PINNGORTITALERIFFIK

GREENLAND INSTITUTE OF NATURAL RESOURCES

GRØNLANDS NATURINSTITUT

Nuuk August 2016

Assessment of lumpfish (*Cyclopterus lumpus*) in West Greenland based on commercial data 2010-2016

Rasmus Hedeholm and Søren Post

Greenland Institute of Natural Resources

Introduction

The lumpfish fishery in Greenland is conducted in the spring from April 1st to June 30th along the Greenland west coast. The fishery peaks in late May/early June. Prior to year 2000, reported roe landings were below 500 t, but in the last decade landings have steadily increased, reaching the highest level in 2013 with 2 124 t (Fig. 1). 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 six management areas, with the onset of the fishery being area dependent due to a timely displaced onset of spawning.

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 2010-2016 on lumpfish and estimate the extent of the fishery.

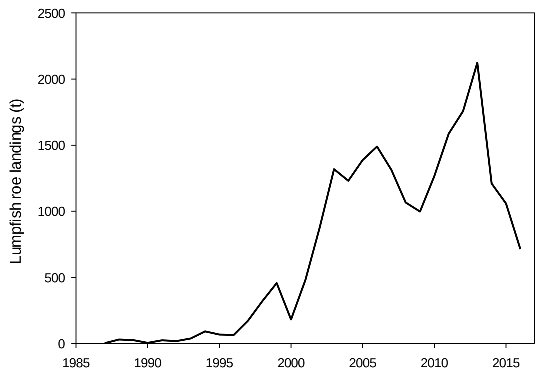

Figure 1: Total lumpfish roe landings (t) from 1987 to 2016.

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 2008-2016.
- A fisherman must have landed a minimum of 500 kg roe from 2008-2016.

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 LPUE script is provided as an appendix to this document. 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 2016 landings were 713 t which is a decrease of 33% compared to 2015 (Fig. 1). The LPUE for the entire west coast decreased by 18% (Fig. 2). This decline was caused by reduced LPUE in in all areas except the most southern area, 1F. LPUE is still highest in NAFO 1D, being 232 kg. pr. landing. which is considerably higher than in other areas where values are similar at approximately 110 kg. pr. landing.

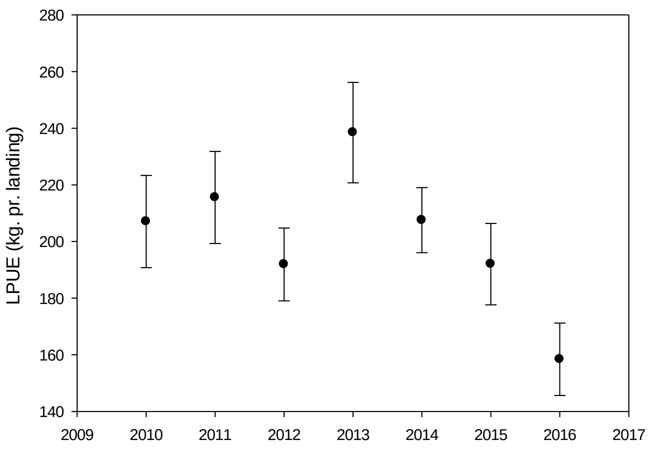

Figure 2: LPUE estimates for the West Greenland area. Error bars are standard errors.

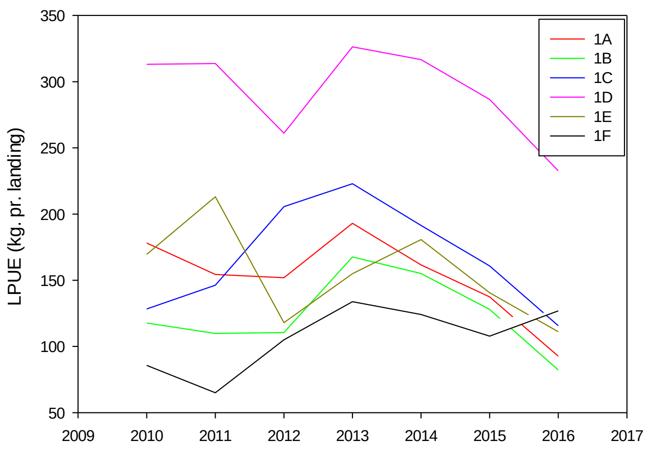

Figure 3: NAFO area specific LPUE estimates.

The fishery is distributed along the entire west coast from 60°N to 71.5°N (Fig. 4). The number of fished field codes along the coast has declined from 265 in 2012 to 226 in 2016 (Table II). The decline is primarily driven by a decline in NAFO 1B, while all other areas have remained constant.
The average length has been surprisingly stable between years considering the low sample size, with 2011 (N=109), 2012 (N=561) and 2013 (N=69) means being within 1.1% of each other (2011-2013 average=37.62

cm) whereas the 2014 (N=273) and 2015 fish (N=244) fish were slightly larger (39.18 cm and 38.3, respectively). There was no sampling from the commercial fishery in 2016.

