PINNGORTITALERIFFIK
GREENLAND INSTITUTE OF NATURAL RESOURCES
GRØNLANDS NATURINSTITUT

Nuuk, October 2022

Assessment of lumpfish (*Cyclopterus lumpus*) in West Greenland based on commercial data 2010-2022

Eqikkaaneq (summary in Greenlandic)

'Kalaallit Nunaata Kitaani Nipisat arnarluit (matuma kingorna arnarlunnik taagorneqassapput) pillugit Aqutsinermi Pilersaarut 2021 – 2025' naapertorlugu uumassusilerituut siunnersuinerat Pinngortitaleriffimmiit matumuuna saqqummiupparput.

Arnarluit suaat 1.475,3 tonsit 2023-mi pisarineqarsinnaasut uumassusilerituuniit innersuussutigineqarput, taamaalilluni siorna 2022-mi pisarineqarsinnaasutut innersuussutigineqartunit allannguisoqarani. Suaat 2022-mi tunineqartut 1.223 tonsiupput, tassa 2022-mi siunnersuinermi pisassiissutigineqarsinnaasutut innersuussutigineqartunit 17 %-inik appasinnerullutik. Piffissami aalajangersimasumi pisarineqartut amerlassusiat 2022-mi 9,7 %-imik qaffariaateqarput, tassa siornamut 2021-mut, sanilliullugit, maannali ukiut 2010-miit 2022 ilangullugu piffissami aalajangersimasumi pisarineqartartut amerlassusiat aatsaat taamak qaffasitsigisumiilerput. Arnarluit pisarineqartartut tamakkiisumik amerlassusiannut aammalu piffissami aalajangersimasumi pisarineqartartut amerlassusaannut tunngassutillit paasissutissat aalisarnermiit pissarsiarineqartarput. Suaat tulaanneqatartut oqimaassusiat uumassusilerituuniit pisassiissutigineqarsinnaasutut innersuussutigineqartartunit aammalumi suattassiissutigineqartartut qiviarlugit, malunnaatilissuarmik ukiuni kingulliunerusuni appasinnerujuarnikuupput.

Piffissami aalajangersimasumi pisarineqartartut ukiuni makkunani aatsaat taamak qaffasitsigisumiilernerini, suut peqqutaallutik pisaasartut amerlassusaat/oqimaassusaat innersuussutigineqartunit appasinnerusarnerat Pinngortitaleriffimmeersunit paasiuminaatsinneqarpoq.

Taamaattumik PInngortitaleriffimmeersut naliliipput naatsorueriaaseq imaluunniit periuseq arnarlunniarnermi atorneqartartoq immaqa nangaanartortalerujussuusoq. Nangaassutigineqarsinnaasut tunuliaquttatut isiginiarlugit Pinngortitaleriffimmeersut aalajangiipput aappaagumut siunnersuineq siorna siunnersuisimanermit allannguuteqassanngikkallartoq. Piffissap aalajangersimasup iluani pisat amerlassusaat, soorlu siorna kisitsisitaa 36 %-imik qaffasinnerusimavoq, tassa aallaavissatut aalajangigaasimasoq, tassalu Aqutsinermi PIlersaarummiittumi (2010-2013-imeersumiittumi) allaqqammat pilersaarutit malinneqarpata pisassiissutaasartut 2023-mi 20 %-inik qaffaavigineqarnissaannik aalajangiussaq ('Piffissami aalajangersimasumi pisat amerlassusaat ukiut marluk matuma siorna siunnersuinerup kisitsisitaannut qanngerunneqassagamik). Taakkuni ukiuni kingulliunerusuni qaffariaat uumassusilerituut siunnersuinerannik qaffaanermik kinguneqaraluarmata, pisassiissutit

tamakkerlugit pisarineqarneq ajorput (pisassiissutaasut 17 %-imik tamakkerneqanngitsoormata). Uumassusilerituut siunnersuinerat maanna atortinneqartoq arnarlunniartarnerup/suanniartarnerup oqalut-tuarisaanerani aatsaat taamak qaffasitsigisumik pisassiisoqarsinnaaneranik innersuussutitaqaraluarpoq, taam-alu pisaqarluartarnerit sunniutaat suli takuneqaratik. Taamaammat Pinngortitaleriffimmeersut innersuussu-tutigaat 2022-mi siunnersuisimaneq allannguuteqartinnagu 2023-mi aamma atuutsinneqaannassasoq.

Resumé (summary in Danish)

Grønlands Naturinstitut (GN) fremfører her en vurdering af stenbiderfiskeriet og præsenterer den biologiske rådgivning i henhold til retningslinjer fra 'Forvaltningsplanen for stenbiderhunner i Vestgrønland 2021-2025'. Den biologiske rådgivning for **2023 er på 1.475,3 tons**, hvilket er samme rådgivning som i 2022. Fangsterne i 2022 var på 1.223 t rogn og 17% under rådgivningen og den fastsatte kvote. Fangstraterne i 2022 steg 9,7% i forhold til 2021 og er nu på højeste niveau for perioden 2010-2022.

