PINNGORTITALERIFFIK

GREENLAND INSTITUTE OF NATURAL RESOURCES

GRØNLANDS NATURINSTITUT

Nuuk, August 2023

Assessment of lumpfish (*Cyclopterus lumpus*) in West Greenland based on commercial data 2010-2023

Eqikkaaneq (summary in Greenlandic)

Nipisanniarneq pillugu naliliineq aamma 'Kalaallit Nunaata Kitaani Nipisat arnarluit (matuma kingorna arnarlunnik taagorneqassapput) pillugit Aqutsinermi Pilersaarut 2021 – 2025' naapertorlugu biologit siunnersuinerat Pinngortitaleriffiup matumuuna saqqummiuppai. Arnarluit suaat 1.475,3 tonsit 2024-mi pisarineqarsinnaasut biologit siunnersuutigaat, taakkulu 2022-mi 2023-milu siunnersuutigineqartut assigaat. Suaat 2023-mi tunineqartut 1.407 tonsiupput, siunnersuutigineqartunit pisassiissutigineqartunillu 4,6 %-imik appasinnerullutik. 2023-mi piffissami aalajangersimasumi pisat (angusinnaasat) amerlassusaat 2022-mut naleqqiullugit 19 %-imik qaffariaateqarput piffissamilu 2010-2023-imi aatsaat taama qaffasitsigisumut inissipput.

Arnarlunniarnerup naliliiffigineqarnerani aalisarnermi kisitsisitigut paasissutissat tunngavigineqarput, tassunga ilanngullugit pisarineqarsinnaasut tamakkiisut aamma piffissami aalajangersimasumi pisat. Suaat ukiuni kingulliunerusuni tulaanneqartartut oqimaassusaat biologit siunnersuinerannit pisassiissutaasunillu malunnaatilimmik ikinnerusarput, tamatuma malitsigisaanik periuseq atorneqartartoq, tassalu piffissami aalajangersimasumi pisat amerliartortut kisinneqartarneranni gang-iisarneq nalorninartoqartoq Pinngortitaleriffik naliliivoq. Nalorninartoqarnera peqqutaalluni amerlanerpaamik 1475,3 tonsit siorna siunnersuutigineqartut assingi siunnersuutigineqaqqissasut Pinngortitaleriffiup inassutigaa. 2022-mi piffissap aalajangersimasup iluani pisat amerlassusaat aqutsiveqarfimmi pilersaarummi allassimasunut (2010-2013) naleqqiullugit 56 %-imik qaffasinnerupput, pilersaarullu malinneqassappat pisassiissutit 2023-mi 20 %-imik qaffanneqarsinnaassapput ('Piffissami aalajangersimasumi pisat amerlassusaat ukiut marluk matuma siorna siunnersuinerup kisitsisitaannut qanngerunneqassagamik). Ukiuni kingullerni biologit siunnersuinerannit appasinnerusumik aalisartoqartarsimavoq, tamannalu peqassutsimut pitsaasumik kinguneqarsinnaavoq piffissallu aalajangersimasup iluani pisat amerleriaateqarnerannut pissutaasinnaavoq. Piffissap aalajangersimasup iluani pisat amerleriaateqarsimanerat biologit qaffasinnerusumik siunnersuuteqarnerannik nassataqarsimavoq, aalisarnermili pisassiissutit/siunnersuutigineqartut (4,6 %-it ataallugit) tamakkerneqarsimanngillat. Siunnersuineq maanna atuutsinneqartoq oqaluttuarisaanermi aatsaat taama qaffasitsigaaq aamma tulaanneqartartut amerlanerisa kingunerat suli takuneqanngilaq. Taamaammat 2022-mi siunnersuineq allanngortinnagu attatiinnarneqassasoq Pinngortitaleriffup inassutigaa.

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 **2024 er på 1.475,3 tons**, hvilket er samme rådgivning som i 2022 og 2023. Fangsterne i 2023 var på 1.407 t rogn og 4,6 % under rådgivningen og den fastsatte kvote. Fangstraterne(effektiviteten) i 2023 steg 19 % i forhold til 2022 og er nu på højeste niveau for perioden 2010-2023.

