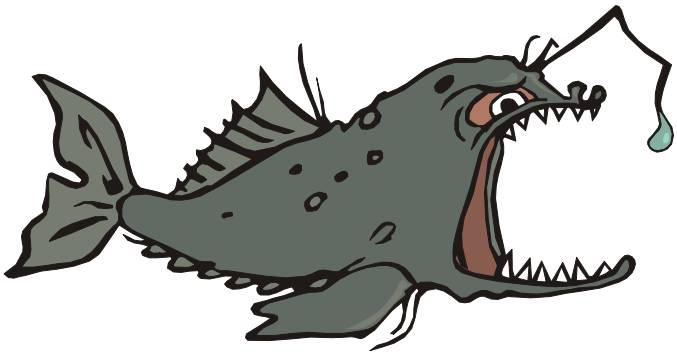
ICES Planning Group on Commercial Catch, Discards and Biological Sampling (PGCCDBS)

Report of the

Anglerfish *Illicia*/Otoliths Ageing Workshop

IPIMAR
Lisbon, Portugal
8-12 November 2004



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Duarte, R., Landa, J., Morgado, C., Marçal, A., Warne, S., Barcala, E., Bilbao, E., Dimeet, J., Djurhuus, H., Jónsson, E., McCormick, H., Ofstad, L., Quincoces, I., Rasmussen, H., Thaarup, A., Vidarsson, T. and Walmsley, S., 2005. Report of the Anglerfish *Illicia*/Otoliths Ageing Workshop. IPIMAR (Lisbon), 47pp.

Abstract

The age information provided for stock assessment of white anglerfish (*Lophius piscatorius*) and black anglerfish (*L. budegassa*) in the ICES area is based on age readings of two different calcified structures, the *illicium* (first ray of the first dorsal fin) and the *sagitta* otolith. The ICES Planning Group on Commercial Catch, Discards and Biological Sampling (PGCCDBS) considered that anglerfish required an improvement in ageing precision due to the different age reading structures and proposed an anglerfish ageing workshop to focus on this problem. Therefore, during 2004 collections of *illicia* and otoliths from the same fish were assembled for both species and circulated amongst interested readers. Results indicated discrepancies between otoliths and *illicia* readings. For white anglerfish there was only 27% agreement between experienced *illicia* readers and one experienced otolith reader (11% for the other experience otolith reader) and for black anglerfish the agreement between *illicia* and otoliths was only 8% for both reference readers. Within each structure, between reader agreement was higher in *illicia* than otoliths (for experienced and non-experienced readers), since for both species *illicia* readings were more precise and less biased compared to otolith readings. The present exchange and workshop results showed that standardization of otolith ageing criteria is necessary and that only after a better agreement between otolith readers would it be possible to analyse further the discrepancies of interpretation between structures. In addition, results from recent validation studies were compared with results from *illicia* readings, suggesting that white anglerfish growth may be faster and black anglerfish growth may be similar or slower than that estimated by *illicia*.

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1 INTRODUCTION

White and black anglerfish (*Lophius piscatorius* and *L. budegassa*) are two important species in European fisheries. They are mainly caught by trawlers and by artisanal fleets using fixed nets.

The geographical distribution of both species is similar with white anglerfish having a more Northern and black anglerfish a more Southern distribution. In the Eastern North Atlantic white anglerfish occurs from the Barents Sea to the Straits of Gibraltar (Figure 1.1) and black anglerfish from the British Isles to Senegal (Figure 1.2). Both species occur in the Mediterranean and Black Sea.

For stock assessment under ICES, three areas are defined and assessed annually (Figure 1.3) - the Southern stock in Divisions VIIIc and IXa, the Northern stock in Divisions VIIb-k and VIIIa,b,d and the stock on the Northern shelf including Divisions IIIa, IVa,b,c and VIa,b. The Northern and Southern stocks are assessed in the WGHMM (ICES Working Group on the Assessment of Southern Shelf Stocks of Hake, Monk and Megrim) using stock production models (Southern stock) and an age-structured model (Northern stock). The age information available for both is provided by age readings from *illicia* (first dorsal fin ray). The Northern shelf stock is assessed in the WGNSDS (ICES Working Group on the Assessment of Northern Shelf Demersal Stocks) using length-structured models and the age information is based on otolith and *illicia* readings, but not used in the assessment.

The ICES Planning Group on Commercial Catch, Discards and Biological Sampling (PGCCDBS) held in Rome in March 2003 considered that anglerfish required an improvement in ageing precision, principally due to the different age reading structures used (*illicia* and otoliths) (ICES, 2003). This group proposed an anglerfish ageing workshop in 2004 to focus on this problem.

Ageing exchanges and workshops are an important forum to:

- Re-confirm ageing criteria,
- Prevent drift,
- Introduce new readers,
- Compare reading structures,
- Provide discussion between Institutes.

During 2004 an *illicia* and otolith collection from the same fish was assembled for white and black anglerfish. Age readers were contacted and collections circulated to all countries. An ageing workshop was planned for November 2004 with the objectives described below.

1.1 Objectives

a) Analyse and discuss the *illicia*/otolith exchange results for both species considering:
   - Between all reader agreement in each structure,
   - Between experienced reader agreement in each structure,
   - Between structure agreement.

b) Discuss recent validation advances.

1.2 Structure of the report

The present report contains the results of the exchange in section 2, regarding the analysis of the age readings (section 2.2.1) and of the images (section 2.2.2.) and contains a revision of recent studies in *Lophius* age validation in section 3. Results of the present exchange are discussed in section 4, focusing also on the age validation results. Conclusions and recommendations are presented in sections 5 and 6. Working documents to the workshop are listed in section 8.

Figure 1.1. White anglerfish (*L. piscatorius*) geographical distribution (Figure from Quincoces, 2002).

Figure 1.2. Black anglerfish (*L. budegassa*) geographical distribution (Figure from Quincoces, 2002).

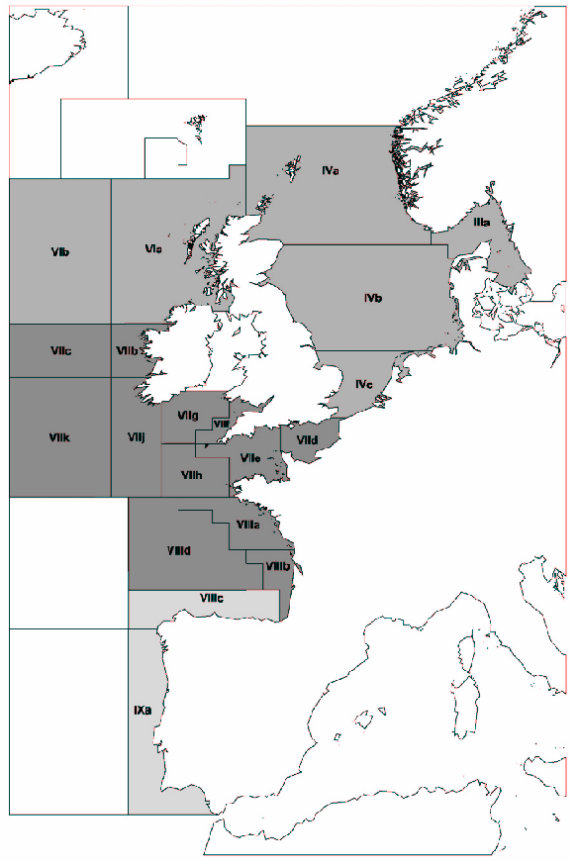

Figure 1.3. Stock units defined by ICES. Southern stock in Divisions VIIIc and IXa, Northern stock in Divisions VIIb-k and VIIIa,b,d and stock on the Northern shelf in Divisions IIIa, IVa,b,c and VIa,b (Figure from Quincoces, 2002).

1.3 Participants

Name	Institute	Country	Exchange	Workshop
Rafael Duarte (coordinator)	IPIMAR	Portugal	X	X
António Marçal	IPIMAR	Portugal	X	X
Cristina Morgado	IPIMAR	Portugal		X
Jorge Landa	IEO	Spain	X	X
Joaquín Barrado	IEO	Spain	X	
Elena Barcala	IEO	Spain		X
Iñaki Quincoces	AZTI	Spain	X	X
Eli Bilbao	AZTI	Spain	X	X
Joel Dimeet	IFREMER	France	X	X
Gráinne Ní Chonchúir	Mar. Inst.	Ireland	X	
Helen McCormick	Mar. Inst.	Ireland	X	X
Sally Warne	CEFAS	UK (England)	X	X
Sarah Walmsley	CEFAS	UK (England)	X	X
Phil Large	CEFAS	UK (England)	X	
Lise Helen Ofstad	FRS	Faroe Islands	X	X
Hanna Elina Djurhuus	FRS	Faroe Islands	X	X
Einar Jónsson	MRI	Iceland		X
Thordur Vidarsson	MRI	Iceland	X	X
Gordon Henderson	MARLAB	UK (Scotland)	X	
Helle Rasmussen	DIFRES	Denmark		X
Aage Thaarup	DIFRES	Denmark		X

Addresses from all participants are in annex 1.

2 EXCHANGE RESULTS

2.1 Material and Methods

The workshop was carried out following the recommendations of the EFAN (European Fish Ageing Network) Report 3 on Guidelines and Tools for Age Reading Comparisons (Eltink *et al*., 2000).

In order to achieve the main objective of the workshop, a collection of *illicia* sections and whole otoliths (s*agitta*) from the same fish (50 white anglerfish and 50 black anglerfish) were circulated amongst interested Institutes during 2004. Digitised images from the *illicia* sections and otoliths accompanied the exchange collection. All *illicia* images had the same magnification while for the otoliths images the magnification varied. The white anglerfish structures were from ICES Area VII (provided by CEFAS) and the black anglerfish structures were from ICES Area IX (provided by IPIMAR). All the *illicia* sections were prepared according to the standard methodology by IPIMAR. The white anglerfish collection comprises total length range of 27 to 96 cm, but smaller individuals are not well represented. The black anglerfish collection comprises total length range of 20 to 68 cm. Table 2.1 gives the readers identification (ID) used in the results, the structures aged by each reader and the ageing experience of each reader for each structure.

Table 2.1. Names of the exchange participants with reader's ID, the collections read by each reader and their level of experience of ageing each structure.

Name	Institute	Country	Reader ID	Exchange age readings				Experience	
				White anglerfish		Black anglerfish			
				illicia	otoliths	*illicia*	Otoliths	*illicia*	otoliths
R. Duarte	IPIMAR	Portugal	R1	**X**	**X**	**X**	**X**	H	L
A. Marçal	IPIMAR	Portugal	R2	**X**	**X**	**X**	**X**	H	L
I. Quincoces	AZTI	Spain	R3	**X**	**X**	**X**	**X**	H	L
J. Landa	IEO	Spain	R4	**X**	**X**	**X**	**X**	H	L
P. Large	CEFAS	England	R5	**X**	**X**	**X**	**X**	L	H
S. Warne	CEFAS	England	R6	**X**	**X**	**X**	**X**	L	H
S. Walmsley	CEFAS	England	R7	**X**	**X**	**X**	**X**	M	L
J. Dimeet	IFREMER	France	R8	**X**		**X**		M	L
J. Barrado	IEO	Spain	R9	**X**	**X**	**X**	**X**	M	L
H. McCormick	Mar. Inst	Ireland.	R10	**X**	**X**	**X**	**X**	M	L
E. Bilbao	AZTI	Spain	R11					M	L
G. Ní Chonchúir	Mar. Inst	Ireland	R12	**X**		**X**		M	L
T. Vidarsson	MRI	Iceland	R13	**X**		**X**		M	L
G. Henderson	MARLAB	Scotland	R14		**X**		**X**	L	H
L. Ofstad	FRS	Faroe Isl	R15	**X**				M	L
H. Djurhuus	FRS	Faroe Isl.	R16	**X**				M	L

H – high; M- medium; L - low

A protocol (Annex 2) for the *illicia*/otoliths exchange was circulated with the collections. The general criteria adopted for ageing the *illicia* exchange collection is described in the Anglerfish Ageing Guide (Duarte *et al*., 2002). It was sent to all participants in order to reinforce the standard criteria. Ageing criteria for reading anglerfish otoliths was provided by CEFAS and was included in the exchange protocol. Gordon Henderson (MARLAB) provided

an alternative otolith ageing protocol, which was used for informative purposes only (Annex 3).

Readers counted the annual rings and marked them in the images. The only information the readers had about the structures was the length range (10 cm range). The ID number of both structures was different in order to avoid comparisons between structures.

Data Analysis

In the present study, with two structures from the same fish, two types of analysis were performed. The first analysed the age reading consistency between readers within each structure (precision) and the second analysed the age reading discrepancies between structures.

The first analysis was performed using an Excel ad-hoc Workbook "AGE COMPARATIONS. XLS" from A.T.G.W. Eltink from RIVO following the recommendations of EFAN (Eltink *et al*., 2000). This analysis is based on a reference age when there are no validated ages available, which is the case for these species. Two independent analyses were performed adopting the modal age of the experienced readers in each structure as the reference age. For *illicia* a modal age from readers with high experience (R1, R2, R3 and R4) was used and an additional analysis was carried out using *illicia* ages from the Institutes which provide or will provide ALK's to the ICES WGHMM for the assessment of the Anglerfish Northern Stock (R8, R9, R10, R11 and R12) (Annex 4). For otoliths, two different reference ages were used due to the low agreement between the high experienced otoliths readers (R5, R6 and R14). Therefore two otolith analyses are presented using R6 and R14 as reference readers. Also, to assess the agreement between readers within each structure the Average Percent of Error (APE) (Beamish and Fournier, 1981) was calculated by species and structure.

$$APE = \frac{100}{n}\sum_{i=1}^{n}\left(\frac{1}{r}\sum_{j=1}^{r}\frac{\left|x_{ij}-\bar{x}_i\right|}{\bar{x}_i}\right)$$

n = number of *illicia*/otoliths
r = number of readings for each *illicia*/otoliths (readers)
xij = the *j* value of age estimation for the *i illicia*/otoliths
$\bar{x}_i$ = average age calculated for the *i illicia*/otoliths

For the second type of analysis, the difference between otolith reference age (R6 and R14) and the *illicia* modal age was calculated for each fish. The differences were quantified and percentages were calculated.

Images

All images with rings marked by reader were observed and images with high agreement between readers were selected. An additional analysis with only results from the selected images using the method from A. T. G. W Eltink from RIVO (Eltink *et al*., 2000) was also performed. The same procedure as in the previous analysis was adopted.

2.2 Results

2.2.1 Age Readings

2.2.1.1 White anglerfish

White anglerfish *illicia*

The *illicia* age reading results by reader, modal age of experienced readers and percentage of agreement are shown in the Annex 5.

The APE for this structure is 16.0%.

The number of age readings, CV, percentage of agreement and absolute bias by reference age are presented in Table 2.2. The CV ranges between 9.0 – 27.3%, and the lowest values correspond to high experienced *illicia* readers (R2, R1 and R4). The percentage of agreement ranged between 24.5 – 70.0%, and the highest agreement with the modal age was from R2, R4 and R1 (high experienced *illicia* readers). Absolute bias (mean age of each reader – reference age) was higher for older ages. Low experienced *illicia* readers showed a tendency to underestimate the ages.

The inter-reader bias test is presented in Table 2.3. Reader R2, R4, R5, R6, R12 and R15 showed no sign of bias when compared with the modal age. Generally, readers involved in ageing the Northern stock showed no or some sign of bias between themselves (R8, R9, R10, R11 and R12) and no sign of bias is observed between the two current Southern stock readers (R2 and R4). By comparing the current Northern and Southern stock readers it is seen that two of the Northern (R8 and R11) showed certainty of bias with the Southern readers. Also, the new Southern and Northern stock reader (R9) showed lower signs of bias with the Northern readers (R8, R10, R11 and R12) than with the Southern readers (R2 and R4). It should be noted that this test is very sensitive to large differences in the assigned ages in just one fish.

The age bias plots by reader (Figure 2.1) showed that in general terms high experienced readers (R1, R2, R4) and other readers involved in *illicia* reading (R8, R9, R10, R11, R12) showed low bias to the modal age and low variability. The high experienced reader R3 showed a tendency to overestimate ages compared to the modal age and a high variability. However this reader no longer routinely reads *illicia*. A third group of new *illicia* readers (R15 and R16) also showed low bias to the modal age and relatively low variability. *Illicia* reader R13 showed higher bias and variability compared to the previous group. Otolith experience readers R5, R6 and R7, with no experience in *illicia* readings, showed high variability and bias.

The additional analysis using the Northern stock readers as reference showed high agreement (APE = 10.4%) (Annex 4).

Table 2.2. The number of age readings, CV, percentage of agreement and absolute bias by reference age (mode of R1, R2, R3 and R4 readings) of white anglerfish *illicia*.