Vurderingen af stenbiderfiskeriet er baseret på data fra fiskeriet, herunder totale fangster og fangstrater. Landingerne har i de senere år ligget betydeligt *under* rådgivningen og de fastsatte kvoter, og GN vurderer, at dette medfører stor usikkerhed på metoden med at gange stigende fangstrater på rådgivningen. Denne usikkerhed er baggrunden for at GN anbefaler, at man bibeholder sidste års rådgivning på maksimalt 1475,3 t. Konkret var fangstraten i 2022 36% højere end den fastsatte reference i forvaltningsplanen (2010-2013), og følges planen kan kvoten forøges med 20% i 2023 ('stigning i fangstraterne ganges på forrige års *rådgivning'*). Gennem en årrække er der fisket mindre end den biologiske rådgivning, og dette kan konkret have haft en positiv effekt på bestanden og forklare stigningen i fangstraterne. Stigningerne i fangstrater har medført en forøgelse af den biologiske rådgivning, men fiskeriet tager ikke hele kvoten/rådgivningen (17% under). Den aktuelle rådgivning er historisk høj og konsekvenserne for dette høje niveau af landinger, er endnu ikke set. GN anbefaler derfor, at rådgivningen fra 2022 fastholdes.

Abstract

Here, The Greenland Institute of Natural Resources (GINR) presents an assessment of the lumpfish fishery. The document explains the biological advice according to guidelines from the 'Management plan for female lumpfish in West Greenland 2021-2025'. **The biological advice for 2023 is 1,475.3 t**, which is the same advice as in 2022. Catches in 2022 were 1,223 t roe and 17% below the advice and the set quota. Catch rates in 2022 increased by 9.7% compared to 2021 and are now at the highest level for 2010-2022.

The assessment is based on data from the fishery, including total catches and catch rates. In recent years, the landings have been significantly below the advice and the set quotas, and GN estimates that this causes uncertainty in multiplying increasing catch rates by the advice. This uncertainty makes GN recommend that last year's advice of a maximum of 1475.3 t be maintained. Concretely, the catch rate in 2022 was 36% higher than

the reference period in the management plan (2010-2013), and if the plan is followed, the quota can be increased by 20 % in 2023 ('increase in catch rates multiplied by previous year's advice'). Over several years, catches have been lower than the biological advice, which may have positively affected the stock and explained the increase in catch rates. The increases in catch rates have led to a rise in the biological advice, but the fishery has not caught the entire quota/advice (17% less). The current advisory is historically high, and the consequences of this high level of landings are yet to be seen. Therefore, GN recommends maintaining the advice from 2022.

Introduction

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

Most of the fishery is conducted from small open boats (<6.5 m) that operate with gill nets that typically fish for 1-3 days. Due to the large mesh size (260 mm), the nets are highly selective and catch predominantly female lumpfish, which are much larger than males (Hedeholm *et al*. 2013). Upon capture, the roe is removed from the fish and stored in large barrels before being landed at land-based facilities. Hence, the number of fish landed is not reported, but the total amount of roe. Due to the size of the fishing vessels, there is an upper limit to the number of nets and barrels each boat can carry. All calculations in this assessment rest on this vital assumption; that the fishermen are assumed to be incapable of increasing fishing effort (nets) due to a decline in lumpfish abundance to maintain the same landings. Hence, kg. roe pr. landing is a proxy of landing per unit effort (LPUE) and can be used as a stock status indicator. If the extent of the fishing area is monitored simultaneously, we believe a reasonable indication of stock status can be provided, although no survey is available. The commercial data available have been of varying quality, and data before 2010 have not been evaluated valid for assessment purposes as those landings often lack supporting information such as fisherman ID and location.

In this document, we describe the assessment procedure, present an LPUE time series from 2010-2022 on lumpfish and estimate the extent of the fishery.

Data

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

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

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

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

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

Analysis

In this document, the procedure is shortly described in words only. All analyses were done in R (R core team, 2021), and the script for calculating LPUE is provided as an appendix to this document, including the data preparation steps. The calculations are derivatives of this script.

Initially, a year and NAFO division-specific LPUE (kg pr. landing) for each fisher is calculated. This LPUE is weighted by the share of the total catch in the respective NAFO division taken by a fisher. All LPUEs 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 LPUEs are weighted by the total west coast landings. This procedure ensures that the fishers and areas with the highest landings are given the highest weight when assessing the stock status.

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

Results

The 2022 landings were 1223 t which is an increase of 7.7 % compared to 2021 (Fig. 1). The TAC of 1476 t in 2022 was therefore not caught. In the northern areas (NAFO 1A-1Ba, 1Bb), 26 % of the subarea-specific TAC was caught, while 30 % and 25 % were caught in 1C and 1D, respectively (Table I) (information about the management areas is provided in the management plan).

