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Measuring lumps: Optimising sampling of the commercial landings of lumpfish (*Cyclopterus lumpus*) in Iceland

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A R T I C L E I N F O

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A B S T R A C T

Lumpfish (*Cyclopterus lumpus*) are the target of commercial fisheries in several countries. However, the collection of biological data for stock assessment purposes is both logistically difficult and expensive. The fishery takes place far from major population centres, over a wide geographical area, and, the roe is extracted at sea and the carcass is not landed in the majority of countries where lumpfish is fished commercially. In Iceland, a new regulation was introduced in 2012 making it mandatory to land the carcass, which led to changes within the industry that made the collection of biological data feasible, and a sampling programme was fully implemented by 2014. This study examines the precision of the sampling scheme and looks for areas in which improvements could be made. The female lumpfish landed by the fishery fell into a narrow length distribution, with the majority of fish between 36 and 47 cm total length. Average length of fish caught in the south-west (Faxaflói) was greater than fish caught on the north coast, highlighting the need to sample over the geographical extent of the fishery. A sample size of 20 fish was sufficient for a reasonably precise estimate of the length frequency of the fish caught by an individual boat. Individual boats caught fish of similar size over time, thus repeated sampling of the same boat should not be considered as separate samples. Fish stored on ice lost ~1.5–2.5% of their weight per day. From 2015–2020, measurements were taken from > 18% of the boats targeting female lumpfish; increasing the sampling effort would lead to only small increases in precision. This analysis provides valuable information in which to base future sampling schemes in other lumpfish fisheries.

1. Introduction

To aid assessment of an exploited fish stock, it is beneficial to have information on the length, weight and age composition of commercial catches. The gathering of such data can be expensive or logistically challenging because, for example, the boats are at sea for extended periods or the fishery lands the catch over a wide geographical area. It is therefore essential to ensure that when designing a sampling scheme, it can attain a sufficient level of precision in the most efficient way possible.

Lumpfish (*Cyclopterus lumpus*) are distributed across the north Atlantic and their range extends as far south as the English Channel (Ellis, 2015) and New England in United States of America (Rackovan and Howell, 2017) in the western and eastern Atlantic respectively. In spring and early summer, lumpfish migrate to coastal waters to spawn. In Norway, Iceland, the west coast of Greenland and the east coast of Canada, abundance is high enough to support a directed commercial fishery (Kennedy et al., 2019). In Iceland, there are separate fisheries for the males and females and only the female fishery is considered in the present study. The females are targeted using large mesh bottom set gillnets (267–292 mm), which are laid in shallow (< 40 m depth) coastal areas. The female lumpfish fishery is primarily a roe fishery, and the carcass has lower value per kg than the roe. Thus, when space is limiting, there is little incentive to land the whole fish and the roe is removed at sea.

Female lumpfish are exclusively targeted by small boats where fishing trips are < 1 day (Kennedy et al., 2019). Many of these boats are based in small communities far from major population centres. For example, the Norwegian fishery primarily takes place in the northern region and the Greenland fishery takes place along a 1600 km coastline with limited infrastructure. In addition, the Greenland fishery is carried out using small open boats, with little extra space for the storage of ungutted fish. With the combination of remoteness and limited space, it can be time-consuming and expensive for personnel to reach areas where the fishing boats are based and whole fish rarely reach processing facilities, thus, biological measurements cannot be taken.

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In Iceland in 2012, it became mandatory to land lumpfish carcasses. The roe could still be removed at sea as long as both the roe and carcass were landed. The proportion of landings consisting of ungutted lumpfish gradually rose from 77% in 2012 to 100% in 2017 (MFRI, 2021). The industry has also shifted from fishers salting and selling their own roe or commissioning a company to do it on their behalf, to fishermen selling the whole fish to roe processors. The result of this is that whole fish from a wide geographical area are concentrated in a small number of locations and many fish can be measured from many boats.

The sampling of lumpfish from commercial catches began in 2008 in a collaboration between BIOPOL (Iceland) and the Marine and Freshwater Research Institute (Iceland). This initially began as personnel accompanying the fishers on fishing trips and measuring large numbers of fish. It would therefore take one day to sample one boat, but many fish could be sampled. However, for other species, measuring many individuals from a single day is of limited value (Helle and Pennington, 2004). Given the change in the lumpfish industry due to the change in the regulations, the sampling regime moved from sampling aboard boats to sampling at the roe processors. The lumpfish fishery in Iceland takes place all around the coast with the exception of the southern coast (Fig. 1). There are seven management areas and boats select a management area for the current season and cannot fish in more than one area. Area B is divided into two areas with area B2 opening later than area B due to issues with bycatch of birds.

The aim of this study is to assess the precision of the current lumpfish sampling scheme in Iceland and identify areas for improvement. Specific questions include whether the timing of the sampling within the season or the landing location has an impact on length measurements, how many boats and how many fish from each boat need to be sampled and what is the effect of storage on weight of the fish. Given the hindrances encountered in the sampling of commercial catches of lumpfish, this analysis of the Icelandic sampling scheme provides valuable information in which to base future sampling schemes in other lumpfish fisheries.