NUMBER OF AGE READINGS

MODAL age	Rafael Reader 1	António Reader 2	Inaki Reader 3	Jorge Reader 4	Phil Reader 5	Sally Reader 6	Sarah Reader 7	Joel Reader 8	Joaquin Reader 9	Helen Reader 10	Eli Reader 11	Grainne Reader 12	Vidarsson Reader 13	Lise Reader 15	Hanna Reader 16	TOTAL
0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	60
3	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	105
4	10	10	10	8	10	9	10	10	8	10	10	10	10	10	10	145
5	6	6	6	6	6	6	6	6	5	6	6	6	6	6	6	89
6	3	3	3	3	3	3	3	3	3	3	3	3	2	3	3	44
7	5	5	4	5	5	5	5	5	3	5	5	5	5	5	5	72
8	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15
9	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	105
10	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15
11	1	1	1	1	1	1	1	1	-	1	1	1	1	1	1	14
12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15
14	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15
15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total 0-15	50	50	49	48	50	49	50	50	43	50	50	50	49	50	50	738

COEFFICIENT OF VARIATION (CV)

MODAL age	Rafael Reader 1	António Reader 2	Inaki Reader 3	Jorge Reader 4	Phil Reader 5	Sally Reader 6	Sarah Reader 7	Joel Reader 8	Joaquin Reader 9	Helen Reader 10	Eli Reader 11	Grainne Reader 12	Vidarsson Reader 13	Lise Reader 15	Hanna Reader 16	ALL Readers
0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2	23%	22%	22%	38%	38%	41%	0%	23%	40%	41%	23%	22%	0%	22%	55%	27.6%
3	0%	22%	20%	18%	28%	27%	21%	20%	12%	15%	14%	23%	23%	22%	13%	22.8%
4	13%	8%	31%	17%	43%	47%	31%	22%	20%	20%	25%	29%	35%	22%	36%	23.9%
5	8%	0%	16%	8%	19%	37%	11%	18%	16%	10%	19%	19%	27%	19%	27%	18.9%
6	11%	0%	13%	9%	29%	24%	12%	14%	9%	9%	9%	18%	24%	14%	9%	15.4%
7	20%	17%	13%	0%	8%	17%	14%	17%	8%	7%	8%	21%	16%	8%	13%	14.4%
8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9	15%	6%	15%	4%	25%	26%	16%	9%	8%	13%	16%	13%	24%	13%	26%	19.7%
10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Weighted mean 0-15	10.3%	9.0%	17.0%	10.8%	23.9%	27.3%	15.0%	15.1%	13.8%	13.7%	14.7%	18.2%	19.8%	15.1%	22.3%	20.7%
RANKING	2	1	10	3	14	15	7	9	5	4	6	11	12	8	13	

PERCENTAGE AGREEMENT

MODAL age	Rafael Reader 1	António Reader 2	Inaki Reader 3	Jorge Reader 4	Phil Reader 5	Sally Reader 6	Sarah Reader 7	Joel Reader 8	Joaquin Reader 9	Helen Reader 10	Eli Reader 11	Grainne Reader 12	Vidarsson Reader 13	Lise Reader 15	Hanna Reader 16	ALL
0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2	50%	75%	75%	50%	50%	50%	100%	50%	75%	50%	50%	75%	100%	75%	25%	63%
3	100%	57%	29%	71%	43%	43%	57%	29%	86%	43%	14%	0%	43%	57%	86%	50%
4	70%	90%	60%	50%	40%	33%	30%	40%	38%	40%	20%	40%	40%	40%	20%	43%
5	83%	100%	17%	83%	17%	17%	67%	17%	40%	67%	33%	33%	17%	50%	50%	46%
6	33%	100%	0%	67%	0%	33%	0%	33%	33%	33%	33%	0%	0%	33%	67%	32%
7	40%	40%	75%	100%	60%	40%	20%	40%	33%	40%	60%	40%	0%	60%	40%	46%
8	100%	0%	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	20%
9	43%	71%	0%	86%	0%	0%	14%	43%	71%	57%	14%	14%	0%	29%	0%	30%
10	100%	100%	0%	100%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	100%	33%
11	100%	0%	0%	100%	0%	0%	0%	0%	-	0%	100%	0%	0%	0%	0%	21%
12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13	0%	100%	0%	100%	0%	0%	0%	0%	100%	0%	0%	0%	100%	0%	0%	27%
14	0%	100%	0%	100%	0%	0%	0%	100%	100%	100%	0%	0%	0%	0%	0%	33%
15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Weighted mean 0-15	60.0%	70.0%	32.7%	68.8%	26.0%	24.5%	34.0%	32.0%	53.5%	42.0%	26.0%	26.0%	28.6%	40.0%	34.0%	39.7%
RANKING	3	1	9	2	12	15	7	10	4	5	12	12	11	6	7	

RELATIVE BIAS

MODAL age	Rafael Reader 1	António Reader 2	Inaki Reader 3	Jorge Reader 4	Phil Reader 5	Sally Reader 6	Sarah Reader 7	Joel Reader 8	Joaquin Reader 9	Helen Reader 10	Eli Reader 11	Grainne Reader 12	Vidarsson Reader 13	Lise Reader 15	Hanna Reader 16	ALL
0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2	0.50	0.25	0.25	-0.50	-0.50	0.00	0.00	0.50	0.50	0.00	0.50	0.25	0.00	0.25	-0.25	0.12
3	0.00	0.14	1.00	-0.29	-0.29	0.00	-0.43	1.00	0.14	0.57	1.00	0.86	0.86	0.14	-0.14	0.30
4	-0.30	-0.10	0.40	0.25	-0.50	-0.11	-0.30	1.10	0.13	0.00	0.70	0.80	0.20	0.30	-0.50	0.14
5	-0.17	0.00	1.50	0.17	-0.50	0.33	-0.33	1.67	0.20	0.33	1.17	0.50	1.83	0.33	-0.50	0.44
6	-0.67	0.00	2.00	0.33	-0.67	0.33	-1.33	1.00	0.67	0.67	0.67	0.33	0.00	1.00	0.33	0.32
7	-1.00	-1.00	0.50	0.00	-0.40	-1.00	-1.20	-0.40	0.67	0.60	-0.40	-0.60	-0.20	-0.40	-0.80	-0.42
8	0.00	2.00	0.00	2.00	2.00	-3.00	-2.00	1.00	2.00	2.00	1.00	-2.00	0.00	1.00	-2.00	0.27
9	-0.71	0.00	3.86	0.14	1.29	-0.71	-2.00	0.86	0.43	0.43	0.86	-0.43	1.43	-0.29	-0.57	0.30
10	0.00	0.00	6.00	0.00	2.00	-1.00	-3.00	1.00	1.00	1.00	2.00	0.00	3.00	2.00	0.00	0.93
11	0.00	1.00	7.00	0.00	3.00	-3.00	-2.00	-1.00	-	1.00	0.00	-2.00	1.00	1.00	1.00	0.50
12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13	-1.00	0.00	6.00	0.00	-4.00	-3.00	-2.00	-1.00	0.00	-2.00	-2.00	-3.00	0.00	-1.00	-2.00	-1.00
14	-3.00	0.00	3.00	0.00	-4.00	-4.00	-2.00	0.00	0.00	0.00	-1.00	-3.00	1.00	-3.00	-4.00	-1.33
15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Weighted mean 0-15	-0.36	-0.02	1.59	0.06	-0.16	-0.45	-0.86	0.74	0.35	0.32	0.58	0.06	0.67	0.12	-0.48	0.14
RANKING	8	1	15	3	5	9	14	13	7	6	11	2	12	4	10	

Table 2.3. Inter-reader bias test of white anglerfish *illicia*.

Inter-reader bias test and reader against MODAL age bias test

	Rafael Reader 1	António Reader 2	Inaki Reader 3	Jorge Reader 4	Phil Reader 5	Sally Reader 6	Sarah Reader 7	Joel Reader 8	Joaquin Reader 9	Helen Reader 10	Eli Reader 11	Grainne Reader 12	Vidarsson Reader 13	Lise Reader 15	Hanna Reader 16
Reader 1		**	**	**	–	–	**	**	**	**	**	*	**	**	–
Reader 2	**		**	–	–	–	**	**	**	*	**	–	**	–	*
Reader 3	**	**		**	**	**	**	**	**	**	**	**	*	**	**
Reader 4	**	–	**		–	–	**	**	**	*	**	–	**	–	*
Reader 5	–	–	**	–		–	*	**	**	*	**	–	**	–	–
Reader 6	–	–	**	–	–		*	**	**	**	**	–	**	*	–
Reader 7	**	**	**	**	*	*		**	**	**	**	**	**	**	*
Reader 8	**	**	**	**	**	**	**		*	–	–	**	–	**	**
Reader 9	**	**	**	**	**	**	**	*		–	–	–	–	–	**
Reader 10	**	*	**	*	*	**	**	–	–		–	–	–	–	**
Reader 11	**	**	**	**	**	**	**	–	–	–		**	–	**	**
Reader 12	*	–	**	–	–	–	**	**	–	–	**		**	**	*
Reader 13	**	**	*	**	**	**	**	–	–	–	–	**		**	**
Reader 15	**	–	**	–	–	*	**	**	–	–	**	–	**		**
Reader 16	–	*	**	*	–	–	*	**	**	**	**	*	**	**	
MODAL age	**	–	**	–	–	–	**	**	**	*	**	–	**	–	*

– = no sign of bias (p>0.05)
* = possibility of bias (0.01<p<0.05)
** = certainty of bias (p<0.01)

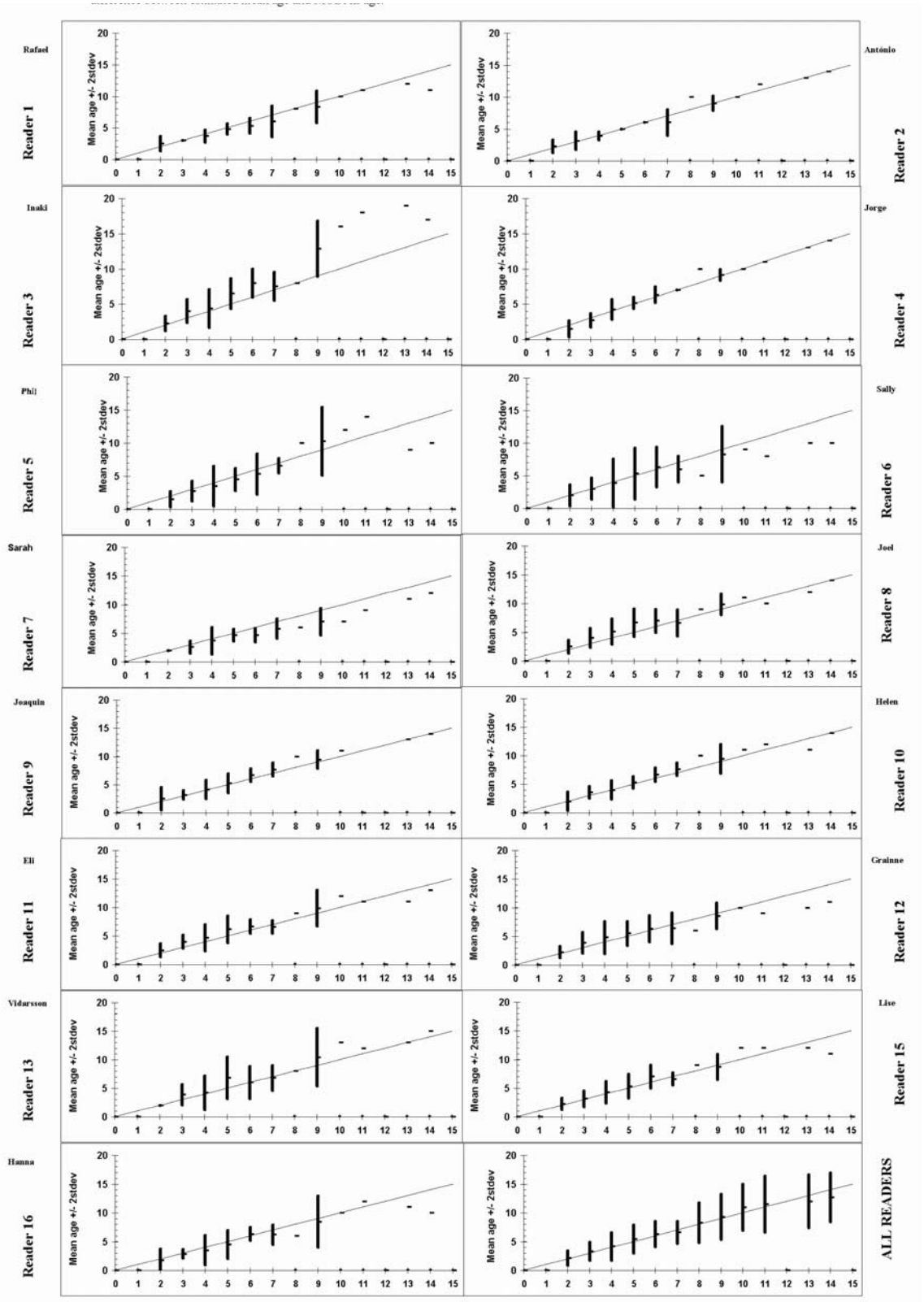

Figure 2.1. Mean age (-) +/- 2stdev versus modal age (solid line), based on results from readers R1, R2, R3 and R4, for white anglerfish aged using *illicia*.

White anglerfish otolith

The otolith age reading results by reader are shown in Annex 5.

The APE for this structure is 33.2%.

The number of age readings, CV, percentage of agreement and absolute bias by reference age are presented in Tables 2.4 and 2.5 for reference age R6 and R14, respectively. The CV ranged between 15.0 – 37.7% (R6) and 15.5 – 41.9% (R14). Experienced otolith readers (R5, R6 and R14) had a high CV.

The percentage of agreement ranged between 0.0 - 30.4% and 0.0 - 33.3% for reference age R6 and R14, respectively. The reader with the highest percentage agreement with the reference age R6 was an experienced otolith reader from the same institute (R5). Using R14 as the reference age the best agreement came from R9 (low experienced otolith reader).

For reference reader R6 absolute bias was least for the readers of the same institute (R5 and R7). When using R14 as the reference age the other experienced otolith readers (R5 and R6) underestimated the ages. Low experienced otolith readers showed a tendency to overestimate the ages for both reference ages (R6 and R14).

The inter-reader bias test is presented in Tables 2.6. Readers R5, R7 and R9 showed no sign or possibility of bias when compared with the reference age R6. Readers R1, R7, R9 and R10 showed no sign or possibility of bias when compared with the reference age R14. Generally, there was a significant bias for every other reader. Also, the two reference readers showed a certainty of bias between themselves.

The age bias plots by reader (Figure 2.2 and 2.3) show that in general all readers showed some bias, irrespective of their level of experience with otoliths. Some consistently overestimated the ages and others underestimated the ages but always with high variability. The results using both reference readers are similar.

Some readers only read about half of the otolith collection corresponding to smaller anglerfish (R1, R2, R9 and R10). The results from these readers had low CV values and variability due to the low number of readings. However these readers showed a tendency to overestimate compared to reference readers (R6 and R14).

Table 2.4. The number of age readings, associated CV's, percentage of agreement and absolute bias for each reader compared to the references ages of reader R6 for white anglerfish aged using otoliths.

NUMBER OF AGE READINGS

	Sally Reader 6	Rafael Reader 1	António Reader 2	Inaki Reader 3	Jorge Reader 4	Phil Reader 5	Sarah Reader 7	Joaquin Reader 9	Helen Reader 10	Eli Reader 11	Gordon Reader 14	TOTAL
	0	4	4	4	4	4	4	3	4	4	3	**38**
	1	10	10	4	6	10	10	4	10	5	10	**79**
	2	2	2	3	-	4	4	1	3	4	4	**27**
	3	4	4	4	8	9	9	5	6	7	9	**65**
	4	2	2	3	3	3	3	2	2	3	3	**26**
	5	-	-	3	3	4	5	4	-	4	5	-
	6	-	-	1	2	4	4	2	-	4	4	-
	7	-	-	1	2	2	2	1	-	1	2	-
	8	-	-	-	1	1	2	-	-	1	1	-
	9	-	-	3	1	2	3	3	-	3	3	-
	10	-	-	-	1	1	1	-	-	1	1	-
	11	-	-	1	2	2	2	2	-	2	2	-
	12	-	-	-	-	-	-	-	-	-	-	-
	13	-	-	-	-	-	-	-	-	-	-	-
	14	-	-	-	-	-	-	-	-	-	-	-
	15	-	-	-	-	-	-	-	-	-	-	-
Total	**0-15**	**22**	**22**	**27**	**33**	**46**	**49**	**27**	**25**	**39**	**47**	**337**

COEFFICIENT OF VARIATION (CV)

	Sally Reader 6	Rafael Reader 1	António Reader 2	Inaki Reader 3	Jorge Reader 4	Phil Reader 5	Sarah Reader 7	Joaquin Reader 9	Helen Reader 10	Eli Reader 11	Gordon Reader 14	ALL Readers
	0	13%	16%	13%	13%	40%	27%	17%	29%	22%	43%	**37.9%**
	1	20%	32%	20%	20%	37%	74%	27%	21%	27%	28%	**43.3%**
	2	20%	16%	16%	-	29%	37%	-	25%	18%	11%	**54.2%**
	3	0%	12%	14%	17%	47%	19%	26%	25%	34%	22%	**42.4%**
	4	35%	0%	22%	29%	43%	20%	28%	0%	31%	20%	**30.8%**
	5	-	-	31%	28%	47%	23%	27%	-	17%	24%	-
	6	-	-	-	11%	35%	38%	13%	-	17%	17%	-
	7	-	-	-	25%	28%	20%	-	-	-	0%	-
	8	-	-	-	-	-	0%	-	-	-	-	-
	9	-	-	4%	-	47%	13%	13%	-	8%	25%	-
	10	-	-	-	-	-	-	-	-	-	-	-
	11	-	-	-	16%	28%	9%	18%	-	11%	34%	-
	12	-	-	-	-	-	-	-	-	-	-	-
	13	-	-	-	-	-	-	-	-	-	-	-
	14	-	-	-	-	-	-	-	-	-	-	-
	15	-	-	-	-	-	-	-	-	-	-	-
Weighted mean	**0-15**	**16.7%**	**21.0%**	**15.0%**	**17.6%**	**37.7%**	**32.5%**	**20.4%**	**22.1%**	**20.6%**	**22.1%**	**41.1%**
	RANKING	**2**	**6**	**1**	**3**	**10**	**9**	**4**	**7**	**5**	**8**	

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	Sally Reader 6	Rafael Reader 1	António Reader 2	Inaki Reader 3	Jorge Reader 4	Phil Reader 5	Sarah Reader 7	Joaquin Reader 9	Helen Reader 10	Eli Reader 11	Gordon Reader 14	ALL
	0	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	**0%**
	1	0%	0%	0%	0%	70%	30%	0%	0%	0%	0%	**13%**
	2	0%	0%	0%	-	75%	25%	0%	0%	0%	0%	**15%**
	3	0%	0%	0%	0%	22%	22%	20%	17%	0%	22%	**12%**
	4	0%	0%	0%	33%	33%	33%	50%	0%	0%	33%	**19%**
	5	-	-	0%	0%	25%	20%	50%	-	0%	20%	-
	6	-	-	0%	50%	0%	0%	50%	-	0%	25%	-
	7	-	-	0%	50%	0%	0%	100%	-	0%	0%	-
	8	-	-	-	0%	0%	0%	-	-	0%	0%	-
	9	-	-	0%	0%	0%	33%	33%	-	0%	0%	-
	10	-	-	-	0%	0%	0%	-	-	0%	0%	-
	11	-	-	0%	0%	0%	0%	0%	-	0%	0%	-
	12	-	-	-	-	-	-	-	-	-	-	-
	13	-	-	-	-	-	-	-	-	-	-	-
	14	-	-	-	-	-	-	-	-	-	-	-
	15	-	-	-	-	-	-	-	-	-	-	-
Weighted mean	**0-15**	**0.0%**	**0.0%**	**0.0%**	**9.1%**	**30.4%**	**18.4%**	**25.9%**	**4.0%**	**0.0%**	**10.6%**	**11.6%**
	RANKING	**7**	**7**	**7**	**5**	**1**	**3**	**2**	**6**	**7**	**4**	

ABSOLUTE BIAS

	Sally Reader 6	Rafael Reader 1	António Reader 2	Inaki Reader 3	Jorge Reader 4	Phil Reader 5	Sarah Reader 7	Joaquin Reader 9	Helen Reader 10	Eli Reader 11	Gordon Reader 14	ALL
	0	3.75	3.50	4.50	3.75	1.25	3.00	3.33	3.25	4.50	1.33	**3.26**
	1	2.50	3.70	6.00	2.83	0.30	1.40	2.00	2.80	3.80	2.50	**2.53**
	2	1.50	2.50	7.33	-	-0.25	1.50	2.00	2.67	6.25	2.75	**3.00**
	3	1.00	1.25	6.50	2.38	-1.22	1.11	1.40	2.00	5.86	1.56	**1.95**
	4	0.00	1.00	4.00	1.33	-1.33	1.00	1.00	1.00	3.33	1.00	**1.31**
	5	-	-	9.00	3.33	-2.00	1.60	1.50	-	6.50	1.40	-
	6	-	-	6.00	0.50	-3.25	-1.50	-0.50	-	4.25	-0.25	-
	7	-	-	4.00	1.50	0.50	0.00	0.00	-	3.00	1.00	-
	8	-	-	-	1.00	-1.00	-2.00	-	-	4.00	1.00	-
	9	-	-	7.33	2.00	1.50	-1.00	-1.00	-	4.00	-1.00	-
	10	-	-	-	3.00	5.00	-1.00	-	-	3.00	3.00	-
	11	-	-	9.00	-2.00	1.50	-3.50	-3.00	-	2.00	-0.50	-
	12	-	-	-	-	-	-	-	-	-	-	-
	13	-	-	-	-	-	-	-	-	-	-	-
	14	-	-	-	-	-	-	-	-	-	-	-
	15	-	-	-	-	-	-	-	-	-	-	-
Weighted mean	**0-15**	**2.14**	**2.86**	**6.30**	**2.15**	**-0.39**	**0.65**	**0.93**	**2.52**	**4.67**	**1.38**	**1.68**
	RANKING	**5**	**8**	**10**	**6**	**1**	**2**	**3**	**7**	**9**	**4**	

Table 2.5. The number of age readings, associated CV's, percentage of agreement and absolute bias for each reader compared to the reference ages of reader R14 for white anglerfish aged using otoliths.

