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Assessment of lumpfish (*Cyclopterus lumpus*) in West Greenland based on commercial data 2010-2019

Greenland Institute of Natural Resources

Resume på dansk
Vi fremfører her en vurdering af stenbiderfiskeriet og præsenterer en toårig rådgivning, baseret på forvaltningsplanen, for den total fangstmængde (TAC) og antal fiskedage. Fangst-barheden (LPUE) faldt i perioden 2018-2019 fra de to foregående år. Dette fald, resulterer i en nedgang i rådgivningen fra 2019 på 1300 t og 41 fiskedage til at være 1159,21 t og 37 fiskedage i 2020 (fald på 10.83%) og 1018,42 t og 32 dage for 2021 (reduktion på 21,66%).

Abstract
Here, we provide an assessment of the lumpfish fishery and make a two-year advice (following the management plan) for the total allowable catch (TAC) and fishing days. The landings per unit effort (LPUE) decreased in 2018 and 2019 from the preceding two years. This decrease resulted in a reduction of the advice from the current 1300 t and 41 fishing days to be 1159.21 t and 37 days in 2020 (reduction of 10.83%) and 1018.42 t and 32 days in 2021 (reduction of 21.66%).

Introduction
The lumpfish fishery in Greenland is conducted in the spring along the Greenland west coast. The fishery peaks around mid-May. Prior to year 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 around 1 000 t. Before 2015, the fishery was unregulated, but in 2015 a management plan was implemented, that operates with TAC and restricted number of fishing days. The West Coast is divided into seven management areas, with the onset of the fishery being area dependent due to a timely displaced onset of spawning.

The majority of the fishery is conducted from small open boats (<6.5m) that operates with gill nets that typically fish for 24 hours. Due to the large mesh size (260mm) 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 landed at land-based facilities. Hence, the number of fish landed is not reported, but only 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 each fisherman is assumed to be incapable of increasing fishing effort (nets) as a response 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 prior to 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 2010-2019 on lumpfish and estimate the extent of the fishery.

Data

Since 2010 each landing has reliably been associated with 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 at least three years from 2008-2019.
- A fisherman must have landed a minimum of 500 kg roe from 2008-2019.

Additionally, a fisherman is considered as a different fisherman if he moves between NAFO areas between 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 where sorted based on the value of the catch, with roe having much higher weight specific value. Applying correct conversion factors allows for roe amount to be converted into whole fish weight, which in turn can be used to estimate the number of fish caught. At present the conversion factor from roe to whole fish is 6.7. Based on unpublished data we believe this is too high, and in the present document, only roe landings are reported. Length data from commercial 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 in the assessment of the stock status.
The field code information is used to get an overview of the extent of the fishery in general, but also to calculate the extent of the fishery in each NAFO division. This is done by simply calculating the number of field codes fished in each year in each NAFO division.

Results

The 2019 landings were 1095.8 t which is an increase of 9.4 % compared to 2018 (Fig. 1). The TAC in 2018 and 2019 of 1300 t was therefore still not caught. In area 1F the subarea specific TAC was close to be caught (93% uptake). In the areas 1E-1Bb only 68% of the area specific TAC was caught. Uncaught TAC from these areas were reallocated to the northern areas, leading to an increased fishery in these areas compared to earlier years. Information about the management areas is provided in the management plan.

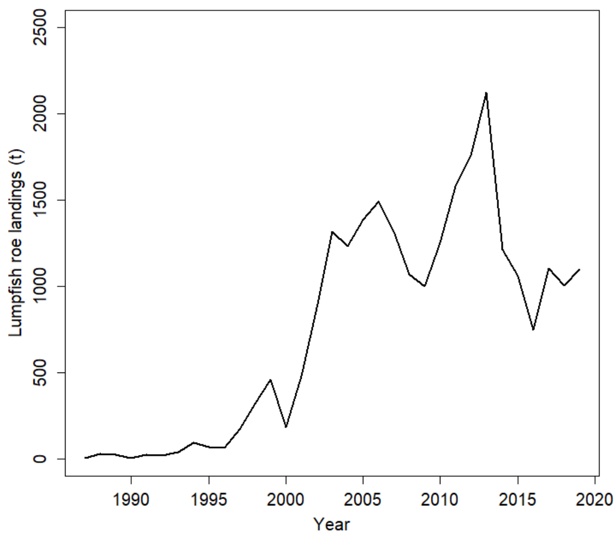
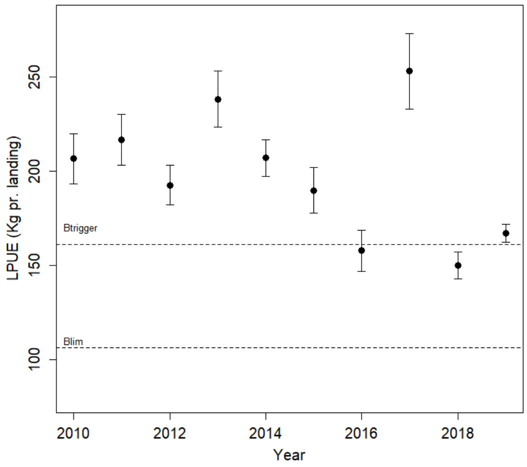