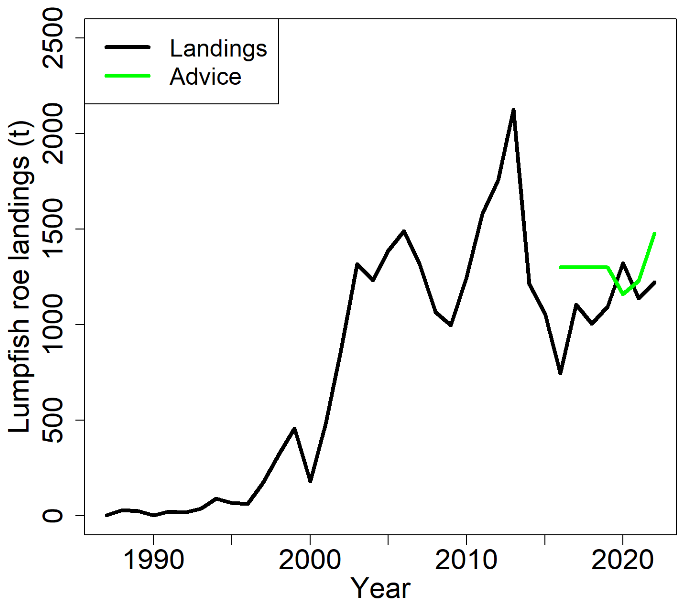

Figure 1: Total lumpfish roe landings (t) from 1987 to 2022 and TAC advice from 2016.

Table I: Landings (roe) by NAFO area in 2022 (from north to south).

NAFO	TAC (t)	Landing (t)	% of the total landings (1223)
1A	198	133	10.9
1Ba	160	133	10.9
1Bb	73	51	4.2
1C	332	367	30.0
1D	372	307	25.1
1E	201	180	14.7
1F	140	52	4.3
Total	1476	1223	100.0

The overall LPUE increased by 9.7% (Fig. 2, Table II). This was driven by an increase in all NAFO areas except 1A and 1D (Fig. 3).

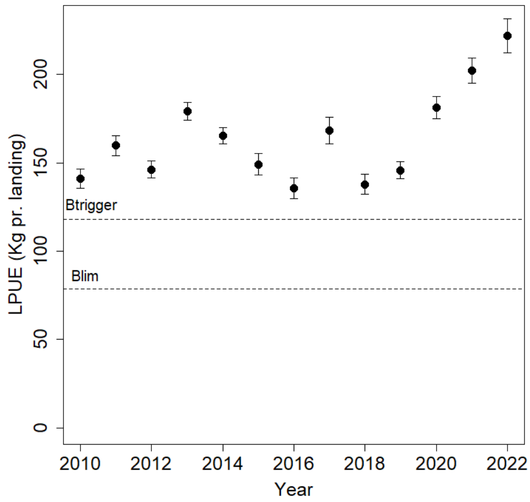

Figure 2: LPUE estimates for the West Greenland area. Vertical bars are standard errors. $B_{trigger}$ and B_{lim} values are indicated.

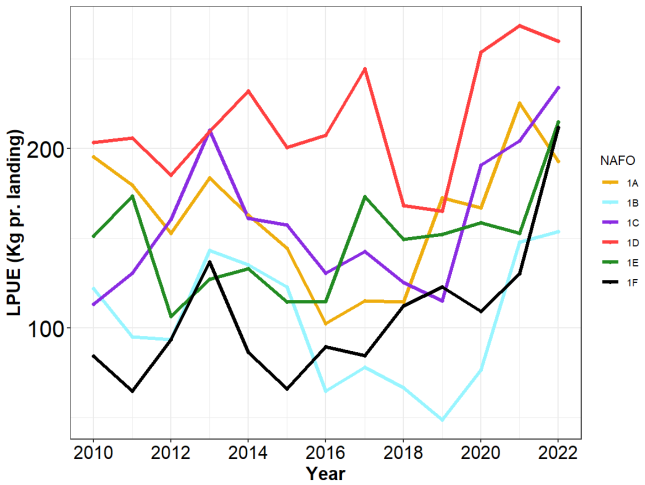

Figure 3: NAFO area specific LPUE estimates.

Table II: LPUE index by year with standard deviations.

Year	LPUE	Standard error
2010	141.1	5.3
2011	159.8	5.7
2012	146.2	4.8
2013	179.2	5.1
2014	165.5	4.7
2015	149.2	6.2
2016	135.6	5.7
2017	168.4	7.5
2018	137.8	5.6
2019	145.9	5.0
2020	181.4	6.3
2021	202.4	7.1
2022	220.0	9.6

The cumulative catches show that a large share in 2022 was taken later than in most recent years, but still within observed for previous years (Fig 4). The late start of the fishery in 2022 did not happen because of a late arrival of the lumpfish, but largely because of a strike by fishers. This strike delayed the start of the fishery by two weeks and took place because of a dispute in prices between the landing companies and the fishery organization KNAPK. As a prominent delay in the fishery could potentially influence the LPUE calculations significantly, we did a sensitivity test where only data from late season was included. Calculations of LPUE with these data (not presented here) showed almost the same picture as when including the entire fishing season. Hence, we continued with the calculations including all data as described in the Data section above.

