PINNGORTITALERIFFIK
GREENLAND INSTITUTE OF NATURAL RESOURCES
GRØNLANDS NATURINSTITUT

Nuuk, September 2021

Assessment of lumpfish (*Cyclopterus lumpus*) in West Greenland based on commercial data 2010-2021

Eqikkaaneq (summary in Greenlandic)

Nipisanniarnermi aqutsinermut pilersaarusiaq (Kalaallit Nunaata kitaata imartaani nipisannik arnarlunniartarnerit aqutsinikkut pilersaarusiorfigineqarnerat 2021-2025) aammalu nipisanniartarnerit nalilersuiffigineqarsimanerat aallaavigalugit ukiumut ataatsimut tamakkiisumik pisassiissutigineqarsinnaasutut innersuussutit matumuuna saqqummiuppagut. Nipisaat suaat 2021-mi tunitsivinnut tulaanneqarsimasut oqimaassuseqarput 1136,8 tonsit, pisarineqarsimasut oqimaassusinngorlugit biologit pisassiissutigineqarsinnaasutut innersuussutigisaasa 7,5 %-iinik ataateqqasimavaat, taamatullu oqimaassusinngorlugu pisassiissutigineqarsimasut taamatoqqissaaq appasinnerussuteqarsimallutik. Pisariuminassusiat (LPUE) 2020-miit 2021-imut kisitsisinngorlugu qaffariaateqarsimavoq, 11,6 %-imik qaffariarsimalluni. Pisariuminassusiannut kisitsisitaat ukiuni 2010-miit 2021-p tunganut qaffasinnerpaaffimminniissimapput ukiuni marlunni kingullerni, aggua-qatigiissillugu ukiunut taakkununnga kisitsisitaat 22,5 %-iullutik, ukiunut naleqqersorfiusunut tassa 2010-miit 2013-imut sanilliussilluni kisitsisitaat ukiuni kingullerni marlunni aamma qaffasinnerusimapput. Nipisaat suanniarnermi aqutsinnikkut pilersaarusiaq naapertorlugu tamakkiisumik pisarineqarsinnaasussat 2021-mi 1229,4 tonsiniit 2022-mi 1475,3 tonsinut qaffariaateqassapput (20 %-imik qaffariaateqassallutik). Malugalugu aqutsinermut pilersaarusiaq nutaaq naapertorlugu tamakkiisumik pisassiissutinik ukiumiit ukiumut qaffariaat annerpaamik 20 % qaangissanngimmagu. Ullut aalisarfiusussat pillugit siunnersuisoqassaarpoq, siunnersuinerlu ukiumut ataasinnarmuulerluni.

Resumé (summary in Danish)

Vi fremfører her en vurdering af stenbiderfiskeriet og præsenterer en etårig rådgivning, baseret på forvaltningsplanen (Forvaltningsplan for stenbiderhunner i Vestgrønland 2021-2025), for den total fangstmængde (TAC). Indhandlingerne i 2021 udgjorde 1136,8 t rogn, som var 7,5 % under den biologiske rådgivning og initiale TAC. Fangstbarheden (LPUE) steg fra 2020 til 2021 med 11,6 %. LPUE har de seneste to år været de højeste for hele perioden 2010-2021 og gennemsnittet for de to år er 22,5 % højere end reference LPUE'en fra 2010-2013. I henhold til forvaltningsplanen, vil det medføre en forøgelse af TAC'en fra 2021 på 1229,4 t til 1475,3 t i 2022 (stigning på 20 %). Obs, jf. den nye forvaltningsplan kan TAC maksimalt forøges med 20 % per år. Der rådgives ikke længere for antallet af fiskedage og der gives rådgivning for et år ad gangen.

Abstract

Here, we assess the lumpfish fishery and recommend a total allowable catch (TAC) following the management plan valid for 2021-2025. Landings of lumpfish roe in 2021 were 1136.8 t, which was 7.5 % below the biological advice and initial TAC. The landings per unit effort (LPUE) increased from 2020 to 2021 by 11.6 %. For the past two years, the LPUE has been the highest for the entire period 2010-2021, and the average for the two years is 22.5% higher than the reference LPUE from 2010-2013. According to the management plan, this will increase the TAC from 2021 of 1229.4 t to 1475.3 t in 2022 (an increase of 20 %). Note, cf. the new management plan TAC can maximally increase 20 % between years. Advice is no longer given for the number of fishing days, and advice is only given for one year at a time.

Introduction

The lumpfish fishery in Greenland takes place in the spring along the Greenland west coast. The fishery peaks around mid-May. Before 2000, reported roe landings were below 500 t, but in the last two decades, landings have steadily increased, reaching the highest level in 2013 with 2 124 t (Fig. 1). Since then, catches have generally decreased, now being slightly above 1 000 t. Before 2015, the fishery was unregulated, but in 2015 a management plan was implemented that operated with TAC and restricted fishing days. This management plan was subsequently updated. In 2021, a new management plan was implemented and applies to the period 2021-2025. This management plan primarily operates with TAC and a limitation of fishing days of 60 days in total. Moreover, the West Coast is divided into seven management areas (NAFO), with area-specific TAC and with an area-dependent onset of the fishery due to a timely displaced onset of spawning.

Most of the fishery is conducted from small open boats (<6.5 m) that operate with gill nets that typically fish for 24-48 hours. Due to the large mesh size (260 mm) the nets are highly selective and catch predominantly female lumpfish, which are much larger than males (Hedeholm *et al*. 2013). Upon capture, the roe is removed from the fish and stored in large barrels before being landed at land-based facilities. Hence, the number of fish landed is not reported, but the total amount of roe. Due to the size of the fishing vessels, there is an upper limit to the number of nets each boat can carry. All calculations in this assessment rest on this vital assumption; that the fishermen are assumed to be incapable of increasing fishing effort (nets) due to a decline in lumpfish abundance to maintain the same landings. Hence, kg. roe pr. landing is a proxy of landing per unit effort (LPUE) and can be used as a stock status indicator. If the extent of the fishing area is monitored simultaneously, we believe a reasonable indication of stock status can be provided, although no survey is available. The commercial data available have been of varying quality, and data before 2010 have not been evaluated valid for assessment purposes as those landings often lack supporting information such as fisherman ID and location.