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 56 % 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 (4.6 % 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 2023 were 1,407 t roe and 4.5 % below the advice and the set quota. Catch rates in 2023 increased by 19 % compared to 2022 and are now at the highest level for 2010-2023.

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 56 % 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 (4.5 % 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 2023 landings were 1407 t which is an increase of 15 % compared to 2022 (Fig. 1). The TAC of 1475,3 t in 2023 was therefore not entirely caught (4.6 % below). In the northern areas (NAFO 1A-1Ba, 1Bb), 29 % of the subarea-specific TAC was caught, while 25 % and 23 % were caught in 1C and 1D, respectively (Table I) (information about the management areas is provided in the management plan).

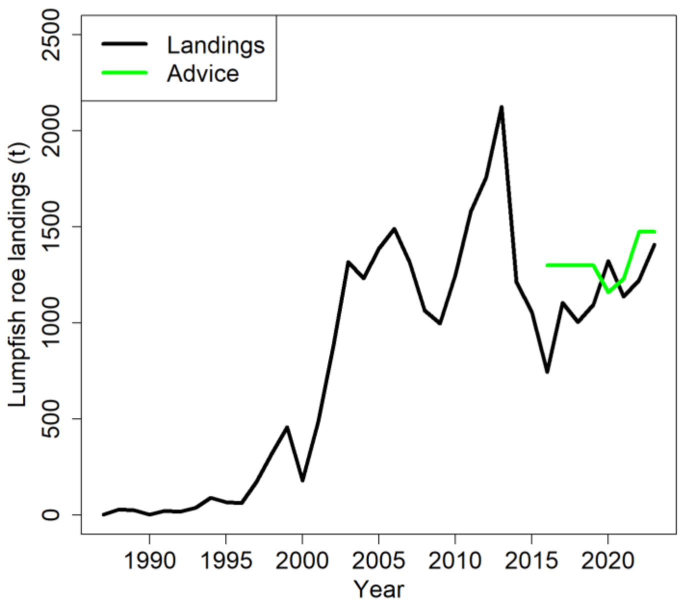
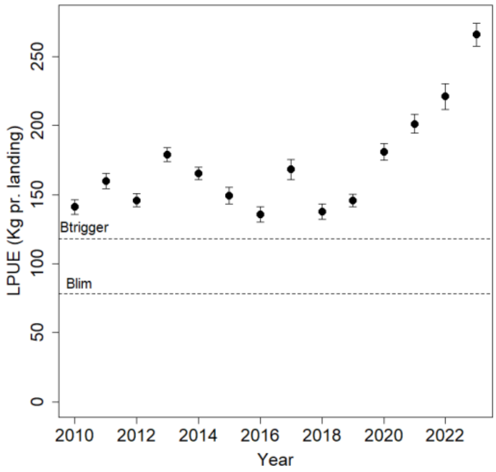


Figure 1: Total lumpfish roe landings (t) from 1987 to 2023 and TAC advice from 2016.

Table I: Landings (roe) by NAFO area in 2023 (from north to south).

NAFO	TAC (t)	Landing (t)	% of the total landings (1407)
1A	181	166	11.8
1Ba	162	173	12.3
1Bb	84	68	4.8
1C	370	349	24.8
1D	362	**317**	22.5
1E	203	203	14.4
1F	112	131	9.3
Total	1475.3	1407	100.0

The overall LPUE increased by 19 % to the highest of the time series (Fig. 2, Table II). This was driven by an increase in all NAFO areas (Fig. 3).



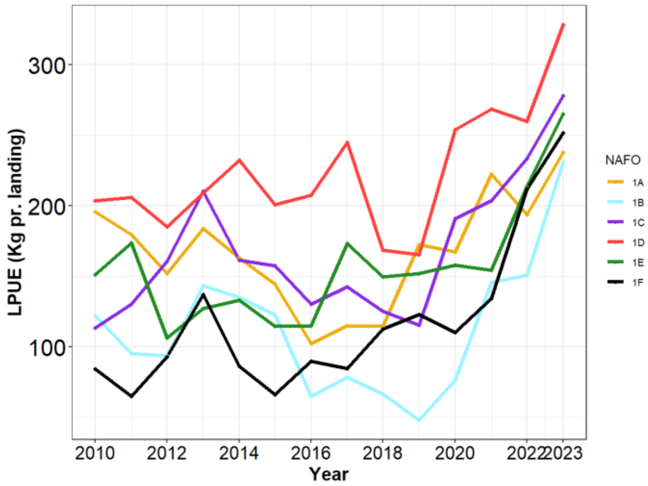


Figure 2: LPUE estimates for the West Greenland area. Vertical bars are standard errors. $B_{trigger}$ and B_{lim} values are indicated.

