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Lumpsucker (*Cyclopterus lumpus*) otoliths: dissection, mounting and age-reading.

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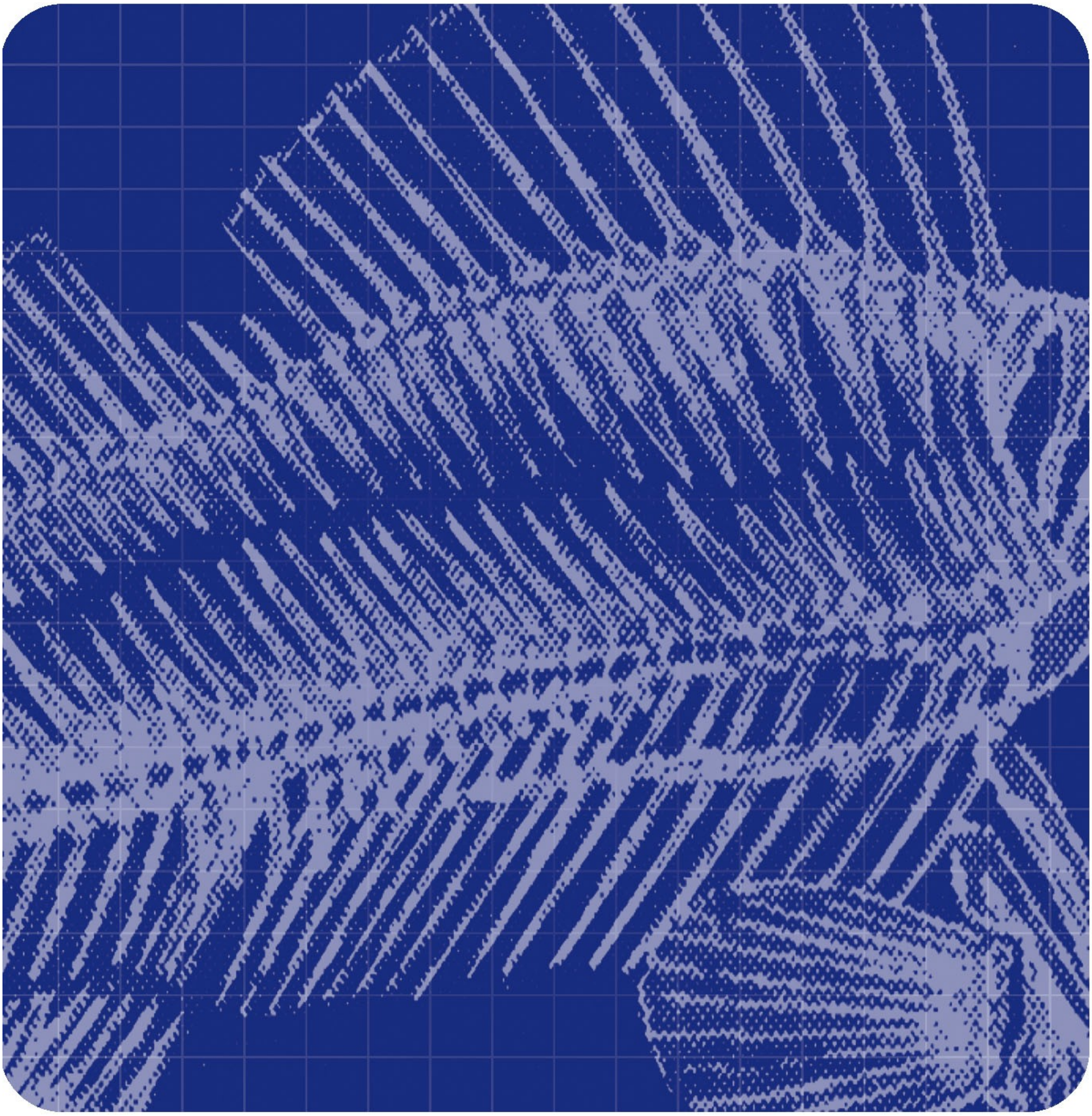

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REPORT

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Summary:
A workshop was held at Institute of Marine Research, Flødevigen Marine Research Station, Arendal, Norway, 17-19 February 1999, to investigate methodes for age-determination of lumpsucker (*Cyclopterus lumpus*) from otoliths. The report summarises the results from the workshop and some subsequent analyses. The otoliths are very small and special training is necessary to locate them. The zonation pattern is relatively distinct and it was usually easy to establish a set of rings assumed to be annuli. The precision of age estimates increased as a result of training and discussions in the group, but was hampered by the lack of verifications available at the time of reading. After the workshop, the resulting age-length relationship was compared to new estimates of length-composition of juvenile lumpsucker prior to and after the migration from the coast. This represents the first documented attempt to verify annuli in otoliths of lumpsucker from Norwegian waters. It is recommended that a new workshop should be arranged to put together more verified age data and to see if a reasonable precision is achievable when the age readings are based on verified patterns.

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1 INTRODUCTION

Lumpsucker (*Cyclopterus lumpus*) is a semipelagic species that, beyond the spawning season, usually occur in the upper 50-60 m of the North Atlantic, and often over abyssal depths in the Norwegian Sea and the Northeast Atlantic (Blacker 1983). In the spawning season the species is widely distributed in coastal areas on both sides of the North Atlantic, where the spawning occurs in the sublittoral zone on rocky substrate. Spent females subsequently disappear, leaving male to guard the nest until the young hatch 6-8 weeks later (Daborn & Gregory 1983).

In Norway, Island, Canada and Denmark lumpsucker is exploited for its high valued roe, whereas the males and the flesh of the females are often discarded. Thus the commercial fishery is highly seasonal, in the north of Norway mainly 5-6 weeks within the period April to mid-June (Bertelsen 1994) and from mid March to the end of May/early June in the South (Torstensen, 1988). The mature females are caught with gillnets on the spawning grounds, mainly with rather small vessels.

In some areas in Norway data of *Catch Per Unit Effort* (CPUE) has been collected from the commercial fishery since the 1980s (Bertelsen 1994; Albert 1999). An increased harvest since the late 80s associated with a reduction in CPUE indicates an overexploitation. Maintenance of high landings throughout the 90s was only possible with a marked increase in effort, resulting in a further increased exploitation level. In the lumpsucker fishery at Iceland a similar trend of a reduction in CPUE was observed during the first half of the 90s (Anon, 1999).

Biomass models for lumpsucker in Norwegian waters have been worked out (Albert *in prep.*; Bertelsen 1998), but these are very simple and defective since the stock composition is largely unknown.

Data on age composition are fundamental in stock assessments. Age structure and population dynamics of lumpsucker (*Cyclopterus lumpus*) has previously been described from Canada (Cox 1920, Cox and Anderson 1922), Denmark (Bagge 1964,1965,1967), Iceland (Sæmundsson 1926, Schopka 1974, Thorsteinsson 1981) and Norway (Myrseth 1971). Sæmundsson (1926) considered them to be at least 5-6 years old at maturity and mentioned that Canadian scientists (probably Cox 1922) reached the same conclusion. Schopka (1974) estimated age at maturity to 3-4 years, with only a small proportion of the stock spawning more than once. In the North Sea, the spawning stock of lumpsucker was found to include the age groups 4-9 with a dominance of the age groups 5 and 6 (Bagge 1967). He also found that only males were represented in the spawning stock at age 4 and were still dominating at age 5. Thorsteinsson (1981, 1983) showed that females from Icelandic waters recruit to the spawning stock at an age of 5-10 years, while the males recruit at 4 years. The spawning stock in this area consisted mainly of 5-8 years old females and 4-7 years old males.