In this document, we describe the assessment procedure, present an LPUE time series from 2010-2021 on lumpfish and estimate the extent of the fishery.

Data

Since 2010 each landing has reliably been associated with the amount of roe (kg.), date, fisherman ID, NAFO division and catch location (field code). Each field code is defined as 1/8-degree latitude * 1/4-degree longitude, which is roughly 14 km*8-14 km depending on latitude.

The data has been filtered to avoid bad data and "unserious" fishermen. Hence:

- A fisherman must have been active for at least three years from 2008-2019.
- A fisherman must have landed a minimum of 500 kg roe from 2008-2019.
- Single landing records above 500 kg are removed to exclude observations where the catches have been collected at larger vessels prior landings (thereby not representing the typical fishery).
- Only landings from Marts-May (incl.) are included.

Additionally, a fisherman is considered different if moving between NAFO areas among years.

Each landing is categorized as "roe", "whole fish", or "gutted fish". The roe from the two latter categories is also landed, and the calculations are therefore only based on the "roe" category. Uncategorized landings were sorted based on the value of the catch; using roe has a much higher weight specific value. Applying correct conversion factors allows for roe amount to be converted into whole fish weight and estimate the number of fish caught. At present, the conversion factor from roe to whole fish is 4 but was 6.7 before 2021. Because of uncertainties with this conversion factor, only roe landings are reported in the present document. Length data of adult female catches are available from 2011. However, sampling has been sporadic and with insufficient coverage of the fishing area.

Analysis

In this document, the procedure is shortly described in words only. All analyses were done in R (R core team, 2014), and the script for calculating LPUE is provided as an appendix to this document, including the data preparations steps. The calculations are derivatives of this script.

Initially, a year and NAFO division specific LPUE (kg pr. landing) for each individual fisherman is calculated. This LPUE is weighted by the share of the total catch in the respective NAFO division taken by the fisherman. All LPUE's from a NAFO area are summarized given a year and NAFO division specific LPUE. To get the LPUE estimate for the entire Greenland west coast, the NAFO division specific LPUE's are weighted by the total west coast landings. This procedure ensures that the fishermen and areas with the highest landings are given the highest weight when assessing the stock status.

The field code information is used to explore the fishery extent in general and to calculate the extent in each NAFO division and between years. This is done by simply calculating the number of field codes fished in each year in each NAFO division.

Results

The 2021 landings were 1136.8 t which is a reduction of 13.9 % compared to 2020 (Fig. 1). The TAC of 1229.9 t in 2021 was therefore not caught. In the northern areas (NAFO 1A-1Ba, 1Bb), 27 % of the subarea specific TAC was caught, while 52 % was caught in 1D and 1C 52 % (Table I) (information about the management areas is provided in the management plan).

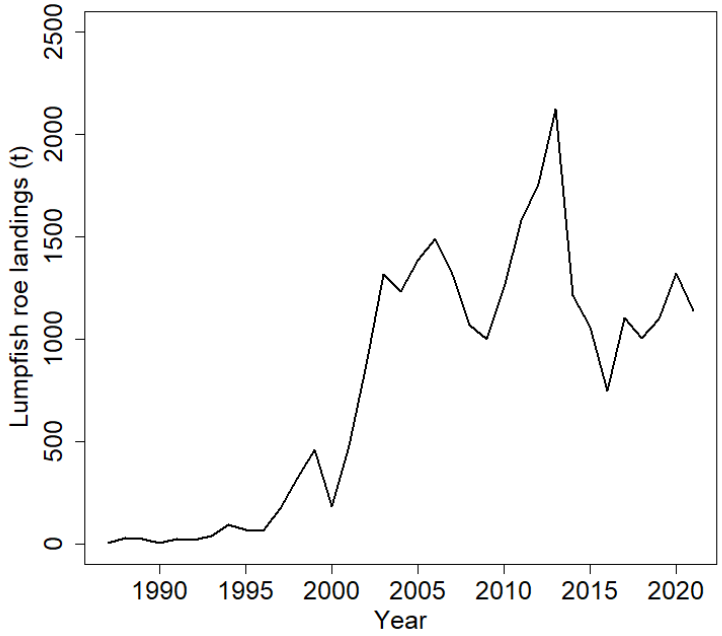

Figure 1: Total lumpfish roe landings (t) from 1987 to 2021.

Table I: Landings (roe) by NAFO area in 2021 (from north to south).

NAFO	TAC (t)	Landing (t)	% of the total landings (1136.8)
1A	150	154.5	13.6
1Ba	125	119.5	10.5
1Bb	57	33.0	2.9
1C	272	295.3	26.0
1D	329	300.0	26.4
1E	177	145.5	12.8
1F	118	89.0	7.8
Total	1229.4	1136.8	100.0

The overall LPUE increased by 11.6% (Fig. 2, Table II). This was driven by an increase in almost all NAFO areas except 1E (Fig. 3).

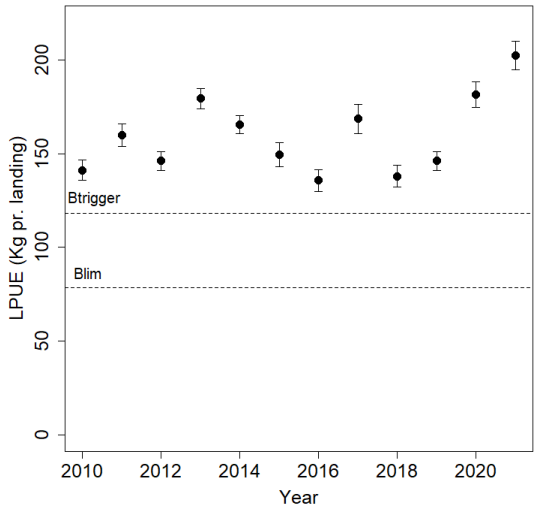

Figure 2: LPUE estimates for the West Greenland area. Vertical bars are standard errors. $B_{trigger}$ and B_{lim} values are indicated.