Figure 3: NAFO area specific LPUE estimates.

Table II: LPUE index by year with standard deviations.

Year	LPUE	Standard error
2010	141.1	5.1
2011	159.8	5.5
2012	146.1	4.6
2013	179.2	4.9
2014	165.5	4.6
2015	149.2	6.0
2016	135.6	5.5
2017	168.4	7.2
2018	137.8	5.4
2019	145.9	4.8
2020	181.4	6.1
2021	202.0	6.9
2022	221.3	9.3
2023	266.0	8.2

The cumulative catches show that a large share in 2023 was taken within a short period and reflects the pattern of the most recent years (Fig 4). As in 2022, the fishery had a late start because of a strike by fishers. This strike delayed the start of the fishery by approximately 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, a sensitivity test was done where only data from late season was included throughout the time series. 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.

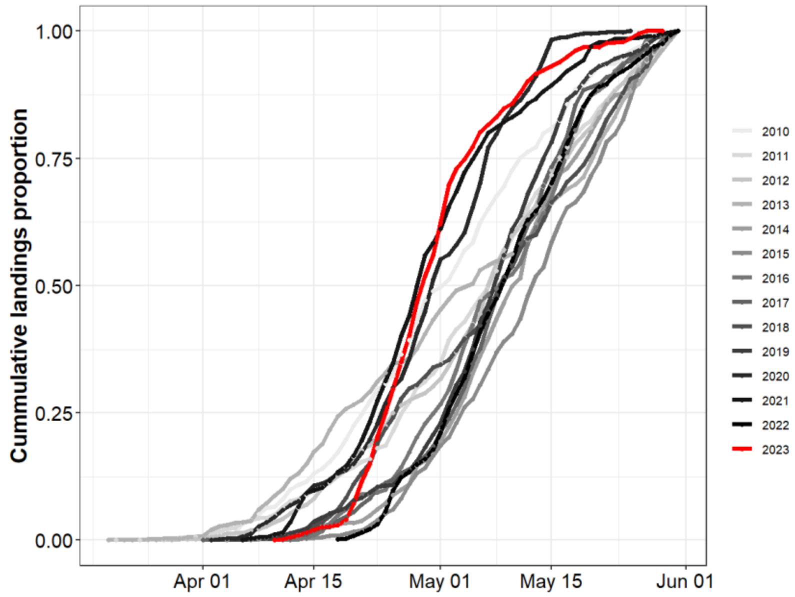


Figure 4: Cumulative landings over the year in proportions by year.

Active fishermen increased in all areas, except 1C (Table III). In 2023, the number of fished field codes reached 200, exceeding last year's count of 182, which was the lowest recorded in the time-series (Table III). Therefore, the previous trend of geographical contradiction in the fishery ceased. At the same time, the number of active fishers also increased but is still below the average (Table III).

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
2023	150	63	177	55	77	16	538	55	35	46	29	31	4	200

The average fish length has been relative 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.

Dedicated studies on bycatch from the lumpfish fishery were conducted from 2019 to 2023. These projects involved the collection and measurement of female lumpfish. In the 2019 project, 823 female lumpfish were collected throughout most of the fishing season from catches around Nuuk. Subsequently, in the projects of 2021, 2022, and 2023 conducted in the same area, 452, 168, and 2167 female lumpfish were measured, respectively, with mean lengths of 38.0 cm, 37.5 cm, and 38.3 cm. A particular trend in the development of the size composition has not been 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 2023 increased by 15 % compared to 2022 but were still below the TAC. The LPUE (266) continued to increase to a time series high and are significantly above the $B_{trigger}$ reference point (156.5). The LPUE in 2023 and catches throughout the season indicate that the fishery was highly effective compared to previous years, aligning with multiple verbal accounts within the industry. Both the number of fishers and the number of fished field codes increased in 2023.

