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Report of the Workshop on Age Determination of Redfish (WKADR)

28 August – 1 September 2006

Vigo, Spain

International Council for the Exploration of the Sea
Conseil International pour l'Exploration de la Mer

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Executive summary

Since 1995, the year of the previous workshop, considerable sampling effort has been directed towards collecting redfish otoliths, more than 300 000 from three major areas: Northeast Arctic, Iceland-Greenland-Irminger Sea, and Newfoundland-Flemish Cap. This effort reflects the fisheries and scientific interest in the species. However, in total only 22% of the otoliths collected have been read, reflecting the low capacity available to participate in age determination, especially for some stocks. This is partially due to the lack of trained technicians and the lack of standardized application of existing accepted and recommended aging criteria. Currently, six laboratories from five different countries determine the age of redfish on a routine basis, although with varying rates of production, with two countries only reading them occasionally. There is a certain degree of heterogeneity among laboratories regarding the methodology used. Otoliths are read across laboratories using three different cross-section methods: broken and burnt, thin sections and broken and bake. Although there are some optical differences in how the annual growth patterns are revealed, the patterns themselves are predetermined and the same basic criteria is used to differentiate annuli from checks for all three methods. The technical pros and cons of each were discussed during the meeting and a comparative analyses of age readings was done during the workshop regarding precision and accuracy.

Clearly, species and/or stocks yielded different biases and variation among readers. The bias varied considerably for Iceland *S. marinus* between readers and a relatively high variation in age estimates was observed for all readers. On average, the broken-and-burnt otoliths were aged 3-4 years older than the broken-and-baked otoliths. This was similar for Irminger Sea *S. mentella* where between-reader bias and high variation in age estimates was evident in all comparisons. The variations among readers were high enough to prevent a proper comparison among methods. No defined trend was detected, even when readings from the same reader using different otolith preparation techniques were analyzed. As an example, the thin-sectioned otoliths sometimes delivered higher age estimates, sometimes lower. The overall bias was comparably low for the northeast Arctic *S. mentella* stock and although still a relatively high variation in age estimates was observed in some readers, in general, the readers produced similar ages.

It is recognized that among readers random differences with respect to interpretations and age estimate errors will always exist. The occurrence of such differences may only be reduced through frequent otolith exchanges and comparative readings. The most serious systematic error or bias discovered during the workshop was that some participants were not taking the thickness of the otolith cross-section into consideration when ageing and therefore did not count along growth axes that included the proximal side of the section. Rather, they were assessing age along a distal (nucleus to dorsal/ventral) axis where not only is it difficult to differentiate checks from annuli but annual growth zones cease to form after about 15–20 years. This resulted in under-ageing. It was also discovered that some readers who counted only along the distal dorsal axis tended to mis-interpret checks as annuli (over-ageing) and thus by chance got the same age as if they had counted on a proximal axis. Recommended and documented criteria indicates that a growth zone should not be identified as an annulus unless it can be followed/traced over a certain distance, preferably to the dorsal tip of the section, from the dorsal area to the sulcus area. An often difficult task is the correct identification of the first few "juvenile" annuli that frequently form in association with prominent checks. Some of the age differences originated from this problem. Measurements of the location of the first few annuli on otoliths from known-age fish or on very clear otoliths have the potential to minimize over-ageing due to counting checks formed in the during the first years. The measurements could serve as a guideline in all routine readings for the same stock.

During the workshop, it was pointed out that there is a scarcity of validation research and/or publications for redfish. Validation due to following strong cohorts, as those conducted in Flemish Cap, can be a great help confirming interpretation of the juvenile portion of the otolith growth pattern where many checks are observed. Although allowing rough validation of older ages, published radiometric research inferred a slight tendency towards underestimation of age by traditional annulus counts.

Apart from the Fish Aging Lab at Pacific Biological Station, Canada, only Norway has implemented a full Quality Assurance system for production redfish age determination. It was agreed that each laboratory should implement a confidence index (readability) for assigning a quality level to each age reading. For circulated otolith material, the different labs are requested to include their quality assignment as a parameter. In addition it is recommended that reference material, of past read otoliths, should always be at the readers' side when reading new otoliths. This will help to avoid drifting away from the standards of criteria application when reading.

During the workshop the information available on redfish growth studies was presented. The calculated growth parameters varied considerably between readers and only slightly between ageing methods. Results showed, however, that the growth curves produced by the thin sections and broken and burn methods did not differ significantly. The group noted that, only in three cases, the data was divided into sexes. Since it is known that males and females show different growth trajectories in redfish, combining sexes prevented conducting correct analyses of the growth. Thus, it was agreed that from 2007 onwards age information will be separated by sex and original data will be fit to growth curves using the same procedure and curves compared by a statistical test. It was not possible to produce specific guidelines for the interpretation of growth structures in otoliths given the lack of common criteria on age reading. However, it was acknowledged that, based on the different life history and biological experiences, differences in growth pattern and hence in its interpretation among species and stocks may exist. In general, there was the perception that readers should know about the biology of fish to interpret properly the otolith growth pattern. It was agreed that considerably more effort and research is needed in this direction in particular for measuring growth increment pattern in the otolith. This technique has been proved in *Sebastes* to be useful to assist in identifying growth patterns related to the biology of the species/stock, as well with environmental features.

Only a few of the redfish stocks defined in the North Atlantic are assessed analytically. The high bias and low precision observed in age determination of redfish have prevented the use of age data for other redfish stocks. The effects of age reading error on the assessment have not been tested thoroughly yet. The workshop recommends that all labs providing age data for assessments for a certain stock should investigate uncertainties in assessments due to age readings in redfish. Within the next two years, these analyses should be performed on those stocks that are currently assessed analytically (Icelandic *S. marinus*, Northeast Arctic *S. marinus*).

The studies conducted since 1995 to combine age readings based on scales and otoliths yielded poor results and virtually no possible conversion factor was obtained. In spite of 1995 workshop recommendations, Russia has continued to read scales of *S. mentella* in the Irminger Sea, but has also collected several thousand scales and otoliths from the same fish in the period 1999-2005. This collection is a great opportunity for further research supporting standardizing redfish ageing methodology as the Russian readers work to adjust application of criteria as recommended during the workshop. That is, considering the proximal zone of the otolith sections and then conducting calibration exchanges where sub-sets of these otoliths are sent to other age reading labs for comparative reading.

The workshop agreed on several sets of exchange samples for the purpose of inter-calibration between ageing labs within the next two years. The results of this exchange should be analyzed during a workshop to be held in 2008.

1 Overview

1.1 Introduction

Redfish (genus *Sebastes*) are distributed and targeted by fisheries throughout the North Atlantic, still being an important fishery resource. Age determination is one of the most important yet unresolved questions in research on redfish in the North Atlantic, in spite reliable age determination data are the basis of age-based analytical assessment of the species and stocks under investigation. Controversy raged around the most appropriate means of age determination, and several attempts have been made to create common criteria (ICES, 1983, 1984, 1991, 1996). While ICES has definitively agreed on the use of otoliths exclusively for redfish age determination, recent studies have revealed that considerable discrepancy in ageing criteria still exists. The slow growth and longevity of North Atlantic redfish has made the issue of accurate age determination particularly difficult to resolve. Thus, different interpretation of the otolith structures of the different redfish species is used by the different countries, finding large differences in age per length class in, at least, *S. mentella* and *S. marinus* around Iceland and in the Irminger Sea.

Due to these discrepancies, redfish otoliths are seldom routinely aged, and hence age based analytical assessment is normally not conducted for any stock. For the alternative length based or age-length based methods, reliable estimates of growth rates are essential. Since the most recent redfish age reading workshop in 1995, a large amount of age readings, otolith exchanges and validation studies have been carried out. Particularly, the recently finished EU project REDFISH has studied and analysed the observed differences and ageing error through an exchange program. Consequently, the labs and staff involved are now in a better position for a further discussion and agreement in an international context.

1.2 Terms of Reference

According to RMC Resolution 2005/2/RMC09 the **Workshop on Age Determination of Redfish** [WKADR] (Co-Chairs: F. Saborido-Rey, Spain; and C. Stransky, Germany) will be held from 28 August – 1 September 2006 in Vigo, Spain, to:

a) review information on age determinations, otolith exchanges and validation work since the most recent redfish age reading workshop in 1995;

b) identify sources of age determination error in terms of bias and precision, describe the corresponding interpretational differences between readers and laboratories, and agree on the ageing criteria;

c) compare different otolith-based age determination methods for redfish and their effect on growth estimates;

d) analyse species- and stock-specific growth rates and growth increment patterns and provide corresponding specific guidelines for the interpretation of growth structures in otoliths;

e) propose a methodology to combine time series of age readings based on scales and otoliths;

f) set up a strategic plan for routine age determinations during the next 5 years and for the inclusion of age data in age-based and (age-)length based analytical assessment of the most important stocks;

g) consider publishing the results in the *ICESCooperative Research Report* series.

WKADR will report by 15 September 2006 for the attention of the Resource Management Committee, North-Western Working Group, Study Group on Redfish Stocks, Arctic Fisheries Working Group and ACFM.

1.3 Workshop structure and working procedure

Participants are listed in the following Section and Annex 1. The agenda for the Workshop as adopted during the opening session of the meeting is provided in Annex 2.

The Workshop was divided into five activities or sessions: i) *Reviewing information on age determinations, otolith exchanges and validation work* (ToR a), ii) *Sources of age determination error in terms of bias and precision. Ageing criteria* (ToR b), iii) *Species- and stock-specific growth rates and growth increment patterns. Impact of age determination methods on growth estimates* (Tor c and d), iv) *Combining time series of age readings based on scales and otoliths* (ToR e)and (v) *Strategic plan for routine age determinations. Improving analytical assessment of the most important stocks* (ToR f). The results and discussions of these sessions are described correspondingly in Section2 to 6 of this report.

Session ii) took most of the time as a large collection of otoliths was read during the workshop and a selected number discussed in plenary. Each session, as well the conclusions and recommendations in relation to the terms of reference, were discussed and reviewed in plenary. The final list of recommendations is included in Section 7 of this report.

1.4 List of participants

Konstantin Drevetnyak	Russia	
Dolores Garabana	Spain	
Edyta Gosz	Poland	
Svend Lemvig	Norway	
Shayne MacLellan	Canada	
Sergey Melnikov	Russia	
Kjell Nedreaas	Norway	
Esther Roman	Spain	
Fran Saborido-Rey	Spain	(Co-chair)
Thorsteinn Sigurdsson	Iceland	
Arne Storaker	Norway	
Christoph Stransky	Germany	(Co-chair)
Kordian Trella	Poland	

Participants' affiliations and e-mail addresses are given in Annex 1.

2 Review information on age determinations, otolith exchanges and validation work

The current review is an update to the last workshop on redfish age determination held in Bremerhaven, Germany in 1995 (ICES, 1996).

Six laboratories from five different countries (Iceland, Norway, Poland, Russia (2), and Spain) determine currently age of redfish on a routine basis, although with a very different emphasis and/or priority. In Germany, redfish otoliths are only read occasionally. Portugal will initiate routine age reading from 2007 onwards. Eastern Canada, having been important contributors in the past, is not determining the age of redfish anymore due to shortages in staff and partly decreased interest in redfish. The Fish Ageing Lab at Pacific Biological Station does not work routinely with redfish (Atlantic *Sebastes* species), but has an important and relevant background with rockfish (pacific *Sebastes* species) age determination, producing age data for an annual average of 9000 rockfish over the last 15 years.

There is a certain degree of heterogeneity among laboratories regarding the methodology used (Table 1). After the 1991 and 1995 redfish ageing workshops most of the laboratories reading scales shifted to an otolith cross-section method. However, Russia has continued to read scales for Irminger Sea *S. mentella*, but has also collected several thousand scales and otoliths from the same fish in the period 1999–2005. Although comparisons of age readings using different structures are being conducted, results are not yet conclusive (see Section 5) and Russia will continue with scale readings for this stock for the time being.

Otoliths are read across laboratories using three different cross-section methods, already described in the previous workshop (ICES, 1996). Currently the most commonly used is the broken and burnt technique (Canada, Iceland, Norway and Russia on Barents Sea), followed by thin sections (Germany and Poland) and broken and baked (Spain). However, Norway will shift in 2006 to the thin-sectioning method to age *S. mentella* in the Barents Sea. The pros and cons of each method discussed during the meeting are summarized in Table 2. Comparative analyses of the three methods were conducted during the meeting, as well discussions on preferred method regarding precision and accuracy (see Section 3). The preparation efficiencies per otolith of the three methods currently used for redfish age determination need to be properly assessed (i.e. time for all steps from pulling otolith out of storage unit to ready for ageing). It is important to do so in order to properly judge & compare before reach conclusions regarding method efficiency. The workshop recommends that the agencies should systematically measure the efficiencies of each potential method as standard process.