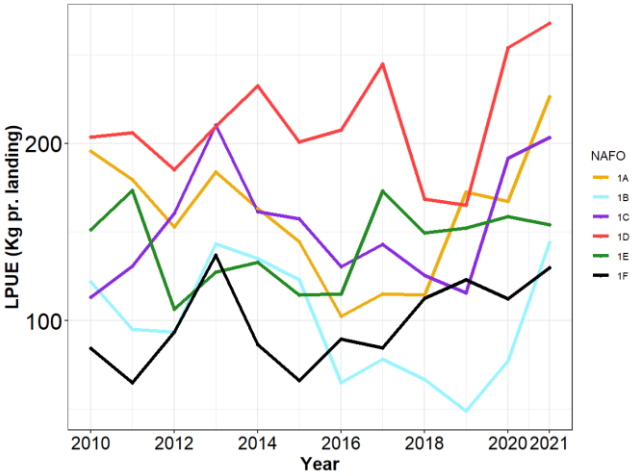

Figure 3: NAFO area specific LPUE estimates.

Table II: LPUE index by year with standard error.

Year	LPUE	Standard error
2010	141.1	5.5
2011	159.8	5.9
2012	146.2	5.0
2013	179.3	5.3
2014	165.5	4.9
2015	149.2	6.4
2016	135.6	5.9
2017	168.5	7.8
2018	137.9	5.9
2019	146.0	5.1
2020	181.3	6.8
2021	202.3	7.6

The cumulative catches show that a large share was taken during a relatively short period and earlier than previous years (Fig. 4, the steeper slope for the red 2021 line). This progress was likely an outcome of an effective/good fishery and the closure of several buying places (factories) along the coast.

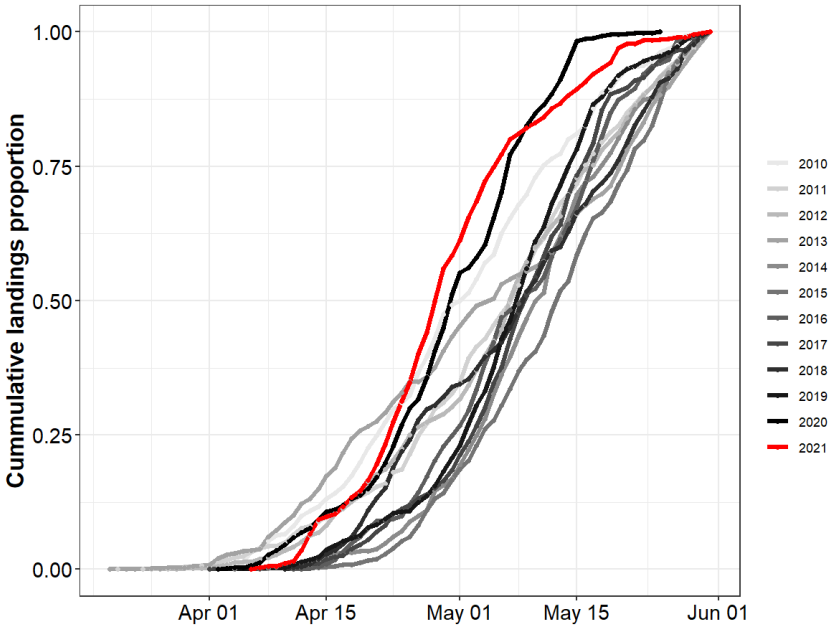

Figure 4: Cumulative landings over the year in proportions by year.

Active fishermen decreased in all areas (Table III). The number of fished field codes decreased from 268 in 2020 to 220 in 2021 but is still in the range of the average for the preceding six years (234) (Table III). Hence, the extension of the fishery dropped below the average, but this happened simultaneously with a decrease in active fishermen.

Table III: Number of field codes fished and active fishermen in each NAFO division and year. Numbers are for all landings for the months Marts-May (incl. landings filtered out for calculating the final LPUE).

Year	Number of fishers						Total	Number of field codes fished						Total
	1A	1B	1C	1D	1E	1F		1A	1B	1C	1D	1E	1F	
2012	218	151	185	152	104	26	836							
2013	180	126	145	181	93	24	749							
2014	123	106	148	95	105	14	591							
2015	114	73	192	93	108	11	591	36	44	56	29	41	3	209
2016	114	74	180	83	87	2	540	53	35	55	28	53	2	226
2017	84	44	194	97	100	15	534	25	28	53	39	47	9	201
2018	138	62	235	116	96	13	660	45	29	62	43	49	9	237
2019	184	71	219	104	102	22	702	60	41	64	35	52	9	261
2020	192	72	224	100	113	20	721	73	48	61	35	49	2	268
2021	146	44	185	72	96	19	562	53	32	57	30	44	4	220

The average fish length has been surprisingly stable between years (considering the low sample size) with 2011 (N=109), 2012 (N=561), and 2013 (N=69) length mean being within 1.1% of each other (2011-2013

average=37.62 cm), whereas 2014 (N=273) and 2015 fish (N=244) were slightly larger (39.18 and 38.3, respectively). There was no sampling from the commercial fishery in 2016-2018. In 2019 and 2021, dedicated studies about bycatch from the lumpfish fishery were carried out. In the 2019 project, 823 female lumpfish were collected (throughout most of the fishing season) from catches around Nuuk. The mean length of these fish was 36.26 cm, thus slightly shorter than in previous years. In the 2021 project, 452 female lumpfish were measured, which had a mean length of 38.0 cm. Yet, a particular trend in the development of the size composition can still not be inferred.

Discussion and advice following the management plan in action

The data used in this assessment seem consistent and provides a valuable tool for assessing the state of the lumpfish stock (given correct assumptions). Landings in 2021 decreased by 13.9 % compared to 2020 and were 7.5 % below the TAC. The LPUE (202.3) increased to the time series high and are now significantly above the $B_{trigger}$ reference point (161). The LPUE in 2021 and catches across the season indicates that the fishery was very effective compared to previous years. This indication agrees with several oral reportings across the industry.