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 1770.6 t in 2023. 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 have in several years been considerably lower than the advice (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 an increased risk of overfishing. The current relatively high advice level for 2023 (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 using 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 be affiliated with uncertainty as marked price and political issues effects the fishing patterns.

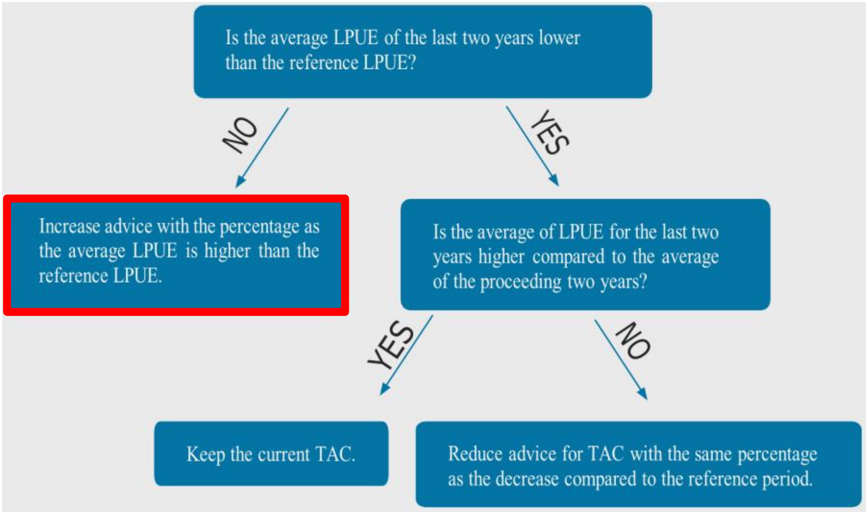


Figure 5: Advisory decision tree. Red box applies for 2023 advice.

Advice for 2024 (red box in fig 5): Increase TAC advice from last year with the same % as the average LPUE of 2022 and 2023 is higher than the ref. period.

2024 advice initial: $2023_{Advice} * (1+((LPUE_{2022\text{-}2023} - LPUE_{ref\ 2010\text{-}2013}) / LPUE_{ref\ 2010\text{-}2013})) = 2024_{TAC}$

2024 advice initial: 1475.3 * (1+((243.6-156.5)/156.5)) = 2296 t

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

2024 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 rest 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., Blicher, M.E. and Grønkjær, P. 2014. First estimates of age and production of lumpsucker (*Cyclopterus lumpus*) in Greenland. Fish. Res. (2014). 149:1-4. http://dx.doi.org/10.1016/j.fishres.2013.08.016.