The number of redfish and rockfish otoliths collected since 1995 by stock are presented in Table 3. It is remarkable that the total number of otoliths collected exceed 300 000. Since 1998 an average of more than 30 000 otoliths per year have been collected, which is a considerable effort and equivalent to that conducted by Fish Aging Lab at Pacific Biological Station, although in this case more than 30 species are aged in a more restricted area. Most of the Atlantic effort has been concentrated in recent years in Iceland/Greenland and Irminger Sea stocks, especially by MRI in Reykjavik. This is partially the consequence of those stocks being the main target of the fishery, as well as research interest.

However, it is also remarkable that in total only 22% of the otoliths collected have been read (excluding 2006 in this estimation). This proportion is not evenly distributed among stocks. In Barents Sea/Norwegian Sea 56% of the *S. mentella* and 100% of the *S. marinus* otoliths have been read (a minimum of 40% in 2005). A total of 26% of the otoliths of the three species in Flemish Cap, and 20% of the Icelandic *S. marinus* have been also read. On the contrary, only 4.6 and 6.6% of the Iceland/Greenland and Irminger Sea *S. mentella* otoliths have been read. This is reflecting on one side the growing interest in these stocks (the number of otoliths collected). But, at the same time it is reflecting the low capacity to cope with age determination, especially for these stocks, partly because lack of people involved and partially because the lack of standard age criteria has prevented laboratories to take this step. In the case of Flemish Cap, while 56% of the otoliths were read in the period 1995–1999, only 9% were read since 2000, showing that problems have been found to allocate effort to this task.

In most of the laboratories there is only one age reader devoted to redfish age determination with the exceptions of Norway and Russia with 2 readers each. Pacific Biological station in Canada has its own Aging lab with 8–9 readers working on a wide variety of species, among them more than 30 rockfish. However, considering stocks, rather than labs, there is more than one age reader for *S. mentella* and *S. marinus* in Barents Sea (Norway and Russia), as well as Irminger Sea *S. mentella* (Germany, Iceland, Norway, Poland). There is only a single reader for Iceland *S. marinus* and *S. mentella*, as well the three species at Flemish Cap. Iceland has placed more effort on *S. marinus*, especially because it is a stock subject to analytical stock assessment, while the stock structure of *S. mentella* around Iceland and in the Irminger Sea has not been clarified yet.

To date, international otolith exchanges to harmonize the criteria and its application have been conducted between Iceland and Norway with *S. marinus* from the two stocks, and between Norway and Russia on northeast Arctic *S. mentella*. In early 2007 an otolith exchange will also be initiated between Spain and Portugal on NAFO redfish, once the latter country has decided to read redfish otoliths routinely.

During the EU-REDFISH project in 2000–2004, a series of exchange schemes was carried out to assess bias and precision of age readings between four readers (Germany, Iceland, Norway and Spain) and between two preparation methods, the break-and-burn and the thin-sectioning cross-section techniques, using otoliths of the two major commercial species, golden redfish (*Sebastes marinus*) and deep-sea redfish (*S. mentella*). The results of this exercise is found in the final report of the project, as well in Stransky *et al.* (2005a), but the major conclusions of this study were:

- Considerable bias between readers and moderate precision was observed for the *S. marinus* readings, especially for ages above 20 years, with coefficients of variation (CV) of 7.7–12.0% and average percent error (APE) of 5.4–8.5%. The percent agreement between readers increased from 17–28% to 45–61% when allowing deviations of ± 1 year and to 80–92% within ± 3 years. *S. marinus* aged from broken and burnt otoliths were estimated to be slightly younger than the same individuals scored from thin-sectioned otoliths.
- The bias and precision estimates obtained from the *S. mentella* material were generally poorer than for *S. marinus* (CV 8.2–19.1%, APE 5.8–13.5%) but similar to reported values for other long-lived fish species. Above 50% agreement was only achieved within ± 3 years.
- Growth functions for both species revealed only minor differences between readers and confirmed slower growth for *S. mentella*.
- Average ages of around 9–10 years were determined for juvenile *S. mentella* of 24–30 cm length, which were likely to have migrated from East Greenland into the Irminger Sea, based on earlier observations.
- Since some of the error in the presented age determinations could be attributed to interpretational differences between readers, further inter-calibration of redfish age criteria application is urgently needed in order to provide consistent input data for stock assessment.

During the workshop meeting it was decided to initiate a new otolith exchange programme among the seven participant countries (see Section 6).

Since 1995 only two validation works have been carried out with redfish. One on Flemish Cap *S. mentella* (Saborido-Rey, 1995, 2001; Saborido-Rey *et al*., 2004) and another on *S. marinus* around Iceland and *S. mentella* off East Greenland and in the Irminger Sea (Stransky *et al*., 2005b). The age of Flemish Cap *S. mentella* was validated up to age 10 following the 1990 strong cohort. Older ages are hard to track in the survey series because of reduced abundance and thus validation is not possible. Considering that redfish live considerably longer than age 10, validation for the entire age range of these species is essential. However, as discussed below, some of the discrepancies in age reading may come from the interpretation of the first annuli where many checks are observed. Thus the validation on Flemish Cap *S. mentella* is a valuable contribution regarding correct age reading criteria definition.

On the other hand, ages of *S. marinus* from around Iceland, as well as *S. mentella* off East Greenland and in the Irminger Sea, were determined using a radiometric ageing technique based on $^{210}Pb/^{226}Ra$ isotope ratios by alpha-spectrometric measurement in otolith core samples, pooled by length group (Stransky *et al*., 2005b). In general, the measured isotope ratios corresponded well with the expected radioactive in growth curves and with traditional age estimates for fish of the same length group. A slight tendency towards an underestimation of age by traditional annulus counts could be inferred from the comparison with the derived radiometric ages. Considerable differences between ageing methods were found for *S. marinus* over 40 cm length and *S. mentella* from the deeper layers of the Irminger Sea. Irminger Sea redfish of the biggest investigated length group (41–45 cm) exhibited the maximum radiometric age recorded (41.3 years). This study confirmed slow growth and high longevity of North Atlantic redfish.

Concerning the Atlantic, only Norway has implemented a Quality Assurance (QA) system for production redfish age determination. It briefly consists of providing a quality code to the reading of each otolith (Table 4) in addition to circulating a reference collection of 30 otoliths every quarter to routinely assess precision amongst Norwegian readers. There are no QA procedures implemented for redfish age determination in any other laboratory.

The Fish Ageing Lab at the Pacific Biological Station is currently, and has for more than 20 years, used a 5 level index to indicate the reader's confidence in assigning an age for groundfish, including rockfish (Table 5). The index is both qualitative and quantitative. The descriptive aspect addresses pattern clarity and the quantitative aspect expresses within repeatability. The index also takes into consideration longevity when assessing the quantitative aspect. The QA/QC procedures have evolved in this lab over 26 years and are currently fully implemented.

Literature on age determinations, otolith exchanges and validation work published since 1995 is presented in Annex 4.

Table 1. Summary of methodological aspects for *Sebastes* age determination.

COUNTRY	STOCK	SPECIES	STRUCTURE	METHOD	# AGE READERS	QC/QA	OBSERVATIONS
Germany	Irminger Sea	*S. mentella*	Otoliths	Thin-section	1	Not implemented	Otoliths read occasionally
Germany	Iceland/Greenland	*S. marinus* and *S. mentella*	Otoliths	Thin-section	1	Not implemented	Otoliths read occasionally
Iceland	Iceland	*S. marinus* and *S. mentella*	Otoliths	Break and burn	1	Partially implemented	*S. marinus* read on a routine basis for stock assessment. *S. mentella* read only occasionally. Regular tests are performed in order to investigate the reliability of the reader.
Iceland	Irminger Sea	*S. mentella*	Otoliths	Break and burn	1	Not implemented	Otoliths read only occasionally
Norway	Barents Sea	*S. mentella* and *S. marinus*	Otoliths	Break and burn	2 (3)	Partially implemented	*S. mentella* and *S. marinus* read on a routine basis for stock assessment since 1990. Since January 2006, thin-section is used as a routine method for *S. mentella*.
Norway	Irminger Sea	*S. mentella*	Otoliths	Break and burn	2 (3)	Not implemented	Otoliths read occasionally since 1993
Poland	Irminger Sea	*S. mentella*	Otoliths	Thin-section	1	Not implemented	Reading since 2005
Russia	Barents Sea	*S. mentella* and *S. marinus*	Otoliths	Break and burn	1	Not implemented	Reading since 1991. *S. mentella* read on a routine basis for stock assessment
Russia	Irminger Sea	*S. mentella*	Scales		2	Not implemented	Reading since 1980
Spain	Flemish Cap	*S. marinus*, *S. mentella* and *S. fasciatus*	Otoliths	Break and baked	1	Not implemented	Reading since 1990. *S. mentella* read on a routine basis for stock assessment.
Canada	Pacific stocks	>30 rockfish species	Otoliths	Break and burn	8	Fully implemented	Read on a routine basis for stock assessment

Table 2. Pros and cons of each of the three methods currently used for redfish age determination. For the description of each method see ICES (1996).

METHOD	PROS	CONS	OBSERVATIONS
Thin sections	• Mass preparation possible. • Good quality pattern possible with resolution up to 1000X if compound scope used. • Easy and compact storage. • Standard location, flat cross-section plane suitable for photography, digital image exchanges & measurments. • Low long-term deteriotation good for reference collections & exchanges	• Expensive preparation materials & equipment. • High manpower needed for preparation. • Processing time can be slow, but improves with mass sectioning. • Low versatility; only 1 chance per otolith to produce good pattern for viewing. Once prepared, no going back to rework, the otolith is destroyed. Biggest impact with mass production method. • Preparation artifacts (angle of mounting & sectioning) easily introduced that reduce pattern quality. Biggest impact with mass production method.	New devices may reduce costs and facilitate the operations. However, the preparation efficiencies per otolith of the three methods need to be properly assessed (i.e. time for all steps from pulling otolith out of storage unit to ready for ageing). It is important to do so in order to properly judge & compare before reach conclusions regarding method efficiency. It is recommended that the agencies should systematically measure the efficiencies of each potential method as standard process.
Broken and burn	• Very low cost preparation materials & equipment. Low manpower required for preparation. • Fast preparation time of about 15-30 sec/otolith. • Good quality pattern possible - burning enhances contrast of pattern. • High versatility; reader can manipulate each otolith half to enhance specific aspects of pattern. • 4 opportunities per otolith pair to produce an age. • Whole otolith surface pattern can be used as “age range finder” for cross-section. Juvenile annuli can be traced from pattern on distal surface onto cross-section plane. Size of first annulus can be compared to that on cross-section • Opportunities for producing good photographic images are moderate to good because of contrast created by burning.	• Otoliths must be prepared individually. • Resolution limited to highest magnifications of dissecting scopes (200X),. • Less controlled than baking & sectioning. Risk of overburning the margin of the otolith section. • Uneven cross-section plane & slight variations in plane of break can cause problems for photography and measurments. • Condition of burnt otolith “may” deteriorate over time & with too much handling, - only moderately suitable for reference collections. • Storage is bulky & is susceptable to deteriation due to brittleness when stored dry & or if fluid media not prepared correctly.	• The biggest advantage of this method is that it is versitile, lending itself to manipulation on an otolith by otolith basis. It allows the reader to change the process to improve pattern clarity through variation of application. • Often, the largest portion of training to age otoliths with this method is in learning the process, not learning to apply the criteria. • Its use is very extensive across countries and species. • For specific studies, otoliths may be cut in half to avoid problems of non-standard plane of section and irregular cross-section plane.
Broken and baked	• Low cost preparation materials & equipment.. • Mass production possible. • Moderately low manpower required for preparation (10-20 sec/oto - this should be measured). • Good quality pattern possible - baking enhances contrast of pattern. • More controlled than burning -uniform contrast of pattern. • Whole otolith surface pattern can be used as “age range finder” for cross-section. Juvenile annuli can be traced from pattern on distal suface onto cross-section plane.	• Less contrast than burnt method. • Less flexible than burning – all otoliths processed same despite individual differences between older and younger bones. • Uneven cross-section plane & slight variations in plane of break can cause problems for photography & measurments. For specific studies otoliths may be sectioned in half to avoid this. • Condition of burnt otolith “may” deteriorate over time & with too much handling, - only moderately suitable for reference collections. • Storage is bulky & is susceptable to deteriation due to brittleness when stored dry & or if fluid media not prepared correctly.	• Its use as routine is restricted to few laboratories. • It does not need previous expertise for a correct use, as there is no learning proccess on burrning.