Figure 1: Total lumpfish roe landings (t) from 1987 to 2019.

The overall LPUE increased by 11.4% (Fig. 2, Table I). This was driven by an increase primarily in NAFO 1A (Fig. 3). The other NAFO areas generally maintained the same LPUE level. NAFO 1D remained at a low level, but is still the area with the largest catches (282 t, 25.7%).



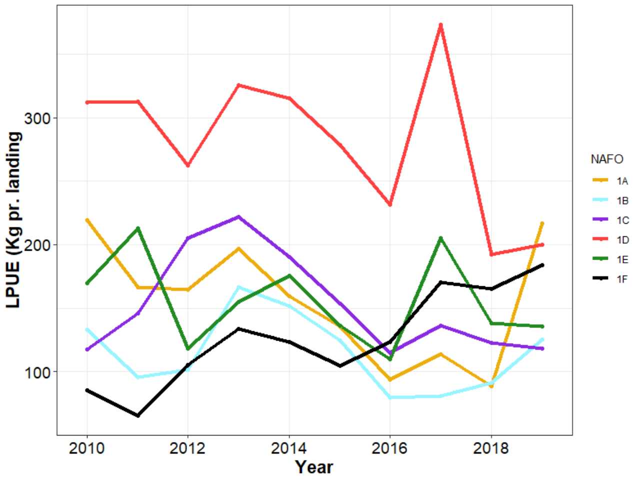


Figure 2: LPUE estimates for the West Greenland area. Vertical bars are standard errors. $B_{trigger}$ and B_{lim} values are indicated.

Figure 3: NAFO area specific LPUE estimates.

Table I: LPUE index by year.

Year	lpue
2010	206.5
2011	216.5
2012	192.5
2013	238.1
2014	206.9
2015	189.7
2016	157.9
2017	253
2018	150
2019	167.2

The cumulative catches shows that a large share of the catches were taken during a relative short time period compared to previous years (Fig. 4, the steeper slope for the red 2019 line). The caches also leveled off earlier than normal. This progress were likely an outcome of the fishery almost started at the same time in the different management areas.