NUMBER OF AGE READINGS

	Gordon Reader 14	Rafael Reader 1	António Reader 2	Inaki Reader 3	Jorge Reader 4	Phil Reader 5	Sally Reader 6	Sarah Reader 7	Joaquin Reader 9	Helen Reader 10	Eli Reader 11	TOTAL
	0	-	-	-	-	-	-	-	-	-	-	-
	1	2	2	2	2	2	2	2	2	2	2	20
	2	3	3	2	3	3	3	3	2	3	3	28
	3	4	4	-	1	4	4	4	1	4	1	27
	4	7	7	4	5	8	8	8	5	8	5	65
	5	5	5	8	9	13	13	13	6	7	12	91
	6	-	-	6	4	7	7	7	6	-	7	-
	7	-	-	-	-	1	1	1	-	-	1	-
	8	-	-	3	3	3	4	4	3	-	3	-
	9	-	-	-	1	1	2	2	-	-	1	-
	10	-	-	1	1	1	1	1	1	-	1	-
	11	-	-	-	-	-	-	-	-	-	-	-
	12	-	-	-	-	-	-	-	-	-	-	-
	13	-	-	-	2	2	2	2	1	-	2	-
	14	-	-	-	-	-	-	-	-	-	-	-
	15	-	-	-	-	-	-	-	-	-	-	-
Total	0-15	22	22	27	33	46	49	49	27	25	39	339

COEFFICIENT OF VARIATION (CV)

	Gordon Reader 14	Rafael Reader 1	António Reader 2	Inaki Reader 3	Jorge Reader 4	Phil Reader 5	Sally Reader 6	Sarah Reader 7	Joaquin Reader 9	Helen Reader 10	Eli Reader 11	ALL Readers
	0	-	-	-	-	-	-	-	-	-	-	-
	1	20%	20%	0%	20%	0%	-	20%	20%	28%	35%	50.0%
	2	33%	0%	13%	17%	0%	87%	50%	28%	17%	25%	49.1%
	3	0%	20%	-	-	40%	58%	52%	-	20%	-	48.6%
	4	20%	28%	17%	20%	32%	67%	43%	15%	21%	39%	53.6%
	5	12%	12%	19%	19%	34%	47%	38%	33%	23%	24%	50.2%
	6	-	-	28%	7%	41%	36%	18%	19%	-	15%	-
	7	-	-	-	-	-	-	-	-	-	-	-
	8	-	-	29%	19%	25%	23%	16%	13%	-	10%	-
	9	-	-	-	-	-	33%	13%	-	-	-	-
	10	-	-	-	-	-	-	-	-	-	-	-
	11	-	-	-	-	-	-	-	-	-	-	-
	12	-	-	-	-	-	-	-	-	-	-	-
	13	-	-	-	34%	0%	7%	18%	-	-	5%	-
	14	-	-	-	-	-	-	-	-	-	-	-
	15	-	-	-	-	-	-	-	-	-	-	-
Weighted mean	0-15	15.5%	17.2%	18.6%	15.6%	26.4%	41.9%	30.6%	19.4%	20.8%	19.7%	46.3%
	RANKING	1	3	4	2	8	10	9	5	7	6	

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	Gordon Reader 14	Rafael Reader 1	António Reader 2	Inaki Reader 3	Jorge Reader 4	Phil Reader 5	Sally Reader 6	Sarah Reader 7	Joaquin Reader 9	Helen Reader 10	Eli Reader 11	ALL
	0	-	-	-	-	-	-	-	-	-	-	-
	1	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	10%
	2	33%	0%	0%	0%	0%	0%	33%	50%	0%	0%	11%
	3	0%	0%	-	0%	0%	50%	25%	0%	25%	0%	15%
	4	43%	29%	0%	80%	0%	13%	13%	60%	50%	0%	28%
	5	0%	60%	0%	22%	0%	8%	23%	33%	29%	0%	14%
	6	-	-	0%	25%	0%	14%	43%	33%	-	0%	-
	7	-	-	-	-	0%	0%	0%	-	-	0%	-
	8	-	-	0%	0%	0%	0%	50%	33%	-	0%	-
	9	-	-	-	0%	0%	0%	0%	-	-	0%	-
	10	-	-	0%	0%	0%	0%	0%	0%	-	0%	-
	11	-	-	-	-	-	-	-	-	-	-	-
	12	-	-	-	-	-	-	-	-	-	-	-
	13	-	-	-	50%	0%	0%	0%	0%	-	50%	-
	14	-	-	-	-	-	-	-	-	-	-	-
	15	-	-	-	-	-	-	-	-	-	-	-
Weighted mean	0-15	18.2%	22.7%	0.0%	24.2%	4.3%	10.2%	22.4%	33.3%	28.0%	2.6%	15.3%
	RANKING	6	4	10	3	8	7	5	1	2	9	

ABSOLUTE BIAS

	Gordon Reader 14	Rafael Reader 1	António Reader 2	Inaki Reader 3	Jorge Reader 4	Phil Reader 5	Sally Reader 6	Sarah Reader 7	Joaquin Reader 9	Helen Reader 10	Eli Reader 11	ALL
	0	-	-	-	-	-	-	-	-	-	-	-
	1	2.50	2.50	3.00	2.50	0.00	-1.00	2.50	2.50	1.50	3.00	1.90
	2	1.00	1.00	3.50	1.33	-1.00	-1.33	0.00	0.50	1.33	2.00	0.75
	3	1.00	1.75	-	2.00	-1.75	-1.00	-0.50	1.00	1.00	2.00	0.26
	4	-0.29	1.00	3.25	0.40	-2.38	-2.25	-1.13	-0.40	0.38	3.20	-0.14
	5	-1.20	-0.40	4.38	0.44	-3.23	-1.69	-0.15	0.17	0.00	3.42	0.08
	6	-	-	7.00	0.75	-2.00	-0.71	-0.14	0.17	-	5.71	-
	7	-	-	-	-	-4.00	-1.00	-4.00	-	-	3.00	-
	8	-	-	7.67	1.00	0.33	0.50	-0.25	0.00	-	3.33	-
	9	-	-	-	2.00	-2.00	-2.50	-3.50	-	-	3.00	-
	10	-	-	7.00	1.00	4.00	-1.00	-2.00	-1.00	-	4.00	-
	11	-	-	-	-	-	-	-	-	-	-	-
	12	-	-	-	-	-	-	-	-	-	-	-
	13	-	-	-	-2.50	2.00	-2.50	-5.00	-6.00	-	0.50	-
	14	-	-	-	-	-	-	-	-	-	-	-
	15	-	-	-	-	-	-	-	-	-	-	-
Weighted mean	0-15	0.18	0.91	4.93	0.64	-1.78	-1.33	-0.67	0.00	0.56	3.38	0.19
	RANKING	2	6	10	4	8	7	5	1	3	9	

Table 2.6. Inter-reader bias test of white anglerfish otoliths. Reference otoliths readings are shadowed.

	INTER READER BIAS TEST										
	Rafael	António	Inaki	Jorge	Phil	Sally	Sarah	Joaquin	Helen	Eli	Gordon
	R1	R2	R3	R4	R5	R6	R7	R9	R10	R11	R14
R1		*	**	-	**	**	*	-	-	**	-
R2	*		**	-	**	**	**	-	-	**	**
R3	**	**		**	**	**	**	**	**	**	**
R4	-	-	**		*	**	**	**	-	**	**
R5	**	**	**	*		-	*	**	**	**	**
R6	**	**	**	**	-		*	*	**	**	**
R7	*	**	**	**	*	*		-	**	**	**
R9	-	-	**	**	**	*	-		-	**	-
R10	-	-	**	-	**	**	**	-		**	*
R11	**	**	**	**	**	**	**	**	**		**
R14	-	**	**	**	**	**	*	-	*	**	

-	= no sign of bias ($p>0.05$)
*	= possibility of bias ($0.01<p<0.05$)
**	= certainty of bias ($p<0.01$)

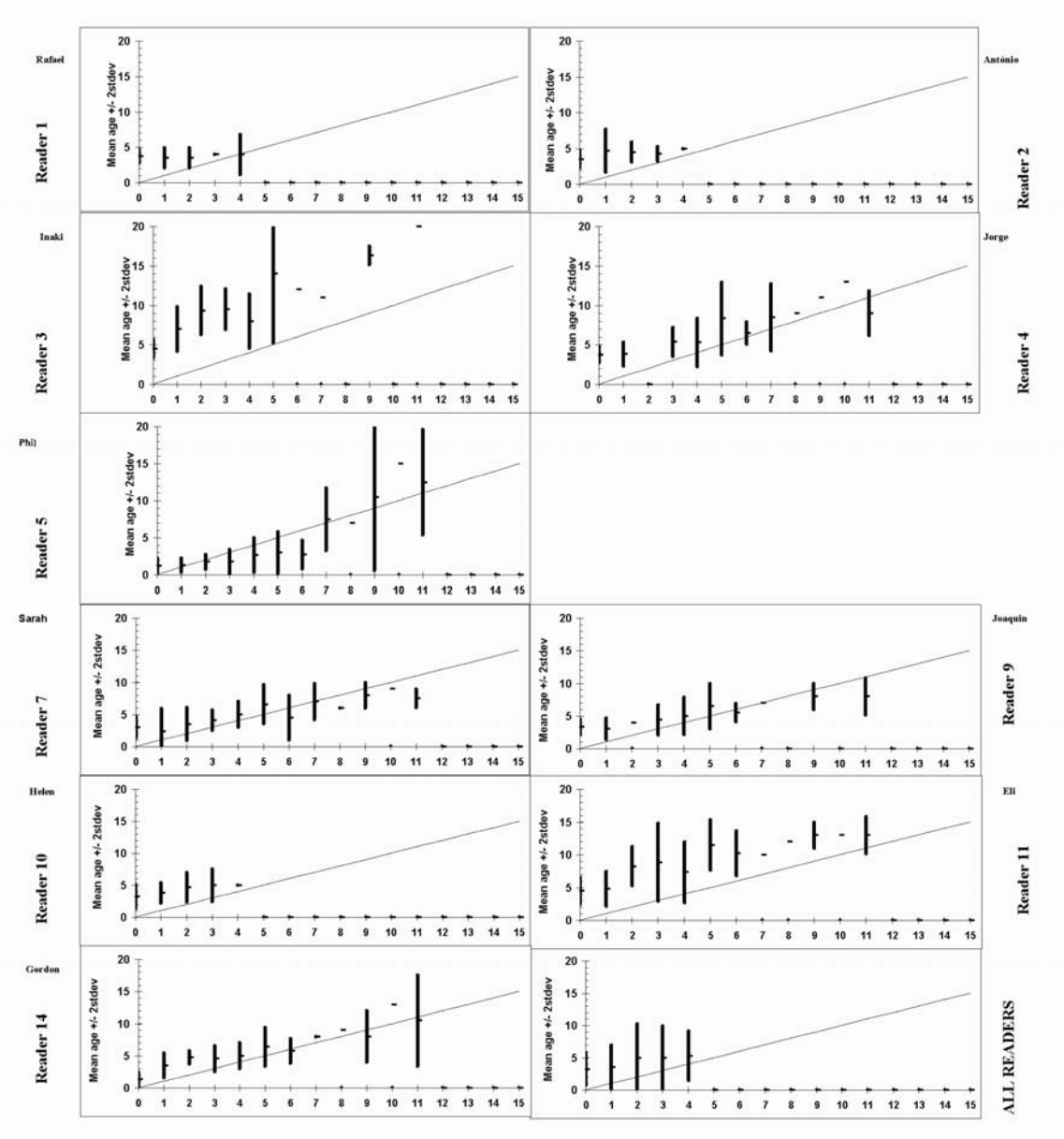

Figure 2.2. Mean age (-) +/- 2stdev versus the reference age (solid line) of reader R6 for white anglerfish aged using otoliths.

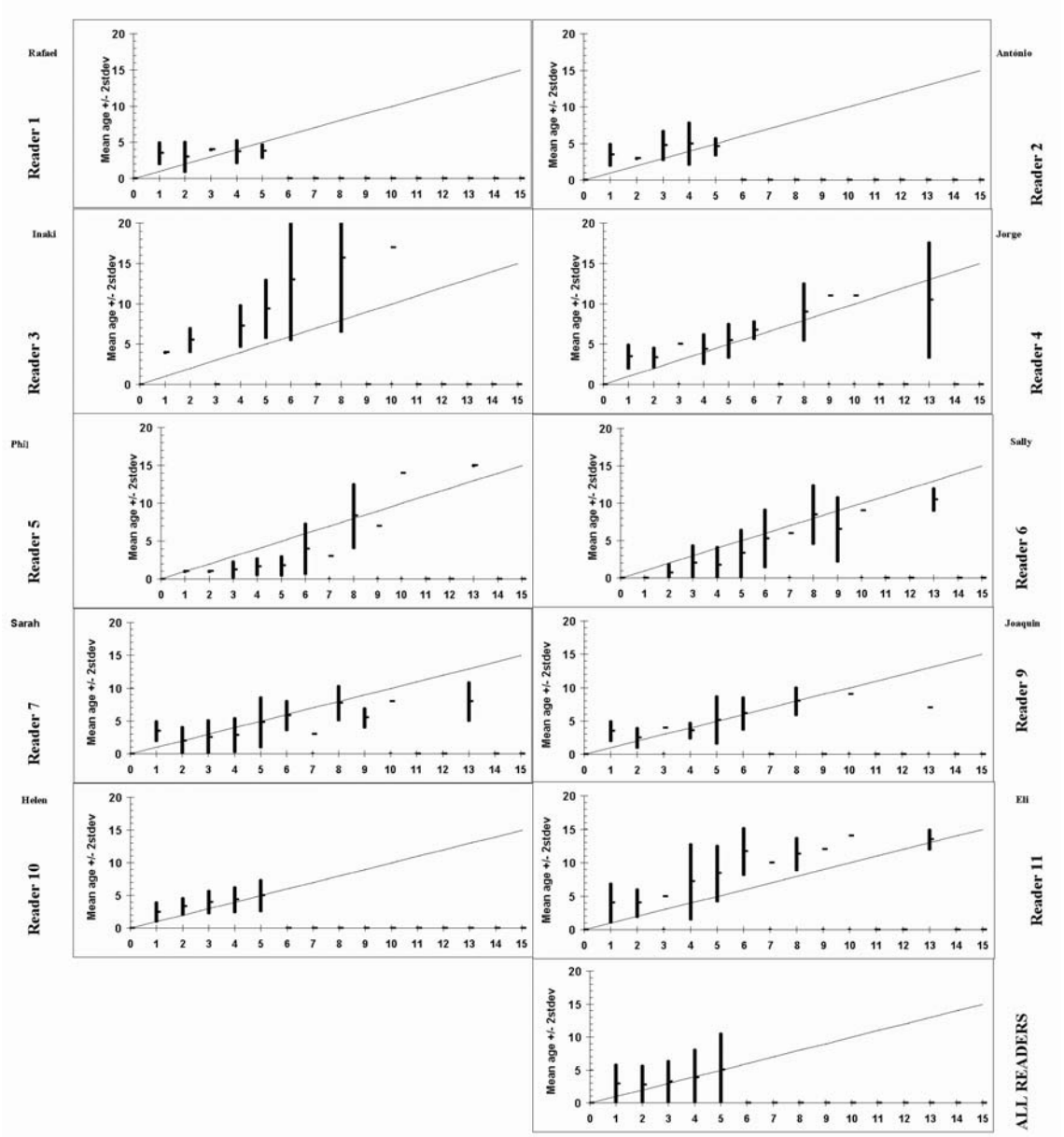

Figure 2.3. Mean age (-) +/- 2stdev versus the reference age (solid line) of reader R14 for white anglerfish aged using otoliths.

White anglerfish *illicia* and otoliths age reading comparison

Table 2.7 presents a summary of the overall reader performance for each structure. Results show that low CV and APE and a higher percentage of agreement came from *illicia*. For both otolith reference readers results showed high CV and a low percentage of agreement (lower for R6 with 11.5%).

Table 2.7. Percentage of agreement, CV's and APE for all readers combined compared to the reference ages of highly experience *illicia* (R1, R2, R3 and R4) and otolith (R6 and R14) readers for white anglerfish.

Reference age	*Illicia* Mode of expert readers (R1, R2, R3 and R4)	Otoliths R6	Otoliths R14
CV	20.7%	41.1%	46.3%
% agreement	39.7%	11.5%	15.3%
APE	16.0%	33.2%	

Table 2.8, Table 2.9 and Figure 2.4 show the frequency of the age differences between the *illicia* and the otoliths readings for the same fish. The *illicia* reference ages used are the modal age of the most experienced readers (R1, R2, R3 and R4) and the otoliths reference ages used are the readings of R6 and R14. When comparing the results between the *illicia* modal age and otoliths readings from R14 (Table 2.8), 27% of the ages were in agreement and 27% showed a difference of +1. For this reader, 72% of the age differences were -1, 0 or +1 and 16% were +2. Only 6% of the age reading differences were above 2 and only 6% were below -1. By analysing the age differences by length interval it is seen that lower differences were obtained in smaller specimens. This was clearly observed for age reader R14, for which until 35cm TL the age difference between *illicia* and otoliths was 0 or +1 and until 70cm TL it was between -2 and +2.

Table 2.8. Frequency (%) of the age differences between the modal *illicia* ages and the otolith readings of R14 by length class for white anglerfish.

Length range	Age difference between Modal *ILLICIA* vs R14 OTOLITH													Total (n)
	-4	-3	-2	-1	**0**	1	2	3	4	5	6	7	8	
25-29					**25**	75								4
30-34					**33**	67								3
35-39			20	40	**40**									5
40-44				40	**60**									5
45-49				50		25	25							4
50-54				33	**33**		33							6
55-59					**50**		50							2
60-64						50	50							2
65-69			33			33	33							3
70-74					**33**			33	33					3
75-79														-
80-84						100								1
85-89						75	25							4
90-94	33				**33**				33					3
95-99														-
Total (n)	1		2	8	**12**	12	7	1	2					45
Total (%)	**2.2**		**4.4**	**17.8**	**26.7**	**26.7**	**15.6**	**2.2**	**4.4**					

Otolith reference reader R14 had a greater similarity to the modal *illicia* readings compared to the readings of R6. For this reader (Table 2.9) only 11% had the same age between *illicia* and otoliths and 70% had and age difference between +1 and +3, with higher values in +2. Differences between readers can be directly compared in Figure 2.4. From the analysed

results it can be seen that in general there was a slight tendency to attribute higher ages when reading *illicia*.

Table 2.9. Frequency (%) of the age differences between the modal *illicia* ages and the otolith readings of R6 by length class for white anglerfish.