These differences in age at maturity may be attributable to real temporal or geographical variation. However, all these studies were based on interpretation of otoliths, using ageing methods that has not been fully verified, and in many cases not even described. The scientists working with lumpsucker today are new in the field, with poor knowledge in ageing this species. Therefore it was felt necessary to establish the method more or less from scratch, and to co-ordinate the reading methods used by the different laboratories.

For this purpose a workshop was arranged, with the objective of evaluating the possibility of reasonably accurate and precise age estimation of lumpsucker from otoliths. It was also realised that a practical way to locate, dissect and prepare the very small otoliths of this species had to be found and described. The main focus of the workshop was to achieve consistency in the reading method. Further, a first approach for validation was also tried, namely comparison of the age estimates with length-frequencies. Available length samples included caches by gears with assumed low size-selectivity (i.e. excluding gill-net samples). Samples of larvae near the coast, juveniles in the high seas, and adults close to coastal spawning grounds were considered.

This report describes the results from the workshop, with focus on the methods that were found practical, the precision between readers, and comparisons with length composition of the stock.

2 MATERIAL AND METHODS

2.1 Participants of the workshop

Participants included those presently involved in research on population ecology of lumpsucker in Norway and Iceland (Table 1). Their experiences in reading otoliths are also presented in the table, which shows that no one was familiar with lumpsucker otoliths in advance. Therefore, printed paper pictures of selected otoliths were distributed among the participants prior to the meeting to be interpreted by all the participants before they met. Thus, when the workshop started, all participants had similar experience with lumpsucker otoliths.

Table 1 Participants of the workshop, and their prior experience with interpretation of otoliths.

Name	Institute	Prior experience
Albert, Ole Thomas	Norwegian Institute of Fisheries and Aquaculture, Tromsø	Experienced reader of gadoid and flatfish otoliths
Bertelsen, Bernt	The Norwegian College of Fishery Science. University of Tromsø	Inexperienced with otolith readings
Jonsson, Sigurdur T.	Marine Research Institute, Reykjavik. Iceland	Inexperienced with otolith readings
Paulsen, Øystein	Institute of Marine Research, Flødevigen Marine Research Station, Arendal, Norway	Photographer. Responsible for the data. Did not read otoliths.
Pettersen, Ivar H.	Bodø Regional University, Department of Fisheries and Aquaculture, Norway	Experienced reader of gadoid and flatfish otoliths
Torstensen, Else	Institute of Marine Research, Flødevigen Marine Research Station, Arendal. Norway.	Experienced reader of clupeoid otoliths (sprat and herring)

2.2 Data sets and reading sessions

The lumpsucker were sampled from the North Sea, Iceland, and coastal waters of both South- and North-Norway. They were partly caught with pelagic trawl during research surveys, and with gillnet by commercial fishermen on spawning grounds. Table 2 gives an overview of the number and size ranges of lumpsucker sampled, the sampling areas and period. Only catch dates were available during interpretation, since information on length and sex could influence the estimates.

1. **Pre-workshop-readings:** Interpretations based on photographs of Data set 1.

2. **Workshop-readings:** Interpretations made with binoculars and a monitor. Otoliths from Data set 1 and Data set 2.

3. **Post-workshop-readings:** Interpretations made with binoculars at the participant’s respective institutions. Otoliths from Data set 3.

Table 2 Overview of fish samples used for age determination by the workshop.

Area	Time period	Size-range (cm)	Sample size (numbers) Data set 1	Data set 2	Data set 3
North Sea	July 1998	24-28	5		
Southern Norway	March 1998	27-38	9	1	
"	April 1998	27-43	5	1	
"	June 1998	7-53	16	3	
"	February 1999	29-36		8	
Northern Norway	April 1993	42-53		2	
"	February 1999	43		1	
Iceland	October 1997	28-44		5	
Iceland	August 1997	15-35		10	
Norwegian Sea **	June 1994	7-39			67
TOTAL		7-53	35	31	67

**Fish samples kindly made available to the WS by Jens Chr. Holst, IMR. Bergen.

Three sets of otoliths were considered. They were called Data set 1 to 3 in Table 2, and were available for reading prior to, at, and after the workshop, respectively. Based on these sets three reading-sessions may be distinguished:

2.3 Dissection and preparation of otoliths

As the otoliths of lumpsucker are very small, it was realised that they may be difficult to find without a proper dissection method. Three different methods were tried out and each of them is outlined below. Note that the fish was completely dead, with no ventricular contractions, before cutting. Otherwise blood would make it even more difficult to see the otoliths. Of the same reason, the fish should be kept with the head somewhat up when cutting.

The horizontal cut

Make a horizontal cut over, but close to the eyes to expose the brain (Figure 1a, upper). Now, the biggest of the otoliths, sagitta, is seen on each side of the brain, located posterior to the three big brain-nerves and anterior to the four minor brain-nerves (Figure 1a, middle). Here they lie within the sacculus (otolith chamber), one on each side of the head. The otoliths are found in the membranous labyrinth. Use a small pincer to lift out each of the otoliths. You will probably have the otoliths hanging in the membrane, as shown in Figure 1a, bottom.

All the three otolith-pairs are found in the end of the membranes. They are all very small, and care must be taken to ensure that the sagitta is selected (see Fig. 4 in Thorsteinsson 1983).

The vertical cut

Make a vertical cut approximately 2 eye-diameters behind the eyes (Figure 1b, upper). The location of the sagitta is shown by the pincer in Figure 1b, bottom. Continue as in method 1.