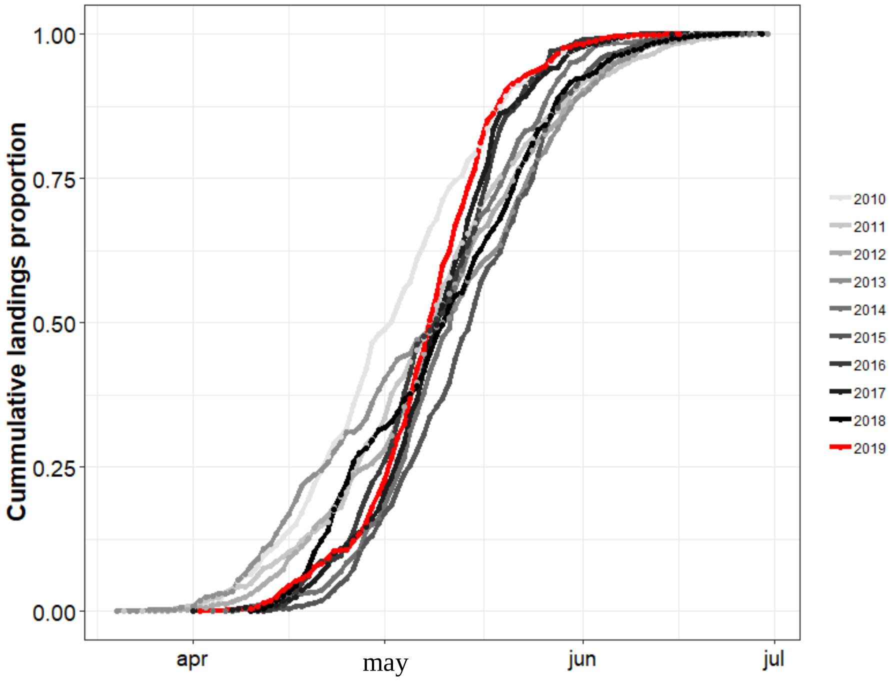


Figure 4: Cumulative catches in proportions

The number of fished field codes decreased from 276 in 2018 to 247 in 2019 (Table II). This decrease was seen in most areas (except 1C, where it increased). Active fishermen also decreased and this was most noticeable for 1D. Hence, the extension of the fishery has dropped to be below the average, but this has happened simultaneously with a decrease in active fishermen.

Table II: Number of field codes fished and active fishermen in each NAFO division and year.

Year	Field codes fished						Total	Number of fishermen						Total
	1A	1B	1C	1D	1E	1F		1A	1B	1C	1D	1E	1F	
2012	72	100	37	61	17	33	320	128	169	144	141	33	64	679
2013	48	83	24	94	19	34	302	77	181	85	172	33	69	617
2014	35	102	38	36	13	37	261	58	136	115	89	36	74	508
2015	21	77	33	58	15	31	235	45	135	113	114	35	66	508
2016	18	70	42	47	25	33	235	45	116	122	113	34	50	480
2017	17	51	40	61	14	43	226	42	90	115	111	29	65	452
2018	28	70	39	72	24	43	276	48	127	133	122	31	55	516
2019	23	66	47	55	19	37	247	48	126	123	92	28	60	477

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 means being within 1.1% of each other (2011-2013 average=37.62 cm) whereas the 2014 (N=273) and 2015 fish (N=244) were slightly larger (39.18 cm and 38.3, respectively). There was no sampling from the commercial fishery in 2016-2018. In 2019, a dedicated study about bycatch from the lumpfish fishery were carried out. In this project, 823 female lumpfish were collected (throughout most of the fishing season) from catches around Nuuk. Mean length of these fish were 36.26 cm, thus slightly shorter than in previous years. Yet, a certain trend in the development of the size composition can still not be inferred.

Discussion and advice following the management plant in action

The data used in this assessment seem consistent, and provides a useful tool in assessing the state of the lumpfish stock (given correct assumptions). Landings in 2019 increased by 9.2% compared to 2018, but is still below the last years TAC of 1300 t. The LPUE increased from the time series all time low in 2018 to now being right above the $B_{trigger}$ reference point (161). From looking at the catches across the season in 2019, it seems like the restriction on fishing days has not limited the catches to a higher degree.
Both the number of fishermen and the number of fished field codes decreased in 2019. Data does not allow us to evaluate if the contraction of the fishery was into better areas, and therefor potentially causing an increase in LPUE irrespective of the amount of lumpfish in the “normal” areas. However, the main decline in field codes fished happened in 1D where number of active fishermen also dropped. In other areas, the fishery remained close to previous years in terms of LPUE and fished field codes. Hence, the slight increase in LPUE from 2018 is most likely a reflection of number of spawning females have not continued the downward trend. However, it is worth noting, that LPUE has declined to be below the reference point period value from 2010-2013 consecutive to years were the TAC has not been caught. So a lower than expected catch has resulted in a LPUE decline from this period.

The advice for number of fishing days and 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. The advice for lumpfish is a two year advice. The advice for the 2019 fishery was provided in 2017, and hence the subsequent advice will be given for the two coming years (2020 and 2021). **Following the decision tree in the management plan, the TAC and fishing days should be reduced from 2019 (1300 t and 41 days) to 2020 by 10.83 % (1159.21 t and 37 days) and from 2019 to 2021 by 21.66% (1018.42 t and 32 days).** See Fig. 6 for calculations. It is worth noting, that even though the 2019 LPUE is slightly above the limit reference point $B_{trigger}$, the last two year average is below. Hence, when setting the TAC for the coming two years, it should be considered that the value of LPUE is currently fluctuating around $B_{trigger}$. The reason for having a two year advice was to dampen large year-to-year fluctuation, which could be expected due to biology of lumpfish and the data (e.g. fishery dependent, relatively low level of detail).