Both the number of fishermen and the number of fished field codes decreased in 2021. However, the data does not allow us to evaluate if the contraction of the fishery was into better areas, and therefore potentially causing an increase in LPUE irrespective of the lumpfish amount in the "normal" areas.

The advice for the quantity for roe catches (TAC) is generated by applying the decision tree in Fig. 5. An elaboration of this procedure is given in the current management plan, Annex 4. The advice for lumpfish is a single year advice, which is a deviation from previous years. **Following the decision tree in the management plan, the TAC should increase from 2021 (1229.4 t) to 2022 by 22.5 %. However, the TAC is only allowed to be raised annually by a maximum of 20 %, which results in the advice of <u>1475.3 t for 2022</u>.** See Fig. 6 for calculations. It is worth noting that the entire TAC for 2021 was not caught, and the fishery ended slightly earlier than in previous years. Therefore, when setting the TAC for the coming year, it should be considered that the value of LPUE might be affiliated with some extra uncertainty. Hence, it could be considered whether an extra uncertainty cap should be implemented as a precaution. Especially when considering the 2022 TAC advice approaches some of the highest catches of the time series (Fig. 1).

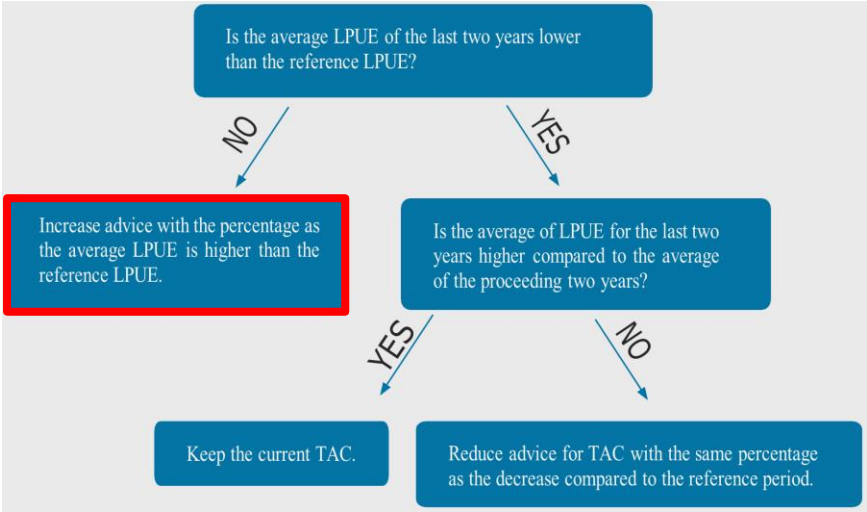

Figure 5: Advisory decision tree. Red box applies for 2022 advice.

Advice for 2022 (red box in fig 5): Increase TAC advice from last year with the same % as the average LPUE of 2020 and 2021 is higher than the ref. period.

2022 advice initial: $2021_{TAC} * (1+((LPUE_{2020-2021} - LPUE_{ref\ 2010-2013}) / LPUE_{ref\ 2010-2013})) = 2022_{TAC}$

2022 advice initial: 1229.4 * (1+((191.8-156.6)/156.6)) = 1506.1 t

As this initial 2022 advice exceed the 2021 advice by 20 %, the 2022 advice is set to be the 2021 advice increased by 20 %.

2022 advice: 1229.4 * 1.2 = 1475.3 t

Figure 6: Procedure for TAC advice.

Large year-to-year fluctuations in the number of spawners can be a result of 1-2 year classes comprising the vast majority of the spawning component (Hedeholm *et al*. 2013, 2017). Single year recruitment anomalies are expected to affect the fishing 3-4 years later. This means that an assessment based on historical landings few years back is sub-optimal, but since there is no measure of the juvenile stock component it currently provides the only option.

We do not provide any estimate of male lumpfish landings as these are unreported (though started on a smaller scale in 2019). However, given the mesh size of the gill nets (260 mm) and the significant sexual size dimorphism (Hedeholm *et al*. 2013) we believe that male catches are low. Davenport (1985) states that based on Icelandic data males are predominantly caught in 170-190 mm gill nets. However, small amounts of males are landed and sold on the domestic market, but catches are surely small and amounts to only a few tonnes. In addition, there is a recreational fishery for females that is not accounted for in this study. The recreational landings are also from 260 mm gill nets, but there is no estimate of the amount. Based on personal communication it is, however, estimated that total recreational roe landings are less than 25 t pr. year, and therefore negligible.

The LPUE estimates presented here rests on vital assumptions. If the fleet change effort (i.e. number of nets pr. boat) the LPUE time series will reflect additional changes than solely population changes. Currently, data does not allow us to evaluate the validity of this assumption but based on seminars and personal communication the fishermen appear to carry the same number of nets regardless of catch rates – the small boats are simply saturated. The assumption that fishermen are "net saturated" also implies that fisherman do not change "set up" between years, e.g. that the effort in regards to nets is fixed. We cannot, however, rule out that certain fishermen changes boat/gear type in the period.

Another vital assumption for this assessment is that fishermen land the catch just after capture, even if this means having only some fraction of the maximum capacity in the boat. We believe this is justified, as lumpfish roe will not stay at premium quality for several days after capture, and the fishermen have no storage facility in their small boats. The validity of this assumption has been well confirmed in seminars. In addition, several landing places (factories) have a rule of maximum time of catch to time of landing.

The LPUE times series is based on high quality data, but given the uncertainty of the assumptions, the relatively short time series, and the lack of biological knowledge on lumpfish means that LPUE estimates are associated with some uncertainty. Therefore, the fishery should be managed based on a precautionary approach until more data is available. Also, the field codes fished is not currently implemented in a formal way in the management plan, which ideally should be considered.

References

Davenport, J. 1985. Synopsis of the biological data on lumpsucker *Cyclopterus lumpus* (Linnaeus, 1758). FAO Fisheries synopsis. No. 147. Rome 1985.

Hedeholm, R., Blicher, M.E. and Grønkjær, P. 2014. First estimates of age and production of lumpsucker (*Cyclopterus lumpus*) in Greenland. Fish. Res. (2013). 149:1-4. http://dx.doi.org/10.1016/j.fishres.2013.08.016.