2. Materials and methods

2.1. Sampling

Length and weight data of lumpfish from the commercial fishery (Table 1) are collected by the Marine and Freshwater Research Institute (MFRI) and BioPol in Iceland periodically throughout the fishing season (late March to early August, exact dates vary between years). Sampling is carried out at factories processing the roe and also at harbours where the fish is landed. In the factories, the fish are stored on ice in a temperature-controlled room until processing and are labelled with the boat name and landing date, which allows the identification of the landing harbour. The fish may have been landed locally or may have been transported from other areas so may have been landed on the same day as measurements took place or up to 6 days previous. Under the current sampling scheme, which has been in place since 2014, 40 haphazardly selected fish are measured from each boat. Processing factories and landing sites are chosen for sampling with the aim to sample catches from all lumpfish areas (Fig. 1), but due to low landings in Areas C and G where each of these areas accounts for < 5% of the total landings, obtaining samples from these areas was not always possible.

2.2. Effect of time and area

Using sampling data from 2014 to 2020 (Table 1), the effect of area and time of year (week number) on mean length was investigated using linear mixed effect models in R 4.0.4 (R Core Team, 2021). The models were fitted using the 'lmer' function in the 'lme4' package. Area and year were included as factor variables, week number was included as a continuous variable and boat sampled was included as a random effect.

In the present study, the coastline was divided into four areas (Faxaflói, Breiðafjórður, Westfjords and the north coast). Three areas correspond with lumpfish management areas, Faxaflói (area A), Breiðafjórður (area B) and Westfjords (area C) while the north coast consists of three lumpfish management areas (D, E and F). The three management areas in the north were combined due to frequent movement of lumpfish between these three areas (Kennedy et al., 2015). There is only limited movement of fish between management areas A, B,

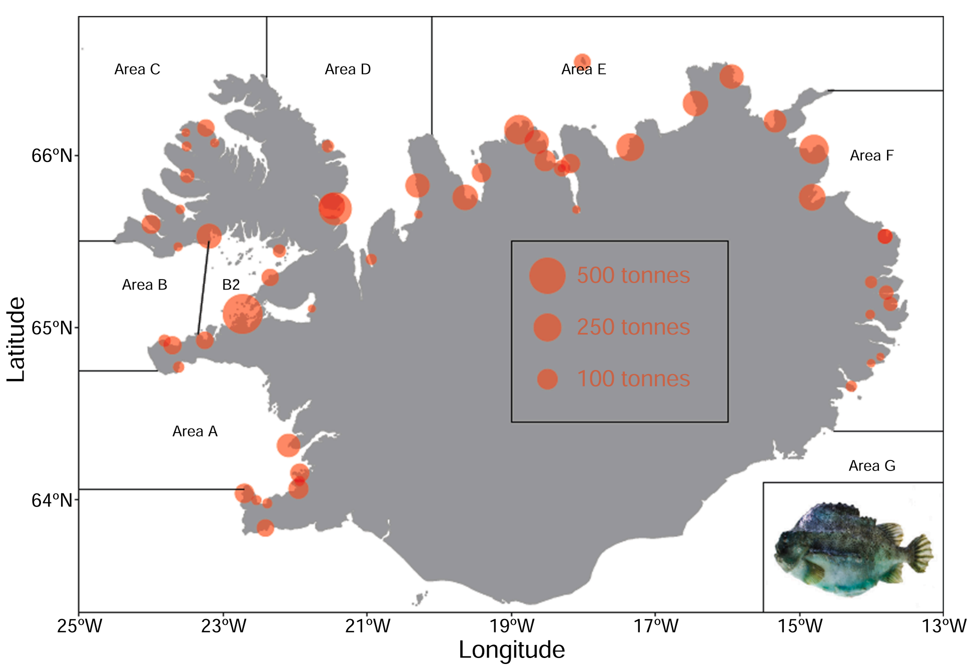

Fig. 1. Map of Iceland with average catch at each landing location for 2014–2020 and the seven lumpfish management areas. Area A = Faxaflói, Area B+B2 = Breiðafjörður, Area C = Westfjords and Area D–F = north coast. Photo insert shows female lumpfish.

Table 1
The number of boats which took part in the female lumpfish fishery (boats), the total number of fish measured (nF), the number of unique boats of which samples were taken from the landings (n), the number of boats which were sampled twice during the fishing (n(2)) season and the number of boats that were sampled by week number from 2014 to 2020. As some boats were sampled 2 or 3 times throughout the fishing season, the sum of boats through the year does not equal the total number of unique boats.