Table 3. Summary of otoliths/scales available since 1995 by species and stock.

		Year												
Species	Area	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006*	Total
S. mentella	Barents sea/Norwegian Sea	3101	1679	3976	4013	4278	5401	5055	2788	2966	3221	2093	557	39128
	Iceland and Greenland	[1]	[1]	[1]	3895	3181	4708	4224	4335	4384	4667	4269	1452	35115
	Irminger Sea stock complex (otoliths)	300[1]	1996[1]	934[1]	7424	5181	4768	6796	2584	3705	4041	7062	1562	46353
	Irminger Sea stock complex (scales)	2476	1109	3932	607	6952	998	6189	3394	7105	2661	4075		39498
	Flemish Cap	1091	1473	1284	1628	1700	1517	1923	1845	1638	2087	1440	757	18383
	Grand Banks of Newfoundland				1958	3625	1582	993	1416	1900	1762	128		13364
S. marinus	Barents sea/Norwegian Sea	2364	2731	2991	1666	1611	1459	1375	1832	1401	2458	1567	453	21908
	Iceland and Greenland	[1]	[1]	[1]	9835	8119	10488	8788	9124	9341	8682	10392	5970	80739
	Flemish Cap	871	1143	1220	947	805	767	865	964	704	652	765	748	10451
	Grand Banks of Newfoundland				77	942	693	328			71			2111
S. fasciatus	Flemish Cap	827	1003	1017	1214	1078	893	1136	974	840	744	820	803	11349
	Grand Banks of Newfoundland									2	68	93		163
S. viviparus	Barents sea/Norwegian Sea				38									38
Total Redfish		**11030**	**11134**	**15354**	**33302**	**37472**	**33274**	**37672**	**29256**	**33986**	**31114**	**32704**	**11745**	**318600**
Rockfish**	West Coast - British Columbia	13667	18972	15320	23899	20392	18077	18966	13489	31033	28463	23047	3880	229205

[1]During 1995-1997 Iceland has collected otoliths for these stocks in similar proportion as in later years, but the exact data is not available yet.

*** Provisional**

*****S. aleutianus, S. alutus, S. aurora, S. babcocki, S. borealis, S. brevispinis, S. caurinus, S. crameri, S. diploproa, S. elongatus, S. emphaeus, S. entomelas, S. flavidus, S. helvomaculatus, S. jordani, S. maliger, S. melanops, S. miniatus, S. mystinus, S. nebulosus, S. nigrocinctus, S. paucispinis, S. pinniger, S. proriger, S. reedi, S. ruberrimus, S. saxicola, S. variabilis, S. variegatus, S. wilsoni, S. zacentrus***

Table 4. Reader's Confidence Index (readability code) for Age Estimates used at Institute of Marine Research, Norway.

READABILITY CODE	QUALITATIVE MEANING
1	The age can be determined accurately
2	Uncertain age estimate
3	Otolith not readable or missing
4	Age may be estimated but spawning zones/spawning age not readable
5	Uncertain, but the reader has chosen the lowest of two consecutive likely ages
6	Uncertain, but the reader has chosen the highest age of two consecutive likely ages

Table 5. Reader Confidence Index for Age Estimates used at Fish Aging Lab at Pacific Biological Station, Canada.

CONFIDENCE INDEX	ABBREVIATION	QUALITATIVE MEANING (PATTERN CLARITY)	QUANTITATIVE MEANING (REPEATABILITY)	AGE EXAMPLES
Good	G	Pattern is very clear with no interpretation problems	Reader would always get the same age	10^{G}, 57^{G}
Fairly good	FG	Pattern is clear with a few easy interpretation problems	Reader would get the same age most of the time	3^{FG}, $58^{\pm 2FG}$
Fair	F	Pattern is fairly clear with some areas presenting easy & moderate interpretation problems	Reader would be within 1 yr all the time for fish <20 & 2-3 for fish > 30 yrs, etc	$13^{\pm 1F}$, $26^{\pm 2F}$
Fairly poor	FP	Pattern is fairly unclear presenting a number of difficult interpretation problems	Reader would be within 2 yrs most of time for fish aged <20 & 3-5 yrs for fish >30yrs, etc	$9^{\pm 2FP}$, $63^{\pm 5FP}$
Poor	P	Pattern is very unclear presenting significant interpretation problems	Reader has little confidence in repeatability of age within 5-10 yrs or more in case of older fish	$14^{\pm 5P}$, $39^{\pm 10P}$

3 Sources of age determination error in terms of bias and precision. Ageing criteria

Several sets of otoliths, covering most of the redfish stocks in the North Atlantic, were used for comparative age reading during the workshop (Table 6). Considering the limited time, only a fraction of the material that was prepared could be read during the workshop. A part of this material had already been exchanged and read by some readers during the EU-REDFISH project in 2000–2003 (Stransky *et al.*, 2005a), increasing the number of possible comparisons.

The readers had various levels of experience and read individually or in groups of two. The catch month of the samples was available to the readers, whereas individual fish information, such as fish length, was not revealed to the readers, in order to prevent prejudice effects. Binocular microscopes were used, with the possibility of different light settings (transmitted and reflected light, shading etc.). A discussion binocular was set up with a camera system and PC connection to allow a group of readers to follow the reading process on a computer screen.

A part of the material had already been prepared broken-and-burnt or as thin-sections before the workshop, while some material was prepared during workshop. For the break-and-burn method, the protocol described by MacLellan (1997) was employed, and some material was broken-and-baked according to the methods described in ICES (1996). The ageing criteria that were used are described in detail in the previous workshop report (ICES, 1996). For the time being, no alterations to these criteria have been made.

Table 6: Redfish otolith samples used for comparisons between readers and preparation methods.

SPECIES	SAMPLING AREA (ICES SUBAREA OR DIVISION)	COUNTRY	SAMPLING DATE OR PERIOD	DEPTH RANGE (M)	FISH TOTAL LENGTH RANGE (CM)	N	PREPARATION METHODS
S. marinus	Iceland (Va)	Iceland	March 1997	247-421	10-54	39	thin-sections, digital pictures
S. marinus	Iceland (Va)	Iceland	April 2005	311-329	30-45	50	break & burn, break & bake
S. mentella	Barents Sea (I-II)	Norway	February 1999	250-420	6-38	30	break & burn, break & bake
S. mentella	Irminger Sea (XII)	Germany	July 1999	200-350	22-41	41	break & burn, break & bake, thin-sections, digital pictures
S. mentella	Irminger Sea (XIVb)	Poland	May 2006	500-790	29-53	38	break & burn, thin-sections
S. mentella	Irminger Sea (XII) and East Greenland (XIVb)	Germany	June/July 1999 and October 1998	200-650	24-30	31	thin-sections, digital pictures

S. marinus from Iceland (ICES Division Va)

Six readers participated in comparative readings of 50 *S. marinus* otoliths from Iceland (Table 7). Most of these readers used already broken-and-burnt material, and two readers read otoliths that were broken-and-baked during the workshop.

The reading bias varied considerably between readers (Figure 1). Readers 3 and 10 showed the best correspondence with the modal age, whereas readers 7 and 8 recorded markedly lower ages for fish that were aged >15 years by the other readers. Relatively high variation in age estimates was observed for all readers. A comparison of reading results obtained from readers 4, 5, 7 and 8 with age estimates of reader 3, who is most experienced with the stock, illustrates that fish aged 15–25 years by reader 3 were mostly aged 10–20 years by the other readers (Figure 2). Fish aged younger than 15 years by reader 3, however, were relatively underestimated in age by the other readers. Reading results of readers 4 and 10, using the break-and-bake technique, corresponded relatively well, with few outliers (Figure 3). Reader 4 used both the break-and-burn technique (with a repeated reading) and broken-and-baked otoliths. Considerably higher ages were read in the broken-and-burnt material, and the correspondence between first and second reading was good (Figure 4). On average, the broken-and-burnt otoliths were aged 3–4 years older than the broken-and-baked otoliths.

Based on an independent evaluation of the results from the comparative readings, seven otoliths were selected for further discussion among all the readers gathered in front of a computer screen. The selected otoliths are shown in bold and underlined in Table 7. This joint discussion of zones and annuli interpretation turned out to be very useful. Random differences and errors will always exist, and the occurrence of such differences may only be reduced by frequent otolith exchanges and comparative readings. The most serious discovered systematic error or bias was the neglect of including the proximal side of the otolith section when counting the annual growth zones. On older fish, i.e. older than 15–20 years it is nearly impossible to distinguish the annuli and count the last growth zones along the dorsal (or ventral) axis. An often difficult task is the correct interpretation of the first few annuli where many checks are observed. Some of the age differences in this material originated from this problem. Measurements (e.g., distance measured from the nucleus to the dorsal tip of the growth zone, and/or from the ventral to the dorsal tip of the growth zone) of the first annuli on known-age fish or on very clear otoliths seem to be the only way out of this problem, and then to use such information as a guideline in all routine readings for the same stock. We also discovered that readers may get the same age simply by chance. That is, they did not identify the same zones as being annuli or checks when counting, but ended up with the same age in the end.

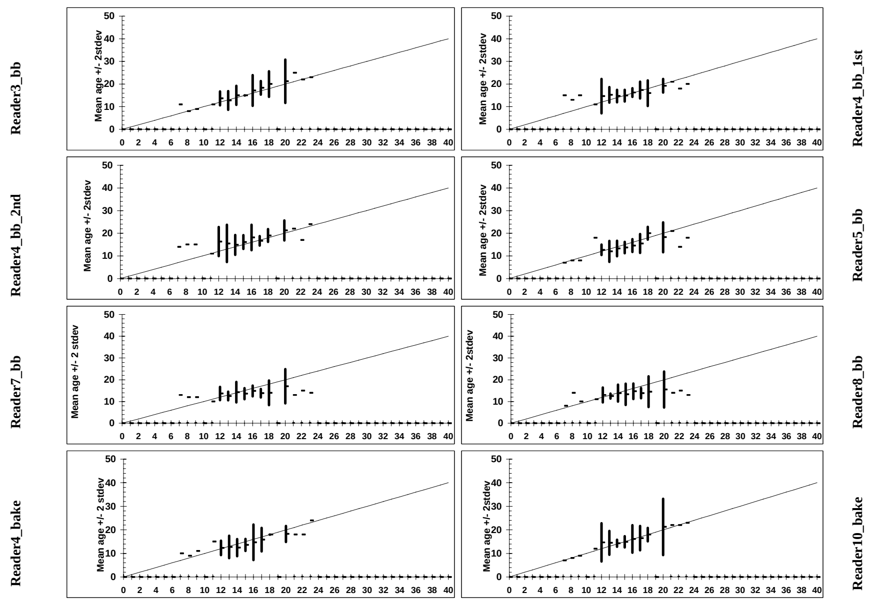


Figure 1. ***S. marinus*** **Iceland. Age-bias plots. The mean ages (in years) read by a certain reader on broken-and-burnt (bb) or broken-and-baked (bake) otoliths are plotted against the modal age over all readings. The error bars around the mean ages represent ± 2 standard deviations. The 1:1 equivalence is given as a straight line.**

Table 7. *S. marinus* Iceland. Age reading results.