Hedeholm, R., Post, S., and Grønkjær, P. 2017. Life history trait variation of Greenland lumpfish (*Cyclopterus lumpus*) along a 1600 km latitudinal gradient. Polar Biology. 40:2489-2498. Doi 10.1007/s00300-017-2160-x.

R Core Team (2014). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL http://www.R-project.org/.

Appendix I

R script used in LPUE calculations.

```
#
#####################################################################################################################################

#setwd('Z:/Luli/37 Stenbider/Indhandlingsdata/2021 - med nyt script')
library(car); library(plyr)

#Preparing data
data2020 <- read.csv('Z:/Luli/37 Stenbider/Indhandlingsdata/2021 - med nyt script/LUM_10_20_1.csv', sep=';', header=T)
data2021 <- read.csv('Z:/Luli/37 Stenbider/Indhandlingsdata/2022/Stenbider2021 v1 08072021.csv', sep=';',dec=".", header=T)
data2021 <- data2021[data2021$AAR==2021,]

#data2020$FISKER_GFLKNR <- data2020$GFLK_NR #Så formatet passer med 2010-2018 data
#data2020$INDHANDLERS_NAVN <- data2020$FISKERS_NAVN
data2020 <- data2020[,c('INDHANDLINGSDATO','INDHANDLINGSSTED_GFLKNR','LANDINGSSTED_GFLKNR','FI-
SKER_GFLKNR','BEHGRD_KODE',"MAENGDE","VAERDI",'FANGSTFELT')]

data2020$day <- as.numeric(as.character(substring(data2020$INDHANDLINGSDATO, 1,2)))
data2020$month <- as.numeric(as.character(substring(data2020$INDHANDLINGSDATO, 4,5)))
data2020$year <- as.numeric(as.character(substring(data2020$INDHANDLINGSDATO, 7,10)))

data2021 <- plyr::rename(data2021 ,c('GFLK_NR'='FISKER_GFLKNR')) #Old name = New name. This sometimes gives a mistake if plyr and dplyr
is loaded, therefore using plyr::
#Obs. der er forskel i datoformatet mm-dd mellem år. Vær sikker på at dette skrives korrekt.
#For 2021 trækket er det MM-DD-YYYY, tidligere er det DD-MM-YYYY
data2021$INDHANDLINGSDATO <- substr(data2021$INDHANDLINGSDATO, 1,10)
common_names <- intersect(names(data2020), names(data2021))
data2021 <- data2021[,common_names]
data2021$day   <- as.numeric(as.character(substring(data2021$INDHANDLINGSDATO, 4,5)))
data2021$month <- as.numeric(as.character(substring(data2021$INDHANDLINGSDATO, 1,2)))
data2021$year  <- as.numeric(as.character(substring(data2021$INDHANDLINGSDATO, 7,10)))

data1 <- rbind(data2020, data2021)
data1 <- data1[!is.na(data1$FISKER_GFLKNR),] #Fjerner observationer hvor der ikke er information om fisker

# data1$day <- as.numeric(as.character(substring(data1$INDHANDLINGSDATO, 1,2)))
# data1$month <- as.numeric(as.character(substring(data1$INDHANDLINGSDATO, 4,5)))
# data1$year <- as.numeric(as.character(substring(data1$INDHANDLINGSDATO, 7,10)))

#Funktion til at beregne fangst feltkode
Funktion <- function(x) {
  if(x == "A") y <- 1
  if(x == "B") y <- 2
  if(x == "D") y <- 3
  if(x == "E") y <- 4
  if(x == "F") y <- 5
  if(x == "G") y <- 6
```

```
  if(x == "H") y <- 7
  if(x == "J") y <- 8
  if(x == "K") y <- 9
  if(x == "L") y <- 10
  if(x == "M") y <- 11
  if(x == "N") y <- 12
  if(x == "P") y <- 13
  if(x == "R") y <- 14
  if(x == "S") y <- 15
  if(x == "T") y <- 16
  if(x == "V") y <- 17
  if(x == "X") y <- 18
  if(x == "Z") y <- 19
  if(x == "+") y <- NA
  if(x == "0") y <- NA
  if(x == "1") y <- NA
  if(x == "2") y <- NA
  if(x == "3") y <- NA
  if(x == "4") y <- NA
  if(x == "5") y <- NA
  if(x == "6") y <- NA
  if(x == "7") y <- NA
  if(x == "8") y <- NA
  if(x == "9") y <- NA
  if(x == "y") y <- NA
  if(x == "") y <- NA
  return(y)
}

y<-NULL
data1$Fk_character1<-substring(data1$FANGSTFELT,1,1)
data1$Fk_character2<-substring(data1$FANGSTFELT,2,2)

num_character1<-sapply(data1$Fk_character1,Funktion)
num_character1<-array(num_character1)
data2<-cbind(data1,num_character1)
num_character2<-sapply(data1$Fk_character2,Funktion)
num_character2<-array(num_character2)
data2<-cbind(data2,num_character2)

data3<-data2
#Beregner lat og lon fra midt pos på feltkoder. Giver en fejl i de første år hvor der mangler info om feltkode
data3$Latitude<- 60 + (1/16) + (1/8)*((19*(as.numeric(as.character(data3$num_character1))-6)+as.numeric(as.character(data3$num_character2))-9))
data3$Longitude<- (58 + (1/8) - (1/4)*as.numeric(as.character(substring(data3$FANGSTFELT,3,5)))) * (-1)

data4 <- data3[,c('year','month','day','BEHGRD_KODE','MAENGDE','FISKER_GFLKNR','VAERDI','FANGSTFELT','Latitude','Longi-
tude','INDHANDLINGSSTED_GFLKNR')]
data4 <- plyr::rename(data4 ,c('BEHGRD_KODE'='BEHGRD','FISKER_GFLKNR'='SAELGER','FANGSTFELT'='FELTKODE')) #Old name =
New name.
```

```
#names(data4)[1:11] <- c('year','month','day','BEHGRD','MAENGDE','SAELGER','VAERDI','FELTKODE','Latitude','Longitude','INDHANDLINGSSTED_GFLKNR')