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.

```
#
##########################################################################################################################
data2020 <- read.csv('Z:/Luli/37 Stenbider/Indhandlingsdata/2021 - med nyt script/LUM_10_20_1.csv', sep=';', header=T, fileEncoding = "Latin1", check.names = F)
data2021 <- read.csv('Z:/Luli/37 Stenbider/Indhandlingsdata/2022/Stenbider2021 v1 08072021.csv', sep=';',dec=".", header=T, fileEncoding = "Latin1", check.names = F)
data2022 <- read.csv('Z:/Luli/37 Stenbider/Indhandlingsdata/2022/Indhandlinger LUM 2020-2022 20220916.csv', sep=';',dec=".", header=T, fileEncoding = "Latin1", check.names = F)
#data2023 <- read.csv('Z:/Luli/37 Stenbider/Indhandlingsdata/2023/Stenbiderindhandlinger 2020-2023 06_06_2023.csv', sep=';',dec=",", header=T, fileEncoding = "Latin1", check.names = F)
data2023 <- readxl::read_xlsx('Z:/Luli/37 Stenbider/Indhandlingsdata/2023/Stenbiderindhandlinger 2020-2023 06.06.2023.xlsx')
# If data looks weird, see if there is an issue with ", or .".

data2021 <- data2021[data2021$AAR==2021,]
names(data2022) <- toupper(names(data2022)) #
data2022 <- data2022[data2022$AAR==2022,]
data2023 <- as.data.frame(data2023[data2023$AAR==2023,])

data2020 <- data2020[,c('INDHANDLINGSDATO','INDHANDLINGSSTED_GFLKNR','LANDINGSSTED_GFLKNR','FISKER_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'))
data2022 <- plyr::rename(data2022 ,c('GFLK_NR'='FISKER_GFLKNR'))

#Different format between years. Syncing these
#For 2021 it is MM-DD-YYYY, while earlier 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)))
data2022$month <- as.numeric(as.character(substring(data2022$INDHANDLINGSDATO, 4,5)))
data2022$year <- as.numeric(as.character(substring(data2022$INDHANDLINGSDATO, 7,10)))

data2023 <- dplyr::rename(data2023, "year"="AAR", "FISKER_GFLKNR"="GFLK_NR")
#data2023$INDHANDLINGSDATO <- ifelse(nchar(data2023$INDHANDLINGSDATO) < 7, NA, data2023$INDHANDLINGSDATO)
```

```
data2023$day   <- as.numeric(as.character(substring(data2023$INDHANDLINGSDATO, 9,10)))
data2023$month <- as.numeric(as.character(substring(data2023$INDHANDLINGSDATO, 6,7)))
data2023 <- data2023[,names(data2022),]
#data2023$INDHANDLINGSDATO <- sub(" UTC", "", data2023$INDHANDLINGSDATO)
data2023 <- data2023[!is.na(data2023$FANGSTFELT),] #Three obs in 2023 have missing info on FANGSTFELT. Remove these

data1 <- rbind(data2020, data2021, data2022, data2023)
data1 <- data1[!is.na(data1$FISKER_GFLKNR),] #Remove obs when no info on fisher

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)
data3<-cbind(data2,num_character2)

#Lat and lon from mid pos of field code.
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.

#NAFO from pos of field code
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)

#Remove data when it is not roe
data13a <- subset(data5, !BEHGRD %in% c('MHUI', 'HEL', 'HEL-M', 'HEL-F', 'HELRSW'))

#Get day of year
data13a$day_of_year <- yday(ymd(paste(data13a$year, data13a$month, data13a$day, sep = "-")))

#Choosing indhandlinger from Marts to May for the LPUE calculations
data13b <- data13a[data13a$month %in% c(3,4,5),]

#Some landings lag info about field code. For these, bying place (indhandlingssted) is used to assign to area. ----
data13b$INDHANDLINGSSTED_GFLKNR <-  as.factor(data13b$INDHANDLINGSSTED_GFLKNR)
```

```
#In 2023 there where some new Indhandlingssteder.
recode_INDHANDLINGSSTED_BY <- c("1010" = "Nanortalik", "1040" = "Narsaq", "1050" = "Paamiut", "1060" = "Nuuk", "1070" = "Maniitsoq",
        "1080" = "Sisimiut", "1100" = "Aasiaat", "1110" = "Qasigiannguit", "1120" = "Ilulissat", "1121" = "Ilulissat",
        "1122" = "Ilulissat", "1123" = "Ilulissat", "1124" = "Ilulissat", "1140" = "Qeqertarsuaq", "1150" = "Uummannaq",
        "1151" = "Uummannaq", "1152" = "Uummannaq", "1153" = "Uummannaq", "1154" = "Uummannaq", "1155" = "Uummannaq",
        "1156" = "Uummannaq", "1157" = "Uummannaq", "1210" = "Arsuk", "1211" = "Nuuk", "1212" = "Nuuk",
        "1213" = "Maniitsoq", "1214" = "Maniitsoq", "1217" = "Kangaatsiaq", "1218" = "Aasiaat", "1219" = "Aasiaat",
        "22111" = "Nanortalik", "22167" = "Upernavik", "22532" = "Qaqortoq", "22597" = "Innaarsuit", "22619" = "Ship",
        "22761" = "Ilulissat", "22810" = "Kangersuatsiaq", "22815" = "Attu", "22818" = "Upernavik", "22835" = "Qaanaaq",
        "22857" = "Sisimiut", "22874" = "Sisimiut", "22876" = "Kuumiut", "22928" = "Sisimiut", "22930" = "Maniitsoq",
        "23011" = "Maniitsoq", "23039" = "Ilimanaq", "23049" = "Maniitsoq", "23137" = "Qeqertarsuaq", "23139" = "Aasiaat",
        "1616" = "Ship", "1651" = "Ship", "1653" = "Ship", "22111" = "Nanortalik", "22162" = "Uummannaq",
        "22167" = "Upernavik", "22479" = "Ilulissat", "22532" = "Qaqortoq", "22597" = "Upernavik", "22619" = "Ship",
        "22761" = "Ilulissat", "22810" = "Upernavik", "22815" = "Aasiaat", "22818" = "Upernavik", "22835" = "Qaanaaq",
        "22857" = "Sisimiut", "22874" = "Sisimiut", "22876" = "Tasiilaq", "22928" = "Sisimiut", "22930" = "Qaqortoq",
        "23103" = "Upernavik", "23104" = "Upernavik", "23105" = "Upernavik", "23106" = "Upernavik", "23108" = "Uummannaq",
        "23011" = "Maniitsoq", "23039" = "Ilulissat", "23049" = "Nanortalik", "23137" = "Qeqertarsuaq", "23139" = "Aasiaat",
        "23275" = "Sisimiut", "23338" = "Sisimiut", "23286" = "Upernavik", "23395" = "Upernavik", "22821" = "Nuuk",
        "22992" = "Maniitsoq", "22993" = "Aasiaat", "23114" = "Nanortalik", "23325" = "Qeqertarsuaq", "23691" = "Upernavik",