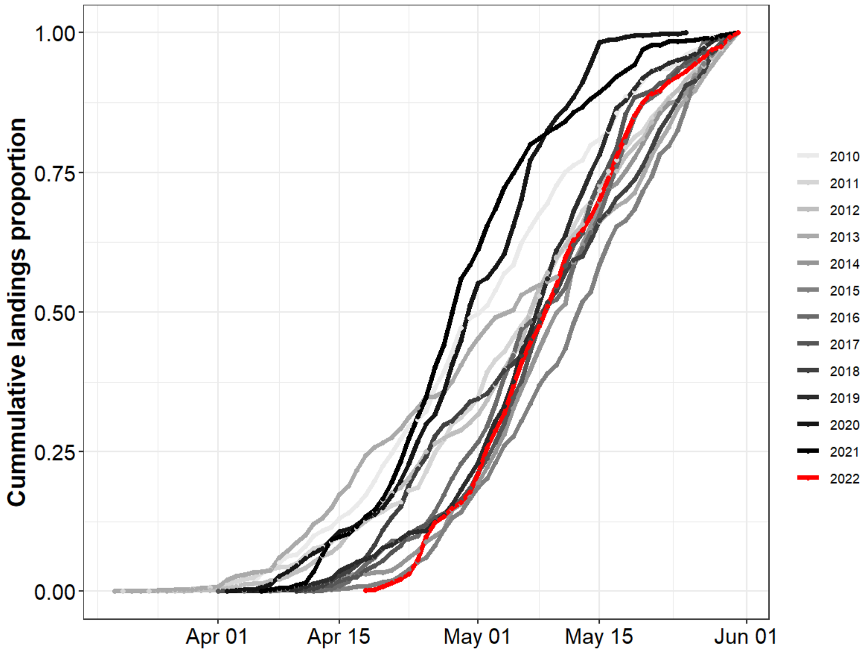

Figure 4: Cumulative landings over the year in proportions by year.

Active fishermen decreased in all areas, except 1B (Table III). The number of fished field codes decreased from 220 in 2021 to 182 in 2022, which is the lowest in the time-series presented here (Table III). Hence, the extension of the fishery dropped below the average, but this happened simultaneously with a decrease in active fishers. As strong reduction in active fishers could influence the LPUE calculations (e.g., up-concentrating serious fishers, which would generate a higher LPUE), we also exclusively made the calculations with fishers being active in all years of the time period. Again, this showed the same picture (results not presented), with 2022 having clearly the highest estimate. Therefore, the calculations seem rather robust.

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

Year	Number of fishers						Total	Number of field codes fished						Total
	1A	1B	1C	1D	1E	1F		1A	1B	1C	1D	1E	1F	
2012	218	151	185	152	104	26	836							
2013	180	126	145	181	93	24	749							
2014	123	106	148	95	105	14	591							
2015	114	73	192	93	108	11	591	36	44	56	29	41	3	209
2016	114	74	180	83	87	2	540	53	35	55	28	53	2	226
2017	84	44	194	97	100	15	534	25	28	53	39	47	9	201
2018	138	62	235	116	96	13	660	45	29	62	43	49	9	237
2019	184	71	219	104	102	22	702	60	41	64	35	52	9	261
2020	192	72	224	100	113	20	721	73	48	61	35	49	2	268
2021	146	44	185	72	96	19	562	53	32	57	30	44	4	220
2022	110	47	177	59	76	2	471	40	27	48	33	32	2	182

The average fish length has been surprisingly stable between years (considering the low sample size) with 2011 (N=109), 2012 (N=561), and 2013 (N=69) length mean being within 1.1% of each other (2011-2013 average=37.62 cm), whereas 2014 (N=273) and 2015 fish (N=244) were slightly larger (39.18 and 38.3, respectively). There was no sampling from the commercial fishery in 2016-2018. In 2019, 2021 and 2022, dedicated studies about bycatch from the lumpfish fishery were carried out. In the 2019 project, 823 female lumpfish were collected (throughout most of the fishing season) from catches around Nuuk. The mean length of these fish was 36.26 cm, thus slightly shorter than in previous years. In the 2021 and 2022 projects, 452 and 168 female lumpfish were measured, which had mean lengths of 38.0 and 37.5 cm respectively. Yet, a particular trend in the development of the size composition can still not be inferred.

Discussion and advice following the management plan in action

The data used in this assessment seem consistent and provide a valuable tool for assessing the state of the lumpfish stock (given correct assumptions). Landings in 2022 increased by 9.7 % compared to 2021 but was still well below the TAC. The LPUE (220.0) increased to the time series high and are now significantly above the $B_{trigger}$ reference point (161). The LPUE in 2022 and catches across the season indicates that the fishery was very effective compared to previous years. This indication agrees with several oral reportings across the industry. Both the number of fishers and the number of fished field codes decreased in 2022. However, the data does not allow us to evaluate if the contraction of the fishery was into better areas, and therefore potentially causing an increase in LPUE irrespective of the lumpfish amount in the "normal" areas.

The advice for lumpfish is single-year advice. Following the Management plan (Annex 4), the advice for the quantity of roe catches (TAC) is generated by applying the decision tree in Fig. 5. Using this decision tree, the TAC should increase by 20 % from 2022 (1475.3 t) to in 2023 (1770.6 t). See Fig. 6 for calculations.