No	Fish Size (cm)	Sex	Reader 3	4*	4**	5	7	8	4	10
			Break & Burn						Break & Bake	
1	43	M	25	20	22	19	18	16	20	18
2	33	M	9	15	15	8	12	10	11	9
3	36	F	17	18	17	12	14	13	16	14
4	39	F	20	16	16	15	15	14	14	16
5	43	M	25	21	22	21	13	14	18	22
6	44	F	18	16	17	16	14	12	19	21
7	34	M	15	14	14	14	14	13	9	14
8	39	F	15	16	14	12	19	18	13	14
9	37	M	22	18	20	19	12	12	18	19
10	39	F	15	16	19	14	13	13	13	15
11	40	F	18	14	18	21	16	17	18	17
12	41	F	20	19	17	15	12	14	17	18
13	43	M	25	20	20	22	15	16	18	30
14	38	F	17	14	15	17	14	15	13	13
15	34	M	10	13	11	10	13	13	11	11
16	38	F	15	12	14	14	15	12	12	14
17	41	F	20	17	16	16	15	15	14	17
18	41	F	22	18	17	14	15	15	18	22
19	38	F	15	15	16	14	11	11	14	15
20	36	F	13	15	13	10	11	12	16	15
21	38	F	19	17	16	16	14	14	13	14
22	35	F	15	15	15	12	13	13	14	15
23	37	F	15	15	19	14	14	14	14	14
24	33	M	11	11	11	18	10	11	15	12
25	34	M	15	13	16	14	15	15	16	14
26	38	F	15	13	15	14	15	15	15	15
27	39	F	20	17	19	18	22	20	19	17
28	40	M	23	20	24	18	14	13	24	23
29	41	F	20	17	21	16	16	16	20	17
30	38	F	12	14	14	11	11	12	11	14
31	34	F	11	15	16	12	16	16	9	11
32	40	F	15	16	15	16	15	13	13	14
33	43	F	16	18	18	14	13	15	15	16
34	39	F	15	16	20	13	13	18	12	15
35	36	M	20	16	23	15	16	17	13	16
36	38	F	15	15	16	13	14	12	13	14
37	30	M	8	13	15	8	12	14	9	8
38	39	M	19	17	18	18	14	12	20	17
39	38	F	12	13	15	12	14	15	11	11
40	34	F	11	15	14	7	13	8	10	7
41	38	F	15	20	24	14	13	10	16	20
42	35	F	15	17	17	12	14	15	13	15
43	34	M	14	19	20	12	12	12	14	19
44	37	F	13	17	19	14	13	12	11	17
45	38	F	15	15	16	14	13	11	12	14
46	39	F	15	16	16	14	14	13	13	16
47	45	F	17	19	17	15	14	14	15	20
48	38	F	14	13	12	14	14	13	14	16
49	42	F	15	14	15	15	13	10	14	18
50	40	F	15	14	15	12	14	13	13	14

* 1st reading; ** 2nd reading

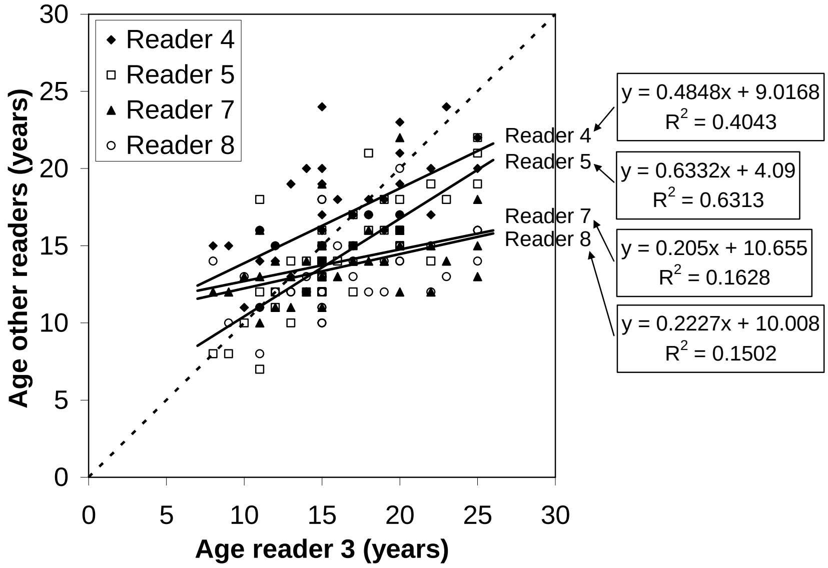


Figure 2. ***S. marinus*** **Iceland. Comparison of ages read by four readers with ages read by reader 3 (being most experienced with the stock), using the break-and-burn technique. The 1:1 equivalence is indicated by a dashed line, and the linear regressions are shown as solid lines, with the corresponding regression formulae and coefficients (R^2).**

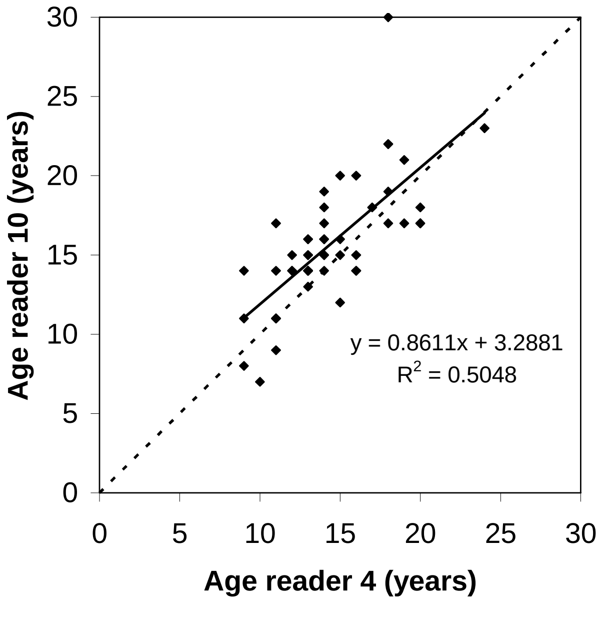


Figure 3. ***S. marinus*** **Iceland. Comparison of ages read by readers 4 and 10, using the break-and-bake technique. The 1:1 equivalence is indicated by a dashed line, and the linear regression is shown as a solid line, with the corresponding regression formula and coefficient (R^2).**

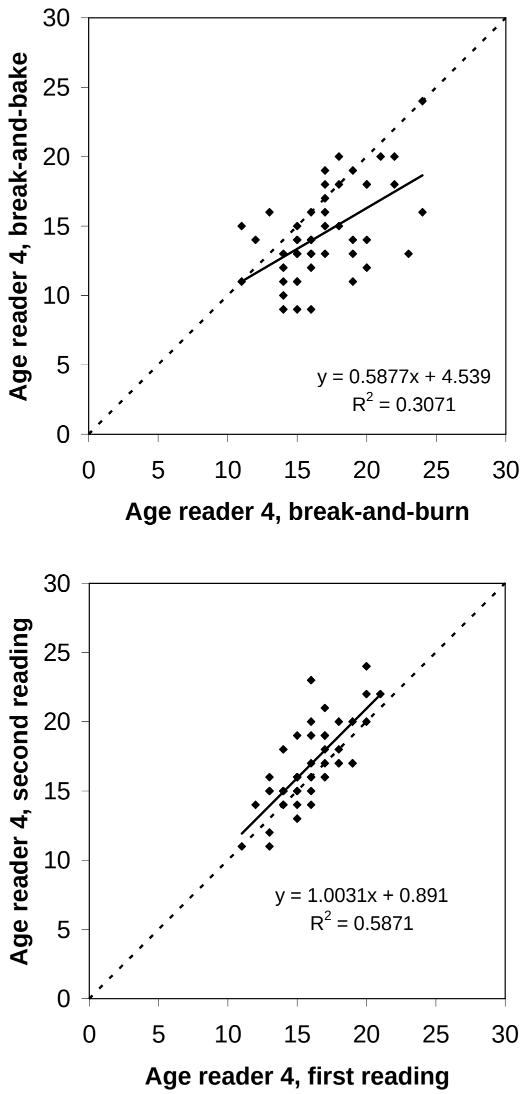


Figure 4. *S. marinus* Iceland. Comparison of ages (in years) read by reader 4, using different otolith preparation techniques (left panel) and comparison of first and second readings of reader 4, using the break-and-burn technique (right panel). The 1:1 equivalence is indicated by a dashed line, and the linear regression is shown as a solid line, with the corresponding regression formula and coefficient (R^2).

S. mentella from the northeast Arctic stock (ICES Subarea II)

The *S. mentella* otoliths from the Barents Sea (n=30) were read by five readers (Table 8). Four readers used broken-and-burnt material, while one reader used broken-and-baked otoliths.

The overall bias was comparably low, but relatively high variation in age estimates was observed for readers 1 and 10 (Figure 5). In general, the readers corresponded well (Figure 6), with reader 1 giving slightly higher estimates and readers 7 and 8 giving slightly lower estimates than reader 5 (who was most experienced with the stock), especially in the age range 10 years and older.

In the same way as described for the Icelandic *S. marinus* sample (see this), six otoliths from this *S. mentella* sample were selected for further discussion among all the readers gathered in front of a computer screen. The selected otoliths are shown in bold and underlined in Table 8. The main reason readers 7 and 8 assessed lower age estimates for older fish was neglecting to take into account the annuli present in the proximal edge of the otolith's cross-section. In older fish the thickness of the otolith increases with age almost exclusively in the proximal edge. In addition, some of the differences originated from incorrect identification of the first few annuli, but especially the 1st annulus. This problem could be overcome by measuring the "average" size of the first annual growth zone to determine the distance it forms from the nucleus. This would provide readers with approximate location of the first annulus. Poor cuts (#4) or poorly burnt sections (#25), especially at the dorsal and ventral tips, also created different age estimates.

Table 8: *S. mentella* Barents Sea. Age reading results.

No	Fish size (cm)	Sex	Reader				
			1	5	7	8	10
			reak & burn				break & bake
1	12	-	4	3	3	3	3
2	13	-	4	3	3	5	4
3	14	-	4	4	4	4	3
4	21	F	4	7	7	5	7
5	19	M	4	6	5	5	6
6	18	M	4	5	5	4	5
7	17	F	5	5	5	5	5
8	22	F	4	7	4	4	4
9	23	M	4	7	7	5	6
10	33	F	10	13	12	11	12
11	31	F	13	11	13	14	11
12	32	F	7	12	11	11	8
13	27	M	7	9	9	8	9
14	29	F	10	10	9	10	9
15	30	F	14	11	11	11	11
16	28	M	10	9	9	10	14
17	15	-	4	4	5	5	-
18	16	-	4	4	4	4	4
19	25	F	4	8	6	8	5
20	24	M	9	8	7	7	7
21	26	F	10	8	8	8	10
22	20	M	6	6	6	6	8
23	34	M	13	12	12	12	15
24	36	M	21	18	14	13	18
25	38	F	25	17	15	14	18
26	37	F	18	16	17	13	-
27	35	M	18	14	14	15	19
28	6	-	1	1	1	1	-
29	11	-	4	4	4	4	2
30	7	-	1	1	1	1	1

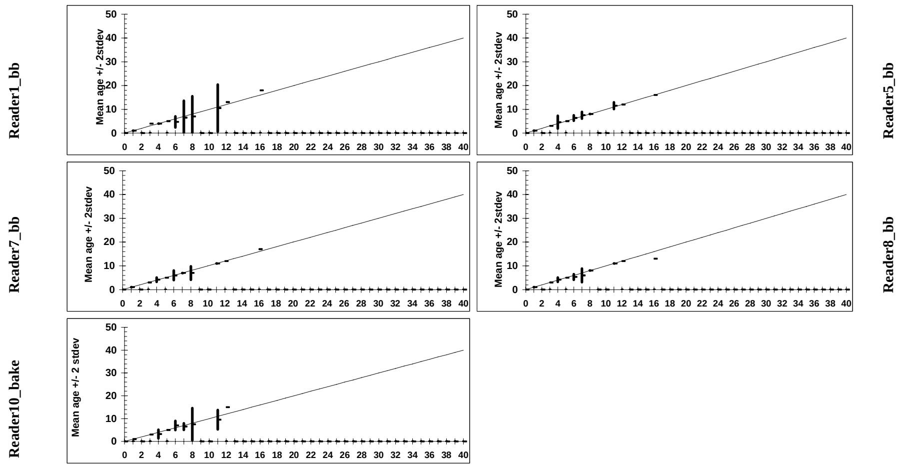


Figure 5. ***S. mentella*** **Barents Sea. Age-bias plots. The mean ages (in years) read by a certain reader on broken-and-burnt (bb) or broken-and-baked (bake) otoliths are plotted against the modal age over all readings. The error bars around the mean ages represent ± 2 standard deviations. The 1:1 equivalence is given as a straight line.**

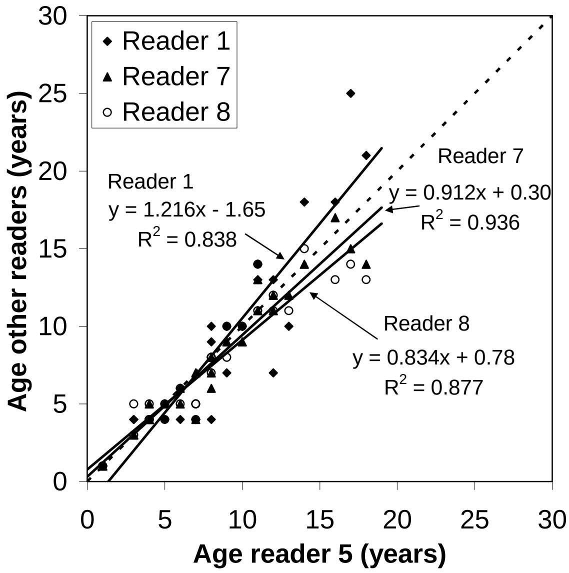


Figure 6. ***S. mentella*** **Barents Sea. Comparison of ages read by three readers with ages read by reader 5 (being most experienced with the stock), using the break-and-burn technique. The 1:1 equivalence is indicated by a dashed line, and the linear regressions are shown as solid lines, with the corresponding regression formulae and coefficients (R^2).**

S. mentella from the Irminger Sea (ICES Subarea XII and Division XIVb)

Two sets of otoliths from pelagic *S. mentella* in the Irminger Sea were read during the workshop. The samples from Subarea XII (n=41) were collected in shallower depths than those from Division XIVb (n=38). The area XII set contained fish of 22–40 cm length and was read by six readers with three different preparation techniques (thin-sections, break-and-burn, break-and-bake; Table 9), while the area XIVb otoliths came from fish of 29–53 cm length and were read by break-and-burn and as thin-sections (Table 10).