Length	Age difference between Modal *ILLICIA* and R6 OTOLITH													Total
range	-4	-3	-2	-1	**0**	1	2	3	4	5	6	7	8	(n)
25-29						20	60	20						5
30-34							67	33						3
35-39					**20**		40	40						5
40-44					**20**	20	40	20						5
45-49						50	50							4
50-54					**17**	17	33	17		17				6
55-59				50		50								2
60-64							50			50				2
65-69				33		33				33				3
70-74					**33**		33		33					3
75-79														-
80-84					**100**									1
85-89			25				25	50						4
90-94				33		33							33	3
95-99														-
Total (n)			1	3	**5**	8	16	8	1	3			1	46
Total (%)			**2.2**	**6.5**	**10.9**	**17.4**	**34.8**	**17.4**	**2.2**	**6.5**			**2.2**	

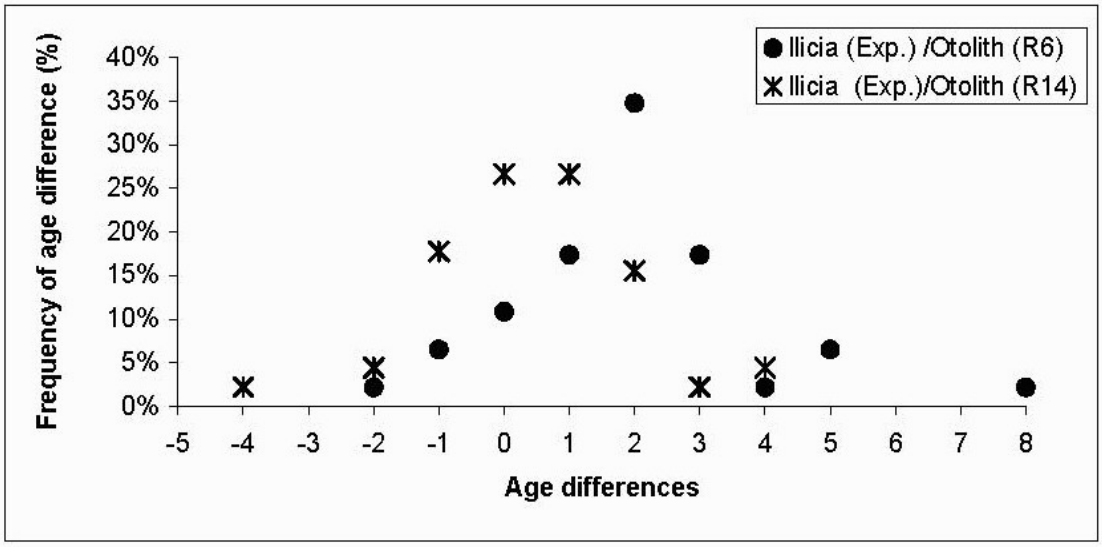

Figure 2.4. Frequency (%)of the age differences between the modal *illicia* ages and the otolith readings of readers R6 and R14 for white anglerfish.

Figure 2.5 shows the mean of all readers mean length at age and the standard deviation from *illicia* and otoliths readings. *Illicia* readings showed lower variability compared to the otoliths readings. From ages 1 to 3 the mean length at age from otoliths readings was higher while from ages 4 to 7 it was similar between structures. After age 7 the mean length at age from otolith readings was lower. The high mean length at age 0 and the similar values in age 1 and 2 are probably related with the scarce number of small fish in the white anglerfish collection, as previously mentioned.

Figure 2.6 shows the mean of mean length at age and the standard deviation from *illicia* readers that provide or will provide ALK's for assessment (R2, R4, R8, R9, R10, R11 and R12) and otolith readings from R14 (whose readings have better agreements with *illicia*). The

otolith readers showed a higher mean length at age compared to the *illicia* readers. These seven *illicia* readers showed low variability.

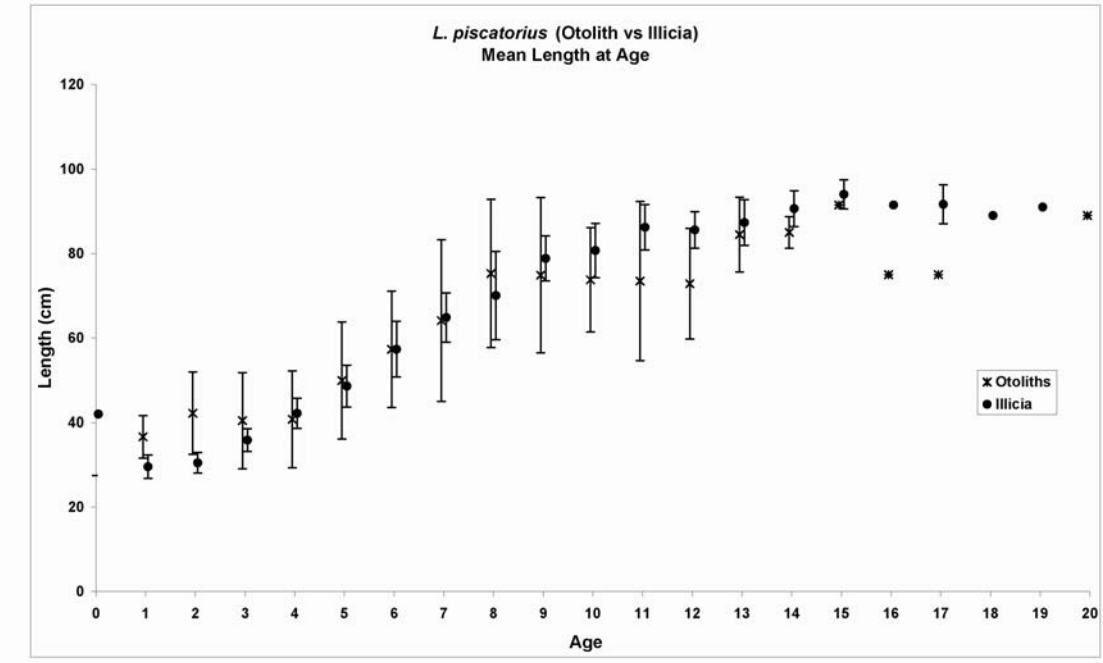

Figure 2.5. Mean and standard deviation of all readers mean length at age for white anglerfish aged using *illicia* and otoliths.

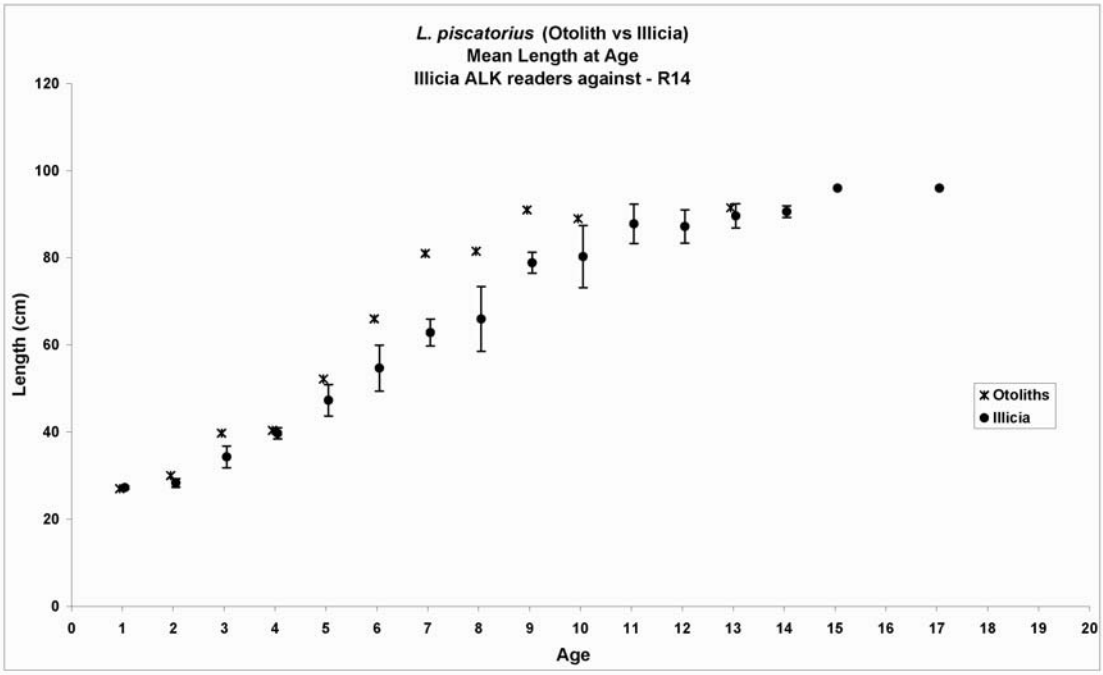

Figure 2.6. Mean and standard deviation of mean length at age from *illicia* readers R2, R4, R8, R9, R10, R11 and R12 that provide or will provide white anglerfish ALK's for assessment and mean length at age from otolith readings from R14.

2.2.1.2 Black anglerfish

Black anglerfish *illicia*

The *illicia* age reading results by reader, modal age of experienced readers and percentage of agreement are shown in Annex 5. The APE for this structure was 22.3%.

Table 2.10. The number of age readings, associated CV's, percentage of agreement and absolute bias for each reader compared to the modal age of readers R1, R2, R3 and R4 readings for black anglerfish aged using *illicia*.

NUMBER OF AGE READINGS

	MODAL age	Rafael Reader 1	António Reader 2	Inaki Reader 3	Jorge Reader 4	Phil Reader 5	Sally Reader 6	Sarah Reader 7	Joel Reader 8	Joaquin Reader 9	Helen Reader 10	Eli Reader 11	Grainne Reader 12	Vidarsson Reader 13	TOTAL
	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	3	6	6	6	5	6	6	6	6	6	6	6	6	6	77
	4	5	5	5	5	5	5	5	5	4	5	5	5	5	64
	5	7	7	7	6	7	7	7	7	4	7	7	7	7	87
	6	8	8	5	8	8	8	8	8	7	8	8	8	7	99
	7	10	10	9	9	10	10	10	10	8	10	10	10	10	126
	8	2	2	2	2	2	2	2	2	1	2	2	2	2	25
	9	1	1	1	1	1	1	1	1	1	1	1	1	1	13
	10	1	1	1	1	1	1	1	1	1	1	1	1	1	13
	11	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	12	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	13	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	14	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	15	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	0-15	50	50	46	46	49	50	50	50	36	50	50	50	49	626

COEFFICIENT OF VARIATION (CV)

	MODAL age	Rafael Reader 1	António Reader 2	Inaki Reader 3	Jorge Reader 4	Phil Reader 5	Sally Reader 6	Sarah Reader 7	Joel Reader 8	Joaquin Reader 9	Helen Reader 10	Eli Reader 11	Grainne Reader 12	Vidarsson Reader 13	ALL Readers
	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	3	14%	16%	13%	0%	22%	30%	27%	23%	16%	14%	24%	35%	28%	29.0%
	4	16%	12%	11%	12%	26%	40%	14%	14%	0%	0%	9%	16%	12%	24.4%
	5	20%	18%	21%	0%	37%	17%	22%	14%	10%	28%	10%	20%	24%	26.5%
	6	15%	11%	27%	0%	35%	24%	11%	7%	15%	16%	15%	17%	15%	25.7%
	7	18%	11%	23%	0%	39%	21%	15%	23%	16%	20%	21%	24%	32%	27.7%
	8	0%	9%	0%	9%	16%	11%	20%	9%	-	13%	8%	16%	13%	30.2%
	9	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	10	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	11	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	12	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	13	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	14	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	15	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Weighted mean	0-15	12.2%	10.0%	13.5%	1.7%	25.0%	18.6%	13.3%	12.1%	10.4%	12.8%	12.1%	16.9%	17.3%	27.2%
	RANKING	6	2	9	1	13	12	8	5	3	7	4	10	11	

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	MODAL age	Rafael Reader 1	António Reader 2	Inaki Reader 3	Jorge Reader 4	Phil Reader 5	Sally Reader 6	Sarah Reader 7	Joel Reader 8	Joaquin Reader 9	Helen Reader 10	Eli Reader 11	Grainne Reader 12	Vidarsson Reader 13	ALL
	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	3	83%	50%	0%	100%	50%	33%	50%	0%	50%	83%	17%	33%	33%	44%
	4	40%	60%	80%	80%	60%	20%	20%	20%	100%	0%	0%	0%	60%	41%
	5	14%	57%	57%	100%	14%	29%	0%	14%	50%	29%	14%	14%	29%	31%
	6	13%	88%	40%	100%	0%	0%	0%	25%	14%	38%	38%	0%	14%	28%
	7	10%	50%	67%	100%	20%	30%	0%	30%	25%	10%	20%	10%	20%	29%
	8	0%	50%	100%	50%	50%	0%	0%	50%	0%	0%	50%	0%	0%	28%
	9	0%	100%	0%	100%	100%	0%	0%	0%	0%	0%	100%	0%	0%	31%
	10	0%	0%	100%	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%	15%
	11	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	12	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	13	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	14	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	15	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Weighted mean	0-15	20.0%	48.0%	41.3%	76.1%	22.4%	16.0%	8.0%	16.0%	33.3%	22.0%	18.0%	8.0%	20.4%	26.4%
	RANKING	8	2	3	1	5	10	12	10	4	6	9	12	7	

RELATIVE BIAS

	MODAL age	Rafael Reader 1	António Reader 2	Inaki Reader 3	Jorge Reader 4	Phil Reader 5	Sally Reader 6	Sarah Reader 7	Joel Reader 8	Joaquin Reader 9	Helen Reader 10	Eli Reader 11	Grainne Reader 12	Vidarsson Reader 13	ALL
	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	3	-0.17	0.50	2.00	0.00	0.67	0.50	-0.17	2.17	0.50	-0.17	1.33	-0.83	1.17	0.58
	4	-0.60	0.40	0.20	-0.20	-0.60	0.00	-0.80	1.00	0.00	-1.00	1.20	-1.20	0.40	-0.09
	5	-1.29	0.29	0.86	0.00	0.00	0.14	-1.43	1.71	0.50	-1.14	1.00	-1.29	1.00	0.01
	6	-1.25	0.25	1.60	0.00	1.75	1.13	-1.38	0.75	0.29	-0.88	1.00	-1.63	2.43	0.25
	7	-1.70	-0.10	1.22	0.00	2.00	0.10	-2.80	1.60	-0.13	-1.30	0.70	-2.10	2.50	-0.01
	8	-3.00	-0.50	0.00	-0.50	1.00	-1.50	-4.50	-0.50	-1.00	-2.50	0.50	-3.50	3.00	-1.00
	9	-2.00	0.00	3.00	0.00	0.00	-1.00	-2.00	1.00	1.00	1.00	0.00	-3.00	3.00	0.08
	10	-3.00	-1.00	0.00	0.00	5.00	-2.00	-3.00	2.00	3.00	-3.00	1.00	-4.00	6.00	0.08
	11	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	12	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	13	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	14	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	15	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Weighted mean	0-15	-1.02	0.12	0.89	-0.04	0.86	0.16	-1.36	1.08	0.25	-0.82	0.76	-1.36	1.49	0.07
	RANKING	9	2	8	1	7	3	11	10	4	6	5	11	13	

The number of age readings, CV, percentage of agreement and absolute bias by reference age are presented in Table 2.10. The CV ranged between 1.7 – 25.0%, and the low values corresponded to experienced *illicia* readers (R4 and R2). The percentage of agreement ranged between 8.0 - 76.10%, and the higher agreement with the modal age was from R4, R2 and R3 (high experienced *illicia* readers). Generally, the absolute bias (mean age of each reader – reference age) was higher for older ages.

The inter-reader bias test is presented in Table 2.11. Reader R2, R4, R5, R6 and R9 showed no bias or a possibility of bias when compared with the modal age. Generally, readers involved in ageing the Northern Stock showed a possibility of bias between themselves (R8 – R11) but there was a certainty of bias with readers R10 and R12. The two current Southern Stock readers showed a possibility of bias between themselves (R2 and R4), but there was no sign of bias by the new reader R9. The new Southern and Northern stock reader (R9), showed high precision and agreement, did not show signs of bias to the Southern stock readers (R2 and R4), but shows certainty of bias to the Northern stock readers (R8, R10, R11 and R12). It should be noted that this test is very sensitive to large differences in the assigned ages in just one fish.

Table 2.11. Inter-reader bias test of black anglerfish *illicia.*

Inter-reader bias test and reader against MODAL age bias tes

	Rafael Reader 1	António Reader 2	Inaki Reader 3	Jorge Reader 4	Phil Reader 5	Sally Reader 6	Sarah Reader 7	Joel Reader 8	Joaquin Reader 9	Helen Reader 10	Eli Reader 11	Grainne Reader 12	Vidarsson Reader 13
Reader 1		**	**	**	**	**	**	**	**	*	**	**	**
Reader 2	**		**	*	*	–	**	**	–	**	**	**	**
Reader 3	**	**		**	–	**	**	–	**	**	–	**	–
Reader 4	**	*	**		**	–	**	**	–	**	**	**	**
Reader 5	**	*	–	**		**	**	–	–	**	–	**	**
Reader 6	**	–	**	–	**		**	**	–	**	**	**	**
Reader 7	**	**	**	**	**	**		**	**	**	**	–	**
Reader 8	**	**	–	**	–	**	**		**	**	*	**	–
Reader 9	**	–	**	–	–	–	**	**		**	*	**	**
Reader 10	*	**	**	**	**	**	**	**	**		**	**	**
Reader 11	**	**	–	**	–	**	**	*	*	**		**	**
Reader 12	**	**	**	**	**	**	–	**	**	**	**		**
Reader 13	**	**	–	**	**	**	**	–	**	**	**	**	
MODAL age	**	–	**	–	*	–	**	**	–	**	**	**	**

– = no sign of bias (p>0.05)
* = possibility of bias (0.01<p<0.05)
** = certainty of bias (p<0.01)

The age bias plots by each reader (Figure 2.7) show that Southern Stock readers (R2 and, R4) and the new Southern and Northern stock reader (R9) showed low bias to the modal age and low variability. All other readers either consistently over or underestimated the age of the fish when compared to the modal age.