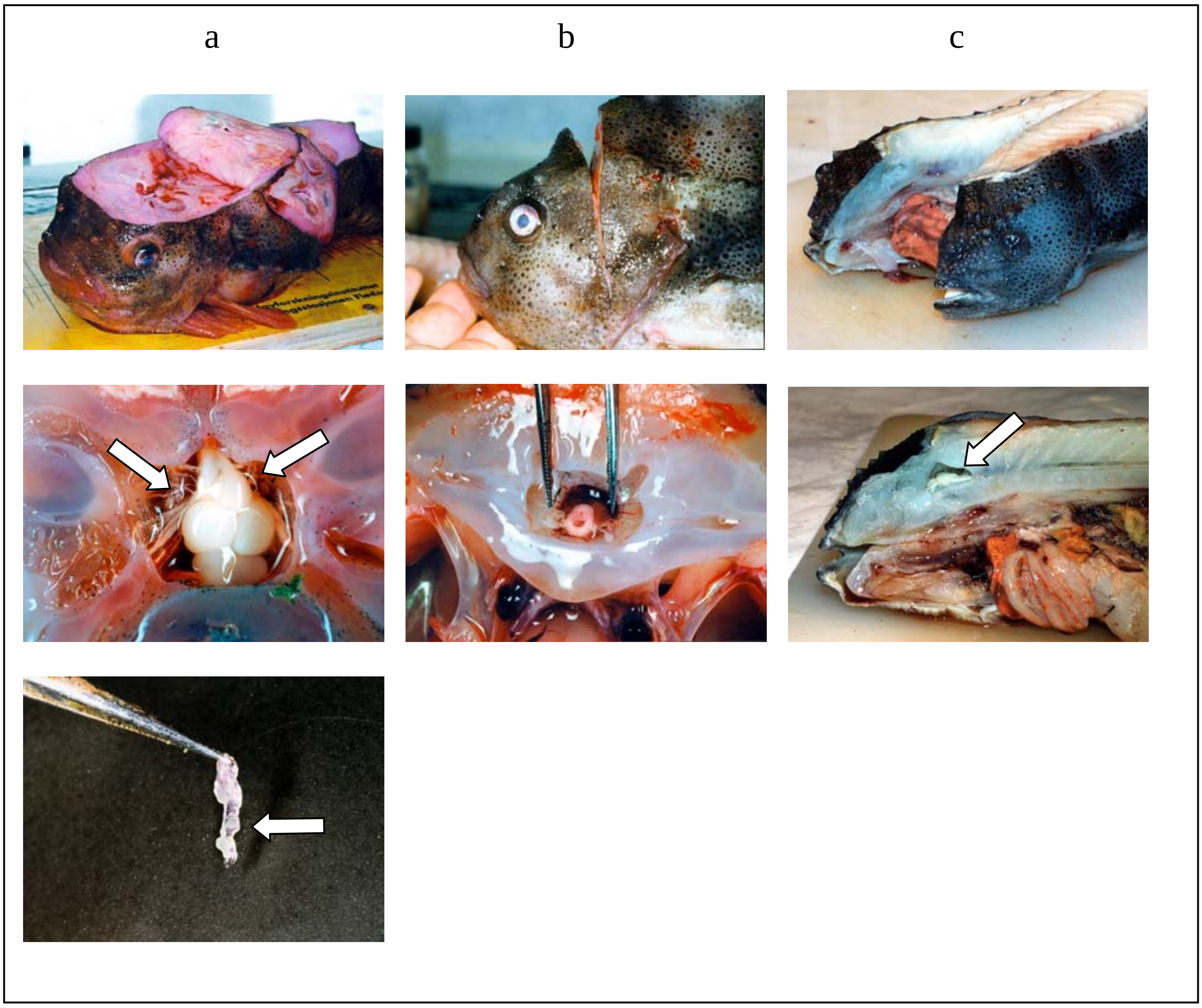

Figure 1 Three different methods for dissection of lumpsucker otoliths. a) ***The horizontal cut*** *is placed just above the eyes. The otoliths are seen on each side of the brain as shown by the arrows. With a pair of pincers each otolith is lifted out together with the membranous labyrinth. b)* ***The vertical cut*** *is placed two eye-diameters behind the eyes and exposes the brain cavity in the head-end of the cut. The pincers show the location of the otoliths. c)* ***The medial cut*** *divides the head in two equal halves. The otoliths are found behind the brain halves, within a hole in the bone tissue. (Photography: Ø. Paulsen)*

The medial cut
Use a medial cut to divide the head in two equal halves (Figure 1c, upper). By removing the two brain halves you will find the otoliths located within a hole in the bone tissue (Figure 1c, bottom). Continue as in method 1. This method is probably the most time-consuming of the three, but is the one less dependent on a precise cut.

Preparation of the otoliths
There are several procedures commonly used for reading otoliths; 1) counting zones on the exterior surface of whole or polished otoliths; 2) reading the broken and possibly charred surface; 3) reading thin sections of the otoliths (cutting). Otoliths may also be stained or submerged in different liquids to improve contrast. At the workshop there was no time to test different preparation methods for lumpsucker otoliths. We chose to read them whole, since this is the usual procedure for small otoliths. The otoliths were mounted in an epoxy resin (Eukitt) on a black plastic tray. In addition to facilitate handling, the Eukitt also resulted in improved contrasts between the zones. Before mounting the otoliths were cleaned using a small brush, and dried on the plastic tray for a few minutes. They were then mounted with the sulcus (inside) down and studied using reflected light.

It was essential to handle the otoliths with care in order not to brake the rostrum of larger otoliths. Care must also be taken when using Eukitt. This is a poisonous liquid and should be handled in proper vacuum-facilities. After drying the otoliths are ready for age estimation.

2.4 Reading and interpretation of zones

In the pre-WS reading session otoliths were read from paper-copies of photographs. At the workshop a binocular was used together with a monitor screen. The post-WS readings were made at the individual institutions using variable equipment. Reflected light with black background was used in all cases.

Age estimation was made by identifying and counting annuli. An annulus was defined as a hyaline (winter) zone assumed to be formed annually in the season with low growth. The opaque (summer) zones represent the seasons with increased growth. Age was determined as age-group, using 1 January as the “birthday”.

The workshop started with a new look on the pre-distributed otoliths, this time presented on the monitor. Here the rules of interpretation were discussed. It was agreed that annuli should be interpreted in such a way that the resulting zonation pattern was of one of two possible types: 1) A gradual decrease in the thickness of opaque zones, or 2) A sudden change from gradually decreasing opaque zones separated by thin hyaline zones, to continuously alternations between thin opaque zones and relatively wide hyaline zones. The second type is often thought to be related to sexual maturation.

It was intended to use digitised picture and image analysing software to measure zone widths but regrettably this was not possible due to problems with the computer program.

2.5 Analyses

Precision estimates and comparisons of individual readers were made using a predefined EXCEL worksheet courtesy of Guus Eltink, Netherlands Institute for Fisheries Research, IJmuiden, Netherlands. A basic concept of this worksheet is to compare individual age estimates with the modal age of individual fish. The modal age of an individual is the estimate that was most frequently given by all the readers combined. In case of two or more ages with equal frequency, the age given by the most experienced reader involved was used. If the age estimate given to an individual fish by Reader 1 – Reader 5 was 2, 3, 4, 4, and 3 years respectively, then 3 were chosen as the modal age. The rational behind this is that the readers were expected to be numbered according to previous experience with age determination of otoliths. If the modal age of an individual is considered as an approximation to the real age, then accuracy of individual estimates may be calculated.

3 RESULTS

3.1 Description of the otoliths and age interpretation

Thorsteinsson (1981) described the otoliths of lumpsucker as rounded and smoothly curved with a wide, massive and smoothly rounded rostrum. This is demonstrated in Figure 2m showing an otolith of a young fish. In larger, older fish the rostrum tends to be more prolonged with a hook-like form (Figure 2a).

It was often difficult to separate true annuli from other checks, which appeared more or less regularly throughout the otoliths. The appearance of the areas near the centre or the margin of the otolith were given particular consideration and gave rise to much discussion. For fish sampled in Mars-April we assumed that there should either be a very thin opaque zone at the margin, representing a newly started summer growth, or a wide hyaline zone representing a nearly completed winter zone. This is also what we found in general (e.g. Figure 2k with hyaline edge and Figure 2l with opaque edge). In June-August we expected a wider opaque zone at the edge. This is also what we generally found (e.g. Figure 2j). There were however also several otoliths with a different margin (e.g. Figure 2h with a hyaline edge in June), resulting in uncertainties of the true age. This is however common with otolith studies and should not be used to disqualify the ageing method. In future analyses this may be studied in more detail using digitised pictures and image analysis software.

The appearance of the nucleus and the first growth zone was also quite variable, probably related to the amount of overgrowth of opaque material in older specimen. In many cases the first or the first two zones were so unclear that the readers were unable to find a reliable age estimate. However, Figure 2 shows that the size of the O-group opaque summer zone was small compared to the I-group summer zone. This means that the size of the innermost opaque zone may be used to distinguish between these two zones. If the first visible opaque zone is large then it should be regarded as the I-group summer zone.