Between-reader bias and high variation in age estimates was evident in all comparisons (Figure 7 to Figure 10). As examples in area XII, deviations of reader 1 from reader 5, using broken-and-burnt otoliths, were mostly positive, while those of reader 6 from reader 5 (thin-sections) were mostly negative (Figure 7). Readers 5 and 10 used two different otolith preparation techniques. In the case of reader 5, the thin-sectioned otoliths delivered higher age estimates as the broken-and-burnt otoliths, whereas reader 10 obtained lower ages from thin-sectioned otoliths than from broken-and-baked ones (Figure 8), especially in the medium age range 20–30 years. Broken-and-burnt otoliths from area XIVb corresponded well for ages 9–15 years, but older fish were given higher ages by reader 1 and younger by reader 6 than by reader 5 (Figure 9, left panel). The thin-sectioned otoliths showed also good reader agreement up to 15 years, but for older fish, readers 6, 9 and 10 provided mostly lower ages than reader 5 (Figure 9, right panel). This is particularly true for reader 9. Readers 5 and 6 used two different preparation techniques. Contrary to the area XII material, reader 5 gave the broken-and-burnt otoliths mostly lower ages than the thin-sectioned otoliths (Figure 10, left panel). Very good correspondence between preparation techniques was observed for reader 6 (Figure 10, right panel).

Three broken-and-burnt and three thin-sectioned otoliths were collected from the Division XIVb (deep) sample and jointly discussed in front of a computer screen. The selected otoliths are shown in bold and underlined in Table 10. From the Subarea XII (shallow) sample, only digital pictures of thin-sectioned otoliths were discussed in plenary (see Table 9 and Figure 11). Similar errors, difficulties and challenges are related to all these otoliths, irrespective of method. First, great differences in age estimates occur when the proximal edge of the otolith section (i.e., otolith thickness) was disregarded and not included in the counting. It was also discovered that some readers, in addition to not including the proximal growth, counted too many annuli along the dorsal axis and thus by chance got the same age. Checks in the dorsal counting axis from nucleus to tip tend to appear prominent causing readers to over-estimate age. It is therefore important to repeat that an annulus should not be included in the age count unless the ring/zone can be followed/traced over a certain distance, preferably to the dorsal tip of the section, or (the other way) from the dorsal area back to the sulcus area. Checks that form along the nucleus-dorsal tip growth axis on the distal side of the otolith section tend to become discontinuous or merge with annuli along the dark/light boundary where annuli “bend” towards the sulcus (MacLellan, 1997). Some of the age differences in this material originated from incorrect interpretation of the first few annuli where many checks are observed. Measurements of the first annuli on known-age fish or on very clear otoliths seem to be the only way out of this problem, and then to use that information as a guideline in all routine readings for the same stock.

However, age methods are based on providing readers with visual cues as criteria to identify growth zones. Thus, measurements, being a useful tool, should be cautiously used. It must help to the reader to only roughly situate the first annuli, and avoid taking precedence over the visual criteria. Annuli width may change among individuals and among years reflecting growth variation. Therefore, measurement ranges must be sufficient to account for the majority of individual variation and it is necessary to re-measure once in a while to test that growth hasn’t changed over time.

Table 9: *S. mentella* Irminger Sea (Sub-area XII, shallow). Age reading results.

No	Fish size (cm)	Sex	Reader 1	Reader 5	Reader 2	Reader 3	Reader 5	Reader 6	Reader 10	Reader 10
			break & burn		thin-sections					break & bake
1	22.5	F	6	4	6	8	8	5	5	6
2	23.5	M	6	4	7	8	8	6	6	6
3	24.5	F	10	5	8	10	7	10	7	13
4	24.5	F	9	7	9	10	8	9	7	11
5	24.5	M	12	6	11	9	6	8	7	9
6	26.5	F	9	7	7	9	8	9	7	11
7	26.5	F	9	7	8	9	8	9	8	9
8	28.5	F	12	9	10	14	10	9	10	12
9	28.5	M	10	7	9	12	8	8	9	10
10	29.5	F	12	9	10	13	9	9	10	11
11	29.5	F	10	7	11	10	10	8	10	12
12	29.5	M	12	7	9	10	8	9	8	10
13	29.5	M	14	6	8	11	8	10	9	11
14	30.5	F	15	9	11	16	12	11	11	13
15	31.5	F	13	10	12	14	13	13	11	12
16	31.5	F	12	10	12	14	11	12	12	12
17	31.5	F	15	9	13	15	13	12	13	12
18	31.5	M	70	10	28	40	32	29	18	32
19	31.5	M	26	43	20	25	22	23	14	22
20	32.5	M	25	24	17	25	23	17	13	23
21	32.5	M	29	24	24	29	26	25	15	26
22	32.5	M	29	31	27	30	32	25	13	25
23	32.5	M	25	19	24	30	28	27	14	24
24	33.5	F	15	22	23	25	23	18	14	20
25	33.5	F	35	16	25	35	28	23	17	29
26	33.5	M	30	23	29	35	30	25	18	30
27	33.5	M	24	16	21	25	23	22	21	22
28	33.5	M	36	19	31	37	36	28	20	31
29	34.5	M	28	27	25	28	28	23	16	27
30	34.5	M	28	16	25	29	27	25	16	26
31	35.5	F	26	17	25	26	25	23	19	24
32	36.5	F	26	23	25	28	28	25	26	24
33	36.5	M	35	20	32	34	37	29	33	30
34	37.5	M	43	35	38	43	40	31	36	37
35	38.5	F	36	24	32	36	38	28	30	33
36	38.5	F	34	34	31	37	39	22	28	-
37	38.5	F	27	38	28	27	27	26	25	25
38	38.5	M	55	28	48	50	56	34	41	49
39	39.5	F	44	53	41	40	46	28	34	39
40	39.5	M	40	15	31	-	36	22	25	25
41	40.5	M	38	14	40	36	34	37	36	34

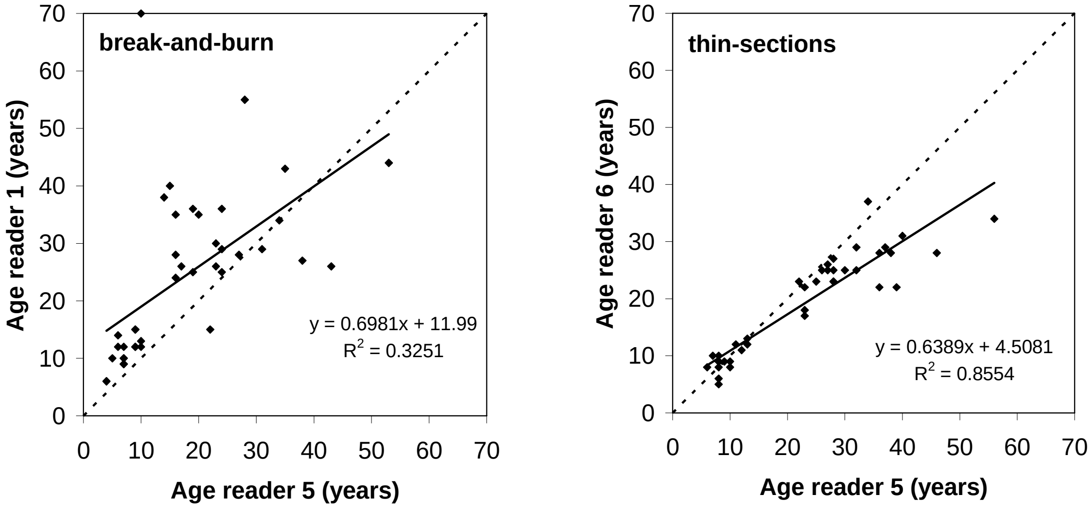


Figure 7. ***S. mentella*** **Irminger Sea (Sub-area XII, shallow). Comparison of ages read by readers 1 and 6 with reader 5, using the break-and-burn technique (left panel) and thin-sections (right panel). The 1:1 equivalence is indicated by a dashed line, and the linear regression is shown as a solid line, with the corresponding regression formula and coefficient (R^2).**

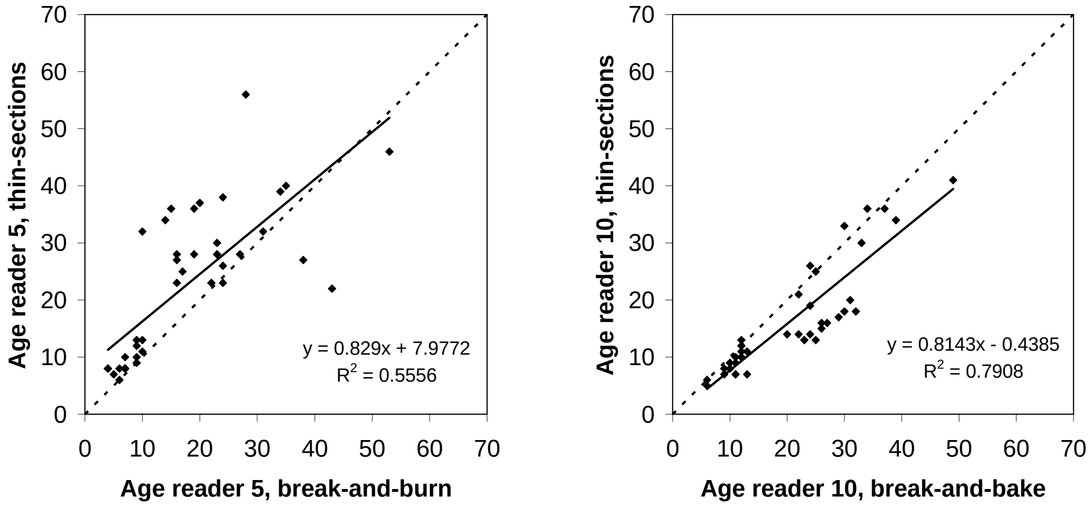


Figure 8. ***S. mentella*** **Irminger Sea (Sub-area XII, shallow). Comparison of ages (in years) read by reader 5 (left panel) and reader 10 (right panel), using different otolith preparation methods. The 1:1 equivalence is indicated by a dashed line, and the linear regression is shown as solid line, with the corresponding regression formula and coefficient (R^2).**

Table 10. *S. mentella* Irminger Sea (Div. XIVb, deep). Age reading results.