#Her beregnes NAFO område udfra position fra feltkoderne
NAFO<-ifelse(data4$Latitude>=68.50,"1A",
  ifelse(data4$Latitude<68.50&data4$Latitude>=66.15,"1B",
  ifelse(data4$Latitude<66.15&data4$Latitude>=64.15,"1C",
  ifelse(data4$Latitude<64.15&data4$Latitude>=62.30,"1D",
  ifelse(data4$Latitude<62.30&data4$Latitude>=60.45,"1E",
  ifelse(data4$Latitude<60.45&data4$Latitude>=55.20,"1F",""))))))

data5<-cbind(data4,NAFO)

#Der vælges kun indhandlinger fra marts-maj
# data6<-subset(data5, month=='3')
# data7<-subset(data5, month=='4')
# data8<-subset(data5, month=='5')
# data9<-subset(data5, month=='6') #Her var det lavet en fejl. Der stod: data9 <- subset(data8, month=='6')
# data10<-rbind(data6,data7)
# data11<-rbind(data10,data8)
# data12<-rbind(data11,data9)
data12 <- data5[data5$month %in% c(3,4,5),]
#TEST of removing observations later than may 15 (140). This is done because 2021 was a year heavily influence management (Clossure of buying places)
# data12$Date <- as.Date(paste(data12$day, data12$month, data12$year, sep = '-'))
# data12$DayOfYear <- yday(data12$Date)
# data12 <- data12[data12$DayOfYear<141,]
# data12 <- data12[data12$month<5,]

#Fjerner data hvor det ikke udelukkende er rogn
data13<-subset(data12,BEHGRD!='MHUI')
data13b<-subset(data13,BEHGRD!='HEL')
data13b<-subset(data13b,BEHGRD!='HEL-M')
data13b<-subset(data13b,BEHGRD!='HEL-F')

#For de steder som mangler feltkode bruges indhandlingssted til at få nafo område. ----
data13b$INDHANDLINGSSTED_GFLKNR <-  as.factor(data13b$INDHANDLINGSSTED_GFLKNR)
data13b$INDHANDLINGSSTED_BY<-recode(data13b$INDHANDLINGSSTED_GFLKNR,"c(1010)='Nanortalik';c(1040)='Narsaq';c(1050)='Paamiut';c(1060)='Nuuk';c(1070)='Maniitsoq';
                    c(1080)='Sisimiut';c(1100)='Aasiaat';c(1110)='Qasigiannguit';c(1120)='Ilulissat';c(1121)='Ilulissat';c(1122)='Ilulissat';
                    c(1123)='Ilulissat';c(1124)='Ilulissat';c(1140)='Qeqertarsuaq';c(1150)='Uummannaq';c(1151)='Uummannaq';c(1152)='Uummannaq';
                    c(1153)='Uummannaq';c(1154)='Uummannaq';c(1155)='Uummannaq';c(1156)='Uummannaq';c(1157)='Uummannaq';c(1210)='Arsuk';
                    c(1211)='Nuuk';c(1212)='Nuuk';c(1213)='Maniitsoq';c(1214)='Maniitsoq';c(1217)='Kangaatsiaq';c(1218)='Aasiaat';c(1219)='Aasiaat';
                    c(22111)='Nanortalik';c(22167)='Upernavik';c(22532)='Qaqortoq';c(22597)='Innaarsuit';c(22619)='Ship';c(22761)='Ilulissat';
                    c(22810)='Kangersuatsiaq';c(22815)='Attu';c(22818)='Upernavik';c(22835)='Qaanaaq';c(22857)='Sisimiut';c(22874)='Sisimiut';c(22876)='Kuumiut';c(22928)='Sisimiut';
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                c(22930)='Maniitsoq';c(23011)='Maniitsoq';c(23039)='Ilimanaq';c(23049)='Maniitsoq';
                c(23137)='Qeqertarsuaq';c(23139)='Aasiaat';c(1616)='Ship';c(1651)='Ship';c(1653)='Ship';c(22111)='Nanortalik';c(22162)='Uummannaq';
                c(22167)='Upernavik';c(22479)='Ilulissat';c(22532)='Qaqortoq';c(22597)='Upernavik';c(22619)='Ship';c(22761)='Ilulissat';
                c(22810)='Upernavik';c(22815)='Aasiaat';c(22818)='Upernavik';c(22835)='Qaanaaq';c(22857)='Sisimiut';c(22874)='Sisimiut';c(22876)='Tasiilaq';
                c(22928)='Sisimiut';c(22930)='Qaqortoq';c(23103)='Upernavik';c(23104)='Upernavik';c(23105)='Upernavik';c(23106)='Upernavik';
                c(23108)='Uummannaq';c(23011)='Maniitsoq';c(23039)='Ilulissat';c(23049)='Nanortalik';c(23137)='Qeqertarsuaq';c(23139)='Aasiaat';
                c(23275)='Sisimiut';c(23338)='Sisimiut';c(23286)='Upernavik';c(23395)='Upernavik';c(22821)='Nuuk';c(22992)='Maniitsoq';c(22993)='Aasiaat';c(23114)='Nanortalik';
                c(23325)='Qeqertarsuaq';c(23691)='Upernavik';c(23733)='Ilulissat';c(29500)='Narsaq';c(68)='Nuuk';c(23374)='Narsaq';c(24052)='Maniitsoq';c(27557)='Narsaq';c(23502)='Maniitsoq';
                c(23514)='Sisimiut';c(23505)='Attu';c(23581)='Aasiaat';c('29501')='Nuuk';c('23692')='Uummannaq';c('23978')='Maniitsoq';c(23503)='Ikamiut';c(24483)='Qasigiannguit';c(25419)='Narsaq';
                c(24429)='Ilulissat'") #, c(24483)='Qasigiannguit' [sopo] mit bud på sted
unique(data13b$INDHANDLINGSSTED_BY) #Tjekker om der er nogle feltkoder som ikke omskrives til område. Der er nogle. Men de er opgjort som MHUI og HEL-F
#efter snak med GFLK er der lavet ændringer i område allokeringen 8-12-2016, RaHe.

data13b$INDHANDLINGSSTED_BY <- as.factor(data13b$INDHANDLINGSSTED_BY)
data13b<-subset(data13b, INDHANDLINGSSTED_BY!='27501') #Fjerner bifangst fra loddefiskeriet i Island