					Week number														
Year	Boats	nf	n	n (2)	13	14	15	16	17	18	19	20	21	22	23	24	25	27	28
2014	221	888	22	2			6	1	1	5	6		1	1	3			1	
2015	316	2378	56	5	1	2	10		12		8	4	1	7		2	9	4	
2016	239	2294	49	11	2	8	2	14	1		1	14	1	6	4	4	5		
2017	246	2672	56	10	16	2	6		1	24			15		1	1			
2018	218	2116	40	13		1	31	1	1		18	1							
2019	240	2798	54	15		12	14			24	6	1	1	4					6
2020	203	2848	46	17				4	26	15				4	7	3			

and C, also, there is limited movement bweeent A–C and the north coast. Area F was included as part of the north coast even though it essentially covers the east coast of Iceland. The reason for this is that the majority of the landings in Area F are taken north of 65ºN (Fig. 1) and fish frequently move between management area E and F (Kennedy et al., 2015).

2.3. Treatment of repeated sampling

Between 2014 and 2020, 73 boats were sampled on two or more occasions per season. In order to assess whether these repeated measures should be treated as independent samples or the two samples should be considered as a single sample, a random effects linear mixed-effects model, with boat and sample as nested grouping factors, was used to assess the level of variation between boats and temporally separated samples of the same boat. Additional models were also considered which included year and area as fixed effects.

2.4. Sources of variability

Using the sampling data from 2015 (selected for the highest number of boats participating in the fishery 2014–2020; Table 1), the contribution of sample size (number of fish) (f) and the number of samples (number of boats) (b) to total variance was estimated using variance component analysis. The length of a fish from the commercial (y) catch can be expressed as

$$y = \mu + \varepsilon_b + \varepsilon_f$$

where μ denotes the mean length of the total commercial catch, ϵ_b (boat component) the difference between the mean length of fish caught by boat b during the fishing season and the grand mean, and ϵ_f the within-sample component. A single sample from each boat is considered representative of all fish landed by that boat during the fishing season. The boats and fish were haphazardly selected, therefore, the variance of y is given by

$$\mathrm{Var}(y) = \sigma_b^2 + \sigma_f^2$$

An ANOVA was used to estimate ϵ_b and ϵ_f for four areas; Faxaflói, Westfjords, Breiðafjörður and the north coast.

To assess various sampling schemes, it is assumed that samples are collected from *nb* boats and from each boat, *nf* are measured. Then the variance of the estimator of the mean length $\hat{\mu}$ (see, e.g., Cochran, 1977) is given by the equation

$$\mathrm{Var}(\hat{\mu}) = (1 - f_b)\frac{\sigma_b^2}{nb} + \frac{\sigma_f^2}{nf}$$

where the finite correction factor, f_b, is the proportion of boats sampled from the respective area. The finite population correction factor for the number of fish sampled was ignored as the number of fish sampled was small in comparison with the number caught. To assess the impact of alternative sampling regimes on total variance of the estimator of mean length, different values for the number of boats and the number of fish were substituted into the equation. Two sampling strategies were considered, the first with samples taken from 10% of the boats fishing within the respective area while varying the number of fish sampled, the second with 40 fish sampled while varying the number of boats which were sampled.

Differences in weight at length and the effect of storage on ice was investigated, for each area and year where both date of landing and date on which the fish measured was available, using linear models.

3. Results

Lumpfish landed by the commercial fishery fell into a narrow unimodal length distribution (Fig. 2) with 95% of the raw length measurements falling between 36 and 47 cm (mean = 40.9) and 95% of the weight measurements falling between 1966 and 4420 g (mean = 3003 g).

Regarding variation in length, the effect of area was significant (Table 2) with a consistently greater length in Faxaflói compared to the north coast with an average difference of 2 cm (Fig. 2). This was also true of weight, with an average difference of 283 g between Faxaflói and the north coast. The fish caught in Breiðafjörður generally showed intermediate values (Table 2; Fig. 2). The effect of year was also of significance with the largest differences between two specific years being 1.3 cm (Table 2). The effect of week number was of low significance.

Three models were evaluated to investigate the effect of repeated sampling, a single year (2020), a single year (2020) with area included in the model and including all data from 2014 to 2020 with year and area included in the model. In all three models, the variance associated with repeated sampling of the same boat was small in comparison with the variance between boats and within a sample (Table 3).

When evaluating the source of variation in length, the variance associated with the fish component stabilised at around 20 fish i.e. measuring greater numbers would not reduce the variance by any significant amount (Fig. 3). The boat component accounted for the majority of the variance for each area, ~60–80%, dependent on area (Table 4).

Differences in how the variance in length changed with increasing percentage of boats sampled (Fig. 4) was, in a large part, driven by the finite correction factor. In 2015, the year used as an example, only 16 boats were fishing around the Westfjords; for comparison, 167 boats were fishing along the north coast. Thus, each additional boat in the different areas would represent an unequal increase in percentage of boats sampled. In the North, the variance of the boat component levelled off at less than 10% of the boats measured, which was ~20 boats. While in the Westfjords, significant drops in variance continued until about 50% of the boats had been sampled, which represented 8 boats.