No	Fish size (cm)	Sex	Reader 1	5	6	5	6	9	10
			break & burn			thin-sections			
1	29	M	9	9	9	9	9	12	9
2	30	F	13	10	11	10	10	12	9
3	32	M	13	12	12	12	12	15	12
4	32	F	10	11	11	10	12	11	10
5	33	M	13	13	11	13	12	13	12
6	33	F	13	14	12	12	14	14	12
7	35	M	14	15	13	15	14	17	14
8	35	F	12	14	14	15	14	12	16
9	35	F	11	14	15	15	14	13	15
10	36	M	11	15	13	15	13	13	15
11	36	M	13	15	15	15	14	15	14
12	36	F	23	18	15	15	13	13	13
13	45	M	48	32	33	29	37	21	30
14	45	F	33	36	24	-	25	24	34
15	45	F	47	27	25	25	-	25	26
16	46	M	57	43	42	39	40	23	40
17	46	F	49	34	32	23	27	17	23
18	46	F	36	24	24	23	24	24	25
<u>19</u>	47	M	61	53	32	24	33	23	32
<u>20</u>	47	F	60	42	32	32	34	21	25
21	42	M	51	25	25	26	24	22	25
22	42	M	32	33	32	33	32	22	20
23	42	F	29	27	24	24	21	22	20
<u>24</u>	42	F	24	31	20	25	23	22	14
25	43	M	51	43	32	45	33	23	47
26	43	M	47	31	30	27	29	23	26
27	43	F	19	32	25	15	24	20	13
28	43	F	34	26	32	25	26	23	24
29	44	M	52	46	38	39	37	27	22
<u>30</u>	44	M	65	42	27	44	26	29	24
31	44	F	26	29	27	21	27	28	21
32	44	F	39	36	34	22	35	32	31
33	45	M	47	36	36	32	34	28	44
34	45	M	60	45	39	42	41	26	27
<u>35</u>	45	F	51	43	34	43	28	30	35
<u>36</u>	45	F	43	32	26	31	27	32	26
37	49	F	38	34	28	35	24	33	35
38	53	F	59	54	43	-	43	25	-

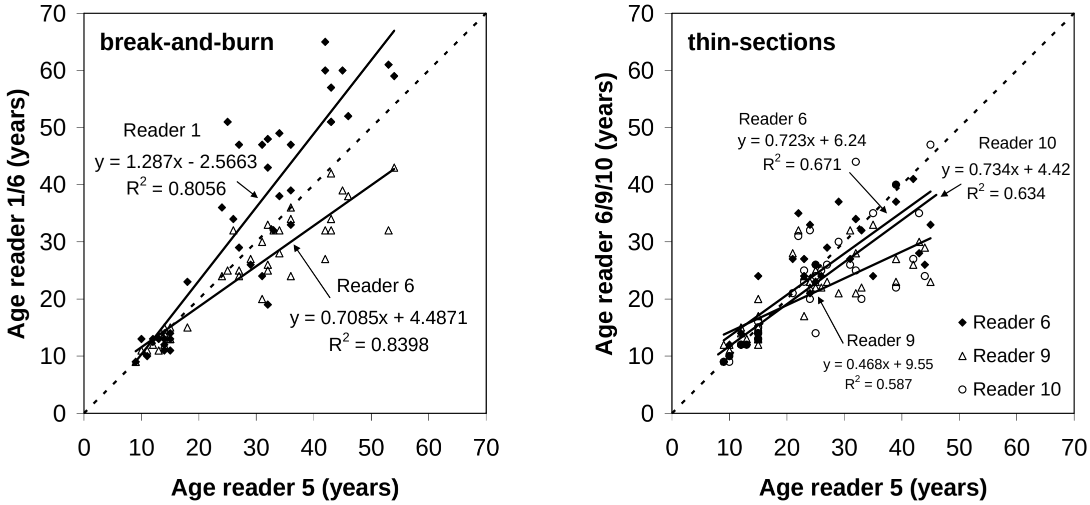


Figure 9. ***S. mentella*** **Irminger Sea (Div. XIVb, deep). Comparison of ages read by readers 1 and 6 with ages read by reader 5, using the break-and-burn technique (left panel), and comparison of ageing results of readers 6, 9 and 10 with reader 5, using thin-sections (right panel). The 1:1 equivalence is indicated by a dashed lines, and the linear regressions are shown as solid lines, with the corresponding regression formulae and coefficients (R^2).**

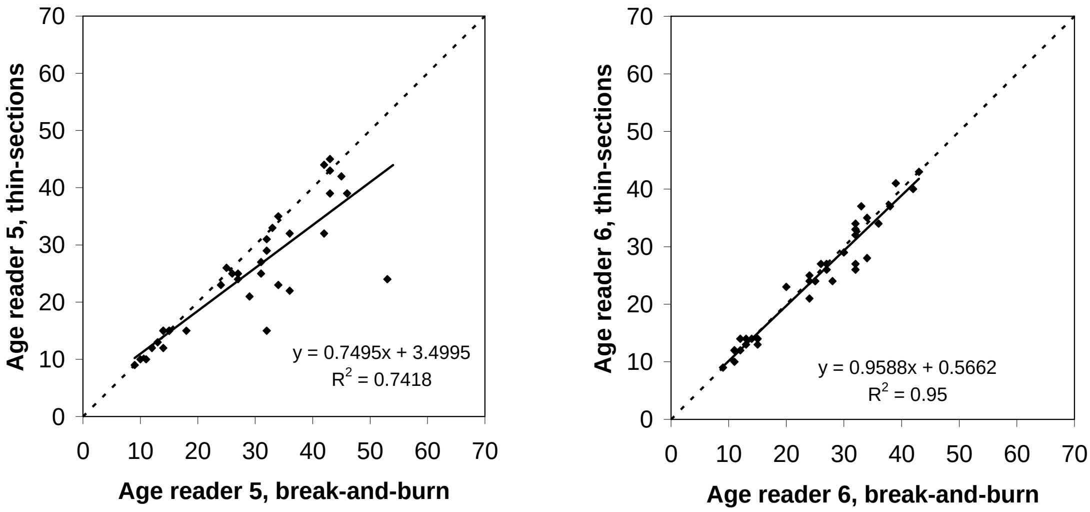


Figure 10. ***S. mentella*** **Irminger Sea (Div. XIVb, deep). Comparison of ages (in years) read by reader 5 (left panel) and reader 6 (right panel), using different otolith preparation methods. The 1:1 equivalence is indicated by a dashed line, and the linear regression is shown as solid line, with the corresponding regression formula and coefficient (R^2).**

Annotated digital pictures

From a total of 111 redfish otoliths, digital pictures of thin-sections had been taken during the EU-REDFISH project and annotated by four readers (Stransky *et al*., 2003). These included *S. marinus* from Iceland and *S. mentella* from the Irminger Sea and East Greenland (Table 6). The readers marked the annuli independently from each other and sent the annotation layers to the co-ordinator who compiled overlay pictures with all reading marks. The results of this exchange were used first of all for a comparison between readers and methods (digital pictures vs. thin-sections; Stransky *et al*., 2003), but in a long-term sense as a basis for discussions on interpretational differences between readers. Before the workshop, four additional readers produced annotation layers to be included in this set of overlay pictures. The completed pictures were sent on DVD to all workshop participants for teaching and calibration purposes and serve as a start for reference collections (see Section6– Quality control).

At the workshop, a few overlay pictures of *S. mentella* otoliths from the Irminger Sea were projected onto a large screen and discussed. Three examples are given below (Figure 11). Apart from a different perception of the first few annuli, the readers often used different reading axes. Most readers read from the nucleus to the dorsal-proximal edge (reading axis II in MacLellan, 1997), while one reader consistently read along the dorsal axis alone. The dorsal axis, however, often shows checks that can confound annuli detection, and as otoliths of older fish only exhibit thickness growth beyond a certain age (after about 12–15 years), this axis alone cannot be used for age estimation. Based on the experience with long-lived Pacific *Sebastes* species (MacLellan, 1997) and recent age validation results (see Section2), growth in the proximal axis (i.e. section thickness) that is not visible on the distal axis, must to be taken into account during the age reading.

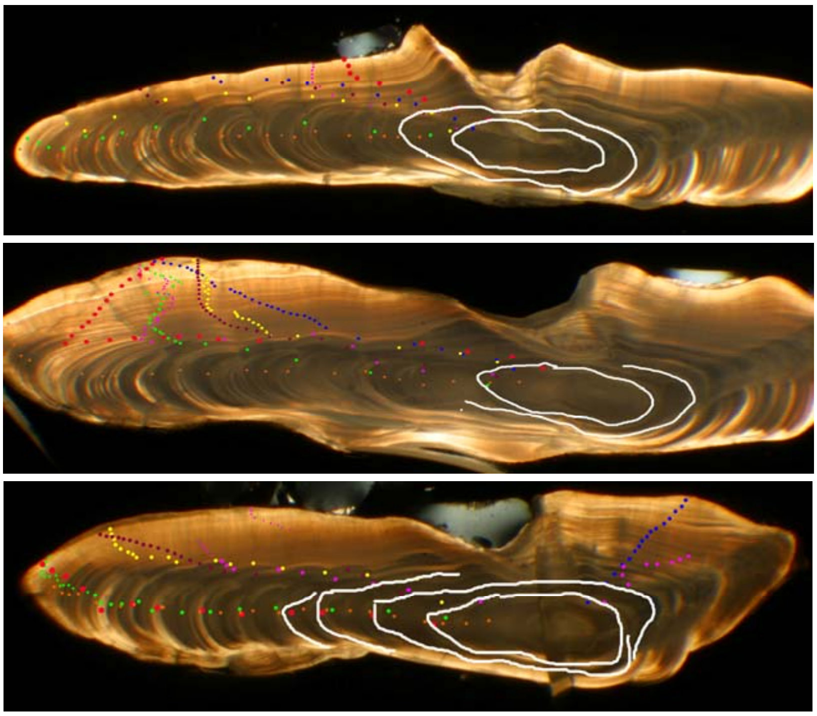


Figure 11. ***S. mentella*** **Irminger Sea (ICES Subarea XII, shallow). Digital pictures of otolith thin-sections, annotated by eight readers. Dots in various colours indicate annuli reading marks set by the different readers. The approximate location of the first few annuli was discussed during the workshop and drawn into the pictures as white lines.**

4 Species- and stock-specific growth rates and growth increment patterns. Impact of age determination methods on growth estimates

During the workshop, the information available on redfish growth studies was updated. A summary of growth parameters estimated for redfish from different areas is shown in Table 11. Data was fitted to von Bertalanffy growth function by each responsible laboratory. The growth curves parameters showed disparate results, especially regarding t_0 which ranged from -9.6 to 1.6. Although L_∞ ranged 37 to 72 cm, 70% of the cases are within 40–50 cm range. The largest L_∞ correspond to age reading based on scales.

Estimation of von Bertalanffy growth parameters may be one way of comparing age determination methods. Since it is difficult and seldom to likely to assign ages of more than about 20 years using scales, the L_∞ based on scale readings is much higher compared with the otolith based estimations (Table 11; Nedreaas, 1990). Similarly, otolith readings disregarding counting annual growth zones on proximal growth axes will also result in an under-estimated age of the older ones and hence a too high L_∞. When comparing different age reading methods using growth parameters as criteria, it is crucial that the entire length range of the species/stock is covered by the input data. Seen from Table 11 it seems that the thin section method in some cases give lower L_∞ than the other methods, but that is probably due to a more narrow length range in the input data.

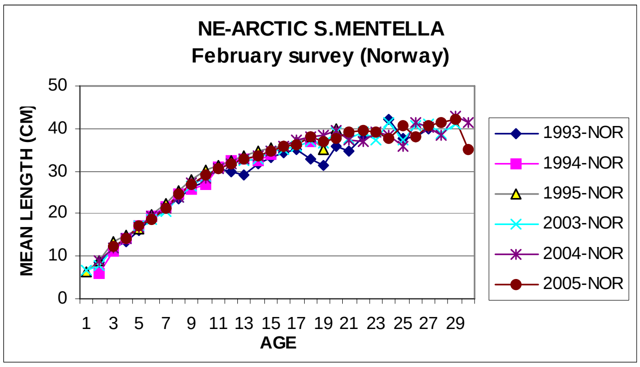
The group noted that only in three cases, the three species in Flemish Cap, the data was divided by sexes. Since it is known that males and females show different growth trajectories in redfish (Saborido-Rey *et al.*, 2004) the fact of combining sexes prevents conducting correct analyses of the growth. The participants acknowledged that in most of the cases sex information existed for each fish in their samples. It was noted thought that the methodology to fit the growth curves may change from lab to lab, which may yield different results hardly comparable. Thus, it was agreed that 2007 age information will be disaggregated by sex and original data provided to IIM (Spain) to fit growth curves using the same procedure and curves compared by the Chow test (Saborido-Rey *et al.*, 2004). It was agreed also to include information about the year, species, area, sex, length, age and age reading method in the database to be exchanged.