        "23733" = "Ilulissat", "29500" = "Narsaq", "68" = "Nuuk", "23374" = "Narsaq", "24052" = "Maniitsoq",
        "27557" = "Narsaq", "23502" = "Maniitsoq", "23514" = "Sisimiut", "23505" = "Attu", "23581" = "Aasiaat",
        "29501" = "Nuuk", "23692" = "Uummannaq", "23978" = "Maniitsoq", "23503" = "Ikamiut", "24483" = "Qasigiannguit",
        "25419" = "Narsaq", "24429" = "Ilulissat", "62132" = "Sisimiut", "38417" = "Nuuk", "27501" = "Nuuk",
        "29446" = "Nuuk")

data13b$INDHANDLINGSSTED_BY <- recode(data13b$INDHANDLINGSSTED_GFLKNR, !!!recode_INDHANDLINGSSTED_BY)

data13b$INDHANDLINGSSTED_BY <- as.factor(data13b$INDHANDLINGSSTED_BY)
data13b<-subset(data13b, INDHANDLINGSSTED_BY!='27501') #Remove bycatches from the capelin fishery in Iceland
data13b<-subset(data13b, INDHANDLINGSSTED_BY!='35117') #Remove some catches in Norway

data13b$NAFO_fra_Indhandlingssted <- recode(data13b$INDHANDLINGSSTED_BY,
                "Nanortalik" = "1F",
                "Narsaq" = "1F",
                "Paamiut" = "1E",
                "Nuuk" = "1D",
                "Maniitsoq" = "1C",
                "Sisimiut" = "1B",
                "Aasiaat" = "1B",
                "Qasigiannguit" = "1B",
                "Ilulissat" = "1A",
                "Qeqertarsuaq" = "1A",
                "Uummannaq" = "1A",
                "Arsuk" = "1E",
                "Kangaatsiaq" = "1B",
                "Upernavik" = "1A",
                "Qaqortoq" = "1F",
                "Innaarsuit" = "1A",
                "Kangersuatsiaq" = "1A",
```

```
                                "Attu" = "1B",
                                "Qaanaaq" = "1A",
                                "Sisimiut" = "1B",
                                "Kuumiut" = "XIVb",
                                "Ilimanaq" = "1A",
                                "Tasiilaq" = "XIVb",
                                "Ikamiut" = "1B")

data13b<-subset(data13b, NAFO_fra_Indhandlingssted!='XIVb') #Remove the few obs from East Greenland

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)

#Hereafter exclude lines where kg price is below 5 kr. There are some uncertainty around this procedure
data13b$value <- data13b$VAERDI / data13b$MAENGDE #kg price
data13c <- subset(data13b, value>5&value<=50) #NY: both upper and lower limit. Generally it is few obs that are removed.

data14<-subset(data13c, MAENGDE>0&MAENGDE<500)

#Dropping variables that are not used.
data14$BEHGRD <- data14$VAERDI <- data14$value <- NULL

#data14 <- data13b #If not selecting from indhandling data
data14$feltkode = as.factor(data14$FELTKODE)

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

#Selecting fishers that are used in the LPUE calculations. Using selveral criteria:
#First calculate number of years individual fishers have been active
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 #A dummy variable used for summarizing
antal_aktive_fiskeaar <- aggregate(indhandlinger_pr_fisherman_pr_aar[,c('dummy2')],list(SAELGER=indhandlinger_pr_fisherman_pr_aar$SAEL-
GER),sum,na.rm=T) #giver antal ?r med indhandlinger pr. fisker

data15 <- merge(data14, antal_aktive_fiskeaar,by='SAELGER') #Combining data

#Exlude lines using some criteria:
#1) A fisher has to be active in at least three years in the  period 2008-current year
data16 <- subset(data15, x >2)

#2) A fisher need to have caugth minimum 500 kg in the perioden 2008-current year
#First total catch for every fisher
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')

#Delete some fishers.
#data18 <- data17 #Hvis der ikke skal selekteres ud fra indhandling i data
data18 <- subset(data17, x.y>500)

#3) We have evaluated that data prior 2010 had to poor quality to be used
data19<-subset(data18, year>2009)

#Create unique fisher ID, e.g. if fisher(seller) move area, he/she is reagarded as a new fisher.
#data19 <- data13b #If not selecting from indhandling i data
data19$SAELGER_unik <- paste(data19$SAELGER, data19$NAFO, sep='_')

#Start analysis
data20 <- aggregate(data19$MAENGDE,list(SAELGER_unik=data19$SAELGER_unik, year=data19$year, NAFO=data19$NAFO), sum,na.rm=T)
#sum the catch for every fisher in every area and year.
data21 <- aggregate(data19$dummy,list(SAELGER_unik=data19$SAELGER_unik, year=data19$year, NAFO=data19$NAFO), sum,na.rm=T)
#Numbers of indhandlinger by seller, area and year.
data22 <- cbind(data20,data21$x) #Combine data

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'

#LPUE for every unique seller/fisher in every area and year.
data22$CPUE_kg_pr_indhandling <- data22$rogn_saelger_pr_aar_pr_omraade/data22$antal_indhandlinger_pr_aar_pr_omraade_pr_fanger

#Table showing number of indhandlinger for every fisher from every area. Combining with LPUE table
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'))

names(data24)[names(data24)=='x']<-'antal_indhandlinger_pr_aar_pr_omraade'

#Weigthing of LPUE by number of indhandlinger.
#Weighting defined by a sellers number of sales/indhandlinger per year and area / number of indhandlinger in the area in the year (e.g. ratio).
data24$weight_til_CPUE <- data24$antal_indhandlinger_pr_aar_pr_omraade_pr_fanger/data24$antal_indhandlinger_pr_aar_pr_omraade

#Multiply weight with cpue (lpue)
data24$vaegtet_CPUE <- data24$CPUE_kg_pr_indhandling * data24$weight_til_CPUE

#Area and year specific lpue with 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'

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