A further illustration of the interpretations made by the participants of the workshop is given below, with reference to the photos in Figure 2a-o. For each picture is given sex, total length, sampling area and date, together with a short description of the interpretation. (The archive numbers were given in parentheses for internal use by the authors.)

a) Male, 30,0 cm. Southern Coast of Norway. 17. February 1999. First annulus clear, second unclear, hyaline edge. The readers agreed on IV-group. (8)

b) Male, 29,0 cm. Southern Coast of Norway. March 1998. All annuli distinct. Deposition of an opaque layer has started on the edge. The readers agreed on III-group. (98-4)

c) Male, 29,0 cm. Southern Coast of Norway. 17. February 1999. First annulus clear, hyaline edge. Most of the readers agreed on IV-group, including a relatively diffuse second ring. (7)

d) Female, 43,0 cm, North Cape, February 1999. First annulus unclear, opaque edge. Most of the readers agreed on IV-group. (10)

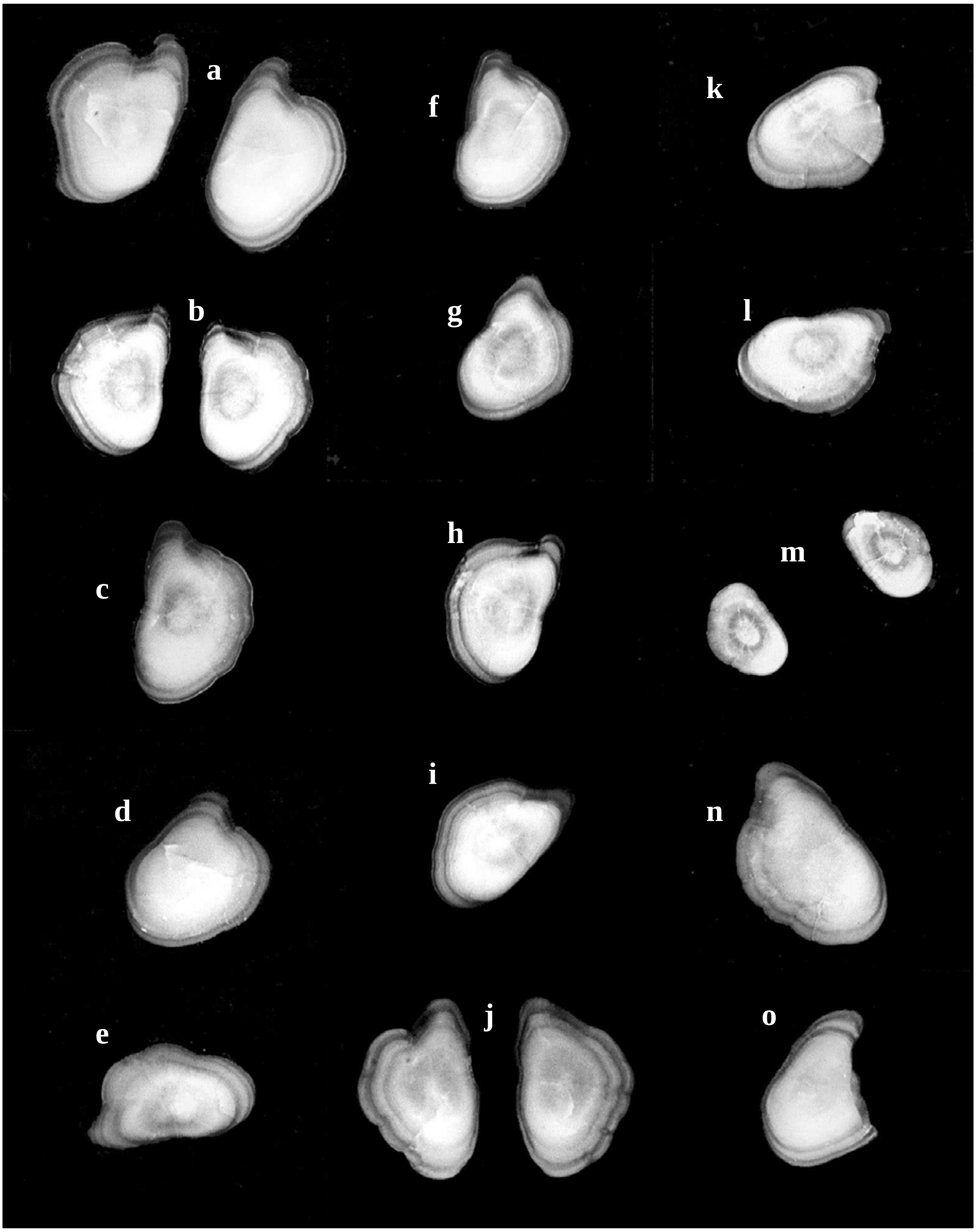

Figure 2. Selected otoliths of lumpsucker. Se text for interpretation. (Illustration by Ø.Paulsen and O. Dahl)

e) Female, 38,0 cm. Southern Coast of Norway. March 1998. The first four rings clear. A very thin opaque layer at the edge. Most of the readers agreed on V-group. (98-5)

f) Male, 31,0 cm. Southern Coast of Norway. 17.February 1999. First annulus clear and a wide hyaline edge. Most of the readers agreed on III-group, excluding a possible second hyaline ring. (1)

g) Male, 27,0 cm. Southern Coast of Norway. March 1998. The first two rings clear and with hyaline edge. The readers agreed on III-group. (98-6)

h) Female, 37,0 cm. Southern Coast of Norway. March 1998. The first two rings clear and with opaque edge at the rostrum. The readers agreed on III-group. (98-7)

i) Male, 27,0 cm. Southern Coast of Norway. April 1998. The first two rings clear and a hyaline edge. The readers agreed on III-group. (98-4)

j) Female, 28,0 cm. Fjord on the West Coast of Norway. June 1998. Three rings clear and a relative broad opaque edge. Most of the readers agreed on III-group. (98-85)

k) Male, 34,0 cm. Southern Coast of Norway. April 1998. The first two rings clear and a hyaline edge. The readers agreed on III-group. (98-2)

l) Male, 32,0 cm. Southern Coast of Norway. April 1998. The first two rings clear and a thin opaque zone at the edge. Most readers agreed on III-group. (98-1)

m) Juvenile, sex unknown, 8,0 cm. Fjord on the West Coast of Norway. June 1998. One ring clear and an opaque edge. The readers agreed on I-group. (98-20)

n) Female, 34,0 cm. Fjord on the West Coast of Norway. June 1998. First two rings relatively clear and a wide opaque edge. Most of the readers agreed on III-group. (98-33)

o) Sex unknown, 36,0 cm. Iceland, October 1997. The nuclear area relatively vague, two clear rings and a thin opaque zone at the edge. The readers agreed on III-group. (Island 14)

3.2 Precision

Our confidence in our own age estimates varies between reading sessions. The pre-WS session was based on interpretation of photographs, by readers that were inexperienced with age determination of lumpsucker, and the post-WS session was based on a whole new set of otoliths. In the WS session, on the other hand, the readers had gained some experience, they had the discussions fresh in mind, and they could compare the binocular image with a larger image on the monitor. Therefore the statistical analysis of the age estimates was based on the age readings from the WS session.