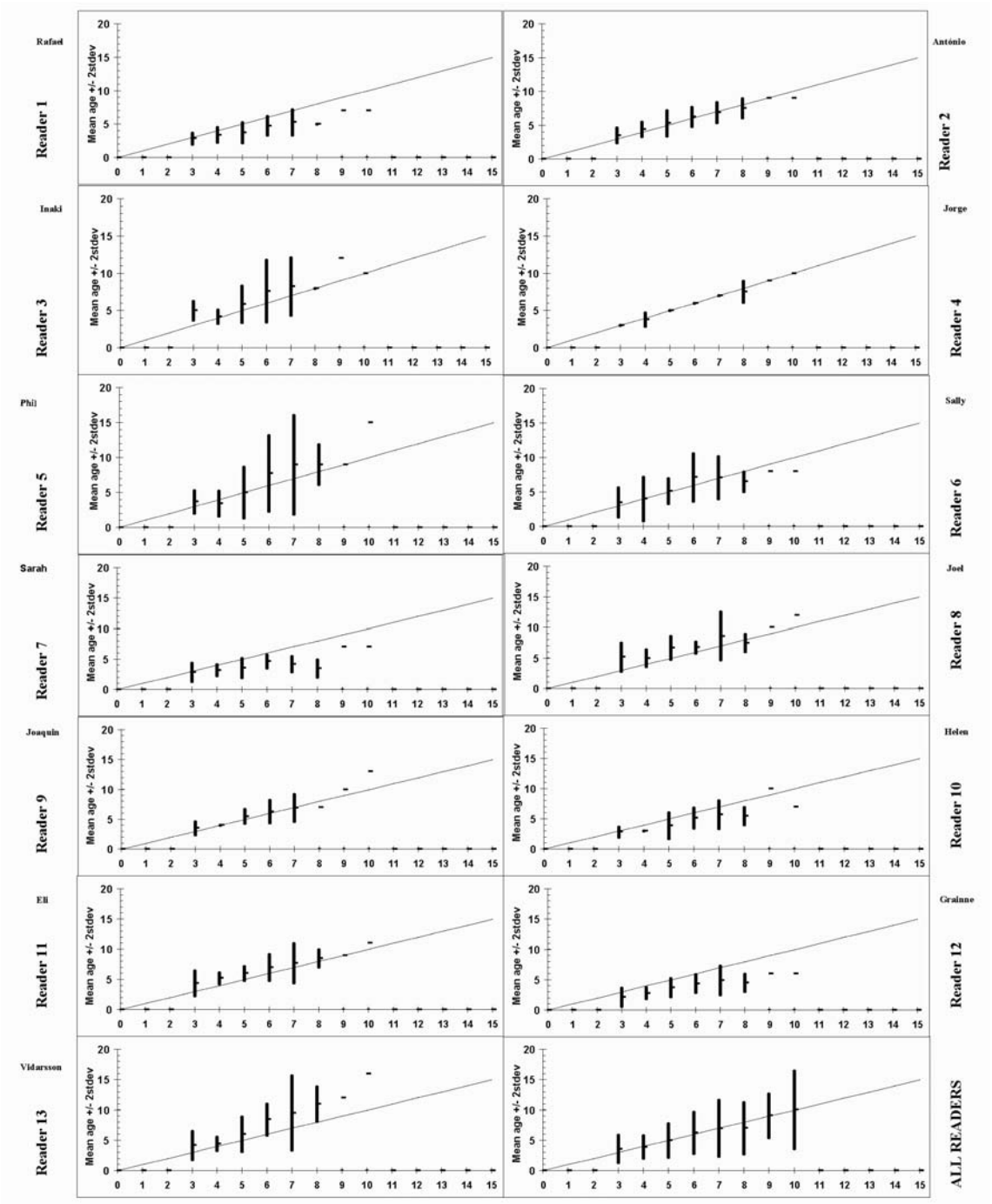

Figure 2.7. Mean age (-) +/- 2stdev versus modal age (solid line), based on results from readers R1, R2, R3 and R4 for black anglerfish aged using *illicia*.

Black anglerfish otoliths

The otolith age reading results by reader, modal age of experienced readers and percentage of agreement are shown in Annex 5.

The APE for this structure was 34.4%. The number of age readings, CV, percentage of agreement and absolute bias by reference age are presented in Tables 2.12 and 2.13. The CV ranged between 18.3 – 57.8%, and 15.4 – 64.8% with reference age R6 and R14, respectively. Experienced otolith readers (R5, R6 and R14) had high CVs (57.8%, 30.7%, 64.8% and 39.9%).

Table 2.12. The number of age readings, associated CV's, percentage of agreement and absolute bias for each reader compared to the reference ages of reader R6 for black anglerfish aged using otoliths.

NUMBER OF AGE READINGS

	Sally Reader 6	Rafael Reader 1	António Reader 2	Inaki Reader 3	Jorge Reader 4	Phil Reader 5	Sarah Reader 7	Joaquin Reader 9	Helen Reader 10	Eli Reader 11	Gordon Reader 14	TOTAL
	0	-	-	-	-	-	-	-	-	-	-	-
	1	5	5	8	4	8	8	3	5	8	8	**62**
	2	5	4	12	13	16	17	8	10	15	16	**116**
	3	4	4	6	6	6	7	3	5	7	7	**55**
	4	3	2	7	7	10	10	7	6	8	10	**70**
	5	-	-	1	1	2	3	2	1	3	3	-
	6	-	-	-	-	-	-	-	-	-	-	-
	7	2	1	3	3	3	3	2	-	3	3	**23**
	8	-	-	-	-	-	-	-	-	-	-	-
	9	-	-	-	-	-	-	-	-	-	-	-
	10	-	-	-	-	-	-	-	-	-	-	-
	11	-	-	-	-	-	-	-	-	-	-	-
	12	-	-	-	-	-	-	-	-	-	-	-
	13	-	-	-	-	-	-	-	-	-	-	-
	14	-	-	-	-	-	-	-	-	-	-	-
	15	-	-	-	-	-	-	-	-	-	-	-
Total	**0-15**	**19**	**16**	**38**	**34**	**47**	**50**	**25**	**27**	**45**	**49**	**350**

COEFFICIENT OF VARIATION (CV)

	Sally Reader 6	Rafael Reader 1	António Reader 2	Inaki Reader 3	Jorge Reader 4	Phil Reader 5	Sarah Reader 7	Joaquin Reader 9	Helen Reader 10	Eli Reader 11	Gordon Reader 14	ALL Readers
	0	-	-	-	-	-	-	-	-	-	-	-
	1	25%	21%	37%	33%	72%	24%	25%	24%	38%	44%	**40.5%**
	2	40%	18%	46%	34%	45%	35%	36%	32%	33%	41%	**38.6%**
	3	9%	20%	40%	10%	65%	26%	20%	64%	31%	26%	**43.3%**
	4	25%	18%	25%	15%	63%	28%	24%	50%	20%	28%	**41.2%**
	5	-	-	-	-	71%	28%	13%	-	24%	14%	-
	6	-	-	-	-	-	-	-	-	-	-	-
	7	33%	-	21%	6%	87%	8%	9%	-	20%	0%	**38.9%**
	8	-	-	-	-	-	-	-	-	-	-	-
	9	-	-	-	-	-	-	-	-	-	-	-
	10	-	-	-	-	-	-	-	-	-	-	-
	11	-	-	-	-	-	-	-	-	-	-	-
	12	-	-	-	-	-	-	-	-	-	-	-
	13	-	-	-	-	-	-	-	-	-	-	-
	14	-	-	-	-	-	-	-	-	-	-	-
	15	-	-	-	-	-	-	-	-	-	-	-
Weighted mean	**0-15**	**26.3%**	**18.3%**	**34.8%**	**22.2%**	**57.8%**	**27.0%**	**25.3%**	**39.2%**	**29.1%**	**30.7%**	**40.8%**
	RANKING	**4**	**1**	**8**	**2**	**10**	**5**	**3**	**9**	**6**	**7**	

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	Sally Reader 6	Rafael Reader 1	António Reader 2	Inaki Reader 3	Jorge Reader 4	Phil Reader 5	Sarah Reader 7	Joaquin Reader 9	Helen Reader 10	Eli Reader 11	Gordon Reader 14	ALL
	0	-	-	-	-	-	-	-	-	-	-	-
	1	0%	0%	0%	0%	50%	0%	0%	0%	0%	13%	**8%**
	2	0%	0%	0%	0%	38%	0%	13%	0%	0%	19%	**9%**
	3	0%	0%	0%	0%	17%	29%	0%	20%	0%	29%	**11%**
	4	0%	0%	14%	0%	0%	20%	14%	0%	13%	20%	**10%**
	5	-	-	0%	0%	0%	33%	50%	0%	0%	0%	-
	6	-	-	-	-	-	-	-	-	-	-	-
	7	0%	0%	33%	0%	0%	33%	50%	-	0%	0%	**13%**
	8	-	-	-	-	-	-	-	-	-	-	-
	9	-	-	-	-	-	-	-	-	-	-	-
	10	-	-	-	-	-	-	-	-	-	-	-
	11	-	-	-	-	-	-	-	-	-	-	-
	12	-	-	-	-	-	-	-	-	-	-	-
	13	-	-	-	-	-	-	-	-	-	-	-
	14	-	-	-	-	-	-	-	-	-	-	-
	15	-	-	-	-	-	-	-	-	-	-	-
Weighted mean	**0-15**	**0.0%**	**0.0%**	**5.3%**	**0.0%**	**23.4%**	**12.0%**	**16.0%**	**3.7%**	**2.2%**	**16.3%**	**9.4%**
	RANKING	**8**	**8**	**5**	**8**	**1**	**4**	**3**	**6**	**7**	**2**	

ABSOLUTE BIAS

	Sally Reader 6	Rafael Reader 1	António Reader 2	Inaki Reader 3	Jorge Reader 4	Phil Reader 5	Sarah Reader 7	Joaquin Reader 9	Helen Reader 10	Eli Reader 11	Gordon Reader 14	ALL
	0	-	-	-	-	-	-	-	-	-	-	-
	1	2.60	4.20	3.75	4.25	0.88	3.50	3.00	2.00	3.63	2.00	**2.90**
	2	2.80	3.25	3.83	5.00	0.06	2.88	2.50	1.20	3.93	1.88	**2.66**
	3	2.75	3.50	2.83	4.83	-0.67	1.29	2.00	2.80	3.86	1.14	**2.38**
	4	3.00	4.00	2.00	3.29	-2.10	1.30	1.71	1.50	2.13	0.90	**1.33**
	5	-	-	1.00	5.00	-3.00	2.33	0.50	1.00	3.67	3.33	-
	6	-	-	-	-	-	-	-	-	-	-	-
	7	6.00	2.00	0.33	3.33	-3.00	0.67	0.50	-	0.67	-2.00	**0.65**
	8	-	-	-	-	-	-	-	-	-	-	-
	9	-	-	-	-	-	-	-	-	-	-	-
	10	-	-	-	-	-	-	-	-	-	-	-
	11	-	-	-	-	-	-	-	-	-	-	-
	12	-	-	-	-	-	-	-	-	-	-	-
	13	-	-	-	-	-	-	-	-	-	-	-
	14	-	-	-	-	-	-	-	-	-	-	-
	15	-	-	-	-	-	-	-	-	-	-	-
Weighted mean	**0-15**	**3.11**	**3.63**	**2.87**	**4.38**	**-0.68**	**2.16**	**1.96**	**1.70**	**3.22**	**1.37**	**2.08**
	RANKING	**7**	**9**	**6**	**10**	**1**	**5**	**4**	**3**	**8**	**2**	

Table 2.13. The number of age readings, associated CV's, percentage of agreement and absolute bias for each reader compared to the reference ages of reader R14 for black anglerfish aged using otoliths.

NUMBER OF AGE READINGS

	Gordon Reader 14	Rafael Reader 1	António Reader 2	Inaki Reader 3	Jorge Reader 4	Phil Reader 5	Sally Reader 6	Sarah Reader 7	Joaquin Reader 9	Helen Reader 10	Eli Reader 11	TOTAL
	0	-	-	-	-	-	-	-	-	-	-	-
	1	1	1	1	1	1	1	1	1	1	1	10
	2	5	5	6	6	6	6	6	4	4	6	54
	3	5	5	8	5	10	9	10	5	7	8	72
	4	3	3	8	7	10	9	10	5	4	8	67
	5	4	2	12	11	13	14	14	5	8	14	97
	6	-	-	-	2	3	3	3	2	2	2	-
	7	1	-	2	-	2	2	2	2	-	2	13
	8	-	-	-	-	-	1	1	-	-	1	-
	9	-	-	-	1	1	2	2	1	1	2	-
	10	-	-	-	-	-	-	-	-	-	-	-
	11	-	-	-	-	-	-	-	-	-	-	-
	12	-	-	-	-	-	-	-	-	-	-	-
	13	-	-	-	-	-	-	-	-	-	-	-
	14	-	-	-	-	-	-	-	-	-	-	-
	15	-	-	-	-	-	-	-	-	-	-	-
Total	0-15	19	16	38	34	47	48	50	25	27	45	349

COEFFICIENT OF VARIATION (CV)

	Gordon Reader 14	Rafael Reader 1	António Reader 2	Inaki Reader 3	Jorge Reader 4	Phil Reader 5	Sally Reader 6	Sarah Reader 7	Joaquin Reader 9	Helen Reader 10	Eli Reader 11	ALL Readers
	0	-	-	-	-	-	-	-	-	-	-	-
	1	-	-	-	-	-	-	-	-	-	-	-
	2	20%	14%	39%	23%	87%	55%	11%	29%	40%	24%	43.9%
	3	34%	21%	21%	23%	63%	35%	27%	25%	35%	36%	47.6%
	4	11%	23%	30%	15%	67%	44%	27%	10%	76%	27%	52.7%
	5	36%	0%	23%	15%	74%	57%	32%	21%	37%	20%	46.5%
	6	-	-	-	9%	58%	16%	37%	24%	8%	20%	-
	7	-	-	20%	-	47%	16%	47%	33%	-	11%	-
	8	-	-	-	-	-	-	-	-	-	-	-
	9	-	-	-	-	-	0%	40%	-	-	22%	-
	10	-	-	-	-	-	-	-	-	-	-	-
	11	-	-	-	-	-	-	-	-	-	-	-
	12	-	-	-	-	-	-	-	-	-	-	-
	13	-	-	-	-	-	-	-	-	-	-	-
	14	-	-	-	-	-	-	-	-	-	-	-
	15	-	-	-	-	-	-	-	-	-	-	-
Weighted mean	0-15	23.6%	15.4%	25.3%	16.1%	64.8%	39.9%	26.6%	20.3%	38.0%	23.0%	47.2%
	RANKING	5	1	6	2	10	9	7	3	8	4	

PERCENTAGE AGREEMENT

	Gordon Reader 14	Rafael Reader 1	António Reader 2	Inaki Reader 3	Jorge Reader 4	Phil Reader 5	Sally Reader 6	Sarah Reader 7	Joaquin Reader 9	Helen Reader 10	Eli Reader 11	ALL
	0	-	-	-	-	-	-	-	-	-	-	-
	1	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	10%
	2	0%	0%	0%	0%	17%	50%	0%	25%	0%	0%	9%
	3	40%	0%	13%	0%	20%	22%	40%	20%	43%	13%	22%
	4	0%	0%	13%	0%	0%	22%	30%	0%	0%	13%	10%
	5	0%	0%	17%	0%	0%	0%	21%	40%	25%	14%	11%
	6	-	-	-	0%	0%	0%	0%	0%	0%	50%	-
	7	0%	-	0%	-	0%	0%	0%	0%	-	50%	8%
	8	-	-	-	-	-	0%	0%	-	-	100%	-
	9	-	-	-	0%	0%	0%	50%	0%	0%	0%	-
	10	-	-	-	-	-	-	-	-	-	-	-
	11	-	-	-	-	-	-	-	-	-	-	-
	12	-	-	-	-	-	-	-	-	-	-	-
	13	-	-	-	-	-	-	-	-	-	-	-
	14	-	-	-	-	-	-	-	-	-	-	-
	15	-	-	-	-	-	-	-	-	-	-	-
Weighted mean	0-15	10.5%	0.0%	10.5%	0.0%	6.4%	16.7%	22.0%	16.0%	18.5%	15.6%	12.6%
	RANKING	6	9	6	9	8	3	1	4	2	5	

ABSOLUTE BIAS

	Gordon Reader 14	Rafael Reader 1	António Reader 2	Inaki Reader 3	Jorge Reader 4	Phil Reader 5	Sally Reader 6	Sarah Reader 7	Joaquin Reader 9	Helen Reader 10	Eli Reader 11	ALL
	0	-	-	-	-	-	-	-	-	-	-	-
	1	2.00	3.00	3.00	2.00	1.00	0.00	2.00	2.00	1.00	2.00	1.80
	2	2.20	3.80	2.00	3.17	-0.17	0.00	1.83	1.25	0.50	2.17	1.69
	3	1.40	2.40	1.38	3.60	-1.20	-1.00	1.30	1.60	1.00	2.25	1.01
	4	1.33	2.67	1.63	3.29	-2.00	-1.44	1.20	1.60	1.50	1.75	0.82
	5	5.50	4.00	1.92	3.73	-2.62	-1.36	0.64	1.20	-1.25	2.07	0.77
	6	-	-	-	1.50	-3.00	-2.33	-0.33	0.00	2.50	1.00	-
	7	1.00	-	0.00	-	-5.50	-2.50	-1.00	-0.50	-	-0.50	-1.46
	8	-	-	-	-	-	-6.00	-2.00	-	-	0.00	-
	9	-	-	-	1.00	-6.00	-4.00	-2.00	-3.00	-3.00	0.50	-
	10	-	-	-	-	-	-	-	-	-	-	-
	11	-	-	-	-	-	-	-	-	-	-	-
	12	-	-	-	-	-	-	-	-	-	-	-
	13	-	-	-	-	-	-	-	-	-	-	-
	14	-	-	-	-	-	-	-	-	-	-	-
	15	-	-	-	-	-	-	-	-	-	-	-
Weighted mean	0-15	2.47	3.13	1.63	3.15	-1.96	-1.40	0.76	1.00	0.30	1.73	0.84
	RANKING	8	9	5	10	7	4	2	3	1	6	

The percentage of agreement ranged between 0.0 - 23.4% and 0.0 - 22.0% considering the reference ages of R6 and R14, respectively. Using R6 as the reference, the reader with the highest percentage of agreement is an experienced otolith reader from the same institute (R5). Using R14 as the reference age the best agreement came from R7 (medium experienced otolith reader).

In terms of absolute bias, using R6 as the reference, all readers except R5 overestimated the ages. When using R14 as the reference age, R5, R6 and R7 (from the same institute) had a tendency to underestimate the ages.

The inter-reader bias test is presented in Table 2.14. All readers showed a certainty of bias to reference reader R6 except R5 who showed a possibility of bias. Reader R10 is the only reader with no bias when compared with the R14. Also, the two reference readers showed a certainty of bias between themselves.

Table 2.14. Inter-reader bias test for black anglerfish otoliths with the results of reader R6 as the reference ages.

	INTER READER BIAS TEST										
	Rafael	António	Inaki	Jorge	Phil	Sally	Sarah	Joaquin	Helen	Eli	Gordon
	R1	R2	R3	R4	R5	R6	R7	R9	R10	R11	R14
R1		**	*	-	**	**	*	*	-	-	-
R2	**		**	-	**	**	**	**	**	*	**
R3	*	**		**	**	**	-	-	-	-	**
R4	-	-	**		**	**	**	**	**	**	**
R5	**	**	**	**		*	**	**	**	**	**
R6	**	**	**	**	*		**	**	**	**	**
R7	*	**	-	**	**	**		-	-	**	**
R9	*	**	-	**	**	**	-		-	*	**
R10	-	**	-	**	**	**	-	-		*	-
R11	-	*	-	**	**	**	**	*	*		**
R14	**	**	**	**	*	**	**	**	-	**	

-	= no sign of bias ($p>0.05$)
*	= possibility of bias ($0.01<p<0.05$)
**	= certainty of bias ($p<0.01$)

The age bias plots by reader (Figure 2.8) show that when the results of reader R6 were used as the reference ages, all readers except R5 overestimated the ages. With the results of reader R14 as the reference age (Figure 2.9) all inexperienced anglerfish otoliths readers showed a tendency to overestimate the ages. In contrast R5 and R6 underestimated all ages and R7 overestimated younger ages and underestimated older ages.