data13b<-subset(data13b, INDHANDLINGSSTED_BY!='35117') #Fjerner fangst fra Norge

data13b$NAFO_fra_Indhandlingssted <-recode(data13b$INDHANDLINGSSTED_BY,"c('Nanortalik')='1F';c('Narsaq')='1F';c('Paamiut')='1E';c('Nuuk')='1D';c('Maniitsoq')='1C';
                    c('Sisimiut')='1B'; c('Aasiaat')='1B'; c('Qasigiannguit')='1B';c('Ilulissat')='1A';c('Qeqertarsuaq')='1A';c('Uummannaq')='1A';c('Arsuk')='1E';
                    c('Kangaatsiaq')='1B';c('Upernavik')='1A';c('Qaqortoq')='1F';c('Innaarsuit')='1A';c('Kangersuatsiaq')='1A'; c('Attu')='1B';
                    c('Qaanaaq')='1A';c('Sisimiut')='1B';c('Kuumiut')='XIVb';c('Ilimanaq')='1A';c('Tasiilaq')='XIVb'; c('Ikamiut')='1B'")

data13b<-subset(data13b, NAFO_fra_Indhandlingssted!='XIVb') #Fjerner fangster fra Østgrønland

data13b$NAFO <- ifelse(is.na(data13b$NAFO), as.character(data13b$NAFO_fra_Indhandlingssted), as.character(data13b$NAFO))
data13b$NAFO <- ifelse(data13b$NAFO=='', as.character(data13b$NAFO_fra_Indhandlingssted), as.character(data13b$NAFO))
data13b$NAFO <- as.factor(data13b$NAFO)
#----

#write.table(data13b, file = "tilsas2.csv", sep = ";", na = "NA", row.names = F)

#Der er linjer uden angivelse af behgrd. For at tjekke om det rogn eller MHUI/HEL regnes en kg pris ud.
#Herefter smides de linjer ud, hvor kg.prisen er under 5 kr. Det er en lille usikkerhed omkring nogle observationer, hvor der er en mængde men ingen værdi. Her kan man ikke se om der er fejlinformeret.
#På nuværende tidspunkt tages de ud.
data13b$value <- data13b$VAERDI / data13b$MAENGDE #kg.prisen udregnes
data13c <- subset(data13b, value>5&value<=50) #NY: ud over nedre grænse er den øvre grænse for kg prisen også defineret. Få observationer (5) bliver fjernet af den øvre grænse.
```

```
#Der er enkelte fejl i data, blandt andet negative mængder, som smides ud her.
data14<-subset(data13c, MAENGDE>0&MAENGDE<500) #NY: Her ertilføjet øvre grænse for indhandling pr gang på 500 kg.

#Her droppes ligegyldige variable.
data14$BEHGRD <- data14$VAERDI <- data14$value <- NULL

#Her laves location om til en kategorisk variabel.
#data14 <- data13b #Hvis der ikke skal selekteres ud fra indhandling i data
data14$feltkode = as.factor(data14$FELTKODE)

#write.table(data14, file = "diverse.csv", sep = ";", na = "NA", row.names = F)

summary_table1 <- aggregate(data14[,c('MAENGDE')],list(FELTKODE=data14$FELTKODE, year=data14$year),sum,na.rm=T)
summary_table1$tons <- summary_table1$x/1000
summary_table2 <- aggregate(data14[,c('MAENGDE')],list(year=data14$year, NAFO=data14$NAFO),sum,na.rm=T)
summary_table2$tons <- summary_table2$x/1000

#Herunder skal de fiskere som skal indgå i beregningerne udvælges. Det sker efter flere kriterier:
#først regnes antallet af år en fisk har været aktiv
data14$dummy <-1
indhandlinger_pr_fisherman_pr_aar <- aggregate(data14[,c('dummy')],list(SAELGER=data14$SAELGER, year=data14$year),sum,na.rm=T) #giver
antal indhandlinger pr år pr. fisker
indhandlinger_pr_fisherman_pr_aar$dummy2 <-1 #en ny dummy variable som vi summerer herunder
antal_aktive_fiskeaar <- aggregate(indhandlinger_pr_fisherman_pr_aar[,c('dummy2')],list(SAELGER=indhandlinger_pr_fisherman_pr_aar$SAEL-
GER),sum,na.rm=T) #giver antal år med indhandlinger pr. fisker

data15 <- merge(data14, antal_aktive_fiskeaar,by='SAELGER') #de to datark kombineres

#Nu smides der linjer ud efter følgende kriterier:
#1) en fisker skal have været aktiv i mindst 3 år i perioden 2008-20XX for at indgå i beregningerne
data16 <- subset(data15, x >2)

#2) En fisker skal have fanget minimum 500 kg er perioden 2008-20xx for at indgå
#først regnes den totale fangstmængde for hver fisker
total_indhandling_pr_fisker <- aggregate(data16[,c('MAENGDE')],list(SAELGER=data16$SAELGER), sum,na.rm=T)
data17 <- merge(data16,  total_indhandling_pr_fisker, by='SAELGER')

#og fiskerne slettes
#data18 <- data17 #Hvis der ikke skal selekteres ud fra indhandling i data
data18 <- subset(data17, x.y>500)

#3) Vi har vurderet at data før 2010 er af for dårlig kvalitet og derfor udelades de.
data19<-subset(data18, year>2009)

#Her gøres hver sælger unik - dvs, at hvis en sælger flytter område er han betragtet som en anden sælger
#data19 <- data13b #Hvis der ikke skal selekteres ud fra indhandling i data
data19$SAELGER_unik <- paste(data19$SAELGER, data19$NAFO, sep='_')

#Nu udskrives en fil som skal bruges til at lave et kort med fiskeintensitet. Dette er gjort 2014
```

```
#write.table(data15, file = "tilsas2.csv", sep = ";", na = "NA", row.names = F)

#Herunder begynder selve analysen
data20 <- aggregate(data19$MAENGDE,list(SAELGER_unik=data19$SAELGER_unik, year=data19$year, NAFO=data19$NAFO), sum,na.rm=T)