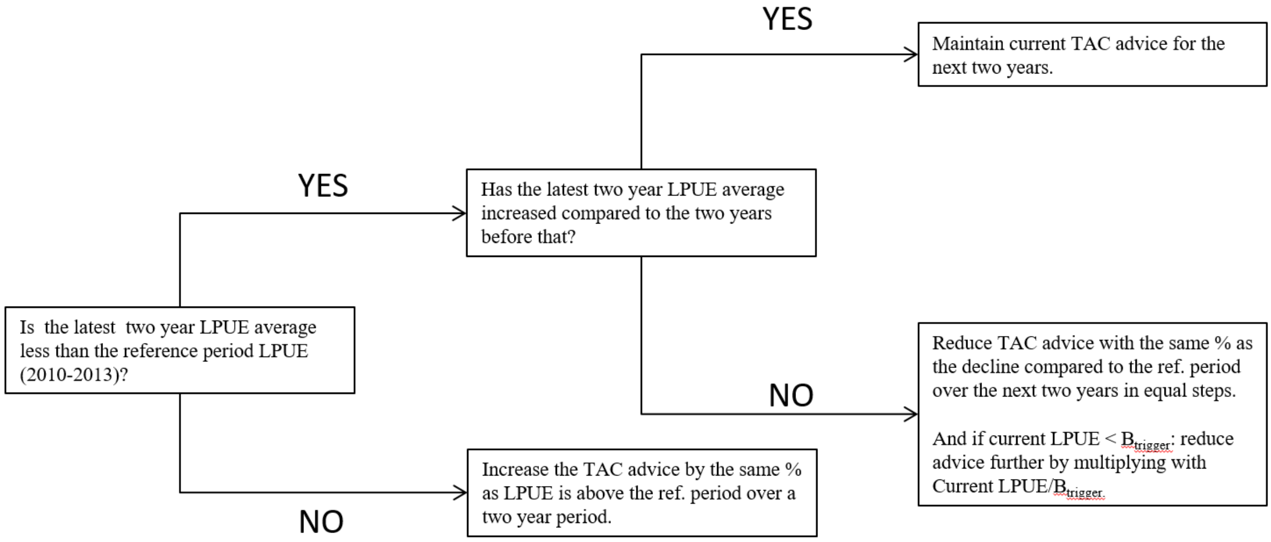


Figure 5: Advisory decision tree.

Advice for 2020 and 2021: reduce TAC advice with the same % as the decline compared to the ref. period over the next two years in equal steps

<u>2020 advice</u>: $2019_{\text{TAC or days}} * (1-(((LPUE_{\text{ref 2010-2013}} - LPUE_{2019}) / LPUE_{\text{ref 2010-2013}}))/ 2_{\text{step}}))$

1300 t * (1-(((213.40 - 167.18) / 213.4)/ 2)) = <u>1159.22 t</u>

41 days * (1-(((213.40 - 167.18) / 213.4)/ 2)) = <u>36.56 days</u>

<u>2021 advice</u>: $2019_{\text{TAC or days}} * (1-((LPUE_{\text{ref 2010-2013}} - LPUE_{2019}) / LPUE_{\text{ref 2010-2013}})))$

1300 t * (1-((213.40 - 167.18) / 213.4)) = <u>1018.42 t</u>

41 days * (1-((213.40 - 167.18) / 213.4)) = <u>32.20 days</u>

Figure 6: Procedure for TAC and fishing day advice for 2020 and 2021.

Large year-to-year fluctuations in the number of spawners can be a result of 1-2 yearclasses comprising the vast majority of the spawning component (Hedeholm et al. 2013). Single year recruitment anomalies are expected to affect the fishing 3-4 years later. This also means that an assessment based on historical landings is sub-optimal, but since there is no measure of the juvenile stock component it 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 (260mm) and the significant sexual size dimorphism (Hedeholm et al. 2013) we believe that male catches are very low. Davenport J. (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. There is also a recreational fishery for females that is not accounted for in this study. The recreational landings are also from 260mm 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 not only reflect 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.

