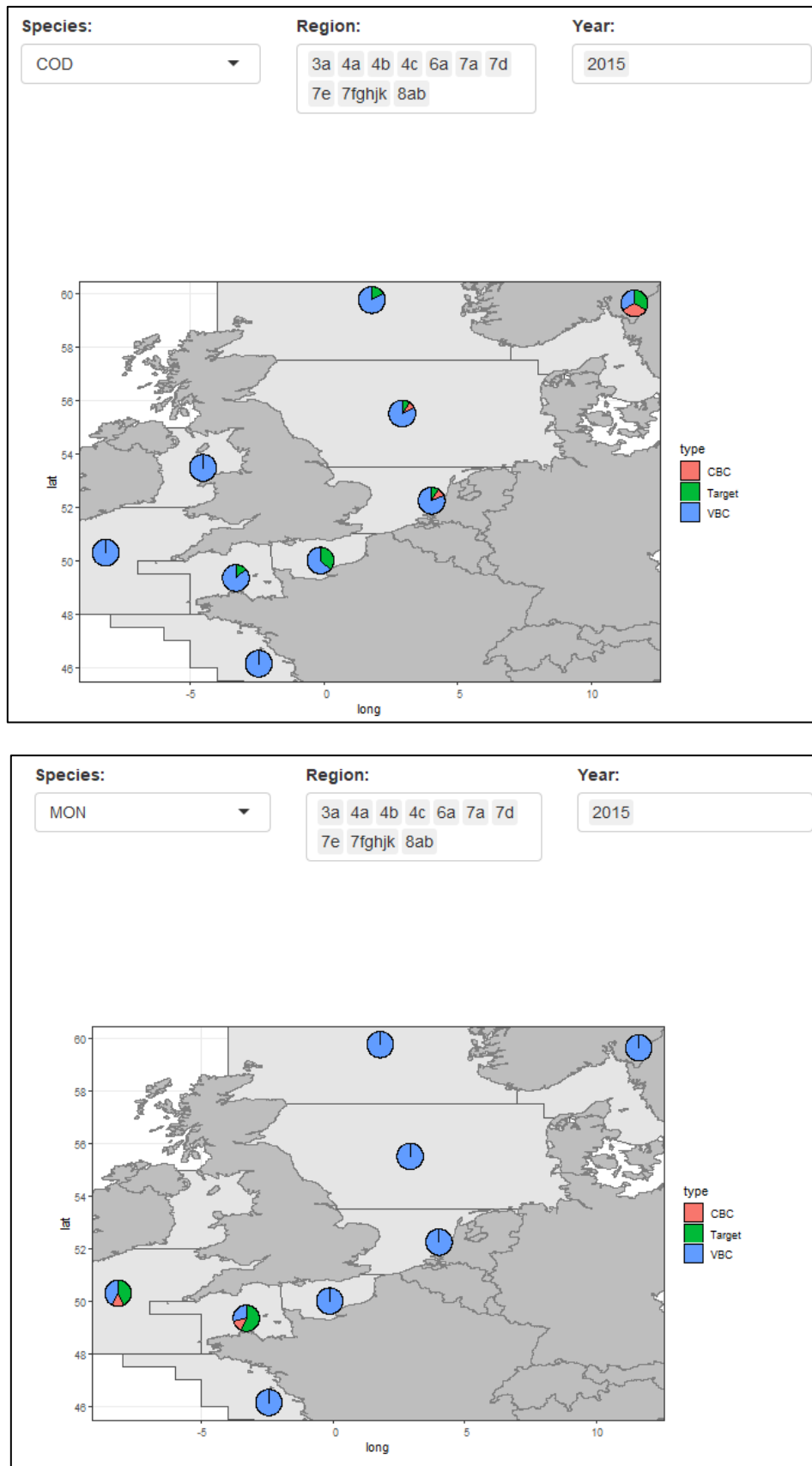
Figure 4.4. Visualisation tool mapping the characterization of species across métiers and regions.