Weight was positively correlated with length but negatively correlated with week number and the number of days of storage (Table 5; Fig. 5). Both year and area were significant factors in the model. However, the variability in the length-weight relationship between years was

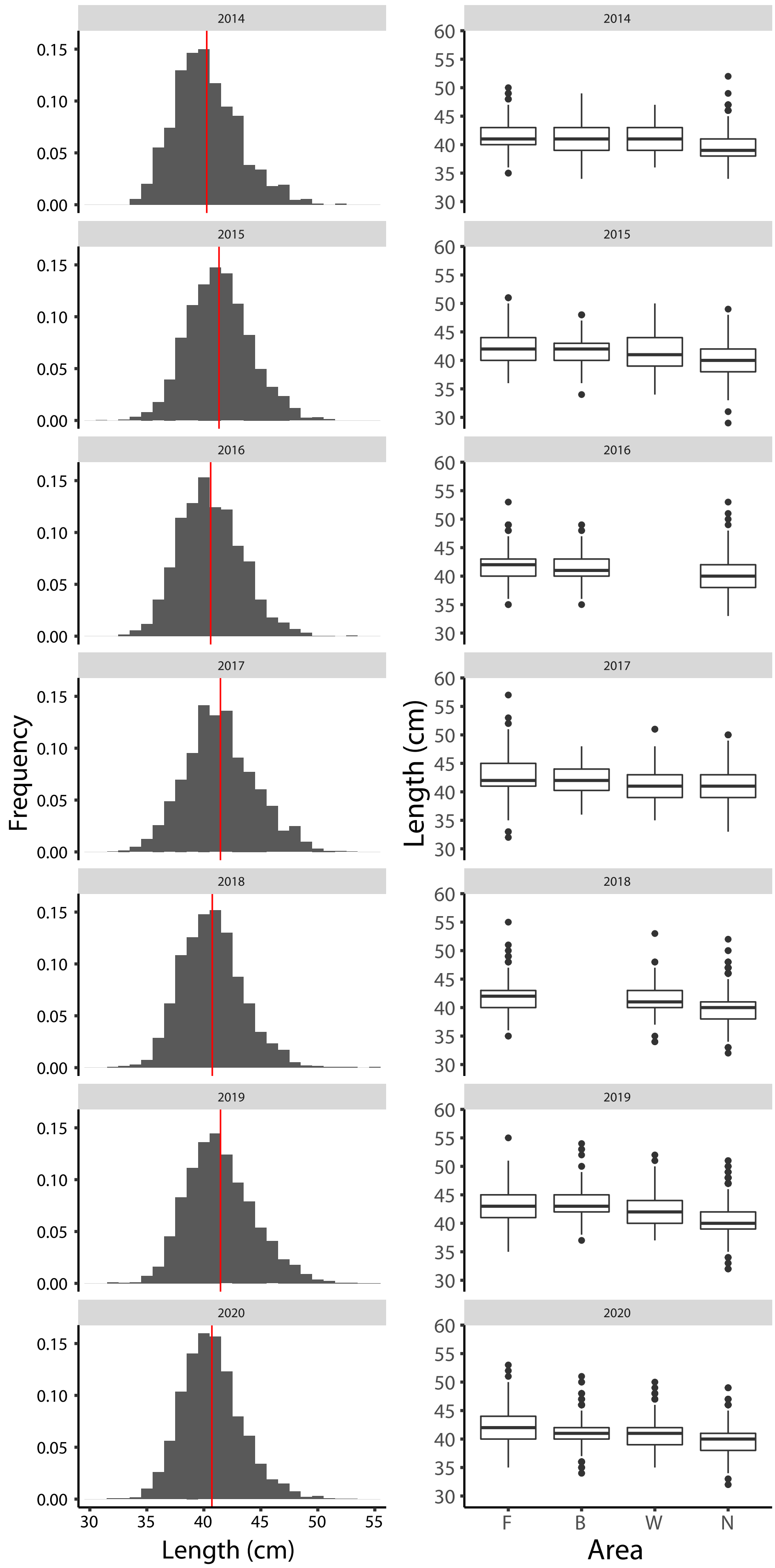

Fig. 2. Length distribution of female lumpfish caught in the commercial fishery in Iceland between 2014 and 2020 with red line indicating mean length for that year (right). Boxplots show same data divided by area: Faxaflói (F), Breiðafjörður (B), around the Westfjords (W), and along the north coast (N). No samples were taken from Breiðafjörður in 2018. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Table 2
Summary of linear mixed effects model for explaining effects on mean length.