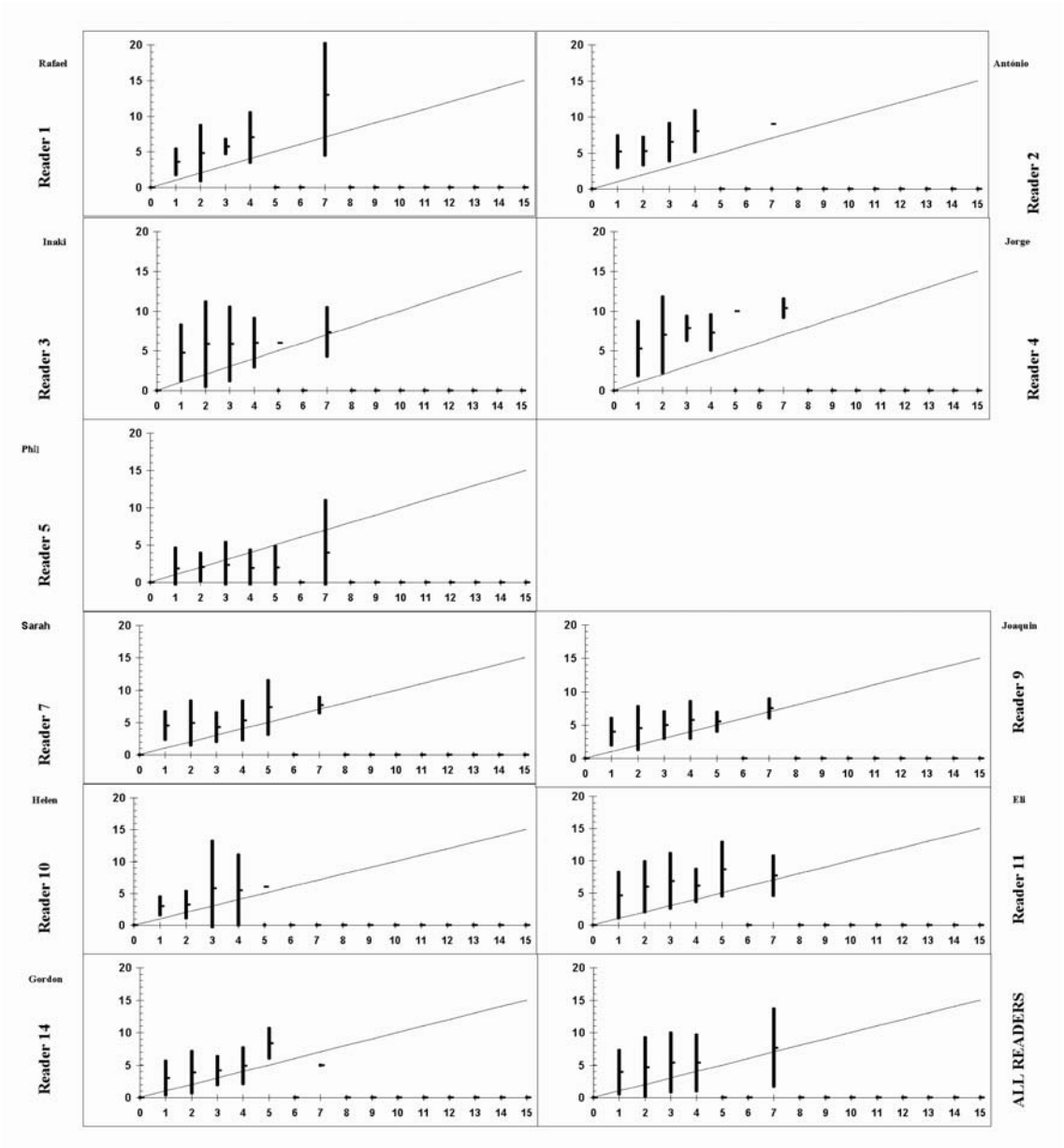

Figure 2.8. Mean age (-) +/- 2stdev versus the reference age (solid line), based on results from reader R6 for black anglerfish aged using otoliths.

Some readers only read part of the otolith collection (R1, R2, R9 and R10), especially otoliths from smaller fishes. The results from these readers can be biased due to the low number of readings.

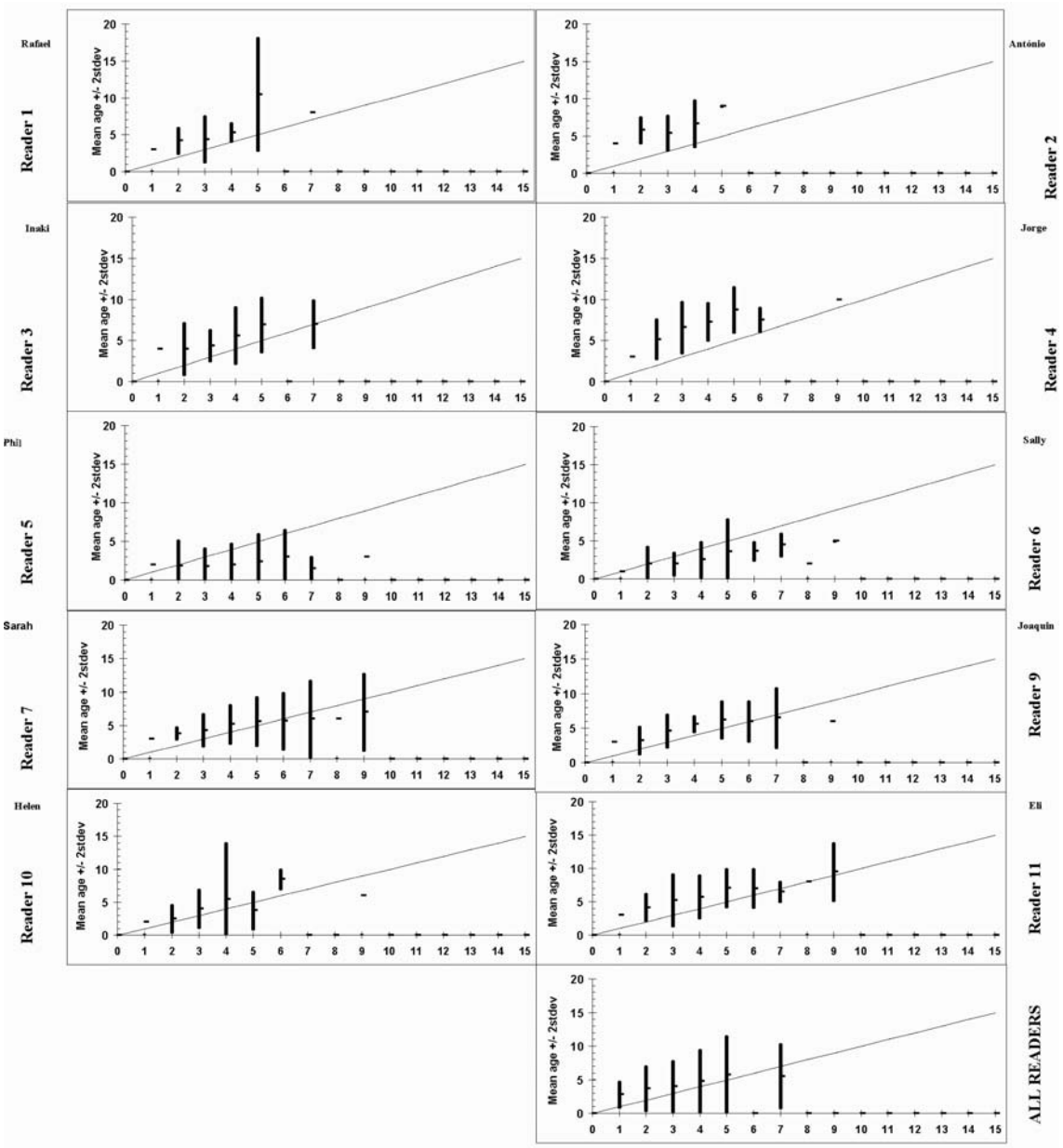

Figure 2.9. Mean age (-) +/- 2stdev versus the reference age (solid line), based on results from reader R6 for black anglerfish aged usng otoliths.

Black anglerfish *illicia* and otoliths age readings comparison

Table 2.15 shows a summary of the overall reader performance for each structure. The results show that *illicia* ages produce lower CV's and APE's and higher percentage of agreement. For otoliths, the results from both reference readers showed a high CV and APE and low percentage of agreement.

Table 2.15. Summary of the results of the overall reader performance for each structure for black anglerfish.

Reference age	*Illicia* Mode of expert readers (R1, R2, R3 and R4)	Otoliths R6	Otoliths R14
CV	27.2%	40.8%	47.2%
% agreement	26.4%	9.4%	12.6%
APE	22.3%	34.4%	

The comparison between *illicia* and otoliths from the same fish is based on the *illicia* modal age of the most experienced readers (R1, R2, R3 and R4) and the otoliths readings from readers R6 and R14. Table 2.16, Table 2.17 and Figure 2.10 show the frequency (%) of the age differences between these structures. When comparing the ages obtained using *illicia* by readers R1, R2, R3 and R4 with those obtained using otoliths by reader R14 (Table 2.16), there was no difference between the *illicia* and otolith readings for 8% of the fish aged. For 64% of fish, the age determined using *illicia* was +1 or +2 that of the age determined using otoliths and in only 8% of fish the *illicia* age was less than that obtained using the otolith (-1 and -2).

Table 2.16. Frequency (%) of the age differences between the modal *illicia* ages and the otolith readings of R14 by length class for black anglerfish.

Length range	Age difference between Modal *ILLICIA* and R14 OTOLITH										Total
	-2	-1	**0**	1	2	3	4	5	6	7	(n)
20-24				100							2
25-29			33	33	17	17					6
30-34		17		17	67						6
35-39			20	40		20	20				5
40-44		11		22	33	33					9
45-49				50	17	33					6
50-54				33	67						3
55-59	50				50						2
60-64											-
65-69											-
Total (n)	1	2	3	13	12	7	1				39
Total (%)	**2.6**	**5.1**	**7.7**	**33.3**	**30.8**	**17.9**	**2.6**				

When comparing with the otolith ages of R6 (Table 2.17), the *illicia* ages of 60% of fish were +2, +3 and +4 of the otolith age. Analysing the age differences by length it can be seen that smaller lengths showed smaller differences. For age reader R14 all length groups showed the highest percentages in differences +1 and +2, while age reader R6 showed an increase in the age difference with increasing length (*illicia* giving higher ages compared to otoliths). Otolith reader R14 had a greater similarity to the modal *illicia* readings compared to R6. Differences between both otolith readers can be directly observed in Figure 2.10. In general there was a

tendency to attribute higher ages when reading *illicia*.

Table 2.17. Frequency (%) of the age differences between the modal *illicia* ages and the otolith readings of R6 by length class for black anglerfish.

Length range	Age difference between Modal *ILLICIA* and R6 OTOLITH										Total
	-2	-1	**0**	1	2	3	4	5	6	7	(n)
20-24				50	50						2
25-29		17	**17**		50	17					6
30-34			**17**		33	33	17				6
35-39				20	20	20	20	20			5
40-44				29			57	14			7
45-49						33	33		33		6
50-54						33		67			3
55-59			**50**		50						2
60-64											-
65-69										100	1
Total (n)		1	**3**	4	8	7	8	4	2	1	38
Total (%)		**2.6**	**7.9**	**10.5**	**21.1**	**18.4**	**21.1**	**10.5**	**5.3**	**2.6**	

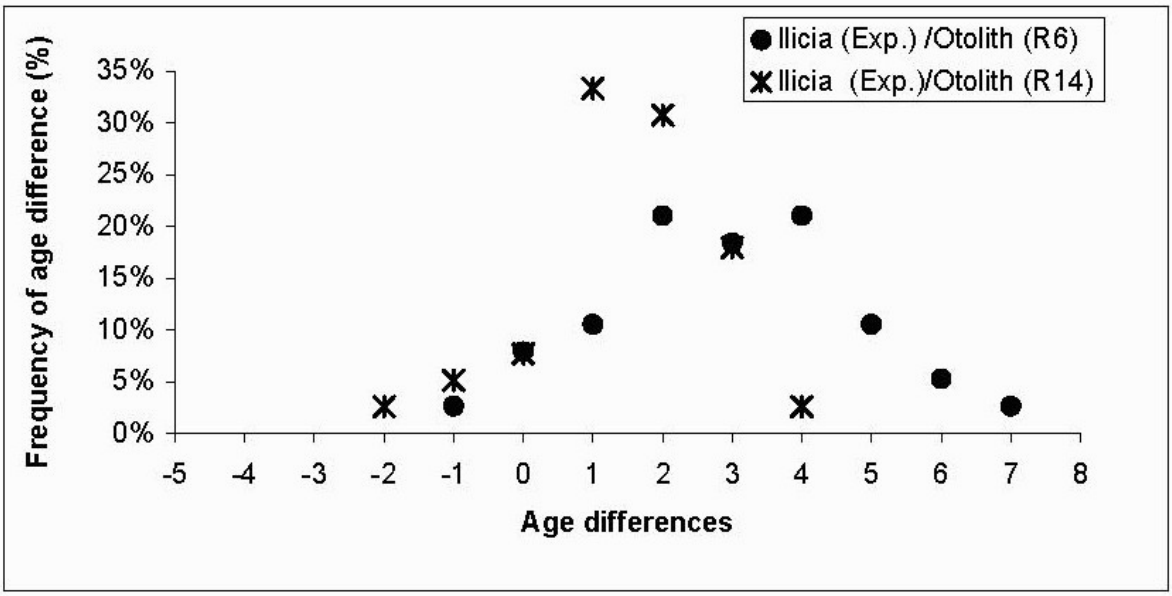

Figure 2.10. Frequency (%) of the age differences between the modal *illicia* ages and the otoliths readings of R6 and R14 for black anglerfish.

Figure 2.11 shows the mean of all readers mean length at age and the standard deviation from *illicia* and otolith readings. The results from the *illicia* readings showed less variability compared to the otolith readings, for age 1, 2 and 3. From ages 1 to 3 the mean length at age calculated using otoliths was higher than when using *illicia* and from ages 4 to 10 the mean length at age and variability from both structures was similar.

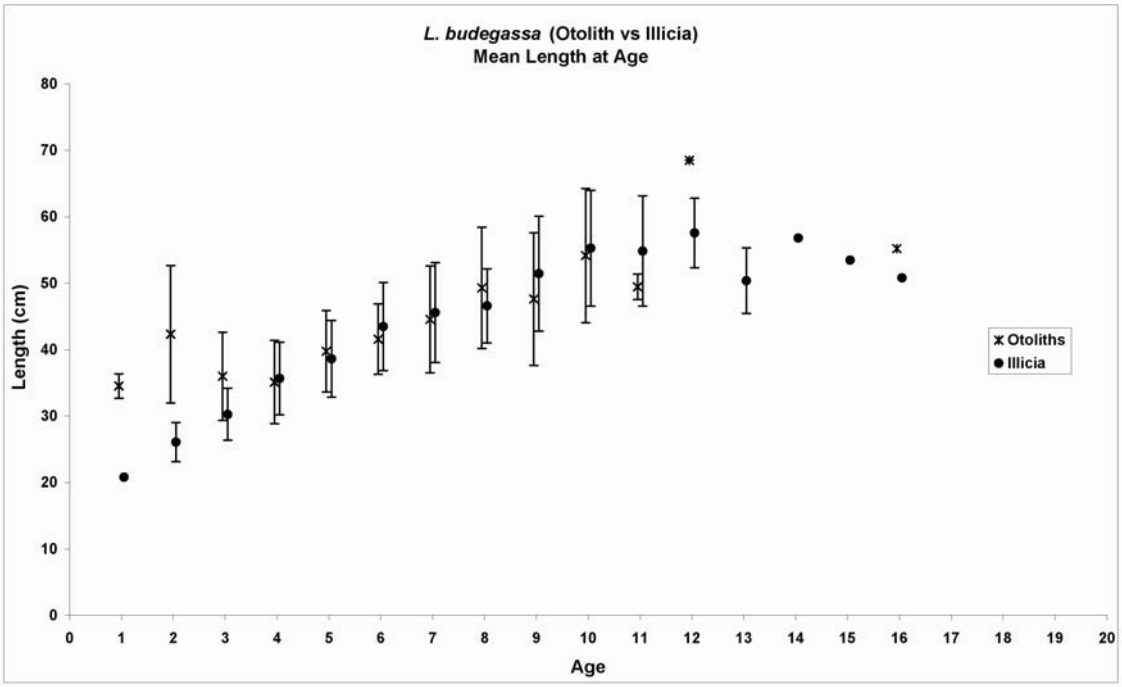

Figure 2.11. Mean and standard deviation of all readers mean length at age for black anglerfish aged using *illicia* and otoliths.

Figure 2.12 shows the mean length at age plus standard deviation of *illicia* readers that provide or will provide ALK for assessment (R2, R4, R8, R9, R10, R11 and R12) and otolith readings from R14, whose readings have better agreements with *illicia*. The otolith reader shows a higher mean length at age compared to the *illicia* readers. These seven *illicia* readers show low variability.

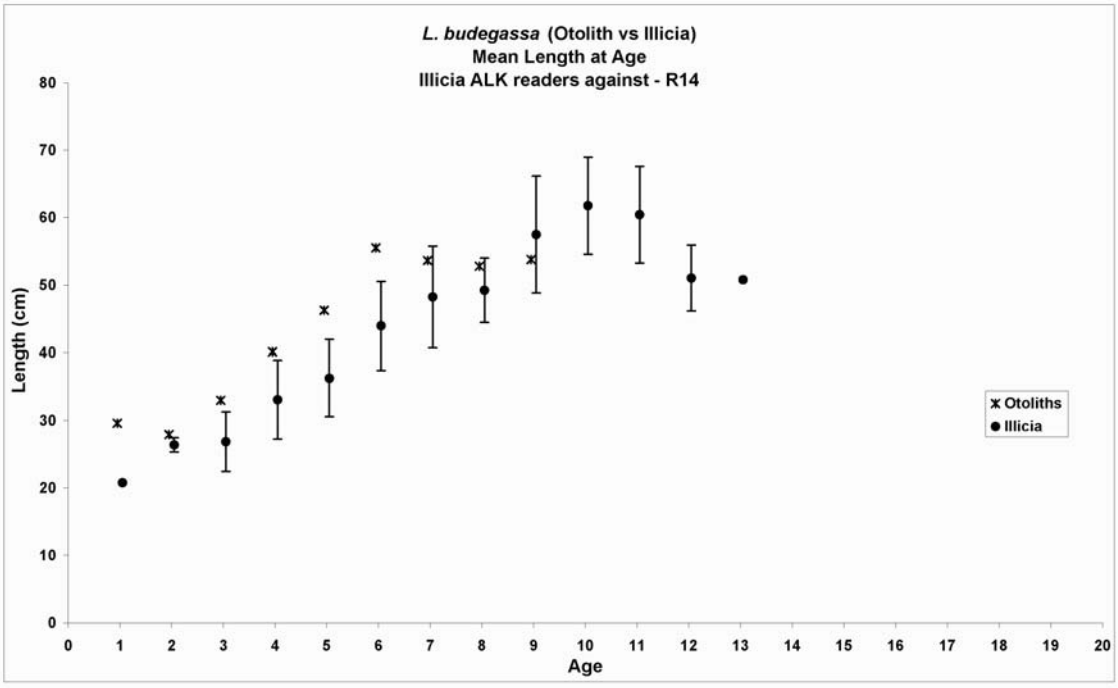

Figure 2.12. Mean and standard deviation of mean length at age from *illicia* readers R2, R4, R8, R9, R10, R11 and R12 that provide or will provide black anglerfish ALK's for assessment and mean length at age from otolith readings from R14.