Table 3 shows summary statistics from the WS session for all readers combined and for each reader separately. There were no discrepancies in the ageing of modal-age-one lumpsucker by the individual readers, as shown by the 100% agreement with modal age. The discrepancy increased with age though. For all readers combined, agreement with modal age was reasonably high up to and including age 4, beyond which it dropped to around 50% (Table 3). This drop was particularly due to one of the readers (Reader 2). Although the agreement with modal age was low for this reader at age 4 (47%), the mean age recorded was close to the modal age (4,1).

The mean age was generally close to modal age for all readers and ages. Of the 25 mean age estimates of modal age 1-5 (5 ages times 5 readers), nine were equal to the modal age. The absolute difference increased with age, and the highest values were -0,4 and -0,6 years for modal age 5. The remaining values were all within +/- 0,3 years. Thus the discrepancies seem to be related to precision more than to any systematic disagreement between the readers.

The precision may be expressed as the coefficient of variation (CV) for all individual age estimates of each modal age. For all readers combined, the CV was rather constant between modal ages (apart from modal age 1 where there was no variation) (Table 3). Thus, standard deviation increased approximately proportional with the modal age. To illustrate the level of precision, we may consider the following example. If 10% of the otoliths were estimated to age two, 80% to age three and 10% to age four, then the modal age would be three with a CV of 15%. None of the individual readers had consistently lower or higher CV than others; e.g. Reader 3 had clearly the lowest CV for modal age 2 but the largest for modal age 5. The precision of the WS readings is summarised in Figure 3, which shows the distribution of individual age estimates for each modal age.

Although proper verification of age estimates was outside the scope of the workshop, some comparisons with length composition were made in order to get an indication of how reasonable the age readings were. Such comparisons are of course based on an implicit assumption that the growth of lumpsucker is not too dependent on sex or other individual differences.

Table 4 shows the age-length relationship resulting from age estimates of individual readers. For each reader and age estimate, if one or two individual fish were more than 5 cm smaller (or larger) than the next smallest (or next largest), those individuals were classified as outliers. There were 14 otoliths that were outliers in at least one of the individual-readers data from the WS (18% of the total number of otoliths). Reader 1 had nine outliers, while the other readers had 2-4 outliers. Three of the outliers were common for two or more readers. Although this appears to be a high number of outliers, the mean length at age was very similar between the readers (Table 5). The variation in length at estimated age was very high in many cases. For Reader 4, age 2, there were no outliers, as defined above, but the length range was extremely wide, from 13 to 41 cm.

According to the preliminary length frequency analyses of the stock (next paragraph), the length ranges 7-12 cm and 18-26 cm should in June exclusively consist of age 1 and 2 respectively. In the WS readings all 7-12 cm individuals were classified as age 1. Although there were only eight individuals in this group, this suggests that high accuracy should be possible for age interpretations of the youngest individuals. For 18-26 cm lumpsucker, the individual readers classified 56, 57, 69, 76 and 63% respectively as age 2. Apart from Reader 4 this seems to suggest rather low accuracy. However, the data were sampled from widely separated areas over most of the year (Table 2), so the length-to-age conversion may not be adequate for all individuals.

Table 3. The mean age recorded, two standard deviations, coefficient of variation, the number of age readings and the agreement with modal age are presented by reading session and modal age, for each reader and for all readers combined. The total number of age readings in a reading session and the weighted means of CV and agreement is given for all ages combined.

	Pre-WS-readings							**WS-readings**							**Post-WS-readings**					
Modal age: Reader	**1**	**2**	**3**	**4**	**5**	**7**	**All ages**	**1**	**2**	**3**	**4**	**5**	**6**	**All ages**	**1**	**2**	**3**	**4**	**6**	**All ages**
1 Mean age recorded	2,4	2,0	4,9	5,8	7,0	7,0		1,0	2,3	2,9	4,1	5,2	6,0		2,0	2,2	3,2	4,0	6,0	
2stdev	1,1	-	1,8	2,5	5,7	-		0,0	1,2	1,0	0,7	0,9	-		0,9	1,3	0,8	0,0	-	
CV (%)	23%	-	19%	22%	40%	-	21%	0%	26%	17%	9%	9%	-	14%	22%	31%	12%	0%	-	21%
Number of age readings	5	1	7	4	2	1	20	8	16	29	15	5	1	74	25	20	18	2	1	66
Agreement with modal age	0%	100%	14%	25%	50%	100%	25%	100%	63%	76%	87%	80%	100%	78%	8%	70%	83%	100%	100%	52%
2 Mean age recorded	1,0	1,5	2,9	3,7	4,0	5,0		1,0	2,2	3,0	4,1	4,4	5,0		1,0	2,2	3,1	3,5	4,0	
2stdev	0,0	1,4	0,5	1,0	2,8	-		0,0	0,8	0,7	1,8	1,1	-		0,0	1,1	1,1	1,4	-	
CV (%)	0%	47%	9%	14%	35%	-	12%	0%	17%	11%	22%	12%	-	13%	0%	24%	18%	20%	-	13%
Number of age readings	7	2	15	6	2	1	33	8	13	29	15	5	1	71	25	19	18	2	1	65
Agreement with modal age	100%	50%	93%	67%	50%	0%	82%	100%	85%	90%	47%	40%	0%	76%	100%	84%	72%	50%	0%	85%
3 Mean age recorded	2,0	4,0	4,3	5,0	4,0	7,0		1,0	2,0	3,0	3,7	4,6	4,0		1,0	1,5	2,3	2,5	3,0	
2stdev	-	0,0	2,3	2,5	2,8	-		0,0	0,0	0,7	0,9	2,7	-		0,0	1,0	1,4	1,4	-	
CV (%)	-	0%	26%	25%	35%	-	23%	0%	0%	11%	12%	29%	-	9%	0%	34%	29%	28%	-	19%
Number of age readings	1	2	16	6	2	1	28	8	16	29	15	5	1	74	25	21	18	2	1	67
Agreement with modal age	0%	0%	31%	50%	50%	100%	36%	100%	100%	90%	73%	0%	0%	82%	100%	52%	44%	0%	0%	66%
4 Mean age recorded	1,0	2,0	3,1	4,0	4,5	4,0		1,0	1,9	2,8	3,7	5,3	5,0		1,0	1,5	2,3	3,0	3,0	
2stdev	0,0	2,0	0,5	0,0	1,4	-		0,0	1,0	1,0	1,2	1,0	-		0,0	1,0	1,5	2,8	-	
CV (%)	0%	50%	8%	0%	16%	-	9%	0%	26%	18%	17%	10%	-	17%	0%	35%	33%	47%	-	21%
Number of age readings	7	3	16	6	2	1	35	8	17	29	15	4	1	74	25	21	18	2	1	67
Agreement with modal age	100%	33%	94%	100%	50%	0%	86%	100%	76%	72%	73%	75%	0%	76%	100%	48%	44%	50%	0%	66%
5 Mean age recorded	1,1	2,0	3,1	3,8	6,0	4,0		1,0	2,2	3,1	4,0	5,2	6,0		2,6	2,7	3,3	2,0	6,0	
2stdev	0,8	0,0	1,0	0,9	2,8	-		0,0	0,8	0,9	1,1	0,9	-		1,5	2,3	4,2	5,7	-	
CV (%)	33%	0%	16%	12%	24%	-	18%	0%	18%	15%	13%	9%	-	13%	29%	43%	63%	141%	-	46%
Number of age readings	7	3	15	5	2	1	33	8	16	29	15	5	1	74	25	21	18	2	1	67
Agreement with modal age	86%	100%	73%	80%	50%	0%	76%	100%	81%	79%	73%	80%	100%	81%	0%	67%	28%	50%	100%	31%
All Mean age recorded	1,3	2,3	3,5	4,4	5,1	5,4		1,0	2,1	3,0	3,9	4,9	5,2		1,5	2,0	2,8	3,0	4,4	
2stdev	1,2	2,0	1,9	2,2	3,6	3,0		0,0	0,9	0,9	1,2	1,6	1,7		1,6	1,7	2,3	2,7	3,0	
CV (%)	47%	44%	27%	25%	35%	28%	32%	0%	21%	15%	16%	16%	16%	15%	51%	42%	40%	44%	34%	45%
Number of age readings	27	11	69	27	10	5	149	40	78	145	75	24	5	367	125	102	90	10	5	332
Agreement with modal age	74%	55%	67%	67%	50%	40%	65%	100%	81%	81%	71%	54%	40%	79%	62%	64%	54%	50%	40%	60%