Finally, the last visualization tool is an attempt to map this further not at the level of the subdivision but at the level of the ICES rectangle, combining the results with the landings by rectangle from the STECF database https://stecf.jrc.ec.europa.eu/dd/effort. The plot on the right is the proportion of targeting by rectangle, and the plot on the left the bubble size is weighted by the corresponding amount of landings in that rectangle (Figure 4.5).
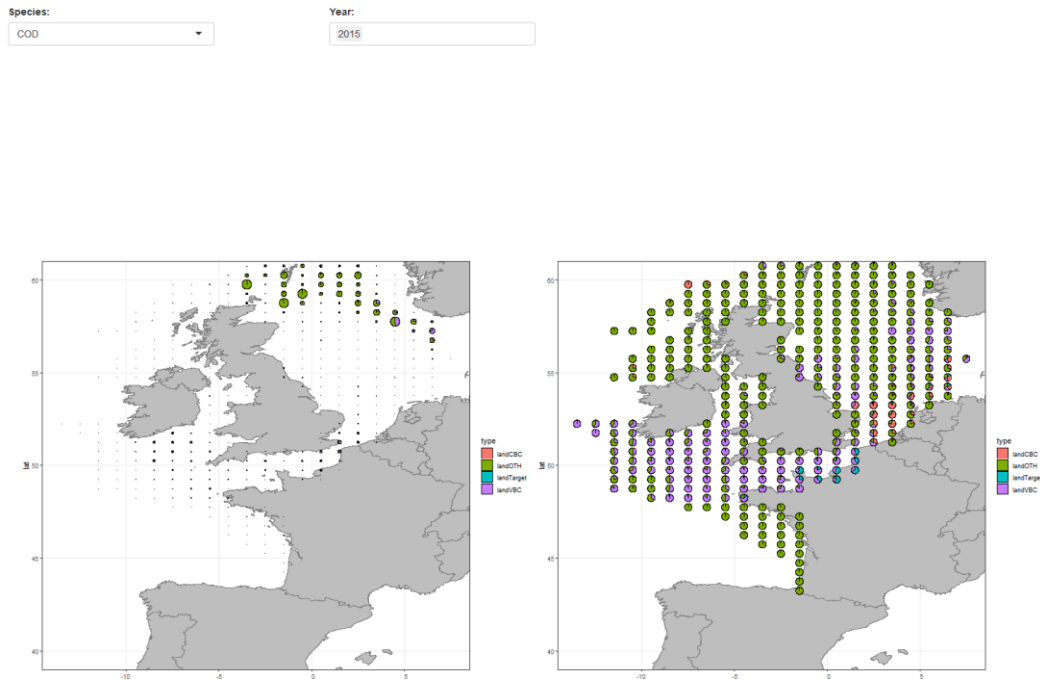

Figure 4.5. Visualisation tool mapping the characterization of species across métiers and ICES rectangle.

5 Conclusion and future work

The workshop demonstrated the genericity of the developed codes, as all participants were able to run the analyses on their own data. This procedure allowed working on national data that could not been shared for confidentiality reason.

All aggregated results were stored in a database to produce the web interface.

The future development will consider applying the approach directly to the Regional Data Base (RDB) instead on relying on the provision of national data by the member of the Workshop.

The results displayed in the web interface are still subjective as they depend upon the threshold set by the user. Some workshop will be planned with managers and fishers' representatives to present the tool and assess how the threshold should be set.

The outputs of this interface will be a list of species with the percentage of landings/catches associated with the different status (target/bycatch). The operational interest of these analyses depends upon our capacity to run the analyses on the overall exploitation (i.e. all countries, all métiers, and all areas). The RDB should then be the relevant database to use if populated by all countries.

Some species have shown different spatial/temporal targeting pattern for the same gear. These differences might be caused by different spatial and/or temporal species and effort distribution causing different technical interaction thorough the year. These technical interactions have now to be better understood to be able to propose alternative management measures.

Annex 1: List of participants

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