2.2.2 Images

The images, with rings marked by each reader, showed that both experienced and non-experienced *illicia* readers generally agreed on the identification of a large number of growth rings. For experienced *illicia* readers the main source of disagreement was the identification of the first annual ring. The annual ring identification in otoliths was more problematic and even experienced readers did not usually agree. From the image observation it can be assumed that the annual ring identification is clearer in *illicia* compared to otoliths.

For this report, a group of images was selected with high agreement of the annual rings and which showed the ring structure most clearly. The criteria for selection of rings in the *illicia* were those established in the anglerfish ageing guide (Duarte *et al*., 2002). Two groups of images were selected. A group with high agreement in *illicia* is shown with the respective otolith (with rings of the two otolith reference readers, R6 and R14) and a group of images with the best concordance in otoliths are also shown with the respective *illicia* (with rings of the four *illicia* reference readers, R1, R2, R3 and R4).

Annex 6 contains all selected images. An additional statistical analysis (Table 2.18) was performed using only the data from the selected images. This analysis shows a higher percentage agreement for *illicia* than for otoliths. In white anglerfish the agreement for *illicia* was 62.1% while otoliths it was 29.2% and in black anglerfish the agreement for *illicia* was 39.9% and for otoliths the agreement was 27.4%.

The experience of the readers in ageing each structure was not taken into account during this analysis. This reinforces the observation that for both species the identification of rings is easier in *illicia* than in otoliths. Between species it was observed that ring identification agreement was higher for white anglerfish than for black anglerfish.

Table 2.18. Statistical analysis of chosen images.

MODEL age
+/- 1 MODEL age

L. budegassa - *illicia*

Sample year	Sample no	Struc. no	Fish length	Landing month	IPIMAR Rafael Reader 1	IPIMAR António Reader 2	AZTI Inaki Reader 3	IEO Jorge Reader 4	CEFAS Phil Reader 5	CEFAS Sally Reader 6	CEFAS Sarah Reader 7	IFREMER Joel Reader 8	IEO Joaquin Reader 9	MI Helen Reader 10	AZTI Eli Reader 11	MI Grainne Reader 12	MRII Vidarsson Reader 13	RANGE r. 1-4 MODAL age	Percent agreement	Precision CV	+/- 1 ring
2000	ank-2	2	44.3	6	5	6	11	6	5	8	5	7	5	5	9	5	8	6	15.4%	29.7%	61.5%
2000	ank-7	7	27.8	8	3	4	5	3	3	3	3	5	3	3	4	2	4	3	53.8%	25.3%	76.9%
2000	ank-9	9	68.5	9	7	9	12	9	9	8	7	10	10	10	9	6	12	9	30.8%	19.8%	61.5%
2001	ank-24	24	27.3	9	4	4	4	4	4	4	3	5	4	3	5	3	5	4	53.8%	17.7%	100.0%
2002	ank-27	27	40.7	2	6	8	-	6	8	8	5	7	7	6	7	5	8	6	25.0%	16.9%	66.7%
2002	ank-33	33	37.1	7	5	7	5	5	7	6	4	7	5	5	6	5	6	5	46.2%	17.1%	69.2%
2003	ank-47	47	41.7	6	4	7	7	7	10	7	4	7	-	5	7	5	8	7	50.0%	26.6%	58.3%
				Total read	7	7	6	7	7	7	7	7	6	7	7	7	7		39.3%	21.9%	70.6%
				percentage agreement	57.1%	57.1%	50.0%	100.0%	42.9%	42.9%	14.3%	14.3%	50.0%	42.9%	28.6%	14.3%	0.0%				
				RANKING	2	2	4	1	6	6	10	10	4	6	9	10	13				
				+/- 1 ring	71.4%	71.4%	50.0%	100.0%	57.1%	71.4%	57.1%	57.1%	100.0%	85.7%	85.7%	57.1%	57.1%				

L. piscatorius - *illicia*

Sample year	Sample no	Struc no	Fish length	Landing month	IPIMAR Rafael Reader 1	IPIMAR António Reader 2	AZTI Inaki Reader 3	IEO Jorge Reader 4	CEFAS Phil Reader 5	CEFAS Sally Reader 6	CEFAS Sarah Reader 7	IFREMER Joel Reader 8	IEO Joaquin Reader 9	MI Helen Reader 10	AZTI Eli Reader 11	MI Grainne Reader 12	MRII Vidarsson Reader 13	FRS Lise Reader 15	FRS Hanna Reader 16	RANGE r. 1-4 MODAL age	Percent agreement	Precision CV	+/- 1 ring
2002	mon-6	6	36.0	1	3	4	4	4	2	4	3	4	4	4	5	5	4	4	2	4	60.0%	23.7%	80.0%
2002	mon-7	7	51.0	1	4	7	7	7	6	7	7	8	8	8	7	7	8	7	5	7	53.3%	16.4%	86.7%
2002	mon-14	14	37.0	1	3	3	3	2	3	3	3	4	3	4	4	4	5	3	3	3	60.0%	21.7%	93.3%
2002	mon-20	20	74.0	2	7	9	12	9	7	6	6	9	9	8	8	9	11	7	8	9	33.3%	20.1%	53.3%
2002	mon-21	21	46.0	1	5	5	5	5	5	6	5	5	5	5	5	6	6	5	3	5	73.3%	13.9%	80.0%
2002	mon-22	22	46.0	3	4	4	4	-	1	-	4	4	4	4	4	4	3	4	3	4	76.9%	24.1%	76.9%
2002	mon-34	34	57.0	3	5	5	6	5	4	4	5	6	5	5	5	4	5	4	5	5	60.0%	13.1%	100.0%
2002	mon-45	45	27.0	4	3	2	2	1	1	2	2	2	2	2	2	2	2	2	2	2	80.0%	23.7%	100.0%
				Total read	8	8	8	7	8	7	8	8	8	8	8	8	8	8	8		62.1%	19.6%	83.8%
				percentage agreement	50.0%	100.0%	75.0%	71.4%	25.0%	57.1%	75.0%	62.5%	87.5%	62.5%	62.5%	50.0%	37.5%	62.5%	37.5%				
				RANKING	11	1	3	5	15	9	4	6	2	6	6	11	13	10	13				
				+/- 1 ring	75.0%	100.0%	87.5%	100.0%	62.5%	85.7%	87.5%	100.0%	100.0%	100.0%	100.0%	75.0%	62.5%	75.0%	50.0%				

L. budegassa - otoliths

Sample year	Sample no	Struct no	Fish length	Landing month	IPIMAR Rafael Reader 1	IPIMAR António Reader 2	AZTI Inaki Reader 3	IEO Jorge Reader 4	CEFAS Phil Reader 5	CEFAS Sally Reader 6	CEFAS Sarah Reader 7	IEO Joaquin Reader 9	MI Helen Reader 10	AZTI Eli Reader 11	FRS Gordon Reader 14	RANGE R14 Gordon Reader 14	Percent agreement	Precision CV	RANGE R6 Sally Reader 6	Percent agreement	Precision CV	RANGE r. 14-6 MODAL age
2000	ank-7	2	27.8	8	6	6	5	-	1	3	3	4	3	9	3	3	40.0%	52.6%	5	28.6%	41.3%	4
2001	ank-22	6	58.2	6	10	9	6	10	2	7	8	7	-	8	5	5	10.0%	33.9%	1	9.1%	36.5%	3
2000	ank-6	28	24.3	8	3	5	3	5	5	1	4	4	3	4	2	2	9.1%	36.5%	3	16.7%	49.6%	3
2002	ank-1	40	28.1	3	4	5	3	-	1	1	6	-	4	3	3	3	33.3%	49.7%	1	28.6%	67.7%	2
2003	ank-39	45	32.5	6	-	-	5	8	1	4	6	5	5	8	5	5	44.4%	40.4%	2	28.6%	46.7%	4
				Total read	4	4	5	3	5	5	5	4	4	5	5		27.4%	42.6%		22.3%	48.4%	
				percentage agreement Gordon	0%	0%	40%	0%	0%	20%	20%	20%	50%	20%	100%							
				percentage agreement t +/- 1 ring _Gord	50%	0%	80%	0%	0%	40%	40%	40%	100%	20%	100%							

L. piscatorius - otoliths

Sample year	Sample no	Struct no	Fish length	Landing month	IPIMAR Rafael Reader 1	IPIMAR António Reader 2	AZTI Inaki Reader 3	IEO Jorge Reader 4	CEFAS Phil Reader 5	CEFAS Sally Reader 6	CEFAS Sarah Reader 7	IEO Joaquin Reader 9	MI Helen Reader 10	AZTI Eli Reader 11	MI Gordon Reader 14	RANGE R14 Gordon Reader 14	Percent agreement	Precision CV	RANGE R6 Sally Reader 6	Percent agreement	Precision CV	RANGE r. 14-6 MODAL age
2002	mon-5	1	27.0	4	3	4	4	4	1	0	4	4	2	3	1	1	18.2%	54.6%	3	12.5%	58.6%	2
2002	mon-8	19	45.0	1	4	4	-	5	1	3	4	-	4	5	3	3	22.2%	33.4%	7	28.6%	24.8%	5
2002	mon-21	20	46.0	1	4	5	-	-	1	3	3	-	5	-	3	3	42.9%	40.8%	3	20.0%	31.4%	3
2002	mon-41	36	70.0	1	-	-	10	7	4	4	6	6	-	10	6	6	37.5%	35.1%	1	20.0%	35.9%	4
2002	mon-18	44	89.0	3	-	-	20	10	10	11	8	9	-	12	8	8	25.0%	35.4%	6	20.0%	50.0%	7
				Total read	3	3	3	4	5	5	5	3	3	4	5		29.2%	39.9%		20.2%	40.3%	
				percentage agreement Gordon	0%	0%	0%	0%	20%	40%	60%	33%	0%	0%	100%							
				percentage agreement t +/- 1 ring _Gord	67%	33%	0%	25%	20%	40%	80%	67%	67%	0%	100%							

3 ATTEMPTS AT VALIDATION

3.1 Introduction

One of the most important aspects of ageing studies is the validation of the ages obtained. According to Beamish *et al*. (1983) age validation is a process of estimating the accuracy of an age estimation method. Validation of an age procedure indicates that the method is sound and based on fact (Kalish, 1995).

Validation methods can be classed as direct or indirect, depending on whether they give support to the population growth rates or whether they assess the periodicity of increment formation in individual fish. Direct methods include tag and release, marking calcified structures and otolith microstructure analysis. The indirect methods such as modal length analysis cannot be considered as validation in the sense of Francis (1995), but they are frequently the only methods available to support the age determinations.

However, to date studies of anglerfish have concentrated on the ageing and few studies have focused on validating the annual nature of the rings, either using the otoliths or *illicia*. Some direct and indirect methods have attempted to validate parts of anglerfish ageing and these are reviewed in the present section.

3.2 Validation studies on white anglerfish

3.2.1 Growth validation using tag-recapture studies

One of the most effective ways of validating age and growth parameters is through the use of tagging studies. Two such studies have been undertaken for anglerfish, one on Northern (ICES Divisions VIIb-k and VIIIa,b,d) and Southern stocks (ICES Divisions VIIIc and IXa) and the other on North-Northern stocks (IIIa, IVa,b,c and VIa,b).

Northern (ICES Divisions VIIb-k and VIIIa,b,d) and Southern (ICES Divisions VIIIc and IXa) stocks

Source: Landa, J. 2004. Attempts of growth validation in *Lophius piscatorius*. Working document to Anglerfish *Illicia*/Otolith Ageing Workshop. IPIMAR. Lisbon, 8-12 November 2004

Material and Methods

- 1098 white anglerfish were tagged in southern European waters between 1995 and 2002 by IEO (Spain), AZTI (Spain), IPIMAR (Portugal) and IFREMER (France).
- Fish were caught by commercial fishing vessels using gillnets and trawls and during demersal trawl surveys.
- Healthy anglerfish 15-104 cm total length were measured, tagged dorsally with a spaghetti T-bar tag, injected ventrally with tetracycline and released.
- The release location was recorded and the tagging programme and rewards were advertised internationally.

Results

A total of 49 individuals were recovered (4.5%), 31 with length measurements. Three individuals were at liberty for ~1 year, while the remainder were at liberty for <3 months (80% of them < 1 month). Only the results from those at liberty for ~1 year are considered here (Table 3.1 and Figure. 3.1).

- The two largest anglerfish recaptured had grown 15-25% more than would have been expected using an annual *illicia*-based ALK.
- The fish released at 41 cm and recaptured at 62 cm total length had grown more than twice that predicted using an annual *illicia*-based ALK.

Table 3.1. Length at capture and recapture and time at liberty for three white anglerfish tagged between 1995 and 2002.

tagged Lt (cm)	recaptured Lt (cm)	tag - rec Lt (cm)	tag - rec t (month)	tag- rec Lt/t (cm/year)	*illicia* ageing Lt/t (cm/year)
41	62	21	15	16.5	6.2
60	67	7	11	7.8	6.2
78	83	5	9	6.5	5.6

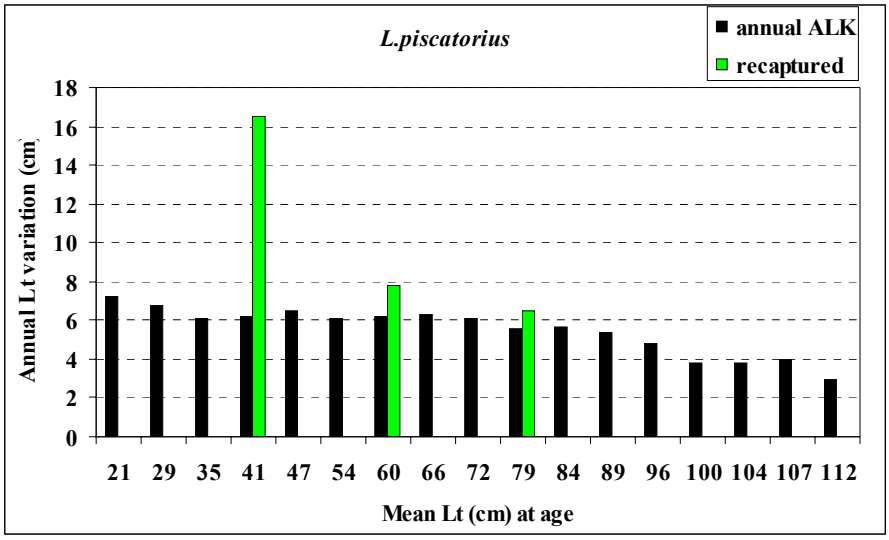

Figure 3.1: Mean age at length of white anglerfish determined using an annual *illicia*-based ALK and size at recapture of three tagged specimens.

North-Northern stock (ICES Divisions IIIa, IVa,b,c and VIa,b)

Source: Laurenson (2003) and Laurenson *et al*. (2005).

A total of 1768 trawl-caught white anglerfish were tagged and released around the Shetland Islands (ICES Sub-area IV) by the North Atlantic Fisheries College (NAFC) in 2000. To date, 79 recaptures (4.5%) have been reported with times at liberty ranging from 5 to 1078 days. Growth rates were calculated using the results from 20 recaptured fish only, as approximately half of recaptures were either reported via fish processors or the information from the fishermen was incomplete. Growth data from another nine fish were discounted, mainly due to short periods at liberty.

The average growth rate determined from 20 fish with periods at liberty of 106-1078 days was 9.4 cm yr^{-1}. This growth rate is faster than estimated by *illicia* ageing in the recent studies and workshops. The lengths at recapture of these fish were 33-81 cm *TL* and 18 of these were 42-63 cm *TL*.

Von Bertalanffy parameters determined from the growth data of recaptured fish were L_∞ = 140 cm, K = 0.104 yr^{-1}. These parameters are reasonably close to those used by the ICES WGNSDS (L_∞ = 140 cm, K = 0.117 yr^{-1} and t_0 = 1.12 yr for females and L_∞ = 110.5 cm, K = 0.154 yr^{-1} and t_0 = 0.91 yr for males).

3.2.2 Verification of the first *annulus* (North-Northern stock)

Source: Wright *et al.* (2002)

Wright *et al.* (2002) investigated the formation of the first annulus using juveniles (16-27 cm *TL*, *n* = 37) collected from routine surveys in the North Sea and ICES Division VIa during April 1999, March 2000 and September 1999. Microincrements in sectioned *lapilli* and growth rings in sectioned *sagitta* and *illicia* were counted.

Within the *lapilli*, Wright *et al.* (2002) identified two types of translucent zone - Wide Translucent Zones (WTZ) and Narrow Translucent Zones (NTZ), which are made up of a series of microincrements. The microincrements in the WTZ were characterised by a decline in increment width over a period of days to weeks but the NTZ showed no such decline. Wright *et al.* (2002) concluded that the WTZ were true annual zones whilst NTZ were possibly related to other processes such as feeding. The relationship between length and age was approximately linear and indicated an average growth rate of 0.91 mm d^{-1}.

Counting the microincrements in the *lapilli*, Wright et al. (2002) determined that the *lapilli* of anglerfish of around 20 cm TL (15-26 cm) captured in March-April had around 200 microincrements (150-240) and those of around 24 cm TL (17-27 cm) captured in September had around 240 microincrements (160-250). Assuming that one microincrement corresponds to one day, the authors suggested that the anglerfish captured in March-April were born ~200 days (6-7 months) previously and had hatched between August and November and the anglerfish captured in September were born ~240 days (7-8 months) previously and had hatched between December and March. These estimates of hatching time correspond well with the results of Afonso-Dias and Hislop (1996) who established that the main spawning

season for white anglerfish in Scottish waters is between November and May. If the assumption that one microincrement represents one day is correct, then Wright *et al*. (2002) suggested that the anglerfish of 15-26 cm TL captured in March-April are Age 1, because they have one WTZ in the *sagitta* (although two WTZ appear in the *illicium*). They also suggested that the anglerfish of 17-27 cm TL captured in September are Age 0 because they have no WTZs in the *sagitta* (although one WTZ appears in the *illicium*) (Figure 3.2). This would suggest a very high growth rate during these first months compared with that suggested by *illicia*.

Comparing otoliths and *illicia*, Wright *et al.* (2002) reported that the first annual ring usually counted in the *illicium* is not present in the otoliths. They suggested that the first *illicium* ring is not a true first annual ring and that one year should be subtracted from the reported ages from *illicia* to compensate. This could explain the discrepancies observed between estimates from otoliths and *illicia* and the higher ages produced by the latter. This result should be considered when setting *illicia* ageing protocols, since at present the counting of *illicia* rings begins with the first ring after the benthic ring.

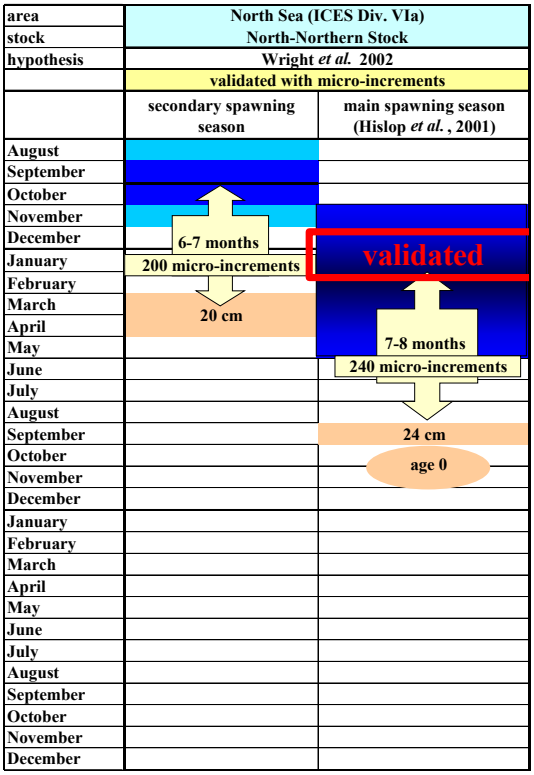

Figure 3.2. Comparisons between white anglerfish otolith microincrement counts and spawning season. Using this method, a fish of approximately 24 cm *TL* (17-27 cm *TL*) in September would be age 0.