However, GN considers the current rule in the Management plan, where the LPUE index is multiplied by last year's advice is incapable of managing the current fishery situation properly (i.e. landings are considerably lower than the advice in recent years (Fig 1)). In the current situation, LPUE has increased to time series high concurrent with catches being lower than the advice. This creates a situation where the advice could increase to unfavorable levels. In case the fleet suddenly decides to fish at very high levels, there is a increased risk of overfishing. The current relative high advice level for 2021 (1475.3 t) has not been fished for several years, and the consequence of fishing at this level is unknown. **Therefore, regarding these circumstances, we advise to use a TAC of maximum 1475.3 t**. Moreover, when setting the TAC for the coming year, it should be considered that the value of LPUE might is affiliated with uncertainty as marked price and political issues effects the fishing patterns.

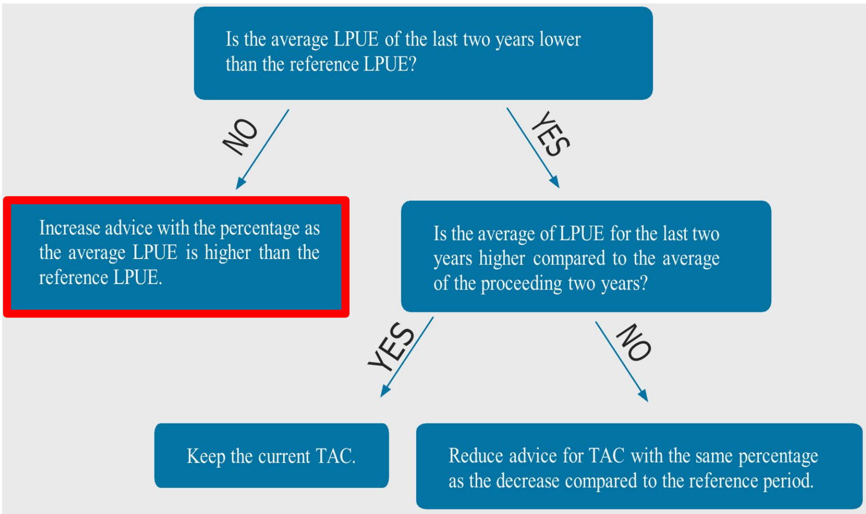

Figure 5: Advisory decision tree. Red box applies for 2023 advice.

Advice for 2023 (red box in fig 5): Increase TAC advice from last year with the same % as the average LPUE of 2021 and 2022 is higher than the ref. period.

2023 advice initial: $2022_{TAC} * (1+((LPUE_{2021\text{-}2022} - LPUE_{ref\ 2010\text{-}2013}) / LPUE_{ref\ 2010\text{-}2013})) = 2023_{TAC}$

2023 advice initial: 1475.3 * (1+((212.2-156.6)/156.6)) = 1999.0 t

As this initial 2023 advice exceed the 2022 advice by 20 %, the 2023 advice is set to be the 2021 advice increased by 20 %.

2023 advice: 1475.3 * 1.2 = 1770.6 t*

Figure 6: Procedure for TAC advice according to the Management ploan. *This is not the final GINR advice.

Large year-to-year fluctuations in the number of spawners can be a result of 1-2 year classes comprising the vast majority of the spawning component (Hedeholm *et al*. 2014, 2017). Single year recruitment anomalies are expected to affect the fishing 3-4 years later. This means that an assessment based on historical landings few years back is sub-optimal, but since there is no measure of the juvenile stock component it currently provides the only option.

We do not provide any estimate of male lumpfish landings as these are unreported (though started on a smaller scale in 2019). However, given the mesh size of the gill nets (260 mm) and the significant sexual size dimorphism (Hedeholm *et al*. 2014) we believe that male catches are low. Davenport (1985) states that based on Icelandic data males are predominantly caught in 170-190 mm gill nets. However, small amounts of males are landed and sold on the domestic market, but catches are surely small and amounts to only a few tonnes. In addition, there is a recreational fishery for females that is not accounted for in this study. The recreational landings are also from 260 mm gill nets, but there is no estimate of the amount. Based on personal communication it is, however, estimated that total recreational roe landings are less than 25 t pr. year, and therefore negligible.

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

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

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

References

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

R Core Team (2021). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

Appendix I

R script used in LPUE calculations.

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

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

#Preparing data
intCurrentYear <- 2022

#2010-2020 data
# data2020 <- read.csv('LUM_10_20_1.csv', sep=';', header=T)
# data2021 <- read.csv('Stenbider2021 v1 08072021.csv', sep=';',dec=".", header=T)
data2020 <- read.csv('Z:/Luli/37 Stenbider/Indhandlingsdata/2021 - med nyt script/LUM_10_20_1.csv', sep=';', header=T)
data2021 <- read.csv('Z:/Luli/37 Stenbider/Indhandlingsdata/2022/Stenbider2021 v1 08072021.csv', sep=';',dec=".", header=T)
data2022 <- read.csv('Z:/Luli/37 Stenbider/Indhandlingsdata/2022/Indhandlinger LUM 2020-2022 20220916.csv', sep=';',dec=".", header=T)
data2021 <- data2021[data2021$AAR==2021,]
names(data2022) <- toupper(names(data2022)) #
data2022 <- data2022[data2022$AAR==2022,]