Linear mixed model fit by REML ['lmerMod']				
Formula: length ~ area + year + week + (1 | boat)				
REML criterion at convergence:		80,690.6		
Scaled residuals:				
Min	1Q	Median	3Q	Max
−4.1769	−0.68	−0.06	0.59	5.33
Random effects:				
Groups	Name	Variance	Std.Dev.	
Boat	(Intercept)	0.24	0.49	
Residual		7.04	2.65	
Number of obs	16,792	groups	Boats, 180	
Fixed effects:				
	Estimate	Std. Error	t value	
(Intercept)	41.66	0.26	159.93	
Area Westfjords	−0.70	0.20	−3.51	
Area Breiðafjörður	−0.17	0.16	−1.11	
Area north coast	−1.99	0.10	−19.14	
year_2015	0.72	0.12	5.85	
year_2016	0.26	0.13	2.01	
year_2017	1.32	0.12	10.57	
year_2018	0.48	0.13	3.72	
year_2019	1.33	0.13	10.60	
year_2020	0.28	0.13	2.11	
year_2021	0.58	0.16	3.58	
week	−0.01	0.01	−0.86	

Table 3
Variance and standard deviation of linear mixed effect models for repeated sampling of lumpfish boats.

Model	Group	Variance	St. dev.
length ~ (1 | boat/sample)	Sample	0.00	0.00
	Boat	0.90	0.95
	Residual	6.25	2.5
length ~ year + (1 | boat/sample)	Sample	0.00	0.00
	Boat	0.26	0.51
	Residual	6.24	2.5
length ~ year + area + (1 | boat/sample)	Sample	0.09	0.29
	Boat	0.38	0.62
	Residual	7.33	2.71

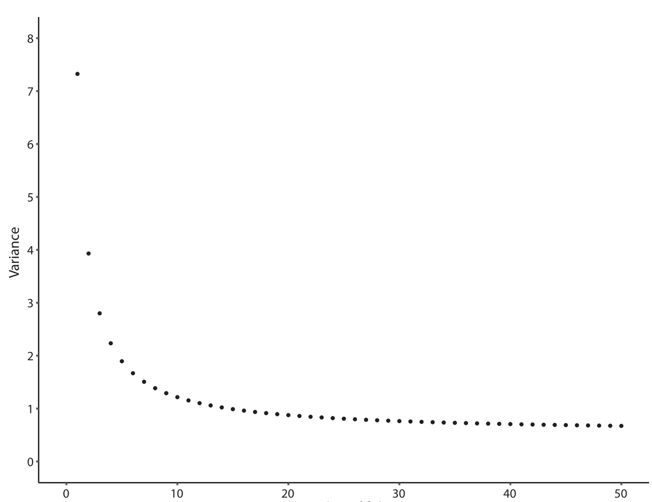

Fig. 3. Precision of the estimate of the mean length of female lumpfish as a function of the number of fish measured per boat.

lowest for fish caught in the north, while greatest for fish caught in the Westfjords (Fig. 6). This variability is correlated with the number of fish measured suggesting that this variation is a result of low sample sizes (Fig. 6). A hypothetical lumpfish of 40 cm stored on ice lost approximately ~1.5–2.5% (mean = 2.15%) of their weight per day for the first

Table 4
Analysis of Variance table (ANOVA) with sources of variation in length within and between samples for each area.

Area	Term	df	sumsq	meansq	Statistic	p value
North coast	Boat	21	547	26	4	0
	Residuals	898	6095	7		
Westfjords	Boat	3	139	46	5	0
	Residuals	155	1566	10		
Breiðafjörður	Boat	14	109	8	1	0
	Residuals	585	3149	5		
Faxaflói	Boat	14	365	26	4	0
	Residuals	684	4678	7		

three days (Fig. 5). However, due to lower number of samples for fish stored for > 3 days, there is less certainty on the rate of weight loss.

4. Discussion

Lumpfish show limited variation in mean length between samples from the same boat, between different boats, between areas and between years. This limited variation is likely due to a combination of the fishing pattern and gear used by individual boats and the life history of this species. In the female lumpfish fishery, individual boats tend to lay their nets at the start of their fishing period and haul them periodically (approximately every 3–4 days) and then set them out again close to where they were hauled. Fish that are caught within close proximity of each other tend to be more similar in regards to attributes such as size, age and maturity than fish that are caught across the geographical range of the population (Pennington et al., 2002), thus it is unsurprising that repeated sampling of the same boat is responsible for only a small proportion of the total variance in the measured samples, given that the fisher is repeatedly fishing in the same area, with the same gillnets which are known to be highly selective (Hamley, 1975).

The boat component accounted for most of the variation in mean length and this could be a result of either, mean fish size within a specific area varying between fishing locations and/or depth (Samaranayaka et al., 1997), or could be due to small differences in the selectivity of the gillnets used by the fishers. The mesh size and length of the head rope is regulated. However, fishers are free to alter both the height and the hanging ratio, both of which, along with other small differences in the rigging of the fishing gear, have the potential to influence the size of the fish caught (Acosta and Appeldoorn, 1995; Samaranayaka et al., 1997).