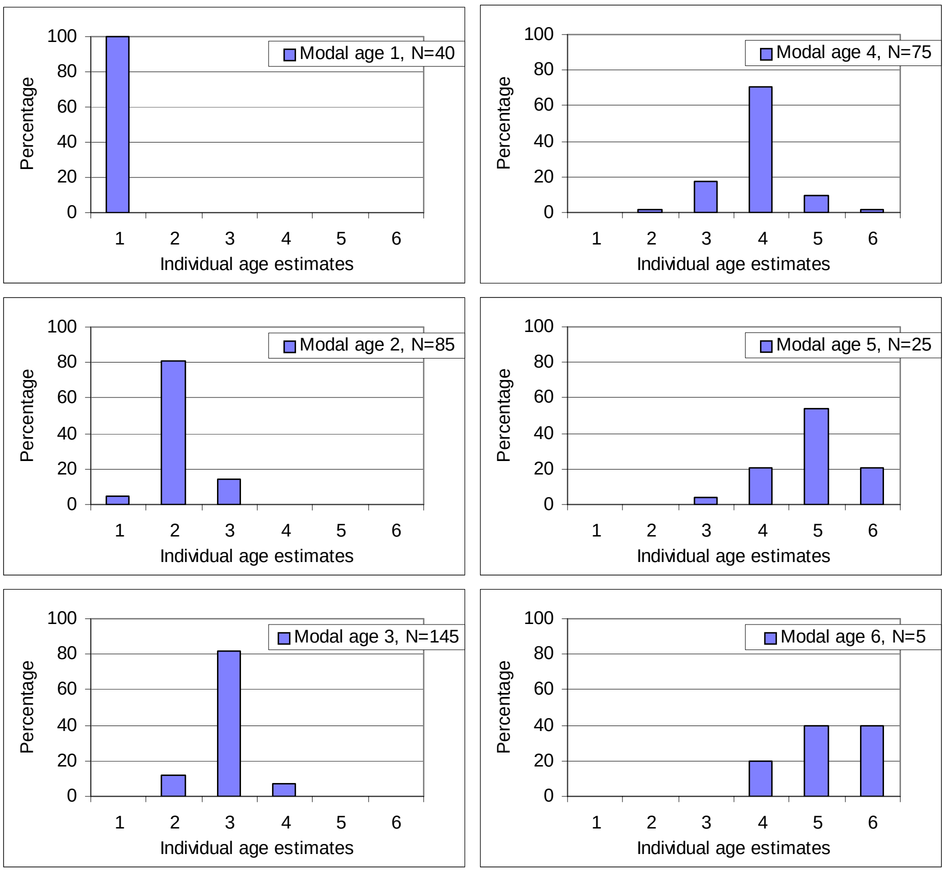

Figure 3 Frequency distribution of individual age estimates by five independent interpreters for each modal age.

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Table 4 WS-readings: Length-age distribution based on modal age and the interpretation of each individual reader. Data from dataset 1 and 2 combined. Interpretations made at the workshop. Outliers (see text) in bold.

		Modal age						Age determined by individual readers: Reader 1						Reader 2						Reader 3						Reader 4						Reader 5					
L	N	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
7	1	1						1						1						1						1						1					
8	1	1						1						1						1						1						1					
9	1	1						1						1						1						1						1					
10																																					
11	4	4						4						4						4						4						4					
12	1	1						1						1						1						1						1					
13	1			**1**						**1**						**1**						**1**					1						1				
14	1			**1**						**1**						**1**					1						1							**1**			
15	1		1						1						**1**						1					1							1				
16																																					
17																																					
18																																					
19	2		2						1												2						2						1	1			
20																																					
21	1		1							1					1						1						1						1				
22	3		1	2				**1**	1	1					1	2					1	2					3						2	1			
23	3		1	2					1	2					1	2					1	2					1	2					1	2			
24	4		3	1					3	1					1	2					2	1				**1**	2	1					2	1			
25	4		4						3	1					4						4						4						3	1			
26																																					
27	8			5	2	1			2	3	2	**1**			1	4	3					7	1				1	5	1					6	1	1	
28	3		1	2					1	1	1				1	2					1	2				**1**		1	1					2	1		
29	5			3	2					3	2					4		**1**				3	2					4	1					3	1	1	
30	2				2						2					1	1					1	1						2						2		
31	7		1	4	2					5	2				1	2	4				1	3	3					5	2				**1**	3	3		
32	2			1	1						2					1			1			1	1				1	1						1		1	
33	2		2							2						1					2						2						**2**				
34	3			2	1					2	1					3						3						2	1					1	2		
35	1			1					**1**							1						1						1						1			
36	2			1	1					1	1					1	1					1	1				1	1						1	1		
37	1			1						1						1						1						1						1			
38	2				1	1						2					1	1					2						1	1					1	1	
39	2					1	1					1	1				1	1					1		1					2							2
40																																					
41	1			1					**1**							1						1					1							1			
42	1					1						1						1					1								1					1	
43	2				2						**2**					1	1					1	1						2					1	1		
44	1			1						**1**						1					**1**							**1**							1		
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51																																					
52																																					
53	2				1	1						1	1					2					1		1				1	1					1	1	
	75	8	17	29	15	5	1	9	15	27	15	6	2	8	12	32	12	6	1	8	18	31	15		2	11	21	25	12	4	1	8	15	28	15	6	2

Tabel 5 Mean length, coefficient of variation and number of observations for each reader and age estimate. Data from the WS readings. Males and females combined.

	Age estimate					Age estimate					Age estimate				
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
	Mean length					**CV**					**N**				
Reader 1	11,3	25,6	28,4	32,1	39,5	0,38	0,24	0,23	0,16	0,21	9	15	27	15	6
Reader 2	10,0	24,3	29,4	32,6	42,3	0,18	0,16	0,24	0,16	0,22	8	12	32	12	6
Reader 3	10,0	25,0	29,3	35,3		0,18	0,28	0,20	0,20		8	18	31	15	0
Reader 4	13,4	25,0	30,2	34,8	42,3	0,50	0,27	0,16	0,23	0,17	11	21	25	12	4
Reader 5	10,0	23,7	28,8	34,6	36,8	0,18	0,24	0,22	0,21	0,26	8	15	28	15	6

Table 6 Post-WS-readings: Length-age distribution based on modal age and the interpretation of each individual reader. Data from dataset 3, which were circulated after the workshop.