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

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

data2021 <- plyr::rename(data2021 ,c('GFLK_NR'='FISKER_GFLKNR')) #Old name = New name. This sometimes gives a mistake if plyr and dplyr
is loaded, therefore using plyr::
data2022 <- plyr::rename(data2022 ,c('GFLK_NR'='FISKER_GFLKNR')) #Old name = New name. This sometimes gives a mistake if plyr and dplyr
is loaded, therefore using plyr::

#Obs. der er forskel i datoformatet mm-dd mellem ?r. V?r sikker p? at dette skrives korrekt.
#For 2021 tr?kket er det MM-DD-YYYY, tidligere er det DD-MM-YYYY
data2021$INDHANDLINGSDATO <- substr(data2021$INDHANDLINGSDATO, 1,10)
common_names <- intersect(names(data2020), names(data2021))
data2021 <- data2021[,common_names]
data2021$day   <- as.numeric(as.character(substring(data2021$INDHANDLINGSDATO, 4,5)))
data2021$month <- as.numeric(as.character(substring(data2021$INDHANDLINGSDATO, 1,2)))
data2021$year  <- as.numeric(as.character(substring(data2021$INDHANDLINGSDATO, 7,10)))

data2022$INDHANDLINGSDATO <- substr(data2022$INDHANDLINGSDATO, 1,10)
common_names <- intersect(names(data2020), names(data2022))
data2022 <- data2022[,common_names]
data2022$day <- as.numeric(as.character(substring(data2022$INDHANDLINGSDATO, 1,2)))
```

```r
data2022$month <- as.numeric(as.character(substring(data2022$INDHANDLINGSDATO, 4,5)))
data2022$year <- as.numeric(as.character(substring(data2022$INDHANDLINGSDATO, 7,10)))

data1 <- rbind(data2020, data2021, data2022)
data1 <- data1[!is.na(data1$FISKER_GFLKNR),] #Fjerner observationer hvor der ikke er information om fisker

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

#Funktion til at beregne fangst feltkode
Funktion <- function(x) {
  if(x == "A") y <- 1
  if(x == "B") y <- 2
  if(x == "D") y <- 3
  if(x == "E") y <- 4
  if(x == "F") y <- 5
  if(x == "G") y <- 6
  if(x == "H") y <- 7
  if(x == "J") y <- 8
  if(x == "K") y <- 9
  if(x == "L") y <- 10
  if(x == "M") y <- 11
  if(x == "N") y <- 12
  if(x == "P") y <- 13
  if(x == "R") y <- 14
  if(x == "S") y <- 15
  if(x == "T") y <- 16
  if(x == "V") y <- 17
  if(x == "X") y <- 18
  if(x == "Z") y <- 19
  if(x == "+") y <- NA
  if(x == "0") y <- NA
  if(x == "1") y <- NA
  if(x == "2") y <- NA
  if(x == "3") y <- NA
  if(x == "4") y <- NA
  if(x == "5") y <- NA
  if(x == "6") y <- NA
  if(x == "7") y <- NA
  if(x == "8") y <- NA
  if(x == "9") y <- NA
  if(x == "y") y <- NA
  if(x == "") y <- NA
  return(y)
}