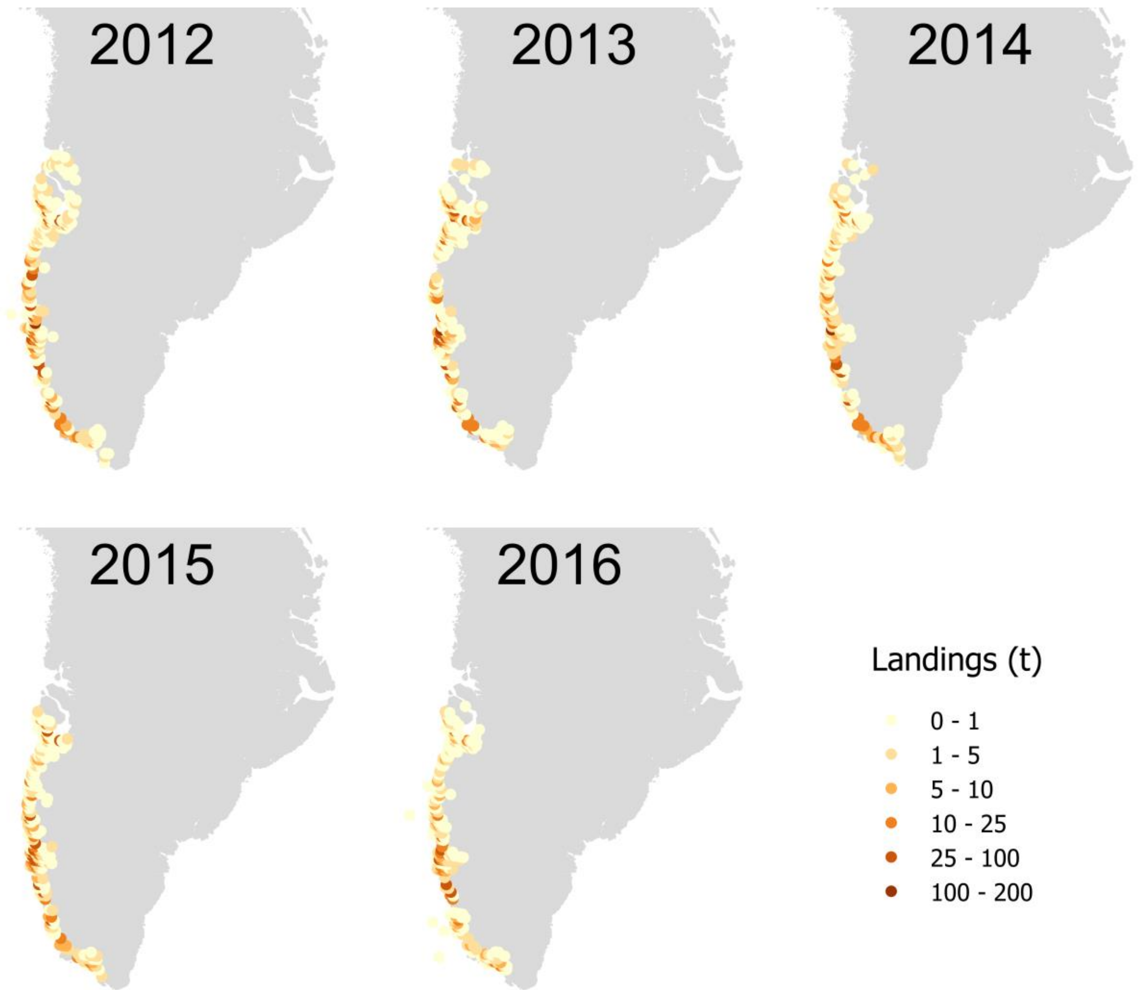

Figure 4: Distribution of lumpfish roe catches (t) summarized by field code.