A vital assumption for this assessment is that the fishermen land their 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 days after capture, and the fishermen have no storage facility in their small boats. This has also been confirmed in seminars. This "net saturation assumption" also implies that a fisherman does not change "set up" between years, meaning that the effort in regards to nets is fixed. We cannot, however, rule out that certain fishermen changes boat/gear type in the period.

The LPUE times series is based on high quality data, but given the assumptions, the relatively short time series and the lack of biological knowledge on lumpfish means that LPUE estimates are associated with some uncertainty, and hence the fishery should be managed based on 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., et al. 2013. First estimates of age and production of lumpsucker (*Cyclopterus lumpus*) in Greenland. Fish. Res. (2013), http://dx.doi.org/10.1016/j.fishres.2013.08.016

Hedeholm, R., et al. 2017. Life history trait variation of Greenland lumpfish (*Cyclopterus lumpus*) along a 1600 km latitudinal gradient. Polar Biology. Doi 10.1007/s00300-017-2160-x.

Hutchings J. 1996. Spatial and temporal variation in the density of northern cod and a review of hypotheses for the stock's collapse. Can J Fish Aquat Sci 53:943–962

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.

```
#
#  HUSK AT ÆNDRE "," TIL "." I DATAARKET FØR GROGRAMMET KØRES!
##########################################################################################################################
# - Beregner LPUE for stenbider og laver tre Excel filer - Første til brug i SAS til at beregne gps pos,
#   der senere benyttes til at lave et fangstkort.Anden og tredje fil giver vægtet LPUE pr område og år henholdsvis.
# - HEL og MHUI kattegorierne frasorteres.
# - Se dokumentet "LPUE procedure brugt i rådgivningen for den vestgrønlandske stenbider.doc" for nærmere beskrivelse af proceduren.
# - Script lavet af RaHe og SoPo 2014. R version 3.1.1
# - Script opdateret Juni 2019, SoPo
##########################################################################################################################

#Oprydning af tidligere arbejde i R.
rm(list = ls(all.names=TRUE))
#Arbejdssti
#setwd('F:/20-39 FiSk/37 Andre fiskarter, invertebrater, blan. forsøgsfiskeri/00 Rådgivning og sagsbehandling/02 Stenbider/00 Data/Oparbejd-ning/2018')

#2019 data
data2019 <- read.csv('Indhandlinger LUM 2019 20190623.csv', sep=';', header=T)
data2019$FISKER_GFLKNR <- data2019$GFLK_NR #Så formatet passer med 2010-2018 data
data2019$INDHANDLERS_NAVN <- data2019$FISKERS_NAVN
data2019 <- data2019[,c('INDHANDLINGSDATO','INDHANDLINGSSTED_GFLKNR','LANDINGSSTED_GFLKNR','FISKER_GFLKNR','IND-HANDLERS_NAVN','CPR_NR','BEHGRD_KODE',"MAENGDE","VAERDI",'FANGSTFELT')]


#data2010_2018 <- read.csv('F:/20-39 FiSk/37 Andre fiskarter, invertebrater, blan. forsøgsfiskeri/00 Rådgivning og sagsbehandling/02 Stenbider/00 Data/Oparbejdning/2018/LUM2010_2018.csv', sep=';', header=T)
data2010_2018 <- read.csv('LUM2010_2018.csv', sep=';', header=T)
data2010_2018 <- data2010_2018[,c('INDHANDLINGSDATO','INDHANDLINGSSTED_GFLKNR','LANDINGSSTED_GFLKNR','FI-SKER_GFLKNR','INDHANDLERS_NAVN','CPR_NR','BEHGRD_KODE',"MAENGDE","VAERDI",'FANGSTFELT')]

data2010_2019 <- rbind(data2010_2018, data2019)

data1 <- data2010_2018
data1 <- data2010_2019
head(data1)
summary(data1)


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)))
```

```
data2a <- data1[,c('year','month','day','BEHGRD_KODE','MAENGDE','INDHANDLINGSSTED_GFLKNR','FISKER_GFLK-
NR','VAERDI','FANGSTFELT')]
names(data2a)[1:9] <- c('year','month','day','BEHGRD','MAENGDE','Location','SAELGER','VAERDI','FELTKODE')
