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Assessment of lumpfish (*Cyclopterus lumpus*) in West Greenland based on commercial data 2010-2014

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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 with the start being timely displaced along the coast, starting the earliest in the south. Prior to 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). The fishery has been unregulated throughout the period, however due to the recent catch increase, a management plan is being implemented from 2014 and a procedure to monitor the status of the stock has been developed.

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, i.e. 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 can be used as a proxy of stock status (LPUE). If the extent of the fishing area fish 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

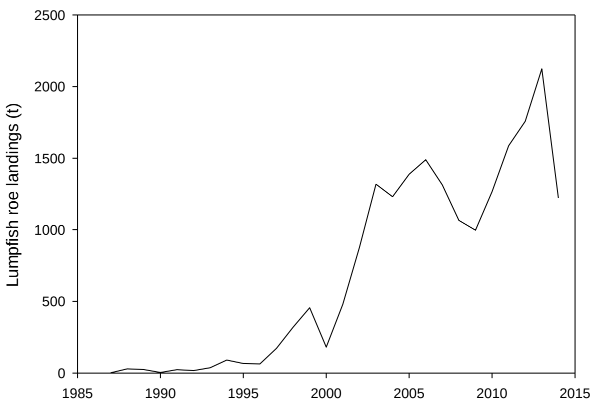

Figure 1: Total lumpfish roe landings (t) from 1987 to 2014.

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 2010-2014 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 2008-2014.
- A fisherman must have landed a minimum of 500 kg roe from 2008-2014.

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 2014 landings were 1 210 t which is a decrease of 43% compared to 2013 (Fig. 1). The LPUE for the entire west coast also decreased, but only by 12% (Fig. 2). This decline was caused by reduced LPUE in

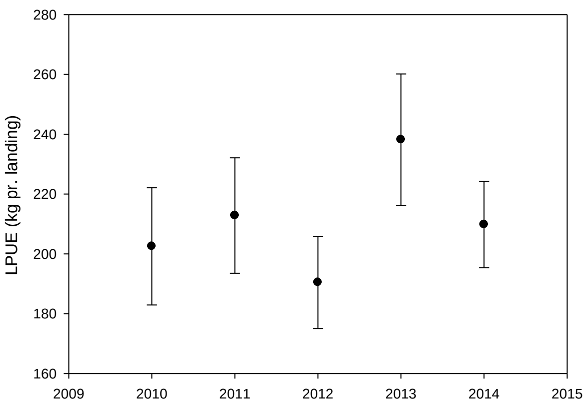

Figure 2: LPUE estimates for the West Greenland area. Error bars are standard errors.

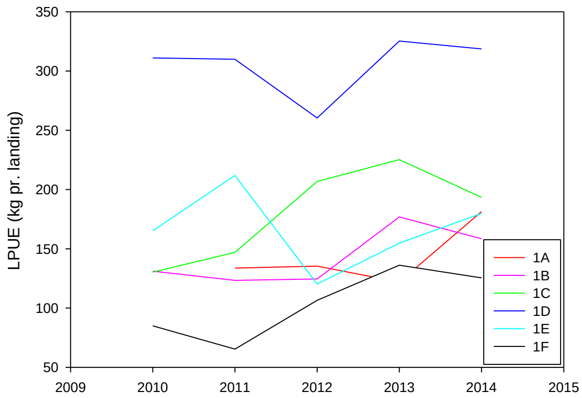

Figure 3: NAFO area specific LPUE estimates.

NAFO areas 1B, 1C, 1D and 1F (Fig. 3). LPUE in NAFO 1E in southwest Greenland and the area furthest north (1A) both showed small increases, but as the majority of the catch is taken in central part of the area (Table I) this is not reflected in the overall LPUE. LPUE in NAFO 1D is around 300 kg. pr. landing. which is considerably higher than in other areas where values are similar at approximately 150 kg. pr. landing.

Table I: NAFO area and year specific lumpfish roe landings (t)

Year	NAFO 1A	NAFO 1B	NAFO 1C	NAFO 1D	NAFO 1E	NAFO 1F
2010		265	292	470	194	30
2011	52	356	275	599	256	42
2012	81	451	377	619	90	138
2013	20	675	270	860	105	193
2014	9	325	267	353	92	164
Total	161	2072	1482	2902	736	567

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 entire coast has declined from 265 in 2012 to 249 in 2013 and 233 in 2014 (Table II).

This decline is driven by a decrease in the most northern area (NAFO 1A) and the area with the highest catches (NAFO 1D) with especially the change from 2013 to 2014 being drastic. The number of active fishermen varies between years, but most noticeably is the large decline in 2014, where only 454 where active, compared to 644 in 2012.

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) fish were slightly larger (39.18 cm).