The otoliths read during the workshop (see previous section) were not enough to fit von Bertalanffy growth curves in order to estimate the effect on growth estimates of different otolith-based age determination methods. However, a comparison of growth curves obtained from four readers and two different methods (thin sections and broken and burn) was performed already (Stransky *et al.*, 2005a) on *S. marinus* from Iceland (Table 11, the first six rows) although in non-sexed specimens. In this study, the calculated growth parameters varied considerably between readers and only slightly between methods. Results showed, however, that the growth curves produced by the two methods did not differ significantly. No significant differences occurred among growth curves based on the reading results of the four age readers for *S. marinus* from Iceland. However, the same study revealed notable differences on growth curves among readers, so it can be hypothesized that the different methods may have also effect on growth estimations.

The new sex disaggregated information will allow also studying deeply the effect of the different age determination method on growth estimates as the current format of the data prevents to conduct this study in detail. It is expected to achieve this goal along 2007.

The possibility of creating specific guidelines for the interpretation of otolith section growth patterns for various redfish stocks was discussed. However, this would be difficult given the lack of standard application of criteria currently in use amongst laboratories. Instead, a general guideline was already presented in the 1995 workshop (ICES, 1996).During the workshop several presentations of the biology of redfish by species and areas were given (see Agenda in Annex 2). It was acknowledged that based on different life history and biological experiences, differences on growth pattern (hence in its interpretation) among species and stocks may exist. Additionally, otolith shape analyses performed during the EU REDFISH project (Stransky, 2005) showed differences in shape, especially in Barents Sea. This is the northernmost stock on redfish distribution, and the daylight variation regarding other stocks may affect growth pattern. This was considered as a good example on how both biology and environmental conditions may create differences in the otolith growth pattern, especially regarding transition zones, as maturation, for example. Thus, readers should know about the biology of fish to interpret properly the otolith growth pattern. However, it was agreed that considerably more effort and research is needed in this direction in particular for measuring growth increment pattern in the otolith. This technique is useful to identify growth patterns to be related with the biology of the species/stock, as well with environmental features, as done in *S. diploproa* (Black *et al*., 2005). Measuring growth increments is a hard task if not performed with the aid of image analysis. It is recommended that all labs with required facilities measure the size of the first few annuli (from the nucleus) in a reference collection in order to analyze growth increment patterns across species and stocks, as well as within stocks among cohorts.

There is other research that could contribute to understanding how to interpret redfish otolith growth patterns. This includes analysis of mean body length at age from surveys conducted at different times of the year. As well, validation studies documenting formation of annual growth increments could establish time of annulus formation. A good example was presented during the workshop when comparing mean length at age of Northeast Arctic *S. mentella* between two surveys conducted in autumn (Russian survey) and the following winter (Norwegian survey), as shown in Figure 12. When comparing the length at age between 2002 and 2005 (Figure 13) it was observed how well the independent routine readings correspond (at least until an age of 10–15) despite the two surveys being conducted one year apart (January 1st is standard birth date used by both countries), and during a time period when the growth increment is considered minimal.



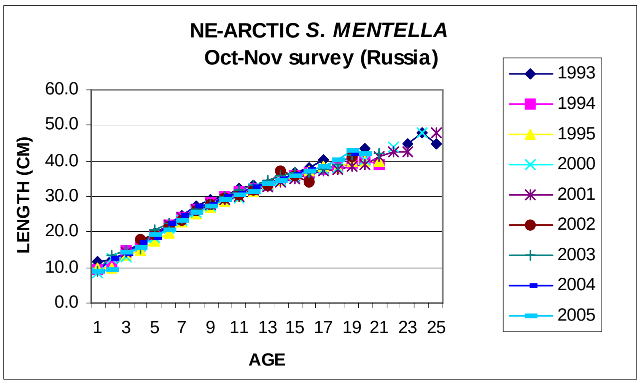


Figure 12. Mean length at age of S. mentella from the Russian autumn survey and the Norwegian winter survey during the last decade. The age has been determined by age readers at the respective laboratories using the otolith break-and-burn method. In Norway a change of age reader happened in 1996.

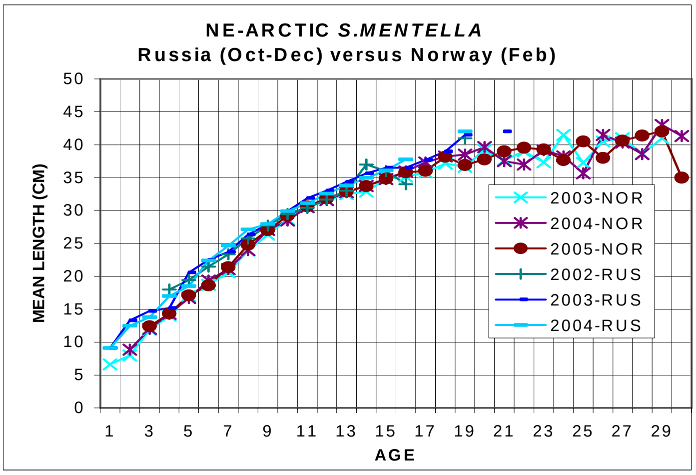


Figure 13. Mean length at age of *S. mentella* from the Russian autumn survey and the subsequent Norwegian winter survey during 2002–2005.

Table 11. Summary of growth parameters estimated for redfish from different areas.

Species	Material	Period	sex	Laboratory[1]	Method	Length range (cm)	N	von Bertalanffy parameters			Reference[1]
								L_{INF}	K	T_0	
S. marinus	Barents Sea	1985-1988	unsexed	3	Break & burn	8-82	488	50.20	0.110	0.080	3
S. marinus	Flemish Cap	1990-2000	males	4	Break & bake	8-51	3215	46.40	0.104	-0.790	4
S. marinus	Flemish Cap	1990-2000	females	4	Break & bake	11-57	2823	58.15	0.069	-1.490	4
S. marinus[2]	Iceland	1997	unsexed	1	Section	10-54	212	52.66	0.095	0.470	1
S. marinus[2]	Iceland	1997	unsexed	2	Section	10-54	199	46.36	0.131	1.587	1
S. marinus[2]	Iceland	1997	unsexed	3	Section	10-54	212	49.55	0.113	1.233	1
S. marinus[2]	Iceland	1997	unsexed	4	Section	10-54	212	49.00	0.121	1.427	1
S. marinus[2,3]	Iceland	1997	unsexed	1-4	Section	10-54	835	50.50	0.105	0.935	1
S. marinus[2]	Iceland	1997	unsexed	2	Break & burn	10-54	108	47.80	0.124	0.913	1
S. marinus	Iceland	1995-2002	unsexed	2	Break & burn	9-82	12974	50.33	0.088	-1.427	2
S. mentella	Barents Sea	1985-1988	unsexed	3	Break & burn	8-58	142	49.00	0.060	-2.470	3
S. mentella	Barents Sea	1995-2005	unsexed	5	Break & burn	5-48	4019	61.13	0.051	-2.243	6
S. mentella	Flemish Cap	1990-2000	males	4	Break & bake	9-47	3588	43.24	0.107	-1.070	4
S. mentella	Flemish Cap	1990-2000	females	4	Break & bake	11-46	3454	45.82	0.096	-1.280	4
S. mentella[4]	Irminger Sea	1999	unsexed	1	Section	22-41	213	40.08	0.066	-8.531	1
S. mentella[4]	Irminger Sea	1999	unsexed	2	Section	22-41	191	39.23	0.073	-6.379	1
S. mentella[4]	Irminger Sea	1999	unsexed	3	Section	22-41	213	39.27	0.069	-9.635	1
S. mentella[4]	Irminger Sea	1999	unsexed	4	Section	22-41	204	38.82	0.117	-2.293	1
S. mentella[4,3]	Irminger Sea	1999	unsexed	1-4	Section	22-41	824	39.31	0.078	-6.797	1
S. mentella[4]	Irminger Sea	1999	unsexed	2	Break & burn	20-52	920	44.27	0.087	-3.492	1
S. mentella[4]	Irminger Sea	1999	unsexed	3	Break & burn	21-50	426	43.06	0.107	-0.894	5
S. mentella	Irminger Sea	2001	unsexed	3	Break & burn	25-49	690	43.69	0.093	-2.463	5
S. mentella	Irminger Sea	2001	unsexed	3	Section	31-48	115	46.76	0.063	-6.577	5
S. mentella	Irminger Sea	1990-2005	unsexed	5	Scale	14-51	7748	71.64	0.042	-2.698	7
S. mentella	Irminger Sea	2005	unsexed	6	Section	26-43	385	37.45	0.136	-0.75	8
S. mentella	Irminger Sea	2006	unsexed	6	Section	28-50	337	48.17	0.065	-5.638	8
S. fasciatus	Flemish Cap	1990-2000	males	4	Break & bake	10-39	2628	40.31	0.119	-1.050	4
S. fasciatus	Flemish Cap	1990-2000	females	4	Break & bake	10-42	2559	44.04	0.103	-1.190	4

[1] See Annex 3 for details

[2] This is the same dataset read by four different laboratories and two different methods

[3]This is the above four data set combined

[4] This is the same dataset read by four different laboratories and two different methods

5 Combining time series of age readings based on scales and otoliths

The 1995 workshop (ICES, 1996) clearly recommended that "all routine age reading for North Atlantic redfish should be done using otoliths". Further, it was recommended that scales and otoliths of the same fish should be collected for another two years, and that scale/otolith comparisons should be carried out thereafter within small working groups. Norway, Russia and Spain followed these recommendations and organised a small age reading workshop in Bergen, Norway, in March 1997 (Saborido-Rey *et al*., 1997a,b). Two sets of material provided scale/otolith comparisons: 25 demersal *S. mentella* samples from the Barents Sea, collected in April 1996, and 89 pelagic *S. mentella* samples from the Irminger Sea, collected September/October 1995. Those comparisons showed good correspondence for the Barents Sea samples, but virtually no possible conversion between scales and otoliths for the Irminger Sea samples, as the younger ages were overestimated and older ages underestimated by scale readings, relative to the otolith readings. The highest age counted in the Irminger Sea scales was 23 years, whereas the otolith readings reached 39 years. As the maximum age of *S. mentella* in the Irminger Sea was recently validated to be at least 41 years (see Section 2; Stransky *et al*., 2005b), the scale readings of the Irminger Sea *S. mentella* are considered invalid, at least for older fish. In spite of observed differences also in young fish, historical data on scales reading can be used to observe recruitment and to use the youngest ages until a given age that should be defined.

Russia has continued to read scales of *S. mentella* in the Irminger Sea, but has also collected several thousand scales and otoliths from the same fish in the period 1999–2005. From the 2005 material, about 900 scale/otolith comparisons were made with fish ranging 26–42 cm of length and reaching 8–18 years of age, according to these readings. In 35% of the cases, the scale and otolith readings corresponded, 45% of the readings deviated by ±1 year, and 2% differed by ±2 years. However, as the Russian reading annotations on digital otolith thin-section pictures, visualised during this workshop (see Section 3), showed that the proximal zone of the otolith sections is not considered by the Russian readers, WKADR recommended that Russia re-reads the otoliths with the criteria of the 1995 workshop (ICES 1996) and sends sub-sets of these otoliths to other age reading labs for comparative reading within an otolith exchange (see Section 6). Also a second set of otoliths/scales is available from the Norwegian Sea from Russia that will be recommendable to read. Sets of these two collections will be included as part of otolith exchange during 2007.

6 Strategic plan for routine age determinations. Improving analytical assessment of the most important stocks

Only a few of the redfish stocks defined in the North Atlantic were assessed analytically, i.e. by catch-at-age or production models based on age data. Currently, only the Icelandic *S. marinus* (Div. Va) is assessed by the BORMICON production model (Björnsson and Sigurdsson, 2003) within the ICES North-Western Working Group (NWWG). In an experimental XSA of this stock (Rätz *et al*., 2004), three-year intervals (considering some uncertainty in age determination) were used as cohorts, which delivered similar biomass predictions as the BORMICON model. Previously, there had been attempts to use Russian scale reading data in a traditional VPA approach for Irminger Sea *S. mentella* (Blinov 1988a,b; Musaibeli, 1989; Pavlov and Galuzo, 1989) in the NWWG. In ICES Subareas I and II (northeast Arctic) experimental VPA/XSA have previously been conducted for *S. mentella* (e.g., ICES, 1997, 2003). For northeast Arctic *S. marinus*, an experimental analytical assessment using Gadget (Fleksibest), developed from BORMICON, has been part of the two most recent annual assessments (ICES 2005, 2006). In the NAFO area, where three species of redfish cohabit and several management units are described, only Flemish Cap stocks are assessed analytically. The present assessment evaluates the status of the Flemish Cap beaked redfish stock, regarded as a management unit composed of two populations from two very similar species (*Sebastes mentella* and *Sebastes fasciatus*). The reason for this approach is that evidence indicates this is by far the dominant redfish group on Flemish Cap. A virtual population analysis (XSA) and a surplus production analysis (ASPIC) were carried out for 1989–2004 and 1989–2002 respectively, providing indicators of stock biomass, female spawning biomass and fishing mortality trends (Avila de Melo *et al*., 2004). Assessment is conducted every two years.