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	22	113	38	43	17	32	265	109	164	158	141	33	61	666
2013	11	106	23	57	19	33	249	100	154	85	171	33	69	612
2014	5	109	37	33	13	36	233	57	131	115	88	36	68	495
2015	21	79	34	59	15	31	239	43	126	105	102	34	60	470
2016	18	69	38	44	25	32	226	41	103	101	96	32	47	420

Discussion

The data used in this assessment seem consistent, and is estimated to provide a useful tool in assessing the state of the lumpfish stock (given correct assumptions). Overall, landings have decreased drastically from 2013 and 2016 had the lowest catches since 2001 (Fig 1). In 2014 and 2015 the winter was longer than usual, meaning that the season was shortened and in 2014 landing facilities and fishermen had a dispute on prices, again shortening the season, resulting in a fishery that started 14 days later than in 2013 (Fig. 5) and with fewer active fishermen (table II). In 2015 a management plan with a restriction on the number fishing days was implemented, resulting in a shorter season, and as a consequence the fishery started later in the season. This implementation was coincident with a 2015 LPUE decline, and the opposite might have been expected as the fishery would be expected to concentrate in the best part of the season following restrictions. It is especially noteworthy that the LPUE decline is consistent across all areas. This trend has continued in 2016, and the LPUE (158 kg/landing) is now well below time series mean of 202 kg/ landing. The current management plan states, that no regulatory actions are to be taken unless the decline in LPUE exceeds 15% compared to the average LPUE in the reference period 2010-2013 (213 kg/landing). The current decline is 26% compared to the reference period and consequently, the TAC should be reduced from 1 500 t to 1 300 t (rounded) and the number of fishing days should be reduced from 47 days to 41 days (due to a reduction over a 2 year period – see management plan). The decline in LPUE is not accompanied by a similar decline in neither number of fishermen (11% decline) or area coverage (5% decline). Lumpfish spawn at age 3-5 and therefore the present fishable population was spawned during the record high catches in 2011-2013. The decline in current LPUE could hence indicate that the fishery in that period could have had an effect on the recruitment to the stock. However, many environmental factors not accounted for here affect recruitment, and the recent decline could also reflect natural stock dynamics. Monitoring the stock should continue, and be extended to include improved data on effort (i.e. number of nets and soaking time) and length measurements of the catch. A recent study documented highly variable fecundities along the West Greenland coast (Hedeholm et al., submitted), and part of the decline in LPUE could be caused by reduced fecundity, and may not necessarily reflect solely an increased number of caught individuals. However, as long as the sole unit of landings is kg of roe, the two factors are inseparable.

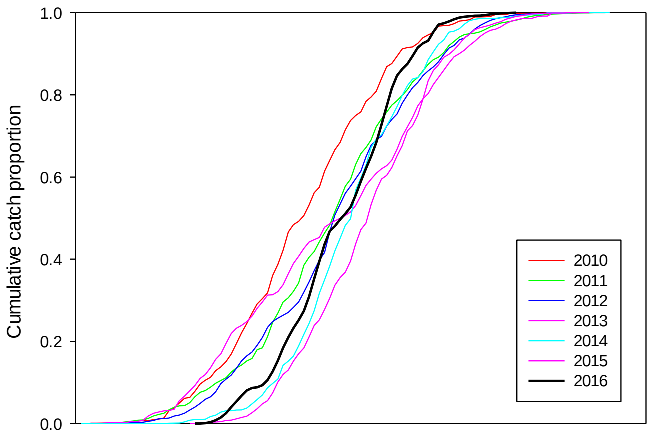

Figure 5: Cumulative catches in proportions

The LPUE in NAFO 1D is considerably and consistently higher than in all other areas. The exact reason for this is unknown but is believed to be a result of the largest boats being located in the largest city, Nuuk. Furthermore, 1D is in the central part of the west coast, suggesting that it could be the primary habitat. The number of fished field codes declined in 2016.

At present, no lumpfish survey exists, but this would be a valuable tool to assess if field codes fished actually do reflect changes in distribution, especially as fisheries have often been able to maintain high catch rates in spite of reduced fish abundance. We do not provide any estimate of male lumpfish landings as these are unreported. 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, a small amount of males are landed and sold on the domestic market, but catches are surely small and amounts to only a few tones. There is also a recreational fishery for females that is not accounted for in this study as landings are minimum estimates. 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, and therefore negligible.

The LPUE estimates presented here rests on vital assumptions. If the fleet can change their 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 recent seminars and personal communication the fishermen appear to carry the same number of nets regardless of catch rates – the small boats are simply saturated.

There are currently no measures of effort besides the number of landings. Another equally vital assumption is therefore 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 his “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 but we have no way of retrieving such information.