There are still several uncertainties surrounding the life history of lumpfish. While the ageing of lumpfish is currently unverified, using the method described by Albert et al. (2002), the lumpfish fishery in Greenland was shown to be catching fish from only two year classes (Hedeholm et al., 2014). Tagging data from the fishery in Iceland indicate that < 10% of the fish tagged return to spawn the following year (Kasper et al., 2014). This indicates high spawning mortality and would result in the fishery being dominated by recruit spawners. Thus, the spawning population consists of a small number of year classes. If landings in the Icelandic fishery consists of a high proportion of recruit spawners, then the bulk of the landings would be from a small number of year classes which would contribute to the limited variability in mean length between years.

It is interesting to note the differences in mean length between areas. It is unclear if this is due to either differences in the age structure or weight at age of the fish in the different areas. A similar phenome occurs in west Greenland where fish caught in the north-west are larger than the fish caught in the south (Hedeholm et al., 2017). Examination of the ages of these fish determined that this difference was due to the fish in the north being older. While a detailed examination of this difference in Iceland is outside the scope of this study, it highlights the need for sampling to cover the entire geographical extent of the fishery. However, the timing of the sampling did not have a significant effect on the estimate of the mean size of fish captured so repeated sampling

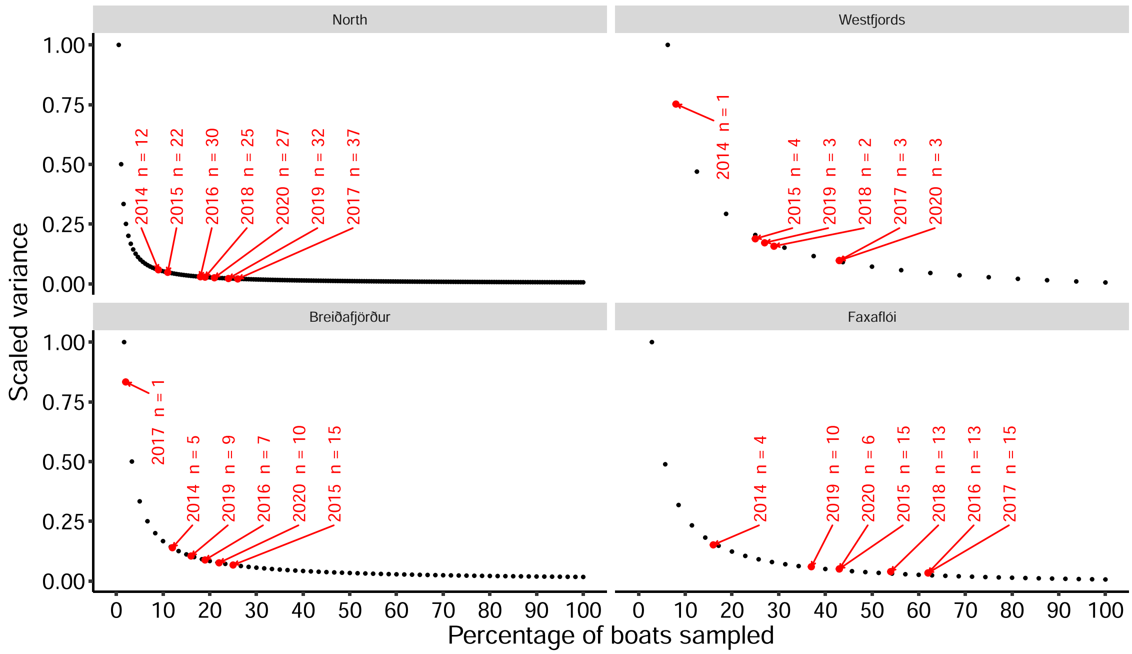

Fig. 4. Precision of the estimate of the mean length of lumpfish as a function of the number of boats sampled (black points), in each area. Each point represents one additional boat sampled. The variance has been scaled to aid comparison between areas. The percentage of boats sampled in each area and year is shown (red points) with the actual number of boats sampled (n). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Table 5
Summary table of linear model for effect on weight.

Term	Estimate	Std. error	Statistic	P value
(Intercept)	−3683.61	90.03	−40.92	0.00
Length	172.60	1.92	90.09	0.00
Year 2018	−29.91	12.66	−2.36	0.02
Year 2019	−58.75	12.38	−4.74	0.00
Year 2020	20.71	12.92	1.60	0.11
Area Westfjords	−70.14	15.78	−4.45	0.00
Area Breiðafjörður	−138.82	42.98	−3.23	0.00
Area north coast	30.17	10.92	2.76	0.01
Days of storage	−47.77	3.29	−14.50	0.00
Week number	−18.44	2.08	−8.85	0.00

throughout the fishing season is not considered necessary.