y<-NULL
```

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

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

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

data4 <- data3[,c('year','month','day','BEHGRD_KODE','MAENGDE','FISKER_GFLKNR','VAERDI','FANGSTFELT','Latitude','Longi-
tude','INDHANDLINGSSTED_GFLKNR')]
data4 <- plyr::rename(data4 ,c('BEHGRD_KODE'='BEHGRD','FISKER_GFLKNR'='SAELGER','FANGSTFELT'='FELTKODE')) #Old name =
New name.
#names(data4)[1:11] <- c('year','month','day','BEHGRD','MAENGDE','SAELGER','VAERDI','FELTKODE','Latitude','Longitude','INDHAN-
DLINGSSTED_GFLKNR')

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

data5<-cbind(data4,NAFO)

#Der v?lges kun indhandlinger fra marts-maj
data12 <- data5[data5$month %in% c(3,4,5),]
#data12 <- data5[data5$month %in% c(5),] #To see if the late start in 2022 and other years affects the results
#TEST of removing observations later than may 15 (140). This is done because 2021 was a year heavily influence management (Clossure of buying
places)
# data12$Date <- as.Date(paste(data12$day, data12$month, data12$year, sep = '-'))
# data12$DayOfYear <- yday(data12$Date)
# data12 <- data12[data12$DayOfYear<141,]

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

#For de steder som mangler feltkode bruges indhandlingssted til at f? nafo omr?de. ----
```

```
data13b$INDHANDLINGSSTED_GFLKNR <-  as.factor(data13b$INDHANDLINGSSTED_GFLKNR)
data13b$INDHANDLINGSSTED_BY<-recode(data13b$INDHANDLINGSSTED_GFLKNR,"c(1010)='Nanortalik';c(1040)='Narsaq';c(1050)='Paa-
miut';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)='Uumman-
naq';
                    c(1153)='Uummannaq';c(1154)='Uummannaq';c(1155)='Uummannaq';c(1156)='Uummannaq';c(1157)='Uumman-
naq';c(1210)='Arsuk';
                    c(1211)='Nuuk';c(1212)='Nuuk';c(1213)='Maniitsoq';c(1214)='Maniitsoq';c(1217)='Kangaatsiaq';c(1218)='Aasiaat';c(1219)='Aa-
siaat';
                    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)='Sisimi-
ut';c(22876)='Kuumiut';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)='Nanorta-
lik';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)='Sisimi-
ut';c(22876)='Tasiilaq';
                    c(22928)='Sisimiut';c(22930)='Qaqortoq';c(23103)='Upernavik';c(23104)='Upernavik';c(23105)='Upernavik';c(23106)='Uperna-
vik';
                    c(23108)='Uummannaq';c(23011)='Maniitsoq';c(23039)='Ilulissat';c(23049)='Nanortalik';c(23137)='Qeqertarsu-
aq';c(23139)='Aasiaat';
                    c(23275)='Sisimiut';c(23338)='Sisimiut';c(23286)='Upernavik';c(23395)='Upernavik';c(22821)='Nuuk';c(22992)='Maniit-
soq';c(22993)='Aasiaat';c(23114)='Nanortalik';
                    c(23325)='Qeqertarsuaq';c(23691)='Upernavik';c(23733)='Ilulissat';c(29500)='Narsaq';c(68)='Nu-
uk';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')='Maniit-
soq';c(23503)='Ikamiut';c(24483)='Qasigiannguit';c(25419)='Narsaq';
                    c(24429)='Ilulissat';c(62132)='Sisimiut' ") #, c(24483)='Qasigiannguit' [sopo] mit bud p? sted
unique(data13b$INDHANDLINGSSTED_BY) #Tjekker om der er nogle feltkoder som ikke omskrives til omr?de. Der er nogle. Men de er opgjort
som MHUI og HEL-F
#efter snak med GFLK er der lavet ?ndringer i omr?de allokeringen 8-12-2016, RaHe.

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

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

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

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

```
data13b$NAFO <- as.factor(data13b$NAFO)
#----

#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 m?ngde men ingen v?rdi. Her kan man ikke se om der er fejlinformeret.
#P? nuv?rende tidspunkt tages de ud.
data13b$value <- data13b$VAERDI / data13b$MAENGDE #kg.prisen udregnes
data13c <- subset(data13b, value>5&value<=50) #NY: ud over nedre gr?nse er den ?vre gr?nse for kg prisen ogs? defineret. F? observationer (5) bliver fjernet af den ?vre gr?nse.

#Der er enkelte fejl i data, blandt andet negative m?ngder, som smides ud her.
data14<-subset(data13c, MAENGDE>0&MAENGDE<500) #NY: Her ertilf?jet ?vre gr?nse for indhandling pr gang p? 500 kg.

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

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

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

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

#Herunder skal de fiskere som skal indg? i beregningerne udv?lges. Det sker efter flere kriterier:
#f?rst regnes antallet af ?r en fisk har v?ret aktiv
data14$dummy <-1
indhandlinger_pr_fisherman_pr_aar <- aggregate(data14[,c('dummy')],list(SAELGER=data14$SAELGER, year=data14$year),sum,na.rm=T) #giver antal indhandlinger pr ?r pr. fisker
indhandlinger_pr_fisherman_pr_aar$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$SAELGER),sum,na.rm=T) #giver antal ?r med indhandlinger pr. fisker

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

#Nu smides der linjer ud efter f?lgende kriterier:
#1) en fisker skal have v?ret aktiv i mindst 3 ?r i perioden 2008-20XX for at indg? i beregningerne
data16 <- subset(data15, x >2)
#data16 <- subset(data15, x >4)
#data16 <- subset(data15, x >9)

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

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

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

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

#Nu udskrives en fil som skal bruges til at lave et kort med fiskeintensitet. Dette er gjort 2014
#write.table(data15, file = "tilsas2.csv", sep = ";", na = "NA", row.names = F)

#Herunder begynder selve analysen
data20 <- aggregate(data19$MAENGDE,list(SAELGER_unik=data19$SAELGER_unik, year=data19$year, NAFO=data19$NAFO), sum,na.rm=T)
#her summeres m?ngden for hver s?lger i hvert omr?de i hvert ?r.
data21 <- aggregate(data19$dummy,list(SAELGER_unik=data19$SAELGER_unik, year=data19$year, NAFO=data19$NAFO), sum,na.rm=T) #her
t?lles hvor mange indhandlinger hver s?lger har i hvert omr?de i hvert ?r.
data22 <- cbind(data20,data21$x) #de to datas?t s?ttes sammen, og herunder omd?bes de nye varialble.

names(data22)[names(data22)=='x']<-'rogn_saelger_pr_aar_pr_omraade'
names(data22)[names(data22)=='data21$x']<-'antal_indhandlinger_pr_aar_pr_omraade_pr_fanger'