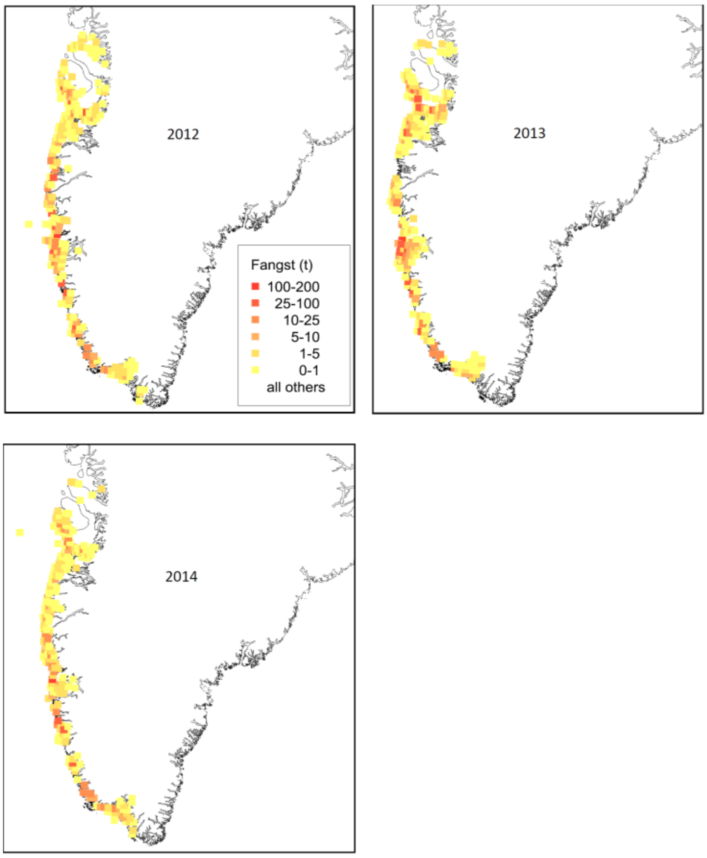

Figure 4: Distribution of lumpfish roe catches (t) summarized by field code.

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

Year	Field codes fished						Number of fishermen					
	1A	1B	1C	1D	1E	1F	1A	1B	1C	1D	1E	1F
2012	22	113	38	43	17	32	20	234	158	138	32	62
2013	11	106	23	57	19	33	10	224	82	167	34	66
2014	5	109	37	33	13	36	8	162	106	80	35	63

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 decreased drastically in 2014 compared to 2013. However, this was most likely caused by other factors than a decline in lumpfish abundance. The winter was longer than usual, meaning that the season was shortened. Also, 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). So in spite of much smaller catches, the LPUE estimate only declined by 12% and is above the time series mean. 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 period 2010-2013. 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. Lastly, lumpfish tend to migrate along the coast when moving towards the spawning grounds, and if this is a northward migration, they may be caught in the process in the Nuuk area. However, given the large LPUE difference, this needs to be addressed in more detail.

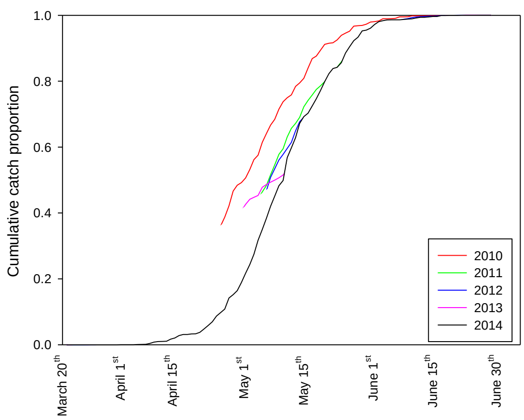

Figure 5: Cumulative catches in proportions

The number of fished field codes declined both in 2013 and 2014. In 2014, the decline could very well be linked to the factors that caused a drop in landings – for instance reduced accessibility caused by ice. However, a continued decline in 2015 could be cause for concern. Any patterns in number of field codes fished should always be looked at in the context of LPUE changes. Fewer field codes fished could both be a result of declining stock, but also the opposite, where the fishermen need to move less to ensure high catches. Given the unusual nature of the 2014 fishery, the coincident declines in LPUE and field codes fished may be an artifact, and not necessarily reflect a population decline. 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 a 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/engine in the period but we have no way of retrieving such information.

Lastly, the use of “motherships” will greatly impede LPUE as a stock indicator tool. Fishermen admit this takes place, but to very little extent. Thus this has not been taken into account.

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.table("LUM2008_2014.txt", header=TRUE, sep=";")

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)='Maniits
oq';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)='Qaana
aq';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)='Qeqer
tarsua-
q';c(23139)='Aasiaat';c(23275)='Sisimiut';c(23338)='Sisimiut';c(23286)='Upernavik';c(23395)='Upernavik';c(22821)='Nuuk';c(22992)='Maniitsoq';c(22
993)='Aasiaat';c(23114)='Nanortalik';c(23325)='Qeqertarsuaq';c(23691)='Upernavik';c(23733)='Ilulissat';c(29500)='Narsaq';c(68)='Nuuk';c(23374)='N
arsaq';c(24052)='Maniitsoq';c(27557)='Narsaq';c(23502)='Maniitsoq';c(23514)='Sisimiut';c(23505)='Attu';c(23581)='Aasiaat';c('29501')='Nuuk';c('236
92')='Uummannaq'")
data10$Location_2 <- as.factor(data10$Location_2)

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')='1B';c('Qeqertarsuaq')='1B';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'")

summary_table1 <- aggregate(data10[,c('MAENGDE')],list(Location_2=data10$Location_2, year=data10$year),sum,na.rm=T)
summary_table2 <- aggregate(data10[,c('MAENGDE')],list(year=data10$year, NAFO=data10$NAFO),sum,na.rm=T)

data10$dummy <-1
indhandlinger_pr_fisherman_pr_aar <- aggregate(data10[,c('dummy')],list(SAELGER=data10$SAELGER, year=data10$year),sum,na.rm=T)
indhandlinger_pr_fisherman_pr_aar$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)

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)

data15$SAELGER_unik <- paste(data15$SAELGER, data15$NAFO, sep='_')

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'))
```