#her summeres mængden for hver sælger i hvert område i hvert år.
data21 <- aggregate(data19$dummy,list(SAELGER_unik=data19$SAELGER_unik, year=data19$year, NAFO=data19$NAFO), sum,na.rm=T) #her
tælles hvor mange indhandlinger hver sælger har i hvert område i hvert år.
data22 <- cbind(data20,data21$x) #de to datasæt sættes sammen, og herunder omdøbes de nye varialble.

names(data22)[names(data22)=='x']<-'rogn_saelger_pr_år_pr_område'
names(data22)[names(data22)=='data21$x']<-'antal_indhandlinger_pr_år_pr_område_pr_fanger'

#Der regnes nu et CPUE for hver unik sælger i hver område i hvert år.
data22$CPUE_kg_pr_indhandling <- data22$rogn_saelger_pr_år_pr_område/data22$antal_indhandlinger_pr_år_pr_område_pr_fanger

#Der laves en tabel som viser antallet af indhandlinger for hver sælger fra hvert område, og den sættes sammen med tabellen med CPUE'en
data23 <- aggregate(data22$antal_indhandlinger_pr_år_pr_område_pr_fanger,list(year=data22$year, NAFO=data22$NAFO), sum,na.rm=T)
data24 <- merge(data22,data23, by=c('year','NAFO'))

#De nye variable omdøbes.
names(data24)[names(data24)=='x']<-'antal_indhandlinger_pr_år_pr_område'

#Der laves en vægtning idet sælgere med flest indhandlinger skal vægte tungest.
#vægten defineres som en sælgers antal indhandlinger pr. år pr område / antal indhandlinger i det område i det år (altså andelen).
data24$weight_til_CPUE <- data24$antal_indhandlinger_pr_år_pr_område_pr_fanger/data24$antal_indhandlinger_pr_år_pr_område

#Herunder ganges vægten sammen med det rå CPUE
data24$vægtet_CPUE <- data24$CPUE_kg_pr_indhandling * data24$weight_til_CPUE

#Disse linjer regner område- og årsspecifikke CPUE'er og tilhørende standard deviation
data25 <- aggregate(data24$vægtet_CPUE,list(year=data24$year, NAFO=data24$NAFO), sum,na.rm=T)
data25b <- aggregate(data24$vægtet_CPUE,list(year=data24$year, NAFO=data24$NAFO), FUN=sd)
names(data25)[names(data25)=='x']<-'CPUE_pr_område_pr_år'
names(data25b)[names(data25b)=='x']<-'SD'

#Disse linjer regner SE for estimaterne
data25b$nrow <- nrow(data24)
data25b$SE <- data25b$SD/sqrt(data25b$nrow)
data26 <- merge (data25,data25b, by=c('year','NAFO'))

#Denne linje giver en excel fil med et vægtet CPUE for hvert område i hvert år med SE.
#write.table(data22, file = "CPUE_pr_område.xls", sep = "\t", row.names = F)

#Herunder regnes nu CPUE for de enkelte år.
#denne linje regner hvor meget der er indhandlet i hvert område i hvert år
data27 <- aggregate(data24$rogn_saelger_pr_år_pr_område,list(year=data24$year, NAFO=data24$NAFO),sum,na.rm=T)
#denne linje regner hvor meget der er indhandlet i hvert år
data27b <- aggregate(data24$rogn_saelger_pr_år_pr_område,list(year=data24$year),sum,na.rm=T)
#de nye variable omdøbes
```

```
names(data27)[names(data27)=='x']<-'kg_pr_område_pr_år'
names(data27b)[names(data27b)=='x']<-'kg_pr_år'

#De to tabeller sættes sammen, og den viser hvor meget der er indhandlet i hvert område i hvert år, og den samlede mængde i hvert år
data28 <-merge (data27, data27b, by='year')

#Idet der ikke fanges lige meget i hvert område i hvert år, vægtes de enkelte områder.
#vægten regnes som mængden pr område pr år / mængden det pågælgende år
data28$weight_til_CPUE <- data28$kg_pr_område_pr_år/data28$kg_pr_år

#Denne tabel indeholder antal indhandlinger pr år pr område, som bruges til CPUE beregning.
data29 <- aggregate (data24$antal_indhandlinger_pr_år_pr_område_pr_fanger,list(year=data24$year,NAFO=data24$NAFO), sum,na.rm=T)
names(data29)[names(data29)=='x']<-'indhandlinger_pr_område_pr_år'

#Tabellerne med vægten (data28) og antal indhandlinger (data29) sættes sammen.
data30 <- merge (data28,data29, by=c('year','NAFO'))

#Der regnes et CPUE for hvert område i hvert år: kg pr område pr år / antal indhandlinger pr område pr år og disse vægtes
data30$CPUE_pr_område_pr_år <- data30$kg_pr_område_pr_år / data30$indhandlinger_pr_område_pr_år
data30$vægtet_CPUE <- data30$CPUE_pr_område_pr_år * data30$weight_til_CPUE
data30<-data30[-1,]    # første linje uden NAFO pga manglende feltkoder

#De vægtede CPUE lægges sammen for hvert år, og der regnes en SD
data31 <- aggregate(data30$vægtet_CPUE,list(year=data30$year), sum,na.rm=T)
data31b <- aggregate(data30$vægtet_CPUE,list(year=data30$year), FUN=sd)
names(data31)[names(data31)=='x']<-'CPUE_pr_år'
names(data31b)[names(data31b)=='x']<-'SD'

#Der regnes SE for estimaterne
data31b$nrow <- nrow(data31)
data31b$SE <- data31b$SD/sqrt(data31b$nrow)
data32 <- merge (data31,data31b, by=c('year'))
print(data32[, c("year","CPUE_pr_år","SD","SE")], row.names = F)
```