In regard to the number of fish sampled per boat, the current sample size of 40 is sufficient to obtain a precise estimate of the size of fish captured by the boat in question. Reducing the number of sampled fish to 20 would result in only a small increase in variation. However, the time saved would be small when weighed against the time needed to prepare for the sampling trip and to travel to the sampling location. The ability to lower the number of samples would be of higher value in other lumpfish fisheries (Norway, Greenland and Canada) where the roe is removed at sea and the carcass is disposed of. Asking each boat to bring a sample of fish to shore ungutted may be met with resistance if the number of fish requested is large as these would take up valuable space in the fishing vessel. Translating these sample size to lumpfish fisheries in other areas would require that there is a similar narrow distribution in length. Lumpfish are also targeted using gillnets in Canada, Greenland and Norway (Kennedy et al., 2019) thus limiting the size range of fish that are caught in the fishery. It is also not expected that there are major differences in life history between the lumpfish caught in Iceland and those caught in other areas, which would result in wider length distributions. In support of this expected limited variability, fish sampled in the fishery in the Gulf of St. Lawrence show a similar size distribution to those caught in Iceland (DFO, 2016).

The number of boats sampled is an important consideration with

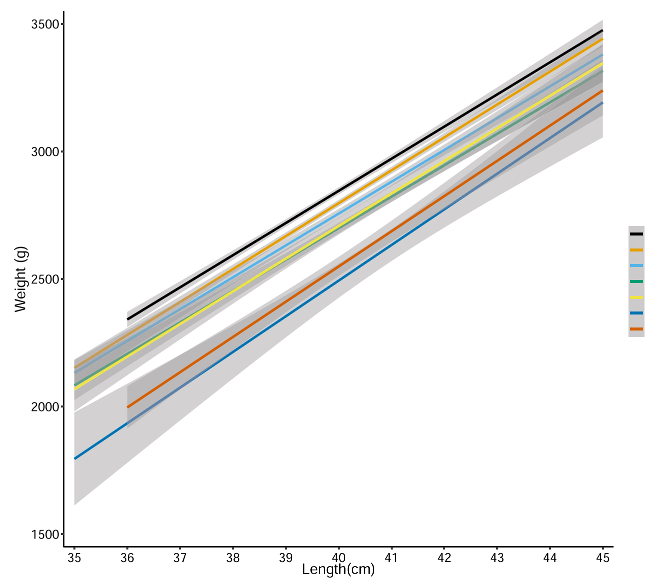

Fig. 5. Linear regression models of length versus weight for lumpfish stored on ice for differing lengths of time. Legend indicates length of time stored in days.

respect to the commercial sampling of lumpfish. Only about 10 (14–35 boats, min-max 2014–2020), 20 (36–60 boats, min-max 2014–2020) and 5% (7–16 boats, min-max 2014–2020) of the lumpfish fishing fleet annually fish in and around Faxaflói, in Breiðafjörður and around the Westfjords respectively. Thus, even if increasing the number of boats sampled in each area increases the precision for that area, this would only result in small gains in terms of the whole fishery. In the north, the variance began to level off after approximately 10% of the fleet had been sampled; the number of boats sampled from 2015 to 2020 exceeded this.

There were several cases of sampling twice from the same boat, which happened most often in Breiðafjörður. As there was limited variation between samples, and boat number and landing date is noted