#Der regnes nu et CPUE for hver unik s?lger i hver omr?de i hvert ?r.
data22$CPUE_kg_pr_indhandling <- data22$rogn_saelger_pr_aar_pr_omraade/data22$antal_indhandlinger_pr_aar_pr_omraade_pr_fanger

#Der laves en tabel som viser antallet af indhandlinger for hver s?lger fra hvert omr?de, og den s?ttes sammen med tabellen med CPUE'en
data23 <- aggregate(data22$antal_indhandlinger_pr_aar_pr_omraade_pr_fanger,list(year=data22$year, NAFO=data22$NAFO), sum,na.rm=T)
data24 <- merge(data22,data23, by=c('year','NAFO'))

#De nye variable omd?bes.
names(data24)[names(data24)=='x']<-'antal_indhandlinger_pr_aar_pr_omraade'

#Der laves en v?gtning idet s?lgere med flest indhandlinger skal v?gte tungest.
#v?gten defineres som en s?lgers antal indhandlinger pr. ?r pr omr?de / antal indhandlinger i det omr?de i det ?r (alts? andelen).
data24$weight_til_CPUE <- data24$antal_indhandlinger_pr_aar_pr_omraade_pr_fanger/data24$antal_indhandlinger_pr_aar_pr_omraade

#Herunder ganges v?gten sammen med det r? CPUE
data24$vaegtet_CPUE <- data24$CPUE_kg_pr_indhandling * data24$weight_til_CPUE

#Disse linjer regner omr?de- og ?rsspecifikke CPUE'er og tilh?rende standard deviation
data25 <- aggregate(data24$vaegtet_CPUE,list(year=data24$year, NAFO=data24$NAFO), sum,na.rm=T)
data25b <- aggregate(data24$vaegtet_CPUE,list(year=data24$year, NAFO=data24$NAFO), FUN=sd)
names(data25)[names(data25)=='x']<-'CPUE_pr_omraade_pr_aar'
names(data25b)[names(data25b)=='x']<-'SD'

#Disse linjer regner SE for estimaterne
```

```
data25b$nrow <- nrow(data24)
data25b$SE <- data25b$SD/sqrt(data25b$nrow)
data26 <- merge (data25,data25b, by=c('year','NAFO'))

#Denne linje giver en excel fil med et v?gtet CPUE for hvert omr?de i hvert ?r med SE.
#write.table(data22, file = "CPUE_pr_omr?de.xls", sep = "\t", row.names = F)

#Herunder regnes nu CPUE for de enkelte ?r.
#denne linje regner hvor meget der er indhandlet i hvert omr?de i hvert ?r
data27 <- aggregate(data24$rogn_saelger_pr_aar_pr_omraade,list(year=data24$year, NAFO=data24$NAFO),sum,na.rm=T)
#denne linje regner hvor meget der er indhandlet i hvert ?r
data27b <- aggregate(data24$rogn_saelger_pr_aar_pr_omraade,list(year=data24$year),sum,na.rm=T)
#de nye variable omd?bes
names(data27)[names(data27)=='x']<-'kg_pr_omraade_pr_aar'
names(data27b)[names(data27b)=='x']<-'kg_pr_aar'

#De to tabeller s?ttes sammen, og den viser hvor meget der er indhandlet i hvert omr?de i hvert ?r, og den samlede m?ngde i hvert ?r
data28 <-merge (data27, data27b, by='year')

#Idet der ikke fanges lige meget i hvert omr?de i hvert ?r, v?gtes de enkelte omr?der.
#v?gten regnes som m?ngden pr omr?de pr ?r / m?ngden det p?g?lgende ?r
data28$weight_til_CPUE <- data28$kg_pr_omraade_pr_aar/data28$kg_pr_aar

#Denne tabel indeholder antal indhandlinger pr ?r pr omr?de, som bruges til CPUE beregning.
data29 <- aggregate (data24$antal_indhandlinger_pr_aar_pr_omraade_pr_fanger,list(year=data24$year,NAFO=data24$NAFO), sum,na.rm=T)
names(data29)[names(data29)=='x']<-'indhandlinger_pr_omraade_pr_aar'

#Tabellerne med v?gten (data28) og antal indhandlinger (data29) s?ttes sammen.
data30 <- merge (data28,data29, by=c('year','NAFO'))

#Der regnes et CPUE for hvert omr?de i hvert ?r: kg pr omr?de pr ?r / antal indhandlinger pr omr?de pr ?r og disse v?gtes
data30$CPUE_pr_omraade_pr_aar <- data30$kg_pr_omraade_pr_aar / data30$indhandlinger_pr_omraade_pr_aar
data30$vaegtet_CPUE <- data30$CPUE_pr_omraade_pr_aar * data30$weight_til_CPUE
data30<-data30[-1,]    # f?rste linje uden NAFO pga manglende feltkoder

#De v?gtede CPUE l?gges sammen for hvert ?r, og der regnes en SD
data31 <- aggregate(data30$vaegtet_CPUE,list(year=data30$year), sum,na.rm=T)
data31b <- aggregate(data30$vaegtet_CPUE,list(year=data30$year), FUN=sd)
names(data31)[names(data31)=='x']<-'CPUE_pr_aar'
names(data31b)[names(data31b)=='x']<-'SD'

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