data2a$MAENGDE <- as.numeric(as.character( sub(",", ".", data2a$MAENGDE))) #Ikke længere nødvendig hvis der bruges engelsk Excel
data2a$VAERDI <- as.numeric(as.character( sub(",", ".", data2a$VAERDI)))

data1<-data2a #work-around for at få resten af programmet til at køre

#install.packages('car')
library("car")
data2<-subset(data1, month=='3')
data3<-subset(data1, month=='4')
data4<-subset(data1, month=='5')
data5<-subset(data1, month=='6')
data6<-rbind(data2,data3)
data7<-rbind(data6,data4)
data8<-rbind(data7,data5)

#Fjerner data hvor det ikke udelukkende er rogn
data9<-subset(data8,BEHGRD!='MHUI')
data9b<-subset(data9,BEHGRD!='HEL')
data9b<-subset(data9b,BEHGRD!='HEL-M')
data9b<-subset(data9b,BEHGRD!='HEL-F')


#write.table(data9b, 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.
data9b$value <- data9b$VAERDI / data9b$MAENGDE #kg.prisen udregnes
data9b <- subset(data9b, value>5)

#der er enkelte fejl i data, blandt andet negative mængder, som smides ud her.
data10<-subset(data9b, MAENGDE>0)

#her droppes ligegyldige variable.
data10$ART <- data10$KVALITET <- data10$BEHGRD <- data10$KVOTE <- data10$VAERDI <- data10$value <- NULL

#her laves location om til en kategorisk variabel.
data10$Location = as.factor(data10$Location)

data10$Location_2<-recode(data10$Location,"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)='Kuumi-
ut';c(22928)='Sisimiut';
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)='Aasi-
aat';c(23114)='Nanortalik';
c(23325)='Qeqertarsuaq';c(23691)='Upernavik';c(23733)='Ilulis-
sat';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)='Ikami-
ut';c(24483)='Qasigiannguit';c(25419)='Narsaq'") #, c(24483)='Qasigiannguit' [sopo] mit bud på sted
unique(data10$Location_2) #Tjekker om der er nogle feltkoder som ikke omskrives til område
#efter snak med GFLK er der lavet ændringer i område allokeringen 8-12-2016, RaHe.

data10$Location_2 <- as.factor(data10$Location_2)
data10<-subset(data10, Location!='35117') #Fjerner fangster fra Norge

#data10<-subset(data10, Location!='27501') #Fjerner bifangst fra loddefiskeriet i Island

data10$NAFO<-recode(data10$Location_2,"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'")
summary(data10)
data10<-subset(data10, NAFO!='XIVb') #Fjerner fangster fra Østgrønland


#write.table(data10, file = "diverse.csv", sep = ";", na = "NA", row.names = F)

summary_table1 <- aggregate(data10[,c('MAENGDE')],list(Location_2=data10$Location_2, year=data10$year),sum,na.rm=T)
summary_table1$tons <- summary_table1$x/1000
summary_table2 <- aggregate(data10[,c('MAENGDE')],list(year=data10$year, NAFO=data10$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
data10$dummy <-1
indhandlinger_pr_fisherman_pr_aar <- aggregate(data10[,c('dummy')],list(SAELGER=data10$SAELGER, year=data10$year),sum,na.rm=T) #giver
antal indhandlinger pr år pr. fisker
indhandlinger_pr_fisherman_pr_aar$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

data11 <- merge(data10, 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
data12 <- subset(data11, 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(data11[,c('MAENGDE')],list(SAELGER=data11$SAELGER), sum,na.rm=T)
data13 <- merge(data12,  total_indhandling_pr_fisker, by='SAELGER')
#og fiskerne slettes
data14 <- subset(data13, x.y>500)

#3) Vi har vurderet at data før 2010 er af for dårlig kvalitet og derfor udelades de.
data15<-subset(data14, year>2009)
head(data15)

#her gøres hver sælger unik - dvs, at hvis en sælger flytter område er han betragtet som en anden sælger
data15$SAELGER_unik <- paste(data15$SAELGER, data15$NAFO, sep='_')

#nu udskrives en fil osm 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
data16 <- aggregate(data15$MAENGDE,list(SAELGER_unik=data15$SAELGER_unik, year=data15$year, NAFO=data15$NAFO), sum,na.rm=T)