The high bias and low precision observed in age determination of redfish, however, have prevented the common use of age data for other redfish stocks. The effects of age reading error on the assessment have not been tested thoroughly yet. Some modelling work (e.g. using GADGET) could help to understand these effects. The workshop recommends that all labs providing age data for assessments for a certain stock should investigate uncertainties in assessments due to age readings in redfish. Within the next two years, these analyses should be performed on those stocks that are currently assessed analytically (Icelandic *S. marinus*, Northeast Arctic *S. marinus*, and Flemish Cap beaked redfish).

The impact of uncertainties can also be studied or reduced by introducing quality control/assurance (QC/QA) measures in each age reading lab. This means developing and documenting standard protocols, conventions and procedures such as the documentation of age reading procedures (including training) and validation studies (see ToR a, b and d), the assessment of reader bias and precision (ToR b), regular exchanges and workshops, and the establishment of reference collections of growth structures. Good digital pictures of broken-and-burnt or thin-sectioned otoliths (see ToR b) could serve as a start for a reference collection. These pictures are available on data storage media and can be circulated quickly, while the original structures are stored securely in labs owning the material. All material read and discussed at the workshop are kept separately by the national labs. The broken-and-baked material is kept in Spain (IIM) as reference set. Reference material from past read otoliths should always be at the readers' side when reading new otoliths. This is to avoid drift caused by inconsistent application of criteria over time. It is especially useful for samples that present difficult to interpret patterns. In particular, a few otoliths (e.g. age 10 and 40 years) that clearly show the juvenile and mature growth patterns can help to avoid over-ageing young and under-ageing old otoliths. These are two common biases expressed by novices and those who do not spend extended time participating in age determination. Agencies should formally document the date that they began to use this criteria consistently.

Concerted actions (EFAN, 2001; TACADAR, 2006; CARE, 2006) have developed guidelines for QC/QA measures. Several national labs have implemented these measures (e.g. Gjøsæter and Nedreaas, 1999, Kimura and Anderl, 2005), and the ICES PGCCDBS (Planning Group on Commercial Catch, Discards and Biological Sampling) will endorse these developments.

The Workshop agreed that QC/QA should be implemented in all labs performing redfish age readings. QA is necessary to ensure good data quality, especially if age readings are going to be used in analytical assessment. The workshop also recommends developing for redfish the specific procedures used as Quality Control to test quality against set standards and the action to be taken when results don't meet standards. As first step, a reading confidence index should be tested within otolith exchanges (see below), agreed in the near future and implemented. But along the next two years specific procedures such as documentation, standardizing criteria and its application, routine exchanges, reference collections, precision testing systems, validation studies, etc. should be discussed by correspondence, agreed and implemented.

Each laboratory should develop and implement a standard documented confidence index of "readability" for assigning a quality assessment to age data. It should incorporate criteria for the readers to quantitatively (estimate precision) and qualitatively (pattern clarity) express the quality of the age estimates they produce. Like an ageing method, the index needs to have criteria and readers must learn be consistent in how they assign the index to each age. This provides reader with a tool to "honestly" express the quality of each age assessment. The index also provides users with the means to make decisions about how to handle age data and which to incorporate into their analyses. So, it is recommended that the readers and data users work together to produce this index. There is a caution to users to recognise the potential for biased analysis results if eliminating all the poor quality data that are e.g. one gender, older individuals etc. As a starting point for developing this tool, the redfish age readers and data users should review suitable indexes evaluating currently in use by other laboratories, test it in their labs, and report to the responsible/coordinating scientist. In addition, when participating in exchanges, different labs are requested to include their quality assignment as a parameter. Agencies are asked to provide documentation of the confidence index of their choice to each other along 2007 during the otolith exchange.

During the next two years, specific procedures such as documentation, standardizing criteria and its application, routine exchanges, reference collections, precision testing systems, validation studies, etc. should be discussed by correspondence, agreed and implemented.

Further otolith exchanges and next workshop

Several otolith exchanges have been set up to be completed during the next two years (Table 12). A part of this material (Irminger Sea *S. mentella* collected in 2000 and 2001, Icelandic *S. marinus* collected in 2000) has been validated radiometrically (Stransky *et al.*, 2005b) and is stored in Germany. In the material from Icelandic *S. marinus* and Flemish Cap redfish, the strong 1990 year-classes can be followed and used as validation. The exchange of Russian *S. mentella* material from the Irminger Sea and Norwegian Sea will also serve the comparison of data series on Russian scale readings and international otolith readings of the same fish (see Section 5).

The workshop recommends holding the next workshop in 2008 to analyse the results of the exchanges, to continue to promote standardisation of methodologies and practices for age determination of redfish and to monitor the progress in QC/QA implementation. The workshop recommends as venue the Fish Aging Lab at Pacific Biological Station, DFO, Nanaimo, Canada, where 8–9 very experienced rockfish agers are working. Together they embody about 150 years of fish ageing experience with several Pacific marine species (groundfish, salmon, herring, shellfish) and age determination methodologies. Agers have been trained using standard protocols with documented procedures (manual & QA/QC). Finally, the facilities available (10 workstations with latest high quality equipment to work at, including a teaching scope) will probably allow working one-on-one with each visiting workshop participant.

Table 12. Otolith exchange sets to be circulated among readers during 2006 and 2007.

Country	Species	Area	Type1	Gear[2]	Sampling period	Structure[3]	Method[4]	Number of otoliths	Co-ordinator	Participating countries	Exchange period
Germany	*S. mentella*	ICES XIVb	Res	Dem	2000	oto	bb	30	Germany	NO, ES, IS, CAN, RUS, POL, DE	Nov 2006-May 2007
Germany	*S. mentella*	ICES XII; NAFO 1F/2H/2J	Res	pel	2001	oto	bb	30	Germany	NO, ES, IS, CAN, RUS, POL, DE	Nov 2006-May 2007
Iceland	*S. marinus*	ICES Va	Com	dem	2000	oto	bb	30	Germany	DE, ES, CAN, RUS, POL, NO, IS	Nov 2006-May 2007
Iceland	*S. marinus*	ICES Va	Res	dem	1995-2005	oto	bb	30 (1990 year-class)	Iceland	ES, CAN, RUS, POL, DE, NO, IS	Dec 2006-Jun 2007
Russia	*S. mentella*	ICES XII,XIV; NAFO 1F	Com	pel	1999-2005	oto	bb	100	Russia	IS, CAN, POL, DE, NO, ES, RUS	Dec 2006-Aug 2007
Russia	*S. mentella*	ICES II (Norw.Sea)	Com	pel	2006	oto/sc	bb	30	Russia	IS, CAN, POL, DE, NO, ES, RUS	Feb 2007-Aug 2007
Spain	*S. marinus*	NAFO 3M	Res	dem	1991-2006	oto	bb/bk	30 (1990 year-class)	Spain	CAN, RUS, POL, DE, NO, IS, ES	Feb 2007-Aug 2007
Spain	*S. mentella*	NAFO 3M	Res	dem	1991-2006	oto	bb/bk	30 (1990 year-class)	Spain	CAN, RUS, POL, DE, NO, IS, ES	Feb 2007-Aug 2007
Spain	*S. fasciatus*	NAFO 3M	Res	dem	1991-2006	oto	bb/bk	30 (1990 year-class)	Spain	CAN, RUS, POL, DE, NO, IS, ES	Feb 2007-Aug 2007

[1] Res= research, com= commercial

[2] dem=demersal, pel= pelagic

[3] oto= otoliths, sc=scales

[4] bb = break-and-burn; bk = break-and-baked; ts = thin-section

7 Recomendations

ToR b

- The reader should avoid ageing along the otolith cross-section's dorsal-distal axis and ALWAYS count annuli along a nucleus to proximal edge axis to avoid i) missing post maturity growth not visible on the dorsal axis and ii) mis-interpreting prominent checks as annuli. Ref. Protocol for redfish age determination, ICES CM 1996/G:1 and MacLellan (1997). Agencies should formally document the date that they began to use this criteria consistently.
- Each laboratory should develop and implement a standard documented confidence index of "readability" for assigning a quality assessment to age data. It should incorporate criteria for the readers to quantitatively (estimate precision) and qualitatively (pattern clarity) express the quality of the age estimates they produce. Agencies are asked to provide documentation of the confidence index of their choice to each other along 2007 during the otolith exchange.
- The first few annuli on known-age fish and on very clear patterned otoliths from each species/stock should be measured. The measurements would provide standardized measurements to identify the likely position of these annuli. Such measurements could be the distance from the nucleus to the dorsal tip of the growth zone, and/or from the ventral to the dorsal tip of the growth zone (i.e. across the nucleus). Agencies should formally document the date that they began to use this criteria consistently.
- Reference material from past read otoliths should always be at the readers' side when reading new otoliths. This is to avoid drift caused by inconsistent application of criteria over time. It is especially useful for samples that present difficult to interpret patterns. Agencies should formally document the date that they began to use this criteria consistently.

ToR c

- Comparisons of otolith preparation methods (break-and-burn, break-and-bake, thin-sectioning) and the analysis of related differences should be continued. As first step, during the otolith exchange in 2007 the collection sets should be prepared with different methods and read by all participating readers.
- The preparation efficiencies per otolith of the three methods currently used for redfish age determination need to be properly assessed (i.e. time for all steps from pulling otolith out of storage unit to ready for ageing). It is important to do so in order to properly judge & compare before reaching conclusions regarding method efficiencey. It is recommended that the agencies should systematically measure the efficiencies of each potential method as standard process.

ToR d

- To estimate VbF growth curves following the same and standardized methods and in sexed fish. Spain will provide a standardization protocol during 2007.
- It is recommended that all labs with required facilities measure the distance of each annulus, or at least the first three annuli**,** from the nucleus, in a reference collection in order to analyze annual growth increment pattern across species and stocks, as well within stock among cohorts. Norway will provide a protocol to be used by all agencies.

ToR e

- There is already a good collection of scales and otoliths in Russia (1999–2005 at least with ca. 1000 thousands otoliths/scales per year), it is recommended that otoliths should be read again by Russian experts considering the proximal growth zone and read also by other countries experts to create the requested database in order to proceed with comparisons. Also a second set of otoliths/scales is available from Norwegian Sea from Russia that will be recommendable to read. Sets of these two collections will be included as part of otolith exchange during 2007, but giving the importance of both scale collections it is recommended to exchange a series of small samples (e.g. 20 otoliths) between Russian experts and the others to provide feedback quickly, along 2007 and 2008.

- As agreed in 1995, it is strongly recommended using only otoliths for age determination of redfish (ICES, 1996)

ToR f

- The workshop agreed on several sets of exchange samples for the purpose of inter-calibration between ageing labs within the next 2 years.
- All labs providing age data for assessments for a certain stock should investigate uncertainties in assessments due to age readings in redfish. Within the next 2 years, these analyses should be performed on those stocks that are currently assessed analytically (Icelandic *S. marinus*, NE Arctic *S. marinus*, Flemish Cap beaked redfish) by responsible laboratories of those stocks.
- The workshop agreed that Quality Control/Quality Assurance (QC/QA) should be implemented in all labs performing redfish age readings. The workshops also recommend developing for redfish the specific procedures used as Quality Control to test quality against set standards and the action to be taken when results don't meet standards. As first step, a reading confidence index should be tested within otolith exchanges (see below), agreed in the near future and implemented. But along the next two years specific procedures such as documentation, standardizing criteria and its application, routine exchanges, reference collections, precision testing systems, validation studies, etc. should be discussed by correspondence, agreed and implemented.
- New workshop to be held in 2008 to analyse the results of the exchanges and to continue to promote standardisation of methodologies and practices for age determination of redfish and to monitor the progress in QC/QA implementation.

ToR g

- As significant progress on redfish age determination, especially regarding the assessment of the efficiency of the various otolith preparation methods and the implementation of QC/QA, is expected during the next two years, the envisaged publication of workshop (and exchange) results in an ICES Cooperative Research Report (CRR) will be collated after the 2008 workshop.

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Most of these references are available for download on the WKADR homepage [http://www.redfish.de/wkadr/].