								Age determined by individual readers																														
		Modal age						Reader 1						Reader 2						Reader 3						Reader 4						Reader 5						
L	N	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	7
6	1	1							1					1						1						1								1				
7	8	7	1					2	6					7	1					8						8							6	2				
8	12	11	1						11	1				11	1					12						12							6	5	1			
9	6	2	3	1					3	3				2	4					6						6							2	2	2			
10	4	2	2						4					2	2					4						4							2	1	1			
11	3	1	2						2	1				1	2					3						3							3					
12	3	1	1	1					1	2				1	2					2	1					3							1	1	1			
13	2		1	1					1	1					1	1				1	1					2							1	1				
14																																						
15																																						
16																																						
17																																						
18	1		1						1							1					1						1						1					
19	2		1	1					1		1				1	1					1	1					2								1	1		
20	1		1																		1						1						1					
21	1			1						1						1					1						1							1				
22	2		1	1						2						1					2						1	1					1		1			
23	2		1	1					1	1					1	1					2						2						1		1			
24	2		2						1						1	1					2						2							1			1	
25	5		2	3					1	3	1				1	2	2				4	1					3	2					1	1	1	2		
26	3		1	1			1			2			1		1	1	1				2	1					2	1					1			1	1	
27	2			1	1					1	1					2					1	1					2								2			
28	1			1						1							1					1						1									1	
29																																						
30																																						
31	1			1						1						1					1						1									1		
32	1				1						1						1					1							1							1		
33																																						
34																																						
35	2			2						1	1					2						2						2							1	1		
36																																						
37																																						
38																																						
39	2			2						2						1	1					2						2								1		1
	67	25	21	18	2	0	1	2	34	23	5	0	1	25	18	16	6	0	0	37	20	10	0	0	0	39	18	9	1	0	0	0	27	16	12	8	3	1

Table 3 also shows results from the pre-WS and post-WS reading sessions. As expected, these age estimates had clearly lower precision than the WS-readings. The mean weighted CV for individual readers was less than 20% for all five readers in the WS session, but only for three and two readers respectively in the pre-WS and post-WS sessions. The reduced precision in the post-WS readings was associated with a clear increase in the difference between modal age and the mean age recorded by each reader for each modal age. These differences were clearly associated with reader more than with age. Thus while Reader 1 and 4 got consistently higher mean age, Reader 3 and 4 got consistently lower mean age. This indicates that after the workshop individual readers developed their interpretation method in separate directions away from the common method used at the workshop. Table 6 shows the resulting age-length relationships. Considering length-range 6-13 cm, Reader 1 and 5 classified 5 and 0% respectively as age 1, while for Reader 3 and 4 the numbers were 95 and 100%. Reader 2 was in between with 36% as age 1. Verification of the first few age groups is clearly crucial for further development of the interpretation method.

3.3 Comparison with independent length-frequencies

In the spring and summer 1999 juvenile lumpsucker were sampled with different kinds of traps made of seaweed (Bertelsen, unpubl.). The experiments were carried out in the littoral in Sifjorden of the island Senja in North Norway. Figure 4a-b show length compositions of the samples from May and June respectively. Juveniles collected in May were mainly in the range 1,5-4,0 cm, with an average length of 2,6 cm. In June they ranged between 2,0-5,0 cm, with an average of 3,6 cm.

In this area the spawning period is mainly from 20 March to 20 May (own unpublished observations) and in previous experiments the first registration of newly hatched juveniles was 9 June, when approximately 250 individuals were found attached to a float (own unpublished observations). These juveniles were only about 5 mm long. In July and August they were found with a length of 5-10 mm.

In the light of these experiments it seems probable that the juveniles in fig. 4a-b were I-group, hatched in the preceding summer. In June a single individual which measured 8,2 cm was also collected. However, the experiments indicate that I-group lumpsucker usually leave the littoral/coast when they reach a length of about 4-5 cm in June.

After leaving the coast, juvenile lumpsucker is found pelagically in the high seas. Figure 4c-d shows length-frequency distributions of lumpsucker caught in pelagic trawl in the Norwegian and Barents Seas during July-August 1991-99 (Data courtesy of J.C. Holst, Institute of Marine Research, Bergen). Figure 5 shows comparable data from the North Sea, Skagerrak and South-Norwegian fjords. It seems probable that the first modal group in each of these frequency distributions represents a single age-group, while the second may represent one or a few age-groups.

According to our age-interpretations, the lower modal group in Figure 4c-d represents the I-group (Table 5). It may seem unreasonable that these individuals with a modal length of 10-12 cm should be the same age as those in Figure 4a-b with modal length 3-4 cm. However, there are several arguments that suggest that this is true.

Firstly, the two length distributions do overlap to some extent for lengths around 5 cm. Since it is reasonable to assume that the migration from the coast is related to growth, the individuals in Figure 4a-b may only be the ones from the extreme lower tail of the total length distribution of the I-group. Secondly, the alternative interpretation, namely that the lower mode in Figure 4c-d represents the II-group, may seem more unreasonable. If the two modes represent two and three year olds respectively, then the growths in length from age one to two has to be much lower than that from age two to three. Thirdly, the zonation pattern in the otoliths also suggests that the growth during the I-group stage is very large compared to the growth of both 0 and II-group. Lastly, the growth pertaining to the interpretation of the lower mode as I-group, is comparable with the observed growth from artificially reared lumpsucker. Figure 6 shows that artificially reared II-group was approximately 20 cm in March. This is between the two modes from July-August (Figure 4c-d).

Thus, if growth in the wild is close to or slightly below that of the reared ones, then the lower mode in Figure 4c-d should represent the I-group.

The length distribution in Figure 4e represents spawning lumpsucker. They were caught with a trap, which is assumed to be almost none-selective to fish size. Similar experiments were made in four years, without any clear difference in length composition of the catches between years. Based on the discussions above, it is tempting to assume that the male spawners were large II-group and older, whereas the females were III-group and older. Data from the artificially reared individuals showed that 86% of the males and 34% of the females matured as II-group (own unpublished results). Since growth in the wild probably is less than in reared conditions, these percentages are probably less in the wild. The length composition of the mature part of the reared fish (Figure 6) was only slightly below that found at the spawning ground (Figure 4e).