```
#Weighted LPUE/CPUE for every area and year with SE.
#write.table(data22, file = "CPUE_pr_area.xls", sep = "\t", row.names = F)

#Catch by area and year
data27 <- aggregate(data24$rogn_saelger_pr_aar_pr_omraade,list(year=data24$year, NAFO=data24$NAFO),sum,na.rm=T)
#Catch by year
data27b <- aggregate(data24$rogn_saelger_pr_aar_pr_omraade,list(year=data24$year),sum,na.rm=T)
names(data27)[names(data27)=='x']<-'kg_pr_omraade_pr_aar' #Rename
names(data27b)[names(data27b)=='x']<-'kg_pr_aar'

#Merging tables. Contains sold amount by area and year, and total catch by year
data28 <-merge (data27, data27b, by='year')

#Weighing lpue from different areas by sold amount.
#Calculated by amount per area / amount of the year
data28$weight_til_CPUE <- data28$kg_pr_omraade_pr_aar/data28$kg_pr_aar

#Number of sales(indhandlinger) per year per area, used for CPUE calculations.
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'

#Table with weighing (data28) and number of sales (data29) are merged.
data30 <- merge (data28,data29, by=c('year','NAFO'))

#CPUE for every area and year: kg per area per year / number of sales per area per year which are weighted.
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,]    # First line without NAFO due to missing field codes

#Weighted CPUE added for every year, with 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'

#SE
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)
```