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GREENLAND INSTITUTE OF NATURAL RESOURCES

GRØNLANDS NATURINSTITUT

Nuuk November 2015

Assessment of lumpfish (*Cyclopterus lumpus*) in West Greenland based on commercial data 2010-2015

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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. 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, 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 (LPUE) can be used as a proxy of stock status. 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

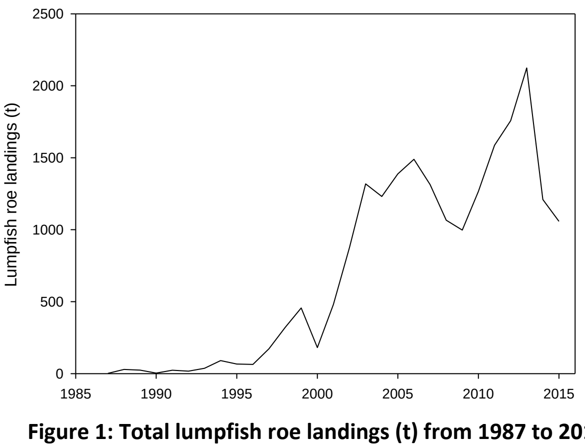

Figure 1: Total lumpfish roe landings (t) from 1987 to 2015.

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 2010-2015 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 2008-2015.
- A fisherman must have landed a minimum of 500 kg roe from 2008-2015.

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 2015 landings were 1 058 t which is a decrease of 13% compared to 2014 (Fig. 1). The LPUE for the entire west coast also decreased, but only by 7% (Fig. 2). This decline was caused by reduced LPUE in

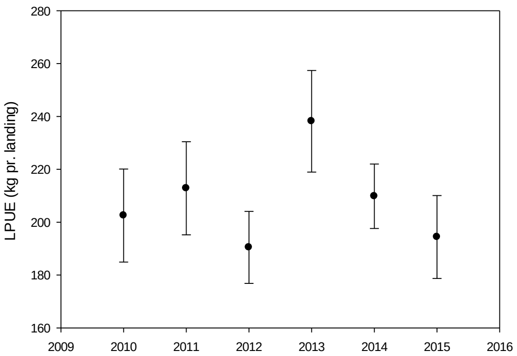

Figure 2: LPUE estimates for the West Greenland area. Error bars are standard errors.

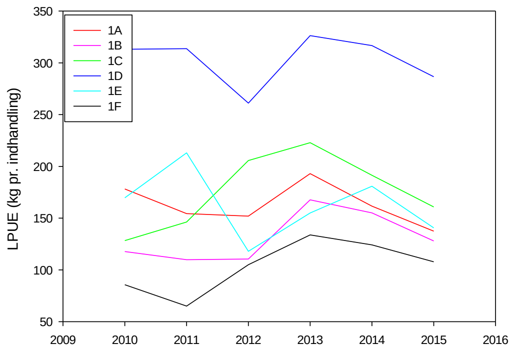

Figure 3: NAFO area specific LPUE estimates.

all NAFO areas (Fig. 3). 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.

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 233 in 2014 but increased slightly in 2015 to 239 (Table II). The major change from 2014 was in the northern part of the area, with NAFO 1B having a decline in the number of fished field codes fished, while an increase was observed in 1A. 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. In 2015 the number increased again to 546.

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).

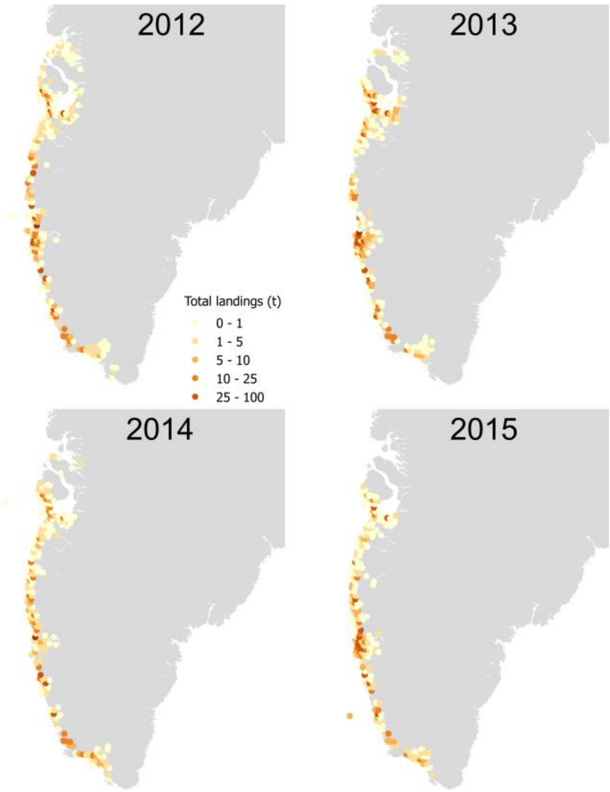

Figure 4: Distribution of lumpfish roe catches (t) summarized by field code.

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
2015	21	79	34	59	15	31	46	149	115	127	38	71

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 and 2015 compared to 2012-2013. However, this was most likely caused by other factors than a decline in lumpfish abundance. The winter was longer than usual in both years, 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 may be an artifact of management plan implementation but it needs to be monitored in coming years.

The 2015 LPUE is together with 2012 at the lowest observed level and is below the tike series mean (208 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 (211 kg/landing) and this is not the case (8% decline).

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.

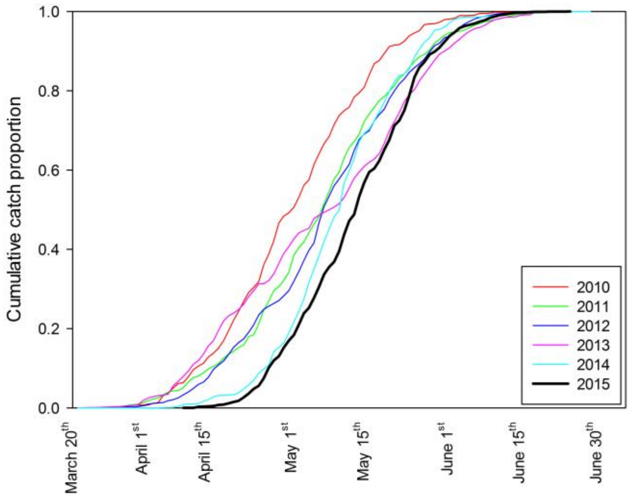

Figure 5: Cumulative catches in proportions

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. Hence the increase in 2015 suggests that the decline in 2013-14 was not related to a declining stock but more likely a result of environmental conditions.

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.

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'))
```