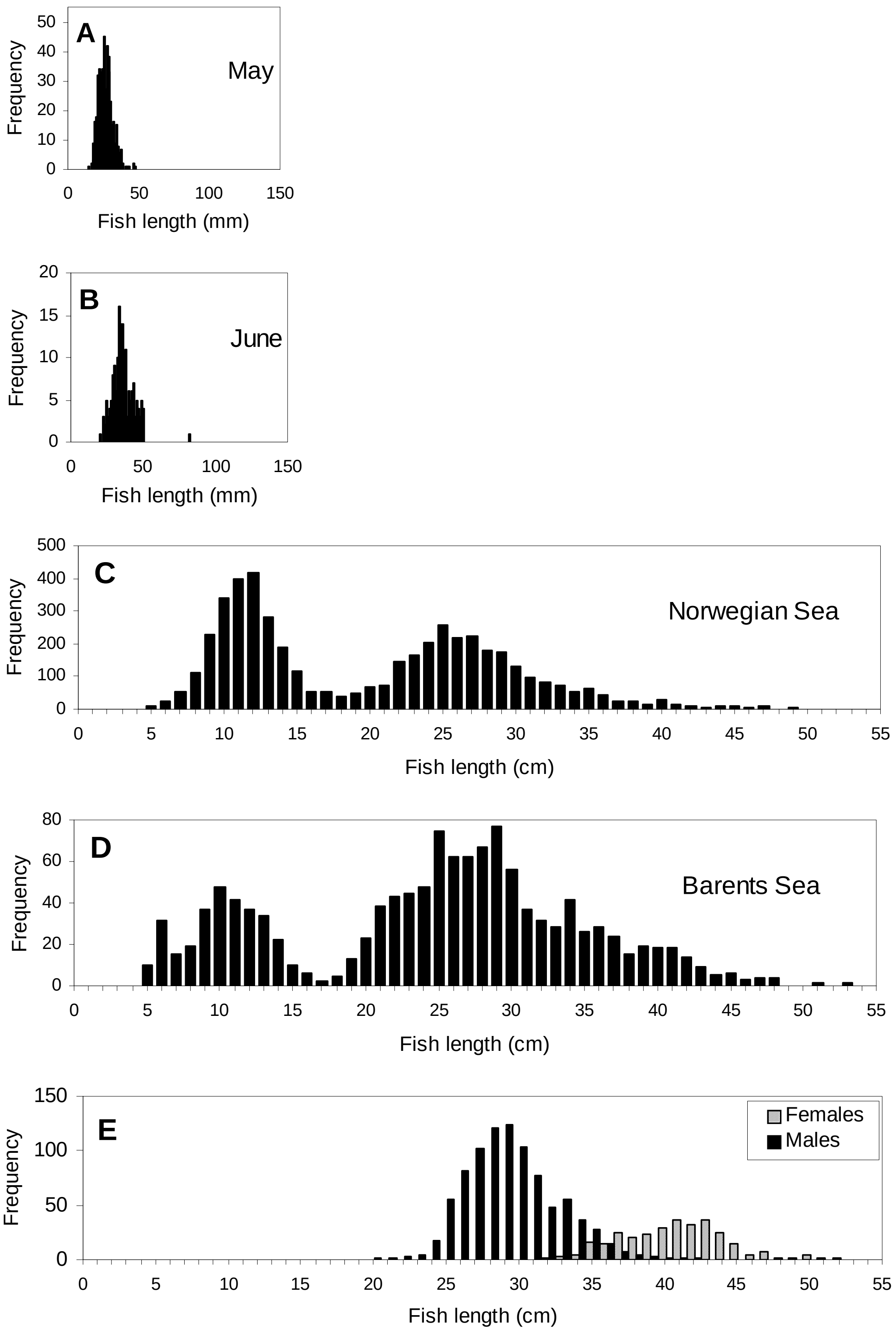

Figure 4 Length frequency distributions of lumpsucker from North-Norway. A and B): Juvenile fish collected from floating seaweed in Sifjorden, Senja, in May and June 1999. C and D): Juveniles caught with pelagic trawl in the Norwegian and Barents Seas in June-August, several years combined. Data courtesy of Jens-Christian Holst, Institute of Marine Research, Bergen. E): Spawning fish caught with a trap in Sifjorden in April 1999.

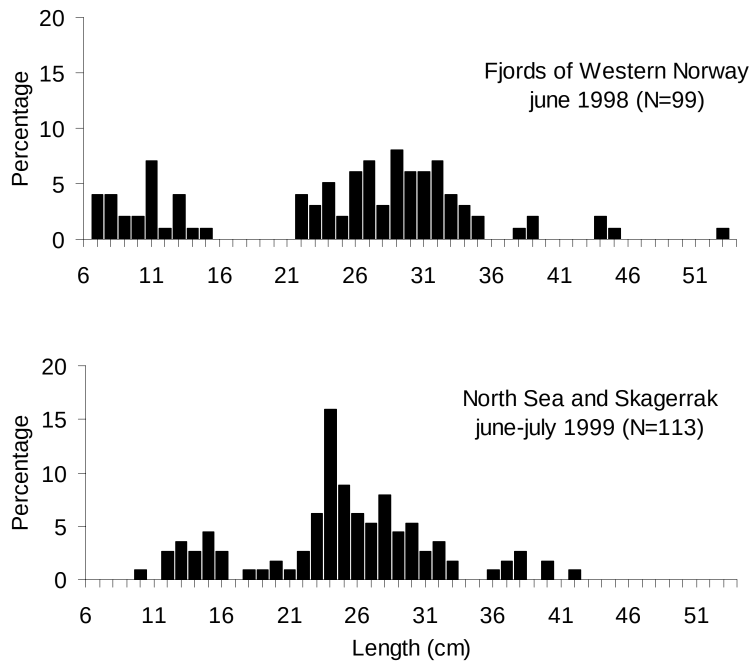

Figure 5 Length frequency distributions of lumpsucker from South-Norway. Fish caught with pelagic trawl.

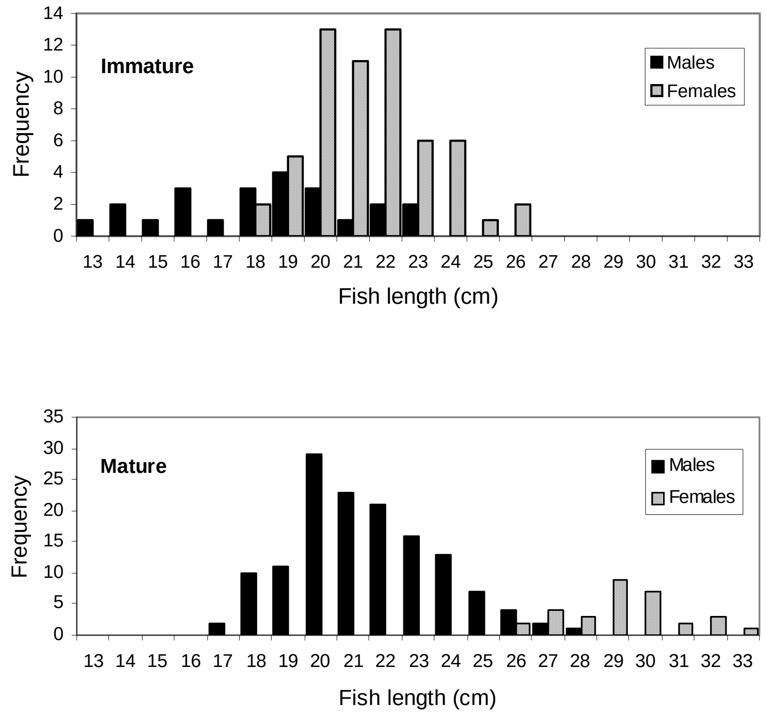

Figure 6 Length frequency distributions of two years old artificially reared lumpsucker. All individuals were hatched in June/July 1997. Lengths were measured 18 Mars 2000.

4 CONCLUSIONS

The workshop established and documented a practical method for dissection and preparation of lumpsucker otoliths. The experience from the workshop and subsequent analyses showed that the zonation pattern of the otoliths is so clear that it should be possible to achieve reliable age estimates. The major problem remaining, is verification of the I-group growth zone. Although length distributions show clearly separated modes, the knowledge of the spatial dynamics in the juvenile phase is too limited to draw final conclusions regarding the age of the modes. In the future, focus of lumpsucker research should be on the duration of the coastal life, and the links between coastal and oceanic abundance and distribution areas, both regarding the outward migration of juveniles and inward migration of the spawning stock. A first approach may be to analyse spatial trends in abundance of individual length groups in the Norwegian and Barents Seas. When the age of the lower modal group is established, a second age-reading workshop should be arranged, to achieve accurate estimates of age-composition in the stock.

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