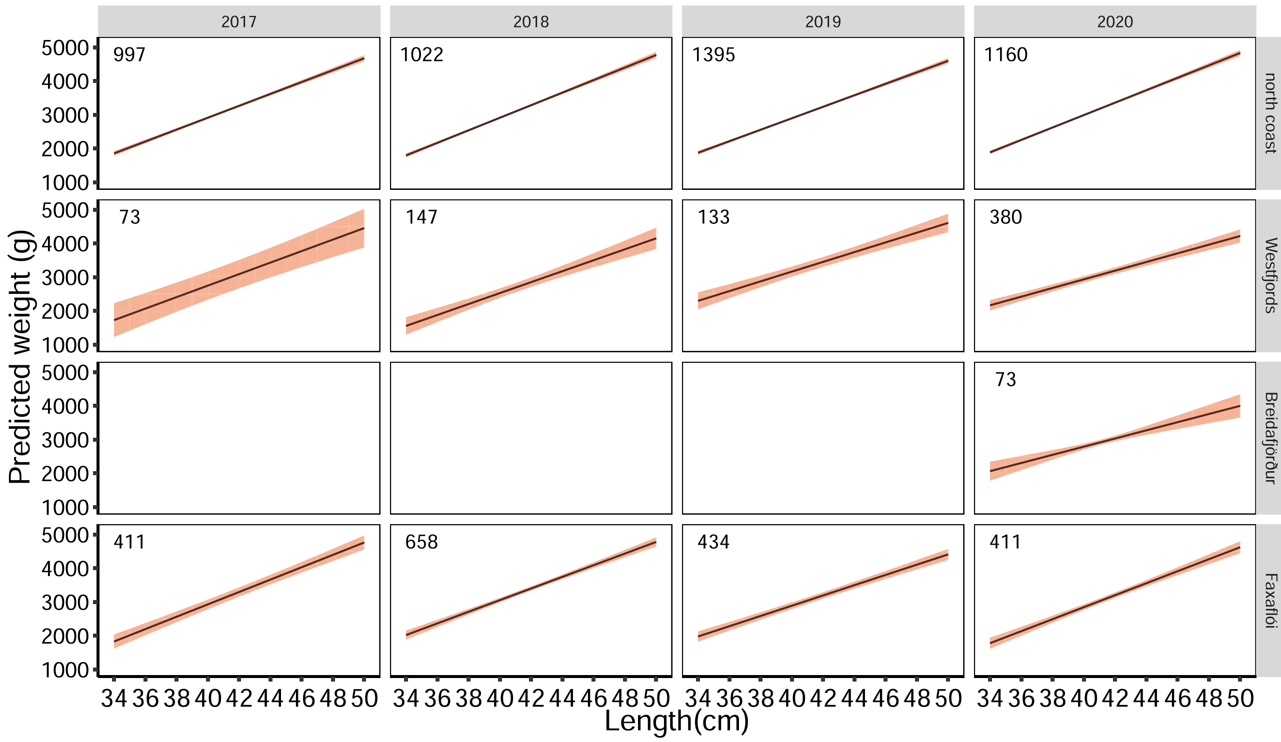

Fig. 6. Predicted weight at length for female lumpfish on day of landing with shaded area showing 95% confidence intervals. Label indicates number of fish measured by area/year.

for each sample, these repeated samples can easily be identified and excluded from the data analysis. The primary problem with repeated sampling from the same boats is that it represents wasted effort if these data are not used. Given that each boat can only fish for a specific number of consecutive days, spacing the sampling days over a greater period than the number of allowed fishing days for each boat should reduce, but not completely eliminate, the double sampling. When at the fish processing facility, it is best to keep instructions as straightforward as possible e.g., "one fish box from each boat". Giving extra instructions to staff is best avoided to retain goodwill as access can only be gained with the cooperation of the factory in question and they are not compensated for their time. The time needed to sample one boat is short (10–15 min) so double sampling does not add much time to the total time needed for a sampling trip. In addition, a repeated sampling may provide an alternate sample with a lower time between landing and sampling than the previous one from that boat.

Unsurprisingly, weight was correlated with length but the variability in weight at length was high in comparison to many other species of fish (pers. obs.). A 40 cm lumpfish typically varied from ~2200 to 3600 g. Standard error of predicted weight at length decreased with increasing sample size and levelled off at ~1000 fish. This would equate to measuring fish from 25 boats assuming a sample size of 40 fish per boat. Weight was negatively correlated with week number, which is probably a result of an increasing proportion of fish that had spawned some or all of their eggs (Kennedy, 2018). Storage on ice also impacted the weight, with fish gradually losing water over time. The results indicate that this decrease in weight can be compensated for, but this will decrease the accuracy of the measurements, especially as storage time increases, due to variability in the rate of water loss over time and between samples. The best strategy would thus be to only include measurements of weight where storage time is low. However, this is not always possible, thus storage time should be adequately recorded for inclusion in future analyses of the data.

The current study illustrates how lumpfish can be effectively sampled from the catch in Iceland as well as suggestions that can aid in the design of a sampling scheme for other lumpfish fisheries. However, what is the value of this data given that lumpfish populations are not currently assessed using age-structured models? The Icelandic and Norwegian assessments are based on ship based surveys, primarily the Icelandic spring groundfish survey and the Barents Sea Ecosystem Survey respectively (Eriksen et al., 2014; Kennedy et al., 2019). Knowledge on the length distribution of the fishery, alongside other information, can aid in the linking of the results of the surveys with the fish that are caught in the fishery (Kennedy and Jónsson, 2017). In addition, fluctuations in the mean length of fish caught in the fishery can be indicative of levels of fishing mortality (Ault et al., 2005) or changes in the environmental conditions experiences by the population which may reflect changes in the productivity of the population (Clausen et al., 2017).

In conclusion, we demonstrate that for an efficient sampling scheme for lumpfish from a commercial fishery, only a small number of length measurements from each boat is required and that double sampling of the same boat should be avoided. It is difficult to assess the number of boats that should be sampled in a lumpfish fishery in another country. However, the present and a previous study (Hedeholm et al., 2017) demonstrates that the sampling should attempt to cover as much of the geographical extent of the fishery as possible. Given the number of boats and the spatial coverage of the boats sampled in the sampling scheme for lumpfish in Iceland, it is considered that the sampling is sufficient for obtaining a representative sample of the fish caught in this fishery. While double sampling cannot always be avoided during sampling trips, it can be reduced by ensuring a sufficient interval between sampling trips.

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CRediT authorship contribution statement

James Kennedy: Conceptualization, Methodology, Validation, Formal analysis, Investigation, Resources, Writing – original draft, Writing – review & editing, Visualization, Supervision, Project administration, Funding acquisition.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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