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 in general the LPUE is associated with uncertainty, and 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, but this 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

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.

```
data1 <- read.csv('C:/Users/rahe/Desktop/LUM2010_2016_2.csv', sep=';', header=T)

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_GFLKNR','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)))
data2a$VAERDI <- as.numeric(as.character( sub(",", ".", data2a$VAERDI)))
data1<-data2a
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)

data9<-subset(data8,BEHGRD!='MHUI')
data9b<-subset(data9,BEHGRD!='HEL')
data9b$value <- data9b$VAERDI / data9b$MAENGDE
data9b <- subset(data9b, value>5)
data10<-subset(data9b, MAENGDE>0)
data10$ART <- data10$KVALITET <- data10$BEHGRD <- data10$KVOTE <- data10$VAERDI <- data10$value <- NULL

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)='Kuumiut';c(
22928)='Sisimiut'; c(22930)='Maniitsoq';c(23011)='Maniitsoq';c(23039)='Ilimanaq';c(23049)='Maniitsoq';
c(23137)='Qeqertarsuaq';c(23139)='Maniitsoq';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(2311
4)='Nanortalik';c(23325)='Qeqertarsuaq';c(23691)='Upernavik';c(23733)='Ilulissat';c(29500)='Narsaq';c(68)='Nuuk';c(23374)='Narsaq';c(24052)='Ma
niitsoq';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'")
unique(data10$Location_2)

data10$Location_2 <- as.factor(data10$Location_2)
#data10<-subset(data10, Location!='27501')
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')='1A';c('Ilulissat')='1B';c('Qeqertarsuaq')='1A';c('Uummannaq')='1A';c('Arsuk')='1E';
c('Kangaatsiaq')='1B';c('Upernavik')='1A';c('Qaqortoq')='1F';c('Innaarsuit')='1A';c('Kangersuatsiaq')='1B'; c('Attu')='1B';
c('Qaanaaq')='1A';c('Sisimiut')='1B';c('Kuumiut')='XIVb';c('Ilimanaq')='1A';c('Tasiilaq')='XIVb'; c('Ikamiut')='1B'")
summary(data10)

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

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
antal_aktive_fiskeaar <- aggrega-
te(indhandlinger_pr_fisherman_pr_aar[,c('dummy2')],list(SAELGER=indhandlinger_pr_fisherman_pr_aar$SAELGER),sum,na.rm=T) #giver antal år
med indhandlinger pr. fisker
data11 <- merge(data10, antal_aktive_fiskeaar,by='SAELGER')
data12 <- subset(data11, x >2)
total_indhandling_pr_fisker <- aggregate(data11[,c('MAENGDE')],list(SAELGER=data11$SAELGER), sum,na.rm=T)
data13 <- merge(data12,  total_indhandling_pr_fisker, by='SAELGER')
data14 <- subset(data13, x.y>500)
data15<-subset(data14, year>2009)
head(data15)
data15$SAELGER_unik <- paste(data15$SAELGER, data15$NAFO, sep='_')

#herunder begynder selve analysen
data16 <- aggregate(data15$MAENGDE,list(SAELGER_unik=data15$SAELGER_unik, year=data15$year, NAFO=data15$NAFO), sum,na.rm=T)
data17 <- aggregate(data15$dummy,list(SAELGER_unik=data15$SAELGER_unik, year=data15$year, NAFO=data15$NAFO), sum,na.rm=T)
data18 <- cbind(data16,data17$x)
install.packages('plyr')
library(plyr)
names(data18)[names(data18)=='x']<-'rogn_saelger_pr_år_pr_område'
names(data18)[names(data18)=='data17$x']<-'antal_indhandlinger_pr_år_pr_område_pr_fanger'
data18$CPUE_kg_pr_indhandling <- data18$rogn_saelger_pr_år_pr_område/data18$antal_indhandlinger_pr_år_pr_område_pr_fanger
data19 <- aggregate(data18$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'))
```

```
names(data20)[names(data20)=='x']<-'antal_indhandlinger_pr_år_pr_område'
data20$weight_til_CPUE <- data20$antal_indhandlinger_pr_år_pr_område_pr_fanger/data20$antal_indhandlinger_pr_år_pr_område
data20$vægtet_CPUE <- data20$CPUE_kg_pr_indhandling * data20$weight_til_CPUE
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'
data21b$nrow <- nrow(data20)
data21b$SE <- data21b$SD/sqrt(data21b$nrow)
data22 <- merge (data21,data21b, by=c('year','NAFO'))

data23 <- aggregate(data20$rogn_saelger_pr_år_pr_område,list(year=data20$year, NAFO=data20$NAFO),sum,na.rm=T)
data23b <- aggregate(data20$rogn_saelger_pr_år_pr_område,list(year=data20$year),sum,na.rm=T)
names(data23)[names(data23)=='x']<-'kg_pr_område_pr_år'
names(data23b)[names(data23b)=='x']<-'kg_pr_år'
data24 <-merge (data23, data23b, by='year')
data24$weight_til_CPUE <- data24$kg_pr_område_pr_år/data24$kg_pr_år
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'

data26 <- merge (data24,data25, by=c('year','NAFO'))
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
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'
data27b$nrow <- nrow(data27)
data27b$SE <- data27b$SD/sqrt(data27b$nrow)
data28 <- merge (data27,data27b, by=c('year'))
```