#her summeres mængden for hver sælger i hvert område i hvert år.
data17 <- aggregate(data15$dummy,list(SAELGER_unik=data15$SAELGER_unik, year=data15$year, NAFO=data15$NAFO), sum,na.rm=T) #her tælles hvor mange indhandlinger hver sælger har i hvert område i hvert år.
data18 <- cbind(data16,data17$x) #de to datasæt sættes sammen, og herunder omdøbes de nye varialble.
#install.packages('plyr')
library(plyr)
names(data18)[names(data18)=='x']<-'rogn_saelger_pr_år_pr_område'
names(data18)[names(data18)=='data17$x']<-'antal_indhandlinger_pr_år_pr_område_pr_fanger'

#der regnes nu et CPUE for hver unik sælger i hver område i hvert år.
data18$CPUE_kg_pr_indhandling <- data18$rogn_saelger_pr_år_pr_område/data18$antal_indhandlinger_pr_år_pr_område_pr_fanger

#der laves en tabel som viser antallet af indhandlinger for hver sælger i hvert område, og den sættes sammen med tabellen med CPUE'en
data19 <- aggregate(data18$antal_indhandlinger_pr_år_pr_område_pr_fanger,list(year=data18$year, NAFO=data18$NAFO), sum,na.rm=T)
data20 <- merge(data18,data19, by=c('year','NAFO'))
#de nye variable omdøbes.
names(data20)[names(data20)=='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).
data20$weight_til_CPUE <- data20$antal_indhandlinger_pr_år_pr_område_pr_fanger/data20$antal_indhandlinger_pr_år_pr_område
#herunder ganges vægten sammen med det rå CPUE
data20$vægtet_CPUE <- data20$CPUE_kg_pr_indhandling * data20$weight_til_CPUE

#disse linjer regner område- og årsspecifikke CPUE'er og tilhørende standard deviation
data21 <- aggregate(data20$vægtet_CPUE,list(year=data20$year, NAFO=data20$NAFO), sum,na.rm=T)
data21b <- aggregate(data20$vægtet_CPUE,list(year=data20$year, NAFO=data20$NAFO), FUN=sd)
```

```
names(data21)[names(data21)=='x']<-'CPUE_pr_område_pr_år'
names(data21b)[names(data21b)=='x']<-'SD'

#disse linjer regner SE for estimaterne
data21b$nrow <- nrow(data20)
data21b$SE <- data21b$SD/sqrt(data21b$nrow)
data22 <- merge (data21,data21b, 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 regens nu CPUE for de enkelte år.
#denne linje regner hvor meget der er indhandlet i hvert område i hvert år
data23 <- aggregate(data20$rogn_saelger_pr_år_pr_område,list(year=data20$year, NAFO=data20$NAFO),sum,na.rm=T)
#denne linje regner hvor meget der er indhandlet i hvert år
data23b <- aggregate(data20$rogn_saelger_pr_år_pr_område,list(year=data20$year),sum,na.rm=T)
#de nye variable omdøbes
names(data23)[names(data23)=='x']<-'kg_pr_område_pr_år'
names(data23b)[names(data23b)=='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
data24 <-merge (data23, data23b, 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
data24$weight_til_CPUE <- data24$kg_pr_område_pr_år/data24$kg_pr_år

#denne tabel indeholder antal indhandlinger pr år pr område, som bruges til CPUE beregning.
data25 <- aggregate (data20$antal_indhandlinger_pr_år_pr_område_pr_fanger,list(year=data20$year,NAFO=data20$NAFO), sum,na.rm=T)
names(data25)[names(data25)=='x']<-'indhandlinger_pr_område_pr_år'

#tabellerne med vægten (data22) og antal indhandlinger (data23) sættes sammen.
data26 <- merge (data24,data25, 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
data26$CPUE_pr_område_pr_år <- data26$kg_pr_område_pr_år / data26$indhandlinger_pr_område_pr_år
data26$vægtet_CPUE <- data26$CPUE_pr_område_pr_år * data26$weight_til_CPUE

#de vægtede CPUE lægges sammen for hvert år, og der regnes en SD
data27 <- aggregate(data26$vægtet_CPUE,list(year=data26$year), sum,na.rm=T)
data27b <- aggregate(data26$vægtet_CPUE,list(year=data26$year), FUN=sd)
names(data27)[names(data27)=='x']<-'CPUE_pr_år'
names(data27b)[names(data27b)=='x']<-'SD'

#der regnes SE for estimaterne
data27b$nrow <- nrow(data27)
data27b$SE <- data27b$SD/sqrt(data27b$nrow)
data28 <- merge (data27,data27b, by=c('year'))
```