3.2.3 Comparisons of age estimates with modes in length frequency distributions

Southern stocks (ICES Divisions VIIIc and IXa)

Source: Landa, J. 2004a. Attempts of growth validation in *Lophius piscatorius.* Working document to Anglerfish *Illicia*/Otolith Ageing Workshop. IPIMAR. Lisbon, 8-12 November 2004.

Results and discussion

The clearest modal length from annual IEO bottom trawl surveys off the northern Spanish continental shelf during October 1994 – October 2003, is around 18 cm *TL*. This could correspond to age 0 or to age 1. The length distribution of the bottom trawl survey during October 1996 shows a modal length at 17 cm *TL*. A modal length of 26 cm was observed in an additional survey in April 1997. It is possible that both modal lengths belong to the same age class, suggesting fast growth (9 cm in 6 months), during autumn and winter when growth is usually slow. It could either correspond to the transition from age 1 to age 2, or from age 0 to age 1. The modal class of 26 cm *TL* agrees with the mean length at supposed age 2 of 29 *TL* cm estimated using the mid-year *illicia*-based ALK.

If we apply the conclusions of Wright *et al.* (2002) regarding the verification of first *annulus* formation in the North-Northern stock to the results of the southern stock and assume that growth in the north-northern stock is similar to that of the southern stock, then we can assume that specimens of 18 cm *TL* captured in October would have grown approximately 180 microincrements. Thus, these specimens could have been born around 180 days (6 months) previously, hatching around April. The Southern stock spawning season was estimated as being between January and June (Duarte *et al.* 2001), which agrees with the hatching date suggested by this work. If this is the case, the modal length of 18 cm *TL* in October would correspond to age 0. The modal length of 26 cm *TL* observed in April 1997 survey and the mean length of 29 cm estimated using the *illicia* ALK would correspond to age 1.

North-Northern stock (ICES Divisions Va,b)

Source: Jónsson, E. 2004 Verification of anglerfish (*Lophius piscatorius*) age estimation through comparison of length modes of age read fish (*illicia*) to length modes of big year-classes appearing in the Icelandic stock. Working document to Anglerfish *Illicia*/Otolith Ageing Workshop. IPIMAR. Lisbon, 8-12 November 2004 (Annex 7).

In order to validate white anglerfish age readings, Jónsson (2004) compared the length modes of fish aged using *illicia* with the length modes of large year-classes that have recently appeared in the Icelandic stock. In general, the age-readings compared very well with modal lengths found in the length distributions obtained during the annual May *Nephrops* survey. The mean length of the smallest mode (possibly 1 year-old fish) was 24-27 cm. The mean length of the next age group (possibly two year-old fish) was 40 cm and for the third group was *ca.* 52 cm. This suggests an annual growth rate of 13-14 cm for the assumed 1 year-olds and at least 12 cm for the 2 year olds.

The modes with the smallest mean length (24-27 cm in May) are assumed to be age 1. This assumption is based on the fact that the few 0-group anglerfish that have been caught in the 0-group pelagic trawl survey conducted during August are 5-15 cm *TL*. The main spawning

season of white anglerfish off the Icelandic coast is spring (April-June), with some exceptional females spawning through out the summer, even as late as September. Thus, the anglerfish appearing in the May *Nephrops* survey with the modal length of 24-27 cm are assumed to be one year old.

3.3 Validation studies on black anglerfish

3.3.1 Growth validation using tag-recapture studies

Northern (ICES Divisons IIIa, IVa,b,c and VIa,b) and Southern (ICES Divisions VIIIc and IXa) stocks

Source: Landa, J. 2004b. Preliminary approach to validate the age of *Lophius budegassa*. Working document to Anglerfish *Illicia*/Otolith Ageing Workshop. IPIMAR. Lisbon, 8-12 November 2004.

Material and Methods

- 847 black anglerfish were tagged in southern European waters between 1995 and 2002 by IEO (Spain), AZTI (Spain), IPIMAR (Portugal) and IFREMER (France).
- Fish were caught by commercial fishing vessels using gillnets and trawls and during demersal trawl surveys.
- Healthy anglerfish 6-88 cm total length (TL) were measured, tagged dorsally with a spaghetti T-bar tag, injected ventrally with tetracycline and released.
- The release location was recorded and the tagging programme and rewards were advertised internationally.

Results

A total of 21 individuals (2.5%) were recovered, 19 with length measurements. Two individuals were at liberty for a long period, while the 70% remainder were at liberty for <1 month. Only the results from those at liberty for ~1 year or more are considered here (Table 3.2 and Figure 3.3).

- One of the specimens tagged (35 cm) and recaptured had a similar growth to that predicted using an annual *illicia*-based ALK.
- The tagged individual (69 cm) recaptured had much slower growth to that predicted using an annual *illicia*-based ALK.

Tables 3.2 Length at capture and recapture and time at liberty for two black anglerfish tagged between 1995 and 2002.

tagged Lt (cm)	recaptured Lt (cm)	tag - rec Lt (cm)	tag - rec t (month)	tag- rec Lt/t (cm/year)	*illicia* ageing Lt/t (cm/year)
35	40.5	5.5	13	4.9	5.7
69	71	2	22	11	3.5

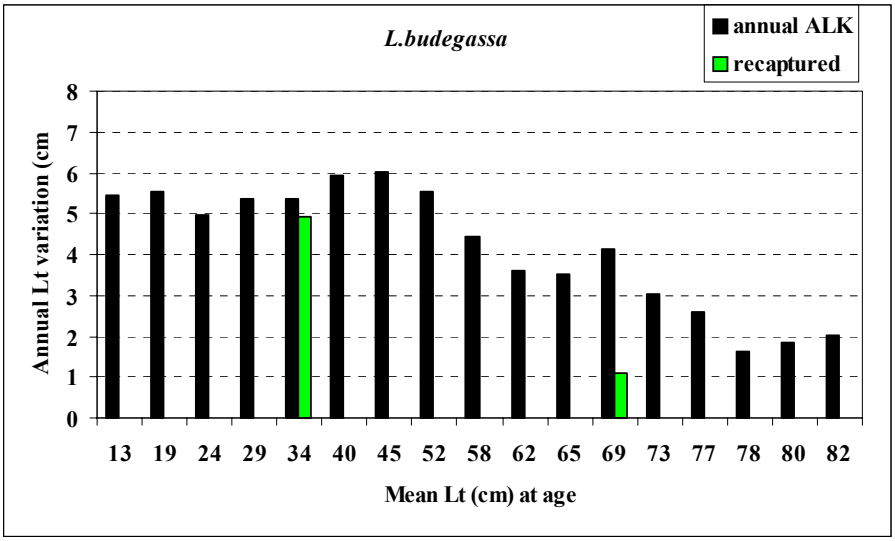

Figure 3.3. Mean age at length of black anglerfish determined using an annual *illicia*-based ALK and size at recapture of two tagged specimens.

3.3.2 Growth of hard parts

Source: Dupouy, H., Pontual, H., Troadec, H., Kergoat, B. and Ogor, A. 2002. An attempt to validate the age of the black anglerfish (*Lophius budegassa*) by marking calcified structures. Working Document of the 4th International Ageing Workshop on European Anglerfish, IPIMAR, Lisbon, 14-18 January 2002.

The absolute growth rate was estimated by measuring the distance from the tetracycline mark to the edge on the vertebra and the time elapsed. Assuming a constant growth rate, the age of the recaptured would be 6.2 years. This value agreed with an age of 6 to 7 years obtained by counting rings in vertebra.

3.4 Summary

3.4.1 White anglerfish

The evidence presented suggests that white anglerfish growth is faster than that estimated by *illicia* ageing in the recent studies and workshops (Table 3.3). This evidence comes primarily from direct validation methods as otolith microstructure and tagging-release but there are also contributions regarding modal lengths.

Table 3.3. Comparison between validation studies and growth estimated using *illicia* for white anglerfish.

Study	Sample size	Age or Lt (cm)	Validation Methodology		Results compared to *illicia* ageing
Wright *et al.* (2002)	37	age 1	microstructure	otoliths microincrements	faster growth
Laurenson *et al.* (2005)	20	42-63	tag-recapture	growth in fish length	faster growth
Landa (2004a)	3	41-78	tag-recapture	growth in fish length	faster growth
Jónsson *et al.* (2004)	-	age 1-5	survey length distribution		faster growth

First ring

Each contribution to the validation of growth refers to a different period in the life of the anglerfish. The valuable evidence of Wright *et al.* (2002) refers to the formation of the first ring, validating that specimens 17-27 cm *TL* captured in September in the North Sea were born between December and March and that they are age 0. Similarly, specimens captured during October surveys in the Cantabrian Sea with a modal length of 18 cm *TL* could also be age 0 individuals that were born during the first months of the survey year.

If we compare the mean and modal lengths at age from the above studies with those obtained in the present workshop and from the most recent work on *illicia* ageing (Table 3.4), it is possible that the supposed first annual ring seen in *illicia* does not correspond to the true first annual ring. This could lead to an overestimation of age when using *illicia*. While there is evidence to support the suggestions of Wright *et al.* (2002), there is no validated reason for counting the first ring in the *illicium*. Wright *et al.* (2002) suggested that 1 year should be subtracted from the reported ages from *illicia* ageing.

Ages older than 1

With regard to the growth of fish of ages older than 1 year, the tag-recapture experiments and the results of length distribution studies also show faster growth than that estimated from *illicia* ageing (Table 3.4). However, in general the recaptures are of the size range 40-80 cm *TL*. Definitive conclusions on growth rates can only be drawn if additional evidence from anglerfish recaptures describing the growth of all size/age classes becomes available. Only then can decisions be made regarding the revision of ageing criteria.

Table 3.4. Length (cm) at first ages from the present workshop compared with the most recent work in growth with *illicia* and the other results of studies of validation for white anglerfish.

Method	*illicia* ageing	*illicia* ageing	microincrements	length distribution	length distribution
Stock	Northern	Southern	North-Northern	North-Northern	Southern
Area	ICES VII	Iberian peninsula	North Sea	Icelandic waters	Cantabrian Sea
Author	present workshop	Landa *et al*. (2001)	Wright *et al*. (2002)	Jónsson *et al*. (2004)	Landa (2004a)
n	50	844	37	505	-
Age	**mean length**	**mean length**	**mean length**	**modal length)**	**modal length**
0.5	-	-	16 - 27		18
1.5	-	19.00		24 - 27	29
2.5	29.13	27.02			

3.4.2 Black anglerfish

We have presented important attempts at validation by the direct validation methods of tag and release and the marking of calcified structures. However, there is not sufficient evidence to justify any change in the present *illicia* ageing criteria (Table 3.5).

Table 3.5. Comparison between validation studies and growth estimated using *illicia* for black anglerfish.

Study	**Sample size**	**Lt (cm)**	**Validation Methodology**		**Results compared to *illicia* ageing**
present work	1	69	tag-recapture	growth in fish length	slower growth
Dupouy *et al*. (2002)	1	35	tag-recapture	growth in fish length	similar growth
Dupouy *et al*. (2002)	1	35	tag-recapture	growth in hard parts	similar growth

4 DISCUSSION

The object of this exchange and workshop was not to exclude or favour one structure or the other for routine ageing in all laboratories. This would be impractical as sampling difficulties and changes to the workload required to prepare the structures would prevent certain institutes from changing to another structure. Also, since institutes do not have collections of both structures for preceding years, such a change would result in the loss of a valuable time series. The main aim of this study was to compare the results obtained using the two structures and to comment on the results.

The results clearly showed that for the same fish agreement between *illicia* and otoliths ages was low. Only 27% of white anglerfish had the same age between *illicia* and otoliths. Also, 49% were aged older with *illicia* than with otoliths and 45% had an age difference of 1 (+1 or -1). These values refer to the ages provided by experienced otolith reader (R14) with the highest agreement to the *illicia* modal age, since the level of agreement was much lower for the other experienced otolith reader (R6). For black anglerfish and the same reader, the agreement between structures was lower than that for white anglerfish. There was only 8% agreement between *illicia* and otolith ages for the same fish and 64% of fish had an age difference of +1 or +2 (*illicia* with higher ages). In addition, 90% of black anglerfish were aged older with *illicia* than with otoliths. For both species it was generally observed that *illicia* ages were higher than otolith ages.

However, the comparison between *illicia* and otoliths must be viewed with caution because of the differences in between-reader agreement within each structure. The results showed that age reading agreement is higher among *illicia* readers than among otolith readers. A group of readers with high or medium experience in *illicia* readings reached a high percentage of agreement (with low CV and bias) between themselves, especially for white anglerfish. This group of readers was or is presently ageing *illicia* on a routine base. However, the otolith results showed higher levels of disagreement among readers. This included experienced otolith readers who had low percentages of agreement and a certainty of bias between themselves.

The higher agreement between *illicia* readers was also observed in the ring identification from the images. The number of rings identified by experienced and inexperienced readers was higher in *illicia* than otoliths. The ring identification agreement for otoliths was low even for experienced readers. Again, conclusions regarding discrepancies between otolith and *illicia* readings must be made bearing in mind the levels of agreement within each structure. In spite of this difficulty, there are some indications that *illicia* readings give ages above otolith readings for the same fish. It should be noted that in general, *illicia* readers have more experience of participation in ageing workshops compared to otolith readers and there is a routine ageing procedure followed by all countries that provide *illicia* age readings for stock assessment purposes.

In a study to compare *illicia* and otolith readings Woodroffe *et al.* (2003) suggested that otoliths provided more precise estimates of age than *illicia*. However, this difference could be explained by the author's low experience of reading *illicia* rather than any true differences in ageing. The correct way to compare age readings is to take the results from experienced readers of each structure, as was done in the present exchange and workshop.

Validation studies are essential for determining that the interpretation of calcified structures corresponds to real annual periods and are the only way to advance our understanding of anglerfish growth. Several validation studies have been undertaken in recent years using tagging methods, otolith microstructure or modes in length frequency distribution (indirect method). The conclusions from these studies were compared with the ageing results obtained from *illicia*. There are some indications that using alternative methods, white anglerfish growth is faster than that estimated using *illicia*. Investigating the microstructure of otoliths and *illicia* of specimens smaller than 27 cm TL, Wright *et al*. (2002) suggested that the first ring in *illicia* is not present in otoliths. Further, the authors suggested that since the first *illicium* ring is not a true annual ring, one year should be subtracted from reported *illicia* ages. This suggestion should be considered with caution since the identification of the first annual ring is the main source of error in *illicia* ageing and according to the established reading criteria it is not clear if the first *illicium* ring identified by Wright *et al*. (2002) as non-annual is the same ring counted regularly in *illicia* as the first annual. This problem highlights the need for detailed validation studies.

The results from tagging experiments and investigations into modal length distributions in ages older than one also indicated faster growth for white anglerfish compared to *illicia* ageing. However, some of these studies were undertaken in more Northerly waters and the results are not directly comparable with the exchange *illicia*. Also, only parts of the size/age distribution ranges were covered by these studies and definitive conclusions can only be drawn when more information is available covering all size/age classes.

The results from this exchange show that there are high levels of agreement between *illicia* readers, especially for white anglerfish. The agreement between otolith readers is lower, which is possibly due to the lower levels of discussion related to the ageing criteria, between readers from different institutions. Otolith age reading criteria should be standardized as only with better agreement among otolith readers would it be possible to more deeply analyse the differences in between-structure agreement. The best way to increase the levels of agreement and reduce bias in the data from different institutes while maintaining the time series of each institute is to standardize the criteria for otoliths/*illicia* and if necessary revise previous readings. This between structure standardization should be based on all validation information available.

5 CONCLUSIONS

- The exchange results indicated discrepancies between *illicia* and otoliths readings from the same fish:
    - For white anglerfish there was only 27% agreement between experienced *illicia* readers and experienced otoliths reader R14. For otolith reader R6 this value was only 11%;
    - For black anglerfish the agreement between *illicia* and otoliths readers was only 8% for both reference otolith readers;
    - For white anglerfish, 49% were aged older with *illicia* than with otoliths by reader R14: 27% were 1 age older and 22% were 2, 3 or 4 ages older;
    - For black anglerfish 84% were aged older with *illicia* than with otoliths by reader R14: 64% were 1or 2 ages older;
    - 24% of white anglerfish and 8% of black anglerfish were aged older using otoliths than using *illicia* by reader R14. For reader R6, these values were only 8% and 3%, respectively;
    - In general, the results suggested that ages from *illicia* readings were higher than those from otolith readings from the same fish;
    - The between structure comparison is dependent on the between reader agreement within each structure, which was low for otoliths.

- Between reader agreement was higher in *illicia* compared to otoliths (for experienced and inexperienced readers). For both species *illicia* readings were more precise and less biased than otolith readings:
    - For white anglerfish the coefficient of variation (CV) was 21% in *illicia* and 41% (with R6 as the reference reader) or 46% (with R14 as the reference reader) in otoliths;
    - For black anglerfish the CV was 27% in *illicia* and 41% (R6) and 47% (R14) in otoliths;
    - For white anglerfish the percentage of agreement was 40% in *illicia* and 12% (R6) or 15% (R14) in otoliths;
    - For black anglerfish the percentage of agreement was 26% in *illicia* and 9% (R6) and 13% (R14) in otoliths;
    - For both species, between reader bias was generally lower in *illicia* than otoliths,;
    - For white anglerfish there was low variability and no significant bias amongs *illicia* readers who contribute or will contribute to annual ALK's for stock assessment (R2, R4, R8, R9, R10, R11 and R12) ;
    - Experienced and inexperienced *illicia* readers generally agreed on the identification of a large number of growth rings, while experienced otolith readers generally did not agree on the identification of growth rings;

- Agreement in the *illicia* ring identification was higher for white anglerfish than black anglerfish;
- The main source of error in *illicia* ageing was related to the identification of the first annual ring.

- The comparison between results from validation studies with *illicia* ageing showed that:
  - White anglerfish growth may be faster than that estimated by *illicia* ageing;
  - Tagged black anglerfish had a similar or slower growth than that estimated from *illicia* ageing.

6 RECOMMENDATIONS

1. Validation studies should be carried out. It is not possible to go further in anglerfish ageing studies without progress in validation. Tagging is a very promising method for validating anglerfish ageing;

2. Otolith readers should standardize the reading method and ageing criteria;

3. *Illicia* readers should analyse the recent progress in validation studies particularly with regard to the identification of the first annual ring and possibly revise ageing criteria;

4. After otolith age reading standardization and the possible *illicia* criteria revision, a second otoliths/*illicia* exchange should be carried out in order to investigate more fully the *illicia*/otolith discrepancies;

5. Information obtained from validation studies (actual and future studies) should be used to assess the levels of bias in otoliths and *illicia* readings and to standardize reading criteria in both structures;

6. New *illicia* or otoliths readers should follow the ageing criteria described in this document;

7. Analysis of the impacts of using otolith or *illicia* age readings in age structured stock assessment models should be carried out in.

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